Algae and Nutrient Modeling for Ventura River
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The purpose of this memorandum is to summarize the model results and findings of algae and nutrient modeling in the Ventura River watershed. The following sections include an introduction to the Ventura River watershed, model description, model calibration and validation, and results of the model-predicted existing loading scenarios and proposed load reduction scenarios.

1.0 Introduction

A number of sites in the Ventura River watershed have been identified as having impaired beneficial uses because of high algae and nutrient levels   caused by nutrient loading from both point and nonpoint sources. To examine relationships among human alterations, including land uses patterns and sewage effluent, nutrient concentrations, and algal biomass within the Ventura River watershed, a numerical model was selected and employed in the watershed system.

1.1 Ventura River Watershed

The Ventura River watershed is primarily located in western Ventura County with a small portion in southeastern Santa Barbara County, California. The watershed drains an area of about 228 square miles. Ventura River has several major tributaries including Matilija Creek, North Fork Matilija Creek, San Antonio Creek, Coyote Creek, and Cañada Larga, and also contains Lake Casitas, which serves as the primary water supply for the area within the watershed.

2.0 Ventura River Watershed Water Quality Model

2.1 The Stream Water Quality Model (QUAL2K)

The Stream Water Quality Model (QUAL2K) was chosen as the framework for the Ventura River algae and nutrient model development and TMDL analysis. QUAL2K is supported and distributed by US EPA and has been widely used for studying the impact of conventional pollutants on streams. The QUAL2K model is suitable for simulating the hydrological and water quality conditions of a natural river or stream. It is a simple one-dimensional model that simulates basic stream transport and mixing processes. The processes employed in QUAL2K address nutrient cycles, algal growth, and dissolved oxygen dynamics. Compared to other available models, QUAL2K is the one best suited for the Ventura River's conditions. Therefore, QUAL2K was selected as the tool to develop the Ventura River water quality model and conduct the TMDL analysis. The model was downloaded from the US EPA website and operated in the Microsoft Excel

program as designed by the program authors. Data inputs of the QUAL2K model for the Ventura River are discussed in the next section.

QUAL2K simulates a river as a set of interconnected segments, where water quality constituent values are computed for each segment. A segment is defined as a river reach with point and nonpoint inflow sources, as well as withdrawals that drive changes in water quality (Figure 2.1). Each segment of the river reach is modeled as having a trapezoidal channel shape, and the water depth is calculated from steady flow in the segment using the Manning equation. Water mass balances are performed by QUAL2K for each segment to determine the discharge longitudinally throughout the river reach.
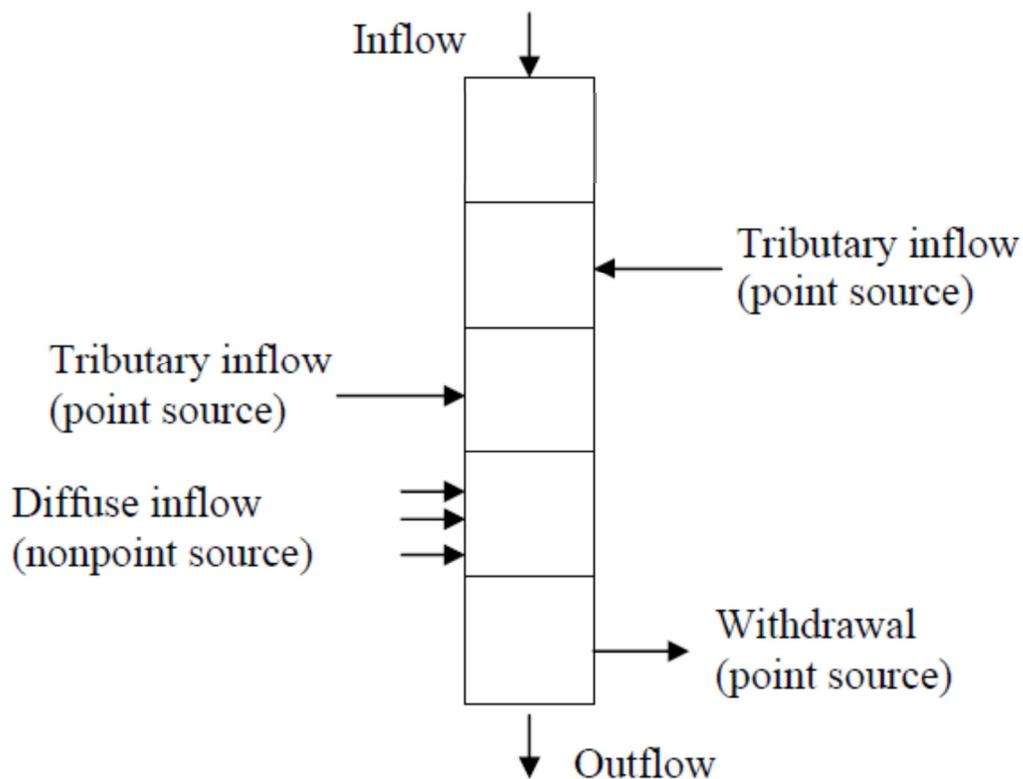
Figure 2.1 Example of QUAL2K segments describing a river reach

For the simulation of water temperature, a heat balance approach is used to describe the sources and sinks of heat for each model segment. The heat fluxes between the water and the atmosphere include short and long wave solar radiation, shading and cloud cover attenuation, conduction, wind advection, and condensation. The heat budget is calculated using a diurnal time scale. Mixing of water between adjacent segments is modeled through water movement from upstream to downstream and dispersive mixing at segment boundaries. Heat fluxes between the water and sediment are also included in QUAL2K.

For each water quality constituent, mass balances are calculated that describe external loading, segment interaction, sediment interaction, and bottom algae interaction (Figure 2.2). In addition to mass balances for each constituent, chemical reactions are specified to each water quality constituent. As a group, these reactions simulate the growth of algae, decay of organic material, and cycling of nutrients that occurs in natural water.
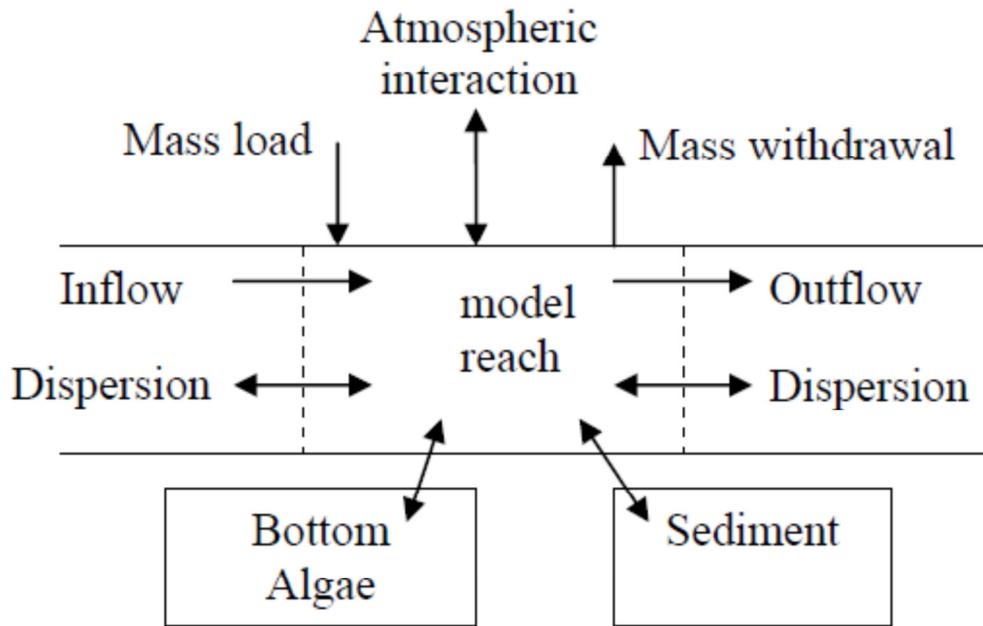
Figure 2.2 Water quality fluxes for QUAL2K model segments

2.2 Ventura River QUAL2K Model Input Data

The Ventura River QUAL2K Model is set up as a one-dimensional, steady-state model. It simulates in-stream water quality conditions including dissolved oxygen, algae as chlorophyll-a, as well as various forms of nitrogen and phosphorous. Water temperature and diurnal changes of algae are also simulated. The major input data groups for the Ventura River QUAL2K Model are summarized below.

2.2.1 Model Segmentation

For modeling, the 28-kilometer section of the Ventura River mainstem between the Matilija Dam and the river mouth was divided into 7 reaches, which consist of a total of 51 computational segments with a number of small segments in each reach. Model segments are homogenous sections of the river. Most of the segments are about 500 meters long. The model extent, segment boundaries, and tributaries are presented in Figure 2.1. A description of the modeled reaches is presented in Table 2-1.

Matilija Creek, North Fork Matilija Creek, San Antonio Creek, Coyote Creek, and Canada Larga are considered point inflow sources of water and constituents. The Ojai wastewater treatment plant (Ojai WWTP) is also considered a concentrated point source. Withdrawal from the Ventura River at Robles Diversion Dam for drinking water is simulated as a point outflow (abstractions). Diffuse inflow sources of water and constituents due to small gains are also included in a given reach. These water sources are included so that inflows and outflows of water can be included to better match river flow data, which was measured by University of California, Santa Barbara (UCSB) at fourteen points throughout the reach.

QUAL2K application for the Ventura River includes all the physical attributes of the river and its tributaries, and allows for an adequate characterization of flow and water quality for a 30-day steady-state simulation.

2.2.2 Hydraulic Characteristics

The Ventura River QUAL2K model uses the Manning formula to describe stream hydraulic characteristics and assumes that the stream has a trapezoidal channel cross-section with zero side slope (i.e., rectangular channel). Field visits to the river shows the river to be highly irregular in depth and width due to natural storm and erosion activities in the watershed. Estimates were made of the width and depth of flow for the dry season in the river based on the field measurement data collected by U.S. Department of the Interior, Bureau of Reclamation and verified by the Los Angeles Regional Water Quality Control Board. The width of the river ranges from 4 to 22 meters under normal flow conditions in the dry season. The slope for the river was estimated based on topographic maps. Stream characteristic inputs are shown in the table below.

Table 2.1 Hydraulic Characteristics in Ventura River Model Reaches

Reach	Reach Length (Km)	Channel Elevation (m)	Channel Bottom Width (m)	Left Side Slope	Right Side Slope	Channel Slope	Manning's n
1	4.33	217.02	3.57	0.0	0.0	0.0199	0.12
2	5.93	128.03	6.36	0.0	0.0	0.0135	0.12
3	2.71	93.88	8.23	0.0	0.0	0.0089	0.10
4	3.22	65.53	11.84	0.0	0.0	0.0066	0.10
5	2.11	48.77	16.09	0.0	0.0	0.0048	0.08
6	6.61	6.1	16.49	0.0	0.0	0.0021	0.08
7	0.90	0	22.07	0.0	0.0	0.0001	0.05

2.2.3 System Parameters

The physical, chemical, and biological processes simulated by QUAL2K are represented by a set of equations that contain many parameters. Some are global constants, some are spatial variables, and some are temperature dependent variables. Detailed descriptions of these parameters and associated

processes are available in the QUAL2K user's manual. Global rate constants used under dry conditions are in Table 2-2.

