Linkage Analysis For

Santa Clara River Nutrient TMDL Analysis
Parts I and II: Hydrology and Water Quality

Prepared for

Santa Clara Nutrient TMDL Steering Committee

On behalf of the
Los Angeles Regional Water Quality Control Board and
Watershed Stakeholder Groups

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I. Introduction

Background

The Los Angeles Regional Water Quality Control Board (LA RWCB) has determined that several segments and tributaries of the Santa Clara River do not meet the water quality criteria for their beneficial uses. As a result, these segments are listed on the 1998 303(d) list of impaired waters. The impairment is caused by excessive ammonia, nitrite/nitrate, organic enrichment, and low dissolved oxygen. Based on consent decree, Total Maximum Daily Loads (TMDLs) must be determined to protect the beneficial uses including recreation, wildlife habitat, and municipal, industrial, and agricultural supply. (LA RWCB 2002)

Objective

The Santa Clara River watershed drains an area of 1,618 square miles, with a wide variety of land uses including mountain forest, urbanized areas, and agricultural land. The watershed lies in Los Angeles and Ventura Counties, California. The flow is highly seasonal and dominated by winter storm events.

The process for TMDL determination involves five steps:

1. Assess the sources of pollution loads in the watershed,
2. Link pollution loads to numerical water quality targets for the impaired segments;
3. Determine the TMDLs for the impaired stream segments;
4. Provide technical assistance to the stakeholders group to fulfill their tasks in developing implementation plans.
5. Prepare a final report

The final report for task 1, referred to in this document as the “Source Analysis Report”, was completed in August 2002 (Systech 2002). This is the linkage analysis report for task 2.

Linkage Analysis Report

The Source Analysis Report lists all sources of point and nonpoint source pollutant load within the Santa Clara River watershed. The purpose of the linkage analysis is to determine the relationships between the pollutant loads and the water quality of river segments in the watershed. This requires determining what portion of pollutants on the soil surface or in the soil are transported to river segments. The linkage analysis must also show how pollutants may be assimilated within river segments. The key to the linkage analysis is a watershed model capable of simulating the physical and chemical processes that affect river hydrology and water quality.

This report discusses the key processes and assumptions of the watershed model, the primary model parameters adjusted in calibration, and the performance of the model in comparison to observed data. This report evaluates the model for its use in calculating TMDLs for the impaired river segments of the watershed. This includes a sensitivity analysis and a discussion of uncertainty. Accompanying this report is the calibrated watershed model, complete with User's Manual (Herr et al. 2000) and Technical Documentation (Chen et al. 2001).

II. Watershed Summary

Area and Topography

The Santa Clara River watershed drains an area of 1,618 square miles in the Transverse mountain range of southern California as shown in Figure 1. Elevations within the watershed range from sea level at the river's outlet near the city of Ventura to 8,800 feet at the summit of Mount Pinos in the northwest corner of the watershed. There are four reservoirs in the watershed: Pyramid Lake and Lake Piru on Piru Creek, Castaic Lake on Castaic Creek, and Bouquet Canyon Reservoir (small unlabeled reservoir in the northeast part of the watershed).

The land areas upstream of the reservoirs are not believed to significantly contribute to the water quality problems of the Santa Clara River. No point or nonpoint management strategy will be implemented in those areas. Due to the budget limitation, it was decided to exclude the tributary watersheds of Pyramid Lake, Lake Piru, and Castaic Lake from modeling analysis. The releases from Lake Piru and Castaic Lake are treated as external inputs to the remaining 1,052 square mile watershed. Bouquet Canyon Reservoir is included in this analysis because its tributary area is small and flow release records are not available.

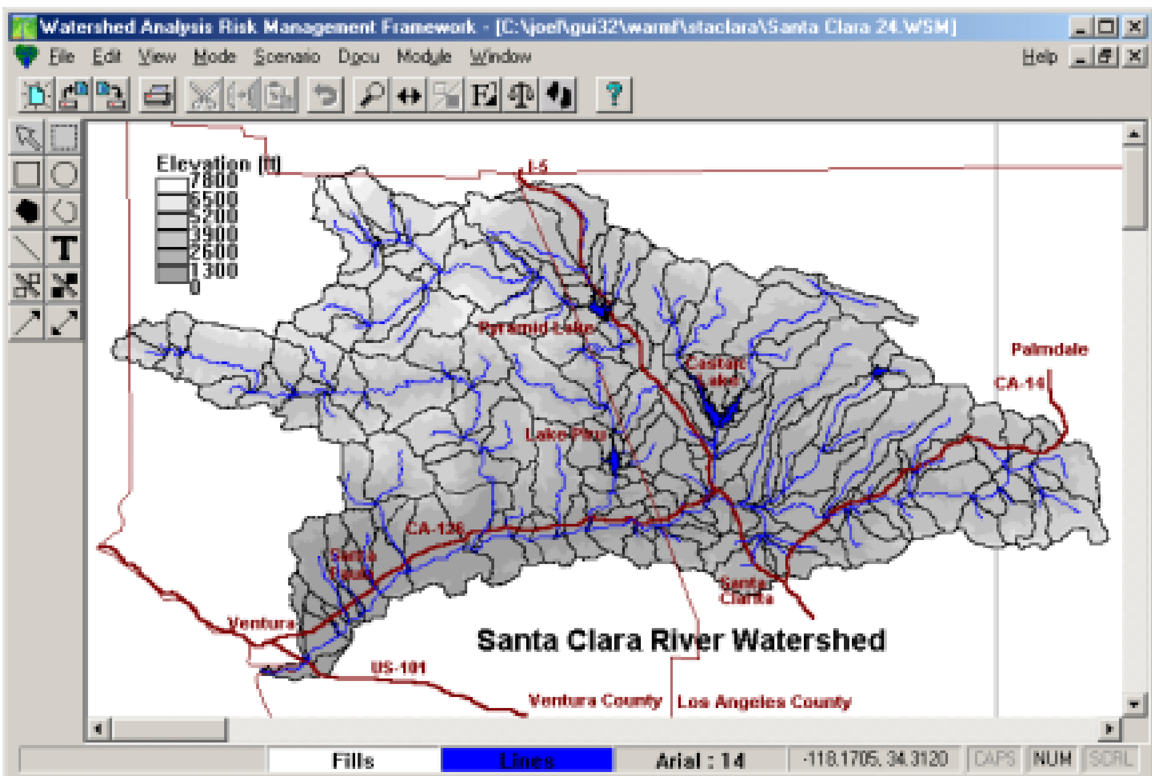

Figure 1: Santa Clara River watershed

Rivers

Rivers in the Santa Clara watershed are broadly defined by topography. Tributaries to the Santa Clara River are relatively narrow and steeply sloping in the canyons to the north of the Santa Clara River. The Santa Clara River itself is a broad sandy wash, only a small portion of which normally contains the shallow flowing water. The Santa Clara River flows generally from east to west from its headwaters south of Palmdale to the Pacific Ocean near Ventura. In identifying river segments, the Santa Clara River has been divided into reaches. There are two separate designations of reaches: one from the United States Environmental Protection Agency (US EPA) and the other from LA RWQCB, as shown in Table 1 and Table 2 (LA RWQCB 2002). ***This report uses the US EPA reach designations***.

Table 1: US EPA Reach designations for the Santa Clara River

Reach	Description
1	Santa Clara Estuary to Highway 101
2	Highway 101 to Freeman diversion dam
3	Freeman diversion dam to above Santa Paula Creek and below Timber Canyon
4	Above Timber Canyon to above Grimes Canyon
5	Above Grimes Canyon to Propane Road
6	Propane Road to Blue Cut gaging station
7	Blue Cut gaging station to west pier Highway 99
8	West pier Highway 99 to Bouquet Canyon Road
9	Bouquet Canyon Road to Lang gaging station
10	Above Lang gaging station

Table 2: LA RWQCB Reach designations for the Santa Clara River

Reach	Description
1	Santa Clara Estuary to Highway 101
2	Highway 101 to Freeman diversion dam
3	Freeman diversion dam to Fillmore “A” Street
4	Fillmore “A” Street to Blue Cut gaging station
5	Blue Cut gaging station to west pier Highway 99
6	West pier Highway 99 to Bouquet Canyon Road
7	Bouquet Canyon Road to Lang gaging station
8	Above Lang gaging station

For the purpose of discussion, the Santa Clara River is divided into eastern, central, and western sections. Figure 2 through Figure 4 show the river reaches of the Santa Clara River and its main tributaries. Reaches and tributaries shown in red are impaired reaches for which a TMDLs must be calculated.

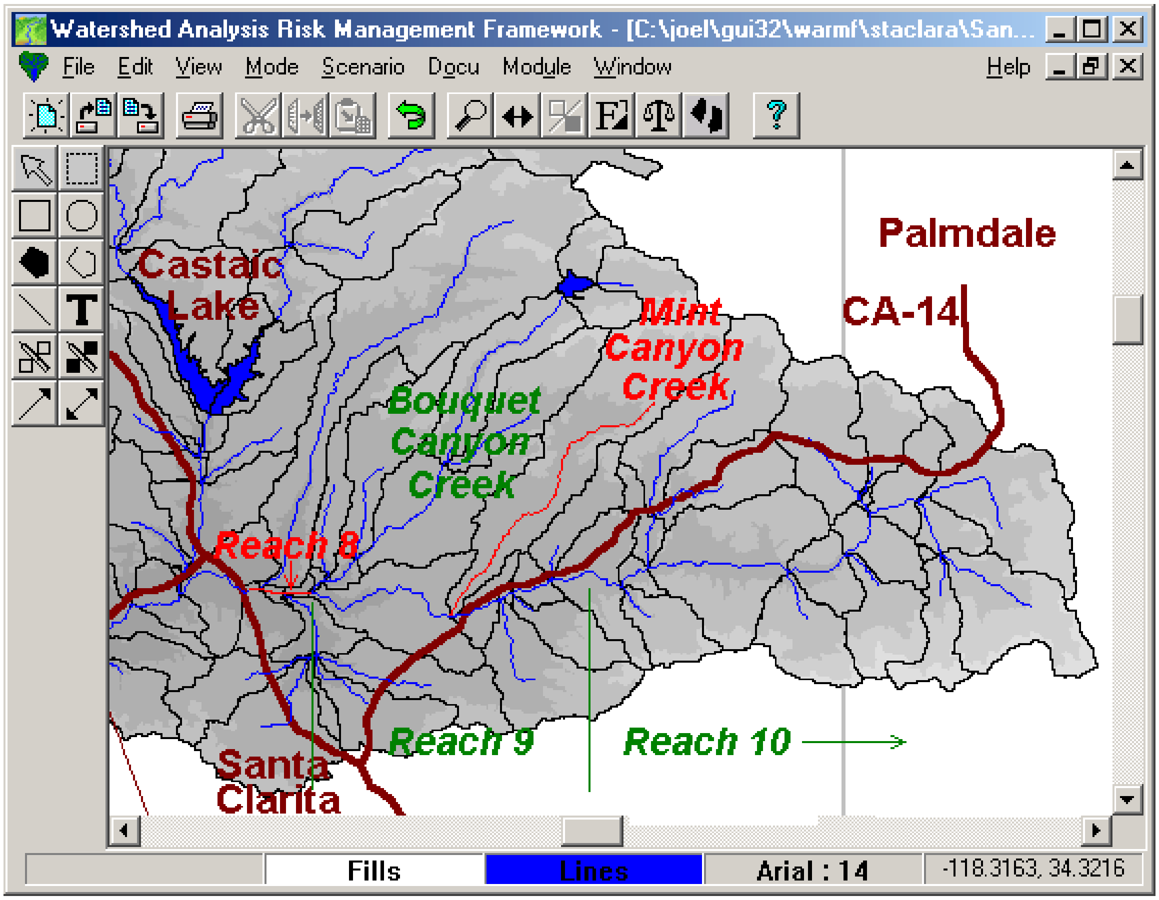

Figure 2: River segments of the eastern Santa Clara River watershed

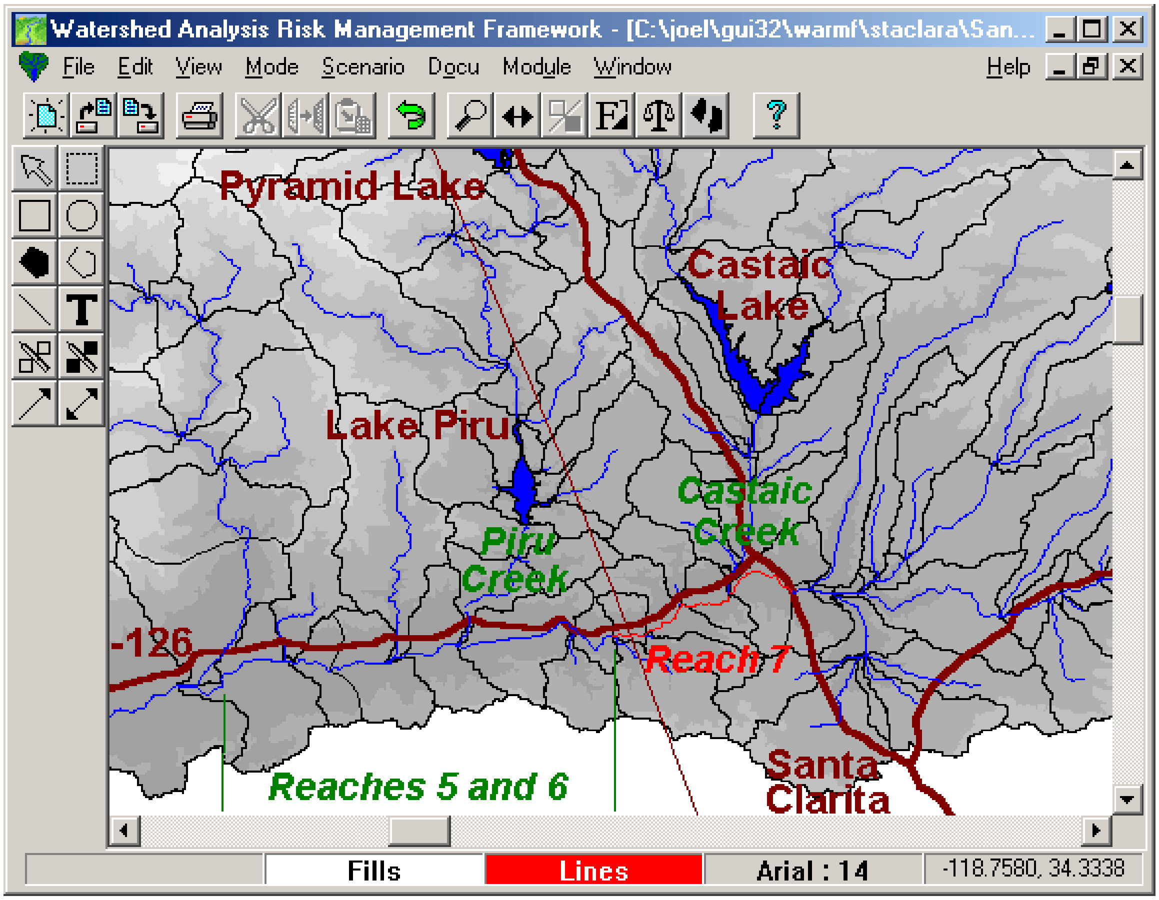

Figure 3: River segments of the central Santa Clara River watershed

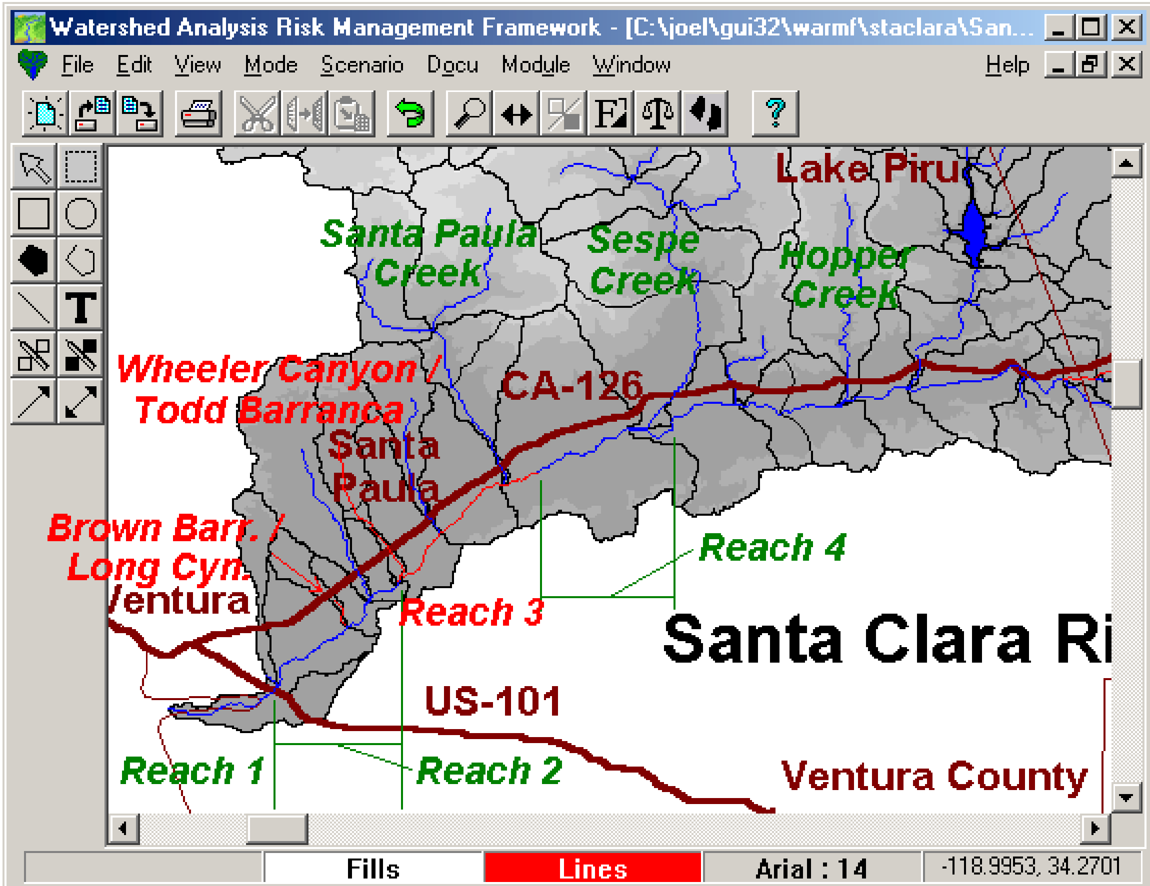

Figure 4: River segments of the western Santa Clara River watershed

Soils and Vegetation

Soils in the watershed can be divided into two basic classes: the upland soils of the mountains and the alluvial soils near the Santa Clara River. The upland soils are approximately one meter thick down to bedrock and the alluvial soils are 18-36 meters thick above an unconfined aquifer (USDA NRCS 1994, UWCD 2002). Native vegetation is approximately 78% scrubland and 17% coniferous forest, with small fractions of other forest, grassland, marsh, and water (US EPA 2001).

Land Use

Approximately 15% of the land in the Santa Clara River watershed has been developed for urban and agricultural use (DWR 2002, SCAG 1993, SCAG 2001). Urban land is primarily in the cities of Ventura, Santa Paula, Fillmore, and Santa Clarita. Agricultural land is primarily in the lowlands near Santa Clara River reaches 1-7. Table 3 shows the land use in each region of the watershed using 2000 data for Ventura County, 1993 data for Los Angeles County, and 2001 data for Santa Clarita.

Table 3: Land use in the Santa Clara River watershed, %

Land Use	Percent
Deciduous	0.51
Mixed Forest	0.92
Orchard	3.92
Coniferous	14.41
Shrub / Scrub	66.30
Grassland	1.98
Park	0.10
Golf Course	0.28
Pasture	0.23
Cropland	0.60
Marsh	0.13
Barren	0.30
Water	0.12
Residential	2.10
High Density Residential	4.84
Comm./Industrial	3.24

Meteorology

The meteorology of the watershed varies greatly by season and by location. Average Annual rainfall varies from 23 cm/year (9 in/year) at the easternmost station in the watershed to 80 cm/year (32 in/year) at a station in the Sespe Creek watershed. 84% of precipitation occurs from December-March (NCDC 2002, Ventura County 2002, LA DPW 2002). Snowfall occurs in the higher altitudes of the mountains in winter. Precipitation is greatest in the mountains and the western part of the watershed. The precipitation decreases eastward across the watershed as shown in Figure 5. Average temperature decreases with increasing elevation and is generally greater inland than along the coast, as shown in Figure 6.

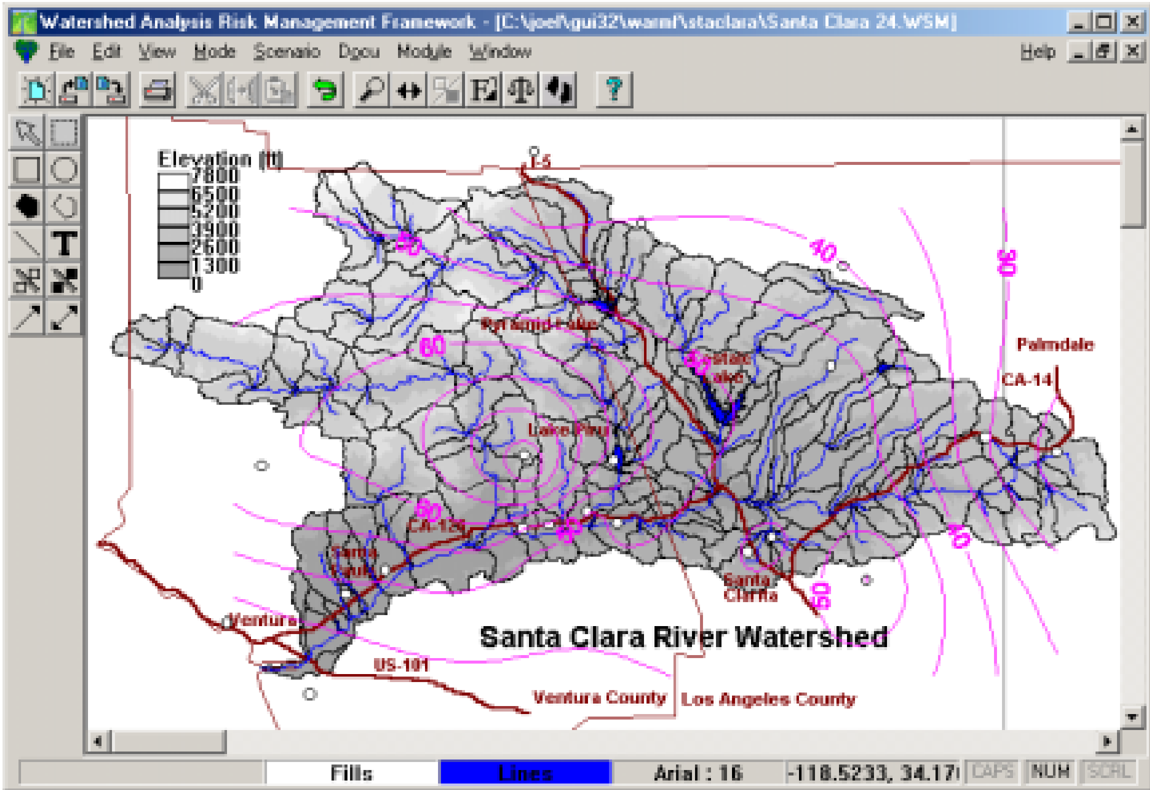

Figure 5: Meteorology stations and precipitation isohyets (cm/year) for the Santa Clara R. watershed

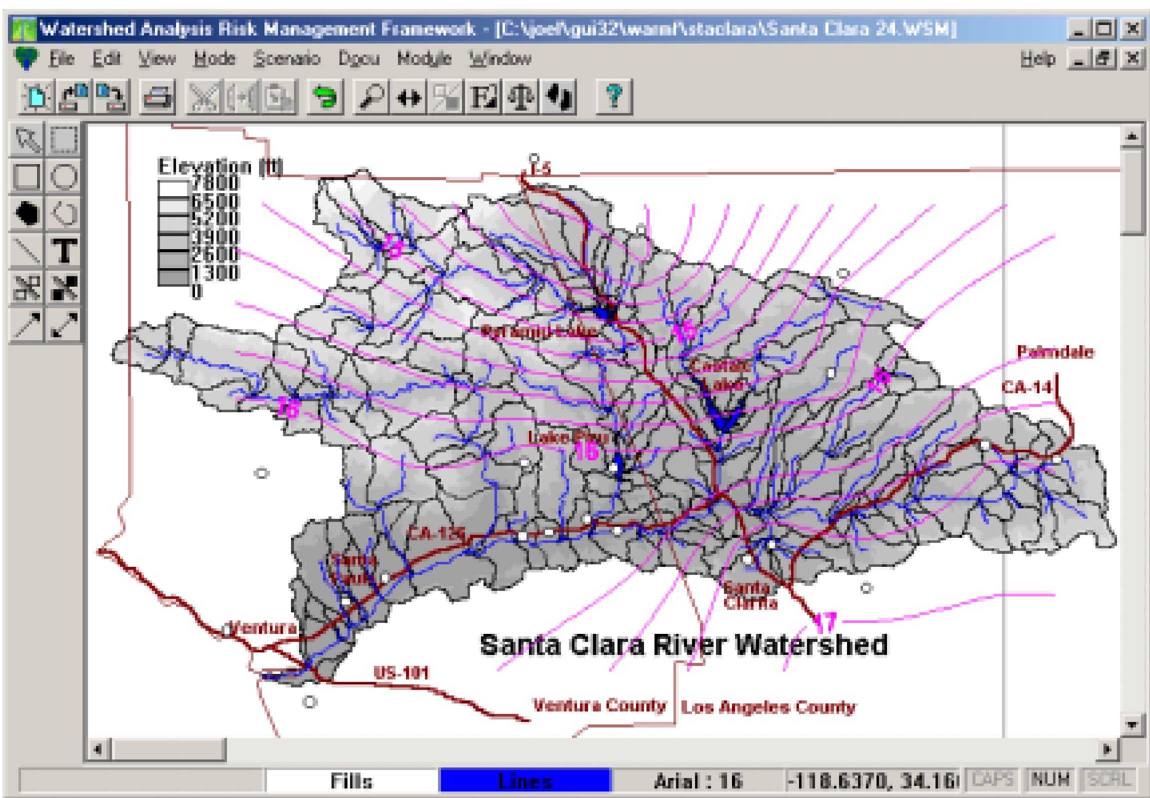

Figure 6: Meteorology stations and temperature isotherms (^{o}C) for the Santa Clara River watershed

Hydrology

The hydrology of the Santa Clara River watershed varies greatly by location. Flow in the western tributaries (Figure 4)is perennial, but flow is intermittent in the eastern part of the watershed (Figure 2). Figure 7 shows the locations of flow gages in the watershed.

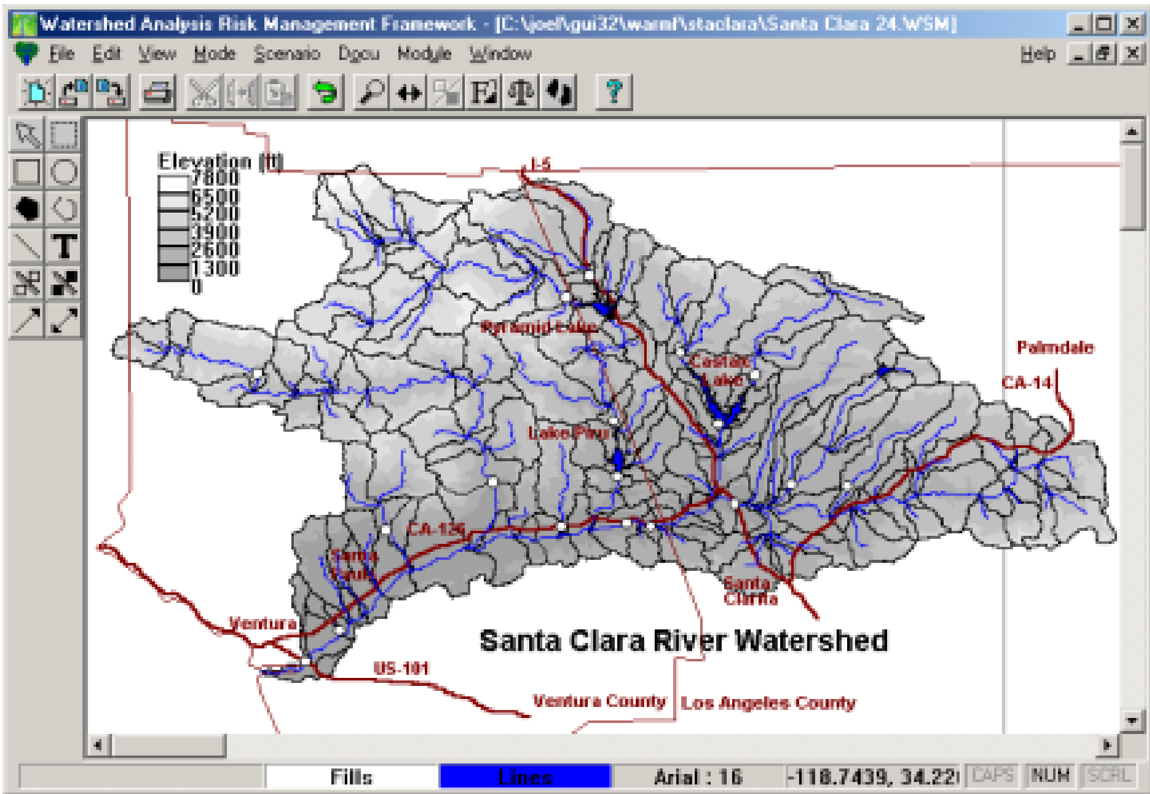

Figure 7: Locations of stream gages

The hydrology changes as the Santa Clara River flows westward from its source south of Palmdale. East of Santa Clarita, flow is intermittent. Reach 9 of the Santa Clara River (Figure 2) has water approximately 66% of the time at its confluence with Bouquet Canyon Creek. Downstream of the Saugus (Reach 8) and Valencia (Reach 7) wastewater reclamation facilities in the vicinity of Santa Clarita, the Santa Clara River has perennial flow. The perennial flow continues to at least the Los Angeles / Ventura county line (Reach 7). From the county line to the Santa Paula area (Reach 4, 5, and 6), there are complex interactions between the surface river water and groundwater. At various locations within this section, the Santa Clara River may be losing water to, or gaining water from, the groundwater. A section of river between the county line and Fillmore is known as the “dry gap” because it rarely contains water. Modeling the hydrology of this river section requires good estimates of where these surface water/groundwater interactions take place and how much water is lost or gained over time.

Hydrologic modeling is key to understanding the fate of pollutants in the watershed. Each source of flow for the Santa Clara River has its own pollutant concentrations. The model must approximate the amount of water coming from each source with as much accuracy as possible under different hydrologic regimes to accurately account for the transport and fate of pollutants.

Water Quality

The water quality of the Santa Clara River is highly dependent upon hydrology. The western tributaries (Figure 4) have naturally lower nutrient concentrations than the eastern tributaries (Figure 2) because the natural vegetation has higher productivity to remove nutrients from the soil and because they have much more flow per unit land area to flush out pollutants. The water quality of the Santa Clara River from Santa Clarita to its outlet is heavily influenced by point sources and groundwater interactions.

Table 4 shows the river segments not meeting their water quality objectives as identified by the Los Angeles Regional Water Quality Control Board in 1998 (LA RWQCB 2002). The locations of the impaired segments are shown in red in Figure 2 through Figure 4.

Table 4: Impaired river segments of the Santa Clara River watershed

River Segment	Cause of Impairment
Mint Canyon Creek	Nitrate, nitrite
Santa Clara River Reach 8	Ammonia, nitrate, nitrite, organic enrichment, low dissolved oxygen
Santa Clara River Reach 7	Ammonia, nitrate, nitrite
Santa Clara River Reach 3	Ammonia
Wheeler Canyon / Todd Barranca	Nitrate, nitrite
Brown Barranca / Long Canyon	Nitrate, nitrite

Figure 8 shows the locations of water quality monitoring stations, which are places where ambient surface water quality was measured at least once. At many stations, data was only collected a few times. Some stations did not collect nutrient data, which is of principal interest to this project.

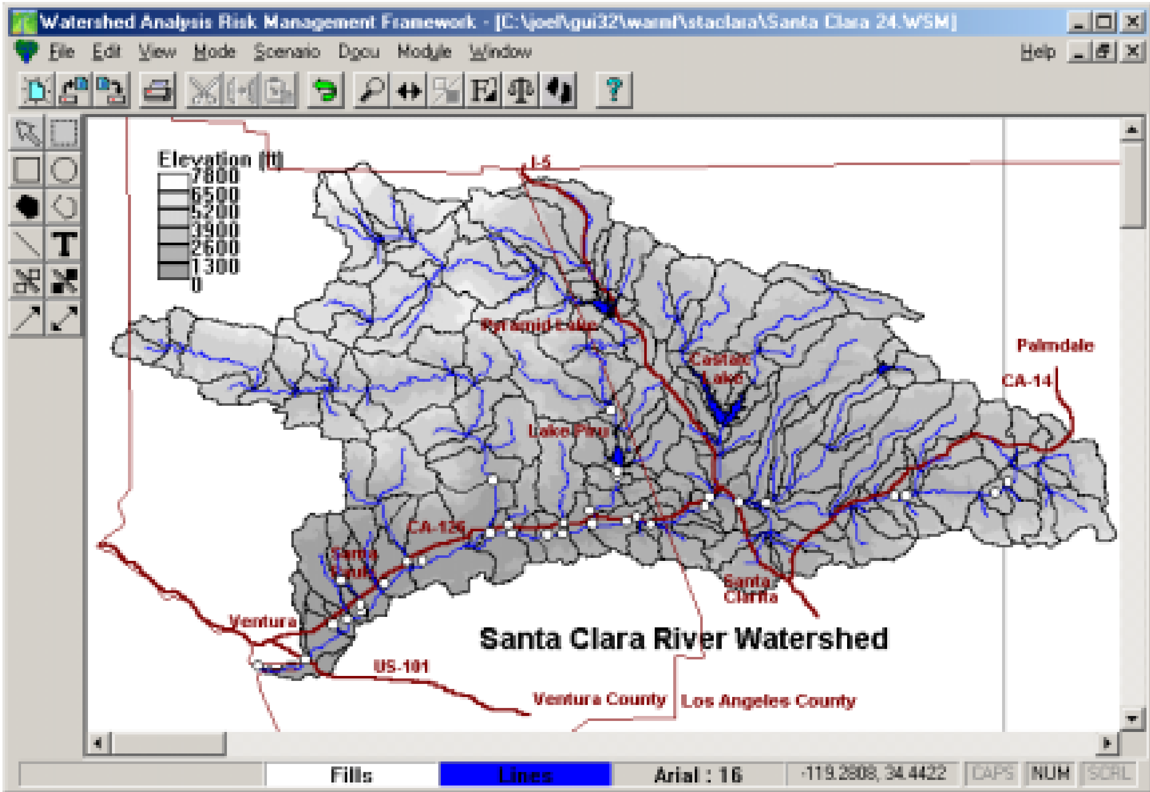

Figure 8: Locations of water quality monitoring stations

III. Watershed Modeling Methodology

Introduction

The watershed model chosen for the Santa Clara River is called the Watershed Analysis Risk Management Framework (WARMF). WARMF is a comprehensive modeling framework which links land catchments, river segments, and reservoir segments into a seamless watershed network. It has a graphical user interface with several modules. WARMF has an engineering module to perform watershed simulation for hydrology, nonpoint source loads, and water quality; a data module for storing and editing data in GIS format; a knowledge module to store reference information; a TMDL module to determine various combinations of point and nonpoint loads to meet the water quality criteria; and a consensus module to help stakeholders develop an implementation plan. A WARMF CD, complete with calibrated model, technical documentation, and user's guide is provided with this report for the stakeholders to use.

The time period selected for modeling was water years 1990-2000 (10/1/1989-9/30/2000). This time period has sufficient data to calibrate the model and includes a variety of hydrologic conditions. In particular, water years 1991 (10/1/1990-9/30/1991) and 1998 (10/1/1997-9/30/1998) represent a very dry year and a very wet year, respectively. These two years will be used to represent critical hydrologic conditions when using the model for watershed management and TMDL calculation.

Physical Representation

The watershed is divided up into land catchments, river segments, and reservoir segments. Each is linked together in a network so that output from catchments is automatically input to the adjacent river segment, and each river segment is connected to the one downstream, to reservoir segments, and back to river segments to form a complete network.

Each catchment is divided into the canopy, land surface, and several soil layers. Below the surface, it is assumed that each soil layer has uniform hydrology and water quality. The nonpoint source load from land catchments include pollutants associated with surface runoff and those associated with ground water accretion to the river segment. Each river segment is assumed to be completely mixed. Reservoir segments are divided into horizontal layers, each of which is assumed to be mixed.

WARMF can be run with any simulation time step. It is typically run with a daily time step because input data is most available at that temporal resolution. The Santa Clara River watershed has been set up to run on a daily time step.

Hydrologic Simulation

Hydrology simulation is based on mass balance of water, driven by precipitation. Water is routed from catchments to river segments, and reservoir segments. Provision is also made to allow for prescribed flows, including point sources, reservoir releases, diversions, and groundwater pumping. The accuracy of hydrologic simulation therefore depends on the accuracy of data for precipitation and prescribed flows.

<u>Catchments</u>

Each catchment is assigned to a meteorology station (shown in Figure 5 and Figure 6). To translate the precipitation amount occurring at a meteorology station to the precipitation occurring at a catchment, a precipitation multiplier is used to account for orographic effects. A temperature lapse rate is used to transpose the temperature at the meteorology station to the temperature at the catchment due to elevation differences between the catchment and the meteorology station.

Falling precipitation is divided into rainfall and snowfall based on temperature. Some rainfall is intercepted by the canopy. The remaining throughfall reaching the soil surface percolates into the soil. Snowfall accumulates and melts on the soil surface with the water volume tracked each day.

WARMF represents the soil by layers. Each layer has its thickness, field capacity, porosity, hydraulic conductivity, and slope. The moisture content of each soil layer is tracked every day. Water percolating into the soil first raises the moisture content to field capacity. Above field capacity, lateral flow occurs by Darcy's Law. If all soil layers reach saturation, overland flow occurs. The complete WARMF technical documentation describes the algorithms used (Chen 2001).

Septic system discharges occur in the Santa Clara River watershed. The number of people served by septics per catchment is specified and the per capita flow and loading is the same for all septic systems.

Subsurface discharges of treated effluent also occur in the watershed. Figure 9 shows the location of State of California permitted subsurface discharges in the Santa Clara River watershed. Each discharge has a schedule of flow and loading. The model assumes that the subsurface discharge spreads evenly over the entire catchment for percolation into the groundwater system.

Catchments can have pumping according to a flow schedule. The pumped water can be used for municipal/industrial purposes, in which case it is removed from the model, or it can be pumped to a river, or it can be applied to the land surface as irrigation. The volume of water is removed from the lowest soil layer of the catchment, and then applied at its destination.

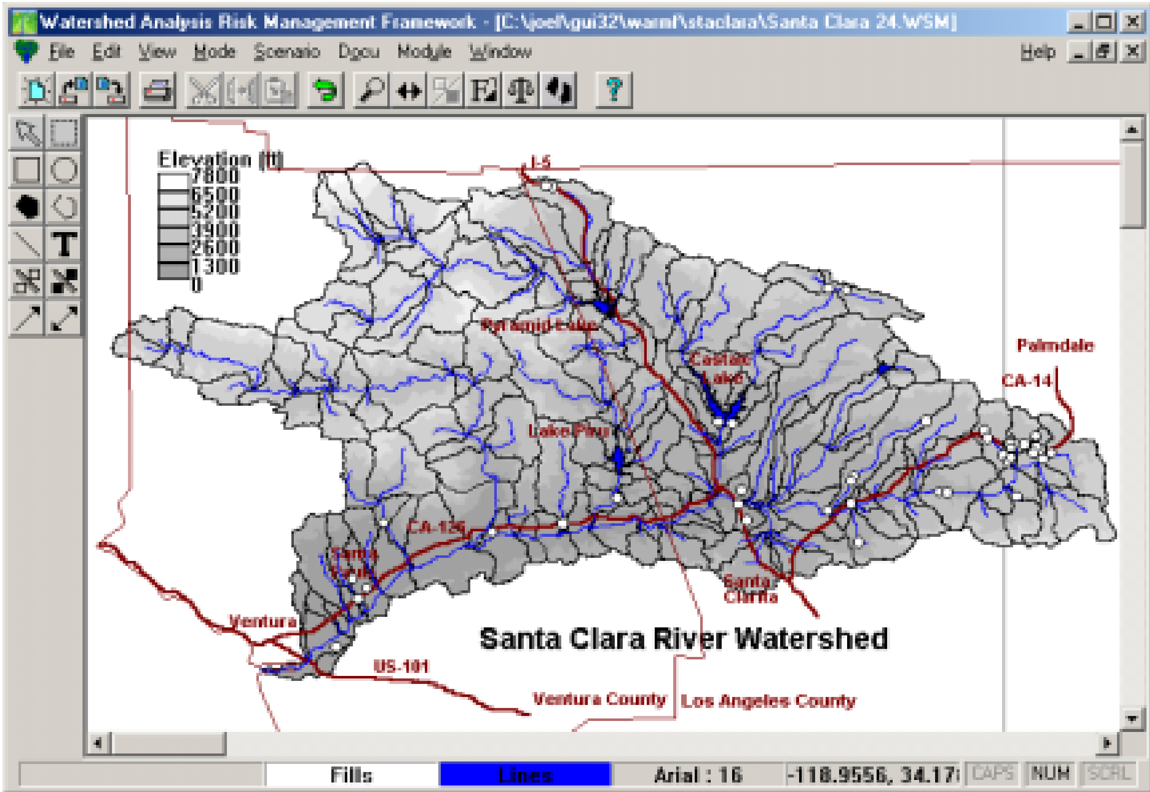

Figure 9: Locations of permitted subsurface discharges

WARMF divides the land surface into land uses. Within each land use, an impervious fraction of the surface may be specified. It is assumed that precipitation falling on impervious surfaces is routed through a storm drain system and discharged to local creeks and thus is not available for evaporation and infiltration into the soil. The travel time through the storm drain system is assumed to be short, so that drained water reaches the local creek in the same (daily) time step in which the precipitation falls. A test was conducted to determine if this assumption is valid for the Santa Clara River.

The test was performed using flow at the Old Road Bridge gage (the downstream end of Reach 8 as shown in Figure 2 near where Interstate 5 crosses the river). The gage is downstream of the Saugus wastewater reclamation facility. The city of Santa Clarita also drains storm water to the Santa Clara River upstream of the Old Road Bridge. Land use for the city is known (SCAG 2001), and impervious fractions were assumed to be 20% for residential, 40% for high density residential, and 60% for commercial/industrial. Impervious runoff can be calculated by multiplying precipitation by impervious area. Figure 10 shows Saugus WWRF flow, gaged flow, and calculated impervious runoff on a logarithmic scale.

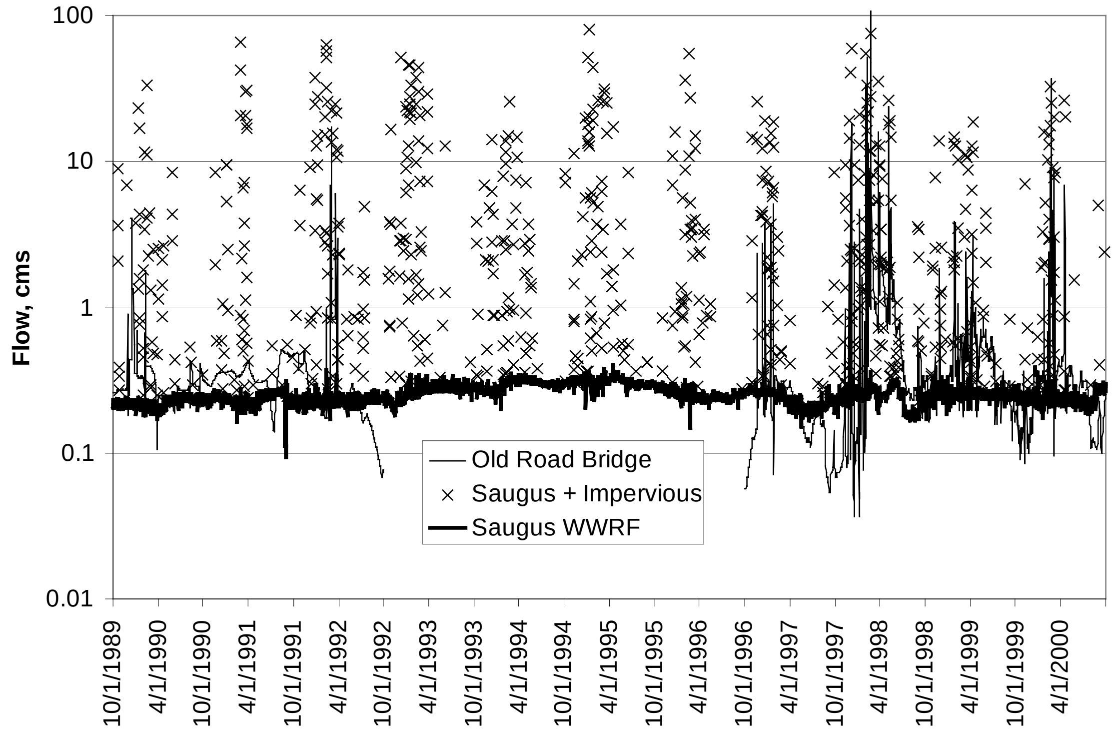

Figure 10: Saugus WWRF Flow, Gaged Old Road Bridge Flow, and Calculated Impervious Flow, m^3/s

For the relatively dry years of 1989-1992, the gaged flow at the Old Road Bridge was almost identical to the Saugus WWWRF flow. The calculated impervious runoff did not have any impact on the river flow. For the wet years of 1996 to 2000, the calculated runoff from impervious area appeared to have contributed flow to the river.

It was determined that all storm water, from pervious and impervious areas, passed through a wide pervious river bed of Santa Clara River. We therefore decided to deactivate the feature for the river to receive immediate runoff from impervious area. The catchment flow was simulated as if the land surface was pervious. Under such assumption, the simulated river flow would not have the peaks associated with storm water in dry years. In wet years, the model would simulate ground water table reaching the land surface, generating faster surface runoff to the river as indicated in the gaged flow data.

The model's treatment of impervious flows thus differs somewhat from what is believed to occur. The model allows percolation of precipitation on impervious surfaces in the catchment in which the precipitation fell. In the field, the storm drain system may transports that precipitation to another catchment, thus transferring the percolation to another location. This treatment by the model could result in travel times to surface water greater than those expected in the field. Since groundwater ammonia concentrations are very low and denitrification is assumed to not significantly occur, this increased travel time is not expected to cause significant error in the concentration of nutrients transported to the river. However, if the model were used at some later date to simulate the transport of other water quality constituents, such as fecal coliform, error could be introduced as a result of the model's formulation.

Rivers

WARMF assumes that all rivers are "gaining" rivers, which means they receive water from subsurface flow but do not lose water to percolation into the river bed. To simulate flow for the Santa Clara River, the flow lost to the river bed was estimated on a daily basis for each river segment. The estimated flow was then diverted from the river segments.

There were estimates of groundwater accretions for two river segments (UWCD (McEachron) 2002). The estimated flow was used in favor of the groundwater lateral flow simulated by WARMF. To accommodate such situation, the horizontal hydraulic conductivity of the soil in the applicable catchments was set to zero in WARMF to prevent the double accounting of groundwater accretion to the river. The estimated ground water accretion was simulated with a pump removing water from the groundwater of each catchment to each adjacent river segment.

Figure 11 shows the river sections that use prescribed gains and losses of water. The red sections have prescribed loss. The green sections have prescribed gain. The yellow sections have both prescribed gain and loss, sometimes gaining and sometimes losing over the course of the simulation. The blue sections only have gains, which are simulated by WARMF.

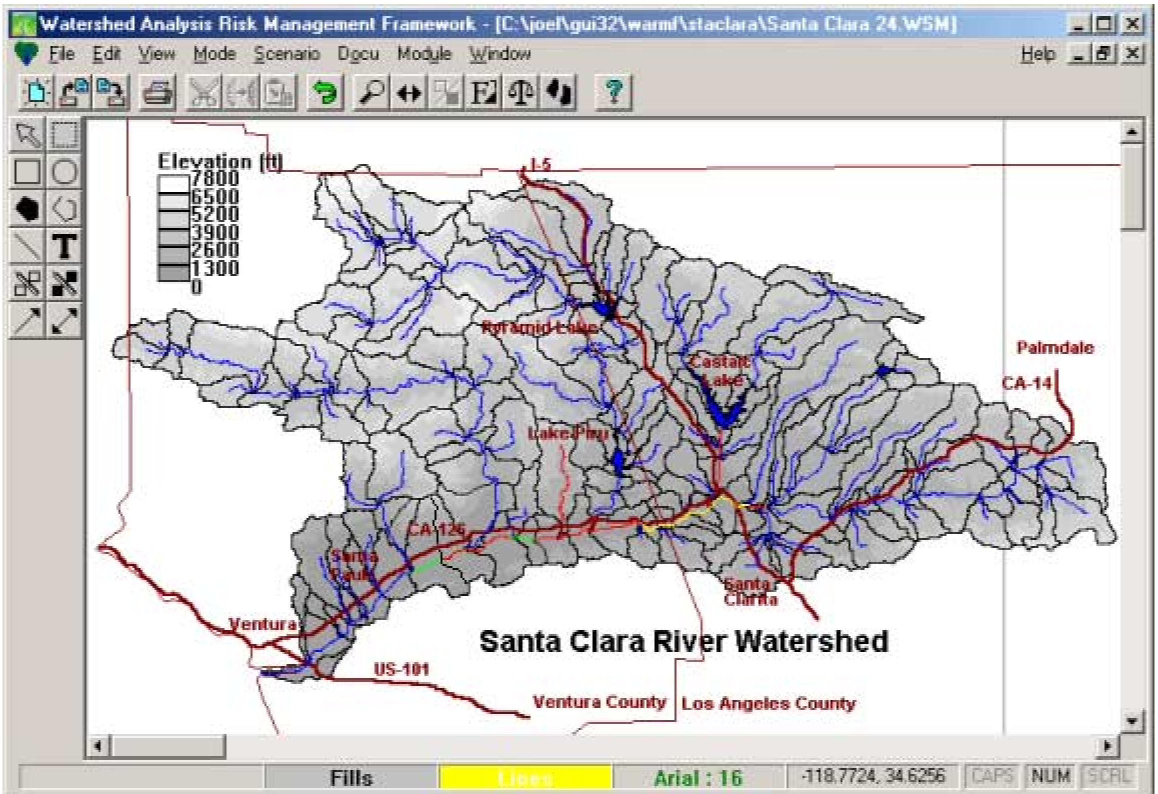

Figure 11: River segments with prescribed gains (green), losses (red), or both (yellow)

There are many point source discharges to the Santa Clara River. Their flow and loading is specified as a time series schedule in the WARMF Data Module. Each point source is linked to a river segment so that its flow and loading is added to the river segment accordingly.

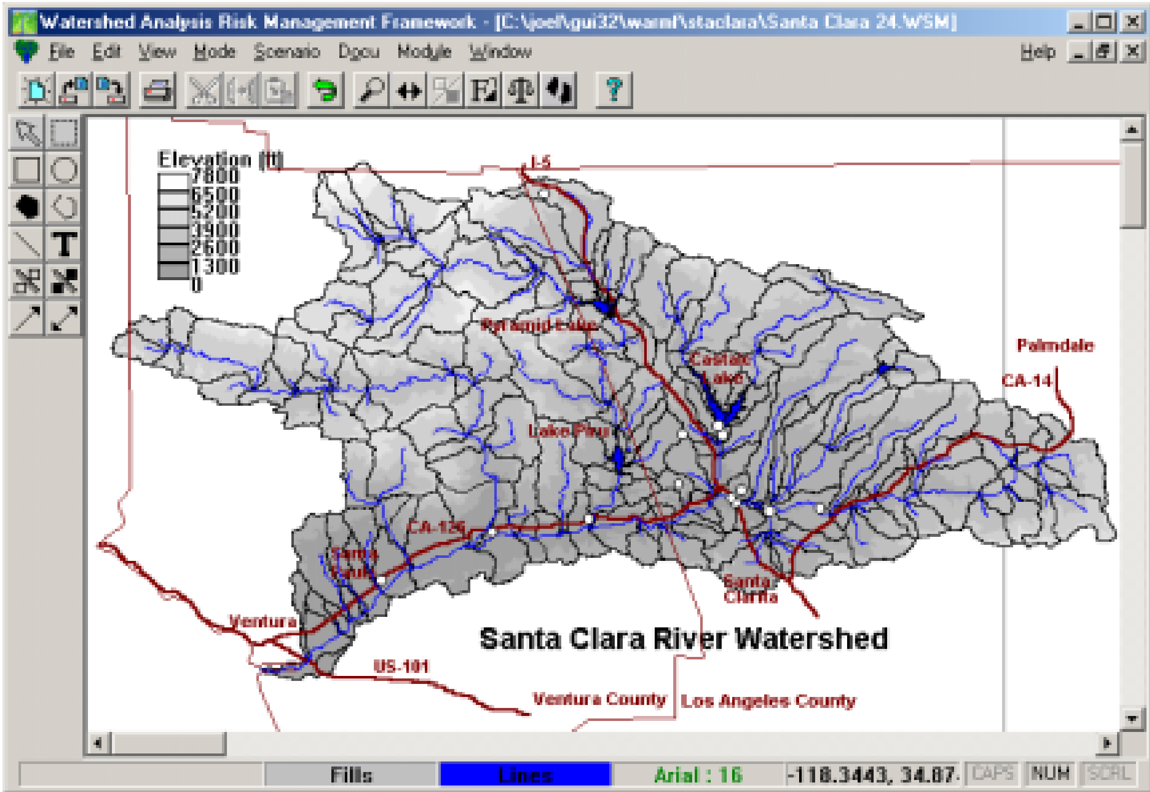

Figure 12: Locations of surface point source discharges

In the rapidly growing Santa Clarita area, groundwater pumping is often required to dewater construction sites. When this occurs, it can contribute significant flow to the Santa Clara River. Figure 13 shows dewatering sites with available flow records during the simulation period. The model extracts the prescribed pumping rates from the groundwater of the catchment and releases it to the adjacent river segment.

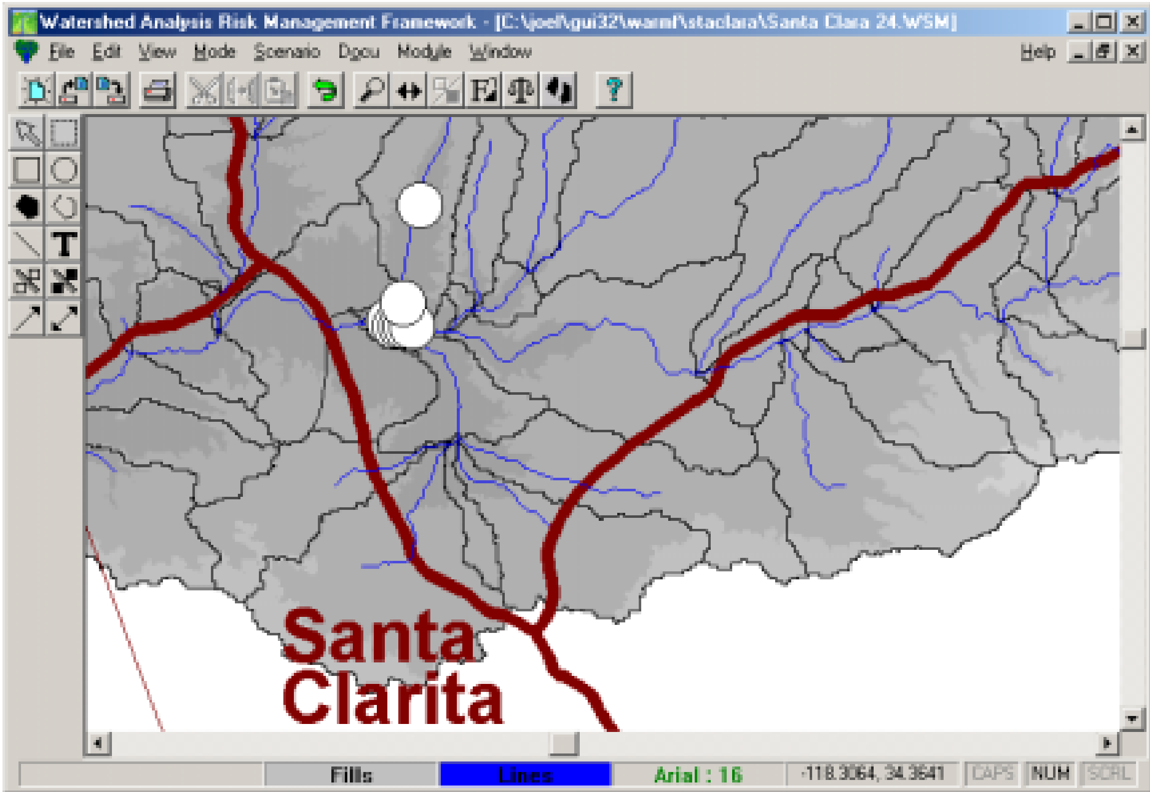

Figure 13: Santa Clarita area with dewatering sites with flow records

In the Santa Clara River, water is also diverted for direct agricultural use and groundwater recharge. Figure 14 shows the locations of these diversions. In WARMF, the specified water is removed from the applicable river segments and applied to the catchment surface as irrigation.

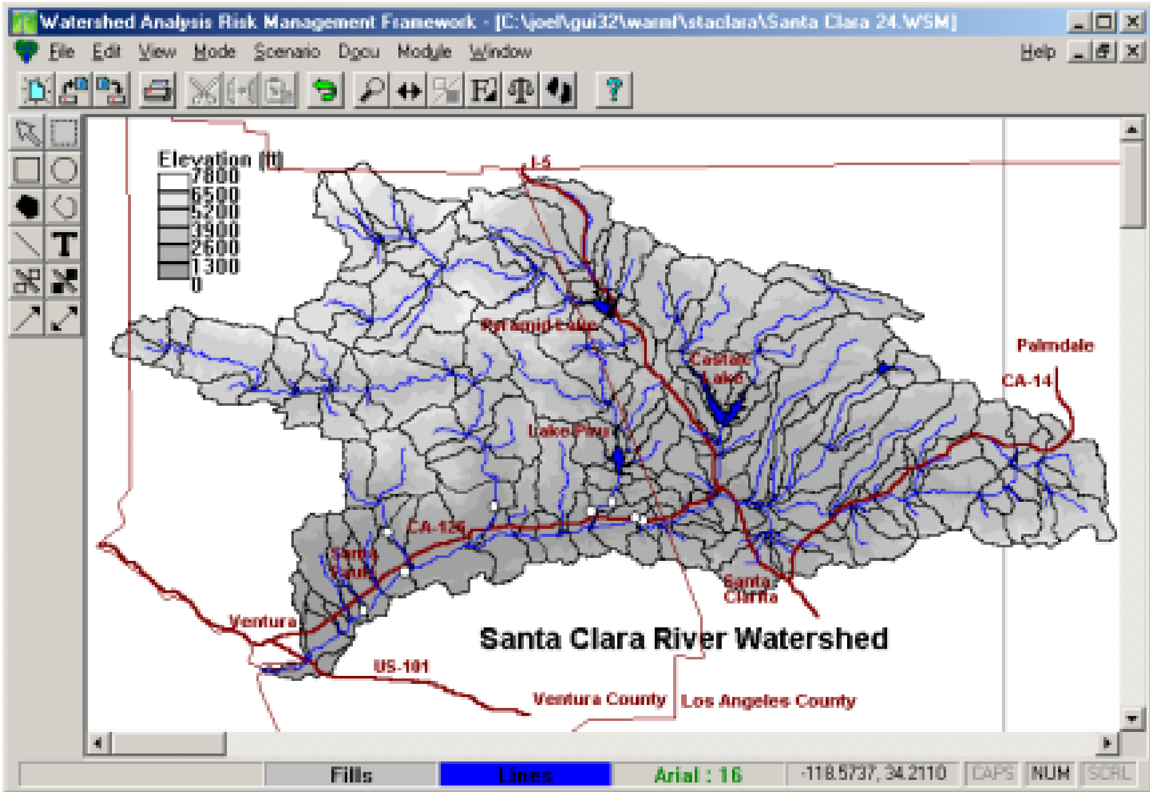

Figure 14: Santa Clara River watershed with diversions

Water Quality Simulation

Water quality simulation is based on mass balance of each chemical constituent. Temperature simulation is based heat transfer with ambient air. As water is routed through catchments, rivers, and reservoir segments, the associated chemical constituents are routed with the water. At each step of the simulation, chemical interactions are simulated to transform the chemicals to other forms. WARMF tracks each chemical with its sources, such as point source, septic system, and land uses. When two quantities of water are mixed, the chemical constituents are also mixed and the source of the new mixture is a mass weighted average of the sources for each chemical.

<u>Catchments</u>

Water quality simulation begins with atmospheric deposition to the land surface. Wet deposition is applied to the canopy and land surface based on the chemical concentrations in rain. Dry deposition is loaded to the canopy and land surface based on a monthly deposition rate and air quality concentrations.

To perform the calculations, WARMF requires monitoring stations with precipitation chemistry and air quality data. Figure 15 shows the locations of the four air quality monitoring stations in the Santa Clara River watershed (CARB 2002). Rainfall chemistry data came from a separate station at Tanbark Flat in the mountains east of the watershed in Los Angeles County (NADP 2002).

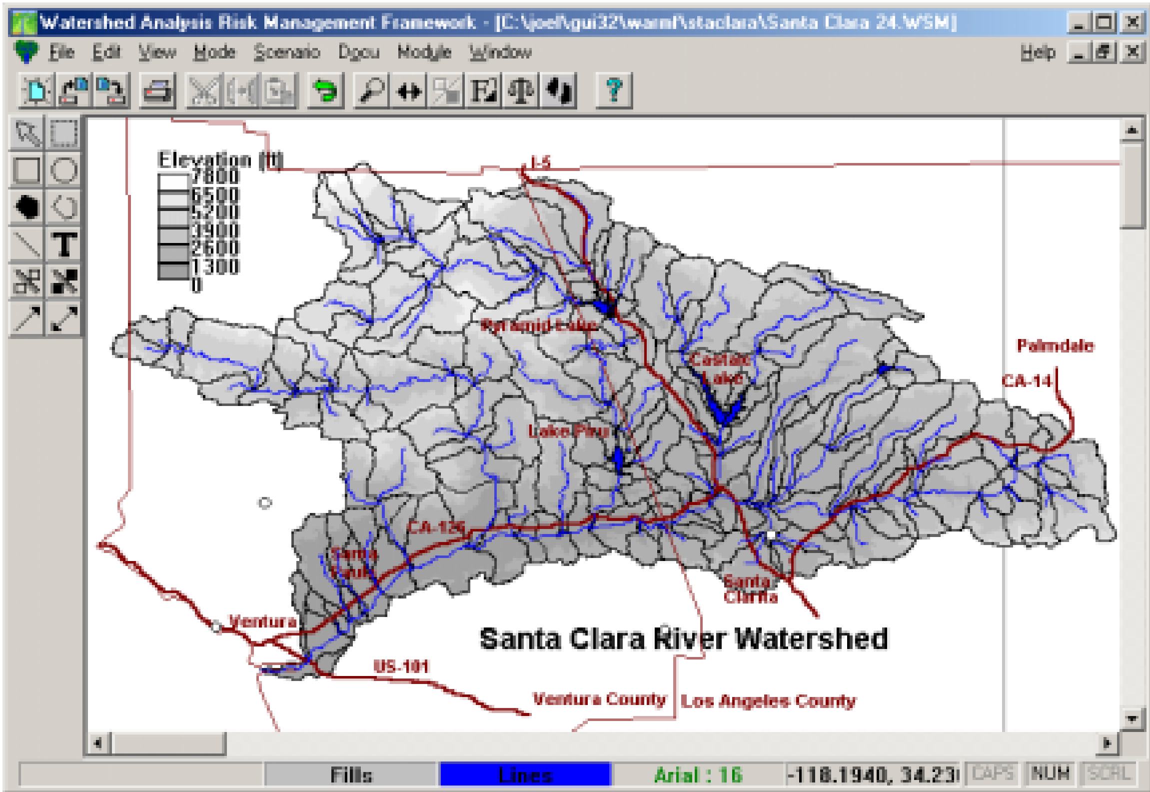

Figure 15: Santa Clara River watershed with air quality monitoring stations

Atmospheric deposition is joined by land application from fertilizers, urban debris, and wildlife. The canopy absorbs some of the total deposition to incorporate into its biomass, and the remainder is then carried by throughfall to the soil surface. As rainfall and snow melt percolate into the soil, they carry the chemical constituents washed down from the canopy. Once inside the soil, chemicals undergo many processes, including competitive cation exchange, anion adsorption, chemical reactions, and uptake by vegetation. pH is calculated from alkalinity and inorganic carbon by tracking the mass of each of the cations and anions. As lateral flow occurs, dissolved constituents are carried with it to river segments. When the soil is saturated, chemicals accumulated on the soil surface flow with overland flow to river segments.

Chemical constituents associated with septic systems and subsurface discharges (Figure 9) are mixed with the constituents already present in the soil layers. Water pumped out of the catchment carries with it the dissolved constituents in the soil solution.

<u>Rivers</u>

Each river segment acts as a mixed tank reactor. All inflows from local catchments, upstream river segments, upstream reservoirs, point sources, and dewatering operations are combined, reacted, and discharged to the downstream segment. Reaeration is simulated to balance dissolved oxygen and carbon dioxide concentrations. pH is calculated from alkalinity and inorganic carbon concentrations.

WARMF also simulates three species of floating algae and periphyton (attached algae) Their growth removes nutrients from the water. Periphyton simulation may be turned on or off for each river segment depending on the suitability of the substrate for periphyton growth.

Model Calibration Process

During model calibration, parameters which are not known are calibrated within reasonable ranges. Calibration is done in three stages: global, seasonal, and specific. Global calibration achieves an overall balance over the course of the simulation period. Seasonal calibration makes the model's predictions follow the seasonal variation in observed data. Specific calibration tunes model parameters so that simulated results match specific observed data points. Model calibration is often a never-ending iterative process.

Calibration proceeds in a certain order. Hydrologic calibration is first, since water quality is highly dependent upon hydrology. Temperature is calibrated with hydrology because of the importance of evapotranspiration and freezing in the hydrologic cycle. Water quality calibration proceeds after hydrologic calibration, but the hydrologic calibration can be revised to better simulate the water quality.

Hydrology

For calibration purposes, many model parameters are considered "known". These parameters, shown in Table 5 are not adjusted during calibration. Calibration parameters shown in Table 6 were adjusted within the range of values shown in the right column for the Santa Clara River watershed. Refer to the WARMF User's Guide (Herr 2000) and Technical Documentation (Chen 2001) for more information on the specific parameters.

Table 5: Key known hydrologic parameters

Type	Parameter	Source
Catchment	Area	Digital Elevation Models (DEMs) (USGS 2002)
Catchment	Slope	DEMs (USGS 2002)
Catchment	Width	DEMs (USGS 2002)
Catchment	Aspect	DEMs (USGS 2002)
Catchment	Land Use	GIS Databases (US EPA 2001, DWR 2002, SCAG 2001)
Catchment	No. Septic Systems	County database (Ventura County 2002) and estimated general numbers (Wagener 2002)
River	Length	DEMs (USGS 2002)
River	Slope	DEMs (USGS 2002)
System	Septic System Flow	Los Angeles County Department of Health Services (Wagener 2002)

Time series input data including meteorology (NCDC 2002, VC FCD 2002, LAC DPW 2002), pumping rates (UWCD (Detmer) 2002), point source flows (LACSD 2002), and diversion rates (Subbotin 2002, UWCD (Detmer) 2002) is not adjusted during calibration. Agricultural pumping rates were not provided for Los Angeles County, but were assumed to be enough for 30 inches per year from April 16 until October 15 on Orchard, Farm, and Golf Course land uses (Daugovich 2002). Errors in time series input data are propagated through WARMF, which sometimes can lead to discrepancies between model predictions and observed data.

Table 6: Calibration parameters for hydrologic simulation

Type	Parameter	Values used
Catchment Surface	Detention Storage	20 %
Catchment Surface	Manning's n	0.3
Catchment Surface	Meteorology Station	
Catchment Surface	Precipitation Weighting	0.8-1.25
Catchment Surface	Temperature Lapse	0–7 ^{o}C
Catchment Surface	Altitude Lapse	0.005–0.009 ^{o}C/m
Catchment Soil Layers	Thickness	23 - 10000 cm
Catchment Soil Layers	Initial Moisture	0.15-0.3
Catchment Soil Layers	Field Capacity	0.15-0.3
Catchment Soil Layers	Saturation	0.27-0.4
Catchment Soil Layers	Horizontal Hydraulic Conductivity	40 – 9000 cm/d
Catchment Soil Layers	Vertical Hydraulic Conductivity (Max. Infiltration Rate)	5 – 9000 cm/d
Catchment Soil Layers	Root Distribution	0-0.75
River	Initial Depth	0.01-0.1 m
River	Manning's n	0.04
River	Convective Heat Factor	1E-6 – 1E-4
System	Land Use Open in Winter	0-1
System	Snow Formation Temperature	3 ^{o}C
System	Open Area Melting Rate	0.08 cm/^{o}C/d
System	Forested Area Melting Rate	0.05 cm/^{o}C/d
System	Open Area Sublimation Rate	0.05 cm/d
System	Forested Area Sublimation Rate	0.05 cm/d
System	Evaporation Magnitude	1.2
System	Evaporation Skewness	1.015
System	Soil Thermal Convection Rate	0.003 cm/s

Calibration begins with system wide parameters affecting global and seasonal balance. The parameters for specific catchments or river segments are then adjusted to match local hydrographs. The hydrologic calibration may be tuned further as part of the water quality calibration.

<u>Water Quality</u>

Water quality calibration follows the same principles as hydrologic calibration. The water quality constituents least dependent upon others are calibrated first. The order of calibration is as follows: temperature, sediment, conservative constituents (major cations and anions), pH, nutrients and dissolved oxygen.

For the Santa Clara River project, many parameters are considered "known" and are not adjusted. The values of these parameters are enumerated in the Source Analysis Report (Systech 2002). Table 7 shows the key known water quality parameters. All time series input data, including air / rain chemistry and point source loading, is not adjusted. Table

8 shows the parameters which are adjusted in water quality calibration, with the values used in the Santa Clara River watershed shown in the right column.

