

FLOOD INSURANCE STUDY



VOLUME 3 OF 5

CONTRA COSTA COUNTY, CALIFORNIA AND INCORPORATED AREAS

Community Name	Community Number
ANTIOCH, CITY OF	060026
BRENTWOOD, CITY OF	060439
CLAYTON, CITY OF	060027
CONCORD, CITY OF	065022
DANVILLE, TOWN OF	060707
EL CERRITO, CITY OF	065027
HERCULES, CITY OF	060434
LAFAYETTE, CITY OF	065037
MARTINEZ, CITY OF	065044
MORAGA, TOWN OF	060637
OAKLEY, CITY OF	060766
ORINDA, CITY OF	060722
PINOLE, CITY OF	060032
PITTSBURG, CITY OF	060033
PLEASANT HILL, CITY OF	060034
RICHMOND, CITY OF	060035
SAN PABLO, CITY OF	060036
SAN RAMON, CITY OF	060710
WALNUT CREEK, CITY OF	065070
CONTRA COSTA COUNTY (UNINCORPORATED AREAS)	060025



REVISED
March 21, 2017



Federal Emergency Management Agency

FLOOD INSURANCE STUDY NUMBER
06013CV003C

**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 16, 2009

Revised Countywide FIS Dates: September 30, 2015
March 21, 2017

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Published Separately – Flood Insurance Rate Map Index
Flood Insurance Rate Maps

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 D

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

Zone VE

Zone VE is the flood insurance rate zone that corresponds to the 1-percent annual chance coastal floodplains that have additional hazards associated with storm waves. Whole-foot base flood elevations derived from the detailed hydraulic analyses are shown at selected intervals 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 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.

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-annual chance floodplains. Floodways and the locations of selected cross sections used in the hydraulic analyses and floodway computations are shown where applicable.

This FIRM includes some flood hazard information that was presented separately on the Flood Boundary and Floodway Maps, where applicable. Historical data relating to the maps prepared for each community up to and including this countywide FIS are presented in Table 14, "Community Map History."

Table 14: Community Map History

COMMUNITY NAME	INITIAL IDENTIFICATION	FLOOD HAZARD BOUNDARY MAP REVISIONS DATE	FIRM EFFECTIVE DATE	FIRM REVISIONS DATE
Antioch, City of	June 28, 1974	October 24, 1975	December 2, 1980	September 18, 1985 September 4, 1987
Brentwood, City of	June 16, 2009	---	June 16, 2009	---
Clayton, City of	May 17, 1974	December 26, 1975	December 4, 1979	September 7, 2001
Concord, City of	June 28, 1974	April 9, 1976	July 5, 1984	September 7, 2001
Contra Costa, County of (Unincorporated Areas)	November 1, 1974	September 6, 1977	July 16, 1987	May 20, 1996 September 7, 2001 December 2, 2003
Danville, Town of	September 27, 1985	---	September 27, 1985	September 7, 2001
El Cerrito, City of	June 28, 1974	December 5, 1975	June 1, 1977	---
Hercules, City of	March 26, 1976	October 22, 1976	September 30, 1982	---
Lafayette, City of	July 26, 1974	December 5, 1975	March 16, 1981	May 20, 1996 December 20, 2002
Martinez, City of	June 28, 1974	---	March 15, 1978	May 2, 2002
Moraga, Town of	November 19, 1976	---	May 19, 1981	---

**TABLE
14**

FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
AND INCORPORATED AREAS

COMMUNITY MAP HISTORY

Table 14: Community Map History, continued

COMMUNITY NAME	INITIAL IDENTIFICATION	FLOOD HAZARD BOUNDARY MAP REVISIONS DATE	FIRM EFFECTIVE DATE	FIRM REVISIONS DATE
Oakley, City of	November 1, 1974 ¹	September 6, 1977 ¹	July 16, 1987 ¹	February 2, 2002
Orinda, City of	January 6, 1988	---	January 6, 1988	July 17, 1997
Pinole, City of	May 24, 1974	October 10, 1975	August 15, 1980	---
Pittsburg, City of	June 21, 1974	November 28, 1975	August 15, 1980	December 18, 1984
				July 2, 1987
				September 7, 2001
Pleasant Hill, City of	May 24, 1974	February 13, 1976	September 30, 1983	December 2, 2003
Richmond, City of	June 28, 1974	January 30, 1976	March 1, 1979	November 17, 1993
				September 7, 2001
San Pablo, City of	March 15, 1974	October 17, 1975	August 1, 1977	January 3, 1983
				November 17, 1993
				April 16, 2004
San Ramon, City of	September 27, 1985	---	September 27, 1985	May 3, 1990
Walnut Creek, City of	November 8, 1974	October 8, 1976	May 1, 1985	May 20, 1996
				October 4, 2002

¹Dates are taken from the Unincorporated Areas of Contra Costa County

**TABLE
14**

FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
AND INCORPORATED AREAS

COMMUNITY MAP HISTORY

7.0 OTHER STUDIES

Information pertaining to revised and unrevised flood hazards for each jurisdiction within Contra Costa 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 Contra Costa 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, FEMA, Federal Insurance and Mitigation Division, 1111 Broadway, Suite 1200, Oakland, California 94607-4052.

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10.0 REVISIONS TO THIS FIS

10.1 Coastal Analyses

For North and Central San Francisco Bay, in the North Bay and into Suisun Bay, storm surge, swell-wave and wind-waves were modeled at a regional scale using numerical models to deterministically predict water levels and wave conditions in the bay (DHI, 2011). Coastal flooding hazards were then evaluated with one-dimensional (1D) transect-based models. Output from the DHI (2011) model of the North and Central San Francisco Bays was utilized to determine off-shore water levels with a 1% annual chance of exceedance. DHI provided 15 minute water level data, and hourly wind wave (seas) and swell information for the 31 years of hindcast. Along moderate to steep shorelines, runup relationships were used to determine the 1% Total Water Level (TWL). Along flat to mild sloping shorelines, the WHAFIS 4.0 model was used to simulate the propagation of waves up the inundated shoreline. No FEMA accredited levees exist within the Contra Costa study area north of the I-580 bridge. All man-made berms and other structures were treated as topographic features and the SWL was extended beyond them to the intersection with high ground.

A total of 97 transects were used in the Contra Costa County Coastal Flood Risk Analysis North of the I-580 bridge. Of the 97 transects, 66 were analyzed using only runup equations, 26 were analyzed using only WHAFIS, and 5 were analyzed using a combination of the runup and WHAFIS procedures. Seven WHAFIS scenarios were also analyzed using runup relationships on inland coastlines. DHI (2011) provided the results of a numerical model study of the North and Central San Francisco Bay. Their model simulated water level and wave conditions throughout North and Central San Francisco

Bay for the period from January 1, 1973 to December 31, 2003 using historic water level and gage records. The coastal flood risk study utilized hourly time series of wave heights, wave periods, and wave directions simulated by the DHI model at various points near the Contra Costa County shoreline. Simulated still water levels, at fifteen minute intervals, were also used in the coastal flood risk study.

All the topography for this analysis was based on the National Oceanic and Atmospheric Administration (NOAA) 2010 Northern San Francisco Bay Area LiDAR, collected in February-April, 2010. LiDAR points taken over water were not included in the topographic TIN. NHC merged bathymetric datasets originally collected by NOAA and used in the DHI (2011) model with the topography to develop a bathymetric TIN for elevations less than 0 ft NAVD88. Elevations were linearly interpolated between the bathymetric and topographic TINs. The winds used in the coastal flood risk study for Contra Costa County were the observed historical winds from Travis Air Force Base, provided by DHI (2011). These winds are the same as used in the DHI (2011) model. All wind speeds are assumed to be average hourly winds. A response based methodology was adopted to calculate the 1-percent-annual exceedance probability (1% AEP) water levels along the shoreline. Transects were used to translate the DHI model output to the shoreline. Each shoreline was analyzed as either a runup shoreline, a WHAFIS shoreline, or a combination runup/WHAFIS shoreline. Runup shorelines are those where wave processes are dominated by shoaling, refraction, wave breaking, and wave runup. WHAFIS shorelines are those where wave properties are dominated by wave dissipation due to marsh vegetation or land use features. These were analyzed with the WHAFIS 4.0 model and were typically low lying shorelines with long reaches of shallow inundation. Where a topographic feature lies in front of a low-lying area likely to be inundated during extreme events, runup procedures were used to define water levels seaward of the feature; WHAFIS was used to determine water levels landward of the shoreline structure. The objective of the methodology is to define coastal flood hazards due to inundation by extreme water levels and wave conditions. These extreme water levels include the 1% Annual Exceedance Probability Still Water Level (1% SWL), the 1% Annual Exceedance Probability Total Water Level (1% TWL), and the 1% Annual Exceedance Probability Wave Crest Elevation (1% WCE). The 1% SWL is determined from the annual maximum still water levels (SWL) at the DHI (2011) model output locations. The 1% TWL is determined at runup transects using the annual maximum total water levels (TWL) computed as the sum of the SWL, wave setup, and wave runup. The 1% WCE is computed at WHAFIS transects as a function of concurrent wave heights and SWL. Transects begin at the 3.2 ft NAVD88 contour and extended shoreward so they are oriented perpendicular to the 8 ft NAVD88 contour line. Transects are generally spaced about every 1000 to 4000 feet along the shoreline to capture typical shoreline characteristics. At a few locations in Contra Costa County East of I-680 bridge, transect spacing can be as high as 12,000 feet as no suitable wave output was provided by DHI (2011) in these areas. Each transect is a site where offshore wave and water level information was translated onshore and coastal flood risks determined. The transects cover the Contra Costa Shoreline from the I-580 bridge to CA-160 highway bridge near Antioch, Ca. Wave setup, runup, overtopping, and overland wave propagation were analyzed at representative transects. Transects are shown on the FIRM panels and depicted in the Transect Location Maps (Figure 2).

The Wave Height Analysis for Flood Insurance Model version 4.0 (WHAFIS 4.0) was used to quantify flood risks along shallow shorelines which may be inundated during high

water events. Along these shorelines, flood risk is a function of the wave crest elevation; which is defined as the sum of the still water level and the portion of the wave above the still water level. As waves propagate over shallow water, the wave height may increase due to the force applied by the wind, or decrease due to depth limitations or dissipative interactions with vegetation and buildings. These processes are accounted for in WHAFIS 4.0.

The 3.2 ft NAVD88 contour was used as the baseline for the WHAFIS transect analyses. This is at approximately the mean sea level for San Francisco Bay. In Atlantic and Gulf Coast studies, the origin of the WHAFIS transect is set to the 0 ft NAVD88 contour. In the San Francisco Bay study area, the 0 ft NAVD88 contour is just below mean lower low water. The LiDAR data only provides topographic information above water levels and the available bathymetric surveys do not meet FEMA standards for flood mapping; hence, the 0 ft NAVD88 contour cannot be accurately identified. The LiDAR provides a relatively accurate location for the 3.2 ft NAVD88 contour. The 3.2 ft NAVD88 contour is the approximate elevation where the low marsh begins and is identifiable on aerial imagery as the interface between marsh vegetation and mudflat or open water. WHAFIS 4.0 is a steady state, wave propagation model which does not account for temporal variation in water level, waves, or wind. The model was developed to simulate overland wave propagation during floods and calculates the spatially variable wave height along a given transect. WHAFIS 4.0 requires user input to specify offshore wave conditions at the start of each transect, ambient wind conditions occurring with the wave and water levels, and land surface characteristics along the transect. Default parameters can be used to specify windspeeds and waves propagating onshore up the transect, however these default values are based on Atlantic Coast studies and are unsuitable for Pacific Coast studies.

Runup was calculated for transects where no significant attenuation occurs between the DHI model output node and the point of wave breaking. Runup was calculated using two methods, depending on shoreline characteristics. The Direct Integration Method (FEMA, 2005) was used to calculate runup for transects with natural, gently sloping ($m < 0.125$) profiles. The Technical Advisory Committee for Water Retaining Structures (TAW) (van der Meer, 2002) method was used for shorelines with structures and steeply sloping ($m > 0.125$) natural shorelines. In both cases, the parametric DIM equations are used to compute static and dynamic wave setup. This follows the procedures outlined by FEMA (2005) and is consistent with the methodology applied in Central San Francisco Bay.

Because FEMA (2005) does not recommend a particular approach for determining runup on vertical structures, the Shore Protection Manual (SPM) method (USACE 1984) as recommended in FEMA's Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update (FEMA 2007), was therefore used to calculate wave runup on vertical walls. The approach utilizes the unrefracted deepwater wave height, wave period, and depth at the toe of the structure to determine runup. The relationships utilize mean wave height to calculate mean runup values, which requires manipulation of computed unrefracted significant wave height, and an adjustment of the mean runup from the relationship to calculate the 2% runup. As recommended by FEMA (2007), the mean wave height was determined to be $0.626H_0$, the mean wave period was adjusted to be $0.85T_p$, and the mean runup was multiplied by 2.2 to provide the 2% runup. Annual TWL (i.e., total runup elevation,) maxima were selected from the 31 years (1973-2003) of hindcast data, and the generalized extreme value (GEV) distribution was employed to determine the 1-percent-annual chance TWL from the annual maxima at each transect.

Wave overtopping was evaluated for transects where the runup elevation exceeded the structure or bluff crest. Overtopping occurs when the computed total water level exceeds the runup slope crest. Overtopping is classified as bore, splash, or spray overtopping depending on the dynamic water level, total water level, and profile crest elevation. Hazards are based on overtopping depth and overtopping velocity. The methods outlined in FEMA (2005) were followed to identify these hazards.

10.2 Coastal Floodplain Boundaries

For this FIS, new flood zones were developed and mapped for the updated North and Central San Francisco Bay coastal hazard analysis described in the above FIS Sections. Detailed flood hazard boundaries along San Francisco Bay were delineated using the National Oceanic and Atmospheric Administration (NOAA) 2010 Northern San Francisco Bay Area LiDAR, collected in February-April, 2010 (NOAA, 2010). Areas inundated by stillwater flooding with minimal wave hazard effects were mapped as Zone AE and the flood hazard boundary is located at the point where the ground elevation equals the stillwater elevation. In areas subject to wave runup, the flood hazard boundary is located at the point where the ground elevation equals the runup elevation, or where overtopping occurs, the boundary is located at the inland extent of overtopping. The Base Flood Elevation (BFE) in these areas is rounded to the nearest whole-foot, though the boundary is mapped using precision to the tenth of a foot. Inundation flooding is mapped inland to the point where it meets continuous high ground or encounters flooding from another flooding source. Salt marsh berms are not considered barriers to flood inundation regardless of height or continuity.

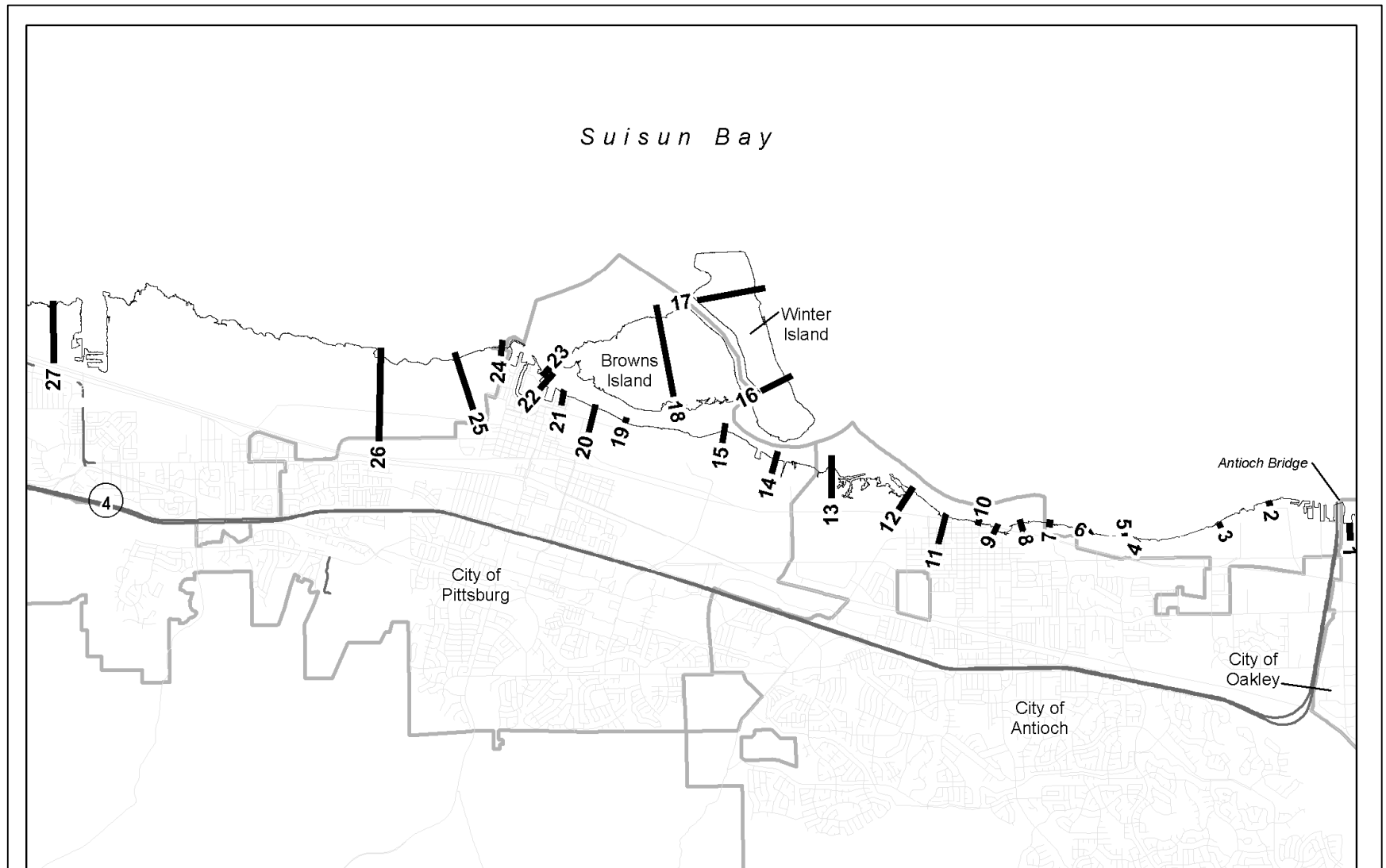
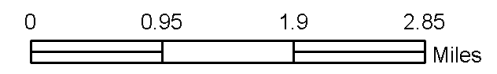


FIGURE 2

FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CALIFORNIA



TRANSECT LOCATION MAP 1

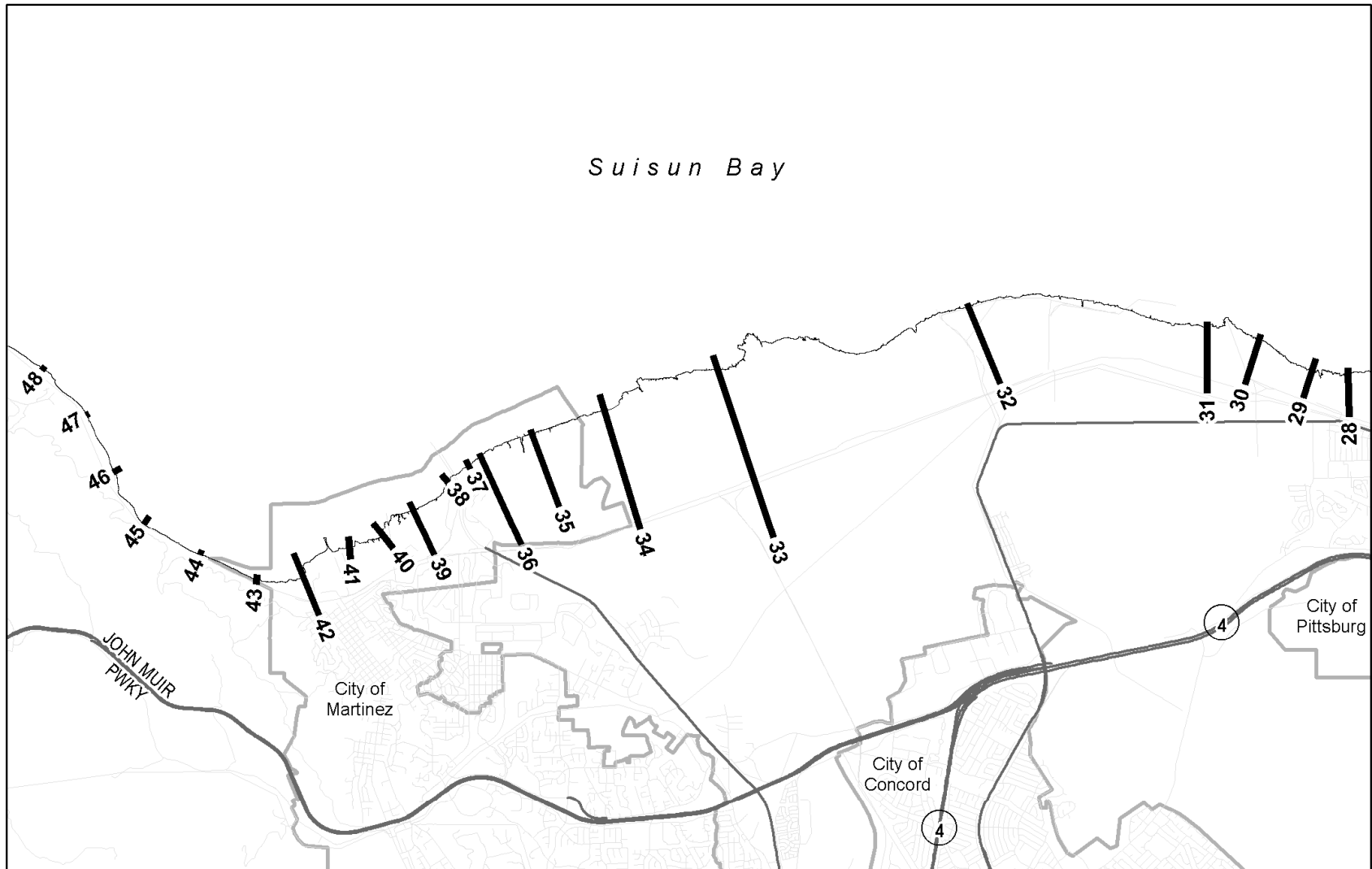


FIGURE 2	FEDERAL EMERGENCY MANAGEMENT AGENCY CONTRA COSTA COUNTY, CALIFORNIA	0 0.95 1.9 2.85 Miles	
	TRANSECT LOCATION MAP 2		

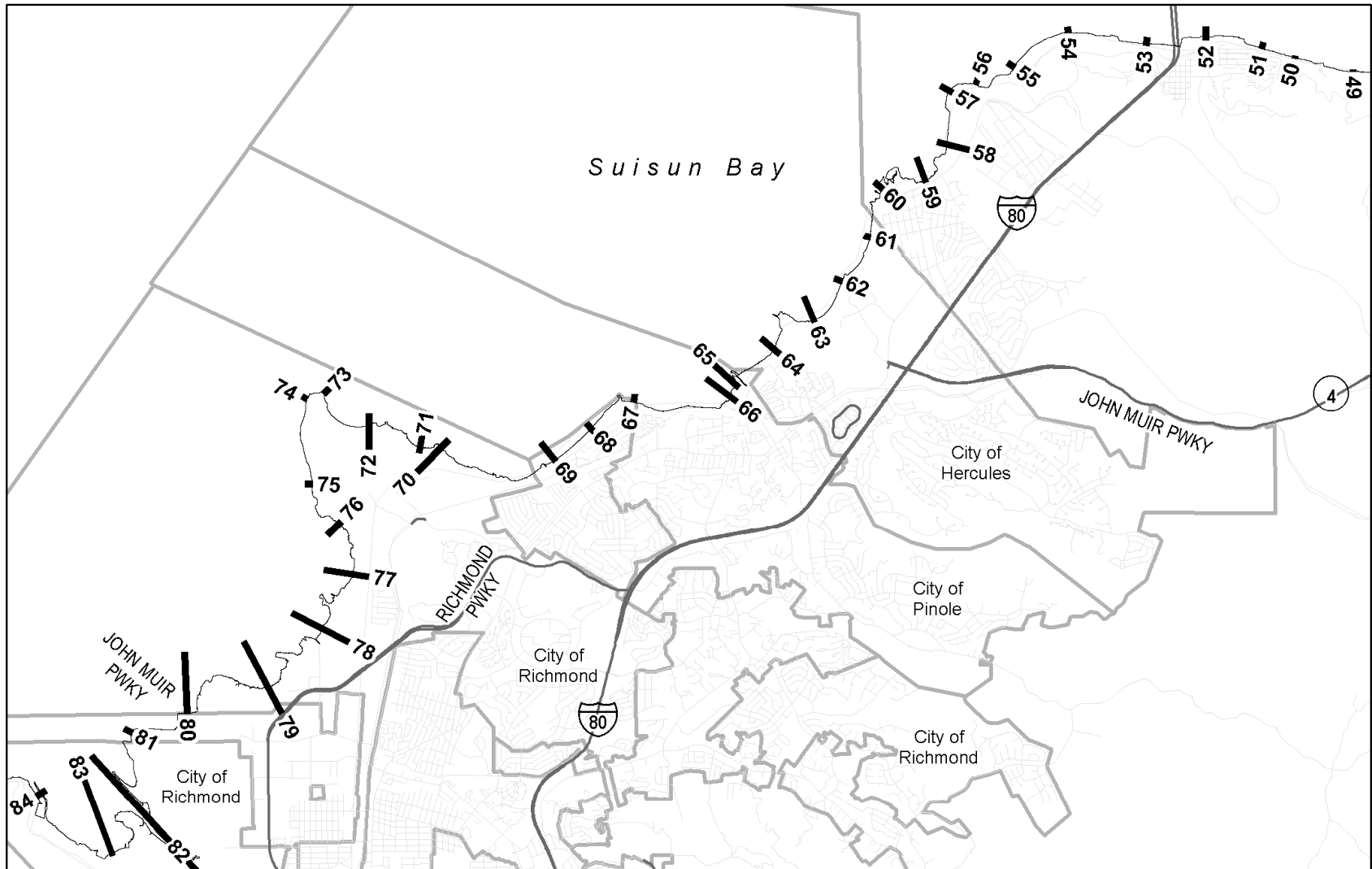


FIGURE 2	FEDERAL EMERGENCY MANAGEMENT AGENCY CONTRA COSTA COUNTY, CALIFORNIA	0 0.95 1.9 2.85 Miles	
	TRANSECT LOCATION MAP 3		

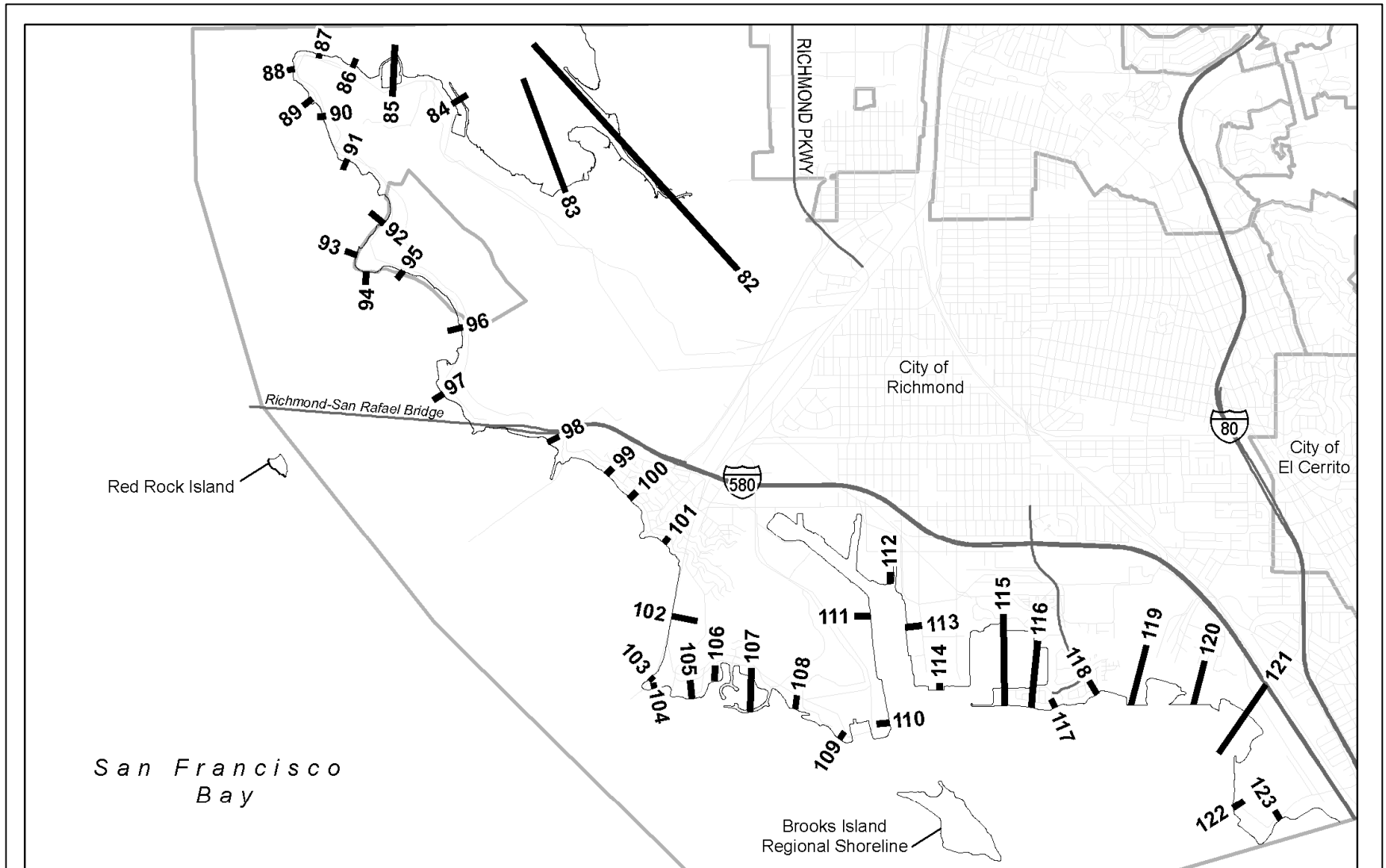
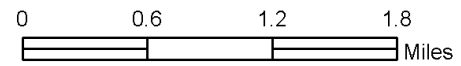


