Natural Condition Report

Ventura River Watershed Hydrology Model

Prepared for:

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1 Introduction

The Ventura County Watershed Protection District has sponsored the development of a watershed simulation model for the Ventura River, funded under a Proposition 50 grant. The simulation model is a mathematical representation of the land area, land management, stream reaches, reservoirs, and water diversions within the watershed. The simulation model converts precipitation time series and other weather inputs into predictions of flow throughout the watershed at a 15-minute time step. It can be used to support water availability and storm flow analyses, and will also support future water quality simulation.

The Ventura River watershed model was developed using the Hydrological Simulation Program – FORTRAN or HSPF, a comprehensive flow and water quality simulation model supported by the U.S. Environmental Protection Agency (USEPA) and the U.S. Geological Survey (USGS). The model represents 228 square miles of land area and 94 individual stream reaches, covering the entire area of the Ventura River watershed. The model also represents land use change over time, including the impacts of major fires.

The *Baseline Model Calibration and Validation Report* (Tetra Tech, 2009) documents the development, calibration, and validation of the watershed model. Model calibration was conducted for the period from October 1996 through September 2006, while validation tests were done on the period from October 1986 through September 1995. A longer period, beginning in October 1967, was then simulated to evaluate model prediction of extreme high flow events. In all, the model is calibrated to seven different continuous flow monitoring gages, with peak storm event information from four additional gages. The model also represents land use change over time, including the impacts of major fires.

Calibration and validation of the model was successful. In general, the model performs well in reproducing all aspects of the water balance and replicating gaged flows. The model also provides good to excellent representation of high flow events at most locations.

This report addresses the question of natural flows in the Ventura River system. Natural flows are those flows that would be present without human intervention. Both high and low flow regimes are of interest. To evaluate natural condition flows, the calibrated model is rerun with all developed land use converted to natural land use and all dams, diversions, irrigation, water withdrawals, and discharges removed. The natural condition scenario is run over the same meteorological input (October 1967 through September 2007) as was used for the calibrated existing conditions model, enabling a direct comparison of results.

Because much of the Ventura River watershed remains undeveloped, substituting natural land use has a relatively small effect on flows. On the other hand, the dams, diversions, and water withdrawals currently in place have a large effect, and tend to reduce flows under existing conditions. However, irrigation of agricultural land does serve to increase instream flows somewhat under dry conditions.

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2 Setting up the Natural Condition Run

Representation of natural conditions involves changes in two general areas – changes to the reach network (including the representation of withdrawals and discharges) and changes to the upland land use.

2.1 Changes to Reach Network, Withdrawals, and Discharges

Several changes to the reach routing are needed to represent natural conditions in the watershed. These are summarized in Table 1.

For the two reservoir reaches (Casitas and Matilija), the natural condition simulation assumed that the dams were not present. The hydraulic behavior of stream reaches in the model is represented through Functional Tables (FTables), so simulation without the reservoirs present required modified FTables. For Matilija Reservoir, an FTable based on channel characteristics immediately below the existing dam was used. For Casitas Reservoir, a new FTable was created using the regional regression approach.

The natural condition scenario assumes that ground water pumping is eliminated, reducing the dewatering of some stream segments. It should be noted that not all stream reach losses to ground water are removed from the model, only those that appear to be primarily driven by local pumping. Other losses to ground water are associated with natural faults in downwelling areas. The natural condition scenario retains these losses for reaches 511 (San Antonio Creek), 825 (Ventura River), 893 (Reeves Creek), and 894 (Thacher Creek).

Areas of natural groundwater upwelling assigned to reaches 310, 882, and 962 are retained in the model. While recent gaining flows in these reaches may be influenced by irrigation water application, this is likely balanced to some extent by well withdrawals.

The model contains one point source discharge – Ojai WWTP, discharging to Reach 875. This discharge is turned off for the natural conditions run.

Table 1. Changes to Reach Network for Natural Conditions Simulation

Model Reach	Name	Revision
001	Live Oak Creek	Keep only exit 1 (natural flow to Reach 841)
311	Ventura River	Eliminate exit 2, which represents Foster Park Diversion
422	Happy Valley Drain	Keep only exit 1 (natural flow to Reach 822)
451	Stewart Canyon	Reroute direct to Reach 881 (eliminate 996)
821	Live Oak Creek	Keep only exit 2 (natural flow to Reach 841)
841	Live Oak Creek	Keep only exit 1 (natural flow to Reach 831)
882	San Antonio Creek	Eliminate exit 2 (losses to groundwater driven by Ojai Valley wells)
904	East Ojai Drain	Keep only natural flow to San Antonio Creek (Reach 511)
912	Ventura River at Robles Diversion	Keep only exit 1 (to Reach 913); eliminate exit 2 (to Robles Diversion) and exit 3 (losses to groundwater driven by Meiners Oaks wells)
913	Ventura River	No change needed; exit 2 (set up as a loss to groundwater) is currently set to zero and not used
921	McDonald Canyon Drain	Keep only exit 1 (natural flow to Reach 421)
994	Live Oak Diversion Basin	Eliminate reach
995	McDonald Canyon Detention Basin	Eliminate reach
996	Stewart Canyon Basin	Eliminate Reach
997	Robles Diversion	Eliminate Reach
998	Lake Casitas	Replace FTable; keep only exit 1 (flow to Reach 251)
999	Matilija Reservoir	Replace FTable; keep only exit 1 (to Reach 912); eliminate losses to groundwater (exit 2); also eliminate groundwater inflows specified on DSN 3055 and GENER 599

2.2 CHANGES TO LAND USE

The natural conditions scenario converts all anthropogenic land uses to natural land uses. The anthropogenic land uses in the model are Agriculture, Orchard, Low Density Developed (pervious and impervious), High Density Developed (pervious and impervious), and Transportation (impervious). One result of this conversion is the removal of all impervious land use from the model. Another result is that all pervious land use classes that use irrigation are removed from the model.

Implementing these changes is relatively straightforward due to the two-stage HRU process used in simulation in which all HRUs are first simulated on a unit area basis with the results stored and subsequently linked to the reach model. The natural conditions land use run thus requires only substitution of the linkage table in the reach model.

As discussed in the Model Calibration Report (Tetra Tech, 2009), the U.S. Forest Service LANDFIRE Existing Vegetation Type (EVT) dataset provides the best estimate of current natural land cover in the Ventura River watershed, while the Southern California Association of Governments (SCAG) land use data provides the best estimate of developed land cover. Both were combined to produce the final land use/land cover data used for the HSPF modeling. Note that EVT includes agricultural and developed land cover classes, which for the most part are spatially contiguous with the SCAG agricultural and developed classes.

LANDFIRE offers another relevant product – the Potential Natural Vegetation Group (PNVG) dataset (Figure 1). PNVG represents vegetation likely to exist under purely natural conditions, including the natural fire regime. Vegetation classes for PNVG are assigned based on a set of rules that accounts for the biophysical setting, including ecoregion, meteorology, elevation/slope/aspect, soils, and existing vegetation to represent what is likely to be present in the absence of human disturbance. In the Ventura watershed, the PNVG rules do not appear to produce an accurate approximation of existing natural vegetation, in part because PNVG underestimates the amount of forest cover in the watershed, which is consistent with a policy of fire suppression. On the assumption that the natural conditions run should represent the natural fire regime, the PNVG was used specify natural land cover conditions.

One issue with the LANDFIRE coverage is that it does not show natural vegetation under the current extent of Lake Casitas and Matilija Reservoir. The area now under Matilija was originally a canyon, while the area now under Casitas included grassland valleys and chaparral canyons. In both cases, the land area shown by LANDFIRE as water was distributed proportionally to the PNVG land use categories in the immediate surrounding subwatersheds.

In contrast to the existing conditions simulation, the natural conditions run is set up without any “recently burned” land use. The model uses this category to represent altered hydrologic characteristics of areas subject to intense burns within the preceding two years. This is not needed with use of the PNVG scenario, which implicitly incorporates more frequent, but less intense understory fires that have a less dramatic impact on hydrology.

Once the natural vegetation land cover was developed for the chosen method, the land cover was converted to vector (polygon) format, intersected with the subbasin GIS file. The slope classes and hydrologic soil group classes were tabulated and apportioned to each land cover polygon, as was done in the existing conditions model.

The natural condition land use coverage is compared to the 2001 land use in Table 2. One consequence of the use of PNVG is that there is substantially less forest area, with a shift to chaparral. This is consistent with active fire suppression under existing conditions. One characteristic of forest in the model is that it has slightly higher soil water holding capacity than chaparral, leading to higher cumulative infiltration and greater baseflows. Therefore, undeveloped areas may have slightly lower baseflows under natural conditions (as represented by PNVG) than under existing conditions with fire suppression.

Table 2. Comparison of Natural Condition Land Use to 2001 Land Use

Land Use	SCAG 2001 (acres)	Natural Condition (acres)
Grassland/Pasture	5,007.5	188.0
Chaparral	63,689.6	117,309.8
Forest	56,938.6	24,472.9
Agriculture	638.2	0.0
Orchards	4,208.7	0.0
Low Density Dev. Pervious	4,486.5	0.0
High Density Dev. Pervious	2,757.0	0.0
Low Density Impervious	708.5	0.0
High Density Impervious	1,215.7	0.0
Transportation	97.4	0.0
Barren	1,776.7	2,138.0
Water	2,584.5	0.0

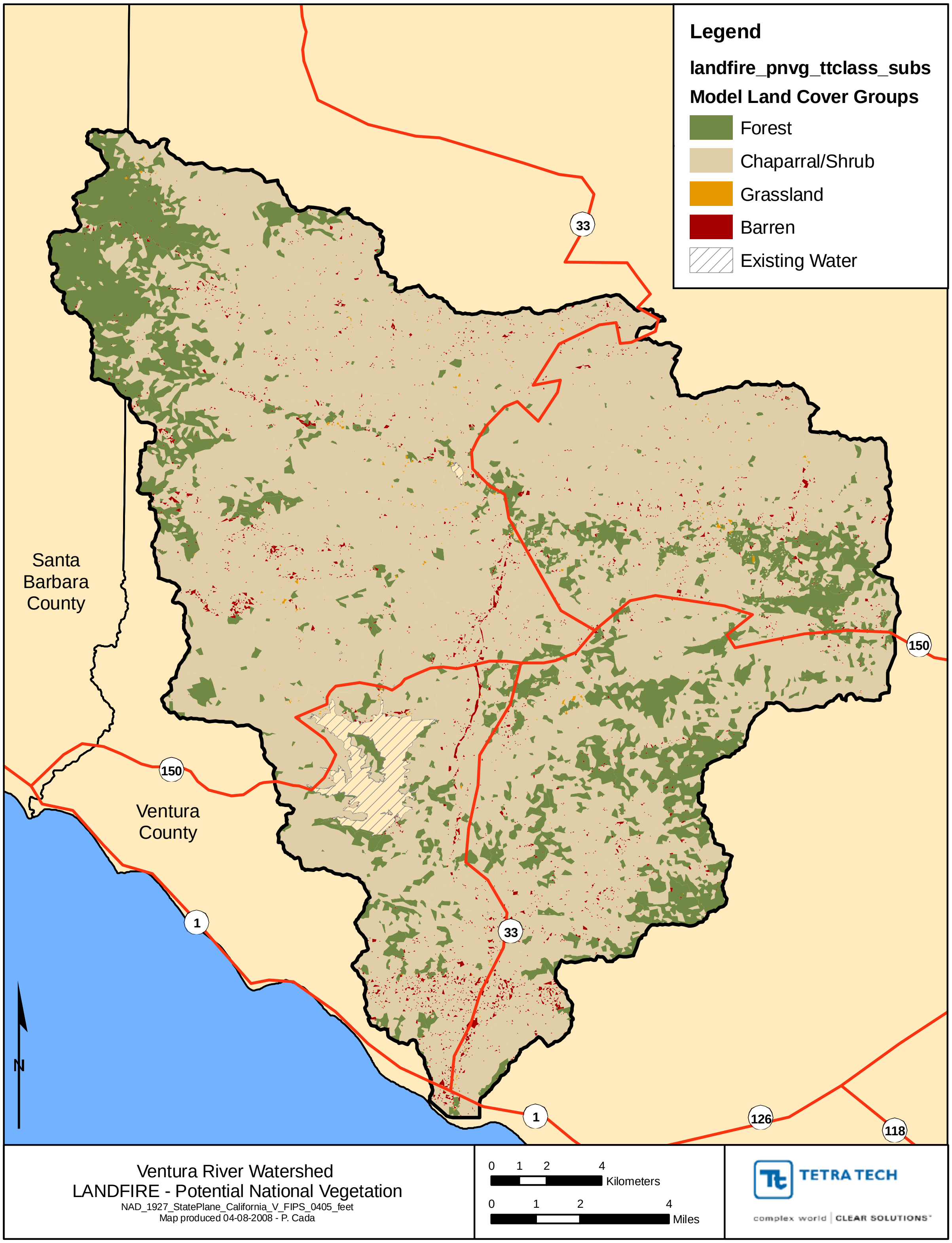

Figure 1. LANDFIRE Potential Natural Vegetation (PNVG) Coverage

Note: Roads are shown for visual reference only and are not included in the PNVG coverage.

