Final Report

Hydrological and Biological Support to Lower Santa Margarita River Watershed Monitoring Program
Water Years 2008-2009

February 21, 2010

Prepared for

United States
Bureau of Reclamation

U. S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Southern California Area Office, Temecula, California

STETSON ENGINEERS INC.

WATER RESOURCE ENGINEERS

FINAL REPORT

HYDROLOGICAL AND BIOLOGICAL SUPPORT TO LOWER SANTA MARGARITA RIVER WATERSHED MONITORING PROGRAM

WATER YEARS 2008-2009

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<u>PREPARED FOR</u>
UNITED STATES BUREAU OF RECLAMATION
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Acronyms and Abbreviation List

ANOVA	Analysis of Variance
AF	Acre-feet
AFY	Acre Feet Per Year
Base	Marine Corps Base Camp Pendleton
BP	Basin Plan
BOD$_5$	Biochemical Oxygen Demand
BURC	Beneficial Use Risk Category
CCR	California Code of Regulations
cfs	Cubic Feet Per Second
chl-*a*	Chlorophyll-*a*
COD	Chemical Oxygen Demand
COLD	Beneficial Use of Cold Freshwater Habitat
CPOM	Course Particulate Organic Matter
CSV	Comma-Separated Values
CTR	California Toxics Rule
CWRMA	Cooperative Water Resource Management Agreement
d/s	Downstream of
DO	Dissolved Oxygen
EMAP	USEPA Environmental Monitoring and Assessment Program
FNWS	Fallbrook Naval Weapons Station
FPUD	Fallbrook Public Utility District
ft msl	Feet Mean Sea Level
GIS	Geographic Information System
HA	Hydrologic Area
HASP	Health and Safety Plan
HSA	Hydrologic Sub Area
HSI	Habitat Suitability Index
HSPF	Hydrologic Simulation Program Frotran
HU	Hydrologic Unit
I-Pool	In-Channel Pool
MCL	Maximum Contamination Level
MWD	Metropolitan Water District
mi^2	Square Miles
mg/L	Milligrams Per Liter
µg/L	Micrograms Per Liter
mg/m^3	Milligrams Per Cubic Meter
µmhos/cm	Micromhos Per Centimeter
MPN/100ml	Most Probable Number per 100ml
µS/cm	MicroSiemens Per Centimeter
MSL	Mean Sea Level
MS4	Municipal Separate Storm Sewer System
N$_2$	Nitrogen Gas
N$_2$0	Nitrous Oxide
NAD27	North American Datum of 1927

NAD83	North American Datum of 1983
ND	Not Detected
ng/L	Nanograms Per Liter
NGVD 29	National Geodetic Datum of 1929
NH_3^-	Un-ionized Ammonia
NH_4^+	Ammonium
NNE	Nutrient Numeric Endpoint
NO_2^-	Nitrite
NO_3^-	Nitrate
NTU	Nephelometric Turbidity Units
NWS	National Weather Service
O-Pool	Off-Channel Pool
OWR	Camp Pendleton Office of Water Resources
PO_4---	Orthophosphate
QA/QC	Quality Assurance / Quality Control
QAPP	Quality Assurance Project Plan
RCFCD	Riverside County Flood Control and Water Conservation District
RCWD	Rancho California Water District
RWQCB	Regional Water Quality Control Board
SDSU	San Diego State University
SMER	Santa Margarita Ecological Reserve
SWFL	Southwest Willow Flycatcher
SMR	Santa Margarita River
SWAMP	State Surface Water Ambient Monitoring Program
SWRCB	State Water Resources Control Board
TDS	Total Dissolved Solids
T&E	Threatened and Endangered
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorus
TSS	Total Suspended Solids
UCMR2	Unregulated Contaminant Monitoring Regulation 2
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WARM	Beneficial Use of Warm Freshwater Habitat
WARMF	Watershed Analysis Risk Management Framework
WRCC	Western Regional Climate Center (Desert Research Institute)
WY	Water Year

Glossary

Alluvium
A geologic term describing beds of sand, gravel, silt, and clay deposited by flowing water.

Analysis of variance
A statistical analysis used to determine if data at two or more monitoring stations are correlated or not (see “correlation”).

Aquifer
A geologic formation or group of formations which store, transmit and yield significant quantities of water to wells and springs. See also “confined aquifer,” “unconfined aquifer,” and “semi-confined aquifer”.

Arroyo Toad
A stocky, blunt-nosed, warty-skinned toad. It has horizontal pupils and a light-colored stripe across the head and eyes. It lives in riparian habitats and is active March through September.

Assimilative Capacity
The ability of a body of water to cleanse itself; its capacity to receive waste waters or toxic materials without deleterious effects and without damage to aquatic life or humans who consume the water.

California Least Tern
A small (the smallest), black-capped tern with yellow bill and legs having a forked tail. Frequents bodies of water with beaches on which it nests. Population declines due to human encroachment and habitat loss.

Correlation
A relation between mathematical or statistical variables which tend to vary or be associated in a way not expected on the basis of chance alone, but rather in a way that could be predicted with a pattern or mathematical equation.

Conductivity
The measurement of the ability of water to carry an electrical current. Conductivity of water is directly related to the concentration of dissolved ionized solids in the water and can provide an approximate concentration of total dissolved solids.

Ephemeral Stream
Stream that flows only during and immediately after a period of rainfall or snowmelt

Exceedance analysis
An analysis of the frequency with which a measurement exceeds a particular value in a given time period.

Fault
A fracture in the earth’s crust, with displacement of one side of the fracture with respect to the other.

Formation
A geologic term that designates a body of rock or rock/sediment strata of similar lithologic type or combination of types.

Geomorphology
The study of land formations and the processes that shape them. The study seeks to understand why landscapes look the way they do and to predict future changes.

Grab Sample
A single sample collected at a particular time and location that represents the composition of the water volume at that time and location

Groundwater
The water contained in interconnected pores located below the water table in an unconfined aquifer or located in a confined or semi-confined aquifer.

Hydrologic Area (HA)
A major logical subdivision of a hydrologic unit, which includes both water-bearing and non-water-bearing formations. It is best typified by a major tributary of a stream, a major valley, or a plain along a stream containing one or more groundwater basins and having closely related geologic, hydrologic, and topographic characteristics. Area boundaries are based primarily on surface drainage boundaries. However, where strong subsurface evidence indicates that a division of groundwater exists, the area boundary may be based on subsurface characteristics.

Hydrologic Sub Area (HSA)
A major logical subdivision of a hydrologic area, which includes both water-bearing and non-water-bearing formations.

Hydrologic Unit (HU)
A classification embracing one of the following features which are defined by surface drainage divides: (1) in general, the total watershed area, including water-bearing and non-water-bearing formations, such as the total drainage area of the San Diego River Valley; and (2) in coastal areas, two or more small contiguous watersheds having similar hydrologic characteristics, each watershed being directly tributary to the ocean and all watersheds emanating from one mountain body located immediately adjacent to the ocean.

Hydrology
Describing the movement, distribution and quality of water in a region.

Impaired Water Body
If a water body fails to meet one or more of its water quality standards that water body is considered impaired and is added to the 303(d) list, which is the section of the Clean Water Act that mandates this assessment and clean up process. Once a water body is listed as impaired for a certain pollutant, the Clean Water Act requires states to create a clean up plan. The main tool for completing this is a process called the “Total Maximum Daily Load,” or TMDL.

Intermittent Stream
A stream that flows for part of the year.

Least Bell's Vireo
A gray, with a white wing bar and faint "spectacles", spring and summer breeding bird that migrates south for the fall and winter. In recent years populations have declined due loss of habitat and the increasing abundance of Brown-headed Cowbirds as a result of increasing agricultural fields. Cowbird control has improved some populations.

Light-footed Clapper Rail
A large, brown with deep rufous breast and long bicolored bill, rail uncommon to common in salt and freshwater marshes. Cryptic and usually solitary, the southwest populations usually do not migrate. Population declines are largely due to habitat loss.

Macroinvertebrate
Aquatic invertebrates which inhabit rivers, ponds, lakes or ocean. Their abundance and diversity can be used as an indicator of ecosystem health and biodiversity. They are a key component of the food chain.

Macrophyton
Macrophytes are floating aquatic plants that can produce oxygen and provide food for wildlife. The lack or overabundance of macrophytes can indicate water quality problems and reduced wildlife populations.

Orographic
Of or relating to mountains; associated with or induced by the presence of mountains. Orographic precipitation is a phenomenon in which the precipitation is directly affected by the presence of mountains through orographic uplifting of air.

Periphyton
Periphyton are algae that grow attached to surfaces such as rocks or large plants. They are primary producers and sensitive indicators to environmental changes in water.

Riparian
A riparian zone is the interface between land and a flowing surface water body. Plant communities along the river margins are called riparian vegetation, characterized by hydrophilic plants.

Southwestern Willow Flycatcher
A small bird with conspicuous light-colored wingbars that breeds in dense willow, cottonwood and woodlands along streams and rivers.

Stoichiometry
The calculation of quantitative relationships between the products and reactants of a balanced chemical reaction.

Taxa
A name designating an organism or group of organisms.

Tidewater Goby
A small (< 2") gray-brown fish with large pectoral fins endimic to California. It frequents lagoons, estuaries and river mouths. Populations are decreasing due to drainage, lowering of water quality, introduced predators and drought.

Unregulated Contaminant Monitoring Regulations 2
The second cycle of the EPA's Unregulated Contaminant Monitoring which is the monitoring of contaminants suspected to be present in drinking water but do not have health-based standards under the Safe Drinking Water Act.

Watershed
An area defined by surface drainage divides. Generally, the land area that contributes to surface water runoff at one point.

Water Table
The surface where groundwater is encountered in a water well in an unconfined aquifer.

Water Year
The period between October 1st of one year and September 30th the next year. This interval is often used because hydrologic systems are typically at their lowest levels near October 1.

EXECUTIVE SUMMARY

The Draft Final Report on the Hydrological and Biological Support to Lower Santa Margarita River Watershed Monitoring Program (Draft Final Report) was prepared under Bureau of Reclamation (Reclamation) Task Order #07PE308086. The Task Order included monitoring water quality, hydrological, and biological parameters of the Santa Margarita River and several of its tributaries. Stetson Engineers Inc. (Stetson) has employed a multi-task approach addressing all the issues specified in the Task Order. These tasks have been undertaken as specified in the project Work Plan, Quality Assurance Project Plan (QAPP), and Health and Safety Plan (HASP), which were submitted in September and October 2007, respectively. Previous reports submitted under this contract include a Draft Semi-Annual Report submitted in April 2008, an Annual Report submitted in November 2008, and a Draft Semi-Annual Report submitted in August 2009. The goals of the project were three-fold: 1) characterize the water quality patterns of the Santa Margarita River; 2) assess assimilative capacity for nutrients, and 3) determine the impacts of the Cooperative Water Resource Management Agreement (CWRMA) upon the hydrology, geomorphology, and biology of the river.

The first and third goals address two key interests for Reclamation and the United States Marine Corp Base Camp Pendleton (Camp Pendleton or Base): the quality of drinking water and quantity of water supply. Water quality and quantity are key aspects of source water protection for the Base, as well as necessary elements for success of the Conjunctive Use Project currently being planned by Reclamation, Camp Pendleton, and Fallbrook Public Utility District (FPUD).

The second goal supports the Reclamation-led Santa Margarita River Executive Management Team, a group of stakeholders seeking to develop a watershed model to characterize the assimilative capacity of the Santa Margarita River for nutrients. In support of this modeling initiative, as well as the recent San Diego Regional Water Quality Control Board (RWQCB) Investigation Order mandating a sampling program for nutrients in the estuary, this water quality monitoring program examines nutrient inputs in a protocol that closely follows that required under the Investigation Order. This program also collects data on riverine indicators of ecological function such as periphyton and macrophyton. By collecting this assortment of data, the program supports use of the existing watershed model to assess the assimilative capacity for nutrients throughout the lower Santa Margarita River, assess attainment of important beneficial uses, support Use Attainability Analyses of beneficial uses, refine Water Quality Objectives, and develop and implement Total Maximum Daily Loads (TMDL).

In addition to downstream water supply, the third goal also examines the influence of CWRMA augmentation flows upon the river, and inter-relates with goals one and two. This examination, required under the terms of the CWRMA, assesses the potential impacts of the CWRMA releases upon water quality, water quantity, wetlands, sensitive species habitat, and river geomorphology.

A number of ambient water quality monitoring programs and studies have been carried out in the watershed. An important first step was to compile these data and identify gaps. Stetson has developed a comprehensive database of water quality and related data (contained in Appendix C).

This Draft Final Report presents data collected during eight quarterly sampling events, four index periods for water chemistry, and six sampling periods for periphyton and macrophyton. In addition, a series of three sampling events were conducted during April, May, and September of 2009 in order to track geomorphology, ecology, and water quality variables that may vary with the CWRMA flow regime. During the final quarter of the first monitoring year (October 2007 through September 2008), the program was modified to incorporate several improvements including addition of reference stream and emergent chemical sampling, additional sampling for periphyton, and additional sampling for pesticides.

To better understand how changes in flows affect geomorphology and sensitive species habitat, the study team conducted a flow experiment that included water quality sampling before and after the annual May 1 CWRMA adjustment. The flow experiment included cross-sectional surveys of the river at five reaches along the Santa Margarita River. The purpose of the cross-sections was to document the current geomorphic condition at each location. These transects may serve as a baseline for future monitoring of geomorphic processes on the watershed. At each of these cross-sections, the team measured flow and collected nutrient and conventional chemistry water quality samples for the purpose of calculating loading and assessing assimilative capacity. The transects were examined for changes to in-channel and off-channel pools during April, May, and September 2009. Parameters analyzed for a given pool include: area, maximum depth, water temperature, conductivity, dissolved oxygen, pH, algae cover, canopy cover, substrate type, and exposure.

Conclusions Regarding Water Quality

Overall, a number of sampled constituents in a number of locations were found to be in exceedance of Basin Plan limits. However, some of these excess constituents, such as nitrogen, appear to be assimilated by the river, at least in some reaches. The data show that several tributaries were contributing high levels of TDS to the lower Santa Margarita River, including De Luz, Devils, Fallbrook, Rainbow, Sandia and Stone Creeks. Elevated TDS concentrations were also present at the Santa Margarita River at FPUD Sump (FPUD Sump).

Several of the tributaries contributed elevated levels of iron, including Arroyo Seco, Adobe, Cole, Roblar, De Luz, Fallbrook, Sandia, and Stone Creeks. Sites on the Santa Margarita River that have high iron concentrations include the FPUD Sump and the Santa Margarita River near Temecula (Gorge). Arroyo Seco, Roblar, and Fallbrook Creeks were sources of elevated manganese levels.

Several tributaries including Cole, De Luz, Devils, Rainbow, Sandia, and Stone Creeks as well as the CWRMA Outfall contribute Total Nitrogen (TN) in excess of Basin Plan limits. TN in exceedance of the Basin Plan limit was detected at all sites on the Santa Margarita River. Nitrate in excess of the Basin Plan limit was detected at De Luz, Devils, Rainbow, Sandia and Stone Creeks as well as at the CWRMA Outfall and the FPUD Sump. Several tributaries including Arroyo Seco, Adobe, De Luz, Devils, Fallbrook, Sandia, and Stone Creeks contributed Total Phosphorus (TP) in excess of Basin Plan limits. TP in exceedance of the Basin Plan limit was detected at all sites on the Santa Margarita River.

Since Adobe and Cole Creeks and Arroyo Seco are designated no impact reference streams representing “background conditions,” elevated levels of constituents within these streams indicate naturally high levels (with only natural sources and aerial deposition accounting for nutrient input). The second year of sampling indicated naturally high levels of TN in the region while TP levels are very variable in the second year with a few sites exceeding the Basin Plan limit. All TN measurements at Cole exceeded the limit while Adobe Creek and Arroyo Seco TN measurements appeared to be trending upward toward the Basin Plan limit over time (although the sampling history for these sites is minimal, and sampling occurrences are limited by the ephemeral nature of the streams).

Pesticides were analyzed on multiple occasions at De Luz and Sandia Creeks as well as at the FPUD Sump and Gorge. Out of 107 pesticides that were analyzed, 15 were detected. Of the 15 detected, 12 pesticides were detected only on the February 2009 sampling date which had high flows. Typically, pesticides may often be detected during storm flows and sporadically at other times. Simazine was ubiquitous during all pesticide sampling events at all four analyzed locations (except on one occasion at Santa Margarita River near Temecula) and increased with storm flows. An increase in pesticide detection during storms appears to be due to the large amount of runoff from agricultural areas and lawns into tributaries to the river.

Pharmaceuticals and other emergent constituents were detected sporadically during the sampling period. The sparse nature of the dataset makes characterization of sources extremely difficult at this time.

The conceptual models for the system were updated based on the findings in the field studies, habitat assessments, and water quality assessments. In general, the conceptual models created through expert discussions, literature review, and reviews accurately predicted the major impacts and threats to the watershed. However, a major change in our understanding is the role that agricultural land uses play in the lower watershed. This land use type seems to have a significant potential impact on water quality and species/habitats. This was evidenced by the nutrient analysis and detections of pesticides. Additionally, the water quality monitoring program considered pharmaceuticals and emerging constituents. These constituents pose a periodic problem in the watershed, usually after peak flow events. Incorporating this new understanding into the conceptual models, it seems that pharmaceuticals and emerging constituents may have posed a threat to key sensitive species, particularly the arroyo toad and tidewater goby.

Long-Term Trends

Analysis of historical and current nutrient, TDS, sulfate, iron, and manganese concentrations at the Gorge and the FPUD Sump indicate that nitrate and TP concentrations at these two sites had been the greatest during the period of the 1980s through the 1990s. The historic data show that manganese and iron concentrations have consistently exceeded the current Basin Plan objectives. Historical sulfate concentrations have generally been below the Basin Plan objective at the Gorge, but have been consistently over the limit at the FPUD Sump location. Since the inception of CWRMA augmentation, concentrations of all nutrient constituents, TDS, iron, and manganese have remained relatively low compared with the historical concentrations and sulfate concentrations have remained within the same range of historical concentrations.

Mass Loadings

Tributaries in agricultural areas (De Luz, Devils, and Sandia Creeks) contributed significant loadings of nitrogen (N as nitrate) to the Santa Margarita River. Of these tributaries, Sandia Creek contributed the highest loadings. Murrieta and Temecula Creeks are both listed as impaired for TN and may have contributed large loadings to the Santa Margarita River based on loading calculations at the Gorge. TN loadings appeared to be high for the entire river from the

Gorge to Ysidora. The majority of TN contribution from these streams was in the form of nitrate.

TP loadings are a concern for the entire river. This is likely due to elevated concentrations at both Murrieta and Temecula Creeks at the head of the Santa Margarita River as well as naturally higher levels of phosphorus in the lower watershed. TP loadings to the river increased downstream, which was likely due to significant contributions from Rainbow and Sandia Creeks.

De Luz, Rainbow, and Sandia Creeks are listed as impaired for TDS. All three of these creeks contributed considerable amounts of TDS to the Santa Margarita River, although De Luz Creek flowed to the Santa Margarita River only during winter months. In the middle and upper watershed, Temecula Creek is listed as impaired for TDS and may have been a large contributor of TDS to the Santa Margarita River based on calculated loadings for the Gorge. TDS loading appeared to be high for the entire river from the Gorge to Ysidora.

Rainbow and Sandia Creeks are listed as impaired for sulfate. Sandia Creek contributed a significant amount of sulfate to the Santa Margarita River. De Luz Creek contributed less due to its intermittent nature. Due to the fact that downstream sulfate data were unavailable, the impact of Sandia Creek sulfate loadings on water quality, downstream of the confluence with the Santa Margarita River, were indeterminate.

De Luz, Rainbow, and Sandia Creeks are listed as impaired for iron. High iron concentrations were detected at these creeks as well as Fallbrook Creek. Of these creeks with elevated levels of iron, Sandia Creek contributed the most. In the middle watershed, Murrieta Creek is listed as impaired for iron and may have been a large contributor to the Santa Margarita River, as iron loadings at the Gorge ranged from 0.4 kg/day to 19 kg/day.

De Luz and Sandia Creeks are listed as impaired for manganese; however, elevated levels of manganese were not detected in these creeks. Fallbrook Creek is not listed, but it had the highest manganese concentrations reported within the study area. The highest manganese loadings from the tributaries occurred during winter flows. Manganese loading at the Gorge was negligible while loadings at the FPUD Sump are substantial. However, the contribution of manganese upstream of the FPUD Sump was uncertain due to the scarcity of sample data from sites in this reach of the river.

Nutrient Assimilative Capacity

Analyzing the ratio of nitrogen to phosphorus provides insight into which was the "limiting nutrient" that controls plant growth when not available in sufficient quantities. The ratio of nitrogen to phosphorus in biomass is approximately 7.2 to 1. Therefore, an N:P ratio in the water that is less than 7.2 suggests that nitrogen is limiting. Alternatively, higher ratios suggest that phosphorus is limiting. Phosphorus appeared to be the limiting nutrient in the upper portion of the study area while nitrogen was the limiting nutrient near and within Camp Pendleton. Adobe Creek and the Santa Margarita River at the Gorge showed strong seasonal variation of nitrogen to phosphorus ratios.

Due to limited loading data, assimilative capacity was calculated for discrete periods rather than annually. A mass-balance approach to analyzing nutrient loadings and transformation within the Lower Santa Margarita River revealed that throughout the year, the Santa Margarita River was able to assimilate TN from the Gorge through the MWD Crossing. Between the MWD Crossing and the FPUD Sump, loadings from tributaries increased and assimilation of all of the TN was not possible. The Santa Margarita River appeared able to recover downstream of the FPUD Sump due to assimilative capacity for TN between the FPUD Sump and Ysidora. TN appeared to be the limiting nutrient in the lower Santa Margarita River and was likely the reason for a high assimilation within that reach. Nitrate assimilation followed similar patterns and made up the largest fraction of TN loadings.

The Nutrient Numeric Endpoint (NNE) spreadsheet model was used to assess whether the reach from the confluence with Rainbow Creek to below the confluence with Sandia Creek was impaired for nutrients, or whether it possessed assimilative capacity for nutrients. Five of the six model runs targeting the BURC I threshold indicated that currently observed mean levels of TN and TP were low enough to consider that Santa Margarita River reach unimpaired.

The ratio of TN to TP observed in the river and its tributaries, as well as the sensitivity analysis for the NNE spreadsheet model, indicated that portions of the Lower Santa Margarita River were not responsive to excessive amounts of TN, but rather they appeared to be limited for phosphorus and solar radiation. Hence the low value of phosphorus relative to nitrogen and the relatively high amount of topographic and canopy shading were likely significant in limiting excessive algae growth.

CWRMA Impacts Upon Hydrology

Based on the mass balance of total flow, augmented flow, and naturally occurring flow, CWRMA releases were a significant portion of the baseflows of the Santa Margarita River.

During the period January 2003 to December 2009, augmentation was 17% of the total flow in the river. On a monthly basis, it ranged from 0% when there were no releases, to 100% of the flow in the river where there was no natural runoff in the river. During summer months, when there was little to no natural runoff in the river, augmentation water was a significant percentage of the total flow, usually more than 90%, illustrating that CWRMA augmentation water had the most significant impact on the flow regime during dry periods. An exceedance analysis revealed that without augmentation, the river at the Gorge would have been dry 24% of the time. With augmentation the river was never dry.

CWRMA Impacts Upon Water Quality

During the CWRMA flow experiment, the reduction of CWRMA flow had the impact of slightly increasing TDS concentrations at the MWD Crossing location. The reduction of CWRMA flows during the flow experiment showed that nitrate as N concentrations increased as a result of CWRMA, also indicating the CWRMA's influence on reducing nitrate concentrations downstream.

Concentrations of TDS, nitrate as N, and TP during the CWRMA augmented years were statistically lower in concentration at the Gorge than in all prior designated periods. At the FPUD Sump, TP exhibited lower concentration during CWRMA period; however, TDS and Nitrate concentrations did not exhibit a significant difference over historical water quality periods. This suggests that the influence of CWRMA may not have extended downstream to the FPUD Sump. It is most likely that the differences in TP and the other constituent (sulfate, pH, and conductivity) concentrations were due to other historical factors, as well as contributions by tributaries.

While the impact of the addition of CWRMA flows was largely inconclusive due to limited data, when compared with current natural flows at the Gorge (with the exception of TDS), the impact of the CWRMA augmentation was significant on downstream water quality. When compared with the water quality of major contributing tributaries, the concentrations of most nutrient components as well as TDS were significantly less than had the CWRMA augmentation flows not been released. While it could not be quantitatively shown to have this effect on water quality in the lower river (i.e. due to infiltration, subflow, and assimilative capacity), the reduced concentrations of nutrient components at Santa Margarita River main stem locations were no doubt caused in part by the addition of the CWRMA flows. However, as the net nutrient assimilative capacity increases downstream, CWRMA dilution appeared to become less of an influence on water quality, as shown by the low concentrations of nutrient components at downstream main stem sampling locations.

CWRMA Impacts upon Wetlands and Sensitive Species Habitat

In an effort to address how changes in the watershed will impact the key sensitive species, a conceptual model was developed based on expert opinion, supporting literature (e.g. recovery plans) and general understanding of species habitat associations, natural history, and life history characteristics. Any changes in habitat due to releases of imported CWRMA water will likely result in changes to the habitat or natural resources used by the sensitive species. In assessing the overall impacts to listed species, a review of each species was conducted, identifying the potential stressors and threats to each individual species. The model indicated that the greatest impact would likely occur directly to the water quality and aquatic habitat, emanating from changes in the chemical and physical characteristics of the water (e.g. pH, DO, temperature, nutrients, metals, turbidity, and pesticides/herbicides). Additional threats would come from invasive species, habitat fragmentation, alteration of the natural fire regime, and geomorphic change. Limited impacts would be seen from changes in hydrologic regime, mostly related to potential decreases in water flow and changes in the extent of flood events. The conceptual model predicts that the greatest impacts to key sensitive species would come from invasive species, metals, pesticides/herbicides, and floods. Moderate impacts would come from turbidity, increases in base flow, pH, dissolved oxygen, nutrients, habitat fragmentation, erosion and sedimentation, bank incision, and temperature. Low impacts are anticipated from increased ponding.

Significant impacts of CWRMA releases on physical pool conditions appeared to be limited to the MWD Crossing reach. Impacts from CWRMA releases became gradually less influential farther downstream. There appeared to be no significant impact upon pool conditions at the Ysidora and Levee reach. The level of CWRMA augmentation appeared to have no major negative impact on the sensitive species examined. Field observations indicated that the augmentation to base flows actually provided significant improvements to available habitat for each of the species of concern. With more available water, the riparian area followed a more natural regime. In much of the upper river, the river flows through a fairly narrow channel and across bedrock. Changes in water flows did not seem to have a significant effect on habitat. However, the CWRMA did seem to influence the depth of the water, which may have directly impacted aquatic species and the types and complexity of available habitat. Lower in the watershed, changes in flow levels had an obvious impact on the amount of available water, pools, and habitat for key species like the arroyo toad. Hydrological effects to track closely would be decreases in flows to the point of providing little water for breeding habitat, or increases in flows that may increase the number of off-channel pools that could support significant populations of bullfrog. This would be extremely detrimental to the arroyo toad, since the bullfrog is known to be a significant predator of the arroyo toad. Overall, it appeared that the CWRMA augmentation flows actually had a beneficial effect on the key sensitive species by increasing the amount of available habitat.

Key Management Questions

The Task Order specified a number of Key Management Questions to be addressed by this study. Table 7-1 in the conclusions section lists both the questions and answers addressed by this monitoring program. The questions were categorized in groups dealing with contaminant sources, hydrodynamics and water quality, and impacts to wildlife, habitat, and wetlands. The answers provided represent short-hand responses for the analysis and findings from throughout this report and the appendices.

Recommendations

The Study Team has assembled the following recommendations to continue development of conceptual models and understanding of the physical processes of the Santa Margarita River. Continued monitoring will facilitate tracking of water quality trends. Increased frequency of data collection will allow for more accurate models and estimates of both assimilative capacity and mass loading. Continued biological monitoring will support the relationships between flow, geomorphology, and habitat.

- General Chemistry:

  Continue to monitor at existing locations to track trends in water quality.

- Pesticides, Pharmaceuticals and Other Emergent Contaminants:

  Conduct sampling for these constituents during storm flows and sample more often and at more locations including major developed tributaries to determine sources.

- Nutrients:

  Continue to monitor at the existing locations as well as two additional sampling locations upstream of the Gorge (Murrieta and Temecula Creeks) in order to establish a sufficient data set for use in regulatory proceedings such as TMDL and Site-Specific Objective development and application of the NNE to set nutrient targets for the watershed. Conduct sampling and investigation focused on more fully characterizing limiting nutrients and identifying specific sources of nutrient loading in order to support water quality management initiatives including TMDLs.

- Sampling Frequency:

  In order to better characterize sources of constituents, and to produce datasets sufficient for calculating annual loadings, sample for all constituents of concern monthly at all locations, capture storm events, and measure flow at the non-USGS gage sites regularly. [Calculation of annual loadings will be a requirement for development of nutrient TMDLs for the watershed, which RWQCB staff members have indicated is a near/mid term regulatory priority.]

- CWRMA Hydrology:

  Continue to collect flow data throughout the year on the Santa Margarita River and tributaries in order to better understand how CWRMA releases at the Gorge affect flow rates downstream.

- CWRMA Water Quality:

  Continue to monitor the water quality of CWRMA releases in order to confirm compliance with Basin Plan limits and characterize the CWRMA's influence upon water quality in the river.

- CWRMA Related Geomorphology:

  To better understand the impact of the CWRMA upon river geomorphology and pool habitats, repeat the flow experiment and pool survey in the absence of beavers, possibly coordinating with agencies responsible for administering "beaver control" programs. The flow experiment should include both reduction and increase of CWRMA flows.

- Background Water Quality:

  Collect water quality samples upstream of the CWRMA outfall, or in both Temecula and Murrieta Creeks, to determine the background water quality of the Santa Margarita River before CWRMA water is released. These creeks are listed as impaired for iron, manganese, nitrogen, phosphorus and TDS indicating they likely impact water quality downstream.

- NNE and River Impairment:

  Collect or assemble a dataset sufficient to run the NNE spreadsheet model for other reaches and tributaries of the river in order to determine where the river is most susceptible to impairment. Likely candidates include the river at the Gorge, and MWD Crossing, and Ysidora, Rainbow Creek, and Sandia Creek.

1.0 INTRODUCTION AND BACKGROUND

This report was prepared under Bureau of Reclamation (Reclamation) Task Order #07PE308086, including monitoring of water quality, hydrological, and biological parameters of the Santa Margarita River and its tributaries. Stetson Engineers, Inc. (Stetson) and San Diego State University (SDSU) (collectively referred to as the "study team") employed a multi-task approach addressing all the issues specified in the Task Order. These tasks were undertaken as specified in the project Work Plan, Quality Assurance Project Plan (QAPP), and Health and Safety Plan (HASP) (Stetson 2007e, 2007d, and 2007a). This is the Final Report.

1.1 STUDY DESCRIPTION

Rivers and streams are highly connected to the relationship between atmospheric and terrestrial processes through the transport of water, nutrients, contamination, and energy (Williamson, et. al, 2008). Reclamation and Camp Pendleton employed this study to collect "sentinel" data used to define this relationship. The goals of the project were three-fold: 1) characterize the water quality patterns of the Santa Margarita River; 2) assess assimilative capacity for nutrients, and 3) determine the impacts of the Cooperative Water Resource Management Agreement (CWRMA) on the hydrology, geomorphology, and biology of the river in accordance with Article 5(g) of the agreement. The first goal addressed two key interests for Reclamation and Camp Pendleton: the quality of drinking water and quantity of water supply. Water quality and quantity are key aspects of source water protection for the Base.

The second goal supported the Reclamation-led Santa Margarita River Executive Management Team as it develops a watershed model to characterize the assimilative capacity of the Santa Margarita River for nutrients. In support of this modeling initiative, as well as the recent Regional Water Quality Control Board (RWQCB) Investigation Order (#R9-2006-076) mandating a sampling program for nutrients in the estuary, this water quality monitoring program was designed to collect data regarding nutrient inputs and eutrophication in a regimen that closely followed that required under the Investigation Order for the estuary (RWQCB, 2006 and CDM, 2007b). This monitoring program also collected data on indicators of ecological function such as periphyton and macrophyton. By collecting this assortment of data, the monitoring program supported use of the watershed model to assess the assimilative capacity for nutrients throughout the lower river, assess attainment of important beneficial uses, support Use Attainability Analyses of designated beneficial uses, refine Water Quality Objectives, and develop and implement Total Maximum Daily Loads (TMDLs). Each of these regulatory processes has been considered by the Base, Reclamation, and their partners within the watershed, and this program provides the data needed to support such processes.

The third goal examined the influence of the CWRMA on hydrological and biological resources of the Santa Margarita River. The CWRMA augments streamflow of the Santa Margarita River to match two-thirds of the natural base flow. Currently, imported water from the Colorado River and California State Water Project is released into the Santa Margarita River to meet minimum flow requirements.

1.2 STUDY AREA

The Santa Margarita River Watershed is located in northern San Diego and southern Riverside Counties, California (Figure 1). The Study area is the Lower Santa Margarita River watershed, which can be defined by the Santa Margarita River, and by the tributaries than drain into the river below the confluence of Temecula and Murrieta Creeks. Outside of, but influencing the study area, is the Upper watershed. The Upper Santa Margarita River watershed is defined by the streams that drain the area upstream of the Gorge and include approximately 588 sq-mi. of drainage area.

1.3 GENERAL WATERSHED CHARACTERISTICS

The Santa Margarita River and its tributary streams, including Murrieta, Temecula, Pechanga, Devils, Stone, Rainbow, Sandia, De Luz, and Fallbrook Creeks drain a watershed nearly 744 sq. mi. in size. The watershed lies in both San Diego and Riverside Counties, with over 60 sq. mi. contained within the bounds of Camp Pendleton. Its headwater streams (Temecula, Murrieta, Wilson, Santa Gertrudis, Tucalota, and Warm Springs) drain off the western slopes of the San Jacinto Mountains, the northern slopes of the Palomar Mountains, and the eastern slopes of the Santa Rosa Plateau to the Temecula Valley. The 27-mile long main stem portion of the river begins at the confluence of Murrieta and Temecula Creeks, at the head of Temecula Canyon, and terminates at the Pacific Ocean at the Santa Margarita Estuary.

The USGS has delineated and classified the Santa Margarita River watershed as the Santa Margarita Hydrologic Unit (HU) 18070302. The hydrologic unit encompasses the total 744 sq. mi. drainage area of the Santa Margarita River. The RWQCB further dissects the HU into Hydrologic Areas (HA) and Hydrologic Sub Areas (HSA). These delineations are based on major tributary watersheds, or a major valley containing one or more groundwater basins and having closely related geologic, hydrologic, and topographic characteristics. Area boundaries are based primarily on surface drainage boundaries. The Lower Santa Margarita groundwater basin is contained in the Ysidora Hydrologic Area (HA 902.10), and is further subdivided into the Lower Ysidora (HSA 902.11), the Chappo (HSA 902.12), and the Upper Ysidora (HSA 902.13) Hydrologic Sub Areas.

FIGURE 1

STETSON ENGINEERS INC.

SANTA MARGARITA RIVER WATERSHED LOCATION MAP

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1.3.1 Geologic Setting

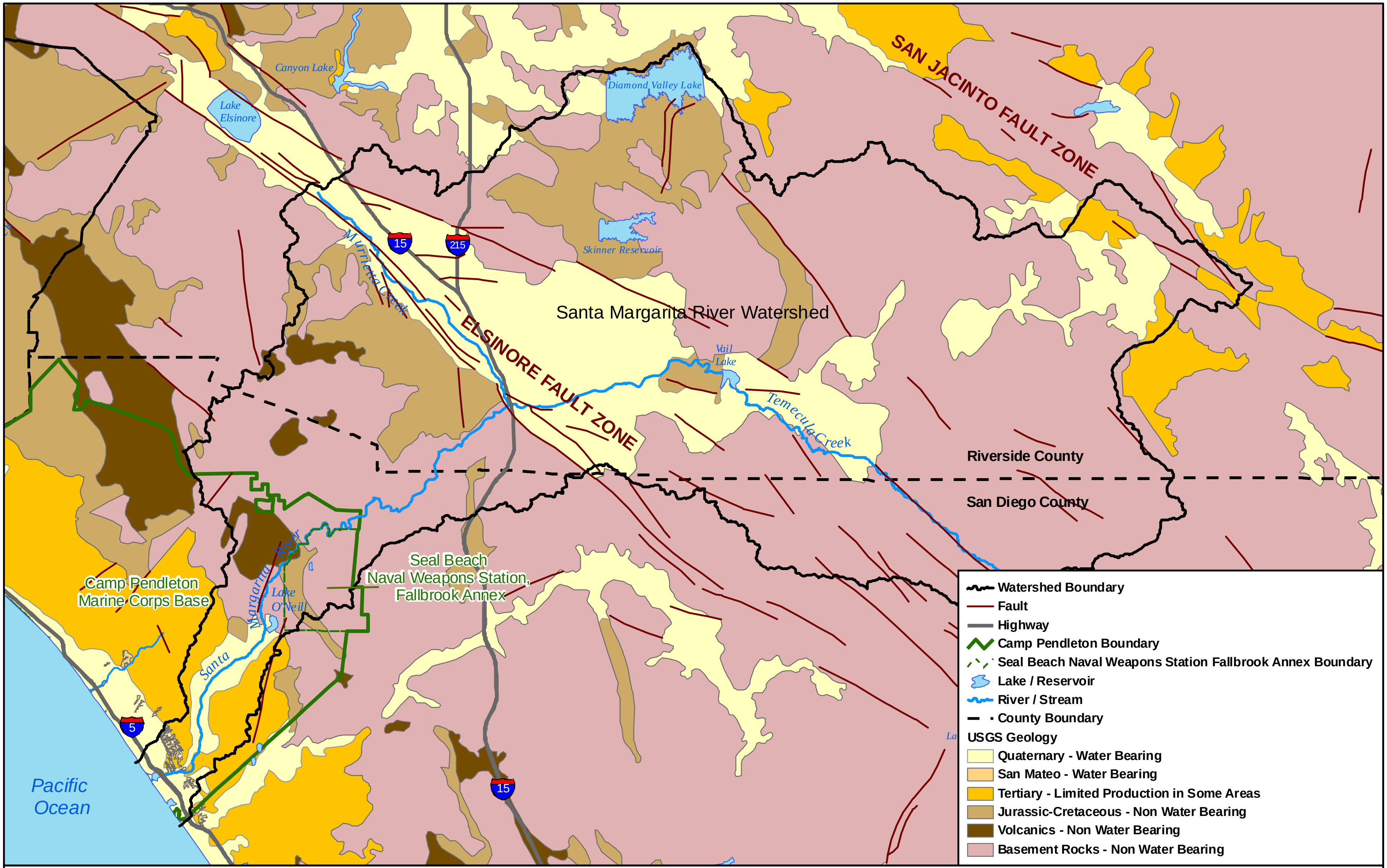
The geology in the vicinity of Camp Pendleton was initially mapped by Worts and Boss (1954). Their report included detailed cross-sections developed from well logs in each groundwater basin on the Base. Worts and Boss distinguished between younger and older water bearing units and delineated the extent of each groundwater basin. In 1973, W. R. Moyle refined and re-published the United States Geological Survey (USGS) geologic map for the Santa Margarita basin. Figure 2 shows the geologic formations and faults in the Santa Margarita River watershed.

The basement rocks of the Peninsular Range Batholith form the hills and mountains that define the upper portions of the Santa Margarita River watershed. These rocks are the oldest geologic units exposed and are comprised of intrusive igneous, metasedimentary, and metavolcanic rocks of Cretaceous and Jurassic age (KJ) that are often resistant to erosion. The younger Cretaceous consolidated bedrock (K) includes the Trabuco Formation, a non-marine fanglomerate, and the Williams Formation, a marine siltstone, sandstone, and cobble conglomerate (SDAG 1975, 1994, and 2001).

During the Tertiary Period, there was continued uplift of the Peninsular Range Batholith, coinciding with various sea level changes. Whenever a relative rise in sea level occurred (a marine transgression), marine strata were deposited on top of terrestrial strata. Conversely, whenever a relative fall in sea level occurred (marine regression), terrestrial strata were deposited over marine strata. Both marine and non-marine sedimentary rocks were deposited during this period, including sandstone, breccia, and shale. The Eocene Santiago Formation (Tsa) is marine silty/clayey sandstone interbedded with greenish-gray siltstone outcrops. The middle to upper Miocene age San Onofre Formation (Tso) consists primarily of breccia with lesser amounts of conglomerate and sandstone. It is found in the lower portions of the Santa Margarita Basin. The Santa Margarita Basin produces groundwater solely from younger alluvium (Qya) deposits of recent (Quaternary) age (SDAG 1975, 1994, and 2001).

1.3.2 Climate

Climate in the Santa Margarita River watershed is characteristic of a Mediterranean climate, experiencing hot dry summers and mild, wet winters. This semi-arid, coastal climate is typical of southern California. The lower watershed’s climate is controlled by the Pacific Ocean, which provides light to moderate precipitation during the winter months (November to April). Occasional heavy rains, creating major flooding events for this region, typically occur in the winter months between December and March.



GEOLOGY IN THE REGION OF THE SANTA MARGARITA RIVER WATERSHED

STETSON ENGINEERS INC.

SOURCES:
1) San Mateo Geology, Kennedy and Tam, 2005.
2) Faults, Saucedo and others, 2000

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FIGURE 2

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Temperatures generally range between 33° and 90° Fahrenheit (Malloy, 2006). The region is exposed to dry easterly Santa Ana winds in the fall and heavy fog in the summer. Frosts are light and infrequent, occurring occasionally in winter, with the growing season ranging from 345 to 360 days. Temperatures are cooler near the ocean and warmer inland. On the coast, the average high temperature is 67° Fahrenheit and the average low is 53° Fahrenheit. Inland, the average high is 80° Fahrenheit and the average low is 47 degrees1 (WRCC, 2009).

Table 1-1 presents the location and period of record for precipitation stations used to characterize rainfall in the lower watershed. Precipitation stations were included from the following agencies: Riverside County Flood Control and Water Conservation District (RCFCD), SDSU, Camp Pendleton Office of Water Resources (OWR), and the National Weather Service (NWS). Table 1-2 presents a summary of annual precipitation. Precipitation occurs mostly between December and April, averaging 10.4 inches in the City of Oceanside and approximately 14 inches at the Wildomar station. Most precipitation is associated with low intensity storms in winter and spring. Historical precipitation data are presented in Appendix A.

TABLE 1-1 PRECIPITATION STATIONS USED TO CHARACTERIZE THE LOWER WATERSHED

Station Name	Operating Agency[1]	Elevation[2] (ft above MSL)	Latitude[3]	Longitude[3]	Period of Record	
					From	To
Wildomar	RCFCD	1,255	33°37’30”	-117°20’06”	10/1914	9/2009
SMER North	SDSU	1,132	33°27’28”	-117°10’15”	1/2004	6/2009
FNWS Ammo Dump	OWR	1,068	33°22’53”	-117°17’08”	7/2002	6/2009
Lake O'Neill	OWR	120	33°19’46”	-117°19’10”	7/1876	6/2009
Oceanside Marina	NWS	100	33°12’35”	-117°23’42”	12/1943	9/2008

[1] All data were received from the specified operating agency in 2009.

[2] Elevation referenced to National Geodetic Vertical Datum of 1929 (NGVD29)

[3] Latitude and Longitude referenced to North American Datum of 1927 (NAD27), except Oceanside Marina which is referenced to North American Datum of 1983 (NAD83).

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[1] Coastal data from National Weather Service (NWS) cooperative system at Oceanside Marina (#046377); Inland data from NWS at Elsinore (#042805)

TABLE 1-2 SUMMARY OF ANNUAL PRECIPITATION

Station Name	Period of Record (Water Years)	Period of Record Statistic (in.)				WY 2008		WY 2009[1]	
		Average	Median	Max	Min	Total (in.)	Percent of Average	Total (in.)	Percent of Average
Wildomar	1914-2009	13.8	11.7	34.8	3.1	14.1	102	12.8	93
SMER North	2004-2009	14.7	10.6	33.1	3.3	16.2	110	10.6	72
FNWS Ammo Dump	2002-2009	12.5	10.7	30.4	0.1	15.0	120	10.7	86
Lake O'Neill	1876-2009	14.0	12.2	35.0	4.3	14.8	106	10.1	72
Oceanside Marina	1944-2005[2]	10.4	9.0	24.6	3.8	---	---	---	---

[1] Values for July through September 2009 are estimated

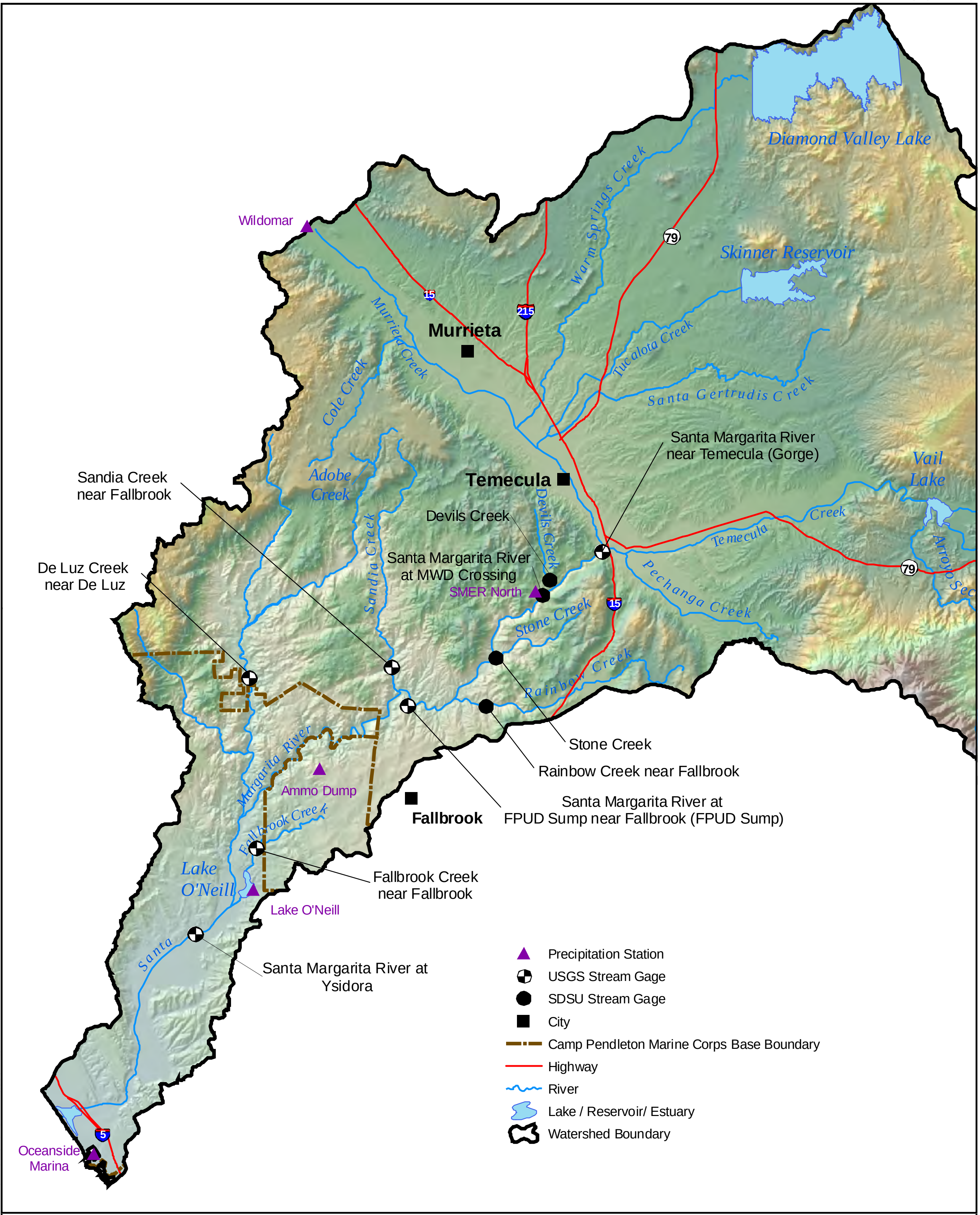
[2] Records at Oceanside Marina for WY 2007-2009 are poor and statistics cannot be computed.

1.3.3 Streamflow

Available streamflow data were compiled from USGS and SDSU. The locations of active stream gage stations in the lower watershed are shown in Figure 3. The USGS maintains five active gages in the study area while SDSU maintains three. The SDSU gages, which have been active for fewer than ten years, record stage only and are not rated for streamflow. A summary of active USGS stream gage station information is shown in Table 1-3. All data presented in this report for USGS stream gages were compiled from the USGS website (USGS Streamflow). SDSU stage gages are listed in Table 1-4. Monthly USGS streamflow records are presented in Appendix Tables B-1 through B-6. Daily streamflow and stage are graphed in Appendix Figures B-1 and B-2. Graphs of historical precipitation and streamflow are presented in Appendix Figure B-3.

The streamflow data characterize Fallbrook Creek and De Luz Creek as ephemeral streams, typical of arid climates where the river is dry for long periods of time in the summer months. The streamflow data characterize the Santa Margarita River and Sandia Creek as more perennial streams. Stone Creek and Devils Creek appear to have year-round flows, though these flows are minimal and may be due to agricultural irrigation return flows.

FIGURE 3



ACTIVE STREAM GAGES AND PRECIPITATION STATIONS IN THE LOWER SANTA MARGARITA RIVER WATERSHED

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TABLE 1-3 ACTIVE USGS STREAMFLOW GAGES IN STUDY AREA THROUGH WY 2009

Gage Name and Number	Period of Record	Drainage Area (mi²)	Elevation[1] (ft. above MSL)	Annual Flow Statistics, AFY Average	Median	Max	Min
Santa Margarita River Near Temecula (#11044000)	1923-present	588	950	16,488	6,169	132,446	1,571
Santa Margarita River at FPUD Sump (#11044300)	1989-present	620	330	30,136	13,127	158,955	3,790
Sandia Creek near Fallbrook (#11044350)	1989-present	21	380	6,945	4,354	26,677	1,897
De Luz Creek at De Luz (#11044800)	1992-present	33	270	4,625	1,867	29,323	264
Fallbrook Creek Near Fallbrook (#11045300)	1993-present	7	190	1,138	665	3,924	127
Santa Margarita River at Ysidora (#11046000)	1923-present	723	75	30,413	10,371	243,988	0

[1] Elevation referenced to NGVD29

TABLE 1-4 SDSU STAGE GAGES IN STUDY AREA

Gage Name	Period of Record	Drainage Area (mi²)	Elevation[1] (ft. above MSL)
Devils Creek	2004-present	2	1,115
Santa Margarita River at MWD Crossing	2002-present	590	742
Stone Creek	2007-2008[2]	4	480

[1] Elevation referenced to NGVD29

[2] Gage was discontinued in January 2009.

1.3.4 Habitat and Species

The Santa Margarita River is the single largest and finest example of a river and estuary system in southern California (Anchor, 2005). The river and estuary support populations of eleven federally-listed endangered species. The relatively undisturbed physical features of the river's floodplain and estuary make a diversity of habitats and abundance of wildlife possible in an otherwise heavily developed coastal region. Table 1-5 lists the federally listed species known to occur in the watershed.

