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US Army Corps
of Engineers
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Special Study on the Lower American River, California

Prepared for
U.S. Bureau of Reclamation
Mid-Pacific Region
and
California Department of Water Resources
Central District

March 1987

SPECIAL STUDY ON THE

LOWER AMERICAN RIVER, CALIFORNIA

PREPARED FOR

U. S. BUREAU OF RECLAMATION - MID-PACIFIC REGION

AND

CALIFORNIA DEPARTMENT OF WATER RESOURCES
CENTRAL DISTRICT

MARCH 1987

DEPARTMENT OF THE ARMY
SACRAMENTO DISTRICT, CORPS OF ENGINEERS
SACRAMENTO, CALIFORNIA

SPECIAL STUDY ON THE LOWER AMERICAN RIVER, CALIFORNIA

EXECUTIVE SUMMARY

A Special Study was conducted by the Sacramento District, Corps of Engineers, at the request of the U.S. Bureau of Reclamation, Mid-Pacific Region (USBR) and the California Department of Water Resources, Central District, with an objective to accomplish the following:

- Review and update the hydrology of the American River and determine areas of potential flooding and flood damages.

- Review and update alternative flood control measures provided to the USBR in 1974 and 1982 and described in previous studies by USBR and DWR.

- Reevaluate the flood control benefits of the alternative measures.

The primary study area is about 23 miles of the lower American River between Nimbus Dam and the Sacramento River. Other areas considered were the American River and its tributaries upstream from Nimbus Dam, Natomas East Main Drainage (NEMD) Canal from the American River upstream to about Dry Creek, Sacramento River from the American River upstream to the Sacramento Weir, and Yolo Bypass and its immediate tributaries and distributaries. Major flood control facilities in the study area are Folsom Dam and Reservoir, located about 25 miles east of Sacramento, and a complex system of levee and channel improvements downstream along the American and Sacramento Rivers and in the Yolo Bypass.

In February 1986, major storms in northern California caused record floodflows in the American River Basin. Peak outflows from Folsom Reservoir of 130,000 cubic feet per second (cfs) exceeded the objective reservoir releases of 115,000 cfs. Prior to this study, it was believed that a flow of 115,000 cfs would not be exceeded more frequently than once in 100 years on the average. Studies of Folsom Reservoir flood operation and flow-frequency relationships were conducted incorporating an additional 25 years of record (1961-1986). These studies show that the February 1986 flood was about a 70-year event and that Folsom Reservoir is capable of controlling only about the 63-year flood to 115,000 cfs. In addition, the currently estimated peak flow for the 100-year flood along the lower American River is about 230,000 cfs.

For economic evaluation purposes and using the updated hydrologic information and other available data, a potential levee failure scenario was formulated and four major flood plains were delineated. Three of the flood plains (north side of river upstream from the NEMD Canal, south side of river near Watt Avenue, and, for rare events, Downtown Sacramento) are primarily affected by flows in the American River. Potential flooding in the fourth area, Natomas, is also influenced by flows in the NEMD Canal and the Sacramento River. Together, these flood plain areas contain an estimated 325,000 people and about $15 billion in damageable property. It is believed the threat to life from flooding is significant. Also, average annual flood damages in the areas are estimated at about $123 million.

A number of measures to reduce the flood threat have been identified in previous studies and reports by USBR, DWR, and the Corps. They generally fall into one or more of the following categories:

- Increase flood control storage in Folsom Reservoir,
- Increase Folsom Reservoir's objective outflows (i.e., increase downstream levee and channel flood carrying capacity),
- Construct new upstream flood control storage,
- Use existing upstream reservoir storage for flood control, and
- Perform structural modification of Folsom Dam to permit increased releases at lower pool elevations.

Two other potential measures include construction of offstream storage and construction of levee and channel improvements along the NEMD Canal.

Primary findings are: (1) an area of Sacramento where over 300,000 people live and having a value of flood damageable property of about $15 billion is estimated to have as low as a 63-year level of flood protection, (2) most of the measures reviewed in this study, or their combinations, are capable of achieving increases in the level of flood protection along main-stem American River to about 100 years, and (3) high levels of protection (i.e., about 200 years or better) can be achieved by construction of new storage upstream from Folsom Reservoir. It was also found that most of the measures could help reduce the potential for flooding in the Natomas area. However, resolution of this specific flood problem was outside the scope of this study, but is being considered in other Corps investigations.

Major impacts of the measures considered, directly relating to the flood control, were developed by the USBR and are described as a part of this study. A summary comparison tabulation of the accomplishments, benefits, costs (to the extent they are known), and impacts to water supply and hydropower is also included. (See Table 16.)

In addition to this special study for the USBR and DWR, the Corps, as the Federal flood control agency, has three flood-related investigations underway in the greater Sacramento area. (See Chapter V.) They include the Congressionally authorized American River Watershed Investigation, Sacramento River Flood Control System Evaluation, and the Dry Creek Investigation. A fourth study, Sacramento Metropolitan Area Reconnaissance Study, is included in the President's Budget for initiation in Fiscal Year 1988. With these studies, the Corps will evaluate potential solutions to flood problems in the area and solicit or confirm non-Federal sponsorship in the implementation of these solutions.

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CHAPTER I - INTRODUCTION

1. General. - In May 1986, the U.S. Bureau of Reclamation - Mid-Pacific Region (USBR) and California Department of Water Resources - Central District (DWR) requested the Sacramento District Army Corps of Engineers to reassess potential flooding, flood damages, and flood control measures along the lower American River. The main objectives of the requests are as follows:

- Review and update the hydrology of the American River and determine areas of potential flooding and flood damages.

- Review and update alternative flood control measures provided to the USBR in 1974 and 1982 and described in previous studies by USBR and DWR.

- Reevaluate the flood control benefits of the alternative measures.

Hydrologic and related reservoir operation studies, flood plain delineations, flood damages, costs, benefits, and impact information are of reconnaissance scope.

2. Study area. - The primary study area comprises the American River generally downstream from Nimbus Dam about 23 miles to the Sacramento River, including locations that could potentially be flooded from high flows in the American River. Other major areas of interest considered in the study included: (1) American River and its tributaries upstream from Nimbus Dam, (2) Natomas East Main Drainage (NEMD) Canal including the Natomas area from American River upstream to about Dry Creek, (3) Sacramento River from American River upstream to Sacramento Weir, and (4) Yolo Bypass. Plate 1 is a map of the American River Basin and vicinity.

The American River Basin encompasses about 2,100 square miles. The headwaters of the basin originate in the Sierra Nevada Mountains at an elevation of about 10,400 feet and flow generally westward. Elevation of the basin where the American River flows into the Sacramento River at Sacramento is near sea level. The upper portion of the basin includes numerous natural lakes. There is a well-developed drainage system consisting of three principal streams, North Fork, Middle Fork, and South Fork. These streams are embedded in deep canyons and flow generally westward. The North and Middle Forks merge near the City of Auburn. The South Fork joins the main-stem in Folsom Lake, located about 25 miles east of Sacramento. The main tributaries downstream from Folsom Lake are Dry and Arcade Creeks.

The basin includes much of El Dorado and Placer Counties and the northern portion of Sacramento County. The population growth rate in each of these counties is projected to exceed the growth rate of the State of California through the year 2020. Table 1 shows the current and projected population for these areas.

TABLE 1

PROJECTED POPULATION - 1986-2020

Location	1986 1/	1990	2000	2010	2020
Sacramento City	322,500	337,769 2/	393,515 2/	458,493 2/	3/
Sacramento Co.	905,500	993,000 4/	1,184,000 4/	1,351,200 4/	1,511,700 4/
El Dorado Co.	106,100	123,100 4/	158,500 4/	193,900 4/	229,000 4/
Placer Co.	140,300	159,400 4/	203,700 4/	245,800 4/	288,000 4/

1/ 1-1-86 Department of Finance, State of California, May 1986.
2/ Sacramento Area Council of Governments, Sacramento City 1990-2020 Projections.
3/ Data not available.
4/ 1990-2020 Projections by Department of Finance, State of California, December 1986.

3. Study participants. - Following are the primary participants in this study:

a. U.S. Bureau of Reclamation - Mid-Pacific Region. - The USBR operates Folsom Dam and Reservoir for water supply, hydropower, and flood control. Operational parameters for flood control are prescribed by the Corps. The USBR contributed funds towards the accomplishment of this study. It also (1) evaluated potential impacts on water supply, hydropower, and related recreation and environmental parameters resulting from possible modifications of Folsom Lake for flood control and (2) estimated costs for various dam and reservoir alternatives upstream from Folsom Lake.

b. California Department of Water Resources - Central District. - The DWR performs maintenance for some project levees along the American River. It contributed funds toward accomplishing this study and is interested in reducing potential flood damage along the lower American River.

c. Sacramento City and County. - Representatives from the City and County of Sacramento have provided field survey data and input on several alternative flood protection measures near Sacramento.

CHAPTER II - EXISTING PROJECTS

4. General. - Flood control facilities in the primary study area include Folsom Dam and a complex system of downstream levee and channel improvements. The American River below Folsom Dam flows through the American River bluffs past Rancho Cordova, into the historical flood plain (where it is leveed on both sides by Federal project and private levees), and empties into the Sacramento River. The lower Sacramento River system consists of a narrow leveed river channel and relief weirs paralleled by a large leveed bypass channel. This system conveys floodwaters of the Sacramento River and its principal tributaries across a broad alluvial valley to the tidewater near Suisun Bay.

5. Folsom Dam. - Folsom Dam is a multiple-purpose project constructed by the Corps and operated by the USBR as part of the Central Valley Project (CVP). Folsom Dam regulates runoff from about 1,860 square miles of drainage area. Folsom Lake has a normal full pool storage capacity of 1,010,000 acre-feet (ac-ft) with a seasonally designated flood control storage space of 400,000 ac-ft. Reservoir releases are controlled by two tiers of flood control outlets located in the main dam; each tier has four outlets 5 feet wide by 9 feet high; five radial-type spillway gates 42 feet wide by 50 feet high; and three radial-type emergency spillway gates 42 feet wide by 53 feet high. The Corps Reservoir Regulation Manual for the project lists pertinent physical and operational features of Folsom Dam and Reservoir. Studies conducted to date under the Safety of Dams Program have indicated that the spillway on Folsom Dam is capable of passing about 70 percent of the Probable Maximum Flood (PMF). A study by the Corps to determine the risk to downstream areas associated with the adequacy of the current spillway and costs for correcting the deficiency will be undertaken when funding becomes available.

6. Nimbus Dam. - Nimbus Dam and its reservoir, known as Lake Natoma, are located about 6 miles downstream from Folsom Dam. Nimbus Dam is a power afterbay to Folsom and a diversion dam constructed and operated by the USBR also as part of the CVP. The reservoir has a capacity of 8,760 ac-ft. Because of the small capacity, it essentially has no regulatory effect on floodflows in the American River.

7. Sacramento River Flood Control Project. - Features of the Sacramento River Flood Control Project associated with the American River Basin consist of levee improvements along the lower American River, NEMD Canal, Sacramento River, and Yolo Bypass. These levees are maintained by non-Federal interests. The location of these levees is shown on Plate 2.

a. American River. - The existing south bank levee along the American River was upgraded in 1948 to Corps standards. The levee extends from the Mayhew Drain at Mayhew Road downstream about 11 miles to the east bank levee of the Sacramento River. The north bank levee from a point near the eastern boundary of Cal Expo to the Sacramento River was constructed and/or upgraded to Corps standards in 1955.

b. Natomas East Main Drainage Canal. - Levees along the NEMD Canal and upstream along both banks of Arcade Creek and the south bank of Dry (also known as Linda) Creek were constructed or included in the Sacramento River Flood Control Project from 1955 to 1957. The reach of the Canal from the American River to Arcade Creek has a design capacity of 16,000 cfs, from Arcade Creek to Dry Creek between 12,600 and 12,900 cfs, and upstream from Dry Creek 1,100 cfs. At these flows the levees were designed for a freeboard of at least 3 feet from American River upstream to about Dry Creek and 2.5 feet farther upstream from Dry Creek.

c. Sacramento River. - Levees along the east and west banks of the Sacramento River between the Sacramento Weir and the American River (see Plate 1) are designed to have 3 feet of freeboard at a flow of 107,000 cfs. Downstream of Sacramento to about Courtland, the design freeboard of the system is also 3 feet but at a flow of 110,000 cfs.

d. Yolo Bypass. - The Yolo Bypass is a complex series of levee and channel improvements from the terminus of the Sutter Bypass to near Rio Vista on the Sacramento River. The Yolo Bypass receives flow from west side tributaries, the Sacramento River, and sometimes from the American River. When the combined flow of the Sacramento and Feather Rivers and Sutter Bypass exceeds about 70,000 cfs, most of the excess spills over the Fremont Weir into the Yolo Bypass. Additionally, when flows in the Sacramento River at the "I" Street Bridge reach 94,000 cfs, gates at the Sacramento Weir are opened,

allowing excess flow into the Yolo Bypass. During extremely high flow conditions, flows from American River will enter the Yolo Bypass via Sacramento Weir. The design capacity of the Yolo Bypass at a freeboard of 6 feet from Fremont Weir to Sacramento Weir is 343,000 cfs, from Sacramento Weir to Putah Creek 480,000 cfs, and from Putah Creek to Sacramento River 500,000 cfs.

8. American River Flood Control Project. - The American River Flood Control Project, constructed by the Corps in 1958 and operated and maintained by DWR, consists of a levee along the north bank of the river (see Plate 2). The levee extends from the upstream terminus of the Sacramento River project levee near the eastern boundary of Cal Expo upstream about 8 miles to the Carmichael Bluffs. The project is designed for 115,000 cfs at minimum 5 feet of freeboard.

9. Others. -

a. Non-Federal levees. - Levees have been constructed by local developers upstream of the project levees on the south bank of American River from the Mayhew Drain to Sunrise Boulevard. A levee constructed from Mayhew Drain upstream about 1 mile is about 4 feet high and can probably accommodate approximately 120,000 cfs with minimum freeboard encroachment. Two other levees were constructed locally, one extending from about the southern boundary of Goethe Park west approximately 1 mile, and the other extending from just downstream of Sunrise Boulevard west about one-half mile.

b. Upstream reservoirs. - There are numerous reservoirs upstream from Folsom. Several of the most significant are listed in Table 2. As can be seen, the total storage capacity in these reservoirs is about 820,000 ac-ft. All of these reservoirs are used for water supply and/or hydroelectric power generation. None have designated flood control space. There are also minor irrigation diversions into and out of the American River Basin. Since the reservoirs are at relatively high elevations, where much of the precipitation occurs as snow, they have no significant effect on flood reduction.

TABLE 2

MAJOR RESERVOIRS IN THE UPPER AMERICAN RIVER BASIN

Reservoir	Stream/American River Tributary 1/	Owner 2/	Elev. Top of Dam (ft)	Capacity (ac-ft)
Lake Clementine	N.F.	COE	716	10,600
L.L. Anderson (French Meadows)	M.F.	PCWA	5271	136,400 3/
Hell Hole	Rubicon Riv-M.F.	PCWA	4630	207,600
Lake Edson (Stumpy Meadows)	Pilot Cr-M.F.	GDPUD	4318	20,000
Loon Lake	Gerle Cr-M.F.	SMUD	6418	76,500
Union Valley	Silver Cr-S.F.	SMUD	4883	271,000 3/
Ice House	S.F. Silver Cr-S.F.	SMUD	5454	46,000 3/
Slab Creek	S.F.	SMUD	1870	16,600
Caples Lake	Caples Cr. - S.F.	PG&E	7960	20,400
Silver Lake	Silver Fork - S.F.	PG&E	7211	3,800
Ralston After Bay	Rubican R. - M.F	PCWA	1189	850
Chili Bar	S.F.	PG&E	1029	3,140
Gerle Div Dam	Gerle Cr. - S.F.	SMUD	5240	1,380
Junction Div Dam	Silver Cr. - S.F.	SMUD	4468	3,250
Camino Div Dam	Silver Cr. - S.F.	SMUD	2918	290
Rubicon Springs Dam	M.F.	SMUD	6246	1,500
Oxbow	M.F.	PCWA	--	2,800
TOTAL				822,110

1/ N.F. - North Fork American River
M.F. - Middle Fork American River
S.F. - South Fork American River

2/ COE - Corps of Engineers
PCWA - Placer County Water Agency
GDPUD - Georgetown Divide Public Utility District
SMUD - Sacramento Municipal Utility District
PG&E - Pacific Gas and Electric Company

3/ Effective storage is reduced during winter months for dam safety.