Table 2.2 Rate Constants in Ventura River QUAL2K model

Parameter	Value	Units	Symbol
Stoichiometry			
Carbon	40	gC	gC
Nitrogen	7.2	gN	gN
Phosphorus	1	gP	gP
Dry weight	100	gD	gD
Chlorophyll	1	gA	gA
Inorganic suspended solids			
Settling velocity	0.3	m/d	v_i
Oxygen			
Reaeration model	Tsivoglou-Neal		
Temperature correction	1.024		θ_a
O_2 for carbon oxidation	2.69	gO_2/gC	r_{oc}
O_2 for NH_4 nitrification	4.57	gO_2/gN	r_{on}
Oxygen inhib CBOD oxidation model	Exponential		
Oxygen inhib CBOD oxidation parameter	0.6	L/mgO_2	K_{socf}
Oxygen inhib nitrification model	Exponential		
Oxygen inhib nitrification parameter	0.6	L/mgO_2	K_{sona}
Oxygen enhance denitrification model	Exponential		
Oxygen enhance denitrification parameter	0.6	L/mgO_2	K_{sodn}
Oxygen inhib phyto resp model	Exponential		
Oxygen inhib phyto resp parameter	0.6	L/mgO_2	K_{sop}
Oxygen enhance bottom algae resp model	Exponential		
Oxygen enhance bottom algae resp parameter	0.6	L/mgO_2	K_{sob}
Slow CBOD			
Hydrolysis rate	1.0	/d	k_{hc}
Temperature correction	1.047		θ_{hc}
Oxidation rate	5	/d	k_{dcs}
Temperature correction	1.047		θ_{dcs}
Fast CBOD			
Oxidation rate	0.2	/d	k_{dc}
Temperature correction	1.047		θ_{dc}
Organic N			
Hydrolysis	0.1	/d	k_{hn}
Temperature correction	1.07		θ_{hn}
Settling velocity	0	m/d	v_{hn}
Ammonium			
Nitrification	1.649	/d	k_{na}
Temperature correction	1.07		θ_{na}
Nitrate			
Denitrification	0	/d	k_{dn}
Temperature correction	1.07		θ_{dn}
Sed denitrification transfer coeff	0	m/d	v_{di}
Temperature correction	1.07		θ_{di}
Organic P			
Hydrolysis	0	/d	k_{hp}
Temperature correction	1.07		θ_{hp}

Parameter	Value	Units	Symbol
Settling velocity	1.999	m/d	v_{op}
Inorganic P			
Settling velocity	0	m/d	v_{ip}
Inorganic P sorption coefficient	0.073	L/mgD	K_{dpi}
Sed P oxygen attenuation half sat constant	1.831	mgO_2/L	k_{spi}
Phytoplankton			
Max Growth	2.5	/d	k_{gp}
Temperature correction	1.07		θ_{gp}
Respiration rate	0.1	/d	k_{rp}
Temperature correction	1.07		θ_{rp}
Excretion rate	0	/d	k_{ep}
Temperature correction	1.07		θ_{ep}
Death rate	0	/d	k_{dp}
Temperature correction	1		θ_{dp}
External Nitrogen half sat constant	15	ugN/L	k_{sPp}
External Phosphorus half sat constant	2	ugP/L	k_{sNp}
Inorganic carbon half sat constant	2.00E-005	moles/L	k_{sCp}
Light model	Half saturation		
Light constant	57.6	langleys/d	K_{Lp}
Ammonia preference	25	ugN/L	k_{hnxp}
Setting velocity	0.15	m/d	v_a
Bottom Algae			
Growth model	Zero-order		
Max Growth	300	mgA/m^2/d	C_{gb}
Temperature correction	1.07		θ_{gb}
Respiration rate	1	/d	k_{rb}
Temperature correction	1.07		θ_{rb}
Excretion rate	0.5		k_{eb}
Temperature correction	1.05		θ_{eb}
Death rate	0.09	/d	k_{db}
Temperature correction	1.07		θ_{db}
External Nitrogen half sat constant	0.052	ugN/L	k_{sNb}
External Phosphorus half sat constant	96.379	ugP/L	k_{sPb}
Inorganic carbon half sat constant	1.00E-05		k_{sCb}
Light model	Half saturation		
Light constant	76.319	langleys/d	K_{Lb}
Ammonia preference	99.982	ugN/L	k_{hnxb}
Detritus (POM)			
Dissolution rate	7.179	/d	k_{dt}
Temperature correction	1.07		θ_{dt}
Fraction of dissolution to fast CBOD	1.00		F_f
Setting velocity	0.236	m/d	v_{dt}
Pathogens			
Decay	0.8	/d	k_{dx}
Temperature correction	1.07		θ_{dx}
Settling velocity	1	m/d	v_x
PH			
Partial pressure of carbon dioxide	347	ppm	P_{co2}

2.2.4 Boundary Conditions and Point Sources

The QUAL2K model uses various data groups to define model boundary conditions. It uses the headwater data group to define upstream boundary conditions of the model domain. Downstream boundary conditions can be defined by the user, or computed internally. The point source data group defines the condition of point source discharges from facilities or small tributaries that enter simulated stream segments.

Headwater conditions for the Ventura River QUAL2K Model were characterized by using water quality monitoring data collected by UCSB at Station 12 (downstream of Matilija Dam), and flow data compiled as part of the Ventura River Hyrdology Model (Tertatech, 2008), which are shown in Table 2.3 for the years of 2006 through 2010 and the TMDL scenarios. Tributaries were modeled as point sources based on water quality data from North Folk Matilija Creek, Matilija Creek, San Antonio Creek and Cañada Larga. Water released from Casitas into Coyote Creek downstream from Casitas Dam is negligible. Thus, Coyote Creek was not considered a point source to the Ventura River.

Annual mean concentrations were determined for all stations in the model and were used as calibration points for the model. Annual means were determined for the applicable monitoring periods during the April-October sampling months. Mean concentrations over the period were used along with mean flows to calibrate the model for annual dry conditions. Dry season (April - October) mean concentrations were then used as the inputs for simulations in critical summer conditions using the rates from the calibrated mean conditions model. The option of internally calculating downstream boundary conditions was selected for development of the Ventura River QUAL2K Model.

Table 2.3 Headwater Conditions in Ventura River Watershed

Headwater Water Quality	Units	2006	2007	2008	2010	TMDL
Headwater Flow	m3/s	3.51	0.254	0.305	0.56	1.03
Prescribed downstream boundary		NO	NO	NO	NO	NO
Temperature	C	24.7	24.7	24.7	24.7	24.7
Conductivity	umhos	862	862	862	862	862
Inorganic Solids	mgD/L	NA	NA	NA	NA	NA
Dissolved Oxygen	mg/L	9.94	9.94	9.94	9.94	9.94
CBOD slow	mgO2/L	NA	NA	NA	NA	NA
CBOD fast	mgO2/L	NA	NA	NA	NA	NA
Dissolved Organic Nitrogen*	ugN/L	74.2	74.2	74.2	74.2	23.6
NH4-Nitrogen*	ugN/L	9.97	9.97	9.97	9.97	0.48
NO3-Nitrogen*	ugN/L	10.0	10.0	5.1	5.1	24.08
Dissolved Organic Phosphorus*	ugP/L	38.1	38.1	38.1	38.1	1.09
Inorganic Phosphorus (SRP)*	ugP/L	12.0	5.0	4.9	4.9	5.70
Phytoplankton	ugP/L	NA	NA	NA	NA	NA
Detritus (POM)	ugA/L	NA	NA	NA	NA	NA
Pathogen	mgD/L	NA	NA	NA	NA	NA
Alkalinity*	mgCaCO3/L	100	100	100	100	100
pH*		8.09	8.09	8.09	8.09	8.09

*Cited from University of California at Santa Barbara (UCSB) 2009 Report and Santa Barbara Channel Keeper monitoring data (2001 through 2008).

2.2.5 Diffuse Sources

The diffuse sources data group defines the condition of uniformly distributed flow over the entire length of the model reach. The uniformly distributed flow could be groundwater inflow and/or distributed surface runoff that is assumed constant over time. Concentrations of nutrients in the inflow were estimated by starting with headwater concentrations and adjusting them as necessary to account for the effect of groundwater input.

The presence of a large number of residential septic tanks in unsewered areas of the Ventura River watershed is perceived as a non-point source of nitrogen and phosphorus to shallow groundwater. Based on the assumption that there are 2131 septic tanks in area draining to the Ventura River and San Antonia Creek, and that residential households generate 200 gallons per day of septic tank influent with nutrient concentrations of 36 mg/L nitrogen and 6 mg/L phosphorus. For these septic systems, 32 percent of the nitrogen loads and 10 percent of the phosphorus loads were assumed to enter the surface water from groundwater. Using the above assumptions, the daily nitrogen and phosphorus loads entering the Ventura River through groundwater are estimated as 41 lb/day and 2.13 lb/day respectively.

3.0 Model Calibration and Validation

The overall model development process involves creation of a set of data that characterizes the physical aspects of the Ventura River and describes the flow and quality at the upstream end of the river and all the tributary inflows. The model was run and the model predictions were compared to a set of measured data describing the in-river water quality. The model was then calibrated by adjusting model parameters to better fit the model prediction to the measured data. Additional data sets of measured data were used then to validate the model to ensure that the model can predict real situations in a reliable manner.

The data requirements for the QUAL2K model for one simulation include flow, water quality, and meteorological data. Data are required for input to the model, as well as to be used for comparison with model output for calibration and validation purposes.

3.1 Model Calibration

The model was calibrated for a typical day in the dry season. Under low flow conditions, the concentration of nutrients would be higher, stream temperature would be higher, and dissolved oxygen concentrations would be lower. The

required set of flow and water quality sampling data for all measurements at all locations were not available for any single day. To best characterize typical dry conditions, a dataset was developed to create a full set of conditions representative of a typical dry day.

For a given site, the mean values of all measured data during the dry season for the period of record for a given constituent were calculated. In other words, the mean values of data were used as a measure of typical dry season conditions. Flow data were compiled as part of the Ventura River Hyrdology Model (Tertatech, 2008) and water quality data were obtained from Santa Barbara ChannelKeeper (monitoring data, 2001-2008) and University of California at Santa Barbara (UCSB) (monitoring data, 2008). This method was used to create representative water-quality measurements and concentrations for all inflow water sources to the modeled reach. The minimum and maximum measurements for the dry season from the period of record of the data were computed and used to define the expected range of conditions during the dry season. The minimum and maximum data were developed for comparison with the calibrated model output to provide visual bounds of expected water quality conditions. Meteorological conditions are represented by hourly data for air temperature, dew point temperature, wind speed, and cloud cover. Hourly meteorological conditions are required for QUAL2K simulations. These data, represented by hourly data for air temperature, dew point temperature, and wind speed, were developed from NOAA weather station data at Oxnard as shown in Figure 3.1. Twenty percent of sky is assumed as the cloud cover during a typical day.

Hydrology was the first model component calibrated because simulation of water quality relies heavily on flow prediction. The hydrology calibration involves a comparison of model results to flow observations at selected locations. The model results for flow rate and water depth along the Ventura River were compared with measured data collected by Regional Board staff on May 12, 2010 and presented in Figure 3.2 and Figure 3.3. The comparisons of model results with observed data for flow rate and water depth are fairly good.

To further calibrate the Ventura River QUAL2K model, flow and water quality conditions in dry weather (April and October) observed by UCSB during 2008 were compared with model predictions. The flow rate and water depth along the Ventura River reach were presented in Figure 3.4 and Figure 3.5.

Inputs for the headwaters and tributaries were based on available data. Water-quality data consisted of measures of water quality at the headwaters and all water inflow points. These data consisted of values of conductivity, pH, and concentrations of dissolved oxygen, nutrient species, phytoplankton, and alkalinity. The input loads used for the Ventura River QUAL2K Model calibration and validation are presented in Table 3.1.

Several graphs for selected parameters obtained by the model are shown below. Figures 3.6 to 3.9 show model calibration results for various forms of nutrients, and benthic chlorophyll-a. Model calibration average results are presented as black lines. Dotted red lines represent minimum and maximum model results. Observed data at the monitoring sites are shown as symbols representing mean, maximum, and minimum values. The calibration results show that nitrate-nitrogen, total nitrogen, total phosphorus and benthic chlorophyll-a are calibrated reasonably well.

