CENTRAL VALLEY PROJECT IMPROVEMENT ACT
PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT

ATTACHMENT B
Fish Habitat Water Quality Technical Information

September 1997

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LIST OF ABBREVIATIONS AND ACRONYMS

af	acre-feet
af/yr	acre-feet per year
CCWD	Contra Costa Water District
CDEC	California Data Exchange Center
cfs	cubic feet per second
CIMIS	California Irrigation Meteorologic Information System
COE	U.S. Army Corps of Engineers
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
DCC	Delta Cross Channel
Delta	Sacramento-San Joaquin River Delta
DFG	California Department of Fish and Game
DWR	California Department of Water Resources
EBMUD	East Bay Municipal Utility District
EC	electrical conductivity
mg/l	milligrams per liter
mS/cm	microsiemens per centimeter
NWS	National Weather Service
PEIS	programmatic environmental impact statement
ppt	parts per thousand
RBDD	Red Bluff Diversion Dam
Reclamation	U.S. Bureau of Reclamation
Service	U.S. Fish and Wildlife Service
SS	suspended solids
SWP	State Water Project
SWRCB	California State Water Resources Control Board
TCD	temperature control device
TDS	total dissolved solids
USGS	U.S. Geological Survey
X2	isocline
μS/cm	microsiemens per centimeter
°F	degrees Fahrenheit
1995 WQCP	Bay-Delta 1995 Water Quality Control Plan

CHAPTER I

INTRODUCTION

Chapter I

INTRODUCTION

The Draft Programmatic Environmental Impact Statement (PEIS) summarizes the evaluation of the direct and indirect impacts of implementing a wide range of actions identified in the Central Valley Project Improvement Act (CVPIA). Details of the information used in the definition of the affected environment and analysis of the environmental consequences are presented in the technical appendices of the Draft PEIS.

This attachment to the Fisheries Technical Appendix presents a summary of habitat and water quality conditions that affect fish in Central Valley streams that are tributary to the Delta and in the Delta. The conditions and analyses described in this attachment were used as background information during the preparation of the Fisheries and the Delta as a Source of Drinking Water technical appendices. The habitat conditions discussed in this attachment included flow, temperature, salinity, and other water quality factors.

CHAPTER II

AFFECTED ENVIRONMENT

Chapter II

AFFECTED ENVIRONMENT

INTRODUCTION

Fish habitat water quality is used as a general term to describe various conditions in a river or reservoir that are required to provide suitable habitat for fish and other aquatic organisms. This report uses fish habitat water quality to describe several basic aspects of the aquatic habitat, including river flow hydraulic parameters (e.g., velocity, depth, width, surface area), reservoir euphotic and littoral zone habitat areas, and selected water quality variables (e.g., temperature, suspended sediment, and salinity) that are important in reservoirs, rivers, or the Sacramento-San Joaquin River Delta (Delta). Figure II-1 provides an overview of the study area for this analysis. These selected water quality variables are relatively easy to measure or calculate and are indicators of habitat conditions that affect fish and aquatic organisms. Aquatic habitat variables provide a direct link between river and reservoir operations and lacustrine, riverine, and estuarine environmental conditions that may affect aquatic organisms.

These selected fish habitat water quality variables may be related to other water quality characteristics that may have effects on fisheries, such as chemicals associated with agricultural drainage. The selected variables described in this chapter are general habitat conditions and provide information at an appropriate level of detail for a programmatic assessment of Centra Valley Project (CVP) operations.

Figure II-2 illustrates the use of habitat water quality variables in the habitat descriptions and impact assessments in this attachment. Surface water hydrology provides the basic framework for describing river and reservoir conditions and exemplifies the year-to-year variability that characterizes California hydrology (see the Surface Water Facilities and Operations Technical Appendix). Operations of the CVP (together with the State Water Project [SWP] and other water projects) provide the basic control of river and reservoir conditions, subject to natural hydrology and demands for water diversions, instream flow requirements, and Delta objectives (see the Surface Water Facilities and Operations Technical Appendix). Fish habitat water quality is described for each reservoir or river segment selected for fish impact assessment. Fish habitat water quality variables are also used for some vegetation and wildlife impact assessments.

The Historical Perspective and Recent Conditions sections of this chapter describe riverine habitat conditions (flow, temperature, suspended solids [SS], and salinity as measured by electrical conductivity [EC]), reservoir habitat conditions (temperature and habitat area), and Delta estuarine conditions (outflow and salinity [measured as EC values]). These habitat conditions are used to determine whether any significant habitat water quality impacts on target fishery habitats would occur as a result of implementation of the CVPIA.

FIGURE II-1
STUDY AREA

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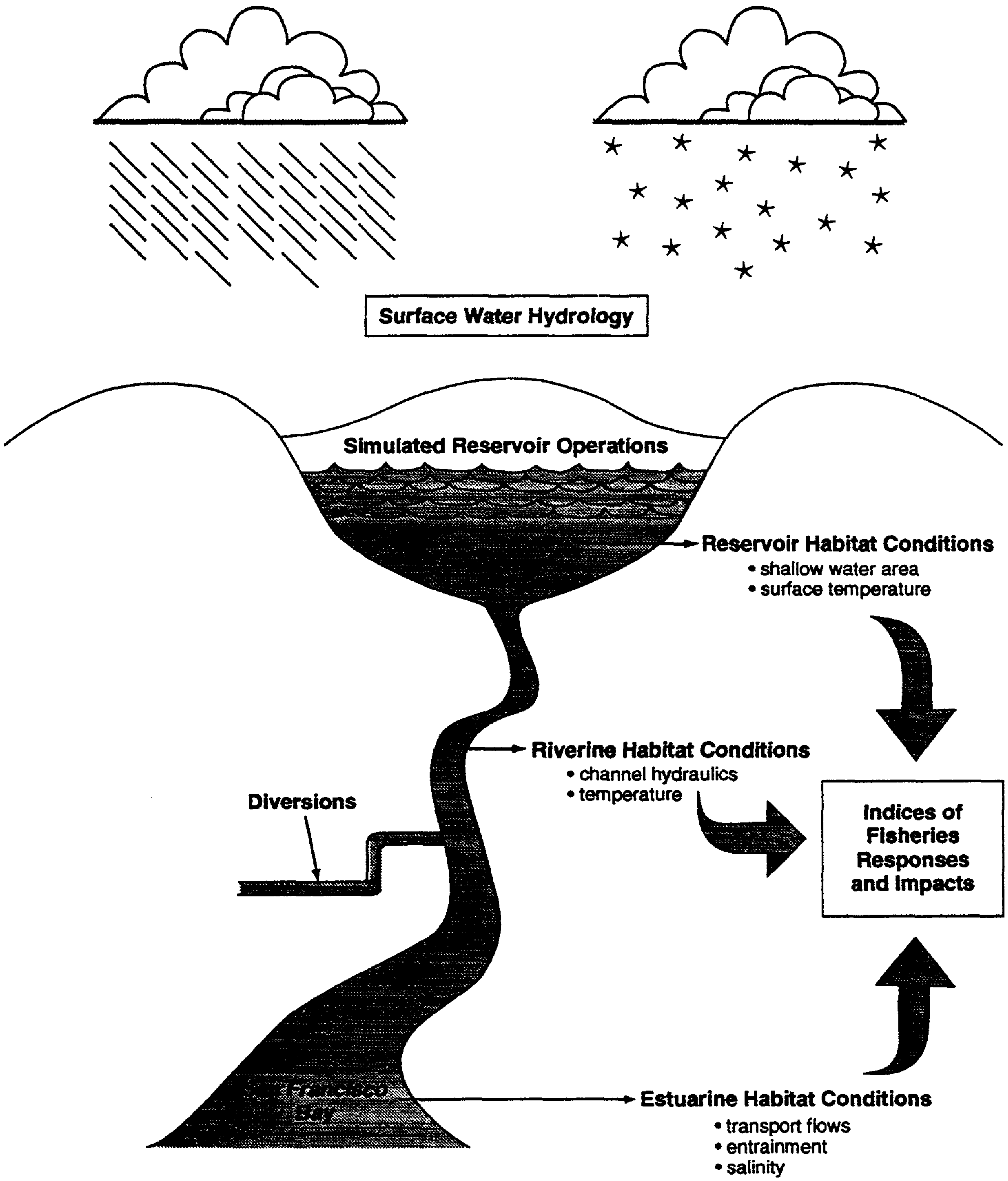


FIGURE II-2

FISH HABITAT WATER QUALITY VARIABLES DESCRIBED AND EVALUATED FOR THE CVPIA PEIS IMPACT ASSESSMENT

Many of the potential responses of the fisheries in regulated streams and in the Delta are highly variable, and estimates of monthly average effects may require more detailed analyses of selected limiting factors or relationships. To support the monthly impact assessment of habitat water quality conditions, historical daily records of flow, CVP operations, meteorology, water temperature, and EC and SS variables from the Sacramento River and tributaries, the San Joaquin and Stanislaus rivers, and the Delta were collected for the 1967-1991 water-year period and compiled in a series of spreadsheet data files. Trinity River temperature data as they apply to water quality in Shasta Lake are included in this attachment.

As shown in Figure II-3, the integrated record of historical daily data is the most accurate description of recent habitat water quality conditions and provides an important basis for impact assessments. Most of the historical CVP operations, hydrology, water quality, and fish abundance data are reported as daily values. Monthly conditions have been described by averaging or integration of the actual daily measurements. This report generally describes habitat water quality conditions within the CVP system of reservoirs and downstream river reaches and Delta channels using monthly average data. Daily historical data were analyzed and used in the PEIS as needed to accurately characterize monthly average conditions.

STUDY AREA

The study area for this attachment includes the Sacramento River and tributaries, the San Joaquin River and tributaries, and the Delta (Figure II-4). The Tulare Basin is not included because its rivers do not normally connect with the San Joaquin River (no anadromous fish), and the CVP does not directly control these rivers (the Friant-Kern Canal delivers water to the Tulare Basin).

STUDY PERIOD

This attachment presents monthly measures of fish habitat water quality conditions for the 1967-1991 water years. This is the period used to measure the targeted doubling of natural production of anadromous fish and includes the period with the most accurate fisheries data. Historical data collected since 1967 are particularly relevant because almost all CVP facilities were constructed and in operation by that date (New Melones Reservoir was not completed until 1978 and was approved by California State Water Resources Control Board [SWRCB] for filling in 1981). Demands for diversions and Delta exports were generally increasing during 1967-1991.

DATA SOURCES

For some important stations on the Trinity, Sacramento, American, and Stanislaus rivers and in the Delta, daily temperature, salinity (measured as EC), and SS data were available for several years in the 1967-1991 period. When combined with appropriate data on daily CVP operations and streamflow, these selected daily water quality records provide a fundamental data base for describing recent habitat conditions, characterize the effects of CVP operations on habitat conditions, and provide information needed to confirm the accuracy of temperature and salinity

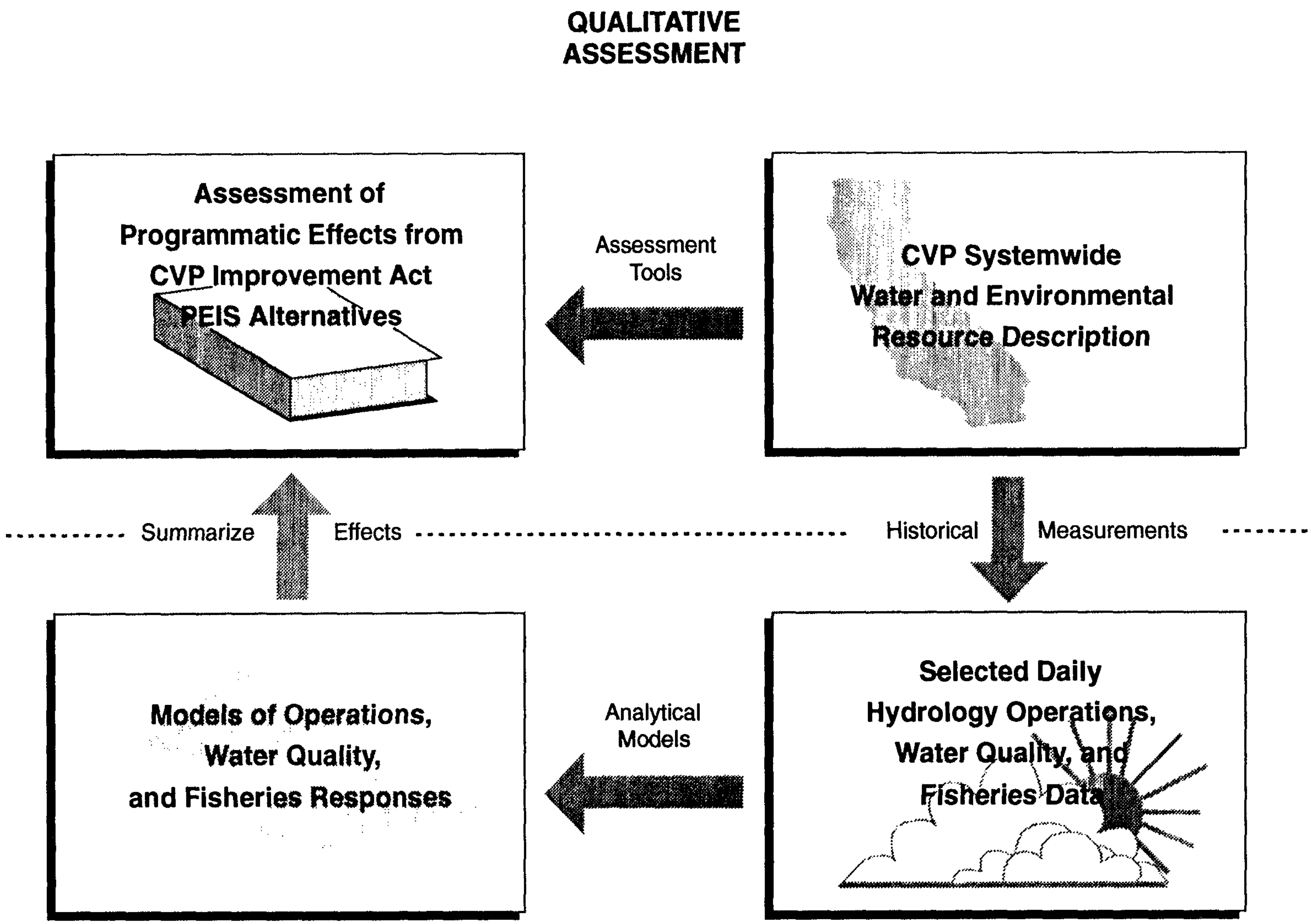


FIGURE II-3

USE OF INTEGRATED DAILY HYDROLOGY OPERATIONS, WATER QUALITY, AND FISHERIES DATA IN CVPIA PEIS IMPACT ASSESSMENTS

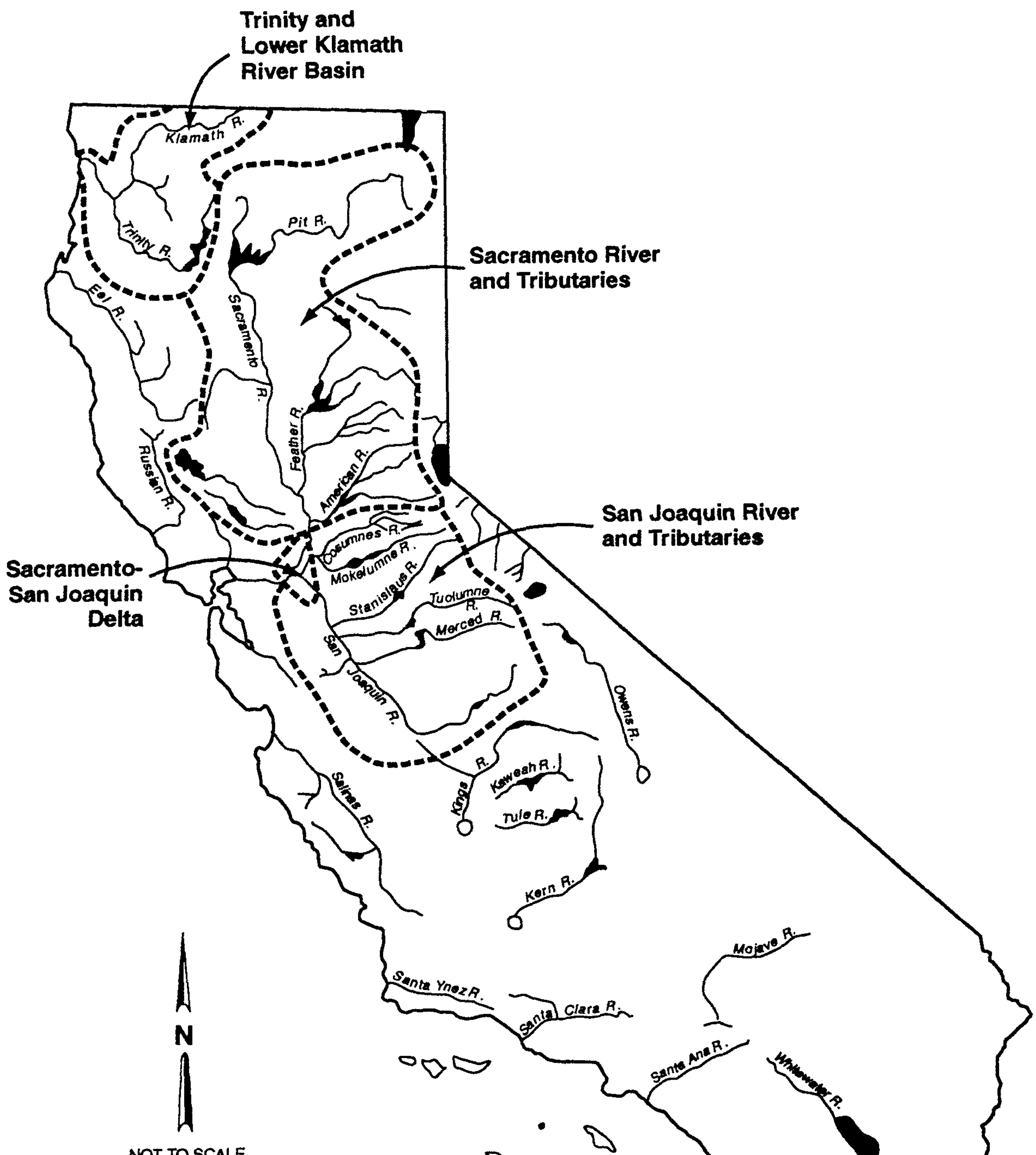


FIGURE II-4

STUDY AREA REGIONS FOR FISH HABITAT WATER QUALITY

models used in impact assessments. However, because daily data are more detailed than necessary for CVPIA PEIS descriptions of environmental resources or impacts, fish habitat water quality is summarized with monthly average data.

U.S. GEOLOGICAL SURVEY WATSTORE DATA

The fish habitat water quality monthly data incorporate information from several existing data bases. Historical monthly river flow data were compiled from the U.S. Geological Survey (USGS) WATSTORE data base of daily flows and periodic water quality samples that was accessed for the Surface Water Supplies and Facilities Operations Technical Appendix. Much of the available water temperature information came from USGS records, which were obtained from the compact-disk version of WATSTORE. The USGS records also include some data on reservoir storage and surface water diversions. The long-term fluctuations in annual hydrology and reservoir storage and diversions are described in the Surface Water Supplies and Facilities Operations Technical Appendix, while the effects of reservoir operations on monthly reservoir and riverine habitat conditions are emphasized in this attachment.

CENTRAL VALLEY PROJECT OPERATIONS RECORDS

The CVP daily operations data for water years 1967-1991 were obtained from the U.S. Bureau of Reclamation (Reclamation) in electronic format and compiled and summarized in the fish habitat water quality data base (daily and monthly average values). However, not all reservoir operations records for this period were available in electronic format. End-of-month reservoir storage and average streamflow values were obtained from USGS and the California Data Exchange Center (CDEC) data bases to complete the historical data base of reservoir operations and riverine habitat conditions for 1967-1991.

METEOROLOGIC DATA

Meteorologic data available from the National Weather Service (NWS) were collected for Redding-Red Bluff, Sacramento-Davis, and Fresno to characterize monthly conditions that control river water temperatures. California Department of Water Resources (DWR) operates the California Irrigation Meteorologic Information System (CIMIS) network of meteorologic stations, begun in 1985, that provides the required data for water temperature modeling. Data from a few selected stations were included in the daily habitat water quality data files for recent years.

DELTA FLOW AND SALINITY MEASUREMENTS

Reclamation and DWR maintained EC monitoring stations at several locations in the Delta during the 1967-1991 water-year period. These measurements were summarized as daily minimum, mean, and maximum values to represent both the average and the daily range of salinity caused by tidal movement at each monitoring location. These data were compiled in the daily Delta habitat water quality files and summarized as monthly average values.

Historical Delta EC data were integrated with the corresponding Delta hydrologic data to provide an accurate characterization of the effects of CVP Delta operations on estuarine EC conditions.

Daily Delta hydrology is already specified in the DAYFLOW data base maintained by DWR. The DAYFLOW records, including daily CVP Delta operations for 1967-1991, were compiled as part of the daily Delta habitat water quality files and summarized as monthly average values.

HISTORICAL PERSPECTIVE

It is difficult to provide a quantitative historical perspective of fish habitat water quality before the completion of the CVP and SWP facilities because few historical records are available. The Historical Perspective chapter of the Fisheries Technical Appendix describes historical factors affecting fisheries abundance, including habitat modifications. Because these factors also affect habitat water quality, the discussion is summarized below.

Between 1852 and 1884, hydraulic mining in the Sierra Nevada foothills washed almost 1 billion cubic yards of sediment into the rivers draining the gold country (California State Lands Commission, 1991). Sand and cobbles filled pools and riffles, and finer materials smothered spawning gravels and marshland habitats. The sediments raised riverbeds and clogged channels and sloughs, changing hydrologic and hydraulic characteristics of the river systems and estuary. A federal injunction in 1884 banned hydraulic mining unless sediments were prevented from washing into streams.

In the late 1800s, dikes and levees were built to develop and protect low-lying agricultural lands. The conversion of wetlands to agricultural land was encouraged by federal and state laws during this period. Land reclamation and levee construction severely degraded riparian habitat by increasing depth and flow velocity and reducing cover and habitat diversity (DWR, 1984). Removal of riparian vegetation increased bank erosion, sedimentation, and water temperatures in streams used for spawning and rearing by chinook salmon and trout.

Water quality in the Sacramento-San Joaquin River system was degraded by several development activities. Agricultural drainage increased salinity and concentrations of pesticides and other toxic substances in the rivers and Delta. Early cities, towns, and homesteads dumped untreated sewage into rivers, sloughs, and bays.

Levee construction and channel dredging have continued into the present period. Contamination of water quality by agricultural drainage, urban runoff, and industrial and municipal discharges are continuing problems. High salinity and pesticide runoff from agricultural lands have been especially severe in the San Joaquin River. Dredging to maintain ship channels in the San Francisco Bay and Delta creates turbidity and resuspends contaminants present in the sediments.

Except for uncontrolled hydraulic mining, most of the factors affecting habitat water quality before 1940 continue to affect the habitat today. In addition, the construction of the large dams altered the temperature regime in the rivers downstream, which affected chinook salmon, steelhead trout, and other game and nongame species. For a period after the large dams were constructed, reservoirs were kept relatively full, and the cold water released from the lower depths of the reservoirs provided cooler summer temperatures in the downstream reaches. More recently, however, the reservoirs have been drawn down further because of increased water demands, resulting in warmer water releases and higher egg mortalities. Winter-run chinook salmon, which spawn in spring and summer downstream of Shasta Lake, have been especially harmed by the warmer water temperatures until recent changes to the operations. The temperature control device Reclamation is installing in Shasta Lake will allow more flexible temperature management operations.

Operations of dams and diversions in the Sacramento-San Joaquin River system and the Delta have altered natural flow regimes by changing the frequency, magnitude, timing, and direction of flow. The timing, duration, and magnitude of high flows in fall, winter, and spring influence migrations and spawning of many fishes in the rivers and estuary. Flows also affect food supply and water temperature. Reverse flows in the Delta may distort normal transport and migration patterns of many fish species, resulting in high mortalities from predation, entrainment, and other causes. Flow regulation can create complex adverse effects that cumulatively reduce fishery potential.

RECENT CONDITIONS

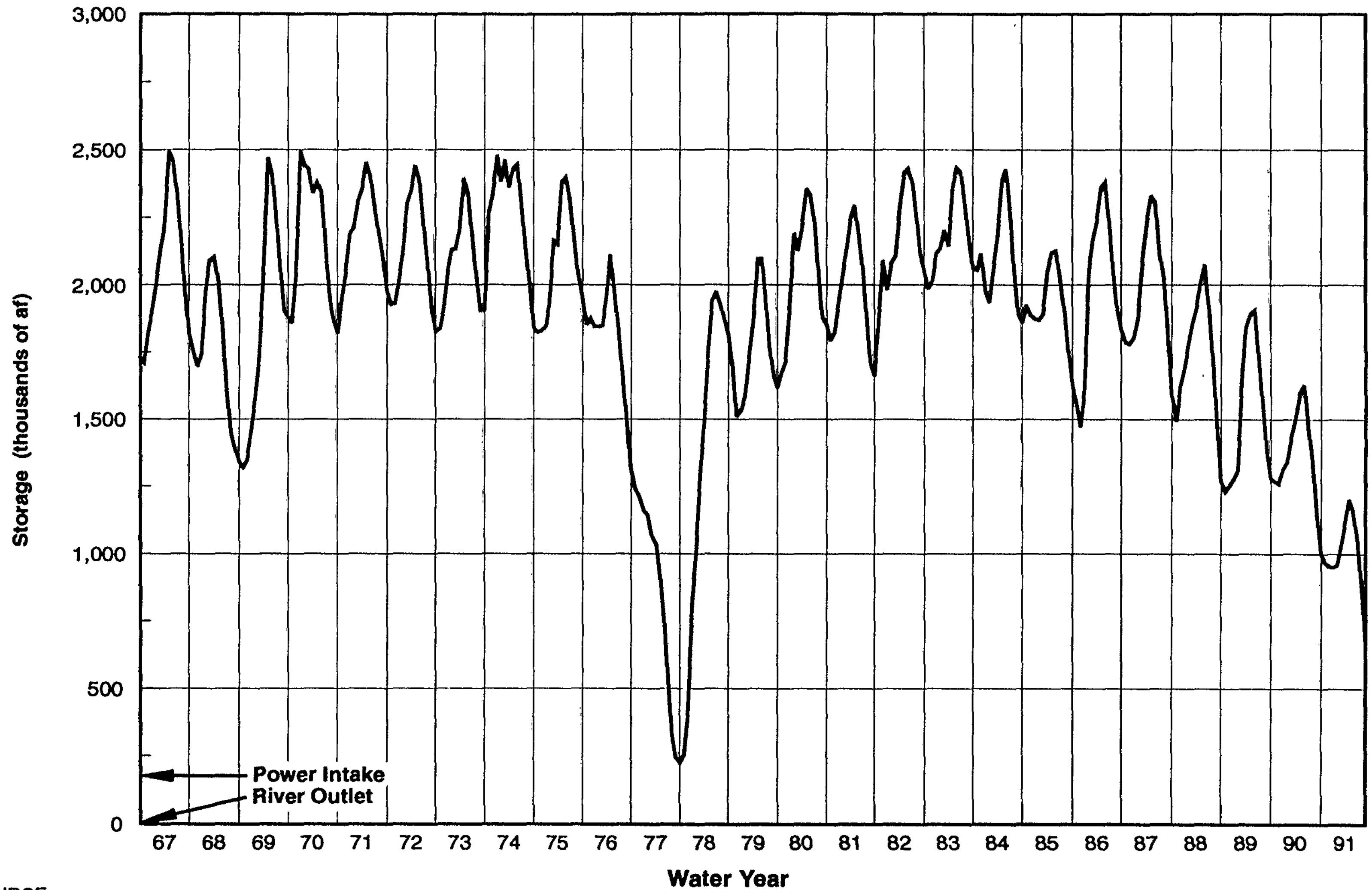
TRINITY RIVER SYSTEM

The Trinity River Division of the CVP facilities was completed in 1963, regulating the water resources of 692 square miles of the upper Trinity River above Lewiston Lake. The major changes in habitat water quality have been caused by the construction of Clair Engle and Lewiston lakes and the subsequent diversion of water to the Sacramento River, with the corresponding reduction in flows on the Trinity River.

Annual diversions from the Trinity River for water years 1967-1991 averaged 1.03 million acre-feet per year (af/yr) of the 1.34-million-af/yr unimpaired Trinity River flow. No in-basin water deliveries are made from the Trinity River Division; however, 340,000 af/yr have been allocated since 1991 for instream environmental use in the Trinity River below Lewiston Lake. The remaining diverted flow, ranging from 1.03 million acre-feet (af) to 649,000 af on average, contributed to Shasta Lake releases to meet downstream water quality and water contracting obligations of the CVP.

Clair Engle Lake

The largest reservoir on the Trinity River is Clair Engle Lake, completed by Reclamation in 1960. Figure II-5 shows historical Clair Engle Lake end-of-month storage from 1967 to 1991. An annual drawdown of approximately 500,000 to 800,000 af occurs during summer and fall, when reservoir storage is reduced to approximately 1.7 million af to 2.1 million af in most years. The maximum storage in Clair Engle Lake is limited to no more than 2.1 million af during the flood season because of Division of Safety of Dams requirements. For water years 1967-1991, carryover (end-of-September) reservoir storage varied from a maximum of 2.16 million af in 1983 to a minimum of 242,000 af in 1977, with an average carryover storage of 1.69 million af.



SOURCE:
CDEC data base maintained by DWR.

FIGURE II-5

HISTORICAL END-OF-MONTH STORAGE FOR CLAIR ENGLE LAKE (1967-1991)

C — 0 8 1 8 9 0

Reservoir Temperatures. Thermal stratification occurs from May through November with the formation of a warm surface layer overlying a cooler and denser bottom layer. During summer, surface temperatures increase and reach approximately 70 to 75 degrees Fahrenheit (°F), while bottom temperatures tend to remain at approximately 40-45°F (Reclamation, 1979). Fall cooling mixes the surface layer deeper and deeper until the reservoir is fully mixed (i.e., "fall overturn"). Surface and bottom temperatures are nearly the same during winter and early spring, ranging from 40°F to 45°F. Surface temperatures begin to stratify and increase again in spring.

Monthly reservoir profile temperatures have been measured by Reclamation (with some additional records by California Department of Fish and Game [DFG] and U.S. Fish and Wildlife Service [Service]). Figure II-6 shows the measured temperatures at several elevations in Clair Engle Lake for 1967-1991. Temperatures below the power outlet (e.g., elevation 2,000 feet) remain almost constant during the year, with a slight gradual warming during summer and more rapid cooling during winter. Temperatures near the power outlet (e.g., elevation 2,100 feet) indicate a gradual warming during summer and fall. The temperature increase depends on the reservoir drawdown, with a much greater temperature rise in years with extreme storage drawdowns (e.g., 1976 and 1977).

Release Temperatures. Clair Engle Lake has three outlets: to Trinity Powerhouse, through a spillway, and through an auxiliary river outlet. Normally, water is released from Clair Engle Lake through a deep outlet (elevation 2,100 feet) to Trinity Powerhouse. Trinity Powerhouse, with a capacity of 140 megawatts and a discharge capacity of approximately 3,900 cubic feet per second (cfs), is operated primarily as a peaking plant and does not run continuously, except during periods of high releases. Excess reservoir storage is released through the spillway (elevation 2,370 feet), and water is warmer than the power outlet releases because it is drawn from closer to the surface. An auxiliary river outlet at an elevation of 2,000 feet has been used in late summer when reservoir storage is low and when releases from the powerhouse are not possible and/or temperatures from the auxiliary outlet would be significantly lower than powerhouse release temperatures (e.g., 1977). The Trinity Powerhouse release temperatures generally match the reservoir temperatures at the 2,150-foot elevation (Figure II-6) because the outlet draws water from a plume-shaped withdrawal zone that extends above the outlet sill (Reclamation, 1979).

Lewiston Lake

Lewiston Lake creates an afterbay reservoir for the Trinity Powerhouse and serves to regulate releases from Clair Engle Lake. Completed by Reclamation in 1962 as a part of the Trinity River Division of the CVP, Lewiston Dam is a 91-foot-high earth-fill structure providing a reservoir capacity of 14,600 af and a surface area of approximately 735 acres. Water is released from Lewiston Lake to the Trinity River or diverted through the Clear Creek tunnel to the Judge Francis Carr Powerhouse just upstream of Whiskeytown Lake on Clear Creek, a tributary to the Sacramento River.

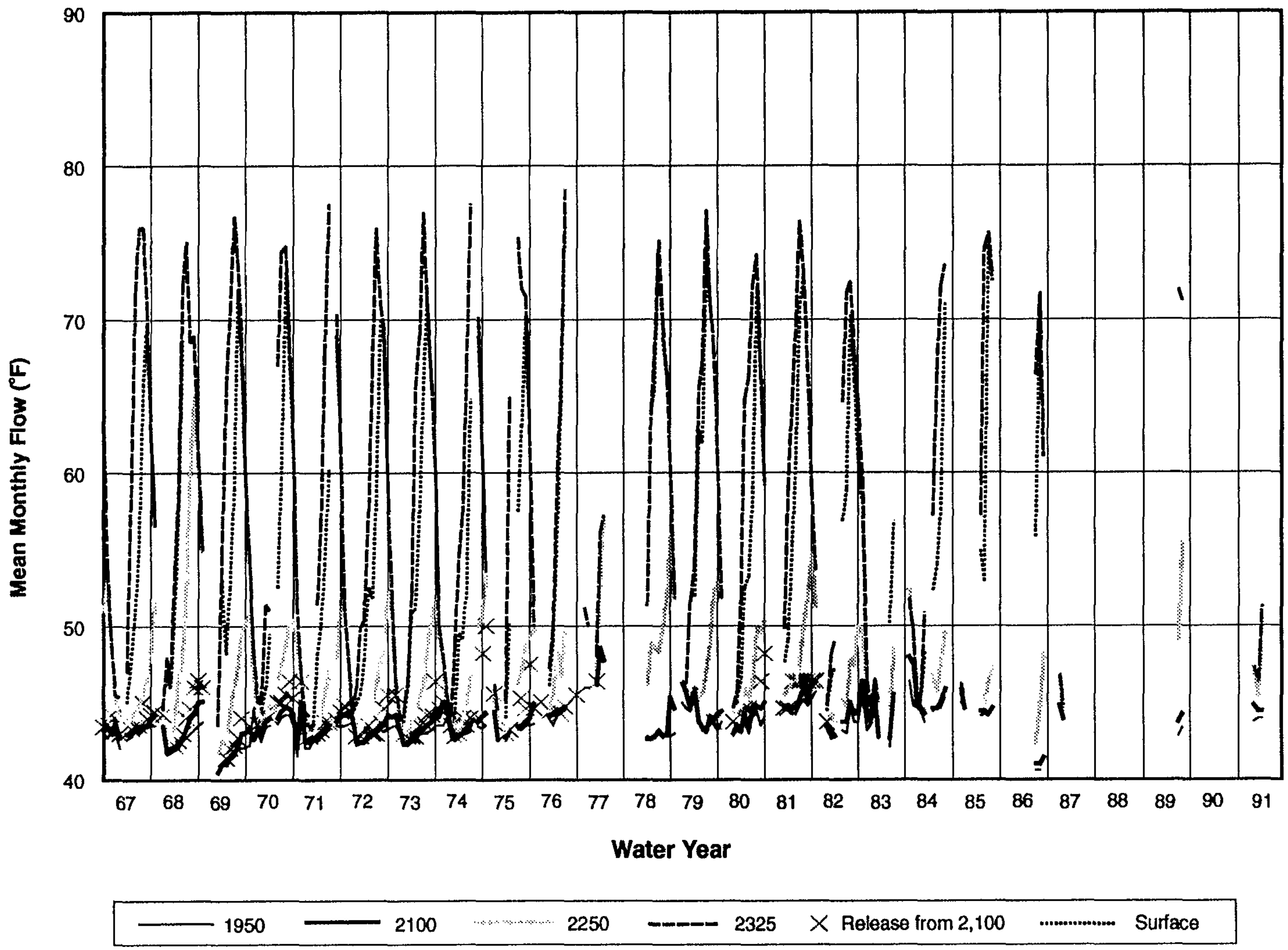


FIGURE II-6

RELEASE TEMPERATURE AND WATER TEMPERATURES AT 1,950-, 2,100- 2,250-, AND 2,325-FOOT ELEVATIONS IN CLAIR ENGLE LAKE (1967-1991)

C-081892

Except in years with uncontrolled spills, most of the water released from Lewiston Lake is diverted though the Clear Creek tunnel to the Judge Francis Carr Powerhouse, which is operated intermittently for peaking purposes (CH2M Hill and Jones & Stokes Associates, 1987). When the powerhouse operates at full capacity, approximately 3,600 cfs is drawn through the Clear Creek tunnel intake that is located near Lewiston Lake at an elevation of 1,887 feet, approximately 14 feet below normal surface elevation of Lewiston Lake. Lewiston Lake water levels are held fairly constant, through concurrent releases from Clair Engle Lake (i.e., the Trinity and Judge Francis Carr powerhouses are operated concurrently).

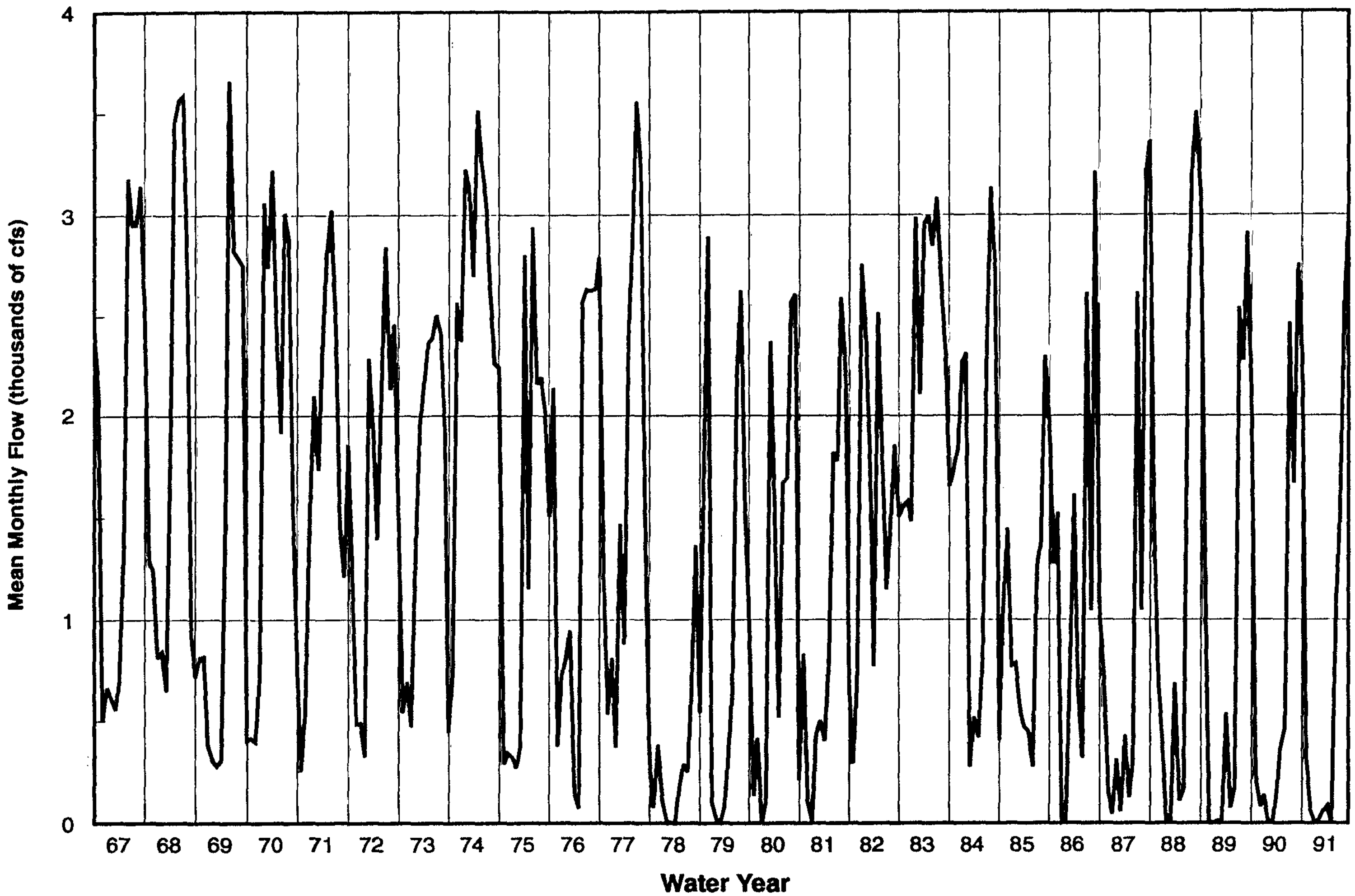
Figure II-7 shows the monthly pattern of Clear Creek tunnel diversions (exports) to the Judge Francis Carr Powerhouse and Whiskeytown Lake for 1967-1991. Diversions have been made almost continuously in wet years to export a maximum of 1.77 million af in 1974. In many years, the diversions are highest during summer and fall, when hydropower demands and benefits are highest. Lower diversions are made in dry years, with a minimum of 217,000 af in 1978.

Reservoir Temperatures. The intermittent operation of Trinity and Judge Francis Carr powerhouses produces highly variable temperatures in Lewiston Lake during spring. When the powerhouses operate at full capacity during summer, the rapid displacement of water prevents thermal stratification from developing, and the resulting water temperature in Lewiston Lake is only a few degrees higher than the typical Clair Engle Lake release temperature of approximately 45°F. When the Judge Francis Carr Powerhouse is not operating during summer, thermal stratification occurs within a few days, and surface temperatures can increase to between 60 and 70°F (Jones & Stokes Associates, 1992).

Release Temperatures. Trinity River Fish Hatchery depends on releases from Lewiston Lake for its water supply and is directly affected by CVP operations. Releases from Lewiston Lake to the Clear Creek tunnel are cold, at temperatures below 50°F. These releases occur when the Judge Francis Carr Powerhouse is operating and can affect the water temperatures of releases from Lewiston to the Trinity River to meet instream flow needs. A temperature curtain surrounding Clear Creek tunnel intake and extending 13 feet below the water surface was installed in 1986 and 1987 to study its effects on temperatures of water diverted to the hatchery and the Trinity River (Jones & Stokes Associates, 1992). Reclamation installed a similar temperature curtain 1 mile upstream of Lewiston Lake in 1992 to allow stratification to develop and allow cool inflows to flow under the warmer surface layer and reduce the warming of Clair Engle Lake releases for diversion into the Clear Creek tunnel.

River Flow. The estimated mean annual unimpaired flow of the Trinity River at Lewiston Lake for 1967-1991 was 1.34 million af. Figure II-8 shows the estimated historical monthly unimpaired flow and regulated flow at Lewiston Lake for 1967-1991.

Suspended Solids and Electrical Conductivity. Excessive stream SS concentrations adversely affect fisheries by clogging spawning gravels with silt, which can prevent alevins from reaching the surface and reduce production of macro-invertebrates. Before the construction of the CVP Trinity River Division, the SS concentration of floodwaters in the Trinity River from the highly erodible watershed would diminish relatively soon after large storms and the sediment



SOURCE:
WATSTORE data base maintained by USGS.

FIGURE II-7

MEAN MONTHLY FLOWS FOR JUDGE FRANCIS CARR POWERHOUSE (1967-1991)

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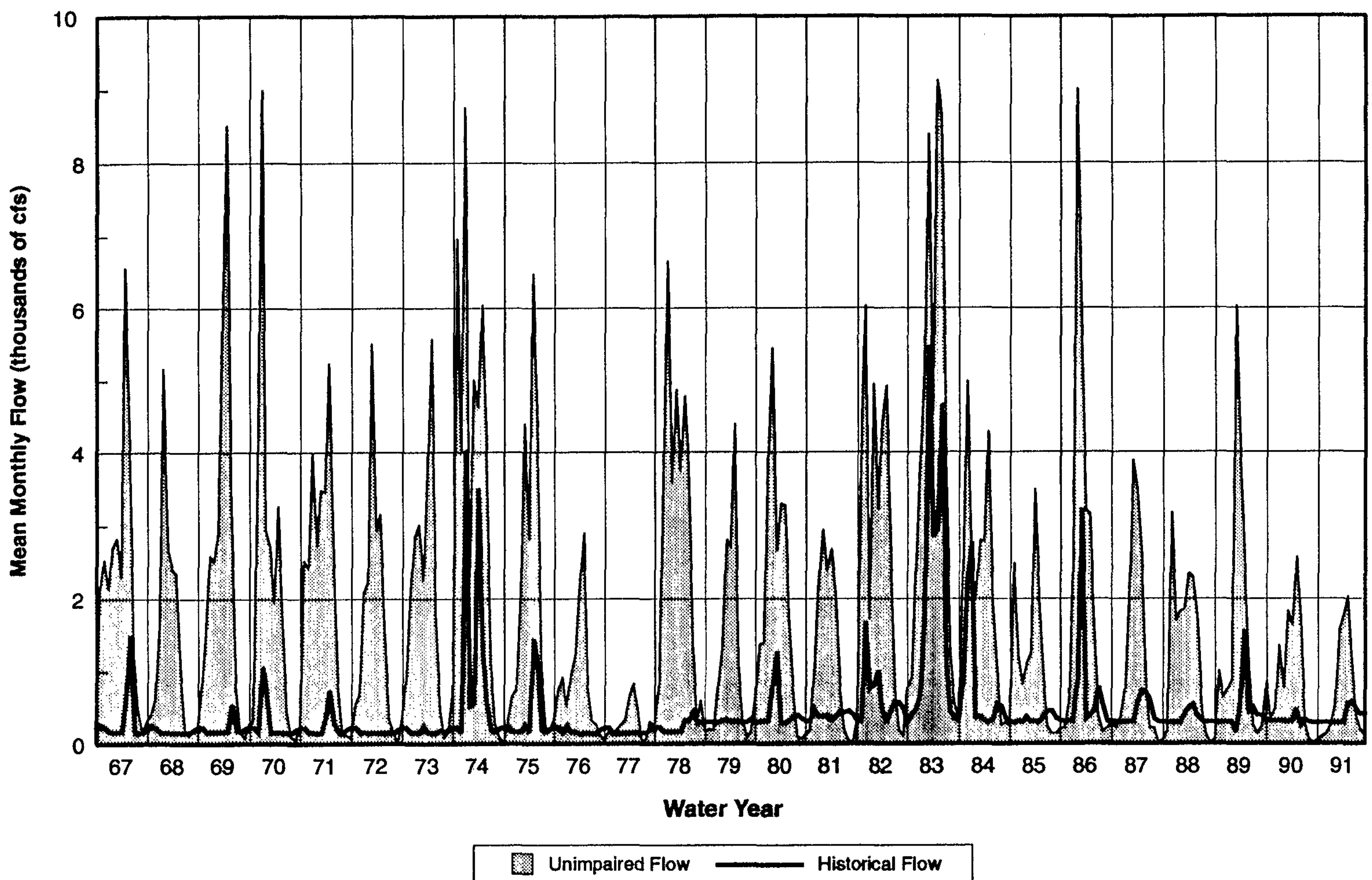
C-081894



SOURCES:
CDEC data base maintained by DWR and
WATSTORE data base maintained by USGS.

FIGURE II-8

MEAN MONTHLY UNIMPAIRED RUNOFF AND HISTORICAL FLOWS FOR TRINITY RIVER AT LEWISTON (1967-1991)

C-081895

would be carried to the sea and deposited as beach sand. Floodflows are now stored in Clair Engle Lake, and the fine, inorganic sediment tends to remain suspended in the lake.

Releases from Clair Engle Lake to Lewiston Lake contain elevated SS concentrations for extended periods of time, especially during high runoff years. The upper layers of Clair Engle Lake usually contain less SS than the lower layers.

SACRAMENTO RIVER REGION

The Sacramento River, which provides more spawning habitat for chinook salmon between Keswick Reservoir and the City of Red Bluff than any other California river, is the largest and most important salmon stream in the state. Shasta Lake and Keswick Reservoir are located just upstream of the City of Redding. Shasta Lake is the largest coldwater source available to the river but exhibits some thermal stratification during summer that leads to warming of lake releases in summer and fall.

Whiskeytown Lake, located on Clear Creek, has a storage capacity of approximately 240,000 af. Although Whiskeytown Lake collects some natural inflow from Clear Creek, most of its inflow comes from the Trinity River through the Clear Creek tunnel and Judge Francis Carr Powerhouse.

Releases from Clair Engle Lake that are not released to the Trinity River are diverted to Whiskeytown Lake through the Clear Creek tunnel and then to the Sacramento River through the Spring Creek tunnel and Powerhouse into Keswick Reservoir. Shasta Lake releases are combined with those diverted from the Trinity River in Keswick Reservoir. River water quality from Keswick Reservoir to Red Bluff Diversion Dam (RBDD) is largely influenced by Shasta Lake releases and Trinity River diversions. These releases have a decreasing effect on water quality as the water progresses downstream from RBDD.

The RBDD is located on the Sacramento River just downstream of Red Bluff. Diversions are made to the Tehama-Colusa and Corning canals. Sacramento River water quality is less influenced by Shasta Lake releases as the river flows toward Sacramento. Colusa Basin Drain discharges tend to degrade Sacramento River water quality. Farther downstream, the Feather and American rivers join the Sacramento River and contribute high-quality water with cooler temperatures and lower SS and EC values.

USGS has operated a water quality monitoring station at Freeport for several years. The data collected at this station represent the combined effects of all Sacramento River Region influences, including the Trinity River diversions. Figure II-9 shows major features of the Sacramento River Region that may influence habitat water quality.

Shasta Lake and Keswick Reservoir

Shasta Lake stores and releases flows of the Sacramento, Pit, and McCloud rivers. Shasta Dam is a 602-foot-high concrete gravity structure providing a storage capacity of approximately 4.55 million af. Water can be released from Shasta Lake through the powerhouse, the low-level or

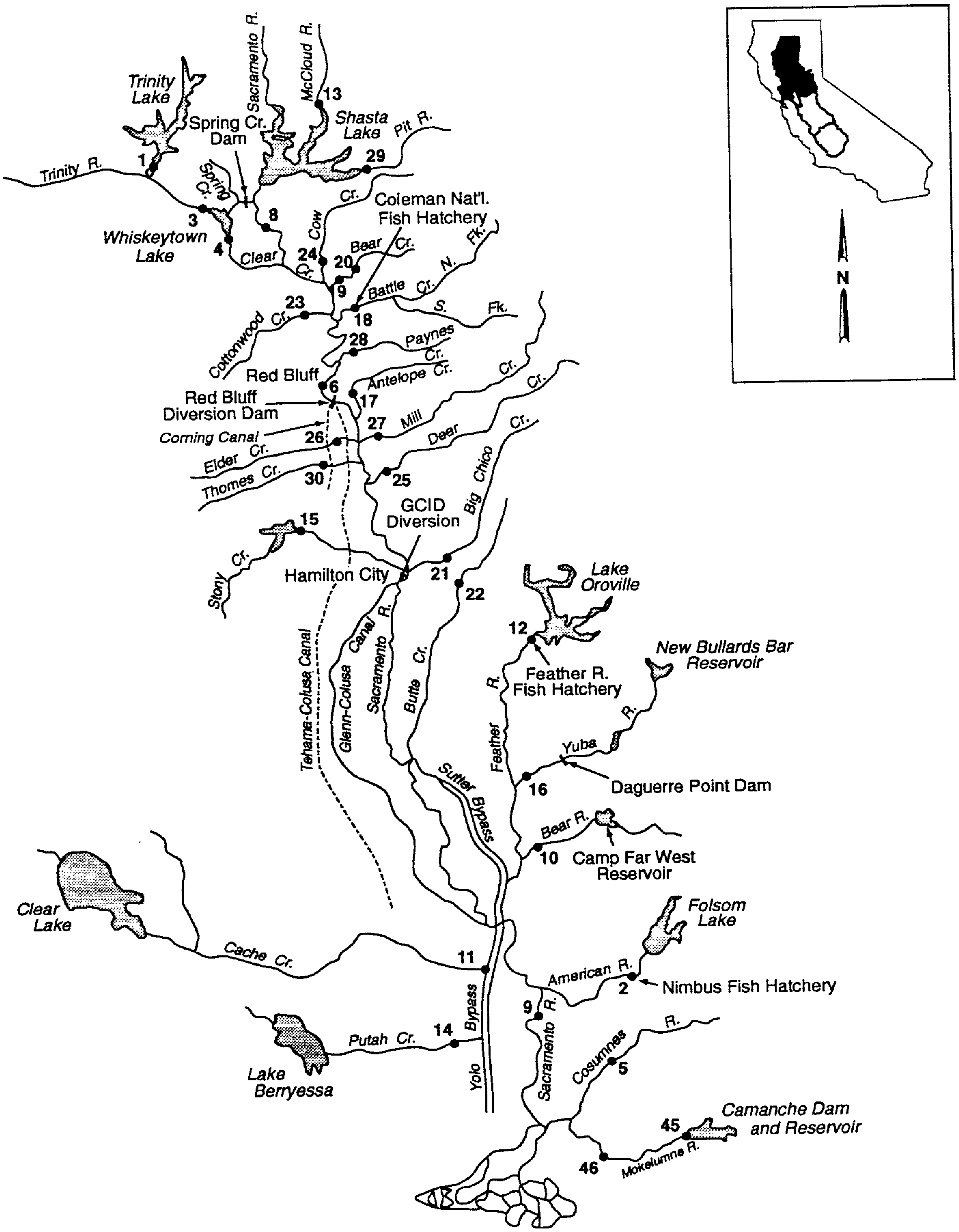


FIGURE II-9

SACRAMENTO RIVER REGION

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high-level river outlet (a mid-level outlet is not currently operational), or the spillway. Table II-1 gives the elevation, area, and storage characteristics for Shasta Lake along with the outlet elevations. The powerhouse intake is located at elevation 815 feet.

Figure II-10 shows Shasta Lake storage for 1967-1991. The average annual unimpaired inflow for 1967-1991 was 5.99 million af/yr. Periods of low storage are likely associated with relatively warm release temperatures. The lowest carryover storage of 630,000 af occurred in 1977. Table II-2 gives the annual carryover storage for Shasta and Whiskeytown lakes along with the annual flows for the upper Sacramento River.

Keswick Reservoir, a 159-foot-high concrete gravity structure, is located 8 miles downstream from Shasta Lake. With a storage capacity of approximately 23,800 af and a surface area of 620 acres, Keswick is a regulating reservoir for releases from the Spring Creek and Shasta powerhouses. The storage and elevation in Keswick Reservoir is maintained by concurrent operation of the powerhouses. The Keswick Powerhouse has a capacity of approximately 16,000 cfs. The 1967-1991 releases from Keswick Reservoir averaged 7.51 million af/yr (Table II-2).

Reservoir Temperatures. Figure II-11 shows monthly temperature data from Shasta Lake for 1967-1991. A strong temperature stratification exists within the reservoir water column during spring, summer, and fall. Stratification reaches its maximum level during mid- to late July, when surface water temperatures increase to approximately 75°F. Water below the powerhouse outlet (i.e., elevation 815 feet) remains cool; temperatures above the outlet increase during summer and fall. The seasonal temperature increase is greatest when reservoir storage is low (Reclamation, 1991).

Release Temperatures. Shasta Lake releases remain relatively cool because they generally come from below the warm surface layer of the reservoir. However, during periods of reservoir drawdown, release temperatures can substantially increase (Reclamation, 1991). Releases from the low-level river outlet (elevation 742 feet) in 1977 and in recent years were cooler. Because these low-level releases bypass the powerhouse, a temperature control device (TCD) is proposed as part of the CVPIA to allow the cooler bottom water to be released through the powerhouse outlets.

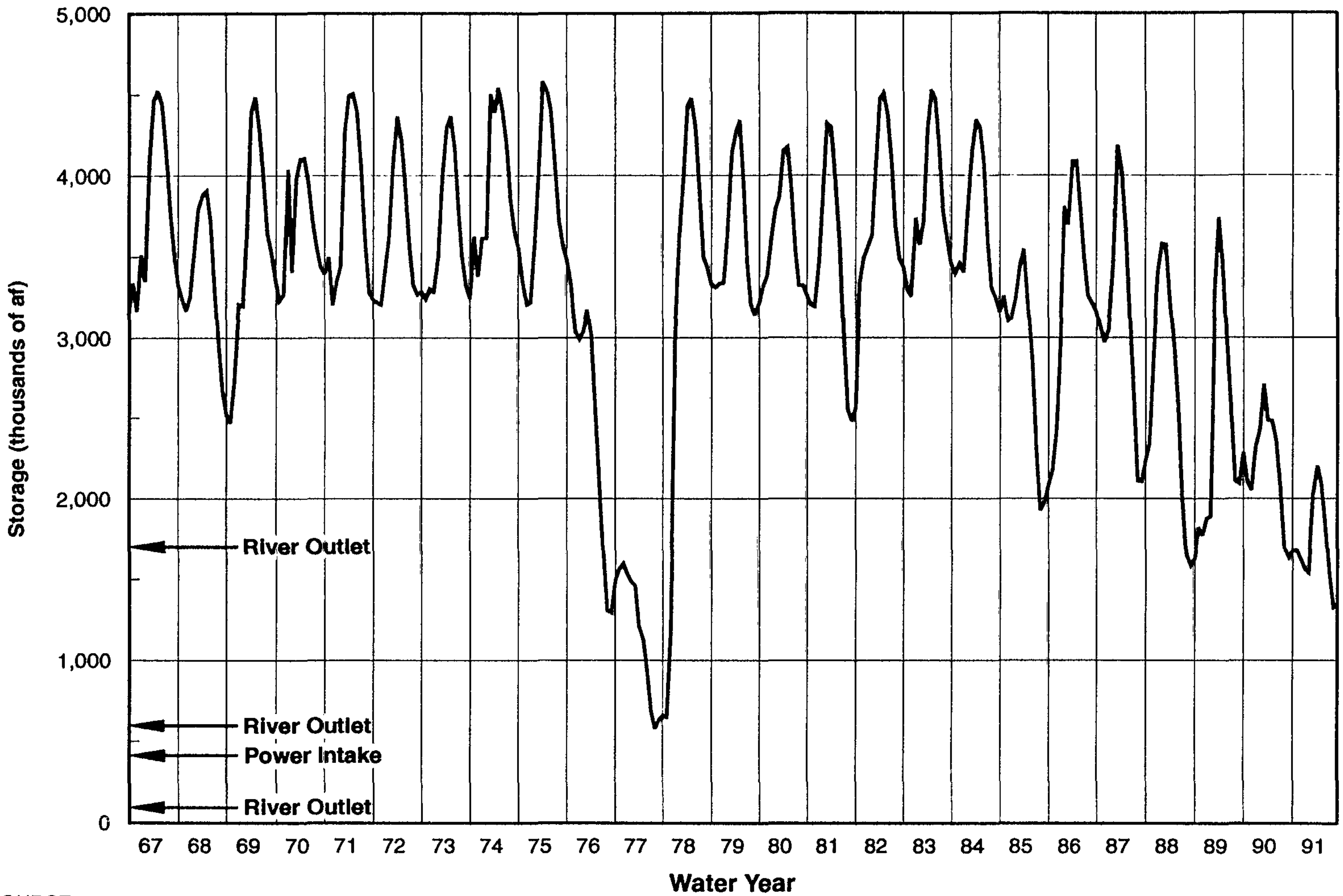
The TCD will have several different openings to allow the powerhouse releases to be drawn from upper-level or lower-level portions of the reservoir from elevations between approximately 725 feet and 1,050 feet. Warmer water will be obtained from near the surface in early spring to reserve the cool water in the lower layers of the reservoir for summer and fall. The TCD is under construction and should be operational in 1997. The temperature simulations of Shasta Lake and the Sacramento River for the PEIS alternatives assumed that the TCD is completed and operated to provide appropriate release temperatures.

TABLE II-1

ELEVATION/AREA/STORAGE RELATIONSHIP FOR SHASTA LAKE

Elevation (feet)	Area (acres)	Incremental Area (acres)	Storage (TAF)	Incremental Storage (TAF)
1070	30,178	1,297	4,635	282
1060	28,881	1,227	4,353	284
1050	27,654	1,227	4,069	284
1040	26,427	1,227	3,784	284
1030	25,200	1,133	3,500	223
1020	24,067	1,134	3,277	223
1010	22,933	1,133	3,053	223
1000	21,800	1,040	2,830	194
990	20,760	1,040	2,636	194
980	19,720	1,040	2,442	194
970	18,680	1,040	2,248	194
960	17,640	1,040	2,054	194
950	16,600	920	1,860	142
940	15,680	920	1,718	142
930	14,760	920	1,576	142
920	13,840	920	1,434	142
910	12,920	920	1,292	142
900	12,000	760	1,150	97
890	11,240	760	1,053	97
880	10,480	760	956	97
870	9,720	760	859	97
860	8,960	760	762	97
850	8,200	633	665	77
840	7,567	634	588	66
830	6,933	633	522	63
820	6,300	633	459	63
810	5,667	587	396	54
800	5,080	540	342	46
790	4,540	540	296	46
780	4,000	400	250	33
770	3,600	400	217	33
760	3,200	400	183	33
750	2,800	400	150	33
740	2,400	343	117	24
730	2,057	286	93	14
720	1,771	285	79	14
710	1,486	286	64	14
700	1,200	171	50	13
690	1,029	172	38	13
680	857	171	25	13
670	686	172	13	13
660	514	171	0	0
650	343	172	0	0
640	171	171	0	0
630	0		0	

NOTES:
TAF = thousand acre-feet.
River outlets are at elevations 742, 842, and 942 feet.
Power intake is at elevation 815 feet.



SOURCE:
CDEC data base maintained by DWR.

FIGURE II-10

END-OF-MONTH STORAGE FOR SHASTA LAKE (1967-1991)

TABLE II-2

ANNUAL HYDROLOGIC CONDITIONS IN THE SACRAMENTO RIVER REGION

	Clear Creek French Gulch	Clear Creek Whiskeytown	Clear Creek Igo	Clear Creek, Spring C PP	Sacramento R. Shasta	Sacramento R. Shasta	Sacramento R. Keswick
Water Year	Historical Flow (TAF)	End-of-September Storage (TAF)	Historical Flow (TAF)	Historical Flow (TAF)	Unimpaired Flow (TAF)	End-of-September Storage (TAF)	Historical Flow (TAF)
67	198	238	98	1,628	7,419	3,506	8,845
68	84	211	64	1,620	4,791	2,670	7,271
69	203	222	104	1,412	7,719	3,528	8,512
70	189	214	221	1,600	7,884	3,441	9,781
71	177	216	88	1,568	7,321	3,275	9,658
72	82	217	54	1,327	5,069	3,267	6,478
73	206	218	88	1,627	6,208	3,317	7,809
74	354	218	185	2,459	10,780	3,658	13,195
75	181	236	87	1,359	6,435	3,570	8,044
76	47	239	52	1,119	3,607	1,295	6,997
77	13	217	42	1,373	2,637	631	4,634
78	273	230	128	693	7,854	3,428	5,893
79	81	234	61	907	4,037	3,141	5,284
80	164	235	82	1,176	6,434	3,321	7,590
81	98	234	71	904	4,124	2,480	5,964
82	215	231	192	1,473	9,071	3,486	9,749
83	424	236	415	2,285	10,850	3,617	13,276
84	158	234	78	1,490	6,642	3,240	8,618
85	77	225	59	783	3,977	1,977	6,219
86	191	234	105	1,214	7,704	3,211	7,918
87	59	230	58	680	3,958	2,108	5,860
88	88	238	63	1,077	3,914	1,586	5,726
89	109	236	72	946	4,734	2,096	5,370
90	69	237	63	701	3,610	1,637	4,922
91	42	209	57	718	3,055	1,340	4,139
Average	**151**	**228**	**103**	**1,286**	**5,993**	**2,753**	**7,510**
Average (cfs)	**209**		**143**	**1,776**	**8,278**		**10,373**

C-081901

TABLE II-2. CONTINUED

	Sacramento R. Bend Bridge	Sacramento R. Bend Bridge	Sacramento R. Butte City	Sacramento R. Grimes	Sacramento R. Verona	Sacramento R. Yolo Bypass	Sacramento R. Freeport
Water Year	Unimpaired Flow (TAF)	Historical Flow (TAF)	Historical Flow (TAF)	Historical Flow (TAF)	Historical Flow (TAF)	Historical Flow (TAF)	Historical Flow (TAF)
67	10,532	11,167	12,475	10,551	20,468	3,666	24,267
68	6,943	8,784	8,878	7,835	11,443	669	13,395
69	11,896	11,699	14,460	10,203	19,426	6,290	23,394
70	11,687	12,736	13,886	8,755	17,288	8,512	20,317
71	10,765	11,718	12,750	10,459	20,074	1,308	22,842
72	6,595	7,366	7,186	6,683	10,896	30	12,488
73	9,712	10,457	12,706	9,599	17,918	3,892	20,787
74	15,850	16,914	19,474	12,352	26,556	7,577	30,705
75	9,446	10,076	11,290	9,381	17,185	952	19,968
76	4,753	7,739	7,024	6,535	9,741	15	10,978
77	3,414	5,040	4,188	3,698	5,194	1	5,505
78	12,053	9,020	11,098	8,212	15,190	2,848	17,716
79	5,658	6,405	6,394	5,958	10,769	154	13,052
80	9,770	9,976	11,249	7,636	16,436	6,511	19,275
81	6,416	7,329	6,918	6,412	10,131	126	11,515
82	13,359	13,114	15,059	10,937	24,684	7,239	30,142
83	17,282	18,540	21,833	13,063	28,471	14,983	34,096
84	9,477	10,822	12,006	9,205	19,153	4,695	22,415
85	5,526	7,145	6,666	6,257	10,456	172	12,209
86	11,184	10,502	11,589	7,176	15,141	10,623	18,137
87	5,297	6,734	6,347	5,881	9,014	35	10,044
88	5,382	6,544	6,091	5,676	8,715	116	9,667
89	6,604	6,538	6,252	5,876	10,685	45	12,261
90	4,729	5,529	5,077	4,720	8,552	21	9,873
91	3,996	4,690	4,334	4,080	6,664	75	7,551
Average	**8,773**	**9,463**	**10,209**	**7,886**	**14,810**	**3,222**	**17,304**
Average (cfs)	**12,062**	**13,071**	**14,101**	**10,892**	**20,456**	**4,451**	**23,901**

NOTE:
TAF = thousand acre-feet.

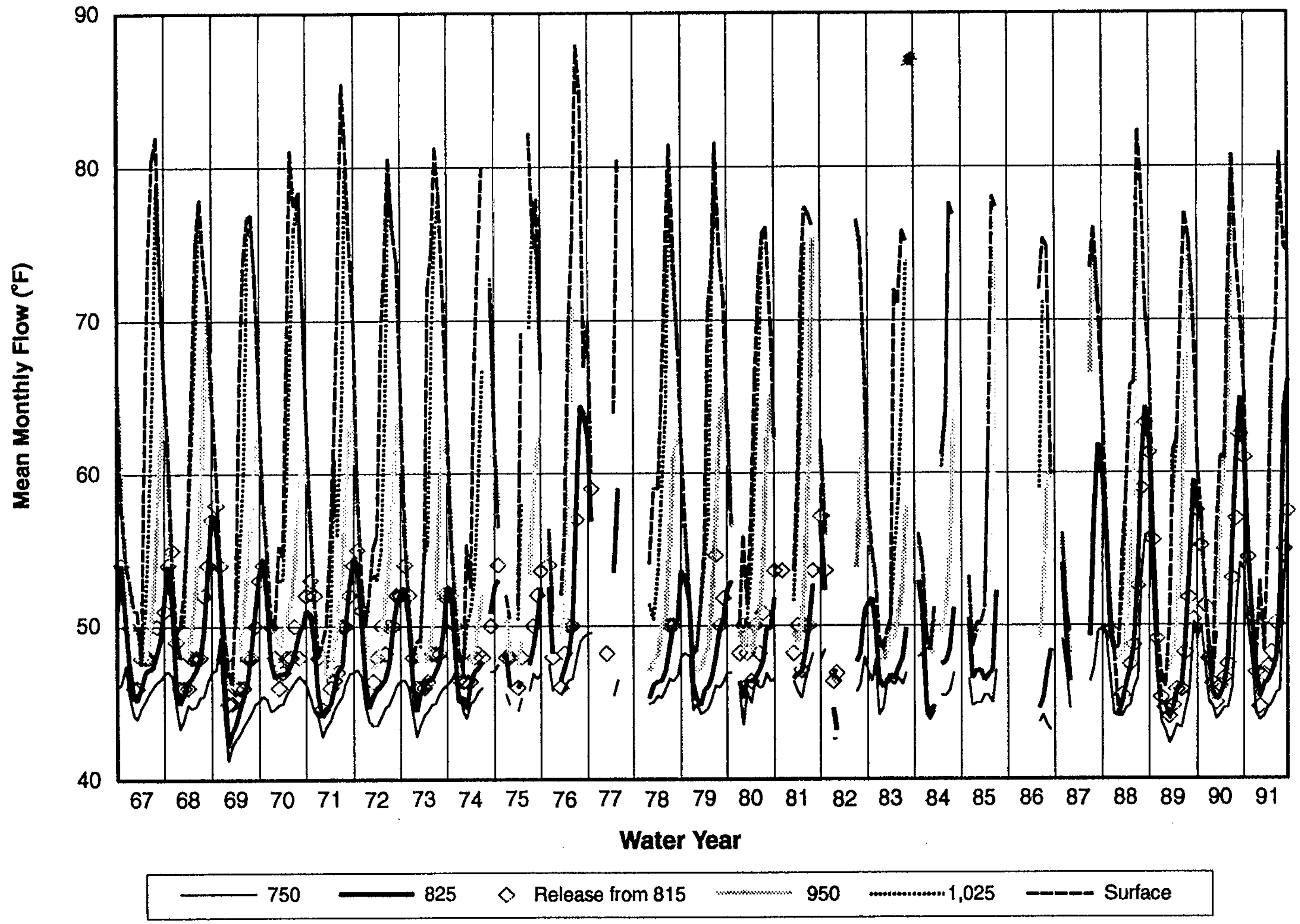


FIGURE II-11

RELEASE TEMPERATURE AND WATER TEMPERATURES AT 750-, 825-, 950-, AND 1,025-FOOT ELEVATIONS IN SHASTA LAKE (1967-1991)

Whiskeytown Lake

Whiskeytown Dam, located on Clear Creek, is a 282-foot-high earth-fill structure providing storage capacity of approximately 241,000 af and a surface area of 3,225 acres. Although Whiskeytown Lake collects some natural inflow from Clear Creek (1967-1991 average inflow of 151,000 af/yr), most of its inflow comes through the Clear Creek tunnel from the Trinity River (1967-1991 average Trinity River diversions of 1.03 million af/yr). Table II-3 gives the geometry characteristics and outlet elevations for Whiskeytown Lake. The Spring Creek tunnel outlet is at elevation 1,085 feet. The Clear Creek releases are made from outlets at elevation 975 feet or 1,110 feet. Figure II-12 shows the Whiskeytown Lake storage for 1967-1991.

Reservoir Temperatures. Figure II-13 shows the Whiskeytown Lake temperatures for 1967-1991. The reservoir exhibits a seasonal temperature stratification, which is the greatest during summer. Surface water temperatures reach a maximum of approximately 75°F, and bottom temperatures are approximately 50°F. A temperature control curtain was installed at the upstream end of Whiskeytown Lake to stabilize the stratification and allow the cool inflows from the Trinity River to flow under the surface layer. A second temperature control curtain was installed around the Spring Creek intake to force the withdrawal zone to remain closer to the bottom so that warm surface water would not be withdrawn.

Release Temperatures. Releases from Whiskeytown Lake to Clear Creek maintain required instream flows and provide downstream irrigation diversions. Most releases from Whiskeytown Lake are made to the Spring Creek Powerhouse. Figure II-14 shows the Judge Francis Carr Powerhouse inflow and Spring Creek release temperatures from Whiskeytown Lake, collected as grab samples, for the 1967-1991 period.

Sacramento River

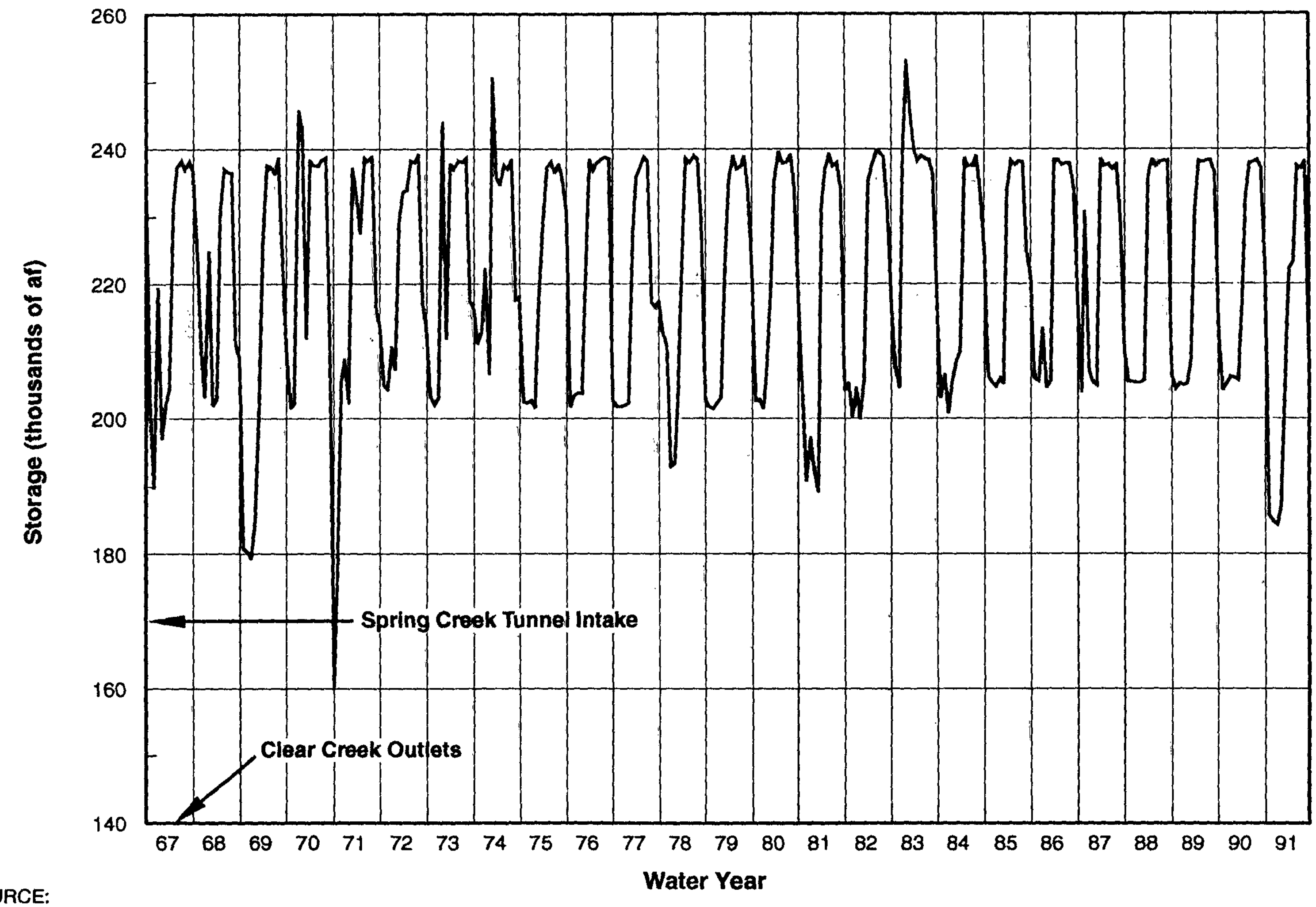
River Flows and Temperatures. Figure II-15 shows the monthly flow at Bend Bridge for 1967-1991. Bend Bridge is the traditional index location for Sacramento River unimpaired runoff (natural runoff without any diversion storage), with an average annual unimpaired flow for 1967-1991 of 8.8 million af/yr (Table II-2). The effects of Shasta Lake storage and Trinity River diversions can be identified by comparing historical flows with unimpaired flows at Bend Bridge. The seasonal pattern of flow at Bend Bridge is characterized by very high flows during some winter months (reservoir flood control releases) and relatively high flows during the summer irrigation season.

Sacramento River temperatures are greatly affected by ambient air temperatures, especially during summer. Ambient air temperatures and tributary contributions combine to produce high summer river temperatures that are harmful to some fishery resources (e.g., chinook salmon eggs and fry) in the river between Keswick Reservoir and RBDD. The effects of high summer water temperatures are more severe during water years with relatively low-flow conditions in late summer. Water temperatures in the primary salmon spawning area (from Keswick Reservoir to RBDD) affect the growth of specific runs during critical reproductive stages (Reclamation, 1991). Figure II-16 shows the effects of Shasta Lake and Whiskeytown Lake releases on daily temperatures below Keswick during 1991. River outlet releases (bypass flows) from Shasta Lake

TABLE II-3
ELEVATION/AREA/STORAGE RELATIONSHIP FOR WHISKEYTOWN LAKE

Elevation (feet)	Area (acres)	Incremental Area (acres)	Storage (TAF)	Incremental Storage (TAF)
1,220	3,458	234	274.4	33.3
1,210	3,224	230	241.1	31.0
1,200	2,994	241	210.1	28.6
1,190	2,753	234	181.5	26.2
1,180	2,519	240	155.3	23.9
1,170	2,279	240	131.4	21.5
1,160	2,039	230	110.0	19.1
1,150	1,809	218	90.8	16.9
1,140	1,591	218	74.0	14.7
1,130	1,373	209	59.3	12.6
1,120	1,164	201	46.7	10.5
1,110	963	176	36.2	8.6
1,100	787	164	27.5	7.0
1,090	623	127	20.6	5.5
1,080	496	113	15.1	4.3
1,070	383	88	10.8	3.3
1,060	295	76	7.4	2.5
1,050	219	61	4.9	1.8
1,040	158	56	3.1	1.3
1,030	102	37	1.8	0.8
1,020	65	26	1.0	0.5
1,010	39	19	0.5	0.3
1,000	20	11	0.2	0.1
990	9	5	0.1	0.1
980	4	3	0.0	0.0
970	1	1	0.0	0.0
960	1		0.0	

NOTES:
TAF = thousand acre-feet.
Clear Creek outlets are at elevations 975 and 1,110 feet.
Spring Creek tunnel intake is at elevation 1,085 feet, with a capacity of 4,400 cfs.



SOURCE:
CDEC data base maintained by DWR.

FIGURE II-12

END-OF-MONTH STORAGE FOR WHISKEYTOWN LAKE (1967-1991)

C-081906

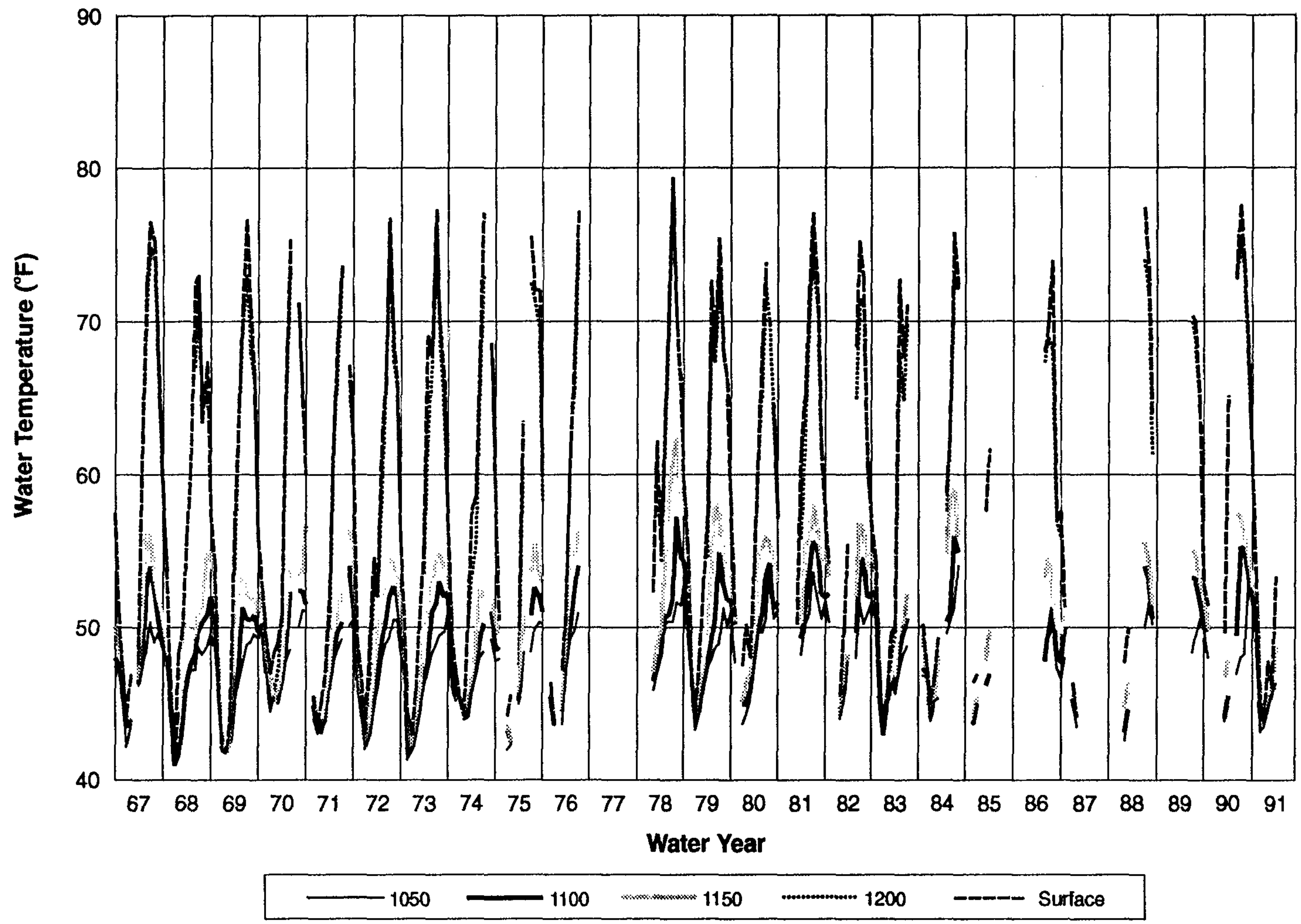
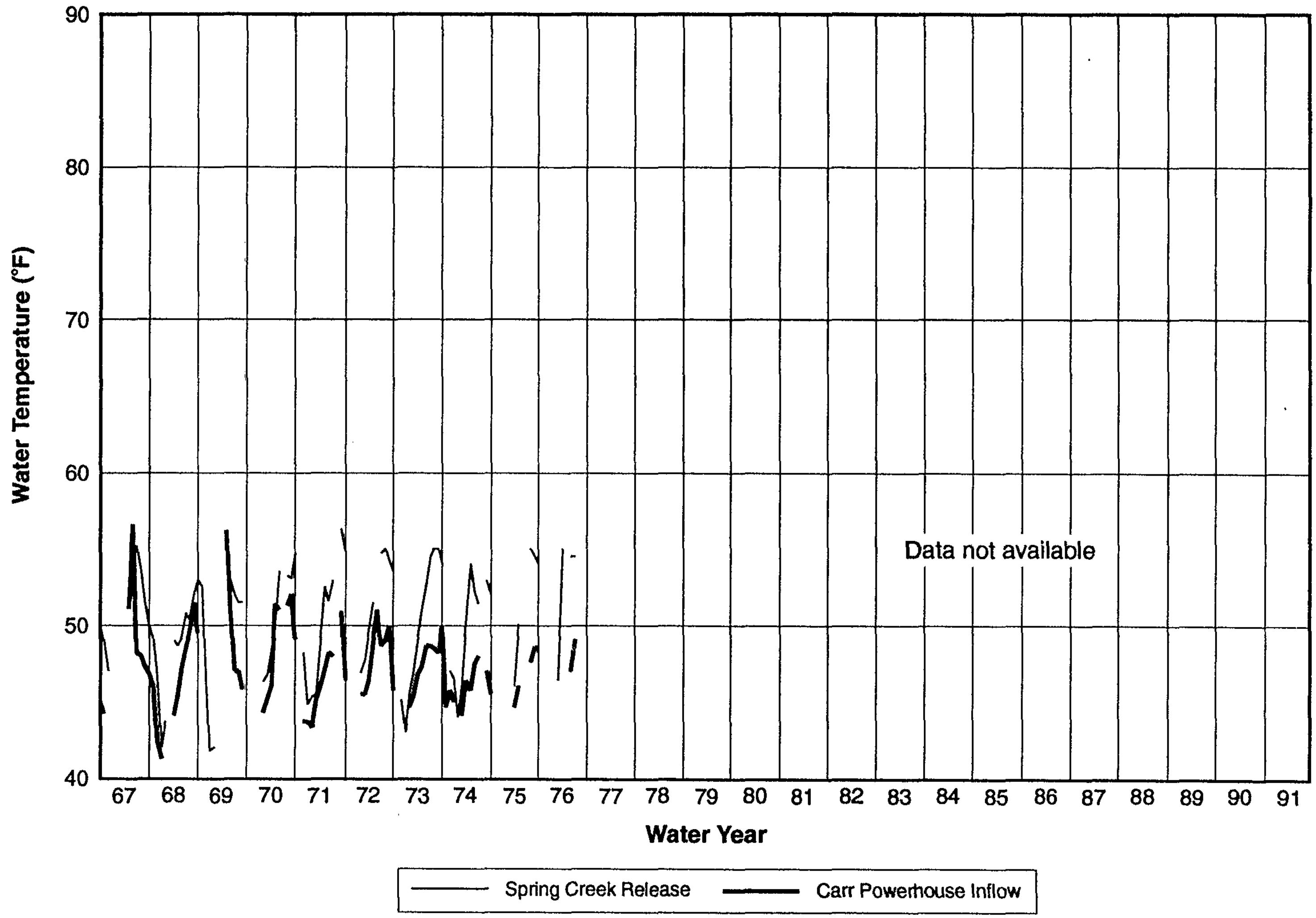


FIGURE II-13

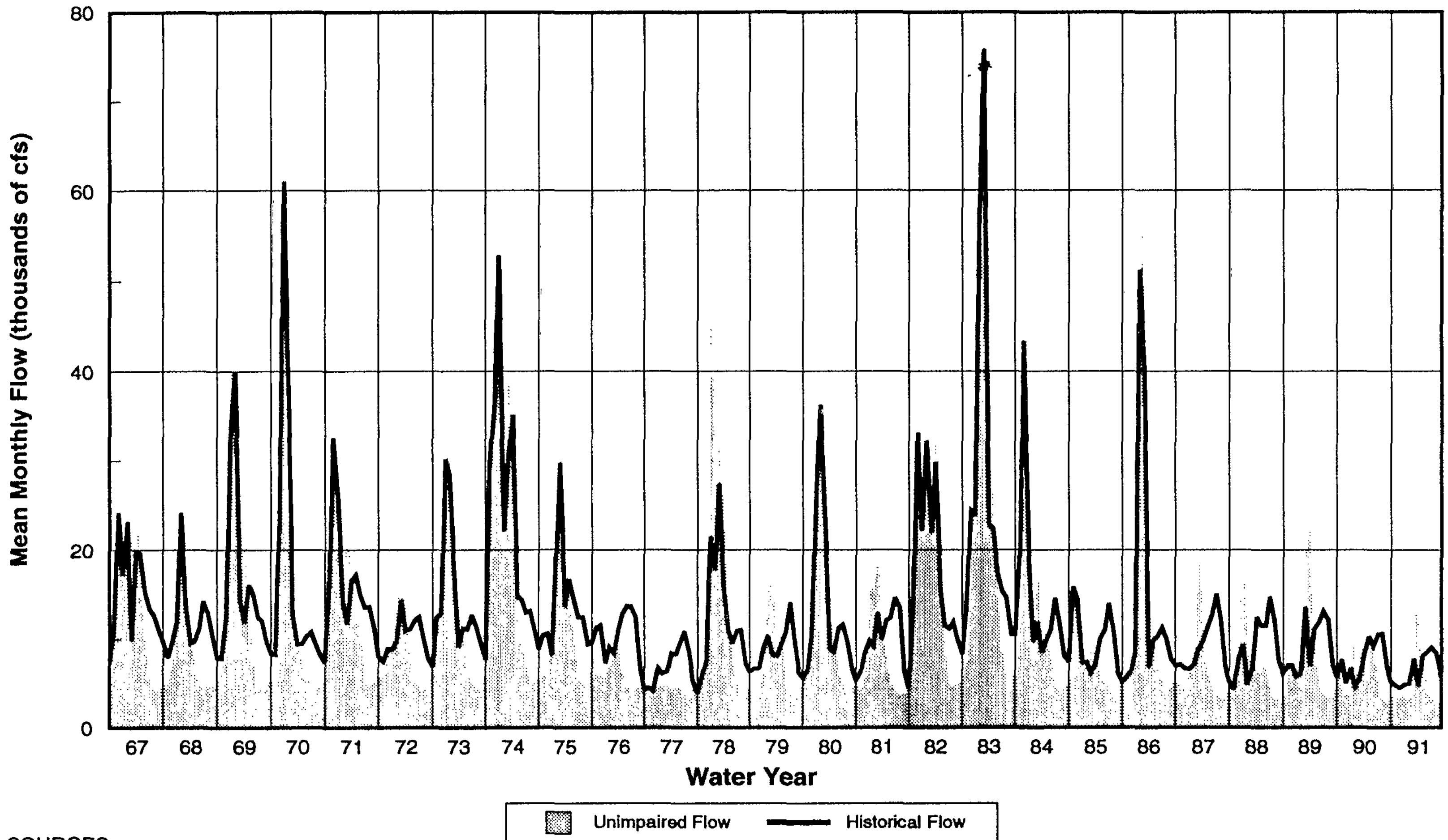
WATER TEMPERATURES IN WHISKEYTOWN LAKE AT 1,050-, 1,100-, 1,150-, AND 1,200-FOOT ELEVATIONS (1967-1991)



SOURCE:
STORET data base maintained by EPA.

FIGURE II-14

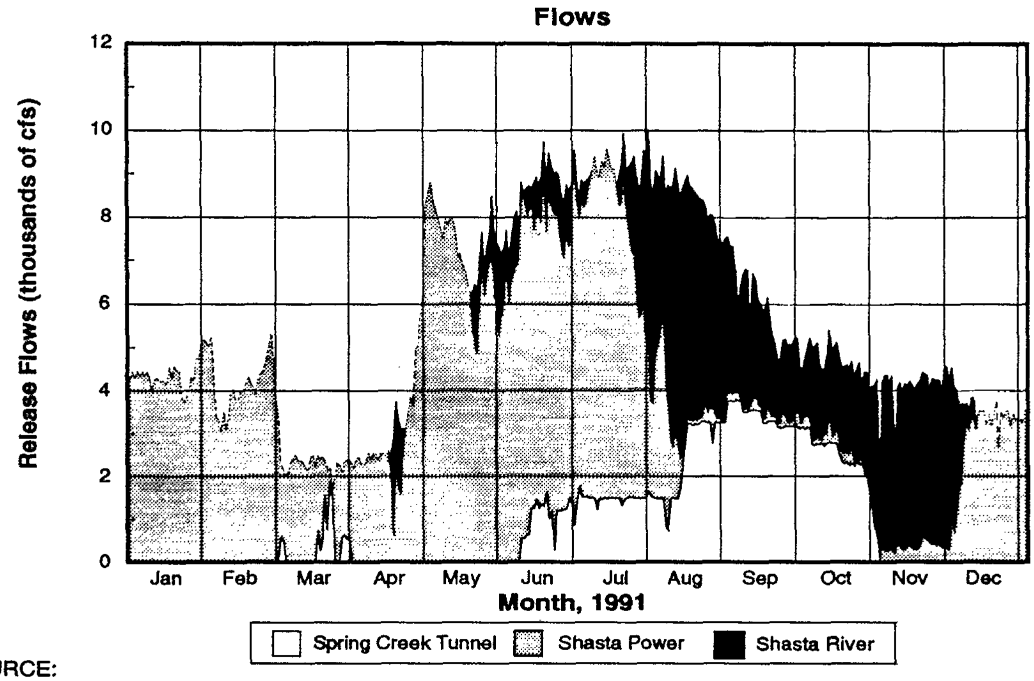
INFLOW AND RELEASE TEMPERATURES FOR WHISKEYTOWN LAKE (1967-1991)



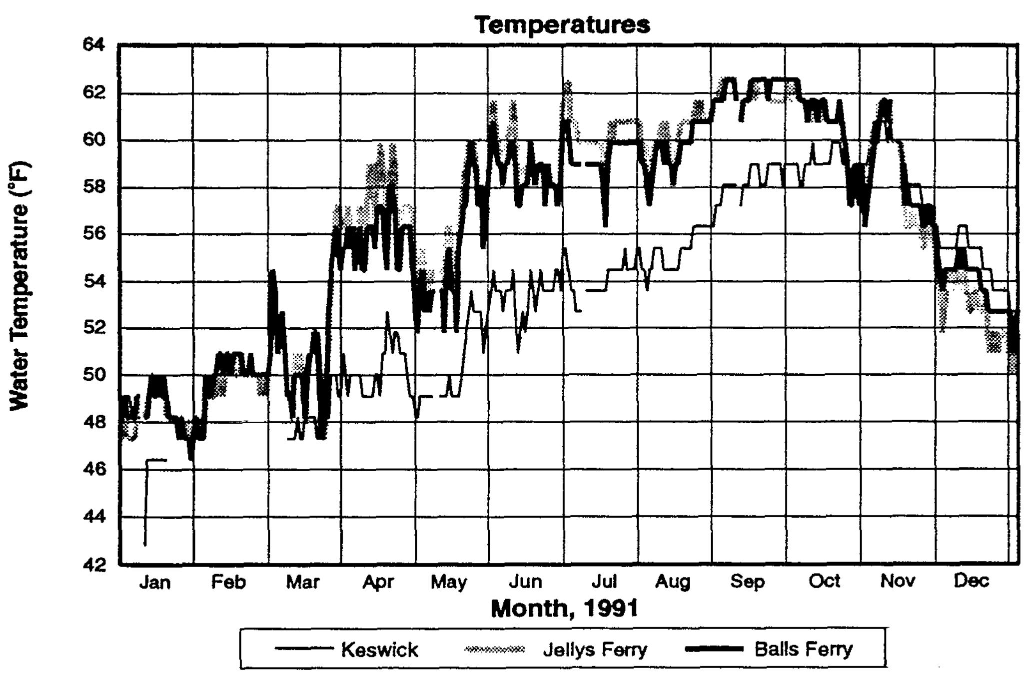
SOURCES:
CDEC data base maintained by DWR and
WATSTORE data base maintained by USGS.

FIGURE II-15

MEAN MONTHLY UNIMPAIRED RUNOFF AND HISTORICAL FLOWS FOR SACRAMENTO RIVER AT BEND BRIDGE NEAR RED BLUFF (1967-1991)



SOURCE:
CVP Operations Center.



SOURCE:
DWR North District and CDEC data base maintained by DWR.

FIGURE II-16

DAILY AVERAGE FLOWS AND MAXIMUM DAILY TEMPERATURES FOR THE UPPER SACRAMENTO RIVER

reduced release temperatures and helped control Sacramento River temperatures between Keswick Reservoir and RBDD from August to November.

