Appendix S
Model Configuration, Calibration and Validation

Basin: Coastal Southern California

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Watershed Background

The Coastal Southern California basin was selected as one of the 15 non-pilot application watersheds for the 20 Watershed study. Watershed modeling for the non-pilot areas is accomplished using the SWAT model only, and model calibration and validation results are presented in abbreviated form.

Water Body Characteristics

The Coastal Southern California basins are located along the southern coast of California. Major subwatersheds included in the 20 Watershed study are the Santa Clara River, Los Angeles River, San Gabriel River, Santa Ana River, San Juan River, and Santa Margarita River (Figure 1). The Coastal Southern California basins are characterized by a mild semi-arid climate with an average rainfall of 15 inches per year. The region is highly urbanized, with land uses ranging from residential, commercial and industrial, recreational, agriculture, to open space. A description of the Santa Ana basin has been included here to represent the Coastal Southern California basins.

The Santa Ana study unit covers an area of about 2,700 square miles in parts of Orange, San Bernardino, Riverside, and Los Angeles Counties. The Santa Ana basin is substantially urbanized: about 32 percent of the land use is residential, commercial, or industrial, and the area is home to more than 4 million people. Agricultural land use accounts for about 10 percent of the watershed.

The Santa Ana River is the largest stream system in southern California, beginning in the San Bernardino Mountains, which reach altitudes exceeding 10,000 feet, and flowing more than 100 miles to the Pacific Ocean near Huntington Beach. The San Jacinto River is a tributary of the Santa Ana River, but it normally terminates at Lake Elsinore.

Average annual precipitation ranges from 12 inches per year in the coastal plain, to 18 inches per year in the inland alluvial valleys, and 40 inches per year in the San Bernardino Mountains. Most of the precipitation occurs between November and March. Consequently, under natural conditions, the Santa Ana River would be intermittent with little or no flow in the summer months.

Groundwater is the main source of water supply in the watershed, providing about 66 percent of the consumptive water demand. Imported water from northern California and the Colorado River is also an important source of water supply, accounting for 27 percent of the consumptive demand. Other sources of supply include surface water derived from precipitation within the basin (4 percent) and recycled water (3 percent).

Enhanced recharge of groundwater is an important component of the hydrologic cycle in the Santa Ana watershed. The volume of water recharged is 37 percent of the volume pumped, with most of the enhanced recharge consisting of surface water derived from precipitation within the basin. Discharge from wastewater treatment facilities is also an important component of the hydrologic cycle, providing base flow in many parts of the drainage network. These activities are among the many factors affecting water quality in the watershed.

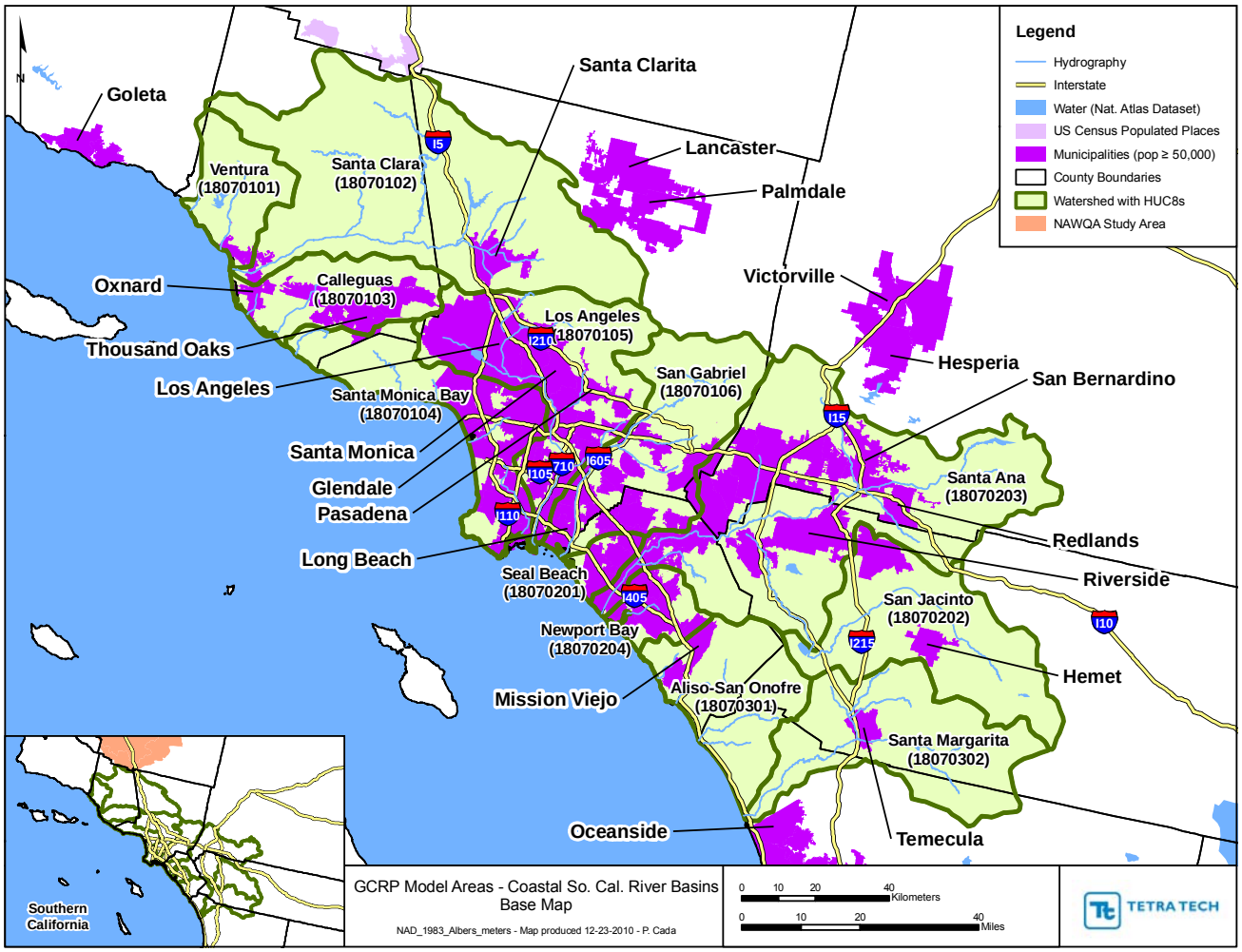

Figure 1. Location of the Coastal Southern California basin.

Soil Characteristics

Soils in the watershed are described in STATSGO soil surveys. SWAT uses information drawn directly from the soils data layer to populate the model.

Land Use Representation

Land use/cover in the watershed is based on the 2001 National Land Cover Database (NLCD) coverage (Figure 2). NLCD land cover classes were aggregated according to the scheme shown in Table 1 for representation in the 20 Watershed model. SWAT uses the built-in hydrologic response unit (HRU) overlay mechanism in the ArcSWAT interface. SWAT HRUs are formed from an intersection of land use and SSURGO major soils. The distribution of land use in the watershed is summarized in Table 2.