FIGURE 2

FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CALIFORNIA



TRANSECT LOCATION MAP 4

Table 15: Transect Data Table

Transect	XY Coordinates (Meters, NAD83 UTM Zone 10N)		Stillwater Elevation (feet NAVD 88) ¹				Zone	BFE
			10% Annual Chance*	2% Annual Chance*	1% Annual Chance	0.2% Annual Chance		
1	6201736.0311	2195109.0153			14	20.4	AE	14
2	6197906.3412	2196308.6480			14	19.3	AE	14
3	6195441.1732	2195330.3615			14	18.5	AE	14
4	6191570.4423	2194587.9680			13	17.6	AE	13
5	6190915.0285	2194940.7920			13	17.4	AE	13
6	6189358.5967	2195075.5337			13	17.3	AE	13
7	6187347.1251	2195687.4433			13	17	AE	13
8	6185885.3972	2195733.0429			13	16.8	AE	13
9	6184865.2549	2195544.1653			13	16.8	AE	13
10	6183973.5572	2195801.1530			13	16.6	AE	13
11	6182366.2307	2196088.9745			13	16.5	AE	13
12	6180822.5465	2197433.5316			12	15.1	AE	12 ²
13	6176938.4991	2199035.7594			12	15.4	AE	12
14	6174349.6086	2199312.2028			12	14.9	AE	12
15	6171875.6484	2200736.2481			11	13.6	AE	11
16	6167160.3363	2201129.4560			11.1	13.2	AE	11
17	6165664.1450	2201802.0596			11.1	13.2	AE	11
18	6164180.8767	2202532.1732			11.0	13.2	AE	11
19	6163691.9705	2203336.1773			11.0	13.2	AE	11
20	6163533.2766	2203623.3158			11	13.2	AE	12 ²
21	6161273.9307	2204998.7396			10.9	12.9	AE	11
22	6158946.4419	2204462.3562			10.8	12.9	AE	11
23	6155409.9661	2204757.2375			10.6	12.5	AE	11
24	6139739.2387	2207430.3814			10.1	11.6	AE	10
25	6137538.8895	2207440.8245			10.1	11.6	AE	10
26	6136042.4523	2207924.4883			10.1	11.6	AE	10
27	6133495.9351	2209141.2510			10.0	11.5	AE	10
28	6130982.3772	2209768.0992			10.0	11.3	AE	10
29	6119765.6148	2210925.3354			9.7	10.8	VE	13 ²
30	6107810.9143	2208817.6296			9.5	10.6	AE	10
31	6102460.8457	2207141.4689			9.5	10.5	AE	10
32	6099160.8891	2205574.9582			9.5	10.5	AE	10
33	6096721.7078	2204544.0300			9.4	10.4	AE	9
34	6096106.1955	2204236.2739			9.4	10.4	AE	9
35	6094951.7724	2203594.3503			9.4	10.3	VE	12 ²
36	6093392.5048	2202349.9260			9.4	10.4	AE	9
37	6091669.5424	2201397.8610			9.4	10.4	AE	9
38	6090520.9226	2200763.1838			9.4	10.4	AE	10 ²
39	6087906.2953	2200068.1064			9.5	10.4	AE	10
40	6086183.3329	2199116.0414			9.5	10.4	AE	10
41	6083636.7828	2200332.8041			9.4	10.3	VE	10 ²
42	6081218.7759	2201995.3992			9.4	10.3	AE	10 ²
43	6079949.3558	2204292.6715			9.4	10.3	VE	13 ²
44	6078521.3075	2206877.1151			9.4	10.3	AE	10 ²
45	6076518.9165	2209144.2038			9.4	10.3	AE	10 ²
46	6073239.2177	2210351.3669			9.4	10.3	AE	9
47	6070564.3680	2211101.6802			9.4	10.3	AE	9 ²
48	6069068.2096	2211774.3166			9.4	10.3	AE	10 ²
49	6066393.1822	2212545.2140			9.4	10.4	VE	11 ²
50	6063619.8937	2212137.3080			9.5	10.5	AE	10

Table 15: Transect Data Table, continued

Transect	XY Coordinates (Meters, NAD83 UTM Zone 10N)		Stillwater Elevation (feet NAVD 88) ¹				Zone	BFE
			10% Annual Chance*	2% Annual Chance*	1% Annual Chance	0.2% Annual Chance		
51	6059924.7240	2212719.3606			9.6	10.5	VE	10 ²
52	6057053.1090	2211132.6184			9.6	10.6	VE	11 ²
53	6055637.8165	2210392.1544			9.6	10.7	AE	10
54	6053864.1718	2210120.1861			9.7	10.7	VE	12 ²
55	6053655.3392	2207525.5625			9.8	10.8	VE	13 ²
56	6052677.5928	2206840.6979			9.8	10.9	VE	12 ²
57	6050667.4918	2205729.9717			9.8	10.9	VE	13 ²
58	6050107.9620	2203233.1379			9.9	11	VE	13 ²
59	6048649.6153	2201241.4308			9.9	11	VE	12 ²
60	6047213.8242	2200448.0597			9.9	11.1	VE	12 ²
61	6045142.9352	2198535.6465			9.9	11.1	AE	11 ²
62	6042936.6018	2197334.9426			9.9	11.2	AE	11 ²
63	6042520.9530	2196730.4491			9.9	11.1	AE	10
64	6039181.5235	2196046.8228			9.9	11.2	VE	12 ²
65	6036856.1614	2194756.4619			9.9	11.2	VE	11 ²
66	6034707.2547	2193912.2132			9.9	11.2	AE	10
67	6030437.7751	2194176.9109			9.9	11.1	AE	10
68	6029176.5431	2194391.6577			9.9	11.1	VE	14 ²
69	6026712.4216	2195491.9673			9.9	11.1	AE	10
70	6024898.8754	2196738.9136			9.9	11.1	VE	12 ²
71	6023591.5617	2196391.3749			9.9	11.1	VE	16 ²
72	6023614.0354	2192280.5564			9.8	11	VE	15 ²
73	6024596.2513	2189824.5902			9.8	11	VE	13 ²
74	6024369.4801	2188199.9543			9.8	10.9	AE	10
75	6022835.3624	2186227.7470			9.8	11	AE	10
76	6020538.0901	2184958.3597			9.8	11	AE	10
77	6017764.7689	2184550.4209			9.8	11	VE	12 ²
78	6014825.0766	2181051.8715			9.8	11	VE	12 ²
79	6013260.7753	2179812.6679			9.7	10.9	AE	10
80	6012911.4446	2178728.4793			9.7	10.9	VE	12 ²
81	6011122.1641	2178256.1094			9.7	10.9	AE	10 ²
82	6008839.7478	2179910.5747			9.7	10.8	AE	10
83	6007599.6737	2179508.6725			9.7	10.9	VE	16 ²
84	6006502.0478	2179941.7476			9.7	10.8	VE	17 ²
85	6005356.4932	2179193.4106			9.7	10.8	VE	11 ²
86	6006158.9775	2178263.7198			9.7	10.8	VE	15 ²
87	6006296.1502	2177673.9603			9.7	10.8	VE	14 ²
88	6007071.3819	2175967.8976			9.7	10.8	VE	14 ²
89	6007895.3005	2174598.8660			9.7	10.8	VE	12 ²
90	6007064.0029	2173389.8461			9.7	10.8	VE	12 ²
91	6007698.7129	2172241.1936			9.7	10.8	VE	13 ²
92	6008704.8895	2172411.9581			9.7	10.8	VE	12 ²
93	6010273.5696	2170707.8491			9.7	10.8	VE	13 ²
94	6009761.4713	2168508.0974			9.7	10.8	VE	13 ²
95	6175162.9121	2202927.5167			12.0	15.1	AE	12
96	6173961.6350	2207136.6290			11.8	14.7	AE	12
97	6168702.1639	2206479.4781			11.0	13.2	AE	11

¹ North American Vertical Datum of 1988

² Wave runup elevation

* Data Not Available

Table 15: Transect Data Table, continued

Transect	XY Coordinates (Meters, NAD83 UTM Zone 10N)		Stillwater Elevation (feet NAVD 88) ¹				Zone	BFE
			10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance		
98	552625.3146	4198338.8249	8.4	9.3	9.8	11.0	VE	16 ²
99	553196.4329	4198025.7818	8.4	9.3	9.8	11.1	VE	18 ²
100	553426.2641	4197788.1146	8.4	9.3	9.8	11.1	VE	16 ²
101	553760.9686	4197345.9841	8.4	9.3	9.7	11.1	VE AE	11 10 ²
102	553836.0504	4196638.5139	8.4	9.3	9.7	11.0	VE AE	12 ² 10
103	553627.5344	4196050.7281	8.4	9.3	9.7	11.0	AE	11 ²
104	553667.8486	4195938.5400	8.4	9.3	9.8	11.1	VE	12 ²
105	554031.1498	4195832.6660	8.4	9.3	9.8	11.2	VE AE	11 ² 10
106	554251.4764	4196003.3665	8.4	9.3	9.8	11.2	AE	10
107	554600.1475	4195706.2580	8.4	9.3	9.8	11.2	VE AE	13 ² 10
108	555036.9054	4195737.3338	8.4	9.4	9.8	11.2	VE	13 ²
109	555472.4478	4195445.7763	8.4	9.4	9.8	11.2	VE	13 ²
110	555961.3234	4195600.9992	8.5	9.4	9.9	11.4	AE	11 ²
111	555774.9812	4196641.4220	8.5	9.4	9.9	11.4	AE	10
112	555967.7760	4196952.5811	8.5	9.4	9.9	11.4	AE	11 ²
113	556114.2538	4196530.0291	8.5	9.4	9.9	11.4	AE	11 ²
114	556445.4135	4195919.4990	8.5	9.4	9.9	11.4	VE	13 ²
115	557080.6402	4195768.6942	8.5	9.4	10.0	11.4	VE AE	13 ² 10
116	557340.3272	4195751.7732	8.5	9.5	10.0	11.4	VE AE	13 ² 10
117	557571.9608	4195747.9598	8.5	9.5	10.0	11.4	VE	12 ²
118	557981.5629	4195879.8137	8.5	9.5	10.0	11.4	AE	11 ²
119	558309.5089	4195774.1294	8.5	9.5	10.0	11.4	VE AE	12 11-10
120	558923.2289	4195778.3581	8.5	9.5	10.0	11.4	VE AE	12 10
121	559165.9727	4195305.6504	8.5	9.5	10.0	11.4	VE AE	12 10
122	559307.3626	4194770.7448	8.5	9.4	10.0	11.4	VE AE	12 ² 10
123	559766.2796	4194654.0848	8.5	9.5	10.0	11.5	VE	12 ²

¹North American Vertical Datum of 1988²Wave runup elevation

10.3 Second Revision – Riverine Analyses

Detailed hydrologic and hydraulic studies were done on Marsh Creek, Frisk Creek, Brushy Creek, Kellogg Creek, and Mt. Diablo Creek. This study was performed by BakerAECOM (the study contractor) under Contract No. HSFHQ-09-D-0368 Task Order No. HSFE09-09-J-0001. The study was completed in August 2014.

The Marsh Creek study reach is approximately 9.1 miles long, has an approximately 0.2 percent longitudinal slope, and is vegetated for its entire length. The entire watershed is approximately 90 square miles with approximately 75% of the watershed agricultural or

open space and the other approximately 25% developed residential or commercial lands. The agricultural and open space lands are concentrated at the headwaters of Marsh Creek with residential development along the downstream portion near the bay.

The Brushy Creek study reach is approximately 5.7 miles long. The creek begins in the Canada de los Vaqueros hills near the border of Contra Costa and Alameda Counties and flows in a generally north to northeast direction until its confluence with Clifton Court Forebay. The watershed is approximately 16.4 square miles and is composed mostly of public lands/open space, agricultural lands and some low density residential development. The Byron Airport is located within the Brushy Creek watershed.

The Frisk Creek study reach is approximately 3.8 miles long. The creek begins in the Canada de los Vaqueros hills and flows in a generally north to northeast direction until it reach the east side of Byron Highway where it turns and flows due north to its confluence with Discovery Bay. The watershed is approximately 12.2 square miles and is composed mostly of public lands/open space, agricultural lands and some low density residential development. The community of Byron is located in the Frisk Creek watershed.

The Kellogg Creek study reach is approximately 6.4 miles long. The Los Vaqueros Reservoir is a drinking water storage reservoir that also captures the upstream flows from Kellogg Creek. Kellogg Creek flows in a generally northern direction until just south of Marsh Creek Road (Highway 4) where it turns to the south and then flows east through a manmade watercourse to its confluence with Discovery Bay. The watershed is approximately 32.2 square miles and is composed mostly of public lands/open space, agricultural lands and some low density residential development.

Mt. Diablo Creek study reach, which is approximately 9.3 miles long, starts in the Mount Diablo State Park and flows to the northwest to its confluence with Suisun Bay. The watershed is located in the City of Concord and Contra Costa County and encompasses land that was part of the former Concord Naval Weapons Base. That base has been decommissioned and will eventually become property of the City of Concord and the county. The watershed is 32.7 square miles and consists of residential and commercial lands in the headwaters and open space on the former Concord Naval Weapons Base lands. Mt. Diablo Creek was studied previously by FEMA but that study ended at Bailey Road and did not show any flood hazards on the Naval Weapons Base.

Hydrologic Analyses

Hydrologic analyses were performed to establish peak discharge-frequency relationships for Marsh Creek, Frisk Creek, Brushy Creek, Kellogg Creek, and Brushy Creek. Specifically, peak discharge values for the 10-, 50-, 100-, and 500-year recurrence intervals were developed as part of the hydrologic studies done by BakerAECOM. Flood hydrographs and peak discharge values for the aforementioned flood events were performed using the US Army Corps of Engineers (USACE) HEC-HMS, version 3.1.0 computer modeling program.

Precipitation data for the 10-, 50-, 100-, and 500-year, 24-hour storms were provided by Contra Costa County Flood Control District. The Natural Resource Conservation Service (NRCS) Type 1 synthetic rainfall pattern was used to distribute these precipitation totals. Land use was determined by reviewing orthophotography and existing land use GIS shape files provided by Contra Costa County. The soil moisture accounting loss method was used and the County provided BakerAECOM with a conversion chart that links landuse with the minimum, average and maximum infiltration rates and the area weighted average infiltration rate was calculated based on this data. The initial infiltration loss was set to the County standard of 0.25 inches. The user specified S-curve option was used in HEC-HMS and the County provide an S-curve that was developed in a 1971 study of Walnut Creek by the Corps of Engineers. This is the County standard. The Muskingum-Cunge 8-point method was used to route and attenuate the hydrographs through the study reaches.

The County provided a HEC-HMS model for Marsh Creek that was modified as necessary to use the rainfall noted above and also to reflect existing landuse conditions. Additionally, the stage-storage-discharge curves for some of the stormwater detention ponds were edited to reflected existing conditions.

For all the approximate study streams, the hydrologic analyses were performed using the U.S. Geological Survey (USGS) regression equations documented in USGS Scientific Investigations Report (SIR) 2012-5113. The peak discharge value for the 100 year recurrence interval was calculated using 1-percent annual chance regression equation given for North Coast Region 1. It was found that equation 1 from USGS SIR 2012-5113 systematically underestimated the 1-percent chance discharge for ungaged (studied) streams in Contra Costa County based on comparisons with gaging station estimates. The regression and gaging station estimates differ by 50 percent, on average. Therefore, the recommendation is to multiply the regression estimates from Equation 1 by 1.5 to account for the bias. The drainage area was calculated using the terrain data obtained from USGS. The mean annual precipitation for the drainage area was calculated using the 800-meter resolution PRISM data developed by Oregon State University.

Hydraulic Analyses

For the February 2012 study in Contra Costa County, field survey data were collected by Harned Surveying and Engineering, Inc. in November 2010 and included structure geometric data and surveyed contraction and expansion cross sections and cross sections at approximately every 1000 feet. This data was supplemented with 2-foot contour data provided by Contra Costa County for all study reaches. Topographic data provided by Contra Costa County was derived from aerial photogrammetric surveys performed in 2008. All invert elevations, culvert diameters and bridge geometries were measured in the field by Harned Surveying and Engineering, Inc.

For all study areas best engineering judgment, utilizing aerial and field survey photos, was used to determine channel and floodplain Manning's 'n' roughness values. The channel roughness coefficient for Brush Creek, Kellogg Creek, and Frisk Creek were 0.03. Roughness coefficients for Mt. Diablo Creek were between 0.03 and 0.05. Roughness coefficients for Marsh Creek ranged between 0.035 and 0.08.

In the overbank areas, roughness coefficients for Brush Creek and Kellogg Creek were 0.035. The overbank roughness coefficient for Frisk was 0.045. The overbank roughness coefficients for Mt. Diablo Creek ranged between 0.035 and 0.08. The overbank roughness coefficients for Marsh Creek ranged between 0.04 and 0.2.

Normal depth was used as the downstream boundary condition for Brushy Creek and Mt Diablo Creek in the February 2012 study. The downstream boundary condition for Frisk was critical depth and the downstream boundary condition for Kellogg Creek was a known water surface elevation for the San Joaquin River at Byron Tract. The downstream boundary conditions for Marsh Creek was a constant stage hydrograph using the effective elevations for the San Joaquin River at Marsh Creek. The slope was measured as the bed slope between the two downstream cross sections.

For the streams studied by detailed methods, water surface profiles for each reach were computed in HEC-RAS version 4.1 for the 10%-, 2%-, 1%-, and 0.2%-annual-chance flood events.

The HEC-RAS hydraulic models were executed under the assumption of subcritical flow to produce the most conservative water surface elevations.

Brushy Creek

Brushy Creek was studied by detailed methods from just downstream of Vasco Road to approximately 1,600 feet upstream of Byron Highway. Approximate methods were used to study three breakout flow locations, as well as the area between 1,600 feet upstream of Byron Highway and Italian Slough.

Cross sections were cut on the County's LiDAR terrain data. This geometric information was augmented using survey data collected in November and December of 2010. Structures in the detailed study area were also surveyed in 2010.

Manning's 'n' roughness values for Brushy Creek range from 0.030 to 0.035. These low values are indicative of the arid sandy terrain, with little to no vegetation.

Normal depth was used as the downstream boundary condition for Brushy Creek. The slope was measured as the bed slope between the two downstream cross sections in the hydraulic model.

Generally, the channel is quite small and carries only a small portion of large flooding events. Most flow during large flooding events (such as the 1% annual chance flood) flows over the flat, unchanneled terrain. As such, the floodplain is quite wide. In some areas, flow may escape the channel and break out in other directions. Three specific breakout flow locations were observed in the mapping and modeling of Brushy Creek.

- Breakout 1 is located just downstream of Armstrong Road. Flow in Breakout 1 flows east, skirting the Byron Airport to the South and eventually meeting the California Aqueduct near the Byron Highway.

- Breakout 2 is located just east of the Byron Airport hangars. Breakout 2 flows southeast, meeting up with Breakout 1.

- Breakout 3 is caused by the elevated embankments of the Byron Highway. Flow restricted by the embankments moves to the southeast, eventually joining up with Breakout 1.

Breakout flows were calculated using the Brushy Creek model by noting the flow distribution in the overbank for the cross section taken at the bifurcation point. It was assumed, for example, that all flow in the right overbank of cross section 24304 would break out to the right (Breakout 1). HEC-RAS performs these calculations using a form of Manning's equation. Breakout discharges were confirmed by comparing the upstream flood elevation of the breakout flows to the elevation on Brushy Creek at the bifurcation point. Since these two values closely matched, it was confirmed that the model was calculating an appropriate amount of breakout flow.

Lateral weirs were not used to model the breakout flows for any of the Brushy Creek breakouts because there is no physical feature resembling a weir in the vicinity of the split – each of which occur in broad, flat, wide open terrain. Sensitivity analysis revealed that lateral weir calculations would be entirely dependent on the location of the lateral weir, which would be arbitrary due to the terrain. Therefore, lateral weir calculations were not considered.

Some Zone X shaded areas were mapped as a part of the Breakout flow analysis. These areas are broad, unconfined, shallow flooding areas, with no discernable channel. These areas include just east of the Airport, and areas downstream of the Byron Highway (flooding caused by “without embankment” conditions on the Byron Highway). In each case, calculations were performed to document average flooding depth of less than one foot.

A floodway was also calculated for the detailed study area of Brushy Creek. Encroachment stations were determined using the equal conveyance reduction method. Floodway delineation was created using engineering judgment between modeled cross sections.

Frisk Creek

The hydraulic model for Frisk Creek begins just downstream of Byron Highway and continues to the confluence with Discovery Bay. A review of the topography along Frisk Creek shows that water will flow along the channel to the southeast where it will then pond before reaching a high enough elevation to start flowing north again. Additionally, just

upstream of Highway 4 the floodplains for Frisk Creek and Kellogg Creek can combine and pond together. In order to determine the impacts of storage upstream of Highway 4 the HEC-HMS model for Kellogg Creek was modified to include a reservoir that captured the inflows from both Frisk and Kellogg Creeks. An outflow curve was developed that incorporated flows under Highway 4 for both Frisk and Kellogg. The peak flows originally determined in the HEC-HMS models were modified in the HEC-RAS models to balance the flows under Highway 4 so that the elevation upstream of the highway was the same on both creeks.

To mimic this ponded situation with a 1 dimensional model Frisk Creek was modeled as two segments one from Byron Highway downstream to a large flat area where water will pond and then a second segment from the ponded area north to Discovery Bay. Along the channel running due north there is levee owned by the U.S. Bureau of Reclamation district 800. The levee is currently accredited and access to the property was denied by the surveyor crew for this project. Instead the top of levee data was obtained from the as-built plans submitted as part of a physical map revision to map the levee as accredited.

The model was first run to determine the water surface elevation along the north-south segment that runs from the ponded area down to Discovery Bay. The upstream elevation from this run was used as downstream boundary condition for the upstream segment of Frisk Creek that runs from Byron Highway downstream to the ponded area.

Cross sections and bridges were surveyed for the main channel of Frisk Creek. Since only the channel portions of the cross sections were surveyed some sections were extended using HEC-GeoRAS and the DEM provided by the county. From the aerial photos and survey photos it appears that Frisk Creek traverses mostly row crop farm fields and has a fairly open channel and the Manning's n values used ranged from 0.03 in the channel to 0.045 in the overbanks. Ineffective flow areas were set using best engineering judgment to prevent active flow in areas not accessible to floodwaters.

A floodway was calculated for Frisk Creek from just downstream of Byron Highway to the ponding area. The floodway is coincident with the floodplain from the ponding area to Highway 4 to maintain this area as storage and to maintain the necessary freeboard to accredit the levee.

Kellogg Creek

The hydraulic model for Kellogg Creek begins just downstream of Vasco Road and continues to the confluence with Discovery Bay. The main channel of Kellogg Creek appears to be the low flow channel with a large portion of the flow over topping the left bank of the creek creating a split flow situation. The overbank flow starts just downstream of Hoffman Road and a lateral structure on the left overbank was used to determine the amount of flow leaving the channel. The split flow path was determined through a review of the topography and aerial photos provided by Contra Costa County. The split flow path and the main channel floodplains merge just upstream of the Union Pacific Railroad but the flowpaths were assumed to flow through different bridge openings in the railroad and then converge just downstream of the Union Pacific Railroad bridge.

Cross sections and bridges were surveyed for the main channel of Kellogg Creek. Since only the channel portions of the cross sections were surveyed some sections were extended

using HEC-GeoRAS and the DEM provided by the county. The cross sections for the split flowpath were created using HEC-GeoRAS and the DEM. The split flowpath crosses underneath the Union Pacific Railroad and this opening was not surveyed. The cross sections upstream and downstream of the bridge (created from the DEM) appeared to provide sufficient information regarding the low chord information and the top of deck information was obtained from the DEM.

From the provided aerial photos the split flow path appears to traverse mostly farm fields of row crops and orchards and the Manning's n values used range from 0.04 to 0.55. Ineffective flow areas were set using best engineering judgment to prevent active flow in areas not accessible to floodwaters. From both the aerial photos and the survey photos the main channel traverses farm fields but in some areas the flow will be contained in the channel and the Manning's n values used range from 0.035 to 0.055. Downstream of the flow split point the channel experiences a naturally higher left bank. For these cross sections ineffective flow settings were used on the left overbank. Since most of the bridges were perched it was determined that there would be no appreciable expansion and contraction effects so the standard contraction/expansion coefficients of 0.1 and 0.3 were not changed.

After the initial model run it was determined that the overbank flooding was only going to be 1 to 3 feet deep and the majority of the overbank area to the north of the stream channel would be shallow flow. It was determined that part of the area can be designated Zone AO depth 2 if the community agrees. Moving downstream the Union Pacific Railroad results in a restriction to the overbank flow and the depths increase substantially so that area is designated Zone AE.

As noted above the floodplain for Kellogg Creek combines with the floodplain for Frisk Creek upstream of Highway 4. Similarly to Frisk Creek, the peak flows on Kellogg Creek were modified from the HEC-HMS results to incorporate the storage upstream of Highway 4.

A floodway was determined for the downstream portion of Kellogg Creek. A floodway was not calculated upstream of the Union Pacific Railroad because the left overbank area has a Zone AO shallow flooding designation and a floodway is not appropriate in a shallow flooding zone. Method 4 was used initially to estimate the floodway encroachment stations. The stations were then imported into Method 1 and adjusted as necessary to reduce the increase in water surface elevation and to create a smooth realistic floodway.

Mt. Diablo Creek

Mt. Diablo Creek was studied by detailed methods from just downstream of Kirker Pass Road to the BNSF Railroad Crossing (near the outlet to Suisun Bay). Detailed methods were also used to study three breakout locations: one near Sutherland Drive, one near Heather Drive, and one across the Navy Munitions Base.

Cross sections were cut on the County's LiDAR terrain data. This geometric information was augmented using survey data collected in November and December of 2010. Structures in the detailed study area were also surveyed in 2010. At certain locations where new survey data was not available, geometric data was taken from the effective model (from Questa Engineering's 2001 study).

Manning's 'n' roughness values for Mt. Diablo Creek range from 0.030 to 0.050 in the main channel, and from .035 to .080 in the overbank areas. This range of values consistent with the effective study and is indicative of some areas of arid sandy terrain, with little to no vegetation, and some areas of highly dense vegetation or urbanization.

Normal depth was used as the downstream boundary condition for Mt. Diablo Creek. Three breakout flow locations were determined along this reach of Mt. Diablo Creek. Total amount of flow breaking out was determined using lateral weir modeling. The breakouts are as follows:

- Sutherland Drive Split flow: Flow during extreme events on Mt. Diablo Creek will break away along Ayers Road and/or Manchester Court. Lateral weir calculations demonstrate that there may be interplay between these two streets (i.e., some flow that is carried off on Ayers Road may return to Mt. Diablo Creek via Manchester Court). Flow that escapes on these two arterials will be carried west along Sutherland Drive and Bonwell Drive, eventually joining up with the breakout flows on Heather Drive. This study shows that 1%-annual chance flows along these streets will average less than 1 foot depth.

- Heather Drive Split flow: Flow during extreme events on Mt. Diablo Creek will break away in the vicinity of Heather Drive. Flow will go south along Heather drive, cut through the residential area to heading towards Laverne Way, eventually making its way to Clayton Road and Galindo Creek. For the purposes of this study, mapping ties in with the effective Zone X shaded on Claycord Avenue. This study shows that 1% -chance annual flows along Heather Drive will be approximately 2 feet in depth, transitioning to less than one foot depth as the flows dissipate through the residential area.

Heather Drive Split is guarded in part by a non-levee embankment (on the left overbank of Mt. Diablo Creek near Heather Drive). Therefore, flow in Mt. Diablo Creek is not lower downstream of the breakout area, accounting conservatively for the possibility that all flow remains in Mt. Diablo Creek.

- Navy Munitions Base Split Flow: Beginning downstream of Bailey Road, flow may break out of the channel to the left, across the Navy Munitions Base. Flow across the munitions base will be broad, flat, and unconfined. This study shows that average 1%-annual chance flood depths will be less than 1 foot in depth. Flow will move in a West-Northwest direction, eventually making its way as sheet flow to the residential neighborhood to the west. For this study, the "Limit of Study" was set at the boundary of the Navy Munitions Base, but it is anticipated that flooding during extreme events may make its way through this inhabited area to the Farm Bureau Road Drain.

A floodway was also calculated for the detailed study area of Mt. Diablo Creek. Encroachment stations were determined using the equal conveyance reduction method. Floodway delineation was created using engineering judgment between modeled cross sections.

Marsh Creek

Marsh Creek was studied by detailed methods from its confluence with Dutch Slough to just upstream of Eureka Avenue. An unsteady HEC-RAS model of the majority of the reach was supplied by Contra Costa County. This model did not include all of the

structures observed on the aerial photos so Baker/AECOM surveyed all of the structures on the studied reach and included them in the model.