Table 7: Key known water quality parameters

Type	Parameter	Source
Catchment	Land Application Rates	Refer to the Source Analysis Report (Systech 2002)
Catchment	Soil Erosivity	MUIR Database (USDA NRCS 2002)
Catchment	Soil Surface Particle Content	MUIR Database (USDA NRCS 2002)
System	Particle Deposition Velocity	Refer to the Source Analysis Report (Systech 2002)
System	Septic System Loading	Refer to the Source Analysis Report (Systech 2002)

Table 8: Calibration parameters for water quality simulation of nitrogen and phosphorus

Type	Parameter	Values used
Catchment Surface	Air Chemistry File	
Catchment Soil Layers	Organic Acid Decay Rate	0.06/yr
Catchment Soil Layers	Nitrification Rate	0.1/d
Catchment Soil Layers	Denitrification Rate	0/d
Catchment Soil Layers	Initial Concentrations	0.001-150 mg/l
Catchment Soil Layers	Cation Exchange Coefficient	12.22 mg/100 g
Catchment Soil Layers	Initial Base Saturation (major cations)	0.001-70%
Catchment Soil Layers	Adsorption Isotherms (minor cations, anions)	0-80 l/kg
River	Aeration Factor	1
River	SOD	0.2g/m^2/d
River	Organic Carbon Decay Rate	0.1/d
River	Nitrification Rate	1/d
River	Denitrification Rate	0-0.5/d
River	Periphyton Switch	OFF
System / Land Use	Cropping Factor	0.01-0.5
System / Land Use	Productivity	0-3 kg/m^2/yr
System / Land Use	Leaf Area Index	0-1.8
System / Land Use	Monthly Update Distribution	0-0.3
System / Land Use	Litter Fall Rate	0-0.16 kg/m^2/mo
System / Periphyton	All Coefficients	Periphyton turned off for all rivers

IV. Model Calibration

Introduction

Hydrology and water quality calibration have been conducted for the Santa Clara River watershed. The calibration results are discussed in three sections: the perennial western tributaries (Figure 4), the intermittent flow eastern tributaries (Figure 2), and the main stem of the Santa Clara River.

Since nutrients are the primary interest, the Santa Clara River Nutrient TMDL Steering Committee has mandated that calibration priority should be given to those nutrients of immediate concern (all forms of nitrogen). Phosphorus and dissolved oxygen are also included because they affect algal growth, which removes nitrogen. Chemical constituents such as pH, the major cations and anions, and total dissolved solids, have received little or no calibration.

Some calibration priority has also been given to simulation of low flow conditions, since those are believed to be the most critical for calculation of TMDLs. However, it is also important to achieve a good overall water balance and representation of peak flows to simulate timing of flows and distribution between high flow and low flow periods.

Calibration is also focused on the impaired streams of the watershed (Table 4). WARMF calculates simulation results for flow and all chemical constituents for all river segments in the watershed. The results presented here are for those locations relevant to the impaired streams and for which there is observed data to compare against simulation results.

WARMF calculates various statistics to quantitatively describe how well model predictions match observed data. The statistics include correlation coefficient, frequency distribution, absolute error, and relative error. Where there are sufficient data points to warrant a statistical comparison, the results are discussed in this report. To interpret the results, one must recognize the advantages and drawbacks of quantitative statistics.

The correlation coefficient, r, is often used to compare two sets of randomly distributed data. In WARMF, the correlation coefficient is used to compare two time series of data. The pairs of observed and simulated data for the same time are used to calculate the correlation coefficient. The pairs of data may not be randomly distributed. Since the time element is removed from the pairs of data, the calculated correlation coefficient assumes that all errors are in magnitude and not in time. In actual time series, there can be errors in magnitude or in time. If the wrong value is predicted, it is a magnitude error. If the right value is predicted, but one or two days late or early, it is a timing error. Errors in magnitude are important for TMDL analysis. Errors in timing may be important for such issues as flood prediction, but are not important for TMDL analysis.

The relative error measures the deviations between the pairs taken from two time series of simulated and observed data. It is the cumulative error, which allows for negative deviation to cancel out the positive deviation. The relative error reveals the overall model bias when there is sufficient data points (e.g. daily observed values) to help cancel out the timing error.

The absolute error measures the precision of the model. The negative deviation does not cancel out the positive deviation in the calculation of absolute error. The absolute error does not take the timing error into account.

In this report, the match between simulated and observed hydrology data will be recorded with the number of observed data points n, correlation coefficient r, and relative error expressed as a percent. Because there are only scattered data points for water quality, the correlation coefficient is poorly suited as a measure of error. Instead, absolute error is reported with relative error as a judge of precision.

Western Perennial Tributaries

Santa Paula Creek, Sespe Creek, and Hopper Creek (Figure 4) are tributaries of the Santa Clara River which are normally perennial. Hopper Creek was dry for periods in 1989-1992 and in 2000 but had water 82% of the time overall (UWCD 2002). Santa Paula and Sespe Creeks had water 100% of the time (USGS 2002). Above the respective gages for these streams, the land is mostly undeveloped with no more than 2% agriculture and 1% urban land uses within those areas (DWR 2002, US EPA 2001).

<u>Hydrology</u>

Seasonal hydrology of the western perennial tributaries is typified by late winter/early spring (January-March) peak flows and gradually declining base flow the rest of the year. The Sespe Creek watershed includes significant snowfall.

Key Assumptions

There is no meteorology data available from the upper parts of the Sespe and Santa Paula watersheds. The nearest stations are Ojai in the southwest and Sespe-Westates in the east. Most of the watershed is at a higher altitude than the meteorology stations.

During the calibration, it was noted that high precipitation was recorded at both Ojai and Sespe-Westates stations. The reported precipitation produced too much water for the river. We used the precipitation weighting factor to adjust the precipitation downward by 10-15%. We also assumed that the temperature of the upper catchments was lower than at the meteorology stations, in rough proportion to altitude. We also assumed that snowfall occurred whenever the air temperature was below 3 ^{o}C. Snow melting would occur when the air temperature is above 0 ^{o}C. .

Simulation Results

There are three gaging stations in this section of the watershed. They are on Santa Paula, Sespe, and Hopper Creeks (Figure 16).

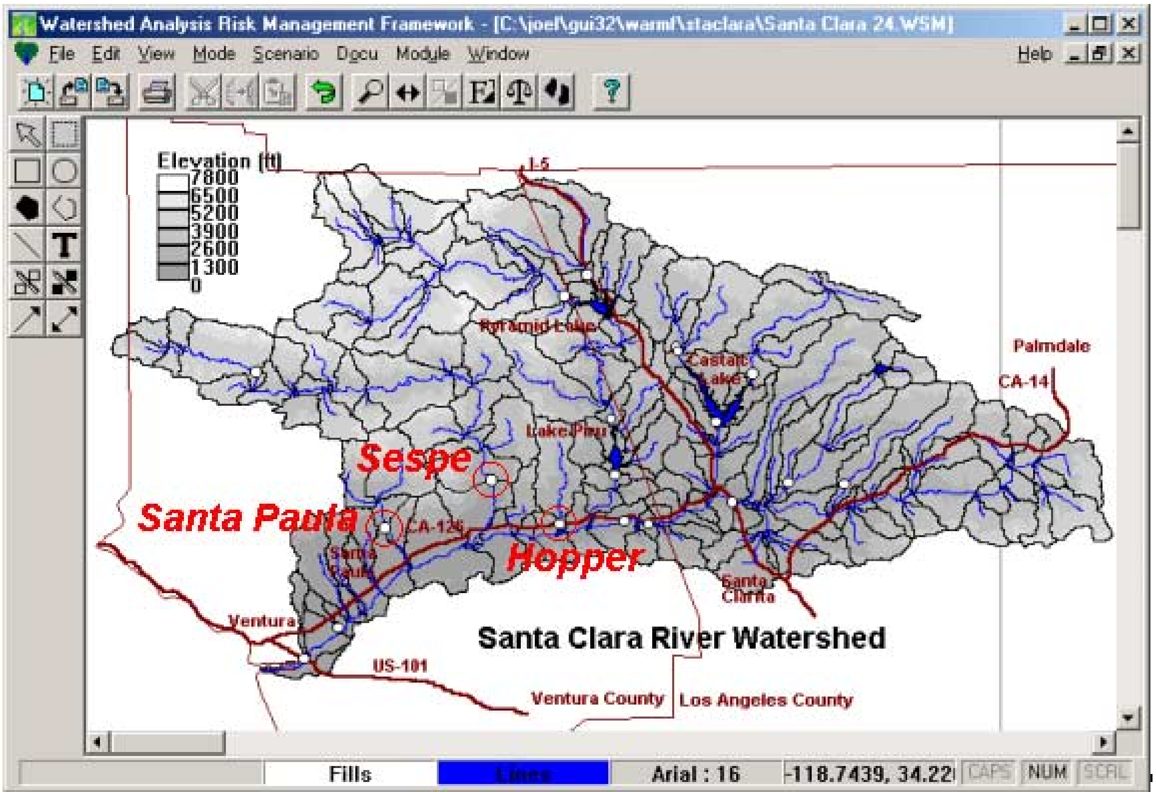

Figure 16: Stream gages in the western tributaries of the Santa Clara River

The simulated and observed flows at these stations are compared in Figure 17 through Figure 22. For each creek the first figure shows the full hydrograph and the second figure shows the same results but only in the 0-2 m^3/s range. The blue lines represent simulation results and the black circles represent observed data.

In general, the model has simulated the seasonal pattern of stream flow. Most of the time, each river has low flow. High flows occurred only during the winter and early spring storms. The model under predicted the peak flows at all three stations. The peak flow discrepancy is highest for Hopper Canyon Creek, intermediate for Sespe Creek, and lowest for Santa Paula Creek. The calibration for Sespe Creek in particular has been optimized for low and medium flow conditions, which is why the low flow error is greatest during 1998, a very wet year.

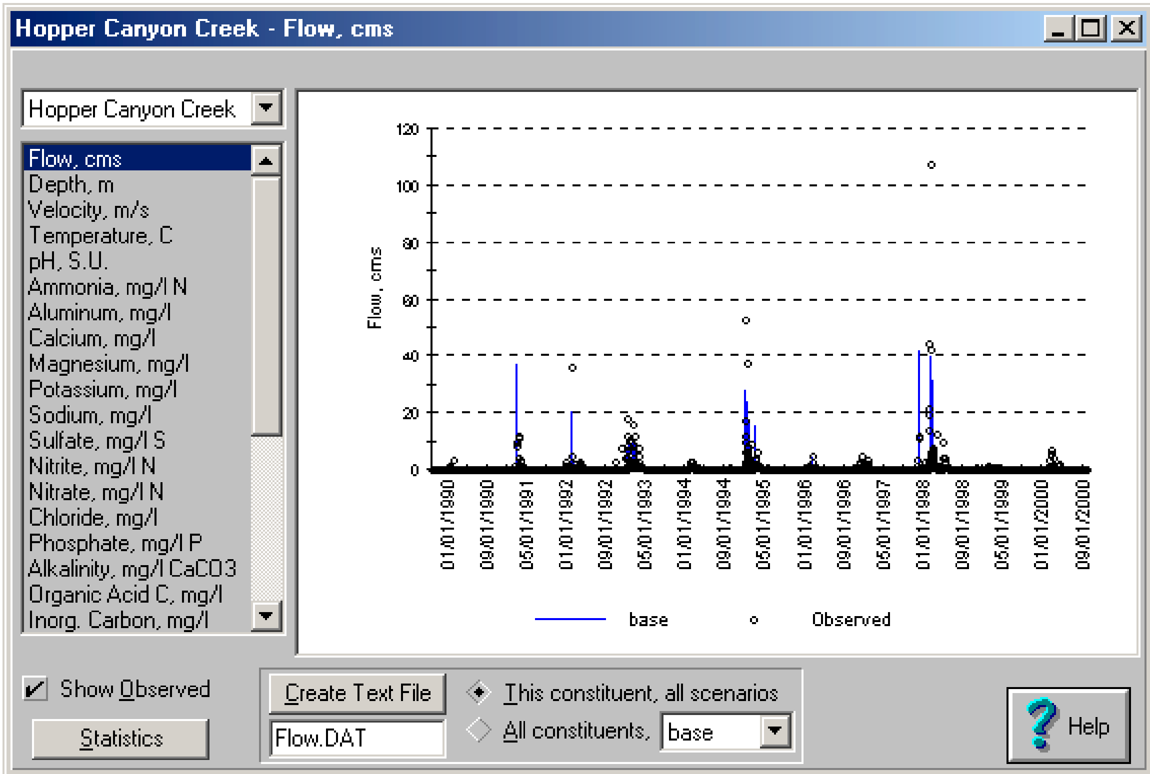

Figure 17: Simulated and Observed Flow for Hopper Creek at Highway 126 (n = 4018; r = 0.61; relative error = -3.6%)

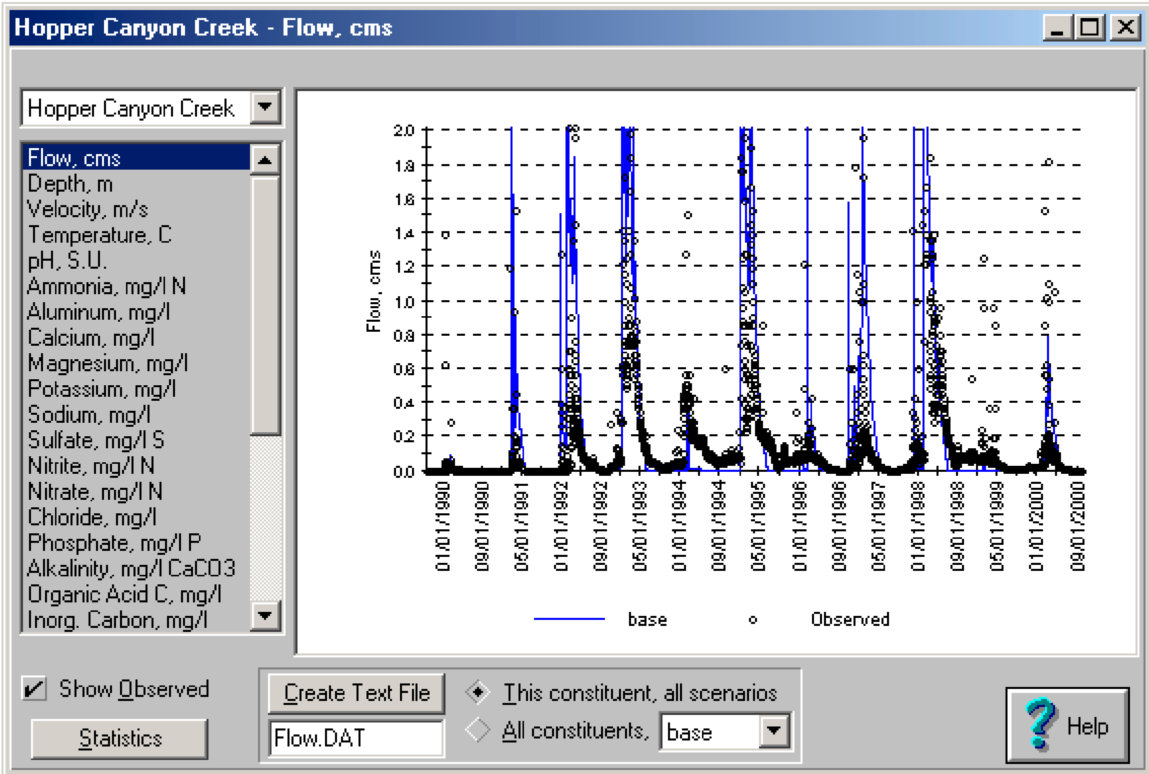

Figure 18: Simulated and Observed Flow: 0-2 m^3/s for Hopper Creek at Highway 126 (n = 3910; r = 0.69; relative error = +41.9%)

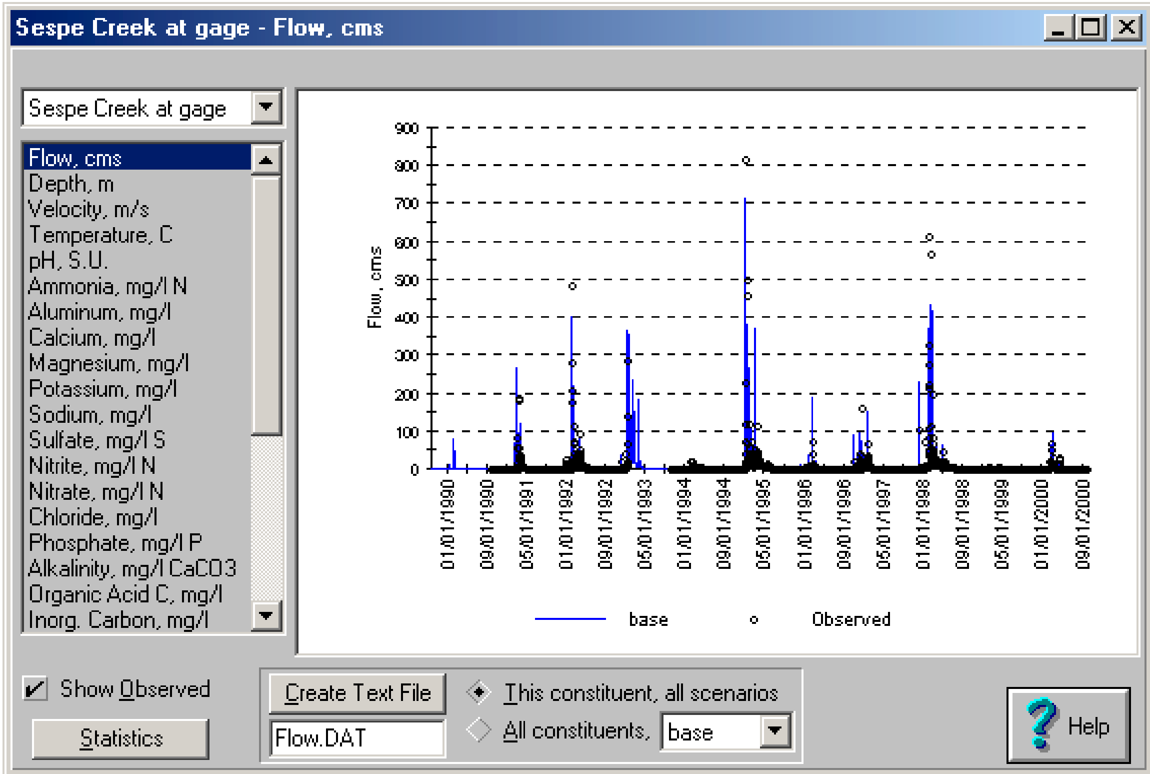

Figure 19: Simulated and Observed Flow for Sespe Creek near Fillmore (n = 3394; r = 0.83; relative error = +12.7%)

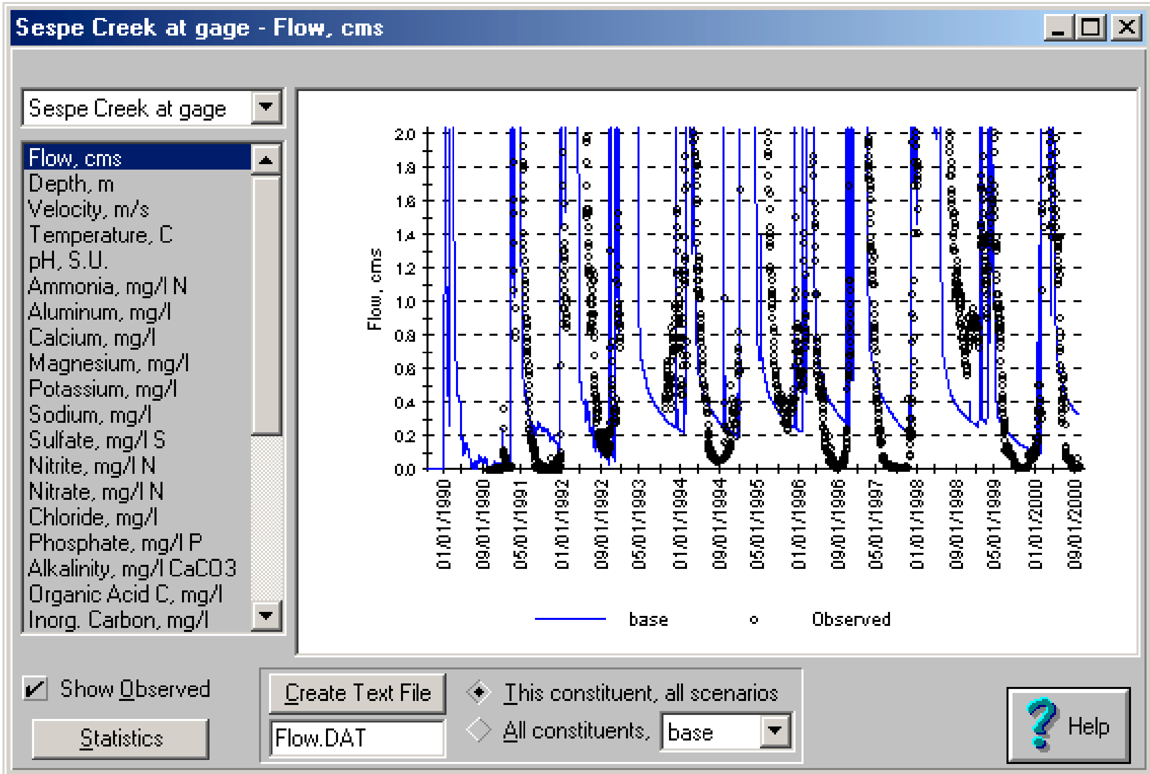

Figure 20: Simulated and Observed Flow: 0-2 m^3/s for Sespe Creek near Fillmore (n = 2678; r = 0.53; relative error = -46%)

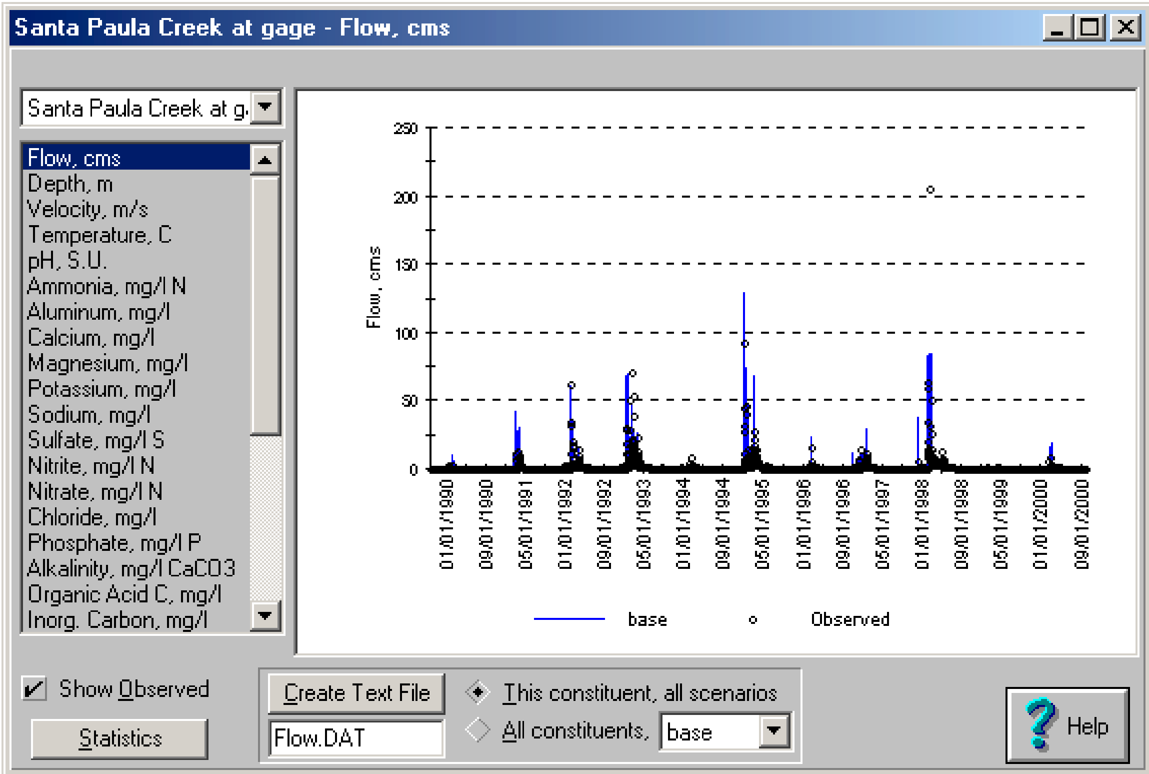

Figure 21: Simulated and Observed Flow for Santa Paula Creek near Santa Paula (n = 4018; r = 0.77; relative error = -0.8%)

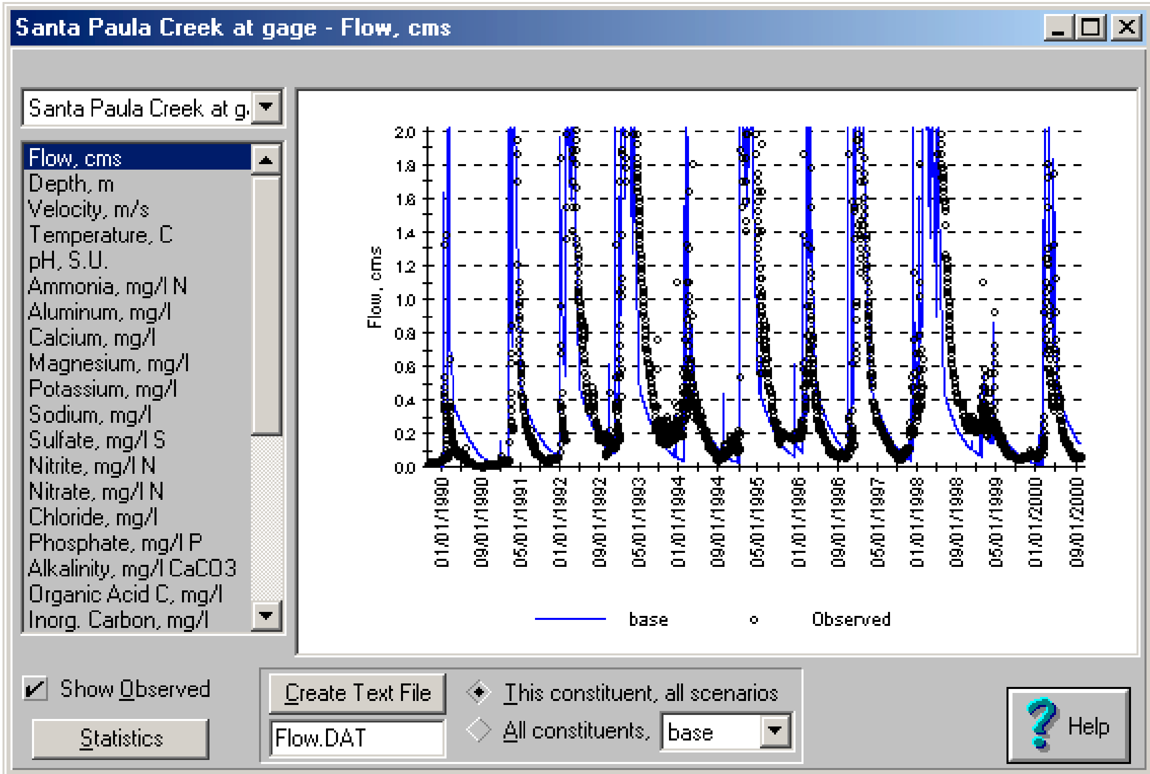

Figure 22: Simulated and Observed Flow: 0-2 m^3/s for Santa Paula Creek near Santa Paula (n = 3607; r = 0.63; relative error = +11.4%)

The simulation results for low flow range show that the model has simulated both rising limb and recession limb reasonably well for each tributary. The match is best for average years, but is not as good for very dry or very wet years. The correlation statistics reflect the difficulty in predicting the timing and magnitude of flows simultaneously.

Figure 23 through Figure 25 compare the frequency distribution of observed and simulated flows for the three gaging stations. The simulated (blue) and observed (black) flow curves fall on top of each other for Santa Paula Creek. The model over predicted the days of low flows (0.01 m^3/s) by less than 2% for Santa Paula Creek.

For Sespe Creek, the simulated frequency distribution curve matches the observed for flow above 1 cms. The model under predicted the days of low flows (0.1 cms) by as much as 25%. For Hopper Creek, the simulated frequency distribution curve matches the observed for flow above 0.2 cms. The model over predicted the days of low flow (0.01 cms) by as much as 40%.

Over all, WARMF has predicted correct frequency of high flows for all three creeks. This is expected, because larger storms measured at the meteorological station were more evenly distributed to all watersheds. The over and under predictions of extreme low flows are probably caused by the uneven distribution of small storms over the three watershed areas. This interpretation assumes that the stream gages have measured the extreme low flows accurately. The calibration of Sespe Creek shows an underrepresentation of flows in the 0.5-1.0 m^3/s range and an overrepresentation of flows between 0.01-0.1 m^3/s.

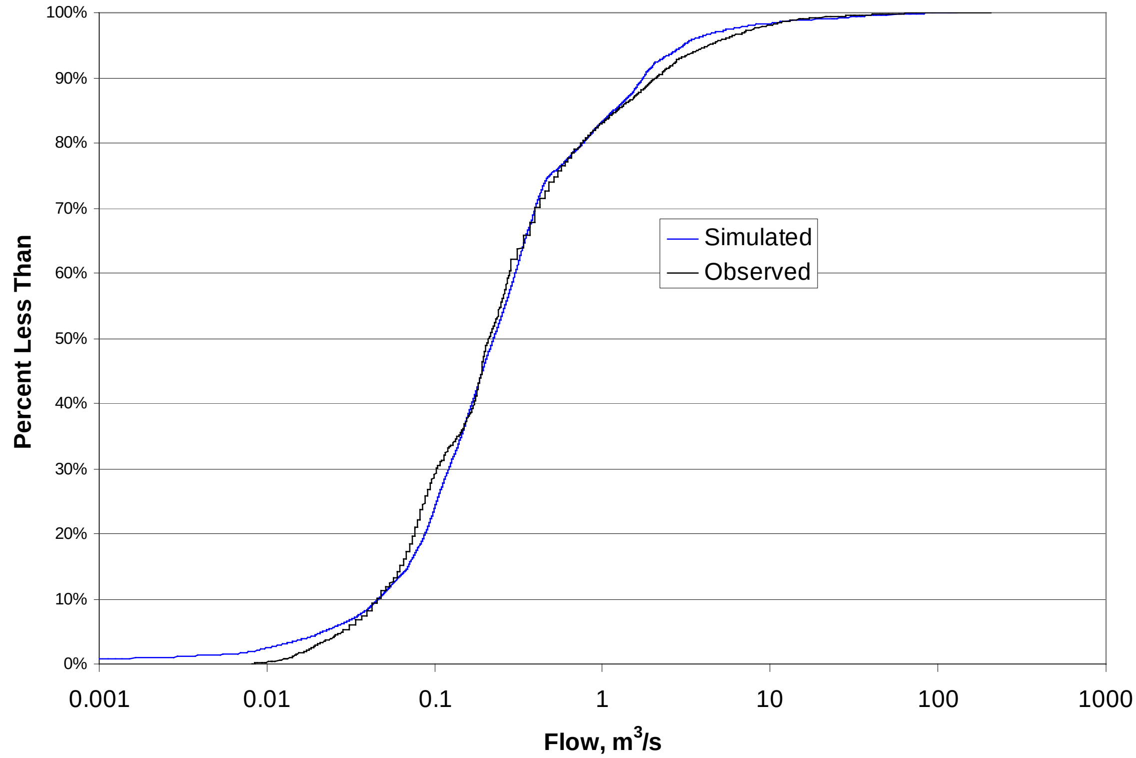

Figure 23: Frequency distribution of flow for Santa Paula Creek

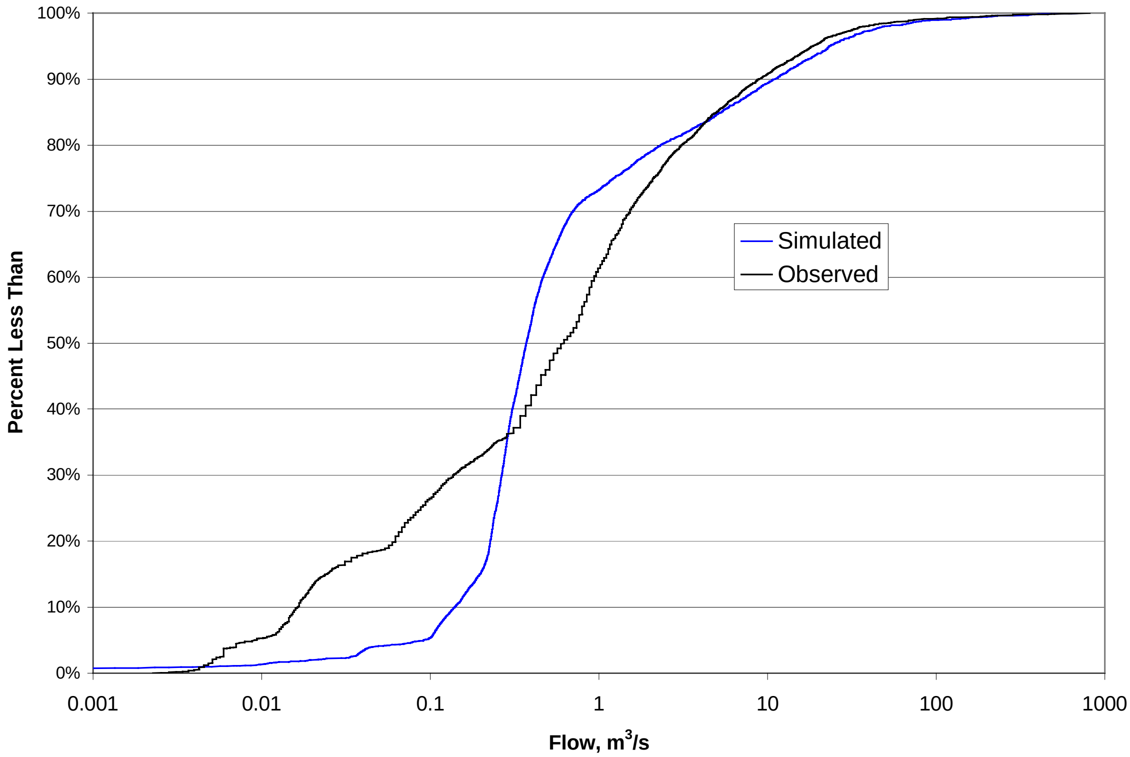

Figure 24: Frequency distribution of flow for Sespe Creek

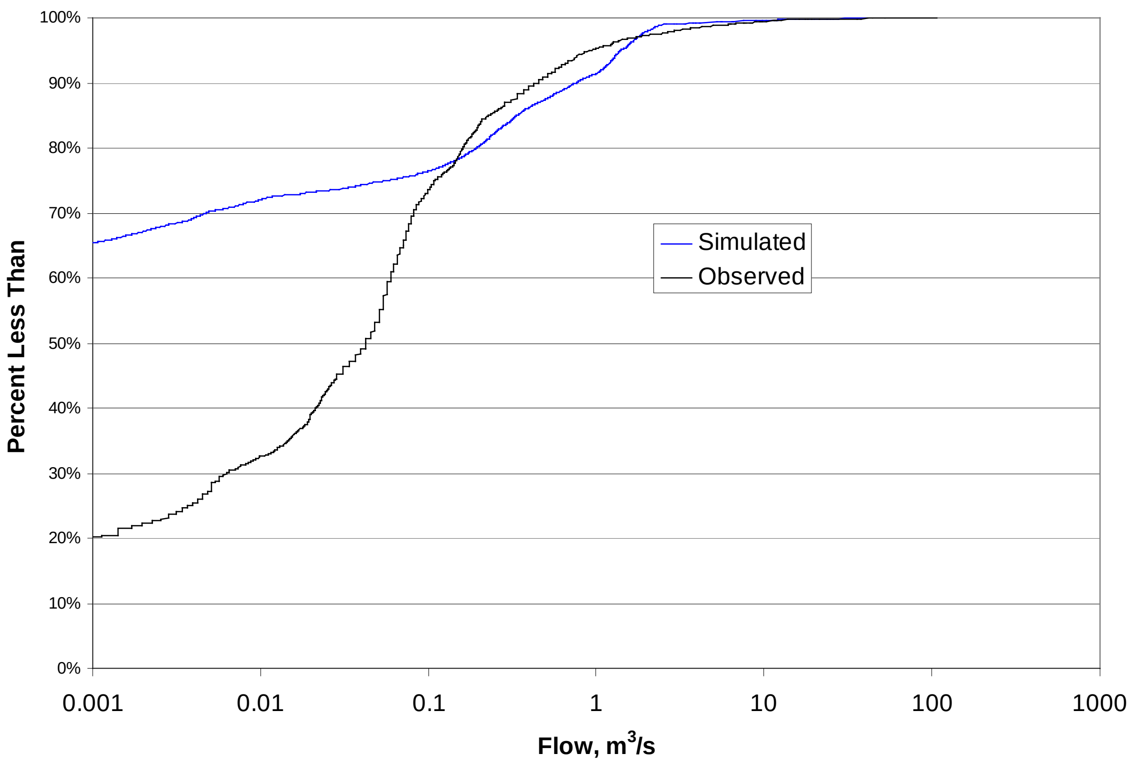

Figure 25: Frequency distribution of flow for Hopper Creek

Water Quality

The water quality of each of the western tributaries is relatively good. Typical ammonia concentrations are less than 0.1 mg/l as N, nitrate is less than 1 mg/l as N, and phosphate is around 0.02 mg/l as P. The water quality monitoring station for Santa Paula Creek is downstream of its gage, near the confluence with the Santa Clara River. Because of that, it includes influences from the intervening land, which is 26% agricultural and 3% urban.

Key Assumptions

The background concentration of nitrate is dependent on the balance between nitrogen loading to the land surface through atmospheric deposition and uptake from the soil by vegetation. Excess is stored in the soil, where nitrification occurs. The flow is high enough in these creeks to flush out any excess nitrate.

Productivity of the vegetation, which affects how much nutrients are taken up, was assumed to be the average of literature values for each type of vegetation on the land. Initial soil concentrations of nutrients were assumed to be very low, in concert with the monitoring data from each creek.

Simulation Results

Simulated results (blue line) and observed data (black circles) are compared in Figure 26 through Figure 34. Ammonia is underpredicted by the model at Santa Paula and Sespe Creeks. However, both simulated and observed show low concentrations, below 0.1 mg/l. Similarly, for nitrate the model underpredicts (Santa Paula) and overpredicts (Sespe) nitrate concentration but is in the correct range of values. Phosphate concentrations are matched precisely for the limited amount of data available. Simulated nitrate for Hopper Creek is clearly too high. The casue of this discrepancy is not known, but the relatively small contribution of flow from Hopper Creek to the lower Santa Clara River means the net effect of this error is small at the Freeman Diversion.

Since the Sespe Creek watershed is in a mountainous area without development, the air quality was assumed to have half the concentration of each constituent as was measured at the Ojai air quality station. Refer to the Sensitivity Analysis section of this document for a discussion of the effect of air quality on water quality in this part of the watershed.

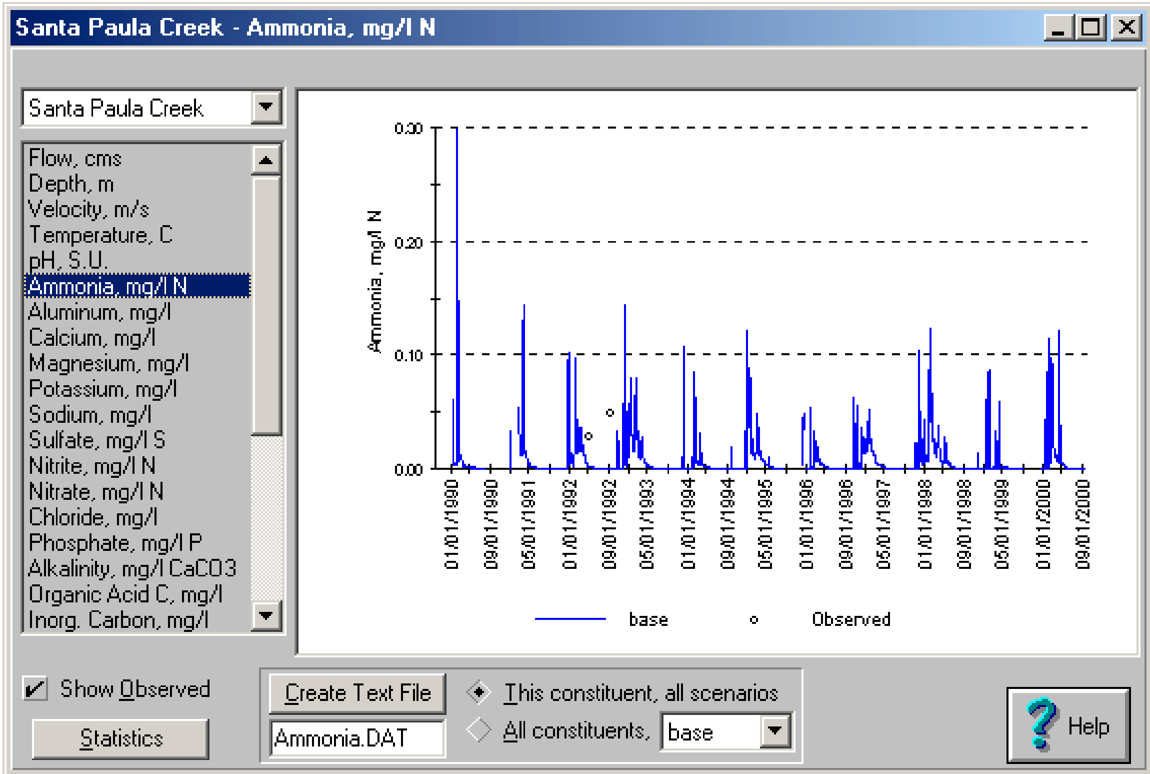

Figure 26: Simulated and Observed Ammonia for Santa Paula Creek at Santa Clara River (n = 2; relative error = -0.04 mg/l; absolute error = 0.04 mg/l)

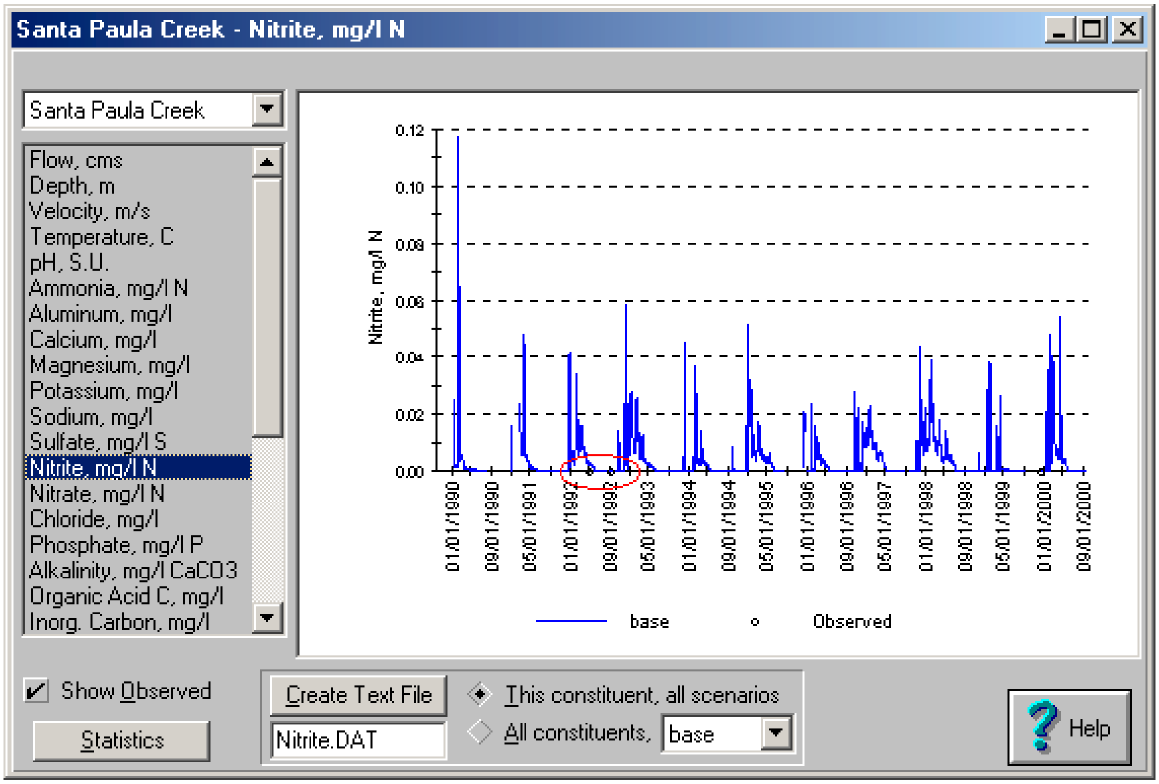

Figure 27: Simulated and Observed Nitrite for Santa Paula Creek at Santa Clara River (n = 2; relative error = 0.00 mg/l; absolute error = 0.00 mg/l)

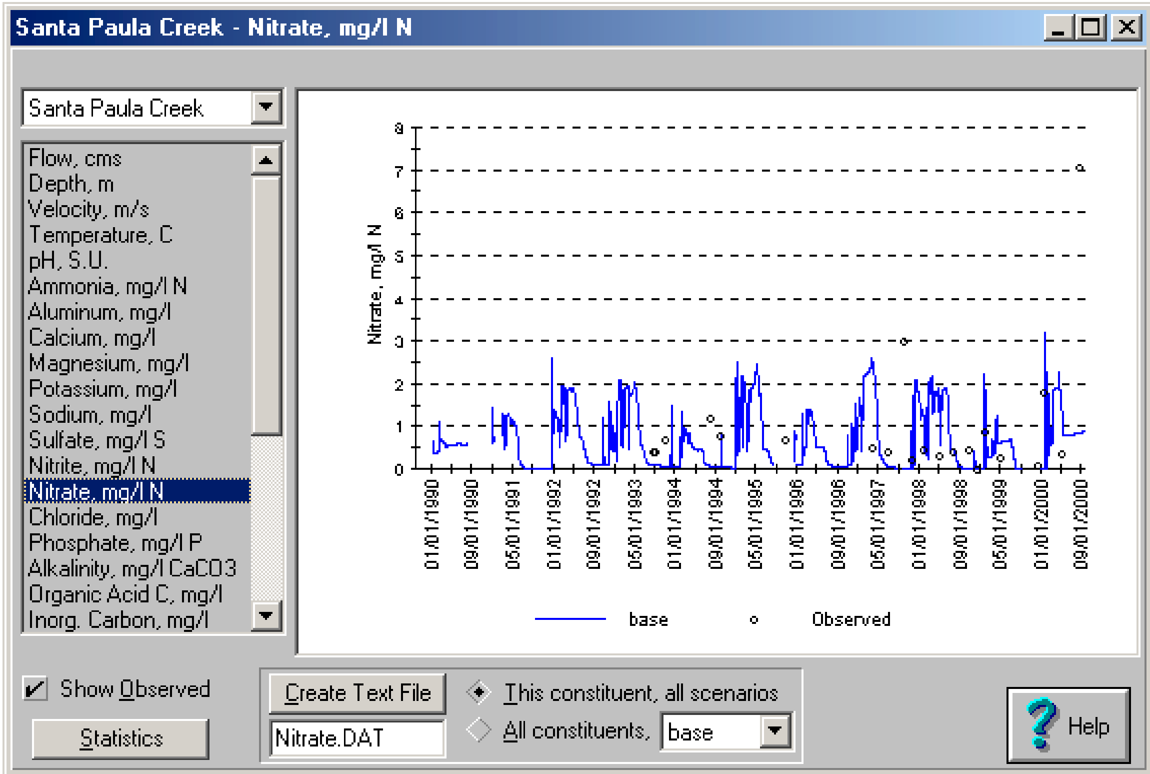

Figure 28: Simulated and Observed Nitrate for Santa Paula Creek at Santa Clara River (n = 18; relative error = -0.43 mg/l; absolute error = 1.04 mg/l)

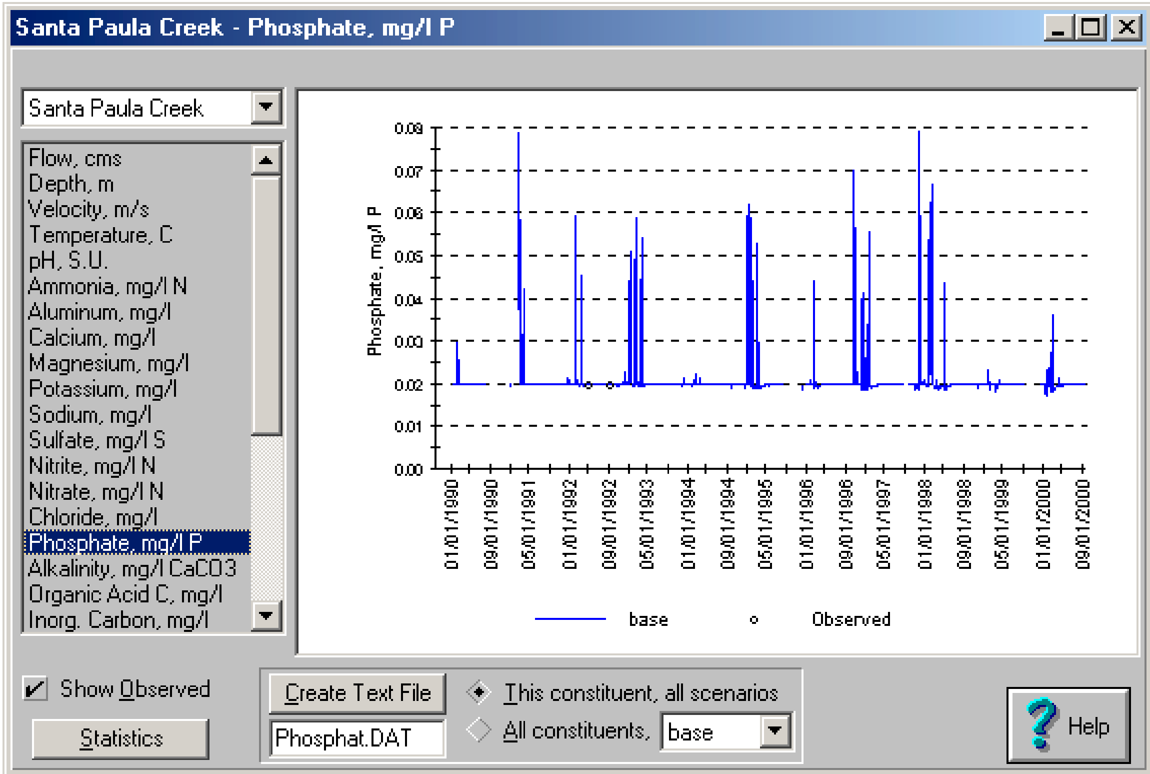

Figure 29: Simulated and Observed Phosphate for Santa Paula Creek at Santa Clara River (n = 2; relative error = 0.00 mg/l; absolute error = 0.00 mg/l)

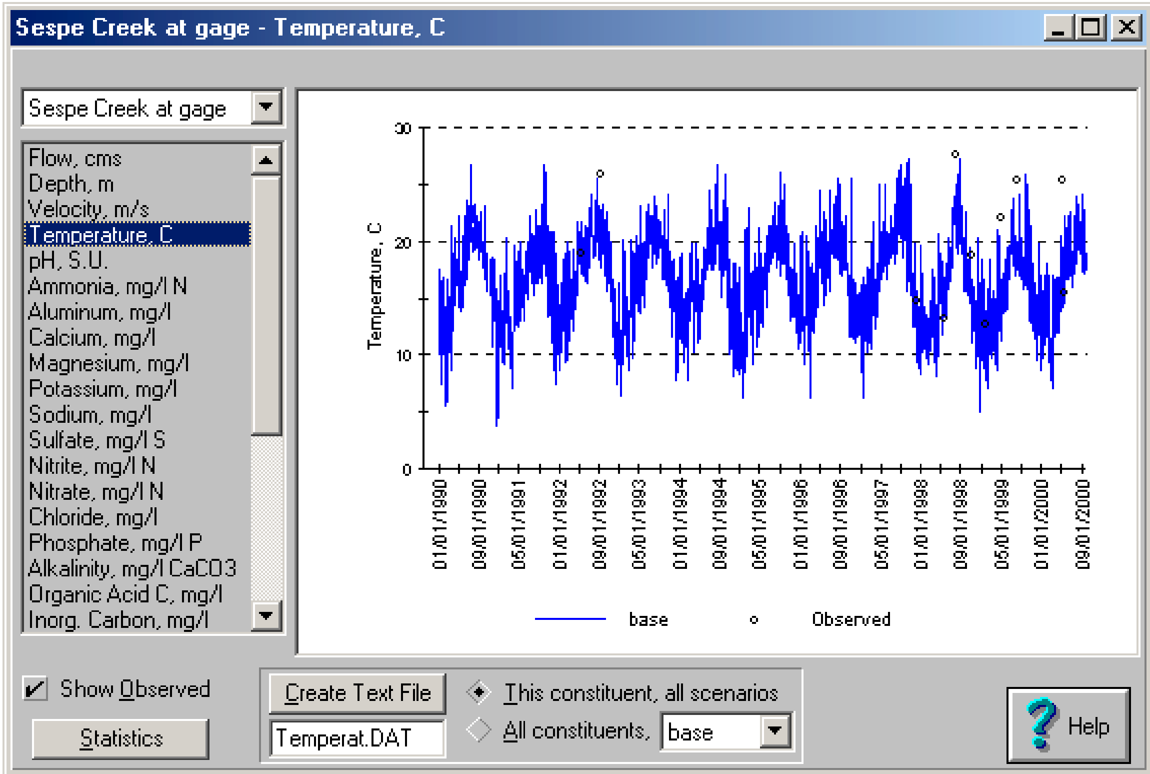

Figure 30: Simulated and Observed Temperature for Sespe Creek near Fillmore (n = 10; relative error = -3.5 ^{o}C; absolute error = 4.0 ^{o}C)

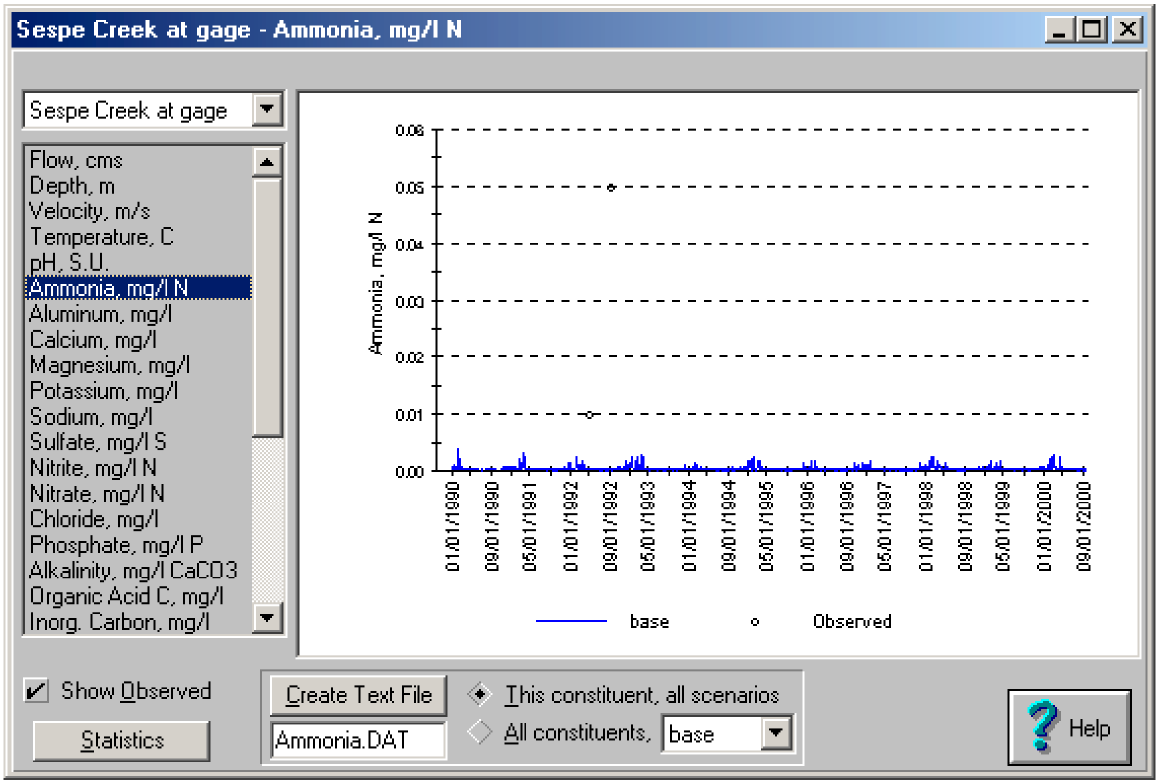

Figure 31: Simulated and Observed Ammonia for Sespe Creek near Fillmore (n = 2; relative error = -0.03 mg/l; absolute error = 0.03 mg/l)

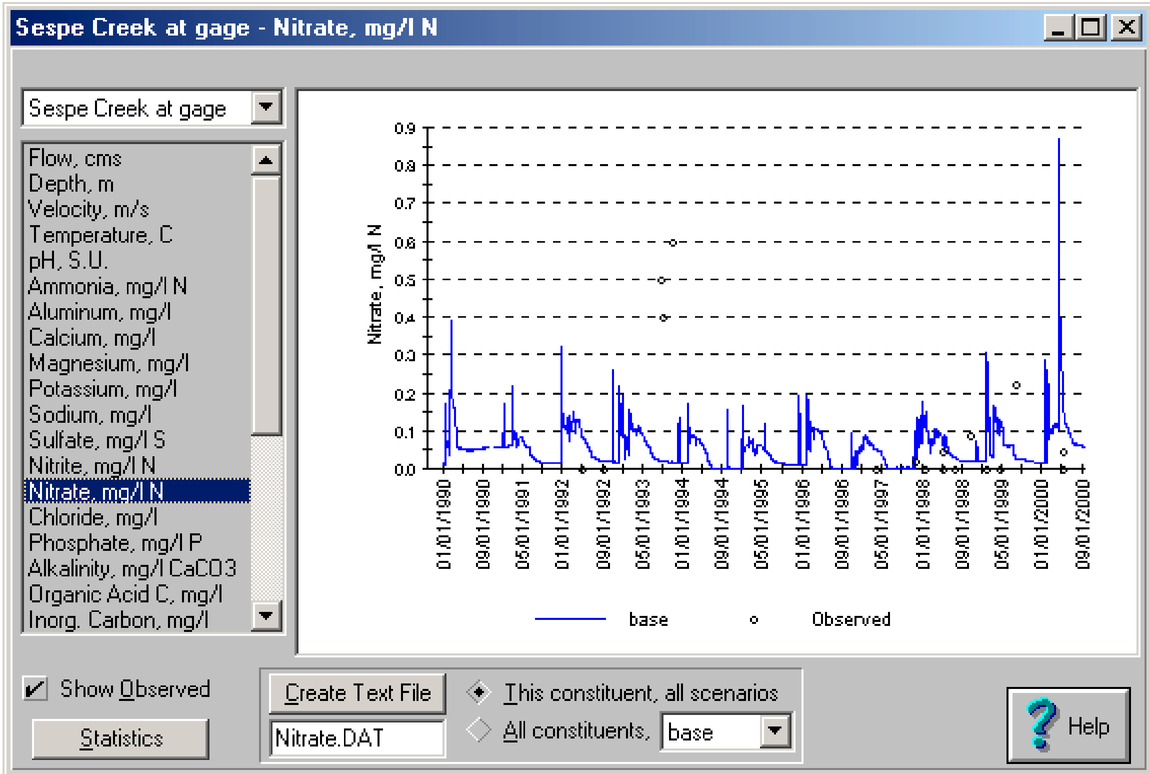

Figure 32: Simulated and Observed Nitrate for Sespe Creek near Fillmore (n = 17; relative error = -0.05 mg/l; absolute error = 0.16 mg/l)

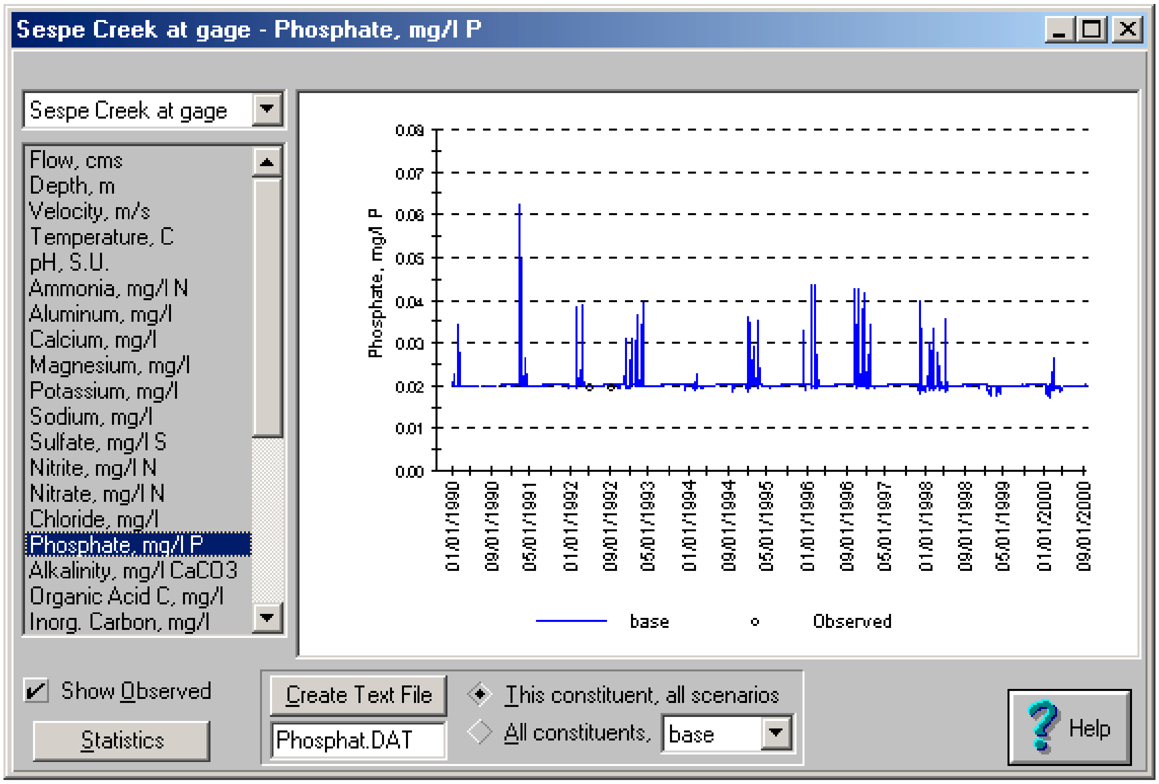

Figure 33: Simulated and Observed Phosphate for Sespe Creek near Fillmore (n = 2; relative error = 0.00 mg/l; absolute error = 0.00 mg/l)

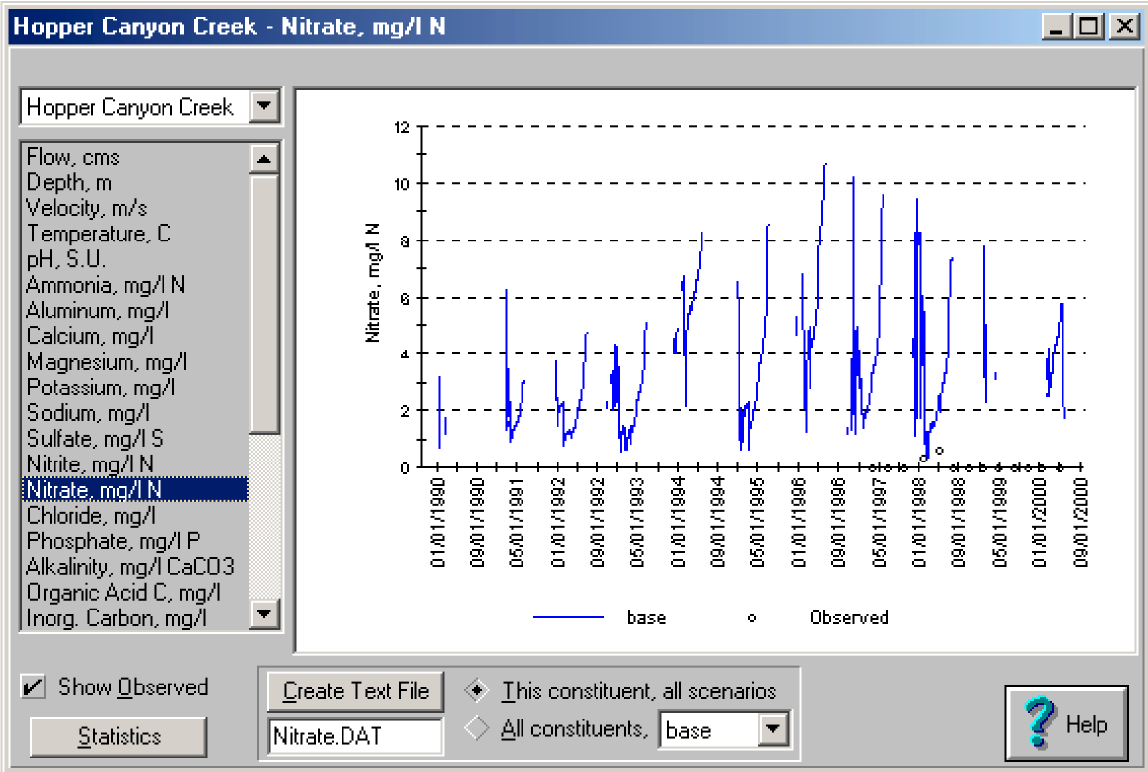

Figure 34: Simulated and Observed Nitrate for Hopper Creek
(n = 4; relative error = 3.93 mg/l; absolute error = 3.76 mg/l)

Eastern Intermittent Tributaries

Mint Canyon Creek and Bouquet Canyon Creek are intermittent tributaries of the Santa Clara River. Mint Canyon Creek and Bouquet Canyon Creek each have limited urban area: 2.2% of Mint Canyon is urbanized and 4.3% of Bouquet Canyon is urbanized. Both have less than 1% agriculture (SCAG 2002, US EPA 2001). Neither of these tributaries has any surface point source discharges or other known artificial sources of water.

The simulation results for Santa Clara River Reaches 9 and 10 (Figure 2), upstream of Bouquet Canyon Creek, are also discussed in this section. These reaches do not have flow data, but do have water quality data. The watershed for reaches 9 and 10 includes a part of Santa Clarita and the Highway 14 corridor. Most of this land is undeveloped. It includes 9.8% urban land, 0.3% agricultural land, and 0.2% golf courses.

Hydrology

The hydrology of this region of the watershed is characterized by brief sharp flow peaks for unusually large storm events, fast recession from those peaks, and no flow at all for part of the year. This hydrograph is due to the thin soil, desert-like climate, and steep canyons.

Key Assumptions

When comparing precipitation records to the gaging data for Mint Canyon Creek and Bouquet Canyon Creek to precipitation records, there are a few obvious mismatches like the one shown in Figure 35. There was one storm event on 2/23/1993. After that, there was no more precipitation, yet the flow gradually increased. The area is not subject to snow hydrology, so there is no logical explanation for the hydrograph.

There were five similar cases in the observed hydrograph of Bouquet Canyon Creek. Figure 36 through Figure 39 present the plots of precipitation events and flow in Bouquet Canyon Creek for 4/3/1990-4/9/1990, 12/4/1993-12/19/1993, 2/27/1995-3/3/1995, and 11/6/1997-11/10/1997. The other case, from 10/1/1995 to 5/31/1996, the recorded flow was a constant 0.02 m^3/s every day.

It was assumed that the unexplained flows were due to the dewatering operations of construction projects. The time and magnitude of the dewatering operations were estimated based on the observed hydrograph and entered into WARMF. It is possible that the unexplained flows in the Bouquet Canyon Creek are the reservoir releases from Bouquet Reservoir, but there are no records available.

