Science Supporting Decisions on Biostimulatory Targets and Management of Eutrophication in the Main Stem of the Santa Margarita River Watershed

Martha Sutula
Jonathan Butcher
Michelle Schmidt
Clint Boschen
Raphael Mazor
David Gillett
Kris Taniguchi-Quan
Katie Irving
Dana Shultz

Southern California Coastal Water Research Project
Technical Report 1185

Science Supporting Decisions on Biostimulatory Targets and Management of Eutrophication in the Main Stem of the Santa Margarita River Watershed

Martha Sutula[1], Jonathan Butcher[2], Michelle Schmidt[2], Clint Boschen[2], Raphael Mazor[1], David Gillett[1], Kris Taniguchi-Quan[1], Katie Irving[1], and Dana Shultz[1]

[1]Southern California Coastal Water Research Project, Costa Mesa, CA
[2]Tetra Tech, San Diego, CA

January 2022
SCCWRP Technical Report #1185

ACKNOWLEDGEMENTS

This report was produced with funding from, and is a grant deliverable to, the San Diego Water Board, in fulfillment of the agreement "Santa Margarita River Watershed Climate-Ready Biostimulatory Targets" (Agreement No. 18-026-150). Previous funding contributed to data collection, synthesis, model development and validation, specifically to the Counties of San Diego (San Diego County Water Authority Project No. 84-6-80006; Phase II, Proposition 84; Project: 6 - Implementing Nutrient Management in the Santa Margarita River Watershed - Phase I) and to Riverside County Flood Control & Water Conservation District, the County of San Diego, and Rancho California Water District Agreement No. 400009708; Phase II, Proposition 84; Implementing Nutrient Management in the Santa Margarita River Watershed – Phase II. Finally, substantial in-kind funding was provided by the County of San Diego, Riverside County Flood Control and Water Conservation District and Camp Pendleton Marine Corps Base. The Santa Margarita River Nutrient Management Initiative Technical and Stakeholder Advisory Groups contributed greatly to the technical quality and management implications of this report. Finally, this report is dedicated to the memory of Betty Fetscher, who was instrumental in developing methodologies behind algal bioassessment and was a beloved friend and colleague.

Prepared for:
As a Deliverable for San Diego Water Board
"Santa Margarita River Watershed Climate-Ready Biostimulatory Targets"
(Agreement No. 18-026-150)

This report should be cited as:

Sutula, M., J. Butcher, M. Schmidt, C. Boschen, R. Mazor, D. Gillett, K. Tanaguchi-Chan, K. Irving, and D. Shultz. 2022. Science Supporting Decisions on Biostimulatory Targets and Management of Eutrophication in the Santa Margarita River Main Stem, California. Southern California Coastal Water Research Project Technical Report #1185. Costa Mesa, CA. www.sccwrp.org

EXECUTIVE SUMMARY

Several stream reaches in the Santa Margarita River (SMR) watershed and estuary are on the 2010 Clean Water Act section 303(d) list of water quality limited segments (303(d) list) for nitrogen (N), phosphorus (P), or eutrophication. The listings are based on exceedances of numeric or narrative interpretations of the biostimulatory objective in the Water Quality Control Plan for the San Diego Basin (SDRWQCB 1994). The availability of more recent scientific advances provides a better framework to evaluate the impacts to water quality and beneficial uses from biostimulatory substances. Considering recent science, SMR stakeholders, in cooperation with the California Regional Water Quality Control Board, San Diego Region (San Diego Water Board), developed a watershed process for evaluating and addressing the 303(d) listings utilizing the best available science and information. Part of this process utilized new monitoring data to update the watershed loading model (HSPF) and develop and calibrate receiving water models (WASP and QUAL2K2) for the mainstem. The HSPF model can simulate the movement of nutrients through the stream drainage network and their exchange with groundwater in the Lower main stem of the SMR. The WASP and QUAL2K receiving water models were used to predict key indicators of eutrophication, including benthic algal abundance (benthic chl-a, ash-free dry mass (AFDM)) and its impact dissolved oxygen (DO), as a function of environmental drivers including total nitrogen (TN) and phosphorus (TP) concentrations, stream wetted channel form and discharge, channel substrate and canopy cover.

This report synthesizes information from those investigations, including major findings and recommendations, to support stakeholder conversations and San Diego Water Board management actions to support SMR watershed beneficial uses. Specifically, this information includes:

- Synthesis of the scientific lines of evidence supporting decisions on biostimulatory targets, specifically for TN, TP, dissolved oxygen, benthic chl-a and AFDM.
- Analyses of how climate change can impact SMR flow and temperature regimes that will alter nutrient loading and other biostimulatory conditions and influence biological integrity.
- Analyses of load allocations by land use and jurisdiction that correspond with Water Board proposed biostimulatory targets in the SMR main stem.

Major Findings

Synthesis of Information to Inform Biostimulatory Targets. We utilized four lines of evidence from statistical and mechanistic models of eutrophication and biointegrity responses to biostimulatory gradients in the wadeable streams of the SMR watershed and compared these values to the 90th percentile of minimally disturbed reference sites in the South Coast region.

1. Mechanistic modeling of DO responses to nutrients and algal biomass
2. Change point analyses for algal and benthic invertebrate assemblages
3. Statewide thresholds protective of CSCI and ASCI REF10
4. Reach-specific thresholds protective of CSCI REF10

The WASP model was used to guide DO target discussions, rather than derive nutrient and benthic chl-a concentrations protective of DO. We found that biostimulatory substances that promote algal growth only contribute to ~30% of the DO budget for the SMR mainstem, while co-factors such as temperature and flow that are more difficult to control play a major role in compliance with the proposed DO target. Algal densities were predicted to be relatively insensitive to reductions in nutrient loads from the watershed and thus are less informative for TN and TP target discussions. We found that a **year-round** COLD DO target is not feasible based on nutrient reductions only, even with a 10% allowable exceedance frequency, because temperature alone will drive some periods of non-compliance.

Synthesis of statewide biointegrity stress-response models and change point analyses show that thresholds at which TN, TP, benthic chlorophyll-a, and AFDM are having adverse effects on benthic invertebrate and algal biointegrity are occurring are very low concentrations, typically within the range of 90^{th} percentile of the statistical distribution of reference sites and the San Diego Basin Plan TN and TP water quality objective of 1.0 mg/L TN and 0.1 mg/L TP. Derivation of site-specific thresholds for SMR based on a site comparator approach produced thresholds slightly above the Basin Plan TN and TP water quality objective, but equivalent to benthic chl-a statewide values. Collectively, this evidence is strong and signaling the extreme sensitivity of Mediterranean streams to nutrients and eutrophication. Biointegrity derived thresholds were in close agreement with the range of change point analyses for TN and TP derived for streams throughout the U.S.

At mainstem sites on the SMR above the Camp Pendleton Lake O'Neil Diversion, one or more biostimulatory indicators routinely exceeded the range of thresholds produced by this synthesis. In the case of benthic chlorophyll-a, ambient biomass was typically 1-3 orders of magnitude higher. For nutrients, exceedances of the upper range of thresholds synthesized here occurred routinely at Fallbrook, below the confluence with Rainbow Creek and at the MWD crossing, all of which are downstream of catchments that are major contributors to nutrient loads in this watershed.

Effects of Climate Change. Numerical watershed and water quality models were used in tandem with flow ecology models to simulate the effects of future project climate change under a "business as usual" scenario (RCMP8.5), which is now considered a worst-case scenario. The SMR mainstem, like other riverine ecosystems, is vulnerable to climate change because (1) aquatic organisms and communities are strongly shaped by water temperatures and flow, (2) water temperatures and flow are strongly climate-dependent, (3) at the interface with altered land use, they are typically directly exposed to numerous human-induced pressures, and (4) many of these human pressures, including water quality and eutrophication, act on the same drivers and therefore have interactive, co-varying effects with climate change. Simulations of the effects of future weather series consistent with three downscaled global climate models (GCMs) consistently predicted a suite of drivers that exacerbated symptoms of eutrophication in the SMR mainstem and degraded biological integrity. Increased water temperature, declining wet season duration and wet/dry season baseflow, and increased nutrient concentrations produced variable but consistent declines in daily oxygen minima and increased diel variability. Projected increases in climate extremes (including peak flows, declining magnitude, and duration of wet and dry season baseflow) adversely impacted biological integrity, as measured by invertebrate and algal indices of biological condition, with increasingly severe effects consistent across two of three GCMs. Optimal thermal habitat for Southern California Steelhead, already compressed in this watershed, showed projected declines. However, flow augmentation from the Cooperative Water Resource Management Agreement (CWRMA) release, which was established to support the water resource requirements of lower watershed landowners (and did not consider environmental flows), is already having a strong positive effect to help remediate the effects of eutrophication and improving biointegrity by reversing flow alteration.

Clearly, uncertainty exists in these predictions. Confidence is highest in climate projections of air temperature and all three GCMs showed consistent projected increases over time. The greatest uncertainty is in projected precipitation and thus while the mean state of baseflow and wet season flow duration is declining, uncertainty and extreme variability exists. Since thermal habitat and dissolved oxygen effects are strongly linked to temperature, these predicted impacts are ones in which we have the most certainty. Prediction in biological outcomes is the most uncertain because WASP and statistical biointegrity models imperfectly capture the non-linear feedbacks and responses of ecosystem physics, chemistry, and food web interactions.

Summary of effects of climate change (based on CNRM-5, HadGEM2-ES365 and MIROC5). A red arrow signifies a negative environmental effect while a blue arrow signified a mitigating or positive environmental effect. The direction of the arrow signifies whether the variable increased (up) or decreased (down).

Ecosystem Attribute	Effect of Climate Change (Based on Three GCMs)	Effect of Baseflow Augmentation (CWRMA Release)
Eutrophication Drivers (Biostimulatory Substances/Conditions)		
Water Temperature	↑	↓
Flow Alteration		
Peak flow	↑↓	No effect
Wet season baseflow	↓↑	↑
Wet season flow duration	↓↑	↑
Dry season baseflow	↓	↑
Nutrients		
Nutrient Concentrations	↑	↓
Nutrient Loads	↑↓	↑
Eutrophication Responses		
Dissolved oxygen		
Daily minima	↓	↑
Diel variability	↑	
Algal biomass	↑↓	↑
Biological Integrity		
Biological integrity, invertebrates and algae	↓	↑
Thermal habitat, for Steelhead	↓	↑

Allowable Loads and Load Allocations. Based on this science, the Water Board staff is considering establishing instream nutrient concentrations for the Santa Margarita River and its tributaries as 1 mg/L for TN and 0.1 mg/L for TP. The Water Board selected seven locations within the drainage area of the SMR for explicit assignment of loading targets and associated allocations. The percent reductions required to meet the allowable loads (i.e., relative to existing loads) were established for each site range from 0% at MWD to 83% at Rainbow Creek for TN and 0% to 52% for TP for dry weather. After total at-source loading targets were computed, TN and TP allocations were established by land use category and jurisdiction for each site.

Recommendations

This study documented the impacts of climate change on eutrophication and biological integrity in stream ecosystems and how baseflow augmentation alleviated those impacts. Here we provide some recommendations on what actions storm water managers could take to mitigate these impacts and are intended to be more broadly applicable than the SMR watershed.

1. ***Restore natural hydrograph.*** CWRMA release showed the potential power of hydrologic restoration to counter effects of climate change. The analysis demonstrated CWRMA baseflow augmentation, although not specifically intended to support environmental flows, was designed to approximate 2/3 of natural flows and countered the effects of both eutrophication and degradation of biological integrity. Restoration of the hydrograph would assure adequate summertime baseflow to provide an abundance of deep pools that are appropriate thermal habitat for Steelhead and other temperature-sensitive species. Opportunities to enhance groundwater infiltration to buffer temperatures and maintain baseflow should be considered. Climate change is increasing the frequency of extreme events, so management actions that are already intended to decrease peak flows through best management practices and low impact development are a key part of the strategy.

2. ***Restore floodplain and channel habitat.*** Floodplain and in channel habitat provide important ecosystem functions, including slowing and storing flood waters, reducing summertime peak temperatures, recharging groundwater, enhanced recycling and retention of land-based nutrients inputs and provision of shade that controls water temperatures. Floodplain restoration is therefore a key strategy to counter the effects of climate change—one that goes hand-in-hand with hydrologic restoration. Establishing buffer setbacks to restore nutrient cycling functions in the tributaries is critical. Channel habitat restoration, removal of impediments to flow (Arizona crossings) and planting of riparian habitat will improve physical habitat that protects biological integrity and increase shade—all of which will reduce eutrophication and protect dissolved oxygen.

3. ***Reduce nutrient concentrations and loads.*** Climate change will exacerbate eutrophication by making more severe many of the principal drivers (temperature, nutrient concentrations, and loads). Projections of declining DO with climate change were more egregious in regions of the SMR mainstems with greater anthropogenic nutrient loads (e.g., below confluence with Rainbow Creek). To reduce the effects of climate change on stream ecosystems, an important strategy is to lower the eutrophication risk that would be exacerbated by climate change by reducing nutrient concentrations and loads.

4. ***Consider changes in the formulation of biointegrity and biostimulatory objectives and targets.*** Results of this study suggest that attainment of current biointegrity, biostimulatory and DO objectives will be more challenging to achieve in the future. We recommend that more consideration be given to how both biological integrity and biostimulatory targets can be structured

in the future to offer flexibility in compliance. One way to do this in the future is to through "natural sources exclusion," in which the rate of non-compliance with targets in reference sites is also applied to non-reference sites. DO objectives should be refined to incorporate explicit considerations of how temperature is considered in DO compliance. DO concentration-based targets ignore the effects of temperature and flow. Using percent saturation targets that scale with temperature would help to address this issue. In addition, seasonal exclusion, be they for high temperature or low flow, would also help to ease issues with compliance. Nutrient load allocations are strongly affected by extreme events. If wet weather load allocations are in place, establishing criteria to exclude extreme events from load allocation may be appropriate. Concentration-based versus load-based TMDLs may be preferable, or a hybrid approach with appropriate exclusions in place.

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

1. INTRODUCTION AND PURPOSE

1.1 Background and Purpose of Document

The Santa Margarita River (SMR) watershed encompasses approximately 750 square miles in northern San Diego and southwestern Riverside counties (Figure 1.1). The SMR begins in the City of Temecula in Riverside County at the confluence of the Temecula and Murrieta Creek systems and flows within San Diego County through unincorporated areas, the community of Fallbrook, and the Marine Corps Base Camp Pendleton. Urban and agricultural land uses in the watershed result in modified flow and increased nutrient supply to the mainstem of the River and the estuary, resulting in eutrophication in some reaches, defined as the increase in the rate of supply and/or *in situ* production of organic matter (from aquatic plants) in a water body. Several river and tributary reaches and the SMR estuary were listed on the 2010 Clean Water Act (CWA) section 303(d) list of water quality limited segments as impaired for biostimulatory substances and conditions linked to eutrophication (see Section 1.3 for detailed explanation; Appendix 1, Table A1 for complete list).

The listings were based on exceedances of a specific numeric interpretation of the biostimulatory narrative objective in the Water Quality Control Plan for the San Diego Basin (Basin Plan, SDRWQCB 1994), for nitrogen and phosphorus that were established in 1975. The availability of more recent scientific advances provides a more modern scientific framework with which to evaluate the effects on water quality and beneficial uses from biostimulatory substances and conditions. The SMR Nutrient Management Initiative (NMI) is a collaboration of stakeholders within the watershed formed in 2011 for the purpose of monitoring, developing modeling and interpretation tools, and synthesizing science to support decisions on biostimulatory targets and watershed management actions to reduce biostimulatory substances and conditions. The intent of the SMR NMI project is to develop scientific information that can be used by the San Diego Water Board, in conjunction with other data, to select the appropriate regulatory approach to restore and protect the beneficial uses impacted by biostimulatory substances for the 303(d) listed water bodies within the SMR watershed. Previous phases of the project produced data (McLaughlin et al. 2013) and models (SPAWAR 2016; Tetra Tech 2018) that were used to establish biostimulatory targets and a total maximum daily load Alternative Restoration Plan for total nitrogen (TN) and total phosphorus (TP) for the SMR Estuary (SMRE). The SMRE Alternative Restoration Plan established load allocations for the watershed to achieve targets in the SMRE.

The goal of this report is to synthesize information from those investigations to support stakeholder conversations and Water Board management actions to support SMR watershed beneficial uses (Table A2, Appendix 1). This report includes the following components:

- Synthesis of the scientific lines of evidence supporting decisions on biostimulatory targets, specifically for TN, TP, dissolved oxygen, and organic matter accumulation, expressed as algal biomass (benthic chlorophyll-a) and ash-free dry mass (AFDM).
- Analyses of how climate change can impact SMR flow and temperature regimes that will alter nutrient loading and other biostimulatory conditions and influence biological integrity.
- Analyses of load allocations by land use and jurisdiction that correspond with Water Board proposed biostimulatory targets in the SMR main stem and how this compares to previously established allocations for the SMRE.

1.2 The SMR NMI Process Plan and Status

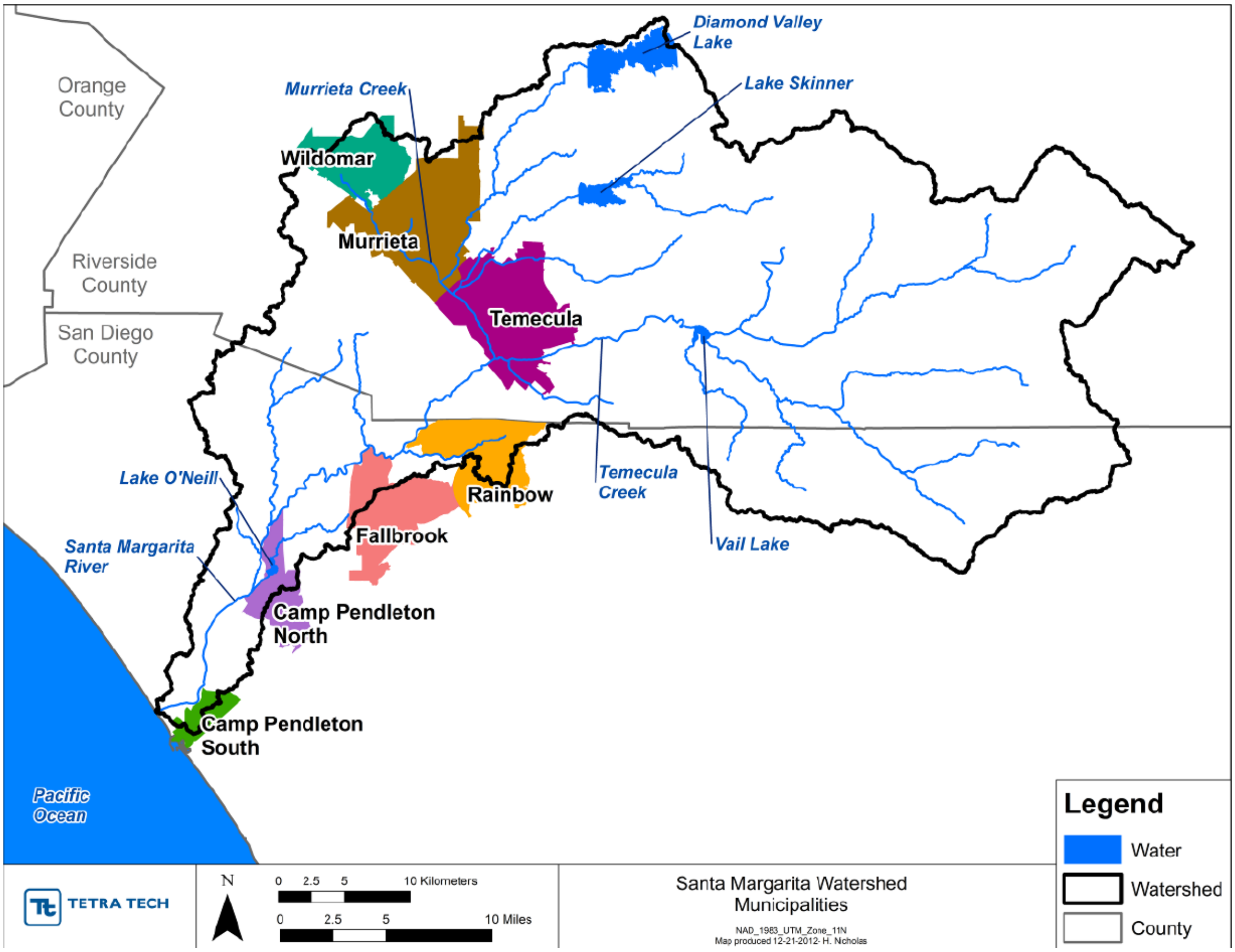


Figure 1.1. Map of Santa Margarita Watershed. Project geographic scope includes area downstream of major reservoirs (Vail, Skinner, and Diamond Valley Lakes) to the estuary at terminus of the watershed.

SMR stakeholders, in cooperation with the San Diego Water Board, developed a process plan (LWA 2015) that summarizes the regulatory and technical tasks to be completed to support decision-making under the SMR NMI project, referred to as the SMR NMI. The Process Plan approach follows the guidance for addressing 303(d)-listed waterbodies in California outlined in *A Process for Addressing Impaired Waters in California* (SWRCB 2005), with modifications to reflect elements specific to biostimulatory substances and considerations based on the recently adopted San Diego Water Board Practical Vision (Practical Vision). The San Diego Water Board has stated its intention to follow the guidance manual in addressing the 303(d) listed waterbodies within the SMR Watershed.

