US Army Corps of Engineers
Sacramento District

Lower Walnut Creek
General Reevaluation Report
Hydrology Appendix

Walnut Creek Basin
Contra Costa County, California

Revised June 2008

WATER MANAGEMENT SECTION
CERTIFICATION FOR INDEPENDENT TECHNICAL REVIEW

Lower Walnut Creek General Reevaluation Report
Walnut Creek Basin, Contra Costa County, California
Hydrology Appendix, Sacramento District
October 2006, Revised June 2008

GENERAL FINDINGS

Compliance with clearly established policy, principles, and procedures, utilizing clearly justified and valid assumptions, has been verified for the subject project. This includes assumptions; methods, procedures and materials used in the analyses; the appropriateness of data used and level of data obtained; and the reasonableness of the results, including whether the product meets the customers' needs consistent with law and existing Corps criteria and policy.

I certify that an independent technical review of the project indicated above has been completed and all technical issues have been identified and resolved. I recommend certification that the quality control process has been completed.

In accordance with CESPD R 11 10-1-8, South Pacific Division Quality Management Plan, May 2000, this letter certifies that the without-project hydrology is appropriate as the basis for use in the hydraulic analysis for the Lower Walnut Creek Project General Reevaluation.

Laurine L. White — 17 July 2008

Laurine L. White
Hydrologist, SPK

Date

James Chieh — 17 July 2008

James Chieh
Independent Technical Reviewer

Date

Ed Townsley — 7/17/08

Edwin Townsley
Chief, Water Management Section, SPK

Date

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1. Purpose

This report discusses the hydrologic characteristics of the Walnut Creek watershed in Contra Costa County, California. It presents flow frequency curves for the San Ramon and Walnut Creek streamflow gages and the development of the general rainflood hydrographs at study area index points for current without-project conditions for the 50-, 20-, 10-, 4-, 2-, 1-, 0.5-, and 0.2-percent exceedence floods (8-Flood Series). The general rainflood hydrographs will be used for floodplain, sediment yield and transport analyses to be performed by the Hydraulic Design Section. The without-project hydrology certification will be provided for the F3 Conference.

2. Scope

The study area for sediment analysis extends from the mouth of Walnut Creek upstream to the confluence of San Ramon and Las Trampas creeks. The Walnut Creek watershed (General Map, Plate 1), covering almost 180 square miles in Contra Costa County, California, contributes flow to the study reach.

This report includes mean seasonal precipitation information, storm and flow frequency analysis for storm-runoff relationships, historical flood analysis, and the development of the watershed model. The watershed model will be used in conjunction with synthetic general rainstorms to generate flood hydrographs with sufficient duration and volume to convey sediment from headwaters and tributaries down to the Carquinez Strait. The hydrographs are developed for numerous index points to assess sediment yield for various tributaries in the Walnut Creek watershed. The watershed computer model developed during previous Corps Walnut Creek hydrology studies (References 4a through 4f) has been revised and augmented using 2005 land use data and recent computer software.

3. Summary

The Walnut Creek channel currently has a problem with sediment accumulation. The channel can no longer support its original channel capacity flows, which intensifies the flooding problem. Figure 1, below, shows the present sediment accumulation in the channel. Hydraulic Design Section will use the hydrology presented here to analyze sediment yield and conveyance from the Walnut Creek headwaters and its tributaries down to the Carquinez Strait.

Flow frequency curves were computed for the San Ramon and Walnut Creek streamflow gage locations based on analysis of the streamflow records. Synthetic general rainstorms, rainfall-runoff model, and flow frequency curves were used to develop flood hydrographs at various index points in the Walnut Creek watershed for eight synthetic flood events. The 8-Flood Series peak flows for selected index points are listed on Table 12A in Section 12, Results. Concurrent flood hydrographs were also computed for index points on Grayson-Murderer's and Pine creeks and other tributaries to Lower Walnut Creek.

Photo 1. View of Walnut Creek looking upstream toward Mt. Diablo. Shows current sediment accumulation.

Preparation of the hydrology for the Lower Walnut Creek Feasibility Study included revision and extension of the existing HEC-1 computer model used in the 1992 Walnut Creek Basin Feasibility Study Hydrology Office Report (Reference 4e), to analyze the rainfall-runoff relationship for the study area. For information on the HEC-1 computer modeling program, see Reference 4g. Recent land use information and unit hydrograph parameters were used to revise and extend the watershed model from the mouth of San Ramon Creek down the Walnut Creek channel to its confluence with Pacheco Slough. Precipitation data and observed flood hydrographs for the January 1982 high flow event were used to validate the model. NOAA Atlas 2 (Reference 4h) and precipitation frequency criteria for Contra Costa County (Reference 4i), based on nearby climatological station records, were used to develop synthetic general rainstorms over the Walnut Creek watershed.

This Lower Walnut Creek GRR Hydrology Appendix was prepared as a collaborative effort between the U.S. Army Corps of Engineers and the project's local sponsor—the Contra Costa County Flood Control and Water Conservation District (CCCFCWCD). The local sponsor provided information needed for the preparation of report plates and for defining the Walnut Creek watershed subbasins and their associated unit hydrograph and loss rate parameters using HEC-GeoHMS software. The CCCFCWCD also provided information on historic flooding; January 1982 precipitation data; storage-outflow information for the Pacheco Creek detention basin; the latest version of the Precipitation Duration-Frequency-Depth Curves for storm computation; GIS data sets on current land use and mean seasonal precipitation; and the Contra Costa County Watershed Atlas.

4. References

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c. Grayson Creek and Walnut Boulevard Channel, Walnut Creek Basin, California, Interim Review Report for Flood Control, Appendix A—Hydrology. U.S. Army Corps of Engineers, Sacramento District. 1972.

d. San Ramon Bypass General Design Memorandum (GDM), Chapter VII—Hydrology. U.S. Army Corps of Engineers, Sacramento District. January 1983.

e. Walnut Creek Basin, California, Feasibility Study Hydrology Interim Office Report. U.S. Army Corps of Engineers, Sacramento District. Revised February 1992.

f. Grayson and Murderer's Creeks Feasibility Study—Phase 1, Walnut Creek Basin, Contra Costa County, California, Hydrology Appendix, U.S. Army Corps of Engineers, Sacramento District. October 2005.

g. Hydrologic Modeling System HEC-1: Flood Hydrograph Package. Department of the Army, U.S. Army Corps of Engineers, Hydrologic Engineering Center. December 1990. <http://www.hec.usace.army.mil/software/legacysoftware/hec1/hec1.htm>

h. NOAA Atlas 2, Precipitation-Frequency Atlas of the Western United States, Volume XI—California. U.S. Department of Commerce, National Weather Service. 1973. < http://www.nws.noaa.gov/ohd/hdsc/currentpf.htm>

i. Precipitation Duration-Frequency-Depth Curves and Mean Seasonal Isohyets Compiled from Precipitation Records, 1879-1973. Contra Costa County Public Works Department, Contra Costa County Flood Control and Water Conservation District. July 1977.

j. Contra Costa County Watershed Atlas. Contra Costa County, California. Reprinted January 2004

k. City-Data Website with information on U.S. cities and towns: <http://www.City-data.com/city/California.html>

l. Geospatial Hydrologic Modeling Extension HEC-GeoHMS User's Manual. Department of the Army, U.S. Army Corps of Engineers, Hydrologic Engineering Center. April 2006. <http://www.hec.usace.army.mil/software/hec-geohms/>

m. Improved Procedure for Determining Drainage Area Lag Values. Department of the Army, U.S. Army Corps of Engineers, Los Angeles District. July 1962.

n. Technical Paper No. 28, Rainfall Intensities for Local Drainage Design in Western United States, for Durations of 20 Minutes to 24 Hours and 1- to 100-Year Return Periods. U.S. Department of Commerce, Weather Bureau, Washington, D.C. 1956.

o. San Ramon Bypass Channel Supplement No. 5 to Design Memorandum No. 2, Walnut Creek Project, Contra Costa County, California. U.S. Army Corps of Engineers, Sacramento District. October 1986.

p. Standard Project Rainflood Criteria, Sacramento-San Joaquin Valley, California. U.S. Army Corps of Engineers, Sacramento District. Revised September 1958.

q. Flood Frequency Analysis HEC-FFA: User's Manual. Department of the Army, U.S. Army Corps of Engineers, Hydrologic Engineering Center. May 1992.

r. Guidelines for Determining Flood Flow Frequency: Bulletin 17B of the Hydrology Subcommittee, Interagency Advisory Committee on Water Data U. S. Department of the Interior, Geological Survey. Revised September 1981.

s. Regional Frequency Computation (REGFQ), User's Manual. Department of the Army, U.S. Army Corps of Engineers, Hydrologic Engineering Center. July 1972. <http://www.iwr.usace.army.mil/inside/products/pub/pubsearchAll.cfm?alpha=R> [The purpose of this program is to perform frequency computations of annual maximum hydrologic events necessary to a regional frequency study.]

t. San Ramon Watershed Hydrology Report. Contra Costa County Flood Control and Water Conservation District. July 1977.

u. Design Memorandum No. 1, Walnut Creek Project, Contra Costa County, California – Lower Pine and Galindo Creeks Chanel Improvements – Supplement No. 2, Chapter IV – Hydrology. U.S. Army Corps of Engineers, Sacramento District. December 1976.

5. Descriptive Information

5.1 <u>General Characteristics</u>**.** The Walnut Creek basin is located in Contra Costa County about 15 miles east of San Francisco Bay, between the Berkeley Hills to the west and Mount Diablo to the east. The watershed comprises approximately 180 square miles and includes the cities of Walnut Creek, Lafayette, Pleasant Hill, Danville, and parts of the cities of Concord, Martinez, San Ramon, Moraga, and Orinda, all of which are in Contra Costa County, California. See Plate 1 for a map of the watershed and vicinity, and the Contra Costa County Watershed Atlas (Reference 4j) for additional descriptive information.

Walnut Creek is formed by the confluence of San Ramon Creek and Las Trampas Creek, and flows in a northerly direction toward Suisun Bay. About 1.9 miles upstream of the bay, Walnut Creek joins with Pacheco Creek. While the official name of the stream flowing into the bay is Pacheco Creek, most of the drainage area belongs to the Walnut Creek basin. The Walnut Creek headwaters are on upper San Ramon Creek in Bollinger Canyon. Downstream of the headwaters, San Ramon Creek flows northwesterly through the San Ramon Valley to its confluence with Las Trampas Creek. San Ramon tributaries include Sycamore, Green Valley, and Sans Crainte creeks. Las Trampas Creek flows from the west to join San Ramon Creek. Tributaries to Las Trampas Creek include Lafayette, Happy Valley, Grizzly, Reliez, and Tice creeks. Downstream of the Las Trampas-San Ramon confluence, Walnut Creek is joined by Pine and Galindo creeks from the east and by Grayson-Murderer's and Pacheco creeks from the west.

Elevations in the watershed range from above 3,000 feet at the headwaters of Pine Creek near the summit of Mount Diablo to about sea level at the mouth of Pacheco Creek. Steep slopes and deep canyons characterize the headwaters of San Ramon, Las Trampas, Grayson-Murderer's, and Pine creeks. The lower watershed is a gently sloping alluvial floodplain, with slopes ranging between 0.5 and 1.5 percent. The topographic map for the watershed is shown on Plate 2. Stream profiles for San Ramon, Las Trampas, Grayson-Murderer's, and Pine creeks, and Walnut Creek channel from Pacheco Slough up to the San Ramon-Las Trampas confluence are plotted on Plate 3. The headwaters of the tributaries are parkland, with scattered deciduous brush and native grasses. Residential development covers the lower watershed and has replaced former grazing land in the hills. Soils are shallow on the ridges and steep slopes, and become progressively deeper as slopes flatten. In the floodplain the soils consist of sand and clay from alluvial fans and terraces.

5.2 <u>Climate</u>**.** The climate of the Walnut Creek Basin is characterized by cool, wet winters and hot, dry summers. Major storms occur between October and April, the period when over 90 percent of the precipitation occurs. Snowfall is rare and has no effect on streamflow in the study area. Mean seasonal precipitation (same as Normal Annual Precipitation) over the study area varies from less than 15 inches at the mouth of Pacheco Creek to about 30 inches in the Lafayette Creek headwaters in the Oakland Hills at the western end of the watershed (see Plate 4 for the mean seasonal precipitation

(MSP) isohyetal map for the basin). Temperatures are normally above freezing but can vary from slightly below freezing in winter to over 100°F in summer. Mean monthly temperatures and precipitation data for the cities of Pleasant Hill and for a nearby NOAA climatological station, Martinez Water Plant (WP), are tabulated on Table 5A. Climatological stations in and around Walnut Creek were discontinued by the early 1980's. The Pleasant Hill climate information is from the City-Data website (Reference 4k). The location of the Martinez WP station is shown on Plate 5.

Table 5A
Average Monthly Temperatures (ºF)
and Precipitation Data
Pleasant Hill and Martinez Water Plant

Month	Average Monthly Temperature (ºF)		Average Monthly Precipitation (in.)	
	Pleasant Hill	Martinez WP	Pleasant Hill	Martinez WP
Jan	46.7	47.0	4.40	4.11
Feb	50.7	51.6	3.90	3.77
Mar	53.9	55.2	3.30	3.09
Apr	58.0	59.2	1.10	0.99
May	63.0	64.5	0.50	0.45
Jun	68.2	69.6	0.10	0.12
Jul	70.7	71.9	0.00	0.02
Aug	70.4	71.6	0.10	0.07
Sep	68.4	69.5	0.30	0.22
Oct	62.5	63.2	1.00	0.88
Nov	53.1	54.0	2.70	2.72
Dec	46.9	47.3	2.90	3.25
Average Annual:	59.4	60.4	Total (in.) 20.30	Total (in.) 19.69

Martinez WP: Period of record used 1971-1975, 1977-2002
Pleasant Hill: data is from http://www.city-data.com/city/California.html

5.3 Stream Gages. The U.S. Geological Survey (USGS) has records for several streamflow gaging stations within the Walnut Creek watershed. All but one of the Walnut Creek watershed stations have been discontinued. Table 5B lists the gaging stations in the Walnut Creek watershed along with their respective periods of record and highest observed peak flows. Plate 5 shows the locations of the streamflow gages listed on Table 5B.

Table 5B
Streamflow Gaging Station Information
Walnut Creek Watershed

USGS Number	Station Name	Drainage Area (sq. mi.)	Period of Record		Peak Flow of Record	
			Start	End	(cfs)	Date
11182500	San Ramon Cr at San Ramon	5.9	1952	present	1,600	13-Oct-62
11182800	San Ramon Cr near Walnut Cr	47.9	1974	1992	7,400	5-Jan-82
11183000	San Ramon Cr at Walnut Cr	50.8	1952	1973	7,980	31-Jan-63
11183500	Walnut Cr at Walnut Cr	79.2	1952	1968	12,200	2-Apr-58
11183600	Walnut Cr at Concord	85.2	1969 1997	1992 1997	13,300	5-Jan-82
11183700	Little Pine Cr near Alamo	1.2	1974	1989	138	4-Jan-82
11184000	Galindo Cr at Concord	7.7	1954	1958	902	2-Apr-58
11184500	Pine Cr at Concord	28.3	1952	1960	1,160	2-Apr-58
11185000	Grayson Cr near Hookston	2.0	1954	1960	602	2-Apr-58
11185100	Grayson Cr near Pacheco	4.3	1954	1958	622	2-Apr-58

6. Storm and Flood Characteristics

6.1 Storm and Flood Characteristics. Historically, floods have been caused by heavy rain during storms occurring in the winter and early spring, such as the storms of December 1955 and March-April 1958. More recently, flood potential has increased in direct proportion to the increase in impervious areas caused by expanding urbanization.

Storms in the Walnut Creek area are of two types, general and local. General storms are widespread, with total storm duration of about 96 hours. General storms in the Walnut Creek area usually have small area thunderstorms embedded in them. The local type storm results primarily from convective action and is characterized by very high rates of precipitation for short durations from several minutes to several hours.

6.2 Flood History. Flooding in the Walnut Creek area is primarily caused by the combination of heavy winter rains and overflow of drainage facilities with limited conveyance capacity. Severe flooding occurred in this way on Walnut Creek and its tributaries in December 1955 and again in March and April of 1958. The 1958 flooding caused the greatest flood damage, when 42.8 inches of rainfall was recorded during an 8-day period.

Numerous smaller floods have occurred in the area prior to 1981. Since then major floods affected the area in 1982, 1983, 1986, 1995, 1997, 1998, and 2002. The January 1997 flood, an estimated 6% chance event, caused damage to about 100 homes in Pleasant Hill. Rainfall in February 1998 and December 2002 caused problems with mudslides and bank erosion.

7. Historical Flood Analysis and Model Development

7.1 Hydrologic Analysis—General. The general rains of January 1982 produced the peak flows of record at the San Ramon Creek near Walnut Creek and the Walnut Creek at Concord streamflow gages. For the 1992 Walnut Creek feasibility study hydrology office report (Reference 4e), the San Ramon Creek HEC-1 model was used to reconstitute the January 1982 flood hydrograph for the San Ramon Creek gage. This was done to check whether the selection of subbasin drainages, and values for composite roughness coefficient "n" and Muskingum routing coefficients were reasonable.

For this revision/expansion of the Walnut Creek hydrology for 2005 conditions, the San Ramon HEC-1 model was expanded to include Las Trampas Creek and the Walnut Creek channel down to Pacheco Creek, along with west- and east-side tributaries like Grayson and Pine creeks. The expanded HEC-1 model includes the index points for which the Hydraulic Design Section will need flood hydrographs for its hydraulic model of the Walnut Creek watershed. Ninety-six-hour general rainstorms were used in conjunction with the HEC-1 model to compute flood hydrographs of sufficient volume and duration to carry sediment from the headwaters streams down to Suisun Bay. The HEC-1 model for the Walnut Creek watershed above the "at Concord" gage was validated using observed hydrograph data for the January 1982 flood at the three watershed streamflow gages, two on San Ramon Creek and one on Walnut Creek downstream of Las Trampas Creek.

7.2 Updated HEC-1 Model. Earlier HEC-1 computer models for the Walnut Creek Basin were developed for the studies listed in References 4a through 4f. The basic HEC-1 model for the San Ramon Creek used in the 1992 Walnut Creek feasibility study hydrology office report (Reference 4e) was used as a starting point for the revised hydrology. The HEC-1 model was extended down the Walnut Creek channel to its confluence with Pacheco Creek, with subbasins added to include index points needed for the current hydrology. The delineation of subbasins and computation of their watershed parameters for 2005 urbanized conditions was performed using GIS data and the HEC-GeoHMS computer program (Reference 4l).

For the most part, the HEC-1 model for Grayson and Murderer's creeks developed for the Grayson and Murderer's Creeks Feasibility Study (see Reference 4f) was used for the Grayson-Murderer's creeks component of this study. The storms centered on the San Ramon and Las Trampas watersheds for the Lower Walnut Creek study are of longer duration than the 3-hour Grayson-centered storms. The exponential loss rate function was used with the Grayson HEC-1 model for these longer storms, to be consistent with the loss rates used with the Walnut Creek HEC-1 model in this study. The exponential loss rate methodology is discussed below in Section 7.5. The base flow was modified as well. The Grayson-Murderer's HEC-1 model, listed at the end of this report as Attachment 2, uses a 10-minute time step because the watershed was so finely subdivided for the Grayson Creek hydrology study. The HEC-1 model for San Ramon and Walnut creeks uses a 15-minute time step, because most of the subbasins in the model are larger. Development of the HEC-1 model for the three components of the Walnut Creek watershed, excluding Grayson Creek, is discussed below.

a San Ramon Creek and San Ramon Bypass. The impervious ratios for San Ramon subbasin loss rates were revised for the current model, based on recent land use information. A tributary subbasin, Sans Crainte Creek, and a flow diversion for the San Ramon Bypass below Sans Crainte Creek were added to the HEC-1 model. The San Ramon Bypass was constructed around 1990 to carry most of the San Ramon Creek flood flows away from the original San Ramon Creek channel and its confluence with Las Trampas Creek. The location of the San Ramon Bypass is shown on Plate 7E.

b. Las Trampas Creek and Lower Walnut Creek HEC-1 Model. The Las Trampas watershed and smaller Walnut Creek channel tributaries down to the confluence with Pacheco Creek were subdivided for the revised HEC-1 model. Lafayette Reservoir subbasin is assumed to be non-contributing to Las Trampas Creek, based on information from CCCFWCD. The 1992 Tice Creek HEC-1 model, with a revised imperviousness ratio, is included as a tributary to Las Trampas Creek.

c. Pine Creek HEC-1 Model. Pine Creek, with its Galindo Creek tributary, has a combined drainage area of about 30 square miles. This is the largest Walnut Creek tributary watershed downstream of Las Trampas Creek. The Pine Creek watershed was subdivided and added to the revised HEC-1 model. Routing parameters for two detention basins, located in the upper reaches of Pine Creek basin, were included in the HEC-1 model.

7.3 Unit Hydrograph Development. Basic unit hydrograph procedures developed by the U.S. Army Corps of Engineers, Los Angeles District, were used for computing the subbasin unit hydrographs. (See Reference 4m for a description of the unit hydrograph procedure.) The procedures use appropriate "S-curve" distribution curves and measurable physical characteristics of the subbasins. For the 1972 revision of the Walnut Creek hydrology study (Reference 4b), an S-curve was developed from a reconstitution of the 2 April 1958 flood hydrograph measured at the San Ramon Creek at San Ramon gage. The gaged drainage is a non-urbanized mountainous basin. The S-curve is presented on Plate 6. Subbasin boundaries for the HEC-1 model are presented on the Subbasin Maps, Plates 7A through 7D. The San Ramon Bypass and original San Ramon Creek channels are shown on Plate 7E.

Unit hydrographs were developed for the Las Trampas and Pine Creeks and the Walnut Creek channel subbasins using the Walnut Creek Mountain S-curve and subbasin physical parameters of drainage area, length of the longest watercourse (L), length along longest watercourse measured upstream to the center of mass of the drainage area (L_{ca}), overall slope of the longest watercourse between headwater and collection point (S), and the basin roughness coefficient (n). The subbasin physical parameters for Las Trampas and Pine creeks and smaller Walnut Creek tributaries were developed using GIS information provided by the Contra Costa County Flood Control and Water Conservation

District (CCCFCWCD). Lower values of “n” reflect increasing urbanization not only in the valley but also in the mountainous subbasins of the Walnut Creek watershed.

The subbasin parameters have been correlated with “Lag time,” the time required for natural unit hydrographs (S-curves) to reach 50% of volume. This correlation, derived from analysis of recorded flood events on watersheds in the Los Angeles metropolitan area, is defined by the following empirical equation:

$$\text{Lag time} = 24 * n\,(L * L_{ca}/S^{0.5})^{\,0.38}$$

where

L = length along the longest watercourse, in miles.

Lca = length along the longest watercourse, measured upstream to the point opposite the center of the area, in miles.

Elevation = the elevation difference between headwater and collection point in the basin, in feet.

Slope = overall slope of the longest watercourse between the headwater and collection point, in feet per mile.

Solution of this equation for various values of “n” is shown on Plate 8. Table 7A lists the subbasins with their lag times, composite roughness coefficents and percent of imperviousness used for both current watershed conditions and the January 1982 flood validation. Percents of imperviousness for Walnut Creek are discussed in Section 7.6. Table 7B lists the subbasins with the rest of their unit hydrograph parameters.