TABLE 1-5 FEDERALLY LISTED THREATENED AND ENDANGERED SPECIES

Aquatic, Riparian, Estuarine, and Beach Habitat Species		Upland and Vernal Pool Habitat Species	
Least Bell's vireo	*Vireo bellii pusillus*	San Diego fairy shrimp	*Branchinecta sandiegoensis*
Southwestern willow flycatcher	*Empidonax traillii extimus*	Riverside fairy shrimp	*Streptocephalus wootoni*
Arroyo southwestern toad	*Bufo californicus*	Stephen's kangaroo rat	*Dipodomys stephensi*
Light-footed clapper rail	*Rallus longirostris levipes*	Coastal California gnatcatcher	*Polioptila californica*
Western snowy plover	*Charadrius alexandrinus nivosus*	San Diego button celery	*Eryngium aristulatum* var. *parishii*
California least tern	*Sternula antillarum browni*	San Diego Ambrosia	*Ambrosia pumila*
California brown pelican	*Pelecanus occidentalis californicus*	Nevin's barberry	*Berberis nevinii*
Tidewater goby (occasional)	*Eucycologobius newberryi*	Thread-leaved brodiaea	*Brodiaea filifolia*
Coastal dunes milk vetch	*Astragalus tener var. titi*	Spreading navarretia	*Navarretia fossalis*
Peregrine Falcon	*Falco peregrinus anatum*	Pacific pocket mouse	*Perognathus californicus*
Brand's phacelia (candidate)	*Phacelia stellaris*	California orcutt grass	*Orcuttia californica*
Southern steelhead (historic)	*Oncorhynchus mykiss irideus*		
California red-legged frog (historic)	*Rana aurora draytonii*		

1.3.4.1 Southern California Riparian Forest

The riparian forest along the Santa Margarita River is likely the most intact such corridor remaining in southern California south of Malibu (Anchor, 2005). Riparian vegetation depends on two key processes: groundwater levels and periodic scouring flood flows. Depth to groundwater is critical for the establishment and maintenance of riparian woodland, vegetation, surface flows, and pools. High flows scour existing vegetation, creating opportunities for recruitment of young trees, resetting succession, and maintaining areas of open friable soils. The riparian forest habitat hosts several listed species, including the federally and state-listed endangered least Bell's vireo, the federally and state-listed endangered southwestern willow flycatcher, and federally endangered arroyo toad. The vireo prefers early succession willow scrub habitat, while the flycatcher prefers taller, more mature willow stands. The arroyo toad depends on open patches of loose sand for burrowing and, within the stream channel, pools with sandy bottoms for laying its eggs. Riparian vegetation also improves aquatic habitat quality by shading the stream and providing physical structure (e.g. roots allow creation of undercut banks) (Anchor, 2005; Stetson, 2007c).

1.3.4.2 Southern California Coastal Stream

The Santa Margarita River coastal stream community provides habitat for native fish such as the arroyo chub and the Pacific lamprey. Additionally, southern steelhead and partially-armored threespine stickleback may have historically occurred in the river. Steelhead still occasionally spawn in nearby San Mateo Creek (NMFS, 2009). Native herpetofauna include arroyo toad, southern Pacific pond turtle, southwestern pond turtle, coast range newt, and historically, the federally threatened California red-legged frog (Stetson, 2007c).

1.3.4.3 Riparian Forest, Coastal Sage Scrub and Chaparral Ensemble

The Santa Margarita supports substantial relatively intact riparian forests along the middle and lower reaches. Some segments, largely on Camp Pendleton, support the Least Bell's Vireo (Rourke and Kus, 2007) and the Southwestern Willow Flycatcher (Kenwood and Kus, 2007). In the same region of the river the coastal sage scrub and chaparral habitats support small populations of the coastal California Gnatcatcher (CalPIF, 2004).

1.3.4.4 Coastal Wetland and Dune Ensemble

Coastal wetlands and dunes at the mouth of the Santa Margarita River provide habitat for the federally endangered tidewater goby, the federally and state-listed endangered California least tern, the federally threatened western snowy plover, the federally and state-listed endangered light-footed clapper rail, and the federal candidate Brand's phacelia, as well as other rare and sensitive species. The tidewater goby periodically inhabits the Santa Margarita River estuary and appears to function in a metapopulation dynamic, periodically experiencing local extirpation and recolonization (Stetson, 2007c). Clapper rails are also a coastal wetlands species with a few recent occurrences in the cattail-dominated portions of the estuary. The tern and the plover nest in the open sand of the coastal dunes. Brand's phacelia is a small plant that inhabits areas of open, sandy soils near the mouth of the Santa Margarita River (Anchor, 2005; Stetson, 2007c).

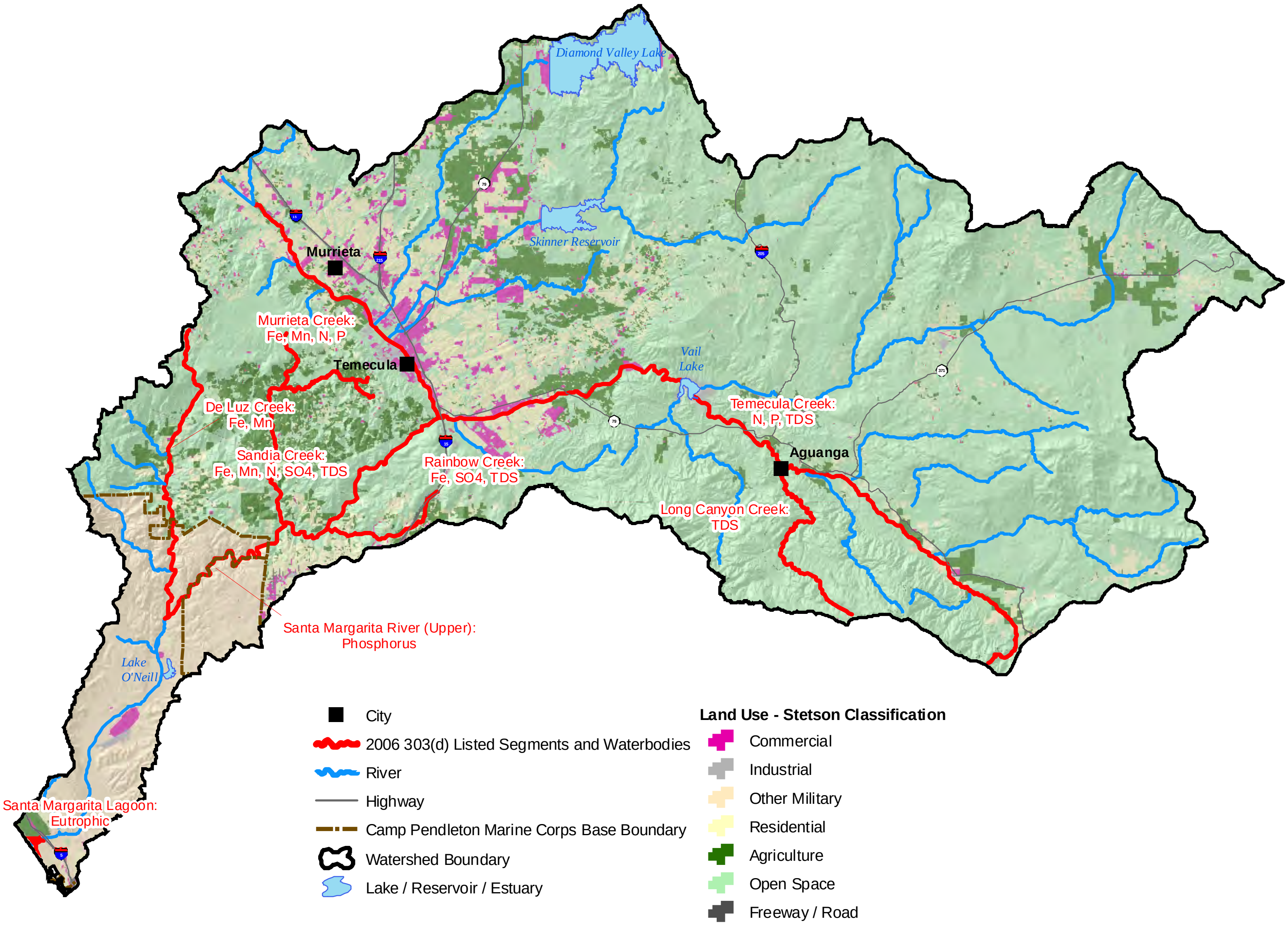
1.4 WATER QUALITY

While the lower watershed is often characterized as an intact, functioning ecosystem, the Santa Margarita River is listed as a California Unified Watershed Assessment Category I watershed, which identifies it as a candidate for increased restoration activities due to impaired water quality or other impaired natural resource goals. Additionally, the lower watershed contains six water bodies listed by the state as “impaired” and the Watershed Management Plan lists impacts from erosion, sedimentation, nutrient enrichment, flooding, an overdrawn aquifer in the Temecula valley, and other products of agriculture and urbanization (Anchor, 2005). The San Diego RWQCB has developed a TMDL for nutrients within Rainbow Creek, a tributary to the main stem of the river. This is the only stream within the watershed for which a TMDL has been developed. The RWQCB is in the process of developing nutrient TMDLs for eutrophic conditions in the Santa Margarita River Estuary using data collected by the “Lagoon TMDL Group,” and the RWQCB has approached stakeholders regarding water quality sampling necessary for TMDL development in the remainder of the watershed. The tributaries and reaches of the Santa Margarita River that have been listed as impaired by the State of California are presented in Table 1-6 and shown graphically in Figure 4. In its draft 2008 303(d) List, the RWQCB has markedly increased the number of impairment designations in the watershed (apparently due to examination of additional data not previously considered, rather than new indications of recent impairment). Eight constituents were added in the lower watershed, and two constituents were proposed for delisting. In the upper watershed, which is outside the scope of monitoring for this study, thirteen constituents were added (there are now twenty-one listings), and two were proposed for delisting. The 2008 303(d) list has not yet been approved by United States Environmental Protection Agency (USEPA).

Despite these conditions, the watershed is one of the least disturbed along the southern California coast (SCCWRP, 2007 and Gorham-Test, 2008), and the Santa Margarita River is the longest free flowing river in the region. A detailed description of the Santa Margarita River watershed and a discussion of potential sources of contamination are provided by Anchor (2005) and Law Crandall (2000).

It should be noted that two significant changes affecting water quality and quantity have occurred in the lower Santa Margarita River during recent years:

- In January 2003, Rancho California Water District (RCWD) began releases of imported water near the head of the Gorge in accordance with the CWRMA; and,
- Camp Pendleton ceased discharge of secondary treated effluent in the lower Santa Margarita River Basin by 2003.



STETSON ENGINEERS INC.

IMPAIRED STREAM SEGMENTS AND WATERBODIES IN THE SANTA MARGARITA RIVER WATERSHED

FIGURE 4

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TABLE 1-6 LIST OF IMPAIRED WATER BODIES IN THE SANTA MARGARITA RIVER WATERSHED IDENTIFIED IN THE 2006 AND 2008 DRAFT 303(d) LIST

Waterbody	2006 List Impairments	Draft 2008 List Impairments
Santa Margarita River Lagoon[1]	Eutrophication	No change.
Santa Margarita River (Lower)	None	Add Enterococcus, Fecal Coliform, Nitrogen, Phosphorus, and Toxicity.
De Luz Creek	Iron, Manganese	Add Nitrogen and Sulfates.
Sandia Creek	Iron, Manganese, Nitrogen, Sulfates, TDS	Delist Manganese and Nitrogen
Rainbow Creek[2]	Iron, Sulfates, TDS	No change.
Santa Margarita River (Upper)	Phosphorus	Add Toxicity.
Murrieta Creek	Iron, Manganese, Nitrogen, Phosphorus	Add Chlorpyrifos, Copper, and Toxicity.
Santa Gertrudis Creek	None	Add Chlorpyrifos, Copper, E. Coli, Fecal Coliform, Iron, and Phosphorus.
Temecula Creek	Nitrogen, Phosphorus, TDS	Delist Nitrogen. Add Toxicity.
Warm Springs Creek	None	Add Iron, Nitrogen, and Phosphorus.
Long Canyon Creek	TDS	Delist TDS.

[1] TMDL development started in 2007; funds have been procured for a second round of sampling, however funding is on hold for TMDL development by the RWQCB.

[2] TMDLs for nitrogen and phosphorus established in 2006.

1.4.1 Sampled Constituent Sources

1.4.1.1 Urban Runoff

There are four major population centers within the watershed. The cities of Temecula and Murrieta are located above the Gorge, and the town of Fallbrook and Camp Pendleton are located below the Gorge. In the mid-1980s, development in the Rainbow Creek area near Fallbrook included many single family residences (Law Crandall, 2000; Anchor, 2005). Sandia and De Luz Creeks also experienced housing development in the mid-1980s (Law Crandall, 2000). Typically urban runoff contributes elevated concentrations of nutrients, salts, metals, insecticides, herbicides, pharmaceuticals, oils, and grease.

1.4.1.2 Agriculture

Large agricultural areas are present near Fallbrook, Temecula, Anza, and the estuary on Camp Pendleton. Avocados and citrus are the primary crops grown near Fallbrook. In the Temecula Valley, grapes, sod, and various other crops are cultivated. In the fields immediately north of the Santa Margarita River estuary, tomatoes, potatoes, and other crops are grown. In the mid-1980s, development in the Rainbow Creek area included several large nurseries, irrigated orchards, field crops, and pastures (Law Crandall, 2000; Anchor, 2005). Sandia and De Luz Creeks also experienced agricultural development in the mid-1980s (Law Crandall, 2000). Typically runoff from agricultural areas contributes elevated concentrations of nutrients (especially nitrate, ammonia, and phosphate), salts, metals, insecticides, herbicides, coliform, and sediment.

1.4.1.3 Reclaimed Water

In the Temecula and Murrieta areas, there are several wastewater treatment facilities. Reclaimed wastewater is used for irrigation at golf courses, landscaped areas, common areas within residential developments, and is spread in percolation ponds. Wastewater from Fallbrook is treated and discharged to a land outfall that is connected to the City of Oceanside's ocean outfall outside the Santa Margarita River watershed (Law Crandall, 2000). Camp Pendleton irrigates a golf course, horse pasture, and landscape with recycled water and disposes of the remainder of its effluent within its southern system via the Oceanside ocean outfall. Septic disposal systems are widespread throughout unincorporated areas of the watershed. Private landowners and larger facilities, such as recreational vehicle parks and campgrounds, discharge to on-site septic systems (Law Crandall, 2000). Recycled water use can contribute to elevated levels of nutrients, salts, and pharmaceuticals.

1.4.2 Document Review and Historical Data Collection

A number of ambient water quality monitoring studies have been performed in the watershed. An important first step was to compile the data from these studies and identify key data gaps. Analysis of these data provided insight into water quality trends. Stetson developed a bibliography of reports and information pertaining to water quality monitoring programs in the Santa Margarita River, as well as a comprehensive web-based database of water quality and related data (Appendix C). In addition to data already collected by Reclamation during the development of its watershed model and the Conjunctive Use Project, Stetson obtained data from the agencies listed in Table 1-7.

TABLE 1-7 AGENCIES CONTRIBUTING DATA

AGENCIES	DATA CONTRIBUTIONS
San Diego County	Water Quality, Periphyton
Riverside County	Water Quality, Precipitation
U.S. Geological Survey	Flow, Groundwater Quality
Santa Margarita River Watermaster	Flow, Water Quality
San Diego State University	Precipitation, Flow, Water Quality
Marine Corps Base Camp Pendleton	Precipitation, Flow, Water Quality
San Diego Regional Water Quality Control Board	Water Quality, Benthic Macro-invertebrates
U.S. Bureau of Reclamation	Water Quality Dataset for WARMF Model and Lagoon TMDL Monitoring
State Surface Water Ambient Monitoring Program (SWAMP)	Water Quality
USEPA Environmental Monitoring and Assessment Program	Water Quality

Surface water and groundwater quality data were collected by Camp Pendleton during 1999 and 2000 (Law Crandall, 2000). The results of this effort provided the first comprehensive database of historical data. The counties of San Diego and Riverside have been performing water quality monitoring in the watershed in compliance with RWQCB requirements under the Large Municipal Separate Storm Sewer System (MS4) program. The California Surface Water Ambient Monitoring Program (SWAMP) is designed to assess the conditions of surface waters throughout the state. The SWAMP water chemistry data included data from other sources, as well as new data collected for the SWAMP report. The new data were collected from the main stem of the Santa Margarita River and De Luz, Sandia, and Rainbow Creeks from 1998 to 2006. The Environmental Monitoring and Assessment Program (EMAP) was designed to monitor and assess national status and trends of ecological resources. The data used for this analysis were from the EMAP Western Pilot Study. The EMAP water quality data were collected from one-time samplings, carried out from 2000 through 2001. The sampling and analysis of the 2008-2009 water quality data collected by Stetson was conducted consistent with the SWAMP protocols, however due to the limitations of the historical datasets, cataloging of all the datasets did not follow the SWAMP protocol. Other than the data collected by Stetson and received through the SWAMP database, no assumption was made as to the compliance of the datasets with SWAMP.

1.4.3 Water Quality Thresholds and Basin Plan Limits

The Water Quality Control Plan for the San Diego Basin (Basin Plan), the California Code of Regulations (CCR), and the California Toxics Rule (CTR) are the primary sources of water chemistry thresholds (RWQCB, 1994). Water chemistry thresholds (limits) for aquatic life and human health standards used herein are presented in Table 1-8. Some anthropogenic chemicals have no applicable regulatory limits; however, sample results can be used to set a baseline and review for trends.

TABLE 1-8 WATER QUALITY THRESHOLDS

Sampled Constituent	Aquatic Life			Human Health (Municipal Supply/Recreation)		
	Threshold	Unit	Source[1]	Threshold	Unit	Source[1]
Aluminum	1	mg/L	BP	1	mg/L	CCR
Ammonia-NH_3^-	0.025	mg/L	BP	None		
Antimony	None			0.0056	mg/L	CTR
Arsenic	0.05	mg/L	BP	0.05	mg/L	CCR
Beryllium	None	mg/L	N/A	0.004	mg/L	CCR
Bicarbonate	None			None		
BOD_5	None			None		
Boron	0.75	mg/L	BP	None		
Cadmium	0.005	mg/L	BP	0.0022	mg/L	CTR
Calcium	None			None		
Chloride	250	mg/L	BP	500[2]	mg/L	CCR
Chromium	0.05	mg/L	BP	0.05	mg/L	CCR
Copper	0.009	mg/L	CTR	1.3	mg/L	CTR
Cyanide	5.2	µg/L	CTR	0.15	mg/L	CCR
Dissolved Oxygen	5	mg/L	BP	None		
Fecal Coliform	None			200	#/ml	BP
Fluoride	1	mg/L	BP	2	mg/L	CCR
Iron	0.3	mg/L	BP	0.3[2]	mg/L	CCR
Lead	0.0025	mg/L	CTR	None		
Manganese	0.05	mg/L	BP	0.05[2]	mg/L	CCR
Mercury	0.77	µg/L	CTR	0.002	mg/L	CCR
Nickel	0.052	mg/L	CTR	0.1	mg/L	CCR
Nitrate as NO_3	10	mg/L	BP	45	mg/l	CCR
Nitrite as N	None			1	mg/l	CCR
Oil and Grease	No visible film	narr.	BP	None		
pH	>6.5 and <8.5	pH	BP	None		
Selenium	5	µg/L	CTR	0.05	mg/L	CCR
Silver	0.0034	mg/L	CTR	0.1[2]	mg/L	CCR
Sodium	60[3]	%	BP	None		
Specific Conductivity	None			None		
Sulfate	250	mg/L	BP	250[2]	mg/L	CCR
Surfactants (MBAS)	0.5	mg/L	BP	0.5[2]	mg/L	CCR
Total Dissolved Solids	500	mg/L	BP	500[2]	mg/L	CCR
Thallium	None			0.002	mg/L	CCR
Total Organic Carbon	None			None		
Total N	1[4]	mg/L	BP	10	mg/L	CCR
Total P	0.1	mg/L	BP	None		
Turbidity	20	NTU	BP	5[2]	NTU	CCR
Zinc	0.12	mg/L	CTR	5[2]	mg/L	CCR
1,2,4-Trichlorobenzene	None			35	µg/L	CTR
1,2-Dichlorobenzene	None			420	µg/L	CTR
1,2-Diphenylhydrazine	None			0.036	µg/L	CTR
1,3-Dichlorobenzene	None			320	µg/L	CTR

	Aquatic Life			Human Health (Municipal Supply/Recreation)		
Sampled Constituent	**Threshold**	**Unit**	**Source[1]**	**Threshold**	**Unit**	**Source[1]**
1,4-Dichlorobenzene	None			63	µg/L	CTR
2,4'-DDD	None			None		
2,4'-DDE	None			None		
2,4'-DDT	None			None		
2,4-Dinitrotoluene	None			0.11	µg/L	CTR
2,6-Dinitrotoluene	None			None		
2-Chloronaphthalene	None			1,000	µg/L	CTR
3,3'-dichlorobenzidine	None			0.021	µg/L	CTR
4,4'-DDD	None			0.000321	µg/L	CTR
4,4'-DDE	None			0.000222	µg/L	CTR
4,4'-DDT	None			0.000222	µg/L	CTR
4-Bromophenylphenylether	None			None		
4-Chlorophenylphenylether	None			None		
Aldrin	None			0.000049	µg/L	CTR
Allethrin by NCI	None			None		
Ametryn	None			None		
Atraton	None			None	L	
Atrazine	None			0.001	mg/L	CCR
Azobenzene	None			None		
Benzidine	None			0.000086	µg/L	CTR
BHC-alpha	None			0.0026	µg/L	CTR
BHC-beta	None			0.0091	µg/L	CTR
BHC-delta	None			None		
BHC-gamma	0.95	µg/L	CTR	0.98	µg/L	CTR
Bifenthrin by NCI	None			None		
bis(2-Chloroethoxy)methane	None			None		
bis(2-Chloroethyl)ether	None			None		
bis(2-Chloroisopropyl)ether	None			None		
Bolstar (Sulprofos)	None			None		
Chlordane (alpha+gamma)	0.0043	µg/L	CTR	0.0008	µg/L	CTR
Chlorpyrifos	None			None		
cis-Nonachlor	None			None		
Cyanazine	None			None		
Cyfluthrin by NCI	None			None		
Cypermethrin by NCI	None			None		
Danitol by NCI	None			None		
DCPA (Dacthal)	None			None		
Deltamethrin by NCI	None			None		
Demeton	0.1	µg/L	CTR	None		
Diazinon	0.17	µg/L	CTR	None		
Dichlorvos	None			None		
Dicofol	None			None		
Dieldrin	0.24	µg/L	CTR	0.000052	µg/L	CTR
Dimethoate	None			None		
Disulfoton	None			None		

Sampled Constituent	Aquatic Life Threshold	Unit	Source[1]	Human Health (Municipal Supply/Recreation) Threshold	Unit	Source[1]
Endosulfan Sulfate	None			62	µg/L	CTR
Endosulfan-I (alpha)	0.056[5]	µg/L	CTR	62	µg/L	CTR
Endosulfan-II (beta)	0.056[5]	µg/L	CTR	62	µg/L	CTR
Endrin	0.036	µg/L	CTR	0.059	µg/L	CTR
Endrin Aldehyde	None			0.29	µg/L	CTR
Endrin Ketone	None			None		
Esfenvalerate by NCI	None			None		
Ethoprop (Ethoprofos)	None			None		
Fenchlorphos (Ronnel)	None			None		
Fensulfothion	None			None		
Fenthion	None			None		
Fenvalerate by NCI	None			None		
Fluvalinate by NCI	None			None		
Heptachlor	0.0038	µg/L	CTR	0.000079	µg/L	CTR
Heptachlor Epoxide	0.0038	µg/L	CTR	0.000039	µg/L	CTR
Hexachlorobenzene	None			0.00028	µg/L	CTR
Hexachlorobutadiene	None			0.44	µg/L	CTR
Hexachlorocyclopentadiene	None			0.001	mg/l	CCR
Hexachloroethane	None			1.4	µg/L	CTR
Isophorone	None			35	µg/L	CTR
Kepone	None			None		
L-Cyhalothrin by NCI	None			None		
Malathion	0.1	µg/L	CTR	None		
Merphos	None			None		
Methoxychlor	0.03	µg/L	CTR	0.03	mg/l	CCR
Methyl Parathion	None			None		
Mevinphos (Phosdrin)	None			None		
Mirex	0.001	µg/L	CTR	None		
Nitrobenzene	None			17	µg/L	CTR
N-Nitrosodimethylamine	None			0.00069	µg/L	CTR
N-Nitrosodi-n-propylamine	None			0.005	µg/L	CTR
N-Nitrosodiphenylamine	None			3.3	µg/L	CTR
Oxychlordane	None			None		
Permethrin by NCI	None			None		
Perthane	None			None		
Phorate	None			None		
Prallethrin by NCI	None			None		
Prometon	None			None		
Prometryne	None			None		
Propazine	None			None		
Resmethrin by NCI	None			None		
Secbumeton	None			None		
Simazine	None			0.004	mg/l	CCR
Simetryn	None			None		
Terbuthylazine	None			None		

Sampled Constituent	Aquatic Life Threshold	Aquatic Life Unit	Aquatic Life Source[1]	Human Health (Municipal Supply/Recreation) Threshold	Human Health (Municipal Supply/Recreation) Unit	Human Health (Municipal Supply/Recreation) Source[1]
Terbutryn	None			None		
Tetrachlorvinphos (Stirofos)	None			None		
Tokuthion	None			None		
Toxaphene	0.0002	µg/L	CTR	0.00028	µg/L	CTR
trans-Nonachlor	None			None		
Trichloronate	None			None		

[1] Sources are compiled from (SCCWRP, 2007) and are denoted as follows: BP - Basin Plan (RWQCB, 1994); CCR – CA Code of Regs Section 64449; CTR = CA Toxics Rule

[2] Secondary Maximum Contaminant Level for consumer acceptance

[3] Objective for sodium is set for irrigation water and is based on a ratio of Na to other cations

[4] Basin Plan sets the water quality objective for total N at a 10-to-1 ratio with total P. Total P is set at 0.1 mg/L therefore, total N is set at 1.0 mg/L

[5] Based on the sum of alpha and beta

1.5 CWRMA

The CWRMA is a contract settlement of a long outstanding dispute of water rights between Camp Pendleton and RCWD. While there are many provisions regarding the management of the Santa Margarita River, its tributaries, and supporting groundwater basins, paragraph 5 of the agreement stipulates the maintenance of minimum base flows at the Gorge. The purpose of these flows is to recreate the natural variability of the Santa Margarita River that occurs during extremely dry, below normal, above normal, and very wet hydrologic conditions. This monitoring program examines the influence of these flows upon the river.

1.5.1 Background

Competing ranching and development interests in the Santa Margarita River watershed led to the first water rights litigation filed in California State Court: Santa Margarita y Las Flores v. Vail Company (in 1923). The State Court water rights case culminated with the 1940 Stipulated Judgment, which was eventually upheld by the Federal Court in 1966. This established the division of water between Camp Pendleton and RCWD, successors to the original plaintiff and defendant, respectively. Based on the Stipulated Judgment, Camp Pendleton would receive 2/3 of the natural flow of the Santa Margarita River while the RCWD would be allocated the remaining 1/3 share of the river. Development of groundwater and surface water resources in the Upper Watershed continued to negatively affect the quantity of water flowing at the Gorge.

Initial discussion between Camp Pendleton and the RCWD commenced in 1987 and continued through May 2002, when the CWRMA was signed. The agreement allows Camp Pendleton to obtain, to the extent defined by the agreement, its 2/3 share of the natural base flows of the Santa Margarita River. The CWRMA also allows Camp Pendleton to receive additional supplies of water during periods of prolonged drought or for emergency needs. Agreed to within the framework of the 1940 Stipulated Judgment, the CWRMA provides guidance for management of the watershed, including safe yield practices, surface water storage provisions and technical oversight procedures.

RCWD began making CWRMA releases in January 2003. The CWRMA was structured such that base flows match monthly variations as well as variations due to changes in hydrologic conditions. Four different hydrologic conditions have been established that prescribe flows for “Extremely Dry,” “Below Normal,” “Above Normal” and “Very Wet” conditions. The flow requirements to the Santa Margarita River were further defined for Winter and Non-Winter periods for each hydrologic condition. While a single flow requirement was established for the January through April winter period, monthly streamflow requirements were established for the

May through December Non-Winter period in Section 5 of the CWRMA. Flow requirements for each hydrologic condition are given in Table 1-9. RCWD is required to provide a minimum of 3.0 cfs at all times, based upon a 10-day running average. RCWD is not required to provide more than 11.5 cfs in any month.

TABLE 1-9 CWRMA SECTION 5 FLOW REQUIREMENTS

Month	Critically Dry (cfs)	Below Normal (cfs)	Above Normal (cfs)	Very Wet (cfs)
January -April	4.5	8.0	17.8	24.1
May	3.8	5.7	11.7	15.7
June	3.3	4.9	9.4	12.2
July	3.0	4.3	7.8	9.7
August	3.0	4.4	7.6	9.2
September	3.0	4.1	7.4	9.4
October	3.0	3.9	7.7	10.1
November	3.0	4.5	8.8	11.5
December	3.3	5.3	10.4	13.5

Source: CWRMA Section 5 Guaranteed Flows at the Gorge
Note: RCWD is not required to provide more than 11.5 cfs in any month

RCWD has a choice of several water sources and methods of release, predominantly choosing to release imported water via an outfall immediately below the confluence of Murrieta and Temecula Creeks. Water at this outfall is supplied by Metropolitan Water District (MWD), released at turnout WR-34. In early 2007, the invasive quagga mussel species was discovered in MWD's water supply. Starting in August 2007, to avoid potentially introducing the species to the Santa Margarita River, RCWD made some releases from their treated potable groundwater supply. This water was released on Murrieta Creek just upstream of the Gorge. During 2009, RCWD extended a pipeline from its potable distribution system to the same location as the outfall from WR-34. Subsequently, all CWRMA make-up releases, from either WR-34 or the potable distribution system, were discharged to the Santa Margarita River at the same location.

1.5.2 Simulation of Natural Flow

A hydrologic model of the upper Santa Margarita River was created during the development of the CWRMA (US/RCWD, 2002). The model was created using the Hydrologic Simulation Program – Fortran software. The model's purpose was to simulate the natural base flow[2] of the Santa Margarita River at the Gorge. The model was run on a daily time-step and was calibrated using flows at the Gorge (USGS 11044000) for water years 1931 through 1936. The simulated period was water year 1931 through 1996. The model is described in Exhibit B of the CWRMA.

1.5.3 Summary of CWRMA Releases

Releases are tracked on a daily basis and reported to the Santa Margarita River Watermaster on an annual basis. Releases by month in acre-feet are presented in Table 1-10. For calendar years 2003 to 2009, releases averaged 4,200 acre-feet per year. For this period, 88% of the water released was imported water from MWD's raw supply. The remaining 12% was released from RCWD's potable supply, primarily in 2008 when quagga mussels were found in MWD's raw water supply.

Table 1-10 Monthly CWRMA Augmentation, 2003 through 2009, Acre-Feet

Month	2003	2004	2005	2006	2007	2008	2009	Total
Jan	510	449	0	450	544	193	*642*	2,788
Feb	459	188	0	607	505	131	*224*	2,115
Mar	508	323	0	423	481	347	*656*	2,738
Apr	481	340	24	510	423	328	*623*	2,729
May	564	206	584	321	249	494	*228*	2,645
Jun	512	155	667	275	219	532	*709*	3,070
Jul	498	167	602	261	219	474	*746*	2,966
Aug	484	184	555	256	209	480	*254*	2,422
Sep	454	177	543	241	204	457	*187*	2,263
Oct	462	111	551	233	208	*481*	*203*	2,248
Nov	226	103	510	236	196	*407*	*189*	1,867
Dec	271	123	362	185	154	*107*	*134*	1,335
Total	5,429	2,525	4,397	3,997	3,609	4,432	*4,795*	29,184

Source: "Discharge per MWD" from Table 11.1 of the Santa Margarita River Annual Watermaster Report (Jenks, 2004, 2005; Binder, 2006, 2007,2008, 2009). *Preliminary values not yet published (Elitharp, 2010).*

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[2] Natural flow in this report means the flow in the river without the influence of storage, diversions, or other man-made structures or activities. The model was calibrated to base flows and was not used to analyze peak events.

Table 1-11 presents the daily flow statistics for CWRMA releases and flow on the Santa Margarita River at the Gorge (USGS 11044000, Santa Margarita River near Temecula). CWRMA flows are released just upstream from the USGS gage at the Gorge, so releases are included in the USGS gage. From January 2003 to December 2009, the daily average and median CWRMA releases were 5.8 cfs and 5.1 cfs, respectively. Daily average and median flows at the Gorge during that same period were 33.5 cfs and 7.8 cfs, respectively.

TABLE 1-11 DAILY FLOW AT THE GORGE AND CWRMA AUGMENTATION (JANUARY 1, 2003 – DECEMBER 31, 2009)

Flow Statistic	Daily Flow at Gorge (USGS 11044000) (cfs)	CWRMA Augmentation Flow[1] (cfs)
Mean	33.5	5.8
Median	7.8	5.1
Min	0.24	0.0
Max	4190	16.1[2]

[1] CWRMA daily release volumes in acre-feet have been converted to an equivalent average daily flow rate in cfs. Source: RCWD (Elitharp, 2010).

[2] Maximum value of 16.1 cfs was observed at the end of an MWD shutdown when water was being provided from two sources. Generally, however, releases do not exceed 11.5 cfs

2.0 METHODS

In order to address the key management questions (presented later in this section), the study team developed a multi-faceted plan of work to focus on measuring water quality, geomorphology, and habitat. Conceptual models were first developed in order to identify the parameters that required field data and empirical measurements required for analysis. The methods used to collect these data are presented in the following section of the report. Methods included water chemistry sampling and a flow manipulation experiment designed to examine changes in water quality, river geomorphology and structure, and sensitive species habitat.

2.1 CONCEPTUAL MODELS

During the document review and data collection activities, the study team developed conceptual models of river processes. These models were developed to aid in understanding the distribution and relationships between target constituents and physical and biological processes. In order to be most effective, both spatial and temporal relationships must be understood. Conceptual models are critical components of monitoring programs by summarizing the current understanding of the system and its complicated relationships (Woodward et al., 1999). The conceptual model explains the current understanding of how the ecosystem functions, and can include information on hydrology, geomorphology, and ecology. Conceptual models include components of species' natural history, where clear links describe interactions between species, habitats, and factors that influence change (stressors, permitted activities, management, and conservation) (Mulder et al., 1999 and Noon 2003). Models also identify the expected response of the system to management (e.g. an increase, decrease, or stabilization of species) while also identifying additional data needs (Gibbs et al., 1999 and Mulder et al., 1999).

Typically, monitoring programs proceed without a complete conceptual model (Mulder et al., 1999), with gaps in understanding being filled throughout the monitoring process. Conceptual models are "living documents" with a mechanism for continued refinement when new information becomes available. Conceptual models can take many forms, including narratives, tables, matrices, or diagrams (Gross, 2003), and can be based on quantitative (empirical), qualitative (descriptive), or theoretical information. For instance, diagrammatic representations show the complicated interconnections of systems. Investigating nutrient dynamics is essential to this study. A conceptual model that describes the seasonal fluxes in nutrient uptake associated with plant metabolism and physical process along the Santa Margarita River can inform the monitoring program as well. The nitrogen cycle, in particular, is complex, with nitrogen species transforming between atmospheric nitrogen, ammonia, nitrate, nitrite, and organic nitrogen. Figure 5 presents the nitrogen species and transformations that occur in the riparian nitrogen cycle. In the aerobic soil layer and in the water column, where dissolved oxygen is present, ammonium (NH_4^+) is transformed by nitrification, first to nitrite (NO_2^-) and then to nitrate (NO_3^-). In anaerobic sediments nitrate is transformed by denitrification to nitrous oxide (N_20) and nitrogen gas (N_2) and typically off-gasses to the atmosphere.

Sources of surface water contaminants include point discharges and non-point sources. Sources may also include releases via physical or biological processes and transformations. Non-point sources include storm drains, vehicle sources, animal sources, atmospheric deposition, and nitrogen fixation. Constituents are lost from the river through physical processes, biological transformations within the river, and via outflow to the estuary and ocean. Examples of within-system processes that lead to sequestration or loss of constituents are burial in sediments and denitrification. Watershed loads of constituents can be estimated based upon data collection at the sampling sites described in Section 2.1.

The conceptual models relate directly to the key management questions presented in the Reclamation Task Order. These management questions were organized into three general categories, as presented in Table 2-1. The questions focused on characterizing water quality, determining whether the river had the ability to assimilate existing levels of nutrients, and assessing potential impacts upon water quality and sensitive species habitats due to the CWRMA.

The conceptual models were used to guide development of the monitoring program. Appendix D contains the conceptual models and interpretation of potential stressors and impacts upon the Santa Margarita River.

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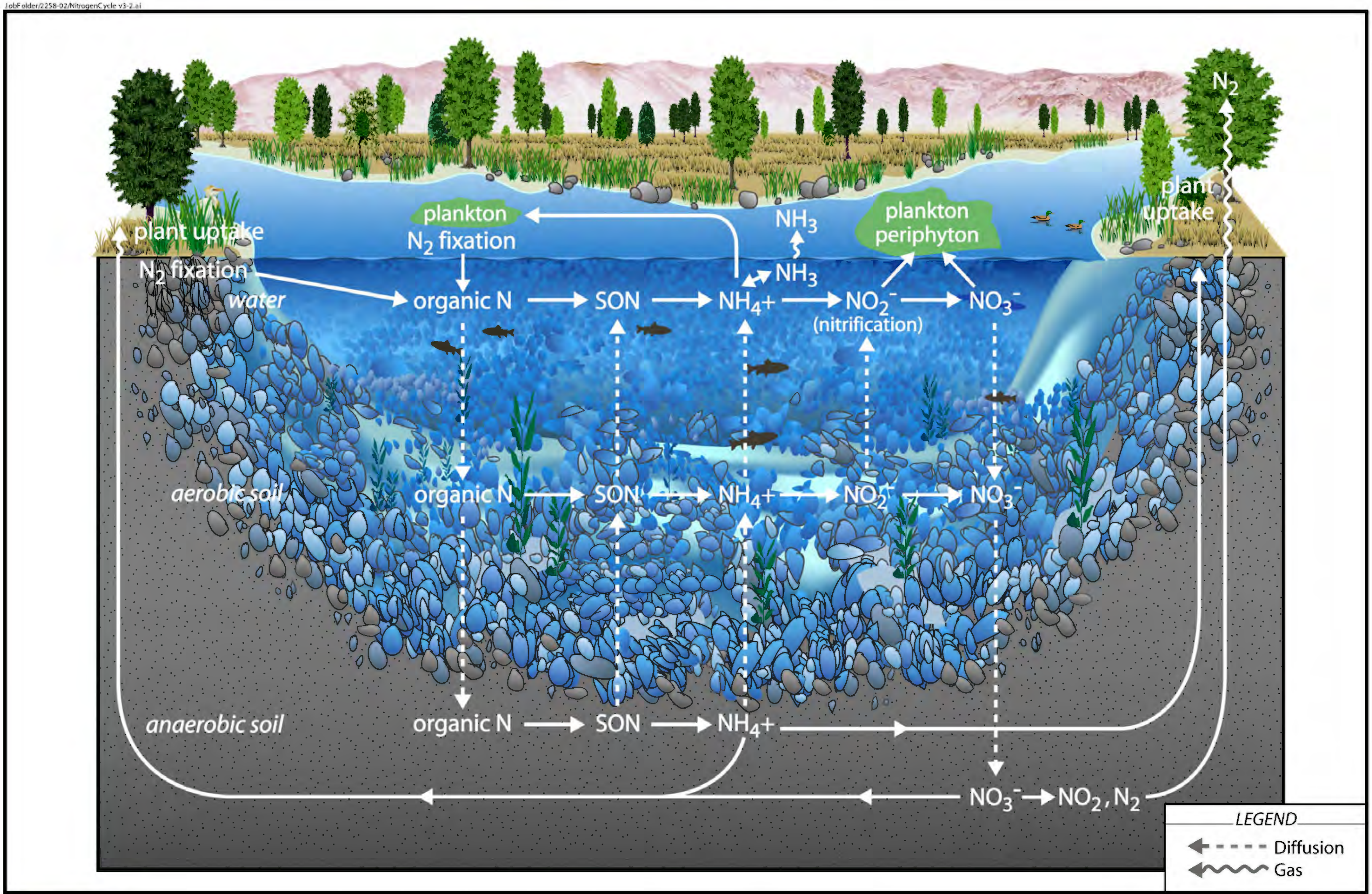


STETSON ENGINEERS INC.

THE NITROGEN CYCLE

FIGURE 5

TABLE 2-1 KEY MANAGEMENT QUESTIONS

Type	Question	Study Task #
Sources	What is the total annual (and daily) flow and mass loads of targeted contaminants from each sampled tributary?	Implied by 1
	Where and when do contaminants enter the main stem of the river? What are the sources, location, and relative levels of contribution of nutrient contamination (land use, fire, aerial deposition, etc.)?	1
	How does the variability in spatial distribution of precipitation in the watershed influence movement of contaminants?	1
	What are the concentrations of targeted contaminants at the base of the watershed before it enters the lagoon? [Being addressed by the Lagoon TMDL project during first year of program]	Not specified
Hydrodynamics and Water Quality	Where and when is water quality impaired along the main stem of the river? [In contrast to reference streams in the watershed]	1
	What is the water quality of imported water released into the river? How does it differ from local water quality (including historic water quality values)?	2
	How does the water augmentation schedule (in accordance with the CWRMA) change base flows relative to historic flows (including changes in temporal and geographic distribution and variation during and among years)?	2
	How do nutrient loading and removal vary seasonally and with changes in flow rates?	1
	Do differences between local and imported water quality at the head of the gorge affect the water quality downstream?	2
	How has water quality in the main stem changed over time?	1
	What is the capacity of the river to remove nutrients from the water column?	1
	How does the sediment transport regime impact water quality, including sequestration of nutrients and other contaminants?	1
Impacts to Wildlife, Habitat, and Wetlands	Does imported water quality influence federally T&E species and riparian habitats?	2
	[T&E species include: arroyo toad, least Bell's vireo, southwest willow flycatcher, tidewater goby, light-footed clapper rail, and least tern.]	
	Are there changes in the extent of riparian habitat or wetlands? Are there changes in the quantity or quality of T&E species habitat? Are there changes in the distribution and abundance of breeding pools for fish, amphibians, and exotic predators? What is the water quality and temperature of the pools?	
	Do differences between local and imported water quality affect the number, distribution, or aerial extent of T&E species?	2
	Do differences between local and imported water quality affect the quality or extent of T&E habitats and wetlands?	2
	Do the additional flows released under the CWRMA result in an increased quantity of T&E habitat and wetlands over pre-2002 levels?	2
	How much surface flow is needed to support current populations of T&E species, including habitat maintenance and regeneration?	2
	Do the discharge patterns of imported water influence T&E species and riparian habitats?	2
	Do restored base flows (due to water augmentation) affect special status species and habitats (including flow levels and flow variability)?	2
	Do restored base flows (due to water augmentation) affect exotic species?	2

2.2 WATER QUALITY COLLECTION METHODS

2.2.1 Approach to Sampling

The three principal methods of water chemistry monitoring included in the program are as follows:

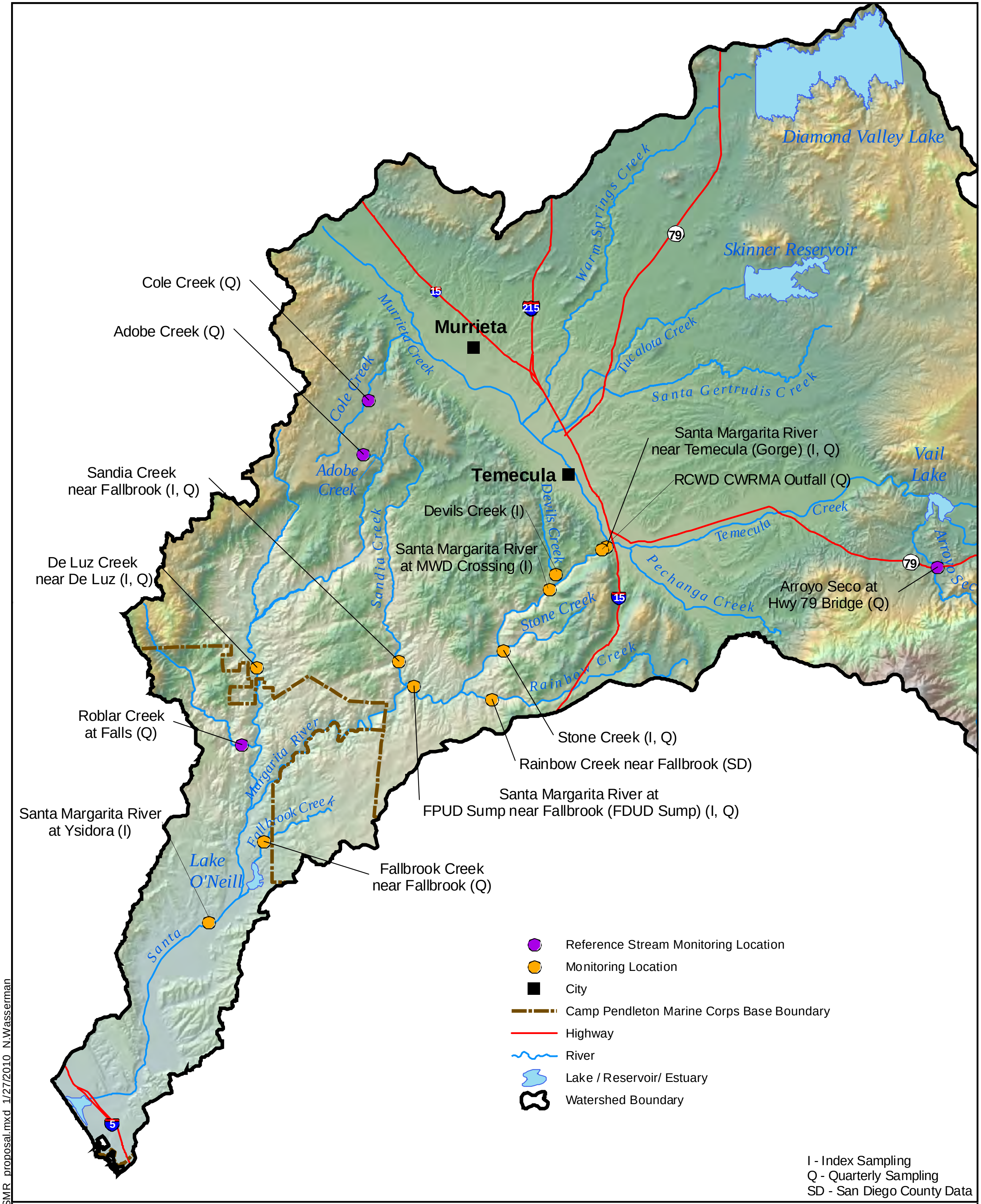
- continuous monitoring of hydrodynamic and water quality parameters (such as conductivity, temperature, pH, dissolved oxygen, and turbidity);
- quarterly grab samples of chemical constituents; and,
- semi-annual grab samples during “index periods” that are meant to capture representative seasonal cycles in nutrient loading.

The water quality monitoring program included sampling general water chemistry constituents, bacteria, metals, a nutrient suite, herbicides and pesticides, emerging chemicals of concern, and pharmaceuticals. Field work methodology followed the EPA’s Wadeable Streams Assessment Field Operations Manual (USEPA, 2004) whenever appropriate. Scientists and technicians collected and preserved samples of stream water to deliver to the analytical laboratory, as well as made *in situ* measurements of specific conductance, dissolved oxygen, pH, turbidity, and temperature. Sample collection methodology is discussed in Section 2.4.

2.2.2 Locations of Sampling

Surface water samples were collected from fourteen monitoring locations, as shown in Table 2-2 and in Figure 6. In addition, field surveys of macrophyton and periphyton populations were conducted at sites near established water quality monitoring stations. Six of the fourteen water quality sampling locations correspond to existing USGS flow gaging stations, allowing for data collected in this study to be added to historical water quality measurements made at these sites. Three of the sampling locations correspond to existing Santa Margarita Ecological Reserve (SMER) flow gaging stations. Having streamflow associated with sampling locations also facilitated calculation of stream loadings of sampled constituents. The sampling stations at Adobe Creek, Arroyo Seco, Cole Creek, and Roblar Creek were designated as reference sites for sampling “background” conditions.

FIGURE 6



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PROJECT WATER QUALITY
MONITORING LOCATIONS IN THE
SANTA MARGARITA RIVER WATERSHED

N

0 2.5 5 Miles

TABLE 2-2 SURFACE WATER QUALITY MONITORING LOCATIONS

Sampling Station Name	USGS Station Number[1]	Latitude	Longitude
Santa Margarita River at Ysidora	11046000	33°18’37”	117°20’52”
Fallbrook Creek at Fallbrook	11045300	33°20’49”	117°19’01”
De Luz Creek at De Luz	11044800	33°25’11”	117°19’15”
Roblar Creek near De Luz Creek	---	33°23’16”	117°19’12”
Sandia Creek near Fallbrook	11044350	33°25’28”	117°14’54”
Adobe Creek	---	33°30’48”	117°15’51”
Santa Margarita River at FPUD Sump	11044300	33°24’29”	117°14’25”
Stone Creek	---	33°25’44”	117°11’43”
Santa Margarita River at MWD Crossing	---	33°27’20”	117°10’18”
Devils Creek	---	33°27’45”	117°10’06”
Santa Margarita River near Temecula (Gorge)	11044000	33°28’26”	117°08’29”
Rancho California Water District CWRMA Outfall[2]	---	33°28’28” 33°28’50” 33°28’50”	117°08’31” 117°08’39” 117°08’38”
Cole Creek	---	33°19’25”	117°09’17”
Arroyo Seco	---	33°27’55”	116°58’20”

[1] “---“ denotes that the monitoring location was not co-located with a USGS gage

[2] The RCWD released water at several locations in response to the presence of quagga mussels in one water supply source.

2.2.3 Timing of Sampling

Table 2-3 presents the targeted time periods of the sampling with respect to the major study elements of the Workplan (Stetson 2007e). The Task Order stipulated a quarterly monitoring program for most constituents plus special “index period” sampling to collect data on nutrient dynamics. The index period protocol was designed to match the protocol specified for the Santa Margarita River Lagoon by the San Diego RWQCB. During each index period, sampling was performed during five days within a two week period. This protocol was developed to collect data necessary for developing a TMDL for eutrophication (nutrient over-enrichment), and since the RWQCB had discussed inclusion of the entire watershed in the TMDL initiative, Camp Pendleton and Reclamation included the necessary nutrient protocol in this monitoring program.

TABLE 2-3 TIMING OF MAJOR ELEMENTS OF THE MONITORING PROGRAM

Year	Month	Quarterly Water Quality Sampling	Continuous Water Quality Sampling	Index Period Sampling (Nutrient Protocol)[1]	Periphyton and Macrophyton Sampling	Geomorphology, Ecology, and Water Quality –CWRMA Flow Experiment
2007	Oct					
	Nov	x	x			
	Dec		x			
2008	Jan		x			
	Feb	x	x	x		
	Mar		x			
	Apr	x	x			
	May		x		x	
	Jun		x			
	Jul	x	x	x		
	Aug		x			
	Sep		x		x	
	Oct	x	x		x	
	Nov		x			
	Dec		x			
2009	Jan		x			
	Feb	x	x	x		
	Mar		x			
	Apr	x	x			x
	May		x		x	x
	Jun		x		x	
	Jul	x	x	x		
	Aug		x			
	Sep		x		2x	x

[1] Index Period nutrient sampling was scheduled in coordination with the Santa Margarita River Lagoon TMDL monitoring project in order to optimize support to the nutrient loading models being developed under the TMDL project. The Mass Emission site (Santa Margarita River at Ysidora) was sampled during the second year of the program, only.

The continuous water quality sampling (collecting measurements at 15-minute intervals continuously for the two year study period) was added by Stetson Engineers in order to “tie together” the quarterly sampling (which is rather infrequent) and to provide insight into diurnal fluctuations in several physical parameters as well as dissolved oxygen. The continuous monitoring is discussed in more detail in Section 2.2.5.3.