10. Flood of record - 1986. - In February 1986, large floodflows in the American River Basin caused record inflow volumes to Folsom Reservoir. A maximum 6-day inflow volume of 1,140,000 ac-ft exceeded the 6-day Reservoir Design Flood volume of 978,000 ac-ft. Because of fairly dry conditions earlier in the water year, about 200,000 ac-ft of storage space happened to be available in the upstream reservoirs. If the flood volume which was stored in those reservoirs had been added to Folsom's inflow, the 1986 flood would have resulted in 5- and 6-day volumes greater than the Standard Project Flood volumes computed in 1961. Releases from Folsom Dam exceeded the objective outflow of 115,000 cfs for about 2 days, and it was necessary to release flows of 130,000 cfs for about 24 hours. During the flood, significant levee erosion occurred along the American River at several locations, and the design 5-foot freeboard was encroached along the north levee in the vicinity of Howe Avenue bridge. In addition, encroachment of nearly 2 feet into the design freeboard of 3 feet occurred along the NEMD Canal, in part due to high stages in the American River. Had these high flows continued much longer or increased, major levee failure and flooding would have been likely along the American River and the NEMD Canal.

11. Flood protection. - The degree of flood protection along the lower American River is estimated based on the expected frequency of flows exceeding the Reservoir Design Flood (400,000 ac-ft of flood control storage with a maximum outflow of 115,000 cfs). The Reservoir Design Flood for Folsom, developed in 1945, is an estimate of the flood that would have resulted from the most critical storm that had been recorded in the climatic region. A study of the precipitation during storms of record in the region indicated that the December 1937 storm was the most critical. The Reservoir Design Flood has a peak flow of 340,000 cfs and a volume of 978,000 ac-ft of runoff in 6 days.

At the time of constructing Folsom Dam, protection against the Reservoir Design Flood was considered to be very high. However, primarily because of additional years of flow record, the Reservoir Design Flood is now estimated to occur much more frequently. Since the completion of Folsom Dam in 1956,

three rain floods have exceeded the volume of the Reservoir Design Flood (December 1955, December 1964, and February 1986).

a. Flow-frequency estimates - unregulated. - In 1961 a statistical analysis was conducted to estimate the likely frequency of occurrence for various flows in the American River at the Fair Oaks gage downstream from Folsom Dam. This analysis indicated that Folsom Dam could control all flows up to the 120-year flood. However, because of the February 1986 flood and since 5 of the 10 largest flows in the basin for 82 years of record have occurred since 1961, and 7 of the 10 largest events have occurred since 1951, a new flow-frequency analysis was conducted. The first step in this reanalysis was to update the unregulated rain flood volume flow-frequency relationships at the Fair Oaks gage. These relationships reflect the flow data collected for the period 1905 to 1954 and adjusted flow data for 1955 to 1986. The adjusted flows account for the effects of French Meadows, Hell Hole, Loon Lake, Union Valley, and Ice House Reservoirs. This adjustment is necessary to provide a consistent record for statistical analysis. Pertinent information about the lag times used to route flows into Folsom is tabulated in Table 3.

Updated rain flood-frequency curves are shown on Plate 3. They reflect 82 years of record (1905 - 1986) for unregulated conditions for the American River at the Fair Oaks gage for 1-, 3-, 5-, 7-, 10-, 15-, and 30-day durations.

b. Flow-frequency estimates - existing conditions. - A revised peak flow-frequency curve was developed for the American River downstream from Folsom Dam. Estimated effects of storage in the reservoirs upstream in the basin were included in the derivation of the curve. The 31 years of actual recorded flow data since construction of the dam were used to define the plotting positions of flows more frequent than about the 50-year exceedence interval. To help define the plotting positions of flows less frequent than the 50-year event, hypothetical flood hydrographs were developed and routed through Folsom. The routing assumed currently applicable criteria, some of which has been updated from that used in the operation during the February 1986 flood. The resultant flow-frequency curve is shown on Plate 4.

TABLE 3

PERTINENT INFORMATION FOR SEVERAL UPSTREAM RESERVOIRS

Reservoir	Drainage Area (sq-mi)	Routing Data		
		Distance to Folsom (river miles)	Average Velocities (fps) 1/	Lag Times (hours)
French Meadows	47	61	3.4	26
Hell Hole	114	68	3.4	29
Loon Lake 2/	30	75	3.6	31
Union Valley	84	57	2.7	31
Ice House	27	64	2.8	33

1/ Feet per second
2/ Loon Lake drains only 8 square miles, but receives the diversions from drainage areas above Hell Hole Reservoir. Up to 1,200 cfs is diverted to Loon Lake; the rest continues downstream to Hell Hole Reservoir.

One of the floods used for routing was the 100-year event. Plate 5 shows a hydrograph for this flood. The reduction in inflow to Folsom Lake due to storage in upstream reservoirs is shown on the rising limb of this hydrograph. A review of historical floods showed that about 47,000 ac-ft of effective upstream storage space would be available during major floods up through about 100-year frequency. No reductions in inflow to Folsom were made for floods larger than the 100-year event because it was assumed that preceding storms would have been sufficient to fill the upstream storage space. Only about 14 percent of the American River Basin lies above these reservoirs.

Pertinent criteria used in the reservoir routings for Folsom are as follows:

- At the beginning of each hypothetical flood, Folsom was assumed to have an initial encroachment of 80,000 ac-ft in the flood control space with a concurrent outflow of 20,000 cfs. This encroachment was used in the routings simulation to account for uncertainties in realtime operation that have been experienced during 20 years of actual operations.

- Releases from Folsom Dam were limited by outlet and spillway capacities. Releases below the spillway crest were made through the eight outlet works; an additional 7,000 cfs was released through the powerhouse.

- Releases were made in conformance with the Flood Control and Emergency Release Diagrams currently in force. The Emergency Release Diagram governs releases greater than the design channel capacity.

c. Standard Project Flood. - The USBR requested that the SPF be reevaluated as part of this study. For this study, the SPF was computed as a percentage of the Probable Maximum Flood (PMF). A PMF was developed in 1980 for the American River Basin to evaluate the adequacy of the Folsom spillway. The PMF represents a flood that may be expected from the most severe combination of critical meteorologic and hydrologic conditions. For this analysis, 60 percent of the PMF was used for the revised SPF, based on SPF/PMF ratios used for similar basins in the Sierra Nevada. Under unregulated conditions, the revised SPF plots at about a 350-year frequency for a 1-day flow, 250-year frequency for a 3-day flow, and a 200-year frequency for a 4-day flow duration. This flood is about 15 percent larger in peak and 34 percent larger in volume than the SPF developed in 1961. For the remainder of this report, the SPF will be referred to as the 250-year event.

d. Summary of Folsom Reservoir flow-frequency. - Table 4 summarizes Folsom Reservoir peak flow-frequency relationships. It shows peak inflows and outflows to the reservoir for selected frequency flood events. The table (also see Plate 4) shows that the reservoir can control all events up to the 63-year flood to outflows of 115,000 cfs or less. It also indicates that above about the 200-year event, the reservoir offers little reduction in inflow; i.e., outflow is approximately equal to inflow.

TABLE 4

FOLSOM RESERVOIR - FLOW FREQUENCY

Flow-Frequency Return Period (yrs)	Peak Inflow (1,000 cfs)	Peak Outflow (1,000 cfs)
50	274	115
63 1/	300	115
85	332	180
100	353	234
200	442	432
250 (SPF)	530	530
500	578	578

1/ Maximum frequency of control.

12. Potential flooding. - Using the above and related pertinent hydrologic information and data about the levee and channel conditions, an analysis was made of the frequency, extent, and damage resulting from major flooding. Following is a description of this analysis and its results.

a. Levee failure. - Levees can fail for several reasons, and it is difficult to predict how and where failures will occur. Levees have been known to fail when water stages are significantly below design freeboard. On the American River during the February 1986 storms, levee damage from erosion occurred at several locations having adequate freeboard. At other locations freeboard was encroached, but significant damages did not occur.

For economic analysis in this study, the levee failure mode assumed was based on encroachment into the levee freeboard and a projection of the impacts of this encroachment on the physical system. High-water-marks and recorded flows for the 1986 flood served as a guide in determining the flows and locations of freeboard encroachment.

The likely first location of levee failure was estimated to occur in the Natomas area from the west levee of the NEMD Canal downstream from Dry Creek when the 3 feet of freeboard was encroached by 2 feet. One foot of remaining freeboard was chosen as the failure threshold primarily because (1) the levee

has withstood nearly this magnitude of encroachment without failure and (2) velocities in the drain would be relatively low. During the February 1986 event, with flows in the river at the mouth of the drain of 130,000 cfs, remaining freeboard of between 1 and 2 feet was observed at several locations along the west levee near Arcade and Dry Creeks. It was assumed a levee failure would occur with American River flows of about 135,000 cfs and flows in the lower NEMD Canal of about 16,000 cfs. This combination of events is expected to have a return period of about once in 70 years. It must be noted that even with flows in the American River controlled to 115,000 cfs, the freeboard of the west NEMD Canal levee can be encroached by backwater and high flows, primarily from Dry and Arcade Creeks, to a stage equal to that resulting from the 135,000 cfs/16,000 cfs combination mentioned above.

The second location of levee failure was estimated to occur along the north project levee between H Street and Howe Avenue into the North Sacramento area with riverflows of 140,000 cfs (also with a return period of about once in 70 years). At this flow, the freeboard of the levee would be about 30 percent encroached upon.

The third location of levee failure was estimated to be on the south side of the river just east of Mayhew Drain with riverflows of 140,000 cfs. The integrity of the private levee at this location is uncertain; the levee is about 5 feet lower than the project levee to the west, and it would have a remaining freeboard of only about 3 feet at a flow of 140,000 cfs.

The fourth location of estimated failure was into the South Sacramento area from a breaching of the Federal project levee just west of Mayhew Drain, with flows of 180,000 cfs (return period of about 85 years). This flow was chosen since at 180,000 cfs (1) the design freeboard on the Federal levees of 5 feet would be encroached by about 2 feet and (2) the upstream private levee would have been failed at a flow of 140,000 cfs, subjecting the Federal levees to outflanking with a flow of 180,000 cfs.

The next location of failure was estimated to be along the north levee east of Watt Avenue in the North Sacramento area near American River Drive, also at a riverflow of 180,000 cfs.

The last area of estimated sequential failure was into Downtown Sacramento with a flow in the river at that location of 180,000 cfs. The frequency of this occurrence is mainly dependent on remaining flows in the river after accounting for upstream losses due to levee breaks. The primary upstream failure to affect the downtown area would be the South Sacramento location. It is estimated that with an outflow from Folsom Dam of about 290,000 cfs, 180,000 cfs could reach the downtown area with a stage great enough to encroach on the levee freeboard. This condition (see Plate 4) has an estimated return period of about 125 years.

It should be mentioned that a railroad embankment which roughly parallels the south side of the south project levee is expected to offer additional flood protection to the downtown area. The elevation of the top of the embankment is similar to the project levee. The City of Sacramento has an emergency plan to seal openings through the embankment (railroad, roadways, footpaths, etc.) in the event of impending flooding. However, for economic purposes in this study, it was assumed that should the south project levee fail, the river stages would be significantly great enough to also cause a breaching of the railroad embankment. As the flood prevention effectiveness of the embankment depends on several critical parameters (stability of the embankment and closures and successful implementation of closure actions), this assumption appeared appropriate for this study.

Plate 6 shows levee and water surface profile information along the American River and in the NEMD Canal. The information is based on construction drawings and high-water-mark surveys taken during the 1986 peak flow of 130,000 cfs. Also shown are estimated profiles for flows in the river of 115,000, 150,000, and 180,000 cfs.

Table 5 is a summary of flows and frequencies for flood plain areas that would be affected by the assumed levee failures.

b. Flood plains.- To help identify major areas potentially subject to flooding, a flood plain was developed for a flow along main-stem American River of 425,000 cfs (return period of about 200 years). It is estimated that this flood plain covers an area of about 100,000 acres and consists of four sub-areas, depending on the location of expected levee failures. The

TABLE 5

FREQUENCY OF LEVEE FAILURE 1/

Flood Plain	American River Flows @ Fair Oaks (1,000 cfs)	American River Flows Near Assumed Failure Location (1,000 cfs)	Flow-Frequency Return Period (yrs)
Natomas 2/	135	135	70
North Sacramento			
- Upstream "H" St. Bridge	140	140	71
- Upstream Watt Ave.	180	180	85
South Sacramento			
- East of Mayhew Drain	140	140	71
- West of Mayhew Drain	180	180	85
Downtown Sacramento	290	180	125

1/ For flood damage estimate purposes only. Actual levee failures may occur at higher or lower flows.
2/ Plus added flow of about 16,000 cfs in lower NEMD Canal.

sub-areas include (1) Natomas, (2) North Sacramento, (3) South Sacramento, and (4) Downtown Sacramento. The Natomas flood area extends from the Sacramento River on the west to the NEMD Canal on the east and from the American River on the south to the Natomas Cross Canal on the north. The North Sacramento flood area is adjacent to the north project levee from about 2 miles east of Watt Avenue, west to the NEMD Canal and includes areas as far north as Dry Creek. The South Sacramento area ranges from about Bradshaw Road in the east to about Business 80 in the west and from the American River on the north to as far south as Sheldon Road. Included in this South Sacramento area are several relatively small areas of potential flooding east of Bradshaw Road and near Sunrise Avenue. The Downtown Sacramento flood plain extends south of the American River to where it meets with the South Sacramento flood plain and is bounded on the west by the Sacramento River and on the east by Highway 99. The estimated area and 1985 population for the flood plain areas are shown in Table 6.

TABLE 6

ESTIMATED POPULATION AND AREA IN THE 200-YEAR FLOOD PLAIN

Flood Plain	1985 Population	Area (acres)
Natomas	21,900	47,900
North Sacramento	55,900	5,800
South Sacramento	199,300	35,200
Downtown Sacramento	48,100	8,800
TOTAL	325,200	97,700

Once levee failures occur, regardless of the frequency, the flooded areas would be similar in the Natomas, Downtown Sacramento, and, to some extent, North Sacramento areas. This is because (1) the ground elevation adjacent to the levees in these locations is low in comparison to the water surface in the river and (2) the volume of runoff available in the American River (and Sacramento River in the case of the Natomas and downtown areas) would fill the flood plains. However, for South Sacramento, the area of flooding would expand as a function of flow diverted from American River, depending on the stage in the river.

It should be mentioned that the Natomas area and possibly portions of South Sacramento and Downtown Sacramento can also be flooded from failure of the east levee of the Sacramento River. An assessment of this flooding potential is being evaluated in the American River Watershed Investigation (see Chapter V).

13. Consequences of flooding.- There would be disastrous consequences from a failure of the American River levees, because the flood plain is highly developed in residential, commercial, industrial, and public properties. Following is a brief description of the potential impacts of flooding on public safety and flood damages.

a. Public safety. - The major adverse impact resulting from a major levee failure would be the loss of human life. The extent of the impact would depend on the location and magnitude of flooding, time of day, warning time, and effective implementation of a flood plain evacuation plan. A cursory assessment was made of the likely consequences of loss of life should a major

levee fail and resulting flooding occur. The assessment assumes the existence of a formal local evacuation plan.