Table 3.1 Loading Conditions of Point Sources in Ventura River Watershed during 2006-2008 for Calibration and Validation

2008										
	Flow	DO	Chlor-a	Org-N	NH4-N	NO2-N+ NO3-N	TN	Org-P	Inor-P	TP
Station	cms	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
San Antonio	0.08	11.74	NA	252	19.8	68.5	340	34	16.67	51
Canada Larga	0.093	4.98	NA	118	3.93	1.7	124	8.93	1.73	11
Ojai WWTP	0.090	11.74	NA	730	90	4160	4980	220	1210	1430

2007										
	Flow	DO	Chlor-a	Org-N	NH4-N	NO2-N+ NO3-N	TN	Org-P	Inor-P	TP
Station	cms	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
San Antonio	0.020	11.74	NA	252	19.8	20.0	292	34	18.0	52
Canada Larga	0.04	4.98	NA	118	3.93	1.7	124	8.93	1.73	11
Ojai WWTP	0.086	11.74	NA	760	300	5730	6790	790	1630	2420

2006										
	Flow	DO	Chlor-a	Org-N	NH4-N	NO2-N+ NO3-N	TN	Org-P	Inor-P	TP
Station	cms	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
San Antonio	0.59	11.74	NA	252	19.8	1950	2222	34	19.0	53
Canada Larga	0.052	4.98	NA	118	3.93	120	242	8.93	17.0	26
Ojai WWTP	0.100	11.74	NA	830	0	5670	6500	790	1870	2660

3.2 Model Validation

To ensure that the model can predict real situations in a reliable manner, additional data sets of measured data were then used to validate the model. Two data sets from 2006 and 2007 were used in the model validation. The model parameters used were the same as in the calibrated model and only different input point sources from tributaries were used as presented in Table 3.1.

Figures 3.10 to 3.13 show model validation results for flow rate and nitrate nitrogen. The model results show that flow rate and nitrate-nitrogen are validated reasonably well with observed data.

4.0 Establishment of Algae and Nutrient TMDLs for Ventura River

After completing model calibration and validation for hydrology and water quality, the model can be applied to the selected modeling scenarios. For the Ventura River algae and nutrient TMDLs, existing source loadings were modeled first and then a source reduction scenario was modeled for the purposed of assigning load and waste load allocations. The model was run with a 180-day accrual period.

4.1 Model Input Loadings

The major contributions of potential nutrient sources by order of significance in the Ventura River watershed for dry weather are summarized as follows:

- Ojai Valley Wastewater Treatment Plant discharge
- Animal waste from horse and cattle facilities
- Runoff from developed urban areas
- Agricultural discharge
- Onsite wastewater treatment and septic system discharges
- Runoff from undeveloped natural areas
- Atmospheric deposition

The annual loads of total nitrogen and total phosphorus for these sources were estimated in detail in the Source Assessment section of the Staff Report and summarized as shown in Table 4.1. For the existing condition in the Ventura River watershed, total annual loads of nutrients from these sources required by the nutrient model for each subwatershed and two tributaries (San Antonio Creek and Cañada Larga) were estimated in the Sources Assessment section of the Staff Report as well and presented in Table 4.2. The total nitrogen concentration and total phosphorus concentration for treated Ojai WWTP effluent were estimated as 5.86 mg/L and 1.38 mg/L, respectively, based on the effluent data of 2000 through 2012. For the reduction scenario, the loads of total nitrogen and total phosphorus in each subwatershed were estimated as shown in Table 4.3.

Table 4.1 Summary of Total Nitrogen (TN) and Total Phosphorus (TP) Loads for Dry Weather in Ventura River Watershed

Source Type	Flow (cfs)	Total Nitrogen Mass (lb/year)	Total Phosphorus Mass (lb/year)
Dry weather runoff from undeveloped area	11.68	6879	1042
Ojai Valley WWTP	3.25	33984	8030
Animal waste from horse and cattle	NA	19860	4700
Septic systems	0.66	14955	779
Agriculture	1.24	10389	41
Dry weather urban runoff	3.46	18480	172
Runoff from Caltrans	NA	701	70
Atmospheric deposition	NA	641	50
Total	20.29	105889	14884

Table 4.2 Summary of Total Nitrogen (TN) and Total Phosphorus (TP) Loads for Existing Scenario in each Subwatershed

Subwatershed	Flow (cfs)	Total Nitrogen Mass (lb/year)	Total Phosphorus Mass (lb/year)
Upper Watershed	36.38	3122	440
Reach 4	0.78	9664	438
Reach 3	0.42	5267	799
Lower Watershed	0.42	11085	923
San Antonio Creek	6.00	17172	1628
Canada Larga Creek	2.47	9999	1796
Ojai Valley WWTP	3.25	33984	8030

Table 4.3 Summary of Total Nitrogen (TN) and Total Phosphorus (TP) Loads for Reduction Scenario in each Subwatershed

Subwatershed	Flow (cfs)	Total Nitrogen Mass (lb/year)	Total Phosphorus Mass (lb/year)
Upper Watershed	36.38	3006	439
Reach 4	0.78	4569	135
Reach 3	0.42	1307	73
Lower Watershed	0.42	4205	129
San Antonio Creek	6.00	6795	324
Canada Larga Creek	2.47	1981	152
Ojai Valley WWTP	3.25	17397	5799

Nitrogen and phosphorus loads from undeveloped runoff, urban runoff, and animal waste from horses/livestock are grouped into six sub-watersheds, which are the Upper Watershed, San Antonio Creek Watershed, Cañada Larga Watershed, Reach 4 Watershed, Reach 3 Watershed and Lower Watershed. These nutrient loads from six sub-watersheds are incorporated as discharges to the Ventura River as point source inputs in the QUAL2K model.

The nutrient loads from agriculture and septic tank systems are modeled as diffuse sources (line sources) and distributed to adjacent stream reaches. For agriculture loads, the diffuse segments start from the headwater to Cañada Larga. The diffuse segments for septic tank systems start from two miles upstream of San Antonio Creek to Foster Park.

4.2 Model Results

A source reduction scenario was developed for nutrient loads from point sources and nonpoint sources in order to reach numeric targets based on a reduction in existing loads. The values presented in Table 4.2 and in Table 4.3 were used to evaluate the water quality in the Ventura River for existing and reduction scenarios simulated by the QUAL2K model.

To compare the model results for the existing and reduction scenarios, the nutrient concentrations along the River are presented after a long term simulation for the dry-weather condition. The modeled nitrate and phosphate concentrations along the River are presented in Figure 4.1 and Figure 4.2, respectively. The maximum and minimum nitrate and phosphate concentrations of measured data between 2006 and 2008 are shown in theses figures. Comparison of model results with the available stream measured data at various locations in the watershed demonstrates that the highest concentration for nitrate and phosphorus constituents along the Ventura River is located at downstream of Ojai WWTP discharge location.

The predicted concentrations of total nitrogen and total phosphorus along the River for the existing and reduction scenarios are presented in Figure 4.3 and Figure 4.4, respectively.

The relationship between chlorophyll a and total nitrogen concentration is established and presented in Figure 4.5 by using the model results and available measured data. It can be seen that for chlorophyll a of 150 mg/m^2, the total nitrogen concentration is 1.15 mg/L. Similarly, the relationship between chlorophyll a and total phosphorus is presented in Figure 4.6 and the corresponding total phosphorus concentration for chlorophyll a of 150 mg/m^2 is 0.067 mg/L.

It can be seen from Figures 4.3 and 4.4 that the existing condition of source inputs cannot meet the required total nitrogen and total phosphorus concentrations for the length of the river between Foster Park and Shell Road and between Stanley Drain and Main Street. However, the modeled results for the reduction scenario showed that the required concentrations can be met all along the Ventura River.

4.3 Model Prediction for the Estuary

To calculate nutrient concentrations in Ventura River Estuary for the specified nutrient loading from the upstream watershed, the California Nutrient Endpoints (NNE) BATHTUB spreadsheet model (version 13) is used. The input parameters of the NNE BATHTUB spreadsheet model are listed in Table 4.4.

Table 4.4 - Input Information for California BATHTUB Spreadsheet Model

Input Parameters	Values	Remark
Lake volume	$0.058877 \times 10^6 \ m^3$	surface area x average depth
Surface area	$52602 \ m^2$	Estimated based on remote sensing imagery
Average depth	1.12 m	Estimated based on measured data
Mixed depth	0.90 m	80 % of average depth
Net evap-precip rate	63 in/year	Gage data
Secchi depth at typical Chl-a	0.5 m	Field data
Typical Chl-a	9.2 ug/L	Field data
P load	932 kg	See Staff Report
N load	7250 kg	See Staff Report
Ortho P load	954 kg	See Staff Report
Inorg N load	4388 kg	See Staff Report
Inflow	$6.56 \ hm^3$	See Staff Report

The predicted growing season water quality concentrations for total nitrogen, total phosphorus, average chlorophyll a, and median secchi depth are presented in Figure 4.7. It can be seen that the concentration of total nitrogen in Ventura River Estuary is estimated to be 1.06 mg/L, which is close to the value of 1.18 mg/L in the river mouth as shown in Figure 4.3 predicted by QUAL2K model.

5.0 Summary

A nutrient model using the QUAL2K framework has been developed and calibrated and validated through comparisons with measured data for the Ventura River watershed. The calibration results show that the model predicts reasonably well for nitrate-nitrogen, total nitrogen, total phosphorus and benthic chlorophyll-a using data from 2008. In addition, the model was validated reasonably well for flow rate and nitrate-nitrogen using data sets from 2006 and 2007.

After completing model calibration and validation for hydrology and water quality, the model was applied to the selected modeling scenarios including the existing condition. The modeled results for the existing and load reduction scenarios demonstrated that the current loadings from Ojai WWTP and other sources should be reduced by at least half of the existing loads so that the required concentrations of of 1.15 mg/L total nitrogen and 0.067 mg/L total phosphorus can be met.

The relationship between chlorophyll a and total nitrogen and total phosphorus are established based on the model results and observed data. If a chlorophyll a value of 150 mg/m^2 is selected as a numeric target, the total nitrogen and total phosphorus concentrations are found to be 1.15 mg/L and 0.067 mg/L from these relationships.

6.0 References

1. "Source Assessment Report: Nitrogen and Phosphorus in the Ventura River Watershed", prepared by Larry Walker Associates, prepared for Ojai Valley Sanitary District, August 2009.
2. "An Assessment of Numeric Algal and Nutrient Targets for Ventura River Watershed Nutrient Total Maximum Daily Loads (TMDLs)", Final Report, prepared by University of California, Santa Barbara, prepared for Los Angeles Regional Water Quality Control Board, May 2009.
3. "Baseline Model Calibration and Validation Report, Ventura River Watershed Hydrology Model", prepared by Tetra Tech, prepared for Ventura County Watershed Protection District, April 2009.
4. "Data Summary Report, Ventura River Watershed Hydrology Model", prepared by Tetra Tech, prepared for Ventura County Watershed Protection District, June 2008.
5. "Hydrology, Hydraulics, and Sediment Studies for the Matilija dam Ecosystem Restoration Project, Ventura, California", Draft Report, U.S. Department of the Interior Bureau of Reclamation, November 2006.

