Franklin – Brown – Sudden – Clark Barranca 2-Dimensional Floodplain Analysis

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1. EXECUTIVE SUMMARY

A planning-level unsteady 2-dimensional (2D) floodplain analysis has been completed for the watersheds of Franklin, Brown, Sudden and Clark (FBSC) Barrancas and their major tributaries located in East Ventura and the adjacent Unincorporated Ventura County area. These four major watersheds all drain to Santa Clara River and have a total drainage area of approximately 13 square miles. Many reaches of these streams are known to have inadequate flow capacities to carry 100-year flood flows and therefore pose potential flood risks to property owners and residents in the both urban and agricultural areas. In addition, the Ventura County Saticoy Operations Yard (SOY), a critical flood control, transportation and fleet operational facility during emergencies, is located within the lower section of the watersheds.

The detailed limit of study for the FBSC project and its tributaries is from approximately the intersection of Kimball Road and Foothill Road in the northwest to Wason Barranca and Foothill Road at the northeast and the Santa Clara River to the south.

Due to flow conveyance inadequacies in the local and regional drainage facilities, the study has found that over 2800 parcels may be subjected to flooding during a 100-year storm event, 1250 of which may require flood insurance in the future. The potential flood damages to residential, commercial, and agricultural properties are estimated to be $96M. Two thirds of the above flood damages are expected within the City, with the remainder within the Unincorporated County areas. The annualized flood damage within the study area is estimated to be $8.7M.

The community of Saticoy is found to be especially vulnerable during a major storm event as commingling flows from several streams and channels will contribute to flooding within the area. Wells Road and the Los Angeles Avenue will be inundated for many hours during major storm events with varying degree of flooding.

Access in and out of the Saticoy Operation Yard will be hampered as a result. The operations yard will experience some inundation as well, and the flood waters may enter parts of the GSA building(s). The PWA building is found to be dry during the 100-year storm event.

The 5, 10, 25, 50, 100 and 500-year storm events have been analyzed to accurately assess potential floodplain conditions during catastrophic events, in addition to more commonly occurring storm events. Detailed mathematical models, inundation maps, base map information, and other supporting data are provided in electronic format. The following are simplified flood hazard maps for the above storm frequencies. Please see Technical Appendix for all detailed data and information.

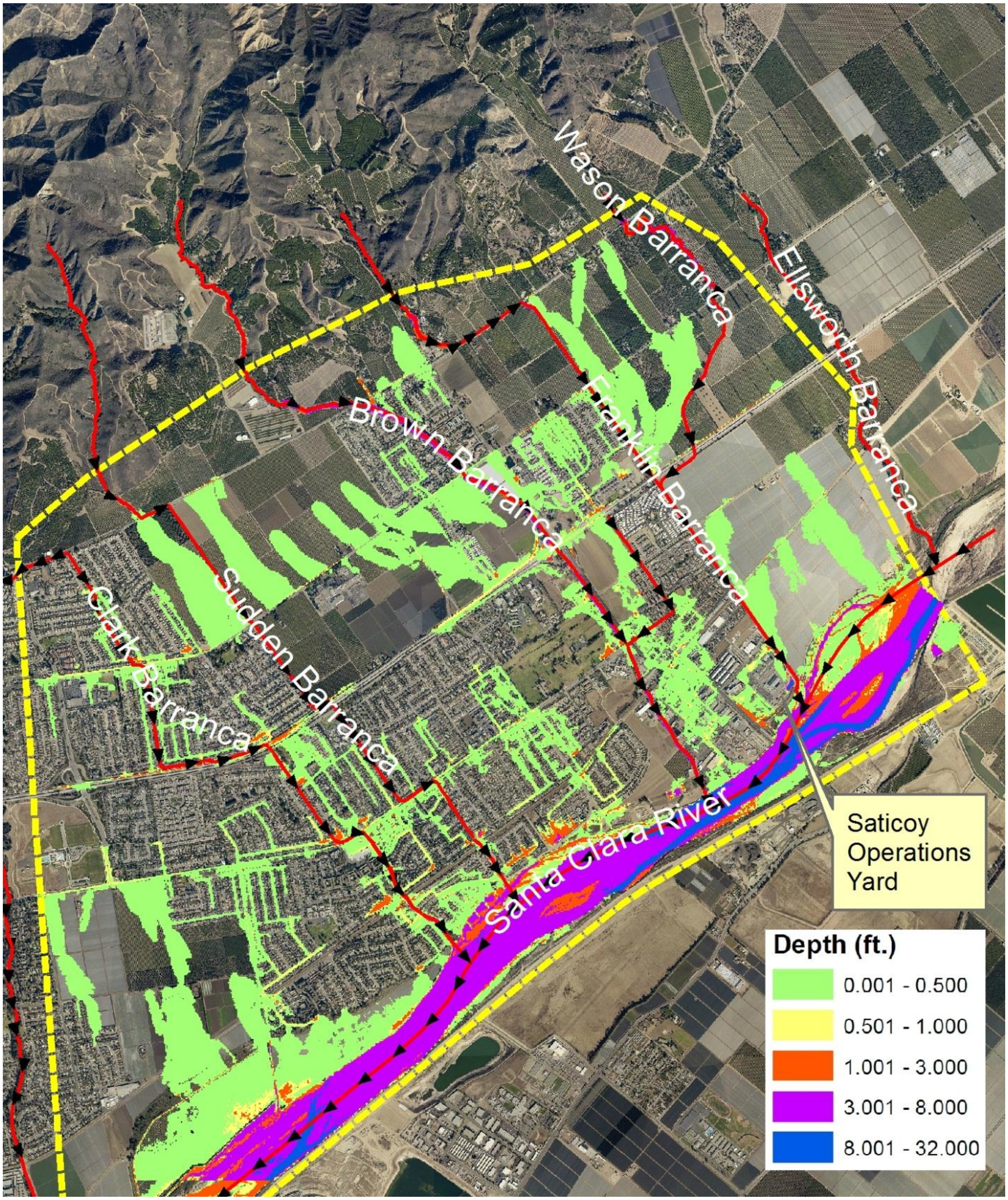


Figure 1 5-Year Flood Hazard Map

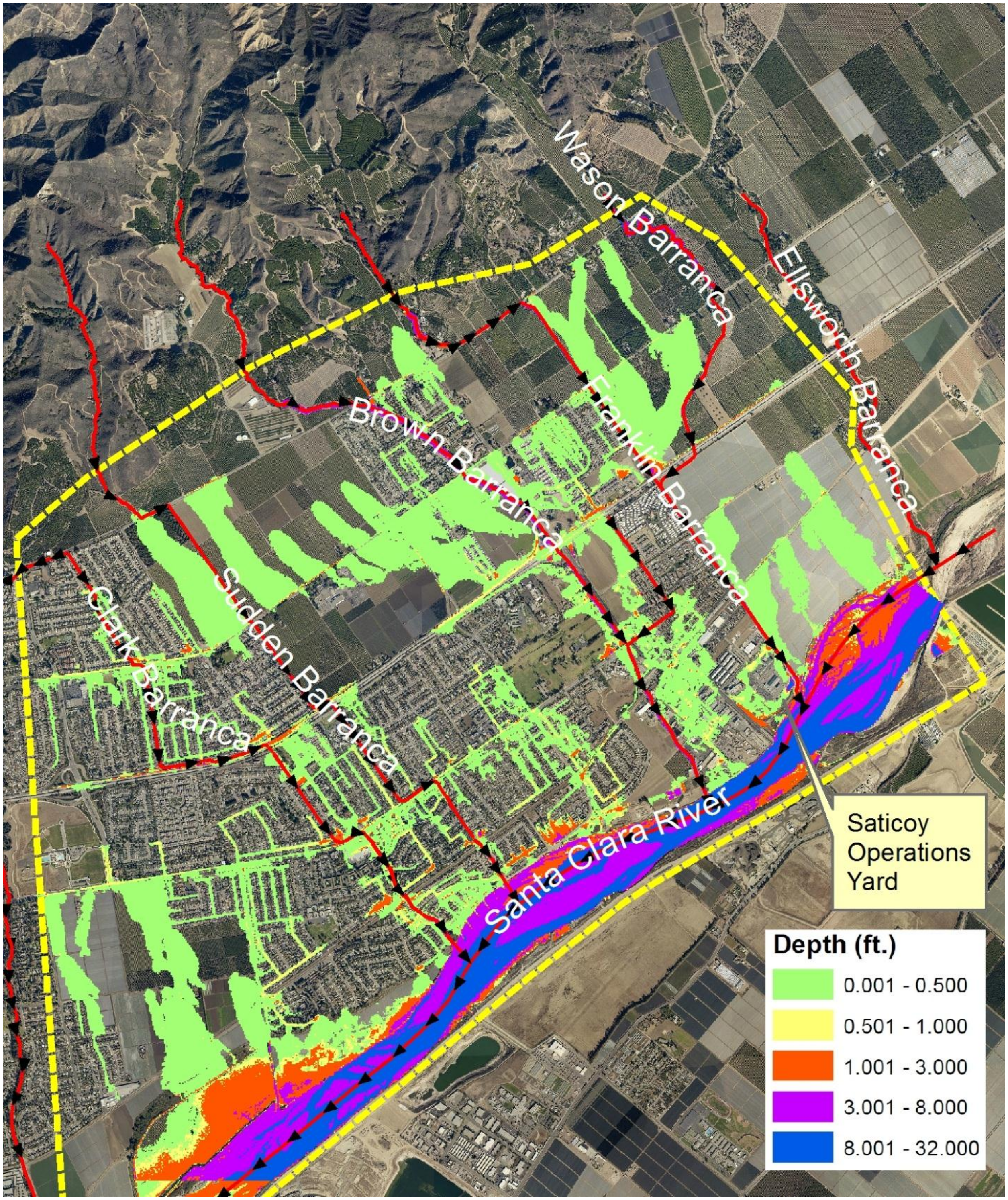


Figure 2 10-Year Flood Hazard Map

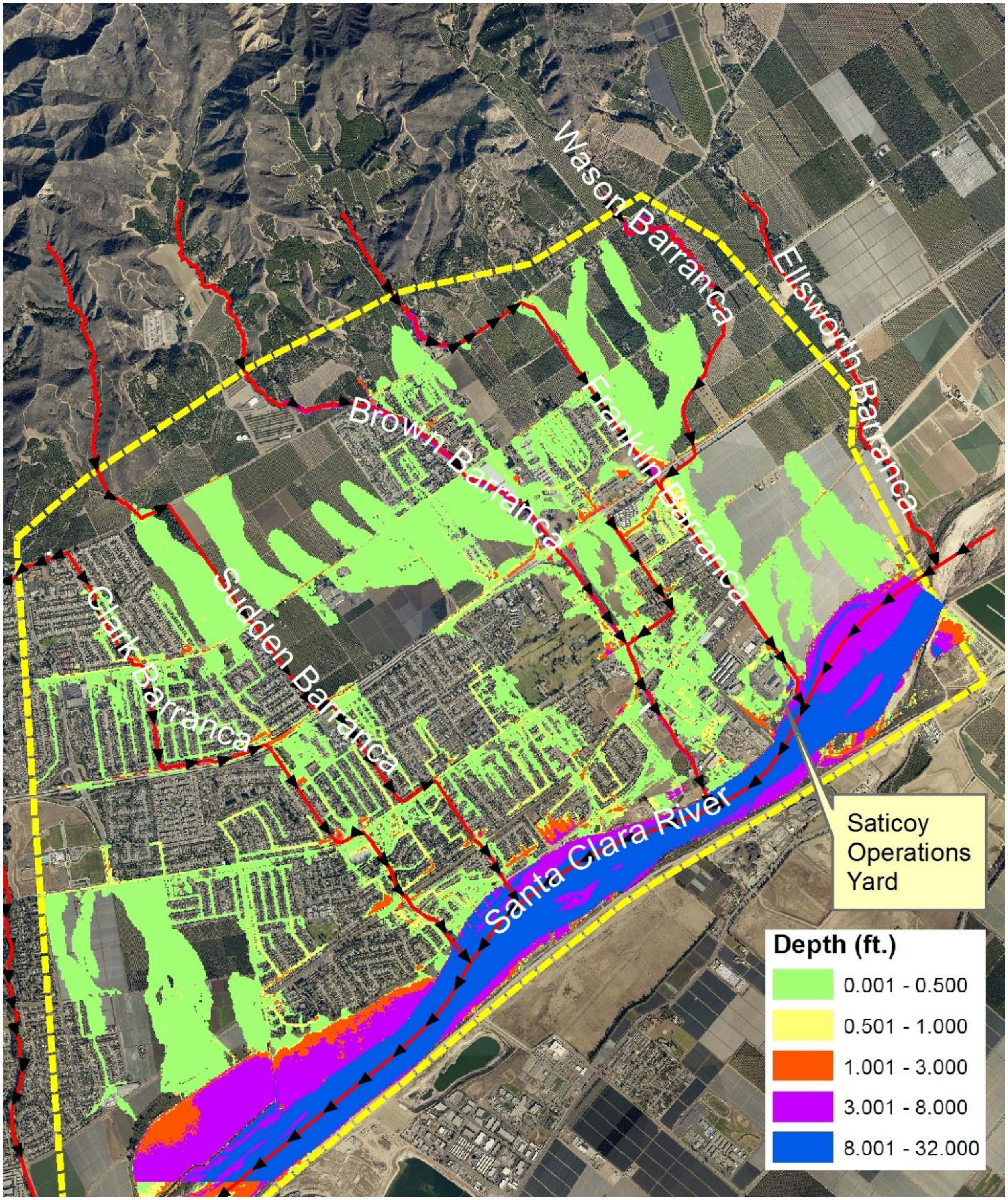


Figure 3 25-Year Flood Hazard Map

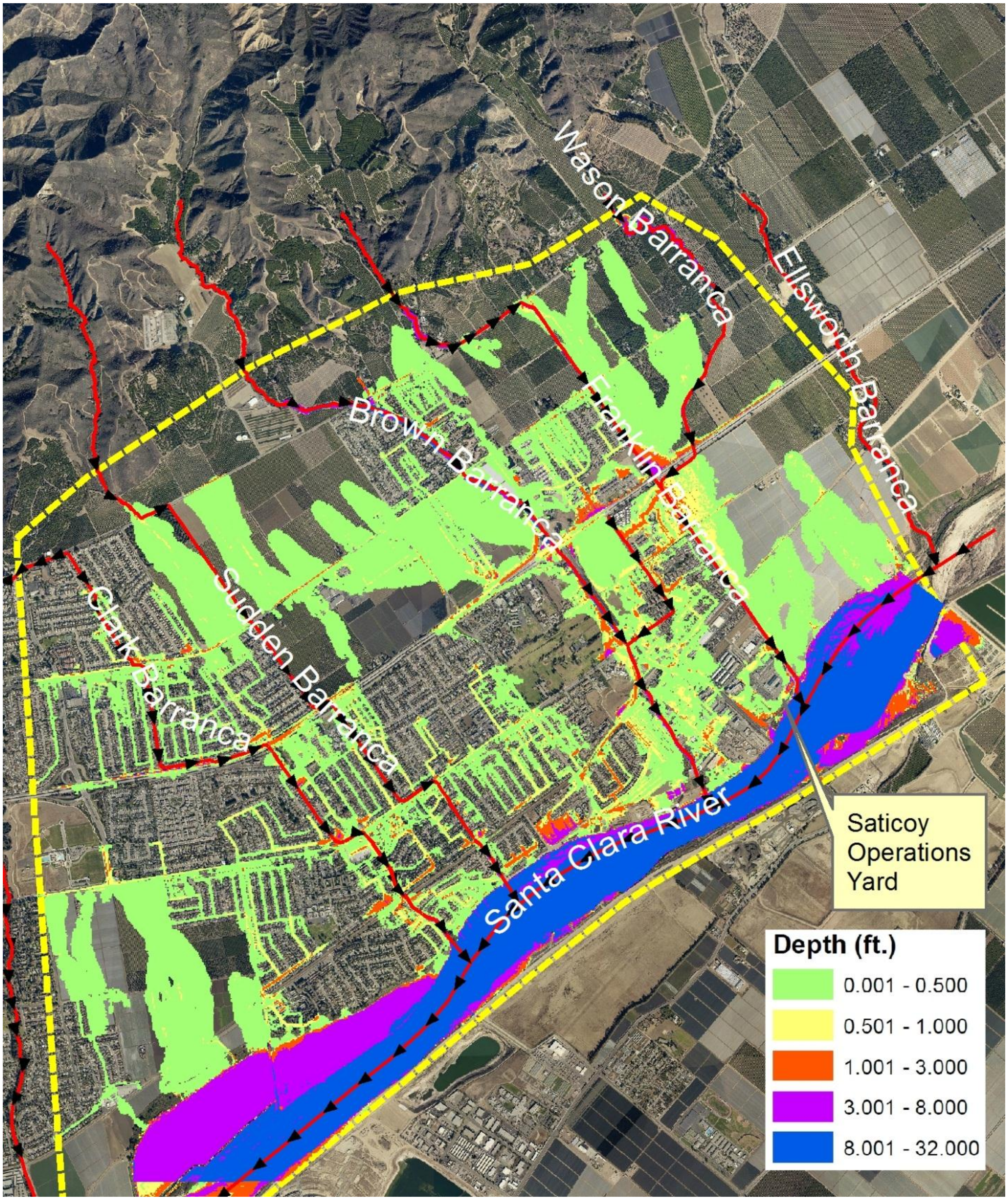


Figure 4 50-Year Flood Hazard Map

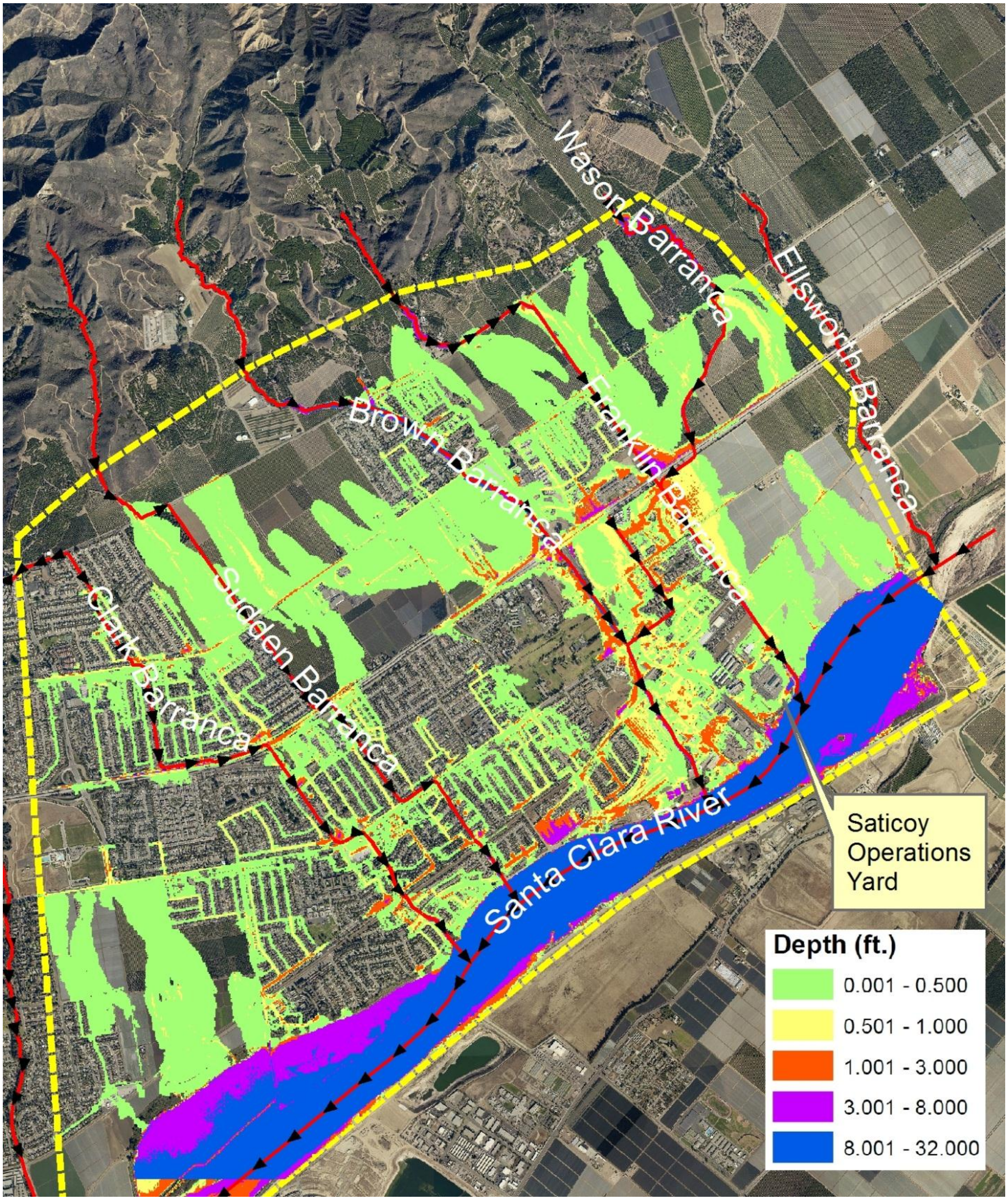


Figure 5 100-Year Flood Hazard Map

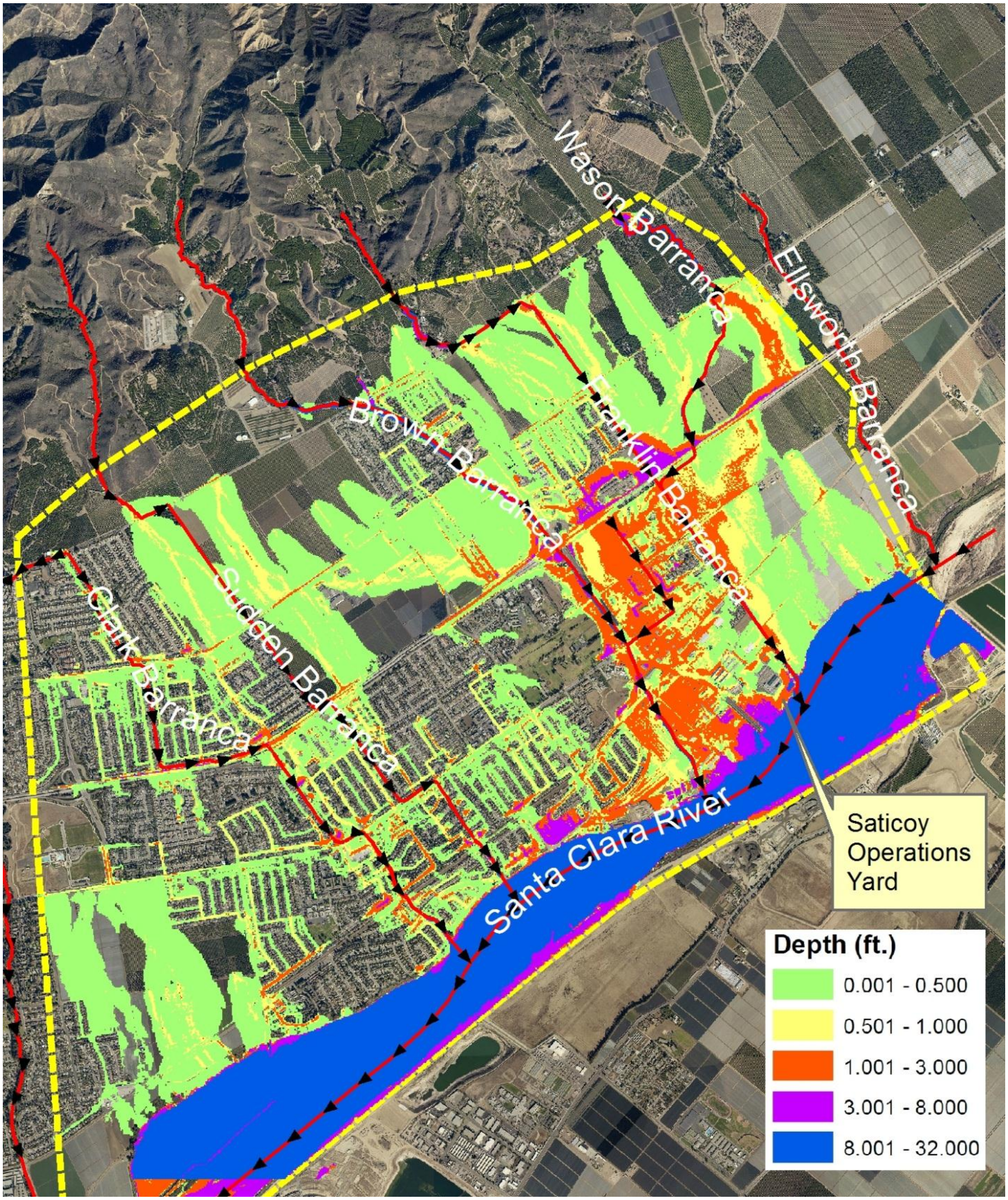


Figure 6 500-Year Flood Hazard Map

2. PROJECT OVERVIEW AND OBJECTIVES

A planning-level 2-dimensional (2D) flood routing study has been completed for the FBSC Barrancas and their main tributaries within the study area shown on the location map below.

The objectives of the project are as follows:

1. Identify access and operational issues at Saticoy Operations Yard during flood emergencies
2. Determine existing drainage deficiencies
3. Develop an integrated modeling tool to assess potential solutions

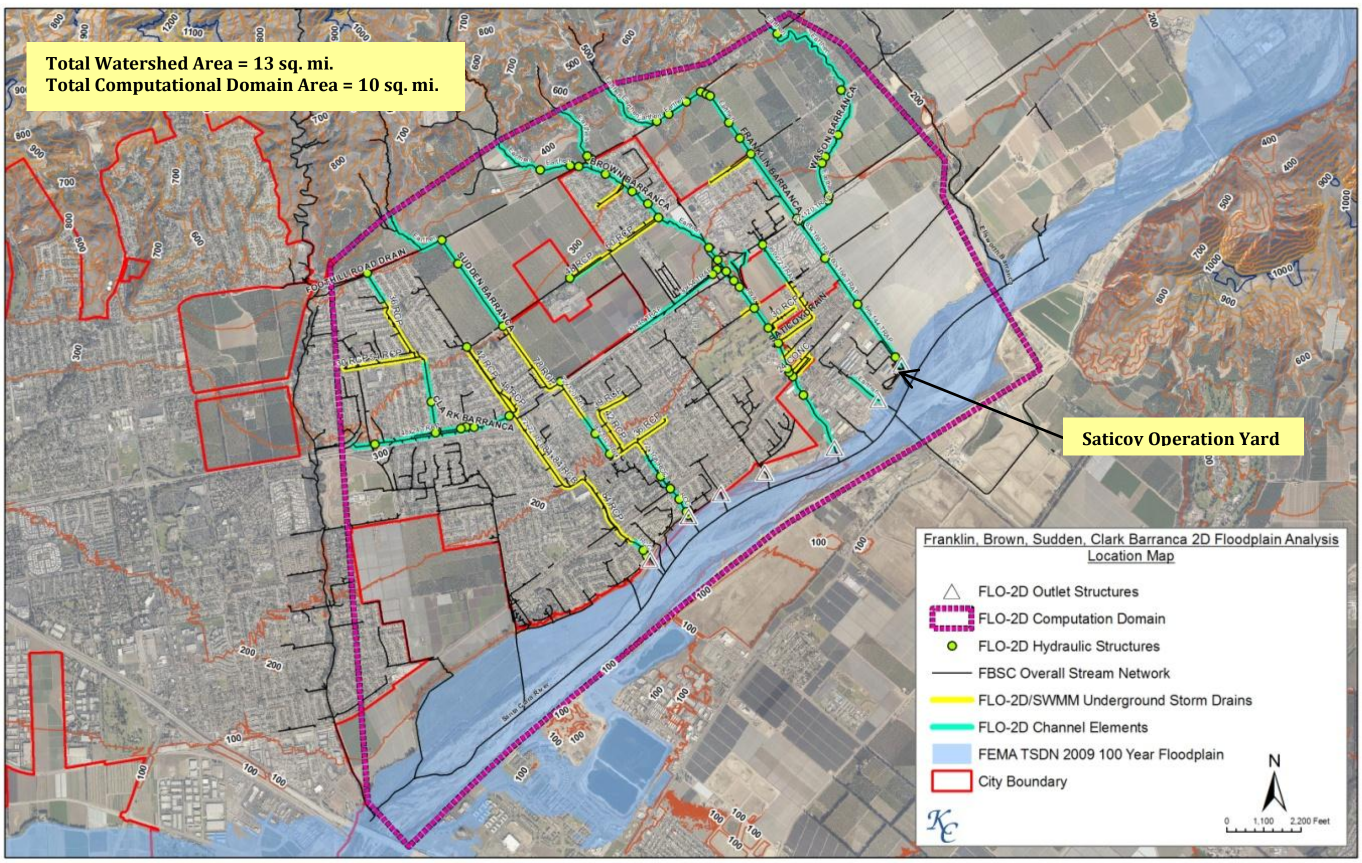


Figure 7 Location Map

The total watershed area for the project is approximately 13 sq. mi. The total FLO-2D computational domain area is approximately 10 sq. mi.

This project area has a number of coalescing alluvial fan and watershed features, and flows from the various watersheds combine to form a larger flood area. Unconfined flooding of this nature requires a two-dimensional flood routing model for accurate flood hazard mapping. This analysis was completed using FLO-2D, EPA SWMM and HEC-RAS software programs.

FLO-2D was selected by VCWPD for application to this project because it can simulate urban flood detail such as buildings, embankments, walls, and infiltration, along with unconfined overflow. In addition, street and channel flow can be simulated and hydraulic structures can be modeled for water surface control. Additionally, FLO-2D is able to compute the channel floodplain flow exchange on a grid element basis, which is critical for the small channels on the floodplain surface. Numerous inflow hydrographs have been created from approved VCWPD hydrology and placed accordingly in key, strategic locations within the study area to most accurately mimic actual storm event flow and distribution.

This 2-dimensional floodplain analysis may be expanded and used as a foundation for a 30% Pre-Design Report in the future, and it can also be used as a part of technical and scientific documentation in support of a Letter of Map Revision (LOMR) for the local Communities at a later date.

For the purpose of this planning-level effort, walls such as sound walls along the freeway, or perimeter walls around subdivisions were not included in the model. The rainfall and infiltration feature of FLO-2D was also not utilized in the model.

3. BACKGROUND INFORMATION & DATA

The following sections provide background information and data that were researched, utilized and/or created as part of this effort.

a. Basemap

Numerous GIS basemap layers were utilized for this project, such as Parcels, Street Centerline, City Boundaries, Ventura County Watershed Protection District (VCWPD) Right-of-Way, VCWPD Facility centerlines, City of Ventura Storm Drain System Atlas, City of Ventura Building Rooflines, City of Ventura General Plan Land Use, County of Ventura Unincorporated Land Use, FEMA Effective DFIRM Floodplain Boundaries and Base Flood Elevations (BFE). 2005 and 2013 aerial photography were also utilized for this project. City of Ventura Building Rooflines depicts the rooflines of all structures present on the 2013 aerial photo. Roofline polygons were reviewed, updated, and then: integrated into the Manning's Roughness Factor layer (described below), incorporated into the flood damage calculations, and utilized for flood hazard visualization purposes.

In addition to the above GIS basemap layers, the Operations and Maintenance (O&M) Division of VCWPD provided their Facility Inventory shapefiles, photos, and Closed Circuit Television Videos (CCTV) of their channels. This information was used to verify dimensions, material and other characteristics of the study channels and structures.

b. Horizontal & Vertical Datum

The current floodplain study is performed in the following datum:

Horizontal Datum: 1983 North American Datum State Plane Coordinates Zone V Feet (NAD83)

Vertical Datum: 1988 North American Vertical Datum Feet (NAVD88)

The 2005 LiDAR and channel design topography were prepared utilizing the NAVD88 vertical datum. In contrast, the majority of construction records and as-built drawings within the study area were prepared using the National Geodetic Vertical Datum of 1929 (NGVD29) vertical datum. These data sets were converted to NAVD by adding +2.46 feet.

NAVD88 Elevations = NGVD29 Elevations + 2.46 feet

c. Record Drawings

More than 300 storm drain Record Drawings were researched and obtained from the following entities for the study area:

- Caltrans
- City of Ventura
- County of Ventura
- Ventura County Watershed Protection District

Many of these plans have also been geo-referenced, allowing them to be loaded into GIS in real coordinates. The scanned and cataloged drawings plans are included with this report and are available in the Technical Appendix.

d. Storm Drain System Atlas / Hydraulic Structures

A composite Drainage System Atlas (Atlas) GIS Geodatabase was created for the study area of interest. Please see Exhibit 8. This Atlas consists of polyline features and their attributes from the most recent City of Ventura Storm Drain Atlas

Geodatabase, the VCWPD facilities centerlines, the County of Ventura Unincorporated area Storm Drain Atlas Geodatabase and the VCWPD O&M Facility Inventory Shapefile. This information consists of storm drain system main lines, laterals, catch basins/inlets, open channels, box conduits, culverts, etc. The line work geometry from these various sources and their attribute tables were merged to make one comprehensive Atlas containing the various storm drains from different agencies/sources.

The composite Atlas was then evaluated for any missing line work or facility attributes (size, slope, material, etc). If missing, this information was added from the appropriate source including City, County, and Caltrans record drawing. If the necessary drawings were not available in GIS format they were geo-referenced and the storm drain alignment was captured by digitizing their centerlines from the rectified drawings. Attributes were also captured from these same drawings. Storm drain attributes were used to calculate the full flow capacity of all storm drains 18" or greater. This full flow capacity information can be found in the field "Capacities" for each individual storm drain segment in the Feature Class. Detailed information is included in the Technical Appendix.

e. Manning's Roughness Factors

The following table and figure contain the initial N-values used for the hydraulic analyses. A GIS polygon layer of Manning's roughness factors was created using a combination of the existing parcel basemap with land use designation, the City of Ventura General Plan Land Use, and available aerial photos. Some minor deviations from the recommended N-values were made during the computational phase of the project, which is explained later on in the report. VCWPD staff were consulted and agreed with the recommended roughness factors utilized for the study. The ranges of values are based on established engineering values in addition to FLO-2D documentation. Please see Exhibit 9 Land Use and Land Cover Map for detailed area-wide map. Figure 8 below presents a snapshot of the larger area map. Table 1 presents the initial Manning's Factors and Froude Numbers used in the 2D model.

Table 1 Overland Flow Manning's Roughness Factors and Limiting Froude Numbers - 2D Hydraulic Analysis

Description	Manning's N-value	Froude Number
Agricultural General	0.050	0.50
Agricultural Orchards	0.080	0.60
Agricultural Strawberries	0.080	0.60
Commercial	0.045	0.90
Industrial	0.055	0.90
Neighborhood High Density	0.080	0.85
Neighborhood Medium Density	0.075	0.80
Neighborhood Low Density	0.070	0.70
Open Space	0.050	0.90
Public / Institutional	0.045	0.90
Parks & Open Space	0.065	0.75
Riverine	0.050	0.70
Right of Way	0.035	0.95
Specific Plan	0.050	0.90
Arterial and Collector roads	0.030	0.95
Arterial and Collector roads	0.030	1.25
Building Structure footprints	0.085	0.70

Table 2 below presents the range of Manning's Factors used in the various 1D and 2D elements of the study: HEC-RAS, EPA SWMM, and FLO-2D (1D channels and 2D overland flow). Although VCWPD Design Manual Manning's factors were used as guidance to set initial values within the study, FLO-2D adjusts the factors based on specified limiting Froude numbers.

