Santa Ana River PMR Submittal

AFFECTED FIRM PANELS:

1	06071C	9335H
2	06071C	9345H
3	06071C	9375H
4	06065C	0043G
5	06065C	0045G
6	06065C	0065G
7	06065C	0667G
8	06065C	0669G
9	06065C	0678G
10	06065C	0679G
11	06065C	0682G
12	06065C	0683G
13	06065C	0684G
14	06065C	0686G
15	06065C	0687G
16	06065C	0688G
17	06065C	0689G
18	06065C	0702G
19	06065C	0705G
20	06065C	0706G
21	06065C	0710G
22	06065C	0726G

AFFECTED CITIES:

1	Eastvale
2	Jurupa Valley
3	Norco
4	Riverside
5	Corona
6	Chino
7	Chino Hills

Submitted by: Riverside County Flood Control
1995 Market Street
Riverside, CA 92501

Table of Contents

Figures

Tables

Study Objective

The Santa Ana River is one of the largest rivers within Riverside County with an area of more than 2200 square miles tributary to it. It extends some 18 miles within the county from the boundary with San Bernardino County down to Prado Dam basin. This study represents an effort by the Riverside County Flood Control & Water Conservation District to update the Santa Ana River FEMA floodplain. Hydraulic analysis is based on a combination of LiDAR and digital photogrammetry taken intermittently around 2006-2010 as well as the United States Army Corps of Engineers 1988 hydrology study which incorporated the effects of Seven Oaks Dam.

This study will update the FEMA floodplain for the Santa Ana River within Riverside County upstream of Prado Dam. It will account for the effects of Seven Oaks Dam (built in 1999), improvements to Prado Dam, aggradation/degradation, and a few recently constructed bridges. In addition, the Levee Certification that was submitted for the Riverside Levees along the Santa Ana River used the flow rates from the 1988 USACE hydrology report as opposed to the effective FEMA flow rate. In order for FEMA to allow the use of the lower USACE flow rates for the Levee Certification, this study has to be approved first as a Physical Map Revision.

Abbreviations

RCFC	Riverside County Flood Control & Water Conservation District
FEMA	Federal Emergency Management Agency
USACE	United States Army Corps of Engineers
SPF	Standard Project Flood
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
LOMR	Letter of Map Revision
LOMR-F	Letter of Map Revision – Based on Fill
CLOMR	Conditional Letter of Map Revision
LiDAR	Light Detection and Ranging
HEC-RAS	Hydrologic Engineering Center – River Analysis System
cfs	cubic feet per second

1.0 Project Description

1.1 Scope

This report summarizes the results of a detailed FEMA floodplain study of the Santa Ana River within Riverside County performed by RCFC. This study updates the existing floodplain mapping to account for changes in topography and the recent construction of Seven Oaks Dam in the city of Mentone. The study reach extends from Prado Dam basin at the downstream limit to more than 6000 feet upstream of the county boundary [Figure 1], a total distance of approximately 18 miles. Topography used for this study is based on a combination of LiDAR and digital photogrammetry taken intermittently between 2008-2010 [Appendix F]. Previous floodplain mapping studies were completed by FEMA in 1980 and the USACE in 1991.

1.2 Description of Study Reach

The 18-mile study reach of the Santa Ana River is located in the northwest sector of Riverside County. Despite widespread urbanization of the watershed, most of the Santa Ana River within the county exists as a natural, ephemeral stream with some manmade encroachments. These encroachments include the 3.4-mile leveed reach at the upstream limit of the study, Riverside Water Quality Control Plant, and the Norco Bluffs slope protection [Figure 2].

The Santa Ana River levees were constructed jointly by USACE and Riverside County. Riverside County completed the levees upstream of the County boundary by 1939 and USACE completed the remaining levees around 1956. These rock-lined levees were designed to protect against the Standard Project Flood. Rock groins were placed in 1995 along the levee to keep low flow away from levee toe [Figure 3]. Currently, RCFC operates and maintains these levees. Maintenance consists of seasonal mowing of the river bottom and periodic redirection of low flows.

About two miles downstream of the levees is the Riverside Narrows. The 1.75-mile reach is about 70% narrower than the upstream floodplain width. This natural constriction causes a significant backwater effect during large storm events. At the downstream end of this reach, is the Riverside Water Quality Control Plant. A levee has been built along the plant adjacent to the river, which further constricts it but does not provide adequate protection against a 100-year flood event.

In general, the river is made up of moderately vegetated reaches consisting of willows and arrundo which are typically uprooted during significant storm events. This, coupled with the prevailing sandy soils, allows the low-flow channel to change paths after large storms.

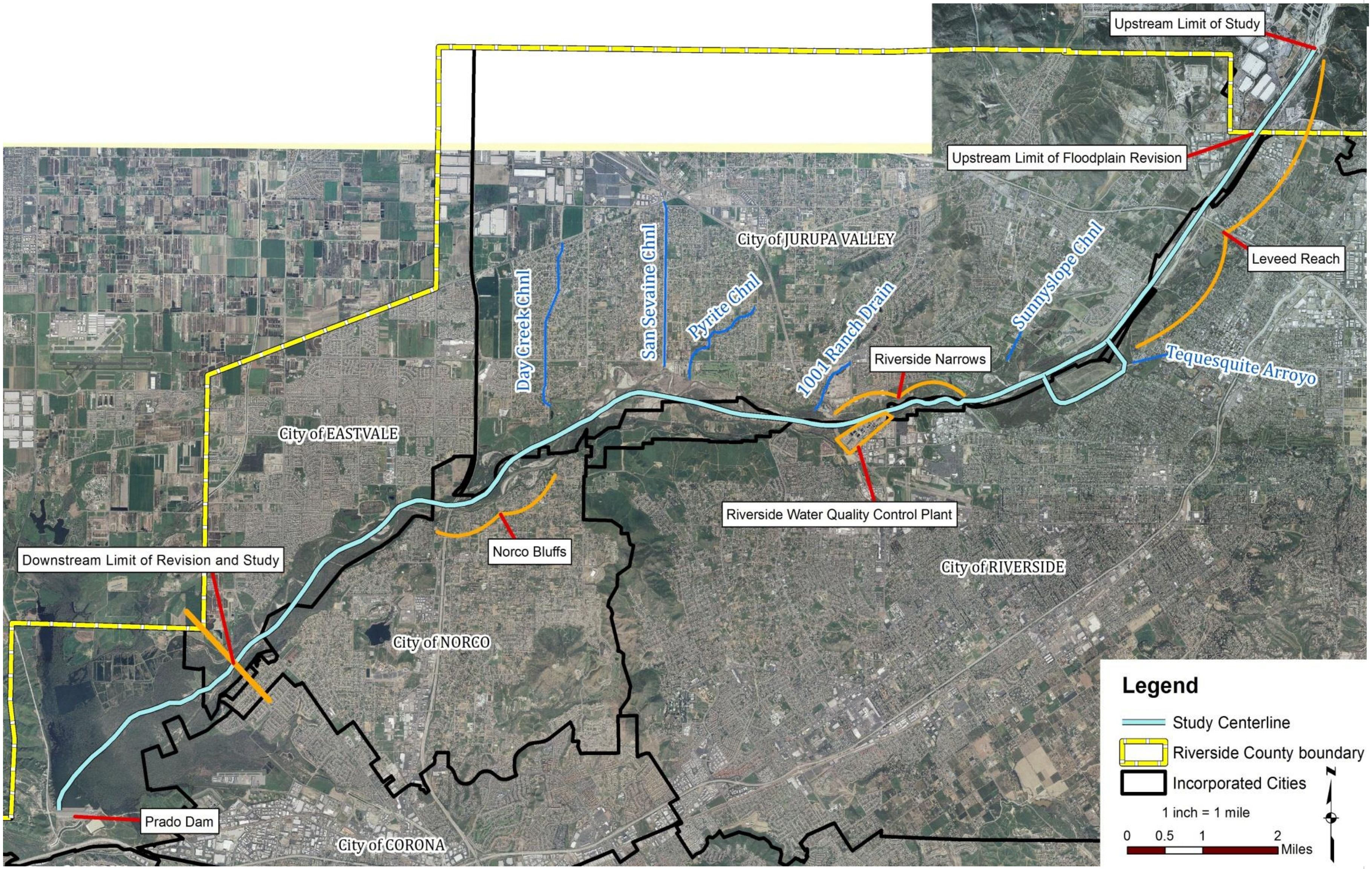

Figure 1: Limits of Santa Ana River Floodplain Study [note baseline is taken from Prado Dam]

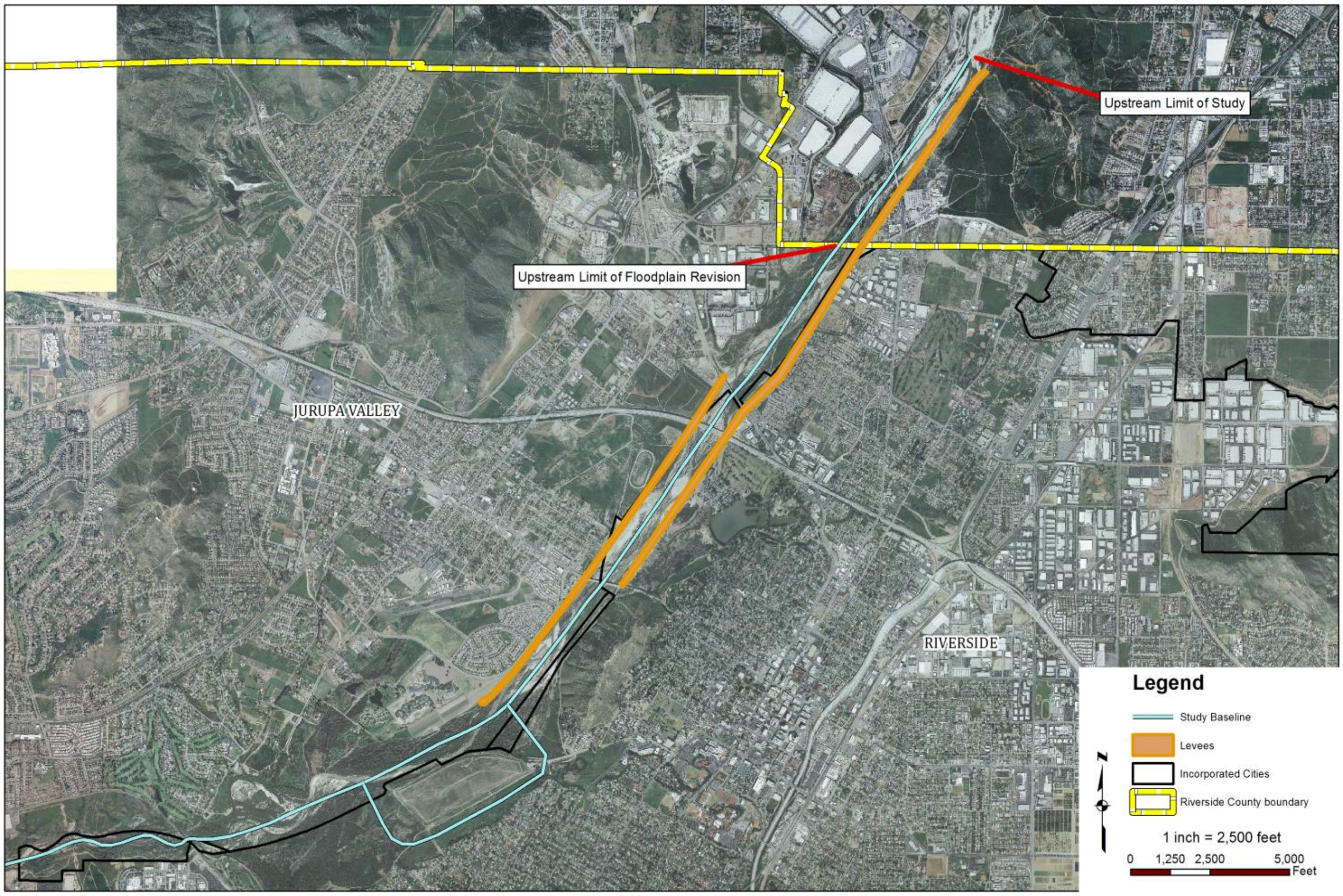

Figure 2: Location of Santa Ana River Levees

Figure 3: Looking upstream at Market Street Bridge

1.3 Previous Floodplain Studies

1.3.1 Mainstem

The FEMA floodplain mapping for Santa Ana River has existed since Riverside County joined the National Flood Insurance Program in 1980. Since its inception, few revisions have been made to the Santa Ana River floodplain within the County. The majority of these consist of LOMR-Fs that were completed for tracts built within the floodplain fringe. These LOMR-Fs established that the developments were free from severe flooding hazards but they did not revise the floodplain mapping. The only revision to have altered the floodplain boundary within the county is FEMA case no. 01-09-085P which was completed in 2001 for the construction of Tract 28784 located in the City of Eastvale. This revision updated the Santa Ana River floodplain to account for the then newly constructed I-15 Freeway bridge crossing. Thus, the current floodplain mapping for the Santa Ana River consists of the original 1980 study and the 2001 revision for Tract 28784. The duplicate hydraulic model for the effective FEMA floodplain is discussed in detail in §3.2.1.

According to the 2008 FIS for the county, peak discharges for FEMA's floodplain study were obtained from the 1975 USACE *Review Report on the Santa Ana River Main Stem*. USACE updated their 1975 Review Report to account for further flood control design efforts, changed conditions, and new data. In 1988, they released the *Design Memorandum No. 1: Phase II GDM on the Santa Ana River Mainstem* which included a volume dedicated to hydrology. This hydrology report gave consideration to the effects of the proposed Seven Oaks Dam (constructed in 1999) as well as improvements to Prado Dam. In 1991, USACE completed the report *Design Memorandum No.2: Feature Design – Seven Oaks Dam, Floodway Delineation* which delineated the Santa Ana River floodplain based on the updated 1988 hydrology report.