On the basis of past floods in other areas, it can be expected that once the order to evacuate the flood plain area is given, about 20 percent of the population will either not be able to evacuate or will choose not to evacuate the flood plain. These people are defined as the population at risk (PAR). As would be expected, the more advanced the warning, the smaller portion of the PAR would incur injury or loss of life. It is estimated that the flood warning time would be between 2 to 6 hours for the North Sacramento, South Sacramento, and Downtown Sacramento areas. However, in the Natomas area, the warning period could be very short since inflows to the drain are uncontrolled. Given a relatively long period of warning, there is the potential that about 0.05 percent of the PAR could lose their lives. Under existing conditions, a major flood affecting all the flood plains, such as a 200-year event, could potentially cause about 33 lives to be lost (6 in North Sacramento, 20 in South Sacramento, 5 in Downtown Sacramento, and 2 in Natomas). However, severe flooding can occur more frequently and also result in significant loss of life. Assuming a short warning period (less than about 1 hour) in Natomas, and considering the potential depth of flooding, it is estimated that over 100 people could conceivably lose their lives in that area alone due to a levee failure.

b. Flood damages. - Estimates were made of flood damages which would result from inundation of properties, the costs incurred for fighting the floods, and the disruption caused by floods.

Sacramento County Assessor's rolls were used to inventory private property structures in the various flood plains and as a basis for estimating their value. The value of the damageable property in a major flood plain (200-year event for this analysis) was estimated at about $13.8 billion (structures and contents) based on current price levels. Public property was not inventoried. Property values and flood damages for most public property in each of the flood plains were based on other Corps studies with similar flood plain development and were estimated at about $1.1 billion. The resulting estimated property values for each of the four major flood plain areas are shown in Table 7.

TABLE 7

DAMAGEABLE PROPERTY VALUES IN THE
200-YEAR FLOOD PLAIN

Flood Plain Areas	Property Values ($ Millions) Private	Public 1/	Total
Natomas	790	330	1,120
North Sacramento	2,790	20	2,810
South Sacramento	7,010	280	7,290
Downtown Sacramento	3,260	490	3,750
TOTAL	13,850	1,120	14,970

1/ Excludes roads, bridges, and utilities.

Projections of future growth in the North, South, and Downtown Sacramento area were made on the basis of California Department of Finance county population projections, county land use plans, availability of undeveloped land in the flood plain, estimated potential for growth and development, and extensions of historical trends. It was assumed that there would be no growth in the Natomas area after 1991 because of the potential for floods to occur more frequently than once in 100-years, on the average.

The average damages, by decade, and average annual equivalent damages for the without-project conditions for the four flood plain areas are shown in Table 8.

TABLE 8

AVERAGE ANNUAL DAMAGES
($1,000,000) 1/

Flood Plain Area	Undiscounted Damages 1986	2000	2100	Equivalent Damages (8-7/8%) 2/
Natomas	16	26	29	26 ~~$49~~
North Sacramento	22	25	25	25
South Sacramento	43	55	56	55
Downtown Sacramento	16	16	16	16
TOTAL	97	122	126	122

1/ 1986 price level and 2000-2100 period of analysis.
2/ October 1986 Federal discount rate.

CHAPTER IV - POTENTIAL MEASURES TO REDUCE FLOOD DAMAGES

14. Potential flood control measures. - A number of flood control measures for the American River have been identified and evaluated in previous studies by the USBR, DWR, and Corps. This chapter describes these measures in light of additional information including the updated hydrology, flood damages, benefits, costs, and related conditions. Specific alternatives derived from several of these measures to achieve two levels of flood protection downstream along the main-stem American River are also included.

Previous and current studies indicate that flood control measures to reduce the flood threat on the American River likely fall into one or more of the following categories:

- Increase flood control storage space in Folsom Reservoir,
- Increase Folsom objective outflows (i.e., increase downstream levee and channel flood carrying capacity),
- Construct new upstream flood control storage,
- Use existing upstream reservoir space for flood control,
- Perform structural modification of Folsom Dam to permit increased releases,
- Construct offstream storage (or out-of-basin diversions), and
- Construct levee and channel improvements along the NEMD Canal.

a. Descriptions. -

(1) Increase flood control storage space in Folsom Reservoir. - Reservoir routing studies were made for various magnitudes of floods with objective reservoir releases of 115,000 cfs to estimate the effects of increasing designated flood control storage space in Folsom. Table 9 shows the resulting estimate of increased flood protection provided by this measure

TABLE 9

INCREASING FOLSOM OBJECTIVE
OUTFLOWS WITH ALTERNATIVE
FLOOD STORAGE CAPACITIES

Measures 1/		Maximum Frequency of Control	Peak Outflow from Folsom For Given Event (1,000 cfs)			
Folsom Flood Control Storage (1,000 ac-ft)	Objective Release (1,000 cfs)	(Return Period - yrs)	100-yr	200-yr	250-yr (SPF)	500-yr
400 2/	115	63	234	432	530	578
500	115	75	190	418	530	578
650	115	94	130	380	530	578
400	130	75	206	428	530	578
500	130	85	171	414	530	578
650	130	104	130	369	530	578
400	150	88	178	418	530	578
500	150	97	160	399	530	578
650	150	112	150	353	530	578

1/ Operating conditions
2/ Existing condition

along main-stem American River. This measure would result in increasing the level of flood protection from 63 years to 75 and 94 years by increasing the flood control storage space to 500,000 and 650,000 ac-ft, respectively. Levels of flood protection for other magnitudes of increased flood space are shown on curve A in the top plot of Plate 7. No structural modifications of Folsom would be required for this measure. However, it would involve swapping water conservation storage for flood control storage (see paragraph 14c). Permanently implementing such a measure would likely require authorization from the Congress.

(2) Increase Folsom objective outflows. - Folsom Reservoir objective outflows are based on the design and capacity of the levees and river channel downstream from the dam. If such outflows are increased, levee and channel

improvements would be required to contain the increased flows. Routing studies were made for various magnitude floods with Folsom flood control storage spaces of 400,000, 500,000, and 650,000 ac-ft with releases of 115,000, 130,000, and 150,000 cfs. Included in Table 9 are summaries of the increased level of downstream flood protection provided from these measures. Plates 8, 9, and 10 show hydrographs of the 100-year flood routed through Folsom under the three objective release conditions and for the three alternative flood control reservations. Curves B and C in the top chart of Plate 7 show the relationship of flood control storage space to exceedence intervals for 130,000 and 150,000 cfs.

Increased objective releases would require levee modifications at several locations downstream along the American River and tributary and distributary streams. The modification would involve increasing height of the levee at various locations throughout the system to maintain adequate freeboard and placement of additional bank protection along American River to account for the higher flow velocities.

Increasing the levee height along American River could be accomplished by adding embankment to the crown and either on the waterside or outside (landside) face of the levees, or a combination of both. The advantage of raising the levee on the waterside face is that minimal rights-of-way would be needed. Also, there would be little interference with adjacent residential, commercial, and public developments. The primary disadvantage of the waterside modification is that impacts on riverine vegetation (see paragraph 14c) could be greater than with landside modification. Under either condition, additional bank protection would be required. It is estimated that for an objective release of 130,000 cfs approximately 12 miles of additional bank protection would be needed, and for 150,000 cfs, about 21 miles would be needed. Potential locations for levee modification are shown on Plate 11.

Modification of the existing flood control system along the Sacramento River, Sacramento Bypass, Yolo Bypass, and along Willow, Lindsey, Cache, Miner, and Steamboat Sloughs would be required to accommodate the higher sustained reservoir releases. About 150 miles of existing levees in the above floodways may need to be raised from 0.5 to about 1 foot, together with construction of about 2 miles of new levee in the Sacramento Bypass.

Levees along NEMD Canal and Arcade and Dry Creeks would need to be raised between 0.5 to 1 foot for an objective release of 130,000 cfs and between 1 and 2 feet for 150,000 cfs. For this study, it was assumed that levees along the northeast side of the confluence of Dry Creek and NEMD Canal would be constructed prior to and independent of any resolution to the American River flood problem. These levees would then need to be raised slightly to accommodate the increased stages due to increased flows in the American River.

(3) Construct new upstream flood control storage. - Additional flood control storage can be achieved by constructing either a single-purpose dam and reservoir or providing space in a multiple-purpose facility. Table 10 shows the results of an analysis of the amount of flood control storage space that would be needed including the 400,000 ac-ft of flood space at Folsom, for six levels of flood protection along main-stem American River.

TABLE 10

NEW UPSTREAM RESERVOIR - REQUIRED FLOOD CONTROL SPACE
(1,000 AC-FT)

Total Flood Storage	Folsom Flood Storage 1/	New Upstream Flood Storage 2/	Level of Protection (Return Period-yrs)
400	400	0	63 (existing)
520	200 2/	320	85
585	200 2/	385	100
650 3/	200 2/	450	110
900	200 2/	700	200
920	200 2/	720	250 (SPF)

1/ Includes maintaining objective release from Folsom at 115,000 cfs.
2/ Except for existing, assumes 200,000 ac-ft of Folsom flood storage will be transferred upstream to new reservoir. Further study will likely show 300,000 ac-ft would be a more appropriate flood control storage space to remain in Folsom.
3/ Flood control space for Authorized Auburn Project.

The USBR, as part of this study, recently compiled information developed by several agencies on potential storage sites identified in the American River Basin in previous studies and evaluations. These are the Granite Canyon, Giant Gap, Salmon Falls, Growlersberg and Alder locations, which are

listed in Table 11 and shown on Plate 12. The USBR estimates that the Giant Gap and Granite Canyon sites could provide some flood control benefit. However, both sites are in rugged mountainous terrain on a reach of the river that now has been included in both the State and Federal Wild and Scenic River Systems, thereby precluding construction of the dams. Essentially all sites previously studied or identified along Middle Fork American River have either been used for a dam and reservoir or are relatively high in the watershed. The only apparently available site, Growlersberg, could control only about 12 square miles, making its impact on flood control negligible. On the South Fork American River, the Salmon Falls and Alder sites are among several previously identified. However, use of the Salmon Falls site is restricted because a reservoir that would exceed approximately 200,000 ac-ft would inundate the historical Gold Discovery site at Coloma, and the Alder site would control only a minor amount of watershed (19 square miles).

TABLE 11

POTENTIAL RESERVOIR SITES IN THE UPPER AMERICAN RIVER BASIN

Site	Stream 1/	Drainage Area (sq mi)	Av. Ann. Runoff (ac-ft/ yr)	Reservoir Storage Capacity (ac-ft)
Granite Canyon	N.F.	96	226,000	300,000
Giant Gap	N.F.	200	396,000	650,000
Growlersburg	M.F. - Canyon Cr.	12	13,900	17,500
Salmon Falls	S.F.	807	940,000 2/	200,000 3/
Alder	S.F. - Alder Cr.	19	18,600	80,000

1/ N.F. - North Fork American River
M.F. - Middle Fork American River
S.F. - South Fork American River
2/ Does not include adjustments for upstream regulation.
3/ Maximum capacity which will not inundate Gold Discovery site at Coloma.

The USBR has concluded that the only practical location for a reservoir upstream from Folsom with a storage capability large enough to accommodate flood spaces identified by the Corps as necessary to significantly reduce downstream floodflows would be on the North Fork American River below the confluence of the North and Middle Forks in the vicinity of the Auburn Dam site.

The USBR and DWR recently evaluated five reservoir sizes at the Auburn Dam site. Four of the sizes, in conjunction with Folsom Reservoir, would provide SPF level of flood protection. They include (1) 750,000 ac-ft single-purpose flood control reservation; (2) 850,000 ac-ft facility which includes incidental power and water supply; (3) 1,250,000 ac-ft reservoir to provide additional amount of water supply and power; and (4) the authorized 2.3 million ac-ft reservoir to provide water supply, power, and instream flow. The fifth reservoir size, 415,000 ac-ft, would provide flood protection against the 100-year flood. It is assumed for both the 750,000 and 415,000 ac-ft reservations that 200,000 ac-ft of Folsom Reservoir's 400,000 ac-ft of flood control storage would be transferred to the upstream site to allow a more efficient flood operation at Folsom.

(4) Use existing upstream reservoir space for flood control. - Acquiring storage for flood control in several existing upstream reservoirs was investigated. Reservoir operation studies for Folsom have assumed that 47,000 ac-ft of storage is usually available for floods equal to or smaller than the 100-year flood. (This amount of storage space has been the minimum observed available in the upstream reservoirs during the flood season.) Space in excess of this level is not reliable. An order-of-magnitude estimate was made of the amount of storage space required in five upstream reservoirs (French Meadows, Loon Lake, Hell Hole, Union Valley, and Ice House) in conjunction with Folsom Reservoir to control the 100-year flood along main-stem American River. The results are shown on Plate 13. As can be seen from the plate, this level of protection can be achieved through a number of combinations of either increased flood control storage space at Folsom Reservoir and/or increased Folsom objective releases in addition to storage acquired in the upstream reservoirs. It should be emphasized that although there is approximately 830,000 ac-ft of storage in these reservoirs, a maximum of only about 200,000 ac-ft can be considered as potentially effective for flood control.

(5) Perform structural modification of Folsom Dam to permit increased releases. - Modifying the existing Folsom Dam to increase the outlet capacity was considered. This could conceptually be accomplished either by modifying the existing spillway or constructing a new spillway.

The objective for modifying the existing spillway would be to allow larger releases earlier in the flood event. The modification would require lowering the crest and installing at least five new radial gates and related components. Reservoir operation studies were conducted to determine the potential for controlled objective releases of 115,000, 130,000, and 150,000 cfs using storage spaces of 400,000, 500,000, and 650,000 ac-ft in Folsom and lowering the spillway 10 and 15 feet, respectively. The results of these studies, shown in Table 12 and on Plate 7, indicate that although lowering the spillway would increase the degree of downstream protection, the increase would be relatively small. To determine the engineering feasibility of lowering the spillway would require additional investigations. It is not known if the structure could accommodate a lowered spillway. Further, the act of lowering the spillway would require longer than one construction season to accomplish. Accordingly, consideration would need to be given to lowering each of the five bays one at a time. The degree of downstream flood protection would thereby be reduced during construction due to the limited spillway capacity.

TABLE 12

EFFECT OF LOWERING EXISTING FOLSOM SPILLWAY
ON DOWNSTREAM FLOOD PROTECTION

Measure 1/		Downstream Flood Protection (Return Period - yrs)		
Flood Control Storage (1,000 ac-ft)	Objective Release (1,000 cfs)	Existing Spillway	Lowered Spillway 10 ft	Lowered Spillway 15 ft
400 2/	115 2/	63	71	71
500	115	75	88	96
650	115	94	101	111
400 2/	130	75	85	85
500	130	85	100	100
650	130	104	115	128
400 2/	150	88	100	100
500	150	97	119	128
650	150	112	137	151

1/ Folsom Operating Condition.
2/ Existing Condition.

The objective for constructing a new spillway would be the same as lowering the existing spillway. Depending on the elevation of the spillway crest, the beneficial effects would be similar to those shown in Table 12. A likely location for a new spillway would be near the end of the south wing dam into Willow Creek.

Raising Folsom Dam could also create additional flood control storage space in the reservoir. However, this measure was not considered further because of the inherent difficulties associated with enlarging the existing structure and the prohibitive construction and relocation costs.

(6) Construct offstream storage (or out-of-basin diversions). - Several measures have been identified for diverting floodflows from the American River or Folsom Reservoir into a storage reservoir nearby or out of the basin.

In earlier studies, the USBR and DWR considered a flood retention basin along Willow Creek, south of the left (south) wing dam at Folsom. Plate 12 shows the location of this basin. As envisioned, the basin would augment storage in Folsom. The proposal has significantly high costs and relatively slight potential for increasing downstream flood protection. The DWR considered a reservoir of about 55,000 ac-ft (approximate physical limitation of the site). With this additional storage, the degree of downstream protection could be only slightly increased (63 to about 70 years). It is believed that this measure has essentially no potential for effective implementation because (1) there is limited ability to increase downstream flood protection, (2) the cost would be great (DWR's estimated cost (1982) was about $100 million), and (3) there is significant current and expected residential and commercial development in the basin area. This measure was not considered further in this study.