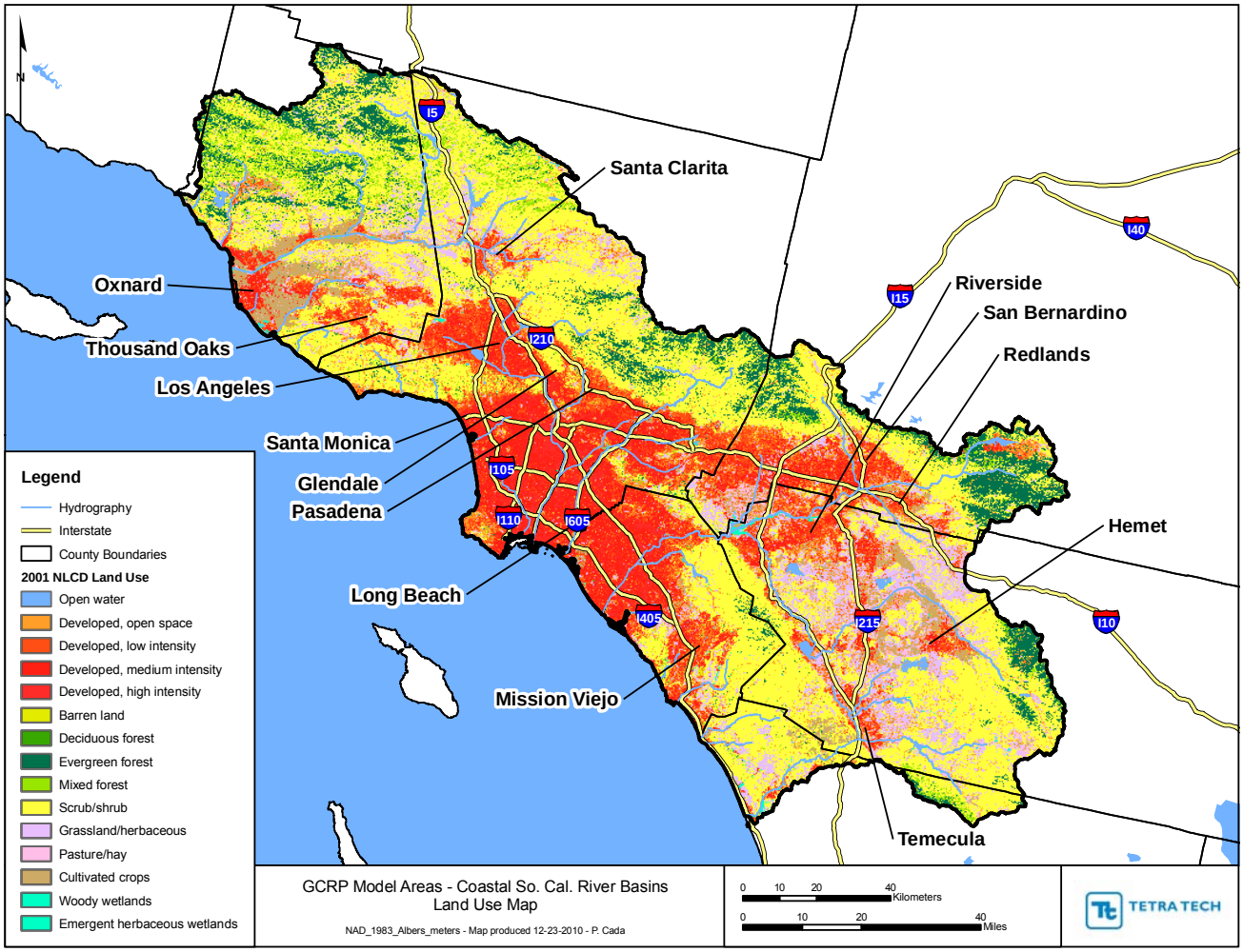

Figure 2. Land use in the Coastal Southern California basin.

Table 1. Aggregation of NLCD land cover classes

NLCD Class	Comments	SWAT class
11 Water	Water surface area usually accounted for as reach area	WATR
12 Perennial ice/snow		WATR
21 Developed open space		URLD
22 Dev. Low Intensity		URMD
23 Dev. Med. Intensity		URHD
24 Dev. High Intensity		UIDU
31 Barren Land		SWRN
41 Forest	Deciduous	FRSD
42 Forest	Evergreen	FRSE
43 Forest	Mixed	FRST
51-52 Shrubland		RNGB

NLCD Class	Comments	SWAT class
71-74 Herbaceous Upland		RNGE
81 Pasture/Hay		HAY
82 Cultivated		AGRR
91-97 Wetland	Emergent & woody wetlands	WETF, WETL, WETN
98-99 Wetland	Aquatic bed wetlands (not emergent)	WATR

Table 2. Land use distribution for the Coastal Southern California basin (2001 NLCD) (mi^2)

HUC 8 watershed	Open water	Developed[a]				Barren land	Forest	Shrubland	Pasture/Hay	Cultivated	Wetland	Total
		Open space	Low density	Medium density	High density							
Santa Clara **18070102**	8.96	80.69	30.65	23.33	1.00	15.55	310.17	1,083.16	8.00	45.07	5.66	**1,612.24**
Ventura **18070101**	3.65	19.67	8.17	7.38	0.82	0.39	89.77	133.11	1.89	6.96	1.18	**273.00**
Los Angeles **18070105**	1.17	86.12	135.76	222.00	67.04	1.87	40.22	252.88	0.11	0.06	1.65	**808.88**
San Gabriel **18070106**	1.88	63.34	90.50	178.98	47.06	3.20	83.04	238.31	0.58	1.21	1.55	**709.64**
Santa Ana **18070203**	9.34	207.49	230.95	203.83	18.97	12.82	193.93	735.50	22.85	25.87	10.17	**1,671.73**
Calleguas **18070103**	0.85	42.66	47.85	40.96	1.85	1.37	3.97	157.25	5.17	68.02	2.42	**372.37**
Santa Monica Bay **18070104**	1.35	62.03	57.97	136.73	72.20	0.74	13.55	199.71	1.98	0.01	0.69	**546.95**
San Jacinto **18070202**	10.50	89.34	39.96	30.42	0.27	3.62	53.83	444.86	23.66	57.40	0.34	**754.20**
Seal Beach **18070201**	0.36	3.95	11.34	46.34	13.61	0.15	0.08	1.74	0.00	1.59	0.38	**79.55**
Newport Bay **18070204**	0.38	21.56	31.91	47.93	13.98	0.69	0.78	29.05	0.36	2.63	0.32	**149.58**
Total	**38.45**	**676.85**	**685.07**	**937.90**	**236.80**	**40.40**	**789.33**	**3,275.57**	**64.60**	**208.82**	**24.36**	**6,978.14**

[a]The percent imperviousness applied to each of the developed land uses is as follows: open space (7.75%), low density (35.39%), medium density (61.31%), and high density (88.93%).

Point Sources

There are numerous point source discharges in the watershed. Only the major dischargers, generally defined as those with a design flow greater than 1 MGD are included in the simulation (Table 3). The major dischargers are represented at long-term average flows, without accounting for changes over time or seasonal variations.

Table 3. Major point source discharges in the Coastal Southern California basin

NPDES ID	Name	Design flow (MGD)	Observed flow (MGD) (1991-2006 average)
CA0053651	SAN BUENAVENTURA, CITY OF	14.000	7.499
CA0054224	SANTA PAULA, CITY OF	2.550	41.259
CA0054216	LA CO SANITATION DISTRICTS	21.600	12.377
CA0054313	LA CO SANITATION DISTRICTS	6.500	5.184
CA0053716	LA CO SANITATION DISTRICTS	15.000	27.341
CA0053953	LOS ANGELES, CITY OF	20.000	12.964
CA0055531	BURBANK, CITY OF	9.000	11.401
CA0001309	BOEING COMPANY	178.000	4.041
CA0056227	LOS ANGELES, CITY OF	80.000	52.668
CA0053911	LA CO SANITATION DISTRICTS	100.000	122.795
CA0054011	LA CO SANITATION DISTRICTS	37.500	31.785
CA0054119	LA CO SANITATION DISTRICTS	25.000	15.331
CA0053619	LA CO SANITATION DISTRICTS	15.000	7.553
CA8000383	CORONA, CITY OF	9.000	5.578
CA0105279	INLAND EMPIRE UTILITIES AGENCY	51.000	59.101
CA8000073	INLAND EMPIRE UTILITIES AGENCY	10.200	11.589
CA8000402	INLAND EMPIRE UTILITIES AGENCY	15.000	12.199
CA0105236	COLTON, CITY OF	8.400	5.309
CA0105295	RIALTO, CITY OF	11.700	6.212
CA0105350	RIVERSIDE, CITY	40.000	45.261
CA8000304	COLTON/SAN BERNARDINO RTT&WRA	40.000	57.208
CA0105376	BEAUMONT, CITY OF	4.000	2.035
CA0105619	YUCAIPA VALLEY WATER DISTRICT	4.500	2.598
CA0105392	SAN BERNARDINO, CITY OF	28.000	28.501
CA0053961	OJAI VALLEY SANITARY DISTRICT	3.000	1.935
CA0053597	CAMARILLO SANITARY DISTRICT	6.750	3.300
CA0055221	SIMI VALLEY, CITY OF	12.500	8.994
CA0056294	THOUSAND OAKS, CITY OF	10.800	8.652

CA0055387	EXXONMOBIL OIL CORP	1.430	2.824
CA8000326	IRVINE RANCH WATER DISTRICT	18.000	12.394

Most of these point sources have reasonably complete monitoring for total suspended solids (TSS). Long term average values of total phosphorus and total nitrogen were assumed based upon the type of point source discharger. The point sources were initially represented in the model with the median of reported values for total phosphorus, total suspended solids and total nitrogen.

Meteorological Data

The required meteorological time series for the 20 Watershed SWAT simulations are precipitation and air temperature. The 20 Watershed simulations do not include water temperature and uses a degree-day method for snowmelt. SWAT estimates Penmann-Monteith potential evapotranspiration using a statistical weather generator for inputs other than temperature and precipitation. These meteorological time series are drawn from the BASINS4 Meteorological Database (USEPA 2008), which provides a consistent, quality-assured set of nationwide data with gaps filled and records disaggregated. Scenario application requires simulation over 30 years, so the available stations are those with a common 30-year period of record (or one that can be filled from an approximately co-located station) that covers the year 2001. A total of 85 precipitation stations were identified for use in the Coastal Southern California watershed model with a common period of record of 10/1/1970-9/30/2001 (Table 4). Temperature records are sparser; where these are absent temperature is taken from nearby stations with an elevation correction.