There are significant differences between the FEMA and USACE floodplain and floodway delineations. These differences are primarily due to the reduced flow rate caused by Seven Oaks Dam and changes in topography. A RCFC memorandum dated March 2, 1992 compares the results of the USACE 1991 study with the FEMA 1988 FIS. This memo is included in Appendix B2. Table 1 shows a comparison of various flow rates for the area downstream of the Union Pacific Railroad bridge crossing known as Riverside Narrows. Figures 4 and 5 show examples of areas where the floodplains differ. In many areas, the USACE floodway is wider than the FEMA floodway. Currently, both studies are used to regulate development along Santa Ana River under County Ordinance 458.13.

Table 1: Comparison of FEMA vs. USACE Peak Flow Rates at Riverside Narrows

Storm Frequency	Flow Rates [cfs]	
	FEMA	*USACE*
10-year	22,000	19,000
50-year	102,000	81,000
100-year	175,000	140,000
500-year	340,000	310,000

Table 2: Comparison of FEMA vs. USACE 100-Year Water Surface Elevations

FEMA [2008 FIS]		USACE			USACE vs. FEMA
Section	*WS Elev [NAVD88]*	*Section*	*WS Elev [NGVD29]*	*WS Elev* [NAVD88]*	
R	821.5	20.29	817.6	820.1	-1.4
Q	778.7	18.13	772.4	774.9	-3.8
P	746.8	16.84	742.9	745.4	-1.4
O	740.7	15.85	735.9	738.4	-2.3
N	739.9	15.56	734.7	737.2	-2.7
M	731.6	15.434	729.5	732	0.4
L	708.7	14.27	709.8	712.3	3.6
K	680.9	12.76	677.1	679.6	-1.3
J	644.7	11.15	645	647.5	2.8
I	631.3	10.54	636.3	638.8	7.5
H	615.6	9.23	618.7	621.2	5.6
G	605.1	7.95	605.2	607.7	2.6
F	601.8	7.54	601.7	604.2	2.4
E	596.6	6.955	594.1	596.6	0
D	586.3	6.72	588.2	590.7	4.4
C	578.7	6.46	582.1	584.6	5.9
B	571.0	6.01	572.1	574.6	3.6
A	558.9	4.81	558.1	560.6	1.7

* 2.5 feet added to NGVD29 water surface elevations to convert to NAVD88

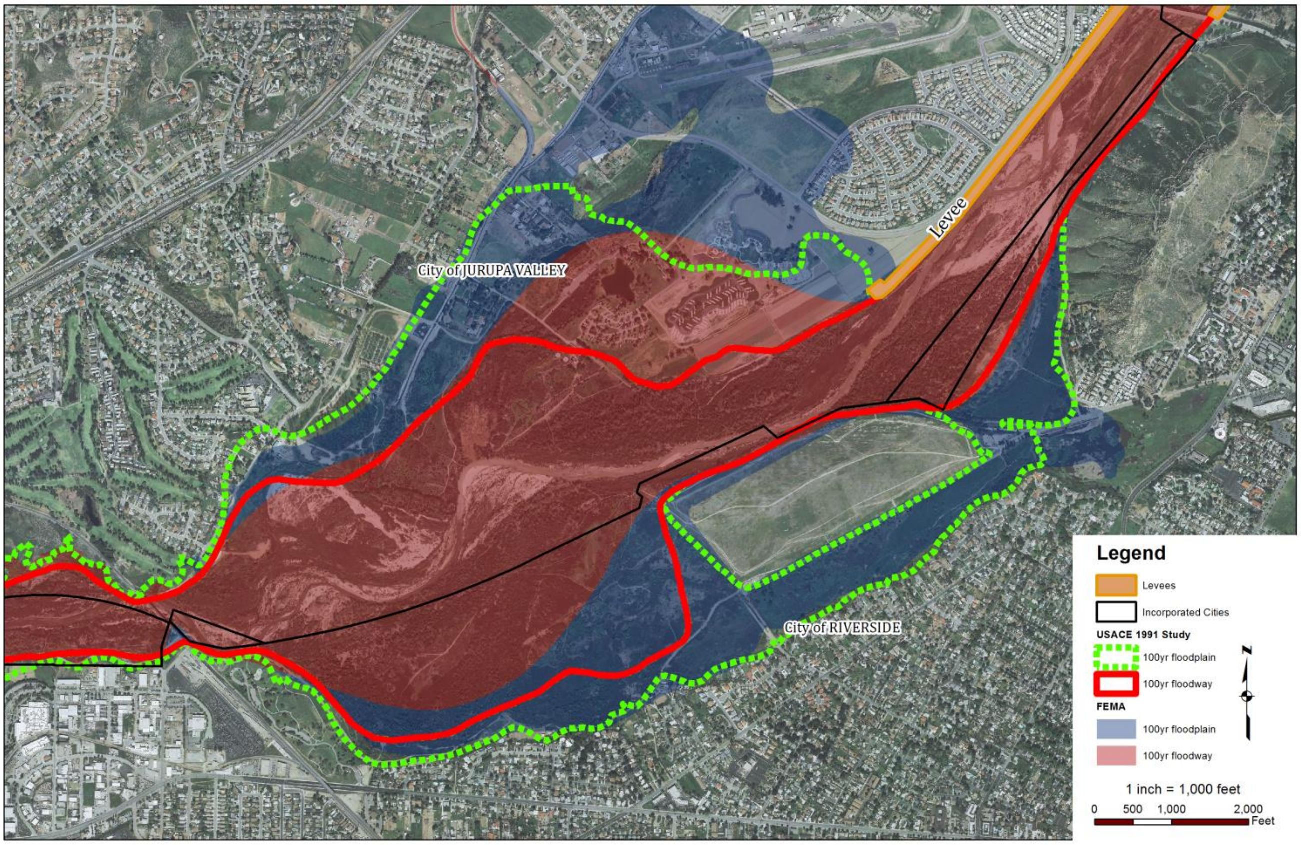

Figure 4: FEMA vs. USACE floodplain delineation, end of leveed reach

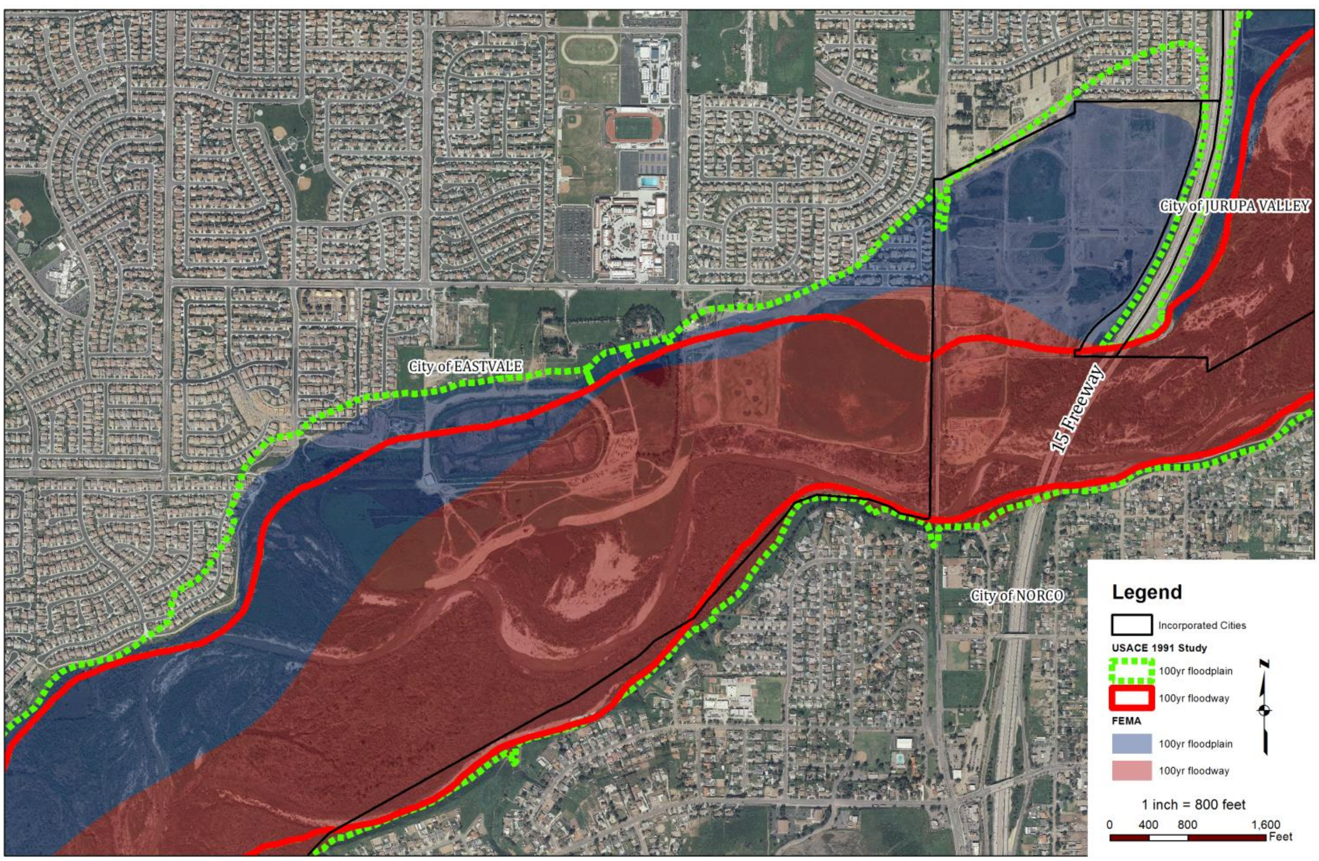

Figure 5: FEMA vs. USACE floodplain delineation, near I-15 Freeway Bridge

1.3.2 Tributaries

Several tributaries to Santa Ana River have also been mapped by FEMA including Tequesquite Arroyo, Sunnyslope Channel, 1001 Ranch Drain, Pyrite Channel, San Sevaine Channel, and Day Creek Channel [Figure 1]. With the exception of Tequesquite Arroyo, the hydraulic analyses for these tributaries are not controlled by backwater from the Santa Ana River. Tequesquite Arroyo does not have a distinct floodplain boundary near the river since the corresponding 100-year flow is contained within a culvert. For this reason, only the FIS profile needs to be revised for Tequesquite Arroyo.

For other reasons, two other tributaries were revised by this floodplain study. Pyrite Channel was updated to account for better topography near the study reach. Day Creek Channel has been improved to a rectangular concrete-lined channel and the CLOMR was approved by FEMA under case no. 12-09-1803R. For this study, the confluence of Day Creek with Santa Ana River will be mapped using the newly constructed channel. Table 3 summarizes the different tributaries along the study reach.

Table 3: Summary of Tributaries along Study Reach

Tributary Name (most upstream first)	FEMA Flood Zone	Detailed Study Controlled by Santa Ana Backwater?	Effects of this Floodplain Study
Tequesquite Arroyo	AE	Yes	FIS Profile Revised
Sunnyslope Channel	AE	No	
1001 Ranch Drain	A	n/a	
Pyrite Channel	A	n/a	Floodplain Revised
San Sevaine Channel	Contained in Channel	n/a	
Day Creek Channel	AE	No	Floodplain Revised

2.0 Hydrology

2.1 Information on Santa Ana River Watershed

2.1.1 Scope

In 1988, USACE released the *Design Memorandum No. 1: Phase II GDM on the Santa Ana River Mainstem* which included a volume dedicated to hydrology. This hydrology report updated the previous 1975 report and gave consideration to the effects of the proposed Seven Oaks Dam (constructed in 1999) as well as improvements to Prado Dam. These reports identified more than 1000 square miles tributary to Prado Dam through Santa Ana River. The flow rates were analyzed with the effects of the proposed dam and increased runoff due to future urbanization. RCFC evaluated key parameters, such as land use and rainfall, utilized in the report to see if the results are still appropriate for use in this floodplain study.

2.1.2 Summary of Hydrologic Methodology used in USACE Hydrology Reports

The USACE hydrology reports for Santa Ana River focus on the analysis of the Standard Project Flood. SPF is defined in USACE Engineering Manual 1110-2-1411 as a flood that "may be expected from the most severe combination of meteorologic and hydrologic conditions that are considered reasonably characteristic of the geographical region involved, excluding extremely rare combinations." Due to the way SPF is derived, it is typically larger than any past recorded flood and represents a "standard for design that would provide a high degree of flood protection."

The 1988 USACE Hydrology Report explains that the standard project storm was determined by evaluating historical storms of record to establish which event produced the "most severe flood-producing rainfall, depth-area duration relationship and isohyetal pattern." The critical storm was determined to be the January 21-24, 1943 historical storm of record[1]. The maximum 24-hour rainfall values for this storm were transposed and centered critically over the San Bernardino and San Gabriel Mountains to determine the most severe isohyetal pattern. Additional parameters were gathered in order to run a HEC-1 analysis of the Santa Ana River watershed and generate present and future condition SPF hydrographs for key locations.

In addition to determining the SPF, discharge-frequency curves for present and future conditions were determined at various locations along Santa Ana River. Future conditions represent the effects of increased urbanization and runoff projected for the watershed. Stream-gage analysis was conducted using five gages for the reach upstream of Prado Dam to create "present" 1975 discharge-frequency curves. Curves for future condition were drawn with the same slope but were adjusted upwardly using ratios from the peak future SPF to present SPF[2]. Similarly, "with project" and "without project" discharge-frequency curves were determined by using the ratio of "without project" SPF to "with project" SPF discharges. The referenced project is Seven Oaks Dam.

[1] A description of this storm is located on page H-8 of the 1975 USACE Hydrology Report
[2] The analysis of these curves is described in detail starting on page H-23 of the 1975 USACE Hydrology Report

2.1.3 Seven Oaks Dam

In November 1999, Seven Oaks Dam was constructed near Mentone in San Bernardino County by the USACE. It has a storage capacity of 145,600 acre-feet and a drainage area of 177 square miles. Table 7-10 of the 1988 USACE Hydrology Report shows that the construction of this dam reduces the 100-year flow at Riverside Narrows by 26%. Table 7-12 of this report details the maximum outflow of 500 cfs during water level rises in Prado Dam and 7000 cfs once the flood event has passed and the water level at Prado Dam begins to fall.