6. "QUAL2K: A Modeling Framework for Simulating River and Stream Water Quality: Documentation and Users Manual." S.C.Chapra and G.J Pelletier. 2003.Civil and Environmental Engineering Dept.,Tufts University, Medford, MA.
7. "Ventura River Flows and Estuary Conditions" Final Report prepared by Tetra Tech, prepared for U.S. EPA Region IX, June 22, 2012.
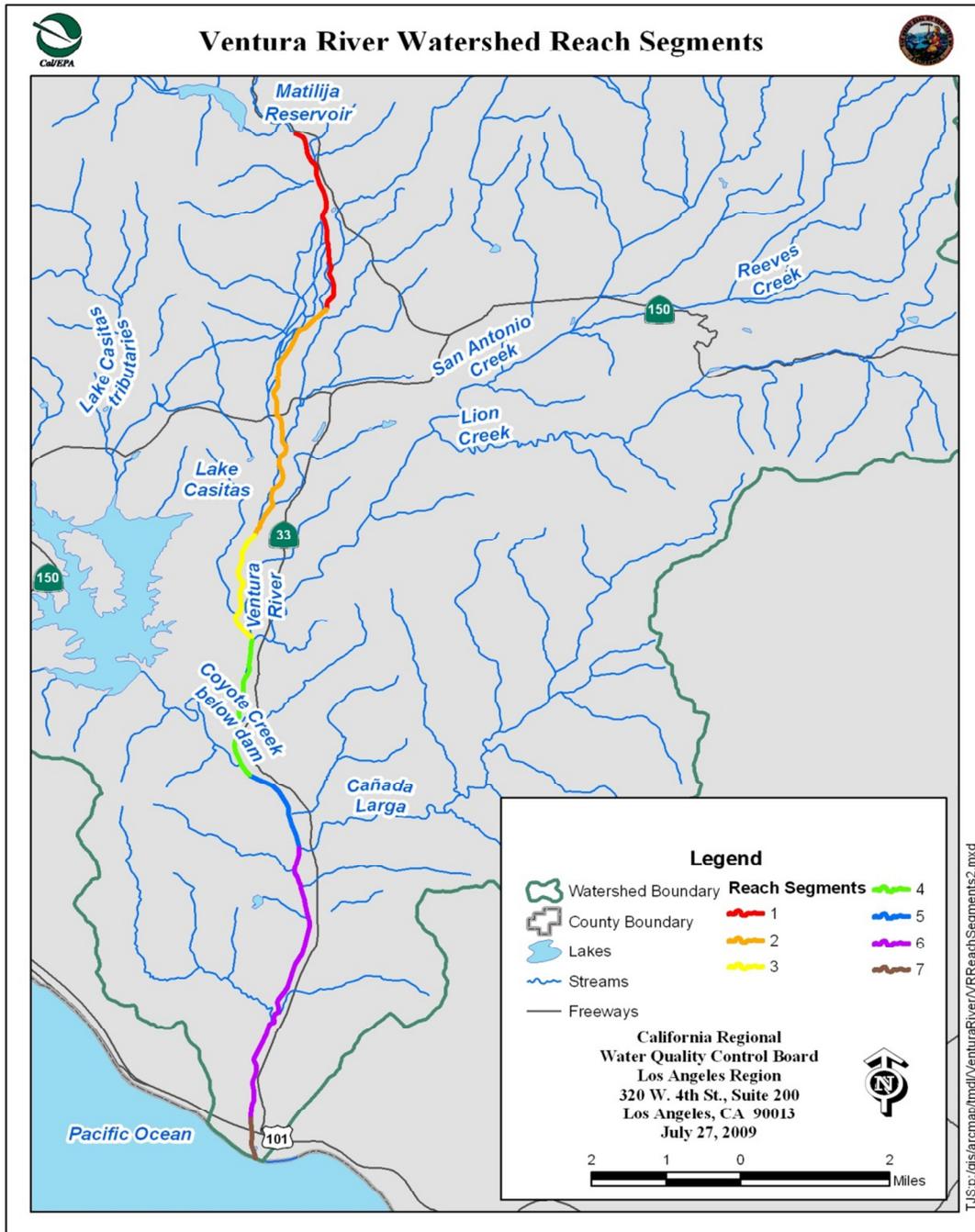
Figure 2.1 Map of Ventura River watershed and model segmentations
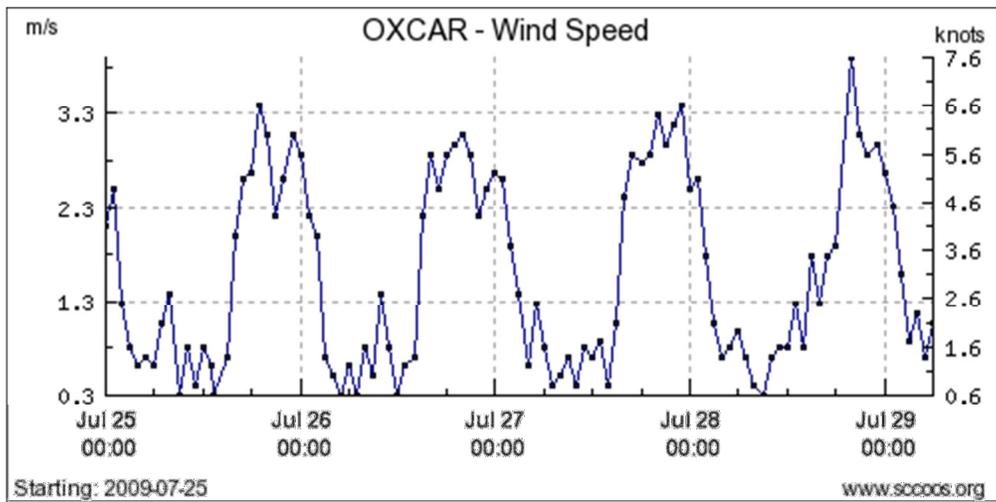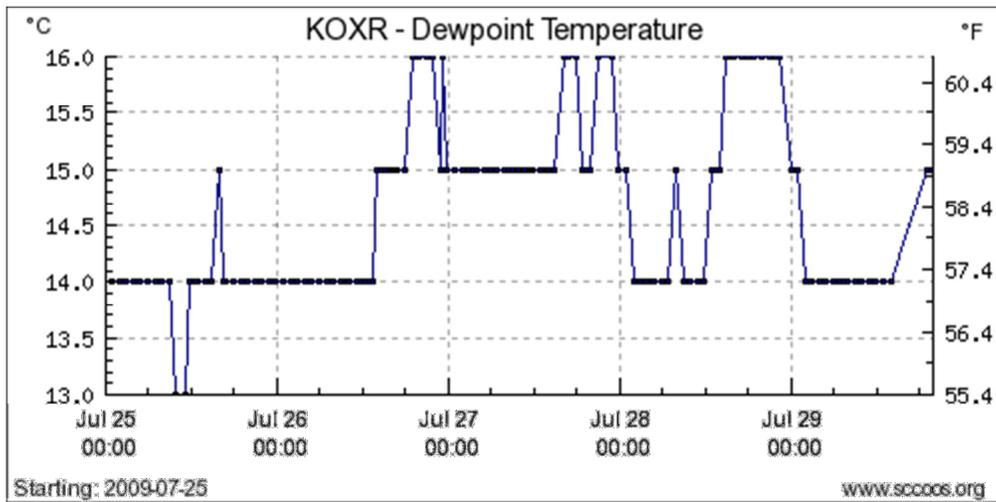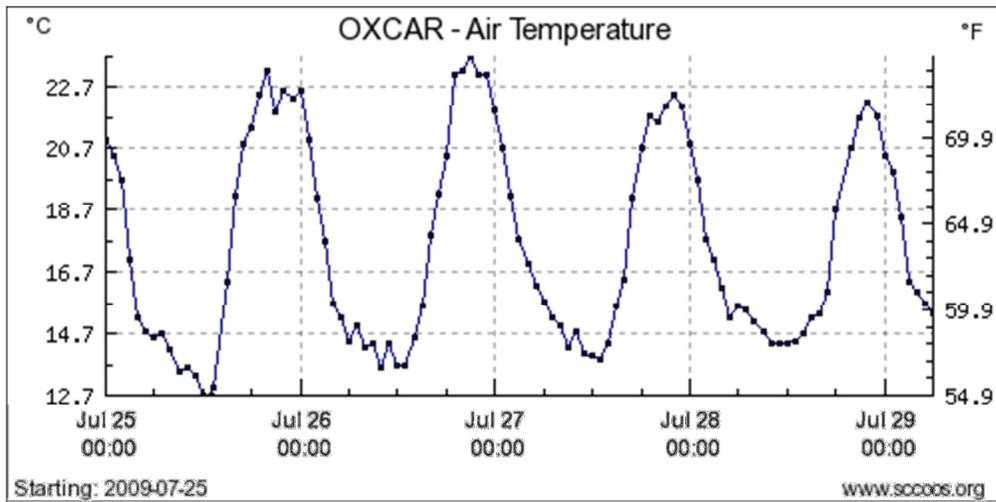
Figure 3.1 Air temperature, dewpoint temperature and wind speed data at Oxnard used in the Ventura River model
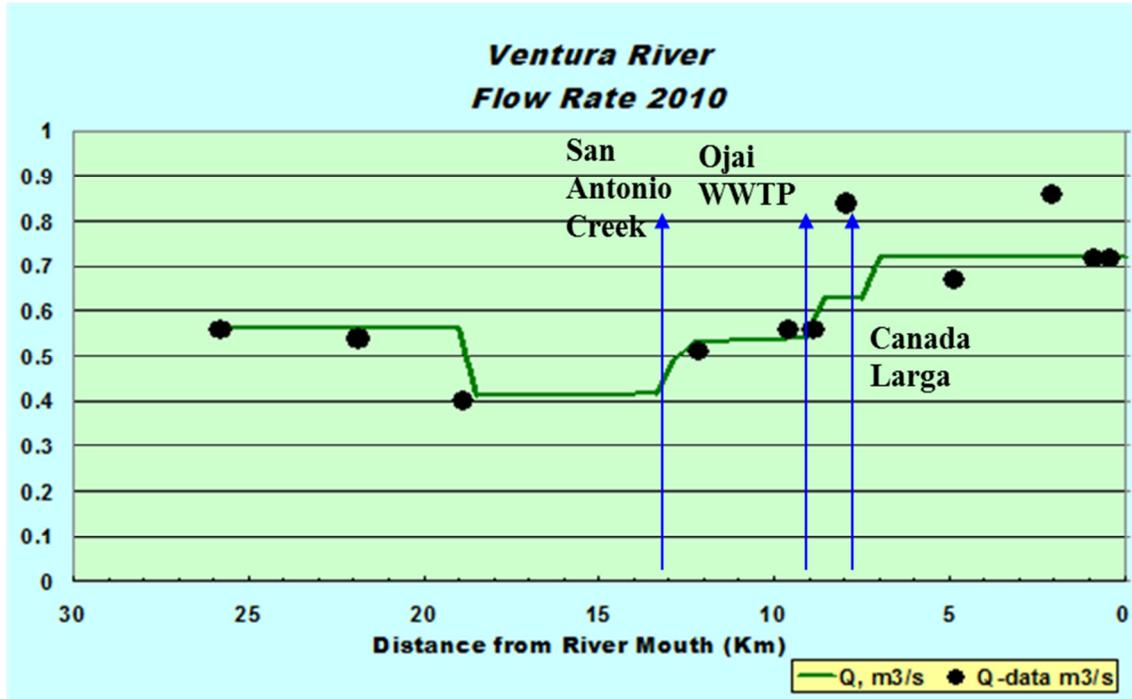
Figure 3.2.Comparison of calculated flow rate with observed data in 2010 for
model calibration
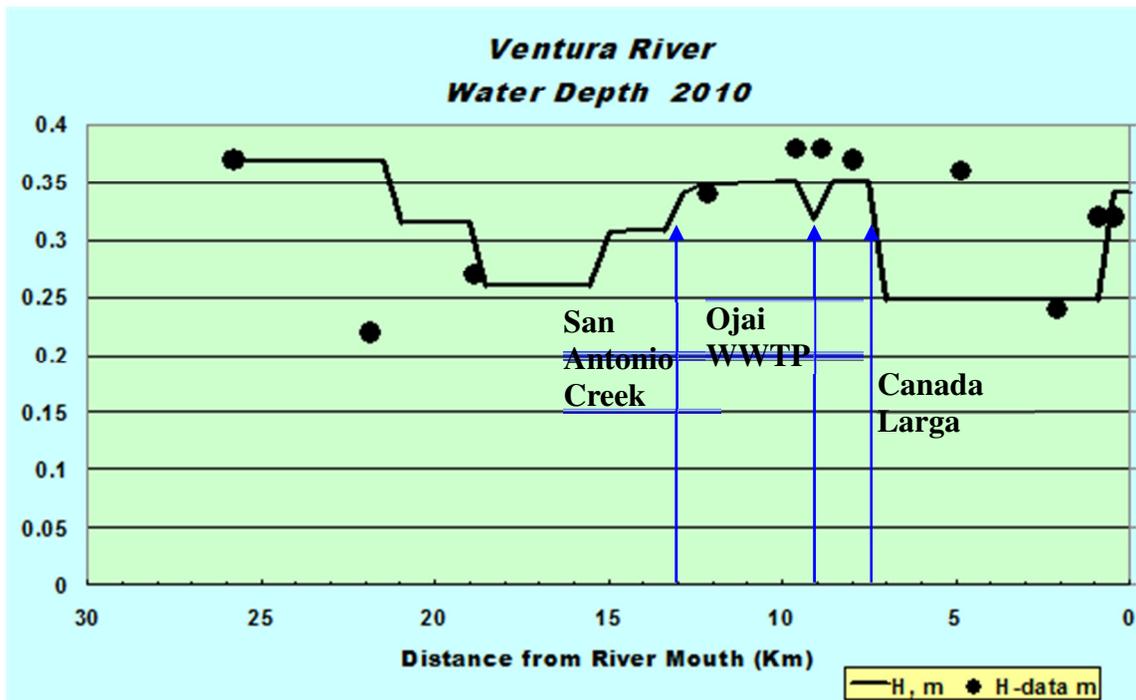
Figure 3.3.Comparison of calculated water depth with observed data in 2010 for
model calibration
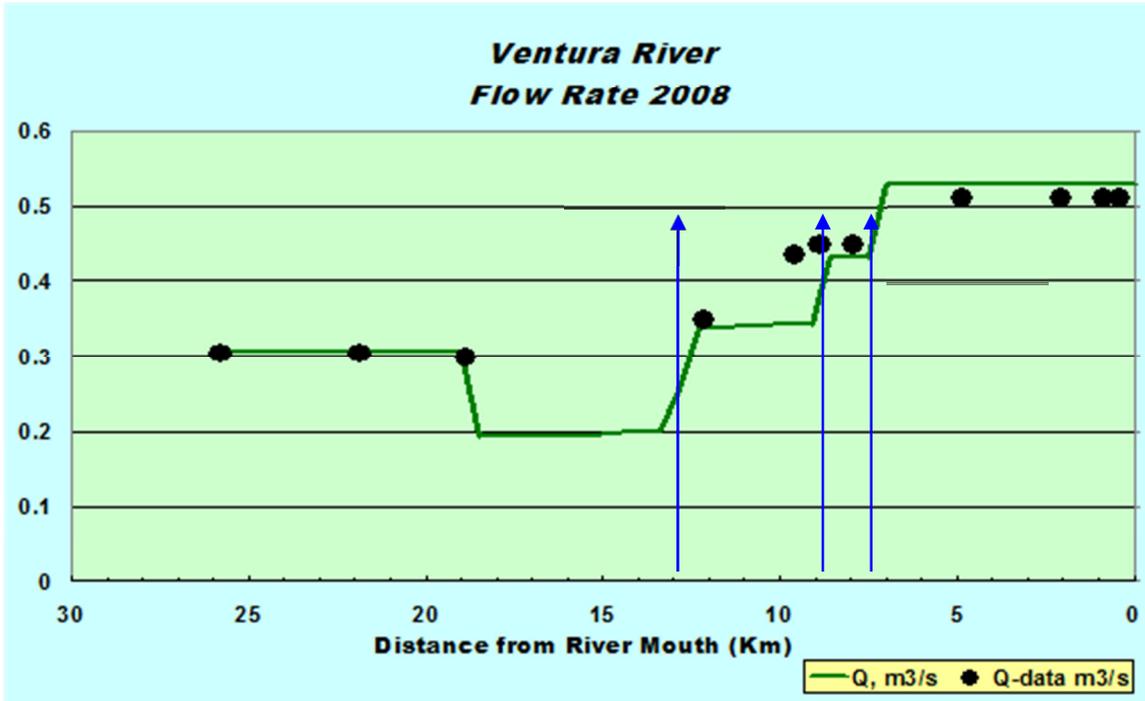
Figure 3.4. Comparison of calculated flow rate with observed data in 2008 for model calibration
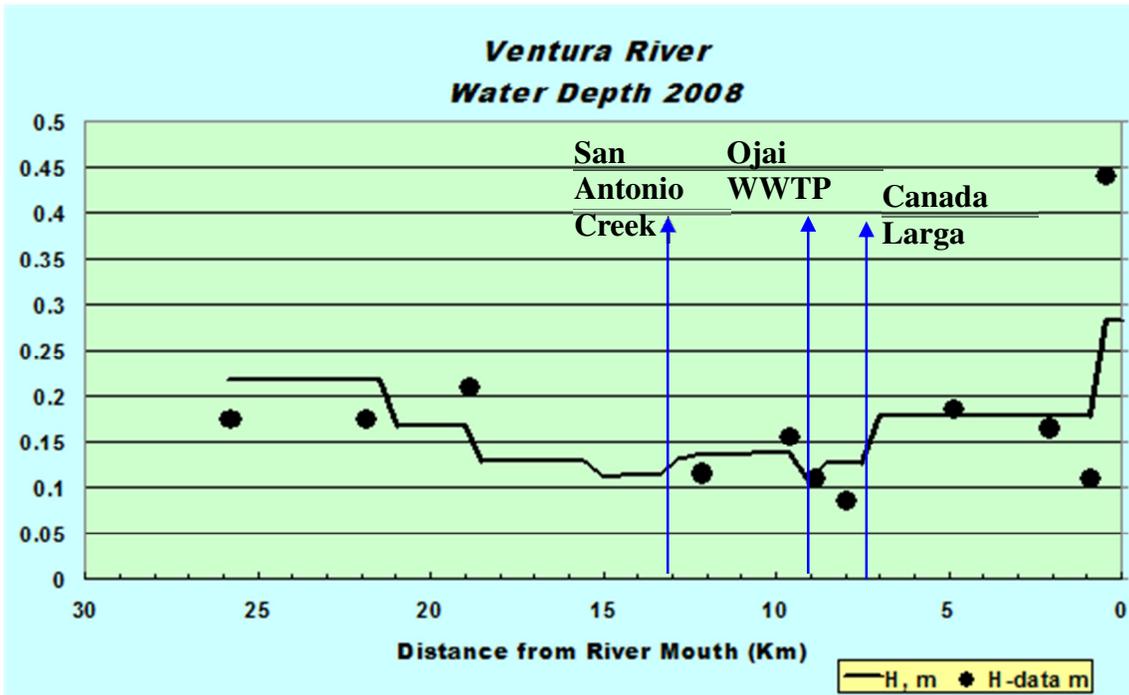
Figure 3.5. Comparison of calculated water depth with observed data in 2008 for model calibration