Table 7A
Walnut Creek Subbasin Descriptions and Unit Hydrograph Parameters, Part 1

Subbasin Code*	Subbasin Description	Drainage Area (sq. mi.)	Lag Time (hrs.)	Composite Roughness Coefficient N	Percent Impervious Factor (in %)	
					Present Conditions	1982 Conditions
USR3	San Ramon Cr nr San Ramon Gage	5.89	1.89	0.07	4.3	4.3
USR2	San Catanio Cr at San Ramon	3	1.10	0.06	26.6	23.9
USR1	Upr San Ramon Cr Local abv Sycamore	4.72	0.87	0.05	43.3	39.0
S3	Upper Sycamore Cr abv Black Hawk	3.88	1.12	0.06	9.5	8.6
S2	Upper Sycamore Cr - U/S of Pt 5	1.12	0.80	0.06	22.9	20.6
S1	Lower Sycamore Cr Local at Mouth	3.26	1.29	0.05	21.5	19.4
SR7	Danville - San Ramon Cr Local abv Green Vy	2.37	0.48	0.04	32.2	29.0
GV4	Upper E.B. Green Valley Cr	2.21	0.63	0.06	11.6	10.4
GV3	Lower E.B. Green Valley Cr	2.86	0.97	0.06	14.9	13.4
GV2U	Upr N.B. Upper Green Valley Cr	1.36	0.41	0.06	11.3	10.2
GV2L	Lwr N.B. Green Valley Cr Local	1.17	0.54	0.05	31.3	28.2
GV1	Lower Green Valley Cr Local at Mouth	1.85	0.78	0.04	24.3	21.9
SR6	San Ramon Cr Local Abv Alamo	6.17	0.89	0.05	21.5	19.4
SR5	Stone Valley Cr at Mouth	2.65	0.76	0.05	26.2	23.6
SR4	Miranda Creek at Mouth	2.27	0.94	0.06	19.4	17.5
SR2	San Ramon Local - Miranda to Sans Crainte	2.58	0.97	0.04	30.9	27.8
SR3	Sans Crainte Cr at Mouth	2.63	0.90	0.05	18.2	16.4
SR1	Lwr San Ramon Cr Local abv Las Trampas	0.44	0.51	0.03	58.3	52.5
LT7	Lafayette Cr U/S of Lafayette Res Trib	2.05	0.65	0.05	42.7	38.4
LT8	Lafayette Reservoir Trib	1.3	N/A	N/A	N/A	N/A
LT6	Happy Valley Tributary	3.45	0.71	0.04	36.9	33.2
LT5	Upper Las Trampas Cr	9.48	1.88	0.06	20.9	18.8
LT4	Reliez Creek at Mouth	3.61	1.06	0.05	27.0	24.3
LT9	Upper Mid Las Trampas Cr	1.16	0.46	0.03	46.8	42.1
LT2	Mid Las Trampas Cr	1.49	0.55	0.03	55.1	49.6
LT3A	Tice Cr abv Rossmoor Deten. Basin	2.65	0.89	0.07	38.4	34.6
LT3B	Tice Cr Local abv Castle Hill	0.49	0.48	0.07	38.4	34.6
LT3C	Castle Hill Cr at Mouth	0.48	0.52	0.08	38.4	34.6
LT3D	Tice Cr Local at Mouth	0.56	0.65	0.06	38.4	34.6
LT1	Las Trampas Cr Local at Mouth	0.12	0.21	0.03	88.2	79.4
W9	Walnut Cr above Indian	1.03	0.42	0.03	59.8	53.8
W8	Walnut Bypass Local Drainage	0.25	0.40	0.03	70.3	N/A
T1	Indian Cr Subbasin	2.04	0.65	0.04	35.3	31.2
W7	Walnut Cr Local Blw Indian Cr	0.64	0.35	0.03	58.4	52.6
B1	Las Casa Via Drainage N of Indian Cr	1.21	0.56	0.04	43.1	38.8
W6	Bancroft Local	0.88	0.47	0.03	66.0	59.4
W5	Mid Walnut Local Drainage U/S Pine Cr	1.11	0.90	0.03	78.8	N/A
P7	Upper Pine Cr	3.16	1.18	0.08	3.1	N/A
P6	Mid Pine Cr	6.77	1.46	0.08	3.8	N/A
P4	Mid Lower Pine Cr	5.24	1.39	0.05	32.9	N/A
P5	West Pine Subbasin	2.8	0.94	0.04	56.9	N/A
P3	Lower Pine Subbasin	1.76	0.58	0.03	72.2	N/A
P2	Galindo Cr at Mouth	7.61	1.90	0.05	43.6	N/A
P1	Pine-Galindo Out	2.72	0.52	0.03	77.6	N/A
W4	Walnut Cr Blw Pine Local	1.59	0.56	0.03	82.1	N/A
TW1	North Trib to Walnut Cr	5.6	1.07	0.03	77.8	N/A
W3	Walnut Local Abv Grayson	0.21	0.23	0.04	81.1	N/A
W2	Walnut Cr below Grayson	0.2	0.28	0.05	67.1	N/A
W1	Walnut Out Local	0.29	0.19	0.05	62.5	N/A
PA2A	Upper Pacheco Cr	1.76	0.55	0.04	69.9	N/A
PA2B	Mid Pacheco Cr	1.40	0.40	0.03	69.9	N/A
PA1	Lower Pacheco Cr	0.83	0.40	0.04	84.9	N/A

* Subbasin codes used in GeoHMS process for definition of subbasin unit hydrograph parameters.
Lag time = the time required for natural unit hydrograph (S-curves) to reach 50% of total volume, in hours.
Composite roughness coefficient "n" = coefficient representing basin roughness and shape.
Percent impervious factor = percent of the subbasin for which runoff is 100%.
SEE PLATE 6 FOR S-CURVE AND PLATE 8 FOR LAG RELATIONSHIPS

Table 7B
Walnut Creek Subbasin Unit Hydrograph Parameters, Part 2

Subbasin Code	Subbasin Description	Drainage Area (sq. mi.)	L (mi.)	Lca (mi.)	Elev Diff (ft.)	Slope (ft./mi.)
USR3	San Ramon Cr nr San Ramon Gage	6.31	6.75	3.65	1478	219
USR2	San Catanio Cr at San Ramon	3.00	4.00	2.00	1280	320
USR1	Upr San Ramon Cr Local abv Sycamore	4.72	3.40	1.50	371	109
S3	Upper Sycamore Cr abv Black Hawk	3.88	4.26	1.93	1299	305
S2	Upper Sycamore Cr - U/S of Pt 5	1.12	2.23	1.08	321	144
S1	Lower Sycamore Cr Local at Mouth	3.26	5.61	2.22	488	87
SR7	Danville - San Ramon Cr Local abv Green Vy	2.37	2.55	1.25	959	376
GV4	Upper E.B. Green Valley Cr	2.21	2.45	1.25	1210	494
GV3	Lower E.B. Green Valley Cr	2.86	3.90	2.10	1490	382
GV2U	Upr N.B. Upper Green Valley Cr	1.36	1.81	0.57	999	552
GV2L	Lwr N.B. Green Valley Cr Local	1.17	2.40	0.94	1140	475
GV1	Lower Green Valley Cr Local at Mouth	1.85	3.50	1.65	630	180
SR6	San Ramon Cr Local Abv Alamo	6.17	3.60	2.15	1519	422
SR5	Stone Valley Cr at Mouth	2.65	3.05	1.40	702	230
SR4	Miranda Creek at Mouth	2.27	3.45	1.80	828	240
SR2	San Ramon Local - Miranda to Sans Crainte	2.58	4.82	2.41	842	175
SR3	Sans Crainte Cr at mouth	2.63	3.45	1.70	697	202
SR1	Lwr San Ramon Cr Local abv Las Trampas	0.44	2.35	1.18	114	45
LT7	Lafayette Cr U/S of Lafayette Res Trib	2.05	2.58	1.21	708	274
LT8	Lafayette Reservoir Trib	1.30	N/A	N/A	N/A	N/A
LT6	Happy Valley Tributary	3.45	4.00	1.88	769	192
LT5	Upper Las Trampas Cr	9.48	8.61	3.59	1725	200
LT4	Reliez Creek at Mouth	3.61	4.90	2.81	1212	247
LT9	Upper Mid Las Trampas Cr	1.16	2.78	1.39	844	304
LT2	Mid Las Trampas Cr	1.49	2.95	1.48	482	163
LT3A	Tice Cr abv Rossmoor Deten. Basin	2.65	2.67	1.20	574	215
LT3B	Tice Cr Local abv Castle Hill	0.49	1.14	0.57	329	289
LT3C	Castle Hill Cr at Mouth	0.48	1.25	0.68	615	492
LT3D	Tice Cr Local at Mouth	0.56	1.63	0.80	209	128
LT1	Las Trampas Cr Local at Mouth	0.12	0.77	0.39	51	66
W9	Walnut Cr above Indian	1.03	2.53	1.26	559	221
W8	Walnut Bypass Local Drainage	0.25	1.66	0.83	156	94
T1	Indian Cr Subbasin	2.04	3.17	1.58	740	233
W7	Walnut Cr Local Blw Indian Cr	0.64	1.59	0.80	226	142
B1	Las Casa Via Drainage N of Indian Cr	1.21	2.84	1.42	567	200
W6	Bancroft Local	0.88	1.98	0.99	65	33
W5	Mid Walnut Local Drainage U/S Pine Cr	1.11	3.98	1.99	67	17
P7	Upper Pine Cr	3.16	3.73	2.30	2692	722
P6	Mid Pine Cr	6.77	5.19	2.34	2561	493
P4	Mid Lower Pine Cr	5.24	5.78	2.89	956	165
P5	West Pine Subbasin	2.80	5.45	2.72	777	143
P3	Lower Pine Subbasin	1.76	3.25	1.62	289	89
P2	Galindo Cr at Mouth	7.61	9.12	4.56	1752	192
P1	Pine-Galindo Out	2.72	2.90	1.45	244	84
W4	Walnut Cr Blw Pine Local	1.59	2.68	1.34	120	45
TW1	North Trib to Walnut Cr	5.60	6.17	3.08	238	39
W3	Walnut Local Abv Grayson	0.21	0.80	0.40	113	141
W2	Walnut Cr below Grayson	0.20	0.77	0.38	135	175
W1	Walnut Out Local	0.29	0.29	0.14	123	424
PA2A	Upper Pacheco Cr	1.76	2.50	1.25	396	158
PA2B	Mid Pacheco Cr	1.40	2.10	1.05	318	151
PA1	Lower Pacheco Cr	0.83	1.82	0.91	286	157

L = length along the longest watercourse, in miles.
Lca = length along the longest watercourse, measured upstream to the point opposite the center of the area, in miles.
Elevation - elevation difference between headwater and collection point in the basin, in feet.
Slope = overall slope of the longest watercourse between the headwater and collection point, in feet per mile.

The 15-minute unit hydrographs in the HEC-1 model for the Walnut Creek watershed subbasins were computed using the above unit hydrograph parameters and Walnut Creek Mountain S-curve. The 15-minute unit hydrograph ordinates for each subbasin are listed on the UI (unit hydrograph) lines associated with that subbasin in the current conditions HEC-1 model (Attachment 1). Diagrams showing the relationship of watershed subbasins and combination points (nodes), for San Ramon, Las Trampas, Pine Creek, and Lower Walnut Creek are presented on Plates 9A through 9D.

7.4 Walnut Creek Model Validation. The U.S. Geological Survey collected 15-minute stage readings for two streamflow gages on the San Ramon Creek (San Ramon Creek at San Ramon and San Ramon Creek near Walnut Creek) and for one gage on Walnut Creek (Walnut Creek at Concord) for the January 1982 flood event. The high flows at the lower San Ramon Creek and the Walnut Creek gages were the peaks of record. The January 1982 storm over the Walnut Creek watershed was a period of continuous rainfall lasting over 30 hours with a more intense 4-hour cell toward the end of the storm. The observed hydrographs at the streamflow gages show a smaller peak or two followed by the final large peak. These hydrographs are shown on Plates 12A through 12C.

7.5 Exponential Loss Rate Function. The initial and constant loss method is suitable for computing flood hydrographs from local or cloudburst storms, such as those presented in the Grayson Creek hydrology report (Reference 4f). However, this loss method was not as successful with the 96-hour storms needed for sediment analysis. Using the relatively large watershed constant loss rate (0.18 inch per hour) over the duration of four days does not leave enough runoff excess to match the observed volumes in the records of the one Walnut Creek and the two San Ramon streamflow gages. For this reason, another HEC-1 loss method was considered for the watershed—the exponential loss rate. The exponential loss rate is an empirical method which relates loss rate to rainfall intensity and accumulated losses. Accumulated losses are representative of the soil moisture storage. Equations for computation of loss are given below. The exponential loss rate function is shown graphically on Plate 10.

$$ALOSS = (AK + DLTKR)\ PRCP^{ERAIN}$$

$$DLTK = 0.2 * DLTKR\ (1 - (CUML/DLTKR))^2$$
for $CUML \leq DLTKR$

$$AK = STRKR / (RTIOL^{0.1\ CUML})$$

where ALOSS is the potential loss in inches per hour during the time interval, AK is the loss rate coefficient at the beginning of the time interval, and DLTK is the incremental increase in the loss rate coefficient during the first DLTKR inches of accumulated loss, CUML. The accumulated loss, CUML, is determined by summing the actual losses computed for each time interval.

DLTKR is the amount of initial accumulated rain loss during which the loss rate coefficient increased. This parameter is considered to be a function primarily of antecedent soil moisture deficiency and is usually storm dependent. STRKR is the starting value of loss coefficient on the exponential recession curve for rain losses. The starting value is considered a function of infiltration capacity and thus depends on such basin characteristics as soil type, land use, and vegetal cover.

RTIOL is the ratio of rain loss coefficient on exponential loss curve to that corresponding to 10 inches more of accumulated loss. This variable may be considered a function of the ability of the surface of a basin to absorb precipitation and should be reasonably constant for large, rather homogeneous areas. ERAIN is the exponent of precipitation for rain loss function that reflects the influence of precipitation rate on basin-average loss characteristics. It reflects the manner in which storms occur within an area and may be considered a characteristic of a particular region. ERAIN varies from 0.0 to 1.0. Estimates of the parameters of the exponential loss function can be obtained by employing the HEC-1 parameter optimization option.

The observed hydrograph for the San Ramon Creek at San Ramon gage for the 03-05 January 1982 storm event was used with the optimization option in the HEC-1 model for the gaged subbasin to optimize the exponential loss parameters of STRKR, DLTKR, RTIOL and ERAIN to be used for the Walnut Creek HEC-1 model for the 96-hour storm series. The optimization results included the optimized exponential loss rate parameters of:

STRKR = 0.50
DLTKR = 3.21
RTIOL = 2.32
ERAIN = 0.70

The hydrograph computed using the optimized exponential loss parameters and the observed hydrograph for San Ramon Creek at San Ramon are plotted for comparison on Plate 12A. These optimized exponential loss parameters were used for the other subbasins upstream of the "at Concord" gage in the HEC-1 model for the January 1982 flood reconstitution.

7.6 Percent Impervious Factor. The percent impervious factor, based on land use, is used with the exponential loss method to indicate what percent of a subbasin will have 100 percent runoff. The Contra Costa County General Plan Land Use table lists different watershed infiltration rates for different types of land use. The exponential loss rates can be used when the infiltration loss for each urbanized subbasin is converted to the percent of imperviousness for the subbasin. This adjustment was made using a formula provided by Contra Costa County:

$$R_{imp} = 1 - [\ (L - 0.02) / (Ip - 0.02)\ ]$$

in which:

R_{imp} = ratio of imperviousness

L = land use loss rate (from Contra Costa County County General Plan Land Use table)

Ip = infiltration rate for pervious surfaces (0.18 inch per hour, based on previous Walnut Creek studies)

The ratio of impervious drainage area was computed for each land use category in the Walnut Creek watershed, and a composite percent of imperviousness was developed for each subbasin, depending on each type of land use and its percent of total drainage in each subbasin. The subbasin composite percents of imperviousness are tabulated on Table 7A.

Because the Walnut Creek watershed was less urbanized in 1982, the percents of imperviousness for the Walnut Creek subbasins for current conditions were reduced by ten percent, to approximate the degree of urbanization duration the January 1982 flood. These percents of imperviousness for 1982 conditions are also listed on Table 7A.

7.7 Base Flow. Three components are used in the HEC-1 program for base flow:

a. STRTQ: flow in cfs in the stream at the start of the hydrograph reproduction, a function of antecedent wetness conditions;

b. QRCSN: flow in cfs below which base flow recession occurs, or ratio of the peak flow at which base flow recession occurs on the falling limb;

c. RTIOR: ratio of recession flow to that flow occurring one hour later.

For the January 1982 HEC-1 flood reproduction model and the loss rate optimization, the base flow parameters used for the San Ramon Creek at San Ramon gage were: starting base flow (STRTQ) of 9 cfs, a value of -0.075, or 7.5 percent of the peak flow, and 1.05 for the ratio of recession flow, RTIOR. For the rest of the subbasins, a starting base flow, STRTQ, of 0.6 cfs per square mile was used for the San Ramon Creek and Walnut Creek subbasins and a STRTQ of 2.0 cfs per square mile for the Las Trampas Creek subbasins. From trial and error to obtain the best January 1982 flood reproductions, the following base flow parameters were used for all the subbasins except San Ramon Creek at San Ramon: a value for QRCSN of -0.15, or 15 percent of the peak flow, and 1.10 for the ratio of recession flow, RTIOR.

Table 7C lists some of the subbasin parameters used to reconstitute the January 1982 flood hydrographs at the three streamflow gages. See Section 7.9 for a discussion of the precipitation pattern and subbasin storm totals.

Table 7C
Historic Flood Reproduction Parameters for January 1982 Flood
from 3 January at 1200 Hours to 6 January at 1200 Hours

Subbasin	Rainfall Pattern Used	Rainfall (in.)	Excess (in.)	Base Flow Parameters		
				STRTQ (cfs)	QRCSN	RTIOR
San Ramon Creek						
San Ramon Cr at San Ramon	15-minute Del Amigo Road Pattern #F	7.50	2.78	9.0	-0.075	1.05
USR2 and USR1		6.59	varies	0.6 cfs/sq. mi.	-0.15	1.10
Upr Sycamore Cr at Bl. Hawk		6.07	2.07	0.6 cfs/sq. mi.	-0.15	1.10
S2 and S1, Sycamore Cr		5.76	varies	0.6 cfs/sq. mi.	-0.15	1.10
SR7 to SR5 and GV		5.84	varies	0.6 cfs/sq. mi.	-0.15	1.10
SR4 to SR1		5.70	varies	0.6 cfs/sq. mi.	-0.15	1.10
Las Trampas Creek						
LT7 to LT4 and LT2	1-Hour Del Amigo Road Pattern #F	7.60	varies	2.0 cfs/sq. mi.	-0.15	1.10
LT3A - Tice Cr		6.50	3.52	2.0 cfs/sq. mi.	-0.15	1.10
LT3B to LT3D - Tice Cr		6.20	varies	2.0 cfs/sq. mi.	-0.15	1.10
LT1 - Las Trampas at Mouth		6.00	5.10	0.6 cfs/sq. mi	-0.15	1.10
Walnut Creek						
W9 to W6, T1 and B1		5.50	varies	0.6 cfs/sq. mi	-0.15	1.10

7.8 Streamflow Routing. Flood hydrographs at downstream index points were developed by routing and combining subbasin hydrographs at the index points, using Muskingum routing steps. A 15-minute routing step was used in conjunction with the 15-minute time ordinate. On Table 7D, K is the travel time (in hours) through the routing reach. X is the Muskingum weighting factor between 0.0 and 0.5. The value for X is higher for higher channel velocities, where the channel slope is steeper or where the stream is moving down a concrete channel. The Muskingum routing coefficients used in the HEC-1 model for the Walnut Creek routing reaches for the January 1982 flood reproduction are listed below on Table 7D.

Table 7D
Walnut Creek Muskingum Channel Routing Parameters
January 1982 Storm Reproduction

Routing Reach	Routing Reach Description	Channel Length (mi.)	Channel Velocity (ft./sec.)	Muskingum Parameters: No. of Rtg. Steps	K (hrs.)	X
San Ramon Creek						
SRC4 – SRC5	Miranda Cr to Sans Crainte Cr	2.54	5.5	3	0.677	0.35
SRC6 – SRC7	Sans Crainte Cr to Las Trampas Cr	1.35	6.5	1	0.305	0.35
Las Trampas Creek						
LT7 – LTC1	Lafayette Cr to Upr. Las Trampas Cr	1.73	8.0	1	0.317	0.35
LTC1 – LTC2	Upr. Las Trampas Cr To Reliez Canyon	1.57	8.0	1	0.289	0.35
LTC2 – LTC3	Reliez Canyon to above Tice Cr	2.09	8.0	2	0.383	0.35
LTC3 – LTC4	Abv. Tice Cr to Mouth of Las Trampas	0.60	6.0	1	0.146	0.35
Walnut Creek						
WC1 – WC2	Mouth of Las Trampas Cr to Walnut Cr gage	0.64	6.0	1	0.157	0.35
WC3 – WC4	Indian Cr to La Casa Via	1.5	10.0	1	0.220	0.40
WC4–WC5	La Casa Via to Bancroft	0.60	5.5	1	0.159	0.35
WC5–WC6	Bancroft to Concord Gage	0.99	5.5	1	0.264	0.35

7.9 <u>Precipitation Used for Flood Reproduction</u>. Records for various recording and daily precipitation stations were archived with the 1983 hydrology report supporting material. Much of the station data was provided by the CCCFCWCD. The original storm isohyetal map could not be located, so a simplified storm isohyetal map for Walnut Creek above the Concord gage was developed using the archived precipitation data. Plate 11 presents the isohyetal map for the storm period, from noon on 3 January to noon on 6 January 1982. Subbasin storm totals used for the January 1982 flood reconstitution, listed on Table 7C, are based on the isohyetal map. Table 7E lists the precipitation stations, associated data, and observed rainfall totals for the early January 1982 storm.

Table 7E
Observed Precipitation for January 1982 Storm

Precipitation Station	Latitude	Longitude	Elev. (ft.)	Rainfall for 3-5 Jan. '82 (in.)			
				3-Jan	4-Jan	5-Jan	Sum
Bald Peak	37.88	122.22	1905	0.58	7.20	0.37	8.15
Berkeley UC	37.87	122.25	345	0.62	6.98	0.13	7.73
Chabot Res on Dam	37.73	122.12	245	2.50	3.17	0.01	5.68
Danville - Camino Tassahara **	37.80	121.94	556	*	*	*	5.06
Danville - La Questa **	37.82	121.99	365	*	*	*	5.90
Danville - Del Amigo Rd	37.82	122.01	365	0.56	5.09	0.35	6.00
Dublin FS	37.73	121.93	355	0.53	3.21	0.33	4.07
EBRPD Morgan Terr.Rd	37.82	121.80	2030	0.49	4.78	0.56	5.83
Fire Training Ctr - Treat Blvd	37.94	122.03	83	0.36	4.54	0.28	5.18
Lafayette - Hamlin Rd **	37.88	122.11	333	*	*	*	7.03
Lafayette Res	37.88	122.13	460	2.15	5.20	0.03	7.38
Marsh Cr FS	37.89	121.87	680	0.31	3.95	0.32	4.58
Martinez 2S	37.97	122.12	230	0.60	*	3.51	4.11
Martinez CCC Fl Control	37.99	122.09	160	0.44	4.91	0.21	5.56
Mt. Diablo USN Microwave	37.88	121.92	3690	0.61	5.31	0.38	6.30
Mt. Diablo St Park	37.85	121.93	1600	0.55	5.83	0.27	6.65
Oakley - Stirrup Dr	37.99	121.75	65	0.39	4.48	0.24	5.11
Orinda Filter Plant	37.90	122.20	350	1.75	5.75	0.03	7.53
Orinda FS 3	37.90	122.17	700	0.77	5.69	0.27	6.73
Pleasant Hill - Grosse **	37.96	122.07	40	*	*	*	5.85
San Pablo Filters	37.92	122.28	220	0.00	1.60	6.02	7.62
San Pablo Res	37.95	122.25	375	2.20	4.75	0.03	6.98
Sobrante Filters	37.95	122.28	250	0.00	2.24	6.37	8.61
St Mary's Col. – Moraga	37.84	122.11	620	0.67	6.37	0.29	7.33
Std Oil Los Medanos	38.00	121.86	130	0.40	2.46	0.09	2.95
Upr San Leandro Filters	37.77	122.17	395	1.40	4.66	0.25	6.31
Upr San Leandro on Dam	37.77	122.08	476	1.99	3.69	0.01	5.69
Walnut Cr 2 ENE	37.90	122.02	220	0.65	4.38	0.03	5.06
Walnut Cr Filters – EBMUD	37.91	122.08	384	0.45	5.20	0.26	5.91

* Daily Precipitation amount is not known.
** Latitude and Longitude are estimated from map

The hourly rainfall pattern used for the HEC-1 model for the flood reconstitution is from the Del Amigo Road station in Danville at an elevation of 365 feet. The station is about two miles northeast of the San Ramon Creek headwaters. The incremental rainfall pattern is displayed at the top of Plate 12A and tabulated on Table 7F. The Del Amigo Road rainfall pattern was also used for the flood reconstitution included in the 1983 hydrology. The rainfall data is in hourly increments, while the HEC-1 model uses a 15-minute time step. The hourly rainfall pattern was divided into 15-minute increments, which were adjusted in the HEC-1 model until the computed flood hydrograph was similar in shape, timing, and magnitude to the observed flood hydrograph. This adjusted 15-minute “Del Amigo Road Pattern F” rainfall pattern was used for the other San Ramon Creek subbasins as well, because the Del Amigo Road station is in the heart of the San Ramon watershed. The Las Trampas Creek and the Walnut Creek subbasins above the “at Concord” gage are farther away from the Del Amigo station, so the more generalized rainfall pattern of “1-hour Del Amigo Road Pattern F,” split into four equal 15-minute increments, was used for them.

Table 7F
January 1982 Hourly
Storm Distribution Pattern

Time Increment (hrs.)	Storm Distribution in %	Time Increment (hrs.)	Storm Distribution in %
3-Jan-82		4-Jan-82	
12	0.0	11	5.0
13	0.0	12	4.2
14	0.0	13	2.7
15	0.0	14	3.5
16	0.0	15	3.5
17	0.2	16	3.5
18	0.2	17	3.0
19	0.7	18	2.0
20	1.3	19	1.7
21	2.3	20	5.2
22	1.3	21	6.8
23	2.2	22	8.2
24	1.2	23	6.3
		24	4.3
4-Jan-82		5-Jan-82	
1	1.5	1	4.0
2	1.0	2	1.5
3	2.7	3	0.2
4	2.3	4	0.0
5	2.2	5	0.0
6	3.3	6	0.0
7	3.0	7	0.0
8	2.7	8	0.2
9	2.5	9	0.0
10	3.8		
		SUM	100.0

Percents are rounded to 1 decimal place

7.10 Model Validation for Flood Simulation. The San Ramon and Walnut creeks HEC-1 model was tested by using it to reproduce the high flow event of early January 1982 at the Walnut Creek and the two San Ramon Creek U.S.G.S streamflow gages. The HEC-1 model was used with the applicable unit hydrographs (see the HEC-1 Model, Attachment 1), Muskingum routing parameters (Table 7D), optimized loss parameters

(Section 7.5), base flow parameters (Section 7.7), precipitation pattern (Table 7F), and subbasin rainfall amounts (Table 7C) discussed above, to compute flood reproductions at the two San Ramon and the downstream Walnut Creek streamflow gages for the January 1982 storm. Plates 12A through 12C present the graphic comparisons between "computed" flood hydrographs and the observed hydrographs at the gages. The observed hydrograph data were in 15-minute increments. The timing of the peak flow between computed and observed hydrographs does not match exactly, because of the difficulty in using a one-hour rainfall pattern adjusted for a 15-minute HEC-1 model. Table 7G lists the differences between computed and observed flood peaks at the streamflow gages for the flood reproduction.

Table 7G
Comparison Between Computed and Observed Flows
for the January 1982 Flood Reproduction

Streamflow Gage	Peak Flow (cfs)		%	3-Day Flood Volume (ac-ft)		%
	Observed	Computed	Difference	Observed	Computed	Difference
San Ramon Cr at San Ramon	1,220	1,160	4.9	1,020	1,040	2.0
San Ramon Cr Nr. Walnut Cr	7,400	7,480	1.1	7,330	7,640	4.2
Walnut Cr at Concord	13,300	13,400	0.8	17,000	15,100	11.2

The successful reconstitution of the peak flow hydrographs for the three stream gages shows that the Walnut Creek HEC-1 model is a good computer model representation of the watershed. The flood reconstitution misses the volume of the smaller preliminary peak flow at the Walnut Creek at Concord gage (Plate 12C), but the reconstitution of the high peak matched very well in shape and magnitude.

8. Modeling the 1% Flood Event

The HEC-1 model used to reconstitute the January 1982 flood was modified to develop the 8-flood hydrograph series for current basin conditions. The degree of urbanization is ten percent higher for the higher current level of urbanization. The San Ramon Bypass diversion routing was added to the model, since the actual bypass was not constructed until several years after the 1982 flood. A storage routing was added downstream for the detention basin on Pacheco Creek. The modifications are discussed in this section. Development of the 8-Flood Series hydrographs for present conditions is discussed in Sections 8, 9, and 10.

The general rain 96-hour storm was used to develop the 1% chance exceedence flood hydrographs for the Walnut Creek sediment conveyance model. This section discusses the 96-hour general storm specific and concurrent centerings, the HEC-1 model for present watershed conditions, and computation of the 1% event runoff hydrographs for sediment transport. Peak flows are higher for some of the 6-hour storm events. The 6-hour storms and flood hydrographs are discussed in Section 10.