2.1.4 Baldwin Lake Ineffective Area

Baldwin Lake is located in the northeast corner of the Santa Ana River Watershed immediately east of Big Bear Lake in San Bernardino County [Figure 6]. 32 square miles are tributary to this lake but according to the 1988 USACE Hydrology Report, this area is ineffective and does not contribute to the Santa Ana River watershed. Topographic data shows that there is a divide between Baldwin Lake and Big Bear Lake. In communication with San Bernardino Flood Control District, it was confirmed that a drainage divide does exist between the two waterbodies.

Figure 6: Santa Ana River watershed above Prado Dam with Seven Oaks Dam & Baldwin Lake

2.2 Evaluation of USACE Hydrology Reports

2.2.1 Scope

The hydrologic assumptions made in the USACE reports were evaluated to determine their applicability in studying the present 2012 condition of the Santa Ana River floodplain. The specific parameters chosen for evaluation were future impervious percentage and rainfall values.

2.2.2 Comparison of USACE assumed future urbanization vs. current 2012 condition

The USACE reports estimated future impervious percentages for each subwatershed based on development trends within the Santa Ana River watershed[3]. These estimations were checked against 2011 aerial photos to determine if they accurately represent the current urbanized condition.

To facilitate this review, the subwatersheds tributary to Prado Dam from the 1988 USACE Hydrology Report were consolidated and weighted impervious percentages were calculated for each group of subwatersheds [Figure 7]. The area tributary to Seven Oaks Dam was excluded from this comparison increased urbanization to the watershed was determined to be negligible. The resulting six subwatershed groups were draped over 2011 aerial imagery obtained from Google Earth [see Appendix C2]. Using the aerial photos, the total urban and natural areas were estimated for each subwatershed group. These areas were then multiplied by a factor to determine the amount of impervious area within the urbanized and natural zones. Weighted impervious percentages were then calculated for each subwatershed group and then for the entire watershed.

The values determined using 2011 aerial photos were then compared with the weighted impervious percentages from the USACE hydrology reports. This comparison indicates that the estimated future urbanized condition from the USACE reports is sufficiently representative of the current 2012 condition of the Santa Ana River watershed. Tables 3 and 4 summarize the results of this evaluation.

Figure 7: Consolidation of Subwatersheds in USACE 1988 Hydrology Report into Groups

[3] These values can be found on Table 7-3 of the 1988 Hydrology Report

Table 4: Percent Impervious Area, USACE 1988 Hydrology

Subwatershed Group	USACE Subwatershed ID	Drainage Area [sq.miles]	% Impervious [future]	S-graph	Impervious Area	Weighted % Impervous	Total Impervious %
1	G1	73	2%	Mountain	1.46	2%	24.3%
	G2	52	2%	Mountain	1.04		
2	F1	17	2%	Mountain	0.34	35%	
	F2	29	50%	Valley	14.5		
	H1	19	2%	Mountain	0.38		
	H2	48	50%	Valley	24		
3	B	43	2%	Mountain	0.86	14%	
	C1	9	15%	Mountain	1.35		
	C2	13	15%	Mountain	1.95		
	D	11	15%	Valley	1.65		
	D1	20	2%	Mountain	0.4		
	D2	17	2%	Mountain	0.34		
	E1	36	40%	Valley	14.4		
4	I	62	50%	Valley	31	41%	
	J	31	30%	Valley	9.3		
	M	136	40%	Valley	54.4		
5	E2	39	30%	Valley	11.7	16%	
	E3	59	10%	Valley	5.9		
	E4	30	10%	Valley	3		
6	L	39	30%	Valley	11.7	28%	
	N	38	25%	Valley	9.5		

Table 5: Percent Impervious, Aerial Photo Estimation

Subwatershed Group		Total/Urban/Natural Area [sq. miles]	% Impervious [aerial photos]	Impervious Area	Weighted % Impervous	Total Impervious %*
1	T	124			5%	28.6%
	U	0	52%	0		
	N	124	5%	6.2		
2	T	115			38%	
	U	80	52%	41.6		
	N	35	5%	1.75		
3	T	152			17%	
	U	40	52%	20.8		
	N	112	5%	5.6		
4	T	280			42%	
	U	186	60%	111.6		
	N	94	5%	4.7		
5	T	125			20%	
	U	40	52%	20.8		
	N	85	5%	4.25		
6	T	61			46%	
	U	53	52%	27.56		
	N	8	5%	0.4		

3.0 Hydraulics

3.1 Model Setup

3.1.1 Scope
The Santa Ana River floodplain study reach extends more than 17 miles from the Prado Dam basin at the downstream limit up to the northern Riverside County boundary. The current condition hydraulic analysis completed for this report includes 10-, 50-, 100-, and 500-year storm events, a floodway analysis, and an analysis of the 100-year storm without levees. A duplicate model replicating the effective FEMA floodplain is also included with this submittal. The floodplain study affects seven different cities: Eastvale, Jurupa Valley, Norco, Corona, Chino, Chino Hills, and Riverside [Figure 8]. Twenty-two FIRMs are affected by this study and are listed in Table 6 and Appendix A3.

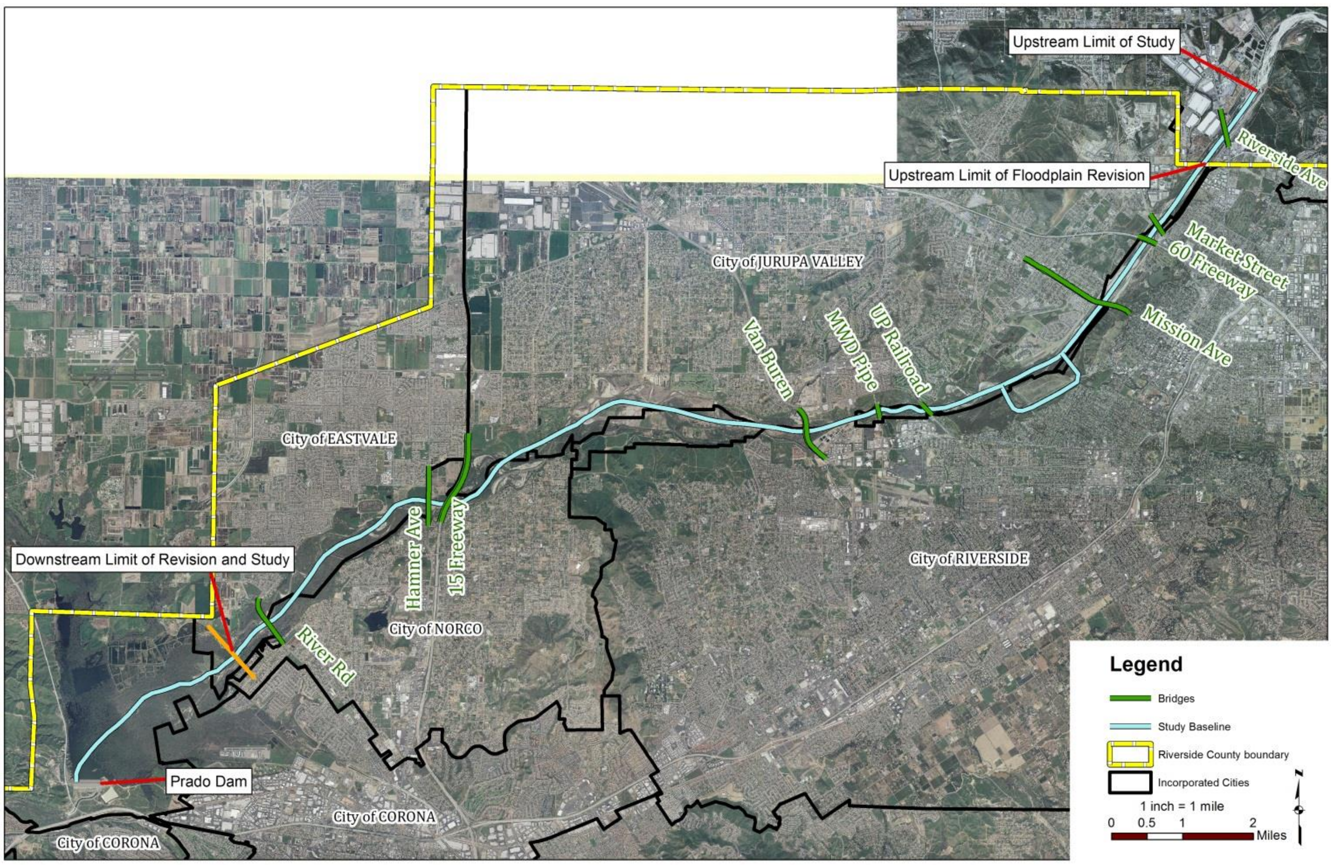

Figure 8: City Limits and 10 Different Bridges within Study Limits

3.1.2 Topography Mapping: a blend of LiDAR flights and digital photogrammetry
Topography used for this study is based on a combination of LiDAR and digital photogrammetry taken intermittently around 2006-2010. This information was supplemented with survey data that was completed to account for the construction of a new bridge & park and to account for significant erosion that occur due to the December 2010 storm. For additional detail, see Appendix F.

3.1.3 Storm Events Modeled

The 10-, 50-, 500-, and 100-year floodplain/floodway storm events were analyzed for this study. In addition, a 100-year "without levee" analysis was completed for the leveed reach upstream of Riverside Narrows by completely removing the levee geometry from each cross section.

3.1.4 Description of Cross Sections

In general, cross sections were taken every 500 feet along the study baseline. In areas that required more detail, additional sections were provided. On average, each cross section is made up of 250 elevation points. The zero station of each section is located at the intersection of the section with the study centerline. The left and right banks have negative and positive stationing, respectively, along the section.

3.1.5 Study Centerline and Bank Stations

Both the 1980 FEMA and 1991 USACE studies for the Santa Ana River floodplain use the existing low flow channel for the stream centerline. It has been noted however, that significant storms can cause migration of the low flow channel as depicted in Figures 9-10. A centerline that follows the low flow channel is not an accurate representation of the flow path or the reach lengths between cross sections during a 100-year storm. Therefore, the centerline for this study represents the main conveyance path that the 100-year discharge would take through the Santa Ana River floodplain. The study baseline stationing is the distance, in feet, upstream of the Prado Dam embankment.

Within a hydraulic model, bank stations separate the channel from the left and right overbanks. The channel of a cross section represents where the majority of the conveyance is located. These three regions [left overbank, main channel, & right overbank] have their own corresponding reach lengths. To accurately represent the conveyance and the reach lengths of the 100-year storm, the bank stations were placed at the edge of the main conveyance area.

Table 6: List of Affected Cities and FIRM Panels

Affected FIRM Panels:

1	06071C	9335H
2	06071C	9345H
3	06071C	9375H
4	06065C	0043G
5	06065C	0045G
6	06065C	0065G
7	06065C	0667G
8	06065C	0669G
9	06065C	0678G
10	06065C	0679G
11	06065C	0682G
12	06065C	0683G
13	06065C	0684G
14	06065C	0686G
15	06065C	0687G
16	06065C	0688G
17	06065C	0689G
18	06065C	0702G
19	06065C	0205G
20	06065C	0706G
21	06065C	0710G
22	06065C	0726G

Affected Cities

1	Eastvale
2	Jurupa Valley
3	Norco
4	Riverside
5	Corona
6	Chino
7	Chino Hills

Figure 9: 2009 Aerial Photo near outlet of San Sevaine Channel

Figure 10: 2011 Aerial Photo near outlet of San Sevaine Channel

3.1.6 Flow Regime & Downstream Boundary Condition

The Santa Ana River is a natural ephemeral river with a mild slope of 18 feet per mile (0.0034 ft/ft) within Riverside County. Previous analysis showed that the slope and geometry of the channel results in a low Froude number indicating that the regime is well within the subcritical range. Therefore, a subcritical flow regime was utilized for the hydraulic analysis.

The downstream boundary condition is based on the Filling-Frequency Curves for Prado Dam contained on Plate 7-45 of the 1988 USACE Hydrology Report. The different filling-frequency curves represent various combinations of present/future watershed conditions and operation of the Prado Dam. Currently, Prado Dam is undergoing improvements to raise the level of flood protection provided by the facility. As of 2012, the dam crest has been elevated and new outlet works have been constructed but the spillway has not yet been raised from 543’ NGVD to 563’ NGVD. Furthermore, downstream retrofitting efforts have not been completed which limits the amount of flow that can be safely released from the dam. For these reasons, the most appropriate curve for the current 2012 condition is the Future Conditions/Historical Operation/Net Storage/Existing Prado Dam Spillway [indicated in blue on Figure 11]. Table 7 summarizes the downstream water surface elevations that were used for the hydraulic analysis.

Table 7: Summary of Downstream Boundary Conditions

Storm Event	Water Surface Elevation [NGVD29]	Water Surface Elevation [NAVD88]
10-year	522.0'	524.5'
50-year	545.0'	547.5'
100-year	554.0'	556.5'
500-year	566.0'	568.5'

3.1.7 Contraction & Expansion Coefficients

The HEC-RAS Hydraulic Reference Manual recommends using contraction and expansion coefficients of 0.1 and 0.3, respectively, for areas of gradual transitions. Where changes in cross section area are more abrupt, these values should be increased. Along the study reach, most transitions between cross sections are gradual thus 0.1 is used for the contraction coefficient and 0.3 for the expansion coefficient in general. Table 8 lists the areas where the changes between sections are more abrupt. For these cross sections, 0.3 was used for the contraction coefficient and 0.5 was used for the expansion coefficient.