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3 Water Balance Results

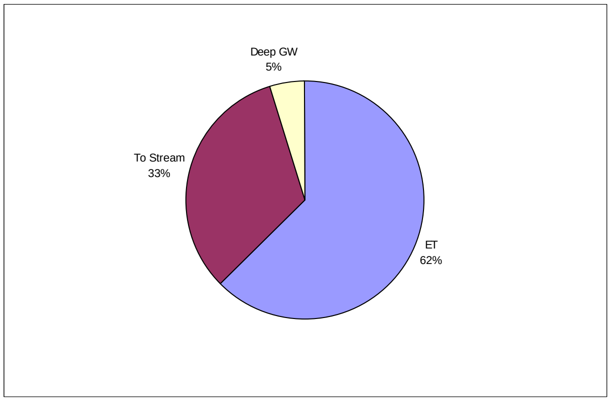
As was done for the Baseline Model Calibration Report, detailed water balance summaries were constructed for water years 1997 through 2007 (the model calibration period). The water balance predicted by the model under existing baseline and natural conditions for these years is summarized in Table 3, Figure 2, and Figure 3.

Table 3 first compares the upland water balance, including land surface runoff, soil moisture, and shallow ground water. Inputs are predominantly precipitation, although some water is also added by irrigation under existing conditions, and by depletion of soil and shallow ground water storage. Differences in the upland water balance between existing and natural conditions are small, but include the elimination of irrigation input (4 percent of the total) and changes in evapotranspiration and storage due to different land cover. Total precipitation to the uplands is a little higher under natural conditions because of the additional land area present due to the removal of Lake Casitas and Matilija Reservoir. Under both existing and natural conditions, about 60 percent of this input is returned to the atmosphere via evapotranspiration, and one-third becomes runoff, while the residual enters deep ground water. This deep ground water is a source of irrigation water, and also interacts with the stream; however, a complete water balance of the ground water component is not possible because a ground water model has not been completed.

The waterbody balance has a number of inputs, beginning with runoff from the land surface, but also including upwelling ground water, point sources, and direct precipitation (the tables show net precipitation, the difference between precipitation and evaporation, which is an input for some reaches and an output for others). Output from the stream reaches and reservoirs includes downstream flow, diversions for consumptive use from Lake Casitas (existing conditions only), evaporation, and losses to ground water. Under existing conditions, downstream flow to the Pacific Ocean constitutes 69 percent of the water entering stream reaches or about 25 percent of precipitation on the watershed. About 16 percent of the surface water flow is diverted for consumption, while the remainder is lost to ground water or evaporation. Under natural conditions, there are no diversions to consumptive use, nor are there reservoir evaporation losses. As a result, the outflow from the Ventura River to the Pacific Ocean increases from 933,677 to 1,199,780 AF over the simulation period, or about 33 percent of the precipitation that falls on the watershed.

Table 3. Water Balance Comparison of Existing Conditions versus Natural Conditions for Ventura River Watershed (Meteorology of October 1996 through September 2007)

	Existing Condition (Baseline)		Natural Condition		Change (AF; Natural Condition minus Baseline)
	Total (AF)	Percent	Total (AF)	Percent	
Upland Balance					
	Input				
Precipitation	3,542,087	93.31%	3,604,889	98.53%	62,802
Irrigation	157,839	4.16%	0	0.00%	-157,839
Change in storage	95,950	2.53%	53,922	1.47%	-42,028
Total Input	3,795,877		3,658,811		-137,066
	Land Surface Output				
ET	2,369,553	62.42%	2,308,038	63.08%	-61,515
To Stream	1,246,021	32.83%	1,199,780	32.79%	-46,241
Deep GW	180,303	4.75%	150,993	4.13%	-29,310
Total Output	3,795,877		3,658,811		-137,066
Waterbody Balance					
	Input				
Runoff	1,246,021	94.23%	1,199,780	96.33%	-46,241
GW in	46,771	3.54%	39,863	3.20%	-6,908
Point Source	27,402	2.07%	0	0.00%	-27,402
Net Direct Precipitation	2,183	0.17%	5,808	0.47%	3,625
Total	1,322,376		1,245,451		-76,926
	Waterbody Output				
Downstream out	933,677	70.61%	1,207,281	96.94%	273,604
Diversions out	216,605	16.38%	0	0.00%	-216,605
GW Loss from Reach	81,123	6.13%	38,170	3.06%	-42,953
Net Rch & Res loss	90,972	6.88%	0	0.00%	-90,972
Total	1,322,376		1,245,451		-76,926



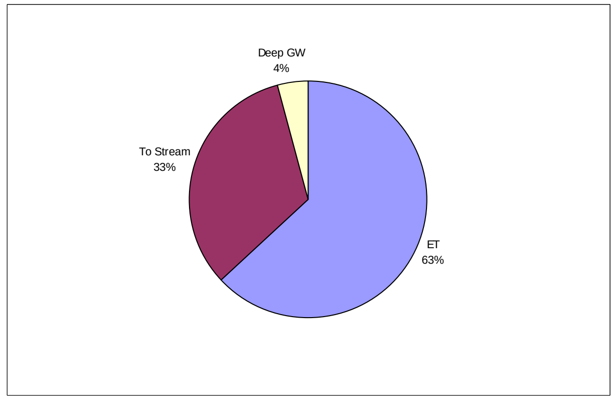
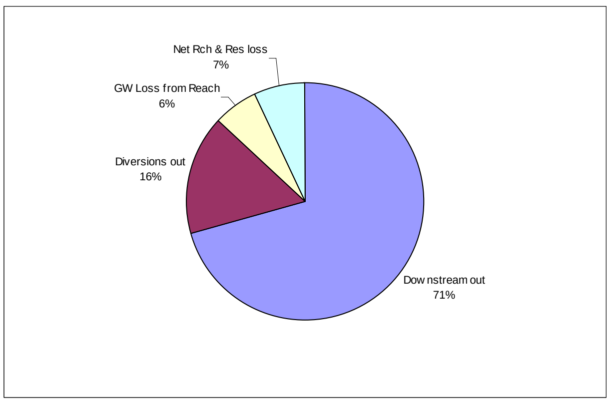


Figure 2. Upland Water Balance for Existing Condition (left) and Natural Condition (right)



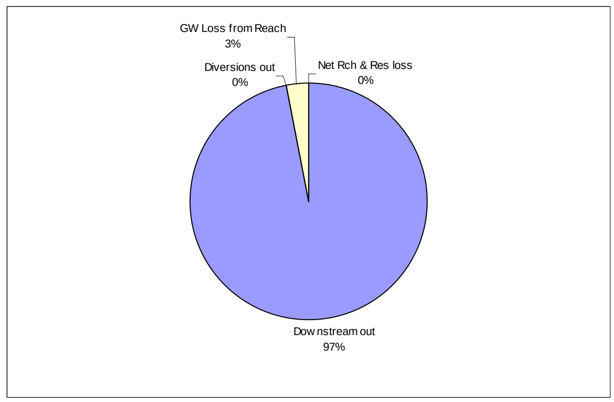


Figure 3. Stream Water Balance for Existing Condition (left) and Natural Condition (right)

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4 Flow Duration-Frequency Analysis

The complete distribution of flows was analyzed for Water Years 1968-2007. As a first step, the average flows over the simulation period are compared in Table 4 for each of the gage locations, plus the mouth of the Ventura River. Little difference is estimated in results for those stations that gage predominantly undeveloped land (Matilija Creek, North Fork Matilija Creek, Coyote Creek, Santa Ana Creek), although average flows under natural conditions are slightly higher. For San Antonio Creek the average flow under natural conditions is slightly lower as this watershed contains significant amounts of irrigated lands. The most dramatic changes are seen in the Ventura River mainstem: Average flows in the river near Meiners Oaks are almost 50 percent higher, due to removal of both Matilija Dam and the Robles diversion to Casitas. They are also about 50 percent higher under natural conditions for Ventura River near Ventura, reflecting the influence of Casitas Dam. The difference is slightly smaller at the mouth of the Ventura River, as existing conditions add in the flow from the Ojai wastewater treatment plant (approximately 3 cfs).

Table 4. Average Flows (cfs) for Existing and Natural Conditions, Water Years 1968-2007

Location	Existing Baseline	Natural Condition
USGS 11114495 Matilija Creek above Reservoir	40.2	40.7
Gage 602/602A Matilija Creek below Dam	47.8	50.0
USGS 11116000 North Fork Matilija Creek	12.3	12.6
USGS 11116550 Ventura River near Meiners Oaks	44.1	65.0
USGS 11117500 San Antonio Creek at Highway 33	25.4	23.3
USGS 11117600 Coyote Creek near Oak View	9.7	9.8
USGS 11117800 Santa Ana Creek near Oak View	7.7	7.9
USGS 11118500 Ventura River near Ventura	82.9	123.8
Mouth of Ventura River	106.2	140.9

More detailed information is available from flow-duration curves. These show the percent of time that flow of a given magnitude is equaled or exceeded.

For those watersheds that are predominantly undeveloped under existing conditions (Figure 4 through Figure 7), the flow-duration curves for existing baseline and natural conditions are very similar. Low flows of a given frequency are slightly lower under natural conditions, reflecting the shift from forest to chaparral without fire suppression, as discussed above.

San Antonio Creek (Figure 8) drains an area with substantial amounts of developed land and irrigated agriculture. Ground water pumping, with associated losses from stream reaches, is removed under the natural conditions scenario; however, irrigation is also removed, resulting in a net reduction in low flow magnitude under natural conditions. Flows above the median value are also higher under existing baseline conditions because of the presence of impervious surfaces that promote runoff rather than infiltration.

The mainstem stations are strongly affected by the removal of dams and diversions. Below the site of Matilija Dam, median and lower frequency flows are higher under natural conditions due to the removal of storage and evaporation losses from the dam (Figure 9). Flows are dramatically different for Ventura River near Meiners Oaks (Figure 10), as existing baseline conditions include both diversions to Casitas above this location and significant alluvial pumping that causes the channel to frequently go dry.

Natural condition flows are much higher at Ventura River near Ventura (Figure 11). This gage location is downstream of the confluence with Coyote Creek and Lake Casitas, so the absence of Casitas Dam under natural conditions is the major factor here. Finally, at the mouth of the Ventura River, natural condition flows are generally higher than under existing conditions, except at the lowest flows (Figure 12). Under existing conditions, low flows are maintained at a higher level by the Ojai wastewater treatment plant discharge.

