EXECUTIVE SUMMARY

US Army Corps
of Engineers
Sacramento District

Post-Flood Assessment for 1983, 1986, 1995, and 1997
Central Valley, California

CHAPTER 1

INTRODUCTION

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INTRODUCTION

The great Central Valley of California, and surrounding foothills and mountains up to the ridge tops of the Sierra Nevada and Coast Range (Figure 1-1), is located in the central portion of the state and covers more than 60,000 square miles. The Central Valley is comprised of two major valleys; the Sacramento Valley in the north and the San Joaquin Valley in the south. The Sacramento Valley encompasses an area of 26,300 square miles and is drained by the Sacramento River. The San Joaquin Valley includes the San Joaquin River Basin (16,700 square miles) which drains the northern half of the San Joaquin Valley, and the Tulare Lake Basin (17,400 square miles), an interior drainage that comprises the southern half. The Sacramento and San Joaquin River basins receive flow from multiple rivers and streams to drain a combined area greater than 43,000 square miles, most of which is on the western slope of the Sierra Nevada. They converge in the Sacramento-San Joaquin River Delta and discharge through San Francisco Bay to the Pacific Ocean. In total, more than 40 percent of the surface water in California flows through the Sacramento and San Joaquin River systems.

Over the years, floods on these two river systems have caused the loss of lives, as well as property damages. The California Department of Water Resources (DWR) has estimated that approximately 90 percent of all natural disasters in the State are flood-related, posing a greater threat to the safety of Californians than even earthquakes. Accordingly, the development, operation, and maintenance of flood management systems have been critical factors in the economic development of California.

The primary objectives of flood management are twofold: reduce loss of life and minimize the economic effects of flood-related natural disasters. Traditionally, two approaches to flood management have been applied: structural and nonstructural. The structural approach features physical structures such as dams and reservoirs, levees, and bypass channels to confine floodflows and direct the flows away from residential, municipal, prime agricultural, municipal, and industrial areas. Nonstructural approaches focus on management and institutional policies which limit and/or regulate development in floodplains, thereby keeping people away from the floodwaters.

Flood damage reduction in the Central Valley began during the initial settlement of the State in the mid-1800's with the construction of levees and bypasses and the use of natural overflow areas. As development continued, the need for additional means for managing floodflows became evident. In the early 1900's, construction of dams and reservoirs for the sole purpose of flood damage reduction, in combination with overflow and bypass areas, was proposed to the Federal Government. A later review of this proposal determined that construction of dams and reservoirs for flood damage reduction alone would not be economically feasible. However, it was recognized that multipurpose dams and reservoirs that included flood management storage, water supply, and power generation could be economically feasible.

The development of multipurpose reservoirs began in 1932 when the California State Legislature authorized the Central Valley Project (CVP). Due to the inability to secure State funding, the Federal Government later authorized and funded the CVP for construction. The CVP includes major dams and reservoirs that provide flood storage on the Sacramento, American, Stanislaus, and San Joaquin rivers. Multipurpose dams and reservoirs on other major rivers in the Sacramento and San Joaquin Valleys were constructed between the 1940's and the 1970's. In 1960, the State Water Project (SWP) was authorized by California voters to develop additional multipurpose projects. The SWP Oroville Reservoir on the Feather River provides flood management, as well as water supply, hydropower, navigation, water-related recreation, and environmental benefits to the State of California.

The completion of New Melones Reservoir on the Stanislaus River in 1980 marked the last major addition to flood management facilities in the Central Valley. Since then, the Central Valley has been subjected to four major floods (1983, 1986, 1995, and 1997) that have revealed problems in the existing system. The most significant event was in January 1997.

FLOODS OF 1997

In January 1997, Californians experienced the largest and most extensive flood disaster in the State's history. Major storms caused record flows on many rivers throughout California. In the Central Valley, the flood management systems for the Sacramento and San Joaquin rivers were pushed to capacity and beyond. Flood storage behind dams reduced floodflows by half or more, saving lives and significantly reducing property damage. However, in some areas, levees were overwhelmed. Levees on Sacramento River tributaries sustained three major breaks. Where levees performed as designed, damage from erosion was significant. On the San Joaquin River, levees failed in thirty four places. Damage to urban and agricultural lands and the cost to replace, restore, and rehabilitate flood damage reached $524 million for the Central Valley of California.

STUDY AUTHORITY

In the House of Representatives Report (105-190) on the 1998 Energy and Water Development Appropriations Bill, Congress recognized the devastating effects of the 1997 floods and directed the Corps to conduct a comprehensive assessment of the flood management systems in the Central Valley.