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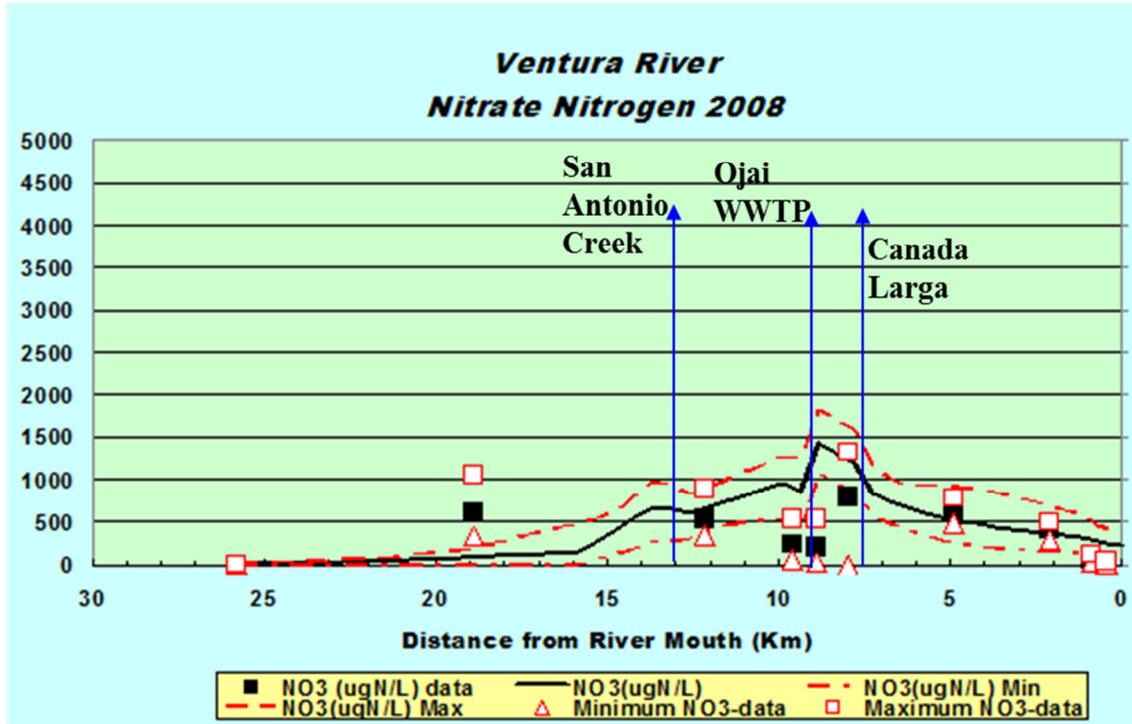
Figure 3.6.Comparison of calculated nitrate nitrogen with observed data in
2008 for model calibration
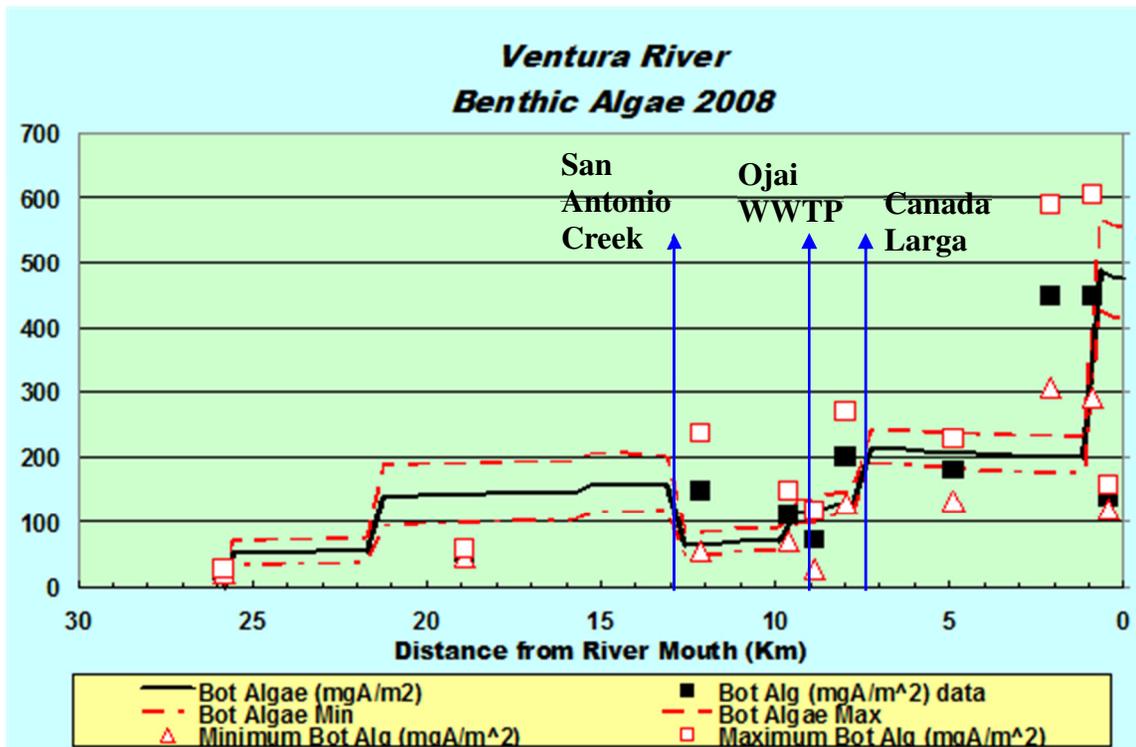
Figure 3.7.Comparison of calculated Benthic Algae with observed data in 2008
for model calibration
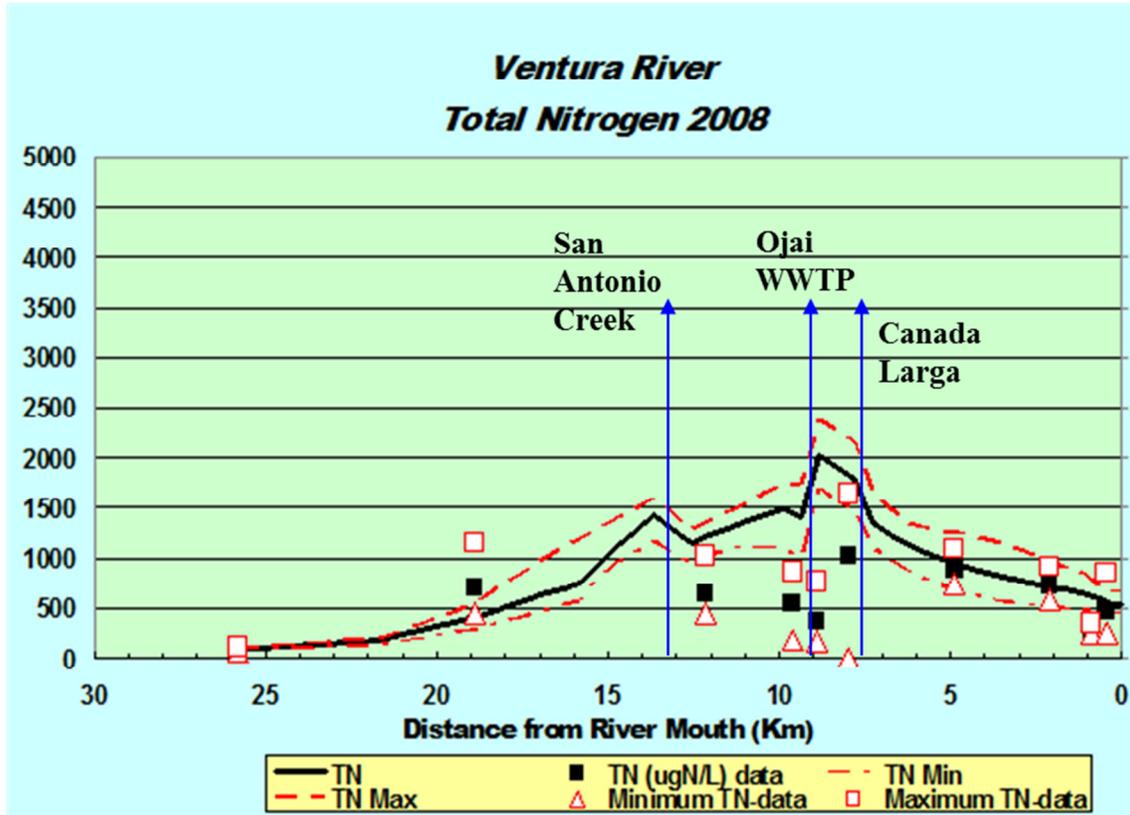
Figure 3.8.Comparison of calculated total nitrogen with observed data in
2008 for model calibration
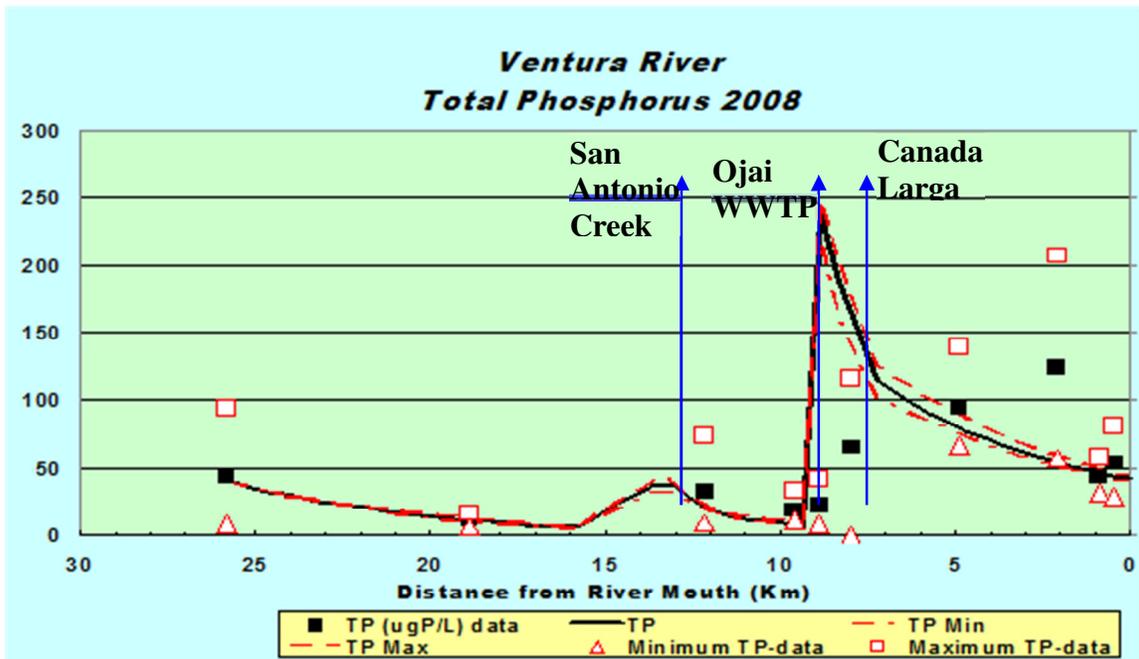
Figure 3.9.Comparison of calculated total phosphorus with observed data in