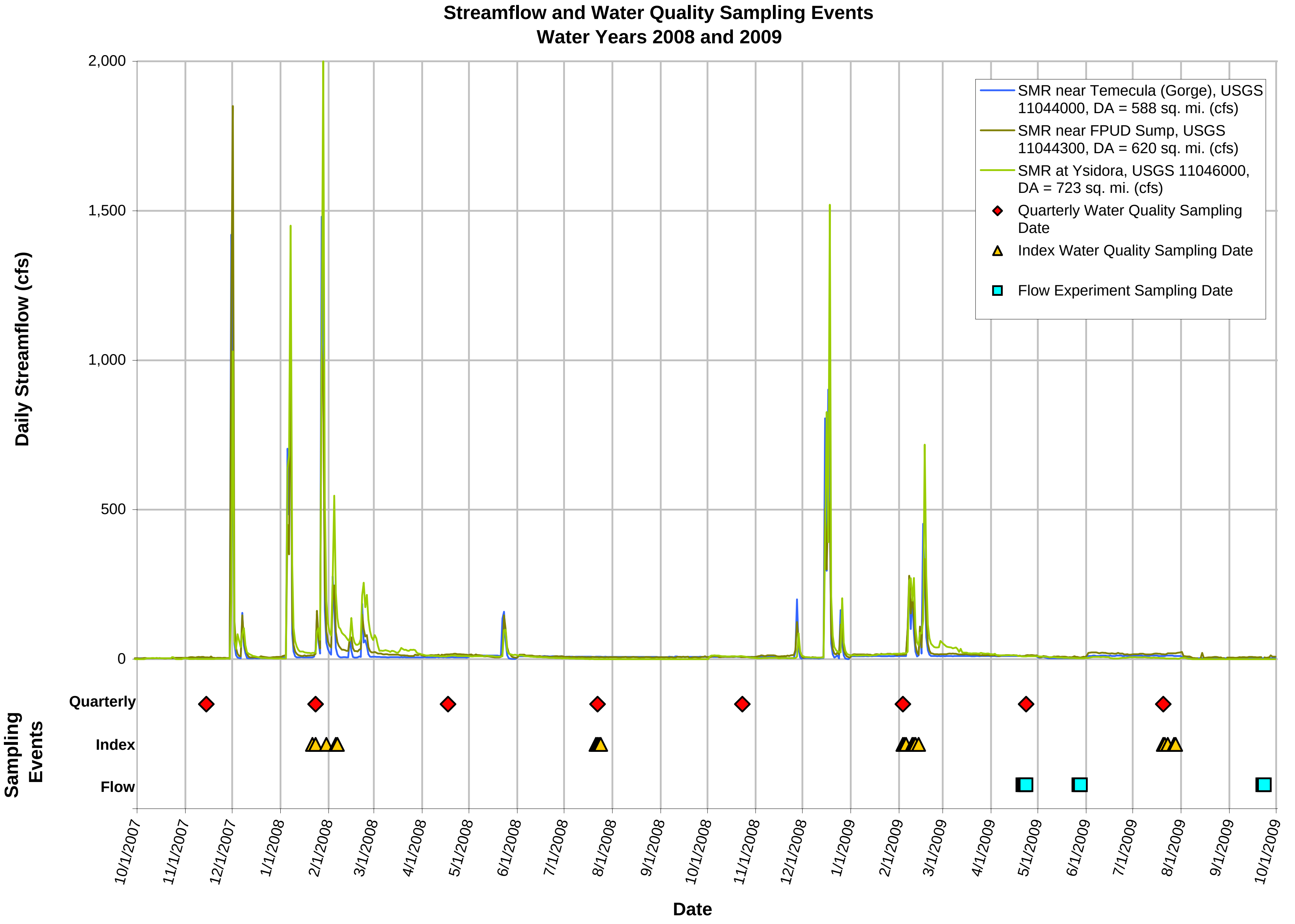
The periphyton and macrophyton sampling was carried out in the spring and fall in accordance with the Task Order. In September of 2008, the Task Order was modified to double the number of periphyton sampling events in order to collect a sufficiently representative dataset.

Figure 7 shows the timing of quarterly and index sampling along with streamflow on the main stem of the Santa Margarita River. Sampling in November, February and April generally coincided with natural rainfall runoff in the river, while sampling in July and October occurred after extended periods of no rainfall in the watershed. The Study team decided to add the CWRMA flow experiment in 2009 in order to focus data collection on the periods immediately preceding and following the regular May 1 hydrological condition determination.

2.2.4 Organization of Sample Suites

Water samples were analyzed for a number of organic, microbiological, and inorganic constituents in accordance with the Task Order. The analyte list was developed by Camp Pendleton's Office of Water Resources based on examining a number of sources, including previous monitoring projects in the watershed and monitoring plans by various organizations including Camp Pendleton, the Bureau of Reclamation, and The Nature Conservancy. A draft monitoring program was compiled by Camp Pendleton and refined in collaboration with the Santa Margarita River Water Quality Monitoring Group and experts from San Diego State University and Scripps Institute of Oceanography. This process is explained in more detail in Stetson Engineers (2007b). Because the list of analytes was extensive, the analytical methods were split into eight sample suites for organizational and logistical purposes, and because not all analytes were sampled at all locations (Table 2-4). Table 2-5 shows the sampling frequency for each sample suite within each site, and the corresponding total number of samples that were collected. Grab samples were taken on a quarterly periods, index periods or both. Quarterly periods consist of four samples taking approximately every three months. Index periods consist of five daily samples taken during a 2-week period twice a year. These tables were used by the field sampling team to prepare for the sampling events, and also allowed the laboratory to prepare sample bottle sets according to which suites were being collected during each sampling event. The column labeled "other analyses" in Table 2-4 contains analytes that were sampled at only some of the monitoring sites. The comprehensive water quality monitoring program is presented in Appendix E.

F:\DATA\2258\Surface Water\Figure (streamflow and sampling dates)



Source: All streamflow data from USGS National Water Information System (NWIS) accessed at http://waterdata.usgs.gov; data for October 2008 through September 2009 are provisional

FIGURE 7

TABLE 2-4 SAMPLING SUITES

Suite 1 – Nutrient Index	**Suite 2 – Quarterly**	**Suite 3 – Metals**	**Suite 4 – Inorganics**
Ammonia-N Total Kjeldahl Nitrogen (TKN) Nitrate as N Nitrite as N Total Nitrogen Ortho Phosphate as P Total Phosphorus Chl a (chlorophyll a) BOD_5 pH Conductivity Dissolved Oxygen	Arsenic Bicarbonate BOD_5 Calcium Chloride Conductivity Copper Dissolved Oxygen Fecal Coliform Fluoride Lead Iron Manganese Nitrate as N Total Nitrogen pH Orthophosphate as P Total Phosphorus Sodium Sulfate Surfactants (MBAS) Total Dissolved Solids Thallium Total Organic Carbon	Cadmium Chromium Nickel Selenium	Boron Cyanide Mercury Oil and Grease
Suite 5 –Inorganics	**Suite 6 – Pesticides/Herbicides**	**Suite 7[1] – EPA UCMR-2**	**Suite 8[1]– EPA UCMR-2 & Pharmaceuticals**
Aluminum Antimony Beryllium Silver Turbidity	Chlorinated Pesticides Organo-phosphorous Pesticides Triazine Herbicides Pyrethroid Pesticides	NDMA Dimethoate Terbufos sulfone BDE-47 BDE-99 HBB BDE-153 BDE-100 1,3-dinitrobenzene TNT RDX Acetochlor Alachlor Metolachlor Acetochlor ESA Acetochlor OA Alachlor ESA Alachlor OA Metolachlor ESA Metolachlor OA NDEA NDBA NDPA NMEA NPYR	Pharmaceuticals Carbamates Semivolatile Organics VOCs Nitrosamines

[1] Sampling Suites 7 (EPA UCMR-2) and 8 (Pharmaceuticals) were added mid-program.

TABLE 2-5 SURFACE WATER SAMPLING FREQUENCY

Monitoring Location & USGS #	***Sample Suite Number***								***Other Analytes***	***Sampling Frequency***	***Total Samples per Analyte***
	1	***2***	***3***	***4***	***5***	***6***	***7***	***8***			
Santa Margarita River at Ysidora (11046000)	✓								--	Index	10
Fallbrook Creek at Fallbrook (11045300)		✓	✓						COD	Quarterly	8
De Luz Creek at De Luz (11044800)	✓								--	Index	20
		✓		✓		✓				Quarterly	8
Roblar Creek		✓							Iron, Manganese, Sulfate, Arsenic, Boron	Quarterly	8
Sandia Creek near Fallbrook (11044350)	✓								--	Index	20
		✓	✓	✓	✓	✓			--	Quarterly	8
Adobe Creek		✓							--	Quarterly	5[1]
Santa Margarita River at FPUD Sump (11044300)	✓								--	Index	20
		✓	✓	✓	✓	✓	✓	✓	TSS	Quarterly	8
Stone Creek	✓									Index	15[1]
		✓								Quarterly	5
Santa Margarita River at MWD Crossing	✓									Index	15[1]
Devils Creek	✓									Index	15[1]
Santa Margarita River near Temecula (11044000)	✓				✓				--	Index	20
		✓		✓		✓			TSS	Quarterly	8
RCWD CWRMA Outfall	✓									Quarterly	8
Cole Creek		✓								Quarterly	5[1]
Arroyo Seco		✓								Quarterly	5[1]

[1] **Added mid-program.**

2.2.5 Sampling Methods

2.2.5.1 Field Measurements of Water Quality

Field water quality measurements; temperature, conductivity, dissolved oxygen, and pH, where measured with a Hanna HI 9828 Multiparameter instrument (meter). At the beginning of each daily sampling event, sensors where checked for proper function and the meter was calibrated using factory produced calibration solutions. At each sampling location the meter was placed in the water mid-channel at a depth greater than six inches where possible. Field readings were recorded following the observed stabilization of the readings.

2.2.5.2 Sampling for Laboratory Analysis

At each sampling location grab samples, as defined in the glossary were taken from flowing water mid-channel at a depth of greater than six inches were possible. Sanitary polyethylene transfer containers were used to transfer sampled water to laboratory provided containers. When necessary to prevent sample contamination from the transfer bottle, laboratory containers were filled directly from the sampled water body, or a glass transfer container was utilized. At the completion of sampling at each site, sample containers were transferred to ice filled containers for subsequent transport to the laboratory. Further deals of the sampling procedures are discussed in Appendix F.

2.2.5.3 Continuous Monitoring

Continuous water quality monitoring was employed at the Santa Margarita River at the FPUD Sump location with the objective of providing seasonal trends to the physical water quality parameters, dissolved oxygen, pH, water temperature, specific conductance, and turbidity to assist in the analysis of other components of this project.

The water quality meter employed was an YSI 6-series Sonde, with optical dissolved oxygen and turbidity sensors installed. The meter was deployed for the period of November 9, 2007 through October 30, 2009 recording field readings every quarter of an hour. The meter was deployed in a steel cased installation positioned on the upstream side of the Sandia Creek Road crossing, adjacent to the USGS 11044300 gage, Santa Margarita River at FPUD Sump near Fallbrook (Table 2-6). This location represented the only feasible location to attach the meter to a fixed body within the river channel. Field visits to conduct maintenance, check for proper function, and collect correlating grab samples were conducted approximately once every month. No analyses or conclusions regarding the continuous water quality data are presented in this report. The data were used to augment other elements of the monitoring program and to provide site-specific data for use within the Nutrient Numeric Endpoint model discussed in Section 5.2.

TABLE 2-6 CONTINUOUS WATER QUALITY MONITORING LOCATIONS

Monitoring Location	Period	USGS Station Number	Latitude	Longitude	Additional Constituents Sampled
Santa Margarita River at FPUD Sump	2007-2009	11044300	33°24’29”	117°14’25”	Turbidity

Collecting samples every 15 minutes throughout the year allowed for a comprehensive interpretation of the quarterly sample data. The study team was able to use the continuous data to better understand the average, minimum, and maximum values for parameters such as temperature, pH, and dissolved oxygen (DO) which can vary considerably throughout each day. Such data were used to tie the quarterly sampling points together (using continuous information) in order to make recommendations on improving sampling intervals and/or locations. The dataset of continuous water quality data provided the most complete picture of seasonal and diurnal variation and supports assessment of sinks and sources throughout the system.

2.2.5.4 Methods for Macrophyton and Periphyton Sample Collection

Macrophyton and periphyton sampling began in May 2008 near existing streamflow gages and macroinvertebrate sampling stations. Periphyton samples were collected and macrophyton surveyed during the Spring and Fall. At Santa Margarita River at Ysidora, periphyton was sampled and macrophyton field surveyed only during the second year of the program. Sample collection and analysis procedures are presented in Appendix G.

Macrophyton and periphyton sampling began during May of 2008. Reach-scale sampling was conducted near existing streamflow gages and macroinvertebrate sampling stations. Sample collection and analysis procedures are presented in Appendix G.

Periphyton samples were collected and macrophyton surveyed once during the Spring and Fall of 2008 and sampled twice during Spring and Fall of 2009, thereafter in keeping with the updated sampling regime. At Santa Margarita River at Ysidora, periphyton sampling and macrophyton field surveys were conducted only during 2009.

2.2.6 Quality Assurance/Quality Control (QA/QC)

Quality assurance and quality control procedures were provided in detail in the project QAPP submitted on October 11, 2007. QA/QC procedures are outlined in Appendix H and covered in detail in the QAPP.

Per the QAPP, all samples were collected following specified procedures using laboratory-prepared containers, properly labeled, and transported under ice. Stetson followed proper sample storage, labeling and chain of custody procedures, collected the required duplicate samples, and followed designated holding time limitations. A detailed description of sampling protocols and laboratory quality assurance and quality control procedures and personnel was included in the QAPP. All data collected as a part of this monitoring program are compatible with the SWAMP quality assurance standards (Puckett, 2002).

2.2.7 Methods for Data Cataloging, Access and Control

Stetson Engineers Inc. created a website dedicated to the storage and maintenance of water quality data pertaining to the Santa Margarita River. Included on the website is a complied database of historical water quality data for the entire watershed. The website uses open source software for both the front-end and the back end: Linux, Apache, MySQL, and PHP were used on the server; HTML, CSS, JavaScript, and Ajax were used on the client side. Data import and export can be performed using comma separated value (CSV) files that are compatible with popular spreadsheet software.

All water quality data collected during the course of this project were uploaded to this website and marked with the number of this contract and the name of the contractor or subcontractor that generated the data. Stetson currently maintains the web site and is prepared to transfer operation and maintenance of the web site to Camp Pendleton at the completion of the project. The CD provided in Appendix C contains the water quality database website import files as well as the Microsoft Access database file used to maintain the data external to the website.

2.3 FLOW EXPERIMENT METHODS

At the end of each calendar year, CWRMA flows are established for the upcoming winter months of January through April. Then, on May 1 of the year, the hydrologic condition is determined and flows are established for the remainder of the year. Thus, every May 1st, the prescribed release flow rate changes. The study team conducted a field experiment to assess how geomorphology, hydrology, ecology, and water quality are influenced by CWRMA augmentation flows. The study team requested that the scheduled May 1 CWRMA flow rate be reduced to the minimum allowable flow rate (3.0 cfs) in order to assess conditions of the River during two distinct flow regimes. Data were collected before and after the May 1, 2009 adjustment of CWRMA flows at reaches immediately downstream of major tributaries.

2.3.1 Modification of CWRMA Flows

The winter 2009 CWRMA release flow rate was 10.3 cfs. 2009 was classified as an above normal hydrologic year and the May 2009 flow rate was established at 11.5 cfs. The study team requested that the May 2009 flow rate be reduced from 11.5 cfs to 3.0 cfs and that the difference in flows be made up in subsequent summer months. RCWD agreed to make these adjustments. The flow reduction plan included a period of five days from May 1 to May 5 in which flows were reduced to an intermediate flow rate of 5.7 cfs. This was designed to create a transition between 10.3 cfs and 3.0 cfs so that the river habitat would not be subject to drastic changes in flow. Flow was reduced to 3.0 cfs on May 6 and maintained there for the rest of the month. Flows for June, July, and August were subsequently increased in order to make up for the reduction in May.

The study team collected the first set of data during April 20-22 when CWRMA flows were maintained at 10.3 cfs. The second sampling period was May 27-29 when flows were at 3.0 cfs. The sampling dates were chosen to reduce the chance of a late-season "scouring" storm interfering with the experiment and to provide sufficient time for the river system to adjust between sampling sessions.

2.3.2 Flow Measurements

The study team measured flow rates at eight locations along the Santa Margarita River and its tributaries. Flows were measured with a Scientific Instruments Model 1205 Mini Current Meter following standard USGS and Reclamation procedures. These measurements represent discrete periods of measured flow, whereas USGS gage streamflow data, as is available on the National Water Information System Web, are based on the continuous measurement of stage and the developed relationship of stage and streamflow for each site.

Measurements were made at half-foot or one-foot intervals, depending on the wetted width of the cross-section. The Six-Tenths Method was utilized to determine mean velocities. This method entails making one velocity reading per vertical cross-section at a point six-tenths of the total distance from the water surface to the channel bottom. This method is recommended when the water depth is between 0.3 and 3.0 feet (USBR 1997), which was the case for all the measurement cross-sections. The velocity was recorded by counting the number of revolutions the meter made during a defined period of time. For every velocity reading, revolutions were counted for a period of forty seconds. A rating equation is provided by Scientific Instruments in which the velocity is calculated from the number of revolutions and time:

$$Velocity = \mathrm{Rev}/Time * 0.9604 + 0.0312$$

The midsection method was used to calculate the total discharge from the cross-sectional and velocity measurements. The following equation was used to calculate the partial discharge using the midsection method:

$$q_x = v_x \left[\frac{b_{x+1} - b_{x-1}}{2} \right] d_x$$

where:

q_x = partial discharge for the area halfway toward the previous vertical and halfway toward the next forward vertical.

v_x = mean velocity at vertical cross-section x; measured using the sixth-tenths method

b_{x+1} = horizontal distance from the initial point to the next forward vertical

b_{x-1} = horizontal distance from the initial point to the previous vertical

d_x = water depth at vertical cross-section x.

2.3.3 Cross-Sections

As part of the field work, Stetson completed cross-sectional surveys of the river at five of the six reaches included in the flow experiment. The purpose of the cross-sections was to document the current geomorphic condition at each location. These transects may serve as a baseline for future monitoring of geomorphic processes on the watershed.

At each of these cross-sections the team measured flow and collected nutrient and conventional chemistry water quality samples for the purpose of calculating loading and assessing assimilative capacity. The water quality sampling was conducted with the same methodology as described in Section 2.2.5.2.

2.3.4 Pool Measurements

As part of the flow experiment, five 1,000 meter sub-reaches of the Santa Margarita River were examined for changes to in-channel (I-Pools) and off-channel (O-Pools) pools during April, May, and September 2009. Parameters analyzed for a given pool included: area, maximum depth, water temperature, conductivity, dissolved oxygen, pH, algae cover, canopy cover, substrate type, and exposure. Field sheets are located in Appendix I. Field sheets also include data collected for transects located every 100 meters within each designated reach. These data were not included in the pool analysis, but did contribute to the NNE analysis discussed in Section 5.2. In the field sheets, pools were originally labeled "Dpool1," "Upool2," etc., designating the relative position of pools observed during that field session. In order to compare pools that were present in two or more months, the pools were relabeled with the revised format: "I-Pool #" and "O-Pool #."

2.3.5 Rapid Biological Assessment Protocol

At each of the sampling locations, a team of biologists assessed a cross section of the Santa Margarita River, at the designated center point of the sampling site, and 500 meters up stream and down stream of the site. The cross section consisted of a segment of the river, approximately 25 meters wide. At each site, the biological and physical characteristics were measured twice: at the start of the high flow events (10.3 cfs), and then again approximately one month after the low flow events (3.0 cfs) were stabilized.

A series of measurements were collected at each site, and used to define the biological condition of the Santa Margarita River and can be found in Appendix I. These measurements are made at each cross section: wetted width, bankfull width, bankfull height, transect substrates, pebble count transect substrates, water depth, particle size class, cobble embeddedness, coarse particulate organic material (CPOM), algal cover, distance from river center and river edge to riparian vegetation edge, distance from river center and edge to trees and saplings (USEPA, 1998).

3.0 ANALYSIS OF WATER QUALITY

Analytical results from the water quality samples identified the concentration of different constituents that were targeted in order to test the conceptual models identified in the previous chapter. Both in-situ filed measurements and laboratory results of grab samples were used to analyze these conceptual models.

The following section describes the results of the various water quality samples collected during this investigation at each location and their relationship to the Basin Plan. The periodic grab samples were used to indicate water quality at the date and time of sampling. It cannot be inferred that concentrations of constituents match these levels either before or after the sampling events. Variation in flow, weather, loadings, river metabolism, and other factors drive variation in water quality. Thus, the value of the data is elevated by increased frequency of sampling. Data sets for sites infrequently sampled provide less reliable information for interpretation.

3.1 WATER QUALITY RESULTS

3.1.1 Field Measurements of Water Quality

Specific conductance, temperature, DO, and pH were measured in-situ during all field visits within the two year sampling period. A tabulation of the field measurements can be found in Appendix I. Table 3-1 presents a summary of exceedances of DO and pH in accordance with Basin Plan regulations. DO exceeded the Basin Plan more than 10% of the sampling events at Adobe Creek, Roblar Creek, Santa Margarita River at Ysidora and Fallbrook Creek. Exceedances occurred in the summer and fall months due to increased water temperatures, low streamflows, and increased algal growth. The Basin Plan limit for pH was exceeded more than 10% of the sampling events at the MWD Crossing and Sandia Creek. Elevated pH was exhibited during winter months during periods of increased runoff. It is likely that an increase in runoff produced an imbalance of ions due to increased concentrations of anions such as sulfate, nitrate, and chloride. There are no Basin Plan limits for specific conductance and temperature, while there are for DO and pH.

TABLE 3-1 SUMMARY OF EXCEEDANCES OF DISSOLVED OXYGEN AND PH

Monitoring Location	Dissolved Oxygen Number of Exceedances	Number of Samples	Percent Exceedance	pH Number of Exceedances	Number of Samples	Percent Exceedance
Adobe Creek	3	5	60%	0	5	0%
Arroyo Seco	0	1	0%	0	1	0%
Cole Creek	0	1	0%	0	1	0%
Roblar Creek	1	6	17%	0	6	0%
SMR at FPUD Sump	0	24	0%	2	24	8%
SMR at MWD Crossing	0	15	0%	3	15	20%
SMR near Temecula	1	24	4%	0	24	0%
SMR at Ysidora	1	10	10%	1	10	10%
De Luz Creek	0	12	0%	1	12	8%
Devils Creek	0	15	0%	0	15	0%
Fallbrook Creek	3	7	43%	0	7	0%
CWRMA Outfall	0	7	0%	0	7	0%
Sandia Creek	0	24	0%	3	24	13%
Stone Creek	0	17	0%	1	17	6%

3.1.2 Laboratory Results of Water Quality Samples

Laboratory results for general constituents, nutrients, pesticides, pharmaceuticals, and Unregulated Contaminant Monitoring Regulations 2 (UCMR2) are presented in the text and in Table 3-2 below. All sampled constituents are addressed in the table, and those constituents found at levels exceeding regulatory limits are discussed in the text. The data and descriptive graphs and maps are presented in Appendix J. Laboratory results are included in Appendix K. Table 3-2 provides a summary of compliance with established regulatory limits for human and aquatic health. Data are presented first for reference tributaries, then for the main stem Santa Margarita River, and finally for the Santa Margarita River tributaries. An “x” in Table 3-2 denotes that the water body exceeded the Basin Plan limit for that particular constituent on at least one occasion. It should be noted that Arroyo Seco, Cole, Adobe, and Roblar Creeks are designated reference streams representing “background conditions.” Elevated levels of constituents in these streams presumably indicate naturally high levels (with only natural sources and aerial deposition accounting for constituent input).

TABLE 3-2 SUMMARY OF COMPLIANCE WITH WATER QUALITY THRESHOLDS[1]

		Reference Streams				SMR Monitoring Locations				Other Tributaries						
Constituent	**Compliant?[2]**	**Adobe Creek**	**Arroyo Seco**	**Cole Creek**	**Roblar Creek**	**SMR at FPUD Sump**	**SMR at MWD Crossing**	**SMR near Temecula**	**SMR at Ysidora**	**De Luz Creek**	**Devils Creek**	**Fallbrook Creek**	**Rainbow Creek**	**RCWD CWRMA Outfall**	**Sandia Creek**	**Stone Creek**
Aluminum	Yes	-	-	-	-		-		-	-	-	-	-	-		-
Ammonia-NH_3^-	No						x							x	x	
Antimony	Yes	-	-	-	-		-		-	-	-	-	-	-		-
Arsenic	Yes						-		-		-		-	-		
Beryllium	Yes	-	-	-	-		-		-	-	-	-	-	-		-
Bicarbonate	NA				-		-		-		-		-			
BOD_5	NA															
Boron	Yes	-	-	-			-		-		-	-	-	-		-
Cadmium	Yes	-	-	-	-		-		-	-	-		-	-		-
Calcium	NA				-		-		-		-		-	-		
Chloride	No				-		-		-		-	x	-			
Chromium	Yes	-	-	-	-		-		-	-	-		-	-		-
Copper	No	-	-	-	-		-		-		-		-	-	x	
Cyanide	No	-	-	-	-		-	x	-	x	-	-	-	-		-
Dissolved Oxygen	Yes	-	-	-			-		-		-		-	-		-
Fecal Coliform	Yes				-		-		-		-		-	-		
Fluoride	Yes				-		-		-		-		-			
Iron	No	x	x	x	x	x	-	x	-	x	-	x		-	x	x
Lead	Yes				-		-		-		-		-	-		
Manganese	No		x		x		-		-		-	x	-	-		
MBAS	Yes				-		-		-		-		-			
Mercury	Yes	-	-	-	-		-		-		-	-	-	-		-
Nickel	Yes	-	-	-	-		-		-	-	-		-	-		-
Nitrate as N	No					x				x	x		x	x	x	x
Nitrite as N	Yes															
Oil and Grease	Yes	-	-	-	-		-		-	-	-	-	-	-		-
pH	No						x	x				x		x	x	
Selenium	Yes	-	-	-	-		-		-	-	-		-	-		-
Silver	No	-	-	-	-	x	-	x	-	-	-	-	-		x	-
Sulfate	No					x	-	x	-	x	x	x	x		x	x
Total Dissolved Solids	No				-	x	-	-	-	x	x	x	x	-	x	x
Thallium	Yes				-		-		-	-	-		-	-		
TOC	Yes	-	-	-	-		-		-	-	-	-	-	-		-
Total Nitrogen	No			x		x	x	x	x	x	x		x	x	x	x
Total Phosphorus	No	x	x			x	x	x	x	x	x	x	x		x	x
Turbidity	Yes	-	-	-	-		-		-	-		-				
Zinc	Yes				-		-		-		-		-	-		
1,2,4-Trichlorobenzene	Yes	-	-	-	-		-		-		-	-	-	-		-
1,2-Dichlorobenzene	Yes	-	-	-	-		-		-		-	-	-	-		-
1,2-Diphenylhydrazine	Yes	-	-	-	-		-		-		-	-	-	-		-
1,3-Dichlorobenzene	Yes	-	-	-	-		-		-		-	-	-	-		-

		Reference Streams				SMR Monitoring Locations				Other Tributaries						
Constituent	**Compliant?[2]**	**Adobe Creek**	**Arroyo Seco**	**Cole Creek**	**Roblar Creek**	**SMR at FPUD Sump**	**SMR at MWD Crossing**	**SMR near Temecula**	**SMR at Ysidora**	**De Luz Creek**	**Devils Creek**	**Fallbrook Creek**	**Rainbow Creek**	**RCWD CWRMA Outfall**	**Sandia Creek**	**Stone Creek**
1,4-Dichlorobenzene	Yes	-	-	-	-		-		-		-	-	-	-		-
2,4-Dinitrotoluene	Yes	-	-	-	-		-		-		-	-	-	-		-
2,6-Dinitrotoluene	Yes	-	-	-	-		-		-		-	-	-	-		-
2-Chloronaphthalene	Yes	-	-	-	-		-		-		-	-	-	-		-
3,3'-Dichlorobenzidine	Yes	-	-	-	-		-		-		-	-	-	-		-
4,4'-DDD	Yes	-	-	-	-		-		-		-	-	-	-		-
4,4'-DDE	No	-	-	-	-	x	-	x	-		-	-	-	-		-
4,4'-DDT	Yes	-	-	-	-		-		-		-	-	-	-		-
Aldrin	Yes	-	-	-	-		-		-		-	-	-	-		-
Atrazine	Yes	-	-	-	-		-		-		-	-	-	-		-
Benzidine	Yes	-	-	-	-		-		-		-	-	-	-		-
BHC-alpha	Yes	-	-	-	-		-		-		-	-	-	-		-
BHC-beta	Yes	-	-	-	-		-		-		-	-	-	-		-
BHC-gamma	Yes	-	-	-	-		-		-		-	-	-	-		-
Chlordane (alpha+gamma)	Yes	-	-	-	-		-		-		-	-	-	-		-
Demeton	Yes	-	-	-	-		-		-		-	-	-	-		-
Diazinon	Yes	-	-	-	-		-		-		-	-	-	-		-
Dieldrin	Yes	-	-	-	-		-		-		-	-	-	-		-
Endosulfan Sulfate	Yes	-	-	-	-		-		-		-	-	-	-		-
Endosulfan-I (alpha)	Yes	-	-	-	-		-		-		-	-	-	-		-
Endosulfan-II (beta)	Yes	-	-	-	-		-		-		-	-	-	-		-
Endrin	Yes	-	-	-	-		-		-		-	-	-	-		-
Endrin Aldehyde	Yes	-	-	-	-		-		-		-	-	-	-		-
Heptachlor	Yes	-	-	-	-		-		-		-	-	-	-		-
Heptachlor Epoxide	Yes	-	-	-	-		-		-		-	-	-	-		-
Hexachlorobenzene	Yes	-	-	-	-		-		-		-	-	-	-		-
Hexachlorobutadiene	Yes	-	-	-	-		-		-		-	-	-	-		-
Hexachlorocyclopentadiene	Yes	-	-	-	-		-		-		-	-	-	-		-
Hexachloroethane	Yes	-	-	-	-		-		-		-	-	-	-		-
Isophorone	Yes	-	-	-	-		-		-		-	-	-	-		-
Malathion	Yes	-	-	-	-		-		-		-	-	-	-		-
Methoxychlor	Yes	-	-	-	-		-		-		-	-	-	-		-
Unregulated Pesticides[3]	NA	-	-	-	-	x	-	x	-	x	-	-	-	-	x	-
Emergent Constituents[3]	NA	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-
Pharmaceuticals[3]	NA	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-
UCMR2s[3]	NA	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-

[1] "-" denotes that the constituent was not measured at the specified site
"x" denotes that the water body exceeded the Basin Plan limit for that particular constituent on at least one occasion

[2] "No" indicates that at least one water body does not meet regulatory thresholds .
"NA" indicates that there is no water quality standard established for this constituent

[3] At least one constituent was detected in this category of water quality

3.1.2.1 Adobe Creek

Adobe Creek served as a reference site for this study. Three of five samples tested for iron were above the Basin Plan limit. All five samples analyzed for Total Nitrogen (TN) were within Basin Plan limits. One of five samples analyzed for Total Phosphorus (TP) exceeded the Basin Plan limit.

3.1.2.2 Arroyo Seco and Cole Creek

Arroyo Seco and Cole Creek served as reference sites for this study. These sites were added during the study period and were only sampled in February 2009 due to the ephemeral nature of these streams. Elevated concentrations of iron and manganese were detected at Arroyo Seco and elevated iron was detected at Cole Creek. The sample at Arroyo Seco exceeded the Basin Plan limit for TP while the sample at Cole Creek exceeded the Basin Plan limit for TN.

3.1.2.3 Roblar Creek at Falls

Roblar Creek served as a reference site for this study. Two of six and one of six samples tested for iron and manganese respectively exceeded Basin Plan limits. Six of six samples analyzed for TN and TP were within Basin Plan limits.

3.1.2.4 Santa Margarita River at FPUD Sump near Fallbrook

The Fallbrook Public Utility District (FPUD) Sump was the closest sampled site on the main stem of the river upstream of Camp Pendleton. Six of eight samples analyzed for total dissolved solids (TDS) exceeded the Basin Plan limit while the other two samples were above the CCR's secondary Maximum Contaminant Load (MCL) for consumer acceptance. Four samples tested for sulfate, one sample tested for iron, and one sample tested for silver of eight samples exceeded Basin Plan limits. Sixteen of 24 samples analyzed for TN exceeded the Basin Plan limit. Six of 24 samples exceeded the Basin Plan limit for nitrate. Five of 24 samples analyzed for TP exceeded the Basin Plan limit. One of seven samples analyzed for 4,4'DDE exceeded the CTR standard.

3.1.2.5 Santa Margarita River at MWD Crossing (SMER)

The MWD Crossing of the river is located within SMER. One of 15 samples tested for pH was above the Basin Plan limit accounting for a 7% exceedance rate (which is allowable by the Basin Plan). Six of 15 samples tested for TN exceeded the Basin Plan limit, while one of the

15 samples exceeded the Basin Plan limit for un-ionized ammonia. Two of 15 samples exceeded the Basin Plan limit for TP.

3.1.2.6 Santa Margarita River near Temecula

The Gorge is the farthest upstream site on the river and indicated elevated levels of constituents originating in the upper watershed. Eight of eight samples analyzed for TDS were above the CCR's secondary MCL for consumer acceptance. Two of eight and one of seven samples detected iron and silver, respectively, above Basin Plan limits. One of eight samples tested for cyanide and sulfate was above Basin Plan limits. Eight of 24 samples analyzed for TN exceeded the Basin Plan limit, while five of the 24 samples exceeded the Basin Plan limit for TP. One of eight samples analyzed for 4,4'DDE exceeded the CTR standard.

3.1.2.7 Santa Margarita River at Ysidora

This sampling location was added in February 2009. All general constituent data complied with Basin Plan, CTR, and CCR limits. Two of ten samples analyzed for TN exceeded the Basin Plan limit. Ten of ten samples analyzed for TP exceeded the Basin Plan limit.

3.1.2.8 De Luz Creek near De Luz

Four of four samples tested for both sulfate and TDS were above Basin Plan limits. One of four samples tested for both cyanide and iron exceeded Basin Plan limits. There were no measured exceedances of the Basin Plan manganese limit, although this tributary is listed as impaired on the 303(d) List for manganese. Twelve of 12 samples analyzed for TN and nitrate exceeded Basin Plan limits. TP concentrations were within the Basin Plan limit except on one occasion in February 2009.

3.1.2.9 Devils Creek at Via Novilla, SMER

Devils Creek is located within the SMER. The only sample tested for sulfate and TDS exceeded both Basin Plan limits. The sample was taken in September 2009 and suggests that further sampling may be needed. Sixteen of 16 samples tested for TN and nitrate exceeded Basin Plan limits while four of the 16 samples exceeded the Basin Plan limit for TP.

3.1.2.10 Fallbrook Creek near Fallbrook

Fallbrook Creek empties directly into Lake O'Neill, which is used to recharge the Upper Ysidora groundwater sub-basin, one of Camp Pendleton's primary sources of water. Six of six samples analyzed for iron and manganese exceeded Basin Plan limits. Four of six samples tested for TDS exceeded the Basin Plan limit while another sample was above the CCR's secondary MCL for consumer acceptance but did not exceed the Basin Plan limit. Chloride, pH, and sulfate each had one Basin Plan limit exceedance in the six samples taken. Six of six samples analyzed for TN were within the Basin Plan limit. Four of four samples analyzed for TP exceeded the Basin Plan limit.

3.1.2.11 Rainbow Creek

Data for Rainbow Creek were provided by San Diego County and are from station 902SMG005. Twenty-four of 24 samples analyzed for TDS exceeded the Basin Plan limit. Twenty-one of 22 samples analyzed for sulfate exceeded the Basin Plan limit. Twenty-four of 24 samples analyzed for nitrate and TN and 21 of 24 samples analyzed for TP exceeded Basin Plan limits.

3.1.2.12 RCWD CWRMA Outfall

The RCWD CWRMA Outfall is located immediately upstream of the Santa Margarita River near Temecula USGS gage. During 2008, samples were taken from potable water released from the System River Meter just upstream of the confluence with Temecula Creek. In 2009, all samples were taken from WR-34 in which releases raw water from MWD into the Santa Margarita River. Two of three samples from WR-34 that were analyzed for TDS exceeded the CCR's secondary MCL for consumer acceptance. Three of eight samples analyzed for TN exceeded the Basin Plan limit (one at WR-34 and two at the System River Meter). One of eight and one of nine samples analyzed for un-ionized ammonia and nitrate, respectively, exceeded Basin Plan limits (System River Meter) TP concentrations were within Basin Plan limits.

3.1.2.13 Sandia Creek near Fallbrook

Nine of nine samples analyzed for sulfate and TDS exceeded Basin Plan limits. One of eight samples analyzed for copper exceeded the Basin Plan limit. Two of eight samples analyzed for iron and silver exceeded Basin Plan limits. Twenty-five of 25 samples analyzed for TN and nitrate exceeded the Basin Plan limit while one of the 25 samples analyzed for un-ionized ammonia exceeded the Basin Plan limit. Six of 25 samples analyzed for TP exceeded the Basin Plan limit.

3.1.2.14 Stone Creek near Stagecoach Lane, SMER

Stone Creek is located within SMER. Six of six samples analyzed for TDS exceeded the Basin Plan limit. One of five and one of six samples tested for iron and sulfate, respectively, exceeded Basin Plan limits. Eighteen of 18 samples analyzed for TN exceeded the Basin Plan limit while eight of 18 samples analyzed for nitrate exceeded the Basin Plan limit. Five of 18 samples analyzed for TP exceeded the Basin Plan limit.

3.1.2.15 San Mateo Creek near San Clemente

San Mateo Creek served as an additional reference stream located north of the Santa Margarita River watershed. The upper watershed of San Mateo Creek is composed primarily of the Cleveland National Forest and has limited human impacts. As opposed to the other reference streams described in this report, San Mateo Creek represents a larger stream class with more consistent annual flows. While the Creek is outside of the scope of this program, data from one sampling site on the creek was included as an additional reference stream. Stetson Engineers has been monitoring this stream as part of a separate monitoring program.

Water quality data for San Mateo Creek between December 2007 and June 2009 are presented in Appendix J. San Mateo Creek did not have any water quality impairments, except for exceeding the Basin Plan limit for iron on one occasion.

3.1.2.16 Summary of Results

Table 3-3 presents ranges of measured concentrations for key constituents for the entire sampling period. A key constituent is one that exceeded the Basin Plan limit numerous times and at multiple locations. The data show that several tributaries were contributing high levels of TDS to the lower Santa Margarita River, including De Luz, Devils, Fallbrook, Rainbow, Sandia and Stone Creeks. Several of the tributaries contributed elevated levels of iron, including Arroyo Seco, Adobe, Cole, Roblar, De Luz, Fallbrook, Sandia, and Stone Creeks. Sites on the Santa Margarita River that had high iron concentrations include the FPUD Sump and the Gorge. Arroyo Seco, Roblar and Fallbrook Creeks were sources of elevated manganese levels. Levels of pH were occasionally elevated (or depressed) outside the acceptable range at several locations, including the Gorge, MWD Crossing, Devils Creek, Fallbrook Creek, CWRMA Outfall and Sandia Creek. The data also showed levels of sulfate exceeding Basin Plan limits at De Luz, Fallbrook, Sandia and Stone Creeks as well as at the Gorge and FPUD Sump. Slightly elevated concentrations of silver (based on the Basin Plan's aquatic life limit) were observed at the FPUD Sump, the Gorge and Sandia Creek. There was also one occurrence of elevated cyanide at the Gorge and De Luz Creek, one occurrence of elevated copper at Sandia Creek and one occurrence of elevated chloride at Fallbrook Creek.

Several tributaries including Cole, De Luz, Devils, Rainbow, Sandia, and Stone Creeks as well as the CWRMA Outfall contributed TN in excess of Basin Plan limits. TN in exceedance of the Basin Plan limit was detected at all sites on the Santa Margarita River. Elevated levels of un-ionized ammonia were detected on one occasion at the CWRMA Outfall, Sandia Creek, and Santa Margarita River at MWD Crossing. Nitrate in excess of the Basin Plan limit was detected at De Luz, Devils, Rainbow, Sandia and Stone Creeks as well as at the CWRMA Outfall and the FPUD Sump. Several tributaries including Arroyo Seco, Adobe, De Luz, Devils, Fallbrook, Sandia, and Stone Creeks contributed TP in excess of Basin Plan limits. TP in exceedance of the Basin Plan limit was detected at all sites along the Santa Margarita River.

TABLE 3-3 SUMMARY OF THE RANGE OF CONCENTRATIONS FOR THE ENTIRE SAMPLING PERIOD FOR KEY CONSTITUENTS (MG/L)[1]

Monitoring Location	Total Nitrogen	Total Phosphorus	Nitrate as N	Iron	Manganese	Total Dissolved Solids	Sulfate
Adobe Creek	0.24 - 0.76	0.02 - 0.13	0.16 - 0.76	0.07 - 1.16	0.01 - 0.04	130 - 315	15 - 31
Arroyo Seco and Cole Creek	0.83 - 1.28	0.04 - 0.13	0.23 - 0.65	1.61 - 1.87	0.01 - 0.09	150 - 208	13 - 21
Roblar Creek	0.00 - 0.15	0.00 - 0.09	0.00 - 0.06	0.09 - 0.61	0.00 - 0.08	---	26 - 95
SMR at FPUD Sump	0.26 - 6.73	0.01 - 0.67	0.26 - 5.92	0.13 - 0.61	0.00 - 0.05	710 - 970	206 - 305
SMR at MWD Crossing	0.28 - 1.47	0.00 - 0.54	0.21 - 1.26	---	---	---	---
SMR near Temecula (Gorge)	0.29 - 2.59	0.00 - 0.45	0.21 - 1.90	0.01 - 0.38	0.01 - 0.4	470 - 680	126 - 299
SMR at Ysidora	0.00 - 1.24	0.12 - 0.20	0.00 - 0.87	---	---	---	---
De Luz Creek	2.77 - 7.87	0.00 - 0.65	1.93 - 7.61	0.12 - 0.46	0.00 - 0.21	1,010 - 1,200	296 - 342
Devils Creek	5.97 - 9.14	0.00 - 0.39	1.65 - 8.94	---	---	1280[2]	368[2]
Fallbrook Creek	0.00 – 0.78	0.15 – 0.46	0.00 – 0.12	0.44 – 0.81	0.05 – 0.67	480 – 1,240	95 – 272
Rainbow Creek	2.42 – 14.70	0.03 – 0.52	2.42 – 14.07	0.00 – 0.30	---	736 – 1,250	230 – 375
RCWD CWRMA Outfall	0.33 – 3.12	0.00 – 0.06	0.13 – 3.20	---	---	480 – 580	159 – 186
Sandia Creek	2.40 – 8.25	0.01 – 0.40	2.33 – 7.88	0.07 – 0.50	0.01 – 0.02	1,080 – 1,200	309 – 347
Stone Creek	1.73 – 5.07	0.00 – 0.01	0.68 – 4.67	0.04 – 0.51	0.00 – 0.02	780 – 1,080	158 – 264

[1] “---“ denotes that the constituent was not analyzed at that monitoring location

[2] One sample was taken for TDS and sulfate at Devils Creek

Table 3-4 through Table 3-6 present the number of times the constituent exceeded the Basin Plan limit, the total number of samples, and the percent exceedance. Figures 8 through 13 depict exceedances of TN, TP, iron, manganese, sulfate, and TDS at monitoring locations within the study area.

Pesticides were analyzed on multiple occasions at De Luz and Sandia Creeks as well as at the FPUD Sump and Gorge. Out of 107 pesticides that were analyzed, 15 were detected. Of the 15 detected, 12 pesticides were detected only on the February 2009 sampling date which had high flows. Simazine was detected frequently at all four sampling sites and ranged between 12 and 2913 ng/L. The only pesticide detected that exceeded CTR standards was 4,4' DDE which was detected at the FPUD Sump and Gorge. Pharmaceuticals and UCMR2s were analyzed at the FPUD Sump and many were detected which are not currently regulated. For more information on the detected pesticides, pharmaceuticals, and UCMR2s, see Appendix J.

TABLE 3-4 SUMMARY OF EXCEEDANCES FOR IRON AND MANGANESE[1]

	Iron			Manganese		
Monitoring Location	**Exceedances**	**Number of Samples**	**% Exceedance**	**Exceedances**	**Number of Samples**	**% Exceedance**
Adobe Creek	3	5	60%	0	5	0%
Arroyo Seco	1	1	100%	1	1	100%
Cole Creek	1	1	100%	0	1	0%
Roblar Creek	2	6	33%	1	6	17%
SMR at FPUD Sump	1	8	13%	0	8	0%
SMR at MWD Crossing	---	---	---	---	---	---
SMR near Temecula	2	8	25%	0	8	0%
SMR at Ysidora	---	---	---	---	---	---
Devils Creek	---	---	---	---	---	---
De Luz Creek	1	4	25%	0	4	0%
Fallbrook Creek	6	6	100%	6	6	100%
Rainbow Creek	0	21	0%	---	---	---
RCWD CWRMA Outfall	---	---	---	---	---	---
Sandia Creek	2	8	25%	0	8	0%
Stone Creek	1	5	20%	0	5	0%

[1] "---" denotes constituent was not sampled at that monitoring location

TABLE 3-5 SUMMARY OF EXCEEDANCES FOR SULFATE AND TOTAL DISSOLVED SOLIDS[1]

	Sulfate			Total Dissolved Solids		
Monitoring Location	Exceedances	Number of Samples	% Exceedance	Exceedances	Number of Samples	% Exceedance
Adobe Creek	0	5	0%	0	5	0%
Arroyo Seco	0	1	0%	0	1	0%
Cole Creek	0	1	0%	0	1	0%
Roblar Creek	0	6	0%	---	---	---
SMR at FPUD Sump	4	8	50%	6	8	75%
SMR near Temecula	1	8	13%	0	8	0%
SMR at MWD Crossing	---	---	---	---	---	---
SMR at Ysidora	---	---	---	---	---	---
De Luz Creek	4	4	100%	4	4	100%
Devils Creek	1	1	100%	1	1	100%
Fallbrook Creek	1	6	17%	4	6	67%
Rainbow Creek	21	22	95%	24	24	100%
RCWD CWRMA Outfall	0	2	0%	0	3	0%
Sandia Creek	9	9	100%	9	9	100%
Stone Creek	1	6	17%	6	6	100%

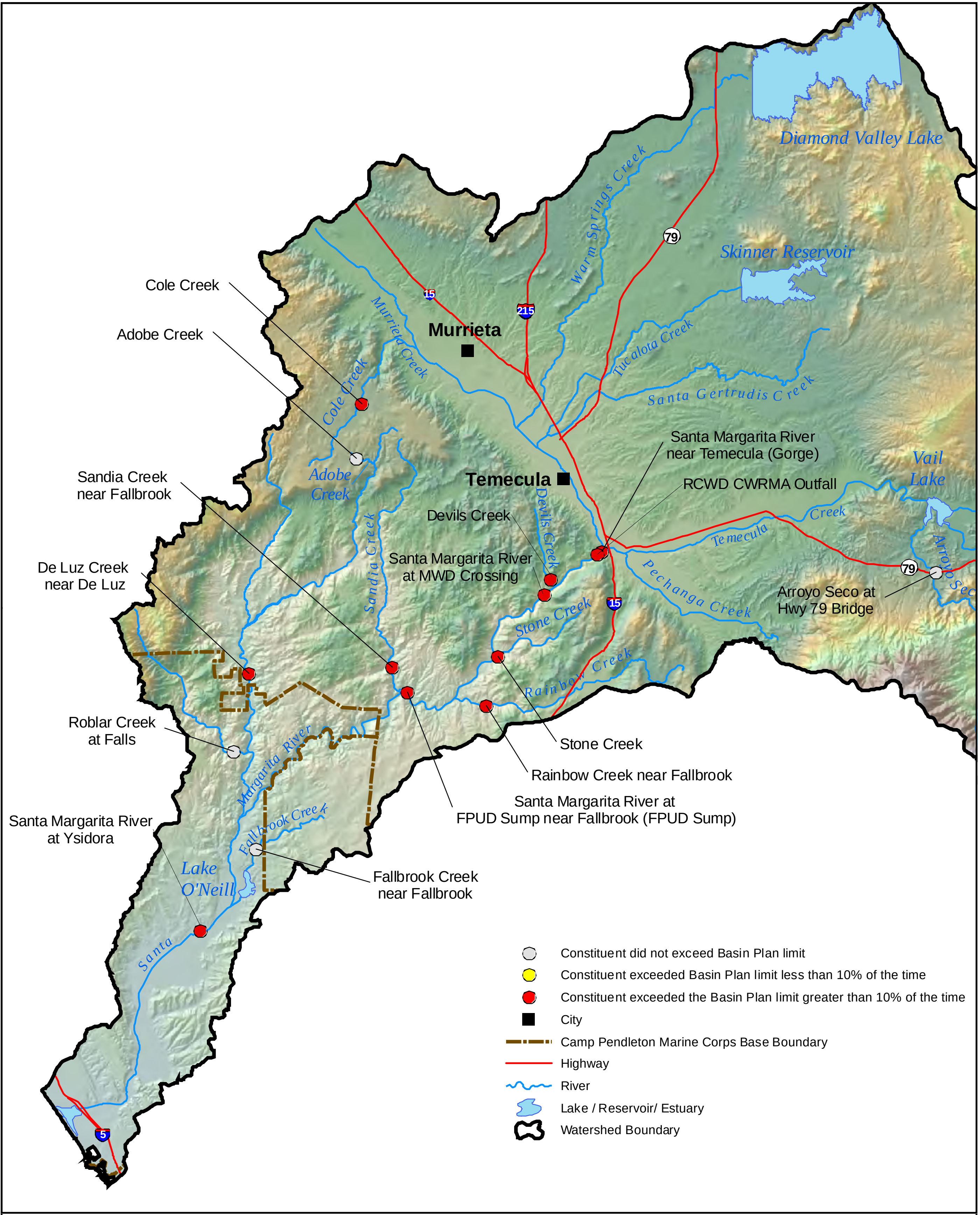
[1] "---" denotes constituent was not sampled at that monitoring location

TABLE 3-6 SUMMARY OF EXCEEDANCES FOR TOTAL NITROGEN AND TOTAL PHOSPHORUS[1]

	Total Nitrogen			Total Phosphorus		
Monitoring Location	Exceedances	Number of Samples	% Exceedance	Exceedances	Number of Samples	% Exceedance
Adobe Creek	0	5	0%	1	5	20%
Arroyo Seco	0	1	0%	1	1	100%
Cole Creek	1	1	100%	0	1	0%
Roblar Creek	0	6	0%	0	6	0%
SMR at FPUD Sump	16	24	67%	5	24	21%
SMR near Temecula	8	24	33%	5	24	21%
SMR at MWD Crossing	6	15	40%	2	15	13%
SMR at Ysidora	2	10	20%	10	10	100%
De Luz Creek	12	12	100%	1	12	8%
Devils Creek	16	16	100%	4	16	25%
Fallbrook Creek	0	6	0%	4	4	100%
Rainbow Creek	24	24	100%	21	24	88%
RCWD CWRMA Outfall	3	8	38%	0	9	0%
Sandia Creek	25	25	100%	6	25	24%
Stone Creek	18	18	100%	5	18	28%

[1] "---" denotes constituent was not sampled at that monitoring location

FIGURE 8



J:/n2258/wqmonstations_SMR_totalnitrogen.mxd 1/27/2010 N.Wasserman

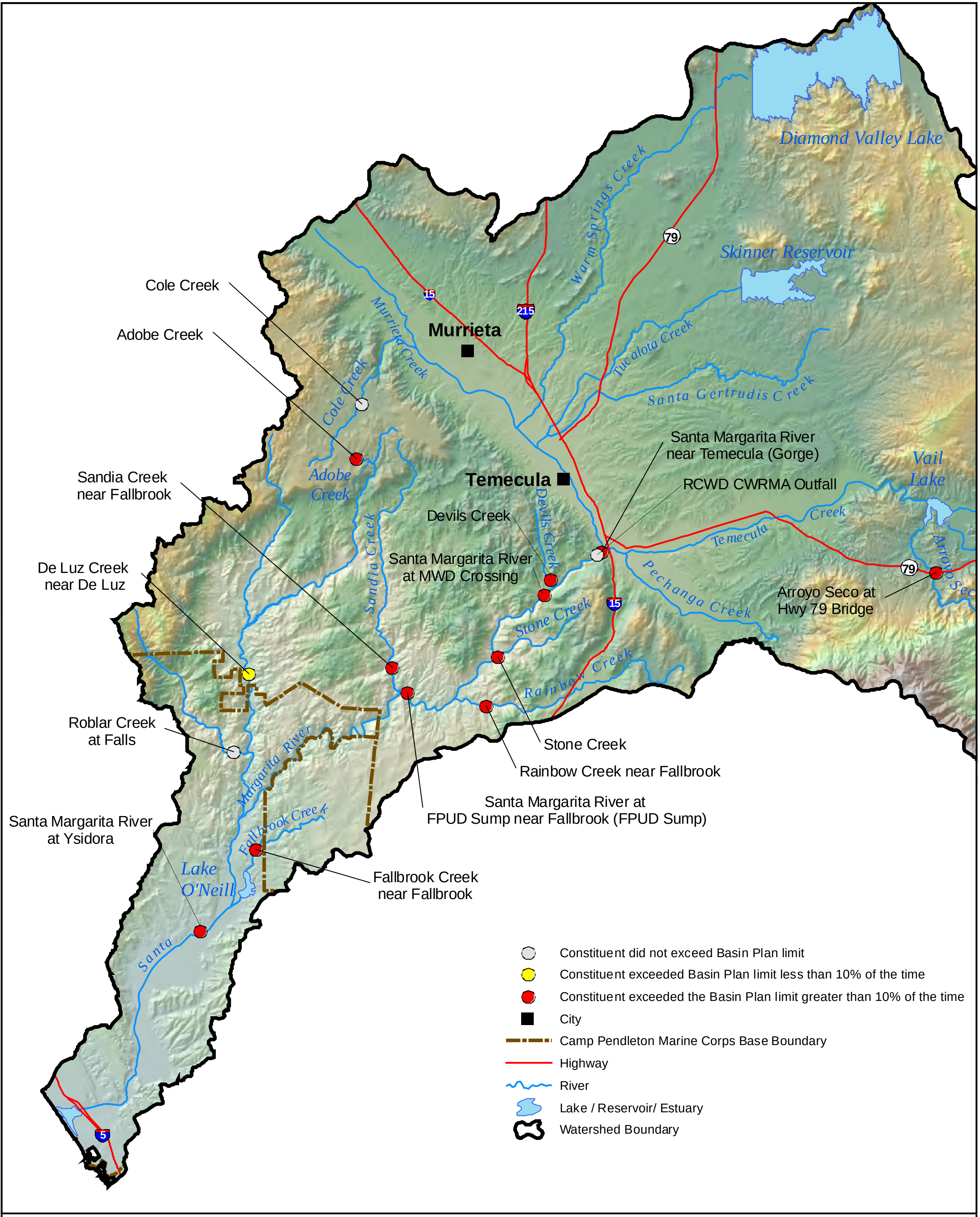
STETSON ENGINEERS INC.

