FLOOD INSURANCE STUDY

YOLO COUNTY, CALIFORNIA
AND INCORPORATED AREAS

COMMUNITY NAME	COMMUNITY NUMBER
DAVIS, CITY OF	060424
*WEST SACRAMENTO, CITY OF	060728
WINTERS, CITY OF	060425
WOODLAND, CITY OF	060426
YOLO COUNTY (UNINCORPORATED AREAS)	060423

*FIS/FIRM published separately

Revised:
May 16, 2012

Federal Emergency Management Agency

FLOOD INSURANCE STUDY NUMBER
06113CV000B

NOTICE TO
FLOOD INSURANCE STUDY USERS

Communities participating in the National Flood Insurance Program have established repositories of flood hazard data for floodplain management and flood insurance purposes. This Flood Insurance Study (FIS) may not contain all data available within the repository. It is advisable to contact the community repository for any additional data.

Part or all of this FIS may be revised and republished at any time. In addition, part of this FIS may be revised by the Letter of Map Revision process, which does not involve republication or redistribution of the FIS. It is, therefore, the responsibility of the user to consult with community officials and to check the community repository to obtain the most current FIS components.

Initial Countywide FIS Effective Date: June 18, 2010

Revised Countywide FIS Date: May 16, 2012

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FLOOD INSURANCE STUDY
YOLO COUNTY, CALIFORNIA AND INCORPORATED AREAS

1.0 INTRODUCTION

1.1 Purpose of Study

This countywide Flood Insurance Study (FIS) investigates the existence and severity of flood hazards in, or revises and updates previous FISs/Flood Insurance Rate Maps (FIRMs) for the geographic area of Yolo County, California, including: the Cities of Davis, West Sacramento, Winters, Woodland, and the unincorporated areas of Yolo County (hereinafter referred to collectively as Yolo County).

This FIS aids in the administration of the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973. This FIS has developed flood risk data for various areas of the county that will be used to establish actuarial flood insurance rates. This information will also be used by Yolo County to update existing floodplain regulations as part of the Regular Phase of the National Flood Insurance Program (NFIP), and will also be used by local and regional planners to further promote sound land use and floodplain development. Minimum floodplain management requirements for participation in the NFIP are set forth in the Code of Federal Regulations at 44 CFR, 60.3.

In some States or communities, floodplain management criteria or regulations may exist that are more restrictive or comprehensive than the minimum Federal requirements. In such cases, the more restrictive criteria take precedence and the State (or other jurisdictional agency) will be able to explain them.

1.2 Authority and Acknowledgments

The sources of authority for this FIS are the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973.

This FIS was prepared to include the unincorporated areas of, and incorporated communities within, Yolo County in a countywide format. Information on the authority and acknowledgments for each jurisdiction included in this countywide FIS, as compiled from their previously printed FIS reports, is shown below.

Davis, City of:	the hydrologic and hydraulic analyses from the FIS report dated November 15, 1979, were performed by the U.S. Geological Survey (USGS) for the Federal Insurance Administration (FIA), under Inter-Agency Agreement No. IAA-H-17-75, Project Order No. 12. That work, which was completed in February 1978. The hydrologic and hydraulic analysis for the December 20, 2002 restudy were performed by

Borcalli and Associates, Inc., for the Federal Emergency Management Agency (FEMA), under Contract No. EMF-98-CO-0082. This work was completed in October 1999.

*West Sacramento, City of: The geographic area comprising the City of West Sacramento was originally studied as part of the FIS for the unincorporated areas of Yolo County, prior to the incorporation of the City of West Sacramento on January 1, 1987. The hydrologic and hydraulic analyses from the Yolo County Unincorporated Area FIS report dated December 16, 1980, were performed by the USGS for the Federal Emergency Management Agency (FEMA) under Interagency Agreement No. IAA-H-17-75, Project Order No. 12. The Yolo County FIS was completed in November 1977.

For the May 17, 1988, FIS, a restudy of tidal flooding in the Sacramento-San Joaquin Delta Area including the area east of Yolo County was performed by the U.S. Army Corps of Engineers (USACE) for FEMA under Interagency Agreement No. IAA-EME-E-1153, Project Order No. 1, Amendments No. 22 and 22(a). The restudy was completed in November 1985. The hydrologic and hydraulic analyses for the second restudy dated January 19, 1995, performed by the USACE, Sacramento District (the study contractor), for FEMA, under Interagency Agreement EMW-87-E-2509, Project Order No. 16, dated April 1, 1987, were completed in January 1989.

Winters, City of: The hydrologic and hydraulic analyses from the FIS report dated December 1, 1978, were performed by the USGS for the FIA, under Interagency Agreement No. IAA-H-17-75, Project Order No. 12. That study was completed in July 1977. The hydrologic and hydraulic analyses from the FIS report dated November 20, 1998, were performed by Borcalli & Associates, Inc., for FEMA, under Contract No. EMF-96-CO-0097. That study was completed in August 1997.

*The FIS and FIRM for this community are published separately.

Woodland, City of: The hydrologic and hydraulic analyses from the FIS report dated April 1979 were performed by the USACE, Sacramento District, for the FIA, under Interagency Agreement Nos. IAA-H-16-75 and IAA-H-7-76, Project Order Nos. 17 and 1, respectively. That work was completed in July 1976.

The hydrologic and hydraulic analyses for the restudy of Cache Creek upstream of County Road 94B were performed by A&M Engineering Consultants of California, for FEMA, under Contract No. EMS-96-CO-0080. That work was completed in March 1998, and supersedes the original study for the described portion of Cache Creek.

The hydrologic and hydraulic analyses for the restudy from County Road 94B to the Cache Creek Settling Basin and Right Overbank Flow Area were performed by Michael Baker, Jr., Inc., for FEMA, under Contract No. EMW-2000-CO-0002. That work was completed in March 2001.

The hydraulic analysis for Cache Creek was performed by Wood Rodgers, Inc and included in the report "Cache Creek South Levee Floodplain Application for Letter of Map Revision," developed for the City of Woodland. The work was completed in September 2009. This restudy also affects the unincorporated areas of Yolo County.

Yolo County (Unincorporated Areas): The hydrologic and hydraulic analyses from the Yolo County Unincorporated Area FIS report dated December 16, 1980, were performed by the USGS for FEMA under Interagency Agreement No. IAA-H-17-75, Project Order No. 12. The Yolo County FIS was completed in November 1977.

A restudy of tidal flooding in the Sacramento-San Joaquin Delta Area including the area east of Yolo County was performed by the USACE for FEMA under Interagency Agreement No. IAA-EME-E-1153, Project Order No. 1, Amendments

No. 22 and 22(a). The restudy was completed in November 1985.

The hydrologic and hydraulic analyses for the second restudy, performed by the USACE, Sacramento District (the study contractor), for FEMA, under Interagency Agreement EMW-87-E-2509, Project Order No. 16, dated April 1, 1987, were completed in January 1989.

The hydrologic and hydraulic analyses for the restudy, excluding the hydraulic analysis for Dry Creek, were performed for FEMA by Ensign & Buckley under Contract No. EMW-94-C-4572. This restudy was completed in December 1996.

The hydraulic analysis for the restudy of Dry Creek was performed for FEMA by Borcalli & Associates, Inc., under Contract No. EMF-96-CO-0097. This restudy was completed in August 1997.

The hydrologic and hydraulic analyses for this restudy were performed by Borcalli and Associates, Inc., for FEMA, under Contract No. EMF-98-CO-0082. This work was completed in October 1999.

The hydraulic analysis for Cache Creek was performed by Wood Rodgers, Inc and included in the report "Cache Creek South Levee Floodplain Application for Letter of Map Revision," developed for the City of Woodland. The work was completed in September 2009. This restudy also affects the unincorporated areas of Yolo County.

On selected FIRM panels, planimetric base map information was provided in digital format from Sacramento Area Council of Governments (SACOG). These data were developed in conjunction with the tax assessor’s parcel base map and published by SACOG in June 2005. Additional information may have been derived from other sources. Users of this FIRM should be aware that minor adjustments may have been made to specific base map features.

The coordinate system used for the production of this FIRM is Universal Transverse Mercator (UTM), North American Datum of 1983 (NAD 83), GRS80 spheroid. Corner coordinates shown on the FIRM are in latitude and longitude referenced to the UTM projection, NAD 27. Differences in the datum and spheroid used in the production of FIRMs for adjacent counties may result in slight positional differences in map features at the county boundaries. These differences do not affect the accuracy of information shown on the FIRM.

1.3 Coordination

Consultation Coordination Officer's (CCO) meetings may be held for each jurisdiction in this countywide FIS. An initial CCO meeting is held typically with representatives of FEMA, the community, and the study contractor to explain the nature and purpose of a FIS, and to identify the streams to be studied by detailed methods. A final CCO meeting is held typically with representatives of FEMA, the community, and the study contractor to review the results of the study.

The following agencies were contacted to obtain maps, information, and data pertinent to the present study: the Yolo County Public Works Department; the Yolo County Flood Control and Water Conservation District; State Reclamation Districts 900 (West Sacramento Area) and 811 (Bryte and Broderick); the State of California; the consulting firm of Murray, Burns and Keinlen; the USACE, and the U.S. Soil Conservation Service (SCS).

The dates of the initial and final CCO meetings held for Yolo County and the incorporated communities within its boundaries are shown in Table 1, "Initial and Final CCO Meetings."

TABLE 1 - INITIAL AND FINAL CCO MEETINGS

Community	For FIS Dated	Initial CCO Date	Final CCO Date
Davis, City of	November 15, 1979	*	July 6, 1978
	December 20, 2002	*	February 8, 2002
		June 1, 2005	
West Sacramento, City of	December 16, 1980	*	April 17, 1979
	May 17, 1988	July 25, 1983	November 7, 1985
	January 19, 1995	*	*
		June 1, 2005	
Winters, City of	December 1, 1978	*	*
	November 20, 1998	*	December 16, 1997
		June 1, 2005	
Woodland, City of	April 1979	November 20, 1974	December 20, 1977
	October 13, 1981	*	*
	April 17, 2001	October 31, 1995	*
	April 2, 2002	March 17, 2000	
		June 1, 2005	
	September 30, 2010		October 19, 2010
Yolo County	December 16, 1980	*	April 17, 1979
(Unincorporated Areas)	May 17, 1988	July 25, 1983	November 7, 1985
	July 6, 1998	*	February 16, 1993
	March 23, 1999	September 3, 1993	September 30, 1997
			December 16, 1997
	April 2, 2002	October 31, 1995	*
	December 20, 2002	*	February 8, 2002
		June 1, 2005	
	September 30, 2010		October 19, 2010

*Data not available

2.0 AREA STUDIED

2.1 Scope of Study

This FIS covers the geographic area of Yolo County, California.

All or portions of the flooding sources listed in Table 2, "Flooding Sources Studied by Detailed Methods," were studied by detailed methods. Limits of detailed study are indicated on the Flood Profiles (Exhibit 1) and on the FIRM (Exhibit 2).

TABLE 2 - FLOODING SOURCES STUDIED BY DETAILED METHODS

Cache Creek	South Fork Willow Slough
Cottonwood Slough	Sutter Slough
Covell Drain	Union Pacific Railroad Drain
Dry Creek	Union School Slough
Dry Slough	Unnamed Overflow Area South of County Road 31
Elk Slough	Unnamed Tributary of Union School Slough
Lamb Valley Slough	Unnamed Tributary of Willow Slough
North Davis Drain	Willow Slough Left Overbank No. 1
North Davis Overflow	Willow Slough Left Overbank No. 2
Sacramento Bypass	Willow Slough
Sacramento Deep Water Ship Channel	Yolo Bypass
Sacramento River	Yolo County Airport Drainage Channel

For this countywide, new behind levee mapping along the Sacramento River, Yolo Bypass, Cache Creek, Putah Creek, Willow Slough, and Willow Slough Bypass has been developed. Areas within the 1-percent annual chance floodplain landward of levees along these flooding sources that do not meet 44 CFR 65.10 have been mapped as Zone A.

This FIS also incorporates the determinations of letters issued by FEMA resulting in map changes (Letter of Map Revision [LOMR], Letter of Map Revision - based on Fill [LOMR-F], and Letter of Map Amendment [LOMA], as shown in Table 3, "Letters of Map Change."

TABLE 3 - LETTERS OF MAP CHANGE

Community	Flooding Source(s)/Project Identifier	Date Issued	Type
City of Winters	Carter Ranch Subdivision, Zone AH Ponding	July 11, 2002	LOMR
City of Woodland/ Yolo County (Unincorporated Areas)	Cache Creek Right Overbank Flooding	July 9, 2003	LOMR

The areas studied by detailed methods were selected with priority given to all known flood hazard areas and areas of projected development and proposed construction.

All or portions of numerous flooding sources in the county were studied by approximate methods. Approximate analyses were used to study those areas having a low development potential or minimal flood hazards. The scope and methods of study were proposed to, and agreed upon by, FEMA and Yolo County.

2.2 Community Description

Yolo County is located in west-central California, approximately 100 miles northeast of the City of San Francisco and west of the City of Sacramento, the state capital. The county has a land area of 1,034 square miles. The City of Woodland is the county seat and the center of agricultural activity in the county. According to the U.S. Census, the 2000 population of Yolo County was 168,660.

Yolo County is bordered by Colusa County to the north, Sutter and Sacramento Counties to the east, Solano County to the south, and Napa and Lake Counties to the west.

Yolo County is well served by transportation facilities. Rail service is provided by the main line and branches of the Southern Pacific Railroad and the Western Pacific Railroad. Major highways include Interstates 505, 880, 80 (U.S. 40), 5, and State Routes 16, 45, 84, 113, and 128. The Port of Sacramento, located in the west Sacramento area of Yolo County, was opened in 1963 and provides deepwater port facilities. The Sacramento Metropolitan Airport, located across the Sacramento River from the City of Woodland, provides regular commercial air service.

Approximately one-third of the county is in the mountainous uplands and gently sloping, hilly terraces of the Coast Ranges above the floor of the Sacramento Valley. Dryland farming and pasture are the primary agricultural uses at the lower elevations, while lands in the higher elevations are used for rangeland (U.S. Department of Agriculture, 1972). Approximately two-thirds of the county lies within the Sacramento Valley between the Coast Ranges and the Sacramento River, also called the Sacramento-San Joaquin Delta area, and has slopes as flat as 5 to 10 feet per mile (U.S. Department of Agriculture, 1969). Most of the county's agricultural activity takes place in the Delta.

The Delta area as a whole has been reclaimed by about 1,100 miles of levees along natural and constructed waterways that segregate it into about 120 tracts locally known as islands. The entire region of approximately 700,000 acres is under the influence of the tides and a large part of the land surface is lower than the water on the opposite side of the levees. Many of the islands are 15 to 25 feet below sea level due to the subsidence of the peat land structure. The numerous waterways and channels convey runoff to lower areas of the Delta and eventually to the Pacific Ocean.

The county itself is drained by the Sacramento River and Yolo Bypass, an integral part of the Sacramento River Flood Control Project. Two major streams, Cache Creek and Putah Creek, cross the county from west to east but drain only a small part of the county. Cache Creek originates at the outlet of Clear Lake in Lake County to the west. With its main tributaries (North Fork Cache Creek, Bear Creek, and Clear Lake), it drains 1,140 square miles, and has a maximum elevation of 6,100 feet. Putah Creek originates in the west at an elevation of 3,000 feet and drains 634 square miles in Lake, Napa, and Yolo Counties. Both Cache and Putah Creeks empty into Yolo Bypass on the eastern side of the county. Willow, Cottonwood, Chickahominy, and Dry Sloughs, located in the southern part of the county between Cache Creek and Putah Creek, drain approximately 204 square miles at the western edge of the county and convey flows to the leveed Willow Slough Bypass that drains to Yolo Bypass; maximum elevations are near 2,500 feet. The Hungry Hollow watershed, located north of Cache Creek and between the Capay and Dunnigan Hills, drains 55 square miles and is a tributary of Cache Creek.

Dry Creek, which drains an area of 22.7 square miles, flows southeasterly near the western edge of the City of Winters and joins Putah Creek south of the city. Dry Creek originates on the steep slopes of Rocky Ridge, a part of the Coast Range.

The northern part of the county is drained by intermittent streams, such as Buckeye, Oat, and Bird Creeks that flow easterly from the Dunnigan Hills to the Colusa Basin Drainage Canal. The canal drains 1,700 square miles in Glenn, Colusa, and Yolo Counties and conveys flows to the Sacramento River at Knights Landing or to Yolo Bypass via Knights Landing Ridge Cut, depending on water-surface elevations in the Sacramento River. The area between the Sacramento River and Yolo Bypass in the southeastern part of the county is drained mostly by pumping. Yolo Bypass near Knights Landing and over Sacramento River over Fremont Weir near Knights Landing and over Sacramento River (Sacramento Bypass) when the capacity of the Sacramento River channel is exceeded. Flows in Yolo Bypass return to the Sacramento River near Rio Vista, 10 miles south of the southern limits of Yolo County.

Predominantly, the Delta remains agriculturally oriented, as evidenced by the fact that more than three-fourths of the entire Delta area is devoted to a wide variety of crops. The rich and fertile peat soils generate an annual gross income from agricultural activities ranging from one-quarter to one-half billion dollars.

The climate in Yolo County is characterized by warm, dry summers and cool, wet winters. The average range of temperatures is between 36 degrees Fahrenheit (°F) in December and 95°F in July. Record extremes range from 11°F to 116°F. Annual rainfall ranges from 16 inches on the valley floor to 30 inches in the mountainous areas at the western edge of the county. Precipitation is primarily of frontal origin, with over 85 percent occurring from November through March. The quantity of storm runoff is greatly affected by the soil type. Soils in the relatively flat farmlands in the eastern part of Yolo County contain appreciable amounts of clay that cause high runoff rates and flooding in the mildly sloping eastern part of the county.

2.3 Principal Flood Problems

Major flooding has occurred in the Yolo County study area in 1937-38, 1940, 1943, 1950, 1955, 1958, 1963, 1967, 1973, 1975, and 1986 (U.S. Department of Agriculture, 1969; State of California, 1964; State of California, 1969; FEMA, 1981; U.S. Department of Agriculture, 1976). Flooding generally occurs in the relatively flat agricultural lands within the eastern two-thirds of the county.

Since the completion of Monticello Dam on Putah Creek (Lake Berryessa) in Napa County, flooding from Putah Creek and Cache Creek (the two largest streams flowing from west to east across the county) occurs only from Cache Creek overflow in the Capay Valley and south of Cache Creek near the City of Woodland, where flooding occurred in 1958 (FEMA, 1981). Flooding also occurs north of Cache Creek in the lowlands of the Hungry Hollow watershed, which is a tributary of Cache Creek. The largest flood in the Cache Creek drainage in recent years occurred during February 1958 and was estimated to be a 4-percent annual chance event (State of California, 1969).

In the northern part of the county, flooding occurs along the Colusa Basin Drainage Canal. Flooding results when precipitation within the basin and runoff from the foothill region to the west combine to far exceed the channel capacity of the canal. The greatest flooding in recent years was in 1958, when flooding along the canal extended 70 miles upstream from Knights Landing (State of California, 1964). Flooding also occurs in the spring and is caused by irrigation practices in the rice fields. Damage can be greater during the spring runoff because it occurs during the growing season.

Flooding frequently occurs in the Cottonwood-Willow Slough watershed south of Cache Creek and in the Dry Slough/Davis watershed north of Putah Creek. The adjacent watersheds are part of the Yolo Creek System. Flows originating in the western part of the watersheds exceed the channel capacity of Dry and Willow Sloughs and their major tributaries, Chickahominy Slough and Lamb Valley Slough, and cause flooding in the relatively flat agricultural lands in the eastern part of the county. Flooding is increased at the eastern side of the county when Sacramento River flows are diverted into Yolo Bypass and gravity flow to the bypass is eliminated. Severe flooding occurred along the Sacramento River and Yolo Bypass in February 1986. Floodwaters pond behind the Yolo Bypass and Willow Slough Bypass levees until floodflows in the bypasses recede.

In the City of Davis, the Dry Slough-Davis watershed area, major flooding occurred in 1937-38, 1940, 1943, 1950, 1955, 1958, 1963, 1967, 1973, and 1975. The 1963 flood was estimated to be a 10-year event (U.S. Department of Agriculture, 1969), and the 1955 flood was a 20-year event (U.S. Department of Housing and Urban Development, unpublished). Flooding in the Davis area is a result of the relatively flat topography of the area and backwater from Willow Slough Bypass and Yolo Bypass to the east. Within the City of Davis, Covell Boulevard and the Southern Pacific railroad restrict the dispersion of local floodflows. Covell Drain will contain the estimated 10-percent annual chance

(10-year) flood throughout the reach studied except at the F Street culvert, where overflow will occur to the area of the pump station near H Street and Covell Boulevard (H Street Pump). The base (1-percent annual chance) flow will exceed the capacity of Covell Drain at all road crossings, causing shallow flooding in overbank areas (Davis Drainage), primarily to the south of Covell Boulevard, terminating in a ponding area west of the Southern Pacific Railroad near the H Street Pump. The 24-hour runoff from the central Davis area in excess of the drainage system capacity will also pond in the same area as the Covell Drain overlow (VTN Corporation, 1975).

During high floodflows, the City of West Sacramento is not protected from flooding by the levees along the Sacramento River and the Yolo Bypass. Yolo Bypass drains water from Cache Creek, Putah Creek and also receives flows from the Sacramento River over Fremont Weir near Knights Landing, and over Sacramento Weir (Sacramento Bypass) when the capacity of the Sacramento River Channel is exceeded. Flows in Yolo Bypass return to the Sacramento River near Rio Vista. The Sacramento River is confined by Project Levees in the study area. Levees in Reclamation Districts (RDs) 811, 537, and 900 are not recognized as providing protection from the 1-percent annual chance flood.

Records indicate that there is a history of stability problems on the RD 900 (West Sacramento) levee between the Southern Pacific Railroad and the Sacramento Deep Water Ship Channel. Slips or subsidence occurred on this reach in 1969, 1975, and 1983 (USACE, undated). Levees in RD 537 and RD 811 are affected by erosion. The soils under these levees consist of firm silty sand and sandy silt. This material provides a firm foundation but is erodible.

The Yolo Bypass east levee has insufficient freeboard in the vicinity of the Southern Pacific Railroad (SPRR) north of Interstate Highway 80. Approximately 1 mile of the Sacramento River right bank levee just upstream of the mouth of the American River and a large portion of the right bank levee south of the Sacramento River Deep Water Ship Channel (SRDWSC) are considered to be structurally unstable. The Yolo Bypass east levee was found to have a short reach of structural instability about halfway between the SPRR and the Sacramento Bypass. Levee stability was not studied for the Yolo Bypass east levee south of the point where the SRDWSC begins to parallel the Yolo Bypass.

The Sacramento River right bank levee just upstream of the American River fails due to inadequate levee stability. Floodwaters flow south to the SPRR embankment then through the street undercrossings at Jefferson Boulevard and Fifth Street. The flooding continues south to the old Sacramento Northern Railway embankment where the flow is restricted by the two smaller undercrossings located at West Capitol Avenue and the old Highway 40. The Sacramento Northern embankment is ultimately overtopped and the floodwaters flow south into the SRDWSC.

The Sacramento River right levee south of the SRDWSC lock fails due to structural instability. Floodwater flows into the city area south of the SRDWSC, fills the entire area, and then overtops and fails the south SRDWSC levee. The SRDWSC then carries the water out of the study area.

The Yolo Bypass east levee just south of the SPRR fails due to encroachment of freeboard. Floodwater flows into the city area north of the SRDWSC, fills the area, and flows into the SRDWSC. Flows in the SRDWSC are large enough that some water flows into and floods the city area south of the SRDWSC.

The 1-percent annual chance flows for the Sacramento River and Yolo Bypass are concurrent events. It is possible for levee failures to occur on both the Yolo Bypass and Sacramento River for the same storm. A scenario assuming a failure on both systems was found to cause the greatest amount of flooding for most of the City of West Sacramento. This scenario would flood the city up to the point where the cross levee at the south limits is overtopped and failed.

Flooding in the City of Winters since the completion of Monticello Dam on Putah Creek has been limited to that caused by overflow from Dry Creek, runoff from the Moody Slough watershed north and west of the City of Winters, and runoff from the business and residential area south of State Highway 128. Approximately every 2 to 5 years, rains producing runoff have caused flooding along the western side of County Road 89 (Railroad Street), from Edwards Street in the City of Winters north to the Moody Slough crossing. Inadequate bridge and channel capacity causes water to overtop County Road 89. The water then continues eastward to Interstate Highway 505, flooding areas along Moody Slough, Willow Canal, and State Highway 128. The low-lying area west of Winters Cemetery is inundated by local runoff.

One of the most severe floods occurred on December 19-20, 1955, when 7.02 inches of rain were recorded in 48 hours. In the City of Winters several basements and businesses were flooded, as was much of the surrounding agricultural area. Traffic on County Road 89 was halted. This flood was approximately a 20-year event.

Low-lying areas of the City of Woodland are subject to periodic flooding due to overflow from Cache Creek, from runoff originating in the western sector of the City, or from overland flow originating west of the City in a gently upward-sloping area defined by the Maple Canal on the southwest and low divide on the north. Flooding from the creek results from heavy rain over the tributary drainage during the period from November through March. On rare occasions, melting snow in the high elevations of the basin could augment runoff from general rain. Overland flow from the west would result from cloudburst-type storms that could be expected to occur anytime from early fall to late spring, but may occur as an extremely severe sequence in conjunction with general winter rainstorms.

Most of the flooding within the City of Woodland occurs as sheet flow. The water-surface elevations of the flooding in these areas are variable and are affected principally by natural and manmade barriers in the flooded areas. Many road fills crossing floodplain areas alter the natural patterns of floodflow.

Although the City of Woodland has no recorded history of flooding, four major flood periods have been documented for the Cache Creek basin during the last half of the 20th century, and 20 severe floods have occurred since 1900. The most severe floods of recent years in the Cache Creek basin downstream from Clear Lake occurred in 1955 and 1956, 1968, 1964, 1965, and 1970.

The west-to-east slope of the land and the series of swales west of the City of Woodland direct runoff from cloudburst storms toward the center of the city. I-5, completed through the City of Woodland area in 1973, forms a barrier to overland flow resulting from very large floods on Cache Creek and diverts such flow into the city.

There are a total of three stream gaging stations located within the restudy area: the Yolo gage, which is readable but not reliable; the Capay gage, located upstream of Capay Diverison Dam; and the Rumsey gage, upstream of the study area. The Capay gage is considered to be the best gage for the purpose of the restudy because of its proximity to the study area. However, the Capay gage was moved in 1984 and relocated farther downstream below Capay Diversion Dam so that the data at the gage after 1984 represent primarily regulated dam flows.

Cache Creek exceeded its design channel capacity of 30,000 cubic feet per second (cfs) in 1955. In 1958 and 1983, Cache Creek rose to the top of both levees and overflowed its banks toward the Cities of Woodland and Davis. According to the USGS, the peak flow in 1983 at the Yolo gage was approximately 33,000 cfs, with an exceedence frequency of approximately a 20-year event. There was at least one levee break downstream from County Road 102. Federal, State, and local agencies patched levee boils at that time to prevent additional levee breaks along both sides of the Cache Creek levee system.

The observed peak flow at the Rumsey gage in March 1995 was approximately 52,000 cfs, with an exceedence frequency of approximately a 2-percent annual chance storm event. An observed peak flow for this event is not available for the Capay gage; however, high-water marks downstream of Capay Diversion Dam were observed. The City of Woodland observed and prepared a sketch of high-water marks in the vicinity of the City of Woodland for the March 1995 event. The observed flood boundaries were prepared for the flow that preceded the peak by 5 hours and do not provide the full extent of the flood boundary.

2.4 Flood Protection Measures

Yolo County is afforded flood protection, either directly or indirectly, by all storage and flood control projects upstream on the Sacramento River and its tributaries. Monticello Dam, which forms Lake Berryessa, is located on Putah Creek, 7 miles west of the City of Winters, in Napa County. It effectively reduces peak flows from the major portion of the drainage (U.S. Department of Agriculture, 1976). In addition, Putah Creek has been diverted through an improved channel (South Fork Putah Creek) which provides additional flood protection to the City of Davis (VTN

Corporation, 1975). Indian Valley Reservoir on North Fork Cache Creek and Clear Lake, the source of Cache Creek, are major flood-control features in the Cache Creek basin. The lower end of Willow Slough has been diverted through an improved channel (Willow Slough Bypass) to Yolo Bypass.

The Sacramento River Flood Control Project was originally adopted in 1911 by the State of California and authorized as a Federal flood-control project in 1917. Within Yolo County, the project consists of levees on the Sacramento River, Cache Creek, and Colusa Basin Diversion Canal; overflow weirs (Fremont and Sacramento); flood diversion channels (Knights Landing Ridge Cut, Yolo Bypass, and Sacramento Bypass); and drainage pumping plants in those areas protected by project levees (State of California, 1964).

In Yolo County, as well as in other counties in the Delta area, levees are classified as either direct agreement, project, or nonproject. Direct agreement levees were either constructed as part of a navigation project or were rebuilt by the Federal Government after a flood and are maintained to Federal standards by local reclamation districts. These levees constitute only about 10 percent of the total Delta levee system. Project levees were either constructed as part of a Federal flood control project, or constructed by local interests and then rebuilt to Federal standards or were adopted as part of a Federal flood control project. About 15 percent of the Delta levee system falls into this category and is maintained to Federal standards by local interests. Nonproject levees were privately constructed, maintained by private owners or local agencies, and often receive minimal maintenance that is rarely performed to any kind of uniform standards. About 75 percent of the Delta levees are in this category.

In the City of Davis, Putah Creek has been diverted through an improved channel (South Fork Putah Creek) and bypasses the city to the south enroute to Yolo Bypass. The original channel, therefore, receives only some flow from the University of California campus and from that portion of the city south of Interstate Highway 80. Runoff from these areas is conveyed from the old Putah Creek channel by conduit and the El Macero Drainage channel to a pump station at Yolo Bypass.

Peak floodflows from Stonegate Drainage are effectively reduced by storage areas created by culverted road crossings west of the City of Davis. At the western corporate limits of the city, a diversion and storage system comprised of Stonegate Channel and Pond is proposed to divert floodflows north to County Road 31 and to provide temporary storage. Floodwaters passing through the proposed channel and pond system will flow eastward (outside corporate limits) along County Road 31 and lands adjacent to State Highway 113.

Improvements made recently to State Highway 113 include an open subway portion through the City of Davis and raising of the roadbed elevation north of the subway portion such that the broad road overflow that has occurred in past years must pass through the culvert north of County Road 31 and Covell Boulevard into Covell Drain. A pumping station is located at Covell Boulevard and State Highway 113 to transfer any floodwaters entering the subway portion of the highway to the Covell Drain. Floodwaters are conveyed by the open Covell Drain and intervening road culverts to the Southern Pacific Railroad Drain (along the western side of the Southern Pacific Railroad), northward to Channel A, and eventually to Willow Slough Bypass and Yolo Bypass to the east.

Drainage areas within the City of Davis are presently served by storm collection systems that drain into storage ponds and/or pumping stations. The ponds serve as retarding basins for floodflows, reducing peak flows prior to their entering drainageways intended to convey floodwaters easterly to Yolo Bypass. A portion of the area adjacent to the east-west mainline route of the Southern Pacific Railroad is serviced by the Core Pond; the residential area north of Covell Boulevard is serviced by Covell Pond; and, residential areas west of State Highway 113 are serviced by the Stonegate and Westwood Ponds. Overflows from the Stonegate and Westwood Ponds would enter the Stonegate Drainage-Covell Drain system. Such overflows, however, would constitute only a minor portion of the total flows in that system and would not increase areas inundated by flows considered in this report. The Stonegate, Westwood, and Covell Ponds are gravity fed; the Core Pond utilizes a conduit system and a pump (VTN Corporation, 1975).

A series of pumps located on H Street near Covell Boulevard transfer storm runoff from the drainage system in the central part of Davis (bounded approximately by Russell Boulevard, Covell Boulevard, State Highway 113, and Southern Pacific Railroad) to the open Southern Pacific Railroad Drain. Flows considered in this study are contained in the Southern Pacific Railroad Drain channel.

The Sacramento River Flood Control Project was originally adopted in 1911 by the State of California and authorized as a Federal flood-control project in 1917. The project consists of a comprehensive system of levees on the Sacramento and American Rivers, Cache Creek, and Colusa Basin Diversion Canal; overflow weirs (Fremont and Sacramento); flood diversion channels (Knights Landing Ridge Cut, Yolo Bypass, and Sacramento Bypass); and drainage pumping plants in those areas with project levees (State of California, 1964). Manmade alterations to the drainage regimen have primarily been in the form of levees to prevent flooding of adjoining lands. The levee systems have necessitated pumping systems to discharge waters originating on the landward side of the levees. Pumps in the areas studied by detailed methods are located (1) southeast of the junction of the Sacramento Bypass and Yolo Bypass levees for the Bryte and Broderick areas, (2) southeast of the junction of the Southern Pacific Railroad and the Yolo Bypass levee and southeast of the junction of Interstate Highway 80 and the Yolo Bypass levee for the West Sacramento area, and (3) adjacent to the east levee for the West Sacramento River Deep Water Channel south of Bevan Road for the Southport area.

The hydraulic regimen of the Sacramento River is controlled by the reservoirs at Shasta Dam and other storage projects in the Sacramento River Basin. Coordinated operations of these dams moderate the river stage by regulating floodflows to a level below the 1-percent annual chance (estimated) discharges. Levees are prevalent along the lower reaches of direct and indirect major tributaries of the Sacramento River. A basic operational function of the project is the transfer of excess floodwater to levees bypasses. The principal improvement is the lower portion of Yolo Bypass. Maintenance and operation of the project works are the responsibility of varied local interests.

In accordance with FEMA criteria for the accreditation of levee systems, a minimum earthen levee freeboard of 3 feet is required in evaluating the ability of levee systems to provide protection from the 1-percent annual chance flood. If an earthen levee does not provide the specified 3-foot freeboard during a 1-percent annual chance flood, it is assumed to fail. Therefore, the floodplains in the area of such an inadequate levee reflect flood conditions as if this flood-control structure did not exist. The criteria used to evaluate protection from the 1-percent annual chance flood are (1) adequate design, including freeboard, (2) structural stability, and (3) proper operation and maintenance. Levees that do not provide protection from the 1-percent annual chance flood are not considered in the hydraulic analysis of the 1-percent annual chance floodplain.

Monticello Dam, which forms Lake Berryessa, is on Putah Creek, approximately 7 miles west and upstream of the City of Winters. The dam reduces the flow of Putah Creek such that all flows considered in this study are contained within its banks. Another structure, Solano Diversion Dam, is 3 miles upstream of the City of Winters on Putah Creek, but has little effect on peak flows in the creek. An old percolation dam is located on Putah Creek along the southeastern edge of the City of Winters, which has an effect on water-surface elevations but does not cause overbank flooding. Along the south side of Dry Creek, in the vicinity of an unnamed tributary to Dry Creek that is approximately 6,200 feet upstream of State Highway 128, a small private levee exists. This levee, located in Yolo County, does not meet the criteria for providing protection from a 1-percent annual chance flood event, as outlined in Section 65.10 of the National Flood Insurance Program and Regulated Regulations (FEMA, 1994).

During major floods, however, Cache Creek overflows its banks upstream of the levees. This overflow is directed toward the City of Woodland by the elevated roadbed of I-5.

Sacramento River Flood Control Project levees extend upstream along Cache Creek from the settling basin, which is northwest of the City of Woodland. During major floods, however, Cache Creek overflows its banks upstream of the levees. This overflow is directed toward the City of Woodland by the elevated roadbed of I-5.

The restudy of Cache Creek in the City of Woodland indicates that there are no existing local flood-protection measures or structures to reduce flood hazards within the restudied reach of Cache Creek in Yolo County and the City of Woodland. The existing Cache Creek levees are not in compliance with the requirements set forth in the NFIP regulations for protecting against the 1-percent annual chance flood.

3.0 ENGINEERING METHODS

For the flooding sources studied in detail in the county, standard hydrologic and hydraulic study methods were used to determine the flood hazard data required for this FIS. Flood events of a magnitude which are expected to be equaled or exceeded once on the average during any 10-, 50-, 100-, or 500-year period (recurrence interval) have been selected as having special significance for floodplain management and for flood insurance rates. These events, commonly termed the 10-, 50-, 100-, and 500-year floods, have a 10-, 2-, 1-, and 0.2-percent chance, respectively, of being equaled or exceeded during any year. Although the recurrence interval represents the long term average period between floods of a specific magnitude, rare floods could occur at short intervals or even within the same year. The risk of experiencing a rare flood increases when periods greater than 1 year are considered. For example, the risk of having a flood which equals or exceeds the 100-year flood (1-percent chance of annual exceedence) in any 50-year period is approximately 40 percent (4 in 10), and, for any 90-year period, the risk increases to approximately 60 percent (6 in 10). The analyses reported herein reflect flooding potentials based on conditions existing in the county at the time of completion of this FIS. Maps and flood elevations will be amended periodically to reflect future changes.

3.1 Hydrologic Analyses

Pre-countywide Analysis

Hydrologic analyses were carried out to establish peak discharge-frequency relationships for each riverine flooding source studied by detailed methods affecting the unincorporated areas of Yolo County and its incorporated communities.

For each community within Yolo County that had a previously printed FIS report, the hydrologic analyses described in those reports have been compiled and are summarized below.

In the detailed study area of Knights Landing in Yolo County, estimated peak discharges and total runoff volumes were based on a Type-I storm distribution (U.S. Department of Agriculture, 1973) of the 24-hour precipitation depths at selected recurrence intervals (U.S. Department of Commerce, 1973) and on runoff potential as determined from the soil groups in Yolo County (U.S. Department of Agriculture, 1972). The 0.2-percent annual chance depth was obtained by logarithmic extrapolation.

In the Madison-Esparto study area, unit hydrographs for the main and tributary drainage areas of South Fork Willow Slough and Lamb Valley Slough were computed for the selected recurrence intervals using the basin characteristics of watershed slope, length, and runoff potential as determined from Yolo County soil groups (U.S. Department of Agriculture, 1972). Runoff depths for each selected recurrence interval were applied to the unit hydrographs to produce the flood hydrographs at various locations within the study area.

The peak discharges for the 10-, 2-, 1-, and 0.2-percent annual chance recurrence intervals from the original study of Yolo County were verified by the USGS using flood-frequency relationships developed in an open-file report by the USGS (U.S. Department of the Interior, 1971).

The peak discharges for Dry Creek were taken from a USACE report entitled “Reconnaissance Study, Hydrology for Winters and Vicinity, California, Northern California Streams” (USACE, 1995). The hydrologic analyses for Dry Creek were taken from a Flood Hazard Analysis report prepared by the SCS (U.S. Department of Agriculture, 1976) using procedures in their Technical Release 20, Hydrologic Evaluation Computer Analysis (U.S. Department of Agriculture, May 1976).

A detailed hydrologic analysis estimating the 1-percent annual chance peak discharges for Willow and Dry Sloughs using the USACE HEC-1 computer program (USACE, 1990) was prepared by Borcalli & Associates, Inc., as part of the Covell Drainage Study for the Yolo County Flood Control and Water Conservation District. The study was published in a report entitled “Covell Drainage System Comprehensive Drainage Plan” (Borcalli & Associates, Inc., 1993). The Borcalli & Associates, Inc., HEC-1 model was reviewed by the study contractor and deemed to be acceptable.

The following data and parameters were used by Borcalli & Associates, Inc., in preparing the HEC-1 model:

1. The drainage area for each subbasin was determined using USGS 7.5-minute topographic maps (U.S. Department of the Interior, 1975; U.S. Department of the Interior, 1980, et cetera; U.S. Department of the Interior, 1959, et cetera).

2. Watershed soil types were determined from the NRCS (formerly the SCS) Soil Survey of Yolo County (U.S. Department of Agriculture, 1972).

3. Infiltration losses were determined using NRCS curve number (CN) methodology. The CN values for the 24-hour-duration storm are based on watershed soil group (A, B, C, or D), land use, vegetation cover type and density, and antecedent moisture condition.

4. Existing land use in Yolo County is based on Yolo County land-use maps prepared by the USACE in 1989 and land-use information provided by the City of Davis.

5. Precipitation data in Yolo County for storm durations of 5 minutes to 10 days and return periods of 2 to 100 years were developed by Mr. James Goodridge.

6. To evaluate the full impact of the volume of runoff due to the large amount of floodplain storage, a storm duration of 10 days was used. The rainfall distribution is based on a hypothetical-frequency storm.