Two ongoing state policy development efforts provide context and opportunities for the SMR NMI to test new tools and discuss implications for potential regulatory targets. First, in November 2020, the San Diego Water Board adopted a policy of Bio-objectives for wadeable streams, based on assessments of benthic invertebrate and algal indices of stream condition. Second, the California State Water Quality Control Board (State Water Board) is in the process of developing a policy for biostimulatory objectives for California inland surface waters. For wadeable streams, this policy will be strongly linked to a program for implementation of biointegrity to support aquatic life. From that project, a suite of biointegrity and biostimulatory science products are available to support watershed discussions of biointegrity endpoints (Mazor et al. 2016; Theroux et al. 2020; Paul et al. 2020) and biostimulatory targets (Mazor et al. in prep; Sutula et al. 2022).

The process specific to the SMR is as follows: 1) Synthesize science, collect monitoring data, and develop tools to evaluate potential eutrophication impacts to beneficial uses from biostimulatory substances and identify potential impairments, 2) If an impairment exists, identify regulatory and management actions to address the impairment through collaborative, outcome-focused efforts that support both human uses and sustainable ecosystems, consistent with the Practical Vision, 3) Where possible and appropriate, take early actions to restore water quality alleviating the impairment, and 4) If the impairment does not exist, evaluate the need for other regulatory actions to support delisting of the unimpaired reaches, based on the technical information and science developed during the Project.

The first stage of the project consisted of modeling and numeric target development for SMRE (Sutula et al. 2016). Baseline monitoring was synthesized (McLaughlin et al. 2013). Science supporting the SMRE Alternative Restoration Plan (ARP) has been completed (SCC-PAC 2016; Tetra Tech 2013; Sutula et al. 2016) and the SMRE ARP was completed in 2019, including the issuing of an investigative order that required monitoring and reporting.

The second and final stage, focused on the SMR main stem, defined as the section of the river from the top of the Gorge (found just below the confluence of Temecula and Murrieta Creeks) to the estuary, focused on the monitoring, modeling and syntheses of numeric biostimulatory targets. New monitoring data were collected in the SMR main stem with detailed data on concentrations and loads of nutrient collected in the tributaries to the main stem (Sutula and Shultz 2022). Models were developed and/or updated and applied to support conversations on biostimulatory targets. Once a recommended set of biostimulatory targets was identified, the watershed loading model was used to quantify the load and waste load allocations needed to meet those targets. In addition, the watershed loading models were used to evaluate nutrient management, and/or restoration strategies required to meet a range of biostimulatory targets and evaluate the attainability of the targets, under future climate change scenarios and under natural condition scenarios.

1.3 Conceptual Model of Biostimulatory Substances and Conditions, Linkage to Eutrophication and SMR Beneficial Uses

"Biostimulatory" substances and conditions (i.e., increased nutrient loads, increased temperature and light, physical habitat alteration or organic matter disposal or deposition, hydromodification[1]) are conditions that can contribute to the accelerated accumulation of organic matter (a.k.a.,

[1] Hydromodification, the alteration of natural flow through a landscape, can cause eutrophication by: 1) increased residence time of water, allowing algae to uptake more nutrients, 2) increasing sedimentation of nutrient rich sediment organic matter, which can then return to the water column via benthic flux, 3) causing water column stratification, which positions algae in the upper level of the water column with optimum heat and light, and 4) scouring of habitats, which can increase light, nutrient laden sediment organic matter, and temperatures.

eutrophication (Nixon 1995), Figure 1.2). Eutrophication has a variety of adverse effects on beneficial uses of streams and rivers. Typical symptoms include a large accumulation of algal biomass, such as planktonic algae biomass (deeper, slow moving rivers) and/or benthic algal biomass (smaller, wadeable streams). This is accompanied by a shift in the algal, invertebrate, and fish community structure towards lower diversity and higher proportion of stress-tolerant taxa, driven in part by habitat smothering, shift in food base, and wider variation in diel ranges of dissolved oxygen (DO) and pH (Figure 1.3). High algal abundance can alter hydrology and interfere with spawning, foraging, and shelter (Biggs 2000; Quinn and Hickey 1990), limit the growth of benthic diatoms as food sources for scraper/grazers (Steinman 1996), and deteriorate water quality (Quinn and Gilliland 1989). These changes can cause trophic level shifts in benthic macroinvertebrates and higher-level consumers that prey upon them (Duffy 2009; Duffy et al. 2007). Studies have shown that increasing eutrophication results in decreased proportional retention of nitrogen and decreased denitrification, thus directly degrading nutrient-related ecosystem services and beneficial uses that streams provide (Alexander et al. 2000).

Together, these adverse effects can impair beneficial uses related to aquatic life uses (coldwater[2], warm water[3], migratory, and spawning), as well as human uses including drinking water, primary, and secondary contact recreation (Figure 1.3; see San Diego Water Board basin plan for a complete list of definitions). Harmful algal blooms[4] can produce toxins and very high ammonia, and nitrate concentrations can also result in direct toxicity to humans, their pets and domestic animals, and aquatic organisms, proliferation of pathogenic bacteria taste/odor problems in municipal drinking water supplies, and compromised aesthetics as well as impacts to other beneficial uses (Biggs 2000; Lembi 2003; Suplee et al. 2009; Fovet et al. 2012).

While nutrient reductions are typically a focal point for remedying biostimulatory impairments, restoration of watershed processes can also decrease biostimulatory conditions (temperature, flow, light regime, physical habitat) and promote biological integrity. Opportunities for such restoration (e.g., improved flow management, physical habitat, or decreased light and temperature through channel and floodplain restoration) can also be evaluated at a watershed scale and could be a focal point for implementation.

This eutrophication conceptual model guides the identification of potential indicators that represent the desired biological endpoints for the River (Table 1.1), i.e., what management actions are intended to protect. It also guides the identification of numeric biostimulatory targets that can be derived to support these endpoints. The indicators listed in Table 1.1 are primarily focused on aquatic life beneficial use (ALU) endpoints, since these were the basis for the 303(d) listing in the SMR watershed.

---

[2] COLD signifies a Cold Freshwater Habitat beneficial use, which supports cold water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish or wildlife, including invertebrates.
[3] Warm Freshwater Habitat (WARM) - Includes uses of water that support warm water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish or wildlife, including invertebrates.
[4] Harmful algal blooms include the toxin producing and/or high biomass accumulation of algae. See Smith et al. (2021) for definition.

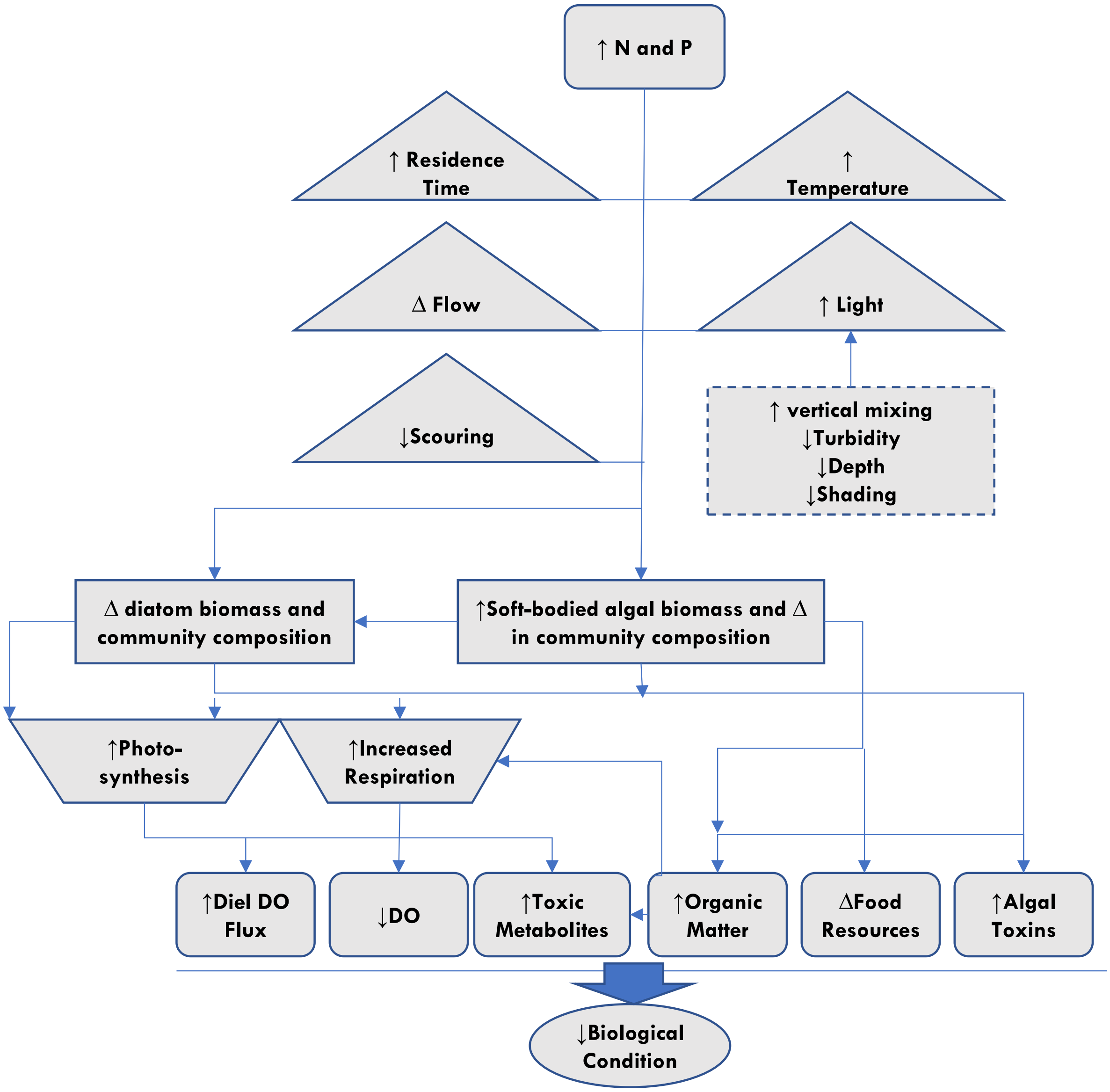


Figure 1.2. Conceptual figure showing the influence of flow regime, light, and temperature on eutrophication. Upward and downward arrows are meant to convey increases or decreases in the variable. N and P are biostimulatory substances, while the triangles are biostimulatory conditions. Shapes below triangles represent biological responses and their physiochemical effects. From Sutula et al. (2022).

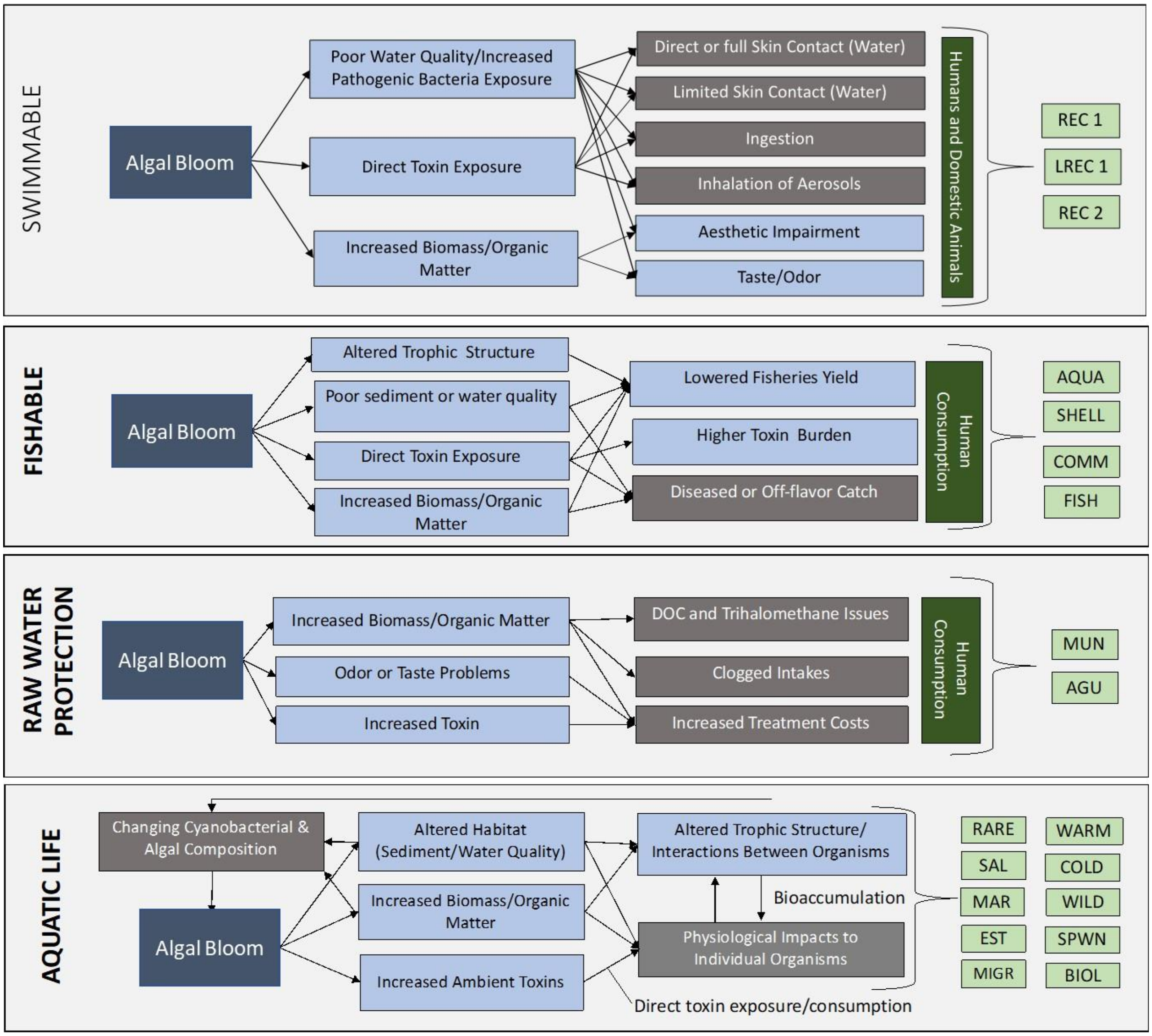


Figure 1.3. From Smith et al. 2021. Conceptual models depicting impact of algal blooms (here designated as harmful algal blooms or HAB) events on core beneficial uses, via pathways of impairment. Light blue boxes represent pathways of impairment of beneficial uses for which groups of indicators and metrics can be used to measure the specific responses (Table 1.1). Definitions for specific beneficial uses shown in the light green boxes can be found on the Water Boards website: *www.waterboards.ca.gov/about_us/performance_report_1314/plan_assess/docs/bu_definitions_012114.pdf*).

Table 1.1. Summary of potential indicator categories and potential measures. Biointegrity indicators (Aquatic life use) and basin plan objectives represent biological endpoints. Potential biostimulatory targets of benthic chlorophyll-a, AFDM, and TN and TP would be derived from models to identify the range of levels that are protective of the biological endpoints.

Indicator Category	Indicator	Measure
Aquatic Life Use Endpoint (Biointegrity)	Benthic Macroinvertebrate Community Structure	California Stream Condition Index (CSCI; a unitless ratio that ranges from 0 [poor conditions] to 1 or higher [reference conditions])
	Benthic Algal Community Structure	Algal Stream Condition Index (ASCI; a unitless ratio that ranges from 0 [poor conditions] to 1 or higher [reference conditions])
Physiochemistry	Dissolved oxygen	DO concentration (mg/L)
Biostimulatory (Nutrients and organic matter)	Organic Matter Accumulation	Benthic chlorophyll-a (mg m-2) Ash-free dry mass (AFDM; mg m-2) Benthic Organic Carbon, N, and Phosphorus
	Nutrients	Total nitrogen (TN; mg/L); Total phosphorus (TP; mg/L)

1.4 Climate Change and Context for Investigation in the SMR

Climate change represents a formidable challenge for water quality managers to protect beneficial uses. California is already experiencing increased average temperatures, with more frequent heat waves (Bedsworth et al. 2018). Regional annual average temperatures are projected to rise Summertime extreme heat events are projected to become longer and hotter. Projections of precipitation changes under current rising emissions trends show reduced winter and spring precipitation, resulting in reductions in cloud cover, increased insolation, increases, decreases, changes in runoff and streamflow from the middle to the end of the 21st century. Drought is projected to become more frequent, intense, and longer lasting than the historical record (severe mega-droughts at least 50 years long; Pierce et al. 2018). All of these factors represent an increase in biostimulatory conditions (Figure 1.3). Independent of eutrophication, flow and temperature have the ability to fundamentally influence the invertebrate and algal community structure, even in minimally disturbed habitats, that could cause a shifting baseline of biological condition indices such the California Stream Condition Index (CSCI; Mazor et al. 2016) or the Algal Stream Index (ASCI; Theroux et al. 2020).

Subsequent to the passage of California's foundational climate change legislation "Safeguarding California," the State Water Board passed a number of resolutions (2007-0059, 2017-0012) that mandated, e.g.,:

> *"develop additional information and consider actions pertaining to climate change and water resources"*

> *"engage in dialogue…on how best to address meeting water quality standards given climate change impacts that contribute to or exacerbate degradation of water quality, including but not limited to increased surface water temperatures, altered surface water*

flows, changes in water chemistry (such as increases in salinity, bacteria, and nutrient concentrations), hydrology, and ecology."

The San Diego Regional Board's Resolution No. R9-2018-0051: Addressing threats to beneficial uses from climate change called for:

> *"Healthy Ecosystems: Protect and restore natural flow regimes" and "Advocate for solutions that protect beneficial uses from effects of climate change: Natural infrastructure solutions (restoration, enhancement, and creation of wetlands) in climate adaptation plans…" and "Water capture, recharge, and reuse solutions over increased effluent discharges."*

The San Diego Water Board is interested in understanding the impacts of climate change on biostimulatory substances (nutrients) and conditions (flow, temperature, turbidity, and light), and how this translates to altered eutrophication and biointegrity in coastal watersheds to formulate the appropriate policy responses, both in the SMR Watershed as well as regionally. The SMR Watershed is a unique case study to consider these questions. The Cooperative Water Resource Management Agreement (CWRMA) agreement, established in 2002 to support the water resource requirements of lower watershed land owners, augments baseflow at the Gorge. Model simulations that explore the effects of flow augmentation can be illustrative to look at how this might be used as a management tool.

1.5 Overarching Approach, Key Questions, and Tools Employed

The conceptual approach for the SMR NMI project involved developing, calibrating, and applying an integrated suite of tools to investigate multiple stressor effects on eutrophication and biointegrity in the SMR main stem and quantify the range of stressors that is likely to protect beneficial uses. The project seeks to answer several types of questions, for which the methods and findings have been organized by report chapter (Table 1.2).

Figure 1.4 gives an overview of the integrated tools that were applied to support the scientific questions in Table 1.2. Four types of tools were employed to answer these questions (see inset box for brief description):

I. **Hydrologic Simulation Program Fortran (HSPF; Bicknell et al. 2014)** is a mechanistic, dynamic, watershed loading model that can be used to simulate the influence of climate and land use on instream flow regimes, heat (temperature), nutrient concentrations and loads, suspended sediments, and dissolved oxygen. The HSPF model was developed and validated for the Stage I SMRE scientific analyses. For this stage, the HSPF model was updated to improve the current land use representation and other factors for the Middle SMR watershed (Tetra Tech 2020a) and was coupled with the HSPF model that was previously developed for the Lower SMR watershed (Tetra Tech 2018). The HSPF models of the Middle and Lower SMR watersheds are also linked to MODFLOW groundwater models to improve the representation of surface water interaction with alluvial aquifers.

II. **Water Quality Analyses Program (WASP)** and **QUAL2Kw** are mechanistic receiving water quality models that simulate the effects of watershed forcing of biostimulatory substances (nutrients) and conditions (flow, temperature, turbidity), as well as site specific light regimes and physical habitat on algal biomass and dissolved oxygen in river surface waters. The WASP model is a dynamic model that was developed and calibrated (Tetra Tech 2020b) in perennial portions of the River (upstream of the Camp Pendleton diversion through the SMR Gorge), while QUAL2Kw is implemented as a steady state model developed and calibrated for the intermittent stretches of the lower mainstem (after the Camp Pendleton diversion), where conditions do not permit the use of WASP (Tetra Tech 2018).

III. **Statewide and SMR-Specific Biostimulatory Biointegrity Stress Response Models (BBSRM)** consist of logistic regression models of the relationship between biointegrity measures (CSCI and ASCI) and biostimulatory substances and conditions. Models (Mazor et al. in prep) and additional syntheses (Sutula et al. 2022) have been developed to support the State Water Boards Biostimulatory amendment and program to implement biointegrity. Analyses were conducted to customize these models for the SMR watershed, based on sites within the statewide bioassessment database that have comparable natural gradients to this watershed (Gillette et al. in prep).

IV. **Regional Flow Ecology and Thermal Tolerance Tools.** Flow and temperature regimes, two major environmental parameters impacted by climate change, can affect biological integrity beyond the direct and indirect effects of eutrophication. The regional flow ecology analysis can identify areas, either currently or under various alternative future or management scenarios, where flow alterations are likely to affect biological integrity, as measured by CSCI and ASCI. The intent is NOT to establish flow criteria, but to inform restoration and management planning, or understand constraints on management expectations. Similarly, identification of ranges and thresholds of thermal tolerance can identify when or under what circumstances conditions may impact focal species and inform restoration and management.