The model supplied by Contra Costa County was in the NGVD 29 datum so the first step was to convert the model to NAVD88. This was done by adding the conversion factor of 2.41 (from the effective FIS) to all elevations in the model. The County did not provide a GIS shapefile of the cross section cutlines so the model was first georeferenced as is and then exported to ArcGIS. A review of the stream centerline and cross sections against the aerial photos showed that both aligned well with the aerial photos so both were used as is.

The cross sections were extended as necessary to contain the flow. In areas where the channel part of the cross section appeared to be a manmade channel, the channel part was maintained with just the overbank part of the section extended. The overbank elevations were obtained from the DEMs provided by the County. Manning's n values were determined from aerial photos and ranged from 0.035 to 0.2. In areas of very dense residential development it was assumed that the houses would block the majority of the flow in the overbanks so ineffective flow settings were used to reflect this.

The downstream boundary condition used was a stage hydrograph with constant elevations taken from the Summary of Elevations table (Table 7) in the effective FIS for Contra Costa County. The 10, 2, 1, and 0.2 elevations used were the elevations for the San Joaquin River at Marsh Creek, 8.1, 8.8, 9.0 and 9.3 feet NAVD88, respectively.

The original model from the County included Dry Creek as a tributary but for this study that reach was separated from the main stem of Marsh Creek in order to include the footbridge that crosses Marsh Creek right at the confluence point. Since HEC-RAS cannot account for a structure right at the confluence point the inflow from Dry Creek was calculated in a separate model and included, conservatively, as a constant inflow into Marsh Creek.

Marsh Creek currently has levees on both the right bank and left bank at the downstream end of the creek. The left bank levee is not certified and it runs for about 1.3 miles starting just downstream of the Sante Fe railroad. The right bank levee is certified for about 2,400 feet from just downstream of the Sante Fe railroad to where it then meets the levee that runs along the right bank of the Contra Costa Canal (an irrigation canal). This levee was certified through LOMR case #06-09-BA94P. An approximate hydraulic analysis was estimated to determine the landside leveed area based on average depths of flooding that may occur if the levee was not providing protection from the base flood. The top of levee varies in elevation from approximately 22 to 20 feet while the BFEs vary from 19 to 16 feet along this reach. The landside ground elevations near the levee average approximately 12 feet along the same reach. Using the upstream BFE with the approximate depths, the area with reduced risk due to flooding was delineated.

The floodway was calculated by importing the peak flows and maximum stages for each cross section from the unsteady model into a steady state HEC-RAS model of Marsh Creek. The steady model was then run first using the Method 4 (equal conveyance) encroachment method and then converted to Method 1 with the encroachment stations modified to reduce surcharges greater than one and to increase negative surcharges. Floodway delineation was terminated at a point approximately 850-feet upstream of Balfour Road because both the 1% annual chance flood and the floodway are contained in

the channel. There are also some small negative surcharges still observed but these were deemed insignificant. The floodway was terminated just downstream of the Sante Fe Railroad bridge because no encroachment is possible due to the levees on both sides of the creek.

Approximate Studies

For all the approximate study streams, the hydraulic analyses were performed using the USACE HEC-RAS, version 4.1 software. Topographic data used to define the stream geometry consisted primarily of the 10-foot Digital Elevation Model (DEM) data derived from the 2-foot contours provided by Contra Costa County. Geometric data for all reaches were developed from the topographic information using the USACE HEC-GeoRAS program, Version 4.2.93 (Reference 4), and input into HEC-RAS for approximate model development. Culvert and bridge geometries were not included in the HEC-RAS model.

For all study areas best engineering judgment, utilizing aerial and field survey photos, was used to determine channel and floodplain Manning's 'n' roughness values.

Separate HEC-RAS models were created for each study area. Normal depth was used as the downstream boundary condition for all the approximate study streams in the June 2014 study. The slope was measured as the bed slope between the two downstream cross sections. The HEC-RAS hydraulic models were executed under the assumption of subcritical flow to produce the most conservative water surface elevations.

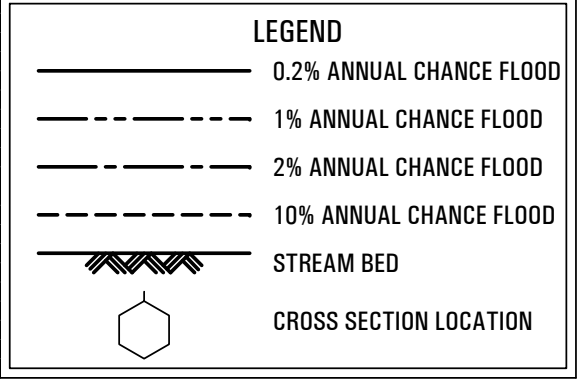
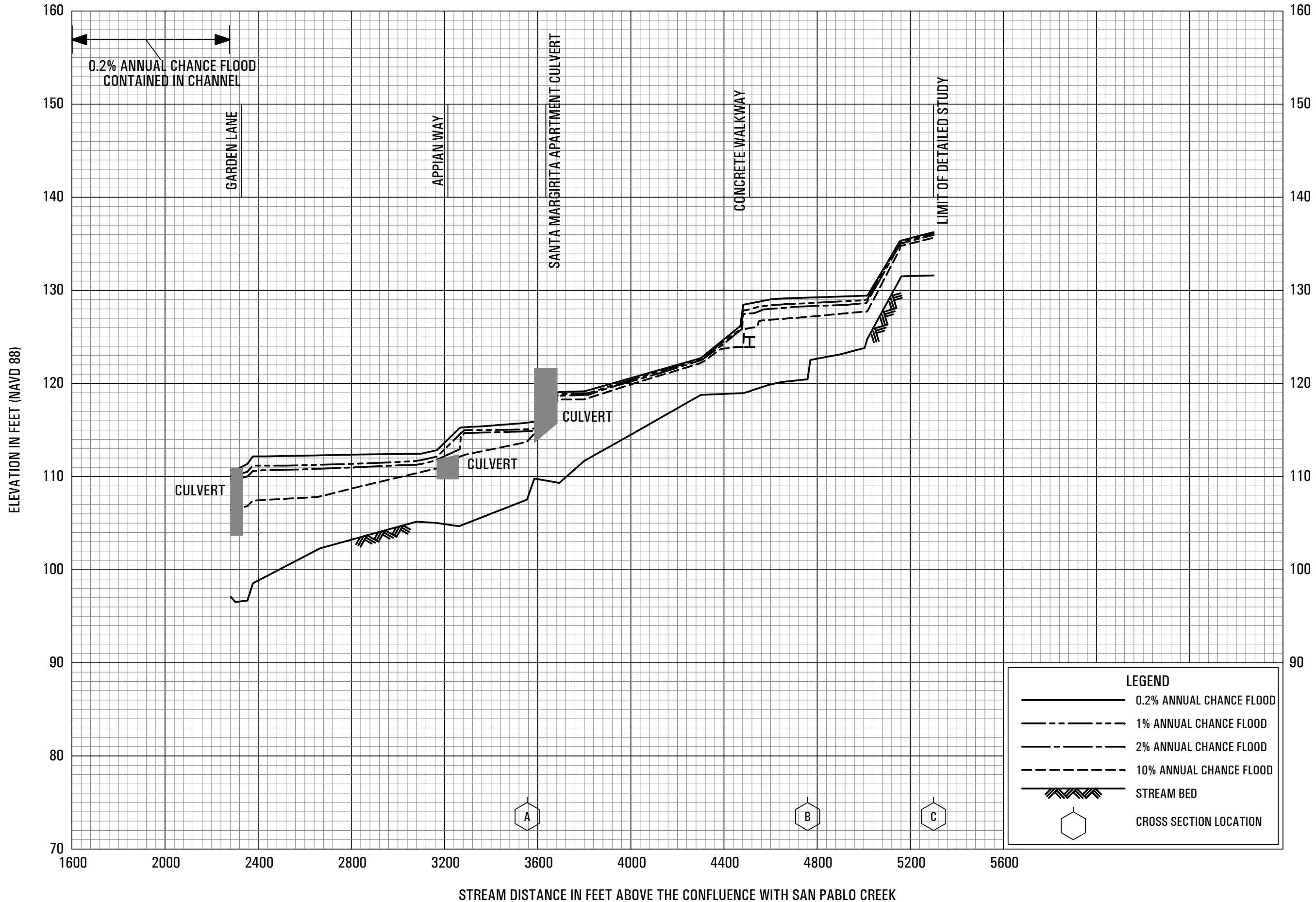
Floodplain and Floodway Mapping

For the February 2012 study in Contra Costa County, new flood zones were developed and mapped for the detailed study reaches described in Section 2.1. In addition, the flood profiles from the effective studies were used to redelineate flood hazards along Appian Creek, Arroyo Del Hambra Creek, East Branch Green Valley Creek, Galindo Creek, Green Valley Creek, Homestead Creek (aka Indian Creek), Las Trampas Creek, Mitchell Creek, Mt Diablo Creek, Mt Diablo Creek Split, West Branch Refugio Creek (aka Ohlone Creek), Pacheco Creek, Peyton Slough, Pinole Creek, Refugio Creek, Reliez Creek, Rodeo Creek, San Pablo Creek, San Ramon Creek, Sand Creek, Shore Acres Creek, Sycamore Creek, Tice Creek, Tice Creek Split, Tributary of Refugio Creek, Tributary of Sans Crainte Creek, Tributary of West Branch Green Valley Creek, West Branch Green Valley Creek, Walnut Creek, and Wildcat Creek.

Flood zones were delineated using a DEM developed from the 2-foot contour data from Contra Costa County. HEC-GeoRAS was used to post-process the model data from HEC-RAS and generate draft floodplain boundaries. The draft floodplain boundaries were reviewed by an engineer and model modifications were made where appropriate. Final floodplain boundaries were derived from manual adjustment of automated floodplain output using engineering judgment. A section of the effective special flood hazard area and floodway along Ohlone Creek was converted to an approximate zone during the redelineation process, in consultation with the Regional engineer, because the base flood elevations were below the updated channel topographic elevations, and the reach faces low development pressure.

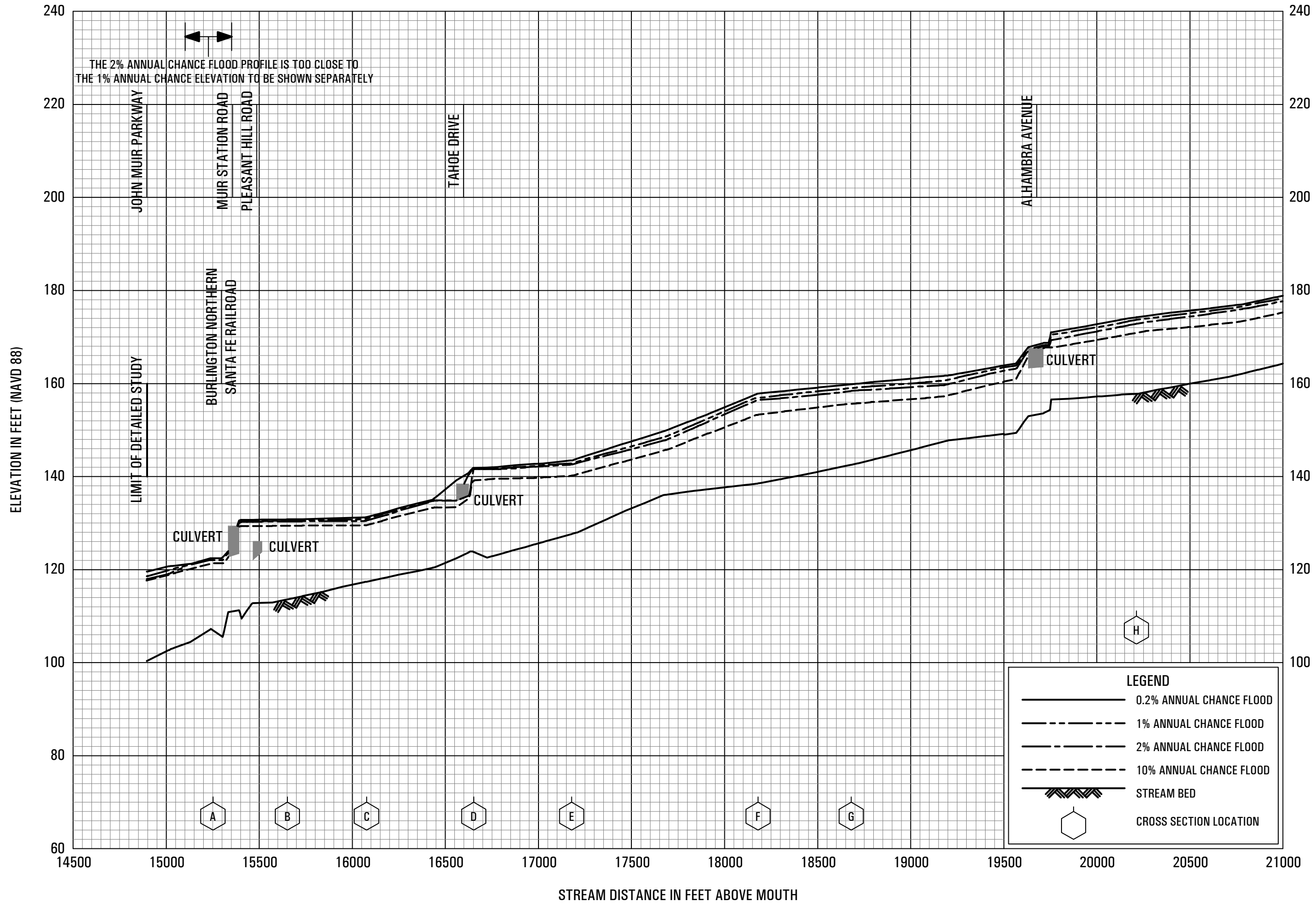
The 10%-, 2%-, 1%-, and 0.2%-annual-chance-flood profiles for all reaches studied by detailed methods were calculated within HEC-RAS and exported to RASPLOT (version 2.5) to develop FIS flood profiles.

Floodway Data Tables were created for the reaches studied by detailed methods. A floodway was calculated for the detailed study area of Brushy Creek. Encroachment stations were determined using the equal conveyance reduction method. Floodway delineation was created using engineering judgment between modeled cross sections. A floodway was computed for both segments of Frisk Creek with the pond area maintained as floodway. For the leveed segment of Frisk Creek the encroachments were set to prevent water from overtopping the levee. The floodway for Kellogg Creek was only calculated below the Union Pacific Railroad. A floodway was not calculated upstream of the Union Pacific Railroad because the left overbank area has a Zone AO shallow flooding designation and a floodway is not appropriate in a shallow flooding zone. A floodway was also calculated for the detailed study area of Mt. Diablo Creek. Encroachment stations were determined using the equal conveyance reduction method. Floodway delineation was created using engineering judgment between modeled cross sections. A floodway was calculated for Marsh Creek for the portion upstream of the Sante Fe Railroad Bridge. The floodway was terminated just downstream of the Sante Fe Railroad bridge because no encroachment is possible due to the levees on both sides of the creek.



FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
 AND INCORPORATED AREAS

FLOOD PROFILES
 APPLAN CREEK

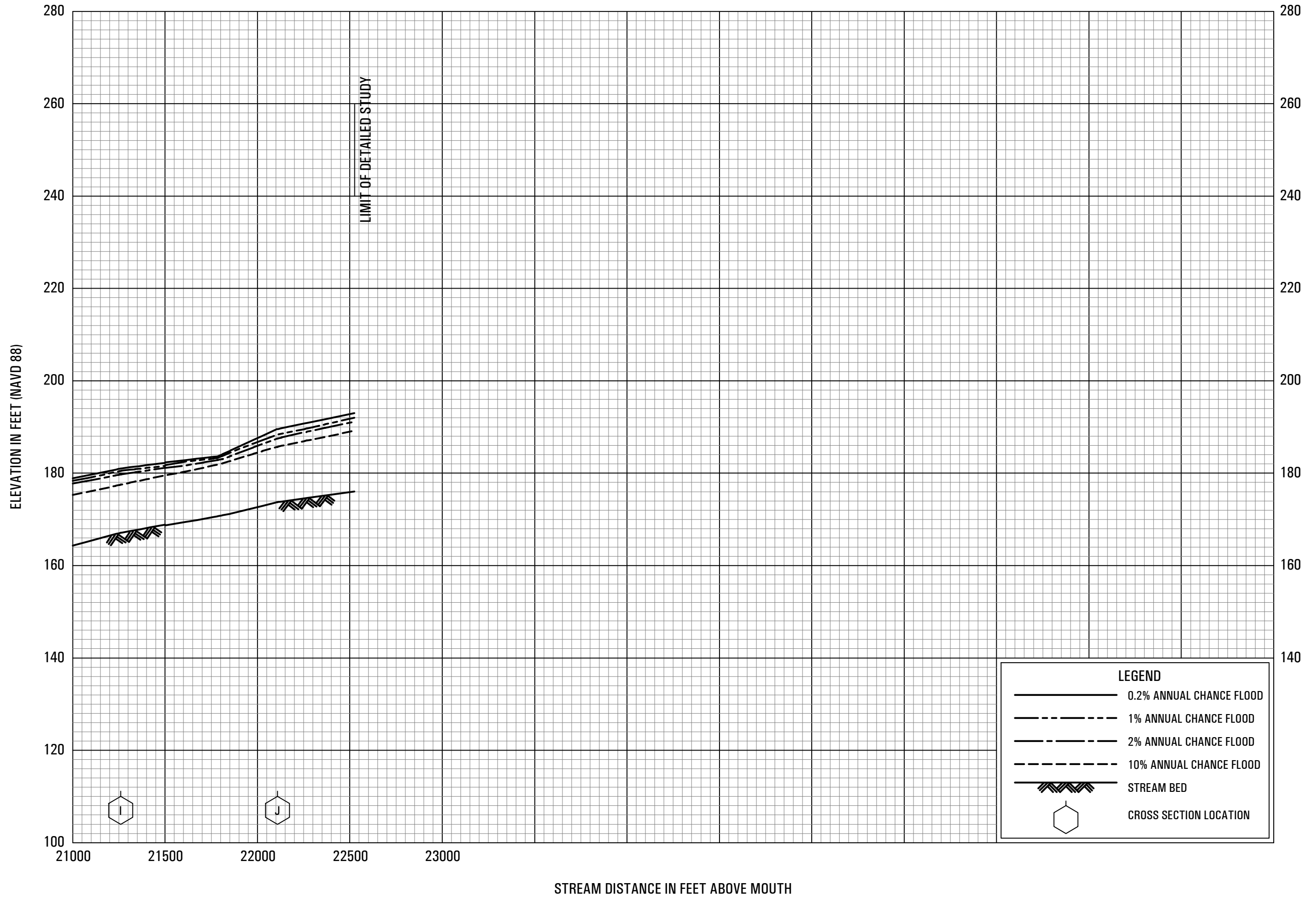


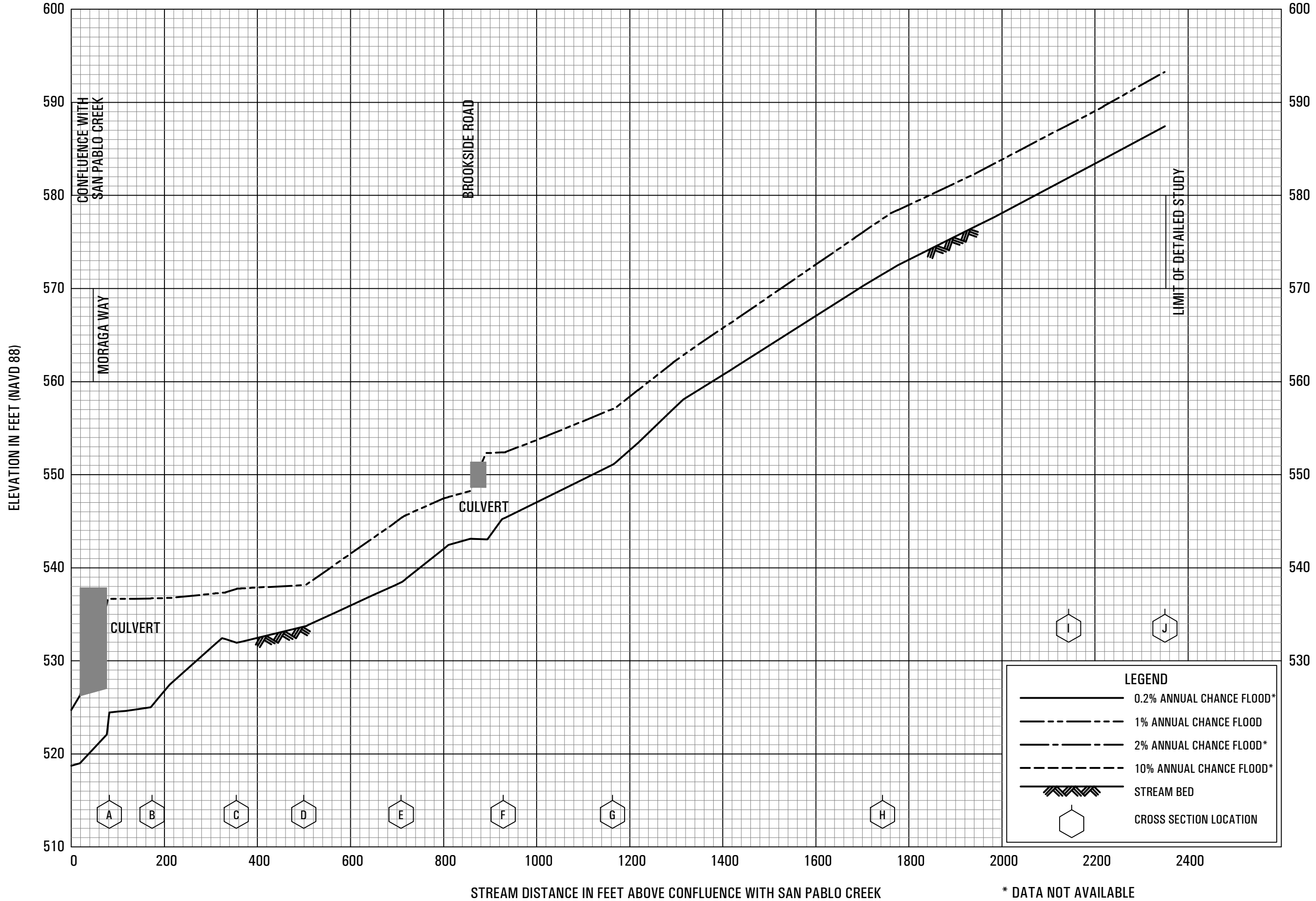
FLOOD PROFILES

ARROYO DEL HAMBRA CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
 AND INCORPORATED AREAS

03P



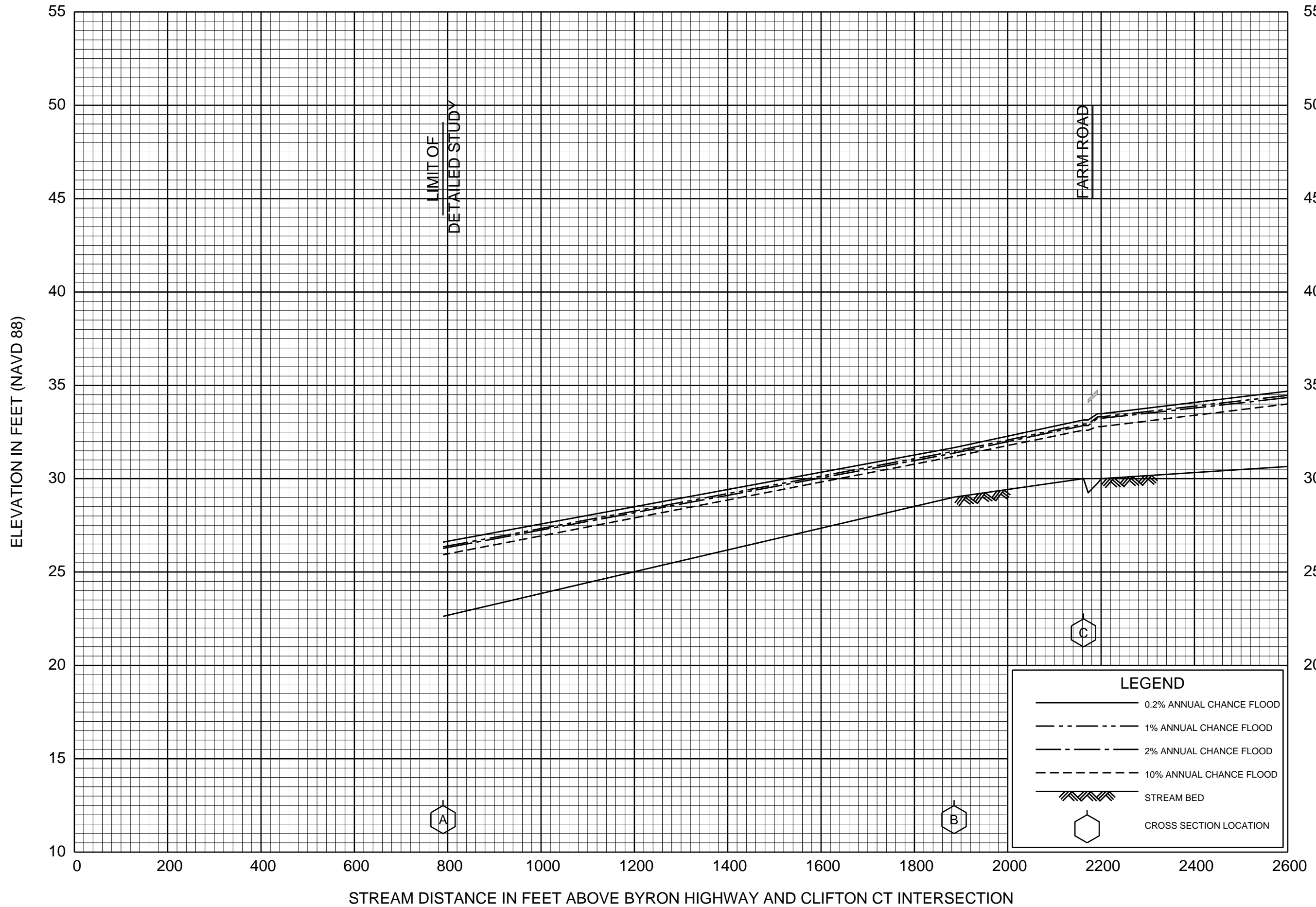


* DATA NOT AVAILABLE

FLOOD PROFILES

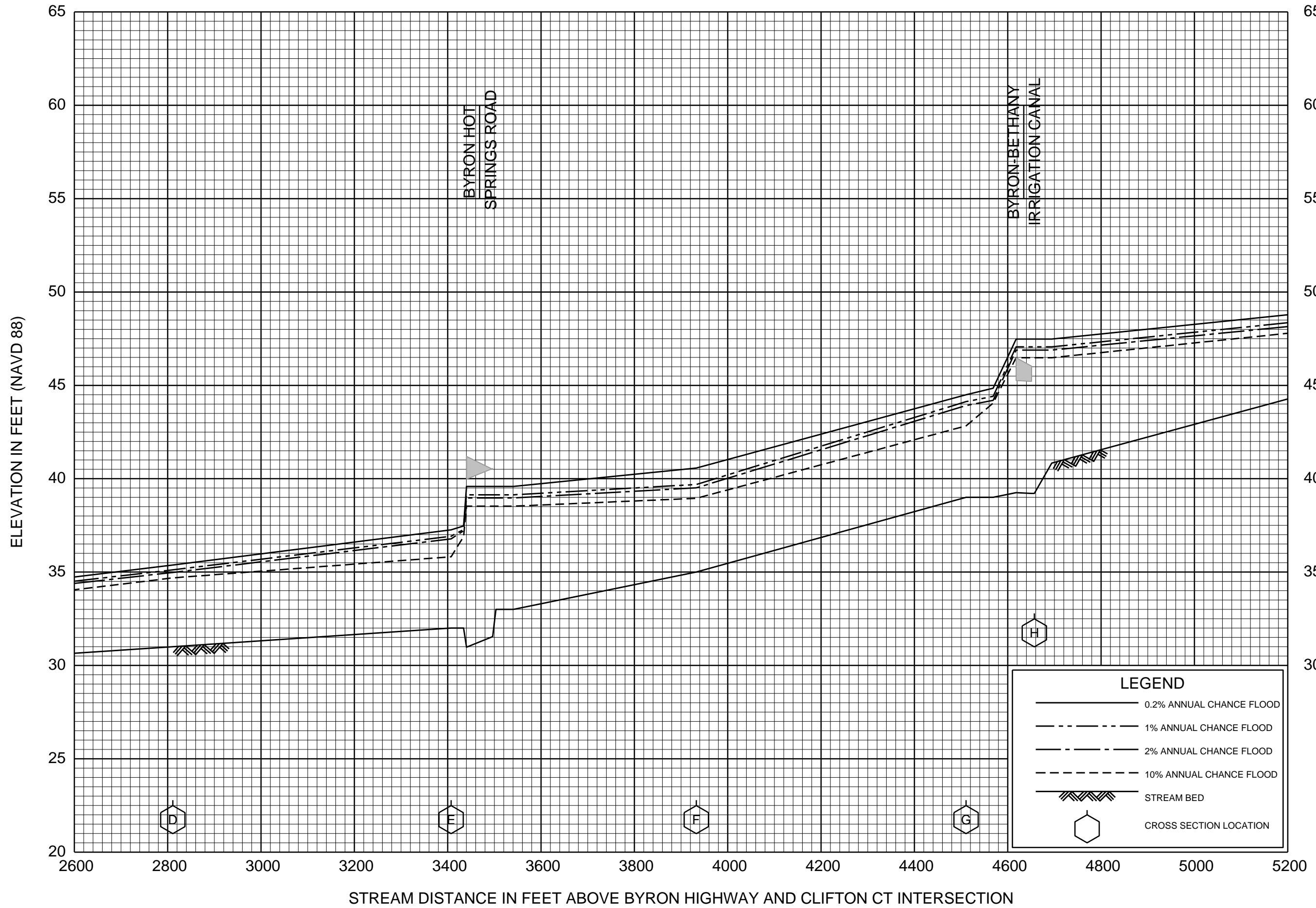
BROOKSIDE ROAD TRIBUTARY

**FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
AND INCORPORATED AREAS**



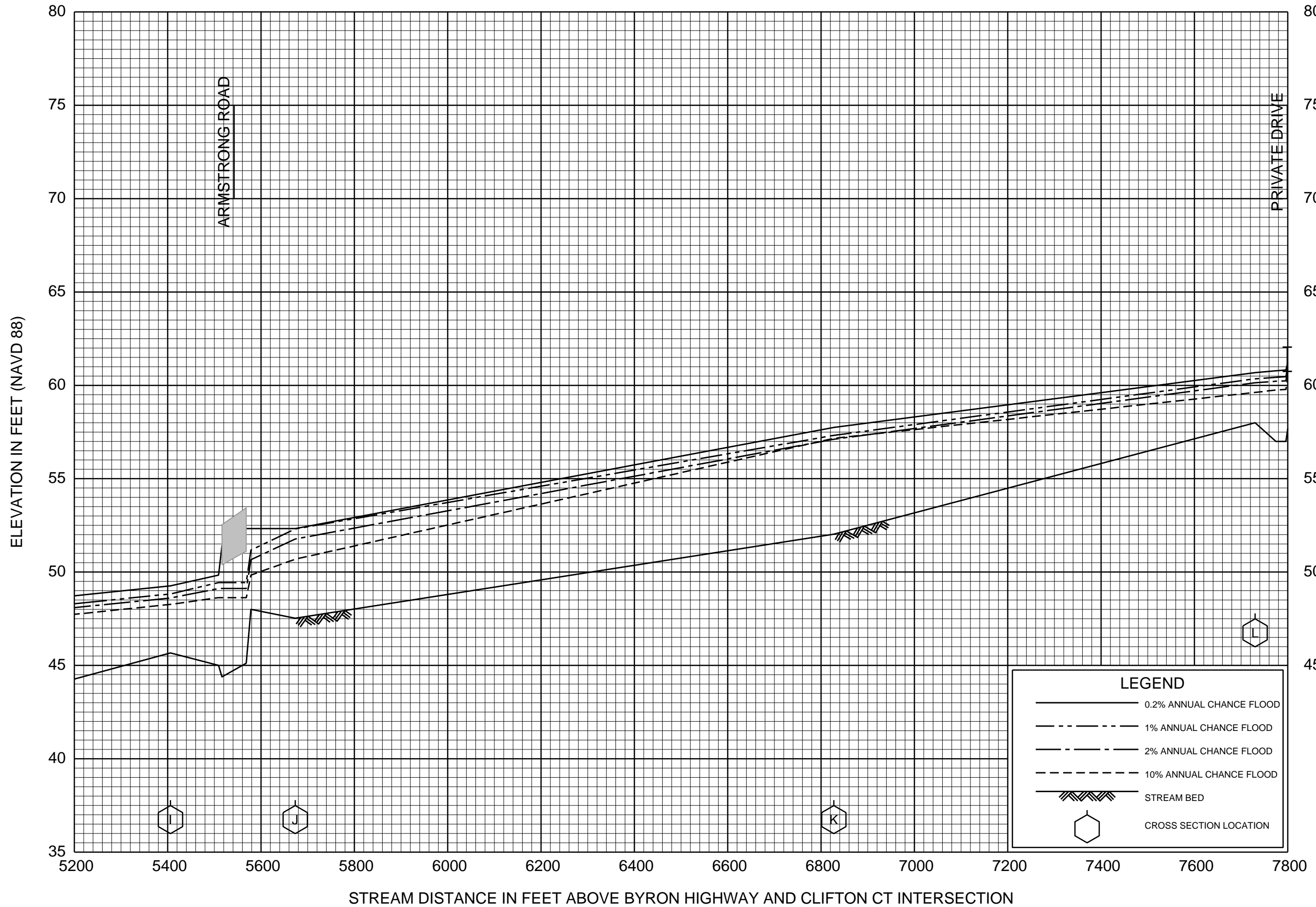
FLOOD PROFILES
BRUSHY CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
AND INCORPORATED AREAS