Table 8: Summary of Sections that have Abrupt Transitions [i.e. Contr = 0.3 / Expan = 0.5]

Cross Sections	Description
108000 - 106870	Contraction upstream of Riverside Avenue Bridge
85500 - 82500	Outlet of the Riverside Levees north of the landfill
2750 - 2250	Outlet of the split flow south of the landfill
77000 - 75365	Contraction upstream of Riverside Narrows
40500 - 35160	Contraction & Expansion near I-15 Freeway & Hamner Avenue

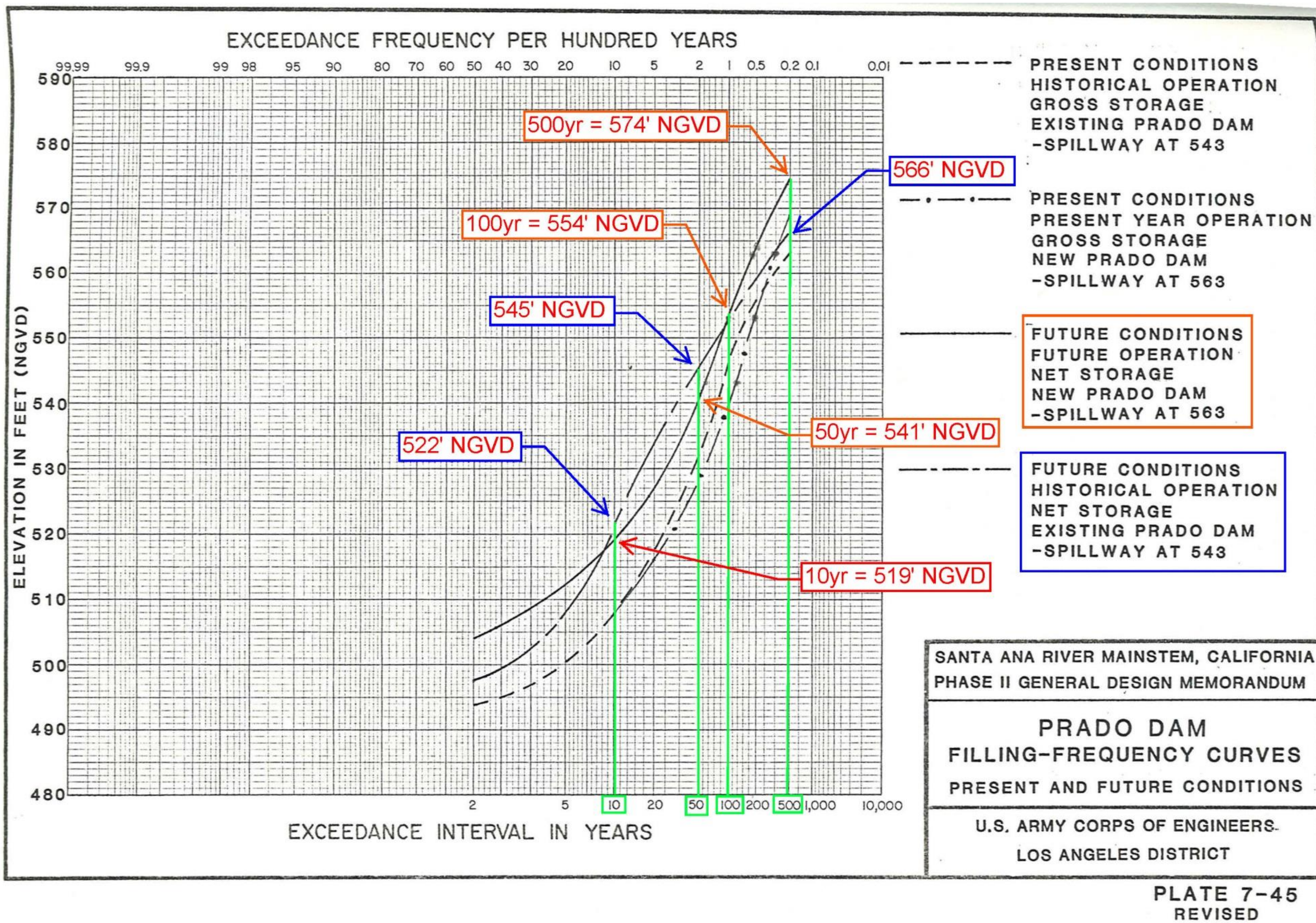

Figure 11: Filling-Frequency Curve from USACE 1988 Hydrology Report, see §3.1.6

3.1.8 Structures Modeled

There are 10 bridges along the study reach of the Santa Ana River [Figure 8]. All of these bridges were modeled using bridge design plans. As-built plans were used to model each bridge except for River Road and Van Buren. Design plans were used for these bridges because as-built plans have not yet been completed for the finished facilities.

Table 9: Summary of Bridge Structures Modeled

Bridge	***As-Built/Design Plan Date***	***Source of Plans***
Riverside Avenue	1976	San Bernardino County Public Works
Market Street	Earthquake Retrofit Plans: 1996 Original: 1956	CalTrans
Highway 60	1961	CalTrans
Mission Blvd	1957	CalTrans
Union Pacific Railroad	1959	Union Pacific
Metropolitan Water District Pipe	1938	MWD
Van Buren Blvd	2009	Riverside County TLMA
I-15 Freeway	1989	CalTrans
Hamner Avenue	1938	Riverside County TLMA
River Road	2008	Riverside County TLMA

A rock levee was constructed by the City of Norco between the I-15 freeway and Hamner Avenue bridge crossings. This levee serves primarily as scour protection during low flows and is inconsequential as a levee during 100-year flows. The levee was modeled as a blocked obstruction to account for the reduction in conveyance.

3.1.9 Location of Ineffective Areas

Along the study reach, there are three areas with unique ineffective flow characteristics: the area immediately downstream of the leveed reach, the Riverside Water Quality Control Plant, and the reach in between the Hamner Avenue and I-15 freeway bridge crossings.

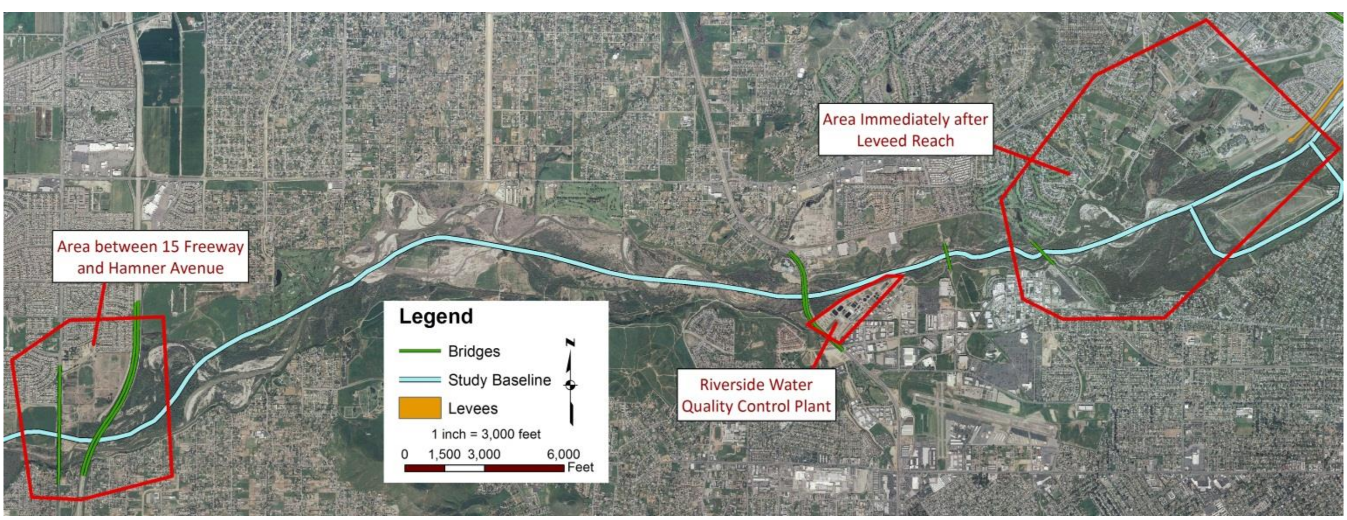

Figure 12: Location of Unique Ineffective Flow Areas

As flow escapes the end of the leveed reach, the floodplain widens into an unconfined area. A two-dimensional floodplain analysis was conducted using FLO-2D to aid in determining how to draw the cross sections and identify the ineffective area in the reach between the levees and Union Pacific Railroad Bridge. This study revealed low velocities in the area northerly of the landfill relative to the main channel along the study baseline. This northerly area, although inundated, does not actively convey flow during a large storm event. Figure 13 shows the limit of the ineffective area for the right bank. Riverside County Economic Development Agency (EDA) constructed a park on fill within this ineffective area near Tract 23395. A survey was conducted on September 19, 2012 to obtain updated elevation data for cross sections 84500, 84000, and 83500. The backup for this survey is included in Appendix F. The region immediately north of the park is relatively lower but has been modeled using a block obstruction since the elevated park separates it from the floodplain by at least 500 feet.

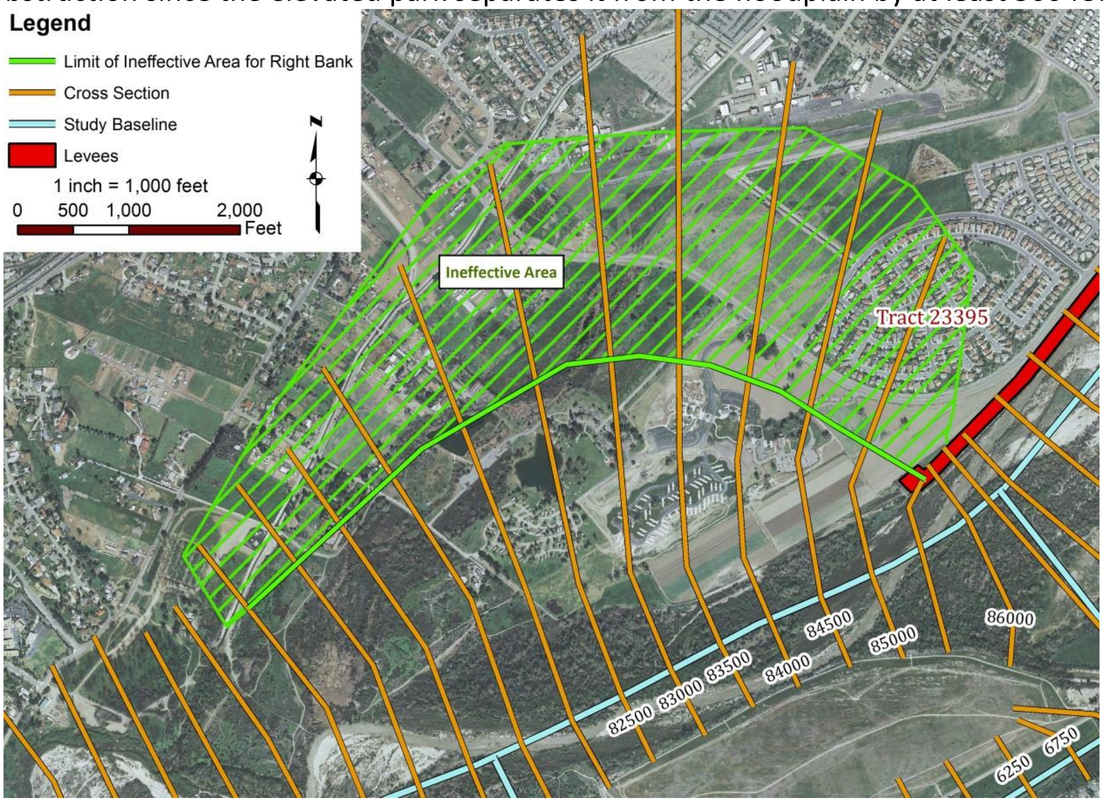

Figure 13: Ineffective Flow Area at the End of the Leveed Reach

Figure 14: Riverside County EDA Park

The Riverside Water Quality Control Plant is located immediately upstream of the Van Buren bridge crossing [Figure 15]. A levee exists along the treatment plant adjacent to the river but does not provide adequate protection during 100-year flows. At the upstream limit of this levee, 100-year flows overtop and enter the treatment plant complex. Not having an outlet, the flow ponds within the treatment plant. This ponding area was modeled by defining the flow on the left bank below the levee crest of cross sections 69750 – 66500 as permanent ineffective area.