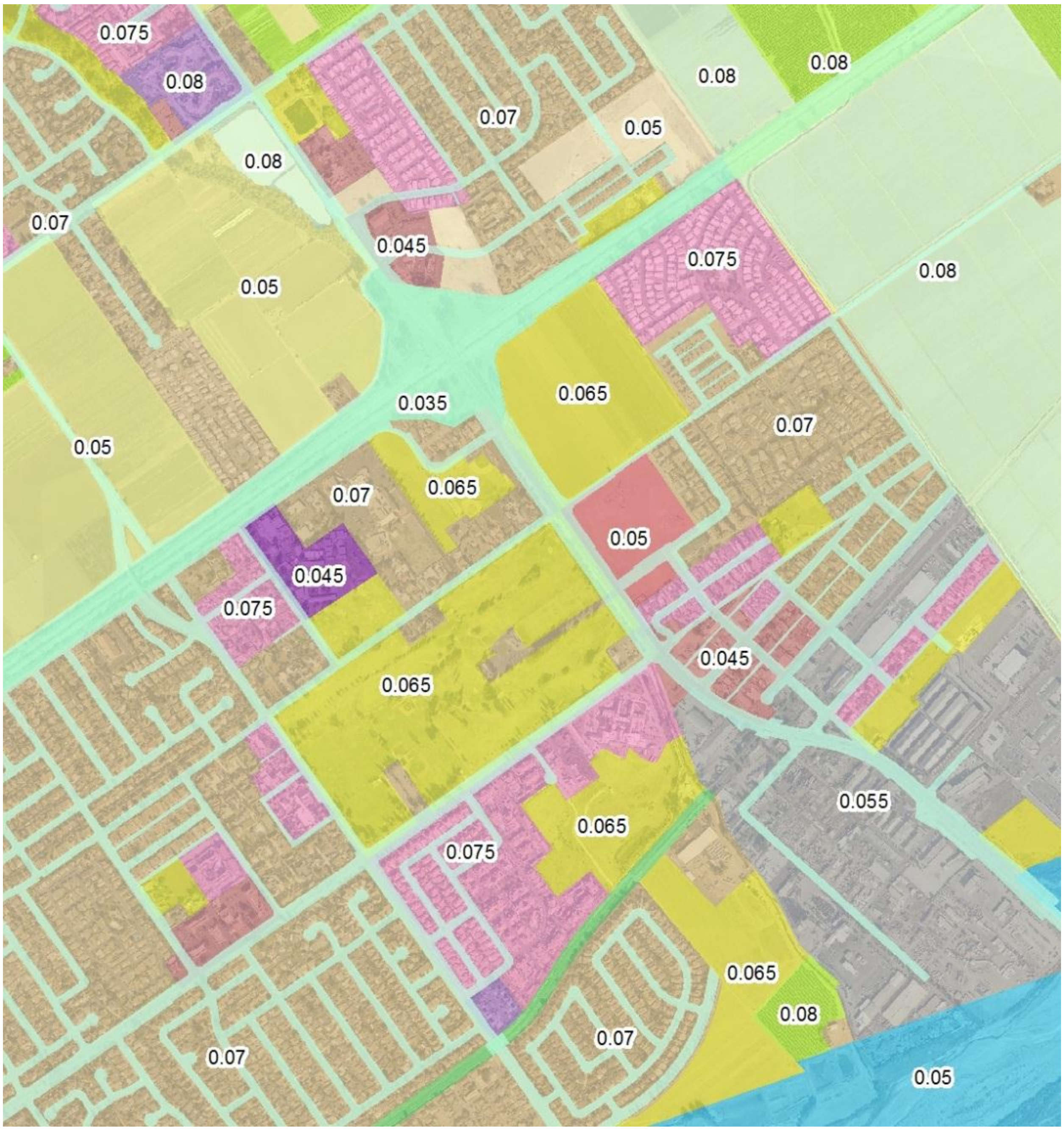


Figure 8 Land Use and Manning's Factors

Table 2 Manning's Roughness Factors for Channel Hydraulics

Facility Type	Model	Range	Initial Values
Concrete Open Channels (rectangular or trapezoidal)	2D Model	0.015-0.025	0.020
Earthen or Engineered channels	2D Model	0.030-0.050	0.035
Natural Irregular Sections Heavy Vegetation	2D Model	0.070	0.070
Natural Irregular Sections light Vegetation	2D Model	0.050	0.050
Natural Irregular Sections grass weeds	2D Model	0.035	0.035
Rock Rip Rap	2D Model	0.030-0.045	0.040
Rock Rip Rap	1D Model	0.030-0.045	0.035
Corrugated Metal Pipes	1D Model	0.027	0.027
Concrete Box Conduits or Open Channels	1D Model	0.015	0.015
Concrete Pipes	1D Model	0.012	0.012

The initial Manning's roughness factors or ranges of n-values recommended for this project in the above Tables 1 and 2 were gathered from several similar projects. VCWPD design manual, HEC-RAS application manual, District's South Branch Arroyo Conejo 2-dimensional model study (2011), Jepson Wash floodplain study (2011), FLO-2D manual or its developer's guidelines were all used to prepare these tables. Ultimately, the developers used n-values that were deemed appropriate for FLO-2D modeling purposes, and to ensure model stability and volume conservation.

f. Composite Topography & Surface

There are two data sources of topography available for this project: the FEMA-compliant Bare Earth Light Detection and Ranging (LIDAR) point cloud acquired by VCWPD representing existing ground conditions dated March 2005, and Rough and Fine Grading Record Plans for areas developed since March 2005. A careful investigation of the 2005 Aerial Imagery compared with the current 2013 Aerial Imagery revealed 7 larger scale developments, ranging in size from 6 to almost 40 acres in size, have been constructed within the study area. The grading plans for these 7 developments (see figure below) were geo-referenced and key elevation contours and spot elevations were captured in GIS reflecting the current topography of the area.

Updated elevation information was then integrated into the bare earth LiDAR data to produce a continuous 3-dimensional surface for the entire computational area. Resulting products include a single composite topographic survey in both Triangulated Irregular Network (TIN) and GRID formats that reflect the current (2013) topography.

This information is available in the Technical Appendix.

Figure 9 Developments Built Since April 2005

g. Field Visits, Photos, Videos

Several field visits were made within the study limits, with VCWPD staff present. All of the field visits were documented with video clips in addition to still photos of critical structures or important points of interest. These field trips and resulting videos were used for facility verification and assisted in the hydraulic modeling of these facilities. The videos and photos are organized by date of the field trip and the geographic location in the Technical Appendix.

h. Summary of Related Studies

The following studies were used and referenced as part of this FBSC 2-dimensional floodplain study. This information can be found in the Technical Appendix.

i. <u>HDR - Brown Barranca Pre-Design Report – December 2005</u>
The purpose of this report was to summarize the results on improving the capacity of Brown Barranca and to recommend a cost-effective plan for implementation that fits within identified right-of-way, land use constraints, engineering design criteria and environmental concerns.

HEC-RAS models created for this study were reviewed in detail and used as general guidance, when applicable, in evaluating the flooding patterns of Brown Barranca and in the creation of the FBSC HEC-RAS models. Important model notes include:

- Modeled peak flows (including flow assumed to the leave Brown) were between 18 and 47 percent lower than those calculated as part of VCWPD's July 2013 FBSC – HSPF Final Report (See Table 4).
- Potential spillovers from Franklin and Wason Barranca breakouts were not considered.
- Single cross-sections were utilized to represent the entire floodplain. Lateral structures and separate out of bank flowpaths were not explicitly included in the model. This results in potential erroneous hydraulic model results (See Figure 10 below).
- The rating curve shown utilized for Telegraph Road at station 9181 starts at an elevation over eighty feet below the cross-section's invert.

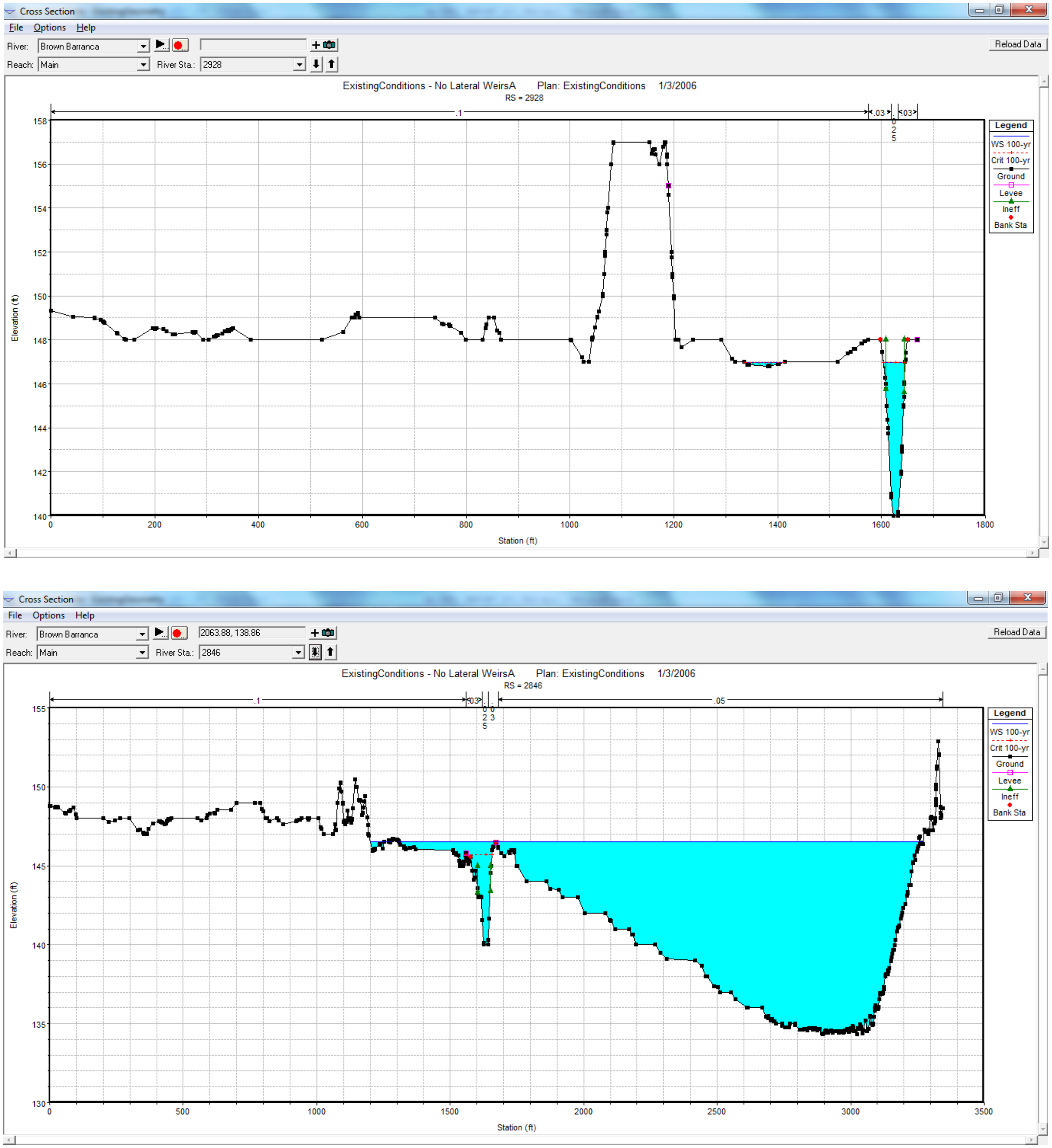


Figure 10 Example of Incorrect Model Assumption

The study area of this report encompassed Brown Barranca from Foothill Road to the Santa Clara River.

ii. ACOE - Santa Clara River Watershed Feasibility Study – Without Project Conditions Overflow Analysis – October 2012

This report presents the results of an assessment of the without project hydraulic conditions within the Santa Clara River watershed. It documents the hydraulic features of the mainline Santa Clara River and its major and minor tributaries.

Hydraulic models for the study reaches, flood hazard areas, hydraulic structures and other reach characteristics were presented in this report. The HEC-RAS models and assumptions were reviewed in detail and used as guidance, when applicable, in creating the FBSC HEC-RAS models. Important model notes include:

- Modeled peak flows for the ACOE study were compared to those generated as part VCWPD's July 2013 FBSC – HSPF Final Report (See Table 4) ACOE flows along:
    - Brown were 2-20% lower,
    - Franklin were 0-22% lower (the larger differences were upstream of Freeway 126),
    - Clark were 23% higher, and
    - Sudden were 35% higher
- Includes numerous lateral structures and reaches used to model estimated overflow areas.
- Rough flow patterns are in general visually similar to this two dimensional study with the exceptions of:
    - Clark Barranca between Freeway 126 and Telephone Road.
    - Sudden Barranca between Telegraph Road and Freeway 126.
- Underground storm drains along Clark and Sudden are modeled as a single culvert.
- HEC-RAS does not include Wason Barranca. But it does include potential overflow from Ellsworth Barranca along Freeway 126.

The study area of this report includes the entire Santa Clara River and some tributaries including parts of the FBSC Barrancas.

iii. VCWPD - Santa Clara River – Franklin-Wason-Brown-Clark-Sudden Watersheds HSPF Design Storm Modeling – Final Report – November 2013

This report documents the work done by VCWPD using the calibrated Santa Clara HSPF Model. The model was used to provide the design storm peaks and hydrographs for the FBSC 2-dimensional hydraulic modeling and floodplain mapping project.

For this study, the subarea boundaries were modified based on the 2005 LiDAR topography, City of Ventura drainage system and requested locations of local runoff hydrographs for use in the FBSC model. Design storm ratios based on stream gage data were provided to convert the HSPF 100-yr peak flows to other storm recurrence levels. Routed storm hydrographs at the downstream end of each subarea reach were provided in spreadsheet format, as well as un-routed local runoff hydrographs for each subarea. Additional details are found in the Hydrology Section below.

iv. VCWPD - Santa Clara River – Franklin-Wason-Brown-Clark-Sudden Watersheds – HSPF Design Storm Modeling – Final Addendum I – December 2013

This report documents the work done by Kasraie Consulting for VCWPD in adapting the design hydrology from the above report for the FBSC study. Kasraie Consulting prepared numerous additional hydrographs based on the regional model results for use in the FLO-2D model. The additional hydrographs were required to minimize the effects of using a hydrograph-based hydrology approach to approximate the spatial distribution of runoff that occurs in a design storm. Further details are found in the Hydrology Section below.

4. HYDROLOGY

a. December 2009 – Santa Clara River HSPF Model

The calibrated Santa Clara River HSPF Model (Aqua Terra 2009) was used to provide the design storm peaks and hydrographs for use in the hydraulic modeling of the study reaches.

The Santa Clara River and its tributaries drain the largest watershed in Ventura County with an area of approximately 1,600 sq. mi. The watersheds within the FBSC 2013 study area comprise about 13 sq. mi. of the total area. Upstream portions of the study watersheds are undeveloped, with downstream portions consisting primarily of agricultural and residential developed land uses.

The primary components of this HSPF model in the vicinity of the FBSC study area are as follows:

- Watershed boundaries were based on the District's forecast model boundaries as shown in Figure 11. In some cases the boundaries intersected urban drainage areas and systems, indicating the boundaries may have been drawn before the present day development conditions.
- The rain for the Saticoy area was specified by assigning one of the District's rain gages to the subareas, consistent with the approach used in the rest of the HSPF model. For the study area, the data from Saticoy gage 175 was used. This gage was located at a County Fire Station at the downstream end of the study area until it was relocated to the District's Saticoy Operations Yard (SOY) in the summer of 2008. Since 1976, this gage has provided short duration rain data that can be used for continuous modeling and frequency analyses.

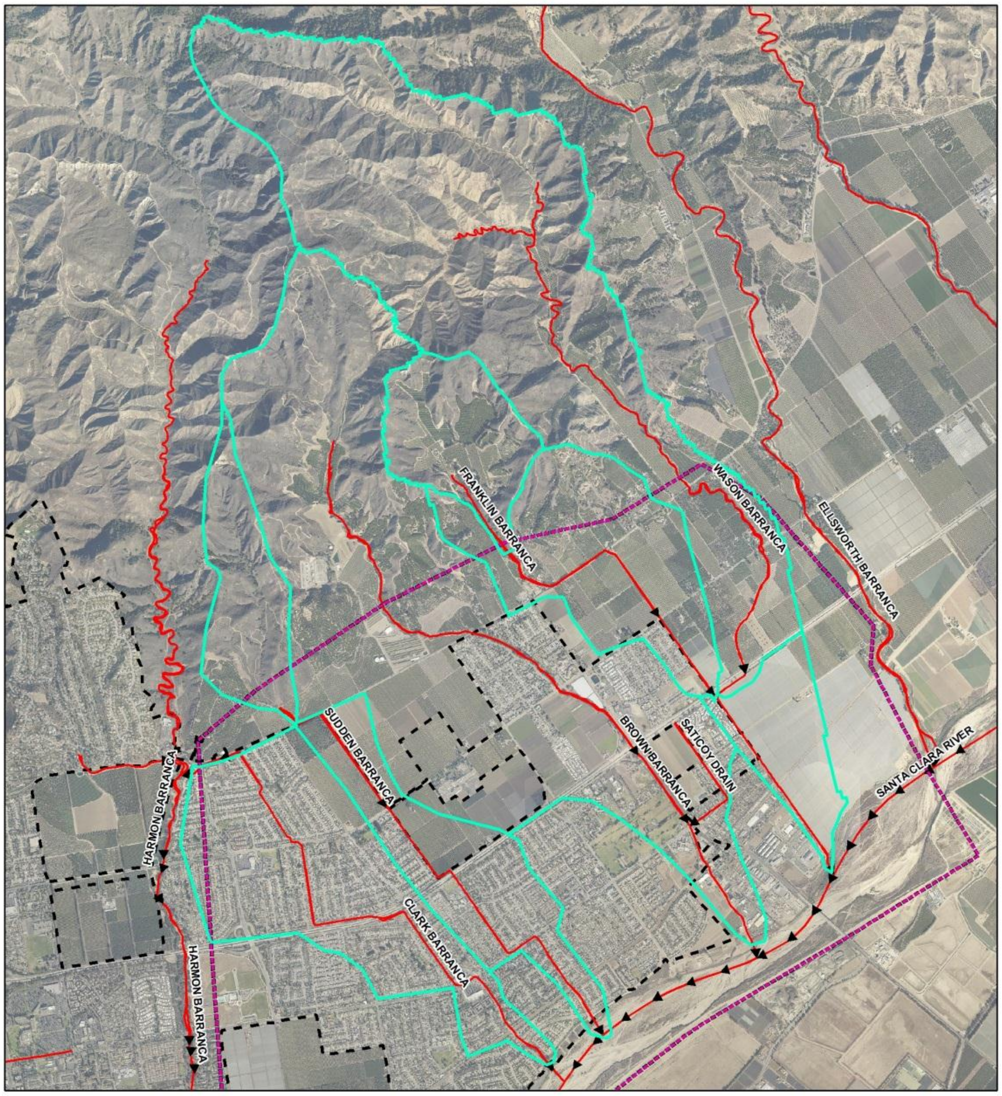


Figure 11 Saticoy Watersheds and HSPF 2009 Boundaries

- The land uses in the model are grouped into eight main categories, forest/woods, shrubland, open space/parks, agricultural land, low, medium and high density residences, and industrial/commercial. The eight land uses were calculated based on GIS coverages showing land uses as of 2005.
- Each pervious and impervious land group is assigned an overland flow length and average slope based on GIS analysis of the different land uses. The overland flow lengths for these subareas generally range from 100-400 ft and slopes range from 0.01 to 0.14 ft/ft.
- Infiltration and watershed storage parameters for each pervious and impervious group was assigned based on the average soil type found in each land use. These multiple parameters control the runoff and infiltration of

rain for the upper and lower soil zones, the interflow zone and percolation to deep groundwater.

- Evaporation in the model is simulated based on time series developed from pan evaporation data.
- Each subarea is provided with a reach represented in the model with stage-storage-discharge parameters. The model uses modified Puls routing to simulate the effects of channel storage on the local inflow. The HSPF conceptual model of flow assumes that all local runoff due to the input rainfall hyetograph is applied to the upper end of a subarea reach and is routed in the channel down to the next subarea.

b. July 2013 – FBSC HSPF Design Storm Modeling Final Report

Santa Clara River – Franklin–Wason–Brown–Clark–Sudden Watersheds

The July 2013 FBSC – HSPF Final Report documents the work done by VCWPD to update the calibrated Santa Clara HSPF Model (Aqua Terra 2009). The larger model was adjusted within the FBSC study area to provide the design storm peaks and hydrographs for two-dimensional hydraulic modeling and floodplain mapping of the Saticoy area tributaries of the Santa Clara River.

All watersheds and sub watersheds within the FBSC 2013 study area, consisting of approximately 10.8 square miles were analyzed in detail. Subarea boundaries were modified based on 2005 LiDAR topo data, the City of Ventura drainage system and requested locations of local runoff hydrographs for use in the hydraulic model. The FTABLES used in the HSPF model to route the subarea runoff in the channel reaches were also revised to include urban storage effects.

Existing drainage facility locations and information were collected from as-built construction plans and put into the City's GIS. This information consisted of storm drain system main lines, laterals, catch basins and inlets, open channels, box conduits, culverts, detention basins, etc. which are privately and/or publicly owned and maintained by the City, VCWPD, Caltrans and other entities.

The hydrologic analysis performed for this study is based on the calibrated Santa Clara River HSPF Model (Aqua Terra 2009). Preparation, calibration and validation of this model are described in detail in the 2009 report, and summarized above, including the meteorological components of the model and the subarea discretization.

The following steps were taken to update the 2009 HSPF model:

- 2005 LiDAR topographic data was used to revise subarea boundaries. The boundaries were further adjusted to be consistent with the City of Ventura local drainage networks and Freeway 126 drainage system.
- Revised boundaries were used to recalculate the land uses in each subarea.
- Subareas shown in Figure 12 were subdivided to provide local runoff data at the locations requested by VCWPD's Advanced Planning Section.
- Stage-storage-discharge data for each reach were developed using Manning's equation to provide the required Ftables for each channel reach.
- The HSPF UCI file was modified to export the peak flows and hydrographs for each subarea. This file was also revised to export the un-routed local runoff peaks and hydrographs from each subarea for Kasraie Consulting to use at intermediate locations in the FBSC hydraulic model.

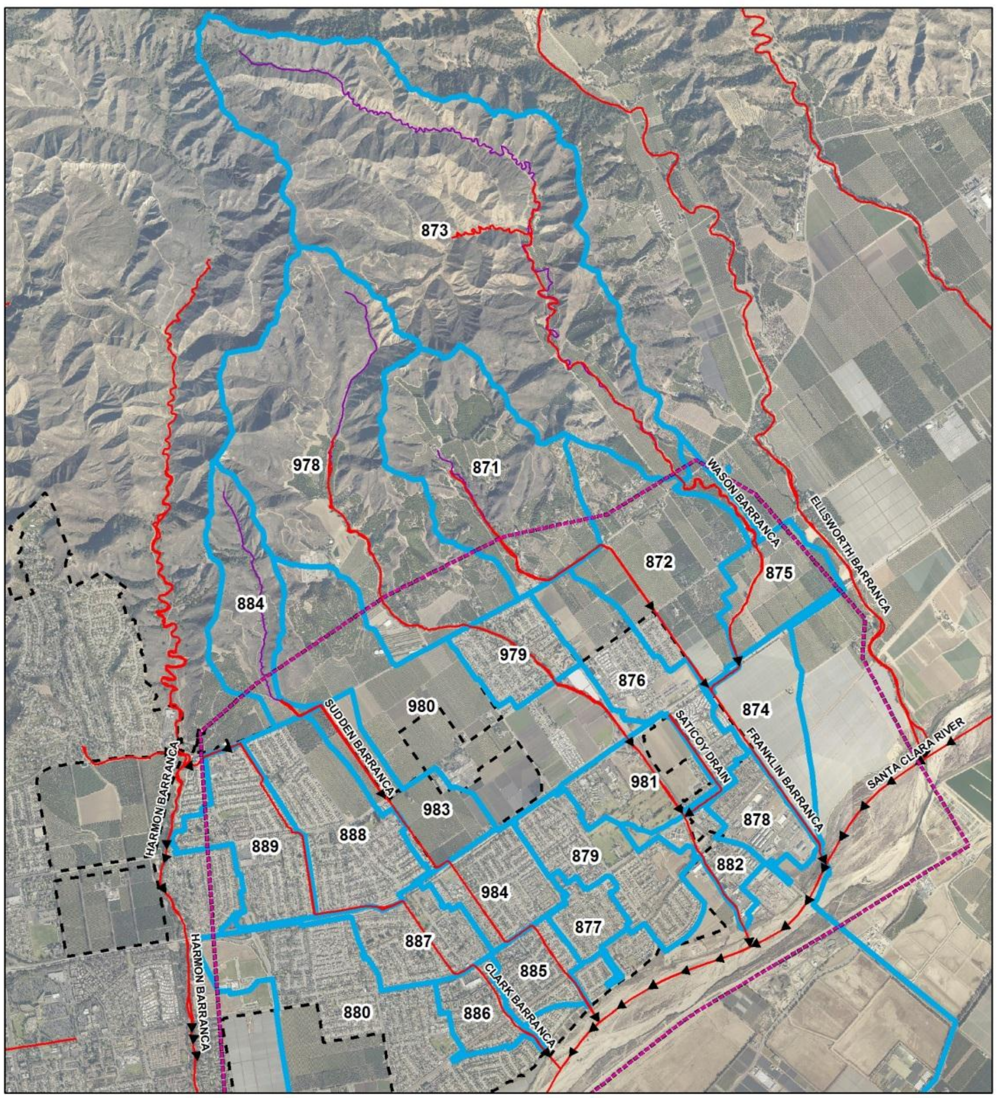


Figure 12– Revised HSPF Subareas

In comparing the revised model results to the original 2009 model results, generally the peak to area ratios from this 2013 model are higher for the largely undeveloped watersheds. Two exceptions are the Upper Franklin and Upper Sudden subareas, which have lower peak to area ratios than the unmodified model. For the more developed watersheds within Clark and Sudden Barrancas, the current ratios are lower, primarily due to urban storage effects included in the routing routine input. Since this modified model has more accurate subarea boundaries based on the 2005 LiDAR topography and Ventura City storm drain network, and uses a consistent approach to routing with the calculated FTABLE data, the current results are considered to be better for design storm modeling.

The FBSC hydraulic analysis required discharges for the 10-, 25-, 50-, 100-, 200- and 500-year storms. The results of flow frequency analyses of Ventura County stream gages were used to develop design storm ratios to convert the Q100 results from the HSPF modeling to other recurrence intervals of interest. Ratios from developed and undeveloped watersheds used to develop the design storm ratios are shown in Table 3.

Table 3 Design Storm Ratios

Storm	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr	500-Yr
Undeveloped Design Storm Ratio	0.144	0.262	0.484	0.711	1.000	1.952
Developed Design Storm Ratio	0.330	0.464	0.660	0.822	1.000	1.502

The July 2013 FBSC – HSPF Final Report and supporting documents can be found in the Technical Appendix.

C. December 2013 FBSC HSPF Design Storm Modeling Final Addendum 1 Santa Clara River – Franklin–Wason–Brown–Clark–Sudden Watersheds

VCWPD's December 2013 FBSC – HSPF Final Addendum documents the work completed by Kasraie Consulting for VCWPD in adapting the design hydrology for the Saticoy area watersheds of Franklin, Brown, Wason, Clark, and Sudden Barrancas. Design storm peaks and hydrographs were used for the two-dimensional floodplain model of the watershed. This design hydrology was originally based on the calibrated Santa Clara HSPF Model (Aqua Terra 2009). The main report (July 2013 FBSC – HSPF Final Report) presented results for the regional-scale subareas included in the HSPF model.

FLO-2D is a combined hydrologic and hydraulic model capable of generating runoff from rainfall inputs that are introduced as a distributed rainfall grid with each grid element having a unique design rainfall amount, intensity and other associated infiltration parameters. However, this functionality was not used due to uncertainties in design rainfall amounts and lack of available flow gage data within the local subareas necessary for a proper review and comparative analyses inside the direct FBSC project area. In an effort to maintain consistency with the larger, calibrated Santa Clara River model, the regional model hydrographs were distributed across the more detailed sub-areas for use in the FLO-2D model. The distributed hydrographs were required to minimize the effects of using a point source hydrology approach by better approximating the spatial distribution of runoff that occurs in a design storm.

Kasraie Consulting subdivided the final HSPF study watersheds shown in Figure 12 into 177 smaller subareas and resultant concentration points as shown in Figure 13. These hydrologic concentration points were then spatially correlated to FLO-2D grid elements and were defined as either floodplain or channel elements. Original HSPF output hydrographs were then pro-rated by area and land use based on the new FLO-2D subareas included in the 20-25 HSPF watersheds. This process was completed for each of the six required storm frequencies (5-, 10-, 25-, 50-, 100- and 500-yr).

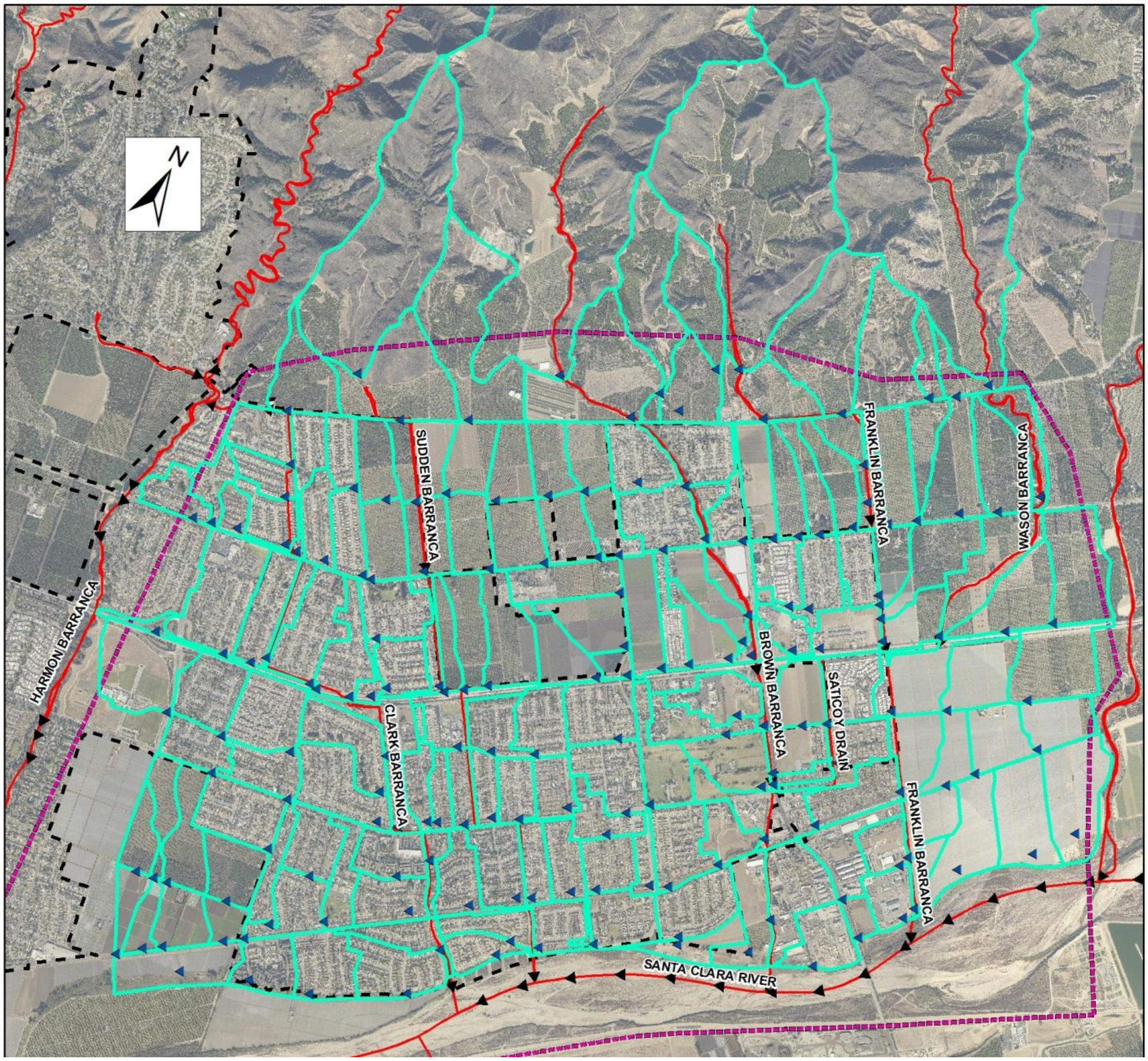


Figure 13 FLO-2D Subareas

Figure 14 shows the general land uses assigned to the FLO-2D subareas for pro-ration purposes. These land uses were used to determine if design storm ratios from undeveloped or mixed use/developed watersheds were applied to the pro-rated HSPF hydrographs in order to obtain the hydrology for storm frequencies other than the 100-yr. Average design storm ratios presented in the main report (VCWPD, 2013) were utilized and are included in Table 3.