A second concept would be to divert flows via a bypass type conveyance system to a detention basin in the Deer Creek watershed about 10 miles south of Folsom Reservoir (see Plate 12). The costly modifications required to accommodate a high flow diversion in addition to significant impacts in the Cosumnes River Basin eliminate this concept as a viable alternative.

(7) Construct levee and channel improvements along NEMD Canal. - One potential solution to the Natomas flood threat from the NEMD Canal is to increase the height of the west levee of the canal. Several of the measures previously discussed involving increasing the objective releases from Folsom Dam include slightly increasing the height of the levees along the canal and upstream along Dry and Arcade Creeks. However, this action is intended to mitigate for the resulting higher stages in the Canal resulting from the higher riverflows and would not appreciably reduce the flood threat to Natomas. This measure would include additional increases in levee height. This measure was not considered further in this study. As explained in Chapter V, resolution of the flood problems in Natomas will be a primary element of other studies being conducted by the Corps.

b. Benefits. - An analysis was made of the estimated economic benefits to flood damage reduction attributable to each of the alternative measures. The benefits were derived by computing the residual average annual flood damages associated with the measures considered and subtracting these from the without-project conditions. The location and progression of estimated levee failure would be essentially the same as under without-project conditions. However, the projected frequency of failure would be dependent on the expected flow-frequency relationship in the American River developed for the various conditions. Table 13 summarizes the results of the benefit analysis.

As mentioned, water stages and resulting frequency of failure of the NEMD Canal west levee are influenced not only by flows in the American River, but also by flows in Dry and Arcade Creeks, and to some extent by stages in the Sacramento River. For economic purposes, it was assumed that peak flows in NEMD Canal are concurrent with sustained high flows in the American River and stages of the Sacramento River. This condition occurred during the February 1986 flood, and the system would probably respond similarly under with- or without-project conditions. The residual damages and benefits shown in Table 13 for Natomas are for a levee break condition along the NEMD Canal. The influences of flooding from other sources are not included.

c. Impacts. - Each of the measures would result in changes, or impacts, to various existing conditions. Following is a brief description of several of the expected major impacts for each measure directly related to achieving the flood control.

TABLE 13

AVERAGE ANNUAL EQUIVALENT RESIDUAL FLOOD DAMAGES AND FLOOD CONTROL BENEFITS
($1,000,000) 1/

Measure		Level of Protection	Natomas 2/ Area		North Sacramento Area		South Sacramento Area		Downtown Sacramento Area		Total	
Folsom Flood Control Storage (1,000 ac-ft)	3/ or 4/	(Return Period - yrs)	Residual Damages	Benefits	Residual Damages	Benefits	Residual Damages	Benefits	Residual Damages	Benefits	Residual Damages	Benefits
Folsom Storage/Outflow Combination												
400 5/	115 3/	63	26.4	0	24.9	0	55.3	0	16.3	0	122.9	0
500	115 3/	75	22.1	4.3	21.1	3.8	50.4	4.9	15.0	1.3	108.6	14.3
650	115 3/	94	18.7	7.7	17.4	7.5	44.8	10.5	12.7	3.6	93.6	29.3
400	130 3/	75	22.4	4.0	20.9	4.0	51.0	4.3	14.8	1.5	109.1	13.8
500	130 3/	85	20.0	6.4	18.1	6.8	47.1	8.2	14.3	2.0	99.5	23.4
650	130 3/	104	16.9	9.5	15.3	9.6	41.5	13.8	12.3	4.0	86.0	36.9
400	150 3/	88	20.4	6.0	16.8	8.1	47.0	8.3	12.9	3.4	97.1	25.8
500	150 3/	97	18.0	8.4	16.8	8.1	47.1	8.2	13.3	3.0	95.2	27.7
650	150 3/	112	16.4	10.0	13.4	11.5	40.6	14.7	11.5	4.8	81.9	41.0
Lowered Folsom Spillway 15 Feet												
400	115 3/	71	23.2	3.2	24.1	0.8	54.4	0.9	15.6	0.7	117.3	5.6
650	115 3/	111	13.1	13.3	14.3	10.6	40.1	15.2	11.3	5.0	78.8	44.1
650	150 3/	151	12.7	13.7	10.9	14.0	33.9	21.4	8.3	8.0	65.8	57.1
New Upstream Storage												
200 6/	320 4/	85	20.1	6.3	18.3	6.6	46.1	9.2	14.3	2.0	98.8	24.1
200 6/	385 4/	100	16.9	9.5	15.7	9.2	41.9	13.4	13.1	3.2	87.6	35.3
200 6/	700 4/	200	10.5	15.9	8.2	16.7	23.6	31.7	7.6	8.7	49.9	73.0
200 6/	720 4/	250 (SPF)	10.5	15.9	4.6	20.3	16.4	38.9	4.5	11.8	36.0	86.9

1/ 1986 price levels, 2000-2100 period of analysis, and 8-7/8 percent interest rate.
2/ Damages and benefits may be higher or lower than shown, depending on the outcome of ongoing hydrology studies for this area.
3/ Objective release in 1,000 cfs.
4/ Upstream flood storage in 1,000 ac-ft with objective release from Folsom Dam of 115,000 cfs.
5/ Existing conditions.
6/ Current studies assume 200,000 ac-ft of the 400,000 ac-ft Folsom Reservoir flood storage would be transferred to new upstream reservoir for better system control. Future studies will likely show that about 300,000 ac-ft should be retained in Folsom.

(1) Increase flood control storage space in Folsom Reservoir. - Increasing the flood control space in the reservoir would result in losses of existing project accomplishments and impacts to the environment. Because of the need to provide a greater space for flood control in the winter months, in many years less water would be (1) in the reservoir in the late spring, summer, and fall, and (2) available for downstream release during certain periods. Accordingly, there would be a loss of existing recreational opportunities and hydropower and water supply revenues to the CVP and unavoidable impacts to reservoir and downstream fish resources.

(a) Recreation. - Primary recreation activities at Folsom Lake include vehicular camping, boat camping, picnicking, boating, and dispersed use. Downstream from the dam, the primary activities are fishing and boating (rafting). The USBR and U.S. Fish and Wildlife Service (FWS) have estimated that increasing the flood control storage space could adversely impact these activities. The degree of impact would be greater for the larger flood space and would also depend on hydrologic conditions of the specific year. More detailed study is necessary to quantify specific impacts on recreation use. However, the following is an indication of the impacts that could be identified.

During normal water years at Folsom Reservoir, there would be no significant differences in the impact to summer reservoir recreation because post-flood season inflows would be great enough in most years to fill the reservoir. During dry years, however, lake visitation would be significantly reduced because of the lower surface elevation and smaller reservoir surface area. The greatest and most frequent impact would be to boating during the fall and winter periods. Under the existing requirement for 400,000 ac-ft of flood control space in Folsom, it is estimated that over 600 boats at Brown's Ravine Marina can remain in the lake for approximately 30 percent of the years. With either the 500,000 and 650,000 ac-ft options, all boats would need to be removed from the water by about November each year and remain out of the reservoir at least through February of the following year. This would result in an estimated loss of 20,000 recreation days annually.

The impact to recreation downstream would primarily result from lower flows during certain years in the late spring and summer. It is estimated

that during normal water years the impact would be minimal for either of the two increased flood space measures. However, during dry years the impact could be more significant.

(b) Water Supply. - The USBR evaluated the impacts on CVP firm water supply yield attributable to increased flood control reservation at Folsom Reservoir. They determined that the average annual yield would decrease by 14,000 and 33,000 ac-ft with the increase to 500,000 and 650,000 ac-ft flood control reservations, respectively.

(c) Hydropower. - The USBR determined that an increase in flood control storage at Folsom Reservoir would have an adverse impact on CVP power accomplishments. The impacts would be a decrease in both project-dependable capacity (PDC) and average annual energy generation. The primary reason for the decrease in average annual generation would be the lower lake elevations which, in turn, would result in lower hydraulic heads and lower efficiencies for power generation. Any decreases in PDC or generation would need to be made up for by purchases of power by Western Area Power Administration from other sources.

Increasing Folsom's flood control storage to 500,000 ac-ft would have no appreciable impact on PDC; however, it would result in a decrease in CVP generation of 12.5 gigawatt-hours (GWH) (1 GWH = 1,000,000 kilowatt hours) per year. An increase to 650,000 ac-ft would result in a decrease of 6 megawatts in PDC and 39.8 GWH per year in generation. In addition, there would be an increase in project pumping energy requirements at the Folsom Pumping Plant due to the lower lake surface elevations. Increases to 500,000 and 650,000 ac-ft flood control storage would result in an increase in pumping energy of 0.3 and 1.1 GWH per year, respectively. This estimate is for water delivered through the existing pumping plant and not for any pumping energy for other anticipated future water deliveries such as to the northern Sacramento area from Folsom Lake. Taking the increased pumping energy into account, the estimated total net decrease in average annual CVP generation is 12.8 and 40.9 GWH per year for increasing the flood control space to 500,000 and 650,000 ac-ft, respectively.

(d) Environmental. - Based on a FWS assessment, no reductions in the lake coldwater fishery from the lower winter lake levels would be expected

because the fishery is maintained by a stocking program. However, reservoir fluctuation greater than 20 feet during spawning has the potential to reduce populations of bass and bluegill. Accordingly, there would be a slight adverse impact on this resource. It is estimated that under existing requirements for 400,000 ac-ft of flood control space in Folsom, salmon production and catch in the lower American River will be reduced from current conditions approximately 13 percent by the year 2020. This projection is not expected to change for an increase in flood control space to 500,000 ac-ft. However, for a flood control space of 650,000 ac-ft, salmon production and catch is projected to decrease 17 percent by the year 2020.

(2) Increase Folsom objective outflows. -

(a) Recreation. - The expected adverse impacts resulting from an increased objective release would be (1) interruption in recreation activity (bicycling, jogging, etc.) on the existing levees during construction and (2) likely lowered recreational experiences due to the required bank protection work. Reduction in reservoir and downstream recreation values due to increasing the flood control space at Folsom would be as explained in the previously discussed measure.

(b) Water Supply and hydropower. - Only those options involving increased flood space at Folsom would adversely impact water supply yields or hydropower. These impacts would be as described above.

(c) Environmental. - Raising the levee with work along the waterside face would involve removing at least 25 acres of woodland, scrub shrub, and grassland habitat along the American River. Necessary riprapping along the river levees would require temporarily removing about an additional 25 acres of flood plain vegetation. The lower American River has been designated as a recreational river under both the State and Federal Wild and Scenic Rivers Acts. In addition, the valley elderberry longhorn beetle, a Federally-listed endangered species, is known to inhabit elderberry plants along the lower American River riparian corridor. Special precautions would be required to avoid adverse impacts to these resources.

Approximately 200 acres of flood plain, agricultural, and riparian lands would be required for widening the Sacramento Bypass.

(3) Construct new upstream flood control storage. - There would be no known adverse impacts on recreation, water supply, or hydropower at Folsom Lake from this measure. As a matter of fact, those accomplishments would be enhanced because of the higher seasonal pool elevation. Environmental impacts associated with the authorized Auburn Dam project have been described in detail in previous reports. A single-purpose dam and reservoir would inundate fewer acres and miles of stream than the authorized full-sized Auburn project. Significant habitat losses would occur in the dam and reservoir area. However, the losses would be somewhat less than those expected under the large Auburn Dam project.

(4) Use existing upstream reservoir space for flood control. - The primary impact of this measure includes reduction in water supply and hydropower revenues to Sacramento Municipal Utility District (SMUD) and Placer County Water Agency (PCWA) at the upstream reservoirs. The reductions in water supply and hydropower revenues were not quantified, although it is believed they would be significant. An impact to wildlife at the upstream reservoirs could result from the increased distance to the lake (i.e., increased exposure to predators) and to the fishery due to the lower water surfaces. However, these impacts would probably not be significant.

(5) Perform structural modification of Folsom Dam to permit increased releases. - There would probably be little or no long-term impacts on water supply, hydropower, or recreation for this measure. Also, environmental impacts resulting from modifying the existing spillway would be minor. During the construction period, downstream flood protection would be decreased for any measure requiring modifying the existing spillway.

d. Costs. -

(1) Increase flood control space in Folsom Reservoir. This measure would not result in any known direct construction costs. However, as indicated above, there would be costs to replace the losses in water supply and power. There would probably also be costs associated with mitigation for adverse impacts to lake recreation and downstream fishery resources.

(2) Increase Folsom objective outflows. - The primary costs of this measure include modification of the downstream levees and channels. Costs for

levee modification were derived primarily based on reconnaissance scope estimates developed in the mid-1970's for the USBR, updated to reflect revised quantities and 1986 price levels. The estimated first costs for the measure are summarized in Table 14.

The costs in Table 14 include an allowance of 10 percent of the construction items to account for mitigation of potential adverse impacts on environmental resources. This relative cost allowance is fairly consistent with mitigation costs of similar bank and levee modification projects. Additional studies are needed to confirm the specific type of measures needed and overall appropriateness of this allowance.

(3) Construct new upstream flood control storage. - USBR and DWR conducted studies aimed at estimating costs for various sizes of Auburn Dam and Reservoir. Table 15 shows the estimated costs (1986 price level) for five sizes of project. As can be seen, costs range from about $1.5 billion for the authorized size of 2.3 million ac-ft to about $530 million for a small, 415,000 ac-ft project.

(4) Use existing upstream reservoir space for flood control. - This measure could not result in any known direct construction costs. In addition to any possible reductions in water supply and hydropower at Folsom due to the likely need for an increase in flood space, the cost for this measure would primarily include acquisition of flood control space from SMUD and PCWA in the upstream reservoirs. This would likely be equal to that necessary to construct replacement power and water supply facilities. No cost estimate was made for this measure.

(5) Perform structural modification of Folsom Dam to permit increased releases. - The estimated cost to lower the spillway was not computed, primarily because of the significant effort required to develop a potentially implementable design. It is believed, however, that the costs would exceed $100 million.

In 1982, DWR estimated the cost to construct a new spillway to Willow Creek at about $100 million. This does not include downstream channel modifications to accommodate the significantly additional periodic flows along Willow Creek, or other receiving streams.

TABLE 14

SUMMARY OF FIRST COSTS - LEVEE AND CHANNEL MODIFICATIONS
($1,000)

Condition		Cost Item	Location			
Levee Modification	Design Flow (1,000 cfs)		American River	NEMD Canal 1/	Other 2/	Total
Waterside	130	Levees	18,500	5,800	15,700	40,000
		Flood Control Structures	--	--	4,400	4,400
		Lands & Damages	2,400	1,200	1,200	4,800
		Relocations	600	2,700	5,500	8,800
		Mitigation	2,100	1,000	2,700	5,800
		Total	23,600	10,700	29,500	63,800
	150	Levees	36,300	8,000	16,900	61,200
		Flood Control Structures	--	--	11,700	11,700
		Lands & Damages	4,100	1,400	1,300	6,800
		Relocations	10,900	3,000	6,400	20,300
		Mitigation	5,100	1,200	3,600	9,900
		Total	56,400	13,600	39,900	109,900
Landside	130	Levees	15,500	5,800	15,700	37,000
		Flood control Structures	--	--	4,400	4,400
		Lands & Damages	2,600	1,200	1,200	5,000
		Relocation	300	2,700	5,500	8,500
		Mitigation	1,800	1,000	2,700	5,500
		Total	20,200	10,700	29,500	60,400
	150	Levees	27,700	8,000	16,900	52,600
		Flood Control Structures	--	--	11,700	11,700
		Lands & Damages	4,600	1,400	1,300	7,300
		Relocations	11,300	3,000	6,400	20,700
		Mitigations	4,300	1,200	3,600	9,100
		Total	47,900	13,600	39,900	101,400

1/ Assumes levees on the northeast edge at the confluence of NEMD Canal and Dry Creek as a pre-project condition.

2/ Primarily along Yolo Bypass and its tributaries and does not include a railroad track extension in the Sacramento Weir area.