Table 4. Precipitation stations for the Coastal Southern California watershed model

COOP ID	Name	Latitude	Longitude	Temperature	Elevation (m)
045218	LYTLE CREEK R S	34.2384	-117.4700		832
046162	NEWHALL S FC32CE	34.3869	-118.5340		379
046569	OXNARD	34.1981	-119.1750	X	15
049087	TUSTIN IRVINE RANCH	33.7026	-117.7530	X	72
047723	SAN BERNARDINO F S 226	34.1344	-117.2530	X	347
040235	ANZA	33.5558	-116.6730		1193
047953	SANTA MONICA PIER	34.0081	-118.4980	X	4
046940	PIRU 2 ESE	34.4062	-118.7550		223
047779	SAN GABRIEL DAM FC425B	34.2054	-117.8600		451
042198	CRYSTAL LAKE FC238C	34.3178	-117.8400		1637
042494	DOWNEY FIRE STN FC107C	33.9297	-118.1450		34
042805	ELSINORE	33.6692	-117.3310	X	392
045632	MILL CREEK INTAKE	34.0915	-116.9360		1507
041369	CAMP ANGELUS	34.1493	-116.9800		1759
047600	RUNNING SPRINGS 1 E	34.2067	-117.0860		1818
048992	TRABUCO CANYON	33.6583	-117.5890		296
046379	OCEANSIDE PUMPING PLT	33.2170	-117.3490		3
040606	BEAUMONT	33.9293	-116.9740		796

042164	CRESTLINE	34.2330	-117.2990		455
048844	TEMECULA	33.5000	-117.1500		95
041484	CANOGA PARK PIERCE COLL	34.1819	-118.5740	X	241
047306	REDLANDS	34.0528	-117.1890	X	402
047470	RIVERSIDE FIRE STA 3	33.9511	-117.3880	X	256
044647	LAGUNA BEACH	33.5472	-117.7800	X	11
046719	PASADENA	34.1483	-118.1440	X	263
046175	NEWPORT BEACH HARBOR	33.6025	-117.8800	X	3
042214	CULVER CITY	34.0051	-118.4120	X	17
047785	SAN GABRIEL FIRE DEPT	34.1061	-118.0990	X	137
041194	BURBANK VALLEY PUMP PLA	34.1868	-118.3480	X	200
045114	LOS ANGELES INTL AP	33.9381	-118.3880	X	30
047050	POMONA FAIRPLEX	34.0811	-117.7650	X	317
040014	ACTON ESCONDIDO FC261	34.4948	-118.2710		905
042941	FAIRMONT	34.7043	-118.4270	X	933
043896	HEMET	33.7459	-116.9400		504
044211	IDYLLWILD FIRE DEPT	33.7572	-116.7060	X	1640
044422	JUNCAL DAM	34.4909	-119.5060		679
044671	LAKE ARROWHEAD	34.2467	-117.1880	X	1586
044863	LEBEC	34.8328	-118.8640		1093
045115	LOS ANGELES DOWNTOWN	34.0511	-118.2350	X	70
046006	MT WILSON NO 2	34.2309	-118.0710	X	1740
046399	OJAI	34.4479	-119.2270	X	227
046657	PALOMAR MOUNTAIN OBSERV	33.3782	-116.8400	X	1692
047473	RIVERSIDE CITRUS EXP ST	33.9670	-117.3610	X	301
047735	SANDBERG	34.7437	-118.7240	X	1375
047776	SAN GABRIEL CANYON P H	34.1553	-117.9070		227
047888	SANTA ANA FIRE STATION	33.7442	-117.8660	X	41
047957	SANTA PAULA	34.3120	-119.1330	X	72
048014	SAUGUS POWER PLANT 1	34.5894	-118.4540		642
049152	U C L A	34.0697	-118.4420	X	131
049285	VENTURA	34.2825	-119.2910		32
044650	LAGUNA BEACH 2	33.5567	-117.8000		64
048230	SIGNAL HILL FC 415	33.7968	-118.1680		30
040144	ALTADENA	34.1819	-118.1380		344

040798	BIG TUJUNGA DAM FC46DE	34.2942	-118.1870		706
042090	COVINA CITY YRD FC387B	34.0920	-117.8800		178
043452	GLENDORA FC 287B	34.1464	-117.8470		280
044628	LA CRESCENTA FC 251C	34.2223	-118.2420		477
046602	PACOIMA DAM FC 33 A-E	34.3326	-118.3990		457
046663	PALOS VERDES EST FC43D	33.7998	-118.3910		66
047749	SAN DIMAS FIRE FC95	34.1072	-117.8050		291
048967	TOPANGA PATROL STN FC6	34.0843	-118.5980		227
048973	TORRANCE	33.8017	-118.3410	X	34
049660	WHITTIER CITY YD FC106C	33.9762	-118.0220		128
041272	CAJON WEST SUMMIT	34.3901	-117.5920		1457
047926	SANTA FE DAM	34.1119	-117.9700		130
047762	SAN FERNANDO PH 3	34.3133	-118.4920		381
041682	CHATSWORTH RESERVOIR	34.2264	-118.6160		277
048092	SEPULVEDA DAM	34.1662	-118.4730		207
040742	BIG BEAR LAKE DAM	34.2414	-116.9740		2077
041057	BREA DAM	33.8906	-117.9260		84
041754	CHUCHUPATE RANGER STN	34.8079	-119.0110		1603
043285	FULLERTON DAM	33.8964	-117.8880		104
046473	ORANGE COUNTY RESERVOIR	33.9379	-117.8850		201
047123	PRADO DAM	33.8904	-117.6450		171
047813	SAN JACINTO R S	33.7870	-116.9580		475
048243	SILVERADO RANGER STN	33.7425	-117.6590		334
046377	OCEANSIDE MARINA	33.2097	-117.3940	X	3
048436	SPADRA LANTERMAN HOSP	34.0419	-117.8090		206
049378	VISTA 2 NNE	33.2294	-117.2260	X	155
045085	LONG BEACH AP	33.8118	-118.1460	X	9
040741	BIG BEAR LAKE	34.2442	-116.9030	X	2060
044181	HURKEY CREEK PARK	33.6830	-116.6830		408
046910	PINE MOUNTAIN INN	34.6001	-119.3490		392
041540	CARPINTERIA RSVR	34.4000	-119.4830		36
045417	MATILIJA DAM	34.4830	-119.2990		98

Watershed Segmentation

The Coastal Southern California basin was divided into 65 subwatersheds for the purposes of modeling (Figure 3). The model encompasses the complete watershed and does not require specification of any upstream boundary conditions for application.

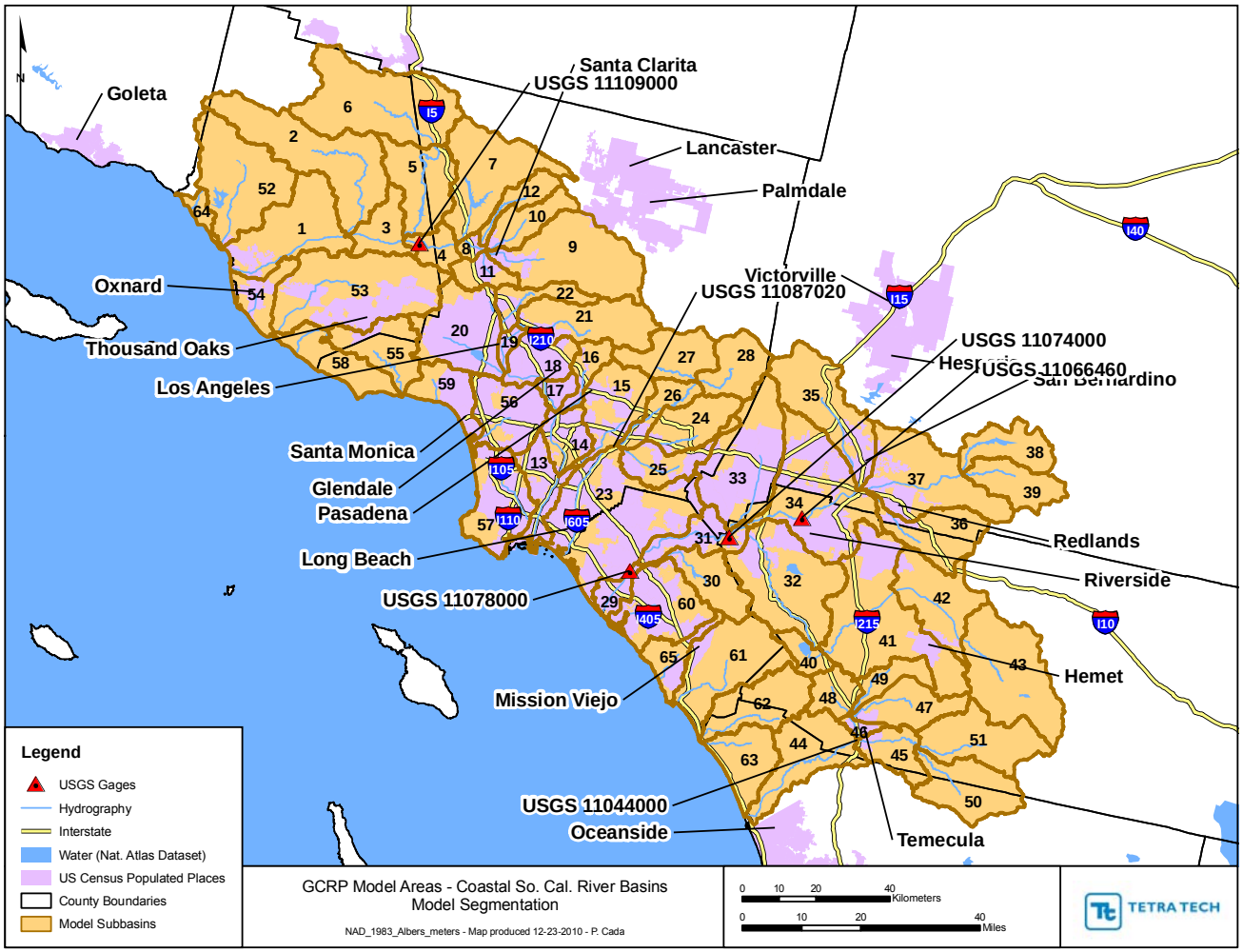

Figure 3. Model segmentation and USGS stations utilized for the Coastal Southern California basin.