2008 for model calibration
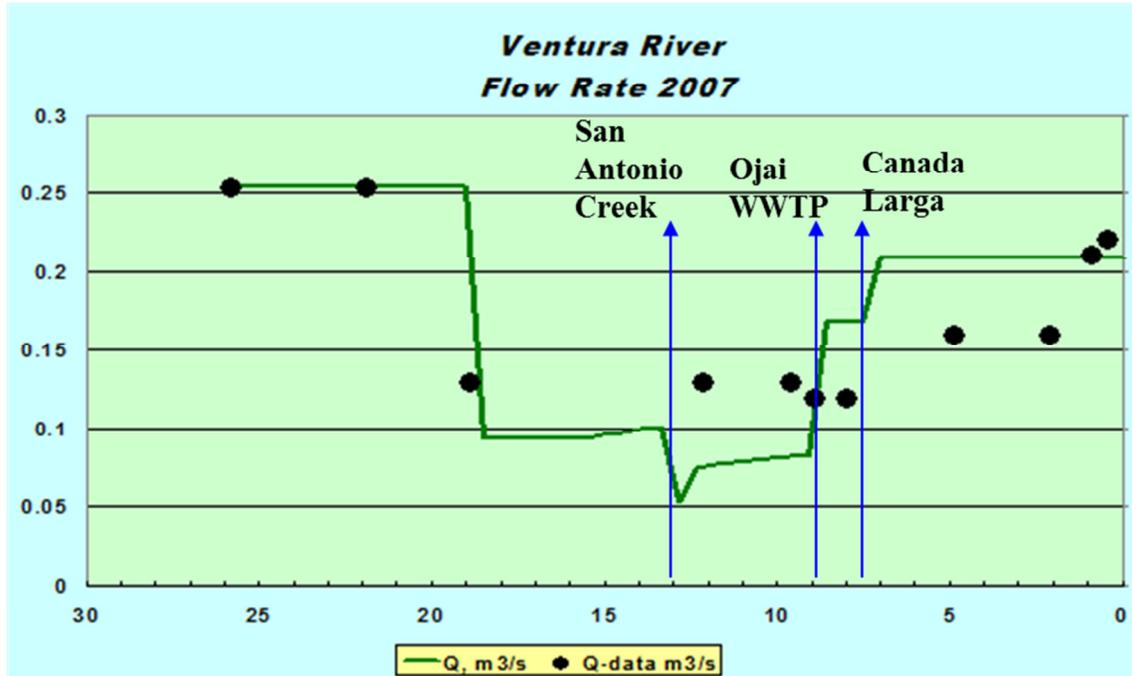
Figure 3.10 Comparison of calculated flow rate with observed data in
2007 for model validation
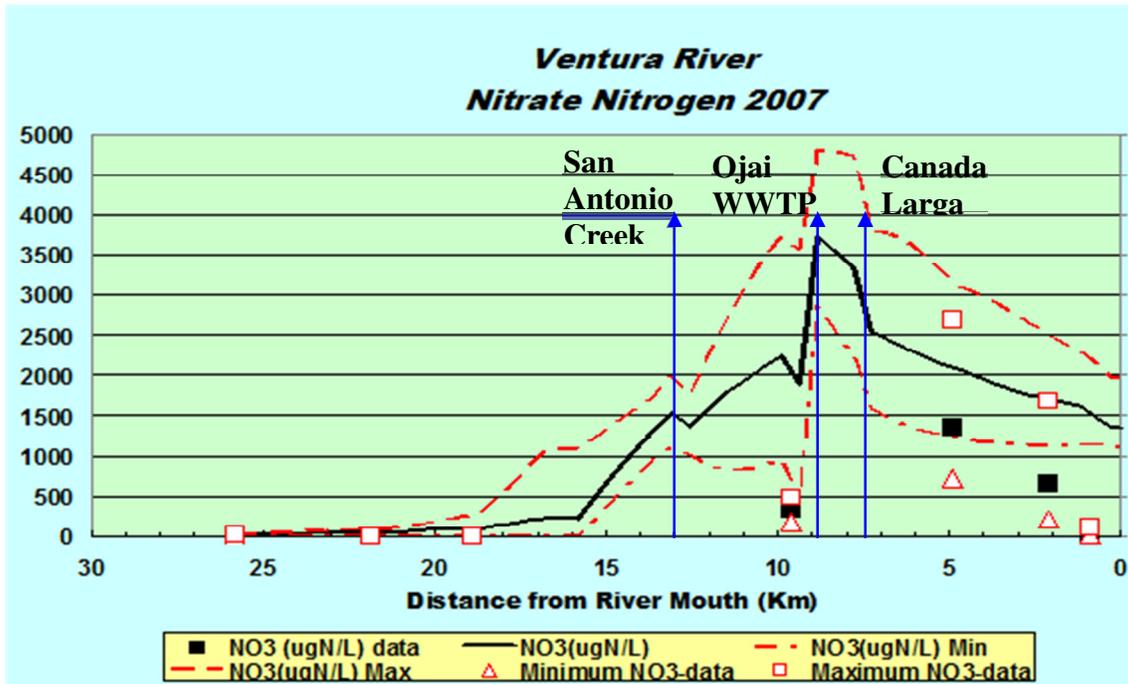
Figure 3.11 Comparison of calculated nitrate nitrogen with observed data in
2007 for model validation
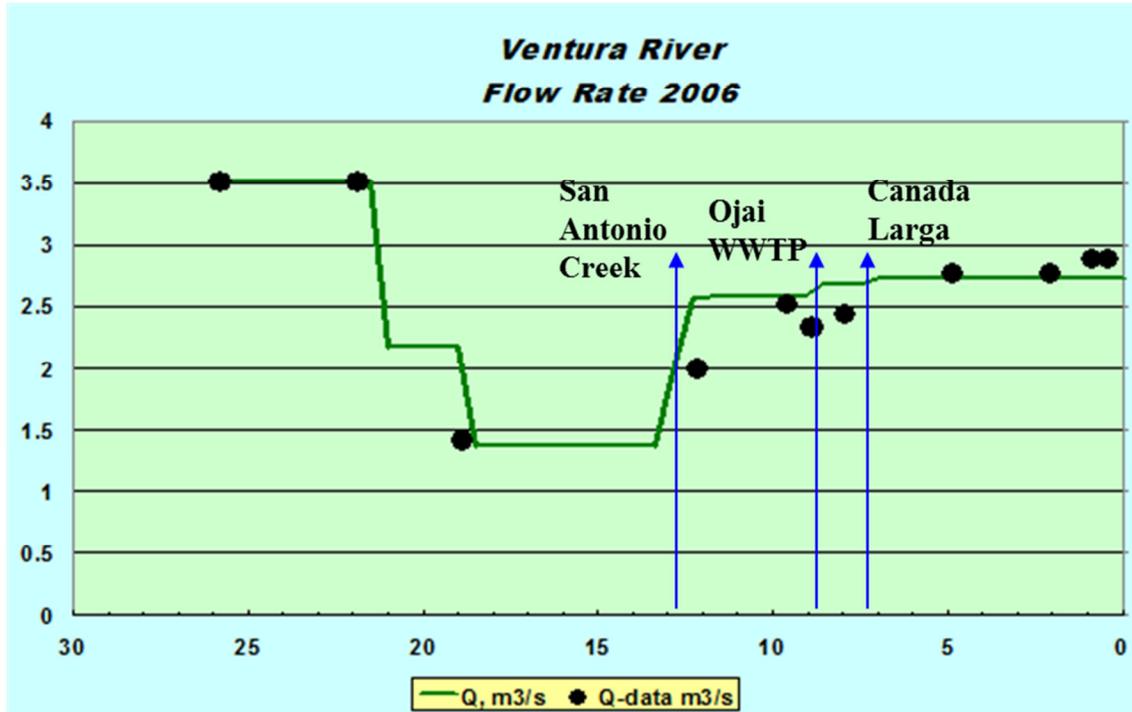
Figure 3.12 Comparison of calculated flow rate with observed data in
2006 for model validation
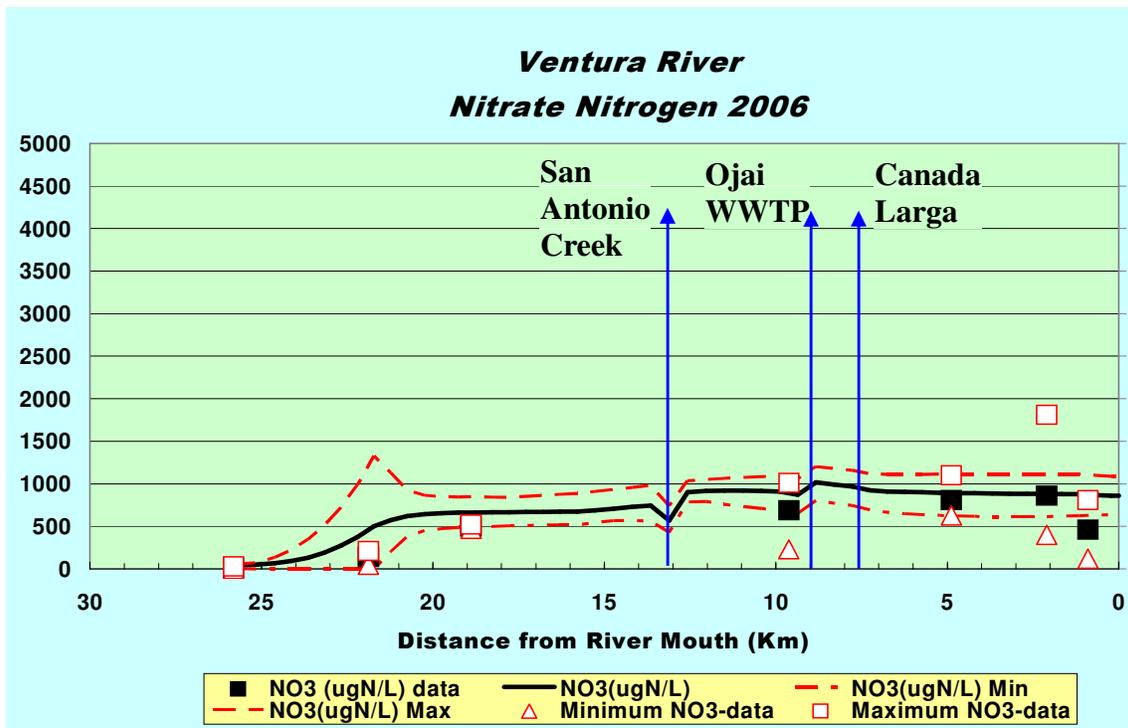
Figure 3.13 Comparison of calculated Nitrate Nitrogen with observed data in
2006 for model validation