TABLE 15

AUBURN DAM AND RESERVOIR COSTS 1/

Size (1,000 ac-ft)	Type	Flood Protection Potential (Return period -yrs)	Cost ($ Millions) To Complete	Spent to Date	Total
2,300 2/	CG 3/	250 (SPF)	1,098	295	1,393
1,250 4/ 2/	CG	250 (SPF)	770	295	1,065
850 4/ 2/	RCC 5/	250 (SPF)	546	295	841
750 6/	RCC	250 (SPF)	345	295	640
415 6/	RCC	100	235	295	530

1/ Source: USBR.
2/ Multiple-Purpose.
3/ Concrete gravity.
4/ To provide initial provisions for subsequently increasing the capacity to the full size would add approximately $20-30 million to these costs.
5/ Roller compacted concrete.
6/ Primary single-purpose flood control.

15. Levels of flood protection. - Each of the measures described can provide an increased level of flood protection along lower American River. A major consideration is the level of flood protection the community desires, can afford, and will assist in providing. Following is a brief description of the scope of potential alternatives capable of providing 85-, 100-, and 200-year or greater levels of flood protection along lower American River. In each case, additional levee improvements (or comparable measures) would be required to provide flood protection in the Natomas area consistent with the level indicated.

An SPF level of flood protection is not discussed below. This is because current Corps policy is that the SPF criterion is no longer being used as a basis for establishing flood control to urban areas. The policy of sizing for a flood control facility should meet the test of providing maximized net National Economic Development (NED) benefits over costs. Accordingly, the degree of protection in a project warranting a Federal interest and involvement in flood control may be different from the SPF.

a. 85-year level flood protection. The 85-year flood has a peak outflow from Folsom Dam of about 180,000 cfs. The most promising measures to achieve this level of protection are as follows:

- Increase the designated flood storage space in Folsom Reservoir to about 590,000 ac-ft while maintaining the current objective release of 115,000 cfs.

- Increase the objective release from Folsom Dam to 150,000 cfs with a corresponding modification in the downstream levees to accommodate the increased flow while maintaining the requirement for 400,000 ac-ft of seasonal flood control space in Folsom Reservoir.

- Combine the two above alternatives. As shown in curve A in the top chart of Plate 7, there are many combinations between storage space and objective release to achieve an 85-year level of protection along main-stem American River, for example, an increase in flood control space in Folsom Reservoir to 520,000 ac-ft with an increase in the objective release to 130,000 cfs.

- Construct additional flood control storage upstream from Folsom Reservoir. As indicated in Table 10, this would consist of retaining about 200,000 ac-ft of flood control storage space in Folsom Reservoir, maintaining the objective release from Folsom Dam of 115,000 cfs, and constructing at least 320,000 ac-ft (520,000 ac-ft total system storage) of flood control storage immediately upstream.

- Combine an increase in Folsom Reservoir flood space with acquired existing upstream storage space for flood control. This could consist of increasing the flood control space in Folsom Reservoir to between 450,000 and 500,000 ac-ft and using between 150,000 and 200,000 ac-ft of storage space for flood control in four existing upstream reservoirs.

b. 100-year level flood protection. - The 100-year flood has a peak outflow of about 230,000 cfs. Likely effective measures to achieve this level of protection are as follows:

- Increase the designated flood storage space and objective release from Folsom. As with the 85-year level of protection, there are many combinations of storage space and objective releases to achieve a 100-year level of protection along main-stem American River. One, for example, (as shown on Plate 6) is an increase in flood control space in Folsom Reservoir to 640,000 ac-ft with an increase in the objective release to 130,000 cfs.

- Construct additional flood control storage upstream from Folsom Reservoir. This would consist of retaining about 200,000 ac-ft of flood control storage space in Folsom Reservoir, maintaining the objective release from Folsom Dam at 115,000 cfs, and constructing at least 385,000 ac-ft (585,000 ac-ft total system storage, see Table 10) of flood control storage immediately upstream.

- Combine an increase in Folsom Reservoir flood space with acquired existing upstream storage space for flood control. This could consist of increasing the flood control space in Folsom Reservoir to about 500,000 ac-ft, maintaining the objective release from Folsom Dam at 115,000 cfs, and using 200,000 ac-ft of storage space for flood control in four existing upstream reservoirs.

c. 200-year level or greater protection. - A high level of flood protection (i.e., about 200 years or greater) is desirable for metropolitan areas where levee failure would result in catastrophic losses to life and property, such as Sacramento. Of the measures assessed in this study, only that of constructing additional flood control space immediately upstream from Folsom Reservoir was found capable of effectively achieving the higher levels of protection along the main-stem American River. Table 10 shows storage space requirements for several large events.

16. Comparison of flood control improvements. - USBR and DWR requested a qualitative comparison of the various measures considered. Accordingly, Table 16 is a summary for each measure of the estimated (1) level of flood protection along main-stem American River, (2) economic average annual flood control benefit, (3) construction cost, to the extent it is known, and (4) potential impacts on water supply and hydropower, also to the extent they are known.

TABLE 16

MEASURE SUMMARY AND COMPARISON

Measure	Folsom Reservoir		Other Storage		Flood Protection 1/	Flood Control Benefits 2/	First Cost of Construction for Flood Reduction	Outputs Foregone 3/		
	Flood Control Space (1,000 ac-ft)	Object Release (1,000 cfs)	New Flood Space (1,000 ac-ft)	Existing (1,000 ac-ft)	(Return Period - yrs)	($ Mil. /yr)	($ Mil.)	Water Supply (1,000 ac-ft /yr)	Hydropower (GWH /yr)	Recreation (1,000 Rec. Days/yr)
Increase Folsom Flood Space	500	115	0	47 5/	75	14	0	14.0	12.8	20 4/
	590	115	0	47	85	24	0	25.4 6/	29.6 6/	20 4/
	650	115	0	47	94	29	0	33.0	40.9 7/	20 4/
Increase Folsom Objective Release 8/	400	130	0	47	75	14	60	0	0	0
	520	130	0	47	85	24	60	16.6 5/	16.6 5/	20 4/
	650	130	0	47	104	37	60	33.0	40.9 7/	20 4/
	400	150	0	47	85	26	100	0	0	0
	500	150	0	47	97	28	100	14.0	12.8	20 4/
	650	150	0	47	112	41	100	33.0	40.9 7/	20 4/
New Upstream Storage 2.3 million ac-ft at Auburn	200 9/	115	720	47	250(SPF)	87	10/	+ 11/	+	+
850,000 ac-ft at Auburn	200	115	720	47	250(SPF)	87	10/	+	+	+
750,000 ac-ft at Auburn, 250-yr only	200	115	720	47	250(SPF)	87	10/	0	+	+
415,000 ac-ft at Auburn, 100-yr only	200	115	385	47	100	35	10/	0	+	+
350,000 ac-ft at Auburn, 85-yr only 5/	200	115	320	47	85	24	-	0	+	+
Existing upstream Storage 100-year only	500	115	0	200	100	35	0	14.3 12/	12.8 12/	20 4/
85-yr only	450/500	115	0	150/200	85	26	0	14.0 12/	12.8 12/	20 4/
Structural Modification of Folsom Raise Dam	400+	115	0	47	100+	35	14/	0	0	0
Lower Spillway 13/	400	115	0	47	71	6	14/	0	0	0
	650	115	0	47	111	44	14/	33.0	40.9	20 4/
	650	150	0	47	151	57	14/	33.0	40.9	20 4/
Offstream Storage Willow Creek	400	115	60	47	70	6	14/	0	0	0
Out of Basin Div.	400	115	NA	47	100+	35	14/	0	0	0

1/ Level of protection along main-stem American River only.
2/ Does not reflect outputs foregone.
3/ Provided by USBR.
4/ Estimated recreation days lost at Folsom Lake resulting from 600 boats needing to be removed from the water.
5/ Vacant space in upstream reservoirs that can be considered for flood control.
6/ Interpolated by Corps from information provided by USBR.
7/ Would also result in a loss in dependable capacity to CVP of about 6 megawatts.
8/ Assume all levee modification on the landside (outside).
9/ See footnote 6/, Table 13.
10/ Being developed by USBR.
11/ Increase in system accomplishments.
12/ Needs to include influence of water supply and hydropower generation lost at upstream reservoirs, which is not known.
13/ Spillway lowered 15 feet. The capability of actually being able to accomplish this measure is not known.
14/ Cost not estimated.

CHAPTER V - ADDITIONAL ACTIONS

17. General.- The Fiscal Year 1987 Appropriations Act with attached Conference Report authorized and funded the Corps to ". . . engage in a one-year reconnaissance study of alternate means of flood control in the American River, California, watershed predicated on the assumption that an Auburn Dam as previously authorized is not constructed." The resulting American River Watershed Investigation reconnaissance phase of this study, which commenced in January 1987 and will be completed by January 1988, is focusing on further evaluation of alternative means of flood control in the watershed from the mouth of the American River to the upper limits of the basin. The reconnaissance study will use essentially all of the information developed for the USBR and DWR previously described. Solutions to flood problems along lower Dry Creek and in Natomas will be fully evaluated as part of the study. The Corps will solicit and evaluate proposals from those who have indicated concerns and will work with the USBR, DWR, local entities, and the public. Additional work will be conducted on (1) hydrologic and hydraulic conditions at and near the confluence of American River and NEMD Canal, (2) levee height and stability conditions along the American River (both project and private levees and those surrounding the Natomas area), and (3) use of space existing in upstream reservoirs for flood control.

A major objective of the reconnaissance study is to determine if there is at least one potential solution to the flood problems that has Federal interest and is supported by a non-Federal sponsor or sponsors. Completion of the reconnaissance phase will include negotiation with a local sponsor for a study cost-sharing agreement for feasibility studies. The effort required will depend on the number of sponsors and the ability of such sponsors to agree on the scope and funds needed to prepare a Feasibility Report for possible project construction authorization by Congress.

Three other flood-related studies of importance are the Sacramento River Flood Control System Evaluation, the Dry Creek Investigation, and the Sacramento Metropolitan Area Reconnaissance Study. The Sacramento River Flood Control System Evaluation Study was initiated in January 1987 and is intended

to evaluate the structural stability of the local project levee system. The Initial Analysis Report for this study is scheduled for completion in mid-1988. The ongoing Dry Creek Investigation is considering solutions to flood problems in the Dry Creek drainage basin. Completion of the Dry Creek Feasibility Report is scheduled for May 1988. The reconnaisance phase of the Metropolitan Area Study, conducted under the Northern California Streams Investigation, is in the President's Budget for initiation in Fiscal Year 1988 and will focus on flood problems and solutions south of the American River for flooding from the Sacramento River and in the West Sacramento area.

CHAPTER VI - SUMMARY OF STUDY FINDINGS

18. Summary.- Pertinent findings resulting from this study are summarized below:

- A serious flood threat exists along the lower American River.

- About 325,000 people live in the flood plain of the lower American River, and the value of potential flood damageable property is estimated at $15 billion.

- Revised hydrological and reservoir operation analyses have indicated that the degree of flood protection is significantly less than previously thought.

- It is currently estimated that, as authorized, Folsom Dam and Reservoir can control objective downstream releases (115,000) for floods up to the 63-year event.

- The estimated average annual equivalent flood damages in the flood plain of the American River amount to about $123 million.

- Identified measures to help increase the level of downstream flood protection include (1) increasing the flood control storage in Folsom Reservoir, (2) increasing Folsom Reservoir outflows (i.e., increasing downstream levee and channel flood carrying capacity), (3) constructing new upstream flood control storage, (4) using existing upstream reservoir space for flood control, (5) modifying Folsom Dam to permit increased releases, (6) constructing offstream storage, and (7) constructing levee and channel improvements along NEMD Canal.

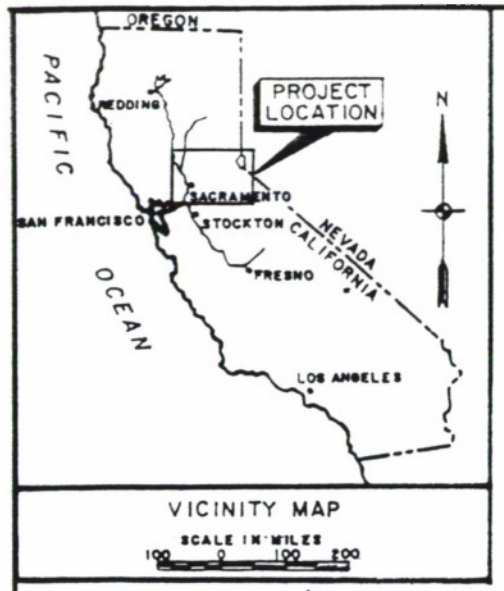
- The potential for loss of life will be reduced by implementing higher levels of protection than currently exist.

- Most of the measures considered would help reduce the potential for flooding in the Natomas area, but resolution of this flood problem was outside the scope of this study and is being considered in other Corps investigations.

- Most of the measures reviewed, or their combinations, can achieve an increase in the levels of flood protection along main-stem American River to about 100 years.

- The total amount of flood control storage required in the basin to control the SPF is currently estimated at 920,000 ac-ft. (Current Corps policy is that the SPF criterion is no longer being used as a basis for establishing flood control storage. The policy of sizing for flood control storage in a reservoir should meet the test of providing maximized net National Economic Development benefits over costs.)

- Of the structural measures analyzed, high levels of flood protection (i.e., about 200 years or better) along main-stem American River can be achieved by construction of new storage upstream from Folsom Reservoir.



VICINITY MAP

SCALE IN MILES
100 0 100 200

TRUCKEE
GRASS VALLEY
LAKE VALLEY RESERVOIR
North Fork American River
FRENCH MEADOWS
HELL HOLE
PLACER COUNTY
EL DORADO COUNTY
LOON LAKE
LAKE TAHOE
SOUTH LAKE TAHOE
Middle Fork American River
Gerle Creek
Pilot Creek
Rubicon River
LAKE CLEMENTINE
AUBURN
GEORGETOWN
GREENWOOD
LAKE EDSON
UNION VALLEY RESERVOIR
Silver Creek
ICE HOUSE
South Fork American River
SLAB CREEK RESERVOIR
Weber Creek
PLACERVILLE
CAMINO
Silver Fork
Caples Creek
CAPLES LAKE
SILVER LAKE
FOLSOM LAKE
LINCOLN
NEWCASTLE
SUTTER BYPASS
FEATHER RIVER
FREMONT WEIR
NATOMAS EAST MAIN DRAINAGE CANAL
ROCKLIN
ROSEVILLE
DRY CREEK
PLACER COUNTY
SACRAMENTO COUNTY
SACRAMENTO RIVER DEEP WATER SHIP CHANNEL
WOODLAND
NORTH HIGHLANDS
ORANGEVALE
FAIR OAKS
FOLSOM DAM
FOLSOM
WILLOW CREEK
NATOMAS AREA
ARCADE CREEK
CARMICHAEL
NIMBUS DAM
SACRAMENTO WEIR
RANCHO CORDOVA
AMERICAN RIVER
WEST SACRAMENTO
DAVIS
YOLO
SACRAMENTO
Middle Fork Cosumnes River
Deer Creek
Cosumnes River
PLYMOUTH
SHELDON RD
ELK GROVE

LEGEND

STATE HIGHWAYS, INTERSTATE HIGHWAYS
COUNTY BOUNDARY
AMERICAN RIVER DRAINAGE BASIN BOUNDARY
LOWER RIVER/FOLSOM RESERVOIR DRAINAGE SEPARATION