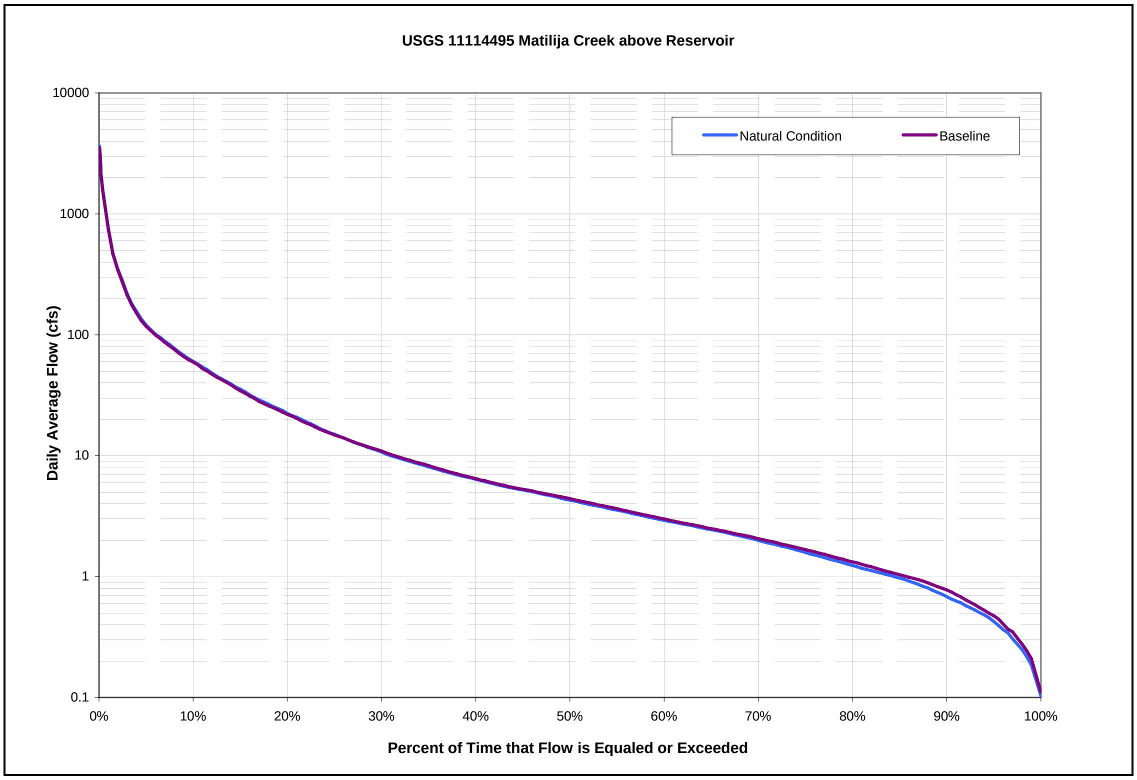

Figure 4. Flow-Duration Curve, Matilija Creek above Reservoir

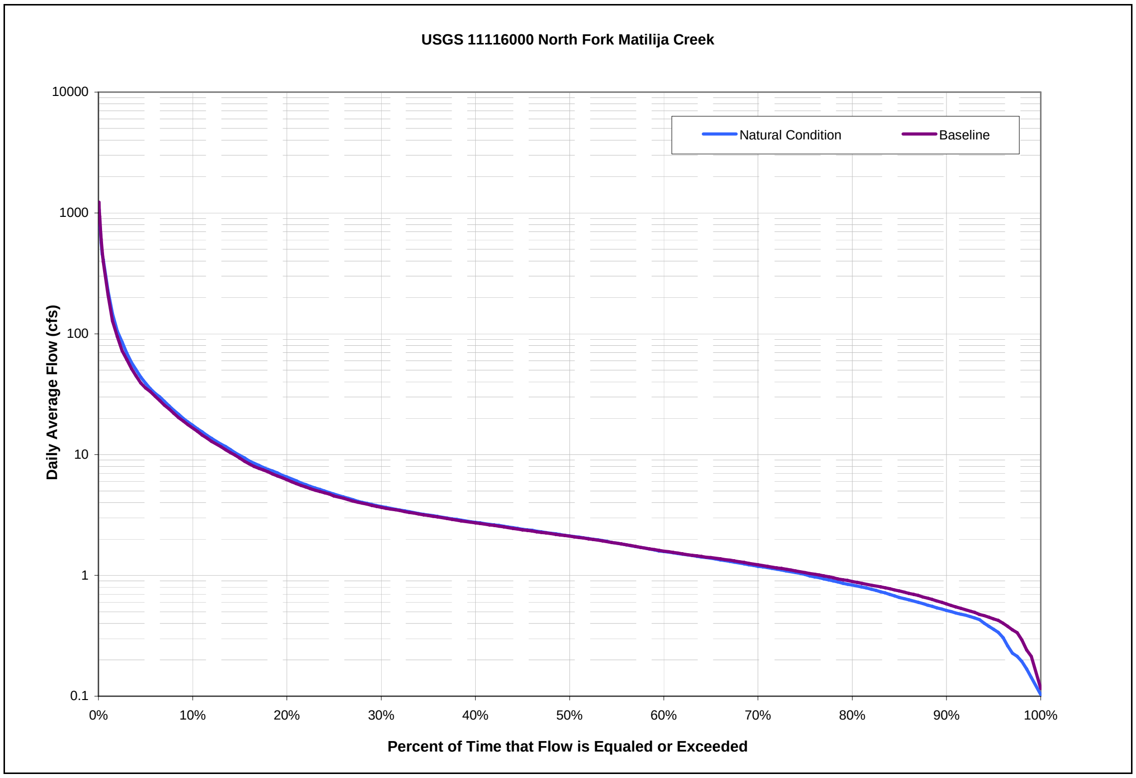

Figure 5. Flow Duration Curve, North Fork Matilija Creek

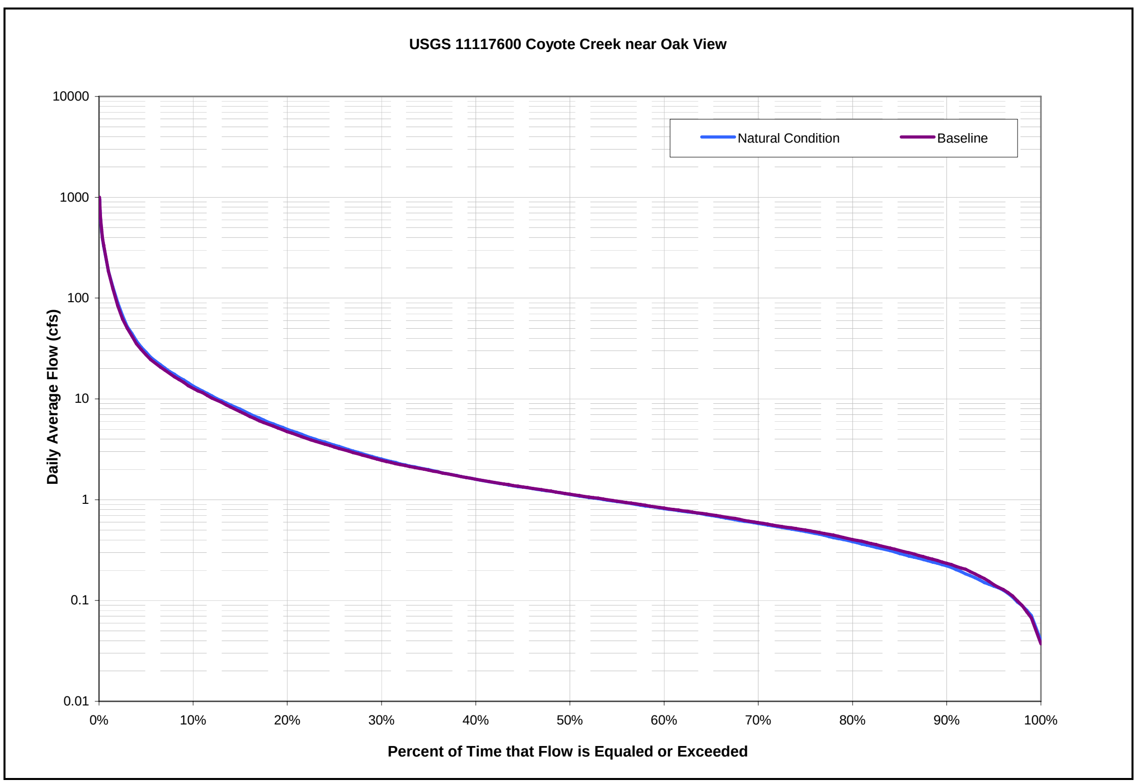

Figure 6. Flow Duration Curve, Coyote Creek near Oak View

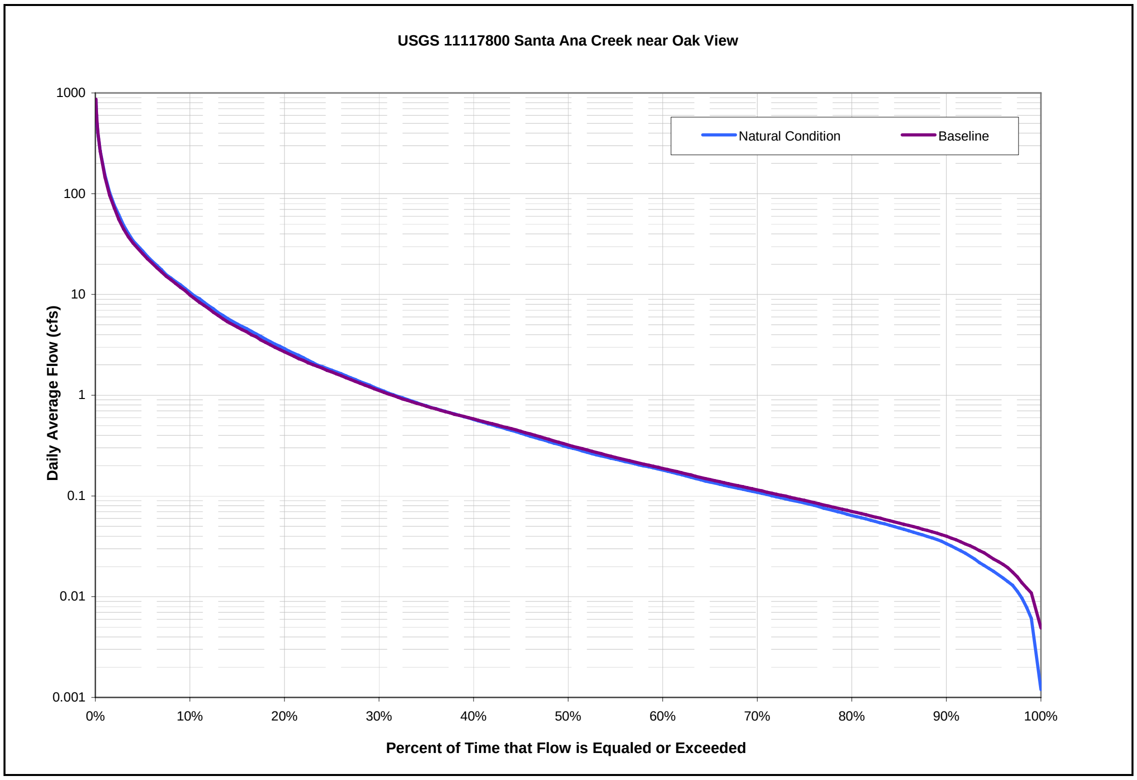

Figure 7. Flow-Duration Curve, Santa Ana Creek near Oak View

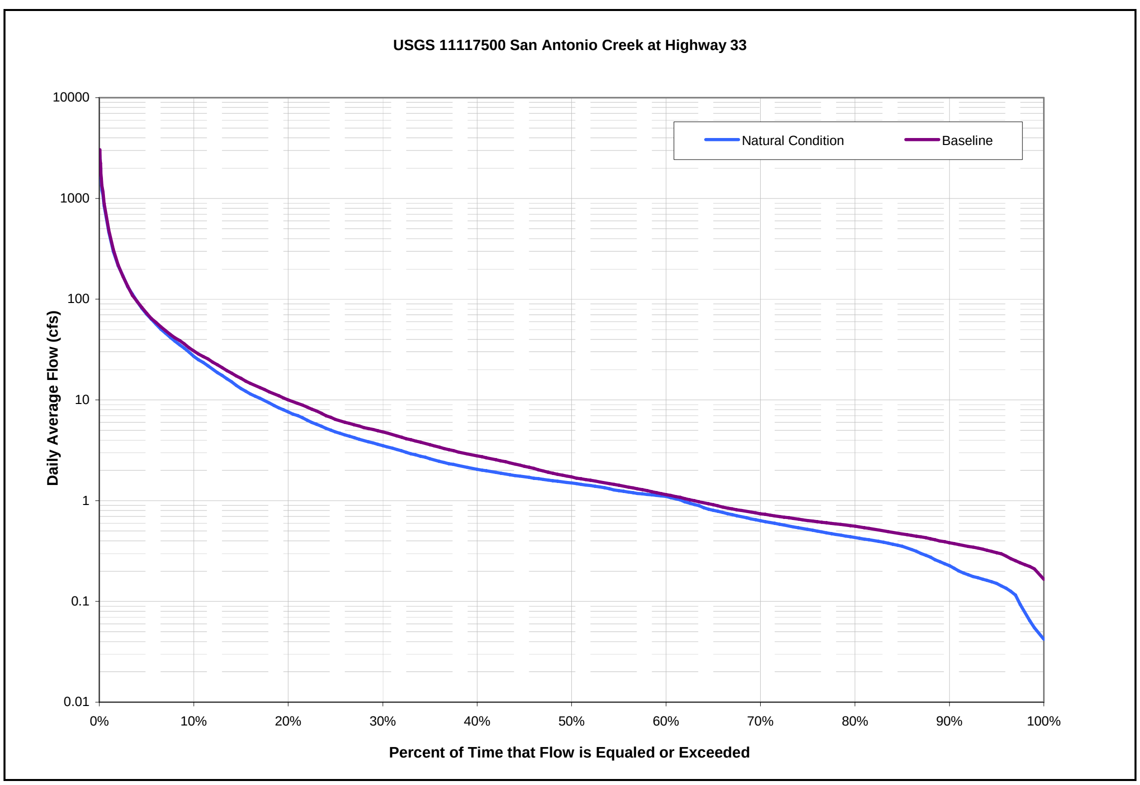

Figure 8. Flow-Duration Curve, San Antonio Creek at Highway 33

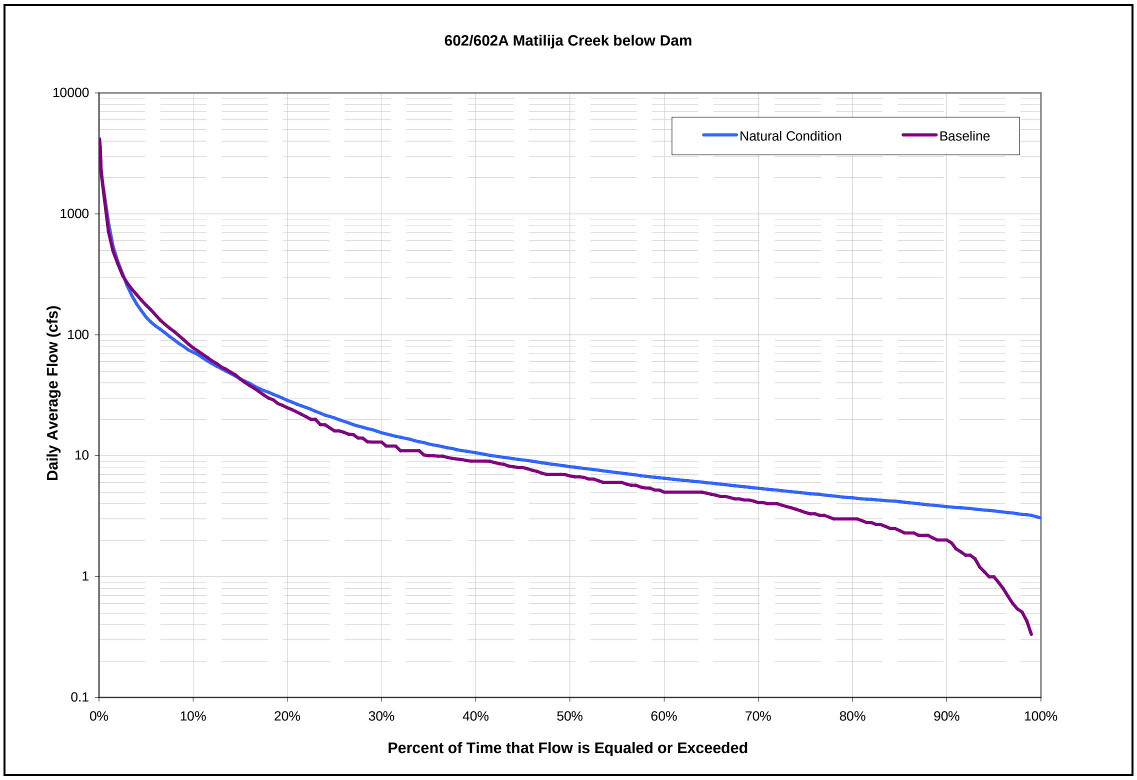

Figure 9. Flow-Duration Curve, Matilija Creek below Dam