7. The NRCS dimensional unit-hydrograph option in HEC-1 was used to develop the synthetic unit hydrograph.

8. Lag times developed for basins as required by this study were determined using the USACE Snyder formula, with a watershed roughness of 0.05. The slopes and lengths of watercourse for basins were determined using USGS topographic maps (U.S. Department of the Interior, 1975; U.S. Department of the Interior, 1980, et cetera; U.S. Department of the Interior, 1959, et cetera).

9. Channel routing was performed using the Muskingum and modified-Puls methods.

Tidal action, tributary basin runoff, and meteorological conditions are the major factors influencing water-surface elevations associated with the Sacramento River.

Frequency analyses of water-surface elevations in the Sacramento River were performed using an analytical study of higher-high-stage-frequency relationships from 24 gaging stations located throughout the Delta area (USACE, 1978). The selected period of record for the analyses (1945 to 1974) is subsequent to construction of Shasta Dam on the Sacramento River and covers the maximum length of record for the majority of the gages. Also, the Delta hydraulic pattern has not changed significantly during that period.

Originally, the stage data were statistically analyzed using the Pearson Type III distribution method included in U.S. Water Resources Council Guidelines (U.S. Water Resources Council, 1977). The resultant curves did not reflect either levee overtopping or levee breaks resulting in extensive areal inundation. Therefore, the shape of the curves was graphically developed to include those conditions. The stage-frequency relationship for each gage was compared with the stage-frequency relationships developed for adjacent gages and, if necessary, adjusted to obtain consistency.

Flood elevations on watercourses in the Sacramento-San Joaquin Delta area were determined using a tidal hydrodynamics computer model (California Department of Water Resources, Tidal Hydrodynamics Computer Model). Based on a network of nodes and a grid of channels connecting the nodes, the model solves two basic equations of one-dimensional dynamic fluid flow. The first is the equation of continuity; the second is the equation of motion. Through numerical integration of these equations using the modified Runge-Kutta or modified Euler methods, the model computes water-surface elevations.

The Sacramento-San Joaquin Delta to the Golden Gage is represented on two grid systems. The coarse grid contains some 250 nodes connected by 325 channels; the fine grid contains 1,200 nodes and 1,800 channels. In addition to physical parameters of the individual channels, the model uses inflow, overflow, evaporation losses, tidal elevations and wind velocity to solve for water-surface elevations. It must be noted that wave action may increase the 1-percent annual chance flood stage by 1.5 to 2.0 feet.

North Davis Overflow was studied from its confluence with Union Pacific Railroad Drain, just west of the Union Pacific Railroad (previously Southern Pacific Railroad), north for approximately 4,900 feet. Union Pacific Railroad Drain was studied from its confluence with North Davis Overflow, just west of the Union Pacific Railroad, for approximately 3,900 feet, to just north of Covell Boulevard in the City of Davis.

The 1-percent annual chance peak flow for North Davis Drain at the Union Pacific Railroad crossing was reduced from 2,612 cfs to 2,140 cfs to reflect attenuation from flood storage occurring within the area located immediately upstream of the crossing, which was not previously considered. Additional modifications to the HEC-1 model for the North Davis Drain and Covell Drain watersheds provided a reduction in the 1-percent annual chance discharge for North Davis Drain at State Highway 113 from 2,554 cfs to 2,522 cfs. The maximum flow that reaches the Union Pacific Railroad Drain from North Davis Overflow is 197 cfs. The total flow used in the model, 1,111 cfs, was used in the HEC-2 model to calculate the amount of water the Overflow loses as split flow over the railroad embankment upstream of the Union Pacific Railroad Drain. That split flow never reaches the confluence since the railroad acts as a control weir upstream. The discharge value at the confluence of North Davis Overflow and Union Pacific Railroad Drain was determined to be 450 cfs.

Peak discharge-frequency relationships for the Stonegate Drainage, west of the City of Davis, were computed by methods used by the SCS (U.S. Department of Agriculture, 1977; U.S. Department of Agriculture, 1973).

Unit hydrographs for the main and tributary drainage areas were computed using the basin characteristics of watershed slope, length, and runoff potential as determined from the soil-cover complexes for Yolo County (U.S. Department of Agriculture, 1972). Estimated depths of runoff for the selected recurrence intervals were based on a Type-I storm distribution (U.S. Department of Agriculture, 1973) of the 24-hour precipitation depths (U.S. Department of Commerce, 1973) for the study area; the 0.2-percent annual chance depth was obtained by logarithmic extrapolation. Application of these runoff depths to the computed unit hydrographs produced the flood hydrograph for each selected recurrence interval.

Routing of the computed flood hydrographs through upstream storage areas created by road crossings was accomplished by the reservoir-storage method (U.S. Department of the Interior, 1960) to obtain peak flows at the western corporate limits of the City of Davis near County Road 98. Routing was continued downstream to obtain peak flows and their time of occurrence at State Highway 113, the beginning of Covell Drain.

Similar flood hydrographs were computed for Davis Drainage at its outlet point, the H Street pumping station, to determine the possible additive effects with overflows from Covell Drain. The total 24-hour runoff volume for the central area of the City of Davis was computed from runoff rates determined for the area (U.S. Department of Agriculture, 1969).

In the City of West Sacramento, backwater conditions are prevalent on all the waterways. For the January 19, 1995 restudy, the Dynamic Wave Operational Model (DWOPER) computer program was being used to develop hydrologic data for the study area. The DWOPER model was calibrated based on flow and stage hydrographs and high water marks recorded during the February 1986 flood. Flow hydrographs were calibrated based on February 1986 flood hydrographs.

The 1-percent annual chance flood hydrograph volume for the Sacramento River was estimated based on historical data recorded at the Verona, I Street, and Freeport gages. The February 1986 flood hydrographs at the Verona and I Street gages were used to estimate the shape of the 1-percent annual chance flood hydrograph for the Sacramento River. For the upper study reach of the Sacramento River, the 1-percent annual chance flood hydrograph has been estimated to be basically the same as the hydrograph for the February 1986 flood. Between the I Street and Freeport gages the 1-percent annual chance floodflow is approximately 3 percent greater than the flow during the February 1986 flood.

HEC-1, a Generalized Computer Program Flood Hydrograph Package (USACE, 1981), was used for all these analyses in the City of West Sacramento. Streamflow routings were based on storage-discharge relationships developed for reaches along each stream.

An analysis of the recorded rainfall data for precipitation stations located both in and just outside the study area indicated that 24-hour storm waves were preeminent during the February 1986 storm. Therefore, a 24-hour general rainstorm was chosen and developed for the streams originating in the greater Sacramento area. Precipitation amounts for computation of the 1-percent annual chance, 24-hour general rainstorms were developed based on an annual rainfall depth-duration frequency analysis for a Sacramento County rainfall recording station (NAVION, No. A00610650) that was selected as being representative for all the study basins because of its central location in the study area. Rainfall amounts for this station and other nearby stations were compared with similar data in the National Oceanic and Atmospheric Administration Atlas 2 for California (U.S. Department of Commerce, 1973) for authentication. Point rainfall amounts were then adjusted (reduced) based on criteria (aerial distribution methodology). Rainfall amounts for the 24-hour storm were determined for subareas of individual basins. The adjusted point rainfall amounts for the selected frequencies were multiplied by the ratio of the subarea Normal Annual Precipitation (NAP) to the total basin NAP. The subarea amounts were then averaged for each basin.

Distribution of the 24-hour general rainstorm amounts for the 1-percent annual chance flood was based on the 96-hour standard project storm criteria presented in a 1971 USACE publication (USACE, 1971).

Where pertinent, the stages for the flow hydrographs on the main stems were combined with the corresponding peak flow hydrographs for the tributary drainages to determine the maximum stage for the tributary systems. Depending on timing and location along the tributaries, the maximum stage on the main stems may or may not coincide with the peak flow for the tributary streams.

The hydrologic analyses for Moody Slough were taken from a Flood Hazard Analysis report prepared by the Natural Resources Conservation Service (NRCS) (formerly the SCS) (U.S. Department of Agriculture, 1976) using procedures in Technical Release No. 20, "Computer Program, Hydrologic Evaluation Computer Analysis (U.S. Department of Agriculture, 1976).

The peak discharges for the 10-, 2-, 1-, and 0.2-percent annual chance recurrence intervals for Moody Slough were verified by the USGS using flood-frequency relations developed in a USGS open-file report entitled "Suggested Criteria for Hydrologic Design of Storm-Drainage Facilities in the San Francisco Bay Region" (U.S. Department of the Interior, 1971).

In the original study for the City of Woodland, flood hydrographs and peak flows for these floods were based on rainfall-runoff computations and statistical analysis of stage and discharge records at gaging stations. The USACE standard project rainfall and flood concept and the unit-hydrograph methods of analysis were used in making rainfall-runoff computations. The operation of Indian Valley Dam was taken into account. The basic procedures used for developing unit hydrographs in this report are outlined by the USACE (USACE, 1957; USACE, 1959). These procedures involve use of an S-curve; physical dimensions of the basin measured from topographic maps; and an estimated basin lag time, which is also related to an average basin roughness factor ("n"). A typical valley S-curve was used to develop unit hydrographs. The computed standard floods were used in conjunction with the log-Pearson Type III method of analysis (U.S. Water Resources Council, 1967) to develop flow-frequency curves for Cache Creek from available streamflow data at the Yolo gage.

Rainfall amounts and distribution for computations of cloudburst floods were based on USACE criteria for general local storms (USACE, 1971). A 3-hour rainfall-frequency curve for the City of Woodland area was patterned after the National Weather Service gage curve for the City of Sacramento and checked with a rainfall-frequency curve developed from the data for the Davis 2 West Southwest gage and Woodland West Northwest gage. Precipitation amounts for the 10-, 2-, 1-, and 0.2-percent annual chance storms were determined from this curve. Standard project precipitation for the Cache Creek basin was taken from a USACE report (USACE, 1974). The Sacramento gage is located approximately 12 miles east of the study area, with 129 years of record; the Davis gage is located 10 miles south, with 105 years of record; and the gage in the City of Woodland has 92 years of record.

For the restudy upstream of County Road 94B, the hydrologic analysis is summarized in a report entitled "Hydrology Report, Yolo County, CA and City of Woodland, CA" (A&M Engineering Consultants of California, 1998). The basis of the hydrologic analysis was an updated report prepared in August 1995 by the USACE, Sacramento District, entitled “Hydrology for Cache Creek, Yolo County, California Reconnaissance Study” (USACE, August 1995). The August 1995 HEC-1 model was calibrated using the 1995 flood events. Satisfactory results were achieved in matching the computed and observed hydrographs.

For the restudy downstream of County Road 94B, the 1-percent annual chance flood for Cache Creek was determined by the USACE, Sacramento District, using the USACE HEC-1 model (USACE, 1990).

Countywide Analyses

A summary of the drainage area-peak discharge relationships for all the streams studied by detailed methods is shown in Table 4, "Summary of Discharges."

TABLE 4 - SUMMARY OF DISCHARGES

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs)			
		10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
CACHE CREEK					
At Capay Dam	1,054	*	*	60,600	76,500
At County Road 94B	*	*	*	63,680	*
COTTONWOOD SLOUGH					
At State Highway 505	17.57	*	*	4,245	*
COVELL DRAIN					
At City of Davis corporate limits (near Anderson Road)	9.5	240	360	390	560
At confluence of Union Pacific Railroad Drain	*	*	*	1,050	*
DAVIS DRAINAGE					
Outlet at H Street Pump	1.7	225	325	365	415

*Data not computed

TABLE 4 - SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs) 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
DRY CREEK					
At mouth	22.67	3,300	5,160	5,950	8,090
Approximately 800 feet upstream of mouth	17.20	2,800	4,300	4,800	6,000
At State Highway 128	16.70	2,660	4,160	4,780	6,500
DRY SLOUGH					
At State Highway 113	47.11	*	*	714[1]	*
Approximately 650 feet upstream of Road 31	46.21	*	*	3,359[1]	*
Approximately 2,500 feet upstream of County Road 95	44.78	*	*	3,614	*
KNIGHTS LANDING DRAINAGE					
At Old Southern Pacific Railroad	0.23	55	70	80	94
LAMB VALLEY SLOUGH					
At County Road 85B	6.60	700	1,050	1,230	1,650
MOODY SLOUGH					
At County Road 89	4.2	730	1,210	1,420	2,000
NORTH DAVIS DRAIN					
At Southern Pacific Railroad	7.57	*	*	2,140	*
At State Highway 113	6.20	*	*	2,522	*
NORTH DAVIS OVERFLOW					
At Southern Pacific Railroad (North Davis Drain Crossing)	*	*	*	1,111	*
At confluence of Union Pacific Railroad Drain	*	*	*	635	*
SACRAMENTO RIVER					
At I Street	23,500	*	*	120,000	*
At Verona	21,300	*	*	93,000	*

*Data not computed

[1]Decrease in flow with increase in area is result of spill

TABLE 4 - SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs)			
		10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
SOUTH FORK WILLOW SLOUGH					
At State Highway 505	22.94	*	*	3,189	*
At County Road 89, near Madison	17.00	1,050	1,600	1,850	2,500
At confluence of Lamb Valley Slough	14.00	880	1,350	1,580	2,080
At State Highway 16, near Esparto	6.90	350	600	700	850
STONEGATE DRAINAGE					
At City of Davis corporate limits (near State Road 98)	7.0	240	350	380	540
UNION PACIFIC RAILROAD DRAIN					
At confluence with North Davis Overflow	*	*	*	450	*
UNION SCHOOL SLOUGH					
At confluence with Willow Slough	27.43	*	*	2,278	*
UNNAMED TRIBUTARY OF WILLOW SLOUGH					
At confluence with Willow Slough	3.18	*	*	645	*
WEST SACRAMENTO-BRYTE-BRODERICK-SOUTHPORT DRAINAGE					
At pump (Main Canal)	10.10	330	600	750	1,000
At pump	3.12	270	440	510	670
At Lake Washington	2.91	245	410	510	640
At Harbor Boulevard	1.64	205	325	370	490
At Interstate Highway 80	1.44	190	305	350	450
At pump	0.50	90	145	170	215

*Data not computed

TABLE 4 - SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs)			
		10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
WILLOW SLOUGH					
At Southern Pacific Railroad	163.20	*	*	10,003	*
At State Highway 113	116.05	*	*	9,116	*
Approximately 2,400 feet upstream of County Road 99	113.23	*	*	8,587	*
Approximately 1,300 feet downstream of County Road 98	105.32	*	*	8,226	*
Approximately 2,600 feet upstream of County Road 98	103.97	*	*	9,190[1]	*
At County Road 27	72.15	*	*	7,508	*
At County Road 95	51.81	*	*	6,970	*
YOLO COUNTY AIRPORT DRAINAGE CHANNEL					
At confluence with Unnamed Tributary of Willow Slough	1.52	*	*	511	*

*Data not computed

[1]Decrease in flow with increase in area is result of spill

The stillwater elevations have been determined for the 10-, 2-, 1-, and 0.2-percent annual chance floods for the flooding sources studied by detailed methods and are summarized in Table 5, "Summary of Stillwater Elevations."

TABLE 5 - SUMMARY OF STILLWATER ELEVATIONS

FLOODING SOURCE AND LOCATION	ELEVATION (feet NAVD)			
	10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
COVELL POND	*	*	45.2	*

*Data not available

3.2 Hydraulic Analyses

Pre-countywide Analysis

Analyses of the hydraulic characteristics of flooding from the source studied were carried out to provide estimates of the elevations of floods of the selected recurrence intervals. Users should be aware that flood elevations shown on the FIRM represent rounded whole-foot elevations and may not exactly reflect the elevations shown on the Flood Profiles or in the Floodway Data tables in the FIS report. For construction and/or floodplain management purposes, users are encouraged to use the flood elevation data presented in this FIS in conjunction with the data shown on the FIRM.

Starting water-surface elevations for streams studied by detailed methods are based on the slope/area method, unless otherwise noted. Split-flow routines were used to determine discharges for overbank flow paths that are hydraulically separated from the main channel. Split flows were based on a weir coefficient of 2.6. Separate HEC-2 analyses were performed to determine the 1-percent annual chance floodplain in overbank areas where the depth of flow is between 1 and 3 feet. These areas are designated Zone AO on the FIRM.

For each stream studied in detail, the boundaries of the 1-percent annual chance flood have been delineated using the flood elevations determined at each cross section. Between cross sections, the boundaries were interpolated using topographic mapping at a scale of 1"=400', with a contour interval of 2 feet (Aerometric Surveys, 1994). For Dry Creek, the boundaries were interpolated using topographic maps at a scale of 1"=400', with a contour interval of 4 feet (Andrea, Inc., 1996).

For Dry Creek, elevations for the floods of the selected recurrence intervals were previously determined by the SCS (U.S. Department of Agriculture, 1976) using WSPIN, a standard water-surface profile computer program (U.S. Department of Agriculture, 1977). The elevations resulting from this analysis were verified by the study contractor using a culvert survey and 16 cross sections furnished by the SCS and the USGS computer programs E-431 (U.S. Department of the Interior, 1976) and A-526 for the detailed study on Dry Creek.

The 1-percent annual chance flow will be contained within the main Dry Creek channel with the exception of an overflow ponding area immediately upstream of State Highway 128. The 0.2-percent annual chance flood event will overtop the east bank in the vicinity of County Road 33 and flow overland until it rejoins Dry Creek in the vicinity of an unnamed tributary to Dry Creek that is approximately 6,200 feet upstream of State Highway 128. In the vicinity of this unnamed tributary, along the south side of Dry Creek, a small private levee exists. This levee does not meet the criteria for providing protection from a 1-percent annual chance flood event, as outlined in Section 65.10 of the National Flood Insurance Program and Related Regulations (FEMA, 1994). In the event that this levee is breached during a 1-percent annual chance flood event, water will flow overland to the south of Dry Creek toward State Highway 128. This overland flow is delineated as Zone X (shaded) because it will have an average depth of less than 1 foot. The with-levee conditions have been delineated along Dry Creek.

Water-surface elevations for floods of the selected recurrence intervals were computed using the USACE HEC-2 program (USACE, 1991). Starting water-surface elevations for Dry Creek were computed using the slope/area method.

Channel and overbank cross sections were determined from surveyed channel cross sections, Yolo County topographic mapping (Aerometric Surveys, 1994), and field measurements of hydraulic structures. Cross sections along Dry Creek were compiled photogrammetrically and, in areas of dense vegetation, field surveys were performed. Hydraulic structure dimensions were determined using as-built construction plans and field measurements.

Roughness coefficients were assigned based on photographs obtained from field visits and methodology described in USGS Water-Supply Paper 2339, "Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains" (U.S. Department of the Interior, 1989).

A small private levee exists along the south side of Dry Creek approximately 6,200 feet upstream of State Highway 128. The with-levee and levee-failed conditions reflected on Exhibit 1, "Flood Profiles," refer to the above-mentioned levee. The with-levee conditions have been delineated along Dry Creek. Water-surface elevations for floods of the selected recurrence intervals were computed using the USACE HEC-2 program (USACE, 1991). Starting water-surface elevations for Dry Creek were computed using the slope/area method.

Water-surface elevations for floods of the selected recurrence intervals were computed using 11 culvert surveys and 37 cross sections on South Fork Willow Slough and Lamb Valley Slough in the Madison-Esparto study area and USGS computer programs E-431 (U.S. Department of the Interior, 1976) and A-526. All data were obtained by field surveys.

Starting water-surface elevations for South Fork Willow Slough were determined using a culvert computation at County Road 89. The South Fork Willow Slough channel can convey the maximum discharge estimated for the 10-percent annual chance recurrence interval through the study area, except in the short reach at the confluence with Lamb Valley Slough. In this reach, overbank flows from the upper reaches of Lamb Valley Slough and South Fork Willow Slough enter the channel from the west at State Highway 16 and subsequently overflow to the east. Starting elevations for Lamb Valley Slough were obtained from the 10-percent annual chance computed profile and estimated overflow elevations for the 2-, 1-, and 0.2-percent annual chance flows at the confluence with South Fork Willow Slough.

In the Madison-Esparto study area, overbank flooding from the estimated 1-percent annual chance flow will occur in the reach upstream of the Winters Canal along Lamb Valley Slough because of backwater from the restrictive hydraulic opening under the canal. A large portion of the floodflows that exceed the capacity of the opening will overflow the canal and travel as overland flow in a southeasterly direction to County Road 21A and beyond. These overland flows will be in the form of shallow sheetflow. Minor overbank flooding will also occur to the north of Lamb Valley Slough between Fremont Street and Yolo Avenue (State Highway 16). The major overland flow along Lamb Valley Slough will occur to the south in the same reach and then flow to the east along State Highway 16 as shallow sheetflow. Additional overbank flow to the north will occur between Alpha Street and the old roadbed of the Southern Pacific Railroad.

The 1-percent annual chance flow will exceed the capacity of the South Fork Willow Slough channel upstream from the study area, and overbank flow will occur as sheetflow along both banks as it approaches State Highway 16. At State Highway 16, the overbank flow to the west will join with the Lamb Valley Slough flows and flow east along State Highway 16 to Madison. Additional overbank flow will occur east of County Road 88B and will flow in a southeasterly direction to the junction of State Highway 16 and County Road 89. Overland flows reaching Madison will drain to the east through a culvert at State Highway 16, a drainageway 700 feet south of State Highway 16, and as flow over County Road 89. East of County Road 89, these overland flows join the Cottonwood Slough (1 mile south) overflows west of Interstate Highway 505.

Floodwaters in the Knights Landing study area flow from the urbanized area eastward through a single culvert in the Southern Pacific Railroad embankment near County Road 116. The magnitude of flooding in this area was based on culvert computations utilizing USGS computer program A-526. Flood profiles are not shown in the Knights Landing drainage area because there are no defined channels.

The 24-hour runoff for the 10- and 1-percent annual chance events was estimated for all tributary drainage areas. The differential runoff between the 10- and 1-percent annual chance events represents the volume of water needed to be stored in each area.

Peak discharges from the American River compound flood-related problems. Floodwaters are diverted at the American River confluence with the Sacramento River and are conveyed to the Yolo Bypass by means of the Sacramento Weir through Sacramento Bypass. In such circumstances, the Sacramento River appears to flow upstream, caused by diversion of floodwaters at the Sacramento Weir.

The Yolo Bypass conveys these diverted flows from the Sacramento River at the City of Sacramento south into Solano County and eventually back into the Sacramento River. The 1% annual chance flood elevations were determined for the Yolo Bypass by interpolating between elevations at tide gaging stations.

Flooding on Elk Slough and Sacramento River Deep Water Ship Channel are controlled by backwater effects from the Sacramento River and Cache Creek, respectively.

The 1-percent annual chance discharges exceed the capacity of the main channel and overbank areas for, Cottonwood, Dry, and Willow Sloughs. As a result, split flow will occur during a 1-percent annual chance storm event at several locations along these stream reaches.

Along Willow Slough, split flow will occur at County Road 95. The manmade channel for Willow Slough, downstream of County Road 95, only has the capacity to convey 320 cfs before overtopping its banks. Split flow will also occur upstream of County Road 98. The flow will cross County Road 98 and rejoin Willow Slough downstream of County Road 98. Split flow from Willow Slough to Dry Slough will occur just upstream of their confluence west of Interstate 113.

Along the south bank of Dry Slough, at the upstream limit of the study, near the intersection of County Road 31 and County Road 95, split flow from Dry Slough will occur. The flow will cross County Road 95 south of County Road 31 and flow in a southeasterly direction before returning to Dry Slough upstream of the downstream crossing of County Road 31 over Dry Slough. This area is designated Zone AO depth 2 feet on the FIRM. Split flow will also occur east of County Road 95. In this area, flow will escape Dry Slough and spill into Unnamed Tributary of Willow Slough over the north bank of Dry Slough.

In addition, flow will spill over the east bank of Dry Slough just upstream of the downstream crossing of County Road 31 into Unnamed Overflow Area South of County Road 31 and over the east bank into North Davis Drain just downstream of the downstream crossing of County Road 31. This spill flows in an easterly direction on the north and south sides of County Road 31. The majority of the flow to the south of County Road 31 spills into North Davis Drain downstream of County Road 97. As the flow approaches the Interstate 113 culverts along North Davis Drain, runoff from the North Davis Drain watershed is added. Due to the limited capacity of the culverts at Interstate 113, ponding will occur on the upstream side of Interstate 113, resulting in an overflow of Interstate 113 near the County Road 29 overpass. As the water approaches the SPRR, the culverts under the railroad only have the capacity to convey 1,590 cfs. The backwater created by the culverts will cause the water to pond at an elevation of 49.1 feet. At this water-surface elevation, some of the flow will escape to the south along the SPRR and join Covell Drain.

A floodway was developed along Willow Slough from the SPRR to County Road 27 based on equal-conveyance reduction from each side of the floodplain.

At the very downstream end of the North Davis Overflow, there were two cross sections used in the model that could either be labeled as Covell Drain or Union Pacific Railroad Drain. Borcalli & Associates, Inc. referred to this reach as Union Pacific Railroad Drain since the cross sections match the typical section upstream of this reach. Also, this reach is a direct projection of the Union Pacific Railroad Drain upstream of its confluence with Covell Drain. Covell Drain has a wider channel section and flows perpendicular to the downstream flow, so Covell Drain logically begins at this confluence. Upstream of this confluence the hydrologic contribution of Covell Drain (peak flow) in North Davis Overflow is gone. The only influence Covell Drain has upstream of this point is a hydraulic backwater effect on Union Pacific Railroad Drain, and subsequently North Davis Overflow.

The first seven sections used in the North Davis Overflow model depict Union Pacific Railroad Drain as flowing under the railroad bridge with contributions from North Davis Overflow. These sections were used to establish downstream conditions in order to model the starting water surfaces for North Davis Overflow. No flow is directly contributed from Covell Drain to North Davis Overflow in the restudied reach; all flow originated from North Davis Drain where it crosses the railroad in Yolo County.

The Overflow and Union Pacific Railroad Drain models begin along the Union Pacific Railroad Drain downstream of its confluence with the Covell Drain. The North Davis Drain model begins just downstream of its crossing of the Union Pacific Railroad. The HEC-2 split-flow option was used to determine the overflow quantity from the North Davis Drain, and the quantity of flow lost over the Union Pacific Railroad embankment, which parallels the east boundary of the Overflow reach, between the North Davis Drain and the confluence with Union Pacific Railroad Drain.

Due to the influence of Covell Drain, two separate models were developed for the flood hazard areas along the Overflow reach. Along this reach, from Covell Drain upstream to North Davis Drain, the mapped area was based on the overflow discharge of 197 cfs. From Covell Drain downstream to the confluence with Union Pacific Railroad Drain, the mapped area was based on the contribution of 184.63 cfs from North Davis Overflow, and the discharge of 450 cfs from Union Pacific Railroad Drain. Because the model for North Davis Overflow extended from the confluence of North Davis Drain to the confluence with Union Pacific Railroad Drain, cross sections from this model were plotted along the Overflow reach.

Where Union Pacific Railroad Drain and North Davis Overflow converge at the railroad bridge crossing, the crossing capacity is too small and creates ponding to the west where overflow out the right bank is created (flowing toward the south to Covell Drain). Immediately to the west of the railroad bridge crossing of Union Pacific Railroad Drain, flow from North Davis Overflow enters the area labeled Covell Pond on the FIRM. The subdivisions just west of the crossing of Union Pacific Drain under the railroad embankment are affected by this ponding area. A pump station just upstream of where Union Pacific Railroad Drain crosses under the railroad embankment receives water from the subsurface drainage pipe system. When a storm event causes exceedence of the capacity of the pumps, the excess water is modeled as backwater and ponding in the adjacent streets and yards. The pumping capacity of 10 cfs is lost when the capacity of the receiving drains is exceeded and there is backflow into the ponds from the drains that is greater than the pumping capacity.

In the City of Davis, water-surface elevations for floods of the selected recurrence intervals were computed using 4 culvert surveys and 22 cross sections in the Stonegate Drainage and proposed Stonegate Channel outside the western corporate limits of the City of Davis, and USGS computer program E-431 (U.S. Department of the Interior, 1976). Nine of these cross sections and one culvert survey were obtained from plans of the proposed Stonegate Channel (Murray-McCormick Environmental Group, 1975) and the remainder were obtained by field surveys.

Computations for the Stonegate Drainage-Stonegate Channel indicate that the Stonegate Channel will contain the flows considered in this study through the north-south reach and, thus, divert floodflows north of the western corporate limits of the City of Davis. The larger discharges, however, will exceed the capacity of the east-west reach of the channel and flow overland along County Road 31 to State Highway 113.

Flows from the Stonegate Drainage and intervening rural drainages were routed through the State Highway 113 culvert to Covell Drain, which enters the corporate limits 800 feet upstream from Anderson Road. There is no inflow to Covell Drain from the city drainage system east of State Highway 113. Water-surface elevations for the selected discharges for Covell Drain were computed using 4 culvert surveys and 15 stream cross sections obtained by field surveys, and the USGS computer program E-431 (U.S. Department of the Interior, 1976). Starting elevations for the computations were determined using a culvert computation at F Street.

The 1-percent annual chance flood levels for the main channels of the Sacramento River and the Yolo Bypass were developed using adjusted historic data. For areas behind levee systems, these 1-percent annual chance levels were compared to surveyed top-of-levee data to determine if the levee was overtopped, encroached into freeboard, or had adequate freeboard. Levee stability was investigated for some levee systems having adequate freeboard. For levees found to have insufficient freeboard and/or structural stability, overland flood routing was conducted.

In 1987-1988, the State of California Department of Water Resources surveyed the levee crowns for the entire study reach for both the left and right banks along the Sacramento River and both the left and right levees along the Yolo Bypass. These top-of-levee profiles were plotted with the February 1986 and 1-percent annual chance flood profiles to identify areas of insufficient freeboard.

The USACE, Sacramento District, has prepared a series of levee stability analytical studies covering the Sacramento Metropolitan Area. Two of these reports, dated May 1988 (USACE, 1988) and August 1988, cover portions of the City of West Sacramento. As agreed upon in the “Time and Cost Estimate,” levee stability would only be considered for areas studied in the two reports. During February of 1986, the study area experienced the flood of record for both the Sacramento River and Yolo Bypass. The USGS report entitled “Profile of Sacramento River, Freeport to Verona, California, Flood of February 1986” (USGS, 1988) was used as the February 1986 flood profile for the Sacramento River. The February 1986 flood profile for the Yolo Bypass was developed from highwater marks established by the USACE, Sacramento District and from data for the two gaging stations located in or near the study reach.

Detailed backwater analyses were not considered practical due to the lack of cross-section data. The 1-percent annual chance flood elevations for the Sacramento River and Yolo Bypass were generated by adjusting the 1986 flood profile using reconnaissance level stage-frequency data developed by the USACE, Sacramento District, for the "Sacramento Metropolitan Area (General Investigation)."

The 1-percent annual chance flood elevations for the Sacramento River were based on data from the three stream gage stations located in or near the study reach and on the documented 1986 flood profile. The stream gages are located near Freeport, I Street, and Verona. The 1-percent annual chance stages for the Verona and I Street gaging stations were developed by the USACE, Sacramento District, Hydrology Section, which also computed the 1-percent annual chance stage at the mouth of the American River.

For the reach of the Sacramento River from the Sacramento Weir upstream to Verona, the 1-percent annual chance peak flow of 93,000 cfs is virtually the same as the 1986 flow of 92,900 cfs.

The maximum 1986 flood stage at I Street was 33.2 feet, while the 1-percent annual chance stage at I Street is 33.4 feet, or 0.2 foot higher. From Freeport to I Street, the river channel stage-discharge relationships would be similar for the entire reach. As a result, the 1-percent annual chance flood elevations from Freeport to I Street were assumed to be 0.2 foot higher than the 1986 flood profile.

The 1-percent annual chance flood elevations for the Yolo Bypass are based on data from the two stream gage stations located in or near the study reach and on the established high water marks for the 1986 flood. The stream gages are located near Woodland and Lisbon, and 1-percent annual chance stages at the gaging stations were developed by the Sacramento District Hydrology Section.

Due to the high winds experienced during the peak of the 1986 flood, it was determined that the surveyed high water marks for the Yolo Bypass represent "Top of Wave" height. The flood levels without wave height, but including wind set, were estimated to be approximately 0.7 to 0.9 foot lower. Using this information, the 1986 flood profile was adjusted 0.7 to 0.9 foot lower than the surveyed "Top of Wave" heights. Based on reconnaissance level hydrology, the 1986 readings for the gages near Woodland and Lisbon are approximately 0.2 foot higher than the developed 1-percent annual chance stages at these two locations. For this study, the 1-percent annual chance elevations are 0.2 foot lower than the 1986 flood profile.

A number of levee failure scenarios for areas having insufficient freeboard and/or structural instability were evaluated. Overland routing of flow hydrographs were performed recognizing the effect of physical features and storage volumes. The controlling failure scenarios are described below.

Over two-thirds of the Sacramento River right bank levee from River Mile 71 upstream to River Mile 77 has less than 3 feet of freeboard for the 1-percent annual chance flood. The Yolo Bypass east levee was found to have insufficient freeboard at two locations: a short reach just upstream of the Sacramento Bypass; and at the Union Pacific Railroad tracks near State Highway 16. As previously agreed upon, levee stability was not investigated for this area.

Several reaches of the Sacramento River right bank levee between Interstate 5 and Verona fail due to insufficient freeboard. The floodwaters flow into RD 1600 and pond behind the Union Pacific Railroad embankment to the south, the Yolo Bypass levee to the west, and the Sacramento River levee to the north and east. Floodwaters overtop and fail the Union Pacific Railroad embankment and flow south ponding behind the Sacramento Bypass, the Yolo Bypass, and Sacramento River levees. The Yolo Bypass levee is ultimately overtopped and failed allowing the floodwaters to flow into the bypass.

The base flood elevation on the Sacramento River Deep Water Ship Channel is controlled by backwater effects from the Sacramento River.

Because no backwater hydraulic model was performed for the Sacramento River and Yolo Bypass, no profile panels were developed.

Moody Slough was determined to be Zone AO, with a depth of 2 feet. Elevations for areas of shallow flooding were determined by the NRCS (U.S. Department of Agriculture, 1976).

Flood elevations in the deep ponding area were determined using inflow-versus-storage relationships in conjunction with field observations and topographic data (City of Woodland, 1967).

In the City of Woodland, analyses of the hydraulic characteristics of flooding from the sources studied were carried out to provide estimates of the elevations of floods of the 1- and 0.2-percent annual chance recurrence intervals. Hydraulic analyses for a portion of Cache Creek in Yolo County, as well as for a portion of the breakout flows from Cache Creek in the City of Woodland, were computed using the USACE HEC-2 computer program (USACE, 1991).

The main channel of the study area is characterized by undersized capacity for the 1-percent annual chance storm event in the downstream reach, as well as by the presence of both left and right levees in the downstream portion of Cache Creek. The 1- and 0.2-percent annual chance flood elevations of the main channel were determined with both levees in place.

The starting water-surface elevation for Cache Creek was obtained by the slope/area method.

Cross-section data for Cache Creek from the Southern Pacific Railroad (SPRR) to Capay Dam were developed from a Digital Terrain Model (DTM) of the Cache Creek floodplain by converting Yolo County Digital Information Files (DXF) into digital HEC-2 format. The basis of the DTM is the 1995 aerial maps (scale 1"=200', contour interval 2 feet) and DXF files obtained from the Yolo County Community Development Agency (Yolo County Community Development Agency, 1995). The aerial mapping coverage depicts stream conditions as recorded in the fall of 1995 after the significant storm event of March 9, 1995. All bridges were surveyed to obtain elevation data and structural geometry.

Photogrammetric mapping was done for Cache Creek downstream of County Road 94B and along the right overbank area (USACE, 2000). A hydraulic analysis for the main channel of Cache Creek in Yolo County was performed using the USACE HEC-UNET computer program (USACE, 1997). The 1-percent annual chance flood elevations within the channel were determined assuming that the left and right levees will not fail. The 1-percent annual chance discharge to the right overbank of Cache Creek was determined by failing the right levee from upstream of the SPRR to the Cache Creek Settling Basin. The right overbank discharges were input to a FLO-2D model (J. S. O'Brien, 2000). A 1,000-foot grid system was developed from the topographic data for the FLO-2D model. Flood elevations computed by the FLO-2D model were used to determine the 1-percent annual chance flood extent and elevations through the City of Woodland to the Yolo Bypass.

The use of a two-dimensional model precludes the development of a flow path baseline and flood profile. Therefore, flood profiles for the right overbank were not developed as a part of this restudy. For site-specific flood elevations, the reader is directed to use the model output.

Locations of selected cross sections used in the hydraulic analyses are shown on the Flood Profiles (Exhibit 1). For stream segments for which a floodway was computed (Section 4.2), selected cross section locations are also shown on the FIRM (Exhibit 2).

The hydraulic analyses for this FIS were based on unobstructed flow. The flood elevations shown on the profiles are thus considered valid only if hydraulic structures remain unobstructed, operate properly, and do not fail.

Flood profiles were drawn showing computed water-surface elevations for floods of the selected recurrence intervals.

Roughness factors (Manning's "n") used in the hydraulic computations were chosen by engineering judgment and were based on field observations of the streams and floodplain areas. Roughness factors for all streams studied by detailed methods are shown in Table 6, "Manning's "n" Values."

TABLE 6 – MANNING'S "n" VALUES

Stream	Channel "n"	Overbank "n"
Cache Creek	0.030-0.075	0.025-0.174
Cottonwood Slough	0.040	0.040
Covell Drain	0.015-0.060	0.040-0.059
Dry Creek	0.015-0.080	0.030-0.040
Dry Slough	0.035-0.075	0.040
North Davis Drain	0.015-0.055	0.015-0.040
North Davis Overflow	0.035-0.045	0.045-0.059
South Fork Willow Slough	0.055	0.040-0.075
Stonegate Drainage Channel	0.030-0.060	*
Union Pacific Railroad Drain	0.040	0.045
Union School Slough	0.055-0.060	0.045-0.055
Unnamed Tributary of Union School Slough	0.055	0.045
Unnamed Tributary of Willow Slough	0.055	0.040-0.075
Unnamed Overflow Area South of County Road 31	0.040	0.040
Willow Slough	0.030-0.060	0.040-0.060
Willow Slough Left Overbank No. 1	0.040-0.060	0.040-0.100
Willow Slough Left Overbank No. 2	0.040	0.040
Yolo County Airport Drainage Channel	0.030-0.045	0.040-0.045

*Data Not Available

Countywide Analyses

Behind Levee Analysis

Some flood hazard information presented in prior FIRMs and in prior FIS reports for Yolo County and its incorporated communities was based on flood protection provided by levees. Based on the information available and the mapping standards of the NFIP at the time that the prior FISs and FIRMs were prepared, FEMA accredited the levees as providing protection from the flood that has a 1-percent-chance of being equaled or exceeded in any given year. For FEMA to continue to accredit the identified levees with providing protection from the base flood, the levees must meet the criteria of the Code of Federal Regulations, Title 44, Section 65.10 (44 CFR 65.10), titled "Mapping of Areas Protected by Levee Systems."

On August 22, 2005, FEMA issued "Procedure Memorandum No. 34 - Interim Guidance for Studies Including Levees." The purpose of the memorandum was to help clarify the responsibility of community officials or other parties seeking recognition of a levee by providing information identified during a study/mapping project. Often, documentation regarding levee design, accreditation, and the impacts on flood hazard mapping is outdated or missing altogether. To remedy this, Procedure Memorandum No. 34 provides interim guidance on procedures to minimize delays in near-term studies/mapping projects, to help our mapping partners properly assess how to handle levee mapping issues.

While documentation related to 44 CFR 65.10 is being compiled, the release of a more up-to-date FIRM for other parts of a community or county may be delayed. To minimize the impact of the levee recognition and certification process, FEMA issued "Procedure Memorandum No. 43 - Guidelines for Identifying Provisionally Accredited Levees" on March 16, 2007. These guidelines allow issuance of the FIS and FIRM while levee owners or communities compile full documentation required to show compliance with 44 CFR 65.10. The guidelines also explain that a FIRM can be issued while providing the communities and levee owners with a specified timeframe to correct any maintenance deficiencies associated with a levee and to show compliance with 44 CFR 65.10.

FEMA contacted the communities in Yolo County to obtain data required under 44 CFR 65.10 to continue to show the levees as providing protection from the flood that has a 1-percent-chance of being equaled or exceeded in any given year.

FEMA understood that it may take time to acquire and/or assemble the documentation necessary to fully comply with 44 CFR 65.10. Therefore, FEMA put forth a process to provide the communities with additional time to submit all the necessary documentation. For a community to avail itself of the additional time, it had to sign an agreement with FEMA. Levees for which such agreements were signed are shown on the final effective FIRM as providing protection from the flood that has a 1-percent-chance of being equaled or exceeded in any given year and labeled as a Provisionally Accredited Levee (PAL). Communities have two years from the date of FEMA's initial coordination to submit to FEMA final accreditation data for all PALs. Following receipt of final accreditation data, FEMA will revise the FIS and FIRM as warranted. However, no PAL agreement has been signed by any of the communities in Yolo County as of the date of this Preliminary FIS.