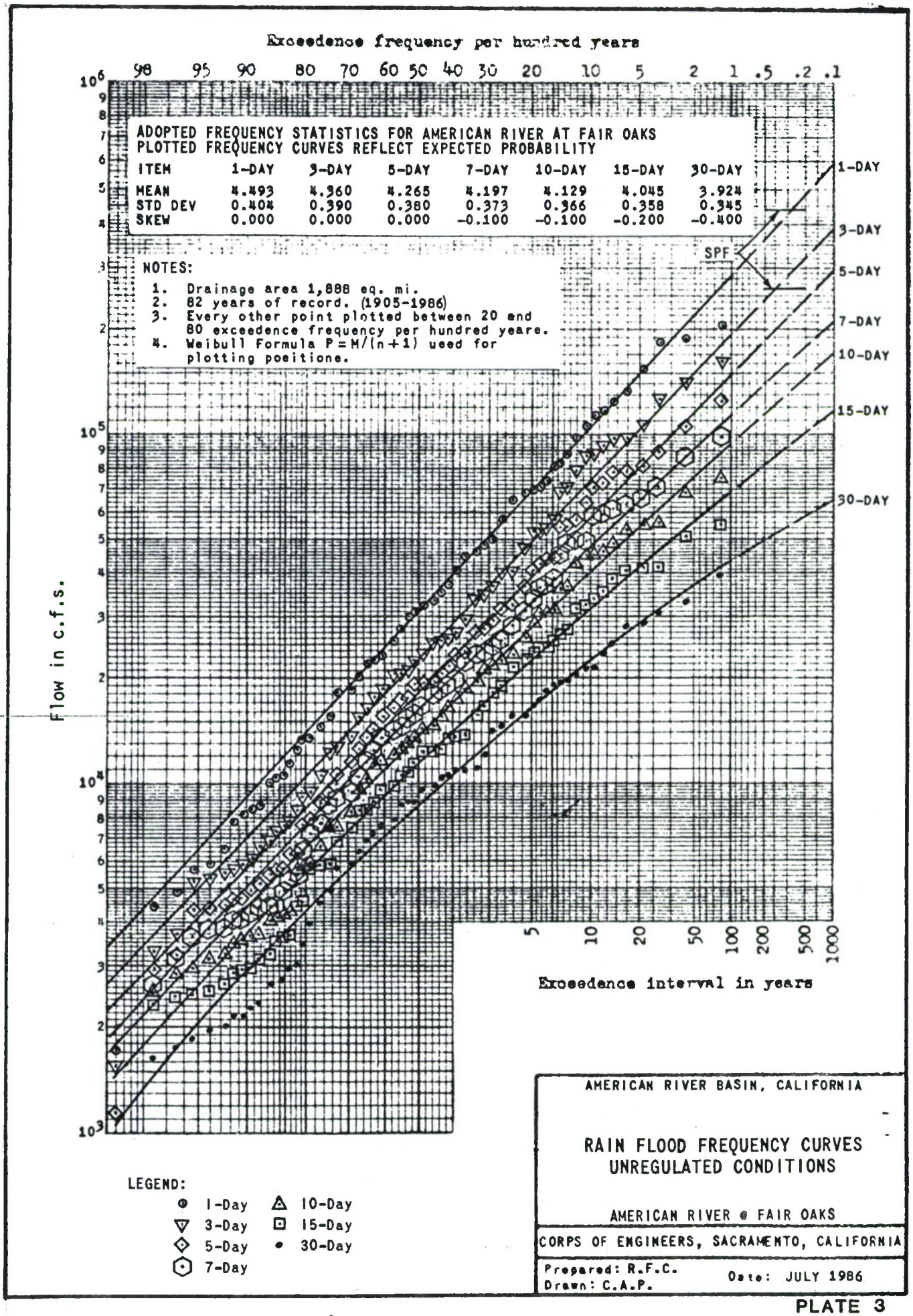
SCALE IN MILES
7 0 7 14 21

AMERICAN RIVER BASIN, CALIFORNIA

LOCATION AND VICINITY MAP

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
FEBRUARY 1987

PLATE 1



AMERICAN RIVER BASIN, CALIFORNIA

RAIN FLOOD FREQUENCY CURVES
UNREGULATED CONDITIONS

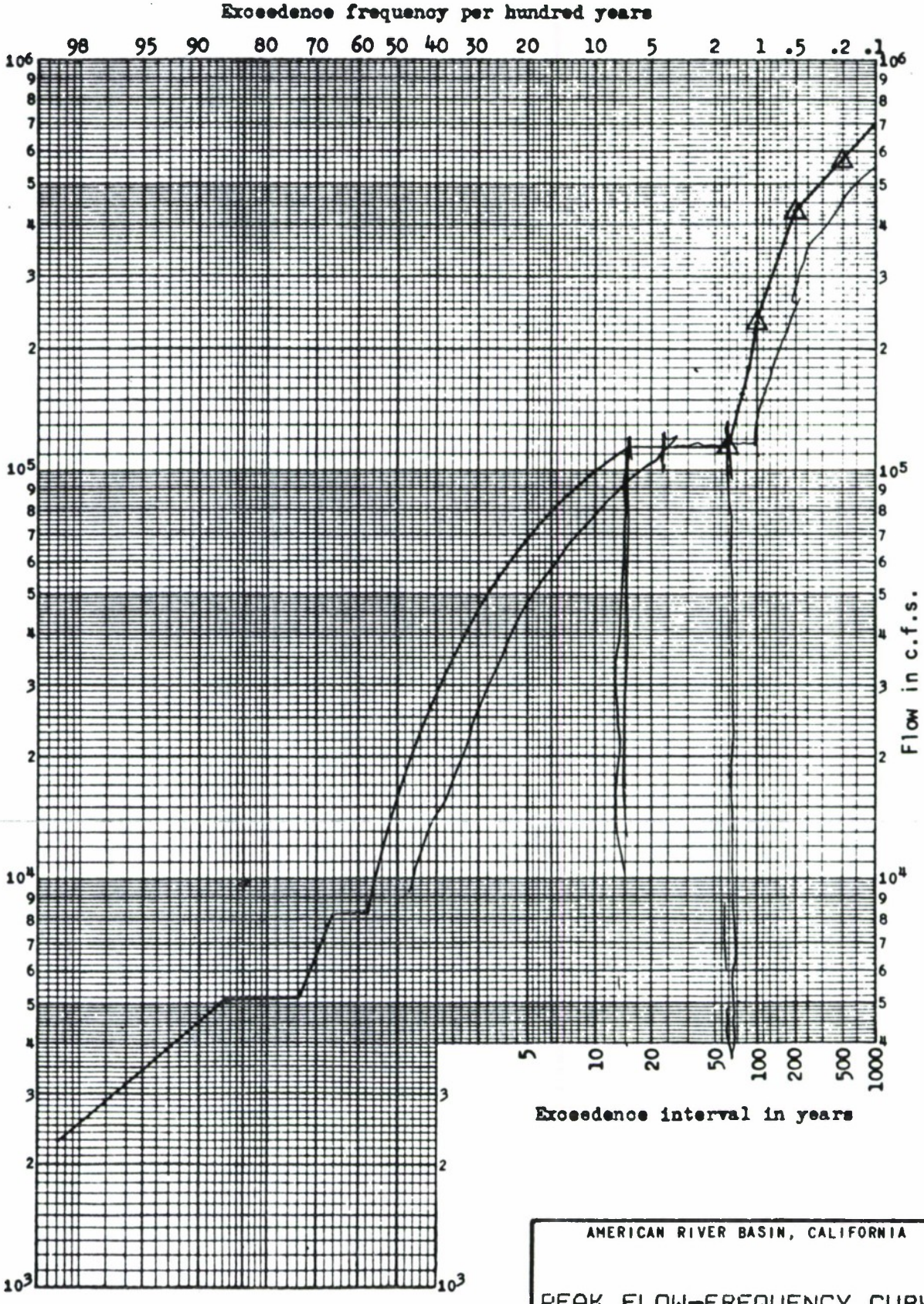
AMERICAN RIVER @ FAIR OAKS

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: R.F.C.
Drawn: C.A.P.

Date: JULY 1986

PLATE 3



Notes:

1. The project curves, to the 50 year event, reflects 32 years of record (1955-1986).
2. The remaining portion of the curve reflect the results of hypothetical flood routings as represented by the plotted points.
3. The hypothetical routings used the present authorized flood operation of Folsom Dam.

AMERICAN RIVER BASIN, CALIFORNIA

PEAK FLOW-FREQUENCY CURVE
EXISTING CONDITIONS

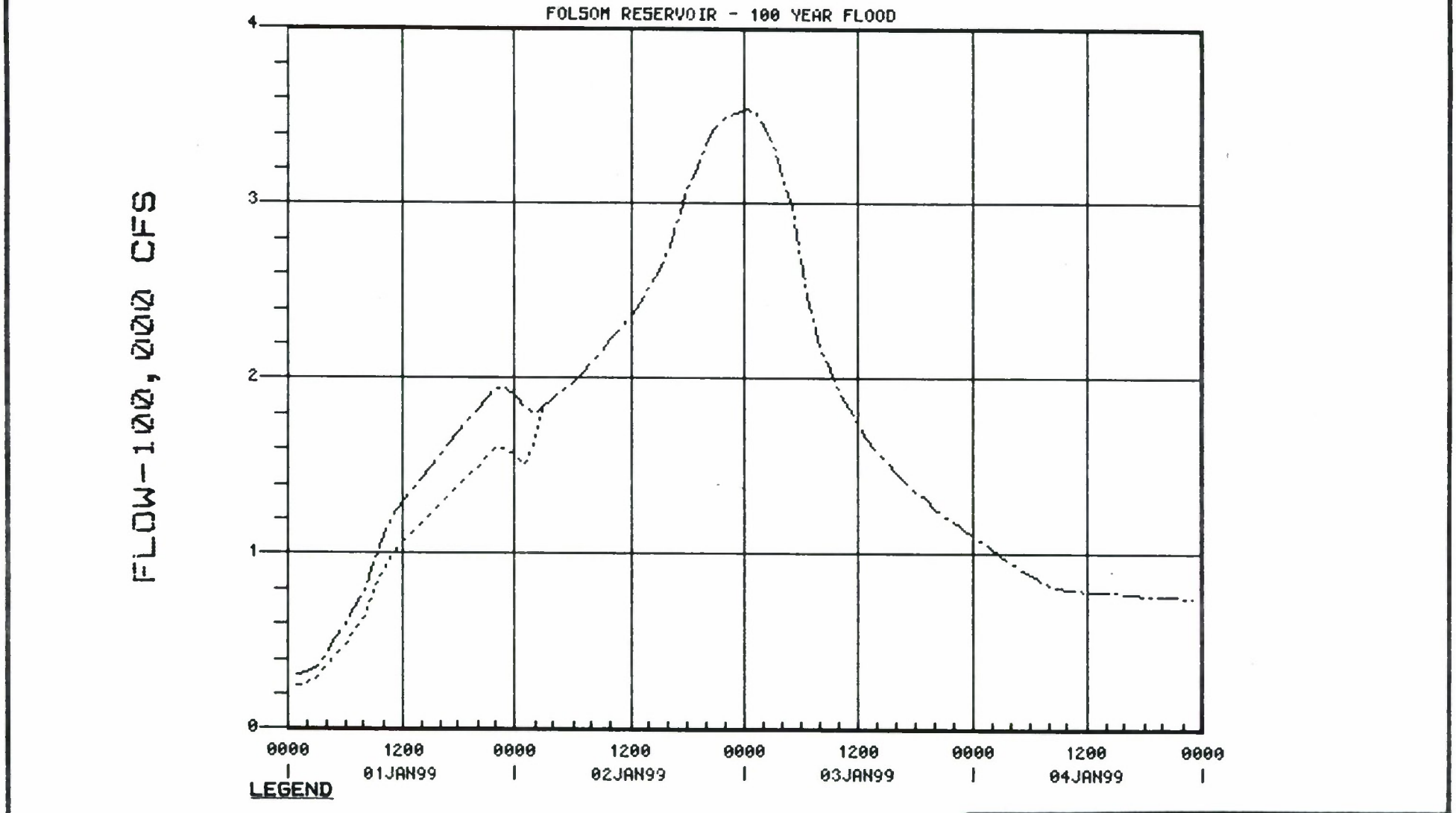
AMERICAN RIVER @ FAIR OAKS

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: R.F.C.
Drawn: C.A.P.

Date: FEB 1987

PLATE 4

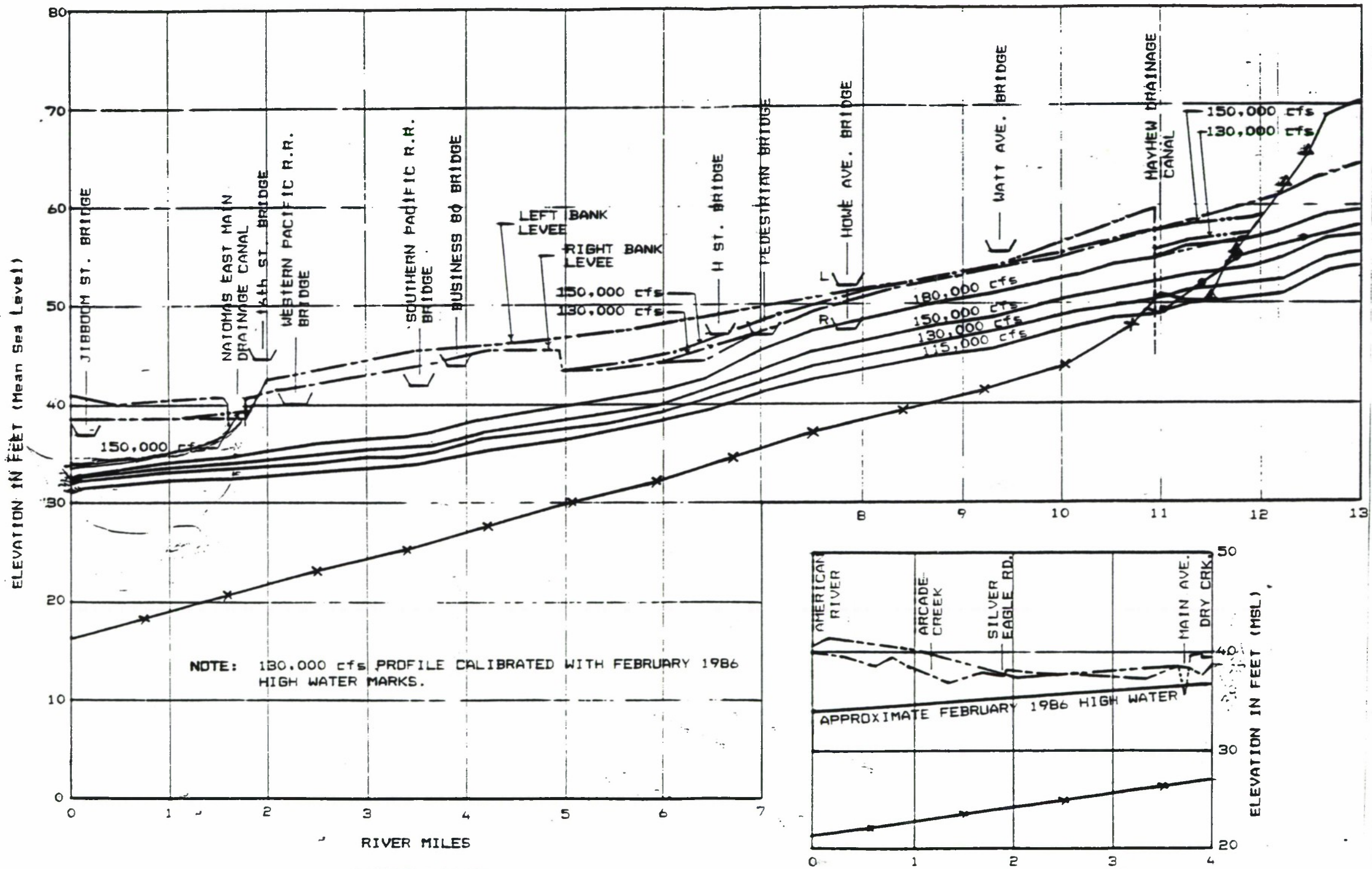


AMERICAN RIVER BASIN, CALIFORNIA

FOLSOM RESERVOIR INFLOW
100-YEAR FLOOD HYDROGRAPHS

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
FEBRUARY 1987

PLATE 5



AMERICAN RIVER

NATOMAS EAST MAIN DRAINAGE CANAL

LEGEND

- River Stage for Indicated Flows
- Average Natural Ground Adjacent to Levees
- Natural Ground Level Adjacent to River-Right Bank
- Natural Ground Level Adjacent to River-Left Bank
- Bridge Soffit
- Top of Levee-Right Bank
- Top of Levee-Left Bank
- Proposed Top of Levee-Right Bank
- Proposed Top of Levee-Left Bank

NOTE:

Levee and Channel Profiles, Sacramento River Flood Control Project, California, March 1957, Corps of Engineers.