In **Chapter 2**, to support stakeholder discussions on biostimulatory targets, we compared existing San Diego Water Board Basin Plan biostimulatory objectives, which has a numeric guidance for TN and TP concentrations, to ranges of biostimulatory thresholds (TN, TP, benthic chlorophyll-a, AFDM) from three lines of evidence:

- From mechanistic, process-based modeling, that meets dissolved oxygen (DO) Basin Plan objectives.
- From statewide empirical stress-response models that are protective of biointegrity (CSCI and ASCI).
- From SMR-specific empirical stress-response models protective of biointegrity (CSCI)

In **Chapter 3**, we used three downscaled global climate models (GCMs), representative of a range of potential future conditions from cool-wet to warm-dry, to force the HSPF watershed loading model with conditions predictive of a future with limited action to limit future emissions (RCP 8.5) and simulated the effects on flow, temperature, and nutrient loads (Tetra Tech 2020a). These predicted changes in SMR watershed conditions were used to investigate changes in receiving water benthic chlorophyll-a and DO (WASP) and effects on biointegrity from flow (regional flow ecology) and temperature alteration (thermal tolerance tools).

In **Chapter 4,** the HSPF model was used to establish, given Water Board proposed biostimulatory targets for TN and TP, the total maximum daily loads (TMDL) and the load allocation.

Table 1.2. Summary of SMR NMI Stage II study questions, supported by the "Santa Margarita River Watershed Climate-Ready Biostimulatory Targets" (Agreement No. 18-026-150), and the report chapter in which their methods and findings can be found. HSPF = Hydrologic Simulation Program Fortran; WASP = Water Quality Simulation Program (WASP), BBSRM = Biostimulatory-Biointegrity Stress Response Models.

Chapter	Topic	Question	Tools employed
2	Science supporting biostimulatory targets	1. What biostimulatory thresholds (TN, TP, DO, Benthic Chla, AFDM) protect aerobic habitat for aquatic life under current conditions? 2. What are the thresholds of biostimulatory indicators that are protective of biointegrity, based on sites within the statewide bioassessment database that have comparable natural gradients to Santa Margarita?	HSPF WASP QUAL2Kw BBSRM
3	Effect of climate change on biostimulatory conditions and implications for watershed management	3. How may future climate change affect flow, temperature, and nutrient loading regimes in SMR mainstem? 4. How does presence of flow augmentation from CWRMA change outcomes of main stem flow, temperature, and nutrient loading regimes under a future with climate change in SMR? 5. What are the implications of the magnitude of these changes for eutrophication outcomes and biointegrity?	HSPF WASP Regional Flow Ecology Thermal Tolerance
4	Load Allocations	6. Given a set of biostimulatory targets proposed by the Water Board, what are the load allocations by land use and jurisdiction in SMR watershed and how do these allocations compare (more or less restrictive) to what was established for the SMRE?	HSPF

Other scientific products relied on these tools and were applied to provide additional lines of evidence to support Water Board conversations regarding biostimulatory targets and implementation needs. For example, the HSPF and WASP model were applied to conduct a natural conditions modeling analysis to examine the streamflow regime and water quality conditions in the Santa Margarita River under the absence of anthropogenic activities below the major reservoirs in Riverside County (Diamond Valley Lake, Vail Lake, and Skinner Lake) and above Camp Pendleton. Several modeling scenarios were developed to evaluate conditions in the perennial section of the river based on natural landscape conditions, with and without the presence of the Comprehensive Water Rights Agreement (CWRMA) discharge. The analysis included modifying the baseline watershed HSPF and receiving water WASP models and is detailed in Appendix 2.

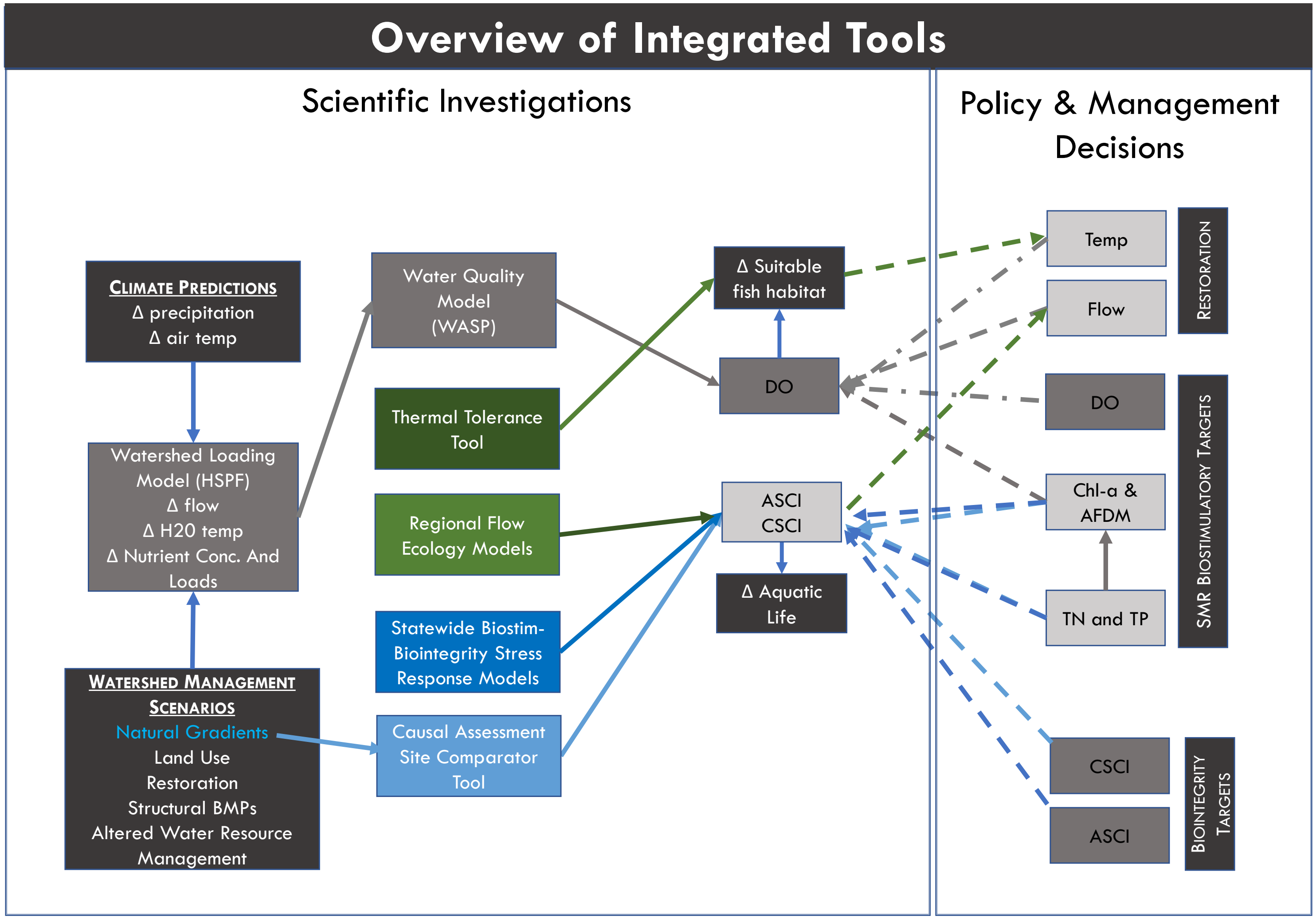


Figure 1.4. Conceptual depiction of the use of SMR project numerical models (HSPF, WASP, QUAL2K) and biointegrity models and tools (statewide and SMR-gradient specific BBSRM, regional flow ecology, thermal tolerance tool) to demonstrate how watershed land use, management scenarios and climate change can impact management endpoints (aquatic life, suitable fish habitat), which are linked to management decisions on biointegrity and biostimulatory targets and related implementation actions, including restoration.

2. Synthesis of Range of Biostimulatory Thresholds Corresponding to Management Endpoints for Eutrophication and Biointegrity

2.1 Introduction

The specific numeric interpretation of the biostimulatory narrative objective in the Water Quality Control Plan for the San Diego Basin (Basin Plan, SDRWQCB 1994) was established nearly 50 years ago. The availability of more recent scientific advances provides a more modern scientific framework with which to evaluate the effects on water quality and beneficial uses from biostimulatory substances and conditions.

This chapter synthesizes the scientific basis for policy decisions on biostimulatory numeric targets. We use the term “targets” to refer to policy decisions on the numeric limits of biostimulatory indicators for wadeable stream uses, while “thresholds” refer to the output of scientific analyses that are intended to inform conversations among the Water Board and its advisory groups on targets. Generally, we define thresholds as either: 1) “the change point at which there is an abrupt change in an ecosystem property or where small changes in an environmental driver produce large responses in the ecosystem” (Grossman et al. 2006); or, 2) “the value of an environmental driver that has a proscribed probability of meeting a management protection goal or endpoint.” Cuffney et al. (2010) further distinguish between resistance thresholds (e.g., a sharp decline in ecosystem condition following an initial no effect zone) and exhaustion thresholds (a sharp transition to zero slope at the end of a stressor gradient at which point the response variable reaches a natural limit).

We compared existing San Diego Water Board Basin Plan biostimulatory objectives, which has a numeric guidance for TN and TP concentrations, to ranges of biostimulatory thresholds (TN, TP, benthic chlorophyll-a, AFDM) from four lines of evidence (Table 2.1):

- From mechanistic, process-based modeling, that links nutrient loading and other biostimulatory conditions to DO Basin Plan objectives.
- From statewide empirical stress-response models that are protective of biointegrity (CSCI and ASCI) and biointegrity change point analyses.
- From SMR-specific empirical stress-response models that are protective of biointegrity (CSCI).
- Range of values for biostimulatory indicators found in minimally disturbed reference sites (a.k.a. reference approach) in the South Coast region, where nutrient and organic matter concentrations are chosen at some statistical percentile of those reference waterbodies.

This chapter is organized into sections that summarize methods and findings for each approach, then a final section compares and discusses the thresholds for their relevance to the SMR watershed.

Table 2.1. Summary of comparisons to evaluate and compare range of biostimulatory targets.

Tool	Biological Endpoint	Biostimulatory Indicator	Gradients Considered	Options on Interpretation
San Diego Water Board Biostimulatory Objective	Narrative	TN and TP	None	Exceedance frequency, aggregation of monitoring data.
Mechanistic modeling	Dissolved oxygen, pH, algal biomass	TN, TP, AFDM, Benthic Chlorophyll-a	Climate Range of discharge conditions (seasonal and interannual) Range of temperature conditions Physical habitat	Options for interpretation of DO and pH basin plan objectives Averaging period Applicable season Numeric target
Mazor et al. in prep	CSCI ASCI		Natural gradients representative reference already factored into CSCI and ASCI (climate, geology, elevation, soils, precipitation, etc.)	Range of chlorophyll-a and AFDM targets to be evaluated
Gillett et al. in prep	CSCI		Model developed from natural gradients specific to SMR	
Ranges of values from minimally disturbed reference sites	N/A	TN, TP, AFDM, Benthic Chlorophyll-a	Natural gradients	Specific percentile of reference considered

2.2 Develop Eutrophication Thresholds from Simulations of Validated Mechanistic Models of the SMR Main Stem

The watershed loading (HSPF) and receiving water quality models (WASP and QUAL2K) were used to interpret how specific DO targets are linked to measures of algal density, ambient nutrient concentrations and loads, and other environmental factors in the different SMR reaches.

Since model development and refinement spanned several funding phases, we first describe those works (2.2.1), then present how the models were applied to inform targets (2.2.2).

2.2.1 HSPF, WASP and QUAL2Kw Model Updates and Calibration

The Santa Margarita watershed is a complex, managed system that includes discharges, diversions, and significant interaction between surface and groundwater. Two phases of the HSPF watershed loading modeling and water quality modeling development and calibration are important to describe: 2015-2018 (Tetra Tech 2018) and 2016-2020 (Tetra Tech 2020a, 2020b). Figure 2.1 shows the current model domain of the HSPF models (for the middle and lower watershed) and the Camp Pendleton water resources model (coupled groundwater - surface water, a.k.a. MODFLOW model).

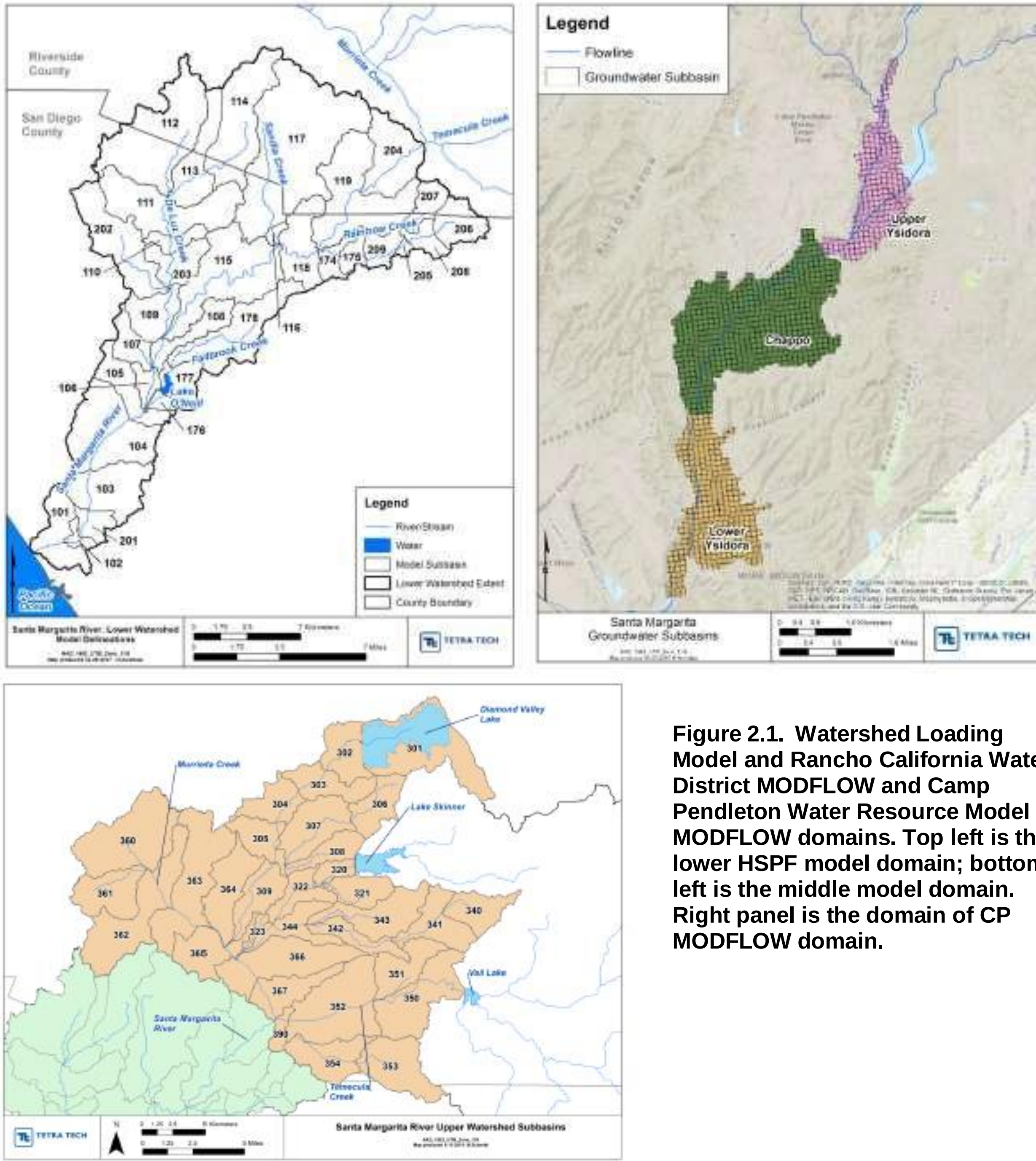


Figure 2-1. Subbasins for the Middle HSPF Model for the Santa Margarita River Watershed.

Figure 2.1. Watershed Loading Model and Rancho California Water District MODFLOW and Camp Pendleton Water Resource Model MODFLOW domains. Top left is the lower HSPF model domain; bottom left is the middle model domain. Right panel is the domain of CP MODFLOW domain.

Two watershed models of the middle and lower drainage areas of the SMR watershed were calibrated, which cover the areas upstream and downstream of the confluence of Murrieta and Temecula Creeks, respectively (Tetra Tech 2018, 2020a). For modeling of the Lower main stem[5] below the Camp Pendleton Point of Diversion (POD) to Lake O'Neil, the Tetra Tech lower HSPF watershed model incorporated results from the Camp Pendleton/Stetson MODFLOW groundwater model to better represent surface-groundwater exchanges in this vicinity; the HSPF model predicts subdaily flows, nutrient loads, and temperature (Tetra Tech 2018). This work enhanced the watershed loading model, with the primary goal of improving the representation of dry weather ambient nutrient concentrations throughout the river network, as well as the simulation of additional constituents necessary to support the receiving water models. This effort improved the linkage between the HSPF and MODFLOW models, which is key to representing conditions downstream of the Camp Pendleton diversion. The MODFLOW calibration was refined, and the application extended to simulate the exchange of both nitrogen and phosphorus between surface and groundwater in the area around Camp Pendleton. The MODFLOW model covers the three alluvial groundwater basins on Camp Pendleton, corresponding to HSPF model subbasins 106 through 103. The lower watershed loading model was calibrated for water years 1995-2016 under the 2018 phase, as the groundwater model currently ends in September 2016 and the discrete and continuous water quality and biological data collected by SCCWRP in the Lower River is within this time frame (Sutula et al. 2022). Detailed results of calibration and model sensitivity analysis are discussed in Tetra Tech (2018).

For modeling of the middle watershed (above the Gorge), the main stem and its tributaries, an updated and recalibrated HSPF model, with an expanded HSPF model domain that covered land use below the dams in the middle watershed, was used model watershed inputs to the Gorge (Tetra Tech 2020a). Watershed land use in the middle watershed was updated. The model refinement also included incorporation of Rancho California's MODFLOW water resources model output to assure that the contribution of groundwater and surface water to the Gorge was appropriately characterized (see Tetra Tech 2020a for details). The watershed loading model was calibrated for water years 1995-2018 under the 2020 funding. Detailed results of calibration and model sensitivity analysis are discussed in Tetra Tech (2020a).

HSPF contains routines that simulate, on a one-dimensional reach-averaged basis, water temperature, nutrients, planktonic algae, attached algae, pH, and the DO balance in response to algae, biochemical oxygen demand (BOD), sediment oxygen demand (SOD), and reaeration. Although HSPF can provide a general representation of these instream processes, a more detailed representation was achieved by linking HSPF to finer temporal and spatial scale receiving water quality models.

Accordingly, in the main stem of the River from the Gorge to the POD on Camp Pendleton, the updated HSPF model was linked to two receiving water models. WASP (EUTRO module) was the tool used for SMR estuary modeling and is an appropriate tool for areas where perennial flow and a reasonable depth is maintained (Figure 2.2); therefore, WASP (continuous simulation) was used for the perennial reach above POD. Those results described are derived from an updated WASP model, calibrated in 2020, based on monitoring results from 2015-2018 (Tetra Tech 2020b). Below the POD, where the flow is intermittent (POD to Ysidora) or ephemeral (below Ysidora), options are

[5] Defined as the Santa Margarita from the confluence with De Luz Creek to the estuary and constituting HSPF subbasins 108 through 101 (plus 201)

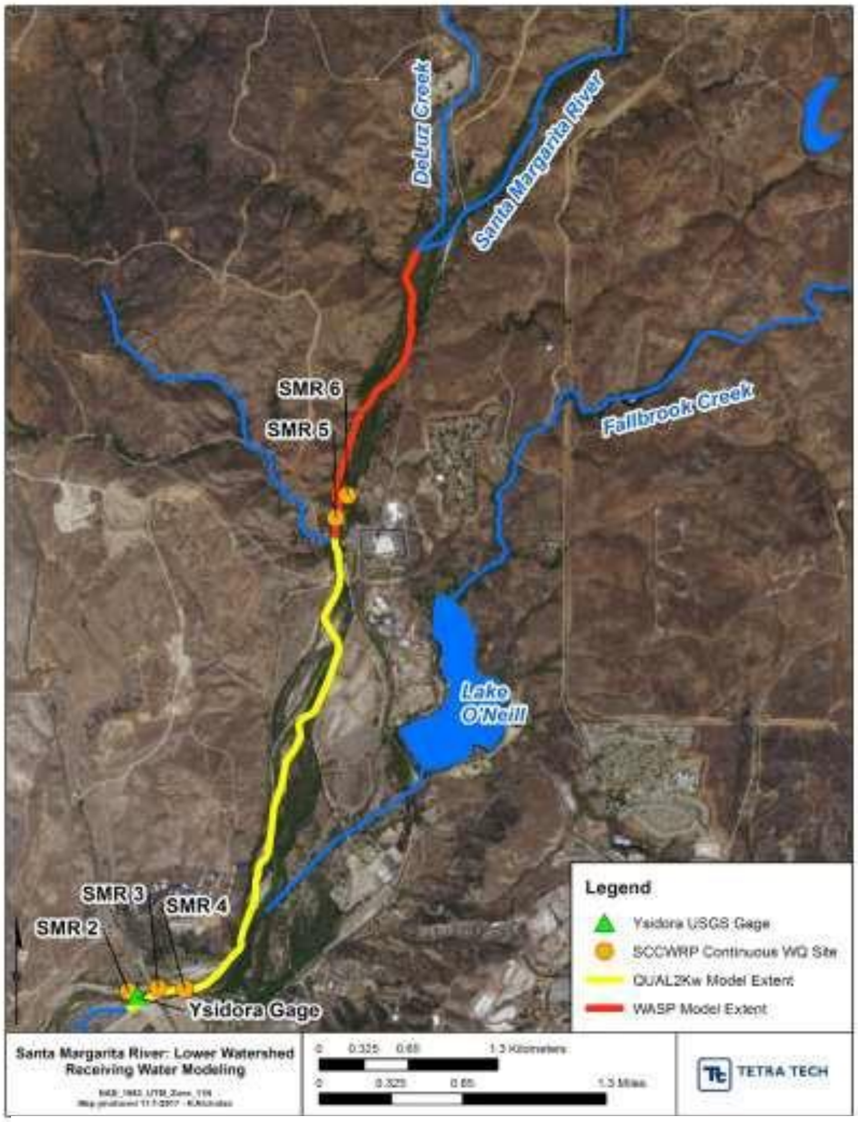


Figure 2.2. Locations of recent monitoring locations vis-a-vis perennial (red) and intermittent flow (yellow) in the Lower SMR. All mainstem locations upstream of the Old Hospital are perennial

limited for modeling because of dry/low water depth conditions that can cause model instability. The QUAL2Kw model is a one-dimensional model that simulates the diel heat budget, diel water quality, phytoplankton, bottom algae, pH, and the full DO balance. The model is implemented for steady flow conditions and is typically used to evaluate one or more sets of critical conditions under which maximum impacts are expected – usually a combination of low flows, high algal biomass, and high thermal inputs. Further, the focus on critical conditions means that periods of no flow that may occur during a continuous simulation do not affect model application; for this reason, QUAL2Kw was applied to simulate eutrophication response between the diversion and Ysidora. The QUAL2LKw model was implemented and calibrated for the section of the mainstem downstream of the POD in 2018, based on data from 2015-2016 (Tetra Tech 2018). The WASP model upstream of the diversion was run continuously over this period, although the focus was eutrophication responses in late spring through summer dry weather periods. In contrast, the QUAL2Kw model was implemented for specific, short periods of continuous monitoring (one to several days with approximately constant conditions).