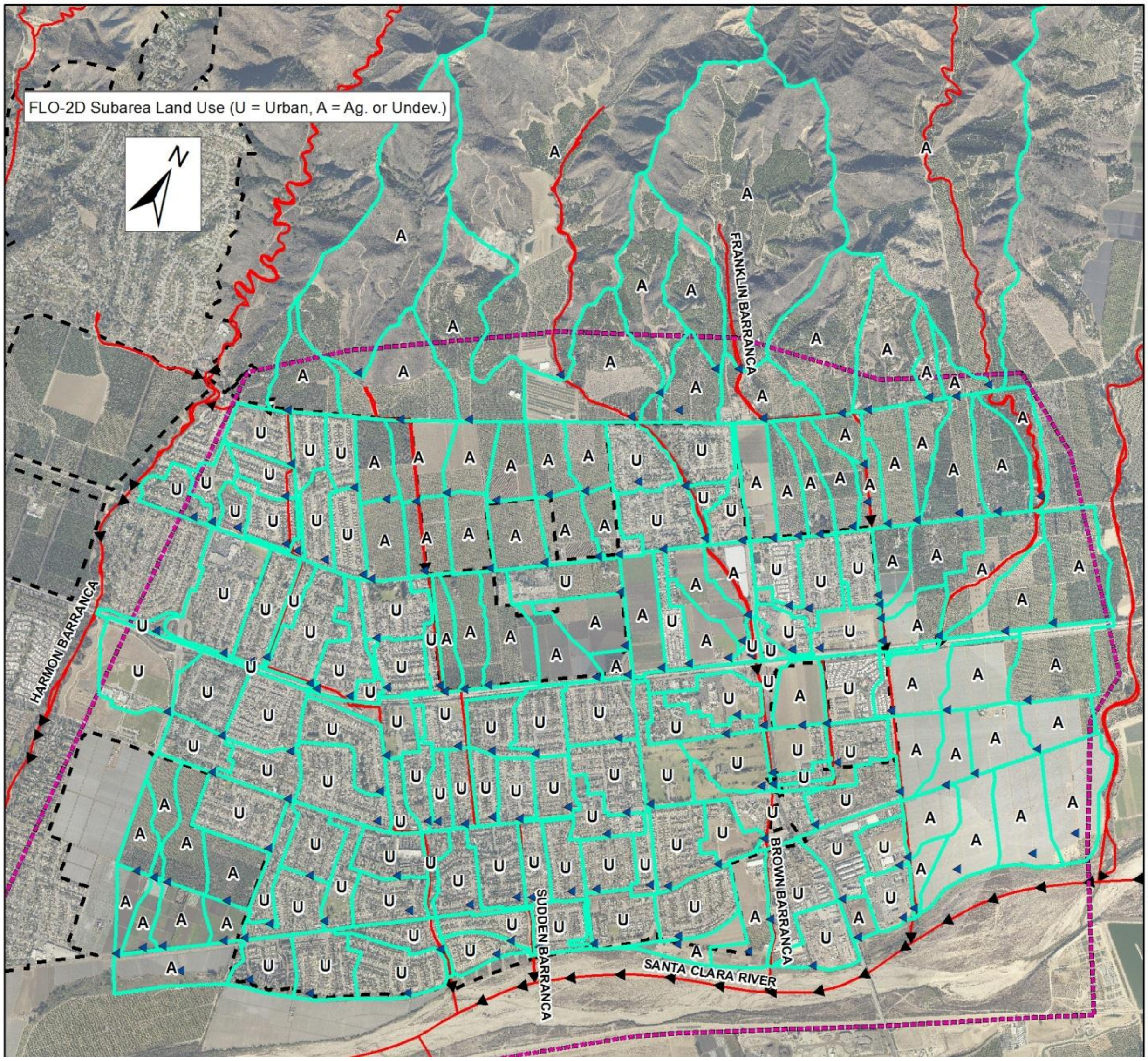


Figure 14 FLO-2D Subarea Land Use (U=Urban, A=Ag or Undeveloped)

The FLO-2D computational domain included several additional areas of direct local drainage to the Santa Clara River. Runoff in these adjacent areas does not contribute to flows within the main FBSC channels, therefore inflow hydrographs for these locations were not provided by the County. These additional areas are shown in Figure 15. Hydrographs from HSPF subareas 874, 884, and 885 were pro-rated based on size to represent local runoff in these locations.

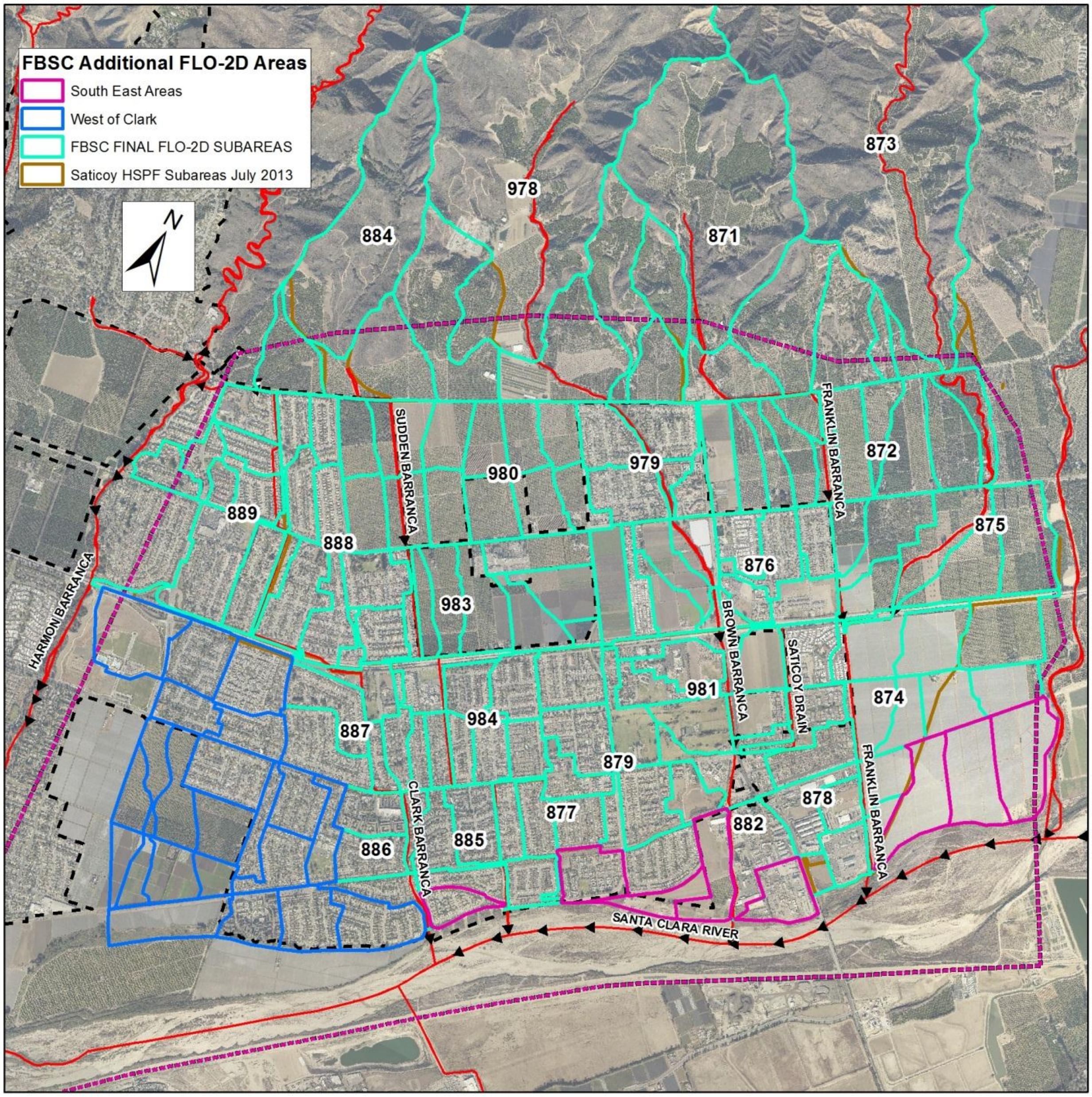


Figure 15 – HSPF Areas and Additional FLO-2D Subareas

FLO-2D peaks and volumes are slightly different than the original HSPF results due to rounding used in the pro-rating calculation and slight differences in area due to adjustments made based on revised topography and the inclusion of the stormwater facility network. Sums of the areas and peak flows used in the FLO-2D model are within 2.5% or less of the HSPF regional data. The Technical Appendix presents a summary of the peak flow/hydrograph volume data used and Table 4 shows a comparison of the HSPF and aggregated FLO-2D data for the entire model.

The District reviewed the results and concluded that the FLO-2D hydrographs described in this report were consistent with the regional HSPF results and are suitable for the FBSC FLO-2D modeling effort.

Table 4 – 100-Year HSPF and Aggregated FLO-2D Data Comparison Table

Subarea Name	HSPF Reach	Area ac.	Local Subarea Peak cfs	Local Subarea Ratio cfs/ac	Routed Flow Peak cfs	Routed Flow Ratio cfs/ac	FLO-2D Area Sum ac.	FLO-2D Area Peak Sum cfs	FLO-2D cfs/ac	Cfs/ac % Change	FLO-2D Area Vol. af	FLO-2D Yield in.
Upper Franklin	871	539.8	1,460.0	2.70	1,020.0	1.89	538.9	1009.8	1.87	0.8%	277.2	6.17
Middle Franklin	872	437.0	888.0	2.03	1,650.0	1.69	435.5	896.9	2.06	-1.4%	255.5	7.04
Upper Wason	873	1,665.5	4,560.0	2.74	2,220.0	1.33	1,662.3	2,220.0	1.34	-0.2%	810.0	5.85
Middle Wason	875	198.9	397.0	2.00	2,270.0	1.22	189.8	381.1	2.01	-0.6%	110.4	6.98
Lower Franklin-Wason	874	199.8	389.0	1.95	3,930.0	1.29	179.2	354.0	1.98	-1.5%	106.5	7.13
Saticoy Op. Yard	878	117.6	391.5	3.33	NC	NC	113.9	379.8	3.33	-0.2%	63.1	6.65
Upper Brown	978	1,006.0	2,700.0	2.68	1,590.0	1.58	1,041.7	1,653.6	1.59	-0.4%	532.5	6.13
Brown Blw Foothill	979	145.5	365.0	2.51	1,750.0	1.52	145.5	365.0	2.51	0.0%	80.0	6.60
Brown Abv 126	980	698.8	1,420.0	2.03	2,720.0	1.47	682.1	1,377.4	2.02	0.6%	389.9	6.86
Brown Abv Teleph.	981	183.6	433.0	2.36	2,950.0	1.45	183.6	428.7	2.33	1.0%	100.0	6.54
Saticoy Drn at Brwn	876	259.1	579.0	2.27	295.0	1.16	259.1	573.2	2.21	2.5%	144.5	6.69
Lower Brown	882	90.5	265.0	2.93	3,330.0	1.40	90.5	265.0	2.93	0.0%	51.0	6.76
Saticoy Ave Drn	879	232.2	565.8	2.44	NC	NC	232.2	560.1	2.41	1.0%	125.7	6.50
54" RCP Nr Sudden	877	76.6	201.9	2.63	NC	NC	76.6	201.9	2.64	-0.1%	43.0	6.74
Upper Sudden	884	231.7	623.0	2.69	372.0	1.61	219.8	353.4	1.61	-0.1%	107.4	5.86
Sudden Below Foothill	983	180.7	347.0	1.92	650.0	1.58	180.5	347.0	1.92	-0.1%	106.0	7.05
Sudden Blw 126	984	165.9	489.0	2.95	801.0	1.39	165.9	489.0	2.95	0.0%	94.0	6.80
Lower Sudden	885	109.0	299.0	2.74	892.0	1.30	109.0	299.0	2.74	0.0%	62.0	6.83
Upper Clark West	889	232.7	703.0	3.02	424.0	1.82	225.2	681.9	3.03	-0.2%	128.0	6.82
Upper Clark East	888	309.2	815.0	2.64	894.0	1.65	317.1	815.0	2.57	2.5%	177.0	6.70
Clark Blw 126	887	175.4	535.0	3.05	1,090.0	1.52	175.8	540.4	3.07	-0.8%	100.0	6.83
Lower Clark	886	93.7	274.0	2.93	1,180.0	1.46	93.7	271.3	2.90	1.0%	52.5	6.72

NC= Routed Hydrograph Not Calculated

Table 5 below shows a comparison of the HSPF Q100 flows used in the study compared to the Q100 flows used in previous studies within the project area. The 2010 FEMA flows are published in the January 20, 2010 FEMA Flood Insurance Study (FIS). The 2005 HDR peak flows were used in the December 2005 HDR – Brown Barranca Pre-Design Report, while the 2012 COE peak flows shown are from the October 2012 Army Corp of Engineers – Santa Clara River Watershed Feasibility Study – Without Project Conditions Overflow Analysis

		2013	2010		2005		2012	
LOCATION		**VCWPD Q100**	**FEMA Q100**	**(HSPF & FEMA) Percent Change**	**HDR Q100**	**(HSPF & HDR) Percent Change**	**COE Q100**	**(HSPF & COE) Percent Change**
Franklin Barranca	At Foothill Road	1,020					835	22%
Franklin Barranca	At Fwy 126	1,650	1,140	45%			1,380	20%
Franklin Barranca	At Santa Clara River	3,930	3,350	17%			3,950	-1%
Brown Barranca	At Foothill Road	1,590			1,353	18%	1,561	2%
Brown Barranca	At Fwy 126	2,720			1,845	47%	2,307	18%
Brown Barranca	At Santa Clara River	3,330	2,660	25%	2,323	43%	2,720	22%
Sudden Barranca	At Foothill Road	372					570	-35%
Sudden Barranca	At Fwy 126	650					N/A	N/A
Sudden Barranca	At Santa Clara River	892					1,370	-35%
Clark Barranca	At Foothill Road	83					N/A	N/A
Clark Barranca	At Fwy 126	894					N/A	N/A
Clark Barranca	At Santa Clara River	1,180					1,540	-23%

Table 5 Hydrology Comparison Table

5. ONE-DIMENSIONAL HYDRAULIC ANALYSIS

Numerous 1-dimensional hydraulic models were prepared as a precursor to the FLO-2D model analysis. The main 1D models utilized for this project consist of HEC-RAS, EPA SWMM, and to a lesser degree, the Federal Highway Administration's HY8 Culvert Design software, and WSPG.

a. HEC-RAS Model Background

Bank to bank (refers to the elevations at which flood flows leave the channel and would instead be considered surface flow) hydraulic characteristics for open channels within the study area were generated using the US Army Corps of Engineers Hydraulic Engineering Center's River Analysis System (HEC-RAS) version 4.1.0 software package. Geometry data for the study area was derived from varying sources. ESRI's ArcMap, Spatial Analyst, 3D Analyst Geographical Information Systems (GIS) software and Hydrologic Engineering Center's Geo-RAS extension for ArcMap were used to evaluate each data source as well as create the base geometry used within HEC-RAS. Final geometry and structure rating curves resulting from the 1-D Hydraulic Analysis were used by the channel routing routine in FLO-2D.

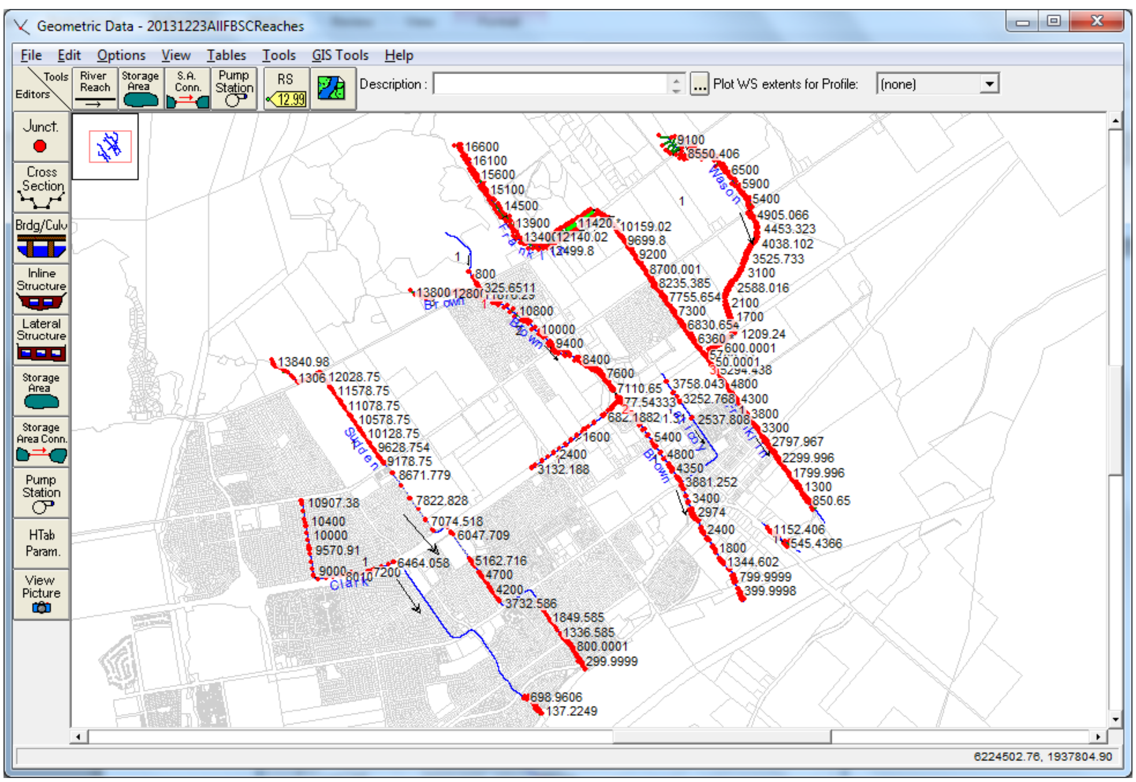


Figure 16 HEC-RAS Bank-to-Bank Model Schematic

b. HEC-RAS Model Development

HEC-RAS models were developed for the main conveyance channels within FBSC as shown in Figure 16.

Open channels within the study area vary and include natural, engineered earthen, and concrete lined. For the improved portions, existing geo-referenced as-builts/record drawings or field measurements were used to create breaklines representing the channel. These breaklines were then incorporated into the bare earth LiDAR to create a composite surface used to extract cross-section geometry. Initially, cross-sections were taken at two hundred foot intervals perpendicular to the direction of flow. Additional sections were added at the upstream and downstream sides of each crossing as well as at locations shown on the as-builts/record drawings where changes in slope or shape of the channel occurred.

Structure geometry was generated from available as-builts/record drawings, VCWPD O&M Facility Inventory, field measurements recorded as part of this study, and previously completed hydraulic models.

All Manning's n-values were assigned to channels and overbank areas consistent with the VCWPD Design Manual. Channel values range from 0.015 for concrete, 0.030-0.035 for improved earthen, and 0.04-0.08 for areas where vegetation exists depending on growth density. Similarly floodplain n-values vary between 0.02 for roads to 0.08 for orchards and other densely vegetated areas.

Downstream boundary conditions for each model were set to normal depth based on the general slope between the last several cross-sections. Many of the improved facilities were designed to flow under super-critical conditions to improve efficiency; therefore the hydraulic analysis was evaluated using a mixed flow regime. As a result upstream boundary conditions were set to critical depth.

Cross-section geometry was exported from HEC-RAS to FLO-2D CHAN.DAT input files. In some instances, where applicable, channels having simplified shapes were defined directly as standard trapezoids or rectangles.

c. SWMM Model Integration

Initially, the plan was to build an EPA SWMM model of the major underground conduits and to integrate the information with FLO-2D. However, due to programming and developmental challenges, the integration of the two models has taken longer than expected. In discussing the issue with VCWPD in late December 2013 and early January 2014, it was decided that instead the standard hydraulic structure tables and internal culverts will be used in order to complete the project in a timely manner. Using hydraulic results from the various HEC-RAS, SWMM, HY8, WSPG models, and record drawings, hydraulic structure tables were prepared and the underground conduits have been incorporated into the FLO-2D model. The inundation and flood hazard maps, statistics, and flood damage assessment presented in this report are all based on the conventional FLO-2D model.

However, the FLO-2D Software company is committed to completing the SWMM-FLO2D integration on this project.

Once that work is completed, an Addendum Report to this report will be prepared. The addendum will present the results of that analysis and it will assess the difference in model results.

The remainder of this chapter discusses the EPA SWMM modeling and its future integration with FLO-2D.

d. SWMM Model Background

Lower portions of the FBSC watersheds are developed and contain numerous underground storm drains. Clark and Sudden Barrancas flow below the surface for over 5000 feet each. To accurately represent these reaches as well as their main inflows, an EPA Storm Water Management Model (SWMM) was created to analyze the hydraulics of underground storm drains 42" in diameter/height and larger within the study area.

FLO-2D is a volume conservation flood routing model that internally calculates all the surface water hydrology and hydraulics including the flood routing in channels, streets and unconfined overland flow. To simulate the exchange of surface flow with underground storm drain systems, FLO-2D was integrated with EPA SWMM Version 5.022.

Both models run simultaneously with FLO-2D being the host model. FLO-2D calculates all hydrologic and hydraulic surface water flood routing while SWMM only solves the conduit hydraulics and flow routing in a given storm drain network. The FLO-2D model computes the storm drain inflow discharge based on the predicted grid element headwater depth and on the inlet geometry. Inlets and outlets function identically based on pressure head in the storm drain system compared to water surface elevation. Water can flow in either direction based on the pressure head differential when dynamic wave routing is applied. This discharge is then exchanged with the SWMM model to compute the storm drain system pipe discharge and the potential return flow to the surface through downstream manholes, outlets and storm drains.

e. SWMM Model Development

PCSWMM 2013 Professional Version 5.4.1528 program was used to create, edit and debug the EPA SWMM model. It is a powerful interface that works with numerous GIS data formats and provides the user tools for streamlining model development, optimization and analysis.

Initial model data development was completed within ArcGIS 10.2 to ensure all of the storm drain line work was correctly captured with proper attributes for import. Storm drain features (inlets/outlets, main lines, laterals, open channels, and culverts) and attributes (pipe geometry, slope, material) from the most recent City of Ventura Storm Drain Atlas Geodatabase, VCWPD facilities centerlines, County of Ventura Unincorporated Area Storm Drain Atlas Geodatabase and VCWPD O&M Facility Inventory Shapefile were merged into a single composite Storm Drain System Atlas (Atlas) GIS Geodatabase. The composite geodatabase was reviewed for consistency. Missing linework and/or attributes necessary for the SWMM model were researched and added based on available record drawings. Additional data fields were added to incorporate existing storm drain attributes into SWMM format (such as converting pipe type listed as text in the geodatabase to an integer value utilized by SWMM). Storm drains 42” and greater were imported as conduits into PCSWMM through its GIS import routine. See Figure 17 – EPA SWMM Model Schematic.

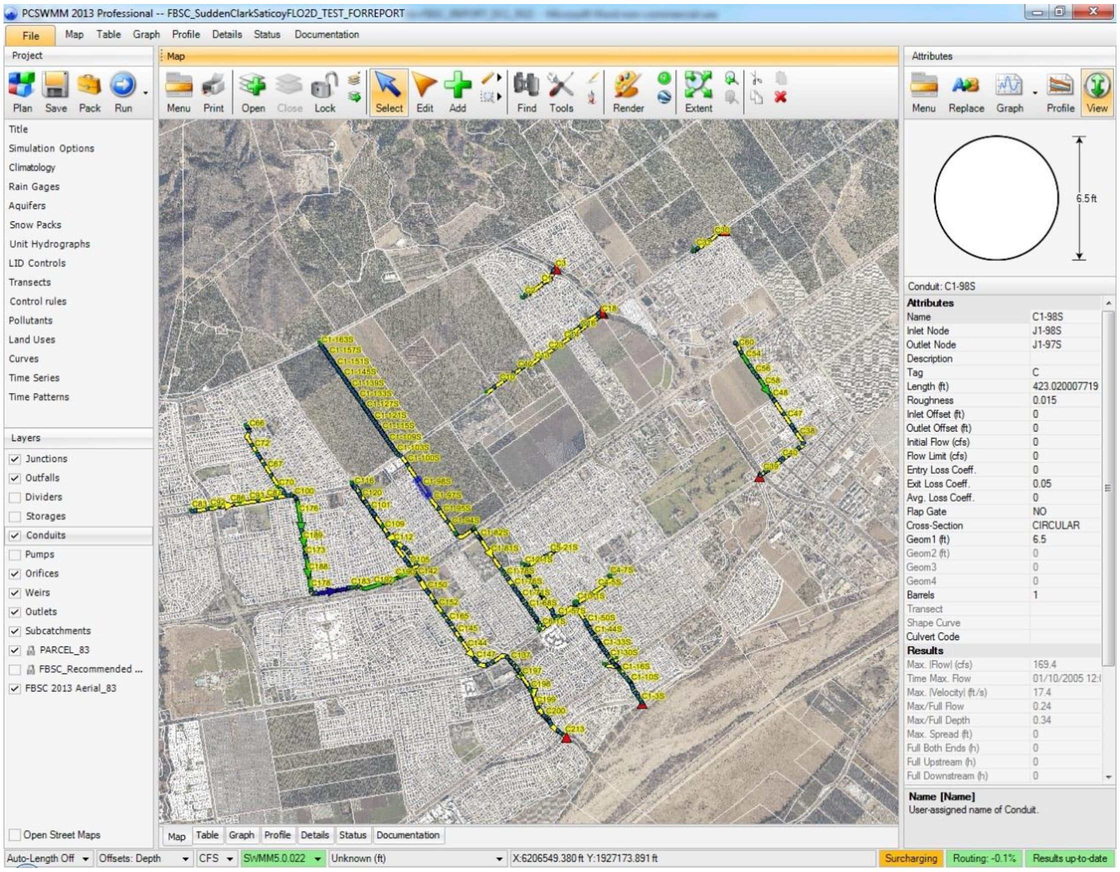


Figure 17 – EPA SWMM Model Schematic

Endpoints from each storm drain were then generated within ArcGIS, duplicates removed (locations where two or more pipes/channels have coincident end points), and then imported into PCSWMM as junctions. Junctions can be modeled in SWMM to represent inlets, manholes, and locations along pipes and open channels where change in slope or shape occurs. Invert elevations for junctions are based on the lowest incoming pipe/channel elevation. Rim elevations were initially set based on a) LiDAR elevations for pipes or b) the invert plus largest depth along channels. Surcharge elevation (if the hydraulic grade line (HGL) exceeds this level flow leaves the storm drain system) for each of the junctions were set based on their function. It was assumed that the HGL would need to exceed the rim elevation by 0.5 feet before a bolted street manhole would pop off due to pressurization, thus losing water from the storm drain system. Manholes or other internal connections that do not have the ability to transfer flow to the surface were assigned an artificially high surcharge elevation.

Catchbasins and their laterals leading to the main system were not explicitly modeled within SWMM, as the main purpose of creating the model is to create the main skeleton for input and integration with FLO-2D. Instead, they are defined directly in the FLO-2D SWMMFLO.DAT file. This process is discussed within the FLO-2D section of the report as well as in the Technical Appendix in more detail.

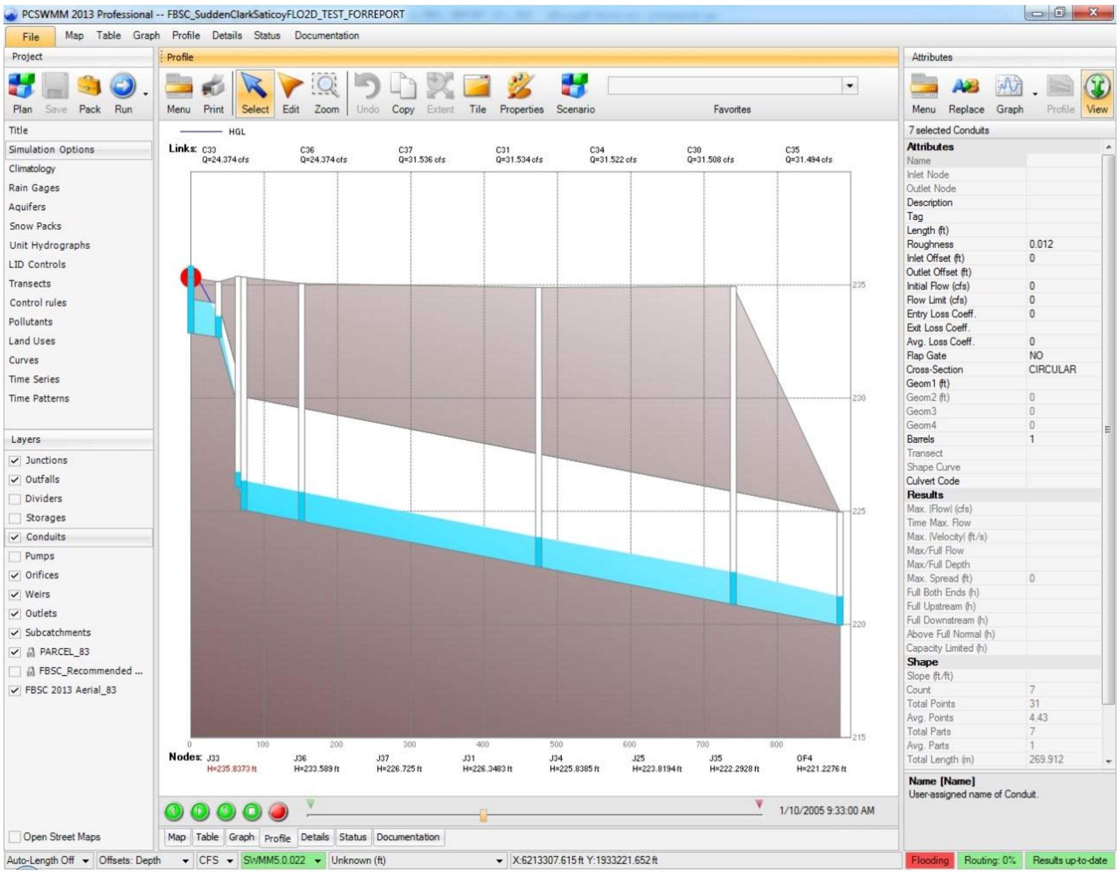


Figure 18 – EPA SWMM Storm Drain Profile

To ensure the SWMM model was set-up correctly for use in FLO-2D, the 10-year storm was run through the storm drain system (it was assumed the entire hydrograph at each entry point makes it into the system). No errors, significant warnings, or numerical instabilities were found.

f. Hydraulic Structure Rating Curve Development

Ninety (90) Hydraulic structure rating tables (depth vs. flow relationships) were developed outside FLO-2D, and entered into the model in HYSTRUC.DAT file.

Rating curves for major bridges, weirs, culverts, and drop structures along the main open channels (defined in FLO2D as channel to channel structures, or floodplain to channels) were developed using HEC-RAS and Microsoft Excel. Flood profiles were generated for varying peak flows ranging from 10-3300 cfs. Water surface profiles incorporate backwater effects, however they do not account for the actual upstream/downstream channel capacity and ensuing outflow from the banks at higher peaks. Instead HEC-RAS artificially raises cross-section endpoints resulting in inflated elevations. However, since the final channel and structure hydraulics are being completed within FLO-2D, this omission is irrelevant. When the channel elevations reach the bank elevations in FLO-2D (which are the same as those in the HEC-RAS model), flow and volume are exchanged with floodplain elements and the upper portions of the rating curve are not utilized.

For culverts under road/channel embankments (defined in FLO-2D as floodplain to floodplain structures) and some entrances to underground storm drains from open channels, the Federal Freeway Administration (FHWA) HY8 culvert package was used assuming no tailwater.

For certain City storm drains, a cluster of catch basin inlets were accounted for in the FLO-2D inlet file ,SWMMFLO.DAT, by assuming a maximum flood depth of 12-24" in the street/intersection that would deliver the design flow that the storm drain was designed for (as shown on the as-built). For example, to account for an underground 42" RCP with a design flow of 90 cfs, a virtual inlet/hydraulic structure table was put into the FLO-2D model inlet file with a depth vs. flow relationship such that the maximum flow was achieved at 9" of flood depth in the street or more.

The following is a typical table:

```
S           STERLING42    0           1           347069      429374
   T          0           0
   T          0.5         50
   T          0.75        90
   T          2           90
```

Figure 19 illustrates locations where rating curves were generated.

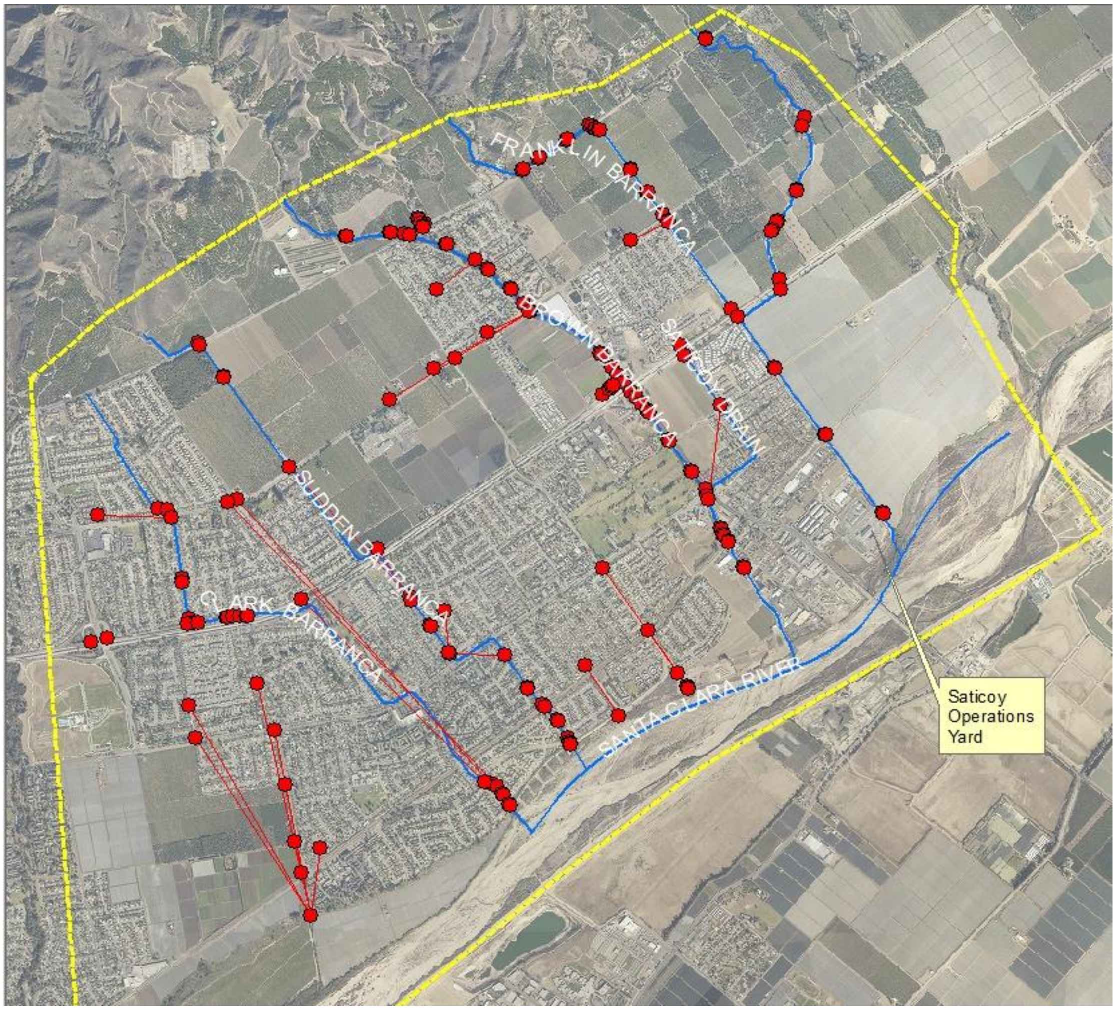


Figure 19 Hydraulic Structure Locations

Due to mathematical instability and surging, a few of the hydraulic structure tables were replaced with FLO-2D's internal culvert processing routine in order to approximate the underground flow separation.

6. TWO-DIMENSIONAL MODEL DEVELOPMENT

a. Introduction

To enhance the resolution and accuracy of the predicted flooding generated by previous 1-Dimensional flood studies, a detailed 2-Dimensional floodplain analysis model is prepared using the FEMA-approved FLO-2D software. The PRO version of the software was used for this study due to the complexity and magnitude of the model. The FBSC model computational domain (coverage of 25 ft grids) yielded approximately 482,000 grid elements with a computational area of 10.8 square miles. The development and results of the FBSC FLO-2D model is discussed in the next two chapters. The computer model was optimized to minimize the final simulation run-time, ensure that there is no channel and floodplain numerical surging and maintain volume conservation. No model calibration was done, as no observed data from recent flooding was available. The FLO-2D model was required as part of the contract. The complete model input and results are included in the Technical Appendix.

b. FLO-2D Model Description

FLO-2D is a 2-Dimensional dynamic flood routing model that simulates channel flow, unconfined overland flow and street flow. It can simulate a flood over complex topography and roughness while reporting on volume conservation; the key to accurate flood distribution. The model uses the full dynamic wave momentum equation and a centered finite difference solution scheme with eight potential flow directions to predict the progression of a flood hydrograph over a system of square grid elements. FLO-2D is a tool for delineating flood hazards, and floodplain zoning or designing flood mitigation measures.