FLOOD PROFILES
BRUSHY CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
AND INCORPORATED AREAS

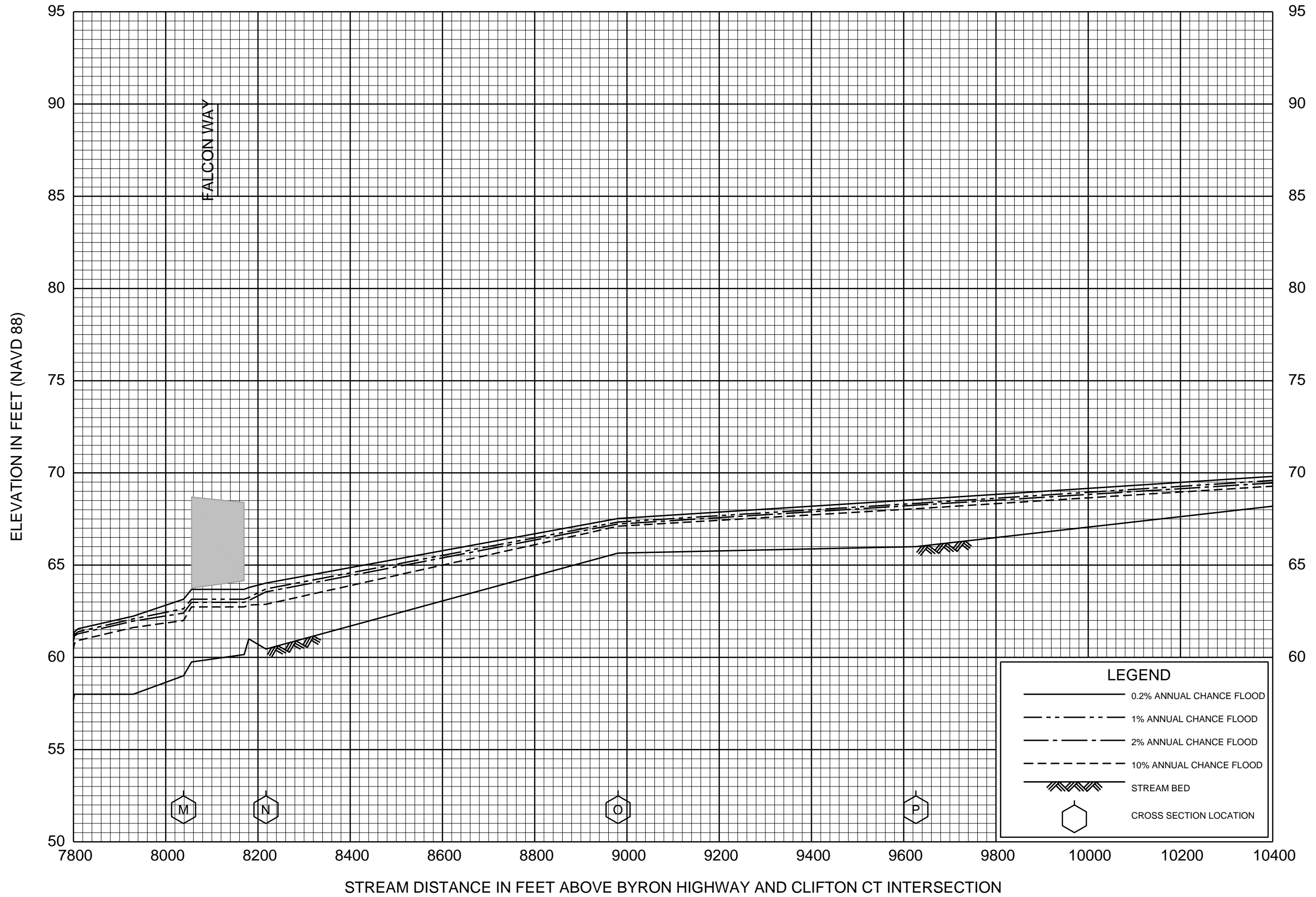


FLOOD PROFILES

BRUSHY CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
 AND INCORPORATED AREAS

05P(c)

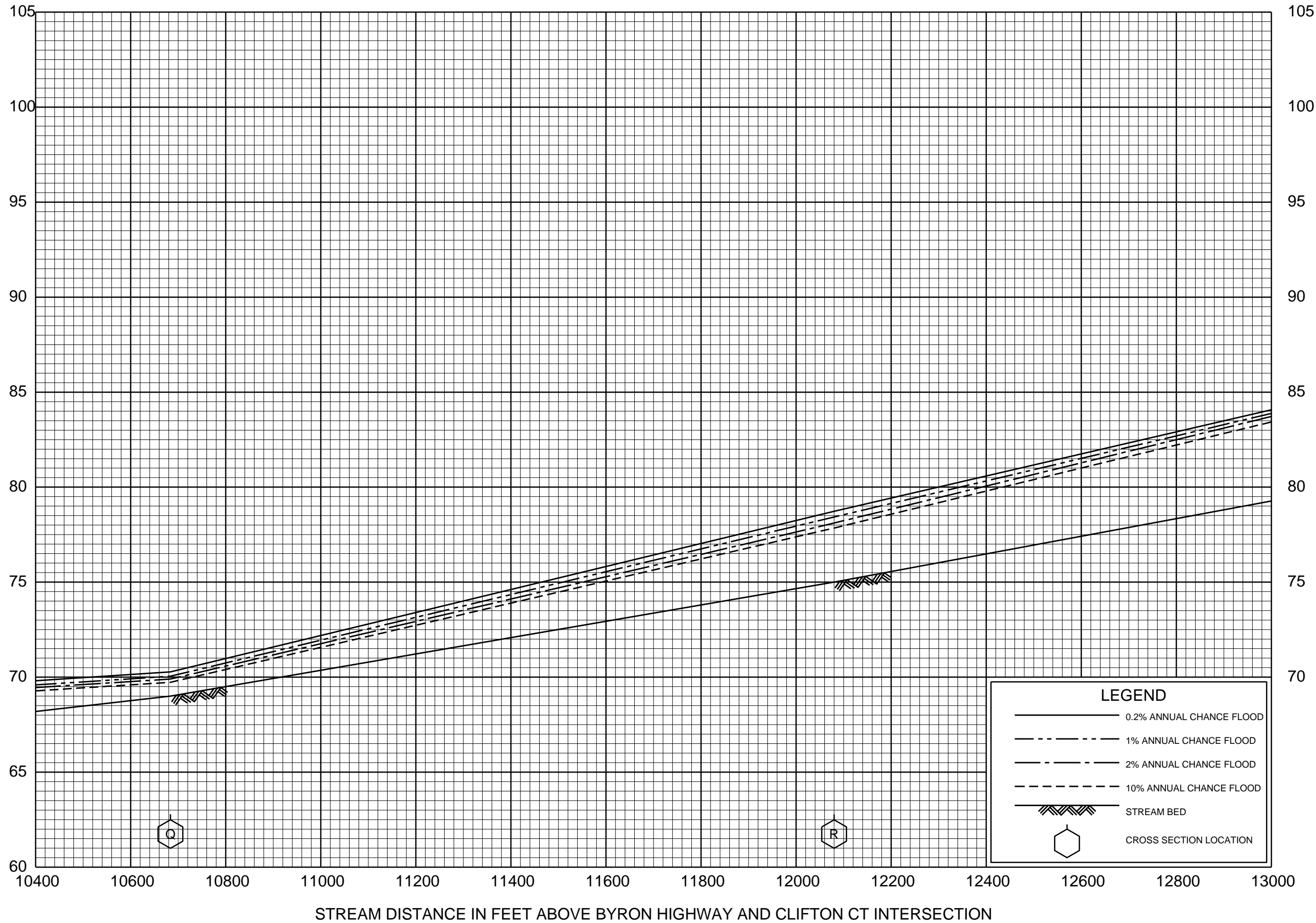


FLOOD PROFILES
BRUSHY CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
AND INCORPORATED AREAS

05P(d)

ELEVATION IN FEET (NAVD 88)



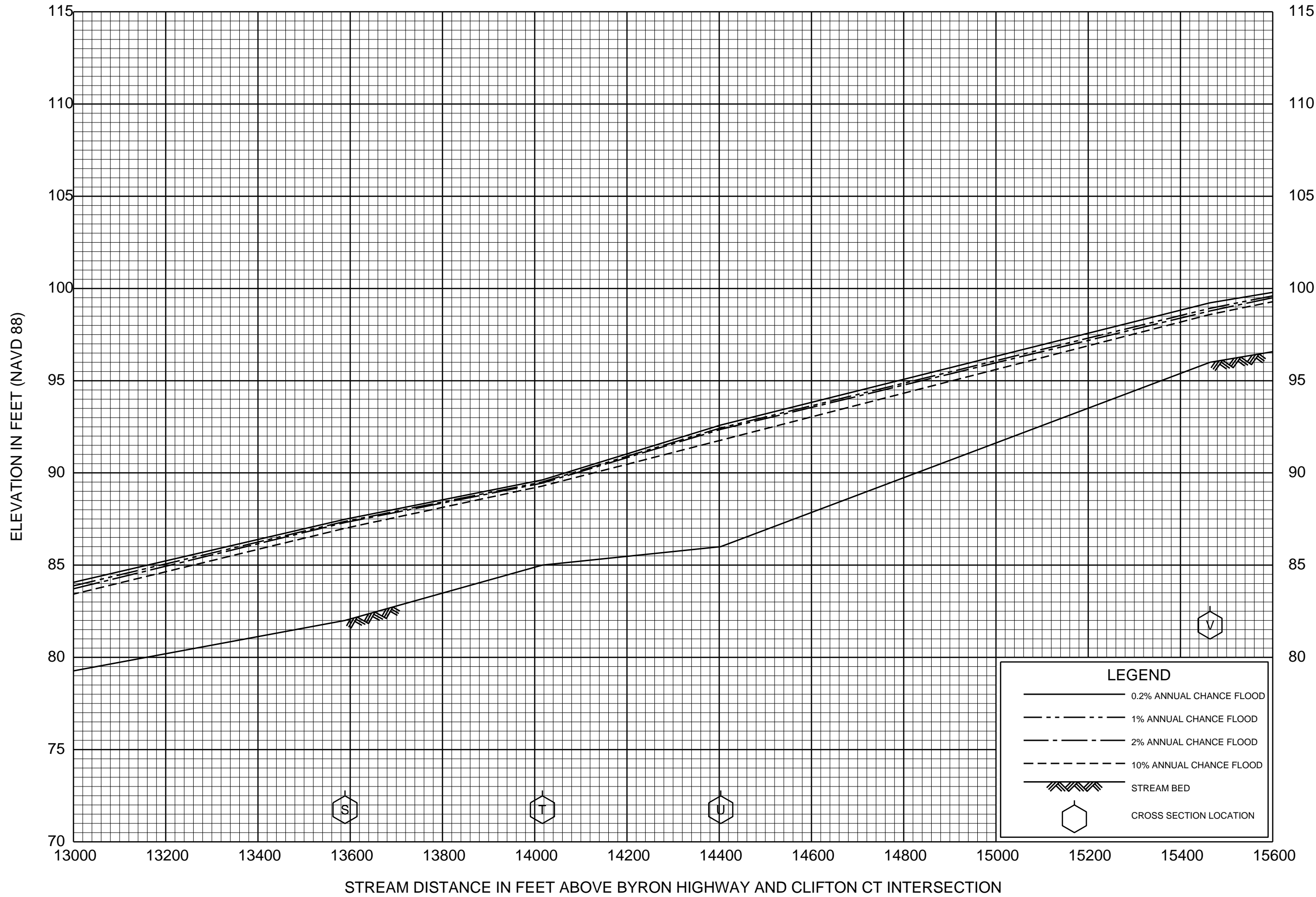
STREAM DISTANCE IN FEET ABOVE BYRON HIGHWAY AND CLIFTON CT INTERSECTION

LEGEND

- 0.2% ANNUAL CHANCE FLOOD
- 1% ANNUAL CHANCE FLOOD
- 2% ANNUAL CHANCE FLOOD
- 10% ANNUAL CHANCE FLOOD
- STREAM BED
- CROSS SECTION LOCATION

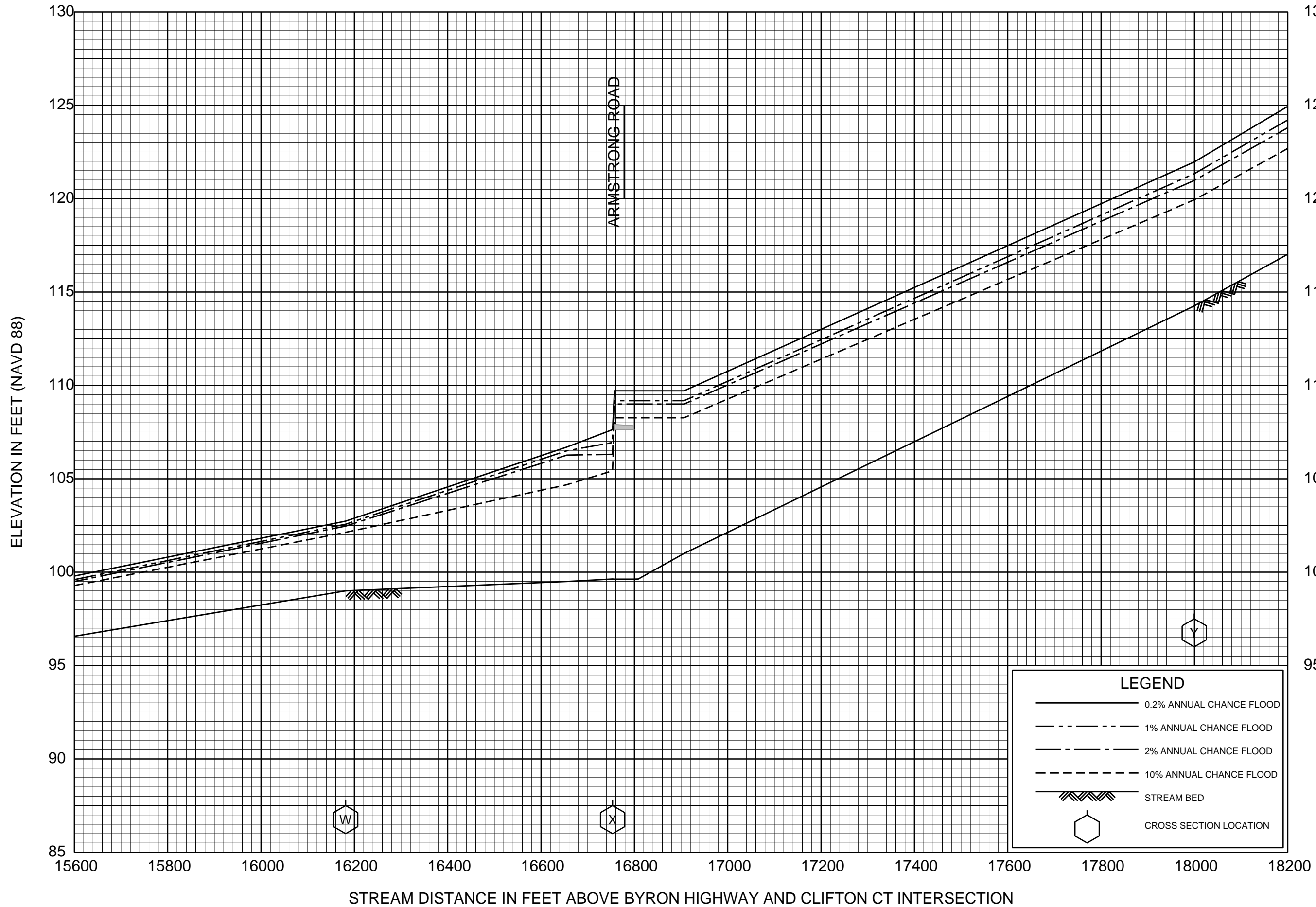
FLOOD PROFILES
BRUSHY CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
AND INCORPORATED AREAS



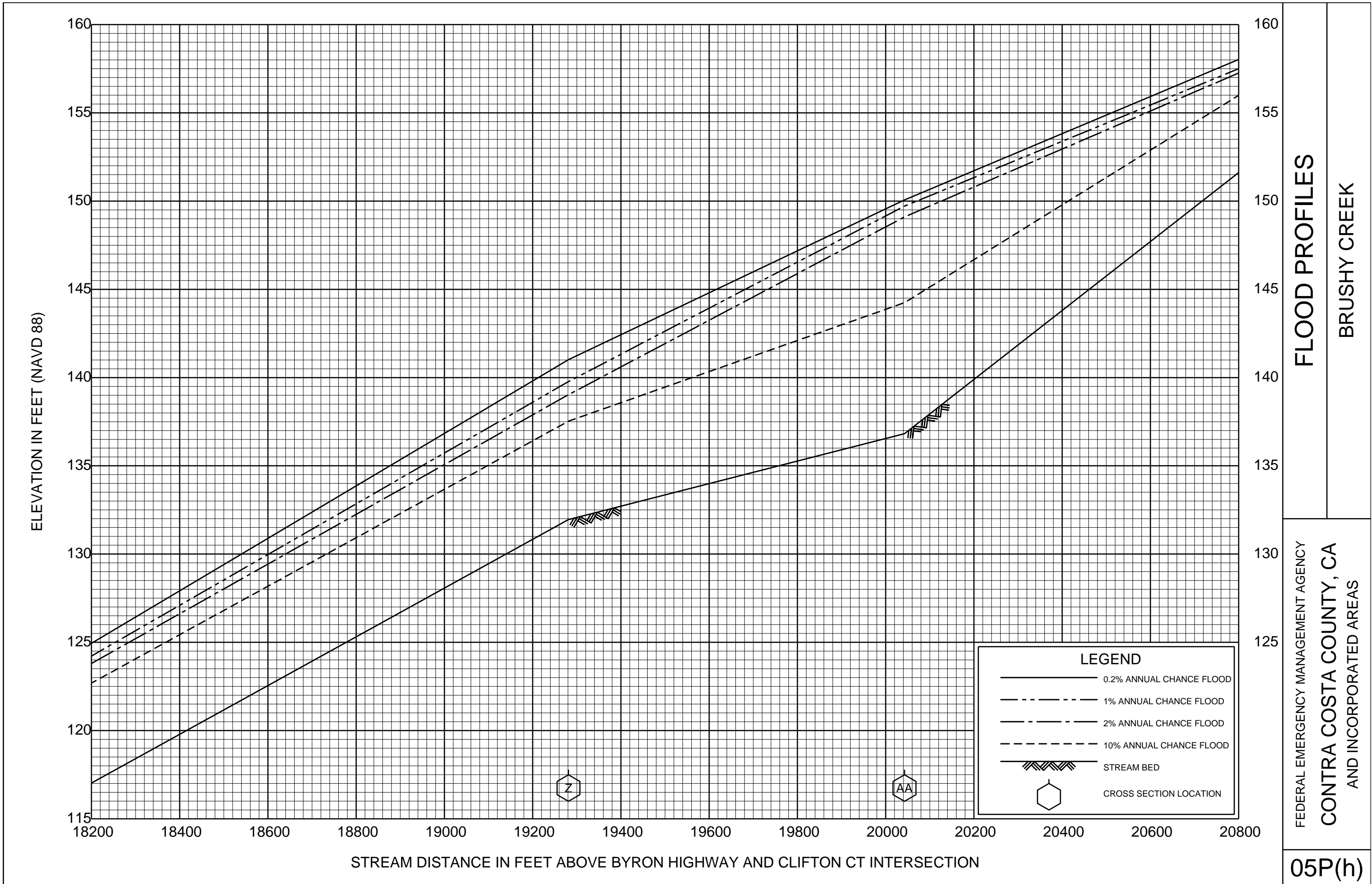
FLOOD PROFILES
BRUSHY CREEK

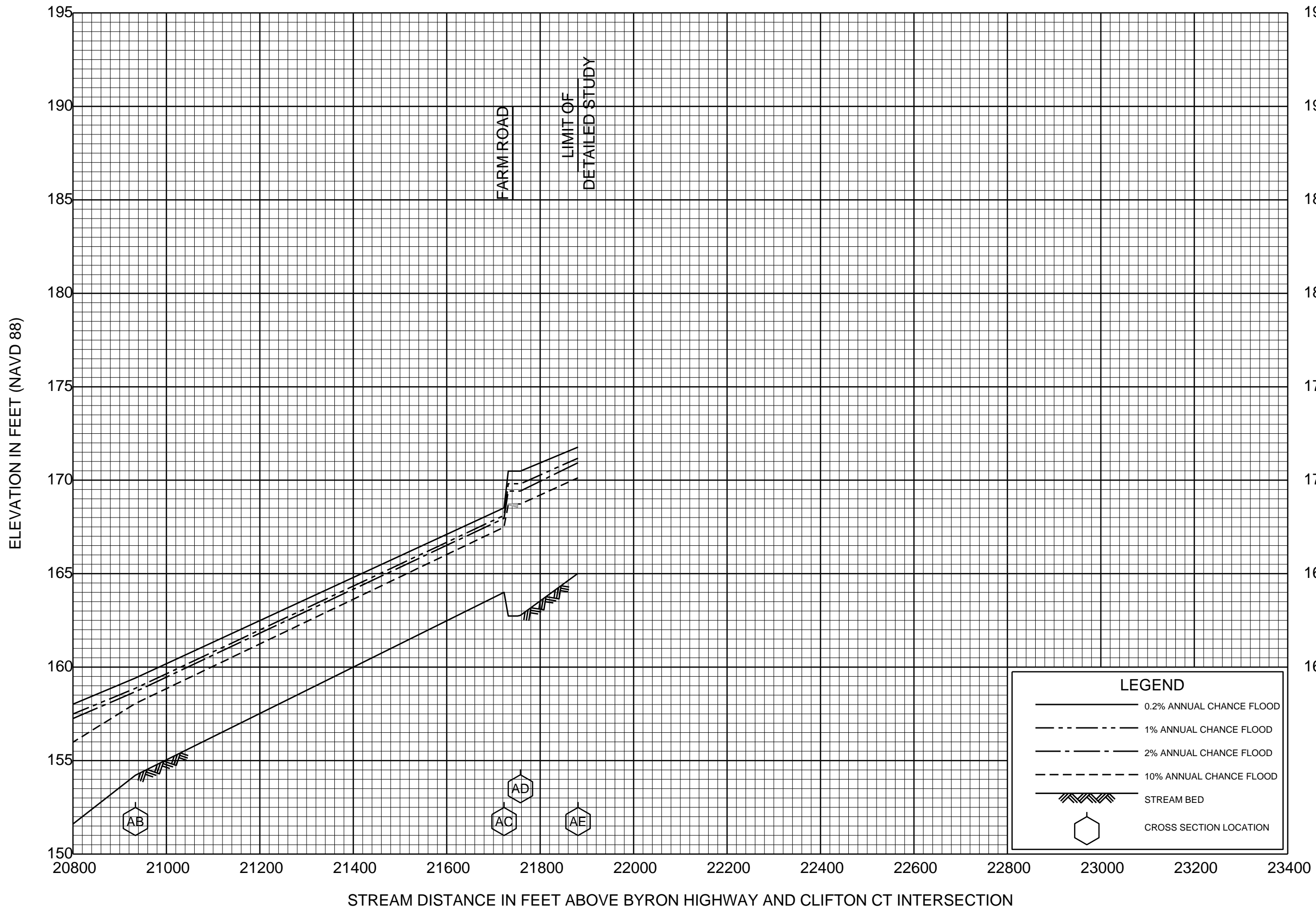
FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
AND INCORPORATED AREAS