Model Calibration. For both WASP and QUAL2Kw, Tetra Tech examined predicted water temperature, as well as concentrations for individual inorganic and organic nutrient species, by comparing means and evaluating relative errors. Consistency was evaluated between observed and simulated benthic algal densities in terms of both AFDM and chlorophyll-a. For DO, Tetra Tech performed statistical comparisons of model predictions to data for daily averages and diel ranges derived from field samples.

Both models were implemented over the period during which detailed eutrophication monitoring data were collected in the Lower and the Upper main stem (2016-2018, Sutula et al. 2022).

In general, both receiving water models exhibited good calibration against observations, with an acceptable error rate (Tetra Tech 2018, 2021). Water temperature, nutrients and DO calibration showed good performance at multiple monitoring locations that can exhibit diverse instream responses.

WASP calibration was most challenging for macroalgae density because of the extreme biomass accumulation in the upper main stem (1000s of mg/m^2) versus values directly above the POD (in the 10s of mg/m^2). Riverine benthic algal habitat is extremely heterogenous. Macroalgae density is also difficult to measure accurately, especially in thick stands of filamentous growth and can be highly variable in space. Algal scour from storm events is not explicitly represented in the model, although algal detrital matter is transported down river, contributing to oxygen demand at lower sites. Sites with bedrock (Gorge, MWD Crossing) provide better resistance to scour than those with cobble and sand (e.g., Fallbrook and the Old Hospital; Tetra Tech 2020b). Thus, in general WASP predicts less variability in time and space compared to the observations at all sites, but the model does a fair job of approximating the average macroalgae condition and performs well regarding the ultimate aquatic endpoint of DO.

2.2.2 Model Application to Derive Biostimulatory Thresholds

The QUAL2Kw[6] and WASP models were used to investigate nutrient concentrations that achieved specific interpretations of the DO objective.

The San Diego County Regional Water Quality Control Board (WQCB) provided the following draft numeric targets for dissolved oxygen in the SMR:

- The COLD beneficial use is applicable perennially to the SMR
- COLD: The 7-day average of daily minima (7DADMin) dissolved oxygen concentration is to be equal to or greater than 6.0 mg/L, with two options under consideration: 1) with and 2) without a 10% allowable exceedance frequency

The Regional Board also requested quantification of exceedances if the following criteria were applied downstream of Rainbow Creek, with and without the 10% exceedance frequency, as well as application of the WARM beneficial use DO criteria:

- COLD: 7DADMin equal to or greater than 6.0 mg/L between December 1 – May 31
- WARM: 7DADMin equal to or greater than 5.0 mg/L between June 1 – November 30

WASP Application to Simulate Water Quality from the Gorge to the Diversion

Sensitivity Analyses. Sensitivity tests described in the WASP model development and calibration report (Tetra Tech 2021) found that algal growth is most sensitive to light availability (e.g., shade), while impacts from modifying nutrient concentrations +/- 20% were minor, which is attributed to the fact that existing nutrient concentrations are well above the saturation state and not significantly

[6] Note that QUAL2Kw results were not updated with new boundary conditions from the upper watershed or evaluated for the 7-day average of daily minima (7DADMin) dissolved oxygen concentration.

limiting algal growth (Figure 2.3a, Tetra Tech 2020).

Predicted DO concentrations were most sensitive to shade and sediment oxygen demand and, to a lesser extent, flow (Figure 2.3b). Furthermore, daytime-nighttime temperature fluctuations, which are influenced by shading and in turn affect DO saturation concentrations, were shown to have a significant impact on DO diel variability. The fraction of the stream that is shaded due to the combined effects of topography and riparian vegetation is a WASP model input. Shade assumptions in the WASP model were based on a review of aerial imagery, LiDAR, and ground-level photography; water temperature observations were also used to refine the shade inputs. In the vicinity of the Gorge, where the stream is partially shaded by surrounding topography, the baseline effective shade in the calibrated WASP model is 30%. Baseline effective shade downstream of the Gorge is 20 percent in the WASP model; simulated water temperatures closely aligned with observed water temperatures providing confidence in the shade assumptions employed in the WASP model.

To isolate the change in diel variability attributed to macroalgal photosynthesis and respiration from change due to temperature, the WASP model was run to simulate macroalgae completely removed from the river (all model segments). Results are summarized in Figure 2.4a. The diel DO variability below the confluence with Rainbow Creek is reduced by about 30 percent when macroalgae are removed from the river. About 39 percent was attributed to changes in DO saturation (i.e., due to water temperature variation throughout day and night) and about 31 percent is attributed to other factors (e.g., SOD). As shown in Figure 2.4b, these components shift throughout the warm months.

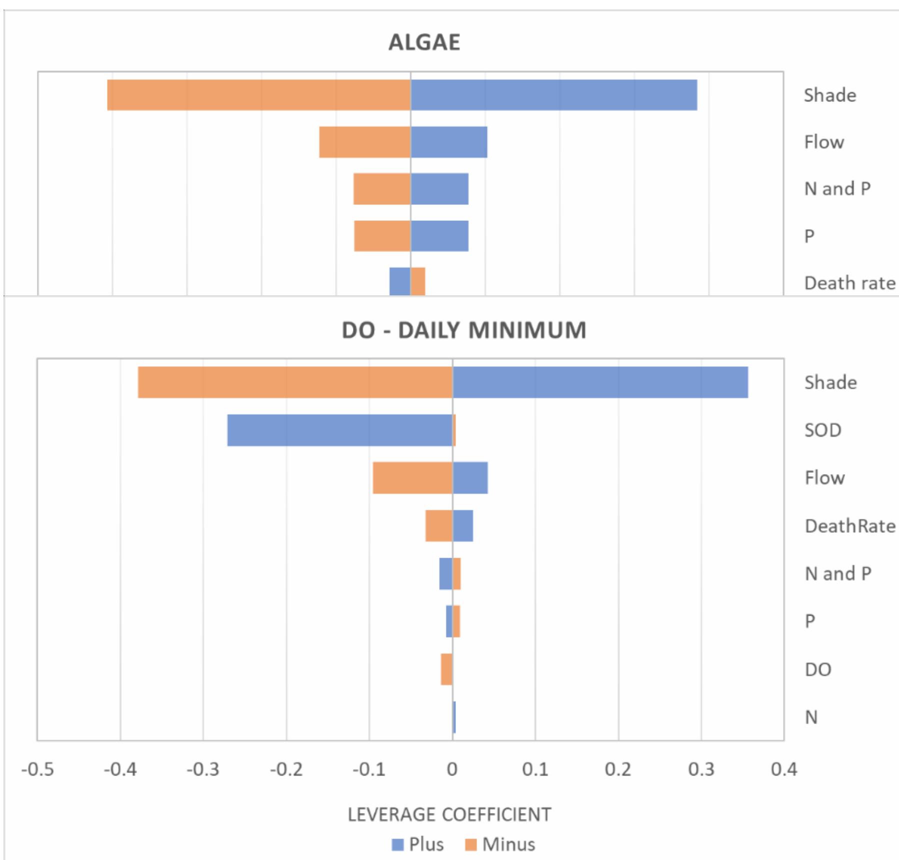


Figure 2.3. From Tetra Tech 2020b. WASP Model Sensitivity Tornado Diagram: Leverage Coefficients for (a-top panel) Macroalgae (benthic + submersed canopy) as Chlorophyll-a near Fallbrook (FB1; April – August) and (b-bottom panel) Daily Minimum Dissolved Oxygen near Fallbrook (FB1; April – August), based on a scenario of + or – 20 % of each of the parameters on the side panel. Note: Leverage Coefficients represent the unit change in the response variable per unit change in the input. Blue positive means a increase in the measure, while orange indicates a decreased effect.

To explore the effects of shade, a follow-up scenario was modeled that applied an 80 percent reduction in nutrient concentrations with an increase in effective riparian shade from vegetation. More specifically, effective riparian shade was doubled for this sensitivity analysis scenario. Improved effective shade ranges from 40 to 60 percent along the river in this scenario, with higher values achieved in the Gorge due to site topography. The feasibility of achieving these levels of effective shade is doubtful. Nevertheless, this scenario provides information about the impact of shade and stream temperature on DO target excursion frequency. This combined nutrient reduction and shade improvement scenario is predicted to result in minimal excursions across the sites of the 7-day average of the DO minimum (7DADMin; Table 2.2), showing stream temperatures play a crucial role in compliance with the DO target.

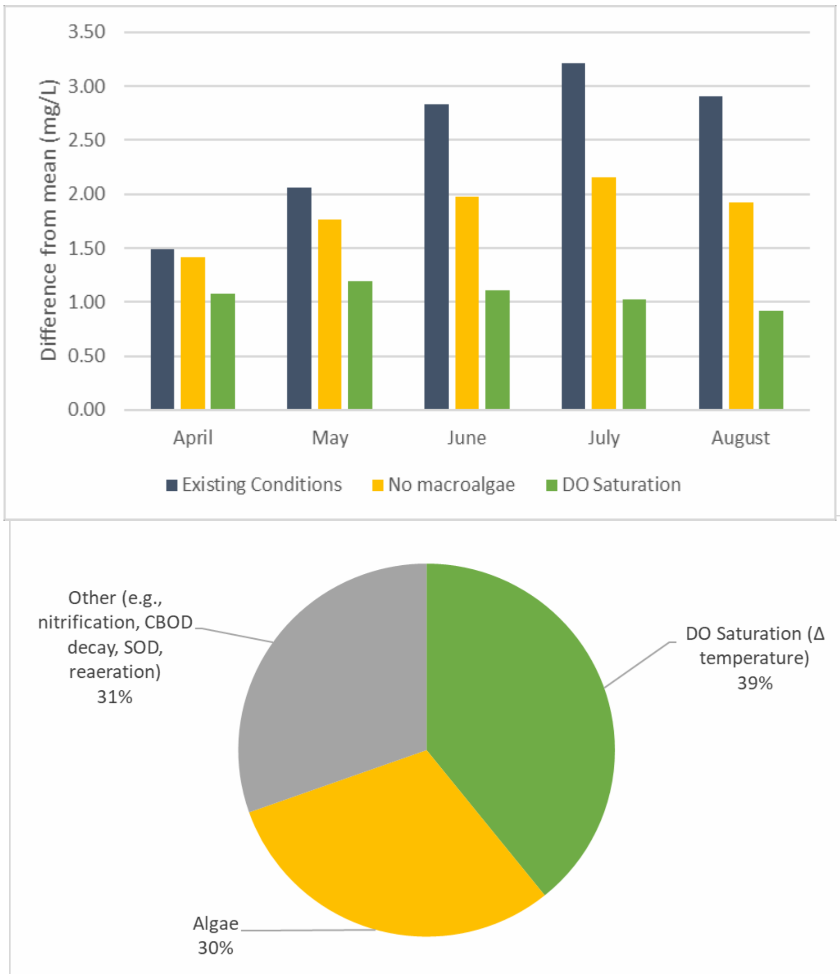


Figure 2.4. (top panel) Mean Monthly DO Diel Variability for Existing Conditions (DO Concentration), No Macroalgae (DO Concentration), and DO Saturation Concentration under Existing Conditions near Rainbow. (bottom panel) Sources Influencing DO Diel Variability in June near Rainbow.

Scenarios to Support Development of Nutrient Targets Based on DO. Scenarios were conducted with the calibrated WASP receiving water model of the SMR to support development of nutrient targets based on the endpoints described above. The scenarios included reducing nutrient concentrations by either 80% or 95% relative to current conditions to examine potential strategies for attainment of the criteria. The sediment diagenesis module in WASP was used to quantify the reductions in sediment oxygen demand (SOD) for the two nutrient reduction scenarios (11% and 13% reductions in SOD, respectively). The average dynamically computed time step for the model over the period of simulation is approximately 30 seconds. A temporal resolution of six-hours was applied in the evaluation of the dissolved oxygen objective. Results for the nutrient reduction scenarios are provided for four key SCCWRP monitoring locations along the river, which include at the Gorge (G1), downstream of Rainbow Creek (RB1), below Fallbrook (FB1), and near the Old Hospital (SMR5).

The modeled relationships between daily average streamflow and daily minimum DO concentration are plotted in Figure 2.5. The lowest daily minimum DO concentrations are associated with the lowest daily average stream flows. However, higher daily minimum DO concentrations (e.g., > 8 mg/L) are also often associated with low stream flows at these sites during cooler weather. At SMR below Rainbow Creek, daily minimum DO ranges from about 2 mg/L to 10 mg/L for streamflow around 0.15 m^3/s. At higher flows (e.g., > 0.5 m^3/s) daily minimum DO concentrations are consistently above 8 mg/L at this site, in part due to the fact that higher flows generally correspond with cooler weather and higher reaeration rates.

Table 2.2. Predicted annual frequency of 7DADMin DO excursions (< 6 mg/L) for COLD beneficial use for nutrient reduction and shade improvement scenario, 10% excursion allowance.

Location	10% Exclusion Allowance	
	Current Conditions	80% Reduction in Nutrients, 2X Riparian Shade
Gorge	6.5%	0.0%
Below Rainbow Creek confluence	28.7%	0.0%
Below Fallbrook	11.7%	0.0%
Near Old Hospital	10.8%	0.0%
Average	**14.4%**	**0.0%**

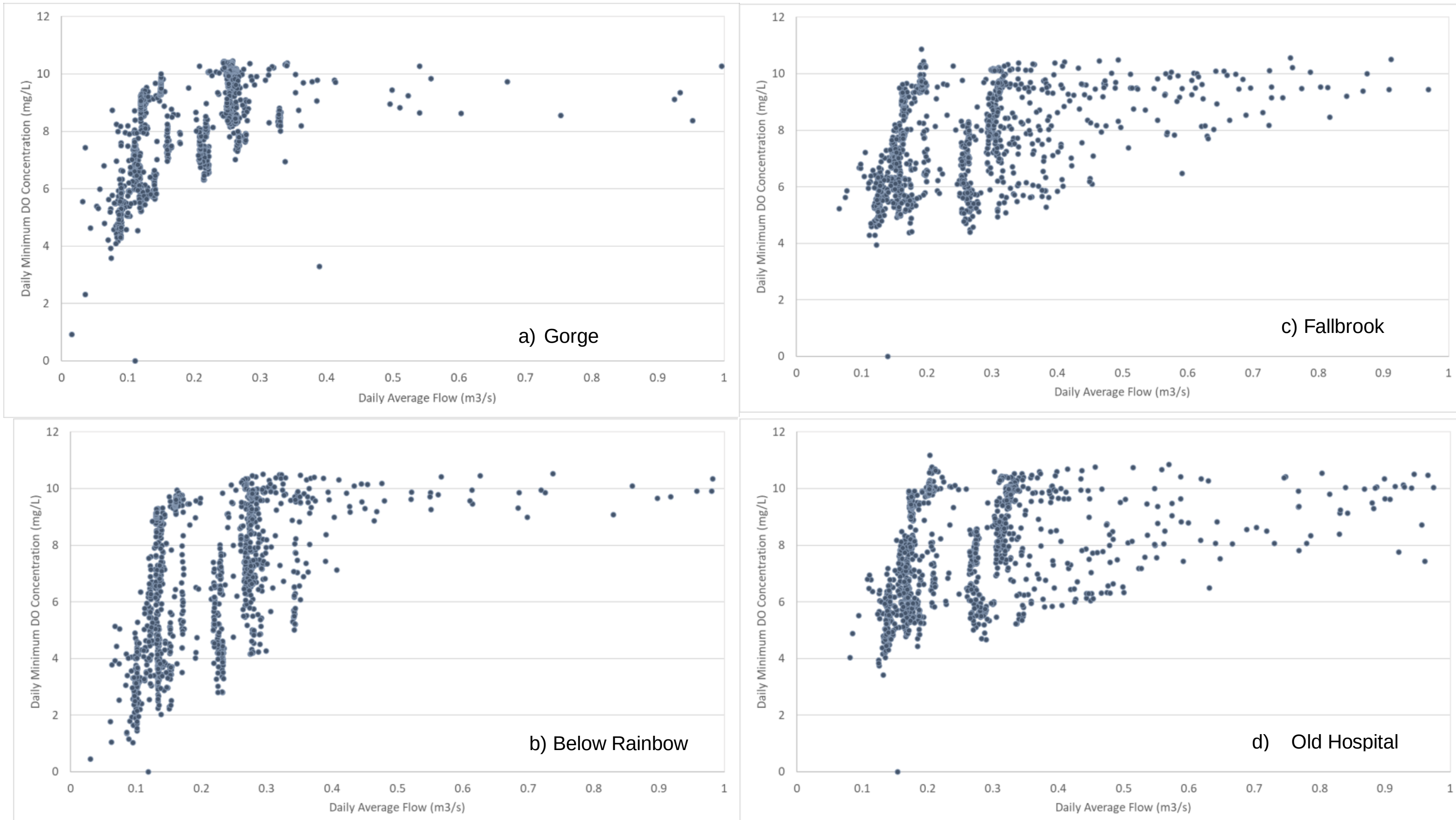


Figure 2.5. Predicted Daily Minimum DO Concentration and Daily Average Flow at SMR Gorge (a), below Rainbow (b), Fallbook (c), and Old Hospital (d).

Dissolved Oxygen. Regressions that relate the year-round median TN (or TP) concentration to the frequency of 7DADMin excursions are presented in Figure 2.6. According to the model, compliance with a year-round COLD DO target is not feasible with nutrient reductions alone, which the sensitivity analyses demonstrate is likely due to the influence of temperature (see Section 2.2.2).