Flows and climate continue to influence Sacramento River temperatures downstream of RBDD. Figure II-17 shows effects of daily flow and climate on Sacramento River daily temperatures for 1978. Flows at Bend Bridge were stable throughout the year. Flows increased dramatically during major storms at Butte City, but a maximum flow of approximately 30,000 cfs was maintained at Grimes because most of these floodflows entered the Sutter Bypass. During spring and summer, flows were remarkably constant from Bend Bridge to Grimes because irrigation diversions are almost balanced by tributary inflows. River temperatures increased dramatically between Bend Bridge and Butte City during summer. Additional warming occurred between Butte City and Grimes, although the river temperatures tend to approach a maximum possible temperature (called the equilibrium temperature), which is determined by climatic conditions.

Figure II-18 shows monthly Sacramento River flows for 1967-1991 at Freeport along with estimates of monthly Yolo Bypass flows. Because the Sacramento River channel has a limited conveyance capacity, a substantial amount of the Sacramento River flow enters the Sutter Bypass below Butte City and then flows through the Yolo Bypass. Feather River and American River flows also may be diverted into the Yolo Bypass at the Sacramento and Fremont weirs.

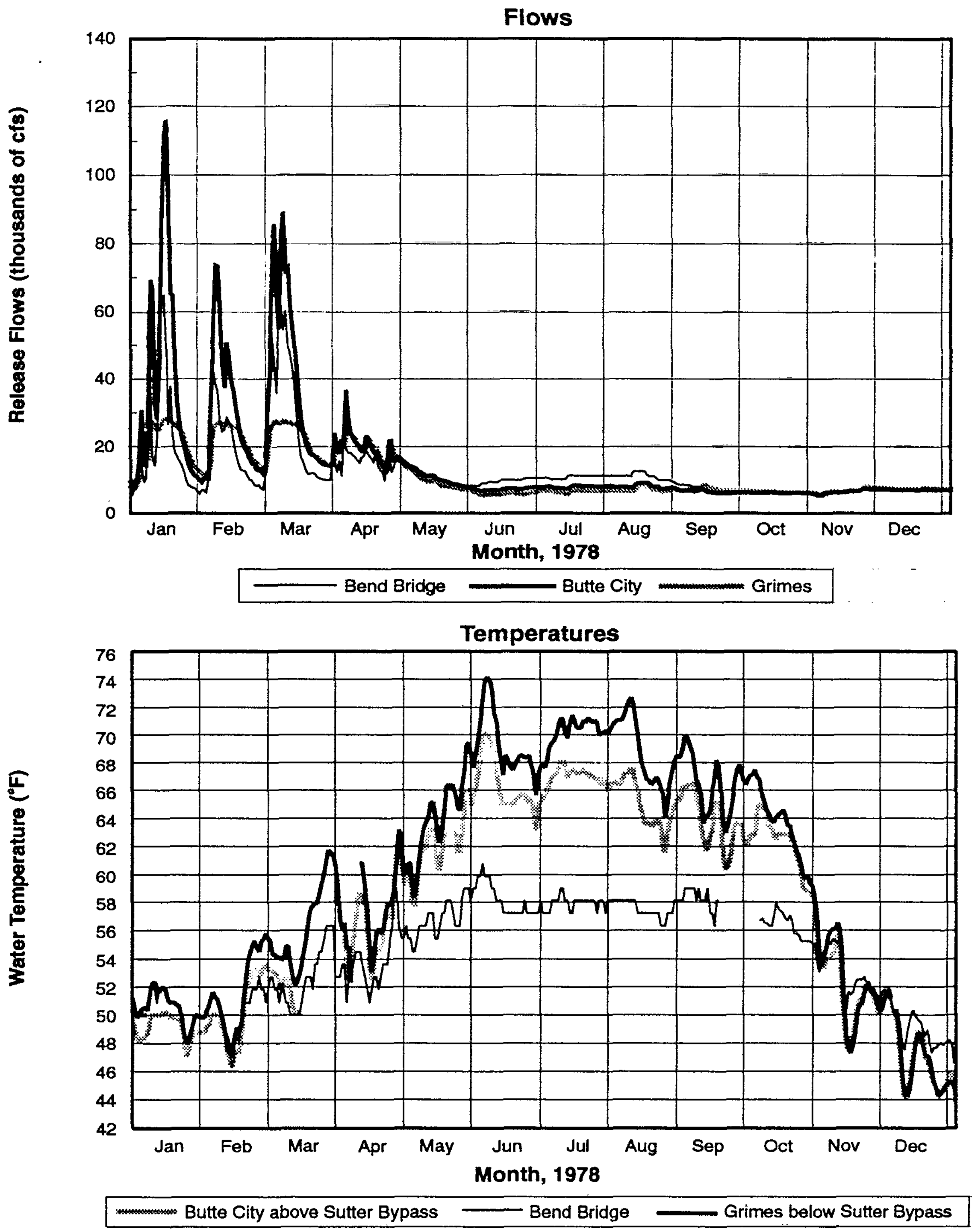
Figure II-19 shows monthly river temperatures at Bend Bridge, Grimes, and Freeport for 1967-1991. Because most of the warming occurs upstream of Grimes, temperatures measured at Freeport are fairly representative of the lower Sacramento River.

Suspended Solids and Electrical Conductivity. Sacramento River SS and EC values are influenced largely by tributary inflows and agricultural drainage. The Colusa Basin Drain contributes substantial quantities of SS, nutrients, and pesticides and elevated EC values (University of California, Davis, 1980). Figure II-20 shows monthly SS concentrations at Freeport for 1967-1991. The highest SS concentrations are associated with runoff events.

Figure II-21 shows monthly EC measurements at Greene's Landing (near Freeport) for 1967-1991. The variation in EC within each month (i.e., maximum, mean, and minimum average daily EC values are shown) is relatively small. Elevated EC values occur during low-flow periods, but the overall variation in Sacramento River EC at Greene's Landing is relatively small, ranging between 100 and 250 microsiemens per centimeter (μS/cm).

Feather River

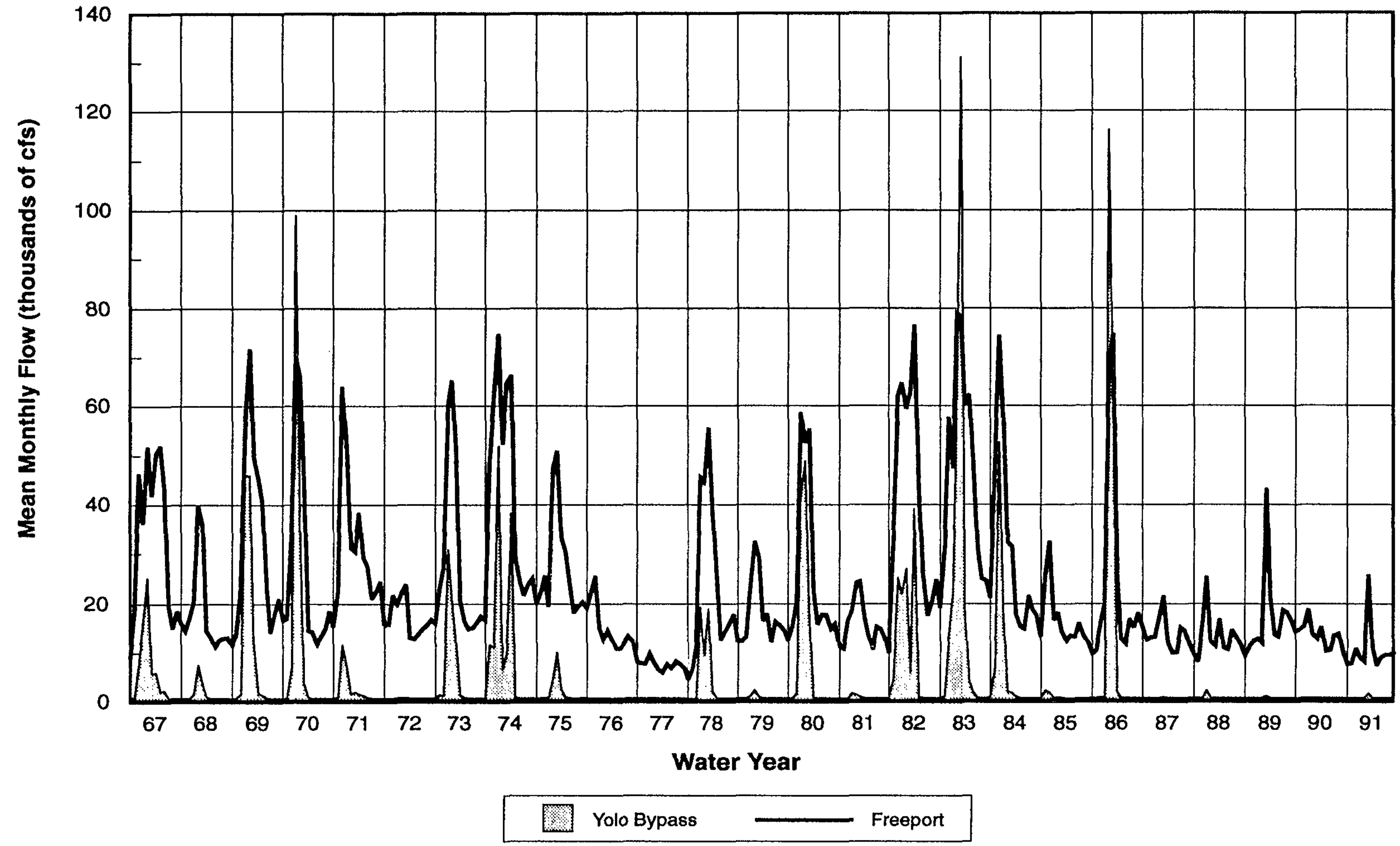
The Feather River contributes a substantial amount of high-quality water to the Sacramento River. Originating in the volcanic formations of the Sierra Nevada, the Feather River flows southwest to Lake Oroville. From the lake, the river flows south to the Thermalito Diversion Pool (16,000-af volume), where it can be pumped back into Lake Oroville, released down the Feather River, or diverted to the Thermalito Forebay (10,000-af volume) and Afterbay (71,000-af volume) reservoirs. A pumpback powerhouse connects these two storage pools. Releases to the Feather River below the diversion pool are regulated by instream flow requirements. The Feather River hatchery is located below the diversion pool. Most of the diverted water is



SOURCE:
WATSTORE data base maintained by USGS.

FIGURE II-17

DAILY AVERAGE FLOWS AND MAXIMUM DAILY TEMPERATURES FOR SACRAMENTO RIVER AT BEND BRIDGE, BUTTE CITY, AND GRIMES

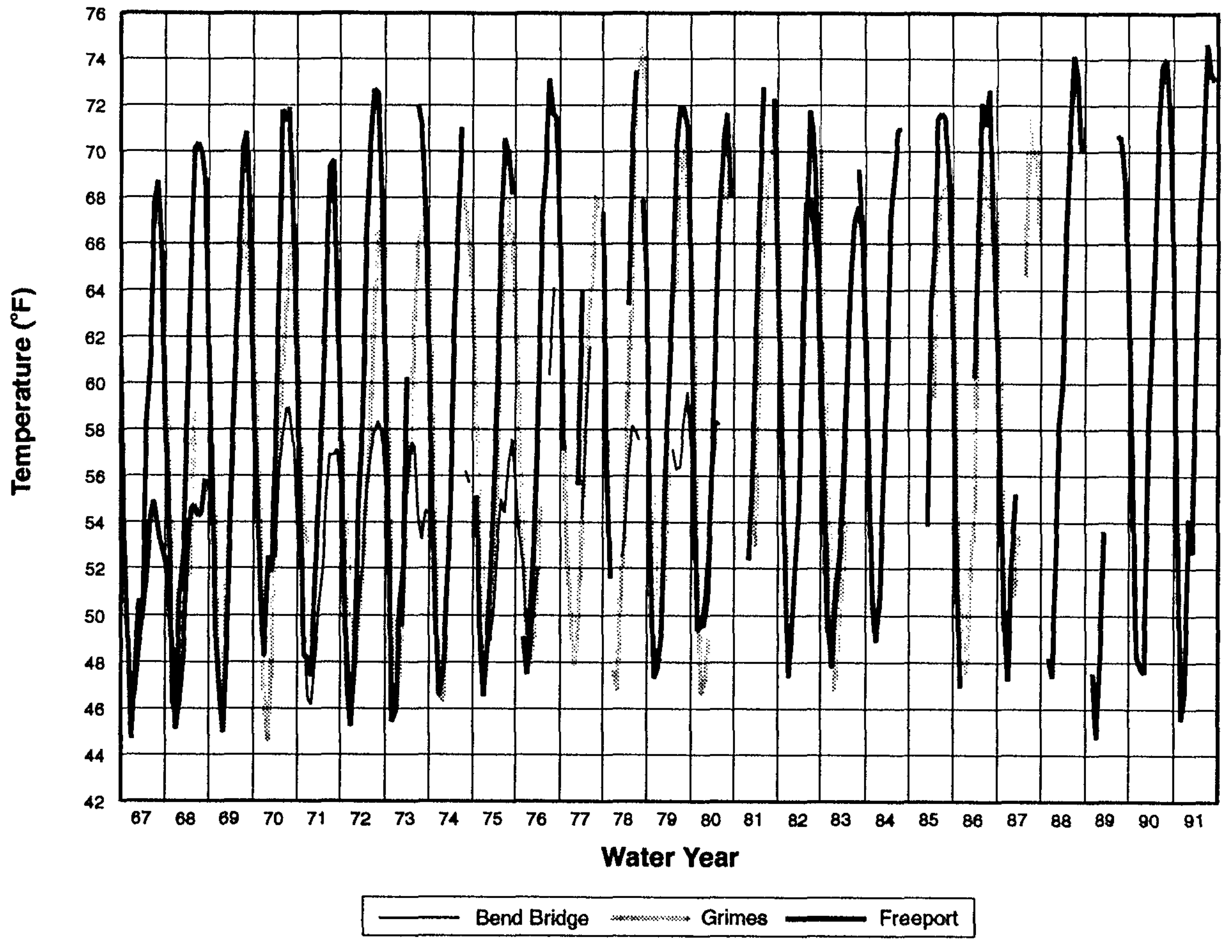


SOURCE:
WATSTORE data base maintained by USGS.

FIGURE II-18

MEAN MONTHLY FLOWS FOR YOLO BYPASS AND SACRAMENTO RIVER AT FREEPORT (1967-1991)

C-081914



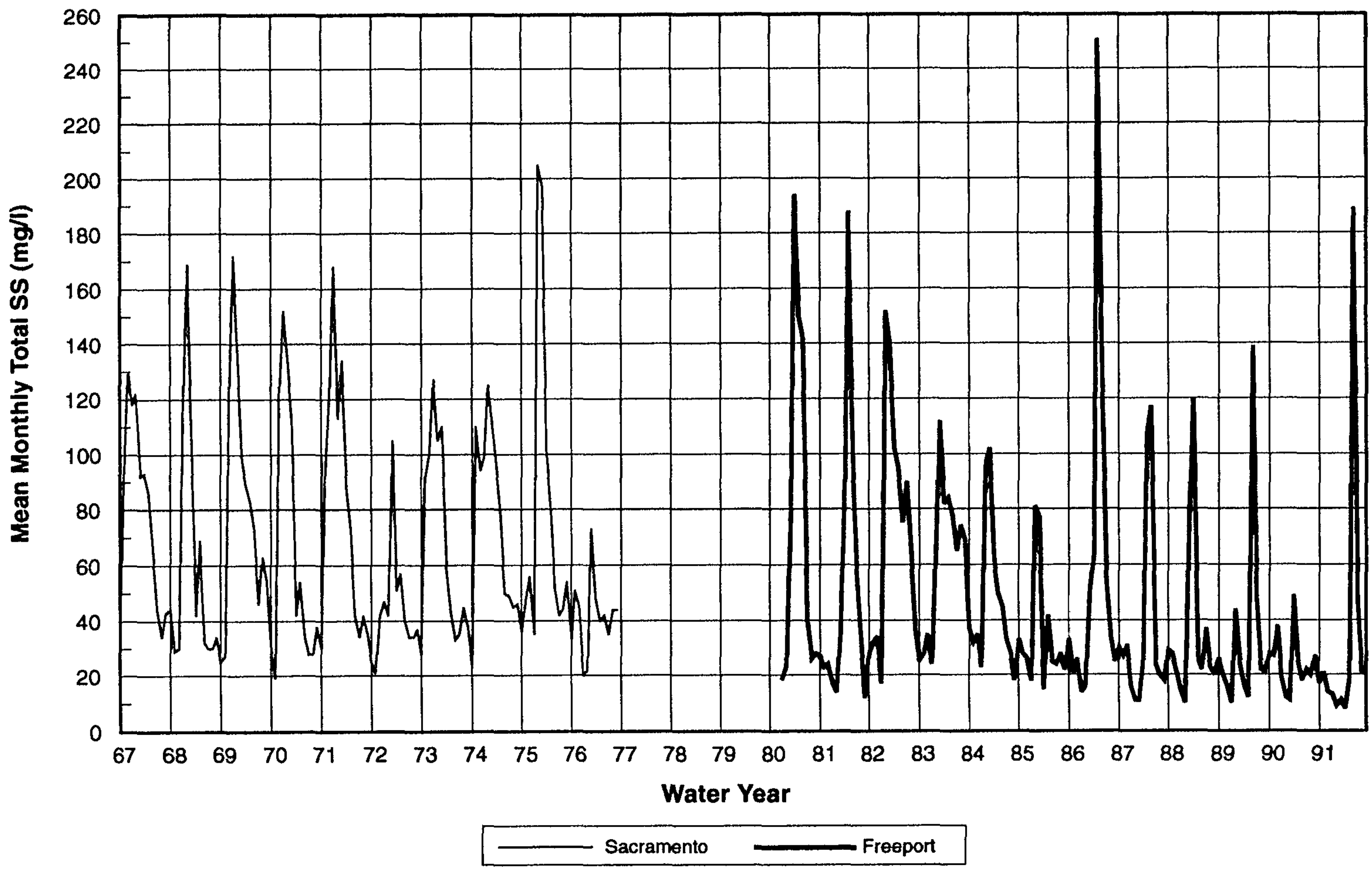
NOTE:
The Bend Bridge data presented here are a combination of data gathered from two USGS stations in the Red Bluff/Bend Bridge vicinity.

SOURCE:
WATSTORE data base maintained by USGS.

FIGURE II-19

MONTHLY MEAN OF MAXIMUM DAILY TEMPERATURES FOR SACRAMENTO RIVER AT BEND BRIDGE NEAR RED BLUFF, GRIMES, AND FREEPORT (1967-1991)

C-081914

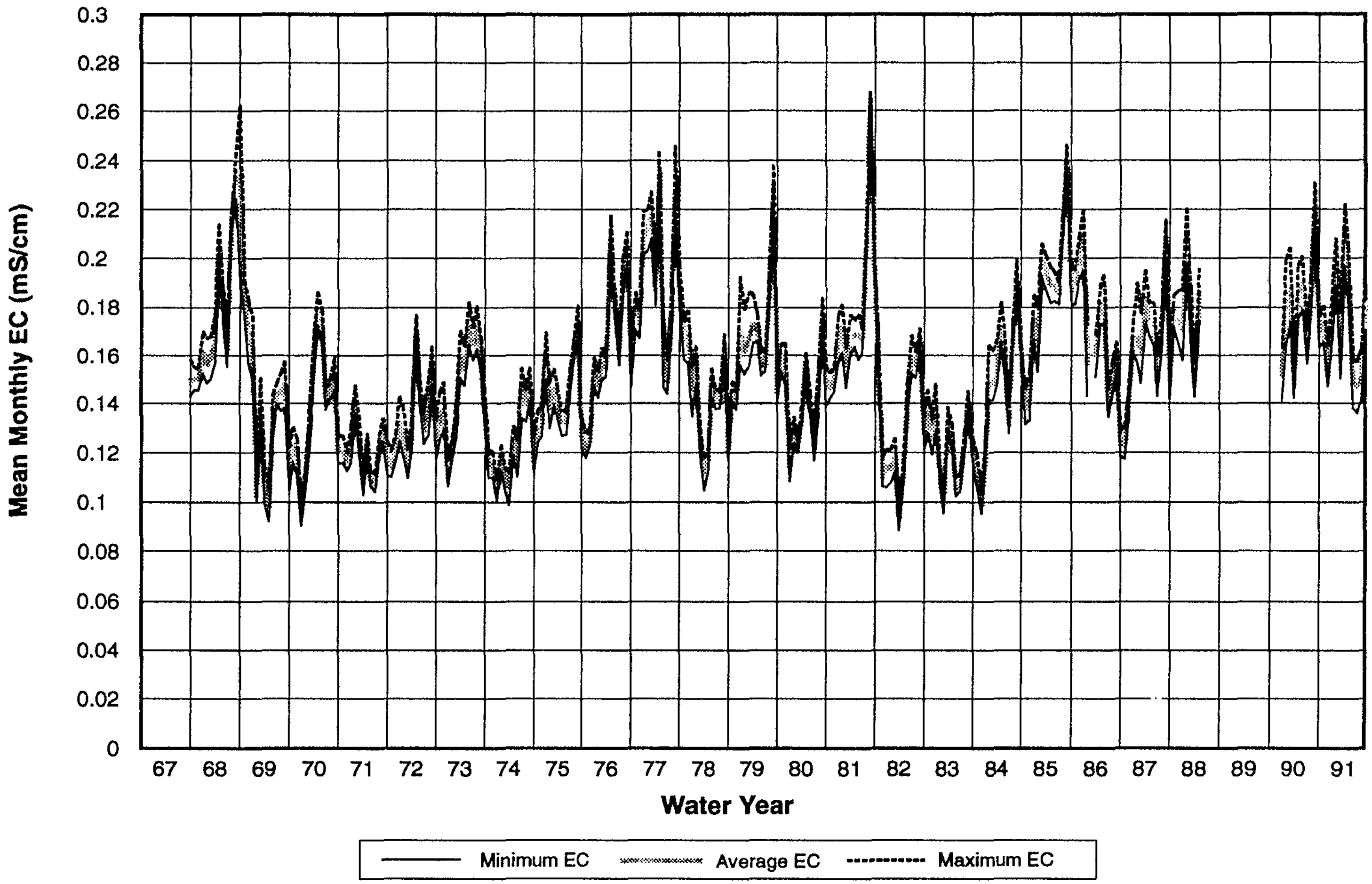


SOURCE:
WATSTORE data base maintained by USGS.

FIGURE II-20

MEAN MONTHLY TOTAL SUSPENDED SOLIDS CONCENTRATIONS FOR SACRAMENTO RIVER AT SACRAMENTO AND FREEPORT (1967-1991)

C-081915



SOURCE:
STORET data base maintained by EPA.

FIGURE II-21

MEAN MONTHLY EC VALUES FOR THE GREENE'S LANDING MONITORING STATION (1967-1991)

returned to the Feather River downstream via the Thermalito Afterbay release, while some water is diverted from the Thermalito Afterbay to various canals. Downstream of the Thermalito Afterbay release, the Feather River is joined by two major tributaries: the Yuba and Bear rivers. The Yuba River joins the Feather River at the City of Marysville; confluence with the Bear River is approximately 15 miles downstream.

Lake Oroville. Lake Oroville has a storage capacity of approximately 3.54 million af. Completed in 1968, the lake functions as the major storage facility for the SWP. The geometry characteristics of Lake Oroville are given in Table II-4. The Hyatt Powerhouse intake is at elevation 615 feet; the 13 temperature control panels can raise the sill elevation in 19-foot increments, from a minimum elevation of approximately 615 feet to a maximum elevation of approximately 860 feet. These are operated to reserve cool water for later in the summer. Panels are raised to lower the effective elevation of the powerhouse outlet and lower the release temperature. Low-level river outlets were used in 1977 to provide cooler water from below the powerhouse outlet.

The target release temperatures for the Feather River Fish Hatchery are less than 56°F in September, and less than 55°F in October and November. The hatchery has recently installed chillers to help control temperatures during late summer and fall of low runoff years when reservoir drawdown makes Lake Oroville release temperatures higher than the target temperatures. Lower temperatures are still necessary to protect natural spawning and rearing of chinook salmon.

Table II-5 gives annual Feather River flows and reservoir operations. Figure II-22 shows the monthly storage in Lake Oroville for 1967-1991. The average annual change in storage has been approximately 1 million af, with an average carryover storage of 2.2 million af. Carryover storage was less than 1 million af in 1977 and 1990.

Figure II-23 shows unimpaired Feather River flows at Oroville and historical monthly Feather River flows at Gridley, downstream of Thermalito Afterbay releases. The effects of Lake Oroville storage and diversions from Thermalito Afterbay are evident. The average 1967-1991 unimpaired flow at Oroville was 4.62 million af/yr (6,386 cfs). The average flow at Gridley was 3.47 million af/yr (4,797 cfs), so the average diversion from Thermalito Afterbay must have been approximately 1,500 cfs (correcting for the 25-year average flow of 100 cfs needed to fill Lake Oroville).

Release Temperatures. Releases from Whiskeytown Lake to Clear Creek maintain required instream flows and provide downstream irrigation diversions. Most releases from Whiskeytown Lake are made to the Spring Creek Powerhouse. Figure II-14 shows the Judge Francis Carr Powerhouse inflow and Spring Creek release temperatures from Whiskeytown Lake, collected as grab samples, for the 1967-1991 period.

TABLE II-4

ELEVATION/AREA/STORAGE RELATIONSHIP FOR LAKE OROVILLE

Elevation (feet)	Area (acres)	Incremental Area (acres)	Storage (TAF)	Incremental Storage (TAF)
910	16,344	543	3,698	161
900	15,801	496	3,538	156
890	15,305	491	3,382	151
880	14,813	479	3,231	146
870	14,334	466	3,086	141
860	13,868	455	2,945	136
850	13,413	444	2,808	132
840	12,969	426	2,676	128
830	12,543	429	2,549	123
820	12,113	423	2,426	119
810	11,691	410	2,307	115
800	11,281	406	2,192	111
790	10,874	402	2,081	107
780	10,472	398	1,974	103
770	10,074	384	1,872	99
760	9,689	361	1,773	95
750	9,328	362	1,678	91
740	8,967	347	1,586	88
730	8,620	340	1,498	84
720	8,279	329	1,414	81
710	7,951	317	1,333	78
700	7,634	325	1,255	75
690	7,309	316	1,180	72
680	6,993	304	1,108	68
670	6,689	289	1,040	65
660	6,400	283	975	63
650	6,117	278	912	60
640	5,839	274	852	57
630	5,565	264	795	54
620	5,302	258	741	52
610	5,044	249	689	49
600	4,795	240	640	47
590	4,554	232	593	44
580	4,323	223	549	42
570	4,100	225	507	40
560	3,875	216	467	38
550	3,659	206	329	36
540	3,454	195	394	34
530	3,258	185	360	32
520	3,074		328	

NOTES:

TAF = thousand acre-feet.
Power plant intake is at elevation 615 feet with panels operating between 615 and 859 feet.
River outlet is at elevation 220 feet.

TABLE II-5

HYDROLOGIC CONDITIONS IN THE FEATHER, YUBA, AND AMERICAN RIVER DRAINAGES

	Feather R. Oroville	Feather R. Oroville	Feather R. Oroville	Feather R. Thermalito Afterbay	Feather R. Gridley	Feather R. Yuba City	Yuba R. Bullards Bar	Yuba R. Smartville
Water Year	Unimpaired Flow (TAF)	End-of September Storage (TAF)	Historical Flow (TAF)	Historical Flow (TAF)	Historical Flow (TAF)	Historical Flow (TAF)	End-of September Storage (TAF)	Unimpaired Flow (TAF)
67	6,276	0	5,740		5,134	599	0	3,299
68	3,471	1,678	549		853	1,127	0	1,585
69	7,069	2,780	968	3,575	4,650	4,945	551	3,673
70	6,239	2,542	1,710	3,585	5,359	5,585	691	2,899
71	5,944	2,730	353	4,150	4,552	4,787	606	2,855
72	3,223	2,612	300	2,033	2,354	2,447	595	1,714
73	4,750	2,729	488	2,922	3,483	3,821	615	2,668
74	8,332	2,397	1,363	6,065	7,506	7,942	737	3,972
75	4,862	2,858	388	2,806	3,237	3,492	617	2,384
76	1,844	1,828	292	1,755	1,960	1,994	344	666
77	995	915	293	800	1,009	1,033	258	370
78	5,682	2,744	250	1,929	2,240	2,605	582	2,986
79	3,024	2,672	293	1,913	2,127	2,319	624	1,729
80	5,537	2,611	1,331	2,816	4,171	4,249	339	3,188
81	2,488	2,354	294	1,496	1,722		376	1,107
82	9,051	2,775	1,510	5,756	7,337	7,928	574	4,964
83	9,440	2,818	1,653	6,797	8,630	9,251	693	4,722
84	5,738	2,529	759	4,206	5,078	5,429	476	3,152
85	2,650	2,132	302	1,910	2,169		531	1,326
86	6,904	2,661	2,291	2,774	5,053		706	3,567
87	2,182	1,979	335	1,352	1,627		615	882
88	1,996	1,529	426	1,185	1,555		542	916
89	3,682	2,150	481	1,381	1,828		621	2,222
90	2,142	1,163	458	1,687	2,092		714	1,236
91	2,058	1,399	451	698	1,103		622	1,172
Average	**4,623**	**2,183**	**931**	**2,765**	**3,473**	**4,386**	**521**	**2,370**
Average (cfs)	**6,386**		**1,286**	**3,819**	**4,797**	**6,057**		**3,274**

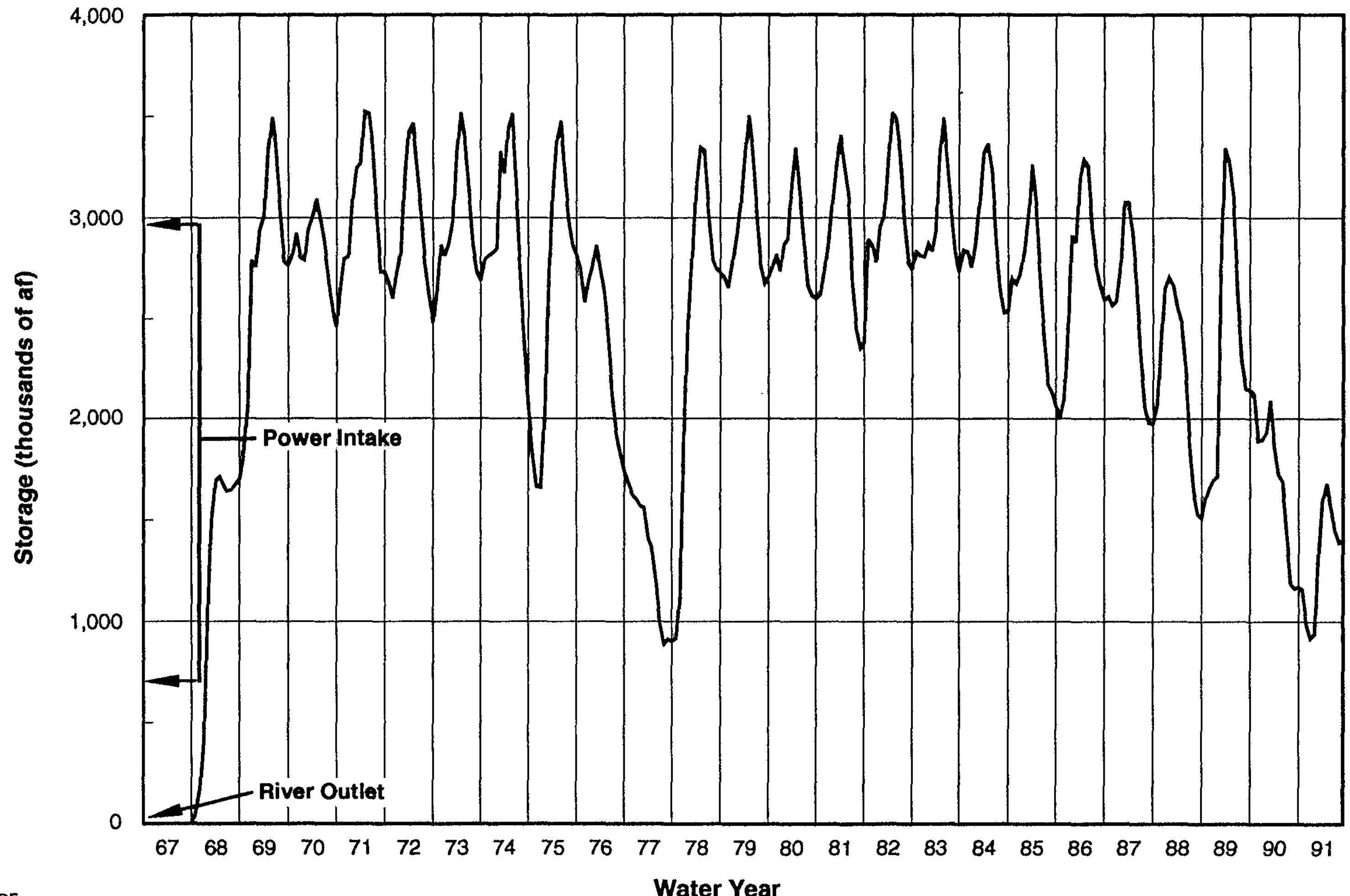
C-081919

TABLE II-5. CONTINUED

Water Year	Yuba R. Smartville Historical Flow (TAF)	Yuba R. Marysville Historical Flow (TAF)	Bear R. North Wheatland Historical Flow (TAF)	Feather R. Nicolaus Historical Flow (TAF)	American R. Folsom End-of September Storage (TAF)	American R. Folsom Unimpaired Flow (TAF)	American R. Fair Oaks Historical Flow (TAF)
67	2,525	2,679	417	8,975	799	3,962	3,801
68	1,039	1,030	144	2,204	551	1,712	2,006
69	2,330	2,630	510	8,557	814	4,455	4,234
70	2,037	2,124	434	8,816	549	3,154	3,607
71	2,150	2,078	389	7,423	686	2,972	2,900
72	1,143	994	127	3,668	659	1,870	2,035
73	1,875	1,939	421	6,520	742	3,017	2,976
74	3,043	3,271	611	12,470	773	4,263	4,353
75	1,839	1,833	227	5,523	773	2,625	2,713
76	793	643	29	2,751	416	798	1,394
77	299	165	2	1,232	147	350	563
78	1,725	1,791	362	4,749	700	3,225	2,354
79	1,098	1,039	185	3,812	710	2,044	2,156
80	2,697	2,777	418	7,918	670	3,873	3,923
81	693	575	43	2,601	600	1,133	1,353
82	3,824	4,242	796	13,547	756	6,172	5,815
83	3,579	3,999	869	14,666	752	6,396	6,421
84	2,577	2,758	539		681	3,890	4,067
85	811	717	135		587	1,583	1,730
86	2,680	2,799	498		653	4,714	4,516
87	646	482	13		430	886	1,198
88	659	500	11		218	851	1,026
89	1,521	1,439	203		571	2,243	1,683
90	705	537	52		178	1,122	1,584
91	841	748	14		506	1,186	919
Average	**1,725**	**1,752**	**298**	**6,790**	**597**	**2,740**	**2,773**
Average (cfs)	**2,383**	**2,419**	**411**	**9,379**		**3,784**	**3,830**

Note:
TAF = thousand acre-feet.

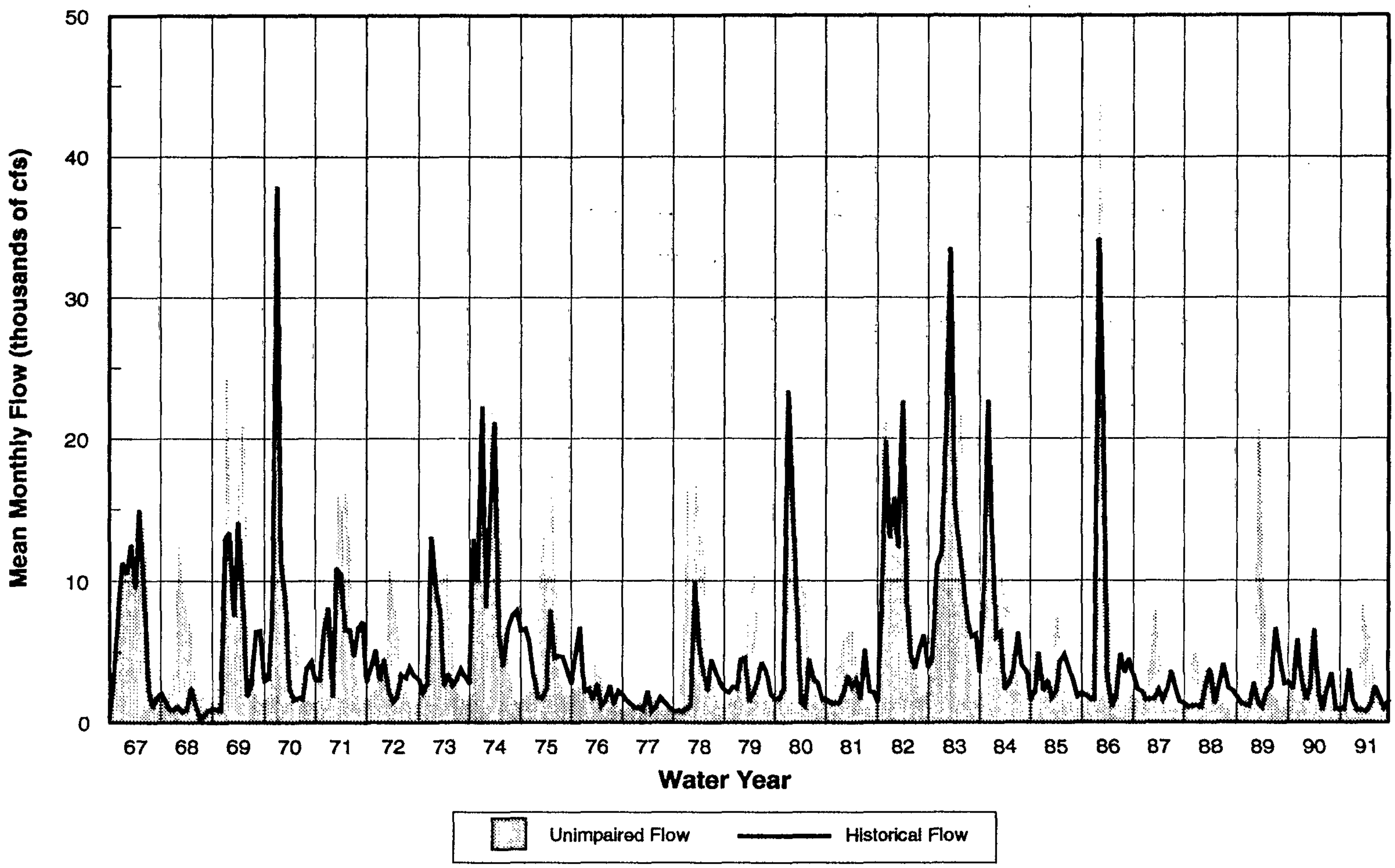
C-081920



SOURCE:
CDEC data base maintained by DWR.

FIGURE II-22

END-OF-MONTH STORAGE FOR LAKE OROVILLE (1967-1991)



SOURCE:
CDEC data base maintained by DWR and
WATSTORE data base maintained by USGS.

FIGURE II-23

MEAN MONTHLY UNIMPAIRED RUNOFF AT OROVILLE AND HISTORICAL FEATHER RIVER FLOWS AT GRIDLEY (1967-1991)

Sacramento River

River Flows and Temperatures. Figure II-15 shows the monthly flow at Bend Bridge for 1967-1991. Bend Bridge is the traditional Sacramento River unimpaired runoff (natural runoff without any diversion storage) index location, with an average annual unimpaired flow for 1967-1991 of 8.7 million af/yr (Table II-2). The effects of Shasta Lake storage and Trinity River diversions can be identified by comparing historical flows with unimpaired flows at Bend Bridge. The seasonal pattern of flow at Bend Bridge is characterized by very high flows during some winter months (reservoir flood control releases) and relatively high flows during the summer irrigation season.

Sacramento River temperatures are greatly affected by ambient air temperatures, especially during summer. Ambient air temperatures and tributary contributions combine to produce high summer river temperatures that are harmful to some fishery resources (e.g., chinook salmon eggs and fry) in the river between Keswick Reservoir and RBDD. The effects of high summer water temperatures are more severe during water years with relatively low-flow conditions in late summer. Water temperatures in the primary salmon spawning area (from Keswick Reservoir to RBDD) affect the growth of specific runs during critical reproductive stages (Reclamation, 1991). Figure II-16 shows the effects of Shasta Lake and Whiskeytown Lake releases on daily temperatures below Keswick during 1991. River outlet releases (bypass flows) from Shasta Lake reduced release temperatures and helped control Sacramento River temperatures between Keswick Reservoir and RBDD from August to November.

Flows and climate continue to influence Sacramento River temperatures downstream of RBDD. Figure II-17 shows effects of daily flow and climate on Sacramento River daily temperatures for 1978. Flows at Bend Bridge were stable throughout the year. Flows increased dramatically during major storms at Butte City, but a maximum flow of approximately 30,000 cfs was maintained at Grimes because most of these floodflows entered the Sutter Bypass. During spring and summer, flows were remarkably constant from Bend Bridge to Grimes because irrigation diversions are almost balanced by tributary inflows. River temperatures warmed dramatically between Bend Bridge and Butte City during summer. Additional warming occurred between Butte City and Grimes, although the river temperatures tend to approach a maximum possible temperature (called the equilibrium temperature), which is determined by climatic conditions.

Figure II-18 shows monthly Sacramento River flows for 1967-1991 at Freeport along with estimates of monthly Yolo Bypass flows. Because the Sacramento River channel has a limited conveyance capacity, a substantial amount of the Sacramento River flow enters the Sutter Bypass below Butte City and then flows through the Yolo Bypass. Feather River and American River flows also may be diverted into the Yolo Bypass at the Sacramento and Fremont weirs.

Figure II-19 shows monthly river temperatures at Bend Bridge, Grimes, and Freeport for 1967-1991. Because most of the warming occurs upstream of Grimes, temperatures measured at Freeport are fairly representative of the lower Sacramento River.

Suspended Solids and Electrical Conductivity. Sacramento River SS and EC values are influenced largely by tributary inflows and agricultural drainage. The Colusa Basin Drain contributes substantial quantities of SS, nutrients, and pesticides and elevated EC values

(University of California, Davis, 1980). Figure II-20 shows monthly SS concentrations at Freeport for 1967-1991. The highest SS concentrations are associated with runoff events.

Figure II-21 shows monthly EC measurements at Greene's Landing (near Freeport) for 1967-1991. The variation in EC within each month (i.e., maximum, mean, and minimum average daily EC values are shown) is relatively small. Elevated EC values occur during low-flow periods, but the overall variation in Sacramento River EC at Greene's Landing is relatively small, ranging between 100 and 250 microsiemens per centimeter (μS/cm).

Feather River

The Feather River contributes a substantial amount of high-quality water to the Sacramento River. Originating in the volcanic formations of the Sierra Nevada, the Feather River flows southwest to Lake Oroville. From the lake, the river flows south to the Thermalito Diversion Pool (16,000-af volume), where it can be pumped back into Lake Oroville, released down the Feather River, or diverted to the Thermalito Forebay (10,000-af volume) and Afterbay (71,000-af volume) reservoirs. A pumpback powerhouse connects these two storage pools. Releases to the Feather River below the diversion pool are regulated by instream flow requirements. The Feather River hatchery is located below the diversion pool. Most of the diverted water is returned to the Feather River downstream via the Thermalito Afterbay release, while some water is diverted from the Thermalito Afterbay to various canals. Downstream of the Thermalito Afterbay release, the Feather River is joined by two major tributaries: the Yuba and Bear rivers. The Yuba River joins the Feather River at the City of Marysville; confluence with the Bear River is approximately 15 miles downstream.

Lake Oroville. Lake Oroville has a storage capacity of approximately 3.54 million af. Completed in 1968, the lake functions as the major storage facility for the SWP. The geometry characteristics of Lake Oroville are given in Table II-4. The Hyatt Powerhouse intake is at elevation 615 feet; the 13 temperature control panels can raise the sill elevation in 19-foot increments, from a minimum elevation of approximately 615 feet to a maximum elevation of approximately 860 feet. These are operated to reserve cool water for later in the summer. Panels are raised to lower the effective elevation of the powerhouse outlet and lower the release temperature. Low-level river outlets were used in 1977 to provide cooler water from below the powerhouse outlet.

The target release temperatures for the Feather River Fish Hatchery are less than 56°F in September, and less than 55°F in October and November. The hatchery has recently installed chillers to help control temperatures during late summer and fall of low runoff years when reservoir drawdown makes Lake Oroville release temperatures higher than the target temperatures. Lower temperatures are still necessary to protect natural spawning and rearing of chinook salmon.

Table II-5 gives annual Feather River flows and reservoir operations. Figure II-22 shows the monthly storage in Lake Oroville for 1967-1991. The average annual change in storage has been approximately 1 million af, with an average carryover storage of 2.2 million af. Carryover storage was less than 1 million af in 1977 and 1990.

Figure II-23 shows unimpaired Feather River flows at Oroville and historical monthly Feather River flows at Gridley, downstream of Thermalito Afterbay releases. The effects of Lake Oroville storage and diversions from Thermalito Afterbay are evident. The average 1967-1991 unimpaired flow at Oroville was 4.62 million af/yr (6,386 cfs). The average flow at Gridley was 3.47 million af/yr (4,797 cfs), so the average diversion from Thermalito Afterbay must have been approximately 1,500 cfs (correcting for the 25-year average flow of 100 cfs needed to fill Lake Oroville).

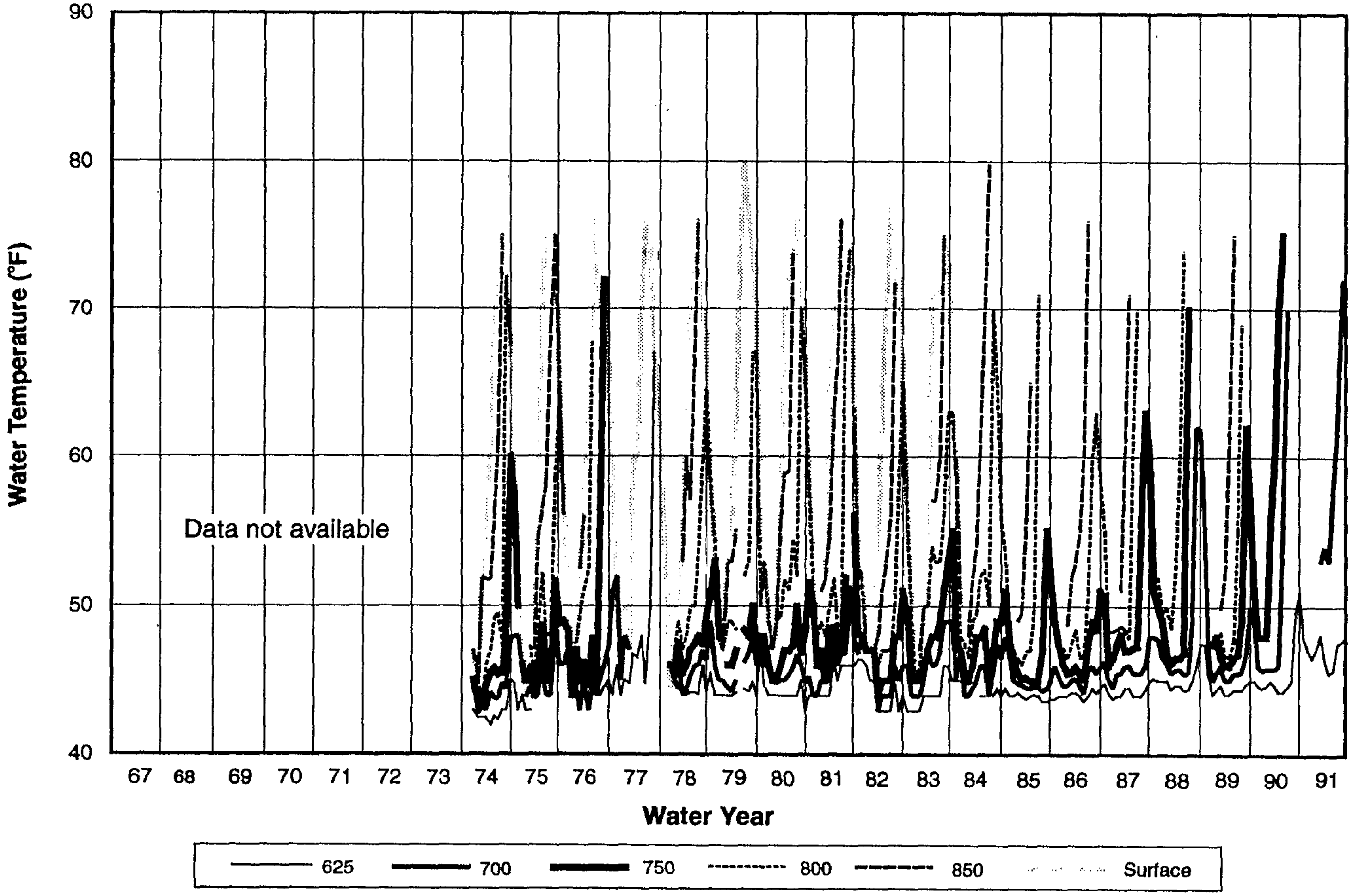
Available temperature measurements in Lake Oroville are shown in Figure II-24. Lake Oroville temperatures indicate that releases may be warmer when reservoir storage is low. The release temperatures are indicated by river temperatures at Oroville, downstream of the Thermalito diversion dam. Figure II-25 shows monthly average water temperatures at Oroville and Nicolaus, downstream of the Yuba River and Bear River confluences. Increasing release temperatures resulting from Lake Oroville drawdown and the worsening effects of meteorological conditions on downstream temperatures can be seen in 1977.

Yuba River Flows and Temperatures. Figure II-26 shows monthly storage in New Bullards Bar Reservoir and Englebright Lake, located on the Yuba River. New Bullards Bar Reservoir contains most of the storage, with a capacity of approximately 966,000 af. Englebright Lake has a capacity of approximately 70,000 af. Figure II-27 shows unimpaired flow and historical monthly Yuba River flows at Smartville, just downstream of Englebright Lake. The 1967-1991 unimpaired flow at Smartville was 2.37 million af/yr (3,274 cfs). Average flow during 1967-1991 at Marysville was 1.75 million af/yr (2,419 cfs). Historical regulated flows are often considerably higher than natural flows during summer. Most of the irrigation diversions from the Yuba River are made at Daguerre Dam, midway between Smartville and Marysville.

Figure II-28 shows monthly average Yuba River temperatures at Smartville and Marysville. Agricultural diversions along the Yuba River may contribute to higher summer temperatures at Marysville because the streamflow downstream of Daguerre Dam is reduced.

American River

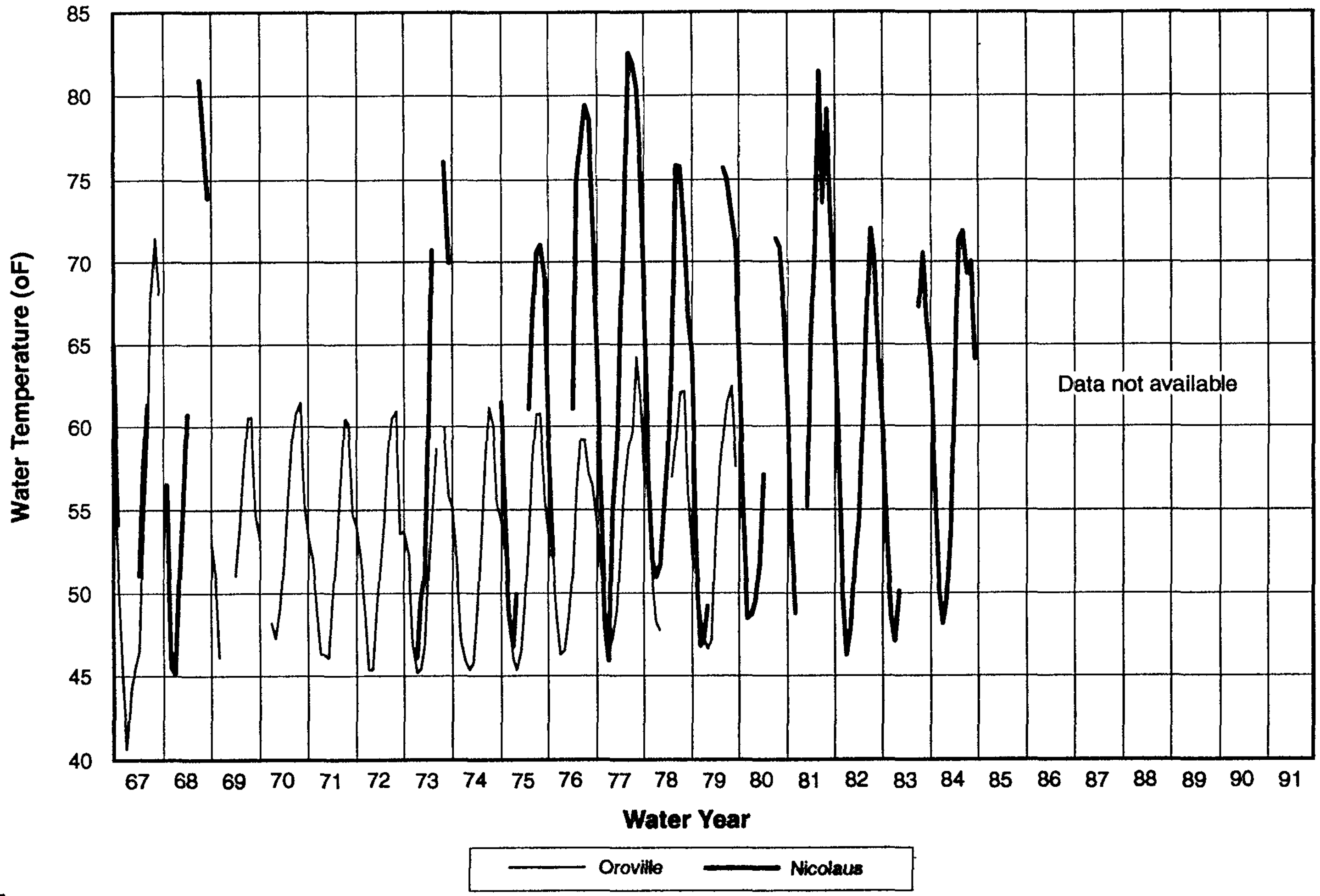
Folsom Lake. Figure II-29 shows monthly storage in Folsom Lake for 1967-1991. Table II-6 gives the lake's geometry characteristics and outlet elevations. Folsom Lake storage capacity is approximately 975,000 af, and the normal annual drawdown is approximately 500,000 af. Very low carryover storage in 1977, 1988, and 1990 may have contributed to warmer releases. Folsom Lake releases are generally made from the powerhouse, with a penstock elevation of 307 feet. The spillway crest is at elevation 418 feet, and river outlets are located at elevations 210 feet and 280 feet. Releases flow into Lake Natoma, with a storage of 9,000 af and a surface area



SOURCE:
Adjusted from various DWR records.

FIGURE II-24

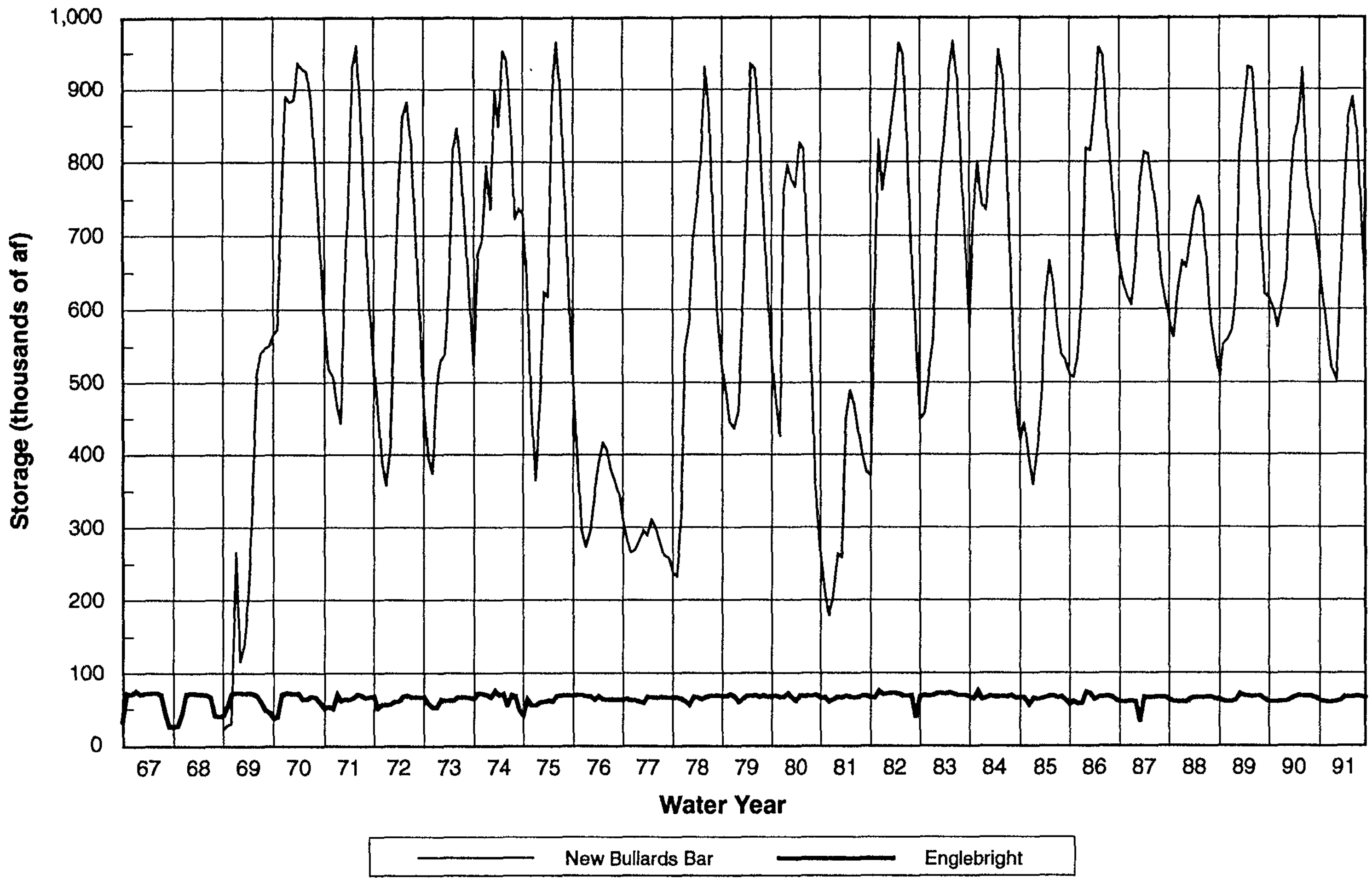
WATER TEMPERATURES IN LAKE OROVILLE AT 625-, 700-, 750-, 800-, AND 850-FOOT ELEVATIONS (1967-1991)



SOURCE:
WATSTORE data base maintained by USGS.

FIGURE II-25

MONTHLY MEAN OF MAXIMUM DAILY TEMPERATURES FOR FEATHER RIVER AT OROVILLE AND NICOLAUS (1967-1991)

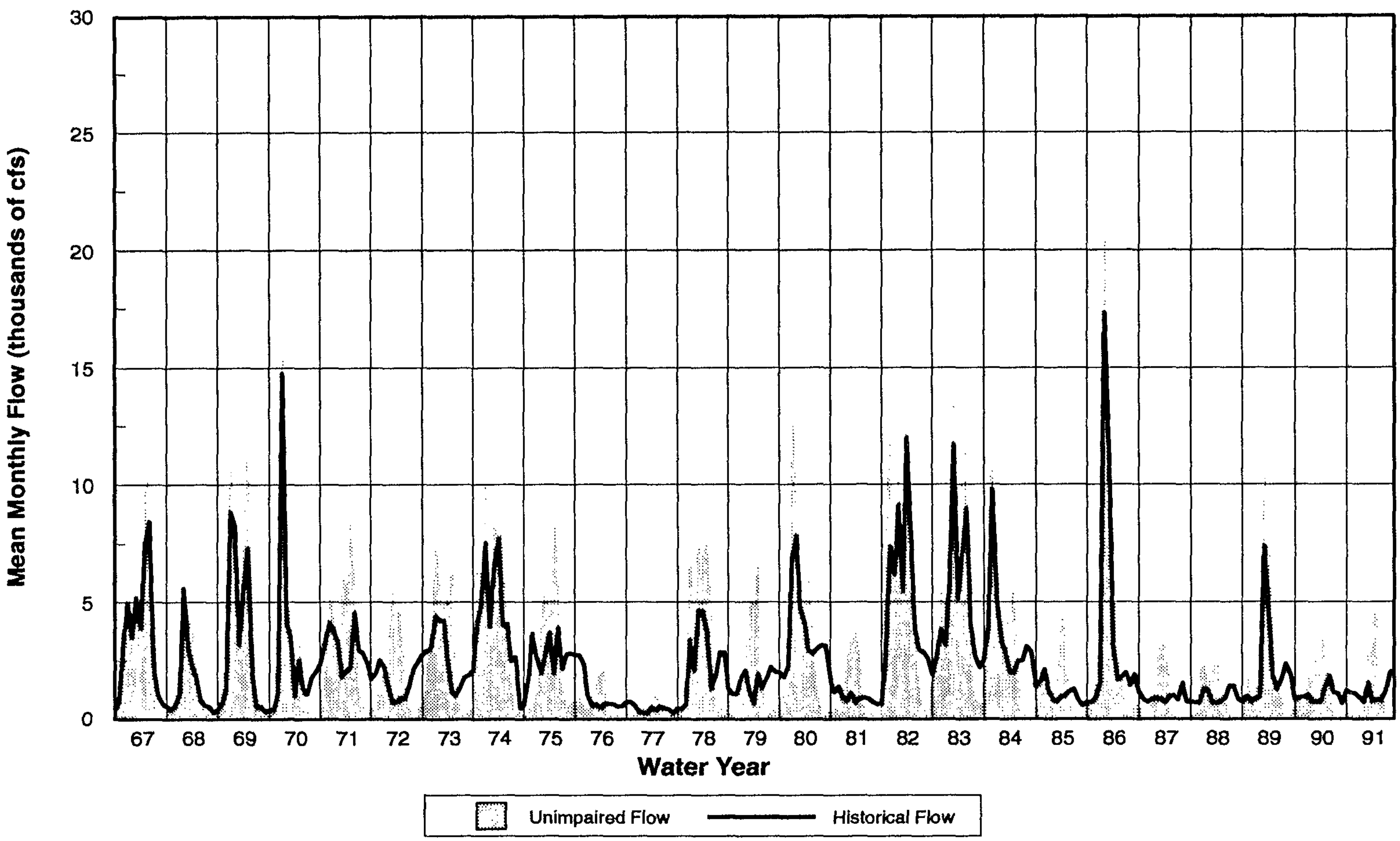


SOURCE:
CDEC data base maintained by DWR.

FIGURE II-26

END-OF-MONTH STORAGE FOR NEW BULLARDS BAR RESERVOIR AND ENGLEBRIGHT LAKE (1967-1991)

C—081928

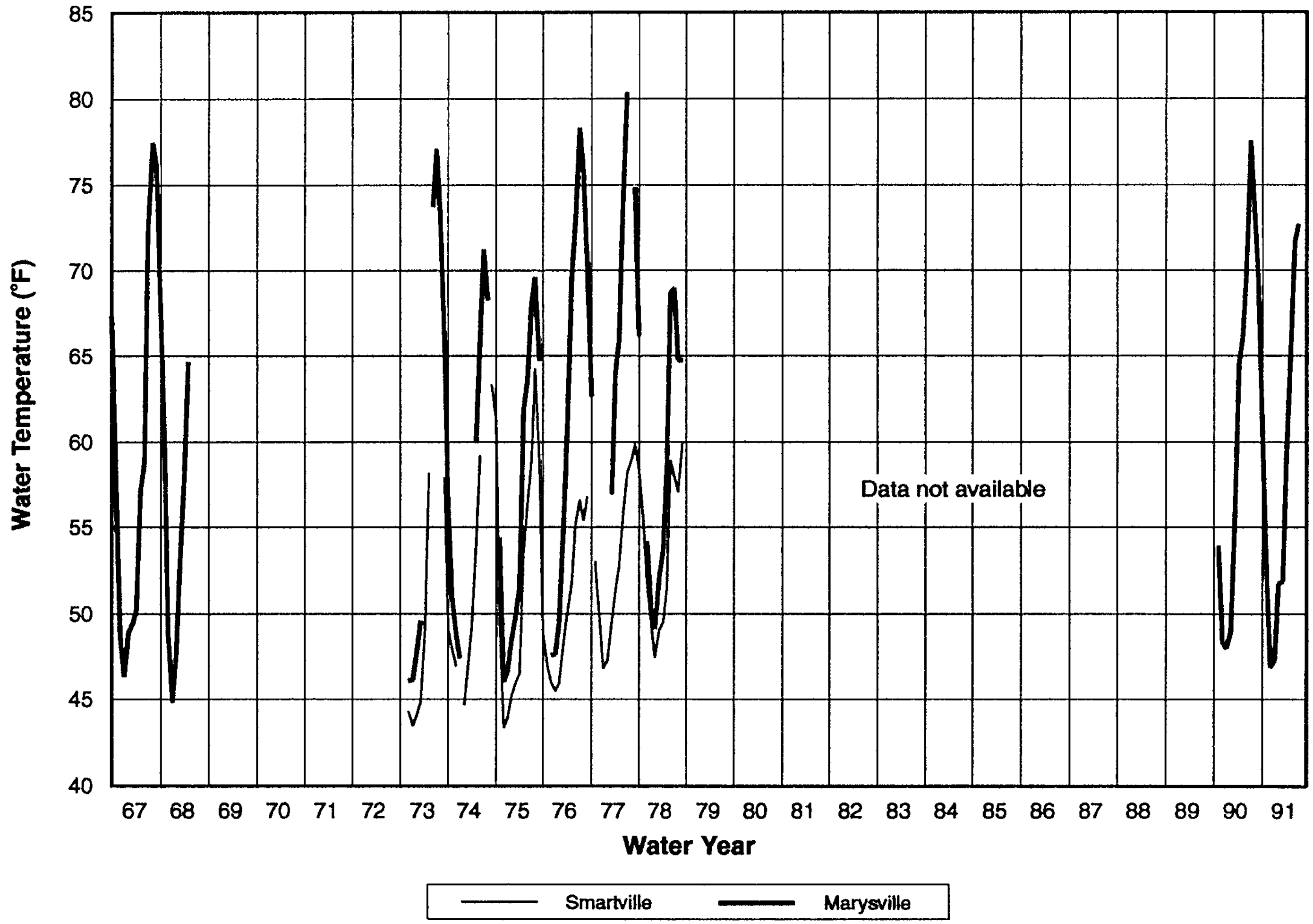


SOURCES: CDEC data base maintained by DWR and
WATSTORE data base maintained by USGS.

FIGURE II-27

MEAN MONTHLY UNIMPAIRED RUNOFF AND HISTORICAL FLOWS FOR YUBA RIVER AT SMARTVILLE (1967-1991)

C-081930

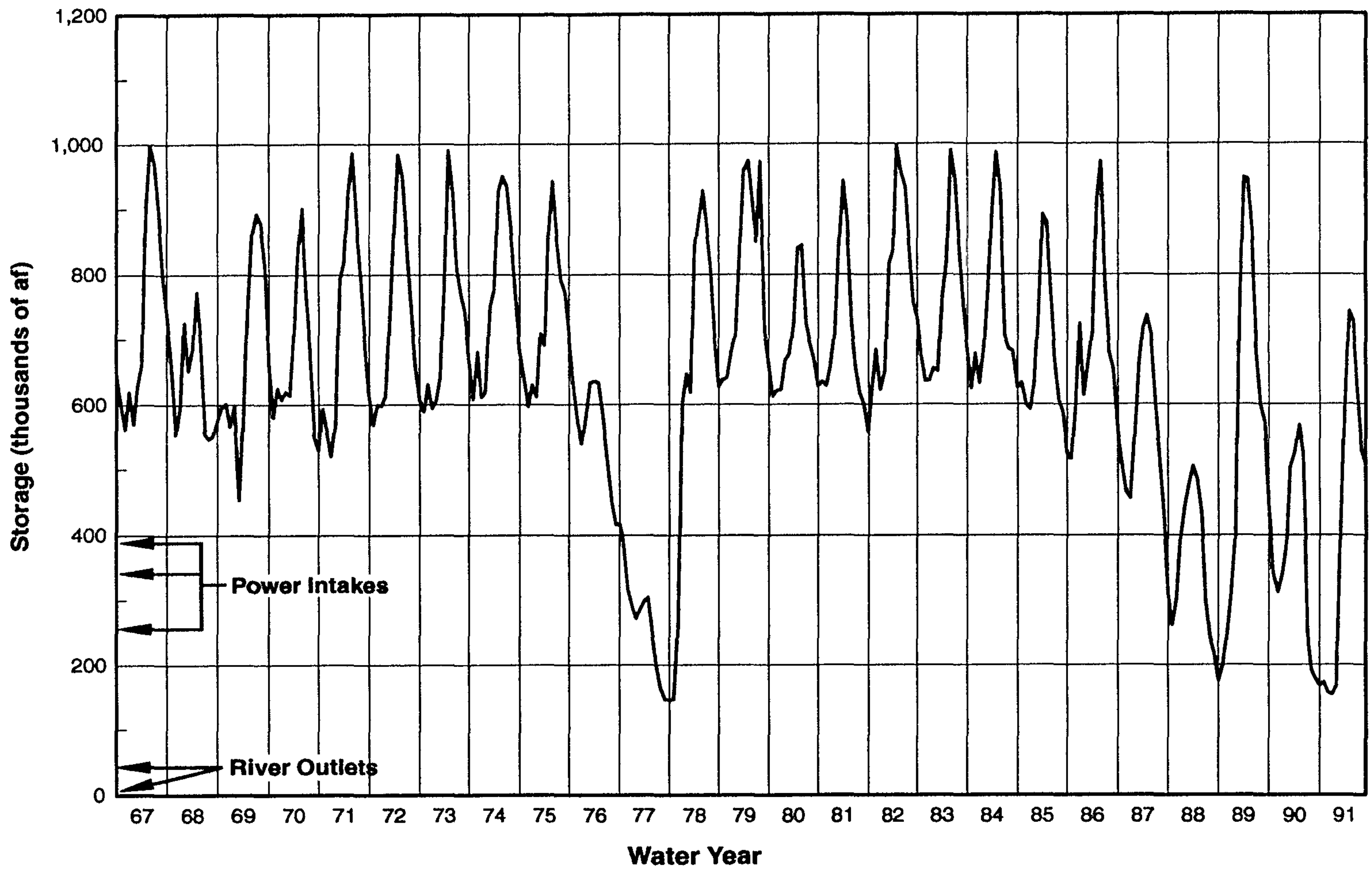


SOURCE:
WATSTORE data base maintained by USGS.

FIGURE II-28

MONTHLY MEAN OF MAXIMUM DAILY TEMPERATURES FOR YUBA RIVER AT SMARTVILLE AND MARYSVILLE (1967-1991)

C — 0 8 1 9 3 0



SOURCE:
CDEC data base maintained by DWR.

FIGURE II-29

END-OF-MONTH STORAGE FOR FOLSOM LAKE
(1967-1991)

C-081931

TABLE II-6

ELEVATION/AREA/STORAGE RELATIONSHIP FOR FOLSOM LAKE

Elevation (feet)	Area (acres)	Incremental Area (acres)	Storage (TAF)	Incremental Storage (TAF)
480.0	12,200.0	500.0	1,990.0	130.0
470.0	11,700.0	600.0	1,060.0	115.0
460.0	11,100.0	600.0	945.0	115.0
450.0	10,500.0	600.0	830.0	90.0
440.0	9,900.0	667.0	740.0	100.0
430.0	9,233.0	708.0	640.0	92.5
420.0	8,525.0	750.0	547.5	85.0
410.0	7,775.0	775.0	462.5	72.5
400.0	7,000.0	800.0	390.0	60.0
390.0	6,200.0	850.0	330.0	55.0
380.0	5,350.0	900.0	275.0	50.0
370.0	4,450.0	733.0	225.0	43.3
360.0	3,717.0	567.0	181.7	36.7
350.0	3,150.0	533.0	145.0	26.7
340.0	2,617.0	450.0	118.3	23.3
330.0	2,167.0	367.0	95.0	20.0
320.0	1,800.0	275.0	75.0	15.0
310.0	1,525.0	275.0	60.0	15.0
300.0	1,250.0	250.0	45.0	12.0
290.0	1,000.0	185.0	33.0	8.0
280.0	815.0	150.0	25.0	7.5
270.0	665.0	125.0	17.5	5.0
260.0	540.0	120.0	12.5	5.0
250.0	420.0	120.0	7.5	5.0
240.0	300.0	160.0	2.5	1.0
230.0	140.0	90.0	1.5	0.5
220.0	50.0	34.0	1.0	0.7
210.0	16.0		0.3	

NOTES:

TAF = thousand acre-feet.
River outlets are at elevations 210 and 280 feet.
Power intake is at elevation 307 feet; tops of panels are at elevations 375, 388, and 401 feet.
Water supply outlet is at elevation 316 feet.
Spillway crest is at elevation 418 feet.

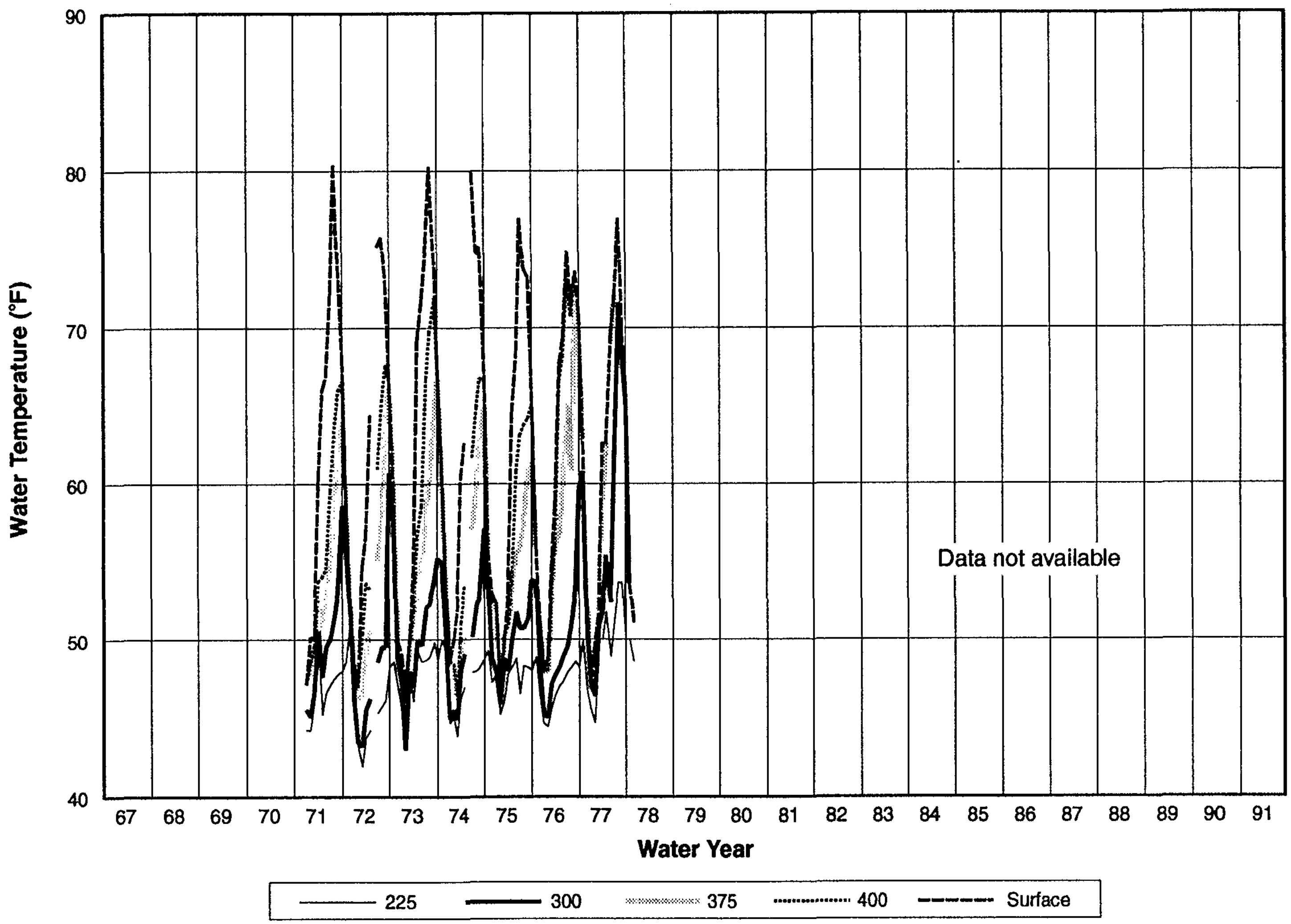
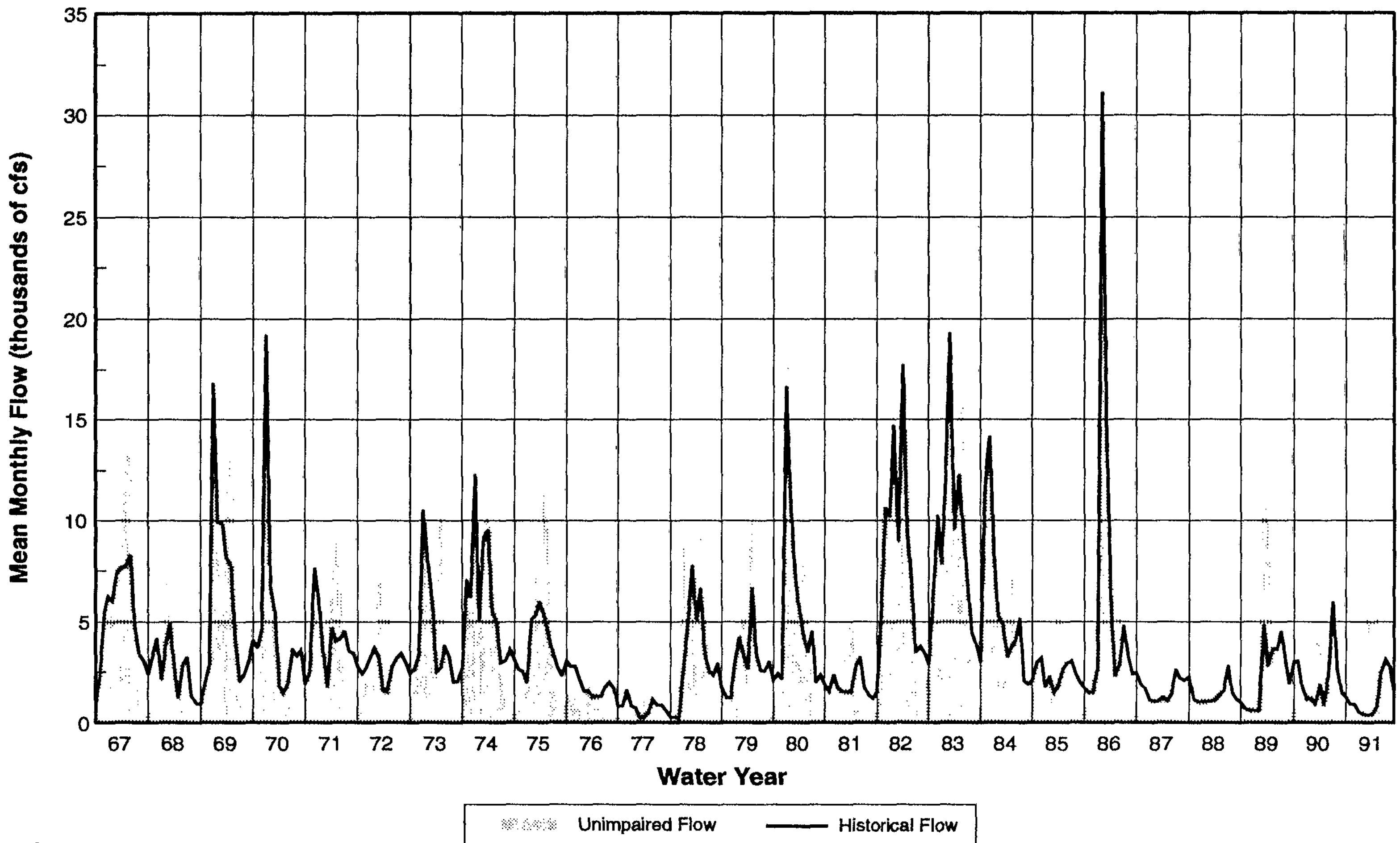


FIGURE II-30

WATER TEMPERATURES IN FOLSOM LAKE AT 225-, 300-, 375-, AND 400-FOOT ELEVATIONS (1967-1991)



SOURCE:
CDEC data base maintained by DWR and
WATSTORE data base maintained by USGS.

FIGURE II-31

MEAN MONTHLY UNIMPAIRED RUNOFF AND HISTORICAL FLOWS FOR AMERICAN RIVER AT FAIR OAKS (1967-1991)

C—081934

at Fair Oaks was 2.74 million af/yr (3,784 cfs). Historical flows during the snowmelt runoff period have often been considerably less than unimpaired flows because snowmelt runoff is captured in Folsom Lake. Conversely, regulated flows in late summer and fall have been higher than natural flows because of reservoir releases for downstream water supply purposes.

Water temperatures are important in the American River downstream of Lake Natoma and in the Nimbus Hatchery. Of particular concern is warm water in fall (September-November), which may have detrimental effects on chinook salmon egg survival for natural redds in the river and for those eggs spawned and incubated in the hatchery. When Folsom Lake was filled in 1955, both warm water and low dissolved oxygen problems were encountered in the American River and at the hatchery. Water temperature at the hatchery (Lake Natoma) did not drop below 60°F until mid-November of 1955. During the first several years of hatchery operation, it was observed that the number of eggs that reached the eyed stage was much smaller for those eggs spawned at temperatures greater than 60°F. From 1957 through 1961, salmon that arrived at the hatchery before temperatures had dropped to below 60°F were transported to the Bear River fish planting base for holding and spawning in cooler water. Incubation success greatly increased in the cooler water.

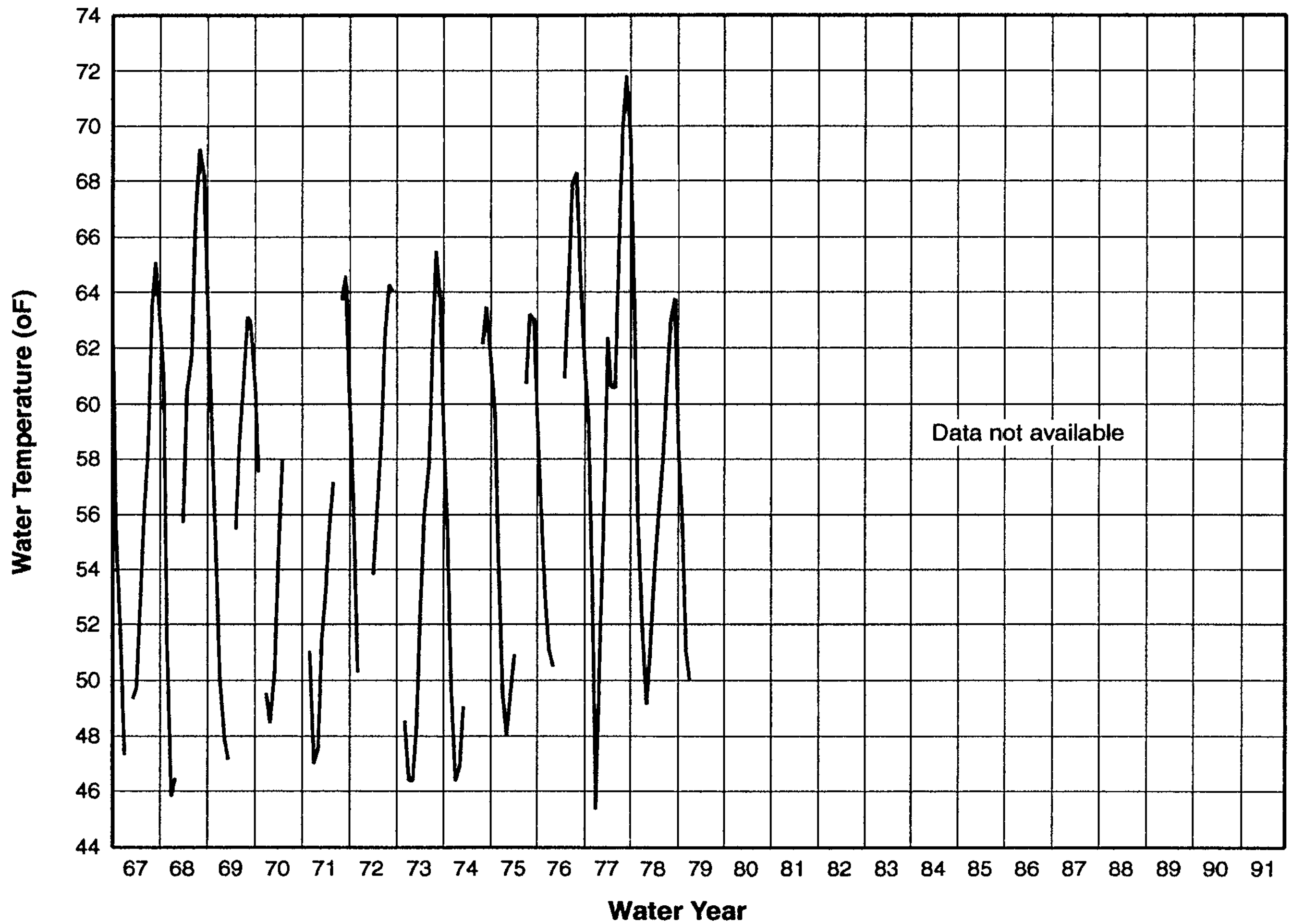
Figure II-32 shows available monthly average American River temperatures at Fair Oaks (downstream of Nimbus Dam). Although USGS temperature records are not available after 1978, the effects of reservoir drawdown and low flows on river temperatures are evident in 1968, 1976, and 1977.

SAN JOAQUIN RIVER REGION

The San Joaquin River Basin encompasses nearly 28,400 square miles. The region stretches from the Delta on the north to the crest of the Tehachapi Mountains on the south. From east to west, it encompasses everything between the crest of the Sierra Nevada and the crest of the Coast Range. Major tributaries to the San Joaquin River include, from south to north, the Merced, Tuolumne, Stanislaus, Calaveras, Mokelumne, and Cosumnes rivers. The Tulare Lake Region provides outflow to the San Joaquin River during extremely wet years only. The rivers have been developed for irrigation and municipal water, hydroelectric generation, and flood control. The main water resource features of the San Joaquin River Region are shown in Figure II-33.

CVP facilities and operations directly affect the habitat water quality and fishery potential of the San Joaquin River and its tributaries. Fishery declines may be related to barriers caused by low San Joaquin River flows, low dissolved oxygen concentrations, high temperatures, and water quality degradation from irrigation return water and municipal discharges.

Chinook salmon is the fishery of primary interest in the San Joaquin River Basin. Before extensive water development, spring-run chinook salmon was the most abundant race. Spring-run chinook salmon were eliminated from the Stanislaus, Tuolumne, and Merced rivers in the 1930s by dam construction. Large runs migrating upstream in the San Joaquin River past the Merced River were eliminated in 1947 following construction of Friant Dam on the San Joaquin River near Fresno.



SOURCE:
WATSTORE data base maintained by USGS.

FIGURE II-32
MONTHLY MEAN OF MAXIMUM DAILY TEMPERATURES
FOR AMERICAN RIVER AT FAIR OAKS
(1967-1991)

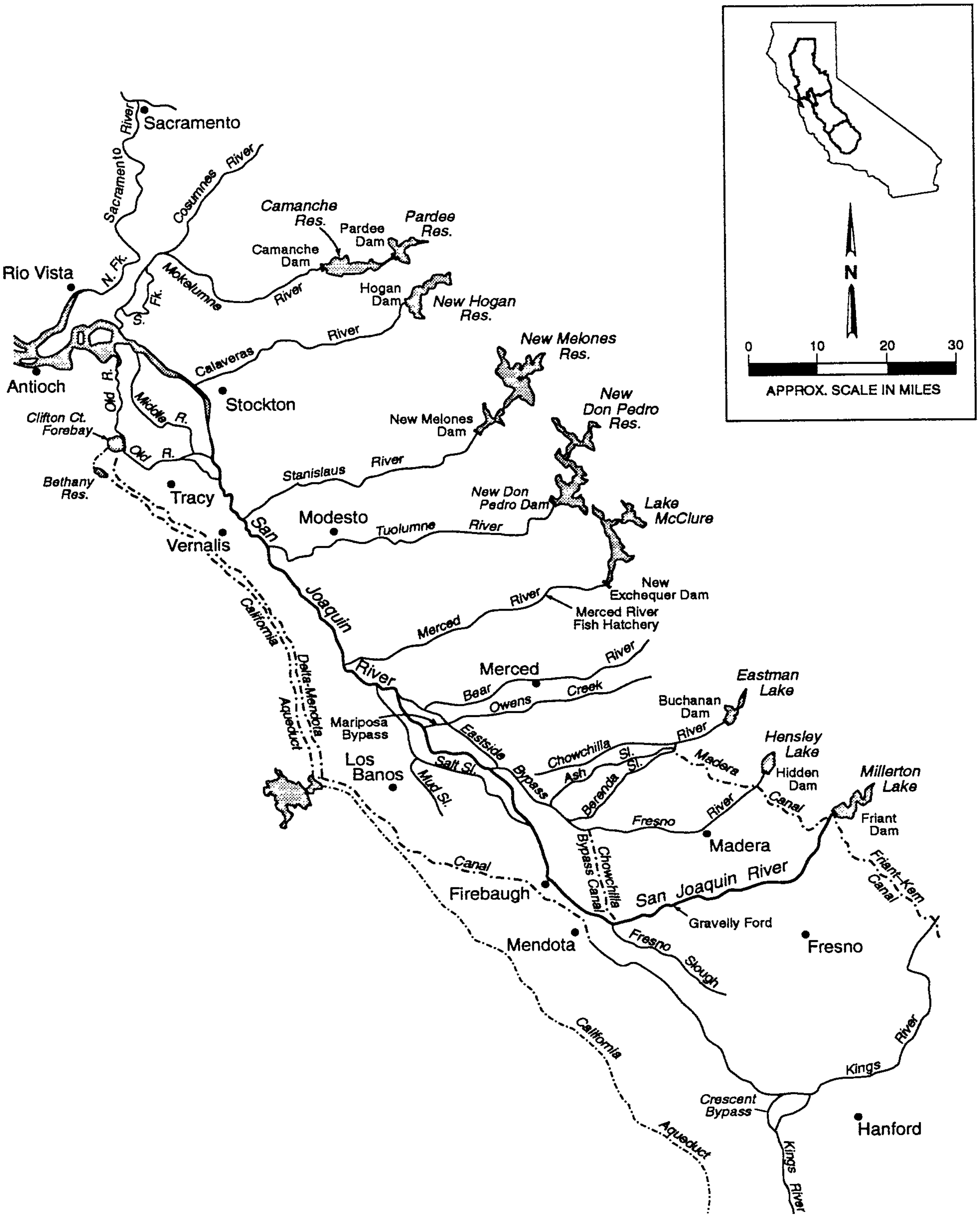


FIGURE II-33

SAN JOAQUIN RIVER REGION

San Joaquin River

The San Joaquin River flow, originating in the Sierra Nevada, is regulated by a series of small hydroelectric projects and Friant Dam. Millerton Lake was created by Friant Dam and has a storage capacity of approximately 520,000 af. From Friant Dam, the Madera Canal conveys water north, and the Friant-Kern Canal conveys water south to the Bakersfield area. River releases from Friant Dam are typically less than 150 cfs, although they may be much greater during storm events and runoff large enough to require spilling. Water diverted at Friant Dam is replaced for users (exchange contractors) along the San Joaquin River by water pumped at the Tracy Pumping Plant from the Delta into the Delta-Mendota Canal to the Mendota Pool. The exchange of water meets the demands of valley farmers downstream of the Mendota Pool, where flows are often quite low. Salt and Mud sloughs convey drainage water to the San Joaquin River upstream of the Merced River confluence. Additional drainage and tributary flows contribute to the San Joaquin River flow at Vernalis, where the San Joaquin River enters the Delta. Table II-7 gives annual flows and reservoir operations for the San Joaquin River and tributary streams.

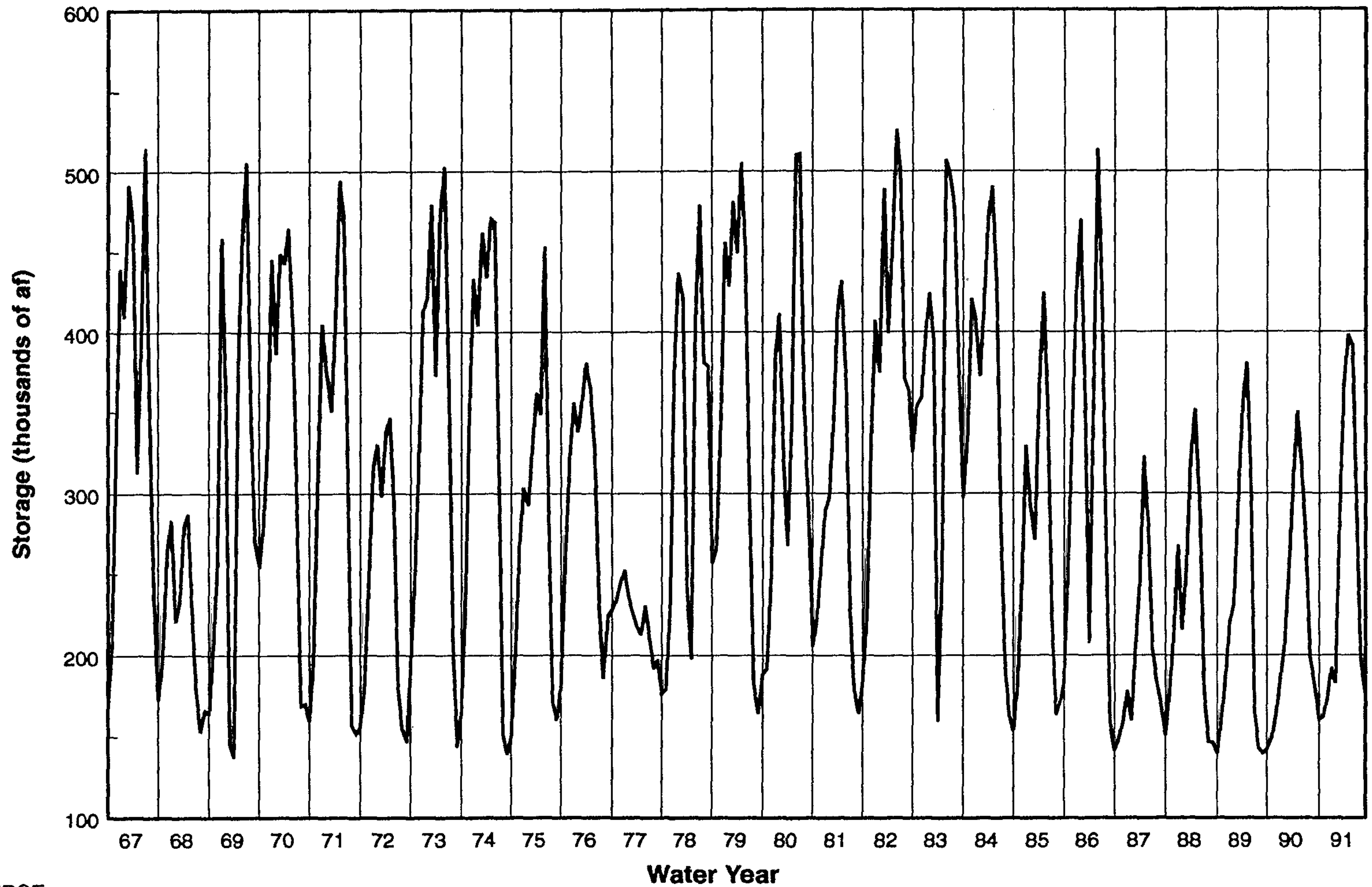
Millerton Lake. Millerton Lake is formed by Friant Dam, which was completed in 1947. Millerton Lake stores runoff from 1,638 square miles of the upper San Joaquin River watershed. Figure II-34 shows the historical end-of-month Millerton Lake storage for 1967-1991. The storage in Millerton Lake ranges between approximately 100,000 af and 500,000 af.