FLOOD PROFILES
BRUSHY CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
AND INCORPORATED AREAS



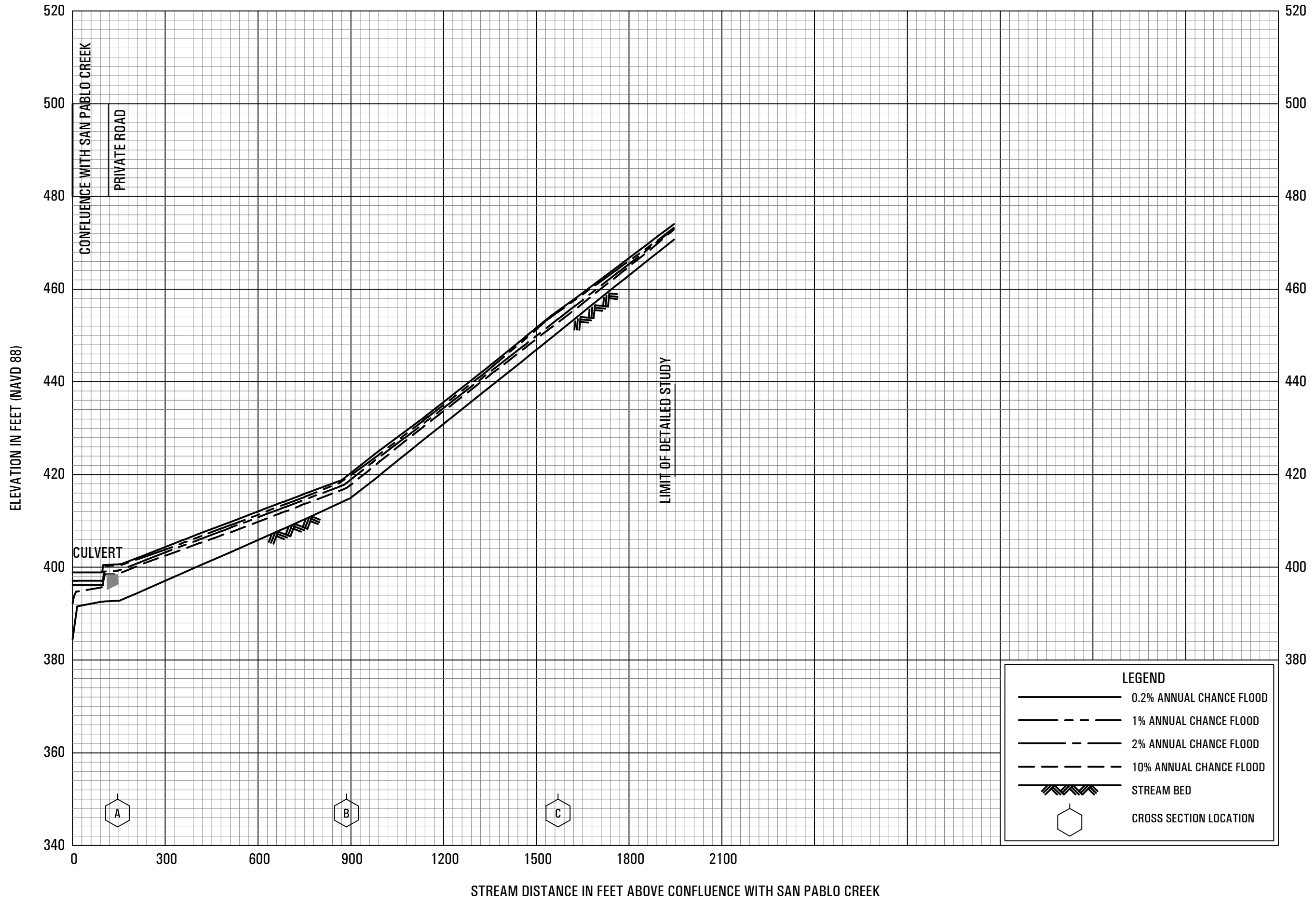


LEGEND	
	0.2% ANNUAL CHANCE FLOOD
	1% ANNUAL CHANCE FLOOD
	2% ANNUAL CHANCE FLOOD
	10% ANNUAL CHANCE FLOOD
	STREAM BED
	CROSS SECTION LOCATION

FLOOD PROFILES

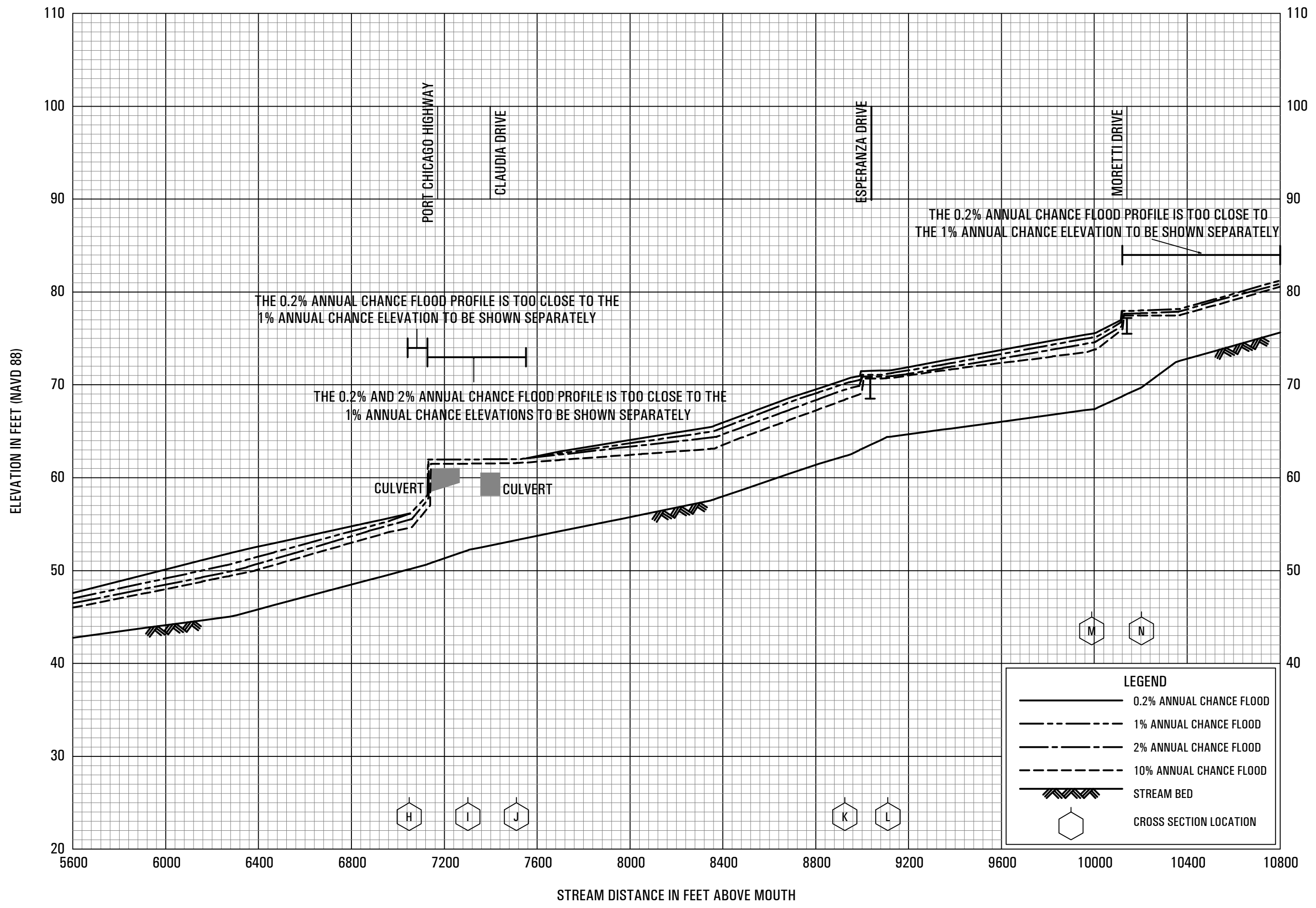
BRUSHY CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY
 CONTRA COSTA COUNTY, CA
 AND INCORPORATED AREAS



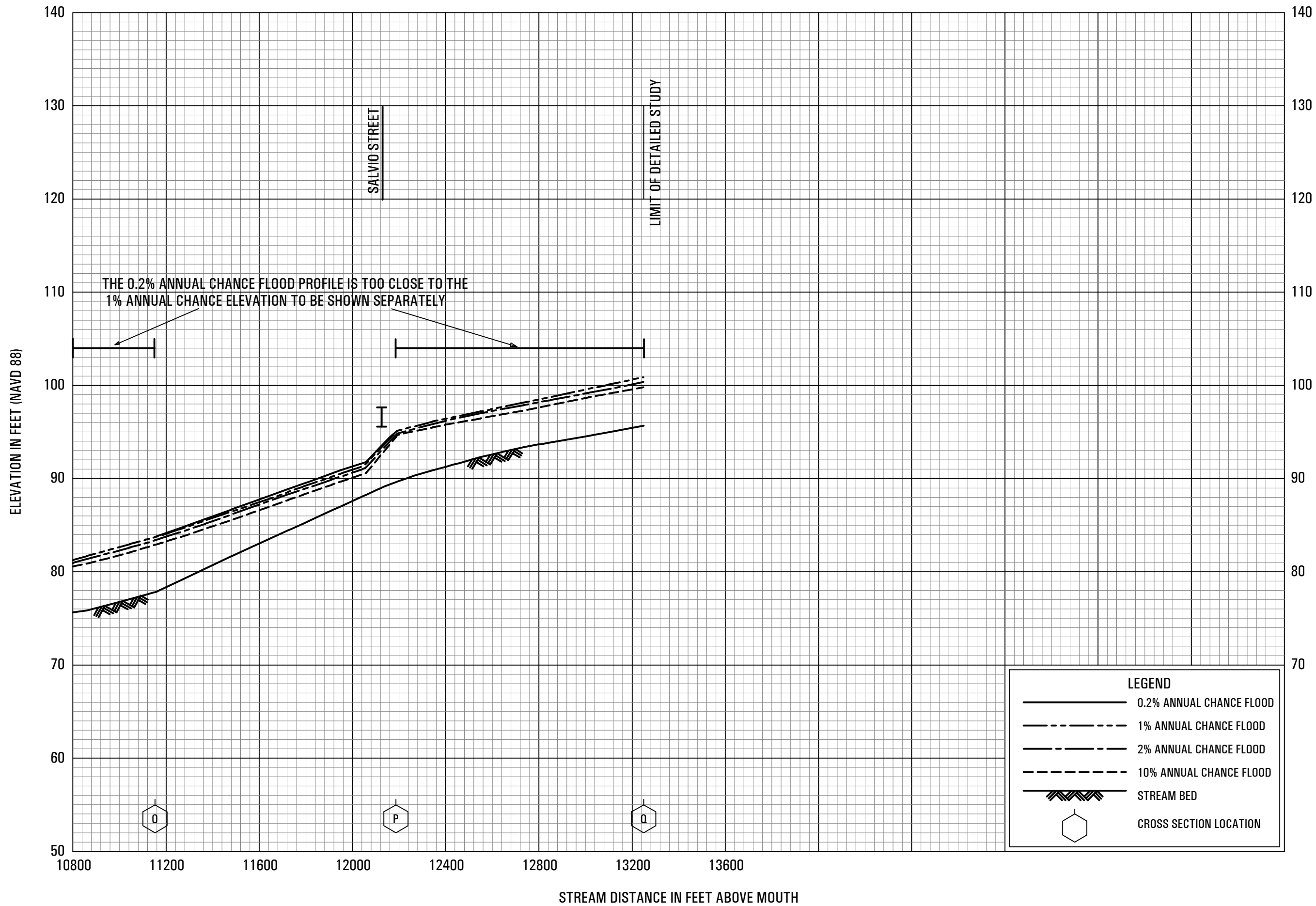
FLOOD PROFILES
CASCADE CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
 AND INCORPORATED AREAS



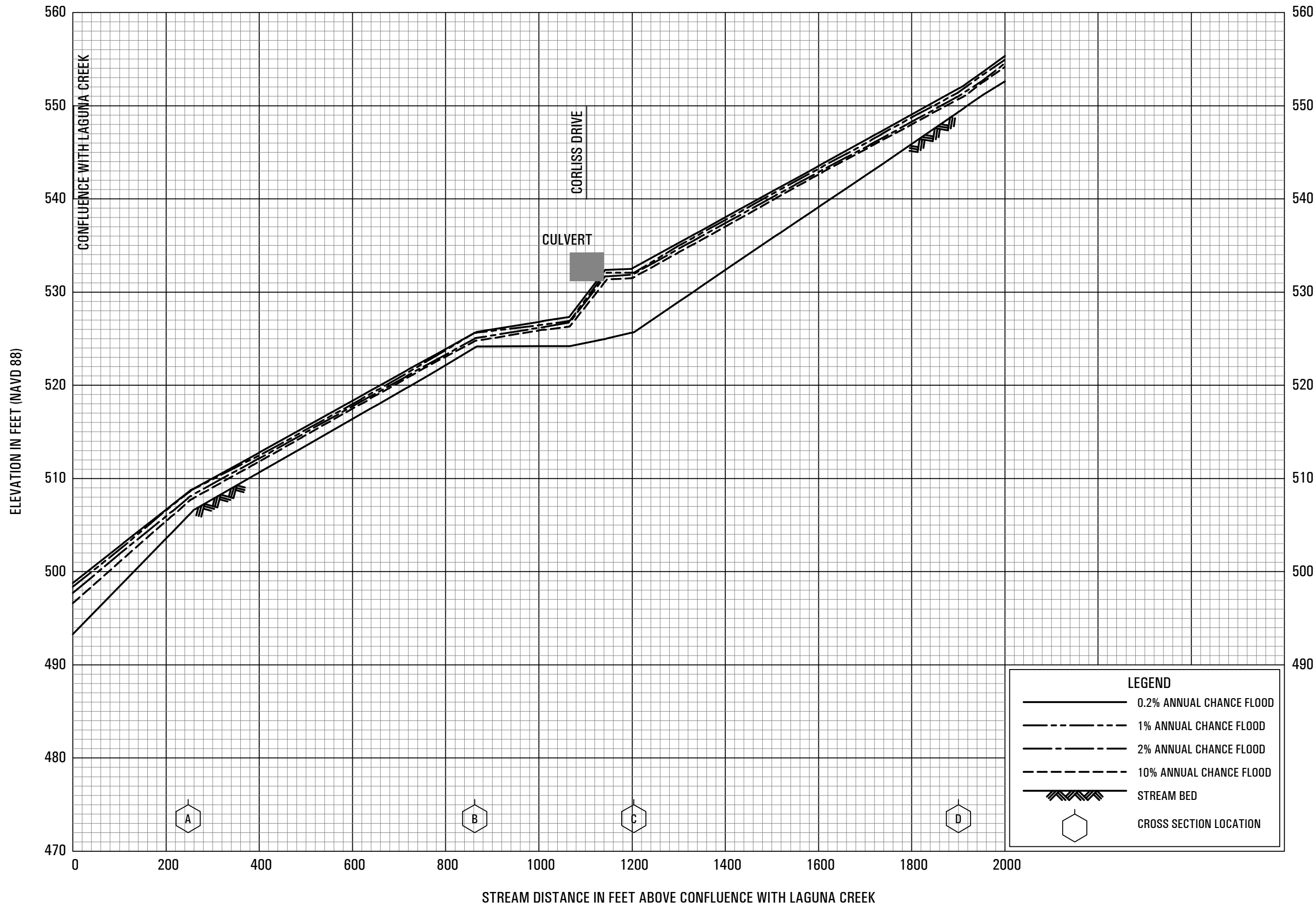
FLOOD PROFILES
CLAYTON VALLEY DRAIN

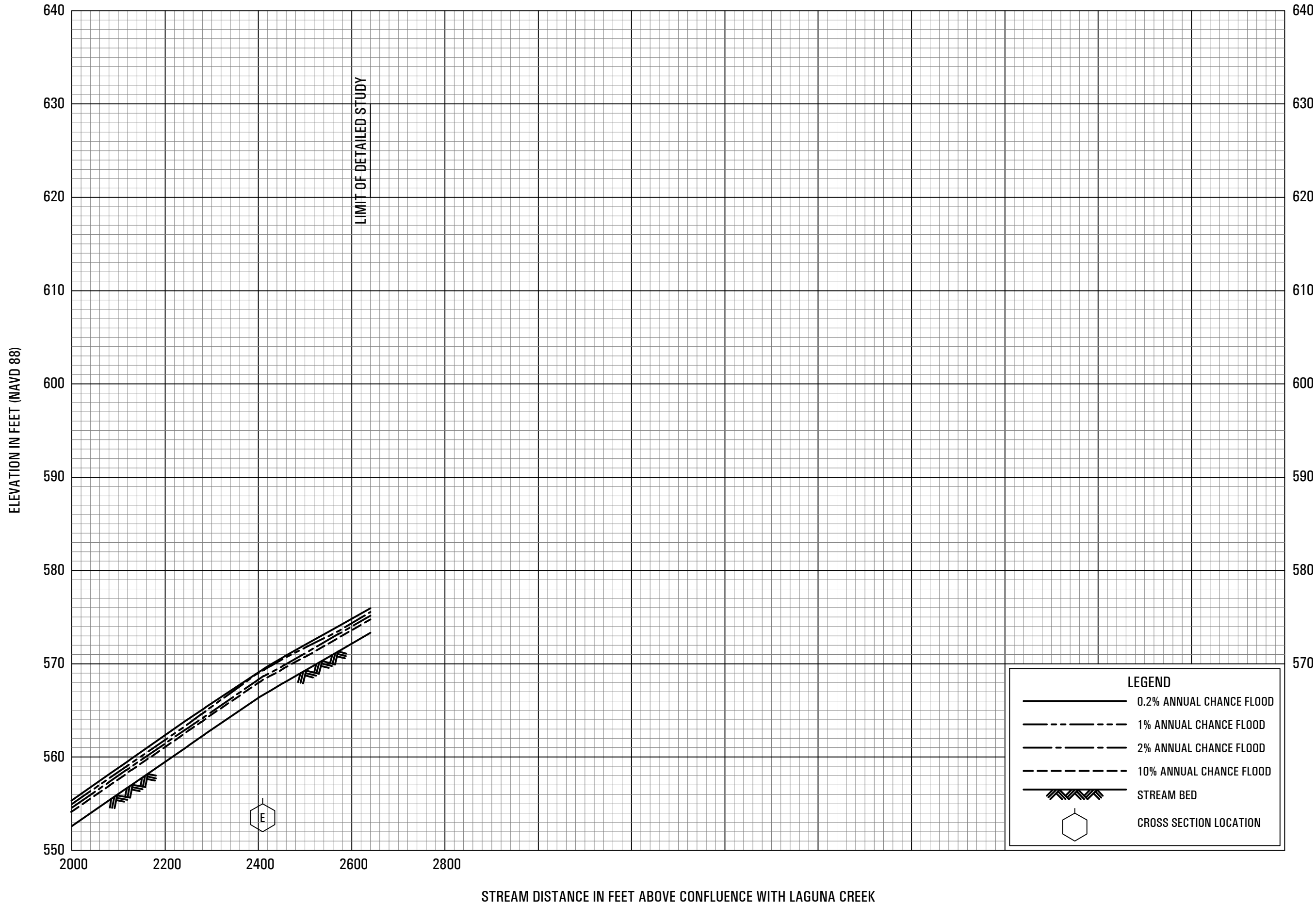
FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
AND INCORPORATED AREAS



FLOOD PROFILES
CLAYTON VALLEY DRAIN

FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
AND INCORPORATED AREAS

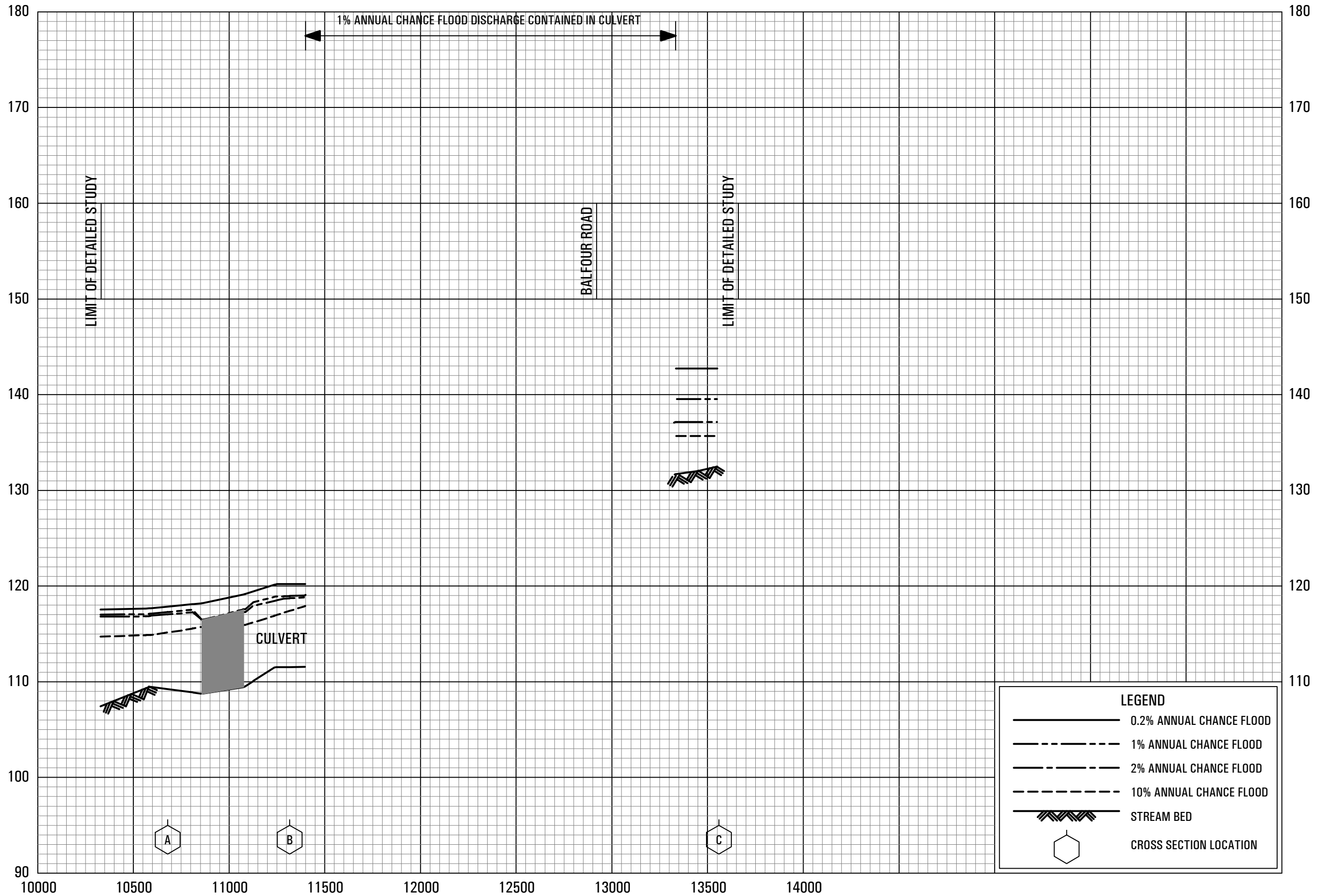




FLOOD PROFILES
CORLISS DRIVE TRIBUTARY

FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
AND INCORPORATED AREAS

ELEVATION IN FEET (NAVD 88)



LEGEND

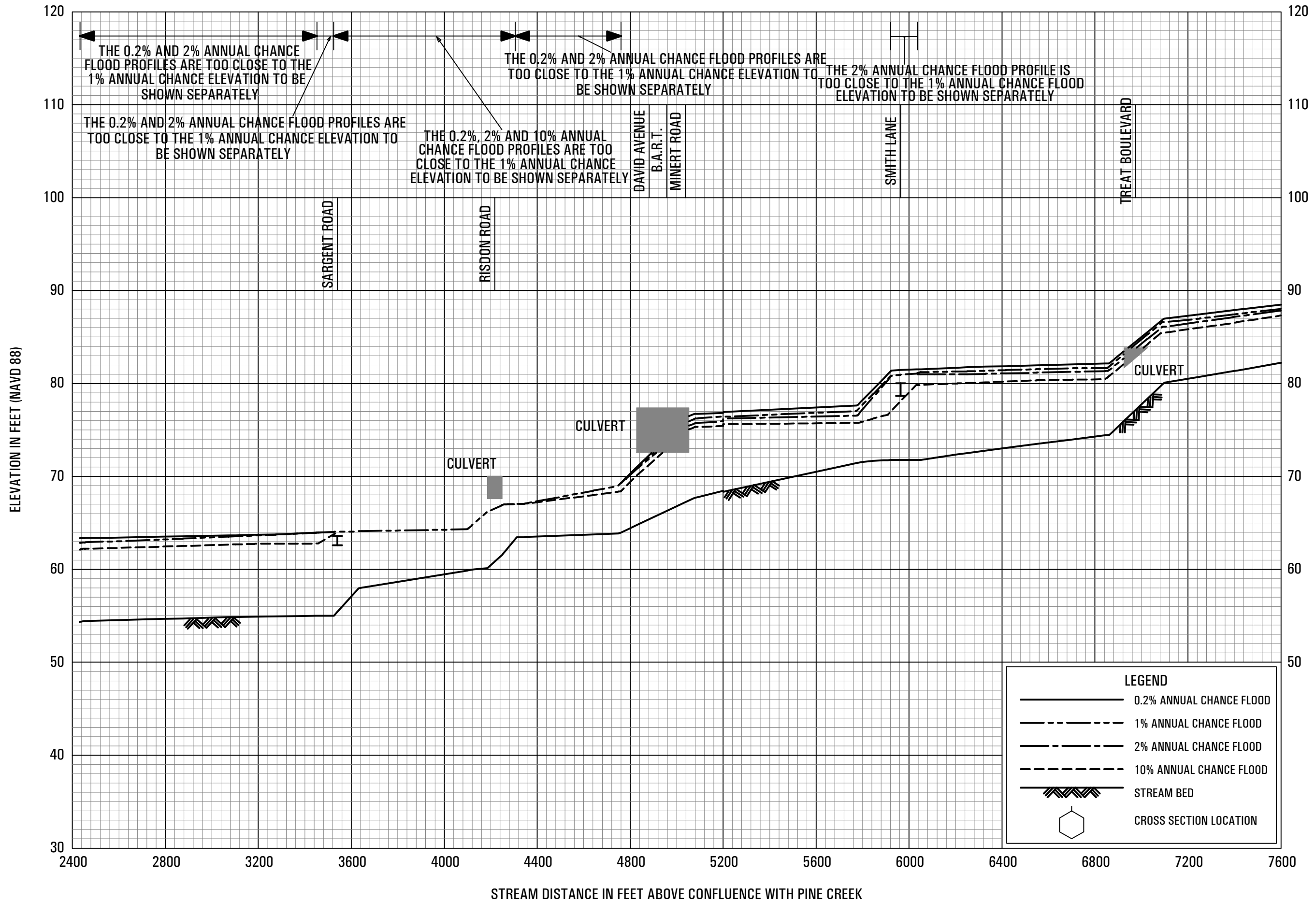
- 0.2% ANNUAL CHANCE FLOOD
- 1% ANNUAL CHANCE FLOOD
- 2% ANNUAL CHANCE FLOOD
- 10% ANNUAL CHANCE FLOOD
- STREAM BED
- CROSS SECTION LOCATION

FLOOD PROFILES

DEER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
 AND INCORPORATED AREAS

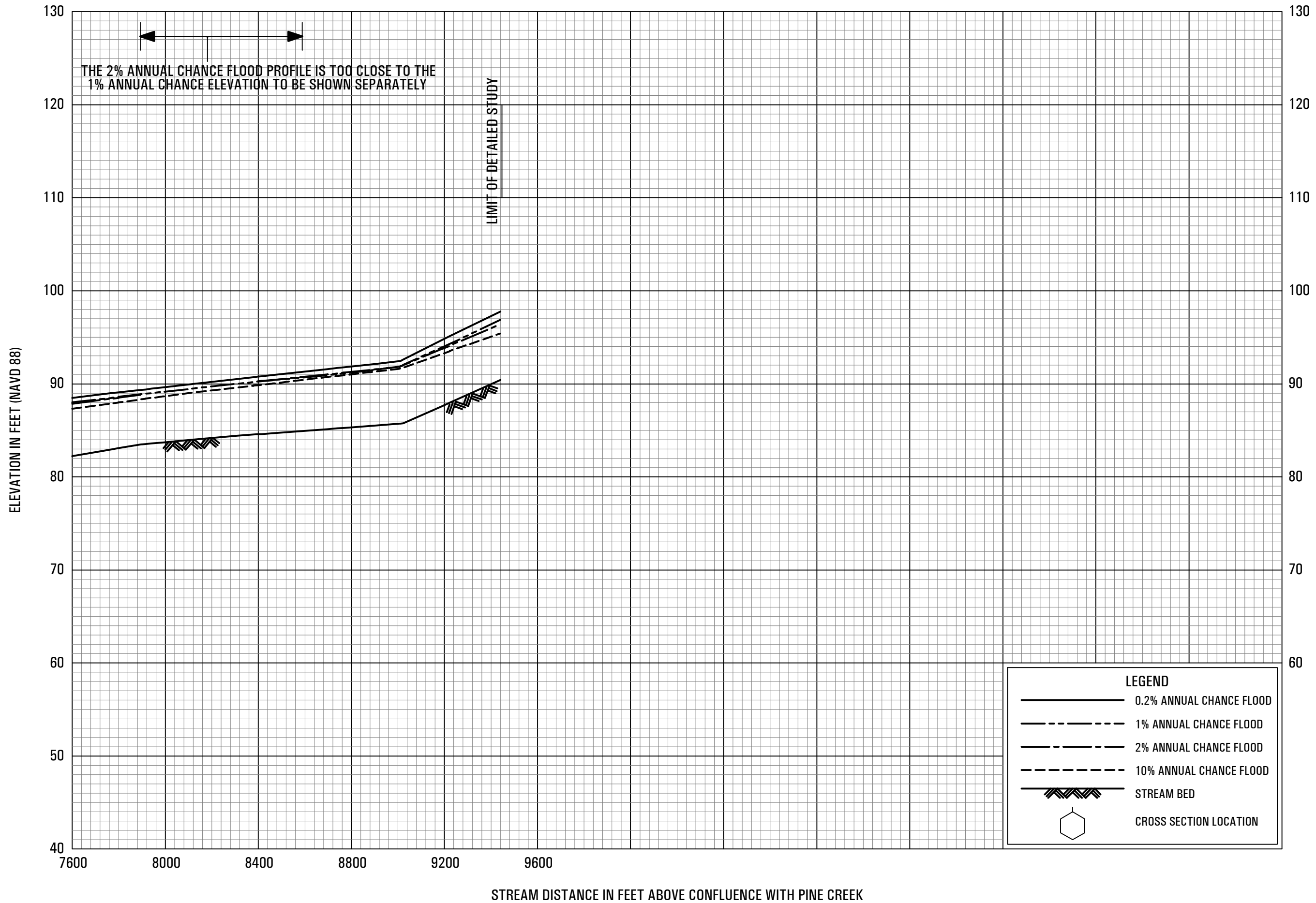
STREAM DISTANCE IN FEET ABOVE CONFLUENCE WITH MARSH CREEK



FLOOD PROFILES

DITCH NO. 2

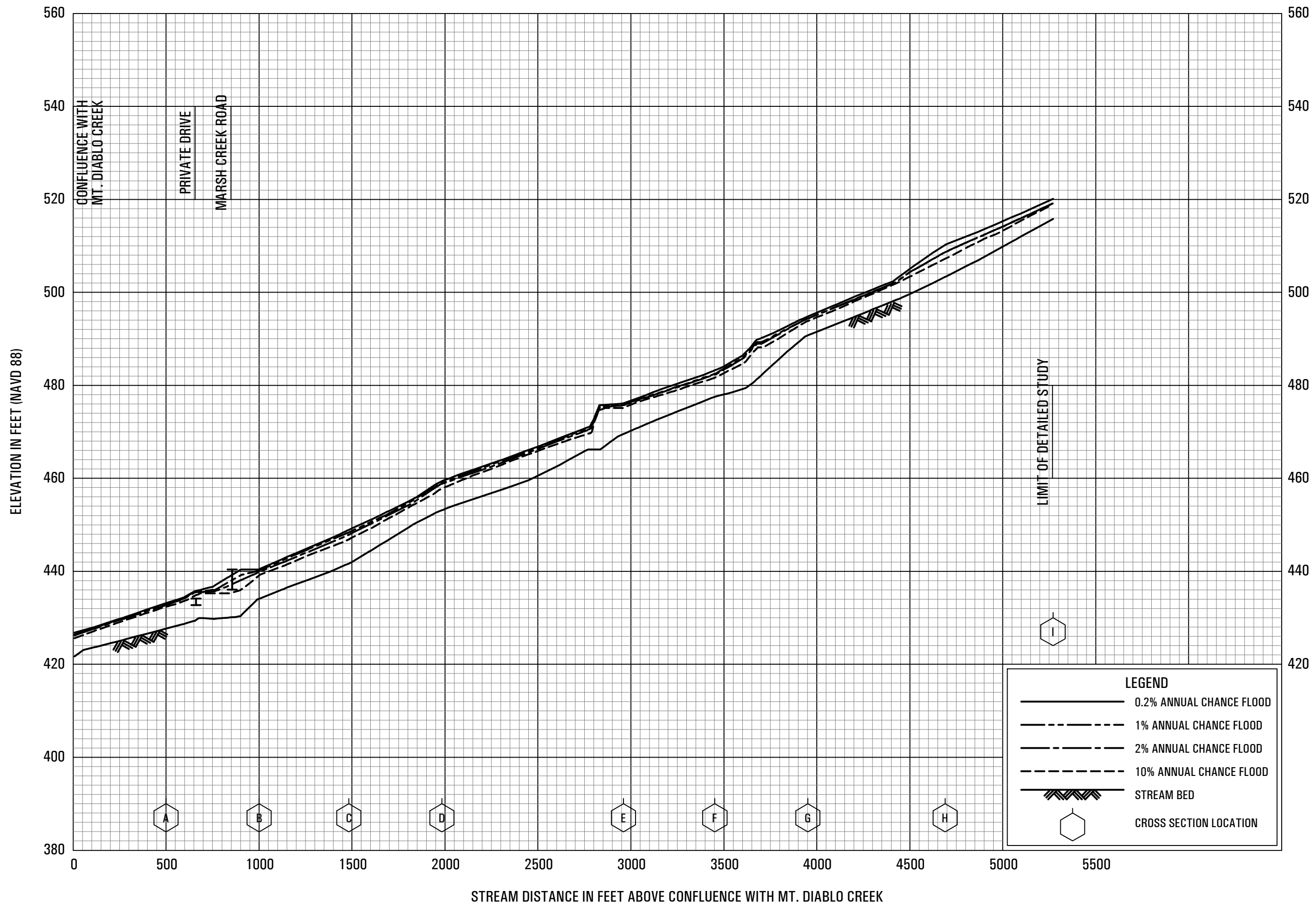
FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
 AND INCORPORATED AREAS