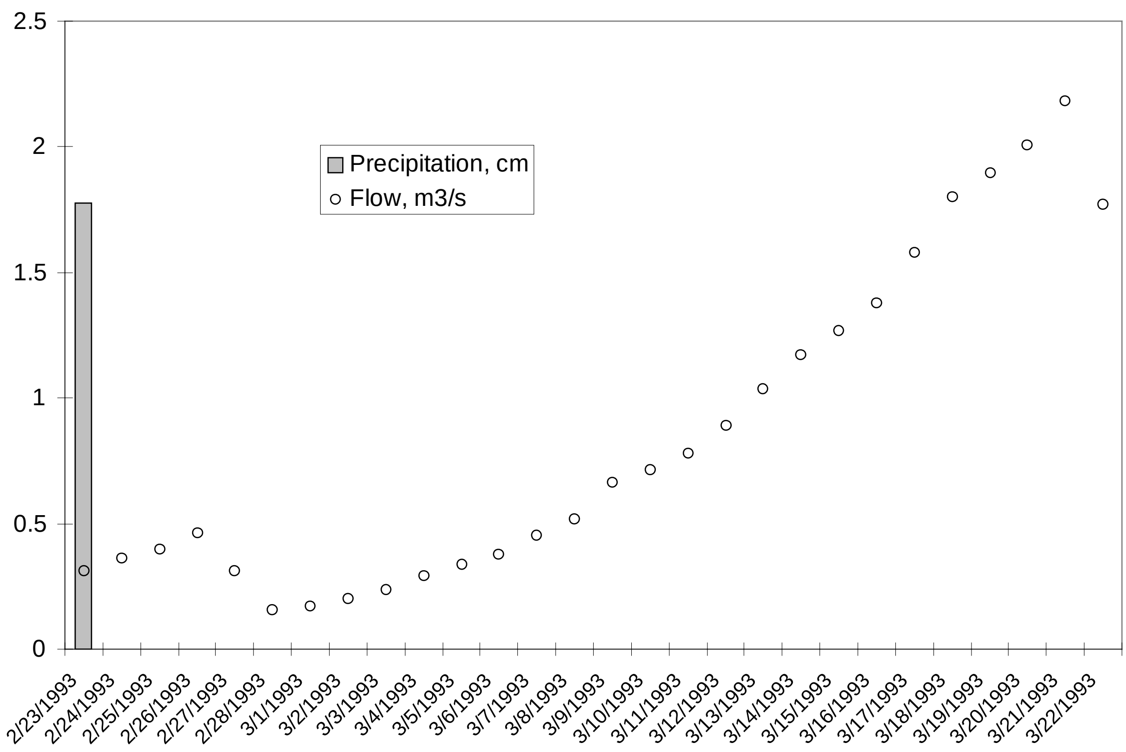

Figure 35: Precipitation and flow for Mint Canyon Creek, 2/23/1993-3/22/1993

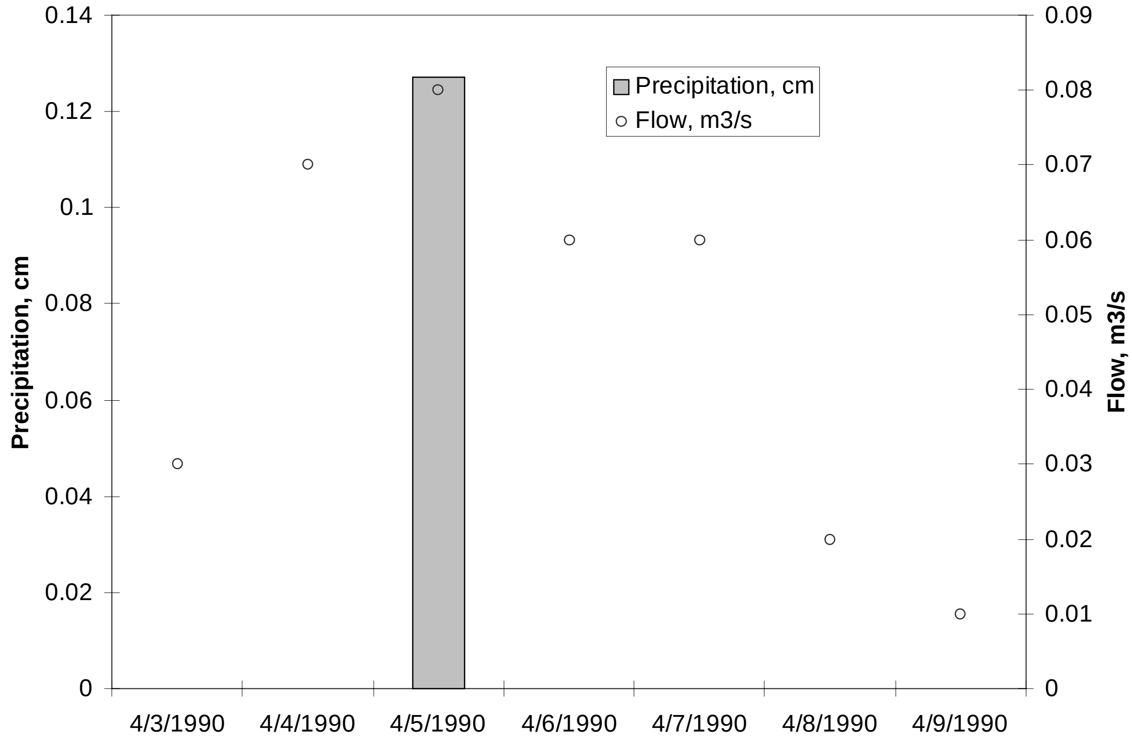

Figure 36: Precipitation and flow for Bouquet Canyon Creek, 4/3/1990-4/9/1990

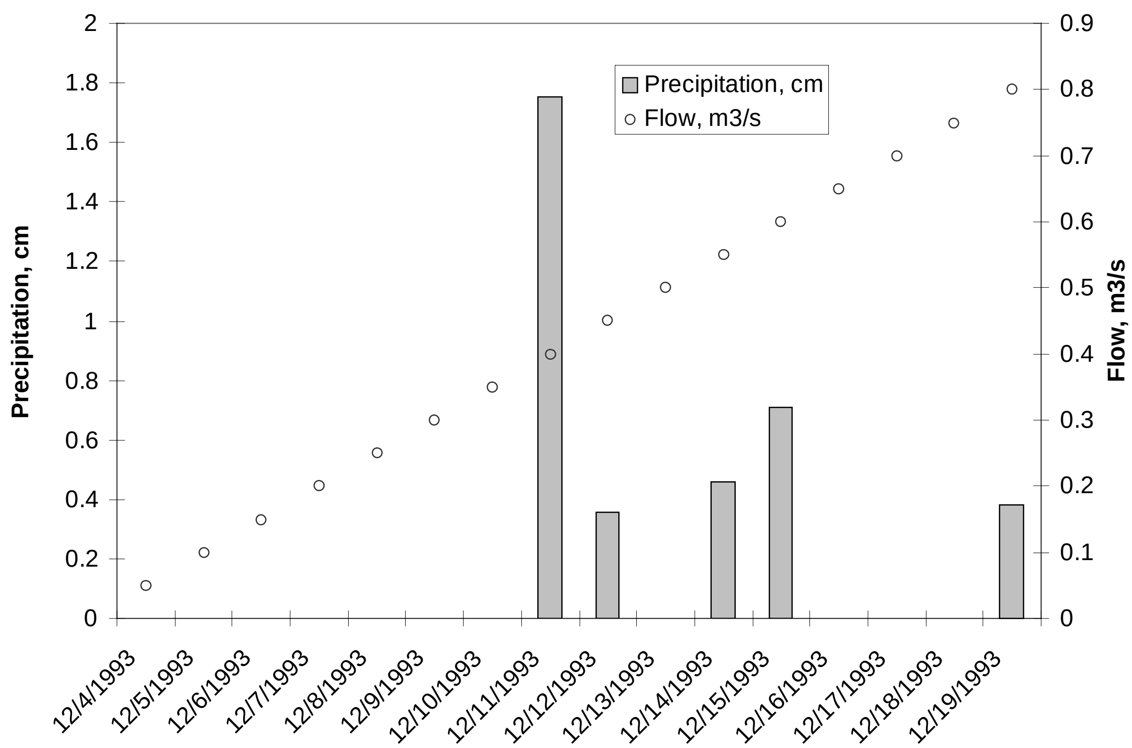

Figure 37: Precipitation and flow for Bouquet Canyon Creek, 12/4/1993-12/19/1993

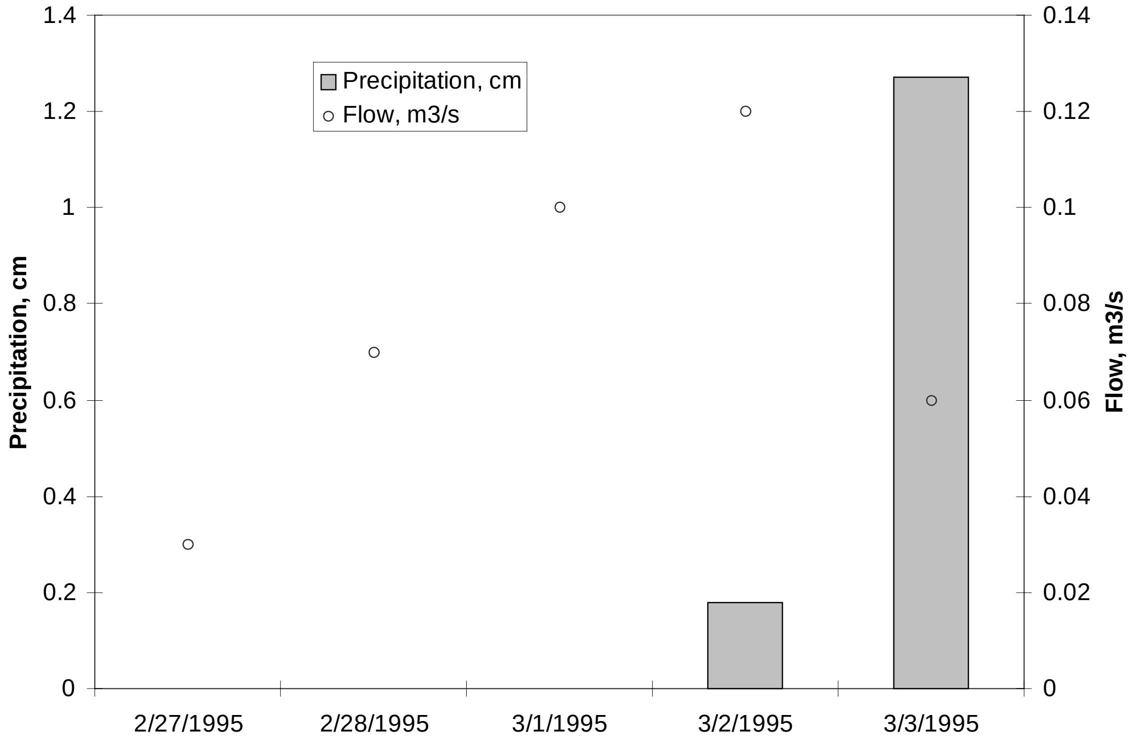

Figure 38: Precipitation and flow for Bouquet Canyon Creek, 2/27/1995-3/3/1995

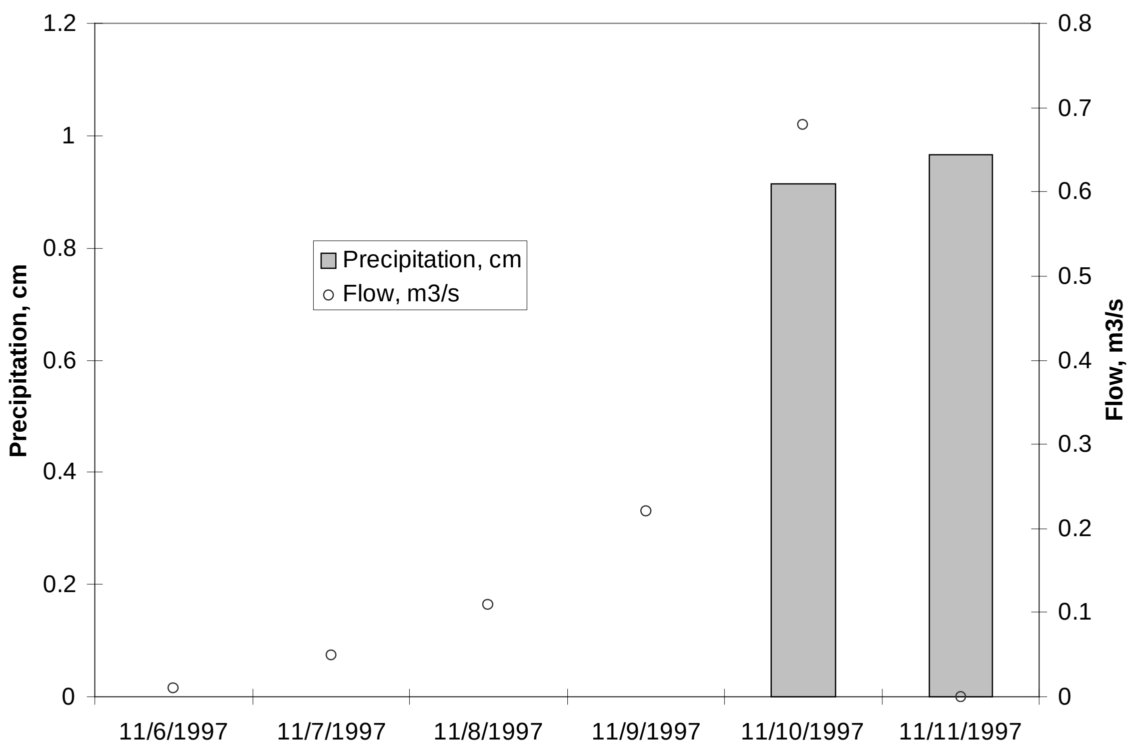

Figure 39: Precipitation and flow for Bouquet Canyon Creek, 11/6/1997-11/10/1997

Simulation Results

For the eastern tributaries, there are two gaging stations: Mint Canyon Creek at Fitch Avenue and Bouquet Canyon Creek at Urbandale (Figure 40).

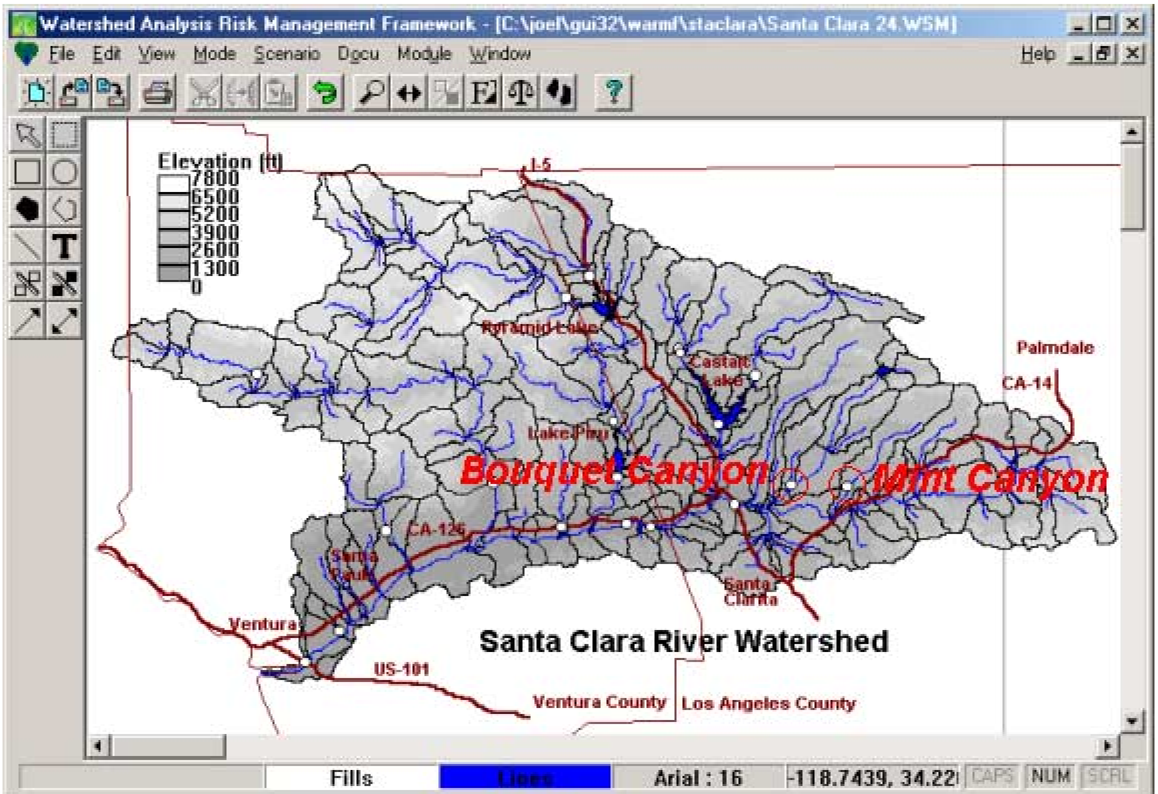

Figure 40: Stream gages in the eastern tributaries of the Santa Clara River

Simulation results (blue) and observed data (black circles) are compared in Figure 41 through Figure 44. For each creek, the first figure shows the full hydrograph and the second shows the same results but only the 0-2 m^3/s range.

WARMF has simulated typical patterns of storm peaks, rapid recessions, and low/zero flows commonly observed in those creeks. For Mint Canyon Creek, the gaging station was not in operation for the model predicted very high flow for January 1992. Simulated results do not match the observed storm peak in January of 1990.

For Bouquet Canyon Creek, the model missed the storm flow for January 1990 and spring of 2000. It predicted a high flow for February 1992, which was not recorded by the gaging station. The model matched well the two highest flow peaks of the simulation period.

The frequency distribution plots of simulated and observed flows are shown in Figure 45 and Figure 46 for Mint Canyon Creek and Bouquet Creek respectively. For Mint Canyon Creek, the curves match well for high flow above 0.03 cms. The model over predicted the number of days for low flow (0.001 cms) by 15%. For Bouquet Creek, the curves match well for high flow above 0.1 cms. The model under predicted the number of days for low flow (0.001 cms) by 12%. This is probably caused by the more even distribution of large storms and uneven distribution of small storms as explained earlier in this report.

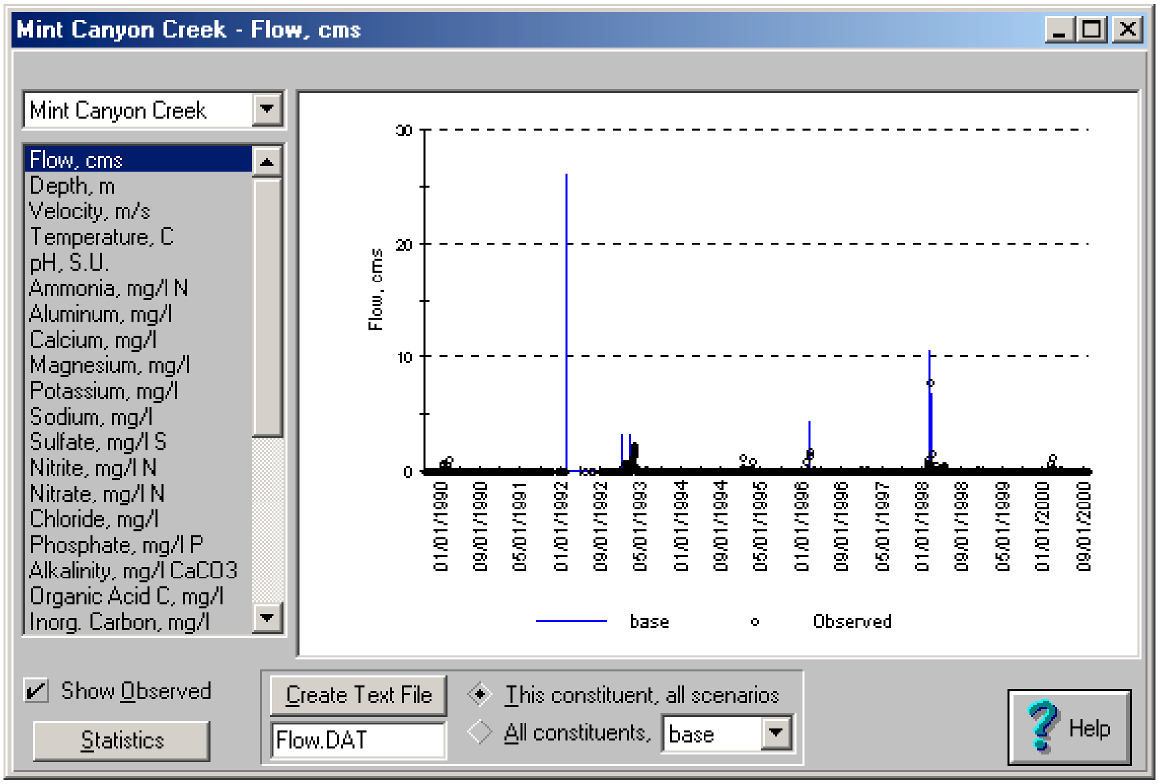

Figure 41: Simulated and Observed Flow for Mint Canyon Creek at Fitch Avenue (n = 3732; r = 0.84; relative error = -10.6%)

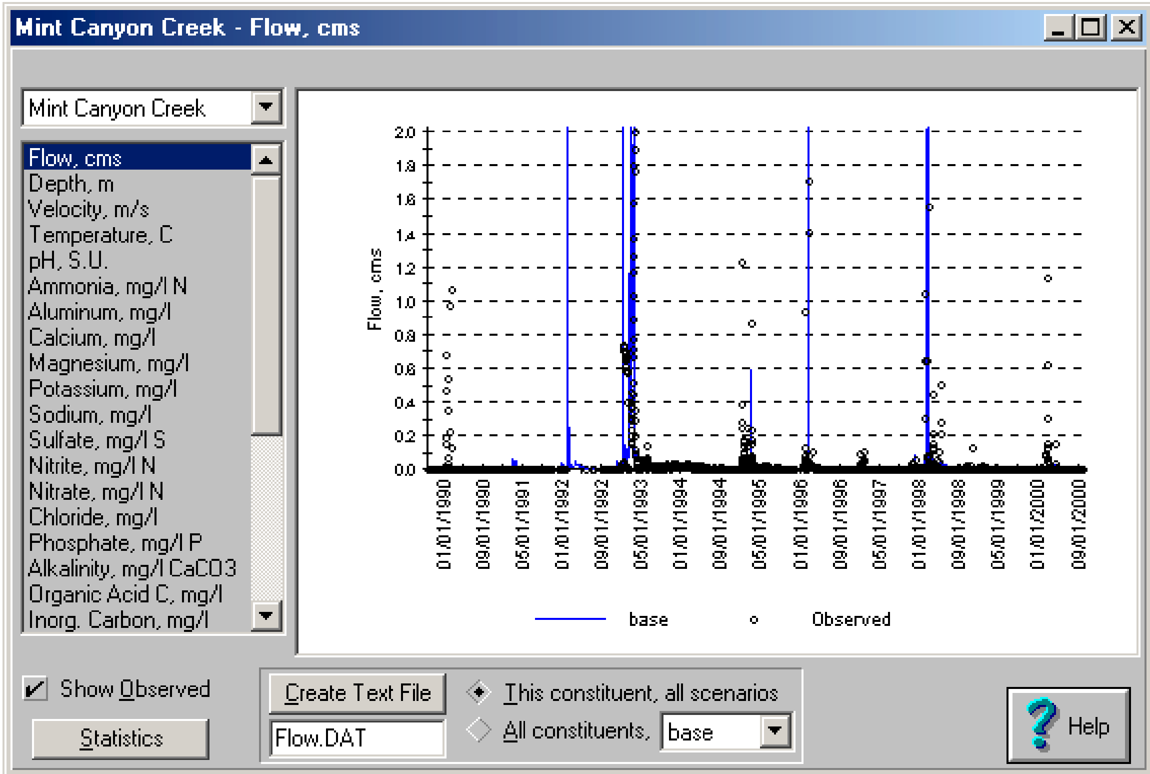

Figure 42: Simulated and Observed Flow: 0-2 m^3/s for Mint Canyon Creek at Fitch Avenue (n = 3729; r = 0.61; relative error = -16.1%)

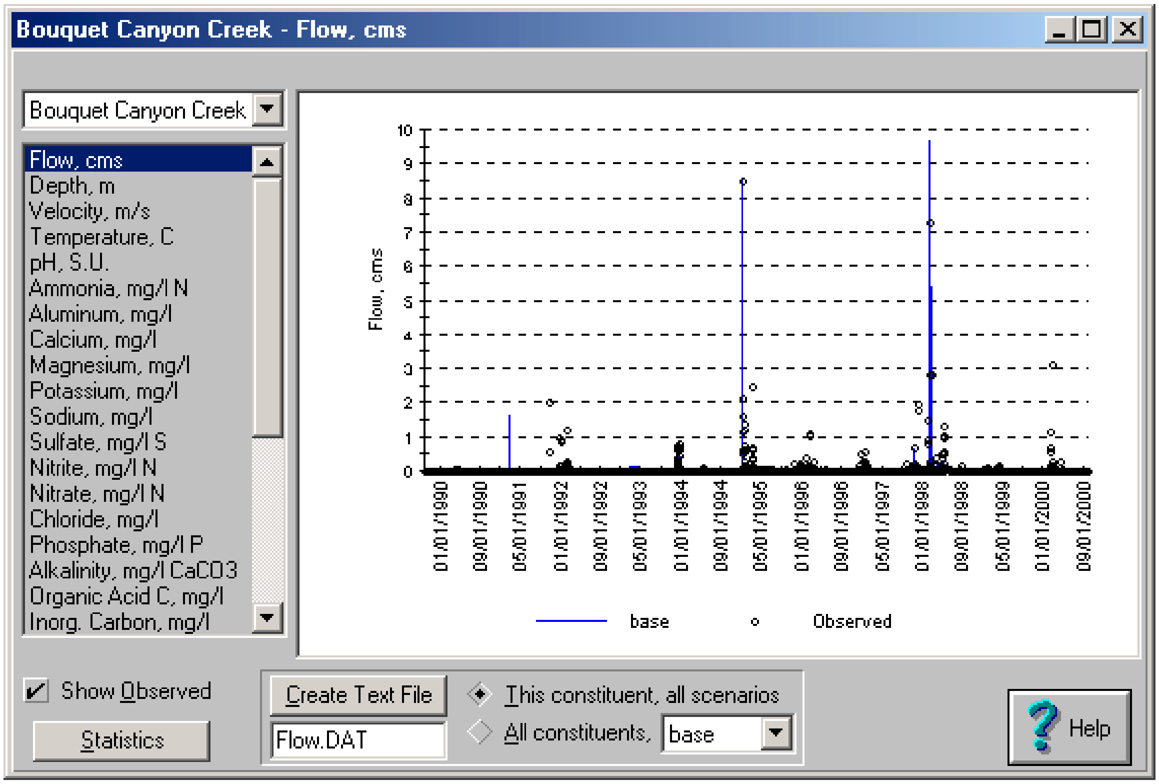

Figure 43: Simulated and Observed Flow for Bouquet Canyon Creek at Urbandale (n = 4018; r = 0.80; relative error = -3.6%)

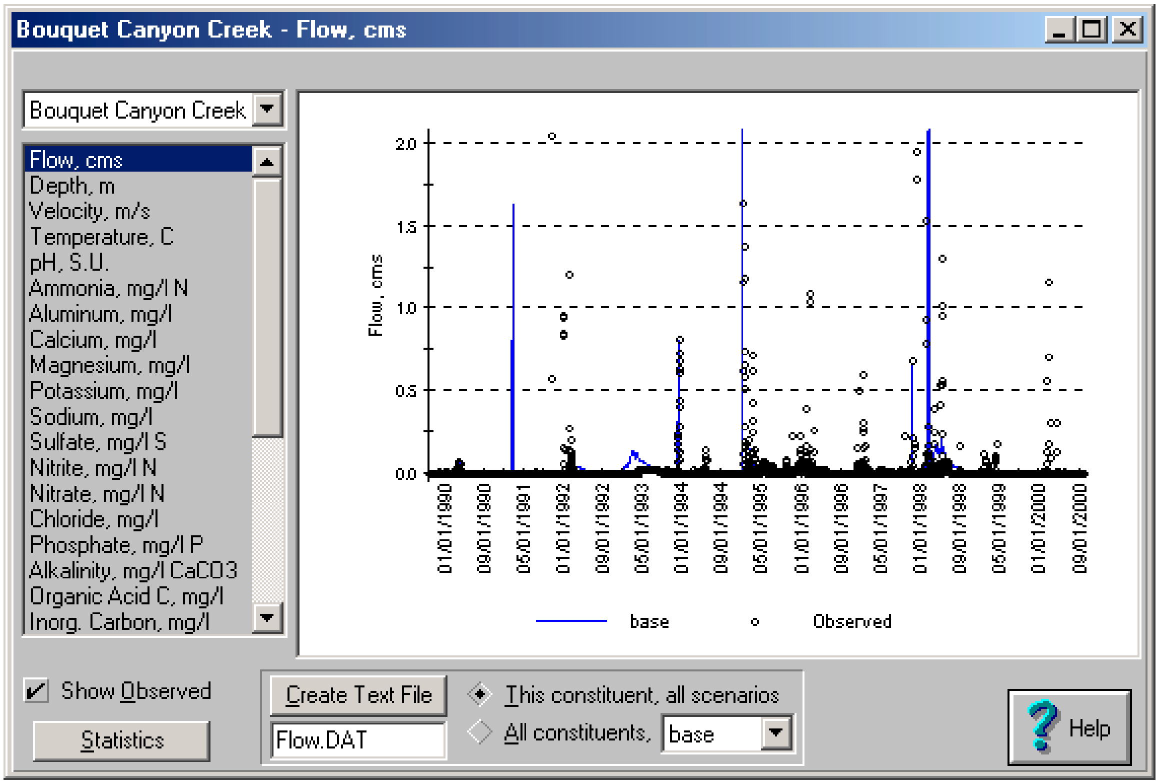

Figure 44: Simulated and Observed Flow: 0-2 m^3/s for Bouquet Canyon Creek at Urbandale (n = 4010; r = 0.30; relative error = +9.3%)

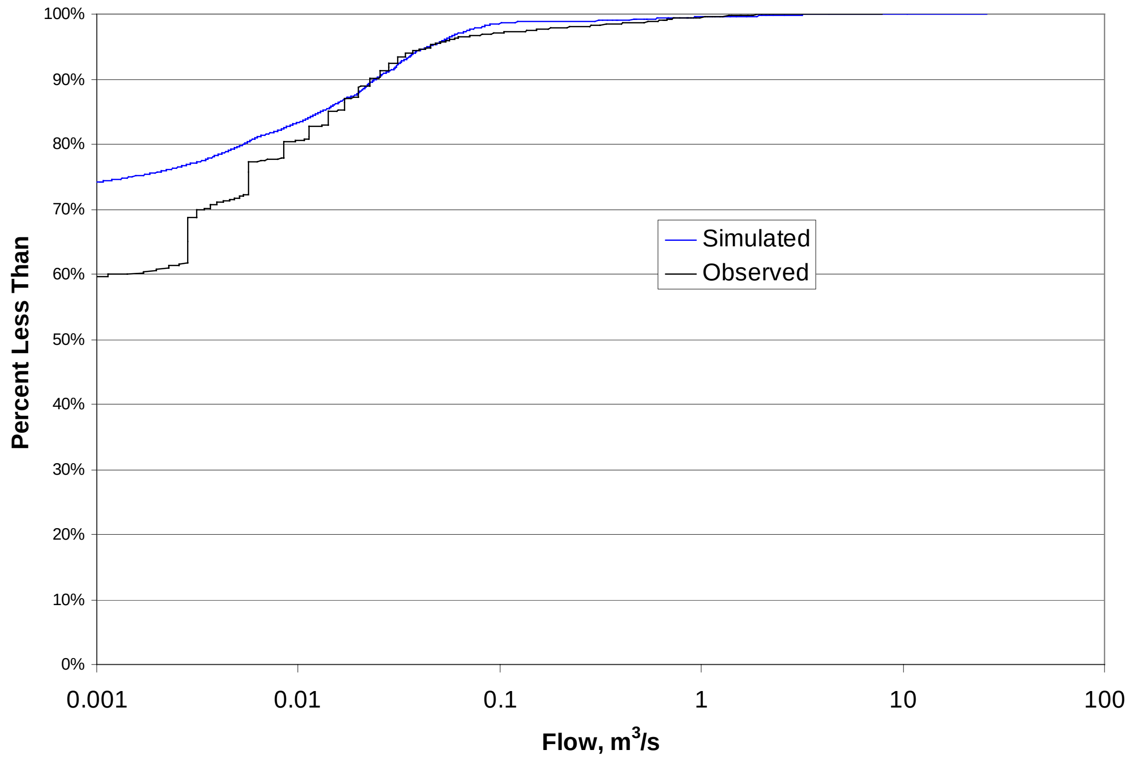

Figure 45: Frequency distribution of flow for Mint Canyon Creek at Fitch Avenue

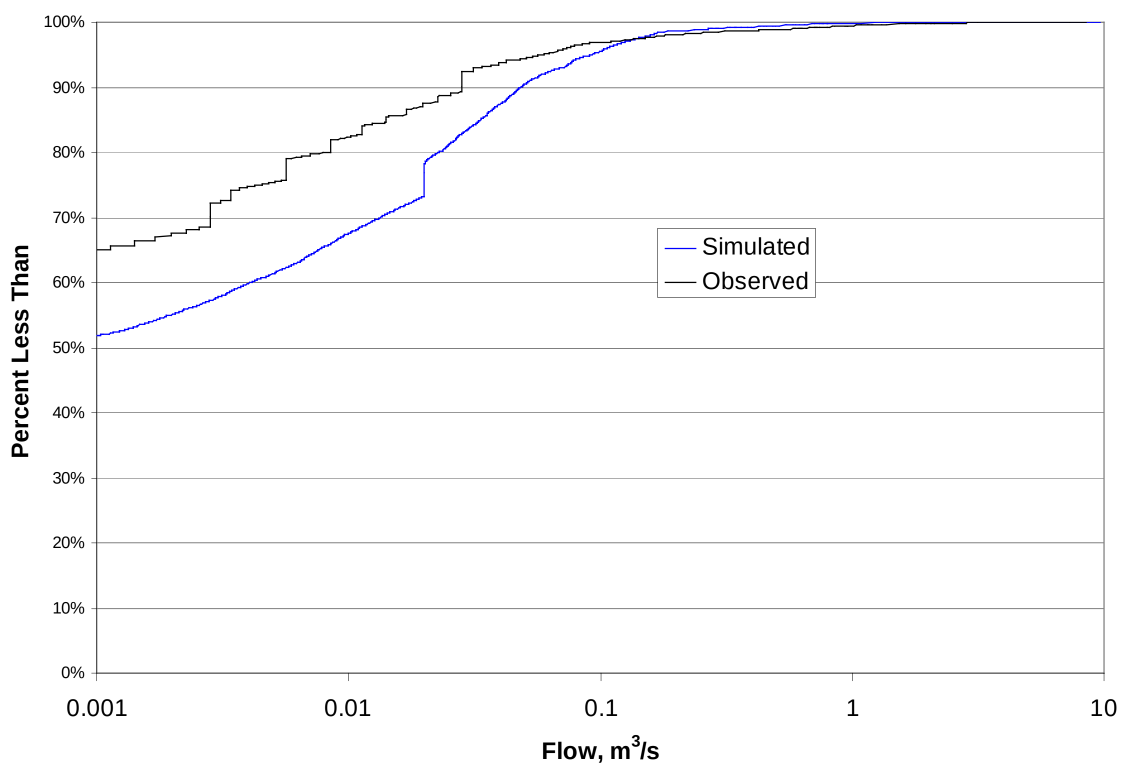

Figure 46: Frequency distribution of flow for Bouquet Canyon Creek at Urbandale

Water Quality

There is no available water quality monitoring data for Mint Canyon Creek. The only data available for Bouquet Canyon Creek is after the simulation period used in this project. Some water quality data has been collected from the Santa Clara River, mostly between February and June when there is flow. Any data collected at very low flow may be difficult for the model to match because the source of such flow could be very localized so that it is not simulated by WARMF.

Key Assumptions

Atmospheric deposition is a major source of nitrogen to the land surface in this part of the watershed. Nutrient uptake by scrubland vegetation is the major sink of nutrients. The difference is accumulated in the soil and concentrated by evaporation. High concentrations of nutrients can result due to the low volume of water to flush the nutrients out to the stream segments.

Simulation Results

During the simulation period, there is only monitoring data from the Santa Clara River at the locations highlighted in Figure 47.

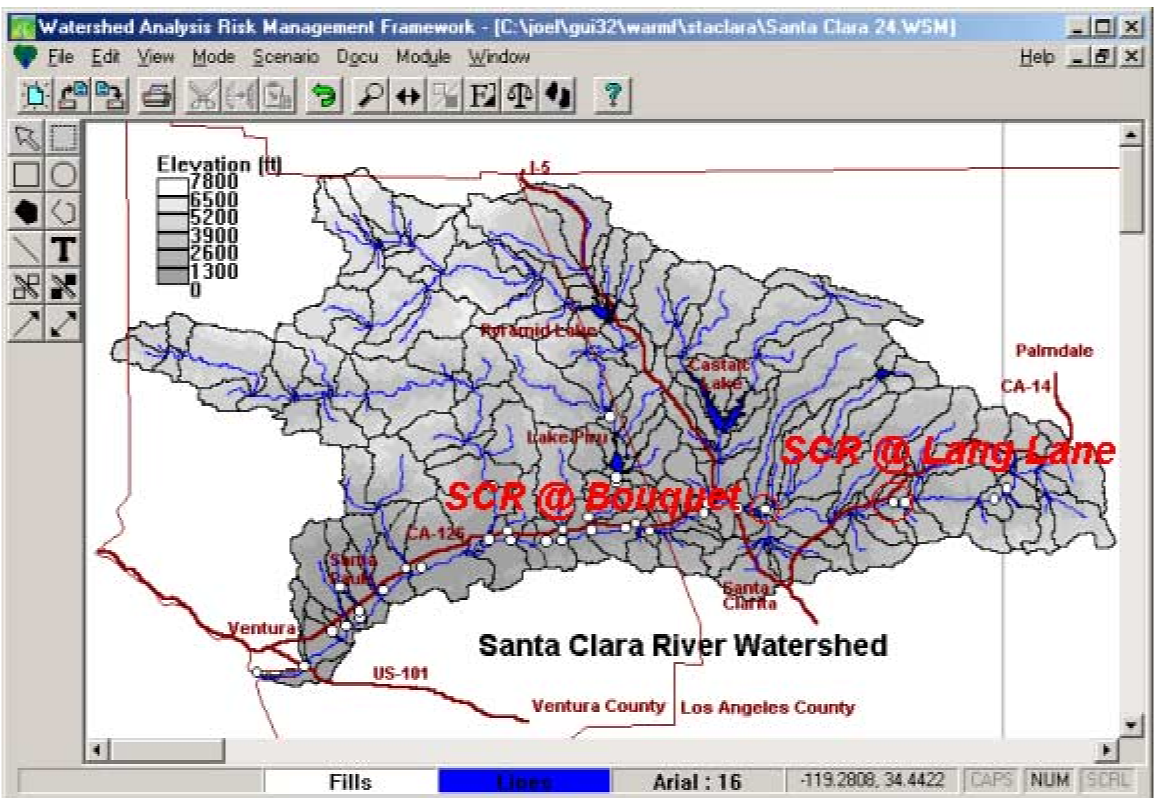

Figure 47: Water quality monitoring stations for the eastern tributaries of the Santa Clara River

Figure 50 compares the simulated and observed water temperature for the Santa Clara Creek at Bouquet Canyon Creek confluence. The model simulates a well behaved seasonal variation of water temperatures, from approximately 5 degrees Celsius in the winter to 30 degrees Celsius in the summer. The observed data indicates that the water was heated up quicker in the spring than predicted. This is a timing issue, because the ranges of simulated and observed temperatures are the same.

Ammonia results at Bouquet Canyon show that the model matches the low values of the observed data. The remaining measured value of 6.7 mg/l in May 1999 may be anomalous, or it may be part of a pattern which more monitoring would reveal. Model simulations and observed data both show low nitrate concentrations in early spring. The May 1999 data from the Santa Clara River at Lang Lane and at Bouquet Canyon show low nitrate, while simulated results show increasing nitrate. This could be caused by a model underestimate of late spring flow, but without gaging data in the area that is difficult to confirm.

The model predicts a rising trend of nitrate when the river flow is diminishing. Refer to the Sensitivity Analysis section of this document for a discussion of the impact of septic systems in this part of the watershed. Red circles have been added to some plots to make observed data more visible.

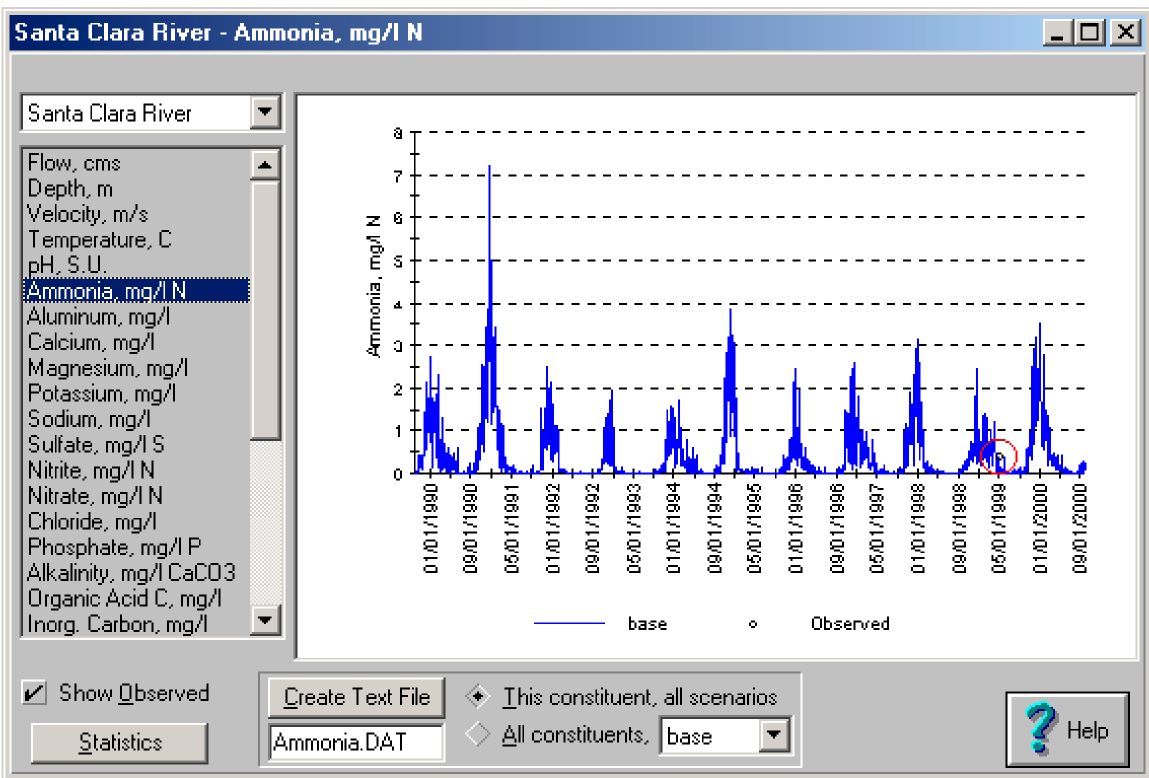

Figure 48: Simulated and Observed Ammonia for the Santa Clara River at Lang Lane (n = 1; relative error = -0.19 mg/l; absolute error = 0.19 mg/l)

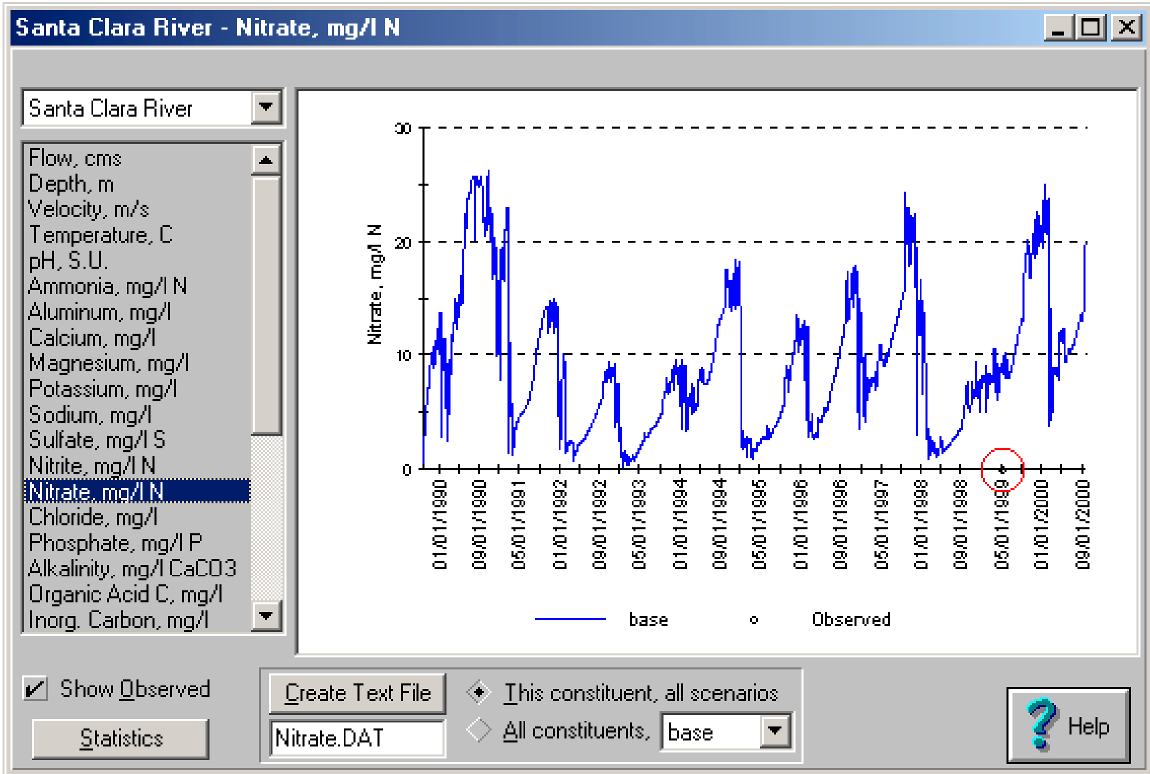

Figure 49: Simulated and Observed Nitrate for the Santa Clara River at Lang Lane (n = 1; relative error = 9.00 mg/l; absolute error = 9.00 mg/l)

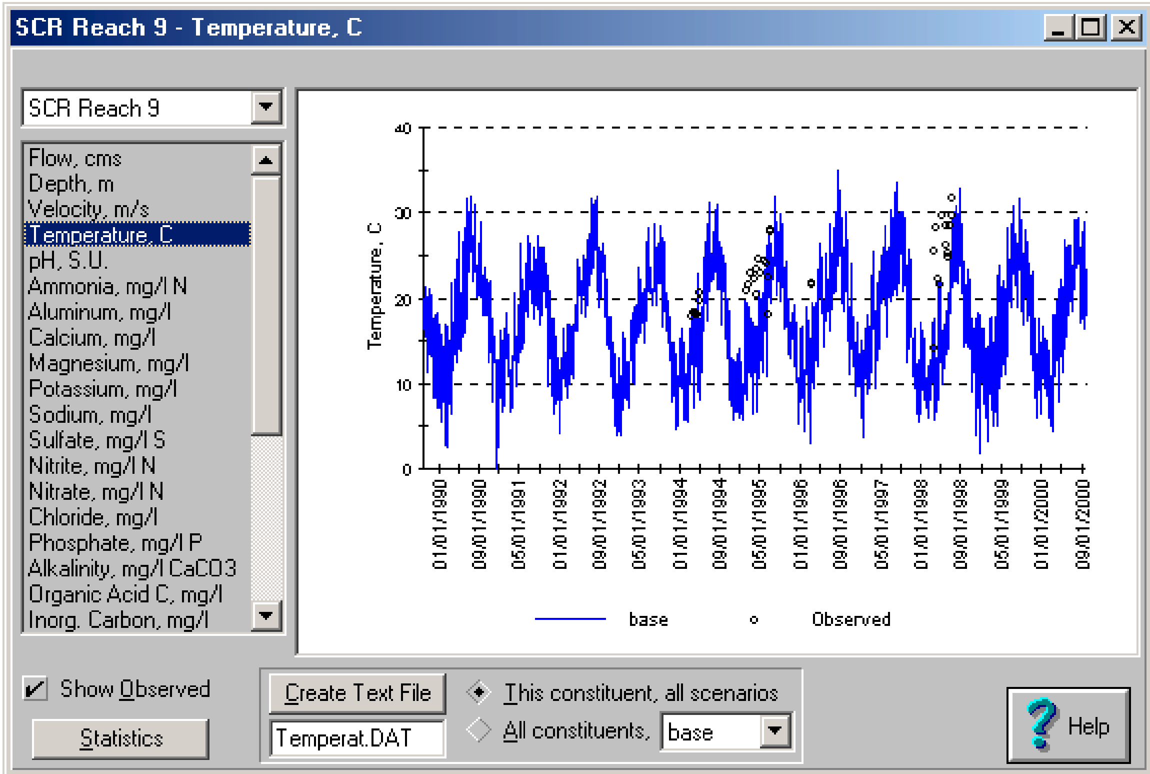

Figure 50: Simulated and Observed Temperature for the Santa Clara River at Bouquet Canyon (n = 36; relative error = -7.1 °C; absolute error = 7.3 °C)

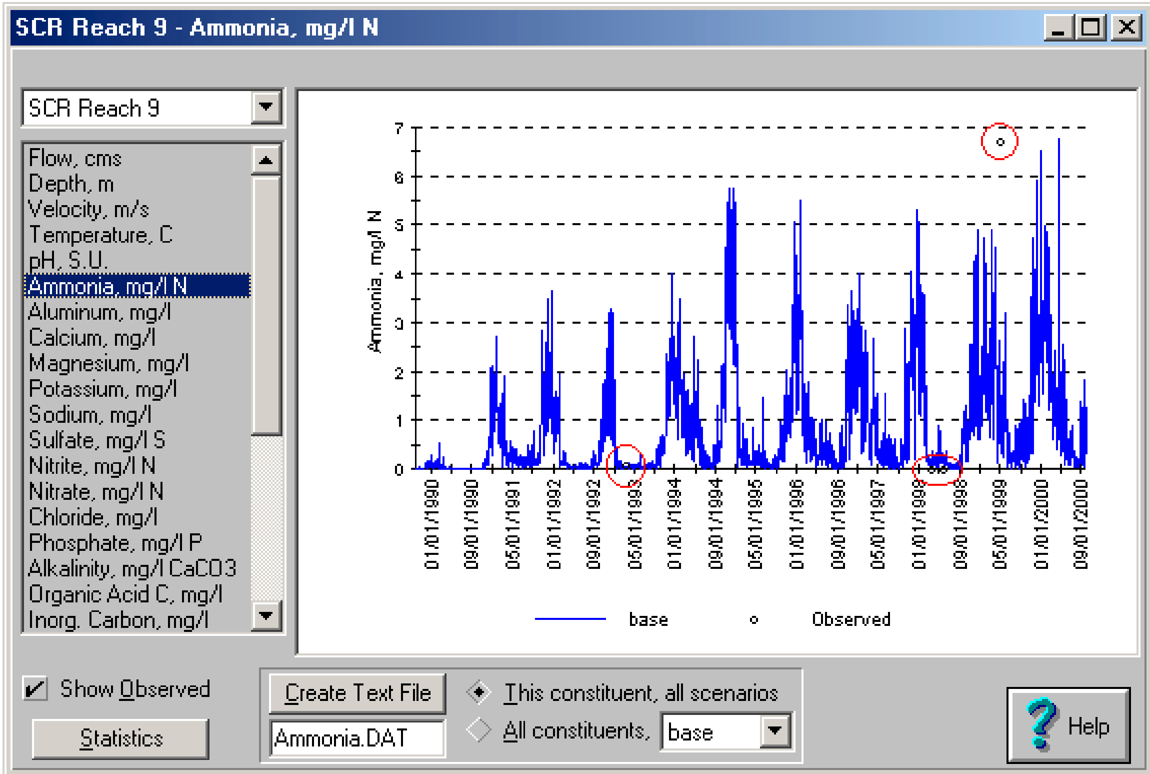

Figure 51: Simulated and Observed Ammonia for the Santa Clara River at Bouquet Canyon (n = 4; relative error = -1.20 mg/l; absolute error = 1.32 mg/l)

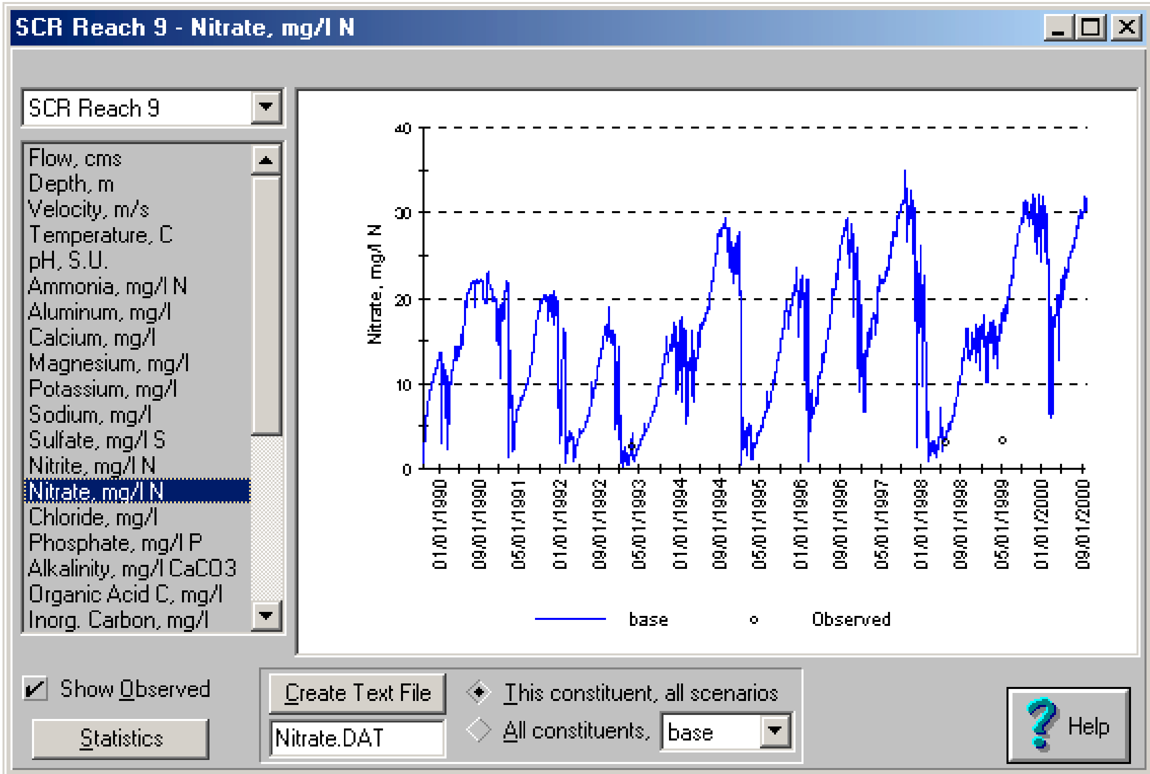

Figure 52: Simulated and Observed Nitrate for the Santa Clara River at Bouquet Canyon (n = 3; relative error = 4.62 mg/l; absolute error = 4.62 mg/l)

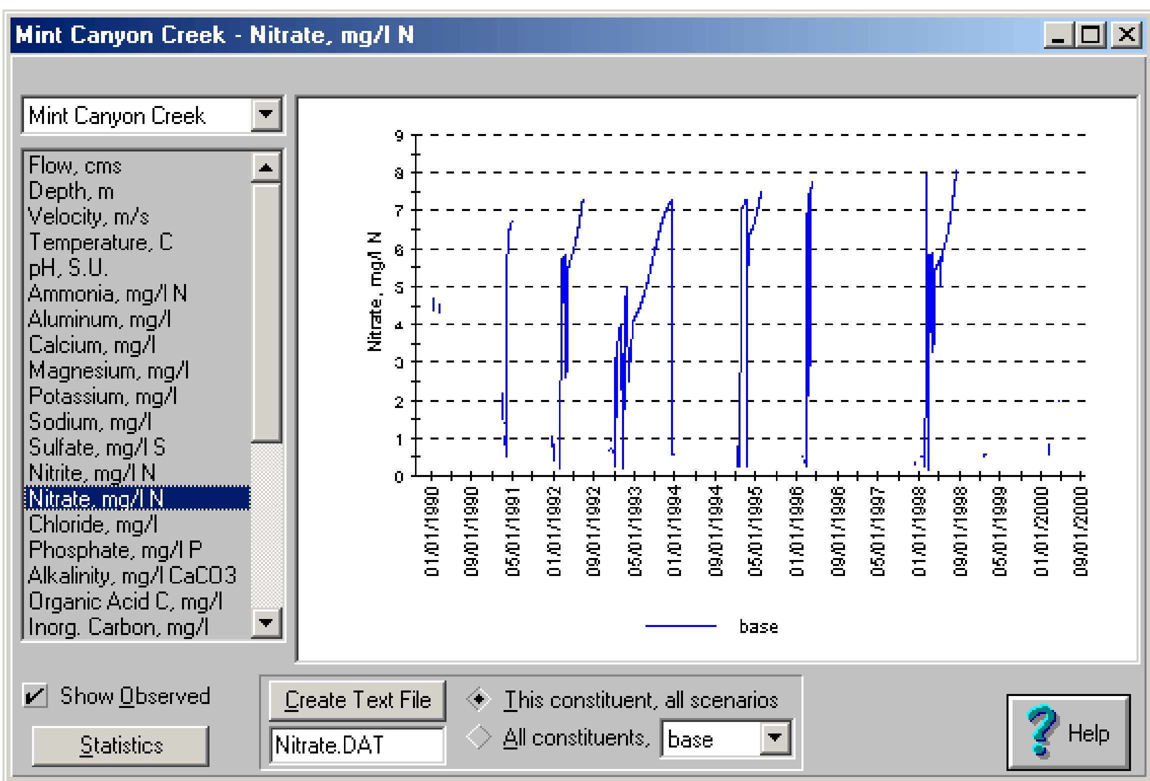

Figure 53: Simulated Nitrate for Mint Canyon Creek

Santa Clara River Reach 8: Bouquet Canyon to Old Road Bridge

This reach of the Santa Clara River (Figure 2) is in the rapidly growing Santa Clarita area. The hydrology and water quality of this reach is dictated not by precipitation, but rather by wastewater reclamation facilities and dewatering projects. These sources are augmented during spring by natural flow from the eastern tributaries and upstream reaches of the Santa Clara River. Modeling of this section of river is largely a matter of doing proper mass balance accounting of flow and water quality.

Hydrology

The hydrology of this section of the river is dominated by the discharge from the Saugus Wastewater Reclamation Facility (WWRF), whose outfall is located just downstream of the confluence of Bouquet Canyon Creek with the Santa Clara River. Another significant source is gain from groundwater in the Round Mountain area just upstream of the Old Road Bridge gage. Flow from the eastern tributaries of the Santa Clara River and the river itself upstream of Bouquet Canyon contributes a small portion of overall flow. The combined gaged flow from Mint Canyon Creek and Bouquet Canyon Creek is approximately 5% of the flow at the Old Road Bridge gage on an annual basis. About 58% of the flow from Mint Canyon and Bouquet Canyon Creeks occurs in February. The water from these sources is sometimes mixed with dewatering operations from local construction projects.

In Mint Canyon Creek and Bouquet Canyon Creek, temporary dewatering projects were identified by finding irregularities in the gaged hydrograph. The irregularities were clear because there was typically zero flow and suddenly increased without any storms. It is not possible to use the same technique to estimate dewatering flows in Reach 8 because flow is perennial and can potentially have many sources. However, there are records for certain dewatering projects beginning in December of 1998.

There are unexplained increases in gaged flow during dry weather: 8/10/1990 to 8/18/1990, 9/19/1990 to 2/26/1991, and 7/30/1991 to 11/27/1991. Some of these flows might be attributable to dewatering operations, but there is too much uncertainty in estimating their location and flow. Therefore, only the dewatering operations with reported flows were entered into WARMF.

Key Assumptions

Hydrology of this reach is modeled by flow balance. The data used includes discharge of the Saugus WWRF, two smaller point sources(H.R. Textron and Magic Mountain), and the gaged flows of Mint Canyon and Bouquet Canyon Creeks. There are also flow records from 20 known dewatering operations in operation at various times from December 1998 through the end of the simulation period. A groundwater model (CH2M Hill 2002) provides flow estimates from groundwater to the river in the Round Mountain area. The groundwater flow estimates were included in the watershed model as prescribed flows.

To estimate losses in this reach, the sum of all known inflows was subtracted from gaged flow at the Old Road Bridge. When the result was negative, that indicated a loss of flow by percolation into the river bed. Figure 54 presents the estimated water losses across the river bed for the river section extending from Saugus WWRF to the Old Road Bridge. Seasonal average loss was used for 10/1992-9/1996, when there is no data from the Old Road Bridge gage.

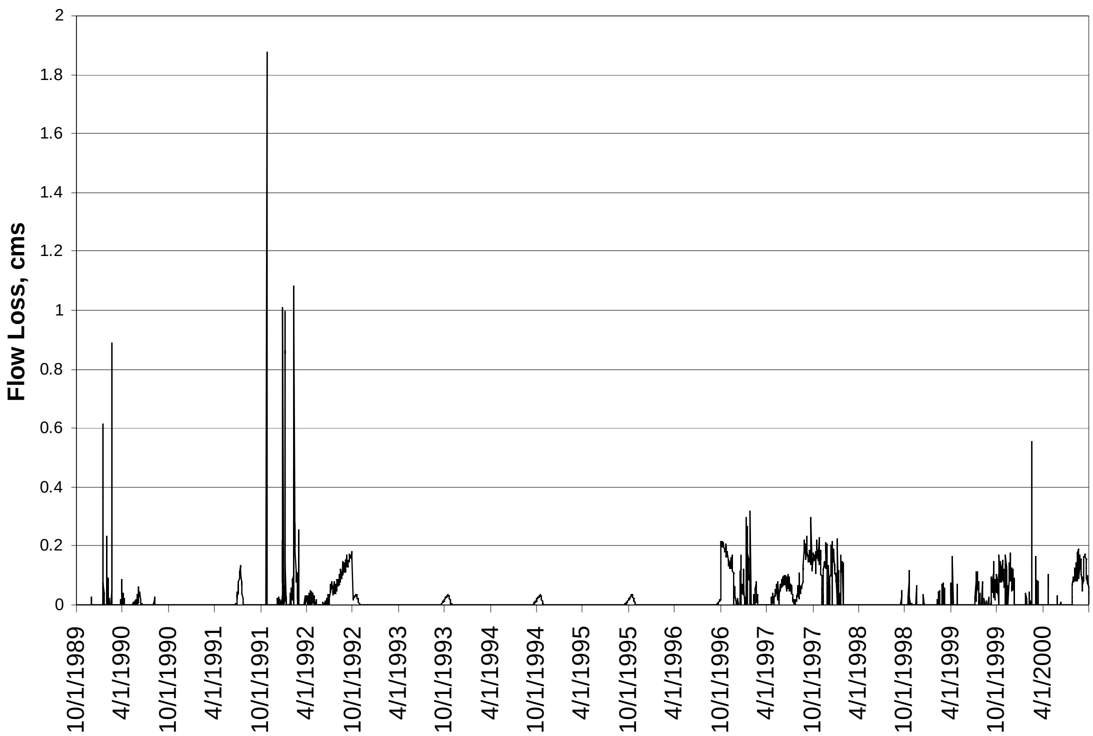

Figure 54: Estimated Flow Loss, Saugus WWRF to Old Road Bridge

Table 9 presents average monthly flow balances for water year 1991, a dry year. Table 10 shows the same flow balance for 1998, a wet year. The known dewatering projects are not shown because they were not in operation during water years 1991 and 1998. Each known source of flow is tabulated. There are no diversions in this reach of the river, so there are no known outputs.

The difference between net known flow and gaged flow is the net gain to the river or loss from the river. Note that since there is no gage on the Santa Clara River at the upstream end of Reach 8, the flows from upstream reaches of the Santa Clara River (9 and 10) are implicitly included within the net gains and losses. Net gains to the river are simulated as natural lateral flow and surface runoff in WARMF. Net losses are simulated with artificial diversions from the river reach at a constant rate per river mile. Losses are calculated on a daily basis for use in simulations.

Table 9: Flow Balance for Santa Clara River Reach 8, m^3/s, Water Year 1991

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Mint Canyon Creek	0	0	0	0	0	0	0	0	0	0	0	0	0
Bouquet Canyon Creek	0	0	0	0	0	0	0	0	0	0.004	0	0	0
Saugus WWRF	0.227	0.242	0.236	0.228	0.215	0.221	0.210	0.226	0.246	0.261	0.242	0.231	0.232
H.R. Textron, Inc.	0	0	0	0	0	0	0	0	0	0	0	0	0
Magic Mountain	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Prescribed Groundwater Gains	0.046	0.071	0.039	0.076	0.048	0.189	0.077	0.034	0.000	0.000	0.000	0.000	0.049
TOTAL KNOWN INPUTS	**0.277**	**0.318**	**0.279**	**0.309**	**0.268**	**0.415**	**0.292**	**0.265**	**0.250**	**0.269**	**0.247**	**0.236**	**0.285**
TOTAL KNOWN OUTPUTS	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
NET KNOWN FLOW	**0.277**	**0.318**	**0.279**	**0.309**	**0.268**	**0.415**	**0.292**	**0.265**	**0.250**	**0.269**	**0.247**	**0.236**	**0.285**
GAGED FLOW	**0.300**	**0.322**	**0.354**	**0.363**	**0.340**	**0.378**	**0.355**	**0.305**	**0.286**	**0.213**	**0.477**	**0.468**	**0.347**
NET GAIN (+) / LOSS (-)	**0.023**	**0.004**	**0.075**	**0.055**	**0.072**	**-0.04**	**0.062**	**0.040**	**0.036**	**-0.06**	**0.230**	**0.232**	**0.061**

Table 10: Flow Balance for Santa Clara River Reach 8, m^3/s, Water Year 1998

	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Mean**
Mint Canyon Creek	0	0.003	0.004	0.002	0.439	0.046	0.005	0.039	0	0	0	0.001	0.045
Bouquet Canyon Creek	0.009	0.047	0.122	0.004	0.630	0.035	0.009	0.212	0.046	0.000	0.000	0.008	0.093
Saugus WWRF	0.240	0.299	0.380	0.250	1.344	0.332	0.257	0.535	0.325	0.196	0.184	0.226	0.381
H.R. Textron, Inc.	0	0	0	0	0	0	0	0	0	0	0	0	0
Magic Mountain	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Prescribed Groundwater Gains	0.037	0.071	0.064	0.272	2.917	1.450	0.277	0.835	0.367	0.101	0.156	0.063	0.551
TOTAL KNOWN INPUTS	**0.291**	**0.425**	**0.575**	**0.533**	**5.334**	**1.868**	**0.553**	**1.626**	**0.743**	**0.302**	**0.345**	**0.303**	**1.075**
TOTAL KNOWN OUTPUTS	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
NET KNOWN FLOW	**0.291**	**0.425**	**0.575**	**0.533**	**5.334**	**1.868**	**0.553**	**1.626**	**0.743**	**0.302**	**0.345**	**0.303**	**1.075**
GAGED FLOW	**0.075**	**0.308**	**1.069**	**0.501**	**17.53**	**1.906**	**1.575**	**2.630**	**0.663**	**0.300**	**0.251**	**0.355**	**2.263**
NET GAIN (+) / LOSS (-)	**-0.22**	**-0.12**	**0.494**	**-0.03**	**12.19**	**0.039**	**1.023**	**1.004**	**-0.08**	**-0.00**	**-0.09**	**0.052**	**1.189**

Simulation Results

Model predictions are compared with observed data in Figure 55 and Figure 56 for the Santa Clara River at the Old Road Bridge. Figure 56 shows the same results as Figure 55, but only the flow range from 0 to 2 m^3/s.

The frequency distribution plot (Figure 57) shows similarity between the magnitude of flows represented in simulations as compared to observed data, with a small overprediction of flow in general. Some of the unexplained flow increases discussed above are evident in Figure 56, particularly 7/30/1991-11/27/1991.

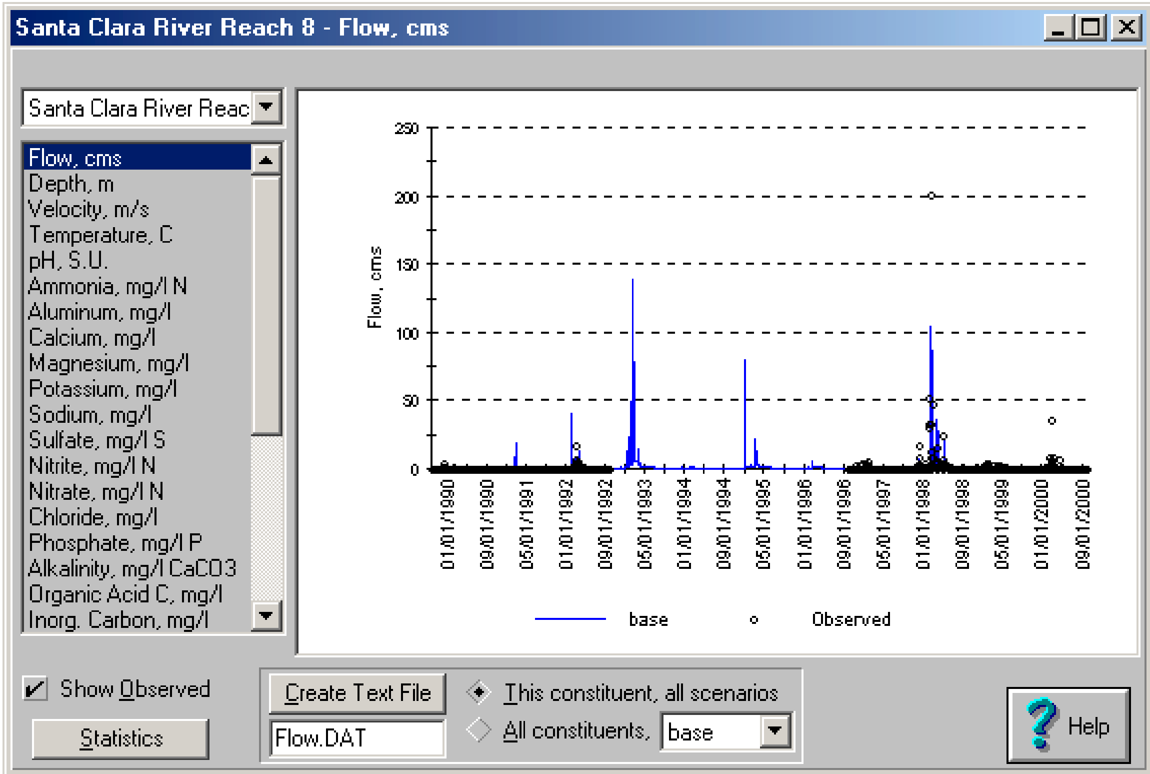

Figure 55: Simulated and Observed Flow, Santa Clara River at Old Road Bridge (n = 2557; r = 0.71; relative error = +16.2%)

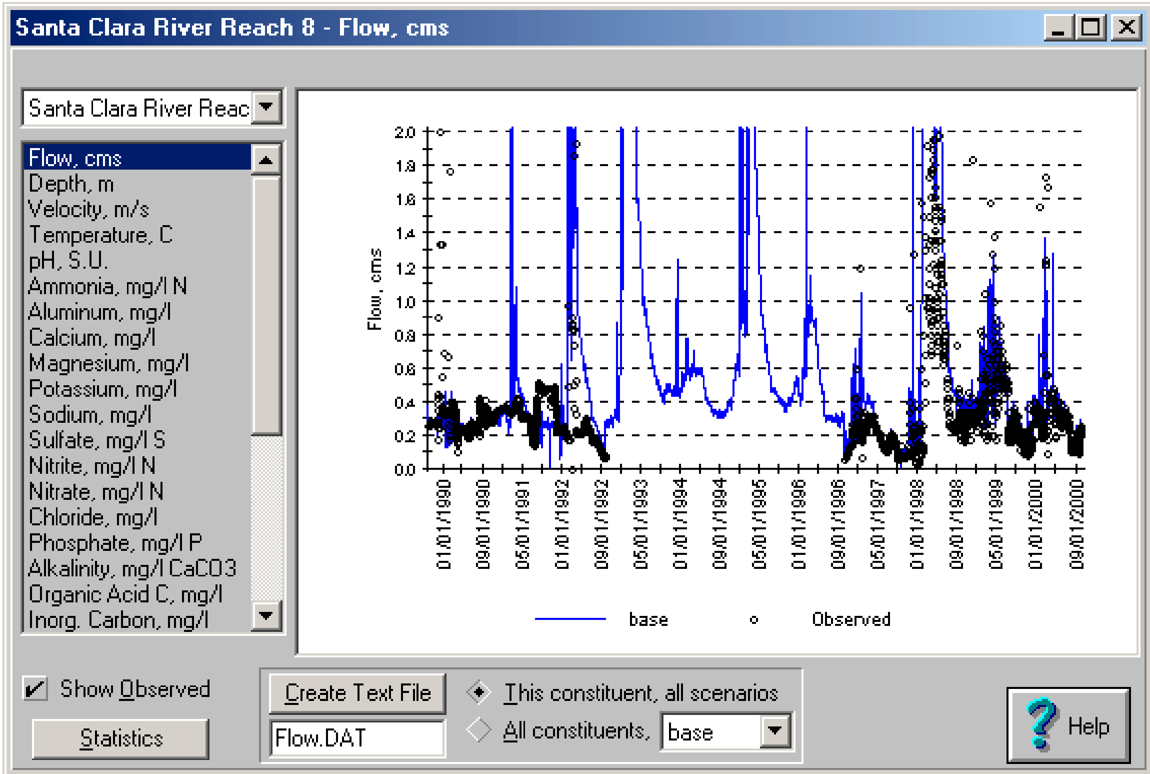

Figure 56: Simulated and Observed Flow: 0-2 m^3/s, Santa Clara River at Old Road Bridge (n = 2480; r = 0.42; relative error = +67.5%)

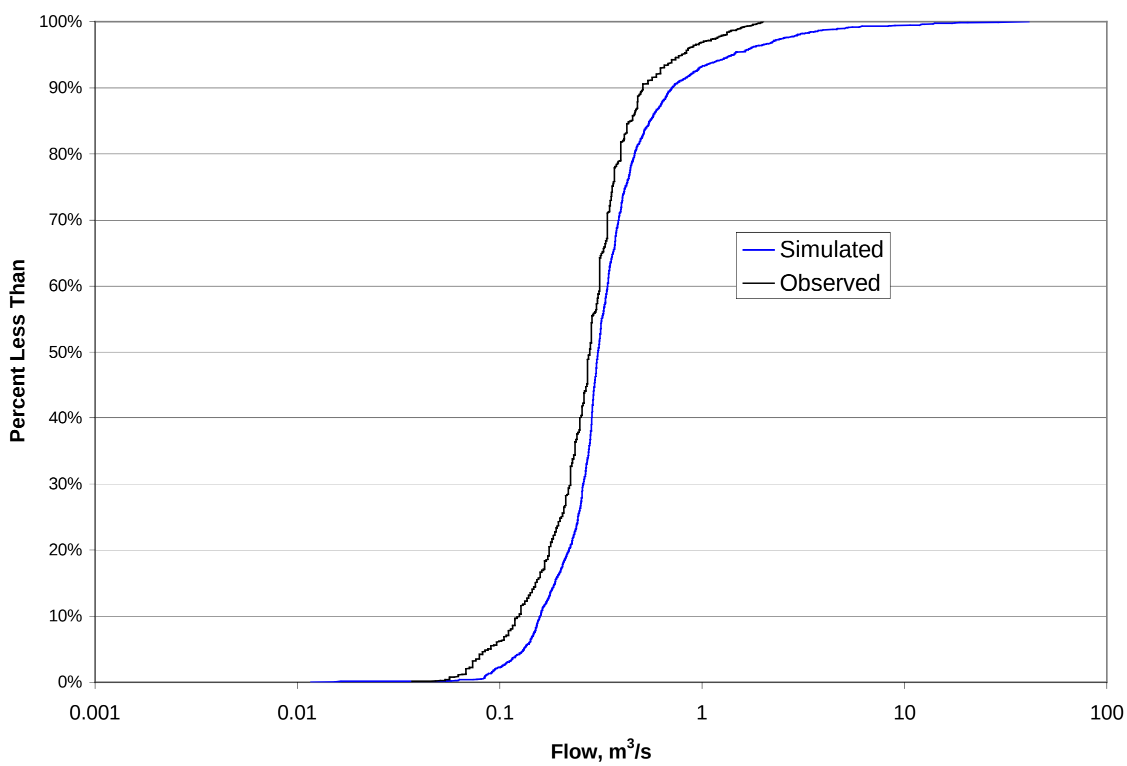

Figure 57: Frequency distribution of flow for Santa Clara River at Old Road Bridge

Water Quality

The Source Analysis Report (Systech 2002) indicates that most of the nutrient loading to Reach 8 of the Santa Clara River comes from direct point source discharges, primarily the Saugus WWRF. Table 9 and Table 10 show that, for most of the year, the effluent from the same treatment plant represents most of the flow in the river. The differences between measured effluent water quality and monitoring data are a result of other flow and loading sources and in-stream assimilation of nutrients.