Channel flow is simulated one-dimensionally with the channel geometry represented by cross section station and elevation data. As a 1-D channel model, secondary currents, super-elevation in bends and vertical and lateral velocity distribution are assumed to be negligible. In this project, prismatic rectangular, trapezoidal, and irregular cross sections were used to represent various engineered or natural channel geometries. FLO-2D can simulate the transition between subcritical and supercritical flow regimes because the full dynamic wave momentum equation is used for flood routing. Channel overbank flow is computed when the channel capacity is exceeded. An interface routine calculates the channel to floodplain discharge exchange including return flow to the channel. Once the flow overtops the channel, it will disperse to other overland grid elements based on topography, roughness and obstructions.

The model can accommodate urban features such as buildings, street flows and hydraulic structures. It can also compute the channel floodplain flow exchange on a grid element basis, which is critical for the channels in the FBSC drainage system. Buildings are depicted by assigning a loss of storage factor to a grid element and by assigning a flow width reduction factor along the boundaries of the grid element. Street flow for the FBSC model was simulated with reduced roughness because the grid elements were sufficiently small to define the interior topography of the streets. Bridges and culverts and other hydraulic structures were simulated using discharge rating tables as a function of flow depth. These are the major features in the FBSC model that will be discussed in this report.

c. Development of the FBSC FLO-2D 25 foot Grid Model

i. DTM data base

A digital terrain model (DTM) from the 2005 LiDAR bare earth elevation data was created. Please see image below.

The elevation data used in the 25 ft grid model was compiled from 41 LiDAR tiles consisting of 35 million points. The original DTM data provided by VCWPD represents bare earth data and was pre-filtered to remove buildings, large bridges and trees in compliance with FEMA specifications for LiDAR.

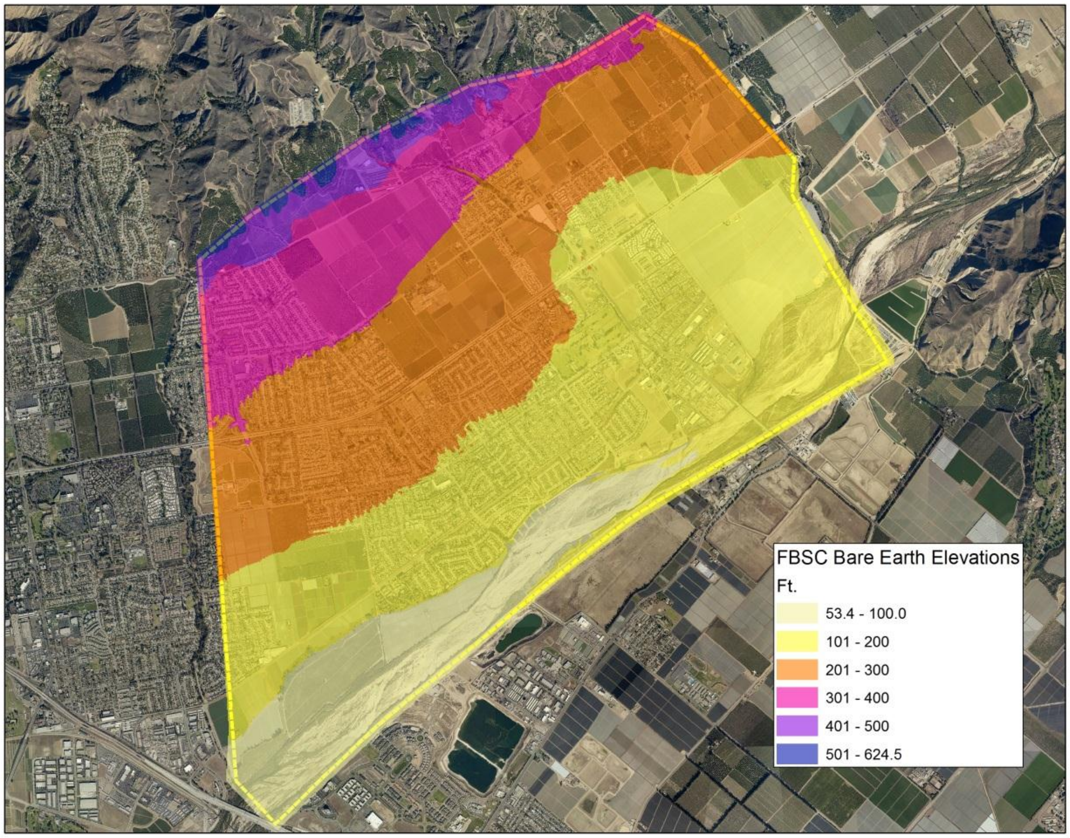


Figure 20 Elevation Point Data

ii. <u>Generating the 25 foot grid system elevation data</u>

The interpolation of the DTM elevation data for the 25 ft grid element elevations was performed with the FLO-2D pre-processor program Grid Developer System (GDS). Each grid element is given a single elevation based on a distance weighted average of the points located within the grid element. Approximately some 6525 grid elements, or roughly 1 percent of the total grids, were void and did not have elevation values assigned to them. The missing elevations are primarily due to large buildings, heavy vegetation and trees, bridge crossings and similar conditions where the bare earth data are removed from the original data set in compliance with FEMA specifications.

To correct for this anomaly, advanced GIS tools were used to create a Triangulated Irregular Network (TIN) surface of the ground elevations. Subsequently a 25-ft Raster Grid was prepared. XYZ values derived from the raster grid were placed into the FLO-2D format to replace those cells preciously void of elevations.

The grid elements that coincided with buildings were given an interpolated elevation based on contiguous grid element elevations. A sample of data was checked to verify that elevation data within the building footprint is an accurate representation of the ground data surrounding the buildings.

The LiDAR elevation data for a few bridges and overpasses was also filtered out. The following image shows an example of missing elevation points across a bridge. The missing grid element elevation data was interpolated by the GDS based on an average of contiguous grid element elevations. In all cases, the elevation data associated with bridges and overpasses accurately reflects the correct ground elevation.

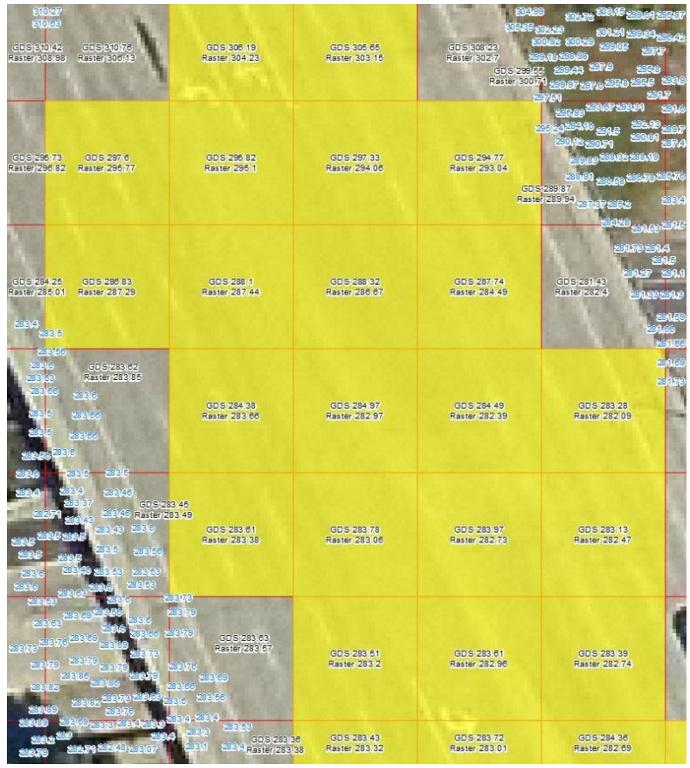


Figure 21 Missing Bridge Point Elevation Example

iii. <u>New Land Development Projects</u>

Since the LiDAR point cloud was acquired by VCWPD representing existing ground conditions dated March 2005, several small and large land development projects have been constructed. Changes in grading and topography as a result of these land development projects affect the direction and depth of runoff and flood waters. Consequently, in these cases, the FLO-2D grid elevations were adjusted to approximate today's topographic condition by reviewing the Rough and Fine Grading Record Plans for areas developed since March 2005.

A careful investigation of the 2005 Aerial Imagery compared with the current 2013 Aerial Imagery revealed 7 larger scale developments, ranging from 6 to almost 40 acres in size, have been constructed within the study area, including the Saticoy Maintenance Yard. Please see Figure 9.

The grading plans for these 7 developments were geo-referenced and key elevation contours and/or spot elevations were captured in GIS reflecting the current topography of the area.

This updated elevation information was then integrated into the bare earth LiDAR data to produce a continuous 3-dimensional surface for the entire computational area as a single composite topographic survey in TIN and GRID formats reflecting the current (2013) topography. This revised topography was then translated into FLO-2D grid format and replaced the old (2005) ground elevations for some 6600 grid elements.

iv. Model Computation Time

The inflow hydrographs prepared for the project are based on 24 hours of rainfall, but calculated out to four days. For FLO-2D modeling purposes, it was decided to run the model for the first 48 hours of the hydrographs, as the last two days is the recession limb of the hydrograph as it draws down to low flow.

Figure 22 below shows a comparison between the Santa Clara River 100-year hydrograph with a peak flow of 226,000 cfs and the cumulative FBSC 100-year hydrograph of 10,000 cfs. The FBSC cumulative hydrograph represents the 4 peak flows for the Franklin, Brown, Sudden and Clark Barranca's simply added together for presentation purposes. There is a 7.5 hour lag time between the peaks of the FBSC streams and the peak on the Santa Clara River. Although the District provided Kasraie Consulting the full 96-hour storm hydrograph for Santa Clara River, they suggested that a 30-hour simulation time would be appropriate for the FLO-2D model to run. Flow in Santa Clara River returns to the original baseflow of approximately 50,000 cfs at 48 hours. Although the local FBSC tributaries will peak earlier than the Santa Clara River, the main influence affecting the boundary condition at their confluence is the 100-year and 500-year flows within the Santa Clara River. At VCWPD's suggestion, the final models were simulated for 30 hours.

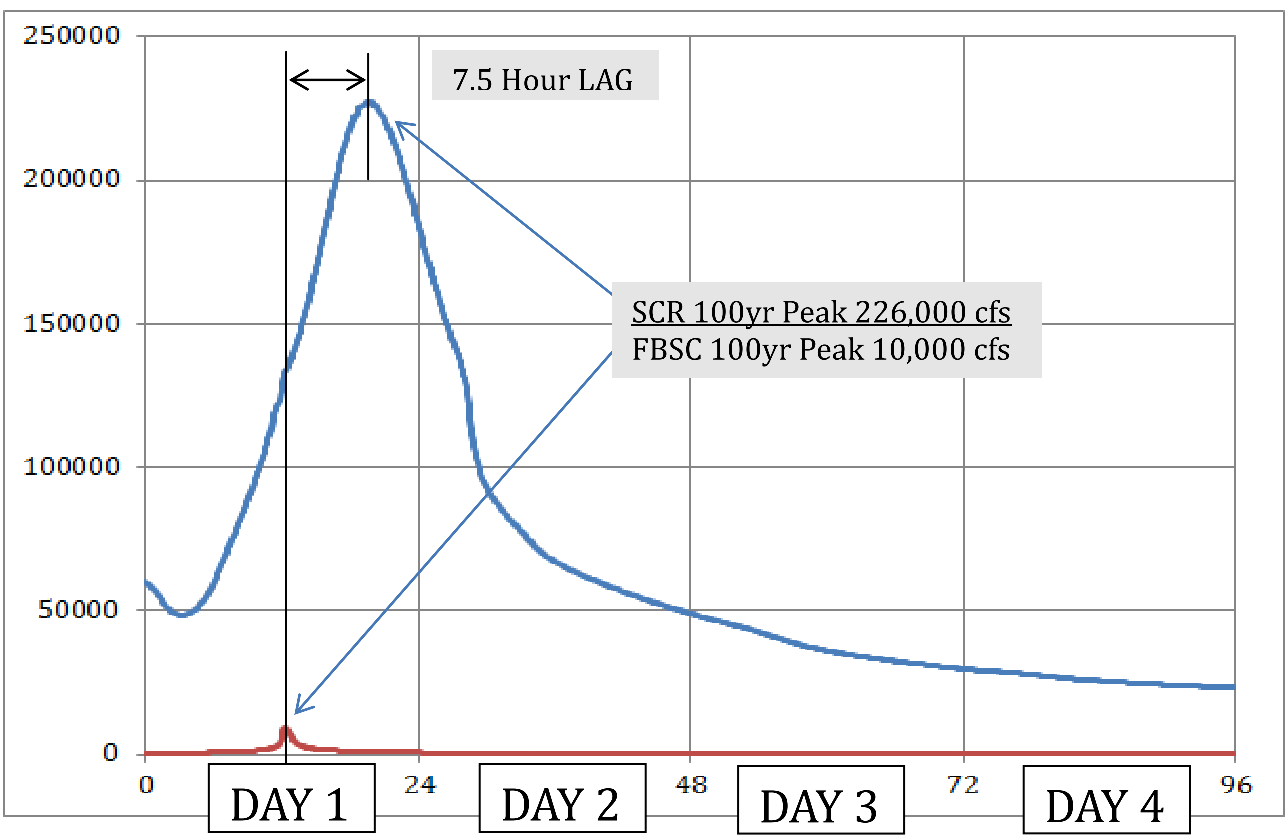


Figure 22 Storm Hydrograph Comparison

7. TWO-DIMENSIONAL STUDY RESULTS & DISCUSSION

Due to the sophistication and complexity of 2D floodplain models and the enormity of the model output and results, it is sometimes difficult to know if the model is working correctly or if the results make scientific sense. Therefore, it is important to compare the results of the 2D models with other tools such as HEC-RAS, and to check channel or culvert flows against the record drawings, or other studies if available. The results of the current models are analyzed and summarized as follows:

a. Hydrograph Comparison
b. Bridge/Culvert Capacity Summary
c. Commingling Flows
d. Reach by Reach Analysis – Wason Barranca
e. Reach by Reach Analysis – Franklin Barranca
f. Reach by Reach Analysis – PWA Saticoy Operations Yard
g. Reach by Reach Analysis – Brown Barranca
h. Reach by Reach Analysis – Saticoy Drain
i. Reach by Reach Analysis – Sudden Barranca
j. Reach by Reach Analysis – Clark Barranca

a. Hydrograph Comparison

Table 6 is a compilation of the 30-hour hydrograph peak flows and volumes from the FLO-2D model and a comparison with the HSPF model.

The HSPF model "routed" flows represent a theoretical projected flow at a given concentration point based on certain assumptions for stream routing, flood storage, and channel/bridge capacity, constriction, obstructions, etc. Whereas the FLO-2D flows represent the results of a detailed unconfined flood routing analysis over the entire study area, taking into account the physical characteristics of the stream network and overbank areas such as streets, buildings, embankments and other features.

The table summarizes the peak flows and volumes at 19 locations along the main FBSC jurisdictional facilities where a "routed" hydrograph was available from the HSPF model. A ratio of the FLO-2D/HSPF values is also presented for comparison purposes.

In places where the FLO-2D "channel element" and HSPF flows match, a 1.0 ratio indicates that the flow is found to be contained in the channel with no break out flows upstream; Brown Barranca upstream of Telegraph Road is an example of such location. A wide deviation from a 1.0 ratio indicates wide spread flooding, and the presence of overbank flooding in addition to main channel flow. Brown Barranca at Freeway 126 is an example of such condition, with a 0.5 ratio.

WASON - FRANKLIN	APS Description	Franklin Main @ Foothill	Franklin Main @ Fwy126	Wason Main @ Foothill	Wason Main @ Franklin Confl.	Franklin Main @ SCR
	Location	Upper Franklin	Middle Franklin	Upper Wason	Middle Wason	Lower Franklin-Wason
	Cum Area ac	540	977	1665	1864	3041
HSPF ROUTED HYDROGRAPHS	Q100 Peak cfs	1020	1650	2220	2270	3930
	VOLUME ACFT	218	432	619	717	1248
	Location	RCH871	RCH872	RCH873	RCH875	RCH874
FLO-2D MODEL CHANNEL HYDROGRAPHS	Q100 Peak cfs	673	889	918	1569	2229
	VOLUME ACFT	147	266	522	693	1088
	GRID ELEMENT	32147	96264	1270	87548	229789
RATIOS (FLO-2D/HSPF)	FLOW	0.7	0.5	0.4	0.7	0.6
	VOLUME	0.7	0.6	0.8	1.0	0.9

BROWN	APS Description	Brown Main @ Foothill	Brown Main @ Telegraph	Brown Main @ Fwy 126	Brown Main @ Telephone	Brown Main @ SCR
	Location	Upper Brown	Brown Below Foothill	Brown Above Fwy 126	Brown Above Telephone	Lower Brown Barranca
	Cum Area ac	1006	1152	1850	2034	2383
HSPF ROUTED HYDROGRAPHS	Q100 Peak cfs	1590	1750	2720	2950	3330
	VOLUME ACFT	397	474	815	905	1085
	Location	RCH978	RCH979	RCH980	RCH981	RCH882
FLO-2D MODEL CHANNEL HYDROGRAPHS	Q100 Peak cfs	1569	1699	1518	1369	1383
	VOLUME ACFT	410	451	649	678	870
	GRID ELEMENT	60379	94732	149289	212851	312634
RATIOS (FLO-2D/HSPF)	FLOW	1.0	1.0	0.6	0.5	0.4
	VOLUME	1.0	1.0	0.8	0.7	0.8

SATICOY DRN - SUDDEN	APS Description	Saticoy Drain @ Brown Confl.	Sudden Main @ Foothill	Sudden Main @ Fwy 126	Sudden Main @ Telephone	Sudden Main @ SCR
	Location	Saticoy Drain at Telephone	Upper Sudden	Sudden Below Foothill	Sudden Below Fwy 126	Lower Sudden
	Cum Area ac	259	232	412	578	687
HSPF ROUTED HYDROGRAPHS	Q100 Peak cfs	295	372	650	801	892
	VOLUME ACFT	130	83	173	260	318
	Location	RCH876	RCH884	RCH983	RCH984	RCH885
FLO-2D MODEL CHANNEL HYDROGRAPHS	Q100 Peak cfs	303	243	405	531	717
	VOLUME ACFT	156	62	151	194	258
	GRID ELEMENT	156524	117989	289710	321415	365578
RATIOS (FLO-2D/HSPF)	FLOW	1.0	0.7	0.6	0.7	0.8
	VOLUME	1.2	0.8	0.9	0.7	0.8

CLARK	APS Description	Clark Main @ Fwy 126	Clark Main @ Fwy 126	Clark Main @ Telephone	Clark Main @ SCR
	Location	Upper Clark West	Plus Upper Clark East	Clark Below Fwy 126	Lower Clark
	Cum Area ac	233	542	717	811
HSPF ROUTED HYDROGRAPHS	Q100 Peak cfs	424	894	1090	1180
	VOLUME ACFT	125	287	381	431
	Location	RCH889	RCH888	RCH887	RCH886
FLO-2D MODEL CHANNEL HYDROGRAPHS	Q100 Peak cfs	155	539	927	944
	VOLUME ACFT	48	164	364	370
	GRID ELEMENT	298486	287345	384631	391055
RATIOS (FLO-2D/HSPF)	FLOW	0.4	0.6	0.9	0.8
	VOLUME	0.4	0.6	1.0	0.9

Table 6 Hydrograph Comparison (30-hour)

b. Bridge/Culvert Capacity Summary

In order to have an understanding about the reasonableness of a flood hazard model, it is helpful to look at bridges or culverts. These structures sometimes constrict the flow and they do not necessarily carry the entire 100-year peak flow. Knowing an approximate flow capacity for these facilities and a simple comparison with the projected flows helps the community or regulatory officials to understand the flood risks that exist throughout the study area.

Table 7 shows the HSPF reach information and the projected flows at key bridge/culvert/channel locations for all studied frequencies (5 – 500-year) in addition to the estimated threshold capacity, frequency and source of the information.

It should be pointed out that the over-topping threshold flow shown in the table is the flow rate at which the bridge/culvert/channel begin to over-top their banks. This number is NOT the bridge design capacity, and no design adequacy or deficiency is inferred. Bridge or channel design capacity and freeboard requirements need to comply with VCWPD's design requirements under open channel flow condition. Whereas, the over-topping threshold flow is for a submerged inlet/outlet condition.

This approximate flow rate and the corresponding storm frequency are shown as a simple way of knowing the degree at which a culvert or bridge crossing is capable of carrying the 100-year flow. This is for reference only.

ITEM	LOCATION	Reach #	FLO-2D Node Number	Cum. Area, ac	EST. Q5	EST. Q10	EST. Q25	EST. Q50	HSPF Q100	EST. Q500	OVER-TOPPING FLOW (CFS)	APPROX FREQUENCY (YEAR)	SOURCE OF INFORMATION / REMARKS
1	Franklin at Foothill	RCH871	16231	540	158	279	504	732	1020	1965	550	30	HEC-RAS XSEC 107+30
2	Franklin at Telegraph	PRORATED	49646	758	213	372	666	962	1335	2556	1200	75	HEC-RAS XSEC 83+40
3	Franklin at 126	RCH872	98334	977	268	466	828	1191	1650	3146	1200	50	HEC-RAS XSEC 59+30
4	Wason at Foothill	RCH873	1270	1666	329	592	1083	1584	2220	4311	675	15	HEC-RAS XSEC 86+10
5	Wason at Telegraph	PRORATED	14324	1694	334	602	1101	1611	2257	4384	1400	35	HEC-RAS XSEC 50+00
6	Wason at 126	RCH875	81679	1864	337	606	1109	1620	2270	4406	1300	35	HEC-RAS XSEC 14+00
7	Franklin-Wason D/S 126	PRORATED	105352	2841	588	1041	1882	2733	3810	7341	1500	15	HEC-RAS XSEC 54+97
8	Franklin-Wason at Railroad	PRORATED	176731	2999	599	1059	1914	2780	3876	7468	1500-2000	25	HEC-RAS XSEC 27+89
9	Franklin-Wason at SCR	RCH874	229789	3041	607	1074	1941	2819	3930	7572	2500	35	HEC-RAS XSEC 11+00
10	Saticoy Operations Yd	RCH878	246770	118	129	182	258	322	392	588	-	-	OVERFLAND FLOW
11	Brown at Foothill	RCH978	58593	1006	260	451	799	1149	1590	3028	2200	200	HEC-RAS XSEC 122+25 (OPEN CULVERT)
12	Brown at Telegraph	RCH979	95416	1152	316	528	908	1283	1750	3261	1800	100	HEC-RAS XSEC 93+20 (REV. 2003-D-001)
13	Brown at Blackburn (Estimated)	PRORATED	123547	1152	581	837	1228	1565	1950	3081	1550	60	HEC-RAS XSEC 73+39 (assumed 200 CFS in double pipes under Telegraph Road from the west)
14	Brown at 126	RCH980	142953	1850	506	836	1424	2002	2720	5034	1500	30	HEC-RAS XSEC 65+52
15	Brown U/S Telephone	RCH981	213687	2034	564	924	1560	2181	2950	5421	2200	50	Y-2-2070 (CAP CALC), HEC-RAS XSEC 38+66
16	Saticoy Drn at Brown	RCH876	157323	255	73	111	172	228	295	501	300	100	Y-2-0453
17	Brown at Railroad	PRORATED	249185	2331	653	1054	1751	2426	3257	5913	1100	15	HEC-RAS XSEC 27+05
18	Brown U/S SCR	RCH882	306949	2383	668	1077	1790	2480	3330	6044	1150	15	HEC-RAS XSEC 20+55
19	Saticoy Avenue Drain	RCH879	329608	232	130	201	319	431	566	988	384	45	CITY PLANS 203383
20	54-Inch RCP Drain at Mammoth	RCH877	326208	77	46	71	114	154	202	353	149	50	CITY PLANS 900452/800312/900965
21	Sudden at Foothill	RCH884	117249	232	56	100	182	266	372	721	475	200	HEC-RAS XSEC 121+38
22	Sudden at Telegraph	PRORATED	198409	341	84	148	267	387	538	1034	828	200	Y-2-1924
23	Sudden at 126	RCH983	254765	412	102	179	322	467	650	1249	1252	500	Y-2-2059
24	Sudden at Telephone	RCH984	319318	578	164	262	433	598	801	1447	1159	200	Y-2-1713
25	Sudden at SCR (NORTHBANK)	RCH885	362750	687	195	306	495	674	892	1580	1230	200	Y-2-1351
26	Clark at Foothill	PRORATED	148858	41	10	18	32	48	67	131	82	100	FOOTHILL RD DIVERSION Y-2-2090
27	Clark at Telegraph	PRORATED	232611	149	89	125	178	223	271	410	408	500	Y-2-2039
28	Clark at 126 West	RCH889	298516	233	138	195	278	348	424	641	350	50	CITY 1975-D-029
29	Clark at 126 East	RCH888	287346	542	274	392	570	722	894	1394	771	55	CALTRANS 627V13C26
30	Clark at Telephone	RCH887	287346	717	338	483	699	883	1090	1689	910	65	Y-2-0627
31	Clark at SCR (NORTHBANK)	RCH886	387130	811	369	525	759	958	1180	1823	1100	100	Y-2-1762

Table 7 Bridge Location and Over-topping Threshold

c. Commingling Flows

A 2-dimensional flood hazard analysis is comprehensive by nature, as it takes all the sources of flooding into account at the same time, as if it is raining equally everywhere in the watershed. This results in coalescing flows from several streams contributing to form a larger floodplain.

A case in point is the community of Saticoy where overbank flood flows from Saticoy Drain will combine with flows from Franklin Barranca and Brown Barranca in addition to the rain that will fall over the area. The four sources of flood waters will commingle to form a larger floodplain area affecting the existing homes and businesses, as well as Wells Road and LA Avenue.

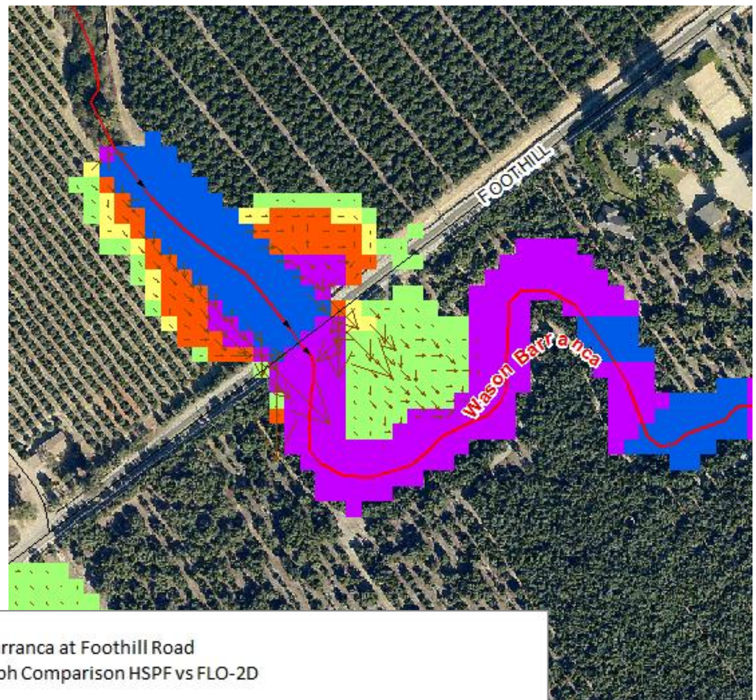
In order to assess the flooding impact from the various individual sources in the future, the District can use the existing FLO-2D models and separate out the watersheds by limiting the inflow hydrographs to a single watershed at a time, and rerunning the model. This single-watershed run will show the depth and extent of flooding from a given channel or stream, and it will further clarify the special flood hazard areas associated with a single channel.

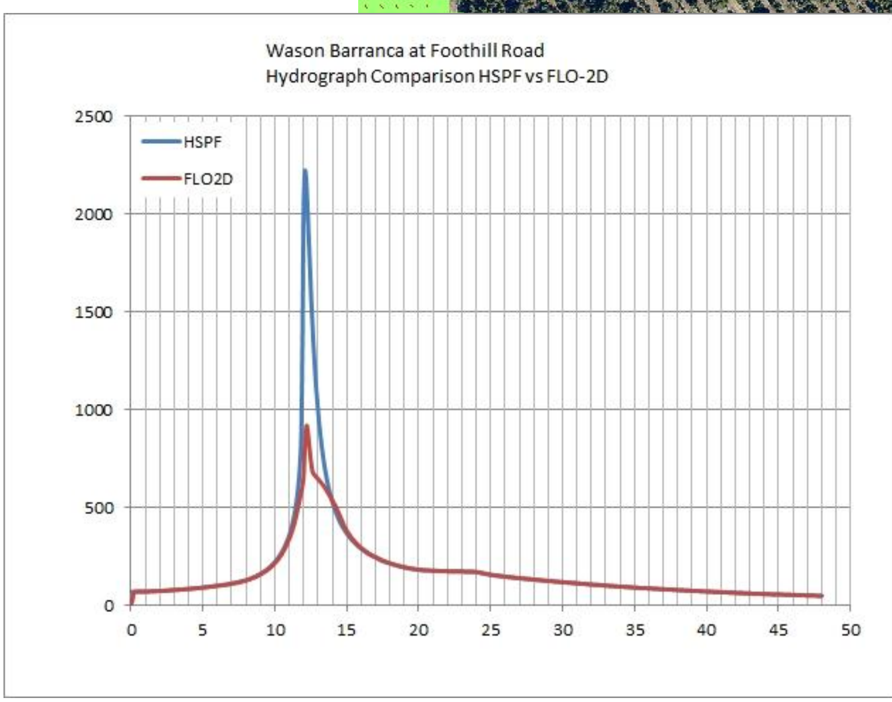
d. Wason Barranca

i. Wason Barranca Reach 1 – U/S of Foothill Road

Upstream of Foothill Road, the natural channel is heavily vegetated with depths varying from approximately 10'-12'. The watershed above this location consists of both natural open space and agriculture. At Foothill Road, the 7'W X 5'H concrete arch culvert has a capacity of 675 cfs based on the HEC-RAS analysis (Sta. 86+10). The projected HSPF Q10 at the culvert is 592 cfs, while the HSPF Q100 is 2220 cfs. This culvert has limited capacity (amount of flow before road overtopping begins) with a storm frequency of approximately the 15 year event.

The modeled Q100 in FLO-2D at the structure is 925 cfs, while the modeled Q100 in HEC-RAS at the structure is 1192 cfs, which includes 703 cfs through the culvert plus 488 cfs flow over the top of the culvert. In the storm events greater than 15-year, overflows will overtop Foothill Road to the east and re-enter the natural Wason channel just downstream of Foothill Road.

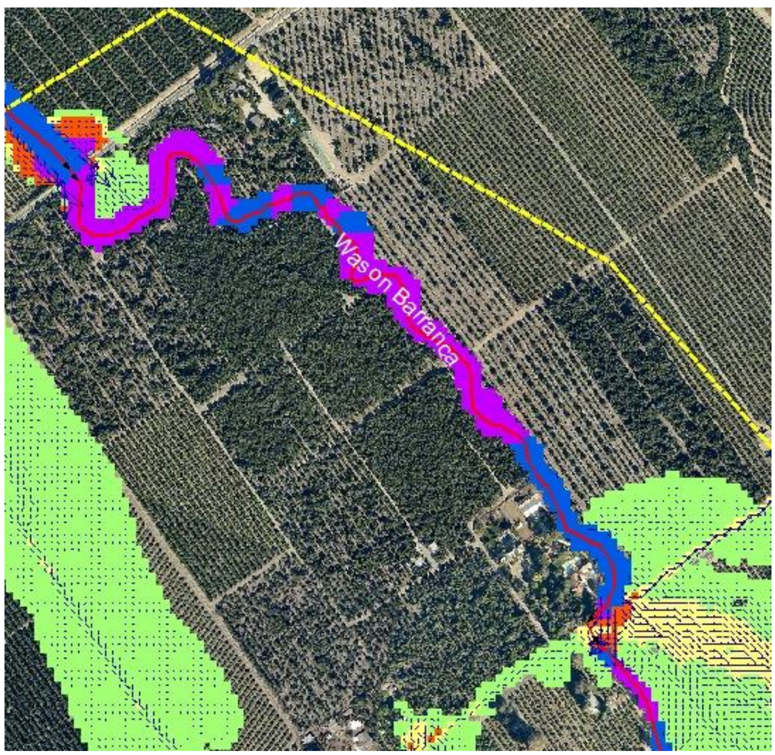




ii. Wason Barranca Reach 2 – D/S of Foothill Road to Telegraph Road

Downstream of Foothill Road, the meandering natural channel varies in depth from approximately 14' to 16'. As it moves through the surrounding agricultural area, all frequency flows are contained in the channel. At Telegraph Road, the 10'W X 9'H arch culvert has a capacity of approximately 1400 cfs from the HEC-RAS bank to bank model and a capacity frequency of 35 years. The projected 100 year flow from HSPF at Telegraph Road is 2257 cfs. Flows in excess of the 35 year event will overtop Telegraph Road on both the east and west sides of the culvert crossing, with the majority traveling over the road on the east side eventually flowing along the north side of Freeway 126 back to the main Wason Barranca channel.

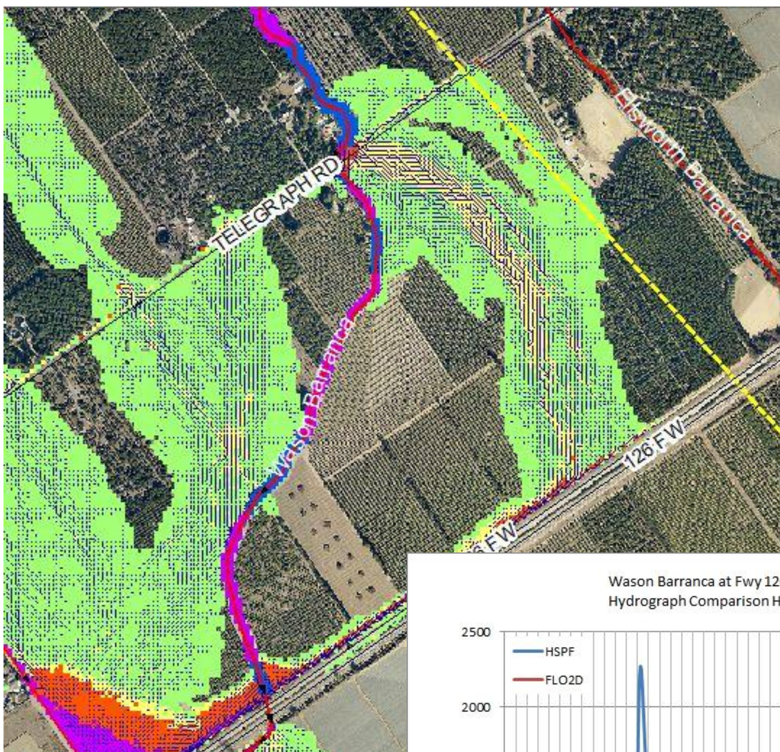
A small amount of water will also flow to the east towards Ellsworth Barranca.