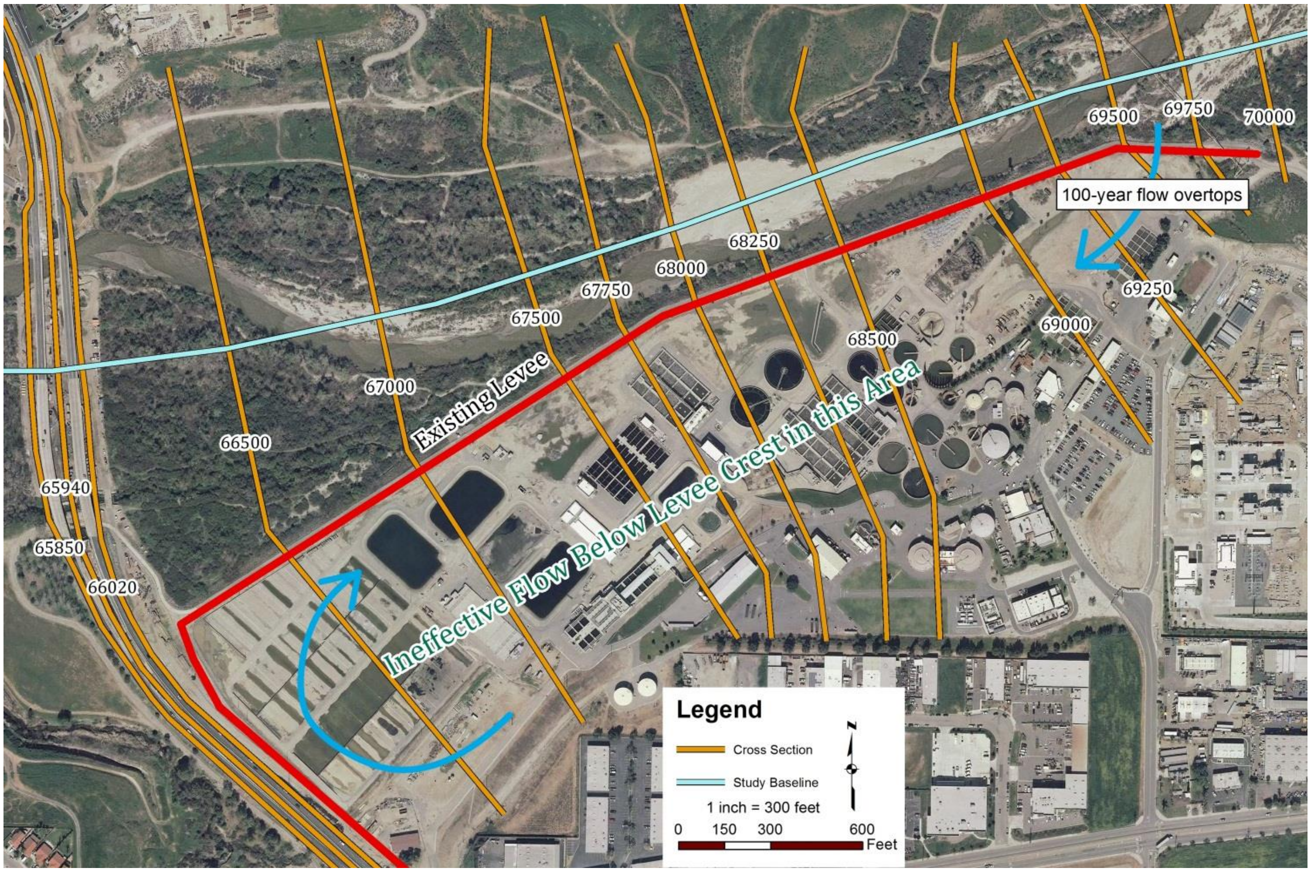

Figure 15: Riverside Water Quality Control Plant

Lastly, the reach between the I-15 Freeway and Hamner Avenue bridge crossings has a large non-conveyance area. During typical seasonal storm events, river flow is conveyed through the bridge at Hamner Avenue. In a large storm event, much of the flow would weir over the Hamner Ave road embankment north of the bridge. A rock levee was constructed along this reach to provide erosion protection against high-frequency storms but not the 100-year event. A FLO-2D study, completed to analyze flow velocities, revealed that the majority of the flow north of the rock levee is ineffective however a portion of this area does flow over the road embankment. To determine the limit of ineffective area for the right bank, a 1.5:1 expansion ratio was used for area downstream of the I-15 freeway. Upstream of Hamner Avenue, a 1:1 ratio was used for the contraction reach. Combining these two created the limit of ineffective area represented in Figure 16 by the bottom green line. This non-conveying area (yellow shading) was modeled using the lowest elevation on the Hamner Avenue road embankment, 592' NAVD88, and setting it as the height of permanent ineffective area from Sections 36100 to 35160. Using a 1.5:1 expansion ratio from the I-15 freeway, an area of complete non-conveyance was defined. Details for the selection of expansion and contraction coefficients are located in Appendix D.

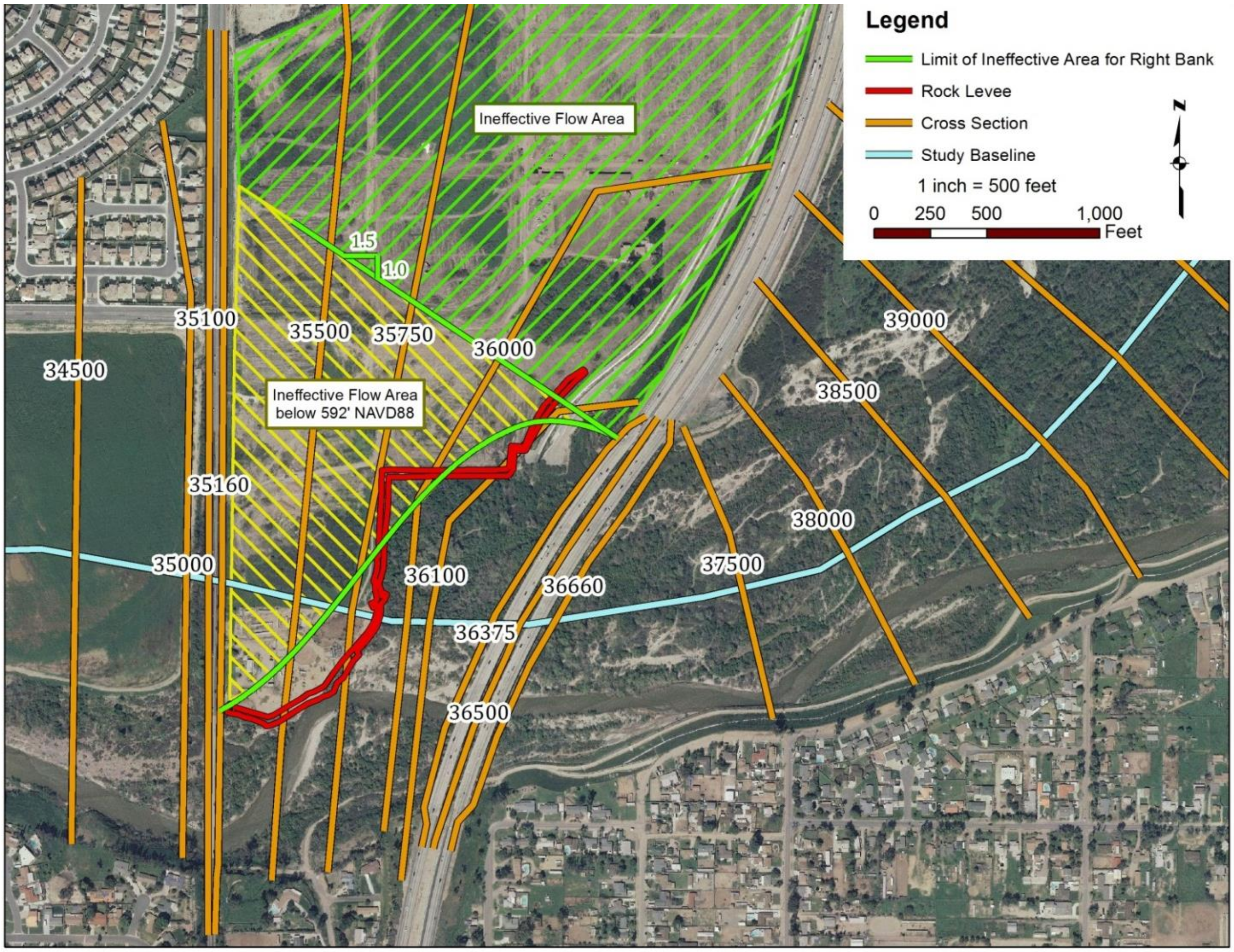

Figure 16: Ineffective Flow Area between I-15 Freeway and Hamner Avenue

3.1.10 Roughness Coefficients

An evaluation was made of the roughness coefficients used in the effective FEMA hydraulic model and the 1991 USACE Floodway Delineation study to determine their applicability to this study. Both studies used the banks of the low-flow stream as the boundary between channel and overbank n-values. Figure 17 shows the channel and overbank n-values in cross section 492 of the FEMA hydraulic model. Recent storms of significant magnitude have caused migration of the low-flow channel thus changing the location of the channel and overbank as defined by the FEMA and USACE floodplain studies. Due to this variation in the low-flow channel and to address all the factors affecting roughness, composite roughness coefficients were determined for the floodplain using Cowen's method. The parameters used for the selection of the variables in Cowen's method were obtained from *Open-Channel Hydraulics* written in 1959 by Prof. Ven Te Chow and USGS Water-Supply Paper 2339. In using the Cowen's method, two areas were analyzed separately from the rest of the study reach because of their unique characteristics: the leveed reach and Riverside Narrows

The Riverside Levees are operated and maintained by RCFC. This maintenance includes mowing of the vegetation within the leveed reach of the Santa Ana River. Additionally, the levees confine flow within this reach thus limiting the variability between cross sections during the 100-year storm. Therefore, the n-value for this reach is considerably lower than the natural, unimproved regions of the Santa Ana River.

The Riverside Narrows is a natural construction along the river that decreases the floodplain width by approximately 60%. 100-year flows going through this constriction experience more losses due to the variation in cross section widths, increased interaction with banks, and dense vegetation. Supporting documents and photos for the selection of roughness coefficients is included in Appendix D2.

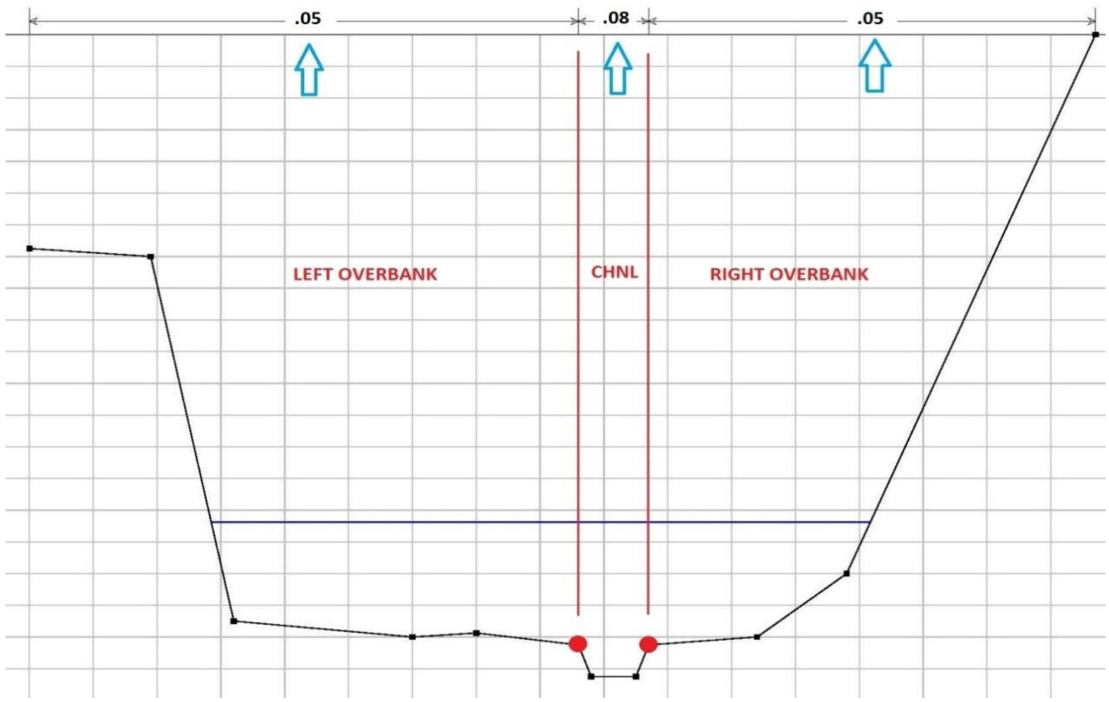

Figure 17: Cross Section 492 from FEMA 1976 Study [blue arrows point at n-value]

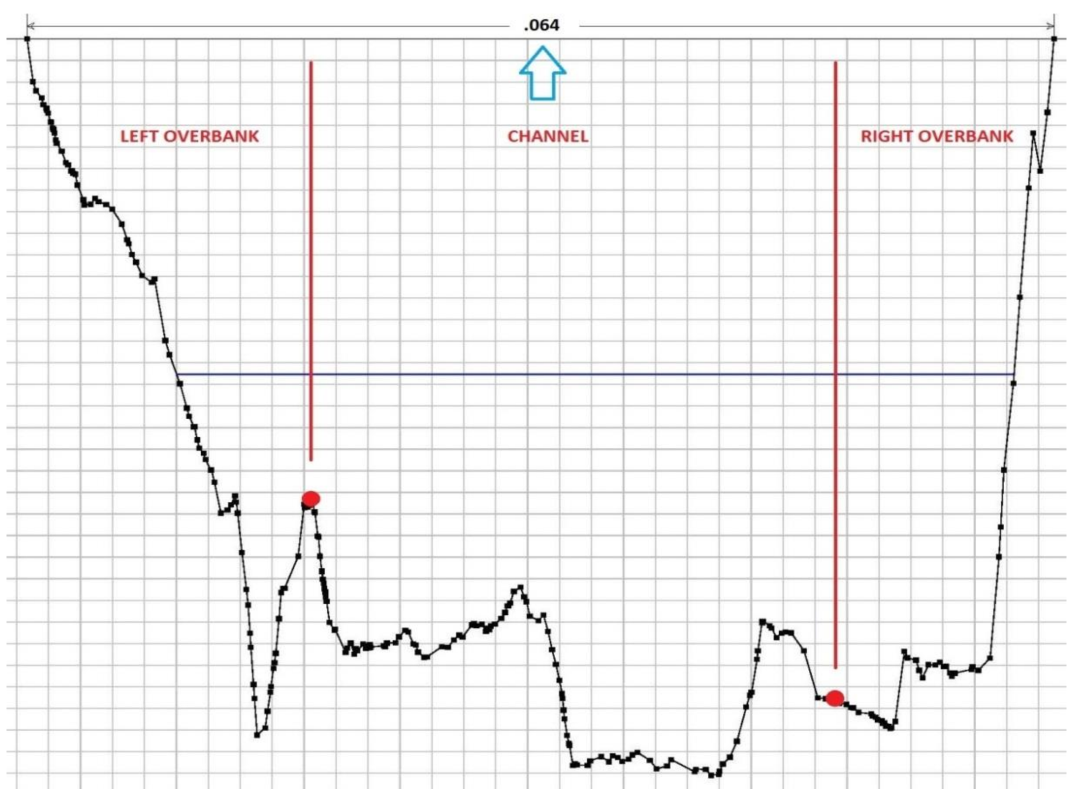

Figure 18: Cross Section 62500 from RCFC Study [blue arrow points at n-value]