Key Assumptions

Table 11 below shows a summary of loading from the Source Analysis Report (Systech 2002). Ammonia, nitrite, and nitrate are added together into total nitrogen loading. “Total Direct Loading” represents loading which enters the river directly. “Total Land Surface Loading” is loading applied to the land surface, a small portion of which may transported to the river by runoff. “Total In stream Loading” is the amount of nitrogen actually in the river as calculated from gaged flow and water quality monitoring data.

Table 11: Loading balance of total nitrogen for Santa Clara River Reach 8, kg/d N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Total Direct Loading	397	1022	715	513	552	407	342	356	374	384	399	430	491
Total Land Surface Loading	427	712	720	1771	1566	1518	1508	1499	1490	372	297	402	1024
Total In stream Loading	541	3482	1188	693	896	434	327	288	283	177	330	505	761

The in-stream loading of total nitrogen is lower than total direct loading from July through November. This indicates that some in-stream processes are removing nitrogen from the river water. Nitrification converts ammonia to nitrate, so it cannot cause a decrease in total nitrogen. There are a few possibilities to explain the loss of nitrogen: losses of flow through the river bed, uptake by periphyton or macrophytes, adsorption by the river bed, and denitrification. Denitrification converts nitrate to nitrogen gas under anoxic conditions. It can occur in the river bed, despite the aerobic condition of the water column. A compilation of collected data indicates that the denitrification rate varies from 0.1/day to 1.6/day in a river not more than 0.5 meters deep (Hirsch 2001).

Simulation Results

The model was used to test the different potential mechanisms for nutrient removal from within Reach 8 of the Santa Clara River. Known flow losses are already simulated, but not frequent enough and large enough to account for the nitrogen loss. Periphyton requires a suitable substrate on which to grow. Suitable habitat includes gravel and bedrocks, so the sandy conditions of the river bed may not be ideal. Assuming that periphyton can grow, model simulations indicate that a reasonable productivity of periphyton can not account for the nitrogen assimilation. The sandy river bed may adsorb ammonia and phosphorus, but not nitrate. The phosphorus data (Figure 74) does not show assimilation in this river reach.

The remaining mechanism for nitrogen removal is denitrification in the river bed. The denitrification rate used was 0.5/day. Refer to the Sensitivity Analysis section of this document for an analysis of the effect of denitrification and of periphyton.

Simulated results show good matches to the observed monitoring data at the Old Road Bridge, as shown in Figure 58 through Figure 61. Red circles have been added to some figures to make some observed data points more visible, not to add emphasis.

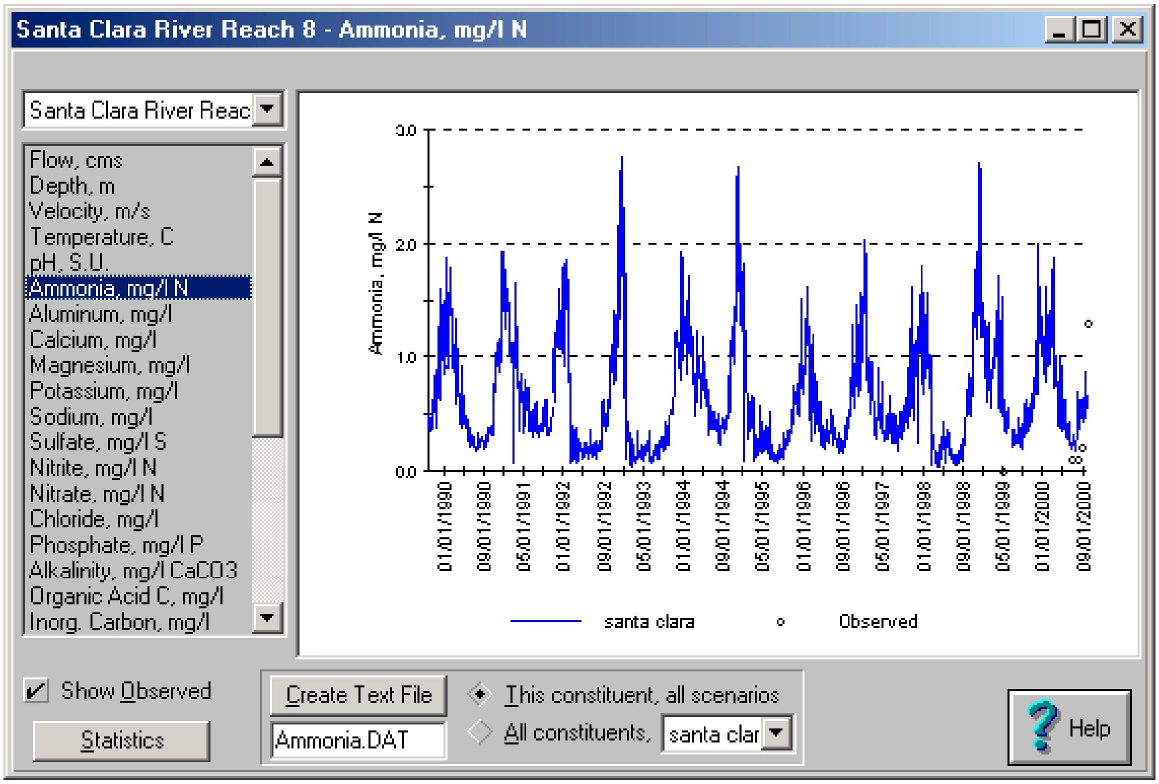

Figure 58: Simulated and Observed Ammonia for the Santa Clara River at Old Road Bridge (n = 5; relative error = 0.11 mg/l; absolute error = 0.37 mg/l)

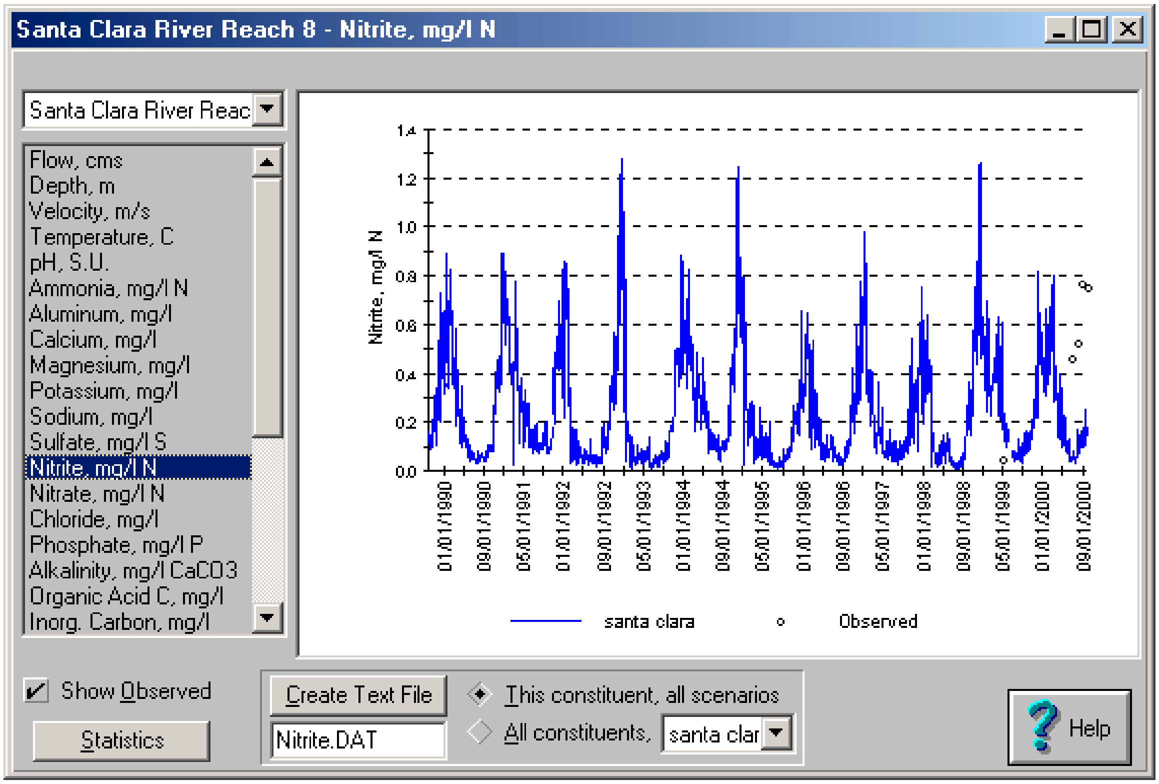

Figure 59: Simulated and Observed Nitrite for the Santa Clara River at Old Road Bridge (n = 5; relative error = -0.39 mg/l; absolute error = 0.43 mg/l)

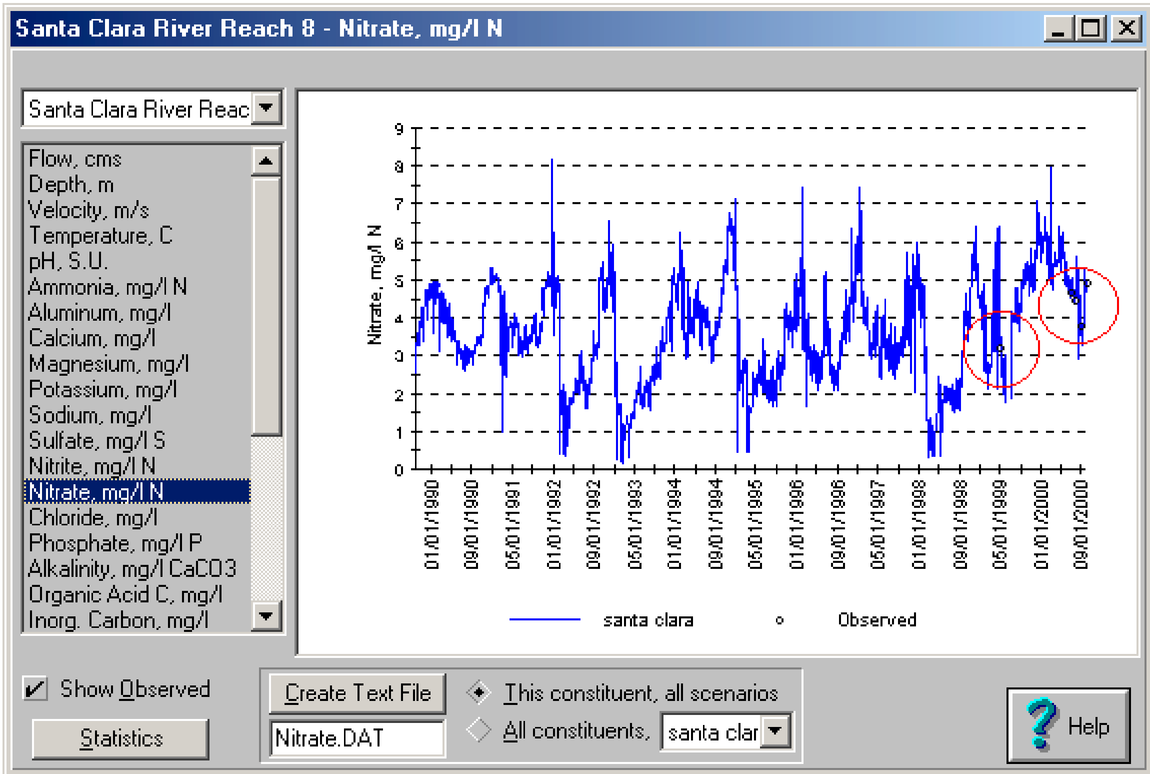

Figure 60: Simulated and Observed Nitrate for the Santa Clara River at Old Road Bridge (n = 5; relative error = -0.68 mg/l; absolute error = 0.74 mg/l)

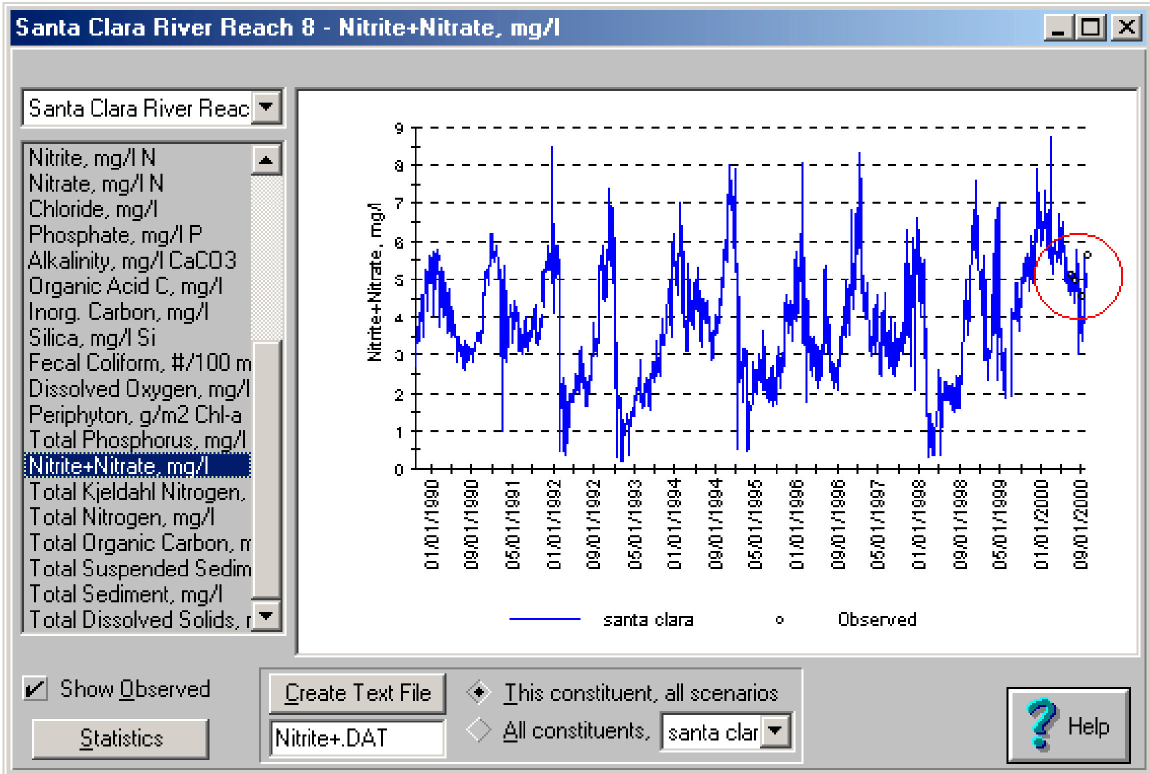

Figure 61: Simulated and Observed Nitrate+Nitrite for the Santa Clara River at Old Road Bridge (n = 4; relative error = -0.60 mg/l; absolute error = 0.60 mg/l)

Santa Clara River Reach 7: Old Road Bridge to Blue Cut

This reach of the Santa Clara River (shown in Figure 3) is between the City of Santa Clarita and the Blue Cut gage near the Los Angeles / Ventura county line. There are four main sources of water to this reach: the flow from Reach 8 of the Santa Clara river, the discharge from the Valencia WWRF, releases from Castaic Lake, and gains from groundwater throughout the reach.

Modeling of this section of river is largely a matter of accounting for flow and pollutants. In addition to the three main sources of water, there are unknown flow inputs from surface runoff and loss across the river bed.

<u>Hydrology</u>

During dry weather, hydrology in this reach is largely governed by discharges from wastewater reclamation facilities and release from Castaic Lake. During wet weather, however, there is significant local runoff. Peak flows at the Blue Cut gage are typically much higher than the peak flows at the Old Road Bridge gage.

Key Assumptions

Hydrology of this reach is modeled with a flow balance. The gage at the Old Road Bridge represents one major input of flow. There is one major point source for which there are daily flow records, the Valencia WWRF just downstream of the Old Road

Bridge. There is one very small point source in this reach, the Val Verde County Park Swimming Pool. Daily discharge from Castaic Lake is also known. A groundwater model predicts the gains from groundwater in the reach (CH2M Hill 2002). The estimated flows from the groundwater model were input to the watershed model as prescribed flows.

There are also two diversions: Rancho Camulos and Newhall Land (Isola). The Rancho Camulos flow was estimated from irrigated acreage and pumping records. Newhall Land provided flow for the Isola diversion.

The Blue Cut gage representing the downstream end of this reach was originally located at the Los Angeles / Ventura county line. On 10/1/1996, it was moved downstream to a location "near Piru". Before the gage moved, the diversions were downstream of the gage and thus not part of this reach. Figure 62 shows both the locations of the "Blue Cut" gage.

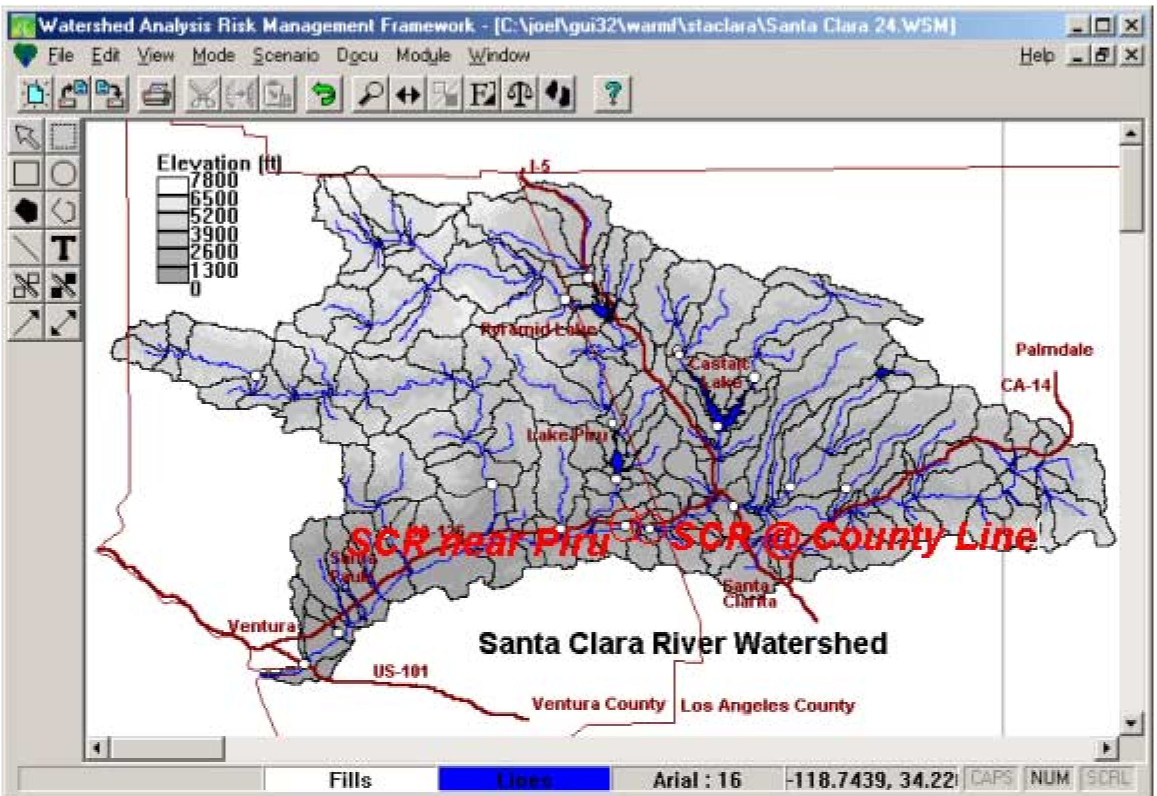

Figure 62: Stream gages for Santa Clara River Reach 7

Given the known inflow and outflow data, a water balance was conducted to determine when the river was gaining through groundwater accretion and when the river was losing by percolation through the river bed. Loss occurs in Castaic Creek when there is release from the Castaic Lake dam and in the Santa Clara River proper. Loss was infrequent in the Santa Clara River when Castaic Creek was not flowing. It was estimated that 50% of flow in Castaic Creek is lost when water is being released from Castaic Lake. This estimate kept the resulting loss from Santa Clara River in line with losses when Castaic Creek is not flowing. In the Santa Clara River Nutrient TMDL Steering Committee meeting of 8/19/2002, Murray McEachron of the United Water Conservation District concurred with the estimated water loss, and indicated that the first 20 ft^3/s was completely lost. Given that the first 20 ft^3/s of Castaic Lake release is lost, it was estimated that 35% of the remainder is lost so that the overall average loss is 50%.

Figure 63 shows the estimated loss of water from Castaic Creek and from the Santa Clara River in Reach 7. Monthly correlation equations were established relative to the Blue Cut gage was established to estimate losses from the Santa Clara River from 10/1992-9/1996, when there is no data from the Old Road Bridge gage with which to calculate daily losses.

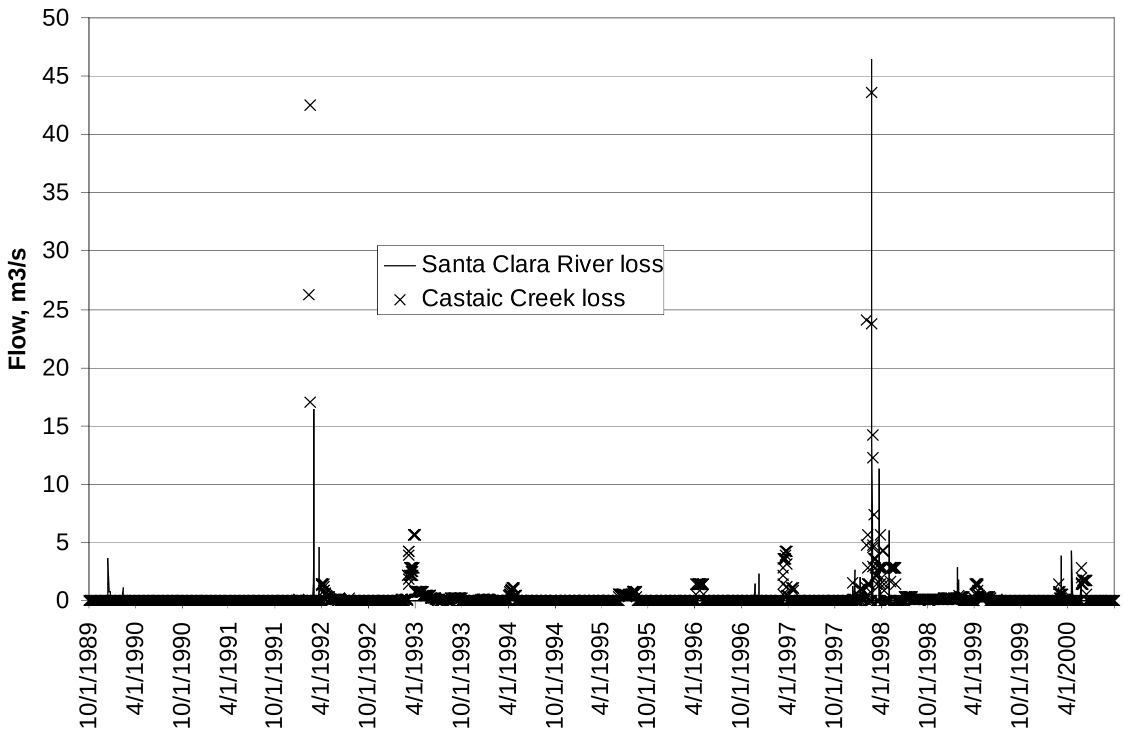

Figure 63: Estimated Flow Loss, Castaic Creek and Old Road Bridge to Blue Cut

Table 12 shows the monthly flow balances for water year 1991, which was a dry year. Table 13 shows the same balance for 1998,a wet year. The diversions are not shown in the 1991 table because at that time they were downstream of the Blue Cut gage.

The difference between net known flow and gaged flow is the net gain to the river or loss from the river. Gains to the river are input as prescribed flow at a constant rate per river mile. This water is pumped from the groundwater of the adjacent catchments. To prevent double accounting, the hydraulic conductivity of the groundwater soil layer in the adjacent land catchments was set to zero to prevent simulation of natural accretion to the river. Under such conditions, WARMF still simulates storm runoff from the land surface.

Losses are input to WARMF as prescribed diversions at a constant rate per river mile. Gains and losses are calculated on a daily basis for use in simulations.

Table 12: Flow Balance for Santa Clara River Reach 7, m^3/s, Water Year 1991

	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Mean**
Old Road Bridge gage	0.300	0.322	0.354	0.363	0.340	0.378	0.355	0.305	0.286	0.213	0.477	0.468	0.347
Valencia WWRF	0.322	0.313	0.313	0.329	0.338	0.324	0.298	0.308	0.307	0.298	0.318	0.337	0.317
Val Verde Community Park	0	0	0	0	0	0	0	0	0	0	0	0	0
Castaic Creek	0	0	0	0	0	0	0	0	0	0	0	0	0
Prescribed Groundwater Gains	0.171	0.266	0.146	0.285	0.179	0.708	0.289	0.128	0	0	0	0	0.181
TOTAL KNOWN INPUTS	**0.793**	**0.901**	**0.814**	**0.977**	**0.857**	**1.409**	**0.942**	**0.740**	**0.593**	**0.511**	**0.795**	**0.806**	**0.845**
TOTAL KNOWN OUTPUTS	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
NET KNOWN FLOW	**0.793**	**0.901**	**0.814**	**0.977**	**0.857**	**1.409**	**0.942**	**0.740**	**0.593**	**0.511**	**0.795**	**0.806**	**0.845**
GAGED FLOW	**0.765**	**0.916**	**0.734**	**0.945**	**1.641**	**7.360**	**0.874**	**0.700**	**0.530**	**0.527**	**0.383**	**0.434**	**1.317**
Castaic Ck Gain (+) / Loss (-)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
NET SCR GAIN (+)/LOSS (-)	**-0.03**	**0.015**	**-0.08**	**-0.03**	**0.784**	**5.951**	**-0.07**	**-0.04**	**-0.06**	**0.016**	**-0.41**	**-0.37**	**0.472**

Table 13: Flow Balance for Santa Clara River Reach 7, m^3/s, Water Year 1998

	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Mean**
Old Road Bridge gage	0.075	0.308	1.069	0.501	17.53	1.906	1.575	2.630	0.663	0.300	0.251	0.355	2.263
Valencia WWRF	0.380	0.370	0.357	0.358	0.401	0.440	0.454	0.453	0.459	0.523	0.525	0.485	0.434
Val Verde Community Park	0	0	0	0	0	0	0	0	0	0	0	0	0
Castaic Creek	0	0	0.143	0.546	9.969	4.950	2.173	3.482	0.022	0.631	0.201	0.221	1.862
Prescribed Groundwater Gains	0.140	0.265	0.238	1.018	10.90	5.419	1.036	3.121	1.371	0.376	0.584	0.237	2.001
TOTAL KNOWN INPUTS	**0.595**	**0.943**	**1.808**	**2.423**	**38.80**	**12.72**	**5.238**	**9.686**	**2.515**	**1.831**	**1.561**	**1.298**	**6.618**
Rancho Camulos diversion	0	0	0	0	0	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.014
Newhall Land (Isola) diversion	0.029	0.029	0.029	0	0	0.015	0.029	0.029	0.029	0.029	0.029	0.029	0.023
TOTAL KNOWN OUTPUTS	**0.029**	**0.029**	**0.029**	**0**	**0**	**0.038**	**0.053**	**0.053**	**0.053**	**0.053**	**0.053**	**0.053**	**0.037**
NET KNOWN FLOW	**0.565**	**0.914**	**1.779**	**2.423**	**38.80**	**12.68**	**5.186**	**9.634**	**2.462**	**1.778**	**1.509**	**1.245**	**6.581**
GAGED FLOW	**0.766**	**1.254**	**2.233**	**2.706**	**53.23**	**11.69**	**4.463**	**16.12**	**2.528**	**1.812**	**1.629**	**1.227**	**8.304**
Castaic Ck Gain (+) / Loss (-)	**0**	**0**	**-0.09**	**-0.40**	**-3.74**	**-1.98**	**-0.91**	**-1.46**	**-0.02**	**-0.59**	**-0.20**	**-0.22**	**-0.80**
NET SCR GAIN (+)/LOSS (-)	**0.200**	**0.340**	**0.547**	**0.677**	**18.16**	**0.992**	**0.185**	**7.939**	**0.088**	**0.623**	**0.321**	**0.203**	**2.523**

Simulation Results

WARMF simulation results (blue) and observed data (black circles) are compared in Figure 64 through Figure 67 for the two gage locations: Santa Clara River at Blue Cut (Los Angeles/Ventura county line) and Santa Clara River “near Piru”. In each case, the first plot shows the complete hydrograph and the second shows the portion with flow less than 5 m^3/s. Frequency distribution plots for each gage are shown in Figure 68 and Figure 69. The frequency distribution shows a very close match for both gages.

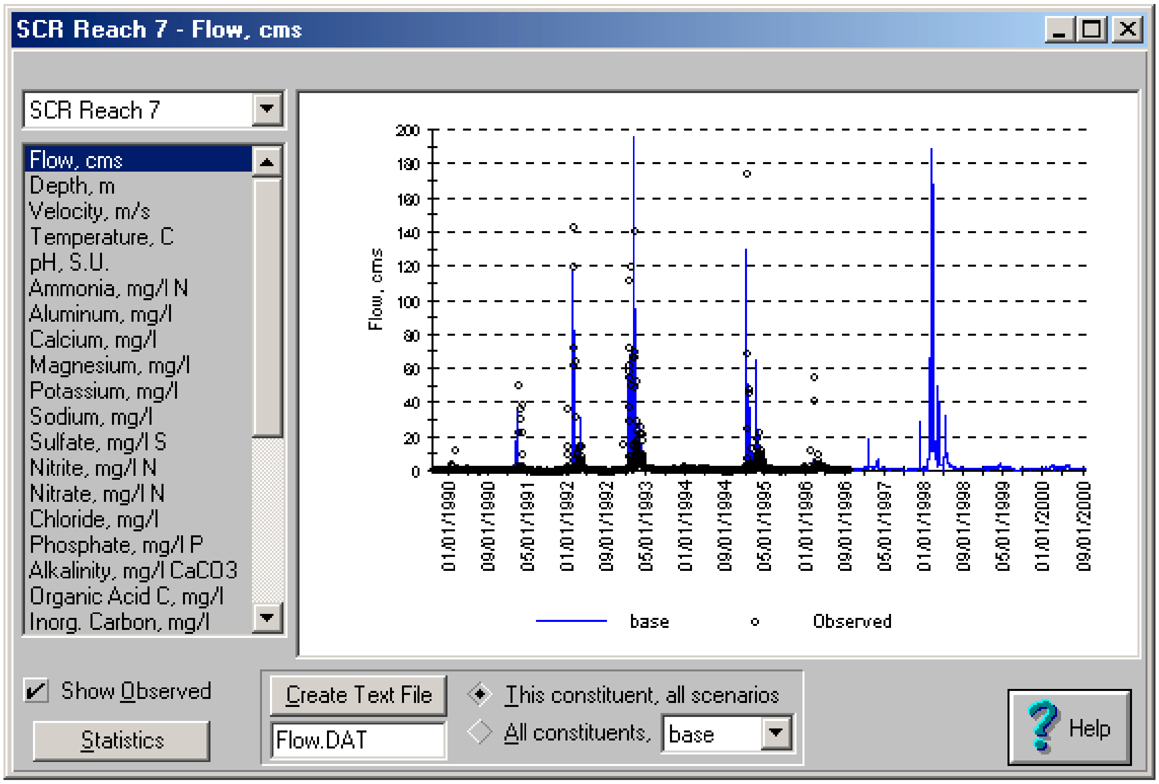

Figure 64: Simulated and Observed Flow, Santa Clara River at L.A./Ventura County Line (n = 2557; r = 0.83; relative error = +3.9%)

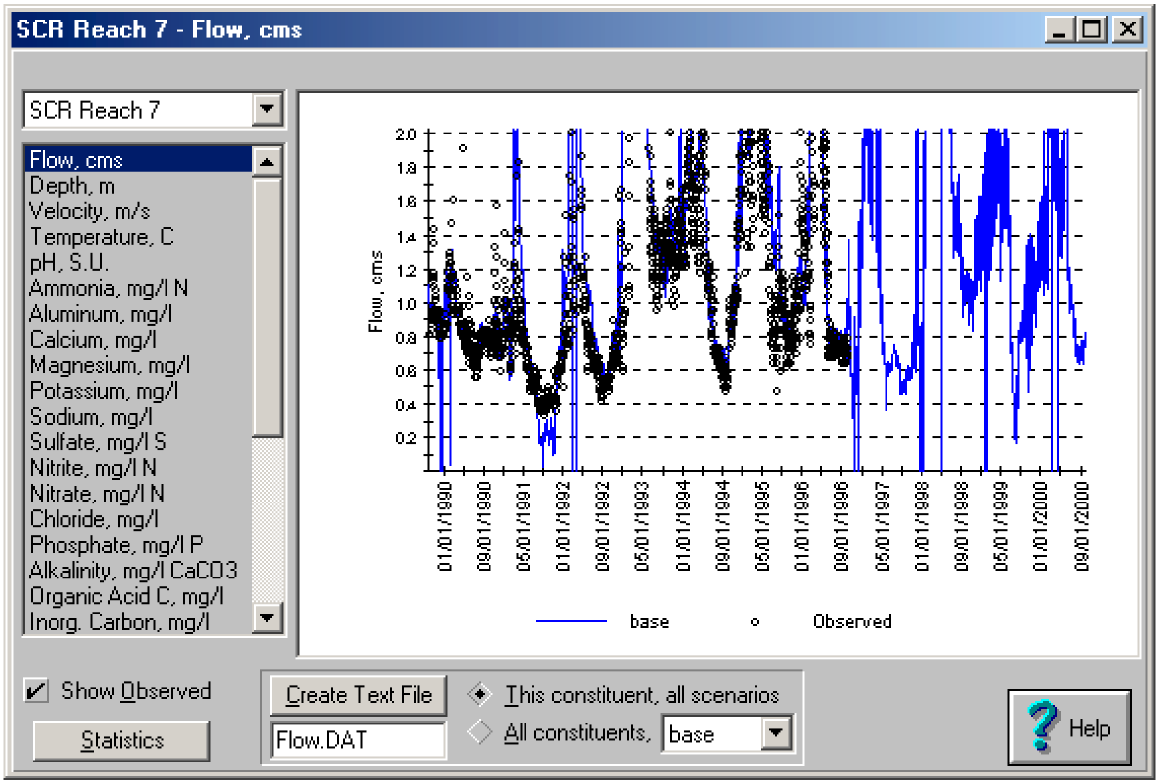

Figure 65: Simulated and Observed Flow: 0-2 m^3/s, Santa Clara River at L.A./Ventura County Line (n = 2151; r = 0.64; relative error = +18.4%)

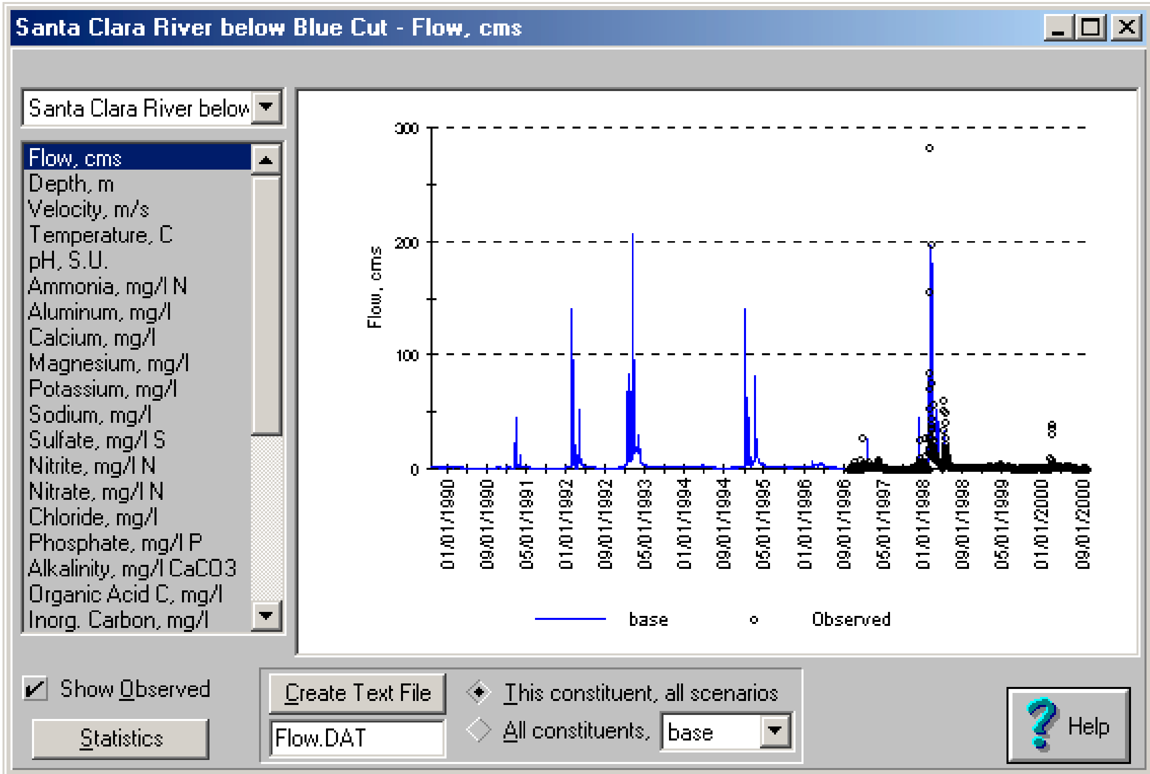

Figure 66: Simulated and Observed Flow, Santa Clara River near Piru (n = 1461; r = 0.67; relative error = -9.1%)

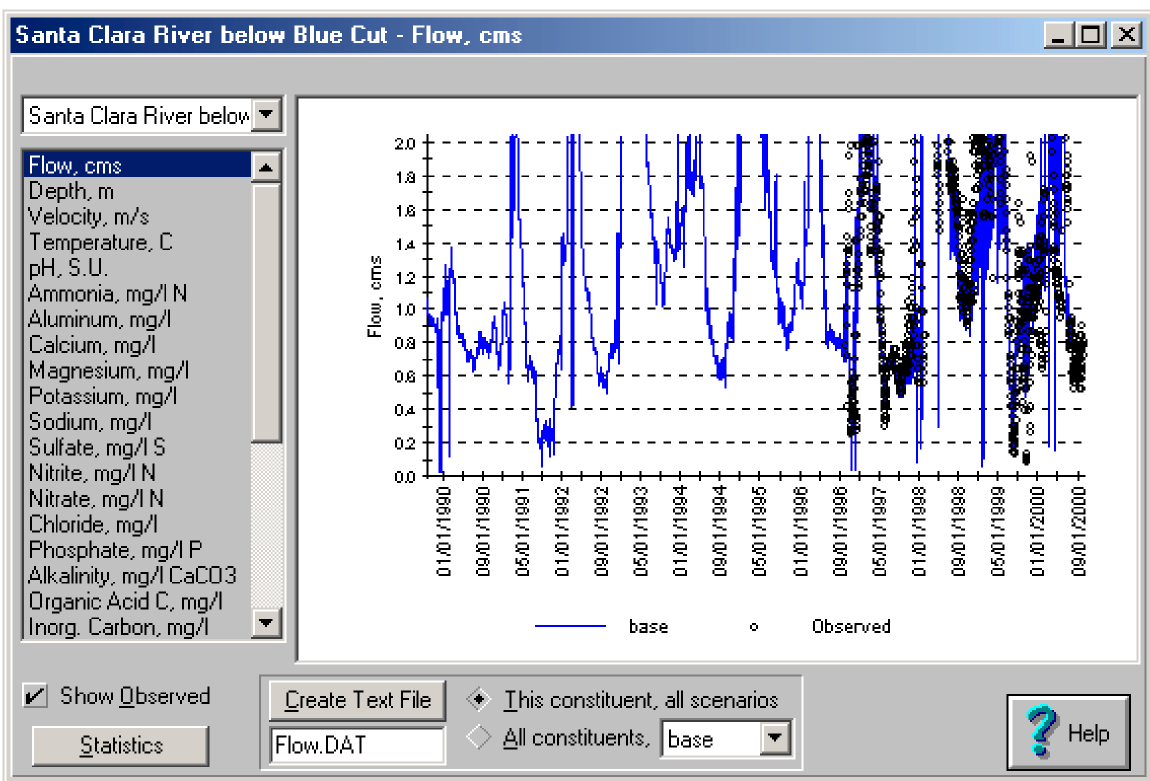

Figure 67: Simulated and Observed Flow: 0-5 m^3/s, Santa Clara River near Piru (n = 1042; r = 0.51; relative error = +8.3%)

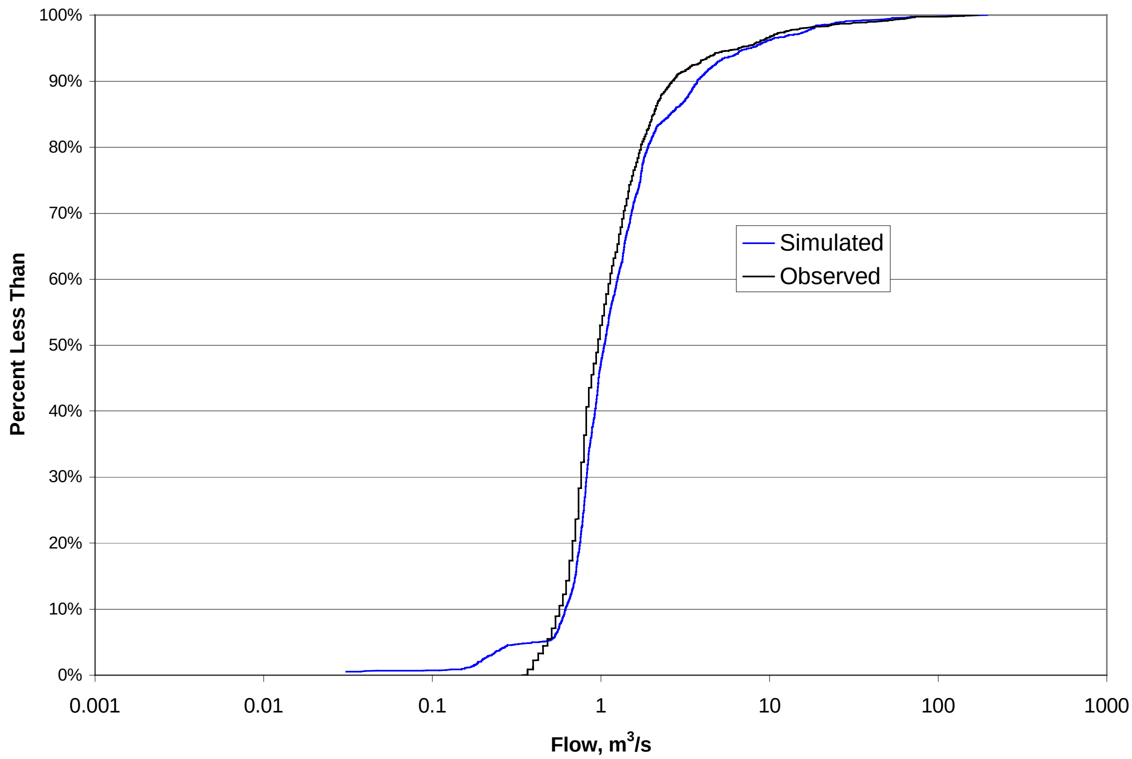

Figure 68: Frequency distribution of flow for Santa Clara River at L.A./Ventura county line

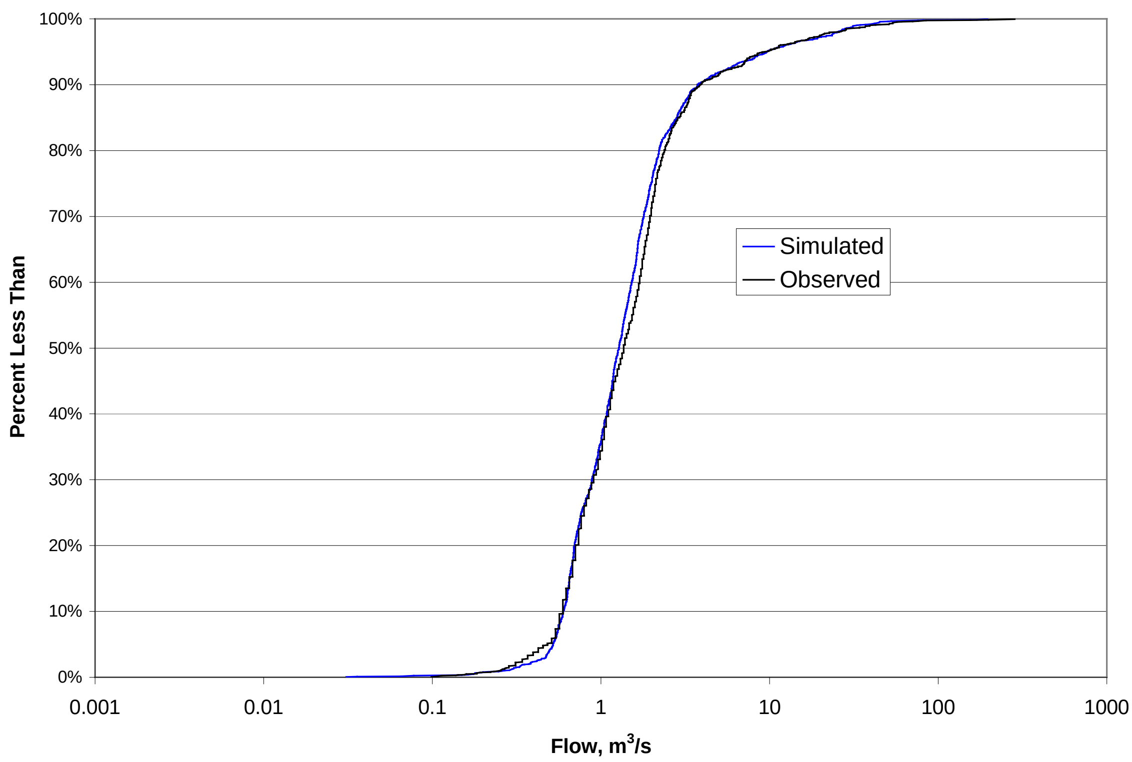

Figure 69: Frequency distribution of flow for Santa Clara River near Piru

Water Quality

During the dry season, the water quality of Reach 7 is dominated by the effluent from the Valencia and Saugus WWRFs and by gains from local groundwater. Castaic Lake releases have low nutrient concentrations and thus provide for dilution when present.

Key Assumptions

Like Reach 8 upstream, there is evidence of denitrification in the river segment downstream of the Valencia WWRF between the Old Road Bridge and Castaic Creek. Downstream of Castaic Creek, however, denitrification appears to be less important. Data recently made available indicates that well waters in the area vary in nitrate concentration from 0 to 9 mg/l as N, with a median of 1.1 mg/l (DWR 1993). The volume of groundwater is large enough so that the groundwater concentration does not change much over the course of the simulation period. A discussion of the sensitivity of simulation results to this initial concentration is included in the Sensitivity Analysis section of this report.

Simulation Results

Simulation of ammonia is good for the Santa Clara River at Castaic Creek except in 1995, 1996, and 2000. Ammonia data from the effluent of Valencia WWRF is available approximately every two weeks and show much variation, from 0 to 32 mg/l N. There was also inconsistency between consecutive measurements. The Saugus WWRF farther upstream shows less variation, having effluent ammonia concentrations ranging from 1 to 15 mg/l N. The conditions at the Valencia treatment plant could explain the highly variable observed data.

Simulation results match observed data well for nitrate in this reach. Simulated phosphorus matches the relatively high observed concentrations very well at Castaic Creek. The downward trend is the direct result of both Saugus and Valencia treatment plants loading less phosphorus to the river even as their flow increased.

At Blue Cut there is very little observed phosphorus over the entire simulation period, while model simulations show the phosphorus being transported downstream. The mass conservation principle suggests that phosphate must be transported downstream. It is not known what process is removing phosphorus in this reach. Red circles have been added to some figures to make some observed data points more visible, not to add emphasis.

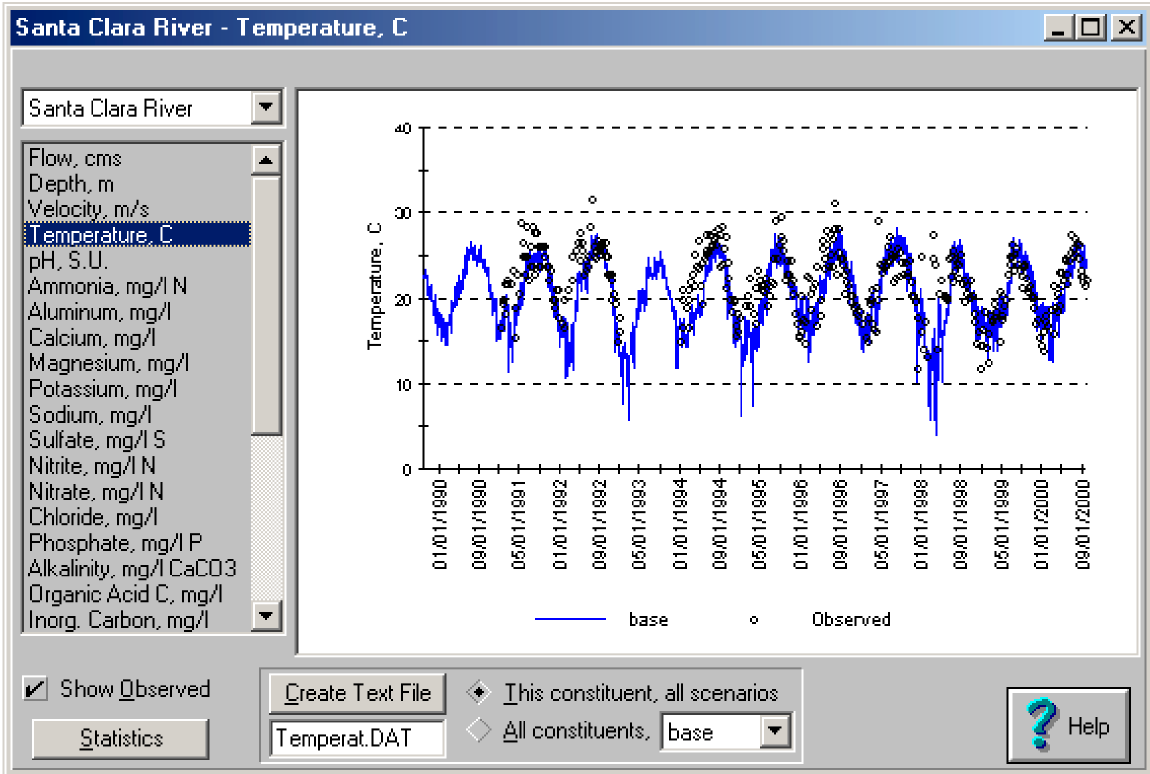

Figure 70: Simulated and Observed Temperature for the Santa Clara River at Castaic Creek (n = 401; relative error = -0.96 ^{o}C; absolute error = 2.31 ^{o}C)

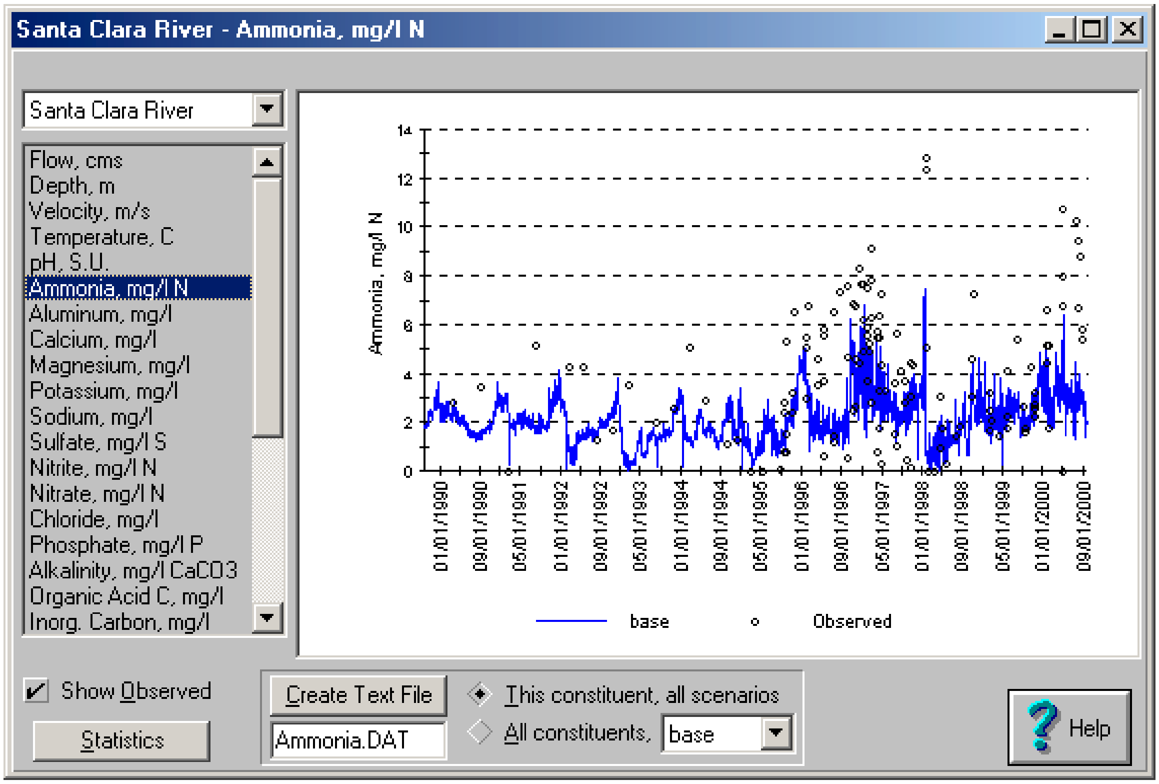

Figure 71: Simulated and Observed Ammonia for the Santa Clara River at Castaic Creek (n = 136; relative error = -1.43 mg/l; absolute error = 2.00 mg/l)

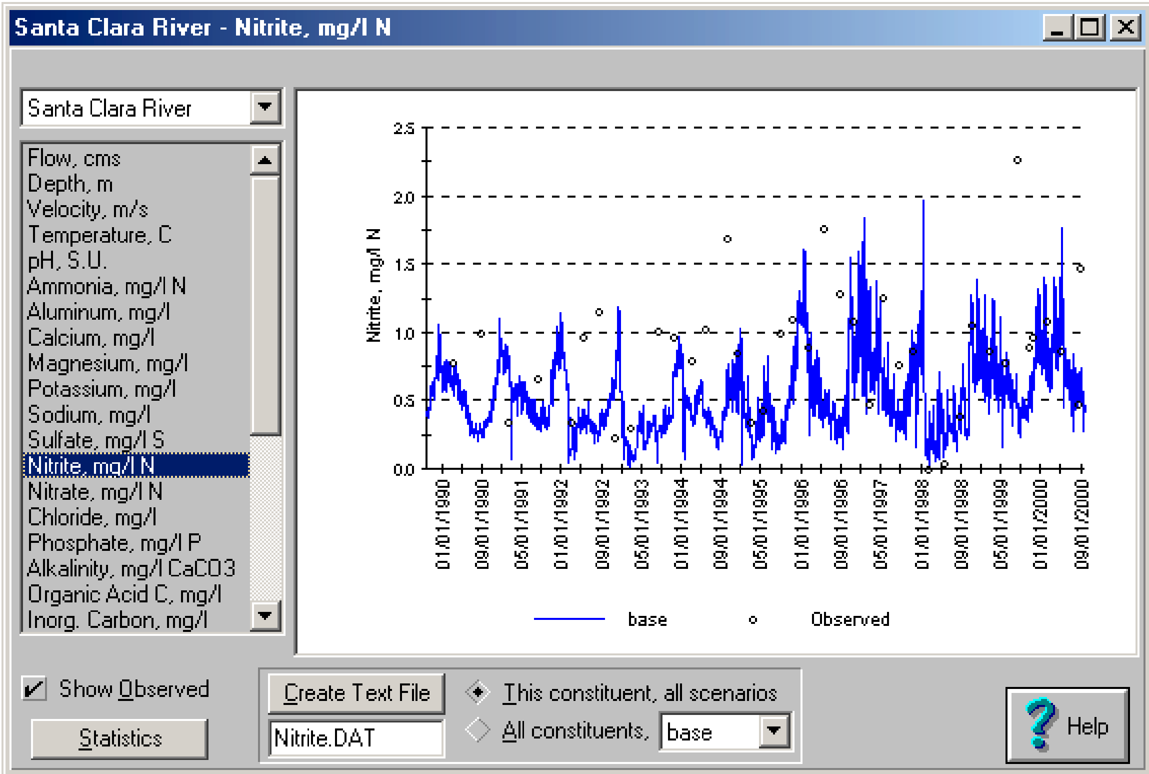

Figure 72: Simulated and Observed Nitrite for the Santa Clara River at Castaic Creek (n = 30; relative error = -0.35 mg/l; absolute error = 0.45 mg/l)

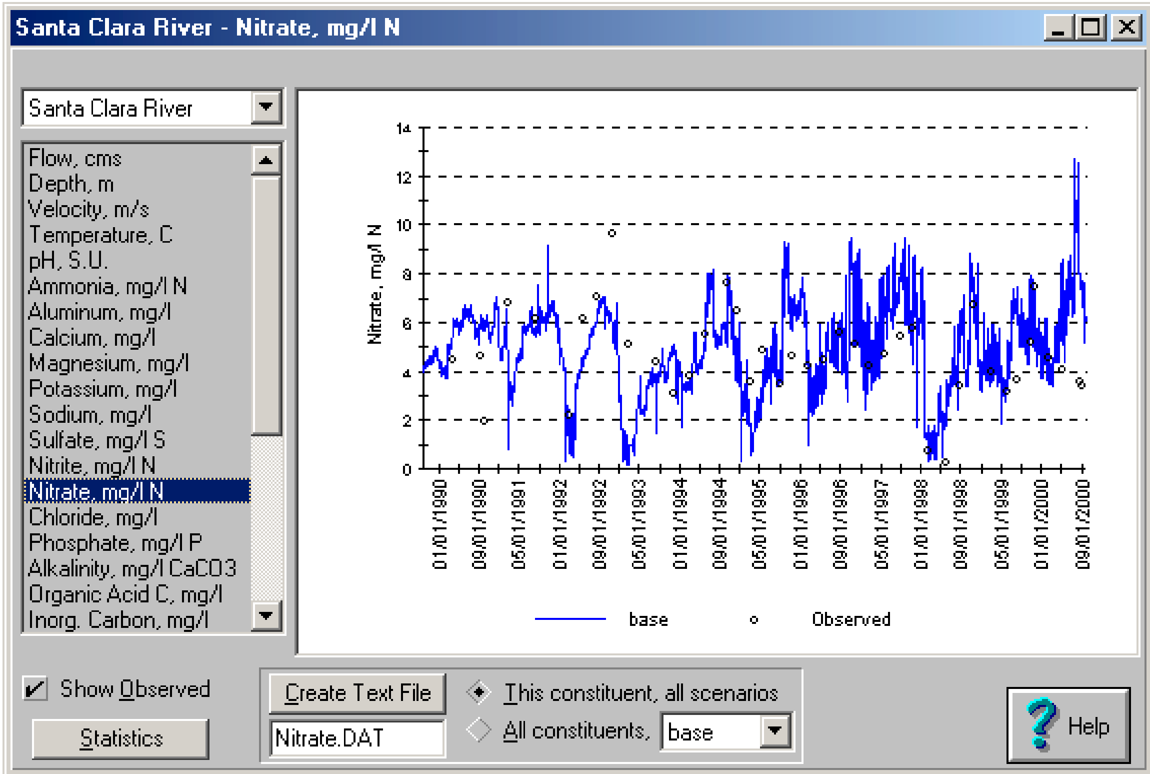

Figure 73: Simulated and Observed Nitrate for the Santa Clara River at Castaic Creek (n = 40; relative error = 0.31 mg/l; absolute error = 1.56 mg/l)

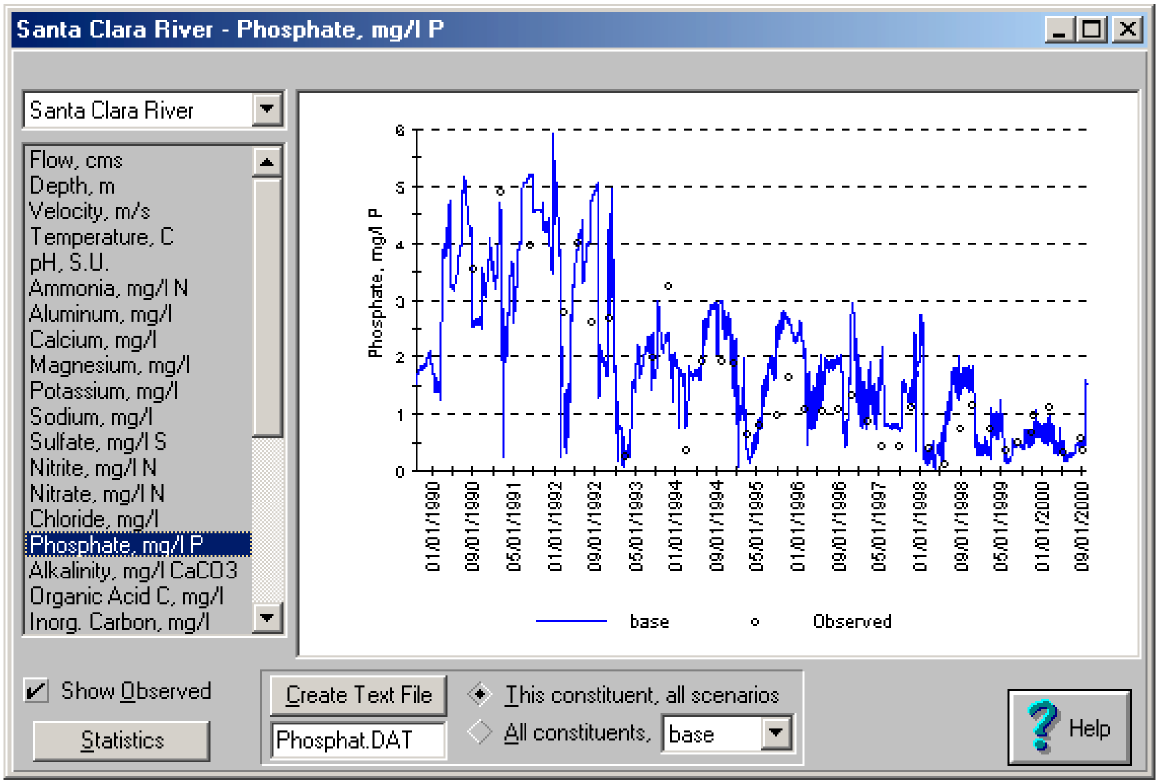

Figure 74: Simulated and Observed Phosphate for the Santa Clara River at Castaic Creek (n = 39; relative error = 0.14 mg/l; absolute error = 0.54 mg/l)

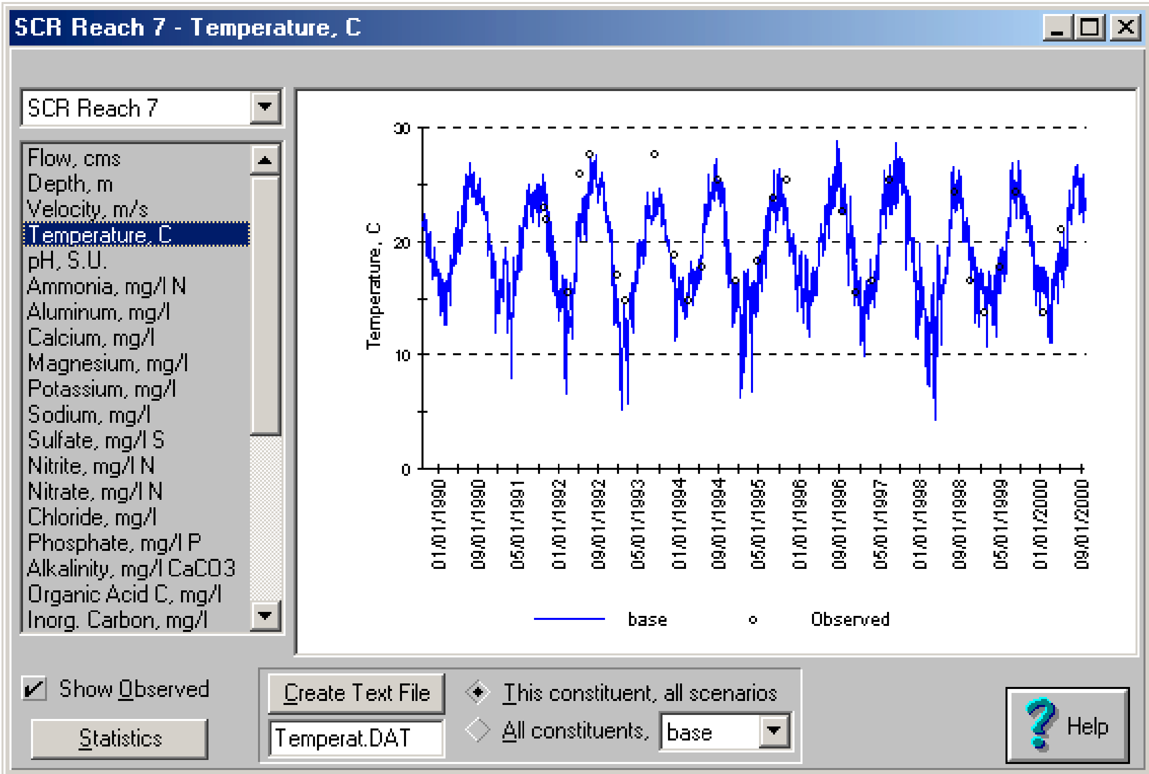

Figure 75: Simulated and Observed Temperature for the Santa Clara River at County Line (n = 20; relative error = -0.53 ^{o}C; absolute error = 1.90 ^{o}C)

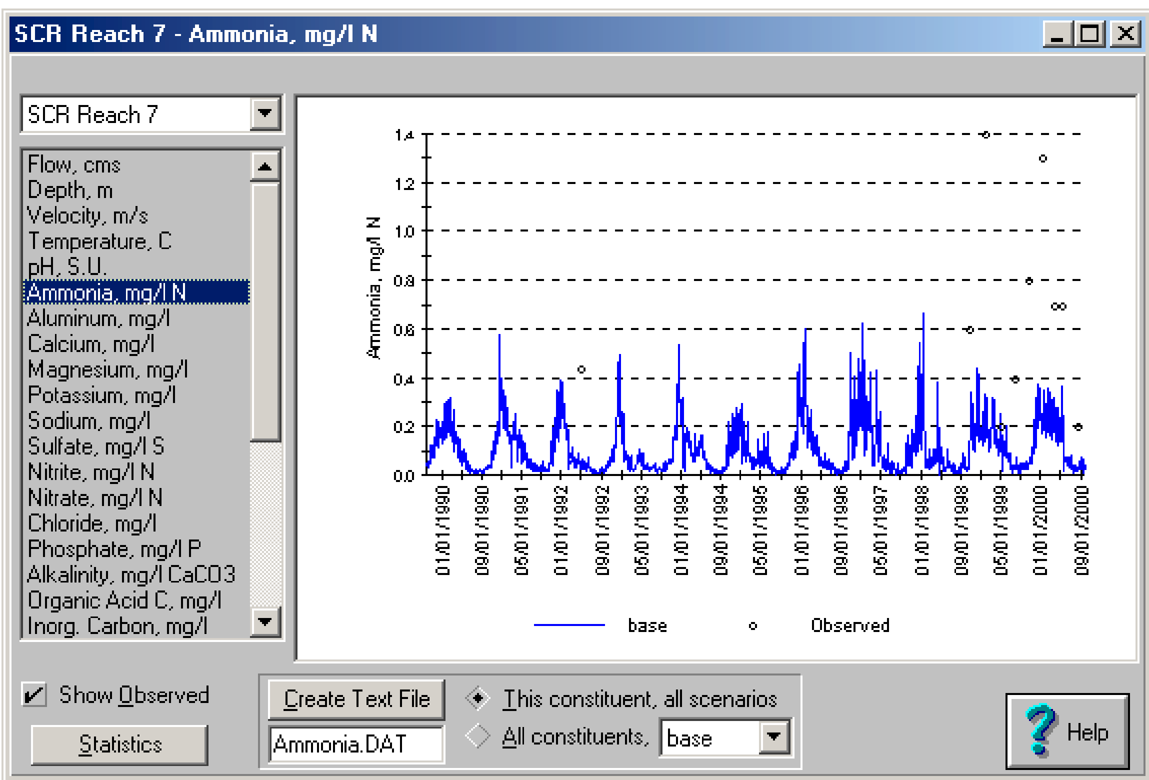

Figure 76: Simulated and Observed Ammonia for the Santa Clara River at County Line (n = 10; relative error = -0.55 mg/l; absolute error = 0.55 mg/l)

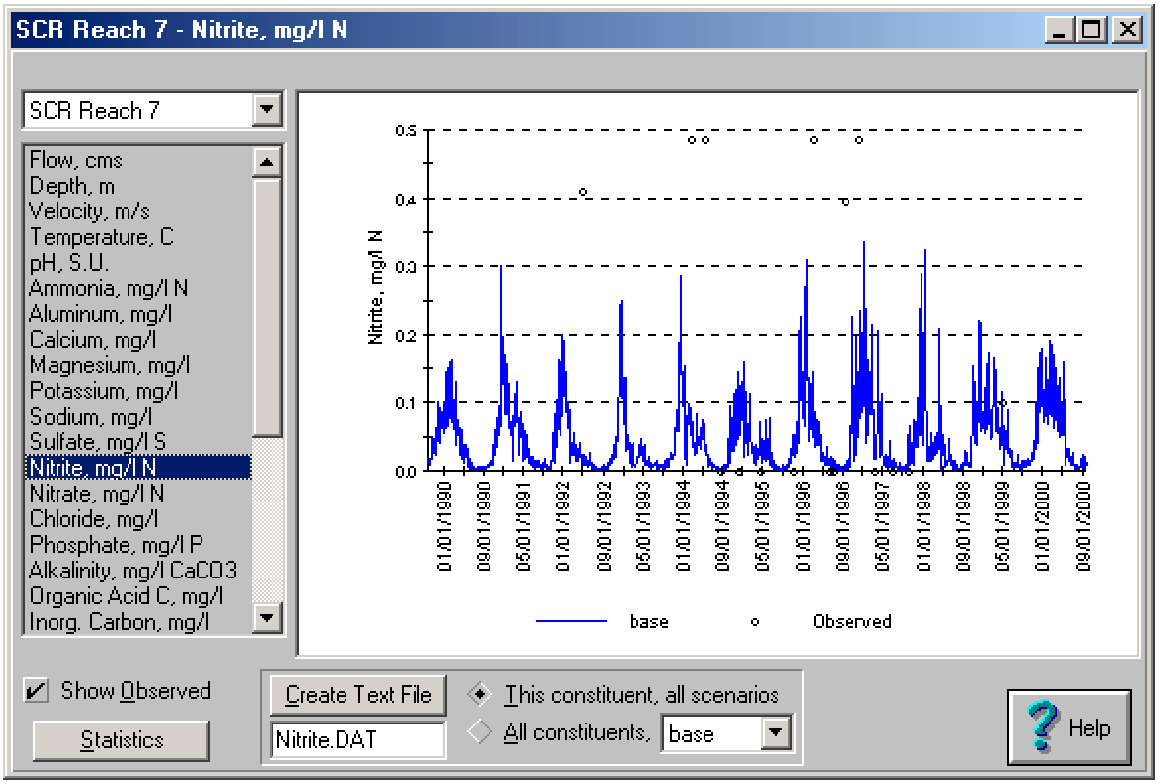

Figure 77: Simulated and Observed Nitrite for the Santa Clara River at County Line (n = 16; relative error = -0.14 mg/l; absolute error = 0.17 mg/l)

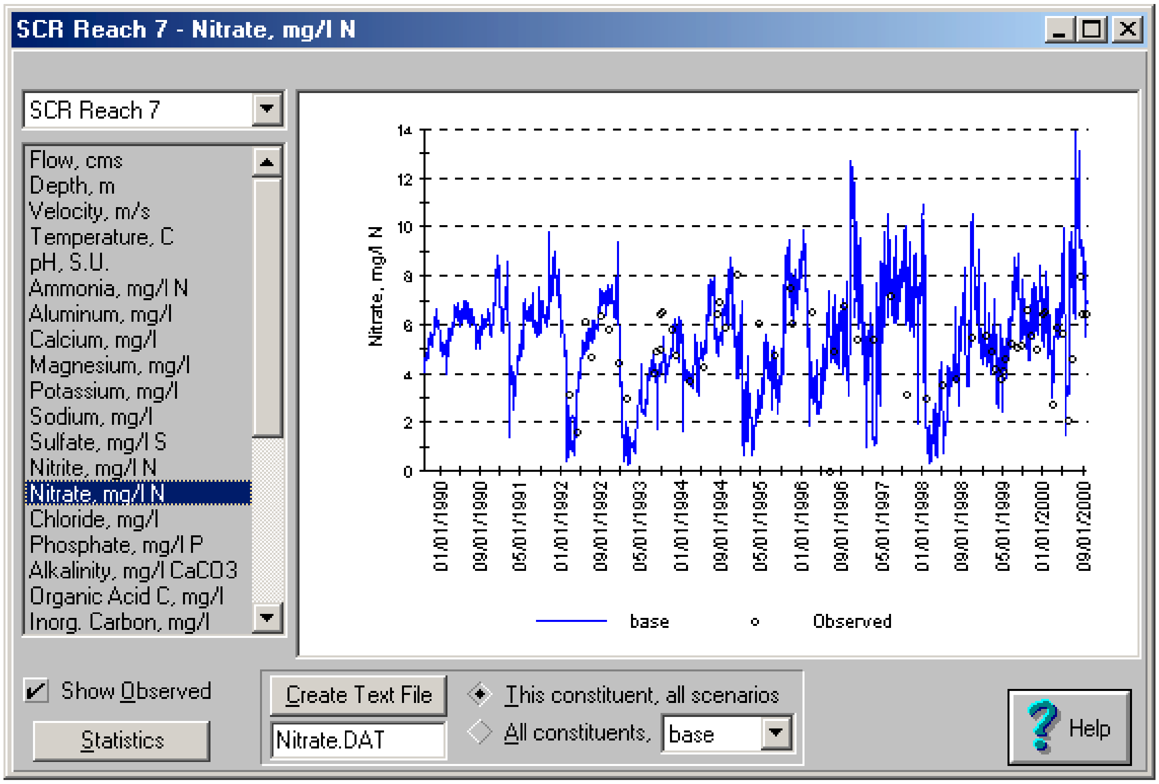

Figure 78: Simulated and Observed Nitrate for the Santa Clara River at County Line (n = 58; relative error = 0.53 mg/l; absolute error = 1.57 mg/l)

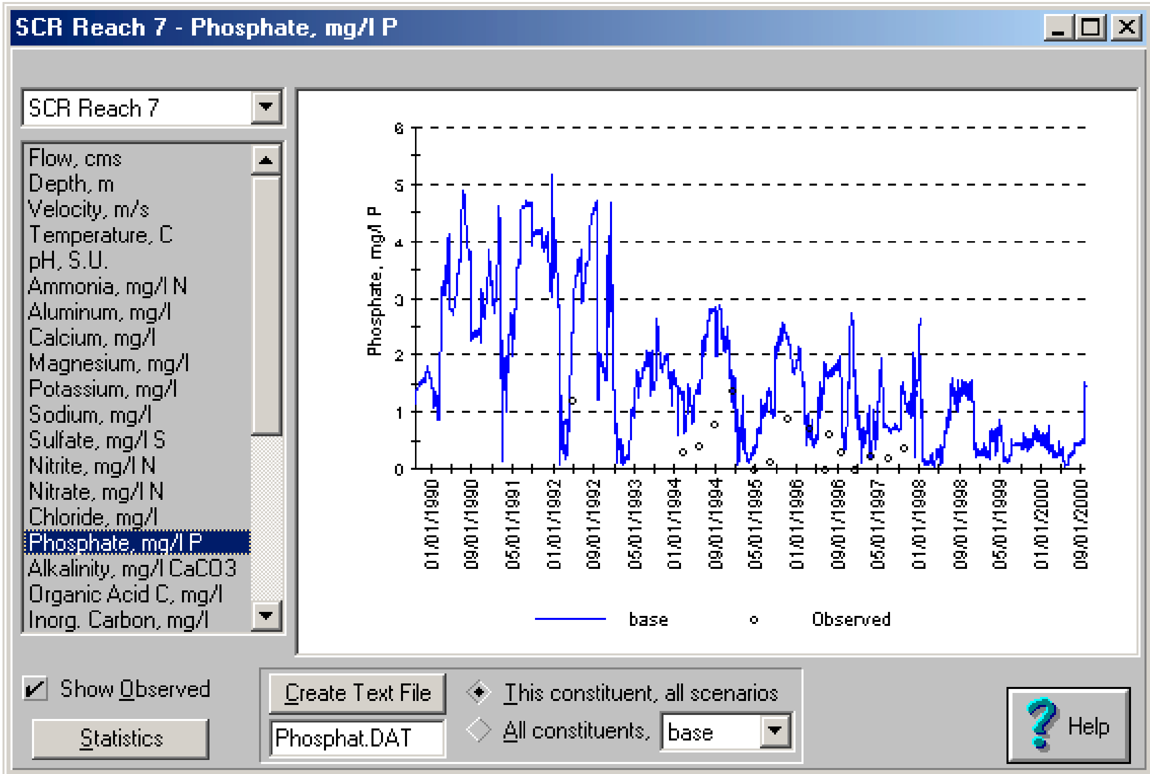

Figure 79: Simulated and Observed Phosphate for the Santa Clara River at County Line (n = 16; relative error = 1.04 mg/l; absolute error = 1.07 mg/l)

Santa Clara River Reaches 3-6: Blue Cut to Freeman Diversion

In these reaches, the Santa Clara River passes through the Piru, Fillmore, and Santa Paula groundwater basins. In this region, the exchange of water between surface water and groundwater is evident. Both hydrology and water quality are heavily dependent upon these interactions.