Figure II-35 shows the unimpaired flow and historical river flow below Friant Dam. The average 1967-1991 unimpaired flow at Friant Dam was 1.87 million af (2,586 cfs). Millerton Lake operates very efficiently and diverts almost all runoff into the Madera and Friant-Kern canals. Some river releases are made during wet years and flow downstream to the Mendota Pool.

Mendota Pool. The Mendota Pool is the discharge point of the Delta-Mendota Canal. Water pumped from the south Delta at the Tracy Pumping Plant and conveyed by the Delta-Mendota Canal is used to replace the San Joaquin River water diverted at Friant Dam. The initial water quality is similar to Delta water quality. Agricultural drainage and pumped groundwater also may enter the Mendota Pool.

San Joaquin River Flows and Temperatures. Downstream of the Mendota Pool, the Merced, Tuolumne, and Stanislaus rivers and numerous other small streams and agricultural irrigation returns contribute to the flows of the San Joaquin River as it enters the Delta at Vernalis. Figure II-36 shows monthly San Joaquin River flows above the Merced River and at Vernalis for 1967-1991. The average flow for 1967-1991 above the Merced River was 1.01 million af/yr (1,388 cfs) and at Vernalis was 3.53 million af/yr (4,870 cfs).

Figure II-37 shows the monthly mean of maximum daily San Joaquin River temperatures at Stevinson (upstream of the Merced River) and Vernalis for 1967-1991. River temperatures rise during summer but are relatively constant along the San Joaquin River, with the tributary inflows contributing cooler water, which may counteract the effects of meteorological warming.



SOURCE:
CDEC data base maintained by DWR.

FIGURE II-34

END-OF-MONTH STORAGE FOR MILLERTON LAKE
(1967-1991)

TABLE II-7

HYDROLOGIC CONDITIONS IN THE SAN JOAQUIN RIVER REGION

	San Joaquin R. Millerton	San Joaquin R. Millerton	San Joaquin R. Below Friant	San Joaquin R. James Bypass Near San Jose	San Joaquin R. Above Merced R.	Merced R. McClure	Merced R. McClure
Water Year	End-of-September Storage (TAF)	Unimpaired Flow (TAF)	Historical Flow (TAF)	Historical Flow (TAF)	Estimated Flow (TAF)	Unimpaired Flow (TAF)	End-of-September Storage (TAF)
67	240	3,220	1,271		1,579	1,711	718
68	166	861	57		209	427	355
69	270	4,036	2,232		3,972	2,193	750
70	170	1,443	89		466	881	561
71	151	1,418	48		244	733	592
72	147	1,036	68		130	548	293
73	144	2,047	291		692	1,112	674
74	139	2,184	136	87	377	1,130	723
75	160	1,795	54		397	1,113	707
76	224	627	80		206	297	243
77	197	362	91	0	118	151	95
78	379	3,402	1,353	550	2,144	1,761	766
79	164	1,827	108	12	430	1,077	67
80	288	2,969	978	578	1,515	1,648	685
81	164	1,069	69	0	267	501	347
82	364	3,322	823	452	1,395	1,957	764
83	371	4,638	3,185	2,317	6,165	2,790	772
84	162	2,039	609	563	1,508	1,176	570
85	171	1,130	64	0	279	568	242
86	159	3,058	988	667	1,775	1,582	694
87	168	758	67	2	328	298	314
88	146	860	79	0	286	415	148
89	140	939	84	0	258	534	140
90	183	743	99	0	250	407	108
91	175	1,031	104	0	140	558	194
Average	**202**	**1,873**	**521**	**327**	**1,005**	**1,023**	**461**
Average (cfs)		**2,586**	**720**	**451**	**1,388**	**1,412**	

TABLE II-7. CONTINUED

Water Year	Merced R. Below Merced Falls Dam Historical Flow (TAF)	Merced R. Stevinson Historical Flow (TAF)	San Joaquin R. Near Newman Historical Flow (TAF)	Tuolumne R. Don Pedro End-of-September Storage (TAF)	Tuolumne R. Don Pedro Unimpaired Flow (TAF)	Tuolumne R. Near La Grange Historical Flow (TAF)	Tuolumne R. at Modesto Historical Flow (TAF)	Stanislaus R. New Melones Unimpaired Flow (TAF)
67	1,211	715	2,294	0	3,095		1,756	1,927
68	746	204	413	0	1,008		552	642
69	1,780	1,275	5,246	0	3,853		2,446	2,212
70	1,029	496	962	0	1,958		978	1,318
71	661	201	445	365	1,685	349	522	1,075
72	821	255	384	362	1,203	166	310	774
73	700	242	934	913	2,035	166	385	1,284
74	1,053	475	852	1,461	2,233	377	602	1,556
75	1,104	538	935	1,597	2,036	562	911	1,241
76	711	224	430	687	667	358	652	370
77	262	65	183	307	384	67	153	155
78	1,037	556	2,700	1,575	2,905	290	470	1,591
79	1,127	557	987	1,606	1,914	664	967	1,165
80	1,575	992	2,507	1,744	3,045	1,511	1,780	1,804
81	789	245	512	1,119	1,056	442	717	592
82	1,488	1,003	2,398	1,747	3,824	1,725	2,015	2,363
83	2,741	2,293	8,458	1,705	4,630	3,466	3,997	2,955
84	1,323	789	2,297	1,512	2,462	1,382	1,671	1,431
85	841	289	577	1,213	1,230	377	594	680
86	1,073	622	2,397	1,672	3,009	1,139	1,340	1,973
87	644	159	487	934	656	281	520	373
88	510	110	396	930	819	78	156	378
89	490	100	357	1,071	1,312	61	134	778
90	377	90	339	992	844	85	157	469
91	406	73	213	947	1,095	83	152	509
Average	**980**	**503**	**1,508**	**978**	**1,958**	**649**	**958**	**1,185**
Average (cfs)	**1,354**	**695**	**2,083**		**2,705**	**896**	**1,323**	**1,636**

TABLE II-7. CONTINUED

	Stanislaus R. New Melones	Stanislaus R. near Knights Flat	Stanislaus R. below Goodwin Dam	Stanislaus R. at Ripon	Calaveras R. New Hogan	Calaveras R. below New Hogan Dam	San Joaquin R. Vernalis
Water Year	End-of-September Storage (TAF)	Historical Flow (TAF)	Historical Flow (TAF)	Historical Flow (TAF)	End-of-September Storage (TAF)	Mean Historical Flow (TAF)	Historical Flow (TAF)
67	16	1,735	1,216	1,359	197	227	5,567
68	11	671	157	266	143	100	1,425
69	12	2,122	1,552	1,718	159	354	10,182
70	13	1,317	724	897	125	218	3,080
71	12		408	553	136	107	1,781
72	11	773	188	282	115	72	1,113
73	11	1,226	680	819	144	216	2,395
74	10	1,454	905	1,054	219	126	2,776
75	12	1,223	590	774	145	213	2,830
76	3	507	102	185	71	80	1,525
77	3	127	5	33	11	61	416
78	44	1,365	858	930	162	69	4,496
79	116	1,050	434	522	177	151	2,629
80	277	1,612	1,009	1,201	149	247	5,994
81	124	756	173	282	103	96	1,766
82	1,358	1,009	508	649	222	306	5,485
83	2,024	2,238	1,671	1,838	218	553	15,459
84	1,841	1,744	1,059	1,252	128	300	6,269
85	1,508	1,007	451	565	101	93	2,104
86	1,948	1,396	858	968	136	272	5,242
87	1,443	905	450	532	59	99	1,810
88	989	788	406	433	15	53	1,165
89	672	872	388	446	22	19	1,058
90	378		267	312	20	30	916
91	296	606	134	191	27	169	656
Average	**525**	**1,152**	**608**	**722**	**120**	**234**	**3,526**
Average (cfs)		**1,592**	**839**	**998**			**4,870**

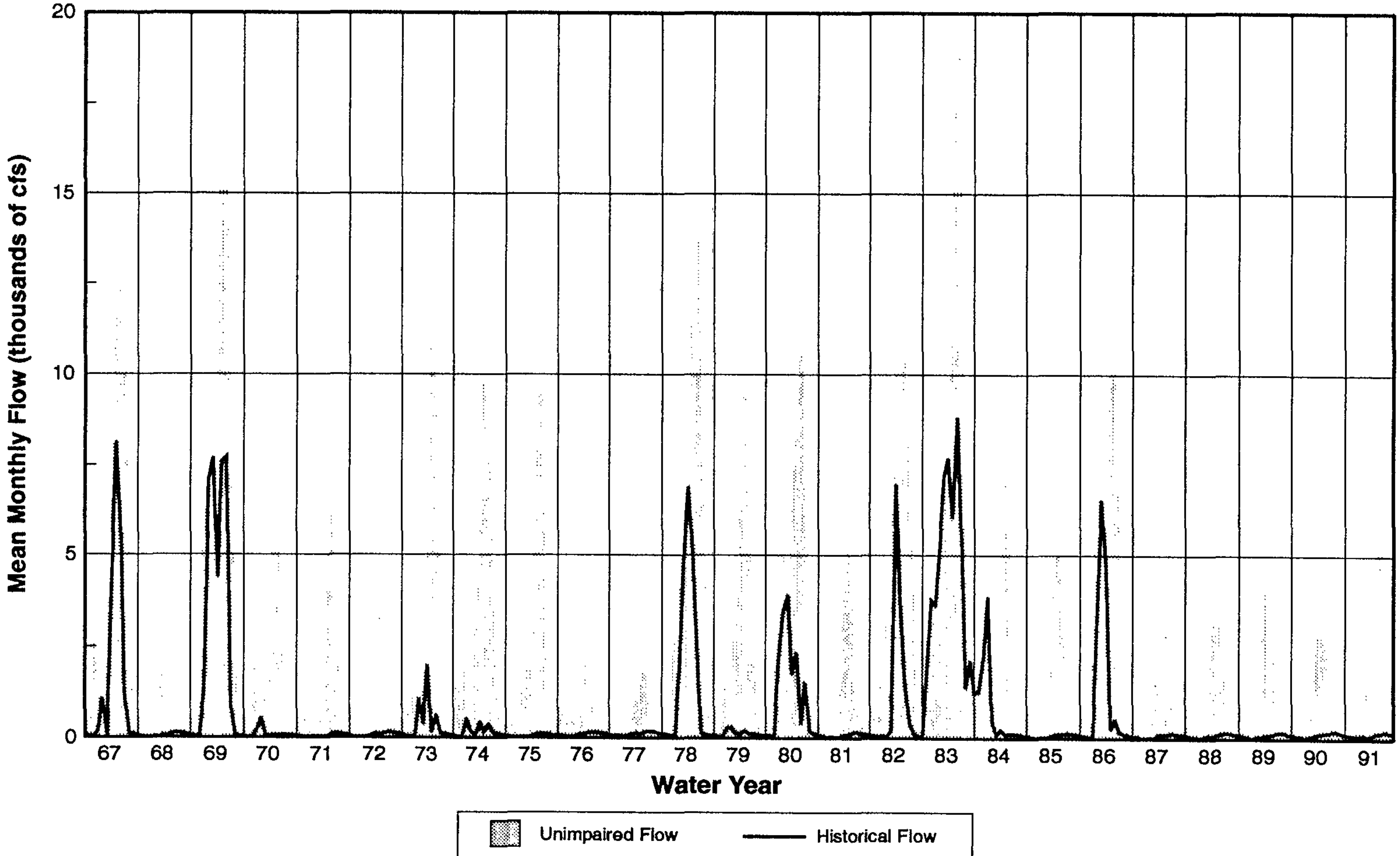
C-081942

TABLE II-7. CONTINUED

	San Joaquin R. Vernalis	San Joaquin R. Vernalis	Mokelumne R. Camanche	Mokelumne R. Camanche	Mokelumne R. Camanche	Mokelumne R. Woodbridge	Cosumnes R. Michigan Bar	Cosumnes R. Michigan Bar
Water Year	Mean TSS (mg/l)	Mean EC (μS/cm)	Unimpaired Flow (TAF)	End-of-September Storage (TAF)	Historical Flow (TAF)	Historical Flow (TAF)	Unimpaired Flow (TAF)	Historical Flow (TAF)
67	72		1,138	323	642	453	626	601
68	76	744	408	219	346	169	189	171
69		378	1,328	304	1,030	805	711	685
70	89	515	909	289	687	496	466	448
71	88	650	784	313	535	337	388	332
72	100	746	527	246	301	117	204	183
73	109	642	795	317	519	340	480	446
74	94	508	999	336	790	615	572	543
75	95		776	338	527	362	392	367
76	113	795	244	186	251	125	65	55
77	87	1,331	129	55	133	16	20	16
78	87		959	338	350	214	495	455
79	78	512	684	343	495	343	344	312
80	72	363	1,141	324	930	773	643	568
81	83		368	256	242	94	129	118
82	75	415	1,522	350	1,262	1,081	1,006	965
83	50	201	1,801	353	1,741	1,575	1,259	1,226
84	75		1,010	350	933	765	580	596
85	95	542	454	246	302	173	178	165
86	83	473	1,226	336	950	814	736	732
87	71	640	252	118	267	155	62	73
88	70	846	256	10	125	23	65	52
89	80	851	553	143	130	23	192	163
90	83	847	336	173	131	27	107	91
91	82	863	341	114	128	41	121	107
Average	**84**	**643**	**758**	**225**	**550**	**397**	**401**	**379**
Average (cfs)			**1,047**		**760**	**549**	**554**	**523**

NOTE:
TAF = thousand acre-feet.

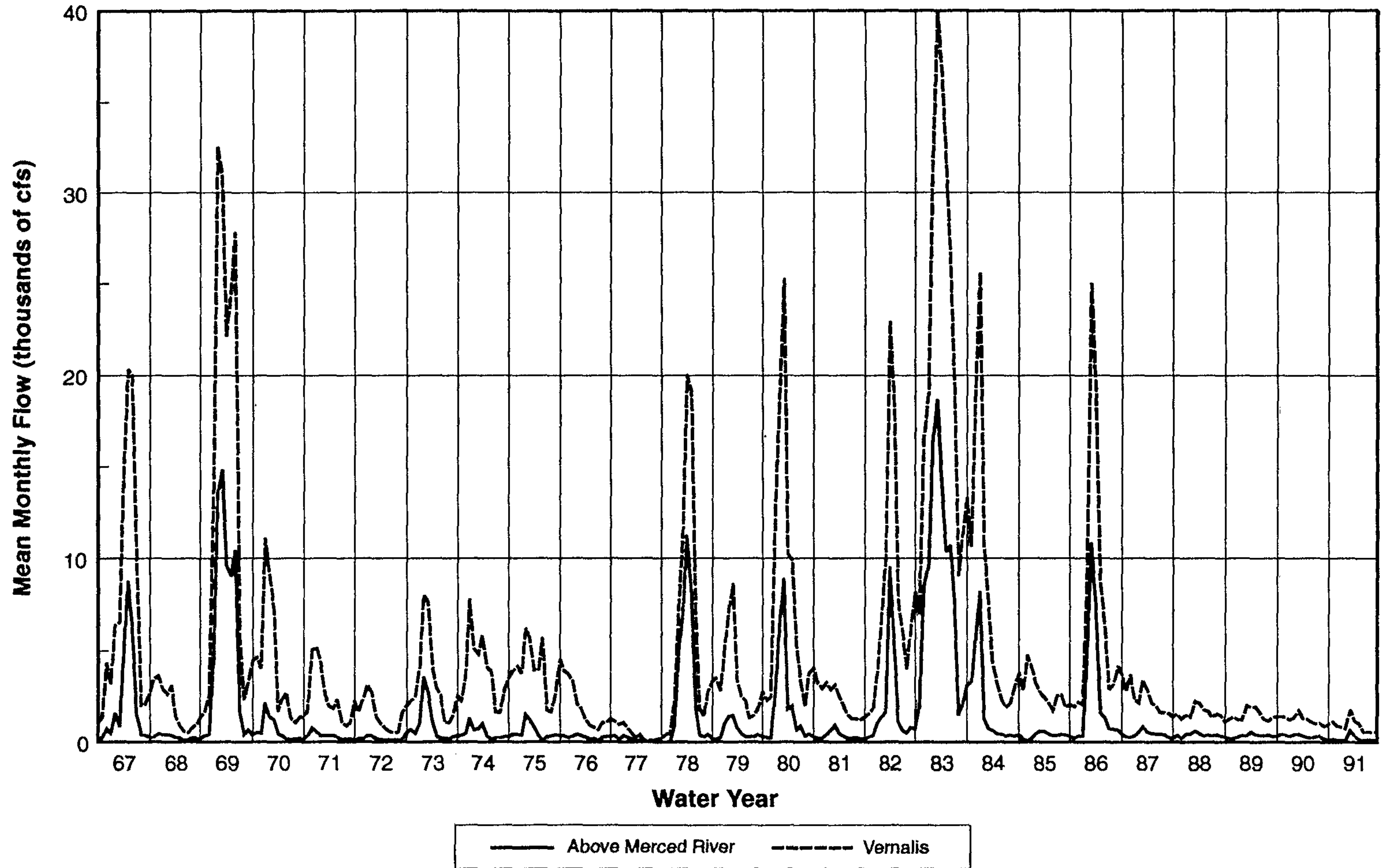
C-081943



SOURCE:
CDEC data base maintained by DWR and
WATSTORE data base maintained by USGS.

FIGURE II-35

MEAN MONTHLY UNIMPAIRED RUNOFF AND HISTORICAL FLOWS FOR SAN JOAQUIN RIVER BELOW FRIANT DAM (1967-1991)

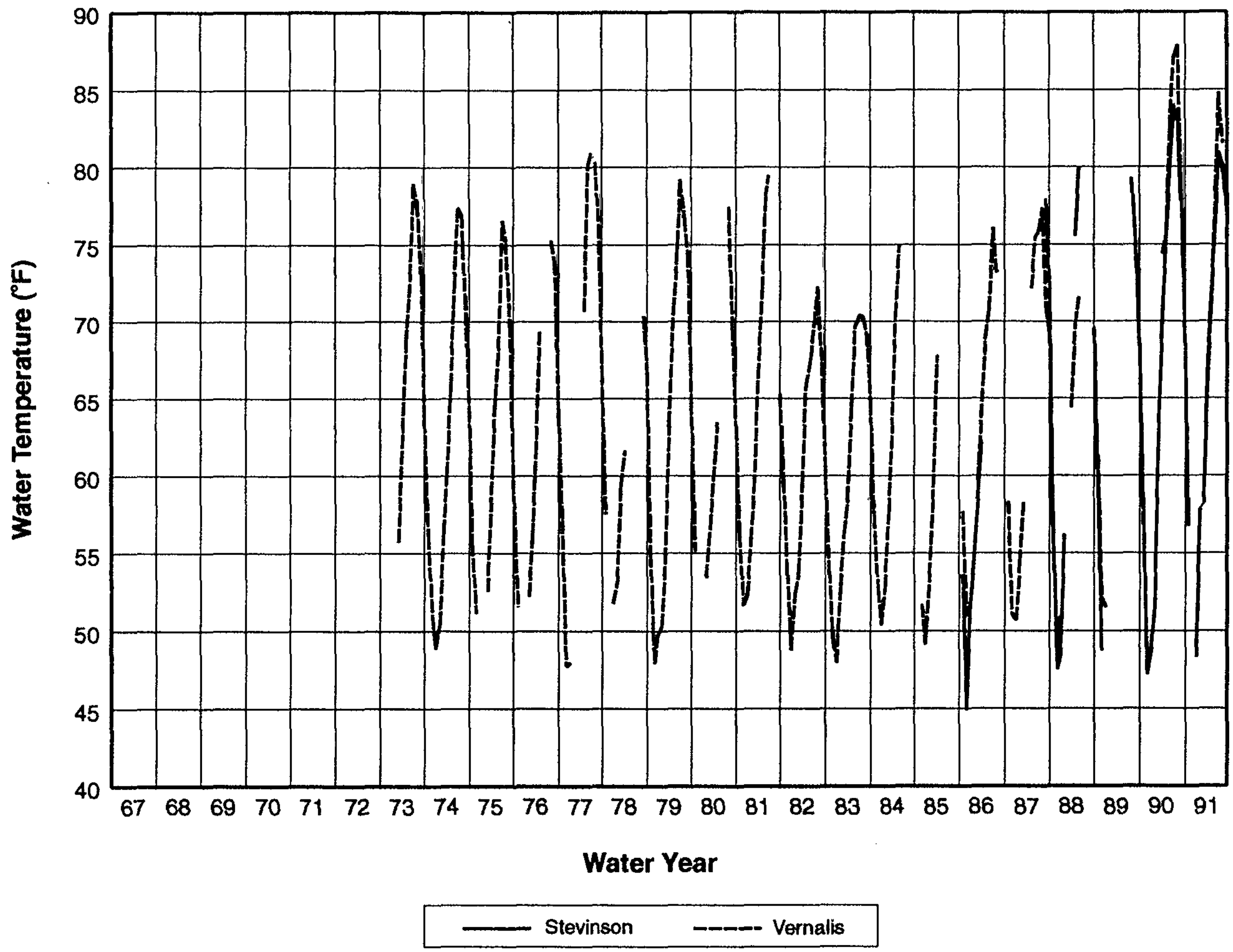


SOURCE:
WATSTORE data base maintained by USGS.

FIGURE II-36

MEAN MONTHLY FLOWS FOR SAN JOAQUIN RIVER ABOVE THE MERCED RIVER (ESTIMATED) AND AT VERNALIS (MEASURED) (1967-1991)

C-081945



SOURCE:
WATSTORE data base maintained by USGS.

FIGURE II-37

MONTHLY MEAN OF MAXIMUM DAILY TEMPERATURES FOR SAN JOAQUIN RIVER AT STEVINSON AND VERNALIS (1967-1991)

Figure II-38 shows monthly San Joaquin River EC measurements for 1967-1991 at Vernalis. The effects of agricultural drainage along the San Joaquin River are generally reduced (diluted) by tributary inflows. The highest EC values are measured during low-flow periods, when agricultural drainage contributes a substantial portion of San Joaquin River flow. Increasing salinity encountered while moving upstream may be a barrier to migratory fish. Selenium, boron, and other contaminants from irrigation drain water also enter the San Joaquin River. Water quality standards for selenium are exceeded frequently above the confluence of the Merced River with the San Joaquin River and, to a lesser extent, below the confluence.

Figure II-39 shows monthly average SS concentrations in the San Joaquin River at Vernalis. SS concentrations are moderately high during runoff periods but remain relatively high throughout the year, ranging from 20 to 200 milligrams per liter (mg/l).

Merced River

The Merced River, like other main tributaries to the San Joaquin River, originates in the Sierra Nevada. Water is impounded by New Exchequer Dam in Lake McClure and released through a series of powerhouses into the Merced River. A substantial portion of the Merced River flow is diverted for irrigation supplies.

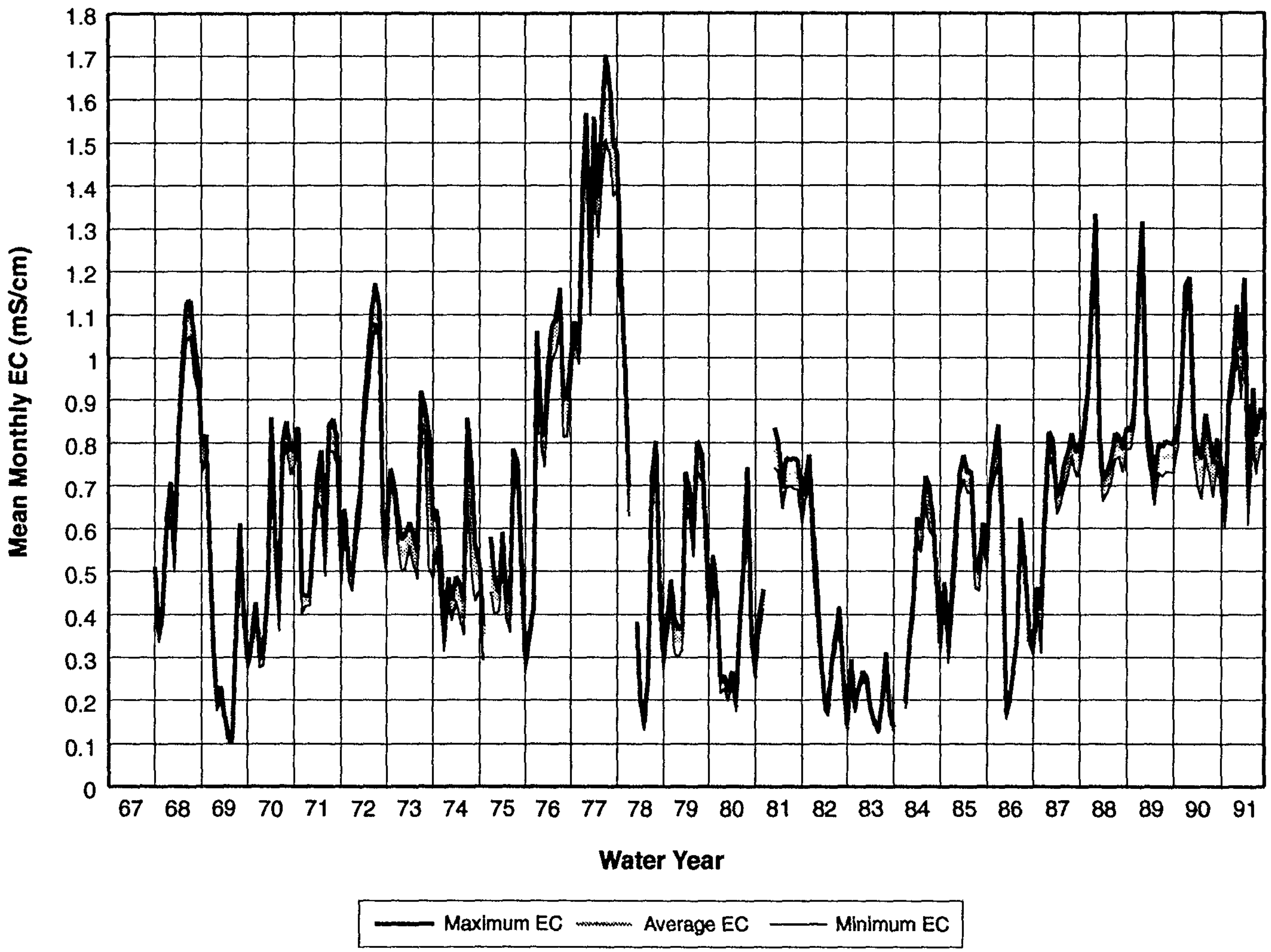
Lake McClure. Lake McClure is formed by New Exchequer Dam, which was completed by the Merced Irrigation District in 1967. The storage capacity of Lake McClure is approximately 1 million af. Figure II-40 shows historical end-of-month storage in Lake McClure for 1967-1991.

Merced River Flows and Temperatures. Figure II-41 shows the mean monthly unimpaired runoff and historical Merced River flows below the Merced Irrigation District diversions at Stevinson for 1967-1991. The average 1967-1991 unimpaired flow was 1.02 million af/yr (1,412 cfs). The average 1967-1991 historical flow below the major Merced River diversions at Stevinson was 503,000 af/yr (695 cfs).

Figure II-42 shows Merced River monthly average temperatures measured downstream at Stevinson, near the confluence with the San Joaquin River. The Merced River Fish Hatchery is located near Merced Falls Dam. Temperature data indicate that substantial warming occurs in this reach of the Merced River during summer (Jones & Stokes Associates, 1994).

Tuolumne River

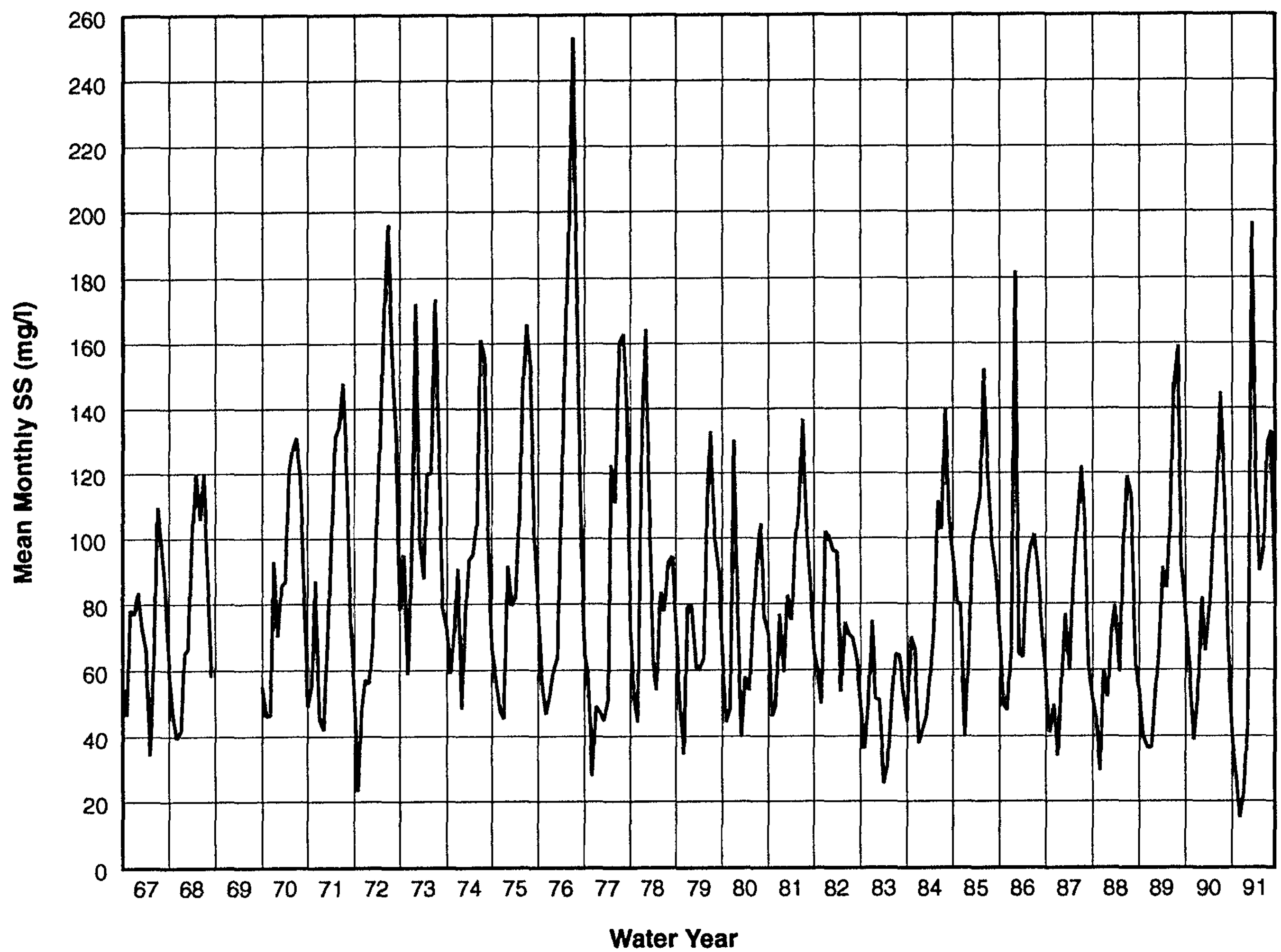
The Tuolumne River originates in the Sierra Nevada. Water is impounded and regulated by several dams in the high Sierra for municipal water supply and power generation, most notably Hetch Hetchy Reservoir, operated by the City and County of San Francisco. Downstream of the San Francisco facilities, Tuolumne River water is impounded and regulated by New Don Pedro Reservoir. Water released from New Don Pedro Reservoir is diverted at La Grange Reservoir into the Turlock and Modesto canals.



SOURCE:
STORET data base maintained by EPA.

FIGURE II-38

MEAN MONTHLY EC VALUES FOR THE VERNALIS MONITORING STATION (1967-1991)

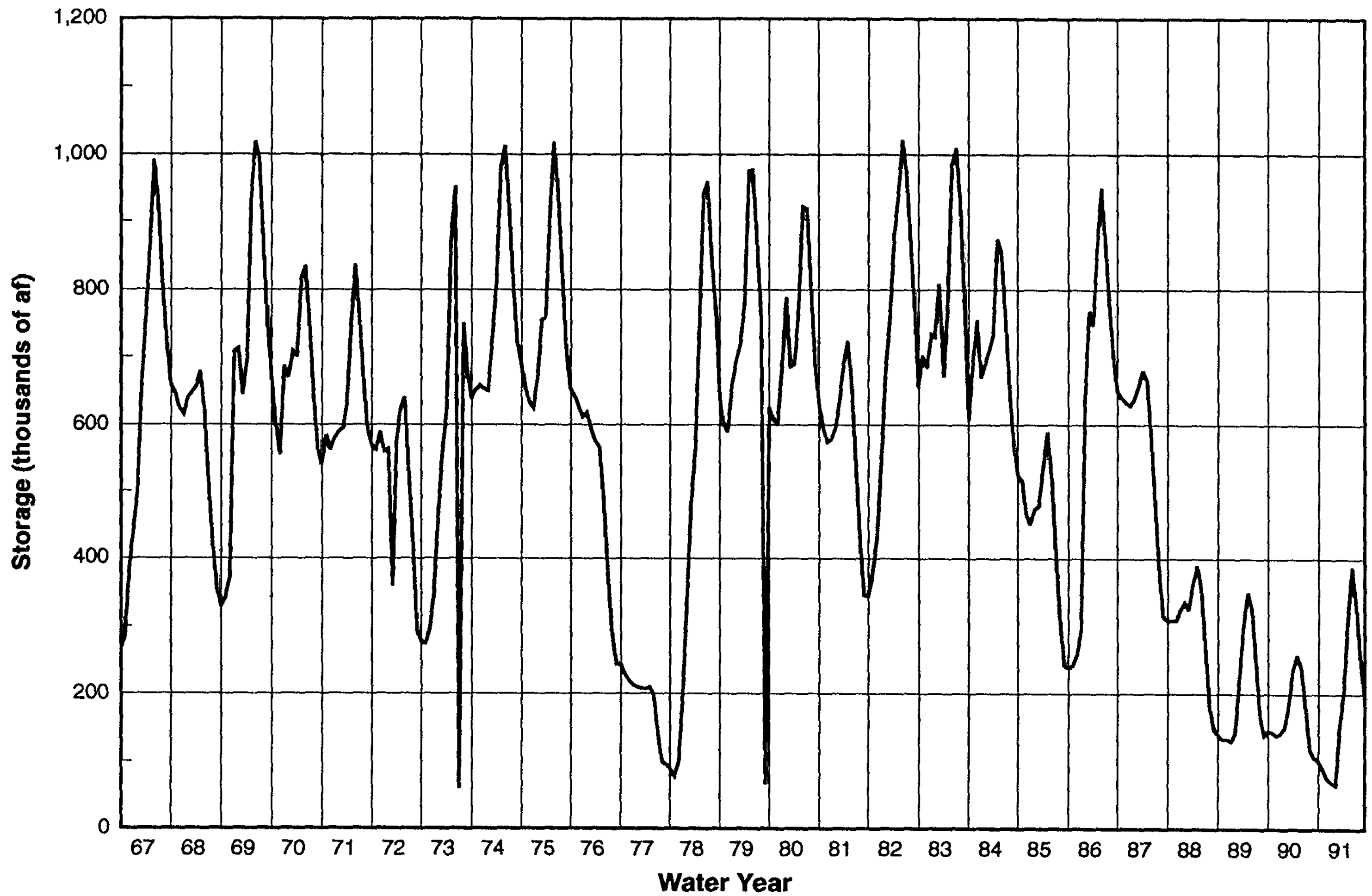


SOURCE:
STORET data base maintained by EPA.

FIGURE II-39

MEAN MONTHLY TOTAL SUSPENDED SOLIDS CONCENTRATION FOR SAN JOAQUIN RIVER AT VERNALIS (1967-1991)

C-081949

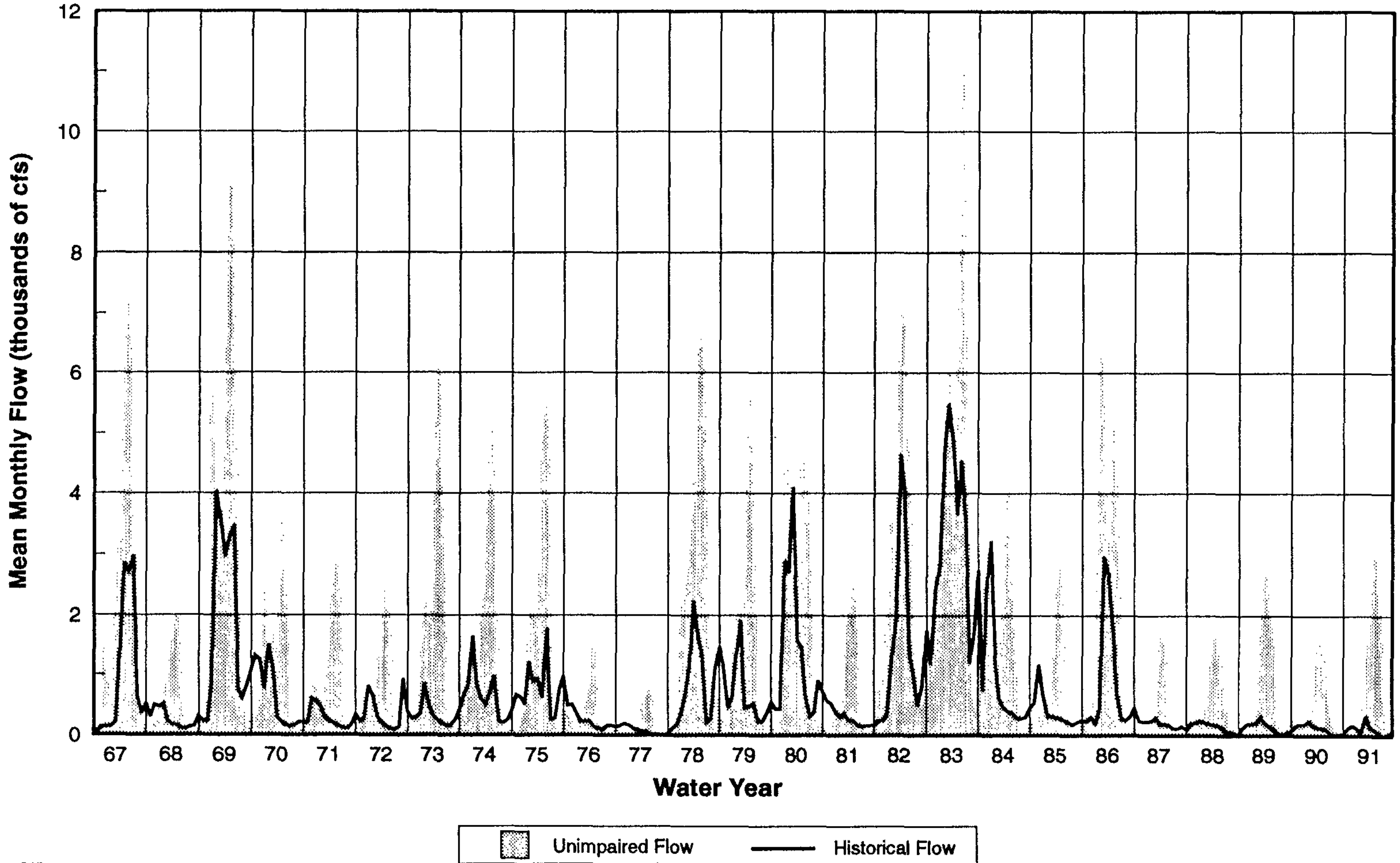


SOURCE:
CDEC data base maintained by DWR.

FIGURE II-40

END-OF-MONTH STORAGE FOR LAKE MCCLURE (1967-1991)

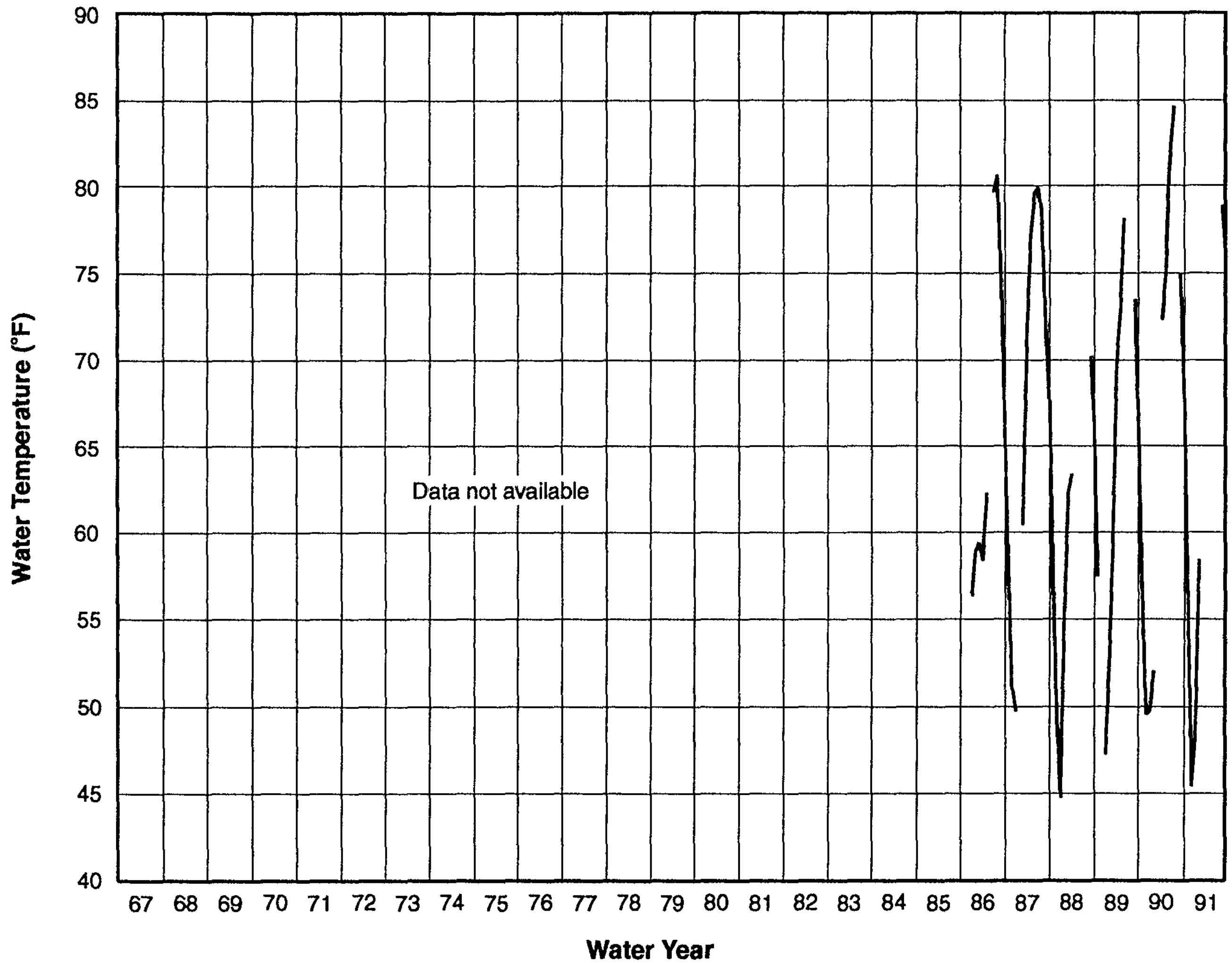
C-081950



SOURCE:
CDEC data base maintained by DWR and
WATSTORE data base maintained by USGS.

FIGURE II-41

MEAN MONTHLY UNIMPAIRED RUNOFF FOR THE MERCED RIVER AT EXCHEQUER DAM AND HISTORICAL FLOWS FOR THE MERCED RIVER AT STEVINSON (1967-1991)



SOURCE:
WATSTORE data base maintained by USGS.

FIGURE II-42

MONTHLY MEAN OF MAXIMUM DAILY TEMPERATURES FOR THE MERCED RIVER AT STEVINSON (1967-1991)

New Don Pedro Reservoir. The largest reservoir on the Tuolumne River is New Don Pedro Reservoir, which was completed by Turlock and Modesto irrigation districts in 1971, with a storage capacity of approximately 2 million af. Figure II-43 shows end-of-month storage in New Don Pedro Reservoir for 1967-1991. Storage at Don Pedro Reservoir began during 1970; however, a smaller reservoir with a storage capacity of 290,000 af was operated beginning in 1923.

Tuolumne River Flows and Temperatures. Figure II-44 shows monthly unimpaired runoff and historical Tuolumne River flows near La Grange Reservoir for 1967-1991. The average 1967-1991 unimpaired flow was 1.96 million af/yr (2,705 cfs). The average 1967-1991 flow below La Grange Reservoir was 649,000 af/yr (896 cfs).

Figure II-45 shows Tuolumne River temperatures at La Grange Reservoir and downstream at Modesto. Seasonal warming between these locations is the dominant feature of habitat water quality in the Tuolumne River. Some effects of New Don Pedro Reservoir drawdown on release temperatures can also be identified.

Stanislaus River

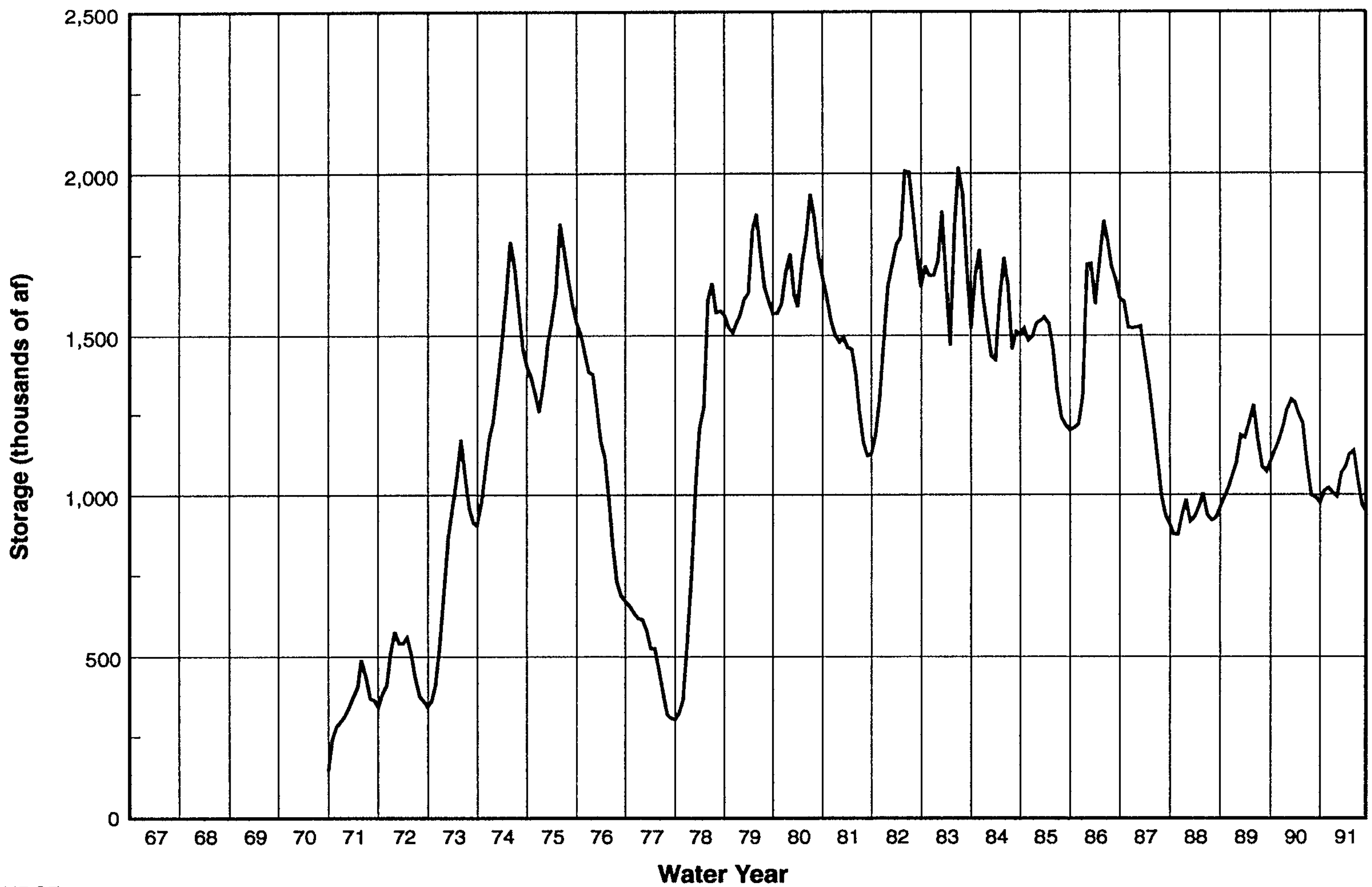
The Stanislaus River originates in the Sierra Nevada. Water is impounded and regulated by numerous dams in the high Sierra for hydroelectric power generation and local water supply. Further downstream, water is impounded and regulated by New Melones Reservoir.

New Melones Reservoir. The largest reservoir on the Stanislaus River is New Melones Reservoir, which was completed by the U.S. Army Corps of Engineers (COE) in 1978 and is operated by Reclamation. The geometry characteristics of New Melones Reservoir are given in Table II-8. Figure II-46 shows monthly storage volume in New Melones Reservoir for 1967-1991. Storage began in 1978, but the full capacity of 2.4 million af was reached only once in 1983. Reservoir storage was nearly depleted during the 1987-1991 drought.

New Melones Reservoir has two outlets: a low-level river outlet at elevation 540 feet and the powerhouse penstock at elevation 760 feet. Releases are usually made through the powerhouse to Tulloch Reservoir. Tulloch Reservoir has a storage capacity of 68,000 af. Releases from Tulloch Powerhouse flow downstream to Goodwin Dam, where diversions are made into the Oakdale and South San Joaquin canals.

Stanislaus River Flows and Temperatures. Figure II-47 shows average monthly unimpaired runoff and historical Stanislaus River flows near Goodwin Dam. The average 1967-1991 unimpaired flow was 1.19 million af/yr (1,636 cfs). The average 1967-1991 flow below Goodwin Dam was 608,000 af/yr (839 cfs).

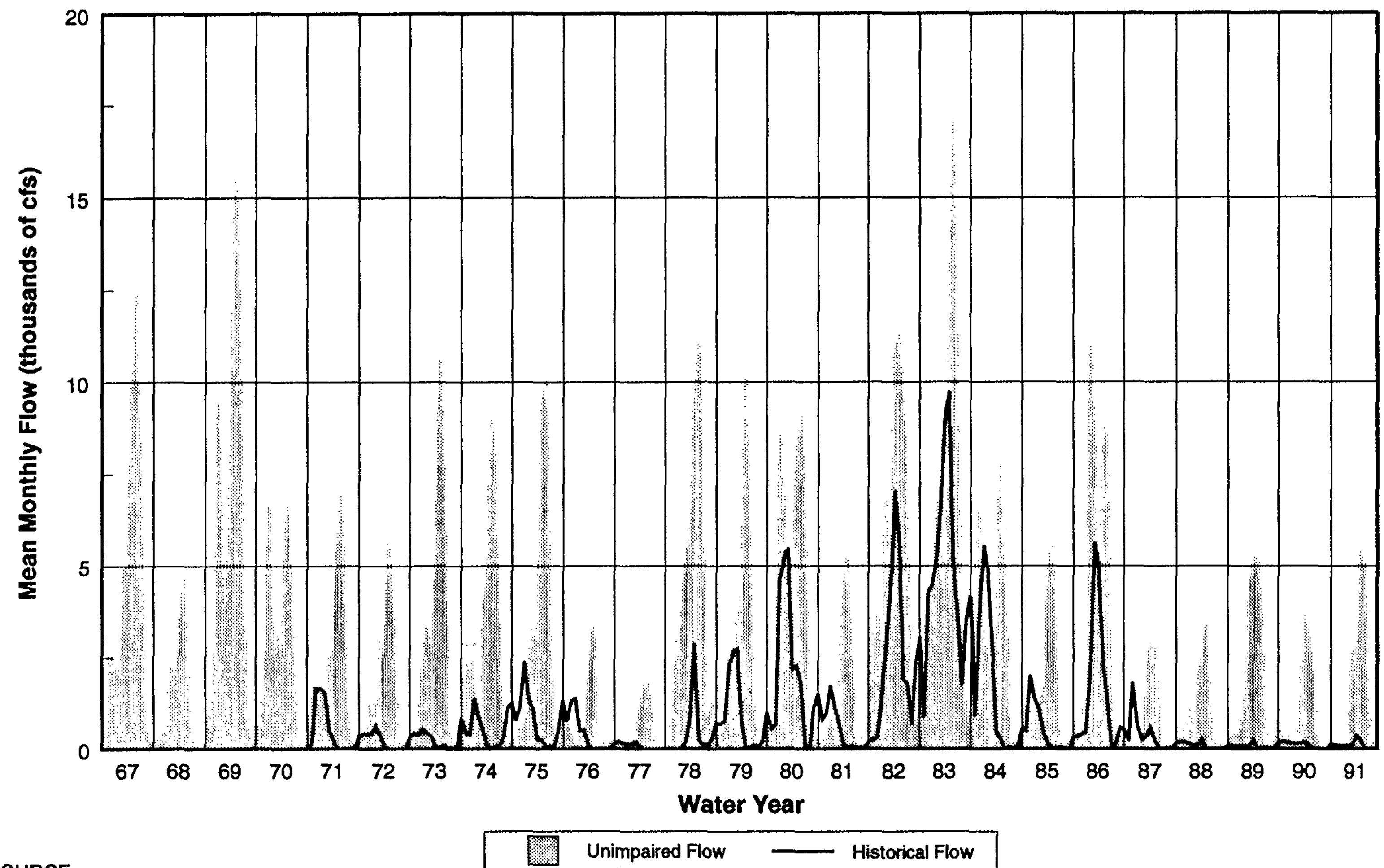
Figure II-48 shows monthly Stanislaus River temperatures below Goodwin Dam and downstream at Ripon. The effects of low-flow years on reservoir release temperatures and downstream warming can be identified. Reclamation has recently completed a water temperature model for New Melones and Tulloch reservoirs and the Stanislaus River (Reclamation, 1993).



SOURCE:
CDEC data base maintained by DWR.

FIGURE II-43

END-OF-MONTH STORAGE FOR NEW DON PEDRO RESERVOIR (1967-1991)

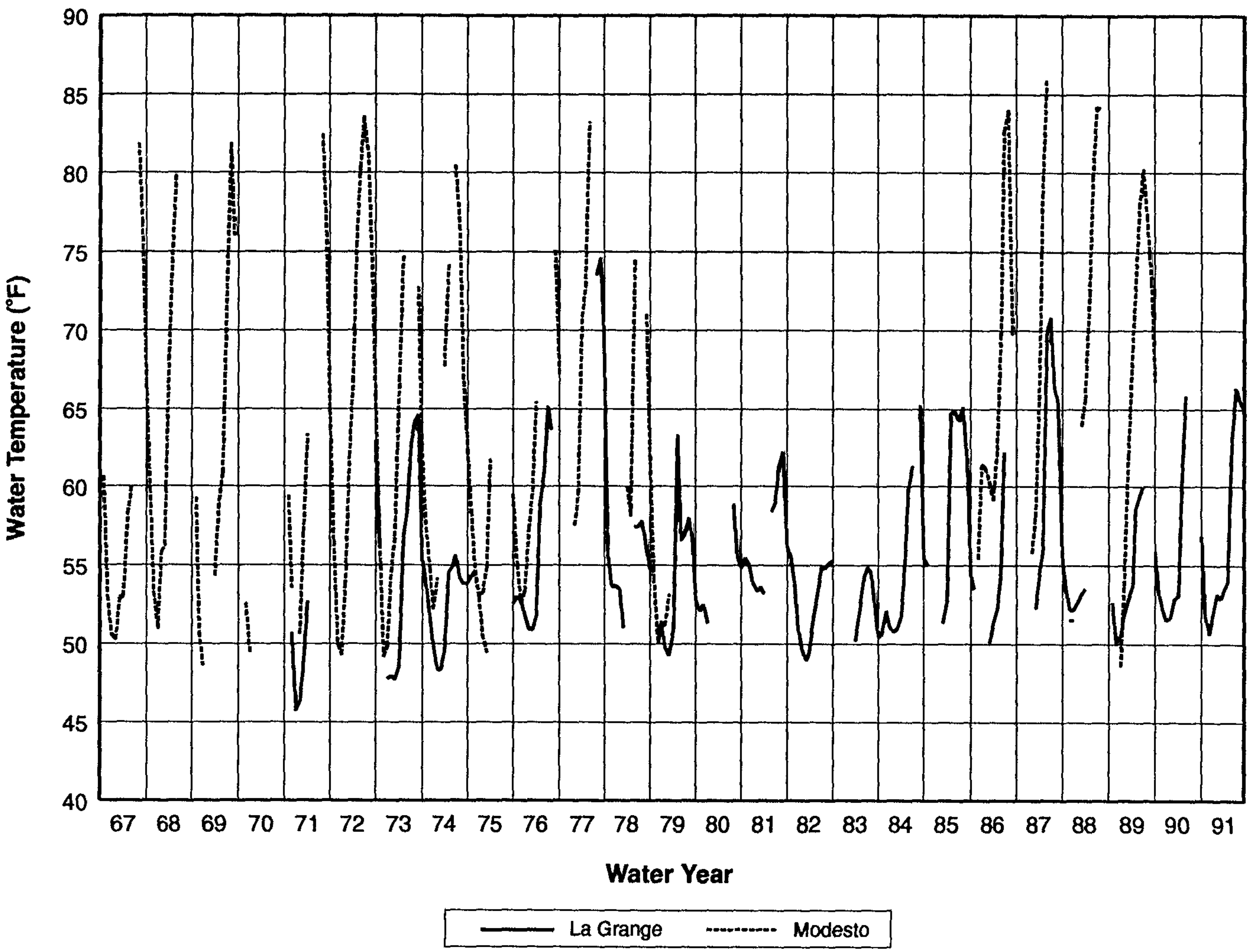


SOURCE:
CDEC data base maintained by DWR and
WATSTORE data base maintained by USGS.

FIGURE II-44

MEAN MONTHLY UNIMPAIRED RUNOFF AND HISTORICAL FLOWS FOR THE TUOLUMNE RIVER NEAR LA GRANGE RESERVOIR (1967-1991)

C-081955



SOURCE:
WATSTORE data base maintained by USGS.

FIGURE II-45

MONTHLY MEAN OF MAXIMUM DAILY TEMPERATURES FOR TUOLUMNE RIVER AT LA GRANGE RESERVOIR AND MODESTO (1967-1991)

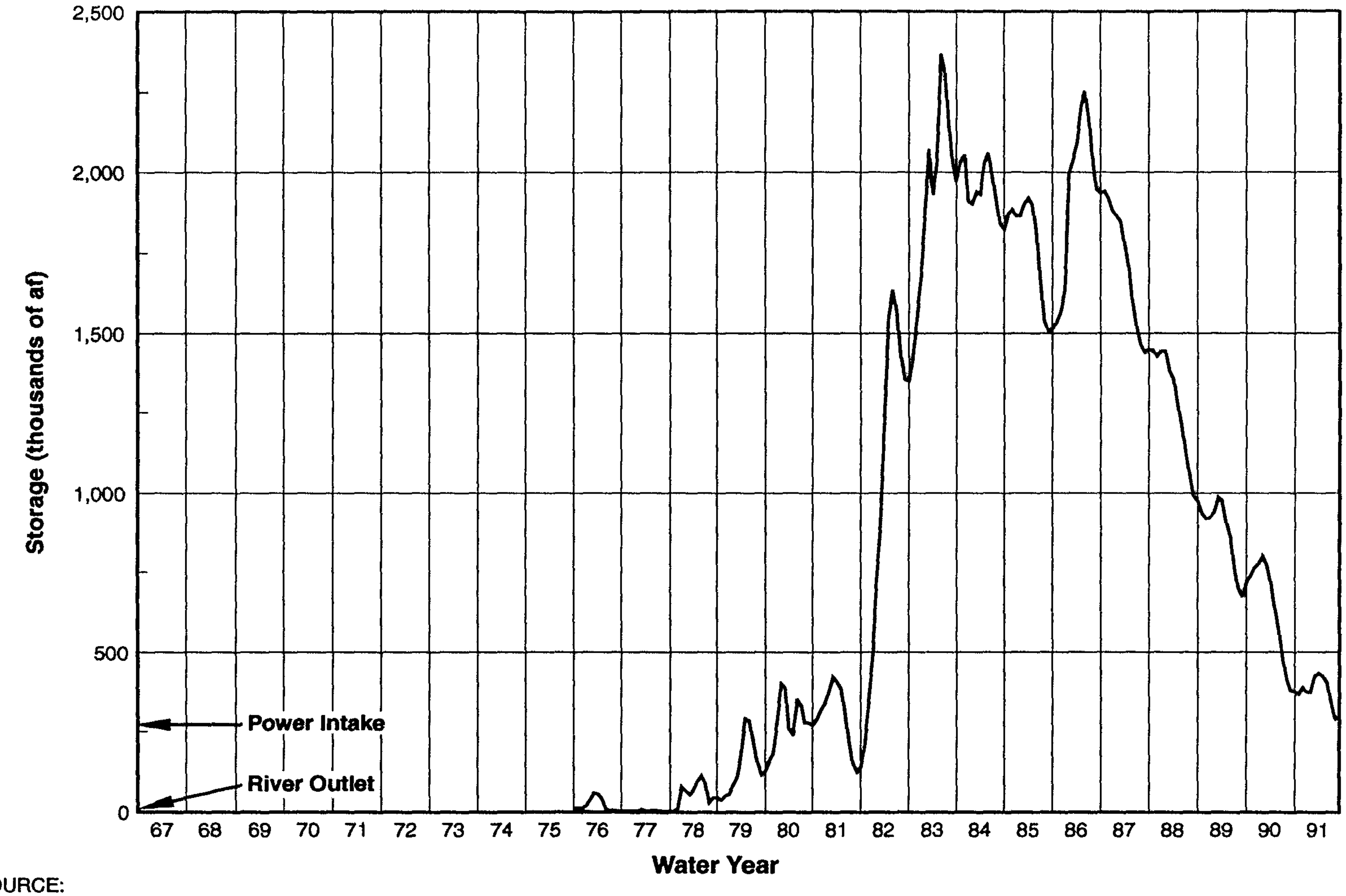
TABLE II-8

ELEVATION/AREA/STORAGE RELATIONSHIP FOR NEW MELONES RESERVOIR

Elevation (feet)	Area (acres)	Incremental Area (acres)	Storage (TAF)	Incremental Storage (TAF)
1,110	13,427	455	2,703.6	131.7
1,100	12,972	428	2,571.8	127.3
1,090	12,544	405	2,444.5	123.2
1,080	12,139	390	2,321.3	119.2
1,070	11,749	379	2,202.1	115.4
1,060	11,370	370	2,086.6	111.7
1,050	11,000	367	1,975.0	108.0
1,040	10,633	361	1,867.0	104.3
1,030	10,272	360	1,762.7	100.7
1,020	9,912	356	1,661.9	97.2
1,010	9,556	355	1,564.8	93.6
1,000	9,201	352	1,471.2	90.1
990	8,849	350	1,381.1	86.6
980	8,499	345	1,294.5	83.1
970	8,154	342	1,211.4	79.7
960	7,812	337	1,131.8	76.3
950	7,475	331	1,055.5	72.9
940	7,144	325	982.6	69.6
930	6,819	318	913.0	66.4
920	6,501	311	846.5	63.3
910	6,190	304	783.2	60.2
900	5,886	295	723.0	57.2
890	5,591	288	665.8	54.3
880	5,303	280	611.5	51.5
870	5,023	273	560.0	48.7
860	4,750	264	511.2	46.0
850	4,486	258	465.2	43.4
840	4,228	250	421.8	40.9
830	3,978	245	380.9	38.4
820	3,733	238	342.5	36.0
810	3,495	232	306.4	33.7
800	3,263	228	272.8	31.4
790	3,035	222	241.4	29.1
780	2,813	217	212.3	26.9
770	2,596	212	185.3	24.8
760	2,384	206	160.5	22.7
750	2,178	203	137.8	20.7
740	1,975	197	117.2	18.7
730	1,778	191	98.5	16.7
720	1,587	184	81.8	14.9
710	1,403	177	67.0	13.0
700	1,226	169	53.9	11.3
690	1,057	161	42.6	9.7
680	896	151	32.9	8.1
670	745	139	24.8	6.7
660	606	126	18.1	5.4
650	480	113	12.8	4.2
640	367	100	8.6	3.1
630	267	83	5.5	2.2
620	184	68	3.3	1.5
610	116	53	1.8	0.9
600	63		1.0	

NOTES:

TAF = thousand acre-feet.
River outlet is at elevation 543 feet.
Power plant intake is at elevation 760 feet.



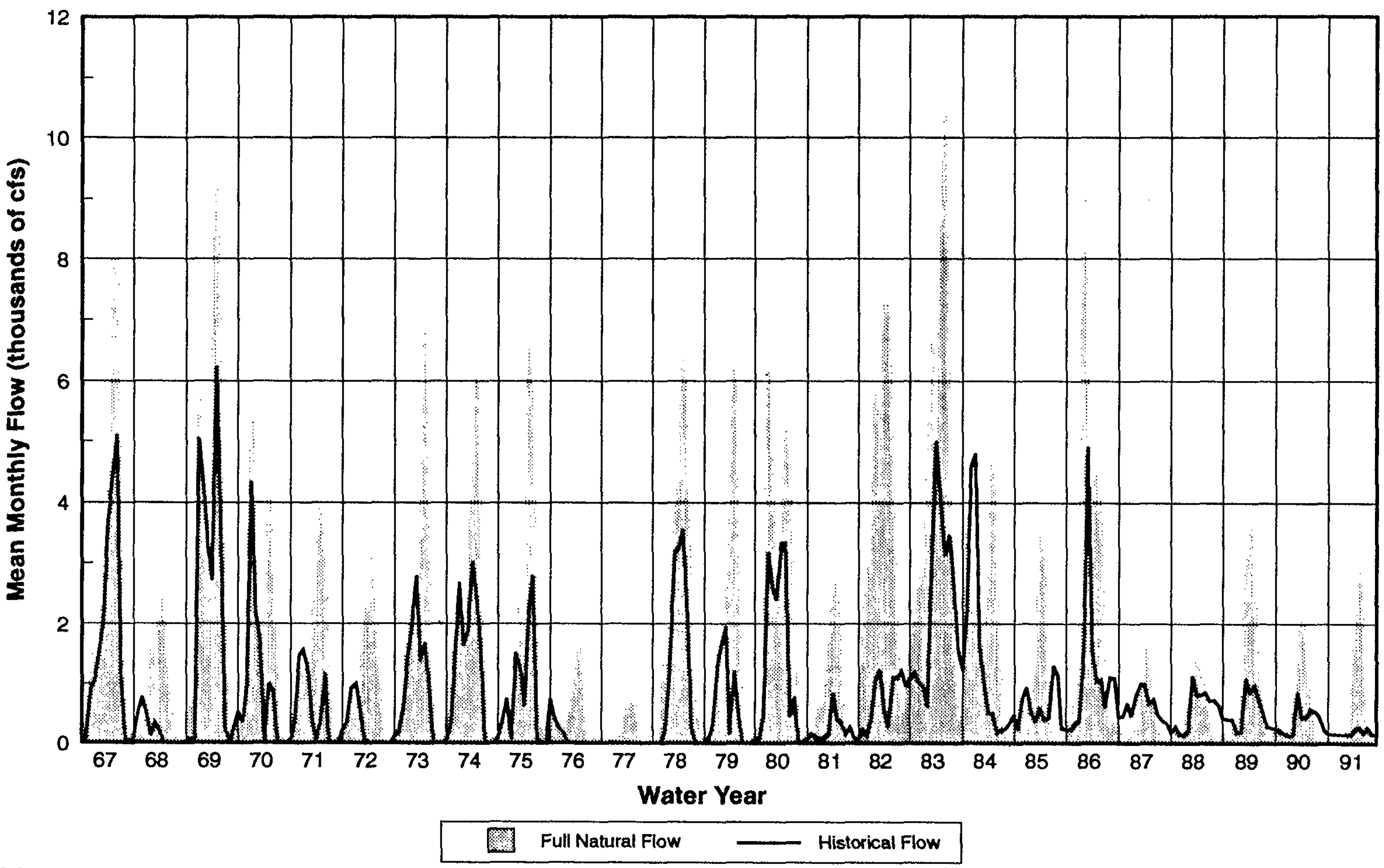
SOURCE:
CDEC data base maintained by DWR.

FIGURE II-46

END-OF-MONTH STORAGE FOR NEW MELONES RESERVOIR (1967-1991)

C-081958

C-081958

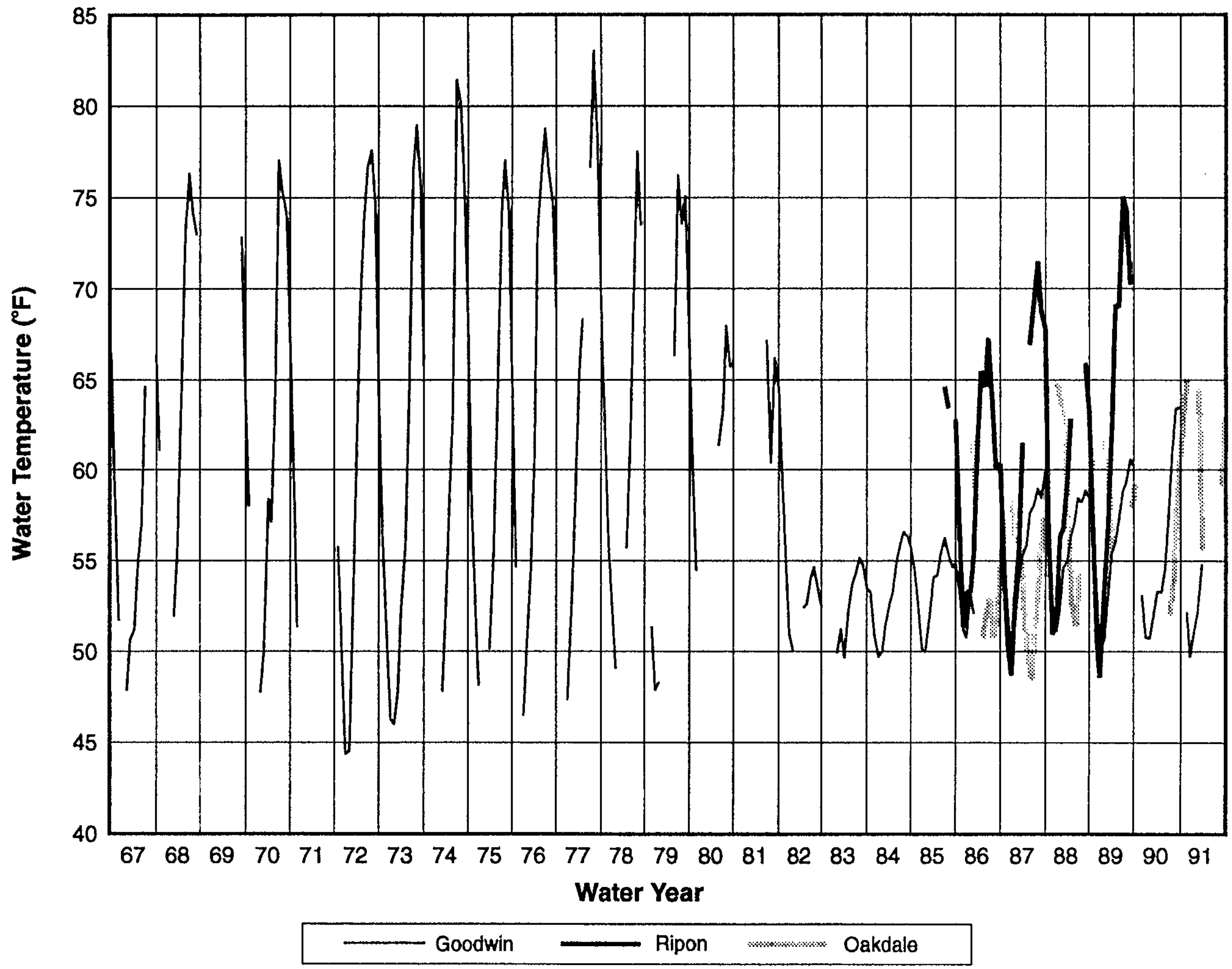


SOURCE:
CDEC data base maintained by DWR and
WATSTORE data base maintained by USGS.

FIGURE II-47

MEAN MONTHLY UNIMPAIRED RUNOFF AND HISTORICAL FLOWS FOR STANISLAUS RIVER NEAR GOODWIN DAM (1967-1991)

C-081959



SOURCE:
WATSTORE data base maintained by USGS.

FIGURE II-48

MONTHLY MEAN OF MAXIMUM DAILY TEMPERATURES FOR STANISLAUS RIVER AT GOODWIN, OAKDALE, AND RIPON (1967-1991)

C—081960

C-081960

Mokelumne River

The Mokelumne River originates in the Sierra Nevada. Water is impounded and regulated by numerous dams in the high Sierra for hydroelectric power generation and local water supply. Farther downstream, water is impounded and regulated by Pardee and Camanche reservoirs, which are operated by East Bay Municipal Utility District (EBMUD). The EBMUD aqueduct diverts water from Pardee Reservoir. Water released from Camanche Reservoir provides water for various downstream uses, including diversions at Woodbridge Dam into Woodbridge Canal. The Mokelumne River Hatchery is located directly below Camanche Reservoir. It was constructed to mitigate impacts on fisheries from the construction of Camanche Reservoir in 1963. Reservoir management affects water quality on the Mokelumne River.

Camanche Reservoir. The largest reservoir on the Mokelumne River is Camanche Reservoir, with a storage capacity of approximately 430,000 af; it provides storage for flood control and downstream water supply. Figure II-49 shows historical end-of-month storage for Camanche Reservoir for 1967-1991. Carryover storage was often above 250,000 af, except during the 1976-1977 and 1987-1991 droughts.

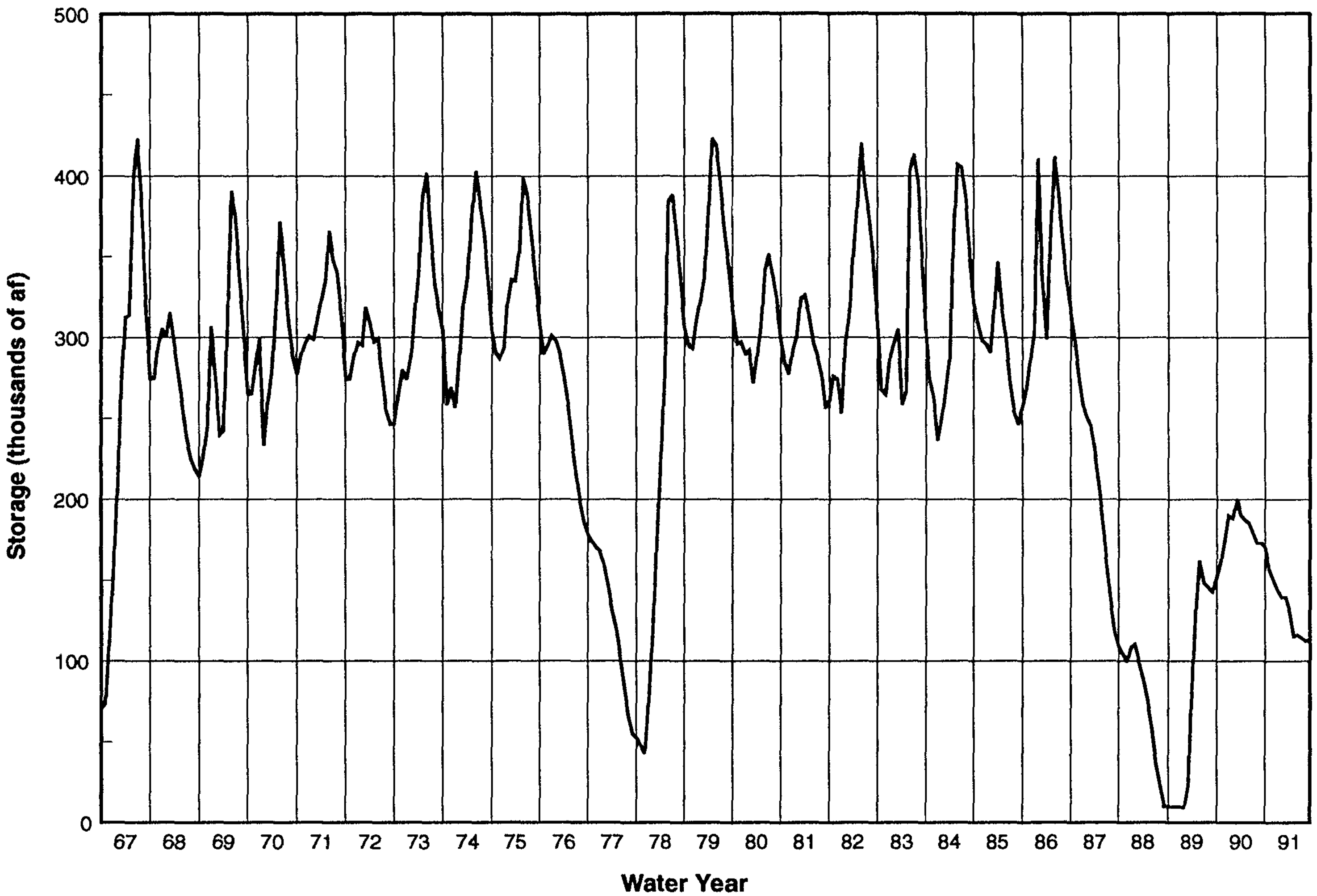
Mokelumne River Flows and Temperatures. Figure II-50 shows monthly unimpaired runoff and historical Mokelumne River flows below Camanche Reservoir for 1967-1991. The average 1967-1991 unimpaired flow was 758,000 af/yr (1,047 cfs). Additional diversions occur downstream at Woodbridge Dam; therefore, flows entering the Delta are less than those shown below Camanche Reservoir. Flows at Woodbridge Dam averaged 397,000 af/yr (549 cfs) for 1967-1991.

Figure II-51 shows Mokelumne River temperatures at Camanche Reservoir and Woodbridge Dam. The effects of Camanche Reservoir drawdown and downstream warming during low-flow summer periods are evident. The Mokelumne River Hatchery temperatures may be lower than river temperatures at these locations because the hatchery receives water directly from Camanche Reservoir.

SACRAMENTO-SAN JOAQUIN RIVER DELTA

The Central Valley is drained by the Sacramento River system to the north and the San Joaquin River system to the south. These two river systems converge into the Delta, which encompasses approximately 680,000 acres interlaced with approximately 700 miles of waterways (Arthur and Ball, 1978). Water flows from the Delta through the Suisun, San Pablo, and San Francisco bays to the Pacific Ocean at the Golden Gate Bridge.

The Delta is the West Coast's largest estuary, one of the country's large systems for fish production, and provides habitat for more than 120 fish species. Delta habitat water quality is strongly influenced by inflows from its rivers, as well as by intrusions of seawater into the western and central portions of the Delta during periods of low outflow that may be influenced by high export pumping. The concentrations of salts and other materials in the river inflows are

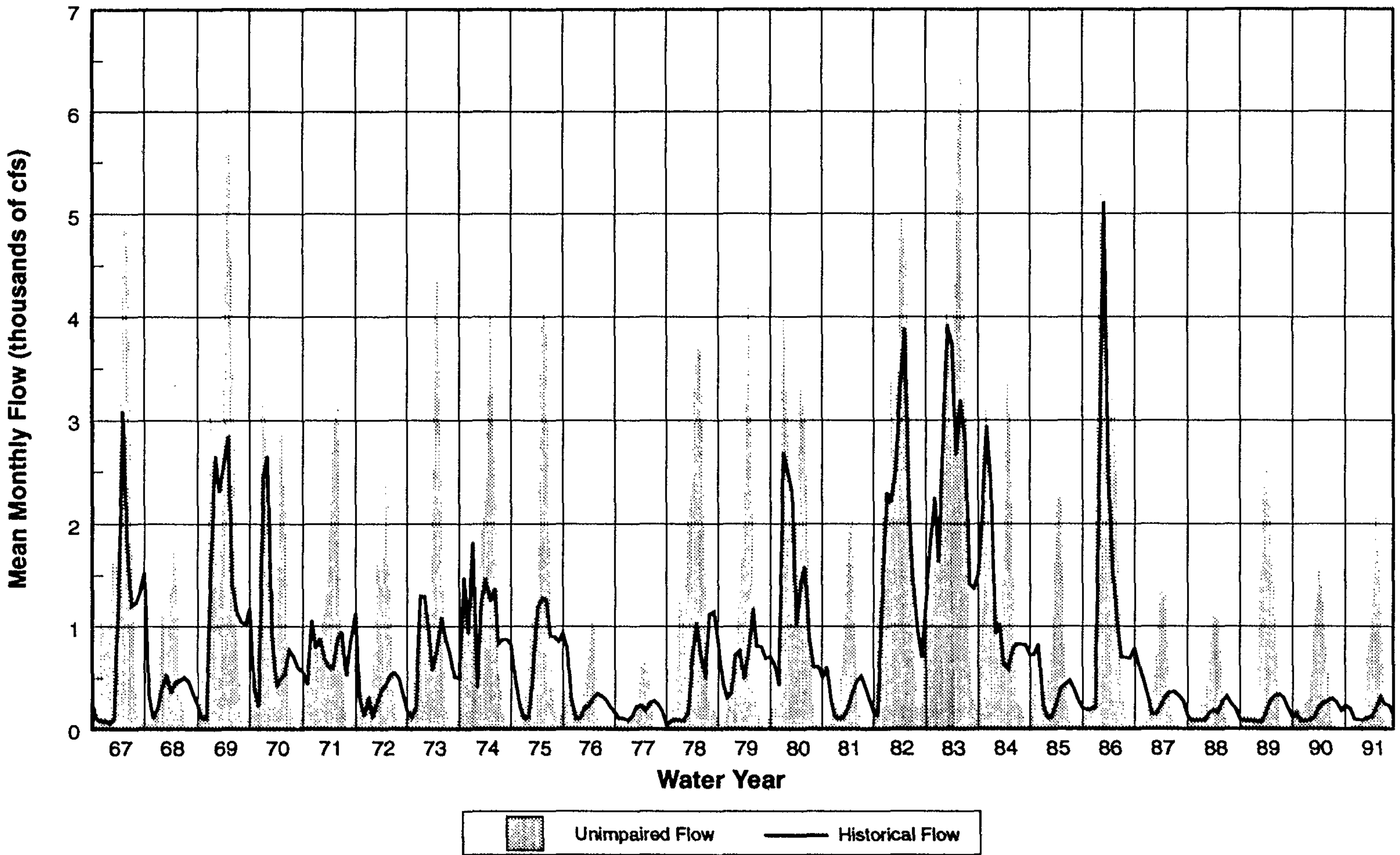


SOURCE:
CDEC data base maintained by DWR.

FIGURE II-49

END-OF-MONTH STORAGE FOR CAMANCHE RESERVOIR (1967-1991)

C-081962

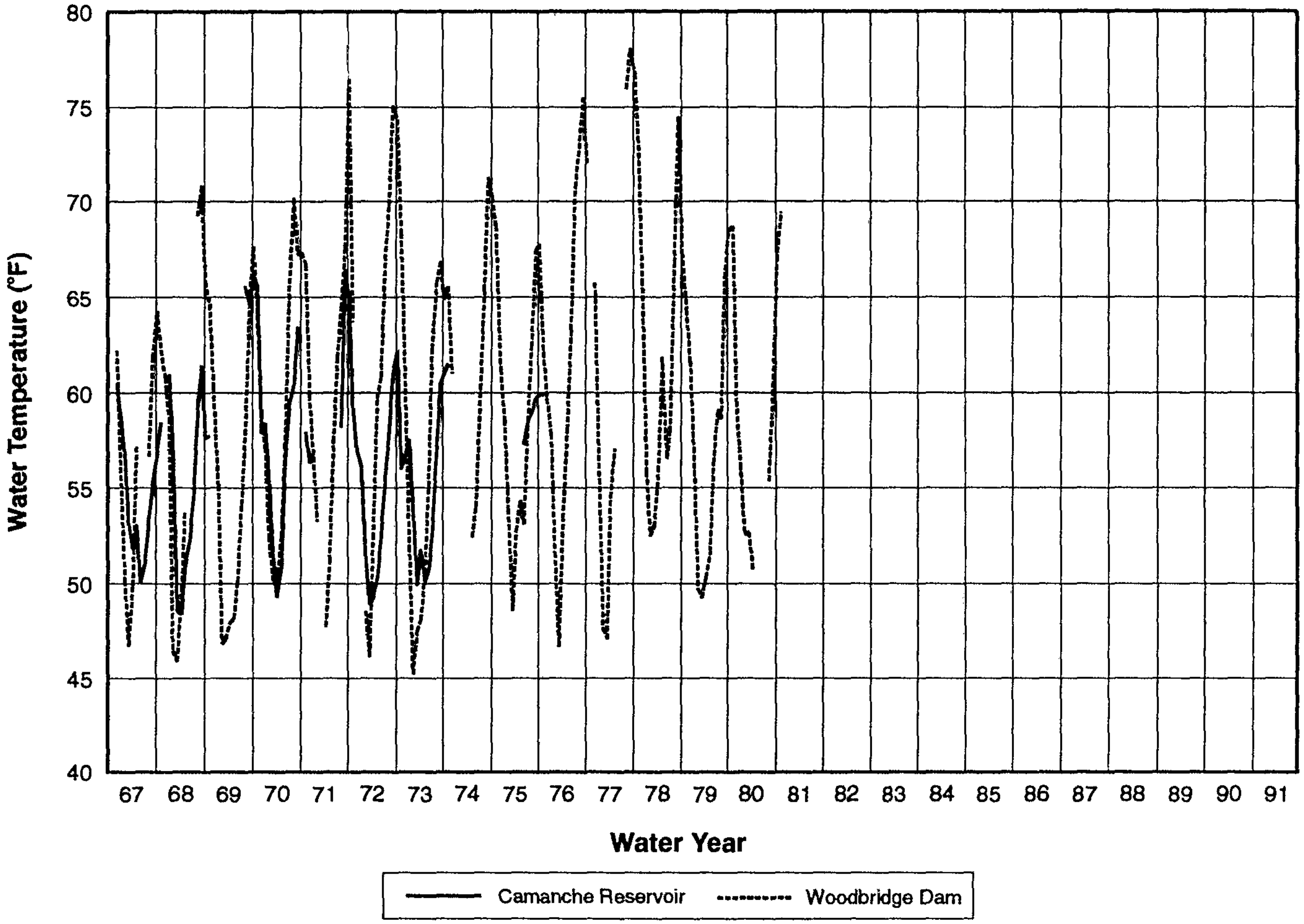


SOURCE:
CDEC data base maintained by DWR and
WATSTORE data base maintained by USGS.

FIGURE II-50

MEAN MONTHLY UNIMPAIRED RUNOFF AND HISTORICAL FLOWS FOR MOKELUMNE RIVER AT COMANCHE RESERVOIR (1967-1991)

C-081963



SOURCE:
WATSTORE data base maintained by USGS.

FIGURE II-51

MONTHLY MEAN OF MAXIMUM DAILY TEMPERATURES FOR MOKELUMNE RIVER AT COMANCHE RESERVOIR AND WOODBRIDGE DAM (1967-1991)

often related to streamflow. The transport and mixing of materials within the Delta strongly depend on river inflows, tidal flows, agricultural diversions and drainage flows, wastewater discharges, exports, and cooling water intakes and discharges.

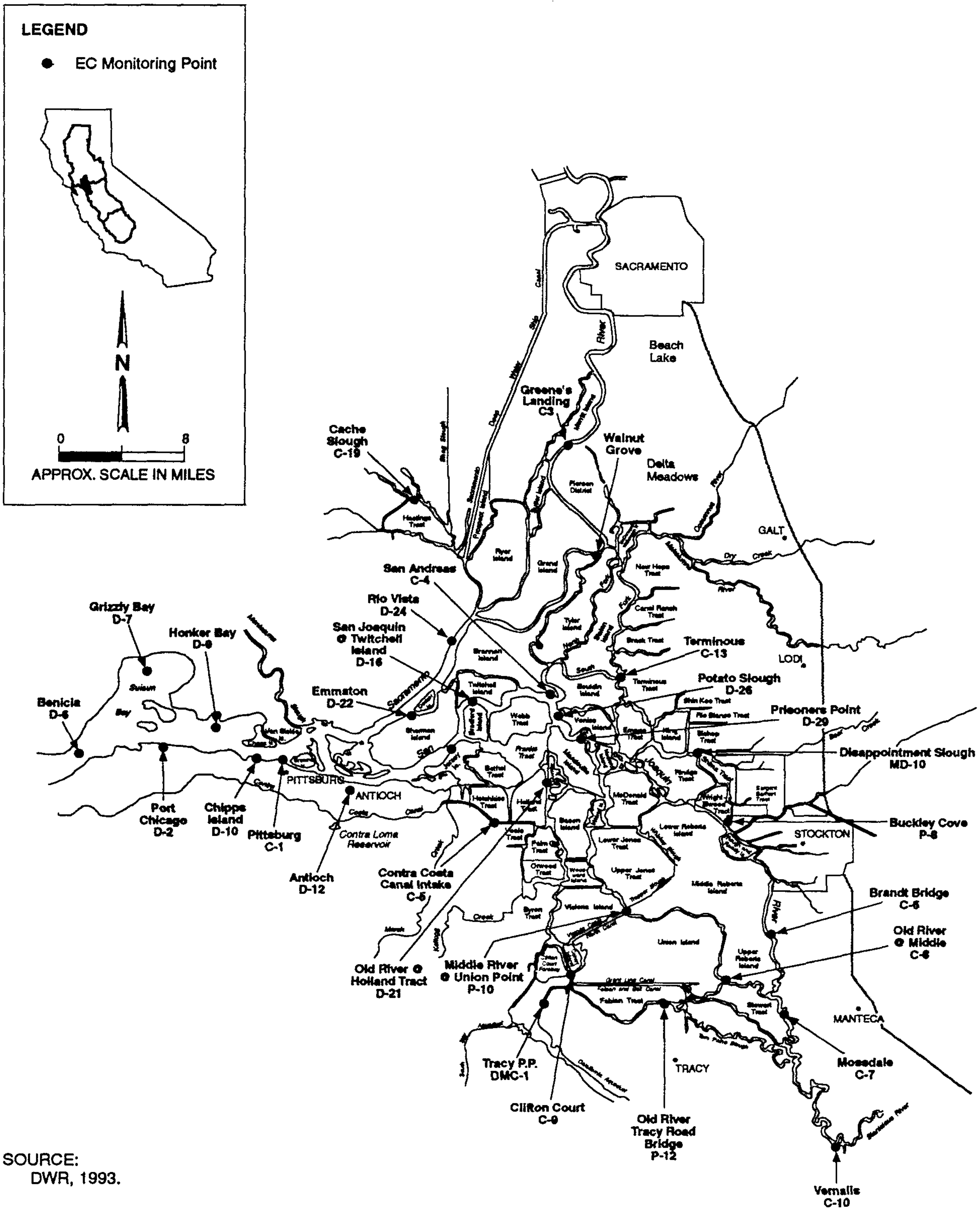
Delta channel geometry, inflows into and within the Delta, and tidal flows are interdependent variables that control seawater intrusion and habitat water quality in the Delta. The mixing of seawater and freshwater creates the entrapment zone, an area of high biological productivity. The entrapment zone, as defined by Arthur and Ball (1980), typically occurs at an EC range of 2,000-10,000 μS/cm, corresponding to 1 to 6 parts per thousand (ppt) of total dissolved solids (TDS) (i.e., salinity). Temperature, SS, light, and nutrients are some of the important factors that control habitat conditions in the entrapment zone. Recently, an index based on the location of the 2-ppt salinity isocline (X2) was established for estimating the upstream location of the entrapment zone. The X2 location is now regulated by the SWRCB as part of the Bay-Delta Plan Accord as defined in the 1995 Water Quality Control Plan (1995 WQCP).

Delta hydrodynamics and salinity intrusion from tidal flows depend on the physical arrangement of Delta channels. The Delta channels are typically less than 30 feet deep, unless dredged, and vary in width from less than 100 feet to more than 1 mile. Although some are edged with riparian and aquatic vegetation, steep mud or riprapped levees border most channels (Kelly, 1966; DeHaven and Weinrich, 1988). To enhance flow and aid in levee maintenance, vegetation is often removed from the channel margins. Figure II-52 shows major Delta channels and locations of several EC measurement stations. Table II-9 gives the annual Delta flows and salinity conditions for 1967-1991.

Delta Facilities. Several important water management facilities are located in the Delta. These include the Contra Costa Pumping Plant at Rock Slough, the CVP Pumping Plant at Tracy, the Delta Cross Channel (DCC) at Walnut Grove, the SWP Banks Pumping Plant, the North Bay Aqueduct Pumping Plant, and Suisun Marsh Salinity Control Structure on Montezuma Slough.

Figure II-53 shows the historical CVP and SWP Delta exports for 1967-1991. Delta exports generally increased throughout that period, except when limited by the drought conditions in 1976-1977 and 1987-1991. The average CVP and SWP exports during 1967-1991 were 4.04 million af/yr (5,575 cfs). The SWP Banks Pumping Plant began operating in 1968, San Luis Reservoir was completed in 1967 and first filled in 1969, and Edmonton Pumping Plant was completed in 1973.

The CVP Tracy Pumping Plant has a maximum pumping capacity of approximately 4,600 cfs, the nominal capacity of the Delta-Mendota Canal at the pumping plant. Although seasonal fluctuations occur in CVP export pumping, filling of the CVP portion of San Luis Reservoir helps to even the demand. CVP facilities also include the DCC and the Contra Costa Canal. The DCC is a gated diversion channel in the Sacramento River near Walnut Grove and Snodgrass Slough. When the DCC gates are open, Sacramento River water can be diverted through natural channels of the lower Mokelumne and San Joaquin rivers toward the pumping plants in the southern Delta.



SOURCE:
DWR, 1993.