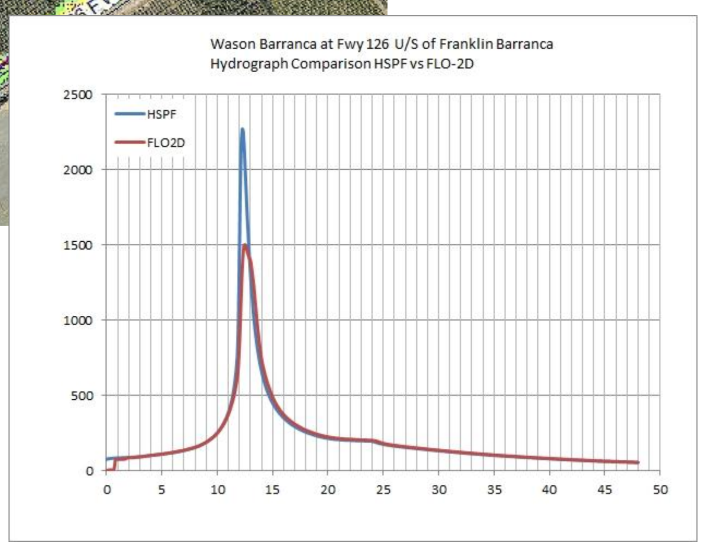
This very shallow surface flow eventually exits the FLO-2D grid modeling area. Due to the small volume of water traveling toward Ellsworth Barranca and the complexities of changing the FLO-2D computational grid, it was decided not to enlarge the model domain to include this additional area.

iii. Wason Barranca Reach 3 – D/S of Telegraph Road to Freeway 126

Downstream of Telegraph Road, the channel transitions to a trapezoidal earthen channel with depths ranging from 6' to 12' and base widths ranging from 14' to 18'. The land use surrounding the channel through this reach is agricultural, mainly orchard and citrus trees. For all frequency storms, some surface flow from the surrounding orchard area will be entering the channel from the north side. The remaining surface flow will travel through the agricultural area in a southwesterly direction ponding in the northeast corner of Freeway 126 and Franklin Barranca. There is a private farm crossing across the Wason channel approximately 1300' upstream from Freeway 126, which consists of a 17'W X 8'H clear-span bridge. At Freeway 126 the projected Q100 from HSPF is 2270 cfs, while the capacity of the Double 10'W X 8'H RCB underneath Freeway 126 has a capacity of 1300 cfs from the HEC-RAS analysis. The FLO-2D model shows the culvert under Freeway 126 as having capacity to carry approximately 1600 cfs.



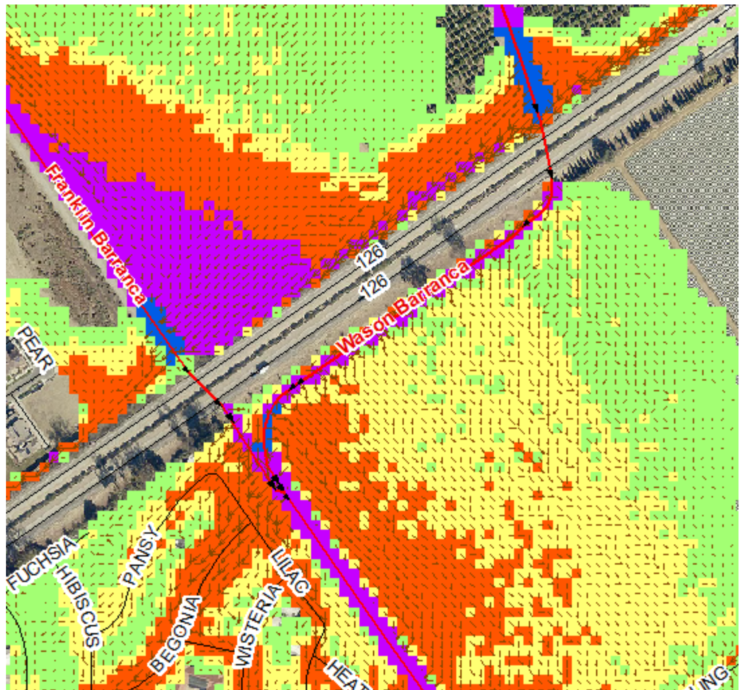
Therefore the estimated capacity frequency for this culvert ranges from a 35 to 50 year event. Flows in excess of the culvert capacity will join the existing surface water traveling in a southwest direction, along the freeway and ponding in the northeast corner of Freeway 126 and Franklin Barranca.

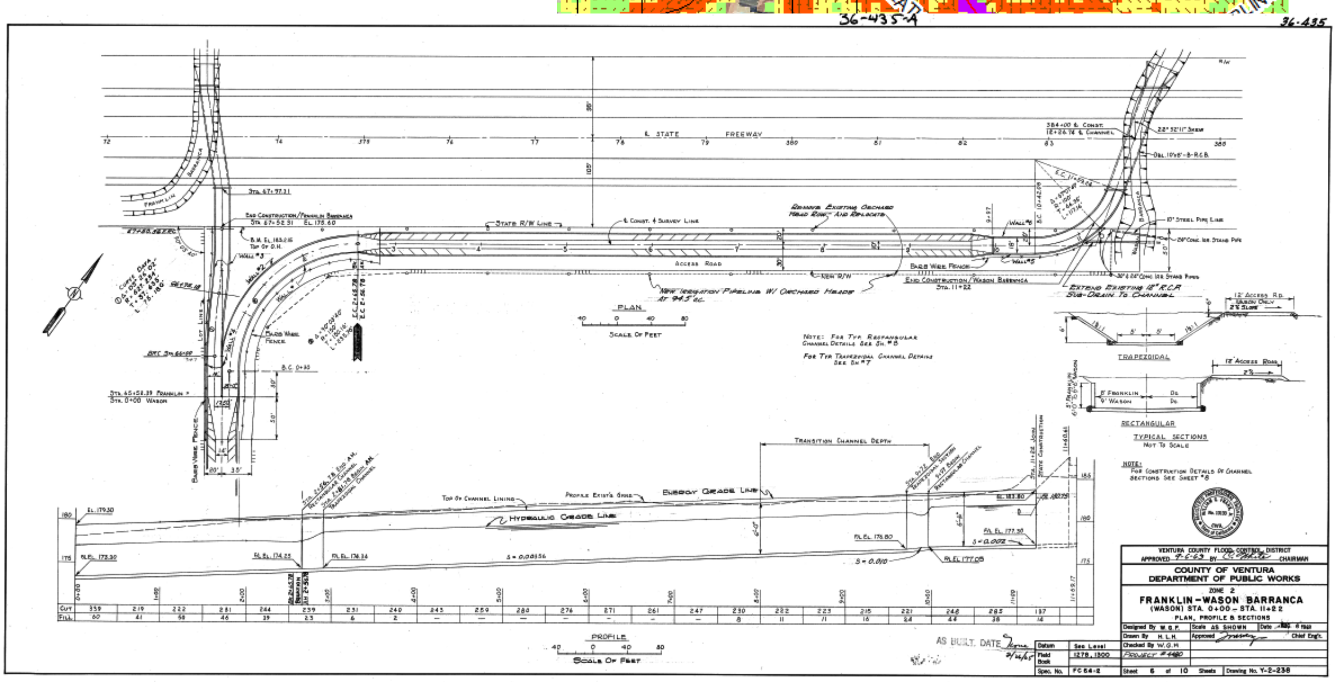


iv. Wason Barranca Reach 4 – D/S of Freeway 126 to Franklin Barranca

Wason Barranca from downstream of Freeway 126 to its confluence with Franklin Barranca is primarily a 10'W X 6'H concrete trapezoidal channel with RCC transition sections at the upstream and downstream end. The design Q from the VCWPD record drawing for this reach is 800 cfs. (see Y-2-238 below)

The estimated Q10 from HSPF for this reach is 606 cfs and the Q100 is 2270 cfs. Flows in excess of channel capacity will overtop and travel in a westerly direction toward Franklin Barranca and also to the south through the farm area.



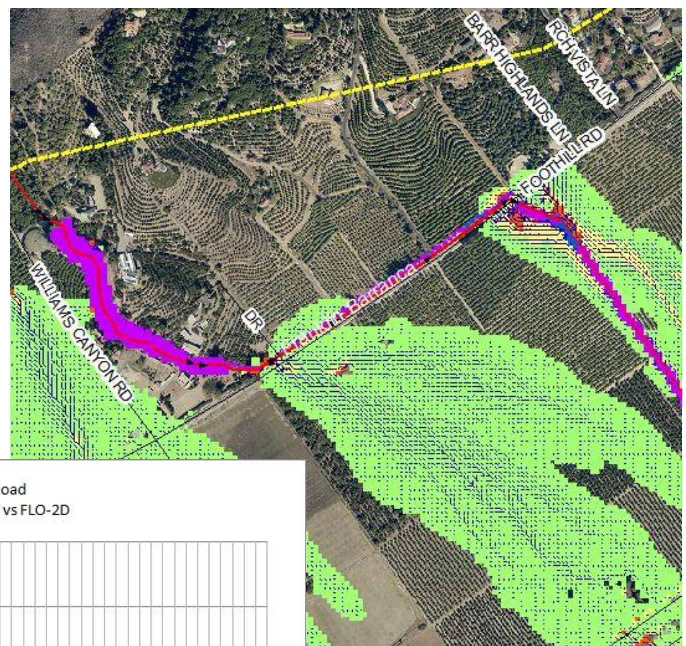


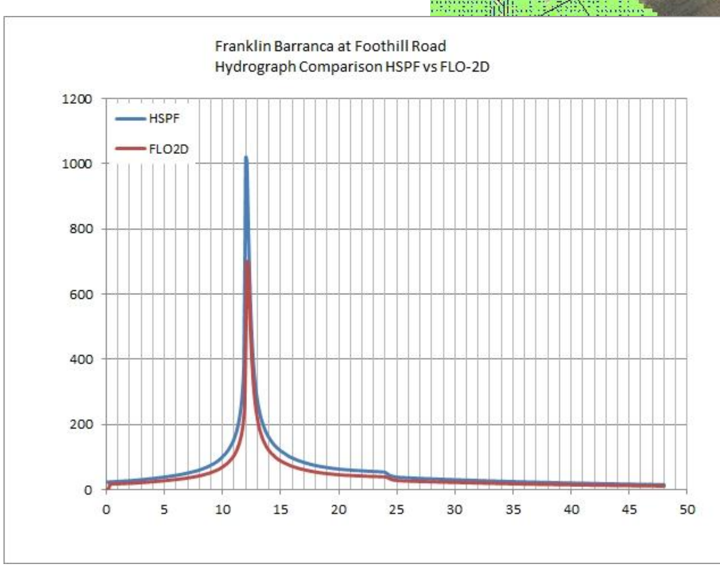
e. Franklin Barranca

i. Franklin Barranca Reach 1 – U/S and Parallel to Foothill Road

This reach consists of a natural earthen channel flowing in a southeasterly direction toward Foothill Road. At Foothill Road, the channel turns toward the northeast and the earthen road side ditch runs parallel along the north side of the road. There are three private drive way crossings along this reach. The trapezoidal earthen ditch has a top width of 20’ – 30’ and depths ranging from 7’-8’. The ditch itself is shown to carry between a 25-year and 40-year flow of up to 625 cfs. Excess flows will overtop the channel before the culvert crossing at Foothill Road and continue as surface flow through the agricultural area to the south. The combination of the small drop structure upstream and the 8’W X 7’H RCB crossing Foothill Road have a combined capacity of ranging from 400 cfs from the FLO-2D model up to 550 cfs based on the HEC-RAS analysis. This is equivalent to a 20 - 30-year flow. The projected HSPF Q10 at this location is 279 cfs and Q100 is 1020 cfs.

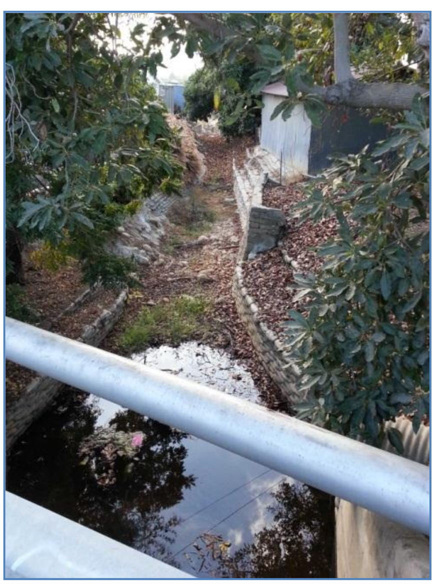
The modeled Q100 in FLO-2D at the structure is 393 cfs, while the modeled Q100 in HEC-RAS at the structure is 447 cfs. Flows in excess of the capacity will overtop Foothill Road, join other surface flow from the east and continue on a path parallel to the existing Franklin channel on its east side.

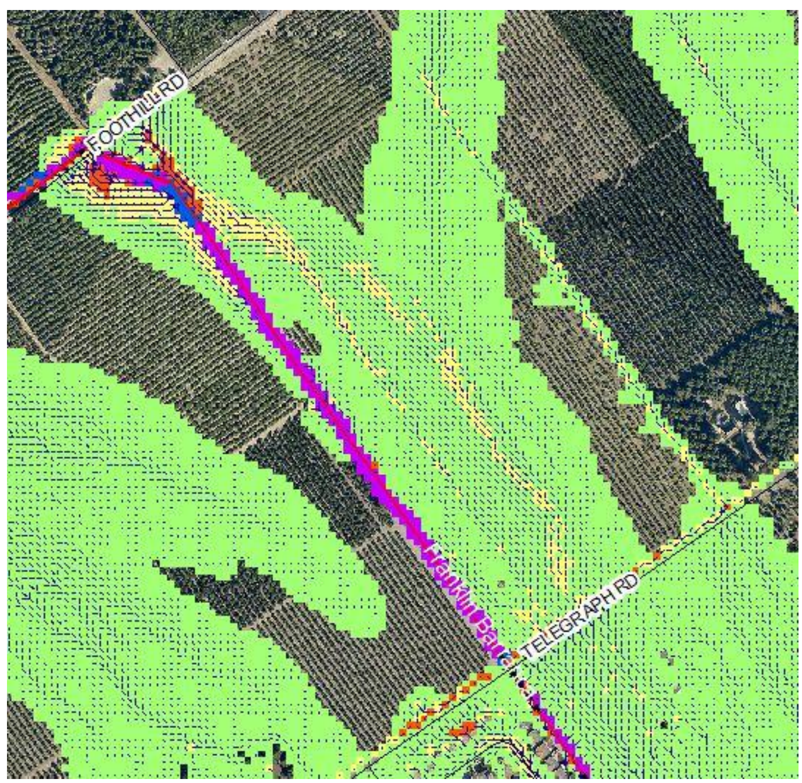




ii. Franklin Barranca Reach 2 – D/S of Foothill Road to Telegraph Road

At the upstream end of this reach, water in excess of the capacity of the Foothill Road culvert in addition to water coming from the east along Foothill Road will overtop and inundate the area immediately downstream. The FLO-2D results for this reach show a bottleneck in Franklin Barranca just downstream of Foothill Road with flows running thru the orchard on the eastside of Franklin Barranca. The channel from Foothill Road to Telegraph Road is an earthen trapezoidal channel with portions of rock rip rap banks on both sides. Channel base width ranges from 8' - 12' and depth's range from 6' to 14'. The channel through this agricultural reach is characterized by four drop structures varying in height from 3.5' to more than 8.5'. Overbank flows from upstream continue through the orchard area toward Telegraph Road. The projected HSPF Q10 at Telegraph Road is 372 cfs and the Q100 is 1335 cfs. The 12'W X 7'H RCB culvert under Telegraph Road has a capacity of 1200 cfs, which is equivalent to the 75-year flow, based on the HEC-RAS analysis. Theoretically, if the projected Q100 reached this point, the water on the east side will continue with the other contributing surface flow in a southeasterly direction parallel to the channel in addition to water overtopping Telegraph Road on the west side. However, due to the culvert and channel deficiency upstream at Foothill Road the total flow within the channel itself is less than the HSPF projected Q's with additional water in the east overbank area, continuing southeasterly through the agricultural area.



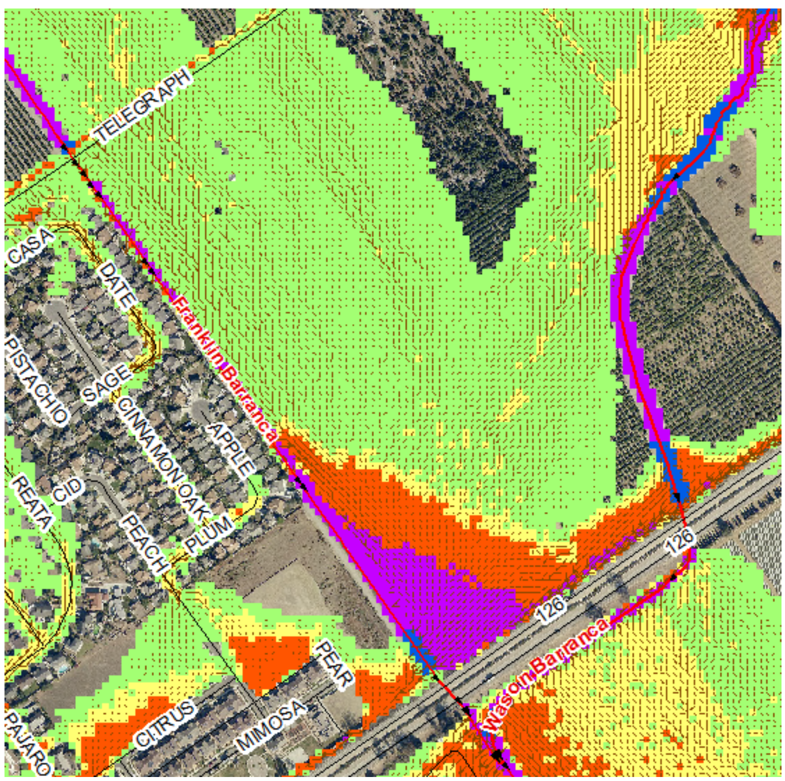


iii. Franklin Barranca Reach 3 – D/S of Telegraph Road to Freeway 126

The upstream 2/3 of this reach (approximately 1500’) is an engineered RCC channel with base widths ranging from 12’-13’ wide and channel heights varying from 5’ – 6’. The lower 1/3 (approximately 800’) of this channel reach is an earthen trapezoidal channel transitioning to a Double 8’W X 10’H RCB underneath Freeway 126.

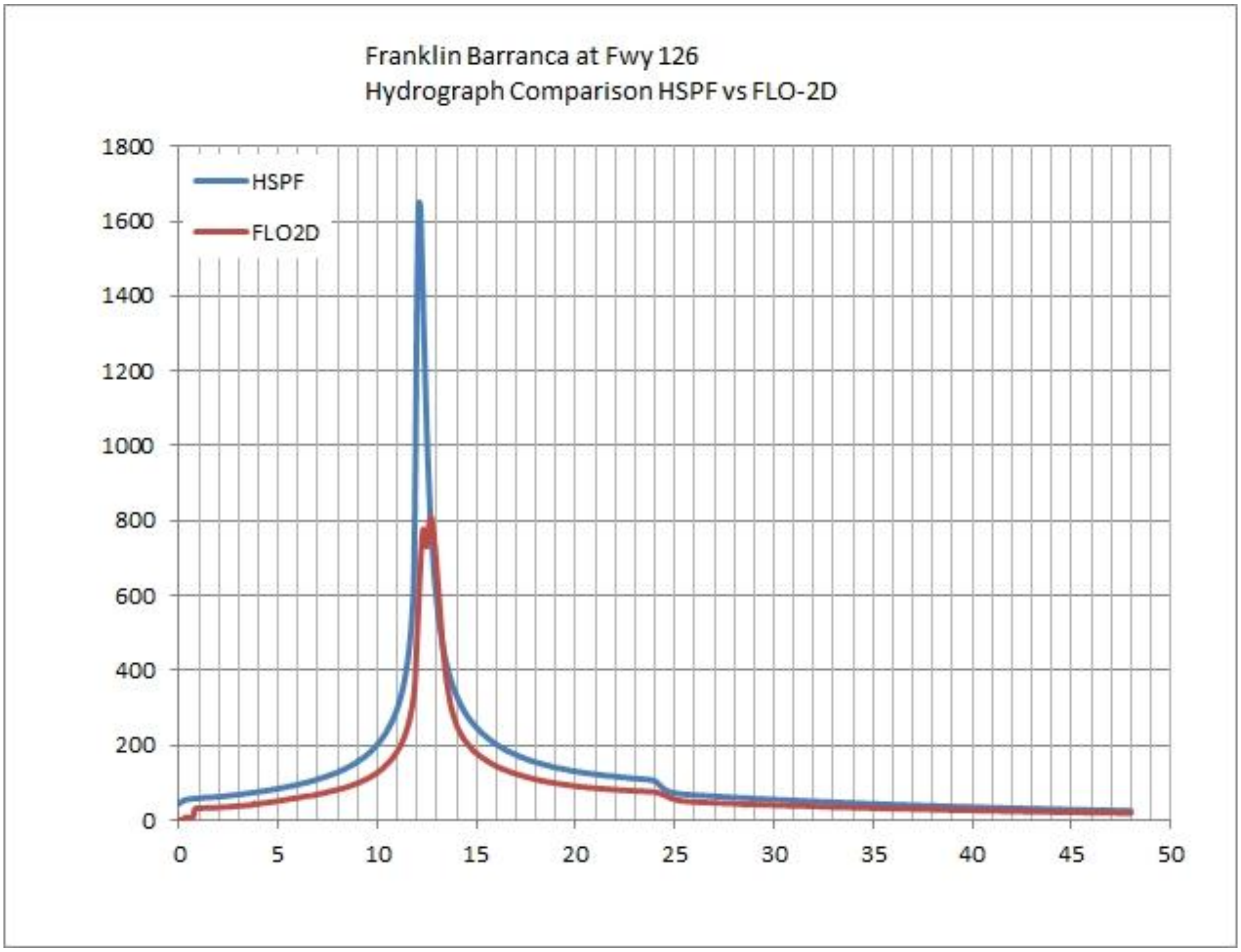
The capacity for this double RCB is 1200 cfs based on the HEC-RAS analysis while FLO-2D calculates a flow of 1158 cfs at the outlet node (element 102522), which equates to a frequency of the 50-year flow. The Design Q from the record drawings for this lower portion of the reach is 1200 cfs. At this location the HSPF projected Q100 is 1650 cfs.

Flow along the left overbank of Franklin through the orchards combined with the southwesterly outflow form Wason create flooding in the northeast corner of Franklin Barranca and Freeway 126 for all frequencies. Flood depths in this area are projected to range from 1.5’ for the 5 year event up to almost 8’ for the 500-year event.



On the west side of the lower portion of this reach, the building pads within the residential tract has been raised approximately 4 to 6 feet. However, adjacent low-lying areas will be affected by overbank flooding from Franklin Barranca due to limitations of the channel and the Freeway 126 culvert.

Although the left and right banks of the channel upstream of Freeway 126 are manmade, they were not intended to function as levees and were not modeled as such. The channel flow in the lower end of the reach (upstream of the ponding area an Freeway 126) is approximately one half of the projected 100-year HSPF peak. Flooding is being exchanged between both the channel and overbank areas, submerging both banks.

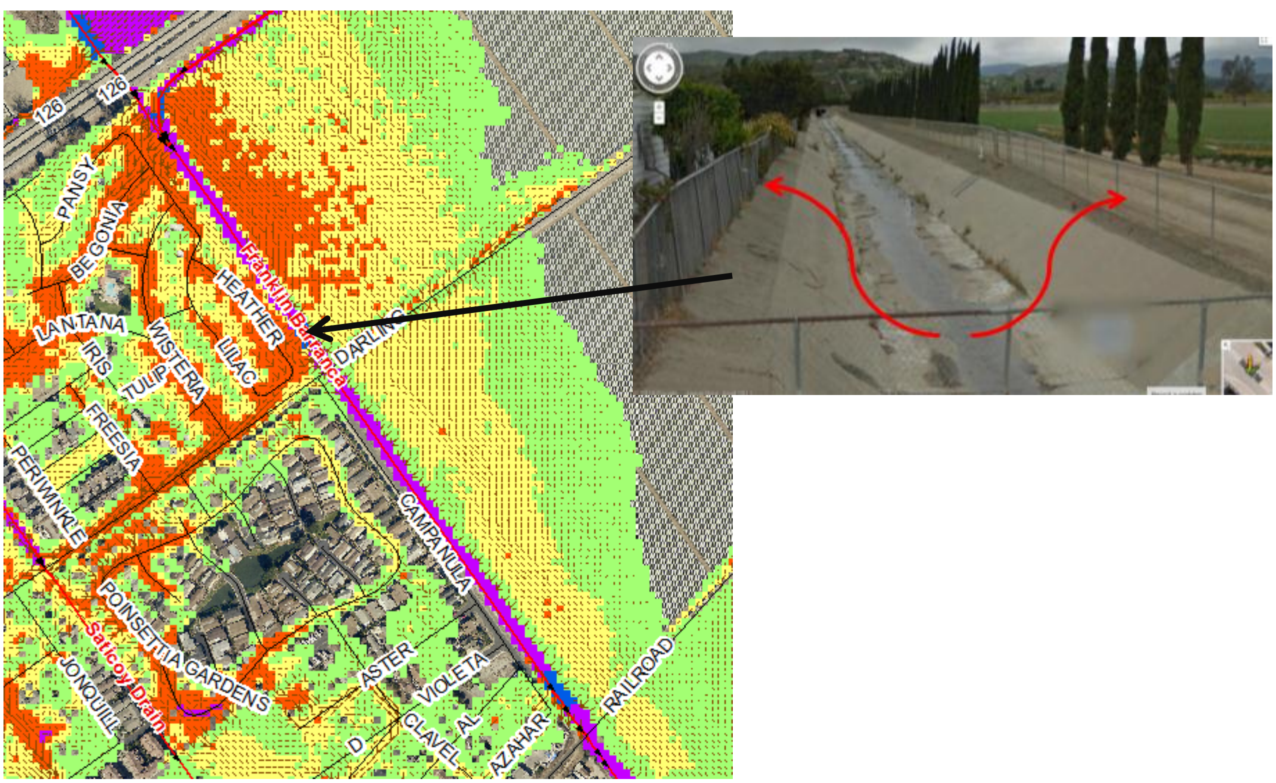


iv. Franklin Barranca Reach 4 – D/S of Freeway 126 to Railroad Tracks

The channel through this reach includes the confluence of Wason Barranca on the upstream end. After the confluence, the trapezoidal channel averages a base width 14' and height of 5' with side slopes of 1.5:1. The record drawing design Q for the channel after the confluence is 1500 cfs, while the projected HSPF Q100 for this upstream section is 3810 cfs. Currently, the channel downstream of the Franklin-Wason Barranca confluence has an estimated 15-year capacity based on the HSPF model, even though it was originally designed for a Q50 in 1965.

Flow overtops the channel due to its limited capacity. Excess water joins surface flow from the surrounding agricultural area to the east, while inundating the mobile home park adjacent to the channel and other areas of Saticoy to the west for all events greater than a 15-year storm.

Upstream of the 25'W X 5'H RCB under Darling Road, a portion of the flooding from the mobile home park returns to the main channel. As the channel continues toward the railroad track crossing, it has capacity for a 25-year storm event. Some overtopping on the west bank of the channel just upstream of the railroad tracks will occur.



v. Franklin Barranca Reach 5 – D/S of Railroad Tracks to Santa Clara River

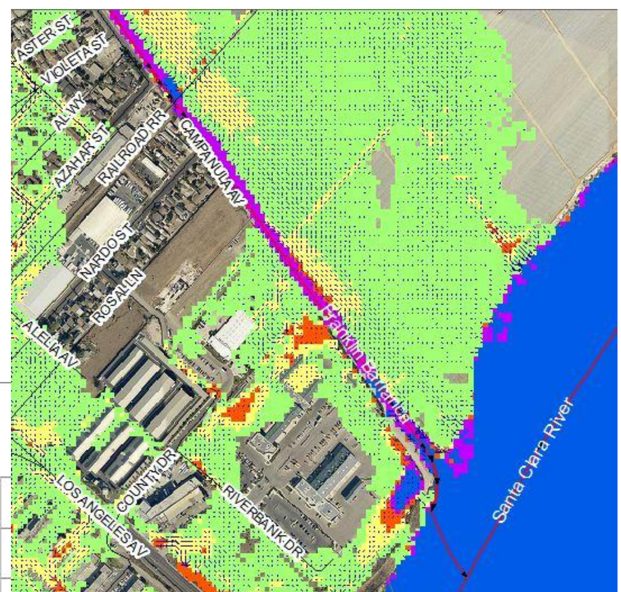
Downstream of the railroad tracks, the Franklin-Wason channel transitions back to a trapezoidal channel with 15' base width and height of 6' with side slopes of 1.5:1. Approximately 1500' downstream from the railroad tracks the channel transitions to a 22'W X 5.25'H RCC. A 12' drop structure is also present approximately 1900' downstream from the railroad tracks.

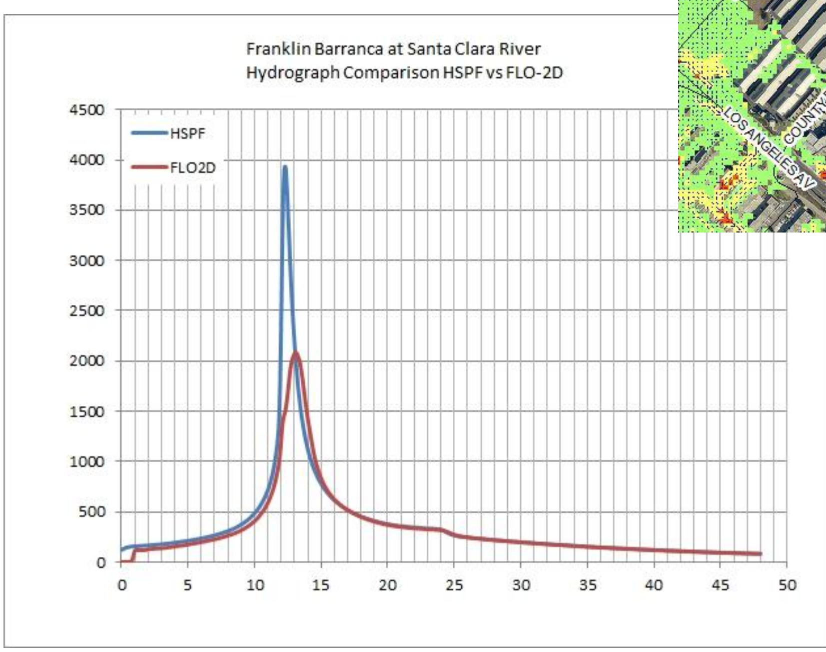
The lower portion of this reach is bordered by the Public Works Saticoy Operation Yard (SOY) to the southwest and agricultural land to the northeast.

This reach of Franklin Barranca theoretically has a flow capacity of 2500 cfs based on the HEC-RAS analysis, or 2234 cfs based on the FLO-2D model (element 229789). This flow is almost equivalent to a 50-year storm event, as the channel capacity is approximately seventy percent of the projected HSPF peak of 3930 cfs.

Some of the water that is in the overbank area to the east will re-enter the channel along the lower end of this reach upstream of the confluence with the Santa Clara River.

Franklin Barranca overflow will contribute to shallow flooding on the PWA SOY property during a 100-year flood event.





f. PWA Saticoy Operation Yard

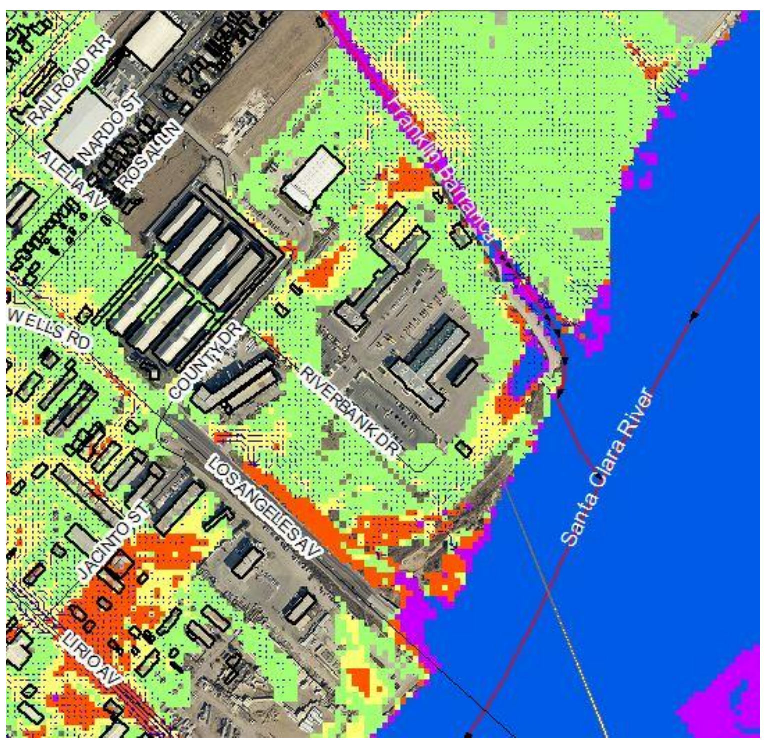
Franklin Barranca concrete-lined trapezoidal channel adjacent to the SOY was originally designed for a 50-year design storm of 1500 cfs back in 1965, which is equivalent to a 15-year storm event based on today's hydrology. In 1982, the lower 700 feet of the channel was reconstructed to include a 22' wide RCC and stabilizers. This reach of the lined channel carries 2500 cfs under normal depth condition, which is approximately equivalent to a 35-year storm. The current HSPF hydrology model peak flow estimates are 2819 cfs and 3930 cfs for the 50-year and 100-year storm events, respectively.

Under existing conditions, inadequacies in the upstream system result in only half, approximately 2000-2500 cfs getting to this reach. A portion of the realized flow will overtop the banks and combine with local runoff to create shallow flooding within the Saticoy Operations Yard (SOY) during a 100-year storm event.

Approximately 20% of the SOY property will be inundated by flow depth of 6 inches or more during a 100-year storm event. The PWA building is not shown to be subjected to flooding; however, the GSA building to the north may sustain as much as 1 foot of inundation. The main access to the SOY from Riverbank Drive and County Drive may be covered by up to 8 inches of flood water during the peak of the 100-year storm.

The existing wall separating the SOY from the property to north might lessen the actual contribution of runoff to the SOY, but as it is customary for 2D floodplain model studies, the perimeter walls are not considered.