FLOOD PROFILES

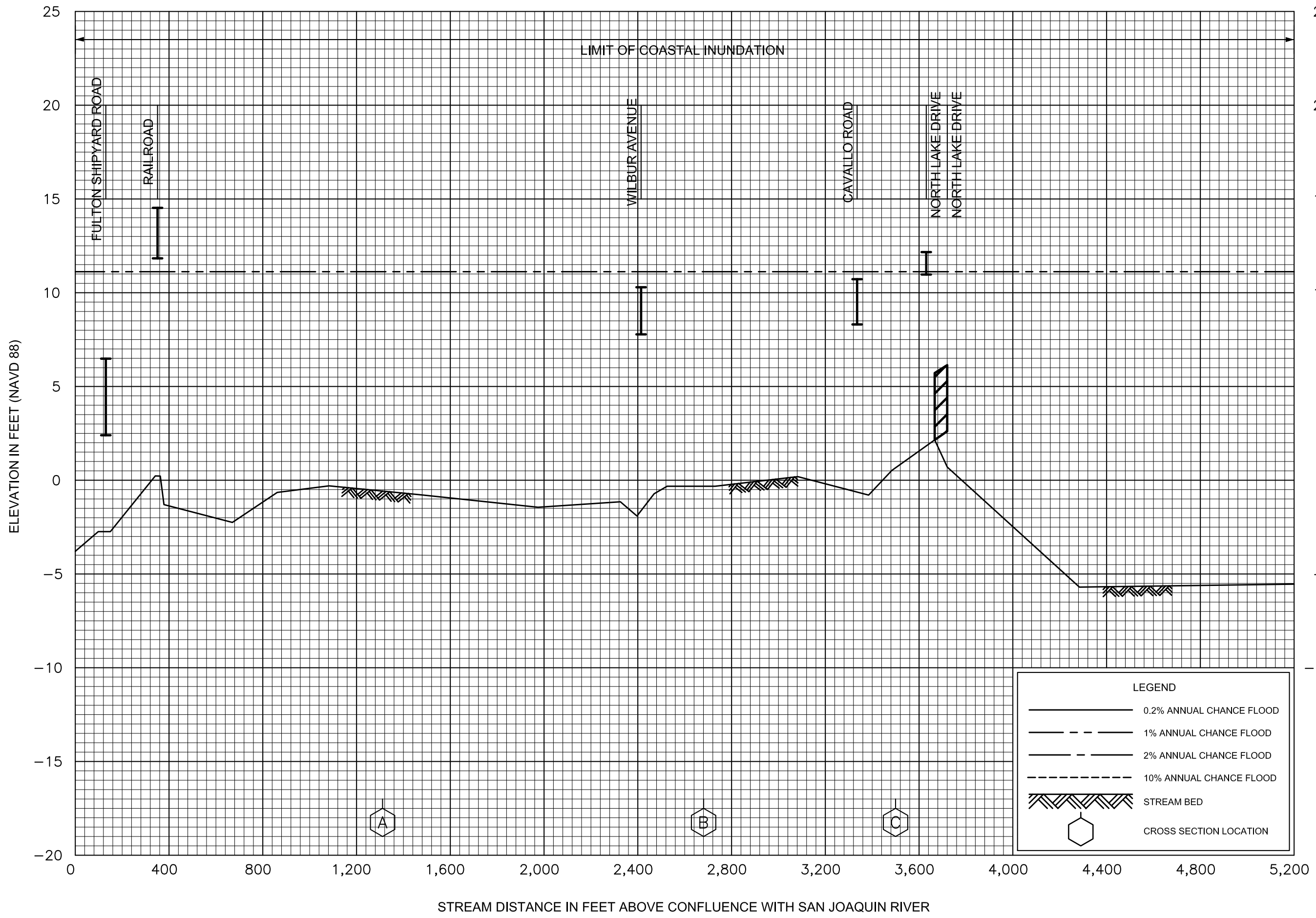
DITCH NO. 2

FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
 AND INCORPORATED AREAS



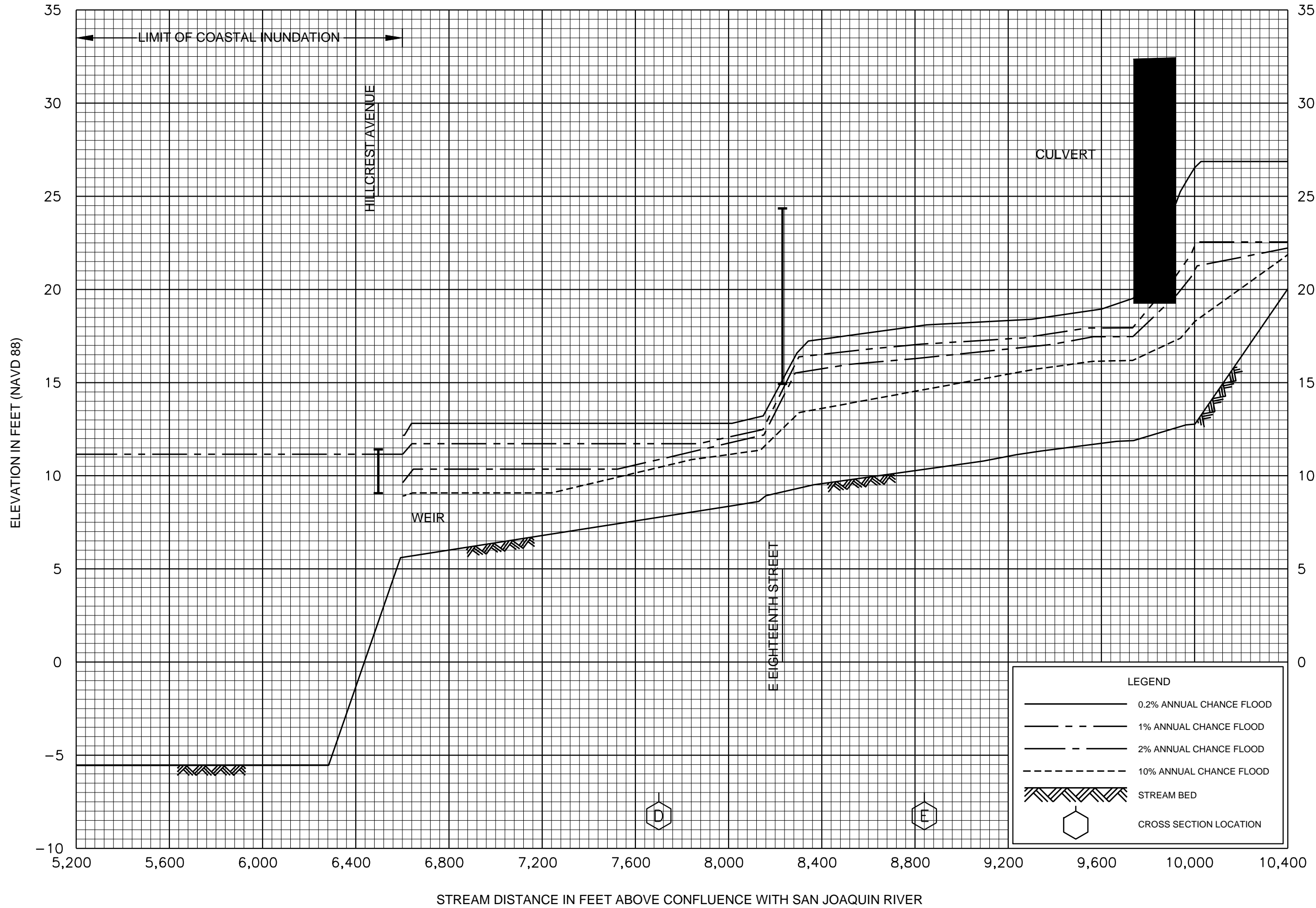
FLOOD PROFILES
DONNER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
AND INCORPORATED AREAS



FLOOD PROFILES
EAST ANTIOCH CREEK

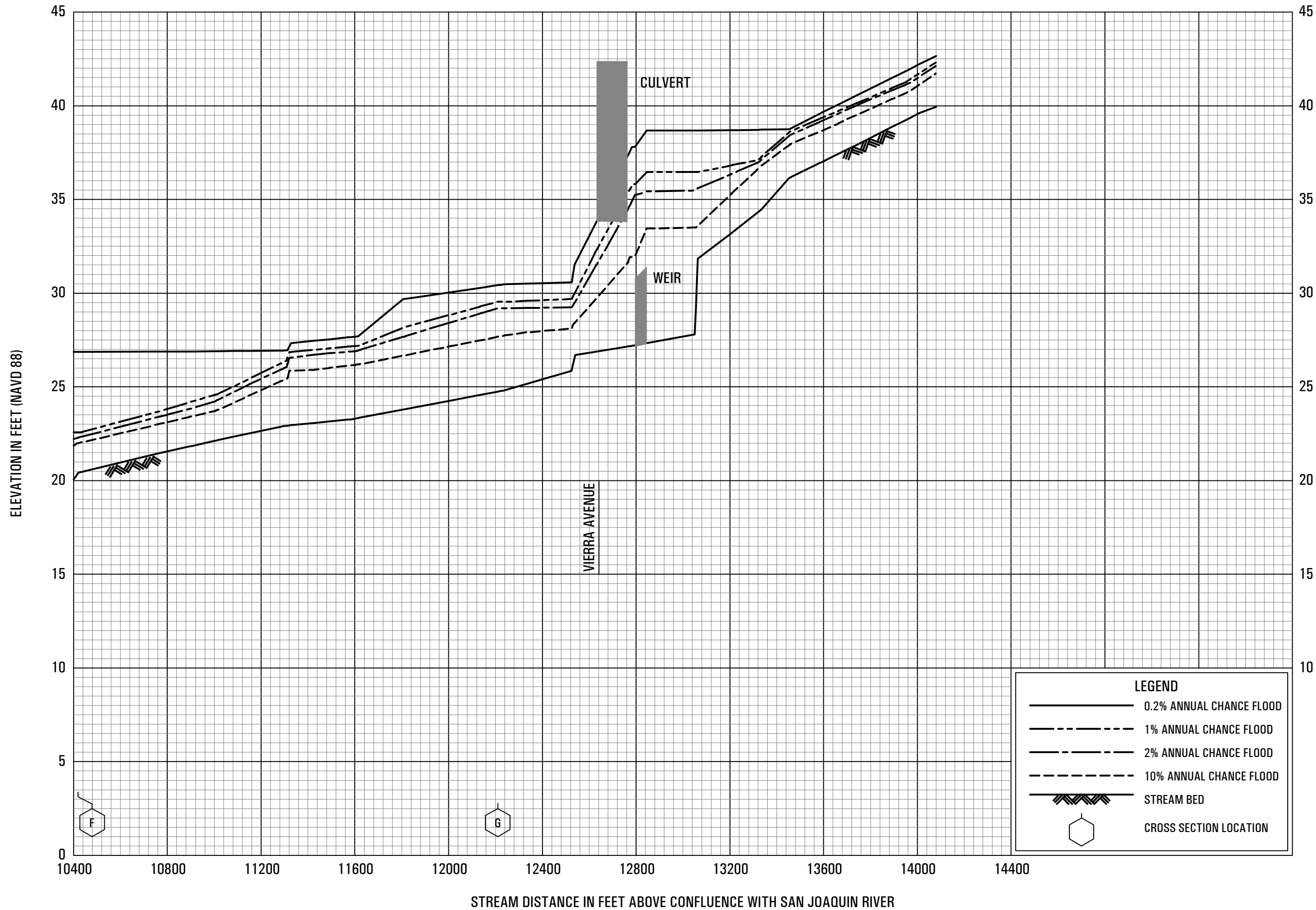
FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
AND INCORPORATED AREAS



FLOOD PROFILES

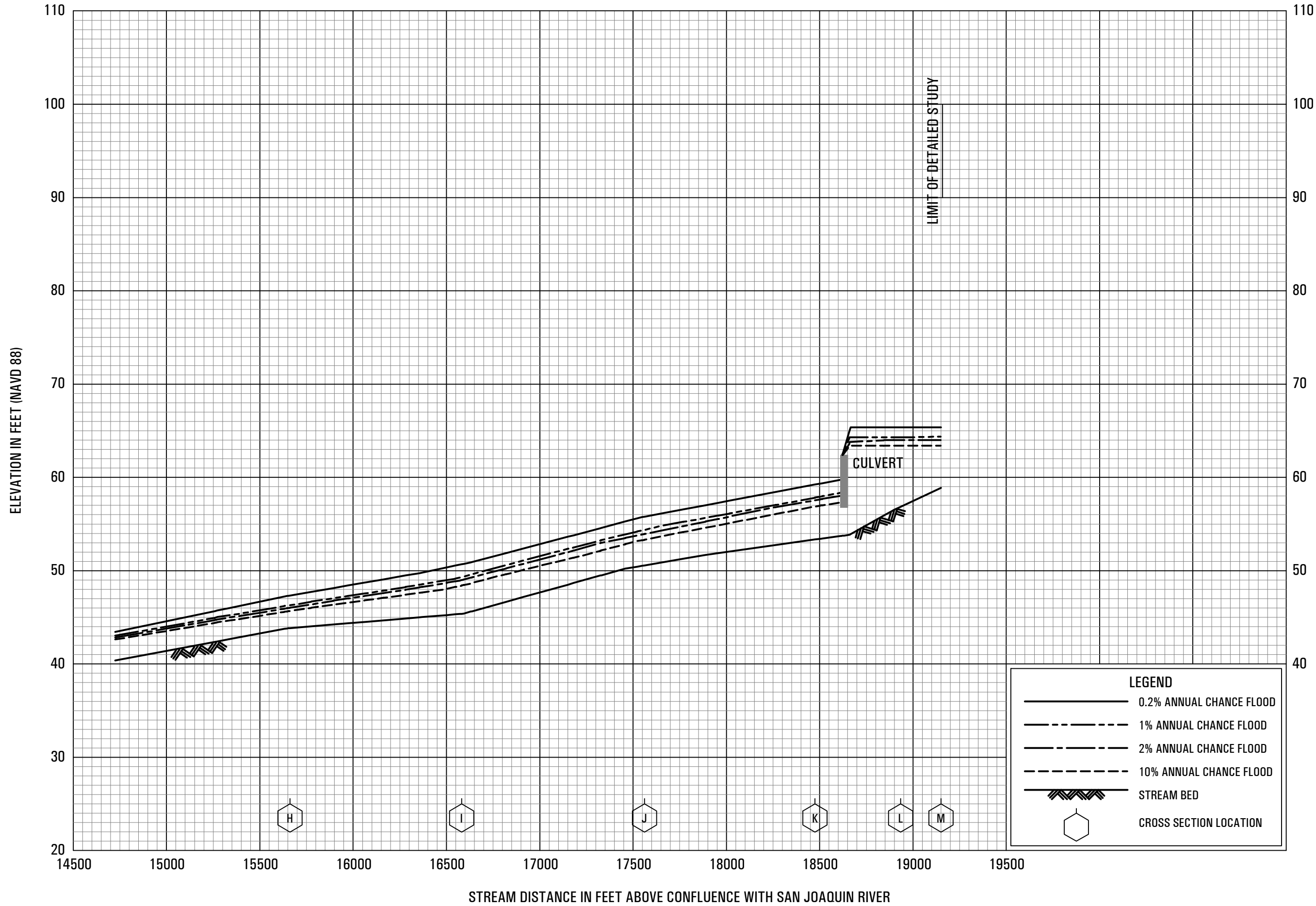
EAST ANTIOCH CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
 AND INCORPORATED AREAS



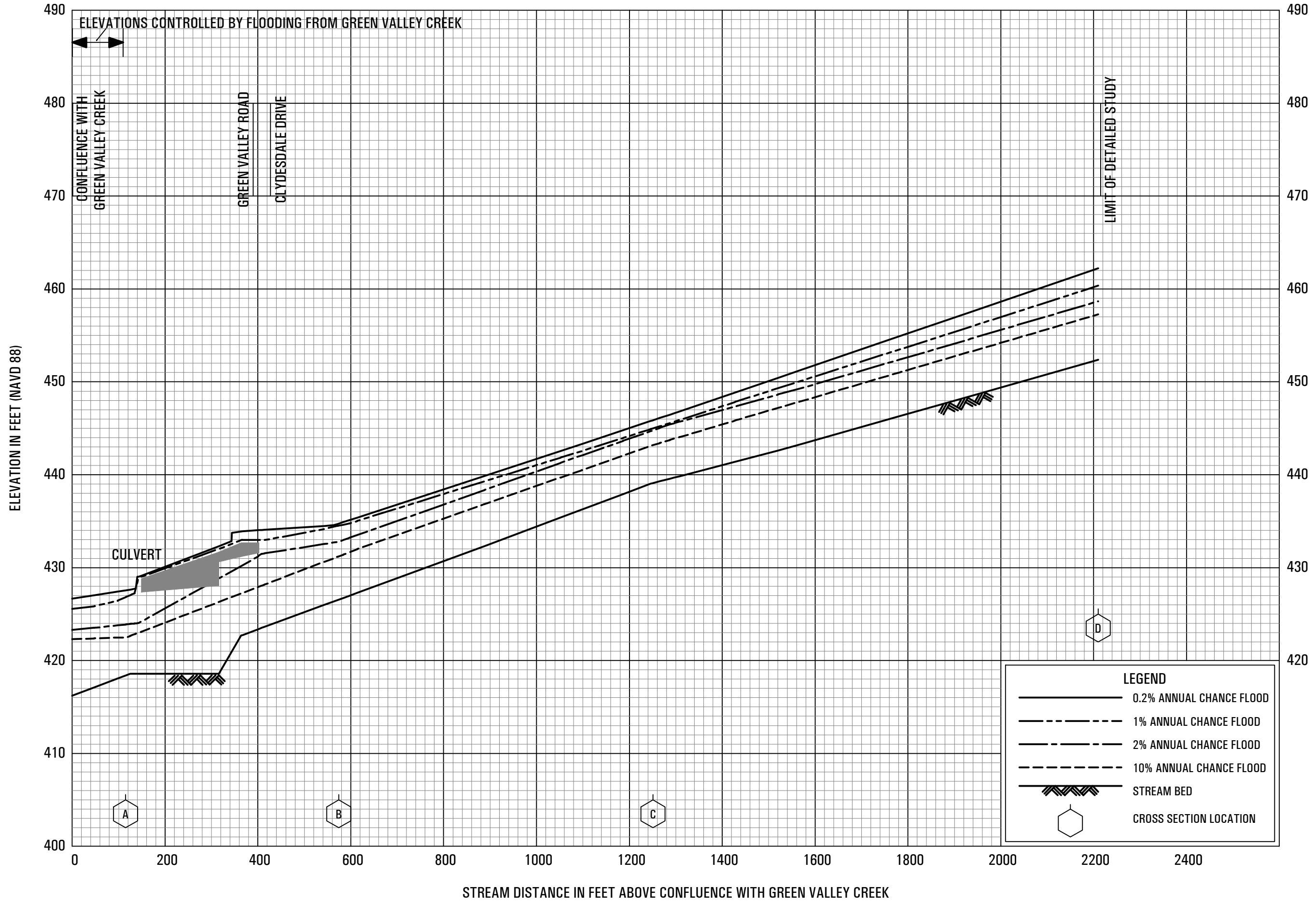
FLOOD PROFILES
EAST ANTIOCH CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
 AND INCORPORATED AREAS



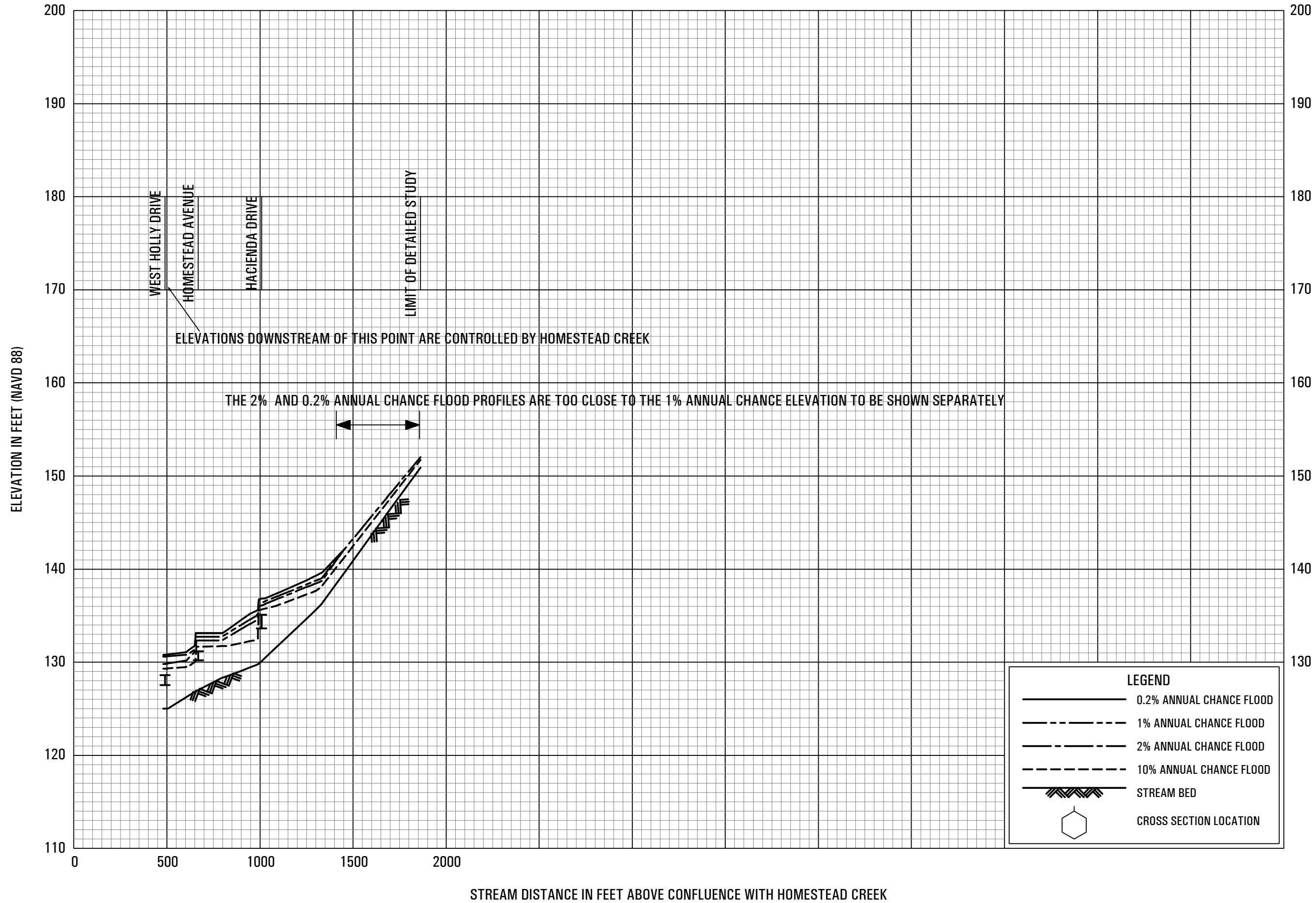
FLOOD PROFILES
EAST ANTIOCH CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
AND INCORPORATED AREAS



FLOOD PROFILES
EAST BRANCH GREEN VALLEY CREEK

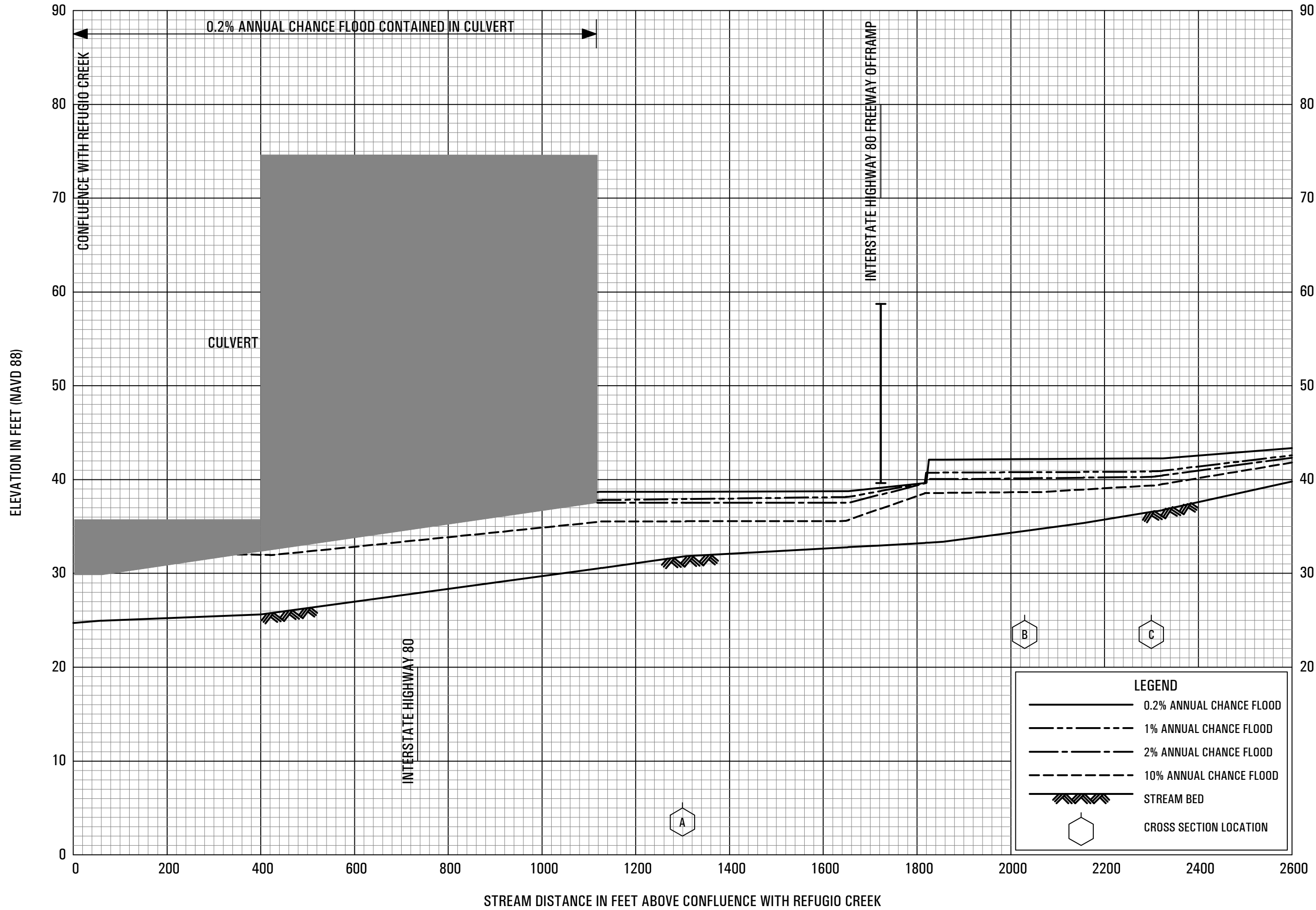
FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
 AND INCORPORATED AREAS