Agriculture is the key land use in the lowlands near the Santa Clara River. The cities of Fillmore and Santa Paula are also within this region. The downstream end of this reach is the Freeman Diversion, where much of the Santa Clara River's flow is diverted to recharge the local groundwater basin.

<u>Hydrology</u>

This is the most hydrologically complex section of the Santa Clara River. Known inflows of water include the gaged flow at Blue Cut, release from Lake Piru, and natural flow from Hopper, Sespe, and Santa Paula Creeks (Figure 4). Known outflows include the Piru Mutual and Piru Creek diversions, the Fillmore Irrigation Canal on Sespe Creek, the Farmers' Diversion on Santa Paula Creek, the Richardson Diversion on the Santa Clara River near Santa Paula, and the Freeman Diversion. When the Blue Cut gage was located at the Los Angeles/Ventura county line, until 10/1/1996, the Rancho Camulos and Newhall Land (Isola) diversions were also in this reach of the Santa Clara River.

Key Assumptions

The United Water Conservation District has extensively studied the surface and groundwater exchange from Blue Cut to Santa Paula Creek. The studies have led to estimate of flow gain and loss for various river segments within this reach (UWCD (McEachron) 2002). Simulated flows were also used in the generation of UWCD loss estimates. This reach can be further divided between the section upstream of Sespe Creek and the section downstream of Sespe Creek. The reaches on both sides of Sespe Creek have a combination of gains and losses.

Table 14 through Table 17 summarize the flow balance for Piru Creek and Hopper Creek, the two major tributaries upstream of Sespe Creek. Water year 1991 is a dry year and water year 1998 is a wet year.

Piru Creek has two diversions, the Piru Mutual Diversion and the Piru Creek Diversion. Some of the water remaining after these two diversions is lost to groundwater. The April outflows are greater than the inflows in Table 14 because at times the scheduled diversions exceed the release from Lake Piru. The net known flow for June and July in Table 15 is greater than the difference between total inflow and total outflow because at times the scheduled diversions are greater than the release flow, but the net river flow can not go below zero on any given day.

Table 14: Flow Balance for Piru Creek from Lake Piru to Santa Clara River, m^3/s, Water Year 1991

	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Mean**
Lake Piru release	0.135	0.155	0.132	0.083	0.087	1.113	0.114	2.440	1.475	0.135	0.111	0.122	0.512
TOTAL KNOWN INPUTS	**0.135**	**0.155**	**0.132**	**0.083**	**0.087**	**1.113**	**0.114**	**2.440**	**1.475**	**0.135**	**0.111**	**0.122**	**0.512**
Piru Mutual diversion	0.044	0.044	0.044	0.023	0.023	0.023	0.066	0.066	0.066	0.066	0.066	0.066	0.050
Piru Creek diversion	0.001	0	0	0.009	0.000	0.084	0.041	0.000	0.006	0	0	0	0.012
Piru Creek loss (UWCD est.)	0.091	0.112	0.089	0.051	0.064	0.140	0.031	0.320	0.228	0.063	0.045	0.056	0.108
TOTAL KNOWN OUTPUTS	**0.135**	**0.155**	**0.132**	**0.083**	**0.087**	**0.247**	**0.137**	**0.386**	**0.299**	**0.129**	**0.111**	**0.122**	**0.169**
NET KNOWN FLOW	**0**	**0**	**0**	**0**	**0**	**0.884**	**0**	**2.054**	**1.175**	**0.005**	**0**	**0**	**0.343**

Table 15: Flow Balance for Piru Creek from Lake Piru to Santa Clara River, m^3/s, Water Year 1998

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Lake Piru release	5.285	0.721	0.165	0.169	3.930	3.945	2.790	2.861	2.453	0.605	0.604	3.474	2.235
TOTAL KNOWN INPUTS	**5.285**	**0.721**	**0.165**	**0.169**	**3.930**	**3.945**	**2.790**	**2.861**	**2.453**	**0.605**	**0.604**	**3.474**	**2.235**
Piru Mutual diversion	0.043	0.043	0.043	0.023	0.023	0.023	0.067	0.067	0.067	0.067	0.067	0.067	0.050
Piru Creek diversion	0.085	0.038	0	0.038	0.000	0.006	0.811	0.970	1.436	0.290	0	0	0.306
Piru Creek loss (UWCD est.)	0.501	0.220	0.122	0.108	0.428	0.485	0.126	0.063	0.000	0.150	0.230	0.443	0.238
TOTAL KNOWN OUTPUTS	**0.629**	**0.301**	**0.165**	**0.169**	**0.451**	**0.514**	**1.004**	**1.100**	**1.503**	**0.508**	**0.298**	**0.510**	**0.596**
NET KNOWN FLOW	**4.656**	**0.420**	**0**	**0**	**3.479**	**3.431**	**1.786**	**1.761**	**0.950**	**0.097**	**0.306**	**2.964**	**1.639**

Between the Hopper Creek gage at Highway 126 and the mouth of the creek at the Santa Clara River, some of Hopper Creek's flow percolates into the soil as shown in Table 16 and Table 17. Even in the wet year of 1998, most of Hopper Creek's flow is lost to the groundwater in August-October.

Table 16: Flow Balance for Hopper Creek from gage to Santa Clara River, m^3/s, Water Year 1991

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Hopper Creek gage	0	0	0	0	0.338	1.538	0.048	0.009	0	0	0	0	0.161
TOTAL KNOWN INPUTS	**0**	**0**	**0**	**0**	**0.338**	**1.538**	**0.048**	**0.009**	**0**	**0**	**0**	**0**	**0.161**
Hopper Creek loss (UWCD est.)	0	0	0	0	0.033	0.177	0.041	0.009	0	0	0	0	0.022
TOTAL KNOWN OUTPUTS	**0**	**0**	**0**	**0**	**0.033**	**0.177**	**0.041**	**0.009**	**0**	**0**	**0**	**0**	**0.022**
NET KNOWN FLOW	**0**	**0**	**0**	**0**	**0.304**	**1.362**	**0.007**	**0**	**0**	**0**	**0**	**0**	**0.139**

Table 17: Flow Balance for Hopper Creek from gage to Santa Clara River, m^3/s, Water Year 1998

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Hopper Creek gage	0.011	0.192	0.916	0.241	11.24	1.872	0.592	1.184	0.287	0.141	0.046	0.084	1.401
TOTAL KNOWN INPUTS	**0.011**	**0.192**	**0.916**	**0.241**	**11.24**	**1.872**	**0.592**	**1.184**	**0.287**	**0.141**	**0.046**	**0.084**	**1.401**
Hopper Creek loss (UWCD est.)	0.011	0.040	0.133	0.077	0.651	0.221	0.108	0.160	0.079	0.066	0.046	0.066	0.138
TOTAL KNOWN OUTPUTS	**0.011**	**0.040**	**0.133**	**0.077**	**0.651**	**0.221**	**0.108**	**0.160**	**0.079**	**0.066**	**0.046**	**0.066**	**0.138**
NET KNOWN FLOW	**0**	**0.152**	**0.783**	**0.164**	**10.59**	**1.650**	**0.484**	**1.024**	**0.208**	**0.076**	**0**	**0.019**	**1.263**

Given the known flow inputs from Piru Creek and Hopper Creek, a flow balance can be set up for the reach of the Santa Clara River between Blue Cut and Sespe Creek (Table 18 and Table 19). All listed losses and gains for various reaches of the Santa Clara River are from UWCD estimates.

Table 18: Flow Balance for Santa Clara River from Blue Cut to Sespe Creek, Water Year 1991

	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Mean**
Blue Cut gage	0.765	0.916	0.734	0.945	1.641	7.360	0.874	0.700	0.530	0.527	0.383	0.434	1.317
Net Piru Creek	0	0	0	0	0	0.884	0	2.054	1.175	0.005	0	0	0.343
Net Hopper Creek	0	0	0	0	0.304	1.362	0.007	0	0	0	0	0	0.139
Fish Hatchery gain	0	0	0	0	0	0	0	0	0	0	0	0	0
Fillmore WWTP	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL KNOWN INPUTS	**0.765**	**0.916**	**0.734**	**0.945**	**1.945**	**9.606**	**0.881**	**2.754**	**1.705**	**0.532**	**0.383**	**0.434**	**1.799**
Rancho Camulos diversion	0	0	0	0	0	0	0	0	0	0	0	0	0
Newhall Land (Isola) diversion	0.029	0.029	0.029	00	0	0.015	0.029	0.029	0.029	0.029	0.029	0.029	0.023
Newhall Bridge to Torrey loss	0.754	0.890	0.669	0.908	1.169	2.357	1.450	0.967	0.660	0.644	0.219	0.258	0.911
Torrey to Hopper Creek loss	0	0.026	0	0.025	0.196	0.685	0.141	1.794	1.008	0.005	0	0	0.325
Hopper Creek to Cavin loss	0	0	0	0	0.452	0.572	0.017	0.004	0	0	0	0	0.085
Cavin to Sespe loss	0	0	0	0	0.075	0.341	0.180	0.196	0.094	0	0	0	0.074
TOTAL KNOWN OUTPUTS	**0.783**	**0.945**	**0.698**	**0.934**	**1.891**	**3.970**	**1.817**	**2.990**	**1.791**	**0.678**	**0.248**	**0.287**	**1.418**
NET KNOWN FLOW	**0**	**0**	**0.036**	**0.011**	**0.054**	**5.636**	**0**	**0**	**0**	**0**	**0.135**	**0.147**	**0.502**

Table 19: Flow Balance for Santa Clara River from Blue Cut to Sespe Creek, Water Year 1998

	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Mean**
Blue Cut gage	0.766	1.254	2.233	2.706	53.23	11.69	4.463	16.12	2.528	1.812	1.629	1.227	8.304
Net Piru Creek	4.656	0.421	0	0	3.482	3.432	1.786	1.761	0.988	0.246	0.306	2.963	1.670
Net Hopper Creek	0	0.152	0.783	0.164	10.59	1.650	0.484	1.024	0.208	0.076	0	0.019	1.263
Fish Hatchery gain	0.060	0.043	0.061	0.106	0.610	1.065	1.236	1.286	1.270	1.130	0.941	0.834	0.720
Fillmore WWTP	0	0	0	0	0.010	0.037	0.036	0	0.006	0	0.039	0.043	0.014
TOTAL KNOWN INPUTS	**5.482**	**1.87**	**3.077**	**2.976**	**67.92**	**17.87**	**8.005**	**20.19**	**5.000**	**3.264**	**2.915**	**5.086**	**11.97**
Newhall Bridge to Torrey loss	0.786	0.977	1.776	1.784	10.45	7.184	5.587	5.586	2.828	2.024	1.735	1.268	3.451
Torrey to Hopper Creek loss	2.790	0.344	0.360	0.229	2.404	4.760	5.145	2.045	1.210	0.690	0.486	1.941	1.859
Hopper Creek to Cavin loss	1.038	0.052	0.436	0.031	8.705	2.309	0.000	1.590	0	0	0	0.611	1.181
Cavin to Sespe loss	0.376	0.074	0.204	0.112	1.799	1.518	1.196	0.959	0.643	0.529	0.443	0.580	0.695
TOTAL KNOWN OUTPUTS	**4.990**	**1.446**	**2.776**	**2.157**	**23.36**	**15.77**	**11.93**	**10.18**	**4.681**	**3.243**	**2.664**	**4.399**	**7.186**
NET KNOWN FLOW	**0.492**	**0.424**	**0.301**	**0.819**	**44.57**	**2.102**	**-3.92**	**10.01**	**0.319**	**0.021**	**0.251**	**0.687**	**4.672**

In addition to Piru Creek and Hopper Creek, there are two major tributaries between the Sespe Creek confluence and the Freeman Diversion: Sespe Creek and Santa Paula Creek. Table 20 through Table 23 summarize the flow balance for these tributaries for water year 1991, a dry year, and water year 1998, a wet year.

Below the Sespe Creek gage, there is one diversion, for the Fillmore Irrigation Canal. Until January 1993, the diversion for the Fillmore Irrigation Canal was upstream of the gage, so the gaged flow for 1991 is net flow after the diversion. Table 20 and Table 21 show the net Sespe Creek flow to the Santa Clara River. At times the scheduled diversion for the Fillmore Irrigation Canal is greater than the available water in Sespe Creek, so the net flow shown reflects the daily average flow which can not be negative.

Table 20: Flow Balance for Sespe Creek from gage to Santa Clara River, m^3/s, Water Year 1991

	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Mean**
Sespe Creek gage	0.006	0.007	0.009	0.071	2.242	25.82	6.355	1.362	0.404	0.103	0.016	0.007	3.033
TOTAL KNOWN INPUTS	**0.006**	**0.007**	**0.009**	**0.071**	**2.242**	**25.82**	**6.355**	**1.362**	**0.404**	**0.103**	**0.016**	**0.007**	**3.033**
TOTAL KNOWN OUTPUTS	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
NET KNOWN FLOW	**0.006**	**0.007**	**0.009**	**0.071**	**2.242**	**25.82**	**6.355**	**1.362**	**0.404**	**0.103**	**0.016**	**0.007**	**3.033**

Table 21: Flow Balance for Sespe Creek from gage to Santa Clara River, m^3/s, Water Year 1998

	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Mean**
Sespe Creek gage	0.017	0.272	5.427	6.233	122.7	19.65	13.40	12.05	5.748	2.575	1.397	1.069	15.88
TOTAL KNOWN INPUTS	**0.017**	**0.272**	**5.427**	**6.233**	**122.7**	**19.65**	**13.40**	**12.05**	**5.748**	**2.575**	**1.397**	**1.069**	**15.88**
Fillmore Irrigation Canal	0.052	0.052	0.052	0	0	0	0.052	0.052	0.052	0.078	0.078	0.078	0.045
TOTAL KNOWN OUTPUTS	**0.052**	**0.052**	**0.052**	**0**	**0**	**0**	**0.052**	**0.052**	**0.052**	**0.078**	**0.078**	**0.078**	**0.045**
NET KNOWN FLOW	**0**	**0.231**	**5.375**	**6.233**	**122.7**	**19.65**	**13.35**	**12.00**	**5.695**	**2.497**	**1.319**	**0.991**	**15.84**

Santa Paula Creek has one diversion between its gage and the Santa Clara River, as shown in Table 22 and Table 23. At times the scheduled flow for Farmers' Diversion is greater than the flow in Santa Paula Creek. The net flow is adjusted so that it can never go below zero on a daily basis.

Table 22: Flow Balance for Santa Paula Creek from gage to Santa Clara River, Water Year 1991

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Santa Paula Creek gage	0.020	0.016	0.027	0.042	0.313	3.879	1.911	0.398	0.217	0.145	0.084	0.056	0.592
TOTAL KNOWN INPUTS	**0.020**	**0.016**	**0.027**	**0.042**	**0.313**	**3.879**	**1.911**	**0.398**	**0.217**	**0.145**	**0.084**	**0.056**	**0.592**
Farmers’ Diversion	0.055	0.055	0.055	0.014	0.014	0.014	0.064	0.064	0.064	0.090	0.090	0.090	0.056
TOTAL KNOWN OUTPUTS	**0.055**	**0.055**	**0.055**	**0.014**	**0.014**	**0.014**	**0.064**	**0.064**	**0.064**	**0.090**	**0.090**	**0.090**	**0.056**
NET KNOWN FLOW	**0**	**0**	**0**	**0.028**	**0.299**	**3.865**	**1.847**	**0.334**	**0.153**	**0.056**	**0**	**0**	**0.548**

Table 23: Flow Balance for Santa Paula Creek from gage to Santa Clara River, Water Year 1998

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Santa Paula Creek gage	0.094	0.210	0.628	0.543	24.08	4.181	3.317	3.458	1.491	0.817	0.505	0.396	3.310
TOTAL KNOWN INPUTS	**0.094**	**0.210**	**0.628**	**0.543**	**24.08**	**4.181**	**3.317**	**3.458**	**1.491**	**0.817**	**0.505**	**0.396**	**3.310**
Farmers’ Diversion	0.041	0.041	0.041	0	0	0	0.020	0.020	0.020	0.057	0.057	0.057	0.030
TOTAL KNOWN OUTPUTS	**0.041**	**0.041**	**0.041**	**0**	**0**	**0**	**0.020**	**0.020**	**0.020**	**0.057**	**0.057**	**0.057**	**0.030**
NET KNOWN FLOW	**0.053**	**0.169**	**0.587**	**0.542**	**24.08**	**4.181**	**3.297**	**3.438**	**1.471**	**0.760**	**0.448**	**0.339**	**3.280**

Given these inflows from the Sespe Creek, Santa Paula Creek, and the Santa Clara River at Sespe Creek, a flow balance can be conducted as shown in Table 24 and Table 25. All the listed Willard Road gains and Sespe to Willard losses are from UWCD estimates. The balance must be conducted to the Montalvo gage downstream of the Freeman Diversion because there is no gaging available at the diversion itself.

Table 24: Flow Balance for Santa Clara River from Sespe Creek to Freeman, Water Year 1991

	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Mean**
Net SCR @ Sespe Creek	0	0	0.036	0.011	0.054	5.636	0	0	0	0	0.135	0.147	0.502
Net Sespe Creek	0.006	0.007	0.009	0.071	2.242	25.82	6.355	1.362	0.404	0.103	0.016	0.007	3.033
Willard Road gain	0.083	0.063	0.056	0.047	0.047	0.089	0.216	0.297	0.293	0.257	0.211	0.180	0.153
Net Santa Paula Creek	0	0	0	0.028	0.299	3.865	1.847	0.334	0.153	0.056	0	0	0.548
Santa Paula WWRP	0.079	0.078	0.077	0.077	0.075	0.080	0.074	0.075	0.077	0.079	0.081	0.082	0.078
TOTAL KNOWN INPUTS	**0.168**	**0.148**	**0.178**	**0.234**	**2.717**	**35.49**	**8.492**	**2.068**	**0.927**	**0.495**	**0.443**	**0.416**	**4.314**
Sespe Creek to Willard loss	0	0	0	0.029	0.657	6.060	2.744	0.927	0.479	0.187	0.116	0.069	0.943
Richardson Diversion	0.017	0.017	0.017	0.001	0.001	0.001	0.003	0.003	0.003	0.019	0.019	0.019	0.010
Freeman Diversion	0	0	0	0.015	0.338	6.849	6.686	1.913	0.915	0.550	0.315	0.250	1.486
TOTAL KNOWN OUTPUTS	**0.017**	**0.017**	**0.017**	**0.045**	**0.996**	**12.91**	**9.433**	**2.843**	**1.397**	**0.756**	**0.450**	**0.338**	**2.439**
NET KNOWN FLOW	**0.151**	**0.131**	**0.161**	**0.190**	**1.720**	**22.58**	**-0.94**	**-0.78**	**-0.47**	**-0.26**	**-0.01**	**0.077**	**1.880**
GAGED FLOW	**0**	**0**	**0**	**0**	**0.749**	**34.97**	**1.034**	**0**	**0**	**0**	**0**	**0**	**3.063**
NET GAIN (+) / LOSS (-)	**-0.15**	**-0.13**	**-0.16**	**-0.19**	**-0.97**	**12.39**	**1.975**	**0.775**	**0.470**	**0.261**	**0.007**	**-0.08**	**1.019**

Table 25: Flow Balance for Santa Clara River from Sespe Creek to Freeman, Water Year 1998

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Net SCR @ Sespe Creek	1.308	0.243	1.045	0.513	48.91	6.232	2.181	9.266	1.113	0.848	0.923	1.847	6.203
Net Sespe Creek	0	0.231	5.375	6.233	122.7	19.65	13.35	12.00	5.695	2.497	1.319	0.991	15.84
Willard Road gain	0.770	0.810	0.948	1.035	1.590	1.882	1.967	2.166	1.894	1.715	1.624	1.658	1.505
Net Santa Paula Creek	0.053	0.169	0.587	0.542	24.08	4.181	3.297	3.438	1.471	0.760	0.448	0.339	3.280
Santa Paula WWRP	0.072	0.086	0.089	0.089	0.125	0.103	0.097	0.099	0.094	0.093	0.092	0.091	0.094
TOTAL KNOWN INPUTS	**2.203**	**1.539**	**8.044**	**8.412**	**197.4**	**32.05**	**20.89**	**26.97**	**10.27**	**5.913**	**4.406**	**4.926**	**26.92**
Sespe Creek to Willard loss	0.528	0.320	3.548	4.341	17.92	14.91	10.22	9.579	3.453	1.937	1.171	1.064	5.670
Richardson Diversion	0.018	0.018	0.018	0.003	0.003	0.003	0.003	0.003	0.003	0.023	0.023	0.023	0.011
Freeman Diversion	3.186	1.505	3.442	4.571	2.281	8.309	7.224	6.108	7.081	5.515	3.044	4.157	4.702
TOTAL KNOWN OUTPUTS	**3.732**	**1.843**	**7.008**	**8.915**	**20.20**	**23.22**	**17.44**	**15.69**	**10.54**	**7.475**	**4.238**	**5.244**	**10.38**
NET KNOWN FLOW	**-1.53**	**-0.30**	**1.036**	**-0.50**	**177.2**	**8.831**	**3.450**	**11.28**	**-0.27**	**-1.56**	**0.168**	**-0.32**	**16.46**
GAGED FLOW	**0**	**0.229**	**11.64**	**2.580**	**201.8**	**30.19**	**45.59**	**31.20**	**7.597**	**2.757**	**0.676**	**0.486**	**27.89**
NET GAIN (+) / LOSS (-)	**1.530**	**0.533**	**10.60**	**3.083**	**24.60**	**21.36**	**42.14**	**19.92**	**7.867**	**4.319**	**0.508**	**0.804**	**11.43**

The dry year condition shown in Table 24 indicates that, in addition to those losses between Willard Road and Blue Cut, there are additional losses. These losses may be between Santa Paula Creek and the Freeman Diversion, or between Freeman Diversion and the Montalvo gage. The net gains during the wet season are from ungaged tributaries and local runoff.

Table 25 shows net gains every month of the year. This is from local runoff from storm events not accounted for in UWCD's gain estimates, flow from Pole Creek, and from tributaries and local runoff between Santa Paula Creek and the Montalvo gage.

Simulation Results

Figure 80 and Figure 81 show the simulated (blue) and observed (black circles) flow at Montalvo. The first figure shows the entire hydrograph; the second shows the same results but only the 0-5 m^3/s portion of the hydrograph. Calibration of that gage has not been done and would be very difficult. Table 24 shows net losses for much of the year. Without knowing actual losses, it would be impossible to calibrate the unknown flows. Table 25 shows net unknown flows which could theoretically calibrated, but the uncertainty in the prescribed groundwater flows is so great that calibration of the unknown flows would still be highly uncertain. The flow at Reach 3 is set based on calibrated flows upstream and specified gains and losses. The losses shown in Table 24 and Table 25 downstream of Santa Paula Creek are not simulated, causing the simulated flow to be too high during low flow as shown in Figure 81. Peak flows are underestimated in the model simulations, resulting in too little flow overall.

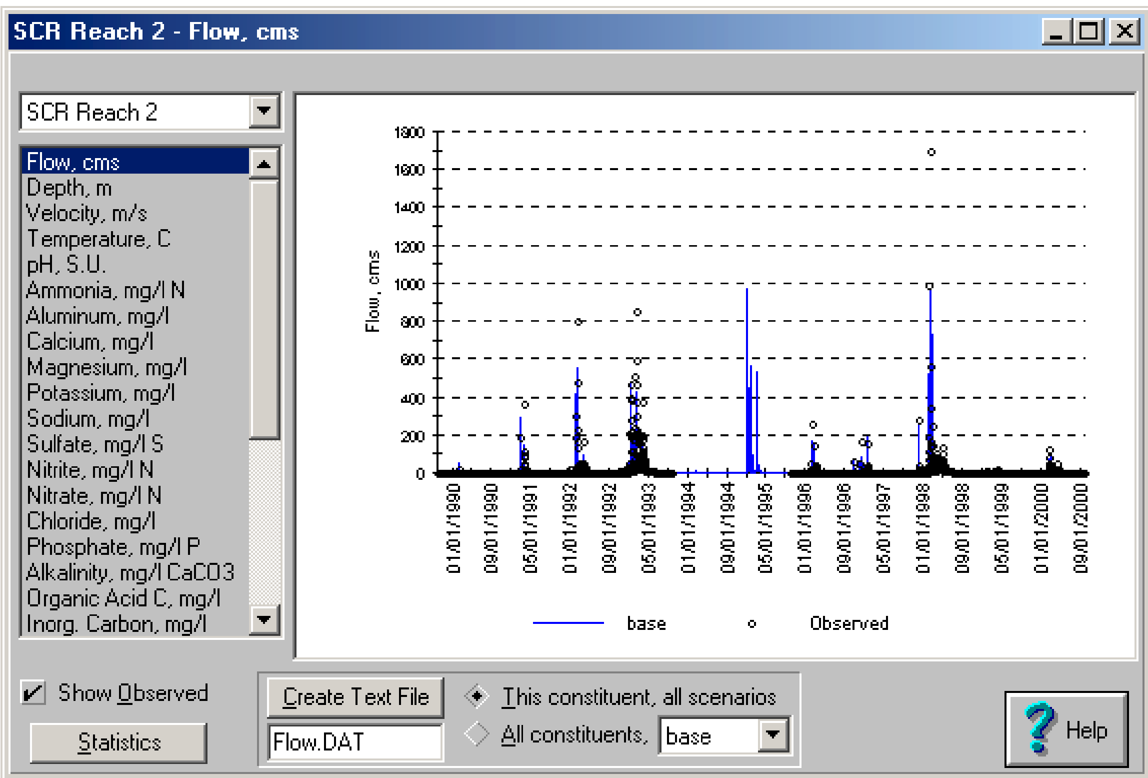

Figure 80: Simulated and Observed Flow, Santa Clara River at Montalvo (n = 3288; r = 0.78; relative error = -32.1%)

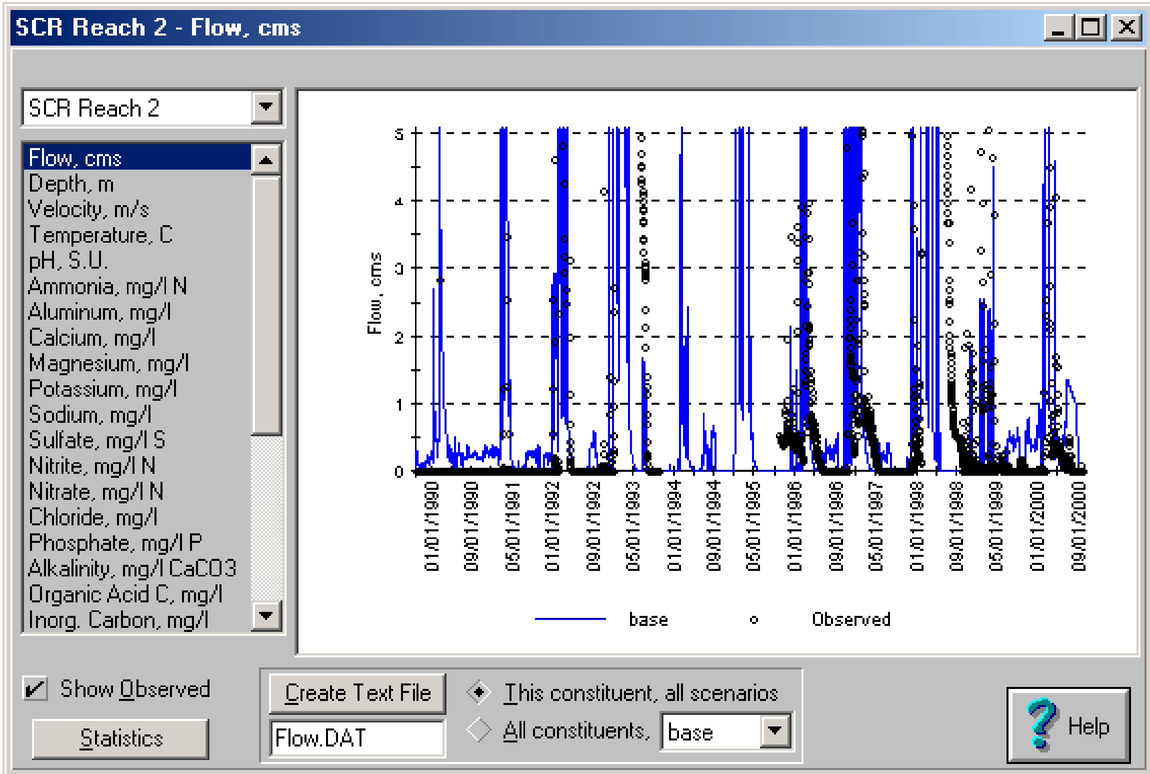

Figure 81: Simulated and Observed Flow: 0-5 m^3/s, Santa Clara River at Montalvo (n = 2670; r = 0.28; relative error = +35.7%)

Water Quality

Water quality in this river section is controlled by the different sources of water. The sources include the Santa Paula WWRF, gain from groundwater near Willard Road, and flow from Sespe Creek. The season of the year and whether or not the year is wet or dry can change the proportion of flow sources reaching the Freeman Diversion.

Table 24 shows that much of the flow reaching the Freeman Diversion in a dry year comes from groundwater gain at Willard Road and the Santa Paula Wastewater Reclamation Plant. That is augmented by Sespe Creek flow reaching Freeman in early spring. Table 25 shows that Sespe Creek and Willard Road groundwater contribute much more flow than the Santa Paula WWRP in a wet year.

Key Assumptions

The initial groundwater nitrate concentration in the Willard Road area is important to water quality simulation because of the large volume of groundwater accretion. Because there is a large amount of storage in the soil, the initial concentration does not change very much over the course of the simulation period. Therefore, the initial concentration represents the concentration of the accreted groundwater.

Well monitoring data in the Willard Road area has nitrate concentrations varying from 0 to 32 mg/l as N, with an average of 5.7 mg/l and a median of 3.4 mg/l. Water quality monitoring data from the Willard Road area show a maximum nitrate concentration of 3.5 mg/l and an average of 1.74 mg/l. Flow in the river at this location is at times exclusively from local groundwater but is often combined with flow from Sespe Creek, whose measured nitrate concentration is always less than 1 mg/l N. Based on this information, the concentration in the local groundwater should be above the observed average of 1.74 mg/l and below the observed maximum of 3.5 mg/l. Calibration of the initial concentration found that 2.5 mg/l provides the best fit with observed data. Refer to the Sensitivity Analysis section of this report for an analysis of how a different assumption about groundwater concentration affects simulation results in Reach 3.

As is the case for Reach 8 and Reach 7, denitrification was an important process in the area downstream of the Santa Paula WWRP. The denitrification rate used was the same as in the area near the Saugus and Valencia WWRFs, 0.5/day.

Simulation Results

Simulations of water quality between the Blue Cut gage and Sespe Creek (the "dry gap") are subject to intermittent flow. When there is zero flow, there is no water quality output. Figure 83 through Figure 91 show the water quality when flow is present in this section of the Santa Clara River. Red circles have been added to some figures to make observed data points more visible, not to add emphasis. Figure 82 shows the locations of the water quality monitoring stations.

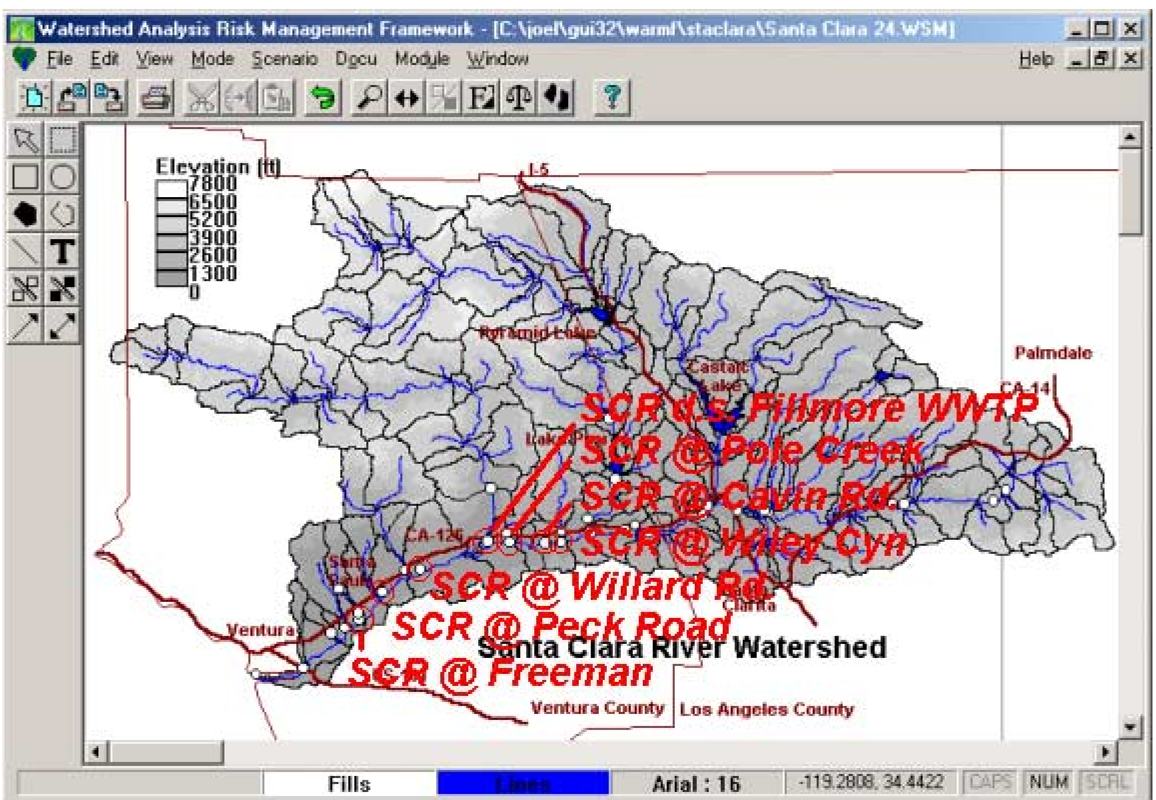

Figure 82: Water quality monitoring stations for Santa Clara River reaches 3-6

For the Santa Clara River at Wiley Canyon, the model matches the low nitrate concentrations for the times when there are observed data. At Cavin Road, the model matches the low nitrate data points but shows no flow when there is a measured value over 2 mg/l N. At Pole Creek, the model matched the observed nitrate concentrations in 1998 and 1999, but overpredicted nitrate in 2000. Downstream of the Fillmore WWTP, nitrite and nitrate are matched well.

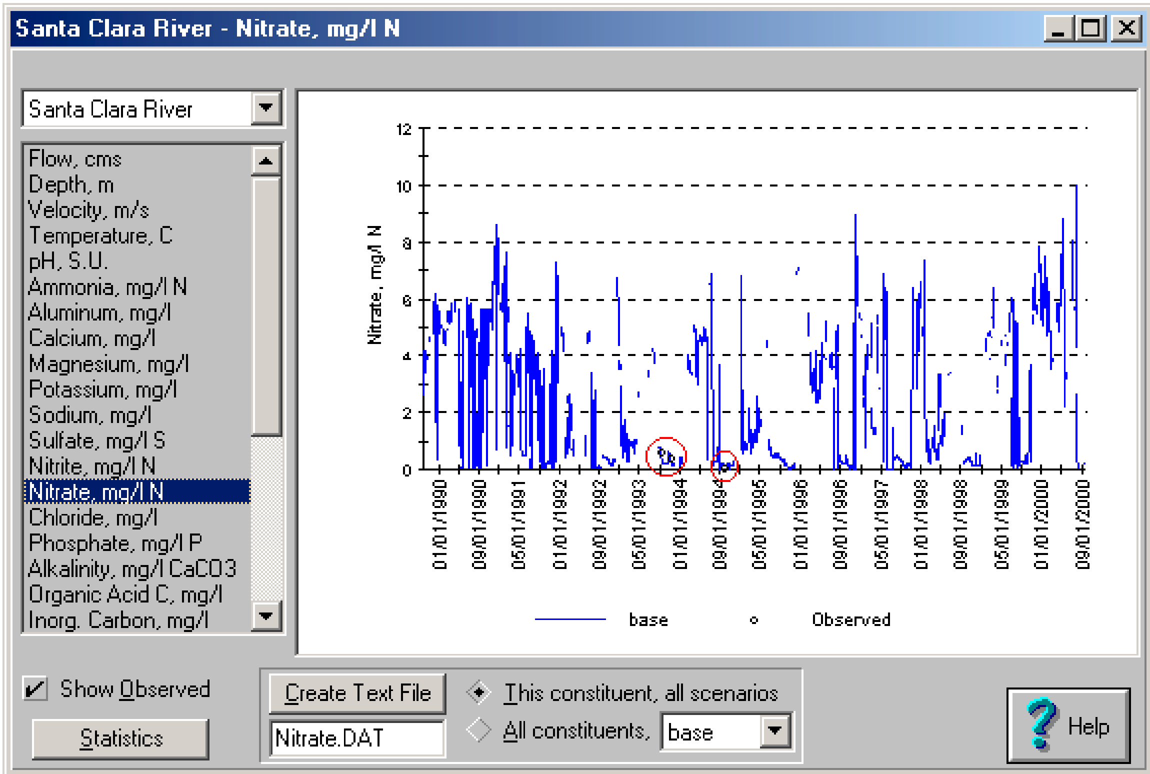

Figure 83: Simulated and Observed Nitrate for the Santa Clara River at Wiley Canyon (n = 3; relative error = 0.13 mg/l; absolute error = 0.13 mg/l)

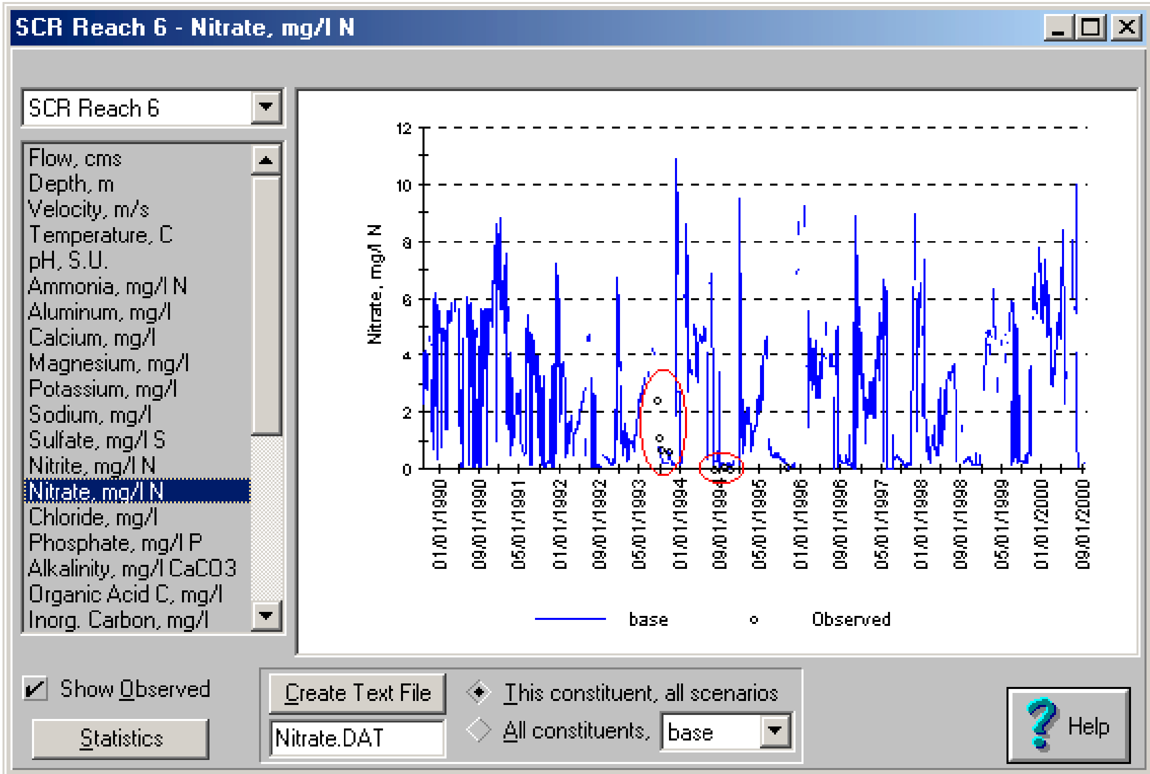

Figure 84: Simulated and Observed Nitrate for the Santa Clara River at Cavin Road (n = 7; relative error = -0.24 mg/l; absolute error = 0.13 mg/l)

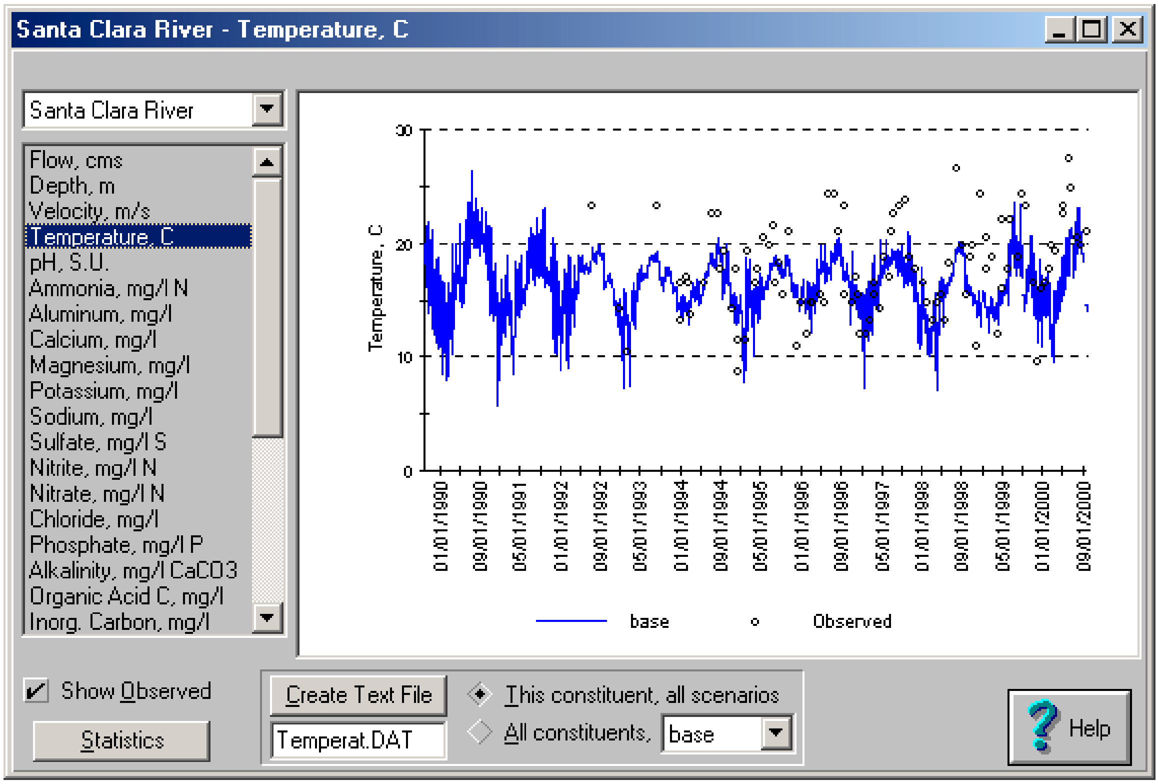

Figure 85: Simulated and Observed Temperature for the Santa Clara River at Pole Creek (n = 96; relative error = -1.83 ^{o}C; absolute error = 3.02 ^{o}C)

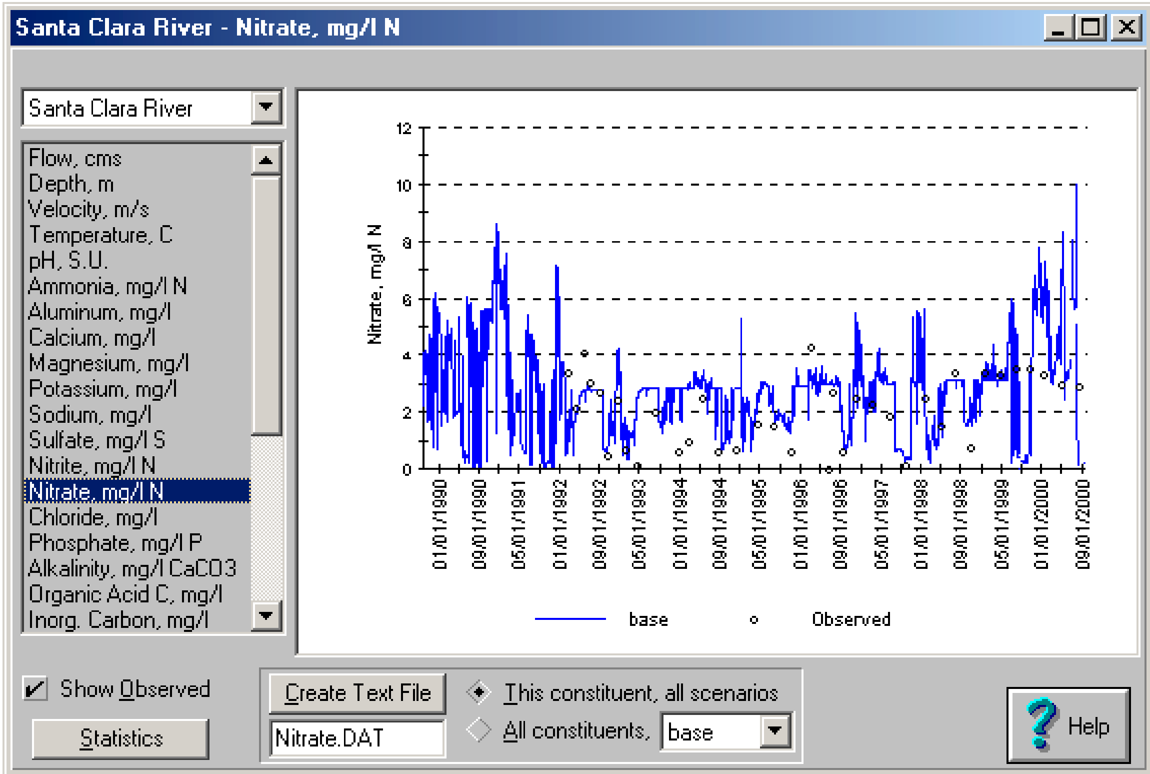

Figure 86: Simulated and Observed Nitrate for the Santa Clara River at Pole Creek (n = 37; relative error = 0.67 mg/l; absolute error = 1.17 mg/l)

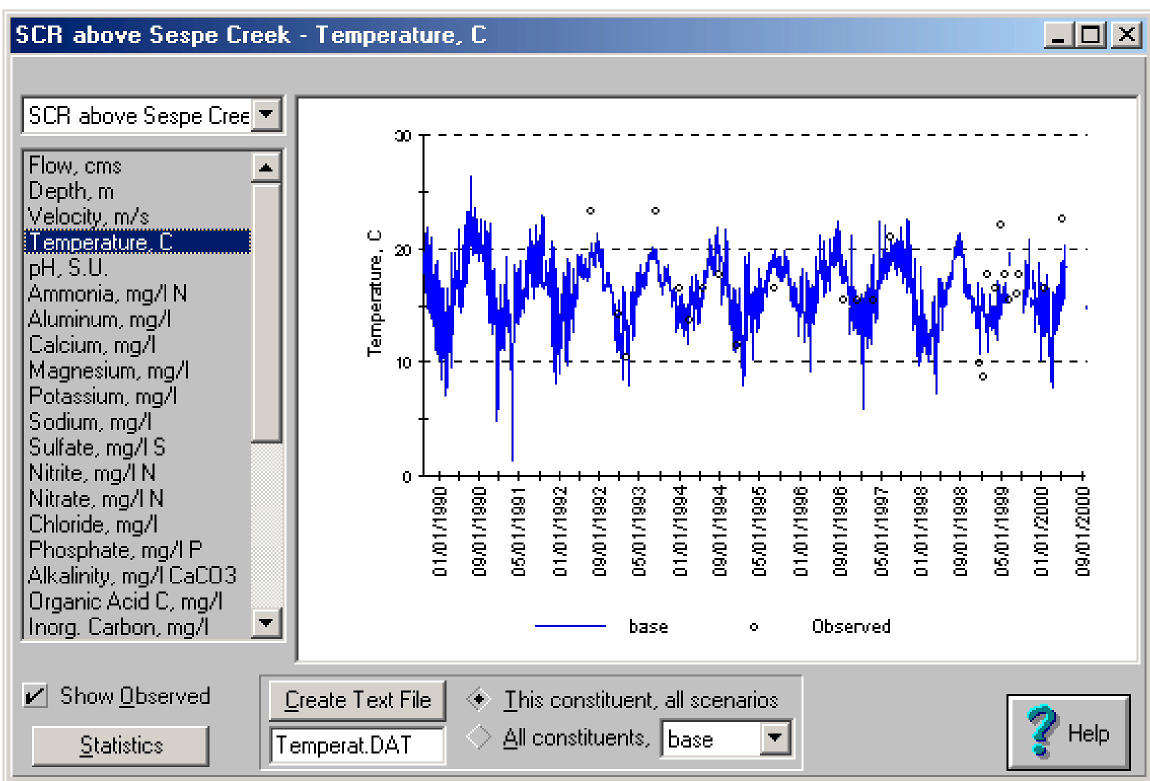

Figure 87: Simulated and Observed Temperature for the Santa Clara River d.s. of Fillmore WRP (n = 23; relative error = -0.91 mg/l; absolute error = 2.96 mg/l)

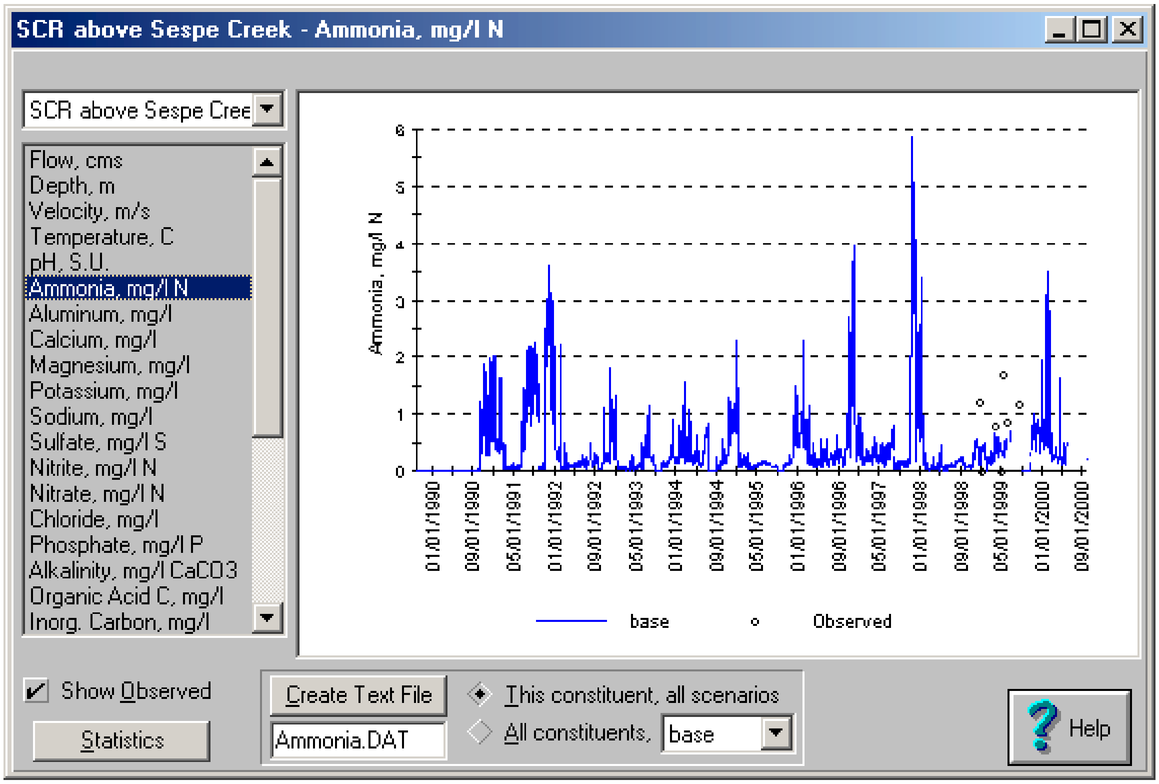

Figure 88: Simulated and Observed Ammonia for the Santa Clara River d.s. of Fillmore WRP (n = 6; relative error = -0.45 mg/l; absolute error = 0.68 mg/l)

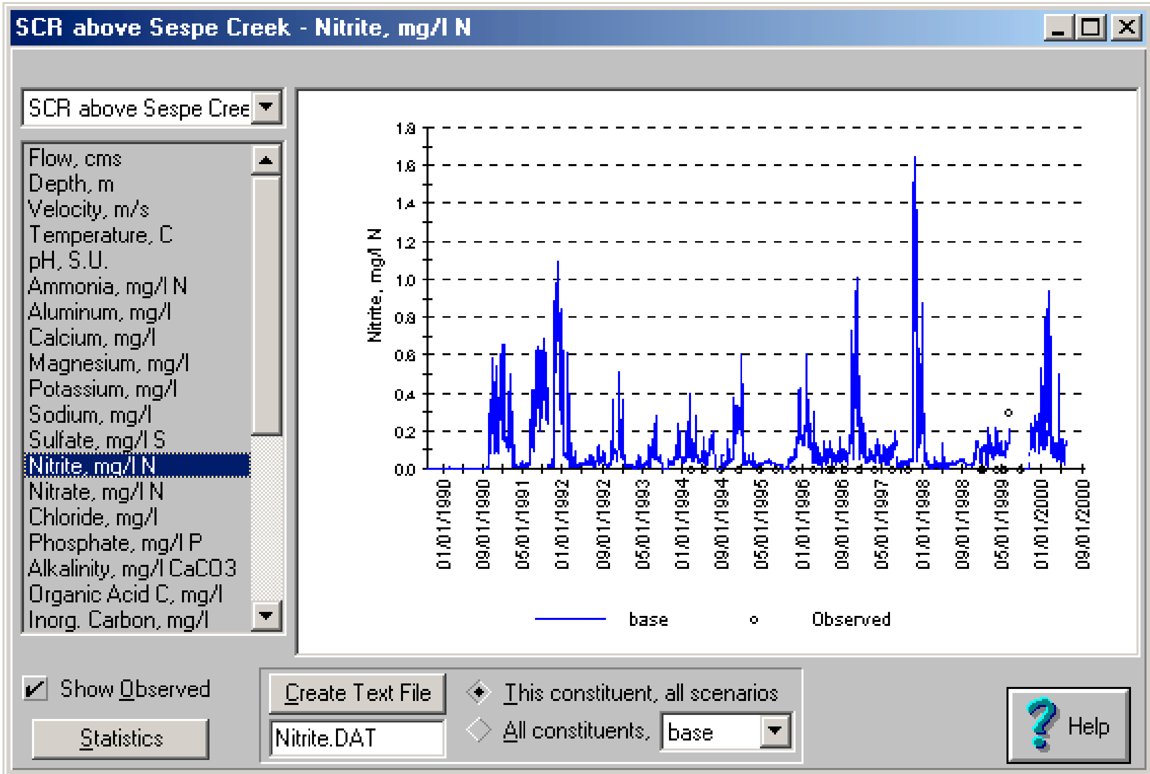

Figure 89: Simulated and Observed Nitrite for the Santa Clara River downstream of Fillmore WRP (n = 21; relative error = -0.07 mg/l; absolute error = -0.09 mg/l)

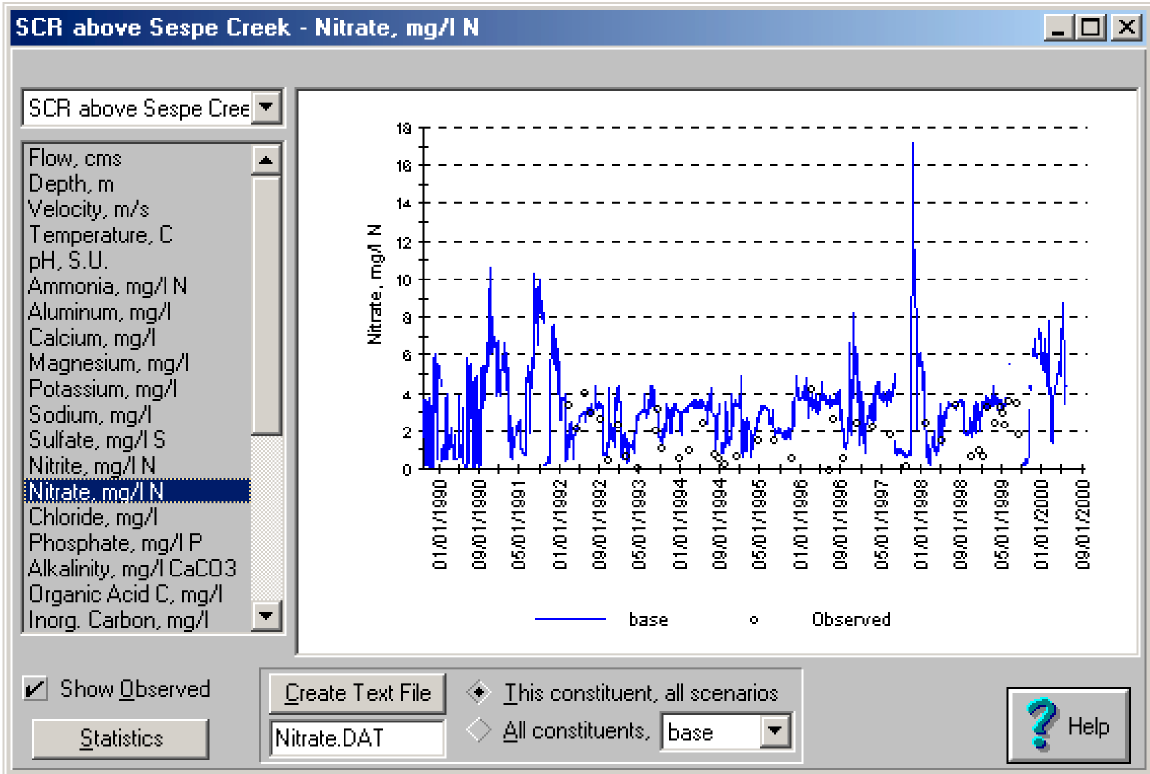

Figure 90: Simulated and Observed Nitrate for the Santa Clara River downstream of Fillmore WRP (n = 42; relative error = 0.99 mg/l; absolute error = 1.23 mg/l)

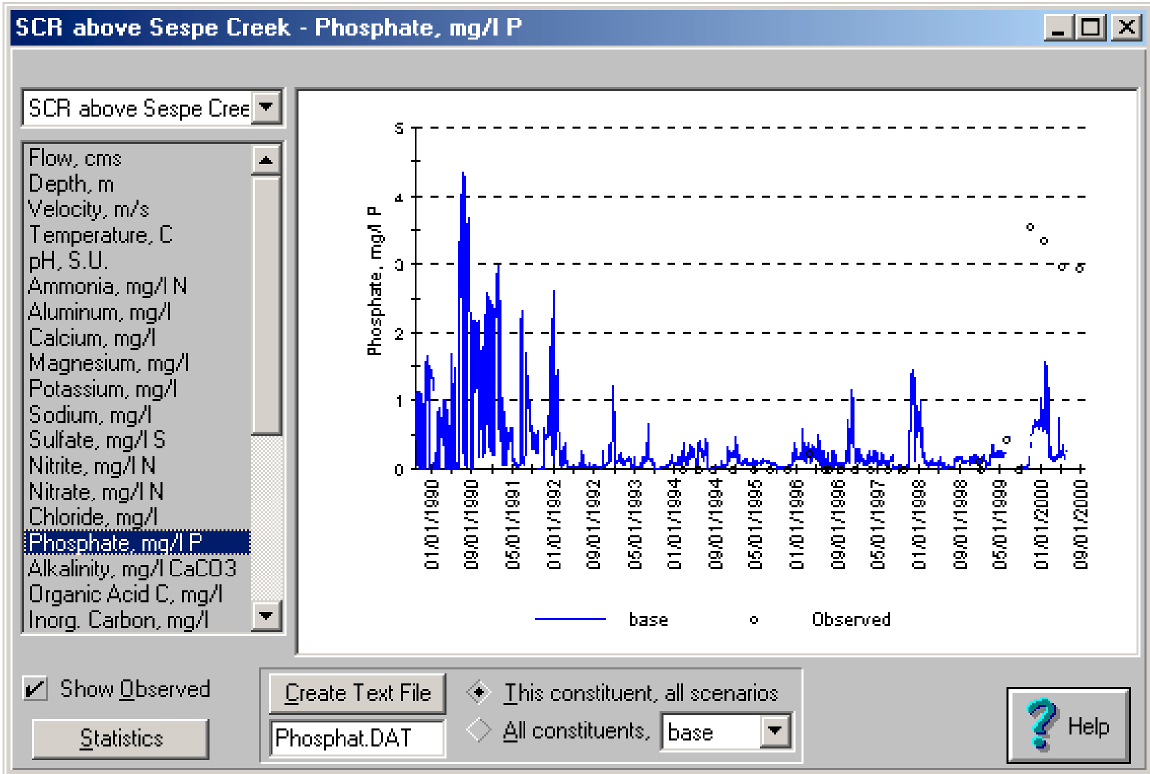

Figure 91: Simulated and Observed Phosphate for the Santa Clara River d.s. of Fillmore WRP (n = 21; relative error = -0.39 mg/l; absolute error = 0.55 mg/l)

From Willard Road to the Freeman Diversion, flow in the Santa Clara River is perennial. Water quality is primarily a blend of Sespe Creek, Willard Road gain from groundwater, and Santa Paula WWRP.