8.1 Previous Storm Modeling. Previous hydrology studies on the Walnut Creek watershed used the Standard Project general storm (SPS, 96-hour duration) and Standard Project Flood (SPF) with a proportionate relationship to the SPS to compute the 1% event general rainstorm. (Reference 4p defines the Standard Project Storm criteria.) Ninety-six-hour general rainstorms and the computed flood hydrographs were used for the Walnut Creek hydrology studies performed in 1972 and 1983 (References 4b and 4d). The hydrology was developed for a watershed area including Walnut Creek downstream of the confluence of San Ramon and Las Trampas creeks. For the 1992 study (Reference 4e), the study area covered San Ramon Creek (about 50 square miles) but not the Las Trampas Creek basin or any of the downstream Walnut Creek channel. Both 6-hour local and 96-hour general rainstorms were developed for the San Ramon Creek. The 6-hour storm produced a higher peak flow, so the 1992 hydrology was based on the local storm and runoff. Not only does the current hydrology study cover a watershed larger than 100 square miles, but flood volumes of several days' duration are needed for the sediment transport analysis. For that reason, the Walnut Creek hydrology for present conditions includes 96-hour general rainstorms and resulting hydrographs for the sediment conveyance analysis.

8.2 1% General Rainstorm Computation. The 1% 96-hour storm used for the Walnut Creek basin flood hydrographs was developed using the mean seasonal isohyets and precipitation duration-frequency-depth curves published by the CCCFCWCD in 1977 (Reference 4i). The rainfall depth-duration curves are based in part on the largest recorded storm (October 1962 at Orinda Filters) that occurred in the Coast Ranges near San Francisco. The storm was centered over an adjacent basin with meteorological characteristics similar to those of the Walnut Creek area. The precipitation depth-duration curves for the 1% chance rainfall for various storm durations up to 96 hours are based on a transposition of the 1962 storm using watershed Mean Seasonal Precipitation (MSP). The MSP isohyetal map for the Walnut Creek watershed is presented on Plate 4. The MSP and 1%, 4%, 10%, 20%, and 50% chance 96-hour storm totals used for the Walnut Creek subbasins are tabulated on Table 8A.

Table 8A
Mean Seasonal Precipitation (MSP) and 50% through 1%
Storm Centering Amounts on the Walnut Creek Subbasins

Subbasin Code	Drainage Area (sq. mi.)	Mean Seasonal Precipitation (MSP)	50% 96-Hour Storm (in.)	20% 96-Hour Storm (in.)	10% 96-Hour Storm (in.)	4% 96-Hour Storm (in.)	1% 96-Hour Storm (in.)
San Ramon Creek							
USR3	5.89	25.68	4.59	6.70	8.24	9.68	12.34
USR2	3.00	23.58	4.17	6.13	7.52	8.85	11.27
USR1	4.72	20.79	3.68	5.40	6.63	7.80	9.94
S3	3.88	19.73	3.49	5.13	6.29	7.41	9.43
S2	1.12	18.75	3.32	4.87	5.98	7.04	8.96
S1	3.26	19.18	3.40	4.98	6.11	7.20	9.17
SR7	2.37	21.78	3.72	5.47	6.71	7.89	10.05
GV4	2.21	19.13	3.27	4.80	5.89	6.93	8.83
GV3	2.86	19.18	3.28	4.81	5.91	6.95	8.85
GV2U	1.36	19.44	3.32	4.88	5.99	7.05	8.97
GV2L	1.17	19.18	3.28	4.81	5.91	6.95	8.85
GV1	1.85	19.69	3.37	4.94	6.06	7.14	9.09
SR6	6.17	23.83	4.08	5.98	7.34	8.64	11.00
SR5	2.65	20.34	3.48	5.10	6.26	7.37	9.39
SR4	2.27	19.56	3.35	4.91	6.02	7.09	9.03
SR2	2.58	22.53	3.85	5.65	6.94	8.16	10.40
SR3	2.63	19.40	3.32	4.87	5.97	7.03	8.96
SR1	0.44	20.45	3.50	5.13	6.30	7.41	9.44
Las Trampas Creek							
LT7	2.05	28.29	4.73	6.90	8.48	9.96	12.70
LT8	1.30	28.03	4.69	6.84	8.40	9.87	12.59
LT6	3.45	26.75	4.47	6.52	8.02	9.42	12.01
LT5	9.48	26.86	4.49	6.55	8.05	9.46	12.06
LT4	3.61	24.63	4.09	6.01	7.38	8.67	11.06
LT9	1.16	24.48	4.12	5.97	7.34	8.62	10.99
LT2	1.49	22.22	3.71	5.42	6.66	7.83	9.98
LT3A	2.65	23.31	3.90	5.68	6.99	8.21	10.47
LT3B	0.49	23.31	3.90	5.68	6.99	8.21	10.47
LT3C	0.48	23.31	3.90	5.68	6.99	8.21	10.47
LT3D	0.56	23.31	3.90	5.68	6.99	8.21	10.47
LT1	0.12	20.76	3.47	5.06	6.22	7.31	9.32

Table 8A (continued)
Mean Seasonal Precipitation (MSP) and 50% through 1%
Storm Centering Amounts on the Walnut Creek Subbasins

Subbasin Code	Drainage Area (sq. mi.)	Mean Seasonal Precipitation (MSP)	50% 96-Hour Storm (in.)	20% 96-Hour Storm (in.)	10% 96-Hour Storm (in.)	4% 96-Hour Storm (in.)	1% 96-Hour Storm (in.)
Walnut Creek							
W9	1.03	20.91	3.50	5.10	6.27	7.36	9.39
W8	0.25	20.13	3.36	4.91	6.04	7.09	9.04
T1	2.04	19.20	3.21	4.73	5.78	6.82	8.69
W7	0.64	19.13	3.20	4.71	5.76	6.80	8.65
B1	1.21	18.04	3.01	4.44	5.44	6.41	8.16
W6	0.88	17.47	2.92	4.30	5.26	6.21	7.90
W5	1.11	17.21	2.88	4.24	5.19	6.12	7.79
P7	3.16	22.05	3.68	5.43	6.64	7.84	9.98
P6	6.77	18.92	3.16	4.66	5.70	6.72	8.56
P4	5.24	16.99	2.84	4.18	5.12	6.04	7.69
P5	2.80	17.11	2.86	4.21	5.16	6.08	7.74
P3	1.76	16.73	2.80	4.12	5.04	5.94	7.57
P2	7.61	17.77	2.97	4.37	5.35	6.31	8.04
P1	2.72	16.48	2.75	4.06	4.97	5.86	7.46
W4	1.59	15.85	2.67	3.95	4.83	5.70	7.25
TW1	5.60	15.64	2.63	3.90	4.76	5.63	7.15
W3	0.21	15.17	2.55	3.78	4.62	5.46	6.94
W2	0.20	14.90	2.51	3.72	4.54	5.36	6.82
W1	0.29	14.75	2.48	3.68	4.49	5.31	6.75
PA2	3.15	16.75	2.82	4.18	5.10	6.03	7.66
PA1	0.83	14.83	2.50	3.70	4.51	5.34	6.78

Table 8A (continued)
Mean Seasonal Precipitation (MSP) and 50% through 1%
Storm Centering Amounts on the Walnut Creek Subbasins

Subbasin Code	Drainage Area (sq. mi.)	Mean Seasonal Precipitation (MSP)	50% 96-Hour Storm (in.)	20% 96-Hour Storm (in.)	10% 96-Hour Storm (in.)	4% 96-Hour Storm (in.)	1% 96-Hour Storm (in.)
Grayson Creek							
5	0.89	22.60	3.85	5.66	6.94	8.17	10.40
3	0.76	22.85	3.89	5.72	7.01	8.26	10.52
4	0.55	21.86	3.72	5.47	6.71	7.91	10.06
6	0.13	20.07	3.42	5.02	6.16	7.26	9.24
7	0.66	19.60	3.34	4.91	6.02	7.09	9.02
2	0.62	21.48	3.66	5.38	6.59	7.77	9.89
1	0.88	20.49	3.49	5.13	6.29	7.41	9.43
8E1	0.22	19.04	3.24	4.77	5.84	6.89	8.76
8W1	0.30	19.41	3.30	4.86	5.96	7.02	8.93
8E2	0.17	18.24	3.10	4.56	5.6	6.60	8.39
8W2	0.11	18.59	3.16	4.65	5.71	6.72	8.56
19	0.64	20.05	3.41	5.02	6.15	7.25	9.23
20	0.28	18.72	3.19	4.69	5.75	6.77	8.62
20N	0.16	18.13	3.09	4.54	5.56	6.56	8.34
9	0.54	19.18	3.26	4.80	5.89	6.94	8.83
10W	0.19	18.21	3.10	4.56	5.59	6.59	8.38
10E	0.42	17.81	3.03	4.46	5.47	6.44	8.20
12	1.68	22.87	3.89	5.72	7.02	8.27	10.53
13	0.25	20.53	3.49	5.14	6.3	7.42	9.45
14	2.13	20.05	3.41	5.02	6.15	7.25	9.23
11	0.59	18.69	3.18	4.68	5.74	6.76	8.60
15W1	0.88	18.08	3.08	4.52	5.55	6.54	8.32
15W2	0.35	17.27	2.94	4.32	5.3	6.25	7.95
15E	0.51	17.10	2.91	4.28	5.25	6.18	7.87
17	0.50	17.66	3.01	4.42	5.42	6.39	8.13
16	1.05	17.60	2.99	4.40	5.4	6.37	8.10
18W	0.98	16.37	2.79	4.10	5.02	5.92	7.53
18E	1.22	16.11	2.74	4.03	4.94	5.83	7.41

8.3 Storm Centerings and Distribution Pattern. The 1% chance general rainstorm for the 96-hour duration was specifically centered on San Ramon Creek in Bollinger Canyon, with concurrent centerings, in descending order, on (1st concurrency) San Ramon Creek and Sans Crainte Creek above their confluence, on (2nd concurrency) Las Trampas Creek and Walnut Creek at the San Ramon Bypass, on (3rd concurrency) Grayson-Murderer's watershed, on (4th concurrency) Pine Creek and Walnut Creek channel at their confluence, and on (5th concurrency) Walnut Creek from its confluence with Pine Creek down to its confluence with Pacheco Creek. Table 10A shows which concurrency applies to which subbasins. The 24-hour depth-area curve on Figure 14 in the NOAA Atlas 2, "Precipitation-Frequency Atlas of the Western United States, Vol. XI—California" (Reference 4h), provided the areal reduction factors to compute the specific and concurrent 96-hour storm depths over the watershed. 24 hours is the longest duration for which a depth-area reduction curve was presented in NOAA Atlas 2. The depth-area reduction for 24-hour duration is so small (91% for 400 square miles) compared with depth-area reduction for a local storm (57% for 30 minutes over 150 square miles) that the 24-hour depth-area curve is applied to the 96-hour duration as well. The NOAA Atlas 24-hour depth-area reduction curve is presented on Plate 13.

The areally reduced 96-hour 1% storm totals for the Walnut Creek subbasins are tabulated above on Table 8A. Table 8B presents a comparison between several subbasin storm depths and the 1% 4-day precipitation totals for several long-term climatological stations in and near the watershed, to show that the 4-day storm totals are reasonable.

Table 8B
Comparison of 1% 4-Day Precipitation
Precipitation Stations and 96-Hour Storm Centerings

Station #	Precipitation Station	# of Years Record	4-Day 10% Total (in.)	4-Day 1% Total (in.)	MSP (in.)
4639	La Fayette Reservoir DWR #E40	63	7.55	11.37	27.50
5378	Martinez WTP DWR #E40	91	5.37	8.09	18.60
5915	Mt. Diablo Junction DWR #E40	47	6.50	9.79	23.80
6501	Orinda Filters DWR #E40	61	8.83	13.29	32.30
7661	St. Mary's College 13 DWR #E40	52	7.89	11.88	27.30
9423	Walnut Cr 2ESE DWR #E40	49	6.03	9.08	19.70
Code	Subbasin	D.A. (sq. mi.)	10%	1%	MSP
USR3	San Ramon Cr at San Ramon gage	5.89	8.24	12.34	25.68
LT5	Upper Las Trampas Cr	9.48	8.05	12.06	26.86
LT3A	Tice Cr abv Rossmoor Deten. Basin	2.65	6.99	10.47	23.31
W9	Walnut Cr above Indian Cr	1.03	6.27	9.39	20.91
5	Murderer's Cr Blw Brookwood Site	0.89	6.94	10.40	22.60
P7	Upper Pine Cr	3.16	6.64	9.98	22.05
B1	La Casa Via	1.21	5.44	8.16	18.04
TW1	North Trib to Walnut Cr	5.60	4.76	7.15	15.64

The 96-hour general rainstorms were temporally distributed using a distribution pattern slightly modified from one used by CCCFCWCD. The original CCCFCWCD distribution pattern did not produce enough excess flow to match the volumes for the 1-, 3-, and 5-day frequency curves at the three streamflow gage locations. The modified 96-hour distribution pattern is tabulated incrementally on Table 8C below and displayed as an accumulative rainfall mass curve on Plate 14.

Table 8C
96-Hour Modified Storm Distribution Pattern

Time Increment Hours	Storm Distribution in %	Time Increment (hrs.)	Storm Distribution in %	Time Increment (hrs.)	Storm Distribution in %	Time Increment (hrs.)	Storm Distribution in %
1	0.00	25	0.00	49	0.16	73	0.49
2	0.00	26	0.00	50	0.24	74	0.32
3	0.00	27	0.00	51	0.32	75	0.49
4	0.09	28	0.00	52	0.57	76	0.81
5	0.32	29	0.00	53	1.70	77	0.57
6	0.32	30	0.00	54	2.11	78	0.57
7	0.49	31	0.00	55	2.82	79	0.00
8	0.49	32	0.00	56	2.82	80	0.00
9	0.08	33	0.00	57	2.82	81	0.08
10	0.08	34	0.00	58	2.82	82	0.16
11	1.87	35	0.00	59	2.82	83	1.95
12	3.41	36	0.00	60	2.82	84	1.62
13	4.54	37	0.00	61	2.10	85	1.22
14	4.79	38	0.00	62	2.13	86	0.81
15	3.41	39	0.24	63	3.00	87	0.57
16	1.87	40	0.08	64	3.00	88	0.00
17	0.32	41	0.24	65	7.30	89	0.00
18	0.00	42	0.41	66	6.49	90	0.00
19	0.00	43	2.76	67	2.35	91	0.00
20	0.00	44	3.16	68	0.81	92	0.00
21	0.16	45	2.35	69	2.03	93	0.00
22	0.00	46	1.95	70	1.87	94	0.00
23	0.00	47	0.57	71	1.62	95	0.00
24	0.00	48	0.16	72	1.46	96	0.00
						SUM	100.00

8.4 <u>Loss Rates and Base Flow</u>. The HEC-1 model for the 1% general rainstorm event used the exponential loss rate parameters optimized for the San Ramon Creek at San Ramon streamgage, discussed in Section 7.5. The percents of imperviousness, listed on Table 7A, vary for the subbasins, depending on the present conditions land use. The percents of imperviousness are based on the detailed Contra Costa County General Plan Land Use table and GIS land use layers. The optimized exponential loss parameters are listed below.

STRKR = 0.50
DLTKR = 3.21
RTIOL = 2.32
ERAIN = 0.70

An initial base flow (STRTQ) of 5 cubic feet per square mile (cfs/sq.mi.) was used for the 1% flood event, based on observations for large floods in the Walnut Creek basin. A hydrograph falling limb base flow parameter (QRCSN) of -0.15, or 15 percent of the peak flow was used for the subbasins. A recession flow ratio (RTIOR) of 1.05 was used for San Ramon Creek at San Ramon gage, and recession flow ratio of 1.10 was used for the rest of the Walnut Creek watershed subbasins, based on the reconstitution of the early January 1982 flood hydrographs for the lower San Ramon and the Walnut Creek at Concord streamflow gages. For the Grayson Creek watershed the following base flow parameters were used: an initial base flow (STRTQ) of 5 cfs per square mile, a falling limb base flow (QRCSN) of 3 cfs/sq.mi., and a recession flow ratio (RTIOR) of 1.10.

8.5 Muskingum Routing Parameters. Flood hydrographs at downstream index points were developed by routing and combining subbasin hydrographs at the index points, using Muskingum routing steps. Channel velocities were estimated for the San Ramon Bypass and reaches of San Ramon, Las Trampas, and Pine creeks, and the Walnut Creek channel, based on measured cross-sections, channel slope, and channel bed (earth or concrete). The channel velocities were used to develop Muskingum routing parameters for the HEC-1 model. A 15-minute routing step was used in conjunction with the 15-minute time ordinate. K is the travel time (in hours) through the routing reach. X is the Muskingum weighting factor between 0.0 and 0.5. The value for X is higher for higher channel velocities, where the channel slope is steeper or where the stream is moving down a concrete channel. The channel velocities and computed Muskingum routing parameters used for the 1% flood are listed in Table 8D. The Muskingum routing parameters used for the Grayson Creek HEC-1 model for all flood events are those listed in the Grayson Creek hydrology appendix (Reference 4f).

Table 8D
Walnut Creek Muskingum Channel Routing Parameters
for the 1% Flood Event

Routing Reach	Routing Reach Description	Channel Length (mi.)	Channel Velocity (ft./sec.)	Muskingum Parameters		
				No. of Rtg. Steps	K (hrs.)	X
San Ramon Creek						
SRC4 – SRC5	Miranda Cr to Sans Crainte Cr	2.54	5.5	3	0.677	0.35
SRC6 – SRC7	Sans Crainte Cr to Las Trampas Cr	1.35	6.5	1	0.305	0.35
Las Trampas Creek						
LT7 – LTC1	Lafayette Cr to Upr. Las Trampas Cr	1.73	8	1	0.317	0.35
LTC1 – LTC2	Upr. Las Trampas Cr to Reliez Canyon	1.57	8	1	0.289	0.35
LTC2 – LTC3	Reliez Canyon to above Tice Cr	2.09	8	2	0.383	0.35
LTC3 – LTC4	Abv. Tice Cr to Mouth of Las Trampas	0.60	6	1	0.146	0.35
Walnut Creek						
WC1 – WC2	Mouth of Las Trampas Cr to San Ramon Bypass	0.64	6	1	0.157	0.35
SRC6–WC2	San Ramon Bypass Channel	1.67	30	1	0.08	0.50
WC3 – WC4	Indian Cr to La Casa Via	1.5	30	1	0.073	0.50
WC4–WC5	La Casa Via to Bancroft	0.60	30	1	0.029	0.50
WC5–WC6	Bancroft to Concord Gage	0.99	14	1	0.104	0.40
WC6–WC7	Concord Gage to Pine Cr	2.34	9	2	0.381	0.35
Pine Creek						
P7 – PC1	Upr. Pine to Mid Pine	3.67	8	3	0.673	0.35
PC1 – PC2	Mid Pine to Mid Lower Pine	4.17	6.5	4	0.941	0.35
PC2 – PC3	Mid Lower Pine to Galindo Cr	1.28	15	1	0.125	0.40
PC3 – PC4	Galindo Cr to Mouth of Pine Cr	0.91	12	1	0.111	0.40
Walnut Creek						
WC8 – WC9	Pine Cr to Mouth of Grayson Cr	0.59	6	1	0.145	0.35
WC10 – WC11	Grayson Cr to Confluence with Pacheco Cr	1.47	4.6	2	0.469	0.25
WC11 – WC12	Blw Grayson Subbasin to Pacheco Cr	1	4.6	1	0.207	0.25
WC12 – BAY	Pacheco Cr to Suisun Bay	1.85	4.6	2	0.59	0.25
Pacheco Creek						
PA2A – PAC1	Detention Basin to Mid Pacheco Cr	1.25	0.7	10	2.619	0.00
PAC1–PAC2	Mid-Pacheco to Walnut Cr	1.25	0.7	10	2.619	0.00

Channel velocities are slower for the 10% chance flood event than for the 1% flood for the Walnut Creek channel reaches. Channel velocities and computed Muskingum routing parameters used for the 10% flood are listed in Section 9, Table 9A, along with the discussion of the 10% general rainflood.

8.6 San Ramon Bypass, Flow Splits, and Detention Basin Routings. The San Ramon Bypass was constructed around 1990 to divert most of the San Ramon Creek flood flows away from the original San Ramon Creek channel and its confluence with Las Trampas Creek. The location of the San Ramon Bypass is shown on Plate 7E. Table 8E lists how the flow is split between the San Ramon Bypass channel and the original downstream San Ramon/Walnut Creek channel. The flow split information is from the San Ramon Bypass Channel "Supplement No. 5 to Design Memorandum No. 2" (Reference 4o). The confluence of the downstream end of the San Ramon Bypass with the original Walnut Creek channel is not far upstream of Ygnacio Valley Road. In the model, the bypass hydrograph is combined with the Walnut Creek channel hydrograph above Indian Valley subbasin.

Table 8E
San Ramon Bypass Flow Split

Total Flow at Confluence Of San Ramon and Sans Crainte Creek (cfs)	Flow Split to San Ramon Bypass (cfs)	Flow Split to Original San Ramon Channel (cfs)
0	0	0
15,200	15,200	0
15,700	15,660	40
16,000	15,950	50
17,000	16,840	160
20,400	19,260	1,140

The hydrograph for subbasin 19, upper eastside East Fork Grayson Creek overflow in the Grayson Creek HEC-1 model, is split downstream between Walnut Creek and East Fork Grayson Creek. The flow split is discussed in the Grayson Creek hydrology appendix (Reference 4f). In the Walnut Creek HEC-1 model, the flow split to Walnut Creek is added to the Walnut Creek channel just upstream of the Walnut Creek at Concord gage location. The flow split for subbasin 19 is listed in Table 8F and is included in Attachment 2, the HEC-1 model for Grayson Creek, at the end of this hydrology appendix.

Table 8F
Subbasin 19 Flow Split Between
Walnut Creek and E.F. Grayson Creek

Flow from Subbasin 19 Flow "Jones Rd." (cfs)	Flow Split to Walnut Cr. "Line A" (cfs)	Flow Split to Subbasin 20 and E.F. Grayson Cr. "Line B" (cfs)
0	0	0
100	75	25
332	249	83
345	262	83
384	292	92
424	327	97
486	389	97
884	707	177

Around 1997 the Viano detention basin was constructed on Pacheco Creek upstream of the Burlington Northern Santa Fe (BNSF) railroad right-of-way. The location of the detention basin is shown on Plate 7B, at the downstream end of the Upper Pacheco Creek subbasin. Table 8G lists the storage routing used to route the Pacheco Creek subbasin PA2A flood hydrographs through the detention basin.

Table 8G
Storage-Outflow Routing for
Pacheco Creek Detention Basin

Elevation (ft.)	Storage (ac.-ft.)	Outflow (cfs)	Elevation (ft.)	Storage (ac.-ft.)	Outflow (cfs)
22.5	0.00	10	26.82	2.35	272
24.12	0.00	52	27.21	2.98	311
24.25	0.01	60	27.81	4.04	373
24.57	0.02	77	28.76	5.87	455
25.02	0.06	101	29.97	8.57	553
25.24	0.31	122	31.28	11.97	646
25.57	0.67	151	32.07	14.68	699
25.96	1.10	186	33.19	18.89	762
26.25	1.52	215	33.33	19.52	770
26.52	1.90	242			

Two detention basins, Pine Creek Reservoir and Kubicek Basin, have been built high up in the non-urbanized part of the Pine Creek watershed. Table 8H lists the HEC-1 storage routing parameters used to route the Pine Creek hydrographs through these detention basins. The location of these basins is shown on Plate 7C.

Table 8H
HEC-1 Storage Routing Parameters
for Pine Creek Detention Basins

Parameter	Pine Creek Reservoir (Upper)		Kubicek Basin (Lower)	
Drainage Area (sq. mi.)	4.21		9.95	
Low Level Outlet Parameters				
Centerline Elev (ft.)	400		190	
X-Sectional Area (sq. ft.)	8.50		28.27	
Discharge Coefficient *c*	0.47		0.52	
Exponent *e*	0.50		0.50	
Spillway Parameters				
Spillway Crest Elev (ft.)	439		212	
Spillway Length (ft.)	50		200	
Discharge coefficient *c*	3.20		3.20	
Exponent *e*	1.50		1.50	
Storage Volume-Elevation Relationship				
	Pine Creek Reservoir		Kubicek Basin	
	Elev (ft)	Vol (ac-ft)	Elev (ft)	Vol (ac-ft)
	400	85	190	3
	405	212	192	50
	410	386	194	176
	415	610	196	376
	420	894	198	636
	425	1246	200	940
	430	1674	202	1277
	435	2185	204	1646
	440	2799	206	2046
	445	3531	208	2475
			210	2933
			212	3417
			214	3929
			216	4469
			218	5042

Rossmoor detention basin is located at the downstream end of Tice Creek headwaters, subbasin LT3A, tributary to the Las Trampas Creek watershed. The detention basin storage routing used for the 1992 Walnut Creek hydrology report (Reference 4e) is also used for the Tice Creek HEC-1 model contributing to Las Trampas Creek and is listed in the Las Trampas Creek section of Attachment 1, the Walnut Creek HEC-1 model.

8.7 <u>1% Chance Flood Hydrographs</u>. The revised HEC-1 model was used with the following to develop the 1% flood hydrographs at index points in the Walnut Creek watershed: (1) the 1% event 96-hour storm totals (Table 8A) and distribution pattern (Table 8C), (2) optimized exponential loss parameters and percents of imperviousness

(Table 7A), (3) base flow parameters, (4) unit hydrographs, (5) Muskingum routing coefficients (Table 8D), (6) the San Ramon Bypass flow split (Table 8E), and (7) detention basin storage-outflow relationships on Pacheco and Pine creeks (Tables 8G and 8H), discussed above. The computed 1% flood peaks and volumes for the 1-, 3-, and 5-day durations for selected locations are listed on Table 8I. The 1% hydrographs computed for the locations of the San Ramon and Walnut creeks streamflow gages are plotted on Plate 15. These hydrographs are for the HEC-1 model only, not the hydrographs used in the hydraulic routing model for sediment analysis or floodplain development. The HEC-1 model for the 1% 96-hour storm and flood on the Walnut Creek watershed is listed as Attachment 1. Plate 9A-D presents diagrams showing the relationship of watershed subbasins and combination points (nodes) for the San Ramon, Las Trampas, Pine and Grayson creeks, and the lower Walnut Creek channel tributaries.