FLOOD PROFILES

EAST BRANCH HOMESTEAD CREEK

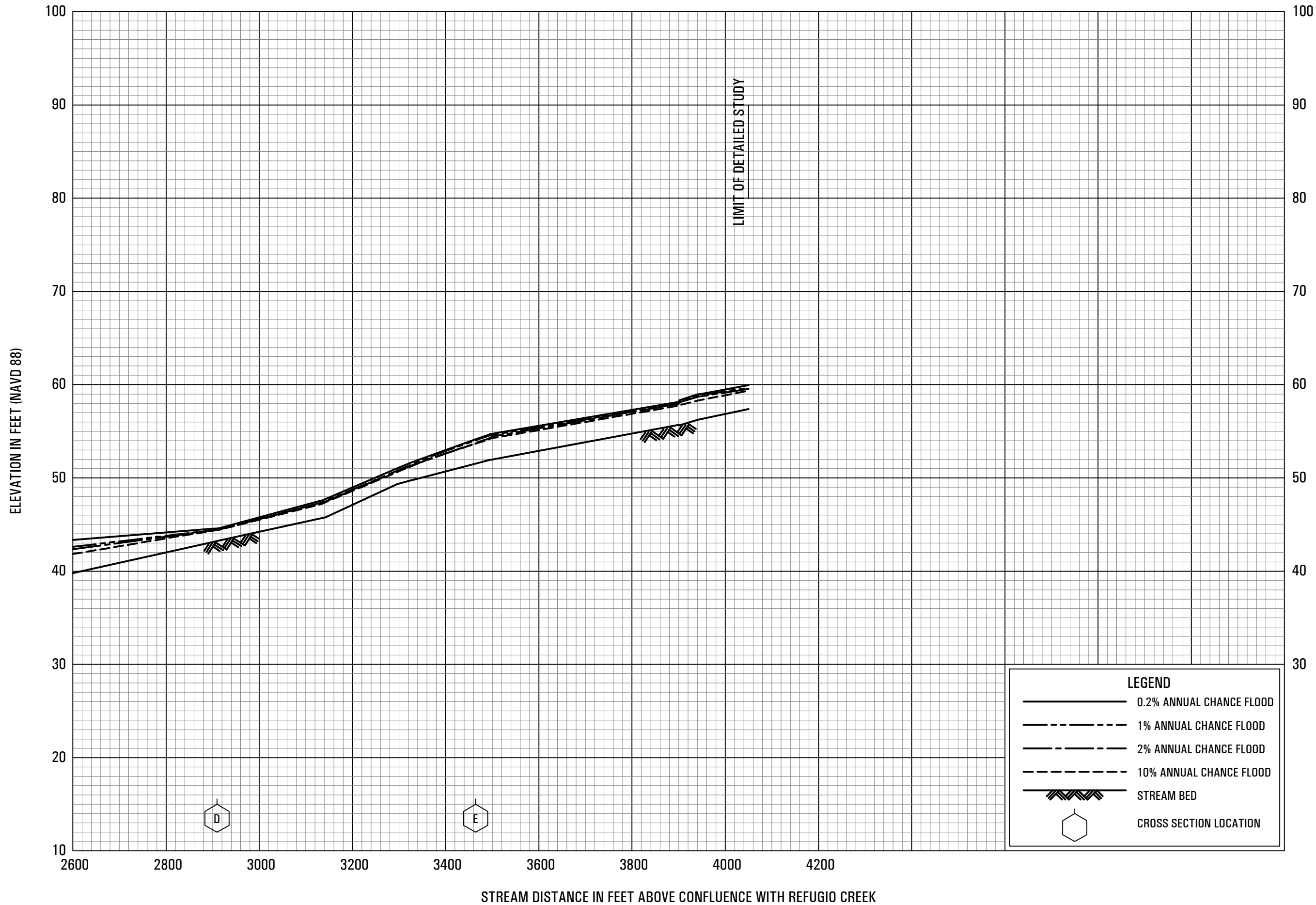
FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
 AND INCORPORATED AREAS



FLOOD PROFILES

EAST BRANCH REFUGIO CREEK

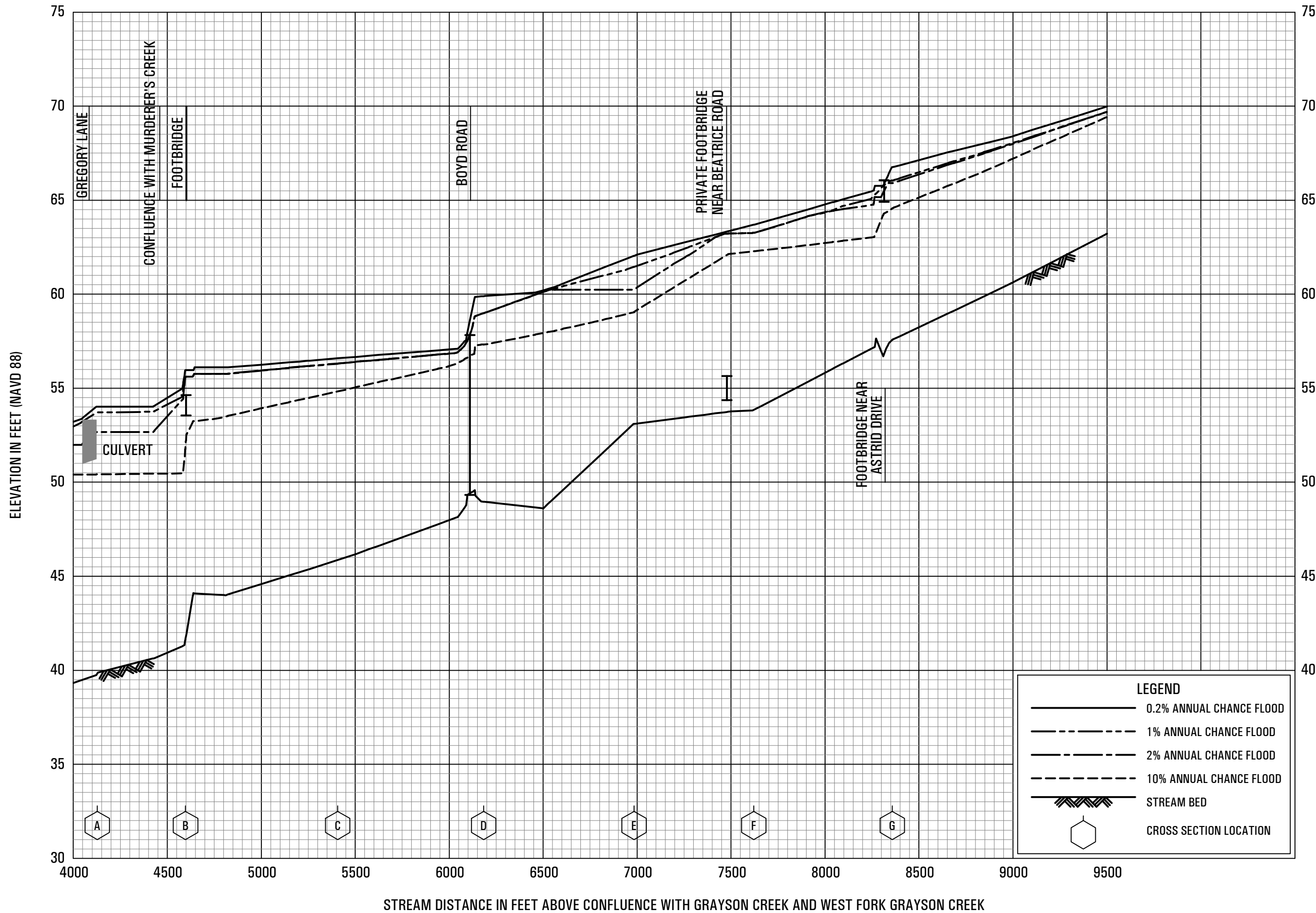
**FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
AND INCORPORATED AREAS**



FLOOD PROFILES

EAST BRANCH REFUGIO CREEK

**FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
AND INCORPORATED AREAS**



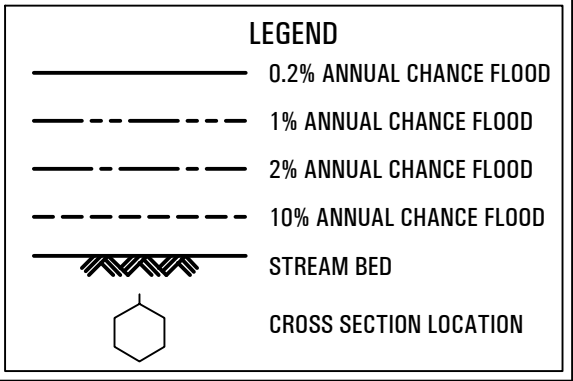
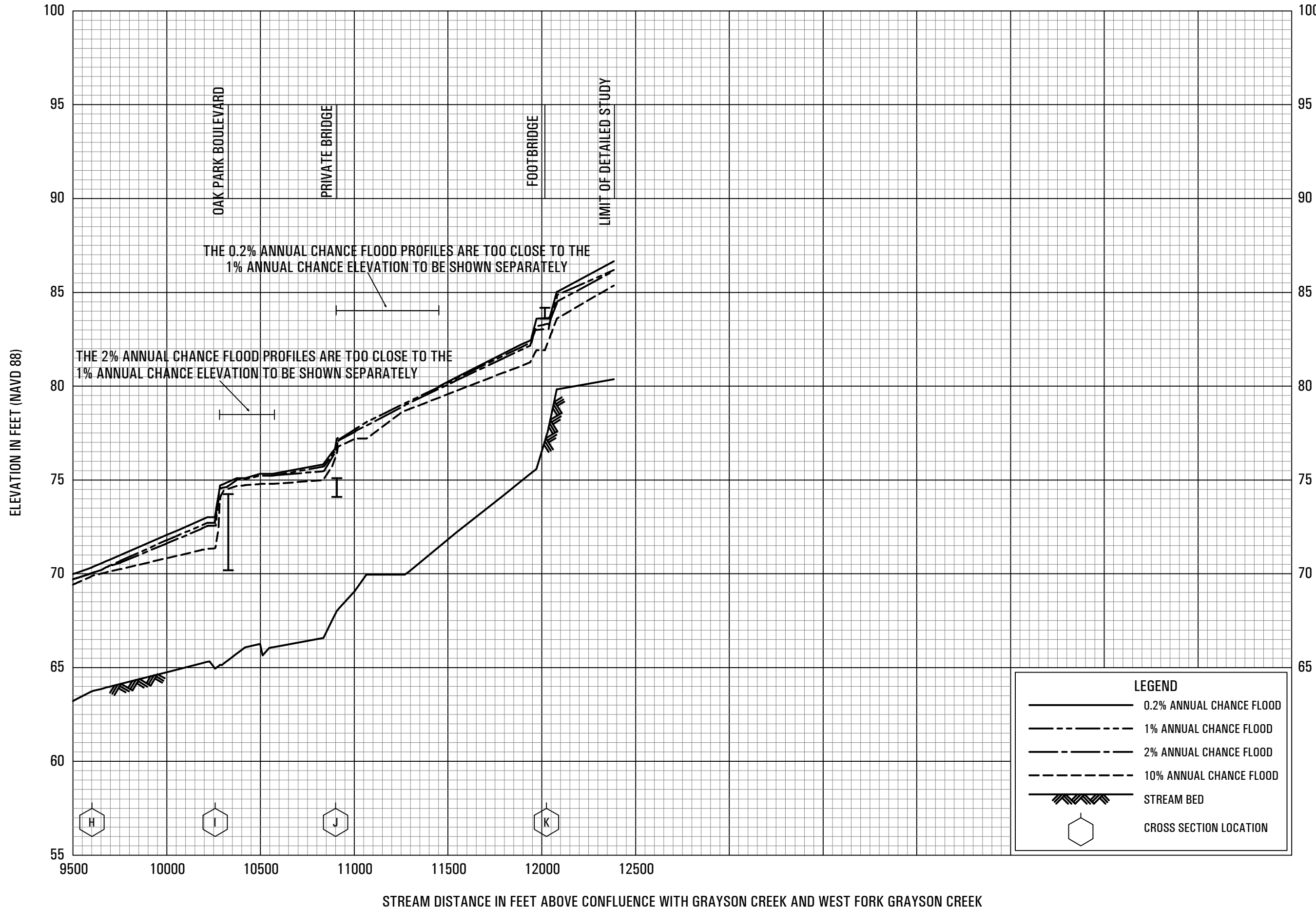
FLOOD PROFILES

EAST FORK GRAYSON CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

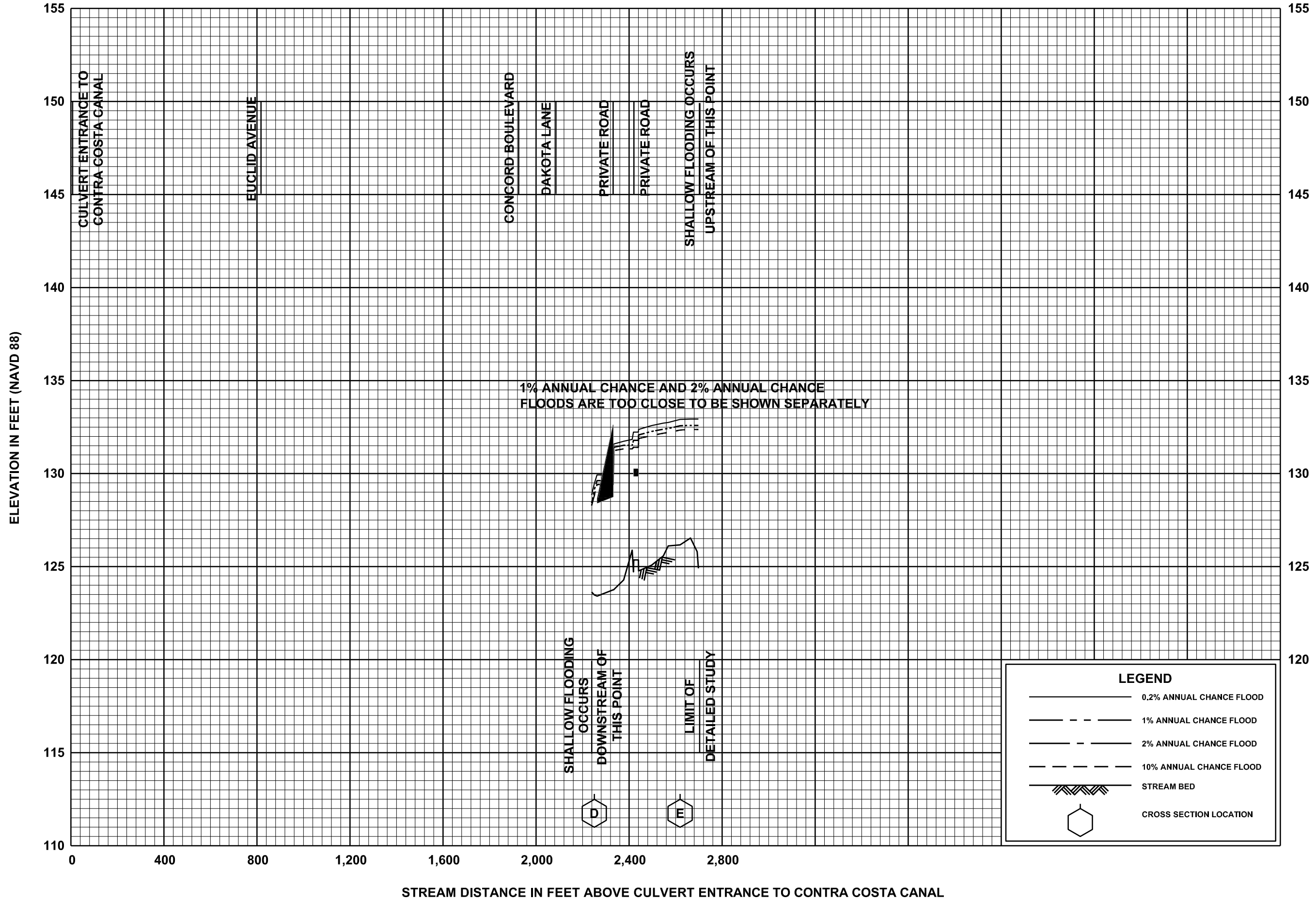
CONTRA COSTA COUNTY, CA

AND INCORPORATED AREAS



FLOOD PROFILES
EAST FORK GRAYSON CREEK

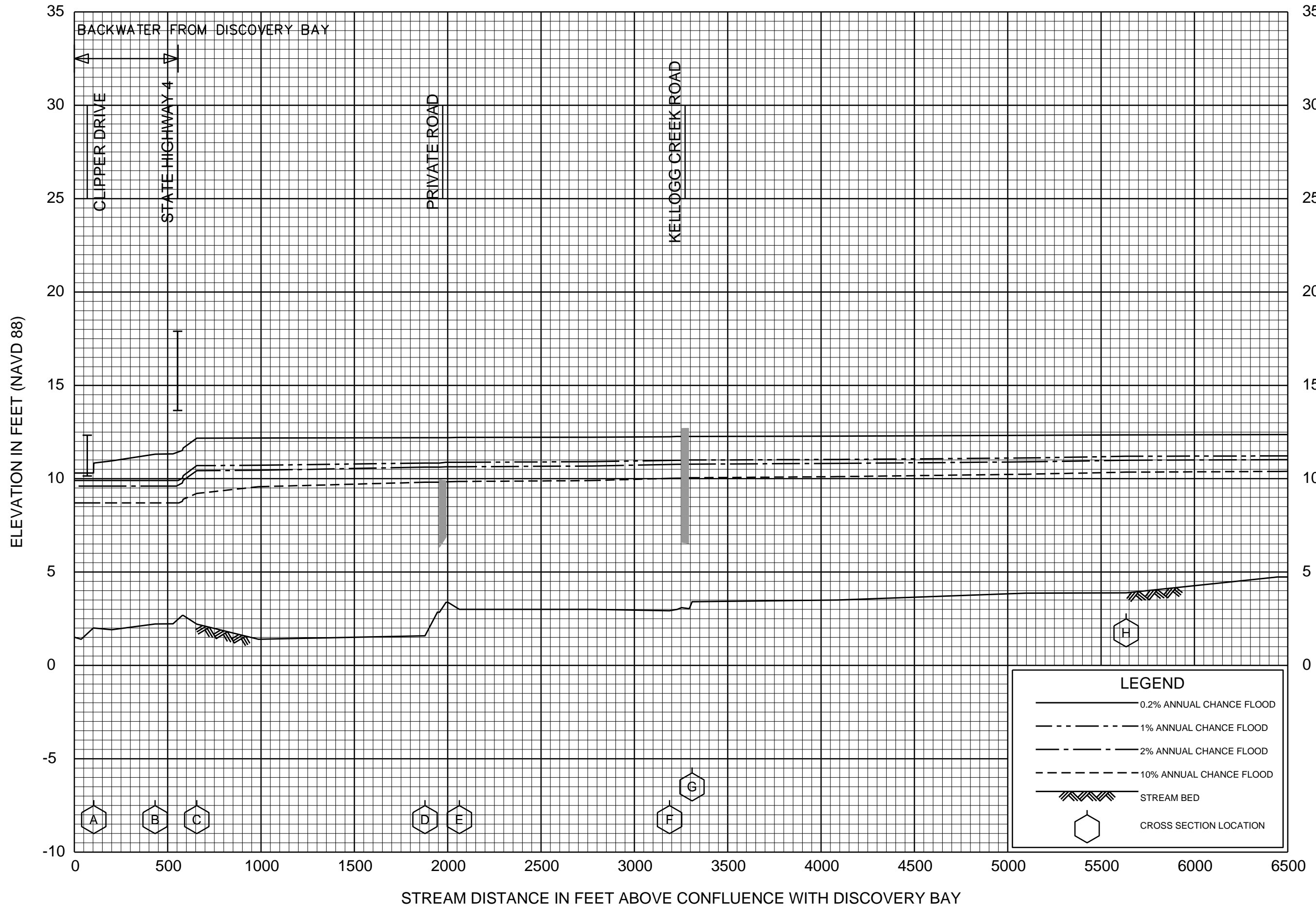
FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
AND INCORPORATED AREAS