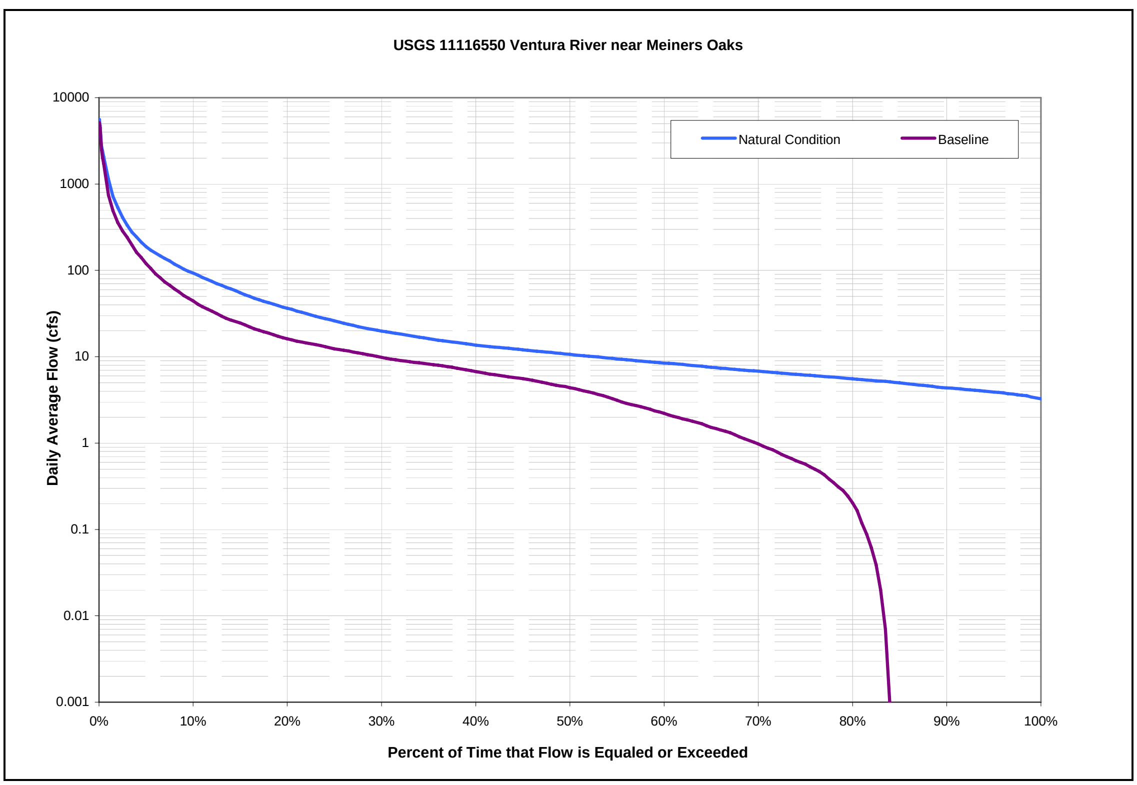

Figure 10. Flow-Duration Curve, Ventura River near Meiners Oaks

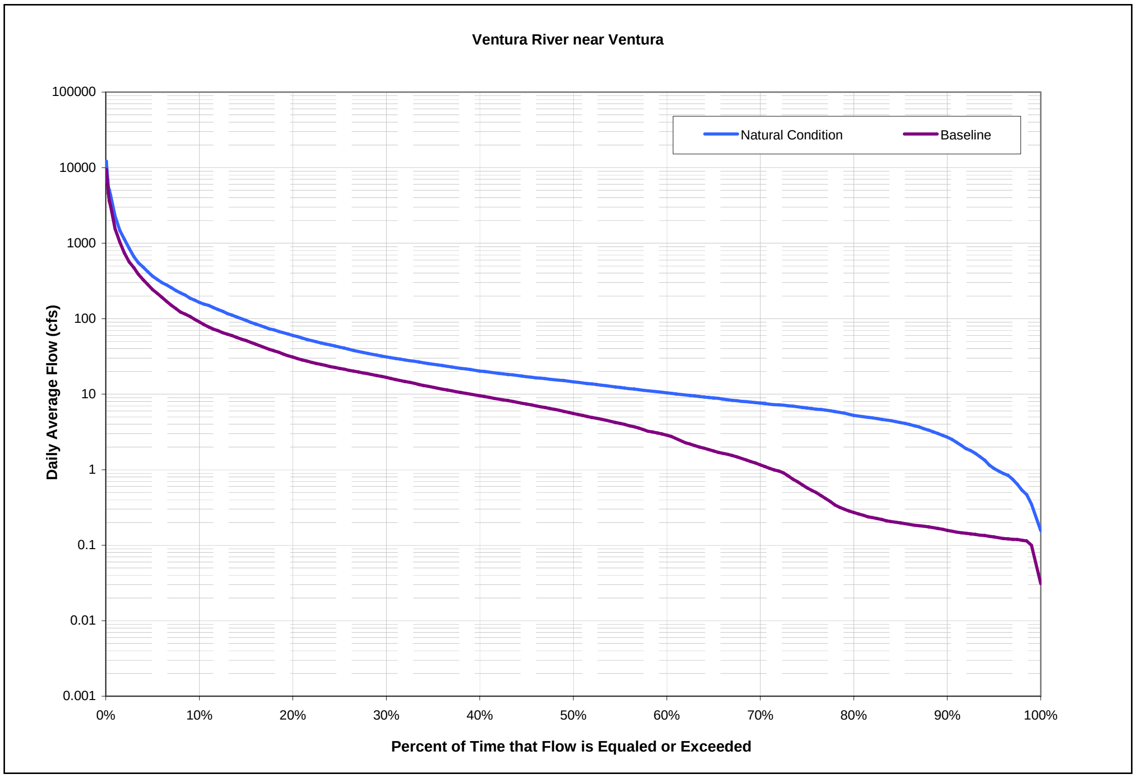

Figure 11. Flow-Duration Curve, Ventura River near Ventura

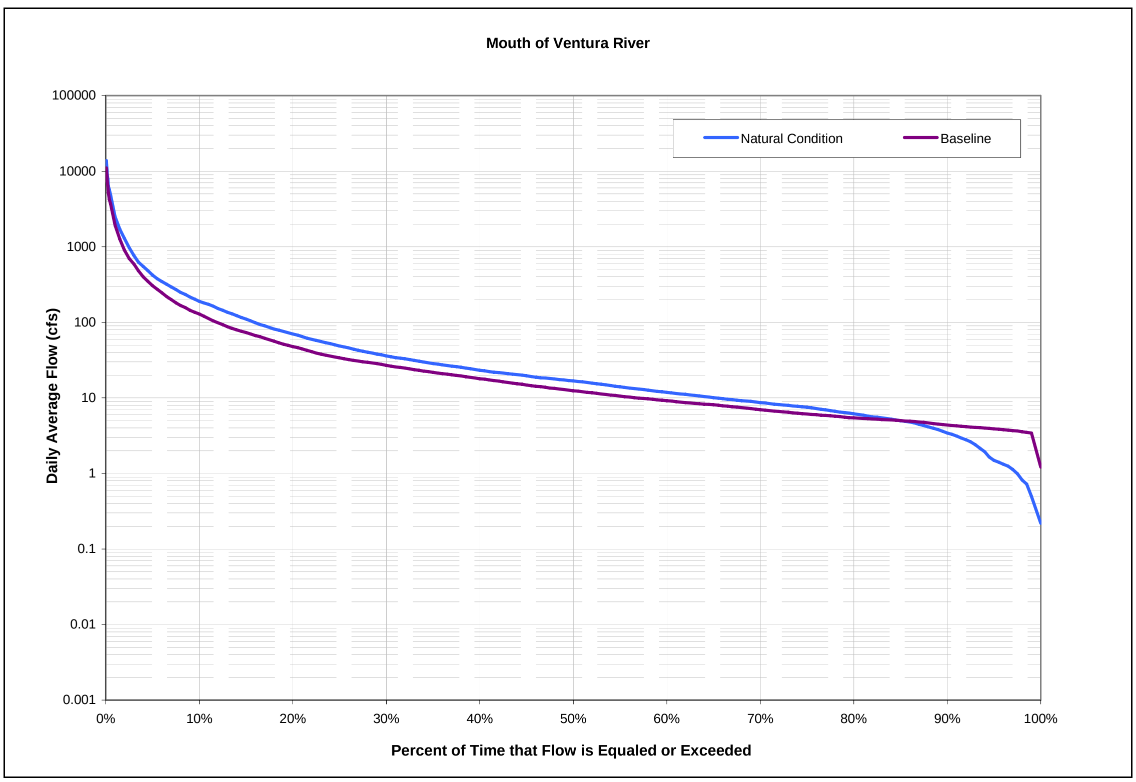

Figure 12. Flow-Duration Curve, Ventura River at Mouth

The frequencies at which low flows are maintained are of particular interest for the support of aquatic life in the Ventura River. The flows exceeded 50 percent of the time (median flow), 80 percent of the time, and 95 percent of the time are summarized in Table 5 through Table 7.