Table 8I
HEC-1 Model 1% General Rain Flood Peak Flows and Volumes
for Various Walnut Creek Watershed Locations

Location	Drainage Area (sq. mi.)	6-Hr 1% Flood Peak (cfs)	96-Hr 1% Flood Peak and Volumes			
			Peak (cfs)	Volumes in average cfs		
				24-Hr	72-Hr	120-Hr
San Ramon Creek at San Ramon Gage	6.31	2,420	1,700	663	338	233
San Ramon Cr above San Crainte Creek	47.78	12,600	10,700	4,520	2,240	1,580
Sans Crainte Cr at Mouth	2.63	1,010	624	207	100	69
San Ramon Cr below SanS Crainte Cr	50.41	12,900	11,000	4,720	2,340	1,650
San Ramon Bypass Flow	N/A	12,900	11,000	4,720	2,250	1,650
Tice Creek at Mouth	4.18	1,410	1,240	474	244	173
Las Trampas Creek abv Walnut Creek	26.76	8,580	7,420	3,050	1,550	1,100
Walnut Cr Below San Ramon Bypass	78.89	21,500	18,500	7,970	3,960	2,820
Walnut Cr at Concord gage	83.67	22,400	19,200	8,450	4,210	3,010
Galindo Creek at Mouth	7.61	1,740	1,520	628	318	223
Pine Creek at Mouth	30.06	4,930	4,450	1,940	1,000	738
Walnut Creek below Pine Creek	114.84	25,800	22,800	10,500	5,270	3,790
Grayson Creek at Mouth	17.60	6,070	4,400	1,450	711	470
Walnut Creek below Grayson Creek	139.84	30,800	27,700	12,600	6,370	4,540
Pacheco Creek at Mouth	3.99	642	586	384	218	156
Walnut Creek below Pacheco Creek	144.32	31,200	28,000	13,100	6,610	4,710

Table 9D presents a comparison of the HEC-1 model 1% flood volumes with the 1% flood volumes for the frequency curves at the three streamflow gages. The differences between the volumes are expressed in percent error. This comparison is discussed at greater length in Sections 9.7 and 9.8.

9. Development of Other Frequency Floods

This section discusses the procedure used to develop hydrographs for the rest of the 8-Flood Series from 96-hour general rainstorms on the Walnut Creek watershed, beginning with the 10% chance flood. Flow frequency curves for peak, 1-, 3-, and 5-day flows were developed for the following streamflow gages: San Ramon Creek at San Ramon, San Ramon Creek at Walnut Creek, and Walnut Creek near Concord. The 10%

event general rainstorm centerings were computed and the Walnut Creek HEC-1 model used to compute flood hydrographs, which were then compared with the flow frequency curves at the three gage locations. If necessary, the HEC-1 model would be adjusted for the 10% flood. The 50%, 20%, and 4% flood hydrographs were developed in the same manner. The 2.0%, 0.5%, and 0.2% flood hydrographs were computed in the HEC-1 model as ratios of the 1% event flood hydrographs.

9.1 <u>Flow Frequency Analysis for Homogeneous Basin</u>. Peak flow frequency curves were developed for the streamflow gages on San Ramon and Walnut creeks as part of the hydrology studies in 1972, 1983, and 1992 (References 4b, d, and e). The San Ramon Creek near Walnut Creek and Walnut Creek at Concord gages were both discontinued in 1992. Records are still collected at the San Ramon Creek at San Ramon gage location, where the upstream watershed has remained largely rural over the entire 50 plus years of record. As part of the current study, a statistical analysis was performed on the records for this location.

The HEC Flood Frequency Analysis (FFA) computer program (see Reference 4q) was used to apply Water Resource Council guidelines (see Reference 4r) to the statistical analysis of San Ramon Creek at San Ramon gaging station. The annual peak flows and flow volumes for annual 1-, 3-, and 5-day durations were analyzed for the period of record currently available, from 1953 to 2005. No low outliers were identified for the peak and one-day flow records; however, the 1977 one-day annual flow is close to being an outlier. Water year 1977 was a low outlier year for the three- and five-day durations. The one-day duration record was reanalyzed with 1977 identified as a low outlier. The FFA statistics, with 1977 as a low outlier for the one-, three-, and five-day durations, are listed on Plate 16A. The flow frequency curves presented on Plate 16A are assumed to be representative of a small Walnut Creek watershed under rural, unregulated conditions.

9.2 <u>Flow Frequency Analysis for Changing Conditions</u>. The gages for San Ramon Creek near Walnut Creek and Walnut Creek at Walnut Creek both have records for the period 1953 to 1992, when they were discontinued. However, both gages were relocated once within that period, with small differences in drainage area. Also, conditions in the watersheds for San Ramon and Las Trampas creeks and Walnut Creek below their confluence have undergone a process of increasing urbanization. The fields, orchards, and other open space that existed in 1952 in the Walnut Creek watershed have been converted to residential and commercial uses, with increases in runoff over time.

Most of the recorded high peak flows (in 1956, 1958, and 1963) occurred when the drainage was rural. A successful flood reconstitution of the last of the high four flows of record for both gages, in January 1982, used an urbanization rate reduced by ten percent from current conditions. For the last few years in the gaged records, when the watershed was more urbanized, the flows and volumes were lower, due to a multi-year drought (1987-1992). The gages were discontinued before the weather pattern became wetter in the 1990s.

The statistical frequency programs, Flood Frequency Analysis (HEC-FFA) and Regional Frequency Computation (REGFQ, Reference 4s), were applied to the recorded data for the two streamflow gages. For the statistical analyses, the records for the lower San Ramon gages "at Walnut Creek" (period of record 1953-1973) and "near Walnut Creek" (period of record 1974-1992) were combined. The FFA analysis identified 1961 as a low flow outlier for the peak flow only. FFA statistics used for the peak and flow durations are listed on the San Ramon Creek at Walnut Creek rainflood frequency curves (Plate 16B). The peak flow statistics are with 1961 as a low outlier. FFA statistics for the annual durations have no outliers. The only changes made to FFA statistics were to use a skew of -0.6 for the peak and 5-day curves, to match the computed statistics for the 1- and 3-day durations.

The records for the Walnut Creek gages "at Walnut Creek" (period of record 1952-1968) and "at Concord" (period of record 1968-1992 and peak flow for 1997) were combined for the statistical analysis. No outliers were identified in the FFA analysis. However, there was considerable difference between the skew for the peak flow and the skews for the annual volumes. The volume frequency curves more reflect the impact of increasing urbanization than the peak flow frequency curve does. A Regional Frequency Computation (REGFQ) analysis was performed on a set of flow volume data that included the periods of record for the upper and lower San Ramon gages and the gage on Walnut Creek. The adjusted statistics for the volume frequency curves at the Walnut Creek at Concord gage are listed on Plate 16C. The adjusted statistics and skew of -0.3 are used for the frequency curves for the 1-, 3-, and 5-day durations. Because the records for the lower San Ramon gage and the Walnut Creek gage are non-stationary, there is some uncertainty in the frequency curves for floods less frequent than the 4% chance event. According to the flow frequency curves, the two San Ramon Creek gages have not experienced a 2% chance flood during the period of record. Flood volumes for the February 1986 high flow event were between a 3% and 2% flood at the Walnut Creek at Concord gage.

9.3 10% General Rainstorm. For the 1992 hydrology study, the 10% event flood hydrographs were computed in the HEC-1 model as runoff from 81 percent of the 10% event local storm amount. In addition to peak flows, flood volumes are needed for the current study, so 4-day 10% general rainstorms were developed using the Mean Seasonal Isohyets and Precipitation Duration-Frequency-Depth Curves published by the CCCFCWCD (Reference 4i). The 10% 96-hour general storm specific and concurrent centerings are in the same order as the 1% general storm discussed in Section 8.3: the specific centering is on San Ramon Creek in Bollinger Canyon, with concurrent centerings, in descending order, on (1^{st} concurrency) San Ramon Creek and Sans Crainte Creek above their confluence, on (2^{nd} concurrency) Las Trampas Creek and Walnut Creek at the San Ramon Bypass, on (3^{rd} concurrency) Grayson-Murderer's watershed, on (4^{th} concurrency) Pine Creek and Walnut Creek channel at their confluence, and on (5^{th} concurrency) Walnut Creek below the Pine Creek confluence down to the confluence with Pacheco Creek. Table 10A shows which concurrency applies to which subbasins. The 24-hour depth-area reduction curve presented on Plate 13 was used to areally reduce the 10% 4-day point rainfall for the specific and concurrent storm centerings over the watershed. The 10% subbasin storm amounts are listed on Table 8A and the 4-day precipitation distribution pattern listed on Table 8C.

9.4 Loss Rates, Base Flow, and Channel Routing for 10% Flood. The HEC-1 model for the 10% general rainstorm event used the exponential loss rate parameters optimized for the San Ramon Creek at San Ramon streamgage discussed in Section 7.5. The percents of imperviousness for the Walnut Creek subbasins are listed on Table 7A. The exponential loss parameters are listed below.

STRKR = 0.50
DLTKR = 3.21
RTIOL = 2.32
ERAIN = 0.70

An initial base flow (STRTQ) of 1.0 cubic foot per second per square mile (cfs/sq.mi.) was used for the 10% flood event, the same rate that was used for the 10% local flood in the Grayson Creek hydrology appendix (Reference 4f). A hydrograph falling limb base flow parameter (QRCSN) of -0.10, or 10 percent of the peak flow, was used for the subbasins. A recession flow ratio (RTIOR) of 1.05 was used for San Ramon Creek at San Ramon gage, and recession flow ratio of 1.10 was used for the rest of the Walnut Creek watershed subbasins. For the Grayson Creek watershed the following base flow parameters were used: an initial base flow (STRTQ) of 1.0 cfs per square mile, a falling limb base flow (QRCSN) of 3 cfs/sq.mi., and a recession flow ratio (RTIOR) of 1.10.

To compute the Muskingum channel routing coefficients, Hydraulic Design Section personnel estimated channel velocities for the 10% event flood hydrographs down the Walnut Creek channel and lower reaches of Pine Creek. A 15-minute routing step was used in conjunction with the 15-minute time ordinate. The channel velocities and computed Muskingum routing parameters used for the 10% flood are listed in Table 9A. For some of these channel reaches, the channel velocities are slower for the 10% flood than for the 1% flood. The Muskingum routing parameters used for the Grayson Creek HEC-1 model for the 8-flood series are those listed in the Grayson Creek hydrology appendix (Reference 4f).

Table 9A
Walnut Creek Muskingum Channel Routing Parameters
for the 10% Flood Event

Routing Reach	Routing Reach Description	Channel Length (mi.)	Channel Velocity (ft./sec.)	Muskingum Parameters No. of Rtg. Steps	K (hrs.)	X
San Ramon Creek						
SRC4 – SRC5	Miranda Cr to Sans Crainte Cr	2.54	5.5	3	0.677	0.35
SRC6 – SRC7	Sans Crainte Cr to to Las Trampas Cr	1.35	6.5	1	0.305	0.35
Las Trampas Creek						
LT7 – LTC1	Lafayette Cr to Upr. Las Trampas Cr	1.73	8	1	0.317	0.35
LTC1 – LTC2	Upr. Las Trampas Cr Reliez Canyon	1.57	8	1	0.289	0.35
LTC2 – LTC3	Reliez Canyon to Above Tice Cr	2.09	8	2	0.383	0.35
LTC3 – LTC4	Abv. Tice Cr To Mouth of Las Trampas	0.60	6	1	0.146	0.35
Walnut Creek						
WC1 – WC2	Mouth of Las Trampas Cr to San Ramon Bypass	0.64	6	1	0.157	0.35
SRC6–WC2	San Ramon Bypass Channel	1.67	25	1	0.098	0.50
WC3 – WC4	Indian Cr to Las Casa Via	1.5	25	1	0.088	0.50
WC4–WC5	La Casa Via to Bancroft	0.60	25	1	0.035	0.50
WC5–WC6	Bancroft to Concord Gage	0.99	11	1	0.132	0.40
WC6–WC7	Concord Gage to Pine Cr	2.34	7	2	0.49	0.35
Pine Creek						
P7 – PC1	Upr. Pine to Mid Pine	3.67	8	3	0.673	0.35
PC1 – PC2	Mid Pine to Mid Lower Pine	4.17	6.5	4	0.941	0.35
PC2 – PC3	Mid Lower Pine to Galindo Cr	1.28	12	1	0.156	0.40
PC3 – PC4	Galindo Cr to Mouth of Pine Cr	0.91	10	1	0.133	0.40
Walnut Creek						
WC8 – WC9	Pine Cr to Mouth of Grayson Cr	0.59	5	1	0.174	0.35
WC10 – WC11	Grayson Cr to Confluence with Pacheco Cr	1.47	3.5	2	0.616	0.25
WC11 – WC12	Blw. Grayson Subbasin to Pacheco Cr	1	3.5	1	0.242	0.25
WC12 – BAY	Pacheco Cr To Suisun Bay	1.85	4.6	2	0.59	0.25
Pacheco Creek						
PA2A – PAC1	Detention Basin to Mid Pacheco Cr	1.25	0.5	15	3.667	0.00
PAC1–PAC2	Mid-Pacheco to Walnut Cr	1.25	0.5	15	3.667	0.00

9.5 <u>10% General Rainflood Hydrographs for Walnut Creek</u>. The revised HEC-1 model was used with the following to develop the 10% flood hydrographs at index points in the Walnut Creek watershed: (1) the 10% event 96-hour storm totals (Table 8A) and distribution pattern (Table 8C), (2) unit hydrographs, (3) optimized exponential loss parameters, (4) percents of imperviousness (Table 7A), (5) the base flow and Muskingum routing parameters (Table 9A) discussed in Section 9.4, (6) the San Ramon Bypass flow split (Table 8E), and (7) detention basin storage-outflow relationships on Pacheco and Pine creeks (Tables 8G and 8H), discussed above. The computed 10% flood peak flows and volumes for the 1-, 3-, and 5-day durations for selected locations are listed on Table 9B. These peak flow and volumes are for the HEC-1 model only, not the peak flows and volumes used in the hydraulic routing model for sediment analysis or floodplain development.

Table 9B
HEC-1 Model 10% General Rain Flood Peak Flows and Volumes
for Various Walnut Creek Watershed Locations

		96-Hr 10% Flood Peak and Volumes			
Location	Drainage Area (sq.mi.)	Peak (cfs)	Volumes in average cfs 24-Hr	72-Hr	120-Hr
San Ramon Creek @ San Ramon gage	6.31	997	364	170	109
San Ramon Cr. above San Crainte Creek	47.78	6,370	2,510	1,160	802
San Crainte Cr at Mouth	2.63	369	110	49	34
San Ramon Cr. Below San Crainte Cr.	50.41	6,550	2,620	1,210	836
San Ramon Bypass Flow	N/A	6,550	2,620	1,210	836
Tice Creek at Mouth	4.18	790	280	138	96
Las Trampas Creek abv Walnut Creek	26.76	4,590	1,800	865	599
Walnut Cr Below San Ramon Bypass	78.89	11,200	4,540	2,120	1,480
Walnut Cr at Concord gage	83.67	11,600	4,830	2,260	1,580
Galindo Creek at Mouth	7.61	932	366	185	126
Pine Creek at Mouth	30.06	2,830	1,210	611	442
Walnut Creek below Pine Creek	114.84	13,800	6,110	2,910	2,050
Grayson Creek at Mouth	17.60	2,740	858	415	274
Walnut Creek below Grayson Creek	139.84	16,600	7,400	3,570	2,500
Pacheco Creek at Mouth	3.99	364	237	133	94
Walnut Creek below Pacheco Creek	144.32	16,700	7,660	3,710	2,600

Comparison of the computed peak flows and volumes with the flow frequency curves for the three streamflow gage locations is discussed in Sections 9.6 and 9.7.

9.6 <u>Computation of 4%, 20%, and 50% General Rainfloods</u>. The procedures discussed in Paragraphs 9.3 to 9.5 were also used to compute flow hydrographs for the 4%, 20%, and 50% floods, part of the 8-Flood Series general rainflood hydrographs to be used in the sediment transport model.

a. Storms. The 96-hour storm centerings for the 4%, 20%, and 50% general rain events were computed for the Walnut Creek watershed, using Mean Seasonal Precipitation (MSP), the Precipitation Duration-Frequency-Depth Curves for 4-days (Reference 4i), and the NOAA Atlas 24-Hour Depth-Area Reduction Curve displayed on Plate 13. The subbasin storm totals for the 4%, 20%, and 50% general rainstorms are listed on Table 8A.

b. Loss Rates. Exponential loss rate parameters optimized for the San Ramon Creek at San Ramon streamgage, discussed in Section 7.5, were used in the initial HEC-1 runs for the 4%, 20%, and 50% general rain events for the Walnut Creek and Grayson subbasins. The percent imperviousness factors for the Walnut Creek subbasins are listed on Table 7A. The percent imperviousness factors used for Grayson Creek are listed in the Grayson Creek hydrology appendix (Reference 4f).

c. Channel Routing. The Muskingum channel routing parameters listed in Table 9A for the 10% flood were used for the 4%, 20%, and 50% general rain events as well.

d. Base Flow Parameters. For the initial HEC-1 run for the 4%, 20%, and 50% general rain events, the following base flow parameters were used: starting base flow (STRTQ) = 0.0 for the more frequent 20% and 50% flood hydrographs; STRTQ = 2.0 cfs/sq.mi. for the 4% flood. For Walnut Creek subbasins, a hydrograph falling limb base flow parameter (QRCSN) of -0.15, or 15 percent of the peak flow, and recession flow ratio (RTIOR) of 1.15 were used. For the Grayson Creek watershed, a falling limb base flow (QRCSN) of 3 cfs/sq.mi., and a recession flow ratio (RTIOR) of 1.15 were used.

e. Initial HEC-1 Run. The HEC-1 model was used with the 4%, 20%, and 50% general rain event 96-hour storm totals (Table 8A) and distribution pattern (Table 8B), unit hydrographs, percent impervious factors (Table 7A), Muskingum routing parameters (Table 9A), San Ramon Bypass flow split, Pacheco storage-outflow relationship, and the base flow and exponential loss parameters discussed above in this section (9.6) to compute preliminary flood hydrographs at index points in the Walnut Creek watershed.

The peak flows and volumes computed in the HEC-1 model for the three streamgage locations were compared with the observed data points and flow frequency curves (Plates 16A-16C) for those locations. The computed peak flows and volumes for the 4% flood event compared well with the flow frequency curves, but computed peak flows and volumes for the 20% and 50% floods were too high.

f. Adjustments. Two parameters were examined as a means of adjusting the HEC-1 model to lower the peaks and volumes of the computed 20% and 50% event hydrographs. First, to decrease the base flow component of the hydrographs, the falling limb base flow parameter (QRCSN) for the Walnut Creek subbasins was changed from

-0.15, or 15 percent of the peak flow, to -0.01, or one percent of the peak flow. The resulting computed hydrographs for the gage locations still appeared too high.

Next, the exponential loss parameters were examined. The DLTKR parameter, the amount of initial accumulated rain loss, is primarily a function of antecedent soil moisture deficiency and is usually storm dependent. The DLTKR parameter was adjusted upward for the 20% and 50% general rainstorms, under the assumption that soil moisture conditions would be drier for those events. The DLTKR parameter was adjusted for each event until the computed peak flows and volumes at the lower San Ramon and the Concord gage locations more closely matched the observed data points on Plates 16B and 16C.

For all floods the ratio of recession flow (RTIOR) was changed from 1.15 to 1.10, based on earlier adjustments to the modeling of the January 1982 flood event, the 1% general rainflood model, and the 10% general rainflood model. Table 9C lists the parameters used in the current HEC-1 model for the five general rainfloods.

Table 9C
Walnut Creek HEC-1 Model Adjustments
For 50%, 20%, 10%, 4%, and 1% Floods

% Chance Flood Event	Base Flow Parameters			Exp. Loss Parameter
	STRTQ	QRCSN	RTIOR	DLTKR
50%				
Walnut Cr	0.0	-0.01	1.10	4.25
Grayson Cr	0.0	3 cfs/sq. mi.	1.10	4.25
20%				
Walnut Cr	0.0	-0.01	1.10	3.75
Grayson Cr	0.0	3 cfs/sq. mi.	1.10	3.75
10%				
Walnut Cr	1 cfs/sq. mi.	-0.10	1.10	3.21
Grayson Cr	1 cfs/sq. mi.	3 cfs/sq. mi.	1.10	3.21
4%				
Walnut Cr	2 cfs/sq. mi.	-0.15	1.10	3.21
Grayson Cr	2 cfs/sq. mi.	3 cfs/sq. mi.	1.10	3.21
1%				
Walnut Cr	5 cfs/sq. mi.	-0.15	1.10	3.21
Grayson Cr	5 cfs/sq. mi.	3 cfs/sq. mi.	1.10	3.21

The same QRCSN base flow rate was used for all of the floods on Grayson Creek, based on the observed flood hydrographs on the West Fork Grayson Creek in 1955, 1956, and 1958. The Grayson Creek hydrographs return to base flow soon after peaking. Most of the Grayson and Murderer's creeks subbasins are small and a value of 3 cfs/sq.mi. for the QRCSN base flow parameter is a very small percent of the peak flow.

9.7 Flow Frequency Curves and General Rainfloods. This section discusses the comparison between the flows computed in the HEC-1 model for the 50%, 20%, 10%, 4%, and 1% general rain floods and the same flows from the flow frequency curves. Table 9D presents a tabulation of the peak flows and volumes from the HEC-1 model for the three stream gage locations, compared with the corresponding flows from the flow frequency curves. The flow frequency curves are presented on Plates 16A, B, and C.

The flow comparison is presented in Table 9D in “% Error,” the measurement of the difference between the HEC-1 flow and the “target flow” from the frequency curve. The formula for percent error is:

Percent Error = 100 x (HEC-1 volume - target volume) / (target volume),
where the “target” volume is from the flow frequency curve.

Table 9D
Comparison of General Rain Flood Flows (HEC-1 Runs)
with Target Flows (from Frequency Curves)
for 50%, 20%, 10%, 4%, and 1% Flood Events

% FLOOD	SAN RAMON CREEK AT SAN RAMON GAGE			
	Peak (cfs)	1-Day (avg. cfs)	3-Day (avg. cfs)	5-Day (avg. cfs)
50% (Freq Curve)	289	76	45	33
50% (HEC-1 Run)	334	78	31	21
% Error	16%	3%	-31%	-36%
20% (Freq Curve)	717	187	109	81
20% (HEC-1 Run)	746	248	96	60
% Error	4%	33%	-12%	-26%
10% (Freq Curve)	1,080	278	161	120
10% (HEC-1 Run)	997	364	170	109
% Error	-8%	31%	6%	-9%
4% (Freq Curve)	1,610	404	232	173
4% (HEC-1 Run)	1,240	467	235	155
% Error	-23%	16%	1%	-10%
1% (Freq Curve)	2,470	598	340	255
1% (HEC-1 Run)	1,700	663	338	233
% Error	-31%	11%	-1%	-9%
% FLOOD	SAN RAMON CREEK AT WALNUT CREEK GAGE			
	Peak (cfs)	1-Day (avg. cfs)	3-Day (avg. cfs)	5-Day (avg. cfs)
50% (Freq Curve)	1,780	525	295	214
50% (HEC-1 Run)	2,030	738	373	246
% Error	14%	41%	26%	15%
20% (Freq Curve)	4,030	1,320	740	531
20% (HEC-1 Run)	4,900	1,750	777	520
% Error	22%	33%	5%	-4%
10% (Freq Curve)	5,840	2,000	1,120	801
10% (HEC-1 Run)	6,550	2,620	1,210	836
% Error	12%	31%	8%	4%
4% (Freq Curve)	8,330	3,000	1,680	1,190
4% (HEC-1 Run)	8,090	3,390	1,660	1,140
% Error	-3%	13%	-1%	-4%
1% (Freq Curve)	12,200	4,620	2,580	1,820
1% (HEC-1 Run)	11,000	4,720	2,340	1,640
% Error	-10%	2%	-9%	-9%
% FLOOD	WALNUT CREEK AT CONCORD GAGE			
	Peak (cfs)	1-Day (avg cfs)	3-Day (avg cfs)	5-Day (avg cfs)
50% (Freq Curve)	3,370	1,060	602	438
50% (HEC-1 Run)	4,100	1,560	797	527
% Error	22%	47%	32%	20%
20% (Freq Curve)	7,360	2,450	1,360	973
20% (HEC-1 Run)	8,800	3,350	1,540	1,010
% Error	20%	37%	13%	4%
10% (Freq Curve)	10,600	3,690	2,020	1,440
10% (HEC-1 Run)	11,600	4,830	2,260	1,580
% Error	9%	31%	12%	10%
4% (Freq Curve)	15,100	5,580	3,020	2,140
4% (HEC-1 Run)	14,200	6,150	3,020	2,120
% Error	-6%	10%	0%	-1%
1% (Freq Curve)	22,400	9,010	4,810	3,380
1% (HEC-1 Run)	19,200	8,450	4,210	3,010
% Error	-14%	-6%	-12%	-11%

Volume frequency curves are for the maximum 1-, 3-, and 5-day volumes (measured from midnight to midnight) while the corresponding values from the HEC-1 hydrographs are for the maximum 24-, 72-, and 120-hour flows. For a flood event where the peak flow occurs around midnight, the 24-hour HEC-1 flow can be considerably higher than the comparable 1-day flow from the frequency curve. Table 9D shows that, for most of the flood events, the 24-hour HEC-1 flows are between 2% and 47% higher than the 1-day frequency curve flows. HEC-1 flows for the 3-day and 5-day volumes are closer to the "target" volumes. Differences between frequency curve flows and the HEC-1 flows are not very critical for the San Ramon Creek at San Ramon gage; these upstream hydrographs are not typical of runoff from the downstream urban watershed. Also, the 50% flood is not a critical event, so the greater differences between HEC-1 flows and frequency curve flows for all three gages are not an issue of concern. Except for the 50% chance flood, the adjusted parameters in Table 9C result in HEC-1 model peak flows and 3- and 5-day volumes that are generally within +/- 12 percent of the target flows for the downstream gages. Considering the problem with adjusting HEC-1 parameters to calibrate the model for five different floods for peak flows and three different volumes to frequency curves for three different gages, the HEC-1 hydrographs for these five floods of the 8-flood series are satisfactory to use for hydraulic modeling purposes.

Despite the modifications made to the 96-hour storm distribution pattern (Table 8C) to increase flood volumes for the 1% flood event, the peak flows from the HEC-1 model are lower than the flow frequency curve peaks at the three streamflow gages. Because the general rain peak flows are smaller, 6-hour storms were used to compute the peak flows needed for floodplain definition. Development of the local storm and flood series for the 1% peak flows in the Walnut Creek watershed is discussed in Section 10.