TOTAL NITROGEN MONITORING LOCATIONS
NOVEMBER 2007 - SEPTEMBER 2009

N

0 2.5 5 Miles

FIGURE 9

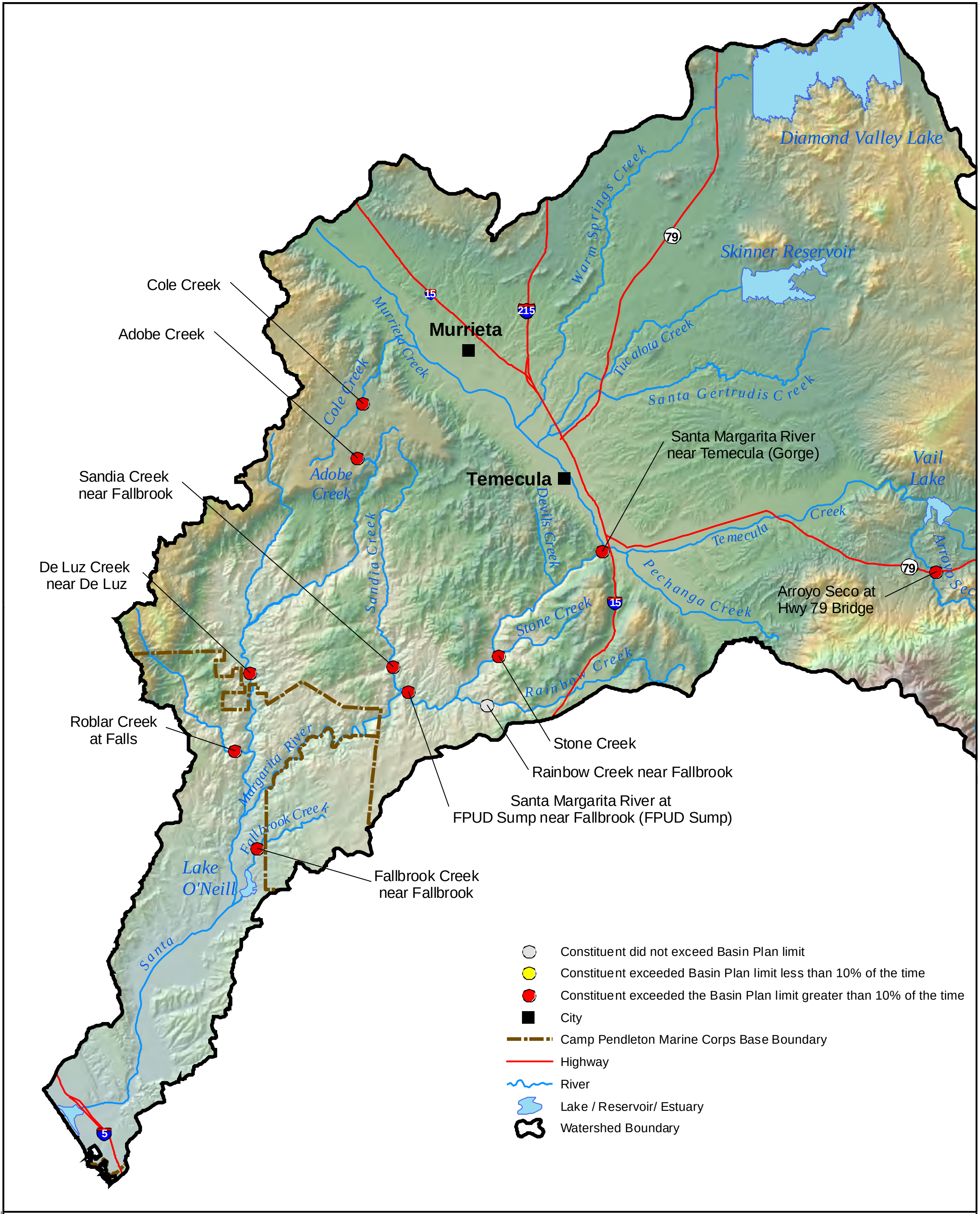


J:/jn2258/wqmonstations_SMR_totalPhosphorus.mxd 1/26/2010 N.Wasserman

STETSON
ENGINEERS INC.

TOTAL PHOSPHORUS MONITORING LOCATIONS
NOVEMBER 2007 - SEPTEMBER 2009

FIGURE 10



○ Constituent did not exceed Basin Plan limit
● Constituent exceeded Basin Plan limit less than 10% of the time
● Constituent exceeded the Basin Plan limit greater than 10% of the time
■ City
Camp Pendleton Marine Corps Base Boundary
Highway
River
Lake / Reservoir/ Estuary
Watershed Boundary

J:/jn2258/wqmonstations_SMR_iron.mxd 11/16/09 N.Wasserman

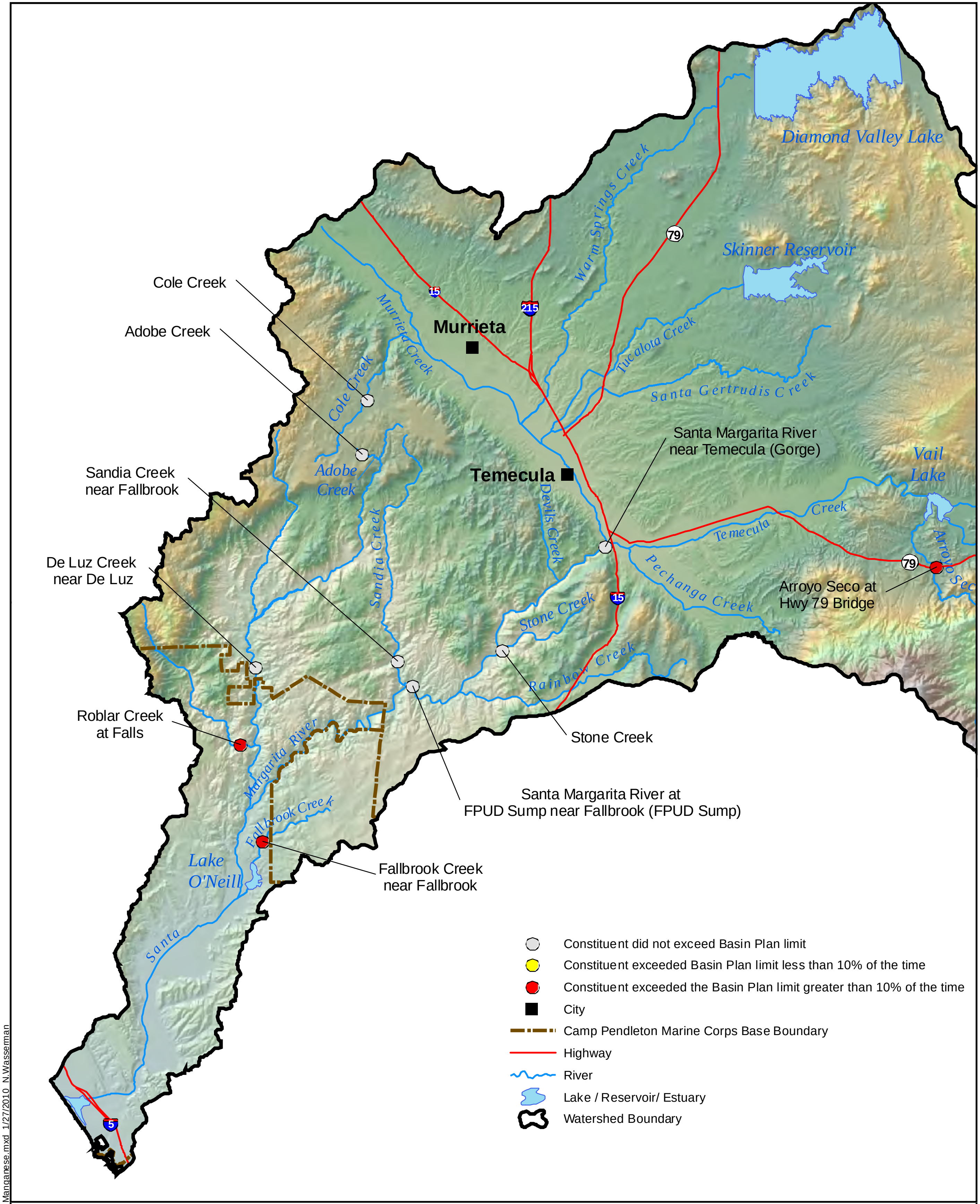
STETSON ENGINEERS INC.

IRON MONITORING LOCATIONS
NOVEMBER 2007 - SEPTEMBER 2009

N

0 2.5 5 Miles

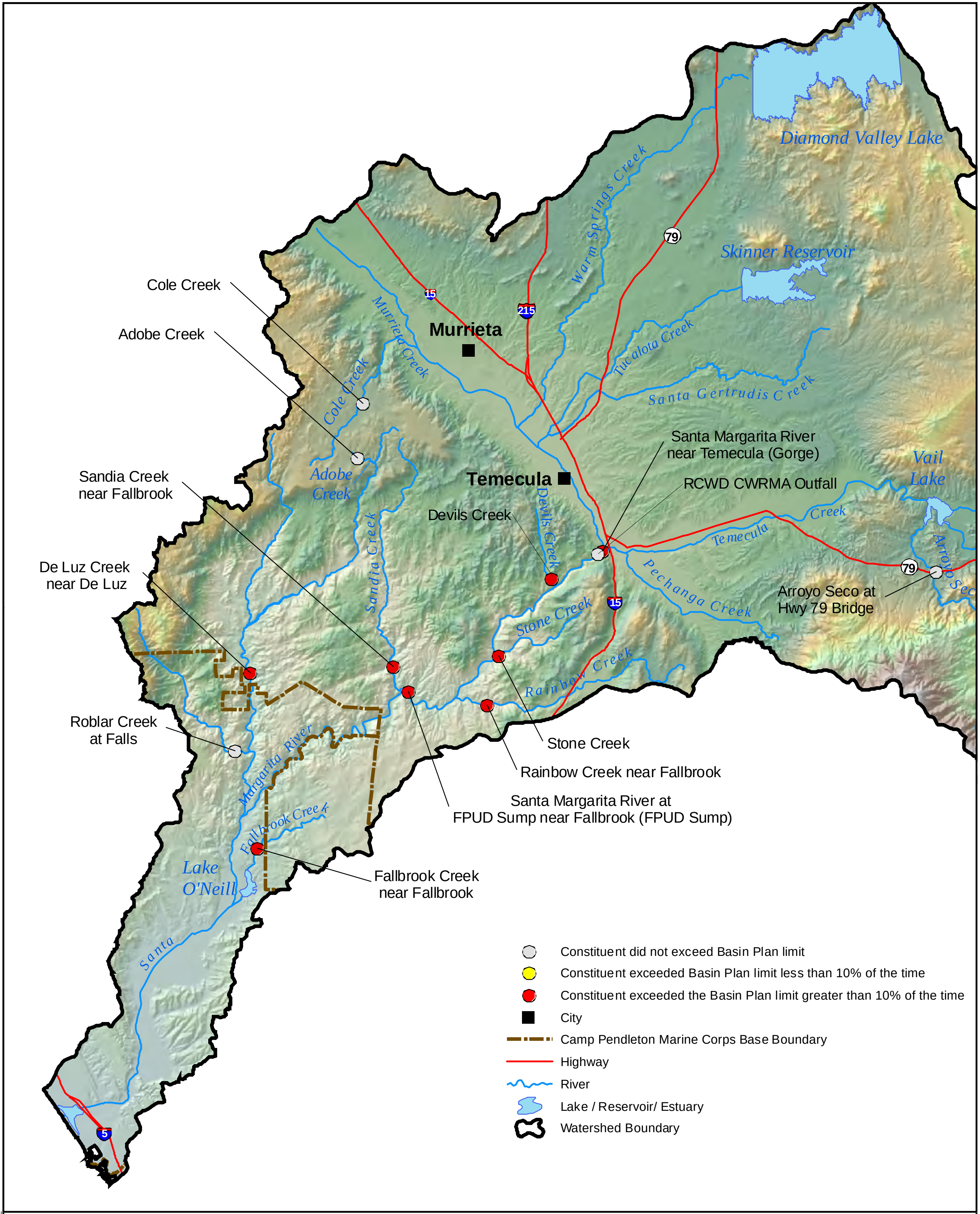
FIGURE 11



J:/n2258/wqmonstations_SMR_Manganese.mxd 1/27/2010 N.Wasserman

STETSON ENGINEERS INC.

MANGANESE MONITORING LOCATIONS
NOVEMBER 2007 - SEPTEMBER 2009



○ Constituent did not exceed Basin Plan limit
● Constituent exceeded Basin Plan limit less than 10% of the time
● Constituent exceeded the Basin Plan limit greater than 10% of the time
■ City
Camp Pendleton Marine Corps Base Boundary
Highway
River
Lake / Reservoir/ Estuary
Watershed Boundary

STETSON ENGINEERS INC.

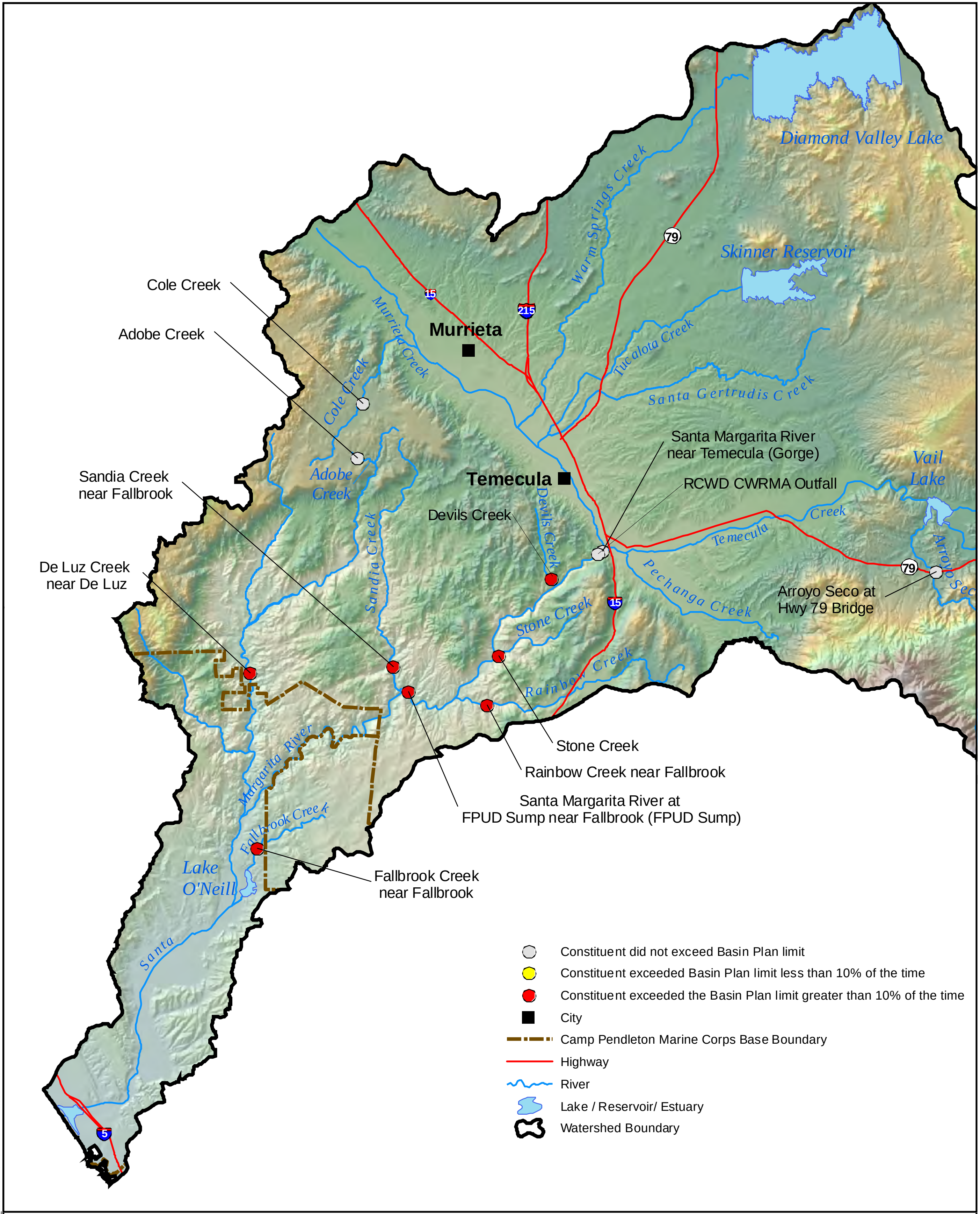
SULFATE MONITORING LOCATIONS
NOVEMBER 2007 - SEPTEMBER 2009

N

0 2.5 5 Miles

J:/jn2258/wqmonstations_SMR_sulfate.mxd 1/27/2010 N.Wasserman

FIGURE 13



STETSON ENGINEERS INC.

TOTAL DISSOLVED SOLIDS MONITORING LOCATIONS
NOVEMBER 2007 - SEPTEMBER 2009

N

0 2.5 5
Miles

J:/n2258/wqmonstations_SMR_tds.mxd 1/27/2010 N.Wasserman

3.1.3 Continuous Water Quality Measurements

The results of the continuous water quality monitoring at the FPUD Sump are presented in Appendix J, Tables J-32 through J-41, as daily average values for water temperature, conductivity, pH, dissolved oxygen, and turbidity for water years 2008 and 2009.

3.1.4 Periphyton and Macrophyton Results

The algae data were collected to support the Nutrient Numeric Endpoint modeling (discussed in Section 5), to provide a baseline for future comparison, and to support future watershed modeling necessary for water quality compliance initiatives such as total maximum daily loads and site specific objectives for water quality.

Five locations were sampled for periphyton and macrophyton in the spring and fall of 2008 and in the spring of 2009 (Sandia Creek, Roblar Creek, De Luz Creek, Santa Margarita River-Gorge, and Santa Margarita River-Fallbrook) in accordance with the methods discussed in Appendix G. In June 2009, two samples were also taken at Santa Margarita River Ysidora. The laboratory results for the periphyton samples are provided in Appendix J. A complete analysis and review of the data follow. A summary of these data are provided in Table 3-7.

Preliminary results suggest that there are substantial differences in the periphyton across the sampling locations, most likely associated with differences in flow rates, temperature, and nutrient regimes. The preliminary data also suggested that there are specific genera of diatoms that are particularly sensitive to changes in the aquatic environment. Based on this information, a preliminary “Diatom Genera vs. Sensitivity Index” was created. This information is derived from existing research on diatoms. We are updating and validating this analysis by using several references and publications, specifically the seminal publication “A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands” by Van Dam, Mertens and Sinkeldam (1994) and “Using diatoms to assess the biological condition of large rivers in Idaho (U.S.A)” by Fore and Grafe, 2002. Additional Indicators can be used when we have water quality data congruent in time with periphyton data.

TABLE 3-7 SUMMARY OF OBSERVED DIATOMS WITH CHARACTERISTICS DERIVED FROM "INDEX OF MANGEMENT/LAB METHODS"

Diatom Genera[1]	Sensitivity Indices[2]						
	Salinity	Low pH	Oxygen	Nitrogen	Trophic	Saprobity	Desiccation
Achnanthes	S[3]		S	S	S	S	
Amphora	T	S		S	T	T	
Aulacoseira	S				S	S	S
Amphipleura							
Amphora							
Anomoeoneis							
Asterionella							
Aulacoseira							
Bacillaria							
Biddulphia							
Brachysira							
Caloneis		S					
Cocconeis		S	T	T	T	S	S
Cyclotella		S	T			T	S
Cymbella	S		S		S	S	
Denticula					S		
Diatoma		S			T	T	S
Diploneis							
Encyonema							
Entomoneis							
Epithemia							
Eunotia	S	T	S		S	S	
Fragillaria		S	S				S
Frustulia							
Gomphonema	S		S				
Gyrosigma							
Hantzschia							
Mastogloia							
Melosira					T	T	
Meridion							
Navicula							
Neidium							
Nitzschia	T	S	T	T	T	T	
Pinnularia	S	T			S	S	
Plagiotropis							
Planothidium							
Pleurosigma							
Reimeria							
Rhoicosphenia							
Rhopalodia							

Diatom Genera[1]	**Sensitivity Indices[2]**						
	Salinity	**Low pH**	**Oxygen**	**Nitrogen**	**Trophic**	**Saprobity**	**Desiccation**
Stauroneis	S				S	S	
Stenopterobia							
Stephanodiscus							
Surirella	T	S		S		S	S
Synedra							
Thalassiosira							

[1] Genera listed are those detected through 2009.

[2] Salinity (freshwater), pH (low), Oxygen (requirement), N (metabolism), Trophic Index (inorganic N and P) concentrations), Saprobity (organic enrichment with biological oxygen demand), Desiccation Index (drying).

[3] S denotes sensitive genera, T denotes tolerant genera, and blanks are unknown at this time.

A total of 239 diatom species in 44 genera were observed across the six water reaches sampled. Thirty-five species were observed only once, 129 species had abundances of tenor less, 21 had abundances of 100 or more and 3 had abundances of more than 1000. The genera with the greatest relative abundance, in descending order, were; *Fragilaria* (27.12%), *Achnanthes* (19.22%), *Cocconies* (17.57%), *and Nitzcshia* (10.51%). *Fragilaria* is sensitive to low pH, low oxygen, and desiccation while *Achnanthes* is sensitive to salinity, low oxygen, nitrogen, trophic index, and saprobity index. *Cocconeis*, on the other hand is tolerant of oxygen, nitrogen conditions and trophic index while retaining sensitivity to low pH, saprobity index and desiccation. Nitzschia is also very tolerant of most of the indices, with the exception of low pH.

Using the data from Table 3-7 and other known indicator genera (based on the referenced literature), the study team was able to compare conditions with measured genera to arrive at a preliminary sensitivity diatom matrix. As an example, genera sensitive to low pH were plotted by relative abundance for the six water courses sampled (see Figure 14). It is clear Sandia Creek and the Santa Margarita River are largely inhabited by periphyton preferring an alkaline habitat (pH of >7). Combining the samples from all sample dates reveals between 70% and 80% relative abundance of alkaline lovers across all sample dates at those two locations. The most common genera preferring high pH conditions were *Amphora, Cocconeis, Diatoma, Diploneis, and Fragilaria.* While water quality samples were not taken in the same time frame as the periphyton samples, it is clear from the measurements made that the average pH is well above 7 in all reaches where periphyton samples were taken. The alkalinity of the water was supported by the fact that genera favoring low pH, such as *Eunotia*, *Neidium, and Pinnularia* were present in the data with a relative abundance of less than 1%.

Another example of the application of these ecological indicators is to look at periphyton sensitivity to saprobity, conditions where there were an excess of nutrients combined with low oxygen saturation. High saprobity implies conditions of poor water quality, low oxygen saturation and high levels of biodegraded organic matter, i.e., pollution. Figure 15 is a graph of the relative abundance of the sampled periphyton genera with low saprobic indices (and sensitive to organic pollution) divided by the relative abundance of sampled periphyton genera that have higher saprobic indices (and are more tolerant to organic pollution). In this chart, large numbers are good. The result clearly shows for half the sample sites pollution was relatively low (low saprobic scores), with Roblar Creek (a reference site) being a major exception. The poor score shown for Roblar Creek implies a water quality class of III – IV, oxygen saturation of 10-25%, and levels of biodegraded organic material in the range of 13-22 mg/l (see Table 3-8). Roblar may be a poor example since the sample area is a small pool at the bottom of a cliff. The Santa Margarita at the Levee (Ysidora and Levee) and De Luz Creek locations are more representative of the streams in the drainage basin and both measured high in nutrients.

High algal biomass can indicate eutrophication while low values may indicate toxic conditions or recent storm events or a spate of heavy grazing. One guideline for the oligotropic-mesotrophic boundary is a mean benthic chlorophyll *a* of 2 $\mu g/cm^2$ or a maximum of 7 $\mu g/cm^2$ and the mesotrophic-eutrophic boundary is a mean of 6 $\mu g/cm^2$ and a maximum of 20 $\mu g/cm^2$. The data sampled from the gorge and from the FPUD Sump areas of the Santa Margarita River over the two year period showed considerable fluctuation, but still within the oligotrophic region (see Figures 16 and 17). These values corresponded to the periphyton saprobic indices of between 1 and 2 that were measured in our samples (see Table 3-9).

This holistic approach to understanding the biotic component of the watershed provides additional insight into the biological integrity within the watershed, and an index by which to compare this integrity across sites. These data have the potential to be used for the improvement of watershed modeling necessary for water quality compliance initiatives such as total maximum daily loads and site specific objectives for water quality.

FIGURE 14

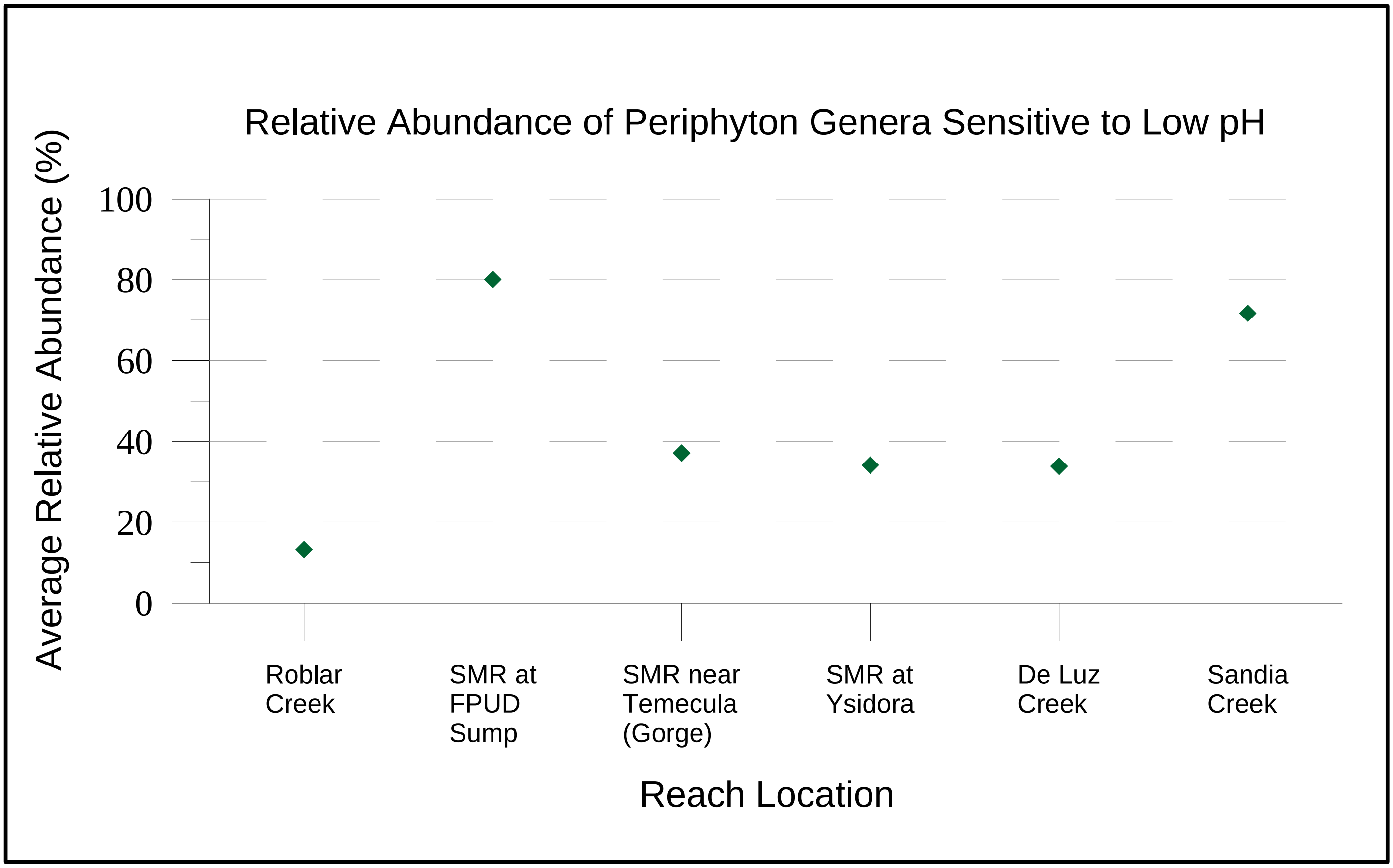
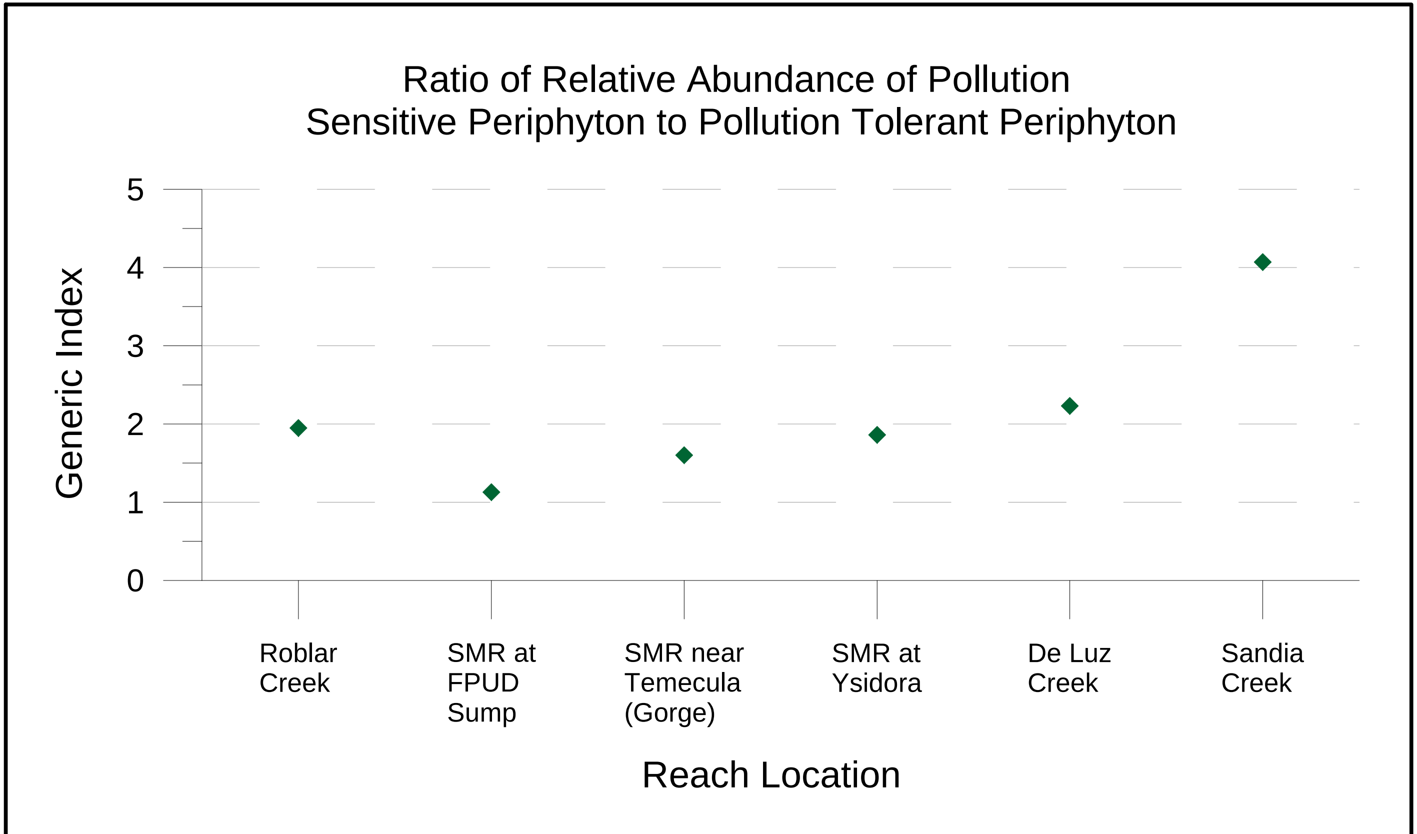


FIGURE 15



Note: Lower ratios indicative of high quality water bodies

FIGURE 16

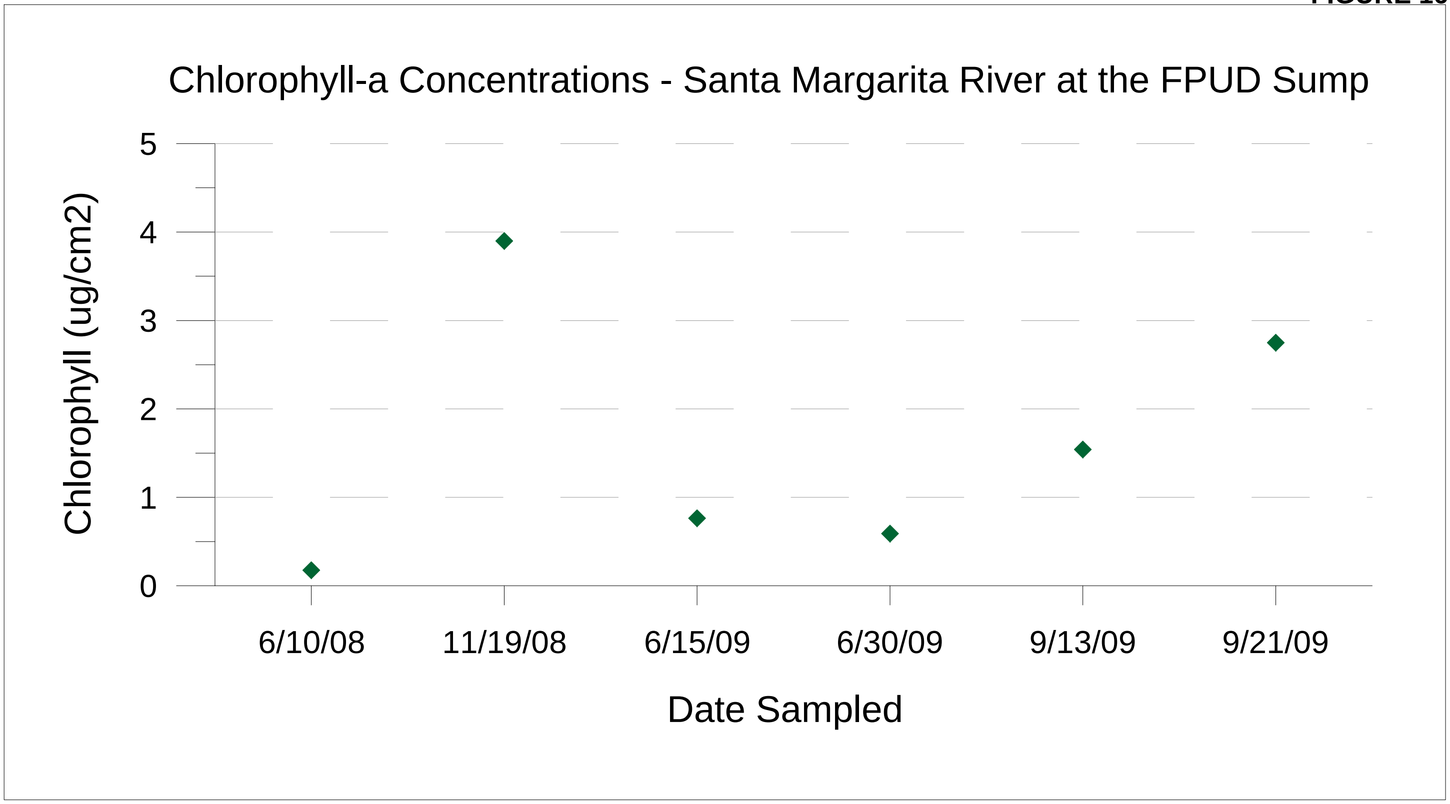


FIGURE 17

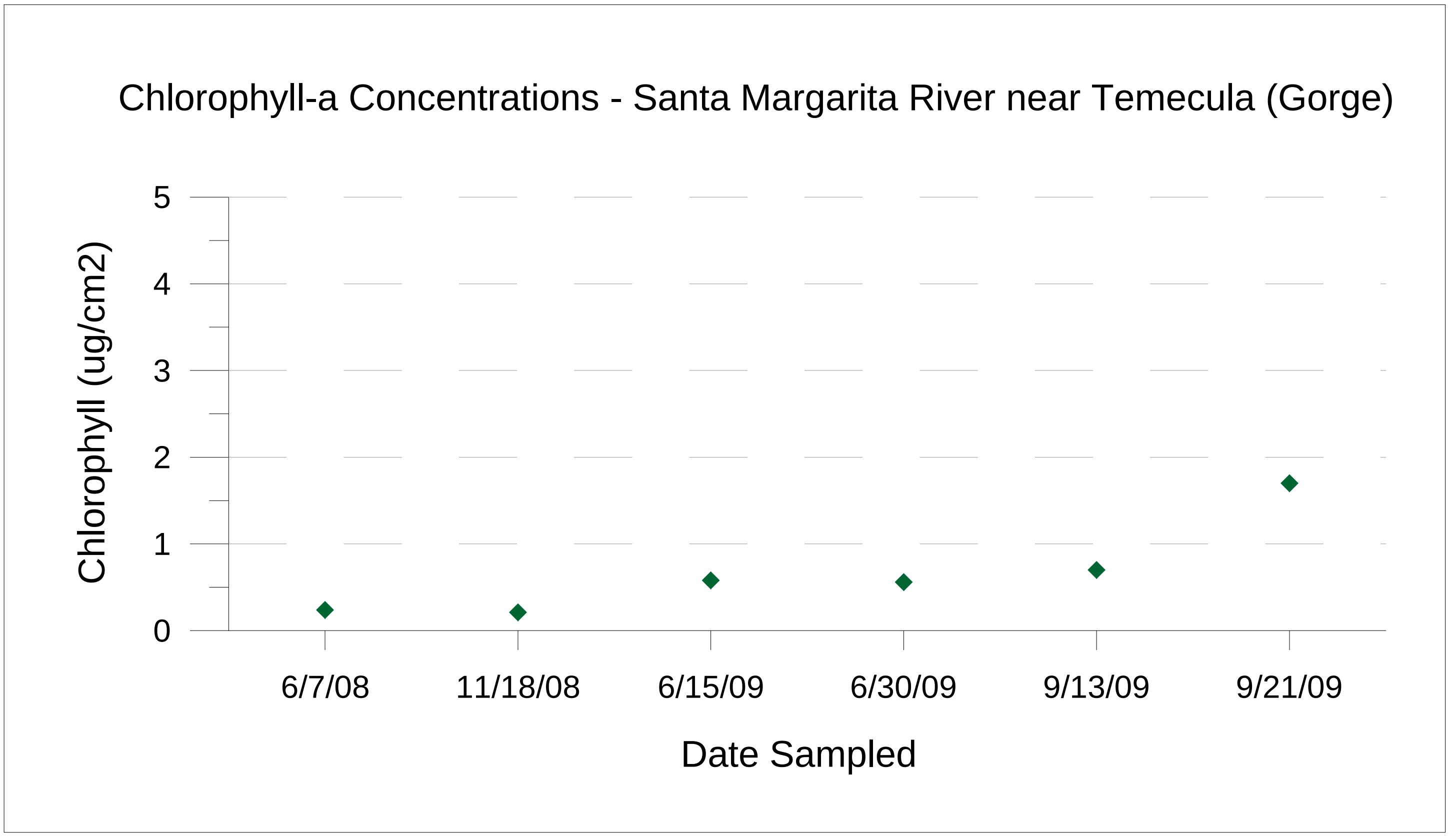


TABLE 3-8 AVERAGE ECOLOGICAL INDICATOR VALUES BY DETECTED GENERA (VAN DAM, ET AL, 1994)

Genus	Ecological Indicators[1]						
	R	H	N	O	S	T	M
Achnanthes	3.4, 0.8	1.7, 0.9	1.3, 0.5	1.4, 0.7	1.4, 0.8	2.0, 1.4	2.7, 1.1
Amphipleura							
Amphora	4.1, 0.6	2.3, 1.0	1.9, 0.4	2.0, 0.8	2.1, 1.0	4.3, 1.4	2.8, 1.2
Anomoeoneis							
Asterionella							
Aulacoseira	2.9, 0.8	1.4, 0.5	1.6, 0.5	1.9, 0.9	1.6, 0.5	2.9, 1.9	1.6, 0.8
Bacillaria							
Biddulphia							
Brachysira							
Caloneis	3.8, 0.8	1.9, 0.8	1.1, 0.4	1.7, 0.7	1.3, 0.7	3.3, 1.2	2.7, 1.3
Cocconeis	4.3, 0.5	2.1, 0.6	2.0, 0.0	2.8, 0.4	1.7, 0.5	5.0, 0.0	2.0, 0.6
Cyclotella	3.6, 0.7	2.2, 1.1	1.6, 0.8	2.1, 1.5	2.1, 1.2	3.7, 1.9	1.4, 0.9
Cymbella	3.3, 0.8	1.5, 0.5	1.1, 0.3	1.1, 0.4	1.3, 0.6	2.3, 1.4	2.6, 1.1
Denticula							
Diatoma	4.4, 0.7	2.2, 0.8	1.8, 0.4	2.0, 0.7	2.1, 0.8	4.1, 0.6	1.2, 0.4
Diploneis	4.1, 0.8	2.0, 0.8	1.0, 0.0	1.0, 0.0	1.1, 0.4	3.0, 0.0	3.6, 0.7
Encyonema							
Entomoneis							
Epithemia							
Eunotia	2.0, 0.4	1.1, 0.3	1.1, 0.4	1.1, 0.3	1.1, 0.4	1.4, 0.6	3.1, 0.6
Fragilaria	3.7, 0.6	2.0, 0.7	1.4, 0.5	1.4, 0.7	1.7, 0.8	3.6, 1.3	1.8, 0.7
Frustulia							
Gomphonema	3.5, 0.7	1.7, 0.5	1.2, 0.5	1.3, 0.7	1.8, 1.0	3.0, 1.6	2.6, 0.7
Gyrosigma							
Hantzschia							
Mastogloia							
Melosira							
Meridion							
Navicula							
Neidium	2.3, 0.8	1.5, 0.5	1.0, 0.0	1.0, 0.0	1.2, 0.4	2.1, 1.4	2.2, 1.0
Nitzschia	3.6, 0.7	2.6, 1.0	2.2, 1.0	2.2, 1.1	2.4, 1.0	4.5, 1.2	2.5, 1.0
Pinnularia	2.5, 0.6	1.3, 0.5	1.4, 0.5	1.8, 1.0	1.4, 0.7	1.8, 1.2	3.1, 0.8
Plagiotropis							
Planothidium							
Pleurosigma							
Reimeria							
Rhoicosphenia							
Rhopalodia							
Stauroneis	3.1, 0.6	1.7, 0.6	1.7, 0.5	1.6, 0.7	1.5, 0.5	2.9, 1.6	3.1, 1.0
Stenopterobia							
Stephanodiscus							
Surirella	3.6, 0.6	2.4, 0.8	1.6, 0.5	2.0, 1.0	1.8, 0.7	3.9, 1.6	2.3, 0.9
Synedra							
Thalassiosira							

[1] Scores may be interpreted from Table 3-9.

TABLE 3-9 CLASSIFICATION OF ECOLOGICAL INDICATORS (VAN DAM, ET AL, 1994)

(R) pH

1 acidobiontic	optimal occurrence at pH <5.5
2 acidophilous	mainly occurring at pH <7
3 circumneutral	mainly occurring at pH ~7
4 alkaliphilous	mainly occurring at pH >7
5 alkalibiontic	exclusively occurring at pH >7
6 indifferent	no apparent optimum

(S) Saprobity

	Water Quality Class	Oxygen saturation (%)	Biodegraded Organic Matter (mg/L)
1 oligosaprobous	I, I-II	>85	<2
2 β-mesosaprobous	II	70 - 80	2 - 4
3 α- mesosaprobous	III	25 - 70	4 - 13
4 α-meso/polysaprobous	II-IV	10 - 25	13 - 22
5 polysaproubous	IV	<10	>22

(H) Salinity

	Cl ions (mg/L)	Salinity (%)
1 fresh	<100	<0.2
2 fresh brackish	<500	<0.9
3 brackish fresh	500 - 1,000	0.9 - 1.8
4 brackish	1,000 - 5,000	1.8 - 9.0

(T) Trophic state

1 oligotraphentic
2 oligo-mesotraphentic
3 mesotraphentic
4 meso-eutraphentic
5 eutraphentic
6 hypereutraphentic
7 oligo- to eutraphentic (hypereutraphentic)

(N) Nitrogen uptake metabolism

1 N-autotrophic taxa, tolerating very small concentrations of organically bound N
2 N-autrophic taxa, tolerating elevated concentrations of organically bound N
3 facultatively N-heterotrophic taxa, needing periodically elevated concentrations of organically bound N
4 obliagately N-heterotrophic taxa, needing continuously elevated concentrations of organically bound N

(M) Moisture

1 never, only very rarely, occurring outside water bodies
2 mainly occurring in water bodies, sometimes on wet places
3 mainly occurring in water bodies, also rather regularly on wet and moist places
4 mainly occurring on wet & moist or temp. dry places
5 nearly exclusively occurring outside water bodies

(O) Oxygen requirements

1 continuously high (~ 100% saturation)
2 fairly high (>75% saturation)
3 moderate (>50% saturation)
4 low (>30% saturation)
5 very low (~10% saturation)

3.2 WATER QUALITY TREND ANALYSIS

An analysis of historical water quality is presented in Appendix M, including time series scatterplots showing historical and current nutrient constituents, TDS, sulfate, iron and manganese concentrations at the Gorge and the FPUD Sump. While the older water quality data were collected prior to the State Surface Water Ambient Monitoring Program and current rigorous QA/QC protocols, comparing contemporary data with historical was the only means available for assessing trends in water quality over these long periods. Issues to be aware of include differences over time in the standards for recording metadata, improvements in instrumentation and methods (for both field and lab), and improvement in quality assurance and quality control.

The analysis in Appendix M revealed that in general, nitrate and total phosphorus concentrations at the Gorge and Fallbrook Sump sites were greatest during the period of the 1980s through the 1990s, and were lower during WY 2008-2009. The historic data show that manganese and iron concentrations have consistently exceed the current BP objectives. Historical sulfate concentrations were generally below the BP objective at the Gorge, but were consistently over the limit at the FPUD Sump location. Since the period of CWRMA augmentation, concentrations of all nutrient constituents, TDS, iron, and manganese have remained relatively low compared with the historical concentrations and sulfate concentrations have remained within the same range as historical concentrations.

4.0 MASS LOADING

The loadings were calculated for six specific periods for which sufficient hydrology and water quality data exist to engender confidence in the findings. These six periods include the two nutrient index sampling periods each year and the first and last field sessions of the CWRMA flow experiment in 2009. Annual mass loading was not calculated from the six daily periods for several reasons. First, besides the two nutrient index periods each year, the remainder of the sampling protocol was quarterly. Such sparse data over the course of only two years was insufficient to support development of yearly loadings. Second, almost all of the samples reflected base flow or ambient winter conditions. Data during storm flows, or even flows immediately post storm, were not available to accurately calculate loading during high volume flows. Therefore, loadings associated with storm event, which are likely important "drivers" of the system (especially for phosphorus, which is often delivered to steams via soil erosion), could not be calculated with the available data. Third, some of the tributaries had limited flow data, making it difficult to calculate loadings. Fourth, the two years of sampling represented only a limited portion of the precipitation and streamflow spectrum. Additional data for drier and wetter periods would add value to the loading calculations. Finally, this monitoring program did not measure the sub-flow of the river or tributaries, which may have constituted an important proportion of the total flow, especially for the intermittent tributaries. Therefore, loadings for discrete periods, only, are presented. With additional data, these loading calculations can be updated and expanded to determine annual loading under various hydrologic conditions.

4.1 HYDROLOGY SUPPORTING LOADING ANALYSIS

Loadings of constituents were strongly correlated with flow. Table 4-1 presents approximate flows used to calculate loadings of sampled constituents. Due to the variation in sampling for quarterly and index constituents, the flows presented in Table 4-1 were not directly applicable to all loading calculations.

Of the six sampling periods used for the loading analysis, two periods represented the wet season (October through April), three periods represented the dry season (May through September), and the April 2009 event was deemed transitional between wet and dry season hydrologic conditions. These sampling periods were chosen in order to show the difference in loadings with varying flow and because they had the most water quality data available.

TABLE 4-1 TRIBUTARY AND SANTA MARGARITA RIVER FLOWS USED TO CALCULATE LOADINGS (CFS)

		WY 2008		WY 2009			
		Jan	**July**	**Feb**	**April**	**July**	**Sept**
	Season	**wet**	**dry**	**wet**	**transitional**	**dry**	**dry**
	Flow Regime	**high**	**normal**	**ambient**	**ambient**	**normal**	**low**
Monitoring Location	**Measurement Source**						
Santa Margarita River near Temecula	USGS 11044000	29.5	8.4	11.0	11.0	11.2	3.0
Devils Creek	Stetson[2]	---	*0.3*	*2.0*	0.3	*0.2*	0.1
Santa Margarita River at MWD Crossing	Stetson[2]	---	*8.0*	*12.0*	12.1	*12.0*	3.1
Stone Creek	Stetson[2]	---	*0.1*	*0.5*	0.1	*0.01*	0.01
Rainbow Creek	USGS 11044250	3.6	0.2	0.7	0.3	0.1	0.1
Santa Margarita River at FPUD Sump	USGS 11044300	54.2	6.6	15.7	13.0	18.6	6.2
Sandia Creek	USGS 11044350	20.8	1.8	6.3	4.0	1.4	1.5
De Luz Creek	USGS 11044800	15.0	0.0	1.2	0.0[3]	0.0	0.0
Fallbrook Creek	USGS 11045300	0.6	0.03	0.9	0.1	0.02	0.0
Santa Margarita River at Ysidora	USGS 11046000	136.0	0.3	20.0	17.6	2.9	0.0

[1] “---“ denotes the flow is unknown

[2] Italics denote estimated flow through visual inspection from field visits (See Appendix I); Data not in italics were either measured by USGS (provisional data) or by Stetson during the flow experiment using methods described in Section 2.3.2.