FEMA coordinated with local communities, the USACE, and other organizations to compile a list of levees that exist within Yolo County. Table 7 lists all levees shown on the FIRM, to include PALs, for which corresponding flood hazard revisions were made.

TABLE 7 – LIST OF LEVEES

Community	**Flood Source**	**Levee Inventory Identification Number**	**USACE Levee**
Yolo County (Unincorporated Areas)	Buckeye Creek	Not Specified	No
City of Woodland Yolo County (Unincorporated Areas)	Cache Creek	52, 53, 55, and 81	Yes

TABLE 7 – LIST OF LEVEES - continued

Community	Flood Source	Levee Inventory Identification Number	USACE Levee
City of Woodland Yolo County (Unincorporated Areas)	Colusa Basin Drainage Canal	94, 95, and 163	Yes
Yolo County (Unincorporated Areas)	Knights Landing Ridge Cut	83, 84, 120, 121, and 162	No
Yolo County (Unincorporated Areas)	Buckeye Creek	Not Specified	No
City of Woodland Yolo County (Unincorporated Areas)	Cache Creek	52, 53, 55, and 81	Yes
City of Woodland Yolo County (Unincorporated Areas)	Colusa Basin Drainage Canal	94, 95, and 163	Yes
Yolo County (Unincorporated Areas)	Knights Landing Ridge Cut	83, 84, 120, 121, and 162	No
City of Woodland Yolo County (Unincorporated Areas)	Old River	85, 118, and 119	No
City of West Sacramento Yolo County (Unincorporated Areas)	Sacramento River	11, 17, 86, 93, 122, 133 through 142, 147, 151, 152, 157, and 168 through 171	Yes
City of West Sacramento Yolo County (Unincorporated Areas)	Sacramento River Toe Drain	148 and 149	Yes
City of Davis Yolo County (Unincorporated Areas)	South Fork Putah Creek	29, 30, 105, and 106	Yes
Yolo County (Unincorporated Areas)	Unnamed Canal between Colusa Basin Drainage Canal and Sacramento River near El Dorado Bend	123 and 124	No

TABLE 7 – LIST OF LEVEES - continued

Community	Flood Source	Levee Inventory Identification Number	USACE Levee
Yolo County (Unincorporated Areas)	Willow Slough	36	No
City of Davis Yolo County (Unincorporated Areas)	Willow Slough Bypass	34 and 35	Yes
City of Davis Yolo County (Unincorporated Areas)	Yolo Bypass	28, 82, 116, 117, 128, and 132	Yes
Yolo County (Unincorporated Areas)	Yolo Bypass	5	No

Approximate analyses of “behind levee” flooding were conducted for all the levees in Table 7 to indicate the extent of the “behind levee” floodplains. Along the Sacramento River, Sacramento River Toe Drain, and Yolo Bypass, the area shown on the most recent FIRM (prior to this current revision) as protected by the levees was assumed to be the area that would be inundated by the 1% annual chance flood if the levees were to fail. For all other reaches, approximate areas of 1-percent annual chance flooding in the event of failure of the levees were determined based on engineering judgment, including use of the FIS and topographic information from the U.S. Geological Survey.

The flooding along the south side of Cache Creek through the City of Woodland was restudied by Wood Rodgers, Inc (September 2009). This revision addressed flooding along the south side of Cache Creek, carrying the flood hydrographs through the City of Woodland, ending downstream at County Road 25 and the Yolo Bypass to account for backwater effects and downstream boundary conditions for flooding affecting the City. The dynamic relationship between the channel hydraulics and floodplain was modeled using the MIKE-FLOOD software produced by the Danish Hydraulic Institute. Two-dimensional flood analysis was performed for 1 percent annual chance flood event. MIKE FLOOD allows the channel and the floodplain to exchange water during each time step, balancing the flow according to the capacities of both for the entire simulation.

Two-foot contours from aerial photogrammetric mapping developed under the USACE Feasibility Study was used to generate the modeling grid for topographic mapping.

The floodplain was generated using "levee removal" methodology whereby segments of the levee were modeled as non-existent from the beginning of each model simulation. The levee along the south side of Cache Creek is several miles long and has several bridge structure-crossings. The flooding in this reach of

Cache Creek affects overland areas as a result of flow obstructions created by bridge and roadways crossings. The bridges were considered as "hard points" and levee segments between bridges as unique levee "failures". This methodology forces more water to flow out of each modeled separate reach (as a stand-alone scenario), when compared to a scenario where all reaches are removed simultaneously. The segmented levee removal methodology reflects more conservative floodplain with higher base flood elevations (BFEs) compared to simultaneous downstream levee removal.

Cache Creek channel has levee embankments along both sides of the creek downstream of Interstate 5 and a short distance upstream. The bridges form "hard points" in the levee system and were utilized as locations for breaking up the levee into removal segments. Various levee removal scenarios along the right bank were analyzed and results of individual removal scenarios were compiled together to reflect the most conservative floodplain extents from all individual components.

3.3 Vertical Datum

All FISs and FIRMs are referenced to a specific vertical datum. The vertical datum provides a starting point against which flood, ground, and structure elevations can be referenced and compared. Until recently, the standard vertical datum in use for newly created or revised FISs and FIRMs was the National Geodetic Vertical Datum of 1929 (NGVD 29). With the finalization of the North American Vertical Datum of 1988 (NAVD 88), many FIS reports and FIRMs are being prepared using NAVD 88 as the referenced vertical datum.

All flood elevations shown in this FIS report and on the FIRM are referenced to NAVD 88. Structure and ground elevations in the community must, therefore, be referenced to NAVD 88. It is important to note that adjacent communities may be referenced to NGVD 29. This may result in differences in base flood elevations across the corporate limits between the communities.

As noted above, the elevations shown in the FIS report and on the FIRM for Yolo County are referenced to NAVD 88. Ground, structure, and flood elevations may be compared and/or referenced to NGVD 29 by applying a standard conversion factor. With the exception of flooding along the Sacramento River, the conversion factor to NAVD 88 is +2.58 feet. For flooding along the main stem of the Sacramento River, the conversion factor to NAVD 88 is +2.47 feet. Lastly, flood elevations in the vicinity of Merritt Island, to the south and east of Elk Slough, are based on corresponding flood elevations from Elk Slough.

For more information on NAVD 88, see Converting the National Flood Insurance Program to the North American Vertical Datum of 1988, FEMA Publication FIA-20/June 1992, or contact the Spatial Reference System Division, National Geodetic Survey, NOAA, Silver Spring Metro Center, 1315 East-West Highway, Silver Spring, Maryland 20910 (Internet address http://www.ngs.noaa.gov).

4.0 FLOODPLAIN MANAGEMENT APPLICATIONS

The NFIP encourages State and local governments to adopt sound floodplain management programs. To assist in this endeavor, each FIS provides 1-percent annual chance floodplain data, which may include a combination of the following: 10-, 2-, 1-, and 0.2-percent annual chance flood elevations; delineations of the 1- and 0.2-percent annual chance floodplains; and 1-percent annual chance floodway. This information is presented on the FIRM and in many components of the FIS, including Flood Profiles, Floodway Data tables, and Summary of Stillwater Elevation tables. Users should reference the data presented in the FIS as well as additional information that may be available at the local community map repository before making flood elevation and/or floodplain boundary determinations.

4.1 Floodplain Boundaries

To provide a national standard without regional discrimination, the 1-percent annual chance flood has been adopted by FEMA as the base flood for floodplain management purposes. The 0.2-percent annual chance flood is employed to indicate additional areas of flood risk in the county. For the streams studied in detail, the 1- and 0.2-percent annual chance floodplain boundaries have been delineated using the flood elevations determined at each cross section. Between cross sections, the boundaries were interpolated for Dry Creek using topographic maps at a scale of 1:2,400, with a contour interval of 1 foot (U.S. Department of the Interior, 1975).

In the Delta area, flood boundaries have been delineated using elevations determined in the hydraulic analyses. Boundaries were interpolated using topographic maps at a scale of 1:24,000, with a contour interval of 5 feet (U.S. Department of the Interior, 1980, et cetera).

In the City of Davis, boundaries were interpolated using topographic maps at a scale of 1:7,200, with a contour interval of 1 foot (The City of Davis, 1977).

Current, reliable topography in the City of Davis area is not available because of apparent differential subsidence. For this reason, the boundaries of the ponding area and the shallow flooding (Covell Drain overflow) area were developed using general topography obtained from field surveys.

In the City of West Sacramento, boundaries were interpolated using topographic maps at a scale of 1:24,000, with contour intervals of 5 and 10 feet (USACE, 1989). For the streams studied in detail, in the unincorporated areas of Yolo County and the City of West Sacramento, flood boundaries were delineated using topographic maps with a scale of 1"=2,000', enlarged to 1"=1,000', and contour intervals of 5 and 10 feet (USACE, 1989).

In the City of Winters, boundaries were interpolated using topographic maps at a scale of 1:4,800, with a contour interval of 4 feet (Andregg, Inc., 1996).

In the City of Woodland, for the overflow area of Cache Creek, the 1-percent annual chance floodplain boundaries have been delineated using the flood elevations determined by the FLO-2D model (J. S. O'Brien, 2000). The boundaries were interpolated between grid cells using topographic maps at a scale of 1"=1,000', with a contour interval of 2 feet (USACE, 2000).

For the flooding sources studied by approximate methods, the boundaries of the 1-percent annual chance floodplains were delineated using topographic maps taken from the previously printed FIS reports, FHBMs, and/or FIRMs for all of the incorporated and unincorporated jurisdictions within Yolo County.

The 1- and 0.2-percent annual chance floodplain boundaries are shown on the FIRM (Exhibit 2). On this map, the 1-percent annual chance floodplain boundary corresponds to the boundary of the areas of special flood hazards (Zones A and AE), and the 0.2-percent annual chance floodplain boundary corresponds to the boundary of areas of moderate flood hazards. In cases where the 1- and 0.2-percent annual chance floodplain boundaries are close together, only the 1-percent annual chance floodplain boundary has been shown. Small areas within the floodplain boundaries may lie above the flood elevations but cannot be shown due to limitations of the map scale and/or lack of detailed topographic data.
For the streams studied by approximate methods, only the 1-percent annual chance floodplain boundary is shown on the FIRM (Exhibit 2).

4.2 Floodways

Encroachment on floodplains, such as structures and fill, reduces flood-carrying capacity, increases flood heights and velocities, and increases flood hazards in areas beyond the encroachment itself. One aspect of floodplain management involves balancing the economic gain from floodplain development against the resulting increase in flood hazard. For purposes of the NFIP, a floodway is used as a tool to assist local communities in this aspect of floodplain management. Under this concept, the area of the 1-percent annual chance floodplain is divided into a floodway and a floodway fringe. The floodway is the channel of a stream, plus any adjacent floodplain areas, that must be kept free of encroachment so that the 1-percent annual chance flood can be carried without substantial increases in flood heights. Minimum federal standards limit such increases to 1.0 foot, provided that hazardous velocities are not produced. The floodways in this FIS are presented to local agencies as minimum standards that can be adopted directly or that can be used as a basis for additional floodway studies.

The floodways presented in this FIS were computed for certain stream segments on the basis of equal conveyance reduction from each side of the floodplain.

Floodway widths were computed at cross sections. Between cross sections, the floodway boundaries were interpolated. The results of the floodway computations are tabulated for selected cross sections (Table 8). The computed floodways are shown on the FIRM (Exhibit 2). In cases where the floodway and 1-percent annual chance floodplain boundaries are either close together or collinear, only the floodway boundary is shown.

For the unincorporated areas of Yolo County, the floodway concept is not applicable. For three of the areas in the county studied by detailed methods, all flooding is in the form of sheetflow. Additionally, for Lamb Valley Slough in the Madison-Esparto area, an increase in the elevation of the 1-percent annual chance flood would increase the overbank flow to the south and east. Therefore, floodways were not developed. A floodway was not developed for Dry Creek because the 1-percent annual chance flood is contained within the channel. Floodways were not developed in the Delta area due to the broad areal extent of flooding. Floodway was computed for Willow Slough. For Cache Creek, floodway was computed upstream of County Road 94B.

In the City of Davis, a floodway was not developed for that portion of Covell Drain west of Anderson Road because the floodway would be confined to the channel. A floodway was not developed for that portion of Covell Drain east of Anderson Road because any increase in the elevation of the base flood would increase overbank flow to central Davis. Therefore, the 1-percent annual chance boundary should be considered the floodway. Floodway was complied for Union Pacific Railroad Drain. Flooding elsewhere in the City of Davis is in the form of shallow, overland flow or shallow ponding and floodways were not developed.

In the City of West Sacramento, no floodways were defined for the Sacramento River or the Yolo Bypass.

In the City of Winters, no floodways were computed for Dry Creek or Moody Slough because a floodway analysis was not included in the scope of work.

No floodways were computed for the City of Woodland.

Encroachment into areas subject to inundation by floodwaters having hazardous velocities aggravates the risk of flood damage, and heightens potential flood hazards by further increasing velocities. A listing of stream velocities at selected cross sections is provided in Table 8, "Floodway Data." In order to reduce the risk of property damage in areas where the stream velocities are high, the community may wish to restrict development in areas outside the floodway.

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	**DISTANCE[1]**	**WIDTH (FEET)**	**SECTION AREA (SQUARE FEET)**	**MEAN VELOCITY (FEET PER SECOND)**	**REGULATORY**	**WITHOUT FLOODWAY** FEET (NAVD)	**WITH FLOODWAY**	**INCREASE**
Cache Creek								
A	86,786	459	7,029	8.6	97.8	97.8	97.8	0.0
B	88,882	1,136	15,637	3.9	99.9	99.9	99.9	0.0
C	90,867	1,608	15,142	4	101.2	101.2	101.2	0.0
D	92,783	1,026	10,262	5.9	103.6	103.6	103.6	0.0
E	94,641	751	8,681	7	107.9	107.9	107.9	0.0
F	96,626	616	7,156	8.5	113.1	113.1	113.1	0.0
G	98,504	950	12,359	4.9	118.4	118.4	118.6	0.2
H	100,139	967	12,674	4.8	119.4	119.4	120.1	0.7
I	101,876	855	10,893	5.6	122.2	122.2	122.5	0.3
J	103,511	725	8,745	6.9	124.3	124.3	124.5	0.2
K	105,276	543	7,588	8	128	128	128.1	0.1
L	106,894	464	6,878	8.8	131.6	131.6	131.8	0.2
M	108,553	376	6,428	9.4	134.1	134.1	134.3	0.2
N	110,194	560	11,402	5.3	137.4	137.4	137.5	0.1
O	111,593	660	11,799	5.1	138	138	138.1	0.1
P	113,264	599	8,506	7.1	138.9	138.9	139	0.1
Q	115,021	736	9,980	6.1	142.7	142.7	142.7	0.0
R	117,003	652	9,987	6.1	144.9	144.9	144.9	0.0
S	118,814	892	9,964	6.1	147.5	147.5	147.5	0.0
T	120,728	675	8,171	7.4	150.1	150.1	150.1	0.0
U	122,560	1,040	13,341	4.5	152.5	152.5	152.5	0.0
V	124,147	1,340	16,335	3.7	153.4	153.4	153.4	0.0
W	126,245	1,565	13,842	4.4	154.8	154.8	154.8	0.0
X	128,233	1,896	12,460	4.9	157.1	157.1	157.1	0.0
Y	129,447	1,777	10,924	5.5	160.1	160.1	160.1	0.0
Z	130,996	2,228	12,308	4.9	163.9	163.9	163.9	0.0

[1] Stream distance in feet above end of Levees in Stilling Basin.

TABLE 8

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA
AND INCORPORATED AREAS

FLOODWAY DATA

CACHE CREEK

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY (FEET (NAVD))	WITH FLOODWAY (FEET (NAVD))	INCREASE
Cache Creek								
AA	132,431	475	4,838	12.5	169.3	169.3	169.3	0.0
AB	133,078	1,379	14,706	4.1	173.4	173.4	173.4	0.0
AC	134,549	1,393	10,298	5.9	174.6	174.6	174.6	0.0
AD	136,523	1,098	9,720	6.2	179.6	179.6	179.6	0.0
AE	138,372	1,430	7,415	8.2	184.4	184.4	184.4	0.0
AF	139,561	1,400	9,641	6.3	190.4	190.4	190.4	0.0
AG	141,552	1,025	9,323	6.5	197.3	197.3	197.3	0.0
AH	143,263	561	6,621	9.2	201.1	201.1	201.1	0.0
AI	144,623	1,000	8,538	7.1	206.1	206.1	206.3	0.2
AJ	145,887	1,029	8,831	6.9	208.8	208.8	209	0.2
AK	147,374	1,341	10,286	5.9	211.6	211.6	211.8	0.2
AL	148,692	1,566	8,311	7.3	213.4	213.4	213.7	0.3
AM	150,010	1,974	12,065	5	219	219	219	0.0
AN	151,963	1,369	8,884	6.8	223.1	223.1	223.2	0.1
AO	153,513	1,460	11,123	5.4	226.4	226.4	226.5	0.1
AP	154,965	577	10,300	5.9	228.2	228.2	228.4	0.2

[1] Stream distance in feet above end of Levees in Stilling Basin.

TABLE 8

FEDERAL EMERGENCY MANAGEMENT AGENCY
YOLO COUNTY, CA
AND INCORPORATED AREAS

FLOODWAY DATA

CACHE CREEK

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	**DISTANCE**	**WIDTH (FEET)**	**SECTION AREA (SQUARE FEET)**	**MEAN VELOCITY (FEET PER SECOND)**	**REGULATORY**	**WITHOUT FLOODWAY** FEET (NAVD)	**WITH FLOODWAY**	**INCREASE**
Union Pacific Railroad Drain								
A	800[1]	86	216	2.0	44.8	44.8	44.9	0.1
B	3,300[1]	25	213	2.1	45.8	45.8	46.4	0.6
Willow Slough								
A	-270[2]	282	2,824	3.5	50.0	50.0	51.0	1.0
B	1,210[2]	193	2,238	4.5	52.1	52.1	52.7	0.6
C	2,250[2]	184	2,245	4.5	53.5	53.5	53.9	0.4
D	3,130[2]	234	2,544	3.9	54.8	54.8	55.1	0.3
E	4,460[2]	368	2,555	3.7	55.9	55.9	56.2	0.3
F	6,345[2]	1,220	5,725	1.6	56.5	56.5	57.1	0.6
G	8,020[2]	1,220	5,874	1.6	57.0	57.0	57.7	0.7
H	9,280[2]	950	3,951	2.4	57.4	57.4	58.1	0.7
I	11,400[2]	1,220	3,946	2.4	59.7	59.7	60.7	1.0
J	12,820[2]	830	3,676	2.5	60.7	60.7	61.6	0.9
K	14,470[2]	1,480	4,500	2.1	61.9	61.9	62.8	0.9
L	15,500[2]	1,230	4,545	2.0	62.5	62.5	63.4	0.9
M	17,220[2]	1,622	6,264	1.5	64.8	64.8	65.1	0.3
N	18,525[2]	1,750	5,452	1.7	65.2	65.2	65.7	0.5
O	19,820[2]	1,250	2,878	3.2	66.5	66.5	66.8	0.3
P	22,350[2]	1,590	4,047	2.2	69.5	69.5	70.3	0.8
Q	23,755[2]	1,360	3,720	2.4	71.2	71.2	72.0	0.8
R	24,770[2]	1,240	3,322	2.7	72.8	72.8	73.5	0.7
S-X*								

1 Feet above Confluence with North Davis Overflow

2 Feet above Southern Pacific Railroad

* Data Not Available

TABLE 8

FEDERAL EMERGENCY MANAGEMENT AGENCY

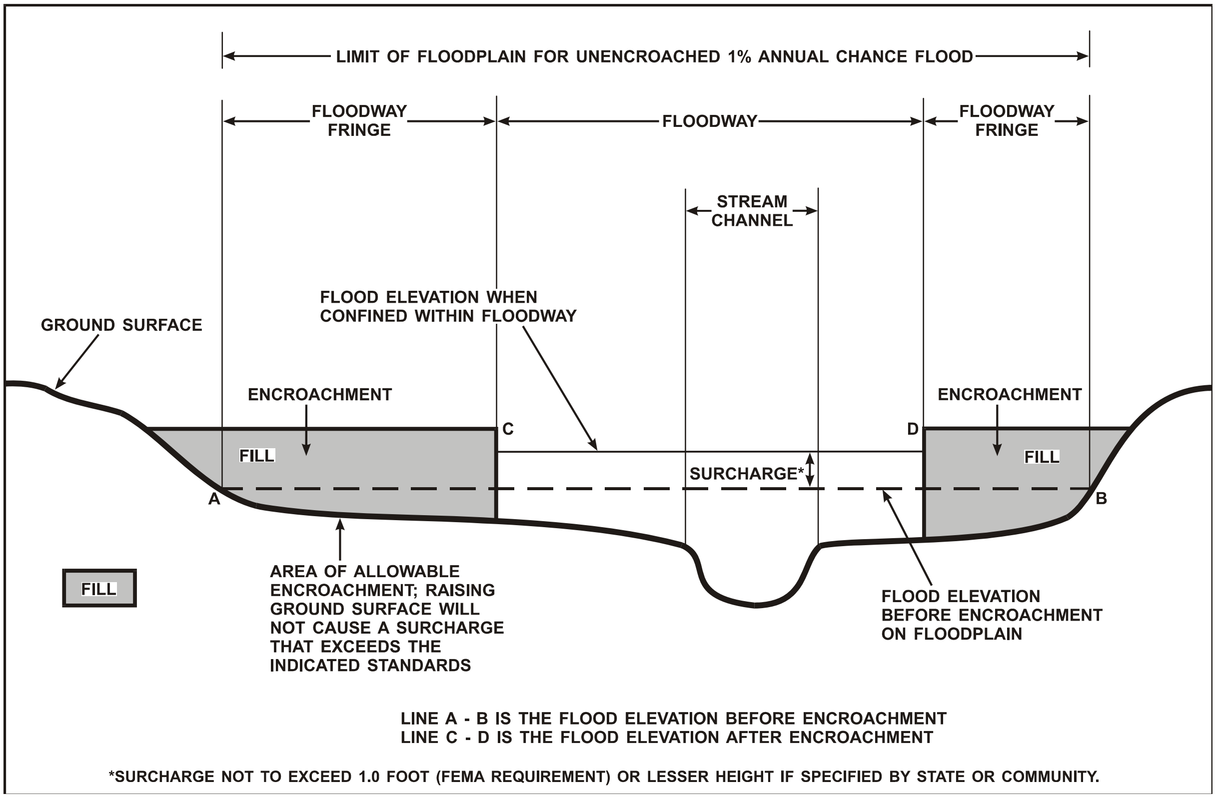
YOLO COUNTY, CA

AND INCORPORATED AREAS

FLOODWAY DATA

UNION PACIFIC RAILROAD DRAIN - WILLOW SLOUGH

The area between the floodway and 1-percent annual chance floodplain boundaries is termed the floodway fringe. The floodway fringe encompasses the portion of the floodplain that could be completely obstructed without increasing the water-surface elevation of the 1-percent annual chance flood by more than 1.0 foot at any point. Typical relationships between the floodway and the floodway fringe and their significance to floodplain development are shown in Figure 1.



FLOODWAY SCHEMATIC Figure 1

5.0 INSURANCE APPLICATIONS

For flood insurance rating purposes, flood insurance zone designations are assigned to a community based on the results of the engineering analyses. The zones are as follows:

Zone A

Zone A is the flood insurance rate zone that corresponds to the 1-percent annual chance floodplains that are determined in the FIS by approximate methods. Because detailed hydraulic analyses are not performed for such areas, no base flood elevations or depths are shown within this zone.

Zone AE

Zone AE is the flood insurance rate zone that corresponds to the 1-percent annual chance floodplains that are determined in the FIS by detailed methods. In most instances, whole-foot base flood elevations derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone AH

Zone AH is the flood insurance rate zone that corresponds to the areas of 1-percent annual chance shallow flooding (usually areas of ponding) where average depths are between 1 and 3 feet. Whole-foot base flood elevations derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone AO

Zone AO is the flood insurance rate zone that corresponds to the areas of 1-percent annual chance shallow flooding (usually sheet flow on sloping terrain) where average depths are between 1 and 3 feet. Average whole-foot depths derived from the detailed hydraulic analyses are shown within this zone.

Zone X

Zone X is the flood insurance rate zone that corresponds to areas outside the 0.2-percent annual chance floodplain, areas within the 0.2-percent annual chance floodplain, and to areas of 1-percent annual chance flooding where average depths are less than 1 foot, areas of 1-percent annual chance flooding where the contributing drainage area is less than 1 square mile, and areas protected from the 1-percent annual chance flood by levees. No base flood elevations or depths are shown within this zone.

Zone D

Zone D is the flood insurance rate zone that corresponds to unstudied areas where flood hazards are undetermined, but possible.

6.0 FLOOD INSURANCE RATE MAP

The FIRM is designed for flood insurance and floodplain management applications.

For flood insurance applications, the map designates flood insurance rate zones as described in Section 5.0 and, in the 1-percent annual chance floodplains that were studied by detailed methods, shows selected whole-foot base flood elevations or average depths. Insurance agents use the zones and base flood elevations in conjunction with information on structures and their contents to assign premium rates for flood insurance policies.

For floodplain management applications, the map shows by tints, screens, and symbols, the 1- and 0.2-percent annual chance floodplains. Floodways and the locations of selected cross sections used in the hydraulic analyses and floodway computations are shown where applicable.

The current FIRM presents flooding information for the entire geographic area of Yolo County. Previously, separate Flood Hazard Boundary Maps and/or FIRMs were prepared for each identified flood-prone incorporated community and the unincorporated areas of the county. This countywide FIRM also includes flood hazard information that was presented separately on Flood Boundary and Floodway Maps (FBFMs), where applicable. Historical data relating to the maps prepared for each community, up to and including this countywide FIS, are presented in Table 9, "Community Map History."

COMMUNITY NAME	INITIAL IDENTIFICATION	FLOOD HAZARD BOUNDARY MAP REVISIONS DATE	FIRM EFFECTIVE DATE	FIRM REVISIONS DATE
Davis, City of	November 8, 1977	None	November 15, 1979	December 20, 2002
*West Sacramento, City of	March 5, 1990	None	March 5, 1990	January 19, 1995
Winters, City of	January 23, 1974	May 7, 1976	December 1, 1978	November 20, 1998
Woodland, City of	October 16, 1979	None	October 16, 1979	October 13, 1981 April 2, 2002
Yolo County (Unincorporated Areas)	October 18, 1977	None	December 16, 1980	May 17, 1988 March 5, 1990 July 6, 1998 March 23, 1999 April 2, 2002 December 20, 2002

*FIS and FIRM published separately

TABLE 9

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA
AND INCORPORATED AREAS

COMMUNITY MAP HISTORY

7.0 OTHER STUDIES

FISs were published for the City of Winters (FEMA, 1978); City of Woodland (FEMA, 1981); City of Davis (FEMA, 1979); City of West Sacramento (FEMA, 1995); the Flood Hazard Boundary Map (FHBM) for Yolo County FEMA, 1977); and the FIS for Yolo County published in 1980 (U.S. Department of Housing and Urban Development, 1980) This study supersedes the aforementioned studies.

Information pertaining to revised and unrevised flood hazards for each jurisdiction within Yolo County has been compiled into this FIS. Therefore, this FIS supersedes all previously printed FIS Reports, FHBMs, FBFMs, and FIRMs for all of the incorporated and unincorporated jurisdictions within Yolo County.

8.0 LOCATION OF DATA

Information concerning the pertinent data used in the preparation of this FIS can be obtained by contacting FEMA, Federal Insurance and Mitigation Division, 1111 Broadway, Suite 1200, Oakland, California 94607-4052.

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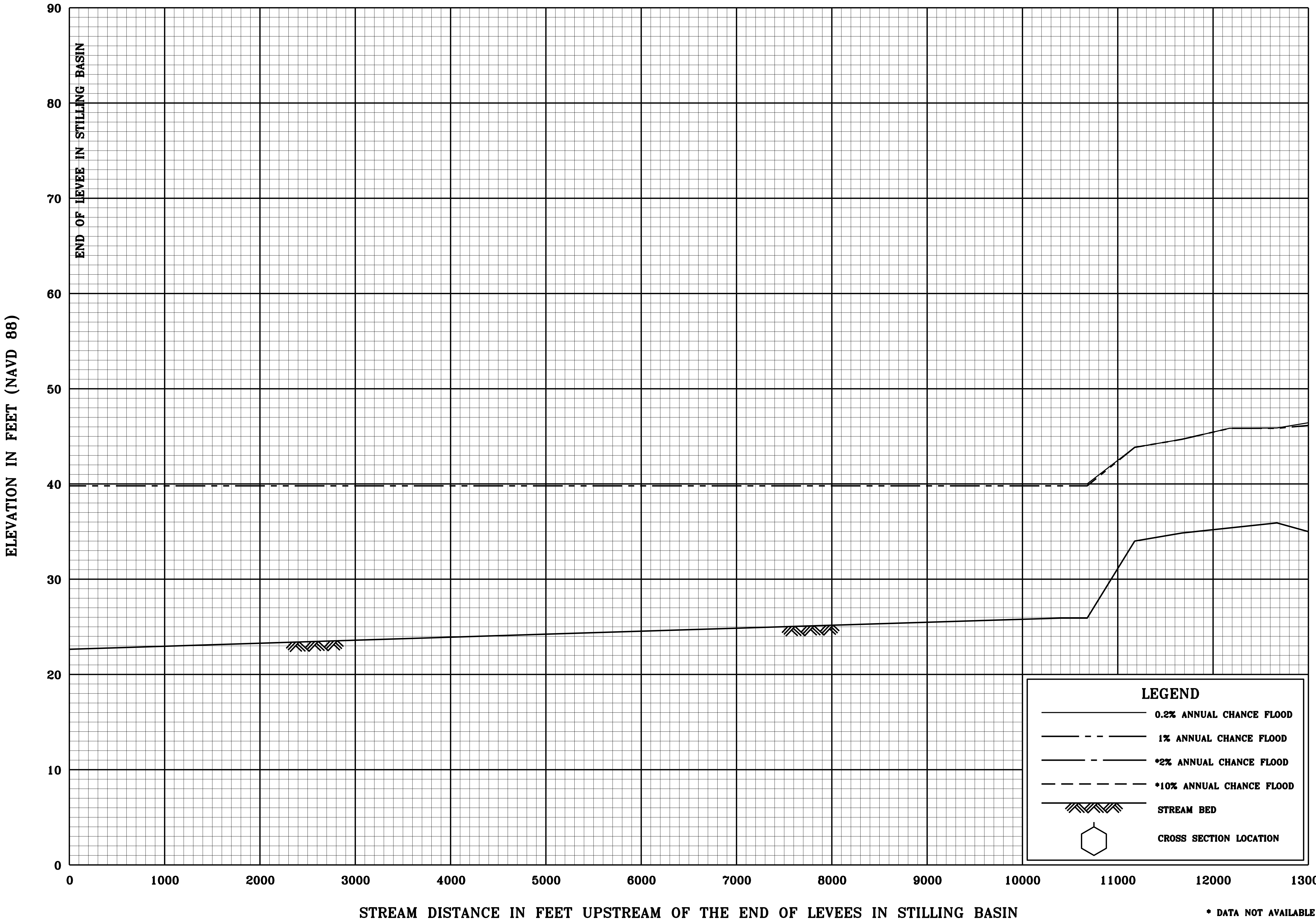


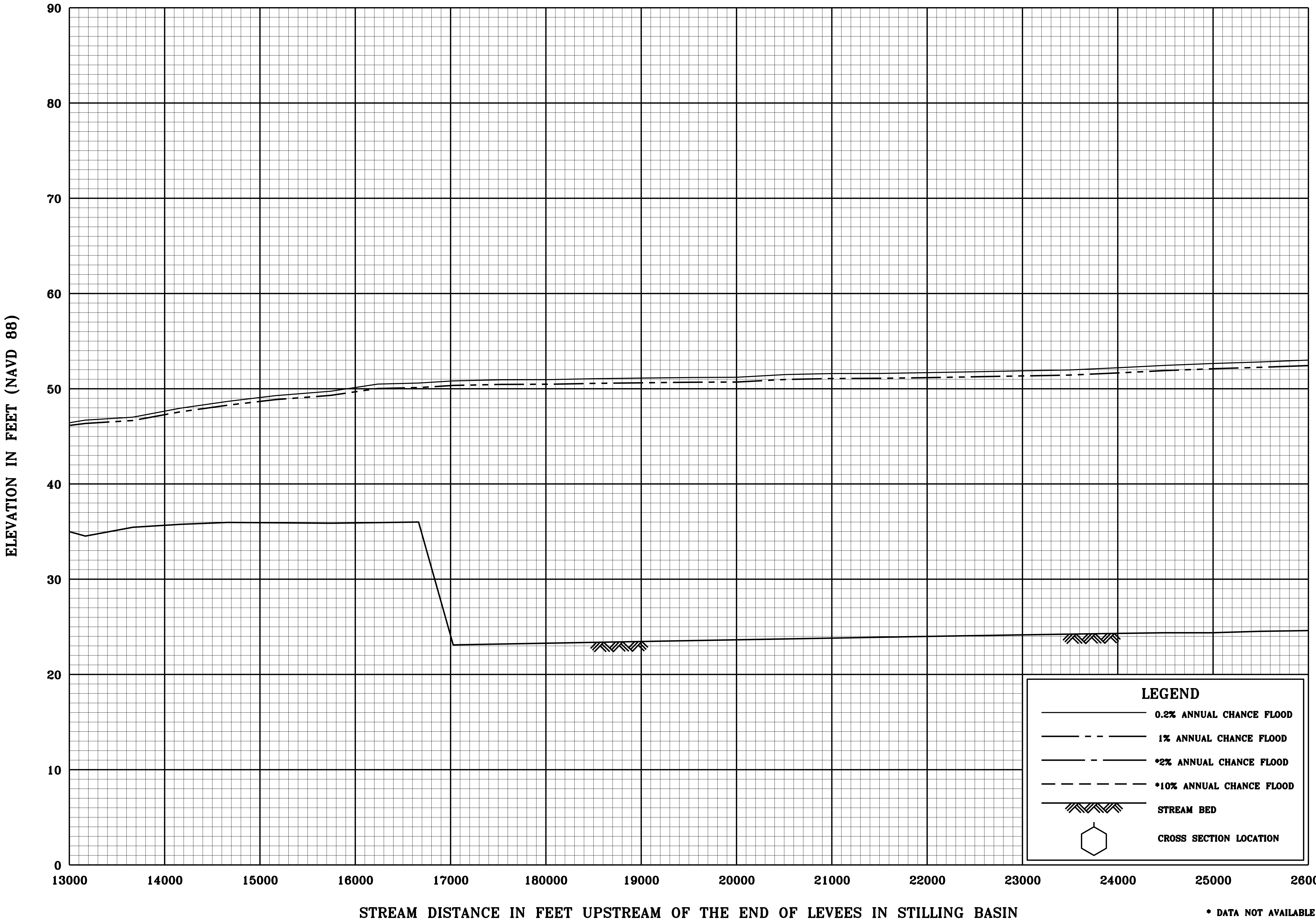
FLOOD PROFILES

CACHE CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA AND INCORPORATED AREAS

01P



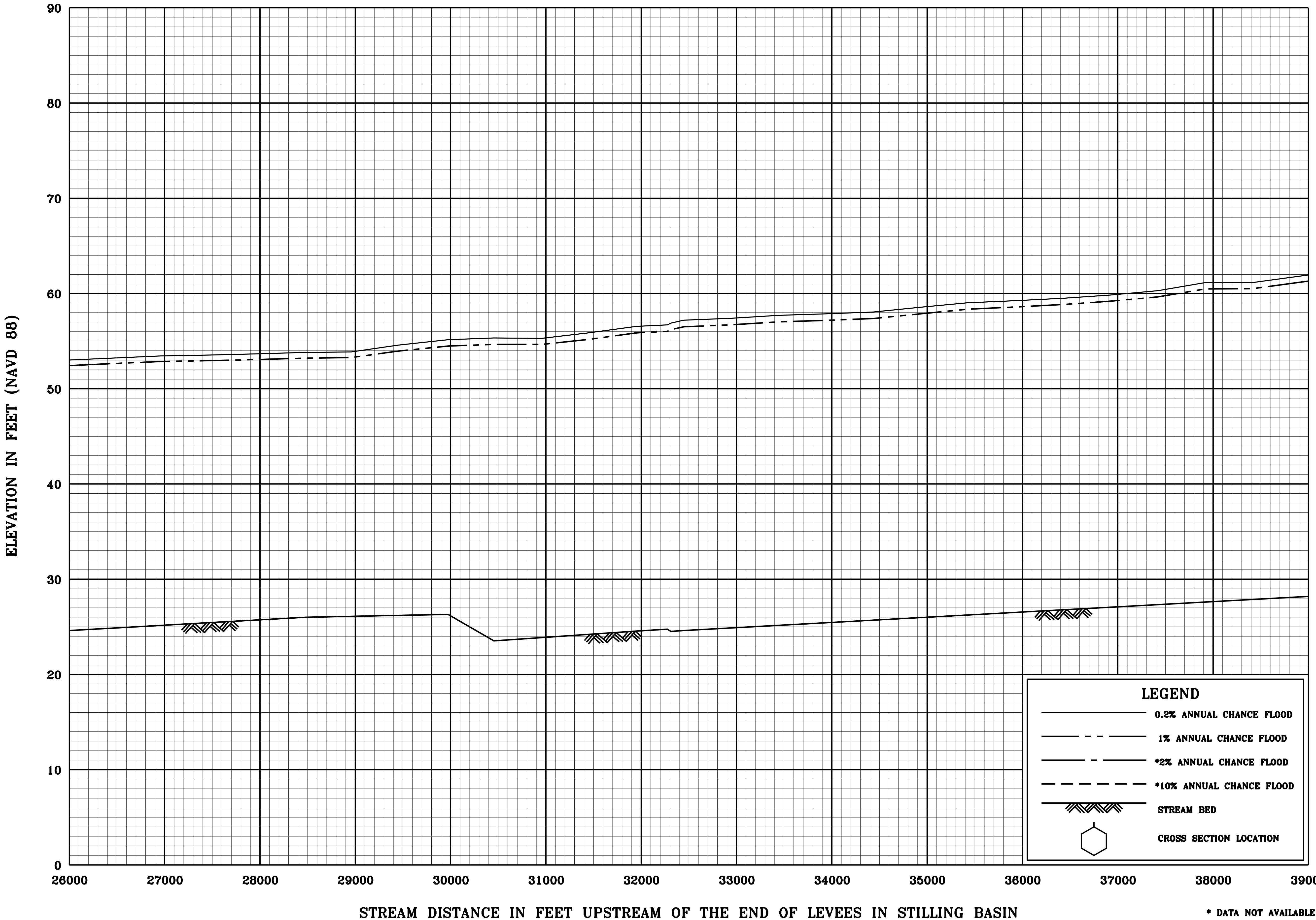
FLOOD PROFILES

CACHE CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA
AND INCORPORATED AREAS