FIGURE II-52

MAP OF DELTA EC MONITORING LOCATIONS

C—081966

TABLE II-9

HYDROLOGIC CONDITIONS IN THE DELTA AND AT SAN LUIS RESERVOIR

	Delta	Delta	Sacramento R. Yolo Bypass	Sacramento R. Freeport	San Joaquin R. Vernalis	Eastside Streams	Delta Tracy	Delta Banks	Delta CVP+SWP
Water Year	Unimpaired Inflow (TAF)	Historical Inflow (TAF)	Historical Flow (TAF)	Historical Flow (TAF)	Historical Flow (TAF)	Historical Flow (TAF)	CVP Export (TAF)	SWP Export (TAF)	Total Exports (TAF)
67	43,824	35,216	3,666	24,267	5,567	1,723	1,254	0	1,254
68	20,451	15,988	669	13,395	1,425	520	1,998	474	2,471
69	52,850	42,245	6,290	23,394	10,182	2,391	1,846	1,033	2,879
70	37,959	33,229	8,512	20,317	3,080	1,415	1,654	416	2,070
71	33,839	26,830	1,308	22,842	1,781	902	1,920	914	2,834
72	19,832	13,993	30	12,488	1,113	365	2,351	1,095	3,445
73	35,070	28,496	3,892	20,787	2,395	1,429	1,849	1,520	3,369
74	50,215	42,596	7,577	30,705	2,776	1,551	2,448	1,918	4,366
75	32,060	24,873	952	19,968	2,830	1,125	2,356	1,554	3,910
76	11,508	12,723	15	10,978	1,525	206	3,017	1,829	4,846
77	6,810	5,953	1	5,505	416	30	1,283	798	2,081
78	43,456	26,201	2,848	17,716	4,496	1,146	2,273	2,083	4,356
79	23,081	16,853	154	13,052	2,629	1,020	2,290	2,185	4,476
80	41,341	33,469	6,511	19,275	5,994	1,830	2,010	2,519	4,529
81	17,189	13,692	126	11,515	1,766	286	2,595	2,133	4,728
82	58,755	45,940	7,239	30,142	5,485	3,038	1,979	2,648	4,627
83	73,123	69,069	14,983	34,096	15,459	4,557	2,508	1,897	4,405
84	38,033	35,240	4,695	22,415	6,269	1,807	2,197	1,649	3,846
85	17,763	14,972	172	12,209	2,104	470	2,795	2,683	5,478
86	47,778	36,107	10,623	18,137	5,242	2,124	2,622	2,671	5,293
87	13,364	12,275	35	10,044	1,810	384	2,764	2,286	5,050
88	14,012	11,089	116	9,667	1,165	143	2,901	2,718	5,619
89	22,003	13,584	45	12,261	1,058	221	2,874	3,101	5,975
90	13,614	10,979	21	9,873	916	169	2,706	3,113	5,819
91	13,895	8,503	75	7,551	656	221	1,411	1,774	3,185
Average	**31,273**	**25,205**	**3,222**	**17,304**	**3,526**	**1,163**	**2,236**	**1,800**	**4,037**
Average (cfs)	**43,195**	**34,813**	**4,451**	**23,901**	**4,870**	**841**	**3,088**	**2,487**	**5,575**

C-081967

TABLE II-9. CONTINUED

Water Year	Delta Delta Outflow (TAF)	Delta Benicia Mean EC (µS/cm)	Delta Port Chicago Mean EC (µS/cm)	Delta Chipps Island Mean EC (µS/cm)	Delta Pittsburg Mean EC (µS/cm)	Delta Collinsville Mean EC (µS/cm)	Delta Emmaton Mean EC (µS/cm)	Delta Rio Vista Mean EC (µS/cm)	Delta Antioch Mean EC (µS/cm)
67	33,561								
68	12,524	16,943	10,284		3,499	2,100	497	200	1,465
69	38,936	9,900	5,508		1,483	812	245	162	632
70	30,332	13,517	7,857		2,279	1,152	290	167	670
71	23,223	9,332	3,769		594	242	152	155	282
72	9,273	16,422	9,785		3,309	1,951	502	184	1,431
73	24,643	12,283	6,911		2,019	1,157	293	182	865
74	37,534	7,849	3,319		688	305	142	150	316
75	20,070	9,585	4,478		574	278	149	155	301
76	6,592	18,885	13,478		4,958	3,073	663	209	2,096
77	2,542	26,830	21,355		11,485	8,725	3,798	847	5,986
78	21,497	15,675	10,462	6,045	5,180	3,392	1,450	484	2,687
79	11,571	17,250	9,537	3,983	3,139	1,764	373	222	1,342
80	28,541	12,645	7,090		2,126	926	268	192	742
81	7,919	20,066	12,115	5,041	4,633	2,491	553	228	1,756
82	41,287	9,244	4,351	1,914	1,735	1,232	395	193	746
83	64,732	4,865	1,399	236	210	165	149	172	190
84	30,634	9,097	4,390	1,339	1,126	518	206	180	417
85	8,465	15,325	10,206		3,753	2,116	482	207	1,475
86	30,535	14,309	8,608	4,471	3,910	2,361	691		1,444
87	6,113	19,052	13,859			3,652	815	212	2,224
88	4,415	24,869	16,856	9,126	8,657	5,786	1,769	314	4,096
89	6,608	24,801	14,008	7,917	7,820	4,593	1,436	287	3,435
90	3,973	24,783	18,176	9,470	8,514	5,456	1,393	250	4,015
91	4,377	25,483	20,143	11,331	12,008	6,757	2,715	402	4,800
Average	**20,396**	**15,792**	**9,914**	**5,534**	**4,074**	**2,542**	**810**	**250**	**1,809**
Average (cfs)	**28,171**								

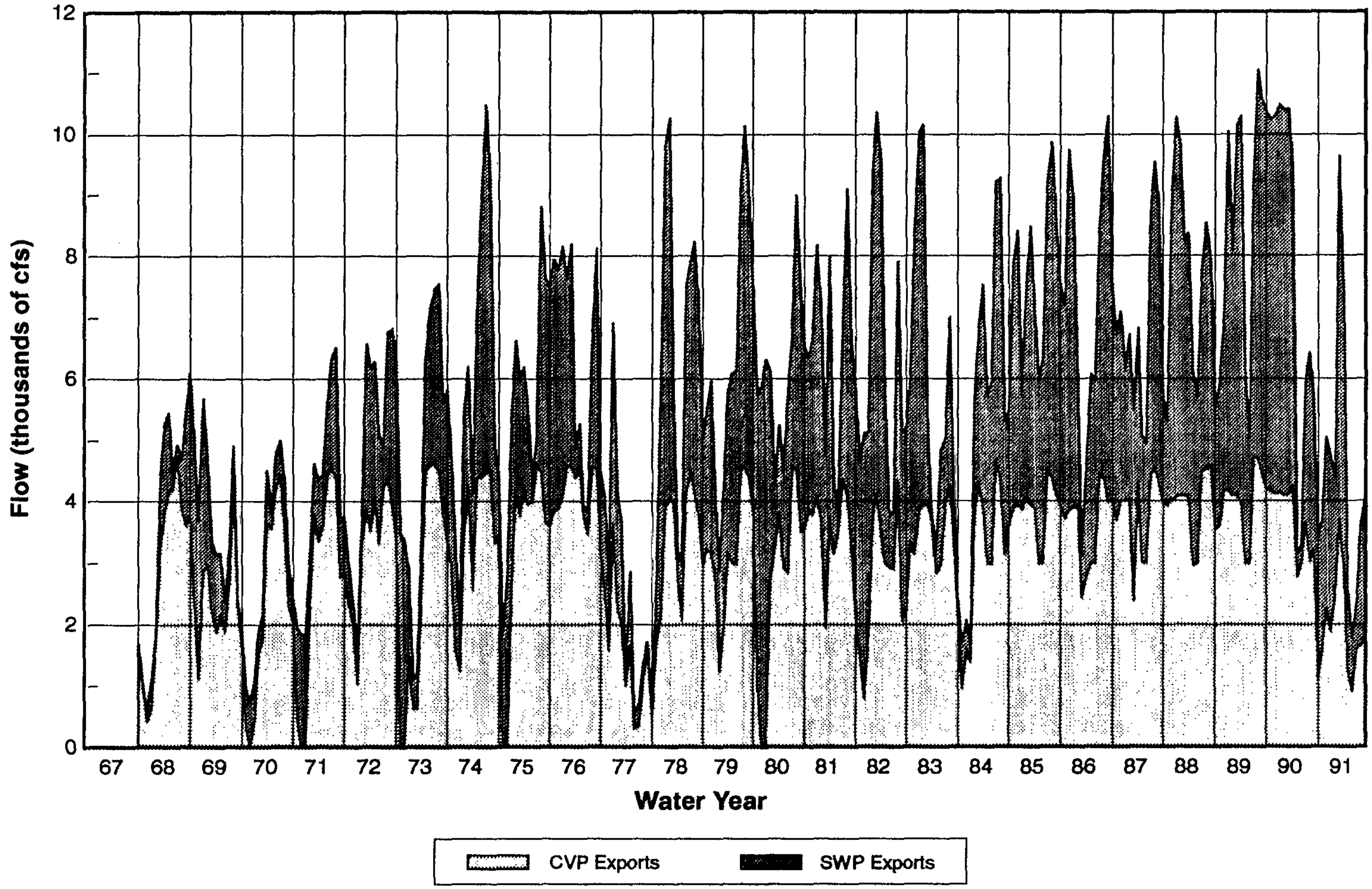
C—081968

TABLE II-9. CONTINUED

Water Year	Delta Jersey Point Mean EC (μS/cm)	Delta Dutch Slough Mean EC (μS/cm)	Delta Union Island Mean EC (μS/cm)	Delta Holland Tract Mean EC (μS/cm)	Delta CCC PP#1 Mean EC (μS/cm)	Delta CCC PP#1 Mean Chlorides (mg/l)	Delta Middle River Mean EC (μS/cm)	Delta DMC Mean EC (μS/cm)	Total San Luis End-of-September Storage (TAF)
67									0
68	532	515		395	494	83	395	517	0
69	278	293	421	224	346	50		395	1,981
70	342	348	535	287	405	65	315	394	1,720
71	199	269	671	243	380	53	333	527	1,736
72	583	523	772	407	445	79	317	465	1,482
73	421	537	623	442	616	92	425		1,691
74	194	272	513	225	313	45	289	431	1,852
75	182	243	490	224	276	37	317		1,032
76	641	577	792	340	368	67	269	407	678
77	2,397	1,826	1,221	1,095	936	236	569	954	274
78		914	700	622	670	134	399	584	1,719
79		496	541	362	486	78	314	381	1,213
80	298	340	382		411	58	288		1,483
81	543	499	681	332	409	64	338	502	263
82	334	373	432	282	470	74	341	440	23
83	188	259	208	227	470	60	234	275	1,940
84	221	282	466	223	379	48	276	372	812
85	529	455	593	330	384	59	321	433	763
86	708	602	520	408	511	83	335	441	1,481
87	741	584	709	425	469	75	350	536	688
88	1,446	890	951	718	767	148	446	671	488
89	1,257	529	899	612	625	124	410	622	365
90	1,293	998	988	626	646	147	359	611	488
91	1,463	1041	943	702	723	163	444	669	654
Average	**672**	**569**	**654**	**424**	**500**	**88**	**352**	**506**	**993**
Average (cfs)									

NOTE:
TAF = thousand acre-feet.

C—081969



SOURCE:
DAYFLOW data base maintained by DWR.

FIGURE II-53

MEAN MONTHLY DELTA EXPORTS AT CVP TRACY AND SWP BANKS PUMPING PLANTS (1967-1991)

The Contra Costa Canal originates at Rock Slough, approximately 4 miles southeast of Oakley. Diversions have historically ranged from 50 to 250 cfs at the unscreened Rock Slough facility (Contra Costa Canal Pumping Plant No. 1). Although the canal and its associated facilities are part of the CVP, they are operated and maintained by the Contra Costa Water District (CCWD).

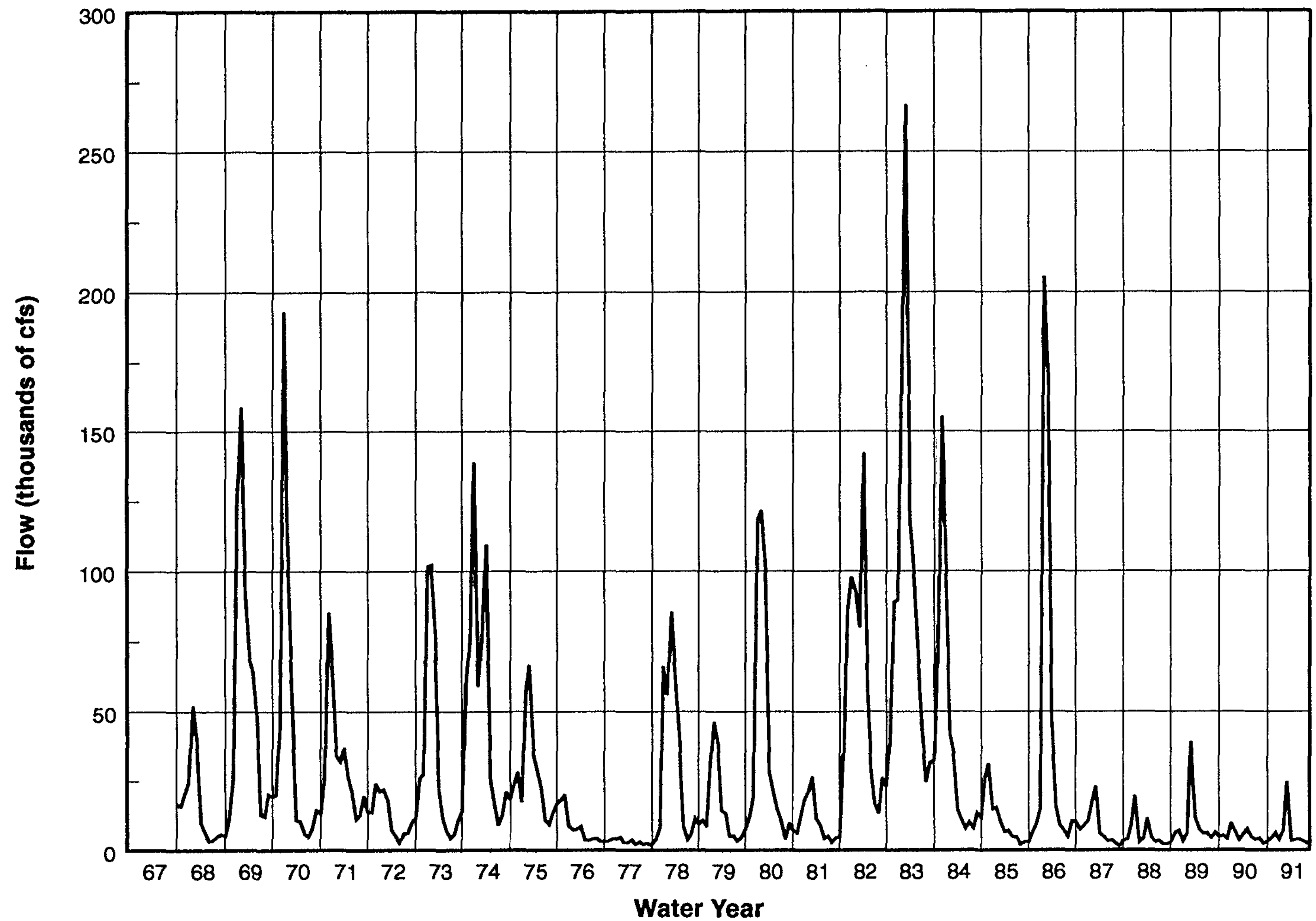
The SWP Banks Pumping Plant supplies water for the South Bay Aqueduct and the California Aqueduct, which has a nominal capacity of 10,300 cfs. Although exports have been limited by the Banks Pumping Plant capacity, an additional four pumps became operational in 1992, increasing the maximum Banks Pumping Plant capacity from 6,800 cfs to approximately 10,300 cfs.

DWR facilities around the Delta include the North Bay Aqueduct, the Suisun Marsh Salinity Control Structure, and several temporary barriers in the south Delta. The SWP pumps water from Barker Slough into the North Bay Aqueduct for use in Napa and Solano counties. Maximum pumping capacity at Barker Slough is 175 cfs (pipeline capacity); the average annual pumping rate is approximately 35 cfs.

The Suisun Marsh Salinity Control Structure spans Montezuma Slough near Collinsville. The structure's primary objective is to meet the water quality criteria in Suisun Marsh that were developed to offset the effects of upstream diversions by the CVP, SWP, and other water diversions. When operating, the salinity control tidal gate structure blocks eastward flow in Montezuma Slough from Grizzly Bay during flood tides and allows westward flow from the Sacramento River near Collinsville during ebb tides. This gate operation scheme produces a net flow of approximately 2,000 cfs into Montezuma Slough from the Sacramento River at Collinsville.

Delta Flows. Average river discharge into the Delta is somewhat lower than unimpaired runoff would be because of upstream diversions and storage of water for urban and agricultural use. However, CVP exports from the Trinity River have increased the historical Sacramento River inflows to the Delta. River inflow to the Delta is estimated to be approximately 80 percent of what it would be without water developments (Figure II-54). One of the principal effects of this decrease in freshwater inflow has been an upstream movement of the salinity gradient transition zone between San Francisco Bay and the tidal reaches of the rivers (Schubel, 1993).

Delta inflow, which averages approximately 25 million af/yr, primarily consists of the flows of the Sacramento, San Joaquin, Mokelumne, Cosumnes, and Calaveras rivers and the Yolo Bypass. Sacramento River water enters the central Delta via the main river channel, through Steamboat and Sutter sloughs, or through the DCC and Georgiana Slough into the tributaries of the Mokelumne River. Sacramento River water also flows through the central Delta via Threemile Slough, except under high San Joaquin River flow conditions. Delta exports and diversions cause water entering the central and eastern Delta via the Mokelumne and San Joaquin rivers to flow west and south through Middle and Old rivers toward the export pumps at the south end of the Delta.



SOURCE:
DAYFLOW data base maintained by DWR.

FIGURE II-55

MEAN MONTHLY DELTA OUTFLOW
(1967-1991)

The entire flow of the San Joaquin River can be drawn toward the pumps through the head of Old River (near Mossdale) during conditions of low river discharge and high exports. The lower San Joaquin River between Antioch and the Mokelumne River can also reverse, carrying a mixture of Suisun Bay and Sacramento River water into the central Delta, when export is sufficiently high.

The Sacramento River maximum channel flow capacity is approximately 80,000 cfs, with flows greater than this capacity diverted into the Yolo Bypass upstream of the City of Sacramento. During late summer of most years, the minimum monthly average Sacramento River flows at Freeport are approximately 10,000 cfs. Flows of less than 10,000 cfs persisted for several months during 1977 and 1991 (Figure II-18). Maintaining salinity control in the Delta with Delta outflow is most critical during these low-flow periods. During periods of high runoff, a large proportion of Sacramento River and Yolo Bypass flows cannot be controlled by upstream reservoirs. Regardless of CVP and SWP reservoir operations, the high runoff flows enter the Delta in response to natural hydrologic conditions.

The monthly average flow in the San Joaquin River for 1967-1991 was 4,870 cfs (Table II-7). The combined average flow in the eastside streams (Mokelumne, Cosumnes, and Calaveras rivers) for the same period was approximately 1,800 cfs. San Joaquin River flows have frequently been less than 1,000 cfs. In recent years, releases from New Melones Reservoir have been used to maintain San Joaquin River flows for salinity control. Most runoff occurs during winter storms, when maximum flows on the San Joaquin River can exceed 20,000 cfs and flows of the combined eastside streams can exceed 10,000 cfs. High flows in the other eastside streams and the Sacramento River generally correspond with periods of high flow in the San Joaquin River.

Delta outflow can be estimated as the difference between Delta inflows and the combination of Delta exports and net channel depletion. Figure II-55 shows the monthly average Delta outflow for 1967-1991. For 1967-1991, the average estimated Delta outflow was approximately 20.4 million af/yr (28,171 cfs) and the maximum monthly average outflow was approximately 260,000 cfs. In almost all years, minimum monthly average Delta outflow has been less than 5,000 cfs during late summer and fall.

Tides and Salinity. The Delta is subject to tidal action and saltwater intrusion. Saltwater intrusion is governed by the flushing action of Delta outflow and the transport of salt upstream through tidal mixing exchange. Seawater intrusion has the greatest effect in the western portion of the Delta, but increased EC had been measured as far upstream as Courtland on the Sacramento River and Stockton on the San Joaquin River during critically dry years before CVP and SWP pumps were constructed (Smith, 1987). The western Delta and Bay region, where saltwater intrusion is greatest, historically has a high EC range.

Historical EC measurements have been analyzed as a function of the effective Delta outflow, which is similar to the antecedent Delta outflow concept suggested by CCWD (Sullivan and Denton, 1994). Because the salinity gradient location is governed by the balance between Delta

C—081974

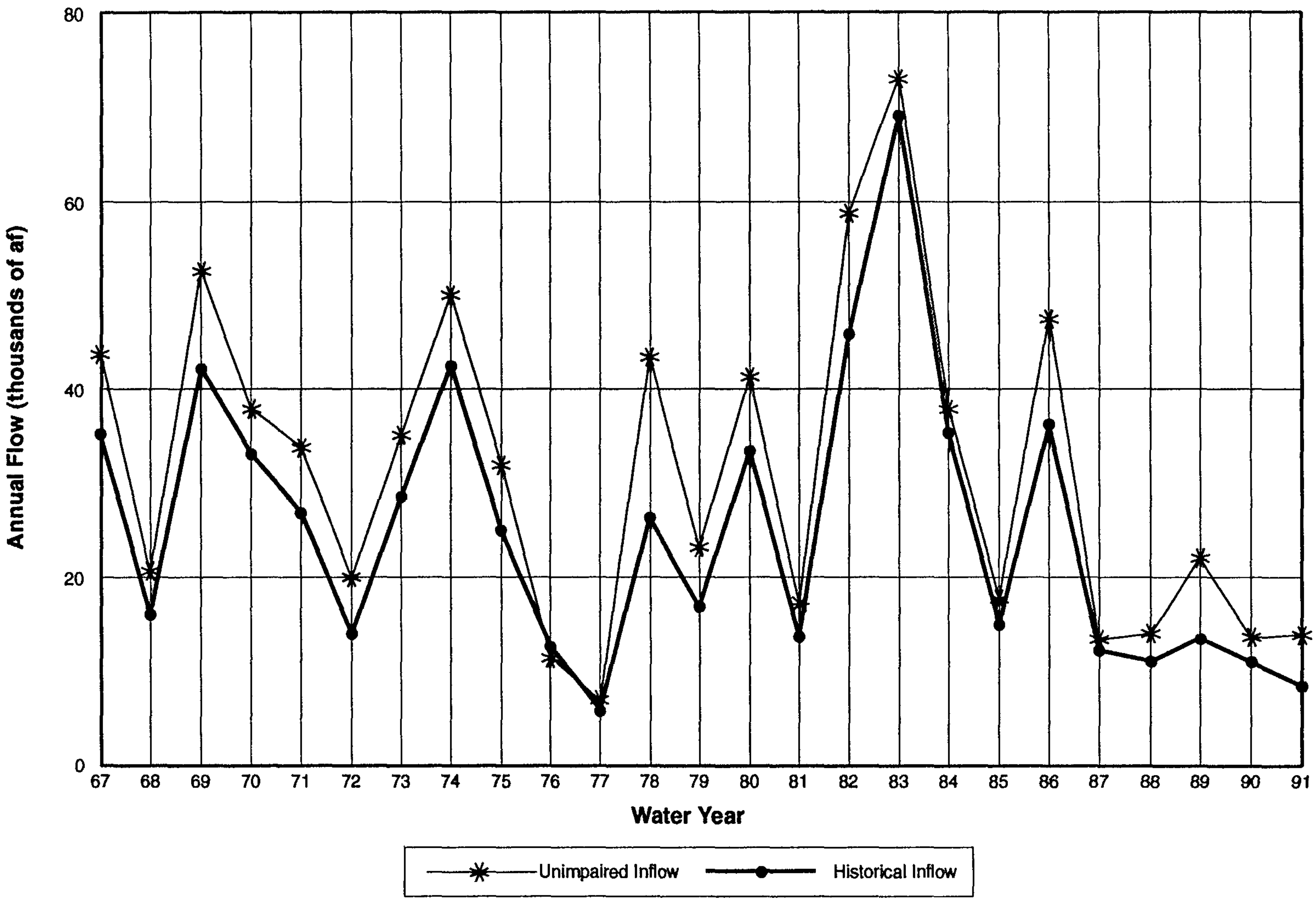


FIGURE II-54

UNIMPAIRED AND HISTORICAL DELTA INFLOW (1967-1991)

outflow and tidal mixing of salinity from San Pablo Bay, the observed EC at a fixed station is a function of the effective Delta outflow. During periods of steady Delta outflow, the average EC value will remain relatively constant (with a large tidal fluctuation). The expected mean EC value at a fixed location in an idealized one-dimensional estuary is a negative exponential function of outflow:

$$EC = a \times \exp(-b \times \text{outflow})$$

However, the observed EC at a location is not immediately changed by an increase or decrease in Delta outflow. During periods of increasing outflow, the EC will be decreasing but will be higher than expected with calculations based on a steady outflow. During periods of decreasing outflow, the EC will be increasing but will be lower than expected based on a steady outflow. This dynamic change in the observed EC can be approximated with a calculated effective outflow. An exponential estimate of the change in the monthly effective outflow has been found to be:

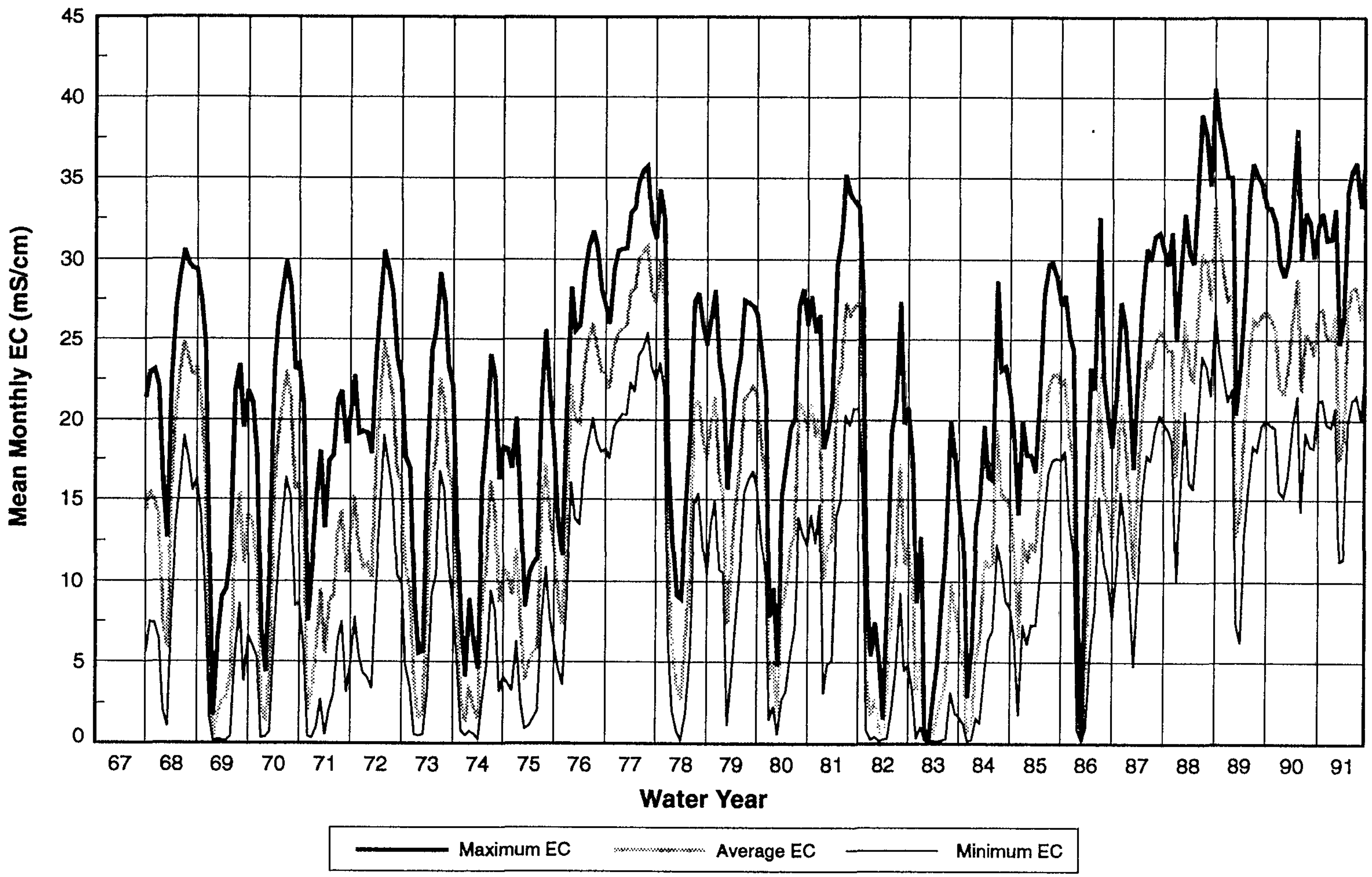
$$\text{Effective Change} = (\text{Outflow} - \text{Effective Outflow}) \times (1 - \exp[-0.0002 \times \text{Effective Outflow}])$$

For example, if the effective Delta outflow is 5,000 cfs, then the response of the effective outflow to a change in outflow would be 63 percent (1 - exp [-.0002 × 5000]). A change in outflow to 10,000 would change the effective outflow to 8,160 (5,000 + 0.63 × 5,000). For an effective outflow of 10,000 cfs, the response to a change in outflow would be 86 percent. For an effective outflow of 20,000 cfs, the response to a change in outflow would be 98 percent.

Figure II-56 shows the historical pattern of monthly average EC at Benicia for 1967-1991. At Benicia, monthly average EC values range from less than 1,000 μS/cm during high Delta outflows to 30,000 μS/cm during low Delta outflows. Comparison with Figure II-55 demonstrates the relationship between monthly average effective Delta outflow and monthly average EC at Benicia. Considerable scatter in the pattern is the result of using monthly average EC values; the effects of daily changes in effective Delta outflow on EC are not always accurately described with monthly average values. The X2 location (EC of about 3 millisiemens per centimeter [mS/cm]) will be downstream of Benicia only at an effective Delta outflow greater than 50,000 cfs.

Figure II-57 shows the historical pattern of monthly average EC at Port Chicago (opposite Roe Island) for 1967-1991. Comparison with Figure II-55 shows the relationship between monthly average effective Delta outflow and monthly average EC at Port Chicago. The X2 location will be in the vicinity of Port Chicago during months with an effective outflow of 25,000 to 30,000 cfs.

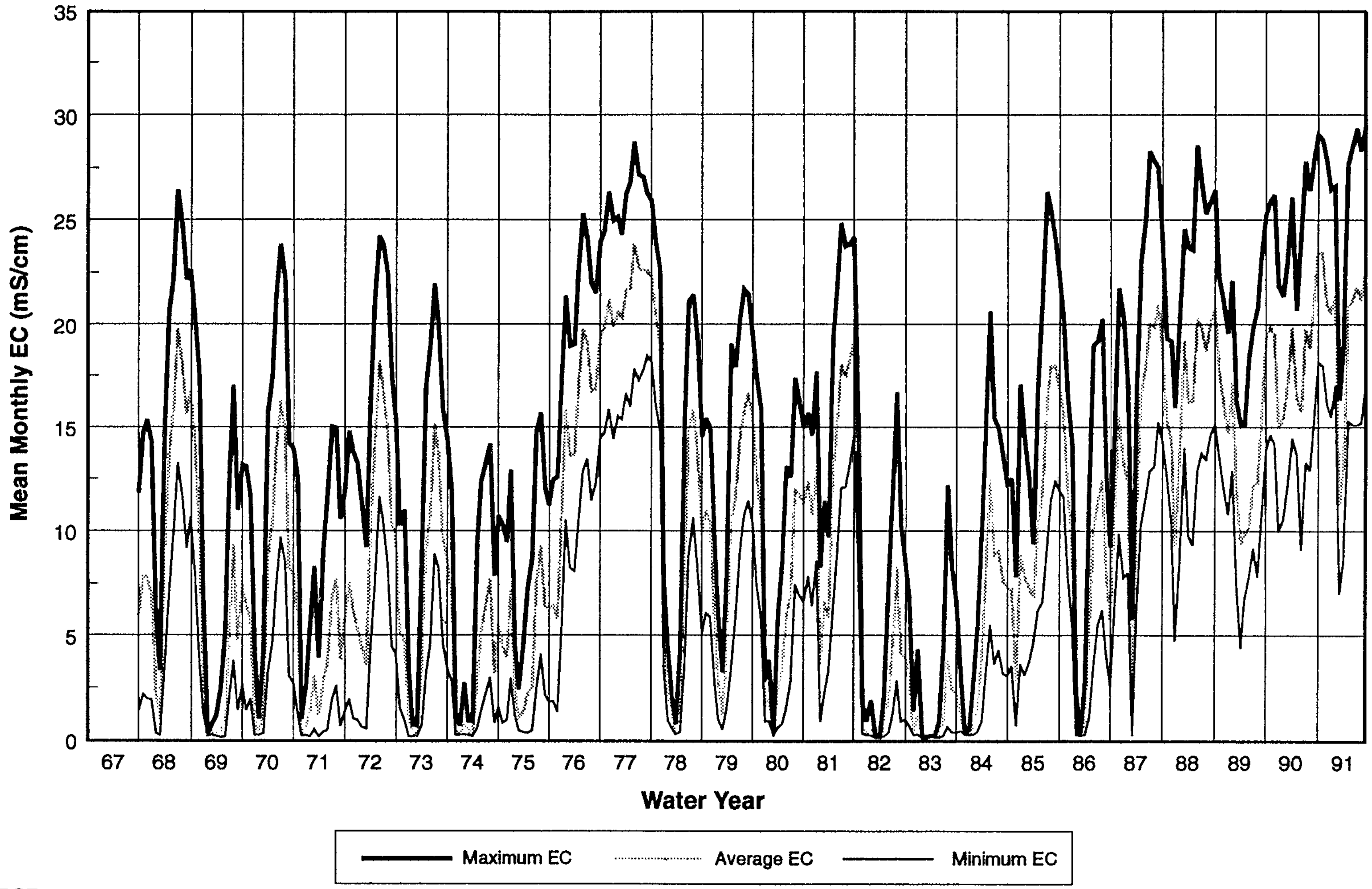
Figure II-58 shows the historical pattern of monthly average EC at Pittsburg (near Chipps Island) for 1967-1991. The relationship between monthly average EC and monthly average effective Delta outflow is similar to that of Port Chicago. At Pittsburg, historical EC values have been approximately 3 mS/cm during months with an effective Delta outflow of approximately 8,000 cfs to 10,000 cfs.



SOURCE:
STORET data base maintained by EPA.

FIGURE II-56

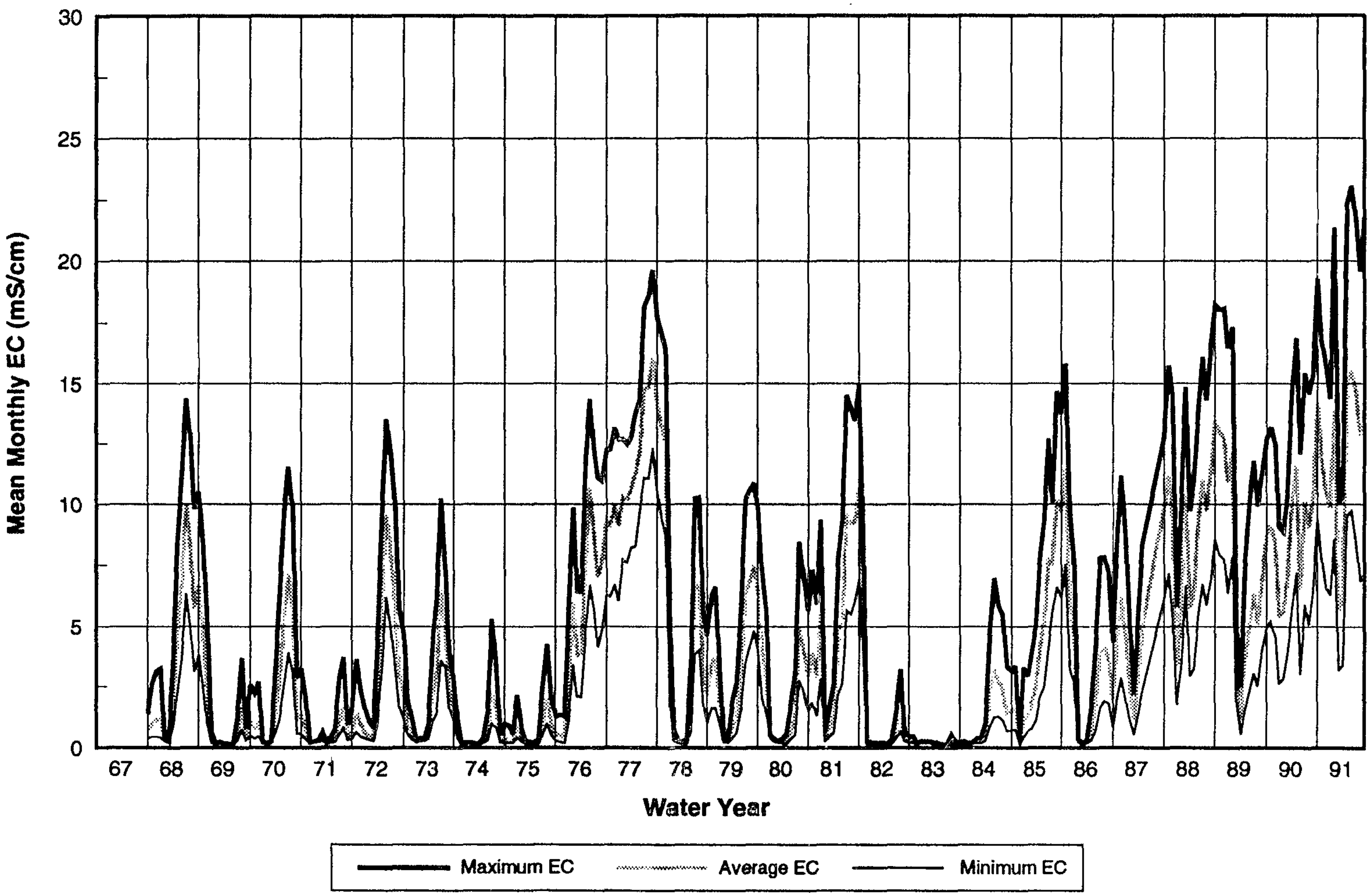
MEAN MONTHLY EC VALUES FOR THE BENECIA MONITORING STATION (1967-1991)



SOURCE:
STORET data base maintained by EPA.

FIGURE II-57

MEAN MONTHLY EC VALUES FOR THE PORT CHICAGO MONITORING STATION (1967-1991)



SOURCE:
STORET data base maintained by EPA.

FIGURE II-58

MEAN MONTHLY EC VALUES FOR THE PITTSBURG MONITORING STATION (1967-1991)

C-081978

Figure II-59 shows the historical pattern of monthly average EC at Collinsville (near the confluence of the Sacramento and San Joaquin rivers) for 1967-1991. At Collinsville, historical EC values have been approximately 3 mS/cm during months with an effective Delta outflow of approximately 7,000 cfs to 8,000 cfs.

Figure II-60 shows the historical pattern of monthly average EC at Emmaton for 1967-1991. The Emmaton monitoring station is located farther up the Sacramento River, where the extent of saltwater intrusion is reduced. Only during a few periods of low effective Delta outflow (approximately 3,000 cfs) did saltwater intrusion of 3 mS/cm extend up the Sacramento River as far as Emmaton.

Figure II-61 shows the 1967-1991 historical pattern of monthly average EC at Jersey Point. The Jersey Point EC monitoring station is located on the San Joaquin River downstream of Threemile Slough. Its salinity is similar to that at the Emmaton station on the Sacramento River side of Threemile Slough. Moderate levels of saltwater intrusion (3 mS/cm) have occurred only during periods of low effective Delta outflow (approximately 3,000 cfs).

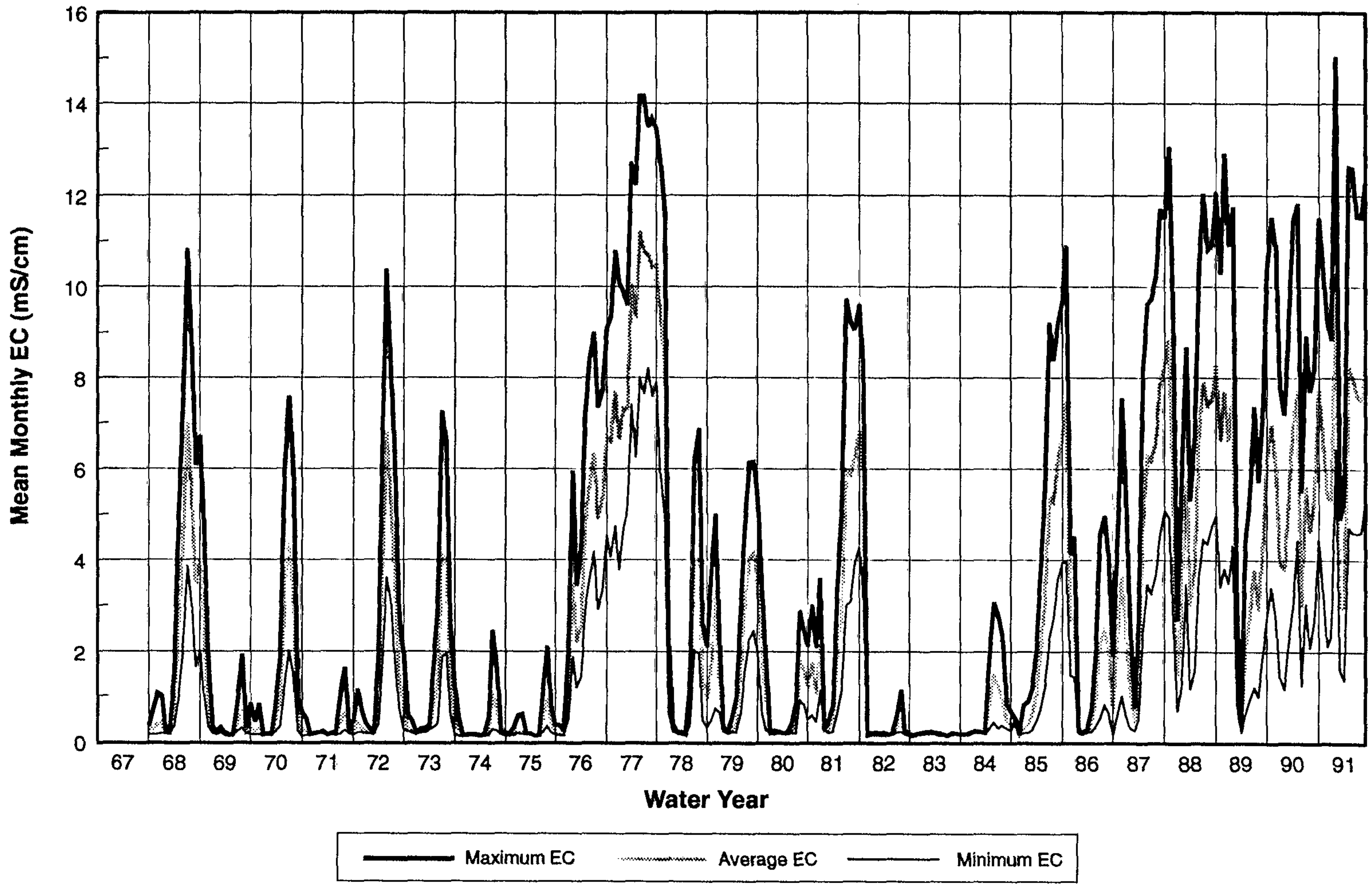
The Contra Costa Canal Pumping Plant is located at the end of Rock Slough. Figure II-62 shows the monthly range of EC at the pumping plant for 1967-1991 along with the corresponding monthly average chloride concentrations at the Contra Costa Canal Pumping Plant. The 1995 WQCP includes an export EC objective of less than 1 mS/cm and a chloride objective of less than 250 mg/l, with a specified number of days per year less than 150 mg/l, depending on the water-year type.

Figure II-63 shows the monthly range of EC measurements in the Delta-Mendota Canal near the CVP Tracy Pumping Plant. Fluctuations in EC values are caused by periods of seawater intrusion, changes in San Joaquin River inflow EC, and agricultural drainage in the southern Delta.

The location of the upstream boundary of the entrapment zone (i.e., X2 index) can be estimated directly by interpolating the available EC measurements. Figure II-64 shows the monthly position of the 3-mS/cm EC gradient (X2) for 1967-1991. The monthly X2 position can be estimated as a function of the monthly average Delta outflow and the previous month's X2 position (Kimmerer and Monismith, 1992) as:

$$\text{New X2 (km)} = 122.2 + 0.3278 \times \text{Old X2 (km)} \quad 17.65 \times \text{Log [Outflow (cfs)]}$$

Seawater intrusion and the movement of X2 is more dynamic than indicated by these monthly average EC and outflow values. For example, Figure II-65 shows daily 1985 Delta outflow in relation to historical daily EC values for several western Delta stations (Benicia, Port Chicago, Pittsburg, Collinsville, and Emmaton). The interpolated daily position of the EC gradient (entrapment zone) and the estimated X2 position are shown in Figure II-66 for 1985.

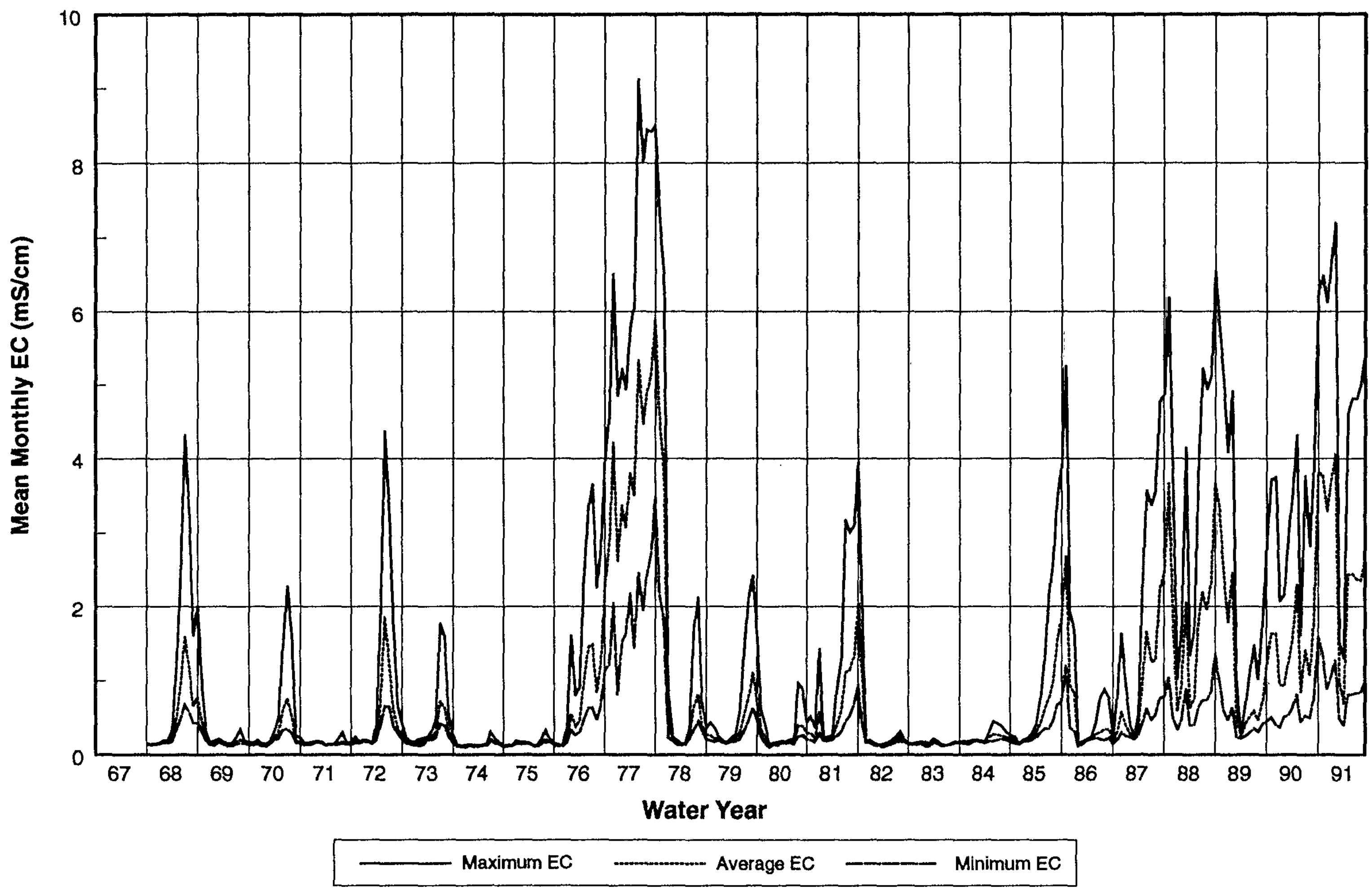


SOURCE:
STORET data base maintained by EPA.

FIGURE II-59

MEAN MONTHLY EC VALUES FOR THE COLLINSVILLE MONITORING STATION (1967-1991)

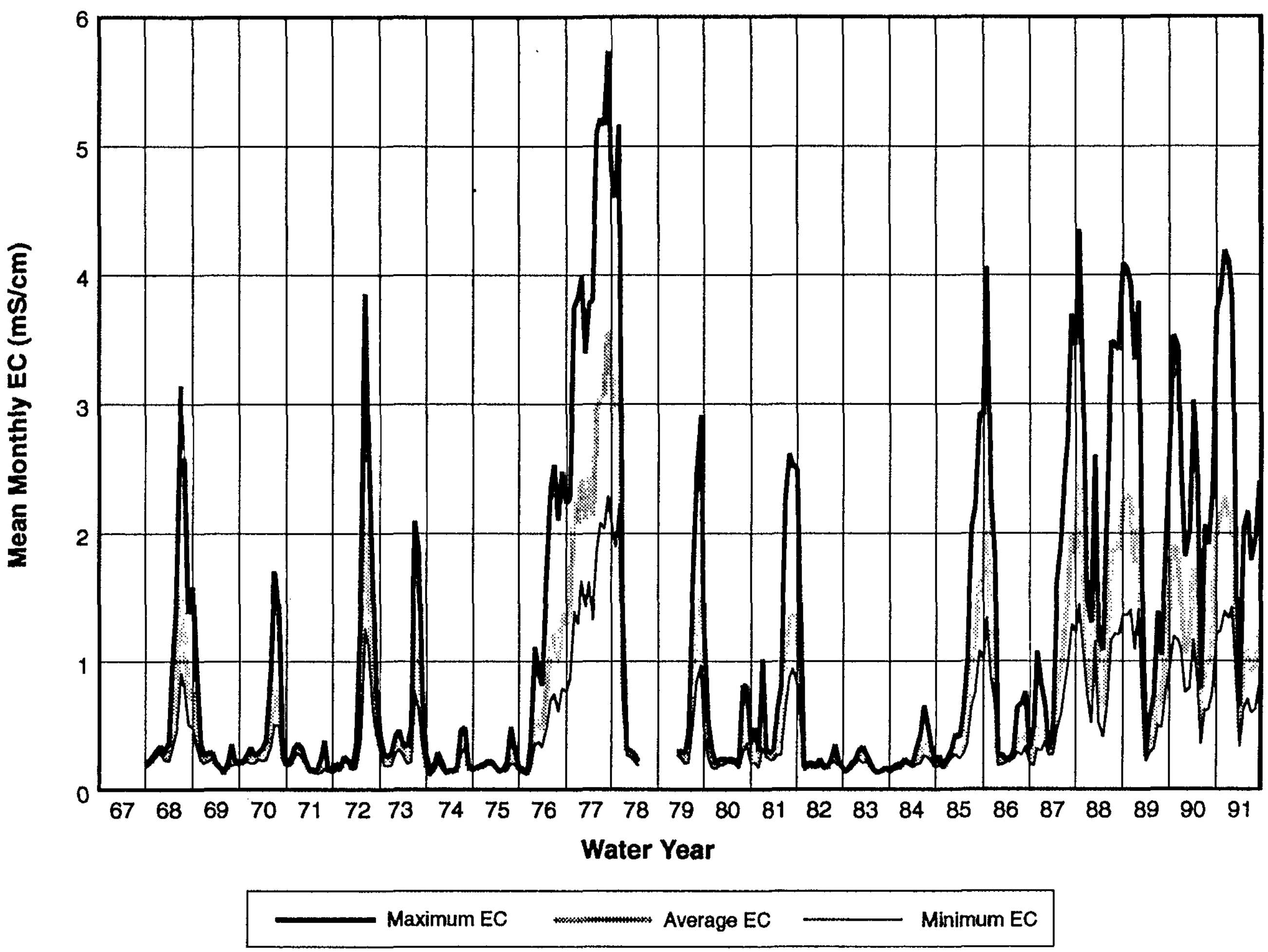
C-081980



SOURCE:
STORET data base maintained by EPA.

FIGURE II-60

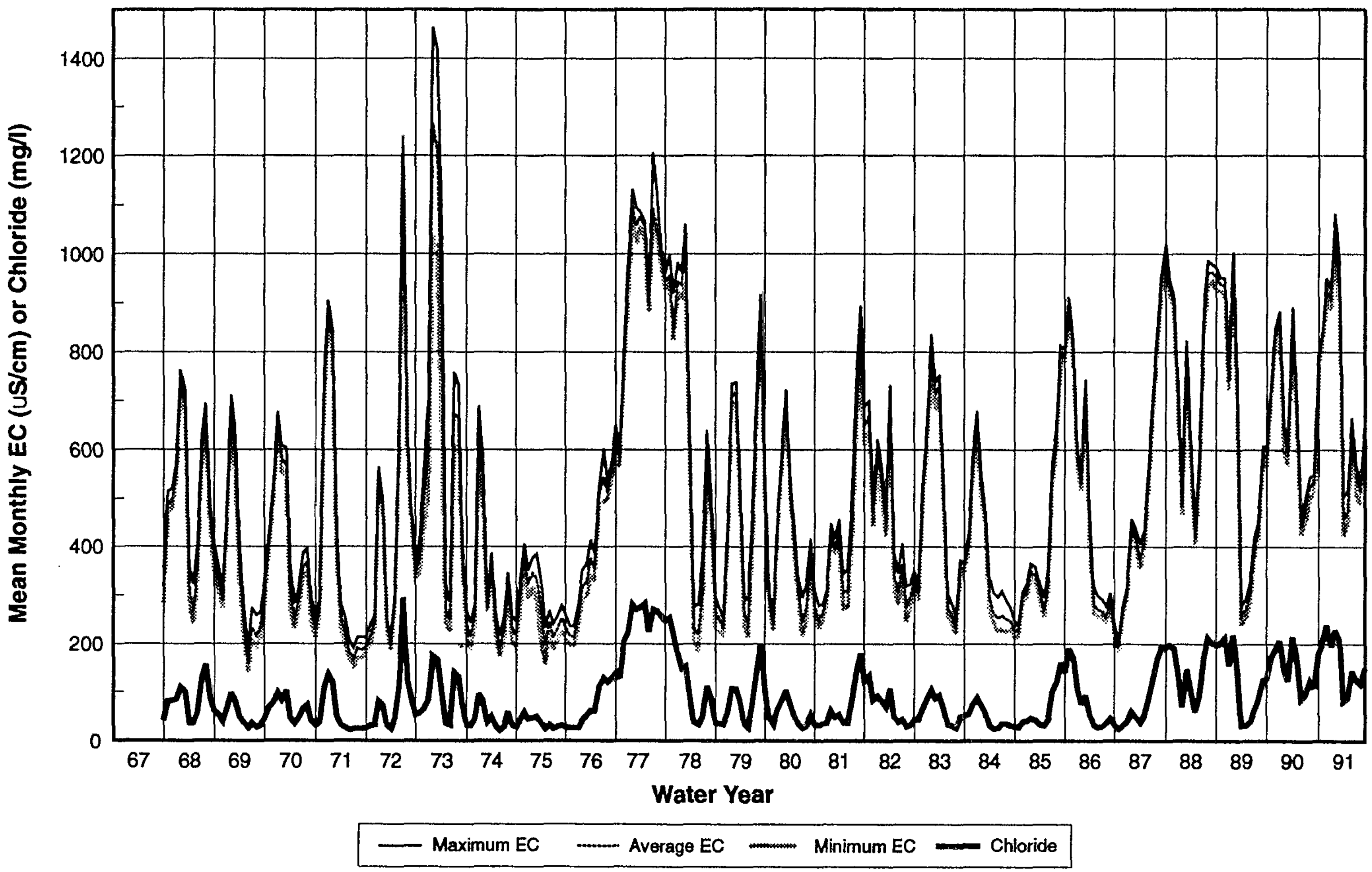
MEAN MONTHLY EC VALUES FOR THE EMMATON MONITORING STATION (1967-1991)



SOURCE:
STORET data base maintained by EPA.

FIGURE II-61

MEAN MONTHLY EC VALUES FOR THE JERSEY POINT MONITORING STATION (1967-1991)

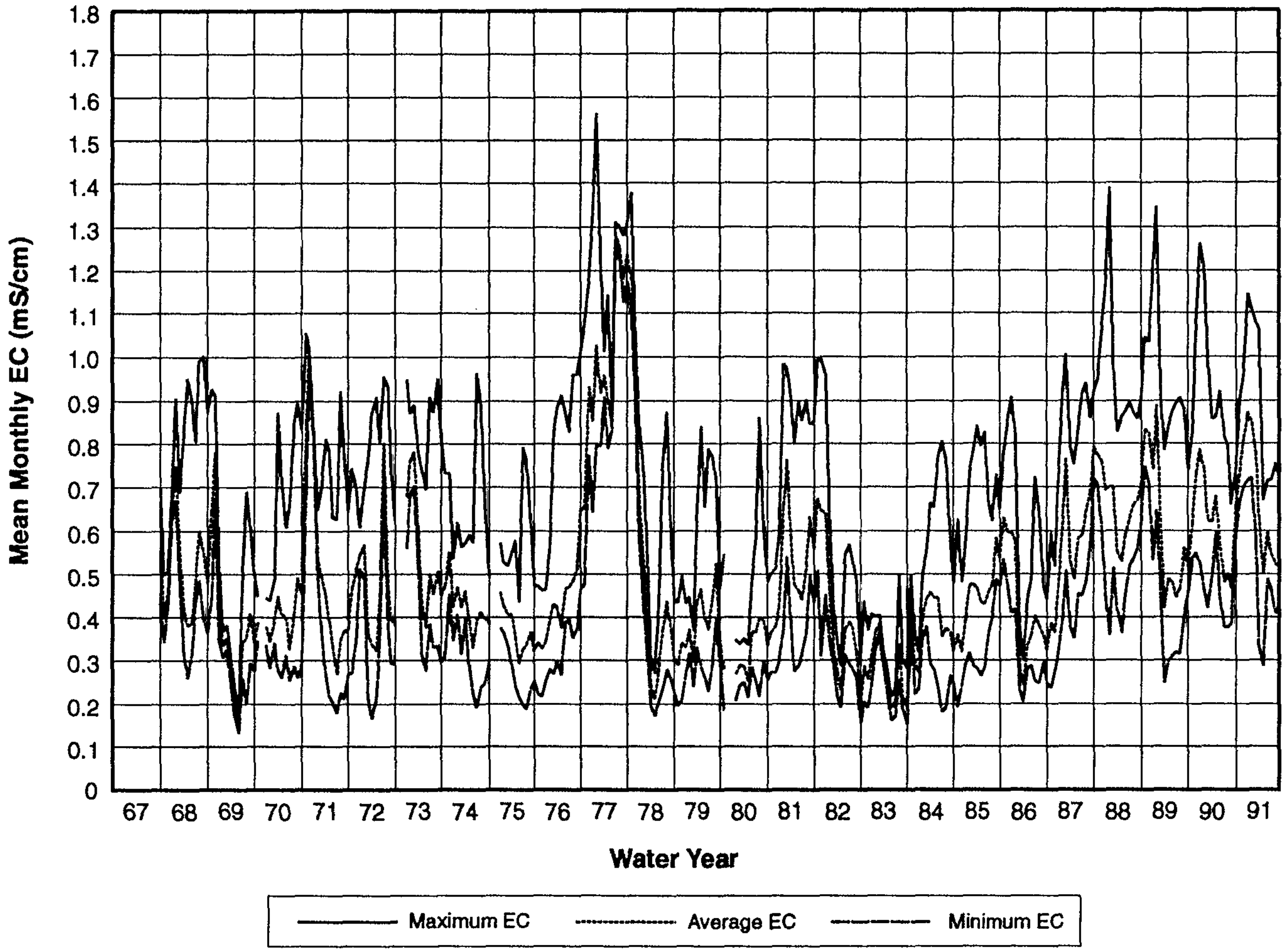


SOURCE:
STORET data base maintained by EPA.

FIGURE II-62

MEAN MONTHLY EC VALUES AND CHLORIDE CONCENTRATIONS FOR THE CONTRA COSTA CANAL PUMPING PLANT NO. 1 MONITORING STATION (1967-1991)

C-081984

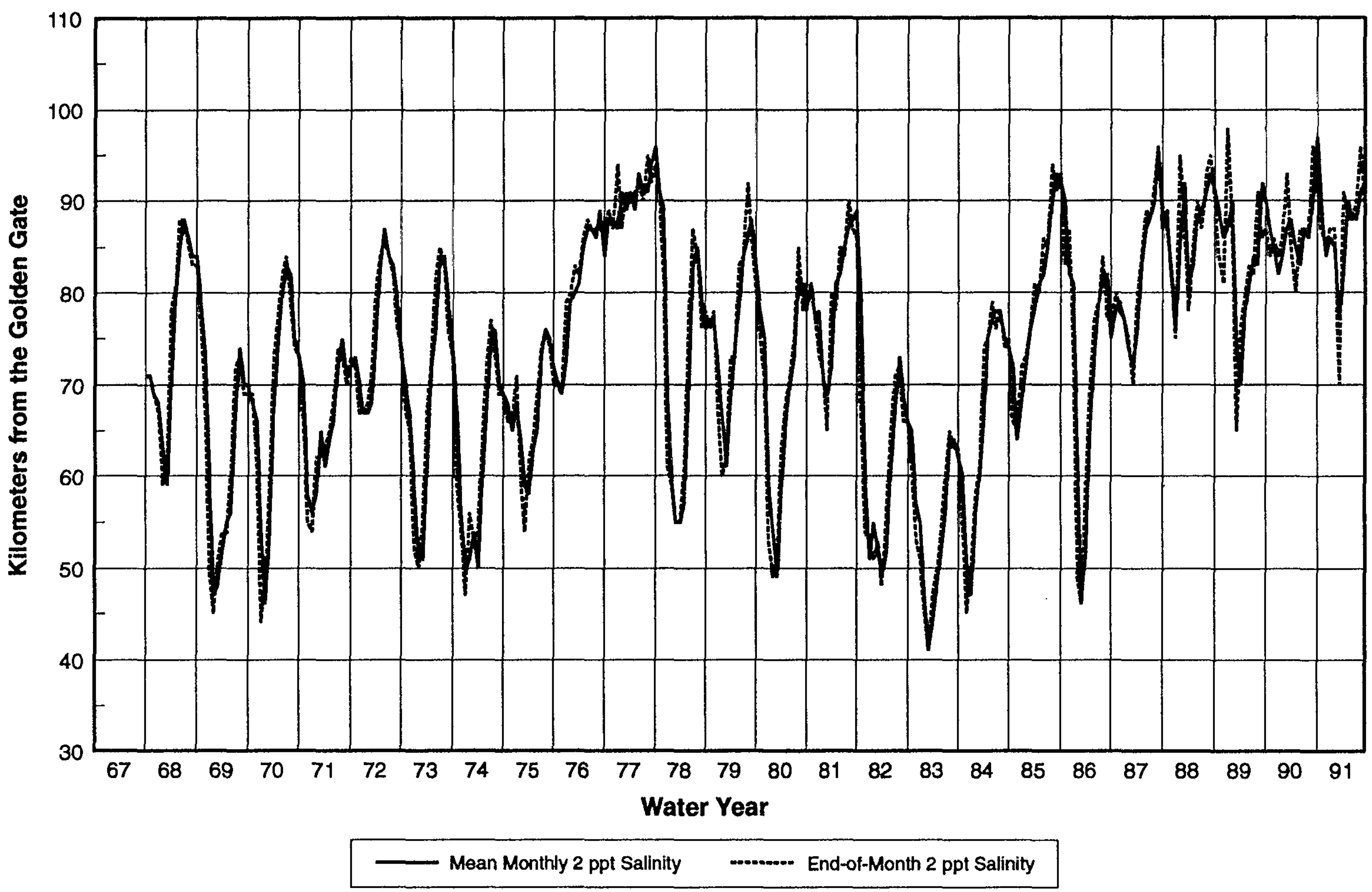


C—081984

SOURCE:
STORET data base maintained by EPA.

FIGURE II-63

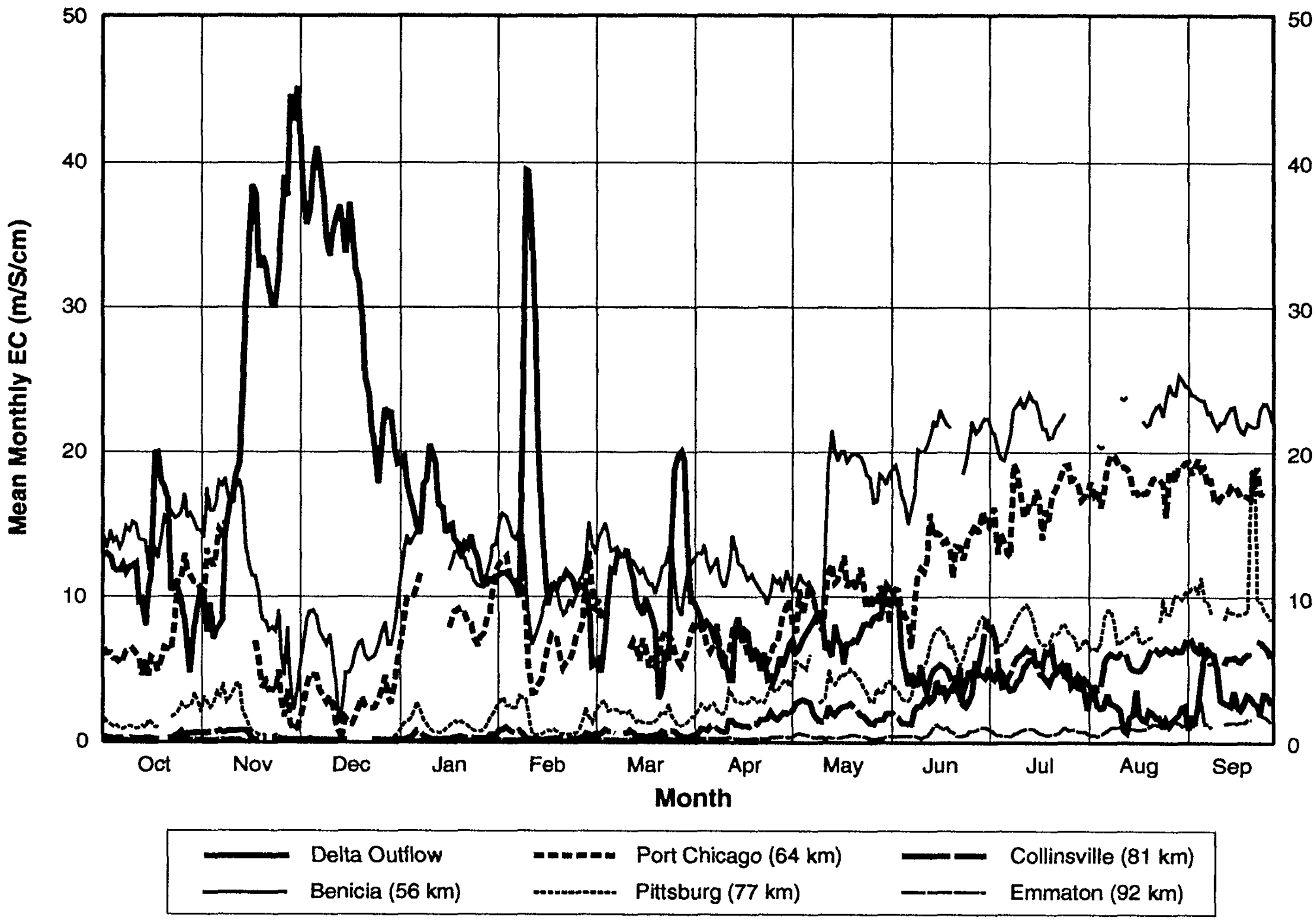
MEAN MONTHLY EC VALUES FOR THE DELTA-MENDOTA CANAL MONITORING STATION (1967-1991)



SOURCE:
STORET data base maintained by EPA.

FIGURE II-64

POSITION OF MEAN MONTHLY X2 (2PPT SALINITY) AND END-OF-MONTH X2 FROM THE GOLDEN GATE BRIDGE (1967-1991)



SOURCE:
STORET data base maintained by EPA.
DAYFLOW data base maintained by DWR.

FIGURE II-65

DAILY AVERAGE EC AT SELECTED STATIONS AND DELTA OUTFLOW (1985)

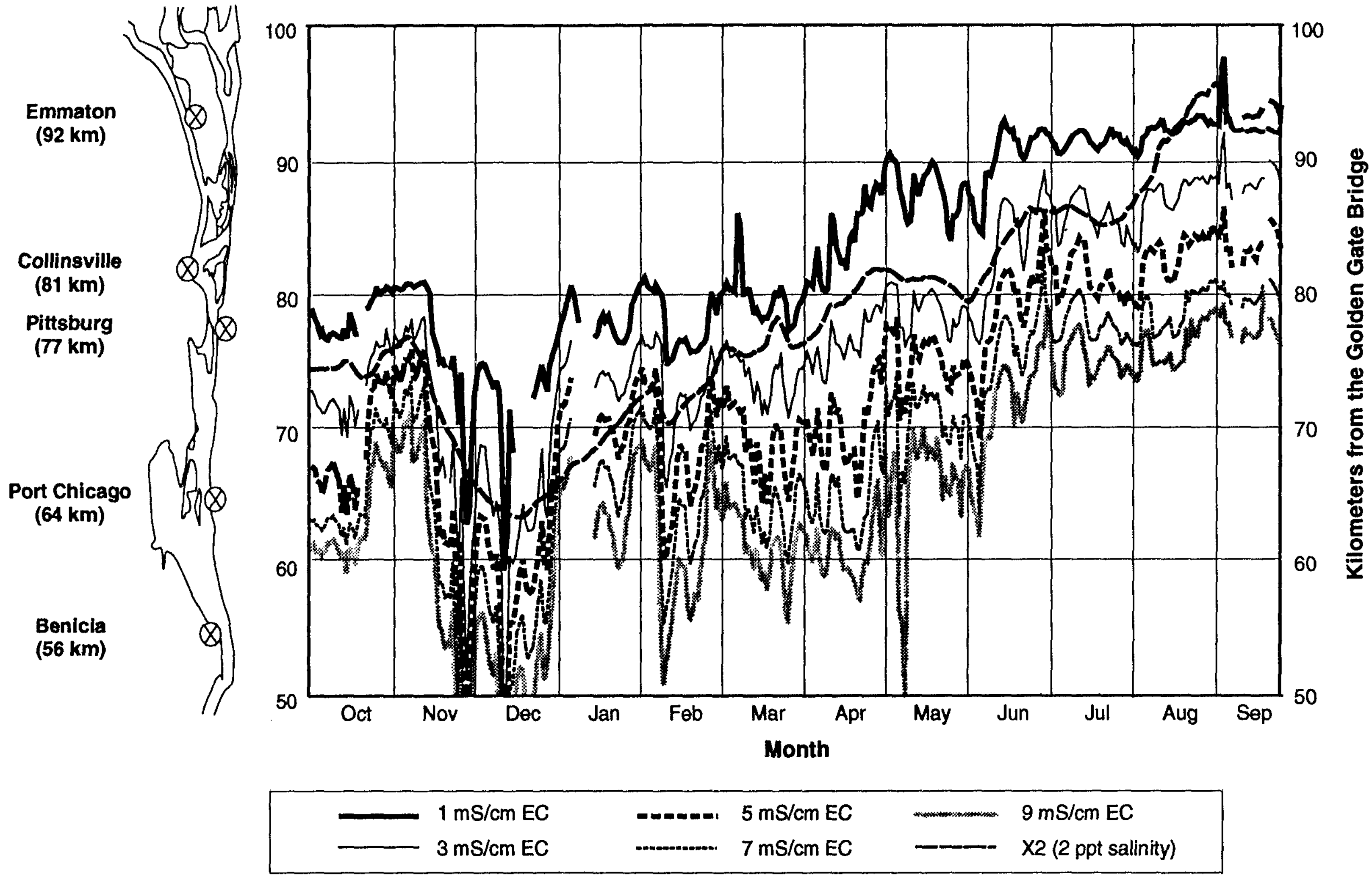


FIGURE II-66

LOCATION OF SALINITY GRADIENT INTERPOLATED FROM DAILY AVERAGE EC MEASUREMENTS AND ESTIMATED X2 POSITION (1985)

CHAPTER III

ENVIRONMENTAL CONSEQUENCES

Chapter III

ENVIRONMENTAL CONSEQUENCES

INTRODUCTION

This chapter includes a summary of the impact assessment methodology for habitat water quality and a discussion of the effects of the No-Action Alternative and Alternatives 1 through 4 on habitat water quality conditions in the Sacramento and San Joaquin River regions consistent with the purposes of the PEIS. Specific conclusions regarding beneficial or adverse impacts resulting from changes in habitat water quality are not evaluated in this chapter. The simulation results described in this chapter were used in the impact analyses for fisheries, vegetation and wildlife, and recreation (see pertinent technical appendices).

IMPACT ASSESSMENT METHODOLOGY

The key habitat water quality parameters evaluated were reservoir storage, elevation, surface area, and release temperature; river flow, depth, width, and temperature; and Delta channel flows, diversions, salinity, and water entrainment. These parameters were used either directly or indirectly in evaluating effects on fisheries, vegetation and wildlife, and recreation. The following is a summary of methods used in the habitat water quality analysis. Detailed descriptions of habitat water quality models used and their calibration are included in the Fish Habitat Water Quality Methodology/Modeling Technical Appendix.

RESERVOIR STORAGE AND RIVER FLOW

Reservoir Storage

Reservoir storage and river flows for the Sacramento Valley were generated with the PROSIM monthly planning model. River flow and reservoir storage in the San Joaquin River Basin were simulated with the SANJASM monthly planning model. These two models are discussed in the PROSIM Methodology/Modeling Technical Appendix and the SANJASM Methodology/ Modeling Technical Appendix. Delta channel depletion, outflow, and exports were also estimated by PROSIM using some of the SANJASM results. River flows and reservoir storage either were used directly to obtain results or were used to estimate other key parameters for fisheries, vegetation and wildlife, and recreation.

The hydrologic modeling conducted for this analysis has not included reoperation of non-CVP and non-SWP reservoirs. The operational scenarios for these reservoirs are based on their historical operations. No attempt has been made to optimize operations, and actual operations could differ from these assumptions. Therefore, the analysis of these reservoirs and the rivers they control is presented at a more general level of detail than the analysis of the CVP and SWP facilities. Further, should water be purchased from these reservoirs, the price of water would be required to include mitigation for adverse impacts that could not be overcome through reoperation, so effects rather than impacts are described for these facilities.

Reservoir and River Water Temperature

Reclamation temperature models were used to simulate reservoir release temperatures and river temperatures. The main model used for the PEIS was the Sacramento River Basin Temperature model (SRBT model) (Reclamation, 1990). The SRBT model was used in combination with a similar model for the Stanislaus River (Reclamation, 1993) to estimate river water temperatures for each PEIS alternative downstream of the major CVP and SWP reservoirs.

The SRBT model consists of a Reclamation-modified version of an earlier COE monthly reservoir model and a stream-temperature model developed by Reclamation based on the steady-state longitudinal equilibrium temperature equation. The SRBT model uses reservoir storage and river flow values from PROSIM and calculates the end-of-month temperature profiles and monthly average release temperatures for the major storage reservoirs. Warming in the regulating reservoirs, which are immediately downstream of the storage reservoirs, is computed as a function of meteorology (e.g., equilibrium temperature and heat exchange coefficient), monthly average release flow, temperature of releases from the upstream storage reservoirs, and regulating reservoir geometry.

Downstream monthly average river temperatures were computed for the Sacramento River from Keswick Dam to Freeport, the Feather River from Thermalito diversion dam to the mouth, and the American River from Nimbus Dam to the mouth, as a function of reservoir release flow and temperature, river geometry, tributary inflows and temperatures, and meteorology. New Melones and Tulloch reservoirs and Stanislaus River temperatures from Goodwin Dam to the mouth were simulated with the Stanislaus River Basin Temperature model developed by Reclamation (Reclamation, 1993), which is very similar to the SRBT model.

The temperatures simulated by these models are discussed in this attachment with a focus on September temperatures because these are often the warmest simulated monthly average release temperatures and provide an index of reservoir release temperatures. Monthly temperatures corresponding to fish life-stage occurrence were used in the Fisheries Technical Appendix.

RESERVOIR AND RIVER GEOMETRY

Reservoir Geometry

Geometry data for each CVP reservoir being evaluated in the PEIS impact assessments were presented in the Affected Environment chapter of this attachment. These data were used to convert output from PROSIM and SANJASM, which is reported as end-of-month volumes, to surface elevation and surface area of shallow water. These reservoir geometry data provide the framework for estimates of lake-level fluctuation and habitat area for fish spawning, habitat area for shoreline wildlife, and summer lake levels for recreation assessment.

River Geometry

River channel geometry is the result of geomorphic and hydrologic processes acting on the soils and alluvial deposits. River channels are composed of sequences of pools and riffles and are characterized by meanders and bends with side channels and overbanks. The riparian corridor habitat is therefore not easily described with simple parameters. However, some of the basic features of the river channel can be generally described as a function of river flow using the concept of river hydraulic geometry.

The total flow in a river channel can be related to an average surface width, an average depth, and an average velocity. Although the river will have wide spots and narrow spots, the average surface width is characteristic of the river channel geometry and will increase somewhat as the flow is increased. The river depth and velocity both vary across the channel and also vary between riffles and pools; however, the average depth and velocity are characteristic of the river channel geometry and both will increase as the flow is increased.

Two types of data from selected USGS gauging stations in the Central Valley were used to develop equations for width, depth, and velocity as a function of flow. Rating tables (river stage versus flow) were used to estimate the relationship between gauge depth and flow. The second set of data was obtained from USGS "Summary of Discharge Measurement Data" tables, which contain the flows, widths, velocities, and cross-sectional areas that were measured by USGS field crews to check the accuracy of the rating tables.

A detailed description of the equations developed from the USGS data is provided in the Fish Habitat Water Quality Methodology/Modeling Technical Appendix. The width equations were used in the fisheries assessment for chinook salmon and steelhead trout spawning success. Estimates of river depth and width generated by these equations are evaluated for each alternative in the Vegetation and Wildlife Technical Appendix.

DELTA CHANNEL FLOWS, DIVERSIONS, ENTRAINMENT, AND SALINITY

Delta Channel Flows and Diversions

Net flows and diversions within the Delta channels control the intrusion of ocean salinity, control the transport of land-derived salinity (i.e., agricultural drainage), and affect the movement and entrainment of fish. The PROSIM and SANJASM models calculate Delta inflows for the Sacramento River at Freeport; the Yolo Bypass; the Mokelumne, Cosumnes, and Calaveras rivers, along with some miscellaneous eastside streams (referred to as eastside inflow); and the San Joaquin River at Vernalis. PROSIM also calculates the CVP and SWP exports, along with the North Bay Aqueduct and CCWD diversions. The net Delta channel depletion is estimated as a part of the consumptive use/depletion analysis calculations (i.e., rainfall and diversions) and is input as a time series for PROSIM simulations. Total Delta outflow is calculated in PROSIM using a water budget for the Delta. The X2 location is calculated from the Delta outflow using the monthly X2 equation (Kimmerer and Monismith, 1992). The PROSIM model was modified to estimate the total DCC and Georgiana Slough flow for various percentages of gate openings, based on DWR's DAYFLOW equations. The PROSIM model also calculates the QWEST flow parameter, based on the CVP and SWP exports, CCWD diversions, DCC and Georgiana Slough flows, eastside inflow, San Joaquin River inflow, and net Delta channel depletions.

Several other Delta channel flows were estimated for CVPIA PEIS impact assessment purposes. These include:

- Old River diversion flow from the San Joaquin River
- Sacramento River flow at Rio Vista
- Threemile Slough flow from the Sacramento River to the San Joaquin River
- San Joaquin River flow at Antioch
- Montezuma Slough flow from the Sacramento River to Suisun Marsh
- Old and Middle river flow between the exports pumps and the central Delta

Each of these Delta channel flows is calculated as a function of Delta inflows and exports. For a detailed discussion of how these flows were estimated, see the Fish Habitat Water Quality Methodology/Modeling Technical Appendix. Estimates of flows within the Delta were used for estimating Delta entrainment (see below) and were used in several other fisheries evaluations (see the Fisheries Technical Appendix).

Delta Entrainment

Delta flows are key input to the Delta transport and entrainment model (DeltaMOVE). The DeltaMOVE model was developed to provide detailed information on the potential net movement of water in and through the Delta, including information on the fate of water from specific Delta locations. The net movement of water may affect the movement of planktonic organisms or provide cues to active movement of fish.

For the CVPIA PEIS, the DeltaMOVE model is used to estimate the percentage of water that may end up being entrained by channel diversions and Delta exports. This entrainment calculation is made for water starting from eight different Delta volume segments. Changes in the percent entrainment estimated by the DeltaMOVE model represent general habitat conditions that may be expected from changes in flow and diversions relative to the No-Action Alternative. The estimated water entrainment for selected Delta volume segment for each month is considered to represent Delta habitat water quality conditions. A detailed description of the DeltaMOVE transport and entrainment model is described in the Fish Habitat Water Quality Methodology/ Modeling Technical Appendix.

The results from the DeltaMOVE model are presented in this attachment. The impact assessment for specific fish species includes assumed monthly timing and spatial spawning distributions and is considered in different fisheries evaluations that use the results from DeltaMOVE (see the Fisheries Technical Appendix).

Delta Salinity

One of the most important habitat variables in the Delta is salinity, commonly measured as EC values. Recent analysis (Kimmerer and Monismith, 1992) has indicated that the mean monthly location of the 2-ppt salinity gradient (approximately 3 mS/cm EC) can be described as a logarithmic function of Delta outflow. Similar analysis (Sullivan and Denton, 1994) has indicated that salinity at each EC measurement station can be described as a function of the effective outflow, which is estimated as a function of previous "antecedent" outflows. Both approaches allow salinity patterns in the estuarine portion of the Delta to be estimated from Delta outflow. A detailed description of these calculations is given in the Fish Habitat Water Quality Methodology/Modeling Technical Appendix.

The salinity patterns for each CVPIA PEIS alternative were approximated from the monthly Delta outflows simulated by PROSIM. These salinity estimates are discussed in this attachment. Estimated salinity values were used in the vegetation and wildlife analysis (see the Vegetation and Wildlife Technical Appendix).

NO-ACTION ALTERNATIVE

The No-Action Alternative is the base condition for the PEIS alternatives analyses. The No-Action Alternative represents conditions in the future assuming a projected 2022 level of development without implementation of the CVPIA. The No-Action Alternative assumes the operation of existing facilities and future facilities that are certain to be constructed by 2022. The No-Action Alternative assumes that these water resource facilities will be operated in accordance with operating rules and criteria that were in effect or being developed as of October 1992 when the CVPIA was adopted. The major operations criteria affecting the CVP facilities include the following items.

- Coordinated Operations Agreement (COA)
- Trinity River minimum streamflows of 340,000 af.
- The Bay-Delta Plan Accord as defined in the SWRCB May 1995 WQCP.
- The 1993 Winter Run Chinook Salmon Biological Opinion as amended in 1995 by the National Marine Fisheries Service (NMFS).
- American River minimum streamflow requirements per Reclamation-modified SWRCB Decision 1400 (D-1400).
- Stanislaus River minimum streamflows of 155,700 af in non-critical years and 98,300 af in critical years per settlement agreements with DFG and the Service.
- New Melones Reservoir operated to meet water quality standards per SWRCB Decision 1422 (D-1422), to the extent possible, on the San Joaquin River at Vernalis.

Other CVP system operations are consistent with the criteria defined in the Long-Term Central Valley Project Operations Criteria and Plan CVP-OCAP (October 1992).

Habitat water quality conditions for the No-Action Alternative are described using simulated reservoir storage volumes (controlling reservoir surface elevation and surface area), reservoir releases for instream flow and downstream diversions (controlling instream habitat and temperature), reservoir release temperatures and downstream river temperatures (controlling fish habitat conditions), Delta channel flows and exports (controlling the entrainment of water and vulnerable life stages of fish), and Delta outflow (controlling estuarine salinity [EC] and estuarine habitat area [X2 location]). The historical 1967-1991 conditions for these habitat water quality variables were described in Chapter II, Affected Environment, of this attachment.

The No-Action Alternative conditions were simulated with the PROSIM and SANJASM operations models, using estimates of expected 2022 demands and operational constraints (see the Surface Water Supplies and Facilities Operations Technical Appendix and the PROSIM and SANJASM methodology/modeling technical appendices). The results of these simulated reservoir operations on habitat water quality conditions in each major tributary are described here. Most of the habitat water quality discussion focuses on May through October conditions because temperatures are highest and river flows are more regulated during this period.

SACRAMENTO RIVER REGION

Upper Sacramento River Flows, Temperatures, and Reservoir Storage

The flows and temperatures in the Sacramento River between Keswick Reservoir and the RBDD are controlled by CVP operations of Clair Engle, Lewiston, Whiskeytown, and Shasta lakes. The Shasta Lake TCD and temperature curtains in Lewiston and Whiskeytown lakes are assumed to be fully operational under the No-Action Alternative. These temperature control facilities are included in the SRBT model to allow Shasta Lake target release temperatures to be specified and to slightly increase the stratification in Whiskeytown Lake to reduce the warming of exports from the Trinity River. Simulations of all the alternatives included these same temperature control facilities.

Figure III-1 shows the simulated monthly Clair Engle Lake release temperatures for May through October for 1922-1990. The release temperatures increase only slightly between May and October of each year as warmer water is gradually pulled down from the surface to the elevation of the reservoir outlet. The May release temperatures are controlled by the meteorology in the winter period and range from slightly less than 40°F to slightly more than 45°F in a few years. The seasonal warming in most years is less than 5°F, with October release temperatures at approximately 45°F. However, relatively warm release temperatures (more than 50°F) are simulated in September and October of some years with the maximum simulated release temperature often occurring in October of each year. November temperatures are influenced by fall cooling that mixes the reservoir to the elevation of the outlet.

Figure III-2 shows the monthly Clair Engle Lake storage volumes for May through October of each year. The May end-of-month storage volume is usually the highest monthly storage for each year. Clair Engle Lake is filled to capacity (approximately 2.5 million af) in only a few years (1941, 1958, and 1983). Reservoir releases normally cause the reservoir storage

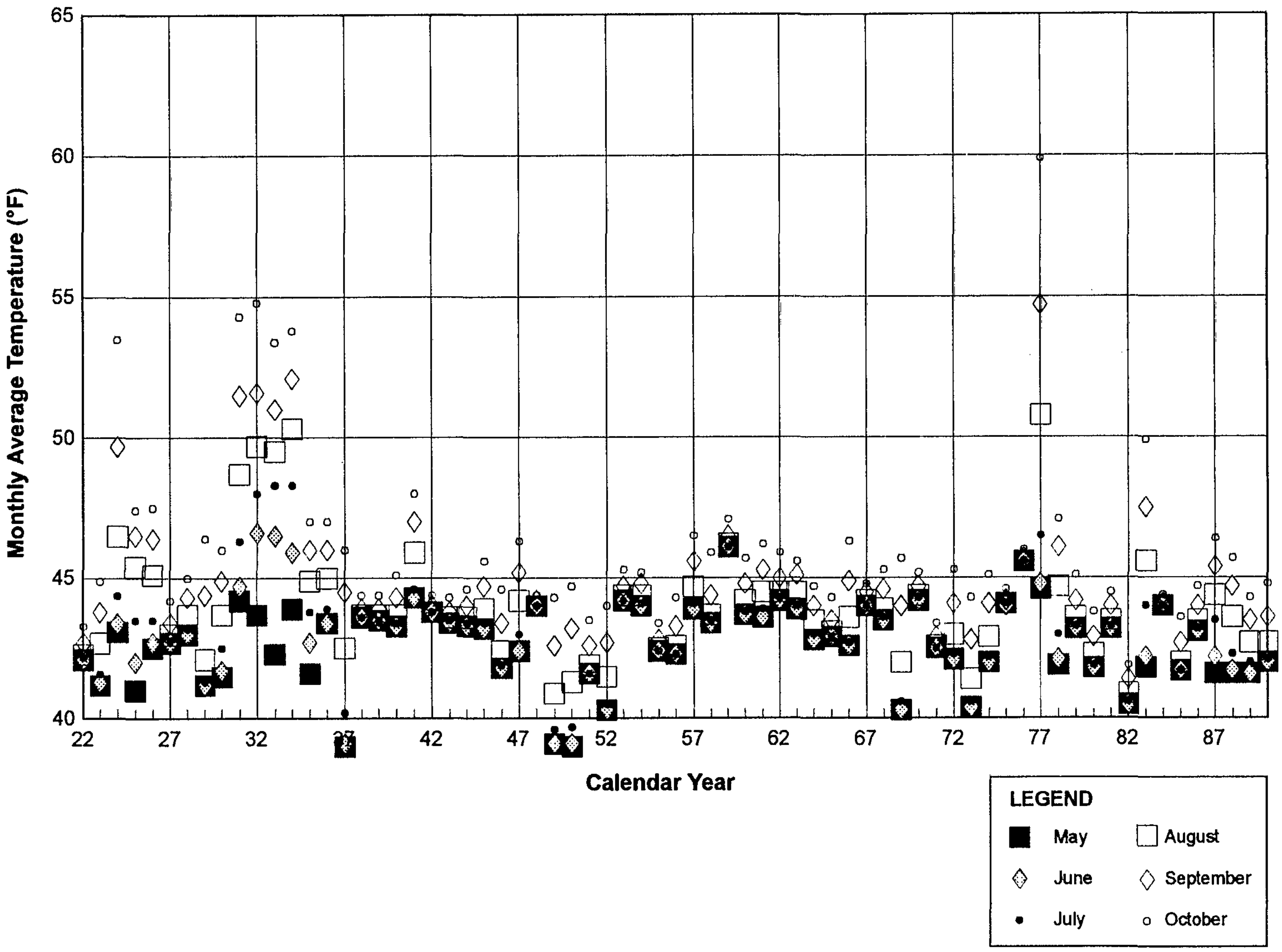


FIGURE III-1

TEMPERATURES OF RELEASES FROM CLAIR ENGLE LAKE UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

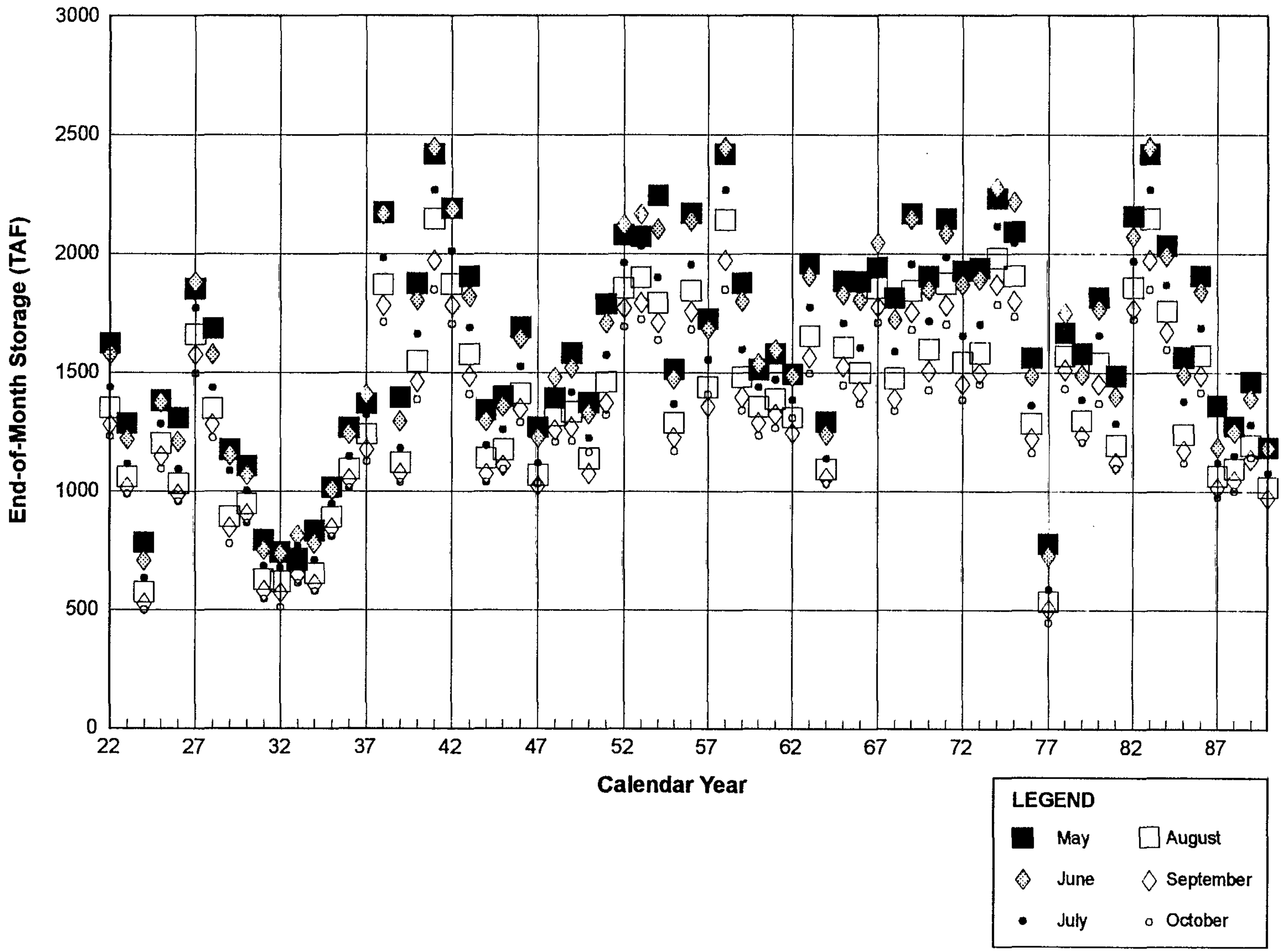


FIGURE III-2

STORAGE IN CLAIR ENGLE LAKE UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

C-081996

volume to decline by approximately 500,000 af from May through October. The highest September and October release temperatures correspond to the lowest September (carryover) storage volumes of less than approximately 750,000 af (1924, 1931-1934, 1977). The release temperatures increase slightly in a few years with high October storage (1941 and 1983) because of high flows through the reservoir during summer. The effect of low carryover storage is the dominant factor controlling Clair Engle Lake release temperatures.