[3] USGS records indicate zero flow; field visit indicated flow occurred but did not reach the Santa Margarita River.

4.2 LOADING CALCULATIONS

The loading of a constituent is the mass of constituent that enters a water body during a certain time period. The concentration of a constituent is the mass of the constituent per volume of water. Loading is calculated by multiplying the concentration by the average flow rate during a given time period. For this study, loadings were calculated by multiplying concentrations by an average daily flow rate. Discrete (non-continuous) daily loadings are presented for January and July of 2008 and February, April, July, and September of 2009. All data discussed in this section are located in Appendix M.

4.2.1 General Chemistry Loadings

This section focuses on loading calculations for general chemistry constituents on the State 303(d) List for Impaired Water Bodies: iron, manganese, sulfate, and TDS. Concentrations of each constituent are presented followed by the calculated discrete loading associated with the particular concentration and flow rate (see Table 4-1 for flow rates). Loadings are rounded to the appropriate number of significant figures.

Discrete iron concentrations and loadings are presented in Table 4-2 in units of mg/L and kg/day respectively. De Luz, Rainbow, and Sandia Creeks are on the 303(d) List for iron. High iron concentrations were also detected at Fallbrook Creek. Of these creeks with elevated levels of iron, Sandia Creek contributed the most, ranging from 0.7 kg/day to 10 kg/day. In the upper watershed, Murrieta Creek is on the 303(d) List for iron and may have been a large contributor to the Santa Margarita River, as iron loadings at the Gorge ranged from 0.4 kg/day to 20 kg/day.

Discrete manganese concentrations and loadings are presented in Table 4-3. De Luz and Sandia Creeks are listed as impaired for manganese. Fallbrook Creek is not listed, but it had the highest manganese concentrations reported within the study area (see Section 3.1.2.10). These creeks contributed manganese loading to the Santa Margarita River totaling between 0.1 kg/day and 1.5 kg/day, but their impacts downstream were indeterminate due to the unavailability of downstream, flow-weighted samples. The highest manganese loadings from these creeks occurred during winter flows. Manganese loading at the Gorge was negligible while loadings at the FPUD Sump were substantial. However, the contributor of manganese upstream of the FPUD Sump was uncertain due to the scarcity of sample data from sites in this reach of the river.

TABLE 4-2 DISCRETE IRON CONCENTRATIONS (MG/L) AND LOADINGS (KG/DAY)[1]

	WY 2008		WY 2009			
Monitoring Location	**Jan**	**July**	**Feb**	**April**	**July**	**Sept**
Concentration						
Santa Margarita River near Temecula	0.248	0.116	0.092	0.049	0.013	---
Devils Creek	---	---	---	---	---	---
Santa Margarita River at MWD Crossing	---	---	---	---	---	---
Stone Creek	---	0.280	0.127	0.090	0.041	---
Rainbow Creek[2]	0.030	0.300	0.000	---	0.008	---
Santa Margarita River at FPUD Sump	0.194	0.610	0.217	0.218	0.086	---
Sandia Creek	0.290	0.175	0.109	0.069	0.298	---
De Luz Creek	0.107	0.000	0.266	0.463	0.000	---
Fallbrook Creek	0.755	0.618	0.444	0.810	0.497	---
Santa Margarita River at Ysidora	---	---	---	---	---	---
Loading						
Santa Margarita River near Temecula	20	2.4	2.5	1.3	0.4	---
Devils Creek	---	---	---	---	---	---
Santa Margarita River at MWD Crossing	---	---	---	---	---	---
Stone Creek	---	0.1	0.2	0.02	0	---
Rainbow Creek[2]	0.3	0.1	0	---	0.01	---
Santa Margarita River at FPUD Sump	15	12	5.9	5.9	2.3	---
Sandia Creek	10	0.7	1.6	0.7	1.0	---
De Luz Creek	2.2	0	0.8	0	0	---
Fallbrook Creek	1.1	0.1	1.0	0.2	0.02	---
Santa Margarita River at Ysidora	---	---	---	---	---	---

[1] "---" denotes no water quality sample was taken for that constituent

[2] Source: San Diego County (Station Code 902SMG005)

TABLE 4-3 DISCRETE MANGANESE CONCENTRATIONS (MG/L) AND LOADINGS (KG/DAY)[1]

Monitoring Location	WY 2008		WY 2009			
	Jan	July	Feb	April	July	Sept
Concentration						
Santa Margarita River near Temecula	0.043	0.025	0.012	0.005	0.009	---
Devils Creek	---	---	---	---	---	---
Santa Margarita River at MWD Crossing	---	---	---	---	---	---
Stone Creek	---	0.008	0.013	0.010	0.016	---
Rainbow Creek[2]	---	---	---	---	---	---
Santa Margarita River at FPUD Sump	0.037	0.047	0.028	0.025	0.032	---
Sandia Creek	0.020	0.012	0.009	0.006	0.010	---
De Luz Creek	0.020	0.000	0.012	0.021	0.000	---
Fallbrook Creek	0.319	0.665	0.050	0.522	0.670	---
Santa Margarita River at Ysidora	---	---	---	---	---	---
Loading						
Santa Margarita River near Temecula	0.02	0	0.3	0.1	0.2	---
Devils Creek	---	---	---	---	---	---
Santa Margarita River at MWD Crossing	---	---	---	---	---	---
Stone Creek	---	0	0.02	0	0	---
Rainbow Creek[2]	---	---	---	---	---	---
Santa Margarita River at FPUD Sump	2.9	1.0	0.8	0.7	0.9	---
Sandia Creek	0.7	0.1	0.1	0.1	0.03	---
De Luz Creek	0.4	0	0.04	0	0	---
Fallbrook Creek	0.4	0.1	0.1	0.1	0.03	---
Santa Margarita River at Ysidora	---	---	---	---	---	---

[1] "---" denotes no water quality sample was taken for that constituent

[2] Source: San Diego County (Station Code 902SMG005)

Discrete sulfate concentrations and loadings are presented in Table 4-4. Rainbow and Sandia Creeks are listed as impaired for sulfate. Sandia Creek contributed a substantial amount of sulfate to the Santa Margarita River ranging from 1,000 kg/day to 11,900 kg/day. De Luz Creek contributed less due to its intermittent nature. Loadings slightly upstream of Sandia Creek at the FPUD Sump ranged from 4,700 kg/day to 23,500 kg/day. The impact of Sandia Creek sulfate loadings on downstream water quality was indeterminate due to the unavailability of downstream, flow-weighted sampling data. Sulfate loadings appeared to be high for the entire river from the Gorge to Ysidora.

TABLE 4-4 DISCRETE SULFATE CONCENTRATIONS (MG/L) AND LOADINGS (KG/DAY)[1]

	WY 2008		WY 2009			
Monitoring Location	**Jan**	**July**	**Feb**	**April**	**July**	**Sept**
Concentration						
Santa Margarita River near Temecula	165	164	154	299	180	---
Devils Creek	---	---	---	---	---	368
Santa Margarita River at MWD Crossing	---	---	---	---	---	204
Stone Creek	---	170	158	264	183	179
Rainbow Creek[2]	374	315	375	---	340	278
Santa Margarita River at FPUD Sump	300	231	247	305	214	---
Sandia Creek	347	336	311	339	317	309
De Luz Creek	342	0	312	324	0	0
Fallbrook Creek	224	210	105	237	95	---
Santa Margarita River at Ysidora	---	---	---	---	---	---
Loading						
Santa Margarita River near Temecula	12,900	3,300	4,200	8,100	4,8900	---
Devils Creek	---	---	---	---	---	100
Santa Margarita River at MWD Crossing	---	---	---	---	---	1,500
Stone Creek	---	40	200	70	5	5
Rainbow Creek[2]	3,300	100	600	---	100	50
Santa Margarita River at FPUD Sump	23,500	4,700	6,700	8,200	5,7800	---
Sandia Creek	11,900	1,400	4,400	3,300	1,000	1,100
De Luz Creek	7,000	0	900	0	0	0
Fallbrook Creek	300	120	200	50	10	---
Santa Margarita River at Ysidora	---	---	---	---	---	---

[1] "---" denotes no water quality sample was taken for that constituent

[2] Source: San Diego County (Station Code 902SMG005)

Discrete TDS concentrations and loadings are presented in Table 4-5. De Luz, Rainbow, and Sandia Creeks are listed as impaired for TDS. All three of these creeks contributed a considerable amount of TDS to the Santa Margarita River, totaling between 3,900 kg/day and 76,100 kg/day. De Luz Creek flowed to the Santa Margarita River only during winter months. In the upper watershed, Temecula Creek is listed as impaired for TDS and may have been a large contributor of TDS to the Santa Margarita River based on calculated loadings for the Gorge ranging from 12,000 kg/day to 53,300 kg/day. TDS loadings appeared to be high for the entire river from the Gorge to Ysidora.

TABLE 4-5 DISCRETE TDS CONCENTRATIONS (MG/L) AND LOADINGS (KG/DAY)[1]

Monitoring Location	WY 2008 Jan	WY 2008 July	WY 2009 Feb	WY 2009 April	WY 2009 July	WY 2009 Sept
Concentration						
Santa Margarita River near Temecula	680	590	580	635	630	---
Devils Creek	---	---	---	---	---	1,280
Santa Margarita River at MWD Crossing	---	---	---	640	---	631
Stone Creek	---	1,010	825	780	1,080	1,020
Rainbow Creek[2]	1,190	964	1,100	1,080	1,050	1,100
Santa Margarita River at FPUD Sump	970	760	795	750	710	---
Sandia Creek	1,200	1,140	1,140	1,120	1,120	1,150
De Luz Creek	1,200	0	1,140	1,050	0	0
Fallbrook Creek	740	1,220	480	1,030	1,240	---
Santa Margarita River at Ysidora	---	---	---	---	---	---
Loading						
Santa Margarita River near Temecula	53,300	12,000	15,600	17,100	16,979	---
Devils Creek	---	---	---	---	---	314
Santa Margarita River at MWD Crossing	---	---	---	19,000	---	4,792
Stone Creek	---	200	1,000	200	26	25
Rainbow Creek[2]	10,500	400	1,900	700	283	189
Santa Margarita River at FPUD Sump	42,800	12,200	29,200	23,900	27,832	---
Sandia Creek	41,200	4,700	16,200	11,000	3,567	4,226
De Luz Creek	24,400	0	3,400	0	0	0
Fallbrook Creek	1,000	100	1,000	200	61	---
Santa Margarita River at Ysidora	---	---	---	---	---	---

[1] "---" denotes no water quality sample was taken for that constituent
[2] Source: San Diego County (Station Code 902SMG005)

4.2.2 Nutrient Loadings

Since nutrient TMDLs are currently being developed for the Santa Margarita River estuary, a discussion of nutrient loading dynamics is presented here. Nitrogen occurs in freshwater systems in several chemical states. Dissolved inorganic nitrogen includes NH_4-, NO_3- and NO_2-. Dissolved organic nitrogen includes amino nitrogen compounds (polypeptides and free amino compounds) and other organic molecules. Most particulate organic nitrogen occurs as bacteria and detritus (Allan and Castillo, 2007). TN includes all dissolved and particulate forms, both organic and inorganic. Nitrogen also occurs in gaseous form as dinitrogen (N_2) and in association with oxygen (NO_x). Sources of nitrogen include atmospheric deposition, fixation of N_2 by cyanobacteria and certain crops, and terrestrial inputs from runoff, groundwater, and weathering of sedimentary rock. Runoff often contributes animal waste (including organic nitrogen) and fertilizer. Atmospheric deposition as precipitation and dry fallout occurs mainly as ammonium and nitrate (Allan and Castillo, 2007).

During base flow, most N inputs are generally from subsoil leaching. At the beginning of a precipitation event, vegetation throughfall can be a significant source of nitrogen loading (Allan and Castillo, 2007). Nitrogen loading often varies seasonally, with the relative contributions of groundwater versus surface water and subsurface runoff causing temporal or spatial variation in nutrient supplies (Allan and Castillo, 2007).

Phosphorus occurs in streams as orthophosphate (PO_4---) dissolved in water or attached to inorganic particles in suspension, as dissolved organic molecules and in particulate organic form mainly in bacteria and detrital particles (Allan and Castillo, 2007). Whitewater rivers and streams, where suspended sediment concentrations are greater, generally have higher concentrations of TP than lower energy rivers and streams. Systems with high rates of erosion are similarly phosphorus-rich. Also, rivers in sedimentary watersheds usually have higher phosphorus levels than rivers in predominately igneous watersheds; of those sedimentary watersheds, those with phosphate-bearing limestone usually have much higher phosphate levels in stream water than rivers flowing through shales or sandstones. Also, geothermal groundwater can be a substantial source of phosphorus (Allan and Castillo, 2007). Thus, the sedimentary soils and hot springs found upstream of the Gorge may provide elevated phosphorus contributions; however, this study does not sample surface water in a location that would address this question.

The limiting nutrient, generally nitrogen or phosphorus, is defined as the nutrient that limits plant growth when it is not available in sufficient quantities. An initial estimate for determining the limiting nutrient can be accomplished by comparing the levels of nutrients in the waterbody with the plant stoichiometry. The ratio of nitrogen to phosphorus in biomass is approximately 7.2 to 1. Therefore, an N:P ratio in the water that is less than 7.2 suggests that nitrogen is limiting. Alternatively, higher ratios suggest that phosphorus is limiting (USEPA, 1999). The N:P ratios for key tributaries and locations on the Santa Margarita River are shown below in Table 4-6.

TABLE 4-6 RATIO OF NITROGEN TO PHOSPHORUS AND LIMITING NUTRIENT IN THE LOWER SANTA MARGARITA RIVER[1]

Monitoring Location	Wet Season	Dry Season	Likely Overall Limiting Nutrient
Adobe Creek	15 – 20	3 – 6	Phosphorus – Wet Nitrogen – Dry
Arroyo Seco and Cole Creek	6 – 29	Dry	Indeterminate
Roblar Creek	0 – 5	2 – 14	Nitrogen
SMR at FPUD Sump	0 – 178	12 – 47	Phosphorus
SMR at MWD Crossing	2 – 73	0 – 73	Phosphorus
SMR near Temecula (Gorge)	0 – 87	13 – 80	Phosphorus – Wet Nitrogen – Dry
SMR at Ysidora	2 – 9	0 – 1	Nitrogen
De Luz Creek	0 – 402	Dry	Phosphorus
Devils Creek	0 – 408	31 – 279	Phosphorus
Fallbrook Creek	2 – 3	~2	Nitrogen
Rainbow Creek	15 – 67	16 – 205	Phosphorus
CWRMA Outfall	0 – 90	17 – 48	Phosphorus
Sandia Creek	12 – 442	24 – 151	Phosphorus
Stone Creek	0 – 174	0 – 383	Phosphorus

[1] Range represents approximate maximum and minimum values during sampling period.

Phosphorus appeared to be the limiting nutrient in the upper portion of the study area while nitrogen was the limiting nutrient near and within Camp Pendleton. Adobe Creek and the Santa Margarita River at the Gorge showed strong seasonal variation of N:P ratios.

For all observed sites except Arroyo Seco, the CWRMA outfall and Fallbrook Creek, nitrate composed the great majority of total nitrogen contribution. The Gorge had a nitrogen regime similar to the CWRMA outfall when flows were dominated by CWRMA releases. The measured ratios of inorganic to organic nitrogen for the various reaches and tributaries are listed in Table 4-7. The analysis was segregated into wet and dry seasons (the wet season is October through April while the dry season is May through September). Inorganic nitrogen includes nitrate-N, nitrite-N, and ammonia-N and is deposited to the surface through precipitation or fertilizers. Organic nitrogen is Total Kjeldahl Nitrogen (TKN) minus ammonia-N. Sources of organic nitrogen include decomposed organic matter such as leaves or animal wastes. These empirical data should replace the use of generic literature values in modeling such as the

Nutrient Numeric Endpoint Model (NNE) and Watershed Analysis Risk Management Framework (WARMF).

TABLE 4-7 RATIOS OF INORGANIC TO ORGANIC NITROGEN IN THE LOWER SANTA MARGARITA RIVER

	Ratio of Inorganic : Organic N*	
Monitoring Location	**Wet Season**	**Dry Season**
Adobe Creek	15.3 – 20.3	3.3 – 7.8
Arroyo Seco and Cole Creek	0.5 – 1.3	Dry Channel
Roblar Creek	~0	0.1 – 0.7
SMR at FPUD Sump	0.8 – 27.2	0 – 9.7
SMR at MWD Crossing	0 – 5.6	0 – 17.3
SMR near Temecula (Gorge)	0 – 10.4	1.4 – 27.7
SMR at Ysidora	0.8 – 4.4	0 – 0.3
De Luz Creek	0 – 27.1	Dry Channel
Devils Creek	0.5 – 126.7	16.1 – 106.7
Fallbrook Creek	0 – 5.9	~0.1
Rainbow Creek	0 – 26.5	Need new data
CWRMA Outfall	0 – 20.4	0 – 70.6
Sandia Creek	0 – 78.9	3.9 – 71.8
Stone Creek	0 – 95.3	5.7 – 98.0

Discrete TN concentrations and loadings are presented in Table 4-8. An average concentration was used for winter and summer loadings. Large contributors of TN to the Santa Margarita River included Devils, Sandia, and De Luz Creeks. These three creeks lie in agricultural areas and fertilizer from agricultural operations may have made its way into the creeks causing increased TN loadings; however, this inference of potential sources was not explicitly examined within this study. Determination of specific sources is needed in order to focus management efforts.

Total input of TN from these three creeks ranged from 12.8 kg/day to 323 kg/day each, with an estimated additional 200 to 300 kg/day contributed by Devils Creek. Sandia Creek is listed as impaired for TN and was the largest contributor of TN to the Santa Margarita River. In the upper watershed, Murrieta and Temecula Creeks are both listed as impaired for TN and may have contributed large loadings to the Santa Margarita River based on loading calculations at the

Gorge (4.3 kg/day to 131 kg/day). TN loadings appeared to be an issue for the entire river from the Gorge to Ysidora. The majority of TN contribution from these streams was in the form of nitrate.

Table 4-8 Discrete Total Nitrogen Concentrations (mg/L) and Loadings (kg/day)[1]

Monitoring Location	WY 2008 Jan	WY 2008 July	WY 2009 Feb	WY 2009 April	WY 2009 July	WY 2009 Sept
Concentration						
Santa Margarita River near Temecula	1.46	0.87	1.05	0.34	0.40	0.60
Devils Creek	---	8.42	7.58	---	8.26	8.19
Santa Margarita River at MWD Crossing	---	1.09	1.10	0.52	0.37	0.89
Stone Creek	---	2.30	1.75	1.83	4.31	4.56
Rainbow Creek[2]	13.50	5.91	6.61	4.79	7.32	6.56
Santa Margarita River at FPUD Sump	5.10	1.01	1.96	1.09	0.42	---
Sandia Creek	7.32	3.95	4.65	4.34	2.70	3.40
De Luz Creek	7.43	0.00	4.08	2.79	0.00	0.00
Fallbrook Creek	0.33	0.53	0.44	0.35	0.78	---
Santa Margarita River at Ysidora	3.54	0.30	0.68	0.02	0.12	0.00
Loading						
Santa Margarita River near Temecula	131	17	25	9.2	11	4.3
Devils Creek	---	6.2	40	---	4.1	2.0
Santa Margarita River at MWD Crossing	---	21	32	15	11	6.8
Stone Creek	---	0.6	2.1	0.5	0.1	0.1
Rainbow Creek[2]	120	2.5	11	3.1	2.1	1.1
Santa Margarita River at FPUD Sump	730	16	65	34	19	---
Sandia Creek	390	17	68	43	10	11
De Luz Creek	270	0	13	0	0	0
Fallbrook Creek	0.5	0.04	1.0	0.1	0.04	---
Santa Margarita River at Ysidora	1,160	0.2	16	0.9	0.8	0

[1] “---“ denotes no water quality sample was taken for that constituent

[2] Source: San Diego County (Station Code 902SMG005)

Discrete TP concentrations and loadings are presented in Table 4-9. An average concentration was used for winter and summer loadings. The upper Santa Margarita River is listed as impaired for TP. Loadings to the head of the river, ranging from 0 kg/day to 21 kg/day, may have been due to contributions from Temecula and Murrieta Creeks, both of which are on the 303(d) List for TP. TP loadings to the Santa Margarita River increased as one moved downstream, which was likely due to substantial contributions from Rainbow and Sandia Creeks. Based on loadings calculations, TP loadings appeared to be somewhat elevated for the entire river from the Gorge to Ysidora.

TABLE 4-9 DISCRETE TOTAL PHOSPHORUS CONCENTRATIONS (MG/L) AND LOADINGS (KG/DAY)[1]

Monitoring Location	WY 2008 Jan	WY 2008 July	WY 2009 Feb	WY 2009 April	WY 2009 July	WY 2009 Sept
Concentration						
Santa Margarita River near Temecula	0.23	0.03	0.15	0.00	0.02	0.03
Devils Creek	---	0.14	0.10	---	0.04	0.05
Santa Margarita River at MWD Crossing	---	0.03	0.17	0.00	0.01	0.00
Stone Creek	---	0.11	0.10	0.01	0.03	0.02
Rainbow Creek[2]	0.32	0.17	0.13	0.22	0.12	0.03
Santa Margarita River at FPUD Sump	0.18	0.04	0.24	0.01	0.01	---
Sandia Creek	0.07	0.11	0.10	0.02	0.02	0.03
De Luz Creek	0.04	0.00	0.23	0.04	0.00	0.00
Fallbrook Creek	---	0.29	0.15	0.17	0.46	---
Santa Margarita River at Ysidora	0.15	0.19	0.13	0.10	0.18	0.00
Loading						
Santa Margarita River near Temecula	21	0.6	0.9	0	0.4	0.3
Devils Creek	---	0.1	0.1	---	0.02	0.01
Santa Margarita River at MWD Crossing	---	0.6	0.8	0	0.1	0
Stone Creek	---	0.03	0	0	0	0
Rainbow Creek[2]	2.8	0.1	0.1	0.1	0.03	0.03
Santa Margarita River at FPUD Sump	35	0.7	0.3	0.41	0.5	---
Sandia Creek	4.0	0.5	0.2	0.2	0.1	0.1
De Luz Creek	1.2	0	0	0	0	0
Fallbrook Creek	---	0.02	0.4	0.03	.02	---
Santa Margarita River at Ysidora	56	0.1	6.6	4.3	0.8	0

[1] "---" denotes no water quality sample was taken for that constituent

[2] Source: San Diego County (Station Code 902SMG005)

5.0 ANALYSIS OF ASSIMILATIVE CAPACITY

The assimilative capacity of a water body is its ability to cleanse itself - its capacity to receive wastewater, for example, and remove harmful constituents from the water column via plant uptake or transform it to different, less harmful constituents via microbial processes.

Nutrient dynamics are complex. The capacity of stream systems to influence the dynamics of nutrients during downstream passage depends upon both abiotic and biotic processes that determine uptake rates and transformations (Tetra Tech, 2006; Allan and Castillo, 2007). These processes, in turn, are governed by a number of environmental factors, especially rate and variability of discharge. It has been postulated that streams can occupy very different nutrient processing states. Those with high rates of nutrient inputs relative to processing capacity and flashy flows are in "throughput mode" most of the time whereas streams with low nutrient inputs relative to demand and more stable flows are in "process-retention mode" (Allan and Castillo, 2007). Additionally, smaller streams with a greater area of streambed relative to water volume often exhibit greater rates of nutrient uptake and transformation. Abiotic exchange mechanisms are influenced by sediment characteristics, pH, and nutrient concentrations in streamwater, and biotic uptake and release varies with overall biological productivity – thus varying seasonally and with flow regimes (Allan and Castillo, 2007). In general, high flows cause more nutrient transport downstream, while low flows enable more nutrient processing in-stream. Variation in discharge on seasonal and annual timescales has a strong influence over whether nutrients are stored or exported, and a very high percentage of nutrient inputs and exports can occur during relatively few high-precipitation and high-flow days (Allan and Castillo, 2007). Nutrients accumulate during low flows when they occur in association with fine particulates, and in biofilms, whose biomass accumulates during periods of low flow (lacking scour capacity) (Tetra Tech, 2006; Allan and Castillo, 2007). Transient storage varies with a number of stream features such as channel geomorphology, stream size, discharge, and flow obstructions (Allan and Castillo, 2007). The transient storage rate is highest in headwaters and drops with increasing stream size.

Precipitation and sorption onto sediments are physical-chemical processes that can have a strong influence upon phosphate and a lesser influence upon ammonium. In general, levels of particulate phosphorus and ammonium increase with increased runoff. The amount of particulate phosphorus often varies temporally with changes in concentration of suspended sediments. Nitrate appears not to be affected very much by physical-chemical removal (Allan and Castillo, 2007). These sorption-desorption processes act as a buffer on nutrient concentrations, removing them when concentrations are high and releasing them when concentrations are low, sometimes months later.

Nutrient uptake and cycling vary in response to biotic demand by primary producers such as algae and heterotrophic microorganisms in biofilms and other sites of high biological activity (Allan and Castillo, 2007), and thus are influenced by environmental factors that control rates of primary and microbial production such as temperature, radiation, shading, grazing, and disturbance (Tetra Tech, 2006). Studies clearly show that nutrient retention is low immediately following disturbances that impact benthic algae. Nitrifying and denitrifying bacteria change the concentrations of various forms of inorganic nitrogen, increasing or decreasing its bioavailability. The denitrifying process takes place in low-oxygen conditions, and rates tend to be higher where there are low flows and shallow depths (Allan and Castillo, 2007).

TN includes all dissolved and particulate forms of nitrogen, both organic and inorganic. Likewise, TP includes all forms of phosphorus and is widely used as an indicator of the overall available phosphorus within a system (Allan and Castillo, 2007). These nutrients are most bioavailable in their dissolved, inorganic forms.

There are several methods for estimating the assimilative capacity of the river for nutrients. The first method consists of a mass-balance approach (Kim et al, 2008). The nutrient output (total mass exported) for each reach and tributary is calculated as a function of water column concentration and volume. The assimilation rate of each reach is calculated through a comparison of the nutrient mass input from upstream versus that which is exported downstream. The assimilation rate can be expressed as a rate per length of reach. In the short term, large amounts of phosphorus can be retained within a reach within sediments. However this storage capacity cannot grow indefinitely, and so with long term monitoring of phosphorus export, calculation of assimilative capacity can become more precise.

The second method for determining nutrient assimilation is often used by regulatory agencies. This approach consists of determining how much of a nutrient can be loaded to a stream before it reaches its water quality objective as set within a Basin Plan. Rather than determine the rate of nutrient uptake, transformation, and retention, this approach focuses upon regulatory limits. Median flow is multiplied by the flow-weighted target concentration for the nutrient, producing the loading capacity or so called “assimilative capacity.”

A third approach is to develop a dynamic watershed model tied to a geographic information system (GIS). This model incorporates land cover and land use analysis to produce a nutrient budget that accounts for all inputs, exports, and internal stores for each delineated reach of the watershed. By quantifying changes in inputs over time and comparing reaches that receive different intensity of human activity, Reclamation, Camp Pendleton, and other watershed managers can increase understanding of local nutrient processing dynamics and rates of assimilation and eutrophication.

This sort of detailed accounting is also useful in determining strategies for reducing loads and implementing TMDLs. Such a nutrient budget is implicit within the WARMF watershed model recently developed by the SMR Executive Management Team (CDM, 2007a).

A fourth method is to use California's new NNE approach (Tetra Tech, 2006; Jungreis and Thomas, 2007; Thomas, 2008). In the NNE, the focus is upon "response variables" such as benthic algal biomass and chlorophyll a content, dissolved oxygen, dissolved organic carbon, macrophyte cover, and water clarity. The NNE develops water quality targets for the response variables rather than targets for the nutrients themselves (e.g., how much algae can be present without impairing designated beneficial uses). Numeric models can then be used to convert the initial water quality targets for the response variables into numeric targets for nutrients. These models can also be used to estimate the assimilative capacity for nutrients.

This study used the mass-balance method and the NNE approach. These methods complement and support the modeling being undertaken by Reclamation in its Phase IV Plan of Study during the next several years, as well as modeling initiated under the auspices of the RWQCB for the purpose of developing TMDLs for nutrients. Contrasting with the WARMF model, the mass-balance and NNE provide additional lines of evidence for developing water quality objectives in keeping with the river's nutrient assimilative capacity.

5.1 MASS BALANCE APPROACH: ASSIMILATION OF NUTRIENTS IN THE SANTA MARGARITA RIVER

The rationale for a mass-balance approach to calculating assimilative capacity is the assumption that if a stream is being loaded with excessive amounts of the nutrients, a portion of those nutrients will not be taken up (assimilated), but will be passed downstream. Using the mass balance approach, the assimilation of a reach of the river was calculated as the difference between upstream (and tributary) loading and the load remaining at the bottom of the reach. If the difference value was negative, the reach had a loading of the constituent in excess of the river's ability to assimilate that constituent. If the value was positive, the river was able to assimilate that amount of the constituent.

In order to determine whether a body of water can assimilate a given constituent, flow must be characterized (Figures 18 and 19, and Table 5-1). In Figure 19, the change in flow for the Santa Margarita River during a five day sampling period is shown. Green indicates a gaining reach and blue indicates a losing reach. Table 5-1 presents a summary of the change in flow for the Santa Margarita River.

Assimilation was calculated for seven separate reaches between the Gorge and Ysidora. Within the most downstream reach, d/s of De Luz to Ysidora, the Base operated the O'Neill

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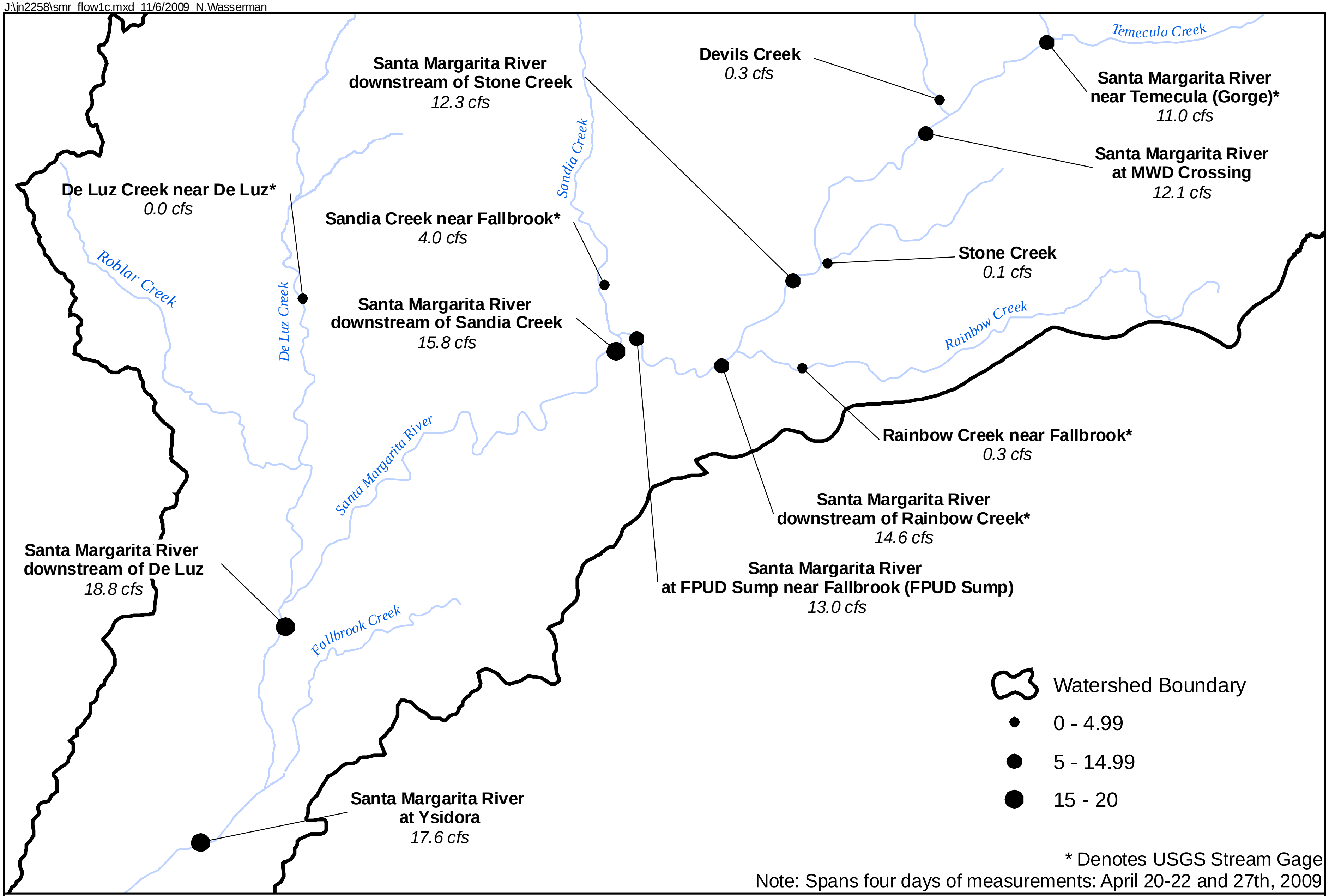

* Denotes USGS Stream Gage

Note: Spans four days of measurements: April 20-22 and 27th, 2009

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FLOW MEASUREMENTS IN APRIL 2009

FIGURE 18

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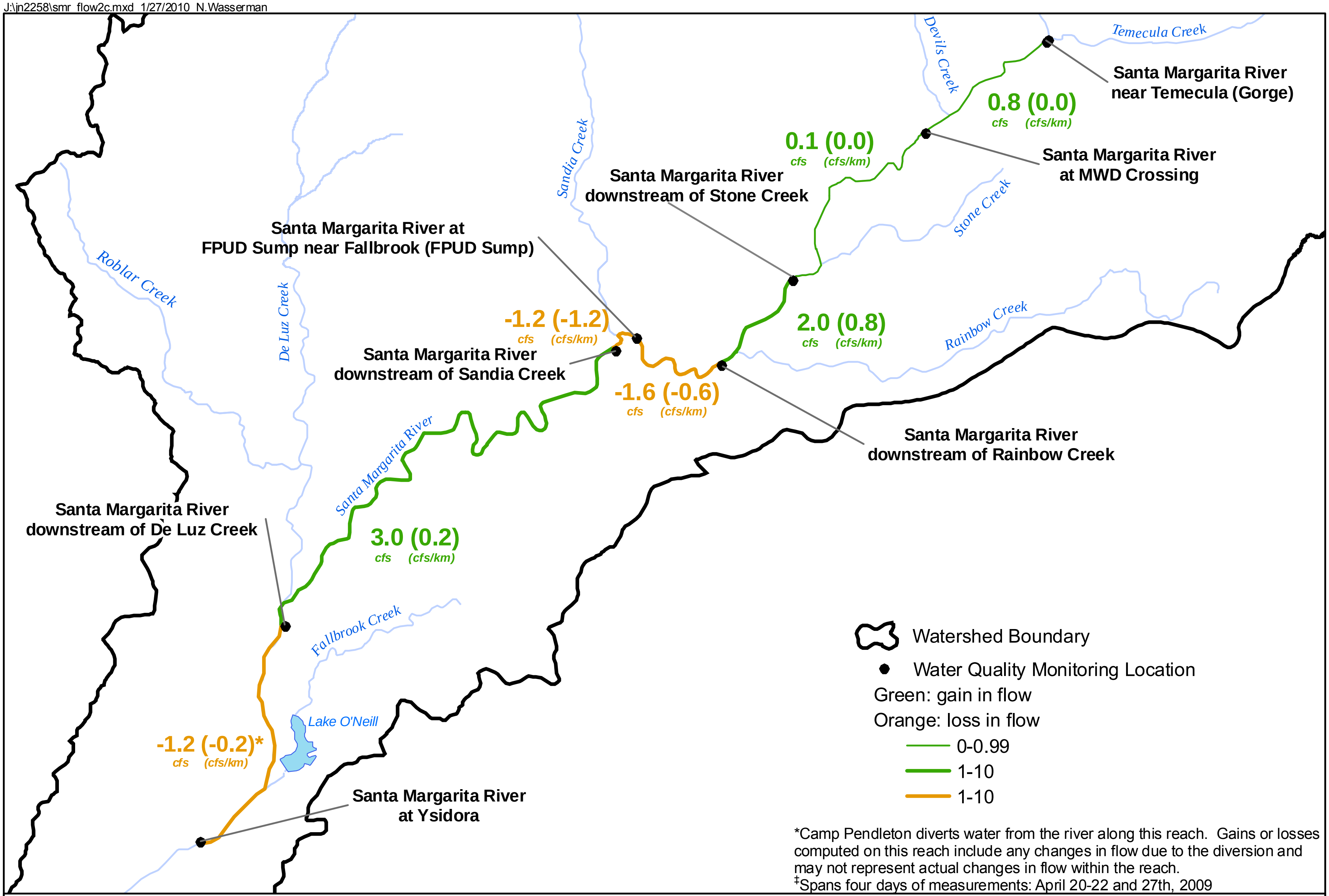

*Camp Pendleton diverts water from the river along this reach. Gains or losses computed on this reach include any changes in flow due to the diversion and may not represent actual changes in flow within the reach.

[‡] Spans four days of measurements: April 20-22 and 27th, 2009

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STREAMFLOW GAINS AND LOSSES IN THE SANTA MARGARITA RIVER IN APRIL 2009[‡]

FIGURE 19

Diversion Ditch and diverted a significant portion of streamflow from the River for storage in Lake O'Neill and groundwater recharge in percolation ponds. As observed during field sampling and streamflow measurements, some of the diverted water returned to the River through groundwater seepage. During this process of diversion and return to the River, significant changes to the constituent concentrations may have occurred. For this report, assimilation was calculated with the effects of the diversion included. Assimilation values may differ when the diversion does not occur.

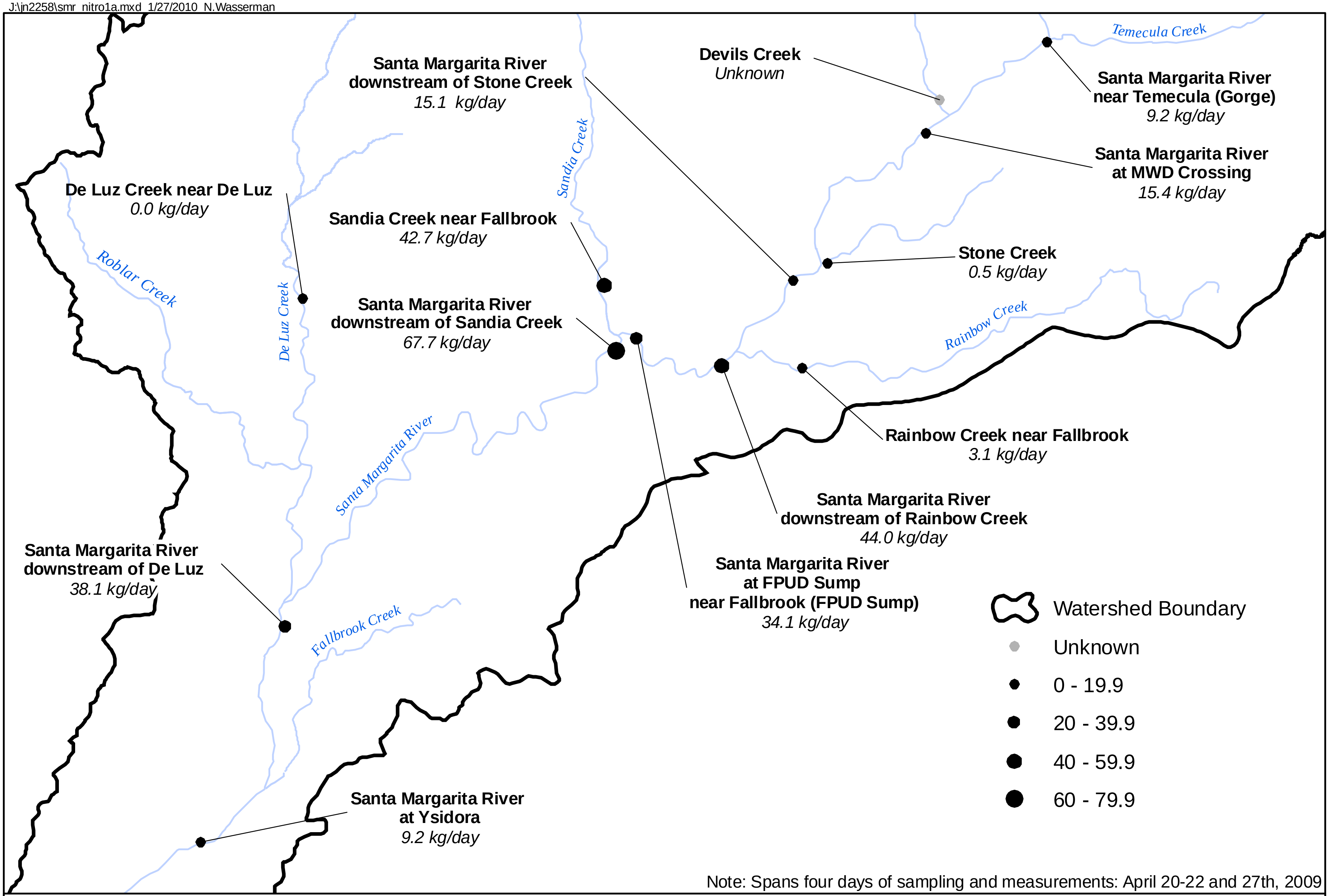
TABLE 5-1 SUMMARY OF THE CHANGE IN FLOW FOR THE SANTA MARGARITA RIVER[1]

Flow, Total (cfs)	**WY 2008**		**WY 2009**				
Santa Margarita River Reach	**Jan/Feb**	**July**	**Feb**	**April**	**May**	**July**	**Sept**
Temecula to MWD Crossing	21.1	(0.4)	(1.0)	0.1	(0.3)	0.6	(0.2)
MWD Crossing to d/s of Stone	21.1	(1.7)	2.5	0.1	0.4	6.5	(0.2)
d/s of Stone to d/s of Rainbow				2.0	0.7		0.3
d/s of Rainbow to FPUD Sump				(1.6)	0.3		(3.0)
FPUD Sump to d/s of Sandia	46.0	(8.1)	(3.2)	(1.2)		(17.1)	
d/s of Sandia to d/s of De Luz				3.0	1.0		(1.2)
d/s of De Luz to Ysidora				(1.2)	(5.0)		(2.8)

Flow per km (cfs/km)	**WY 2008**		**WY 2009**				
Santa Margarita River Reach	**Jan/Feb**	**July**	**Feb**	**April**	**May**	**July**	**Sept**
Temecula to MWD Crossing	1.4	(0.1)	(0.3)	0.03	(0.1)	0.2	(0.1)
MWD Crossing to d/s of Stone		(0.2)	0.2	0.02	0.1	0.6	(0.04)
d/s of Stone to d/s of Rainbow				0.8	0.3		0.1
d/s of Rainbow to FPUD Sump				(0.6)	0.1		(0.8)
FPUD Sump to d/s of Sandia	2.2	(0.4)	(0.2)	1.2		(0.8)	
d/s of Sandia to d/s of De Luz				0.2	0.1		(0.1)
d/s of De Luz to Ysidora				(0.2)	(0.9)		(0.5)

[1] Parentheses indicate a losing reach; no parentheses indicate a gaining reach.

Figures 20 and 21 present daily loadings of TN and TP during a five day sampling period in April 2009. The month of April was chosen for graphic representation because the most samples along the Santa Margarita River were taken during that month, enabling the study team to characterize water quality changes within and between many reaches on the river. The values presented in Figures 20 and 21 were used in calculating assimilative capacities for reaches of the Santa Margarita River during this sampling period. It is important to understand that loading rates and assimilation rates can vary substantially for a number of reasons. Since most of the sampling



Note: Spans four days of sampling and measurements: April 20-22 and 27th, 2009

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DAILY LOADING OF TOTAL NITROGEN IN APRIL 2009

N

0 2 4 Kilometers

FIGURE 20

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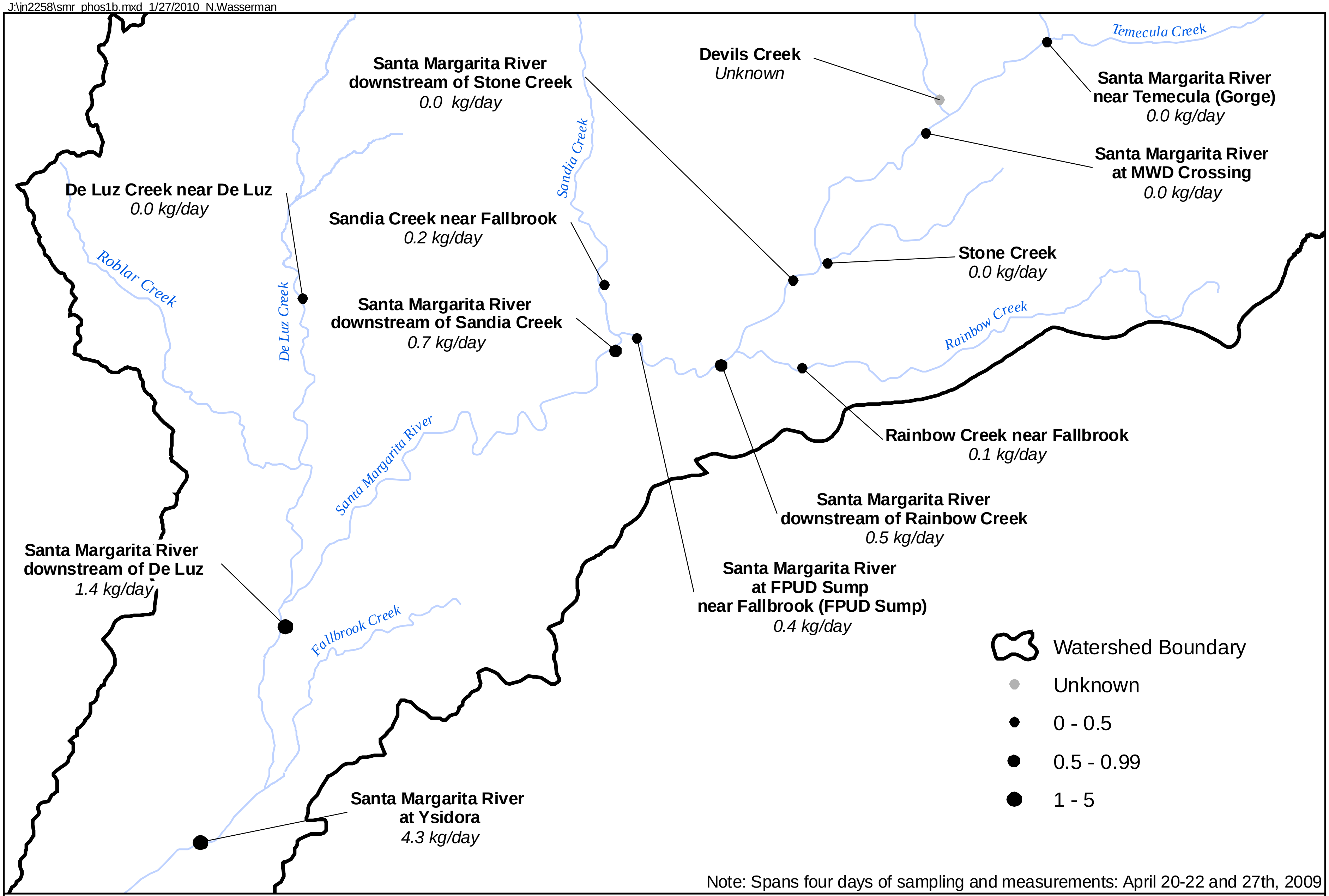

Note: Spans four days of sampling and measurements: April 20-22 and 27th, 2009

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DAILY LOADING OF TOTAL PHOSPHORUS IN APRIL 2009

FIGURE 21

events did not occur during or immediately after precipitation events, the loadings and assimilation rates during periods of stormwater runoff have not been characterized.

Figures 22 and 23 present the assimilation amount for TN and TP during the sampling event in April. The total assimilation for each reach is presented, as well as the assimilative rate per km of the reach (in parentheses). In Figures 22 and 23, the reaches of the Santa Margarita River are colored according to whether they were able to assimilate the constituent (red) or if there was lack of assimilation [excess of the constituent] (blue). The colored markings are also scaled to represent the relative amount (or lack) of assimilation.

A summary of TN assimilation for the Santa Margarita River is described in Table 5-2. Nitrite was not included in the assimilation analysis because of negligible nitrite concentrations observed. Throughout the period, the Santa Margarita River appeared able to assimilate TN from the Gorge through the MWD Crossing. Between the MWD Crossing and the FPUD Sump, loadings from tributaries increased and flooded the river with excess TN. The Santa Margarita River appeared able to recover downstream of the FPUD Sump and had a high assimilative capacity for TN between the FPUD Sump and Ysidora. TN appeared to be the limiting nutrient in the lower Santa Margarita River and was likely the reason for a high assimilation within that reach. Another possible reason for high assimilation of TN within the FPUD Sump to Ysidora reach was diversion and infiltration. Nitrate assimilation followed similar patterns and made up the largest fraction of TN loadings.

Organisms transform nutrients over time, converting them into usable forms. Ammonia-N is converted by bacteria to organic nitrogen within a few days (Sawyer et al. 2003). Organic nitrogen is generally converted to nitrate within 50 days (Sawyer et al. 2003). Nitrate, ammonia-N, and total organic nitrogen assimilative capacities are given in Table 5-3, Table 5-4, and Table 5-5 respectively. TN concentrations within the study area consisted mainly of nitrate, which is converted more quickly by organisms. Nitrate values for both assimilative capacity and the lack of assimilative capacity were consistently higher than ammonia-N and organic nitrogen combined. It can be concluded that the water bodies within the study area did not have elevated loadings of ammonia-N and organic nitrogen and that their nitrogen assimilative capacities (or lack thereof) were driven by nitrate loading.

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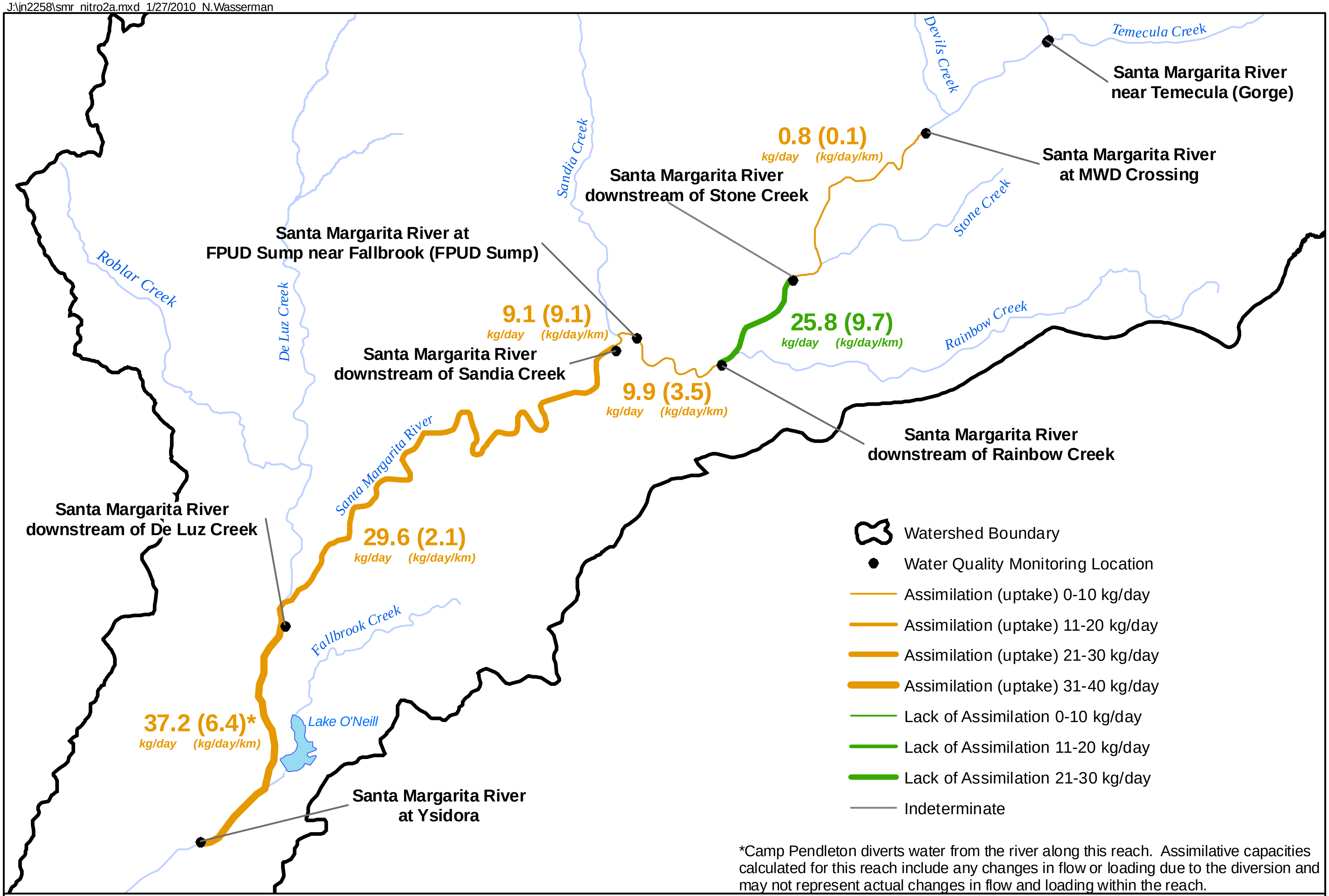

*Camp Pendleton diverts water from the river along this reach. Assimilative capacities calculated for this reach include any changes in flow or loading due to the diversion and may not represent actual changes in flow and loading within the reach.