Table 10: Cowen's method for Leveed Reach

Cowen's Method for Determining n using 100-year flow				*based on USGS WSP2339*
Channel Conditions		Values		Selected Values
Base n value	Concrete	n_b	0.012 - 0.018	0.022
	Fine Sand*		0.020 - 0.028	
	Firm Soil/Earth**		0.022 - 0.028	
	Coarse Sand		0.026 - 0.035	
	Gravel		0.028 - 0.035	
	Cobble		0.030 - 0.050	
	Boulder		0.040 - 0.070	
Degree of Irregularity	Smooth	n_1	0.00	0.002
	Minor		0.001 - 0.005	
	Moderate		0.006 - 0.010	
	Severe		0.011 - 0.020	
Variation in channel cross section	Gradual	n_2	0.00	0.002
	Alternating occasionally		0.001 - 0.005	
	Alternating frequently		0.010 - 0.015	
Obstructions	Negligible	n_3	0.000 - 0.004	0.002
	Minor		0.005 - 0.015	
	Appreciable		0.020 - 0.030	
	Severe		0.040 - 0.050	
Vegetation	Low	n_4	0.002-0.010	0.012
	Medium		0.010-0.025	
	High		0.025-0.050	
	Very High		0.050-0.100	
Ratio of Meandering	Minor	m	1.00	1.000
	Appreciable		1.15	
	Severe		1.30	
$n = (n_b + n_1 + n_2 + n_3 + n_4)m$				**0.040**

Table 11: Cowen's method for Riverside Narrows

Cowen's Method for Determining n using 100-year flow				*based on USGS WSP2339*
Channel Conditions		Values		Selected Values
Base n value	Concrete	n_b	0.012 - 0.018	0.026
	Fine Sand*		0.020 - 0.028	
	Firm Soil/Earth**		0.022 - 0.028	
	Coarse Sand		0.026 - 0.035	
	Gravel		0.028 - 0.035	
	Cobble		0.030 - 0.050	
	Boulder		0.040 - 0.070	
Degree of Irregularity	Smooth	n_1	0.00	0.008
	Minor		0.001 - 0.005	
	Moderate		0.006 - 0.010	
	Severe		0.011 - 0.020	
Variation in channel cross section	Gradual	n_2	0.00	0.005
	Alternating occasionally		0.001 - 0.005	
	Alternating frequently		0.010 - 0.015	
Obstructions	Negligible	n_3	0.000 - 0.004	0.004
	Minor		0.005 - 0.015	
	Appreciable		0.020 - 0.030	
	Severe		0.040 - 0.050	
Vegetation	Low	n_4	0.002-0.010	0.02
	Medium		0.010-0.025	
	High		0.025-0.050	
	Very High		0.050-0.100	
Ratio of Meandering	Minor	m	1 [actual 1.025]	1.025
	Appreciable		1.15	
	Severe		1.30	
$n = (n_b + n_1 + n_2 + n_3 + n_4)m$				**0.065**

Table 12: Cowen's method for the Study Reach Excluding Riverside Narrows & the Leveed Reach

Cowen's Method for Determining n using 100-year flow				*based on USGS WSP2339*
Channel Conditions		Values		Selected Values
Base n value	Concrete	n_b	0.012 - 0.018	0.026
	Fine Sand*		0.020 - 0.028	
	Firm Soil/Earth**		0.022 - 0.028	
	Coarse Sand		0.026 - 0.035	
	Gravel		0.028 - 0.035	
	Cobble		0.030 - 0.050	
	Boulder		0.040 - 0.070	
Degree of Irregularity	Smooth	n_1	0.00	0.005
	Minor		0.001 - 0.005	
	Moderate		0.006 - 0.010	
	Severe		0.011 - 0.020	
Variation in channel cross section	Gradual	n_2	0.00	0.004
	Alternating occasionally		0.001 - 0.005	
	Alternating frequently		0.010 - 0.015	
Obstructions	Negligible	n_3	0.000 - 0.004	0.004
	Minor		0.005 - 0.015	
	Appreciable		0.020 - 0.030	
	Severe		0.040 - 0.050	
Vegetation	Low	n_4	0.002-0.010	0.025
	Medium		0.010-0.025	
	High		0.025-0.050	
	Very High		0.050-0.100	
Ratio of Meandering	Minor	m	1.00	1
	Appreciable		1.15	
	Severe		1.30	
$n = (n_b + n_1 + n_2 + n_3 + n_4)m$				**0.064**

3.1.11 Split flow downstream of Leveed Reach

At the downstream terminus of the leveed reach is the Tequesquite Landfill. The 100-year flow at this location would split with some flow going north of the landfill and some going south. Both the FEMA and USACE floodplain studies did not model this area as split flow but selected to use cross sections that extended through the landfill. A split flow analysis is ideal when water surface elevations are considerably different along each reach downstream of a split. It was decided to model this area using split flow to establish separate base flood elevations for the northern and southern reach. Figure 19 depicts the cross section configuration for the split flow analysis. The hydraulic model results indicate that only 10% of the 100-year flow goes south of the landfill. Water surface elevations south of the landfill are an average of 2 feet lower than the corresponding ones north of the landfill.

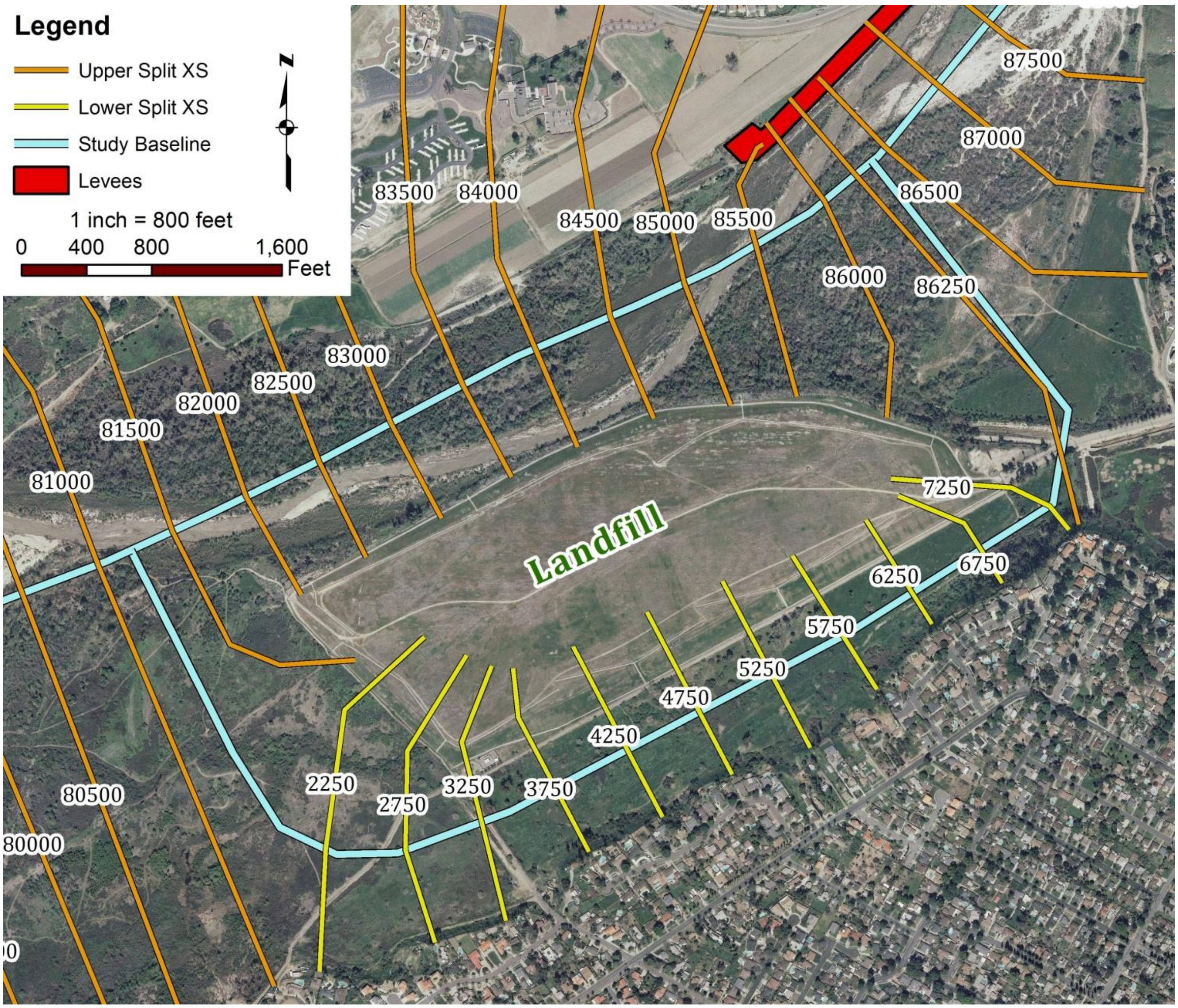

Figure 19: Split Flow Analysis Downstream of Leveed Reach

3.1.12 Pyrite Channel Zone A Floodplain

The Pyrite Channel tributary was analyzed to correct the existing floodplain boundary and tie-in the revised Santa Ana River floodplain. Backup from the original FEMA floodplain study for Pyrite Channel indicates a 100-year storm would generate 5,800 cfs of flow from a drainage area of 11.5 square miles. In order to study this tributary, the original LiDAR topography had to be supplemented with topography dated November 18, 2003 to encompass the entire reach that would be revised. This digital mapping is based on a 4-foot contour interval and was developed using digital photogrammetric methods. Figure 20 depicts the cross section alignment for the separate hydraulic model completed for Pyrite Channel. Although this tributary was analyzed using detailed methods, the flood zone will remain Zone A.

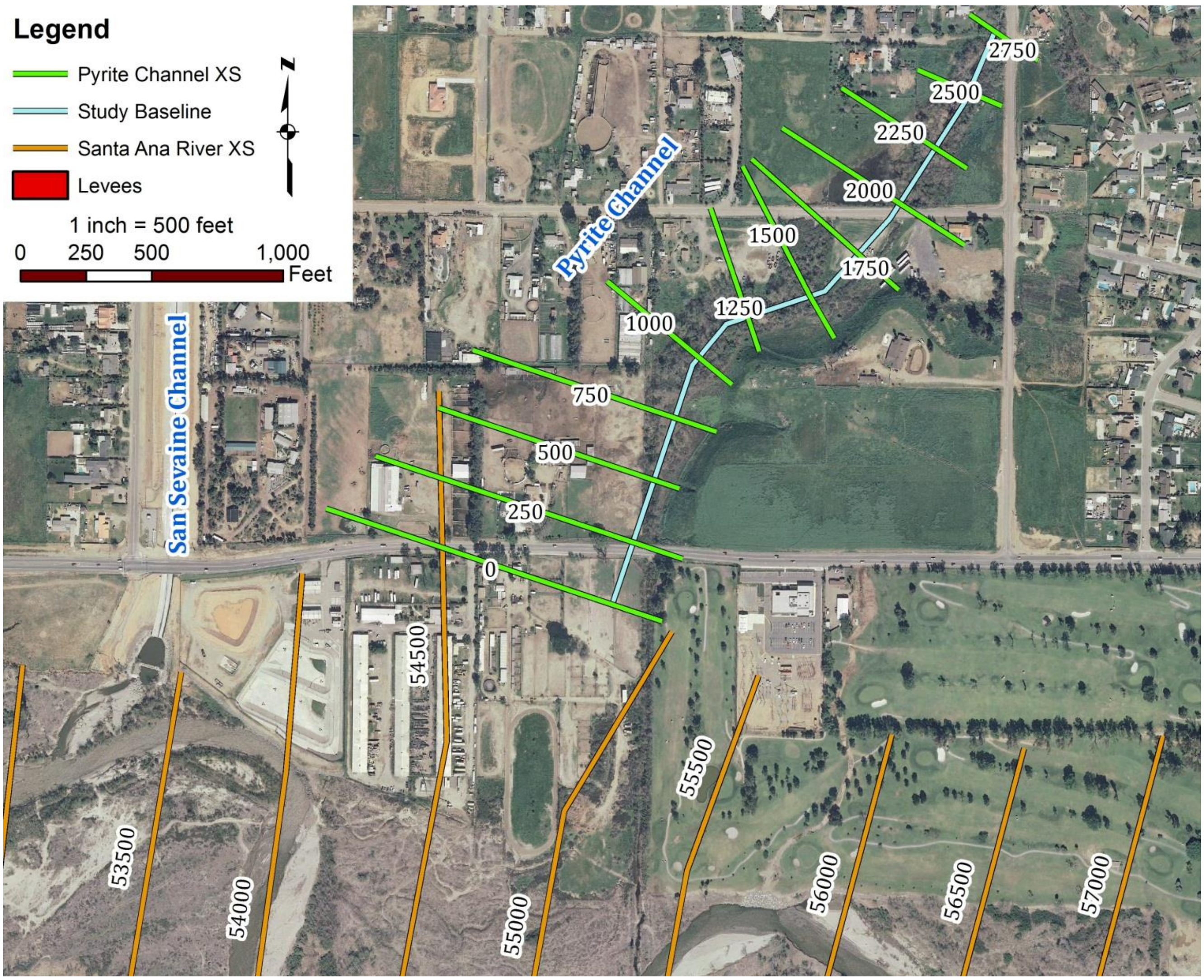

Figure 20: Analysis for Pyrite Channel tributary

3.1.13 Separate 500-Year/100-Year without Levee Models

To accurately model the 500-year floodplain, separate cross-section geometries were created for two areas: the leveed reach (Sections 111000 to 79000) and the reach near the I-15 Freeway and Hamner Ave bridge crossings (Sections 43500 to 35750).