9.8 Computation of 2.0%, 0.5%, and 0.2% Floods. For the Grayson Creek hydrology study, the 2.0%, 0.5%, and 0.2% flood hydrographs were developed as ratios of the 1% flood hydrograph, using ratios from the urbanized peak flow frequency curve for the Murderer's-East Fork Grayson creeks confluence (see Plate 13 in the Grayson Creek hydrology appendix (Reference 4f)). The same methodology is used to develop the 2.0%, 0.5%, and 0.2% general rainflood hydrographs for the current study. Flood volumes, not peak flows, are more critical for sediment transport analysis, so ratios based on the 1-, 3- and 5-day volume frequency curves, instead of the peak flow curves, are used to develop the hydrographs for the 2.0%, 0.5%, and 0.2% general rainflood hydrographs. Volume frequency curves for the two downstream gages, San Ramon Creek at Walnut Creek and Walnut Creek at Concord, were used because they are representative of most of the runoff from the urbanized watershed. The upstream gage, San Ramon Creek at San Ramon, has a small rural drainage area, and runoff here is not typical of most of the Walnut Creek basin.

As an example of how to develop the ratio for flood hydrograph computation, the steps to compute the ratio for the 2% event flood hydrographs are:

(1) For San Ramon Creek at Walnut Creek gage (SR at WC), take the ratio of the 2% 1-day volume to the 1% 1-day volume. This ratio is listed as 0.821 in Table 9E.

(2) Take the same ratios at this gage for the 2% 3-day and 5-day volumes. These ratios, 0.821 and 0.823, are also listed in Table 9E.

(3) Follow steps (1) and (2) for the Walnut Creek at Concord gage (WCF at Conc). These ratios are 0.800, 0.805, and 0.808.

(4) The average of the 6 ratios above, for the 2% 1-, 3-, and 5-day volumes, is 0.813, the ratio used in the HEC-1 model to compute the 2% event general rainflood hydrographs based on the 1% flood hydrographs.

The same method was used to compute the ratios for the 0.5% and 0.2% flood hydrographs, based on the 1% flood hydrographs. The flood ratios listed in Table 9E, below, were applied to the 1% Walnut Creek HEC-1 model to compute the 2.0%, 0.5%, and 0.2% general rainflood hydrographs at the various locations in the Walnut Creek watershed. The same ratios were applied to the Grayson Creek HEC-1 model for concurrent general rainflood hydrographs; analysis of volume-frequency relationships was not included in previous Grayson Creek hydrology studies and duration flow ratios for that watershed are not known.

Table 9E
General Rain Event 8-Flood Series
Ratios to 1% Flood to Use
for 2%, 0.5%, and 0.2% Floods in HEC-1 Model

Gage Location of Frequency Curve	8-Flood Series Event (% Chance)	Ratio of Series Event Volume in Frequency Curve to 1% Volume in Frequency Curve			Ratio (Average of 6 Ratios) to 1% Hydrograph to Compute Hydrographs for Flood Series Event
		1-Day Vol	3-Day Vol	5-Day Vol	
SR at WC	2%	0.821	0.821	0.823	2% Flood Ratio
WC at Conc	2%	0.800	0.805	0.808	0.813
SR at WC	1%	1.000	1.000	1.000	1% Flood Ratio
WC at Conc	1%	1.000	1.000	1.000	1.000
SR at WC	0.5%	1.184	1.183	1.180	0.5% Flood Ratio
WC at Conc	0.5%	1.219	1.213	1.209	1.198
SR at WC	0.2%	1.430	1.429	1.422	0.2% Flood Ratio
WC at Conc	0.2%	1.539	1.521	1.511	1.476

Notes: SR at WC = San Ramon Creek at Walnut Creek gage frequency curve (Plate 16B)
WC at Conc = Walnut Creek at Concord gage frequency curve (Plate 16C)

Table 9F lists the 2.0%, 1.0%, 0.5%, and 0.2% general rainflood volumes, in day cfs, for the three gaging station locations, based on applying the ratios in Table 9E to the 1% flood HEC-1 model.

Table 9F
Comparison of General Rain Flood Flows (HEC-1 Runs)
with Target Flows (from Frequency Curves)
for 2%, 1%, 0.5%, and 0.2% Flood Events

% FLOOD	SAN RAMON CREEK AT SAN RAMON GAGE		
	1-Day (avg. cfs)	3-Day (avg. cfs)	5-Day (avg. cfs)
2% (Freq Curve)	501	286	214
2% (HEC-1 Run)	539	275	189
% Error	8%	-4%	-12%
1% (Freq Curve)	598	340	255
1% (HEC-1 Run)	663	338	233
% Error	11%	-1%	-9%
0.5% (Freq Curve)	694	393	295
0.5% (HEC-1 Run)	795	405	279
% Error	15%	3%	-5%
0.2% (Freq Curve)	818	461	347
0.2% (HEC-1 Run)	979	499	343
% Error	20%	8%	-1%
% FLOOD	SAN RAMON CREEK AT WALNUT CREEK GAGE		
	1-Day (avg. cfs)	3-Day (avg. cfs)	5-Day (avg. cfs)
2% (Freq Curve)	3,800	2,120	1,500
2% (HEC-1 Run)	3,840	1,900	1,340
% Error	1%	-10%	-11%
1% (Freq Curve)	4,620	2,580	1,820
1% (HEC-1 Run)	4,720	2,340	1,650
% Error	2%	-9%	-9%
0.5% (Freq Curve)	5,470	3,050	2,150
0.5% (HEC-1 Run)	5,660	2,810	1,980
% Error	3%	-8%	-8%
0.2% (Freq Curve)	6,610	3,690	2,590
0.2% (HEC-1 Run)	6,970	3,460	2,440
% Error	5%	-6%	-6%
% FLOOD	WALNUT CREEK AT CONCORD GAGE		
	1-Day (avg. cfs)	3-Day (avg. cfs)	5-Day (avg. cfs)
2% (Freq Curve)	7,200	3,870	2,730
2% (HEC-1 Run)	6,870	3,430	2,450
% Error	-5%	-11%	-10%
1% (Freq Curve)	9,010	4,810	3,380
1% (HEC-1 Run)	8,450	4,210	3,010
% Error	-6%	-12%	-11%
0.5% (Freq Curve)	11,000	5,840	4,090
0.5% (HEC-1 Run)	10,100	5,050	3,600
% Error	-8%	-14%	-12%
0.2% (Freq Curve)	13,900	7,320	5,120
0.2% (HEC-1 Run)	12,500	6,220	4,440
% Error	-10%	-15%	-13%

Table 9F includes a comparison in percent error between the HEC-1 volumes and the frequency curve volumes for the three gages. While most of the HEC-1 flows are within +/- 15% of the target flows for all three gages, there is a problem in that most of the HEC-1 volumes for the Walnut Creek at Concord gage are at least 10% lower than the target volumes. As explained in Section 9.2, Flow Frequency Analysis for Changing Conditions, there is some uncertainty in the flow frequency curves for floods rarer than the 4% event. The general rainflood hydrographs for the index points listed in Table 12A were provided to Hydraulic Design Section for the Walnut Creek sediment conveyance model. Hydraulic Design Section plans to use these hydrographs in a sensitivity analysis, so the slightly lower hydrographs are acceptable for their purposes.

10. 6-Hour Storms and Flood Hydrographs

While the 4-day general rainflood hydrographs discussed in Sections 8 and 9 have volumes that are good matches for the flow frequency curves at the lower San Ramon and Walnut Creek streamflow gages, the peak flows for the 1% general rainflood are too low to match the peak flow frequency curves at the two gages. In the 1992 Walnut Creek hydrology study (Reference 4e), general and 6-hour local rainstorms were developed for San Ramon Creek. The local storms produced the higher peak flows in the watershed. The 6-hour storm centering procedure, used for the Grayson Creek hydrology study (Reference 4f) for computing concurrent peak flows along San Ramon Creek, was used for the current study to compute the specific flood peaks for San Ramon Creek. Only the 2% and less frequent local floods were developed, because the general rainflood hydrographs for the 50% through 4% floods (discussed in Sections 8 and 9) match pretty closely the peak flows and volumes of the flow frequency curves for the lower San Ramon and Walnut Creek gages. As with the Grayson Creek methodology, the 6-hour flood hydrographs for the 2%, 0.5% and 0.2% flood events are ratios of the 1% local flood.

10.1 <u>6-Hour 1% Event Storm</u>. The 1% 6-hour storm used to compute peak flows along Walnut Creek was developed using the mean seasonal isohyets and precipitation-frequency-depth curves for the 6-hour storm duration published by the CCCFCWCD in 1977 (Reference 4i). The 1% chance 6-hour rainstorm, as with the 4-day storm, was specifically centered on San Ramon Creek in Bollinger Canyon, with concurrent centerings, in descending order, on (1^{st} concurrency) San Ramon and Sycamore creeks above their confluence, on (2^{nd} concurrency) San Ramon Creek down to its confluence with Sans Crainte Creek, on (3^{rd} concurrency) Las Trampas Creek and Walnut Creek at the San Ramon Bypass, on (4^{rd} concurrency) Grayson-Murderer's watershed, on (5^{th} concurrency) Pine Creek and Walnut Creek channel at their confluence, and on (6^{th} concurrency) Walnut Creek from its confluence with Pine Creek down to its confluence with Pacheco Creek. Table 10A shows which concurrencies apply to which subbasins; they are the same for both the 1% 6-hour storm and the 1% general rainstorm.

The 6-hour depth-area curve on Figure 14 in the NOAA Atlas 2, "Precipitation-Frequency Atlas of the Western United States, Vol. XI—California" (Reference 4h), provided the areal reduction factors to compute the specific and concurrent 6-hour storm depths over the watershed. The NOAA Atlas 6-hour depth-area reduction curve is presented on Plate 13. The areally reduced 6-hour 1% storm amounts for the Walnut Creek subbasins are tabulated below on Table 10A.

Table 10A
1% 6-Hour Storm Centering Amounts
on the Walnut Creek Subbasins

Subbasin Code	Drainage Area (sq.mi.)	Mean Seasonal Precip. (MSP)	1% 6-Hour Storm (in.)
San Ramon Creek			
Storm Centering on USR3			
USR3	6.31	25.68	3.59
(1st Concurrency)			
USR2	3.00	23.58	3.33
USR1	4.72	20.79	2.93
S3	3.88	19.73	2.78
S2	1.12	18.75	2.65
S1	3.26	19.18	2.71
(2nd Concurrency)			
SR7	2.37	21.78	2.90
GV4	2.21	19.13	2.54
GV3	2.86	19.18	2.55
GV2U	1.36	19.44	2.59
GV2L	1.17	19.18	2.55
GV1	1.85	19.69	2.62
SR6	6.17	23.83	3.17
SR5	2.65	20.34	2.71
SR4	2.27	19.56	2.60
SR2	2.58	22.53	3.00
SR3	2.63	19.40	2.58
SR1	0.44	20.45	2.72
Las Trampas Creek			
(3rd Concurrency)			
LT7	2.05	28.29	3.45
LT8	1.30	28.03	3.42
LT6	3.45	26.75	3.26
LT5	9.48	26.86	3.28
LT4	3.61	24.63	3.01
LT9	1.16	24.48	2.99
LT2	1.49	22.22	2.71
LT3A	2.65	23.31	2.84
LT3B	0.49	23.31	2.84
LT3C	0.48	23.31	2.84
LT3D	0.56	23.31	2.84

Subbasin Code	Drainage Area (sq.mi.)	Mean Seasonal Precip. (MSP)	1% 6-Hour Storm (in.)
Walnut Creek (cont.)			
(5th Concurrency)			
P6	6.77	18.92	2.39
P4	5.24	16.99	2.15
P5	2.80	17.11	2.16
P3	1.76	16.73	2.12
P2	7.61	17.77	2.25
P1	2.72	16.48	2.09
(6th Concurrency)			
W4	1.59	15.85	2.03
TW1	5.60	15.64	2.00
W3	0.21	15.17	1.94
W2	0.20	14.90	1.91
W1	0.29	14.75	1.89
PA2A	1.76	17.52	2.24
PA2B	1.40	15.79	2.02
PA1	0.83	14.83	1.90
Grayson Creek			
(4th Concurrency)			
5	0.89	22.60	2.90
3	0.76	22.85	2.94
4	0.55	21.86	2.81
6	0.13	20.07	2.58
7	0.66	19.60	2.52
2	0.62	21.48	2.76
1	0.88	20.49	2.63
8E1	0.22	19.04	2.45
8W1	0.30	19.41	2.49
8E2	0.17	18.24	2.34
8W2	0.11	18.59	2.39
19	0.64	20.05	2.58
20	0.28	18.72	2.41
20N	0.16	18.13	2.33
9	0.54	19.18	2.46
10W	0.19	18.21	2.34

Table 10A
1% 6-Hour Storm Centering Amounts
on the Walnut Creek Subbasins

Subbasin Code	Drainage Area (sq.mi.)	Mean Seasonal Precip. (MSP)	1% 6-Hour Storm (in.)	Subbasin Code	Drainage Area (sq.mi.)	Mean Seasonal Precip. (MSP)	1% 6-Hour Storm (in.)
LT1	0.12	20.76	2.53	10E	0.42	17.81	2.29
Walnut Creek				12	1.68	22.87	2.94
(3rd Concurrency)				13	0.25	20.53	2.64
W9	1.03	20.91	2.55	14	2.13	20.05	2.58
W8	0.25	20.13	2.46	11	0.59	18.69	2.40
(5th Concurrency)				15W1	0.88	18.08	2.32
T1	2.04	19.20	2.43	15W2	0.35	17.27	2.22
W7	0.64	19.13	2.42	15E	0.51	17.10	2.20
B1	1.21	18.04	2.28	17	0.50	17.66	2.27
W6	0.88	17.47	2.21	16	1.05	17.60	2.26
W5	1.11	17.21	2.18	18W	0.98	16.37	2.10
P7	3.16	22.05	2.79	18E	1.22	16.11	2.07

The storm was temporally distributed using the storm distribution pattern from the 1977 San Ramon Hydrology Report (Reference 4t). The pattern, listed on Table 10B, is the same one used for the 6-hour storms in the 1992 Walnut Creek feasibility Study hydrology (Reference 4e).

Table 10B
6-Hour Storm Distribution Pattern

15-Minute Time Increment	Incremental % of 6-Hour Rainfall	15-Minute Time Increment	Incremental % of 6-Hour Rainfall	15-Minute Time Increment	Incremental % of 6-Hour Rainfall
1	2.1	9	4.8	17	19.0
2	2.5	10	4.3	18	6.3
3	3.8	11	2.6	19	4.0
4	4.5	12	2.5	20	3.0
5	6.0	13	2.2	21	2.5
6	3.0	14	2.5	22	2.4
7	2.3	15	5.0	23	2.2
8	2.5	16	7.9	24	2.1
				SUM	100.0

10.2 <u>Loss Rates for Local Storm</u>. The exponential loss method should be used with the local storm, to be consistent with the loss rate methodology used for the general rainstorms. However, the exponential loss parameters optimized for the 1% general rainflood do not work for the 6-hour flood; the resulting peak flows are too low. Another HEC-1 exponential loss optimization was performed for the January 1982 storm on San Ramon Creek at San Ramon, this time with the assumption that the initial loss component has been satisfied. The higher excess rainfall contributes to a higher peak flow. For this

HEC-1 optimization run the loss parameters of ERAIN and DLTKR were set equal to 0.0. The optimization results in the exponential loss parameters listed below:

STRTKR = 0.20
DLTKR = 0.00
RTIOL = 1.53
ERAIN = 0.00

These optimized exponential loss parameters were used for the subbasins in the Walnut Creek HEC-1 model for the 6-hour storm.

10.3 Base Flow. The base flow parameters used for the 1% general rainflood events were also used for the 1% local storm. An initial base flow (STRTQ) of 5 cubic feet per square mile (cfs/sq.mi.) was used. A hydrograph falling limb base flow parameter (QRCSN) of -0.15, or 15 percent of the peak flow, and recession flow ratio (RTIOR) of 1.10 were used for the subbasins. For the Grayson Creek watershed the following base flow parameters were used: an initial base flow (STRTQ) of 5 cfs per square mile, a falling limb base flow (QRCSN) of 3 cfs/sq.mi., and a recession flow ratio (RTIOR) of 1.10.

10.4 1% Local Flood Hydrographs. The Walnut Creek HEC-1 model was used with the 1% event 6-hour storm totals and distribution pattern (Tables 10A and 10B), base flow parameters, and optimized local storm exponential loss rates discussed above, to develop the 1% local flood hydrographs needed for floodplain analysis of the Walnut Creek channel. The 1% local flood peak flows from the HEC-1 model for the three Walnut Creek streamflow gages are listed on Table 10D.

10.5 Peak Flow Frequency Analysis. The flood flow ratios listed in Table 10C below were used with the Walnut Creek HEC-1 model for the 6-hour 1% flood event to compute the 2.0%, 0.5%, and 0.2% local flood hydrographs at the various locations in the Walnut Creek watershed. The ratio listed for each flood is the average of two ratios, the ratio of that flood peak to the 1% flood peak on the peak flow frequency curves for the lower San Ramon Creek gage and the Walnut Creek at Concord gage. For consistency the same ratios were applied to the Grayson Creek HEC-1 model for concurrent 6-hour flood hydrographs.

Table 10C
6-Hour Local Flood Series Ratios

8-Flood Series Local Flood Event	Ratio of HEC-1 Run for 1% 6-Hour Flood to Compute Hydrographs for Flood Series Event (Ratio)
50%	N/A
20%	N/A
10%	N/A
4%	N/A
2%	0.837
1%	1.000
0.50%	1.165
0.20%	1.386

N/A = not valid for 6-hour storm

The ratios listed above for the 6-hour floods were used with the HEC-1 model for the 1% local flood to compute the hydrographs for the 2%, 0.5%, and 0.2% local floods on Walnut Creek. Table 10D lists the computed peak flows at the three Walnut Creek streamflow gages for the 2%, 1%, 0.5%, and 0.2% local floods as well as listing the corresponding peak flows from the computed peak flow frequency curves for comparison.

Table 10D
HEC-1 Model 2%, 1%, 0.5%, and 0.2% 6-Hour Rain Flood
Peak Flows for the Three Gaging Station Locations

Location	Drainage Area (sq. mi.)	6-Hr Flood Peak and Volumes 2% (cfs)	1% (cfs)	0.5% (cfs)	0.2% (cfs)
San Ramon Creek at San Ramon gage	5.89				
Peak Flow Frequency Curve		2,040	2,470	2,920	3,520
HEC-1 Model		2,020	2,420	2,820	3,350
Comparison in % Error		-1.0%	-2.4%	-3.8%	-4.8%
San Ramon Cr at Walnut Creek	50.4				
Peak Flow Frequency Curve		10,300	12,200	14,200	16,800
HEC-1 Model		10,800	12,900	15,000	17,800
Comparison in % Error		4.9%	5.7%	5.6%	6.0%
Walnut Creek at Concord	85.2				
Peak Flow Frequency Curve		18,700	22,400	26,200	31,400
HEC-1 Model		18,700	22,400	26,100	30,800
Comparison in % Error		0.0%	-0.0%	-0.4%	-1.9%

11. Comparison with Previous Hydrology Studies

This section presents a comparison between the peak flows computed in the HEC-1 model for the San Ramon Creek and Walnut Creek gages and Las Trampas, Pine, and Grayson creeks with peak flows from previous Walnut Creek hydrology for those watersheds. To be in agreement with previous Walnut Creek hydrology, the peak flows for present conditions should not exceed the design hydrology flows for San Ramon, Las Trampas and Walnut creeks that were presented in the 1983 report (Reference 4d). The previous Walnut Creek hydrology reports were checked for 1% peak flow tabulations and peak flow frequency curves for the San Ramon and Walnut Creek gaging stations.

The peak flows listed in Tables 11A through 11D for the present conditions HEC-1 model are presented for comparison with previous HEC-1 hydrology, and are not the same as peak flows computed by hydraulic models for those locations for use in either the floodplain or the sediment transport inundation analyses. Only flood peaks, not flood volumes, are compared with flows computed in previous hydrology studies. The 1983 report (Reference 4d) presented peak flow frequency curves without an analysis of runoff volumes. The flow frequency curves presented in the 1972 report (Reference 4b) for 1-day and longer durations at the two San Ramon gages and the Walnut Creek gage only included data for water years prior to 1972. The current study frequency analysis includes 20 additional years of data for the lower San Ramon and Walnut Creek at Concord gages and more than 30 years of additional data for the San Ramon Creek at San Ramon gage.

11.1 <u>1983 Hydrology Project Design Flows</u>. Table 11A presents a comparison between the project design flows and present conditions (2006) 1% event peak flows for several locations above the Walnut Creek at Concord streamflow gage.

Table 11A
Peak Flow Comparison Between 2006 Study
and 1% Project Design Flows (1983 Report)

Index Point	Drainage Area (sq. mi.)	Design Flow (1% event)		2006
		(Specific) (cfs)	(Concurrent) (cfs)	1% Peak (cfs)
San Ramon Cr above Sans Crainte Cr	47.80	13,200	N/A**	12,600
Sans Crainte Cr at Mouth	2.63	2,000	N/A	1,010
San Ramon Cr above Bypass	50.40	15,200	11,500	12,900
Las Trampas Cr above Tice Cr	21.20	8,250	N/A	7,240 #
Tice Cr at Mouth	4.18	2,000	N/A	1,410 #
Local Walnut Cr abv Bypass *	25.54	10,000	6,800	8,850 #
San Ramon Bypass at Mouth	52.13	15,200	11,500	12,900
Walnut Cr below Bypass	77.67	22,000	N/A	21,500

* Mostly Las Trampas Creek flow

** N/A is not applicable or not available

Concurrent flood peak

The project design flows listed in Table 11A are from the 1983 Walnut Creek hydrology report (Reference 4d). The design peak flows listed above for San Ramon Creek above San Ramon Bypass (the same design peak flows for the San Ramon Bypass) and for Las Trampas Creek below Tice Creek are for a 1% storm centered above each. Adding these flows would result in a peak flow downstream rarer than the 1% flood event, so the project design peak flow for Walnut Creek below the San Ramon Bypass results either from the specific flow for San Ramon Creek above the bypass with a concurrent flow on Las Trampas Creek, or a specific flow on Las Trampas Creek with a concurrent flow on San Ramon Creek above the bypass.

For the 2006 hydrology study, the 1% storm event was centered on San Ramon Creek with the concurrent storm on Las Trampas Creek. According to the 1983 report, the concurrent flow on Las Trampas Creek at mouth is 6,800 cfs; for the 2006 study, the concurrent flood peak is 8,850 cfs. Nevertheless, whether the storm is centered on Las Trampas Creek or on San Ramon Creek, the 1% design flow for Walnut Creek below the San Ramon Bypass canal is 22,000 cfs. For the 2006 study, the 1% event peak flow for this location in the HEC-1 model is slightly less than design flow.

11.2 <u>San Ramon and Walnut Creeks</u>. Table 11B presents a comparison among the peak flows from the 2006 Walnut Creek HEC-1 model, the peak flows for San Ramon Creek in the 1992 hydrology report (Reference 4e), and 1% design peak flows and peak flow frequency curves in 1972 (References 4b and 4c) and 1983 (Reference 4d).

Peak flows computed for the 1992 study are for the San Ramon Creek above Sans Crainte Creek, with a drainage area of 47.9 square miles. The "1972-1983" peak flows for this location are from the 1983 flow frequency curve. The "1972-1983" peak flows for the downstream San Ramon Creek below Sans Crainte Creek location, with a drainage area of 50.8 square miles, are from the 1972 flow frequency curve.

Peak flows listed in Table 11B for the 1992 and 2006 hydrology studies are for the 6-hour local floods. It was determined during these analyses that for the 2% chance and larger floods, 6-hour storms produce higher flood peaks than the general rainstorms at the San Ramon at Walnut Creek and Walnut Creek at Concord gage locations.

The peak flow frequency curves for Walnut Creek at Concord gage developed in 1972 and 1983 are not the same. The Walnut Creek at Concord peak flows for "1972-1983" in Table 11B are from the 1972 frequency curve, because the 1% peak flow for the 1983 frequency curve is 3,000 cfs lower than the 1% design flow at that location.

Table 11B
Peak Flow Comparison with Previous Corps Studies
San Ramon Creek and Walnut Creek

Location Description	**Peak Flow in cfs**		
2.0% Flood (6-hour) Peak Flow (cfs)	2006	1992	1972-1983
San Ramon Cr above Sans Crainte	10,500	10,200	10,800
San Ramon Cr below Sans Crainte	10,800	N/A	12,200
Walnut Cr at Concord	18,700	N/A	18,200
1% Flood (6-hour) Peak Flow (cfs)	2006	1992	1972-1983
San Ramon Cr above Sans Crainte (47.9 sq. mi.)	12,600	12,900	13,200
San Ramon Cr below Sans Crainte (50.8 sq. mi.)	12,900	N/A	15,200
Walnut Cr at Concord (85.2 sq. mi.)	22,400	N/A	22,200
0.5% Flood (6-hour) Peak Flow (cfs)	2006	1992	1972-1983
San Ramon Cr above Sans Crainte	14,600	15,500	16,200
San Ramon Cr below Sans Crainte	15,000	N/A	18,500
Walnut Cr at Concord	26,100	N/A	27,000
0.2% Flood (6-hour) Peak Flow (cfs)	2006	1992	1972-1983
San Ramon Cr above Sans Crainte	17,400	N/A	20,200
San Ramon Cr below Sans Crainte	17,800	N/A	23,200
Walnut Cr at Concord	30,800	N/A	33,500

N/A = Not available. Beyond the scope of the study.

The peak flows listed above in Table 11B for the 2006 Lower Walnut Creek study for the 2.0%, 1%, 0.5%, and 0.2% floods are, for the most part, smaller than the flows used in the 1972, 1983, and 1992 hydrology reports. Where the 2006 peak flows are larger, the difference is no more than 3%.

11.3 Pine Creek. Hydrology for Pine and Galindo creeks was included in "Supplement 2 to the Design Memorandum No. 1 for the Walnut Creek Project" in 1976 (Reference 4u). In that study, peak flows for the project design (1% event) local rainfloods were developed for Year 2020 land use, with channel improvement and two upstream detention basins in place. Table 11C presents the peak flows for several index points for specific local storms on the Pine Creek watershed, for 2020 project conditions. The 10% flood peaks for Year 2020 land use conditions in the table are based on flow frequency curves presented in the 1976 report. The peak flows listed for comparison for present conditions (2006) are for concurrent storms on Pine Creek at locations equivalent to the 1976 study index points. The 2006 peak flows were computed without consideration for routing through the two upstream detention basins. Because the detention basins are so high in the watershed, their influence on downstream peak flows was considered slight. Concurrent peak flows and hydrographs on Pine Creek computed for the 2006 study are considerably lower than those computed from the storms centered over Pine Creek in the 1976 Pine Creek hydrology study.