Table 5. Comparison of Flows Exceeded 50 Percent of the Time (cfs)

Location	Existing Baseline	Natural Condition
USGS 11114495 Matilija Creek above Reservoir	4.41	4.28
Gage 602/602A Matilija Creek below Dam	6.80	8.13
USGS 11116000 North Fork Matilija Creek	2.11	2.13
USGS 11116550 Ventura River near Meiners Oaks	4.39	10.64
USGS 11117500 San Antonio Creek at Highway 33	1.72	1.49
USGS 11117600 Coyote Creek near Oak View	1.14	1.13
USGS 11117800 Santa Ana Creek near Oak View	0.32	0.31
USGS 11118500 Ventura River near Ventura	5.56	14.65
Mouth of Ventura River	12.45	16.77

Table 6. Comparison of Flows Exceeded 80 Percent of the Time (cfs)

Location	Existing Baseline	Natural Condition
USGS 11114495 Matilija Creek above Reservoir	1.32	1.23
Gage 602/602A Matilija Creek below Dam	3.00	4.48
USGS 11116000 North Fork Matilija Creek	0.89	0.83
USGS 11116550 Ventura River near Meiners Oaks	0.20	5.55
USGS 11117500 San Antonio Creek at Highway 33	0.56	0.43
USGS 11117600 Coyote Creek near Oak View	0.40	0.38
USGS 11117800 Santa Ana Creek near Oak View	0.07	0.06
USGS 11118500 Ventura River near Ventura	0.27	5.23
Mouth of Ventura River	5.44	6.15

Table 7. Comparison of Flows Exceeded 95 Percent of the Time (cfs)

Location	Existing Baseline	Natural Condition
USGS 11114495 Matilija Creek above Reservoir	0.47	0.43
Gage 602/602A Matilija Creek below Dam	1.00	3.49
USGS 11116000 North Fork Matilija Creek	0.44	0.36
USGS 11116550 Ventura River near Meiners Oaks	0.00	3.90
USGS 11117500 San Antonio Creek at Highway 33	0.31	0.15
USGS 11117600 Coyote Creek near Oak View	0.14	0.14
USGS 11117800 Santa Ana Creek near Oak View	0.02	0.02
USGS 11118500 Ventura River near Ventura	0.13	1.04
Mouth of Ventura River	3.89	1.49

5 Storm Event Peaks

Human influences impact peak runoff in the watershed in a number of ways. Impervious surfaces associated with development cause increased runoff, although the amount of impervious area in the watershed is relatively small. On the other hand, the storage capacity provided by Lake Casitas, Matilija Reservoir, and several smaller detention basins significantly reduces peak flows. A variety of other modifications to the natural drainage pattern have also been made.

The USGS PeakFQ program provides flood-frequency analyses according to Bulletin 17-B methodology (USGS, 1982). This analysis was applied to both existing and natural condition simulated annual peak series for water years 1968-2007. For consistency with the model calibration report, the Bulletin 17-B procedure was applied to the complete annual peak series without any corrections for low outliers.

When the Bulletin 17-B procedure is used to fit all of the data, including the low outliers, the resulting log-mean, log standard-deviation, and log-skew values are such that the fitted Log Pearson III curve may become inflated on the high end of the data set, resulting in overestimation of the magnitude of extreme flood events. To address this issue, Bullard (2002) recommended use of a top end fitting procedure to estimate flood peaks on the Ventura River mainstem. In this type of analysis the peak flows and plotting positions, or the equivalent return period, are fit with a curve by a least squares analysis procedure. The resulting regression equation is then used to determine the peak flow for the desired return periods. Bullard suggested that fitting the top seven peak events was sufficient for extrapolation.

The comparison of storm event peaks presented below uses the Bulletin 17-B procedure for consistency with the calibration report. The reader should note that the resulting peak estimates are not official design or FEMA Flood Insurance Study estimates, but rather are intended for comparison between existing and natural conditions. Peak estimates for a variety of recurrence periods ranging from the 100-year event to the 2-year event are shown in Table 8 through Table 13. The corresponding log-Pearson III Bulletin 17-B fits are shown in Figure 13 through Figure 22.

In general, the differences in estimated peaks between existing and natural conditions are small for watersheds without significant flow modification. Peaks under existing conditions are higher for Fox Canyon Drain and Happy Valley Drain as routing modifications have diverted additional area to these drains. On the other hand, peak flows are predicted to be much higher under natural conditions for the Ventura River mainstem, reflecting the removal of the Casitas and Matilija dams.

Table 8. Comparison of 100-Year Storm Runoff Peaks (cfs; Bulletin 17-B Methodology)

Gage Location	Existing Condition	Natural Condition	Percent Difference from Existing Condition
North Fork Matilija Creek	43,760	44,030	0.6%
Ventura River near Meiners Oaks	136,300	189,300	38.9%
Fox Canyon Drain	1,753	1,679	-4.2%
Happy Valley Drain	2,879	1,804	-37.3%
San Antonio Creek at Hwy 33	43,190	46,470	7.6%
Ventura R near Ventura	128,700	218,100	69.5%
Coyote Creek near Oak View	19,090	18,610	-2.5%
Santa Ana Creek near Oak View	39,330	36,120	-8.2%
Canada Larga at Ventura Ave	20,720	21,370	3.1%
Ventura River at Mouth	129,600	229,500	77.1%

Disclaimer: The estimates provided in this table are generated from application to a limited data set for the purposes of comparing flood peaks during the model simulation period. Therefore, these numbers are not official design or FEMA Flood Insurance Study estimates.

Table 9. Comparison of 50-Year Storm Runoff Peaks (cfs; Bulletin 17-B Methodology)

Gage Location	Existing Condition	Natural Condition	Percent Difference from Existing Condition
North Fork Matilija Creek	28,710	28,430	-1.0%
Ventura River near Meiners Oaks	84,120	119,800	42.4%
Fox Canyon Drain	1,322	923	-30.2%
Happy Valley Drain	2,206	1,052	-52.3%
San Antonio Creek at Hwy 33	32,360	34,860	7.7%
Ventura R near Ventura	89,440	151,000	68.8%
Coyote Creek near Oak View	14,290	13,890	-2.8%
Santa Ana Creek near Oak View	26,370	23,760	-9.9%
Canada Larga at Ventura Ave	16,170	16,550	2.4%
Ventura River at Mouth	94,800	165,900	75.0%

Disclaimer: The estimates provided in this table are generated from application to a limited data set for the purposes of comparing flood peaks during the model simulation period. Therefore, these numbers are not official design or FEMA Flood Insurance Study estimates.

Table 10. Comparison of 25-Year Storm Runoff Peaks (cfs; Bulletin 17-B Methodology)

Gage Location	Existing Condition	Natural Condition	Percent Difference from Existing Condition
North Fork Matilija Creek	17,730	17,250	-2.7%
Ventura River near Meiners Oaks	48,460	71,190	46.9%
Fox Canyon Drain	970	483	-50.2%
Happy Valley Drain	1,626	580	-64.4%
San Antonio Creek at Hwy 33	23,140	24,640	6.5%
Ventura R near Ventura	59,210	98,600	66.5%
Coyote Creek near Oak View	10,170	9,864	-3.0%
Santa Ana Creek near Oak View	16,510	14,700	-11.0%
Canada Larga at Ventura Ave	11,980	12,170	1.6%
Ventura River at Mouth	66,110	112,700	70.5%

Disclaimer: The estimates provided in this table are generated from application to a limited data set for the purposes of comparing flood peaks during the model simulation period. Therefore, these numbers are not official design or FEMA Flood Insurance Study estimates.

Table 11. Comparison of 10-Year Storm Runoff Peaks (cfs; Bulletin 17-B Methodology)

Gage Location	Existing Condition	Natural Condition	Percent Difference from Existing Condition
North Fork Matilija Creek	8,161	7,757	-5.0%
Ventura River near Meiners Oaks	19,980	31,030	55.3%
Fox Canyon Drain	607	185	-69.5%
Happy Valley Drain	997	231	-76.8%
San Antonio Creek at Hwy 33	13,350	13,580	1.7%
Ventura R near Ventura	30,730	49,240	60.2%
Coyote Creek near Oak View	5,760	5,595	-2.9%
Santa Ana Creek near Oak View	7,608	6,787	-10.8%
Canada Larga at Ventura Ave	7,148	7,161	0.2%
Ventura River at Mouth	36,810	58,500	58.9%

Disclaimer: The estimates provided in this table are generated from application to a limited data set for the purposes of comparing flood peaks during the model simulation period. Therefore, these numbers are not official design or FEMA Flood Insurance Study estimates.

Table 12. Comparison of 5-Year Storm Runoff Peaks (cfs; Bulletin 17-B Methodology)

Gage Location	Existing Condition	Natural Condition	Percent Difference from Existing Condition
North Fork Matilija Creek	3,817	3,557	-6.8%
Ventura River near Meiners Oaks	8,395	13,860	65.1%
Fox Canyon Drain	395	79	-80.1%
Happy Valley Drain	618	98	-84.1%
San Antonio Creek at Hwy 33	7,693	7,253	-5.7%
Ventura R near Ventura	16,300	24,680	51.4%
Coyote Creek near Oak View	3,229	3,152	-2.4%
Santa Ana Creek near Oak View	3,475	3,179	-8.5%
Canada Larga at Ventura Ave	4,144	4,098	-1.1%
Ventura River at Mouth	20,600	29,650	43.9%

Disclaimer: The estimates provided in this table are generated from application to a limited data set for the purposes of comparing flood peaks during the model simulation period. Therefore, these numbers are not official design or FEMA Flood Insurance Study estimates.

Table 13. Comparison of 2-Year Storm Runoff Peaks (cfs; Bulletin 17-B Methodology)

Gage Location	Existing Condition	Natural Condition	Percent Difference from Existing Condition
North Fork Matilija Creek	816	737	-9.6%
Ventura River near Meiners Oaks	1,447	2,747	89.8%
Fox Canyon Drain	179	17	-90.4%
Happy Valley Drain	234	20	-91.7%
San Antonio Creek at Hwy 33	2,432	1,797	-26.1%
Ventura R near Ventura	4,596	5,898	28.3%
Coyote Creek near Oak View	937	935	-0.2%
Santa Ana Creek near Oak View	661	679	2.7%
Canada Larga at Ventura Ave	1,226	1,181	-3.7%
Ventura River at Mouth	6,220	6,721	8.1%

Disclaimer: The estimates provided in this table are generated from application to a limited data set for the purposes of comparing flood peaks during the model simulation period. Therefore, these numbers are not official design or FEMA Flood Insurance Study estimates.