The USACE levees between Sections 111000 to 86250 were designed to provide 3 feet of freeboard during the SPF. In comparing the SPF to the stream-gage analysis completed in the USACE hydrology reports, the SPF peak flow rate corresponds to a 190-year return frequency. An analysis was conducted to determine whether the levees could contain the 500-year flow rate of 310,000 cfs. The results from the hydraulic model indicate that during a 500-year storm the levees would not have adequate freeboard and would be overtopped at some locations. Therefore, cross sections were extended to contain the entire 500-year floodplain width.

The 500-year storm would overtop the freeway embankment north of the I-15 bridge crossing. The orientation of the 500-year cross sections differs from the 100-year between sections 43500 to 35750 in order to account for this overtopping. Figure 21 depicts the two different cross section orientations within this reach.

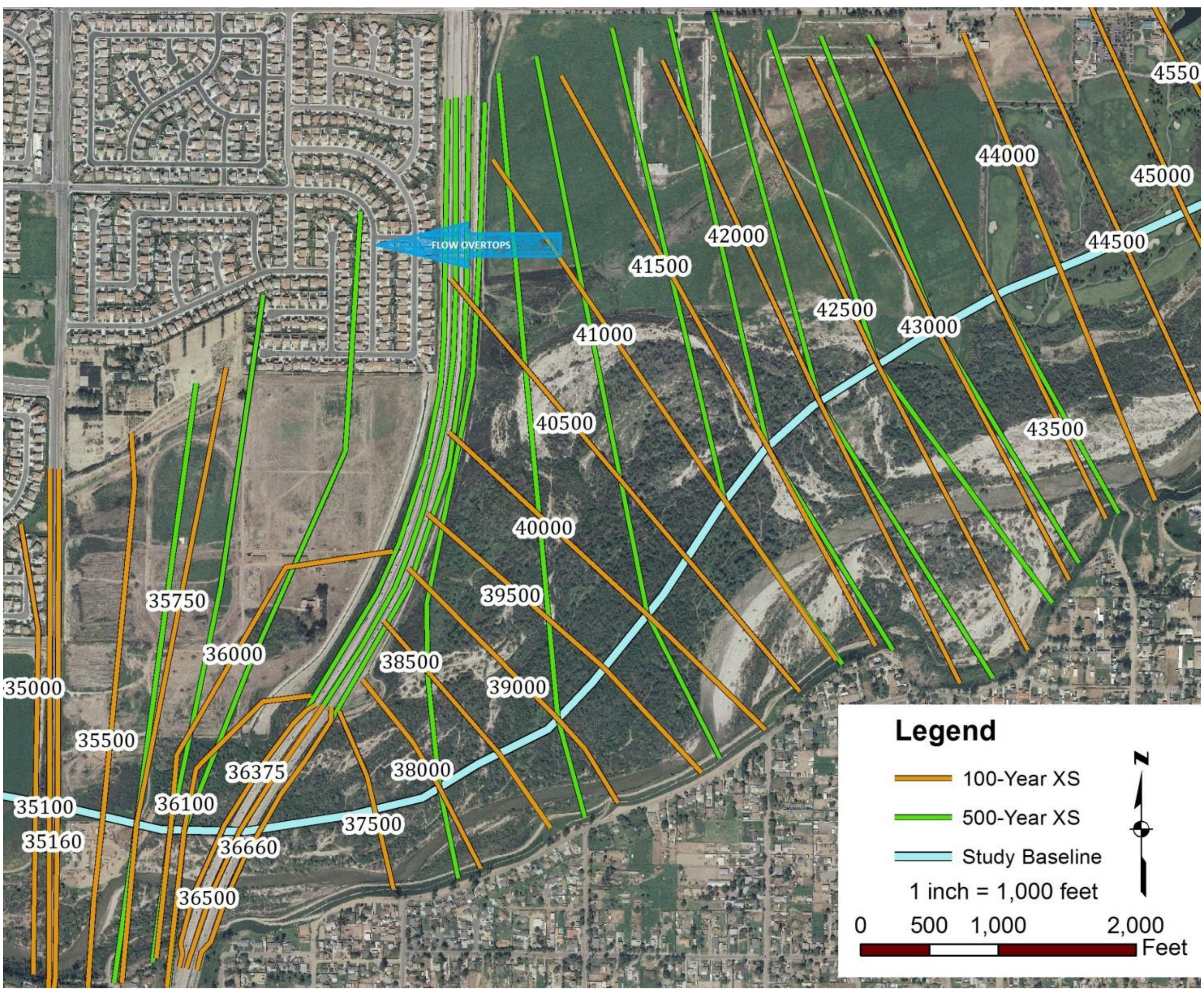

Figure 21: 100-year vs. 500-year cross section geometries [near I-15 freeway]

The 100-year without levee model uses the 500-year cross sections for the leveed reach (Sections 111000 to 79000) and the 100-year cross sections for the remaining study area. The points making up the levee geometry were deleted from each section and the model was run with the 100-year peak flow rate. This study was completed to remap the X-Protected by Levee delineation behind the Riverside Levees.

3.1.14 Floodway Delineation

Initially, an attempt was made to preserve the effective FEMA floodway boundary. Encroachment stations were entered into the current condition hydraulic model by measuring the distance of the floodway boundary from the centerline along each cross section. The surcharges generated from these encroachments were greater than the 1-foot tolerance in some areas. Table 12 summarizes where the majority of these greater than 1-foot surcharges occur. Additionally, some cross sections had negative surcharges. Due to the negative and greater than 1-foot surcharges, the FEMA floodway boundary could not be used for the current condition hydraulic model. A table showing each cross section along with FEMA encroachment stations and surcharges is included in Appendix D2.

Table 13: Location of > 1-foot Surcharges using FEMA Floodway

Location	***River Stations***	***Max Surcharge [feet]***
Upstream of Market Street bridge	104500 - 100500	2.9
Near San Sevaine Channel Outlet	59500 - 48500	1.8
Downstream of Hamner Avenue bridge	34500 - 23000	4.7

The encroachments utilized for this study produce an optimized floodway boundary. The Method 4 encroachment method was used in HEC-RAS to calculate encroachments that would produce surcharges around 0.9 of a foot. These results were refined using the Method 1 encroachment method to create a floodway that met the FEMA requirement for surcharges that are not negative or greater that a foot. In general, encroachments were incorporated only in areas that were developable and the resulting floodway is wider than the effective FEMA floodway in many locations. At the location of steep banks or high velocity flow, the floodway width is equal to the floodplain width. Table 13 summarizes these sections where the floodplain was not encroached for the floodway analysis. A table showing each cross section along with encroachment stations and surcharges is included in Appendix D2.

Table 14: Locations where Floodway = Floodplain for the Encroachment Analysis

Location	***River Stations***	***Comments***
Levee Reach	104000 - 100000	Left Bank only
	99500 - 92000	
	91900 - 91700	Right Bank only
	91600 - 88000	
	87500 - 86250	Right Bank only
	86000 - 85500	
Tequesquite Landfill below levees	85000 - 81500	Left Bank only
Riverside Narrows [down to the Riverside Treatment Plant]	78000 - 76000	Left Bank only
	75365 - 69500	
	69250 - 65850	Right Bank only
Downstream of Van Buren bridge to I-15 Freeway crossing	65500 - 61000	Left Bank only
	49500 - 48500	Left Bank only
	44500 - 43500	Left Bank only
	41500 - 40000	Left Bank only
USACE Norco Bluffs	40000 - 36375	
I-15 Freeway crossing to River Road	36100 - 22000	Left Bank only

Table 15: Summary of Hydraulic Models

Flood Event Analyzed	**HEC-RAS file names**				**Description**
	Project	*Geometry*	*Steady Flow*	*Plan*	
Duplicate Effective	DupEffect	Original HEC2	Original HEC2	Original 1976 HEC2	HEC-RAS model of HEC2 microfiche backup received from FEMA
		Original + 15 Freeway LOMR	Original HEC2	Original + 15 Freeway LOMR	Original 1976 HEC2 plan updated using data from LOMR 01-09-085P
Current Condition 50-year & 100-year Floodplain/Floodway	Santa Ana River PMR	LiDAR DTM_100yr	USACE flow_100yr-50yr	100yr-50yr	100-year floodplain using 2006-2010 LiDAR & 1988 USACE Hydrology Report flow rates
Current Condition 10-year Floodplain		LiDAR DTM_10yr	USACE flow_10yr	10yr	10-year floodplain using 2006-2010 LiDAR. Split flow not modeled at Tequesquite Landfill
Current Condition 500-year Floodplain		LiDAR DTM_500yr	USACE flow_500yr	500yr	500-year floodplain using 2006-2010 LiDAR & 1988 USACE Hydrology Report flow rates
Current Condition 100-year without levee		100yr w/o levee	100yr w/o levee	100yr w/o levee	100-year floodplain between sections 110500 - 85500. Levee geometry has been removed

3.2 Hydraulic Results

3.2.1 Duplicate Effective

A request was submitted to the FEMA Engineering Library to obtain the original hydraulic model for the Santa Ana River 1980 floodplain study. The backup provided by the Engineering Library consisted of scanned microfiche of HEC-2 runs completed in late 1976. Several different models were included in this backup but only the most current and complete model was utilized to create the effective FEMA model for the study reach. The model selected from this backup contained data for the entire reach within the county, used the effective 100 and 500-year flow rates, but did not have a floodway analysis. The microfiche of this model is located in Appendix D1.

There has only been one revision of the FEMA floodplain since the original study was adopted by Riverside County in 1980. Letter of Map Revision 01-09-085P was completed by WEBB in 2002 for a tract located near the I-15 freeway bridge crossing and revised the floodplain boundary in this area to account for the new I-15 freeway embankment [Appendix D1]. The effective floodplain mapping for Santa Ana River was made digital on August 28, 2008 and consists of the original 1980 study coupled with the aforementioned LOMR. Therefore, the duplicate effective model incorporates the hydraulic backup for LOMR 01-09-085P into the original 1976 HEC-2 model. Table 12 summarizes the additional sections that were incorporated in the model by this LOMR. The input parameters from these two studies were compiled into a HEC-2 format and run using HEC-RAS version 4.1.

Table 16: Summary of Sections Added to Original 1976 HEC-2 model by LOMR 01-09-085P

Section ID			*Comments on LOMR Sections*
On FIRM	*Original 1976 Data*	*LOMR 01-09-085P*	
I	346	346	Identical to 1976 data
	318	318	
H	282	282	Revised using 1989 Topo
G	248	248	
F	214	214	
		200.1	Added for I-15 Freeway Crossing
		198.7	
		197.3	
		195	
	190.4	190.4	Revised using 1989 Topo
E	184.4	184.4	Identical to 1976 data
	184.2	184.2	Hamner Bridge revised
	184	184	Identical but ineffective area removed
D	172	172	Revised using 1989 Topo
C	162	162	

A quality assurance check was completed to ensure that the cross section geometry did not contain erroneous points. Comparison of the duplicate effective model and the current FIS profiles reveals a discrepancy between the river stationing. This discrepancy does not allow the duplicate effective model to match the effective data within the water surface elevation tolerances.

3.2.2 100-Year Floodplain

Throughout most of the study reach, the resulting 100-year water surface elevations are higher than those published in the FEMA FIS. In 1999, Seven Oaks Dam was constructed reducing the 100-year peak flow rate around 20%. Regardless, the water surface elevations from this study are an average of 2 feet higher. This increase seems to be attributed to higher streambed elevations due to aggradation. Table 15 provides a comparison of the 100-year water surface elevations from the FEMA 1980 study, USACE 1991 study, and the results of this RCFC report.

A comparison of thalweg elevations from the 2010 LiDAR data to the streambed elevations from the 1980 FEMA study reveal a 7-foot increase near River Road. In general, the streambed within the Santa Ana River has been increasing in elevation with the exception of the leveed reach. The comparison between recent topographic info and the 1980 FEMA study shows that the leveed reach has experienced degradation. These results coincide with the 1991 USACE hydraulic study for the Santa Ana River. The USACE study showed an increase in water surface elevations despite the construction of Seven Oaks Dam. A discussion of the relationship between the USACE 1991 study and the FEMA floodplain is provided in an RCFC memo located in Appendix B2.

Table 17: Comparison of 100-Year Water Surface Elevations from FEMA/USACE/RCFC Studies

FEMA FIS		USACE 1991 Study			RCFC 2012 Study	
Section	*WS Elevation [NAVD88]*	*Section*	*WS Elevation [NAVD29]*	*WS Elevation [NAVD88]*	*Section*	*WS Elevation [NAVD88]*
R	821.5	20.29	817.6	820.1	100500	818.0
Q	778.7	18.13	772.4	774.9	89500	774.8
P	746.8	16.84	742.9	745.4	82500	747.3
O	740.7	15.85	735.9	738.4	78000	735.9
N	739.9	15.56	734.7	737.2	76000	734.4
M	731.6	15.434	729.5	732.0	75365	732.9
L	708.7	14.27	709.8	712.3	70000	716.1
K	680.9	12.76	677.1	679.6	62500	684.5
J	644.7	11.15	645.0	647.5	53500	646.3
I	631.3	10.54	636.3	638.8	50000	633.6
H	615.6	9.23	618.7	621.2	45000	617.8
G	605.1	7.95	605.2	607.7	41000	607.2
F	601.8	7.54	601.7	604.2	39000	604.9
E	596.6	6.955	594.1	596.6	35160	596.7
D	586.3	6.72	588.2	590.7	34000	589.7
C	578.7	6.46	582.1	584.6	32500	580.8
B	571.0	6.01	572.1	574.6	29500	572.6
A	558.9	4.81	558.1	560.6	26000	562.1

FEMA requires levees to have at least 3 feet of freeboard for the 100-year storm event and 4 feet of freeboard within 100 feet of a bridge. If a levee system does not meet this criterion it is considered incapable of providing protection against a 100-year flood. The Riverside Levees were designed to protect against the Standard Project Flood, which is defined by USACE as the flood that would result from the most severe combination of meteorologic and hydrologic conditions considered reasonably characteristic of the geographical area. The 100-year hydraulic analysis indicates that there is sufficient freeboard along the levees except at the location of the left bank spillway for Lake Evans (Section 91900). Due to the lack of freeboard for the spillway, the inundation area behind the levee under elevation 784.5’ NAVD88 was mapped as a floodplain.