02P



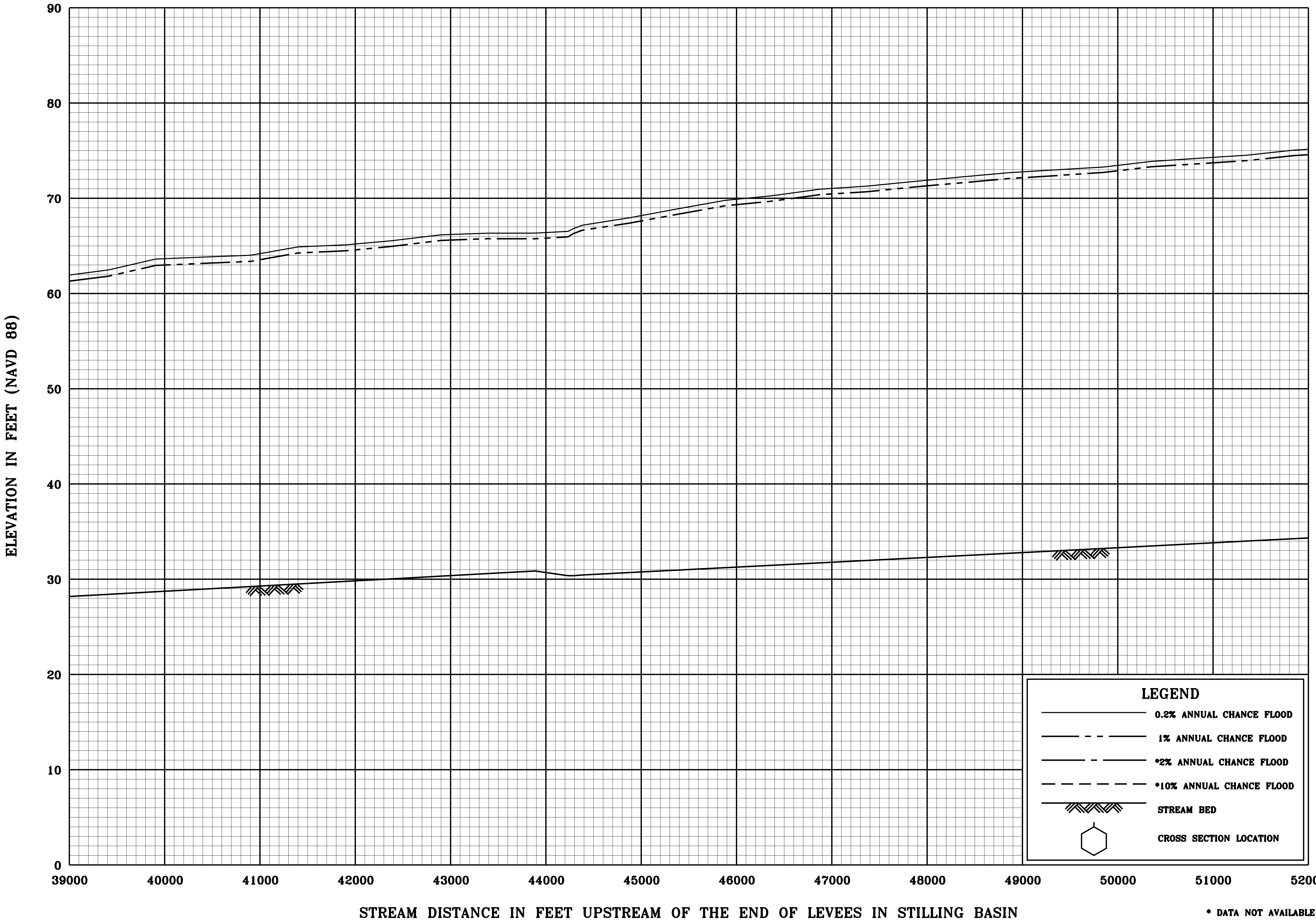
FLOOD PROFILES

CACHE CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA
AND INCORPORATED AREAS

03P



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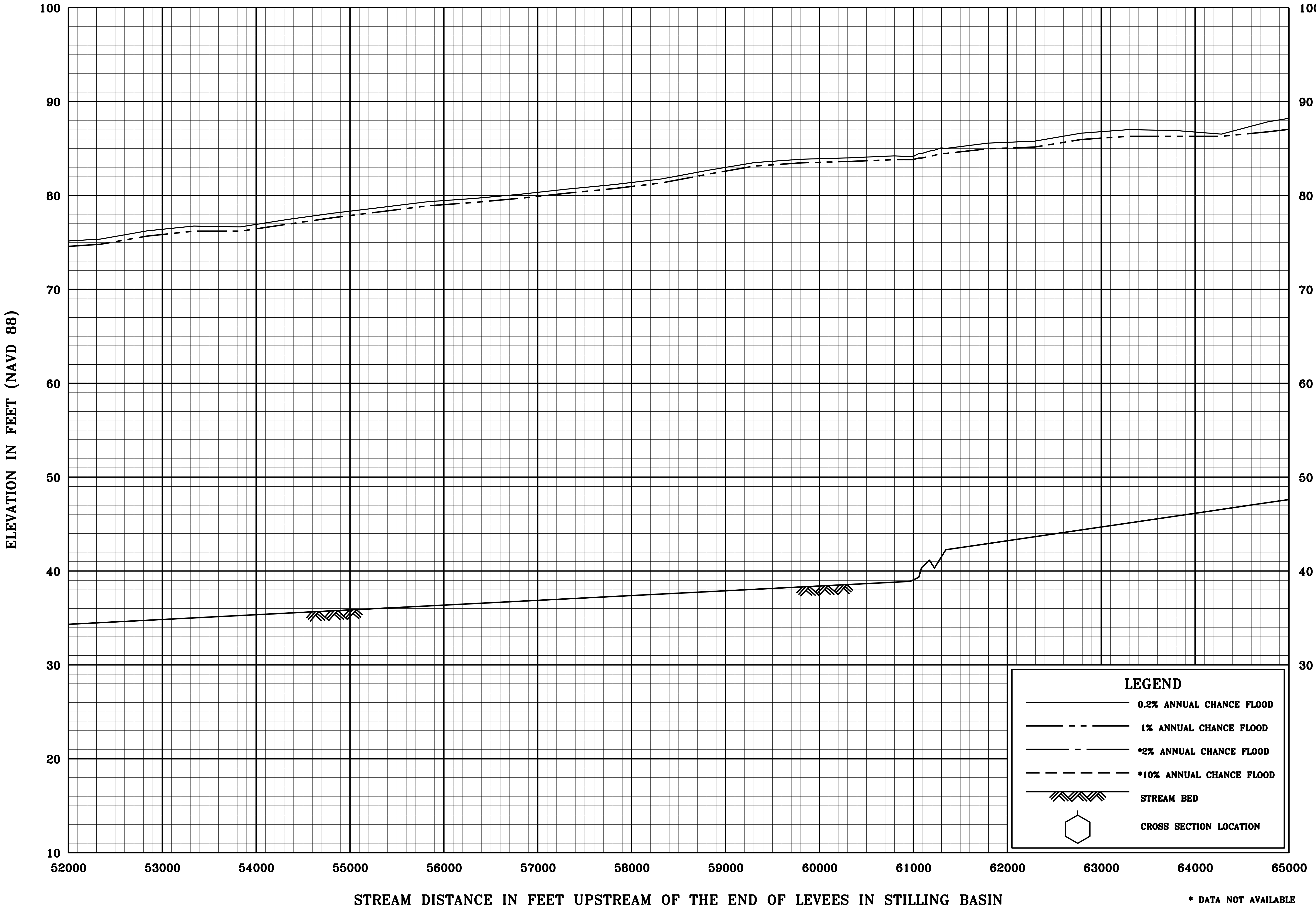
FLOOD PROFILES

CACHE CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA AND INCORPORATED AREAS

04P

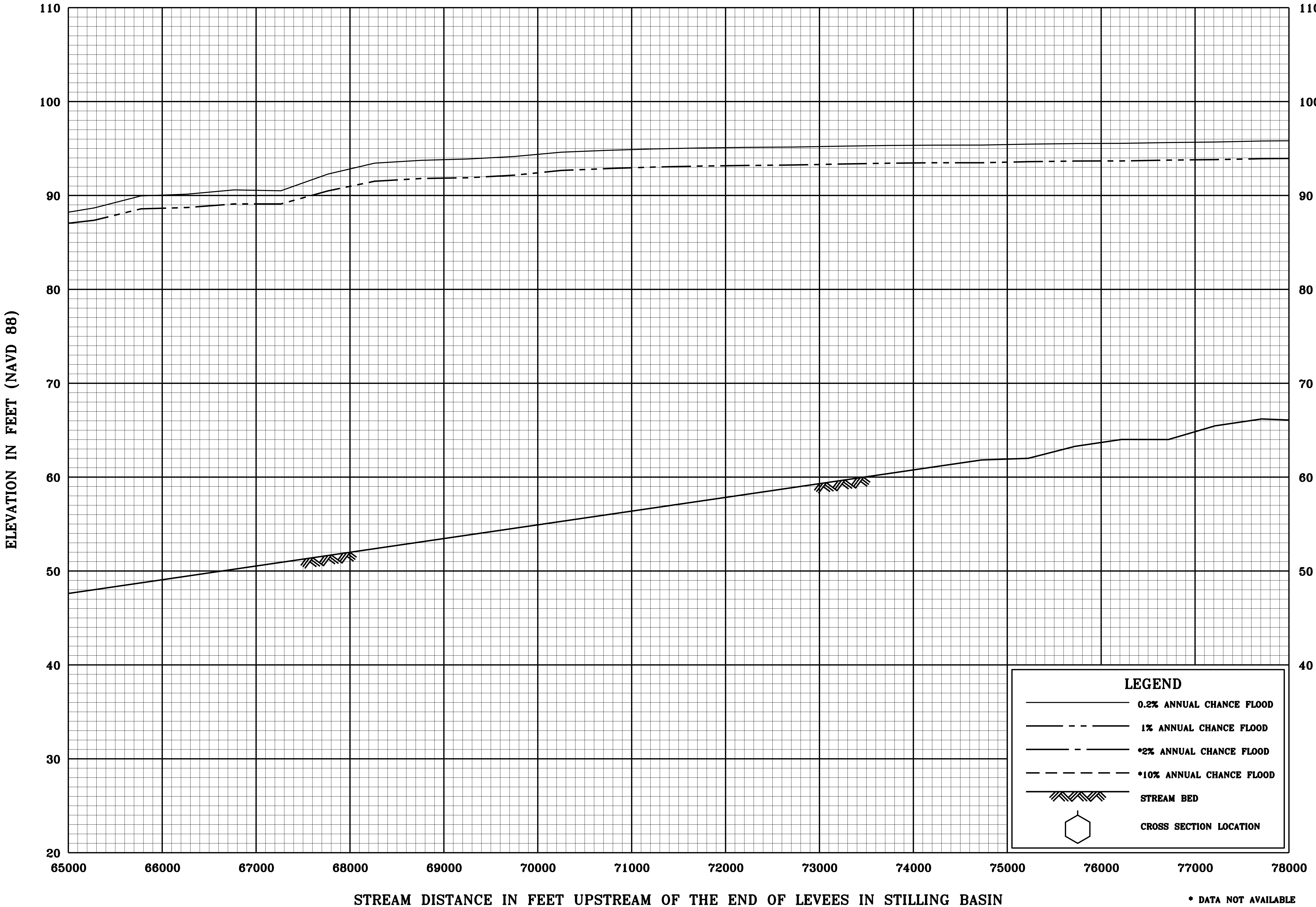


FLOOD PROFILES

CACHE CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA
AND INCORPORATED AREAS



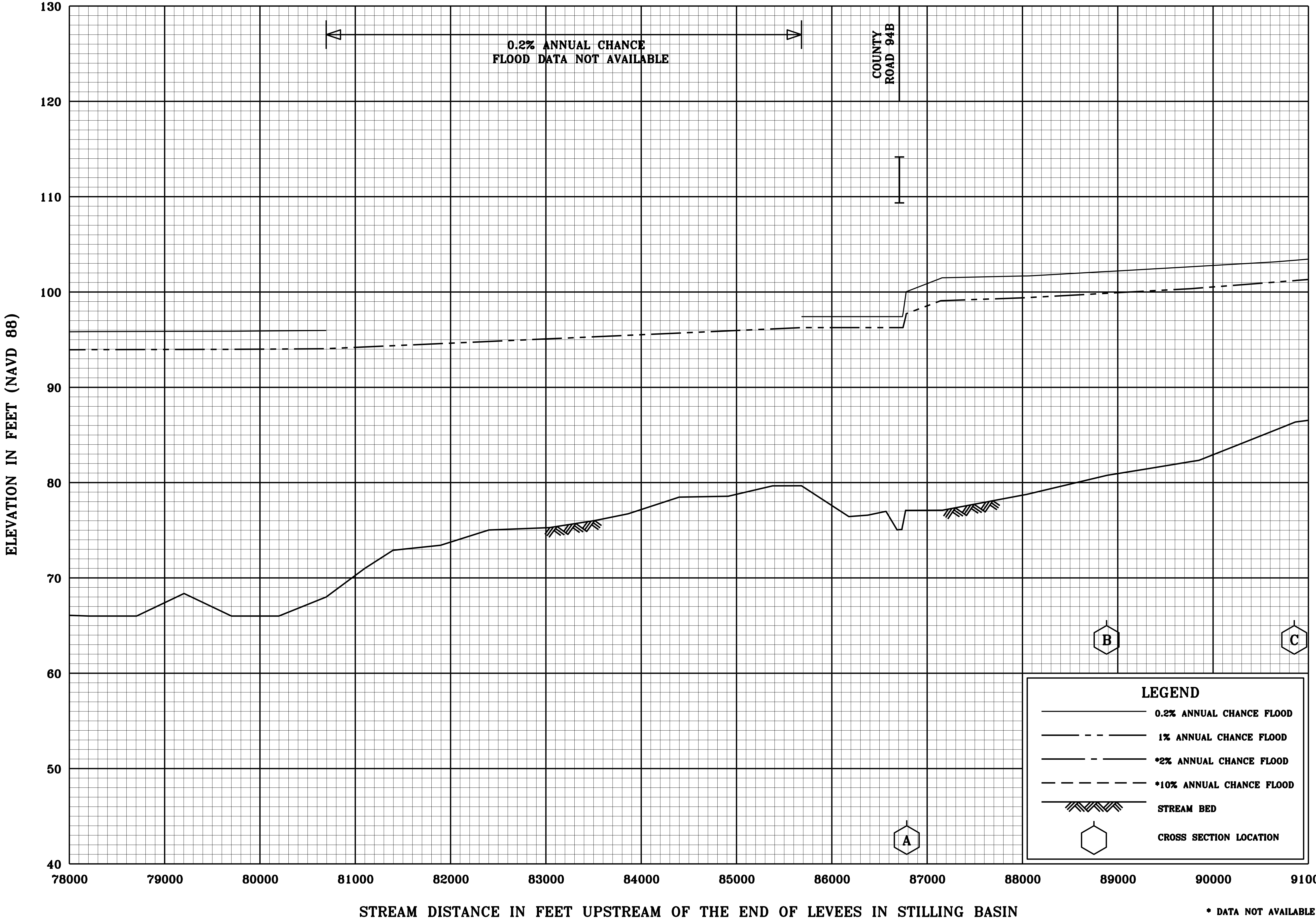
FLOOD PROFILES

CACHE CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA
AND INCORPORATED AREAS

06P



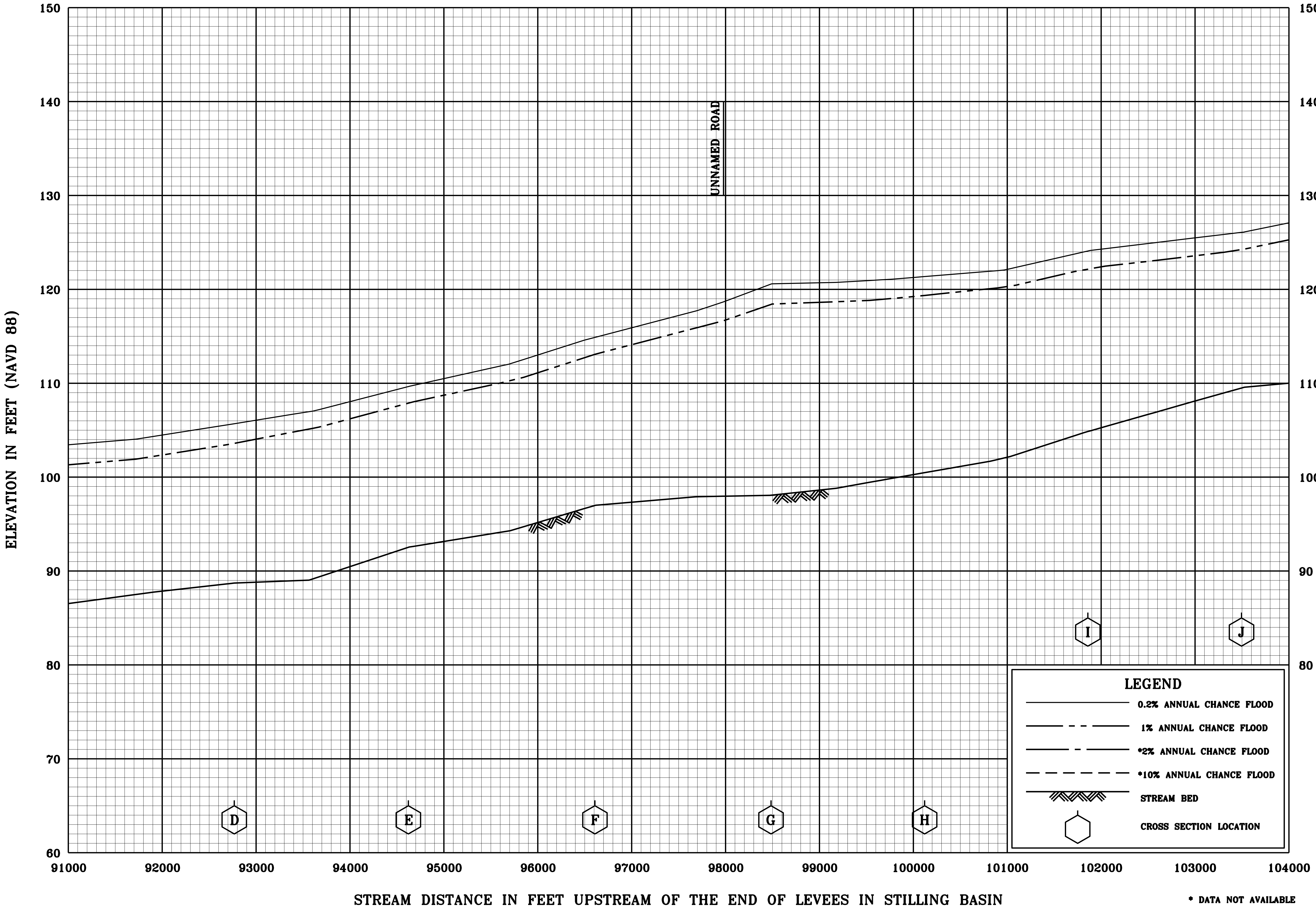
FLOOD PROFILES

CACHE CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA
AND INCORPORATED AREAS

07P

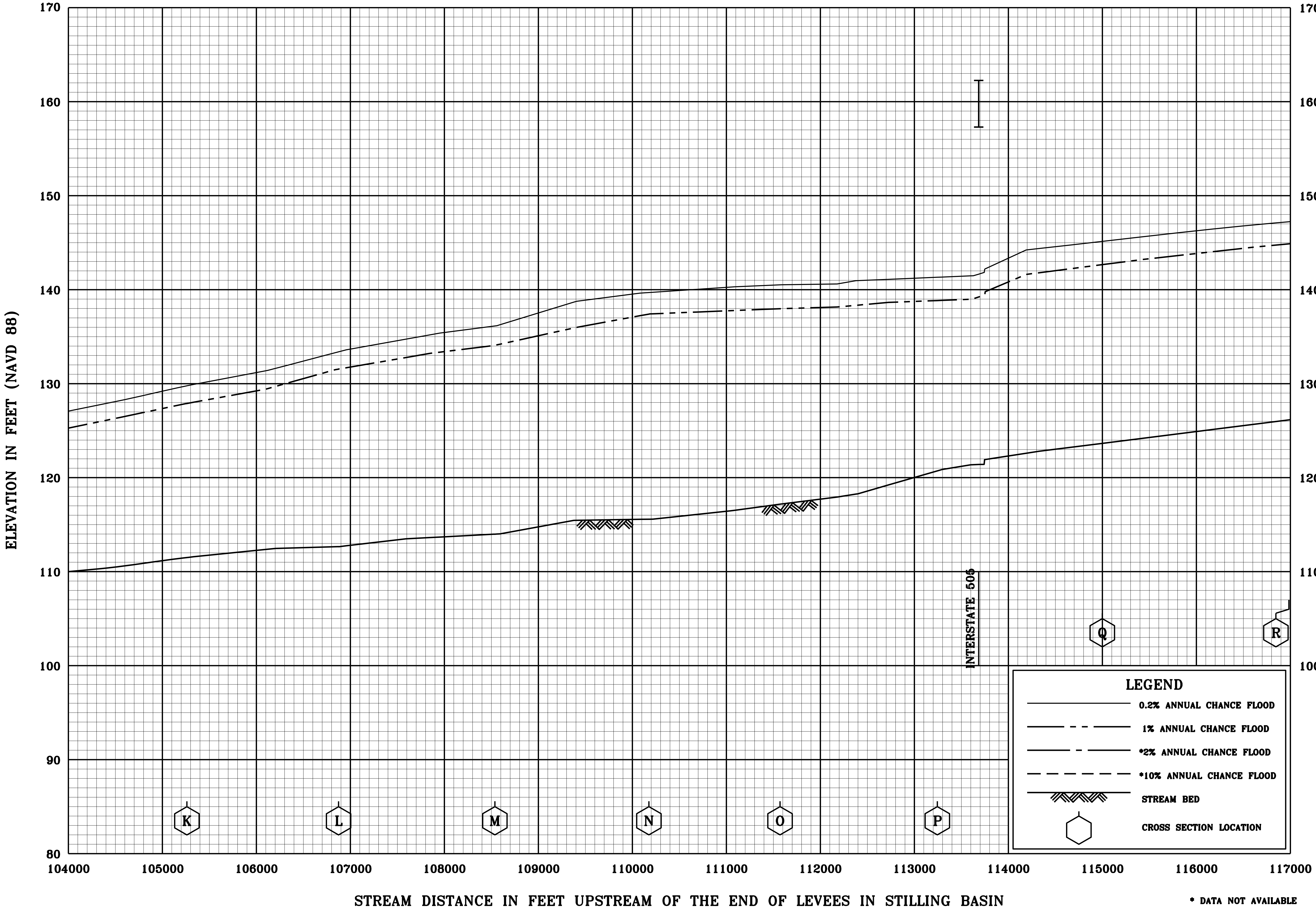


FLOOD PROFILES

CACHE CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA AND INCORPORATED AREAS



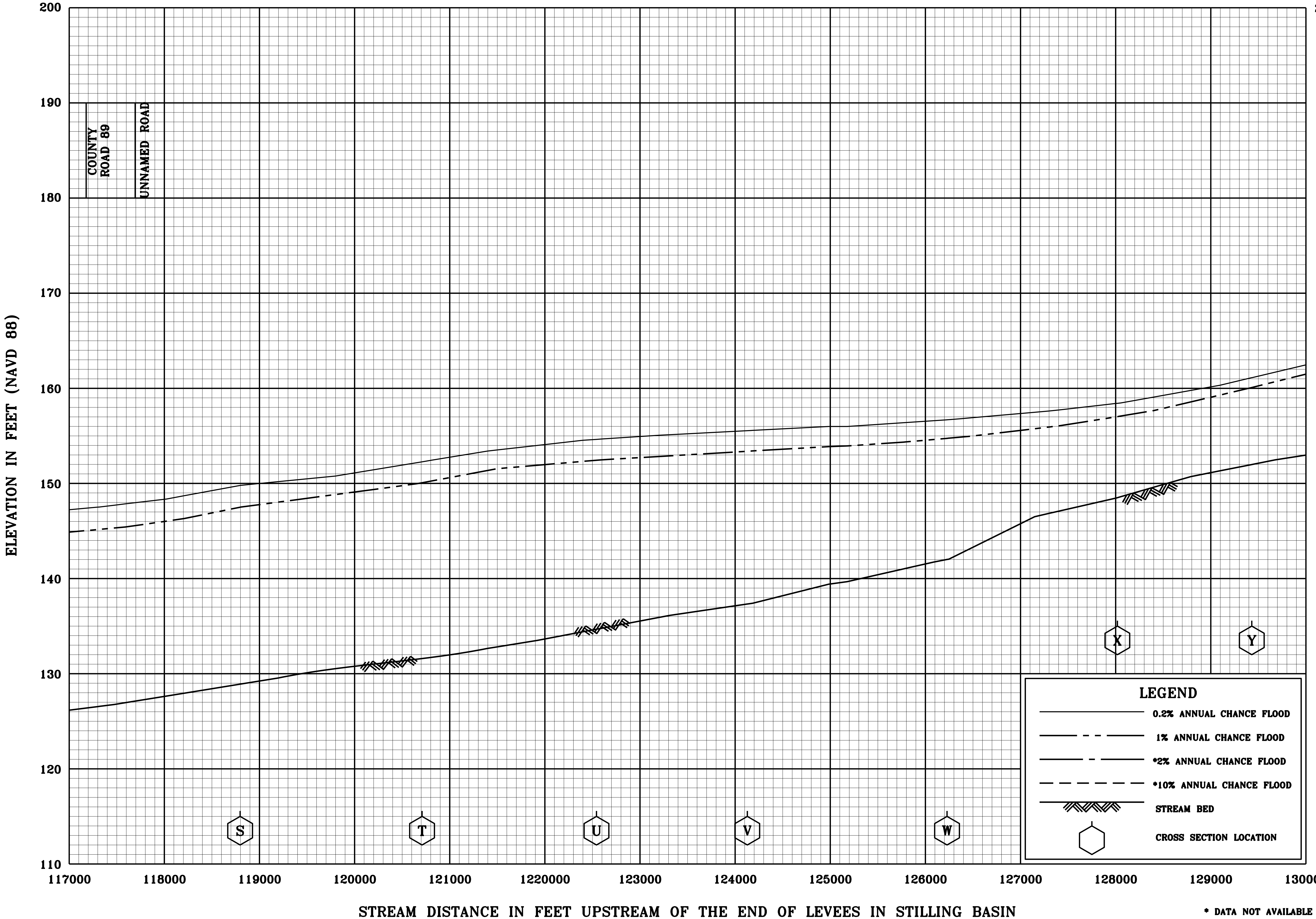
FLOOD PROFILES

CACHE CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA AND INCORPORATED AREAS

09P



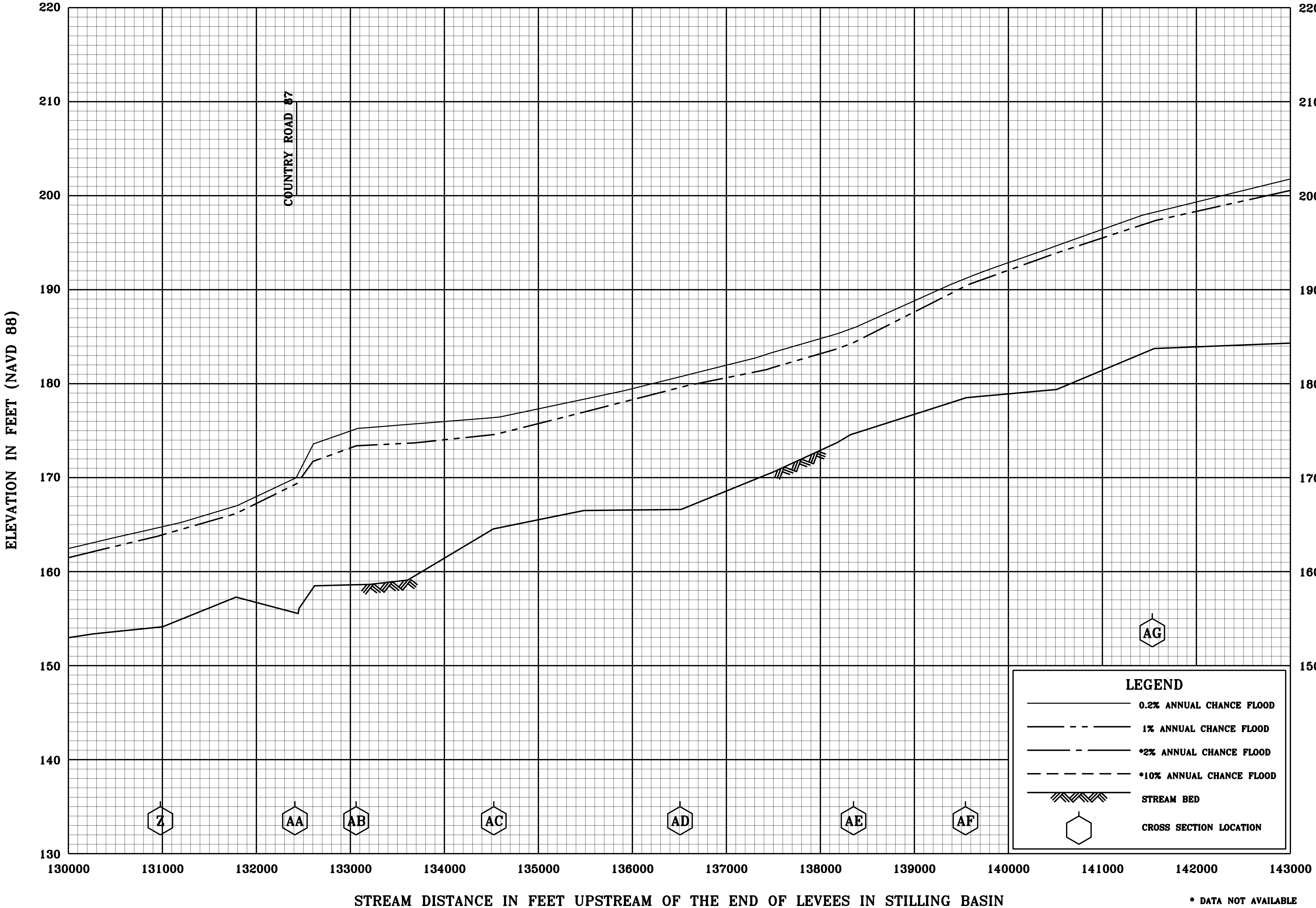
FLOOD PROFILES

CACHE CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA
AND INCORPORATED AREAS

10P

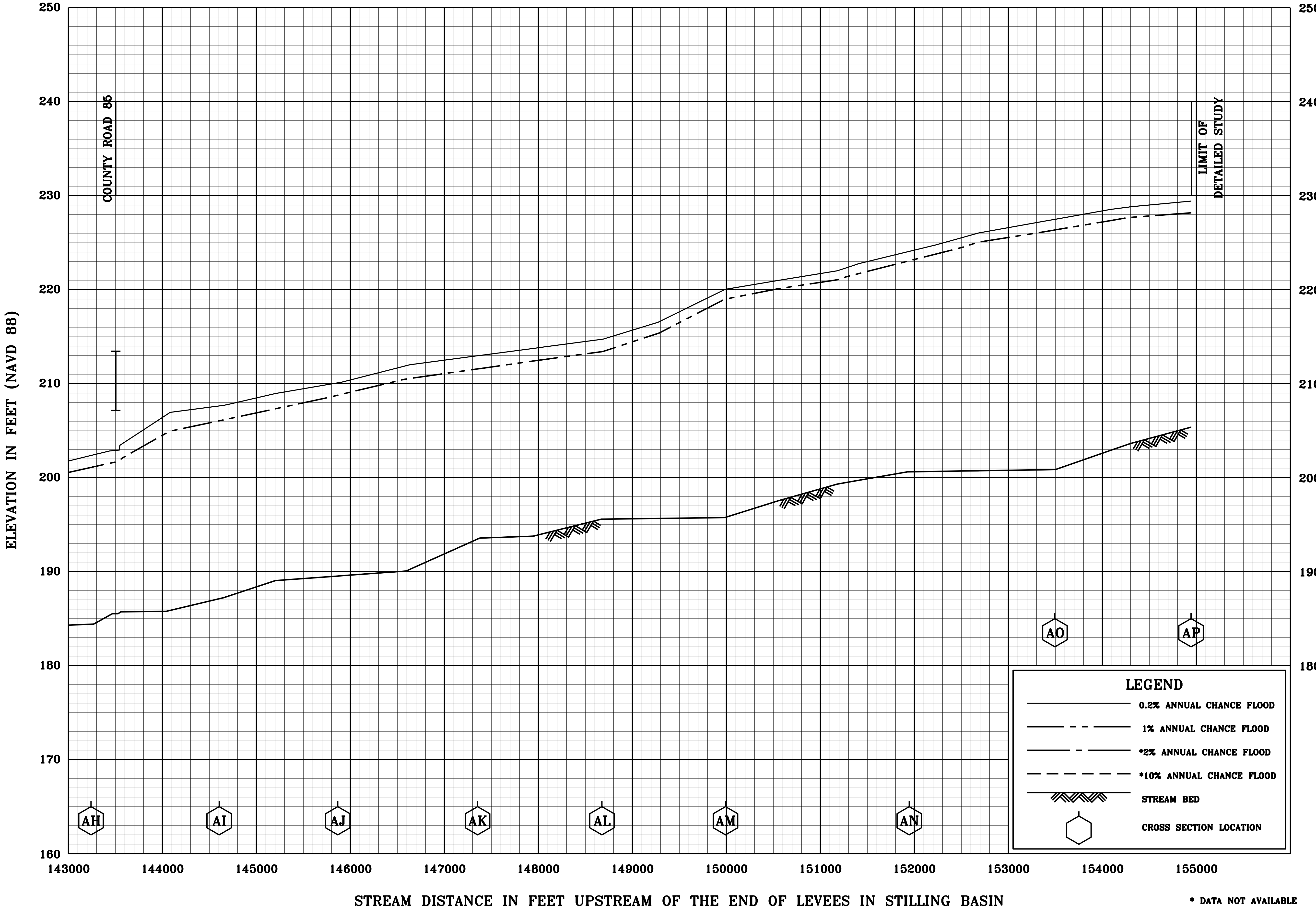


FLOOD PROFILES

CACHE CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA AND INCORPORATED AREAS

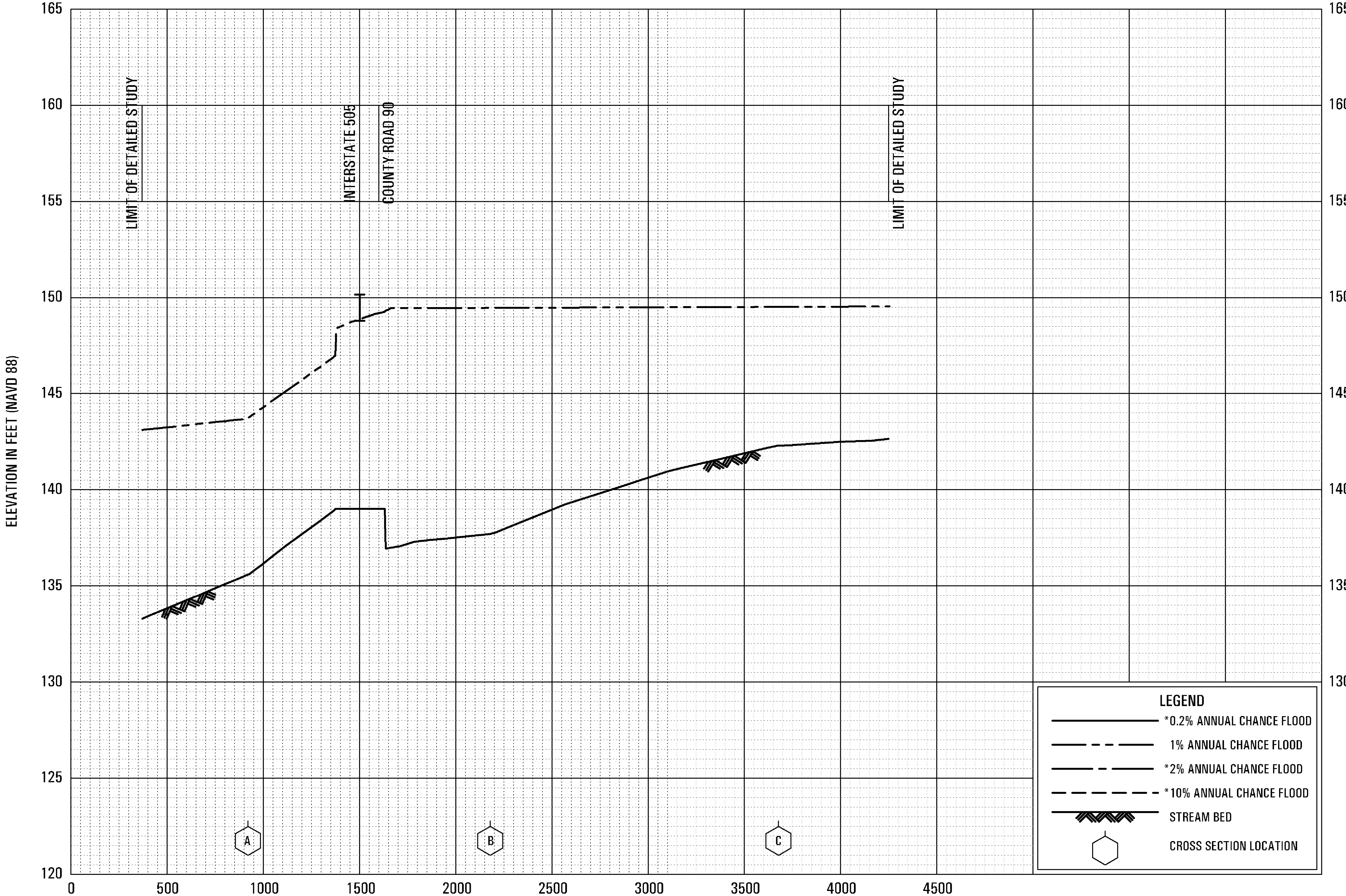


FLOOD PROFILES

CACHE CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA AND INCORPORATED AREAS