Figure III-3 shows the simulated monthly (May through October) temperature for Lewiston Lake. These simulated temperatures are the release temperature to the Trinity River and the temperature of the inflow to Whiskeytown Lake from the Judge Francis Carr Powerhouse. Warming of approximately 5 to 10°F occurs in Lewiston Lake during the summer months. Greater warming is simulated during months with lower flows. The highest temperatures are simulated in the low-flow years because low Clair Engle Lake storage and low release flows both contribute to increased temperatures in Lewiston Lake.

Figure III-4 shows the simulated monthly (May through October) Clair Engle Lake release flows for 1922-1990. The May, June, and July release flows are the highest, usually in the range of 2,000 cfs to 4,000 cfs. The August, September, and October flows are somewhat lower, usually in the range of 1,000 cfs to 2,000 cfs. The greatest potential for warming in Lewiston Lake therefore occurs in August, September, and October for these simulated flow conditions for the No-Action Alternative.

Figure III-5 shows the simulated monthly (May through October) release temperatures from Whiskeytown Lake through the Spring Creek power plant into Keswick Reservoir. The seasonal warming from May through October is much greater than for the Clair Engle Lake releases because of the relatively small volume of Whiskeytown Lake. August, September, and October temperatures are approaching or greater than 55°F in most years. Temperatures in the driest years are the highest, with some October temperatures approaching 60°F (1931-1934 and 1977).

Figure III-6 shows the simulated monthly (May through October) release temperatures from Shasta Lake into Keswick Reservoir. There is usually no simulated seasonal warming of release temperatures from Shasta Lake because the TCD is simulated with monthly target temperatures that are between 45°F and 48°F. The simulated Shasta Lake release temperatures are equal to the target temperature unless there is no water with that temperature in the reservoir. For example, this occurs in the simulations for 1931, 1959, and 1976, when the lowest May temperature in the reservoir is higher than the target May temperature of 46°F because of warm winter meteorology. The target temperature for September and October is simulated as 40°F, so the coolest available reservoir water is released in both of these months. There is often enough cool water for the average September release temperature to remain below 45°F, but the October release temperatures are often considerably higher than the September release temperatures because the reserve of cool reservoir water is depleted.

Figure III-7 shows the monthly Shasta Lake storage volumes for May through October of each year. The May end-of-month storage volume is usually the highest monthly storage for each year in Shasta Lake. Reservoir releases normally cause the reservoir storage volume to decline from May through October by approximately 1.5 million af. Shasta Lake is filled to

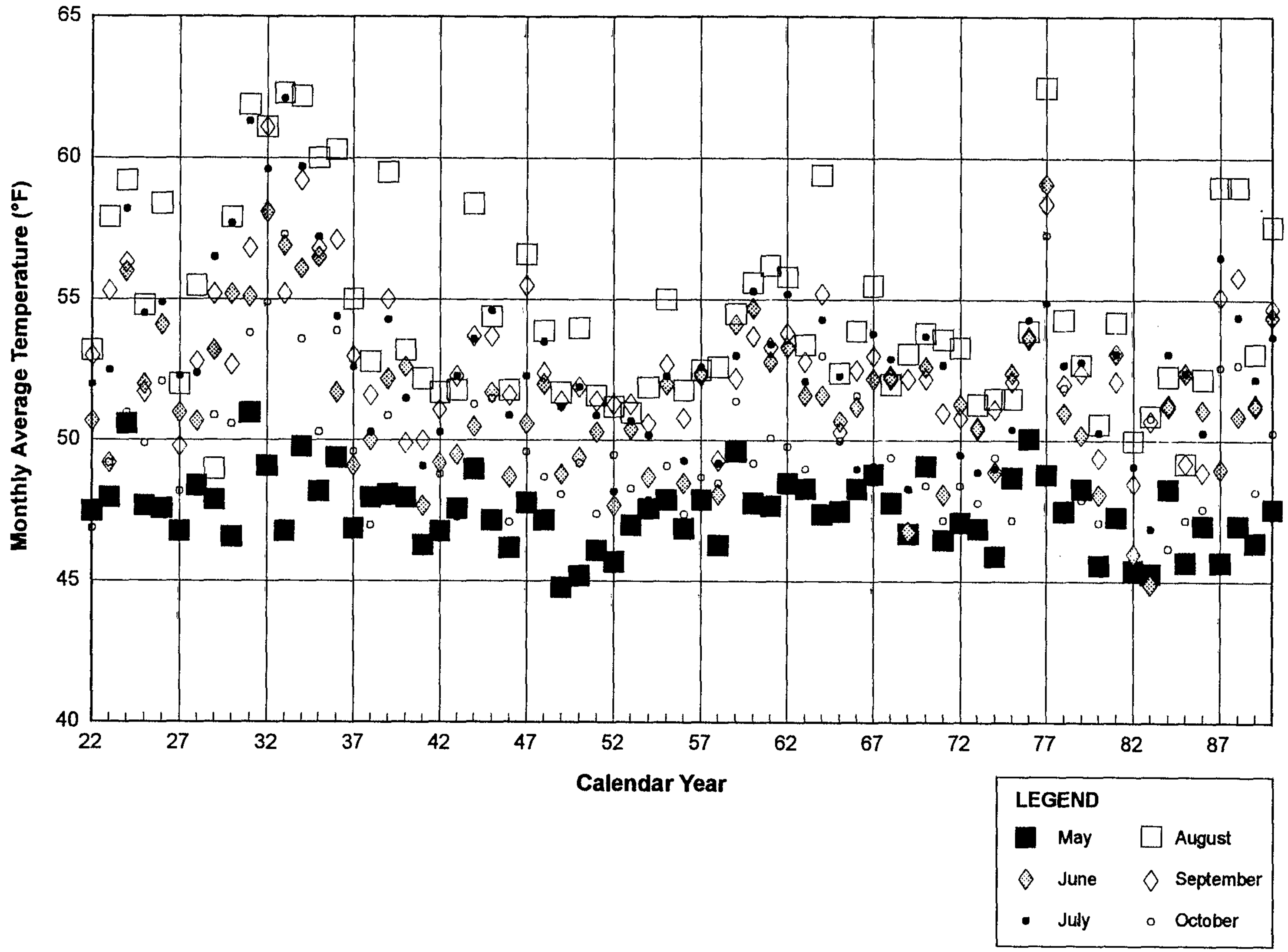


FIGURE III-3

TEMPERATURES OF RELEASES FROM LEWISTON LAKE UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

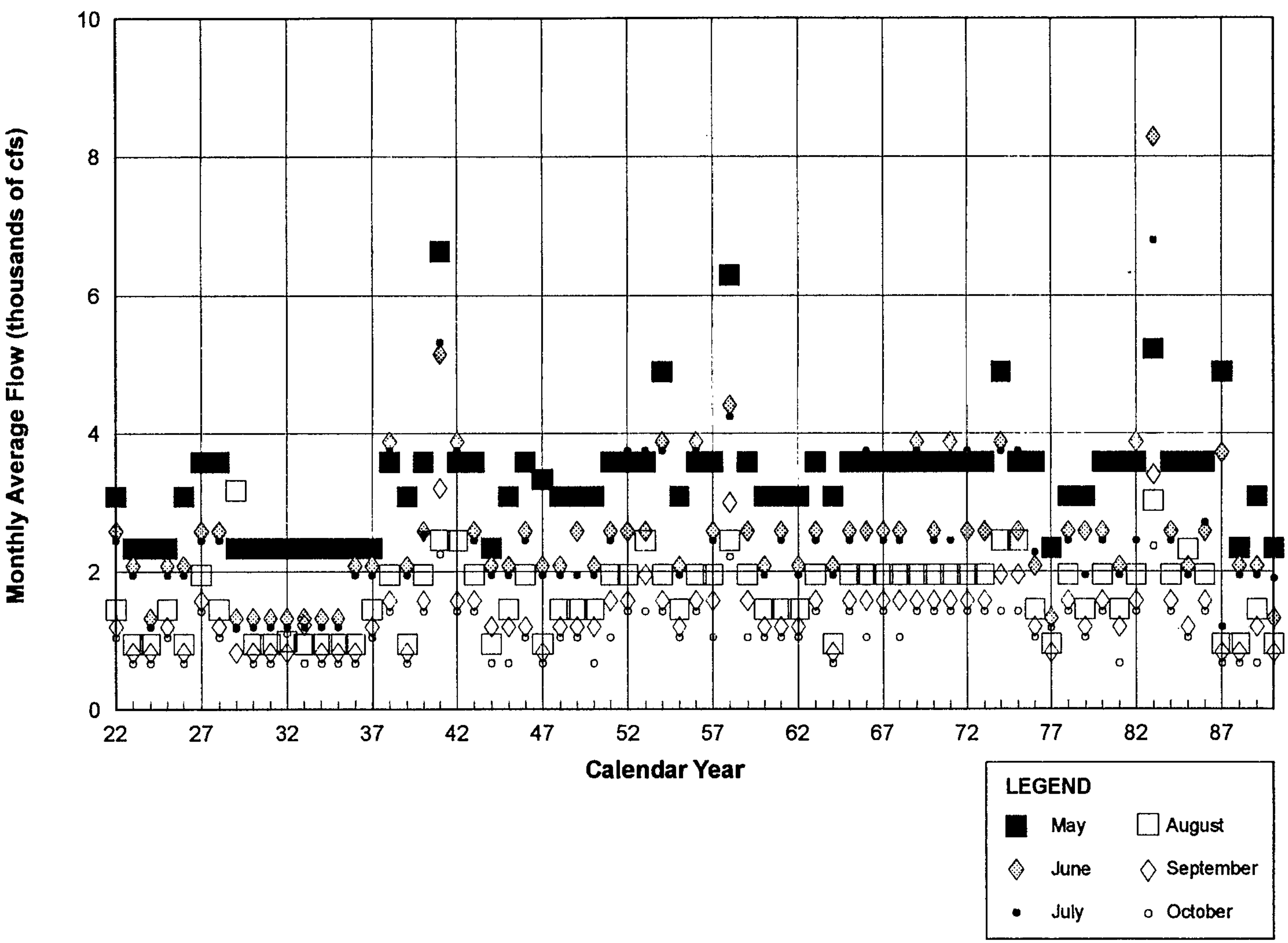


FIGURE III-4

RELEASE FLOWS FROM CLAIR ENGLE LAKE
UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

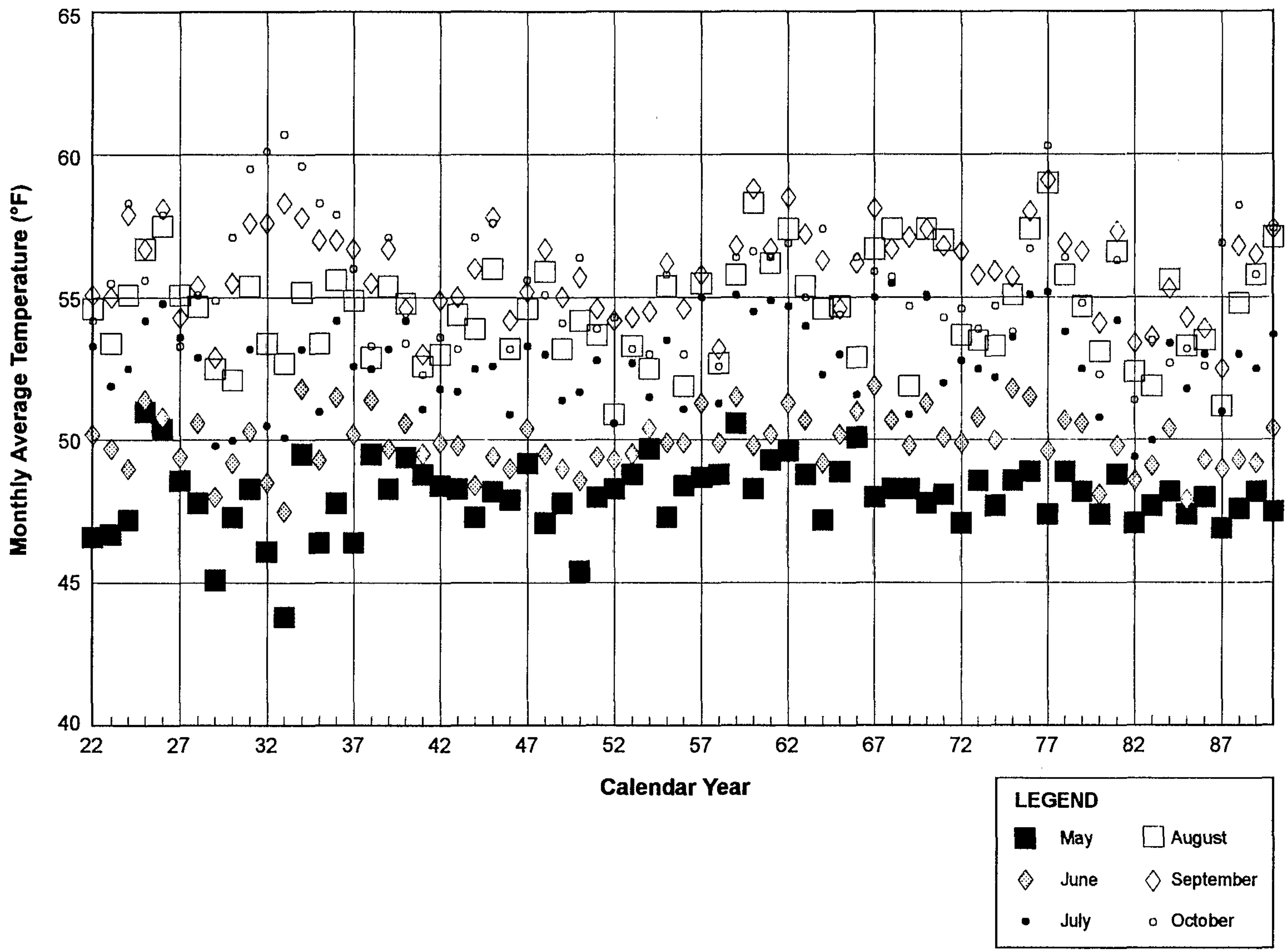


FIGURE III-5

TEMPERATURES OF SPRING CREEK RELEASES FROM WHISKEYTOWN LAKE UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

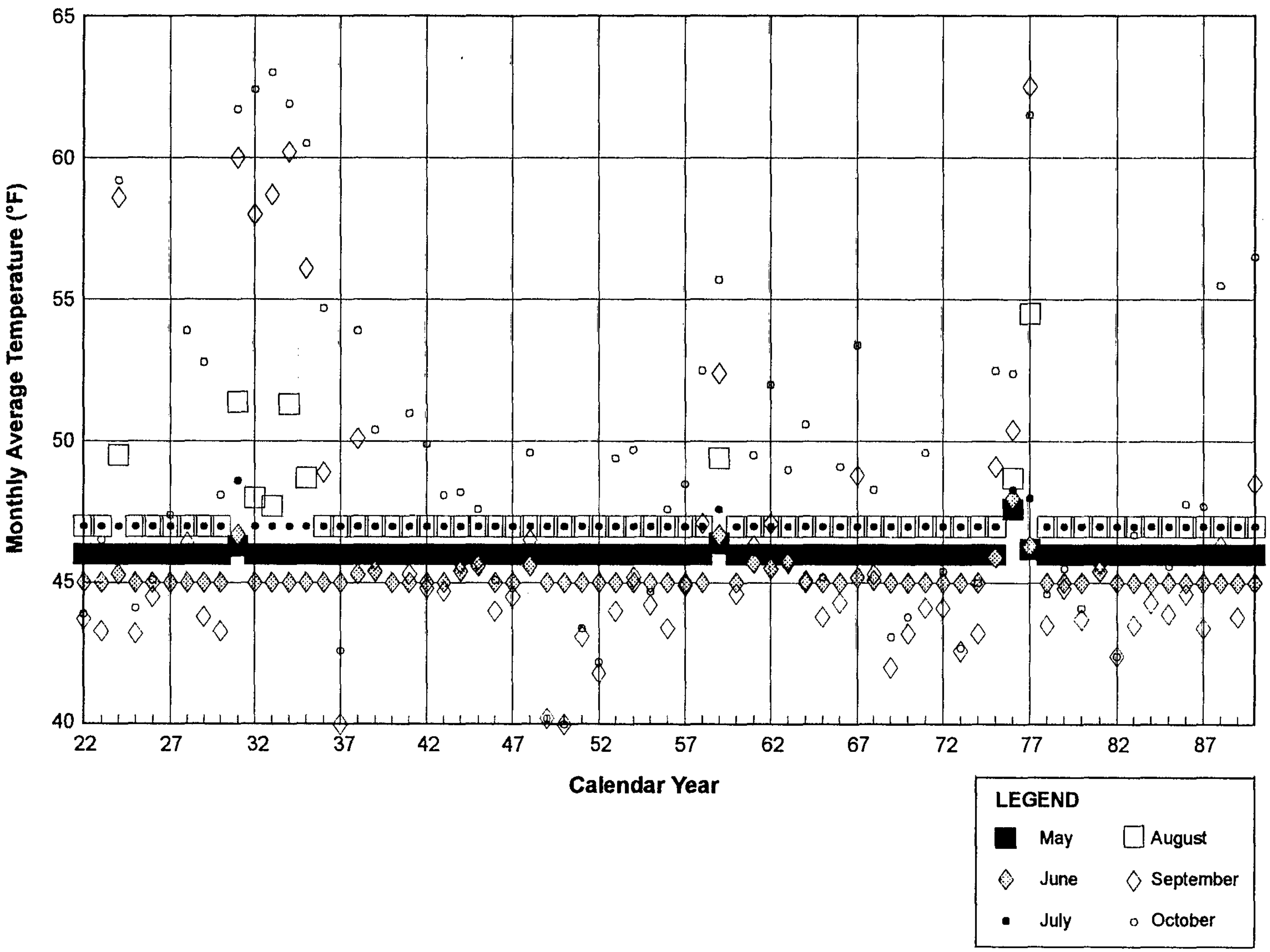


FIGURE III-6

TEMPERATURES OF RELEASES FROM SHASTA LAKE UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

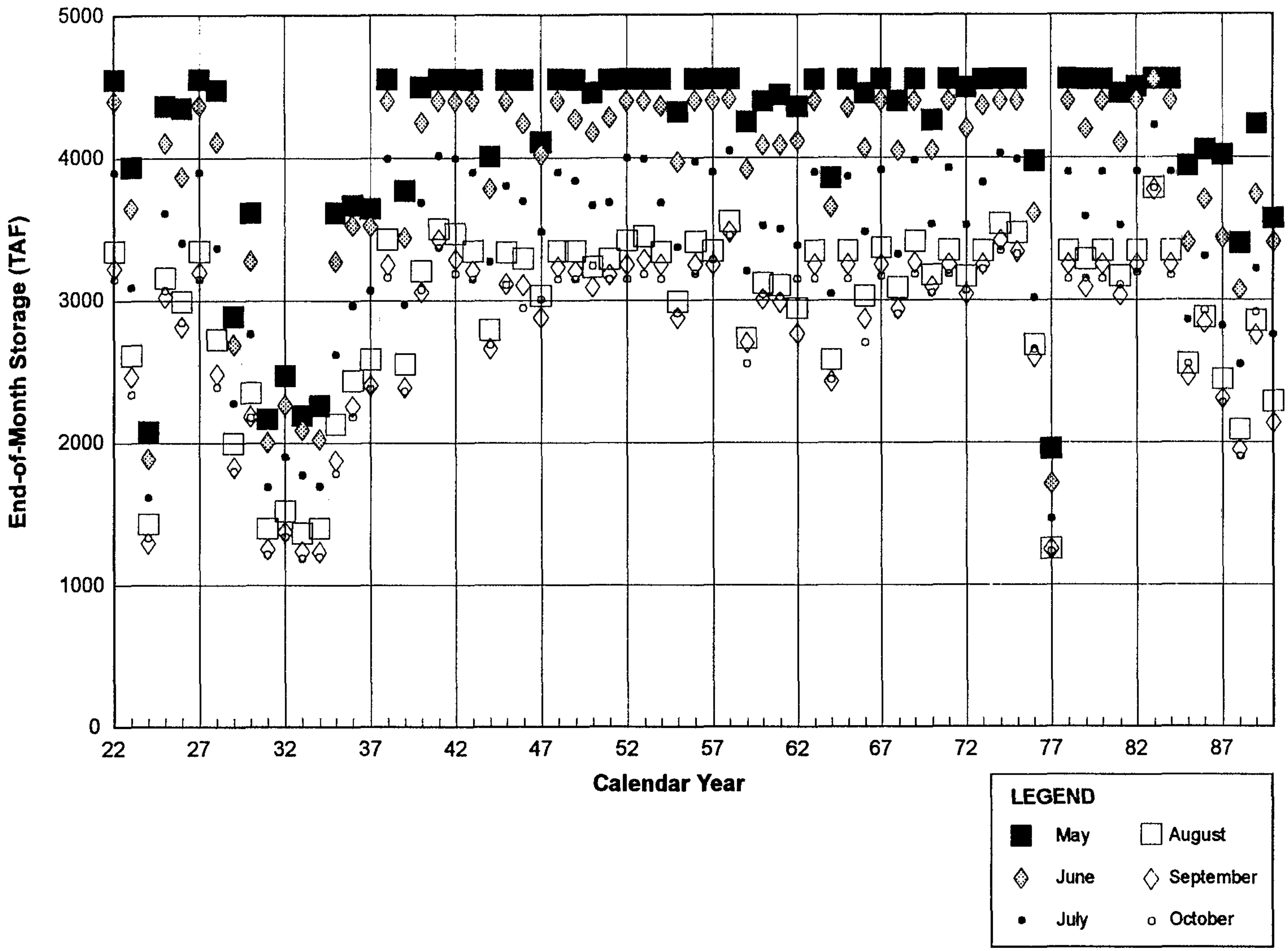


FIGURE III-7

STORAGE IN SHASTA LAKE UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

capacity (approximately 4.5 million af) in most years. The highest September and October release temperatures (greater than 50°F) correspond to the lowest September (carryover) storage volumes of less than approximately 2.0 million af (1924, 1929, 1931-1935, 1977, and 1988).

Figure III-8 shows the monthly Keswick Reservoir release temperatures for May through October of each year. The Keswick Reservoir release temperatures are slightly higher than the Shasta Lake release temperatures because of the higher Spring Creek temperatures and the warming that is simulated to occur in Keswick Reservoir. There is very little simulated seasonal warming from May through October, with release temperatures of less than 50°F in almost all months (May through October) of most years. The highest release temperatures (greater than 55°F) occur in September and October of years with the lowest Shasta Lake carryover storage, which are often the same years with low Clair Engle Lake carryover storage and correspondingly high Spring Creek power plant temperatures (1924, 1931-1935, 1959, and 1976-1977).

Figure III-9 shows the simulated monthly (May through October) flows below Keswick Reservoir for 1922-1990. The highest monthly flows are simulated in May through August. Keswick Reservoir releases are usually between 10,000 cfs and 15,000 cfs for these spring and summer months except in the years of lower runoff. Simulated flows in September and October are somewhat less, with flows ranging from 4,000 cfs to 8,000 cfs in these months.

Figure III-10 shows the simulated monthly (May through October) temperatures at the RBDD. The simulated temperatures are usually slightly higher than the objective of 56°F for protection of spawning winter-run salmon and eggs during incubation (SWRCB WR Orders 90-5, 91-1, and 92-2). The simulated RBDD temperatures exceed 60°F in only a few months of a few years. The objective of 56°F is applicable at upstream locations (e.g., Bend Bridge) in years with low Shasta Lake storage. The effects of these elevated temperatures are evaluated for winter-run and fall-run chinook salmon in the Fisheries Technical Appendix.

Clear Creek Flows and Temperatures

Figure III-11 shows the simulated monthly (May through October) temperatures of releases from Whiskeytown Lake into Clear Creek. The seasonal warming from May through October is approximately 5°F, but the simulated October release temperatures are less than 50°F in every year. These release temperatures are lower than the Spring Creek power plant releases into Keswick Reservoir because the Clear Creek outlet is deeper. Simulations of all the PEIS alternatives assumed that releases are made from the low-level outlet, although some historical releases have been made from the high-level outlet.

Figure III-12 shows the simulated monthly (May through October) temperatures in Clear Creek downstream of Saeltzer diversion dam (located at river mile [RM] 8). The simulated seasonal warming in Clear Creek between Whiskeytown Lake and Saeltzer diversion dam is approximately 10°F. Because of the cool release temperatures, the simulated temperatures in this downstream reach usually remain at less than 60°F. The late summer and fall temperatures are often greater than 55°F. The possible effect on chinook salmon spawning and incubation in Clear Creek is evaluated in the Fisheries Technical Appendix.

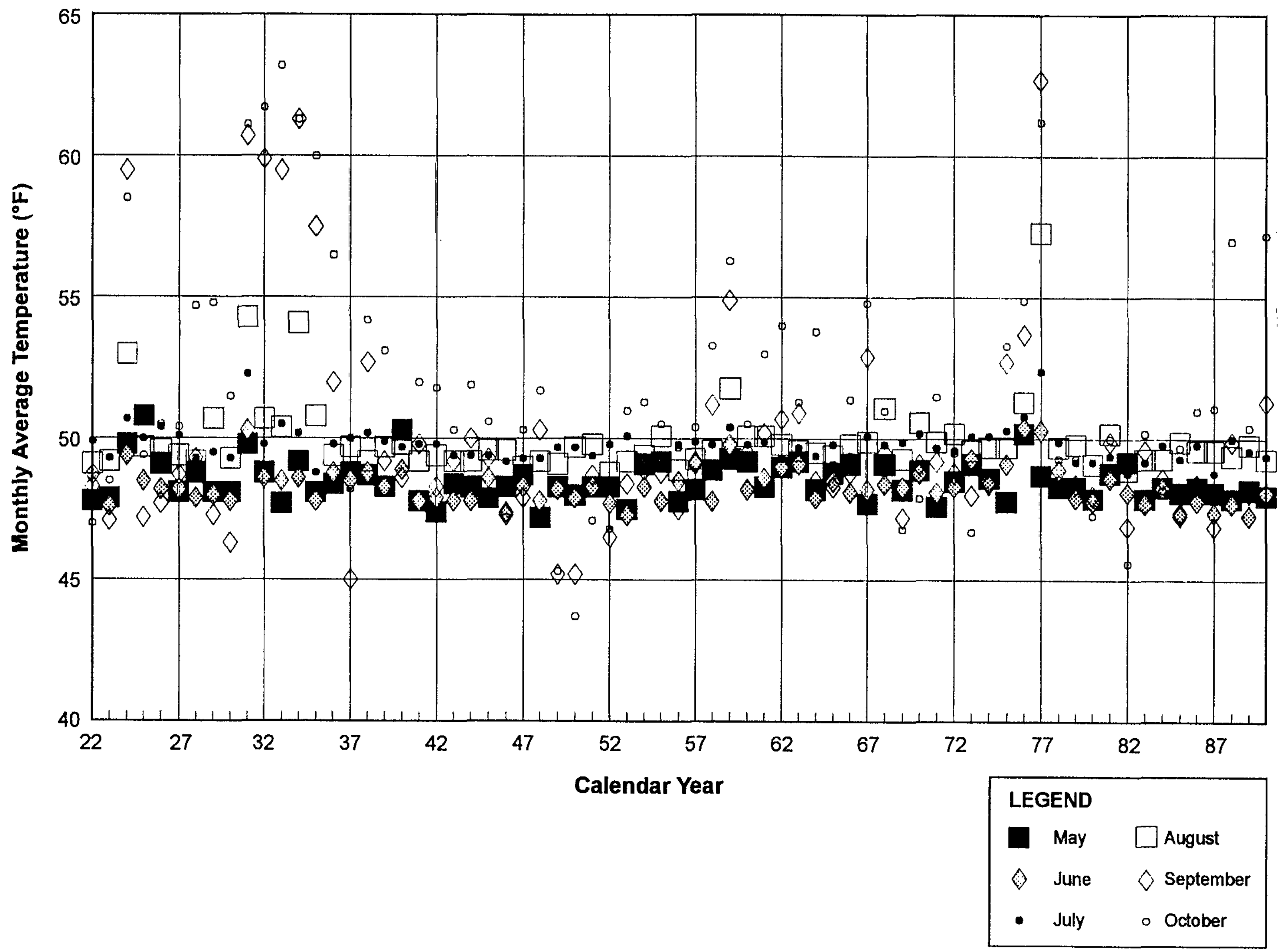


FIGURE III-8

TEMPERATURES OF RELEASES FROM KESWICK RESERVOIR UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

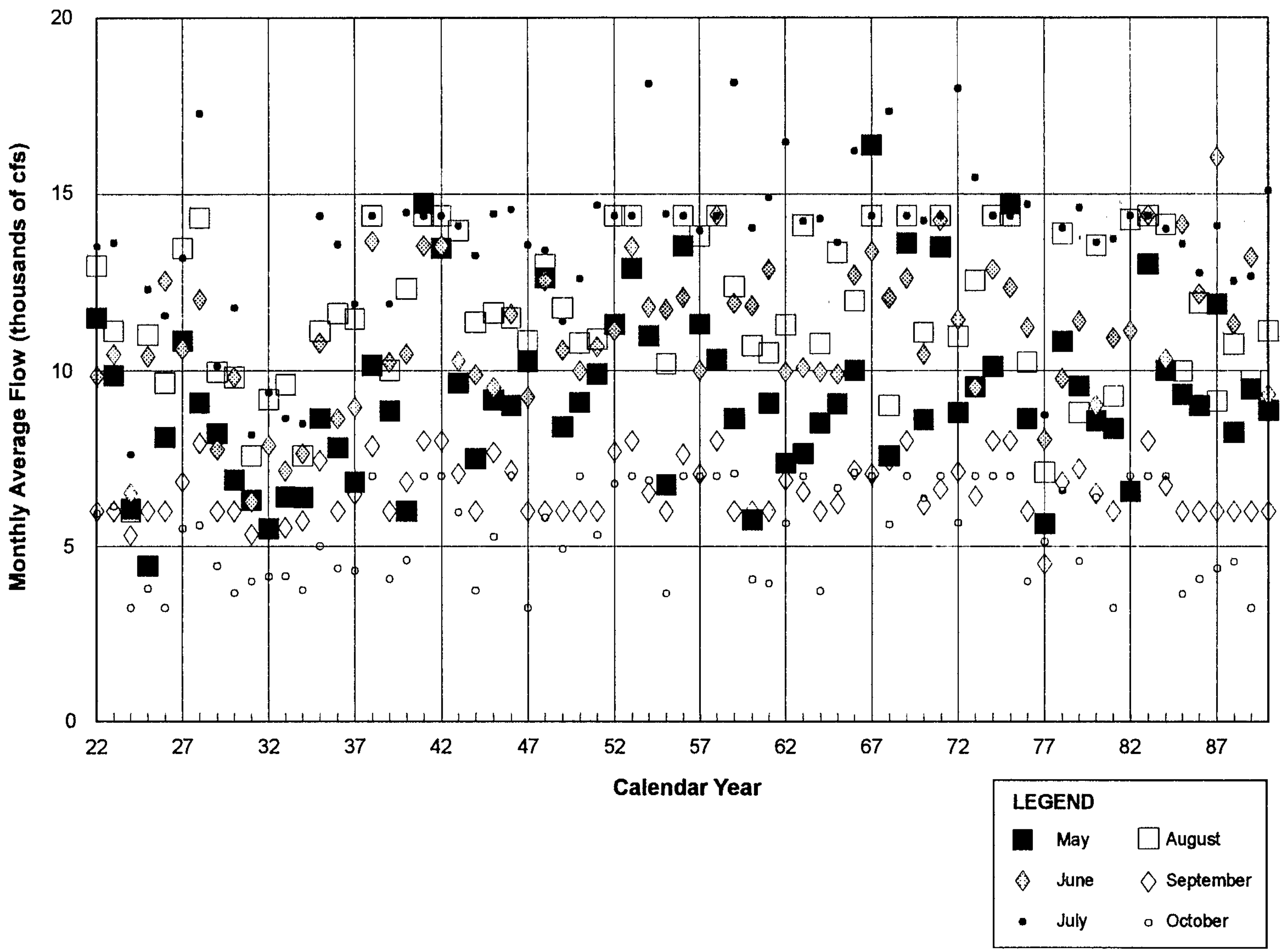


FIGURE III-9

RELEASE FLOWS FROM KESWICK RESERVOIR UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

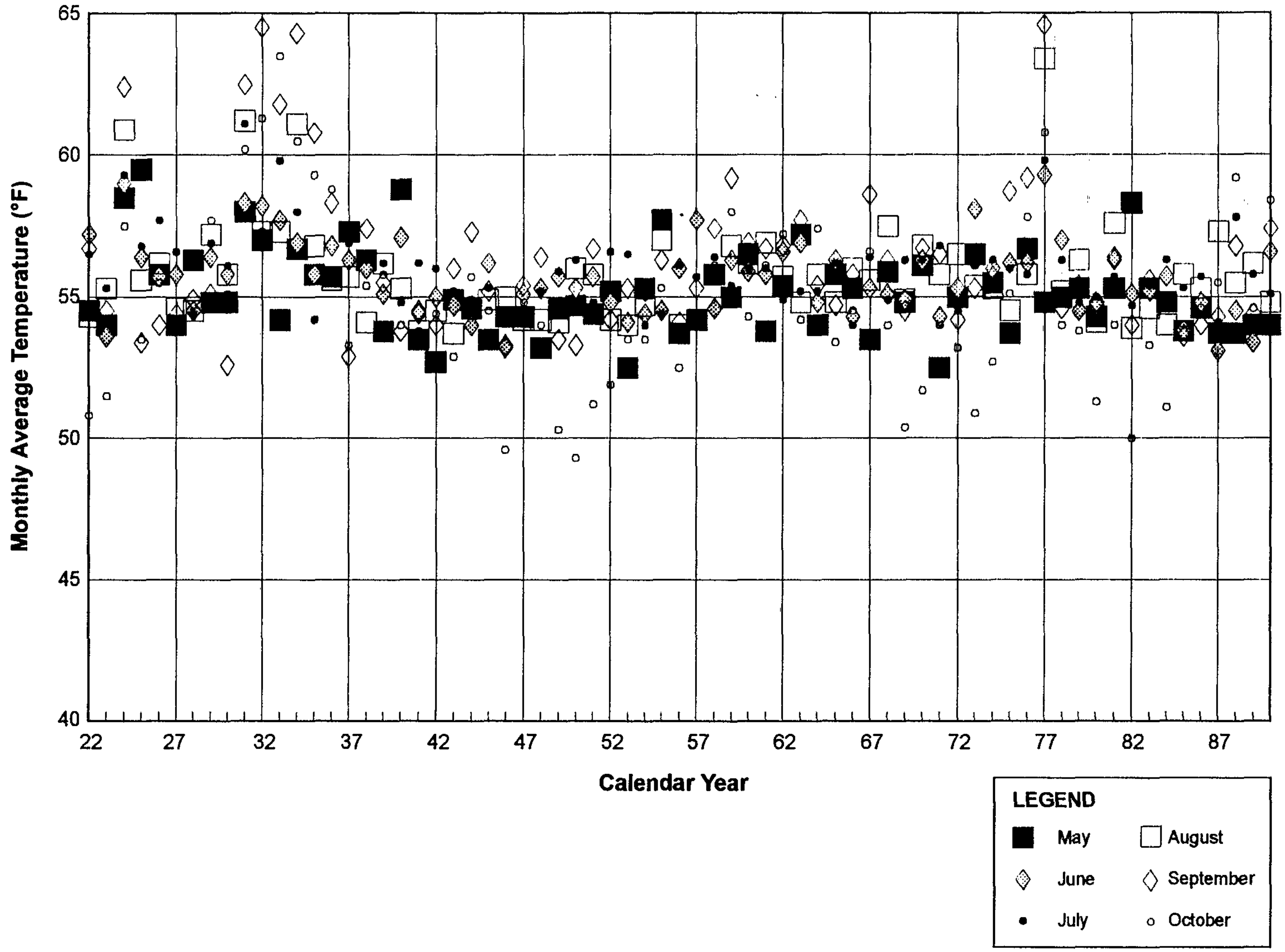


FIGURE III-10

TEMPERATURES AT RED BLUFF DIVERSION DAM UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

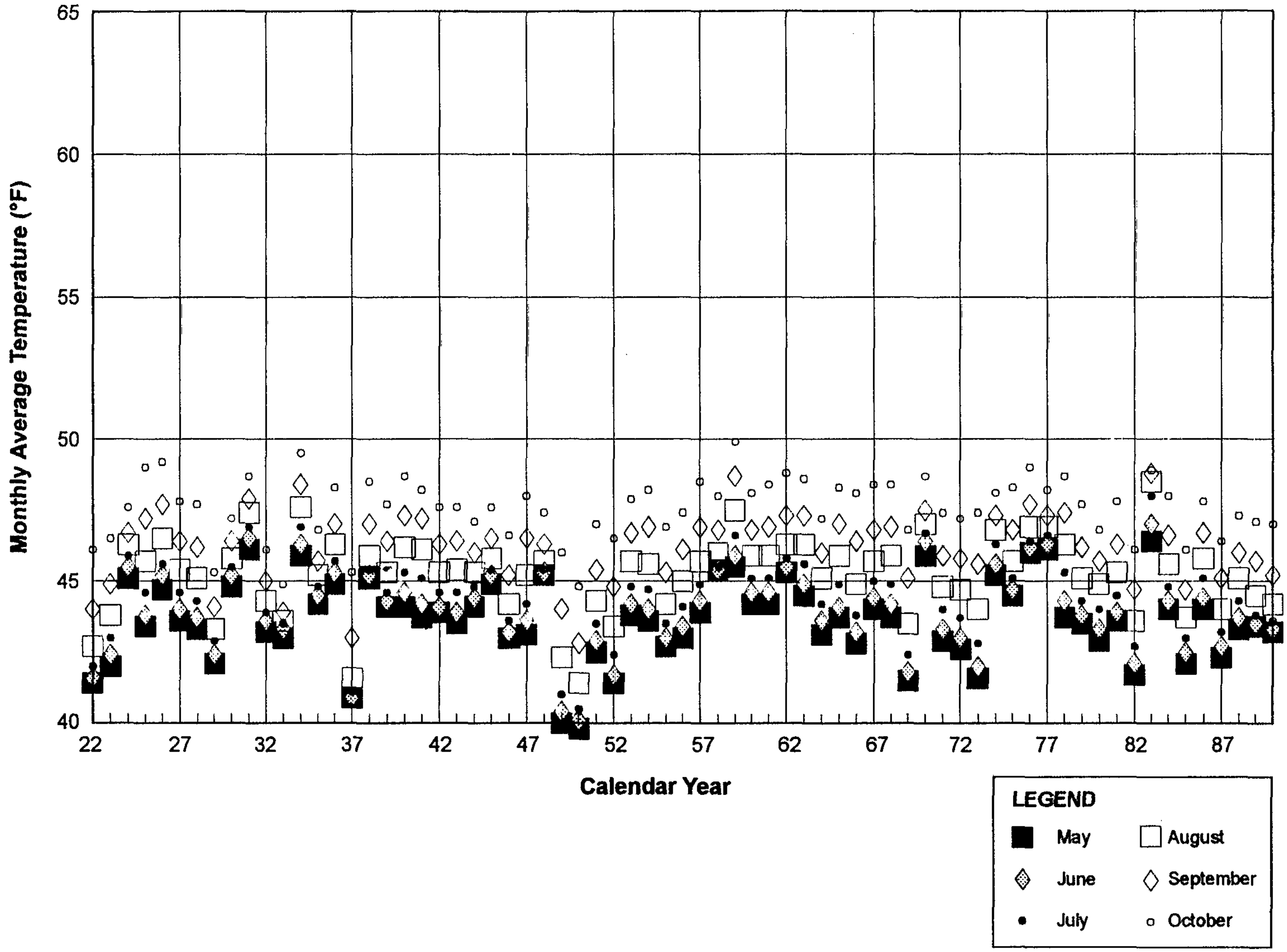


FIGURE III-11

TEMPERATURES OF CLEAR CREEK RELEASES FROM WHISKEYTOWN LAKE UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

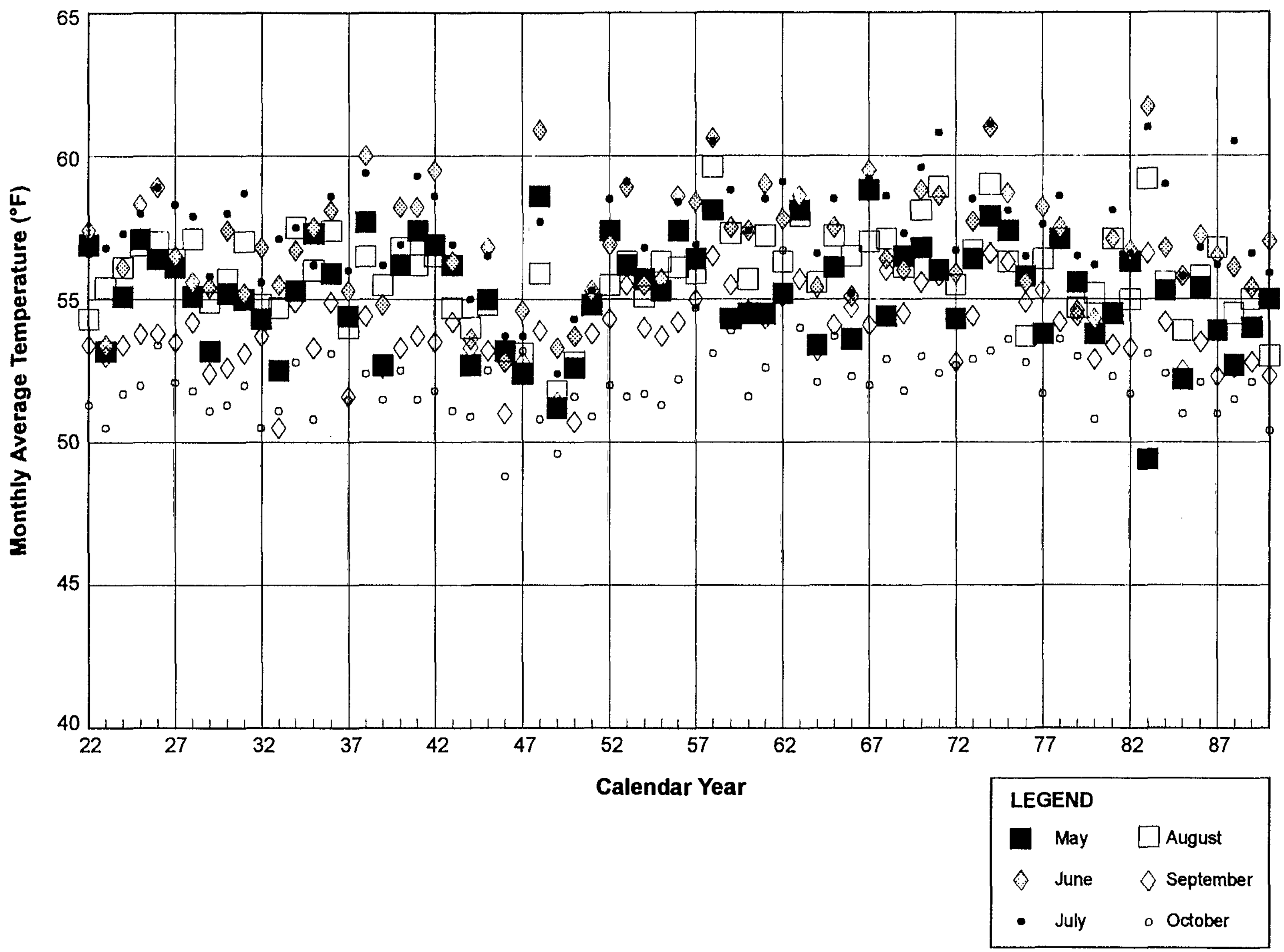


FIGURE III-12

TEMPERATURES IN CLEAR CREEK BELOW SAELTZER DIVERSION DAM UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

Simulated Clear Creek flows are completely governed by the instream flow requirements. The No-Action Alternative flow requirements for Clear Creek are 50 cfs in most months, with 100 cfs required in November and December.

Feather River Flows, Temperatures, and Reservoir Storage

Figure III-13 shows the simulated monthly (May through October) release temperature from Lake Oroville. The existing temperature control panels in Lake Oroville are used to control release temperatures throughout the year, as described in Chapter II, Affected Environment. Target temperatures are used in the temperature model and the simulation results indicate that the target temperatures are achieved in all years. The simulated (target) September and October release temperatures are 53°F and 52°F, respectively.

Figure III-14 shows the monthly Lake Oroville storage volumes for May through October of each year. The May end-of-month storage volume is usually the highest monthly storage for each year in Lake Oroville. Lake Oroville is filled to capacity (approximately 3.5 million af) in most years. Reservoir releases normally cause the reservoir storage volume to decline from May through October, but the variation in the reservoir storage decline is much greater than for Shasta Lake. The decline in Lake Oroville storage is less than 500,000 af in some years but is greater than 2.0 million af in other years. The simulated carryover storage is maintained above 1.0 million af in all years. These variations in Lake Oroville storage have no effect on the simulated release temperatures.

Figure III-15 shows the simulated monthly (May through October) temperatures in the low-flow channel section of the Feather River, between the Thermalito diversion dam and the Thermalito Afterbay release to the Feather River. Temperatures in this section are slightly higher than the release temperatures, but September and October temperatures are generally below 56°F (corresponding to Feather River hatchery temperatures).

Figure III-16 shows the simulated monthly (May through October) temperatures in the Feather River near Gridley, approximately 10 miles downstream of the Thermalito Afterbay discharge. Considerable warming occurs during the summer months in the Thermalito reservoir and in the Feather River itself. September temperatures are often greater than 65°F and October temperatures are often greater than 60°F. The possible effect of these relatively high river temperatures on chinook salmon spawning and incubation in the Feather River is evaluated in the Fisheries Technical Appendix.

Figure III-17 shows the simulated monthly (May through October) flows in the Feather River below the Thermalito Afterbay discharge for 1922-1990. The simulated flows are generally between approximately 3,000 cfs and 12,000 cfs during May through September, corresponding to the peak demand period for SWP exports from the Delta. May releases can be higher because of flood control releases. Simulated July and August flows are usually the highest for each year. The simulated October flows are the lowest, ranging from approximately 2,000 cfs to 4,000 cfs.

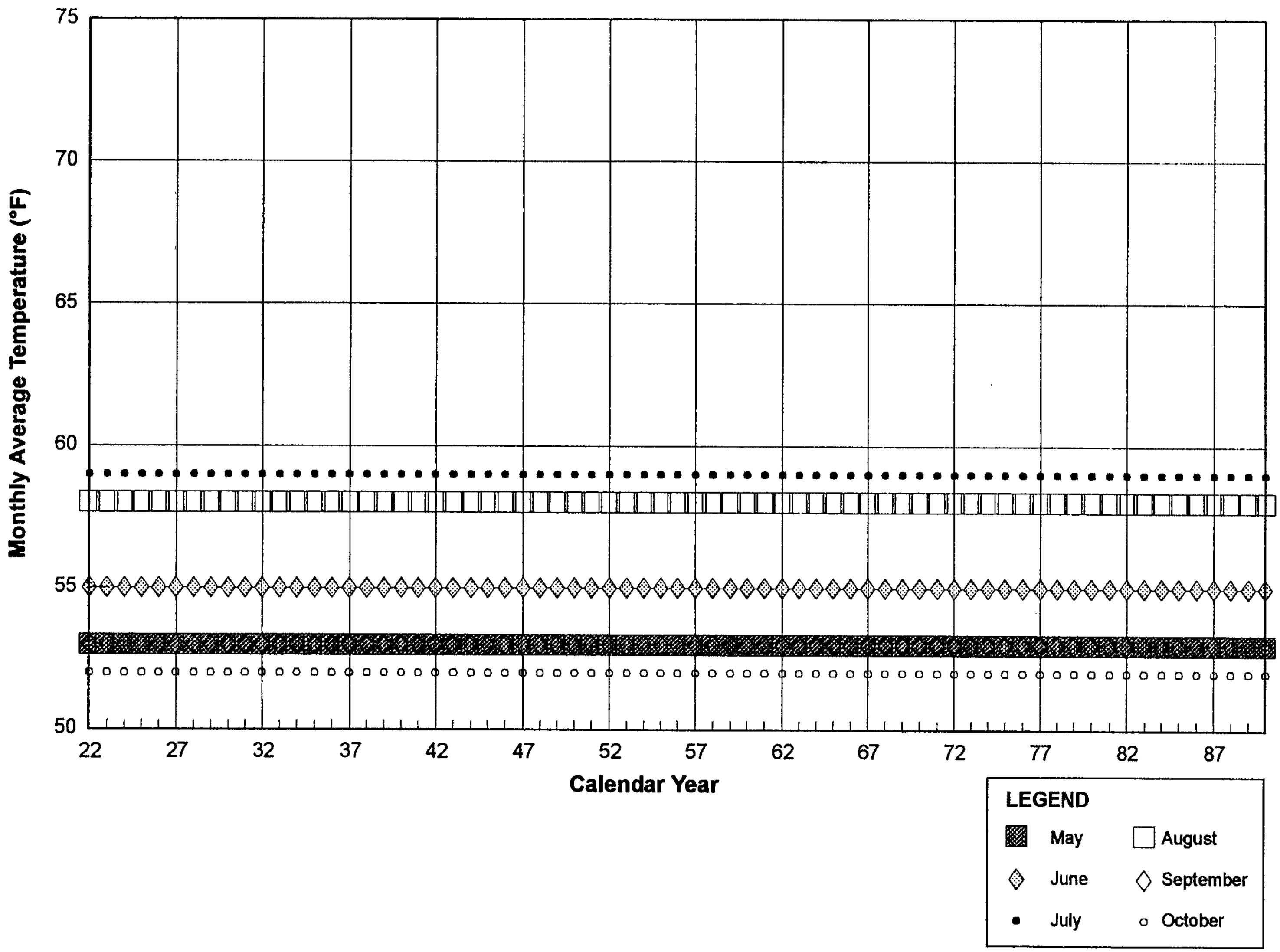


FIGURE III-13

TEMPERATURES OF RELEASES FROM LAKE OROVILLE UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

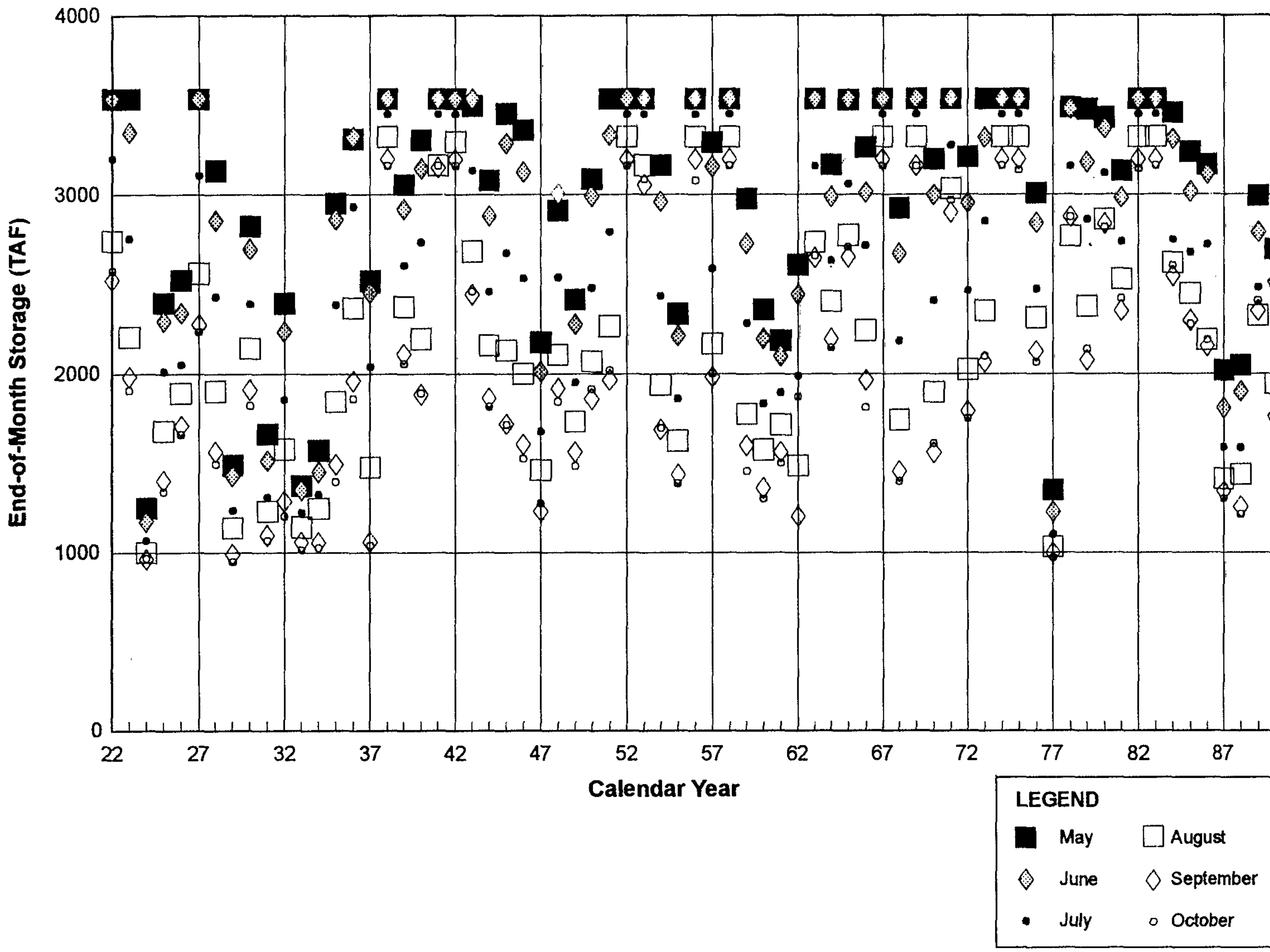


FIGURE III-14

STORAGE IN LAKE OROVILLE UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

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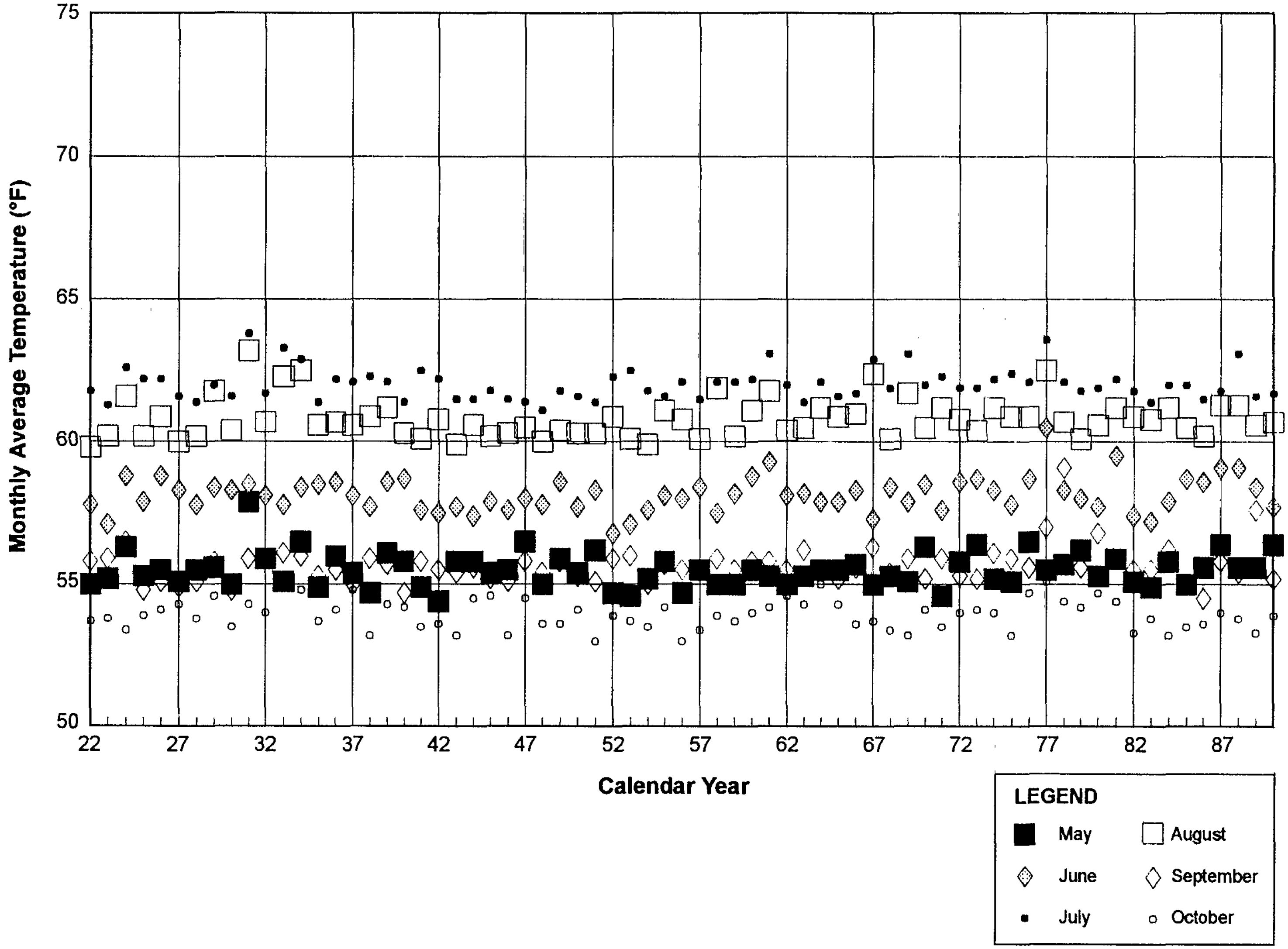

FIGURE III-15

TEMPERATURES IN THE FEATHER RIVER LOW-FLOW CHANNEL UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

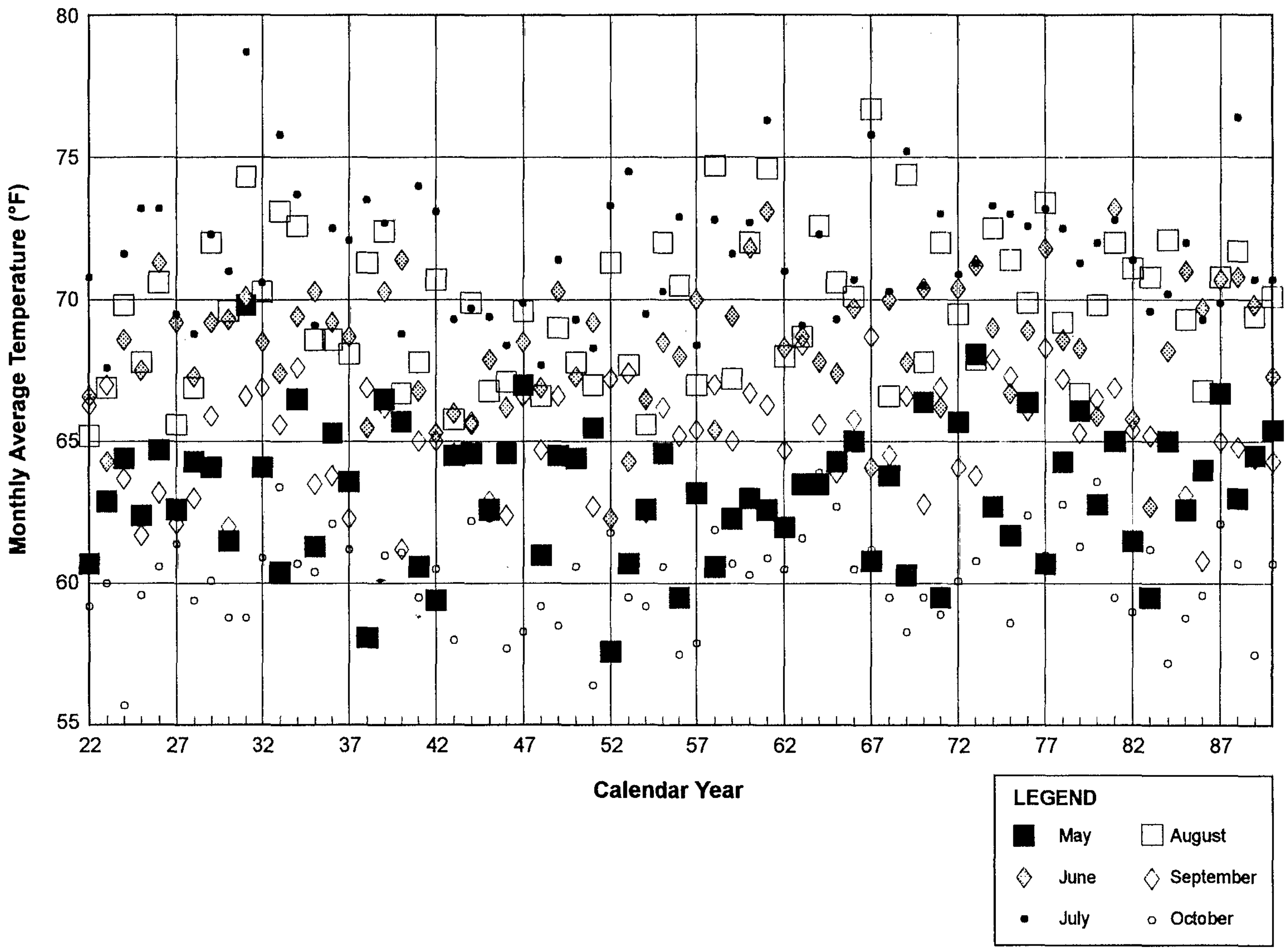

FIGURE III-16

TEMPERATURES IN THE FEATHER RIVER AT GRIDLEY UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

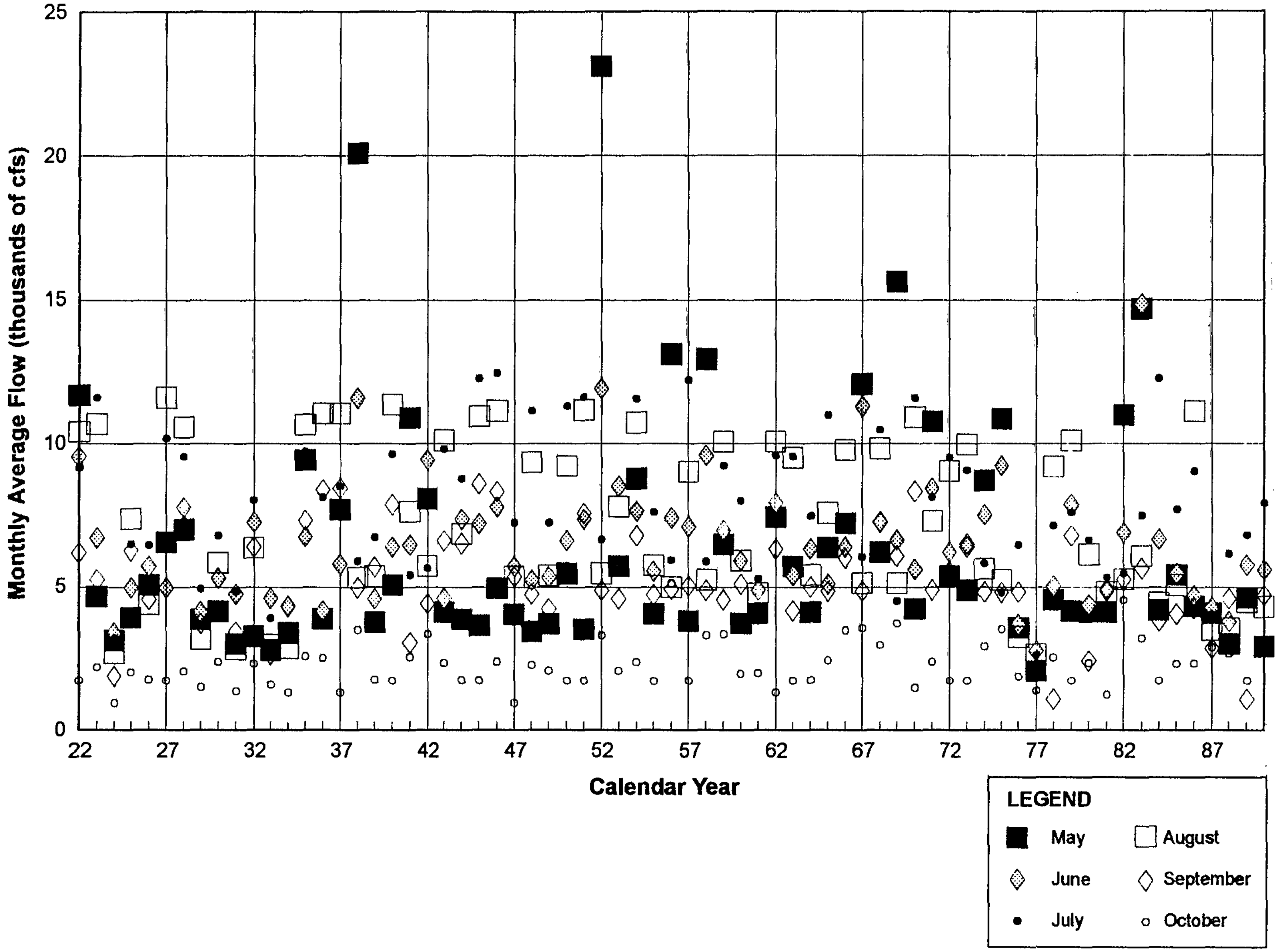

FIGURE III-17

FLOWS IN THE FEATHER RIVER BELOW THE THERMALITO AFTERBAY RELEASE UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

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American River Flows, Temperatures, and Reservoir Storage

Figure III-18 shows the simulated monthly (May through October) release temperature from Folsom Lake. Folsom Lake flood control operations are based on the interim 400,000-af fixed flood control requirements. The existing temperature control panels in Folsom Dam are used to obtain near-surface releases throughout summer, as described in Chapter II, Affected Environment. Target temperatures are used in the temperature model to maintain a cool-water reserve for release in October. The simulation results indicate that warm-water releases (above 65°F) are made in July, August, and September of each year so that a cool-water release can be achieved in October. However, as a result of earlier releases and reservoir drawdown, cool October releases are often not possible, and October release temperatures range from less than 55°F in a few years to more than 65°F in several years.

Figure III-19 shows the monthly Folsom Lake storage volumes for May through October of each year. The May end-of-month storage volume is usually the highest monthly storage for each year in Folsom Lake. Folsom Lake is filled to capacity (approximately 1.0 million af) in most years. Reservoir releases normally cause the reservoir storage volume to decline from May to October. The decline in Folsom Lake storage is usually between 400,000 af and 600,000 af. The carryover storage is maintained above 400,000 af in most years, with extremely low carryover storage (100,000 af) simulated in 1977. These variations in Folsom Lake storage have relatively little effect on the simulated October release temperatures, which range from less than 55°F to more than 65°F.

Figure III-20 shows the monthly (May through October) temperatures in the American River below Nimbus Dam (corresponding to Nimbus hatchery intake temperatures). The Nimbus Dam release temperatures are slightly higher than the Folsom Lake release temperatures because of warming in Lake Natoma that depends on meteorology and flow conditions. Relatively warm releases are simulated in the summer recreation months of July, August, and September. The October release temperatures generally fluctuate between approximately 55°F and 65°F, with releases in a few years warmer than 65°F. Downstream of Nimbus Dam, the river flows warm slightly as a result of meteorology and flow conditions. The possible effect of these relatively high river temperatures on steelhead trout and chinook salmon spawning and incubation in the American River is evaluated in the Fisheries Technical Appendix.

Figure III-21 shows the simulated monthly (May through October) flows in the American River below Nimbus Dam for 1922-1990. The simulated flows are generally between approximately 1,000 cfs and 5,000 cfs during May through October, corresponding to the peak demand period for CVP exports from the Delta. May and June flows can be higher because of flood control releases in some years.

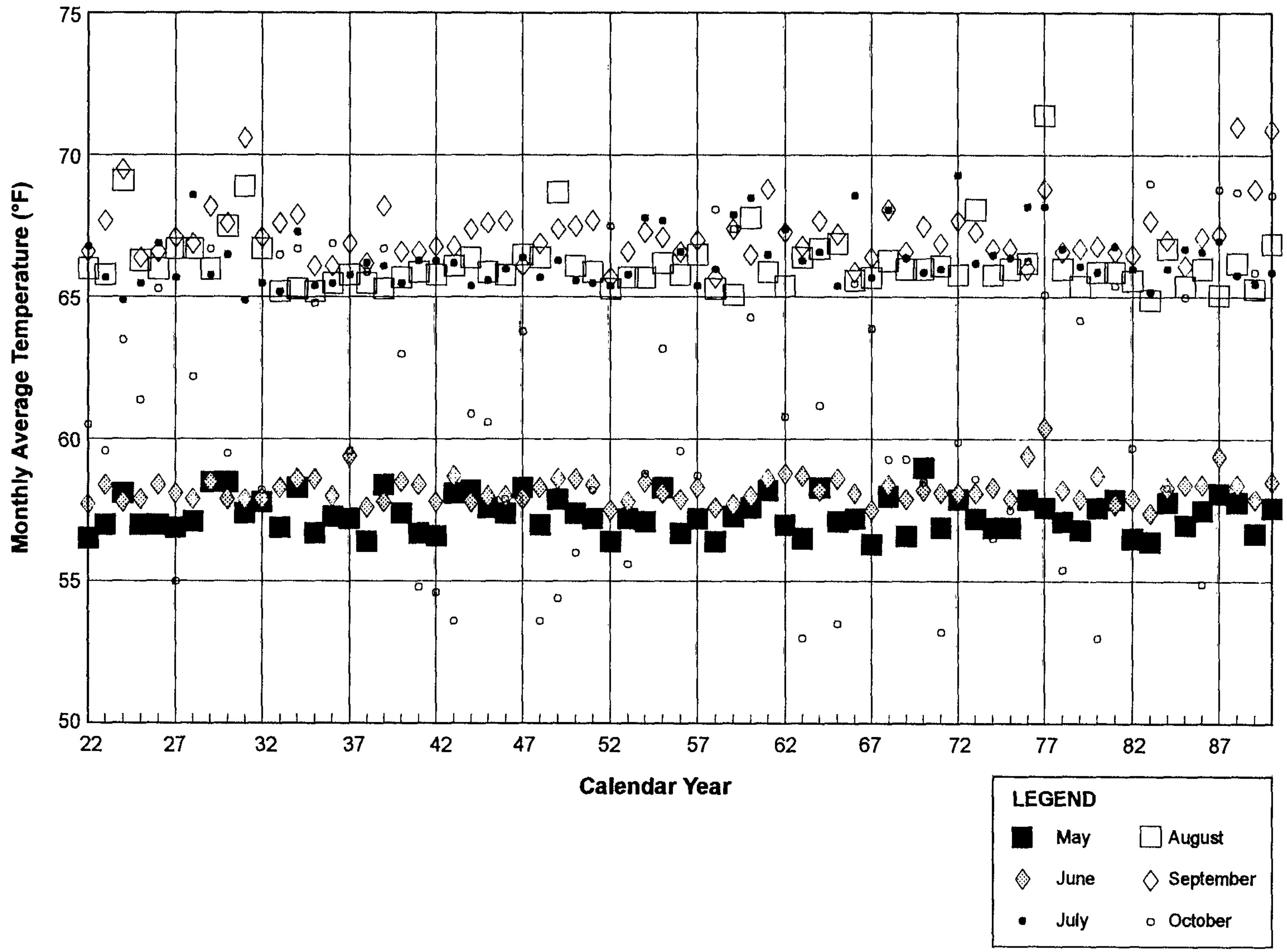

FIGURE III-18

TEMPERATURES OF RELEASES FROM FOLSOM LAKE UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

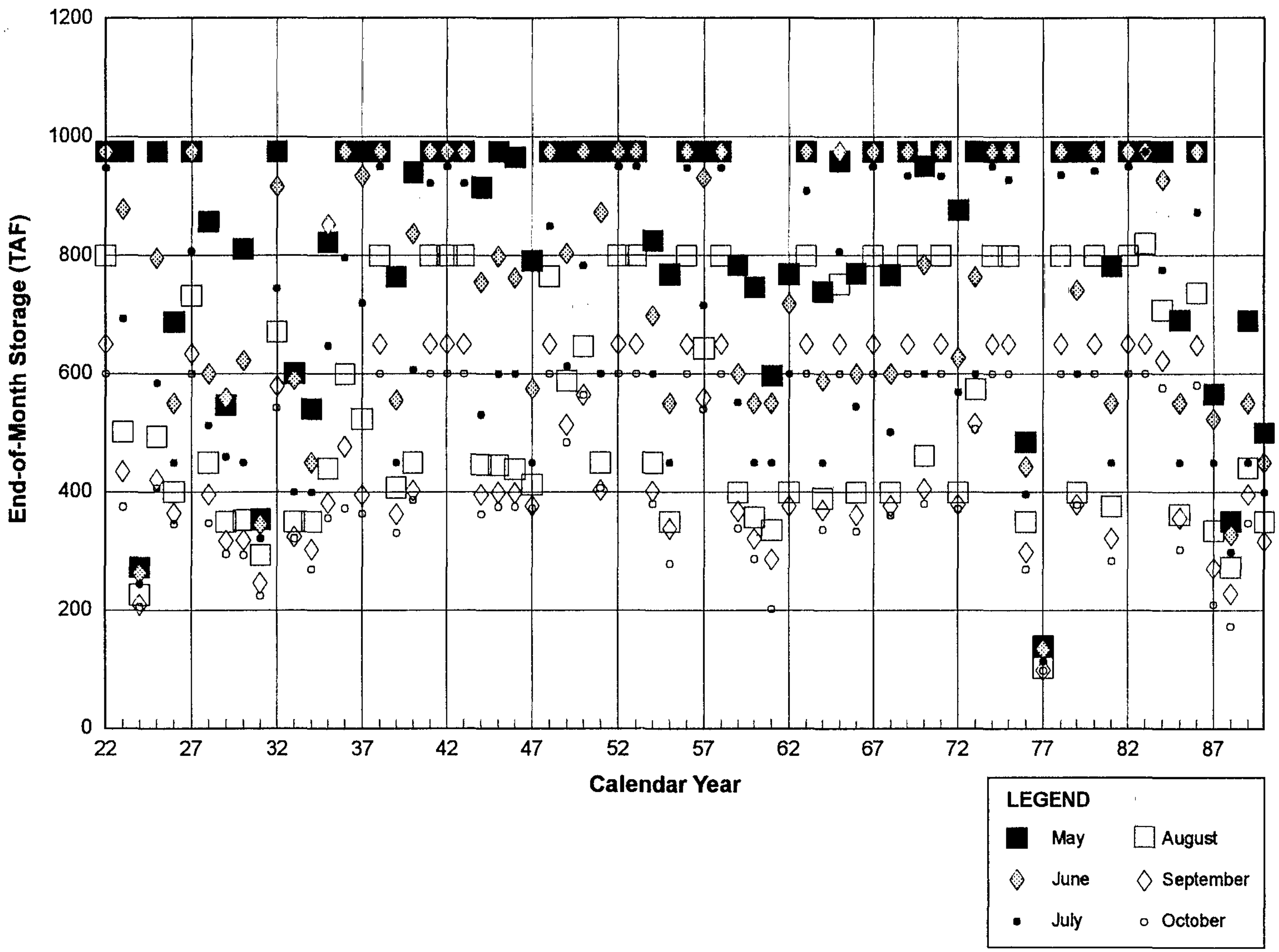

FIGURE III-19

STORAGE IN FOLSOM LAKE UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

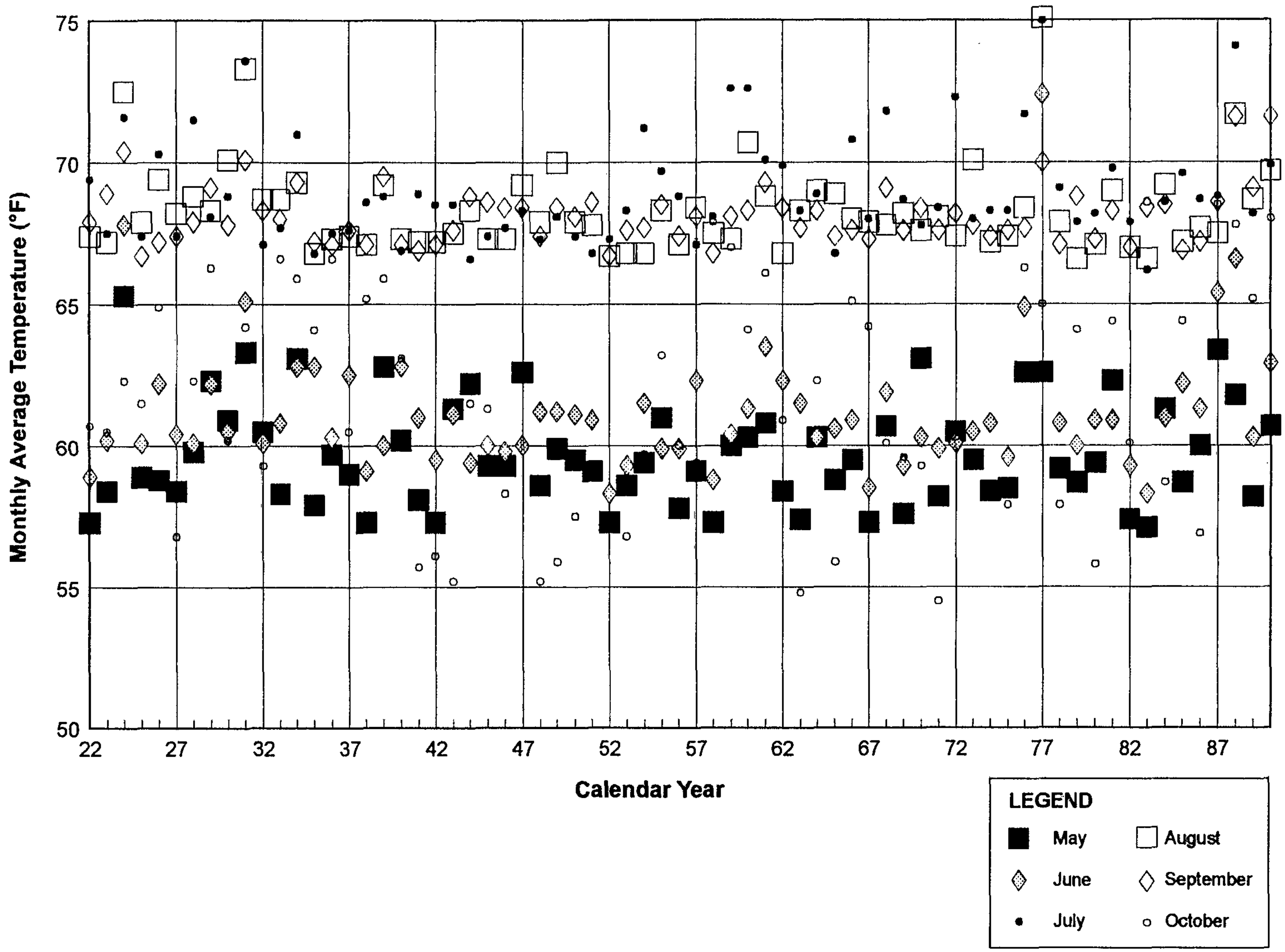

FIGURE III-20

TEMPERATURES IN THE AMERICAN RIVER BELOW NIMBUS DAM UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

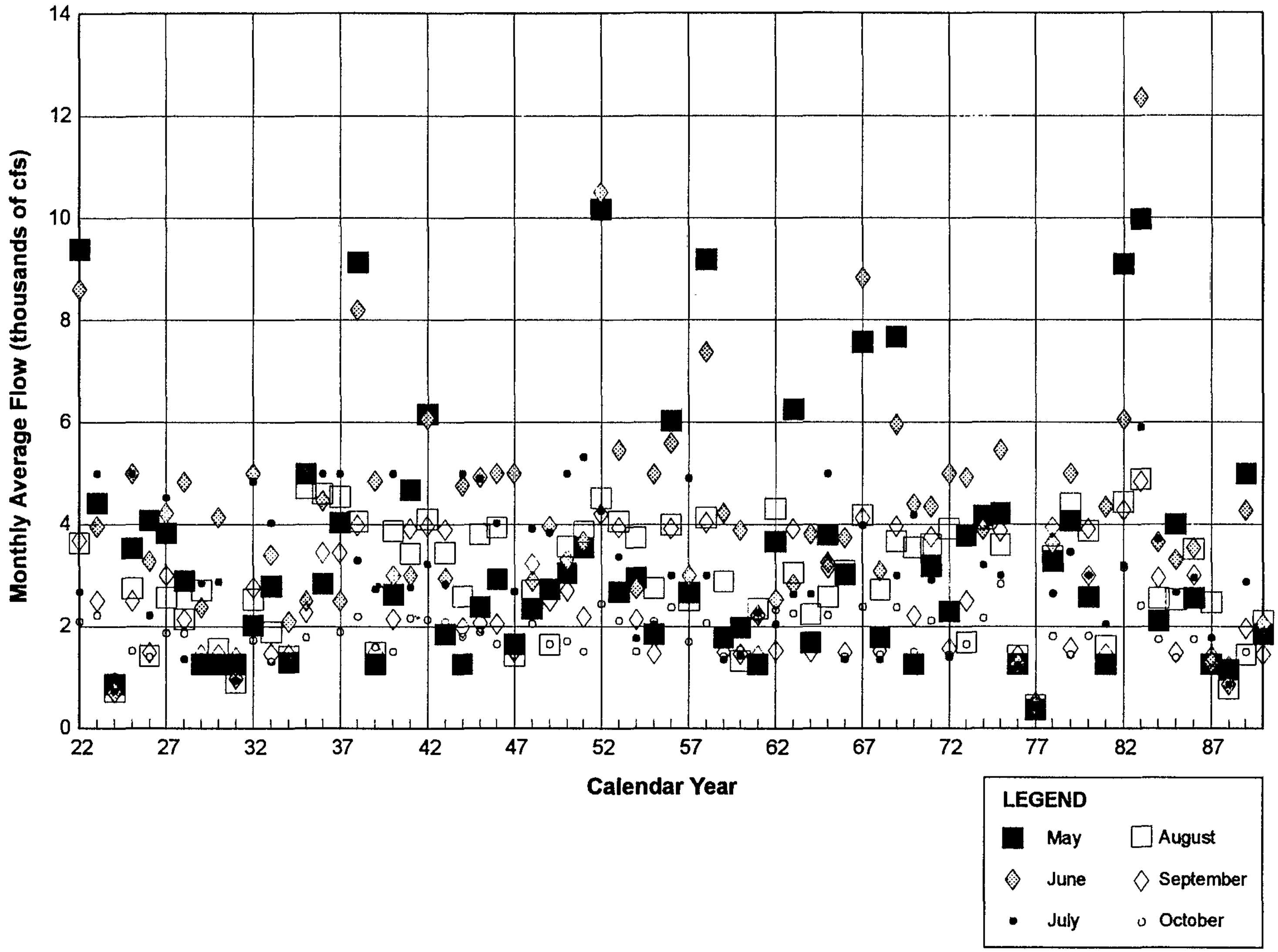

FIGURE III-21

RELEASE FLOWS FROM NIMBUS DAM UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

SAN JOAQUIN RIVER REGION

Stanislaus River Flows, Temperatures, and Reservoir Storage

Figure III-22 shows the simulated monthly (May through October) release temperature from New Melones Reservoir. The May release temperatures vary from approximately 45°F to above 50°F in some years because there is considerable year-to-year variation in the winter temperatures that control the early spring temperatures. The seasonal increase of the release temperatures is approximately 5°F in many years, so that release temperatures in September and October remain below 55°F. The releases from New Melones Reservoir are the inflow to Tulloch Reservoir. Tulloch Reservoir is simulated with another reservoir temperature model. Tulloch Reservoir releases flow into Goodwin Reservoir, a regulating reservoir that releases to the Stanislaus River.

Figure III-23 shows the monthly New Melones Reservoir storage volumes for May through October of each year. There is considerable variation in the maximum storage volume from year to year. The June end-of-month storage volume is usually the highest monthly storage for each year in New Melones Reservoir because of substantial snowmelt runoff in April, May, and June. New Melones Reservoir is filled to capacity (approximately 2.5 million af) in only approximately 20 percent of the years because the average runoff is a relatively small fraction of the reservoir volume. Reservoir releases normally cause the reservoir storage volume to decline between June and October. The decline in New Melones Reservoir storage is usually between 400,000 af and 600,000 af. The simulated carryover storage is maintained above 500,000 af in almost all years. These variations in New Melones Reservoir storage have some effect on the simulated release temperatures, with the warmest temperatures associated with the lowest carryover reservoir storage (less than 1.0 million af). Tulloch Reservoir is managed with a nearly constant volume (68,000 af), so there is no additional effect of Tulloch Reservoir carryover storage volume changes on Tulloch Reservoir release temperatures.

Figure III-24 shows the monthly (May through October) release temperatures for Goodwin Dam, downstream of Tulloch Reservoir. The Goodwin Dam release temperatures are approximately 5°F higher than the New Melones Reservoir release temperatures in May, and this difference in release temperature is increased to almost 10°F in October. Most of the seasonal increase in Goodwin Dam release temperature actually occurs in Tulloch Reservoir because Tulloch Reservoir volume is small relative to the outflow volume, and the cool water from the lower layers of the reservoir is released during summer. Relatively warm releases (greater than 55°F) are simulated in the summer recreation months of June, July, and August of most years. The September and October release temperatures generally fluctuate between approximately 55°F and 60°F, with releases warmer than 60°F in only a few years, corresponding to the lowest New Melones Reservoir carryover storage volumes.

Figure III-25 shows the monthly (May through October) Stanislaus River temperatures at Oakdale, located approximately 20 miles downstream of Goodwin Dam. September temperatures at Oakdale are the highest (approximately 65°F) in most years, with warming of approximately 5°F occurring in the river downstream of Goodwin Dam. October temperatures

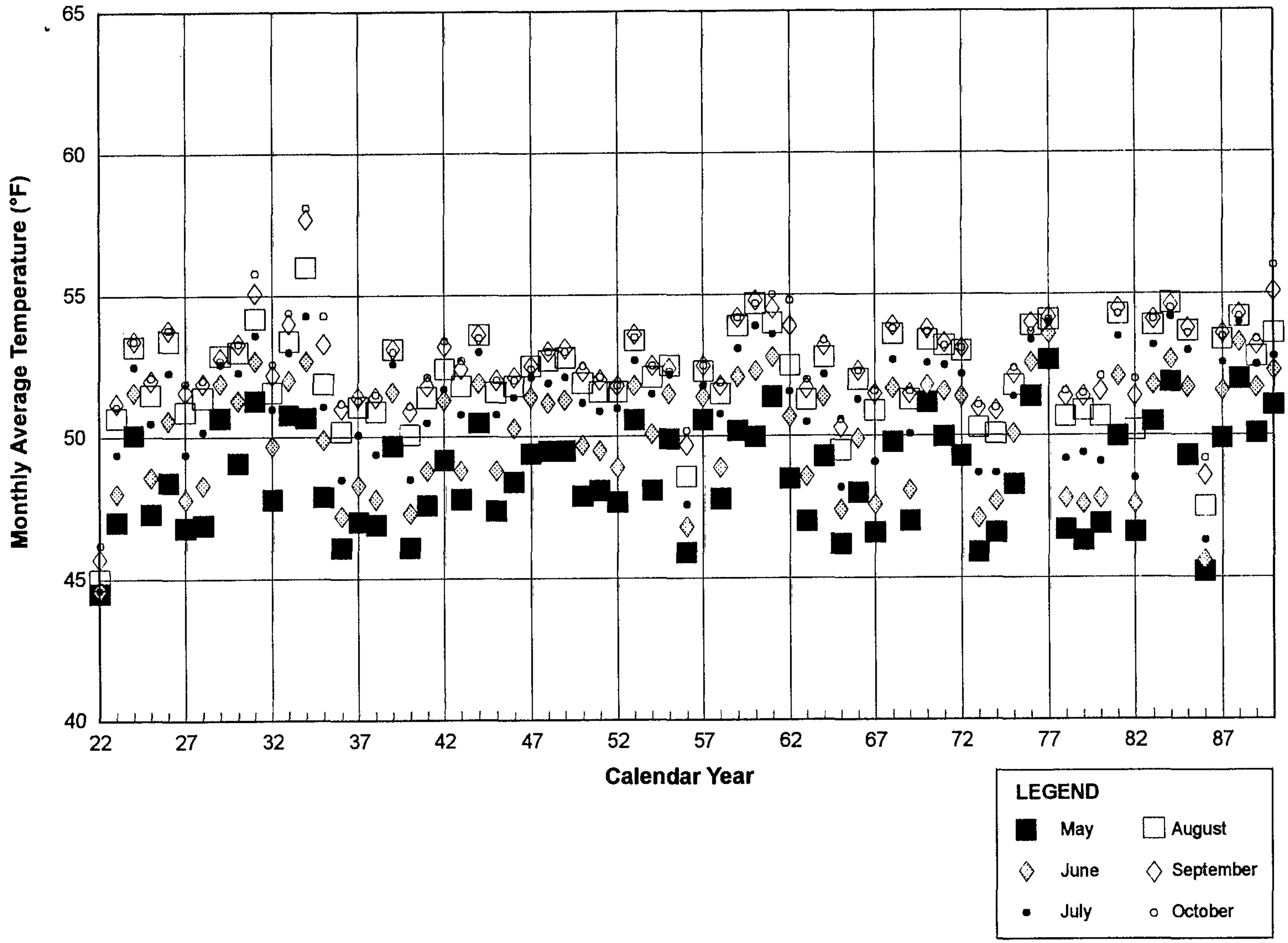

FIGURE III-22

TEMPERATURES OF RELEASES FROM NEW MELONES RESERVOIR UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

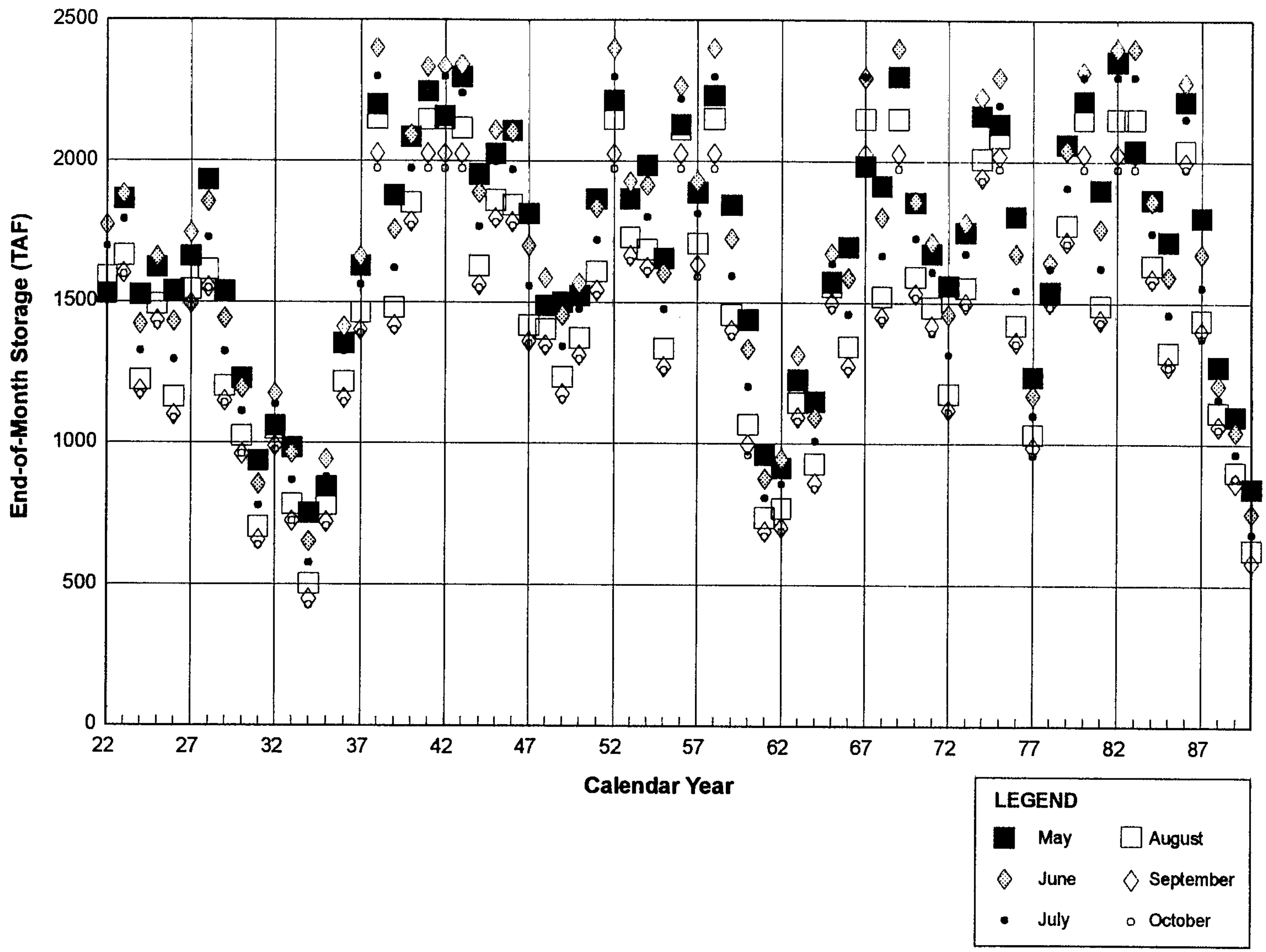

FIGURE III-23

STORAGE IN NEW MELONES RESERVOIR UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

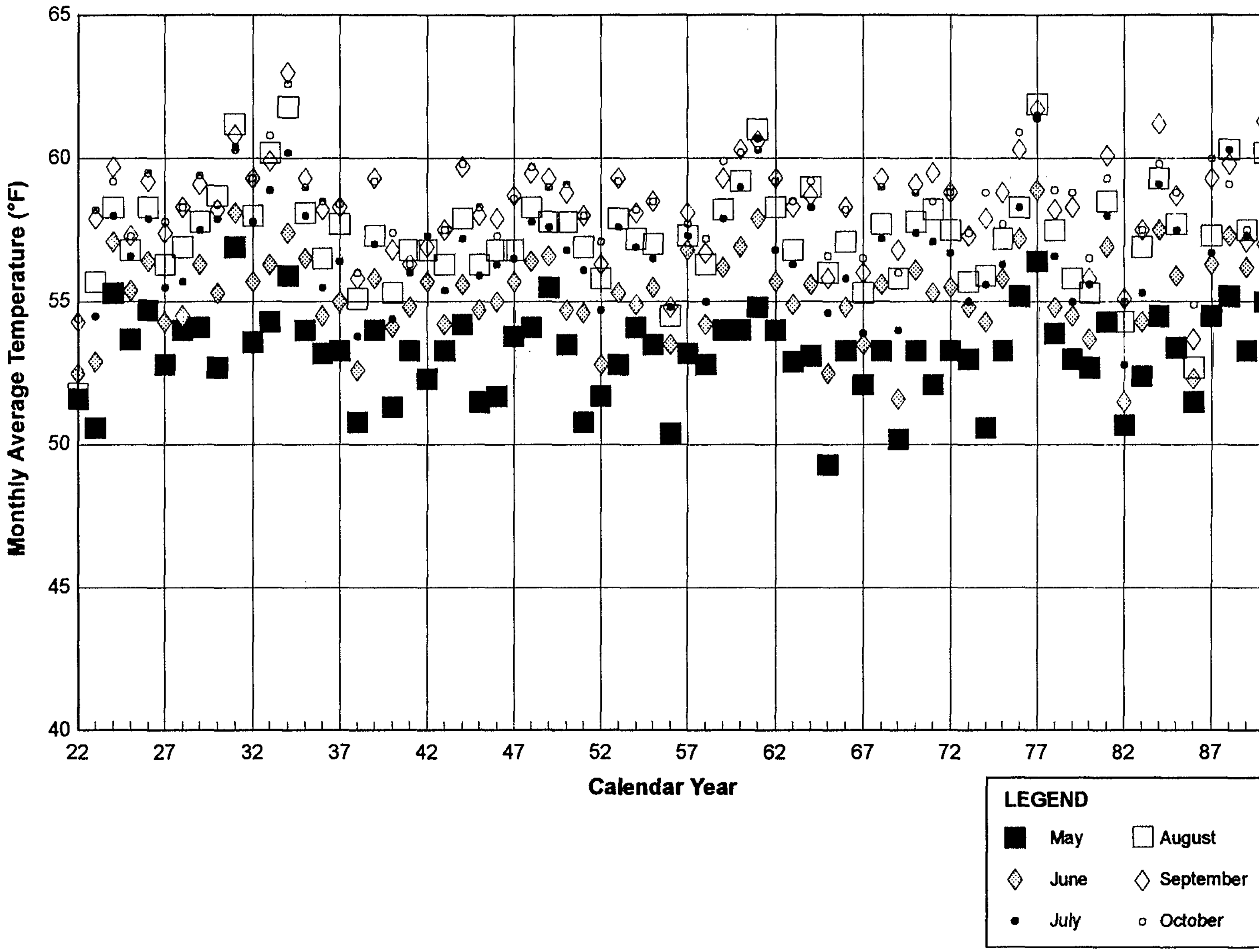

FIGURE III-24

TEMPERATURES OF RELEASES FROM GOODWIN DAM UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

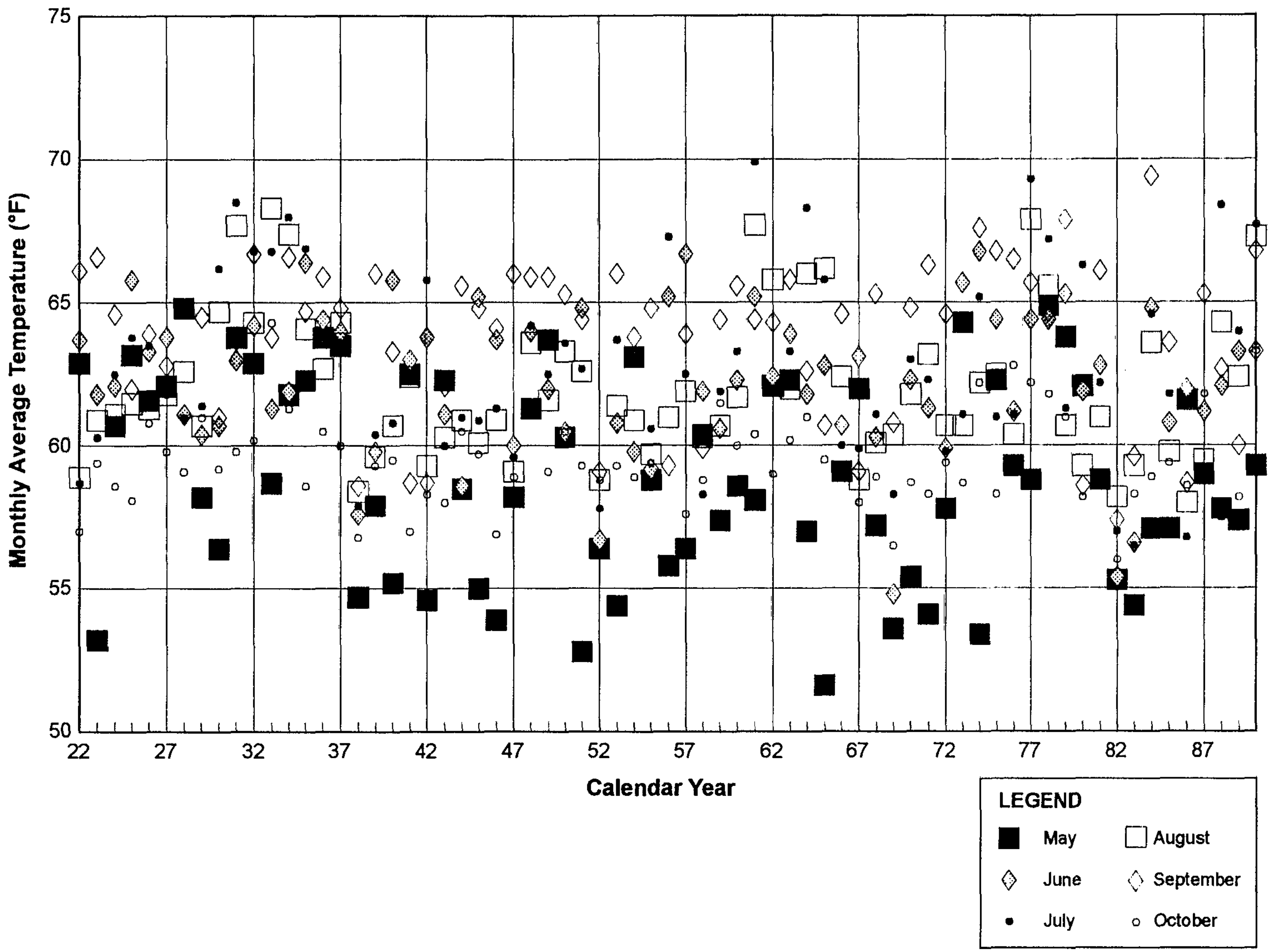

FIGURE III-25

TEMPERATURES OF THE STANISLAUS RIVER AT OAKDALE UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

are slightly lower than September temperatures and are approximately equal to the temperatures of releases from Goodwin Dam (approximately 55-60°F). The possible effect of these relatively high river temperatures on chinook salmon spawning and incubation in the Stanislaus River is discussed in the Fisheries Technical Appendix.