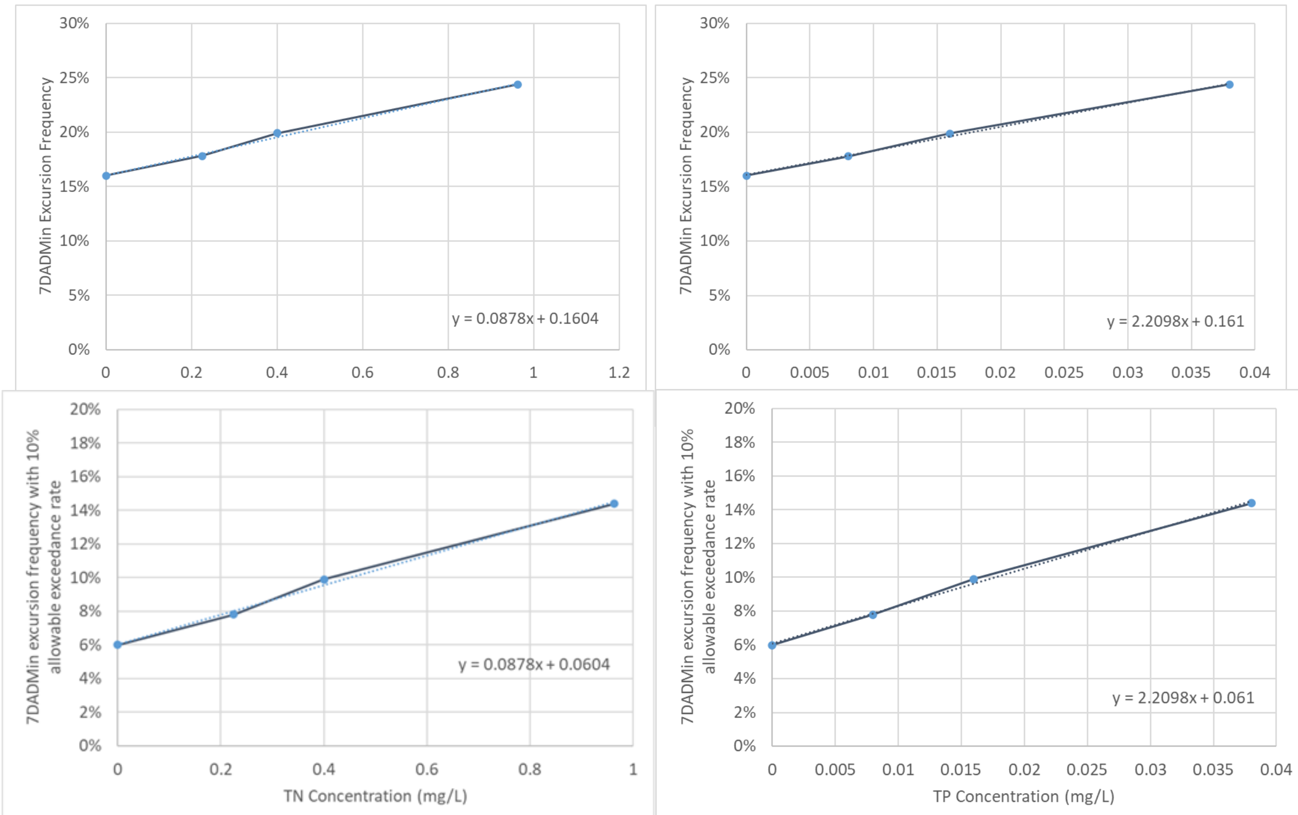


Figure 2.6. Median TN concentration (mg/L, top left panel) and TP (mg/L, top right panel) average 7DADMin excursion frequency of the DO target across monitoring sites (Gorge, below Fallbrook, below Rainbow, and near Old Hospital) with no allowable exceedence frequency versus that with an allowable 10% exceedence frequency for median TN concentration (mg/L, bottom left panel) and TP (mg/L, bottom right panel).

When the COLD beneficial use is applicable year-round at these sites without a 10% exceedance frequency, a nutrient reduction of 95 percent relative to current conditions translates to year-round median TN and TP concentrations of about 0.225 mg-N/L and 0.008 mg-P/L (Table 2.3), which still results in exceedances ~15% of the time. With a 10% allowable exceedance frequency, that percentage drops to 5-8%. The linear regression equations show that a TN or TP concentration of zero is predicted to still result in 7DADMin excursions.

When the WARM DO target of 5 mg/L is applied seasonally downstream of Rainbow Creek (which would require a Use Attainability Analysis[7] but is explored here to guide that potential

---

[7] According to US EPA (https://www.epa.gov/wqs-tech/use-attainability-analysis-uaa), a "*use attainability analysis (UAA) is a*

option), there are a lower frequency of exceedances with its application. Exceedances still occur, most notably below Rainbow Creek. Understandably, the exceedance frequency is even lower when a 10% allowance is applied (Table 2.4).

Generally, there is small difference in the frequency of excursions across the sites between the 80% and 95% nutrient reduction scenarios; the difference averaged across the sites is about 2.1 percent (i.e., 19.9% versus 17.8%).

Table 2.3. Predicted frequency of DO excursion by perennial site and overall average, then under 80-95% load reduction under different seasons, based on zero and a 10% exceedance frequency.

Location	0% Exclusion Allowance			10% Exclusion Allowance		
	Current	TN, TP Reduction		Current	TN, TP Reduction	
		80%	95%		80%	95%
7DADMin DO excursions (< 6 mg/L) for COLD beneficial use, Year-round						
Gorge	16.5%	13.4%	11.3%	6.5%	3.4%	1.3%
Below Rainbow Cr. confluence	38.7%	36.9%	35.5%	28.7%	26.9%	25.5%
Below Fallbrook	21.7%	15.7%	12.9%	11.7%	5.7%	2.9%
Near Old Hospital	20.8%	13.6%	11.5%	10.8%	3.6%	1.5%
Average	**24.4%**	**19.9%**	**17.8%**	**14.4%**	**9.9%**	**7.8%**
7DADMin DO excursions (< 6 mg/L) for COLD beneficial use, April through September						
Gorge	32.8%	26.6%	22.4%	22.8%	16.6%	12.4%
Below Rainbow Cr. confluence	72.7%	69.6%	67.9%	62.7%	59.6%	57.9%
Below Fallbrook	43.2%	31.1%	25.7%	33.2%	21.1%	15.7%
Near Old Hospital	41.3%	27.0%	22.8%	31.3%	17.0%	12.8%
Average	**47.5%**	**38.6%**	**34.7%**	**37.5%**	**28.6%**	**24.7%**
7DADMin DO excursions (< 6 mg/L) for COLD beneficial use, October through March						
Gorge	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Below Rainbow Cr. confluence	4.3%	3.7%	2.6%	0.0%	0.0%	0.0%
Below Fallbrook	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Near Old Hospital	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Average	**1.1%**	**0.9%**	**0.7%**	**0.0%**	**0.0%**	**0.0%**

Table 2.4. Predicted frequency of 7DADMin excursions (< 6 mg/L) for COLD beneficial use, Dec. 1 – May 31. Exceedances were only calculated for sites that could be considered for seasonal use (i.e., Gorge was excluded because of current salmonid use).

Location	0% Excursion Allowance	10% Excursion Allowance

structured scientific assessment of the factors affecting the attainment of uses specified in Section 101(a)(2) of the Clean Water Act (the so called "fishable/swimmable" uses). A UAA must be conducted for any water body when a state or authorized tribe designates uses that do not include the uses specified in section 101(a)(2) of the Act or when designating sub-categories of these uses that require less stringent criteria than previously applicable."

	Current	Nutrient Reduction		Current	Nutrient Reduction	
		80%	**95%**	**80%**	**80%**	**95%**
7DADMin excursions (< 6 mg/L) for COLD beneficial use, December 1 – May 31						
Below Rainbow Creek confluence	8.8%	7.3%	6.0%	0.0%	0.0%	0.0%
Below Fallbrook	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%
Near Old Hospital	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%
7DADMin excursions (< 5 mg/L) for WARM beneficial use, June 1 – November 30						
Below Rainbow Creek confluence	57.5%	51.0%	46.0%	47.5%	41.0%	36.0%
Below Fallbrook	3.7%	0.4%	0.0%	0.0%	0.0%	0.0%
Near Old Hospital	5.3%	2.0%	1.7%	0.0%	0.0%	0.0%
Year-round 7DADMin excursions (< 5 mg/L for June 1 – November 30 and <6 mg/L for December 1 – May 31						
Below Rainbow Creek confluence	33.0%	29.1%	26.0%	23.0%	19.1%	16.0%
Below Fallbrook	2.0%	0.2%	0.0%	0.0%	0.0%	0.0%
Near Old Hospital	2.9%	1.0%	0.8%	0.0%	0.0%	0.0%

Total Nitrogen and Phosphorus Concentrations. Use of the model to predict median instream concentrations gives some sense of the percent reduction in concentration or load that would be needed during specific periods, depending on the biostimulatory targets chosen. Predicted TN under the reduction scenarios was consistently above Basin Plan numeric guidance of 1 mg/L TN during the April through September time frame, but lower than that number during the October through March period. In contrast, predicted TP under the reduction scenarios is well below the Basin Plan numeric guidance of 0.1 mg/L TP throughout the year, which is not the case in monitored water quality (Sutula and Shultz 2022).

A nutrient reduction of 95% relative to current conditions translates to year-round median TN and TP concentrations of about 0.225 mg-N/L and 0.008 mg-P/L. The percent reductions in the load at SMR near the Old Hospital are also provided in Table 2.5. For example, an 80% reduction in nutrients from the watershed results in a 57.9 percent reduction in the year-round TN load at the Old Hospital. For comparison, the TN load reduction (applied uniformly) required for the Basin Plan (1 mg/L) is 7% at the Old Hospital (reduce from current level of 1.077 mg N/L and the TP load reduction (applied uniformly) required for the Basin Plan (0.1 mg/L) is 0% (i.e., the current year-round TP concentration at the Old Hospital is 0.042 mg/L, which is lower than 0.1 mg/L; Table 2.6). Note these analyses represent a simple load reduction; there are other ways to obtain the median target concentration with a lower load reduction (i.e., by strategizing reductions for dry weather/low flows).

Table 2.5. Predicted median instream total nitrogen concentration (mg/L), by time of year and effective load reduction at Old Hospital when load reduction at given upstream sites is achieved.

Location	Current Conditions	Nutrient Reduction	
		80%	95%
Predicted median instream total nitrogen concentration (mg/L), Year-round			
Gorge	0.658	0.195	0.089
Below Rainbow Creek confluence	1.029	0.474	0.289
Below Fallbrook	1.087	0.477	0.269
Near Old Hospital	1.077	0.453	0.251
Average	**0.963**	**0.400**	**0.225**
Load reduction at Old Hospital		***57.9%***	***76.7%***
Predicted median instream total nitrogen concentration (mg/L), April through September			
Gorge	0.766	0.223	0.103
Below Rainbow Creek confluence	1.222	0.571	0.359
Below Fallbrook	1.304	0.552	0.335
Near Old Hospital	1.432	0.664	0.375
Average	**1.181**	**0.503**	**0.293**
Load reduction at Old Hospital		***53.6%***	***73.8%***
Predicted median instream total nitrogen concentration (mg/L), October through March			
Gorge	0.557	0.154	0.069
Below Rainbow Creek confluence	0.871	0.376	0.208
Below Fallbrook	0.858	0.344	0.195
Near Old Hospital	0.857	0.330	0.178
Average	**0.786**	**0.301**	**0.163**
Load reduction at Old Hospital		***61.5%***	***79.2%***

Table 2.6. Predicted median instream total phosphorus concentration (mg/L), by time of year and effective load reduction at Old Hospital when load reduction at given upstream sites is achieved.

Location	Current Conditions	Nutrient Reduction	
		80%	95%
Predicted median instream total phosphorus concentration (mg/L), Year-round			
Gorge	0.032	0.009	0.004
Below Rainbow Creek confluence	0.040	0.018	0.009
Below Fallbrook	0.039	0.017	0.009
Near Old Hospital	0.042	0.019	0.009
Average	**0.038**	**0.016**	**0.008**
Load reduction at Old Hospital		***54.8%***	***78.6%***
Predicted median instream total phosphorus concentration (mg/L), April through September			
Gorge	0.043	0.012	0.005
Below Rainbow Creek confluence	0.056	0.025	0.014
Below Fallbrook	0.056	0.028	0.015
Near Old Hospital	0.058	0.035	0.017
Average	**0.053**	**0.025**	**0.013**
Load reduction at Old Hospital		***39.7%***	***70.7%***
Predicted median instream total phosphorus concentration (mg/L), October through March			
Gorge	0.020	0.004	0.002
Below Rainbow Creek confluence	0.024	0.011	0.006
Below Fallbrook	0.023	0.011	0.006
Near Old Hospital	0.029	0.012	0.006
Average	**0.024**	**0.010**	**0.005**
Load reduction at Old Hospital		***58.6%***	***79.3%***

Benthic and Submersed Algal Chlorophyll-a. According to the model predictions, a 95% nutrient load reduction would still produce algal biomass that is roughly an order of magnitude greater than a potential target of 35 mg chlorophyll-a m^{-2} (Table 2.7). Furthermore, the predicted benthic chlorophyll-a was demonstrated to be relatively insensitive to nutrient concentrations at these levels (see Section 2.2.2).

Table 2.7. Predicted median instream benthic chlorophyll-a concentration (mg m-2), by time of year as a function of current condition and 80 to 95% load reduction.

Location	Current Conditions	Nutrient Reduction	
		80%	95%
Predicted median instream chlorophyll-a concentration, benthic and submersed algae, year-round			
Gorge	593	529	476
Below Rainbow Creek confluence	573	534	453
Below Fallbrook	414	357	286
Near Old Hospital	403	333	265
Average	**495**	**438**	**370**
Predicted median instream total nitrogen concentration (mg/L), April through September			
Gorge	577	537	504
Below Rainbow Creek confluence	558	522	479
Below Fallbrook	327	302	272
Near Old Hospital	308	286	248
Average	**442**	**412**	**376**
Predicted median instream total nitrogen concentration (mg/L), October through March			
Gorge	551	447	361
Below Rainbow Creek confluence	466	419	364
Below Fallbrook	459	392	318
Near Old Hospital	437	377	285
Average	**478**	**409**	**332**

QUAL2Kw Application for Below Point of Diversion

Sensitivity Analyses. QUAL2Kw is run over a shorter duration and thus applications are constrained by these timeframes (typically diel conditions). Tetra Tech (2018) found that conditions in the lower mainstem of SMR appear to be strongly influenced by detrital matter transported from the upper river, such that the receiving water models are not appropriate for assessing the impact of onsite nutrient reductions on compliance with absolute DO objectives (e.g., DO < 5 mg/L). Instead, only nutrient reductions associated with Lower main stem targets expressed as diel variability can be evaluated, despite the fact that Water Board has chosen not to pursue a diel DO target for SMR. There are several reasons for why the QUAL2Kw model cannot be used to inform nutrient targets:

First, daily mean DO was most sensitive to the upstream DO boundary condition and SOD, which is the oxygen demand exerted on the water column by decomposition of organic matter within stream sediment. Daily average DO had relatively low sensitivity to algal dynamics associated with changes in N and/or P loads and concentrations. The implication of this finding is that allochthonous (external) sources of organic matter and their biological oxygen demand are driving the mean trend in DO, not live algal biomass produced on site by local ambient TN and TP. This finding is supported by observations of very high AFDM at the Old Hospital and Ysidora sites, despite much lower values of live algal biomass (Sutula and Schultz 2021). C:N ratios of the benthic organic matter suggest that the carbon source is labile (algal or bacterial) rather than terrestrial woody debris (Sutula and Shultz 2022).

Second, stream segments were shallower and warmer when boundary flow was reduced, increasing DO diel variability significantly. Lower reaeration, SOD, or DO in upstream mainstem waters produced larger diel variability in DO. Simulated lower N and P was shown to be effective at reducing DO diel variability. Isolated reductions of either N or P were less effective but still narrowed the diel range.

Third, QUAL2K2w sensitivity analyses showed that benthic chlorophyll-a was most responsive to changes in flow volume and SOD in the intermittent stream reaches near the Ysidora gage. Decreases in flow were associated with increases in benthic chlorophyll-a density as shallower relatively slow-moving streams are likely to experience algal proliferation. Increases in SOD were associated with increases in benthic chlorophyll-a density likely due to changes in nutrient availability from detrital decay. Benthic chlorophyll-a was sensitive to reduction in headwater N and P.

Dissolved Oxygen Diel Thresholds. QUAL2Kw predicts that the concentrations of TN and TP necessary to remain below a diel DO range threshold of ±3.0 mg/L are lower than San Diego Water Board Basin Plan biostimulatory numeric guidance of 1.0 mg/L TN and 0.1 mg/L TP. A significant reduction of TN to 0.1 mg/L OR TP to 0.01 mg/L results in a simulated DO diel range of 1.9 mg O/L (Figure 2.7).

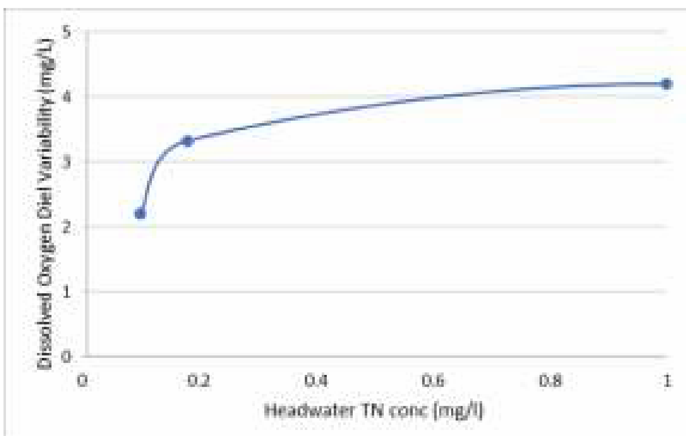


Figure 2.7. QUAL2Kw modeled DO diel variability as a function of TN and TP concentrations reductions, where TP concentration = 0.1*TN (e.g., at TN of 1, TP=0.1, etc.). See Tetra Tech (2018) for detailed explanation of factors controlling response.

2.3 Thresholds Derived from Biostimulatory-Biointegrity Empirical Stress-Response Models

Sutula et al. (2022) is completing a comprehensive synthesis of the scientific basis for biostimulatory targets, in support of the statewide wadeable stream biointegrity-biostimulatory policy amendment, a document which is expected to be available for public review in the fall 2021. During the review, they utilized three approaches to summarize the scientific basis for biostimulatory thresholds protective of aquatic life: 1) statistical change point detection (Figure 2.8, left panel), 2) Mazor et al. (in prep) regression methods to relate stressors to quantitative ecosystem service targets (e.g., percentile of index of biological integrity corresponding to a percentile of reference sites; Figure 2.8, right panel, EPA 2010), and 3) published literature-derived values from regions other than California. That work is summarized in **Section 2.3.1.**

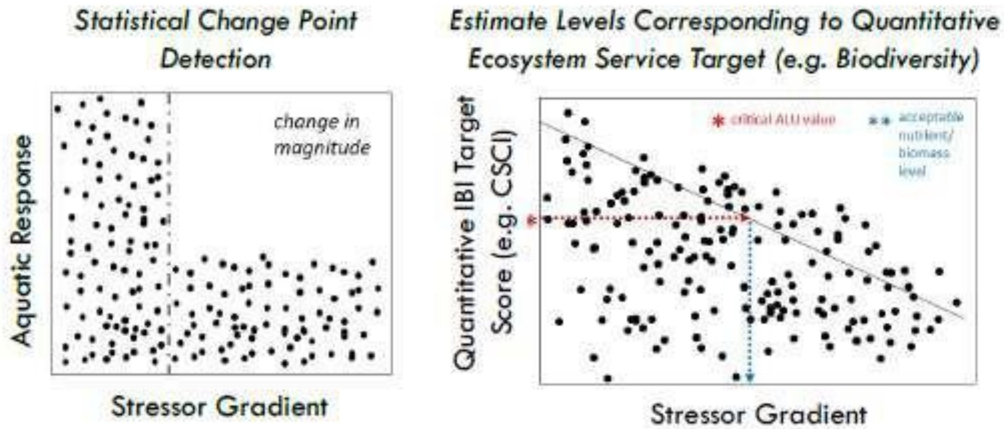


Figure 2.8. From Sutula et al. (2022). Examples of two statistical approaches used to derive quantitative thresholds (EPA 2010).

Sutula et al. (2022) found evidence for biostimulatory thresholds (in bold) based on the linkage to the following aquatic life measures (in italics):

- ↑ **TN, TP, Benthic Chlorophyll-a, and AFDM** ↓ *Algal, BMI Community Integrity*
- ↑ **TN, TP, Sestonic Chlorophyll-a** ↓ *Algal, BMI, Fish Community Integrity*
- ↓ **DO** ↓ *Fish and Invertebrate Physiological and Lethal Impacts, BMI Community Integrity*
- ↑ **pH Range** ↓ *Fish and Invertebrate Physiological and Lethal Impacts*
- ↑ **TN, TP**, Benthic Chlorophyll-a↑ **DO Diel Variability** ↓ *Fish, Algal, BMI Community Integrity*
- ↑ TN TP, Sestonic Chlorophyll-a ↑ **Cyanotoxins** ↑ *Fish, Algal, BMI, Wildlife Physiological/Lethal Impacts*

In this synthesis, we focus on TN, TP, benthic chlorophyll-a and AFDM. Algal percent cover did not have a strong relationship with aquatic life (Figure 2.10), but evidence for its use to protect REC2 is presented in Section 2.3.2.

One of the biggest challenges these approaches have to grapple with is the heterogeneity of natural, underlying gradients inherent in the data used to create the models. With stream systems important natural gradients across a data set include underlying geology, channel geometry, biogeography, precipitation, temperature, and hydroperiod, all of which interact to influence the taxonomic composition of the biota that live in the stream (Gasith and Resh 1999; Mazor et al. 2016), as well as the way eutrophication manifests in the stream (e.g., Nijboer and Verdonschot 2004; Dodds 2007; Paerl et al. 2011). Gillett et al. (in prep) developed an approach for deriving locale-specific eutrophication stress-response relationships within a medium-sized coastal watershed in Southern California. The goals of that study were to: 1) develop an approach to model of eutrophication stress on benthic invertebrate assemblages for multiple discrete sites and stream reaches within the watershed using data from a large bioassessment data set; and 2) determine the similarity or differences in biotic response to eutrophication across the watershed.

We follow a similar approach at that of Sutula et al. (2022), including pertinent information from their review (Section 2.3.1), augmenting with recent findings of locale-specific models for SMR

(Gillett et al. in prep; Section 2.3.2).