**LIMIT OF DETAILED STUDY APPROXIMATELY 1,150 FEET DOWNSTREAM OF INTERSTATE 505

*DATA NOT AVAILABLE

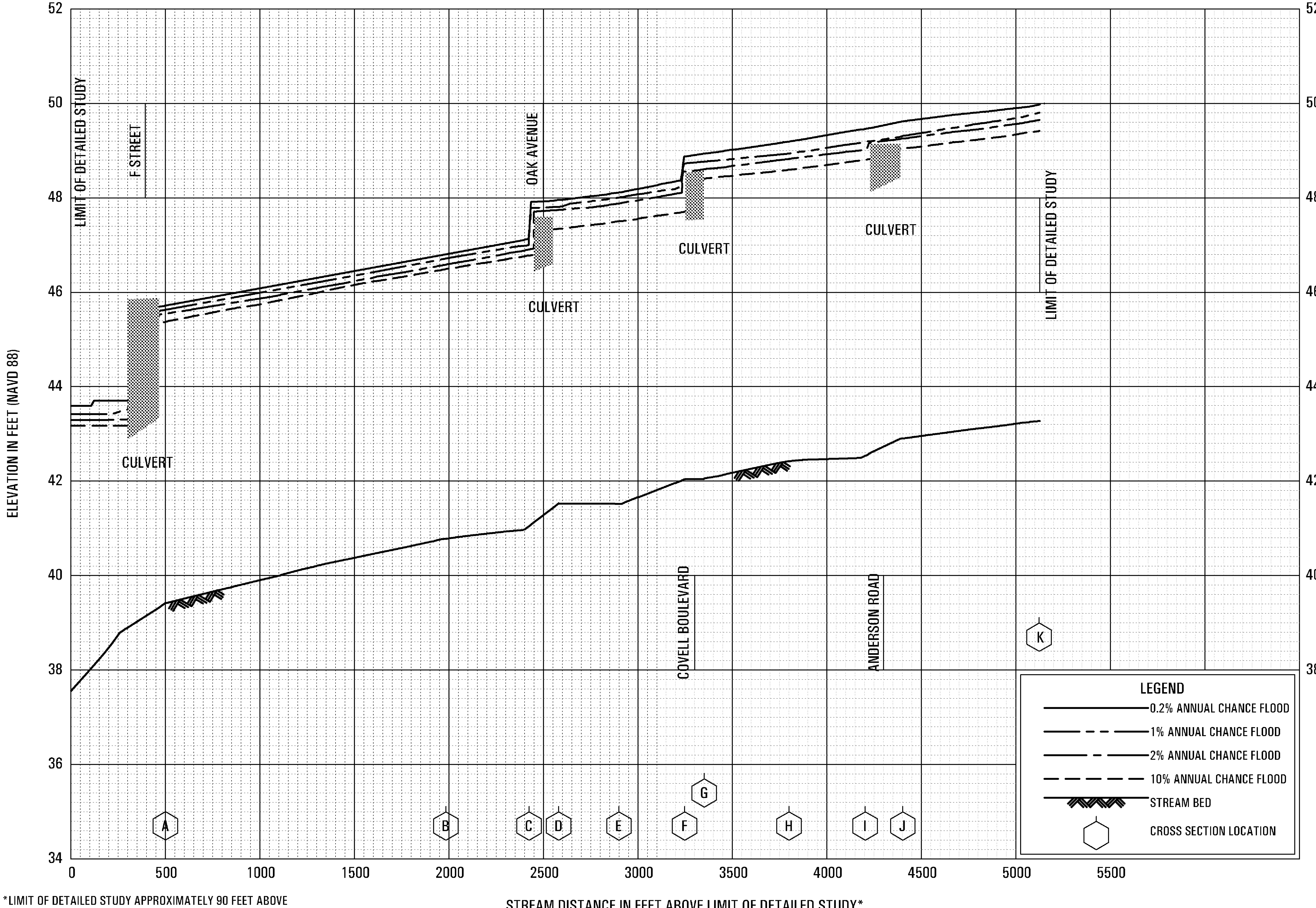
FLOOD PROFILES

COTTONWOOD SLOUGH

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

AND INCORPORATED AREAS



*LIMIT OF DETAILED STUDY APPROXIMATELY 90 FEET ABOVE CONFLUENCE WITH UNION PACIFIC RAILROAD DRAIN

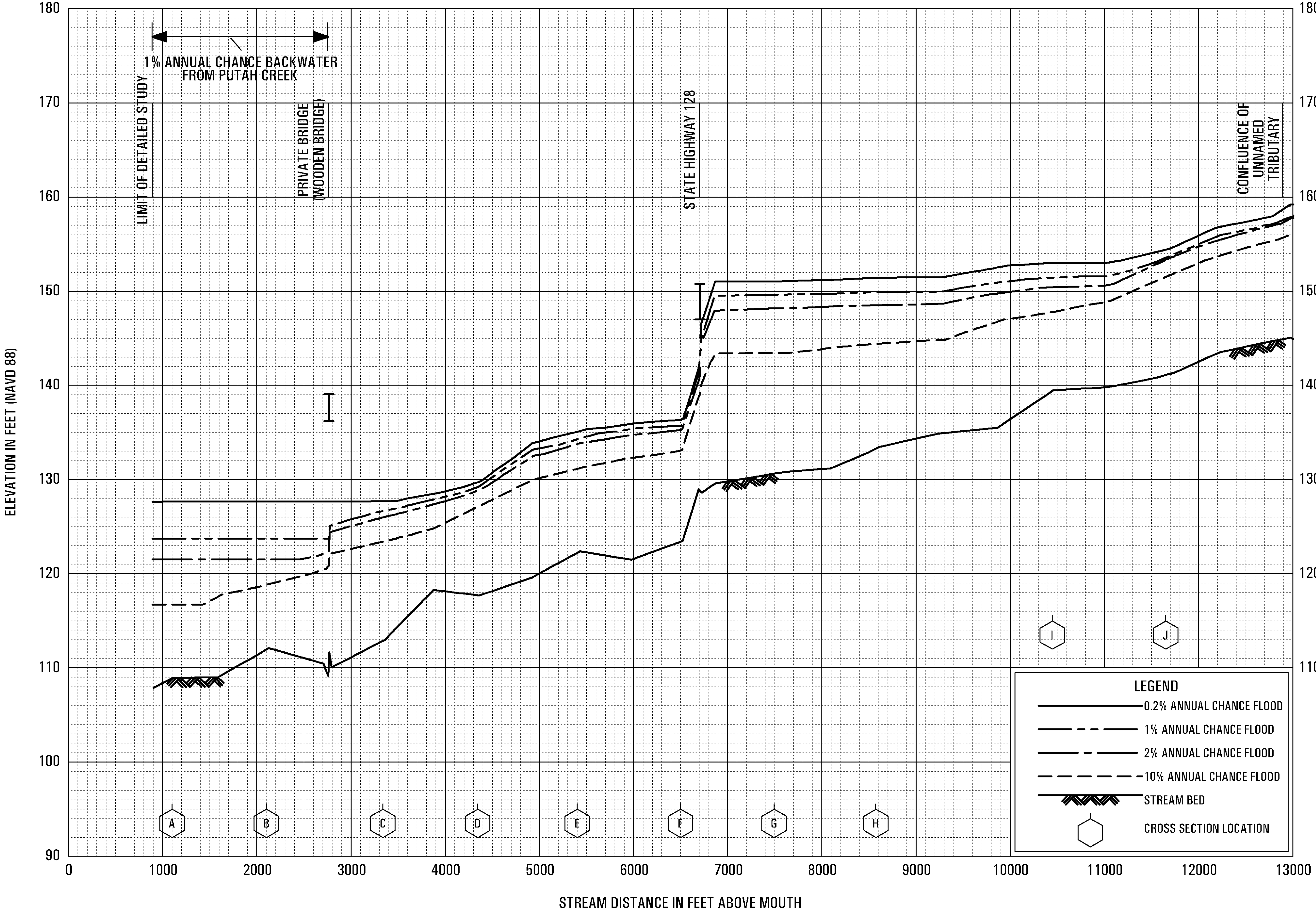
FLOOD PROFILES

COVELL DRAIN

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

AND INCORPORATED AREAS

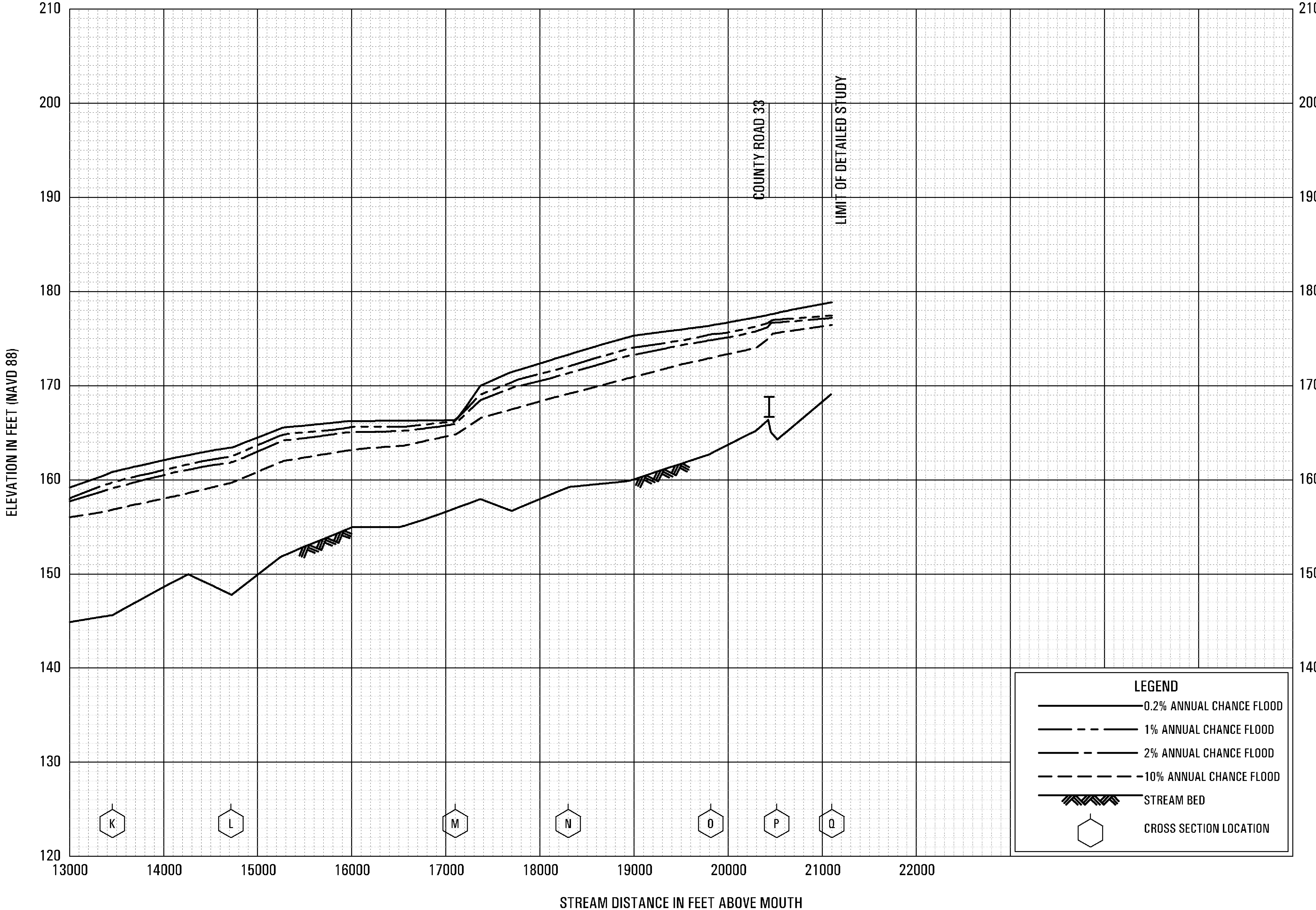


FLOOD PROFILES

DRY CREEK (WITH LEVEE)

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA
AND INCORPORATED AREAS



FLOOD PROFILES

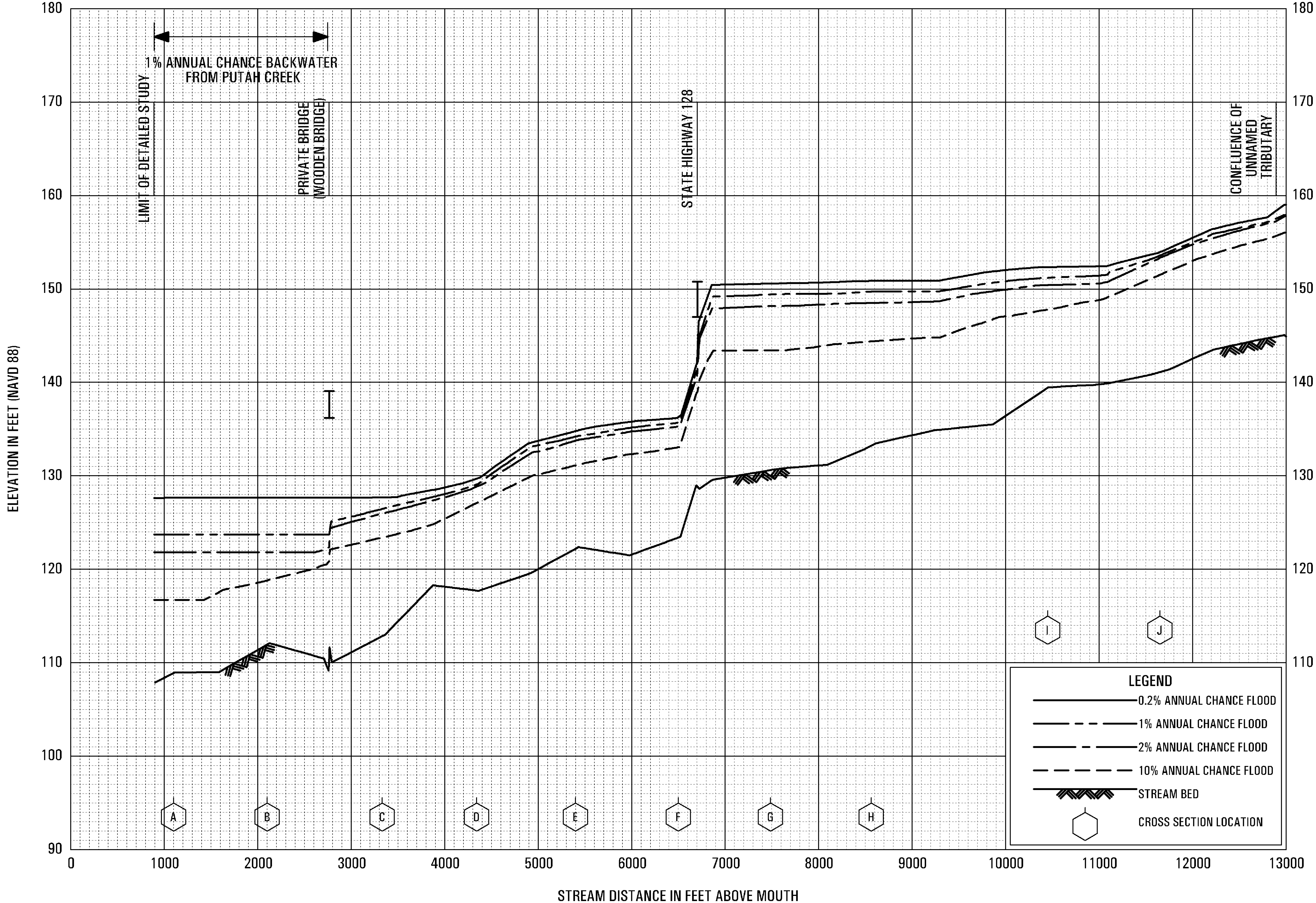
DRY CREEK (WITH LEVEE)

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

AND INCORPORATED AREAS

15P

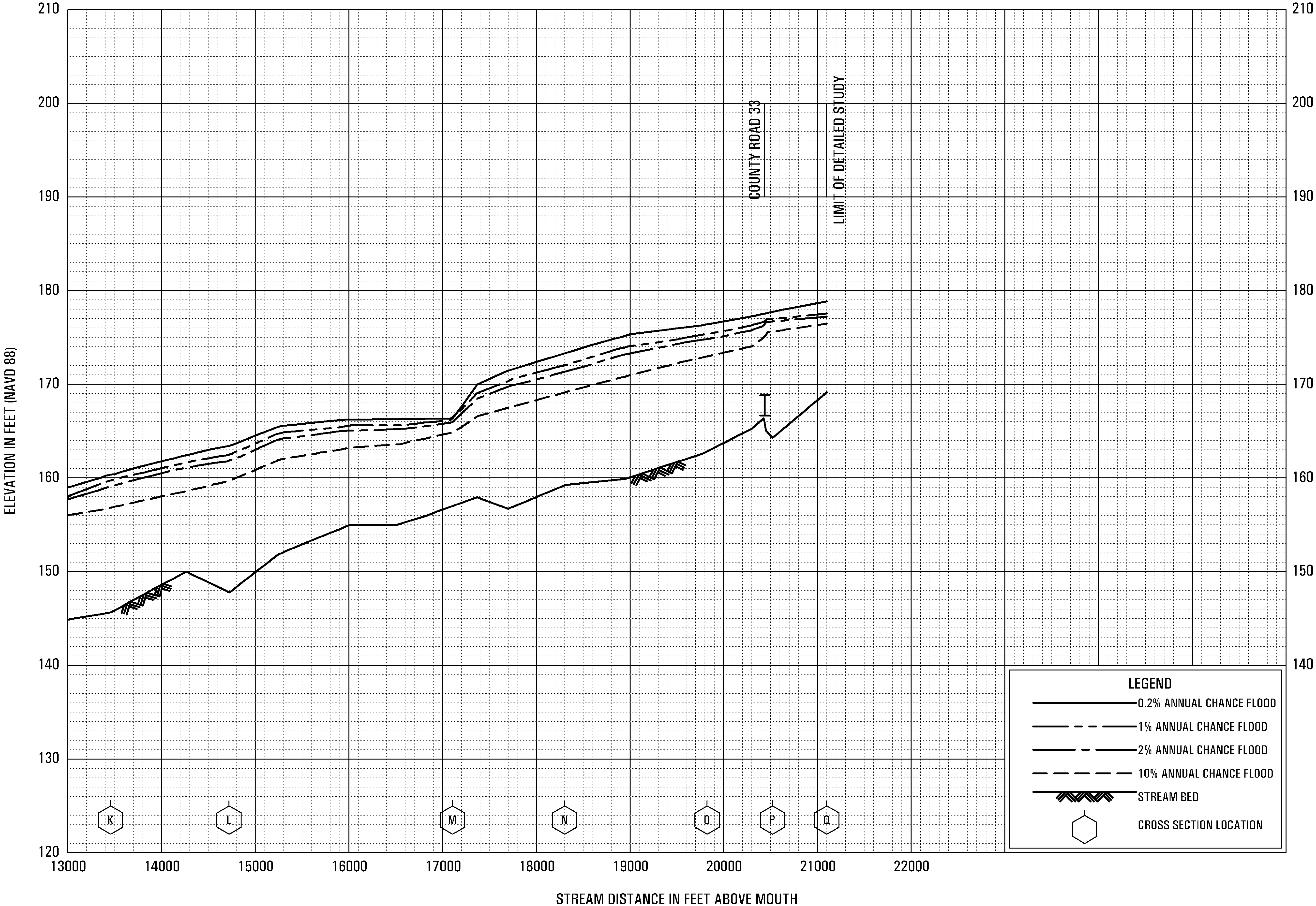


FLOOD PROFILES

DRY CREEK (WITHOUT LEVEE)

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA AND INCORPORATED AREAS



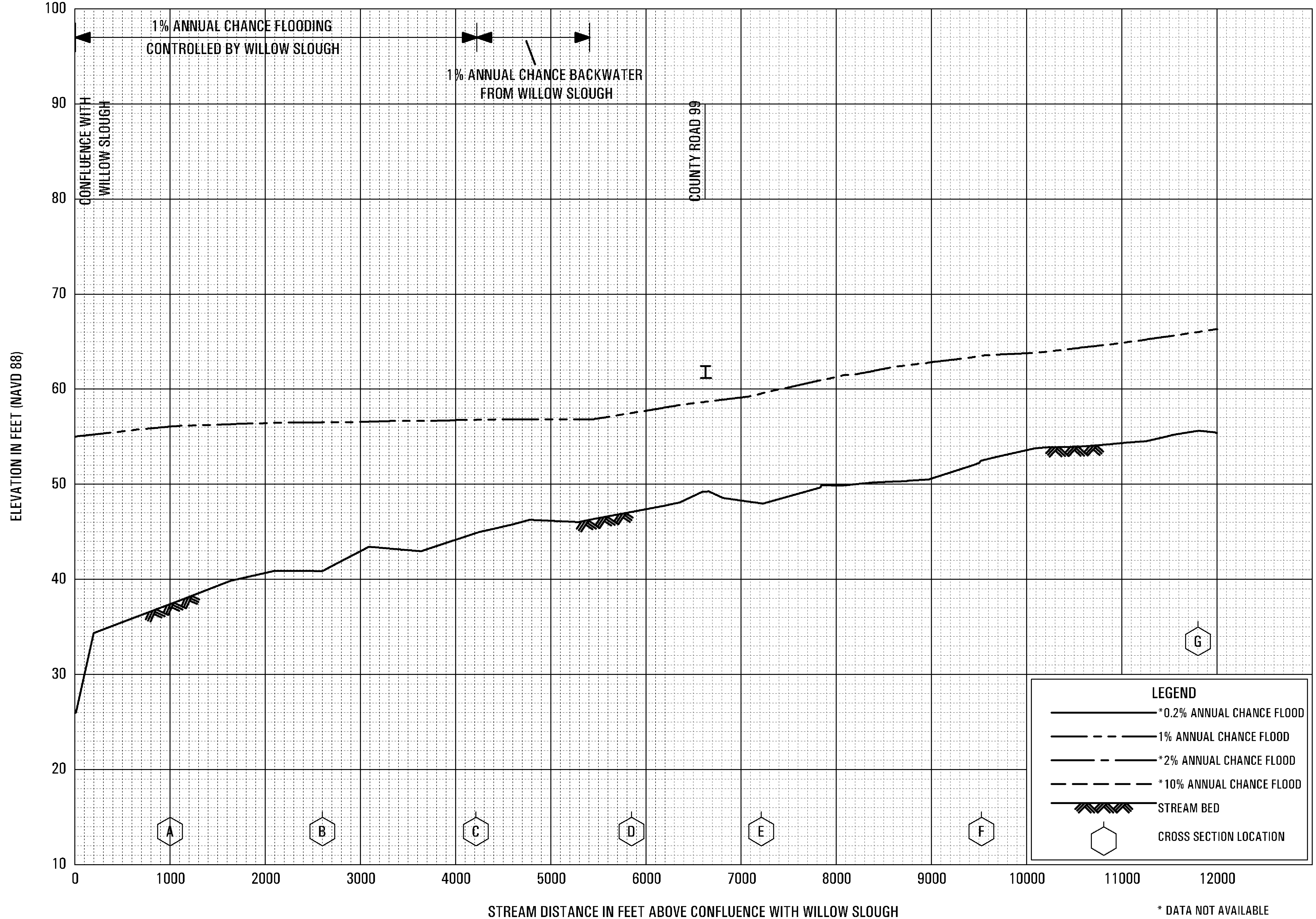
FLOOD PROFILES

DRY CREEK (WITHOUT LEVEE)