FLOOD PROFILES

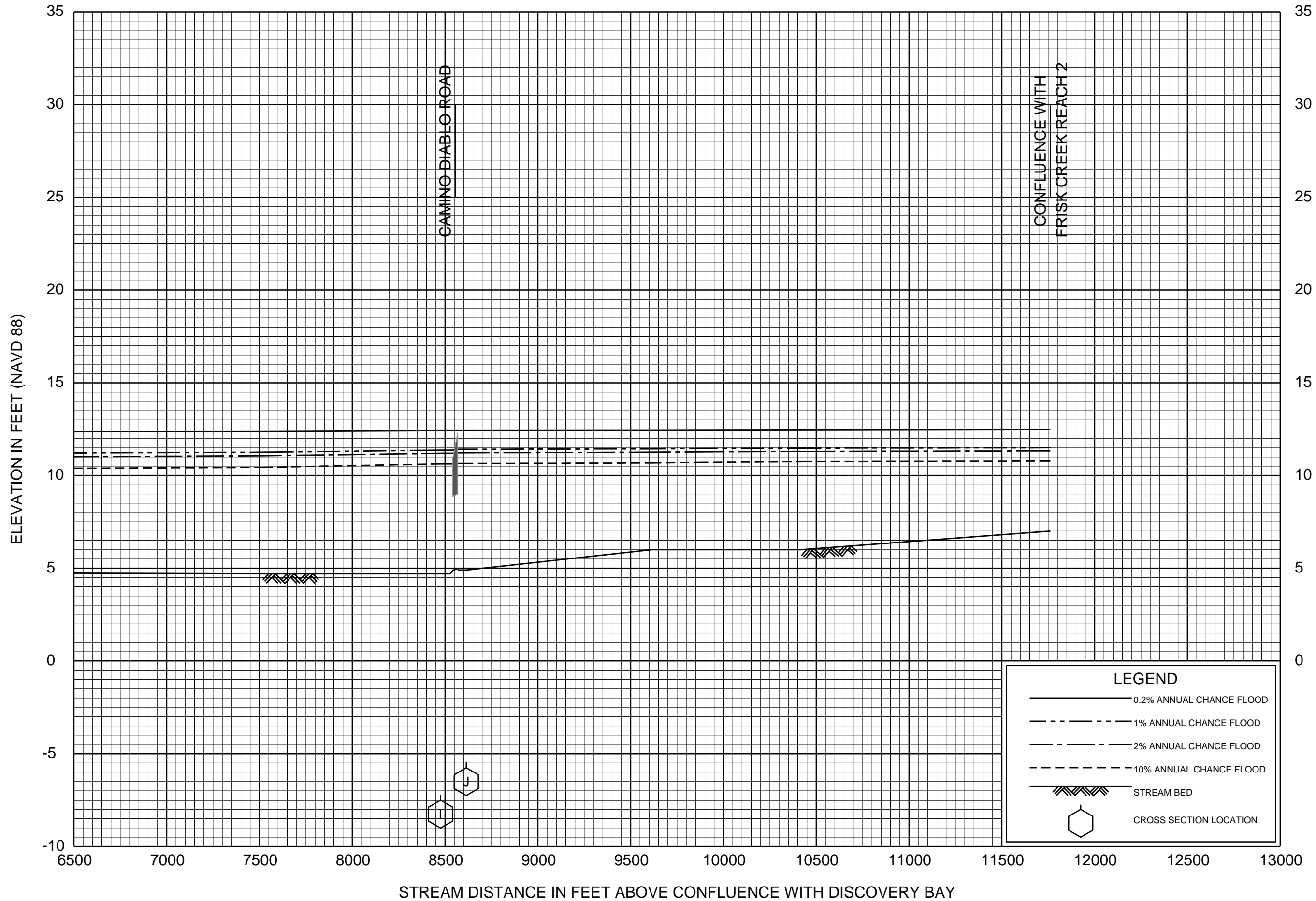
FARM BUREAU ROAD DRAIN

FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
 AND INCORPORATED AREAS



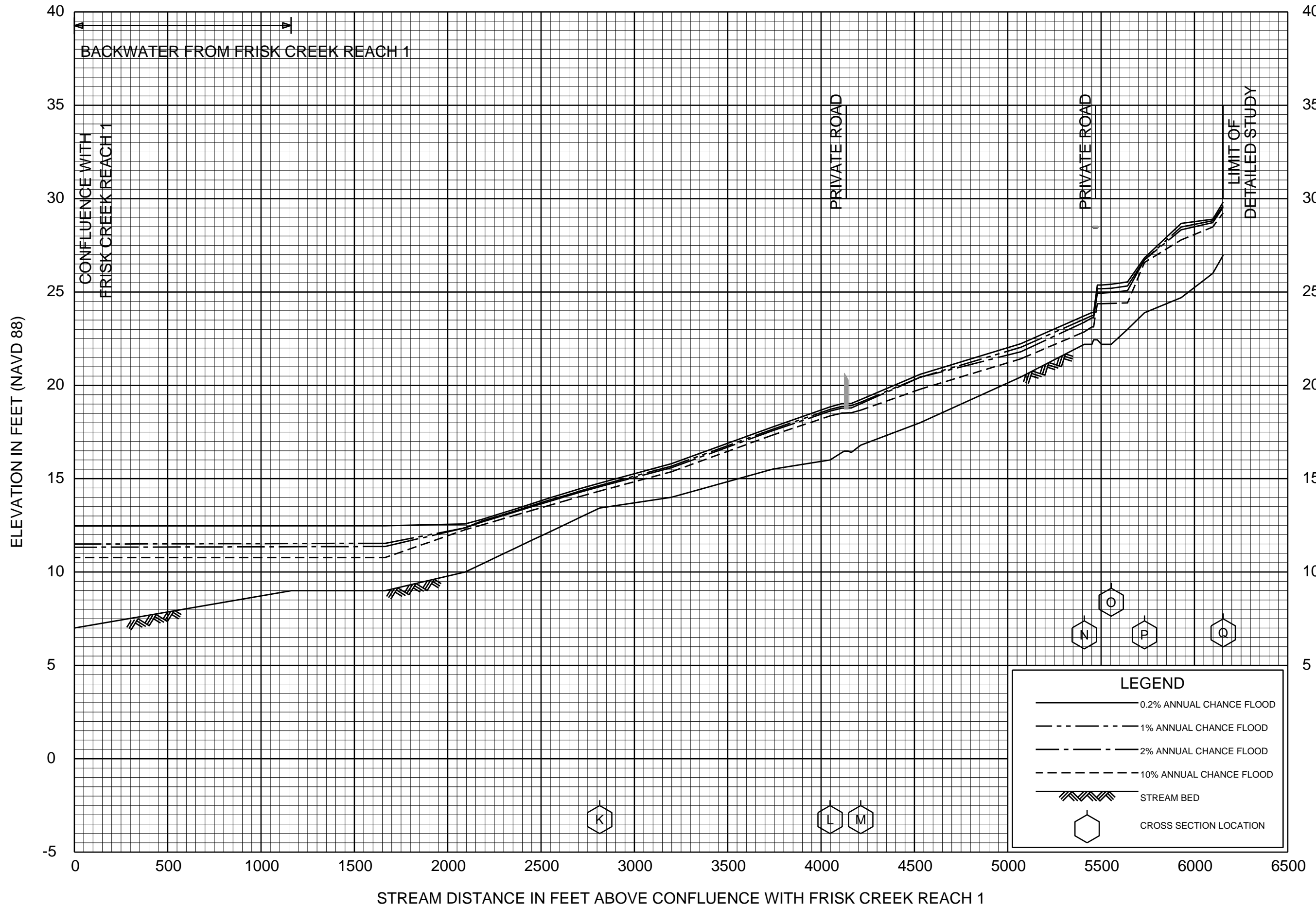
FLOOD PROFILES
FRISK CREEK REACH 1

FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
AND INCORPORATED AREAS



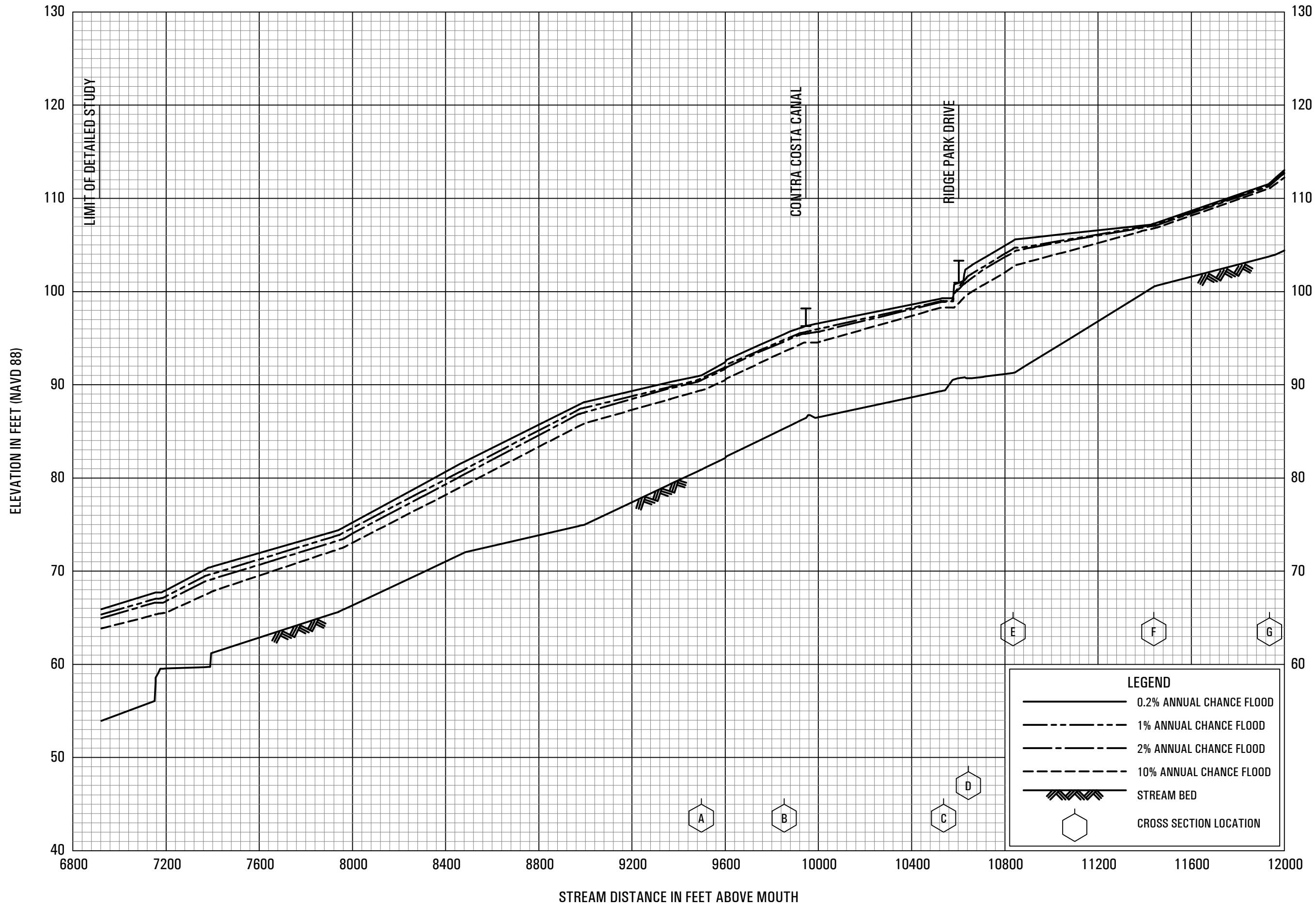
FLOOD PROFILES
FRISK CREEK REACH 1

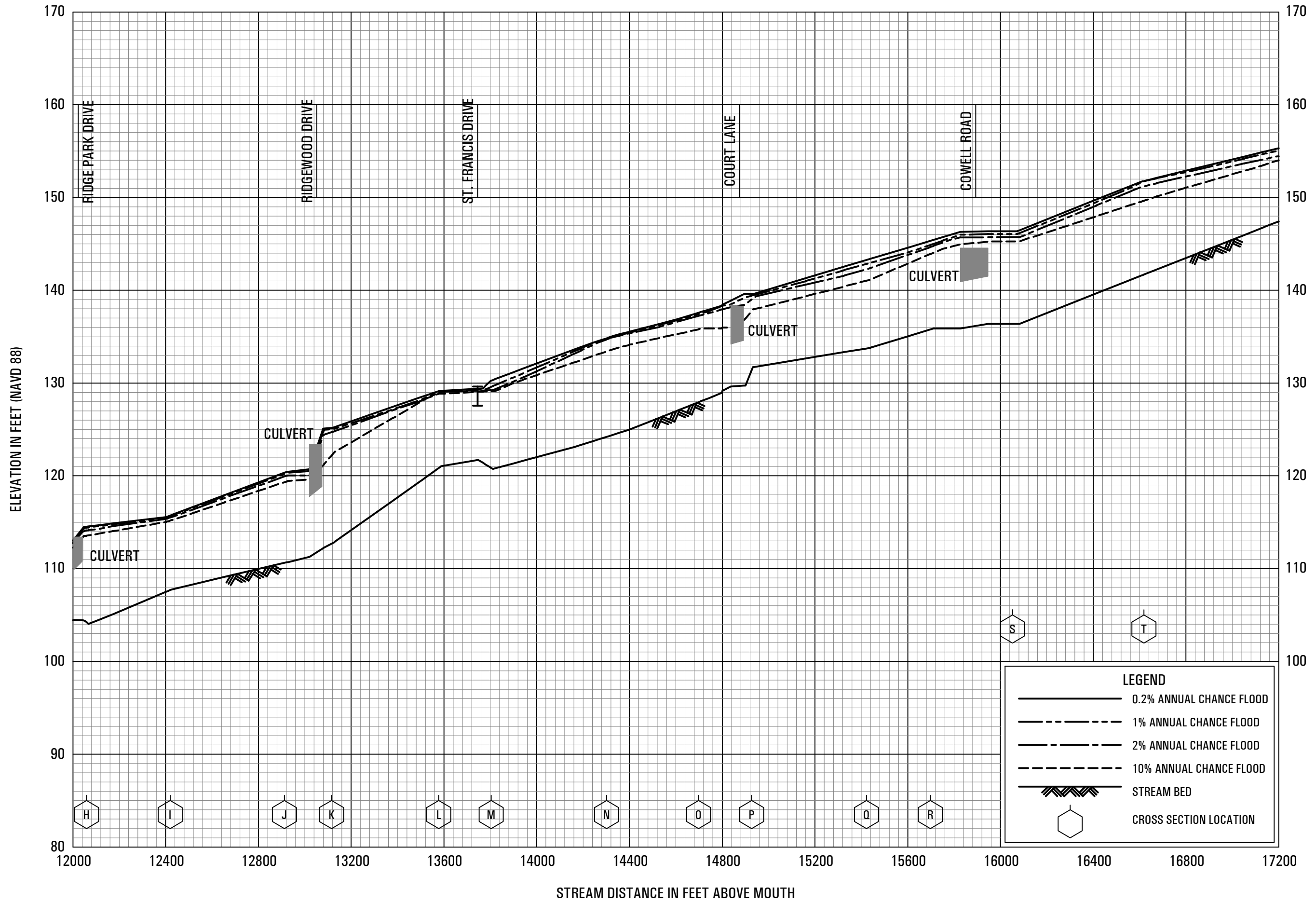
FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
AND INCORPORATED AREAS



FLOOD PROFILES
FRISK CREEK REACH 2

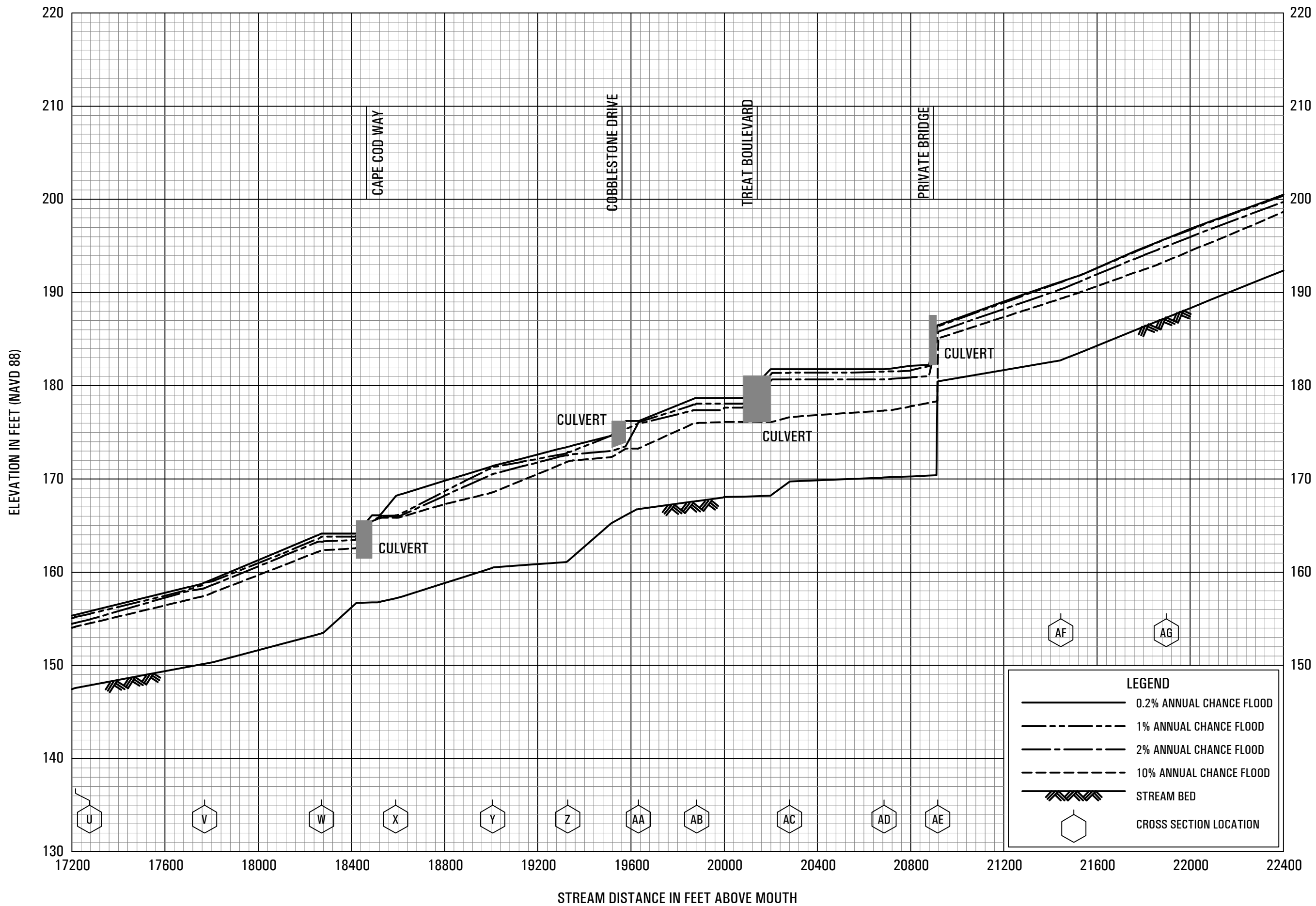
FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
AND INCORPORATED AREAS





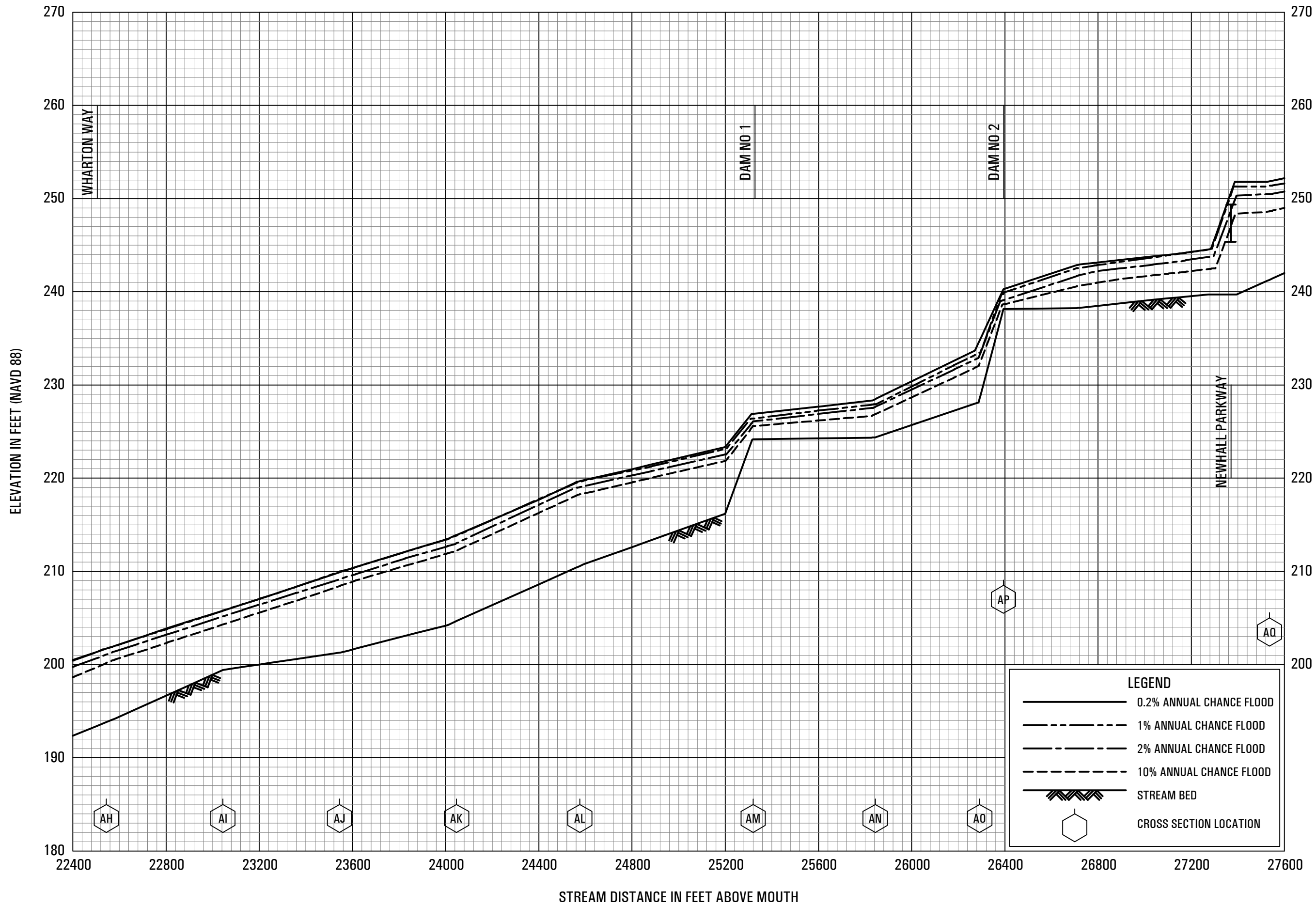
FLOOD PROFILES
GALINDO CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
AND INCORPORATED AREAS

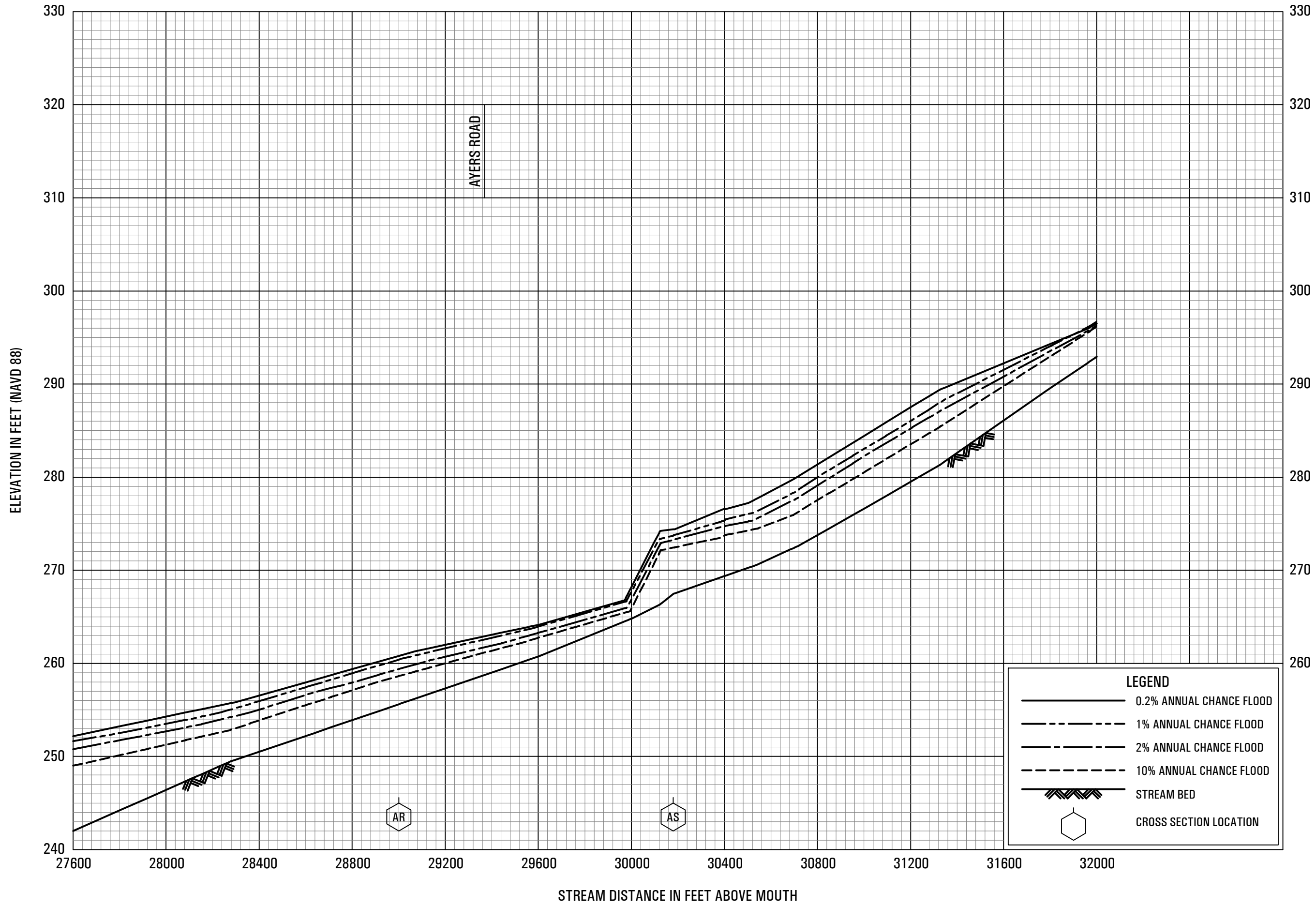


FLOOD PROFILES
GALINDO CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY
CONTRA COSTA COUNTY, CA
AND INCORPORATED AREAS



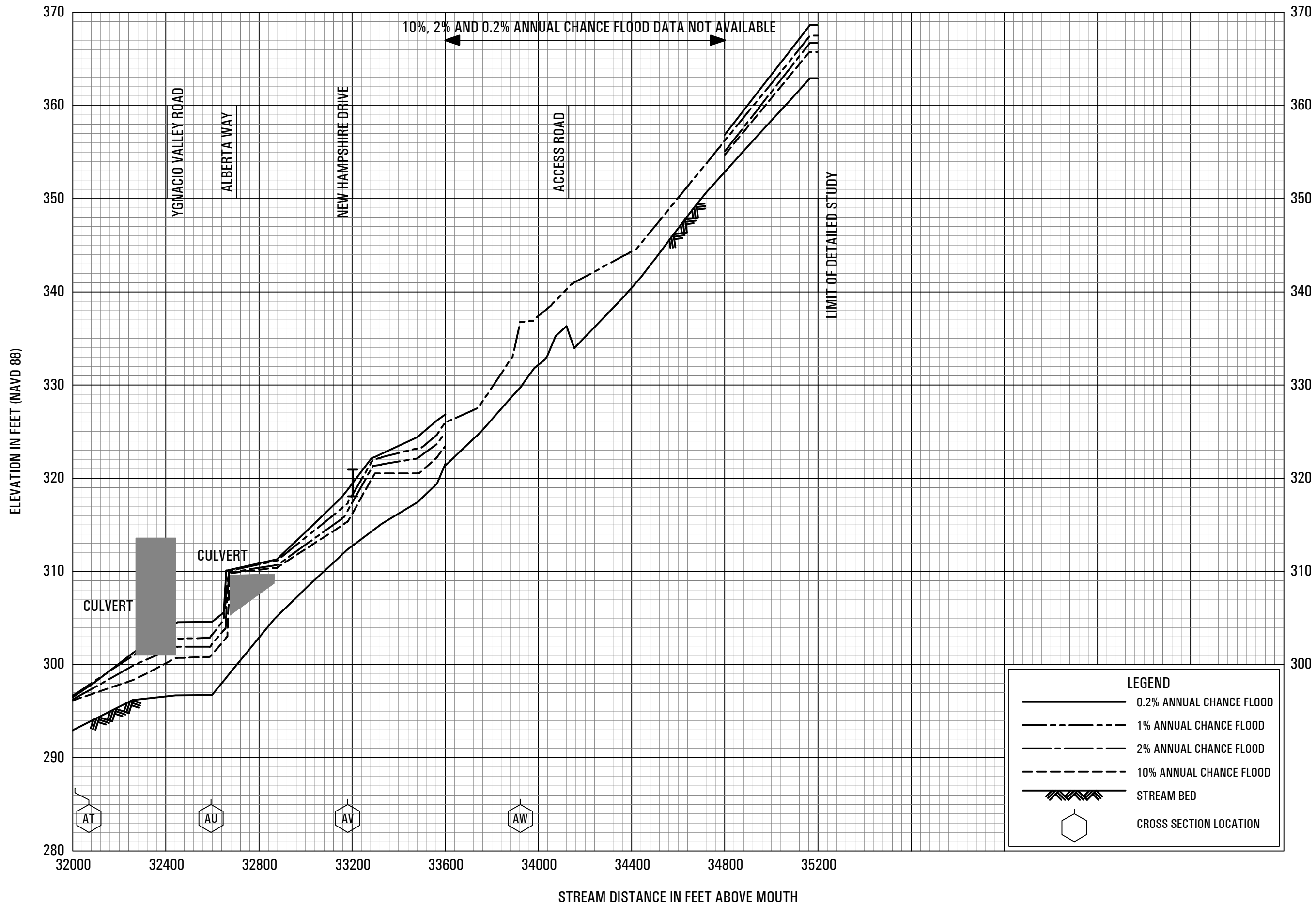
FEDERAL EMERGENCY MANAGEMENT AGENCY
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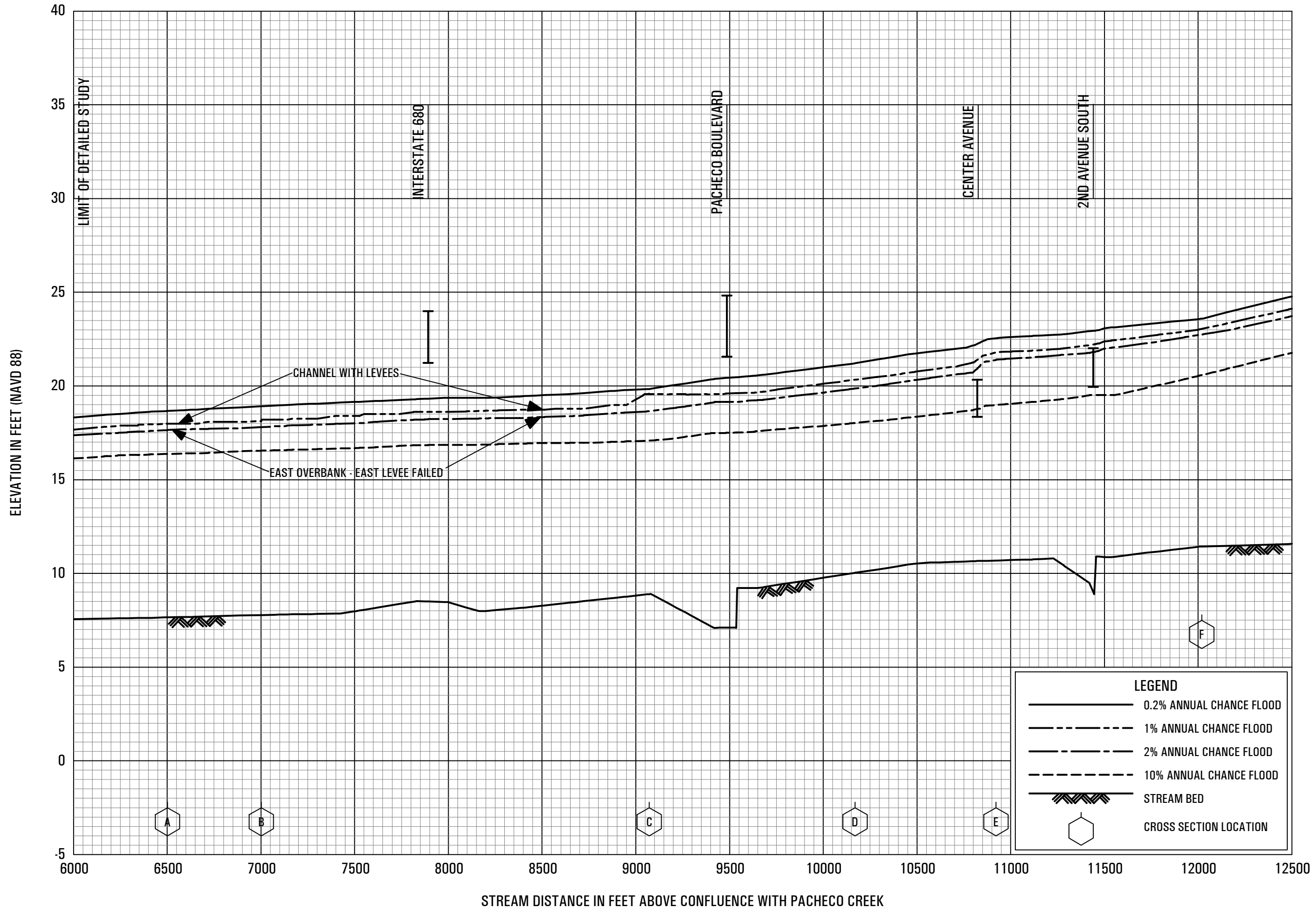
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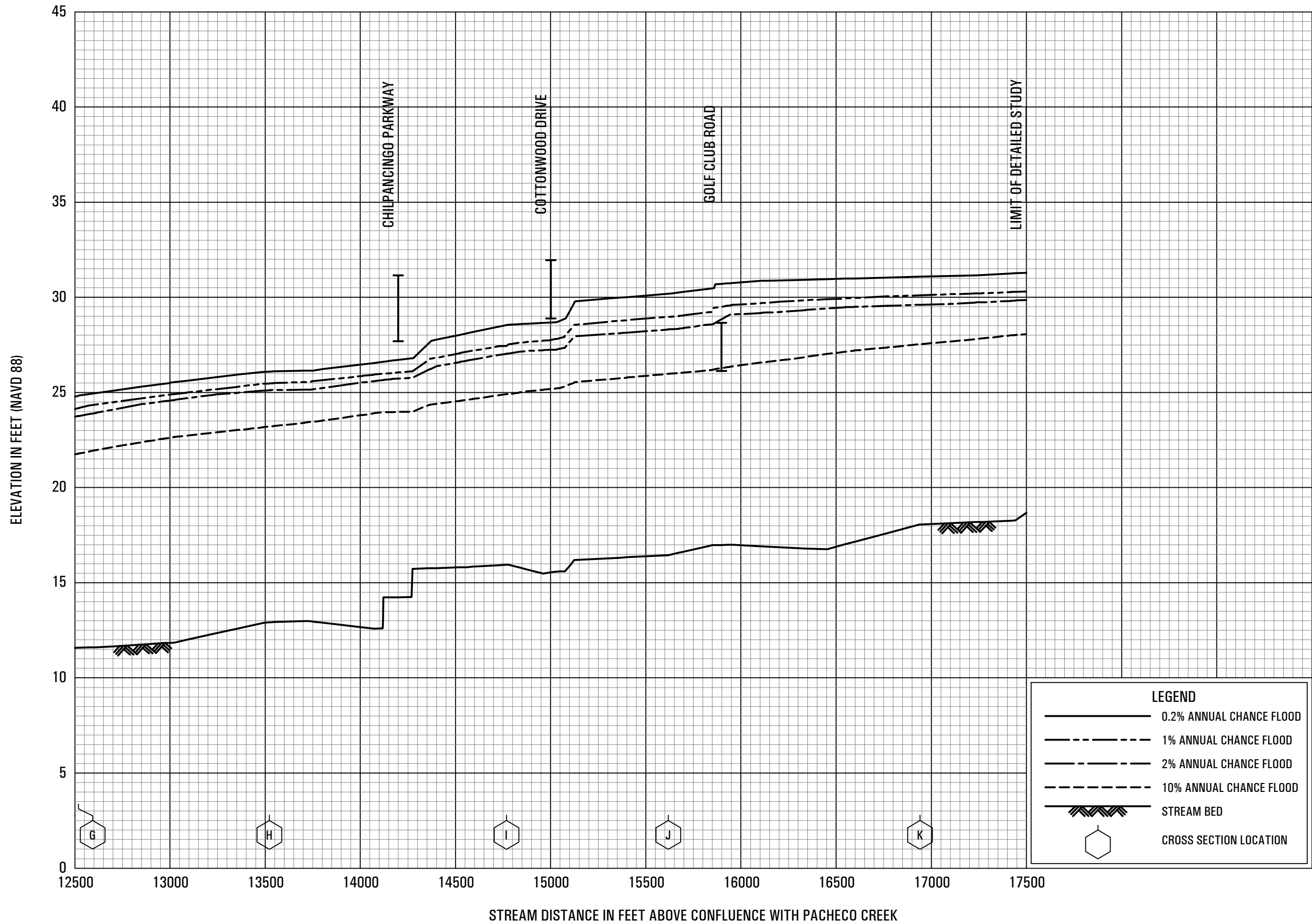
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