Calibration Data and Locations

The specific site chosen for initial calibration was the Santa Ana River at MWD Crossing, a flow and water quality monitoring location that approximately coincides with the mouth of an 8-digit HUC. The Santa Ana River watershed was selected because there is a good set of flow and water quality data available and the watershed lacks major point sources and impoundments. Additional calibration and validation was pursued at multiple locations (Table 5). Parameters derived on the Santa Ana River were not fully transferable to other portions of the Coastal Southern California basin, and additional calibration was conducted at multiple gage locations.

Table 5. Calibration and validation locations in the Coastal Southern California basin

Station name	USGS ID	Drainage area (mi^2)	Hydrology calibration	Water quality calibration
Santa Ana River at MWD Crossing, CA	11066460	852	X	X
Santa Margarita River near Temecula, CA	11044000	588	X	X
Santa Ana river below Prado Dam, CA	11074000	2,258	X	
San Gabriel River above Whittier Narrows Dam, CA	11087020	2,692	X	
Santa Clara River near Piru, CA	11109000	2,183	X	

The model hydrology calibration period was set to Water Years 1991-2001 (within the 32-year period of record for modeling). Hydrologic validation was then performed on Water Years 1981-1991. Water quality calibration used calendar years 1991-2001, while validation used 1981-1991.

SWAT Modeling

Assumptions

There are numerous diversions and impoundments in the Coastal Southern California basin. Since the objective of the 20 Watershed modeling effort is to measure relative change, only major impoundments and/or diversions have been represented in the model. Vail Lake and Prado Dam were the two impoundments represented in the Coastal Southern California model. Vail Lake is located on the Temecula Creek, a tributary of Santa Margarita River. Prado Dam is located on the Santa Ana River. Pertinent reservoir information including surface area and storage at principal (normal) and emergency spillway levels for the reservoirs were obtained from the US Army Corps of Engineers. The SWAT model provides four options to simulate reservoir outflow: measured daily outflow, measured monthly outflow, average annual release rate for uncontrolled reservoir, and controlled outflow with target release. Keeping in view the 20 Watershed climate change impact evaluation application to future climate scenarios, it was assumed that the best representation of the reservoirs were to simulate them without supplying time series of outflow records. Therefore, target release approach was used in the GCRP-SWAT model.

Hydrology Calibration

A spatial calibration approach was adopted for GCRP-SWAT modeling for the Coastal Southern California basin. A systematic adjustment of parameters has been adopted and some adjustments are applied throughout the basin. Most of the calibration efforts were geared towards getting a closer match between simulated and observed flows at the outlet of calibration focus area.

Land Use / Soil / Slope Definition

A 5/10/5 percent threshold was used for land use/soil/slope in the SWAT model while defining the HRUs. Urban land use classes were exempted from the HRU overlay thresholds.

The calibration focus area (Santa Ana River at MWD Crossing) includes six subwatersheds and is generally representative of the general land use characteristics of the overall watershed with the exception of a higher percentage of cultivated lands. The parameters were adjusted within the practical range to obtain reasonable fit between the simulated and measured flows in terms of Nash-Sutcliffe modeling efficiency and the high flow and low flow components as well as the seasonal flows.

The water balance of the whole Coastal Southern California basin predicted by the SWAT model over the 32-year simulation period is as follows:

```
PRECIP =    494.8 MM
SNOW FALL =   24.25 MM
SNOW MELT =    23.76 MM
SUBLIMATION =     0.50 MM
SURFACE RUNOFF Q =   143.40 MM
LATERAL SOIL Q =   85.39 MM
TILE Q =     0.00 MM
GROUNDWATER (SHAL AQ) Q =    94.83 MM
REVAP (SHAL AQ => SOIL/PLANTS) =    1.99 MM
DEEP AQ RECHARGE =     9.06 MM
TOTAL AQ RECHARGE = 105.88 MM
TOTAL WATER YLD =   277.58 MM
```

```
PERCOLATION OUT OF SOIL =   61.28 MM
ET =    225.2 MM
PET =   1712.7MM
TRANSMISSION LOSSES =    46.04 MM
```

Hydrologic calibration adjustments focused on the following parameters:

- CN2 (initial SCS runoff curve number for moisture condition II)
- ESCO (soil evaporation compensation factor)
- SURLAG (surface runoff lag coefficient)
- SOL_AWC (available water capacity of the soil layer, mm water/mm of soil)
- ALPHA_BF (baseflow alpha factor, days)
- GW_DELAY (groundwater delay time, days)
- GWQMIN (threshold depth of water in the shallow aquifer required for return flow to occur, mm)
- GW_REVAP (groundwater "revap" coefficient)
- CH_N1 (Manning's "n" value for tributary channels)
- CH_N2 (Manning's "n" value for main channels)
- CH_K1 (Effective hydraulic conductivity in tributary channel alluvium)
- CH_K2 (Effective hydraulic conductivity in main channel alluvium)
- SFTMP (Snowfall temperature)
- SMTMP (Snowmelt base temperature)
- SMFMX (Maximum melt rate for snow during the year)
- SMFMN (Minimum melt rate for snow during the year)

The calibration achieves a moderately high coefficient of model fit efficiency. Calibration results for the Santa Ana River at MWD Crossing are summarized in Figure 4, Figure 5, Figure 6, Figure 7 and Table 6.

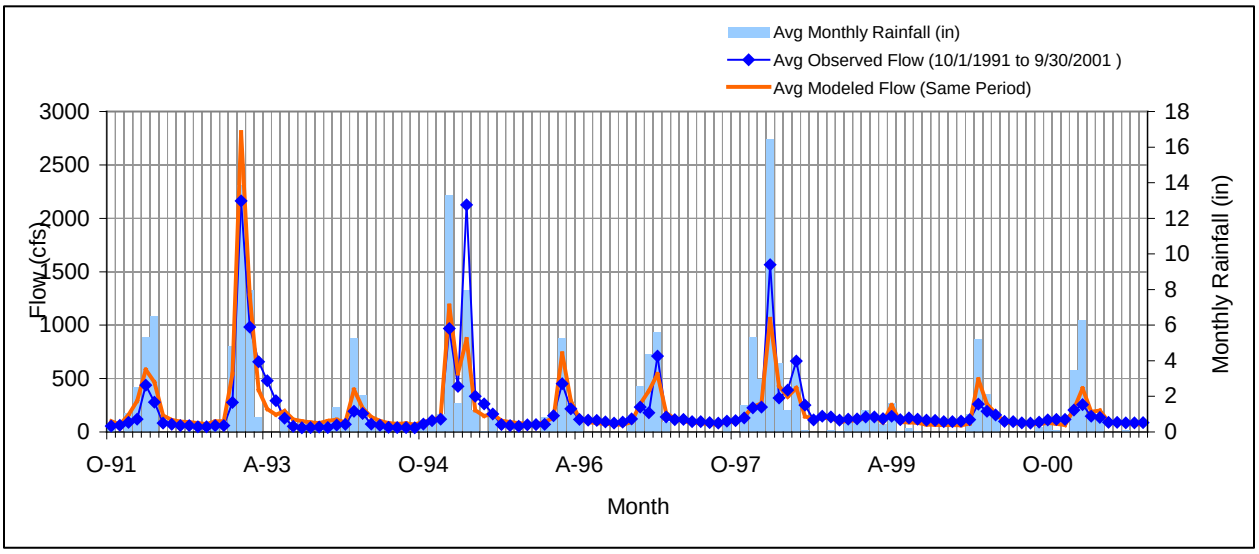

Figure 4. Mean monthly flow at USGS 11066460 Santa Ana River at MWD Crossing, CA – calibration period.