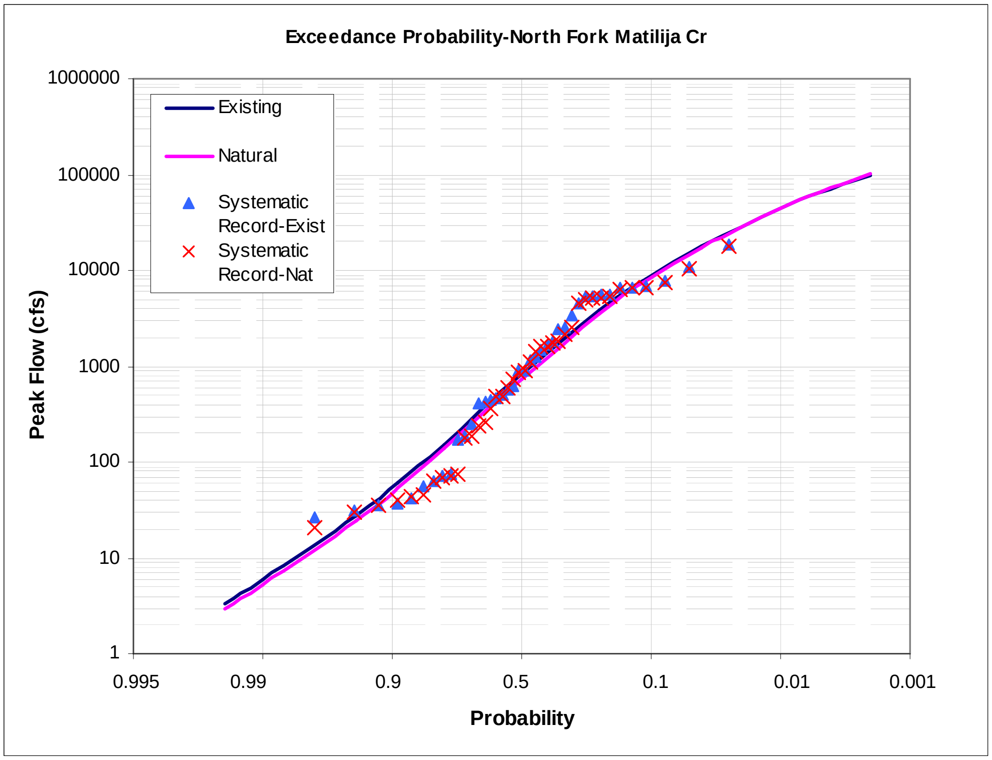

Figure 13. Bulletin 17-B Fit to Peak Flows, North Fork Matilija Creek

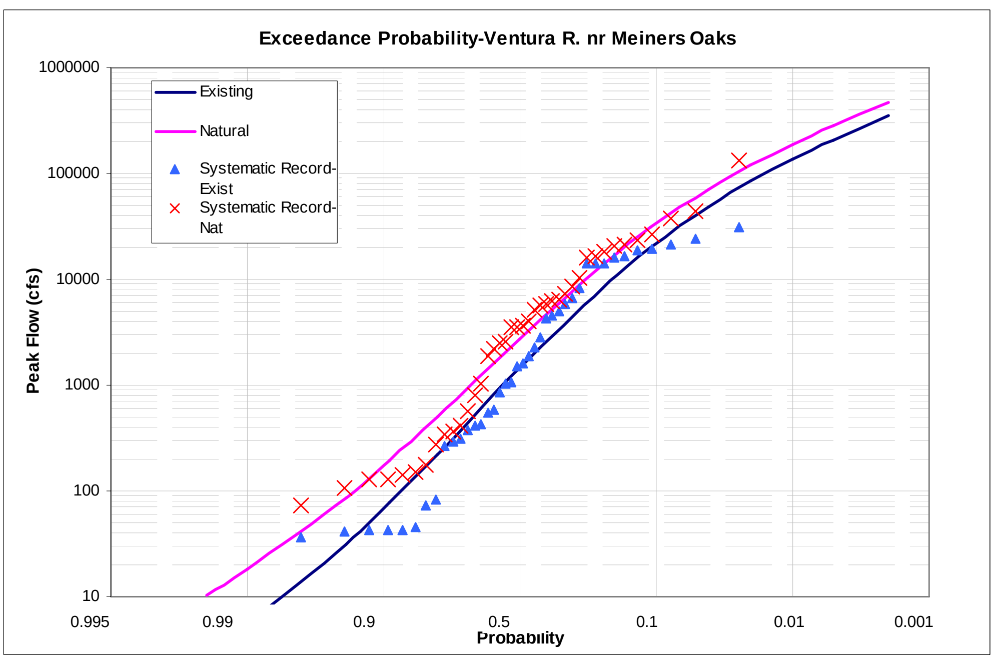

Figure 14. Bulletin 17-B Fit to Peak Flows, Ventura River near Meiners Oaks

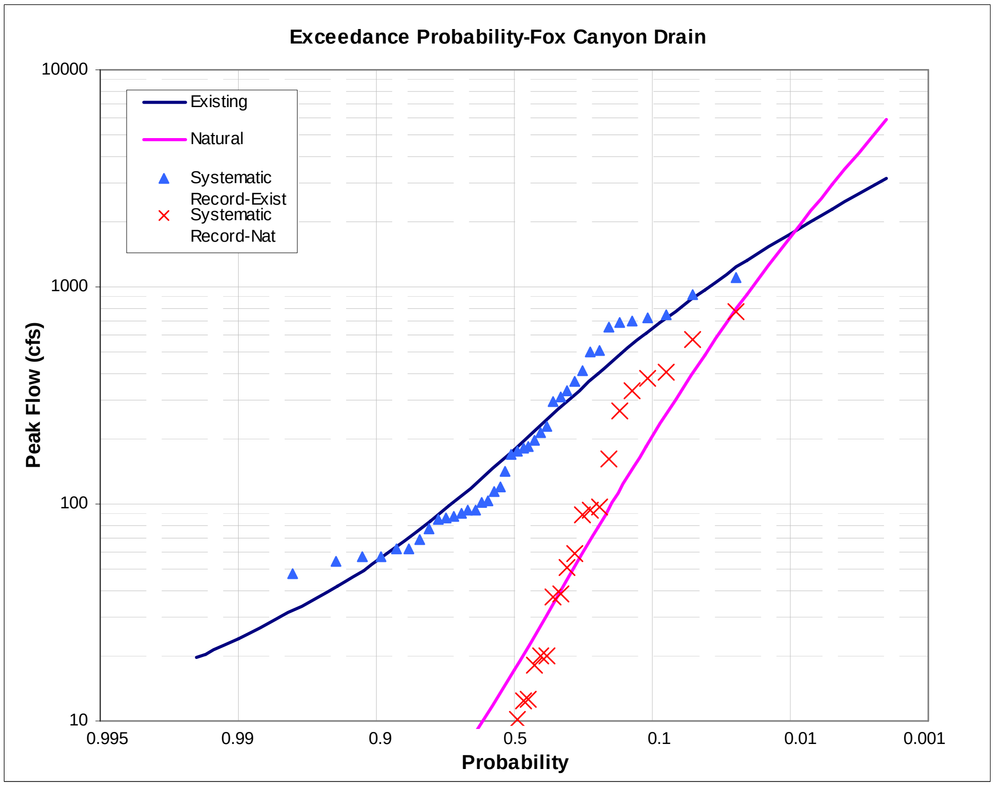

Figure 15. Bulletin 17-B Fit to Peak Flows, Fox Canyon Drain

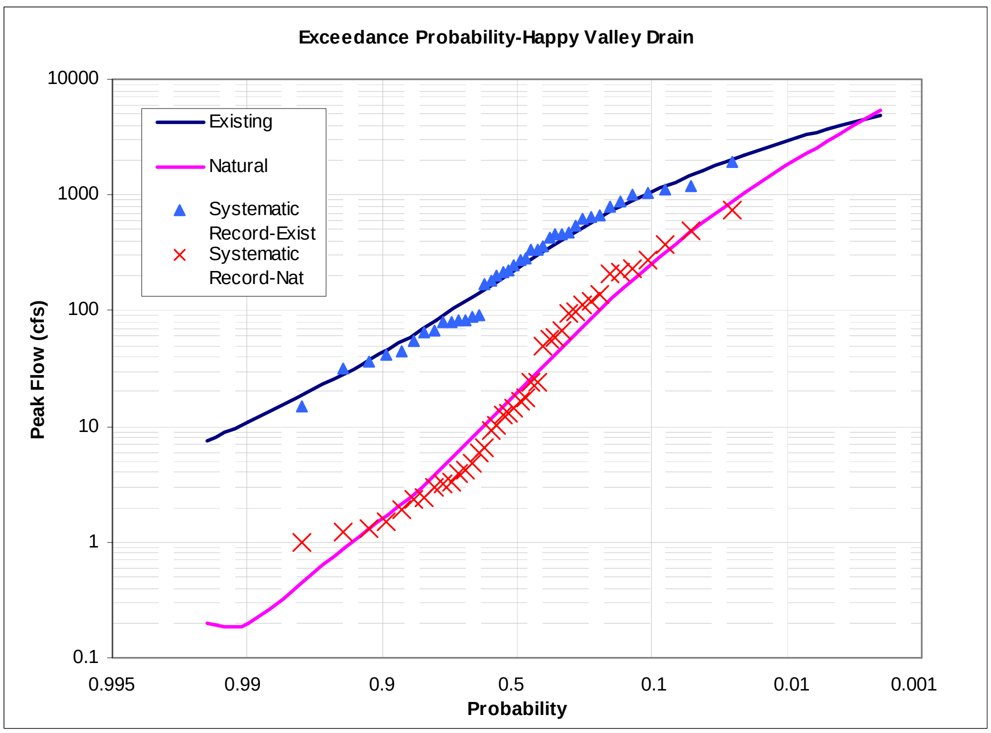

Figure 16. Bulletin 17-B Fit to Peak Flows, Happy Valley Drain

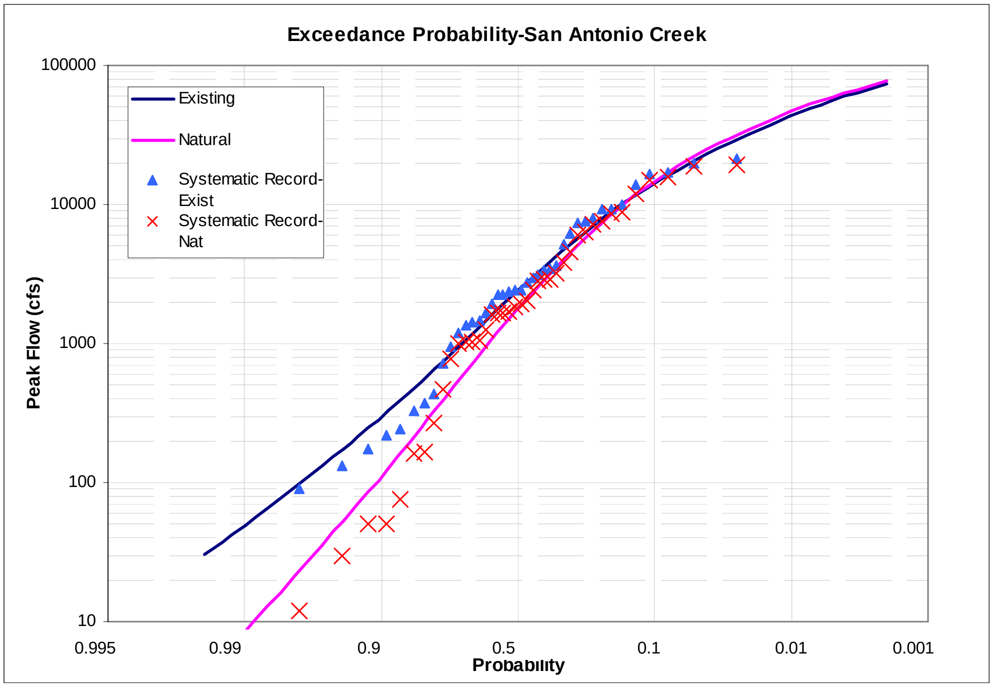

Figure 17. Bulletin 17-B Fit to Peak Flows, San Antonio Creek at Hwy 33

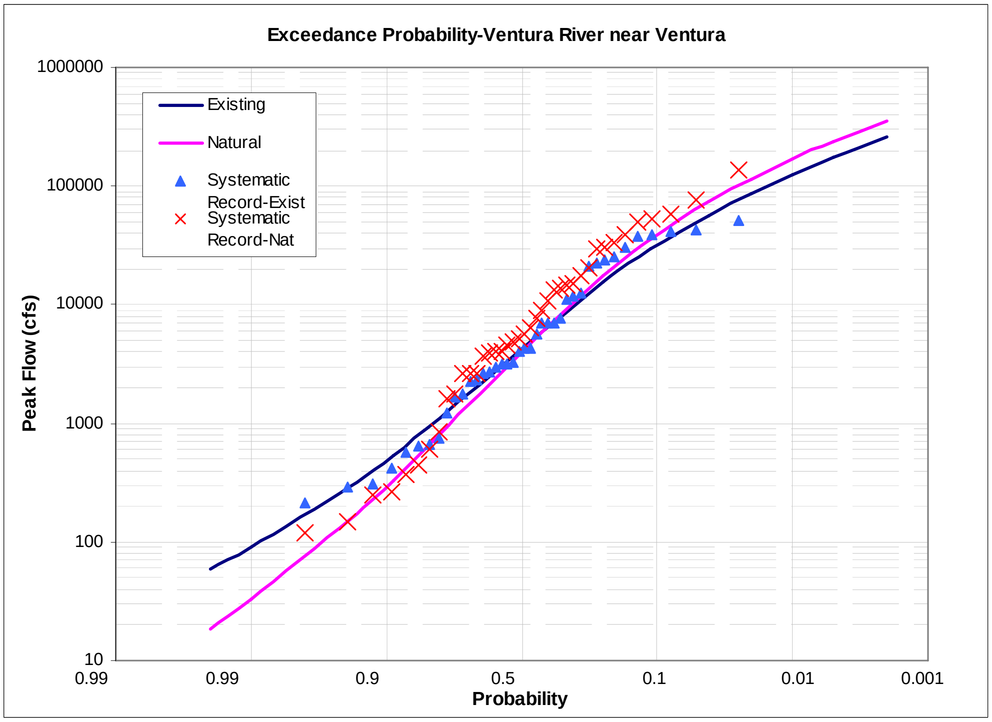

Figure 18. Bulletin 17-B Fit to Peak Flows, Ventura River near Ventura

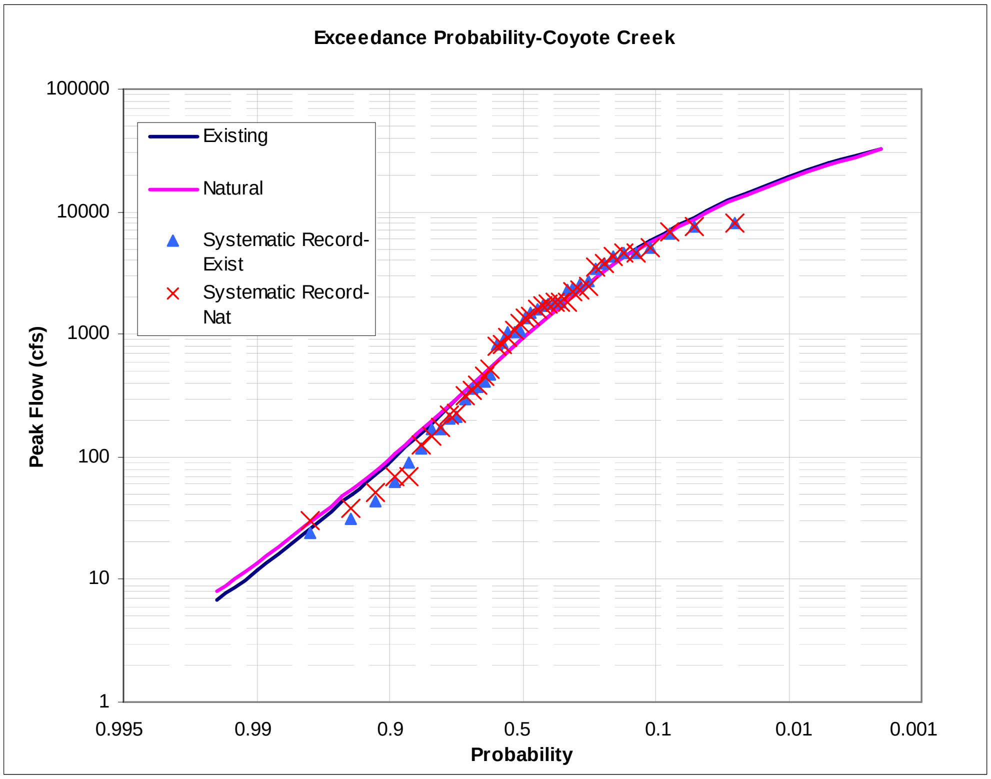

Figure 19. Bulletin 17-B Fit to Peak Flows, Coyote Creek near Oak View

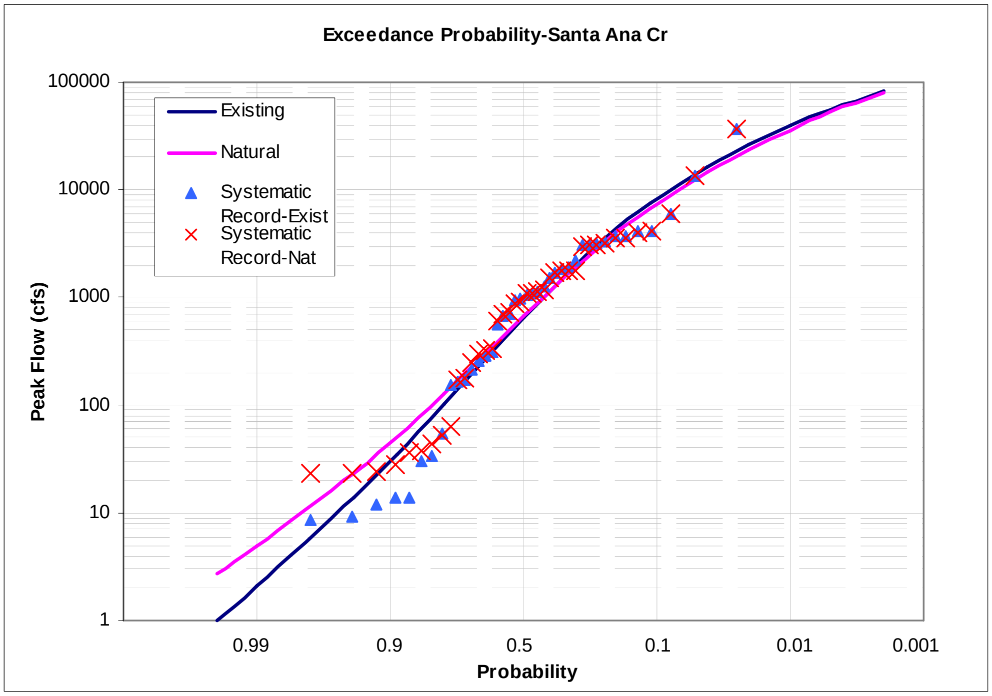

Figure 20. Bulletin 17-B Fit to Peak Flows, Santa Ana Creek near Oak View

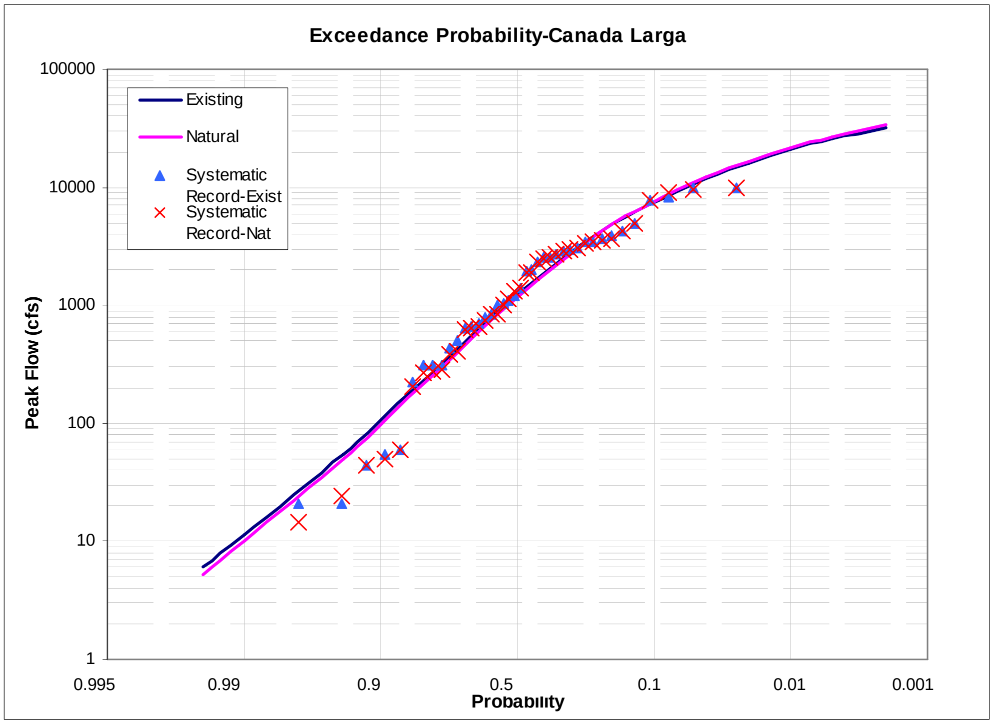

Figure 21. Bulletin 17-B Fit to Peak Flows, Canada Larga at Ventura Ave.

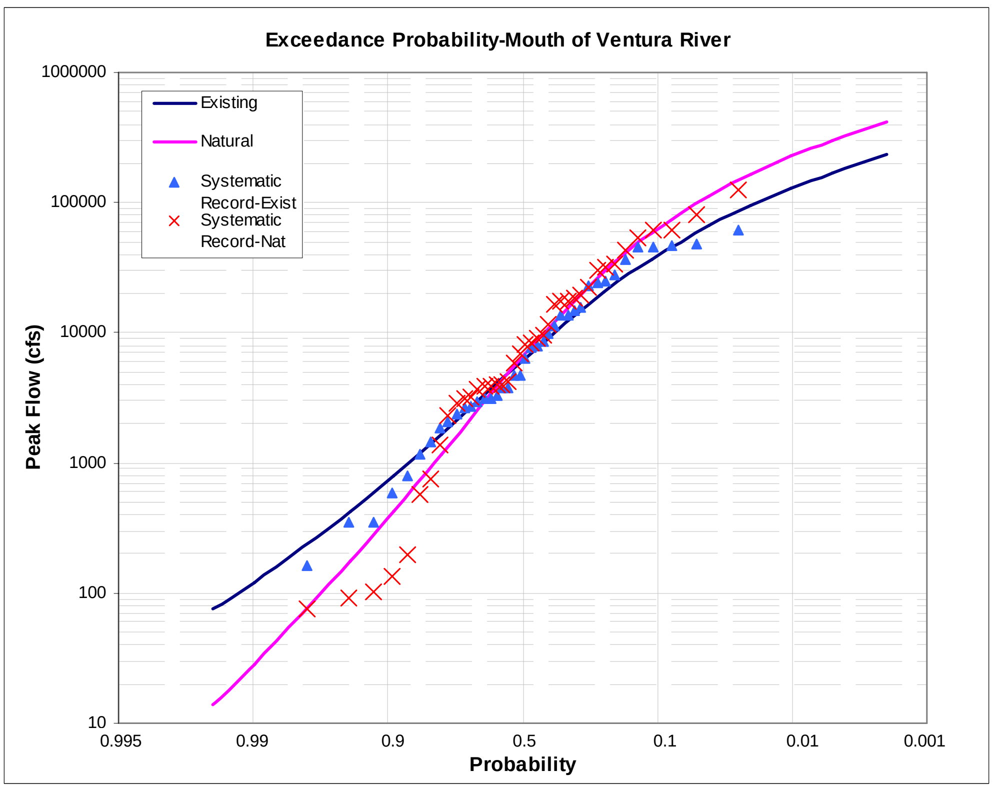

Figure 22. Bulletin 17-B Fit to Peak Flows, Ventura River at Mouth

As noted above, the Bulletin 17-B estimates are sensitive to the position of the higher probability (lower recurrence interval) annual peak estimates. An alternate view of the difference between existing and natural conditions is obtained by comparing the maximum flow peak over the 40-year simulation period (Table 14). The results are qualitatively similar to those presented above, with large increases for the mainstem Ventura River and decreases for Fox Canyon Drain and Happy Valley Drain.