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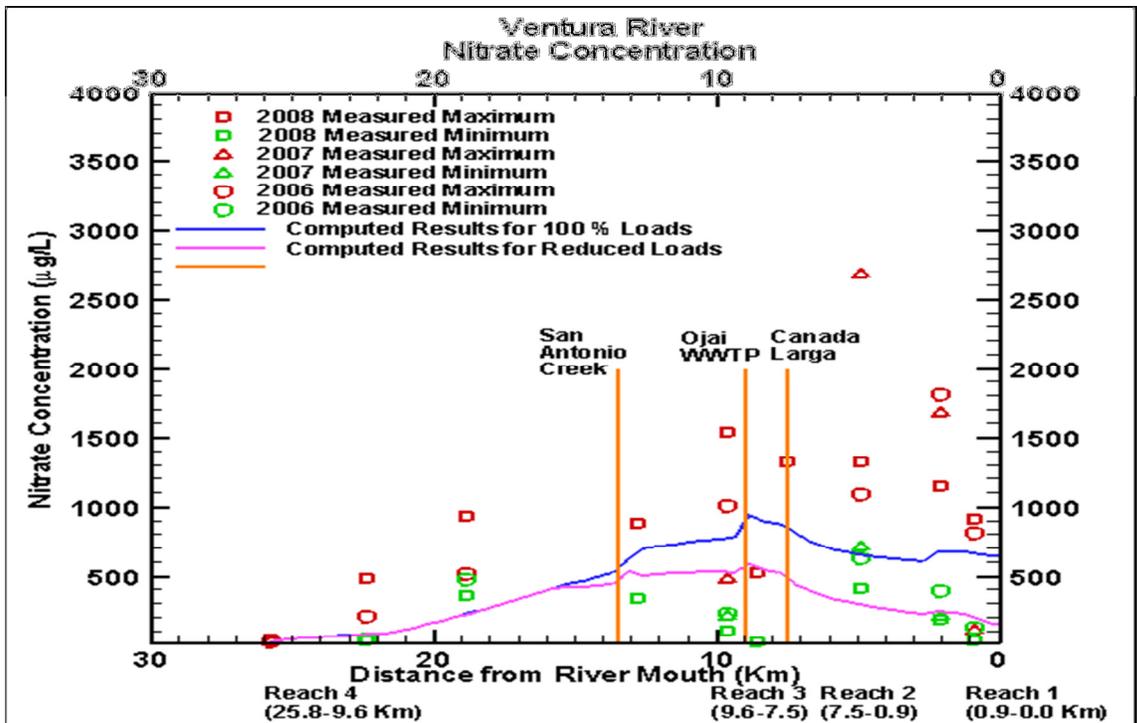
Figure 4.1 Nitrate concentrations along the Ventura River for different modeling scenarios in the periods of 2006 through 2008.
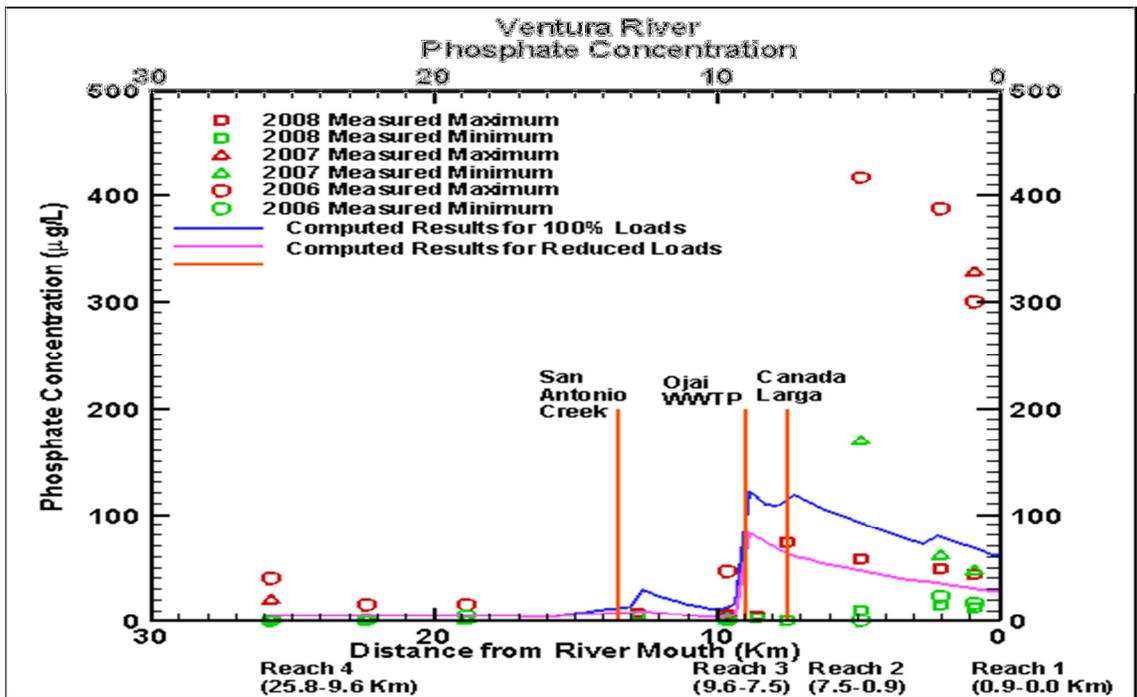
Figure 4.2 Phosphate concentrations along the Ventura River for different modeling scenarios in the periods of 2006 through 2008.
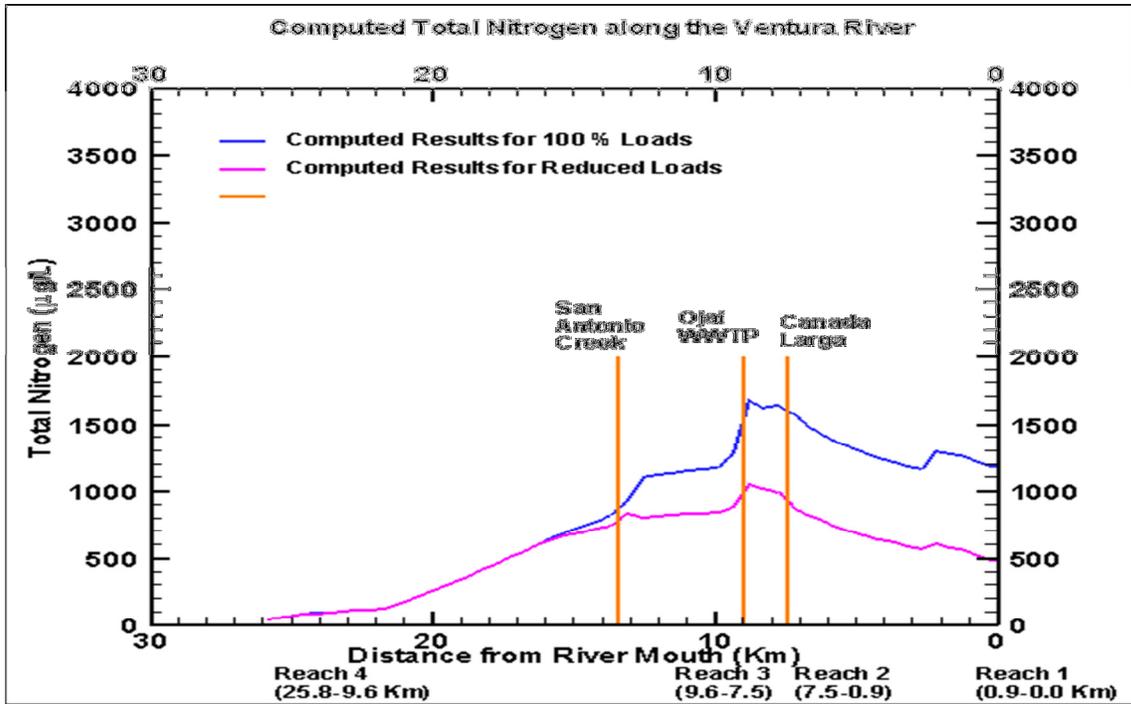
Figure 4.3 Total nitrogen concentrations along the Ventura River for different
modeling scenarios.
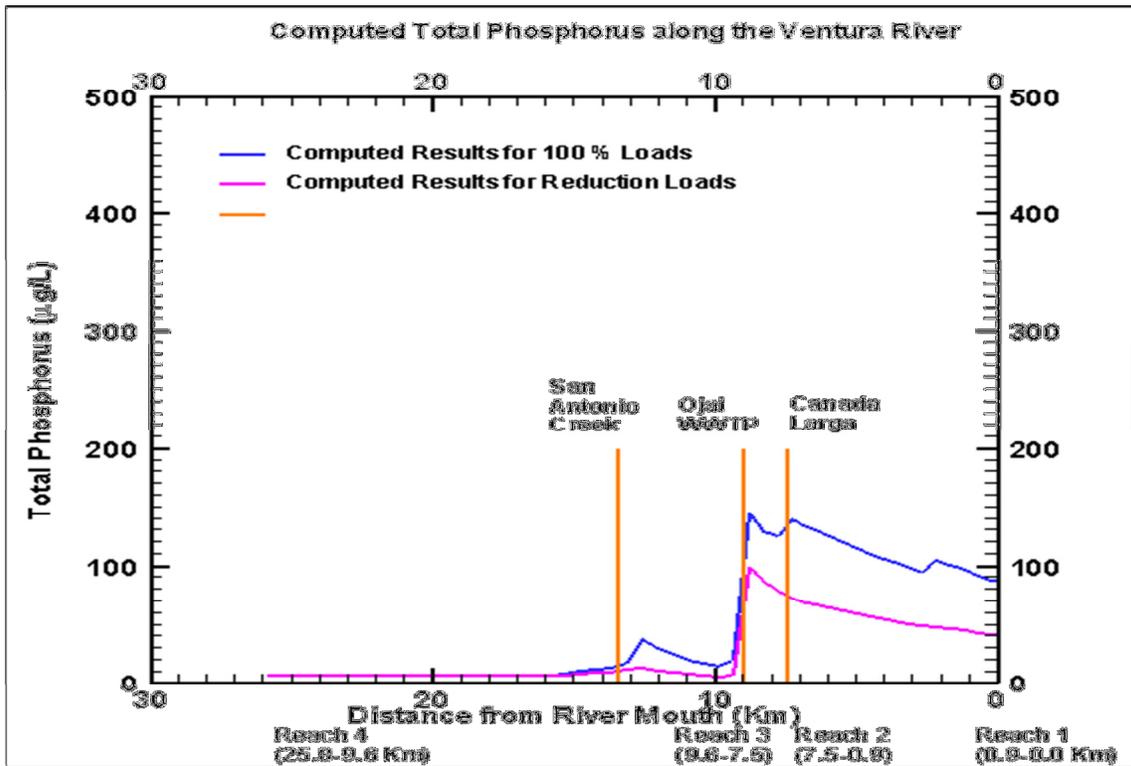
Figure 4.4 Total phosphorus concentrations along the Ventura River for different
modeling scenarios.
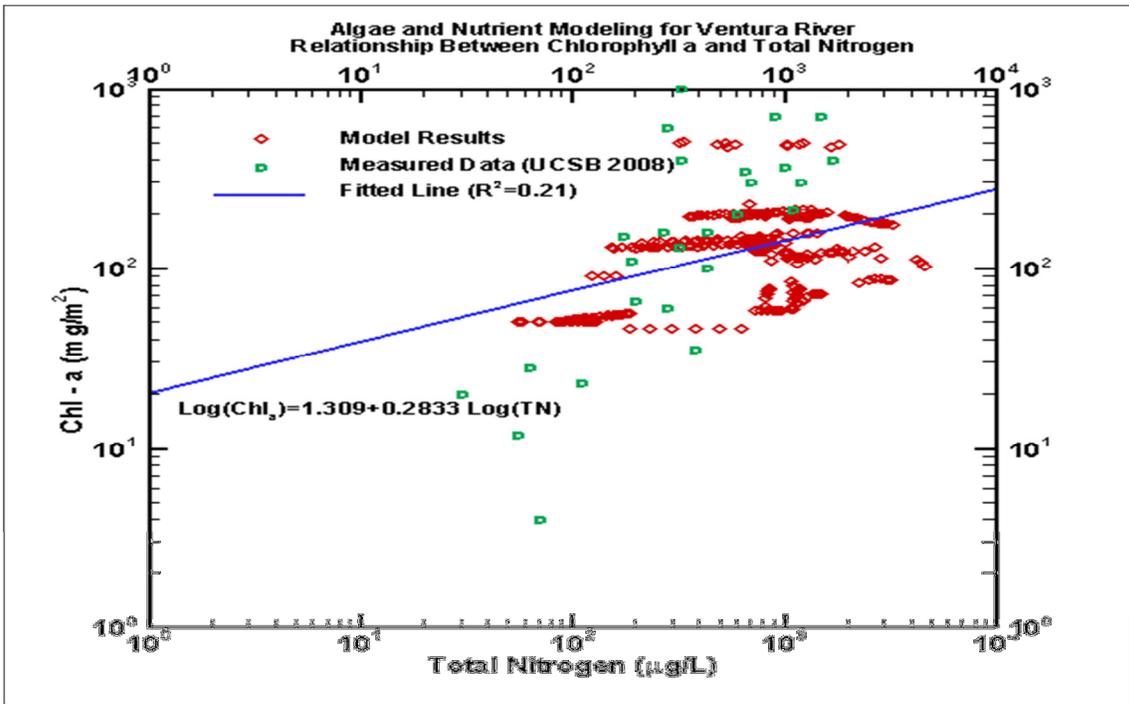
Figure 4.5 Relationship between chlorophyll a and total nitrogen concentrations in the Ventura River.
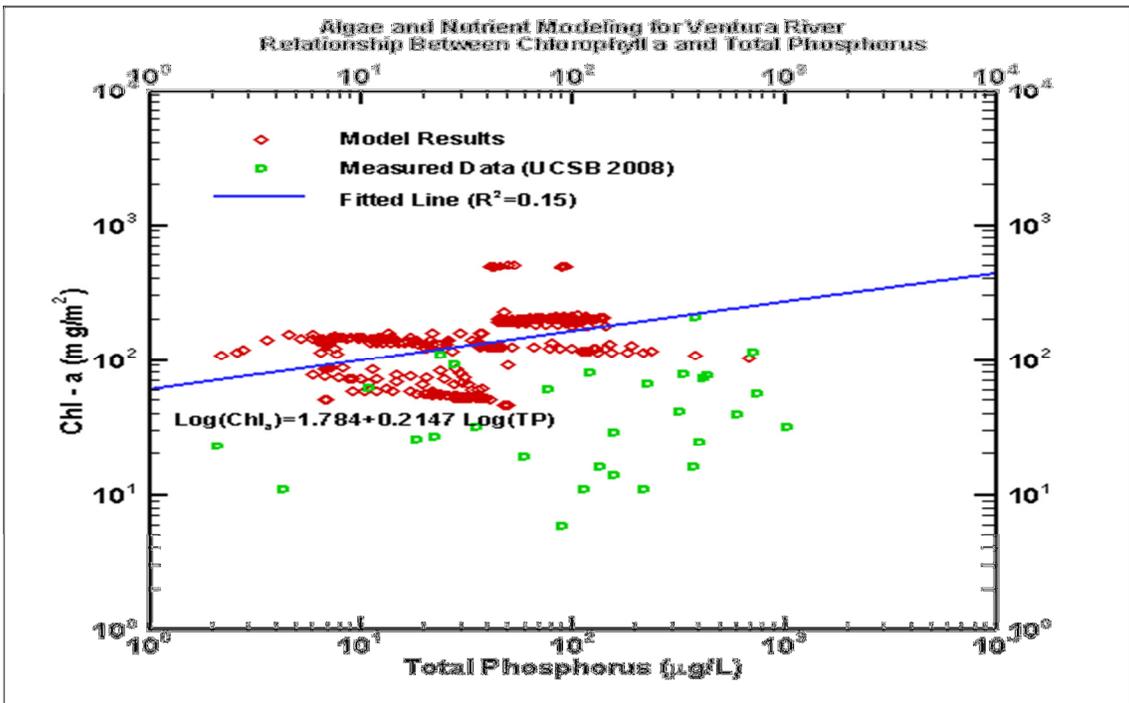
Figure 4.6 Relationship between chlorophyll a and total phosphorus concentrations in the Ventura River.