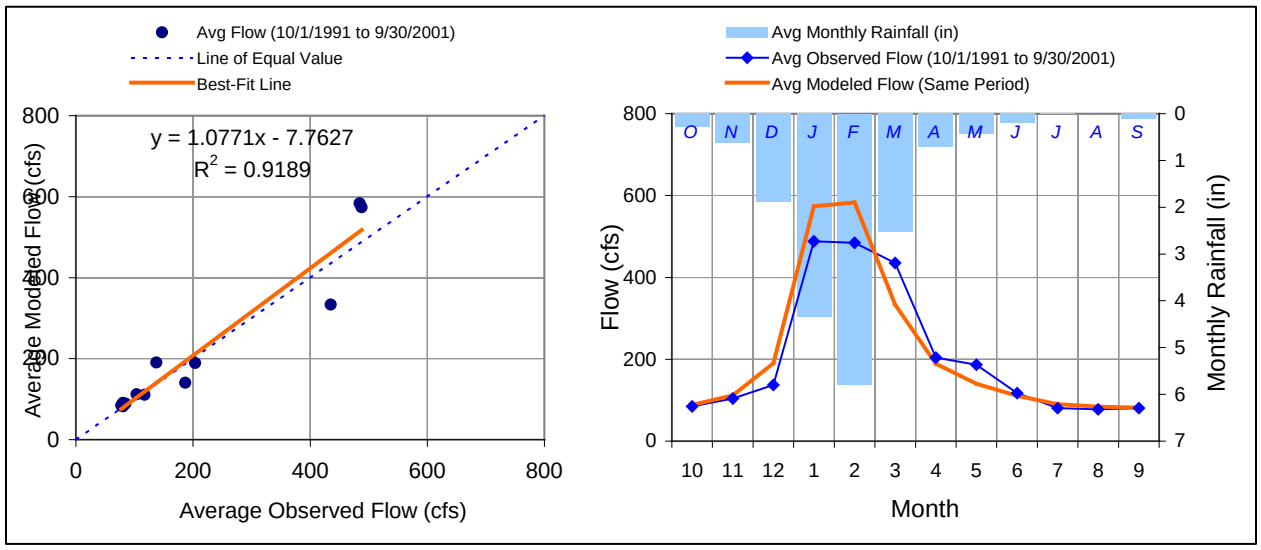

Figure 5. Seasonal regression and temporal aggregate at USGS 11066460 Santa Ana River at MWD Crossing, CA – calibration period.

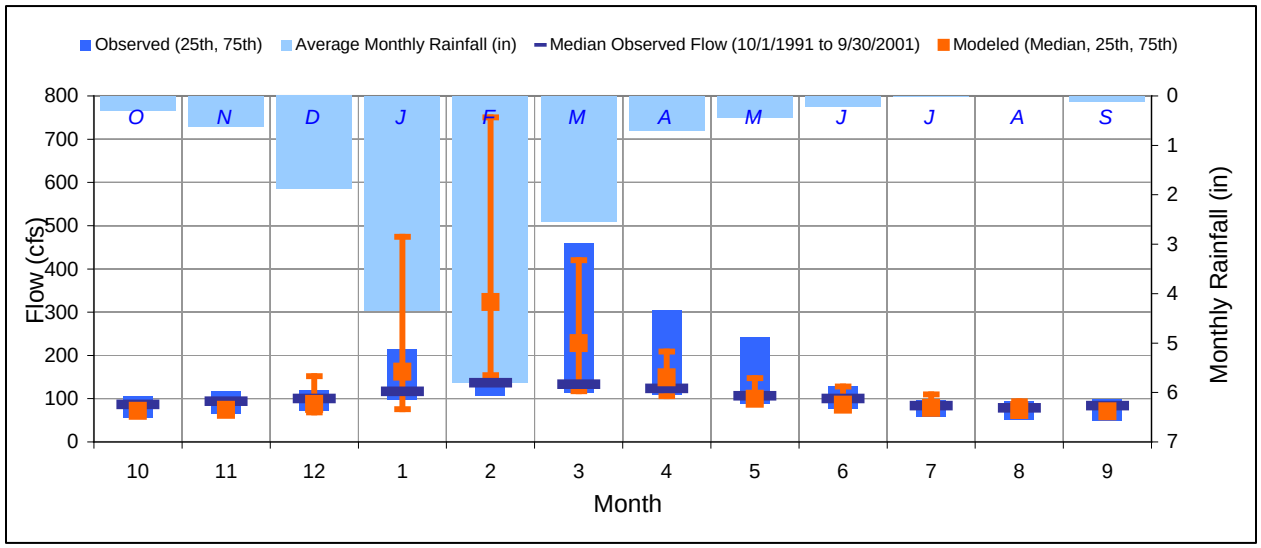

Figure 6. Seasonal medians and ranges at USGS 11066460 Santa Ana River at MWD Crossing, CA – calibration period.

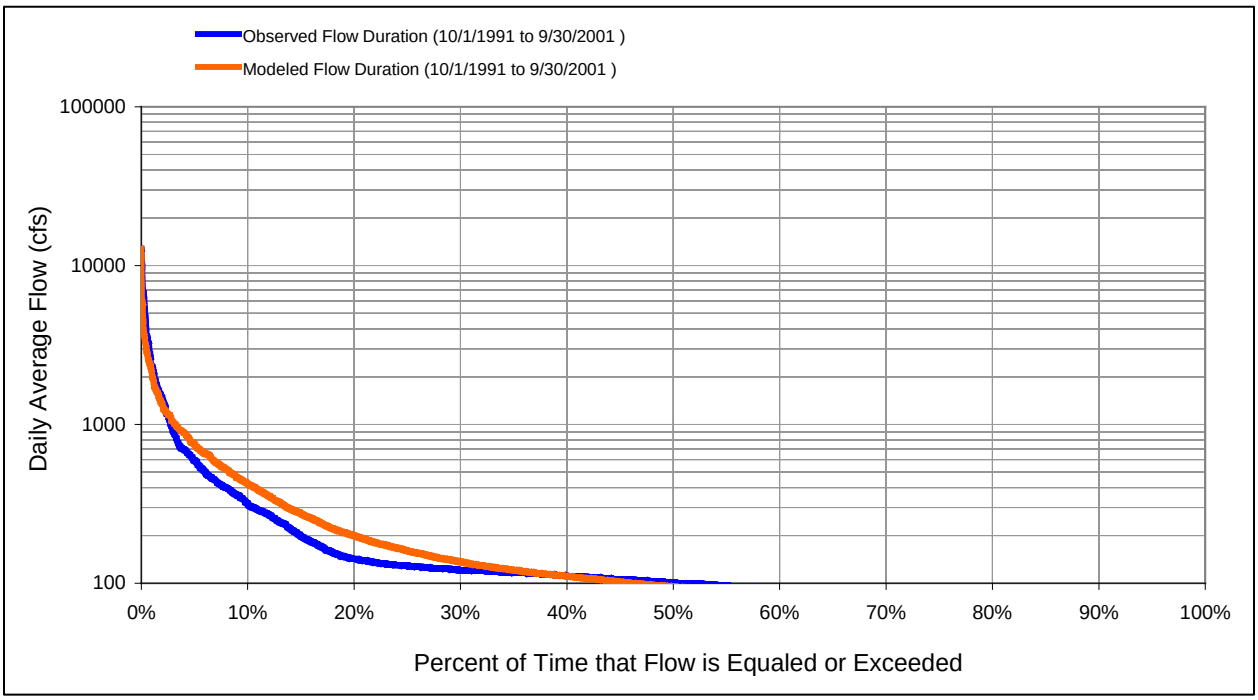

Figure 7. Flow exceedance at USGS 11066460 Santa Ana River at MWD Crossing, CA – calibration period.

Table 6. Summary statistics at USGS 11066460 Santa Ana River at MWD Crossing, CA – calibration period

SWAT Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM OUTLET 34 10-Year Analysis Period: 10/1/1991 - 9/30/2001 Flow volumes are (inches/year) for upstream drainage area		USGS 11066460 SANTA ANA R A MWD CROSSING CA Hydrologic Unit Code: 18070203 Latitude: 33.96862566 Longitude: -117.4483806 Drainage Area (sq-mi): 852	
Total Simulated In-stream Flow:	**3.40**	Total Observed In-stream Flow:	**3.28**
Total of simulated highest 10% flows:	**1.74**	Total of Observed highest 10% flows:	**1.82**
Total of Simulated lowest 50% flows:	**0.60**	Total of Observed Lowest 50% flows:	**0.56**
Simulated Summer Flow Volume (months 7-9):	**0.34**	Observed Summer Flow Volume (7-9):	**0.32**
Simulated Fall Flow Volume (months 10-12):	**0.52**	Observed Fall Flow Volume (10-12):	**0.44**
Simulated Winter Flow Volume (months 1-3):	**1.95**	Observed Winter Flow Volume (1-3):	**1.85**
Simulated Spring Flow Volume (months 4-6):	**0.58**	Observed Spring Flow Volume (4-6):	**0.67**
Total Simulated Storm Volume:	**1.22**	Total Observed Storm Volume:	**1.38**
Simulated Summer Storm Volume (7-9):	**0.02**	Observed Summer Storm Volume (7-9):	**0.03**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*	
Error in total volume:	3.71	10	
Error in 50% lowest flows:	7.28	10	
Error in 10% highest flows:	-4.65	15	
Seasonal volume error - Summer:	7.40	30	
Seasonal volume error - Fall:	19.91	30	
Seasonal volume error - Winter:	5.46	30	
Seasonal volume error - Spring:	-13.35	30	
Error in storm volumes:	-11.70	20	
Error in summer storm volumes:	-46.22	50	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.625	Model accuracy increases	
Baseline adjusted coefficient (Garrick), E':	0.438	as E or E' approaches 1.0	

Hydrology Validation

Hydrology validation for Santa Ana River at MWD Crossing was performed for the period 10/1/1981 through 9/30/1991. The validation achieves an acceptable coefficient of model fit efficiency (Figure 8, Figure 9, Figure 10, Figure 11 and Table 7).