Table 14. Comparison of Maximum Simulated Flows (cfs) over 1968-2007 Simulation Period

Gage Location	Existing Condition	Natural Condition	Percent Difference from Existing Condition
N Fork Matilija Cr	18,800	18,200	-3.2%
Ventura R near Meiners Oaks	31,300	132,000	321.7%
Fox Canyon Dr	1,100	774	-29.6%
Happy Valley Dr	1,960	745	-62.0%
San Antonio Cr at Hwy 33	21,200	19,200	-9.4%
Ventura R near Ventura	52,000	136,000	161.5%
Coyote Cr near Oak View	8,040	8,170	1.6%
Santa Ana Cr near Oak View	37,100	37,200	0.3%
Canada Larga at Ventura Ave	10,000	9,940	-0.6%
Ventura River at Mouth	61,800	124,000	100.6%

In general, the presence or absence of reservoirs is the dominant factor differentiating between peak flow estimates for existing and natural conditions. The ways in which the reservoirs influence the storm peaks can be seen in more detail through examination of predictions at Ventura River near Ventura (near Foster Park) for several of the larger storms during the simulation period.

Figure 23 and Figure 24 show the flow response at the Ventura River near Ventura gage for events of March 4, 1978 and March 10, 1995 respectively. In both cases, the natural condition peak is higher, while the presence of the reservoirs serves to attenuate the peak and extend the receding limb of the hydrograph.