Federal Study Authority

The Corps has a long history of water resource development in the Central Valley through its flood damage reduction and navigation missions. Section 306 of the Water Resources Development Act of 1990 added environmental protection as a primary Corps mission.

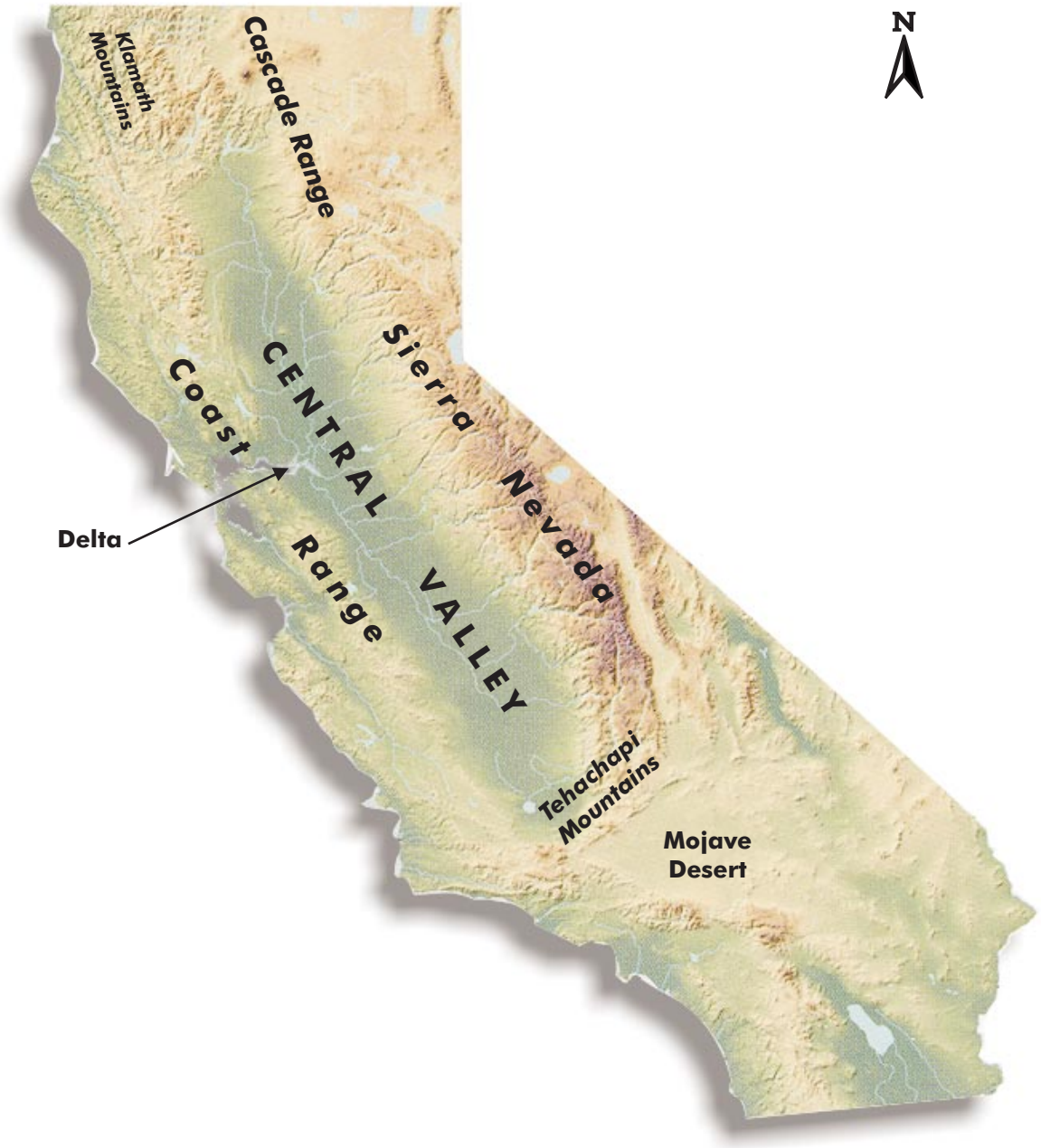
Funding for the study was provided in the Energy and Water Development Act of 1998. In its Report (105-190) on the 1998 Energy and Water Development Appropriations Bill, the House of Representatives provided guidance in the following language:

***Sacramento River and San Joaquin River Basins Comprehensive Study, California.**–In response to the devastating floods of 1997, the Committee has added funds and directs the Corps of Engineers to conduct a comprehensive assessment of the entire flood control system within the existing study authorizations. . .These comprehensive investigations will include: (1) preparation of a comprehensive post-flood assessment for the California Central Valley (Sacramento River Basin and San Joaquin River Basin), (2) development and formulation of comprehensive plans for flood control and environmental restoration purposes, and (3) development of a hydrologic/hydraulic model of the entire system including the operation of the existing reservoirs for evaluation of the current flood control system. Not later than 18 months after the date of enactment of this Act the Secretary shall transmit an interim report describing results of the post-flood assessment and the assessment of the existing flood control system and its deficiencies.*

STUDY SCOPE

This Post-Flood Assessment has been prepared in accordance with the Congressional Authorization to support the Sacramento and San Joaquin River Basins Comprehensive Study. The report describes recent (1983, 1986, 1995, 1997) major floods in the Sacramento and San Joaquin River basins and the extent of damages sustained and prevented. The analysis identifies system deficiencies, including locations of past failures, and estimates of property and populations currently at risk. To provide an understanding of the current flood management system and its operations during these recent floods, the historical development of flood protection as well other historical floods (prior to 1983) is provided. The current flood management system is described, including a summary of flood protection facilities and their operating objectives and constraints.

The report is organized in six chapters. Chapter 1 describes the need for the report and cites Federal and State of California legislative directives to proceed with the study. Chapter 2 provides a historical perspective of flooding and the development of flood protection in the Central Valley, from the mid-1800s to present. Chapter 3 describes the existing flood protection facilities in the Central Valley and their operating criteria. Chapter 4 provides an overview of the multiple agencies involved in the operation of flood protection facilities. Chapter 5 describes the effects of four recent floods in the Central Valley. For each event (1983, 1986, 1995, and 1997), storm and prestorm conditions are described, system breaks are identified, the extent of flooding is shown, and damages sustained and prevented are summarized. In addition, the results of a site-specific damage survey taken after the 1997 flood in Yuba County are presented. Chapter 6 summarizes problems with the existing flood protection system, the results of updated flood frequency analyses that include the last four major floods, and areas at risk of flooding. For each area at risk, agricultural and urban land areas, property values, and population at risk are summarized.



POST FLOOD ASSESSMENT FOR
1983, 1986, 1995, and 1997

FIGURE 1-1
PHYSIOGRAPHIC REGIONS
IN CALIFORNIA

US Army Corps of Engineers
Sacramento District
March 1999

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EXECUTIVE SUMMARY

During the past two decades, the Central Valley of California has experienced several of the most devastating floods of the past century. Four recent major floods (in 1983, 1986, 1995, and 1997) caused widespread and extensive damage in the Sacramento and San Joaquin Valleys, resulting in substantial repair, replacement, and rehabilitation efforts throughout the flood management systems.

In January 1997, Californians experienced one of the largest and most extensive flood disasters in the State's history, with flood damages of $524 million in the Central Valley. Responding to this disaster, Congress directed the Corps of Engineers to conduct a comprehensive assessment of the flood management systems in the Central Valley. Authorization and funding for a Post-Flood Assessment was provided in the Energy and Water Development Act of 1998, which gave directions for: *"preparation of a comprehensive post-flood assessment for the California Central Valley (Sacramento River Basin and San Joaquin River Basin)..."*

The Post-Flood Assessment focuses on the impact of major floods in the Sacramento and San Joaquin River basins during 1983, 1986, 1995, and 1997. It also describes the development of flood protection in the Central Valley during the past 150 years. This includes descriptions of major flood events prior to 1983 and a summary of flood protection facilities and their operating objectives and constraints.

For each of the four recent floods evaluated, The Post-Flood Assessment describes prestorm and storm conditions, system problems (including reservoir management concerns, levee failures, and extent of flooding); corrective actions taken; economic damages sustained due to flooding; and economic damages prevented through the operation of the flood management system. The Post-Flood Assessment also identifies problems in the existing flood management system, and estimates the populations and value of property at risk of flooding.