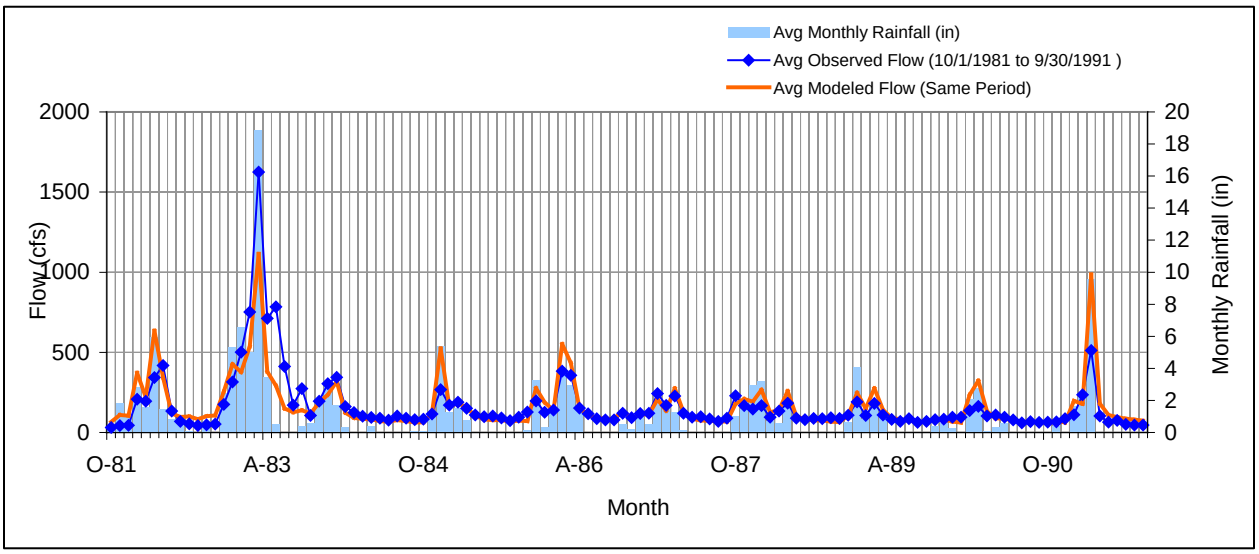

Figure 8. Mean Monthly Flow at USGS 11066460 Santa Ana River at MWD Crossing, CA – Validation Period

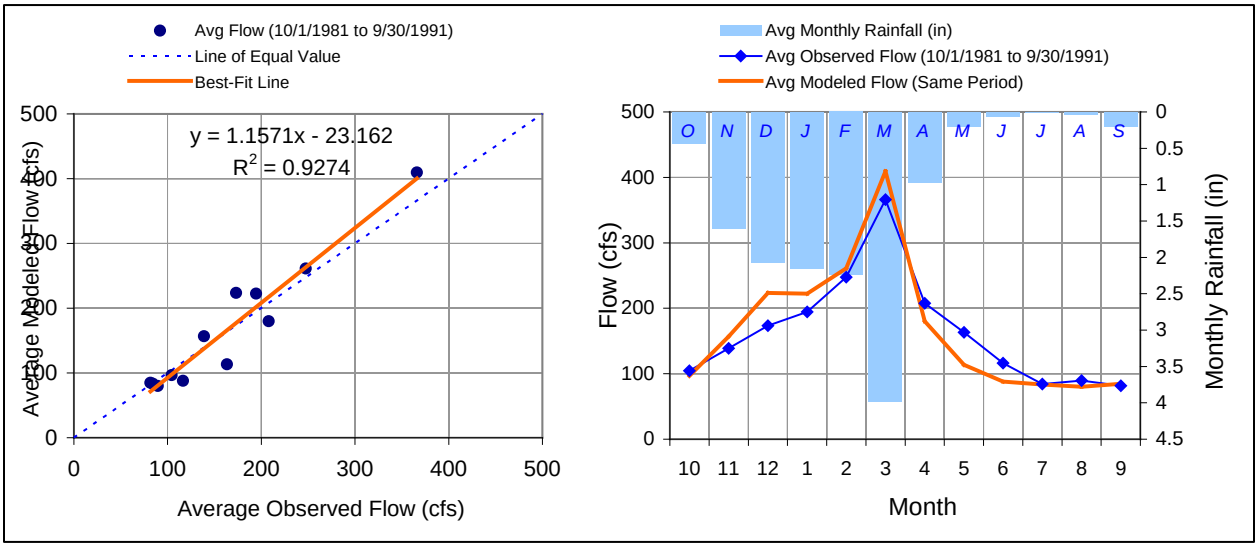

Figure 9. Seasonal regression and temporal aggregate at USGS 11066460 Santa Ana River at MWD Crossing, CA – validation period.

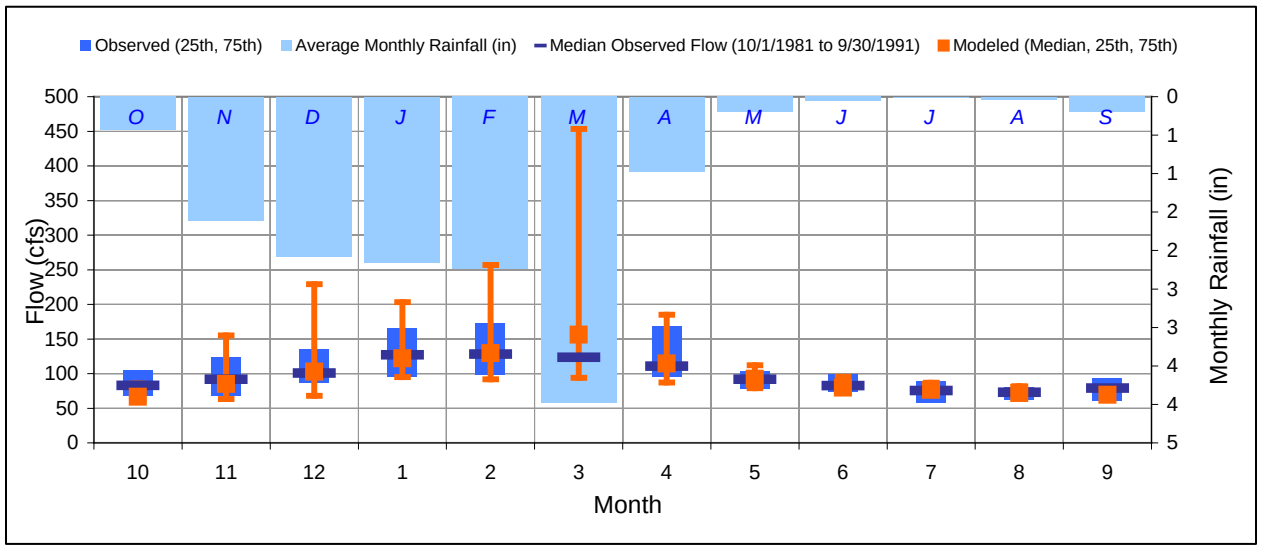

Figure 10. Seasonal medians and ranges at USGS 11066460 Santa Ana River at MWD Crossing, CA – validation period.