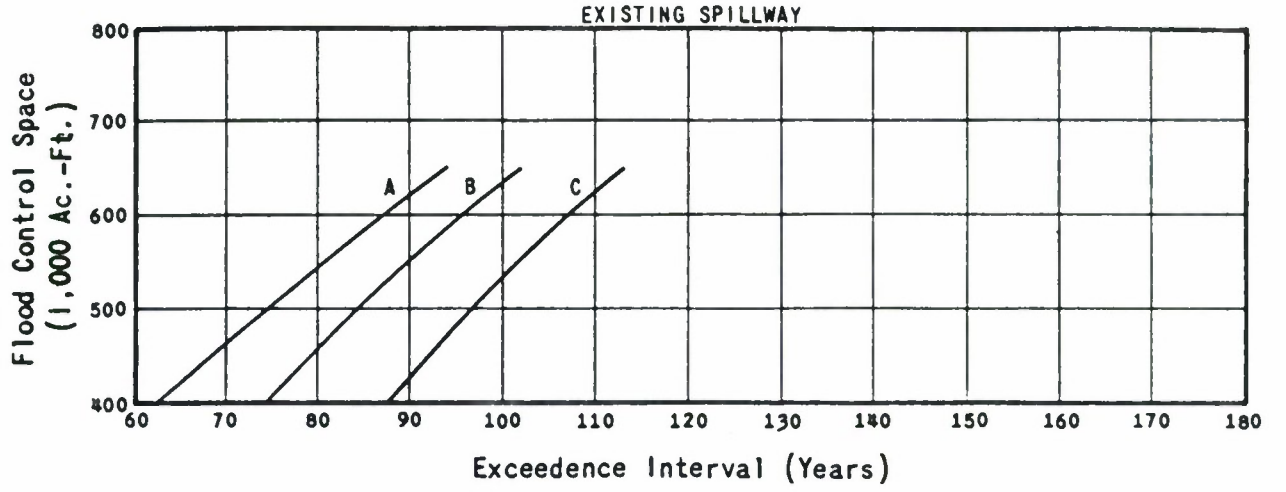
Computed Water Surface Profiles, Calibrated with February 1986 High Water Marks, Corps of Engineers.

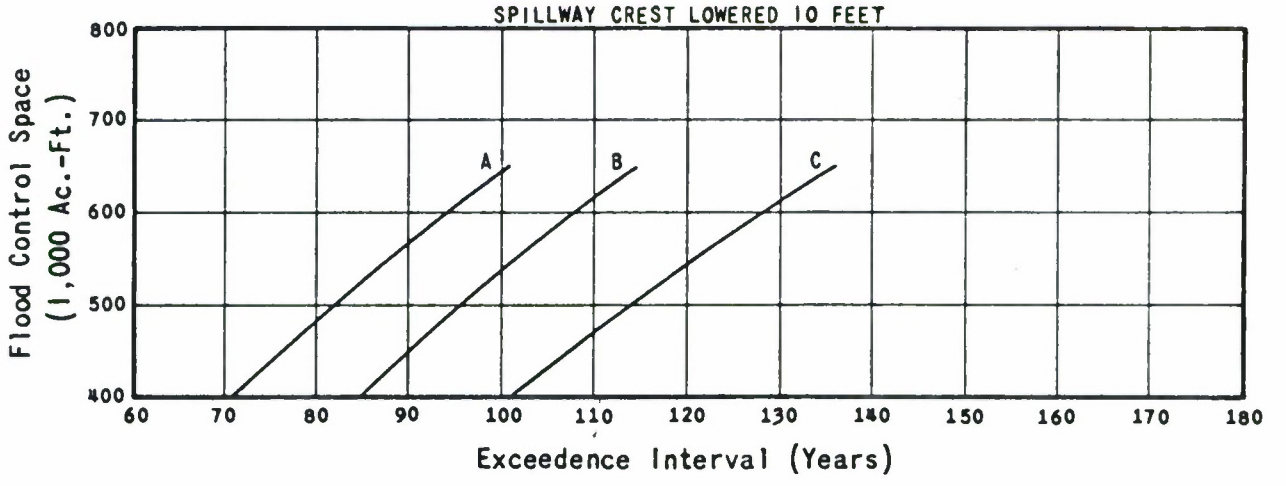
Report on American River Floodplain, California, March 1, 1963, Corps of Engineers.

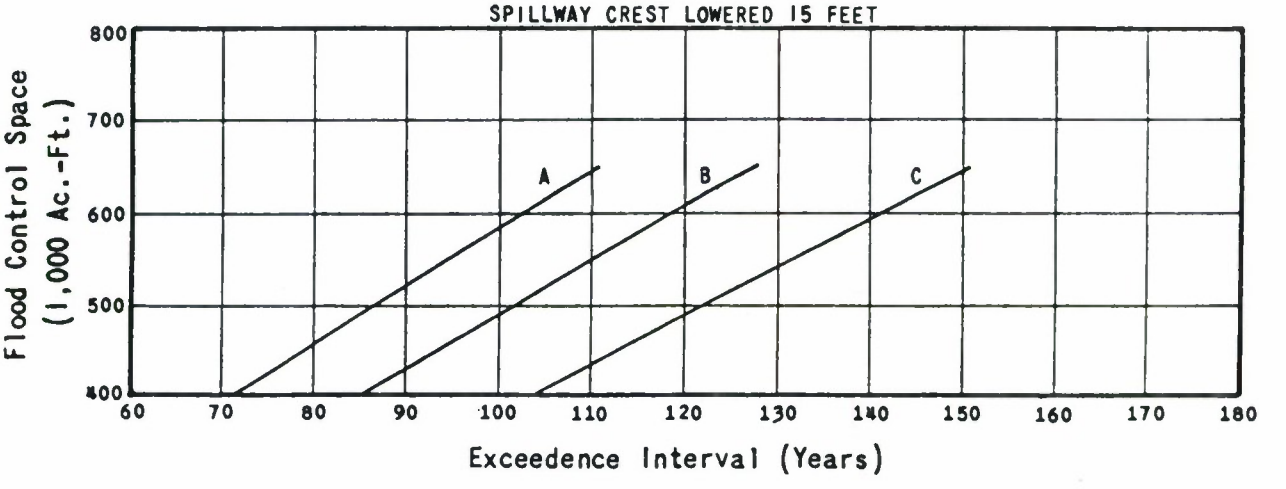
AMERICAN RIVER BASIN
CALIFORNIA

LEVEE AND RIVER FLOW PROFILES

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
FEBRUARY 1987







LEGEND:

A Channel capacity - 115,000 cfs
B Channel capacity - 130,000 cfs
C Channel capacity - 150,000 cfs

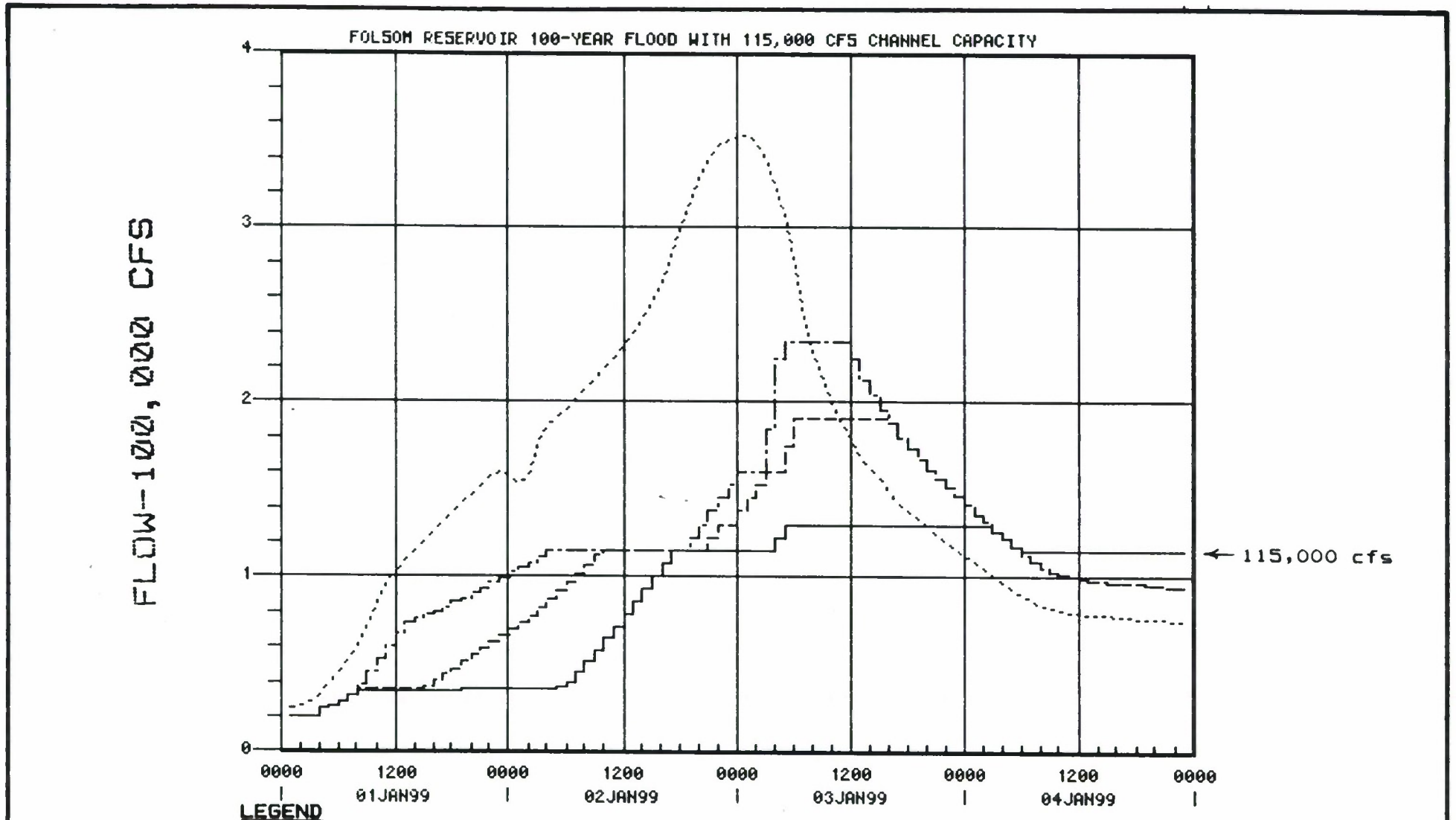
NOTE:
Emergency spillway release diagram used.