Table 11C
1% and 10% Peak Flow Comparison with Previous Corps Study
for Pine Creek

1% Event Peak Flow in cfs				
Node Location	Location Description	2020 (1975) Pine Cr. Study	2006 Concurrent Concurrent 6-Hour	2006 Concurrent Concurrent 96-Hour
43	Pine Creek at Ditch blw BART Bridge (18.60 sq. mi.)	5,880	2,780	2,340
141	Galindo Creek at Mouth (8.70 sq. mi.)	3,850	1,740	1,520
140	Pine Cr below Galindo Creek (28.15 sq. mi.)	9,300	4,360	3,820
14	Pine Creek at Mouth (28.96 sq. mi.)	9,300	4,930	4,450
10% Event Peak Flow in cfs				
Node Location	Location Description	2020 (1975) Pine Cr. Study	2006 2006 Concurrent 6-Hour	2006 2006 Concurrent 96-Hour
43	Pine Creek at Ditch blw BART Bridge (18.60 sq. mi.)	2,300	N/A	1,520
141	Galindo Creek at Mouth (8.70 sq. mi.)	1,600	N/A	932
140	Pine Cr below Galindo Creek (28.15 sq. mi.)	3,640	N/A	2,430
14	Pine Creek at Mouth (28.96 sq. mi.)	3,640	N/A	2,830
	N/A = Not available, not computed for this study.			
	2020 (1976) = Year 2020 conditions assumed in 1976 study			

11.4 Grayson Creek. Table 11D presents a comparison between the concurrent peak flows for several locations on Grayson Creek computed for this study (2006) with the specific peak flows computed for the 2005 Grayson Creek hydrology appendix (Reference 4f) for the 1% and 10% chance events. The concurrent peak flows are all at least 200 cfs less than the specific peak flows.

Table 11D
1% and 10% Peak Flow Comparison
with 2005 Corps Study for Grayson Creek

1% Event Peak Flow in cfs				
Node Location	Location Description	2005 Specific 3-hr.	2006 Concurrent 6-hr.	2006 Concurrent 96-hr.
208	Murderer's Cr at mouth (2.99 sq. mi.)	2,000	1,640	1,020
209	E.F. Grayson above Murderer's (3.38 sq. mi.)	1,810	1,480	963
210A	Murderer's-E.F. Grayson Index Pt. (6.37 sq. mi.)	3,840	3,120	1,980
212	W.F. Grayson Cr at Mouth (4.65 sq. mi.)	2,160	1,890	1,280
214	Grayson Cr below W.F. Grayson (12.2 sq. mi.)	6,550	5,490	3,620
215	Grayson Cr below Flame Drive Cr (15.5 sq. mi.)	7,410	6,360	4,440
10% Event Peak Flow in cfs				
Node Location	Location Description	2005 Specific 3-hr.	2006 Concurrent 6-hr.	2006 Concurrent 96-hr.
208	Murderer's Cr at Mouth (2.99 sq. mi.)	1,110	N/A	636
209	E.F. Grayson above Murderer's (3.38 sq. mi.)	1,060	N/A	609
210A	Murderer's-E.F. Grayson Index Pt. (6.37 sq. mi.)	2,190	N/A	1,240
212	W.F. Grayson Cr at Mouth (4.65 sq. mi.)	1,130	N/A	784
214	Grayson Cr below W.F.Grayson (12.2 sq. mi.)	3,660	N/A	2,260
215	Grayson Cr below Flame Drive Cr (15.5 sq. mi.)	4,040	N/A	2,770

N/A = Not available, not computed for this study.

12. Results

Previous hydrology for the Walnut Creek watershed has been re-analyzed. New methodologies were used to develop a more detailed HEC-1 computer model of the Walnut Creek watershed for current conditions. This model incorporates the San Ramon Bypass flow diversion. Flow frequency curves for the San Ramon Creek at San Ramon, San Ramon Creek near Walnut Creek, and Walnut Creek at Concord streamflow gage locations were revised, not only for the peak flows but also for the 1-, 3-, and 5-day volumes.

The HEC-1 model for present urban conditions on the Walnut Creek watershed was used to compute Walnut Creek subbasin hydrographs for the 8-Flood Series and concurrent flood hydrographs for Pine Creek and other tributaries. For the hydraulic modeling phase of the study, an HEC-RAS model will be used to route these hydrographs downstream for floodplain and sediment transport analysis. Table 12A lists the peak flows at the index points for the 8-Flood Series developed in this Hydrology Appendix. Peak flows for the 50% through 4% floods are from 96-hours storms, while the peak flows for the 2% through 0.2% floods are from 6-hour storms.

The updated hydrology presented in this report is appropriate for the F3 Conference.

Table 12A
8-Flood Series Peak Flows at Selected Index Points

Node/ Subbasin	D.A. (sq.mi.)	8-Flood Series Peak Flows in cfs							
		50%	20%	10%	4%	2%	1%	0.50%	0.20%
San Ramon Creek above Bypass									
SRC4	45.2	1,910	4,620	6,180	7,630	10,300	12,300	14,300	17,000
SRC5	47.78	1,980	4,780	6,370	7,870	10,500	12,600	14,600	17,400
SRC6	50.41	2,030	4,900	6,550	8,090	10,800	12,900	15,000	17,800
San Ramon Creek below Bypass									
SRC7	50.85	43	76	96	115	215	257	300	447
Las Trampas/Tice Creeks									
LTC3	21.24	1,590	2,970	3,840	4,670	6,060	7,240	8,440	10,000
TC2	3.62	292	546	698	836	1,090	1,280	1,510	1,850
TC3	4.18	330	618	790	949	1,200	1,410	1,650	2,000
LTC4	25.54	1,900	3,560	4,590	5,580	7,190	8,580	10,000	11,900
San Ramon Creek below Las Trampas									
WC1	76.39	1,920	3,610	4,660	5,650	7,270	8,690	10,100	12,100
WC2A	77.42	1,980	3,700	4,770	5,800	7,410	8,850	10,300	12,400
San Ramon Bypass									
abv WC2	0.25	2,040	4,930	6,580	8,130	10,800	12,900	15,000	17,400
Walnut Creek below Las Trampas Creek									
WC2	77.67	3,940	8,490	11,200	13,700	18,000	21,500	25,100	29,600
WC3	79.71	4,000	8,620	11,400	13,900	18,300	21,800	25,400	30,100
WC4	81.56	4,060	8,730	11,500	14,100	18,500	22,100	25,700	30,500
WC5	82.44	4,100	8,790	11,600	14,200	18,500	22,200	25,800	30,500
E.F. Grayson Flow Split to Walnut Creek									
19 Div.		49	87	110	132	234	279	325	387
Walnut Creek below Concord Gage									
WC6	82.44	4,100	8,800	11,600	14,200	18,700	22,300	26,100	30,800
WC7	83.56	4,130	8,830	11,600	14,300	18,600	22,300	26,000	30,600
Pine/Galindo Creeks									
PC2	17.97	355	855	1,260	1,540	1,980	2,360	2,720	3,170
PC2	19.73	492	1,060	1,520	1,870	2,330	2,780	3,210	3,760
P2	7.61	335	693	932	1,140	1,460	1,740	2,030	2,410
PC3	27.34	811	1,730	2,430	2,980	3,660	4,360	5,040	5,950
PC4	30.06	1,020	2,050	2,830	3,460	4,140	4,930	5,710	6,740
Walnut Creek below Pine Creek									
WC8	113.62	4,850	10,400	13,800	16,900	21,700	25,800	30,100	35,600
WC9	121.02	5,150	10,900	14,400	17,600	22,400	26,700	31,100	36,800
Grayson Creek at Mouth									
G	17.6	1,050	2,120	2,740	3,320	5,080	6,070	7,080	8,420
Walnut Creek below Grayson Creek									
WC10	138.62	5,980	12,500	16,600	20,200	25,800	30,800	35,800	42,600
WC11	139.11	5,900	12,400	16,400	20,000	25,700	30,600	35,700	42,300
Pacheco Creek									
PA2A (rtd)	1.76	155	264	331	397	570	655	722	807
PAC1	3.16	176	287	372	448	759	906	1,050	1,250
PAC2	3.99	186	281	364	441	538	642	746	886
Walnut Creek below Pacheco Creek									
WC12	143.1	6,050	12,600	16,700	20,400	26,200	31,200	36,300	43,100
at Bay	143.1	5,970	12,400	16,500	20,100	25,800	30,800	35,900	42,600

ATTACHMENT 1
HEC-1 MODEL FOR SPECIFIC 1% 96-HOUR STORM
ON WALNUT CREEK WATERSHED

```
ID  FILENAME WC96100.DAT - LATEST VERSION REVISED 2 JUNE 2008
ID  REVISED IN MAY 2008 MODEL BY ADDING
ID  THE TWO UPR PINE CREEK DETENTION BASINS
ID  THIS IS THE 100-YEAR 96-HOUR STORM FOR WALNUT CREEK BASIN
ID  TEST RECESSION STRTQ OF -6, QRCSN OF -.15, AND RTIOR = 1.10
ID  THIS AUG 2006 REVISION INCLUDES SCOTT'S CHANNEL VELOCITIES
ID  FOR LOWER WALNUT CREEK
ID  REVISED DECEMBER 2005 AND AGAIN IN APRIL & MAY 2006
ID  USE K CURVE FOR LOSS RATES
ID  STRTKR = 0.5, DLTKR = 3.21, RTIOL = 2.32, ERAIN = 0.7
ID  USE PERCENT IMPERVIOUS FOR PRESENT DAY LAND USE
ID   ADD MODEL DOWN TO SUISUN BAY
ID   NO LAFAYETTE RES - ALSO 8 FT/SEC DOWN LAS TRAMPAS CR (1983 STUDY)
ID  SPECIFIC CTRNG ON BOLLINGER CANYON
ID  1ST CONC ON SR+SYCAMORE, 2ND ON LOWER SR
ID  3RD CONC ON LAS TRAMPAS, 4TH CONC ON GRAYSON, 5TH ON PINE
ID  FILLING IN HEC1 MODEL FOR LOWER WALNUT CREEK STUDY
ID  TEST OF INSERTING GRAYSON @ MOUTH 10-MIN HYDROGRAPH
ID  WALNUT CREEK WATERSHED
ID  FOR TIMING OF PEAK FLOW WITH GRAYSON CR CONFLUENCE
ID  SAN RAMON CREEK AT INDEX POINT
ID  * * * * * * * * * * * * * * * *
ID  FOR THIS RUN, WALNUT CR IS SPECIFIC, GRAYSON CR IS 4TH CONC
ID  * * * * * * * * * * * * * * * *
ID  ASSUME 5 MPH FROM WC AT WC GAGE TO GRAYSON CREEK
ID  USE 5 CFS PER SQ.MI. STARTING BASE FLOW
ID  QRCSN OF 3 CFS PER SQ.MI.
ID  WITH LOWER STORM AMOUNTS FOR PINE AND LOCAL DOWNSTREAM
ID  FLOW AT 6 FEET PER SECOND UPSTREAM OF WALNUT CREEK GAGE
ID   SAME CONDITIONS AS 1992 REPORT
ID   USING PAUL WU'S MODEL FOR SAN RAMON CREEK
ID   USING BASE FLOW RATE OF 5 CSM
ID                      WALNUT CREEK BASIN, CALIFORNIA
*FREE
*DIAGRAM
*
*
IT 15,01FEB92,0100,480
IO 0 1 0
* JR FLOW 1.204 1.0 .810 .630 .296
*
*
KK USR3, 01, (40) SAN RAMON CR NR SAN RAMON GAGE (BOLINGER CYN - A1)
BA 6.31
BF -5.0 -0.15 1.05
* SPECIFIC 1% 96-HR ON BOLLINGER
PB 12.34
ZR=PI A=PCP DISTRIB B=MOD-CCC STORM C=PRECIP-INC E=15MIN F=TEST8 96HR
LE 0.5 3.21 2.32 0.7 4.3
UI 184,384,933,1744,1754,1376,1147,921,739,624
UI 535,476,420,364,310,278,260,240,227,218
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UI 197,180,170,158,145,135,124,118,109,101
UI 98 95 93 91 88 87 86 83 82 80
UI 76 75 72 67 65 60 56 50 46 40
UI 36 30 27 24 11 10 10 8 7 3
ZW  A=SAN RAMON CR B=AT SAN RAMON C=FLOW F=100YR 96HR
*
KK  02    STORAGE ROUTING BELOW AREA  01 NEAR GAGE
KO 1 1 0
RS 1 STOR -1
SV 0 10 20 150 500 1100 2000 2180 2280 2500
SQ 0 930 1870 2350 2800 3280 3750 4750 6000 9000
* ZW  A=SAN RAMON CR B=@ SR GAGE C=FLOW E=15MIN F=100YR 6HR MAR
*
KK USR2,  05, (41) SAN CATANIO CREEK AT SAN RAMON (A2)
BA 3.00
BF -5.0 -0.15 1.10
* 1ST CONC ON MID SAN RAMON & SYCAMORE @ CONFLUENCE
PB 11.27
LE 0.5 3.21 2.32 0.7 26.6
UI 211,865,1437,1027,714,512,402,321,253,211
UI 189,181,160,132,114,100,90,82,78,75
UI 72,70,66,62,58,53,46,40,33,28
UI 22,13,10,8,7,2
*
KK  06   SAN RAMON CR TOTAL AT SAN RAMON (A1+A2)
HC 2
*
*
KK 07  ROUTE SAN RAMON TO CONFLUENCE WITH SYCAMORE CR
RM 3 0.648 0.35
*
KK USR1, 10, (39) (UPPER) SAN RAMON CREEK LOCAL ABOVE SYCAMORE CR (C1)
BA 4.72
PB 9.94
LE 0.5 3.21 2.32 0.7 43.3
UI 346,1256,2892,2547,1315,838,583,433,337,276
UI 230,190,162,136,119,103,89,77,64,54
UI 45,35,25,17,11,3
*
KK  11   SAN RAMON CR TOTAL ABOVE SYCAMORE CR
HC 2
*
KK S3, 15, (42) UPPER SYCAMORE CR ABOVE BLACK HAWK (B1)
BA 3.88
PB 9.43
LE 0.5 3.21 2.32 0.7 9.5
UI 271,1098,1808,1326,930,672,523,411,335,283
UI 244,214,190,168,148,131,121,106,102,97
UI 92,87,83,77,72,64,58,47,44,39
UI 33,28,22,17,12,10,8,7,5,4
UI 2 1
*
KK 16  ROUTE UPPER SYCAMORE TO BELOW BLACK HAWK
RM 1 0.220 0.35
*
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KK S2, 20, (43) (MID) UPPER SYCAMORE CR - U/S OF PT5 (B2)
BA 1.12
PB 8.96
LE 0.5 3.21 2.32 0.7 22.9
UI 98,368,804,538,275,182,123,95,75,61
UI 50,42,34,30,25,22,18,15,12,10
UI 7 5 3 1
*
KK  21  COMBINE SYCAMORE - U/S OF PT 5 (B1+B2)
HC 2
*
KK  22  ROUTE B2 TO SYCAMORE TO MOUTH
RM 3 0.834 0.35
*
KK S1, 25, (38) (LOWER) SYCAMORE CR LOCAL AT MOUTH (C2)
BA 3.26
PB 9.17
LE 0.5 3.21 2.32 0.7 21.5
UI 119,304,706,1208,1541,1021,653,464,339,280
UI 224,191,160,139,123,108,96,83,76,67
UI 60,56,51,46,42,38,34,30,27,24
UI 21,18,15,12,9,7,5,2,1
*
KK  26   SYCAMORE CR TOTAL AT MOUTH
HC 2
*
KK 27  SAN RAMON CR PLUS SYCAMORE CR (C1+C2)
HC 2
*
KK  28  ROUTE SAN RAMON CR TO ABOVE GREEN VALLEY
RM 1 0.332 0.35
*
KK SR7, 30, (37) (DANVILLE) SAN RAMON CREEK LOCAL ABOVE GREEN VALLEY CREEK
(F1)
BA 2.37
* 2ND CONC ON LOWER SAN RAMON CREEK
PB 10.05
LE 0.5 3.21 2.32 0.7 32.2
UI 1258,1948,886,508,350,264,192,151,137,124
UI 107,83,54,25,10
*
KK  31   SAN RAMON CR TOTAL ABOVE GREEN VALLEY CREEK
HC 2
*
KK GV4, 35, (44) UPR E.B. GREEN VALLEY CR - UPPER EAST BRANCH (D1)
BA 2.21
PB 8.83
LE 0.5 3.21 2.32 0.7 11.6
UI 581,1686,971,569,378,275,218,173,140,120
UI 105,94,84,75,61,48,36,26,19,12
UI 9 2
*
KK 36, UPPER EAST BRANCH TO JCT WITH OTHER BRANCH
RM 1 0.367 0.35
*
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KK GV3, 40, (31) (LOWER NB) GREEN VALLEY CR - LOWER EAST BR  LOCAL (D2)
BA 2.86
PB 8.85
LE 0.5 3.21 2.32 0.7 14.9
UI 259,1187,1396,931,629,462,351,280,227,196
UI 170,149,127,112,101,90,84,80,75,71
UI 65,60,52,44,37,32,23,19,15,11
UI 9 7 3
*
KK  41   COMBINE EAST BR GREEN VALLEY CREEK
HC 2
*
KK GV2U, 45, (45) (UPR NB) UPPER GREEN VALLEY CR -(BRYAN BASIN) UPPER OTHER
BR (D3)
BA 1.36
PB 8.97
LE 0.5 3.21 2.32 0.7 11.3
UI 955,1064,470,274,189,136,105,88,74,56
UI 40,28,15,8,4,2
*
KK 46  ROUTE OTHER BR TO JCT WITH EAST BRANCH
RM 1 0.325 0.35
*
KK GV2L, 50, (31) (LWR NB) GREEN VALLEY CR LOCAL ABOVE JCT WITH EAST BRANCH
(D4)
BA 1.17
PB 8.85
LE 0.5 3.21 2.32 0.7 31.3
UI 462,960,471,275,180,139,106,81,68,60
UI 53,48,40,30,22,14,7,5,2,1
*
KK  51  COMBINED FLOW ABOVE E.B. GREEN VALLEY CR
HC 2
*
KK 52  GREEN VALLEY CR COMBINED ABOVE LOCAL AT MOUTH
HC 2
*
KK 53  ROUTE GREEN VALLEY CR TO MOUTH
RM 2 0.406 .35
*
KK GV1, 55, (35) (LOWER) GREEN VALLEY CREEK LOCAL AT MOUTH  (F2)
BA 1.85
PB 9.09
LE 0.5 3.21 2.32 0.7 24.3
UI 170,659,1371,842,445,289,202,151,121,98
UI 80,66,56,48,41,35,28,24,19,14
UI 9,6,2
*
KK  56   GREEN VALLEY CR TOTAL AT MOUTH
HC 2
*
KK 57  SAN RAMON CR PLUS GREEN VALLEY CR
HC 2
*
KK 58  SAN RAMON CR ROUTED FROM GREEN VY TO ABOVE ALAMO
```

```
RM 2 0.555 0.35
*
KK SR6, 60, (46) (SAN RAMON VY) SAN RAMON CR LOCAL ABOVE ALAMO (F3)
BA 6.17
PB 11.00
LE 0.5 3.21 2.32 0.7 21.5
UI 432,1550,3588,3441,1771,1114,784,580,448,367
UI 307,256,215,181,158,139,120,104,88,75
UI 63,51,38,27,18,9,1
*
KK  61   SAN RAMON CR TOTAL ABOVE ALAMO
HC 2
*
KK SR5, 65, (30) STONE VALLEY CR AT MOUTH (E1)
BA 2.65
PB 9.39
LE 0.5 3.21 2.32 0.7 26.2
UI 396,1706,1265,754,515,367,275,233,196,168
UI 133,114,102,95,90,84,78,68,58,44
UI 35,20,12,8,4
*
KK SR4, 70, (27) MIRANDA CREEK AT MOUTH (E2)
BA 2.27
PB 9.03
LE 0.5 3.21 2.32 0.7 19.4
UI 225,1027,1122,729,486,359,271,214,179,158
UI 132,117,103,92,83,74,68,65,60,56
UI 52,46,38,31,30,20,15,10,7,6
UI 2
*
KK 71  COMBINE SAN RAMON, STONE VY, MIRANDA
HC 3
*
KK 72  ROUTE SAN RAMON DOWNSTREAM TO SAN CRAINTE
* ROUTE DOWNSTREAM 2.54 MILES
* FELOCITY ABOUT 5.5 FT/SEC
* RECALCULATED MUSKINGUM ROUTING FOR DISTANCE TO SAN CRAINTE
RM 3 0.677 0.35
*
KK  SR2, SAN RAMON LOCAL - MIRANDA TO SAN CRAINTE CR
BA 2.58
PB 10.40
LE 0.5 3.21 2.32 0.7 30.9
* ADJUSTED UNITGRAPH FROM ORIGINAL COMPUTATION
UI 189,686,1580,1392,719,458,319,236,185,151
UI 126,104,89,74,65,56,49,42,35,30
UI 25,19,14,9,6,2
*
KK 76, SAN RAMON TOTAL ABV SAN CRAINTE CREEK
*  ABOUT EQUIVALENT TO SAN RAMON CR NR WALNUT CR GAGE
*  2.10 MILES DOWNSTREAM OF MIRANDA CREEK AT MOUTH
*  WHAT IS CURRENT DRAINAGE AREA HERE?
HC 2
* ZW  A=SAN RAMON B=ABV SAN CRAINTE C=FLOW F=100YR 96HR
*
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*
KK SR3, (25) SAN CRAINTE CR AT MOUTH
BA 2.63
PB 8.96
LE 0.5 3.21 2.32 0.7 18.2
UI 767 863 1249 957 513 393 312 232 210 157
UI 150 122 113 99 89 82 71 68 55 52
UI 41 38 34 30 27 22 20 14 11
*
KK 61  SAN RAMON CR PLUS SAN CREINTE CR
*  ABOUT EQUIVALENT TO SAN RAMON CR "AT WALNUT CR" GAGE
HC 2
ZW A=SAN RAMON CR B=AT WALNUT CR C=FLOW F=100YR 96HR
*
KK 61SP, SPLIT FLOW BETWEEN SAN RAMON BYPASS & ORIG SR CHANNEL
KM DQ IS THE FLOW BEING DIVERTED TO SAN RAMON BYPASS
* FLOW SPLIT USING MANNING'S N OF 0.012
* FROM DESIGN REPORT IN HYD DES SECTION
DT DIVBY
DI 0 15200 15700 16000 17000 20400
DQ 0 15200 15660 15950 16840 19260
* DQ 0 0 40 50 160 740
*
KK 6R  ROUTE SAN RAMON CR TO LAS TRAMPAS CR
* ABOUT 1.35 MILES DOWNSTREAM TO LAS TRAMPAS CR
* ABOUT 6.5 FT/SEC
RM 1 0.305 0.35
*
KK SR1, 6L, (16) (LOWER) SAN RAMON CR LOCAL ABV LAS TRAMPAS CR
* BA 0.60
BA 0.44
PB 9.44
LE 0.5 3.21 2.32 0.7 58.3
* UI 25 74 163 291 267 160 105 77 59 46
* UI 37 32 27 24 21 18 16 14 13 11
* UI 10 9 8 7 7 6 5 4 4 3
* UI 2 2 1 1
UI 204 316 188 104 70 51 40 32 26 22
UI 19 16 13 10 9 7 5 4
*
KK 6C  COMBINED SAN RAMON CR ABV LAS TRAMPAS CR
HC 2
* ZW  A=SAN RAMON CR B=ABV LAS TRAMPAS C=FLOW E=15MIN F=100YR 96HR
*
KK LT7, 50  LAFAYETTE CR UPSTREAM OF LAFAYETTE RES TRIBUTARY
BA 2.05
LE 0.5 3.21 2.32 0.7 42.7
* 3RD CONC ON LAS TRAMPAS CREEK (NOT SAME AS RUN 1)
PB 12.70
* LEAVE UNIT GRAPH ALONE
UI,1128,1745,716,435,293,217,170,137,113,93
UI,72,56,46,35,25,11.0
*
* KK 51  LAFAYETTE RESERVOIR
* * LAFAYETTE RESERVOIR NON-CONTRIBUTING
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* BA 1.30
* LU 0.25 0.17
* PB 12.59
* * LEAVE UNIT GRAPH ALONE
* UI 409 493 667 408 273 168 149 112 94 83
* UI 66 61 53 47 43 37 34 29 25 22
* UI 18 17 15 12 11 8 5.0
*
* KK 51C  COMBINE LAFAYETTE CR + RESERVOIR
* HC 2
*
KK 50-24 ROUTE LAFAYETTE TO LAS TRAMPAS CREEK CONFLUENCE
* ASSUME ~ 8 FT/SEC
RM 1 0.317 0.35
* RM 1 0.317 0.40
* RM 1 0.363 0.35
*
KK LT6, 17  HAPPY VALLEY TRIBUTARY
BA 3.45
LE 0.5 3.21 2.32 0.7 36.9
PB 12.01
* LEAVE UNIT GRAPH ALONE
UI,1160,1479,1889,915,681,472,357,303,236,204
UI,183,149,136,123,104,95,82,66,59,51
UI,44,40,31,25.0
*
KK 17-24  ROUTE HAPPY VALLEY TRIB - MOUTH TO LAS TRAMPAS CONFLUENCE
* ASSUME ~ 8 FT/SEC
RM 1 0.102 0.35
* RM 1 0.102 0.40
* RM 1 0.125 0.35
*
*
KK LT5, 24  UPPER LAS TRAMPAS CREEK
BA 9.48
LE 0.5 3.21 2.32 0.7 20.9
PB 12.06
* I LIKE THIS REVISED UNITGRAPH
UI 100 350 780 1300 1900 2200 2150 1800 1460 1160
UI 920 780 695 615 545 480 420 370 335 305
UI 275 250 230 215 205 197 190 185 180 175
UI 170 165 160 155 150 145 140 135 130 125
UI 120 115 110 105 100 96 92 88 84 80
UI 77 74 71 69 67 65 63 61 59 57
UI 55 53 51 49 47 45 43 41 39 36
UI 33 30 28 25 4.0
*
KK 24C LAS TRAMPAS CR + HAPPY VY + LAFAYETTE CR
HC 3
*
KK 24-RC ROUTE LAS TRAMPAS CR TO RELIEZ CYN MOUTH
* ASSUME ~ 8 FT/SEC
* NEW RTG REACH IS 1.57 MILES
RM 1 0.289 0.35
* RM 1 0.289 0.40
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*
KK LT4, 18  RELIEZ CREEK AT MOUTH
BA 3.61
LE 0.5 3.21 2.32 0.7 27.0
PB 11.06
* MINOR REVISIONS OK
UI 223 748 1165 1330 1051 790 590 455 333 285
UI 245 210 180 164 150 137 125 114 104 95
UI 87 80 74 69 64 59 54 49 44 39
UI 35 31 27 24 21 18 15 12 9 7
UI 5 3.0
*
KK LT9 UPPER MID LAS TRAMPAS - NEW SUBBASIN
BA 1.16
LE 0.5 3.21 2.32 0.7 46.8
PB 10.99
UI 609 990 409 249 168 124 97 78 65 54
UI 43 33 27 22 16 11
*
KK 18C  COMBINE RELIEZ CR WITH LAS TRAMPAS CREEK
HC 3
*
KK 18-20  ROUTE RELIEZ CYN TO PT 20
* ASSUME ~ 8 FT/SEC
RM 2 0.383 0.35
* RM 2 0.383 0.40
*
KK LT2 MID LAS TRAMPAS - NEW SUBBASIN
BA 1.49
LE 0.5 3.21 2.32 0.7 55.1
PB 9.98
UI 647 968 693 370 250 178 134 111 93 79
UI 68 57 47 38 32 27 23 17 12 4
*
*
KK 20C  COMBINE LAS TRAMPAS FLOWS AT PT 20
HC 2
*
KK 20WC ROUTE LAS TRAMPAS FROM 20 TO SAN RAMON CR CONFLUENCE
* ABOUT 3150 FT DOWNSTREAM
*  ABOUT 6 FT/SEC
RM 1 0.146 0.35
*
*
KK LT3A, 101 TICE CR ABV ROSSMOOR DETENTION BASIN (185)
BA 2.65
PB 10.47
LE 0.5 3.21 2.32 0.7 38.4
UI 274 1328 1304 834 550 415 306 235 208 180
UI 154 130 108 93 87 83 79 76 72 67
UI 60 53 43 32 23 17 13 8 5 3
*
KK 102 TICE CR STORAGE ROUTING THRU ROSSMOOR DETEN.BASIN
KO 1 1 0
RS 1 STOR -1
```

```
SV 0 0.15 1.02 3.12 6.77 11.86 18.07 25.07 32.92 41.62
SV 43.0 48.7
SQ 0 25 38 152 361 569 743 907 1174 1555
SQ 1700 2500
*
KK 103 ROUTE TICE CR TO CONFLUENCE WITH CASTLE HILL CR
RM 1 0.203 0.35
*
KK LT3B, 105 TICE CREEK LOCAL ABOVE CASTLE HILL CR (187)
BA 0.49
PB 10.47
LE 0.5 3.21 2.32 0.7 38.4
UI 245 391 188 110 74 54 42 34 28 24
UI 20 16 12 10 8 6 4
*
KK 106 TICE CR TOTAL ABOVE CASTLE HILL CR (187)
HC 2
*
KK LT3C, 110 CASTLE HILL CREEK AT MOUTH (1795)
BA 0.48
PB 10.47
LE 0.5 3.21 2.32 0.7 38.4
UI 197 401 189 112 71 57 43 32 27 25
UI 23 20 17 12 7 4 2 1
*
KK 111 TICE CR PLUS CASTLE HILL CREEK (1796)
HC 2
*
*
KK 112 ROUTE TICE CREEK TO MOUTH (OF TICE CREEK)
RM 1 0.332 0.35
*
KK LT3D, 115 TICE CREEK LOCAL AT MOUTH (1662)
BA 0.56
PB 10.47
LE 0.5 3.21 2.32 0.7 38.4
UI 206 281 307 138 99 76 57 44 38 33
UI 27 24 21 18 16 14 11 9 8 7
UI 6 4 3
*
KK 116 TICE CREEK TOTAL FLOW AT MOUTH (1662)
HC 2
*
* KK 26WC  ROUTE TICE CREEK TO SAN RAMON CREEK CONFLUENCE
* ABOUT 1460 FEET
* TOO SHORT TO ROUTE
*
KK LT1  LAS TRAMPAS CREEK LOCAL AT MOUTH
BA 0.12
PB 9.32
LE 0.5 3.21 2.32 0.7 88.2
* LEAVE UNIT GRAPH ALONE
UI 171 67 30 18 12 7 4 1.0
*
*
```

```
KK LTMO  LAS TRAMPAS CREEK TOTAL ABV WALNUT CREEK
HC 3
* ZW  A=LAS TRAMPAS CR B=@ MOUTH C=FLOW E=15MIN F=100YR 96HR
*
* * * * * * * * * * * * * * * * * * * * * * *
* * * * * * * * * * * * * * * * * * * * * * *
*
KK WCLT  WALNUT CREEK BLW LAS TRAMPAS CREEK
HC 2
*
KK 6R  ROUTE WALNUT CR (ORIG CHANNEL) TO SAN RAMON BYPASS
* THIS IS LOCATION OF FORMER "WALNUT CR AT WALNUT CREEK" GAGE
* ASSUME 6 FT/SECOND
* CHANNEL REACH IS 3400 FT DOWNSTREAM OF LAS TRAMPAS CONFLUENCE
RM 1 0.157 0.35
*
KK W9  WALNUT ABOVE INDIAN
BA 1.03
PB 9.39
LE 0.5 3.21 2.32 0.7 59.8
* LEAVE UNIT GRAPH ALONE
UI,591,873,358,217,146,108,85,68,56,45
UI,35,27,22,17,11,2.0
*
KK W7C  COMBINE WC WITH LOCAL W7
HC 2
*
* * * * * * * * * * * * * * * * * * * * * * * * * * * *
* * * * * * * * * BRING BACK SAN RAMON BYPASS
* * * * BRING BACK DIVERSION, RTE DOWN, ADD LOCAL
* INSERT DIV DOWN SAN RAMON BYPASS
KK MDA1, RETRIEVE DIVERTED S.R. BYPASS FLOW
KM  RETRIEVE DIVBY
DR DIVBY
*
*
KK MDAR ROUTE DOWN SAN RAMON BYPASS
* AUG 06 CHANNEL VELOCITY REVISION HERE
* USE 30 FT/SEC (100-YEAR)
* CHANNEL REACH IS  1.67 MILES
RM 1 0.08 0.5
*
* * * * NOW ADD LOCAL
KK W8 WALNUT BYPASS LOCAL DRAINAGE
BA 0.25
PB 9.04
LE 0.5 3.21 2.32 0.7 70.3
UI 161 209 86 51 35 26 20 16 13 10
UI 7 6 4 3
*
KK 28C  COMBINE RTD WALNUT BYPASS + LOCAL FLOW
HC 2
*
KK 6T  WALNUT CREEK BELOW LAS TRAMPAS CR
* 11183500 WALNUT CREEK AT WALNUT CREEK GAGE
```

```
* TOTAL D.A. = 79.2 SQ.MI.
*  THIS IS 3400 FT DOWNSTREAM OF LAS TRAMPAS CONFLUENCE
HC 2
*
KK T1  INDIAN CREEK SUBBASIN
BA 2.04
PB 8.69
LE 0.5 3.21 2.32 0.7 35.3
* INSERT NEW UNITGRAPH FOR HIGHER DRAINAGE AREA
UI 747 1013 1123 499 364 278 205 161 139 119
UI 97 87 78 66 58 50 40 35 31 27
UI 20 17 13
*
KK 45C  COMBINE WALNUT CREEK WITH INDIAN CREEK
HC 2
*
KK 45R ROUTE WALNUT CREEK FROM INDIAN CREEK TO LA CASA VIA SUBBASIN
* AUG 06 CHANNEL VELOCITY REVISION HERE
* USE 30 FT/SEC (100-YEAR)
*   DISTANCE DOWNSTREAM IS 1.5 MILES
RM 1 0.073 0.5
*
KK W7 WALNUT (LOCAL) BELOW INDIAN CR CONFLUENCE
BA 0.64
PB 8.65
LE 0.5 3.21 2.32 0.7 58.4
UI 501 518 213 120 82 61 47 36 27 20
UI 15 10 2
*
KK B1 LA CASA VIA DRAINAGE NORTH OF INDIAN CREEK
BA 1.21
LE 0.5 3.21 2.32 0.7 43.1
PB 8.16
UI 517 766 574 304 205 142 111 91 76 65
UI 55 47 39 32 26 23 18 15 11 6
*
KK W7C COMBINE WALNUT CREEK FLOW AT LA CASA VIA
HC 3
*
KK W7R  ROUTE WALNUT CREEK FROM LA CASA VIA TO BANCROFT
* AUG 06 CHANNEL VELOCITY REVISION HERE
* USE 30 FT/SEC (100-YEAR)
* DISTANCE DOWNSTREAM IS 3144 FEET
RM 1 0.029 0.5
*
KK W6 BANCROFT LOCAL SUBBASIN
BA 0.88
LE 0.5 3.21 2.32 0.7 66.0
PB 7.90
UI 447 718 328 194 131 97 75 61 50 42
UI 34 27 21 18 14 10 4
*
KK W6C  COMBINE WALNUT CREEK WITH BANCROFT LOCAL
HC 2
*
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```
KK W6R1 ROUTE WALNUT CREEK TO "AT CONCORD" GAGE LOCATION
* AUG 06 CHANNEL VELOCITY REVISION HERE
* USE 14 FT/SEC (100-YEAR)
* DISTANCE DOWNSTREAM IS 5220 FEET
* 11183600  WALNUT CREEK AT CONCORD GAGE (85.2 SQ.MI.)
* ZW  A=WALNUT CR B=@ CONCORD GAGE C=FLOW E=15MIN F=100-YR 6HR
RM 1 0.104 0.4
*
KK RCG RECALL DSS FILE FLOW DIV FROM GRAYSON SUBBASIN 19
BA 0.01
IN 10 01FEB92 0100
ZR=QI  A=19 FLOW DIV B=TO WC C=FLOW E=10MIN F=100YR 96HR
IN 15
ZW  A=19 FLOW DIV B=TO WC C=FLOW E=15MIN F=100YR 96HR
*
*
KK CG COMBINE WALNUT CREEK WITH FLOW DIV FROM SUBBASIN 19
HC 2
ZW A=WALNUT CR B=AT CONCORD C=FLOW F=100YR 96HR
*
KK W6R2  ROUTE WALNUT CREEK FROM CONCORD GAGE TO PINE CREEK MOUTH
* AUG 06 CHANNEL VELOCITY REVISION HERE
* USE 9 FT/SEC (100-YEAR)
* DISTANCE DOWNSTREAM IS 2.34 MILES
RM 2 0.381 0.35
*
KK W5 MID WALNUT LOCAL DRAINAGE UPSTREAM OF PINE CREEK
BA 1.11
LE 0.5 3.21 2.32 0.7 78.8
PB 7.79
* GRAPHICALLY ADJUSTED UNITGRAPH
UI 105 300 500 465 280 195 155 125 100 80
UI 65 58 52 47 43 39 35 31 28 25
UI 22 19 17 15 13 11 10 9 8
UI 6 5 3
*
KK W5C COMBINE WALNUT CREEK WITH MID WALNUT LOCAL
HC 2
*
*
* *********************************************************
* *********************************************************
* * * * * * * * * PINE CREEK BASIN
*
KK P7, 15  UPPER PINE CREEK
BA 4.21
*  BA 3.16
* 5TH CONCURRENCY ON PINE CREEK
PB 9.98
LE 0.5 3.21 2.32 0.7 3.1
* REVISED UNITGRAPH IS BETTER
* UI 150 400 807 1100 1000 720 530 390 300 265
* UI 235 208 183 162 145 130 118 108 99 91
* UI 84 78 73 68 63 59 56 53 50 47
* UI 44 41 38 35 32 29 26 23 20 17
```