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

AND INCORPORATED AREAS



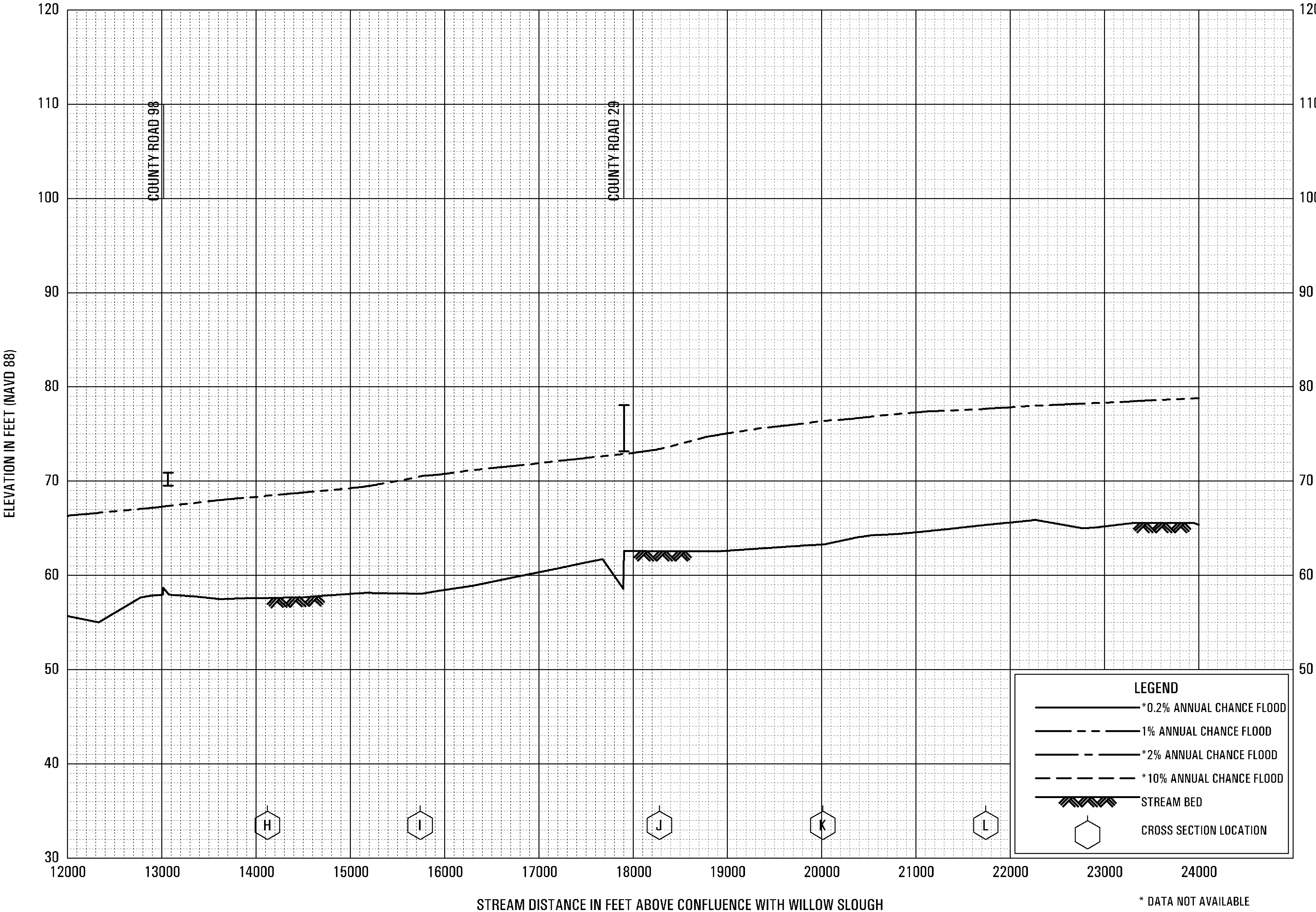
FLOOD PROFILES

DRY SLOUGH

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

AND INCORPORATED AREAS



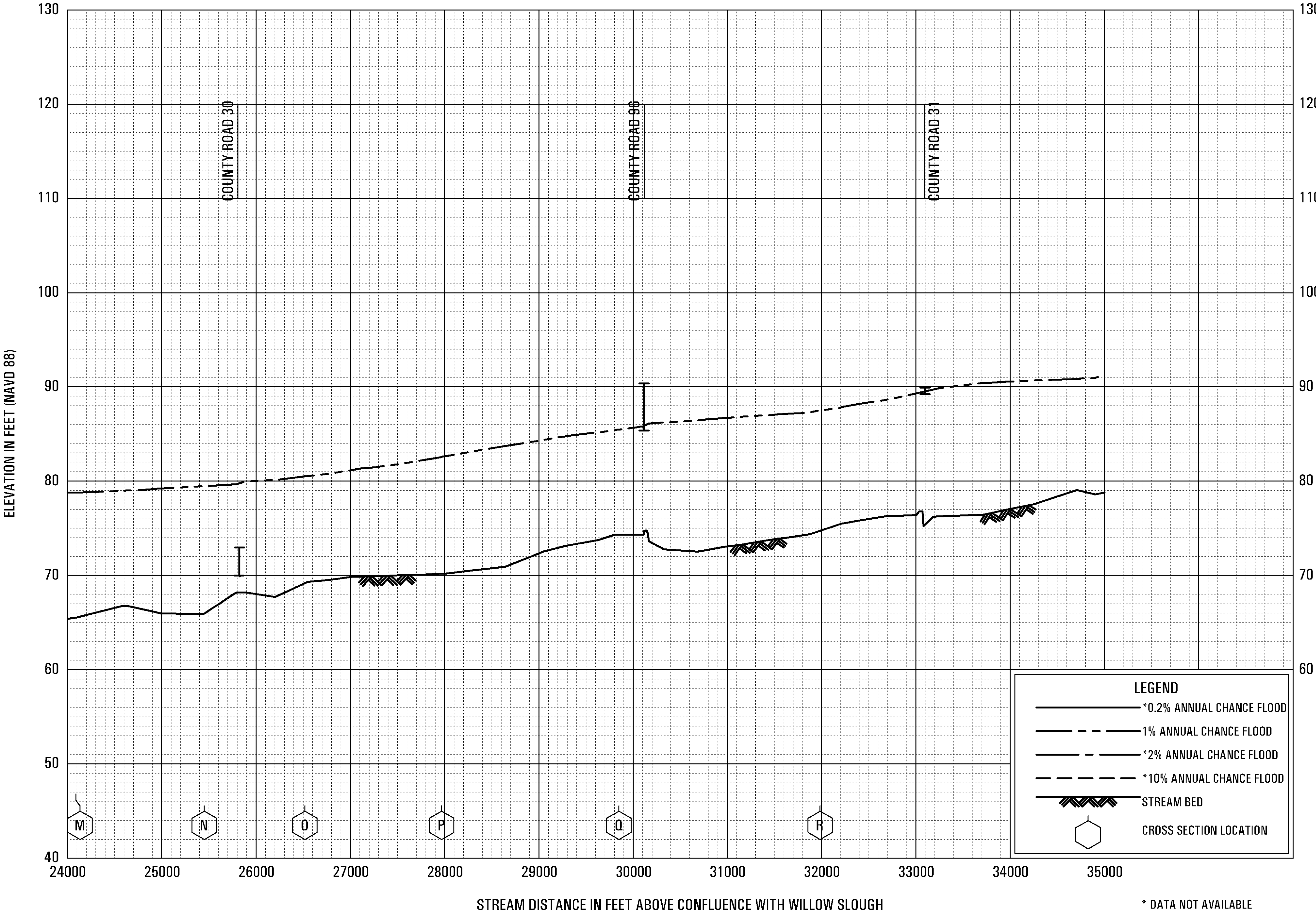
FLOOD PROFILES

DRY SLOUGH

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

AND INCORPORATED AREAS



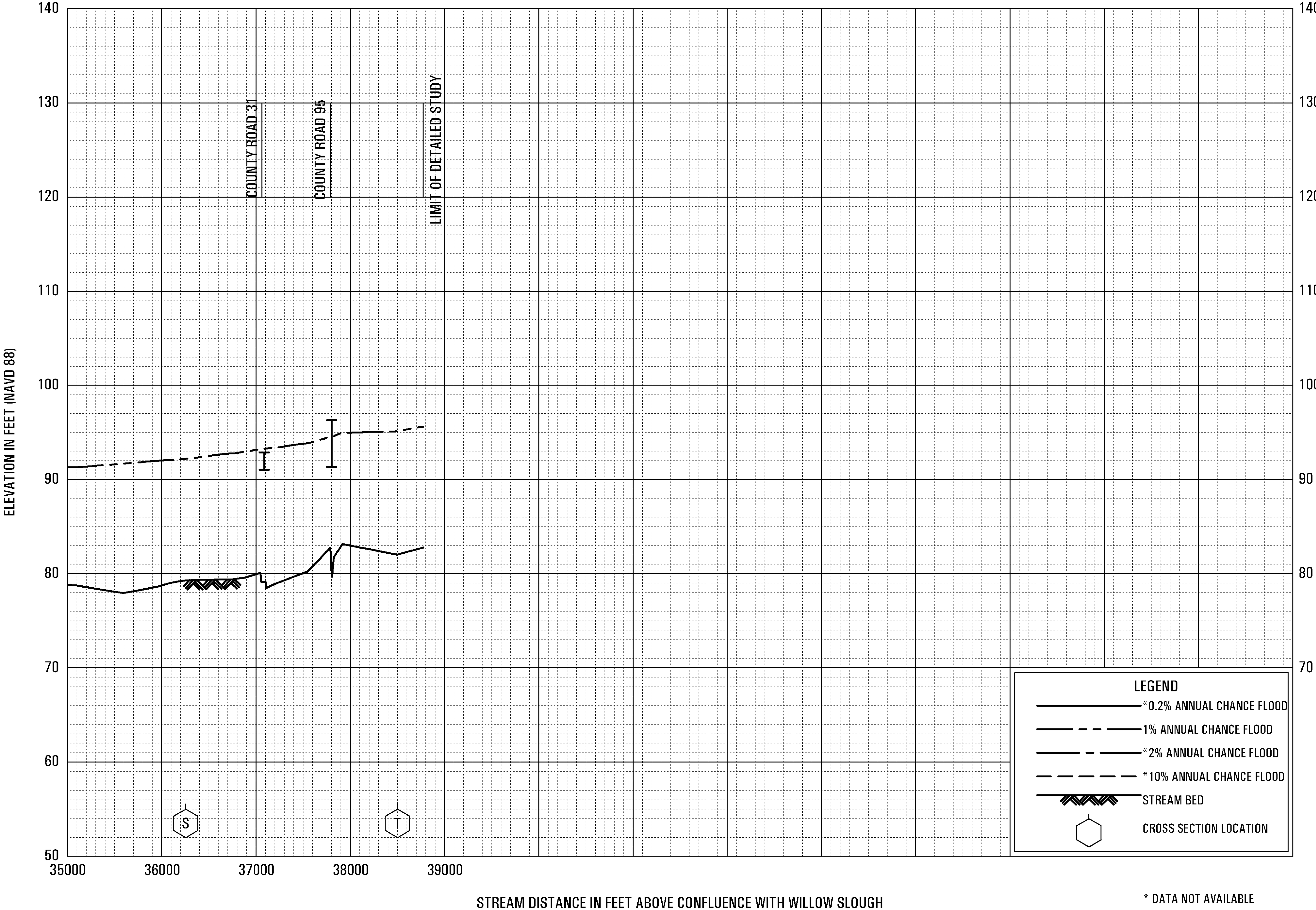
FLOOD PROFILES

DRY SLOUGH

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

AND INCORPORATED AREAS



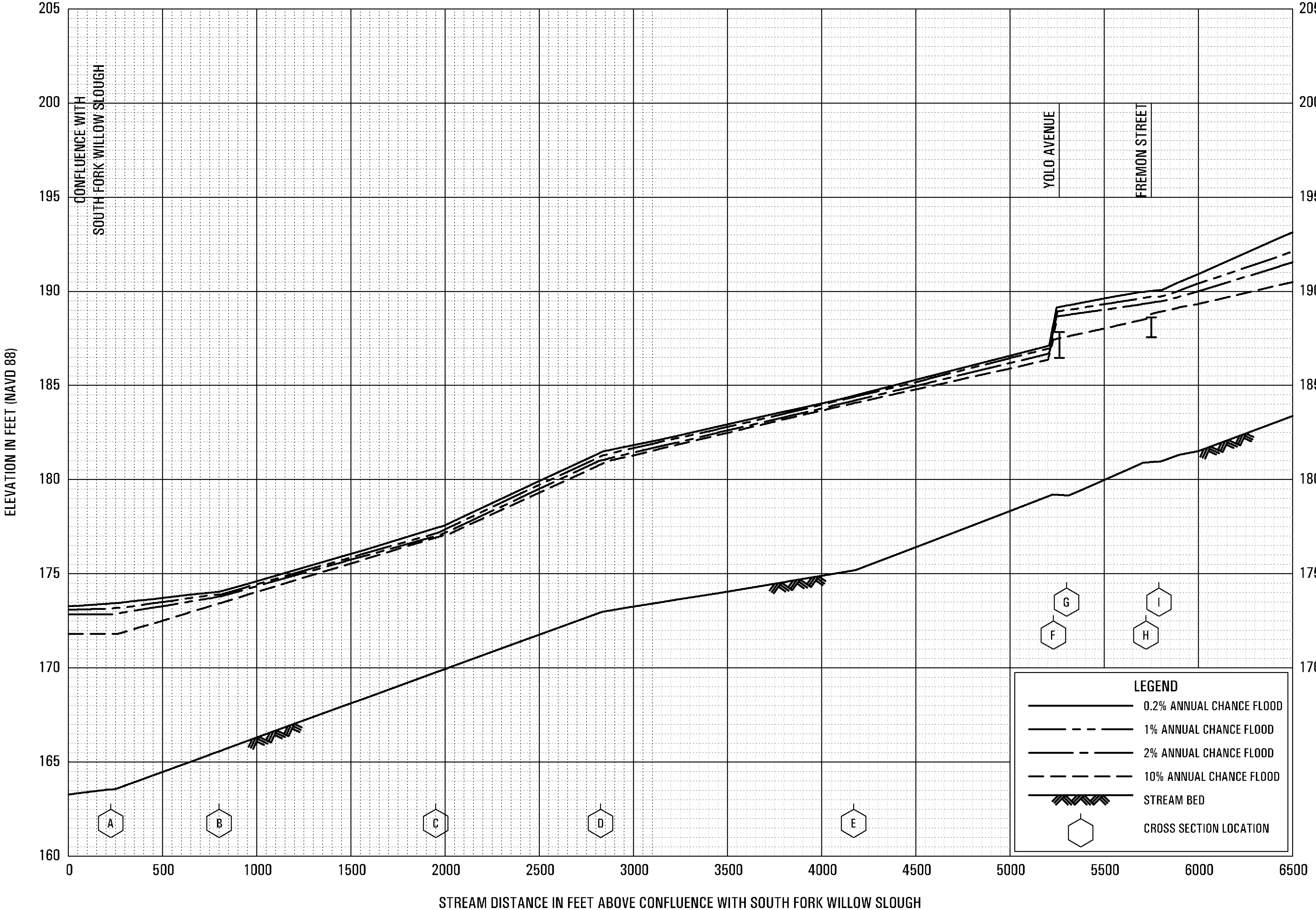
FLOOD PROFILES

DRY SLOUGH

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

AND INCORPORATED AREAS



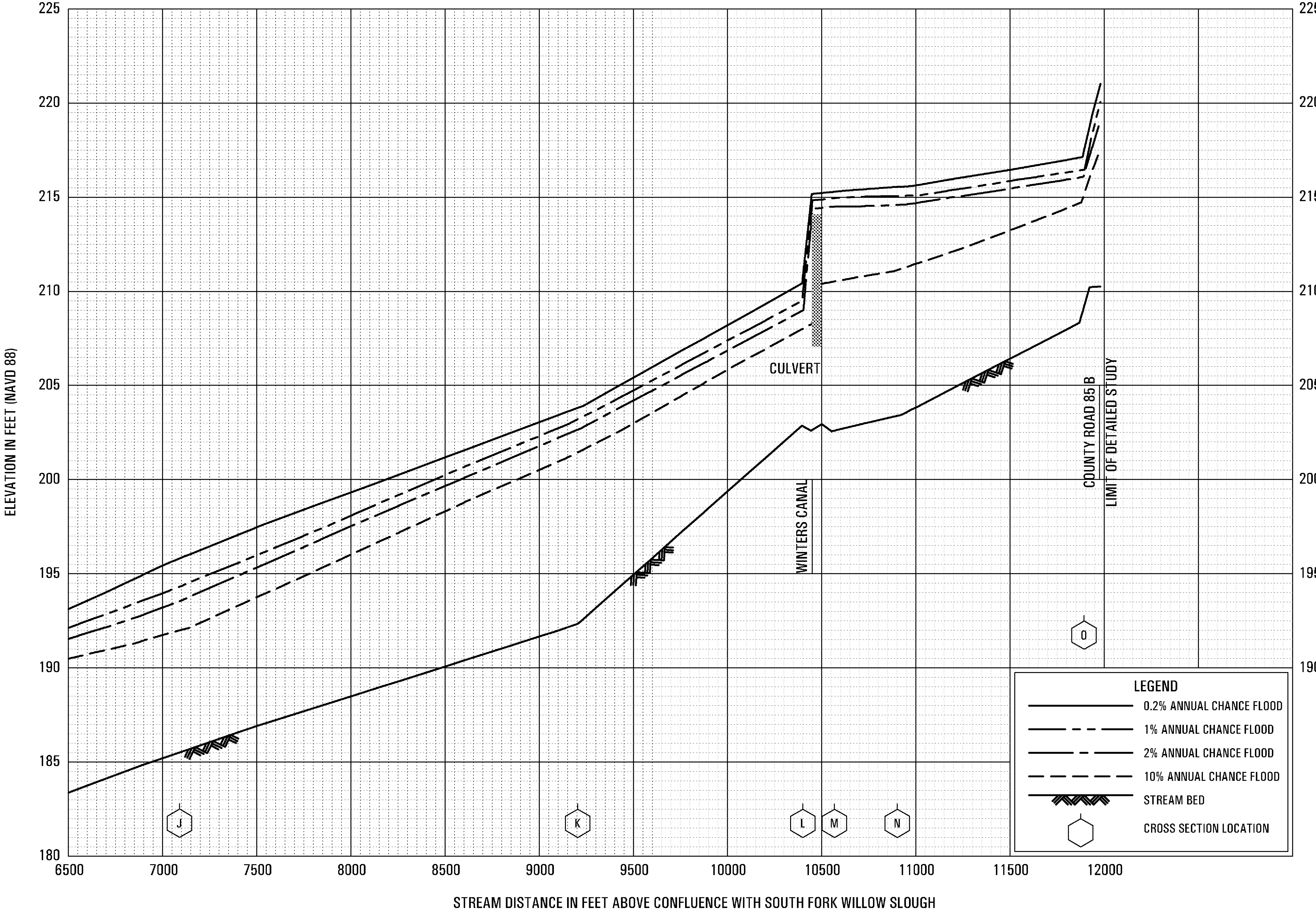
FLOOD PROFILES

LAMB VALLEY SLOUGH

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA
AND INCORPORATED AREAS

22P



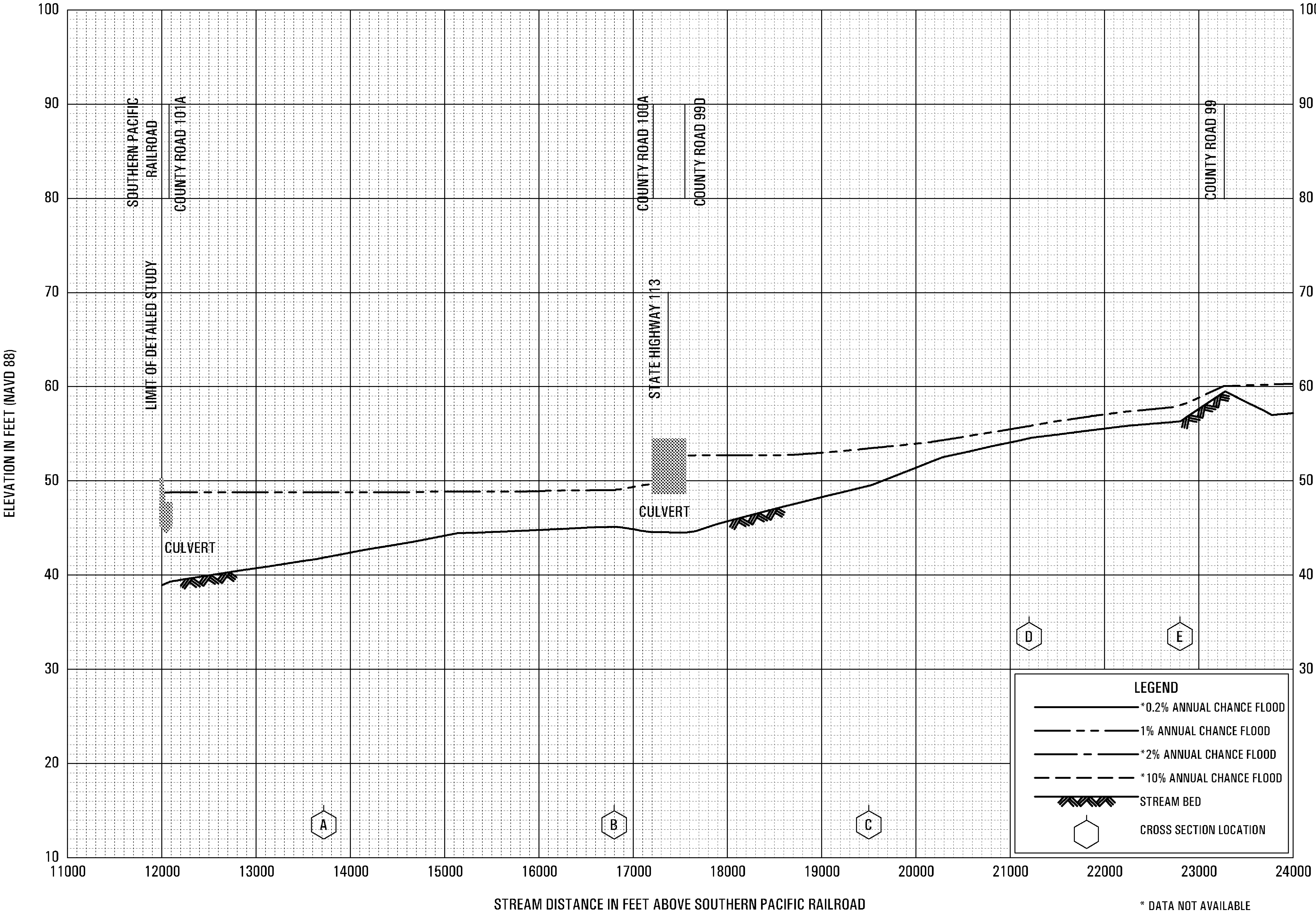
FLOOD PROFILES

LAMB VALLEY SLOUGH

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

AND INCORPORATED AREAS



* DATA NOT AVAILABLE

FLOOD PROFILES

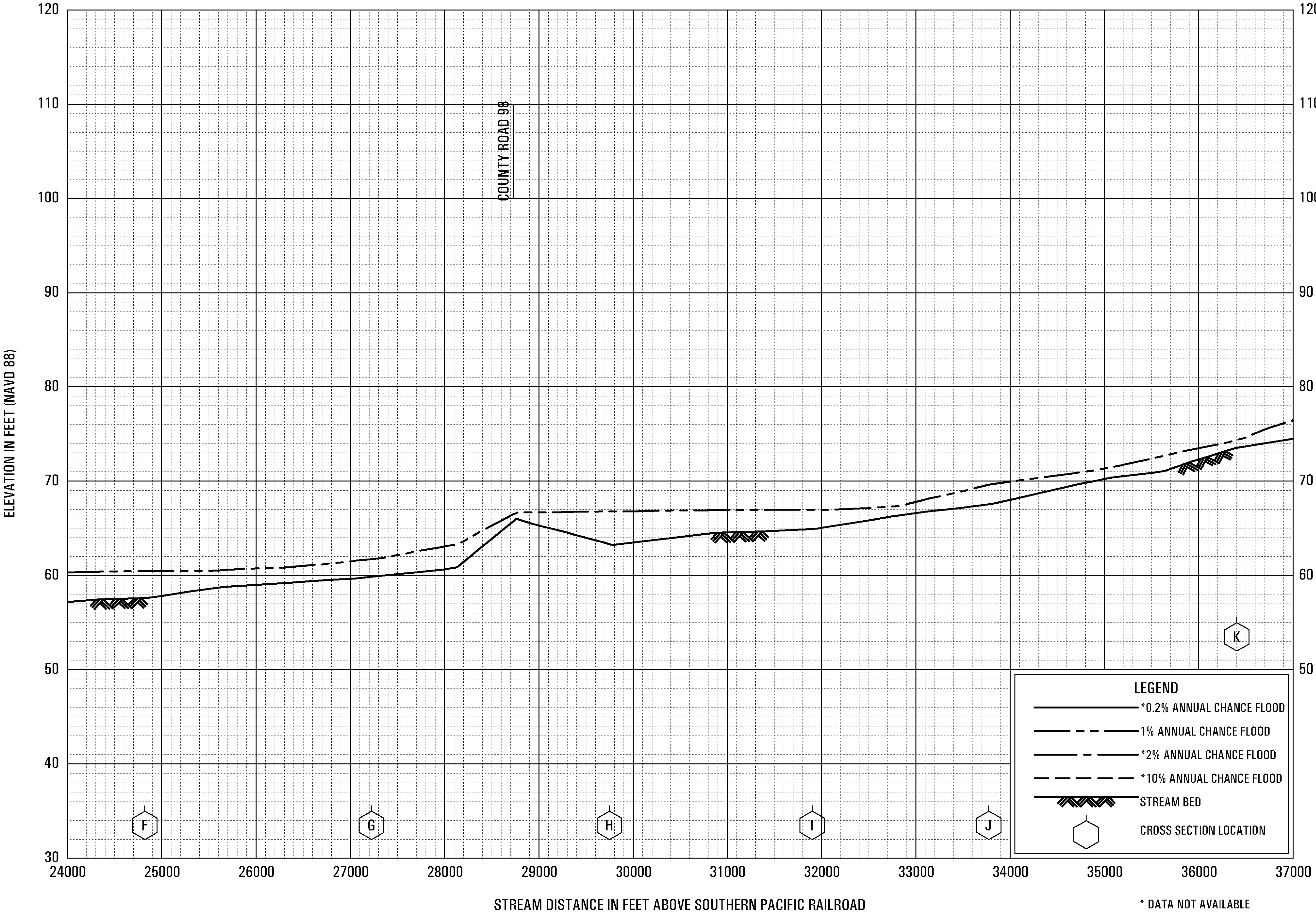
NORTH DAVIS DRAIN

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

AND INCORPORATED AREAS

24P



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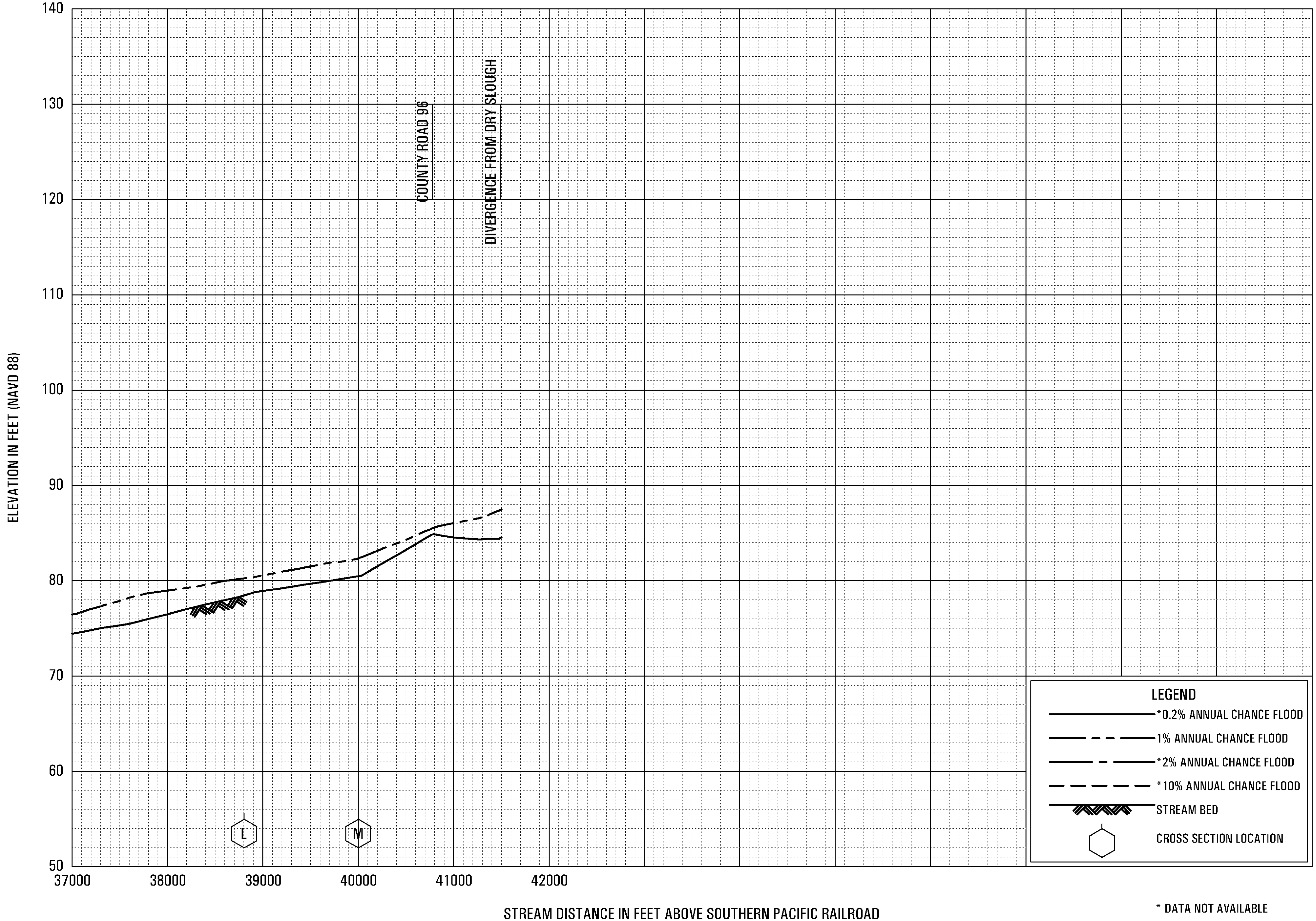
FLOOD PROFILES

NORTH DAVIS DRAIN

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

AND INCORPORATED AREAS



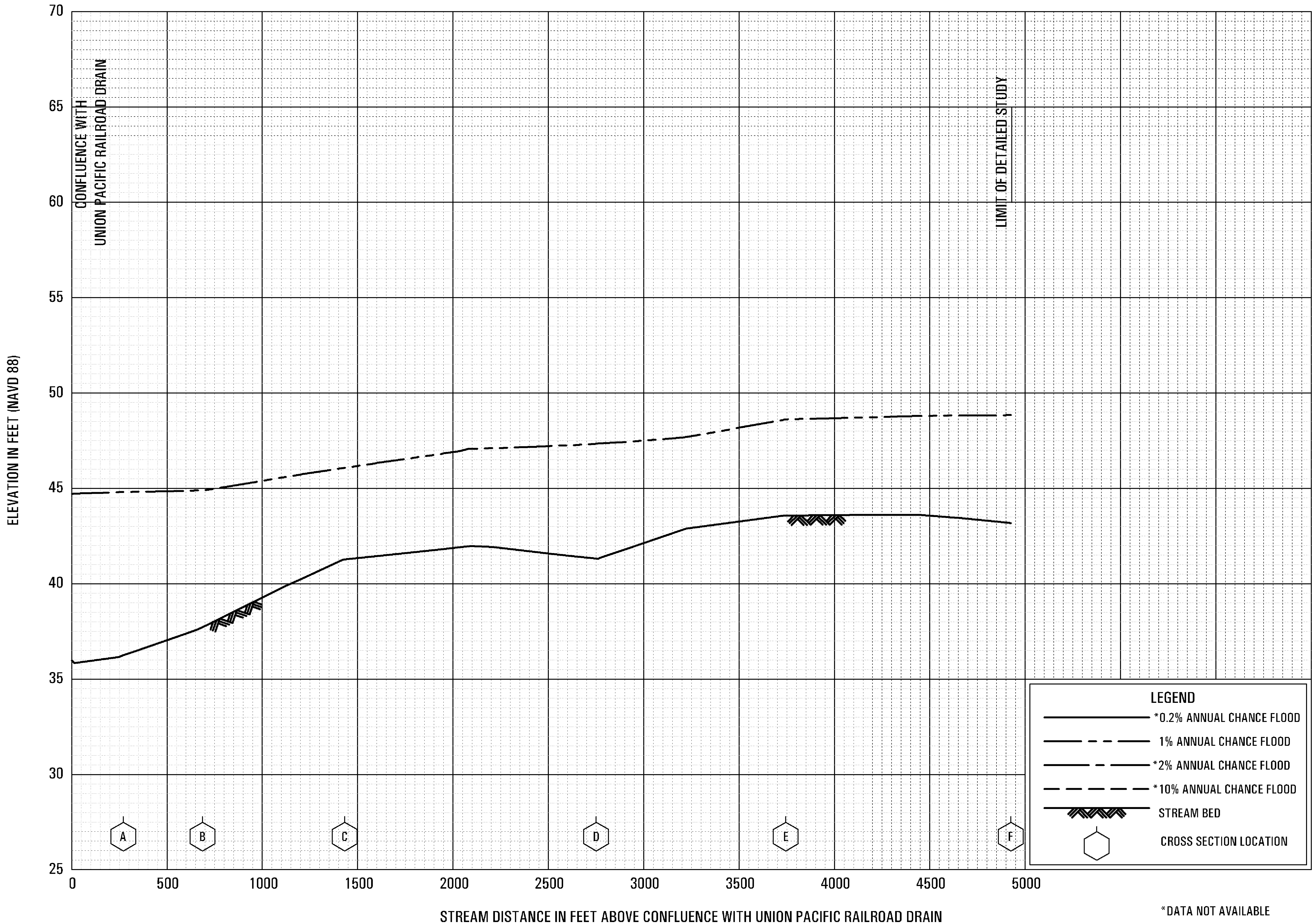
FLOOD PROFILES

NORTH DAVIS DRAIN

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

AND INCORPORATED AREAS



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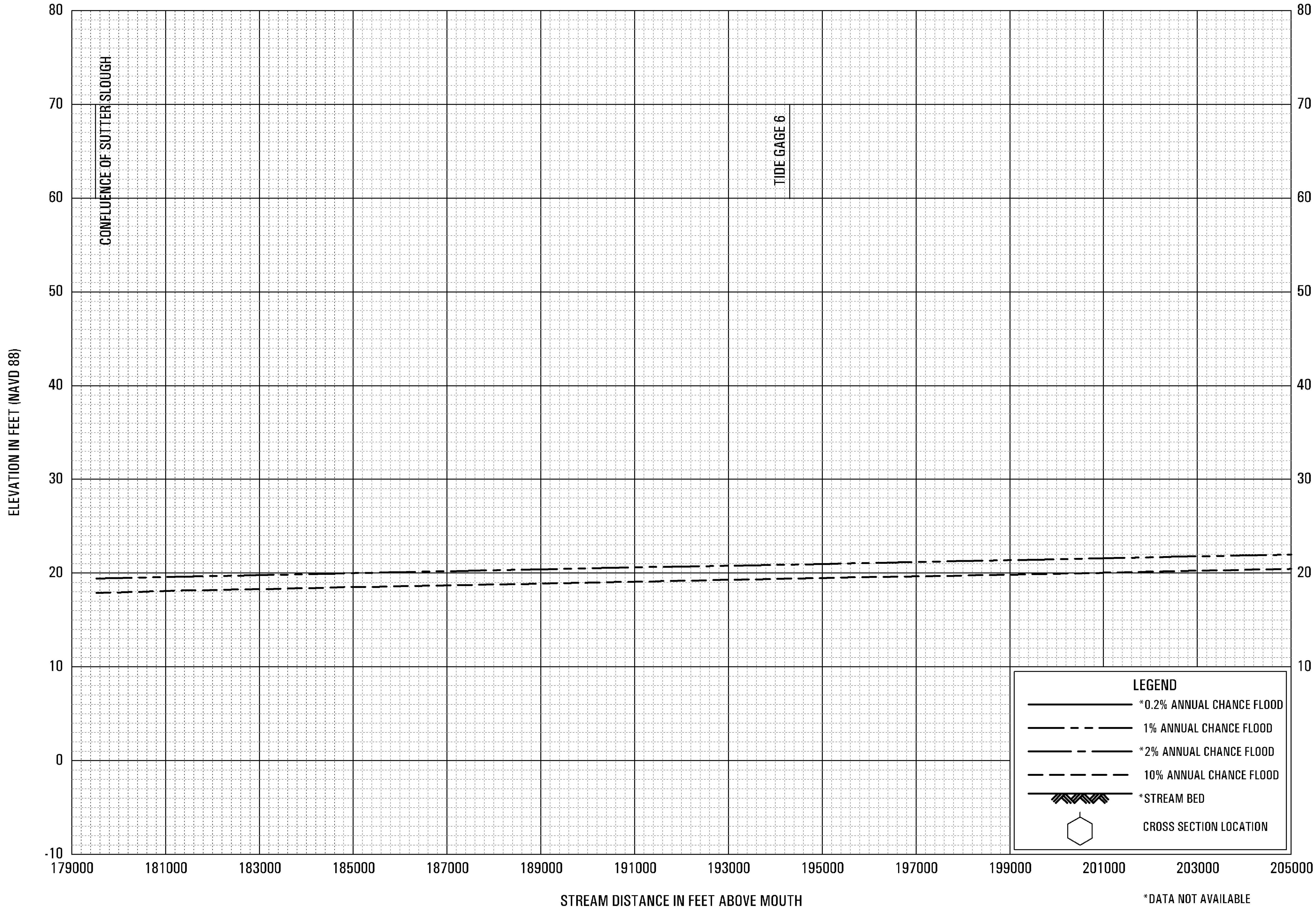
FLOOD PROFILES

NORTH DAVIS OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA
AND INCORPORATED AREAS



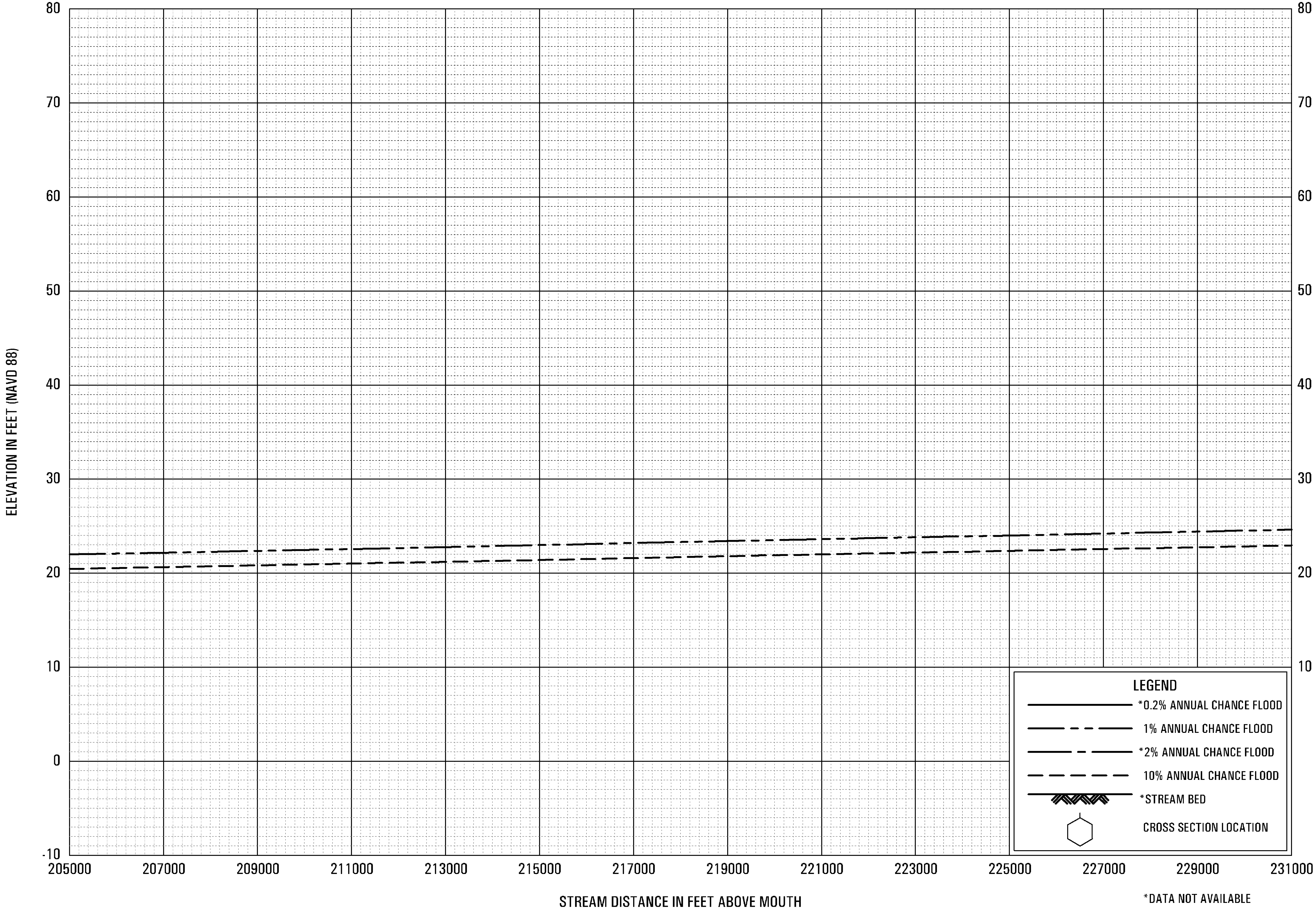
FLOOD PROFILES

SACRAMENTO RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

AND INCORPORATED AREAS



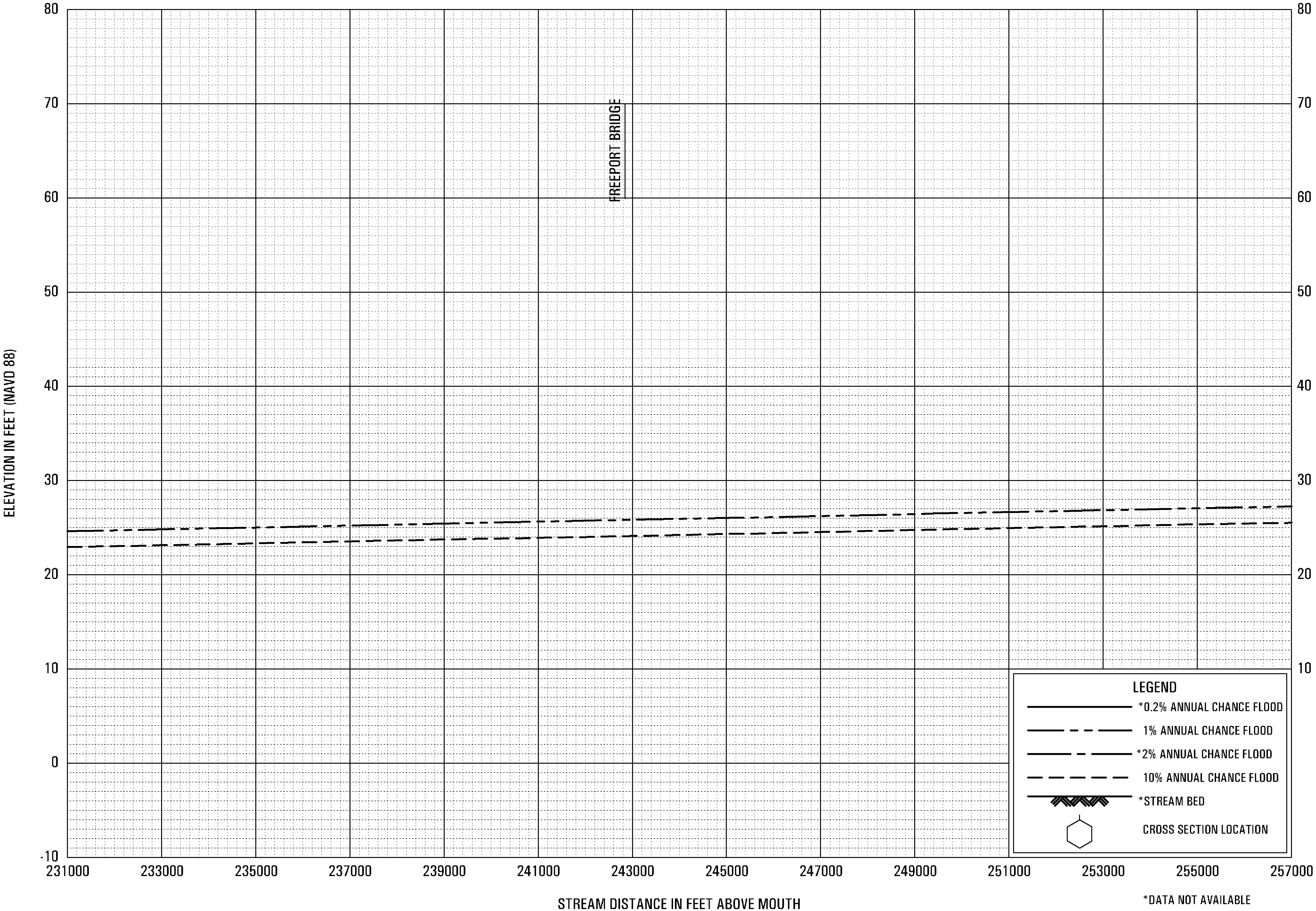
FLOOD PROFILES

SACRAMENTO RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

AND INCORPORATED AREAS



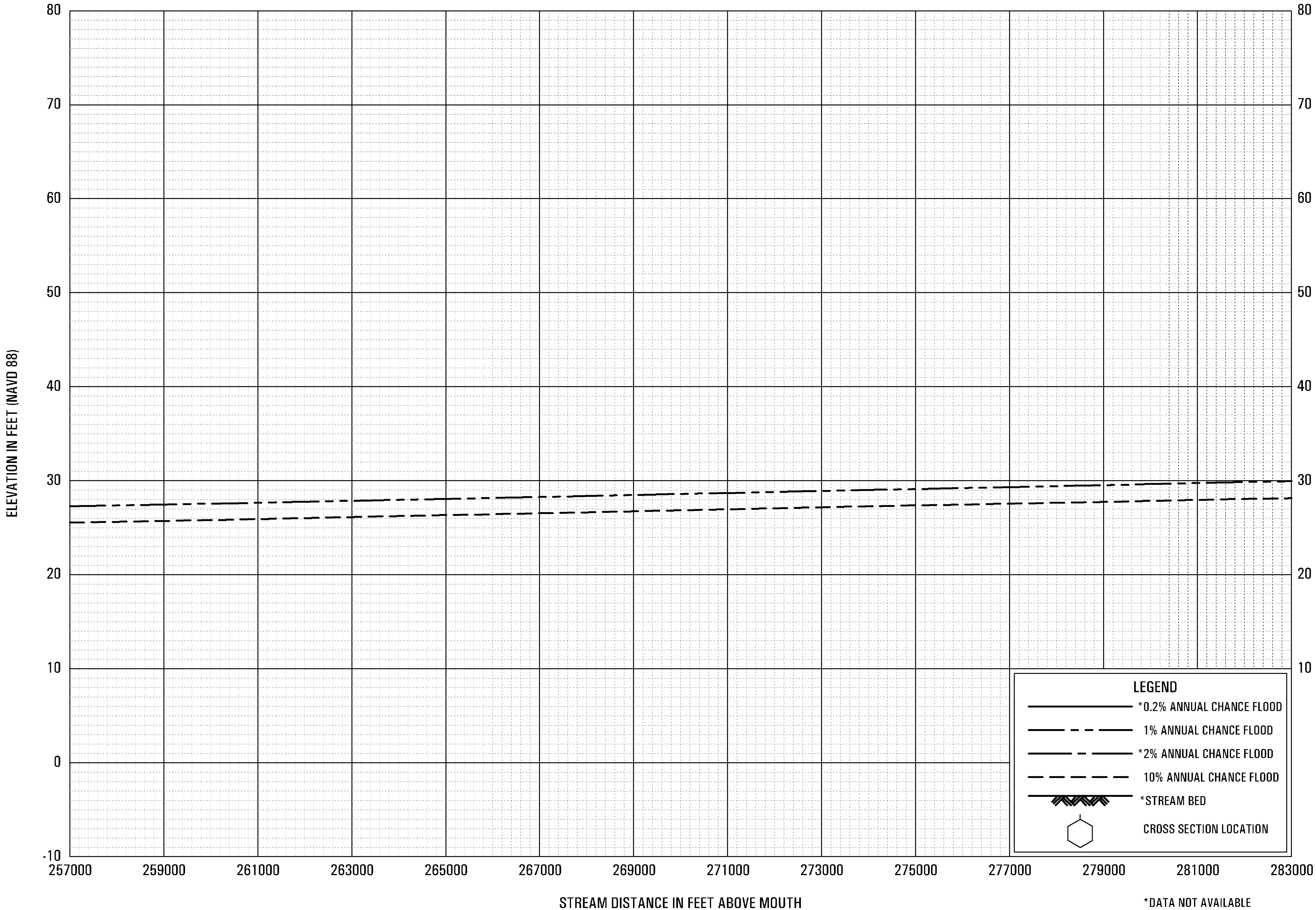
FLOOD PROFILES

SACRAMENTO RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

AND INCORPORATED AREAS



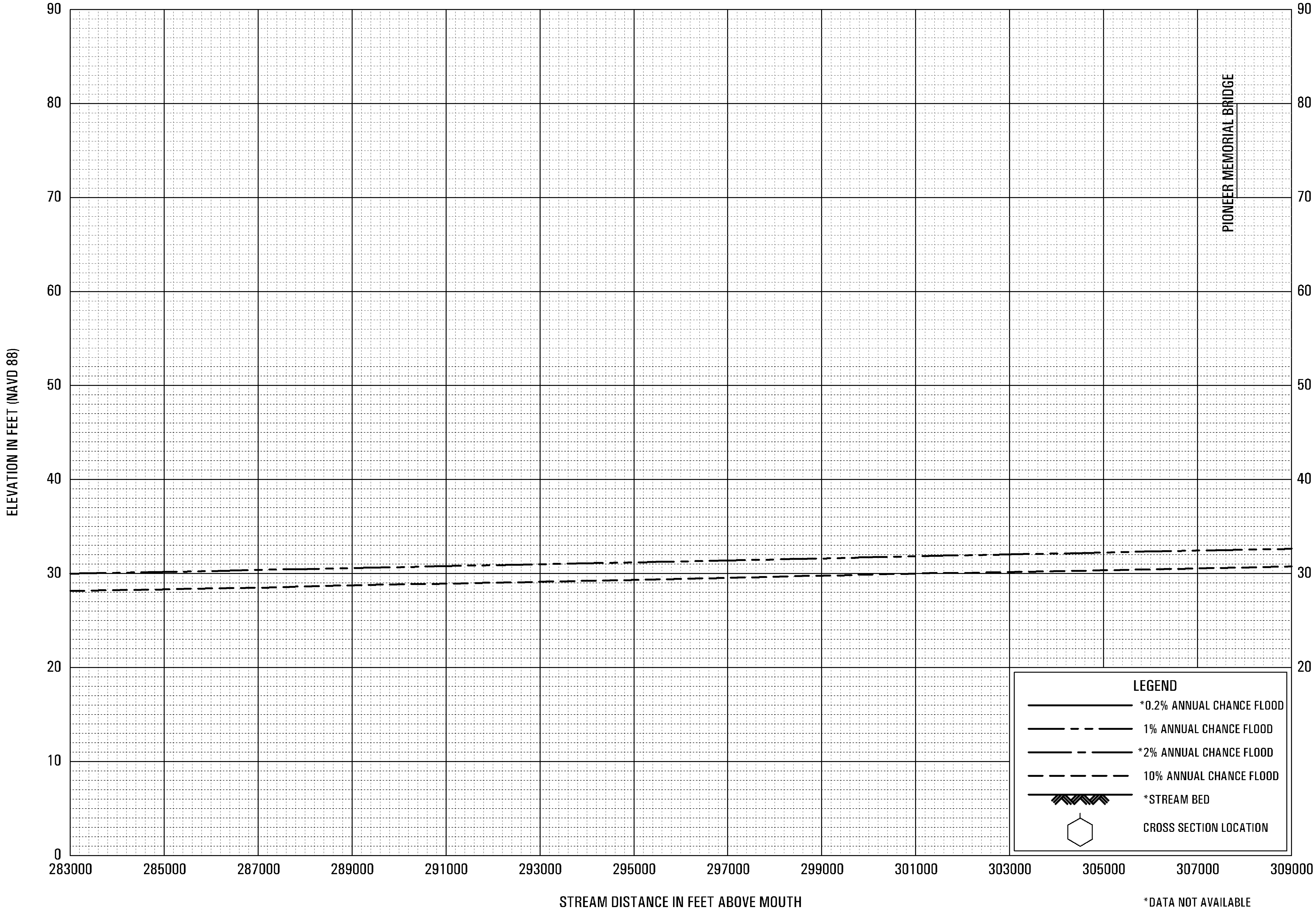
FLOOD PROFILES

SACRAMENTO RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA
AND INCORPORATED AREAS

31P



FLOOD PROFILES

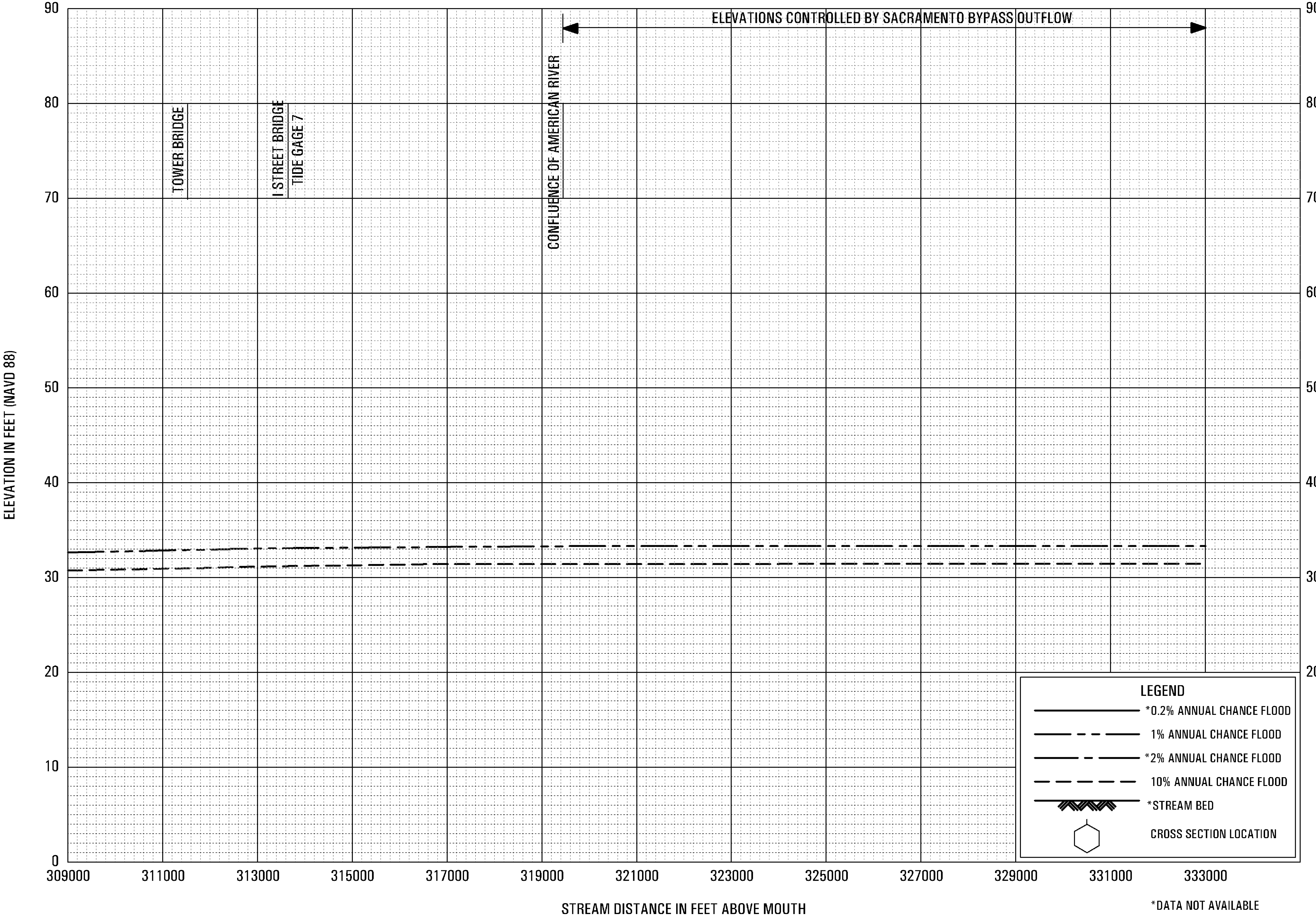
SACRAMENTO RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

AND INCORPORATED AREAS

32P



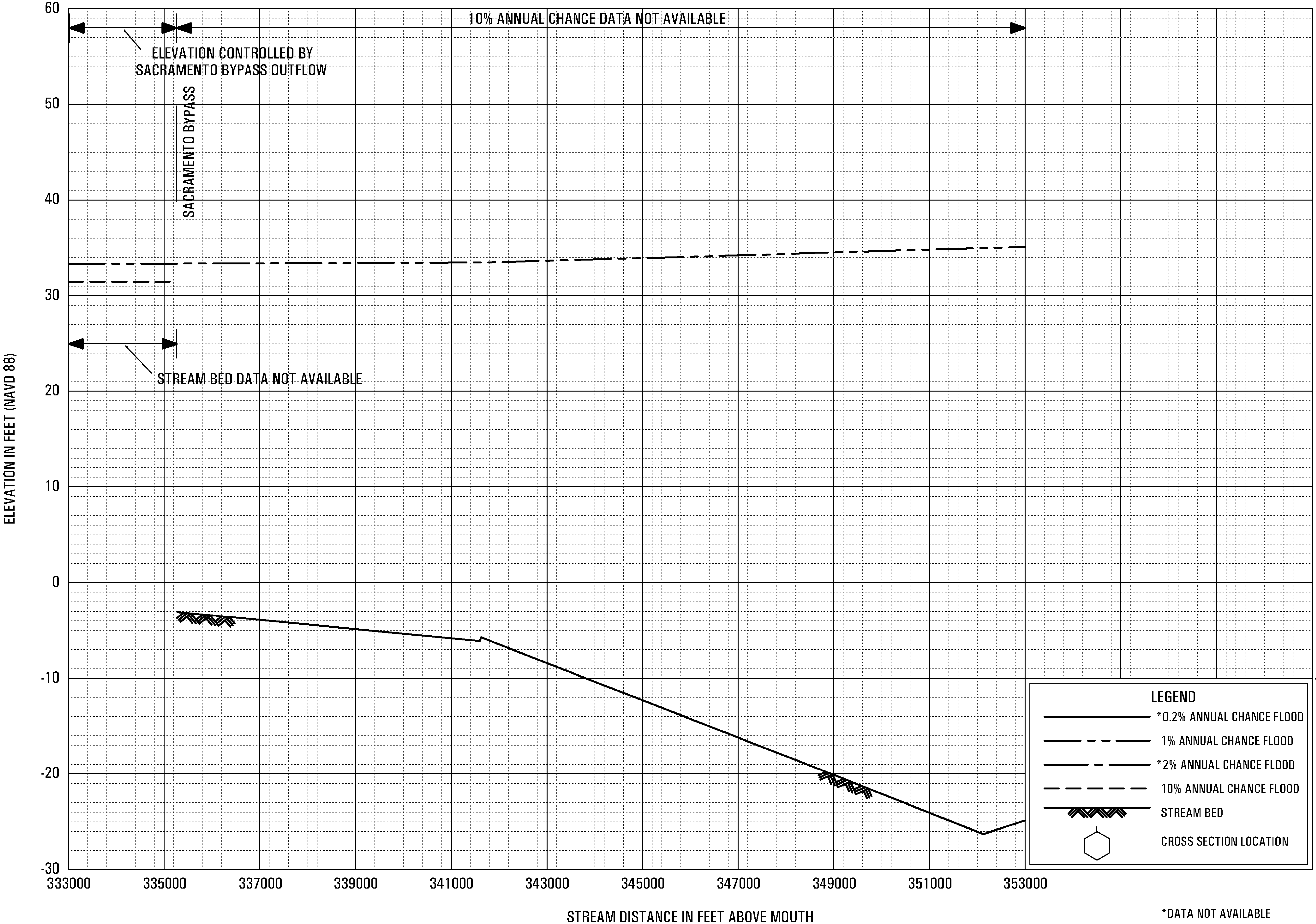
FLOOD PROFILES

SACRAMENTO RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

AND INCORPORATED AREAS

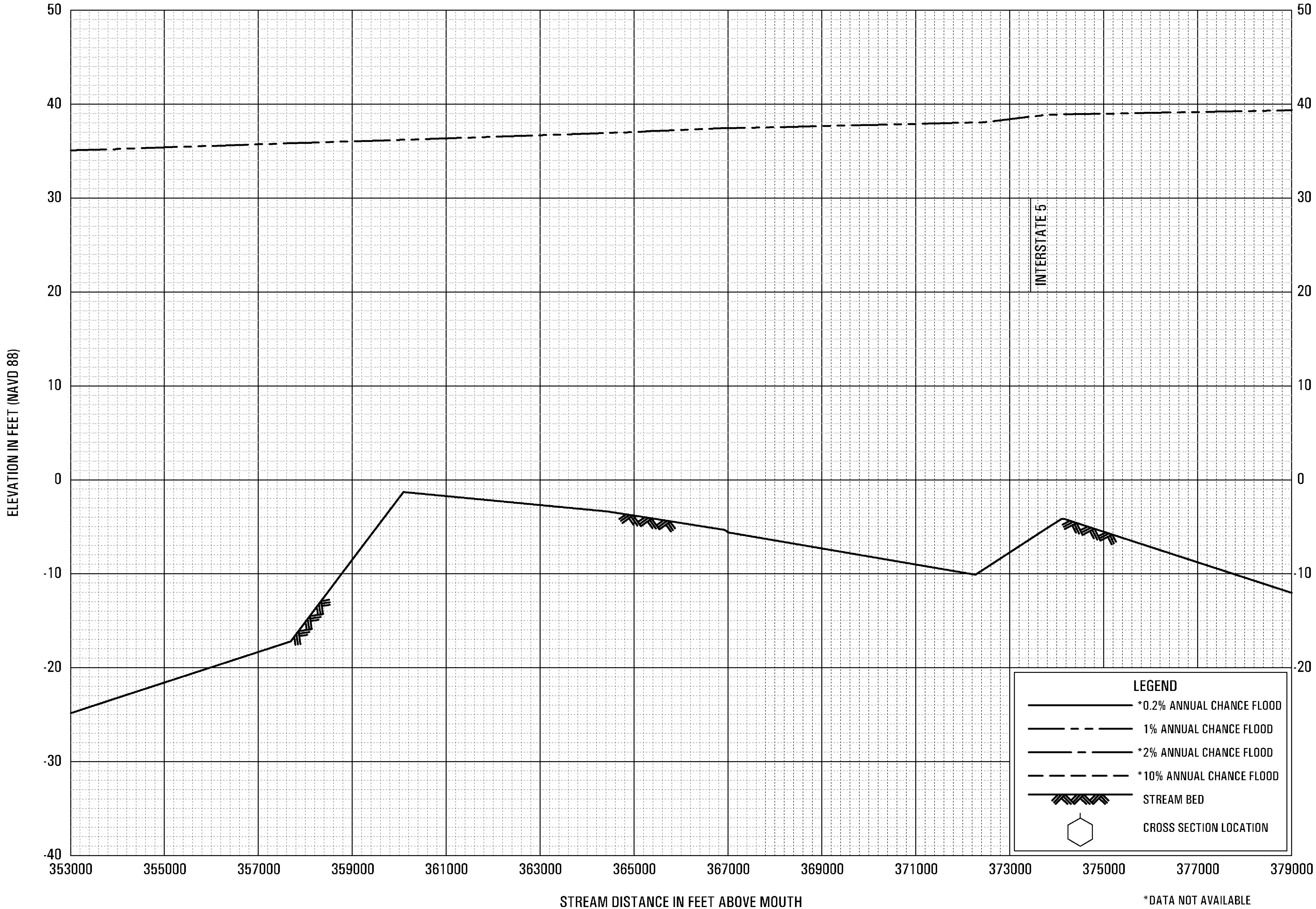


FLOOD PROFILES

SACRAMENTO RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA
AND INCORPORATED AREAS