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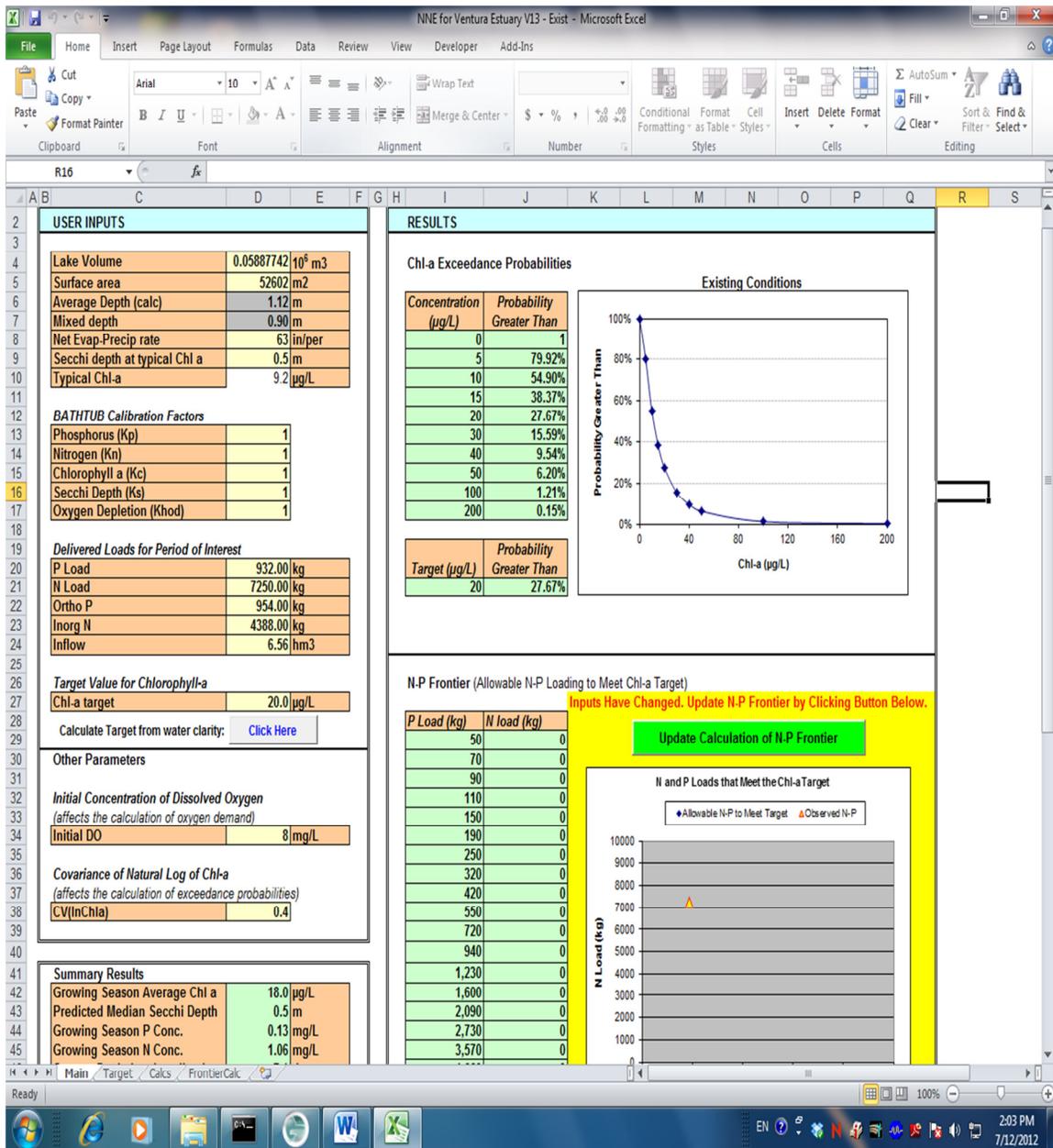
Figure 4.7 Predicted total nitrogen and total phosphorus concentrations induced by the loads entering into the Estuary from upstream of Ventura River Watershed by using NNE BATHTUB Spreadsheet Model.

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