2.3.1 Biostimulatory Thresholds Protective of Aquatic Life Related Uses from Statewide Models

Basis for Protection Endpoints. Several studies of California wadeable streams have established a range of aquatic life use protection endpoints, based on a percentile of reference approach (Figure 2.9) for BMI (Mazor et al. 2016) and algae (Theroux et al. 2020). A biological condition gradient (BCG) model, developed through expert interpretation of raw taxonomic data, provided further support for interpreting the relevance of percentile of reference approach to loss of ecosystem structure and function along the BCG gradient (Paul et al. 2020). Figure 2.10 shows the crosswalk of CSCI 30th, 10th and 1st percentile of reference with BCG categories. BCG Bin 3 (evident loss of structure, minimal loss of ecological function) was most closely related to the 10th percentile of reference, while BCG 4 was closely related to the 1st percentile (moderate loss of structure, minor loss of function [Paul et al. 2020]). ASCI was updated since this BGC analysis was done and thus it cannot contribute here, but these bins roughly correspond to ASCI-Diatom (D) scores of 0.94 (30th percentile), 0.86 (10th percentile), and 0.75 (1st percentile).

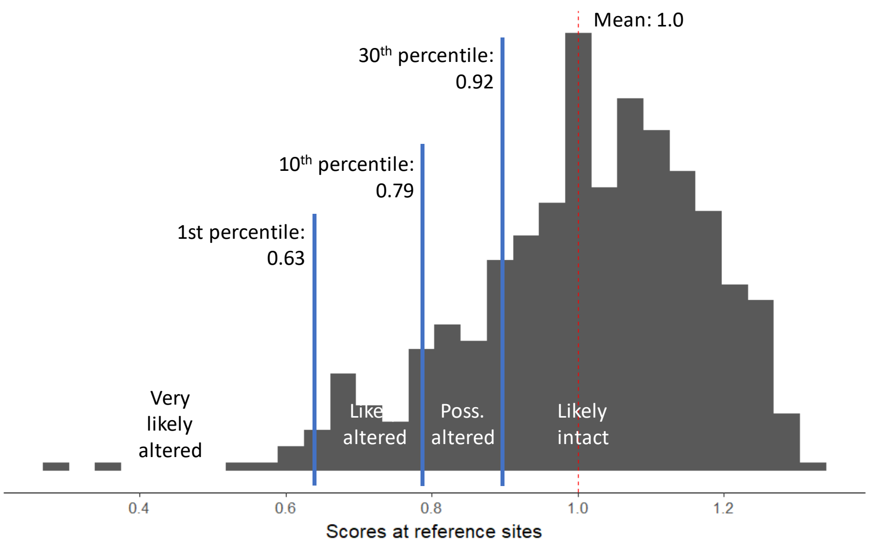


Figure 2.9. Graphical representation of the percentile of reference approach, as applied to CSCI scores from reference sites, showing the 30th, 10th and 1st percentile, with narrative descriptions of condition "bins." Data from Mazor et al. (2016).

Available literature, synthesized here, provides a range of TN, TP, benthic chlorophyll-a, and AFDM thresholds, derived at a statewide scale, that represent a range of protection of aquatic life related beneficial uses. Mazor et al. (in prep) provides evidence for thresholds protective of BMI and algal community structure, based on stress-response modeling (Figure 2.11). These values were further compared with change points derived for individual taxa, and with selected percentile of reference of values for these indicators for the South Coast region, and with published literature and adopted criteria in other U.S. states. Statistical approaches used in these studies do not allow for distinguishing thresholds between COLD and WARM uses.

Mazor et al. (in prep) derived these thresholds at a 90% relative probability that they are protective of CSCI and the ASCI at a range of stringency of protection levels, from the 30th to the 1st percentile of reference, using logistic regression models. These percentiles of reference represent different narratives of ecological protection, grounded in the degree of "intactness" of the biological community (Mazor et al. 2016). Sensitivity of relative probability level was explored (80%, 90%, and 95%); the full range of threshold combinations explored are available in Mazor et al. (in prep), supplemental Table 3. However, the 90th percentile or higher is recommended for further consideration based on the greatest number of models that were statistically validated. Specific biostimulatory thresholds varied on desired level of protection (30th versus 1st percentile of reference), which we highlight as a policy decision. Three indices are available for ASCI, but the diatom and hybrid versions, herein referred to as ASCI_D and ASCI_H, had a better signal to noise ratio in its response to environmental gradients (Theroux et al. 2020) than the SBA ASCIs (ASCI_S). Information for all ASCI indices is presented in Mazor et al. (in prep) or Theroux et al. (2020).

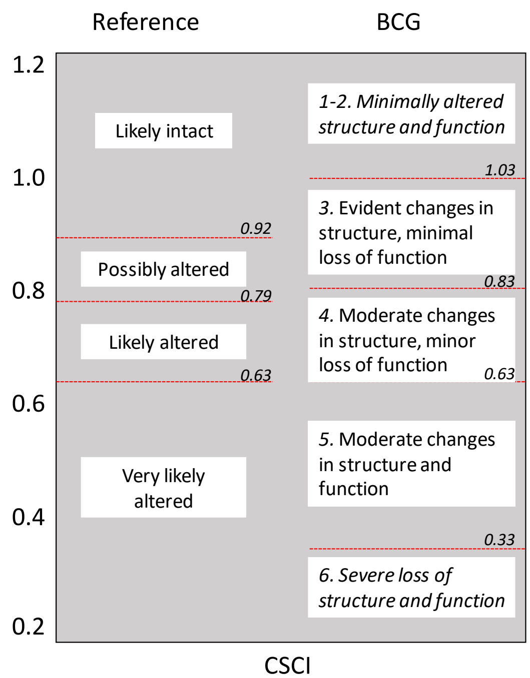


Figure 2.10. Crosswalk of BCG narratives and BCG-derived CSCI to a percentile of reference narratives and scores (left side of panel). Figure not drawn to scale. Data from Paul et al. (2020).

Total Nitrogen and Total Phosphorus. In general, thresholds of response of both BMI and algae occurred across a tight range of TN and TP values (Figure 2.11-2.12), though diatoms were generally more sensitive to increases in nutrient concentrations than BMI (Mazor et al. in prep). Specific thresholds varied on level of desired protection (30th versus 1st percentile of reference), but analyses for the 10th percentile of reference for the indices yielded thresholds of 0.32 to 0.59 mg/L TN and 0.08 to 0.10 mg/L TP (Table 2.8).

These CSCI 10th percentile TN and TP ALU protection and most change point thresholds were just above the 90th percentile of reference stream reaches (0.31 mg/L TN and 0.039 mg/L TP, Table 2.9, Mazor et al. (in prep). ASCI_D and ASCI _H thresholds were below the 90th percentile of reference sites (Table 2.9), but within the median to 75th percentile of ambient stream concentrations in South Coast (Table 2.10).

Benthic Chlorophyll-a and AFDM. In general, thresholds of aquatic response of both BMI and algae to benthic chlorophyll-a (live algal biomass) versus AFDM (total live algal biomass and detrital organic matter) occurred across reasonably narrow values at the 30th and 10th percentiles, with a wide range at the 1st reference percentile. As with TN and TP, algae were either equally generally more sensitive than BMI to these organic matter variables (Figure 2.11), Table 2.8, Mazor et al. in prep). Using the 10th percentile of reference as CSCI and ASCI_H ALU protection endpoints yielded 23-26 mg/m^2 chlorophyll-a and 13-20 g/m^2 AFDM.

These CSCI and ASCI 10th percentile benthic chlorophyll-a and AFDM ALU protection and change point thresholds were below the 90th percentile of South Coast reference stream reaches (34 mg/m^2 and 60 g/m^2, respectively: Table 2.8).

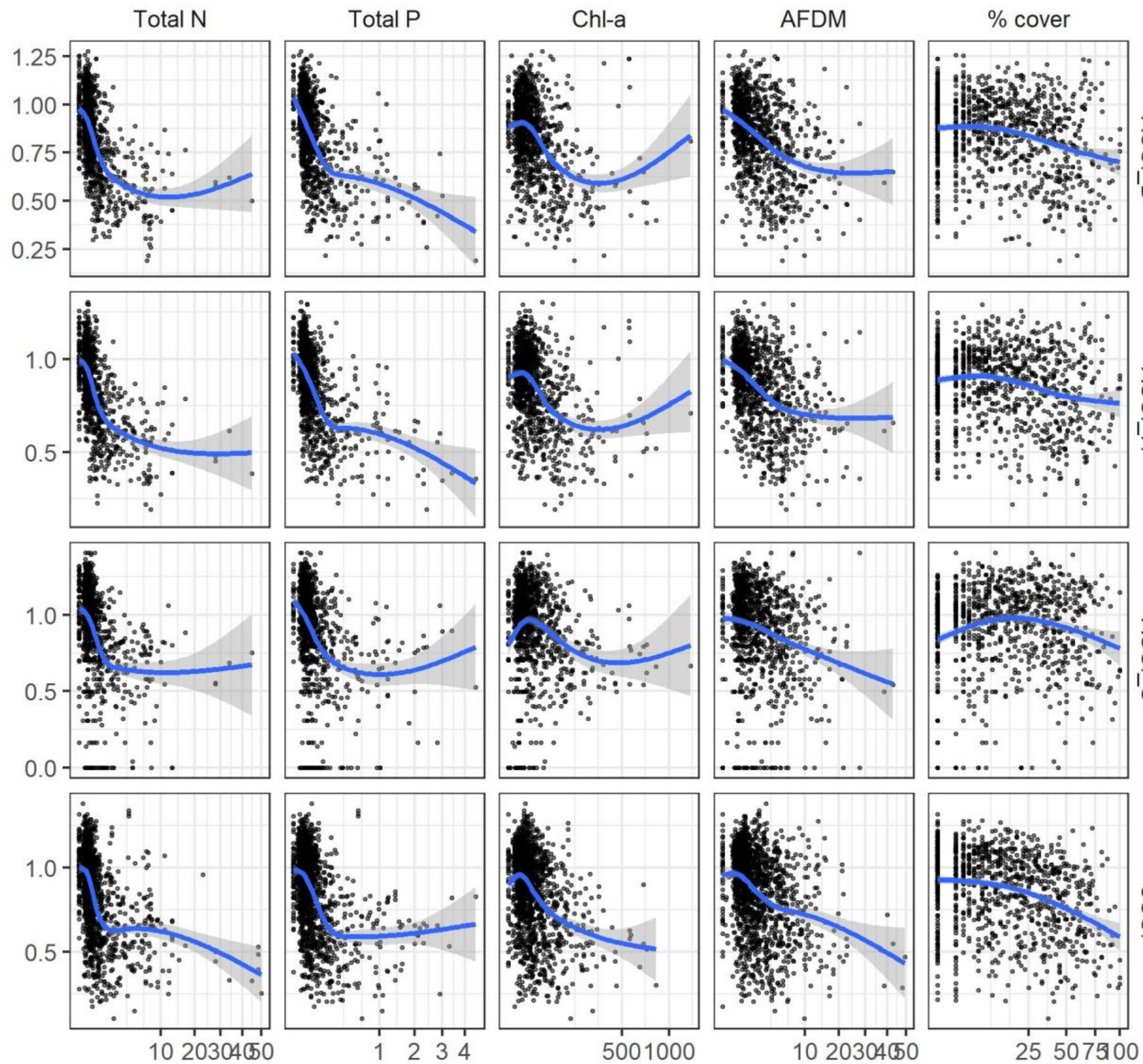


Figure 2.11. Biointegrity scores in relation to eutrophication indicators. Blue lines represent a fit from a general additive model; gray ribbons represent the 95% confidence interval around the fit (from Mazor et al. in prep).

Table 2.8. From Mazor et al. (in prep). Thresholds for eutrophication indicators based on a 90% relative probability of achieving the 10th percentile of reference biointegrity goals, with the 95% confidence interval around eutrophication thresholds and relative risk estimates. All thresholds shown below passed validation (i.e., the lower 95% confidence interval of the relative risk estimate was greater than 1 for both calibration and validation data sets), except for the ASCI_S threshold for total P (as indicated with italic font). Bold font indicates the most conservative threshold. Blank cells indicate that a threshold or confidence interval limit could not be identified within the evaluated ranges.

Index		Eutrophication threshold			Relative risk	
		Threshold	Lower 95% CI	Upper 95% CI	Cal	Val
Total N (mg/L)						
	ASCI_D	0.17	0.08	0.26	2.44	2.58
	ASCI_H	**0.13**	0.07	0.18	3.35	2.70
	ASCI_S		2.54			
	CSCI	0.64	0.42	0.87	4.17	3.17
Total P (mg/L)						
	ASCI_D	**0.027**	0.011	0.042	2.16	2.65
	ASCI_H	**0.027**	0.012	0.041	2.58	2.51
	ASCI_S	0.685	0.423	1.329	1.63	4.42
	CSCI	0.102	0.066	0.146	3.95	3.05
Chlorophyll-a (mg/m^2)						
	ASCI_D	23.7	9.0	37.5	1.84	2.17
	ASCI_H	**22.5**	9.9	34.2	2.35	2.20
	ASCI_S	191.3	120.4		2.90	2.76
	CSCI	26.1	17.7	34.8	2.39	2.39
AFDM (g/m^2)						
	ASCI_D	**12.8**	4.5	18.8	19.2	29.3
	ASCI_H	**12.8**	5.3	18.8	22.4	30.7
	ASCI_S	63.8	45.0	92.3	24.4	28.7
	CSCI	21.8	14.3	29.3	24.6	31.8

Table 2.9. Comparison of thresholds protective of biointegrity [statewide thresholds based on 10th percentile of reference (based on methods of Mazor et al. in prep), reach-specific biostimulatory thresholds derived for SMR mainstem sites protective of CSCI REF10 (based on methods of Gillett et al. in prep)], and statistical 90th percentile of minimally disturbed references sites in the South Coast region. Measurements above statewide CSCI thresholds are in bold and measurements above reach specific thresholds are in red.

Thresholds	Benthic chlorophyll-a (mg/m2)	AFDM (g/m2)	TN (mg/L)	TP (mg/L)
90th Percentile of Minimally Disturbed Reference Sites (n = 115), sampled April -September				
90thile	34	62	0.31	0.039
Statewide Thresholds Protective of REF10 (Mazor et al. in prep)				
ASCI_D	24	13	0.17	0.027
ASCI_H	23	13	0.13	0.027
CSCI	26	22	0.64	0.102
Reach-Specific Thresholds Protective of CSCI REF10 (Gillett et al. in prep), sampled April-September				
Ysidora	29	25	1.14	0.13
Old Hospital	39	23	1.24	0.15
Fallbrook	39	24	1.26	0.15
Below Rainbow	31	29	1.25	0.12
MWDXing	30	29	1.23	0.12
Gorge	31	30	1.21	0.12
SCCWRP Data	April - Sept	April - Sept	**Jan-Sept**	**Jan-Sept**
SMR Main Stem Mean and (in parentheses) 90th percentile for Year 1 Data				
Ysidora	**28** **(62)**	16 **(28)**	0.23 (0.30)	0.06 (0.08)
Old Hospital	**35 (39)**	**41 (73)**	0.47 **(0.99)**	0.05 (0.06)
Fallbrook	Not reported (NR)	NR	**0.94** **(1.54)**	0.04 (0.04)
Below Rainbow	NR	NR	**0.90** **(1.57)**	0.04 (0.03)
MWDXing	NR	NR	0.59 **(0.71)**	0.02 (0.03)
Gorge	NR	NR	0.56 (0.59)	0.05 (0.05)
CWRMA Release	Not applicable	Not applicable	0.44 (0.45)	0.02 (0.02)
SMR Main Stem Mean and (in parentheses) 90th percentile for Year 1 Data				
Ysidora	**26** **(41)**	**32 (41)**	0.18 (0.21)	0.07 (0.08)
Old Hospital	12 (24)	**142 (240)**	0.27 (0.42)	0.06 (0.08)
Fallbrook	**3349 (6109)**	**58 (119)**	**4.50 (9.63)**	0.05 (0.09)
Below Rainbow	**4133 (9252)**	**190 (424)**	**3.46 (7.44)**	0.05 **(0.14)**
MWDXing	**2183 (3544)**	**128 (246)**	**1.59 (2.90)**	0.80 **(0.12)**
Gorge	**1284 (2292)**	**110 (527)**	**0.66 (0.87)**	0.09 **(0.13)**
CWRMA Release	Not applicable	Not applicable	**0.65 (0.72)**	0.05 (0.08)

Table 2.10. Median, 75th, and 95th percentiles of raw (unweighted) TN, TP benthic chlorophyll-a, AFDM, and macroalgal percent cover (PCT_MAP), statewide and by region, at Reference sites (both probability and targeted datasets included). SE: standard error of the mean; CI: confidence interval (95%). From Fetscher et al. 2014.

Statistic by Biostimulatory Indicator type		Statewide	South Coast
		n=263	n=74
Chlorophyll-a (mg/m^2)	Median	6.9	12.5
	75^{th}	14.6	24.4
	95^{th}	44.1	124.8
AFDM (g/m^2)	Median	5.4	16.3
	75^{th}	11.9	26.8
	95^{th}	34.0	130.6
Macroalgal percent cover (%)	Median	7.0	9.5
	75^{th}	22.9	26.0
	95^{th}	45.7	60.0
TN (mg/L)	Median	0.091	0.138
	75^{th}	0.161	0.308
	95^{th}	0.462	0.925
TP (mg/L)	Median	0.019	0.018
	75^{th}	0.032	0.035
	95^{th}	0.074	0.106

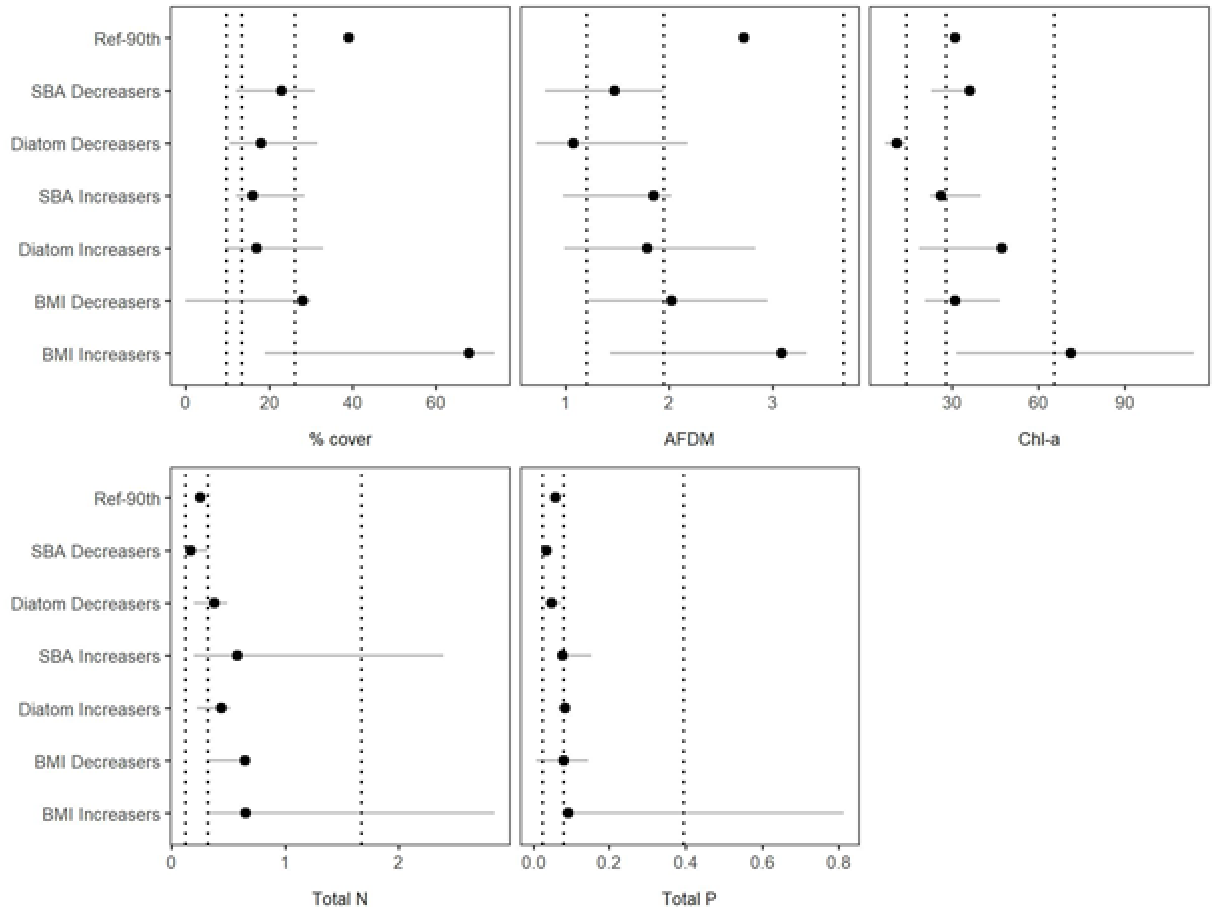


Figure 2.13 Titan plots showing change points in species presence/absence as a function of increasing TN (left panel) and TP concentration (right panel). From Mazor et al. (in prep). "Decreasers" are stress-intolerant taxa that decrease in abundance as the X axis stressor variable increases. "Increasers" are stress tolerant taxa that increase in abundance as the X axis stressor variable increases. SBA= soft bodied algae. Vertical lines show the 30th, the 10th and 1st percentile of statewide reference sites, from left to right.

2.3.2 Biostimulatory Thresholds Protective of Biological Integrity, Streams with Natural Gradients Similar to the SMR Watershed

Approach. Using the statewide bioassessment database, Gillett et al. (in prep) identified sites that were ecologically similar to wadeable streams sampled in the SMR watershed based upon their expected biological similarity, modelled from the expected taxonomic composition for each site (Mazor et al. 2016) and each reach (Beck et al. 2019). Within each group of ecologically similar sites, the probability of supporting reference condition stream invertebrates –CSCI score >=0.79, after Mazor et al. (2016) – across a gradient of eutrophication stress was modelled with logistic regression. Stressor thresholds with a 90% probability of supporting reference condition stream biota were compared across the entire watershed to examine the stream invertebrate and eutrophication relationships in an environmentally heterogeneous watershed.