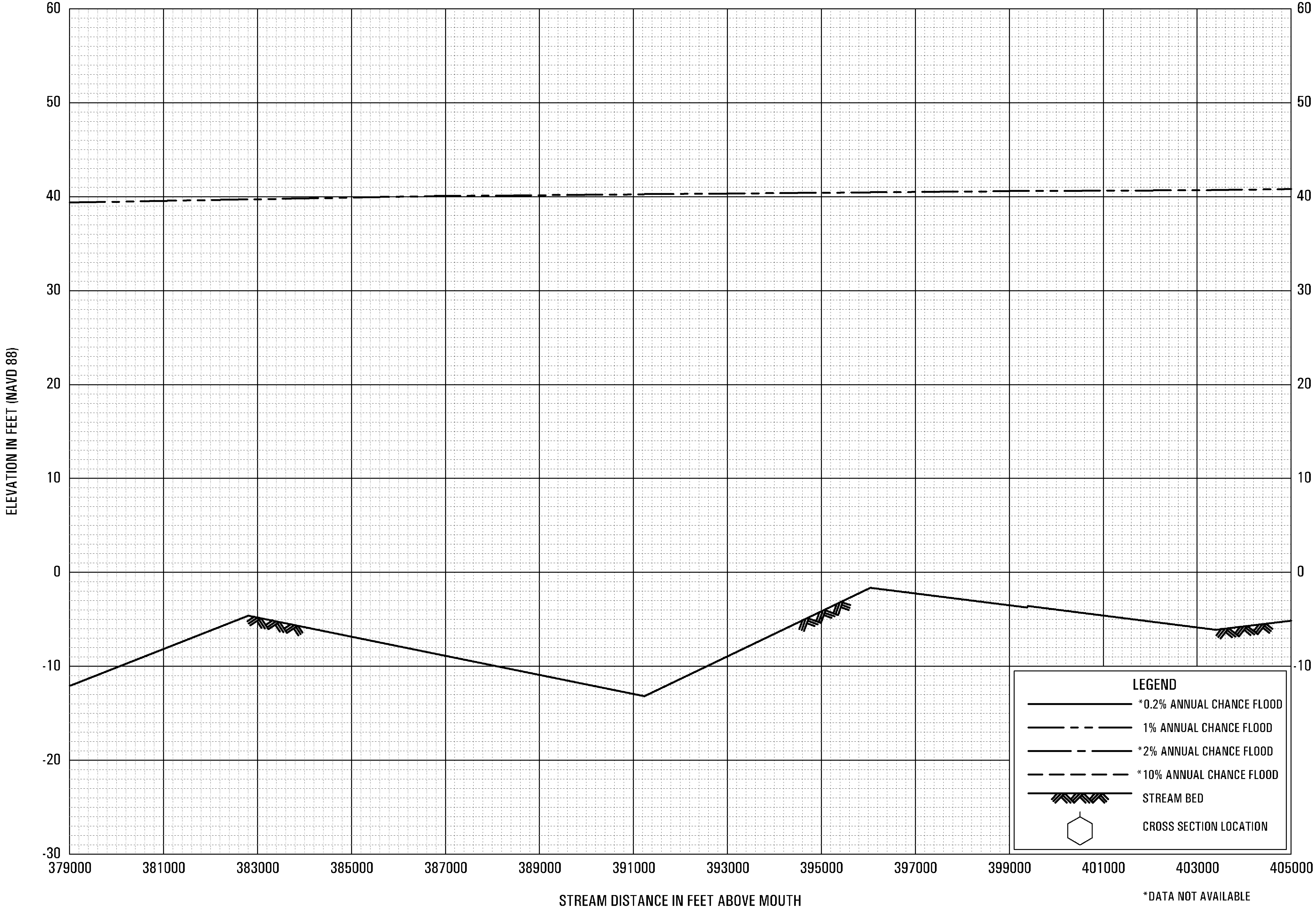
FLOOD PROFILES

SACRAMENTO RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

AND INCORPORATED AREAS



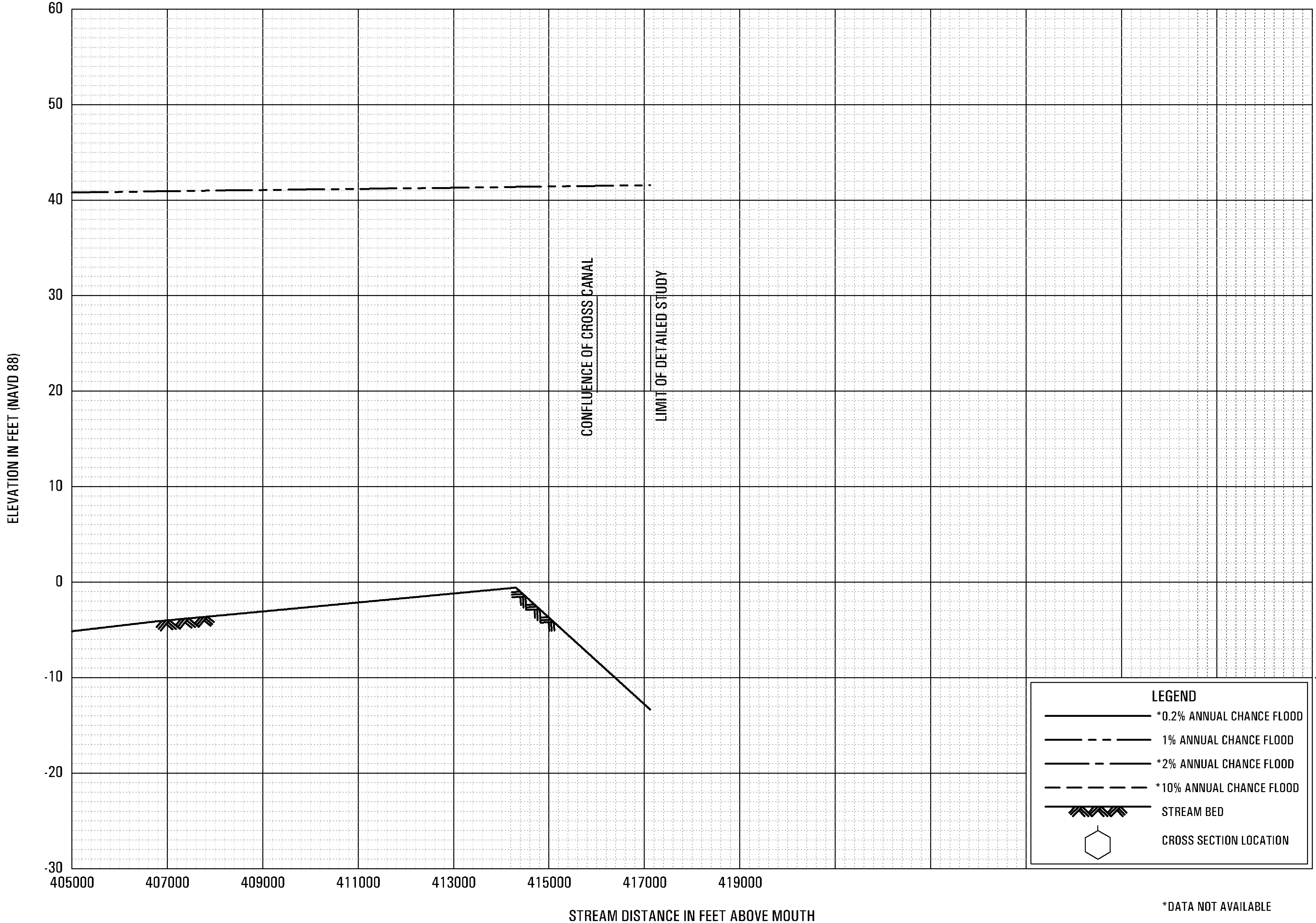
FLOOD PROFILES

SACRAMENTO RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

AND INCORPORATED AREAS



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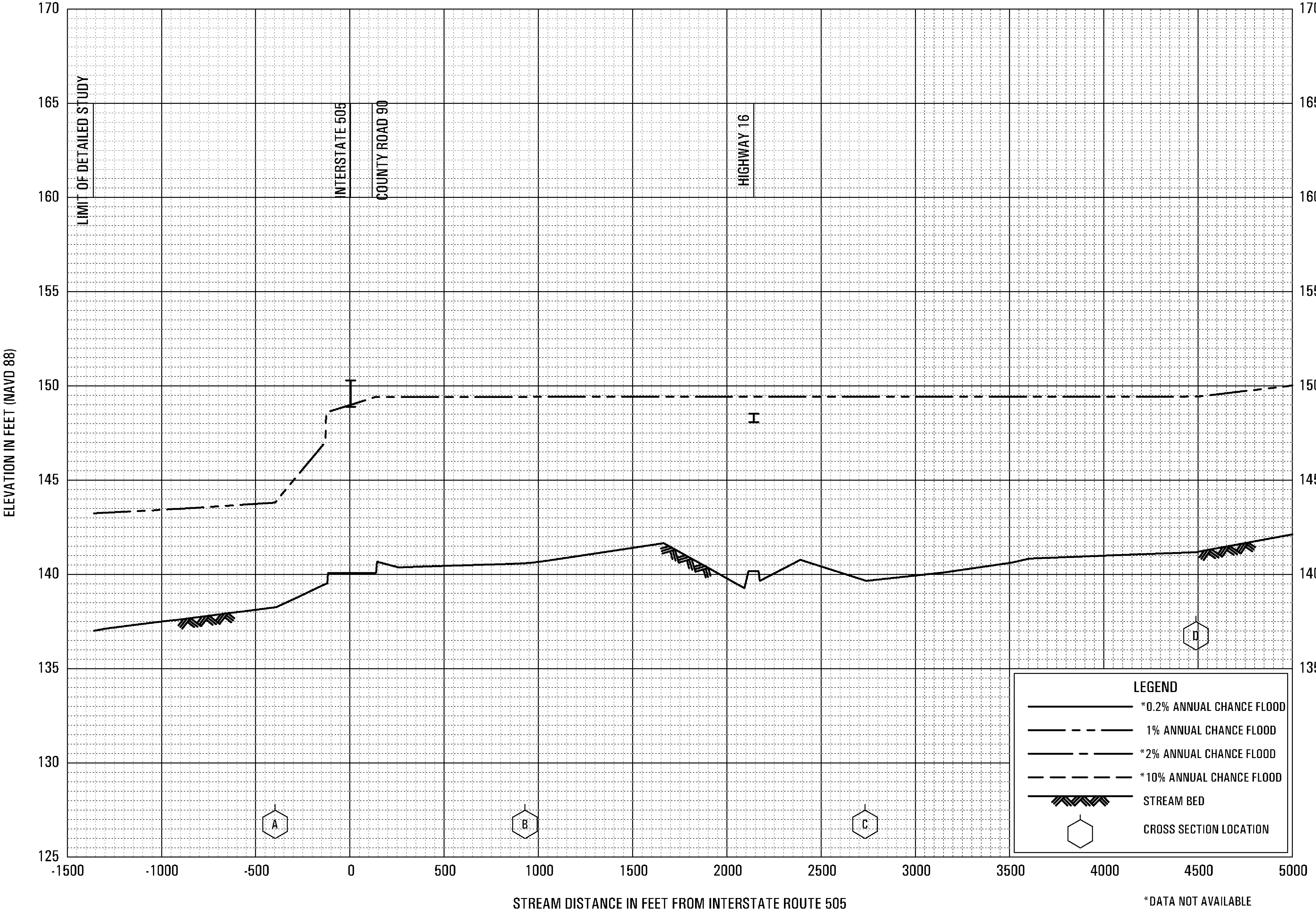
FLOOD PROFILES

SACRAMENTO RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA
AND INCORPORATED AREAS



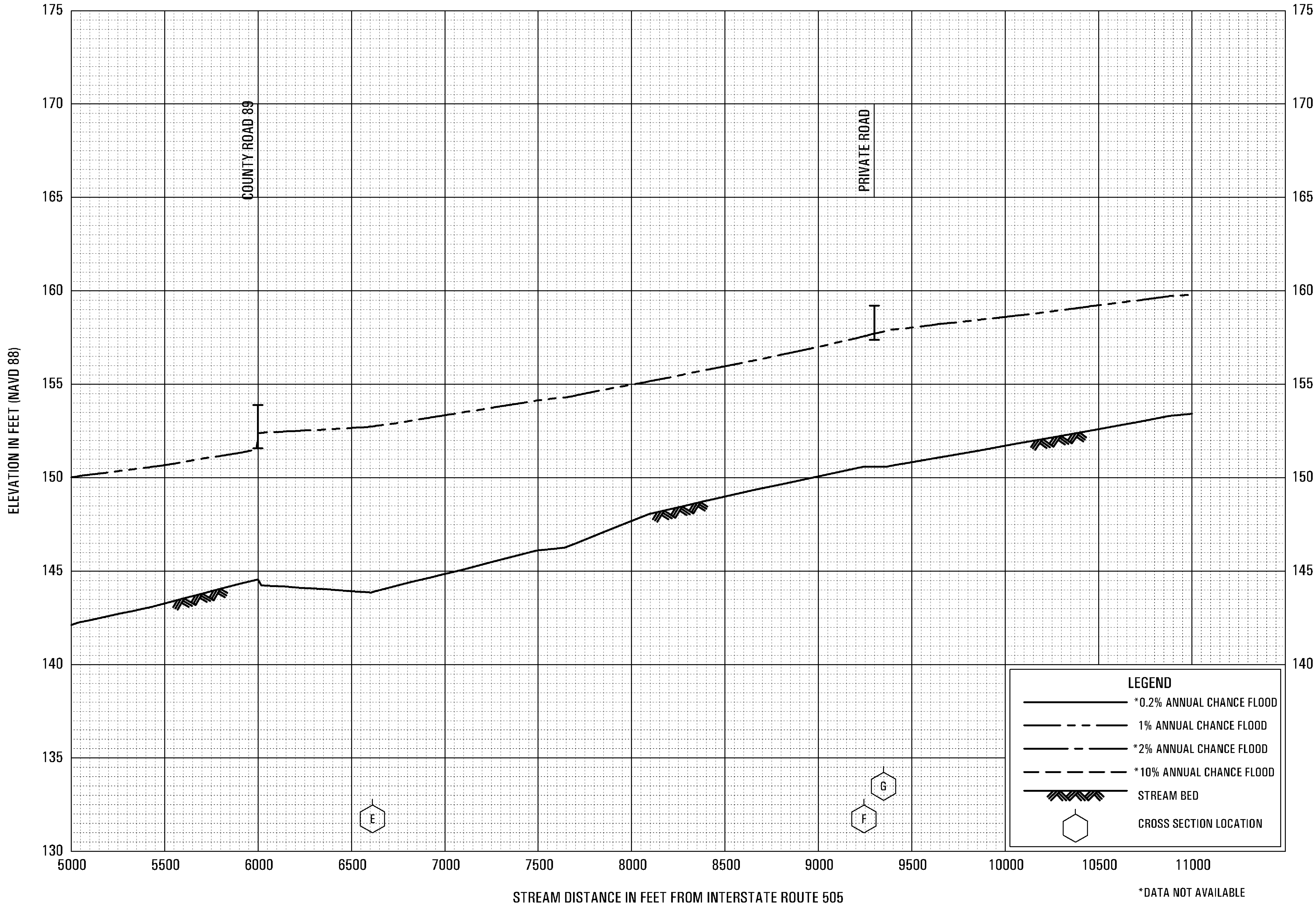
FLOOD PROFILES

SOUTH FORK WILLOW SLOUGH

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

AND INCORPORATED AREAS

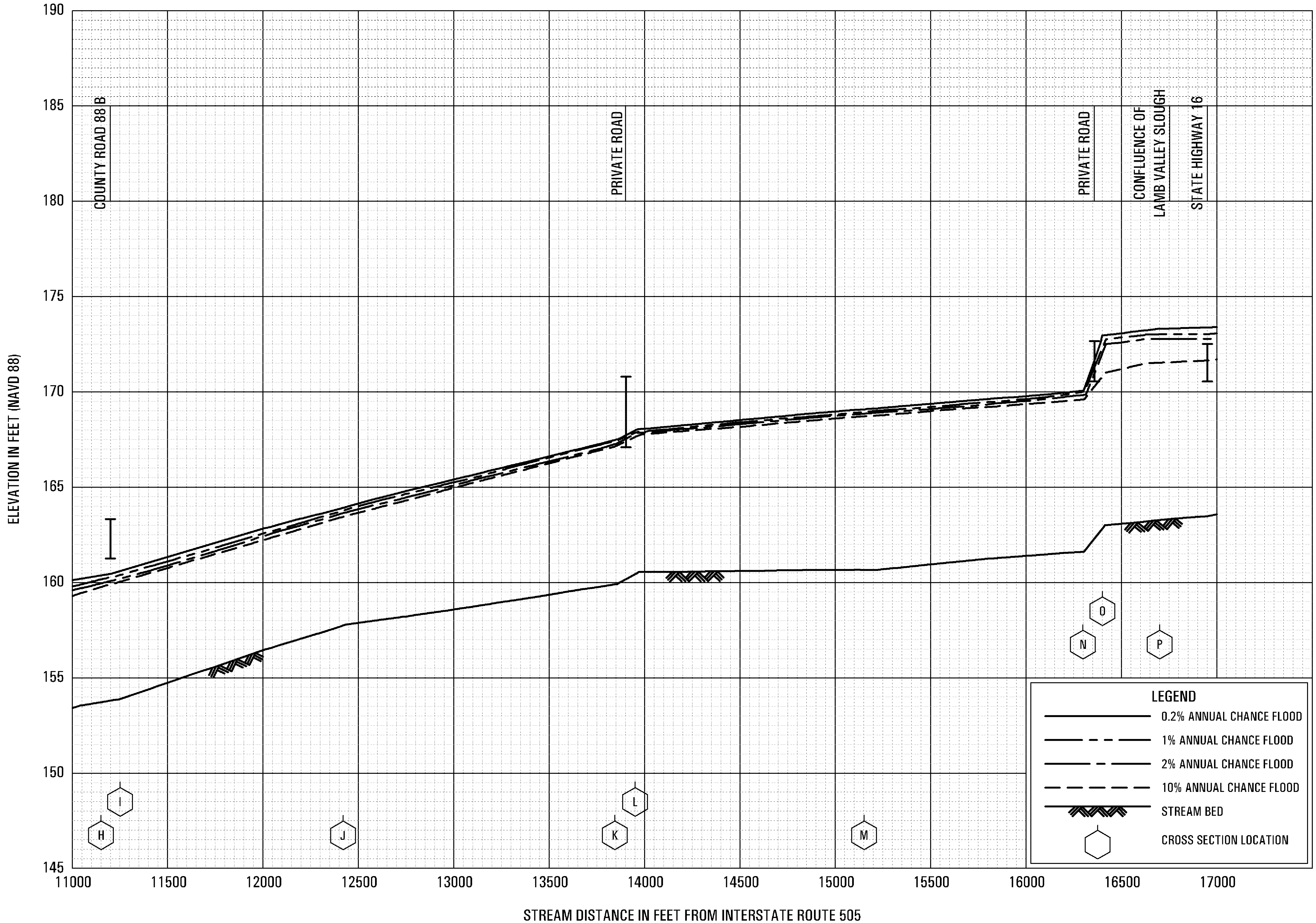


FLOOD PROFILES

SOUTH FORK WILLOW SLOUGH

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA
AND INCORPORATED AREAS



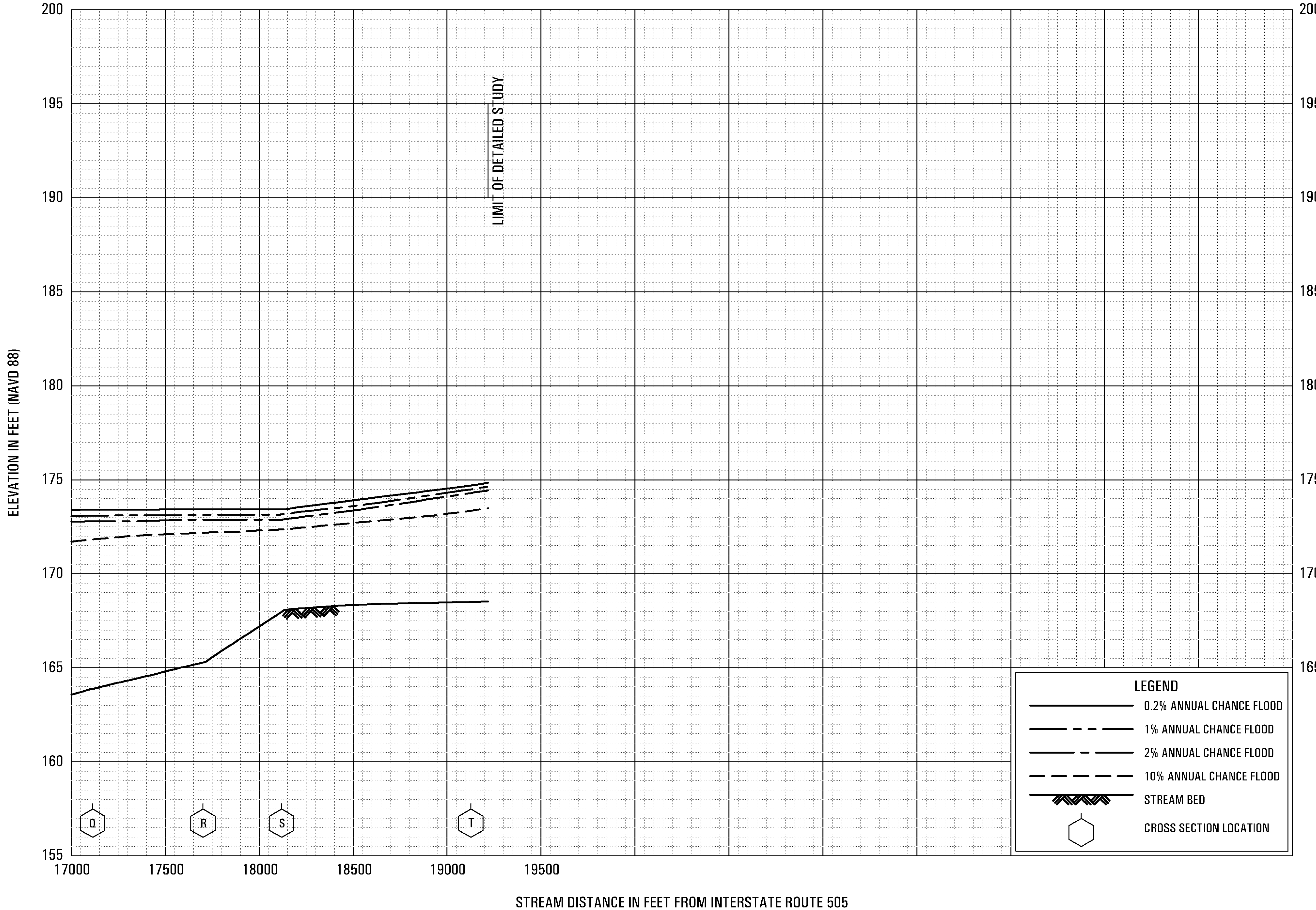
FLOOD PROFILES

SOUTH FORK WILLOW SLOUGH

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

AND INCORPORATED AREAS



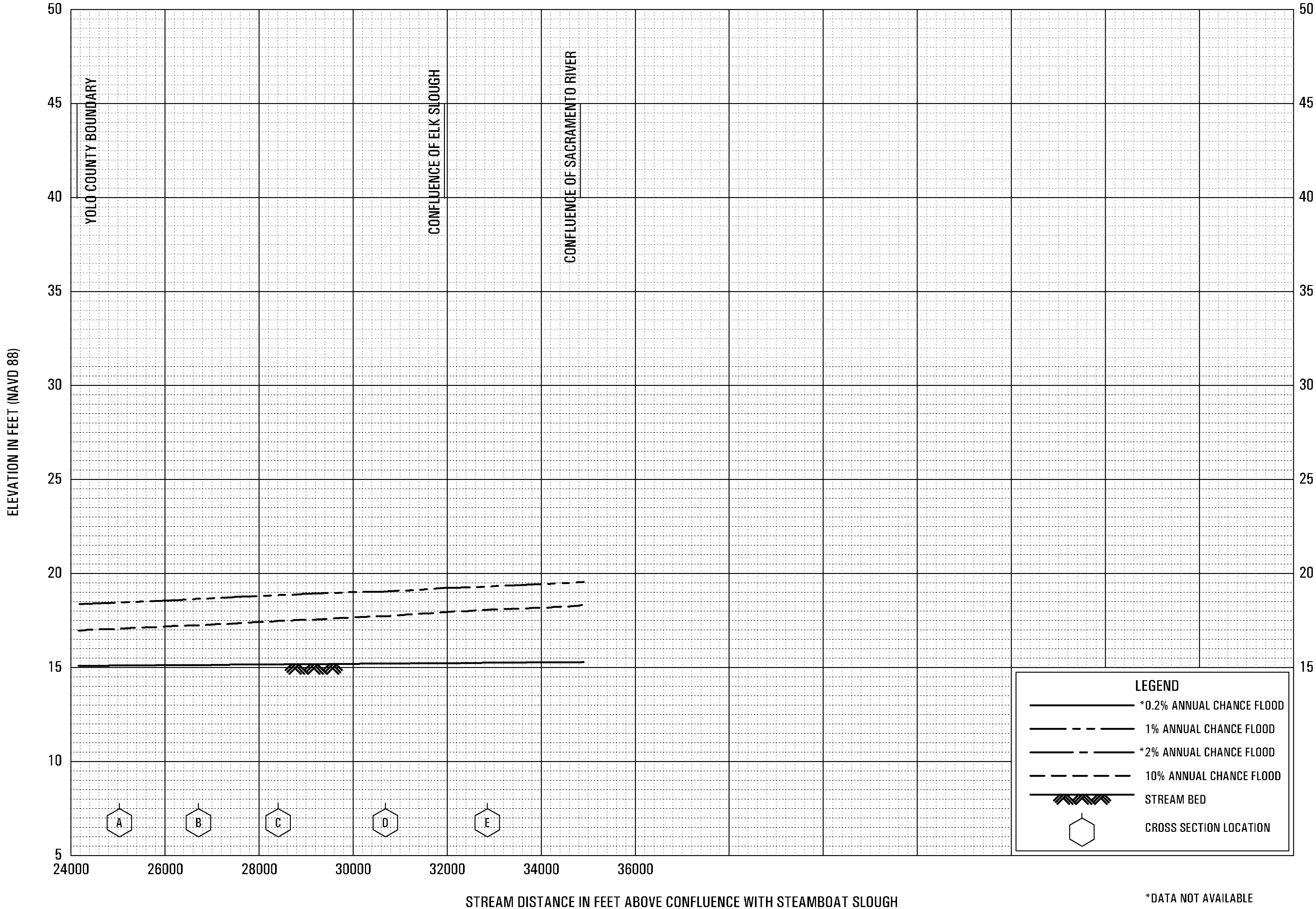
FLOOD PROFILES

SOUTH FORK WILLOW SLOUGH

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

AND INCORPORATED AREAS



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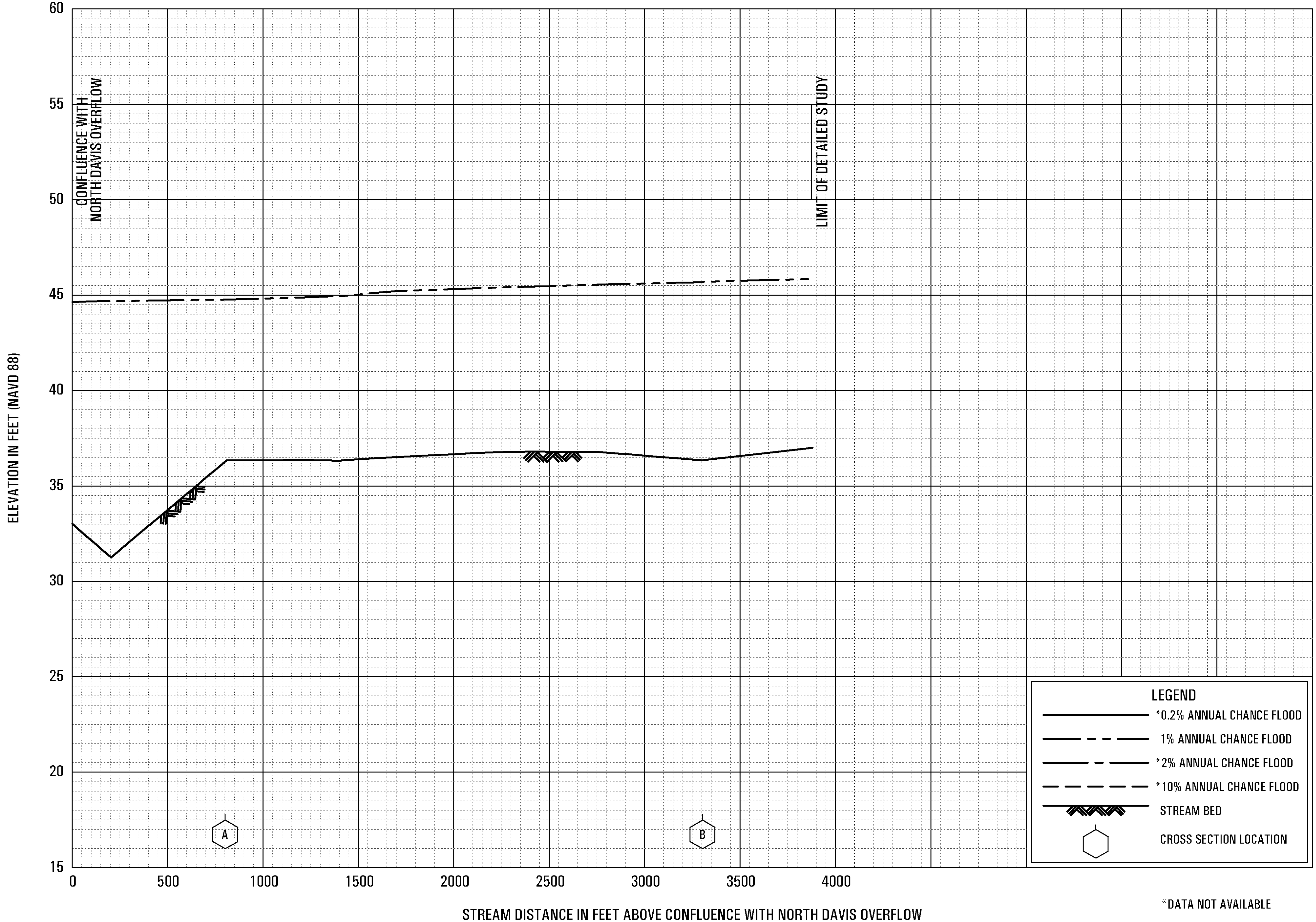
FLOOD PROFILES