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* UI 14 12 10 8 6 3
* MULTIPLY THE ABOVE UNITGRAPH BY 1.33 (4.21/3.16)
UI 200 532 1073 1463 1330 958 705 519 399 352
UI 313 277 243 215 193 173 157 144 132 121
UI 112 104 97 90 84 78 74 70 67 63
UI 59 55 51 47 43 39 35 31 27 23
UI 19 16 13 11 8 4.0
* * ** * * * * * * * * * * * * * * * * * * * * * * *
*
KK RP7B  ROUTE UPR PINE CR THROUGH DETENTION BASIN
RS 1 ELEV 400.0
SV 85.0 212.0 386.0 610.0 894.0 1246.0 1674.0 2185.0 2799.0 3531.0
SE 400.0 405.0 410.0 415.0 420.0 425.0 430.0 435.0 440.0 445.0
SS 439.0 50.0 3.20 1.5
SL 400.0 8.5 0.47024 0.5
* ****************************************************************
*
KK 15-14  ROUTE UPPER PINE CR TO MID PINE CREEK
* USE PETER'S ROUTING OF 8 FT/SEC
* DISTANCE OF 3.67 MILES
RM 3 0.673 0.35
* RM 3 0.673 0.4
*
KK P6, 14  MID PINE CREEK
PB 5.72
* BA 6.77
PB 8.56
LE 0.5 3.21 2.32 0.7 3.8
* REVISED UNITGRAPH - USE THIS
* UI 150 500 1100 1664 1900 1750 1350 1050 850 685
* UI 575 510 455 410 370 335 305 280 255 230
* UI 210 195 180 165 155 146 138 131 125 119
* UI 113 107 101 95 89 83 77 71 66 61
* UI 56 51 46 41 36 31 26 22 17 12
* UI 9 6.0
* MULTIPLY THE ABOVE HYDROGRAPH BY 0.845 (5.72/6.77)
UI 127 423 930 1406 1606 1479 1141 887 718 579
UI 486 431 384 346 313 283 258 237 215 194
UI 177 165 152 139 131 123 117 111 106 101
UI 95 90 85 80 75 70 65 60 56 52
UI 47 43 39 35 30 26 22 19 14 10
UI 8 5.0
*
*
KK CP6 COMBINE UPPER PINE CR PLUS MID PINE CREEK
KM  THEN ROUTE THROUGH RESERVOIR
HC 2
*
KK RP6B  ROUTE MID PINE CREEK COMB FLOW THROUGH LWR PINE DET BASIN
RS 1 ELEV 190.0
SV 3.0 50.0 176.0 376.0 636.0 940.0 1277.0 1646.0 2046.0 2475.0
SV 2933.0 3417.0 3929.0 4469.0 5042.0
SE 190.0 192.0 194.0 196.0 198.0 200.0 202.0 204.0 206.0 208.0
SE 210.0 212.0 214.0 216.0 218.0
SS 212.0 200.0 3.20 1.5
```

```
* low level outlet has 2 pipes, each with 28.274 sq.ft x-section area
SL 190.0 56.548 0.5164 0.5
* *******************************************************************
*
*
*
KK 14-13  ROUTE MID PINE CR TO LOWER PINE CREEK
*  USE 6.5 FT/SEC
* NEW DISTANCE IS 4.17 MILES
* OLD DISTANCE IS 5.53 MILES
RM 4 0.941 0.35
*
KK P4 MID LOWER PINE
BA 5.24
LE 0.5 3.21 2.32 0.7 32.9
PB 7.69
* REV UG BASED ON PREVIOUS REVISED LOWER PINE UG
UI 150 449 871 1330 1597 1418 985 773 649 549
UI 469 394 324 284 254 230 212 195 180 165
UI 152 140 130 122 115 108 102 97 92 87
UI 82 77 73 68 64 60 56 52 49 45
UI 42 38 35 31 28 24 21 17 14 12
UI 9
*
KK P5 WEST PINE SUBBASIN
BA 2.80
* BF 14 8 1.05
LE 0.5 3.21 2.32 0.7 56.9
PB 7.74
* REV UG BASED ON REV OF MID LOWER PINE
UI 200 600 1115 1150 697 470 355 300 265 235
UI 208 183 160 147 133 121 110 100 92 84
UI 76 69 62 55 49 43 37 31 25 20
UI 15 11 7 3
*
KK P5C COMBINE WEST PINE, MID LWR PINE, RTD MID PINE
* START OF CONCRETE CHANNEL
HC 3
*
KK P5R ROUTE MID LOWER PINE TO MOUTH OF GALINDO CREEK
* AUG 06 CHANNEL VELOCITY REVISION HERE
* USE 15 FT/SEC (100-YEAR)
* NEW DISTANCE IS 1.28 MILES
RM 1 0.125 0.4
*
* * * add galindo + lwr local + rtd flow
KK P3 LOWER PINE SUBBASIN
BA 1.76
LE 0.5 3.21 2.32 0.7 72.2
PB 7.57
UI 721 1045 874 453 293 211 168 137 115 92
UI 81 71 62 51 40 34 30 25 19 14
UI 7
*
KK P3C  COMBINE PINE CREEK ABOVE GALINDO CR
```

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HC 2
*
KK P2 GALINDO CREEK AT MOUTH
BA 7.61
LE 0.5 3.21 2.32 0.7 43.6
PB 8.04
* NEW REVISED GALINDO UG BASED ON ORIG REV GALINDO
UI 179 408 761 1196 1484 1816 1837 1506 1223 1011
UI 821 679 582 506 435 370 326 294 266 241
UI 223 207 192 179 167 157 146 136 128 122
UI 116 112 108 104 101 98 95 91 88 85
UI 82 78 75 72 68 65 62 59 55 52
UI 49 46 42 39 36 33 29 26 23 20
UI 16 13 10 7
*
KK P2C  COMBINE PINE CR LOCAL, RTD PINE + GALINDO CR AT MOUTH
HC 2
*
KK P2R  ROUTE PINE CR FROM GALINDO CREEK TO WALNUT CR
* AUG 06 CHANNEL VELOCITY REVISION HERE
* USE 12 FT/SEC (100-YEAR)
* TRAVEL DISTANCE IS 4800 FEET
RM 1 0.111 0.4
*
KK P1 PINE-GALINDO OUT LOCAL SUBBASIN
BA 2.72
LE 0.5 3.21 2.32 0.7 77.6
PB 7.46
* ORIG UG LOOKS OK
UI 1240 1900 1193 653 441 320 248 198 165 138
UI 118 100 81 64 55 44 35 25 10
*
KK P1C COMBINE PINE CREEK FLOW AT MOUTH
HC 2
*
KK P1C2 COMBINE PINE CREEK AND WALNUT CREEK AT MOUTH PINE CREEK
HC 2
*
KK P1R ROUTE WALNUT CR FROM PINE CREEK TO GRAYSON CREEK
* AUG 06 CHANNEL VELOCITY REVISION HERE
* USE 6.0 FEET PER SECOND (100-YEAR)
* TRAVEL DISTANCE IS 3138 FEET
RM 1 0.145 0.35
*
KK W4 WALNUT BLW PINE LOCAL SUBBASIN
BA 1.59
LE 0.5 3.21 2.32 0.7 82.1
PB 7.25
UI 683 1017 749 398 268 188 145 119 100 84
UI 73 61 51 42 34 30 24 19 14 7
*
KK TW1 NORTH TRIB TO WALNUT (CONCORD DRAIN)
BA 5.60
LE 0.5 3.21 2.32 0.7 77.8
PB 7.15
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* USE REVISED UNITGRAPH
UI 350 1000 1760 2100 1750 1230 860 660 510 411
UI 344 316 294 274 255 237 220 204 188 172
UI 156 142 128 116 105 96 88 80 72 65
UI 58 51 44 37 31 25 19 14
*
KK W4C COMBINE WALNUT BLW PINE LOCAL + CONCORD DRAIN
HC 2
*
* KK W4R ROUTE COMBINED LOCALS TO MOUTH OF GRAYSON CREEK
* TOO SHORT TO ROUTE
*
KK W3 WALNUT LOCAL ABOVE GRAYSON
BA 0.21
LE 0.5 3.21 2.32 0.7 81.1
PB 6.94
* USE ORIGINAL UNITGRAPH
UI 282 123 54 32 22 14 9 5 1
*
KK W3C COMBINE WALNUT CREEK ABOVE GRAYSON CREEK
HC 3
ZW A=WALNUT CR B=ABV GRAYSON CR C=FLOW E=15MIN F=100YR 96HR
*
*
KK Z  IMPORT 10-MIN 100-YR 6-HR GRAYSON CR AT MOUTH
BA 17.6
IN 10 01FEB92 0100
ZR=QI  A=GRAYSON CR B=G AT MOUTH C=FLOW E=10MIN F=100YR 96HR
IN 15
ZW  A=GRAYSON CR B=G AT MOUTH C=FLOW E=15MIN F=100YR 96HR
*
KK  Z2  COMBINE WALNUT CR AND GRAYSON CR
KO 1 2 0
HC 2
* ZW  A=WALNUT + GRAYSON B=BLW GRAYSON CR C=FLOW E=15MIN F=100YR 96HR
*
KK W3R ROUTE WALNUT CREEK FROM GRAYSON CR TO PACHECO CR
* AUG 06 CHANNEL VELOCITY REVISION HERE
* USE 4.6 FT/SEC (100-YEAR)
* TRAVEL DISTANCE IS 1.47 MILES
RM 2 0.469 0.25
*
KK W2 WALNUT BELOW GRAYSON SUBBASIN
BA 0.20
LE 0.5 3.21 2.32 0.7 67.1
PB 6.82
* USE ORIGINAL UNITGRAPH
UI 212 145 57 33 23 17 12 8 6 3
*
KK W2R ROUTE TO PACHECO CREEK
* AUG 06 CHANNEL VELOCITY REVISION HERE
* USE 4.6 FT/SEC (100-YEAR)
* TRAVEL DISTANCE IS 1.0 MILE
RM 1 0.207 0.25
*
```

```
KK W1 WALNUT OUT LOCAL SUBBASIN
* WALNUT CREEK LOCAL AT PACHECO CREEK
BA 0.29
LE 0.5 3.21 2.32 0.7 62.5
PB 6.75
UI 447 156 66 40 23 13 4
*
KK W1 COMBINE WALNUT CREEK ABOVE PACHECO CREEK
HC 3
*
* KK PA2 UPPER PACHECO CREEK
* BA 3.15
* LE 0.5 3.21 2.32 0.7 69.9
* PB 7.66
* * USE ORIGINAL UNITGRAPH
* UI 1043 1313 1698 872 632 425 335 282 212 190
* UI 166 138 127 111 98 90 74 64 55 47
* UI 43 37 30 26 18 7
*
KK PA2A  UPR PACHECO ABV DETENTION BASIN
BA 1.76
LE 0.5 3.21 2.32 0.7 69.9
PB 8.02
* ORIGINAL UG FROM UNIT HYDROGRAPH EXECUTABLE
UI 770 1157 812 435 294 211 157 130 109 92
UI 79 68 55 44 37 31 26 21 14 3
*
KK PA2S  ROUTE UPR PACHECO THRU DETENTION BASIN
KO 1 1 0
RS 1 STOR -1
SV 0.0 0.0 0.01 0.02 0.06 0.31 0.67 1.10 1.52 1.90
SV 2.35 2.98 4.04 5.87 8.57 11.97 14.68 18.89 19.52
SE 22.5 24.12 24.25 24.57 25.02 25.24 25.57 25.96 26.25 26.52
SE 26.82 27.21 27.81 28.76 29.97 31.28 32.07 33.19 33.33
SQ 10 52 60 77 101 122 151 186 215 242
SQ 272 311 373 455 553 646 699 762 770
ZW A=PACHECO CR B=BLW DETENTION BASIN C=FLOW F=100-YR 96HR
*
KK PAS2R  ROUTE TO MID PACHECO
* AUG 06 CHANNEL VELOCITY REVISION HERE
* TRAVEL DISTANCE IS ABOUT 1.25 MILES
* USE 0.7 MILE PER HOUR CHANNEL VELOCITY
RM 10 2.619 0.0
*
KK PA2B  MID PACHECO
BA 1.40
LE 0.5 3.21 2.32 0.7 69.9
PB 7.22
* ORIGINAL UG FROM UNIT HYDROGRAPH EXECUTABLE
UI 913 1166 479 286 193 143 110 87 70 54
UI 41 32 24 15
*
KK PA2  COMBINE UPR AND MID PACHECO
HC 2
ZW A=PACHECO CR B=COMB WITH MID PACHECO C=FLOW F=100-YR 96HR
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```
*
KK PA2R ROUTE UPR PACHECO TO MOUTH
* AUG 06 CHANNEL VELOCITY REVISION HERE
* TRAVEL DISTANCE IS ABOUT 1.25 MILES
* USE 0.7 MILE PER HOUR CHANNEL VELOCITY
RM 10 2.619 0.0
*
*
KK PA1 LOWER PACHECO CREEK
BA 0.83
LE 0.5 3.21 2.32 0.7 84.9
PB 6.78
* USE ORIGINAL UNITGRAPH
UI 534 693 285 170 115 85 66 52 42 32
UI 24 20 15 10 1
*
KK PA1C COMBINE PACHECO CREEK AT MOUTH
HC 2
*
KK W1C COMBINE PACHECHO WITH WALNUT CREEK
HC 2
*
KK W1R ROUTE WALNUT CREEK FROM PACHECO CREEK TO BAY
* AUG 06 CHANNEL VELOCITY REVISION HERE
* TRAVEL DISTANCE IS ABOUT 1.85 MILES
* USE 4.6 MILE PER HOUR CHANNEL VELOCITY
RM 2 0.590 0.25
ZW A=WALNUT CR B=EST FLOW AT BAY C=FLOW F=100-YR 96HR
*
*
ZZ
```