The Post-Flood Assessment found that in both the 1986 and 1997 floods, near catastrophic damages were narrowly avoided. Both of these floods pushed the existing flood management system beyond its limits, resulting in numerous system failures. In summary,

- Existing flood management systems functioned, but were clearly overtaxed
- Combined damages from four recent floods exceed $1.6 billion
- Another flood like those of 1986 or 1997 would likely result in similar or greater devastation
- Storms greater than those of January 1997 are possible, and the resulting flooding could be catastrophic
- The flood management system is in desperate need of upgrade and modification

BACKGROUND

The Great Central Valley of California, located between the Sierra Nevada and Coast Range Mountains, covers more than 60,000 square miles, approximately the same area as the State of Florida. The Central Valley contains two valleys that join at their lowest elevations at the Sacramento-San Joaquin River Bay Delta Estuary. The Sacramento Valley comprises about 26,300 square miles in the northern portion of the Central Valley, and is drained by the Sacramento River. San Joaquin Valley comprises the southern portion of the Central Valley. The San Joaquin River drains 16,700 square miles in the northern half of the San Joaquin Valley. The Tulare Lake Basin is a 17,400 square mile area of interior drainage in the southern half of the San Joaquin Valley. In total, more than 40 percent of the surface water in California flows through the Sacramento and San Joaquin River systems.

Due to its climate and geography, flooding is a frequent and natural event in the Central Valley. The Sacramento River basin has been subject to floods that result from winter and spring rainfall as well as combined rainfall and snowmelt. The San Joaquin River basin has been subject to floods that result from both rainfall that occurs during late fall and winter months, and unseasonable and rapid melting of the snowpack during the spring and early summer months. Over the past 150 years, floods on the Sacramento and San Joaquin River systems have caused the loss of lives and substantial property damages. During that same time, the construction of flood damage protection and water supply projects in the Central Valley allowed extensive development of highly productive agricultural lands and the growth of urban centers. Today, the Central Valley produces over 45 percent of the fresh fruits and vegetables in the nation.

HISTORY

The discovery of gold in the Sierra Nevada Foothills in 1848 marked the beginning of the California Gold Rush, which brought two important developments that shaped flood management in the Central Valley. First, aggressive mining techniques, particularly hydraulic mining of gold in the Sierra Nevada, discharged extensive sediment into streams tributary to the Central Valley. It has been estimated hydraulic mining washed up to 53 million cubic yards of material into the streams and canyons tributary to the Sacramento and San Joaquin rivers each year. This vast amount of material reduced downstream channel capacity, resulting in increased flooding of the lower lying areas. Second, with the great influx of people into the State, the demand for goods grew tremendously, prompting the agricultural development of the fertile tule lands along Central Valley rivers.

Flood management systems in the Sacramento and San Joaquin River basins were developed incrementally over many years in response to major floods. Between 1850 to 1900, the Sacramento River basin was affected by 12 major floods and the San Joaquin River basin experienced 16 major floods. During that period, flood protection focused on local concerns, and primarily consisted of building or raising levees as landowners protected their lands from the increasingly common floods caused by the influx of mining debris. This work, however, was not coordinated on a regional or system-wide basis and often resulted in conflicting solutions.

Following major flood events in 1907 and 1909, plans were laid for more regional flood management systems. The Jackson Report, compiled by the California Debris Commission, proposed the construction of the Sacramento River Flood Control Project. Thus began the construction of many levees, weirs, and bypasses in the Sacramento Valley, including levees on the Sacramento, Feather, Yuba, Bear, and American rivers; and overflow areas in the Butte Basin, Sutter, and Yolo Bypasses. The Lower San Joaquin River and Tributaries Project, authorized in 1944, included the construction of levees on the San Joaquin River downstream from the Merced River. Upstream of the Merced River, the State of California constructed bypasses to protect lands adjacent to the San Joaquin River.

Starting in the 1940's, multipurpose dams and reservoirs that provide storage for flood protection, water supply, hydroelectric power generation, environmental requirements, and recreation were constructed on major rivers in the Sacramento and San Joaquin River basins. Some of the multipurpose dams were constructed as part of the Federal Central Valley Project and the California State Water Project, while others were constructed and operated by the Corps of Engineers, or numerous local entities.

RECENT FLOODS

Between 1900 and 1997, the Sacramento and San Joaquin River basins experienced 13 destructive floods. The most recent floods—in 1983, 1986, 1995, and 1997—caused extensive damages in both basins and raised questions about the adequacy of the current flood management systems and land use in the floodplains. Although the existing flood management systems functioned during recent floods and prevented over $38 billion in potential damages, they were clearly overtaxed as evidenced by numerous failures and damages in excess of $1.6 billion.

DAMAGES SUSTAINED AND PREVENTED IN RECENT FLOODS
(values in $ millions)

Event (Year)	Damages Sustained			Damages Prevented		
	Sacramento River Basin	San Joaquin River Basin	Total	Sacramento River Basin	San Joaquin River Basin	Total
1983	$91	$324	$415	$2,833	$247	$3,080
1986	$172	$15	$187	$9,881	$324	$10,205
1995	$305	$193	$498	$3,541	$156	$3,697
1997	$301	$223	$524	$20,417	$811	$21,228

Note :Values represent conditions and price levels for the year of the event.