Summary of Results for 100-Year Floodplain Analysis

- Water surface elevations (outside of the leveed reach) are an average of 2 feet higher than the elevations shown on the effective FEMA profiles
  - Largely attributed to higher streambed elevations caused by aggradation
  - Leveed reach has experienced substantial degradation. On average, streambed elevations for the thalweg are 5 feet lower than the elevations shown on the FEMA profiles.
- Riverside Levees do not have adequate freeboard at the location of the spillway near Lake Evans (Section 91900). The inundation area behind the levee under elevation 784.5’ NAVD88 was mapped as a floodplain [Figure 22].
- Floodplain width does not change significantly except at the following locations
  - area north of Tequesquite Landfill near the end of the Riverside Levees [Figure 23]
  - golf course near confluence of Pyrite Channel [Figure 24]
- The entire reach of the Santa Ana River within Riverside County is being revised. Therefore, there is no need for a tie-in analysis of the water surface profiles since they will be completely replaced.

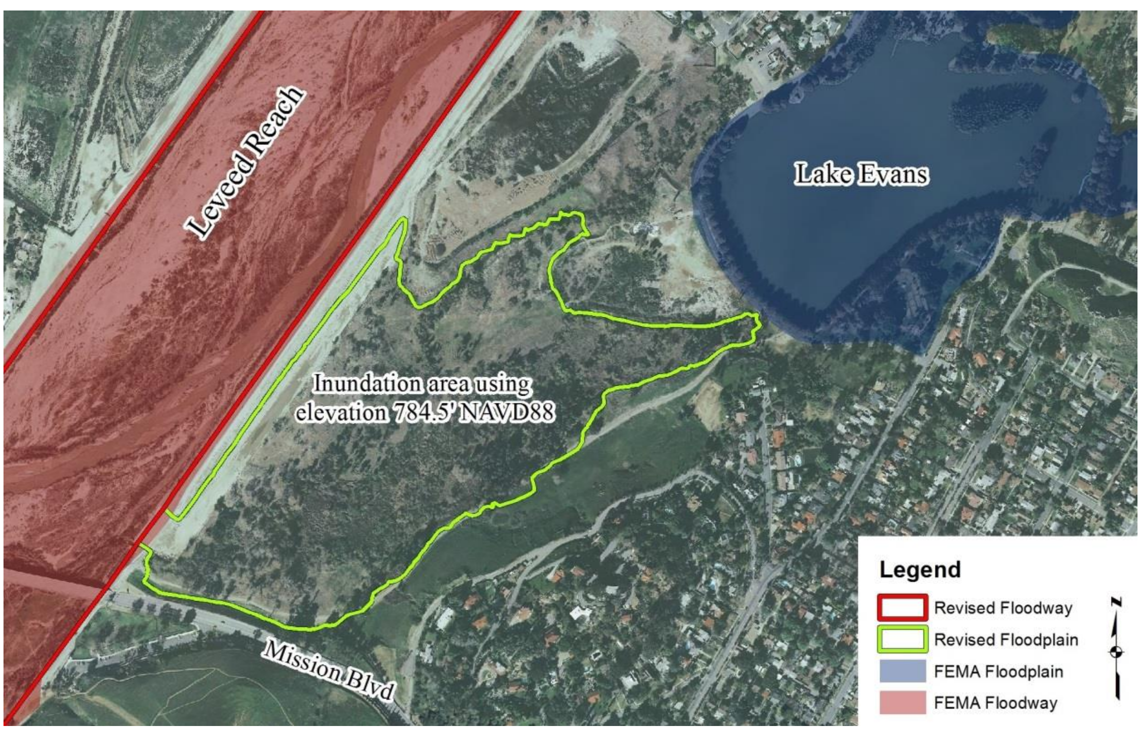

Figure 22: Inundation Area behind Spillway near Lake Evans

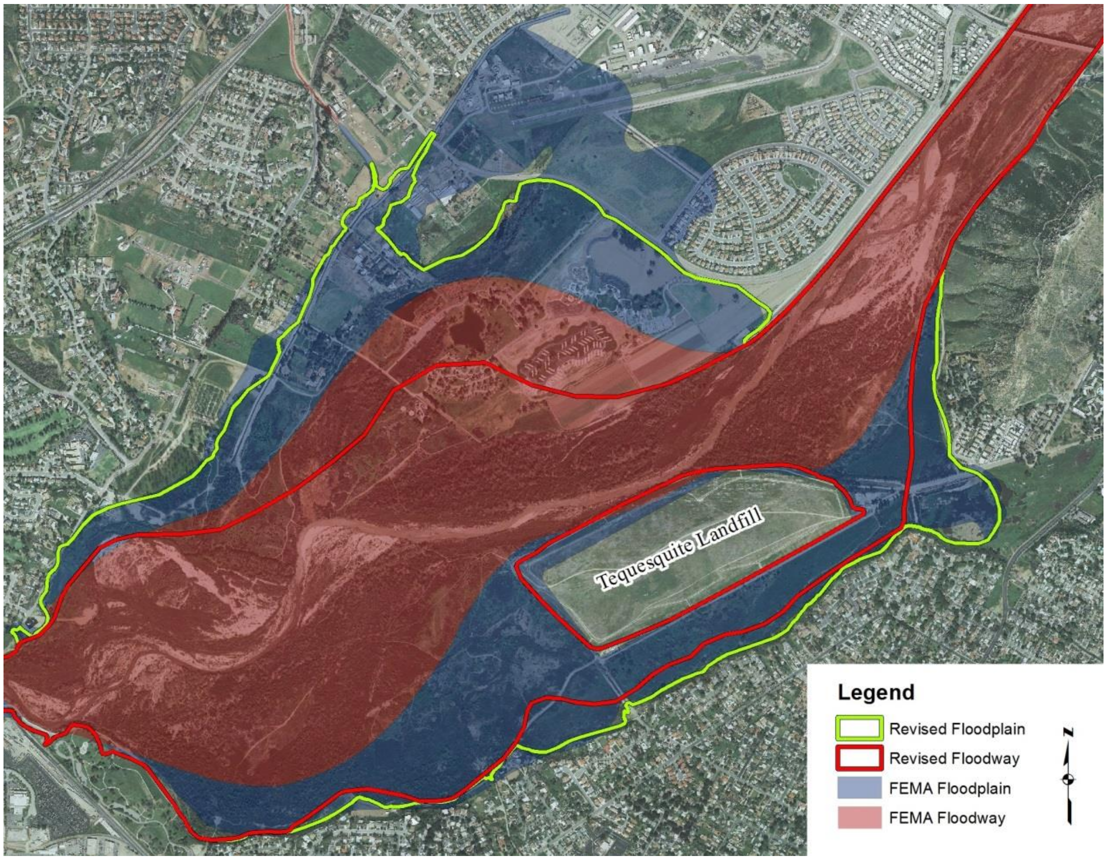

Figure 23: Revised vs. FEMA Floodplain/Floodway near Tequesquite Landfill

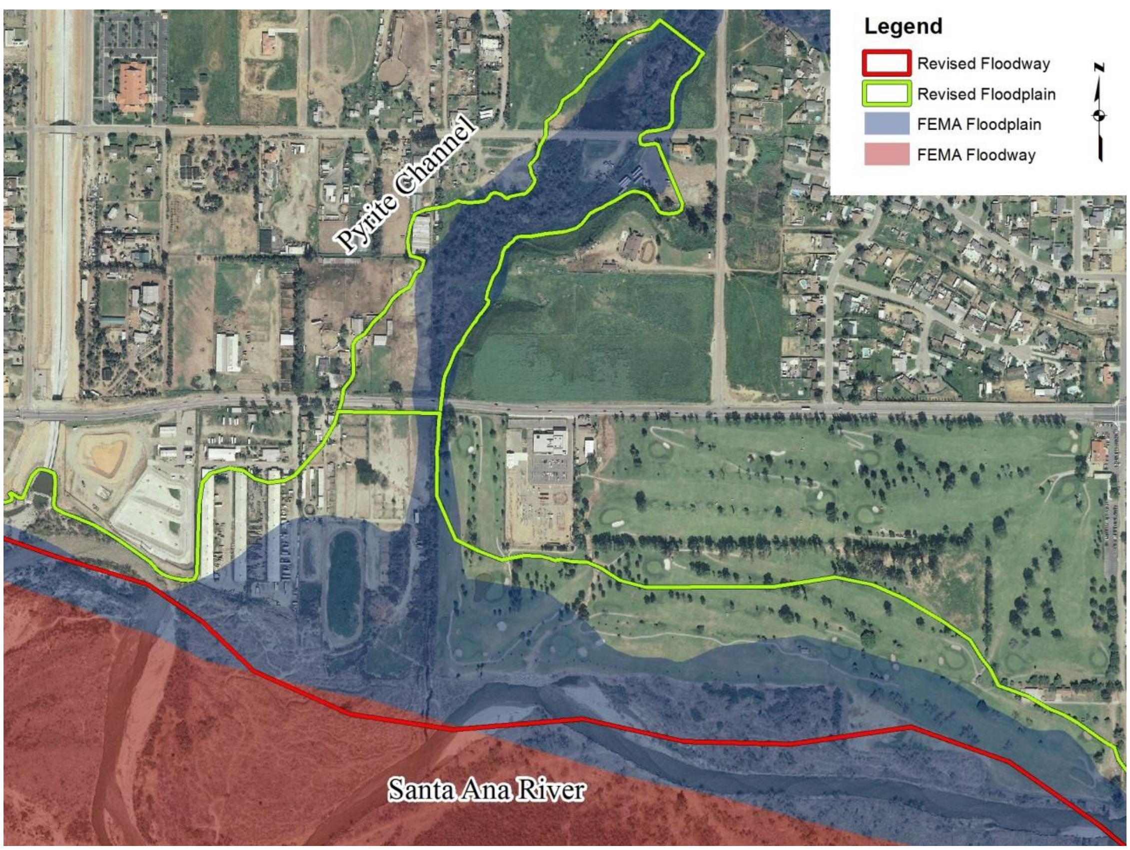

Figure 24: Revised vs. FEMA Floodplain/Floodway at confluence of Pyrite Channel

3.2.3 100-Year Floodway

- The revised floodway is narrower than the FEMA floodway with the following exceptions
  - Upstream Study Limit to Market Street Bridge (Sections 103600 – 98750)
  - Area immediately upstream & downstream of Tequesquite Landfill [Figure 25]
  - A few locations near confluence with San Sevaine Channel (Sections 59000 – 47500)
  - 3,000 feet west of Hamner Avenue to Downstream Study Limit (Sections 32000 – 17000)
- Table 13 identifies locations where floodway width is equivalent to floodplain width
- Optimized floodway does not have surcharges that are negative or greater than 1.0 foot

Table 18: Comparison of Floodway Water Surface Elevations from FEMA/USACE/RCFC Studies

FEMA FIS		**USACE 1991 Study**			**RCFC 2012 Study**	
Section	*WS Elevation [NAVD88]*	*Section*	*WS Elevation [NAVD29]*	*WS Elevation [NAVD88]*	*Section*	*WS Elevation [NAVD88]*
R	822.5	20.29	817.6	820.1	100500	818.0
Q	779.7	18.13	772.4	774.9	89500	774.8
P	747.8	16.84	743.1	745.6	82500	748.3
O	741.7	15.85	736.5	739.0	78000	735.9
N	739.9	15.56	735.2	737.7	76000	734.4
M	731.6	15.434	730.3	732.8	75365	732.9
L	708.7	14.27	710.6	713.1	70000	716.5
K	680.9	12.76	678.0	680.5	62500	685.1
J	645.7	11.15	646.0	648.5	53500	647.1
I	632.3	10.54	637.2	639.7	50000	634.4
H	615.6	9.23	619.7	622.2	45000	618.6
G	606.0	7.95	606.2	608.7	41000	607.4
F	602.2	7.54	602.4	604.9	39000	605.2
E	596.6	6.955	595.1	597.6	35160	597.1
D	586.8	6.72	589.1	591.6	34000	590.6
C	579.3	6.46	583.0	585.5	32500	581.7
B	571.8	6.01	573.0	575.5	29500	572.7
A	559.9	4.81	559.0	561.5	26000	562.4

3.2.4 Prado Dam Back Basin Floodplain

The USACE has improved the Prado Dam to better regulate the additional flows to Santa Ana River caused by urbanization. The 1988 Hydrology Report completed by the USACE discusses these various improvements and their effect on the ponding elevation during different storm frequencies. These changes create a new hydraulic boundary condition for the Santa Ana River as discussed in §3.1.6. This new boundary condition is shown on Figure 11 and was used for the hydraulic study of the Santa Ana River. In addition to affecting the Santa Ana River, the floodplain for the Prado Dam back basin has also been revised to reflect the varying ponding elevations for each storm frequency shown on the FEMA FIRMs. These revisions are based on 1-foot contour topography from September 2008 that was provided by USACE. Appendix L contains annotated FIRMs, topographic workmaps, and revised profiles for the Prado Dam back basin floodplain.

Table 19: Summary of Tributaries for Prado Dam Floodplain

Tributary Name	FEMA Flood Zone	Detailed Study Controlled by Santa Ana Backwater?	Effects of this Floodplain Study
North Norco Channel	AE	Yes	FIS Profile Revised
Temescal Wash	AE	Yes	FIS Profile Revised
Cucamonga Creek	Contained in Channel	n/a	
Chino Creek	Shaded X	No	Floodplain Revised