Stream benthic macroinvertebrate and eutrophication data were obtained from the SMC/SWAMPT data portal (https://smc.sccwrp.org/) collected between 2001 and 2019. For each bioassessment site and stream reach, ecologically similar sites were selected from a California-wide data set of over 6,200 bioassessment sampling events. Sites were selected based upon their expected biological similarity, as described in Gillett et al. (2019). Pair-wise Bray-Curtis dissimilarity values between the SMR site and potential site are calculated from expected taxa capture probabilities extracted from a state-wide Observed-to-Expected (O:E) index. This approach approximates the ability of any two steam reaches to support similar BMI communities in the absence of anthropogenic disturbance using taxa profiles and capture probabilities predicted from underlying natural gradients (see Mazor et al. 2016). Sites were considered ecologically similar to a given SMR site if their expected Bray-Curtis dissimilarities were less than 0.1 between the two sites (Table 2). Similarly, for each stream reach, ecologically similar sites were identified using expected taxa capture probabilities extracted from a state-wide Observed to Expected index built upon StreamCat (landscape or GIS) data (Beck et al. 2019). Between 482 and 1,138 ecologically similar sites were identified for each bioassessment site within the SMR watershed based on those landscape characteristics. Of those, at least 113 had "great similarity" based on an expected biological similarity < 0.05. Nearly all of the ecologically similar sites were located within the coastal and inland chapparal regions of Southern California, with a few sites located in central or northern coastal California.

For each SMR site/reach and their ecologically similar sites, a logistic regression model was created with probability of a CSCI score >=0.79 as the response variable and one of the five eutrophication stressors as the predictor variable (i.e., 5 regressions per site/reach), using the same logistic regression models as Mazor et al. (in prep). For graphical display (Figures 2.15-2.16), sites and reaches were groups into three subregions as follows: lower (below Del Luz Creek), middle (De Luz to Gorge), and upper (above Gorge).

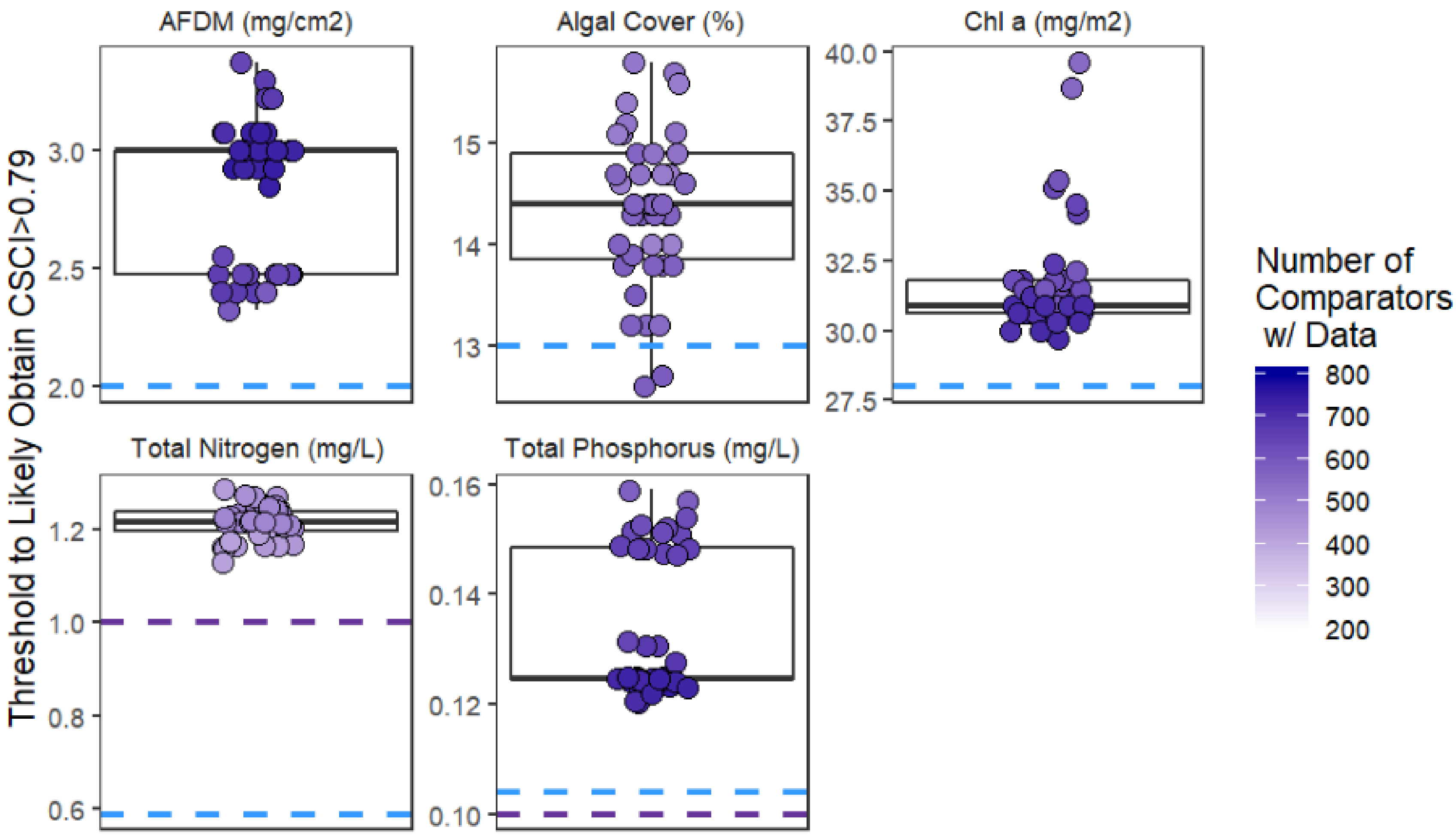


Figure 2.14. Site-specific thresholds for the 46 bioassessment sites in the SMR watershed, based on ecologically similar sites in the state bioassessment database. The darker purple the color, the greater the number of comparator sites that were found for that particular sites. Blue dash line is statewide threshold from Mazor et al. (in prep), purple dashed line is Basin Plan. The data range show the distributionod thresholds for each of the site, so if you have a split in the graph, it means that you would expect different sensitivities to that stressor (e.g., TP and AFDM) based on the distinct biological communities found that those distinct group of sites.

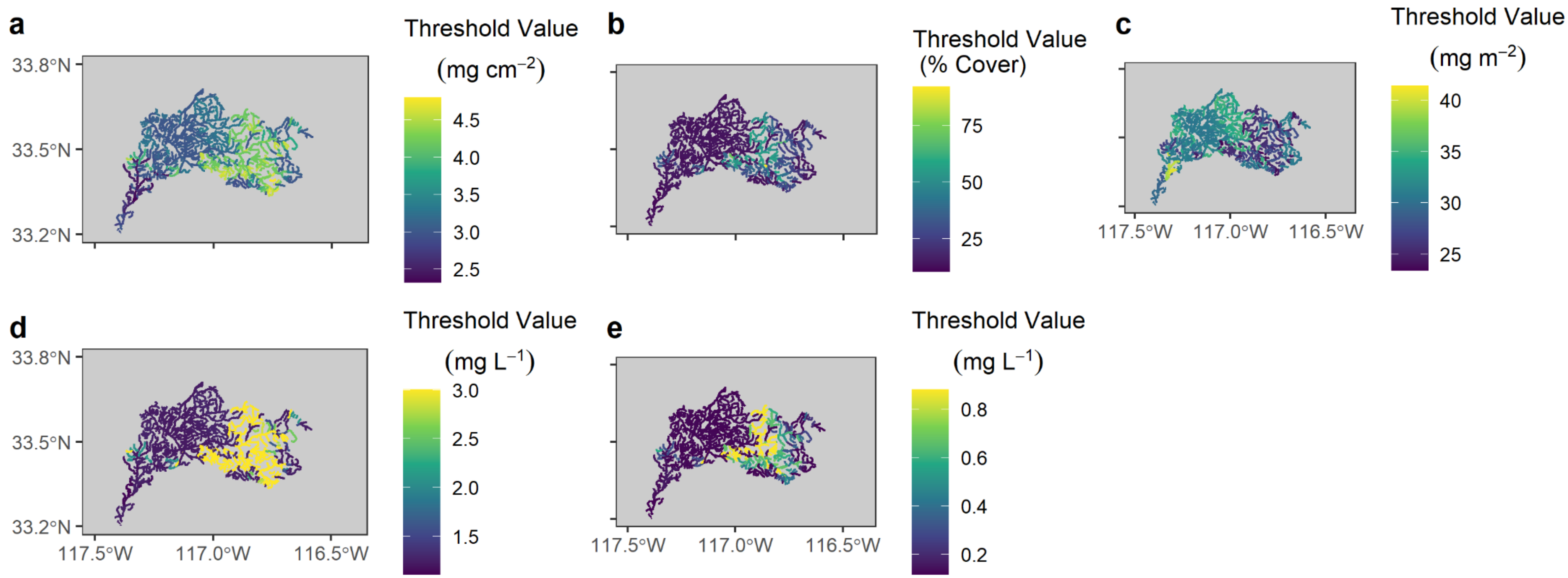


Figure 2.15. Graphical representation of reach-specific thresholds for (a) AFDM (mg/cm^2), (b) % cover, (c) benthic chlorophyll-a (mg/m2), (d) TN (mg/L), and (e) TP (mg/L) for the SMR watershed, grouped in as lower (below Del Luz Creek), middle (De Luz to Gorge), and upper (above Gorge). From Gillett et al. (in prep).

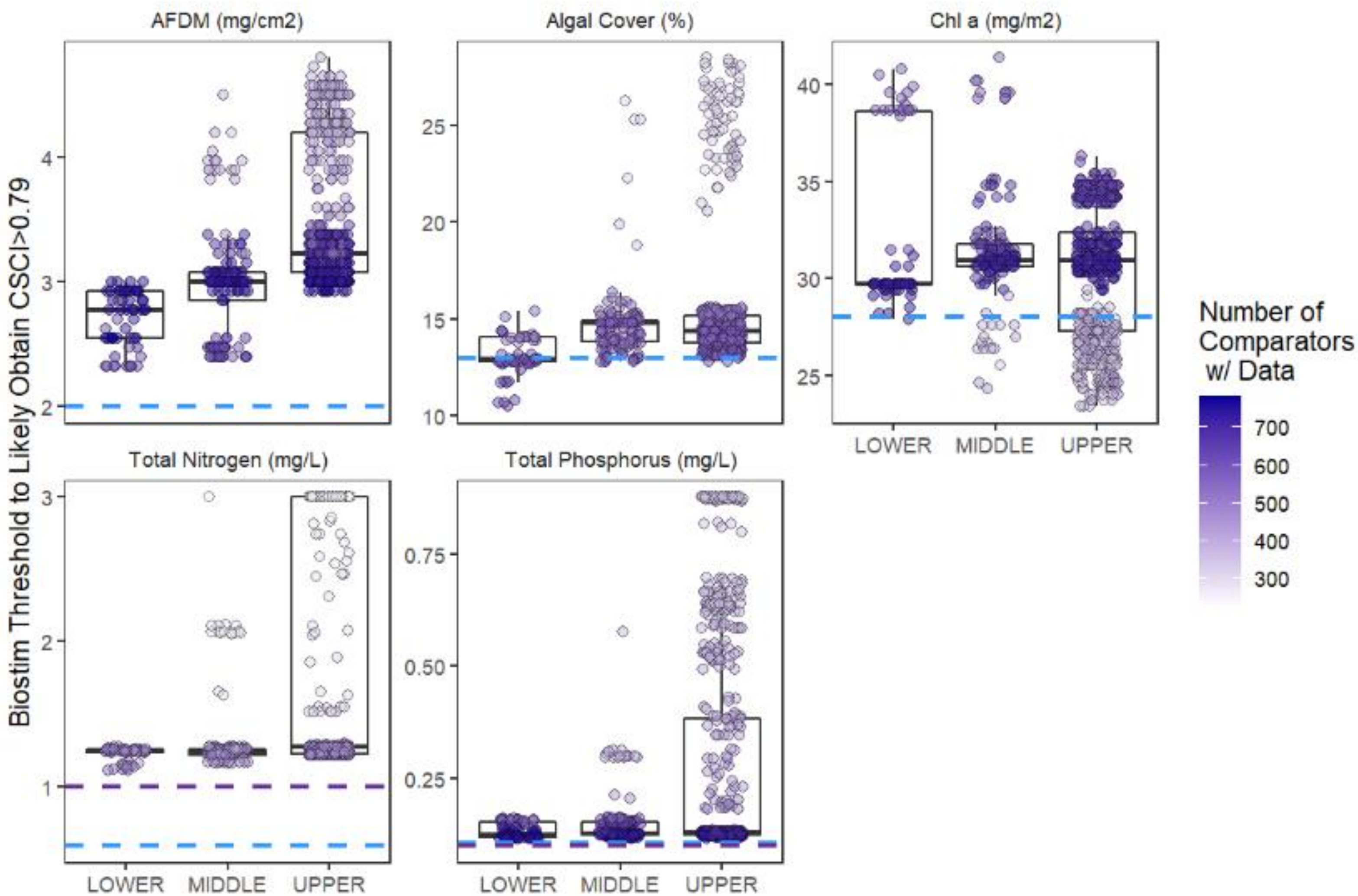


Figure 2.16 Thresholds predicted for the each SMR reach (see Figure 2.16) for the the SMR watershed, grouped in as lower (below Del Luz Creek), middle (De Luz to Gorge), and upper (above Gorge). From Gillett et al. (in prep). Color bar represents number of data point. The upper designations includes areas above the dams, which tend to have higher thresholds than those areas below the dams (see Figure 2.15). Blue dash line is statewide threshold from Mazor et al. (in prep), purple dashed line is Basin Plan. Values with light colors represent sites for which data density of comparator sites was low and therefore confidence in these thresholds is low.

Findings. The thresholds for biostimulatory indicators are given for 46 SMR bioassessment sites (Figure 2.14) and for SMR reaches, based on the expected natural gradients detectable in the stream reach as assessed by StreamCAT (Figure 2.15-2.16, Table 2.9). Thresholds in the lower and middle watershed group (below the Gorge, synonymous with our study area) were 1.14-1.25 mg/L TN and TP of 0.12-0.15 mg/L, slightly higher than Basin plan numbers (Table 2.9). Benthic chlorophyll-a ranged from 28-40 mg/m^2, with the SMR mainstem ranging from 29-31 mg/m^2. Similarly, AFDM ranged from 23-35 mg/m^2, with the SMR mainstem ranging from 23-30 g/m^2. Thus reach-specific values attuned to natural gradients found in the SMR mainstem appear higher than statewide values found in Mazor et al. (in prep), the 90th percentile of minimally disturbed reference sites (Mazor et al. in prep), and existing SD Water Basin Plan numeric guidance (1.0 mg/L TN and 0.1 mg/L TP).

2.4 Macroalgal Percent Cover, Benthic Chlorophyll-a Impacting Recreational Use

Aesthetic nuisance conditions are caused by the fraction of stream surface covered by visible benthic algal mats, especially filamentous green algae (e.g., *Cladophora* spp). EPA recommends end user surveys to determine levels of macroalgal cover or algal biomass that is linked to impacts on recreational use. Although California has not undertaken recreational use surveys, two Western states, Montana (Suplee et al. 2009) and Utah (Jakus et al. 2017), completed surveys employing a similar rigorous methodology, with highly consistent findings on levels of percent macroalgal cover and (related) benthic algal biomass that represent “desirable” recreational user experiences (Figure 2.17). Both Suplee et al. (2009) and Jakus et al. (2017) found that benthic chlorophyll-a of 150 mg/m^2, with associated macroalgal cover categories > 20% resulted in a 30-70% drop in percent “desirable” responses either by mail- or on-river surveys. This is consistent with Welch (1998; > 20%, > 150 mg/m^2) for north American temperate streams and a West Virginia study (Responsive Management, 2012; > 25%). These literature values of > 20 to > 25% cover that are representative of recreational aesthetic impacts are within the same range of the percent macroalgal cover range that was protective of 90% confidence level REF10 thresholds for CSCI (13%) and ASCI (21%) (Mazor et al. in prep).

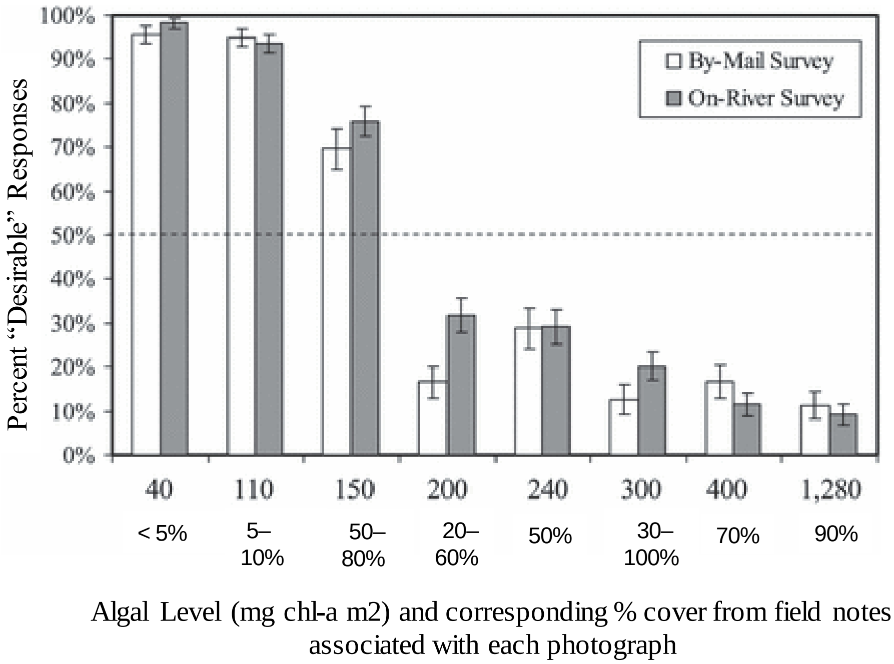


Figure 2.17. Percent desirable responses from the By-Mail and On-River Surveys. Each histogram set of two bars represents a photograph, with associated benthic chlorophyll-a (40-1,280 mg/m^2 and underneath the representative percent cover range taken from field notes associated with each photograph below each biomass estimate. Error bars are the 95% confidence level of each proportion, expressed as percent error. Modified from Suplee et al. (2009).

Differences between California versus Montana and Utah benthic algal biomass protocols are problematic for making comparisons between biomass levels that are deemed protective of recreational use. For example, Montana DEQ requires the "Hoop Method" be used for all samples where filamentous algae is present, regardless of stream substrate, in which the floating mat is sampled comprehensively within an area roughly equivalent to the bottom of a 5-gallon bucket. This contrasts with California's Fetscher et al. (2009) protocol, which is optimized for algal taxonomy and therefore likely representing a biased low benthic chlorophyll-a estimate of the filamentous mat at higher biomass levels (Sutula et al. 2022). The implication of this is that REC2 algal thresholds from Montana (Suplee et al. 2009) and Utah (Jakus et al. 2017) cannot be used as a basis for California biomass thresholds protective of REC2.

Sutula et al. (2021) analyzed California ambient stream bioassessment data to look at the relationship between % cover categories and benthic chlorophyll-a, using the dataset and approaches described in Mazor et al. (in prep; Figure 2.18). Benthic chlorophyll-a of 19 to 41 mg/m^2 had 90% probability of meeting macroalgal percent cover goals in the range of 13% to 30%, which was roughly comparable to CSCI and ASCI 90% probability REF10 thresholds of 28-58. In contrast, 50% goal, which the Central Coast Water Board has utilized to protect REC2 (Worcester et al. 2010), corresponded to a biomass of 123 mg/m^2. This value exceeds exhaustion thresholds for BMI and algal aquatic life protection (Fetscher et al. 2014), at CSCI and ASCI ranges that have narratives "very likely altered" (Mazor et al. 2016) with moderate to severe loss of structure and function (Paul et al. 2020).