Flood of 1983

Water year 1983 was one of the wettest this century in California, a result of the "El Nino" weather phenomenon. Northern and Central California experienced flooding incidents from November through March due to numerous storms. In early May, snow water content in the Sierra exceeded 230 percent of normal, and the ensuing runoff resulted in approximately four times the average volume for Central Valley streams. System failures in the Sacramento River Basin were limited to a private levee on the Sacramento River and one failure on Cache Creek. In the San Joaquin River Basin, levee breaks caused flooding at four locations along the San Joaquin River. In the Delta, four levees failed, resulting in partial or total flooding of some islands. Damages exceeded $91 million and $324 million in the Sacramento and San Joaquin River basins respectively.

Flood of 1986

Flooding in 1986 resulted from a series of four storms over a 9-day period during February. Rains from the first three storms saturated the ground and produced moderate to heavy runoff before the arrival of the fourth storm. Precipitation at Four Trees in the Feather River Basin set both a 24-hour rainfall record for the Sierra Nevada and the monthly record for any station in the State. System breaks in the Sacramento River Basin included disastrous levee breaks in the Olivehurst and Linda area on the Feather River. In the San Joaquin River Basin and the Delta, levees break along the Mokelumne River caused flooding in the community of Thornton and the inundation of four Delta islands. Damages exceeded $172 million and $15 million in the Sacramento and San Joaquin River basins respectively.

Flood of 1995

"El Nino" conditions in the Pacific forced major storm systems directly into California during much of the winter and early spring of 1995. The largest storm systems hit California in early January and early March. The major brunt of the January storms hit the Sacramento River Basin and resulted in small stream flooding primarily due to storm drainage system failures. The March 1995 storms were focused on the coastal ranges, and caused high flows in some of the San Joaquin River Basin west side tributaries. In particular, Arroyo Pasajero produced extremely high flows that collapsed bridges on Interstate 5 near Coalinga, killing 6 people. In total, flooding damages in 1995 exceeded $305 million and $193 million in the Sacramento and San Joaquin River basins respectively.

Flood of 1997

December 1996 was one of the wettest Decembers on record. Watersheds in the Sierra Nevada were already saturated by the time three subtropical storms added more than 30 inches of rain in late December 1996 and early January 1997. The third and most severe of these storms lasted from December 31, 1996, through January 2, 1997. Rain in the Sierra Nevada caused record flows that stressed the flood management system to capacity in the Sacramento River Basin and overwhelmed the system in the San Joaquin River Basin. Levee failures due to breaks or

overtopping in the Sacramento River Basin resulted in extensive damages. In the San Joaquin River Basin, dozens of levees failed throughout the river system and produced widespread flooding. The Sacramento-San Joaquin River Delta also experienced several levee breaks and levee overtopping. Damages exceeded $301 million and $223 million in the Sacramento and San Joaquin River basins respectively.

DAMAGE SURVEY

As part of the Post-Flood Assessment, site-specific relationships between depth of water and economic damages were developed. The relationships are based on surveys of 260 residences in the town of Arboga, near the Feather River, that were affected by extensive flooding in January 1997. Homes in Arboga experienced a wide range of flooding depths, ranging from very little water to depths in excess of 20 feet with structures totally covered. Results from this study will be used to estimate damages to other single story homes in California's Central Valley. The results will also be combined with studies in other areas of the country to improve estimates of nonphysical costs and the effects of duration, velocity, sediment, and lead-time on flood damage.

ASSESSMENT OF CURRENT FLOOD MANAGEMENT SYSTEM

The current flood management systems in the Sacramento and San Joaquin River basins reflect this incremental development of flood protection projects, and require extensive coordination among several agencies to operate and maintain. Although flood management systems in the Sacramento and San Joaquin River basins have prevented billions of dollars in damages over time and have contributed greatly to the economic development of the State of California and the Nation, flood-related problems still exist.

SUMMARY OF FLOOD PROBLEMS

The flood management systems designed early in this century do not now have the capacity to convey peak floodflows experienced in the past decade.
For many parts of the system, the level of flood protection is not known and may not correlate to the value of property at risk of flooding.
Levee structural integrity is not reliable in some parts of the systems.
The cost to maintain the system is extremely high because of erosive floodflows or sedimentation.
No public or private entity has responsibility for maintaining flow-carrying capacity of the San Joaquin River channel from the Merced River downstream to the Delta.
The current operation plans for existing reservoirs, lack of system operations models, and the need for additional storage, preclude optimal use of storage in the flood management system.