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ASSIMILATION OF TOTAL NITROGEN IN THE SANTA MARGARITA RIVER IN APRIL 2009

FIGURE 22

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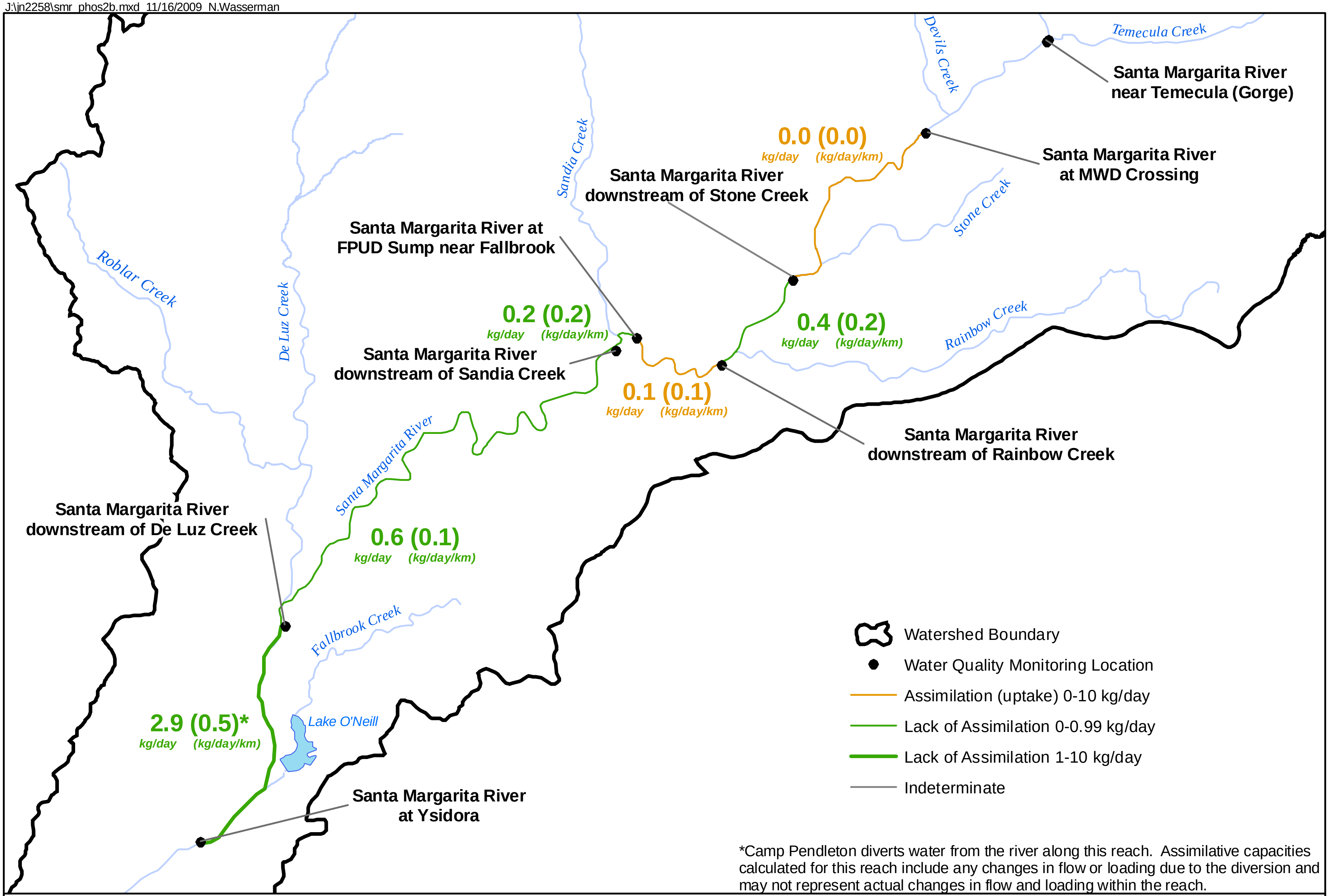

*Camp Pendleton diverts water from the river along this reach. Assimilative capacities calculated for this reach include any changes in flow or loading due to the diversion and may not represent actual changes in flow and loading within the reach.

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ASSIMILATION OF TOTAL PHOSPHORUS IN THE SANTA MARGARITA RIVER IN APRIL 2009

N

0 2 4 Kilometers

FIGURE 23

A summary of the Santa Margarita River's capacity to assimilate TP is depicted in Table 5-6. Overall, the Santa Margarita River appeared to have excess loadings of TP throughout the year. The excess increased as one moved downstream. The Santa Margarita River reach spanning from the Gorge to the MWD Crossing was the only reach that consistently was able to assimilate TP throughout the year. Devils Creek generally did not contribute large loadings of TP within this reach.

TABLE 5-2 SUMMARY OF ASSIMILATION OF TOTAL NITROGEN IN THE SANTA MARGARITA RIVER[1, 2]

Total Nitrogen, Total (kg/day)	**WY 2008**		**WY 2009**				
Santa Margarita River Reach	**Jan/Feb**	**July**	**Feb**	**April**	**May**	**July**	**Sept**
Temecula to MWD Crossing	(483)	2	33	---[3]	0.7	4	(1)
MWD Crossing to d/s of Stone		8	(20)	1	(4)	(6)	1
d/s of Stone to d/s of Rainbow				(26)	(6)		(11)
d/s of Rainbow to FPUD Sump				10	8		14
FPUD Sump to d/s of Sandia	225	33	130	9		28	
d/s of Sandia to d/s of De Luz				30	34		14
d/s of De Luz to Ysidora				37	8		2
Total Nitrogen per km (kg/day/km)	**WY 2008**		**WY 2009**				
Santa Margarita River Reach	**Jan/Feb**	**July**	**Feb**	**April**	**May**	**July**	**Sept**
Temecula to MWD Crossing	(33)	1	9	---[3]	0.2	1	(0.1)
MWD Crossing to d/s of Stone		1	(2)	0.1	(1)	(1)	0.1
d/s of Stone to d/s of Rainbow				(10)	(2)		(4)
d/s of Rainbow to FPUD Sump				3	2		4
FPUD Sump to d/s of Sandia	11	2	6	9		1	
d/s of Sandia to d/s of De Luz				2	2		1
d/s of De Luz to Ysidora				6	1		0.4

[1] Parentheses denote lack of assimilation and an excess of the constituent in the Santa Margarita River. Numbers without parentheses denote the ability of the Santa Margarita River to assimilate the constituent.

[2] Total nitrogen loadings and capacities may not equal the sum of its reported constituents due to nitrite not being reported.

[3] Indeterminate: the assimilative capacity is indeterminate due to the unavailability of Devils Creek water quality.

TABLE 5-3 SUMMARY OF ASSIMILATION OF NITRATE IN THE SANTA MARGARITA RIVER[1]

Nitrate (kg/day)	**WY 2008**		**WY 2009**				
Santa Margarita River Reach	**Jan/Feb**	**July**	**Feb**	**April**	**May**	**July**	**Sept**
Temecula to MWD Crossing	(415)	(3)	36	---[2]	1	3	0.5
MWD Crossing to d/s of Stone		8	(18)	1	(41)	(4)	0.2
d/s of Stone to d/s of Rainbow				(18)	(61)		(10)
d/s of Rainbow to FPUD Sump				8	8		11
FPUD Sump to d/s of Sandia	350	28	124	6		22	
d/s of Sandia to d/s of De Luz				26	34		11
d/s of De Luz to Ysidora				38	8		0

Nitrate per km (kg/day/km)	**WY 2008**		**WY 2009**				
Santa Margarita River Reach	**Jan/Feb**	**July**	**Feb**	**April**	**May**	**July**	**Sept**
Temecula to MWD Crossing	(28)	(1)	10	---[2]	0.2	1	0.1
MWD Crossing to d/s of Stone		1	(2)	0.1	(1)	(0.3)	0.03
d/s of Stone to d/s of Rainbow				(7)	(2)		(4)
d/s of Rainbow to FPUD Sump				3	2		3
FPUD Sump to d/s of Sandia	17	1	6	6		1	
d/s of Sandia to d/s of De Luz				2	2		1
d/s of De Luz to Ysidora				7	1		0

[1] Parentheses denote lack of assimilation and an excess of the constituent in the Santa Margarita River. Numbers without parentheses denote the ability of the Santa Margarita River to assimilate the constituent.

[2] Indeterminate: the assimilative capacity is indeterminate due to the unavailability of Devils Creek water quality.

TABLE 5-4 SUMMARY OF ASSIMILATION OF AMMONIA-N FOR THE SANTA MARGARITA RIVER[1]

Ammonia-N, Total (kg/day)	**WY 2008**		**WY 2009**				
Santa Margarita River Reach	**Jan/Feb**	**July**	**Feb**	**April**	**May**	**July**	**Sept**
Temecula to MWD Crossing	(3.0)	4.0	(1.1)	---[2]	0.0	(0.1)	(1.0)
MWD Crossing to d/s of Stone		1.4	1.2	0.0	0.0	(0.8)	0.0
d/s of Stone to d/s of Rainbow				(1.4)	0.0		(0.02)
d/s of Rainbow to FPUD Sump				(1.4)	0.0		1.0
FPUD Sump to d/s of Sandia	(8.0)	0.1	(0.7)	0.2		1.8	
d/s of Sandia to d/s of De Luz				2.7	0.0		0.0
d/s of De Luz to Ysidora				(0.4)	0.0		0.0

Ammonia-N per km (kg/day/km)	**WY 2008**		**WY 2009**				
Santa Margarita River Reach	**Jan/Feb**	**July**	**Feb**	**April**	**May**	**July**	**Sept**
Temecula to MWD Crossing	(0.2)	1.1	(0.3)	---[2]	0.0	(0.03)	(0.3)
MWD Crossing to d/s of Stone		0.1	0.1	0.0	0.0	(0.1)	0.0
d/s of Stone to d/s of Rainbow				(0.5)	0.0		(0.01)
d/s of Rainbow to FPUD Sump				(0.5)	0.0		0.3
FPUD Sump to d/s of Sandia	(0.4)	0.0	(0.03)	0.2		0.1	
d/s of Sandia to d/s of De Luz				0.2	0.0		0.0
d/s of De Luz to Ysidora				(0.1)	0.0		0.0

[1] Parentheses denote lack of assimilation and an excess of the constituent in the Santa Margarita River. Numbers without parentheses denote the ability of the Santa Margarita River to assimilate the constituent.

[2] Indeterminate: the assimilative capacity is indeterminate due to the unavailability of Devils Creek water quality.

TABLE 5-5 SUMMARY OF ASSIMILATION OF TOC FOR THE SANTA MARGARITA RIVER[1]

Total Organic Nitrogen, Total (kg/day)	**WY 2008**		**WY 2009**				
Santa Margarita River Reach	Jan/Feb	July	Feb	April	May	July	Sept
Temecula to MWD Crossing	(64.)	(0.1)	(1.3)	---[2]	0.0	1.1	0.1
MWD Crossing to d/s of Stone		(1.2)	(4.6)	0.0	0.0	(1.2)	0.4
d/s of Stone to d/s of Rainbow				(6.1)	0.0		(1.3)
d/s of Rainbow to FPUD Sump				3.5	0.0		1.5
FPUD Sump to d/s of Sandia	(83)	5.3	5.8	2.7		3.7	
d/s of Sandia to d/s of De Luz				1.2	0.0		3.0
d/s of De Luz to Ysidora				(0.5)	0.0		2.1
Total Organic Nitrogen per km (kg/day/km)	**WY 2008**		**WY 2009**				
Santa Margarita River Reach	Jan/Feb	July	Feb	April	May	July	Sept
Temecula to MWD Crossing	(4.3)	(0.03)	(0.4)	---[2]	0.0	0.3	0.01
MWD Crossing to d/s of Stone		(0.1)	(0.4)	0.0	0.0	(0.1)	0.1
d/s of Stone to d/s of Rainbow				(2.3)	0.0		(0.5)
d/s of Rainbow to FPUD Sump				1.2	0.0		0.4
FPUD Sump to d/s of Sandia	(4.0)	0.3	0.3	2.7		0.2	
d/s of Sandia to d/s of De Luz				0.1	0.0		0.2
d/s of De Luz to Ysidora				(0.1)	0.0		0.4

[1] Parentheses denote lack of assimilation and an excess of the constituent in the Santa Margarita River. Numbers without parentheses denote the ability of the Santa Margarita River to assimilate the constituent.

[2] Indeterminate: the assimilative capacity is indeterminate due to the unavailability of Devils Creek water quality.

TABLE 5-6 SUMMARY OF ASSIMILATION OF TOTAL PHOSPHORUS FOR THE SANTA MARGARITA RIVER[1]

Total Phosphorus, Total (kg/day)	**WY 2008**		**WY 2009**				
Santa Margarita River Reach	**Jan/Feb**	**July**	**Feb**	**April**	**May**	**July**	**Sept**
Temecula to MWD Crossing	(11)	0.1	0.2	---[2]	0.2	0.3	0.3
MWD Crossing to d/s of Stone		0.03	0.6	0.0	(0.2)	(0.4)	0.0
d/s of Stone to d/s of Rainbow				(0.4)	(0.1)		(0.2)
d/s of Rainbow to FPUD Sump				0.1	(0.03)		0.1
FPUD Sump to d/s of Sandia	(15)	1.0	(6.1)	(0.2)		(0.2)	
d/s of Sandia to d/s of De Luz				(0.6)	(0.5)		(0.1)
d/s of De Luz to Ysidora				(2.9)	(1)		0.3
Total Phosphorus per km (kg/day/km)	**WY 2008**		**WY 2009**				
Santa Margarita River Reach	**Jan/Feb**	**July**	**Feb**	**April**	**May**	**July**	**Sept**
Temecula to MWD Crossing	(1)	0.03	0.1	---[2]	0.1	0.1	0.1
MWD Crossing to d/s of Stone		0.0	0.1	0.0	(0.04)	(0.04)	0.0
d/s of Stone to d/s of Rainbow				(0.2)	(0.1)		(0.1)
d/s of Rainbow to FPUD Sump				0.1	(0.01)		0.02
FPUD Sump to d/s of Sandia	(1)	0.1	(0.3)	(0.2)		(0.01)	
d/s of Sandia to d/s of De Luz				(0.1)	(0.04)		(0.0)
d/s of De Luz to Ysidora				(0.5)	(0.2)		0.04

[1] Parentheses denote no assimilation and an excess of the constituent in the Santa Margarita River. Numbers without parentheses denote the ability of the Santa Margarita River to assimilate the constituent.

[2] Indeterminate: the assimilative capacity is indeterminate due to the unavailability of Devils Creek water quality.

5.2 NNE APPROACH

The USEPA Region 9 and the State of California have developed a new approach for calculating nutrient numeric endpoints for use in water quality programs. The NNE is used to develop water quality targets for “response variables” such as algal density. The initial water quality targets are then converted into numeric targets for nutrients based on numerical models.

In January 2007, the USEPA and California State Water Resources Control Board (SWRCB) jointly published a Final Draft memorandum entitled Nutrient Numeric Endpoints for TMDL Development: Santa Margarita River Case Study (Case Study). There were a number of problems with the case study (as examined by Jungreis and Thomas, 2007). The application of site-specific empirical data for input to the NNE model herein will help ensure a realistic and technically defensible site-specific application of this approach within the Santa Margarita River watershed into the future.

5.2.1 Basis for NNE Approach

Nutrients, including nitrogen compounds and phosphorous, are naturally occurring and vary in relationship to soils, geology, and land cover. Recent research has demonstrated the shortcomings of using ambient nutrient concentrations within a waterbody alone to predict eutrophication, particularly in streams (Tetra Tech, 2006). Ambient concentration data may not be effective in assessing eutrophication and the subsequent impact on water use because algal productivity depends on several additional factors such as morphology, light availability, flooding frequency, biological community structure, etc. Except in extreme cases, nutrients alone do not impair beneficial uses. Rather, they cause indirect impacts to protected uses through excessive algal growth or low dissolved oxygen levels.

Rather than using pre-defined nutrient limits that may or may not cause impairment by themselves, the intention of the NNE approach is to select nutrient response indicators for evaluating risk of use impairment. The objective is to control excess nutrient loads/concentrations to levels such that the risk of impairing the designated uses is limited to a low level. If the nutrients have a low probability of impairing uses, regardless of actual levels measured at a given point in time in the water column, then water quality standards can be considered met.

The NNE approach addresses the need for a nutrient criteria framework containing, in addition to nutrient concentrations, targeting information on secondary biological indicators such as benthic algal biomass, benthic chlorophyll, dissolved oxygen, macrophyte cover, and water clarity. The NNE approach is a compromise between applying statistical nutrient criteria (which may have little relevance to the support of a given beneficial use) and developing true site-specific criteria. The secondary indicators are supposed to provide a more direct risk-based linkage to beneficial uses than the nutrient concentrations alone.

5.2.2 Beneficial Use Risk Categories

Within the NNE framework, waterbodies are classified into three categories, termed Beneficial Use Risk Categories (BURCs). BURC I waterbodies are not expected to exhibit impairment due to nutrients, while BURC III waterbodies have a high probability of impairment due to nutrients. BURC II waterbodies are in an intermediate range, where additional information and analysis may be needed to determine if a use is supported, threatened, or impaired. The NNE has pre-established targets for response indicators defining the boundaries between BURC I/II and BURC II/III. These target boundaries are 100 and 150 mg chlorophyll *a* (chl-*a*) per m^2 for the beneficial use of cold freshwater habitat (COLD) and beneficial use of warm freshwater habitat (WARM) beneficial uses respectively, and 150 and 200 mg- chl-*a* /m^2 for WARM.

Since the Santa Margarita River is designated with the more stringent COLD beneficial use, the BURC I threshold is 100 mg of chl-*a*/m^2 of river bed. If the NNE result is over 150 mg of chl-*a*/m^2 of river bed, then the Santa Margarita River would be categorized as impaired. If the NNE result is 150 mg of chl-a/m^2 of river bed, then the Santa Margarita River would not be categorized as impaired for nutrients, however more study would be necessary to definitively determine whether beneficial uses are supported.

If the NNE result indicates BURC I, then the water body has demonstrated assimilative capacity for the current nutrient loadings.

5.2.3 Results

The parameters used, results, and sensitivity analyses are presented in Appendix N. A summary is provided here. Site-specific empirical data were collected, including nutrient concentrations, canopy cover, water temperature, turbidity, and other variables, and input to the NNE spreadsheet model. The model was run twelve times, and overall, the NNE appeared to indicate that the Santa Margarita River reach at the FPUD Sump was unimpaired for nutrients during May to September of 2009.

All six model runs targeting the BURC II algae threshold indicated that observed mean levels of TN and TP were lower than levels that would indicate impairment. Since BURC II was achieved, the spreadsheet model was repeated with the lower BURC I target values. Five of the six model runs targeting the BURC I threshold indicated that observed mean levels of TN and TP were low enough to consider the Santa Margarita River reach at the FPUD Sump unimpaired.

The sensitivity analysis for the revised QUAL2K method indicated that algae growth in the Fallbrook Sump reach was responsive to changes in the amount of total nitrogen and total phosphorus as well as solar radiation. The spreadsheet model produced no similar sensitivity analysis for Dodds 2002.

6.0 ANALYSIS OF CWRMA IMPACTS

The Santa Margarita River has seen a reduction in base flows since the 1940s due to hydrology, water development, or a combination of each. The CWRMA is intended to restore base flow to mimic natural conditions and support the natural variability of streamflow in the Santa Margarita River. The purpose of this section is to describe how the addition of CWRMA releases has changed the flow rates, geomorphology, and water quality of the river.

6.1 IMPACT TO HYDROLOGY

Based on the mass balance of total flow, augmented flow, and naturally occurring flow, CWRMA releases were a significant portion of the base flows of the Santa Margarita River, especially during drier summer months. The sections below describe how the introduction of CWRMA flows has impacted the hydrology of the river.

6.1.1 Flow Comparison

The USGS gage at the Gorge (11044000) is downstream of the release points for both the MWD imported raw water and the RCWD potable water. Thus, all CWRMA releases are measured by the USGS gage at the Gorge. It follows, then, that the flow in the river without augmentation may be estimated by subtracting the CWRMA augmentation from the USGS gaged flow. Losses between the two release points and the USGS gage are assumed to be minor.

Daily statistics describing the flow at the Gorge with and without augmentation are shown in Table 6-1. With augmentation, the mean daily flow in the river was 33.5 cfs, compared to 27.9 cfs without augmentation. Similarly, the added water increased the median daily flow from 0.4 cfs to 7.8 cfs. The influence of CWRMA augmentation on the daily flows was most pronounced during periods of low precipitation, primarily the summer months. At the Gorge, CWRMA augmentation water has increased base flows during seasonally dry periods.

Table 6-2 gives the total monthly flows measured at the Gorge (USGS gage 11044000), including CWRMA releases (see Table 1-10). The average annual flow for calendar years 2003 through 2009 was 24,300 acre-feet. Table 6-3 lists the percentage of flow at the Gorge that is due to augmentation. During this analysis period, augmentation was 17% of the total flow in the river. On a monthly basis, it ranged from 0%, when there were no releases[3], to 100% of the flow in the river when there was no natural runoff in the river.

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[3] When streamflow in the river from rainfall events exceeds the CWRMA flow requirement, RCWD is not required to make any releases.

TABLE 6-1 DAILY FLOW STATISTICS AT THE GORGE, WITH AND WITHOUT CWRMA AUGMENTATION (JANUARY 1, 2003 – DECEMBER 31, 2009)

Daily Flow Statistic	Gaged Flow at Gorge[1] (USGS 11044000) (cfs)	CWRMA Augmentation Flow[2] (cfs)	Flow at Gorge without Augmentation (cfs)
Mean	33.5	5.8	27.9
Median	7.8	5.1	0.4
Min	0.24	0.0	0.0
Max	4190	16.1	4190

Sources: USGS daily discharge, gage 11044000; CWRMA augmentation from RCWD (Elitharp, 2010).

[1] CWRMA augmentation water is included in the gage measurement here such that: (Flow without Augmentation) = (Gaged Flow) – (CWRMA Augmentation).

[2] CWRMA daily release volumes in acre-feet have been converted to an equivalent average daily flow rate in cfs.

TABLE 6-2 GAGED FLOW AT THE GORGE (USGS GAGE 1104400) - TOTAL FLOW, INCLUDING CWRMA AUGMENTATION, 2003 THROUGH 2009, ACRE-FEET

Month	2003	2004	2005	2006	2007	2008	2009	Total
Jan	732	510	34,748	1,398	489	11,378	634	49,889
Feb	8,904	2,898	27,007	2,166	601	2,208	3,798	47,582
Mar	5,409	601	3,703	2,023	511	411	664	13,322
Apr	2,350	470	1,082	2,647	512	387	645	8,093
May	676	267	974	365	239	1,250	224	3,995
Jun	549	209	722	295	200	583	680	3,238
Jul	517	188	651	277	193	495	708	3,030
Aug	497	195	597	271	187	469	241	2,456
Sep	477	182	586	248	180	455	176	2,304
Oct	495	7,789	719	247	191	480	*184*	10,104
Nov	443	1,399	521	279	2,998	916	*184*	6,739
Dec	755	7,073	335	256	2,241	5,776	*2,907*	19,342
Total	21,804	21,780	71,645	10,471	8,541	24,806	11,046	170,093

Source: USGS daily discharge, gage 11044000. *Provisional data.*

Note: Monthly augmentation amounts can be greater than gaged flows due to gage inaccuracy and variation in reporting.

TABLE 6-3 PERCENTAGE OF FLOW IN RIVER AT USGS GAGE 11044000 DUE TO CWRMA AUGMENTATION, 2003 THROUGH 2009

Month	2003	2004	2005	2006	2007	2008	2009	Total
Jan	70%	88%	0%	32%	100%	2%	100%	6%
Feb	5%	6%	0%	28%	84%	6%	6%	4%
Mar	9%	54%	0%	21%	94%	84%	99%	21%
Apr	20%	72%	2%	19%	83%	85%	97%	34%
May	83%	77%	60%	88%	100%	40%	100%	66%
Jun	93%	74%	92%	93%	100%	91%	100%	95%
Jul	96%	89%	92%	94%	100%	96%	100%	98%
Aug	98%	95%	93%	94%	100%	100%	100%	99%
Sep	95%	97%	93%	97%	100%	100%	100%	98%
Oct	93%	1%	77%	94%	100%	100%	100%	22%
Nov	51%	7%	98%	84%	7%	44%	100%	28%
Dec	36%	2%	100%	72%	7%	2%	5%	7%
Total	25%	12%	6%	38%	42%	18%	43%	17%

To illustrate the relationship between augmentation flows and natural river runoff, the total flow in the river for calendar years 2005 and 2006 is graphed in Figure 24. These years were chosen because they represent a wet year (2005) and a dry year (2006) during the CWRMA release period. The gray portion of each bar represents the CWRMA augmentation releases during each month and the black portion of the bar is the flow in the river without augmentation. The sum of the two bars is the total flow measured in the river at the Gorge at USGS gage 11044000. Generally, the provisions of the CWRMA prescribe that less water be released in dry years and more in wet years. This is true for the two years shown in Figure 24, especially during the summer months. The first three months of 2005 had no releases because natural flows were so high that RCWD was not required to make any releases during that period.

The seasonal variation in releases and flows shown in Figure 24 is typical of the analysis period: during winter months, natural runoff was higher, and augmentation was a smaller percentage of total flow. During summer months, when there is little to no natural runoff in the river, augmentation water was a significant percentage of the total flow, usually more than 90%. This again illustrates that CWRMA augmentation water had the most significant impact on the flow regime during dry periods.

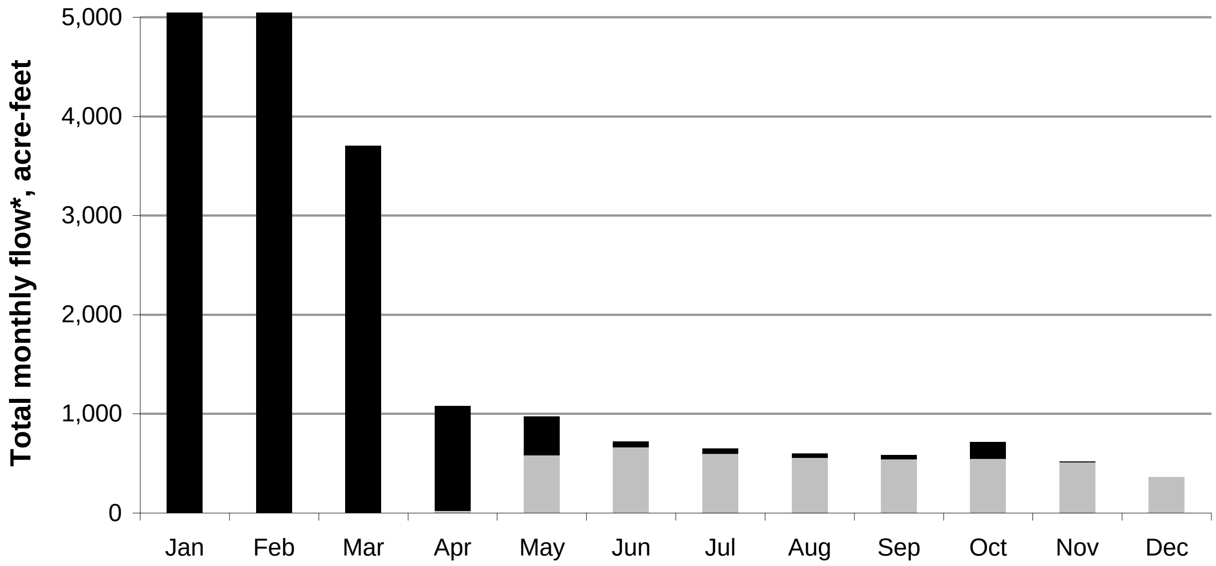
6.1.2 Santa Margarita River Hydrologic Model

For this report, the CWRMA Santa Margarita River hydrologic model described in Section 1.5.2 has been updated through calendar year 2008. No additional calibration has been done, and all

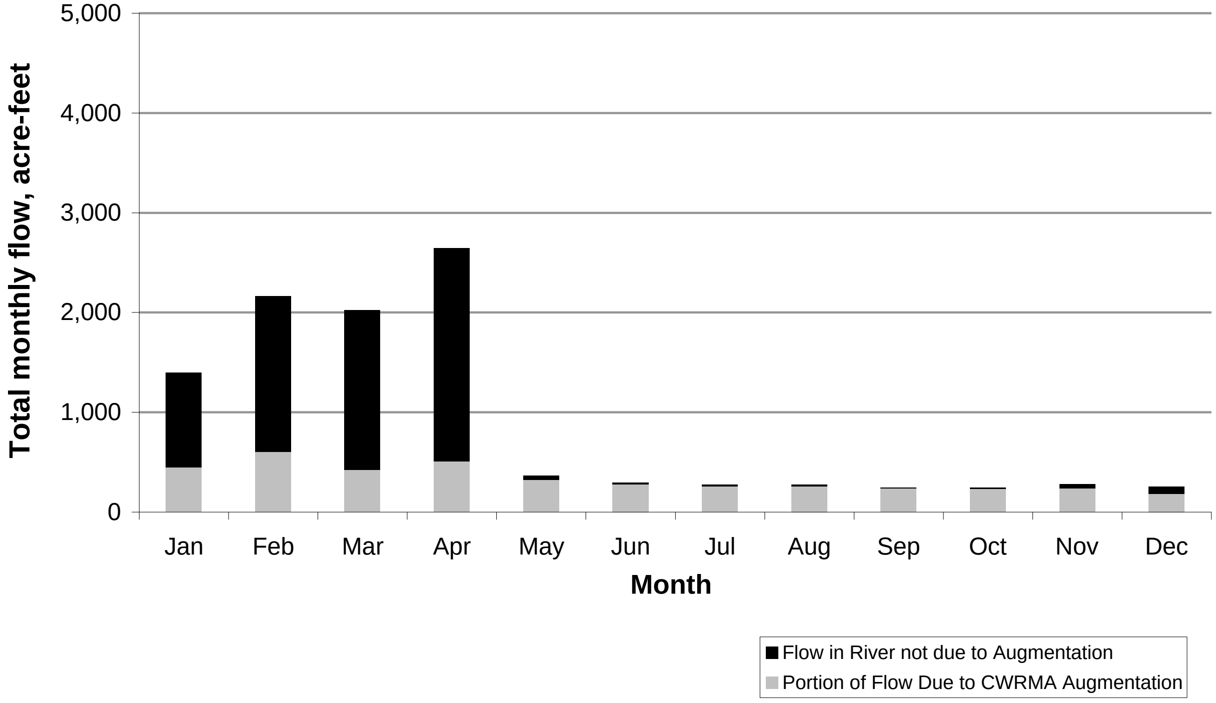
FIGURE 24

Monthly Flow and Augmentation on the Santa Margarita River near Temecula (Gorge)

Wet Year: Calendar Year 2005



Dry Year: Calendar Year 2006



* Y-axis truncated at 5,000 acre-feet in order to show detail at lower flows. Total flows in river exceeded 5,000 acre-feet in January and February 2005 and were 34,700 and 27,000 acre-feet, respectively

F:\DATA\2258\Surface Water\[CWRMA Daily and Monthly Stats for Report v2.1.xls]Figure 24 parameters from the original model files remain the same. To extend the model, three sets of inputs were compiled: (1) daily precipitation at Wildomar; (2) monthly evaporation at Vail Lake; and (3) daily inflows at Vail Lake. Precipitation at Wildomar was obtained from RCFCD. Vail Lake evaporation and inflows were obtained from RCWD. RCWD computed net inflow to Vail Lake on a monthly basis, so these monthly inflows were distributed to daily flows using the USGS gage on Temecula Creek at Aguanga (USGS 11042400). Preparation of the inputs followed the procedures used for the original CWRMA Hydrologic Simulation Program Fortran (HSPF) model.

The result of the model extension is a daily record of simulated natural flow at the Gorge during the CWRMA release period of January 1, 2003 through December 31, 2008. Daily flow statistics for the natural flow are presented in Table 6-4.[4] As expected, natural flows are generally greater than the gaged flows, even with augmentation. The median daily natural flow is 8.8 cfs.

The CWRMA Section 5 augmentation flow requirements were established based on maintaining two-thirds of base flow, which was defined as the median natural flow as simulated in the HSPF model for water years 1931 through 1996. With the update of the HSPF model through December 2008, median natural flows for the CWRMA release period have been estimated and compared to the actual augmentation. Median average daily natural flow and augmentation are presented by month in Table 6-5. Augmentation is also expressed as a percent of the median natural flow and ranges from 36% (March and December) to 102% (August). On an annual basis, median daily average augmentation (5.2 cfs) was 59% of the median natural base flow (8.8 cfs) for the period January 1, 2003 through December 31, 2008. This value of 59% is close to the target value of two-thirds established by the CWRMA.

Monthly deviation from the target flow of two-thirds of the median natural flow may be explained by a few factors. First, the Section 5 flow requirements were based on the hydrology of the period from WY 1931 to 1996. The six years from 2003 to 2008 included two critically dry years, one below normal year, two above normal years, and one very wet year. According to the hydrologic index, it is close to a balanced hydrologic period. However, the six-year period is short when compared to the historical period of 1931 to 1996 and variations within individual months may significantly affect the statistics. Thus, differences in hydrology may explain why augmentation was more or less than two-thirds natural flow. Additionally, CWRMA has several ways in which credits are earned and applied; in the short-term, these credits may affect the monthly median statistics.

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[4] The statistics presented in Table 6-4 for the Gorge and for flow without augmentation are for the period January 1, 2003 through December 31, 2008. This period was used so that a comparison could be made to the hydrologic model, which covers that same period. As a result, statistics presented in Table 6-4 do not match those presented in Table 1-10 and Table 6-1, which include more recent data through December 31, 2009.

TABLE 6-4 DAILY FLOW STATISTICS AT THE GORGE, WITH AND WITHOUT CWRMA AUGMENTATION (JANUARY 1, 2003 – DECEMBER 31, 2008)

Daily Flow Statistic	Gaged Flow at Gorge[1] (USGS 11044000) (cfs)	CWRMA Augmentation Flow[2] (cfs)	Flow at Gorge without Augmentation (cfs)	Simulated Natural Flow (cfs)
Mean	36.6	5.6	31.1	34.8
Median	7.7	5.2 [3]	0.5	8.8 [3]
Min	0.24	0.0	0	2.8
Max	4,190	16.1	4,190	4,190

[1] CWRMA augmentation water is included in the gage measurement here such that: (Flow without Augmentation) = (Gaged Flow) – (CWRMA Augmentation)

[2] CWRMA daily release volumes in acre-feet have been converted to an equivalent average daily flow rate in cfs.

[3] Diffferences between the median presented here and the CWRMA flow requirements of 2/3 base flow may be caused by: (a) the relatively short (six-year) period over which the percentages are computed; (b) variations in hydrology between recent years and the long-term historical record; and (c) the CWRMA credit systems, which result in modified flow requirements that may be greater than or less than those stipulated in Section 5 of CWRMA.

TABLE 6-5 COMPARISON OF MEDIAN CWRMA AUGMENTATION TO MEDIAN NATURAL FLOWS AT THE SANTA MARGARITA RIVER NEAR TEMECULA

		Median Average Daily Augmentation, CY 2003 to 2008	
Month	Simulated Base Flow[1], CY 2003 to 2008	cfs	As Percent of Median Natural Flow[2]
January	10.7	7.7	72%
February	14.1	5.5	39%
March	16.4	5.9	36%
April	11.1	5.8	52%
May	8.2	5.2	63%
June	6.7	5.2	78%
July	5.5	5.0	90%
August	5.3	5.4	102%
September	5.4	5.5	101%
October	6.2	3.9	63%
November	6.8	4.1	60%
December	8.8	3.2	36%

[1] Simulated base flow is the median monthly natural flow as simulated in the HSPF model

[2] Diffferences between the percentages presented here and the CWRMA flow requirements of 2/3 base flow may be caused by: (a) the relatively short (six-year) period over which the percentages are computed; (b) variations in hydrology between recent years and the long-term historical record; and (c) the CWRMA credit systems, which result in modified flow requirements that may be greater than or less than those stipulated in Section 5 of CWRMA.

6.1.3 Flow Exceedance Analysis

Figure 25 is an exceedance analysis of daily flows at the Gorge, with and without augmentation water. Simulated natural flow is also included. The graph shows what percent of the time flows are exceeded. The exceedance is based on daily flows. The 50% exceedance is also known as median flow, or the flow that is exceeded 50% of the time.

A comparison of the augmented and non-augmented flows to the simulated natural flow shows the importance of the CWRMA augmentation water. Clearly, the addition of CWRMA water created flows in the river that more closely resembled the natural flows. In Figure 25, flow without augmentation (red solid line) had a minimum flow of 0 cfs at 76% exceedance. This means that, without augmentation, the river would have been dry 24% of the time. With augmentation (black solid line), though, the river was never dry at the Gorge (it had a minimum value of .24 cfs[5] at 100% exceedance). This shows the importance of the CWRMA augmentation: the river had more water more often and daily flows more closely resembled natural conditions.

6.1.4 Flow Experiment Analysis on Reaches

After CWRMA augmentation is released at the Gorge, it is subject to losses and gains as it flows downstream. Losses may include evapotranspiration and streambed infiltration, and gains may include rising groundwater, precipitation runoff, and irrigation runoff. The gains and losses may vary seasonally.

The study team measured flow rates at eight locations along the Santa Margarita River and its tributaries. These data were combined with USGS and SDSU measurements at six additional locations to create a complete picture of flows between the Gorge and the Santa Margarita River at Ysidora.

Flows along the main stem are highly dependant on CWRMA releases. During April 2009 when CWRMA releases were higher (10.3 cfs), flows along the main stem were also higher. In May and September 2009, CWRMA releases were smaller (3.5 cfs and 3.2 cfs, respectively), thereby reducing flow downstream along the main stem.

The flow measurements were used to create a preliminary picture of where and when gains and losses occur on the main stem of the Santa Margarita River. A water balance was computed at each tributary confluence to determine how much each main stem reach was gaining or losing at three points in time (April, May, and September 2009). Figures 26, 27, and 28 show the gaining and

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[5] Though the minimum recorded flow at the Gorge during this period was 0.24 cfs, minimum flow is more typically 3.0 cfs. RCWD maintains a 3.0 cfs minimum at the Gorge, based on a 10-day running average.

F:\DATA\2258\Surface Water\CWRMA Daily and Monthly Stats for Report v2.1

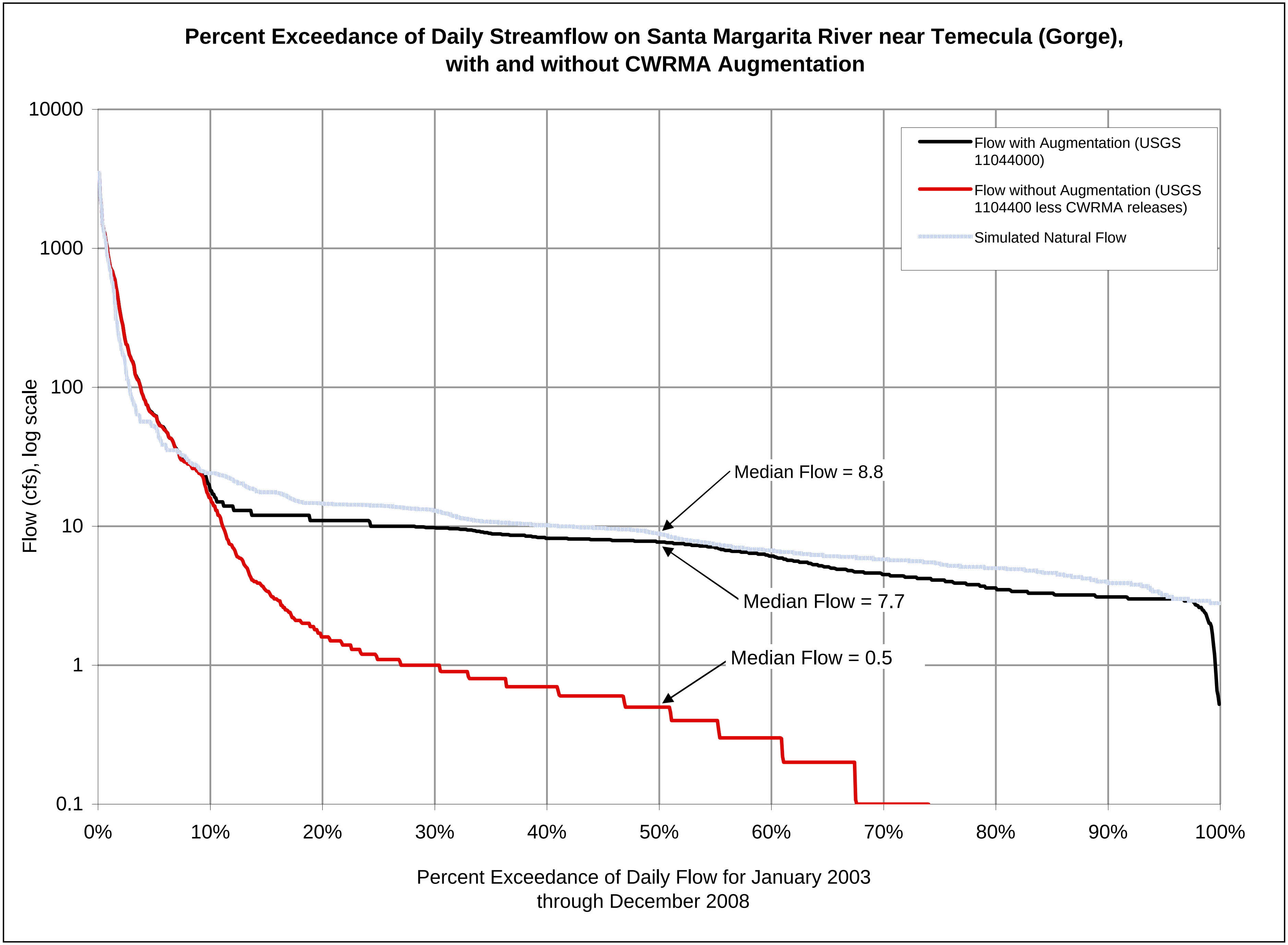
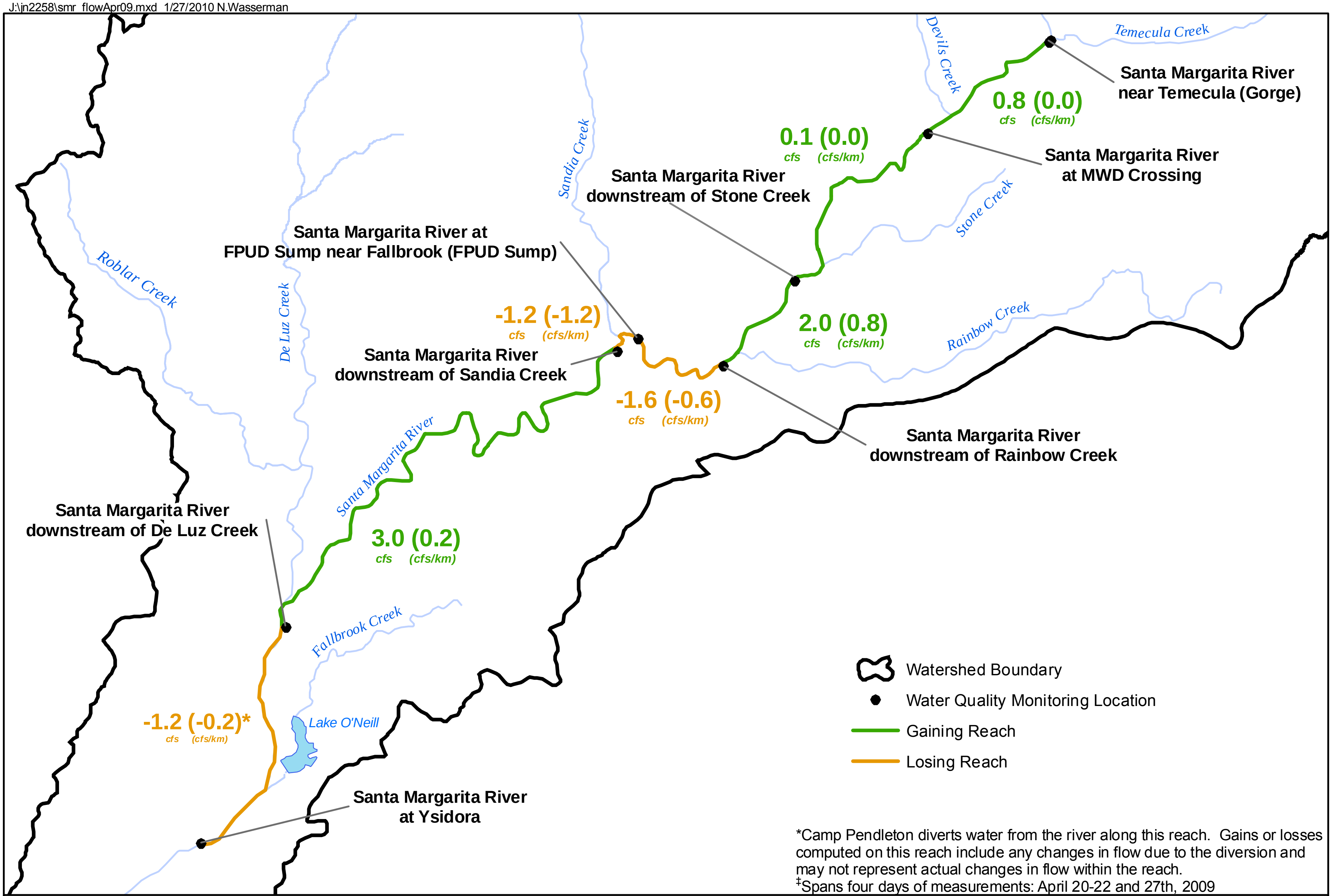

Percent Exceedance of Daily Streamflow on Santa Margarita River near Temecula (Gorge), with and without CWRMA Augmentation

FIGURE 25

J:\jn2258\smr_flowApr09.mxd 1/27/2010 N.Wasserman



*Camp Pendleton diverts water from the river along this reach. Gains or losses computed on this reach include any changes in flow due to the diversion and may not represent actual changes in flow within the reach.

‡Spans four days of measurements: April 20-22 and 27th, 2009

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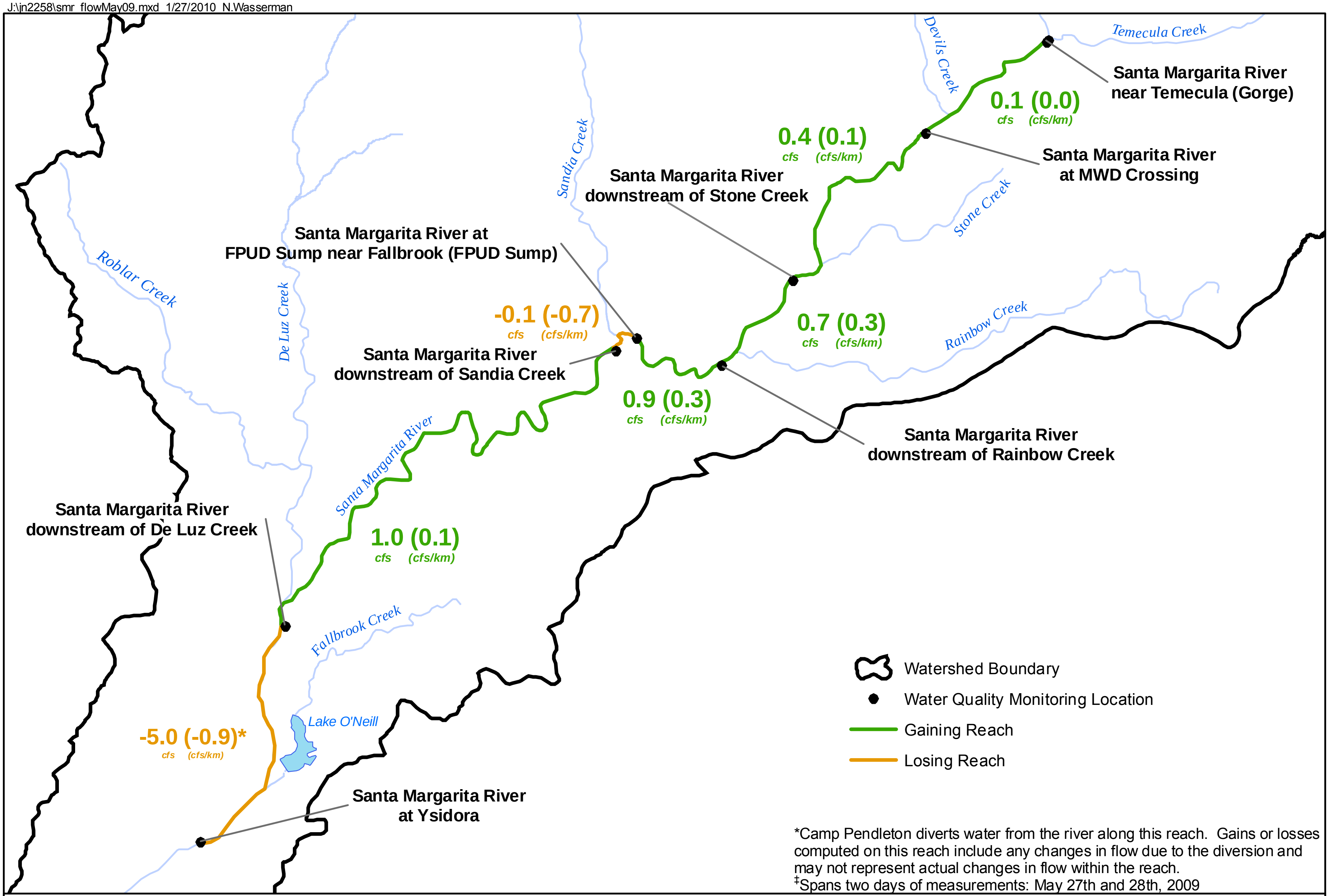
GAINING AND LOSING REACHES IN THE SANTA MARGARITA RIVER IN APRIL 2009‡

N

0 2 4 Kilometers

FIGURE 26

J:\jn2258\smr_flowMay09.mxd 1/27/2010 N.Wasserman



*Camp Pendleton diverts water from the river along this reach. Gains or losses computed on this reach include any changes in flow due to the diversion and may not represent actual changes in flow within the reach.

‡Spans two days of measurements: May 27th and 28th, 2009

STETSON
ENGINEERS INC.