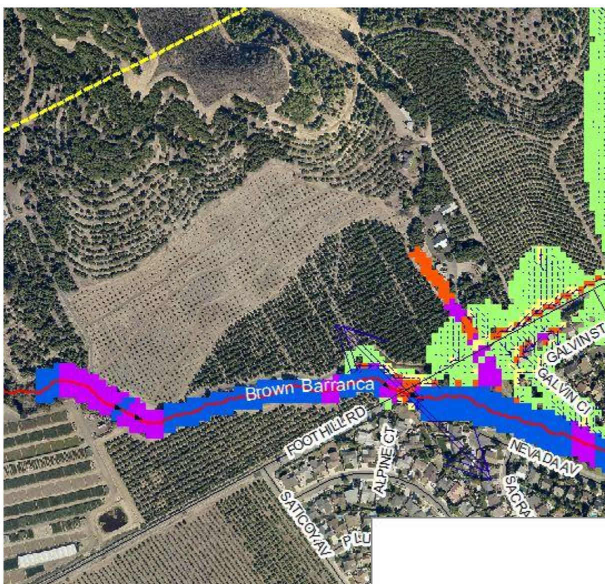
Future improvements to the upstream Franklin Barranca drainage system may result in increased runoff reaching the Santa Clara River and the SOY. This condition could inadvertently increase the flooding within the yard from Franklin Barranca.



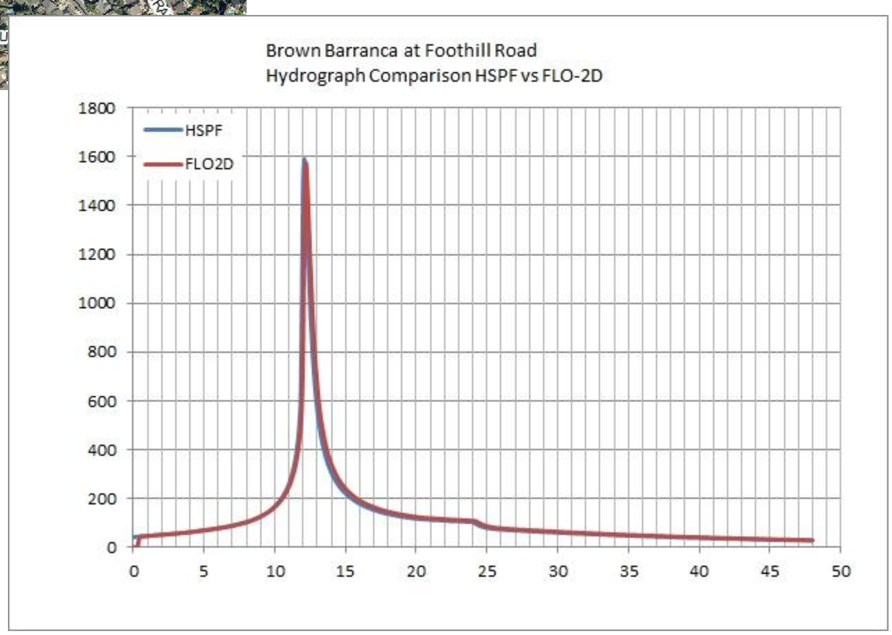
g. Brown Barranca

i. Brown Barranca Reach 1 – U/S of Foothill Road

The deep natural channel through this reach is heavily vegetated and contains a private farm crossing approximately 1200' upstream of Foothill, in addition to large semi-circle shaped stabilizer structure approximately 300' upstream of Foothill Road. Both the stabilizer and farm crossing were included in the FLO-2D model as hydraulic structures. The channel depth varies from 20' to over 30' within this reach. Due to the depth of the upstream channel, flows up to and including the 100-year event are contained within the channel upstream of the culvert. At Foothill Road, the 10'W X 8.5'H arch culvert is currently 80% full of sediment. For this project, this culvert was modeled as being 100% open. Ventura County Transportation Department Operations and Maintenance Division informed the District that this culvert is scheduled to be cleaned out in the Summer of 2014. With the culvert completely open, the estimated capacity from HEC-RAS analysis is 2200 cfs, which is equivalent to the 200-year event.



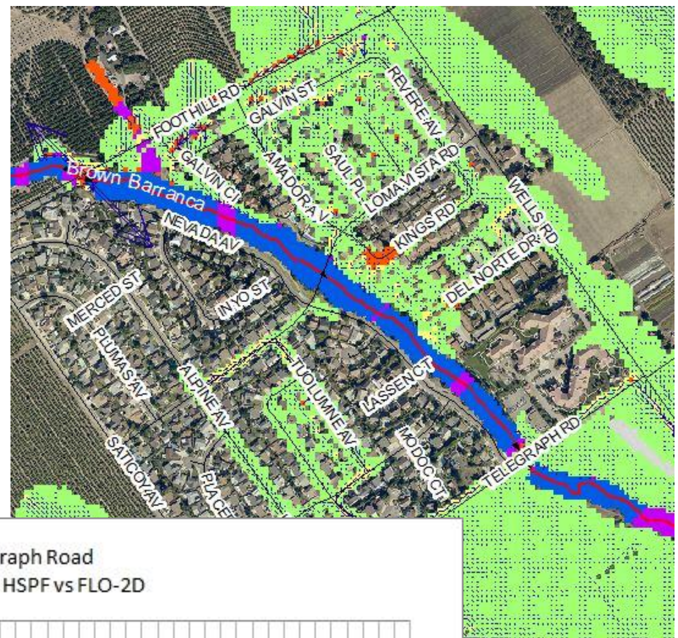
Under current conditions, the culvert will carry approximately 450 cfs, equivalent to the Q10 flow. The modeled Q100 in FLO-2D at the structure is 1424 cfs, while the modeled Q100 in HEC-RAS at the structure is 1590 cfs.

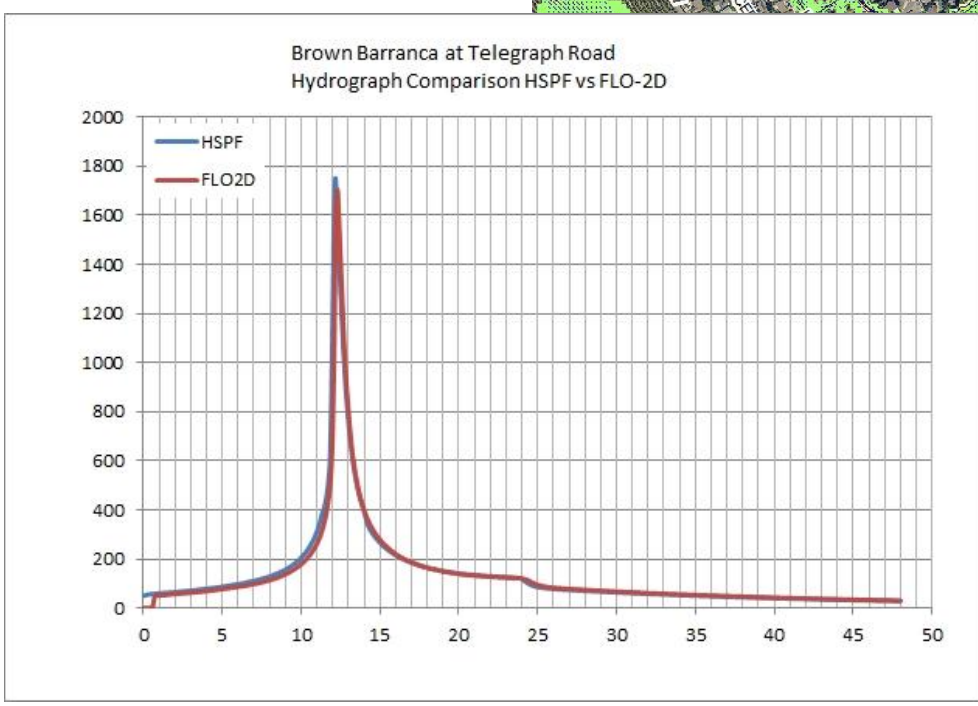


ii. Brown Barranca Reach 2 – D/S of Foothill Road to Telegraph Road

Downstream of Foothill Road the deep natural channel contains all of the flows up to and including the projected 100-year flow of 1750 cfs. For the 500-year flow, the potential for a small amount of channel overtopping may occur on the south side of the channel just downstream of Foothill Road. The upstream portion of the channel also is affected by overland flow coming from Foothill Road to the northeast. This main path of this overland flow from Foothill Road is in a southeasterly direction on Amador Avenue and Galvin Circle with water reentering the channel at the terminus of Galvin Circle, at Loma Vista and other locations. This reach of channel also has 3 drop structures/stabilizers ranging from 10' to 14' in height.

At Telegraph Road, the projected Q100 from HSPF is 1750 cfs and the 10'W X 10'H RCB transition to 10'W X 8.5'H RC Arch culvert and has a capacity of approximately 1800 cfs based on HEC-RAS analysis and the design drawings 2003-D-001.



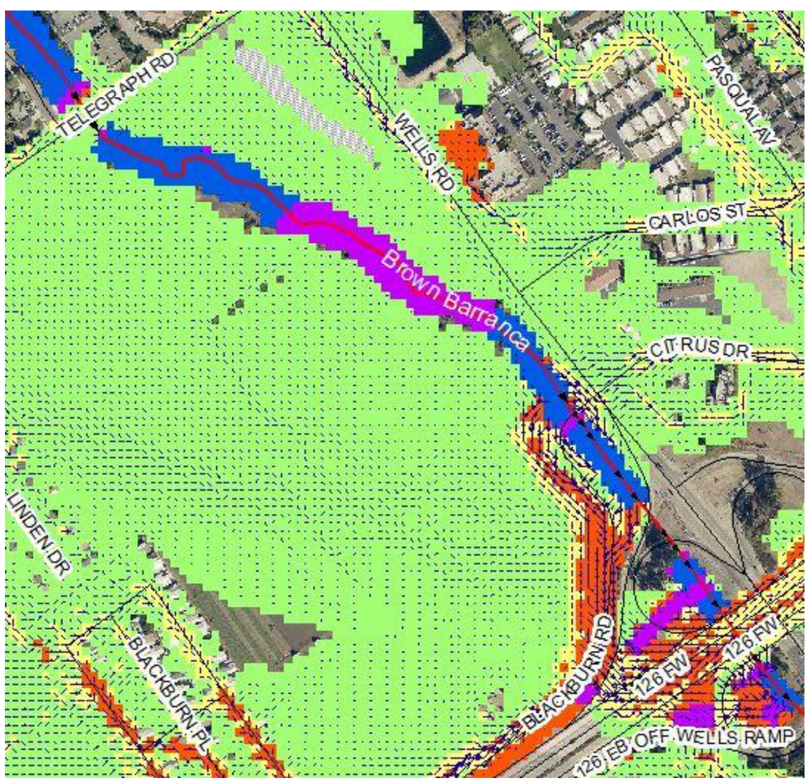


iii. Brown Barranca Reach 3 – D/S of Telegraph Road to Blackburn Road

Downstream of Telegraph Road, the natural channel continues through the surrounding agricultural areas which is characterized by shallow flooding from overflow on Telegraph Road impacting the private agricultural property on the west side of the channel. This shallow surface flow travels in a southeasterly direction toward the Brown Barranca/Wells Road/Freeway 126 interchange.

For events greater than a 25-year storm, water will overtop the channel upstream of the Double 8'W X 6'H RCB culvert at Blackburn Road and will travel overland on both the east and west sides, with the majority flowing to the southwest toward Freeway 126. Between the 50 and 100-year event, approximately 100-250 cfs leaves the channel with the majority expected to overtop Wells Road at Blackburn Road.

The capacity of the Blackburn Road culvert is approximately 1314 to 1550 cfs based on FLO-2D and HEC-RAS analyses, respectively. The projected Q100 at this location is approximately 1900-2000 cfs based on the projected 1750 cfs through the Telegraph Road Culvert plus the two incoming storm drains under Telegraph Road that deliver water to Brown Barranca from the area to the west.



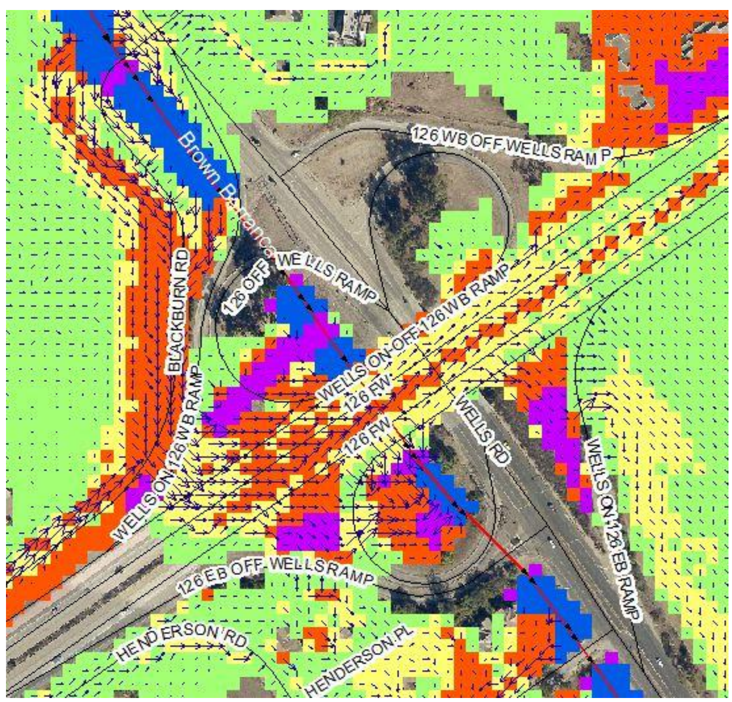
iv. Brown Barranca Reach 4 – D/S of Blackburn Road to Freeway 126

Due to the capacity issues upstream, this reach is defined by a large volume of water reaching Freeway 126 west of the channel. This water overtops the Freeway with some of the water re-entering the open channel on both the north and south sides. The remaining surface flow will travel northeasterly along Freeway 126 through the Wells Road overpass toward the Saticoy Drain watershed.

At the Freeway 126 on and off ramps, the Double 8'W X 6'H RCB has a limited capacity with water overtopping and following Blackburn Road to Freeway 126. There is a short reach of approximately 200' of open channel before the Triple 8'W X 6' H RCB underneath Freeway 126.

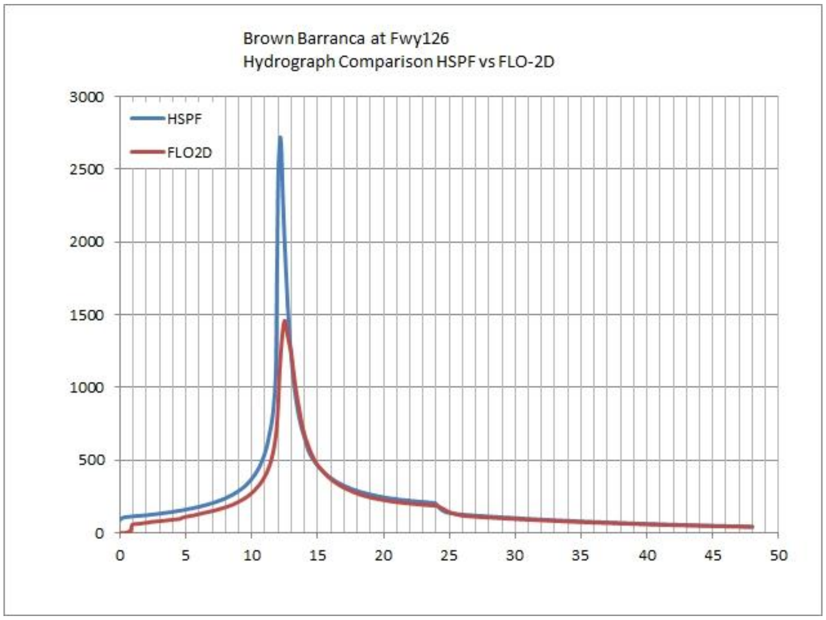
The original 100-year HSPF model shows that an additional 1000 cfs will be added to the main channel flow on Brown Barranca to the Freeway 126 triple 8'W X 6'H RCB's. In reality, much of this flow would accumulate in the Caltrans open channel running west to east parallel to the north side of Freeway 126. The two sets of double 5'W X 3'H RCB culverts along this channel have an approximate capacity (flow before embankment is overtopped) of 300 – 325 cfs. Due to this inadequate capacity, much of the modeled flow in the Caltrans channel overtops Freeway 126 and flows easterly down the Freeway.

As a result of the backwater effect from the downstream side of the freeway, the Triple RCB underneath Freeway 126 has an estimated capacity of 1500 cfs, which is equivalent to a 30-year flow, based on HEC-RAS analysis, versus 1407 cfs from the FLO-2D model. The projected HSPF Q10 at this location is 836 cfs while the Q100 is 2720 cfs.



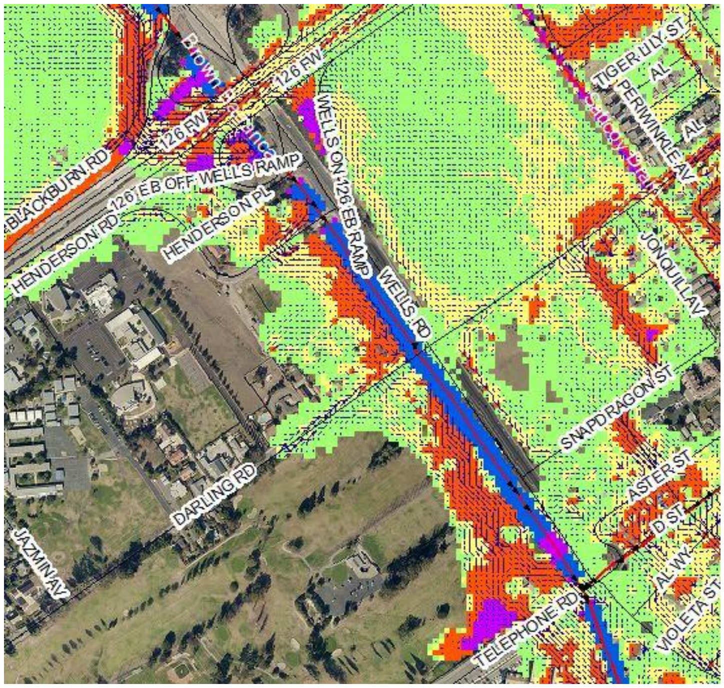
v. Brown Barranca Reach 5 – D/S of Freeway 126 to Telephone Road

As Brown Barranca continues in a southeasterly direction downstream of Freeway 126, a short 200’ open concrete trapezoidal section immediately downstream between the Freeway and the south on/off ramps will have overflow water entering from the west from the Freeway and areas upstream.



The RCC channel transitions to another Triple 8’W X 6’ H RCB under the on/off ramps on the south side before transitioning to another short open reach, less than 200’, of open concrete trapezoidal channel. For storm events greater than a 50-year storm, the Triple 8’W X 6’ H RCB underneath Henderson Road will not have capacity, with water overtopping the channel banks and spilling on the west side of the channel and flowing on the surface with existing water parallel to the channel. Downstream of Henderson Road some of the surface flow will reenter the open earthen trapezoidal channel upstream of Darling Road.

Downstream of Darling Road and the 22’W X 7’H culvert underneath it, the earthen trapezoidal channel has limited capacity between a 10-year and 25-year storm. On the northeast side of the reach, Wells Road is elevated which prevents any inundation of the roadway from Brown Barranca at all storm frequencies up to and including the 100-year event between Freeway 126 and Snapdragon Street.

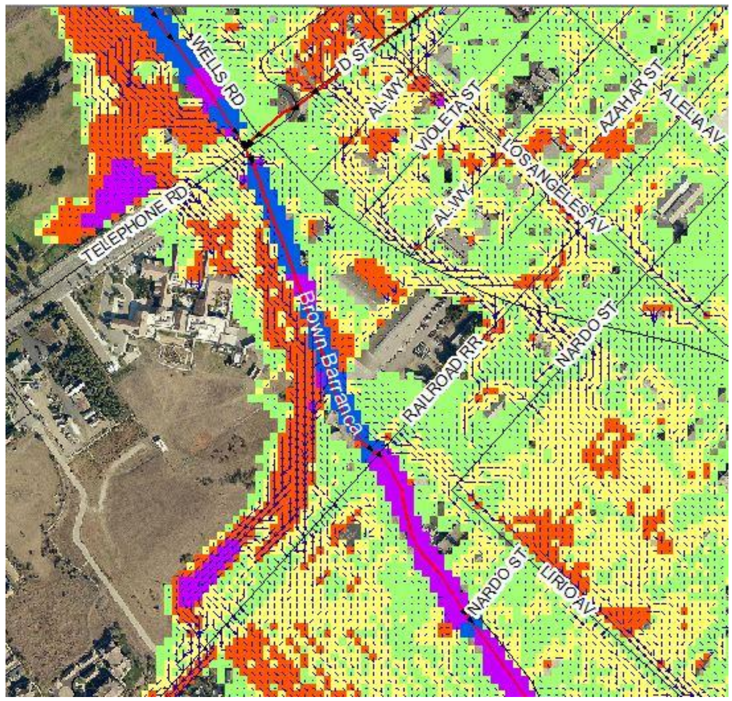


At Telephone Road the projected 100-year flow from HSPF is 2950 cfs with the capacity of the 22'W X 9'H culvert underneath Telephone Road being 2200 cfs, which is equivalent to the 50-year event. However, upstream overflow results in only 1345 cfs reaching the Telephone Road culvert. The 78" RCP with a 300 cfs capacity, Saticoy Drain, also junctions with Brown Barranca underneath Telephone Road.

Downstream of Telephone Road, overflow from the channel joins the large amount of existing flooding on both the east and west sides, traveling in a southeasterly direction toward Santa Clara River.

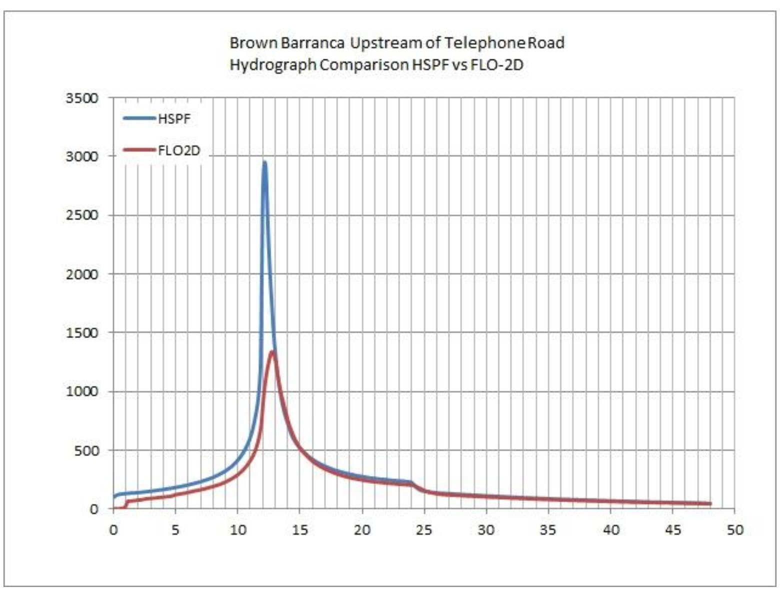
vi. Brown Barranca Reach 6 – D/S of Telephone Road to Railroad Tracks

The natural bottom trapezoidal channel continues downstream of Telephone Road and ranges from 8-12’ in height and 15-25’ in bottom width. There are 2 private farm crossings between Telephone Road and the railroad tracks. The FLO-2D model shows the channel carrying up to approximately 1850 cfs until about 250’ upstream of the railroad tracks, where the abandoned farm crossing causes a constriction of the channel. Overflow from the channel at this location occurs at storm frequencies of 25-year and greater, or approximately 1750 cfs. This overflow water will join the existing flow overtopping Telephone Road on the west side.



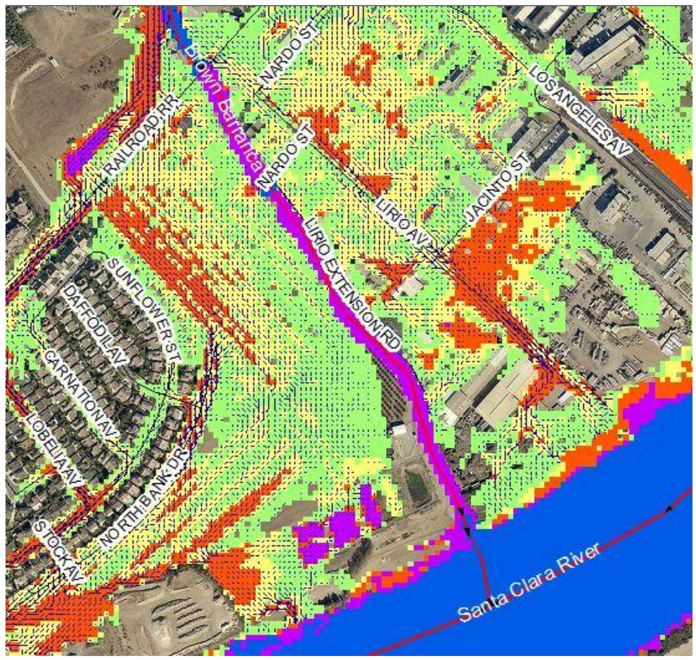
On the east side, the majority of the surface water will flow down Wells Road, with the potential for a small amount to flow to the west toward the open channel.

At the railroad tracks, the 28.5’ wide bridge has capacity to carry approximately the 15-year flow or 1100 cfs, though a lot of water has already exited the channel upstream and will not be reaching this location.

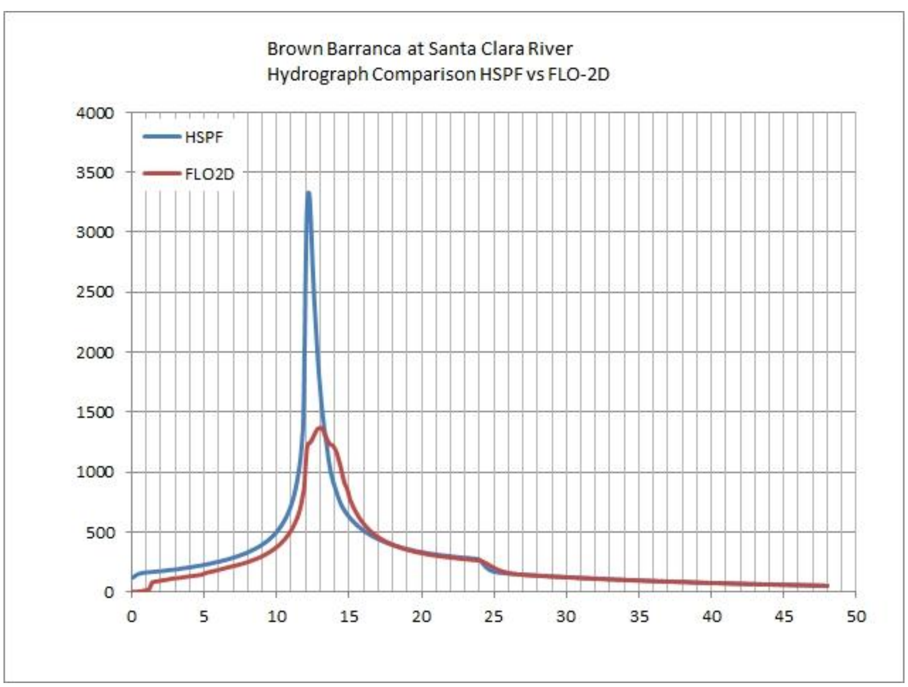


vii. Brown Barranca Reach 7 – D/S of Railroad Tracks to Santa Clara River

As the natural bottom trapezoidal channel continues downstream of the railroad tracks, it can carry the flow up to and including the 15-year event or approximately 1400 cfs. For these lower frequency storm events, surface water also has the potential to enter the open channel on the east side. For the 50-year storm event and greater, water will exit the channel on its west side near Nardo Street and join the large amount of water already overtopping the railroad tracks and areas north. The agricultural area to the west of this reach is almost completely inundated for events 50-year or greater.



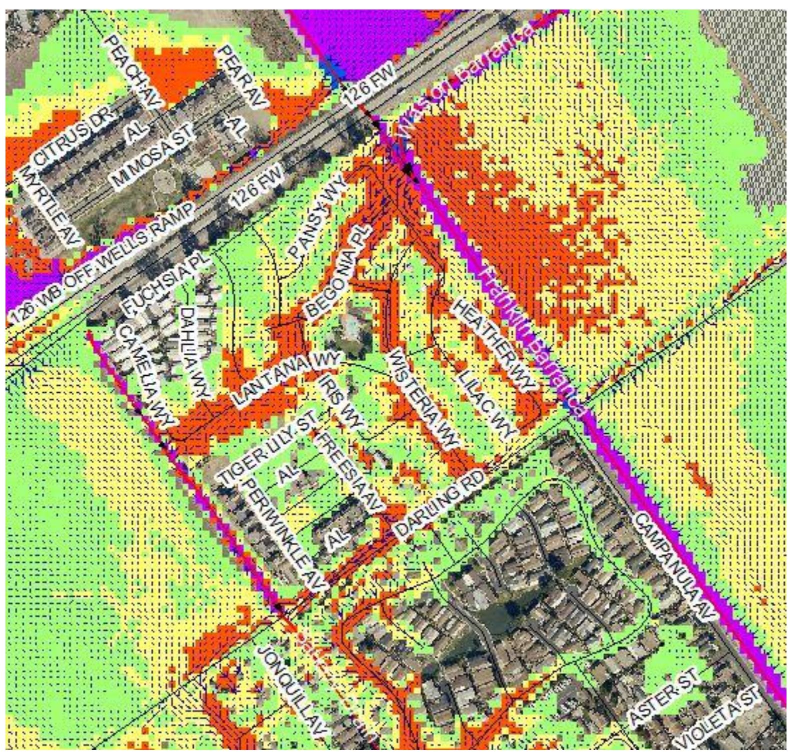
On the downstream end of this reach the HSPF projected Q10 is 1077 cfs, while the Q100 is 3330 cfs. The FLO-2D model shows approximately 1400 cfs within the channel, as much of the flow has already exited the channel and entered the floodplain area.



h. Saticoy Drain

i. Saticoy Drain Reach 1 – Freeway 126 to Darling Road

Saticoy Drain begins just upstream of Freeway 126 as 2 - 48” RCP’s underneath the freeway. The area upstream of Freeway 126 is mostly residential and the inlet to the double pipes receives most of its runoff via Pajaro Avenue with additional water coming from the east along the freeway. On the downstream side of the freeway, the pipes transition to an earthen trapezoidal channel with 9’ bottom width, 6’ of depth and side slopes of 1.5:1. This portion of open channel has some areas of concrete and/or rip-rap bank stabilization along both banks. To the west of this downstream reach, the agricultural area will have water that has overtopped the Freeway flowing in a southerly direction for all modeled storm frequency events. To the east, the potential for water spilling from the Franklin-Wason confluence and reaching Saticoy Drain for the higher frequency storms exists. Approximately 700 feet downstream of the freeway the channel transitions to an 18’ bottom width, 6.5’ deep earthen bottom trapezoidal channel with 2:1 rock riprap side slopes. This portion is roughly 550 feet in length and at the downstream end transitions to the 10’W X 5’ H RCB under Darling Road. At this location the projected HSPF Q10 is 111 cfs and the Q100 is 295 cfs. Local flow combines with the overflows from the Franklin-Wason confluence resulting in a combined FLO-2D peak of 400-450 cfs. The RCB and connecting 78” RCP have a capacity of 300 cfs, resulting in excess flow leaving westward and combining with the overflow from Brown Barranca along Freeway 126.

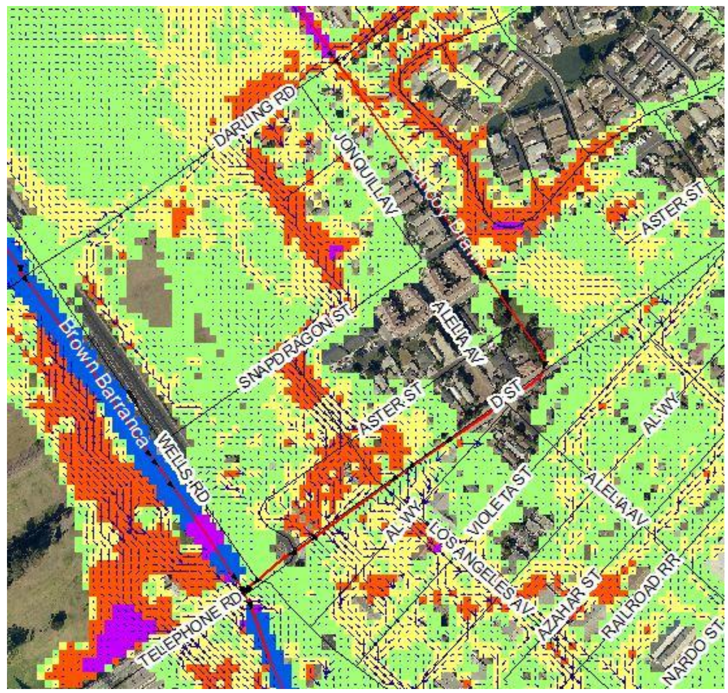


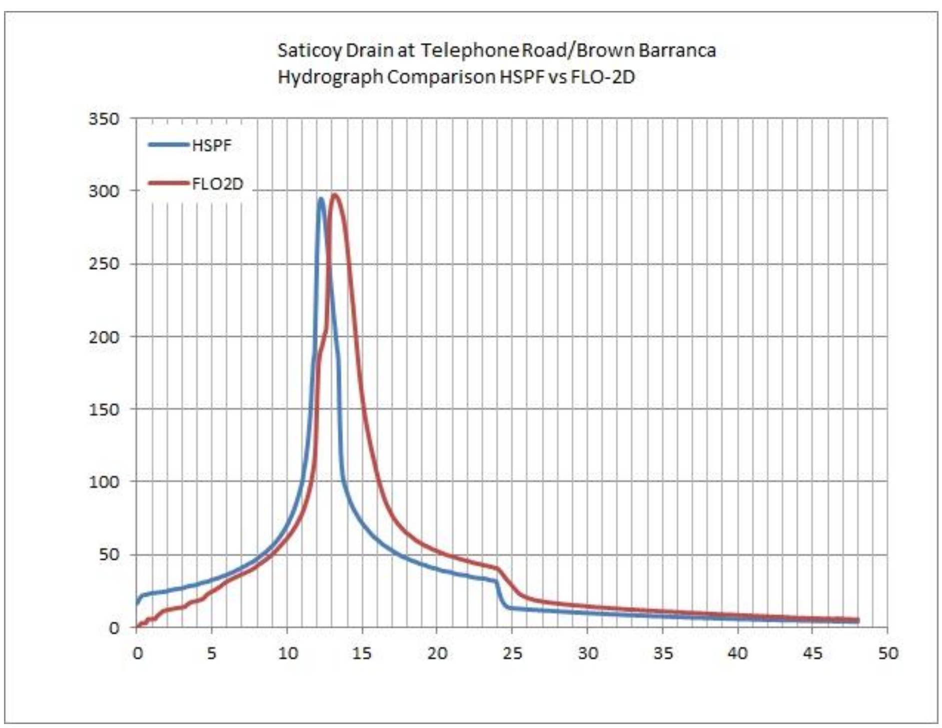
The area between Wells Road and the channel portion of Saticoy Drain is subject to flooding, with the main concentration heading southeast along Wells Road/Los Angeles Avenue, eventually joining other outflows from Franklin Barranca to inundate the areas between Franklin Barranca and Brown Barranca.

ii. Saticoy Drain Reach 2 – D/S of Darling Road to Brown Barranca

On the downstream side of Darling Road the RCB transitions to a 78" RCP with 300 cfs capacity as shown on Y-2-0442. The 78" RCP continues in a southerly direction for approximately 1200 feet before turning to the west and continuing for another 1200 feet to its junction with Brown Barranca underneath Telephone Road.