Figure III-26 shows the simulated monthly (May through October) flows in the Stanislaus River below Goodwin Dam for 1922-1990. The simulated flows are generally less than approximately 1,000 cfs except in years with flood control releases (i.e., 1983) and years with simulated releases to help satisfy San Joaquin River inflow requirements at Vernalis. The instream flow requirements for fish are generally approximately 200 cfs, with some additional releases simulated for water quality control at Vernalis. September and October flows are generally the lowest, with simulated flows of approximately 200 cfs.

Other Reservoir Storage and River Flow Conditions

The recreation and fisheries habitat assessments for several other reservoirs in the San Joaquin River system depend on the simulated monthly storage volumes and downstream release flows. The simulated No-Action Alternative storage patterns for these reservoirs and downstream flows are discussed in this section. These reservoirs are Camanche Reservoir on the Mokelumne River, New Don Pedro Reservoir on the Tuolumne River, Lake McClure on the Merced River, and Millerton Lake on the San Joaquin River. Reservoir release temperatures and river temperatures are not simulated or evaluated for these facilities.

The reservoirs in the San Joaquin River Basin were simulated with SANJASM using approximate reservoir operating rules based on historical operations. The basic diversion demands and instream flow requirements were simulated, but the discretionary releases for power generation and possible reductions in diversions during low-flow periods were not simulated (see complete description in the Surface Water Supplies and Facilities Operations Technical Appendix). These simulation results for reservoir storage volume and downstream flows are considered adequate for purposes of PEIS impact assessment of fisheries, vegetation and wildlife, and recreation resources.

Figure III-27 shows the monthly storage volumes for Camanche Reservoir on the Mokelumne River for May through October of each year. The maximum storage volume for each year occurs in May or June. Camanche Reservoir is filled to capacity (approximately 425,000 af) in more than half of the simulated years. In wet years, the seasonal drawdown at the end of September is relatively small (approximately 50,000 af), but the simulated October storage is approximately 100,000 af lower than September storage (simulated flood control operations). In dry years, the maximum storage is simulated in May, and a seasonal drawdown of approximately 75,000 af occurs between May and October (with October storage approximately the same as September storage). Carryover storage is usually greater than 200,000 af, but minimum carryover storage (less than 100,000 af) occurs in approximately 10 percent of the years.

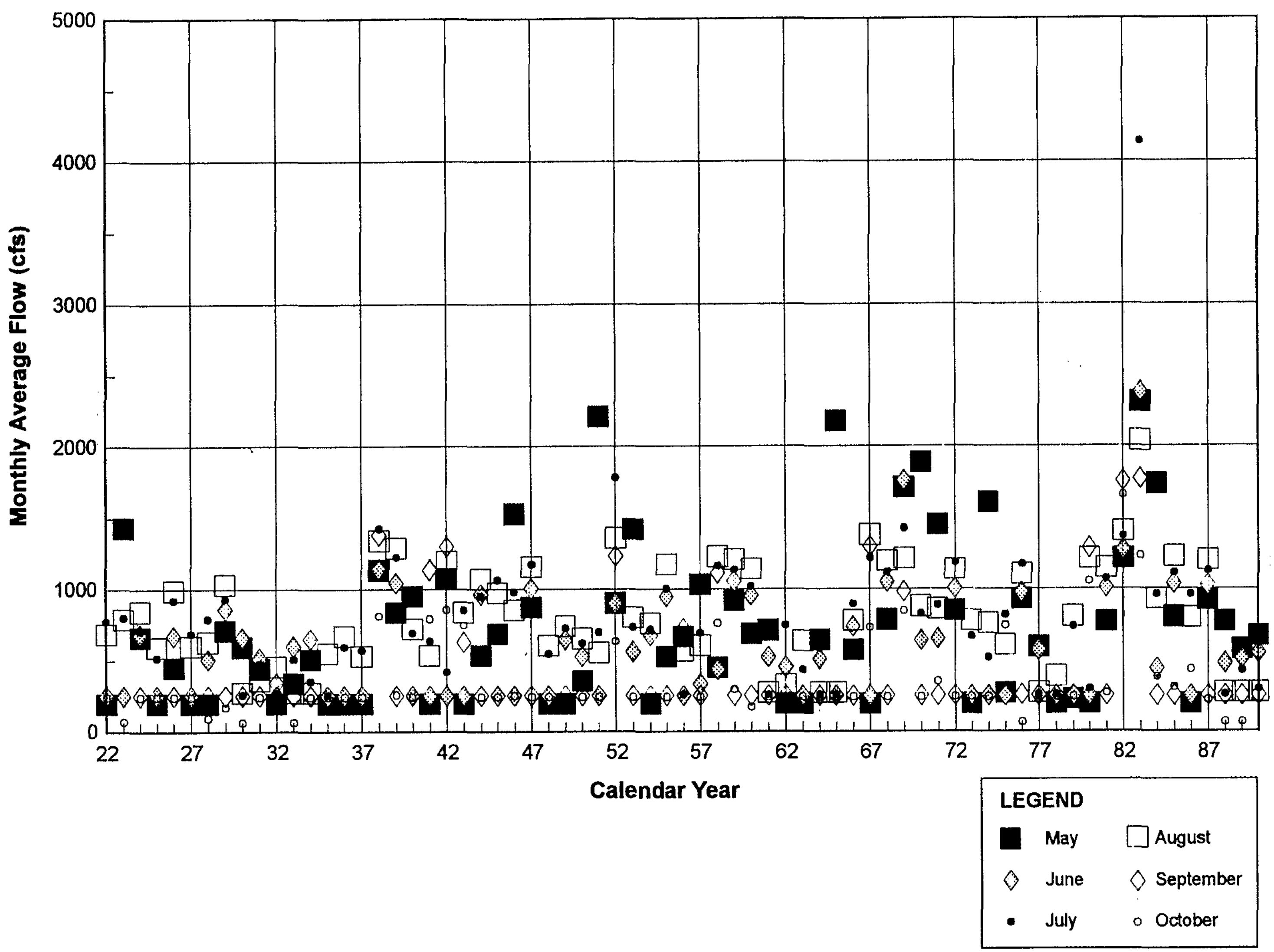

FIGURE III-26

RELEASE FLOWS FROM GOODWIN DAM UNDER THE
CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

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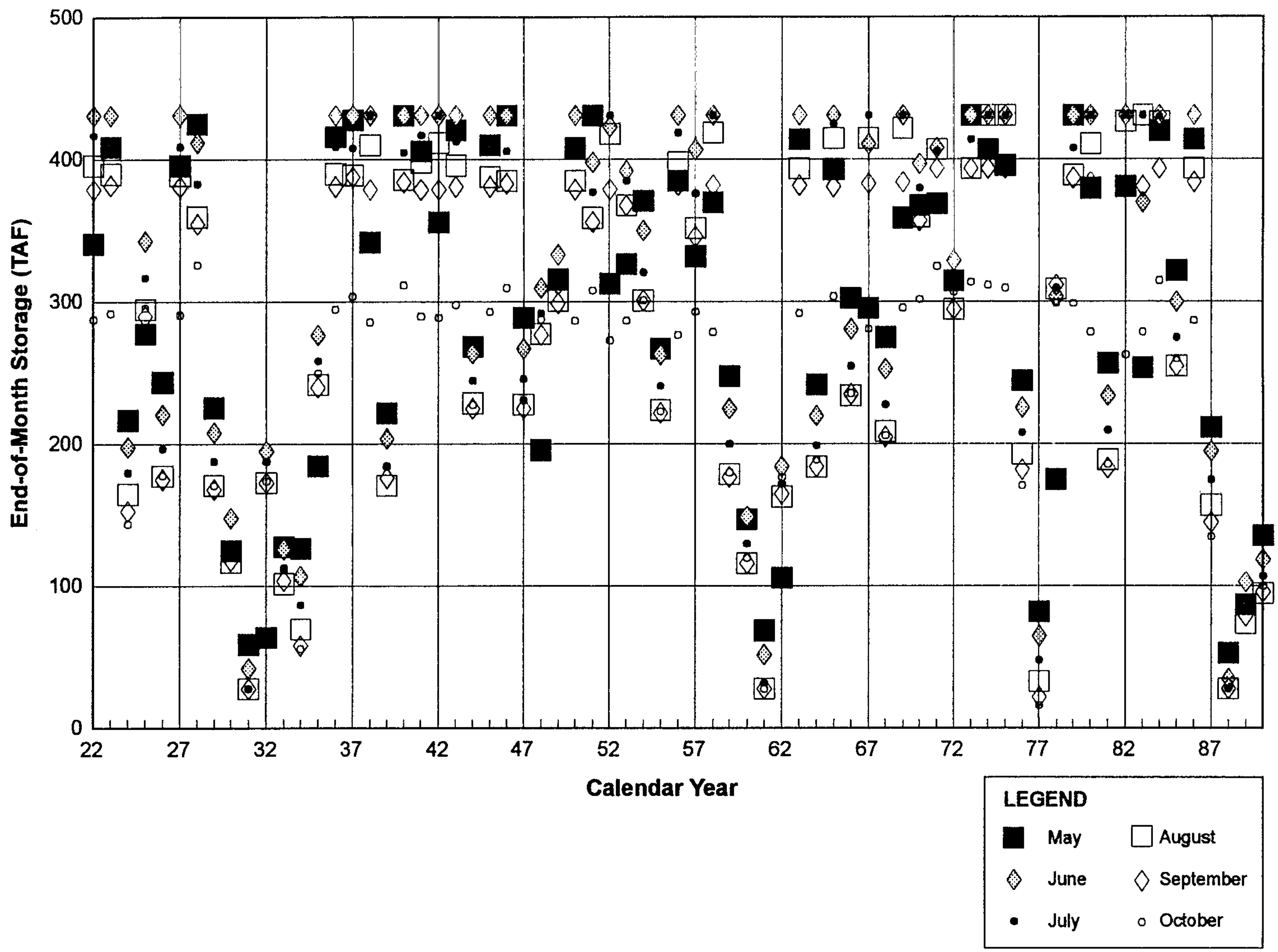

FIGURE III-27

STORAGE IN CAMANCHE RESERVOIR UNDER THE
CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

C-082027

Figure III-28 shows the simulated monthly (May through October) flows in the Mokelumne River below Camanche Reservoir for 1922-1990. These flows are a combination of instream flows and releases for downstream diversions. The monthly flows decline slightly from May through October. The simulated flows are generally less than approximately 750 cfs except for flood control releases that occur in some months (May, June, and October) in approximately half the years. September and October flows are generally the lowest, with simulated flows of approximately 250 cfs.

Figure III-29 shows the monthly storage volumes for New Don Pedro Reservoir on the Tuolumne River for May through October of each year. The maximum storage volume for each year normally occurs in June or July. New Don Pedro Reservoir is filled to capacity (approximately 2.0 million af) in approximately half of the years. In wet years, the seasonal fluctuation in storage from May through October is less than 500,000 af. In dry years, the maximum simulated storage is usually in May, and a seasonal drawdown of approximately 500,000 af occurs between May and October. The carryover storage is usually greater than 1.5 million af, although carryover storage of less than 1.0 million af is simulated in approximately 10 percent of the years.

Figure III-30 shows the simulated monthly (May through October) flows in the Tuolumne River below La Grange diversion dam for 1922-1990. These flows are a combination of instream flows and flood control releases. The simulated flows are generally less than approximately 100 cfs except for flood control releases during May through August of approximately 25 percent of the years.

Figure III-31 shows the monthly storage volumes for Lake McClure on the Merced River for May through October of each year. The maximum storage volume for each year normally occurs in June. Lake McClure is filled to capacity (approximately 1.0 million af) in approximately half of the years. In wet years, the seasonal drawdown in storage from June to October is approximately 300,000 to 400,000 af. In dry years, the maximum simulated storage is usually in May, and a seasonal drawdown of up to 250,000 af occurs between May and October (i.e., 1931, 1976, 1977). The carryover storage is usually greater than 400,000 af, with carryover storage of less than 400,000 af simulated in only 10 percent of the years.

Figure III-32 shows the simulated monthly (May through October) flows in the Merced River below Crocker-Hoffman diversion dam for 1922-1990. These flows are a combination of instream flows and flood control releases. The simulated flows are generally less than approximately 250 cfs except for flood control releases in some months (May through July, and October) in approximately 25 percent of the years.

C-082028

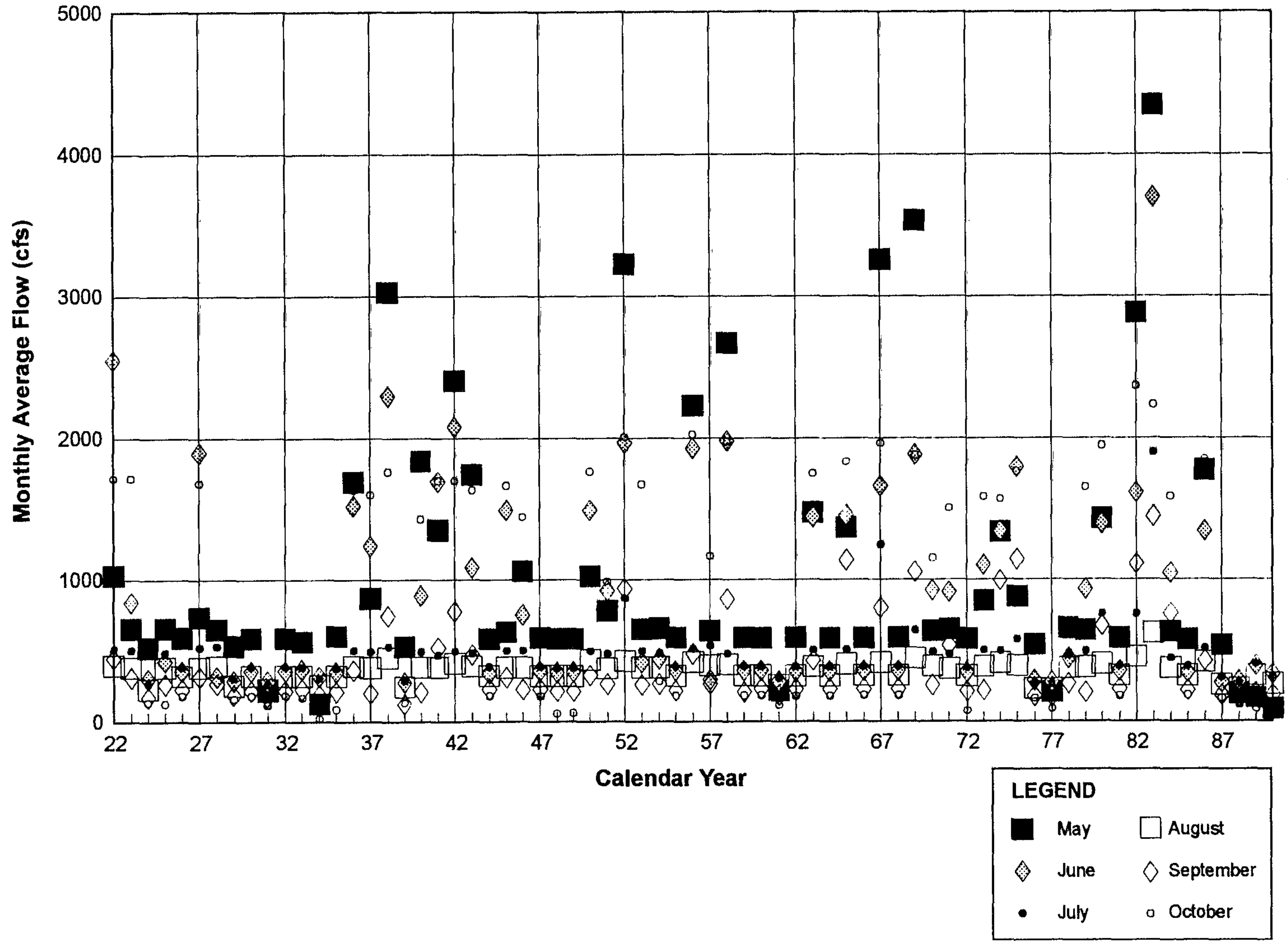

FIGURE III-28

FLOWS BELOW CAMANCHE RESERVOIR UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

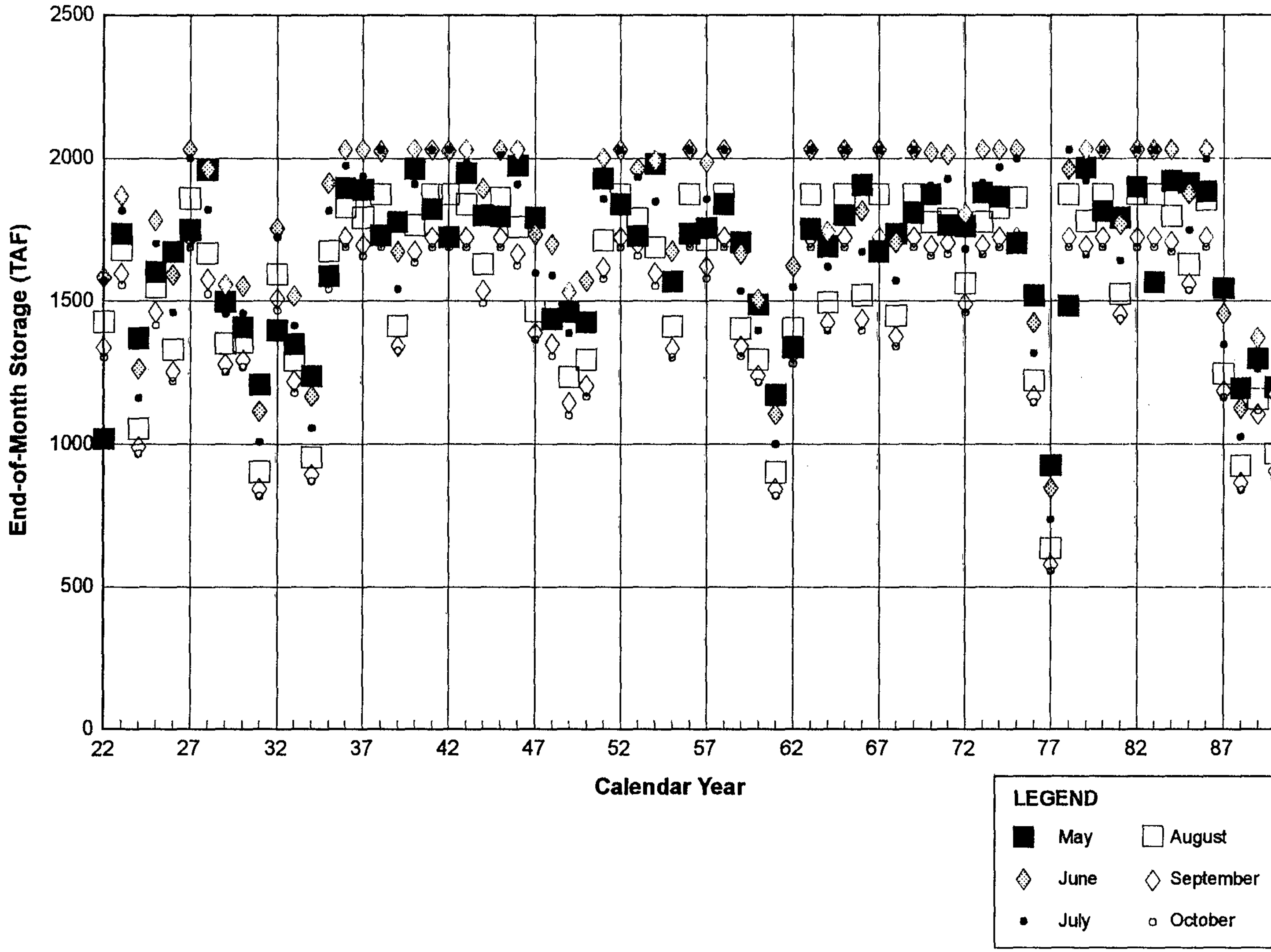

FIGURE III-29

STORAGE IN NEW DON PEDRO RESERVOIR UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

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C-082030

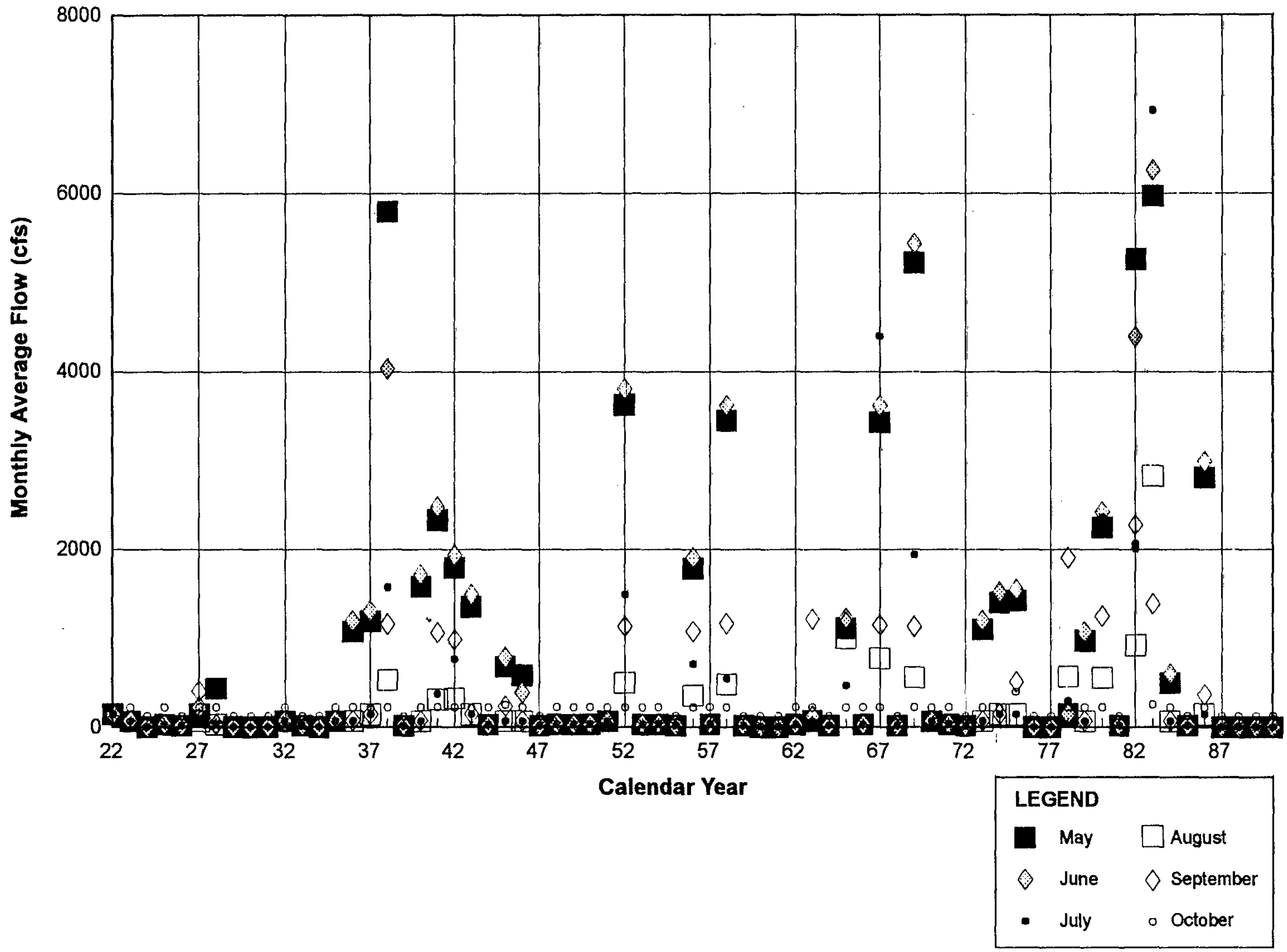

FIGURE III-30

FLOWS IN THE TUOLUMNE RIVER BELOW LA GRANGE UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

C-082031

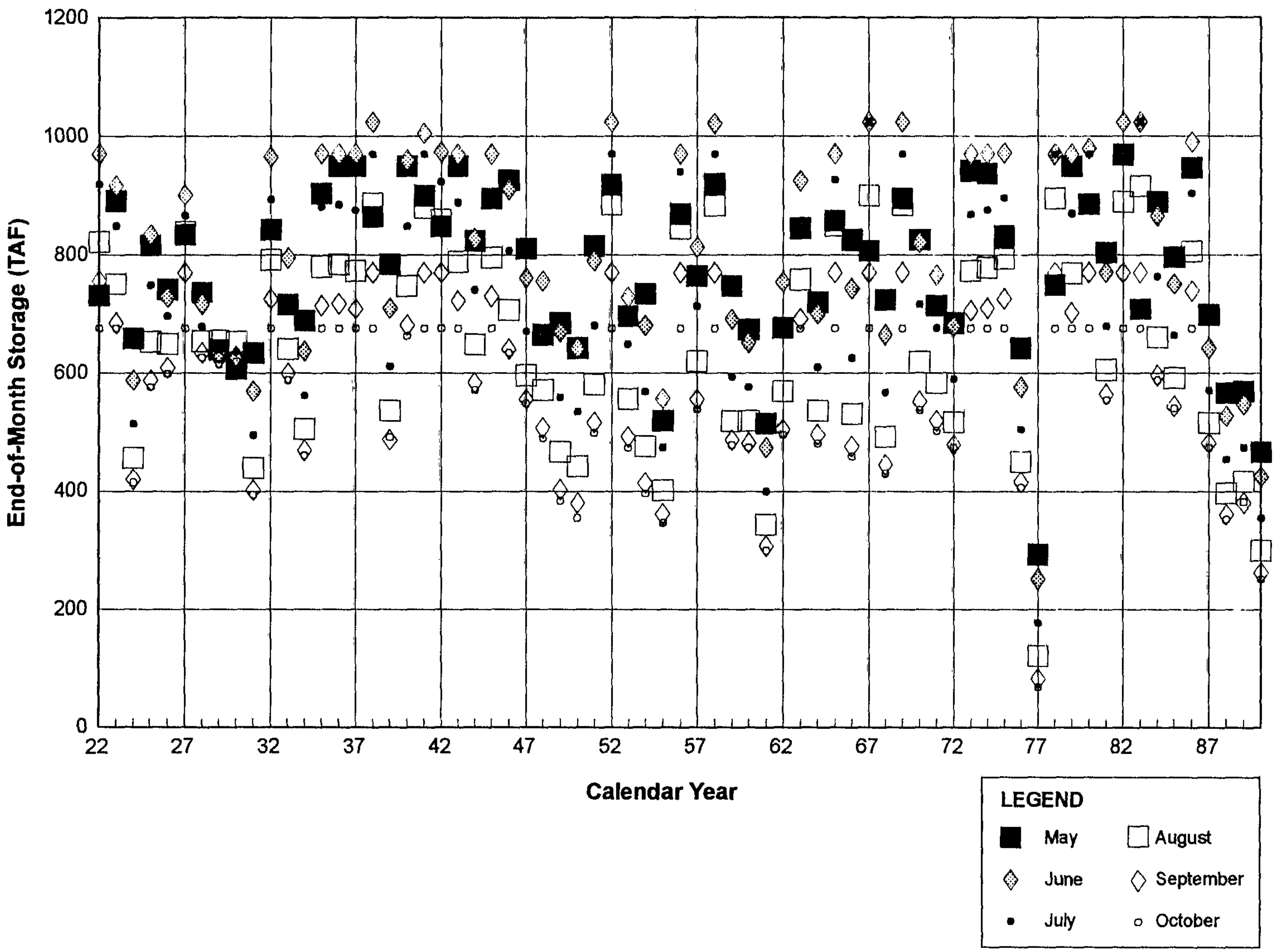

FIGURE III-31

STORAGE IN LAKE McCLURE UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

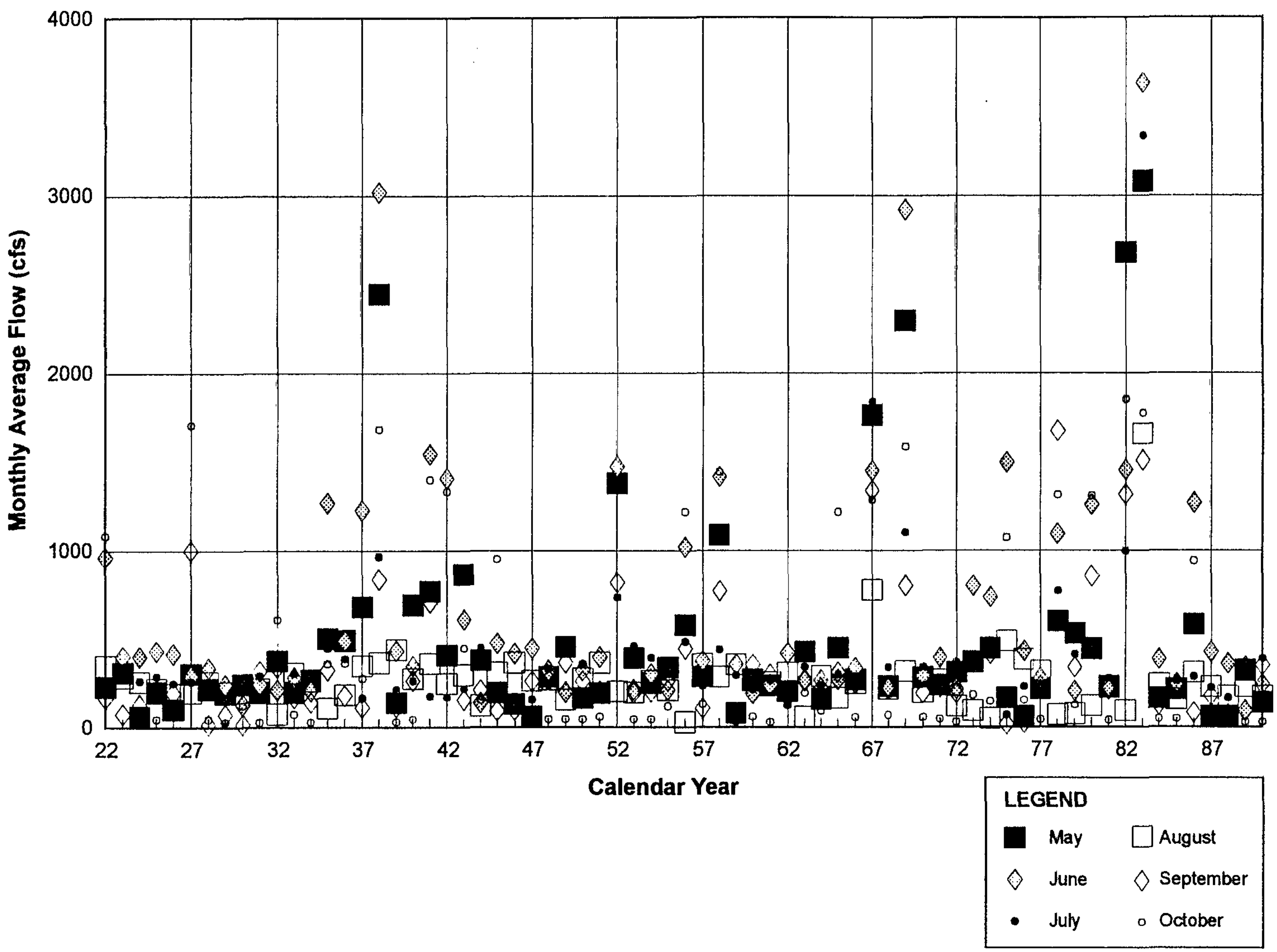

FIGURE III-32

FLOWS IN THE MERCED RIVER BELOW MERCED FALLS UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

C-082033

Figure III-33 shows the monthly storage volumes for Millerton Lake on the San Joaquin River for May through October of each year. The maximum storage volume for each year normally occurs in May or June. Millerton Lake is filled to capacity (approximately 500,000 af) in less than half of the years. The carryover storage is usually approximately 150,000 af. Millerton Lake is operated as a regulating facility for the Madera and Friant-Kern canals, and very little flow is released to the San Joaquin River. In wet years, the seasonal fluctuation in storage from May through October is approximately 350,000 af. In dry years, the seasonal fluctuation in storage volume is reduced by the available storage.

Figure III-34 shows the simulated monthly (May through October) flows in the San Joaquin River below Friant Dam for 1922-1990. These flows are a combination of small releases for downstream demands and occasional flood control releases. The simulated flows are generally less than approximately 200 cfs except for flood control releases in May and June of approximately 25 percent of the years.

Figure III-35 shows the simulated monthly (May through October) flows in the San Joaquin River at Vernalis for 1922-1990. These flows are a combination of releases from each of the San Joaquin River tributaries for instream flows and occasional flood control releases. The simulated flows are generally between approximately 1,000 cfs and 2,000 cfs except for flood control releases in May through July of approximately 25 percent of the years. The Vernalis inflow objectives of the 1995 WQCP were not simulated as flow requirements for the No-Action Alternative.

San Luis Reservoir

Figure III-36 shows the monthly (combined CVP and SWP) San Luis Reservoir storage volumes for May through October of each year. The maximum storage volume for each year normally occurs in April because San Luis Reservoir is filled from Delta exports ahead of the irrigation season. San Luis Reservoir is filled to capacity (approximately 2.0 million af) in approximately half of the years. Seasonal drawdown normally begins in May. The simulated carryover storage is usually between 250,000 af and 500,000 af. San Luis Reservoir is operated as a regulating facility for the San Luis-California Aqueduct and the Delta-Mendota Canal. The seasonal drawdown can be as high as 1.75 million af if the full operating storage capacity is used. In dry years, the seasonal fluctuation in storage volume is reduced by the available storage volume.

SACRAMENTO-SAN JOAQUIN RIVER DELTA

Delta Flows and Salinity Conditions

The Delta flow and salinity conditions for the No-Action Alternative were calculated from the PROSIM model simulation results. Each of the major inflows to the Delta, as well as the total CVP and SWP exports, net channel depletions, and Delta outflow is calculated in PROSIM. The Delta channel net flows, water entrainment, and estuarine salinity conditions are estimated as described in the Fish Habitat Water Quality Methodology/Modeling Technical Appendix. The period of February through July was selected for focused discussion as the most important for

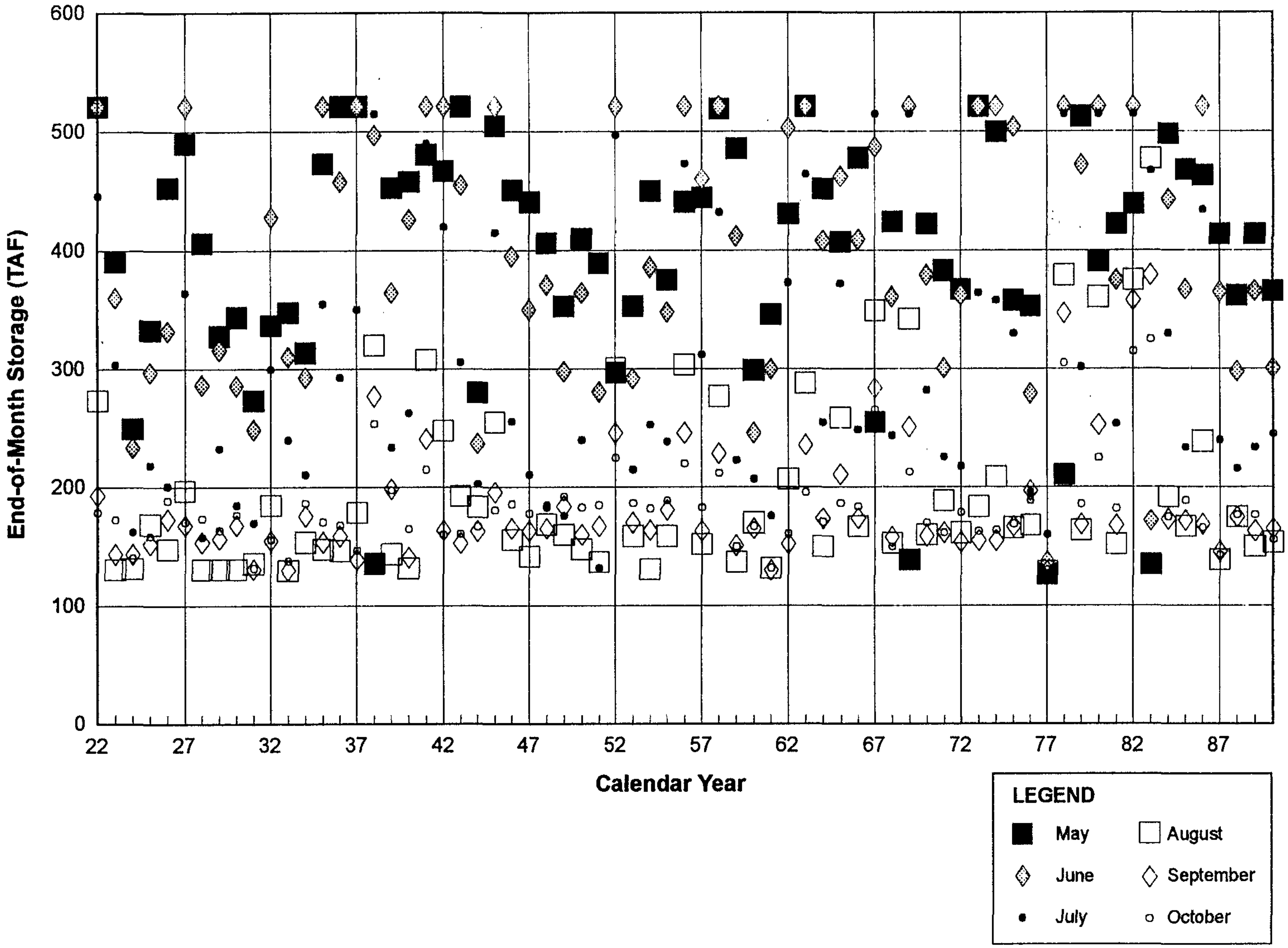

FIGURE III-33

STORAGE IN MILLERTON LAKE UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

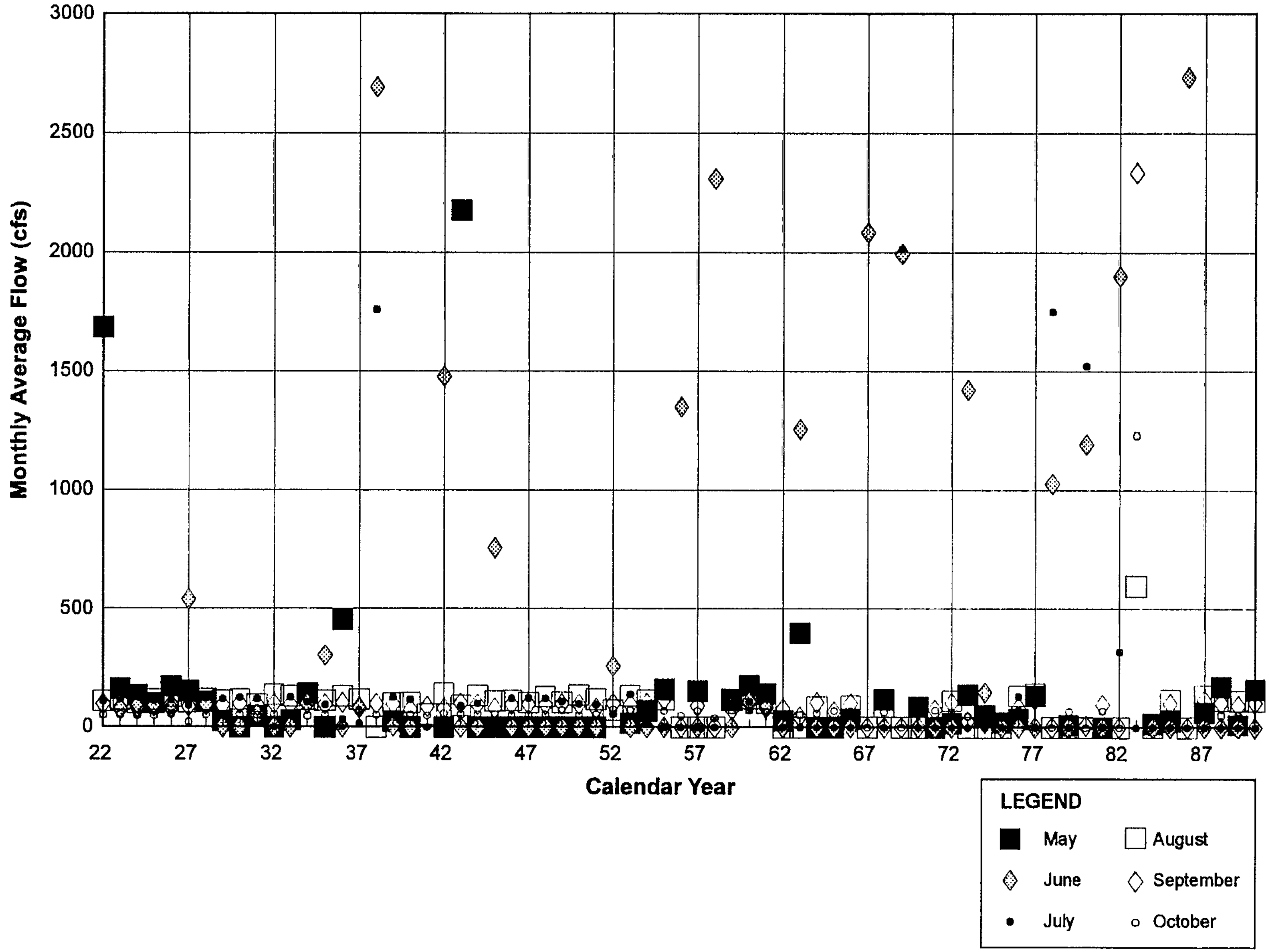

FIGURE III-34

RELEASE FLOWS FROM FRIANT DAM UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

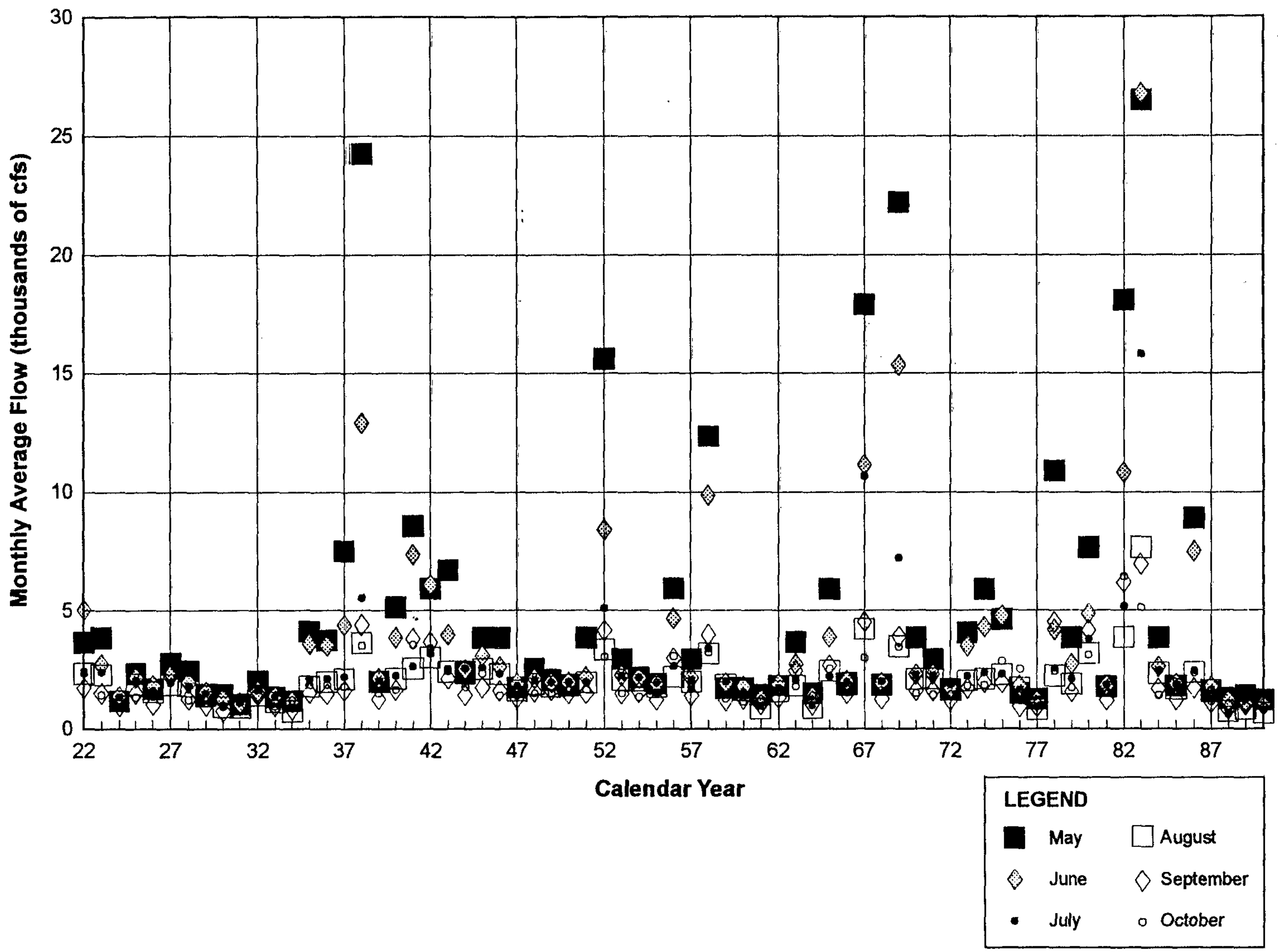

FIGURE III-35

FLOWS IN THE SAN JOAQUIN RIVER AT VERNALIS UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

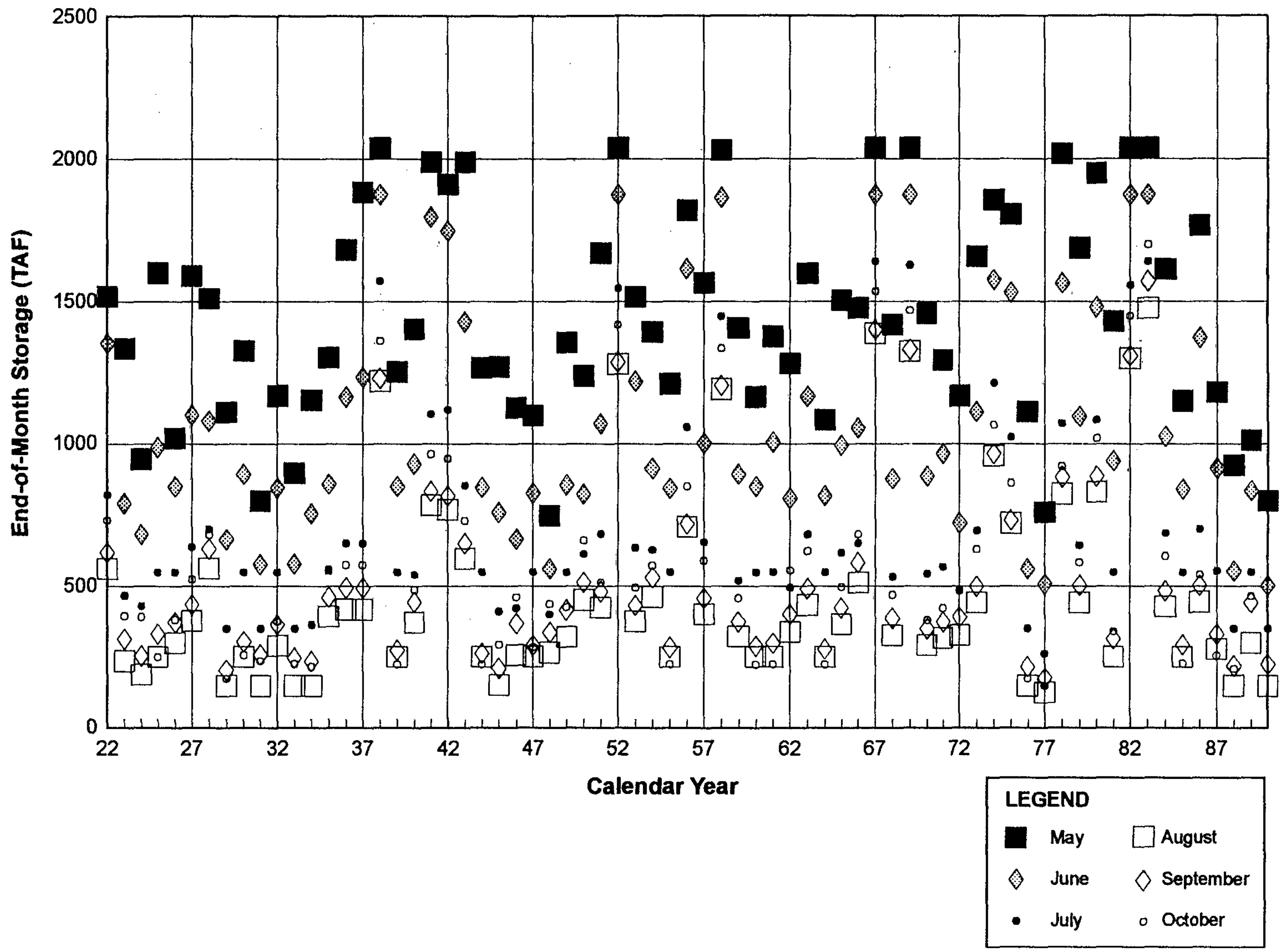

FIGURE III-36

STORAGE IN SAN LUIS RESERVOIR UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

spawning, rearing, and outmigration life stages of important fish species in the Delta. The simulated Delta habitat water quality conditions for the No-Action Alternative are described here. The fisheries assessment is based on habitat conditions in all months, including the November-January period for outmigration of juvenile spring-run chinook salmon.

Figure III-37 shows the simulated monthly (February through July) total Delta inflows. Approximately 20 percent of the years have at least one month (February, March, or April) of simulated inflow that is greater than 100,000 cfs. The majority of Delta inflows during controlled reservoir release periods are between approximately 20,000 cfs and 40,000 cfs.

Figure III-38 shows the simulated monthly (February through July) total Delta exports (combined SWP and CVP). The maximum simulated monthly exports occur in January and February because the permitted export capacity is simulated to be 12,700 cfs. The assumed monthly export capacity in March is approximately 12,000 cfs. The maximum permitted exports in other months are approximately 11,500 cfs. However, these maximum monthly exports are simulated only approximately half of the time because the exports are also limited by the Bay-Delta 1995 Water Quality Control Plan (1995 WQCP) objectives for the percentage of Delta inflow that can be exported.

Figure III-39 shows the simulated monthly (February through July) total Delta outflows. Minimum required Delta outflow (including X2 objectives) varies from approximately 5,000 cfs to 25,000 cfs, depending on water year and runoff conditions. Simulated Delta outflows in excess of these minimum requirements occur in one or more months of approximately half of the years. Simulated Delta outflow of greater than 50,000 cfs for at least one month between February and July occurs in almost half the years.

Figure III-40 shows the simulated monthly (February through July) total DCC and Georgiana Slough flows. The DCC is closed for monthly Sacramento River flows greater than 25,000 cfs and is always closed during February through late May for protection of outmigrating fish and striped bass larvae. The total simulated DCC and Georgiana Slough flow ranges from approximately 2,000 cfs to 10,000 cfs during February through July. This diversion flow is directly related to simulated Sacramento River flow at Freeport. However, closure of the DCC gates at high flows tends to moderate the fluctuations in the total diversion flow, with an average simulated diversion flow of approximately 5,000 cfs.

Figure III-41 shows the simulated monthly (February through July) QWEST flows, representing the net flows in the central Delta channels near the mouth of the Mokelumne River. Positive QWEST indicates that the sum of the Delta exports and channel depletion is less than the sum of the flows of the San Joaquin River, eastside streams, and the DCC and Georgiana Slough. A negative QWEST indicates that some water from Threemile Slough or from the lower San Joaquin River is needed to supply the Delta exports and channel depletion. Closure of the DCC or increasing exports will decrease the simulated QWEST flow.

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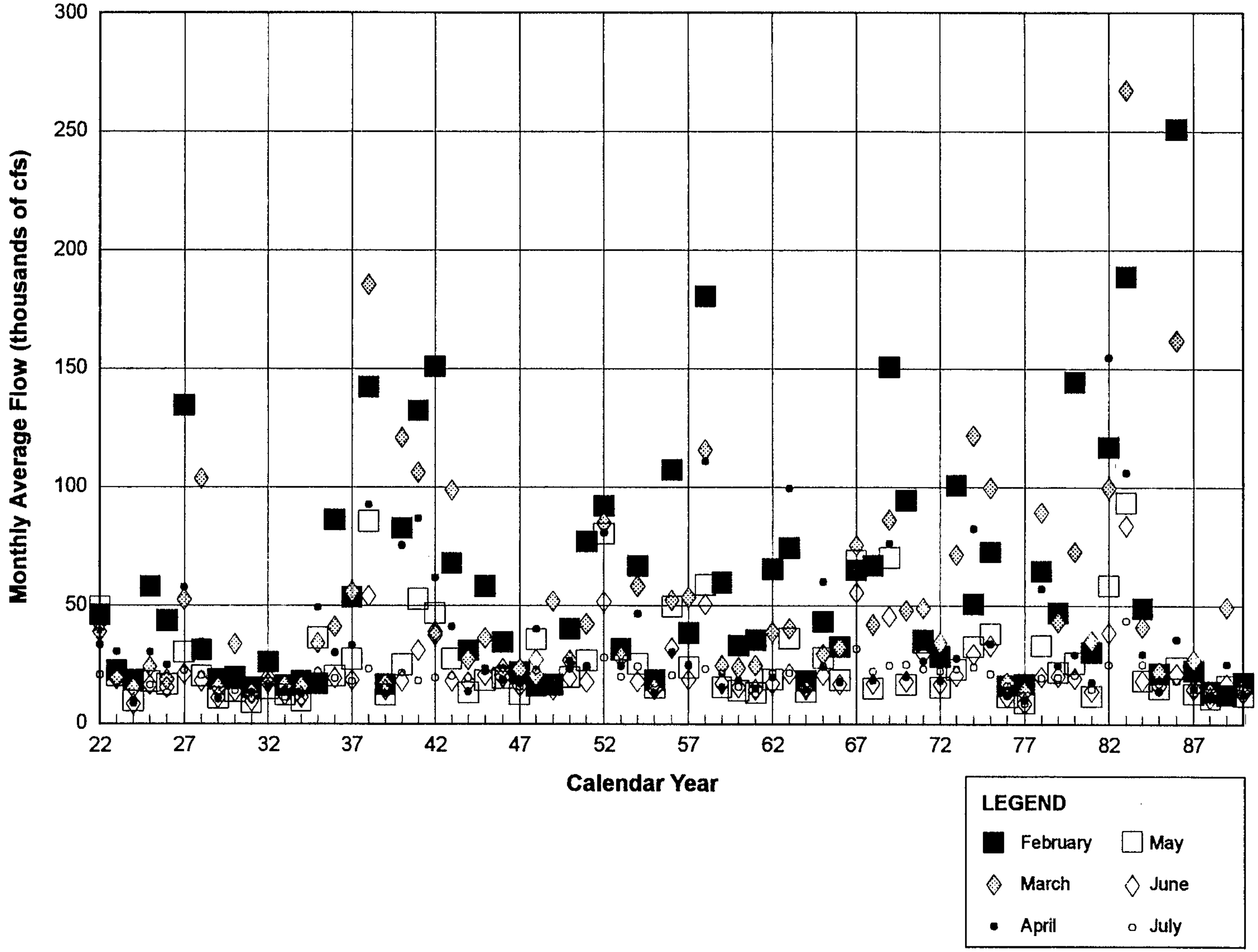


FIGURE III-37

TOTAL DELTA INFLOW UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

C-082040

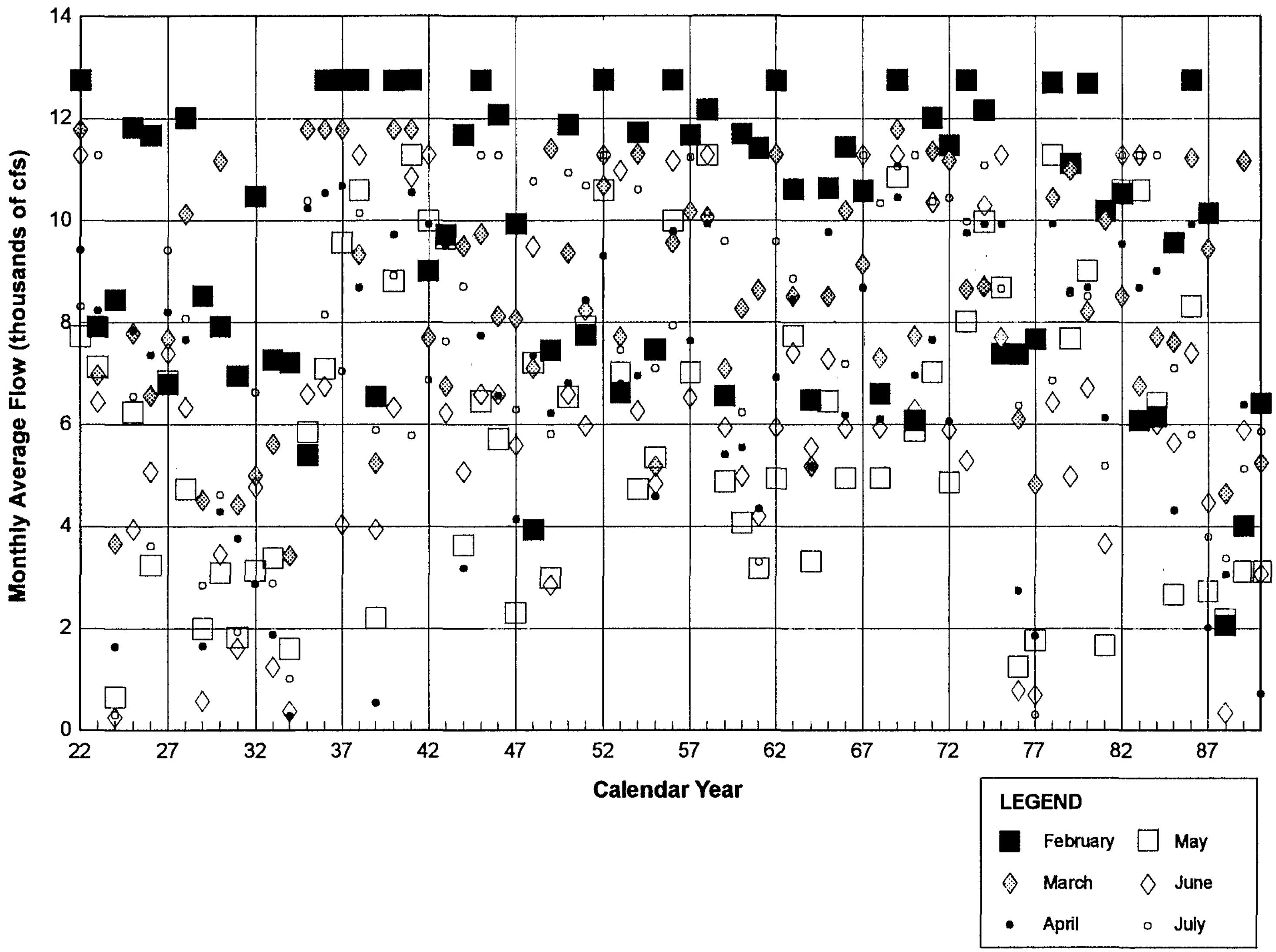


FIGURE III-38

TOTAL CVP AND SWP DELTA EXPORTS UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

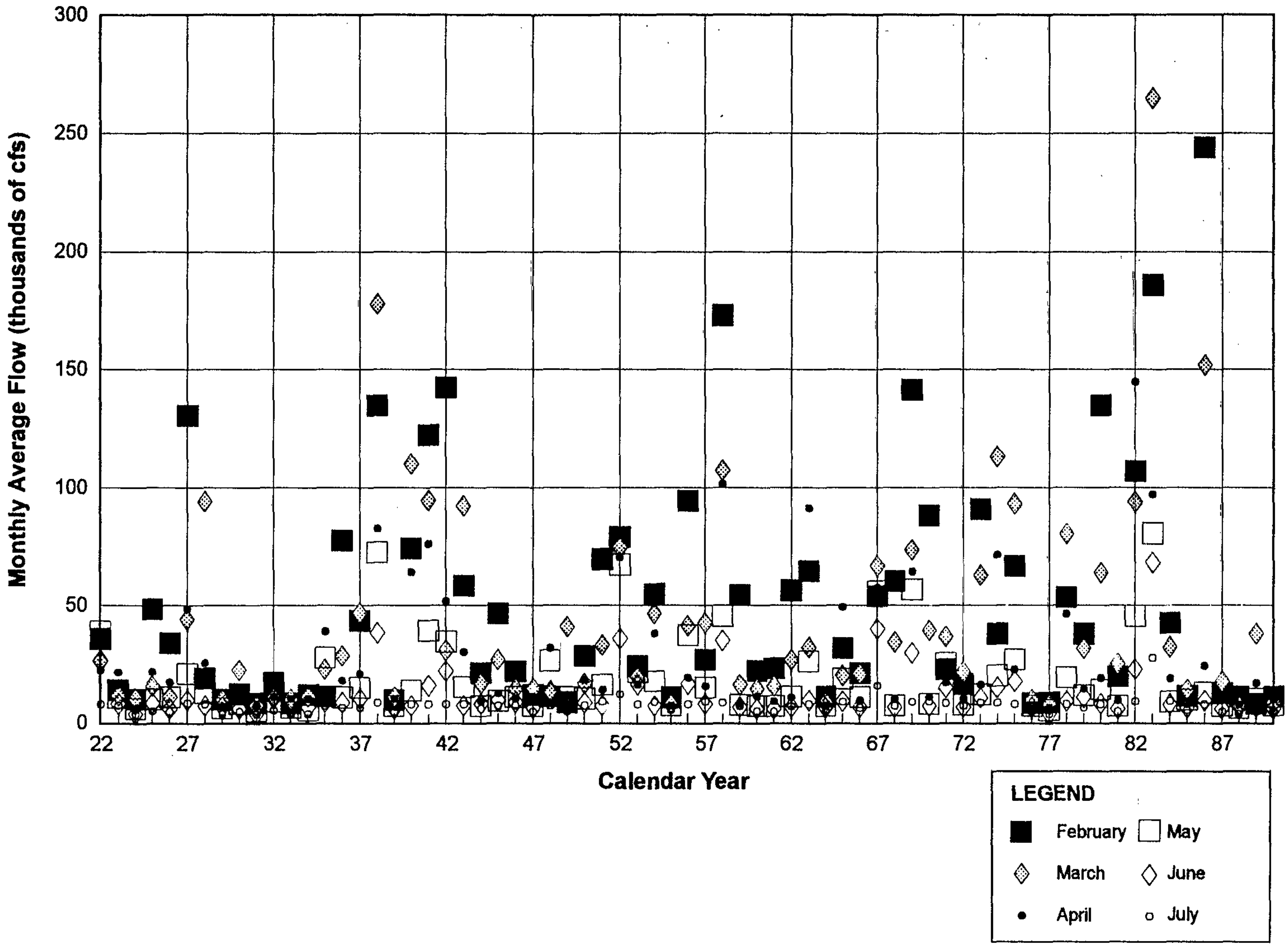


FIGURE III-39

DELTA OUTFLOW UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

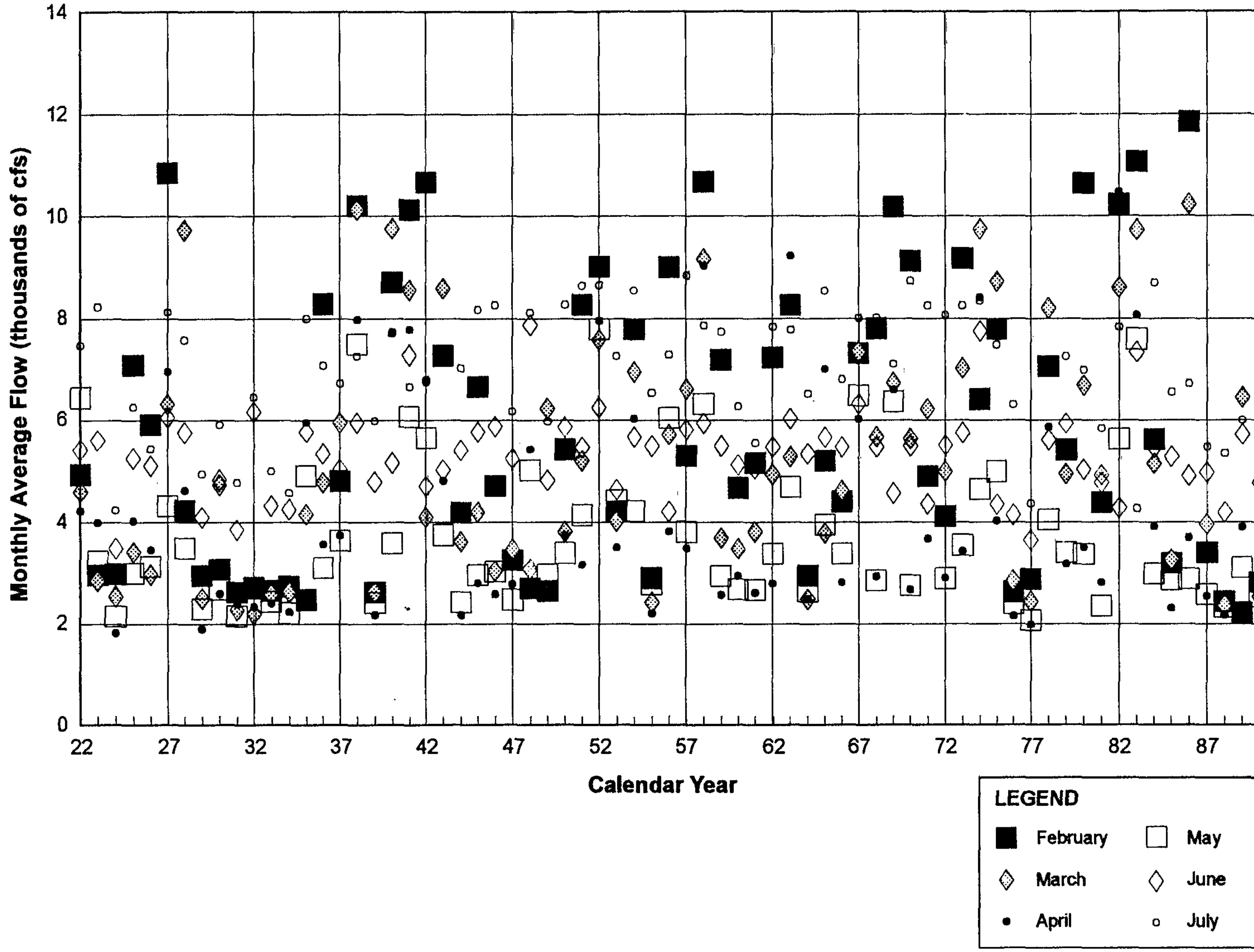


FIGURE III-40

SUM OF FLOWS AT THE DELTA CROSS CHANNEL AND GEORGIANA SLOUGH UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

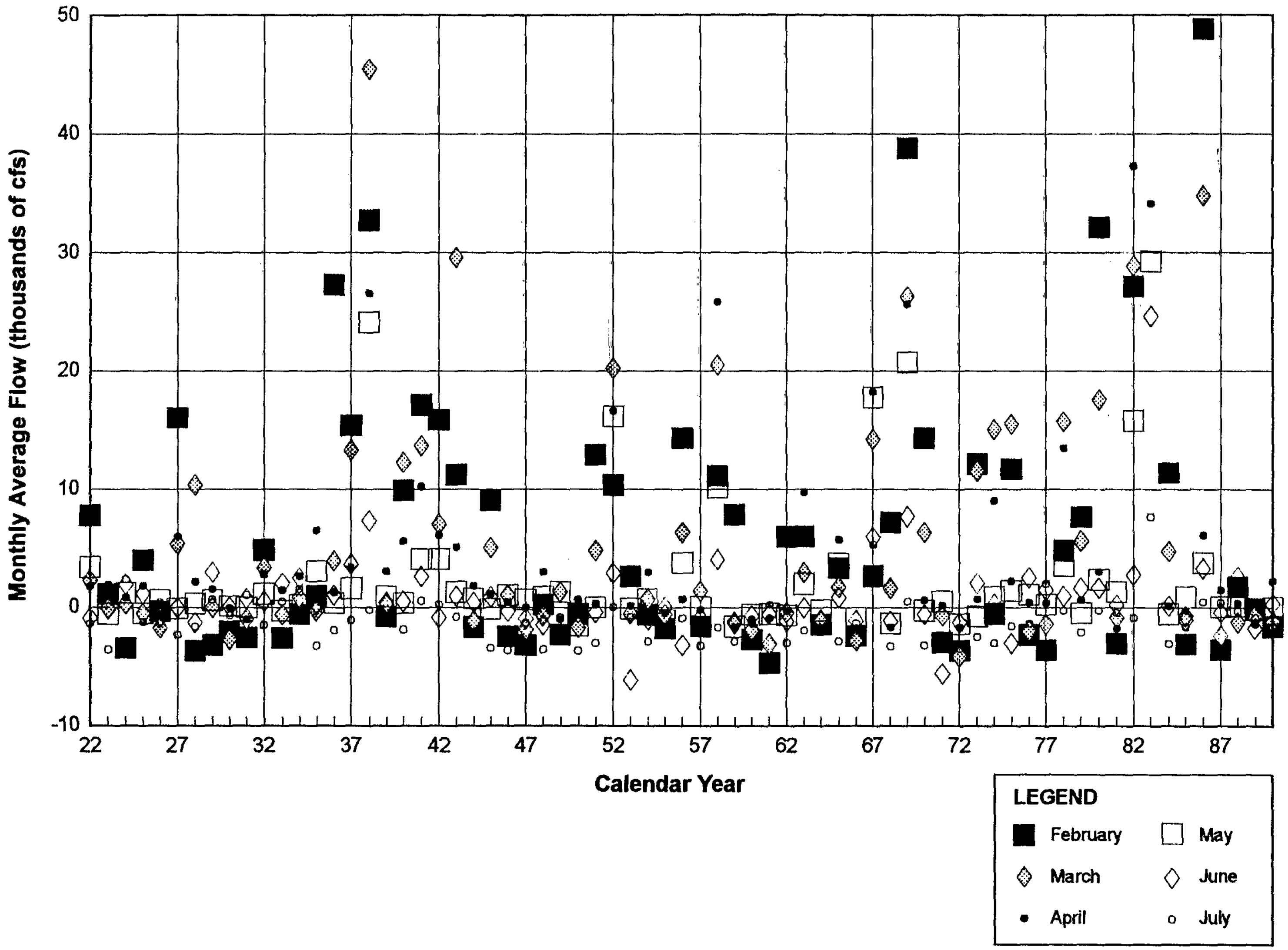


FIGURE III-41

QWEST FLOWS UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

C-082044

Figure III-42 shows the simulated monthly (February through July) ratio of total Delta exports (SWP and CVP) to total Delta inflow. The 1995 WQCP objectives for the percentage of Delta inflow that can be exported in February depend on January runoff (e.g., 35 percent if January runoff is greater than 1.5 million af, 45 percent if January runoff is less than 1.0 million af). The 1995 WQCP objectives for the export-to-inflow ratio are 35 percent from March to June and 65 percent in July through January. The simulated export-to-inflow ratio is lowest during periods of high inflow, when the maximum export capacity is a relatively small percentage of total inflow. The simulated export-to-inflow ratio in February is greater than 35 percent in approximately 25 percent of the years. The majority of the export-to-inflow ratios for March through June are less than 35 percent because the inflows are greater than required for maximum export capacity. However, the July export-to-inflow ratio is always less than the WQCP objective of 65 percent because the combination of channel depletions and required Delta outflow is greater than 35 percent of the inflows. Therefore, the Delta outflow objectives limit the percentage of inflows that can be exported at less than 65 percent in July. This situation may also occur for some of the other months during periods of relatively low inflow.

Figure III-43 shows the simulated monthly (February through July) percent entrainment for water from the Sacramento River Delta volume segment. As described in the Fish Habitat Water Quality Methodology/Modeling Technical Appendix, water (and vulnerable life stages of fish) moves from the Sacramento River Delta segment (e.g., near Rio Vista) through Threemile slough and then upstream into the central and south Delta segments to be entrained in channel diversions or Delta exports. Simulated percent entrainment for February, March, and April are the lowest, ranging from zero to approximately 20 percent. Simulated percent entrainment for the spring months is higher, ranging from approximately 5 percent to 25 percent in May, 20 percent to 30 percent in June, and 30 percent to 40 percent in July.

Figure III-44 shows the simulated monthly (February through July) percent entrainment for water from the San Joaquin River Delta volume segment. Water (and vulnerable life stages of fish) moves from the San Joaquin River Delta segment (e.g., between Antioch and the mouth of the Mokelumne River) upstream into the central and south Delta segments to be entrained in channel diversions or Delta exports. Simulated percent entrainment for March and April is the lowest, ranging from zero to approximately 30 percent. Simulated February percent entrainment is sometimes higher, approaching 40 percent in approximately 25 percent of the years. Simulated percent entrainment for the spring months is higher, ranging from approximately 20 percent to 30 percent in May, 30 percent to 40 percent in June, and 40 percent to 60 percent in July. The July entrainment indices are highest because the allowable export-to-inflow ratio is 65 percent.

Figure III-45 shows the simulated monthly (February through July) percent entrainment for water from the central Delta volume segment. Water is entrained in agricultural diversions and south Delta exports. Simulated percent entrainment is much higher than for the Sacramento River or San Joaquin River Delta volume segments because the net movement of water from this volume is often upstream toward the exports. The simulated percent entrainment depends on the ratio of exports to QWEST flow, as described in the Fish Habitat Methodology/Modeling Technical Appendix. The simulated percent entrainment is often between 50 percent and 90 percent.

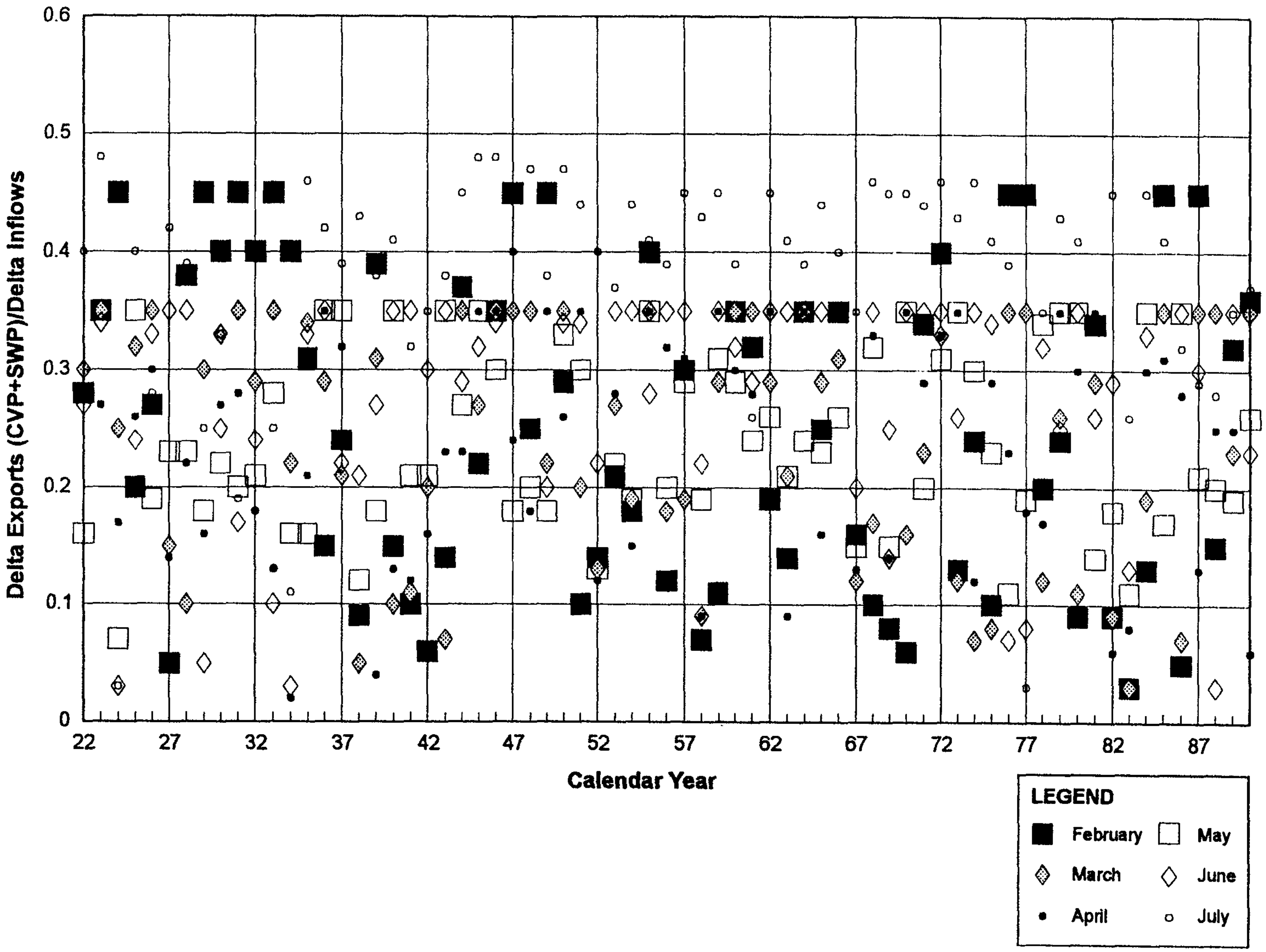


FIGURE III-42

RATIO OF DELTA EXPORTS TO DELTA INFLOWS UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

C—082046

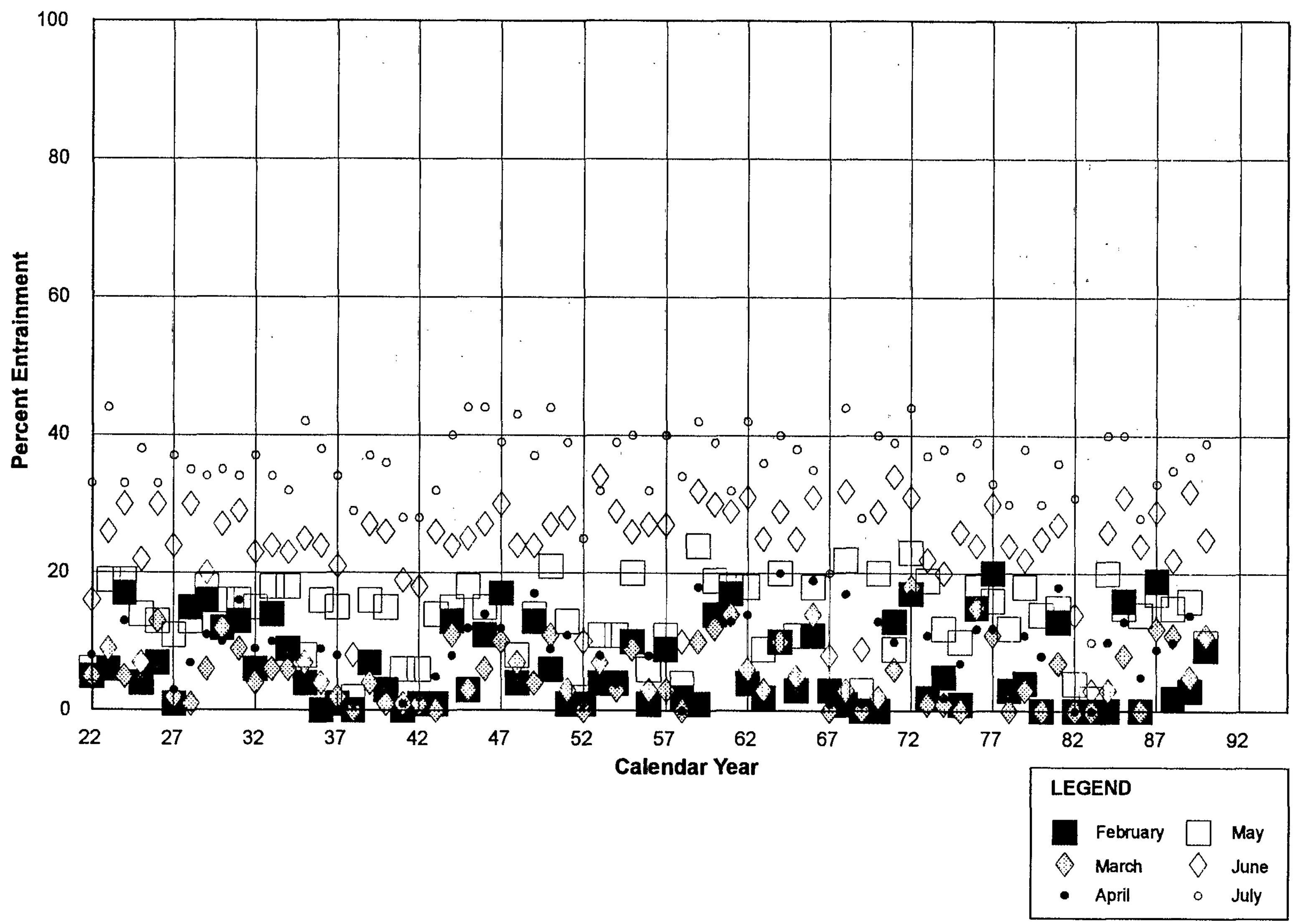


FIGURE III-43

ENTRAINMENT OF WATER FROM THE SACRAMENTO RIVER DELTA VOLUME UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

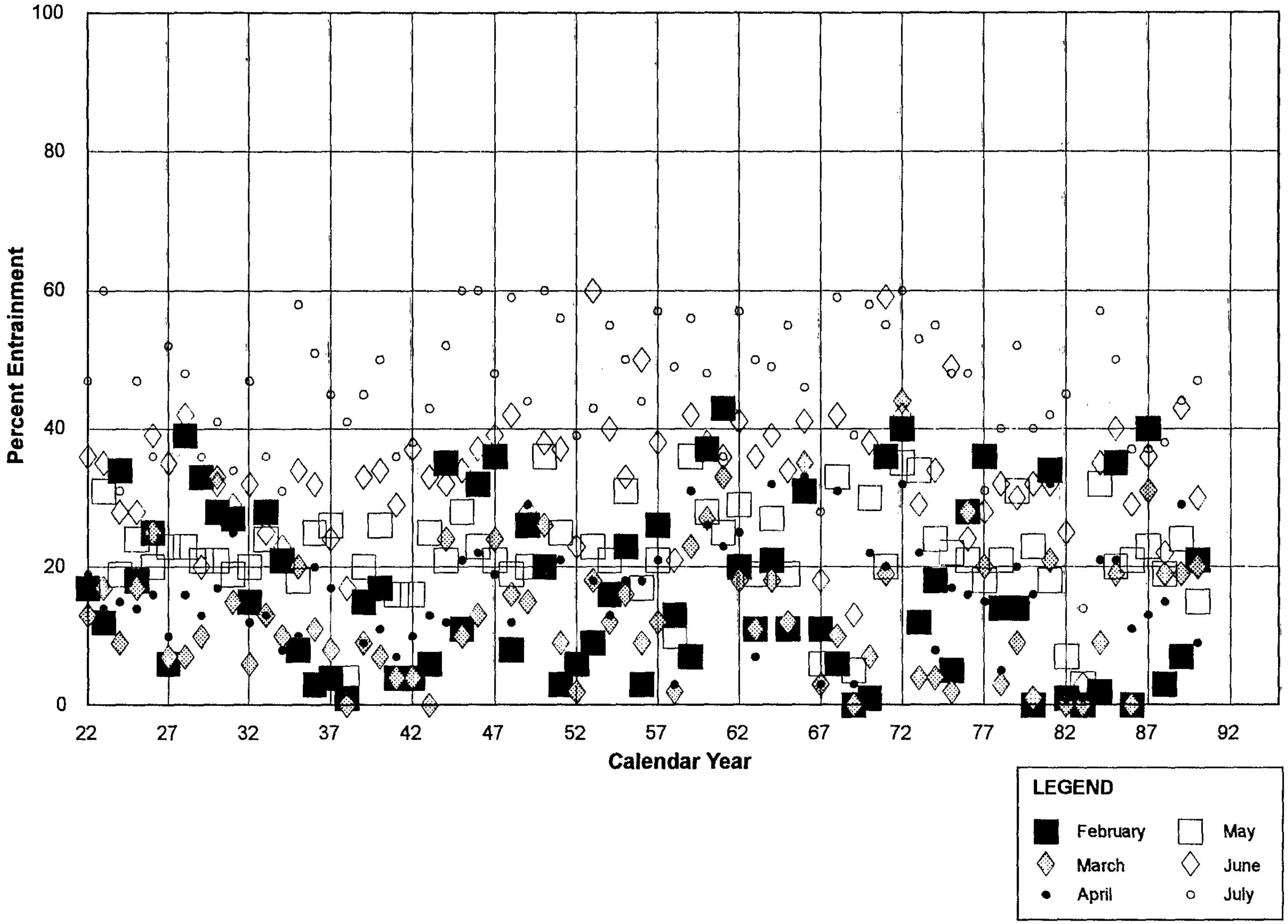
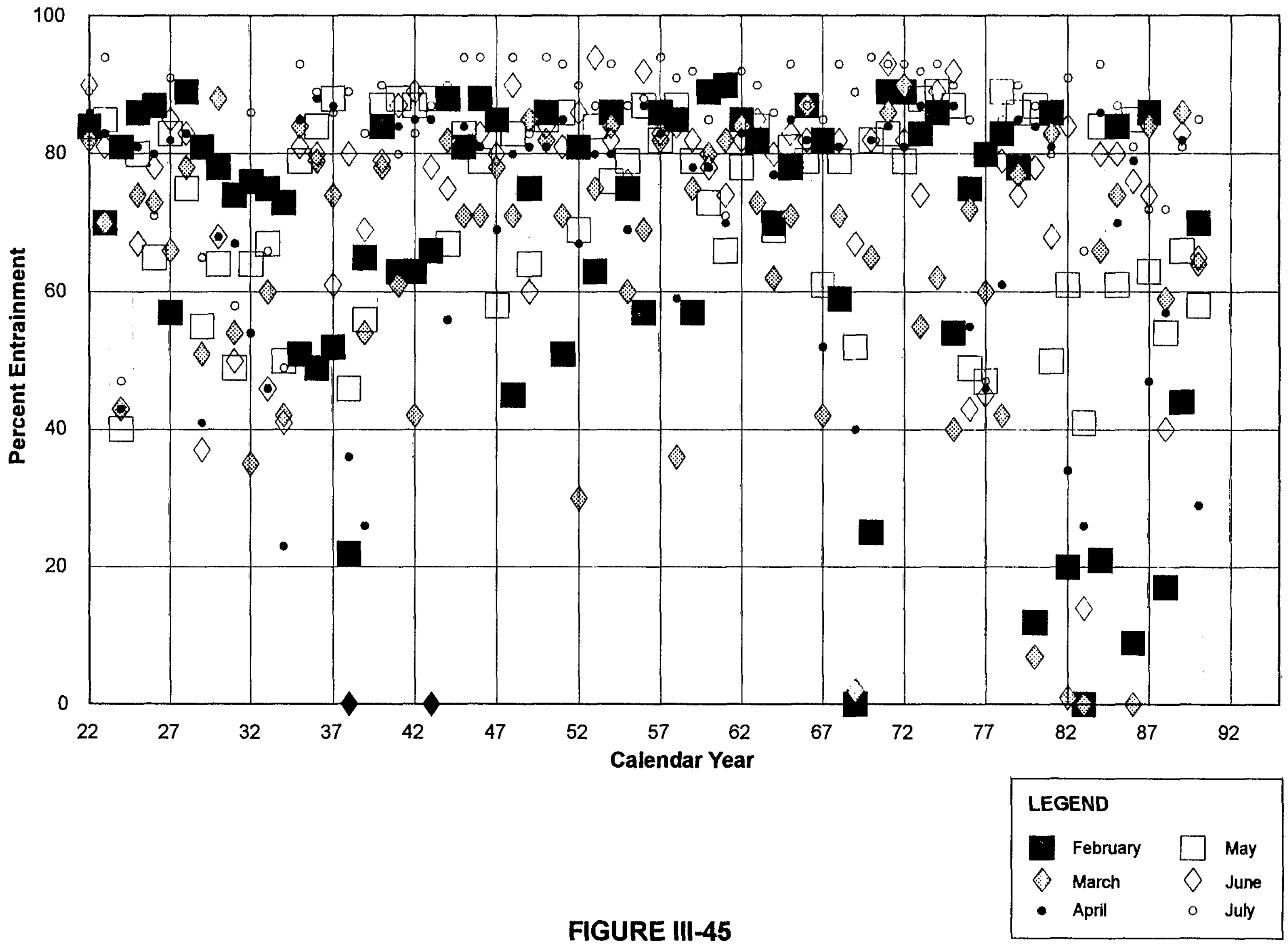


FIGURE III-44

ENTRAINMENT OF WATER FROM THE SAN JOAQUIN RIVER DELTA VOLUME UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990



C-082049

FIGURE III-45

ENTRAINMENT OF WATER FROM THE CENTRAL DELTA VOLUME UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

Figure III-46 shows the simulated monthly (February through July) salinity (EC) at Jersey Point. Jersey Point is on the San Joaquin River and is one of the 1995 WQCP compliance locations for salinity objectives to protect agricultural diversions in the central Delta. The simulated EC of the Sacramento River inflow is about 0.2 mS/cm. Jersey Point EC values remain relatively low (less than 0.5 mS/cm) during the winter months (February through April) because Delta outflow remains greater than about 10,000 cfs. However, simulated Jersey Point EC values are often greater than 0.5 mS/cm in the spring months (May through July). In some years with low Delta outflow, the simulated June and July EC values are greater than 1.0 mS/cm.