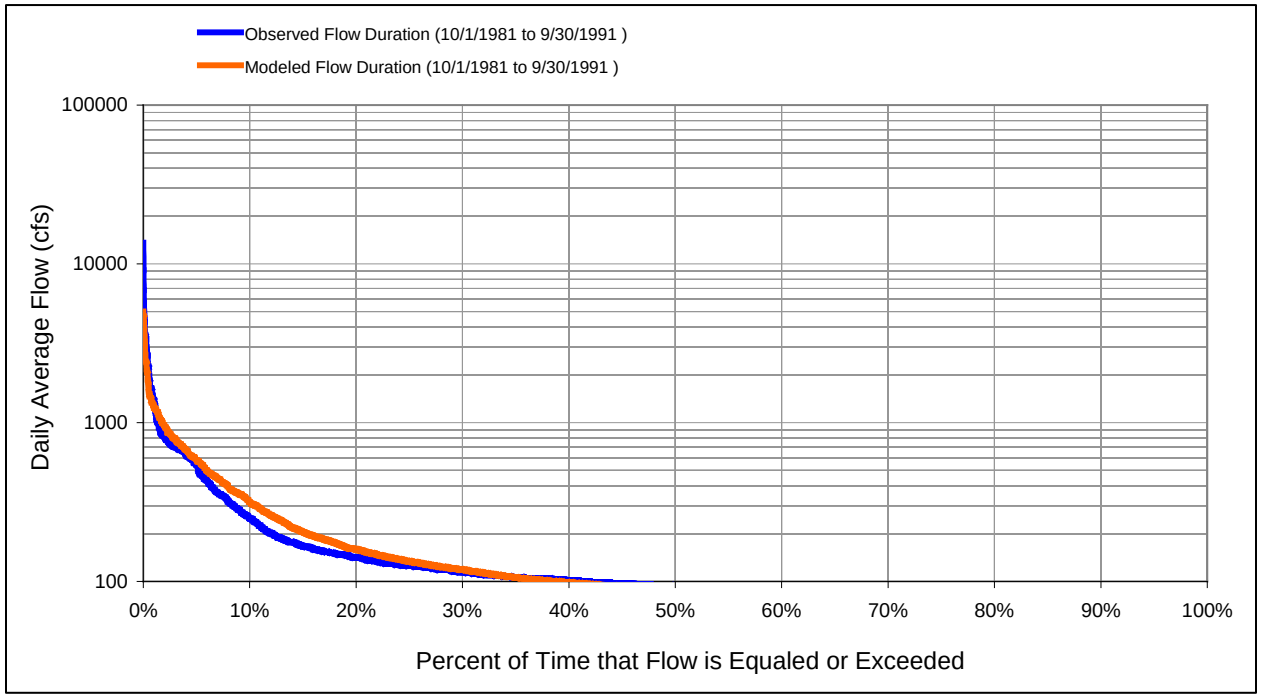

Figure 11. Flow exceedance at USGS 11066460 Santa Ana River at MWD Crossing, CA – validation period.

Table 7. Summary statistics at USGS 11066460 Santa Ana River at MWD Crossing, CA – validation period

SWAT Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM OUTLET 34 10-Year Analysis Period: 10/1/1981 - 9/30/1991 Flow volumes are (inches/year) for upstream drainage area		USGS 11066460 SANTA ANA R A MWD CROSSING CA Hydrologic Unit Code: 18070203 Latitude: 33.96862566 Longitude: -117.4483806 Drainage Area (sq-mi): 852	
Total Simulated In-stream Flow:	**2.65**	Total Observed In-stream Flow:	**2.61**
Total of simulated highest 10% flows:	**1.20**	Total of Observed highest 10% flows:	**1.24**
Total of Simulated lowest 50% flows:	**0.58**	Total of Observed Lowest 50% flows:	**0.57**
Simulated Summer Flow Volume (months 7-9):	**0.33**	Observed Summer Flow Volume (7-9):	**0.34**
Simulated Fall Flow Volume (months 10-12):	**0.64**	Observed Fall Flow Volume (10-12):	**0.56**
Simulated Winter Flow Volume (months 1-3):	**1.18**	Observed Winter Flow Volume (1-3):	**1.06**
Simulated Spring Flow Volume (months 4-6):	**0.50**	Observed Spring Flow Volume (4-6):	**0.65**
Total Simulated Storm Volume:	**0.89**	Total Observed Storm Volume:	**0.85**
Simulated Summer Storm Volume (7-9):	**0.03**	Observed Summer Storm Volume (7-9):	**0.06**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*	
Error in total volume:	1.61	10	
Error in 50% lowest flows:	1.21	10	
Error in 10% highest flows:	-2.74	15	
Seasonal volume error - Summer:	-2.97	30	
Seasonal volume error - Fall:	14.41	30	
Seasonal volume error - Winter:	10.63	30	
Seasonal volume error - Spring:	-21.87	30	
Error in storm volumes:	4.72	20	
Error in summer storm volumes:	-49.23	50	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.587	Model accuracy increases	
Baseline adjusted coefficient (Garrick), E':	0.368	as E or E' approaches 1.0	

Hydrology Results for Larger Watershed

As described above, parameters determined for the gage at the Santa Ana River were initially transferred to other gages in the watershed. However, changes to subwatershed level parameters were required to fit the model to the observed flows. In all, calibration and validation was pursued at a total of five gages throughout the watershed. Results of the calibration and validation exercise are summarized in Table 8 and Table 9, respectively. Calibration and validation results were acceptable at most gages.

Table 8. Summary statistics (percent error): all stations - calibration period

Station	USGS 11044000	USGS 11074000	USGS 11087020	USGS 11109000 (1996 –2001)
Error in total volume:	-14.16	-0.63	-2.03	-27.78
Error in 50% lowest flows:	-34.24	-48.91	-9.33	-58.29
Error in 10% highest flows:	-24.17	17.53	-5.28	-6.60
Seasonal volume error - Summer:	63.03	-39.86	-10.77	-52.09
Seasonal volume error - Fall:	14.79	-33.47	-27.72	-13.02
Seasonal volume error - Winter:	-20.76	13.39	4.18	-12.67
Seasonal volume error - Spring:	20.89	14.16	-3.02	-61.49
Error in storm volumes:	-30.11	-33.40	-18.43	21.68
Error in summer storm volumes:	0.26	-41.45	-84.03	-74.54
Nash-Sutcliffe Coefficient of Efficiency, E:	0.746	0.635	0.539	0.290
Baseline adjusted coefficient (Garrick), E':	0.571	0.218	0.363	0.192

Table 9. Summary statistics (percent error): all stations - validation period

Station	USGS 11044000	USGS 11074000	USGS 11087020
Error in total volume:	29.64	9.60	-7.95
Error in 50% lowest flows:	-7.02	-37.19	37.06
Error in 10% highest flows:	7.39	30.78	-1.74
Seasonal volume error - Summer:	156.76	-22.67	-25.74
Seasonal volume error - Fall:	153.72	-9.62	-9.15
Seasonal volume error - Winter:	-4.59	32.70	-1.41
Seasonal volume error - Spring:	122.83	9.33	-14.90
Error in storm volumes:	2.38	-17.19	-29.85
Error in summer storm volumes:	339.73	-36.25	-65.40
Nash-Sutcliffe Coefficient of Efficiency, E:	0.456	0.372	0.589
Baseline adjusted coefficient (Garrick), E':	0.256	-0.067	0.073

Water Quality Calibration and Validation

Initial calibration and validation of water quality was done on the Santa River at MWD Crossing (USGS 11066460), using 1998-2000 for calibration due to limited water quality data availability. No water quality data were available for the validation period. As with hydrology, calibration was performed on the later period as this better reflects the land use included in the model.

Calibration adjustments for sediment focused on the following parameters:

- SPCON (linear parameter for estimating maximum amount of sediment that can be re-entrained during channel sediment routing)
- SPEXP (exponential parameter for estimating maximum amount of sediment that can be re-entrained during channel sediment routing)
- CH_COV (channel cover factor)
- CH_EROD (channel erodibility factor)
- USLE_P (USLE support practice factor)

Simulated and estimated sediment loads at the Santa Ana River station for both the calibration and validation periods are shown in Figure 12 and statistics for the two periods are provided separately in Table 10. The key statistic in Table 10 is the relative percent error, which shows the error in the prediction of monthly load normalized to the estimated load. Table 10 also shows the relative average absolute error, which is the average of the relative magnitude of errors in individual monthly load predictions. This number is inflated by outlier months in which the simulated and estimated loads differ by large amounts (which may be as easily due to uncertainty in the estimated load due to limited data as to problems with the model) and the third statistic, the relative median absolute error, is likely more relevant and shows better agreement.

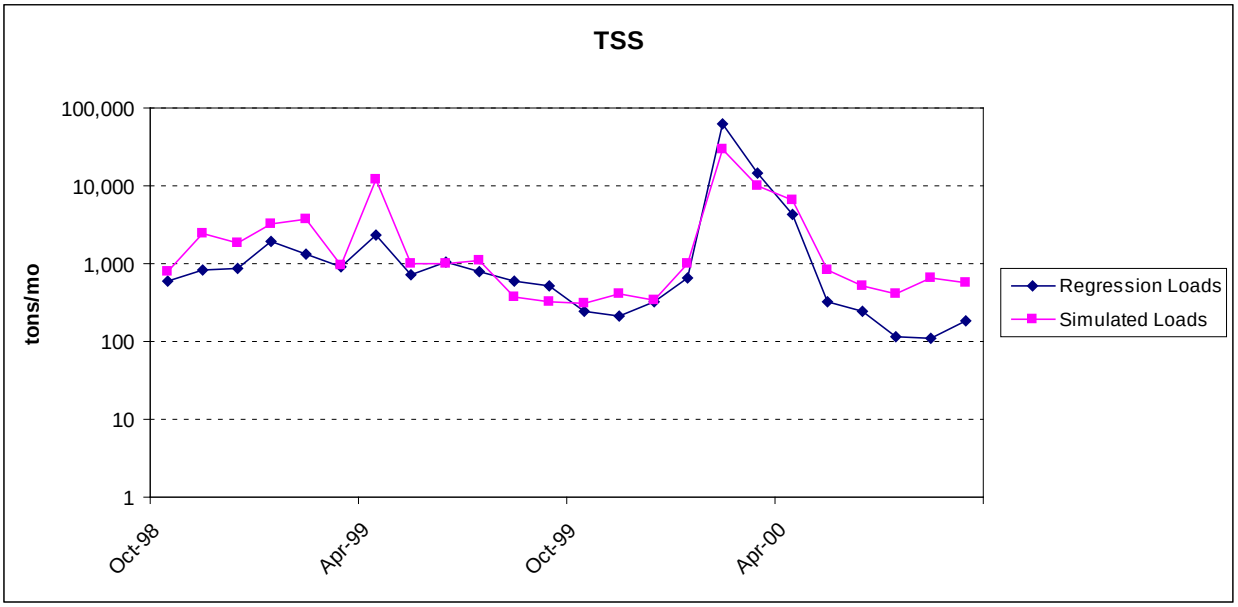

Figure 12. Fit for monthly load of TSS at USGS 11066460 Santa Ana River at MWD Crossing, CA.