Figure 92 though Figure 95 compare simulation results with observed data for the Santa Clara River at Willard Road. The observed nitrite concentrations at Willard Road are zero. The simulated nitrite varies between 0 and 0.04 mg/l for most of the simulation, which is essentially zero. The predicted nitrate concentration ranges between 0.2 to 3 mg/l, which is in the same range of observed values. The flat spots on the graph correspond to time periods when estimated losses between Sespe Creek and Willard Road result in the flow at Santa Paula Creek being entirely from groundwater gains in the Willard Road area. Note also the gradual increase in nitrate concentration over the course of the simulation from 2.5 mg/l to 3.0 mg/l. Although WARMF is not intended to predict groundwater nitrate concentrations, it is showing a long-term increase in nitrate. The model predicts a phosphate concentration less than 0.2 mg/l, similar to the measured values. There is no phosphate monitoring data from 1990-1992 to corroborate the high phosphate concentrations predicted by the model. Red circles have been added to some figures to make observed data points more visible.

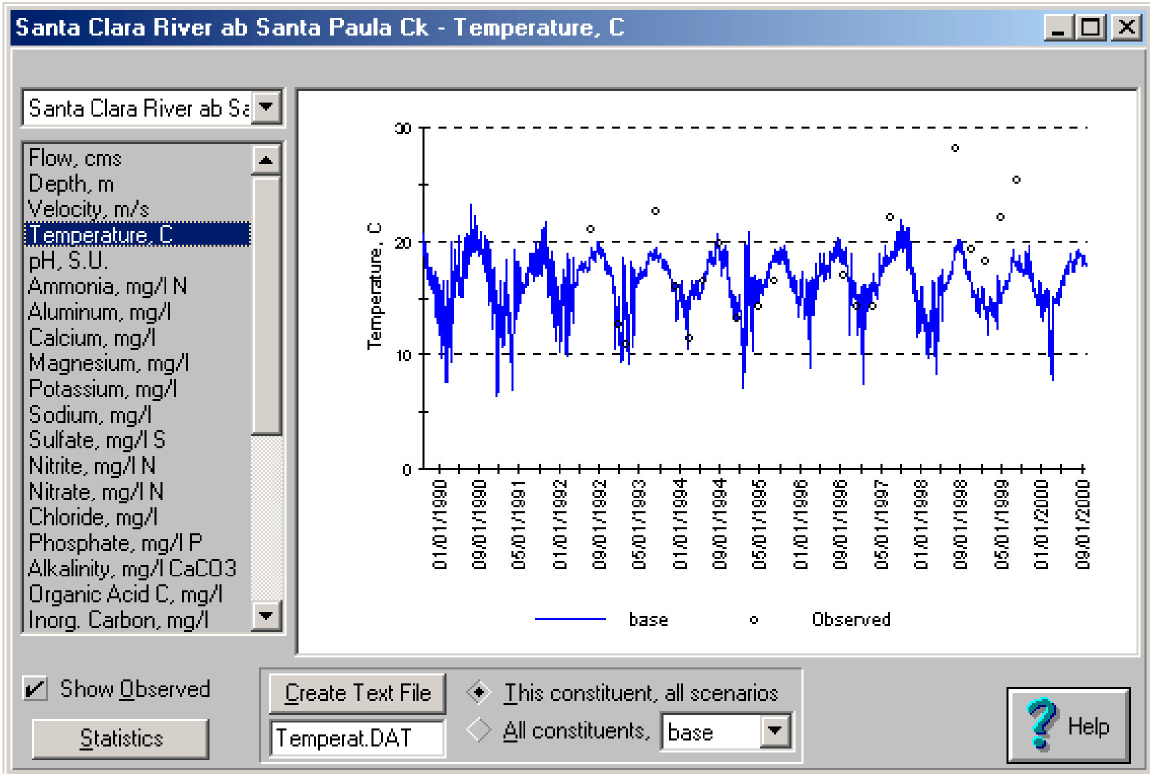

Figure 92: Simulated and Observed Temperature for the Santa Clara River at Willard Road (n = 20; relative error = -1.36 ^{o}C; absolute error = 2.83 ^{o}C)

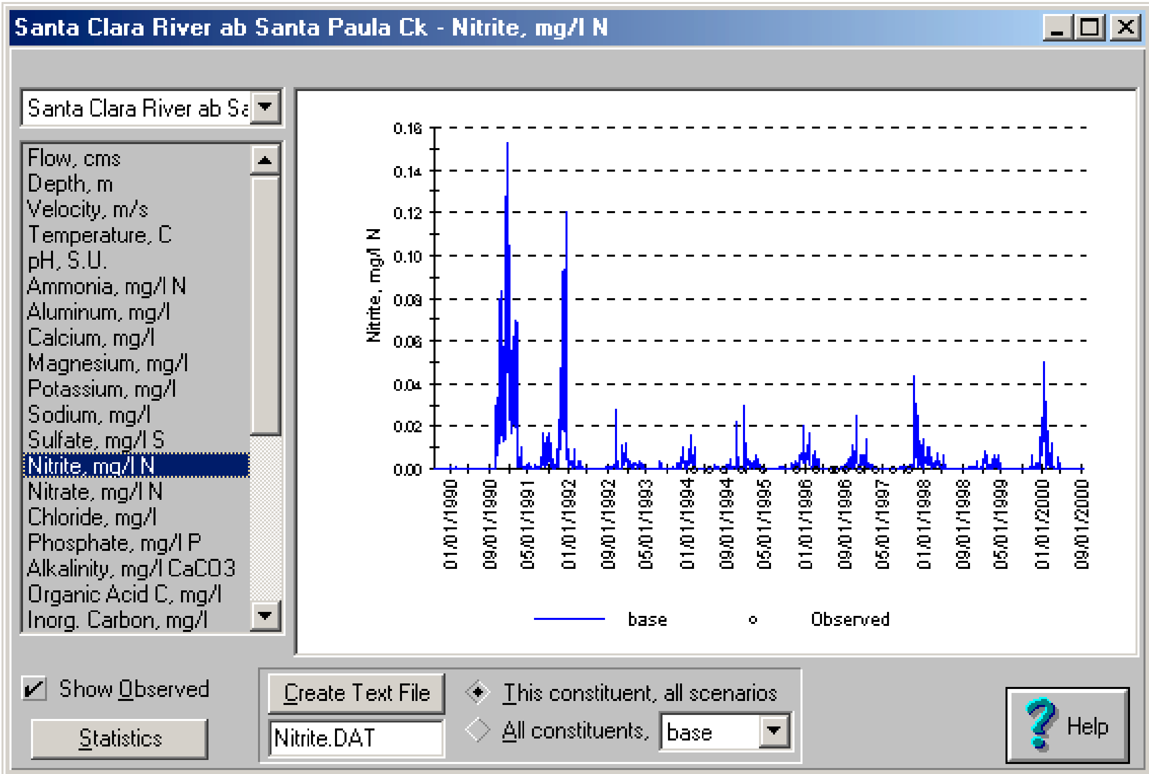

Figure 93: Simulated and Observed Nitrite for the Santa Clara River at Willard Road (n = 14; relative error = 0.00 mg/l; absolute error = 0.00 mg/l)

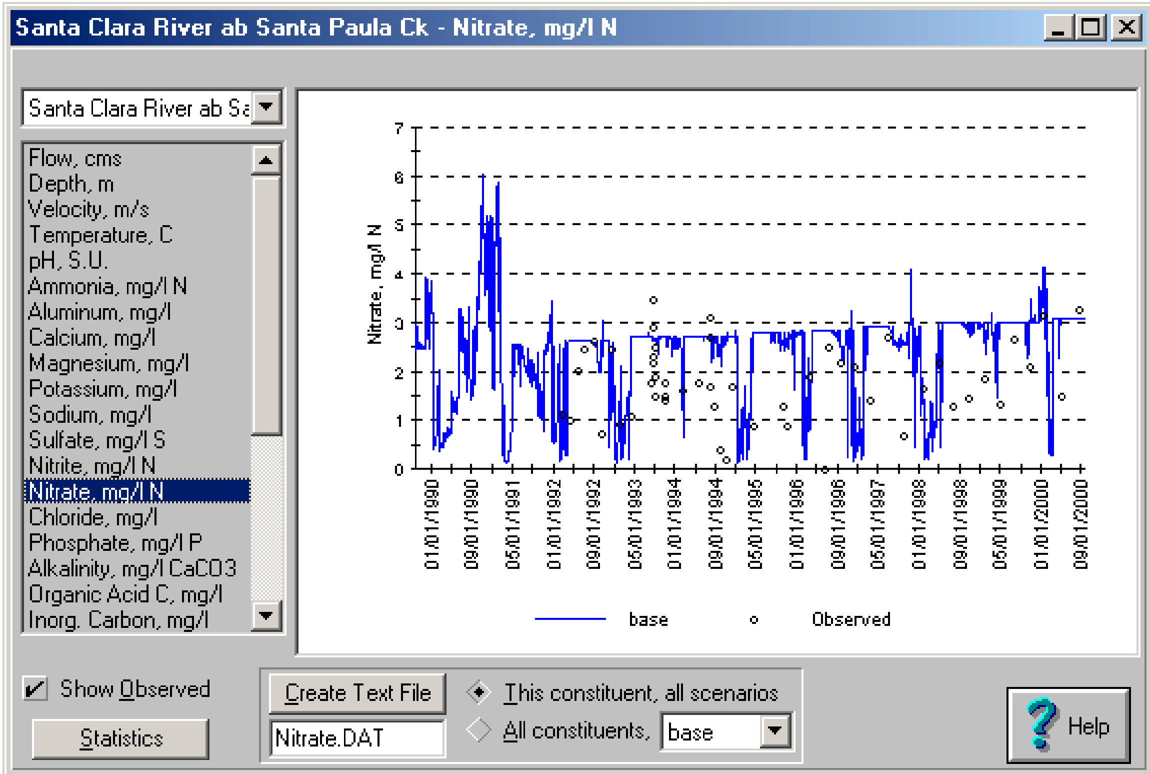

Figure 94: Simulated and Observed Nitrate for the Santa Clara River at Willard Road (n = 48; relative error = 0.85 mg/l; absolute error = 0.95 mg/l)

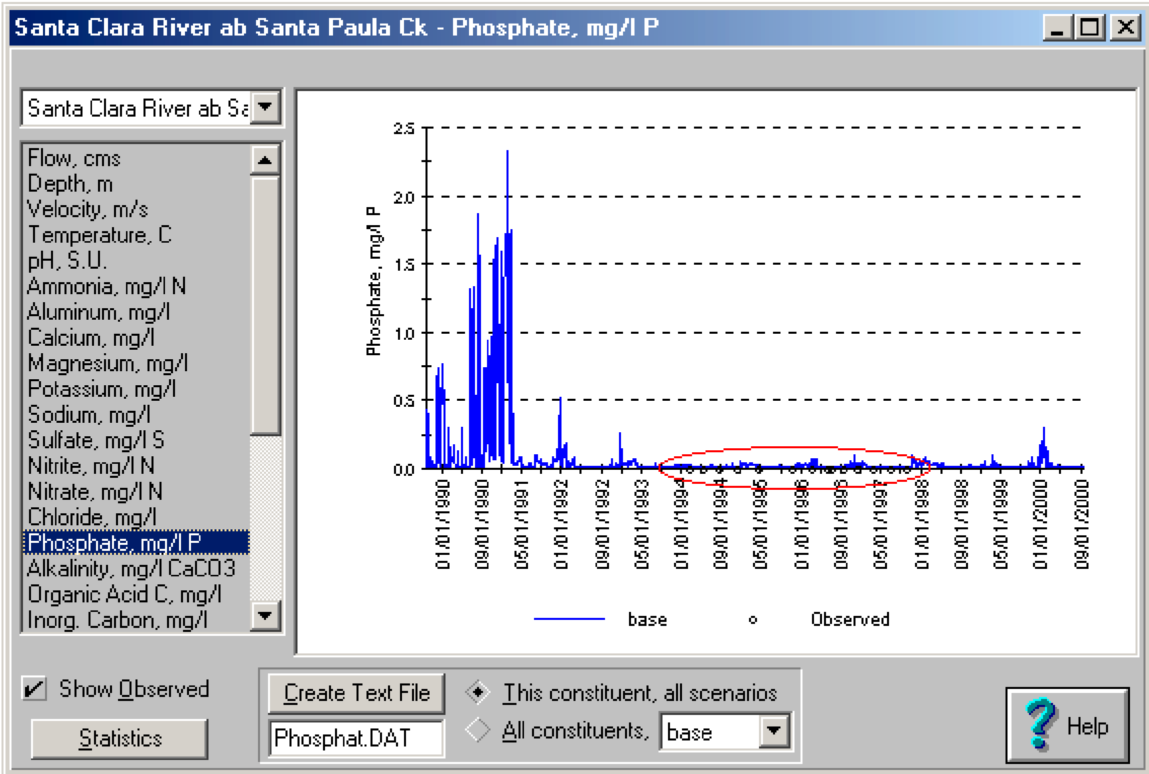

Figure 95: Simulated and Observed Phosphate for the Santa Clara River at Willard Road (n = 14; relative error = 0.02 mg/l; absolute error = 0.02 mg/l)

Figure 96 through Figure 100 compare the simulated and observed temperature and concentrations of nitrite, nitrate, and phosphate for the Santa Clara River at Peck Road, immediately downstream of the Santa Paula WWRP. Ammonia concentrations are underpredicted in the model, possibly because the model's representation of the watershed assumes that the effluent will be able to react throughout the entire reach from Santa Paula Creek to Peck Road, whereas the monitoring data was collected 300 feet downstream of where the effluent enters the river. The simulated nitrite concentration ranges generally from 0 to 0.2 mg/l compared to the observed values of 0 to 0.3 mg/l. The simulated nitrate concentration generally ranges from 0.1 to 2.5 mg/l, compared to the observed values of 1 to 3 mg/l. The simulated phosphate concentration is generally below 0.2 mg/l as observed. However, the observed data shows two data points with a concentration as high as 2 mg/l, which was not simulated by the model.

The peaks in nitrite and nitrate concentrations in fall 1990 / winter 1991 reflect a very dry flow condition when effluent from the Santa Paula WWRP represented as much as 50% of the total flow in the Santa Clara River. The discussion of model performance at Freeman Diversion has a more in-depth analysis of this time period.

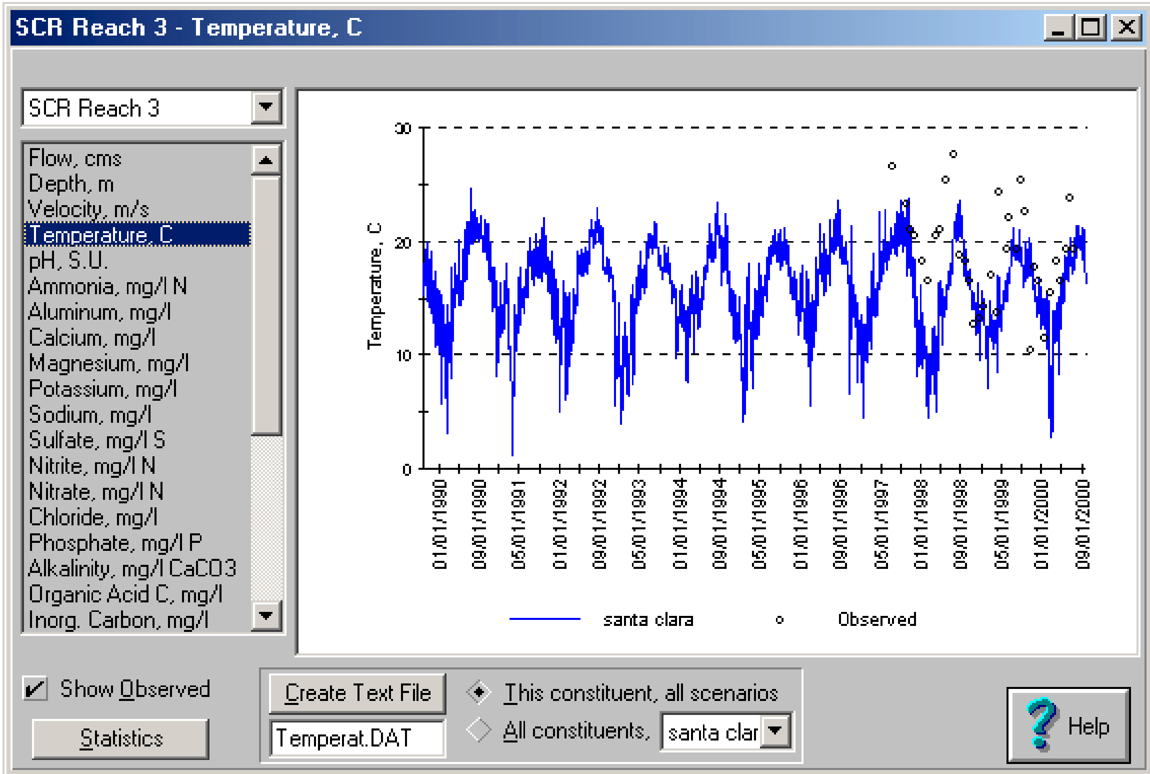

Figure 96: Simulated and Observed Temperature for the Santa Clara River at Peck Road (n = 36; relative error = -3.36 ^{o}C; absolute error = 4.10 ^{o}C)

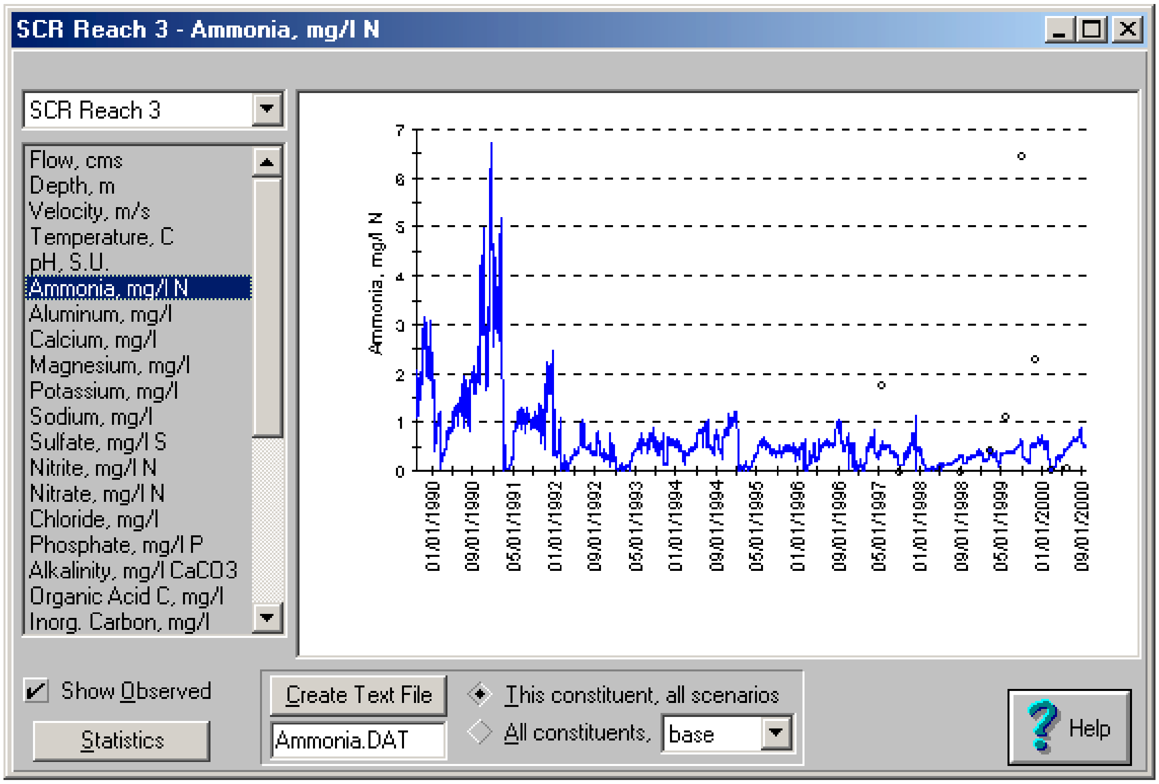

Figure 97: Simulated and Observed Ammonia for the Santa Clara River at Peck Road (n = 9; relative error = -1.00 mg/l; absolute error = 1.16 mg/l)

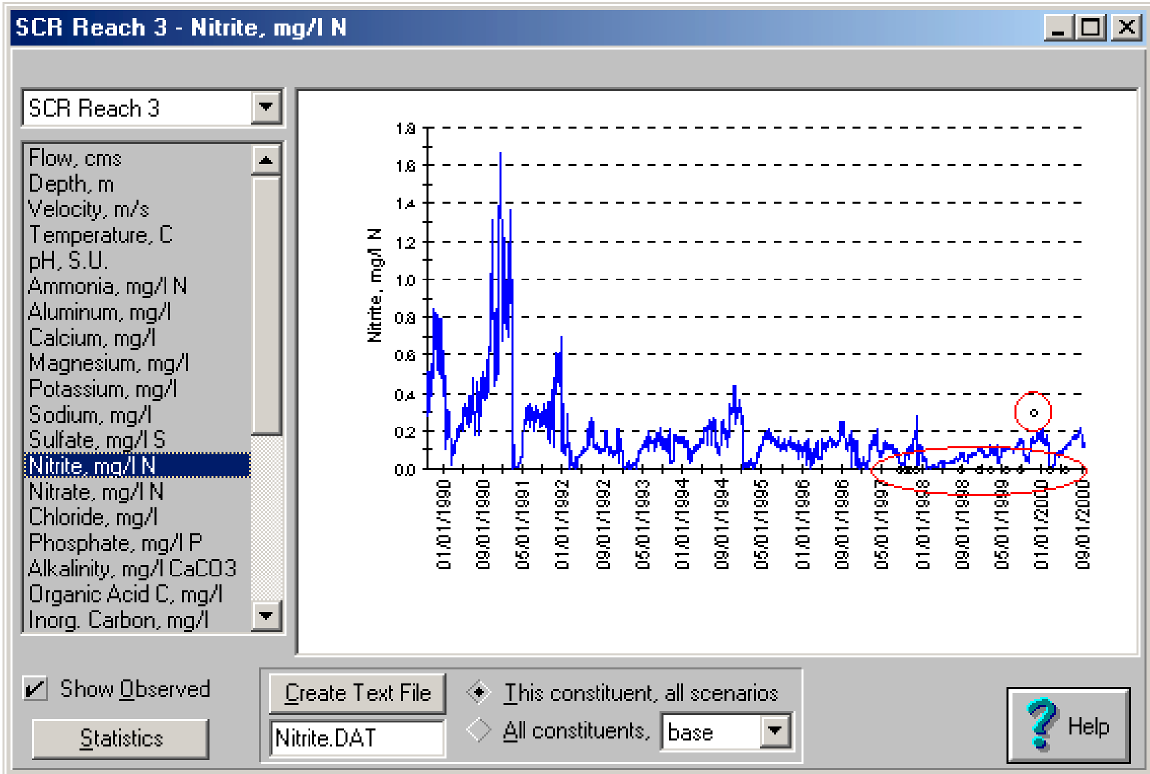

Figure 98: Simulated and Observed Nitrite for the Santa Clara River at Peck Road (n = 12; relative error = 0.08 mg/l; absolute error = 0.10 mg/l)

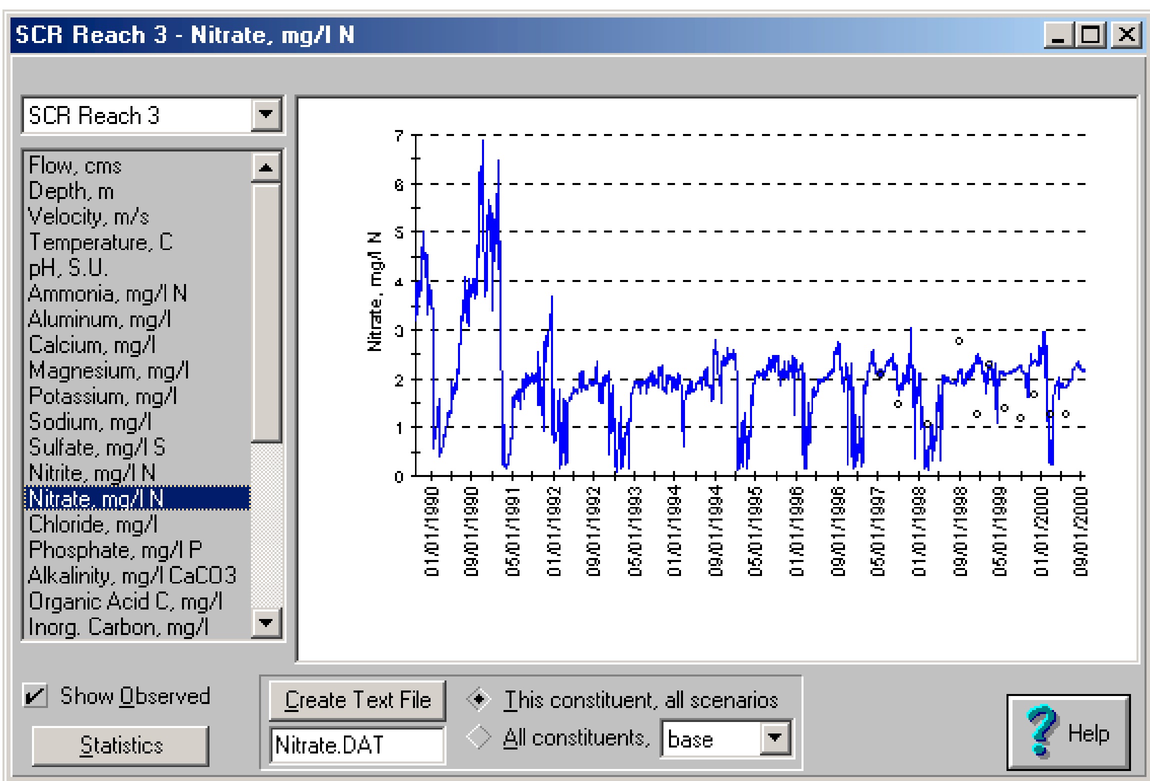

Figure 99: Simulated and Observed Nitrate for the Santa Clara River at Peck Road (n = 11; relative error = 0.24 mg/l; absolute error = 0.56 mg/l

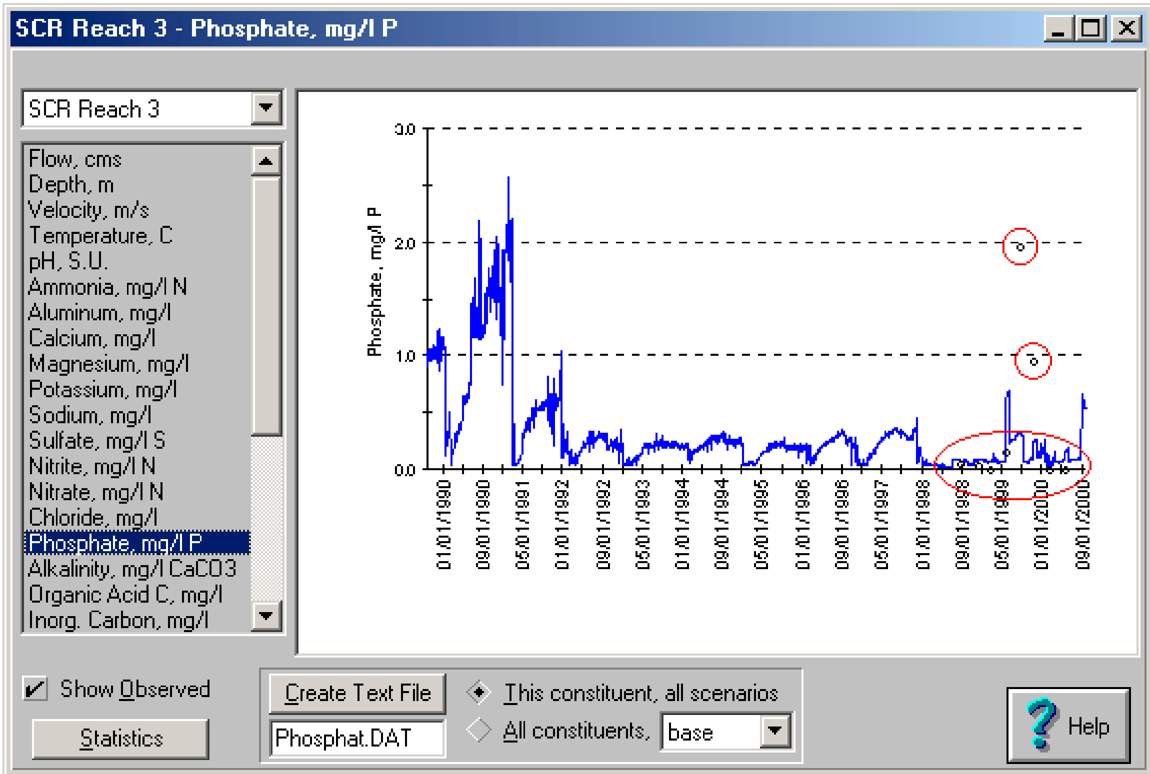

Figure 100: Simulated and Observed Phosphate for the Santa Clara River at Peck Road (n = 8; relative error = -0.24 mg/l; absolute error = 0.35 mg/l)

Figure 102 through Figure 106 present the comparisons of simulated and observed temperature and concentrations of ammonia, nitrite, nitrate, and phosphate for the Santa Clara River at Freeman Diversion. The model predicts low ammonia concentrations as observed. The model also predicts near zero concentrations of nitrite as observed. The observed data show two high values of about 1.2 mg/l, which were not simulated by the model. The model follows the observed nitrate concentration well. Unfortunately, there is no monitoring data to confirm the high predicted nitrate concentration for 1990-1991. For phosphate, the model simulates the concentration below 0.5 mg/l as observed but data is lacking to confirm the high simulated concentrations in 1990-1992.

The concentration peaks of ammonia, nitrite, and nitrate in fall 1990 / winter 1991 occurred when flow was very low. Daily discharge data is available from 10/1/1991 through 2/26/1991 when flow was lowest for Sespe Creek, Santa Paula Creek, and the Santa Paula WWRP. Daily flow estimates for the Willard Road groundwater source were provided by UWCD. UWCD also estimated daily flow in the Santa Clara River above Sespe Creek to be zero during the whole time period (UWCD (McEachron) 2002). During this period, flow from the Santa Paula WWRP represented an average of 42%, and as much as 50%, of the flow reaching the Freeman diversion. On average, 33% of the flow came from Willard Road. The remaining 25% came from Santa Paula and Sespe Creeks, but the combined total from these sources ranged as low as 11% of the total. The daily breakdown of flow is shown in Figure 101.

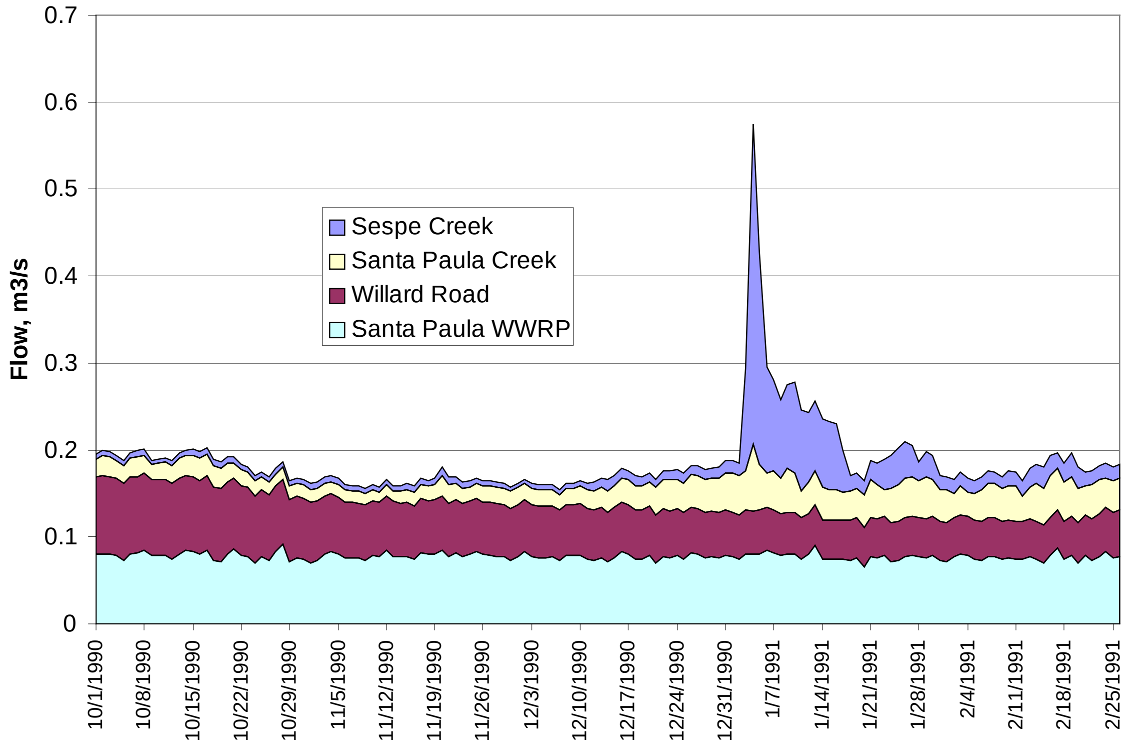

Figure 101: Breakdown of Flow at Freeman Diversion, 10/1/1990-2/26/1991

Observed data indicates that Sespe Creek and Santa Paula Creek have low nitrate concentration (< 1 mg/l N). Willard Road groundwater was estimated to have a concentration of 2.5 mg/l, which is lower than the median groundwater concentration from local well data. Effluent monitoring data from the Santa Paula WWRP indicates discharged nitrate concentrations from 1.4 to 8.7 mg/l as N. However, measured ammonia discharge concentrations from the Santa Paula WWRP ranged from 16 to 34 mg/l N. Much of that ammonia is nitrified in the river. Even taking denitrification of nitrate into account, a mass balance indicates that high nitrate must have occurred during that time period. A discussion of this has been added to the revised report.

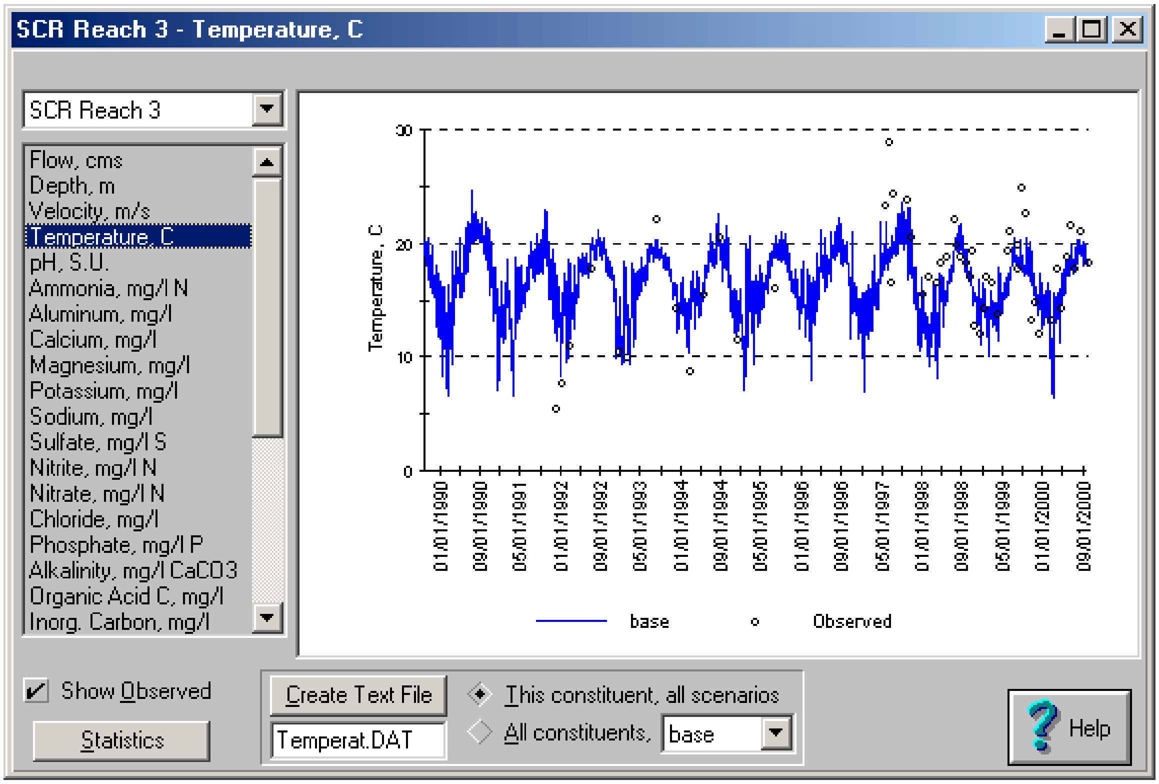

Figure 102: Simulated and Observed Temperature for the Santa Clara River at Freeman Diversion (n = 53; relative error = -0.70 ^{o}C; absolute error = 2.72 ^{o}C)

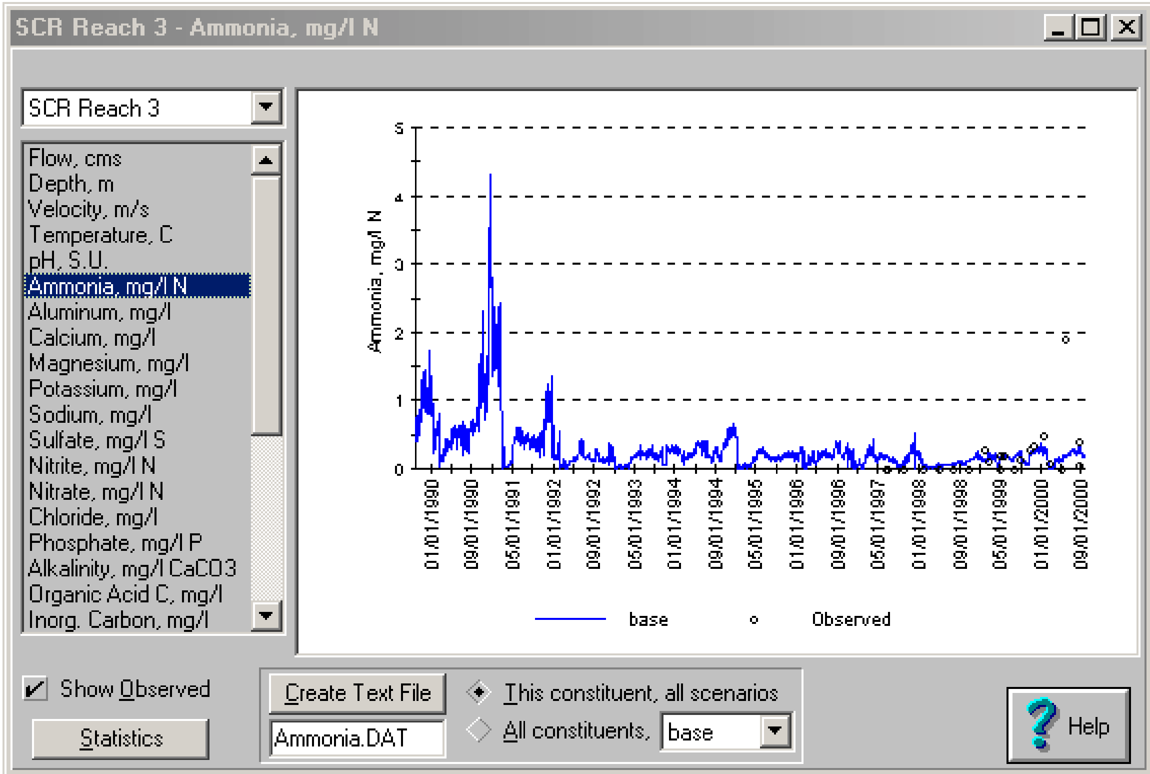

Figure 103: Simulated and Observed Ammonia for the Santa Clara River at Freeman Diversion (n = 22; relative error = -0.04 mg/l; absolute error = 0.21 mg/l)

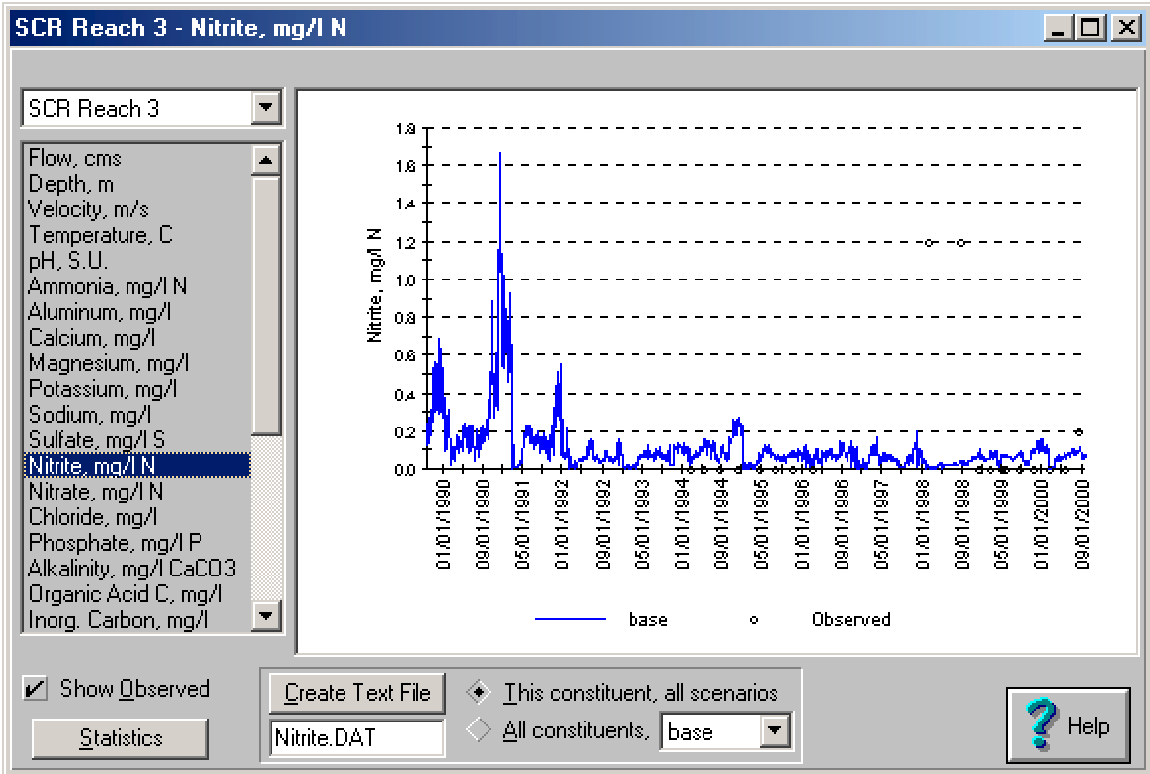

Figure 104: Simulated and Observed Nitrite for the Santa Clara River at Freeman Diversion (n = 19; relative error = -0.06 mg/l; absolute error = 0.20 mg/l)

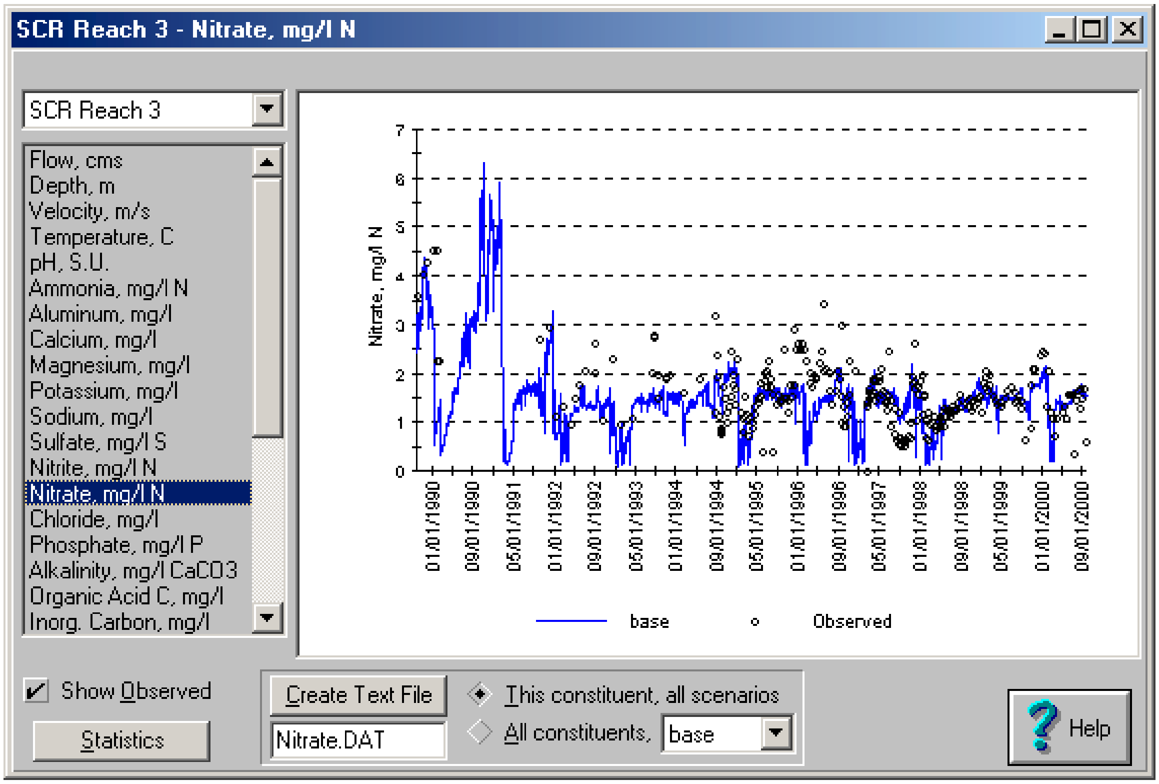

Figure 105: Simulated and Observed Nitrate for the Santa Clara River at Freeman Diversion (n = 276; relative error = -0.14 mg/l; absolute error = 0.43 mg/l)

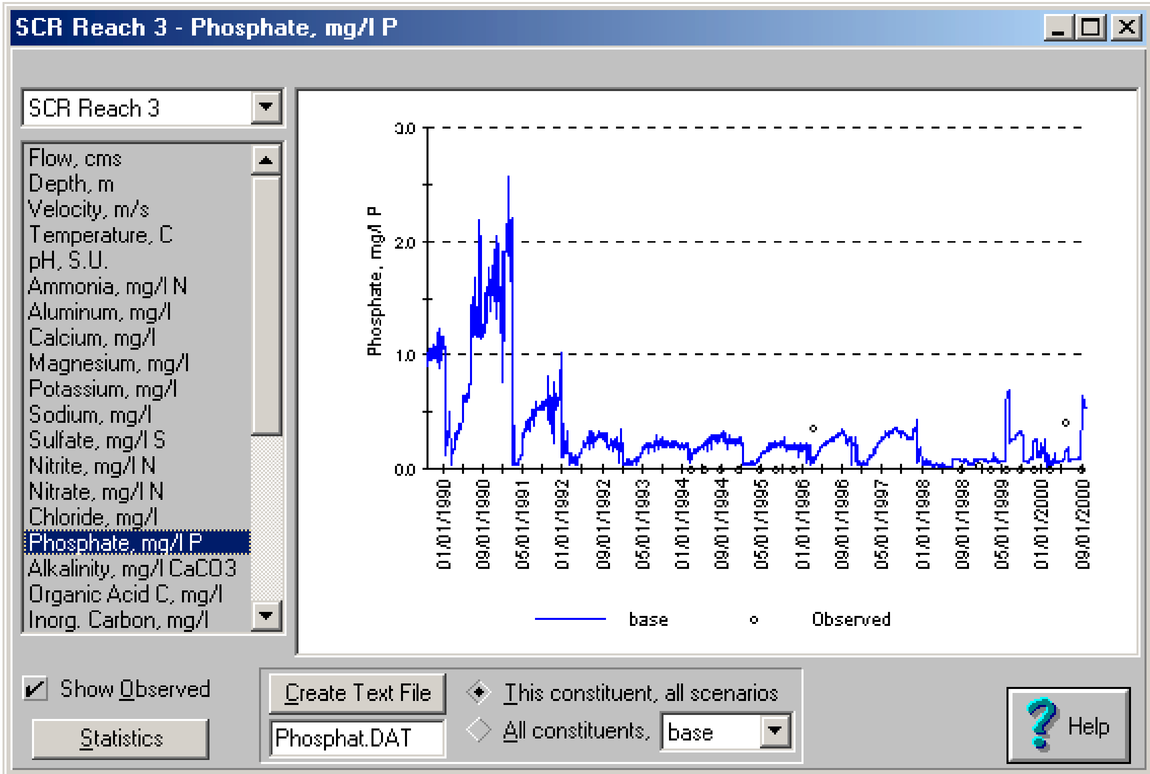

Figure 106: Simulated and Observed Phosphate for the Santa Clara River at Freeman Diversion (n = 17; relative error = 0.11 mg/l; absolute error = 0.18 mg/l)

Wheeler Canyon / Todd Barranca

This impaired tributary of the Santa Clara River is divided into two sections: Wheeler Canyon is in the mountains, and Todd Barranca is in the lowlands near the river. The watershed area of Todd Barranca is very small, but the area it passes through has agricultural use and groundwater discharges. The water table is high in this area, indicating the likelihood of groundwater entering Todd Barranca.

<u>Hydrology</u>

There is no gaging station for Todd Barranca, so its hydrology is largely unknown.

Key Assumptions

The only basis to use to calibrate the hydrology of the watershed was the observed nitrate data. Attempting to follow the range and pattern of this data can help provide a very rough estimate of the hydrology.

Simulation Results

Simulated flow for Todd Barranca is shown in Figure 107 and Figure 108, but there is no observed data with which to compare it. The hydrograph is typical of the area, with sharp peak flows during early spring storms but low base flow. The simulation almost always predicts more than zero flow.

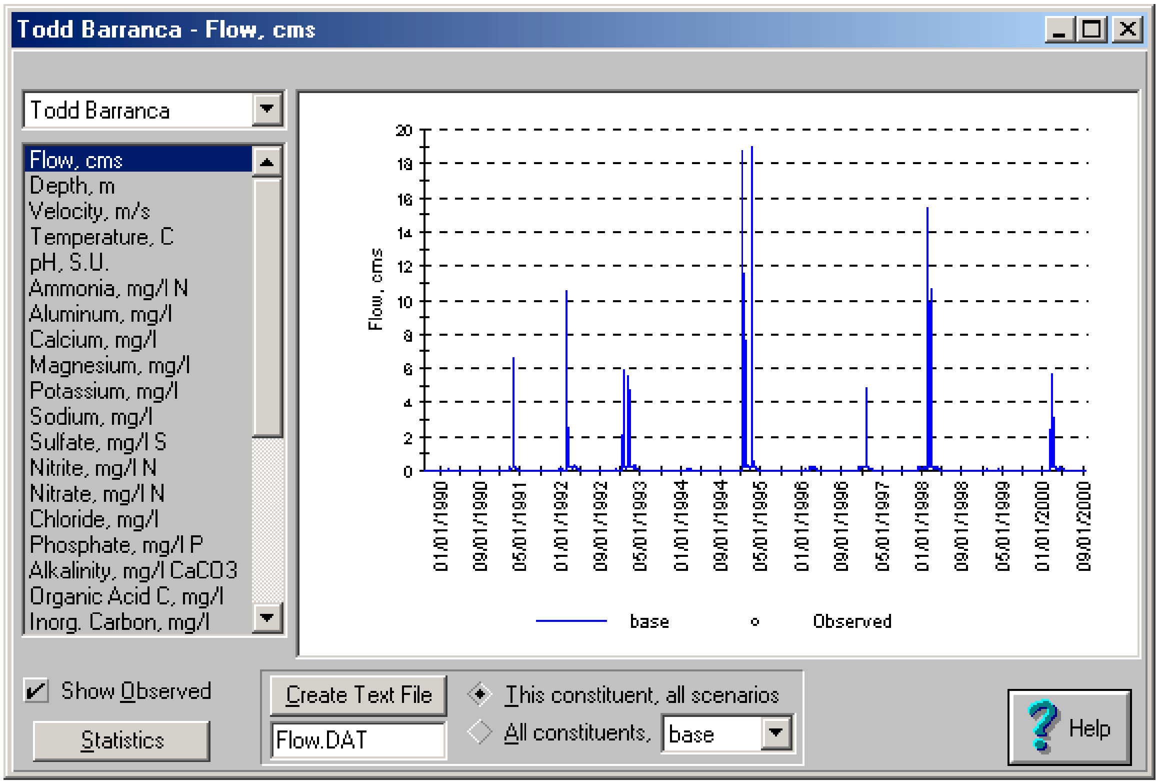

Figure 107: Simulated Flow for Lower Todd Barranca

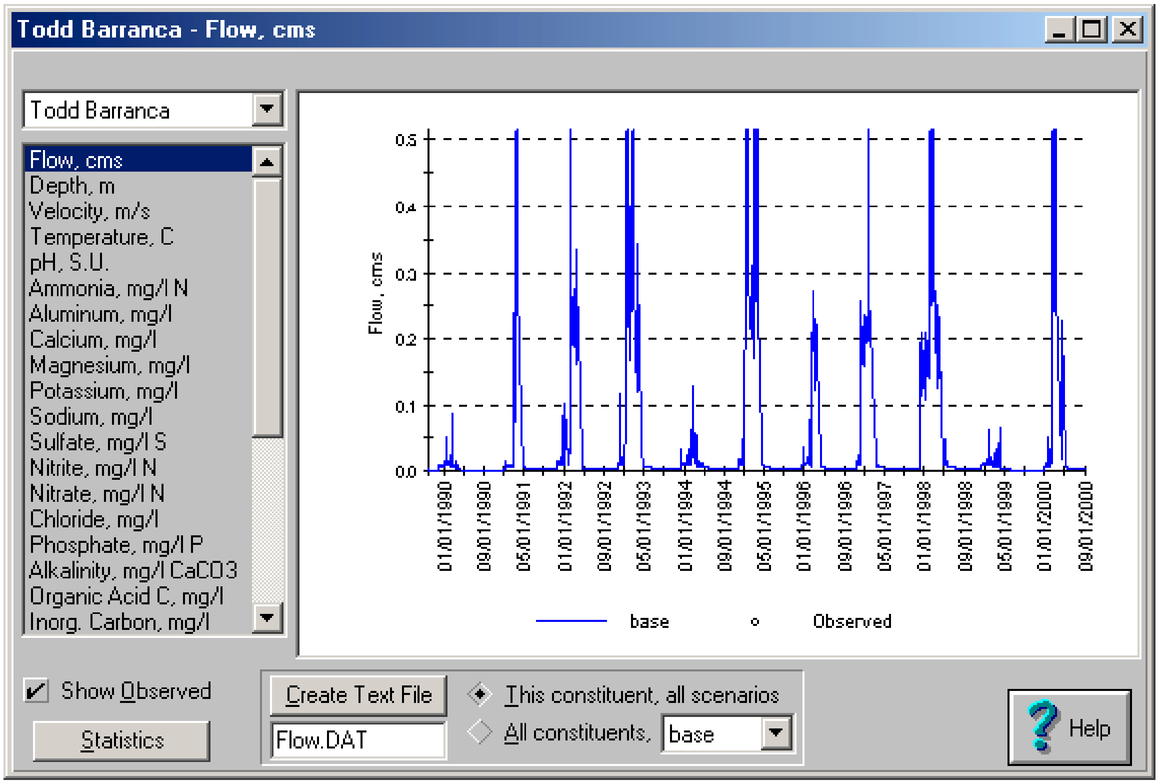

Figure 108: Simulated Flow: 0-0.5 m^3/s for Lower Todd Barranca

Water Quality

The water quality of Todd Barranca has low ammonia and phosphate concentrations typical of groundwater. Observed nitrate concentration is high, however, averaging 9.5 mg/l as nitrogen.

Key Assumptions

There are two permitted subsurface dischargers near Todd Barranca, the Todd Road Jail and Saticoy Food Corp. In both cases, the only data available is the "baseline flow" in the State of California groundwater discharge permit database. The discharge from each was assumed to have constant concentrations of 25 mg/l NH_4-N and 5 mg/l NO_3-N (refer to the Source Analysis Report for more information on this assumption).

Simulation Results

Figure 109 shows that the model simulates the nitrate concentration to fluctuate from 0 to 20 mg/l as observed.

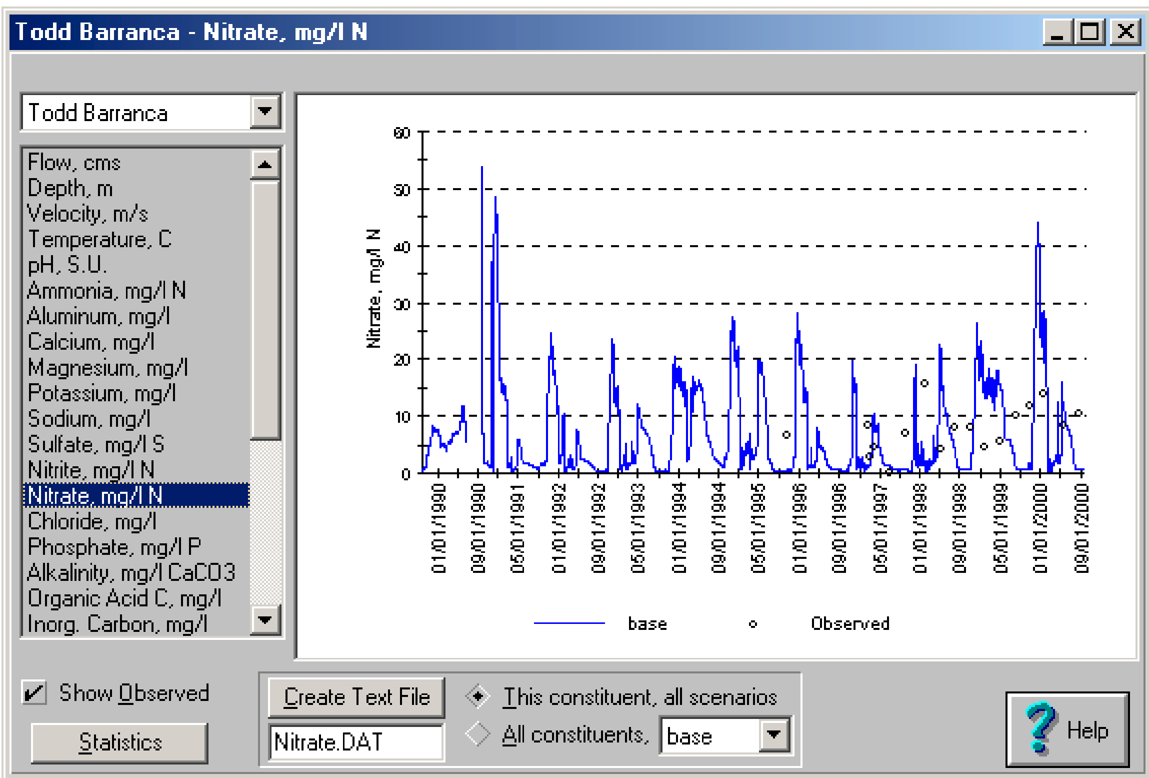

Figure 109: Simulated and Observed Nitrate for Lower Todd Barranca (n = 16; relative error = -2.09 mg/l; absolute error = 7.67 mg/l)

Brown Barranca / Long Canyon

This tributary of the Santa Clara River is impaired by nitrite/nitrate. Its watershed occupies a 7 km^2 area, partly in the hills and partly in the lowlands near the Santa Clara River.

Hydrology

There is no gage on this tributary, and little basis to use to estimate hydrology.

Key Assumptions

The model's physical parameters which affect hydrology have been set to match Santa Paula Creek, the nearest gaged tributary of the Santa Clara River.

Simulation Results

There is no gaged flow to calibrate the hydrologic simulation for this section of the Santa Clara River. The pattern of simulated hydrograph is similar to gaged hydrograph for nearby streams. They are judged to be reasonable.

Water Quality

There is no water quality monitoring data of nutrients for this tributary.

Key Assumptions

There are no point sources in this watershed. Refer to the Source Analysis Report for the loading assumptions associated with potential nonpoint sources of pollution

Simulation Results

There is no water quality data in this section of the river to support model calibration.

Summary

In the Santa Clara River, water quality modeling requires proper hydrologic accounting. This includes the accounting of uncontrolled flows (natural unimpaired flow and water losses or gains across the riverbed), managed flows with good records (reservoir releases, large diversions, and point source discharges), managed flows with poor records (dewatering operations, small diversions, and small point source discharges). Simulations of Santa Paula, Sespe, and Hopper Creeks show good water balance and reasonable correlation. Simulations of Mint Canyon Creek and Bouquet Canyon Creek show the intermittent flow typical of the eastern tributaries. The flow accounting on the Santa Clara River is reasonable from Santa Clarita through Freeman diversion. In a heavily managed river like the Santa Clara River, the accuracy of simulation depends on the accuracy of managed flow data. The estimates of groundwater gains and losses between Blue Cut and Santa Paula Creek are also key to predicting flow and water quality. At this point, the model has been calibrated to match the seasonal pattern and range of observed values. Further improvement can be made with more data and time in the future.

V. Sensitivity Analysis

Introduction

The WARMF model for the Santa Clara River contains many different parameter inputs. For those listed in Table 5 and Table 7, there is little uncertainty. The parameters listed in Table 6 and Table 8 are less well known. For the lesser known parameters, sensitivity analysis can be performed to evaluate how their parameter values affect the match between model predictions and observed data. Appropriate parameter values can be selected quickly during the model calibration.

The sensitivity analysis can also be used to determine the effect of pollution sources on the predicted water quality responses. For the Santa Clara River nutrient TMDL study, the analysis can provide information about the relative importance of controlling point source discharges, atmospheric deposition (air quality), septic system, fertilizer applications, dewatering operations in order to meet the water quality standards for nutrients (ammonia, nitride and nitrate).

Sensitivity to Calibration Parameters

The following tests compare the calibrated base case for the Santa Clara River with hypothetical changes in calibration to examine their effect on the calibration. The first two cases change soil properties to examine the effect these have on hydrology and then water quality. The other four cases examine the sensitivity of the model results to key water quality assumptions made in calibration. In all cases, the parameter values are changed from the values used in the calibration base case. The responses are evaluated in terms of their effect on hydrologic and water quality calibrations.

<u>Horizontal Hydraulic Conductivity and Soil Layer Thickness</u>

The horizontal hydraulic conductivity and soil layer thickness control the groundwater accretion to the river segments. This is an important source of unregulated flow to the Santa Clara River. Both parameters will affect the hydrograph, particularly during low flow periods. With the steep canyon topography, any reasonable horizontal hydraulic conductivity will lead to a rapid rise of flow during a storm. A thin soil layer will provide very little groundwater storage to sustain low flow after the storms.

The Sespe Creek watershed was chosen for this sensitivity analysis. All the catchments upstream of the Sespe Creek gage near Fillmore have been simulated with three soil layers. The lowest of these in the calibrated base case has a thickness of 40 cm and a horizontal hydraulic conductivity of 150 cm/d. The conductivity is set so that simulation results follow gaging data reasonably well in both wet and dry years, without having an ideal match in either case.

The first test case uses a hydraulic conductivity of 300 cm/d instead of 150 cm/d and keeps the soil thickness the same as the base case. The second test case uses the same hydraulic conductivity as the base case but changes the soil thickness in the lowest layer from 40 cm to 30 cm. The complete hydrograph is very similar for the base case and the two test cases. Figure 110 shows a comparison of frequency distribution between the different cases and observed data. Table 26 summarizes the flow responses between the base case and two test cases as compared to observed data. Figure 111 and Table 27 show the hydrograph and statistics for flow between 0 and 2 m^3/s.

The results indicate that reducing horizontal hydraulic conductivity and/or reducing soil layer thickness do not improve the match between simulated and observed hydrographs, which are dominated by few high flows and many low flows. In the range of 0 to 2 m^3/s, the correlation coefficient of the test cases is similar to the base case. However, the relative error of the test cases is greater than in the base case.

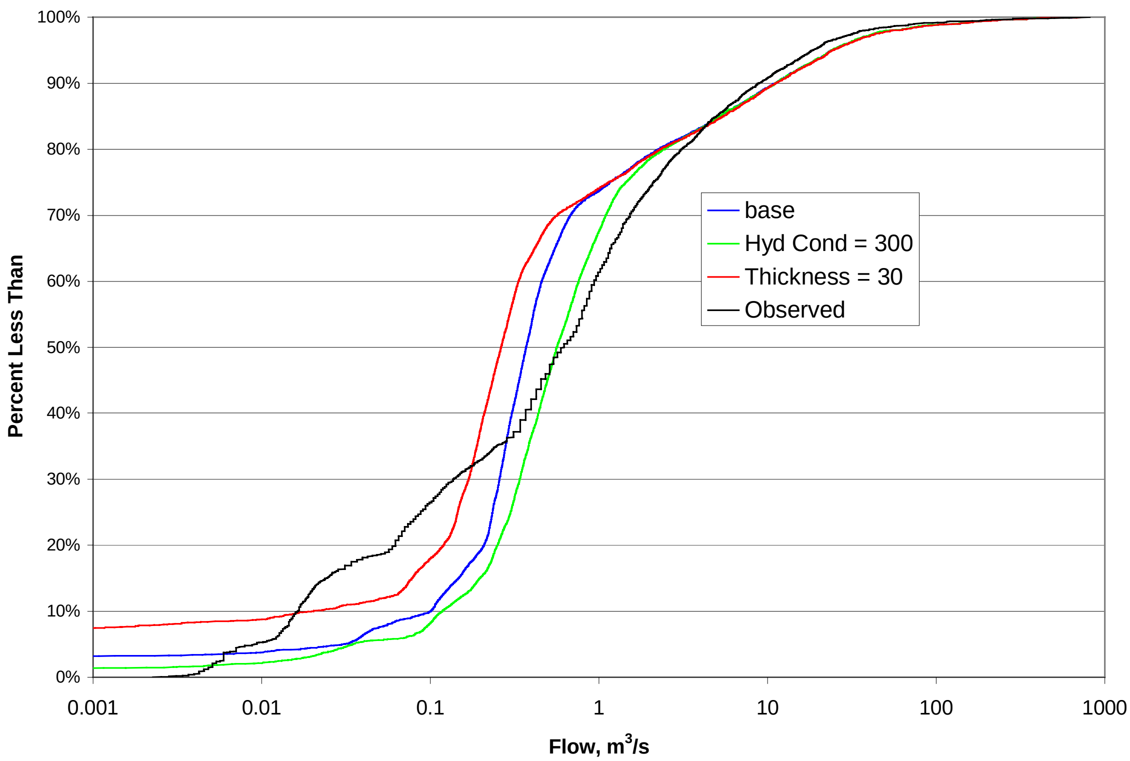

Figure 110: Simulated base case (blue), hydraulic conductivity test case (green), soil thickness test case (red), and observed flow frequency distribution for Sespe Creek near Fillmore

Table 26: Calibration statistics for flow at Sespe Creek near Fillmore

Model Scenario	Number of Points	Correlation Coeff r	Relative Error, %
Base Case	3394	0.83	12.7
H.C. = 150 cm/d	3394	0.83	13.5
Thickness = 30 cm	3394	0.83	14.1

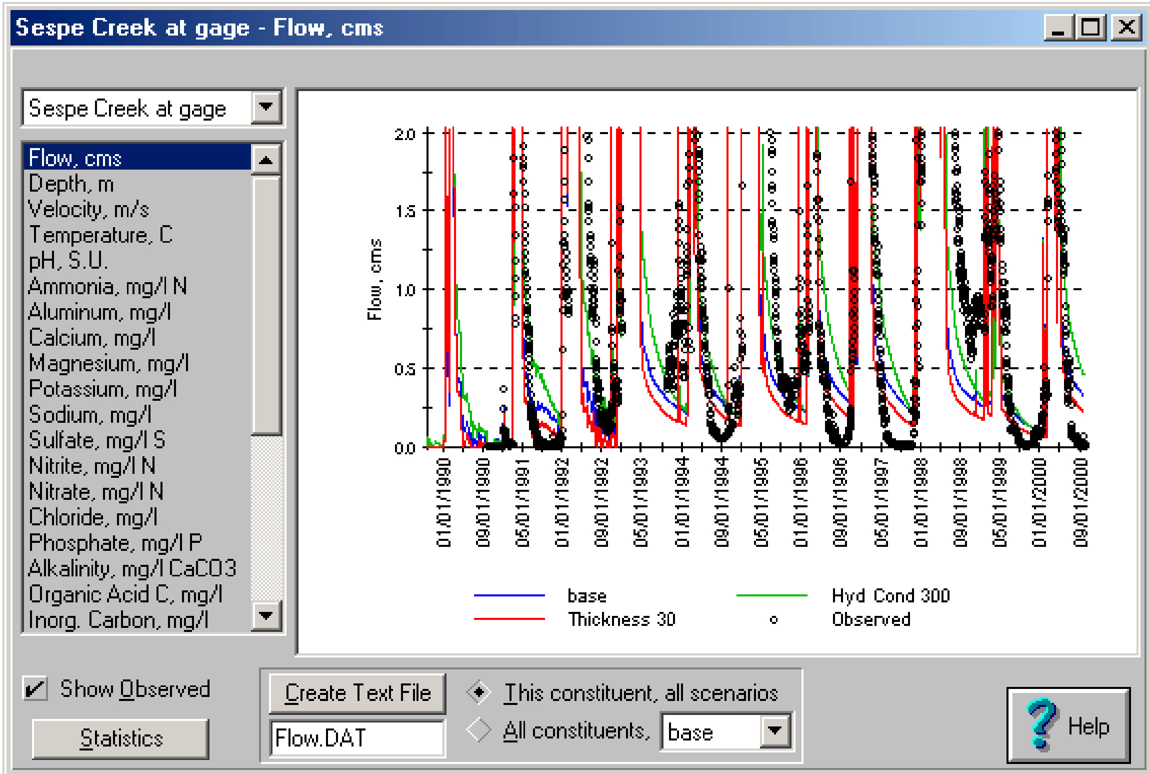

Figure 111: Simulated base case (blue), hydraulic conductivity test case (green), soil thickness test case (red), and observed flow: 0-2 m^3/s for Sespe Creek near Fillmore

Table 27: Calibration statistics for 0-2 m^3/s flow at Sespe Creek near Fillmore

Model Scenario	Number of Points	Correlation Coeff r	Relative Error, %
Base Case	2517	0.50	-9.5
H.C. = 300 cm/d	2517	0.56	16.9
Thickness = 30 cm	2517	0.48	-25.7

Changing the soil properties can have an effect on water quality in two ways: by changing the nitrate concentration in Sespe Creek itself and by changing the proportion of flow coming from Sespe Creek in the Santa Clara River downstream. Figure 112 through Figure 114 show graphical comparisons of nitrate in Sespe Creek and at two locations on the Santa Clara River downstream of Sespe Creek. The calibration statistics are shown in Table 28 through Table 30.