SUTTER SLOUGH

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

AND UNINCORPORATED AREAS



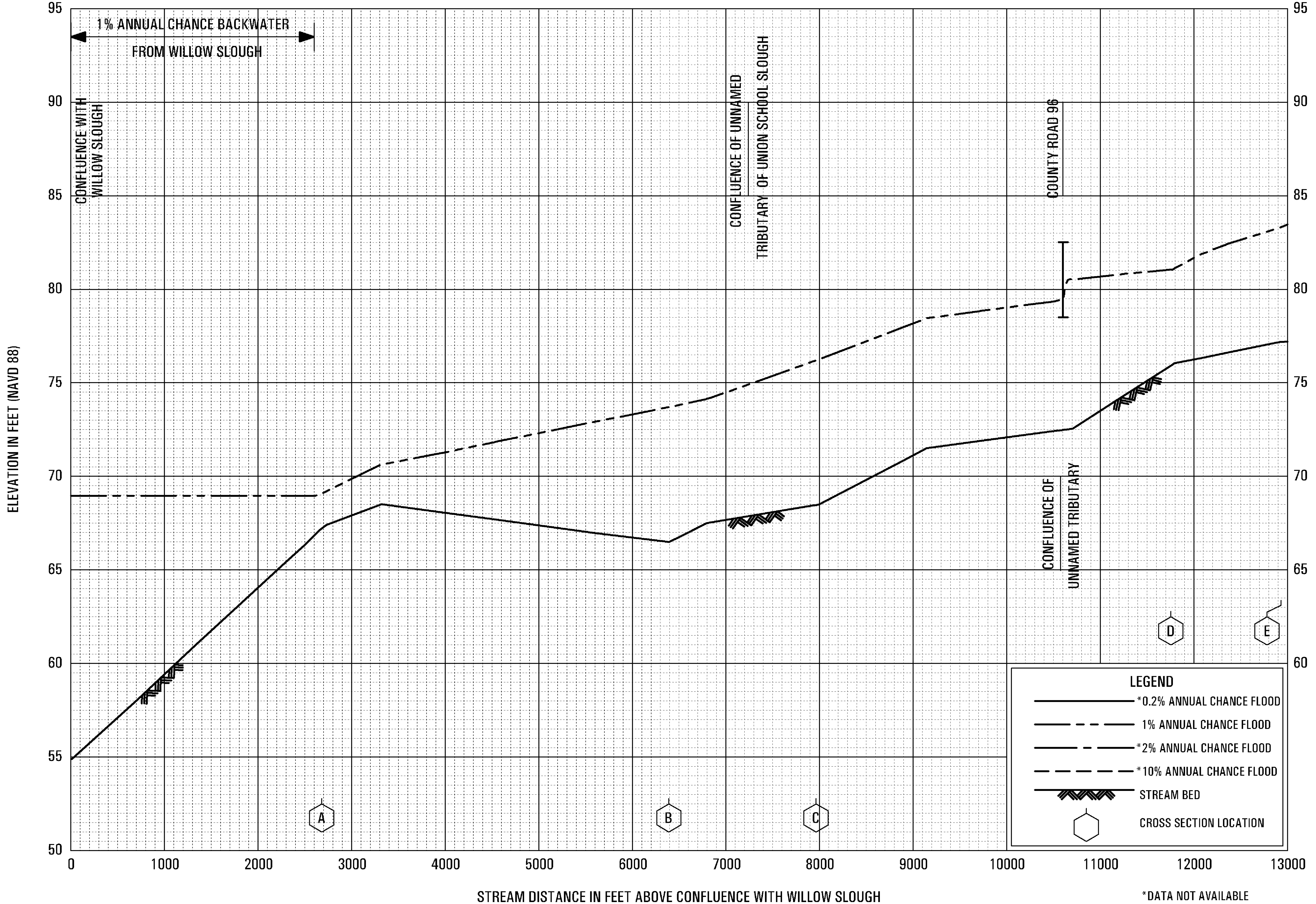
FLOOD PROFILES

UNION PACIFIC RAILROAD DRAIN

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

AND INCORPORATED AREAS



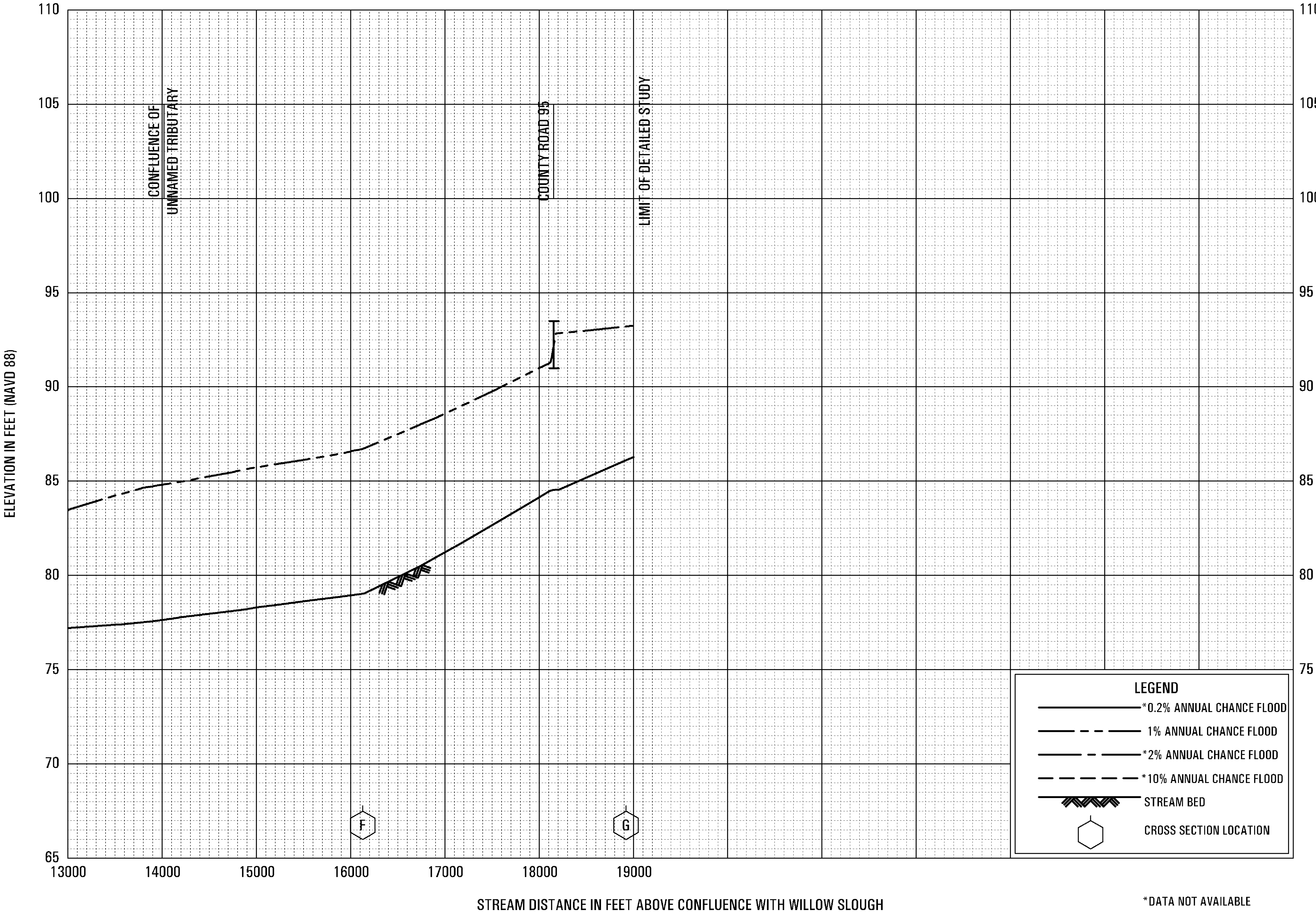
FLOOD PROFILES

UNION SCHOOL SLOUGH

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

AND INCORPORATED AREASA



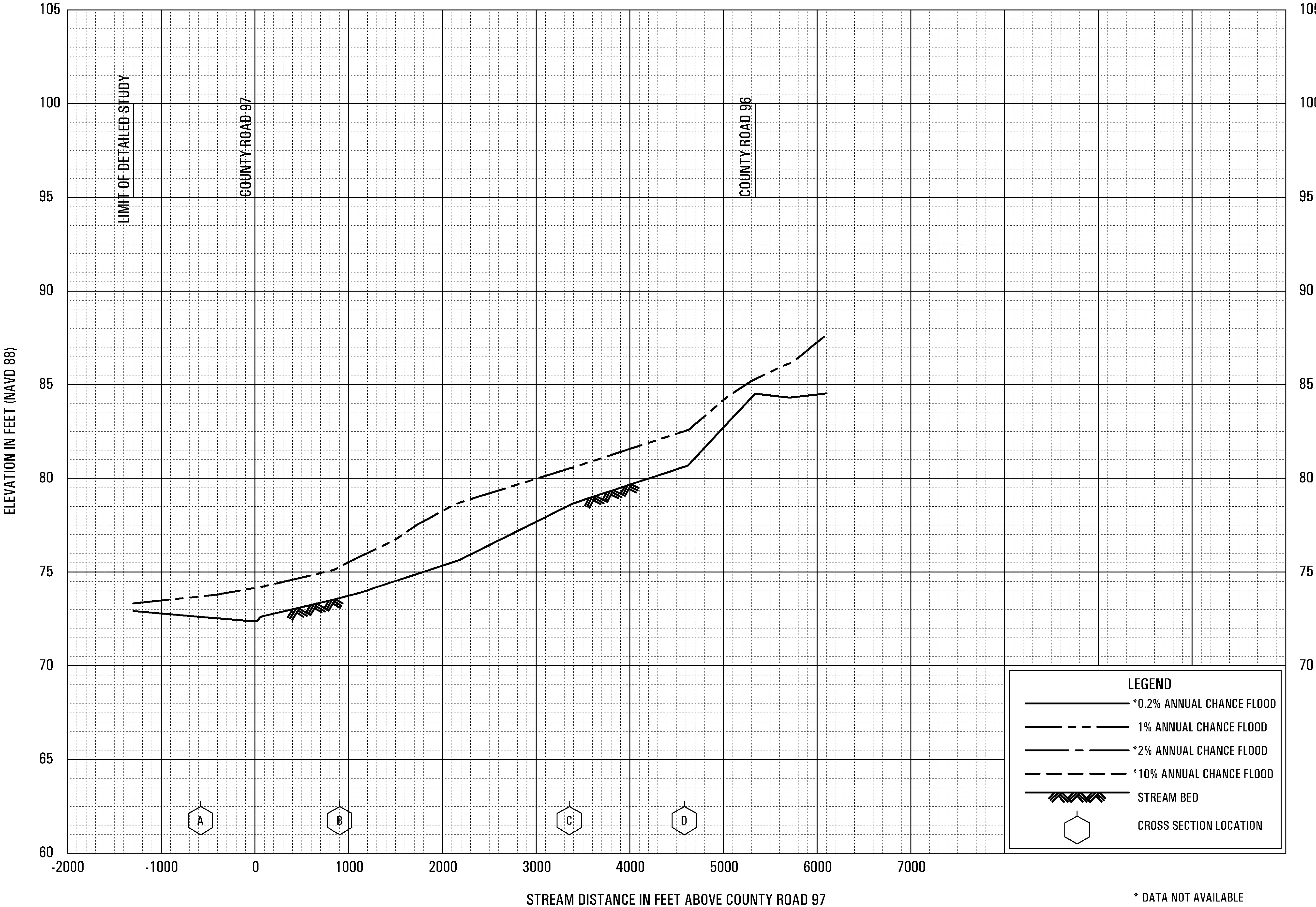
FLOOD PROFILES

UNION SCHOOL SLOUGH

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

AND INCORPORATED AREASA



* DATA NOT AVAILABLE

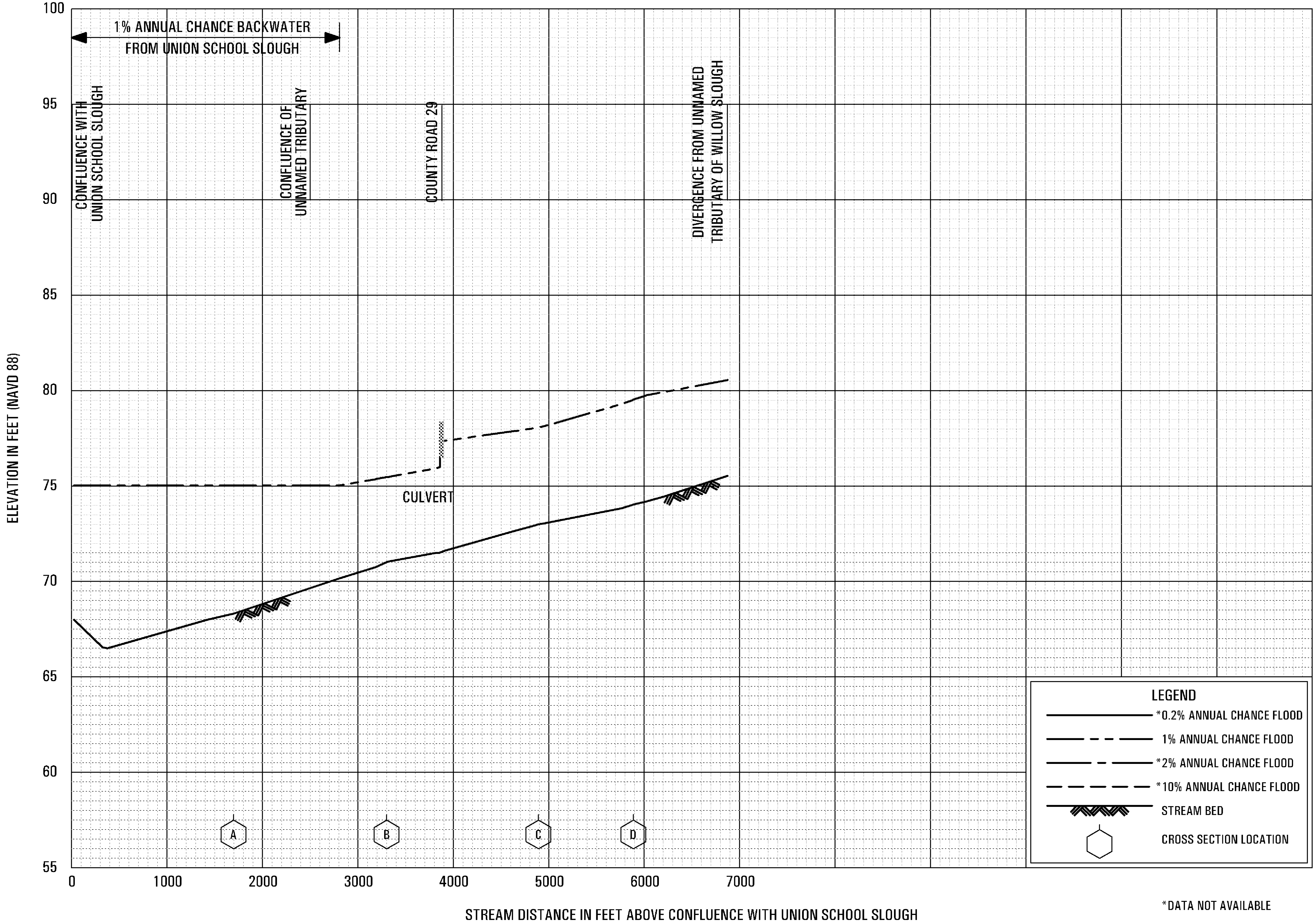
FLOOD PROFILES

UNNAMED OVERFLOW AREA SOUTH OF COUNTY ROAD 31

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

AND INCORPORATED AREAS

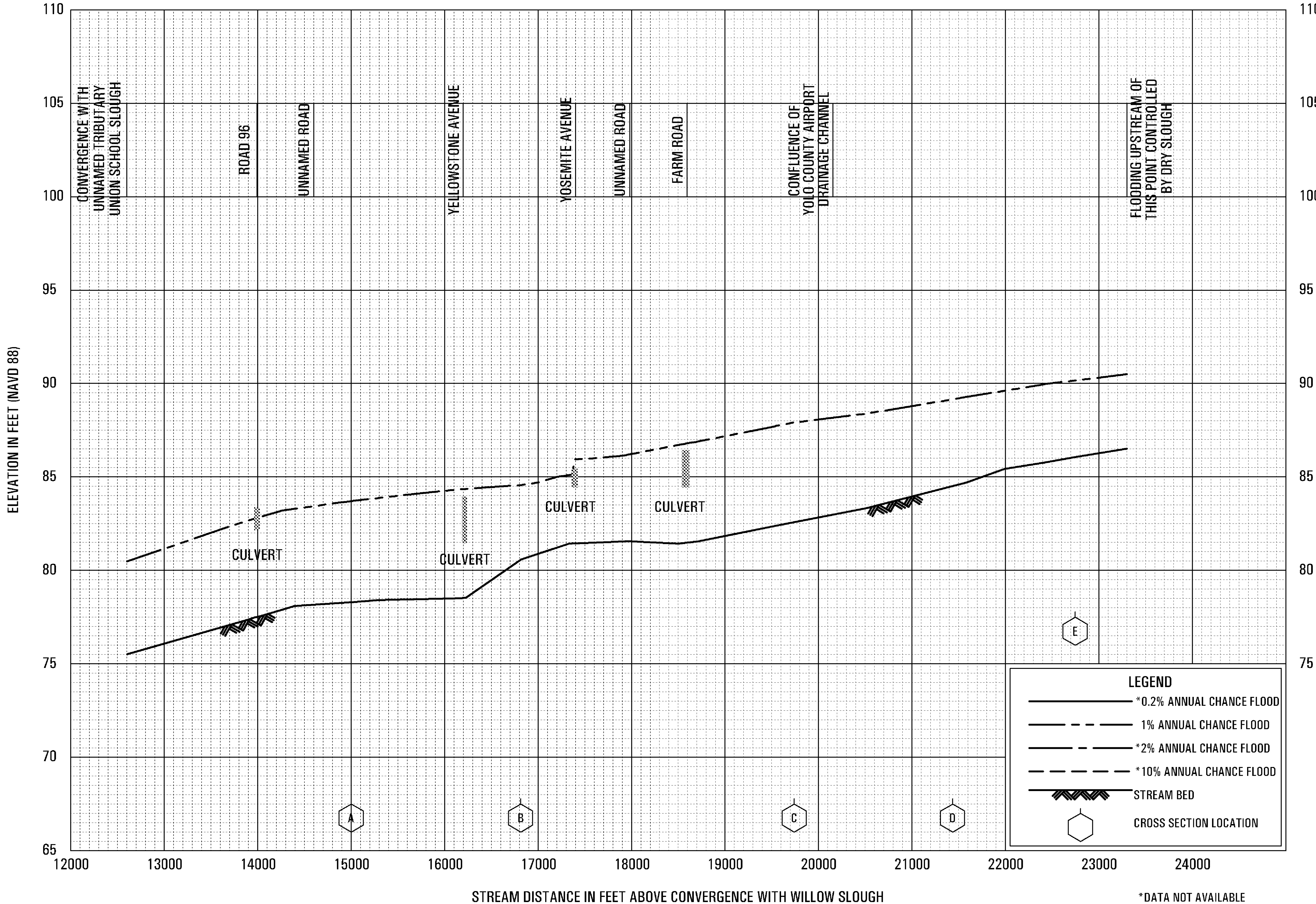


FLOOD PROFILES

UNNAMED TRIBUTARY OF UNION SCHOOL SLOUGH

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA
AND INCORPORATED AREAS



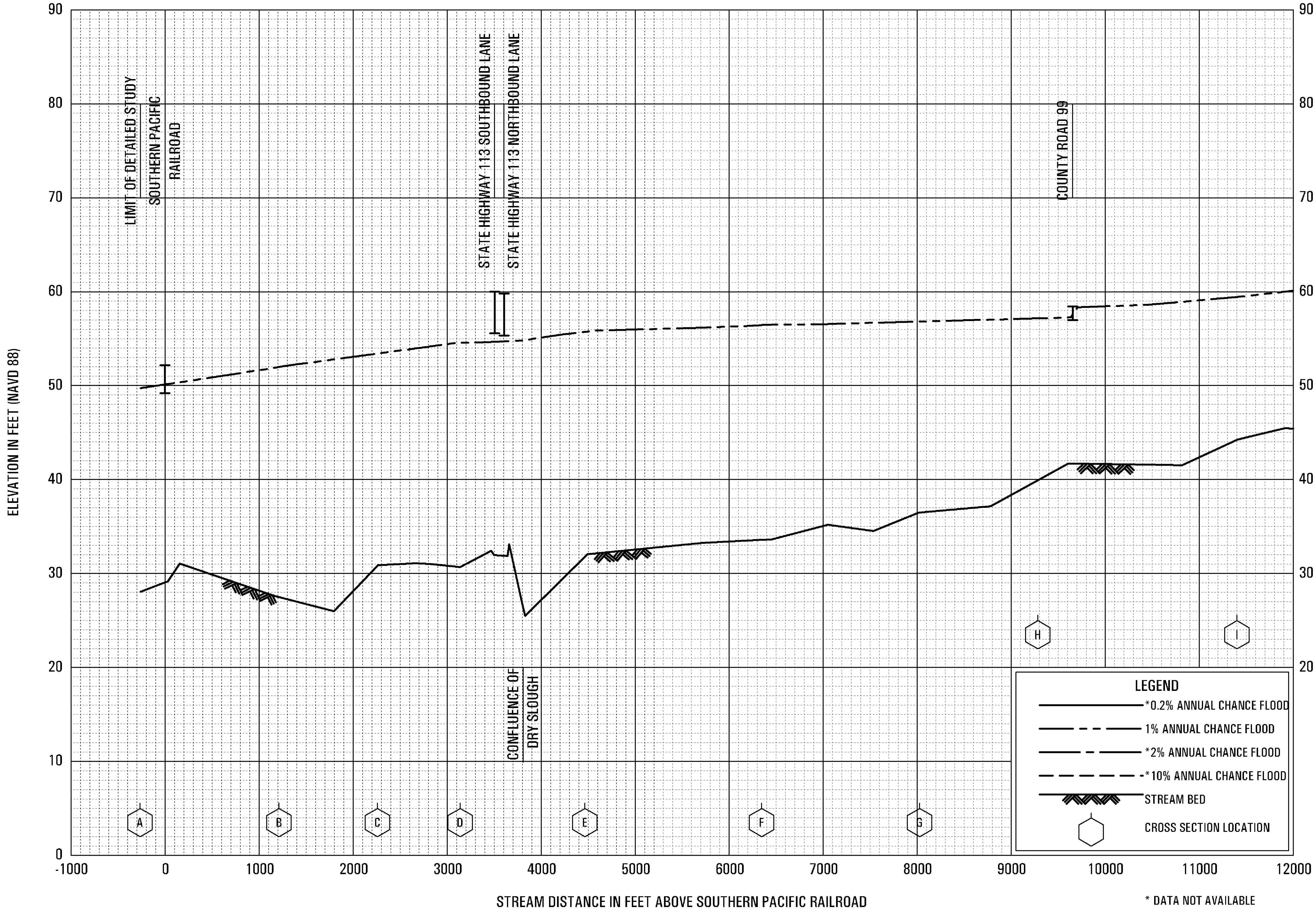
FLOOD PROFILES

UNNAMED TRIBUTARY OF WILLOW SLOUGH

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

AND INCORPORATED AREAS



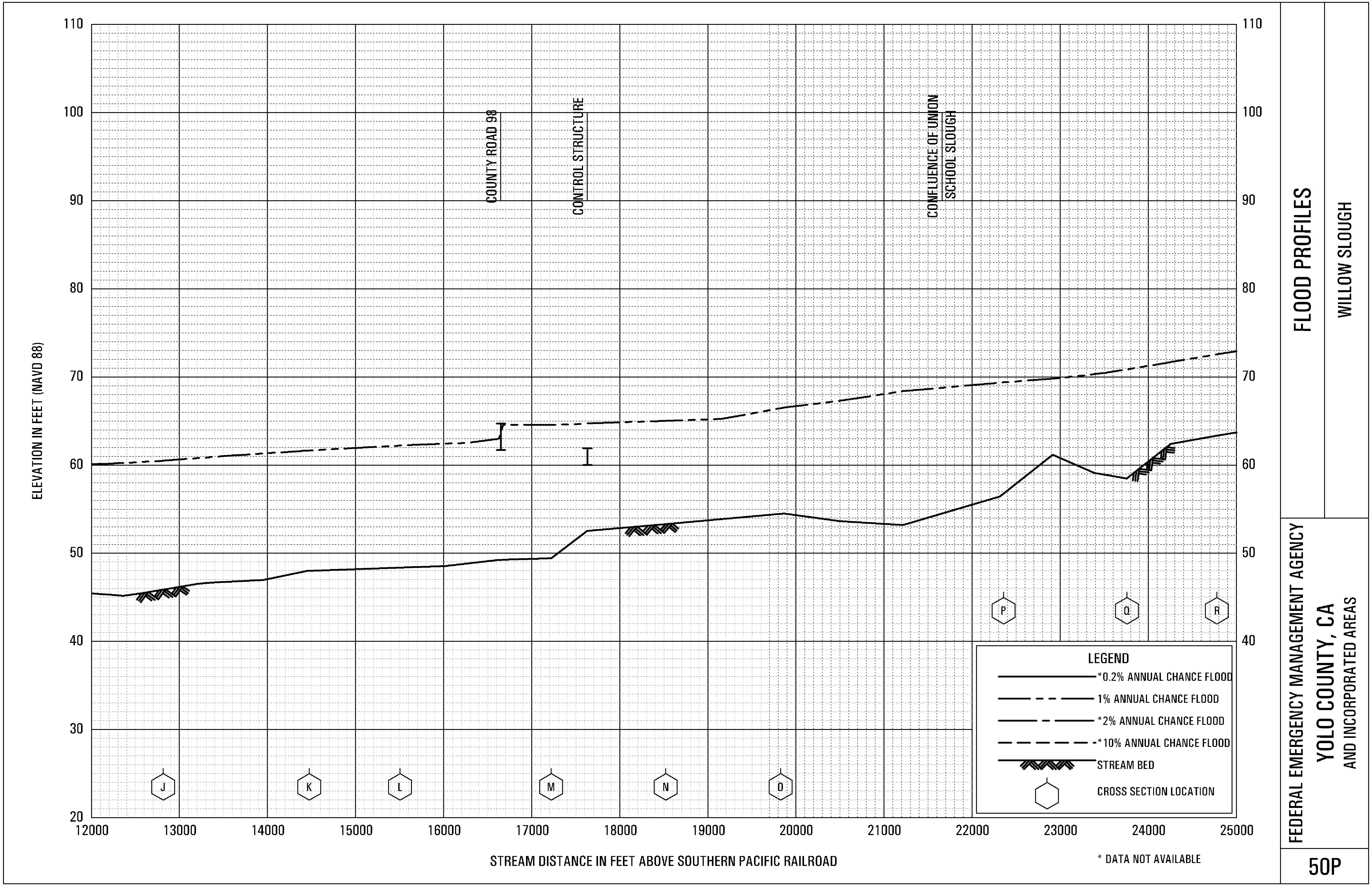
FLOOD PROFILES

WILLOW SLOUGH

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

AND INCORPORATED AREAS



FLOOD PROFILES
WILLOW SLOUGH
FEDERAL EMERGENCY MANAGEMENT AGENCY
YOLO COUNTY, CA
AND INCORPORATED AREAS
50P
ELEVATION IN FEET (NAVD 88)
STREAM DISTANCE IN FEET ABOVE SOUTHERN PACIFIC RAILROAD
COUNTY ROAD 98
CONTROL STRUCTURE
CONFLUENCE OF UNION SCHOOL SLOUGH
LEGEND
*0.2% ANNUAL CHANCE FLOOD
1% ANNUAL CHANCE FLOOD
*2% ANNUAL CHANCE FLOOD
*10% ANNUAL CHANCE FLOOD
STREAM BED
CROSS SECTION LOCATION
* DATA NOT AVAILABLE
J
K
L
M
N
O
P
Q
R
20
30
40
50
60
70
80
90
100
110
12000
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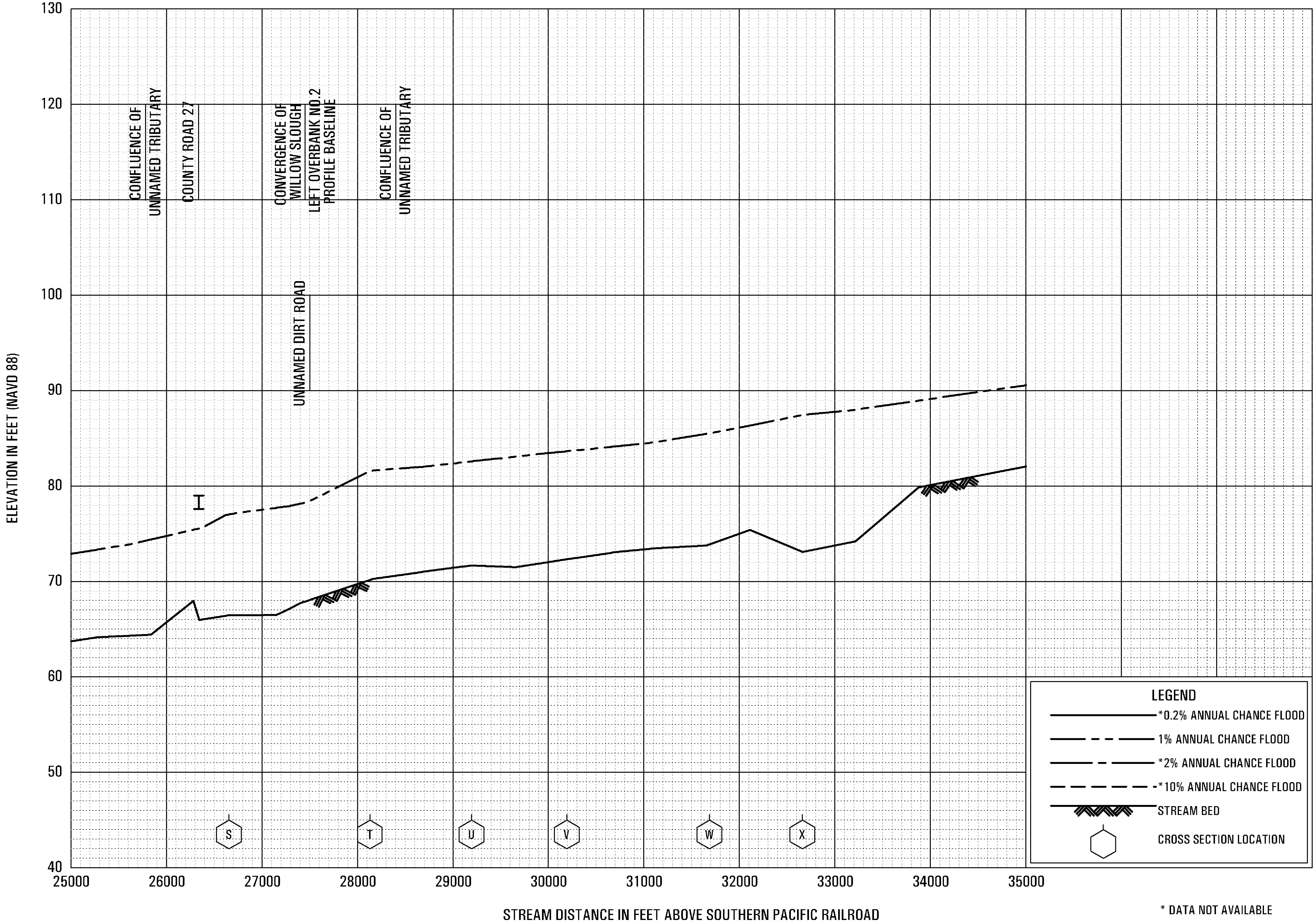
22000
23000
24000
25000



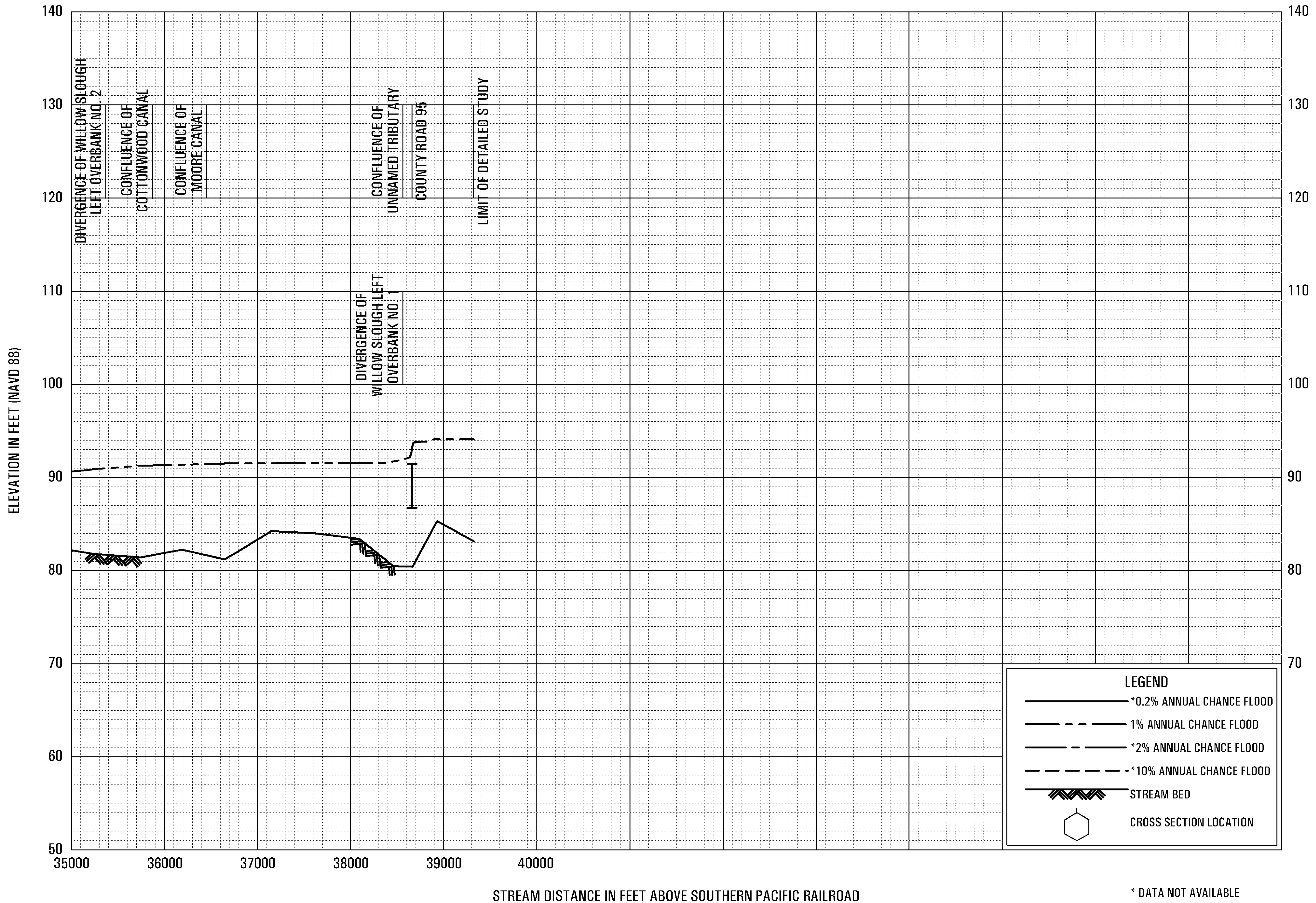
FLOOD PROFILES

WILLOW SLOUGH

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

AND INCORPORATED AREAS



FLOOD PROFILES

WILLOW SLOUGH

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

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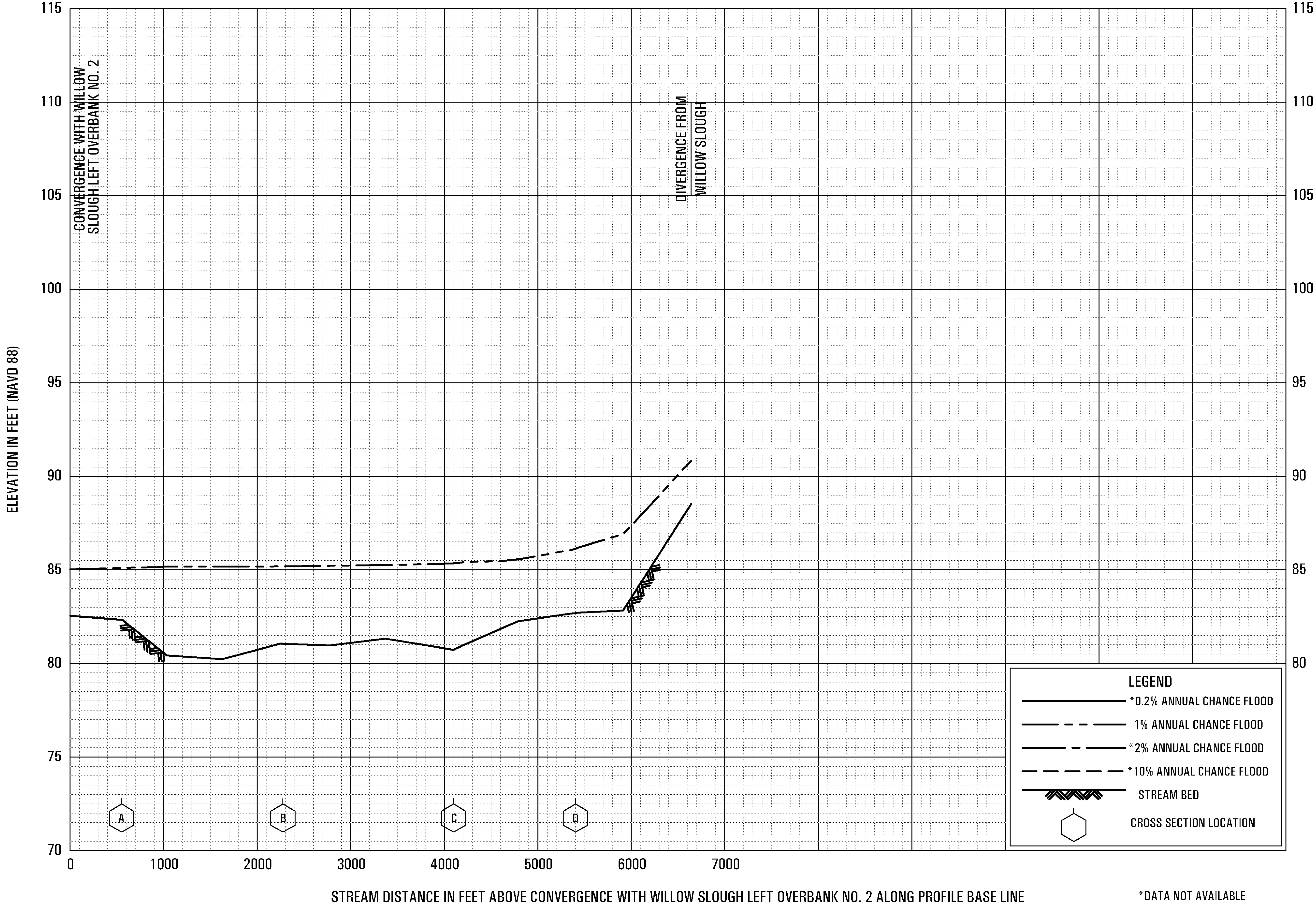


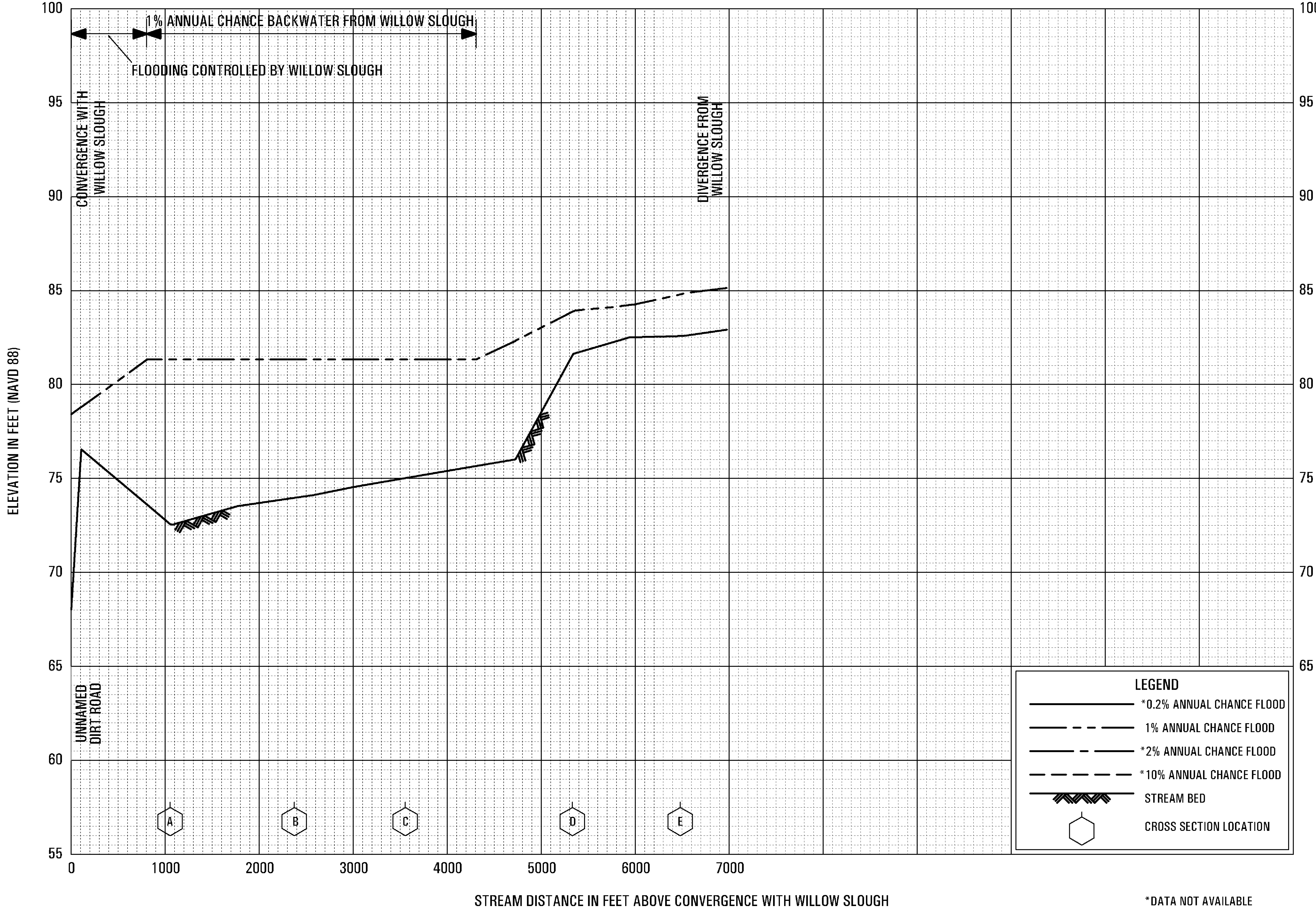
FLOOD PROFILES

WILLOW SLOUGH LEFT OVERBANK NO. 1

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

AND INCORPORATED AREAS



*DATA NOT AVAILABLE

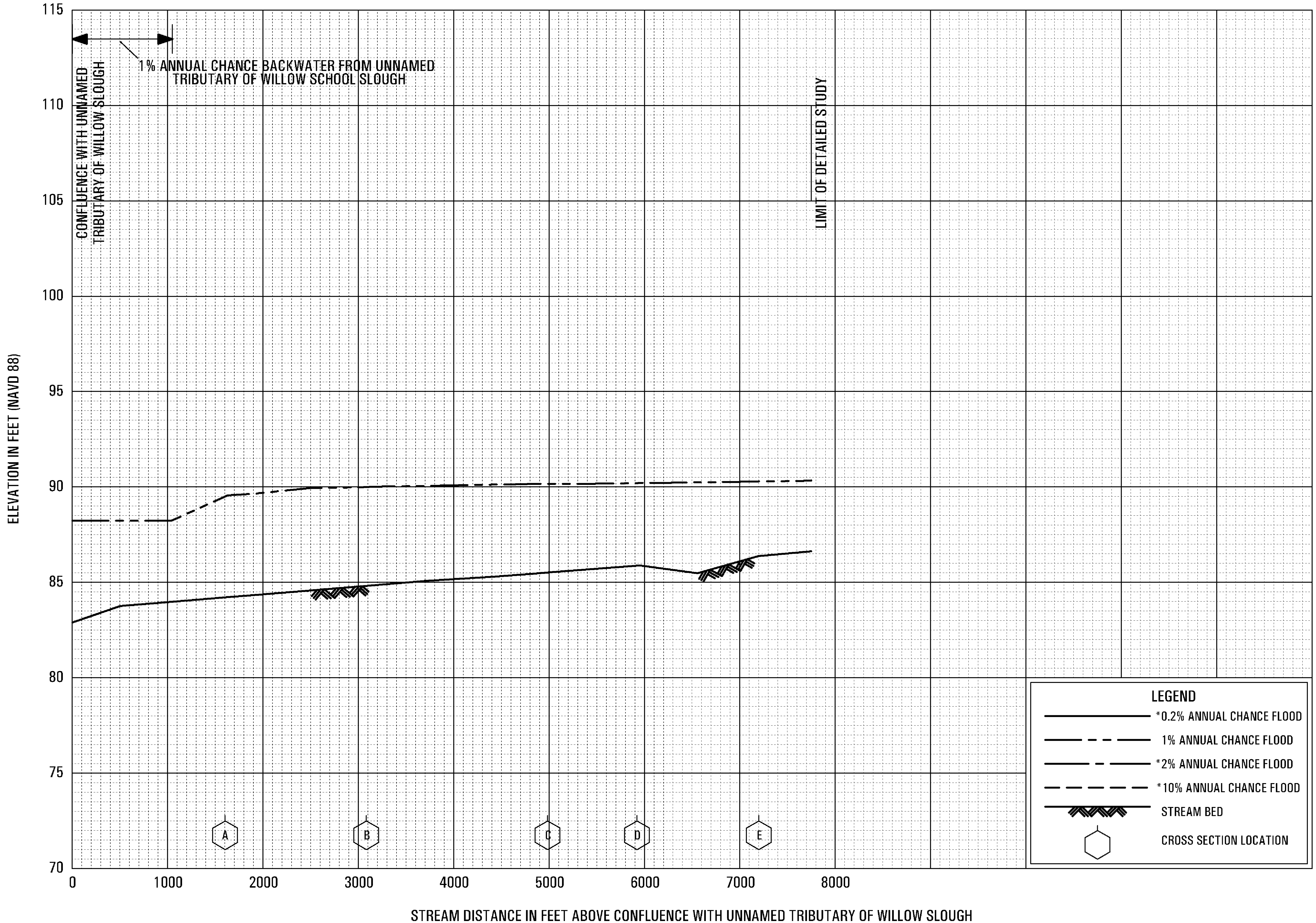
FLOOD PROFILES

WILLOW SLOUGH LEFT OVERBANK NO. 2

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

AND INCORPORATED AREAS



FLOOD PROFILES

YOLO COUNTY AIRPORT DRAINAGE CHANNEL

FEDERAL EMERGENCY MANAGEMENT AGENCY

YOLO COUNTY, CA

AND INCORPORATED AREAS