Figure III-47 shows the simulated monthly (February through July) salinity (EC) at Collinsville. Collinsville is the upstream station for control of the X2 location in the 1995 WQCP objectives (February through June). An EC value of approximately 3 mS/cm corresponds to the 2-ppt salinity objective. Delta outflows of more than 7,000 cfs are required to move X2 downstream of Collinsville. The simulated EC values at Collinsville are always less than 3 mS/cm in February, March, and April. Simulated EC at Collinsville is greater in May, June, and July because outflow requirements are lower, with EC values ranging between approximately 1 mS/cm and approximately 3 mS/cm. June and July EC values exceed 3 mS/cm in approximately 20 percent of the years.

Figure III-48 shows the simulated monthly (February through July) salinity (EC) at Chipps Island. Chipps Island is the middle station for control of the X2 location in the 1995 WQCP objectives (February through June). Delta outflows of more than 12,000 cfs are required to move X2 downstream of Chipps Island. The simulated EC values at Chipps Island are almost always less than 3 mS/cm in February, March, and April (approximately 10 percent of these months have EC values greater than 3 mS/cm). Simulated EC at Chipps Island is greater in May, June, and July because outflow requirements are lower, with EC values ranging between approximately 1 mS/cm and approximately 5 mS/cm. June and July EC values exceed 5 mS/cm in approximately 20 percent of the years.

Figure III-49 shows the simulated monthly (February through July) salinity (EC) at Port Chicago (across from Roe Island). Port Chicago is the downstream station for control of the X2 location in the 1995 WQCP objectives (February through June). Delta outflows of more than 30,000 cfs are required to move X2 downstream of Port Chicago (i.e., 65 km). The simulated EC values at Port Chicago are often greater than 3 mS/cm in February, March, and April (approximately 50 percent of these months have EC values greater than 3 mS/cm). Simulated EC at Port Chicago is greater in May, June, and July because outflow requirements are lower, with EC values ranging between approximately 1 mS/cm and 15 mS/cm in May, between approximately 5 mS/cm and 15 mS/cm in June, and between approximately 10 mS/cm and 20 mS/cm in July.

Figure III-50 shows the simulated monthly (February through July) salinity (EC) at Benicia. Benicia is located at the downstream end of Suisun Bay and therefore characterizes the highest salinity conditions within Suisun Bay. Simulated EC at Benicia is often higher than the 15-mS/cm value that is considered the downstream extent of the entrapment zone. Delta

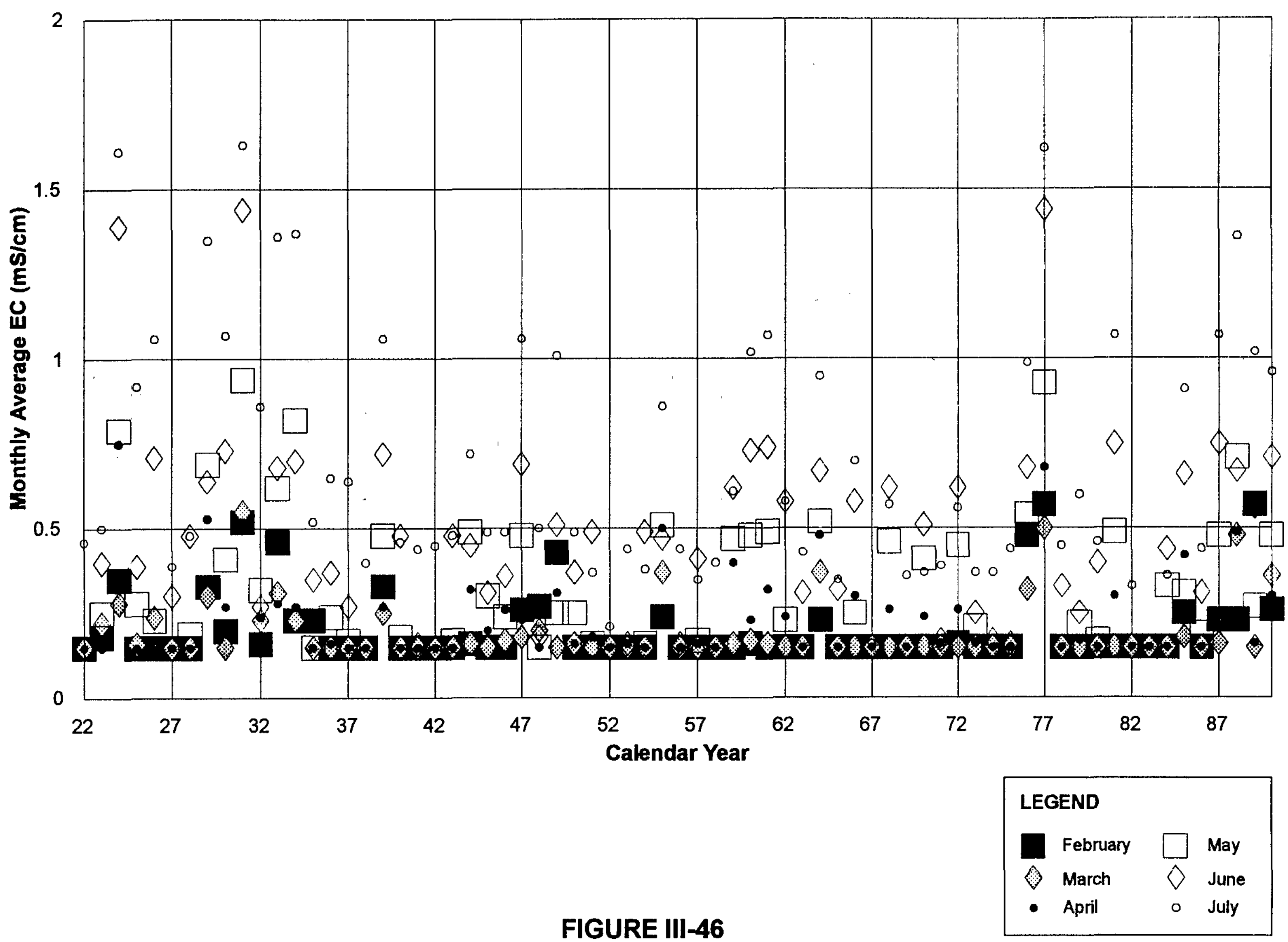


FIGURE III-46

ELECTRICAL CONDUCTIVITY AT JERSEY POINT UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

C—082051

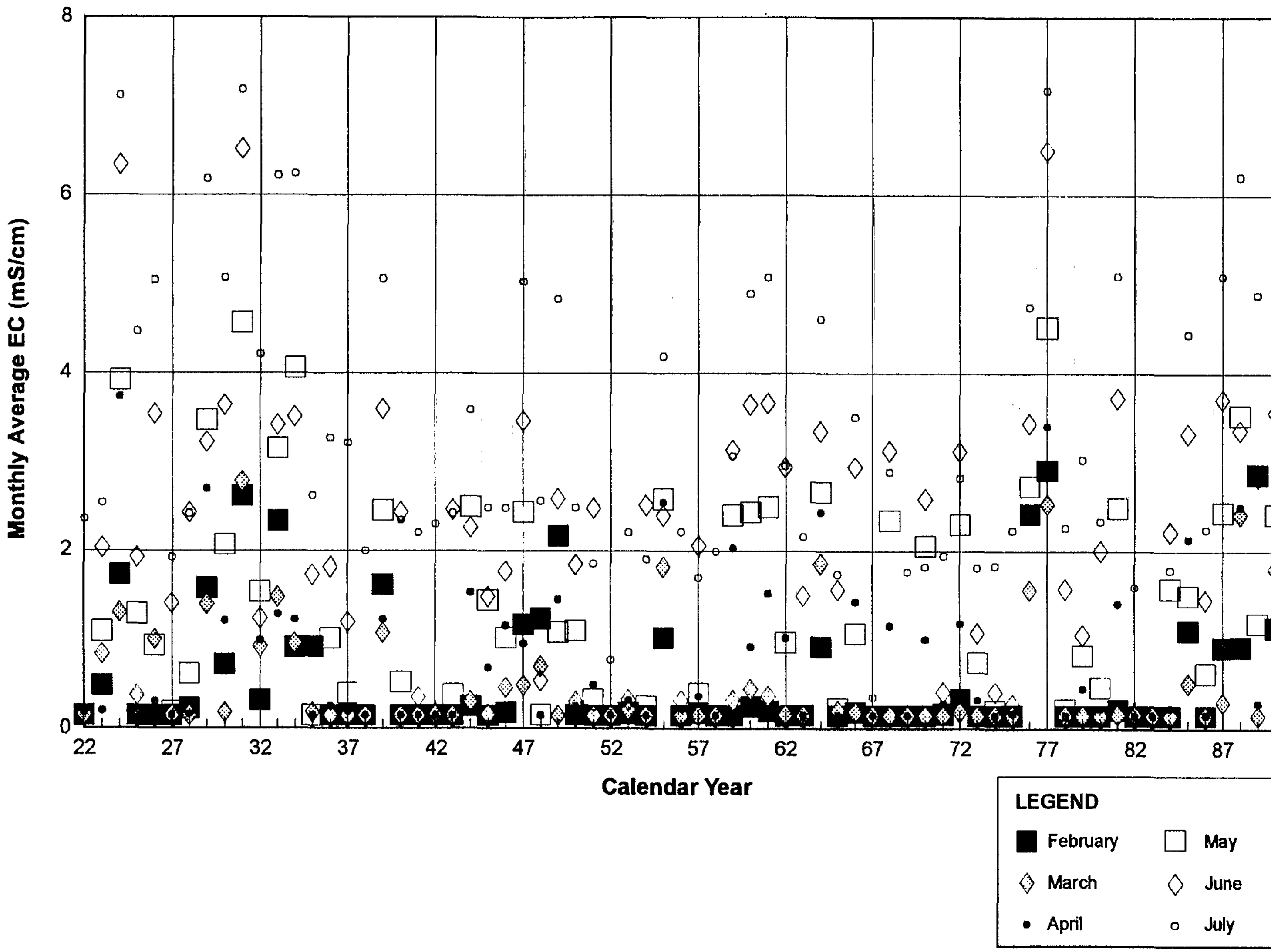


FIGURE III-47

ELECTRICAL CONDUCTIVITY AT COLLINSVILLE UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

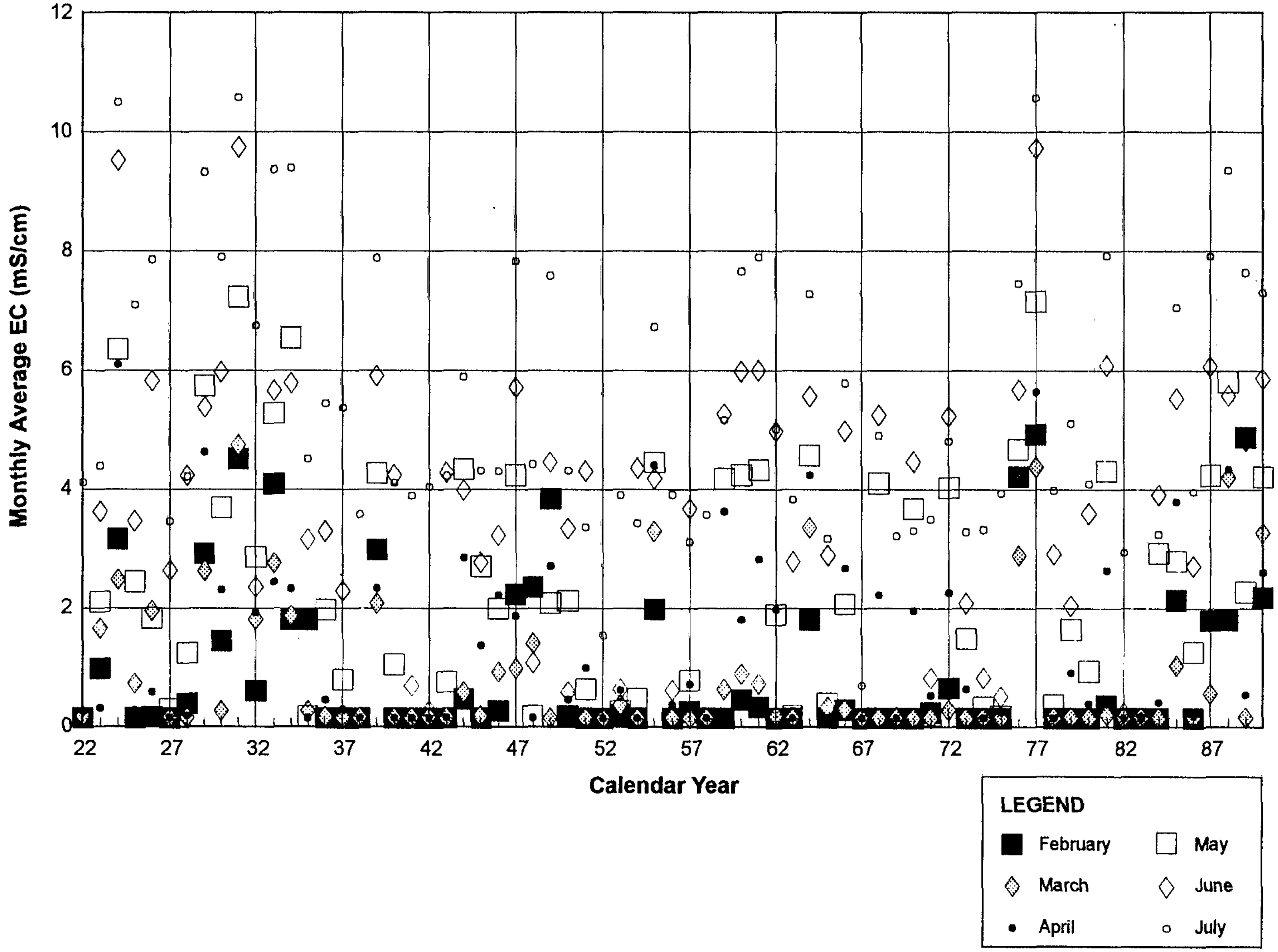


FIGURE III-48

ELECTRICAL CONDUCTIVITY AT CHIPPS ISLAND UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

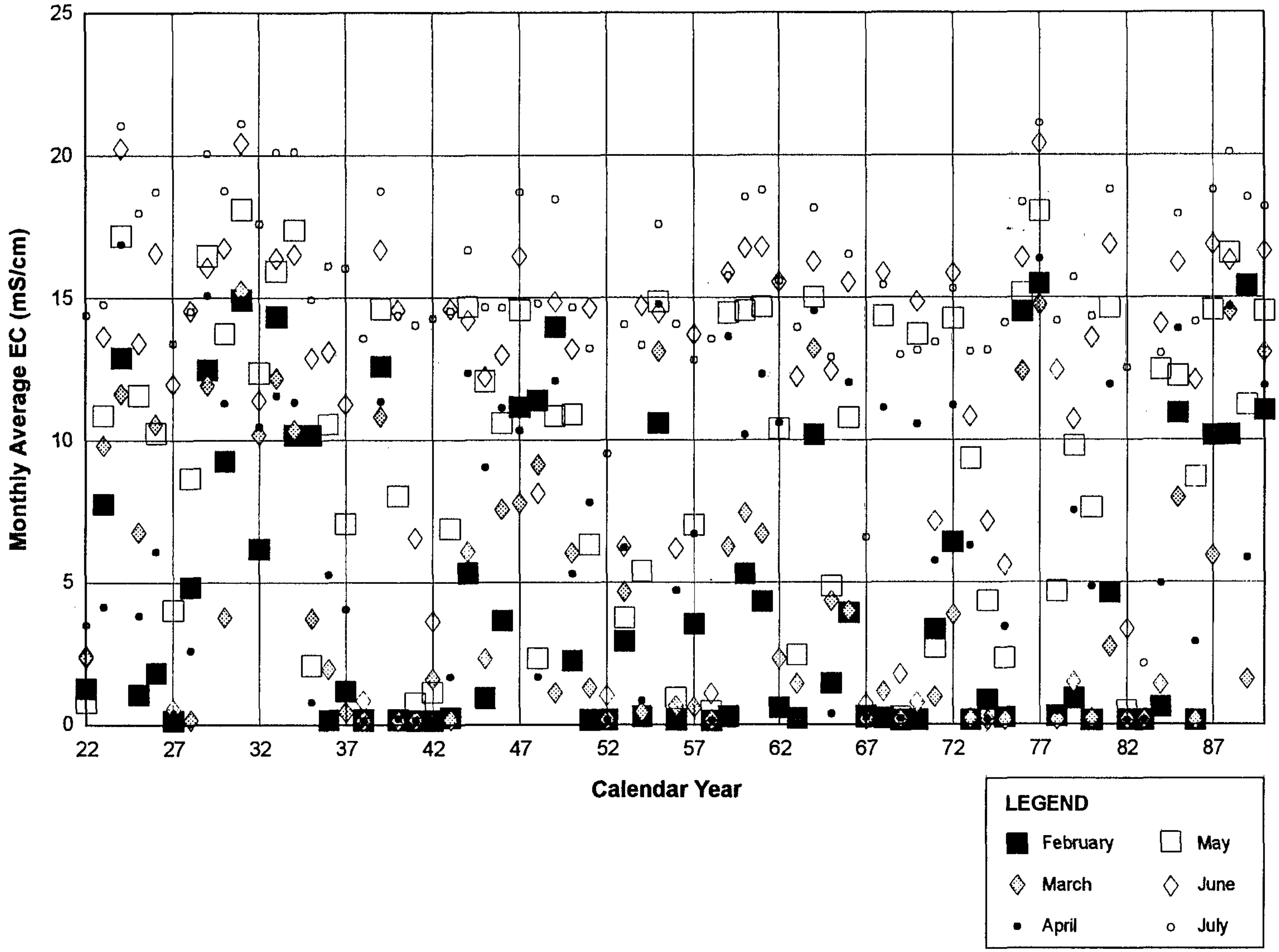


FIGURE III-49

ELECTRICAL CONDUCTIVITY AT PORT CHICAGO UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

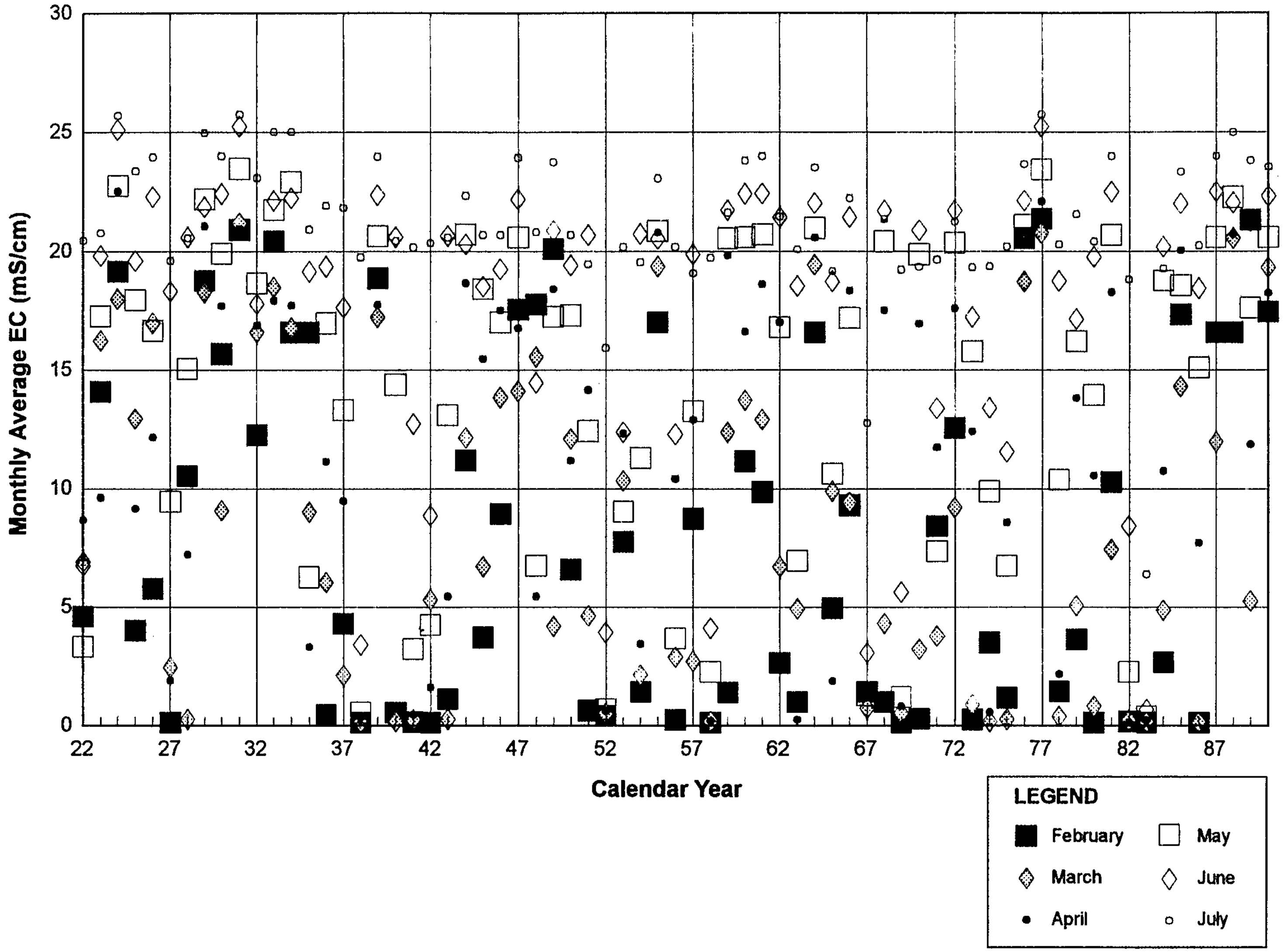


FIGURE III-50

ELECTRICAL CONDUCTIVITY AT BENICIA UNDER THE CVPIA PEIS NO-ACTION ALTERNATIVE, 1922-1990

outflows of more than 60,000 cfs are required to move X2 downstream of Benicia (i.e., 56 km). Simulated EC values in June and July range from approximately 20 mS/cm to 25 mS/cm, with some lower values in wet years.

SUMMARY OF ALTERNATIVES ANALYSIS

Alternatives 1 through 4 were simulated with the PROSIM and SANJASM operations models, reservoir and river temperature models, and Delta salinity and entrainment models. The results from the monthly simulations of reservoirs and downstream flow conditions, including Delta exports and outflow, are compared with the simulations for the No-Action Alternative. The results of these comparative reservoir simulations can be characterized using the values for end-of-September carryover reservoir storage (to reflect the cumulative effects of increased releases for instream flows).

For each alternative, monthly average simulated flow values for the 1922-1990 period (e.g., January 1922-January 1990) are compared with the average monthly flows for the No-Action Alternative. September river temperatures downstream of the major reservoirs (i.e., Sacramento, Feather, American, and Stanislaus rivers) are used to compare simulated temperature conditions. Monthly salinity at four Suisun Bay locations (Collinsville, Chipps Island, Port Chicago, and Benicia) are used to compare simulated salinity conditions for the four alternatives. Monthly entrainment calculations for water originating in the Sacramento River, San Joaquin River, and central Delta volume segments of the Delta are used to compare general entrainment conditions during the months of January through June. The evaluation of environmental impacts associated with these changes in reservoir operations that are caused by different instream flow requirements and diversion and export demands under the four alternatives are described in the technical appendices for other resource topics (e.g., fisheries, recreation, and vegetation and wildlife).

SACRAMENTO RIVER REGION

Upper Sacramento River Flows, Temperatures, and Reservoir Storage

Figure III-51 shows simulated end-of-September carryover storage volume for Clair Engle Lake under Alternatives 1 through 4 compared with the simulated carryover storage volume under the No-Action Alternative for 1922-1990. The simulated carryover storage is slightly less for each of the alternatives compared with the carryover storage under the No-Action Alternative in almost every year. The simulated values are nearly identical under Alternatives 1 through 4 because the same increased Trinity River flows were simulated for each alternative.

Figure III-52 shows simulated average monthly releases from Lewiston Lake to the Trinity River under Alternatives 1 through 4 compared with the simulated flows under the No-Action Alternative. The instream flow requirements are increased from the No-Action Alternative conditions and simulated as identical under Alternatives 1 through 4. The Trinity River flows are dependent on water-year type (Trinity River inflow), but only the average monthly flows are

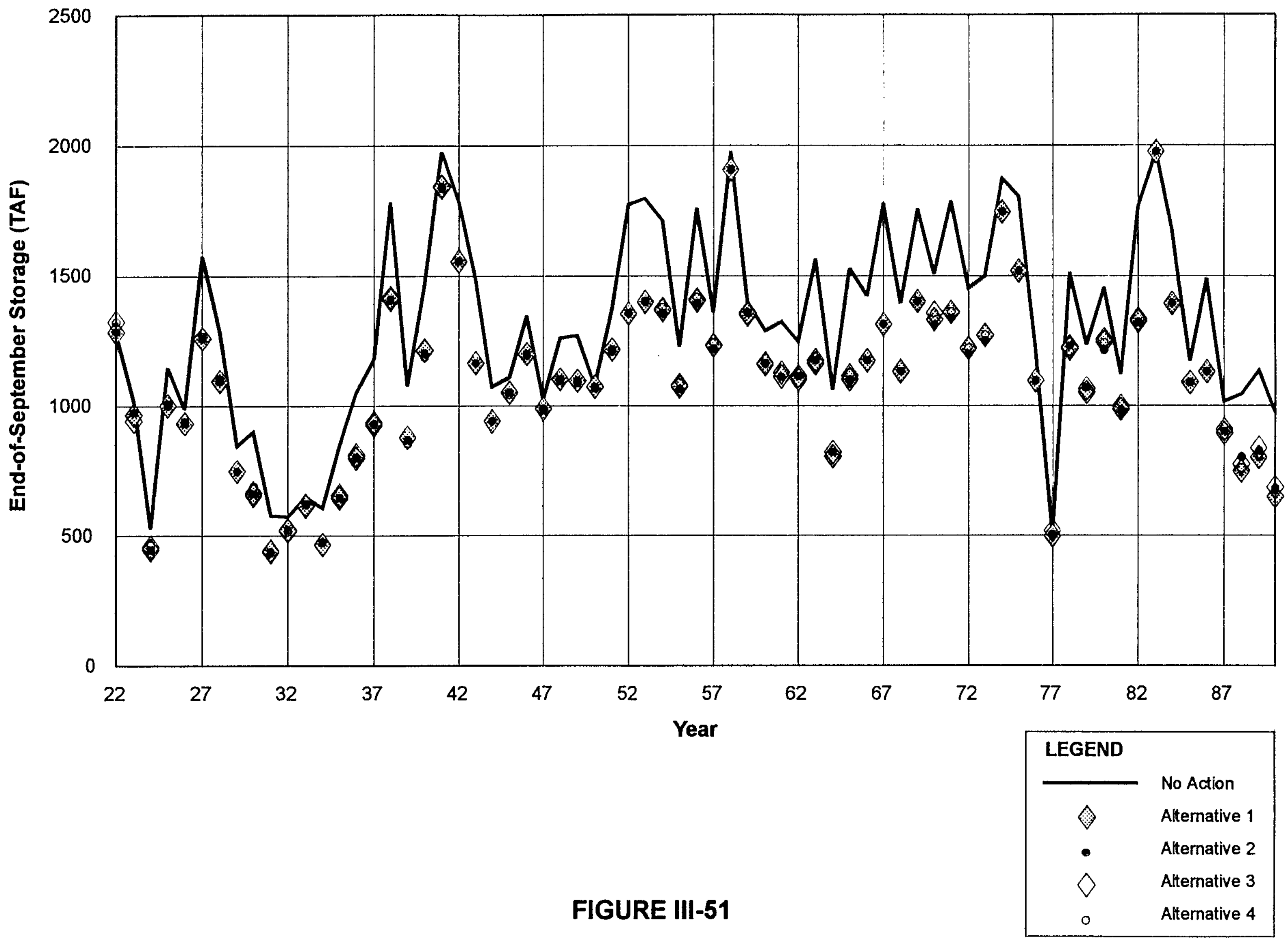


FIGURE III-51

END-OF-SEPTEMBER STORAGE IN CLAIR ENGLE LAKE UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

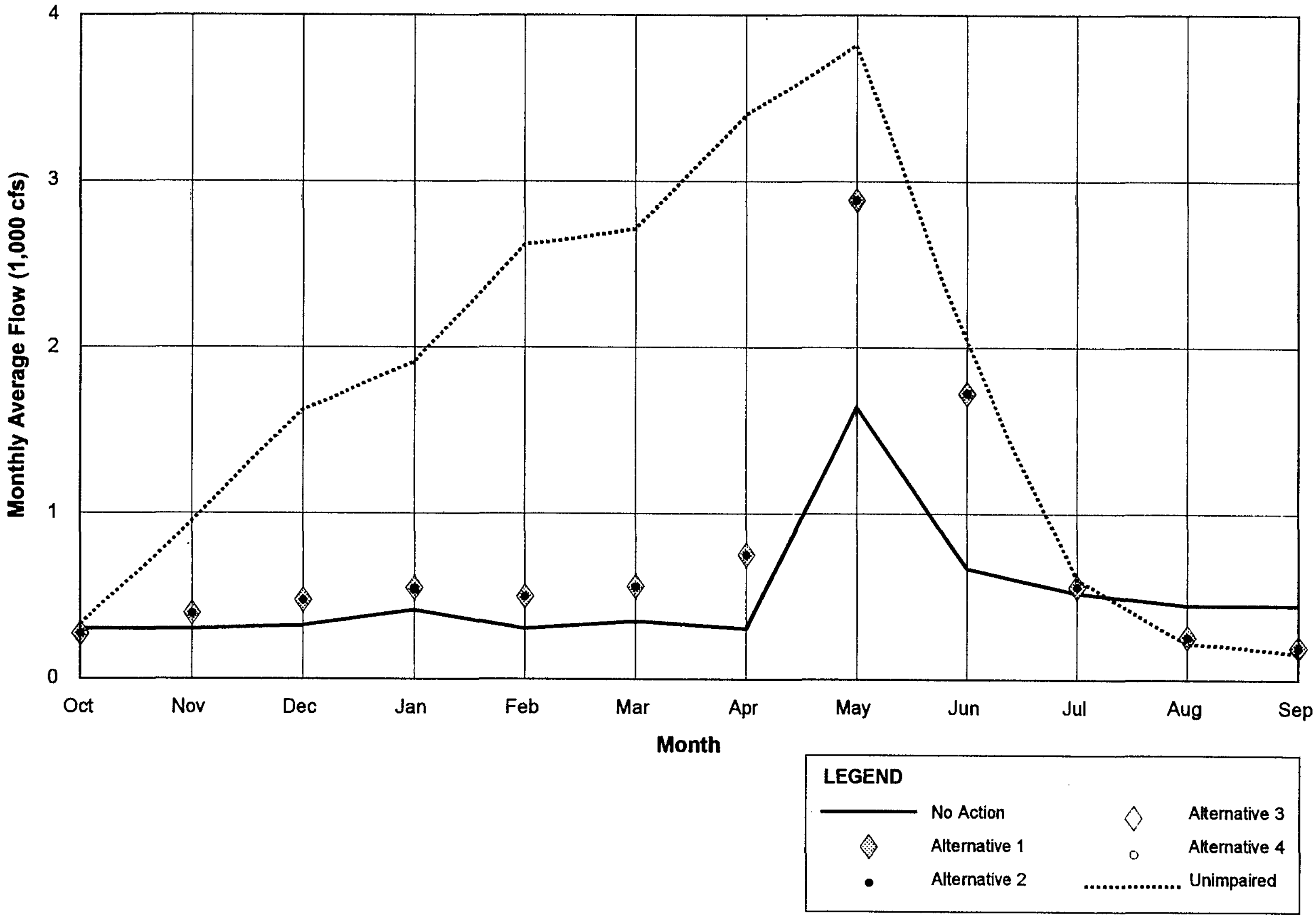


FIGURE III-52

MONTHLY AVERAGE FLOWS IN THE TRINITY RIVER BELOW LEWISTON DAM UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

shown here. Average monthly releases to the Trinity River increased from November through June, with largest increases in May and June to improve salmon and steelhead outmigration conditions. Trinity River releases are slightly reduced in August and September. The average monthly unimpaired (natural) Trinity River flows are shown for comparison; the simulated instream flows closely follow the natural river flows for the months of May through October.

Figure III-53 shows simulated monthly average diversions from Whiskeytown Lake to the Spring Creek power plant and Keswick Reservoir under Alternatives 1 through 4 compared with the simulated flows under the No-Action Alternative. Most of this flow originates from the Trinity River. The simulated No-Action Alternative diversions from the Trinity River are greatest during the summer months (April through July), when hydropower benefits and downstream diversions are greatest. Simulated diversions for Alternatives 1 through 4 follow the same seasonal pattern but are reduced by an average of 250 cfs. The monthly simulated Trinity River diversions vary from year to year because they are dependent on Clair Engle Lake storage (relative to Shasta Lake storage) and incorporate temperature objectives for the Sacramento River below Keswick.

Figure III-54 shows simulated end-of-September carryover storage volume for Shasta Lake under Alternatives 1 through 4 compared with the simulated carryover storage volume under the No-Action Alternative for 1922-1990. The simulated carryover storage is substantially less under each of the alternatives compared with the carryover storage under the No-Action Alternative in approximately 15 percent of the years because of limited water supply conditions.

The simulated carryover storage volumes are nearly identical under Alternatives 1 through 4 because the same changes in instream flows below Keswick Reservoir and reductions in Trinity River diversions are simulated.

Figure III-55 shows simulated monthly release flows from Keswick Reservoir under Alternatives 1 through 4 compared with the simulated flows under the No-Action Alternative. Instream flow requirements below Keswick Reservoir are changed (increased) under Alternatives 1 through 4 and are simulated to depend on Shasta Lake storage. Because Keswick Reservoir releases are made to supply downstream diversions as well as Delta export and Delta outflow requirements, the increased instream flow requirements at Keswick Reservoir simulated under Alternatives 1 through 4 do not often require additional releases. The simulated monthly Keswick Reservoir releases are reduced slightly (i.e., average reduction of approximately 500 cfs to 1,000 cfs) in April through July because of lower exports from the Trinity River.
The unimpaired (natural) flows at Keswick Reservoir are shown for comparison; the effects of Shasta Lake storage and releases to satisfy summer downstream demands are evident.

Figure III-56 shows the simulated September temperatures for releases from Keswick Reservoir under Alternatives 1 through 4 compared with the simulated temperatures under the No-Action Alternative for 1922-1990. Simulated September temperatures under Alternatives 1 through 4 are nearly identical to the simulated temperatures under the No-Action Alternative. A few differences between alternatives are the result of slightly different simulated Shasta Lake carryover storage volumes (lower carryover results in higher temperatures). The slightly

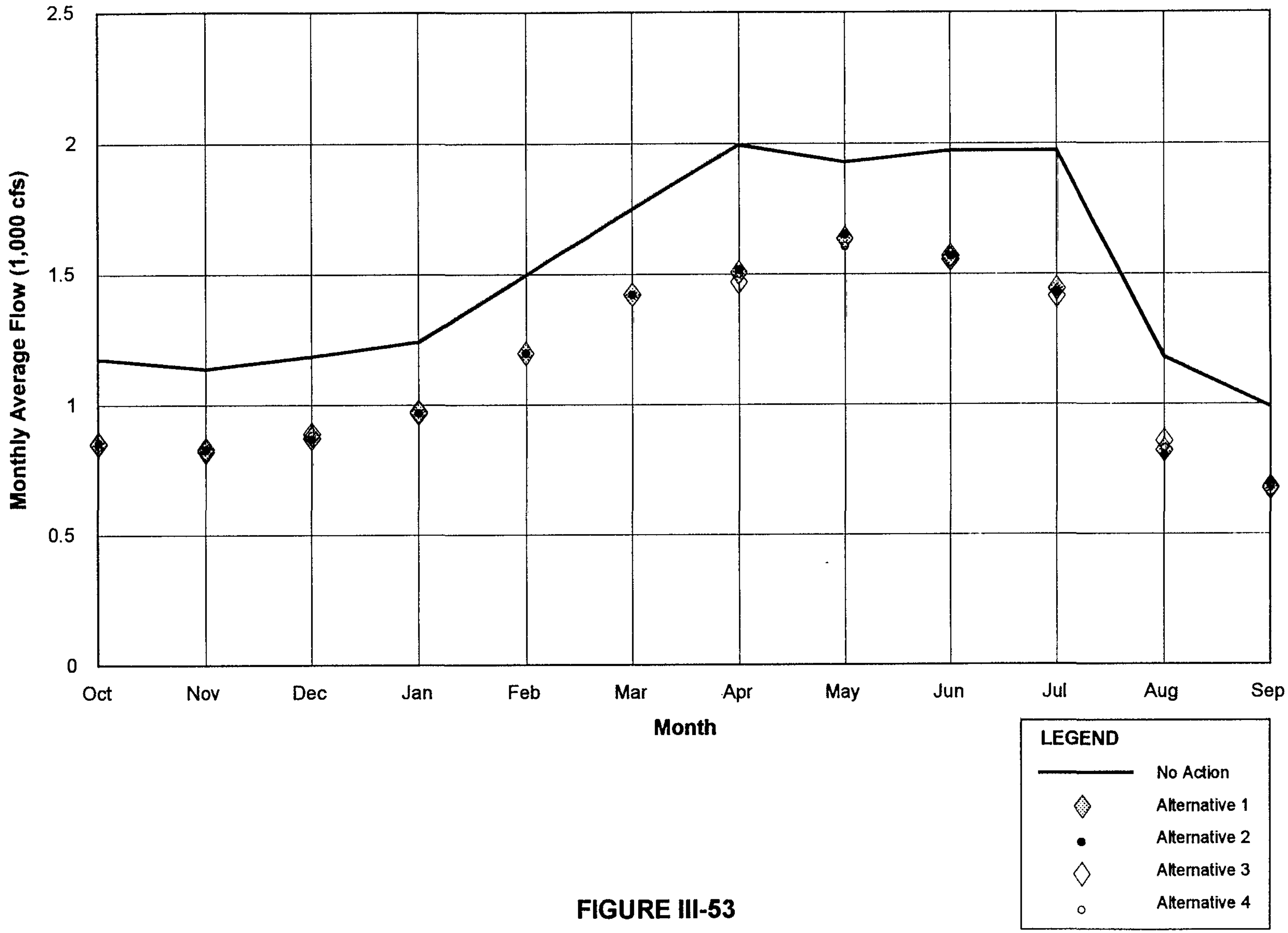


FIGURE III-53

MONTHLY AVERAGE FLOWS AT THE SPRING CREEK POWER PLANT UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

C—082060

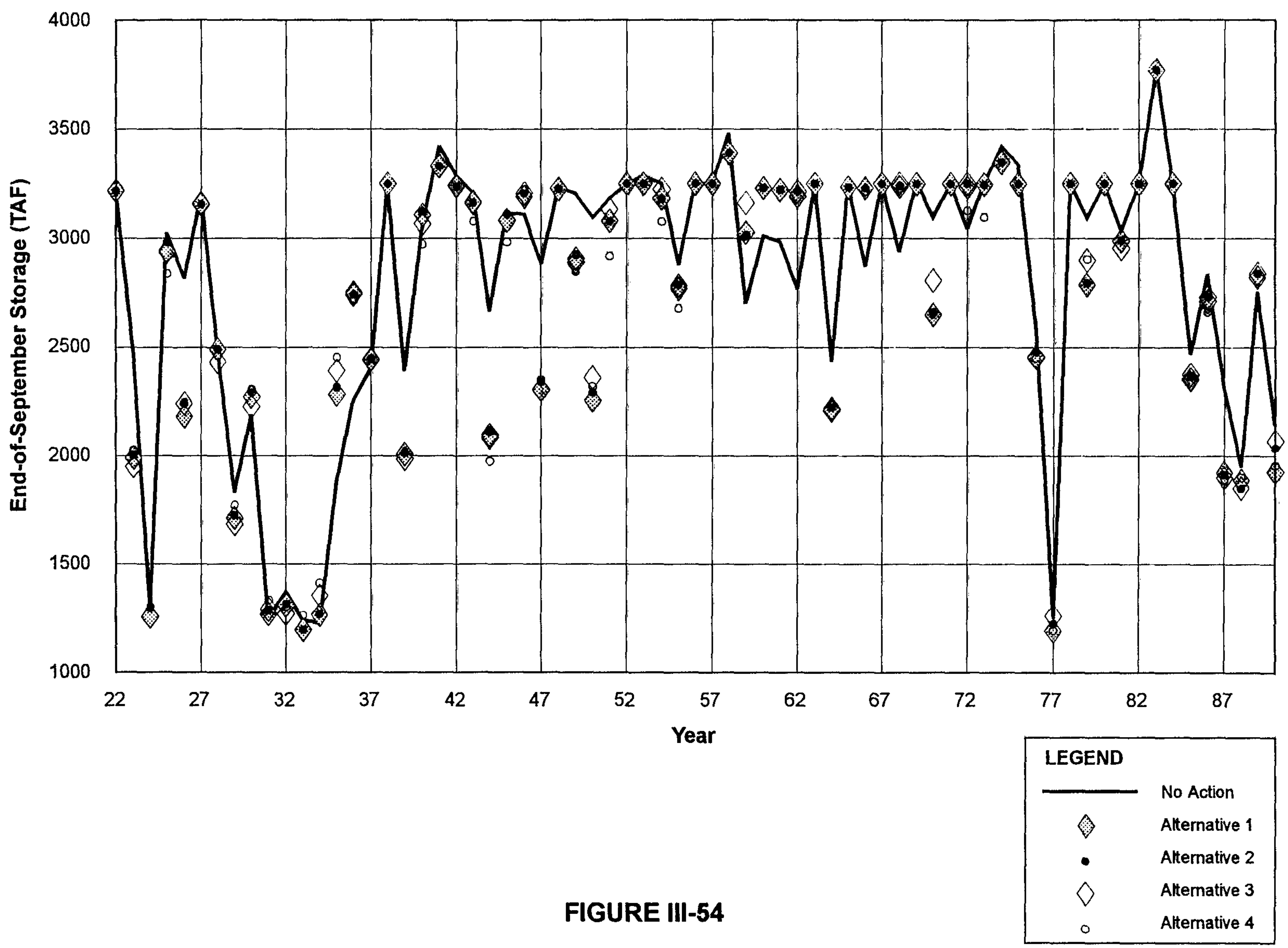


FIGURE III-54

END-OF-SEPTEMBER STORAGE IN SHASTA LAKE UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

C—082061

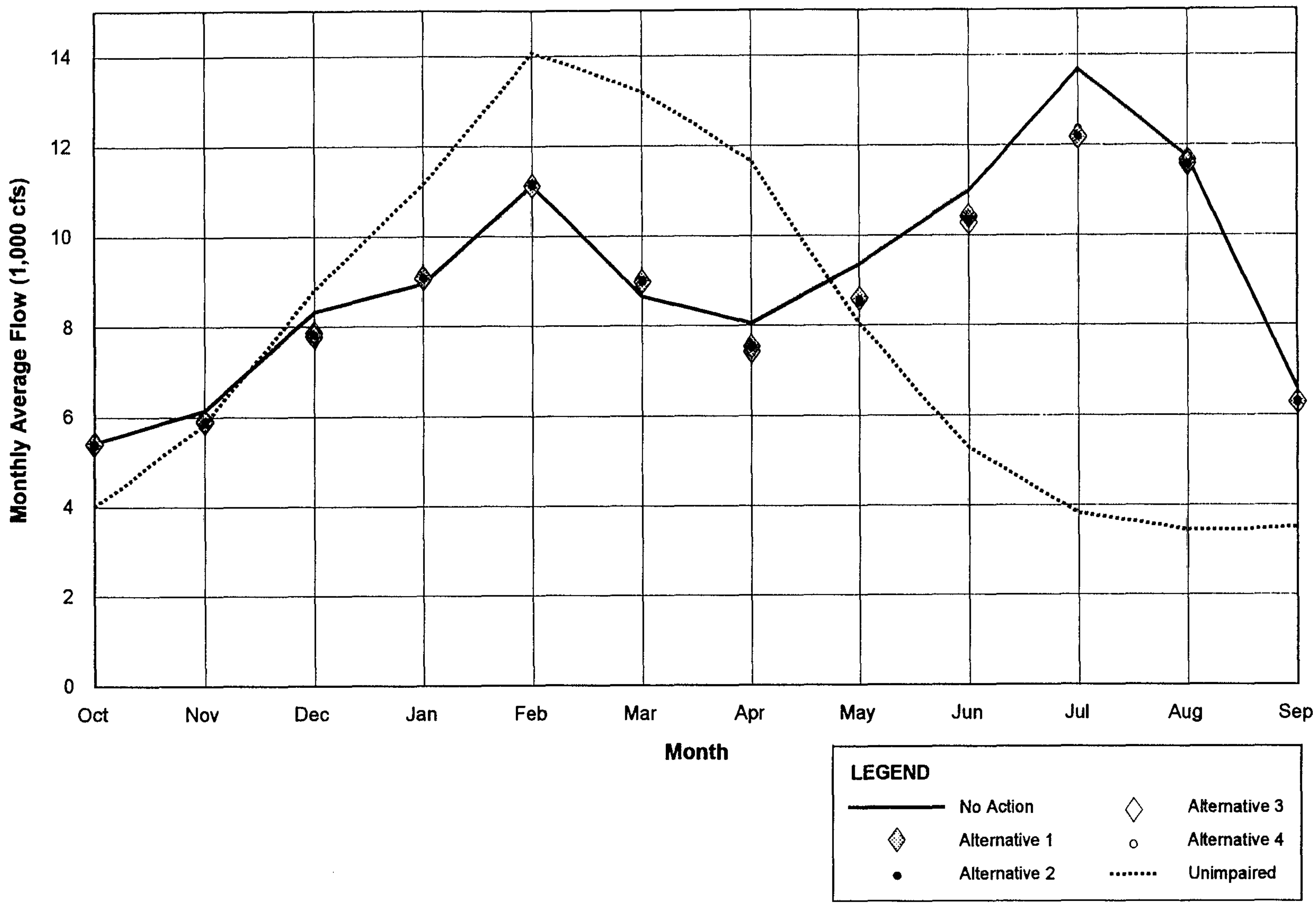


FIGURE III-55

MONTHLY AVERAGE FLOWS IN THE SACRAMENTO RIVER BELOW KESWICK RESERVOIR UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

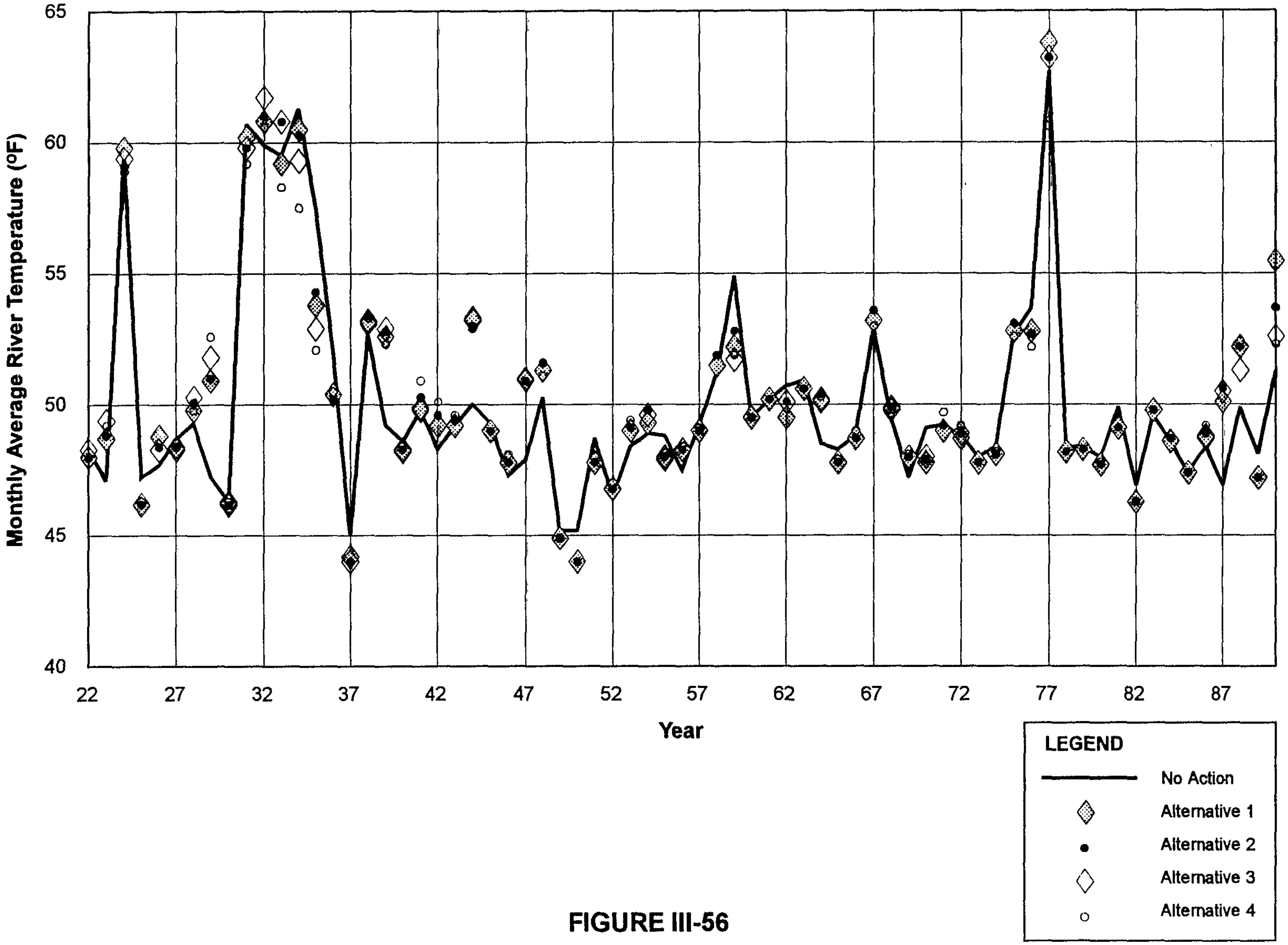


FIGURE III-56

AVERAGE SEPTEMBER TEMPERATURES IN THE SACRAMENTO RIVER BELOW KESWICK RESERVOIR UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

increased simulated Lewiston Lake temperatures caused by lower summer (July through September) releases from Clair Engle Lake do not increase the simulated Keswick Reservoir release temperatures because Shasta Lake releases dominate the July through September release flows from Keswick Reservoir.

Clear Creek Flows and Temperatures

Figure III-57 shows the simulated September temperatures for Whiskeytown Lake releases (from the low-level outlet) to Clear Creek under Alternatives 1 through 4 compared with the simulated temperatures under the No-Action Alternative for 1922-1990. Simulated September temperatures under each of the alternatives are nearly identical. The simulated September temperatures under Alternatives 1 through 4 are increased from the No-Action Alternative temperature in most years by approximately 5°F because of increased Trinity River diversion temperatures and the higher release flows to Clear Creek, which cause more withdrawal from the middle (warmer) lake levels in Whiskeytown Lake. The simulated Clear Creek release temperatures in September (i.e., 50-55°F) under each alternative are approximately 5°F lower than the simulated Lewiston Lake temperatures (i.e., 55-60°F) because the cold-water reserve in Whiskeytown Lake moderates the releases from the low-level outlet.

Feather River Flows, Temperatures, and Reservoir Storage

Figure III-58 shows simulated end-of-September carryover storage volume for Lake Oroville under Alternatives 1 through 4 compared with the simulated No-Action carryover storage volume for 1922-1990. The simulated carryover storage is slightly less under Alternatives 1 through 4 compared with the carryover storage under the No-Action Alternative in approximately 15 percent of the years but is slightly higher in a few years. The slight differences in simulated carryover storage volume under Alternatives 1 through 4 are caused by changes in releases from Lake Oroville that are necessary to satisfy Delta outflow and COA requirements.

Figure III-59 shows simulated monthly Oroville Dam releases under Alternatives 1 through 4 compared with the simulated flows under the No-Action Alternative. The instream flow requirements for the Feather River are not changed from the No-Action Alternative conditions under Alternatives 1 through 4. Simulated monthly flows under Alternatives 1 through 4 are slightly increased from No-Action Alternative flows in July, August, and September. The unimpaired flows indicate the effects of Lake Oroville storage and summer releases for downstream diversions in the Delta.

Figure III-60 shows the simulated September temperatures in the Feather River below Thermalito Afterbay under Alternatives 1 through 4 compared with the simulated temperatures under the No-Action Alternative for 1922-1990. Simulated September temperatures under Alternatives 1 through 4 are similar to the simulated temperatures under the No-Action Alternative. A few differences between Alternatives 1 through 4 are the result of slightly different simulated September release flows, which affect warming in Thermalito Afterbay and the Feather River. The effect of Lake Oroville carryover storage is not a factor because the Lake Oroville release temperature is simulated as a target temperature that is the same under each alternative.

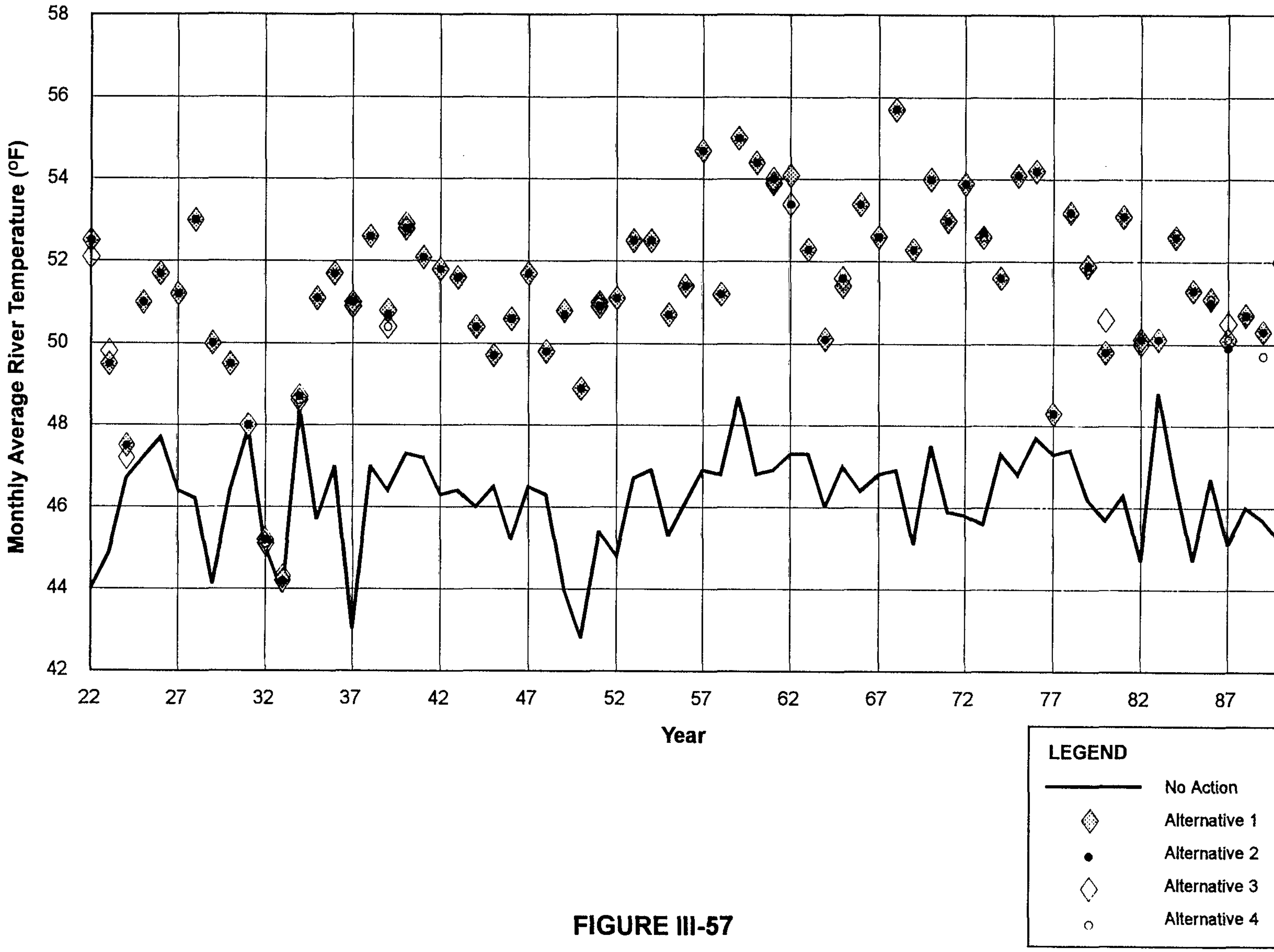


FIGURE III-57

AVERAGE SEPTEMBER TEMPERATURES IN CLEAR CREEK BELOW SAELTZER DIVERSION DAM UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

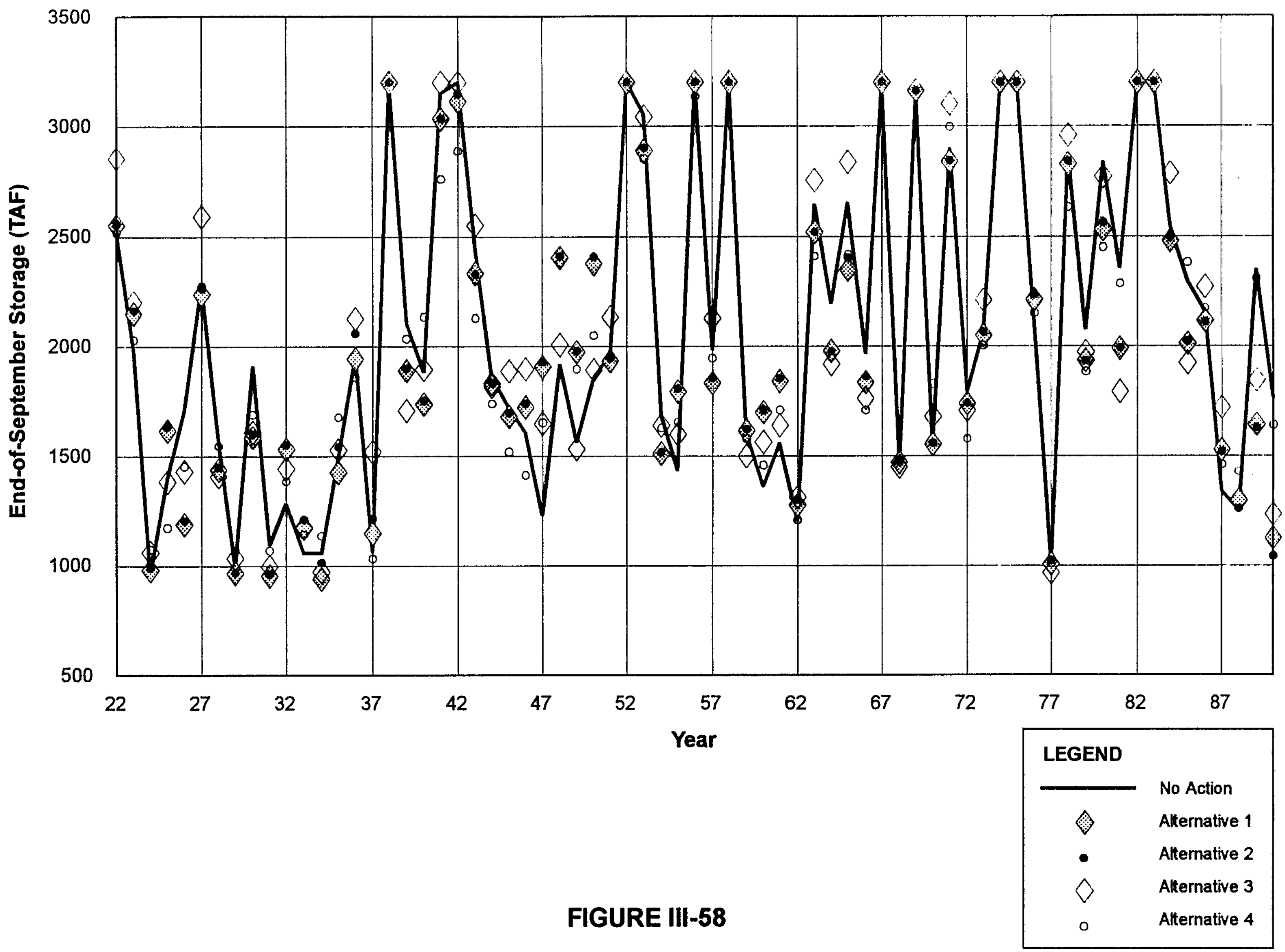


FIGURE III-58

END-OF-SEPTEMBER STORAGE IN LAKE OROVILLE UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

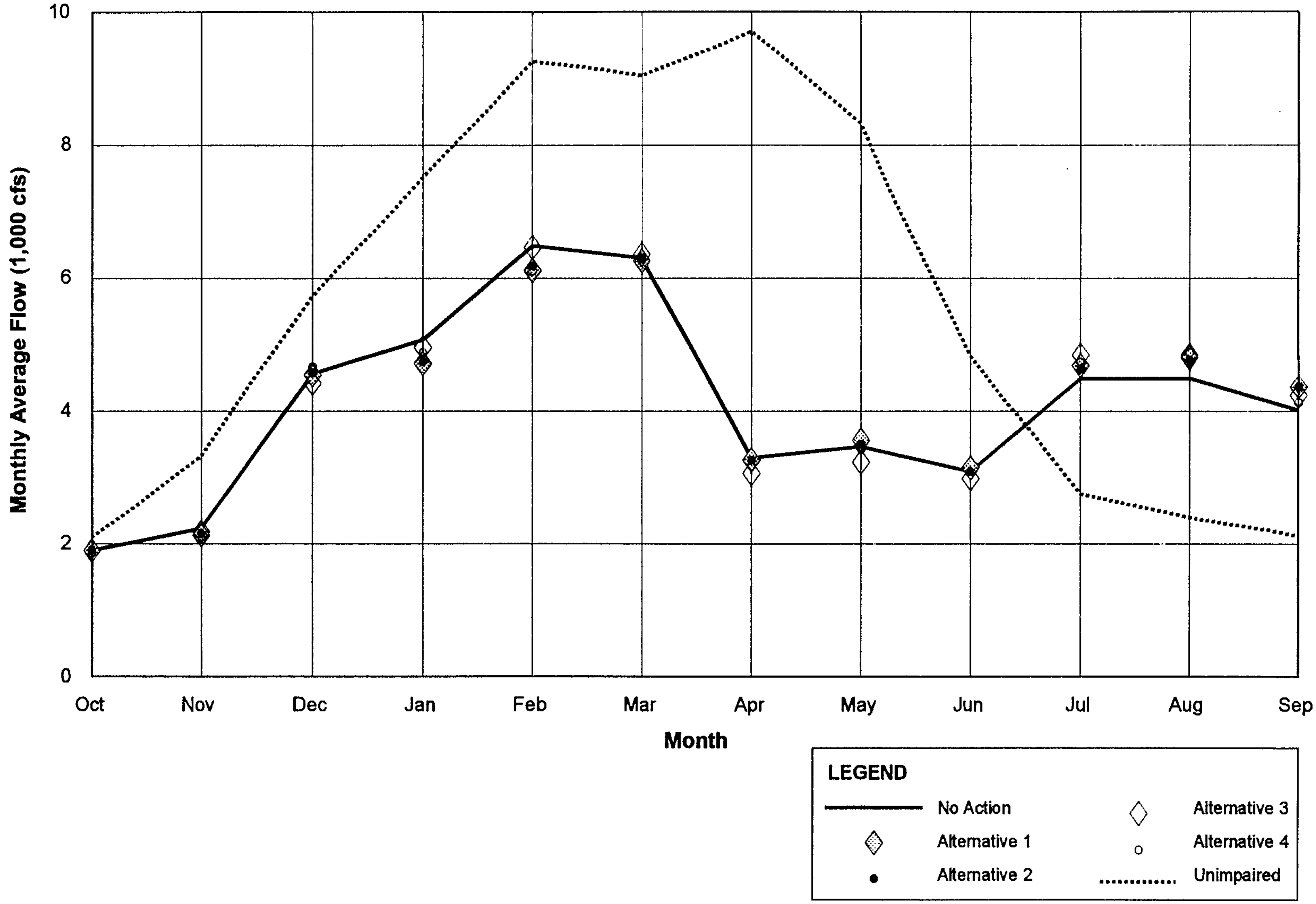


FIGURE III-59

MONTHLY AVERAGE FLOWS IN THE FEATHER RIVER BELOW THERMALITO AFTERBAY UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

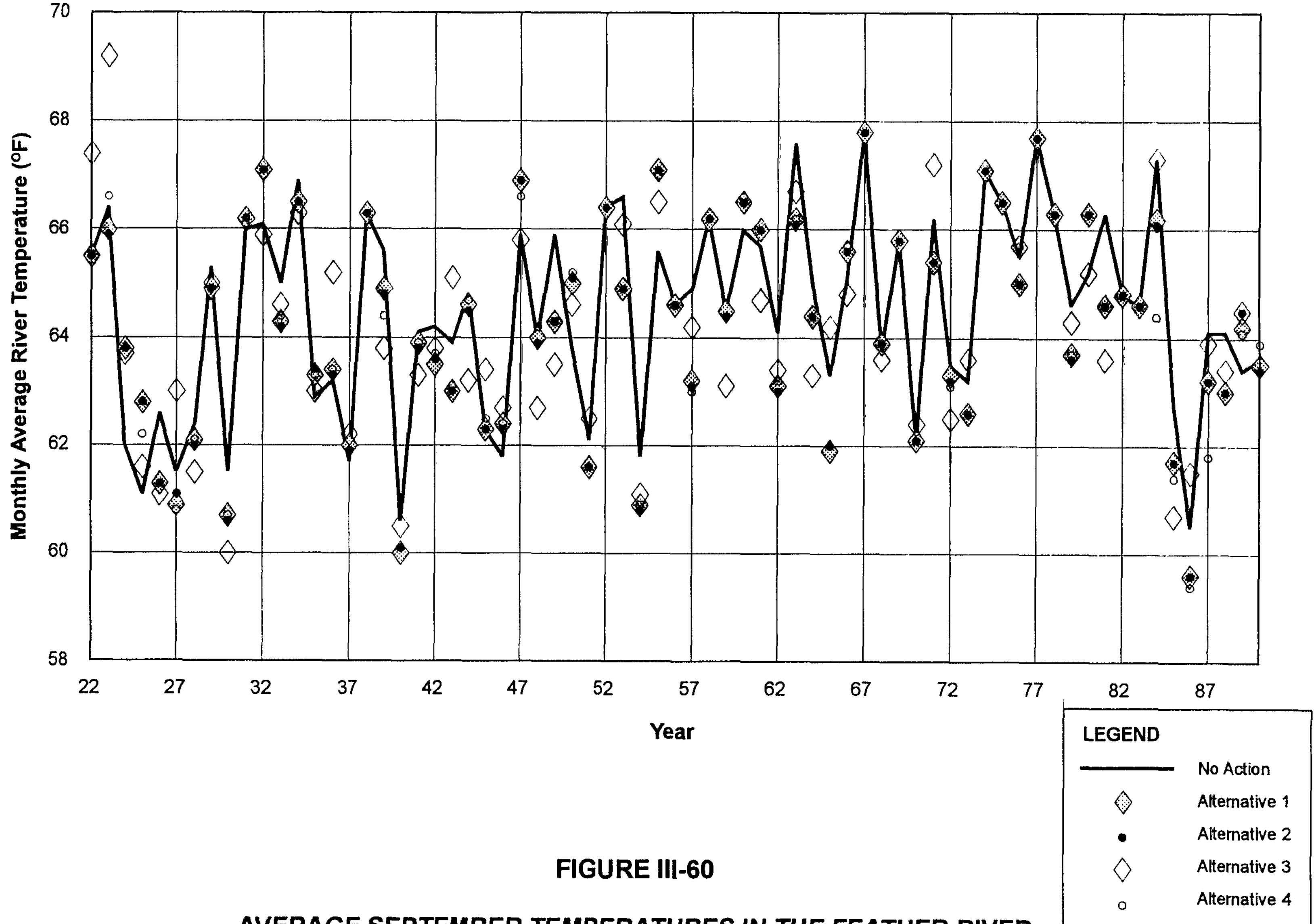


FIGURE III-60

AVERAGE SEPTEMBER TEMPERATURES IN THE FEATHER RIVER BELOW THE THERMALITO AFTERBAY RELEASE UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

C—082068

American River Flows, Temperatures, and Reservoir Storage

Figure III-61 shows simulated end-of-September carryover storage volume for Folsom Lake under Alternatives 1 through 4 compared with the simulated No-Action Alternative carryover storage volume for 1922-1990. The simulated maximum allowable carryover storage of 650,000 af is identical under each of the alternatives. The simulated carryover storage volumes under Alternatives 1 through 4 are sometimes approximately 100,000 af higher than the simulated carryover storage under the No-Action Alternative because the instream flow objectives are lower in summer (and higher in fall and winter).

Figure III-62 shows simulated monthly American River flows below Nimbus Dam under Alternatives 1 through 4 compared with the simulated flows under the No-Action Alternative. The instream flow requirements for the American River are increased slightly under Alternatives 1 through 4. The simulated instream flows under Alternatives 1 through 4 are dependent on reservoir storage volumes. The unimpaired flows indicate the effects of Folsom Lake storage and releases for instream flows and downstream diversions in summer. The instream flow objectives for Alternatives 1 through 4 are closer to the natural flow pattern than No-Action Alternative flows.

Figure III-63 shows the simulated September temperatures in the American River below Nimbus Dam under Alternatives 1 through 4 compared with the simulated temperatures under the No-Action Alternative for 1922-1990. Simulated September temperatures under Alternatives 1 through 4 are higher than the simulated temperatures under the No-Action Alternative because of lower September flows in about 50 percent of the years. The simulated September release temperatures are generally 67-71 °F for each alternative, as well as the No-Action Alternative.

SAN JOAQUIN RIVER REGION

Stanislaus River Flows, Temperatures, Reservoir Storage

Figure III-64 shows simulated end-of-September carryover storage volume for New Melones Reservoir under Alternatives 1 through 4 compared with the simulated No-Action Alternative carryover storage volume for 1922-1990. The simulated carryover storage is nearly identical under Alternatives 1 through 4 compared with the carryover storage under the No-Action Alternative in most years. Increases in releases for instream flows are generally balanced by reduced diversions.

Figure III-65 shows simulated monthly Stanislaus River flows below Goodwin Dam under Alternatives 1 through 4 compared with the simulated flows under the No-Action Alternative. The instream flow requirements for the Stanislaus River are slightly higher under Alternatives 1 and 2 and considerably higher under Alternatives 3 and 4. The simulated instream flows under Alternatives 1 through 4 as well as the No-Action Alternative are partially dependent on downstream water quality and April and May pulse-flow requirements on the San Joaquin River at Vernalis. Simulated average flows are also higher in April, May, and June under all

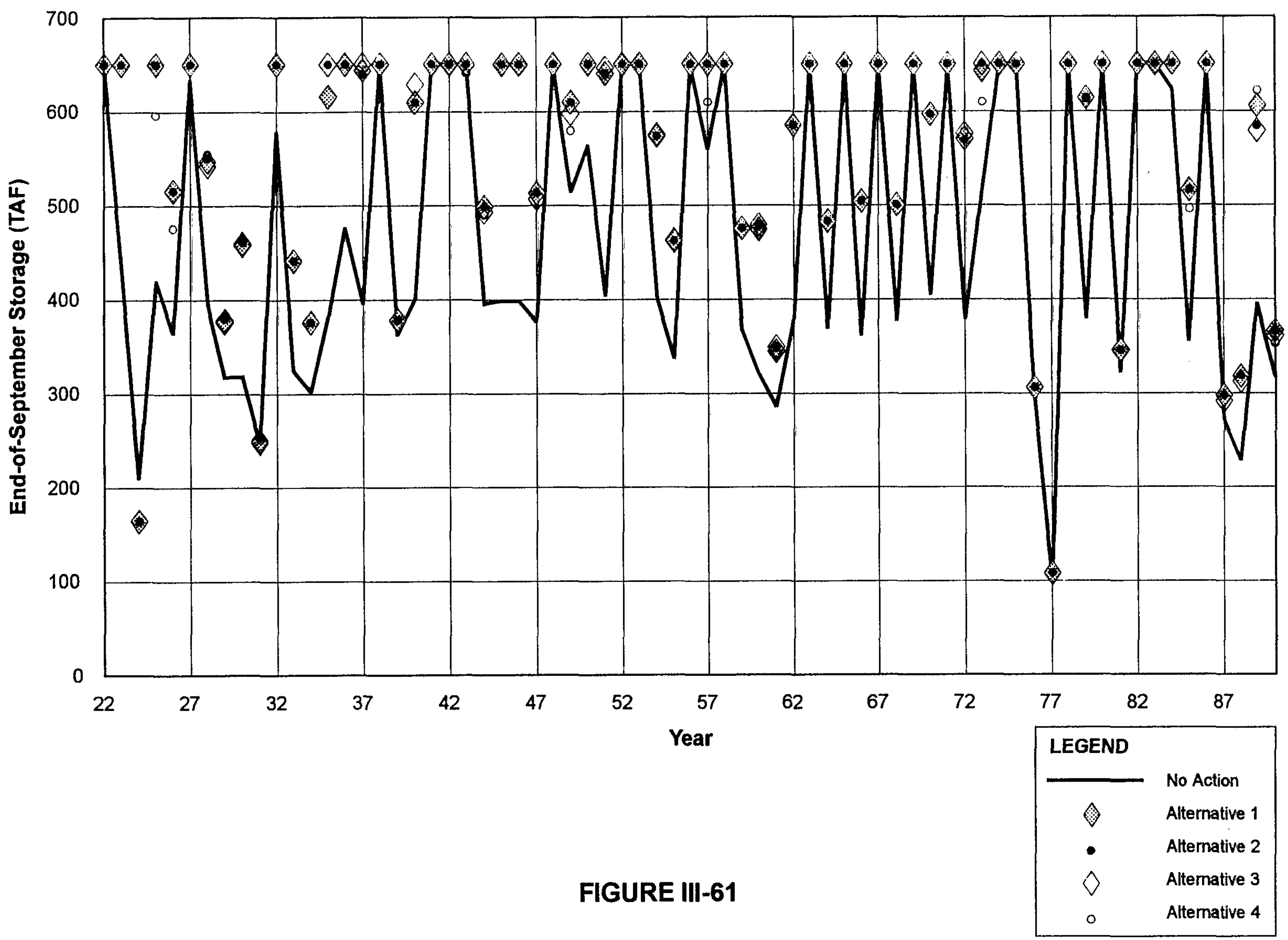


FIGURE III-61

END-OF-SEPTEMBER STORAGE IN FOLSOM LAKE UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

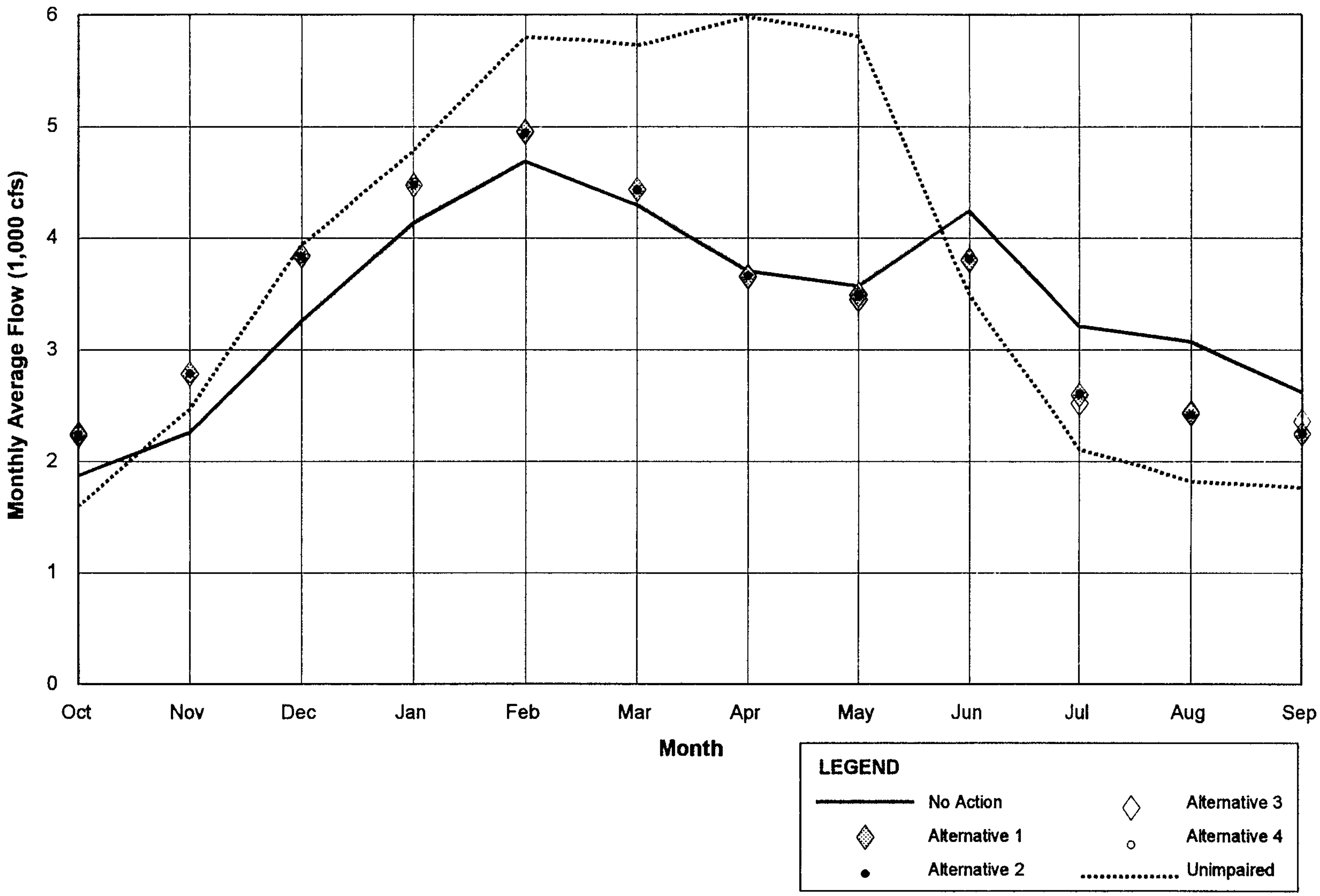


FIGURE III-62

MONTHLY AVERAGE FLOWS IN THE AMERICAN RIVER BELOW NIMBUS DAM UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

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C-082071

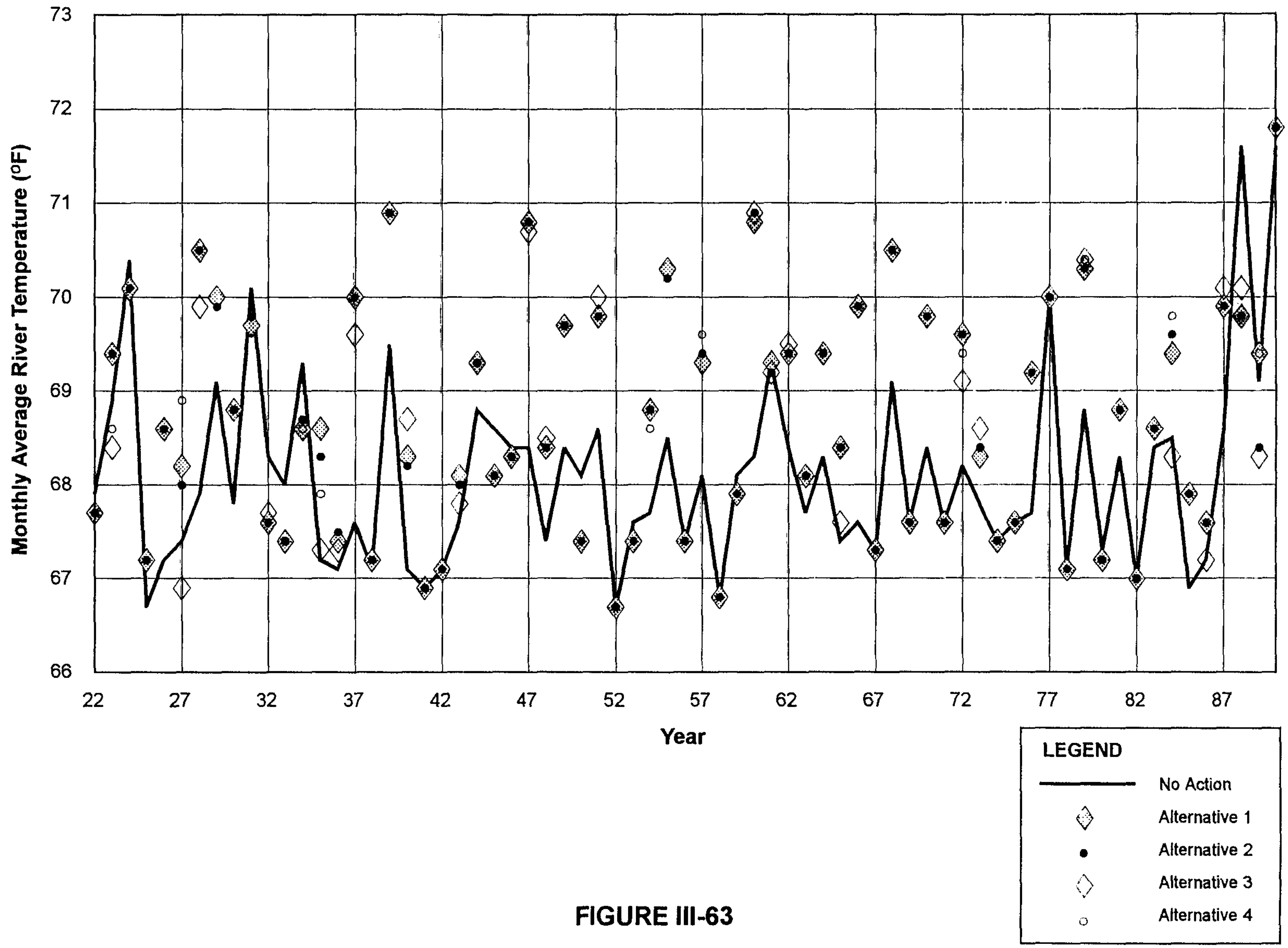

FIGURE III-63

AVERAGE SEPTEMBER TEMPERATURES IN THE AMERICAN RIVER BELOW NIMBUS DAM UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

C-082072

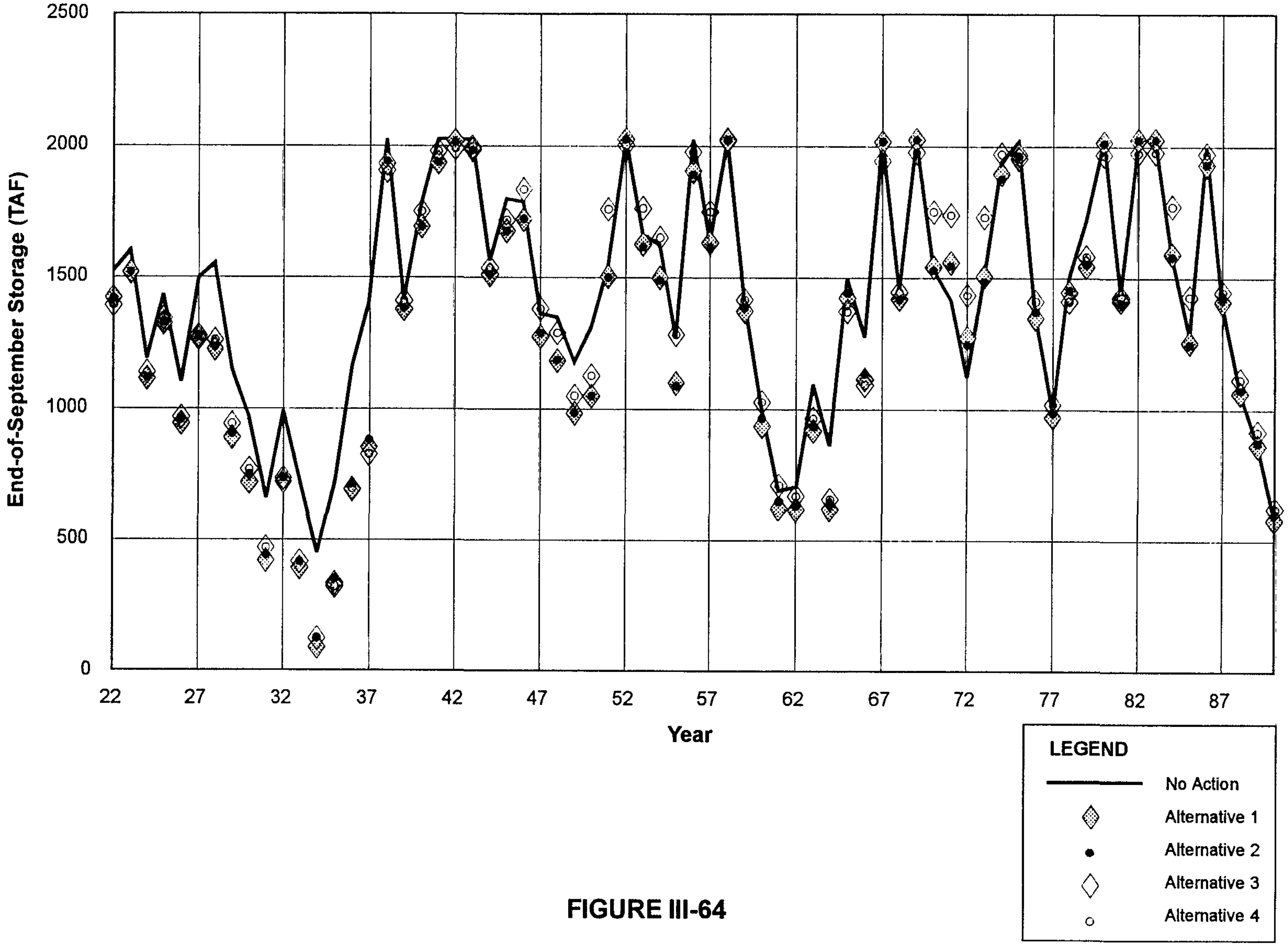

FIGURE III-64

END-OF-SEPTEMBER STORAGE IN NEW MELONES RESERVOIR UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

C-082073

C-082073

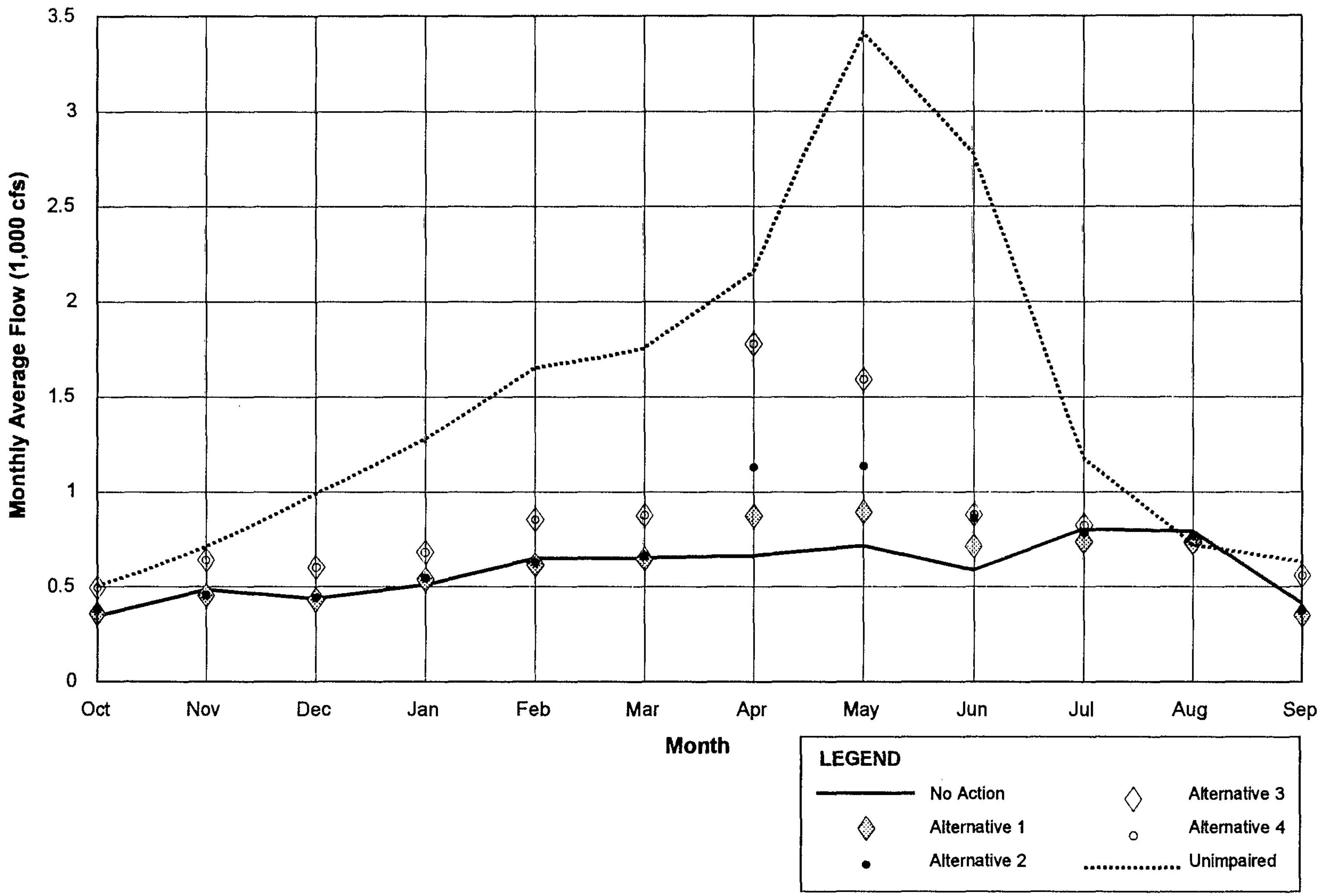

FIGURE III-65

MONTHLY AVERAGE FLOWS IN THE STANISLAUS RIVER BELOW GOODWIN DAM UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

alternatives, with large increases simulated under Alternatives 3 and 4. These April and May flows are high under Alternatives 3 and 4 to attempt to satisfy the Anadromous Fish Restoration Program (AFRP) pulse-flow recommendations for the Stanislaus River and the San Joaquin River at Vernalis. The monthly average unimpaired flow for the Stanislaus River indicates the effects of snowmelt on the natural runoff pattern in April, May, and June, with peak average runoff in May. The effects of storage in New Melones Reservoir and diversions from Tulloch Reservoir and Goodwin Dam are evident from comparison of the simulated downstream releases from Goodwin Dam. The average simulated No-Action Alternative instream flows are relatively uniform throughout the year, with a flow of about 500 cfs. The increased instream flows provided under Alternatives 1 and 2 supplement the spring flows (i.e., pulse flows) in April, May, and June. Additional instream flows provided under Alternatives 3 and 4 further increase April and May pulse flows and also raise flows in the months of October through March, primarily for the benefit of fall-run salmon.

Figure III-66 shows the simulated September temperatures in the Stanislaus River below Goodwin Dam under Alternatives 1 through 4 compared with the simulated temperatures under the No-Action Alternative for 1922-1990. Simulated September temperatures under Alternatives 1 through 4, particularly Alternatives 3 and 4, are slightly higher than simulated temperatures under the No-Action Alternative. The simulated September release temperatures are generally 55-60°F under each alternative, as well as the No-Action Alternative. The slightly higher temperatures under the action alternatives are the result of lower simulated New Melones Reservoir carryover storages and different September release flows.

Reservoir Storage and River Flow Conditions for Other Reservoirs

The recreation and fisheries habitat assessments for several other reservoirs in the San Joaquin River system depend on the simulated monthly storage volumes and downstream release flows. The simulated storage patterns for these reservoirs and downstream flows are discussed in this section for Alternatives 1 through 4 compared with the simulated No-Action Alternative. These reservoirs are Camanche Reservoir on the Mokelumne River, New Don Pedro Reservoir on the Tuolumne River, Lake McClure on the Merced River, and Millerton Lake on the San Joaquin River.

The reservoirs in the San Joaquin River Basin were simulated with SANJASM using approximate reservoir operating rules. The basic diversion demands and instream flow requirements were simulated, but the discretionary releases for power generation and possible voluntary reductions in diversions during low-flow periods were not simulated. Some of the alternatives include assumed increased instream flow requirements that would be obtained through purchase of water from willing sellers and reduction in the diversions from below these storage reservoirs. The simulation results for reservoir storage volume and downstream flows are considered adequate for purposes of PEIS impact assessment of fisheries, vegetation and wildlife, and recreation resources.

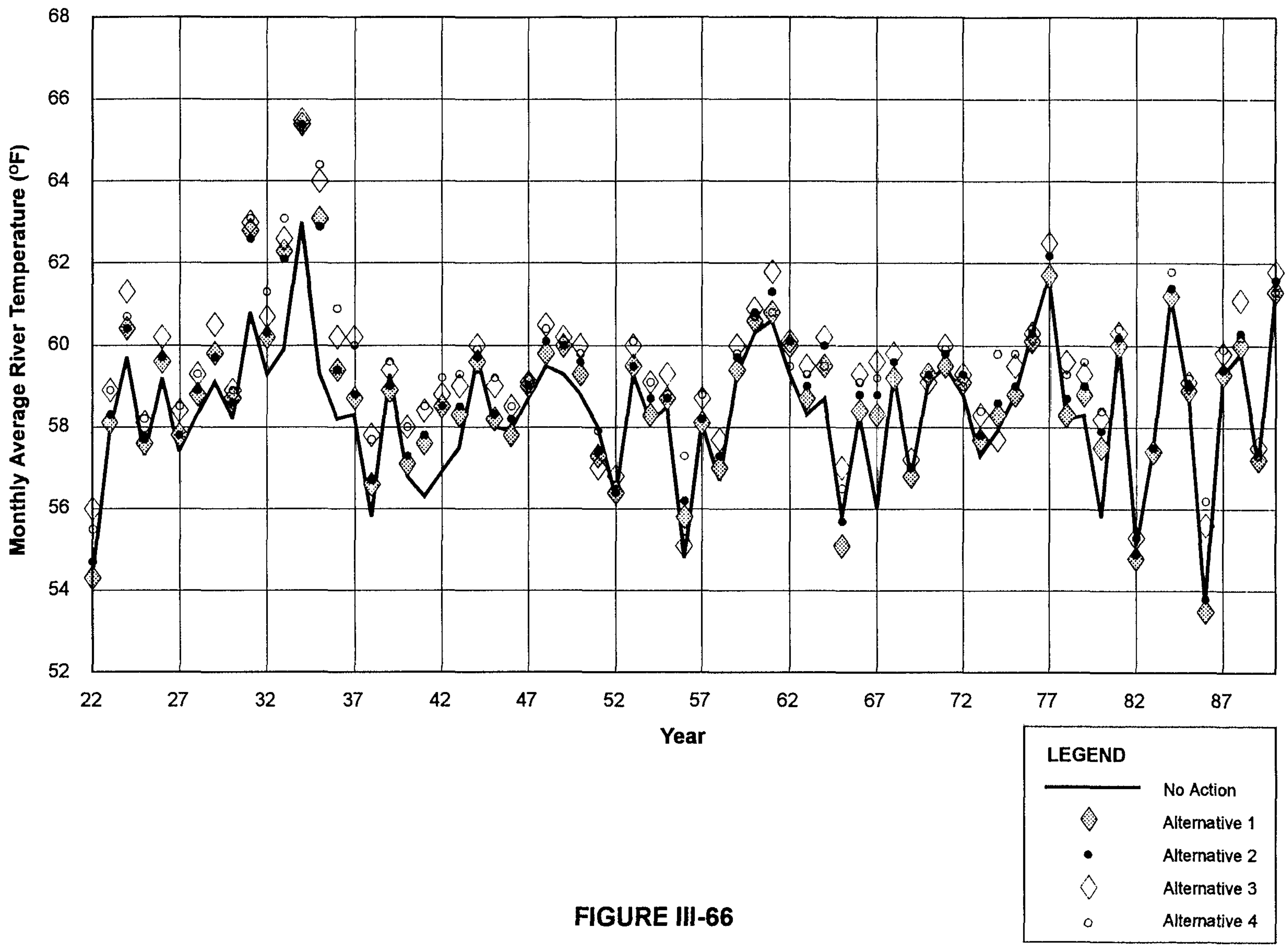

FIGURE III-66

AVERAGE SEPTEMBER TEMPERATURES IN THE STANISLAUS RIVER BELOW GOODWIN DAM UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

Figure III-67 shows simulated end-of-September carryover storage volume for Camanche Reservoir on the Mokelumne River under Alternatives 1 through 4 compared with the simulated carryover storage volume under the No-Action Alternative for 1922-1990. The simulated carryover storage is nearly identical under Alternatives 1 through 4 and the No-Action Alternative in most years.