Although the RCP along this reach has capacity to carry the projected 100-year delivered flow, the large amount of surface flow coming from Franklin-Wason to the east that impacts the upstream Reach 1 open channel and the resulting overflow from the channel immediately upstream of Darling Road, will flow overland in a southwesterly direction concentrating at Wells Road and Telephone Road.

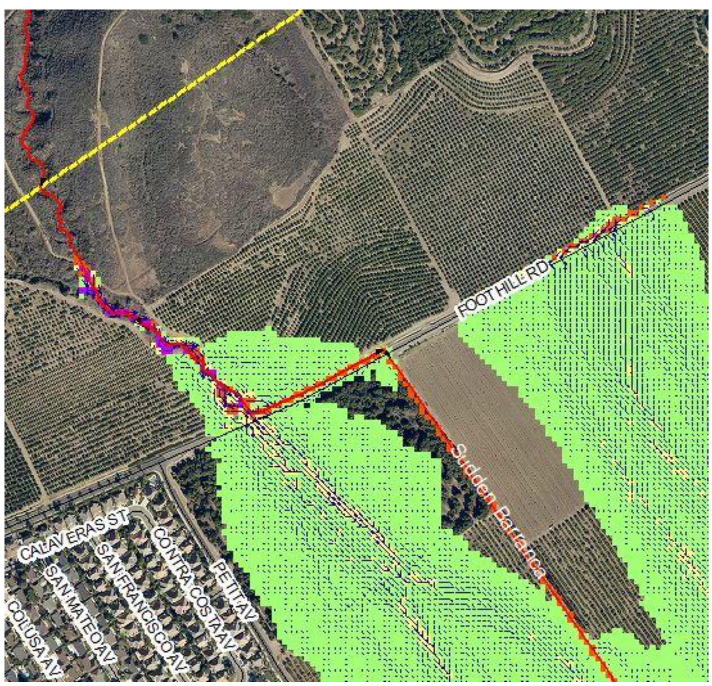




i. Sudden Barranca

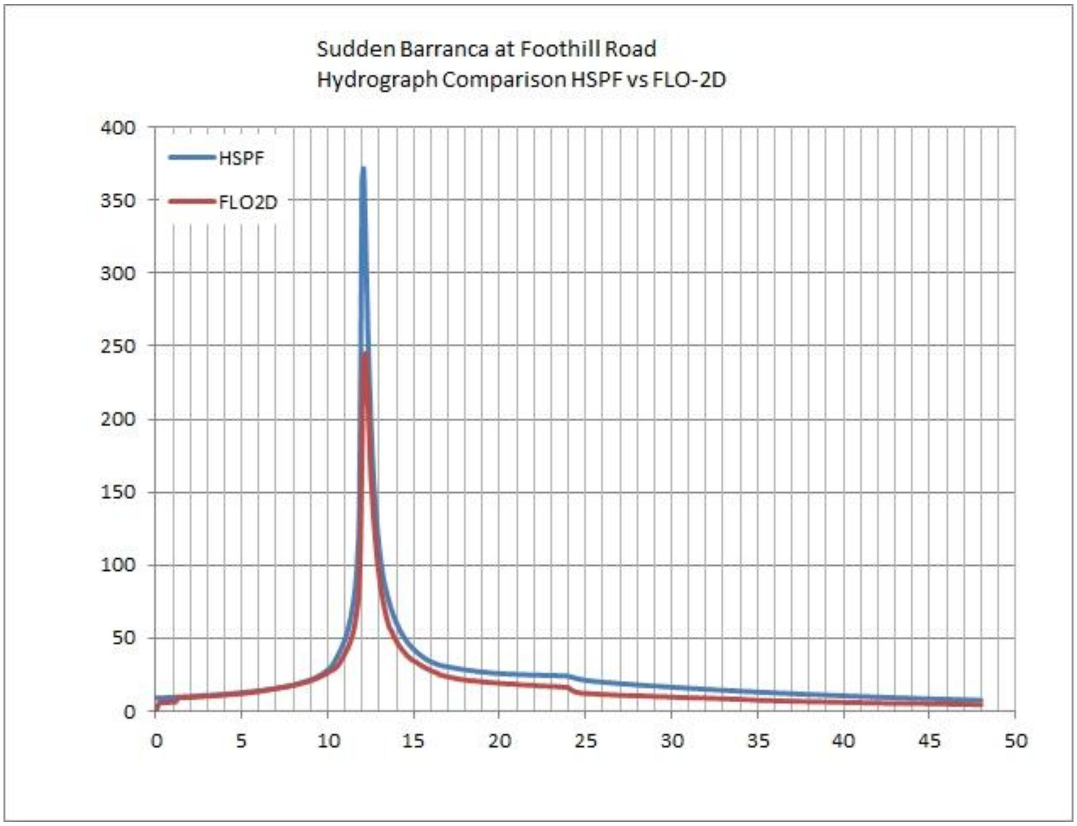
i. Sudden Barranca Reach 1 – U/S and parallel to Foothill Road

Upstream of Foothill Road, the contributing watershed is mixed open space and agriculture. The shallow (2-4') and wide (~60-80') natural channel flows in a southeasterly direction toward Foothill Road at which point it turns to the east, transitions to a concrete trapezoidal channel with base width of 6', height of 4' and side slopes 2:1. This trapezoidal channel runs parallel to Foothill Road on the north side. Because the channel upstream of Foothill Road is heavily vegetated, and LiDAR does not show a well-defined channel, water will get out of the natural channel at various locations upstream of Foothill Road for all studied storm frequencies. As the flows approach the road, only 58 cfs of the initial projected Q100 of 353 cfs makes it into the modeled FLO-2D channel. A small amount of water overtopping will travel to the east through the surrounding agriculture area, reentering trapezoidal channel along Foothill Road. In addition to the water exiting the channel upstream of Foothill Road, at the transition to the trapezoidal channel water will overtop Foothill Road for all frequencies and flow in southeasterly direction through the orchard area south of Foothill Road.



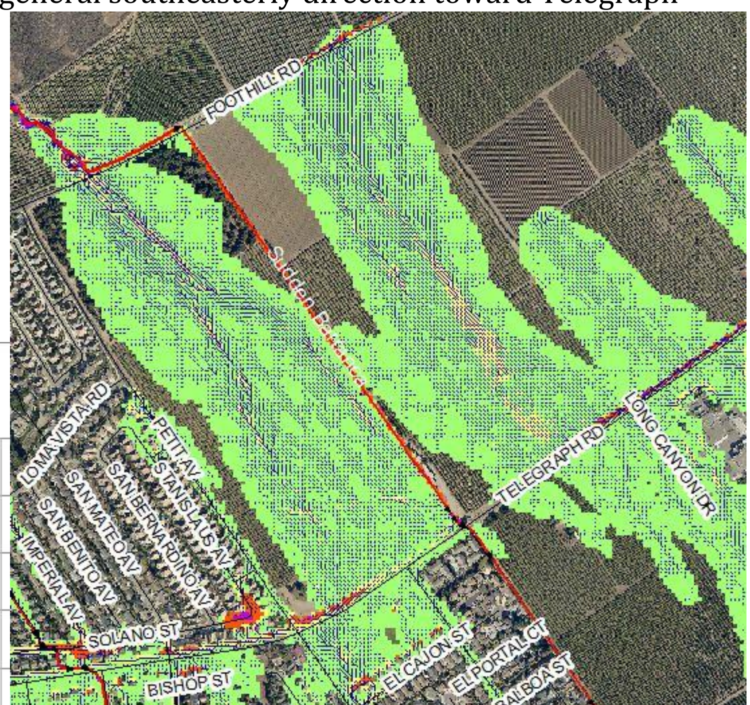
Immediately upstream of the Foothill Road culvert, the trapezoidal channel transition to the a 10'W X 10'H RCC with a 6' Drop Structure into the 6'W X 6'H RCB culvert under Foothill Road. The projected HSPF Q10 at this location is 100 cfs while the Q100 is 372 cfs. The capacity of this culvert underneath Foothill Road is estimated at 475 cfs based on HEC-RAS, which is equivalent to the 200-year storm event.

The modeled Q100 in FLO-2D at the structure is 250 cfs, while the modeled Q100 in HEC-RAS at the structure is 432 cfs. Due to the large volume of runoff exiting the system upstream, the main Sudden Barranca channel will not convey the projected 100-year flow. See the 100-year hydrograph comparison plot below.

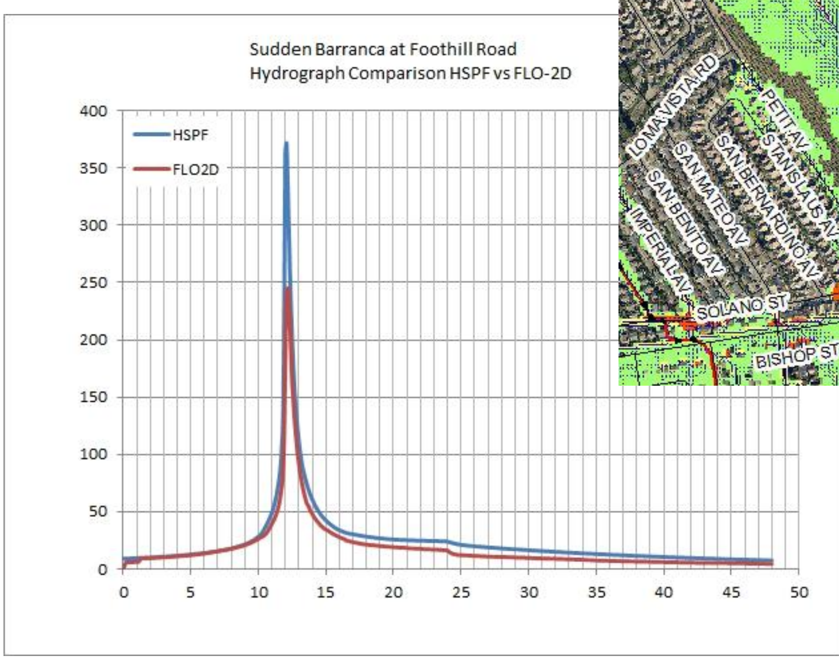


ii. Sudden Barranca Reach 2 – D/S of Foothill Road to Telegraph Road

Downstream of Foothill Road, the channel is a concrete trapezoidal channel with base width of 3', height of 5' and side slopes of 2:1. It flows in a southeasterly direction through the agriculture areas, which consists mostly of orchard. There is one private farm crossing in this reach, 820' downstream of Foothill Road, but it has capacity to carry in excess of the 100-year flow. The channel itself along this reach has capacity to carry up to and including the 50 year flow for the entire reach, but at the 100-year flow, there is some breakout from the channel on its west side 1650' downstream Foothill Road. Because of the large breakout upstream of the channel, the channel itself has some additional capacity in this reach. The surrounding area is characterized by large amounts of surface flow through the orchards on both the east and west side. The water present on west side of the channel is from the breakout upstream of Foothill Road as described in Reach 1. Most of this water travels parallel with the channel, with a small amount entering the open channel on the downstream end. Technically, partly within the Brown Barranca watershed, the flow on the east side is from overtopping Foothill Road and flows in the same general southeasterly direction toward Telegraph Road.

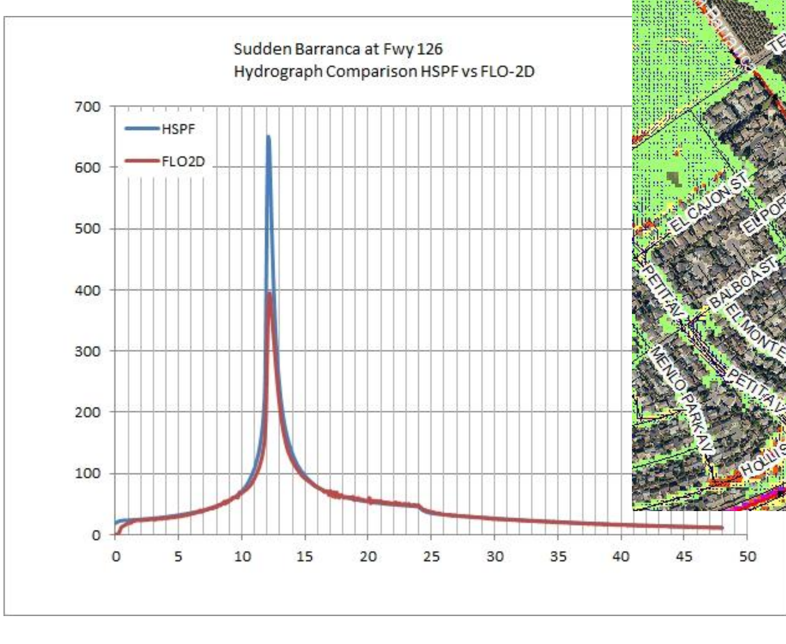


The 6'W X 6' RCB crossing Telegraph Road has a capacity of 828 cfs as shown on Y-2-1924. The HSPF Q10 at this location is 148 cfs while the Q100 is 538 cfs.



iii. Sudden Barranca Reach 3 – D/S of Telegraph Road to Freeway 126

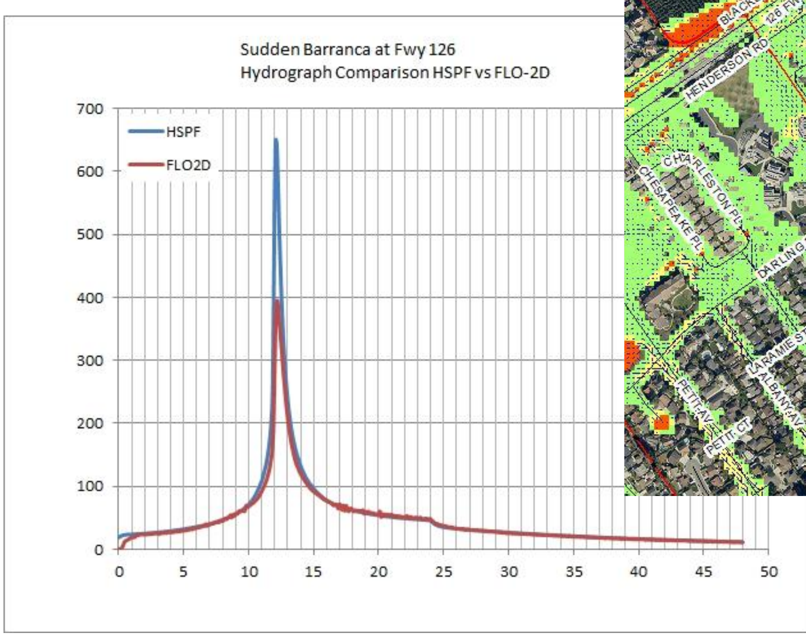
230’ downstream of Telegraph Road, the 6’W X 6’H RCB transitions to a 78” RCP. The east overbank area for this reach consists of orchards while the west overbank area is a residential neighborhood. There is no flooding shown above the upper portion of the 78” RCP, because the RCB at Telegraph Road currently has capacity to carry the delivered flow due to breakouts upstream and at Foothill Road. But at the downstream end, approximately 130’ north of the freeway, the 78” RCP transitions to a 90” RCP as it turns to the northeast, running parallel to the north side of the Freeway 126. This area has the potential for some flooding due to inefficiencies in the storm drain system junctions and inlets. The large amount of surface overflow to the west of the 78” RCP through this reach concentrates along Petit Road and other smaller streets running in a north-south direction, eventually reaching Freeway 126, where a small amount of water will enter the open Clark Barranca channel north of the freeway, and the remaining majority of the water ponding and overtopping the freeway for all frequency storms. The east side of this reach is characterized by additional shallow flooding through the orchard for storm events of 50-year or greater. This water then ponds on the north side of the freeway with some overtopping the freeway and continuing in a southeast direction. The 90” RCP transitions to a 108” RCP as it crosses under Freeway 126. The HSPF projected Q10 at this location is 179 cfs while the Q100 is 650 cfs. Based on Y-2-2059, the design capacity for the 108” RCP under the Freeway is 1252 cfs, which is equivalent to the 500-year flow. Due to the large volume of breakouts upstream, the delivered flow within the pipe system is less than the HSPF Q’s at this location.

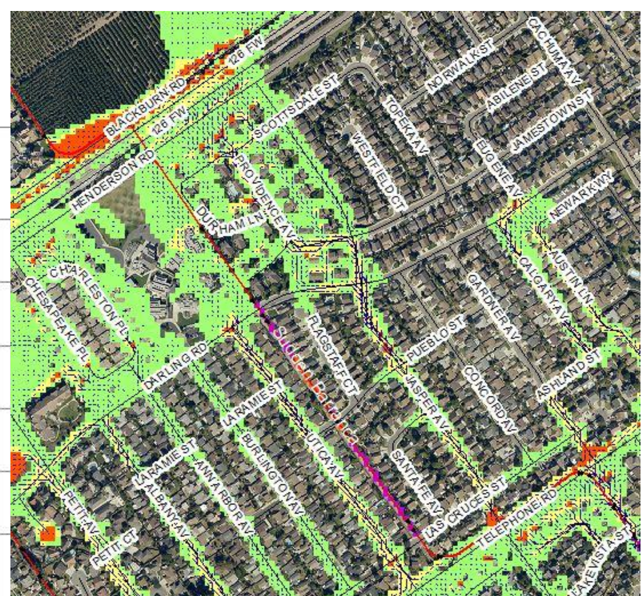


iv. Sudden Barranca Reach 4 – D/S of Freeway 126 to Telephone Road

Downstream of Freeway 126, the 108" RCP transitions to a 10'W X 6'H RCB. 970' feet downstream, at Darling Road, the RCB transitions to a 10'W X 6'H RCC. As in the other reaches upstream, this RCC currently contains the flow for all storm frequencies, due to the large volume of flow that has already left the system upstream, contributing to the floodplain. 650' downstream of Darling Road, at Pueblo Street, the open channel becomes a 10'W X 6'H RCB under the road. For the 500-year simulation, FLO-2D shows a small amount of overtopping over the west bank with the water joining the existing surface flow down Utica Avenue. Downstream of Pueblo Street, the RCB transitions back to an 8.5'W X 7.5'H RCC. 680' downstream of Pueblo Street, the RCC transitions to a 9'W X 7.5'H RCB underneath Las Cruces Street. Due to water leaving the system upstream, the FLO-2D model shows a Q100 of only 410 cfs within the channel between Pueblo Street and Las Cruces Street, while the RCB underneath Las Cruces Street has a design capacity of 1159 cfs based on Y-2-1713. Downstream of Las Cruces Street, the 9'W X 7.5'H RCB continues parallel to Telephone Road on the north side before crossing Telephone Road just west of its intersection with Gardner Avenue.

This reach is characterized by large amounts of surface flow north of Darling Road which then concentrates as street flow along the north-south oriented streets south of Darling Road. At Telephone Road, a majority of this street flow will travel to the west joining with the overflow from Clark Barranca overtopping Telephone Road to the east and west of Petit Avenue.

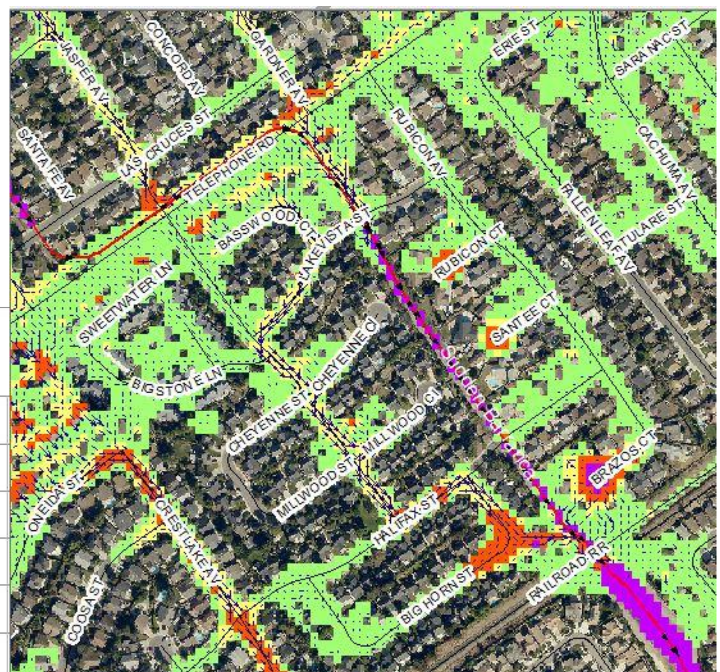


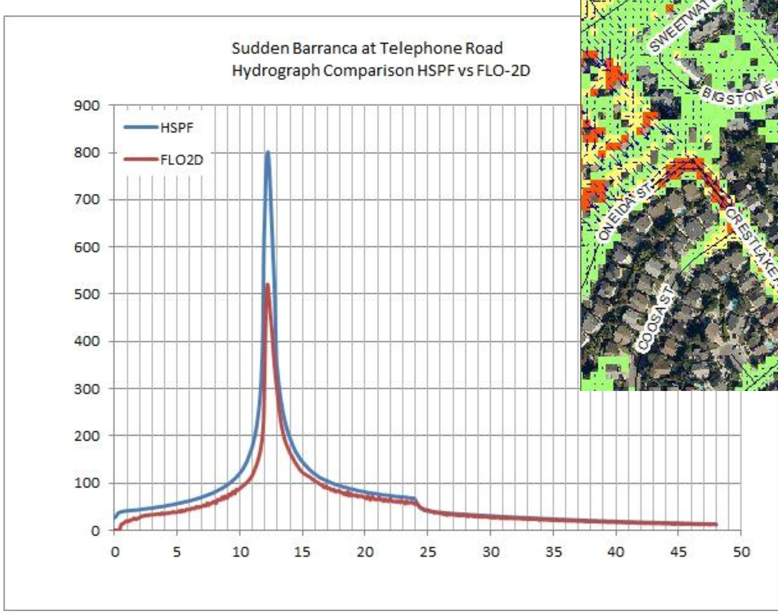


v. Sudden Barranca Reach 5 – D/S of Telephone Road to Railroad Tracks

The 9’W X 7.5’H RCB continues downstream of Telephone Road for approximately 350’ feet to Lake Vista Street, where it transitions to a 9’W X 6’H RCC. The area from Telephone Road to Lake Vista Street is characterized by shallow flooding coming from Telephone Road for all frequency storms. A small amount of this water will re-enter the open channel downstream of Lake Vista Street, but the majority flows to the west along Lake Vista Street to Jasper Avenue. 220’ upstream of Halifax Street the 9’W X 6’H RCC changes to a 9’W X 6.5’H RCC before becoming a 9’W X 6.5’H RCB underneath Halifax Street.

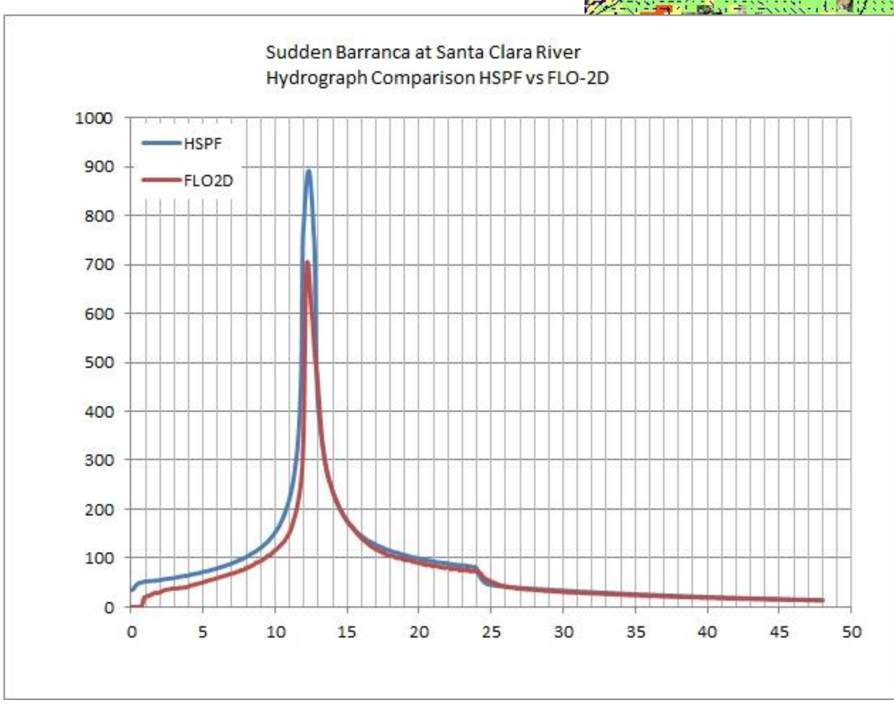
Downstream of Halifax Street, the 9’W X 6.5’H RCC continues in a southeasterly direction toward the Railroad Tracks before becoming a 9’W X 8.5’H RCC 160’ upstream of the Railroad Tracks. For this downstream section of RCC, the FLO-2D model shows a Q100 in the channel ranging from 538 cfs just downstream of Halifax Street to 663 cfs just upstream of the Railroad Tracks. The design capacity for this channel section ranges from 1183 cfs to 1240 cfs. The FLO-2D model shows some water entering the open channel just upstream of the Railroad Tracks from both Brazos Court on the east and Big Horn Street on the west. At the Railroad Tracks the RCC transitions to an 8’W X 7’ Arch Culvert with a design capacity of 1240 cfs.





vi. Sudden Barranca Reach 6 – D/S of Railroad Tracks to Santa Clara River

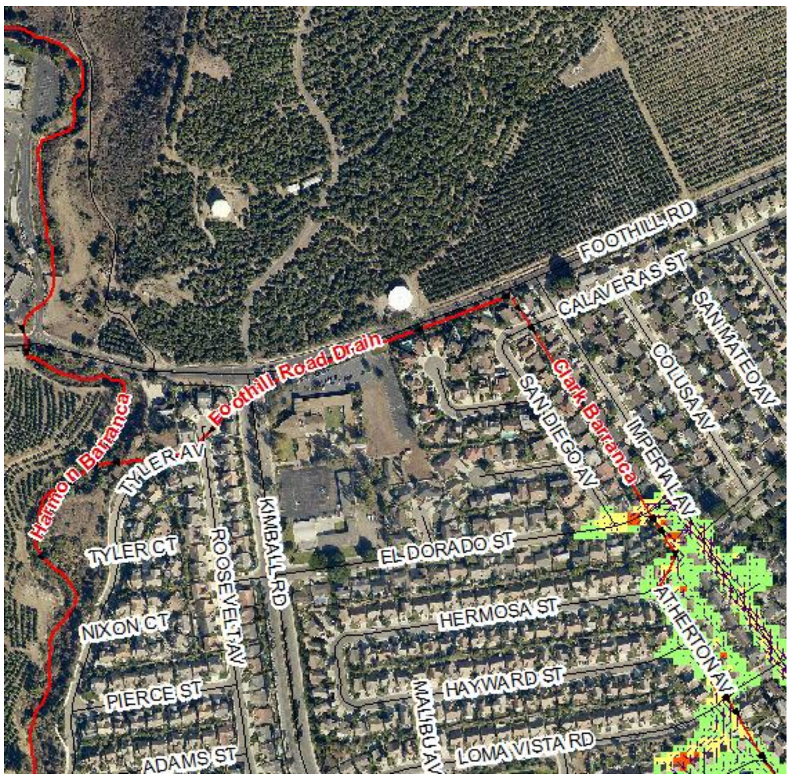
Immediately downstream of the Railroad Tracks the channel invert drops by about 8'. The channel immediately downstream is a natural bottom trapezoidal. A large 19' drop structure is present in the channel 370' downstream from the Railroad Tracks. After the drop structure, the natural bottom trapezoidal channel continues until it reaches the 30'W X 8'H RCB under North Bank Drive. Some shallow flooding along North Bank Drive from the breakouts above will overtop at this location and re-enter the open channel on the downstream side of North Bank Drive.



j. Clark Barranca

i. Clark Barranca Reach 1 – U/S to Foothill Road

Upstream of Foothill Road the watershed consists of mainly orchards. At Foothill Road, small ditches on the north side collect runoff from the areas to the north directing the flow to the 4'W X 4'H RCB underneath Foothill Road just west of Imperial Avenue. Built in 1991, Foothill Road Drain Unit I project connected a new 54" RCP to the existing 4'W X 4'H RCB underneath Foothill Road which carries flows west to Harmon Barranca. From Y-2-2090, the Foothill Road Drain is designed to carry Q50's ranging from 82-127 cfs and Q100's ranging from 104-160 cfs. Foothill Road Drain has 100-year capacity and will carry the HSPF projected Q100 of 67 cfs. For the 500-year flows, there will be some overtopping of Foothill Road on the west side of the original trapezoidal channel, just west of Imperial Avenue.



ii. Clark Barranca Reach 2 – D/S of Foothill Road to Telegraph Road

Downstream of Foothill Road the shallow water overtopping during the 500-year event will travel southerly on San Diego Avenue to El Dorado Street. No water is shown within the existing open trapezoidal channel between Foothill Road and El Dorado Street, due to the diversion upstream from Foothill Road Drain. Downstream of El Dorado Street, the channel transitions to a 36” RCP which runs underneath Atherton Street. At El Dorado Street adjacent to the channel, surface flow for all frequency storms, splits with some of the water following the general alignment of the RCP along Atherton Avenue and additional water traveling in an easterly direction along El Dorado Street to Imperial Avenue, where it flows in a southeasterly direction. Upstream of Loma Vista, the 36” RCP transitions to a 42” RCP with a design Q50 of 88 cfs and design Q100 of 106 cfs. As the water on Imperial Avenue continues toward Solano Street on the east side, the overflow on the west side will overtop Loma Vista and continue in a southeasterly direction. Downstream of Loma Vista the 42” RCP becomes a 48” RCP until Solano Street at which point it joins with the 42” RCP from the west along Solano Street and becomes a 66” RCP and turns south under Solano Street, transitioning to a 13’W X 4.5’H RCB at Telegraph Road.

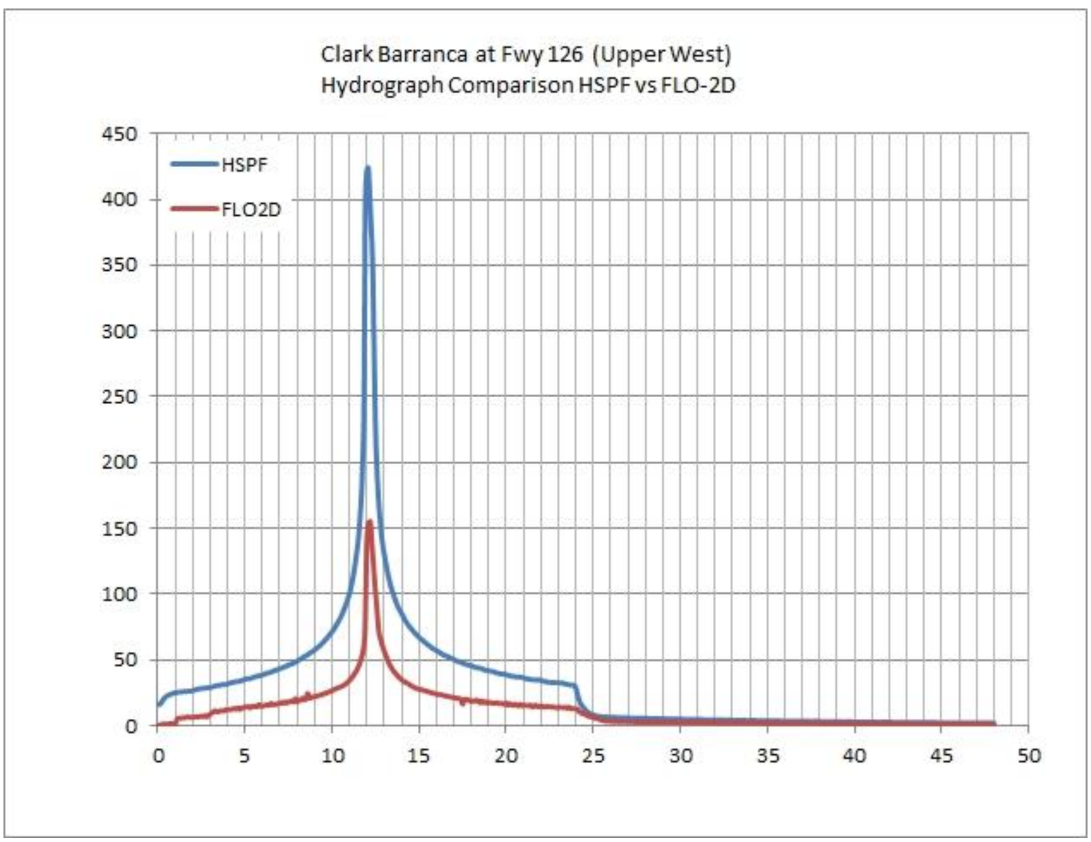
Along Solano Street near the intersection with Imperial Avenue the surface flow reaching this area will travel to the east to San Mateo Avenue where it will flow to the south, reaching Telegraph Road, where the water will split with some continuing east along Telephone Road and the remaining water will continue south on San Mateo Avenue. Shallow amounts of water will also be overtopping Telegraph Road throughout this area for all storm frequencies. The projected HSPF Q10 at Telegraph Road is 125 cfs and the Q100 is 271 cfs. The design capacity for the RCB under Telegraph Road is 408 cfs, as shown on Y-2-2039.

iii. Clark Barranca Reach 3 – D/S of Telegraph Road to Freeway 126

The 13'W X 4.5'H RCB underneath Telegraph Road transitions to a concrete trapezoidal channel with a base width of 4.5' and a height of 3.5' and side slopes of 2:1. No overtopping of the channel itself is shown for any of the modeled storm events, with FLO-2D showing a Q100 of 140 cfs within the channel until just north of Freeway 126. There is no overtopping of the channel itself because water has left the system and is flowing within the streets in parallel to the channel. Inflows within FLO-2D were modeled by adding the prorated hydrographs to floodplain elements within the streets. Flow from these locations then follows the topography until it reaches hydraulic structures representing the inlets to the stormwater pipe system. Because Clark Barranca is primarily underground, the FLO-2D has modeled it as a long culvert, with no inlets coming into along the way. Due to City storm drain capacity limitations (typically Q10), and lack of inlets into the underground Clark Barranca element in the FLO-2D model, excess flow continues southward down streets towards Freeway 126 and does not reach the Clark Barranca channel. Within the surrounding streets the flood depths are generally less than 0.5' and contained within the curb and gutter. Approximately 1330' downstream from Telegraph Road, the trapezoidal channel changes to an 8'W X 3.5'H RCB under Balboa Street transitioning back to the trapezoidal channel downstream. As the channel approaches Freeway 126, it becomes an 8'W X 3'H RCB as it bends to the east.

As it runs along the north side of and parallel to Blackburn Road, it becomes a 10'W X 4'H RCC. Much of the surface flow from the north crosses Blackburn Road in this area and enters the Caltrans trapezoidal channel along the north side of Freeway 126. As the channel continues in an easterly direction along Blackburn Road, approximately 200' to the east of Lakewood Avenue, the RCC transitions to a 8'W X 4'H RCB underneath Blackburn Road and junctioning with the existing trapezoidal channel on the north side of Freeway 126. This concrete trapezoidal channel has a base width of 10' and height of 5' with 1:1 side slopes. Some of the surface flow from Blackburn Road in addition to runoff from the Freeway will enter the channel along this section.