AMERICAN RIVER BASIN, CALIFORNIA

FOLSOM DAM OPERATION FOR DOWNSTREAM CONTROL

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
FEBRUARY 1987

PLATE 7

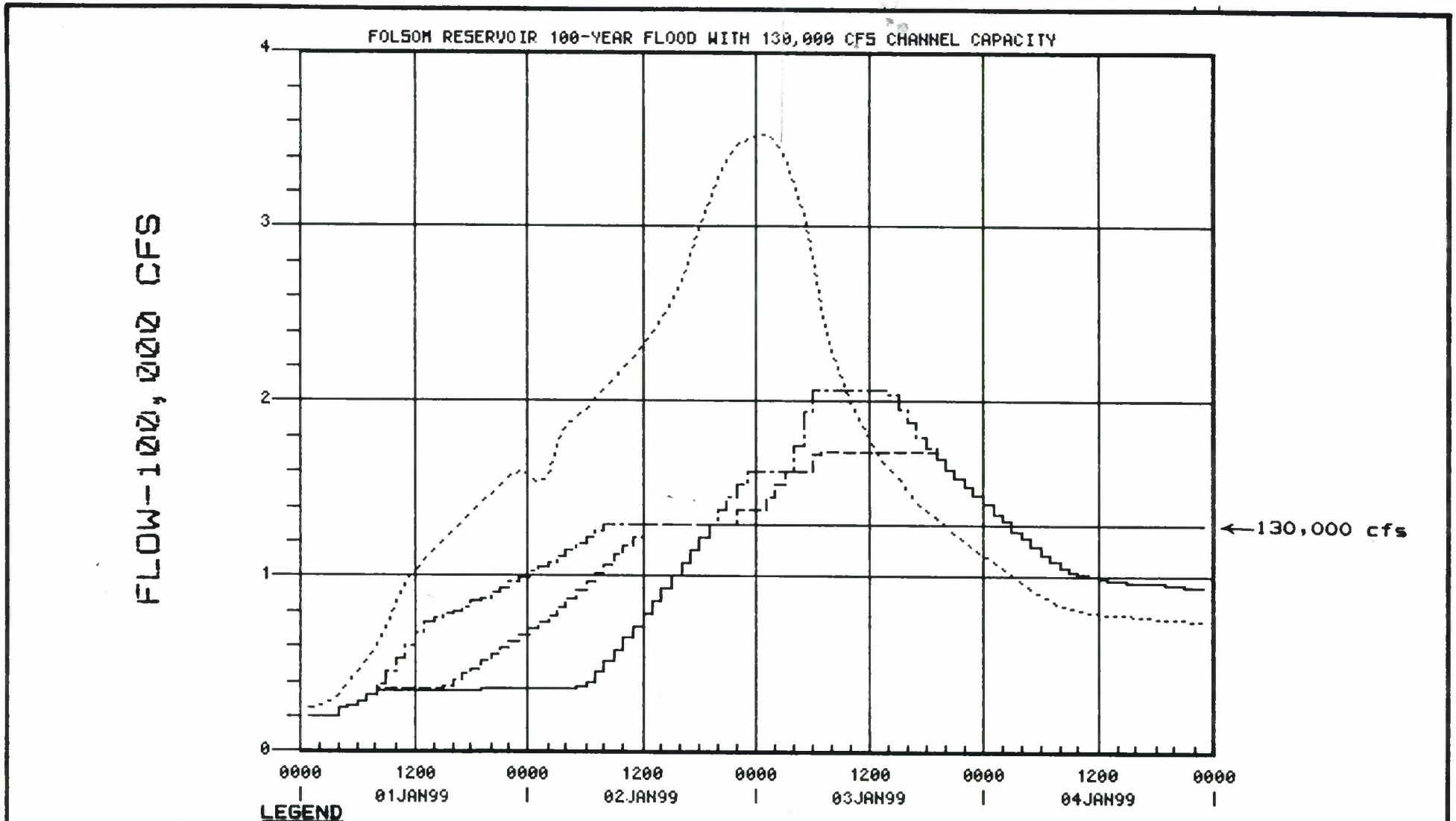


AMERICAN RIVER BASIN, CALIFORNIA

FOLSOM ROUTING
100-YEAR HYDROGRAPH
@115,000 CFS RELEASE

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
FEBRUARY 1987

PLATE 8

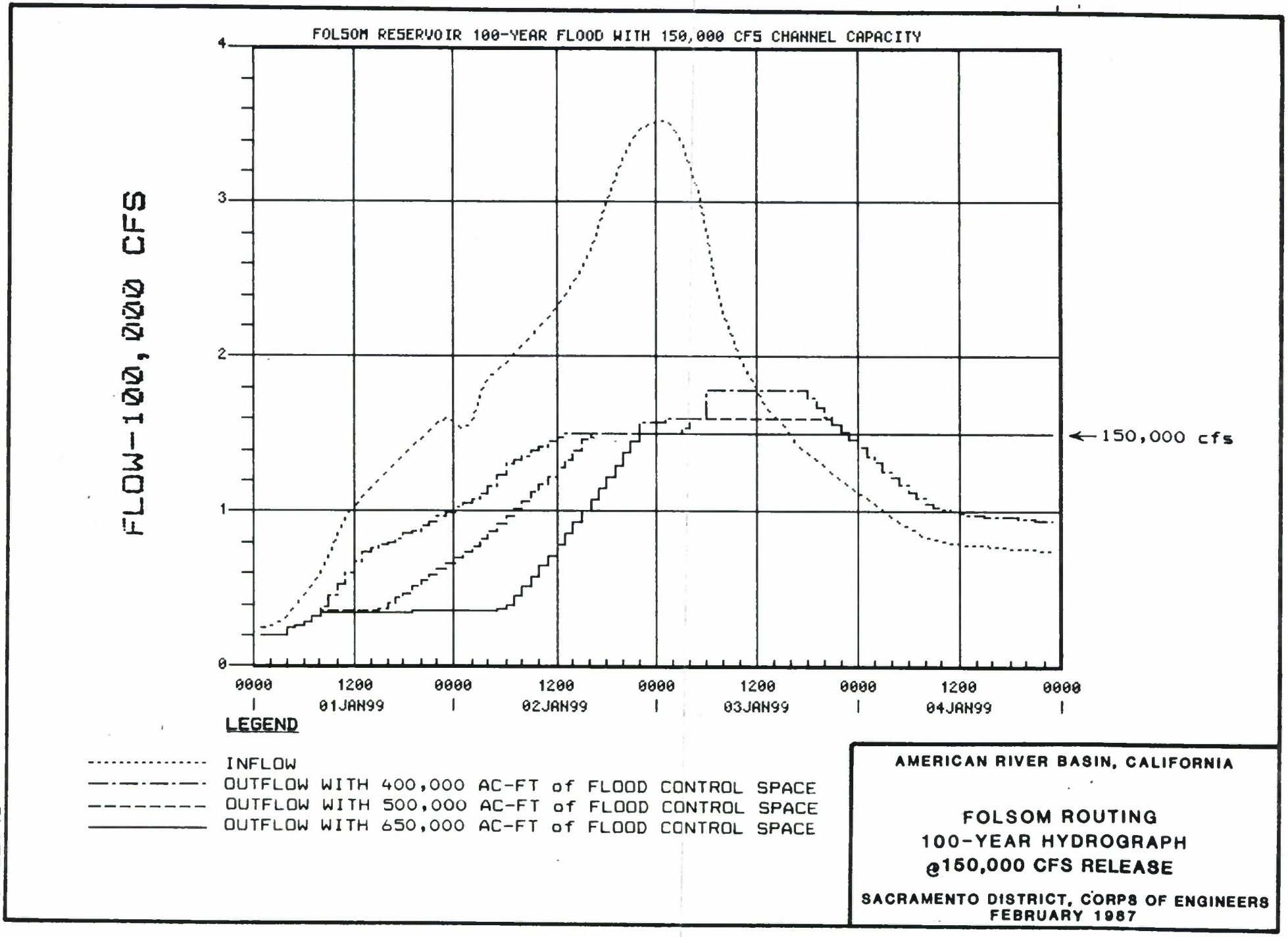


AMERICAN RIVER BASIN, CALIFORNIA

FOLSOM ROUTING
100-YEAR HYDROGRAPH
@130,000 CFS RELEASE

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
FEBRUARY 1987

PLATE 9



AMERICAN RIVER BASIN, CALIFORNIA

FOLSOM ROUTING
100-YEAR HYDROGRAPH
@150,000 CFS RELEASE

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FEBRUARY 1987

PLATE 10

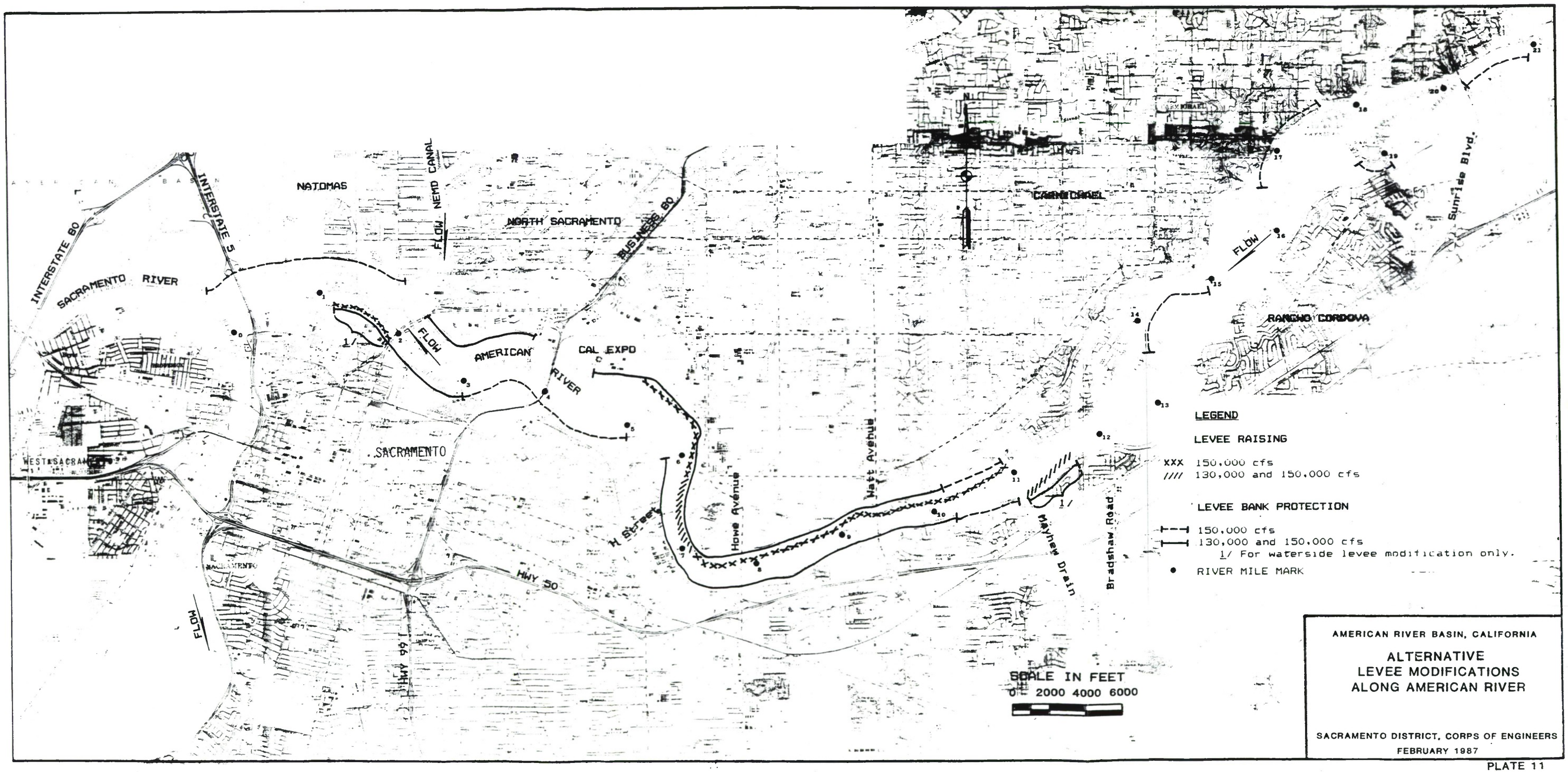
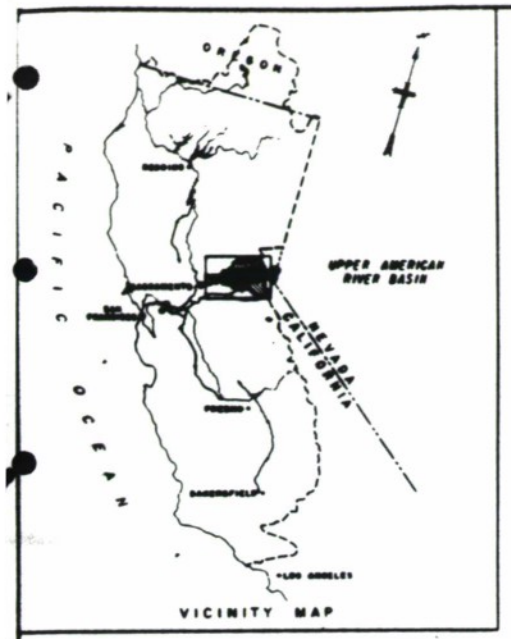

INTERSTATE 80
INTERSTATE 5
SACRAMENTO RIVER
NATOMAS
NEMO CANAL
FLOW
NORTH SACRAMENTO
BUSINESS 80
CAMP CORAL
Sunrise Blvd.
FLOW
RANCHO CORDOVA
1/
FLOW
AMERICAN
RIVER
CAL EXPO
SACRAMENTO
WEST SACRAMENTO
H Street
Howe Avenue
Watt Avenue
Mayhew Drain
Bradshaw Road
HWY 50
HWY 99
FLOW
1/
LEGEND
LEVEE RAISING
XXX 150,000 cfs
//// 130,000 and 150,000 cfs
LEVEE BANK PROTECTION
150,000 cfs
130,000 and 150,000 cfs
1/ For waterside levee modification only.
RIVER MILE MARK
SCALE IN FEET
0 2000 4000 6000
AMERICAN RIVER BASIN, CALIFORNIA
ALTERNATIVE
LEVEE MODIFICATIONS
ALONG AMERICAN RIVER
SACRAMENTO DISTRICT, CORPS OF ENGINEERS
FEBRUARY 1987

PLATE 11



SOURCE:
U.S. Department of the Interior
Bureau of Reclamation

SCALE IN MILES

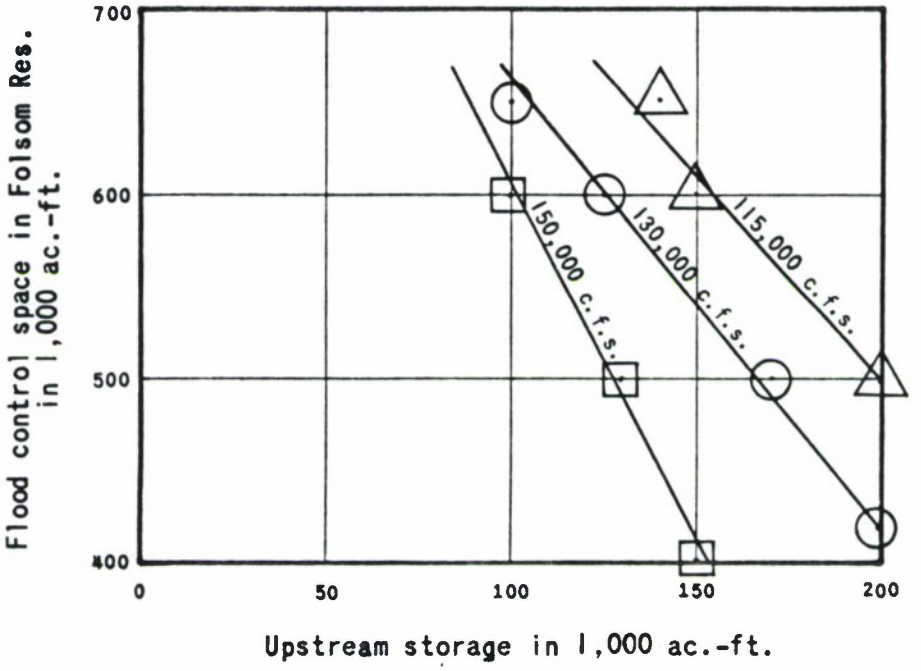
1 0 1 2 3 4 5

AMERICAN RIVER BASIN, CALIFORNIA

AUBURN DAM AND RESERVOIR AND VICINITY

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
FEBRUARY 1987

PLATE 12



NOTES:

1. Curves indicate assumed channel capacity in the American River below Folsom Dam.
2. The max. upstream storage that would be effective in the system is 200,000 ac.-ft.
3. Routings reflect little or no surcharge in Folsom Reservoir.
4. Upstream storage is to be proportionally divided among the five upstream Reservoirs: (1) French Meadows, (2) Hell Hole, (3) Loon Lake, (4) Union Valley, (5) Ice House.
5. Upstream Reservoirs control approx. 14% of the drainage area and approx. 18% of the runoff.

AMERICAN RIVER BASIN, CALIFORNIA

REQUIRED STORAGE SPACE FOR EXISTING UPSTREAM RESERVOIRS 100-YEAR PROTECTION

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
FEBRUARY 1987

PLATE 13

TO: Defense Technical Information Center
ATTN: DTIC-O
8725 John J. Kingman Road, Suite 0944
Fort Belvoir VA 22060-6218

22 October 2008

FROM: US Army Corps of Engineers
Sacramento District Library
1325 J Street, Suite 820
Sacramento CA 95814-2292

SUBJECT: Submission of technical reports for inclusion in Technical Reports Database

The enclosed documents from USACE Sacramento District are hereby submitted for inclusion in DTIC's technical reports database. The following is a list of documents included in this shipment:

ADB344304 • Lemon Reservoir Florida River, Colorado. Report on reservoir regulation for flood control, July 1974

ADB344333 • Reconnaissance report Sacramento Metropolitan Area, California, February 1989

ADB344346 • New Hogan Dam and Lake, Calaveras River, California. Water Control Manual Appendix III to Master Water Control Manual San Joaquin River Basin, California, July 1983

ADB344307 • Special Flood Hazard Study Nephi, Utah, November 1998 (cataloged)

ADB344344 • Special Study on the Lower American River, California, Prepared for US Bureau of Reclamation – Mid Pacific Region and California Dept. of Water Resources..., March 1987

ADB344313 • Transcript of public meeting Caliente Creek stream group investigation, California, held by, the Kern County Water Agency in Lamont, California, 9 July 1979

ADB344302 • Initial appraisal Sacramento River Flood control project (Glenn-Colusa), California, 10 February 1989

ADB344485 • Report on November-December 1950 floods Sacramento-San Joaquin river basins, California and Truckee, Carson, and Walker rivers, California and Nevada, March 1951

ADB344268 • Reexamination Little Dell Lake, Utah, February 1984

ADB344197 • Special report fish and wildlife plan Sacramento River bank protection project, California, first phase, July 1979

ADB344264 • Programmatic environmental impact statement/environmental impact report Sacramento River flood control system evaluation, phases II-V, May 1992

ADB344201 • Hydrology office report Kern river, California, January 1979

ADB344198 • Kern River – California aqueduct intertie, Kern county, California, environmental statement, February 1974

ADB344213 • Sacramento river Chico Landing to Red Bluff, California, bank protection project, final environmental statement, January 1975

ADB344265 • Cottonwood Creek, California, Information brochure on selected project plan, June 1982

ADB344261 • Sacramento river flood control project Colusa Trough Drainage Canal, California, office report, March 1993

ADB344343 • Detailed project report on Kern River-California aqueduct intertie, Kern County, California. February 1974

ADB344267 • Sacramento River Flood Control Project, California, Right Bank Yolo Bypass and Left Bank Cache Slough near Junction Yolo Bypass and Cache Slough, Levee construction, General Design, Supplement No. 1 to Design Memorandum #13, May 1986

ADB344246 • Redbank and Fancher Creeks, California, General Design Memorandum #1, February 1986

ADB344260 • Cache Creek Basin, California, Feasibility report and environmental statement for water resources development Lake and Yolo counties, California, February 1979

ADB344199 • Sacramento River Deep Water Ship channel, California, Feasibility report and environmental impact statement for navigation and related purposes, July 1980

ADB344263 • Sacramento River flood control project, California, Mid-Valley area, phase III, Design Memorandum, Vol. I or II, June 1986

ADB344262 • Marysville Lake, Yuba River, California, General Design Memorandum Phase I, Plan Formulation, Preliminary Report, Appendixes A-N, Design Memorandum #3, March 1977

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Thank you,

Frances J. Sweeney
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