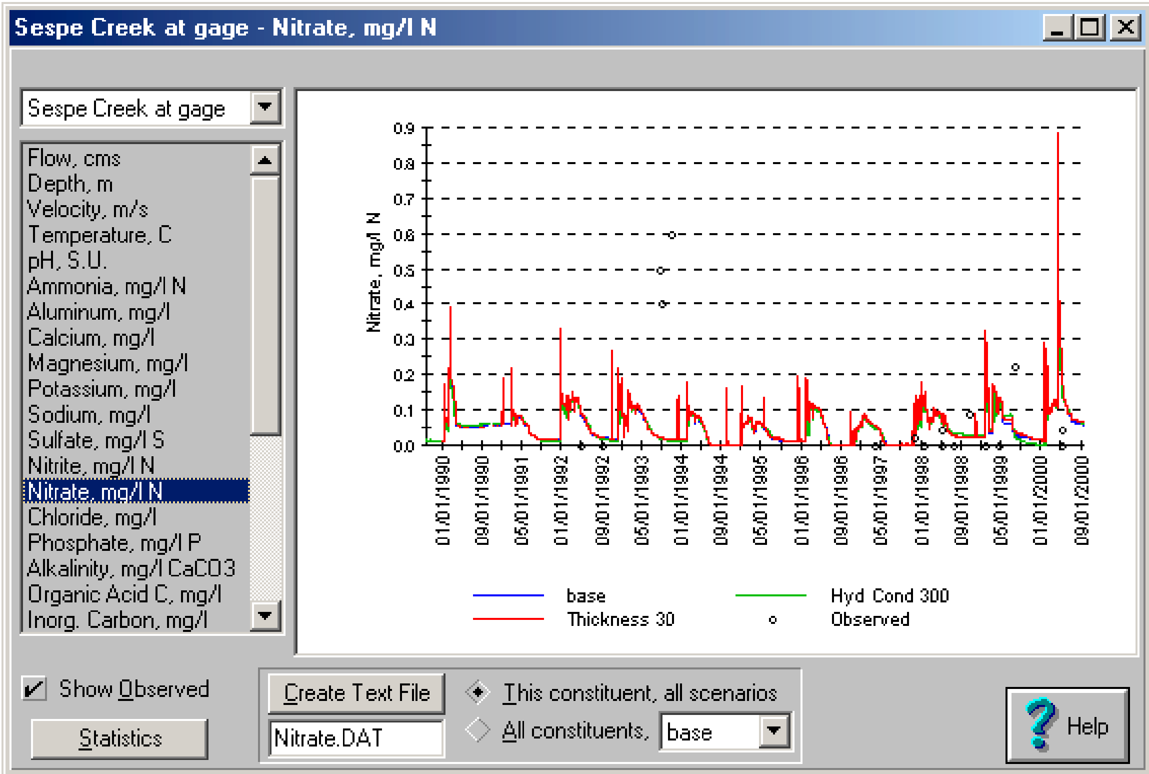

Figure 112: Simulated base case (blue), hydraulic conductivity test case (green), soil thickness test case (red), and observed nitrate for Sespe Creek near Fillmore

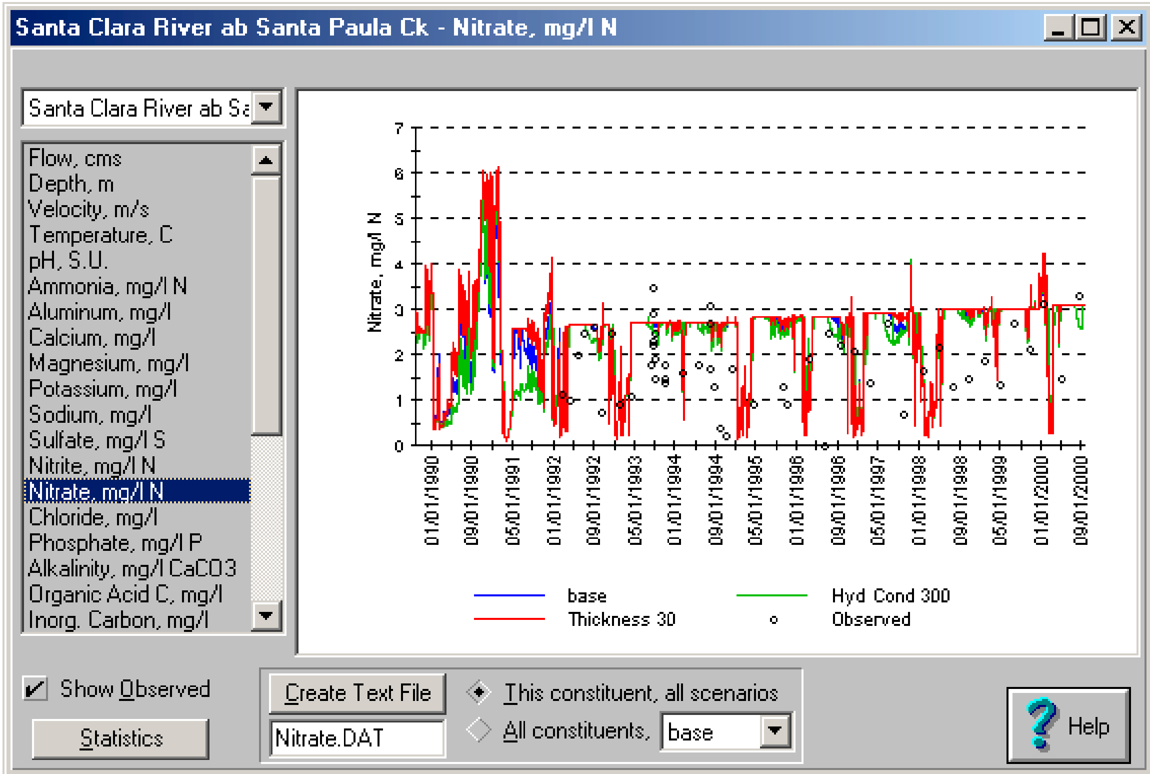

Figure 113: Simulated base case (blue), hydraulic conductivity test case (green), soil thickness test case (red), and observed nitrate for Santa Clara River at Willard Road

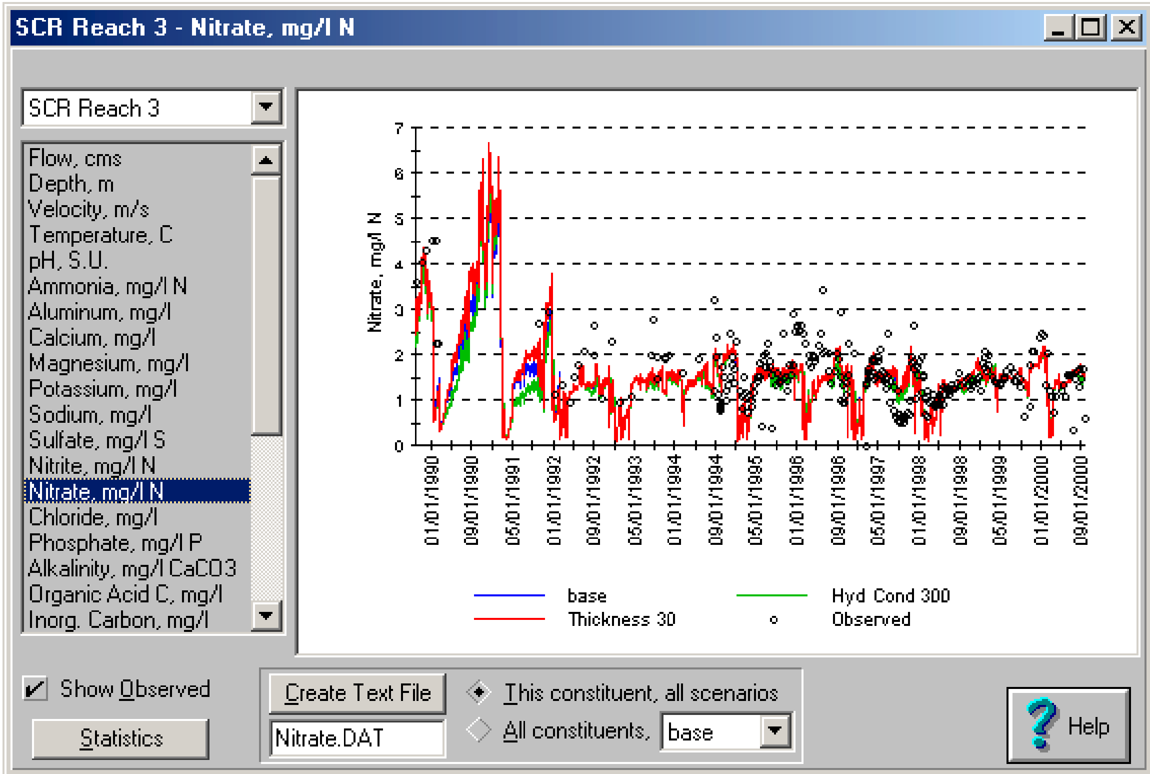

Figure 114: Simulated base case (blue), hydraulic conductivity test case (green), soil thickness test case (red), and observed nitrate for Santa Clara River at Freeman Diversion

Table 28: Base case and test case statistics for nitrate at Sespe Creek near Fillmore

Model Scenario	Number of Points	Relative Error, mg/l	Absolute Error, mg/l
Base Case	17	-0.05	0.16
H.C. = 150 cm/d	17	-0.05	0.15
Thickness = 30 cm	17	-0.04	0.17

Table 29: Base case and test case statistics for nitrate at Santa Clara River at Willard Road

Model Scenario	Number of Points	Relative Error, mg/l	Absolute Error, mg/l
Base Case	48	0.85	0.95
H.C. = 150 cm/d	48	0.77	0.91
Thickness = 30 cm	48	0.87	0.98

Table 30: Base case and test case statistics for nitrate at Santa Clara River at Freeman Diversion

Model Scenario	Number of Points	Relative Error, mg/l	Absolute Error, mg/l
Base Case	276	-0.14	0.43
H.C. = 150 cm/d	276	-0.17	0.43
Thickness = 30 cm	276	-0.12	0.44

Both the test cases showed only small changes in nitrate concentration resulting from the change in hydrology. The quality of the calibration was similar for the base case and the two test cases. The hydrologic calibration of Sespe Creek does not seem to greatly affect the nitrate concentration of the Santa Clara River downstream.

United Water Conservation District (UWCD) Estimated Flows

The United Water Conservation District has estimated gains and losses in various stretches of the Santa Clara River and its tributaries between Blue Cut and Santa Paula Creek. These estimates are based on measured flows, groundwater table elevations, and historic estimates of flow losses. These estimates have been refined once over the course of this modeling study, and they can be set in different ways to better simulate flows under one flow regime or another. These flows are key to the accounting of hydrology and its accompanying water quality from Blue Cut to Freeman Diversion.

The test case for this sensitivity analysis multiplies all estimated gains and losses between Blue Cut and Freeman Diversion by 0.8. Such a scenario is not necessarily a realistic alternative estimate of groundwater interactions with surface water, but it does provide a basis with which to estimate the sensitivity of the model to changes in estimated flows. The only gage for comparison is at Montalvo, downstream of the Freeman Diversion, which has not undergone calibration. The complete hydrograph is very similar for the base case and the two test cases. Figure 115 shows a comparison of frequency distribution between the different cases and observed data. Table 31 summarizes the flow responses between the base case and the test case as compared to observed data. Figure 116 and Table 32 show the hydrograph and statistics for flow between 0 and 5 m^3/s.

The results indicate that changing the estimated river gains and losses does affect flow at Montalvo in the flow range from about 0.01 m^3/s to 10 m^3/s. The correlation coefficients for the base case and test case are similar, but the relative error for the low flow range is much higher in the test case.

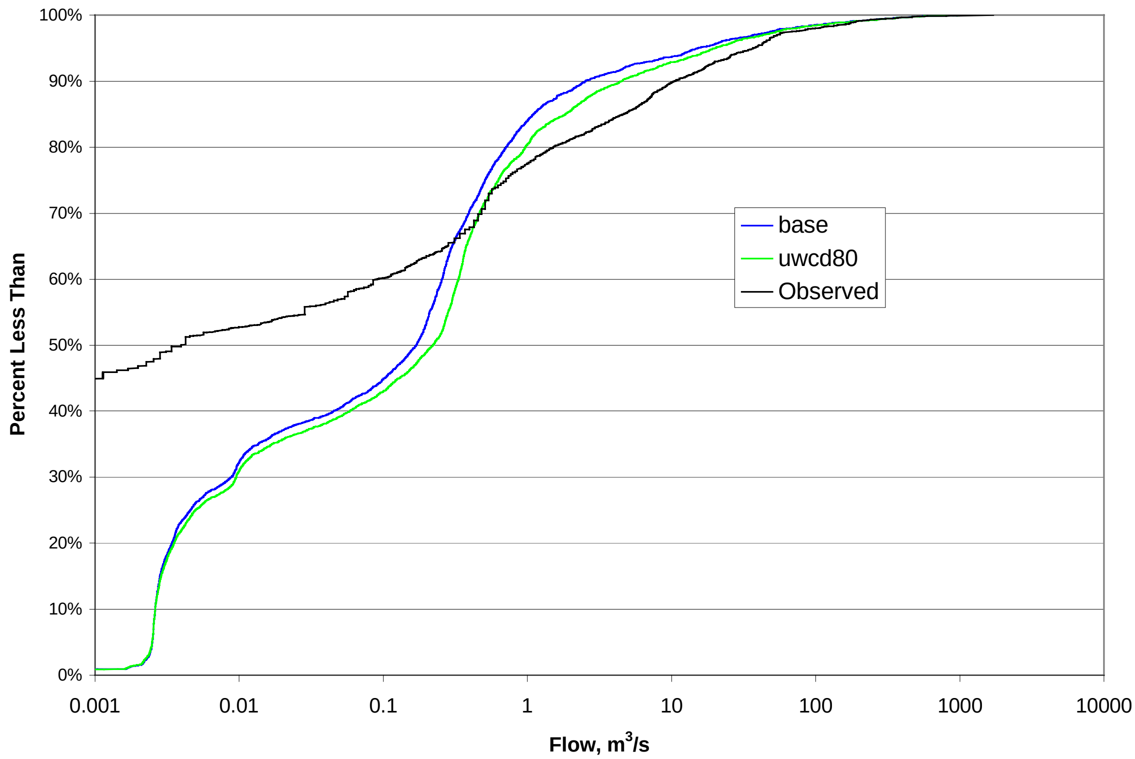

Figure 115: Simulated base case (blue), 80% UWCD flows test case (green), and observed flow frequency distribution for Santa Clara River at Montalvo

Table 31: Calibration statistics for flow at Santa Clara River at Montalvo

Model Scenario	Number of Points	Correlation Coeff r	Relative Error, %
Base Case	3288	0.78	-32.1
UWCD 80	3288	0.78	-25.7

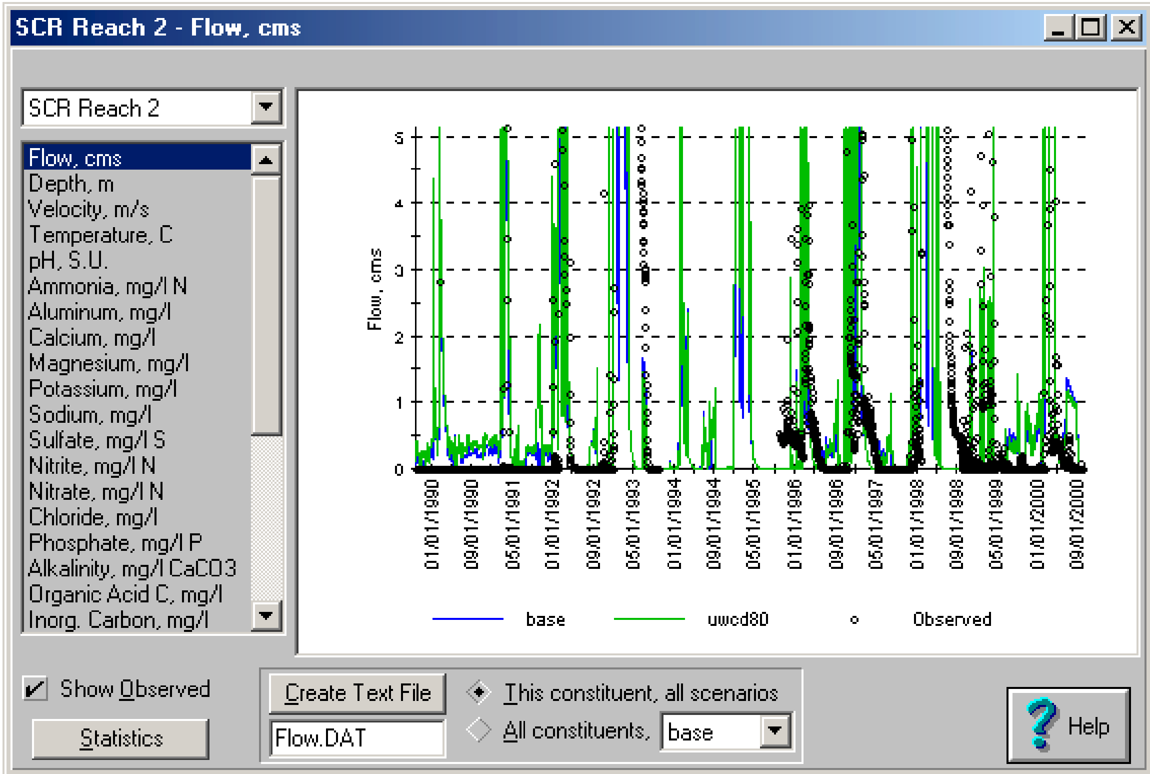

Figure 116: Simulated base case (blue), 80% UWCD flows test case (green), and observed flow: 0-5 m^3/s for Sespe Creek near Fillmore

Table 32: Calibration statistics for 0-5 m^3/s flow at Santa Clara River at Montalvo

Model Scenario	Number of Points	Correlation Coeff r	Relative Error, %
Base Case	2807	0.28	35.7
UWCD 80	2807	0.29	73.8

Changing the prescribed river gains and losses can have an affect on water quality by changing the proportion of flow coming from its various sources. Figure 112 through Figure 114 show graphical comparisons of nitrate in Sespe Creek and at two locations on the Santa Clara River downstream of Sespe Creek. The calibration statistics are shown in Table 28 through Table 30.

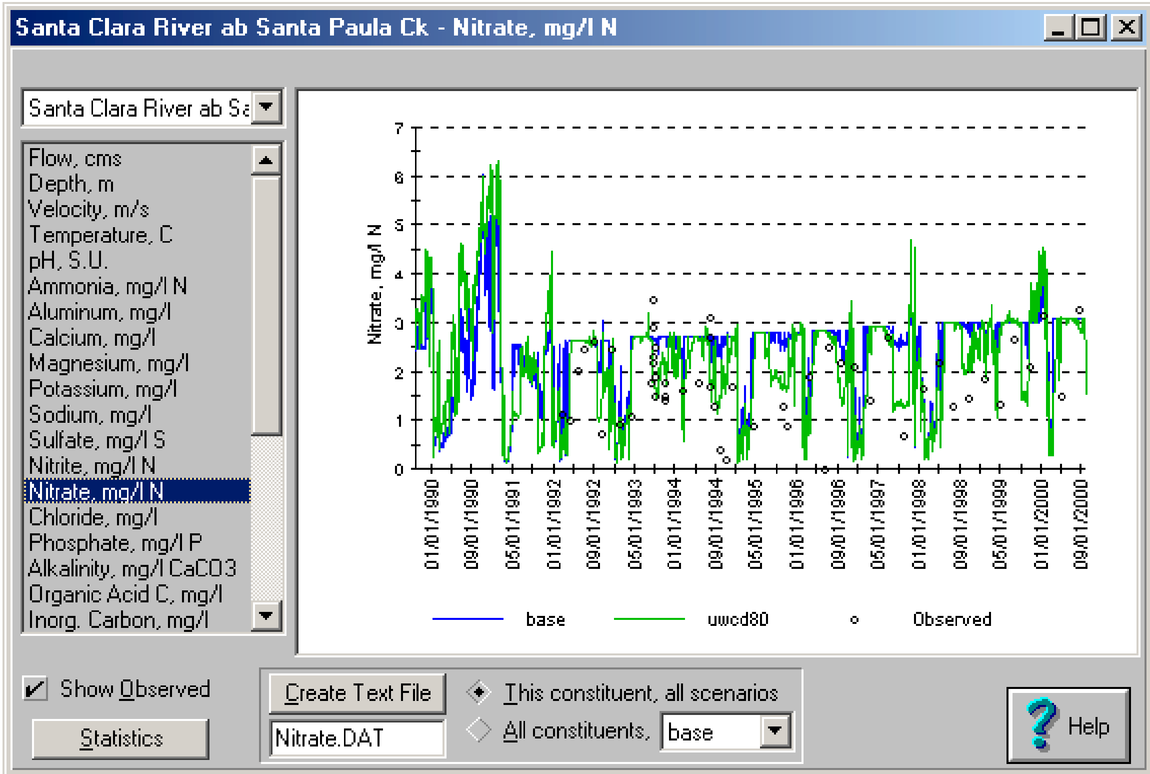

Figure 117: Simulated base case (blue), 80% UWCD flow test case (green), and observed nitrate for Santa Clara River at Willard Road

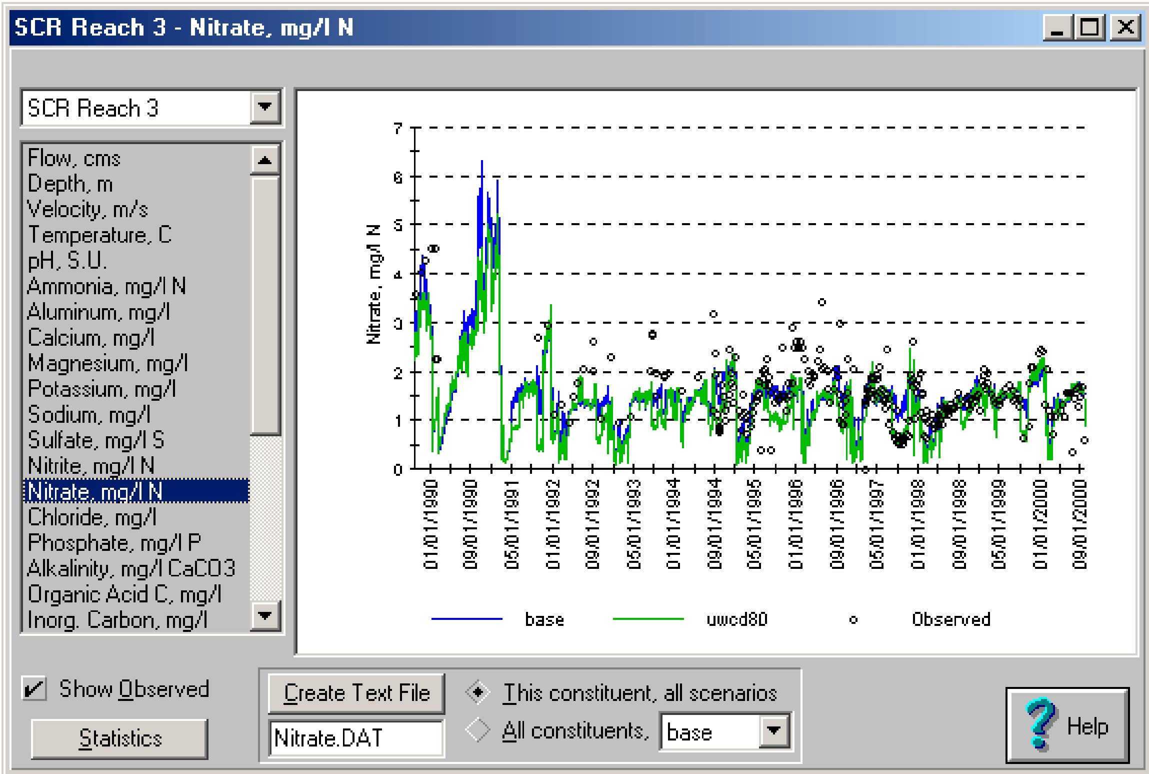

Figure 118: Simulated base case (blue), 80% UWCD flow test case (green), and observed nitrate for Santa Clara River at Freeman Diversion

Table 33: Base case and test case statistics for nitrate at Santa Clara River at Willard Road

Model Scenario	Number of Points	Relative Error, mg/l	Absolute Error, mg/l
Base Case	48	0.85	0.95
UWCD 80	48	0.44	0.68

Table 34: Base case and test case statistics for nitrate at Santa Clara River at Freeman Diversion

Model Scenario	Number of Points	Relative Error, mg/l	Absolute Error, mg/l
Base Case	276	-0.14	0.43
UWCD 80	276	-0.30	0.43

The test case seems to show a better fit to the observed data at Willard Road than the base case condition. The relative error of the test case is worse at Freeman Diversion, however.

Periphyton and Denitrification Rate

The Old Road Bridge is downstream of the Saugus WWRF. Water quality monitoring from that location shows less total nitrogen than is present in the effluent from the Saugus WWRF.

The base case hypothesized that denitrification in the river bed is removing nitrogen from the water column. The base case assumed that there was no periphyton to remove nitrogen. In one test case, the denitrification rate was set to zero to examine the impact of no nitrogen removal in that reach of the river. In the second test case, periphyton growth was added to remove more nitrogen from the water column. For this case, it was further assumed that the periphyton did not recycle its nitrogen content back to the water column at death.

Figure 119 presents the simulation results for the calibration base case and other test cases in comparison to the observed data. Table 35 shows the statistics of the comparisons.

Without denitrification, the model predicted much higher nitrate concentrations than indicated by the data. Clearly, there is a nitrogen removal process occurring in this reach of the Santa Clara River. The periphyton case shows modest additional removal of nitrate. Periphyton, by itself, cannot remove sufficient nitrate to match the observed data. Neither of the test cases appear to improve the statistics of the comparisons.

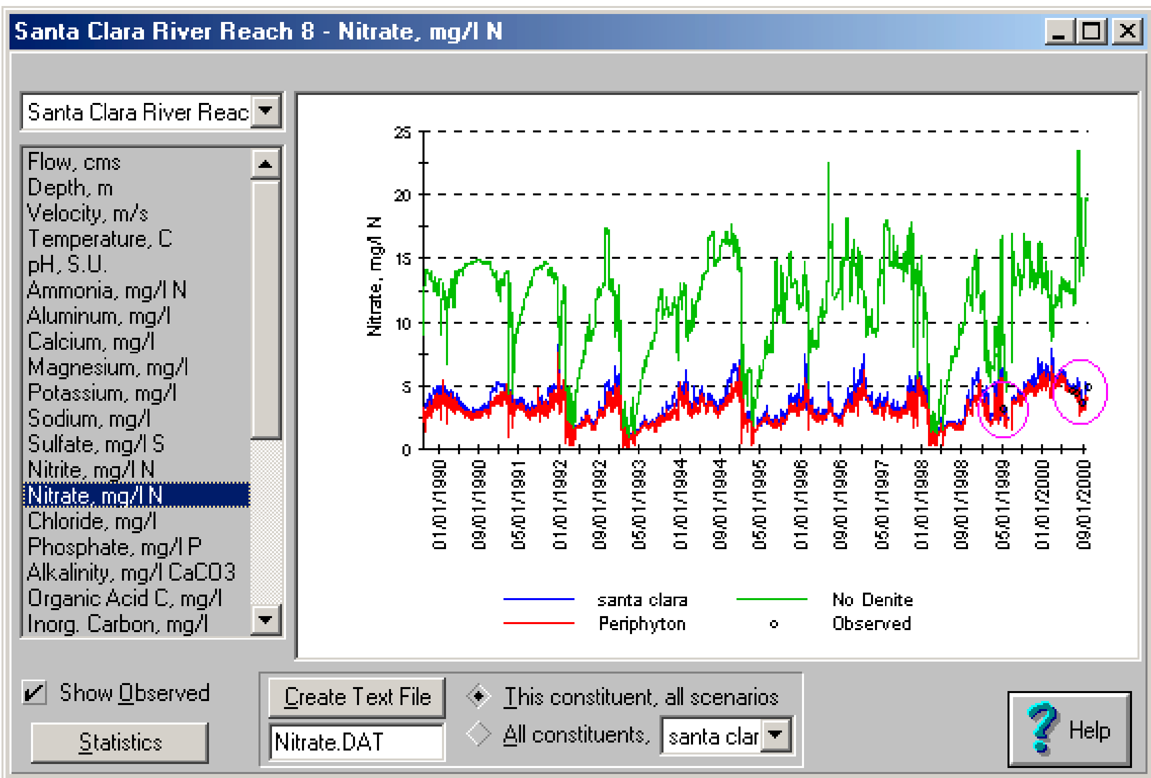

Figure 119: Simulated base case (blue), no denitfication test case (green), periphyton test case (red), and observed nitrate for Santa Clara River at Old Road Bridge

Table 35: Base case and test case statistics for NO_3-N at Santa Clara River at Old Road Bridge

Model Scenario	Number of Points	Relative Error, mg/l	Absolute Error, mg/l
Base Case	5	+0.09 mg/l	0.15 mg/l
No Denitrification	5	+10.30 mg/l	10.3 mg/l

Periphyton On	5	-0.44 mg/l	0.47 mg/l

Initial Groundwater Nitrate Concentration: Reach 7

Reach 7 of the Santa Clara River (Figure 3) receives groundwater accretion from the adjacent catchments. The initial nitrate concentration in the groundwater is directly linked to the resulting load of nitrate from the groundwater to the river.

The base case assumed NO_3-N concentration of 1.1 mg/l. This test case assumes 5 mg/l instead. A comparison of the two cases and observed data is shown in Figure 120, Figure 121, Table 36, and Table 37 for the two locations near Blue Cut with water quality monitoring data.

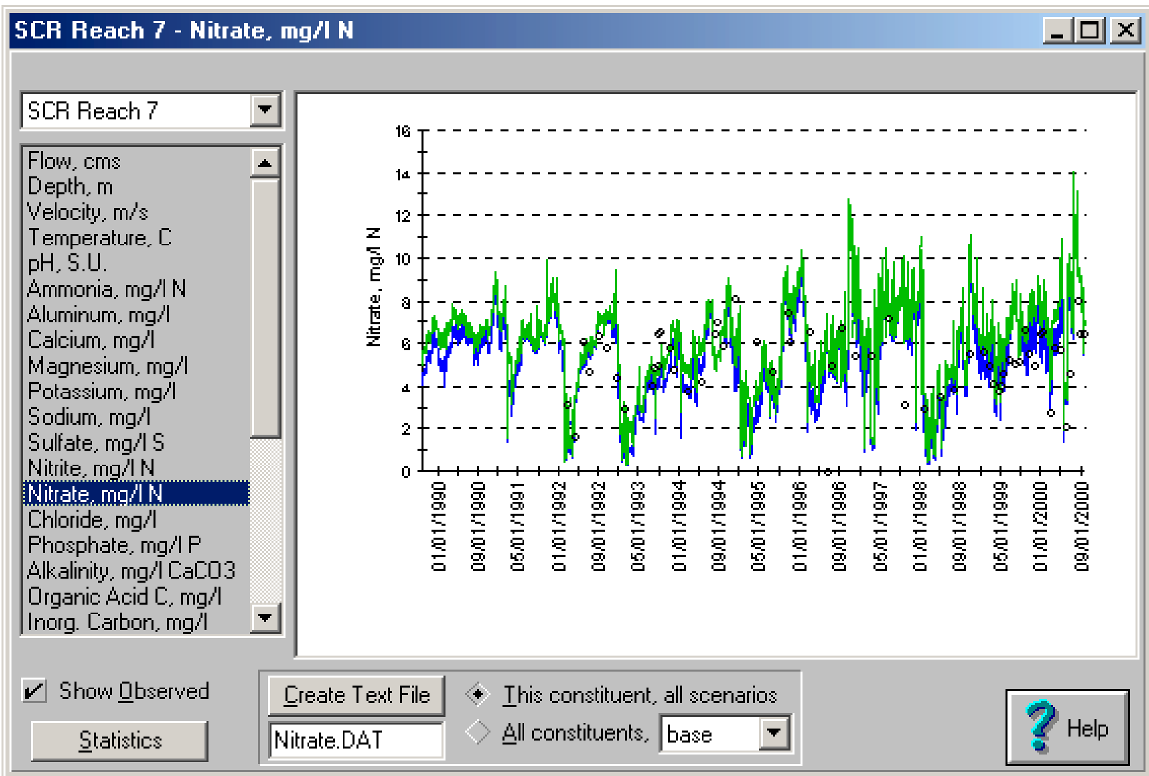

Figure 120: Simulated base case (blue), 5 mg/l initial NO_3-N test case (green), and observed nitrate for Santa Clara River at Los Angeles / Ventura county line

Table 36: Base case and test case statistics for nitrate at Santa Clara River at Los Angeles / Ventura county line

Model Scenario	Number of Points	Relative Error, mg/l	Absolute Error, mg/l
Base Case	58	0.53	1.57
5 mg/l Initial NO_3-N	58	1.14	1.76

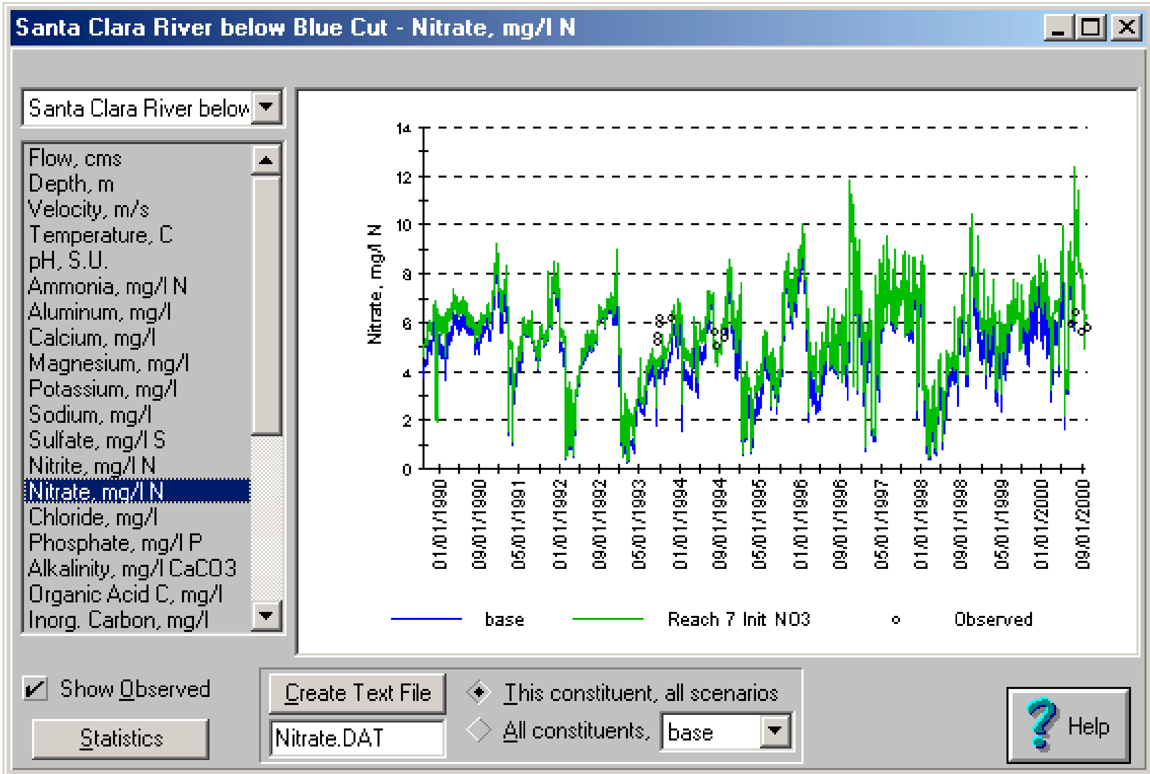

Figure 121: Simulated base case (blue), 5 mg/l initial NO_3-N test case (green), and observed nitrate for Santa Clara River near Piru

Table 37: Base case and test case statistics for nitrate at Santa Clara River near Piru

Model Scenario	Number of Points	Relative Error, mg/l	Absolute Error, mg/l
Base Case	11	0.26	1.36
5 mg/l Initial NO_3-N	11	0.49	1.26

From the test run, we can see that the simulation results do show a modest change in response to the large change in input initial groundwater nitrate concentration adjacent to Reach 7 of the Santa Clara River. Most of the flow and loading coming to this reach is from sources other than groundwater, but the above figures and tables indicate that the model does respond to different assumptions about groundwater nitrate concentrations.

Initial Groundwater Nitrate Concentration: Reach 3

Reach 3 of the Santa Clara River (Figure 4) receives groundwater accretion near Willard Road. The initial nitrate concentration in the groundwater at that location is directly linked to the resulting load of nitrate from the groundwater to the river.

The base case assumed nitrate concentration of 2.5 mg/l N for the groundwater. For the test case, that concentration was raised to 3.5 mg/l. A comparison of the two cases and observed data is shown in Figure 122, Figure 123, Table 38, and Table 39 for Willard Road and the Freeman Diversion.

The results indicate that nitrate concentrations at Reach 3 are sensitive to the initial nitrate concentration of groundwater at the Willard Road area. This is indicative of the relative importance of the groundwater accretion to the water quality downstream.

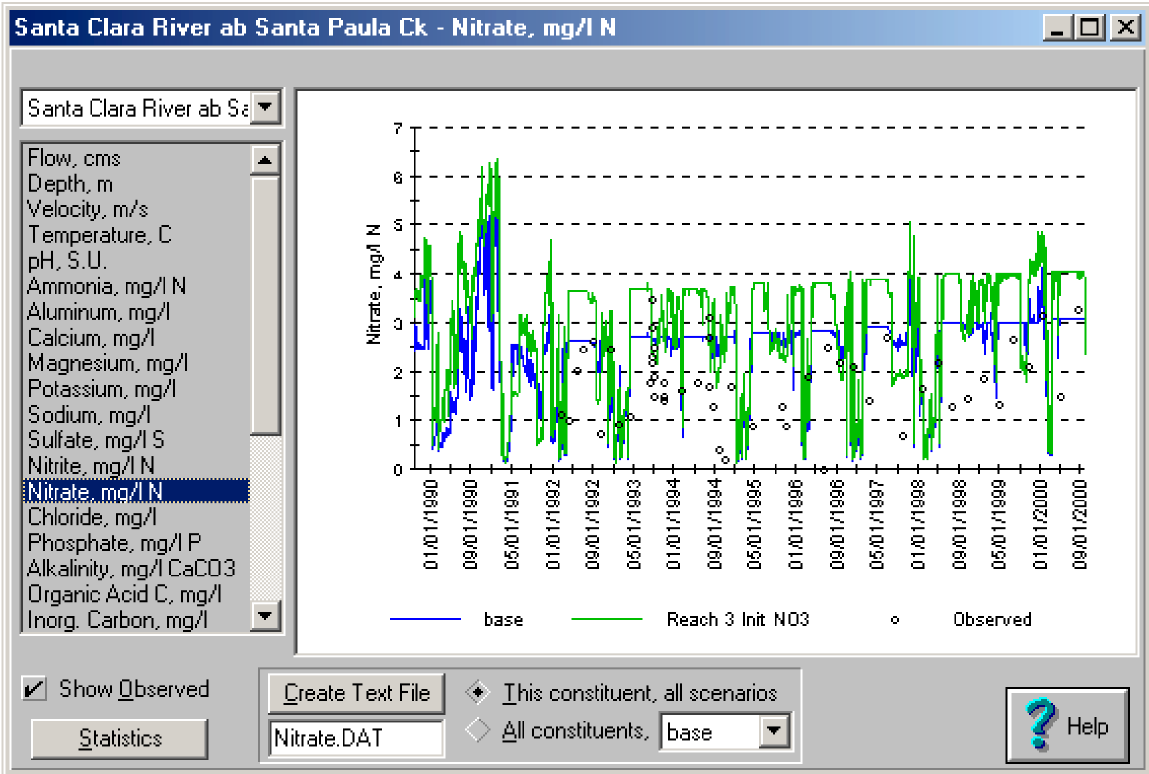

Figure 122: Simulated base case (blue), 3.5 mg/l initial NO_3-N test case (green), and observed nitrate for Santa Clara River at Willard Road

Table 38: Base case and test case statistics for nitrate at Santa Clara River at Willard Road

Model Scenario	Number of Points	Relative Error, mg/l	Absolute Error, mg/l
Base Case	48	0.85	1.31
3.5 mg/l Init. NO_3-N	48	0.95	1.33

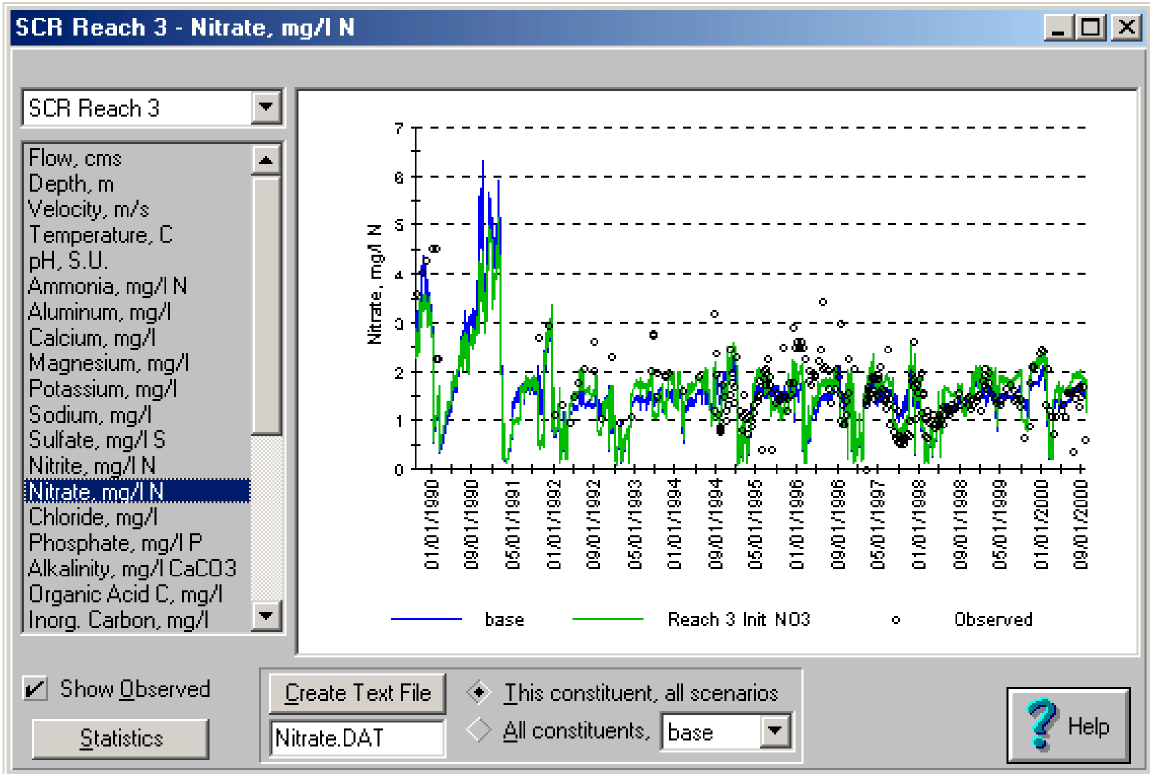

Figure 123: Simulated base case (blue), 3.5 mg/l initial NO_3-N test case (green), and observed nitrate for Santa Clara River at Freeman Diversion

Table 39: Base case and test case statistics for nitrate at Santa Clara River at Freeman Diversion

Model Scenario	Number of Points	Relative Error, mg/l	Absolute Error, mg/l
Base Case	276	-0.14	0.60
3.5 mg/l Init. NO_3-N	276	-0.05	0.56

Sensitivity to Nonpoint Source Loading of Nitrogen

There are point and nonpoint sources discharges of nitrogen to the Santa Clara watershed. The nonpoint source nitrogen can be derived from atmospheric deposition, fertilizer application, septic tank effluent, and subsurface discharges.

In this section, the sensitivity analysis is performed to examine the relative importance of nonpoint source nitrogen on the nitrate concentrations in the Santa Clara River. The nonpoint nitrogen loads used can be found in the Source Analysis Report (Systech 2002).

Atmospheric Deposition

According to the Source Analysis Report (Systech 2002), the primary source of nitrogen loading to the Sespe Creek watershed is from atmospheric deposition. The air quality data used by the model to calculate atmospheric deposition is based on a station at the city of Ojai southwest of the watershed.

The Sespe Creek watershed is large and mostly undeveloped area in the mountains. The air quality there is expected to be better than in the city. As a result, in the model assumes that the concentration of all air quality constituents in the Sespe Creek watershed are half that measured at the Ojai station. A sensitivity analysis was performed to determine the effect of this assumption on the water quality of Sespe Creek.

The calibration base case used half the concentrations in the air quality data of Ojai station to calculate atmospheric deposition. For the test case, the concentrations of all constituents (including ammonia and nitrate) in the air and in the precipitation were put back to their original values measured at Ojai. Figure 124 through Figure 126 and Table 40 through Table 42 show the results.

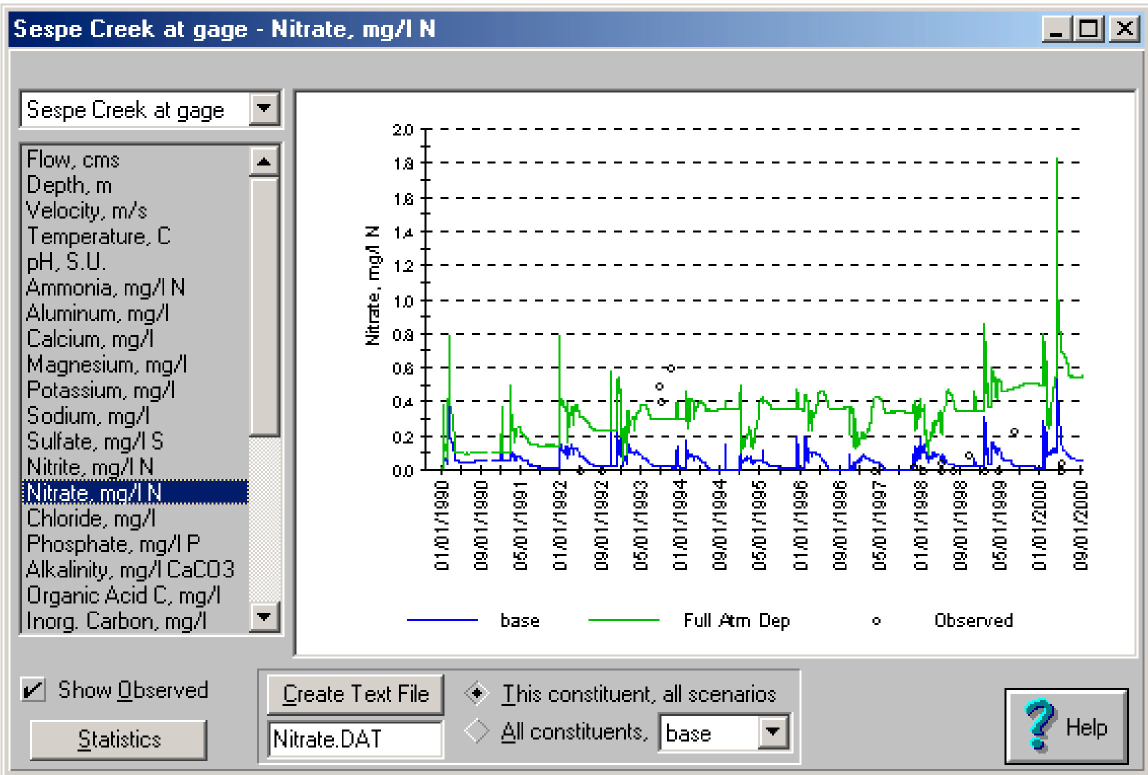

Figure 124: Simulated base case (blue), full atmospheric deposition test case (green), and observed nitrate for Sespe Creek near Fillmore

Table 40: Base case and test case statistics for nitrate at Sespe Creek near Fillmore

Model Scenario	Number of Points	Relative Error, mg/l	Absolute Error, mg/l
Base Case	17	-0.05	0.16
Full Atmos. Dep.	17	0.28	0.35

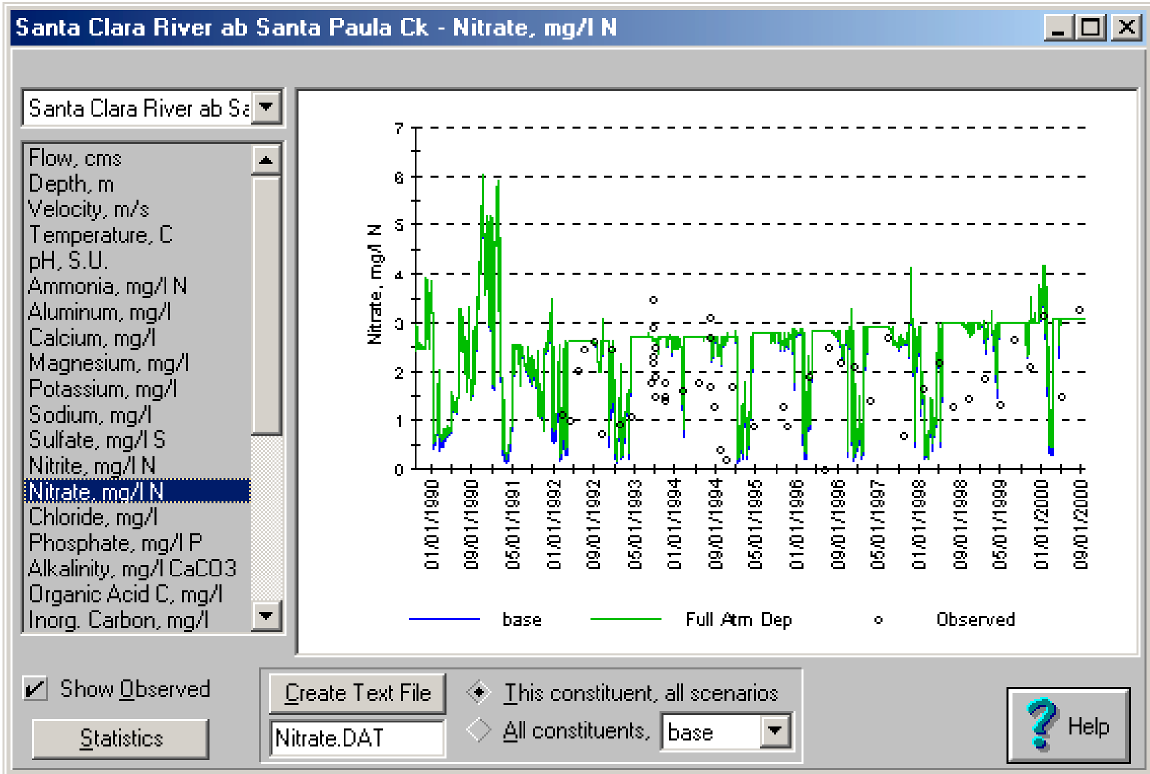

Figure 125: Simulated base case, full atmospheric deposition test case, and observed nitrate for Santa Clara River at Willard Road

Table 41: Base case and test case statistics for nitrate at Santa Clara River at Willard Road

Model Scenario	**Number of Points**	**Relative Error, mg/l**	**Absolute Error, mg/l**
Base Case	48	0.85	0.95
Full Atmos. Dep.	48	0.86	0.95

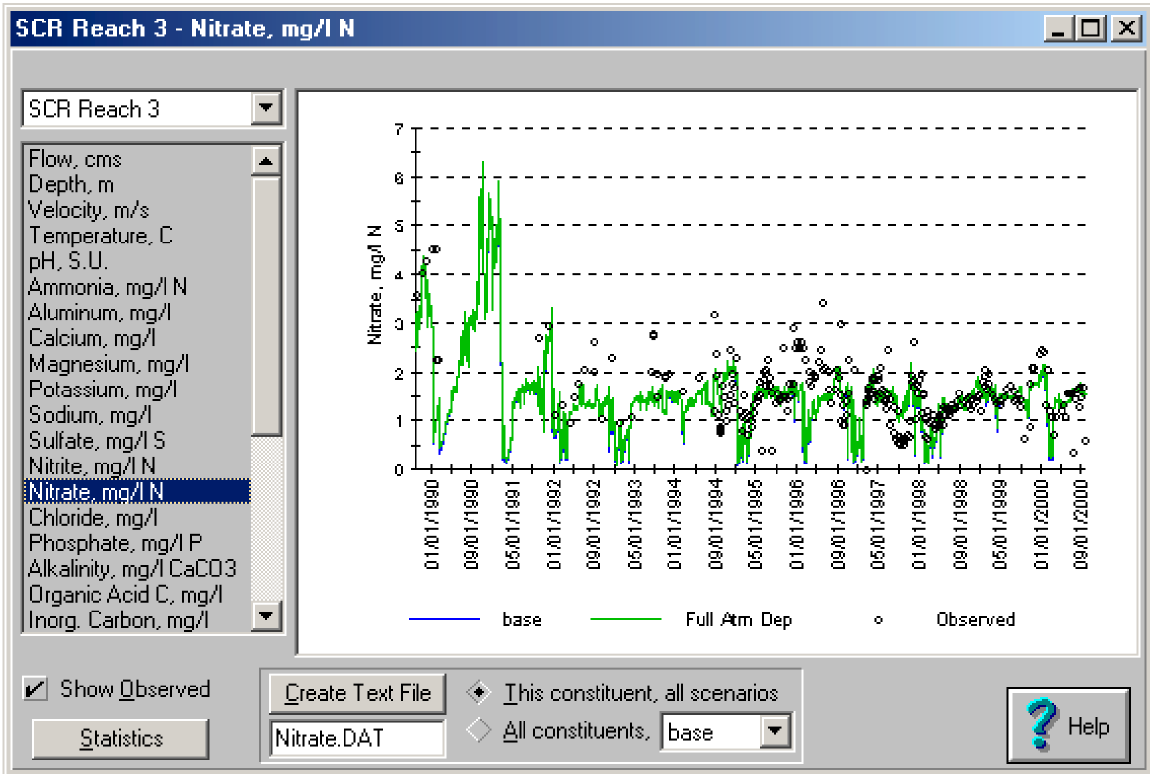

Figure 126: Simulated base case, full atmospheric deposition test case, and observed nitrate for Santa Clara River at Freeman Diversion

Table 42: Base case and test case statistics for nitrate at Santa Clara River at Freeman Diversion

Model Scenario	Number of Points	Relative Error, mg/l	Absolute Error, mg/l
Base Case	275	-0.14	0.43
Full Atmos. Dep.	275	-0.13	0.43

Using the full atmospheric deposition introduces error in the nitrate calibration in Sespe Creek, but has little effect on nitrate concentrations in the Santa Clara River downstream.

Fertilizer Application

A general consensus was reached among many stakeholders familiar with the Santa Clara River watershed on the approximate amount of fertilizer used on orchards, row crops, and golf courses as indicated in the Source Analysis Report (Systech 2002). However, there was some uncertainty in the final fertilization rates.

To test the sensitivity of model results to different fertilization rates, a test case was created cutting the fertilization rates in half for orchards, row crops, and golf courses in the region from Sespe Creek to the Freeman Diversion. A comparison of the two cases and observed data is shown in Figure 127, Figure 128, Table 43, and Table 44 for Willard Road and the Freeman Diversion.

The test shows little short-term impact on the simulated nitrate concentration of the Santa Clara River. The fertilizer is applied to the watershed catchments. Over fertilization in excess of the need of crops can in principle lead to raising the nitrate concentration in the groundwater. Such impact is gradual that may require a very long-term simulation, which is not performed by WARMF for this study. Long-term increase of nitrate concentration in the Willard Road groundwater system can affect the nitrate concentration in Reach 3 of the Santa Clara River, as discussed earlier in this report.

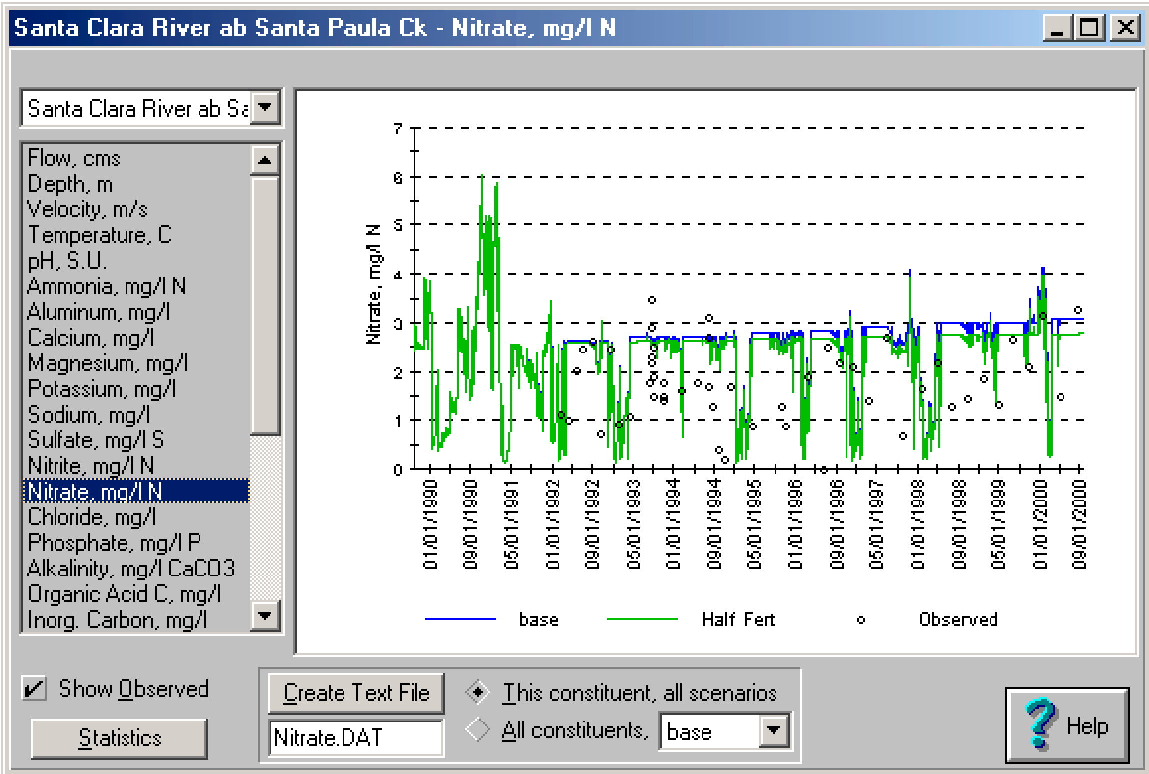

Figure 127: Simulated base case (blue), half fertilization test case (green), and observed nitrate for Santa Clara River at Willard Road

Table 43: Base case and test case statistics for nitrate at Santa Clara River at Willard Road

Model Scenario	Number of Points	Relative Error, mg/l	Absolute Error, mg/l
Base Case	48	0.85	0.95
Half Fertilization	48	0.72	0.85

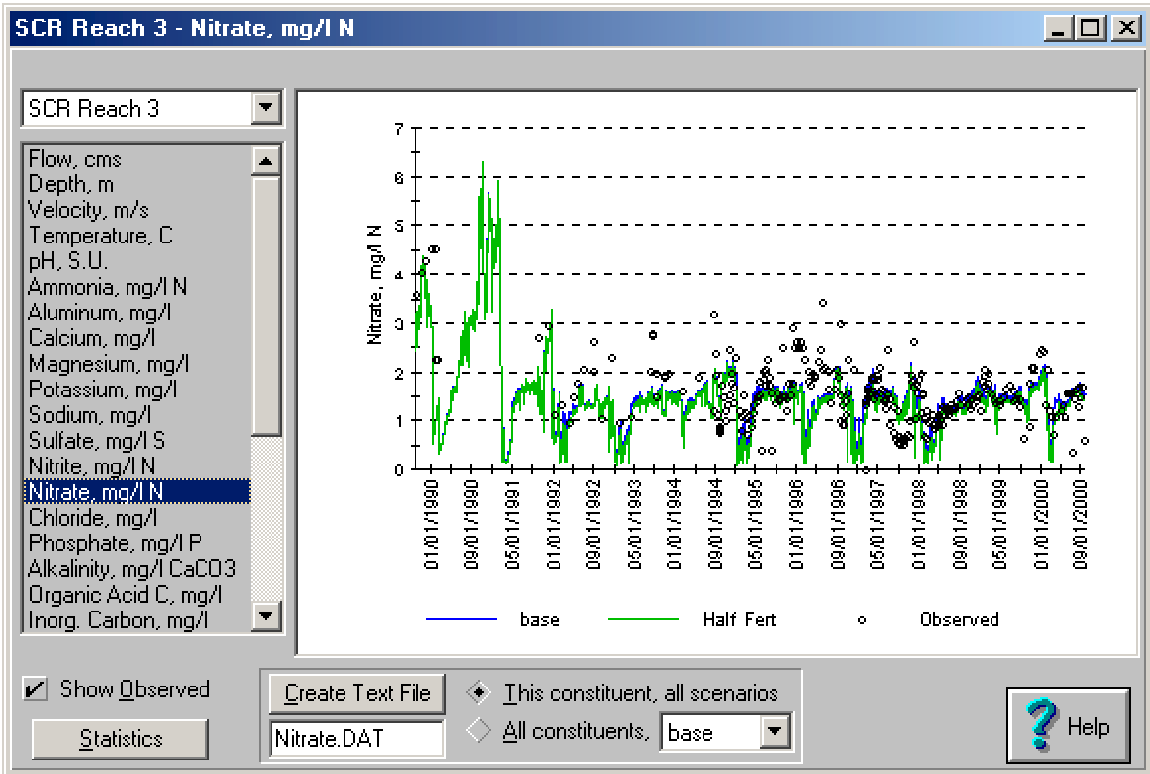

Figure 128: Simulated base case (blue), half fertilization test case (green), and observed nitrate for Santa Clara River at Freeman Diversion

Table 44: Base case and test case statistics for nitrate at Santa Clara River at Freeman Diversion

Model Scenario	Number of Points	Relative Error, mg/l	Absolute Error, mg/l
Base Case	276	-0.14	0.43
Half Fertilization	276	-0.24	0.46

Septic Systems

Both Los Angeles County and Ventura County keep records of septic systems. The Ventura County database provides sufficient information for us to place each septic system to their respective catchments. Los Angeles County database does not lend itself to the same kind of analysis. We assumed that the total number of septic systems in the Los Angeles County portion of the Santa Clara River watershed were distributed uniformly throughout the watershed outside of the immediate Santa Clarita area.

This sensitivity analysis tests the water quality impact if there were actually only half as many septic systems as assumed in Los Angeles County. Figure 129 and Table 45 show the comparison between the base case and test case for ammonia upstream of the Saugus WWRF in Santa Clarita in Reach 9 of the Santa Clara River; Figure 130 and Table 46 show the sensitivity of the model for nitrate at the same location. Red circles are added to make observed data points more visible, not to add emphasis.

The comparison shows that septic systems contribute a very small fraction of the nitrogen to the Santa Clara River upstream of the Saugus WWRF. Below the Saugus WWRF, they represent an even smaller fraction of the overall loading of nitrogen to the Santa Clara River. The model is thus insensitive to the number of septic systems expected in the Los Angeles County portion of the watershed.

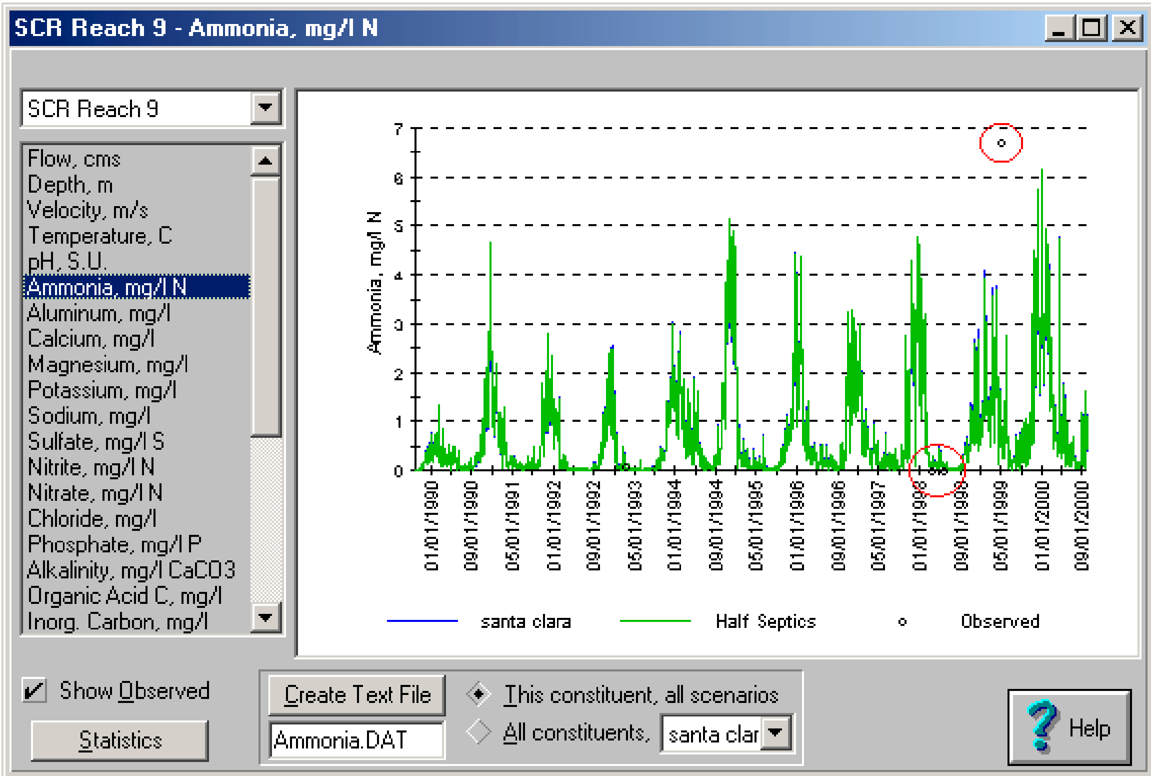

Figure 129: Simulated base case (blue), half septics test case (green), and observed ammonia for Santa Clara River at Bouquet Canyon

Table 45: Base case and test case statistics for NH_3-N at Santa Clara River at Bouquet Canyon

Model Scenario	Number of Points	Relative Error, mg/l	Absolute Error, mg/l
Base Case	4	-1.36	1.43
Half Septics	4	-1.37	1.43

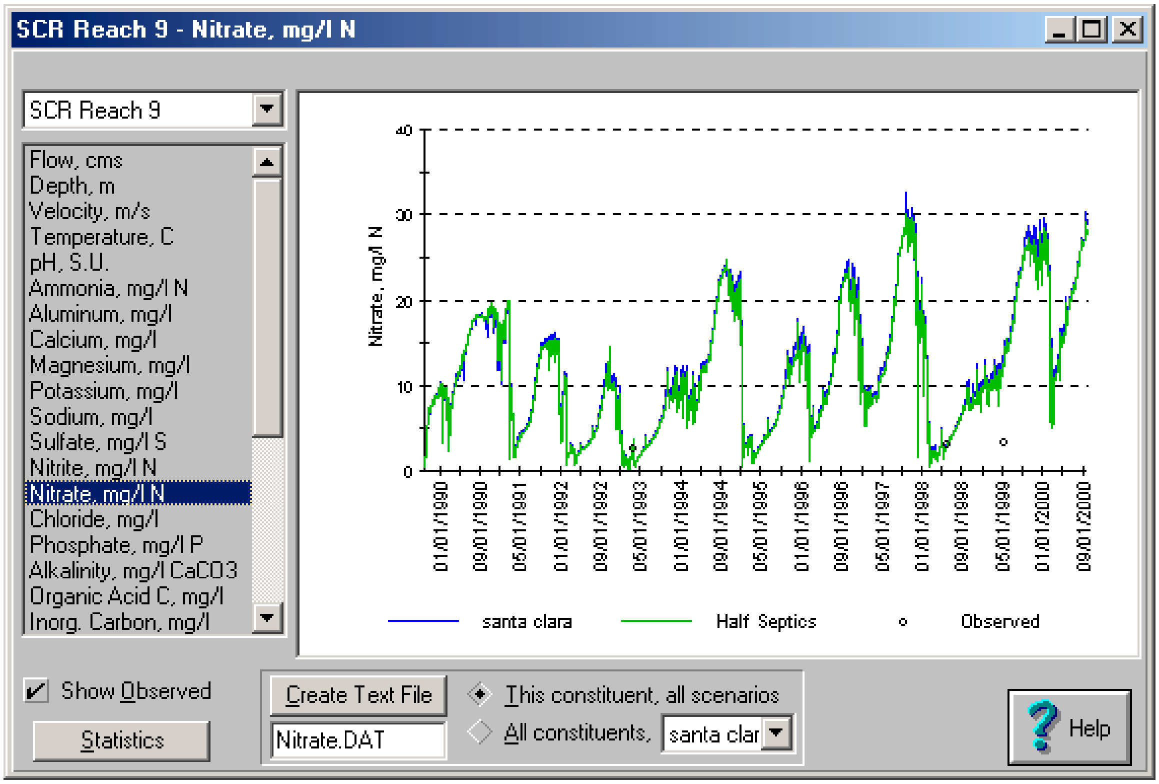

Figure 130: Simulated base case (blue), half septics test case (green), and observed nitrate for Santa Clara River at Bouquet Canyon

Table 46: Base case and test case statistics for NO_3-N at Santa Clara River at Bouquet Canyon

Model Scenario	Number of Points	Relative Error, mg/l	Absolute Error, mg/l
Base Case	3	2.77	3.32
Half Septics	3	2.43	3.07

VI. Linkage Analysis

Introduction

The purpose of the Santa Clara River watershed modeling is to determine the linkage between inputs to the Santa Clara River and the water quality of the river. WARMF provides such linkage by simulating the hydrology, the nonpoint source loads from land catchments, and then the resulting receiving water quality resulting from the point and nonpoint source loads of pollutants.

There are three ways to look at loading: from the source, where it enters the river, and when it is in the river. The Source Analysis Report (Systech 2002) details the loading from the source. This loading is input to the watershed model.

The second form of loading is referred to as "Regional Loading" in WARMF because it reflects the loading to streams within a region of the watershed. It includes direct point sources and that portion of nonpoint sources which is transported to rivers by runoff. Nonpoint sources such as atmospheric deposition and fertilization are classified by the land use in which they occur. Direct regional loading does not take into account any in-stream assimilation of pollutants.

The third method of looking at loading is called "Source Contributions" in WARMF. Source Contributions traces the pollutants in the river at a certain location to its origins in terms of point and nonpoint sources. This view of loading does take into account in-stream processes which assimilate pollutants.

Regional Pollutant Loads

The regional loading output of WARMF shows direct pollutant loads to waterbodies within a region. The Santa Clara River watershed is divided into 6 regions: Mint Canyon Creek, Santa Clara River Reach 8, Santa Clara River, Reach 7, Santa Clara River Reach 3, Wheeler Canyon/Todd Barranca, and Brown Barranca/Long Canyon. The regions are color coded on the basin map (e.g. like blue for Mint Canyon Creek region in the eastern part of the watershed and yellow for the small Brown Barranca/Long Canyon region in the western part of the watershed). The break point of each region is a water quality impaired river segment for which a nutrient TMDL must be determined. The loading sources are tracked back to each land use, direct wet and dry atmospheric deposition to lakes, septic systems, and point sources (from surface and subsurface discharges). The direct precipitation and dry deposition to lakes only applies to Bouquet Reservoir in the Reach 8 region, since that is the only lake simulated by WARMF. Loading from prescribed groundwater flows is listed separately from point and nonpoint sources. The regional loads of ammonia, nitrite, nitrate, and phosphorus are discussed here.