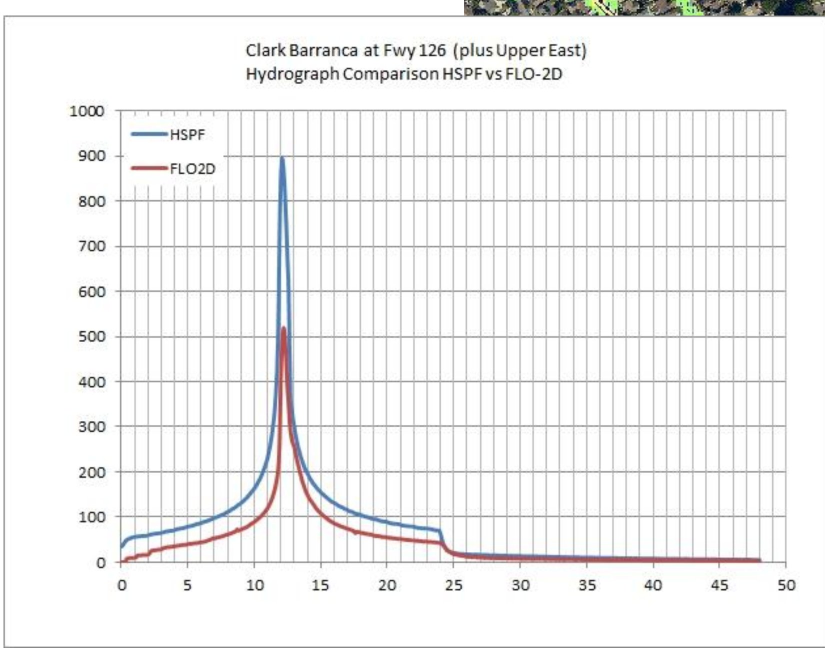
The FLO-2D model shows a Q100 ranging from 450-580 cfs inside the channel before it turns south and goes underneath Freeway 126. At this location the projected Q100 from HSPF is 894 cfs. The channel becomes a Double 5'W X 5'H RCB underneath Freeway 126 near Petit Road. It junctions with the Petit Road storm drain system underneath the Freeway, becoming a triple 5'W X 5'H RCB. The surrounding area is characterized by flood depths ranging from 0.5' up to 3' for the 100 year storm, inundating Blackburn Road, Freeway 126 and areas to the north and south. See 100-year hydrograph comparison plot below.



iv. Clark Barranca Reach 4 – D/S of Freeway 126 to Telephone Road

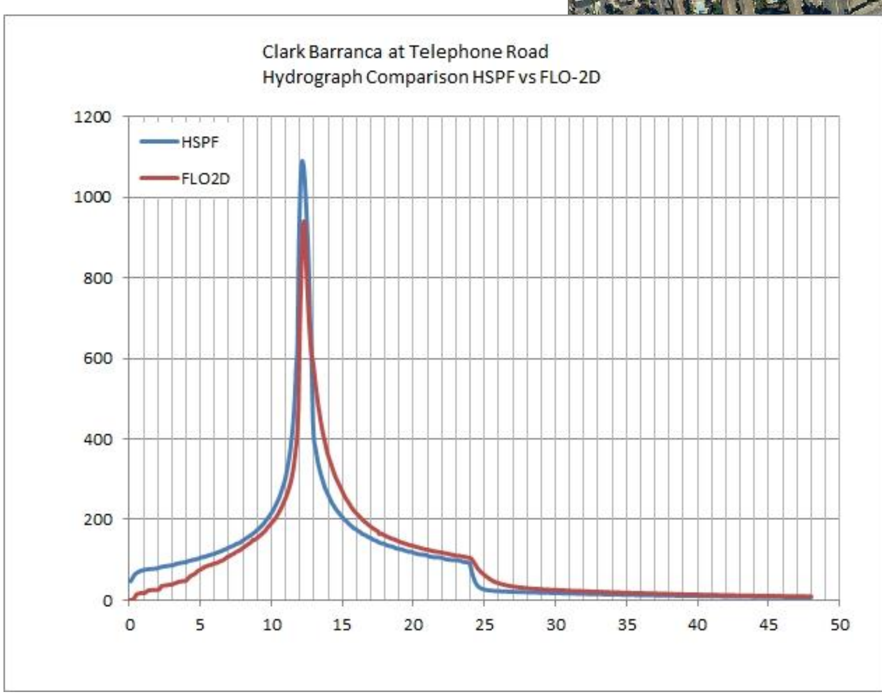
The channel transitions to a 7'W X 7'H RCB downstream of Freeway 126 and continues in a southeasterly direction until it reaches Telephone Road. The full flow capacity calculated for this RCB ranges from 665 to 820 cfs. The surrounding streets carry flows in a southeasterly direction toward Telephone Road, with 100-year depths less than 1.0'. As the 7'W X 7'H RCB turns toward the east at Telephone Road it becomes a 7'W X 8'H RCB along the north side of Telephone Road. The 7'W X 8'H RCB channel then turns toward the south crossing Telephone Road. The entire area surrounding Telephone Road and Petit Road will have flooding ranging in depths from 0.5' to just over 1.0' during the 100-year event. Flows for the underground portion of this system from Freeway 126 to the Santa Clara River are transferred directly from the inlet to the outlet of the system. Intermediate inlet locations were not modeled.

As a result, excess flows as well as local inflow hydrographs continue southeasterly along surface streets with deeper ponding occurring at the intersections of Greensboro Road and Denver Street, Albany Avenue and Las Cruces Street. See 100-year hydrograph comparison plot.



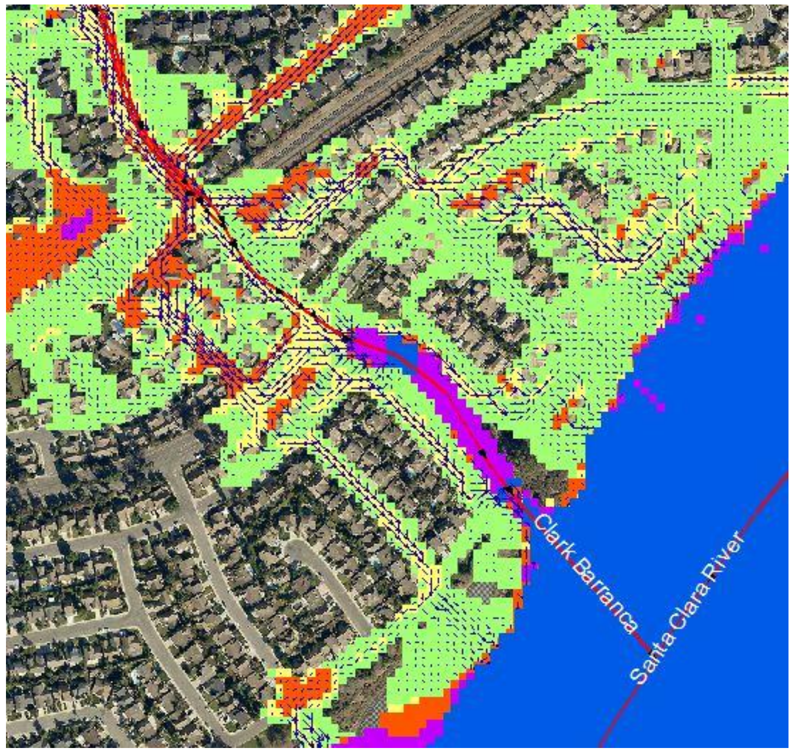
v. Clark Barranca Reach 5 – D/S of Telephone Road to Railroad Tracks

On the immediate downstream side of Telephone Road the 7'W X 8'H RCB becomes a 8'W X 8'H RCB. 200' downstream of Telephone Road the 8'W X 8'H RCB transitions to a 5' RCP and parallel 7.5' RCP as it continues southeasterly under Petit Road. The portion of Petit Road from Telephone Road to the Railroad Tracks will have flood depths ranging from 0.5' to 1.5' for the 100-year event. Flows from Lucerne Street on the east side of Petit Road and other surrounding streets will convey water to Petit Road. At the Railroad Tracks this surface flow on Petit Road will split to the east and west inundating the residential areas to the southwest and southeast with 100-year flood depths ranging from 0.5' up to a few small areas with 2.5' depth. Deeper ponding from the excess flows and inflow hydrographs also occur at the intersection of Neath Street and Exeter Avenue. See 100-year hydrograph comparison plot below.

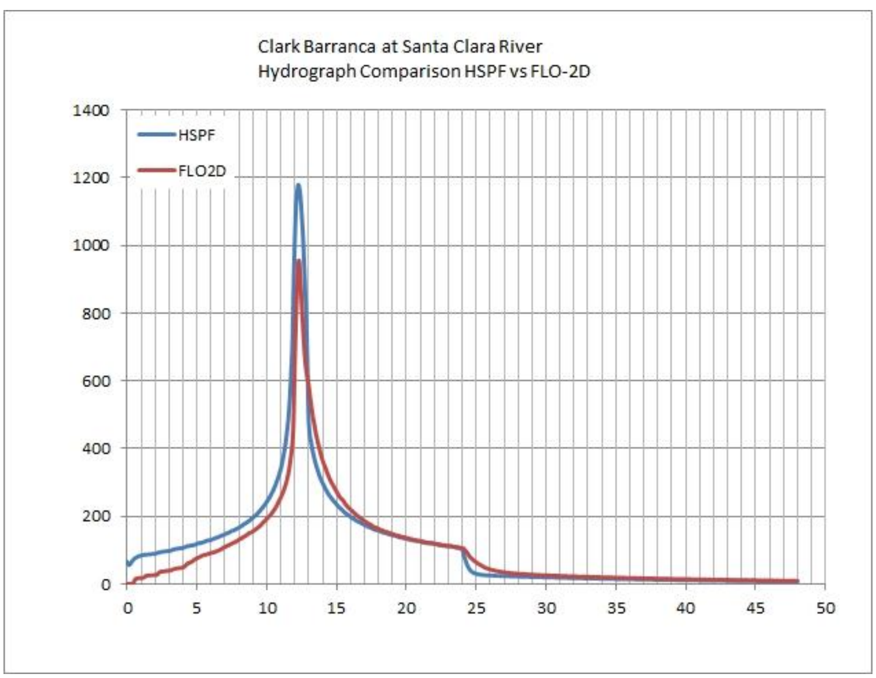


vi. Clark Barranca Reach 6 – D/S of Railroad Tracks to Santa Clara River

100' downstream of the Railroad Tracks, the parallel 5' and 7.5' RCP junction and transition to a 7'W X 7'H RCB as it continues to the Santa Clara River. Water flowing south on Carson Way to North Bank Drive and traveling to the east will inundate the North Bank Drive at the channel outlet to Santa Clara River with 100-year depths of 0.5' to 1.5' eventually overtopping the road and entering the natural channel on the downstream side.



Additional water from Carson Way will continue in a southerly direction concentrating and flowing along Arroyo Seco Drive and San Joaquin Avenue. For the natural channel just downstream of North Bank Drive the projected HSPF Q100 is 1180 cfs, while the FLO-2D model shows Q100 in the channel ranging from 730 – 965 cfs. See 100-year hydrograph comparison plot below.



8. FLOOD DAMAGE ASSESSMENT AND STATISTICS

a. Introduction

VCWPD District facilities within the FBSC watersheds were designed to either pass the 50-year flood event with additional added freeboard or the 100-year event, whichever is greater. Non-District facilities such as the natural portions of channels along Brown, Franklin, Sudden, and Wason as well as City stormdrains have capacities that vary. As a result flooding occurs due to restrictions in the stormdrain system preventing runoff from making it to the main channels, outflows from current facilities for events larger than the original design capacity, and overtopping due to a reduction in event capacity resulting from increased flood flow calculations. Resultant flood damages were estimated based on the US Department of Housing and Urban Development (HUD) methods and parameters (1975) provided by the District's Advance Planning Section.

b. Generalized Flood Damage Methodology

The HUD methodology is generally applied to residential areas. Based on the number of floors, whether a basement is present, and the depth of flooding; a percentage of the structure's value is assigned to represent both damage to the building and damage to its contents. A HUD Damage Summary Table containing these percentages was created from the original document provided by the District and interpolated at 0.1' intervals.
For this study, the process was also applied to non-residential structures. Agricultural damages were assigned based on $25,000 per flooded acre which is consistent with the District's 2009 Lower Calleguas Creek report assumptions.

c. Evaluation

In general, most flood damage assessments utilize a 1-D modeling scheme that generates a single water surface elevation across the entire modeled floodplain, with varying depths based on the floodplain topography. This methodology results in a flat pool that is inconsistent with real world conditions within urban areas and locations where the channel overbanks are appreciably lower than the main channel. The resultant floodplain would then be intersected with available parcels to determine overall flood damages.

The analysis for this study employs 2-D modeling using FLO-2D based on a 25'x25' cell size. The added detail due to calculating flood routing on cell by cell basis rather than a single cross-section, allows us to include features such as streets and their adjacent areas within the conveyance computations. In many cases, the more comprehensive analysis shows flooding to be mostly within the street.

Using solely a spatial assessment with the parcel data may overestimate the predicted damages for the various storm events. Instead, more precise building footprints were used for this purpose. This information was originally digitized by the City of Ventura and checked and/or supplemented by Kasraie Consulting.

Where available, County Assessor parcel data needed for the HUD methodology such as the number of floors, total square footage, land-use description, taxable land value, and taxable improved value were attached to the buildings through a spatial join. Parcels having more than one building resulted in duplicate data; structures in these cases were dissolved into one feature based on the unique APN number of the parcel. If County Assessor data was not available within the version of the database used, it was estimated using ESRI's ArcMap and Google Earth applications.

Due to California Prop 13, taxable values for properties included in the County Assessor parcel database do not reflect actual market value. Instead, market values as of April 2014 were estimated from the realty tracking website www.Zillow.com were utilized. The project area was divided into 30 separate categories based on either building type or neighborhood. For each category, home values were calculated for a sample set and a median value per square foot was determined. For commercial, industrial, and public lands $275/square foot was used, which is consistent with the 2012 Upper Calleguas Flood Damage Assessment. Total Market Values were determined by taking the square footage of each structure and multiplying it by the median value per square foot. For the HUD Methodology, damages are calculated based on only the value of the structure. For parcels that contain separate structure (improved) and land values (used for tax purposes, not market value), a ratio of structure to total taxable value was determined. This ratio (as-is, no adjustments for outliers) was then applied to the Total Market Value for each property. For all other properties, the average ratio of 0.58 was used.

Maximum flood depths to the nearest tenth of a foot for each recurrence interval were determined by exporting the flood depth layer from the FLO-2D model, converting it to a TIN (triangulated irregular network) surface, and then intersecting it with the digitized building layer (See Figure 23). The HUD Damage Summary Table was joined to the digitized buildings layer based on flood depth to calculate damages for the structure and its contents.

Figure 23   100-Year Event Damage Overlay Example

A summary of flood damages and annualized costs for depths greater than or equal to 6-inches (consistent with the 2012 Upper Calleguas Damage Assessment) are listed below (Table 8). Annualized costs were determined using the methodology within the FEMA Benefit Cost Analysis (BCA). They represent the amount of damage that can be expected annually based on the probability of each of the modeled recurrence intervals happening.

Storm Event	Number of Parcels	Number of Structures	Property Values ($M)	Land Values ($M)	Structure Values ($M)	Structure Value Ratio	Structure Damage Costs ($M)	Content Damage Costs ($M)	Agricultural Damage Costs ($M)	Damage Costs per Storm Event ($M)
5	1335	444	$309.2	$124.0	$185.1	59.9%	$18.7	$8.9	$1.0	$28.6
10	1623	590	$405.1	$163.5	$241.7	59.7%	$24.6	$11.3	$1.1	$37.0
25	2052	964	$580.9	$235.6	$345.3	59.4%	$35.4	$16.7	$1.4	$53.5
50	2443	1295	$747.8	$305.1	$442.7	59.2%	$46.0	$22.1	$2.5	$70.6
100	2863	1727	$991.1	$407.6	$583.5	58.9%	$61.9	$30.5	$4.0	$96.3
500	3673	2518	$1,425.5	$586.3	$839.2	58.9%	$98.7	$47.8	$9.6	$156.1
ANNUALIZED COSTS, $M (5-500YR)							$5.7	$2.7	$0.3	$8.7
Mean Annual Costs ($/year) are based on the formula contained in FEMA's Benefit-Cost Analysis Tool V5.2.3										

Table 8   Studywide Flood Damage Costs for Depths Greater Than 6-inches

Additional summaries by watershed and jurisdiction are also included (Tables 9–20) below. This information can be utilized to prioritize future capital improvement projects within the project area.

Damages by Watersheds

Storm Event	Number of Parcels	Number of Structures	Property Values ($M)	Land Values ($M)	Structure Values ($M)	Structure Value Ratio	Structure Damage Costs ($M)	Content Damage Costs ($M)	Agricultural Damage Costs ($M)	Damage Costs per Storm Event ($M)
5	133	66	$74.4	$32.2	$42.3	56.8%	$5.5	$2.7	$0.3	$8.4
10	174	113	$92.1	$40.5	$51.7	56.1%	$7.0	$3.4	$0.3	$10.7
25	240	176	$139.7	$61.3	$78.4	56.1%	$9.7	$4.8	$0.3	$14.8
50	295	272	$197.1	$85.7	$111.4	56.5%	$13.3	$6.6	$0.6	$20.5
100	367	404	$259.3	$111.1	$148.2	57.2%	$17.9	$9.1	$1.1	$28.1
500	477	529	$346.8	$143.8	$203.0	58.5%	$29.9	$14.2	$2.4	$46.4
ANNUALIZED COSTS, $M (5-500YR)							$1.6	$0.8	$0.1	$2.5
Mean Annual Costs ($/year) are based on the formula contained in FEMA's Benefit-Cost Analysis Tool V5.2.3										

Table 9 Brown Barranca Watershed Flood Damage Costs for Depths Greater Than 6-inches

Storm Event	Number of Parcels	Number of Structures	Property Values ($M)	Land Values ($M)	Structure Values ($M)	Structure Value Ratio	Structure Damage Costs ($M)	Content Damage Costs ($M)	Agricultural Damage Costs ($M)	Damage Costs per Storm Event ($M)
5	342	124	$71.9	$25.1	$46.8	65.1%	$4.3	$2.0	$0.0	$6.3
10	402	142	$105.1	$38.9	$66.1	63.0%	$5.9	$2.7	$0.0	$8.6
25	480	179	$138.4	$51.0	$87.4	63.1%	$8.0	$3.6	$0.0	$11.6
50	581	208	$161.7	$59.0	$102.7	63.5%	$9.5	$4.3	$0.0	$13.8
100	663	243	$186.4	$68.8	$117.5	63.1%	$11.1	$5.2	$0.0	$16.3
500	895	327	$265.7	$100.4	$165.3	62.2%	$16.2	$7.5	$0.0	$23.7
ANNUALIZED COSTS, $M (5-500YR)							$1.3	$0.6	$0.0	$1.8
Mean Annual Costs ($/year) are based on the formula contained in FEMA's Benefit-Cost Analysis Tool V5.2.3										

Table 10 Clark Barranca Watershed Flood Damage Costs for Depths Greater Than 6-inches

Storm Event	Number of Parcels	Number of Structures	Property Values ($M)	Land Values ($M)	Structure Values ($M)	Structure Value Ratio	Structure Damage Costs ($M)	Content Damage Costs ($M)	Agricultural Damage Costs ($M)	Damage Costs per Storm Event ($M)
5	41	21	$7.4	$3.7	$3.7	50.6%	$0.7	$0.3	$0.3	$1.3
10	53	24	$7.7	$3.8	$3.9	50.6%	$0.9	$0.4	$0.4	$1.7
25	72	71	$16.9	$8.4	$8.5	50.3%	$1.4	$0.7	$0.6	$2.7
50	91	79	$19.7	$9.6	$10.1	51.3%	$1.6	$0.8	$1.2	$3.7
100	116	94	$20.5	$9.9	$10.6	51.6%	$1.8	$0.9	$1.8	$4.5
500	146	130	$32.9	$15.5	$17.4	53.0%	$2.6	$1.2	$4.4	$8.2
ANNUALIZED COSTS, $M (5-500YR)							$0.2	$0.1	$0.1	$0.4
Mean Annual Costs ($/year) are based on the formula contained in FEMA's Benefit-Cost Analysis Tool V5.2.3										

Table 11 Franklin Barranca Watershed Flood Damage Costs for Depths Greater Than 6-inches

Storm Event	Number of Parcels	Number of Structures	Property Values ($M)	Land Values ($M)	Structure Values ($M)	Structure Value Ratio	Structure Damage Costs ($M)	Content Damage Costs ($M)	Agricultural Damage Costs ($M)	Damage Costs per Storm Event ($M)
5	50	20	$9.1	$3.8	$5.3	58.2%	$0.4	$0.2	$0.0	$0.6
10	51	20	$8.4	$3.7	$4.7	56.3%	$0.4	$0.2	$0.0	$0.6
25	98	30	$13.8	$5.6	$8.2	59.5%	$0.7	$0.4	$0.0	$1.1
50	118	42	$16.1	$6.6	$9.5	59.2%	$0.9	$0.4	$0.0	$1.3
100	139	53	$19.5	$8.2	$11.3	58.1%	$1.1	$0.5	$0.0	$1.6
500	169	79	$30.3	$12.5	$17.8	58.8%	$1.8	$0.9	$0.0	$2.7
ANNUALIZED COSTS, $M (5-500YR)							$0.1	$0.1	$0.0	$0.2
Mean Annual Costs ($/year) are based on the formula contained in FEMA's Benefit-Cost Analysis Tool V5.2.3										

Table 12 Mammoth Street-54" RCP Watershed Flood Damage Costs for Depths Greater Than 6-inches

Storm Event	Number of Parcels	Number of Structures	Property Values ($M)	Land Values ($M)	Structure Values ($M)	Structure Value Ratio	Structure Damage Costs ($M)	Content Damage Costs ($M)	Agricultural Damage Costs ($M)	Damage Costs per Storm Event ($M)
5	145	27	$15.6	$6.1	$9.4	60.7%	$0.8	$0.4	$0.0	$1.2
10	181	34	$18.4	$7.1	$11.3	61.4%	$1.0	$0.5	$0.0	$1.5
25	216	52	$28.3	$11.0	$17.3	61.1%	$1.6	$0.7	$0.0	$2.3
50	259	63	$32.9	$12.9	$20.0	60.9%	$1.8	$0.9	$0.0	$2.7
100	305	85	$42.1	$17.5	$24.6	58.5%	$2.3	$1.1	$0.1	$3.4
500	410	139	$73.2	$32.7	$40.4	55.2%	$3.8	$1.8	$0.3	$5.9
ANNUALIZED COSTS, $M (5-500YR)							$0.2	$0.1	$0.0	$0.3
Mean Annual Costs ($/year) are based on the formula contained in FEMA's Benefit-Cost Analysis Tool V5.2.3										

Table 13 Montgomery Avenue Watershed Flood Damage Costs for Depths Greater Than 6-inches

Storm Event	Number of Parcels	Number of Structures	Property Values ($M)	Land Values ($M)	Structure Values ($M)	Structure Value Ratio	Structure Damage Costs ($M)	Content Damage Costs ($M)	Agricultural Damage Costs ($M)	Damage Costs per Storm Event ($M)
5	31	13	$25.2	$10.5	$14.7	58.3%	$1.3	$0.8	$0.0	$2.1
10	35	14	$26.6	$11.1	$15.5	58.4%	$1.4	$0.8	$0.0	$2.3
25	44	18	$29.0	$12.2	$16.9	58.1%	$1.6	$0.9	$0.0	$2.5
50	70	41	$52.5	$22.0	$30.6	58.2%	$2.8	$1.6	$0.0	$4.5
100	118	117	$121.5	$50.8	$70.8	58.2%	$6.7	$3.9	$0.0	$10.6
500	163	250	$190.4	$80.7	$109.7	57.6%	$12.6	$7.1	$0.0	$19.7
ANNUALIZED COSTS, $M (5-500YR)							$0.4	$0.2	$0.0	$0.6
Mean Annual Costs ($/year) are based on the formula contained in FEMA's Benefit-Cost Analysis Tool V5.2.3										

Table 14 Saticoy Yard Watershed Flood Damage Costs for Depths Greater Than 6-inches

Storm Event	Number of Parcels	Number of Structures	Property Values ($M)	Land Values ($M)	Structure Values ($M)	Structure Value Ratio	Structure Damage Costs ($M)	Content Damage Costs ($M)	Agricultural Damage Costs ($M)	Damage Costs per Storm Event ($M)
5	156	54	$37.4	$12.4	$24.9	66.7%	$2.3	$1.0	$0.0	$3.2
10	195	72	$50.2	$17.4	$32.8	65.3%	$3.0	$1.3	$0.0	$4.3
25	223	95	$58.8	$19.5	$39.4	66.9%	$4.0	$1.8	$0.0	$5.8
50	274	116	$67.9	$22.9	$44.9	66.2%	$4.8	$2.2	$0.1	$7.1
100	303	146	$86.1	$29.8	$56.3	65.4%	$6.1	$2.9	$0.1	$9.1
500	364	211	$113.8	$39.0	$74.8	65.7%	$8.5	$4.0	$0.2	$12.7
ANNUALIZED COSTS, $M (5-500YR)							$0.6	$0.3	$0.0	$0.9
Mean Annual Costs ($/year) are based on the formula contained in FEMA's Benefit-Cost Analysis Tool V5.2.3										

Table 15 Saticoy Avenue Drain Watershed Flood Damage Costs for Depths Greater Than 6-inches

Storm Event	Number of Parcels	Number of Structures	Property Values ($M)	Land Values ($M)	Structure Values ($M)	Structure Value Ratio	Structure Damage Costs ($M)	Content Damage Costs ($M)	Agricultural Damage Costs ($M)	Damage Costs per Storm Event ($M)
5	52	31	$19.7	$8.0	$11.6	59.2%	$1.0	$0.5	$0.0	$1.5
10	66	47	$29.9	$12.6	$17.3	57.9%	$1.5	$0.7	$0.0	$2.2
25	140	177	$66.4	$29.9	$36.5	54.9%	$3.5	$1.7	$0.0	$5.2
50	177	289	$98.2	$45.1	$53.2	54.1%	$5.4	$2.8	$0.0	$8.2
100	234	372	$132.9	$61.0	$71.8	54.1%	$7.8	$4.0	$0.0	$11.8
500	299	536	$194.7	$88.7	$105.9	54.4%	$13.0	$6.5	$0.3	$19.8
ANNUALIZED COSTS, $M (5-500YR)							$0.5	$0.2	$0.0	$0.7
Mean Annual Costs ($/year) are based on the formula contained in FEMA's Benefit-Cost Analysis Tool V5.2.3										

Table 16 Saticoy Drain Watershed Flood Damage Costs for Depths Greater Than 6-inches

Storm Event	Number of Parcels	Number of Structures	Property Values ($M)	Land Values ($M)	Structure Values ($M)	Structure Value Ratio	Structure Damage Costs ($M)	Content Damage Costs ($M)	Agricultural Damage Costs ($M)	Damage Costs per Storm Event ($M)
5	339	86	$47.2	$21.4	$25.8	54.6%	$2.3	$1.0	$0.0	$3.3
10	408	122	$65.3	$27.6	$37.8	57.8%	$3.3	$1.4	$0.0	$4.7
25	470	164	$87.9	$35.8	$52.2	59.3%	$4.7	$1.9	$0.1	$6.6
50	499	183	$100.0	$40.4	$59.6	59.6%	$5.5	$2.3	$0.1	$7.8
100	534	210	$120.7	$49.4	$71.3	59.1%	$6.7	$2.9	$0.1	$9.6
500	651	308	$173.8	$71.0	$102.7	59.1%	$9.9	$4.3	$0.3	$14.5
ANNUALIZED COSTS, $M (5-500YR)							$0.7	$0.3	$0.0	$1.0
Mean Annual Costs ($/year) are based on the formula contained in FEMA's Benefit-Cost Analysis Tool V5.2.3										

Table 17 Sudden Barranca Watershed Flood Damage Costs for Depths Greater Than 6-inches

Storm Event	Number of Parcels	Number of Structures	Property Values ($M)	Land Values ($M)	Structure Values ($M)	Structure Value Ratio	Structure Damage Costs ($M)	Content Damage Costs ($M)	Agricultural Damage Costs ($M)	Damage Costs per Storm Event ($M)
5	4	2	$1.4	$0.8	$0.6	41.0%	$0.2	$0.1	$0.3	$0.6
10	4	2	$1.4	$0.8	$0.6	41.0%	$0.2	$0.1	$0.3	$0.6
25	4	2	$1.7	$1.0	$0.8	44.6%	$0.3	$0.1	$0.4	$0.7
50	4	2	$1.7	$1.0	$0.8	44.6%	$0.3	$0.1	$0.5	$0.9
100	5	3	$2.2	$1.2	$1.1	47.5%	$0.3	$0.2	$0.8	$1.3
500	5	8	$4.1	$2.0	$2.1	50.7%	$0.5	$0.2	$1.8	$2.5
ANNUALIZED COSTS, $M (5-500YR)							$0.0	$0.0	$0.1	$0.1
Mean Annual Costs ($/year) are based on the formula contained in FEMA's Benefit-Cost Analysis Tool V5.2.3										

Table 18 Wason Barranca Watershed Flood Damage Costs for Depths Greater Than 6-inches

Damages by Jurisdiction

Storm Event	Number of Parcels	Number of Structures	Property Values ($M)	Land Values ($M)	Structure Values ($M)	Structure Value Ratio	Structure Damage Costs ($M)	Content Damage Costs ($M)	Agricultural Damage Costs ($M)	Damage Costs per Storm Event ($M)
5	85	39	$235.4	$92.4	$143.0	60.8%	$14.5	$6.5	$0.1	$21.1
10	102	54	$321.7	$127.6	$194.1	60.3%	$19.6	$8.6	$0.1	$28.3
25	134	135	$482.2	$193.3	$289.0	59.9%	$29.2	$13.3	$0.1	$42.7
50	174	200	$593.8	$239.3	$354.5	59.7%	$36.4	$16.8	$0.2	$53.4
100	235	302	$724.7	$294.6	$430.1	59.3%	$45.1	$21.1	$0.4	$66.6
500	404	513	$1,066.0	$226.8	$839.2	78.7%	$98.7	$47.8	$0.6	$147.1
ANNUALIZED COSTS, $M (5-500YR)							$4.5	$2.0	$0.0	$6.6
Mean Annual Costs ($/year) are based on the formula contained in FEMA's Benefit-Cost Analysis Tool V5.2.3										

Table 19 City of Ventura Area Flood Damage Costs for Depths Greater Than 6-inches

Storm Event	Number of Parcels	Number of Structures	Property Values ($M)	Land Values ($M)	Structure Values ($M)	Structure Value Ratio	Structure Damage Costs ($M)	Content Damage Costs ($M)	Agricultural Damage Costs ($M)	Damage Costs per Storm Event ($M)
5	21	9	$73.7	$31.6	$42.1	57.1%	$4.2	$2.4	$0.9	$7.5
10	30	15	$83.4	$35.8	$47.6	57.0%	$5.0	$2.8	$1.0	$8.7
25	40	24	$98.7	$42.3	$56.4	57.1%	$6.2	$3.4	$1.3	$10.8
50	60	49	$154.0	$65.7	$88.3	57.3%	$9.6	$5.4	$2.2	$17.2
100	97	101	$266.4	$113.1	$153.4	57.6%	$16.8	$9.3	$3.6	$29.8
500	206	273	$359.5	$153.7	$205.8	57.2%	$29.7	$15.4	$9.0	$54.1
ANNUALIZED COSTS, $M (5-500YR)							$1.2	$0.7	$0.3	$2.1
Mean Annual Costs ($/year) are based on the formula contained in FEMA's Benefit-Cost Analysis Tool V5.2.3										

Table 20 Unincorporated County Areas Flood Damage Costs for Depths Greater Than 6-inches

d. Statistics

As a planning level study, this set of FLO-2D modeling is not intended to replace the existing FEMA floodplain analysis included in the 2010 Ventura County and Incorporated Area Flood Insurance Study (FIS). However, it is useful to compare them to avoid confusion regarding why their flooding extents differ so greatly.

Out of the four main tributaries within the FLO-2D model domain, only portions of Franklin (Darling Road to the Santa Clara River) and Brown (approximately 400-500 feet upstream of Telegraph Road to the downstream side of Freeway 126) were studied in detail. In both cases, the FIS hydrology results in significantly lower flows (17-25%) at their outlets than those from the current HSPF model that was provided by the District.

Based on these flows and the HEC-RAS model used to determine the stream hydraulics, Franklin does not overtop during a 1% annual chance event and was mapped as an approximate zone (no profiles or BFEs) due to mapping constraints. The majority of the detailed segment of Brown included in the FIS is mainly in an area where the channel is deep and incised, thus containing the 1% annual chance flood. Additionally, the FIS study assumes that all of the excess runoff from the watershed makes it to the channels, which is not necessarily the case due to limited capacities of the stormwater network (inlets and pipes) that empties into the main channels.

Immediately upstream of Freeway 126, the mapping and modeling show that the flow overtops the channel into the adjacent agricultural area. This is area was still being used for agriculture at the time of the 2013 aerial photography. The remainder of Brown, until its confluence with the Santa Clara River is mapped as an approximate zone.
For these reasons, when we spatially overlay the effective floodplain with the County parcels and digitized structures, a limited number are shown to be affected (see Table 21).

	County Unincorporated			**City**			**Subtotals**			**Totals**	**Total Parcels Within Study Area**	**% of Parcels Within Study Area Subject to Mandatory Flood Insurance**
	Residential	Comm. / Industrial	Open Space/Ag	Residential	Comm. / Industrial	Open Space/Ag	Residential	Comm. / Industrial	Open Space/Ag	(All Catgeories)		
Structures	0	0	0	0	0	1	0	0	0	**1**	9475	0.0%
Parcels	2	8	35	5	2	15	7	10	50	**67**	11769	0.6%

*Based on FEMA Effective Zones A, AE, AH, AO

Table 21 FEMA Effective Floodplain (2010) – Structures and Parcels Subjected to Mandatory Flood Insurance By Land Use*

In contrast, the FLO-2D study encompasses flooding over the entire study area. This includes situations where restrictions in the storm drain system create localized flooding as well as outflows from the main channels of Franklin, Brown, Sudden, and Clark. Due to this added detail, a significantly larger amount of parcels and structures are shown to be affected by flooding (see Table 22).

	County Unincorporated			City			Subtotals			Totals	Total Parcels or Structures Within Study Area	% of Parcels or Structures Within Study Area Subject to Mandatory Flood Insurance
	Residential	Comm. / Industrial	Open Space/Ag	Residential	Comm. / Industrial	Open Space/Ag	Residential	Comm. / Industrial	Open Space/Ag	(All Catgeories)		
Structures	43	70	7	642	11	2	685	81	9	**775**	9475	8.2%
Parcels	37	79	60	993	34	50	1030	113	110	**1253**	11769	10.6%
** 100yr Flood Depth 1.00 Foot and Deeper												

Table 22 FLO-2D 100-Year Event - Structures and Parcels Subjected to Flood Insurance By Land Use**