Figure III-68 shows simulated monthly Mokelumne River flows below Camanche Reservoir under Alternatives 1 through 4 compared with the simulated flows under the No-Action Alternative. The instream flow requirements for the Mokelumne River below Camanche Reservoir are shifted under Alternatives 3 and 4 to follow instream flow priorities established by the AFRP for the Mokelumne River. The monthly average unimpaired flows indicate the effects of storage and diversion on the Mokelumne River.

Figure III-69 shows simulated end-of-September carryover storage volume for New Don Pedro Reservoir under Alternatives 1 through 4 compared with the simulated carryover storage volume under the No-Action Alternative for 1922-1990. The simulated carryover storage is identical under Alternatives 1 and 2 and the No-Action Alternative in most years. The simulated carryover storage volumes under Alternatives 3 and 4 are lower than the simulated carryover storage under the No-Action Alternative because of increased spring and summer instream flow objectives.

Figure III-70 shows simulated monthly Tuolumne River flows below La Grange diversion dam under Alternatives 1 through 4 compared with the simulated flows under the No-Action Alternative. The instream flow requirements for the Tuolumne River are increased under Alternative 2 and increased considerably more under Alternatives 3 and 4. Simulated average monthly flows are increased in April through October under Alternatives 3 and 4, with the largest increases simulated in April and May. The monthly average unimpaired flows indicate the relatively large effects of storage and diversion on the Tuolumne River.

Figure III-71 shows simulated end-of-September carryover storage volume for Lake McClure on the Merced River under Alternatives 1 through 4 compared with the simulated carryover storage volume under the No-Action Alternative for 1922-1990. The simulated carryover storage is nearly identical under Alternatives 1 through 4 and the No-Action Alternative in most years, although changes in the releases for instream flows and diversions sometimes result in slightly different carryover storage.

Figure III-72 shows simulated monthly Merced River flows below Crocker-Hoffman diversion dam under Alternatives 1 through 4 compared with the simulated flows under the No-Action Alternative. The instream flow requirements for the Merced River are increased under Alternative 2 in April and May and increased considerably more under Alternatives 3 and 4. Simulated average monthly flows are increased slightly in most months under Alternatives 3 and 4, with the largest increases simulated in April and May. The monthly average unimpaired flows indicate the effects of storage and diversion on the Merced River.

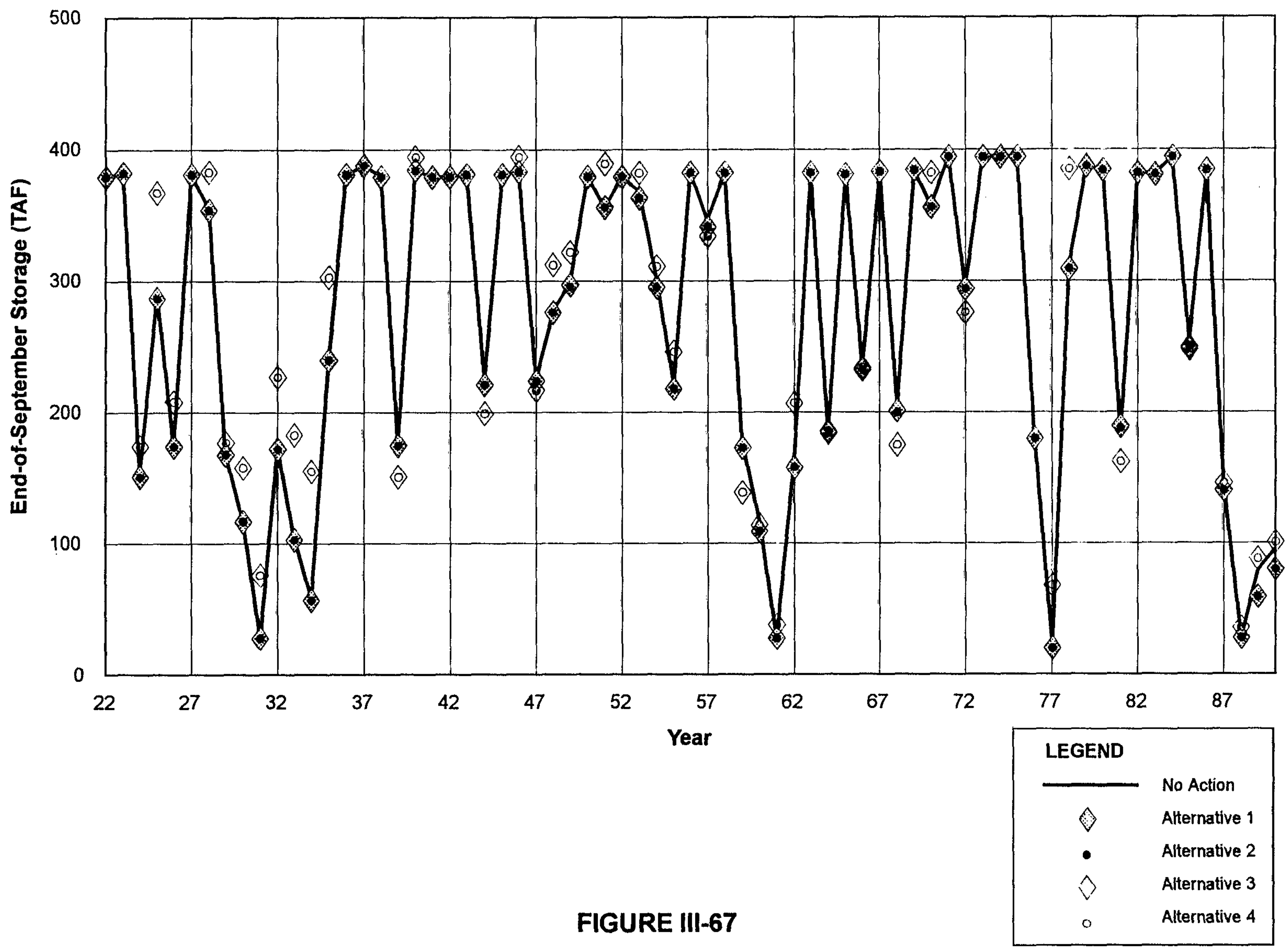

FIGURE III-67

END-OF-SEPTEMBER STORAGE IN CAMANCHE RESERVOIR UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

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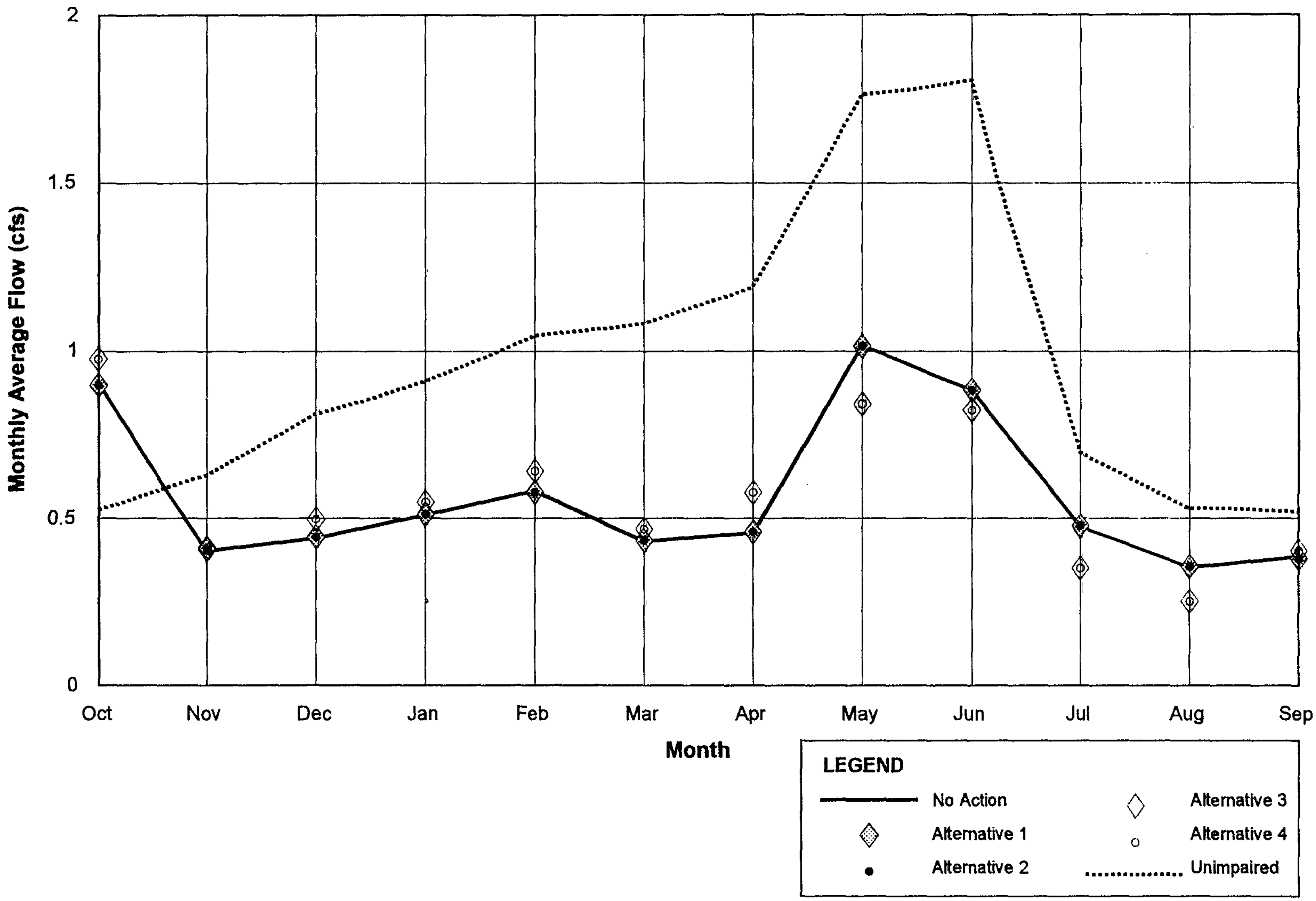

FIGURE III-68

MONTHLY AVERAGE FLOWS IN THE MOKELUMNE RIVER BELOW CAMANCHE RESERVOIR UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

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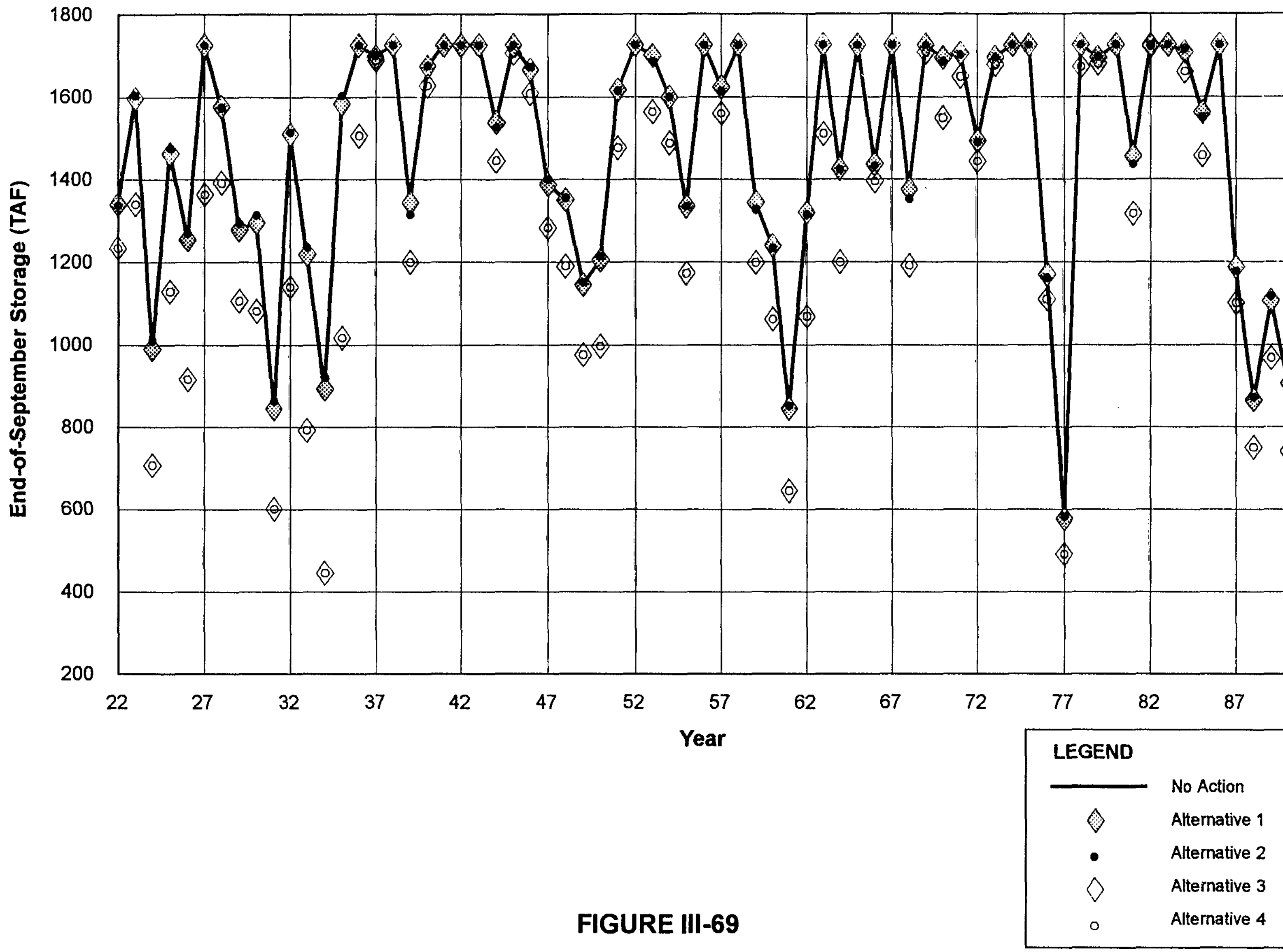

FIGURE III-69

END-OF-SEPTEMBER STORAGE IN NEW DON PEDRO RESERVOIR UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

C-082080

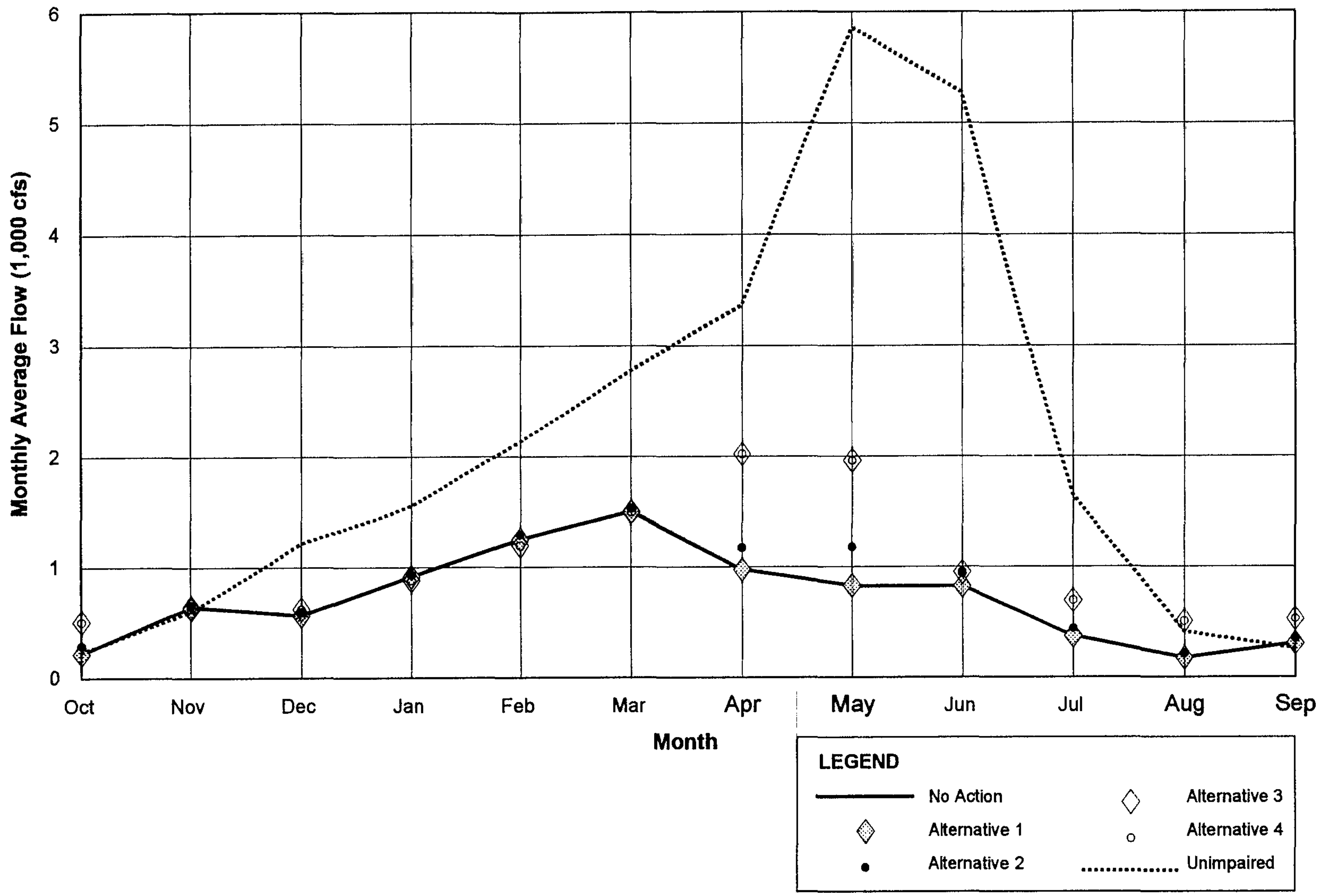

FIGURE III-70

MONTHLY AVERAGE FLOWS IN THE TUOLUMNE RIVER BELOW LA GRANGE UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

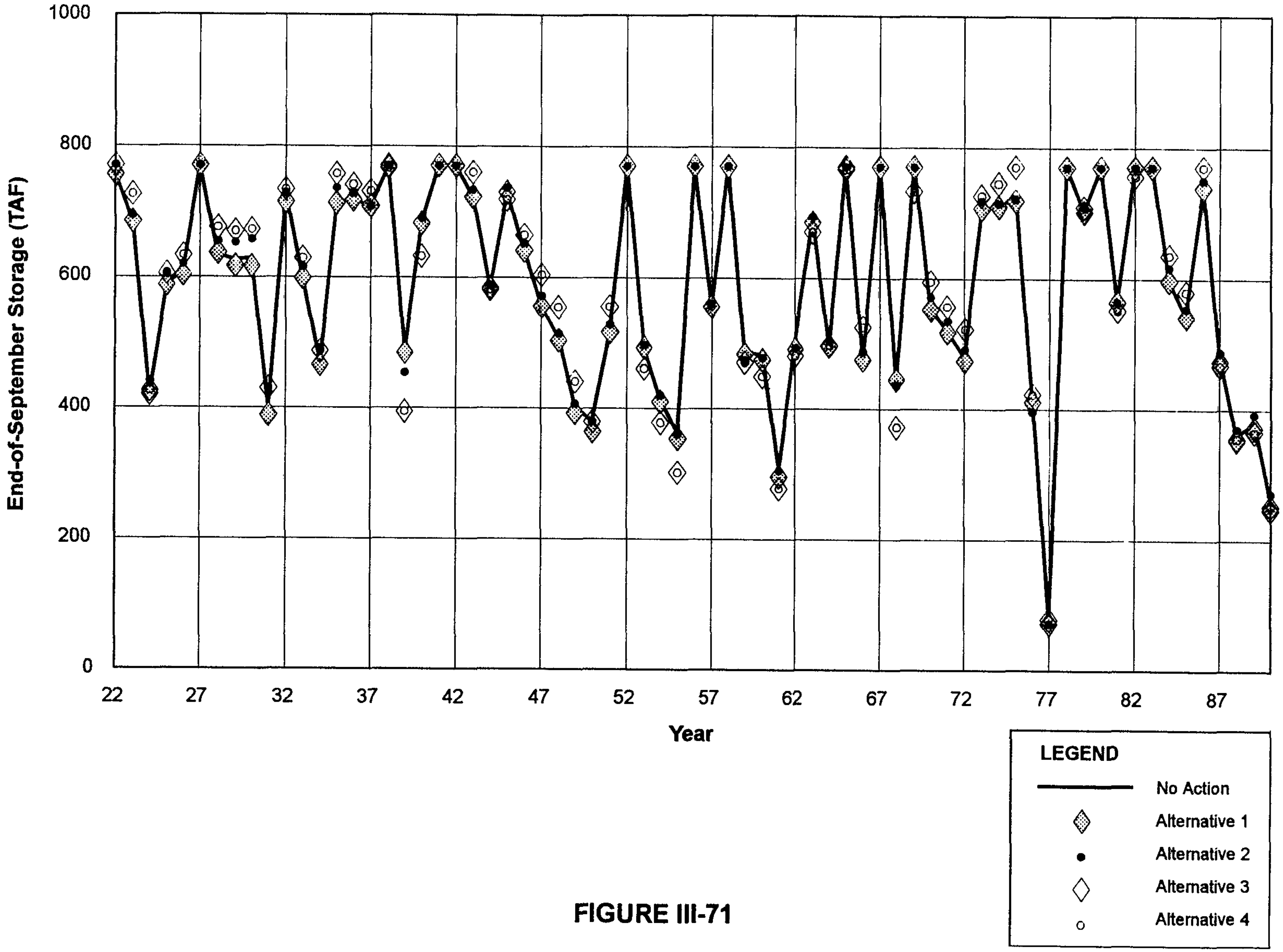

FIGURE III-71

END-OF-SEPTEMBER STORAGE IN LAKE MCCLURE UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

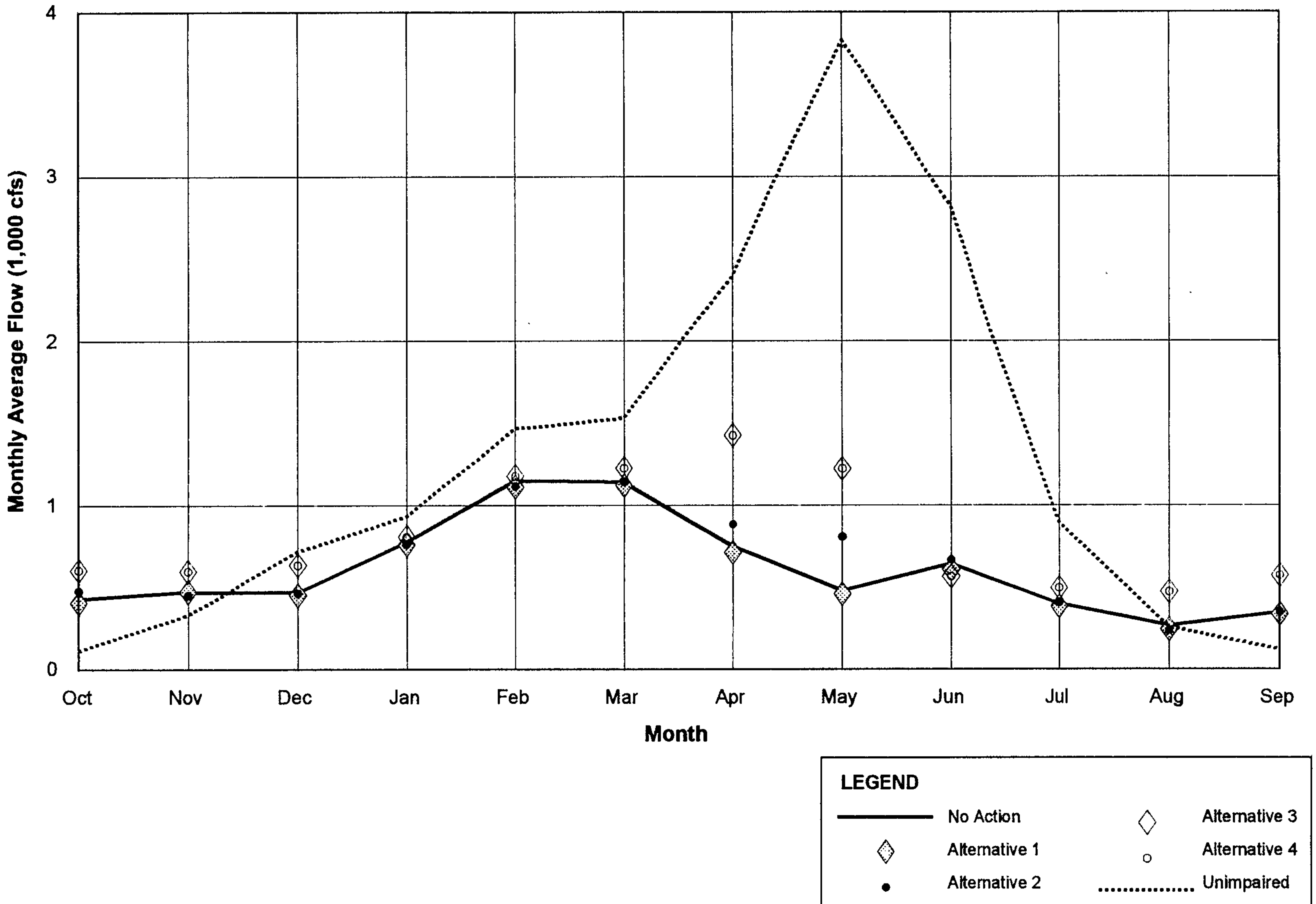

FIGURE III-72

MONTHLY AVERAGE FLOWS IN THE MERCED RIVER BELOW CROCKER-HOFFMAN DAM UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

Figure III-73 shows simulated end-of-September carryover storage volume for Millerton Lake on the San Joaquin River under Alternatives 1 through 4 compared with the simulated carryover storage volume under the No-Action Alternative for 1922-1990. The simulated carryover storage under Alternatives 1 through 4 is identical to the carryover storage under the No-Action Alternative because Millerton Lake is simulated to be independent of the other reservoirs under Alternatives 1 through 4 and the No-Action Alternative and no changes in diversions or downstream release requirements are simulated.

Figure III-74 shows simulated monthly San Joaquin River flows at Vernalis under Alternatives 1 through 4 compared with the simulated flows under the No-Action Alternative. Flow at Vernalis is dependent on releases from the four major upstream tributary reservoirs (i.e., New Melones Reservoir on the Stanislaus River, New Don Pedro Reservoir on the Tuolumne River, Lake McClure on the Merced River, and Millerton Lake on the San Joaquin River), as well as local runoff and drainage flows during the irrigation season. The instream flow requirements for the San Joaquin River at Vernalis are not simulated directly but are simulated indirectly with increased tributary flow requirements. Simulated average monthly flows are increased slightly in all months under Alternatives 2 through 4, with the largest increases simulated in April and May under Alternatives 3 and 4. The monthly average unimpaired flows indicate the effects of upstream storage and diversion on the San Joaquin River. September and October simulated flows are slightly higher than unimpaired flows. Peak flows usually occur in April, May, and June because of snowmelt runoff.

San Luis Reservoir

Figure III-75 shows simulated end-of-September carryover storage volume for San Luis Reservoir under Alternatives 1 through 4 compared with the simulated No-Action Alternative carryover storage volume for 1922-1990. The simulated carryover storage volumes are very similar under Alternatives 1 through 4 and the No-Action Alternative because San Luis Reservoir is simulated as a regulating reservoir for Delta exports to satisfy demand on the Delta-Mendota Canal and San Luis-California Aqueduct. Because annual exports and demands are very similar under Alternatives 1 through 4 and the No-Action Alternative, the San Luis Reservoir carryover storage under Alternatives 1 through 4 is similar to carryover storage under the No-Action Alternative. The carryover storage of approximately 200,000 af was maintained under all the alternatives by limiting delivery of water from San Luis Reservoir.

SACRAMENTO-SAN JOAQUIN RIVER DELTA

Delta Exports and Percent Entrainment

Most of the spawning and rearing stages of juvenile fish that may be vulnerable to entrainment in Delta diversions and exports occur primarily during February through June. The DeltaMOVE model was used to estimate the percentage of these vulnerable organisms that would be entrained during February through June. The percent entrainment depends on the monthly simulated Delta channel flows and exports, as well as the location of the spawning (see the Fish Habitat Water Quality Methodology/Modeling Technical Appendix). The monthly entrainment estimates for the No-Action Alternative have been described for each of the three important spawning

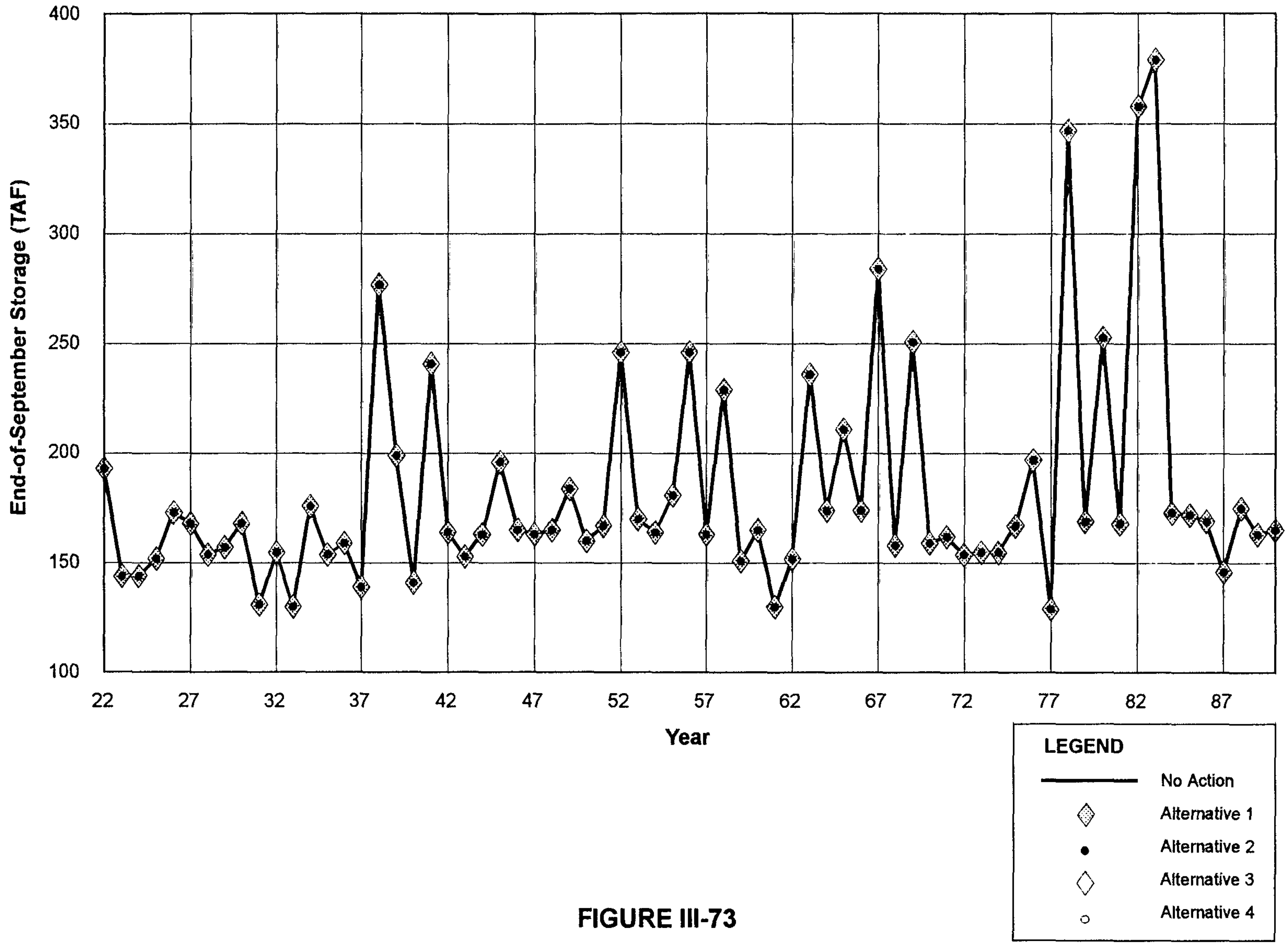

FIGURE III-73

END-OF-SEPTEMBER STORAGE IN MILLERTON LAKE UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

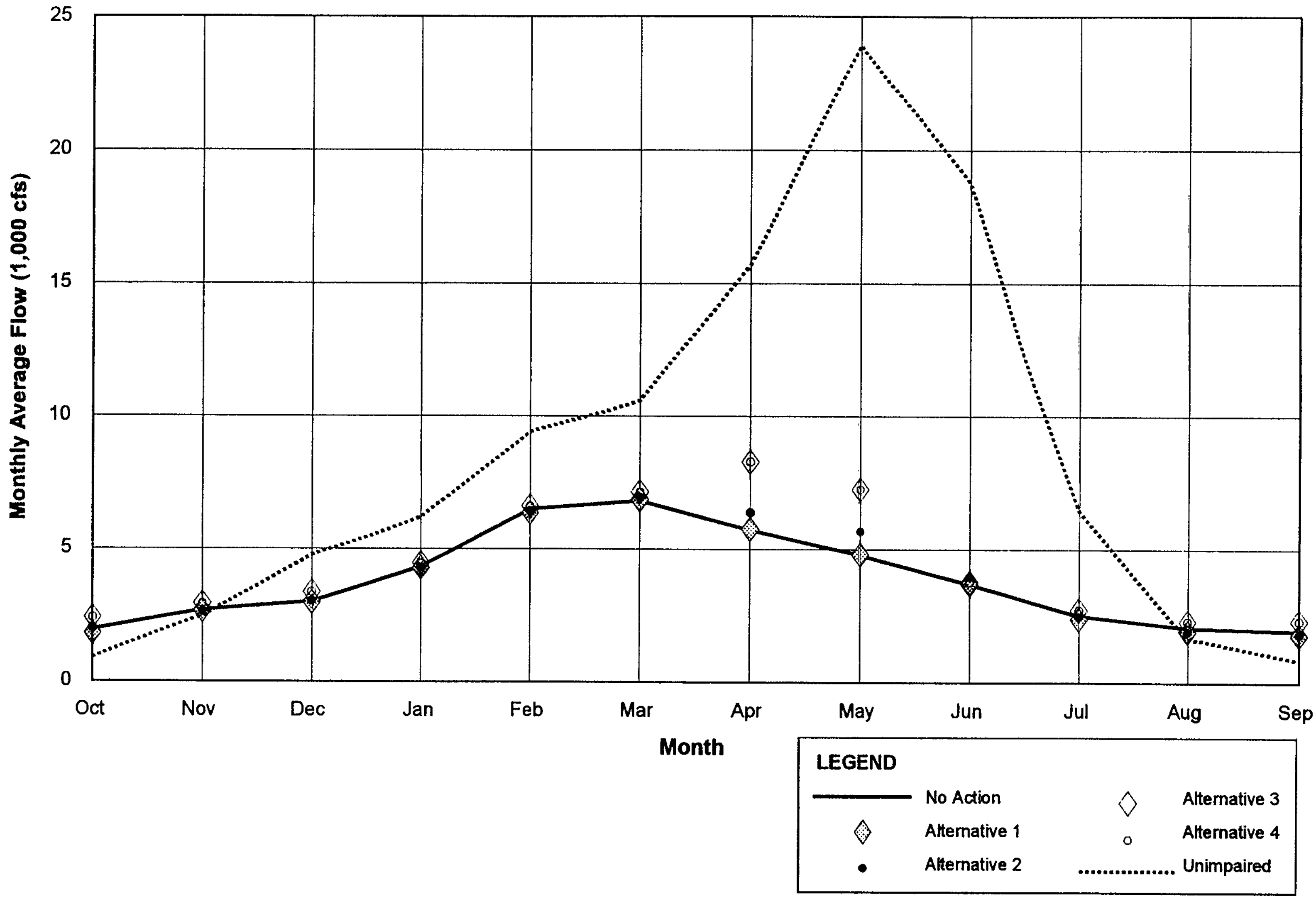

FIGURE III-74

MONTHLY AVERAGE FLOWS IN THE SAN JOAQUIN RIVER AT VERNALIS UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

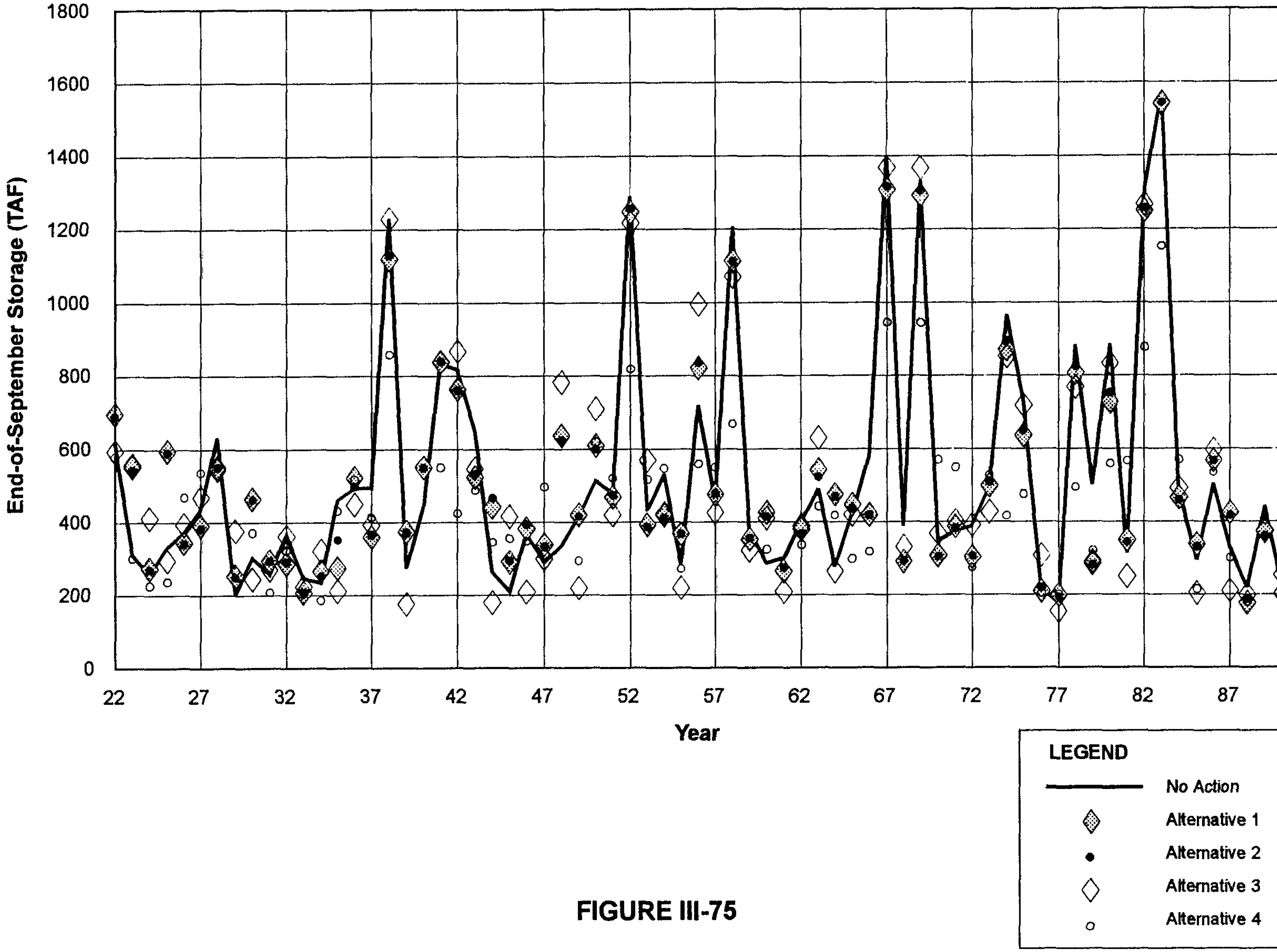

FIGURE III-75

END-OF-SEPTEMBER STORAGE IN SAN LUIS RESERVOIR UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

segments of the Delta. To evaluate annual average entrainment habitat conditions, a uniform monthly relative abundance for these vulnerable life stages has been assumed for February through June (i.e., 20 percent each month). The entrainment results for the three most important spawning locations in the Delta are shown in this section. The evaluation of these entrainment patterns for specific fish species is described in the Fisheries Technical Appendix.

Figure III-76 shows the simulated average February-June combined CVP and SWP Delta exports for 1922-1990 under Alternatives 1 through 4 compared with the average exports under the No-Action Alternative. Exports are variable during these months but often decrease as available water for pumping declines (e.g., limited by 1995 WQCP percent of inflow) and available storage in San Luis Reservoir is filled (see Figure III-38 for monthly No-Action Alternative exports). Total average CVP and SWP export pumping for February through June under the No-Action Alternative ranges from approximately 2,500 cfs to 10,000 cfs. Simulated pumping under Alternatives 1 and 2 is very similar to pumping under the No-Action Alternative. Simulated pumping under Alternative 3 is generally higher than under the No-Action Alternative because increased streamflows in the spring months allow slightly higher export pumping under the 1995 WQCP objectives. Simulated pumping under Alternative 4 is less than under the other alternatives because the increased streamflows to meet AFRP objectives are not exported, and exports are limited for additional protection of resident and migration fish species. Simulated Delta diversions during February through June are made for both salt leaching and crop irrigation and average approximately 1,500 cfs during years with limited rainfall.

Figure III-77 shows the simulated average February-June percent entrainment of water from the Sacramento River Delta volume segment for 1922-1990 under Alternatives 1 through 4 compared with the simulated percent entrainment under the No-Action Alternative. Water (and vulnerable life stages of fish) moves from the Sacramento River Delta volume segment through Threemile Slough or around Sherman Island into the San Joaquin River, central, and south Delta volume segments to be entrained in channel diversions or Delta exports. The simulated total average percent entrainment (i.e., average percent entrainment for combined channel diversions and exports) from the Sacramento River Delta volume segment for February through June under The No-Action Alternative ranges from 1 percent (1983) to approximately 20 percent (1972). The simulated total percent entrainment under Alternatives 1 through 4 is similar to the simulated percent entrainment under the No-Action Alternative. Simulated total percent entrainment is usually lower under Alternative 4 than under the other alternatives because of increased streamflows and reduced export pumping to satisfy AFRP objectives.

Figure III-78 shows the simulated average February-June percent entrainment of water from the San Joaquin River Delta volume segment for 1922-1990 under Alternatives 1 through 4 compared with the simulated percent entrainment under the No-Action Alternative. Water (and vulnerable life stages of fish) moves from the San Joaquin River volume segment into the central and south Delta volume segments to be entrained in channel diversions or Delta exports. The simulated total average percent entrainment (i.e., average percent entrainment for combined channel diversions and exports) from the San Joaquin River Delta volume segment for February through June under the No-Action Alternative ranges from 1 percent (1983) to more than 35 percent (1972), although the average entrainment in most years is between 10 percent and

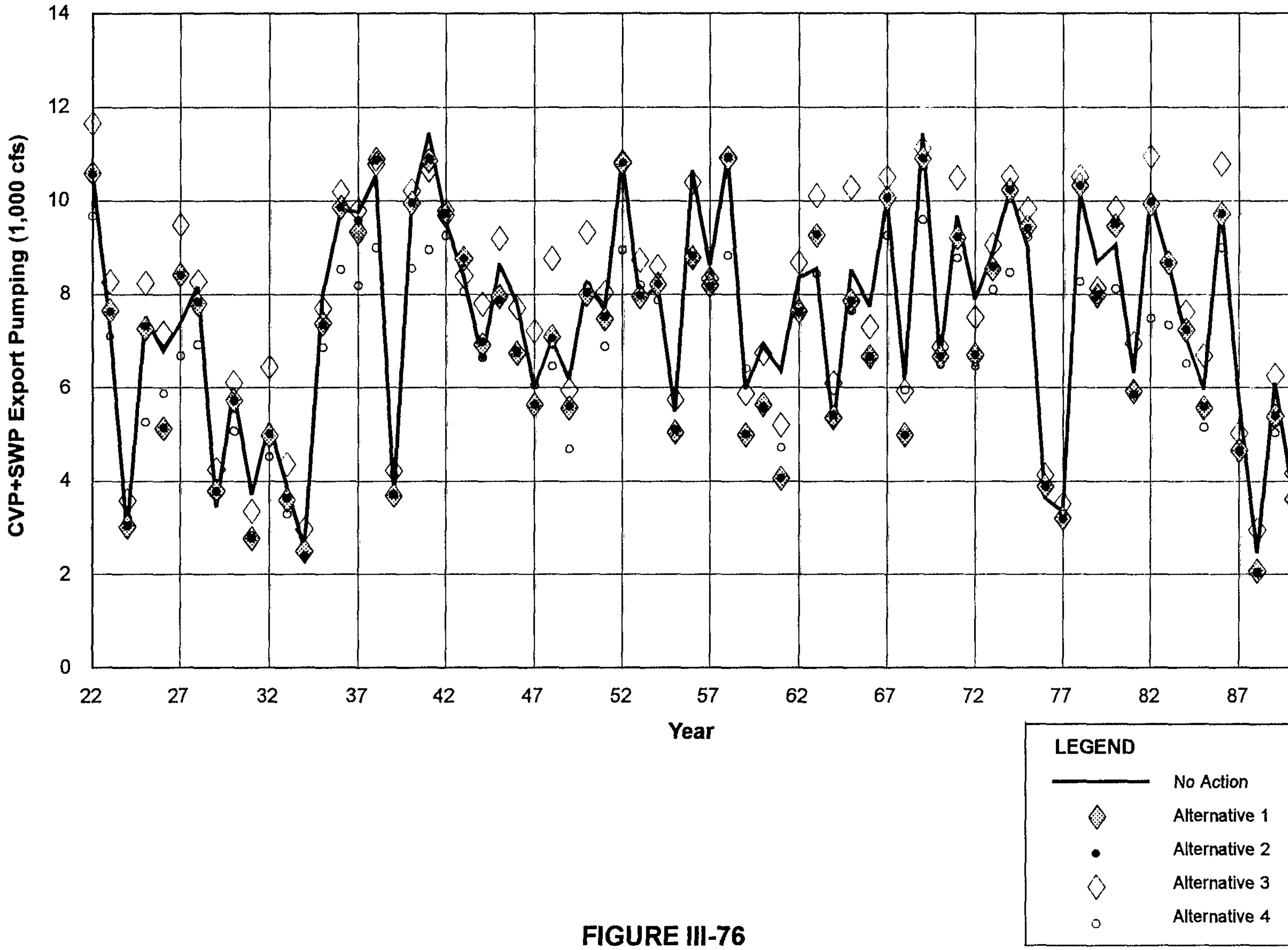

FIGURE III-76

AVERAGE FEBRUARY-JUNE DELTA EXPORTS UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

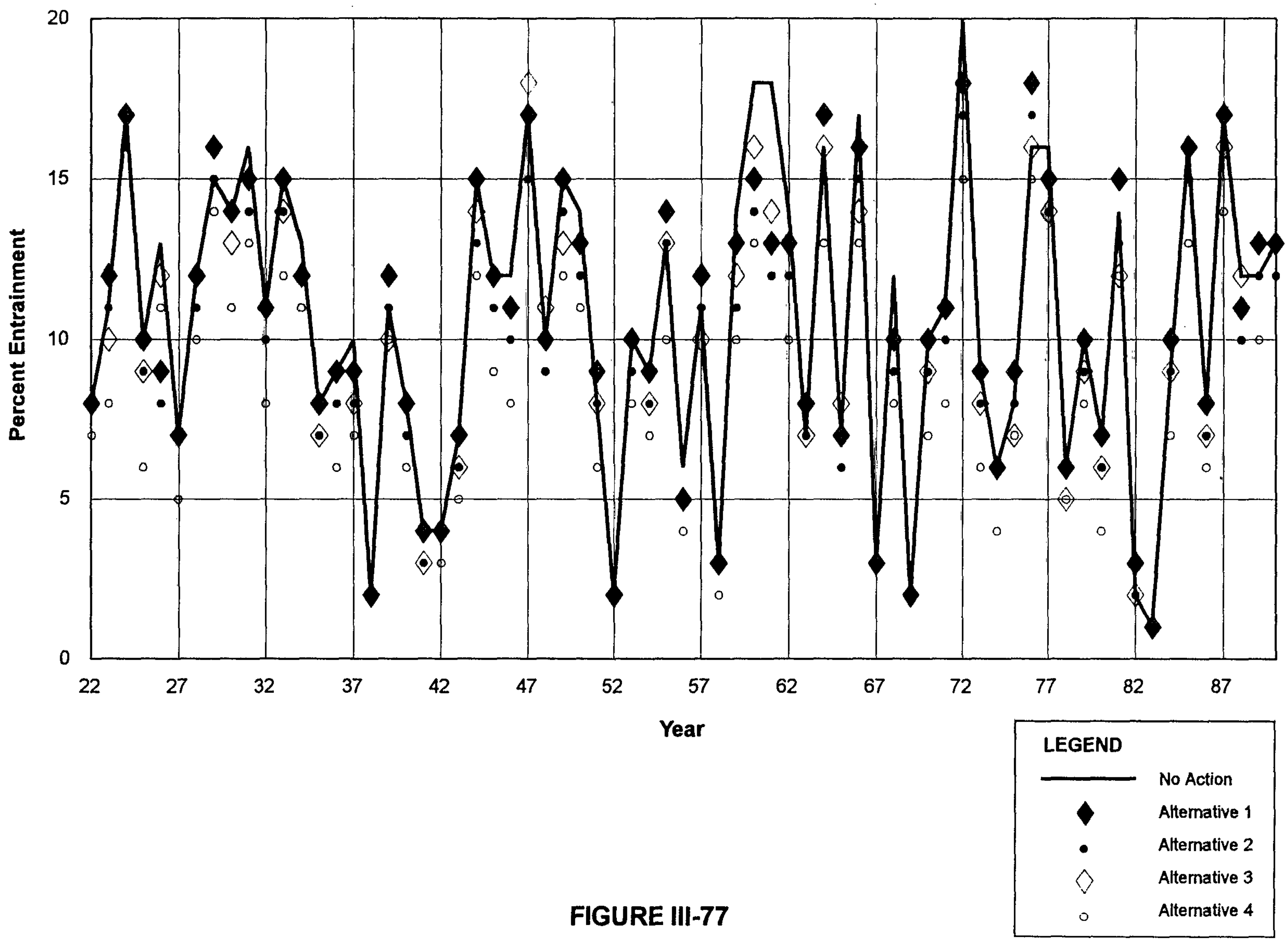

FIGURE III-77

AVERAGE FEBRUARY-JUNE PERCENT ENTRAINMENT OF WATER STARTING IN THE SACRAMENTO RIVER DELTA VOLUME UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

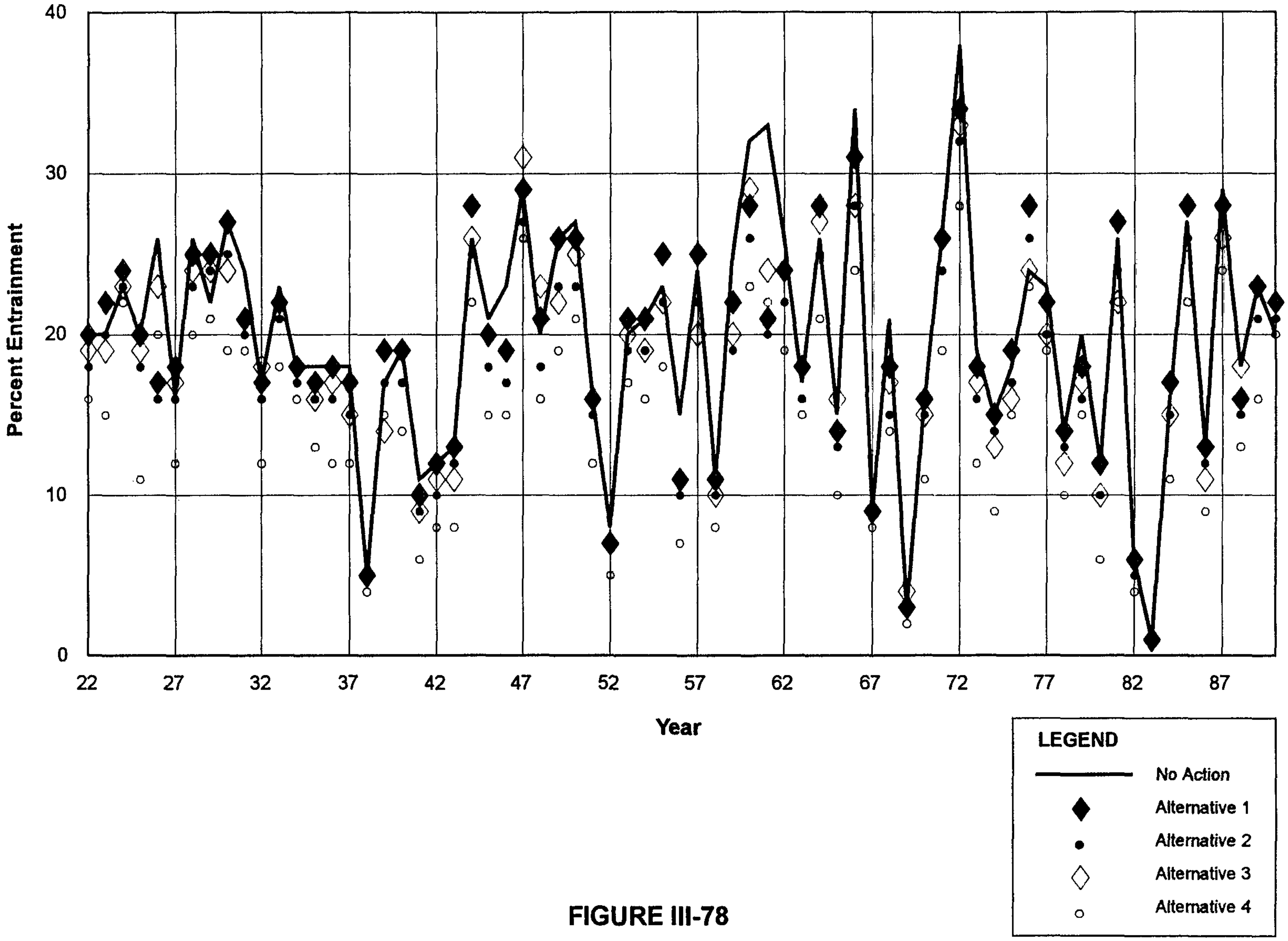

FIGURE III-78

AVERAGE FEBRUARY-JUNE PERCENT ENTRAINMENT OF WATER STARTING IN THE SAN JOAQUIN RIVER DELTA VOLUME UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

30 percent. The simulated total percent entrainment under Alternatives 1 through 4 is usually less than the simulated percent entrainment under the No-Action Alternative. Simulated total percent entrainment under Alternative 4 is usually considerably lower (i.e., 1 percent to 5 percent) than under the other alternatives because of increased streamflows and reduced export pumping to satisfy AFRP objectives.

Figure III-79 shows the simulated average February-June percent entrainment of water from the central Delta volume segment for 1922-1990 under Alternatives 1 through 4 compared with the simulated percent entrainment under the No-Action Alternative. Water (and vulnerable life stages of fish) from the central Delta volume segment is entrained in channel diversions or Delta exports. The simulated total average percent entrainment (i.e., average percent entrainment for combined channel diversions and exports) from the central Delta volume segment for the February-June period under the No-Action Alternative ranges from approximately 20 percent (1983) to 85 percent in several years. The average entrainment in most years is between 60 percent and 80 percent, indicating that spawning in the central Delta is much more vulnerable to entrainment than spawning in other segments of the Delta. The simulated total percent entrainment under Alternatives 1 through 3 is usually about the same as simulated percent entrainment under the No-Action Alternative. Simulated total percent entrainment is usually considerably lower under Alternative 4 (i.e., 10 percent to 20 percent) than under the other alternatives because of increased streamflows and reduced export pumping to satisfy AFRP objectives.

Western Delta and Suisun Bay Salinity (EC)

The simulated salinity in the western Delta and Suisun Bay is dependent on the simulated Delta outflow, as described in the Fish Habitat Water Quality Methodology/Modeling Technical Appendix. The five locations used to characterize habitat water quality salinity conditions are Jersey Point, Collinsville, Chipps Island, Port Chicago, and Benicia. The monthly salinity conditions are shown for each location using the 10th percentile, median (50th percentile), and 90th percentile monthly salinity values under Alternatives 1 through 4 compared with the salinity values under the No-Action Alternative.

Figure III-80 shows the simulated monthly Delta outflow values for Alternatives 1 through 4 compared with the simulated Delta outflow for the No-Action Alternative. The 10th percentile (low) Delta outflow values are slightly higher in some months under Alternatives 1 through 3 because of increased instream flows to meet AFRP objectives. Delta outflow is increased in the spring months (April and May) under Alternative 4 because of increased streamflows and reduced export pumping to satisfy AFRP objectives. The 50th percentile (median) Delta outflow values are also slightly higher in some months under Alternatives 1 through 3 because of increased instream flows to meet AFRP objectives. Delta outflow is increased in the spring months (April and May) under Alternative 4 because of increased streamflows and reduced export pumping to satisfy AFRP objectives. The 90th percentile (high) Delta outflow values for Alternatives 1 through 4 are similar to the No-Action Alternative outflows because these relatively high flows are governed by storm events and reservoir spilling operations, which are only indirectly modified by changes in AFRP objectives for instream flow.

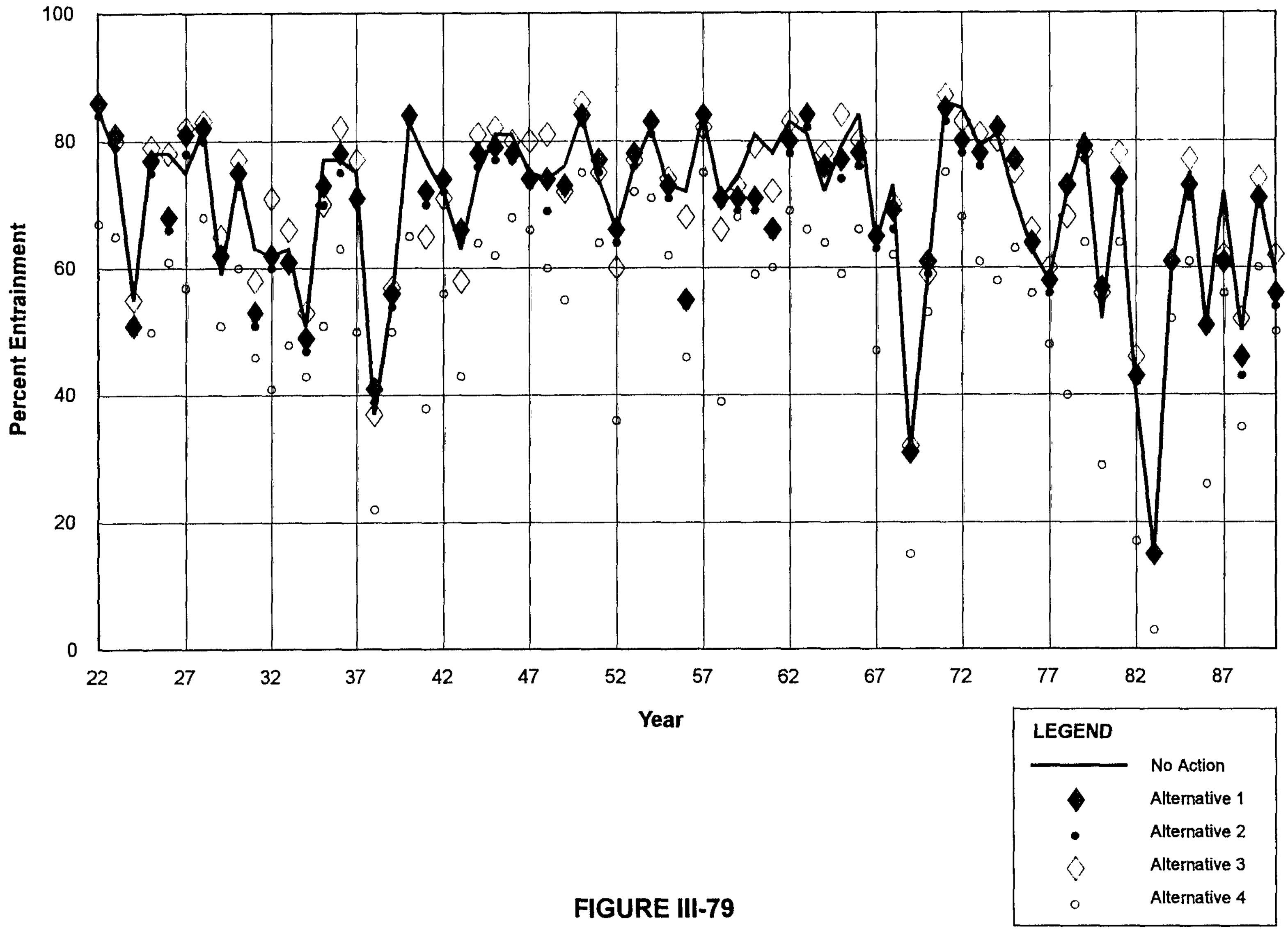

FIGURE III-79

AVERAGE FEBRUARY-JUNE PERCENT ENTRAINMENT OF WATER STARTING IN THE CENTRAL DELTA VOLUME UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

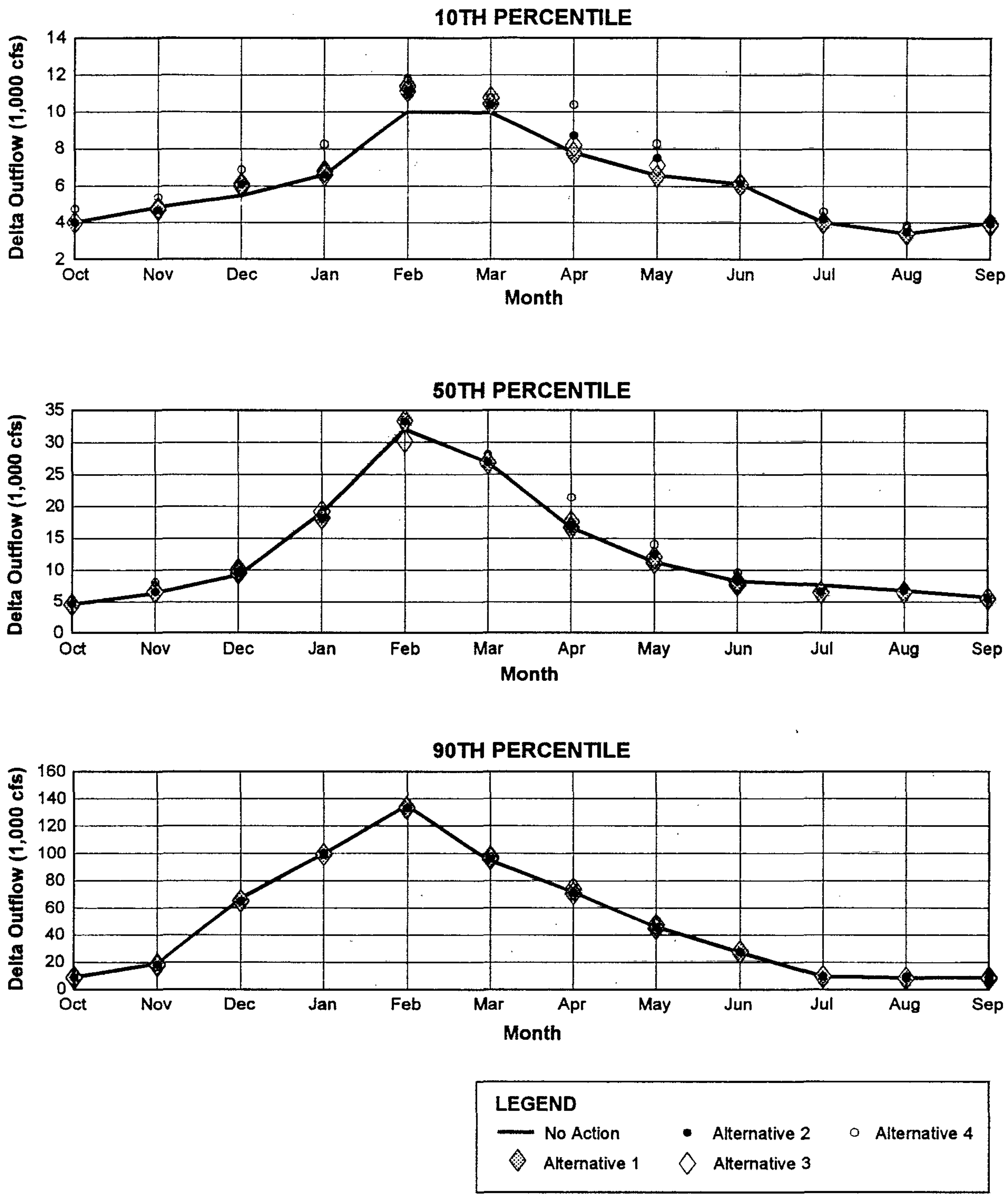

FIGURE III-80

COMPARISON OF LOW, MEDIAN, AND HIGH MONTHLY DELTA OUTFLOW UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

Figure III-81 shows the simulated monthly salinity (EC) values for Jersey Point under Alternatives 1 through 4 compared with the simulated salinity under the No-Action Alternative. Jersey Point is a compliance location for the 1995 WQCP agricultural salinity objectives. The simulated 10th percentile EC values for Jersey Point are always less than 0.5 mS/cm in all months. The September values are higher under Alternatives 1 and 2 (lower outflow) but the other monthly values are similar under all the alternatives because these low EC values are governed by high outflows. The simulated median monthly EC values for Jersey Point are similar for each alternative except that October and November values under Alternative 4 are lower (i.e., higher outflows). The simulated 90th percentile EC values for Jersey Point are similar for each alternative except that values under Alternative 4 are lower (i.e., higher outflows) in several months.

Figure III-82 shows the simulated monthly salinity (EC) values for Collinsville under Alternatives 1 through 4 compared with the simulated salinity under the No-Action Alternative. Collinsville is the upstream station for control of the X2 location in the 1995 WQCP objectives. An EC value of approximately 3 mS/cm corresponds to the 2-ppt salinity objective. The simulated 10th percentile EC values for Collinsville are always less than 3 mS/cm in all months. These low EC values correspond to the highest Delta outflow values. Simulated 10th percentile EC values for Collinsville for each alternative are similar for most months. September values are higher for Alternatives 1 and 2, while Alternative 4 values are less than the No-Action Alternative EC in July and August. The simulated median EC values for Collinsville are somewhat lower under Alternative 4 than under the No-Action Alternative in May through December. The simulated 90th percentile EC values for Collinsville are somewhat lower under Alternative 4 than under the No-Action Alternative in several months because of slightly higher simulated Delta outflows.

Figure III-83 shows the simulated monthly salinity (EC) for Chipps Island under Alternatives 1 through 4 compared with the simulated salinity under the No-Action Alternative. Chipps Island is the middle station for control of the X2 location in the 1995 WQCP objectives. The simulated 10th percentile EC values for Chipps Island are always less than 3 mS/cm in November through June under all the alternatives. These low EC values correspond to the highest Delta outflow values. Simulated 10th percentile EC values for Chipps Island are higher in September under Alternatives 1 and 2 but are somewhat less under Alternative 4 in July and August. The simulated median EC values for Chipps Island are somewhat lower under Alternative 4 in May through December. The simulated 90th percentile EC values for Chipps Island are somewhat lower under Alternative 4 than under the No-Action Alternative in several months because of slightly higher simulated Delta outflows.

Figure III-84 shows the simulated monthly salinity (EC) for Port Chicago (across from Roe Island) under Alternatives 1 through 4 compared with the simulated salinity under the No-Action Alternative. Port Chicago is the downstream station for control of the X2 location in the 1995 WQCP objectives. The simulated 10th percentile EC values for Port Chicago are always less than 3 mS/cm in December through June under each alternative. These low EC values correspond to the highest Delta outflow values. Simulated 10th percentile EC values for Port Chicago are similar under all the alternatives. The simulated median EC values for Port Chicago

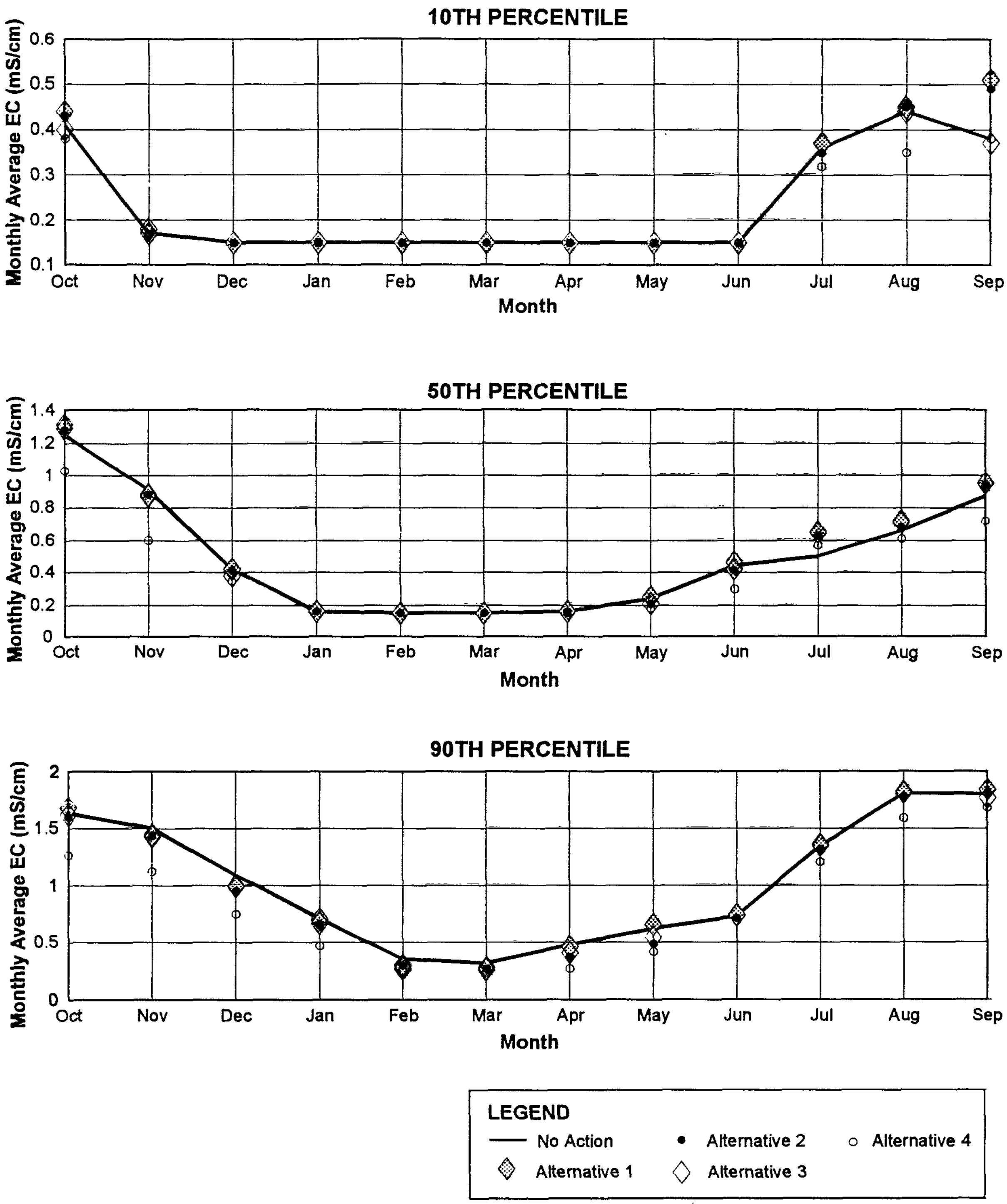

FIGURE III-81

COMPARISON OF LOW, MEDIAN, AND HIGH MONTHLY ELECTRICAL CONDUCTIVITY AT JERSEY POINT UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

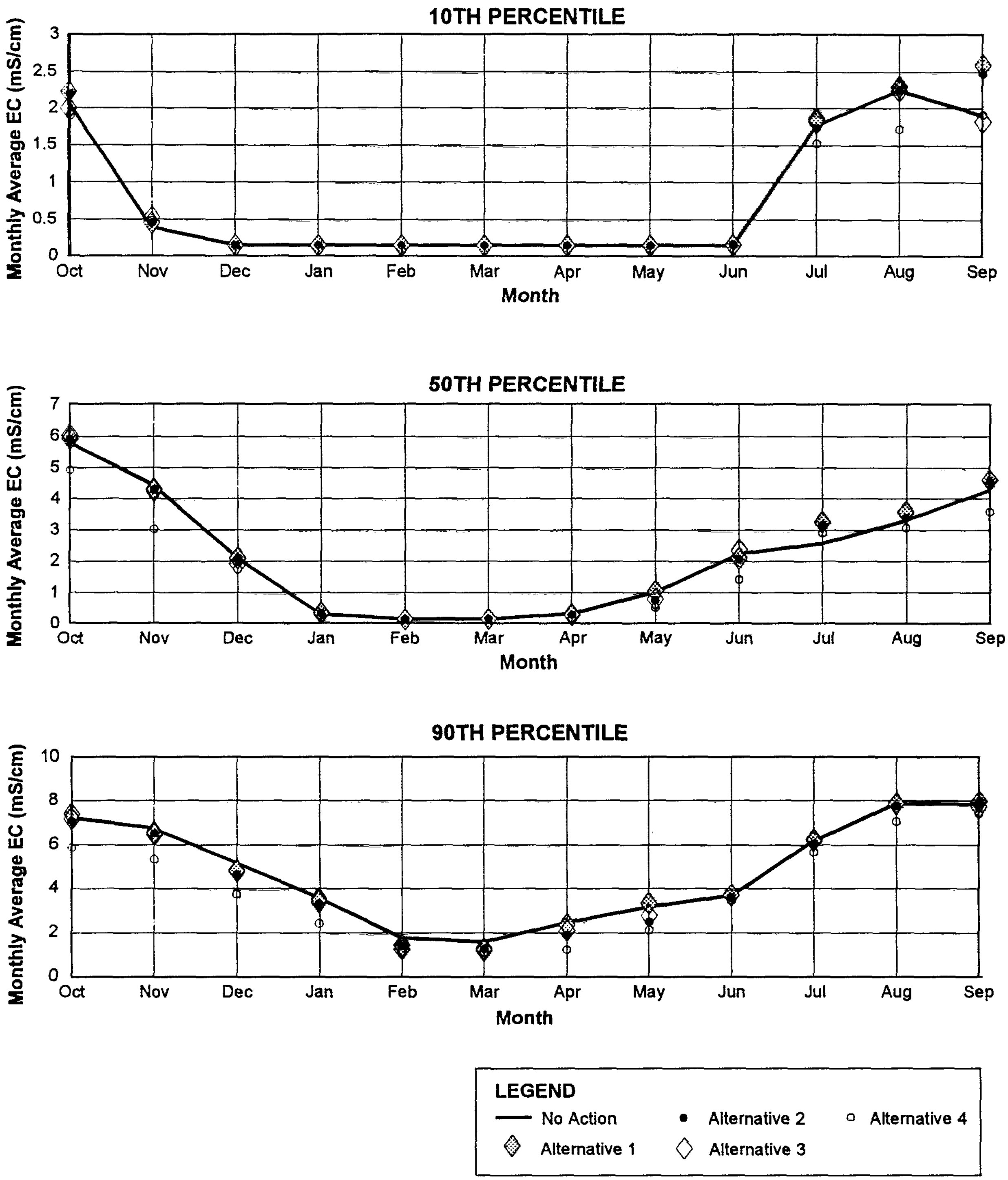

FIGURE III-82

COMPARISON OF LOW, MEDIAN, AND HIGH MONTHLY ELECTRICAL CONDUCTIVITY AT COLLINSVILLE UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

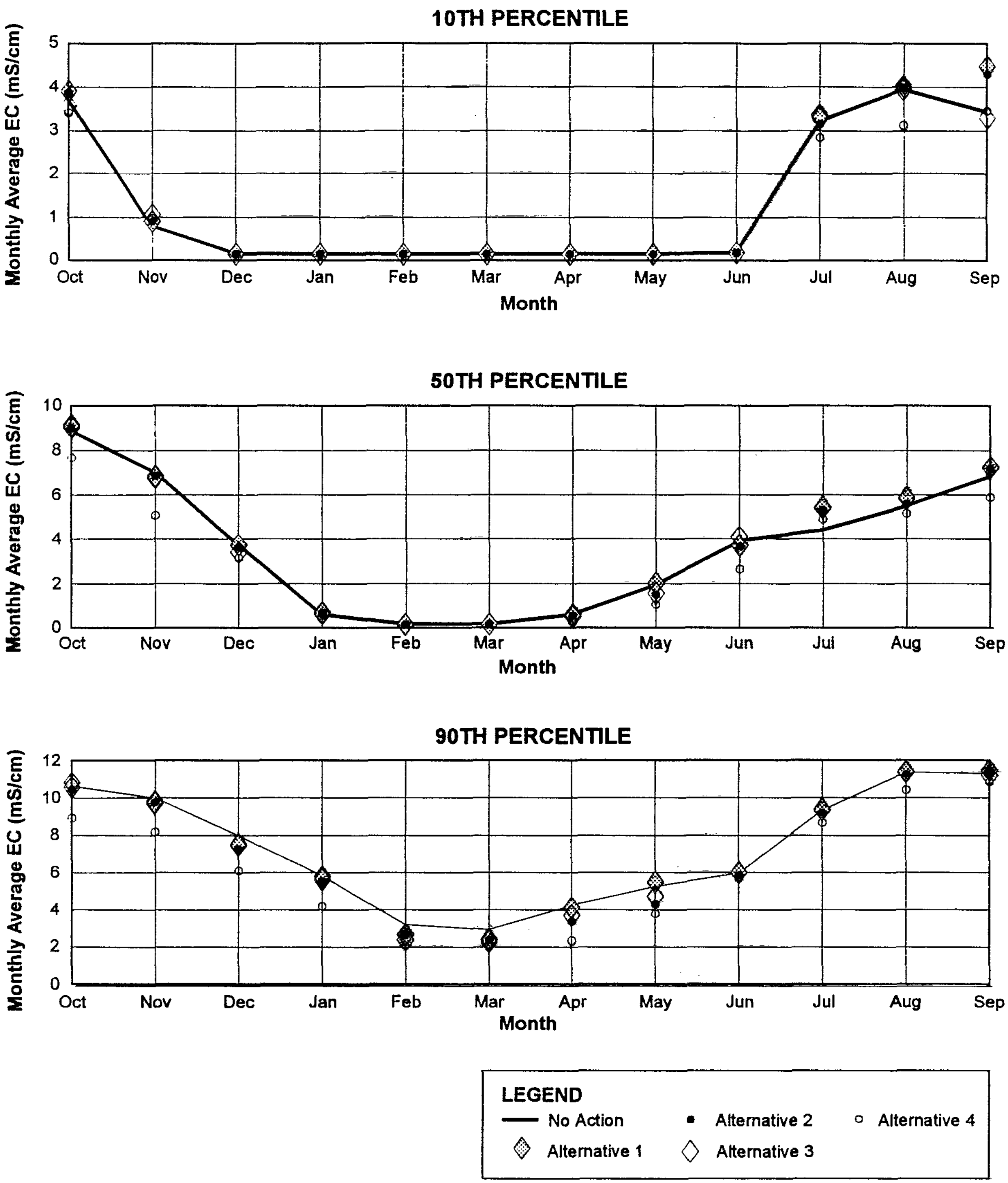

FIGURE III-83

COMPARISON OF LOW, MEDIAN, AND HIGH MONTHLY ELECTRICAL CONDUCTIVITY AT CHIPPS ISLAND UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

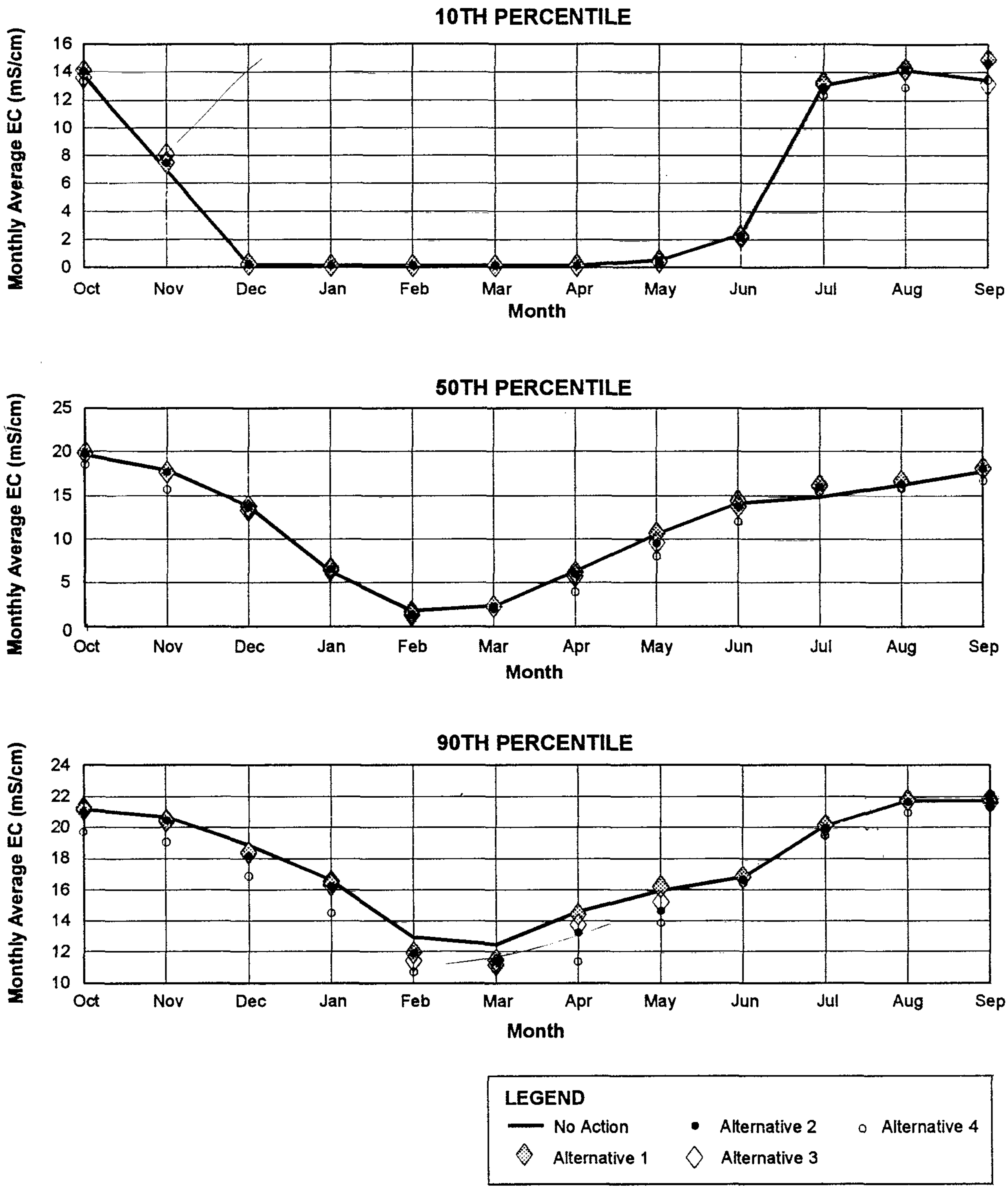

FIGURE III-84

COMPARISON OF LOW, MEDIAN, AND HIGH MONTHLY ELECTRICAL CONDUCTIVITY AT PORT CHICAGO UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

are somewhat lower under Alternative 4 than under the No-Action Alternative in April through June and September through November. The simulated 90th percentile EC values for Port Chicago are somewhat lower under some alternatives in February through May because of slightly higher simulated Delta outflows. The simulated 90th percentile EC values are lower under Alternative 4 than under the No-Action Alternative for several months because of much higher simulated Delta outflows during the periods of lowest Delta outflows.

Figure III-85 shows the simulated monthly salinity (EC) for Benicia under Alternatives 1 through 4 compared with the simulated salinity under the No-Action Alternative. Benicia is at the downstream end of Suisun Bay and therefore characterizes the highest salinity conditions in Suisun Bay. The simulated 10th percentile EC values for Benicia are less than 3 mS/cm in December through May under each alternative. These low EC values correspond to the highest Delta outflow values. Simulated 10th percentile EC values for Benicia are similar under Alternatives 1 through 4. The simulated median EC values for Benicia are somewhat lower under Alternative 4 than under the No-Action Alternative in April through June. The simulated 90th percentile EC values for Benicia are somewhat lower under Alternatives 1 through 4 than under the No-Action Alternative in February and March because of slightly higher simulated Delta outflows. The simulated 90th percentile EC values are much lower under Alternative 4 than under the No-Action Alternative in October through May because of higher simulated Delta outflows.

Figure III-86 shows the simulated monthly location of the 2-ppt salinity gradient (X2) under Alternatives 1 through 4 compared with the simulated X2 location under the No-Action Alternative. Benicia is approximately 56 km upstream of the Golden Gate Bridge, Port Chicago is 64 km upstream, Chipps Island is 74 km upstream, and Collinsville is 81 km upstream. The simulated 10th percentile X2 values (highest outflow) are downstream of Benicia in January through April under each alternative. These low X2 values correspond to the highest Delta outflow values. Because the X2 position is governed by the logarithm of flow, the 10th percentile X2 values under Alternatives 1 through 4 are very similar to the values under the No-Action Alternative. The simulated median X2 values are somewhat lower under Alternative 4 than under the No-Action Alternative in April, May, and June. The simulated 90th percentile X2 values are somewhat lower under several alternatives than under the No-Action Alternative in February through May because of slightly higher simulated Delta outflows. The simulated 90th percentile X2 values are much lower under Alternative 4 than under the No-Action Alternative in several months because of much higher simulated Delta outflows during the periods of lowest Delta outflows.

The effects of these estuarine salinity conditions on estuarine fish species rearing and tidal wetlands vegetation are described in the Fisheries Technical Appendix and the Vegetation and Wildlife Technical Appendix.

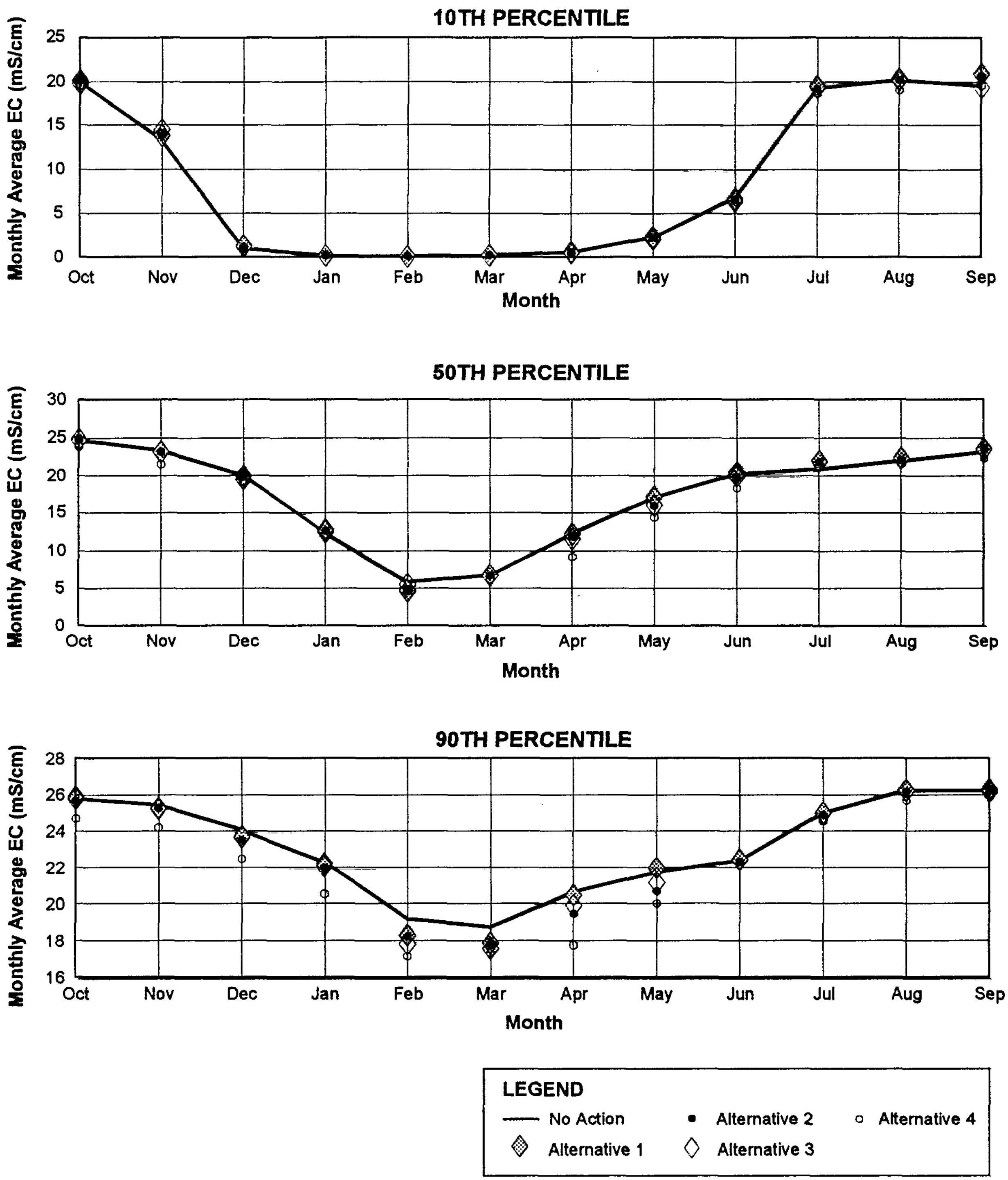

FIGURE III-85

COMPARISON OF LOW, MEDIAN, AND HIGH MONTHLY ELECTRICAL CONDUCTIVITY AT BENICIA UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

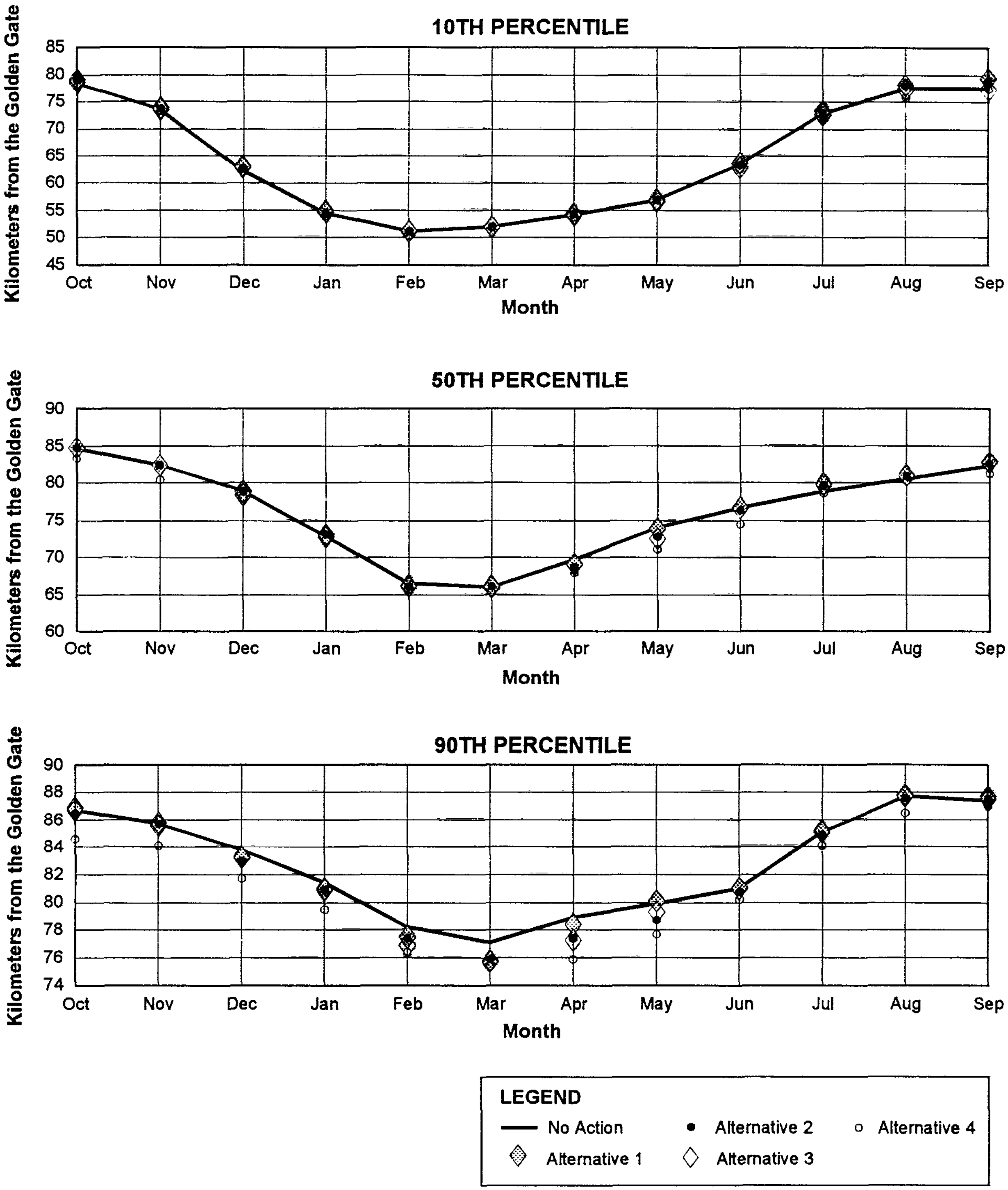

FIGURE III-86

COMPARISON OF LOW, MEDIAN, AND HIGH MONTHLY X2 POSITIONS UNDER THE CVPIA PEIS ALTERNATIVES, 1922-1990

CHAPTER IV

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Chapter IV

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