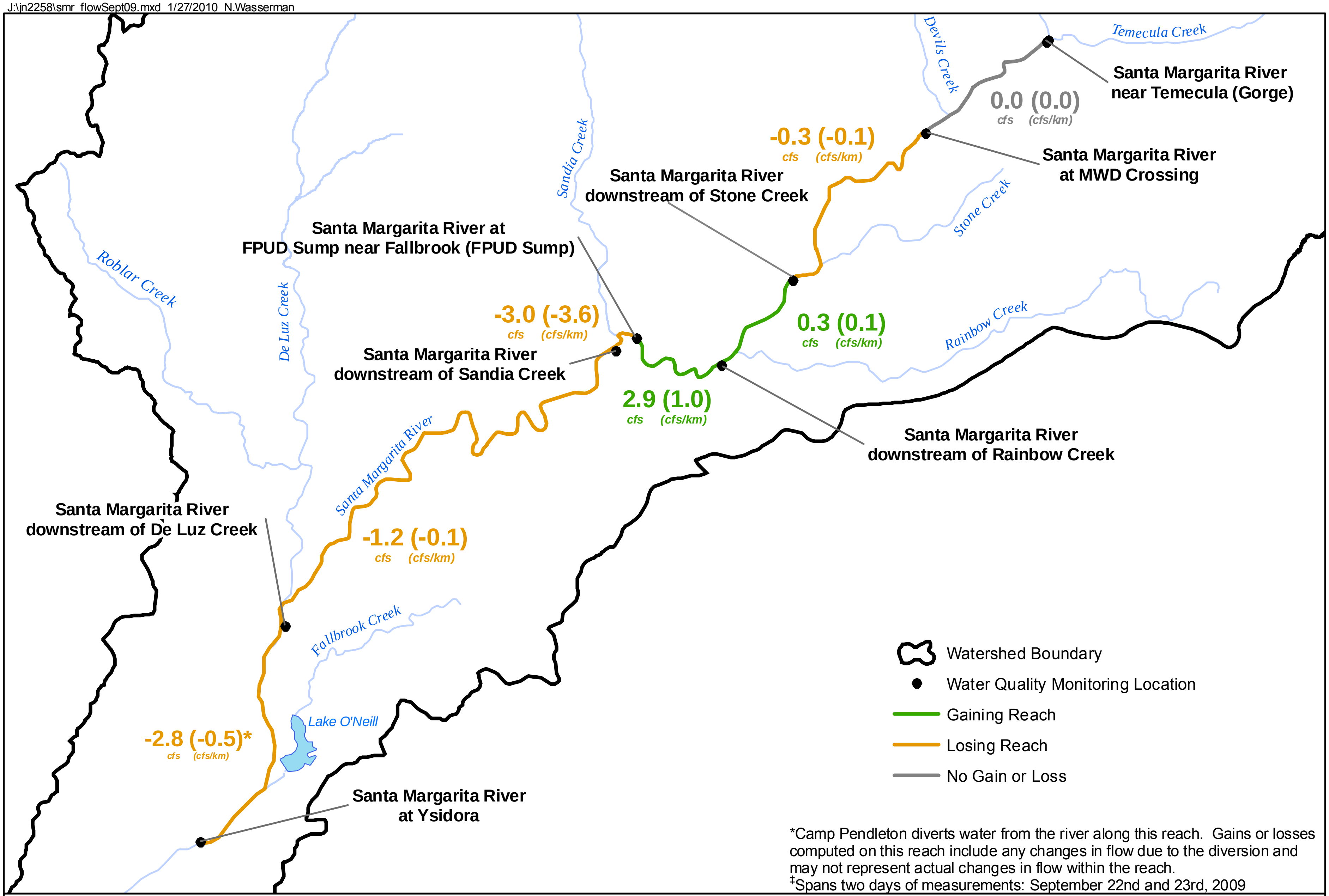
GAINING AND LOSING REACHES IN THE SANTA MARGARITA RIVER IN MAY 2009‡

N

0 2 4
Kilometers

FIGURE 27

J:\jn2258\smr_flowSept09.mxd 1/27/2010 N.Wasserman



*Camp Pendleton diverts water from the river along this reach. Gains or losses computed on this reach include any changes in flow due to the diversion and may not represent actual changes in flow within the reach.

‡Spans two days of measurements: September 22nd and 23rd, 2009

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GAINING AND LOSING REACHES IN THE SANTA MARGARITA RIVER IN SEPTEMBER 2009‡

FIGURE 28

losing reaches in the study area. On the most downstream reach in this analysis, between Deluz Creek and Ysidora, Camp Pendleton diverted water to Lake O'Neill and a series of recharge ponds. The losses computed on this reach included those due to the diversion and may not represent actual changes in flow on the reach.

This analysis is a preliminary step. Only three sampling periods were used; therefore, additional data should be collected in order to more accurately describe gains and losses on the river. Recommendations for this are discussed in Section 7.0.

TABLE 6-6 FLOW MEASUREMENTS ALONG THE SANTA MARGARITA RIVER AND ITS TRIBUTARIES

Location	Measurement Source	April 2009 Date	April 2009 Flow (cfs)	May 2009 Date	May 2009 Flow (cfs)	Sept 2009 Date	Sept 2009 Flow (cfs)
Main Stem							
Santa Margarita River near Temecula	USGS 11044000	22-Apr	11.0	28-May	3.1	22-Sep	3.0
Santa Margarita River at MWD Crossing	Stetson	22-Apr	12.1	28-May	3.4	22-Sep	3.1
Santa Margarita River d/s of Stone Creek	Stetson	21-Apr	12.3	27-May	3.9	22-Sep	2.9
Santa Margarita River d/s of Rainbow Creek	Stetson	21-Apr	14.6	28-May	4.8	23-Sep	3.3
Santa Margarita River near FPUD Sump	USGS 11044300	23-Apr	13.0	28-May	5.7	23-Sep	6.2
Santa Margarita River d/s of Sandia Creek	Stetson	20-Apr	15.8	27-May	9.0	23-Sep	4.0
Santa Margarita River d/s of De Luz Creek	Stetson	27-Apr	18.8	27-May	10.0	23-Sep	2.8
Santa Margarita River at Ysidora	USGS 11046000	27-Apr	17.6	27-May	5.0	23-Sep	0.0
Tributaries							
CWRMA Release	MWD WR-34	22-Apr	10.3	28-May	3.5	22-Sep	3.2
Devils Creek	Stetson	22-Apr	0.3	28-May	0.2	22-Sep	0.1
Stone Creek	Stetson	22-Apr	0.1	28-May	0.1	22-Sep	0.01
Rainbow Creek	USGS 11044250	21-Apr	0.3	27-May	0.24	22-Sep	0.07
Sandia Creek	USGS 11044350	21-Apr	4.0	27-May	3.9	22-Sep	1.5
De Luz Creek	Stetson	n/a	0	n/a	0	n/a	0

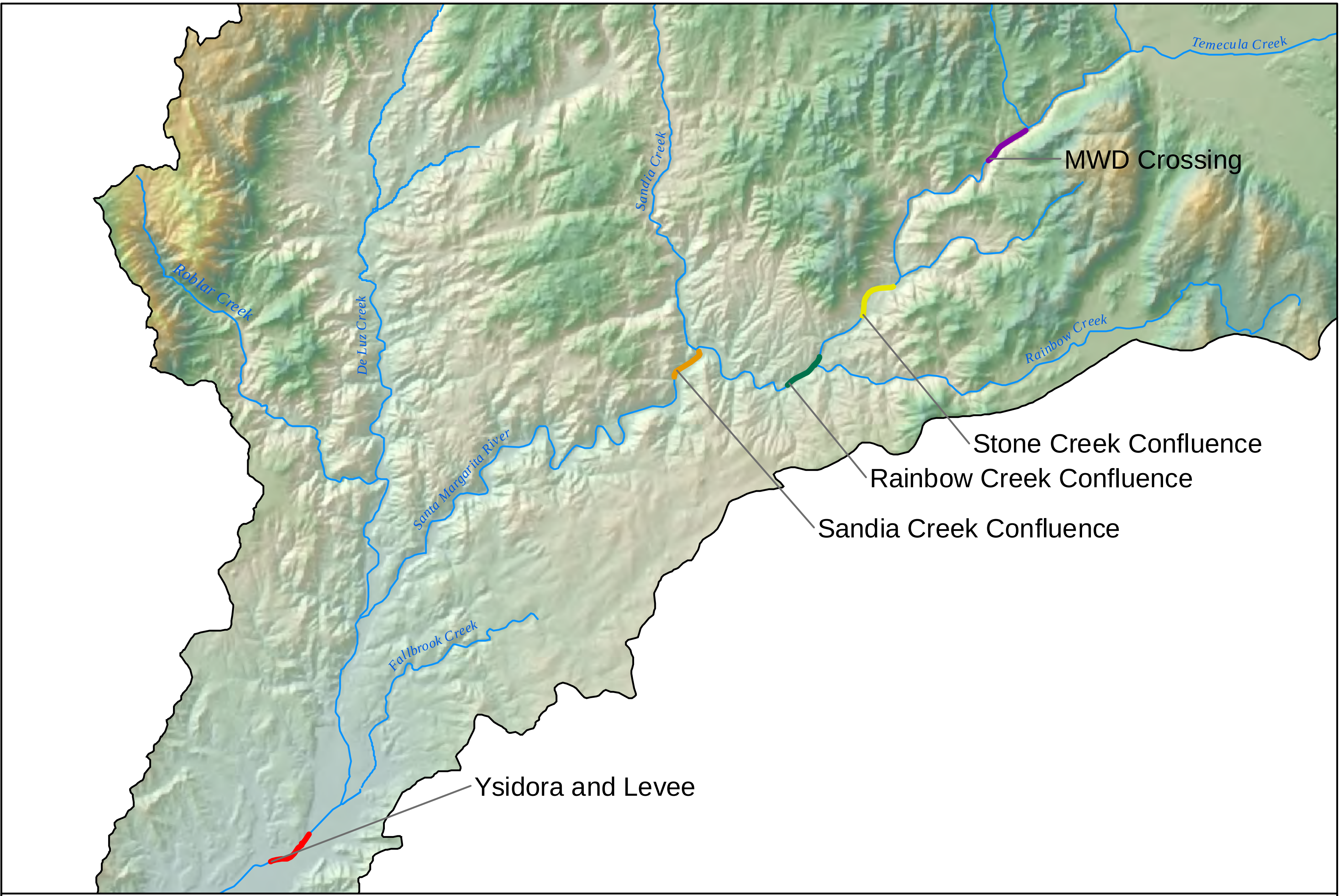
6.2 CWRMA IMPACT TO GEOMORPHOLOGY

Data from the geomorphology study, including cross-sections and pool measurements, are presented in Appendix O. The geomorphology observations included substrate, presence and dimensions of in-channel and off-channel pools, surveyed cross sections, and water level. Also sampled were water quality parameters for the stream and pools. While these sub-reaches had been characterized based on aerial photography and ground truthing (Stetson, 2001), they had not been previously field sampled in detail, so there was no baseline from which to compare for analysis of change. This limited the scope of geomorphological analysis within this study. However, during the flow experiment, changes in flow levels facilitated examination of how such changes influence changes in pool frequency and dimension, as well as water quality of these pools.

The goal of the pool survey was to determine how variation in CWRMA augmentation flows influences downstream pool parameters. These pool characteristics are important factors for evaluating habitat value. The five transects that were explored for pools are depicted in Figure 29, which include: the Santa Margarita River at MWD Crossing (MWD Crossing), the Santa Margarita River downstream of the Stone Creek confluence (Stone Creek confluence), the Santa Margarita River downstream of the Rainbow Creek confluence (Rainbow Creek confluence), the Santa Margarita River downstream of the Sandia Creek confluence (Sandia Creek confluence), and the Santa Margarita River at Ysidora and Levee (Ysidora and Levee). Pools were characterized during April, May, and September 2009 in which the river was flow during all three of these months.

Figures 30 through 34 depict the locations of the pools and which months they were present. Figure 35 presents a summary of the number of pools present at all five transects during April, May, and September 2009. MWD Crossing reach had the highest total number of pools present within the three months of surveying. The Stone Creek confluence had a number of off-channel pools in April, two in May, and none in September while having no in-channel pools in April and a number of them in May and September. The increased in-channel pooling was due to the presence of beavers in May and September. The Rainbow Creek confluence had a limited number of pools during the surveyed months. The Sandia Creek confluence had a number of pools in April and May while only having two in September. Ysidora and Levee had a limited number of off-channel pools in April and May and none in September due to no flow through that reach of the river. There were no in-channel pools present in all three months at this transect.

Analysis of variance (ANOVA) was performed in order to determine which parameters significantly changed between the surveyed months. ANOVAs were performed on the in-channel and off-channel pools for each reach individually and all pools combined for the entire span of the



LOCATIONS OF POOL MEASUREMENTS

FIGURE 29

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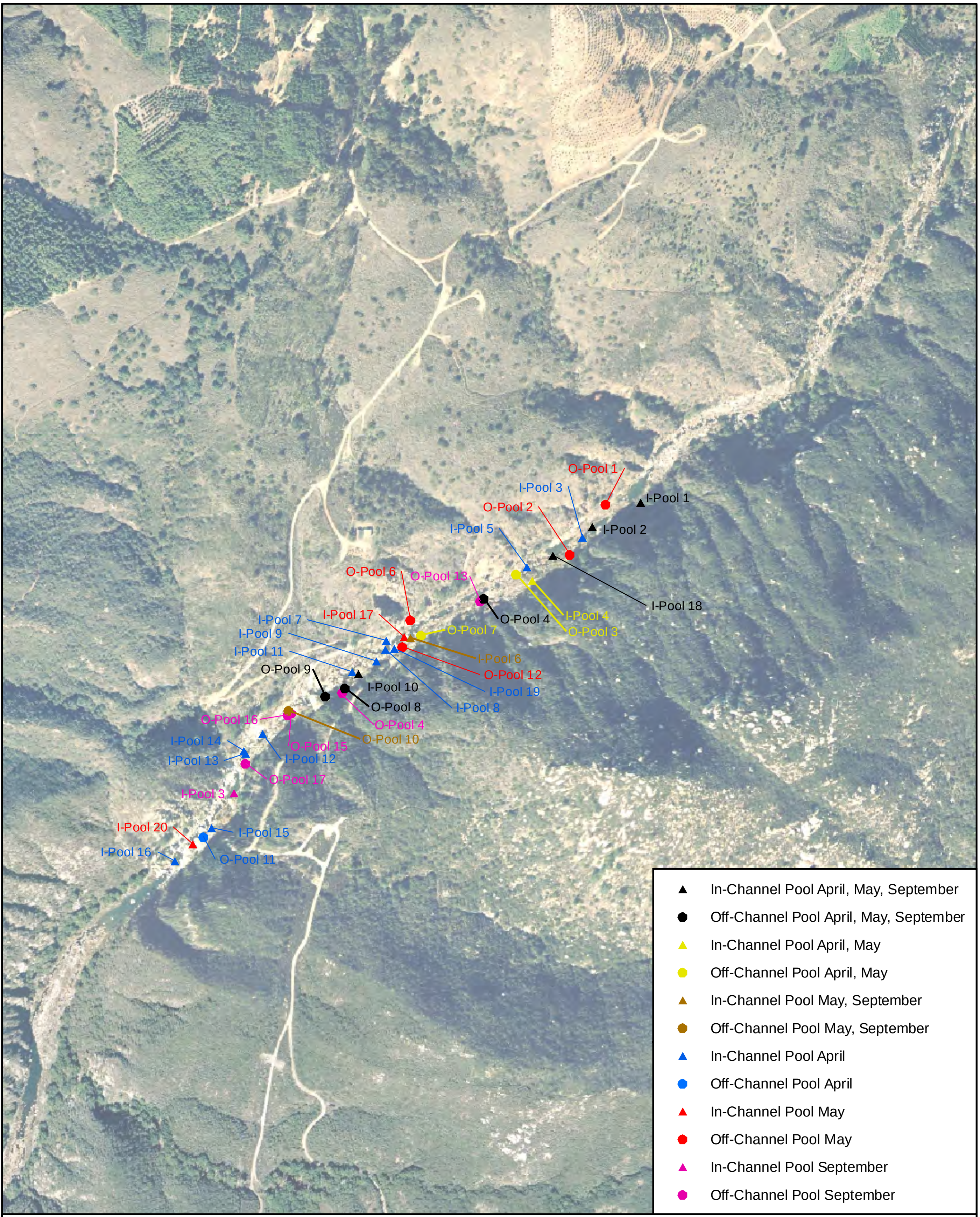
J:\jn2258\smr_PoolSurveyReaches.mxd 11/12/2009 N.Wasserman

FIGURE 30



POOL LOCATIONS, 2009
SANTA MARGARITA RIVER AT MWD CROSSING

STETSON ENGINEERS INC.

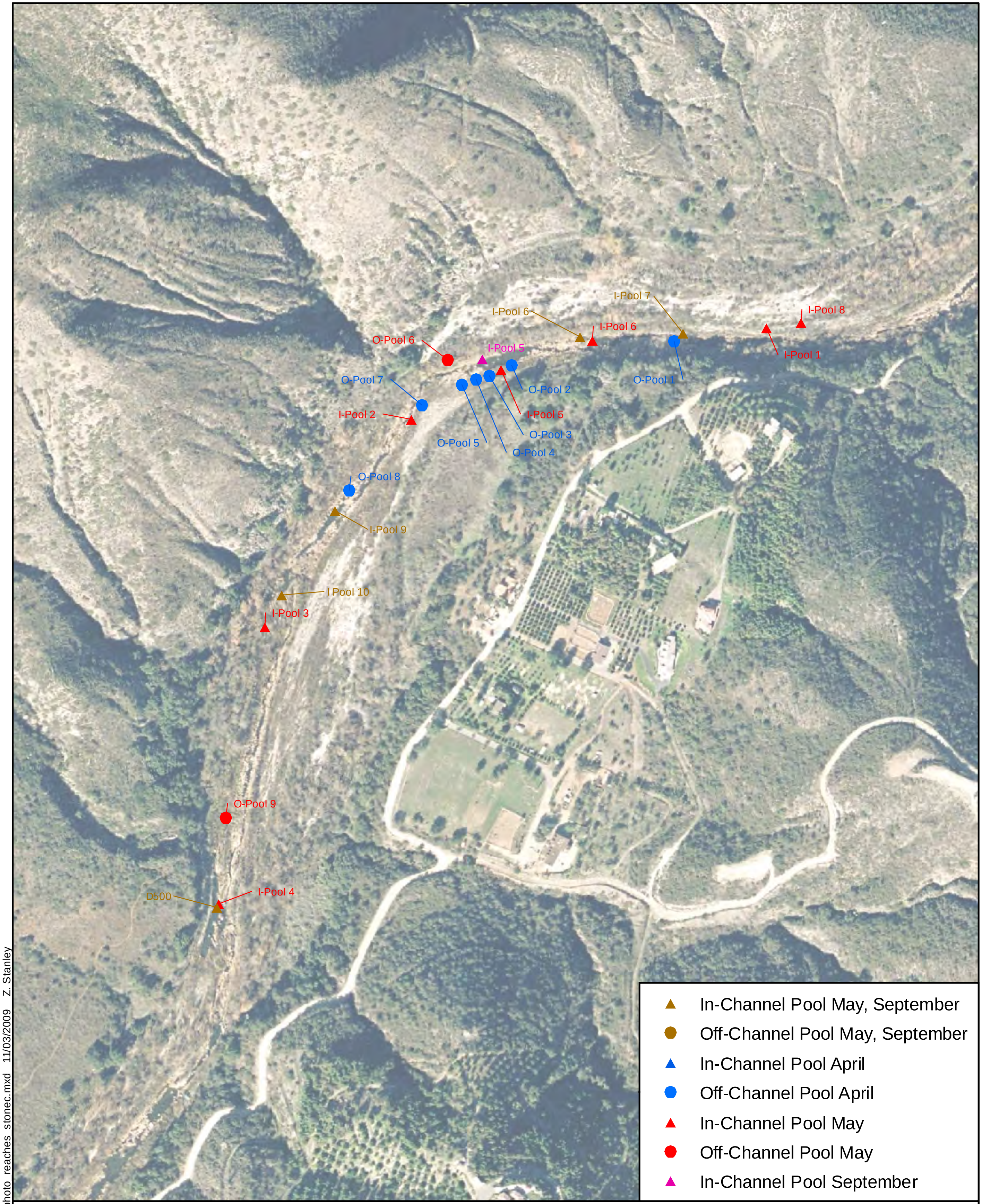
SOURCE: AirphotoUSA Aerial Photo, 2004.

N

0 250 500 Feet

j:\jn2258\subwtrsheds_airphoto_reaches_140e.mxd 11/03/2009 Z. Stanley

FIGURE 31



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STETSON ENGINEERS INC.

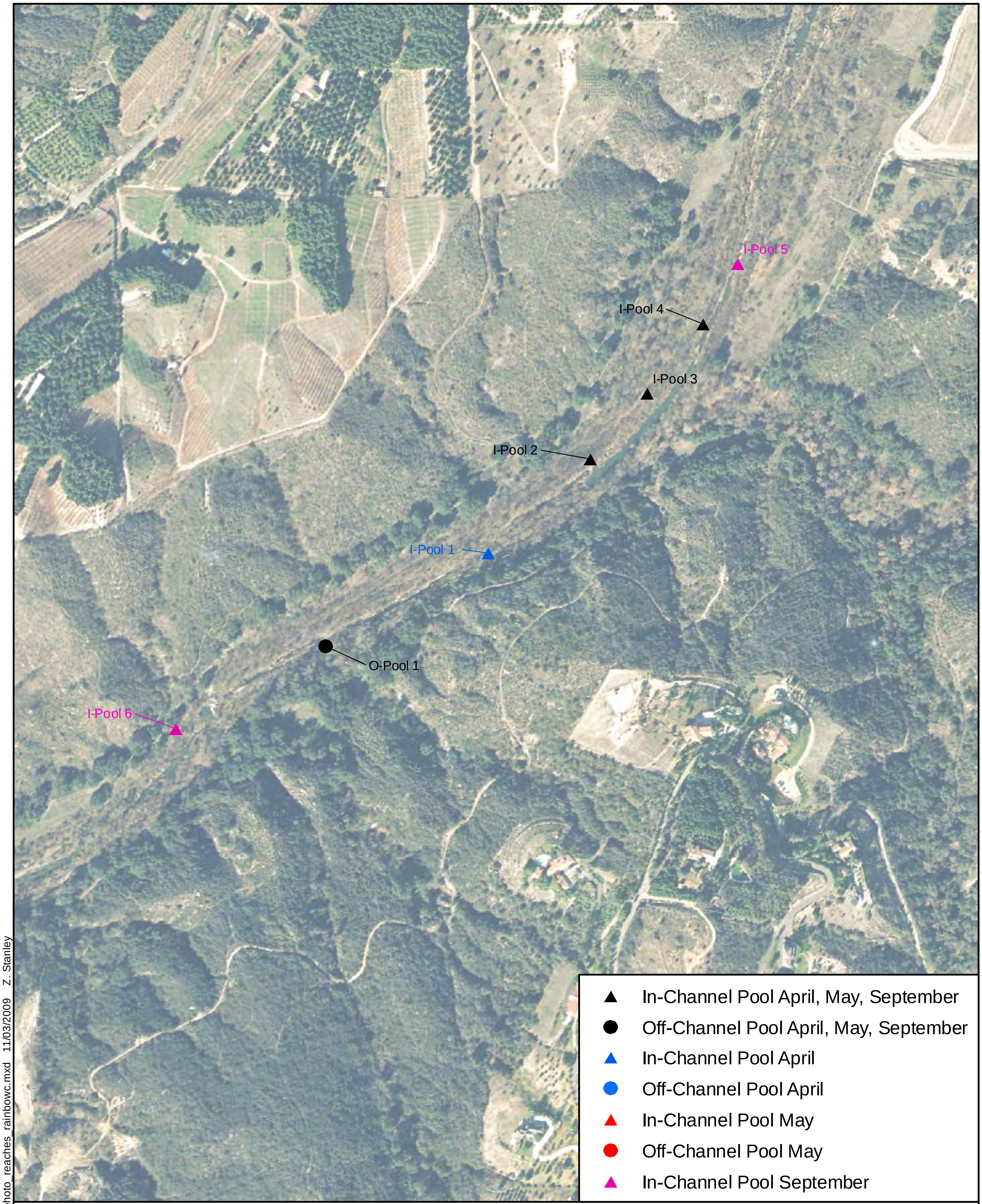
POOL LOCATIONS, 2009
SANTA MARGARITA RIVER AND STONE CREEK CONFLUENCE

SOURCE: AirphotoUSA Aerial Photo, 2004.

N

0 250 500 Feet

FIGURE 32



STETSON ENGINEERS INC.

POOL LOCATIONS, 2009
SANTA MARGARITA RIVER AND RAINBOW CREEK CONFLUENCE

SOURCE: AirphotoUSA Aerial Photo, 2004.

N

0 250 500 Feet

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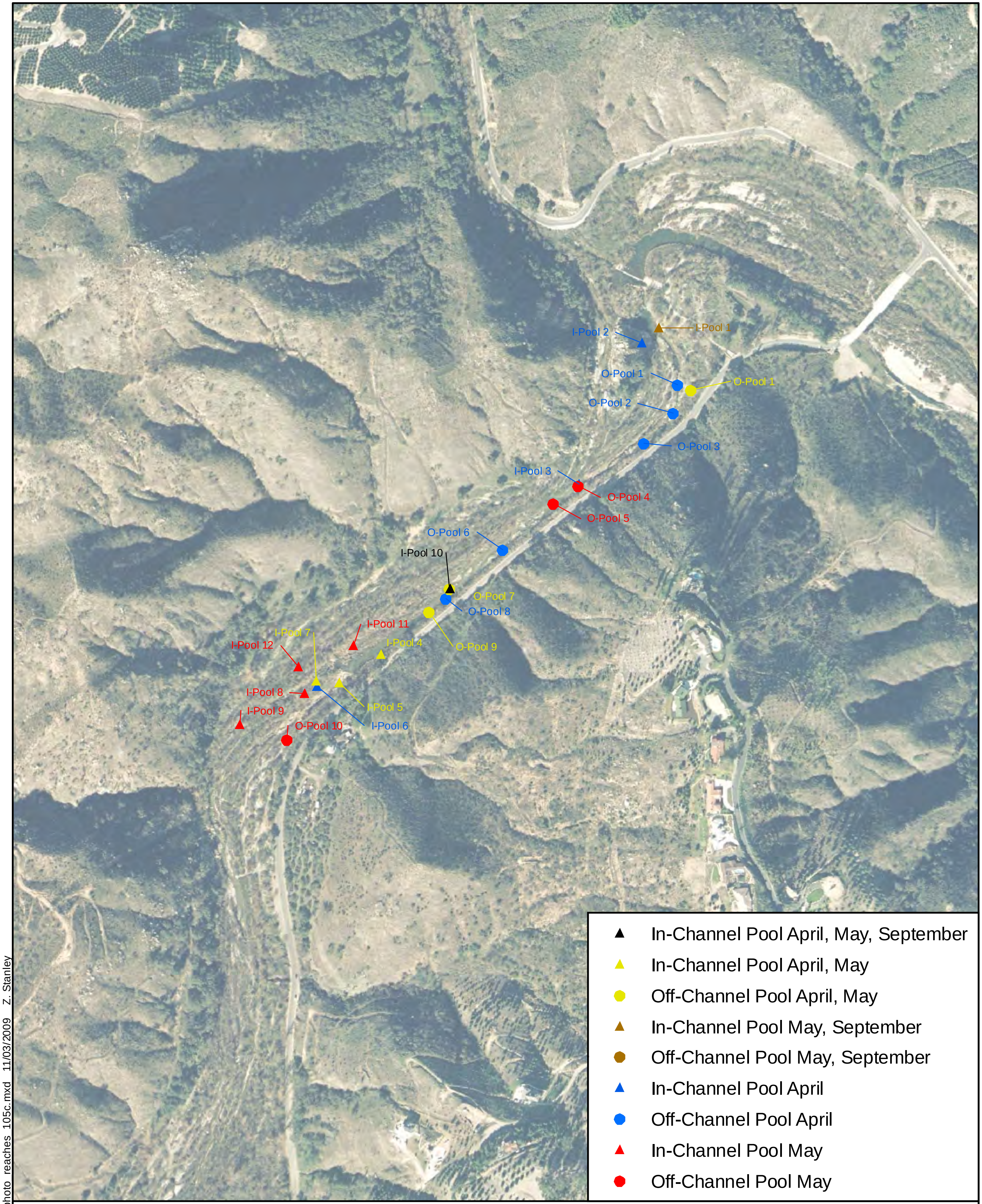
FIGURE 33



STETSON ENGINEERS INC.

POOL LOCATIONS, 2009
SANTA MARGARITA RIVER AND SANDIA CREEK CONFLUENCE

SOURCE: AirphotoUSA Aerial Photo, 2004.

N

0 250 500 Feet

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FIGURE 34

● Off-Channel Pool April, May

● Off-Channel Pool May

POOL LOCATIONS, 2009
SANTA MARGARITA RIVER AT YSIDORA AND LEVEE

SOURCE: AirphotoUSA Aerial Photo, 2004.

0 260 520 Feet

STETSON ENGINEERS INC.

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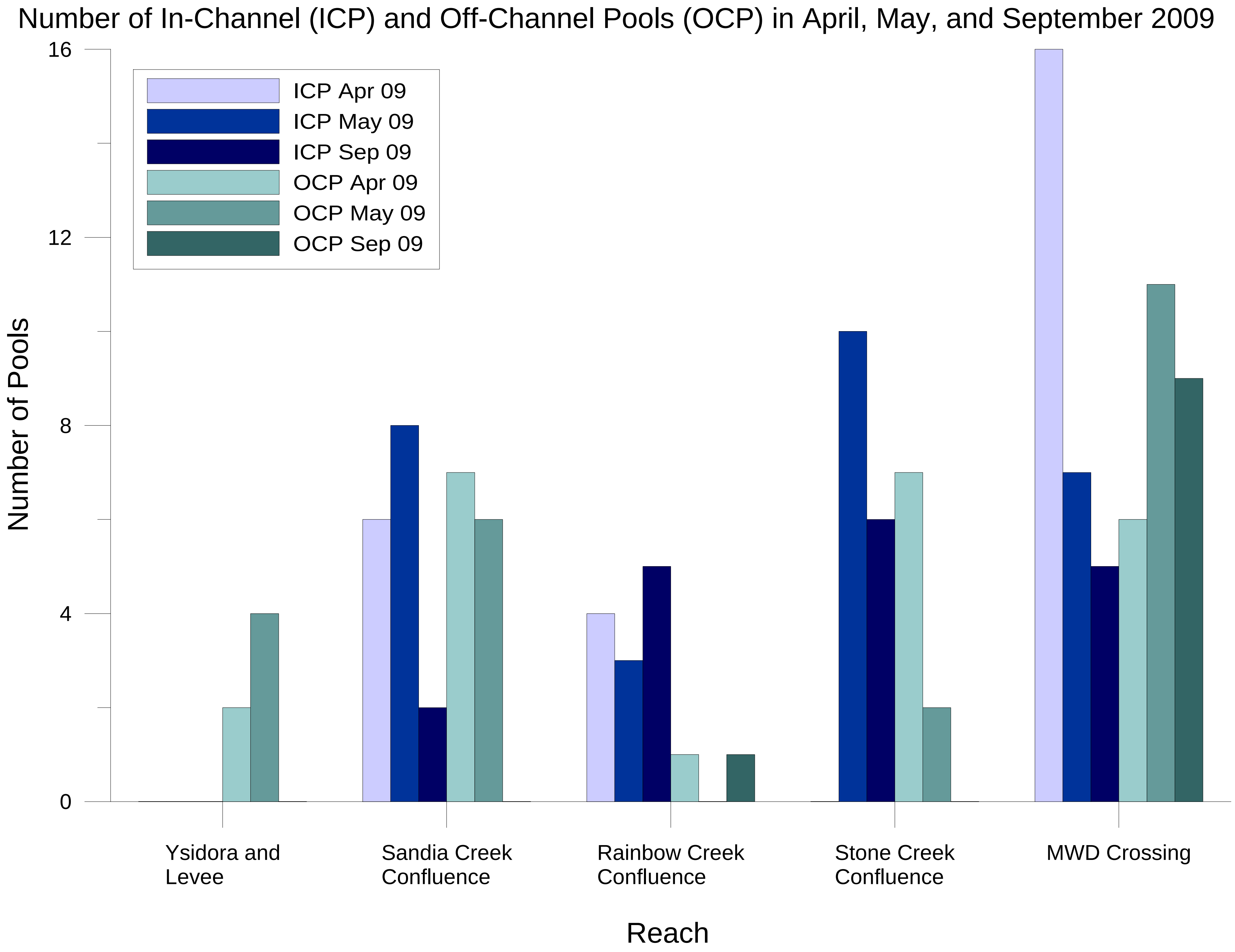

Number of In-Channel (ICP) and Off-Channel Pools (OCP) in April, May, and September 2009
Number of Pools
0
4
8
12
16
ICP Apr 09
ICP May 09
ICP Sep 09
OCP Apr 09
OCP May 09
OCP Sep 09
Ysidora and Levee
Sandia Creek Confluence
Rainbow Creek Confluence
Stone Creek Confluence
MWD Crossing
Reach

FIGURE 35

Santa Margarita River that was surveyed. Results from these ANOVAs are presented in Appendix O and are summarized in Table 6-7. A parameter is deemed significantly different between April, May and September if the calculated p-value is less than 0.05.

TABLE 6-7 ANOVA ANALYSIS OF POOLS ALONG THE SANTA MARGARITA RIVER

P-Values[1]	Pool Area	Pool Depth	Algae Cover	Canopy Cover	Exposure
MWD Crossing[2]	0.830	~0	~0	0.230	~0
Stone Creek Confluence	0.280	0.600	0.100	0.550	0.003
Rainbow Creek Confluence	0.940	0.110	0.560	0.330	0.540
Sandia Creek Confluence	0.990	0.003	0.030	0.660	0.180
Ysidora and Levee[3]	0.140	0.090	0.940	0.730	0.440
Significantly Different?	**Pool Area**	**Pool Depth**	**Algae Cover**	**Canopy Cover**	**Exposure**
MWD Crossing[2]	No	Yes	Yes	No	Yes
Stone Creek Confluence	No	No	No	No	Yes
Rainbow Creek Confluence	No	No	No	No	No
Sandia Creek Confluence	No	Yes	Yes	No	No
Ysidora and Levee[3]	No	No	No	No	No

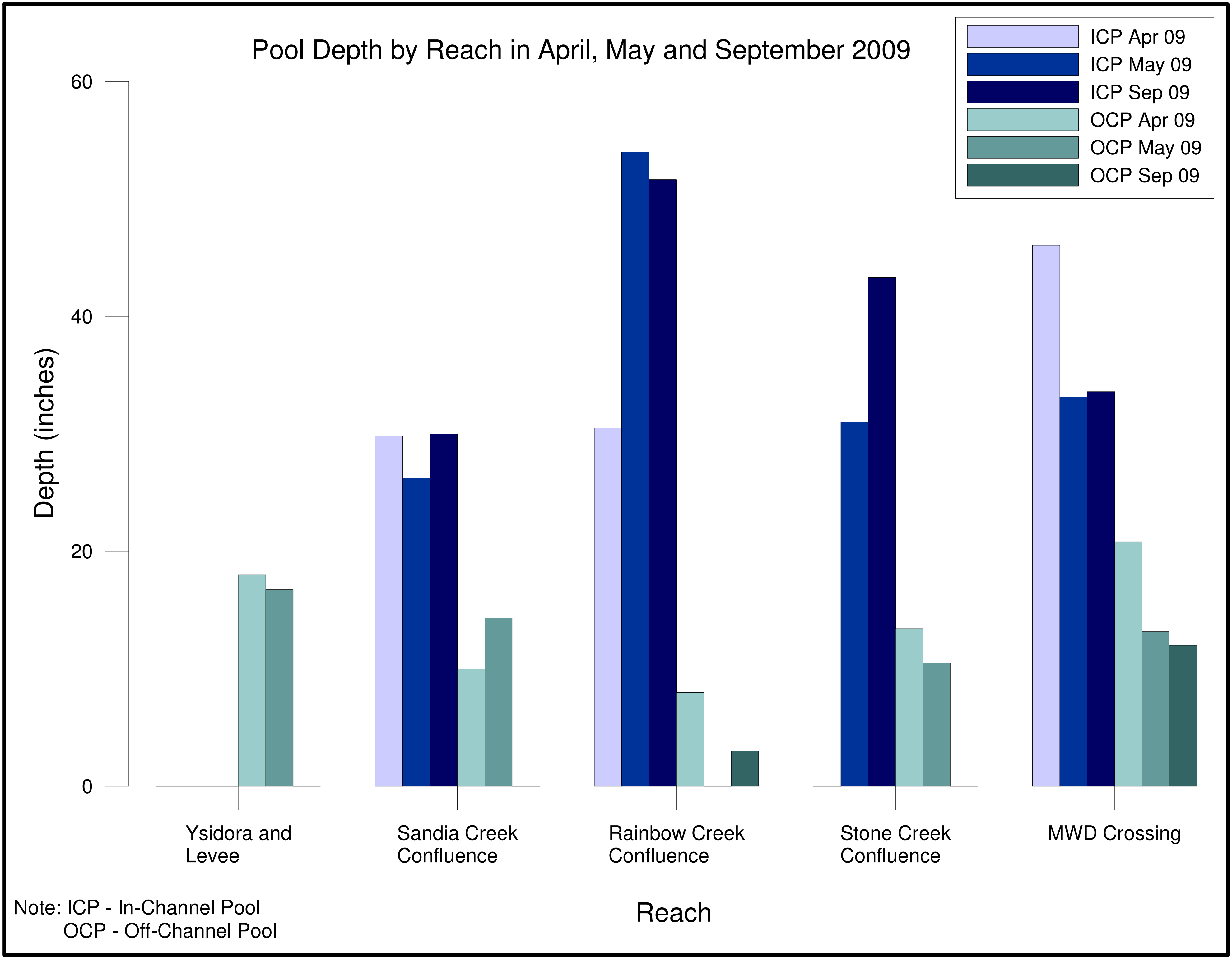
[1] P-Values less than 0.05 indicate significant differences of the measured parameter between the April, May, and September 2009 sampling dates.

[2] MWD Crossing includes May and September only.

[3] Ysidora and Levee reach includes April and May only.

Water temperature, pH, and dissolved oxygen readings are presented in Table O-3 of Appendix O. The water temperature, pH, and dissolved oxygen concentrations appear to be significantly different in some reaches and not in others. It is unclear whether these differences are related to the CWRMA, as these parameters typically vary diurnally, and the reaches were surveyed at different times during the day. Pool areas and canopy cover do not vary significantly during the survey period, while the pool depths did change significantly. Other than water temperature, it appeared that there were no significant changes at the Ysidora and Levee reach during the surveyed months; this was likely due to its distance from the CWRMA outfall, intervening tributary contributions, and the Camp Pendleton diversion and recharge operations upstream.

Figure 36 presents the average pool depth by reach in April, May, and September 2009. The biggest impact on pool depth was at the MWD Crossing. Pool depths decreased significantly in both



Note: ICP - In-Channel Pool
OCP - Off-Channel Pool

FIGURE 36

off-channel and in-channel pools from April to May while September pool depths were about the same as in May. This was expected since this reach is closest to CWRMA outfall. The general trend of the remaining transects was a decrease in pool depth from April to May and variable depths in September. Mixed trends in pool depth were found in downstream reaches from MWD Crossing. This may be attributed to other factors such as beaver dams and debris jams.

A summary of changes in algae cover for all five transects is presented in Figure 37. Algae cover increased from April to May in both off-channel and in-channel pools as the CWRMA flow decreased. An increase in algae cover from April to May also occurred in the Rainbow and Sandia Creek confluence. The biggest impact on algae cover was at MWD Crossing reach. Algae cover increased from April to May in both off-channel and in-channel pools. An increase in algae cover from April to May also occurred in the Rainbow and Sandia Creek confluence.

It can be concluded that the May 1 reduction in CWRMA flows did not negatively affect algal growth. In general, algae will continue to amass throughout the season as long as there are no scouring flows. The amount of algal matter increases through time if the favorable conditions are present

6.3 CWRMA IMPACT TO WATER QUALITY

6.3.1 Discrete Water Quality Analysis

Water quality samples were collected at both the Gorge and at the CWRMA Outfall. These discrete samples were used to analyze the impact of CWRMA on water quality of Santa Margarita River. By comparing sampling results of both sites occurring on the same day, it was possible to remove the loading contributions of CWRMA and approximate the water quality condition of the natural base flow contributions. However this analysis was made more difficult due to the limited number of events in which natural streamflow and CWRMA releases occurred at the same time. Of all the sampling events in this study, this condition was met only twice, on April 17, 2008, and February 3, 2009. Confounding the situation, on April 17, 2009, the CWRMA augmentation water source was the RCWD potable water supply (discharge point approximately 2,500 feet upstream on Murrieta Creek), whereas on February 2009, the water source was MWD. On April 17, 2008 the natural flow (Gorge minus CWRMA) was approximately 1.1 cfs and on February 3, 2009 the natural base flow was approximately 3.9 cfs. During both of these events this natural base flow represents ambient non-storm event streamflow.

During the April 2008 sampling event, natural base flow TDS concentrations (as calculated by mass balance) were 1028 mg/L whereas concentrations at the Gorge and from CWRMA releases

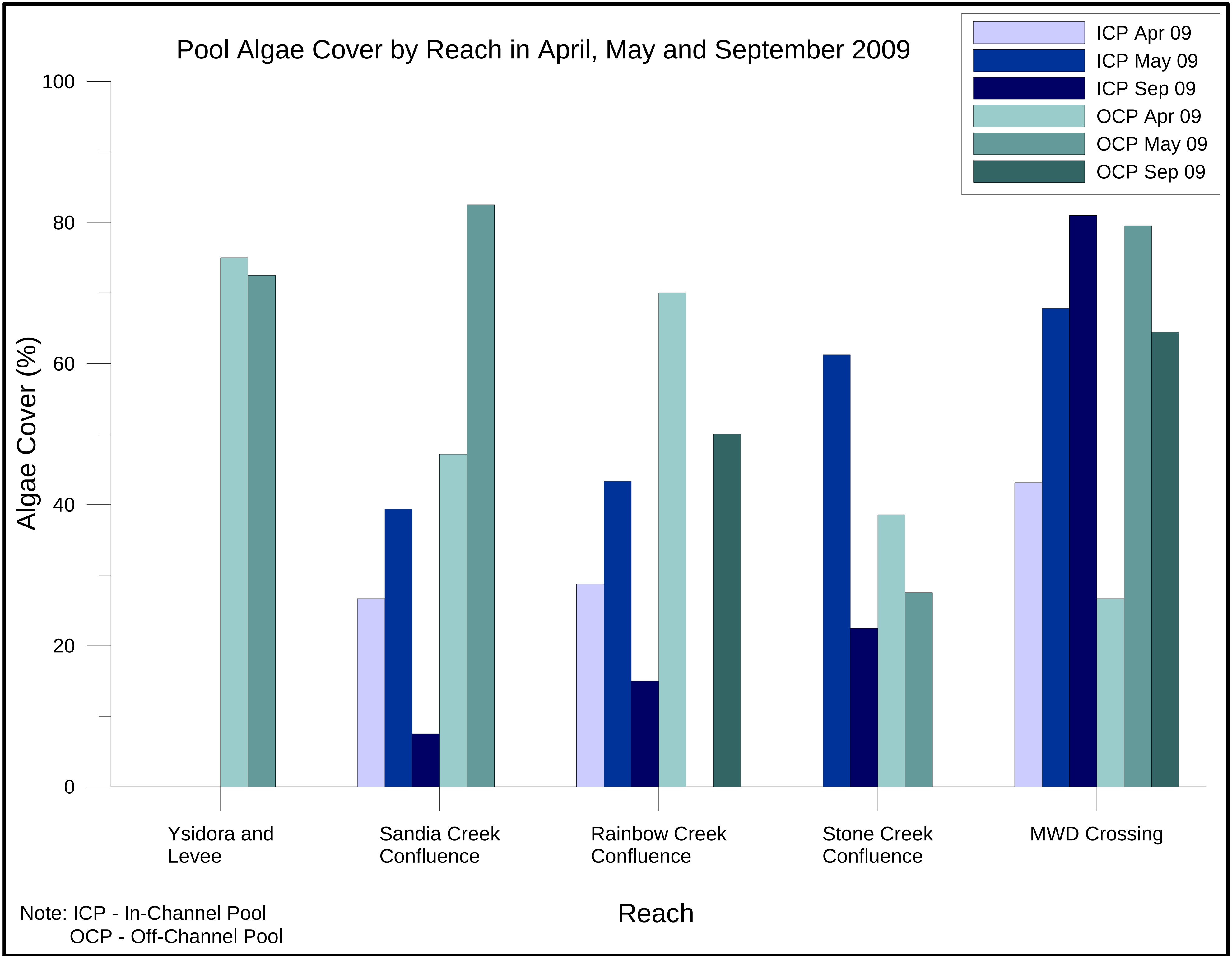

Pool Algae Cover by Reach in April, May and September 2009
ICP Apr 09
ICP May 09
ICP Sep 09
OCP Apr 09
OCP May 09
OCP Sep 09
Algae Cover (%)
100
80
60
40
20
0
Ysidora and Levee
Sandia Creek Confluence
Rainbow Creek Confluence
Stone Creek Confluence
MWD Crossing
Reach
Note: ICP - In-Channel Pool
OCP - Off-Channel Pool

FIGURE 37

were 580 mg/L and 480 mg/L, respectively. During this sampling event, the CWRMA provided a 56% dilution factor. During this same day sulfate concentrations show a similar dilution factor of 60%. TDS and sulfate were not sampled at these locations on February 3, 2009. When applied to the nutrient component concentrations this analysis was inconclusive for both April 17, 2008 and February 3, 2009, due to the low detected concentration levels.

In April, the TDS concentration of the CWRMA augmentation water was less than that measured at the Gorge, indicating that on that day, CWRMA augmentation had the effect of reducing TDS concentration in the river at that location. Without additional data, though, it is unknown whether this trend persists. Table 6-8 shows the flow and TDS and Sulfate concentrations for the April 23, 2009 sampling event.

TABLE 6-8 COMPARISON OF CWRMA AUGMENTATION AND NATURAL RUNOFF WATER QUALITY IN APRIL 2008

Flow Source	Flow Rate (cfs)	TDS Concentration (mg/L)	Sulfate Concentration (mg/L)
Total Flow at Gorge	6.3	580	187
CWRMA Outfall (Potable)	5.2	480	159
Natural Runoff	1.1	1,028	313

6.3.2 Historical Water Quality Analysis

To assess the influence of CWRMA on water quality of the Santa Margarita River, comparison of current (CWRMA augmentation) water quality data, and historical water quality was conducted. Comparisons of CWRMA (2003-2009) water quality were made with the following temporal periods: Pre-CWRMA (all data before 2003), Pre-live stream discharge of wastewater at Murrieta Creek (all data before the 1998 initiation of the reclaimed wastewater discharge pilot project), and Pre-flow augmentation (all data before 1989).

These temporal periods were selected to coincide with periods of quantified flow augmentation that may have had a significant influence on water quality in the River. During the period of WY 1989 through 2002, RCWD released an average of 1,043 AF per year during the months of May through October to Murrieta Creek and the River. During the period of WY 1998 through WY 2002, RCWD released an average of 1,776 AF per year to Murrieta Creek as part of the 2 MGD Demonstration Project6 (Jenks, 2004).

ANOVA analysis was performed comparing these historical data sets with the CWRMA data. The statistical results are summarized Table 6-9 and complete statistical results are presented in Appendix M.

While the older water quality data were collected prior to the State Surface Water Ambient Monitoring Program and current rigorous QA/QC protocols, comparing contemporary CWRMA-era data with historical data was necessary for assessing the influence of the CWRMA releases upon "natural flows." Issues to be aware of include differences over time in the standards for recording metadata, improvements in instrumentation and methods (for both field and lab), and improvement in quality assurance and quality control.

TABLE 6-9 ANOVA COMPARISON OF CWRMA PERIOD WATER QUALITY CONCENTRATION – SANTA MARGARITA RIVER NEAR TEMECULA

Constituent	Pre-Flow Augmentation (Prior to 1989)	Pre-Live Stream Discharge (Prior to 1998)	Pre-CWRMA (Prior to 2003)
TDS	**Lower**	**Lower**	**Lower**
Specific Conductance	Not Significant	Not Significant	Not Significant
Nitrate as N	**Lower**	**Lower**	**Lower**
Nitrite as N	No Data	Not Significant	**Higher**
Ammonia as N	No Data	Insufficient Data	Not Significant
Total Nitrogen	Insufficient Data	**Lower**	Not Significant
Total Phosphorus[1]	**Lower**	**Lower**	**Lower**
Sulfate	Insufficient Data	Not Significant	Not Significant
Manganese	Insufficient Data	Not Significant	Not Significant
Iron	Insufficient Data	Not Significant	Not Significant

[1] Analysis of total phosphorus included historical total phosphate data.

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[6] The 2 MGD Demonstration Project was discontinued October 18, 2002. During WY 2003, October 1st through 18th 2002, 104 AF of reclaimed water was released to Murrieta Creek (Jenks, 2004).

Concentrations of TDS, nitrate as N, and TP during the CWRMA augmented years were statistically lower in concentration than in all prior periods, and CWRMA period TN concentrations were statistically lower than the period prior to live stream discharge. All other constituents analyzed (nitrate, ammonia, TKN, orthophosphate, conductivity, sulfate, iron, and manganese) exhibited no statistical difference in concentration with historical data sets.

The same analysis was conducted for water quality at the FPUD Sump to assess if differences in water quality at this location may have been due to the same conditions and temporal changes as at Santa Margarita River near Temecula. While TP exhibited a significant difference (lower concentration during CWRMA period), TDS and nitrate concentrations did not show significant differences. This contrasts with the Santa Margarita River near Temecula, where all three constituents had significant statistical differences over the historical time periods. This suggests that the influence of the flow augmentation and live stream discharge in the Upper Basin doid not extend downstream to the FPUD Sump. It is likely that the differences in TP and the other constituents (sulfate, pH, and conductivity) concentrations erre due to other historical factors, as well as contributions by tributaries.

6.3.3 Flow Experiment Nutrient Loading

The collection of flow weighted water quality samples at locations along the Santa Margarita River main stem and major tributaries during the April May Flow experiment provided the opportunity to calculate water quality concentrations of the natural base flow in the Santa Margarita River. Following a similar methodology as was applied for Section 6.3.1, constituent concentrations of the natural base flows were calculated for main stem sampling locations downstream of the Gorge.

During the flow experiment, the reduction of CWRMA flow from 10.3 to 3.0 cfs had the impact of increasing TDS concentrations by 30 mg/L at the MWD Crossing location over the period of April to May. During this period, a slight decrease in TN and nitrate was seen which is not consistent with the historical analysis. While this analysis was carried out on reaches farther downstream, these results were inconclusive most likely due to the compounding factors influencing water quality concentrations with the increasing downstream distance.

6.4 INFLUENCE ON SENSITIVE SPECIES AND HABITAT

There are six federally listed threatened or endangered species (one amphibian, one fish and four birds) which reside within or along the lower Santa Margarita River and which may be affected by the CWRMA augmentation. Changes in habitat from the CWRMA would likely manifest in changes to the habitat or natural resources used by these sensitive listed species. The potential impacts of each of the fifteen identified stressors have been developed and are discussed, by species, in Appendix D. The discussion focuses on the breeding habitat, foraging and diet, and nesting requirements for each species and the potential effects of the stressors on those life cycles.

This analysis of CWRMA impacts upon sensitive species and habitat indicated no major impacts. The analysis was based upon on a one month controlled water level change which was representative of a moderate duration water level change within the Santa Margarita River. Prolonged changes in water level of one meter in depth, or more, can significantly modify the riparian habitat (moving the boundaries in or out), scour the channel and modify the Arroyo Toad habitat and the Tidewater Goby habitat. In areas where the river shifted in one direction or another during the low water, were areas where the channel tended to meander. This was particularly noticeable at Ysidora and at the confluences of the Stone and Sandia Creeks. At Ysidora during the low water period, aquatic macrophytes increased because of the exposed river bed. The low flow, low water period favors the Arroyo Toad during the breeding season (March to July) (Brehme, et al, 2006). A broader summary of potential impacts of hydrological changes to the sensitive species follows.

The sections below present a summary of potential CWMRA influences upon each sensitive species.