ATTACHMENT 2
HEC-1 MODEL FOR CONCURRENT 1% 96-HOUR STORM
ON GRAYSON CREEK WATERSHED

```
ID  FILENAME GC96TEST.DAT
ID  100-YR 96-HR CONCURRENT STORM ON GRAYSON CR
ID  USE MODIFIED CCC 96-HR PRECIP PATTERN
ID  CHANGED BASE FLOW RTIOR TO 1.10 TO BE CONSISTENT WITH WC MODEL
ID  THE ABOVE CHANGE MADE ON 2 JUNE 2008
ID  INSERT K CURVE LOSS RATES AND PERCENT IMPERVIOUS
ID  96-HOUR CONC 100-YEAR STORM FOR GRAYSON CREEK HEC-1 MODEL
ID  LATEST VERSION JAN 2006 WITH CCC UNITGRAPH PARAMETERS
ID    INCLUDING MUSKINGUM WITH SCOTT'S VELOCITIES
ID  USE NOAA AREAL REDUCTION CURVE FOR 96-HR STORM
ID  ADDED ROUTING STEPS ON UPPER MURDERERS CREEK
ID  CHANGED 10-MINUTE STORM DISTRIBUTION PATTERN
ID  MODEL IN TEN-MINUTE INCREMENTS
ID  PRESENT DAY NO PROJECT CONDITIONS
ID  THIS IS MODEL FOR GRAYSON/MURDERERS
ID  FOR PRESENT DAY NO PROJECT CONDITIONS
ID  FOR CONSISTENCY WITH WALNUT CR MODEL, USE RTIOR = 1.10
ID   USE BASE FLOW = 3 CFS/SQ.MI.RECESSION & 5 CFS/SQ.MI STRTQ
ID  500-YR/100-YR RATIO USED WILL BE 140.3 PERCENT
ID  CREATED APRIL 16, 1990
ID  LATEST RUN ON 3 JUNE 2008
ID                        WALNUT CREEK BASIN, CALIFORNIA
*FREE
*DIAGRAM
*
IT 10,01FEB92,0100,720
IO 1 1 0
* JR FLOW .827
*
KK 5, (1465) MURDERERS CR SUB 1 BLW BROOKWOOD BASIN @ PL HILL RD
KO 1 1 0
BA 0.89
BF -5.0 3.0 1.10
LE 0.5 3.21 2.32 0.7 31.1
* LU 0.25 0.13
PB 10.40
* DONE SEE BELOW ACTION ITEM - CONVERT DISTRIBUTION TO 10-MINUTE 96-HOUR
IN 15 01FEB92 0100
ZR=PI A=PCP DISTRIB B=MOD-CCC STORM C=PRECIP-INC E=15MIN F=TEST8 96HR
IN 10
* DONE ACTION ITEM - 10MINUTE UG
UI 393 447 641 477 263 196 160 115 106 80
UI 75 63 56 51 44 42 35 34 28 25 6
UI 21 19 17 15 14 10 10 7 4
*
* ACTION ITEM - IS THIS TOO SHORT FOR 10 MINUTES? - YES
* *  TOO SHORT TO ROUTE
KK 202  ROUTE BROOKWOOD FLOW DOWNSTREAM TO NEAR ELEM. SCHOOL
RM 1 0.075 0.35
*
KK 3, (1463) MURDERERS CR TRIB BLW GREENHILLS BASIN @ PL HILL RD
```

```
KO 1 1 0
BA 0.76
BF -5.0 2.0 1.10
PB 10.52
LE 0.5 3.21 2.32 0.7 25.6
* LU 0.25 0.14
* DONE ACTION ITEM - NEED 10MIN UG
UI 463 669 570 295 189 138 110 89 74 60
UI 53 46 40 33 26 23 20 16 13 10
UI 6
*
* ACTION ITEM - IS THIS TOO SHORT FOR 10 MIN? - YES
* * TOO SHORT TO ROUTE
KK 206  ROUTE FROM GREENHILLS DOWNSTREAM TO NEAR ELEM.SCHOOL
RM 1 0.082 0.35
*
KK 4, (1464) MURDERERS CR LOCAL NR PLEASANT HILL ELEM.SCHOOL (207)
KO 1 1 0
BA 0.55
BF -5.0 2.0 1.10
PB 10.06
LE 0.5 3.21 2.32 0.7 49.8
* LU 0.25 0.10
* DONE ACTION ITEM - NEED 10 MIN UG
UI 390 608 344 193 130 95 74 60 49 41
UI 35 28 22 18 15 12 9 6
*
KK 207A (211)  MURDERERS CR TOTAL NR PLEASANT HILL ELEM.SCHOOL (207)
KM THIS IS LOCATION OF BYPASS B
HC 3
* ZW A=207A-MURDERERS CR B=COMB-PL HILL SCH C=FLOW E=10MIN F=100-YR 96HR
*
* *
KK 6, (1466) MURDERERS CR LOCAL NR KEATS CIRCLE (1427)
KO 1 1 0
BA 0.13
BF -5.0 0.0 1.10
PB 9.24
LE 0.5 3.21 2.32 0.7 53.5
* LU 0.25 0.09
* DONE ACTION ITEM - CONVERT TO 10 MIN UG
UI 196 147 56 34 23 17 13 8 6 4
UI 1
* ZW A=6-MURDERERS CR B=LOC NR KEATS CIR C=FLOW E=10MIN F=100-YR 96HR
*
KK 207B, (216) MURDERERS CR TOTAL NR KEATS CIRCLE (BYPASS LINE B) (1427)
HC 2
*
KK 217  ROUTE MURDERERS CR TO CONFLUENCE WITH GRAYSON CR (208)
* SCOTT'S RTG FOR 1% & 10% IS ~ 7 FT/SEC - NO CHANGE TO RTG
RM 1 0.218 0.35
*
KK 7, (1467) MURDERERS CR LOCAL AB GRAYSON CONFLUENCE (208)
KO 1 1 0
BA 0.66
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BF -5.0 2.0 1.10
LE 0.5 3.21 2.32 0.7 54.5
* LU 0.25 0.09
PB 9.02
* DONE ACTION ITEM NEED 10 MIN UG
UI 435 656 454 244 165 119 89 73 61 52
UI 44 38 31 24 21 18 14 11 8 1
* ZW A=7-MURDERERS CR B=LOCAL-ABV E.F. C=FLOW E=10MIN F=100-YR 96HR
*
KK 208, (221)  MURDERERS CR AB. CONFLUENCE WITH GRAYSON CR (208)
KO 1 1 0
HC 2
*
KK 2, (1462) GRAYSON R ABOVE SUNNYVALE ST (706)
BA 0.62
BF -5.0 2.0 1.10
PB 9.89
LE 0.5 3.21 2.32 0.7 34.8
* LU 0.25 0.12
* DONE ACTION ITEM NEED 10 MIN UG
UI 272 307 443 337 182 138 111 81 74 55
UI 53 43 40 35 31 29 25 24 19 18
UI 14 13 12 11 10 8 7 5 4
* ZW A=2-EF GRAYSON B=HEADWATERS WEST C=FLOW E=10MIN F=100-YR 96HR
*
KK 1, (1461) EB OF EF GRAYSON LOCAL BELOW SUNNYVALE
BA 0.88
BF -5.0 3.0 1.10
LE 0.5 3.21 2.32 0.7 51.7
* LU 0.25 0.10
PB 9.43
* 10 MIN UG
UI 591 898 592 321 217 157 120 95 80 68
UI 58 50 41 31 27 22 18 14 8
* ZW A=1-EF GRAYSON B=HEADWATERS EAST C=FLOW E=10MIN F=100-YR 96HR
*
KK 206A, GRAYSON CR. COMBINED BELOW SUNNYVALE
KO 1 1 0
HC 2
* ZW A=1+2-EF GRAYSON B=COMB-EF HEADWATERS C=FLOW E=10MIN F=100-YR 96HR
*
KK 306R, ROUTE EF GRAYSON CR TO END OF MOKEL AQUEDUCT
* SCOTT'S RTG FOR 1% & 10% IS ~ 6 FT/SEC - NO CHANGE TO RTG
RM 1 0.155 0.35
*
KK 8E1, (1482) EASTSIDE GRAYSON TRIB @ MOKEL.AQUEDUCT (560)
KO 1 1 0
BA 0.22
BF -5.0 1.0 1.10
PB 8.76
LE 0.5 3.21 2.32 0.7 60.0
* LU 0.25 0.08
* DONE - ACTION ITEM NEED 10 MIN UG
UI 178 282 116 70 47 35 28 22 18 15
UI 12 9 8 6 4 2
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* ZW A=8E1-EF GRAYSON B=LOCAL-MOKEL AQ EAST C=FLOW E=10MIN F=100-YR 96HR
*
KK 8W1, (1483) WESTSIDE GRAYSON TRIB @ MOKEL AQUEDUCT
KO 1 1 0
BA 0.30
BF -5.0 1.0 1.10
PB 8.93
LE 0.5 3.21 2.32 0.7 47.2
* LU 0.25 0.10
* DONE - ACTION ITEM NEED 10 MIN UG
UI 198 297 207 111 75 54 40 33 28 24
UI 20 17 14 11 9 8 7 5 4 1
* ZW A=8W1-EF GRAYSON B=LOCAL-MOKEL AQ WEST C=FLOW E=10MIN F=100-YR 96HR
*
KK 206AA, COMBINE EF GRAYSON CR FLOW @ MOKEL AQUEDUCT
HC 3
*
KK 19, (1473) UPPER EASTSIDE EF GRAYSON OVERFLOW AREA
BA 0.64
BF -5.0 2.0 1.10
PB 9.23
LE 0.5 3.21 2.32 0.7 59.3
* LU 0.25 0.09
* DONE - ACTION ITEM NEED 10 MIN UG
UI 442 680 416 229 155 112 87 70 57 48
UI 41 35 28 22 19 16 12 8 2
* * * * * * * * * * * * * ** ** * * * * *
* ZW A=19-EF GRAYSON B=EAST OVERFLOW HEADWATER C=FLOW E=10MIN F=100-YR 96HR
*
KK 19R, ROUTE SUBBASIN 19 FLOW TO SUBBASIN 20
* ACTION ITEM NEED 10 MIN RTG
* NEED DISTANCE AND PIPE ROUTING HERE
* INSERT FAKE LAG FOR THIS RUN
RT 0 2 1
* * RM 1 0.154 0.35
*
KK 19SP, SPLIT FLOW BETWEEN WALNUT CREEK AND EF GRAYSON CR
KM DQ IS THE FLOW BEING DIVERTED TO JONES RD & WALNUT CREEK
DT DIVWC
DI 0 100 332 345 384 424 486 884
DQ 0 75 249 262 292 326 389 707
* flow to SUBBASIN 20 (TO Grayson) is
* 0 25 83 83 92 97 97 177
* ZW A=19-UPR EAST OVERFLOW B=BLW SPLIT C=FLOW E=10MIN F=100-YR 96HR
*
KK 20, (1474) MID EASTSIDE EF GRAYSON OVERFLOW AREA
BA 0.28
BF -5.0 1.0 1.10
PB 8.62
LE 0.5 3.21 2.32 0.7 65.9
* LU 0.25 0.07
* DONE - ACTION ITEM NEED 10 MIN UG
UI 222 360 147 90 61 45 35 28 23 20
UI 16 12 10 8 6 4
* ZW A=20-EF GRAYSON B=LOCAL BLW SPLIT C=FLOW E=10MIN F=100-YR 96HR
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*
KK 206B, COMBINE FLOWS FOR SUBBASIN 19 AND 20
HC 2
* ZW A=19+20 EAST OVERFLOW B=U-S CULVERT C=FLOW E=10MIN F=100-YR 96HR
* * * * * * * * * * * * * * * * * * * * * * *
*
*
* KK 20R, ROUTE EF GRAYSON FLOW SPLIT TO EF GRAYSON CREEK
* NEED DISTANCE AND PIPE RTG HERE
* ASSUME TOO SHORT TO ROUTE
*  RT 0 2 1
* * RM 1 0.154 0.35
*
KK 206C, (20C2) COMBINE EASTSIDE OVERFLOW W/ EF AT MOKEL AQUEDUCT
HC 2
*
KK 311R, ROUTE EF GRAYSON CR TO MURDERERS CR CONFLUENCE
* SCOTT'S RTG FOR 1% AND 10% IS ~ 6 FT/SEC - NO CHANGE TO RTG
RM 1 0.186 0.35
*
KK 8E2, (1481) EF GRAYSON CR LOCAL EASTSIDE ABV MURDERERS CR
BA 0.17
BF -5.0 1.0 1.10
PB 8.39
LE 0.5 3.21 2.32 0.7 73.4
* LU 0.25 0.06
* DONE -ACTION NEED 10 MIN UG
UI 109 161 122 64 43 30 23 19 16 14
UI 12 10 8 7 6 5 4 3 2 2
* ZW A=8E2-EF GRAYSON B=EAST LOCAL-ABV MURD C=FLOW E=10MIN F=100-YR 96HR
*
KK 8W2, (1484) EF GRAYSON CR LOCAL WESTSIDE ABV MURDERERS CR
BA 0.11
BF -5.0 0.0 1.10
PB 8.56
LE 0.5 3.21 2.32 0.7 41.3
* LU 0.25 0.11
* DONE - ACTION NEED 10 MIN UG
UI 89 141 58 35 24 18 14 11 9 8
UI 6 5 4 3 2 1
* ZW A=8W2-EF GRAYSON B=WEST LOCAL-ABV MURD C=FLOW E=10MIN F=100-YR 96HR
*
KK 209A, (316) COMBINED EF GRAYSON CR ABV MURDERERS CREEK
HC 3
*
KK 20N, (1486) LOWER EF EASTSIDE GRAYSON CREEK OVERFLOW
BA 0.16
BF -5.0 0.0 1.10
PB 8.34
LE 0.5 3.21 2.32 0.7 69.0
* LU 0.25 0.07
* DONE - ACTION NEED 10 MIN UG
UI 115 179 99 56 38 27 21 17 14 12
UI 10 8 6 5 4 4 3 1
* ZW A=20N-EF GRAYSON B=LOCAL U-S CULVERT C=FLOW E=10MIN F=100-YR 96HR
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*
KK 209, (20NC) COMBINE EF GRAYSON PLUS LOWER OVERFLOW
HC 2
*
KK 210, (317) GRAYSON CR PLUS MURDERERS CR (210)
HC 2
* ZW A=FOR JAN B=MURDERERS-EF GRAYSON C=FLOW E=10MIN F=100-YR 96HR
*
* *
KK 131, ROUTE GRAYSON-MURDERERS CR FROM 10 (210) TO 213 @ WF GRAYSON (21)
* SCOTT'S RTG FOR 1% IS 16.2 FT/SEC - CHANGED THE RTG BELOW
RM 1 0.082 0.35
* RM 1 0.220 0.35
*
KK 9, (1487) PLEASANT HILL SUBAREA 5 ABV GRAYSON CR
BA 0.54
BF -5.0 2.0 1.10
LE 0.5 3.21 2.32 0.7 53.8
* LU 0.25 0.09
PB 8.83
* DONE -  ACTION NEED 10 MIN RTG
UI 339 498 393 206 138 94 76 62 52 44
UI 36 32 27 23 18 15 13 11 9 6
* ZW A=9-EF GRAYSON TRIB B=BLW MURD CONFLUENCE C=FLOW E=10MIN F=100-YR 96HR
*
KK 12, ROUTE LOCAL DRAINAGE DOWN GRAYSON CR TO WF GRAYSON (21)
* SCOTT'S RTG FOR 1% IS 16.2 FT/SEC - CHANGED RTG BELOW
RM 1 0.082 0.35
* RM 1 .179 0.35
*
KK 10E, (1477) LOCAL GRAYSON CR DRAINAGE EASTSIDE ABV WF GRAYSON (21)
BA 0.42
BF -5.0 1.0 1.10
LE 0.5 3.21 2.32 0.7 66.5
* LU 0.25 0.07
PB 8.20
* DONE - ACTION NEED 10 MIN UG
UI 244 342 331 163 104 81 63 50 41 35
UI 31 26 23 20 17 13 11 10 9 7
UI 5 3
* ZW A=10E-GRAYSON LOCAL EAST B=ABV WF GRAYSON C=FLOW E=10MIN F=100-YR 96HR
*
KK 10W, (1478) LOCAL GRAYSON CR DRAINAGE WESTSIDE ABV WF GRAYSON
BA 0.19
BF -5.0 1.0 1.10
LE 0.5 3.21 2.32 0.7 71.1
* LU 0.25 0.07
PB 8.38
* DONE - ACTION NEED 10 MIN UG
UI 166 241 99 60 40 30 23 19 15 12
UI 9 7 6 4 3
* ZW A=10W-GRAYSON LOCAL WEST B=ABV WF GRAYSON C=FLOW E=10MIN F=100-YR 96HR
*
KK 213, (131) COMBINED UPPER GRAYSON CR ABV WEST FORK GRAYSON CR
HC 4
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*
*
* * * * * * * * * * * * * * * * *
* * * WEST FORK OF GRAYSON CREEK
KK 12, (1488) W.F GRAYSON CR AT TAYLOR BLVD
BA 1.68
BF -5.0 5.0 1.10
LE 0.5 3.21 2.32 0.7 9.4
* LU 0.25 0.17
PB 10.53
* DONE - ACTION NEED 10 MIN UG
UI 100 400 1000 740 590 440 360 312 266 224
UI 189 162 138 123 111 102 94 87 81 75
UI 70 66 62 58 54 50 46 42 39 37
UI 37 35 30 30 28 22 22 22 19 19
UI 19 15 15 15 12 11 11 9 7 7
UI 5
* ZW A=12-WF GRAYSON HDWTRS B=ABV TAYLOR BLVD C=FLOW E=10MIN F=100-YR 96HR
*
* REMOVE CULVERT RTG - SUBTITUTE DIVERSION TO MANGINI CR HERE
KK DIV   DIVERSION FROM WF GRAYSON CR TO MANGINI CR
KM DIVERTED FLOW TO MANGINI CREEK BEHIND TAYLOR RD
DT DIV1
DI 0,292,356,405,478,629,722,1244
DQ 0,0,21,40,69,137,184,350
*
* KK 43CU CULVERT ROUTING UNDER TAYLOR BLVD
* KM  2-48" CMP
* RS 1 STOR 0
* SV 0 5 10 20 40 62 70 80
* SQ 0 125 162 217 307 374 475 600
*
KK 13, (1469)  TRIB TO WEST FORK GRAYSON CR AT TAYLOR BLVD
BA 0.25
BF -5.0 1.0 1.10
LE 0.5 3.21 2.32 0.7 56.9
* LU 0.25 0.14
PB 9.45
* DONE - ACTION NEED 10 MIN UG
UI 185 293 147 85 57 42 33 26 22 18
UI 15 12 10 8 6 5 3 0
* ZW A=13-WF GRAYSON TRIB B=ABV TAYLOR BLVD C=FLOW E=10MIN F=100-YR 96HR
*
KK 12C  COMBINE W.F GRAYSON CR AND TRIB BLW TAYLOR BLVD
KM  ASSUME OUTFLOW EQUIVALENT TO HOOKSTON GAGE
HC 2
*
*
*
KK 15-20 ROUTE WF GRAYSON FROM TAYLOR BLVD TO MOUTH
* SCOTT SAYS ~ 14.8 FT/SEC - USE SAME 10% AND 1%
RM 1 0.189 0.35
* RM 2 0.358 0.35
*
KK 14, (1470) MANGINI CREEK AT TAYLOR BLVD
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BA 2.13
BF -5.0 6.0 1.10
LE 0.5 3.21 2.32 0.7 32.7
* LU 0.25 0.13
PB 9.23
* DONE - ACTION NEED 10 MIN RTG
UI 799 799 1251 1301 689 534 389 325 262 219
UI 191 163 149 127 120 103 99 85 84 71
UI 71 57 57 44 42 37 35 31 28 24
UI 21 18 14 9
* ZW A=14-MANGINI CR B=ABV TAYLOR BLVD C=FLOW E=10MIN F=100-YR 96HR
*
* INSERT DIV FROM WF GRAYSON TO MANGINI CR HERE
KK MDA1, RETRIEVE DIVERTED W.F. GRAYSON CR ABV TAYLOR BLVD
KM  RETRIEVE DIV1
DR DIV1
*
KK  MUSKINGUM ROUTING FOR DIVERTED FLOW TO MANGINI CR
RM 3 0.425 0.25
*
* KK 17, CULVERT ROUTING SUBBASIN 42
* KM  DOUBLE BOX CULVERT 2-10'X6'
* RS 1 STOR 0
* SV 0 10 20 30 40 60 80 100 112 120
* SQ 0 1300 1800 2110 2320 2650 2890 3070 3160 6000
*
* KK 18R CULVERT ROUTING THRU TAYLOR BLVD?
* KM DOUBLE BOX CULVERT 2-12'X6'
* RS 1 STOR 0
* SV 0 5 10 15 21 30 42
* SQ 0 1250 1680 2000 2300 3750 5900
*
KK MC  COMBINE MANGINI AND WF GRAYSON DIVERTED FLOW
HC 2
*
KK 18-20 ROUTE MANGINI CR FROM TAYLOR BLVD TO MOUTH WF GRAYSON
* SCOTT SAYS ~ 14.8 FT/SEC - USE FOR 10% AND 1%
RM 1 0.156 0.35
* RM 2 0.327 0.35
*
KK 11, (1468) WF GRAYSON CR LOCAL ABV MOUTH
BA 0.59
BF -5.0 2.0 1.10
LE 0.5 3.21 2.32 0.7 57.4
* LU 0.25 0.09
PB 8.60
* DONE - ACTION NEED 10 MIN UG
UI 355 509 448 231 145 109 86 70 57 47
UI 42 36 31 26 21 18 16 13 11 8
UI 6
* ZW A=11-WF GRAYSON LOCAL B=AT MOUTH C=FLOW E=10MIN F=100-YR 96HR
*
KK 212, (40C)  COMBINED FLOW WF GRAYSON CR AT MOUTH
KM  CALL IT EQUIVALENT TO WF GRAYSON CR NR PACHECO GAGE
KM   EVEN THOUGH THIS LOCATION IS DOWNSTREAM OF THE GAGE
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HC 3
*
KK 214, (21) CONFLUENCE OF E.F. AND W.F. GRAYSON CREEK
HC 2
* ZW A=GRAYSON CR B=BLW WEST FORK C=FLOW E=10MIN F=100-YR 96HR
*
* KK 214-214B - ROUTE GRAYSON CR 2300 FT DOWNSTREAM TO FLAME DRIVE CR
* SCOTT SAYS 16 FT/SEC - TOO SHORT TO ROUTE
* RM 2 0.407 0.35
*
KK 214B TO 215 ROUTE GRAYSON CR FROM 2300 FT TO FLAME DRIVE CR
* SCOTT SAYS 5.8 FT/SEC - FOR 100-YEAR EVENT
RM 2 0.310 0.35
* RM 2 0.407 0.35
*
KK 15W1, (1480) WESTSIDE GRAYSON TRIB NORTH OF WF GRAYSON CR
BA 0.88
BF -5.0 3.0 1.10
LE 0.5 3.21 2.32 0.7 39.0
* LU 0.25 0.12
PB 8.32
* DONE - ACTION NEED 10 MIN RTG
UI 399 464 649 450 266 185 160 109 101 81
UI 71 64 53 51 42 40 35 31 28 22
UI 21 18 16 14 12 11 7 6
* ZW A=15W1-WESTSIDE GRAYSON TRIB B=BLW WF@MOUTH C=FLOW E=10MIN F=100-YR 96HR
*
KK 15R, ROUTE WESTSIDE TRIB DOWN TO PACHECO I.P.
* - USE SAME ROUTING AS ABOVE - 5.8 FT/SEC FOR 100-YR EVENT
RM 2 0.310 0.35
* RM 2 0.406 0.35
*
KK 15W2, (1485) WESTSIDE GRAYSON LOCAL ABV MCCOLLUM CR
BA 0.35
BF -5.0 1.0 1.10
LE 0.5 3.21 2.32 0.7 30.4
* LU 0.25 0.13
PB 7.95
* DONE - ACTION NEED 10 MIN UG
UI 231 347 241 129 87 63 47 39 32 27
UI 24 20 16 13 11 9 8 6 4 1
* ZW A=15W2-WESTSIDE GRAYSON LOCAL B=ABV MCCOLLUM C=FLOW E=10MIN F=100-YR
96HR
*
KK 15E, (1479) EASTSIDE GRAYSON LOCAL ABV MCCOLLUM CR
BA 0.51
BF -5.0 2.0 1.10
LE 0.5 3.21 2.32 0.7 81.6
* LU 0.25 0.05
PB 7.87
* DONE - ACTION NEED 10 MIN UG
UI 220 244 358 285 147 117 90 69 60 47
UI 45 35 34 28 26 23 21 20 17 16
UI 12 12 10 9 8 7 6 5 4 1
* ZW A=15E-EASTSIDE GRAYSON LOCAL B=ABV MCCOLLUM C=FLOW E=10MIN F=100-YR 96HR
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*
KK 15C,  COMBINE GRAYSON CREEK ABOVE MCCOLLUM CR
HC 4
*
KK 17, (1472) MCCOLLUM CREEK AT MOUTH
BA 0.50
BF -5.0 2.0 1.10
LE 0.5 3.21 2.32 0.7 37.8
* LU 0.25 0.12
PB 8.13
* DONE - ACTION NEED 10 MIN UG
UI 208 222 339 297 139 122 85 73 57 49.
UI 42 37 33. 28. 27. 23. 22. 19. 18. 15.
UI 14. 11. 11. 9. 9. 7. 7. 6. 5. 4.
UI 1.
* ZW A=17-MCCOLLUM CR B=AT MOUTH C=FLOW E=10MIN F=100-YR 96HR
*
KK 16, (1471) FLAME DRIVE CREEK AT MOUTH
BA 1.05
BF -5.0 3.0 1.10
LE 0.5 3.21 2.32 0.7 45.0
* LU 0.25 0.11
PB 8.10
* DONE - ACTION NEED 10 MIN UG
UI 403 403 643 656 311 269 181 164 122 111
UI 90 82 70 64 56 52 47 43 39 36
UI 32 29 26 21 20 18 17 14 13 11
UI 10 7 6
* ZW A=16-FLAME DRIVE CR B=AT MOUTH C=FLOW E=10MIN F=100-YR 96HR
*
KK 215, (16C)  COMBINED GRAYSON CREEK FLOW AT 2ND AVE SOUTH
HC 3
*
KK 16R  ROUTE GRAYSON CR FROM FLAME DRIVE CR TO MOUTH
KO 1 2
* SCOTT SAY ~ 4.5 FT/SEC - USE FOR 100-YEAR
RM 3 0.554 0.35
* RM 3 0.422 0.35
ZW A=GRAYSON CR B=G AT MOUTH C=FLOW E=10MIN F=100YR 96HR
*
KK 18E, (1475) LOWER GRAYSON INTERIOR DRAINAGE EAST
BA 1.22
BF -5.0 4.0 1.10
LE 0.5 3.21 2.32 0.7 30.3
* LU 0.25 0.13
PB 7.41
* DONE - ACTION 10 MIN UG
UI 294 294 294 428 478 478 351 196 196 183
UI 120 120 120 84 81 81 68 60 60 55
UI 47 47 46 38 38 38 33 31 31 29
UI 26 26 25 21 21 21 16 16 16 14
UI 13 13 12 10 10 10 8 8 8 6
UI 5 5 2
* ZW A=18E-INTERIOR DRAINAGE B=EAST ABV MOUTH C=FLOW E=10MIN F=100-YR 96HR
*
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KK 18W, (1476) LOWER GRAYSON INTERIOR DRAINAGE WEST
BA 0.98
BF -5.0 3.0 1.10
LE 0.5 3.21 2.32 0.7 42.8
* LU 0.25 0.11
PB 7.53
* DONE - ACTION 10 MIN UG
UI 335 335 481 546 420 224 217 136 136 102
UI 92 81 68 66 53 53 44 43 39 36
UI 34 30 30 24 24 20 18 17 15 15
UI 12 12 10 9 8 6 5
* ZW A=18W-INTERIOR DRAINAGE B=WEST ABV MOUTH C=FLOW E=10MIN F=100YR 96HR
*
* KK 18C, COMBINED FLOW (WITH INTERIOR DRAINAGE) AT GRAYSON MOUTH
* HC 3
KK DIV  RETRIEVE EASTSIDE OVERFLOW AREA 19 DIVERSION TO WALNUT CREEK
DR DIVWC
ZW A=19 FLOW DIV B=TO WC C=FLOW E=10MIN F=100YR 96HR
*
ZZ
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