Table 10. Model fit statistics (observed minus predicted) for monthly sediment loads using stratified regression at USGS 11066460 Santa Ana River at MWD Crossing, CA

Statistic	Calibration period (1998-2000)
Relative Percent Error	19.0%
Relative Average Absolute Error	62.5%
Relative Median Absolute Error	7.6%

Calibration adjustments for total phosphorus and total nitrogen focused on the following parameters:

- RHOQ (algal respiration rate at 20° C)
- PHOSKD (phosphorus soil partitioning coefficient)
- PSP (phosphorus availability index)
- RS1 (Local algal settlement rate in the reach at 20° C)
- AL1 (Fraction of algal biomass that is nitrogen)
- AL2 (Fraction of algal biomass that is phosphorus)
- MUMAX (Rate of oxygen uptake per unit NO_2-N oxidation at 20° C)
- RHOQ (Algal respiration rate at 20° C)
- RS2 (benthic source rate for dissolved P in the reach at 20° C)
- RS3 (Benthic source rate for NH_4-N in the reach at 20° C)
- RS5 (organic P settling rate in the reach at 20° C)
- BC4 (rate constant for mineralization of organic P to dissolved P in the reach at 20° C)
- RS4 (rate coefficient for organic N settling in the reach at 20° C)
- CH_ONCO (Channel organic nitrogen concentration)
- CH_OPCO (Channel organic phosphorus concentration)
- SDNCO (Denitrification threshold water content)
- CDN (Denitrification exponential rate constant)

Results for the phosphorus simulation are shown in Figure 13 and Table 11. Results for the nitrogen simulation are shown in Figure 14 and Table 12. The model fit is generally acceptable.

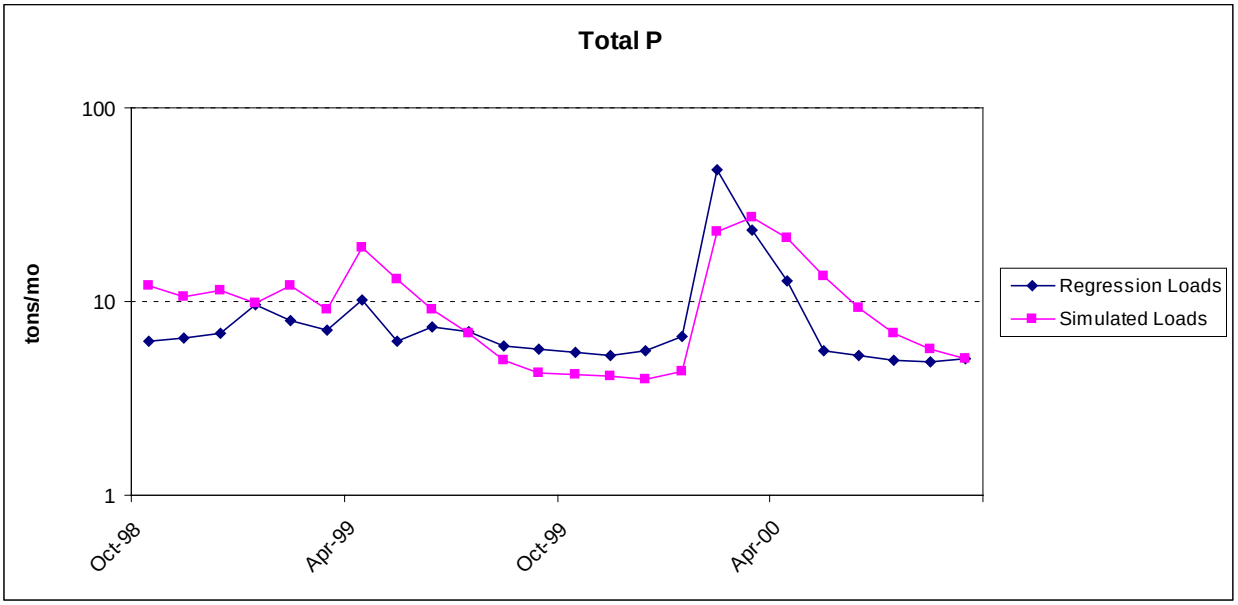

Figure 13. Fit for monthly load of total phosphorus at USGS 11066460 Santa Ana River at MWD Crossing, CA.

Table 11. Model fit statistics (observed minus predicted) for monthly phosphorus loads using stratified regression at USGS 11066460 Santa Ana River at MWD Crossing, CA

Statistic	Calibration period (1998-2000)
Relative Percent Error	-14.7%
Average Absolute Error	45.8%
Median Absolute Error	23.7%

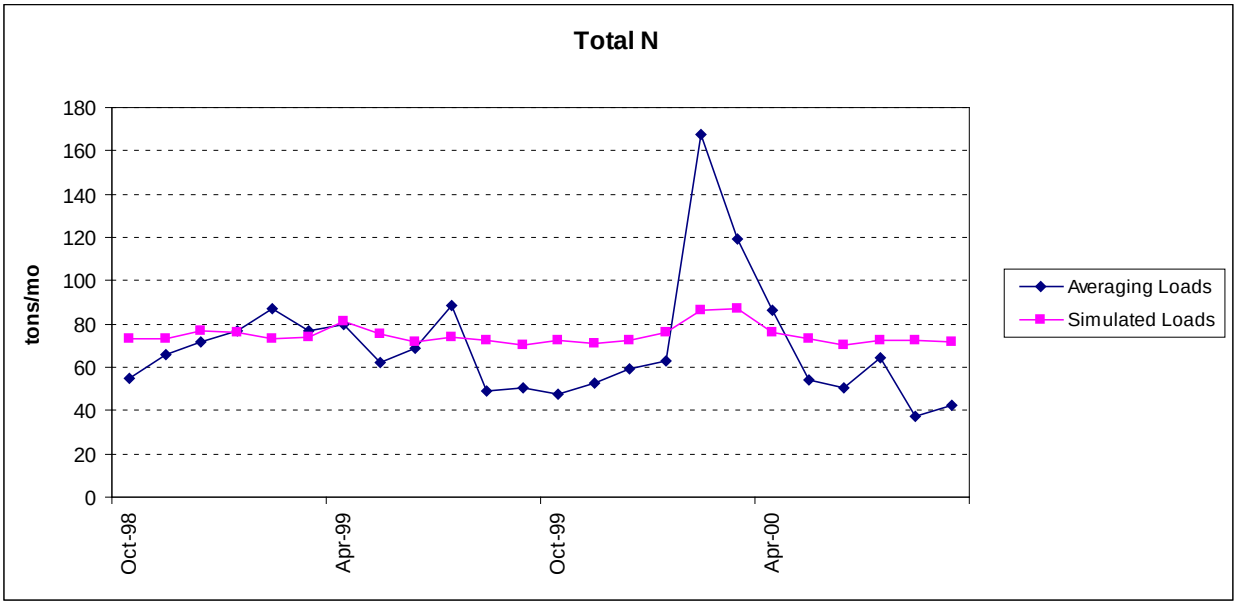

Figure 14. Fit for monthly load of total nitrogen at USGS 11066460 Santa Ana River at MWD Crossing, CA.

Table 12. Model fit statistics (observed minus predicted) for monthly total nitrogen loads using averaging estimator at USGS 11066460 Santa Ana River at MWD Crossing, CA

Statistic	Calibration period (1998-2000)
Relative Percent Error	-5.5%
Average Absolute Error	24.6%
Median Absolute Error	19.2%

Water Quality Results for Larger Watershed

As with hydrology, a spatial calibration approach was adopted. Santa Ana River watershed SWAT model parameters for water quality were transferred to other portions of the watershed with necessary changes to subbasin level parameters. Summary statistics for the SWAT water quality calibration and validation at other stations in the watershed are provided in Table 13 and Table 14.

Table 13. Summary statistics for water quality at all stations – calibration period 1991-2001

Station	USGS 11044000
Relative Percent Error TSS Load	98.0%
Relative Percent Error TP Load	-17.7%
Relative Percent Error TN Load	41.7%

Table 14. Summary statistics for water quality at all stations – validation period 1981-1991

Station	USGS 11044000 (1987 – 1991)
Relative Percent Error TSS Load	97.5%
Relative Percent Error TP Load	1.6%
Relative Percent Error TN Load	75.0%

References

USEPA (United States Environmental Protection Agency). 2008. Using the BASINS Meteorological Database (Version 2006). BASINS Technical Note 10. Office of Water, U.S. Environmental Protection Agency, Washington, DC.