6.4.1 Tidewater goby (*Eucyclogobius newberryi*)

The tidewater goby appears to spend all life stages in lagoons, estuaries, and river mouths. The species is benthic in nature and its habitat is characterized by brackish, shallow lagoons and lower stream reaches where the water is fairly still but not stagnant. Tidewater gobies prefer a sandy substrate for breeding but they can be found on rocky, mud, and silt substrates as well. Tidewater gobies often migrate upstream into tributaries as far as 1 kilometer from the estuary. Evidence demonstrates reproduction in these upstream tributaries.

There are several threats to the goby, and some of these would potentially be related to changes in hydrology. Tidewater gobies are vulnerable to introduced predators and exotic estuarine species of goby. The brackish zone, preferred by the tidewater goby, is often modified or eliminated by human created barriers, typically at the upstream terminus of channelization. In addition to the loss of coastal marsh caused by water diversions and alteration of flows, water diversions and alterations of water flows may negatively affect the species breeding and foraging activities. Reductions in water flows may allow aggressive plant species to colonize the otherwise bare sand/mud substrates of lagoon margins, thus degrading the open sand/mud substrate needed by the tidewater goby for breeding. Decreases in stream flows would reduce the depth of streams, preventing tidewater gobies from venturing upstream from lagoons. Groundwater overdrafting would decrease the amount of fresh water reaching the lagoons, thus contributing to a reduction or elimination of the brackish zone. Additional water withdrawal would further reduce tidewater goby habitat.

Nutrient over-enrichment of water could contribute to eutrophication of lagoon water and the associated decreases in dissolved oxygen. Additional flows could cause the lagoon to rise and increase the frequency of breaching experienced under natural conditions, causing erratic fluctuations in water level. These erratic fluctuations would result in decreases in habitat that increase chance of predation and leave spawning burrows exposed to the air. The sudden draining of a lagoon in late spring or summer also could allow marine water to dominate the lagoon for months until winter rains return.

The barrier sandbar and sand content of the lagoon are dependent on sediment supplies from upstream. Interruption of sediment flow by upstream barriers would be a cause of wasting away of sandy beaches. Lack of sediment flow into lagoons hinders formation of barrier bars and helps cause many of the attendant difficulties of anthropogenic breaching during the dry season by allowing tidal influence to alter the breeding substrate and salinity levels. Table 6-10 shows the potential impacts upon the tidewater goby due to changes in hydrology.

TABLE 6-10 POTENTIAL IMPACTS OF HYDROLOGICAL CHANGES ON THE TIDEWATER GOBY

Stressors	Impact	Risk
Turbidity	Little or no effect	High
Invasive species	Can eradicate a population	High
Increases in base flow	May eliminate breeding substrate and increase nutrients and dissolved oxygen	High
Decreases in base flow	May encourage plant growth which disrupts breeding and reduces depth of streams and preventing migration	High
Flood flashiness	May eliminate breeding substrate	Moderate
Bank incision	Channelization may be a problem	Low
Habitat fragmentation	Probably no effect	Low
Erosion, sedimentation	Too much may eliminate breeding substrate, some needed to form barrier bars.	High
Ponding	Possibly needed, likes still water	Low
pH	Unknown effect	Unknown
Dissolved oxygen deficit	Could reduce population	High
Temperature	Species tolerates a wide range	Moderate
Nutrients	Increases plant growth which destroys breeding substrate. Also increases dissolved oxygen	High
Metals	Effect on fish not known, but may influence food chain	High
Pharmaceuticals	Impact on health, reproduction, and varied other impacts (e.g. endocrine disruptors)	High
Pesticides/Herbicides	Effect on fish not known, but may influence food chain	High

As shown in the hydrological analysis, the CWRMA imported water discharge exhibits the greatest influence upon the river during the dry season, when the CWRMA restores base flow that had been reduced or eliminated due to groundwater discharges in the middle watershed (Temecula Valley). The restoration of base flow may enhance breeding and foraging habitat, although this issue will be examined in greater detail in future reports. The data indicate that the CWRMA water chemistry is not likely to negatively impact the goby.

6.4.2 Arroyo Toad (*Buffo microscaphus californicus*)

The arroyo toad requires shallow, slow moving stream habitats and riparian habitats that are disturbed naturally and on a regular basis, primarily by flooding. Arroyo Toad has been found over much of the Santa Margarita River basin below altitudes of 610 ft. In southern California, adult arroyo toads use open sites such as overflow pools, old flood channels, and pools with shallow margins up to the sixth order streams. Breeding sites are generally shallow pools with less than 12 inches of clear water and have flow rates less than 0.2 ft per second. The bottoms of the pools are composed of sand or well sorted fine gravel, with components of large gravel or cobble present.

Arroyo toads are negatively affected by introduced aquatic predators (fishes, crayfish and bullfrogs) roads and road crossings, and introduced plants. Agricultural runoff often contains contaminants such as herbicides, pesticides and fertilizers that may affect arroyo toads directly or indirectly. Contaminants may kill toads, affect development of larvae, or affect their food supplies or habitat. There is a potential for losses from the application of granular fertilizers, particularly ammonium nitrate, which is highly caustic and has caused mass injuries and mortality to frogs and newts in Europe. High nutrient loads may alter the invertebrate community distribution and populations, leading to decreased survival of the arroyo toad tadpoles due to competition of predation and may reduce the food supply of adult toads.

The arroyo toad is susceptible to alterations in hydrology. Altered water flows would affect stream hydrology and inhibit upstream bank scouring reducing the amount of sand and gravel deposition necessary to sustain arroyo toad breeding habitat. Reduced water flows would cause breeding pools to dry up prematurely in the summer. Unseasonable flooding due to the release of reservoir overflow could cause habitat destruction or disturb eggs and kill larvae. Persistent releases throughout the normal dry season could also cause changes in vegetation by encouraging the growth of riparian species, some native (willow, sycamore, cattails) and some introduced (tamarisk and giant reed) in low frequency flood zones. This growth would stabilize the banks, deepens channels beyond a depth suitable for breeding pools, and shades the water, thus lowering the water temperatures below the level required for larval growth and survival.

Natural and unnatural disturbances such as droughts and floods may have negative impacts on arroyo toads and their habitat. Drought, especially of prolonged duration, results in a temporary loss of suitable habitat, particularly breeding pools. Adult and juvenile toads are affected directly by droughts when suitable foraging conditions occur for shorter time periods. Female toads in particular may be adversely affected by drought. Under drought conditions, females may not be able to obtain adequate energy reserves for egg production before the male toads cease calling, leading to reproductive failure for that season. If the life span of the arroyo toad averages 5 years or less prolonged droughts could prevent successful breeding or recruitment long enough to extirpate some populations. Natural cycles of drought and flood can have beneficial effects by reducing or eliminating populations of introduced species that did not evolve under similar conditions. Table 6-11 shows the potential impacts upon the arroyo toad due to changes in hydrology.

TABLE 6-11 POTENTIAL IMPACTS OF HYDROLOGICAL CHANGES ON THE ARROYO TOAD

Stressors	Impact	Risk
Turbidity	May degrade breeding ponds	High
Invasive species	Can eradicate a population	High
Increases in base flow	May eliminate breeding substrate and destroy eggs and larvae	High
Decreases in base flow	May cause breeding ponds to dry prematurely	Moderate
Flood flashiness	May eliminate breeding ponds and destroy eggs but also can remove dense vegetation from banks which is beneficial	High
Bank incision	Probably necessary for gravel generation, also for dense vegetation removal	High
Habitat fragmentation	May inhibit finding mates	High
Erosion, sedimentation	Too much may eliminate breeding substrate, some needed to form gravel for breeding	Moderate
Ponding	Some needed for breeding	Moderate
pH	Unknown effect	Unknown
Dissolved oxygen deficit	Could reduce population	High
Temperature	Needs cool water for egg hatching	Moderate
Nutrients	High loads harmful	High
Metals	May be harmful to the toads	High
Pharmaceuticals	Impact on health, reproduction, and varied other impacts (e.g. endocrine disruptors)	High
Pesticides/herbicides	Has been shown to be harmful	High

Exotic species introduced into arroyo toad habitat can negatively affect the population. Introduced predators can kill them and other species may out-compete the arroyo toad for specialized breeding habitat or food. In addition to the introduced predators, introduced plants can have a negative effect on arroyo toads and their habitat. Tamarisk and giant reed can form dense stands which may have higher rates of evapotranspiration than native vegetation, increasing the rate at which breeding pools dry.

As shown in the hydrological analysis, the CWRMA imported water discharge exhibits the greatest influence upon the river during the dry season, when the CWRMA restores “base flow” that had been reduced or eliminated due to groundwater discharges in the Temecula Valley. The restoration of base flow presents mixed impacts to the arroyo toad, increasing flows that provide breeding and foraging habitat, while also providing such habitat for introduced predators. The data indicate that the CWRMA water chemistry is not likely to negatively impact the toad. CWRMA water may act to dilute threatening high-nutrient irrigation “return flows” from agriculturally heavy catchments.

6.4.3 Light Footed Clapper Rail (*Rallus longirostris levipes*)

Principal habitats for the light footed clapper rail are low portions of coastal wetlands dominated by tall dense cordgrass (*Spartina* sp.), in the low littoral zone, wrack deposits in the low marsh zone, and hummocks of high marsh within the low marsh zone. Fringing areas of high marsh serve as refugia during high tides and although used infrequently, may be extremely important at reducing mortality during high tides.

In a study to compare populations and various habitat parameters, insight was provided into the habitat preference of rails. A difference in the number of pairs appears correlated to the lack of cordgrass stands providing sufficient cover and low elevations of many of the cordgrass stands. Severe storms and excessive runoff can adversely affect the marsh community. Patches of cordgrass may be torn away or matted down to the extent that rails cannot use them for nesting. Major fresh water intrusion, extensive sedimentation, and increased mobility of pollutants are believed to be affecting invertebrate populations and destroying some clapper rail food resources.

Potential predators on eggs, nestlings, or adults include California ground squirrel, Old World rats, striped skunk, feral house cats, dogs, gray fox, Virginia opossum, and a variety of raptorial birds. Table 6-12 lists the potential impacts of hydrological changes upon the rail.

TABLE 6-12 POTENTIAL IMPACTS OF HYDROLOGICAL CHANGES ON THE LIGHT-FOOTED CLAPPER RAIL

Stressors	Impact	Risk
Turbidity	May reduce prey	Moderate
Invasive species	Can eradicate cordgrass	High
Increases in base flow	May destroy nests or nesting sites	Moderate
Decreases in base flow	May make nests vulnerable to predators	Moderate
Flood flashiness	May eliminate nesting areas and destroy nests	High
Bank incision	May destroy nesting areas	Moderate
Habitat fragmentation	Unknown	Moderate
Erosion, sedimentation	Too much may eliminate breeding areas and may interfere with foraging	Moderate
Ponding	Habitat needs regular tidal flushing	Low
pH	Unknown effect	Unknown
Dissolved oxygen deficit	May have negative effects on prey population	Moderate
Temperature	May affect prey population	Moderate
Nutrients	May affect prey population	Moderate
Metals	Will affect prey population	Moderate
Pharmaceuticals	Impact on health, reproduction, and varied other impacts (e.g. endocrine disruptors)	Moderate
Pesticides/herbicides	Will affect prey population	High

The data indicate that the CWRMA water chemistry is not likely to negatively impact the rail. Additional study would be necessary to determine whether changes in water chemistry are likely to impact rail prey species.

6.4.4 California least tern (*Sterna antillarum browni*)

Least terns arrive in the study area from mid-April to early May. Least terns form colonies on bare or sparsely vegetated sand or dried mudflats along coasts or rivers, but also on sandy or shell islands and gravel and sand pits. Colonies generally locate near lagoons, estuaries, rivers or along the coast. The least turn usually chooses a nesting location in an open expanse of light colored sand, dirt, or dried mud close to a lagoon or estuary with a dependable food supply. Formerly, sandy ocean beaches regularly were used, but increased human activity on most beaches has made many of them uninhabitable. As a result, terns have been forced to nest on mud and sand flats back from the ocean, and on man made habitats such as airports and land fills. Table 6-13 lists the potential impacts of hydrological changes upon the California least tern. There is no indication that CWRMA imported water poses any impact to the California least tern.

TABLE 6-13 POTENTIAL IMPACTS OF HYDROLOGICAL CHANGES ON THE CALIFORNIA LEAST TERN

Stressors	Impact	Risk
Turbidity	May reduce foraging ability	Moderate
Invasive species	May reduce prey increase competition	Moderate
Increases in base flow	May destroy nests or nesting sites	Moderate
Decreases in base flow	May reduce foraging area	Moderate
Flood flashiness	May eliminate nesting areas and destroy nests	Moderate
Bank incision	May destroy nesting areas	Low
Habitat fragmentation	Unknown	Unknown
Erosion, sedimentation	Too may interfere with foraging	Moderate
Ponding	Unknown effect	Low
pH	Unknown effect	Unknown
Dissolved oxygen deficit	May have negative effects on prey population	Moderate
Temperature	May affect prey population	Moderate
Nutrients	May affect prey population	Moderate
Metals	Potential effect on prey population	Moderate
Pharmaceuticals	Impact on health, reproduction, and varied other impacts (e.g. endocrine disruptors)	Moderate
Pesticides/herbicides	Potential effect on prey population	Moderate

6.4.5 Southwest willow flycatcher (*Empidonax traillii extimus*)

The southwest willow flycatcher (SWFL) breeds in patchy to dense riparian habitats. The vegetation characteristics of these habitats are very important for SWFL nesting sites. Thickets of tree and shrub species are used for nesting. The trees and shrubs range in a height from 6 to 98 feet, with dense foliage from the ground to about 13 feet above ground. In some instances, dense foliage may exist only at the shrub level or as a low dense canopy.

In addition to dense riparian thickets, another characteristic common to most occupied SWFL sites is that they are near lentic (quiet, slow moving, swampy, or still) water. Nesting plants are typically rooted or overhang slow moving or standing water. Sites are typically located along slow moving stream reaches, at river backwaters, in swampy abandoned channels, oxbows, marshes, and at the margins of impounded water (beaver ponds, inflows of streams into reservoirs). In the instance where flycatchers occur along moving streams, they tend to be of relatively low gradient (slow moving with few or widely spaced riffles of other cataracts). SWFL habitats are dependent on hydrological events such as scouring floods, sediment deposition, periodic inundation, and ground water recharge for them to become established, develop, be maintained and ultimately to be recycled through disturbances.

Water diversion, coastal development and decrease in natural flows would cause loss of SWFL habitat. Without the movement of channels, deposition of alluvial sediments, and erosion of aggraded flood plans, it becomes harder for native plants to establish and flourish. Exotic species can create dense vegetation, as with Tamarisk, but the risk to fires and loss of native vegetation can lead to a decline of SWFL populations. Exotic plant species are found to have lesser value to SWFL than native plant species.

According to the SWFL Recovery Plan, the SWFL population at Camp Pendleton has remained fairly constant at under two dozen territories for the past two decades, despite the availability of additional apparently suitable habitat to support population expansion.

The SWFL is generally not found nesting in confined floodplains where only a single narrow strip of riparian vegetation less than approximately 33 ft. wide develops, although they may use such vegetation if it extends out from larger patches and during migration.

In some years, studies have shown, predation was the single largest cause of nest failure. Predation on SWFL eggs and nestlings is documented for the common king snake, gopher snake, Cooper's hawk, red tailed hawk, great horned owl, western screech owl, yellow breasted chat, and argentine ants. Other potential predators of the nests are other snakes, lizards, chipmunks, weasels, raccoons, ring-tailed cats, foxes and domestic cats. Predation of adults in not often observed although it is likely. Table 6-14 lists the potential impacts of hydrological changes upon the flycatcher.

TABLE 6-14 POTENTIAL IMPACTS OF HYDROLOGICAL CHANGES ON THE SOUTHWESTERN WILLOW FLYCATCHER

Stressors	Impact	Risk
Turbidity	Minor effect	Low
Invasive species	Brown-headed cowbirds a problem, exotic plants are of less value to the species	High
Increases in base flow	Some level needed to regenerate the stream system and plant community	Low
Decreases in base flow	May cause the understory to die off and water table to decrease thereby stressing the trees	Moderate
Flood flashiness	May damage the stream system and plant community	Moderate
Bank incision	May be a problem if it removes large pieces of the habitat	Moderate
Habitat fragmentation	Encourages cowbird parasitism, flycatcher needs a minimum habitat size	Moderate
Erosion, sedimentation	May be a problem if it changes the plant community	Low
Ponding	Probably no effect if no trees killed	Low
pH	Unknown effect	Unknown
Dissolved oxygen deficit	May have negative effects on prey population	Low
Temperature	Extremes may kill nestlings	Low
Nutrients	May affect prey population and change understory	Low
Metals	May affect prey population	Moderate
Pharmaceuticals	Impact on health, reproduction, and varied other impacts (e.g. endocrine disruptors)	Low
Pesticides/herbicides	May affect prey population	Moderate

As shown in the hydrological analysis, the CWRMA imported water discharge exhibits the greatest influence upon the river during the dry season, when the CWRMA restores “base flow” that had been reduced or eliminated due to groundwater discharges in the Temecula Valley. CWRMA flows do not contribute much to the disturbance regime that so heavily influences SWFL habitat, however the restoration of base flow likely increases the pondedness and extent of lentic waters that the flycatchers prefer. The data indicate that the CWRMA water chemistry is not likely to negatively impact the flycatcher.

6.4.6 Least Bell's vireos (*Vireo bellii pusillus*)

Least Bell's vireos are obligate riparian breeders, typically inhabiting structurally diverse woodlands along watercourses. They occur in a number of riparian habitat types, including cottonwood-willow woodlands/ forests, oak woodlands, and mule fat scrub. They prefer dense, low, shrubby vegetation, generally early successional stages in riparian areas, brushy fields, young second-growth forest or woodland, scrub oak, coastal chaparral, and mesquite brushlands.

There are two habitat features which are essential for the vireo: 1) the presence of dense cover within 3 to 6 feet of the ground, where nests are typically placed and 2) a dense, stratified canopy for foraging. Plant species composition does not appear to be as important a determinant of nesting site selection as habitat structure. Early succession of riparian habitat typically supports the dense shrub cover required for nesting and also a structurally diverse canopy for foraging. If permitted to persist, willows and other species form dense thickets in approximately 10 to 15 years and become suitable habitat for least Bell's vireo.

The least Bell's vireo is susceptible to impacts due to hydrological and land use changes. As human populations increased in California, riparian woodlands were cleared and dams were built. As a result, large amounts of least bell's vireo breeding habitat were inundated or removed. Impounding water upstream and diverting water to canals and cropland lowered water tables downstream so that dense vegetation could not grow or was reduced. Flood control projects and channelization of rivers further reduced available vireo habitat. Livestock grazing destroyed the choice lower strata of vegetation preferred by the least Bell's vireo and provided foraging areas for brown headed cowbirds. Cowbirds have caused a decline in least Bell's vireo populations by brood parasitism. Table 6-15 lists the potential impacts of hydrological changes upon the vireo.

TABLE 6-15 POTENTIAL IMPACTS OF HYDROLOGICAL CHANGES ON THE LEAST BELL'S VIREO

Stressors	Impact	Risk
Turbidity	Minor effect	Low
Invasive species	Brown-headed cowbirds a problem	High
Increases in base flow	Needed to regenerate the stream system and plant community	Low
Decreases in base flow	May cause the understory to die off and water table to decrease thereby stressing the trees	Moderate
Flood flashiness	Only if riparian area destroyed	Moderate
Bank incision	May be a problem if it removes large pieces of the habitat	Low
Habitat fragmentation	Encourages cowbird parasitism	Moderate
Erosion, sedimentation	May be a problem if it changes the plant community structure	Low
Pondedness	Probably no effect if no trees killed	Low
pH	Unknown effect	Unknown
Dissolved Oxygen	May have negative effects on prey population	Low
Temperature	Extremes reduce nestling survival	Low
Nutrients	May affect prey population and change understory	Moderate
Metals	May affect prey population	Moderate
Pesticides/herbicides	May affect prey population	Moderate

As shown in the hydrological analysis, the CWRMA imported water discharge exhibits the greatest influence upon the river during the dry season, when the CWRMA restores "base flow" that had been reduced or eliminated due to groundwater discharges in the Temecula Valley. CWRMA flows do not contribute much to the disturbance regime that so heavily influences least Bell's vireo habitat. The data indicate that the CWRMA water chemistry is not likely to negatively impact the vireo.

Table 6-16 provides an overview of the observed hydrological changes during the flow experiment in 2009, as well as the estimated changes in sensitive species habitat extent. In summary, each of the six species has the potential to be affected to some level by one or more of the stressors, although the current level of augmentation appears to have no major impact. In fact, observations indicate that the augmentation to base flows actually provides significant improvements to available habitat for each of the species of concern. With more available water, the riparian area follows a more natural regime. In much of the upper river, the river flows through a fairly narrow channel and across bedrock. Changes in water flows do not seem to have a significant affect on habitat. However, it does seem to influence the depth of the water, which may directly impact aquatic species and the types and complexity of available habitat. Lower in the watershed, changes in the CWRMA have an obvious impact on the amount of available water, pools, and habitat for key species like the arroyo toad. Hydrological effects to track closely would be decreases in flows to the point of providing little water for breeding habitat, or actually increasing the amount of pools or other off-channel areas that could support significant populations of the bullfrog. This would be extremely detrimental to the arroyo toad, since the bullfrog is known to be a significant threat and predator on the arroyo toad.

In the absence of the CWRMA, the decreases in base flows would create a much narrower river, which would ultimately impact the adjacent riparian corridor. If water (both surface water and subflows) is constrained to a narrower channel, the amount and area of available riparian habitat could be significantly impacted, directly impacting those species that depend directly on the interface between the water and terrestrial habitat (e.g. rail and tern). Further reductions in the aquatic channel may also reduce the amount of vegetation surrounding the river. Willows, cottonwood trees, and other riparian vegetation types could be significantly reduced, and constrained to a much more narrow area. If this occurred, species like the flycatcher and vireo would have significantly reduced available habitat, ultimately impacting their ability to forage, breed, and ultimately survive in the watershed. Overall, it appears that the CWRMA augmentation flows actually have a beneficial effect on the key sensitive species by increasing the amount of available habitat.

TABLE 6-16 CHANGES IN STREAM ATTRIBUTES DUE TO WATER LEVEL CHANGE

	Transect Substrates					Instream Habitat Complexity		Channel	Dist. To (m)	Dist. To (m)	LBVI and SWFL Habitat		Arroyo Toad Habitat
Stream	Depth (cm)	Microalgae	Macroalgae Attached	Macroalgae Unattached	Macrophytes	Filamentous Algae	Aquatic Macrophytes	Type Change	Far Edge of Riparian from Bank	Riparian Near Edge from Center	LBVI	SWFL	
SMR at Ysidora, upstream	-30	Increase	Increase	Slight Increase	Same	Decrease	Increase	No run, more riffle	Shifted right by 6 m.	Shifted right by 6 m.	Good, present, no change	Good to marginal, no change	Good, no change
SMR at Ysidora, middle	-5	Increase	Decrease	Decrease	Decrease	Same	Decrease	All riffle	Same	Same	Good, no change	<10% chance, no change	Good, no change
SMR at Ysidora, downstream	Same	Decrease	Increase	Decrease	Same	Increase	Same	More run and riffle, less glide	Same	Same	Marginal to good, change	Poor to marginal, no change	Possible, degraded.
SMR at Stone Creek, upstream	-70	Disappeared	Same	Same	Decreased	Same	Same	More pool and split channel	River shifted right ~1m	River shifted right ~1m	Good, no change	Marginal, no change	Not good, no change
SMR at Stone Creek, middle	0	Same	Same	Same	Same	Same	Same	Same	River shifted left ~4m	River shifted left ~4m	Good, no change	Moderate, no change	Possible, no change
SMR MWD Xng, upstream	-5	Same	Same	Same	Same	Same	Same	Less water	Same	Same	Marginal, no change	Poor, no change	No habitat
SMR MWD Xng, middle	-3	Same	Same	Same	Same	Same	Same	Less water	Same	Same	Moderate, no change	Poor, no change	No habitat
SMR MWD Xng, downstream	-50	Decreased at edges	Same	Same	Same	Increased	Same	Much less water	Same	Same	Poor to marginal	No habitat	No habitat
SMR at Sandia Creek, upstream	0	Increase	Same	Same	Same	Same	Same	Same	Same	Same	Good, no change	Good, no change	No habitat
SMR at Sandia Creek, middle	-10	Tripled in thickness	Same	Same	Same	Same	Same	Same	Same	Same	Moderate, no change	Poor to marginal, no change	25% potential
SMR at Sandia Creek, downstream	~-5	~Six times thicker	Same	Same	Less present	More	More	More riffle	Shifted left 12.5 m	Shifted left 12.5m	Good, one present, no change	Poor to marginal, no change	~65% potential, no change
SMR at Rainbow Creek, upstream	-15	Same	Same	Same	Same	Same	Same	Same	Same	Same	Marginal to moderate, no change	Poor, no change	No habitat
SMR at Rainbow Creek, middle	-15	Same	Same	Same	Same	Same	Same	Slower, lower	Same	Same	Marginal to moderate, no change	Poor, no change	No habitat
SMR at Rainbow Creek, downstream	-8	Same	Same	Same	Same	Same	Same	Slower, lower	Same	Same	Good, no change	Moderate to good, no change	No habitat

[1] Changes from higher levels of flow to lower levels.

7.0 CONCLUSIONS AND RECOMMENDATIONS

The study team completed a multi-disciplinary project examining water quality, hydrology, biology, and geomorphology in the lower Santa Margarita River watershed. The conclusions from this study, including a summary of the answers to the management questions posed in the Task Order, are presented throughout this section of the report. Recommendations are also provided to identify the continued effort required to expand the understanding of the physical processes of the river and provide for better management of its resources.

7.1 CONCLUSIONS REGARDING WATER QUALITY

Some constituents sampled during this study were found to be in exceedance of Basin Plan limits at different locations. However, constituents such as nitrogen, in excess of the Basin Plan limits, appear to be assimilated by the river in some reaches. The following sections address the concentration levels of sampled constituents from various perspectives.

The conceptual models were updated based on the findings in the field studies, habitat assessments, and water quality assessments. In general, the conceptual models created through expert discussions, literature review, and reviews accurately predicted the major impacts and threats to the watershed. However, a major change in our understanding is the role that agricultural land uses play in the lower watershed. This land use type seems to have a significant potential impact on water quality and species/habitats. This was evidenced by the nutrient analysis and detections of pesticides. Additionally, the water quality monitoring program considered pharmaceuticals and emerging constituents. These constituents pose a periodic problem in the watershed, usually after peak flow events. Incorporating this new understanding into the conceptual models, it seems that pharmaceuticals and emerging constituents may pose a threat to key sensitive species, particularly the arroyo toad and tidewater goby.

7.1.1 Elevated Levels of Sampled Constituents

The elevated concentrations of some constituents, as they relate to the Basin Plan limits, are outlined below. The following constituents are addressed based on their relationship to known impaired water bodies as well as impact to downstream water users.

- <u>TDS:</u> Several tributaries contributed high levels of TDS to the lower river, including De Luz, Devils, Fallbrook, Rainbow, Sandia, and Stone Creeks. Elevated TDS concentrations were also present at the FPUD Sump.

- Iron: Arroyo Seco, Adobe, Cole, Roblar, De Luz, Fallbrook, Sandia, and Stone Creeks contributed high levels of iron. The FPUD Sump and the Gorge also showed elevated levels of iron.
- Manganese: Arroyo Seco, Roblar, and Fallbrook Creeks were sources of elevated manganese levels.
- Sulfate: Concentrations that exceeded the Basin Plan limits were found in De Luz, Fallbrook, Sandia, and Stone Creeks, as well as at the Gorge and FPUD Sump.
- Silver: Elevated concentrations, based on the Basin Plan's aquatic life limit, were observed at the FPUD Sump, the Gorge, and Sandia Creek.
- TN: Concentrations in excess of the Basin Plan limits were observed in Cole, De Luz, Devils, Rainbow, Sandia, Stone Creeks, the CWRMA Outfall, and selected sites along the Santa Margarita River.
- TP: Concentrations in excess of the Basin Plan limits were observed in Arroyo Seco, Adobe, De Luz, Devils, Fallbrook, Sandia, Stone Creek and at all sites along the Santa Margarita River.
- Limiting Nutrient: Phosphorus appeared to be the limiting nutrient in the upper portion of the study area while nitrogen was the limiting nutrient near and within Camp Pendleton.
- Pesticides: Simazine was ubiquitous during all pesticide sampling events at all four analyzed locations (except on one occasion at Santa Margarita River near Temecula) and increased with storm flows. Detection of pesticides was directly related to increased storm flows as supported by the February 2009 sampling event.
- Pharmaceuticals: These and other emergent constituents were detected sporadically during the sampling period. The sparse nature of the dataset makes characterization of sources extremely difficult at this time.

7.1.2 Long-Term Trends

Analysis of historical and current nutrient, TDS, sulfate, iron, and manganese concentrations at the Santa Margarita River near Temecula and at FPUD Sump showed that TN and TP were the greatest during the period of the 1980s through the 1990s. Historical data show that manganese and iron concentrations consistently exceeded the current Basin Plan objectives. Sulfate concentrations were generally below the Basin Plan objective at the Santa Margarita River near Temecula, but were consistently over the limit at the FPUD Sump location.

Following the inception of CWRMA augmentation, concentrations of all nutrients, TDS, iron, and manganese have remained relatively low. During the same period, sulfate concentrations have remained within the same range as historical concentrations.

7.1.3 Mass Loadings

De Luz, Devils, and Sandia Creeks contributed significant loadings of nitrogen (mostly as nitrate) to the Santa Margarita River due to agricultural land use. Of these tributaries, Sandia Creek contributed the highest loadings, up to 390 kg/day during the winter 2008 sampling event. In the upper watershed, Murrieta and Temecula Creeks are both listed as impaired for TN and may have contributed large loadings to the Santa Margarita River based on loading calculations. TN loadings appeared to be high for the entire river from the Gorge to Ysidora. The majority of TN contribution from these streams was in the form of nitrate.

TP loadings were a concern for the entire river likely due to elevated concentrations at both Murrieta and Temecula Creek and naturally occurring higher levels of phosphorus in the lower watershed. TP loadings to the river increased downstream, averaging 5 kg/day at the Gorge and 14 kg/day at Ysidora over the six sample events. The downstream increase in loading was likely due to significant contributions from Rainbow and Sandia Creeks.

De Luz, Rainbow, and Sandia Creeks are listed as impaired for TDS. All three of these creeks contributed considerable amounts of TDS to the Santa Margarita River, totaling between 3,900 kg/day and 76,100 kg/day over the six sampling events. In the upper watershed, Temecula Creek is listed as impaired for TDS and may have been a large contributor of TDS to the Santa Margarita River. TDS loading appeared to be high for the entire river from the Gorge to Ysidora.

Rainbow and Sandia Creeks are listed as impaired for sulfate. Based on the six sampling events, Sandia Creek contributed a substantial amount of sulfate to the Santa Margarita River, up to 12,000 kg/day. Rainbow Creek contributed less due to lower flows. The impact of Sandia Creek sulfate loadings on water quality downstream of the confluence with the Santa Margarita River was not determined due to lack of data.

De Luz, Rainbow, and Sandia Creeks are listed as impaired for iron. High iron concentrations were detected at these creeks as well as Fallbrook Creek. Of these creeks with elevated levels of iron, Sandia Creek contributed the most. Murrieta Creek is listed as impaired for iron and may have been a large contributor to the Santa Margarita River, as iron loadings at the Gorge ranged from 0.4 kg/day to 20 kg/day.

De Luz and Sandia Creeks are listed as impaired for manganese, however elevated levels of manganese were not detected on these creeks. Fallbrook Creek is not listed, but it had the highest manganese concentrations reported within the study area, ranging from 0.03 kg/day to 0.4 kg/day over the six sample periods. The highest manganese loadings from the tributaries occurred during winter flows. Manganese loading at the Gorge was negligible (averaging 0.1 kg/day) while loadings at the FPUD Sump were significant in comparison (averaging 1.3 kg/day). However, the contribution of manganese upstream of the FPUD Sump was uncertain due to the scarcity of sample data from sites in this reach of the river.

Due to a limited dataset and inability to match sampled constituent concentrations with storm flows, the loading calculations in this study were constrained to discrete periods, rather than annual loading periods. Additional data, including increased sampling frequency and measurement during storm flows, are required to extend loading calculations to an annual period.

7.1.4 Assimilative Capacity

Due to limited loading data, assimilative capacity was calculated for discrete periods. Analysis of the discrete assimilative capacities developed during this monitoring program indicates that the Santa Margarita River was able to assimilate TN through the MWD Crossing and from the FPUD Sump through Ysidora. Between the MWD Crossing and the FPUD Sump, tributaries flood the river with excess TN and appear to overwhelm assimilative capacity.

7.1.4.1 Mass Balance Technique

A mass-balance approach to analyzing nutrient loadings and transformation within the Lower Santa Margarita River revealed that throughout the period, the Santa Margarita River was able to assimilate a limited amount of TN from the Gorge through the MWD Crossing, averaging 8 kg/day. Between the MWD Crossing and the FPUD Sump, loadings from tributaries increased and assimilation of all additional TN was not possible. The Santa Margarita River was able to recover downstream of the FPUD Sump and had a high assimilative capacity for TN between the FPUD Sump and Ysidora averaging 98 kg/day. TN appeared to be the limiting nutrient in the lower Santa Margarita River and was likely the reason for a high assimilation within that reach. Nitrate assimilation followed similar patterns and made up the largest fraction of TN loadings.

Overall, the Santa Margarita River had excess loadings of TP throughout the year, and the excess increased as one moves downstream. The Santa Margarita River reach spanning from the Gorge to the MWD Crossing appeared to assimilate TP throughout the year, however lower in the watershed this did not occur.

7.1.4.2 NNE Approach

The NNE spreadsheet model was used to assess whether the reach from the confluence with Rainbow Creek to below the confluence with Sandia Creek is impaired for nutrients, or whether it possesses assimilative capacity for nutrients. Five of the six model runs targeting the BURC I threshold indicated that currently observed mean levels of TN and TP were low enough to consider that Santa Margarita River reach unimpaired.

The ratio of TN to TP observed in the river and its tributaries, as well as the sensitivity analysis for the NNE spreadsheet model, indicated that portions of the Lower Santa Margarita River were not responsive to excessive amounts of TN, but rather they were limited for phosphorus and solar radiation. Hence the low value of phosphorus relative to nitrogen and the relatively high amount of topographic and canopy shading were likely significant in limiting excessive algae growth.

7.1.4.3 Summary of Assimilative Capacity

Review of nitrogen to phosphorus ratios concludes that phosphorus was the limiting nutrient in the upper portion of the study area while nitrogen was the limiting nutrient lower in the system, near and within Camp Pendleton. Adobe Creek and the Santa Margarita River at the Gorge showed strong seasonal variations of nitrogen to phosphorus ratios. The mass loadings analysis also confirmed this observation. The sensitivity analysis of the NNE (at the FPUD Sump only) appeared to indicate that algae abundance varied with TN, TP, and solar radiation. Thus, the NNE implied no specific limiting factor.

The loadings analysis of the river (performed for discrete periods over two years) revealed that TP loading often increased from upstream to downstream, suggesting that TP often was not fully assimilated. The same analysis revealed that TN was assimilated more often and over more reaches of the river than TP.

7.2 CONCLUSIONS REGARDING THE CWRMA AUGMENTATION FLOWS

The impact to water quality and quantity of the Santa Margarita River from CWRMA releases were investigated in the lower watershed. Results from the investigation indicated that augmentation at the Gorge increased base flows, improved water quality, and supported sensitive species habitat. In order to better understand how changes in flows affect geomorphology and sensitive species habitat, the study team conducted a flow experiment featuring sampling before and after the annual May 1 CWRMA adjustment. The results of these analyses are discussed in the following section.

7.2.1 CWRMA Impacts Upon Hydrology

Based on the mass balance of total flow, augmented flow, and naturally occurring flow, CWRMA releases were a significant portion of the base flows of the Santa Margarita River, especially during drier summer months. During the period January 2003 to December 2009, augmentation was 17% of the total flow in the river. On a monthly basis, it ranged from 0% when there were no releases, to 100% of the flow in the river where there was no natural runoff in the river. During summer months, when there was little to no natural runoff in the river, augmentation water was a significant percentage of the total flow, usually more than 90%, illustrating that CWRMA augmentation water had the most significant impact on the flow regime during dry periods. An exceedance analysis revealed that without augmentation, the river (Gorge) would have been dry 24% of the time. With augmentation the river was never dry.

Between January 2003 and December 2009, the mean daily flow in the river was 33.5 cfs, compared to 27.9 cfs if CWRMA augmentation did not occur. Similarly, CWRMA releases increased the median daily flow from 0.4 cfs to 7.8 cfs during the same time period. Further investigation of monthly releases indicated that CWRMA augmentation significantly affected the flow of the river during both winter and non-winter periods. The wide-ranging variability of the Santa Margarita River due to the cyclic nature of the southwestern United States hydrology indicated CWRMA impacts the Santa Margarita River during all months of the year.

7.2.2 CWRMA Impacts upon Water Quality

During the flow experiment, the reduction of CWRMA flow had the impact of slightly increasing TDS concentrations at the MWD Crossing location. This demonstrates the influence of low TDS CWRMA augmentation flows in diluting high TDS on the main stem of the Santa Margarita River.

Concentrations of TDS, nitrate as N, and TP during the CWRMA augmented years were statistically lower in concentration than in all prior designated periods. TN concentrations were also statistically lower during CWRMA releases than the period prior to live stream discharge. All other constituents analyzed (nitrate, ammonia, TKN, orthophosphate, conductivity, sulfate, iron, and manganese) exhibited no statistical difference in concentration with historical data sets.

The same analysis was conducted for water quality at the FPUD Sump to assess if differences in water quality at this location may have been due to the same conditions and temporal changes as at the Gorge. While TP exhibited a significant difference (lower concentration during CWRMA period), TDS and Nitrate concentrations did not exhibit a significant difference over these historical water quality periods. This was in contrast to the Gorge, which exhibited significant differences for all three of these constituents. This suggests that the influence of CWRMA may not extend downstream to the FPUD Sump. It is most likely that the differences in TP and the other constituent (sulfate, pH, and conductivity) concentrations were due to other historical factors, as well as contributions by tributaries.

While the assessment of the impact of CWRMA flows was largely inconclusive due to limited data, when compared with current natural flows at the Gorge (with the exception of TDS), the impact of the CWRMA augmentation was significant on downstream water quality. When compared with the water quality of major contributing tributaries, the concentrations of most nutrient components, as well as TDS, were significantly less than had the CWRMA augmentation flows not been released. While it could not be quantitatively shown to have this effect on downstream water quality (i.e. due to infiltration, sub flow, and assimilative capacity), the reduced concentrations of nutrient components at Santa Margarita River main stem locations were no doubt caused in part by the diluting quality of the higher quality CWRMA flows. However, as the net nutrient assimilative capacity increased downstream, CWRMA dilution appears to become less of an influence on water quality, as shown by the low concentrations of nitrogen components at downstream main stem sampling locations.

7.2.3 CWRMA Impacts upon Wetlands and Sensitive Species Habitat

The impacts of CWRMA releases upon physical pool conditions appeared to be limited to the MWD Crossing reach. Impacts from CWRMA releases became gradually less influential farther downstream. There appeared to be no significant impact upon pool conditions at the Ysidora/Levee reach. Also, beavers significantly altered the conditions at the Stone Creek confluence and may have had more of an impact on downstream reaches than CWRMA releases.

The level of CWRMA augmentation appeared to have no major negative impact on the sensitive species examined. In fact, observations indicated that the augmentation to base flows actually provided significant improvements to available habitat for each of the species of concern. With more available water, the riparian area followed a more natural regime. In much of the upper river, the river flowed through a fairly narrow channel and across bedrock. Changes in water flows did not seem to have a significant effect on habitat. However, the CWRMA did seem to influence the depth of the water, which may directly impact aquatic species and the types and complexity of available habitat. Lower in the watershed, changes in flow levels have an obvious impact on the amount of available water, pools, and habitat for key species like the arroyo toad. Decreases in flows, to the point of providing little water for breeding habitat, or increases in flows that may increase the number of off-channel pools that could support significant populations of bullfrog, should be monitored in the future. Extreme base flow conditions would be extremely detrimental to the arroyo toad, since the bullfrog is known to be a significant predator of the arroyo toad.

In the absence of the CWRMA, the decreases in base flows would create a much narrower river, which would ultimately impact the adjacent riparian corridor. If water (both surface water and subflows) is constrained to a narrower channel, the amount and area of available riparian habitat could be significantly impacted, directly impacting those species that depend directly on the interface between the water and terrestrial habitat (e.g. rail and tern). Further reductions in the aquatic channel may also reduce the amount of vegetation surrounding the river. Willows, cottonwood trees, and other riparian vegetation types could be significantly reduced, and constrained to a much more narrow area. If this occurred, species like the flycatcher and vireo would have significantly reduced available habitat, ultimately impacting their ability to forage, breed, and ultimately survive in the watershed.

7.2.4 Summary of CWRMA Releases

The following is a brief summary of the analysis of CWRMA releases to the hydrology, water quality, and sensitive species habitat of the Santa Margarita River. Detailed analysis and description of the CWRMA impacts are provided in Chapter 6 of this report.

- Median Flow: CWRMA releases increased the median daily flow at the Gorge from 0.4 cfs to 7.8 cfs between January 2003 and December 2009.
- Average Flow: The average daily flow at the Gorge increased from 27.9 cfs to 33.5 cfs based on CWRMA augmentation only.
- Temporal Impacts: CWRMA releases had significant impacts to the flow of the Santa Margarita River during all months of the year.
- Water Quality: CWRMA releases resulted in lower concentrations of TDS and TP at the Gorge and MWD Crossing.
- Water Quality: TP exhibited a significant reduction in concentration during CWRMA period at the FPUD Sump. TDS and Nitrate concentrations did not exhibit a significant difference over these historical water quality periods at the FPUD Sump.
- Nutrient Assimilation: Reduced concentrations of nutrient components at Santa Margarita River main stem locations were caused in part by the diluting quality of the lower-concentration CWRMA flows.

- <u>Sensitive Species Habitat:</u> CWRMA augmentation flows had a beneficial effect on the key sensitive species by increasing the amount of available habitat.

7.3 KEY MANAGEMENT QUESTIONS

Table 7-1 lists the questions addressed by this monitoring program. The questions were categorized in groups dealing with contaminant sources, hydrodynamics and water quality, and impacts to wildlife, habitat, and wetlands. The answers provided represent short-hand responses for the analysis and findings from throughout this report and the appendices.

TABLE 7-1 KEY MANAGEMENT QUESTIONS AND ANSWERS

Type	Questions	Answers
Sources	What are the relative contributions for targeted contaminants from each land use type or from regulated facilities?	Nutrients, pesticides, and TDS were contributed predominately from agricultural and urban areas. Pesticides – Agricultural runoff, urban runoff. Metals often originate in urban runoff, however some originate from natural sources. Relative loadings for constituents of concern are provided in the report.
	What is the daily rainfall in the watershed?	Rainfall in the study area averages between 10 to 14 inches per year. Historical precipitation data are given in Appendix A.
	What is the total annual (and daily) flow and mass loads of targeted contaminants from each sampled tributary?	Relative loadings for constituents of concern from tributaries are provided in the report and in Appendix N.
	Where and when do contaminants enter the main stem of the river? What are the sources, location, and relative levels of contribution of nutrient contamination (land use, fire, aerial deposition, etc.)?	Relative loadings for constituents of concern from tributaries are provided in the report and in Appendix N.
	How does the variability in spatial distribution of precipitation in the watershed influence movement of contaminants?	Since different tributaries (with different land uses) contribute loadings of various constituents are different rates, variation in precipitation patterns drive differences in loadings and concentrations.
	What are the concentrations of targeted contaminants at the base of the watershed before it enters the lagoon? [Being addressed by the Lagoon TMDL project during first year of program]	The concentrations of sampled constituents, including those sampled during 2008 by CDM, are presented in the report and in Appendix J.
Hydrodynamics and Water Quality	Where and when is water quality impaired along the main stem of the river? [In contrast to reference streams in the watershed]	Various constituents are present in levels exceeding Basin Plan limits in several tributaries and on the river. Concentrations of constituents and graphics depicting levels of impairment are presented in the report and in Appendix J.
	What is the water quality of imported water released into the river? How does it differ from local water quality (including historic water quality values)?	The CWRMA water quality and differences between it and historical water quality are presented in Appendix M. Concentrations of TDS, nitrate, and TP during the CWRMA augmented years were statistically lower in concentration than in all prior designated periods, and CWRMA period TN concentrations were statically lower than the period prior to live stream discharge. All other constituents analyzed (ammonia, TKN, orthophosphate, conductivity, sulfate, iron, and manganese) exhibited no statistical difference in concentration with historical data sets.
	How does the water augmentation schedule (in accordance with the CWRMA) change base flows relative to historic flows (including changes in temporal and geographic distribution and variation during and among years)?	CWRMA augmentation increased base flows throughout the period. In summer months, augmentation water represented nearly all of the flow at the Gorge, indicating the river would be dry much of the time without augmentation. A simulation of pre-development natural flow on the river indicated that CWRMA augmented base flows more closely resembled a historical natural flow regime rather than the existing impaired flow regime.
	How do nutrient loading and removal vary seasonally and with changes in flow rates?	Loadings of nutrients and other constituents for which water bodies are listed as impaired are presented in the report and in Appendix N. These loadings have been prepared for six discrete periods, illustrating seasonal variation. Most constituent loading increased with precipitation events and high flows.

Type	Questions	Answers
	Do differences between local and imported water quality at the head of the gorge affect the water quality downstream?	Comparing CWRMA-era water quality with historical water quality at the FPUD Sump, TP was significantly lower during CWRMA period, while TDS and nitrate concentrations did not exhibit a significant difference over historical water quality periods.
	How has water quality in the main stem changed over time?	In general, water quality appears better now for most sampled constituents than in the past. The CWRMA appears to provide a beneficial diluting affect.
	What is the capacity of the river to remove nutrients from the water column?	Nutrient assimilative capacity is discussed in the report and in Appendix N. Assimilative capacity varied along the river for both TN and TP. Overall, the river appeared to be able to assimilate total nitrogen from the Gorge through the MWD Crossing and from the FPUD Sump through Ysidora. Between the MWD Crossing and the FPUD Sump, tributaries flooded the river with excess TN and appeared to overwhelm assimilative capacity. The reach spanning from the Gorge to the MWD Crossing was able to assimilate TP throughout the year, however lower in the watershed this did not occur.
	How does the sediment transport regime impact water quality, including sequestration of nutrients and other contaminants?	Phosphorus adsorbs to sediments and is often introduced to the river during high flow, high erosion events. Once in the river, the phosphorus can remain adsorbed until water chemistry, including ambient phosphorus and oxygen levels, change.
Impacts to Wildlife, Habitat, and Wetlands	Does imported water quality influence federally T&E species and riparian habitats? [T&E species include: arroyo toad, least Bell's vireo, southwest willow flycatcher, tidewater goby, light-footed clapper rail, and least tern.] Are there changes in the extent of riparian habitat or wetlands? Are there changes in the quantity or quality of T&E species habitat? Are there changes in the distribution and abundance of breeding pools for fish, amphibians, and exotic predators? What is the water quality and temperature of the pools?	The influence of CWRMA water quality upon sensitive species and their habitats is discussed in section 6.4 of the report and in Appendix D. Overall, the CWRMA water quality does not appear to negatively impact the T&E species. The flow experiment showed that CWRMA augmentation flows do contribute to base flow, adding water volume and off-channel pools. T&E species habitat appears to benefit from these additional flows. Higher flows increase the number of off-channel pools to a point, and then these pools are inundated. The CWRMA appears to have the highest influence on the presence of pools in the Gorge to FPUD Sump reach, with less influence as one progresses downstream.
	Do differences between local and imported water quality affect the number, distribution, or aerial extent of T&E species?	There is no indication that observed differences in water quality affect the number, distribution, or extent of T&E species.
	Do differences between local and imported water quality affect the quality or extent of T&E habitats and wetlands?	There is no indication that observed differences in water quality affect the quality or extent of T&E species habitat or wetlands.
	Do the additional flows released under the CWRMA result in an increased quantity of T&E habitat and wetlands over pre-2002 levels?	Based on the mass balance of total flow, augmented flow, and naturally occurring flow, CWRMA releases are a significant portion of the base flows of the river, especially during drier summer months, contributing an unquantified amount of added volume of aquatic habitat, increased wetted perimeter, and off-channel pool habitat.

Type	Questions	Answers
	How much surface flow is needed to support current populations of T&E species, including habitat maintenance and regeneration?	Current flows are sufficient to support current populations of T&E species, however there are insufficient data to determine whether different flow levels would continue to support current populations. A key supporting element for existing habitat is seasonal variation in flows and scouring effects. The CWRMA flow augmentation regime provides seasonal variation. Scouring effects appear to be provided by higher flows driven by precipitation events.
	Do the discharge patterns of imported water influence T&E species and riparian habitats?	See previous question and answer. This issue is discussed in detail in Appendix D.
	Do restored base flows (due to water augmentation) affect special status species and habitats (including flow levels and flow variability)?	CWRMA releases are a significant portion of the base flows of the river, especially during drier summer months. This higher base flow (closer to historical levels) contributes an unquantified amount of added volume of aquatic habitat, increased wetted perimeter, and off-channel pool habitat. Most of the added habitat appears in the Gorge to FPUD Sump reach. Downstream the influence of the CWRMA flows appears much less significant.
	Do restored base flows (due to water augmentation) affect exotic species?	Restored base flows do add additional pool habitat for exotic species such as catfish, carp, and bullfrog.

7.4 RECOMMENDATIONS

The Study Team has assembled the following recommendations to continue development of conceptual models and understanding of the physical processes of the Santa Margarita River. Continued monitoring will facilitate tracking of water quality trends. Increased frequency of data collection will allow for more accurate models and estimates of both assimilative capacity and mass loading. Continued biological monitoring will support the relationships between flow, geomorphology, and habitat.

- General Chemistry:

  Continue to monitor at existing locations to track trends in water quality.

- Pesticides, Pharmaceuticals and Other Emergent Contaminants:

  Conduct sampling for these constituents during storm flows and sample more often and at more locations including major developed tributaries to determine sources.

- Nutrients:

  Continue to monitor at the existing locations as well as two additional sampling locations upstream of the Gorge (Murrieta and Temecula Creeks) in order to establish a sufficient data set for use in regulatory proceedings such as TMDL and Site-Specific Objective development and application of the

NNE to set nutrient targets for the watershed. Conduct sampling and investigation focused on more fully characterizing limiting nutrients and identifying specific sources of nutrient loading in order to support water quality management initiatives including TMDLs.

- Sampling Frequency:

  In order to better characterize sources of constituents, and to produce datasets sufficient for calculating annual loadings, sample for all constituents of concern monthly at all locations, capture storm events, and measure flow at the non-USGS gage sites regularly. [Calculation of annual loadings will be a requirement for development of nutrient TMDLs for the watershed, which RWQCB staff members have indicated is a near/mid term regulatory priority.]

- CWRMA Hydrology:

  Continue to collect flow data throughout the year on the Santa Margarita River and tributaries in order to better understand how CWRMA releases at the Gorge affect flow rates downstream.

- CWRMA Water Quality:

  Continue to monitor the water quality of CWRMA releases in order to confirm compliance with Basin Plan limits and characterize the CWRMA's influence upon water quality in the river.

- CWRMA Related Geomorphology:

  To better understand the impact of the CWRMA upon river geomorphology and pool habitats, repeat the flow experiment and pool survey in the absence of beavers, possibly coordinating with agencies responsible for administering "beaver control" programs. The flow experiment should include both reduction and increase in CWRMA flows.

- Background Water Quality:

  Collect water quality samples upstream of the CWRMA outfall, or in both Temecula and Murrieta Creeks, to determine the background water quality of the Santa Margarita River before CWRMA water is released. These creeks are listed as impaired for iron, manganese, nitrogen, phosphorus and TDS indicating they likely impact water quality downstream.

- NNE and River Impairment:

  Collect or assemble a dataset sufficient to run the NNE spreadsheet model for other reaches and tributaries of the river in order to determine where the river is most susceptible to impairment. Likely candidates include the river at the Gorge, and MWD Crossing, and Ysidora, Rainbow Creek, and Sandia Creek.

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