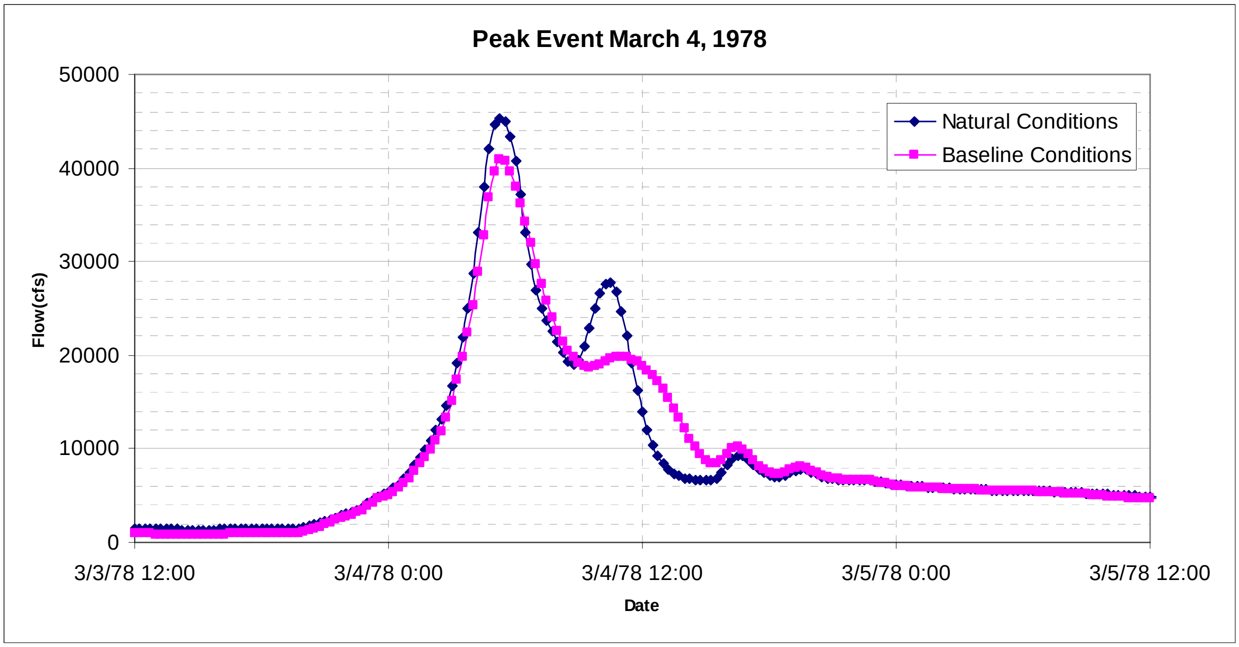

Figure 23. Ventura River near Ventura, Event of 3/4/1978

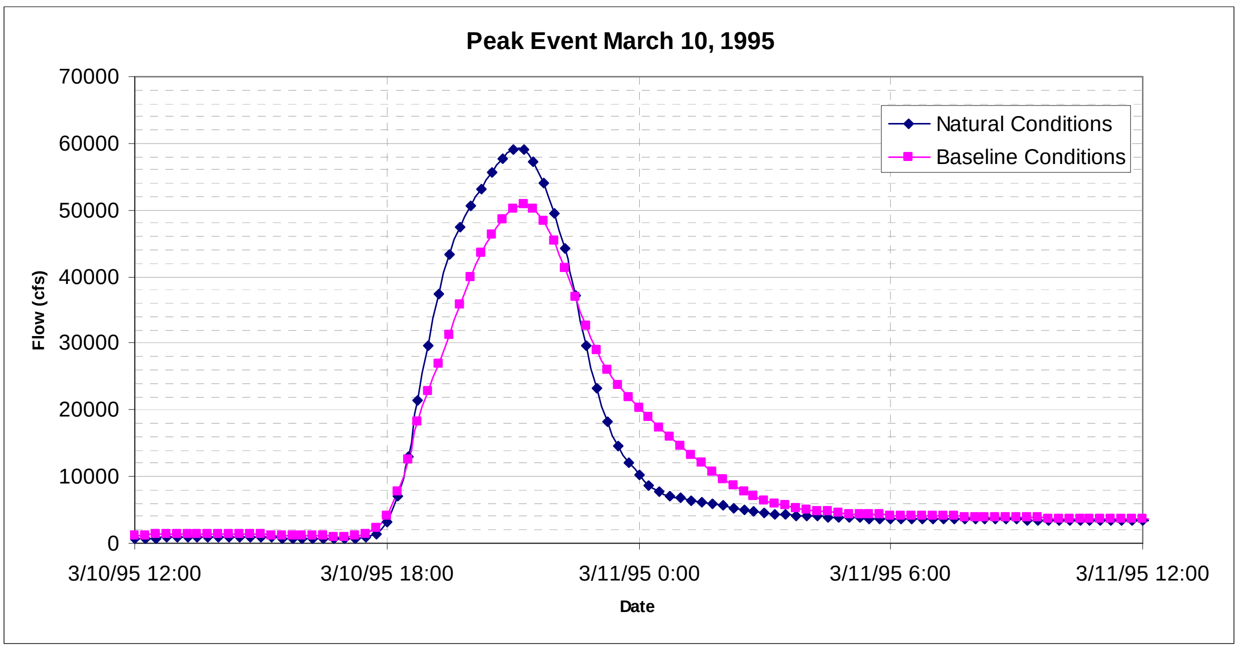

Figure 24. Ventura River near Ventura, Event of 3/10/1995

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6 References

Bullard, L.L. 2002. Ventura River Peak Flow Flood Frequency Study for Use with Matilija Dam Ecosystem Restoration Feasibility Study, Ventura County, California. U.S. Dept. of the Interior, Bureau of Reclamation. Technical Service Center, Denver, CO.

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Appendix A. Response to Comments

Tetra Tech provided a draft of the Ventura River *Natural Condition Report* to VCWPD on April 15, 2009. VCWPD distributed the draft for comment, and received one comment letter, from Hawks and Associates, dated July 15, 2009. This letter addresses items from both the *Natural Condition Report* and the earlier *Model Calibration Report*. The comment letter is reproduced below, followed by responses to questions raised in the letter.

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Hawks & Associates

Engineering Hydrology Planning Surveying

Memorandum

TO: Scott Holder; Ventura County Watershed Protection District

FROM: Paul Glenn, Bill O'Brien; Hawks & Associates

DATE: July 15, 2009

SUBJECT: Ventura River HSPF Model – Natural Conditions Model Comments

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General Comments

In general, the HSPF model simulates the watersheds response to precipitation very well at a coarse level (large sub-basin areas) and it appears as though the data that comprises the model was developed at very refined level and well thought out. This should provide modelers who want more detailed analysis of certain reaches a good set of boundary conditions.

This natural conditions model would be a good tool to test the hydromodification effects of development. Taking some of the gauged areas, quantifying the new impervious area, and tabulating the effects of impervious area on peak and volume of runoff would help in some of the stormwater regulations that have recently been considered.

Specific questions…

Why were the peak flows developed using the Bulletin 17-B approach when the report on page 21 specifically recognizes that the Bullard's method (2002) to fit the high end peaks is more appropriate to the Ventura River? We strongly recommend the peaks be developed using Bullard's method and to not create a new set of peak flow estimates for the Ventura River. This comment also applies to the Calibration Report.

Is there a way to quantify the San Antonio Creek spreading grounds effects on the Ojai Groundwater Basin? It seems as though a simple groundwater model could be developed based on the size of the ponds to determine the effects as the validation period started in 1987 and the ponds were active until 1985.

Why was 50% of the diversion demand used for outflow demand at Foster Park and not 100%-- it is our understanding that groundwater and surface water are fully connected in the area?

Why is the segment of the San Antonio Creek near Ojai represented as an outflow demand based on groundwater wells, when most the Ojai Basin is largely a deep, confined aquifer (Hydrogeology of the Ojai Groundwater Basin: Storativity and Confinement, masters degree

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thesis by Jordan Kear, 2005)?

A discussion of the effects of the initial groundwater storage assumption and the buffering effect of the Ojai Valley Groundwater Basin needs to be presented. The groundwater assumptions have a huge effect on the Ojai Valley flow that goes to San Antonio Creek. We note that irrigation was not included in the natural condition. Please mention the effect of not using water supply wells from the small purveyors and Golden State Water Company.

What is the sensitivity of the HSPF model to ground water assumptions?

How do the groundwater assumptions affect the estimated duration of flow in the tributaries?

Formatting

It would be helpful to have the units of measure in the tables.

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MEMORANDUM

To:	Scott Holder (VCWPD)	**Date:** July 22, 2009
From:	Jonathan Butcher	**Project:** Ventura River Model
Subject:	Comment Response	**Tt Pjn:** 100-FFX-T22254-15

Responses to questions raised in the letter from Hawks & Associates are provided below.

Flood Peak Estimation

Hawks & Associates suggested that flood peaks be presented using Bullard's method, rather than the Bulletin 17-B approach. The reasons for using the Bulletin 17-B approach are explained below

It was not the purpose of the Model Calibration report to produce final estimates of peak flows, but rather to document and assure the proper performance of the model. To this end it was determined that it was preferable to compare estimates of 100-year flood peaks developed using the standard Bulletin 17-B (log Pearson) methodology, without modifications to the time series.

Bullard (2002) noted that low outliers are present in the Ventura River peak flow records. When the Bulletin 17-B procedure is used to fit all of the data, including the low outliers, the resulting log-mean, log standard-deviation, and log-skew values are such that the fitted Log Pearson III curve may become inflated on the high end of the data set, resulting in over-estimation of the magnitude of extreme flood events. To address this issue, Bullard recommended use of a top end fitting procedure. In this type of analysis the peak flows and plotting positions, or the equivalent return period, are fit with a curve by a least squares analysis procedure. The resulting regression equation is then used to determine the peak flow for the desired return periods. Bullard suggested that fitting the top seven peak events was sufficient for extrapolation.

While Bullard's approach is acceptable for FEMA planning purposes, it is also somewhat subjective and subject to strong influence from the plotting positions of the top seven peaks. It is thus not as desirable for use in model calibration compared to the Bulletin 17-B procedure that uses the full set of simulated annual peaks. The report is careful to note that the peak estimates "are generated from application to a limited data set for the purposes of comparing observed and modeled flood peaks during the model simulation period. Therefore, these numbers are not official design or FEMA Flood Insurance Study estimates."

In the Natural Condition report, the Bulletin 17-B procedure was again used to provide a consistent basis of comparison to the Model Calibration report.

The model has also been used to produce top-end fitting estimates of the 100-year recurrence flows. These have been documented to VCWPD in a separate memorandum. They are not included in the report itself precisely to avoid creating confusion with the official FEMA flood peak estimates.

Groundwater Representation

The remainder of the comments from Hawks & Associates concerned the representation of ground water and its interconnections with surface water. As noted in our earlier response to comments on the *Model Calibration Report*, Tetra Tech fully agrees that it would be desirable to undertake additional work to model the interaction of groundwater and surface water, particularly along San Antonio Creek and the Ventura River mainstem where most of the irrigation wells and irrigated land are located. Indeed, we have specifically recommended this to VCWPD, on p. 192 of the report: "Ideally, a dynamic groundwater flow model (e.g., MODFLOW) would be developed and could be linked to provide the reach losses and deep groundwater discharge time series to the HSPF model." Unfortunately, construction, calibration, and testing of such a model is a time-consuming and expensive effort for which funding is not currently available. If possible, such work should be pursued in the future to support development of a comprehensive water management strategy for the Ventura River watershed.

Regarding the specific questions raised by Hawks & Associates, we note the following:

- Effects of the San Antonio Creek spreading grounds have not been included in the model. Use of the spreading grounds was discontinued after the fire of 1985, while the model validation period does not begin until 1987. No records of the amounts diverted to the spreading grounds have been located. We agree that the spreading grounds may have had an effect on groundwater levels present in the Ojai Groundwater Basin in 1987, but have no way of quantifying this at present. If and when a groundwater model of the basin is developed the spreading grounds and their impact should be included.
- The Foster Park diversion is simulated as exerting 50 percent of its demand on water in the mainstem Ventura River. As HSPF is a surface water model, the key need for the model is a determination of the amount of this demand that directly affects surface flows. It is our understanding that water is withdrawn from pipes buried in the alluvium. Water entering these pipes comes both from flow in the river and from underlying groundwater. We agree that ground water and surface water appear to be fully connected in this area; however, this does not mean that 100 percent of the demand will be satisfied directly from the river, as a portion of the demand will likely be satisfied by surfacing ground water. Indeed, it is clear that specifying 100 percent of this demand from the river leads to an overestimation of flows downstream. The 50 percent value was adopted as a rough approximation that appears to provide a reasonable fit to instream flows. Better simulation of the effects of this withdrawal on the river will require a linked surface-ground water model.
- The segment of the San Antonio Creek near Ojai is represented as exerting a demand on surface streams in the area, likely driven by groundwater withdrawals. The comment notes that most of the Ojai Basin in this area is a deep confined aquifer, limiting connection to surface water. However, it is believed that there is a strong locus of groundwater downwelling associated with faults near the northern end of the Ojai Groundwater Basin. It is losses from streams passing through this area that are represented as an outflow demand in the model.
- A comment requests a "discussion of the effects of the initial groundwater storage assumption and the buffering effect of the Ojai Valley Groundwater Basin." We agree that these are important issues; however, we do not have a way to represent them at this time without at least a mass-balance model of the groundwater basin. As noted above, HSPF is a surface water (and shallow groundwater) model. Interactions with deep groundwater basins are specified as empirical monthly time series that either have constant seasonal patterns or are varied from year to year to provide a reasonable fit to instream flow gaging. While effects of initial storage are undoubtedly important, we do

not have a way to quantify these effects at this time. If a groundwater model is constructed in the future, this will likely provide a significant improvement for low flow simulations in the surface water model.

- A comment asks about "the effect of not using water supply wells from the small purveyors and Golden State Water Company." These details will be important to the construction of a groundwater model of the basin. At this time, lacking such a groundwater model, they cannot be explicitly included in any quantitative way. The effects of these additional withdrawals are implicitly included in the model through the general empirical representations of exchanges with deep ground water.
- The final comments ask about the sensitivity of the HSPF model to groundwater assumptions, and how these assumptions affect the estimated duration of flow in the tributaries. It is clear that the model predictions are highly sensitive to these assumptions. For example, the 25th percentile flow observed in San Antonio Creek at Highway 33 (for water years 1998-2007) declines from 0.54 cfs in June to 0 cfs in August. During this period simulated losses to groundwater from streams in the San Antonio Creek watershed total about 4.6 cfs, while recharge from deep groundwater to the stream is about 1 cfs. Thus, the magnitude of the summer low flows is largely determined by the balance of exchanges between surface and ground water. Greater precision in these results can only be attained through the development of a groundwater model.