Ammonia

Loading is displayed on bar charts on the WARMF map, as shown in Figure 131. Each bar chart represents a colored region on the map. Magenta represents point sources, green represents nonpoint sources, and light blue is loading from groundwater. In each case, the left bar is 1991 loading and the right bar is 1998 loading. Based on the bar charts, the primary source of ammonia is point sources.

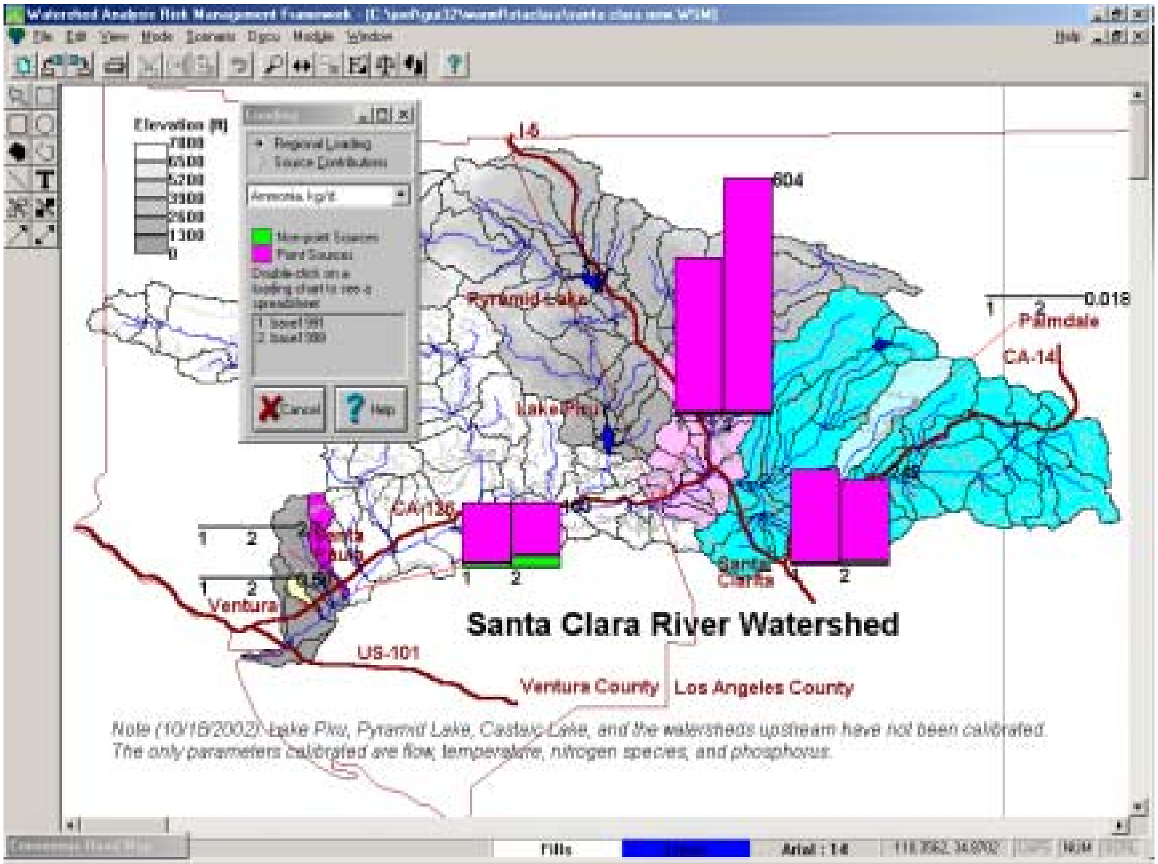

Figure 131: Ammonia regional direct loading, 1991 (left) and 1998 (right)

Double-clicking on a loading chart brings up a spreadsheet with a detailed breakdown of the loading between all sources. Table 47 and Table 48 show the breakdown of ammonia loading for each region of the watershed.

For water year 1991, which is a dry year, there is little point or nonpoint source load of ammonia to Mint Canyon, Wheeler Canyon/Todd Barranca, and Brown Barranca/ Long Canyon. The point source load to Todd Barranca is from subsurface discharges. The point source loads to Reach 8, Reach 7, and Reach 3 are 242, 397, and 163 kg/d respectively. The nonpoint source loads to Reaches 8, 7, and 3 are 2, 0, and 9 kg/d respectively. Groundwater loading was near zero in all cases.

For water year 1998, which is a wet year, there is more point and nonpoint source loads of ammonia to Mint Canyon, Wheeler Canyon/Todd Barranca, and Brown Barranca / Long Canyon. The point source loads to Reach 8, Reach 7, and Reach 3 are 208, 601, and 136 kg/d respectively. The nonpoint source loads to Reaches 8, 7, and 3 are 7, 3, and 26 kg/d respectively. As in 1991, groundwater loading was near zero in all cases.

There was a substantial increase of point source ammonia from the region tributary to Reach 7 between 1991 and 1998. This is caused by the growth of cities, unrelated to the weather conditions. The nonpoint point loads of ammonia to Reaches 8, 7, and 3 are all higher in 1998, which are attributable to storm runoff.

Table 47: Ammonia loading to each region's rivers for water year 1991, kg/d

Source	Mint Cyn Creek	SCR Reach 8	SCR Reach 7	SCR Reach 3	Wheeler Cyn / Todd Barr.	Brown Barr. / Long Cyn
Groundwater	0	0.00389	0.0147	0.0120	0	0
Deciduous	0	0.000558	0.000499	0.0997	0	0
Mixed Forest	0	0.000152	0	0.118	0	0
Orchard	0	0.00117	0.00000813	0.614	0.0442	0.0235
Coniferous	0	0.00218	0.000118	2.05	0.0174	0
Shrub / Scrub	0.000761	0.0183	0.150	4.69	0.0185	0.0431
Grassland	0.0000300	0.00174	0.000107	0.0665	0.00277	0.00195
Park	0	0.000142	0	0.00136	0	0.000637
Golf Course	0	0.0333	0	0.0100	0	0
Pasture	0.0000222	0.000896	0.000897	0.000929	0	0
Farm	0	0.0352	0.0773	0.105	0.116	0.105
Marsh	0	0	0.00110	0.000161	0	0
Barren	0.00000291	0.000436	0.000129	0.000164	0.000100	0
Water	0	0.000289	0.00000884	0	0	0
Residential	0.00000812	0.00344	0.00354	0.0181	0.00169	0
High Dens. Res.	0.00000522	0.000920	0.00431	0.0183	0.00180	0
Comm./Industrial	0	0	0	0	0	0
Other Nonpoint	0	0	0	0	0	0
Direct Precip.	0	0.240	0	0	0	0
Direct Dry Depos.	0	0.322	0	0	0	0
Septic Systems	0.0000642	1.62	0.0267	0.422	0.0200	0.000733
Point Sources	0	240	397	154	0.874	0
TOTAL	0.000895	242	397	163	1.10	0.175

Table 48: Ammonia loading to each region's rivers for water year 1998, kg/d

Source	Mint Cyn Creek	SCR Reach 8	SCR Reach 7	SCR Reach 3	Wheeler Cyn / Todd Barr.	Brown Barr. / Long Cyn
Groundwater	0	0.0425	0.155	0.174	0	0
Deciduous	0	0.00178	0.00199	0.289	0	0
Mixed Forest	0	0.0174	0	0.333	0	0
Orchard	0	0.00816	0.0000515	1.77	0.102	0.0668
Coniferous	0	0.770	0.00311	5.67	0.0954	0
Shrub / Scrub	0.0133	2.43	1.43	15.2	0.0923	0.132
Grassland	0.000523	0.00913	0.00364	0.261	0.00713	0.00599
Park	0	0.00327	0	0.00656	0	0.00193
Golf Course	0	0.0246	0	0.00871	0	0
Pasture	0.000387	0.0584	0.00674	0.00405	0	0
Farm	0	0.0368	0.652	1.17	0.215	0.377
Marsh	0	0	0.00512	0.000798	0	0
Barren	0.0000514	0.0163	0.000418	0.000916	0.000572	0
Water	0.00000913	0.0127	0.0000409	0	0	0
Residential	0.000144	0.0678	0.0371	0.0778	0.00647	0
High Dens. Res.	0.0000925	0.0108	0.0444	0.0845	0.00372	0
Comm./Industrial	0	0	0	0	0	0
Other Nonpoint	0	0	0	0	0	0
Direct Precip.	0	0.859	0	0	0	0
Direct Dry Depos.	0	0.123	0	0	0	0
Septic Systems	0.00370	2.43	0.243	1.41	0.0527	0.00115
Point Sources	0.0000333	208	601	136	2.12	0
TOTAL	0.0182	215	604	162	2.70	0.585

Nitrite

Loading is displayed on bar charts on the WARMF map, as shown in Figure 132. Each bar chart represents a colored region on the map. Magenta represents point sources, green represents nonpoint sources, and light blue is loading from groundwater. In each case, the left bar is 1991 loading and the right bar is 1998 loading. Based on the bar charts, the primary source of nitrite is point sources.

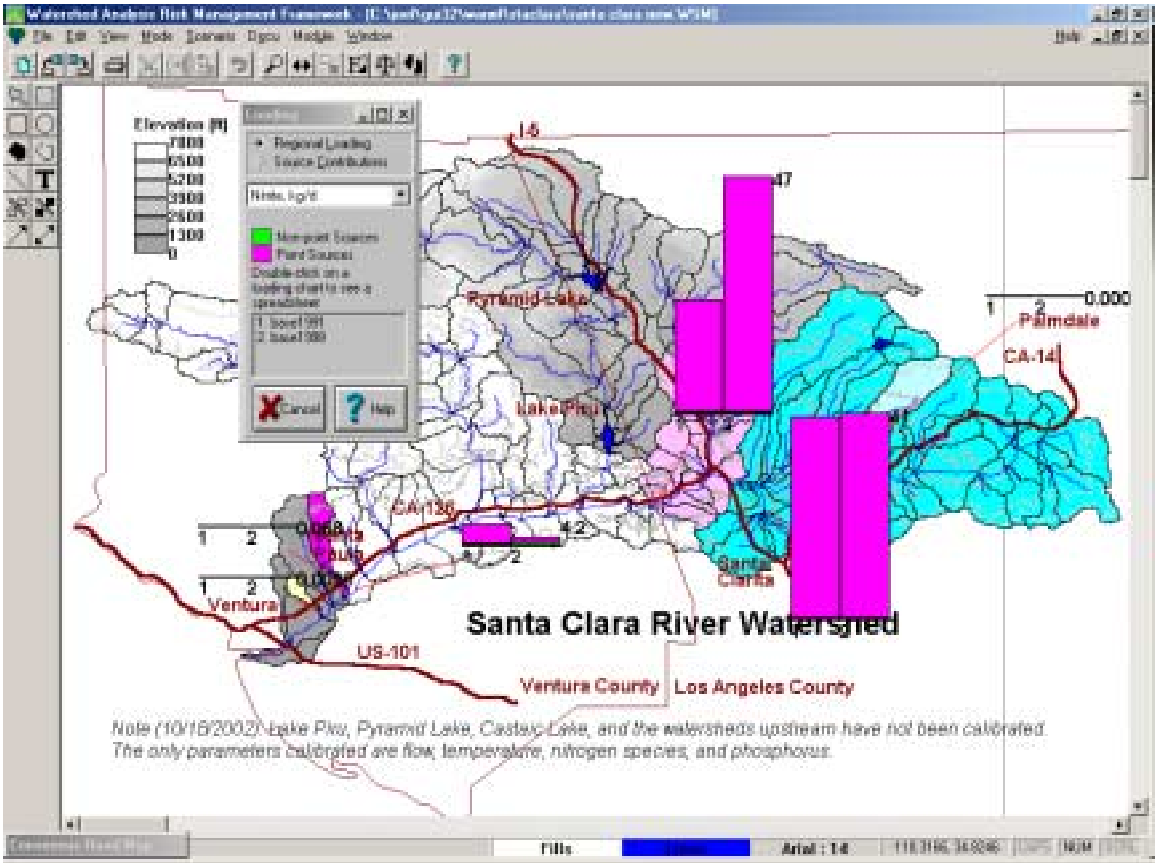

Figure 132: Nitrite regional direct loading, 1991 (left) and 1998 (right)

Double-clicking on a loading chart brings up a spreadsheet with a detailed breakdown of the loading between all sources. Table 49 and Table 50 show the breakdown of nitrite loading for each region of the watershed for a dry year and a wet year, respectively.

For the dry year of 1991, there is very little loading of nitrite to Mint Canyon Creek, Wheeler Canyon/Todd Barranca, and Brown Barranca/ Long Canyon regions. The point source loads to Reach 8, Reach 7, and Reach 3 are 41, 23, and 4 kg/d respectively. The nonpoint source loads to Reaches 8, 7, and 3 are 0, 0, and 0.2 kg/d respectively.

For the wet year of 1998, there is very little loading of nitrite to Mint Canyon Creek, Wheeler Canyon/Todd Barranca, and Brown Barranca/ Long Canyon. The point source loads to Reach 8, Reach 7, and Reach 3 are 41, 47, and 1 kg/d respectively. The nonpoint source loads to Reaches 8, 7, and 3 are 0.1, 0, and 0.5 kg/d respectively.

Table 49: Nitrite loading to each region's rivers for water year 1991, kg/d

Source	Mint Cyn Creek	SCR Reach 8	SCR Reach 7	SCR Reach 3	Wheeler Cyn / Todd Barr.	Brown Barr. / Long Cyn
Groundwater	0	0.0000858	0.000327	0.000245	0	0
Deciduous	0	0.0000177	0.00000723	0.00240	0	0
Mixed Forest	0	0.00000664	0	0.00279	0	0
Orchard	0	0.0000316	0	0.0135	0.000651	0.000500
Coniferous	0	0.000200	0.00000868	0.0531	0.000425	0
Shrub / Scrub	0.0000221	0.00164	0.00164	0.102	0.000413	0.000675
Grassland	0	0.0000606	0.00000595	0.00113	0.0000463	0.0000306
Park	0	0.0000223	0	0.0000182	0	0.00000997
Golf Course	0	0.0000243	0	0.0000430	0	0
Pasture	0	0.000159	0.0000146	0.0000174	0	0
Farm	0	0.0000469	0.00135	0.00250	0.00179	0.00257
Marsh	0	0	0.0000162	0.00000341	0	0
Barren	0	0.0000680	0.00000303	0.00000320	0.00000236	0
Water	0	0.0000560	0	0	0	0
Residential	0	0.000424	0.0000389	0.000432	0.0000339	0
High Dens. Res.	0	0.000139	0.0000250	0.000306	0.0000281	0
Comm./Industrial	0	0	0	0	0	0
Other Nonpoint	0	0	0	0	0	0
Direct Precip.	0	0	0	0	0	0
Direct Dry Depos.	0	0	0	0	0	0
Septic Systems	0.00000721	0.000260	0.000565	0.0119	0.000363	0.000111
Point Sources	0	40.7	22.5	3.96	0.0126	0
TOTAL	0.0000314	40.7	22.5	4.15	0.0163	0.00389

Table 50: Nitrite loading to each region's rivers for water year 1998, kg/d

Source	Mint Cyn Creek	SCR Reach 8	SCR Reach 7	SCR Reach 3	Wheeler Cyn / Todd Barr.	Brown Barr. / Long Cyn
Groundwater	0	0.000982	0.00362	0.00355	0	0
Deciduous	0	0.0000319	0.0000347	0.00618	0	0
Mixed Forest	0	0.000416	0	0.00689	0	0
Orchard	0	0.0000527	0	0.0359	0.00223	0.00114
Coniferous	0	0.00129	0.0000679	0.119	0.00160	0
Shrub / Scrub	0.000147	0.0224	0.0108	0.282	0.00151	0.00182
Grassland	0.00000578	0.000143	0.0000784	0.00399	0.000105	0.0000826
Park	0	0.0000690	0	0.0000725	0	0.0000267
Golf Course	0	0.0000773	0	0.0000923	0	0
Pasture	0.00000428	0.00115	0.000101	0.0000737	0	0
Farm	0	0.000264	0.00792	0.0187	0.00436	0.00670
Marsh	0	0	0.0000667	0.0000119	0	0
Barren	0	0.000297	0.00000591	0.0000180	0.00000942	0
Water	0	0.000256	0	0	0	0
Residential	0.00000185	0.000955	0.000167	0.00153	0.000103	0
High Dens. Res.	0.00000119	0.000233	0.0000988	0.00109	0.0000517	0
Comm./Industrial	0	0	0	0	0	0
Other Nonpoint	0	0	0	0	0	0
Direct Precip.	0	0	0	0	0	0
Direct Dry Depos.	0	0	0	0	0	0
Septic Systems	0.000366	0.00387	0.00314	0.0319	0.00120	0.0000432
Point Sources	0.00000329	41.3	47.4	0.979	0.0449	0
TOTAL	0.000529	41.4	47.4	1.49	0.0561	0.00981

Nitrate

Loading is displayed on bar charts on the WARMF map, as shown in Figure 133. Each bar chart represents a colored region on the map. Magenta represents point sources, green represents nonpoint sources, and light blue is loading from groundwater. In each case, the left bar is 1991 loading and the right bar is 1998 loading.

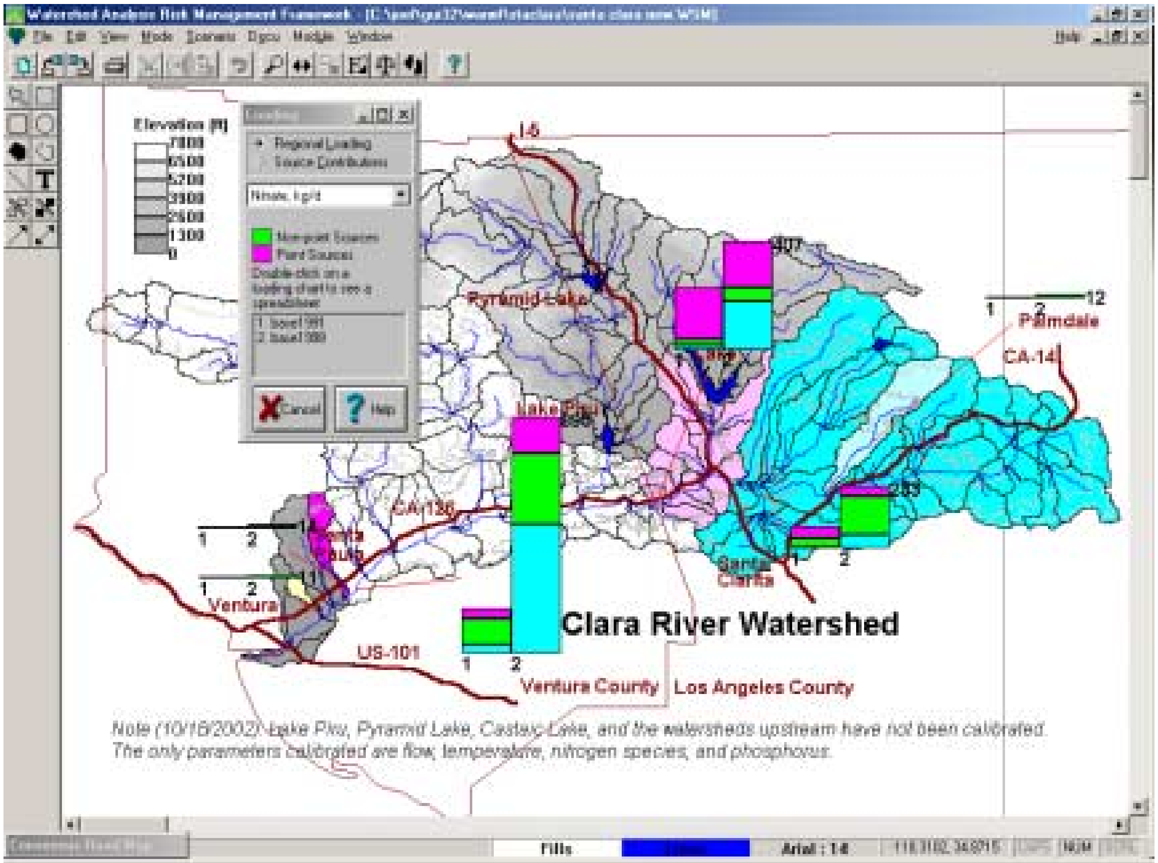

Figure 133: Nitrate regional direct loading, 1991 (left) and 1998 (right)

Double-clicking on a loading chart brings up a spreadsheet with a detailed breakdown of the loading between all sources. Unlike ammonia and nitrite, nonpoint sources and groundwater contribute a large amount of loading to the impaired river segments. Table 51 and Table 52 show the breakdown of nitrate loading for each region of the watershed for a dry year and a wet year, respectively.

For the dry year of 1991, the nonpoint source loads of nitrate to Mint Canyon Creek, Wheeler Canyon/Todd Barranca, and Brown Barranca/ Long Canyon are about 2 to 7 kg/d. The point source loads to Reach 8, Reach 7, and Reach 3 are 41, 200, and 41 kg/d respectively. The nonpoint source loads to Reaches 8, 7, and 3 are 32, 17, and 88 kg/d respectively. Loading from groundwater accounted for 5, 17, and 33 kg/d respectively. The large nonpoint source contribution of nitrate to Reach 3 is due to the groundwater accretion in the Willard Road and Fish Hatchery areas.

For the wet year of 1998, the nonpoint source loads of nitrate to Mint Canyon Creek, Wheeler Canyon/Todd Barranca, and Brown Barranca/ Long Canyon are about 10 to 12 kg/d. The point source loads to Reach 8, Reach 7, and Reach 3 are 39, 173, and 141 kg/d respectively. Loading from groundwater was much greater than in the dry year, accounting for 52, 182, and 491 kg/d respectively. The nonpoint source loads to Reaches 8, 7, and 3 are 132, 52, and 263 kg/d respectively.

As expected, nonpoint source and groundwater loads of nitrate are much higher during the wet year (1998) than the dry year (1991). About 20% of the load to Reach 3 was from groundwater in the dry year, but 55% in the wet year. Groundwater loading is also much higher as a percentage in the wet year in Reach 8 and Reach 7. The percentage of loading from point sources is correspondingly much lower in the wet year than the dry year. The percentage of nonpoint source loading was higher in the wet year for Reach 8 and Reach 7, but for Reach 3, 55% of the dry year loading was nonpoint source but only 30% of the wet year loading.

Table 51: Nitrate loading to each region for water year 1991, kg/d

Source	Mint Cyn Creek	SCR Reach 8	SCR Reach 7	SCR Reach 3	Wheeler Cyn / Todd Barr.	Brown Barr. / Long Cyn
Groundwater	0	4.65	17.4	33.4	0	0
Deciduous	0	0.0174	0.115	0.613	0	0
Mixed Forest	0	0.360	0	0.250	0	0
Orchard	0	0.0484	0.00586	12.5	0.594	1.29
Coniferous	0	1.58	0.0283	15.6	0.445	0
Shrub / Scrub	2.22	26.2	8.92	55.5	0.389	1.29
Grassland	0.0875	0.202	0.0355	0.940	0.0266	0.0583
Park	0	0.0866	0	0.0103	0	0.0190
Golf Course	0	0.200	0	0.295	0	0
Pasture	0.0648	1.29	0.148	0.100	0	0
Farm	0	0.392	6.76	3.63	1.10	4.18
Marsh	0	0	0.246	0.0284	0	0
Barren	0.00870	0.279	0.0369	0.0249	0.00237	0
Water	0.00154	0.158	0.00229	0.0000111	0	0
Residential	0.0236	0.818	0.152	0.125	0.0255	0
High Dens. Res.	0.0152	0.194	0.140	0.140	0.0126	0
Comm./Industrial	0	0	0	0	0	0
Other Nonpoint	0.000204	0.00247	0.00125	0.434	0.000326	0.000102
Direct Precip.	0	0.342	0	0	0	0
Direct Dry Depos.	0	0.191	0	0	0	0
Septic Systems	0.00113	0.0133	0.0980	0.904	0.0144	0.00754
Point Sources	0.0000344	41.3	200	41.2	2.88	0
TOTAL	2.42	78.4	234	166	5.49	6.84

Table 52: Nitrate loading to each region for water year 1998, kg/d

Source	Mint Cyn Creek	SCR Reach 8	SCR Reach 7	SCR Reach 3	Wheeler Cyn / Todd Barr.	Brown Barr. / Long Cyn
Groundwater	0	51.7	182	491	0	0
Deciduous	0	0.0385	0.216	1.46	0	0
Mixed Forest	0	1.93	0	0.866	0	0
Orchard	0	0.0879	0.00767	31.8	1.54	2.53
Coniferous	0	5.09	0.140	47.8	2.48	0
Shrub / Scrub	11.2	120	31.7	160	2.28	2.53
Grassland	0.440	1.03	0.171	3.61	0.114	0.115
Park	0	0.251	0	0.122	0	0.0370
Golf Course	0	0.150	0	0.557	0	0
Pasture	0.326	5.27	0.360	0.186	0	0
Farm	0	0.601	17.5	12.2	2.19	5.57
Marsh	0	0	0.459	0.0560	0	0
Barren	0.0438	1.05	0.0710	0.0443	0.0147	0
Water	0.00778	0.647	0.00155	0.0000156	0	0
Residential	0.119	3.13	0.526	0.582	0.141	0
High Dens. Res.	0.0765	0.621	0.395	1.37	0.0417	0
Comm./Industrial	0	0	0	0	0	0
Other Nonpoint	0.000671	0.00559	0.00152	0.725	0.000401	0.0000909
Direct Precip.	0	1.11	0	0	0	0
Direct Dry Depos.	0	0.0638	0	0	0	0
Septic Systems	0.00985	0.144	0.210	2.00	0.0464	0.00367
Point Sources	0.000252	39.1	173	141	5.33	0
TOTAL	12.2	233	407	895	14.2	10.8

Phosphorus

Loading is displayed on bar charts on the WARMF map, as shown in Figure 134. Each bar chart represents a colored region on the map. Magenta represents point sources, green represents nonpoint sources, and light blue is groundwater loading. In each case, the left bar is 1991 loading and the right bar is 1998 loading.

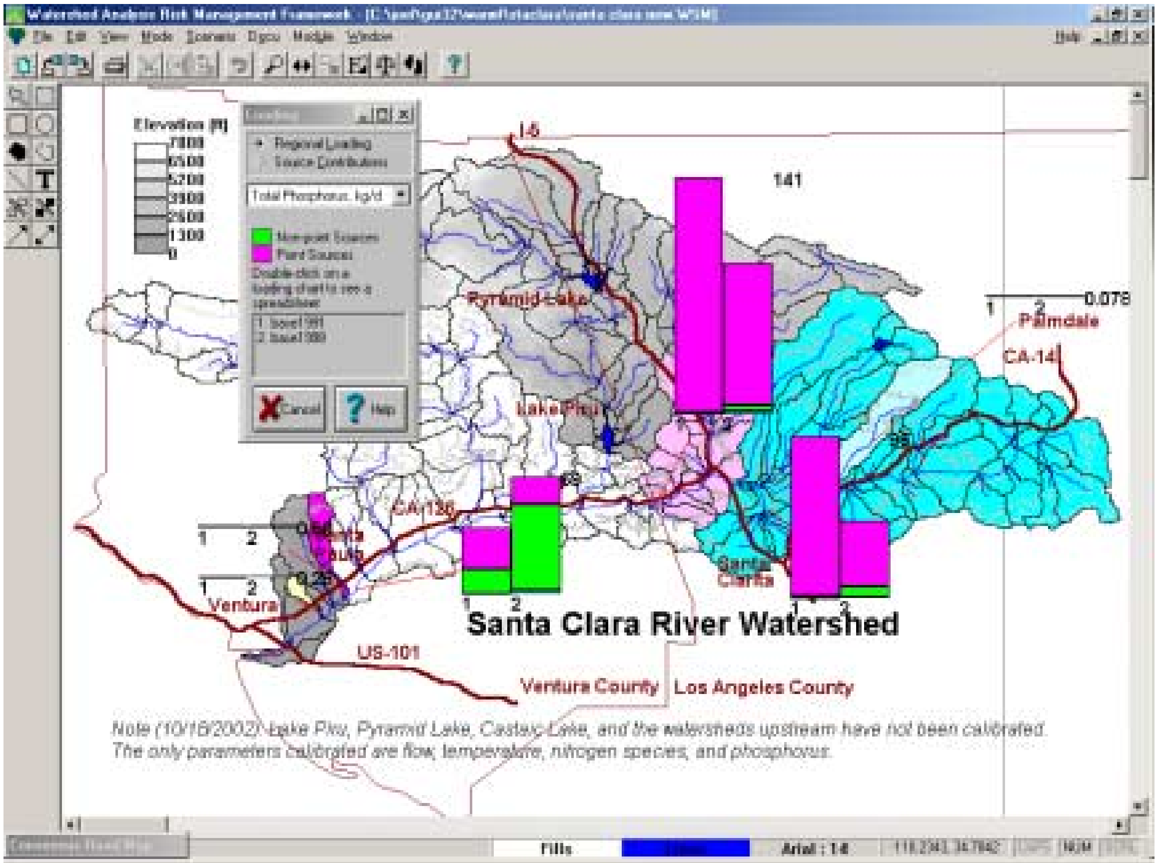

Figure 134: Phosphorus regional direct loading, 1991 (left) and 1998 (right)

Double-clicking on a loading chart brings up a spreadsheet with a detailed breakdown of the loading between all sources. Point sources contribute most phosphorus loading except in the Reach 3 region. Table 53 and Table 54 show the breakdown of phosphorus loading for each region of the watershed for a dry year and a wet year, respectively.

For the dry year of 1991, there is little point or nonpoint source loads of phosphorus to Mint Canyon Creek, Wheeler Canyon/Todd Barranca, and Brown Barranca / Long Canyon. The point source loads to Reach 8, Reach 7, and Reach 3 are 40, 85, and 17 kg/d respectively. The nonpoint source loads to Reaches 8, 7, and 3 are 0, 0, and 14 kg/d respectively. Groundwater contributed very little loading of phosphorus in all cases.

For the wet year of 1998, there is little point or nonpoint source loads of phosphorus from the Mint Canyon, Wheeler Canyon/Todd Barranca, and Brown Barranca/ Long Canyon regions. The point source loads to Reach 8, Reach 7, and Reach 3 are 46, 90, and 69 kg/d respectively. The nonpoint source loads to Reaches 8, 7, and 3 are 6, 3, and 51 kg/d respectively. Groundwater contributed less than 1, 2, and 2 kg/d, respectively, to Reaches 8, 7, and 3.

Table 53: Phosphorus loading to each region for water year 1991, kg/d

Source	Mint Cyn Creek	SCR Reach 8	SCR Reach 7	SCR Reach 3	Wheeler Cyn / Todd Barr.	Brown Barr. / Long Cyn
Groundwater	0	0.0419	0.157	0.133	0	0
Deciduous	0	0.000131	0.000473	0.00521	0	0
Mixed Forest	0	0.000628	0	0.00524	0	0
Orchard	0	0.0139	0.0000188	1.98	0.0219	0.000731
Coniferous	0	0.0151	0.000317	2.85	0.00901	0
Shrub / Scrub	0.00256	0.106	0.0421	8.14	0.00389	0.00135
Grassland	0.000101	0.00123	0.000290	0.0322	0.000124	0.0000611
Park	0	0.000485	0	0.0000126	0	0.0000197
Golf Course	0	0.000281	0	0.000379	0	0
Pasture	0.0000749	0.00526	0.000567	0.000456	0	0
Farm	0	0.00672	0.186	0.400	0.0184	0.0813
Marsh	0	0	0.00104	0.0000904	0	0
Barren	0.00000983	0.00328	0.0000942	0.0000744	0.0000218	0
Water	0.00000175	0.00152	0.00000375	0	0	0
Residential	0.0000270	0.00901	0.000702	0.00497	0.000204	0
High Dens. Res.	0.0000174	0.00270	0.000483	0.000829	0.0000136	0
Comm./Industrial	0	0	0	0	0	0
Other Nonpoint	0	0	0	0	0	0
Direct Precip.	0	0	0	0	0	0
Direct Dry Depos.	0	0	0	0	0	0
Septic Systems	0.00258	0.164	0.114	0.481	0.0549	0.0000801
Point Sources	0.0000297	95.8	141	24.2	0.0525	0
TOTAL	0.00540	96.1	141	38.3	0.161	0.0835

Table 54: Phosphorus loading to each region for water year 1998, kg/d

Source	Mint Cyn Creek	SCR Reach 8	SCR Reach 7	SCR Reach 3	Wheeler Cyn / Todd Barr.	Brown Barr. / Long Cyn
Groundwater	0	0.465	1.68	1.92	0	0
Deciduous	0	0.00296	0.000587	0.0108	0	0
Mixed Forest	0	0.0371	0	0.0107	0	0
Orchard	0	0.216	0.0000146	7.29	0.159	0.00193
Coniferous	0	0.335	0.00353	10.5	0.0393	0
Shrub / Scrub	0.0161	1.71	0.237	28.3	0.0141	0.00258
Grassland	0.000633	0.0123	0.00220	0.130	0.000434	0.000117
Park	0	0.00788	0	0.0000976	0	0.0000378
Golf Course	0	0.00111	0	0.00105	0	0
Pasture	0.000469	0.0769	0.00179	0.00170	0	0
Farm	0	0.0738	1.52	3.16	0.0432	0.277
Marsh	0	0	0.00216	0.000177	0	0
Barren	0.0000562	0.0345	0.000502	0.000107	0.0000724	0
Water	0.00000999	0.0262	0.0000159	0	0	0
Residential	0.000169	0.105	0.00567	0.0190	0.000726	0
High Dens. Res.	0.000109	0.0257	0.00188	0.00288	0.0000372	0
Comm./Industrial	0	0	0	0	0	0
Other Nonpoint	0	0	0	0	0	0
Direct Precip.	0	0	0	0	0	0
Direct Dry Depos.	0	0	0	0	0	0
Septic Systems	0.0601	2.80	1.15	1.36	0.188	0.000219
Point Sources	0.000692	39.5	84.9	16.7	0.145	0
TOTAL	0.0783	45.5	89.5	69.4	0.590	0.282

Source Contribution Loads

The source contributions loading output of WARMF is the way to directly view the pollutant sources at a given location. Because of processes like flow loss to groundwater and denitrification, much of the regional loading detailed in the section above may be lost in certain sections of the watershed. Source contributions loading takes these processes into account. As in regional loading, the loading sources are tracked back to each land use, direct wet and dry atmospheric deposition to lakes, septic systems, and point sources (from surface and subsurface discharges). The direct precipitation and dry deposition to lakes only applies to Bouquet Reservoir upstream of Reach 8, since that is the only lake simulated by WARMF. There is also a portion of the loading from reservoir releases. Reservoir releases include flows from Bouquet Reservoir, Castaic Lake, and Lake Piru. Following are discussions of the sources of ammonia, nitrite, nitrate, and phosphorus.

<u>Ammonia</u>

Loading is displayed on bar charts on the WARMF map, as shown in Figure 135. Each bar chart represents an impaired segment pointed to by its red line. Magenta represents point sources, green represents nonpoint sources, and light blue represents reservoir releases and groundwater loading combined. In each case, the left bar is 1991 loading and the right bar is 1998 loading.

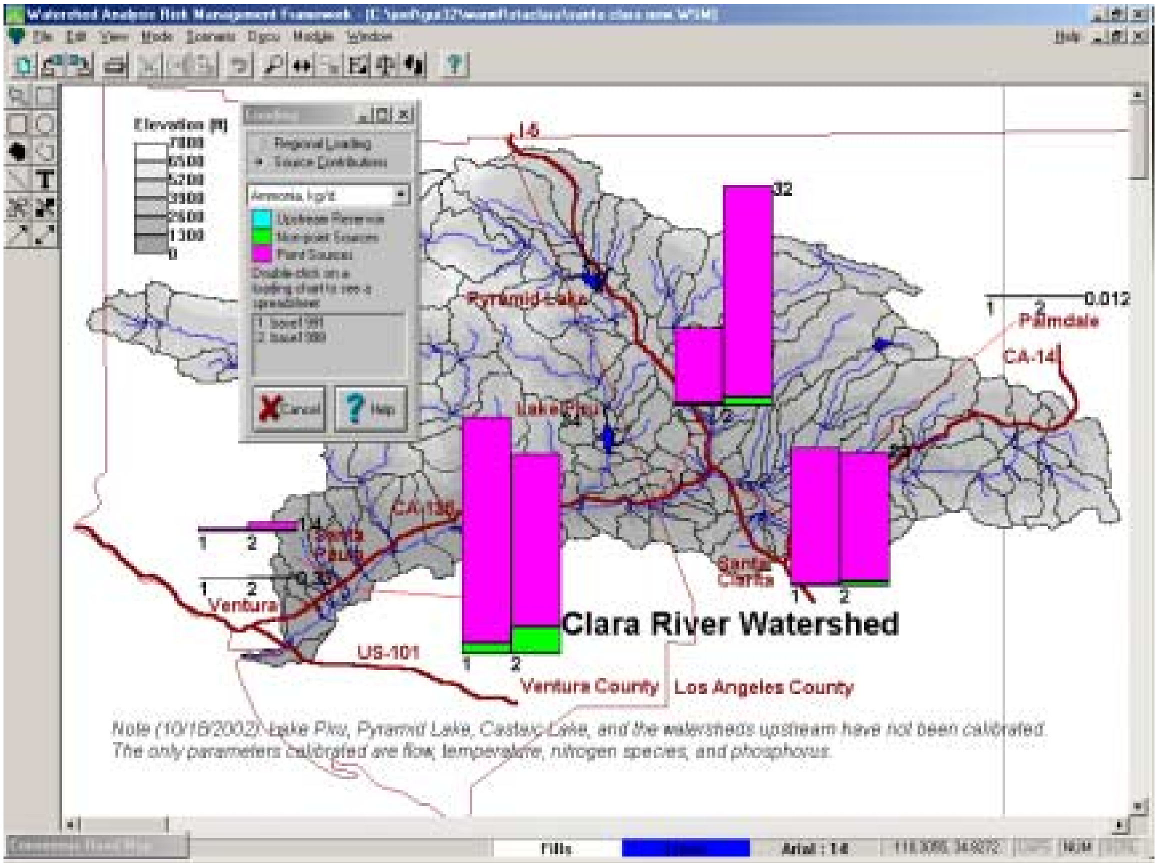

Figure 135: Ammonia source contributions loading, 1991 (left) and 1998 (right)

Double-clicking on a loading chart brings up a spreadsheet with a detailed breakdown of the loading between all sources. As with regional loading, the source contributions loading for ammonia shows that most of the ammonia in each impaired segment came from point sources. Table 55 and Table 56 show the breakdown of the sources of ammonia loading for each impaired river segment of the watershed for a dry year and a wet year respectively.

For the dry year 1991, the point source load contributions in Reaches 8, 7, and 3 are 20, 11, and 33 kg/d respectively. The nonpoint source contributions are near zero for Reaches 8 and 7 and 1 kg/d in Reach 3. For the wet year 1998, the point source load contributions in Reaches 8, 7, and 3 are 19, 31, and 25 kg/d respectively. The nonpoint source load contribution in Reach 3 is only 4 kg/d for the wet year of 1998. Loading from groundwater is minimal. The reason why nonpoint source and groundwater load of ammonia is low is because the background concentration of ammonia is low in groundwater and surface water as shown in water quality monitoring data for streams in undeveloped areas (Figure 26, Figure 31, Figure 48, and Figure 51).

Table 55: Ammonia source contributions in each impaired river segment for water year 1991, kg/d

Source	Mint Cyn Creek	SCR Reach 8	SCR Reach 7	SCR Reach 3	Wheeler Cyn / Todd Barr.	Brown Barr. / Long Cyn
Reservoir Release	0	0.00000454	0.00000125	0.000748	0	0
Groundwater	0	0.00227	0.00421	0.00323	0	0
Deciduous	0	0.000309	0.000302	0.0178	0	0
Mixed Forest	0	0.0000149	0.00000472	0.0282	0	0
Orchard	0	0.000547	0.000136	0.106	0.0261	0.0141
Coniferous	0	0.000235	0.000123	0.325	0.00708	0
Shrub / Scrub	0.000421	0.00354	0.0550	0.614	0.00827	0.0263
Grassland	0.0000166	0.000822	0.000152	0.0108	0.00160	0.00119
Park	0	0.0000414	0.0000126	0.000463	0	0.000389
Golf Course	0	0.0120	0.000210	0.000492	0	0
Pasture	0.0000123	0.000225	0.000452	0.0000594	0	0
Farm	0	0.0128	0.0365	0.0321	0.0660	0.0622
Marsh	0	0	0.000511	0.0000142	0	0
Barren	0.00000161	0.000140	0.000106	0.0000170	0.0000412	0
Water	0	0.000120	0.0000424	0.00000331	0	0
Residential	0.00000449	0.00129	0.00129	0.00367	0.000861	0
High Dens. Res.	0.00000289	0.000378	0.00138	0.00644	0.00109	0
Comm./Industrial	0	0	0	0	0	0
Other Nonpoint	0.000108	0.00509	0.0119	0.0508	0.000634	0.0000223
Direct Precip.	0	0	0	0	0	0
Direct Dry Depos.	0	0	0	0	0	0
Septic Systems	0.0000323	0.00146	0.00766	0.0881	0.0111	0.000399
Point Sources	0	19.6	10.8	32.8	0.496	0
TOTAL	0.000601	19.6	10.9	34.1	0.619	0.105

Table 56: Ammonia source contributions in each impaired river segment for water year 1998, kg/d

Source	Mint Cyn Creek	SCR Reach 8	SCR Reach 7	SCR Reach 3	Wheeler Cyn / Todd Barr.	Brown Barr. / Long Cyn
Reservoir Release	0	0.000860	0.0477	0.0102	0	0
Groundwater	0	0.0276	0.0601	0.0399	0	0
Deciduous	0	0.000713	0.00109	0.0391	0	0
Mixed Forest	0	0.00464	0.00131	0.0648	0	0
Orchard	0	0.000556	0.000243	0.398	0.0553	0.0387
Coniferous	0	0.0125	0.00610	0.692	0.0338	0
Shrub / Scrub	0.00850	0.334	0.499	1.34	0.0342	0.0764
Grassland	0.000335	0.00363	0.00145	0.0428	0.00350	0.00346
Park	0	0.000660	0.000227	0.00234	0	0.00112
Golf Course	0	0.00774	0.000313	0.00191	0	0
Pasture	0.000248	0.0174	0.00705	0.000863	0	0
Farm	0	0.00922	0.267	0.466	0.120	0.214
Marsh	0	0	0.00188	0.000120	0	0
Barren	0.0000330	0.00438	0.00155	0.000287	0.000203	0
Water	0.00000586	0.00280	0.000752	0.0000881	0	0
Residential	0.0000921	0.0135	0.0142	0.0155	0.00265	0
High Dens. Res.	0.0000592	0.00290	0.0132	0.0283	0.00207	0
Comm./Industrial	0	0	0	0	0	0
Other Nonpoint	0.000202	0.0331	0.0706	0.185	0.00199	0.0000344
Direct Precip.	0	0	0	0	0	0
Direct Dry Depos.	0	0	0	0	0	0
Septic Systems	0.00221	0.0200	0.0631	0.304	0.0275	0.000650
Point Sources	0.0000199	18.6	30.6	25.1	1.17	0
TOTAL	0.0117	19.1	31.7	28.7	1.45	0.335

Nitrite

Loading is displayed on bar charts on the WARMF map, as shown in Figure 136. Each bar chart points to the impaired segment it refers to with a red line. Magenta represents point sources, green represents nonpoint sources, and light blue represents reservoir releases and groundwater loading combined. In each case, the left bar is 1991 loading and the right bar is 1998 loading.

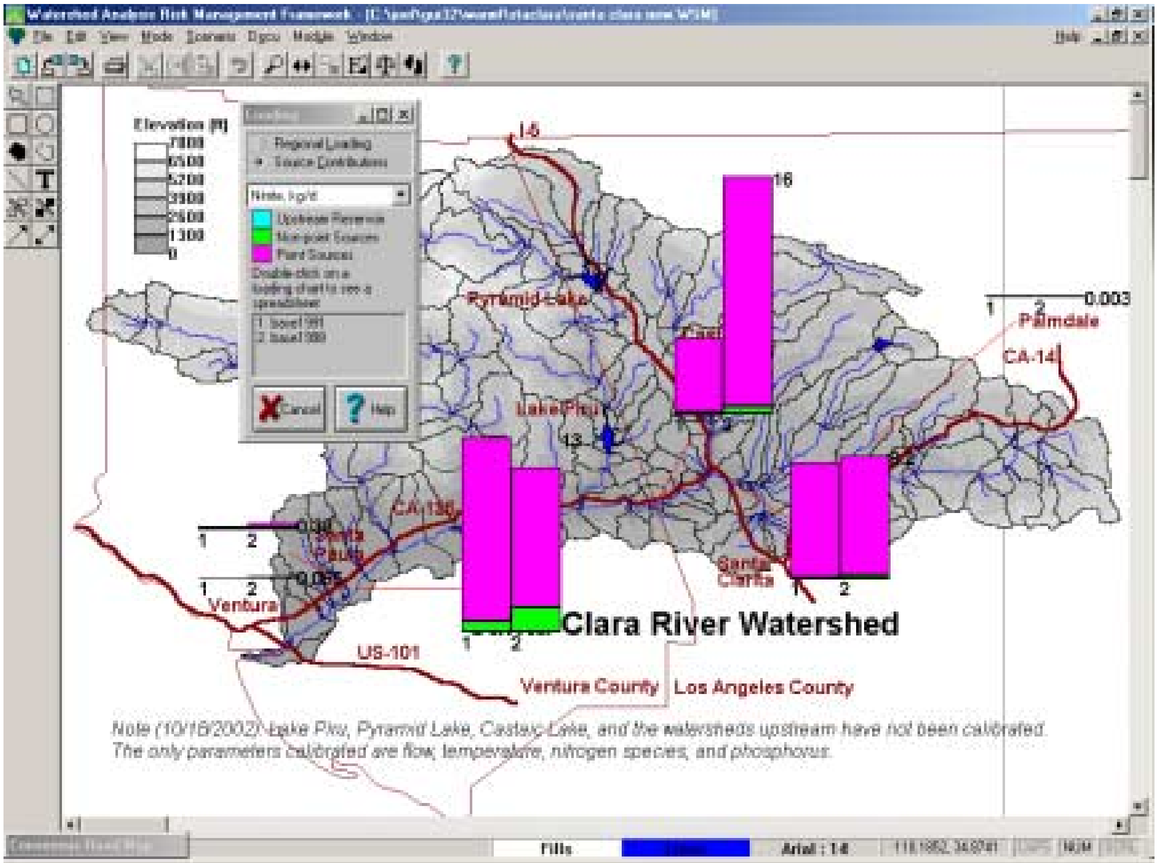

Figure 136: Nitrite source contributions loading, 1991 (left) and 1998 (right)

Double-clicking on a loading chart brings up a spreadsheet with a detailed breakdown of the loading between all sources. Most nitrite comes from point sources, although a significant amount comes from the nitrification of nonpoint source ammonia in Reach 3. Table 57 and Table 58 show the breakdown of the sources of nitrite loading for each impaired river segment of the watershed for a dry year and a wet year respectively.

For the dry year 1991, the point source load contributions in Reaches 8, 7, and 3 are 8, 5, and 13 kg/d respectively. The nonpoint source contributions are zero for Reaches 8 and 7 and 1 kg/d for Reach 3. For the wet year 1998, the point source load contributions in Reaches 8, 7, and 3 are 8, 16, and 11 kg/d respectively. The nonpoint source load contribution to Reach 3 is 2 kg/d for the wet year of 1998. Very little nitrite load comes from nonpoint sources and groundwater because the background concentration of nitrite in groundwater and surface water is naturally very low.

Table 57: Nitrite source contributions in each impaired river segment for water year 1991, kg/d

Source	Mint Cyn Creek	SCR Reach 8	SCR Reach 7	SCR Reach 3	Wheeler Cyn / Todd Barr.	Brown Barr. / Long Cyn
Reservoir Release	0	0.00000243	0	0.000269	0	0
Groundwater	0	0.000576	0.00144	0.00115	0	0
Deciduous	0	0.0000793	0.0000928	0.00922	0	0
Mixed Forest	0	0.00000530	0.00000163	0.0138	0	0
Orchard	0	0.000138	0.0000477	0.0494	0.00653	0.00354
Coniferous	0	0.000102	0.0000471	0.165	0.00272	0
Shrub / Scrub	0.000112	0.00142	0.0217	0.325	0.00289	0.00651
Grassland	0.00000440	0.000216	0.0000691	0.00496	0.000420	0.000295
Park	0	0.0000149	0.00000524	0.000175	0	0.0000960
Golf Course	0	0.00276	0.0000917	0.000174	0	0
Pasture	0.00000326	0.0000973	0.000156	0.0000282	0	0
Farm	0	0.00296	0.0121	0.0133	0.0166	0.0158
Marsh	0	0	0.000145	0.00000598	0	0
Barren	0	0.0000594	0.0000404	0.00000717	0.0000158	0
Water	0	0.0000429	0.0000173	0.00000124	0	0
Residential	0.00000120	0.000405	0.000583	0.00178	0.000260	0
High Dens. Res.	0	0.000119	0.000633	0.00257	0.000272	0
Comm./Industrial	0	0	0	0	0	0
Other Nonpoint	0.0000240	0.00151	0.00358	0.0183	0.000158	0.00000530
Direct Precip.	0	0	0	0	0	0
Direct Dry Depos.	0	0	0	0	0	0
Septic Systems	0.0000108	0.000816	0.00337	0.0422	0.00286	0.000129
Point Sources	0	7.71	4.95	12.4	0.125	0
TOTAL	0.000157	7.72	4.99	13.0	0.158	0.0264

Table 58: Nitrite source contributions in each impaired river segment for water year 1998, kg/d

Source	Mint Cyn Creek	SCR Reach 8	SCR Reach 7	SCR Reach 3	Wheeler Cyn / Todd Barr.	Brown Barr. / Long Cyn
Reservoir Release	0	0.000392	0.0268	0.00396	0	0
Groundwater	0	0.00689	0.0229	0.0148	0	0
Deciduous	0	0.000207	0.000412	0.0202	0	0
Mixed Forest	0	0.00162	0.000697	0.0318	0	0
Orchard	0	0.000176	0.0000974	0.159	0.0145	0.00983
Coniferous	0	0.00647	0.00291	0.334	0.0130	0
Shrub / Scrub	0.00210	0.136	0.227	0.632	0.0126	0.0193
Grassland	0.0000829	0.00122	0.000749	0.0168	0.00101	0.000873
Park	0	0.000311	0.000111	0.000873	0	0.000281
Golf Course	0	0.00176	0.000157	0.000679	0	0
Pasture	0.0000614	0.00706	0.00349	0.000363	0	0
Farm	0	0.00231	0.1000	0.152	0.0309	0.0546
Marsh	0	0	0.000684	0.0000500	0	0
Barren	0.00000813	0.00192	0.000764	0.000118	0.0000779	0
Water	0.00000145	0.00114	0.000371	0.0000351	0	0
Residential	0.0000229	0.00600	0.00682	0.00671	0.000893	0
High Dens. Res.	0.0000147	0.00118	0.00615	0.0112	0.000533	0
Comm./Industrial	0	0	0	0	0	0
Other Nonpoint	0.0000449	0.0111	0.0246	0.0674	0.000498	0.00000817
Direct Precip.	0	0	0	0	0	0
Direct Dry Depos.	0	0	0	0	0	0
Septic Systems	0.000672	0.00948	0.0292	0.132	0.00741	0.000172
Point Sources	0.00000604	8.03	15.4	9.39	0.303	0
TOTAL	0.00302	8.22	15.9	11.0	0.384	0.0850

Nitrate

Loading is displayed on bar charts on the WARMF map, as shown in Figure 137. Each bar chart refers to an impaired river segment pointed to by its red line. Magenta represents point sources and green represents nonpoint sources, and light blue represents reservoir releases and groundwater loading combined. In each case, the left bar is 1991 loading and the right bar is 1998 loading.

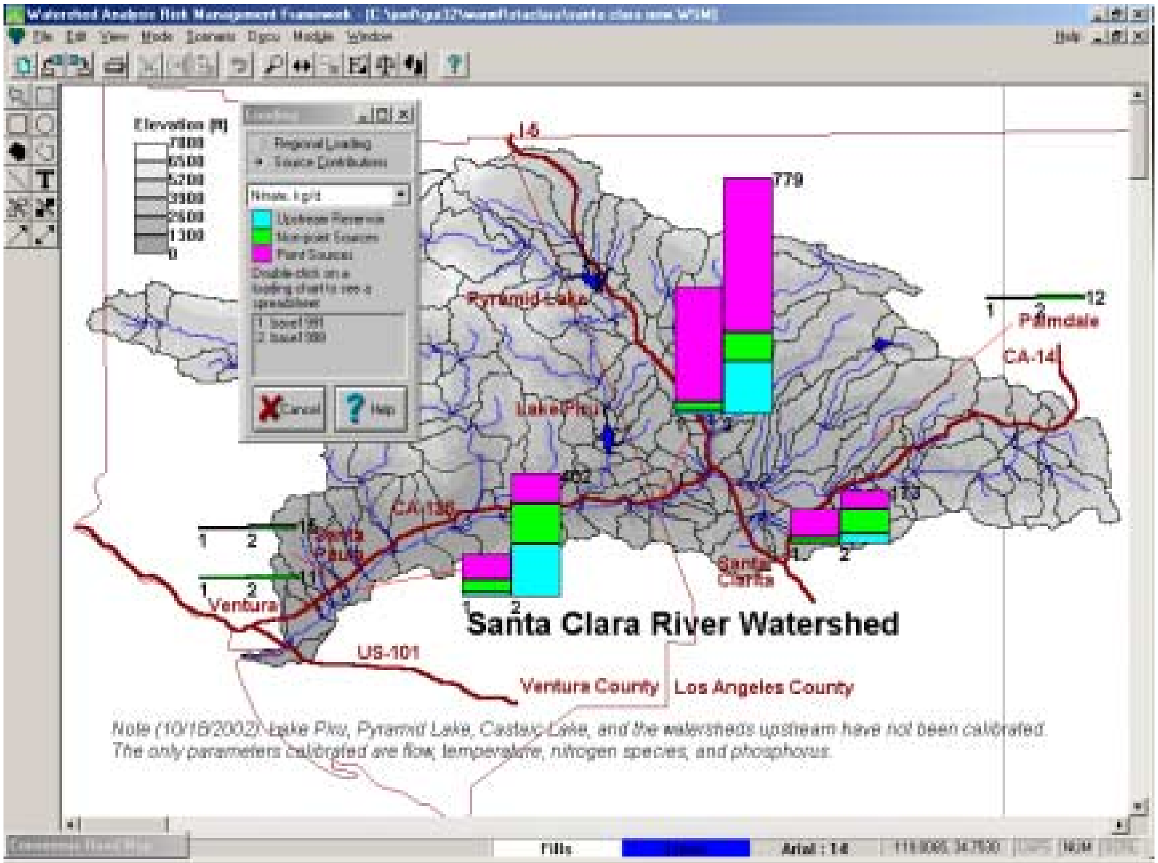

Figure 137: Nitrate source contributions loading, 1991 (left) and 1998 (right)

Double-clicking on a loading chart brings up a spreadsheet with a detailed breakdown of the loading between all sources. Nitrate in the impaired reaches is a blend of point sources, nonpoint sources, and reservoir releases. Table 59 and Table 60 show the breakdown of the sources of nitrate loading for each impaired river segment of the watershed for a dry year and a wet year respectively.

In the dry year, nonpoint sources represented 15% of nitrate in Reach 8 (17 kg/d), 6% of nitrate in Reach 7 (24 kg/d), and 28% of nitrate in Reach 3 (38 kg/d). In the wet year, nonpoint sources were 45% of the loading in Reach 8 (78 kg/d), 12% of the loading in Reach 7 (93 kg/d), and 32% of the loading in Reach 3 (128 kg/d). Reservoir releases contributed minimal loading in the dry year. Release from Castaic Lake contributed 3% of the nitrate in Reach 7 in the wet year (21 kg/d). The combination of releases from Castaic Lake and Lake Piru represented 1% of the nitrate in Reach 3 in the wet year (5 kg/d). In the dry year, groundwater contributed 3% of nitrate in Reach 8 (3 kg/d), 3% of nitrate in Reach 7 (14 kg/d), and 11% of nitrate in Reach 3 (14 kg/d). In the wet year, groundwater was 20% of the loading in Reach 8 (35 kg/d), 20% of the loading in Reach 7 (154 kg/d), and 42% of the loading in Reach 3 (170 kg/d).

Table 59: Nitrate source contributions in each impaired river segment for water year 1991, kg/d

Source	Mint Cyn Creek	SCR Reach 8	SCR Reach 7	SCR Reach 3	Wheeler Cyn / Todd Barr.	Brown Barr. / Long Cyn
Reservoir Release	0	0.00187	0.00104	0.277	0	0
Groundwater	0	3.06	13.6	14.3	0	0
Deciduous	0	0.0111	0.114	0.178	0	0
Mixed Forest	0	0.220	0.116	0.175	0	0
Orchard	0	0.0204	0.0161	5.72	0.606	1.30
Coniferous	0	0.435	0.246	7.68	0.455	0
Shrub / Scrub	2.22	14.4	15.6	20.8	0.399	1.30
Grassland	0.0875	0.140	0.109	0.342	0.0275	0.0589
Park	0	0.0308	0.0181	0.00686	0	0.0192
Golf Course	0	0.131	0.0486	0.117	0	0
Pasture	0.0648	0.727	0.528	0.0487	0	0
Farm	0	0.199	6.44	2.39	1.13	4.21
Marsh	0	0	0.227	0.0182	0	0
Barren	0.00870	0.145	0.116	0.0122	0.00242	0
Water	0.00154	0.0806	0.0481	0.00376	0	0
Residential	0.0236	0.396	0.363	0.0943	0.0262	0
High Dens. Res.	0.0152	0.100	0.183	0.0974	0.0130	0
Comm./Industrial	0	0	0	0	0	0
Other Nonpoint	0.000957	0.0129	0.0565	0.234	0.000915	0.000168
Direct Precip.	0	0	0	0	0	0
Direct Dry Depos.	0	0	0	0	0	0
Septic Systems	0.00116	0.384	0.281	0.614	0.0208	0.00786
Point Sources	0.0000347	89.6	376	82	3.15	0
TOTAL	2.44	110	414	135	5.83	6.89

Table 60: Nitrate source contributions in each impaired river segment for water year 1998, kg/d

Source	Mint Cyn Creek	SCR Reach 8	SCR Reach 7	SCR Reach 3	Wheeler Cyn / Todd Barr.	Brown Barr. / Long Cyn
Reservoir Release	0	0.228	20.5	4.74	0	0
Groundwater	0	35.4	154	170	0	0
Deciduous	0	0.0174	0.211	0.597	0	0
Mixed Forest	0	1.02	0.606	0.634	0	0
Orchard	0	0.0308	0.0253	16.8	1.58	2.55
Coniferous	0	1.99	1.33	23.2	2.53	0
Shrub / Scrub	11.2	68.1	68.1	71.1	2.34	2.57
Grassland	0.440	0.591	0.479	1.60	0.117	0.116
Park	0	0.0869	0.0525	0.0711	0	0.0376
Golf Course	0	0.0926	0.0517	0.261	0	0
Pasture	0.326	3.15	2.16	0.298	0	0
Farm	0	0.231	16.6	10.0	2.26	5.68
Marsh	0	0	0.421	0.0605	0	0
Barren	0.0438	0.549	0.380	0.0612	0.0151	0
Water	0.00778	0.280	0.164	0.0200	0	0
Residential	0.119	1.52	1.42	0.561	0.144	0
High Dens. Res.	0.0765	0.317	0.560	0.810	0.0429	0
Comm./Industrial	0	0	0	0	0	0
Other Nonpoint	0.00155	0.0485	0.185	0.631	0.00181	0.000166
Direct Precip.	0	0	0	0	0	0
Direct Dry Depos.	0	0	0	0	0	0
Septic Systems	0.0110	0.713	0.761	1.68	0.0654	0.00405
Point Sources	0.000263	59.1	512	99.3	6.03	0
TOTAL	12.2	173	779	402	15.1	11.0

Phosphorus

Loading is displayed on bar charts on the WARMF map, as shown in Figure 138. Each bar chart represents an impaired river segment pointed to by a red line. Magenta represents point sources, green represents nonpoint sources, and light blue represents reservoir releases and groundwater loading combined. In each case, the left bar is 1991 loading and the right bar is 1998 loading.

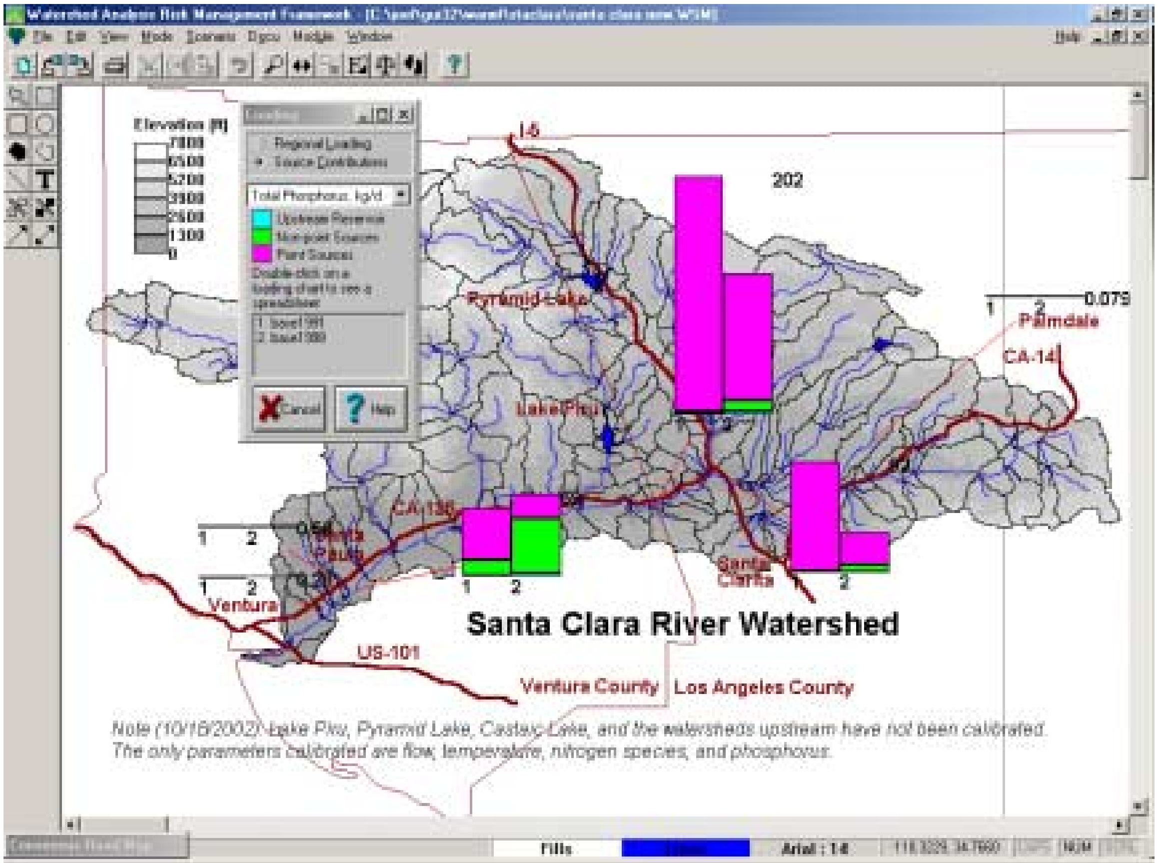

Figure 138: Phosphorus source contributions loading, 1991 (left) and 1998 (right)

Double-clicking on a loading chart brings up a spreadsheet with a detailed breakdown of the loading between all sources. Point sources contribute most of the phosphorus in the impaired reaches of the watershed, although there is significant phosphorus from nonpoint sources in Reach 3. Table 61 and Table 62 show the breakdown of the sources of phosphorus loading for each impaired river segment of the watershed for a dry year and a wet year respectively.

As with ammonia, background concentrations of phosphorus are low in groundwater and surface waters without point sources (Figure 29 and Figure 33). In the dry year, most phosphorus in the Santa Clara River comes from point sources. In 1998, however, 67% of phosphorus in Reach 3 came from nonpoint sources, especially from the dominant natural land covers, scrubland and coniferous forest. Orchard contributed 14% of the nonpoint source portion of phosphorus in 1998 in Reach 3. Groundwater contributed less than 1% of phosphorus in the dry year. In the wet year, groundwater contributed 1%, 2%, and 3%, respectively, in Reaches 8, 7, and 3. In Todd Barranca, 25% of the phosphorus was from point sources. In Mint Canyon Creek and Brown Barranca, most or all of the phosphorus was from nonpoint sources.

Table 61: Phosphorus source contributions in each impaired river segment for water year 1991, kg/d

Source	Mint Cyn Creek	SCR Reach 8	SCR Reach 7	SCR Reach 3	Wheeler Cyn / Todd Barr.	Brown Barr. / Long Cyn
Reservoir Release	0	0.0000704	0.0000710	0.00836	0	0
Groundwater	0	0.0419	0.198	0.162	0	0
Deciduous	0	0.000129	0.000598	0.00384	0	0
Mixed Forest	0	0.000317	0.000313	0.00508	0	0
Orchard	0	0.0138	0.0137	1.69	0.0219	0.000731
Coniferous	0	0.0146	0.0138	2.34	0.00900	0
Shrub / Scrub	0.00256	0.106	0.142	6.63	0.00389	0.00135
Grassland	0.000101	0.00132	0.00158	0.0254	0.000124	0.0000611
Park	0	0.000481	0.000479	0.0000996	0	0.0000197
Golf Course	0	0.000284	0.000279	0.000430	0	0
Pasture	0.0000748	0.00529	0.00581	0.00116	0	0
Farm	0	0.00671	0.190	0.464	0.0183	0.0813
Marsh	0	0	0.00103	0.000145	0	0
Barren	0.00000983	0.00327	0.00336	0.000669	0.0000218	0
Water	0.00000175	0.00148	0.00148	0.000295	0	0
Residential	0.0000270	0.00895	0.00952	0.00563	0.000204	0
High Dens. Res.	0.0000174	0.00270	0.00314	0.00130	0.0000136	0
Comm./Industrial	0	0	0	0	0	0
Other Nonpoint	0.000115	0.00652	0.0161	0.0619	0.000547	0.000170
Direct Precip.	0	0	0	0	0	0
Direct Dry Depos.	0	0	0	0	0	0
Septic Systems	0.00257	0.159	0.246	0.393	0.0549	0.0000801
Point Sources	0.0000296	92.1	201	44.5	0.0525	0
TOTAL	0.00551	92.5	202	56.3	0.161	0.0837

Table 62: Phosphorus source contributions in each impaired river segment for water year 1998, kg/d

Source	Mint Cyn Creek	SCR Reach 8	SCR Reach 7	SCR Reach 3	Wheeler Cyn / Todd Barr.	Brown Barr. / Long Cyn
Reservoir Release	0	0.00106	0.367	0.129	0	0
Groundwater	0	0.463	2.11	1.94	0	0
Deciduous	0	0.00286	0.00321	0.0103	0	0
Mixed Forest	0	0.0169	0.0158	0.0177	0	0
Orchard	0	0.207	0.193	6.44	0.159	0.00193
Coniferous	0	0.318	0.299	8.66	0.0393	0
Shrub / Scrub	0.0160	1.63	1.72	23.5	0.0141	0.00258
Grassland	0.000633	0.0123	0.0131	0.109	0.000434	0.000117
Park	0	0.00672	0.00617	0.00316	0	0.0000378
Golf Course	0	0.00110	0.000982	0.00162	0	0
Pasture	0.000469	0.0673	0.0641	0.0284	0	0
Farm	0	0.0675	1.56	3.91	0.0432	0.277
Marsh	0	0	0.00210	0.000657	0	0
Barren	0.0000562	0.0292	0.0270	0.0144	0.0000724	0
Water	0.00000998	0.0172	0.0158	0.00613	0	0
Residential	0.000169	0.101	0.0981	0.0660	0.000726	0
High Dens. Res.	0.000109	0.0223	0.0221	0.0134	0.0000371	0
Comm./Industrial	0	0	0	0	0	0
Other Nonpoint	0.000407	0.0339	0.0739	0.245	0.00205	0.000546
Direct Precip.	0	0	0	0	0	0
Direct Dry Depos.	0	0	0	0	0	0
Septic Systems	0.0601	2.62	3.48	2.62	0.188	0.000219
Point Sources	0.000692	27.1	109	20.8	0.145	0
TOTAL	0.0787	32.7	119	68.5	0.592	0.282

Summary

Regional pollution loads and source contributions of pollutants to the water quality impaired segments were calculated by WARMF. The results show that point source loads contribute almost all of ammonia, nitrite, and phosphorus in the water quality impaired segments of the Santa Clara River watershed. Nitrate in impaired segments comes from a combination of point, nonpoint, and groundwater sources. The nonpoint source load contribution is higher in the wet year.

VII. Conclusion

To provide a linkage between pollution loads and water quality in the Santa Clara River requires a watershed model. The success of the watershed model is largely dependent upon proper hydrologic accounting. The accounting of uncontrolled flows in the western part of the watershed and the accounting of managed flows for point source waste discharges, groundwater accretion, water gains and losses across the river bed and groundwater dewatering operations are all important.

Simulations of Santa Paula, Sespe, and Hopper Creeks show good water balance and reasonable correlation. Simulations of Mint Canyon Creek and Bouquet Canyon Creek show the intermittent flow typical of the eastern tributaries. The flow accounting on the Santa Clara River is reasonable from Santa Clarita through Freeman diversion. In a heavily managed system like the Santa Clara River, the reliability of managed flow data is uncertain. The calibrated model is set up to minimize the errors of the data by flow balance.

The primary purpose of the model is to calculate TMDLs for the water quality impaired river segments in the watershed. There is little data to calibrate the three smaller impaired tributaries (Mint Canyon Creek, Wheeler Canyon / Todd Barranca, and Brown Barranca.Long Canyon). The flow and pollutants are routed downstream to the main stem of the Santa Clara River where data is more plentiful. The linkage analysis indicates the importance of point sources, managed flows, and groundwater interactions between Blue Cut and Santa Paula Creek, for which there is good data available.

The water quality of concern is nutrients, principally ammonia, nitrite, and nitrate. Point source loads contribute ammonia, nitrite, and nitrate to the impaired river segments. Nonpoint source loads also contribute nitrate to the impaired river segments through groundwater accretion. Denitrification, which removes nitrate from the water, appears to occur in the river bed of the impaired river segments, located in most cases below the wastewater treatment plant discharges. Because of the assimilation processes occurring within river segments of the watershed, it is important to distinguish between loading *to* the rivers, and loading *in* the rivers, the latter of which is directly reflective of water quality.

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