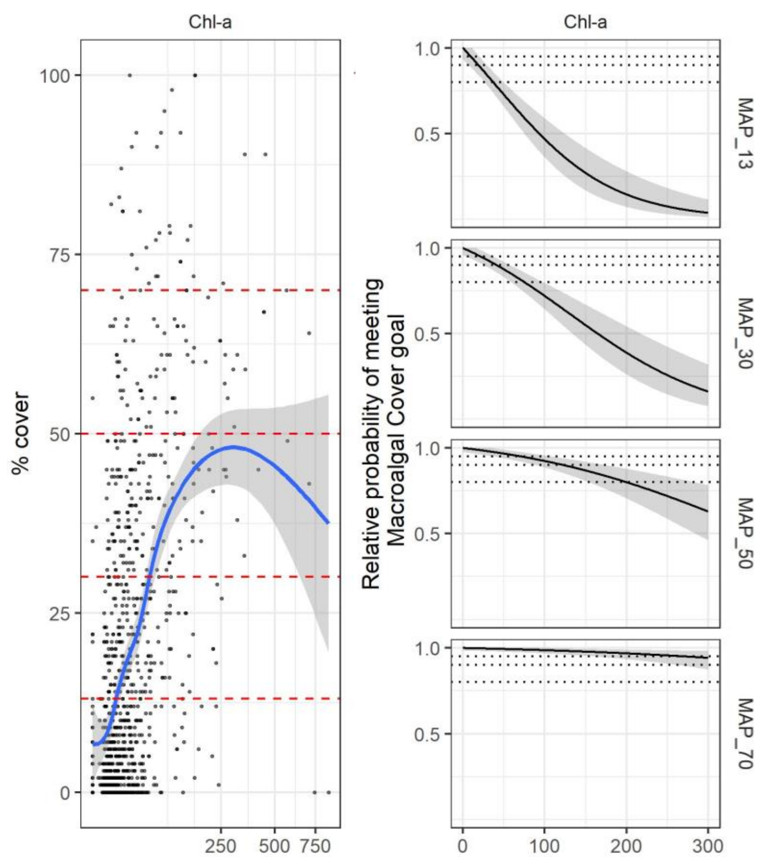


Figure 2.18. Scatter plot of benthic chlorophyll-a on X-axis versus percent cover on Y-axis (left panel) and relative probability of meeting attached macroalgal percent cover (MAP) goal of 13%, 30%, 50%, and 70% cover (right panel). Dashed red lines in graph on left represent this range of cover endpoints. Dashed lines on the right panel graphic indicate threholds associated with different levels of confidence from 95%, 90%, and 80% (top to bottom).

However, percent cover, as currently measured by the Fetscher et al. (2009) SOP, is not recommended as a primary line of evidence because 75th and 90th reference ranges are substantially higher than those suggested by user surveys.

2.5 Discussion

We utilized three lines of evidence from statistical and mechanistic models of eutrophication and biointegrity responses to biostimulatory gradients in the wadeable streams of the SMR watershed and compared these values to the 90th percentile of minimally disturbed reference sites and to the San Diego Basin plan biostimulatory numeric guidance.

- Mechanistic modeling of DO responses to nutrients and algal biomass
- Change point analyses for algal and benthic invertebrate assemblages
- Statewide thresholds protective of CSCI and ASCI REF10
- Reach-specific thresholds protective of CSCI REF10

These approaches were generally equally or more protective than thresholds utilized to protect REC2 (aesthetics). REC1 threats from cyanobacterial HABs and associated cyanotoxins were not considered in these analyses.

Drivers of Dissolved Oxygen and Implications for Biostimulatory Targets

We found that biostimulatory substances that promote algal growth actually contribute to ~30% of the DO budget for the SMR mainstem, while conditions such as temperature and flow play a major role in compliance with the proposed DO target. Algae were predicted to be relatively insensitive to nutrient load reductions and thus was less informative for TN and TP target discussions.

However, the mechanistic model was extremely useful to guide discussion of the appropriate interpretation of the DO target. The WASP modeling served to demonstrate key points that are germane for the discussion of interpretation of the DO objective for SMR main stem. First, the model shows compliance with a **year-round** COLD DO target is not feasible based on nutrient reductions only, even with a 10% allowable exceedance frequency, which the sensitivity analyses demonstrate is likely due to the influence of temperature (see Section 2.2.2). Second, when the WARM DO target of 5 mg/L is applied seasonally at Fallbrook, below Rainbow Creek confluence, and Old Hospital, there is a lower frequency of exceedances with its application, with the model pointing to the greatest number of exceedances still occurring below Rainbow, where we note that nutrients are often an order of magnitude above the basin plan TN and TP objectives.

Thus, compliance with a year-round COLD beneficial use target of 7-day mean of daily minima > 6 mg/L cannot be reached without including a 10% allowable exceedance frequency because temperature will drive some periods of non-compliance. Below Rainbow Creek confluence, where steelhead are not expected to oversummer because of thermal habitat preferences (i.e., routinely exceeding 21°C), compliance is feasible with a WARM DO target of 5 mg/L and 10% allowable exceedance frequency.

Implications of Analyses for Biostimulatory Targets Protective of Biointegrity

The collective works of Mazor et al. (in prep) and Sutula et al. (2022) show that thresholds at which TN, TP, benthic chlorophyll-a, and AFDM are having adverse effects on benthic invertebrate and algal biointegrity are occurring are very low, typically within or below the 90th percentile of the statistical distribution of reference sites (Fetscher et al. 2014; Table 2.10), or in the case of Gillett et al. (in prep), slightly above. Collectively, this evidence is strong and signals the extreme sensitivity of Mediterranean streams to eutrophication.

Thresholds derived from ALU biointegrity goals (Mazor et al. in prep) and change point analyses (Fetscher et al. 2014) were in close agreement with the range of change point analyses for TN and TP in streams throughout the U.S. (Table 2.11). This consistency of statewide CSCI and ASCI-derived thresholds is surprising given that most studies were conducted in different biogeographic provinces (i.e., east of the Rocky Mountains), across a diverse array of stream types (Evans-White et al. 2009), in regions with cooler climates and those with higher levels of precipitation year-round than that which represents the bulk of our study region, and some were conducted in rivers rather than wadeable streams. Mazor et al. (in prep) findings are most comparable to that of Jessup et al. (2015) in New Mexico wadeable streams, because of geology, topographic gradients, and flow regime (Table 2.12). The range of California wadeable stream thresholds are also squarely within the range of adopted nutrient criteria in the U.S., which range from 0.18 – 2.0 mg/L TN and 0.03 – 0.49 mg/L TP (Table 2.13), while those derived for natural gradients similar to the Santa Margarita River watershed by Gillett et al. (in prep) were considerably higher than the norm.

Although benthic chlorophyll-a is a commonly measured parameter in eutrophication assessments of wadeable streams, far less literature outside of California has been devoted to quantifying thresholds protective of BMI or a balanced algal community, compared to nutrients (Table 2.11). BMI REF10 thresholds with a 90% relative probability level (28 mg/m^2) are somewhat higher than the mean monthly benthic chlorophyll-a of 13-20 mg/m^2 were associated with a 50% reduction in the percentage of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa in New Zealand streams (Biggs 2000). The distinction between mean versus peak is critical in interpreting impacts. Biggs (2000) found that benthic invertebrates can continue to thrive when benthic algal abundance is elevated for a short duration, but that more substantial adverse effects would occur with chronic algal blooms. Unfortunately, time course sampling that would be helpful to relate the one-time sample taken during the perennial stream assessment spring-summer index period to mean monthly or maximum statistics has not been conducted for California on a large scale sufficient to support comparable analysis. These values are substantially lower than that of Miltner et al. (2010), who found a change point at 107 mg/m^2 related to changes in the abundance of EPT taxa in Ohio streams, but within the same range (40 mg/m^2) of predicted benthic chlorophyll-a that is protective of having a low percent (i.e., < 5%) of cyanobacteria abundance (Carleton et al. 2009).

Although thresholds arising from the present study were derived based on biointegrity measures specific to algal and benthic macroinvertebrate assemblage composition, comparisons may be made to literature linked to other aquatic life. For example, Biggs (2000) asserted that protection of salmonids affords a slightly higher algal biomass threshold than is protective of sensitive benthic invertebrate species; mean monthly benthic algal biomass in New Zealand streams that are "renowned for their trout fisheries" was 23 mg/m^2, with average maximum biomass of 171 mg/m^2.

Implications for Diagnosis of Eutrophication the SMR Main Stem

The applied combination of models, monitoring data, and syntheses was useful in illustrating the nature of biostimulatory problem in the SMR Lower and Upper mainstem. Concentrations of TN and TP at the Gorge and all biostimulatory indicators in the Lower main stem could generally be found in the range between the 90th percentile of South Coast reference sites and the biointegrity thresholds of adverse effect found in the literature (Mazor et al. in prep; Gillett et al. in prep); the difference between these values is within analytical variability of many commercial labs that analyze nutrients and field variance of measured benthic chlorophyll-a. Clearly for the Lower mainstem, decisions on statistics (allowable exceedance frequency, averaging, critical period) could determine whether this reach is considered to be "impaired," a policy decision by the Water Board. Decisions on how to apply these thresholds (allowable exceedance frequency, averaging, critical period) become more important in determining whether the Lower main stem is exceeding targets.

At mainstem sites above the Point of Diversion, one or more biostimulatory indicators routinely exceeded the range of thresholds produced by this synthesis. In the case of benthic chlorophyll-a, ambient biomass as typically 1-3 orders of magnitude higher. For nutrients, exceedances of the upper range of thresholds synthesized here occurred routinely at Fallbrook, below the confluence with Rainbow and the MWD crossing, all of which are downstream of catchments are major contributors to nutrient loads in this watershed (Tetra Tech 2020a).

The observation that the Gorge reach has lower nutrient concentrations, but extremely high algal biomass is intuitively confusing. It may be the case that the CWRMA release provides sufficient flow and nutrient concentrations, in combination with other sources and a favorable substrate, to continuously stimulate macroalgal blooms, which can further take advantage of upstream pulses of nutrients through luxury uptake and storage. Thus, these elevated blooms may be function high loads, rather than high nutrient concentrations per se. Tetra Tech found that removal of the CWRMA release from WASP modeling reduced the predicted algal biomass at the Gorge by ~20% (see chapter 3). The CWRMA release buffers water temperatures, increases DO throughout the mainstem, and maintains sufficient flow for fish and other aquatic life, so management decisions that affect CWRMA releases and the role it plays in maintaining watershed health should be carefully considered.

Table 2.11. Change point thresholds for stream responses to nutrient concentrations, summarized across aquatic life indicators. Min: Minimum reported threshold. Max: Maximum reported threshold. TP and TN concentrations are in mg/L.

Citation	Region	ALI measure(s)	Gradient(s)	Threshold detection method	min. TP	max. TP	min. TN)	max. TN
Fetscher et al. 2014	California	BMI, algae	Biomass, nutrients	TITAN, nCPA, CART, piecewise regression, BRT	0.011	0.267	0.13	2.1
Jessup et al. 2015	New Mexico	BMI, algae, DO minima, DO diel variability	Biomass, nutrients	nCPA	0.029	0.067	0.26	0.52
Baker et al. 2010	Everglades	BMI	TP	TITAN and nCPA	0.015	0.019	-	-
Black et al. 2011	Western U.S.	Diatoms	TN, TP	Piecewise regression	0.03	0.28	0.59	1.79
Caskey et al. 2013	Indiana	Fish and BMI	Biomass, nutrients	nCPA	0.083	0.144	1.03	2.61
Miltner 2010	Ohio	BMI	Biomass, nutrients	nCPA	0.048	0.078	-	-
Evans-White et al. 2009	KS., MS, NE	BMIs	TN, TP	nCPA	0.05	0.05	1.04	1.04
Paul et al. 2007	SE PA	BMIs, diatoms	TP	nCPA	0.038	0.064	-	-
Qian et al. 2003	Florida Everglades	BMIs	TP	Change point with nonparametric & the Bayesian methods	0.011	0.014	-	-
Richardson et al. 2007		Algal, macrophyte and BMI	TP	Bayesian change point analysis	0.008	0.024	-	-
Smith et al. 2010	New York	BMI, diatom	TN, TP	nCPA	0.009	0.07	0.41	1.2
Smith et al. 2007	New York	BMIs	TP, NO_3	Hodges-Lehmann estimation	0.065	0.065	0.98 (NO_3)	0.98 (NO_3)
Smucker et al. 2013	Connecticut	Diatoms	TP	Boosted regression trees	0.019	0.082	-	-
Stevenson et al. 2008	Mid-Atlantic Highlands	Diatoms	TP	Loess regression & regression trees	0.012	0.027	-	-
Wang et al. 2007	Wisconsin	Fish, BMIs	TN, TP	Regression tree analysis & 2-dimensional KS techniques	0.06	0.09	0.54	0.61
Weigel and Robertson 2007	Wisconsin	Fish, BMIs	TN, TP	Regression tree analysis	0.06	0.06	0.64	0.64

Table 2.12. Candidate nutrient threshold values based on 90th percentile of reference and stress-response change point analyses in wadeable streams of New Mexico, based on frequency distributions and ranges of endpoints by nutrient and stream class (reflecting gradient and underlying geology). See Jessup et al. (2015) for additional details.

		TN Flat	TN Moderate	TN Steep
TN	Reference 90th quantile	0.69 mg/L	0.42 mg/L	0.30 mg/L
	90% confidence interval	0.62 – 0.85	0.38 – 0.51	0.26 – 0.34
	Stressor-response median	0.52 mg/L	0.33 mg/L	0.26 mg/L
		TP High-Volcanic	TP Flat-Moderate	TP Steep
TP	Reference 90th quantile	0.105 mg/L	0.061 mg/L	0.030 mg/L
	90% confidence interval	0.089 – 0.114	0.051 – 0.069	0.016 – 0.053
	Stressor-response median	0.067 mg/L	0.066 mg/L	0.029 mg/L

Table 2.13. Summary of CA numeric TN and TP translator (San Diego Board) and adopted nutrient criteria for rivers and streams across U.S. States and Territories. All TN and TP values are given in mg/L. Guam values are for Nitrate-N and phosphate-P. Dashes represent no indication that numbers were derived or established.

State	Year Published	Criteria Categories	Total Nitrogen	Total Phosphorus
California, San Diego	2016	Numeric translator	1.0	0.1
Minnesota	2015	North	-	0.05
		Central	-	0.1
		South	-	0.15
Wisconsin	2010	Rivers	-	0.1
		Streams	-	0.075
Florida	2012	Panhandle West	0.67	0.06
		Panhandle East	1.03	0.18
		North Central	1.87	0.3
		Peninsular	1.54	0.12
		West Central	1.65	0.49
New Jersey	1981/2011		--	0.1
Hawaii	2014	Wet season (Nov-Apr)	0.25	0.05
		Dry season (May-Oct)	0.18	0.03
American Samoa	2013		0.3	0.175
Northern Marianas	2014	Class 1 (no discharge)	0.75	0.1
		Class 2	1.5	0.1
Guam	2010	S1 (no discharge)	0.025 NO3	0.10 orthoP
		S2	0.05 NO3	0.20 orthoP
		S3	0.10 NO3	0.50 orthoP
Puerto Rico	2016	SD	1.7	0.16
New York	2016		--	0.020-0.100

Montana	2014		0.3	0.020-0.039
Colorado	2012	Cold	1.25	0.11
		Warm	2.01	0.17

Table 2.14. Summary of literature sources of benthic chlorophyll-a thresholds (mg/m2) for wadeable streams

Region	**Type**	**Protection Endpoint**	**Benthic Chla (mg/m-2)**	**Source**
California	Wadeable streams	CSCI and H20 mean change point Oxygen saturated Algal spp Oxygen Depleted Algal spp.	19-40 45 115	Fetscher et al. 2014
New Zealand	Wadeable streams	50% reduction EPT taxa, Mean monthly High quality trout fisheries	13-20 Mean of 23, with maximum of 171	Biggs 2000
	Blue Earth River (site specific)	Low percentage of cyanobacterial abundance	40	Carleton et al. 2009
North American Streams and Rivers	Oligotrophic Mesotrophic Eutrophic	Reference based approach, based on data distribution of full disturbance gradient; mean values	< 20 20-70 > 70	Dodds et al. 1998
Indiana	Wadeable streams	Invertebrate and fish community metrics EPT Taxa	20.9 mean low 98.6 mean high 27.2	Caskey et al. 2013

3. Effects of Climate Change on Biostimulatory Conditions and Eutrophication Effects in the SMR Watershed

3.1 Introduction

Global climate change is anticipated to alter watershed hydrology and regional temperature regimes, with more weather extremes (droughts, extreme weather events) and higher average air temperatures. These factors are anticipated to increase biostimulatory conditions that can exacerbate eutrophication and degrade biological integrity. The southwestern region of the U.S. is already experiencing increased average temperatures, with more frequent heat waves. Recent climate model experiments project that, by the end of the 21st century, annual average temperatures in the San Diego Region will increase by about 2.2-3.3ºC under the RCP 4.5 scenario, or 3.8-5.0ºC under RCP 8.5 (Cayan et al. 2013; Pierce et al. 2018; Pachauri et al. 2014; Jennings et al. 2018). Summertime heat waves are projected to become longer and hotter. Projections of precipitation changes under the current rising emissions trend show reduced winter and spring precipitation, resulting in reductions in cloud cover (increased insolation), runoff and streamflow from the middle to the end of the 21st century. Drought is projected to become more frequent, intense, and longer lasting than in the historical record (severe mega-droughts at least 50 years long). The San Diego Water Board is interested in understanding the effects of climate change on eutrophication and biointegrity in coastal watersheds, how biostimulatory targets should accommodate conditions that could be exacerbated by climate change, and additional management and policy implications that should be considered.

The SMR watershed is an ideal location to understand the effects of climate change on eutrophication and biological integrity in the Southwest for several reasons. First, SMR has a robust dataset from collective stakeholder and state investments in bioassessment and eutrophication monitoring, comprised of BMI and algal assemblage information, organic matter distribution, and comprehensive set of eutrophication drivers (e.g., nutrients, flow, and water temperature) with which to undertake such analyses. Second, California wadeable streams represent a tremendous diversity of topographic elevation, climate, hydrogeomorphology and biotic communities (Ode et al. 2016). Third, SMR has a suite of mechanistic, process based watershed loading and riverine water quality (eutrophication) models that can be used to simulate the effects of climate change on riverine temperature, flow, nutrient concentration and loads as well as their effects on algal biomass and dissolved oxygen. Fourth, California has an environmental flows framework, from which alterations in flow and temperature can be used to project effects on benthic invertebrate and algal assemblages as well as thermal habitat for fish and other aquatic life. Fifth, SMR is the beneficiary of flow augmentation to assure litigated water rights of lower watershed water resources needs. Presence of this flow augmentation allows for a realistic case study of how this management tool can influence eutrophication and biointegrity outcomes. Finally, stakeholders in the SMR watershed are assembled and engaged in a joint fact-finding process to determine the scientific basis for biostimulatory targets and explore the implications for watershed management and environmental policy.

The goal of this part of the study is to evaluate the potential effects of climate change on hydrology and water quality in the SMR watershed. Three major questions served as a guide for this effort:

1. How will potential future climate impact streamflow, nutrient loading, and water temperature regimes in the SMR?

2. What are the implications of potential future climate on eutrophication outcomes (i.e., algal

chlorophyll-a, dissolved oxygen) and on biological integrity (benthic invertebrate and algal assemblages and thermal habitat for fish)?

3. How does absence of flow augmentation altered streamflow, nutrient loading, and water temperature effects under potential future climate have on biointegrity and eutrophication?

This chapter summarizes the findings of the climate change study, which are detailed in two manuscripts in preparation (Sutula et al. in prep-a.; Irving et al. in prep).

3.2 Methods

3.2.1 Overarching Approach

To examine these questions and investigate the effects of climate change (Figure 3.1), three linked mechanistic models were used in addition to biological integrity interpretation tools that link changes in flow and temperature to effects simulate the effects of future climate projections relative to current day on benthic algae, benthic invertebrates, and thermal habitat for aquatic life.

Future climate projections are uncertain and are best used to describe a probability envelope of potential future conditions (an “ensemble of opportunity”; Mote et al. 2011) to which adaptation may be needed. As such, three GCMs from the Coupled Model Intercomparison Project Phase 5 (CMIP5; IPPC 2014) set were selected based on recommendations in California’s 4th Climate Assessment (Pierce et al. 2018) for the Santa Margarita climate change impact study:

- HadGEM2-ES365 (warmer/drier for California)
- MIROC5 (near the middle of the range for annual average air temperature changes, but characterized as “unlike” other GCMs for California)
- CNRM-CM5 (cooler/wetter for California)

In addition to the GCMs, we chose the Representative Concentration Pathway (RCP) 8.5. The RCP is an index of future radiative forcing by greenhouse gasses (e.g., RCP 8.5 represents radiative forcing of 8.5 W/m2 in year 2100) and various RCPs are evaluated in CMIP5 due to uncertain projections of future population growth, energy use patterns, and associated greenhouse gas emissions. RCP 8.5 includes higher greenhouse gas concentrations, and thus greater radiative forcing and higher global atmospheric temperatures than RCP 4.5. RCP 8.5 was selected for this study because it more closely approximates the trends in greenhouse gas emissions and concentrations observed since 2005.

The mechanistic models included two calibrated watershed models of the middle and lower drainage areas of the SMR watershed, which cover the areas upstream and downstream of the confluence of Murrieta and Temecula Creeks, respectively (Tetra Tech 2018; Tetra Tech 2020a). The watershed models provide continuous hydrologic and water quality from the drainage area, which serve as inputs to a receiving water model. The receiving water model was using the WASP version 8.4 , which spans from the headwaters of the river mainstem at the Santa Margarita Gorge near Temecula to the Old Hospital on the United States Marine Corps (USMC) Camp Pendleton base, where the flow regime shifts from perennial to intermittent due to water management practices on Camp Pendleton. The watershed and receiving water models were calibrated for hydrology and water quality as described in the modeling reports (Tetra Tech 2018; Tetra Tech 2020a; Tetra Tech 2020b).

In addition to the mechanistic modeling analyses, a flow ecology analysis was used to quantify alterations of natural hydrological conditions and link them specifically to receiving water effects on biological integrity, as measured by the CSCI and ASCI. This involves assessing climate change effects on hydrologic alteration as a deviation from a natural reference condition, then analyzing specifically which portions of the SMR hydrograph (baseflow, peak flow, flow duration) show hydrologic alteration likely affecting biological communities.

In addition, changes in flow and temperature can alter the thermal habitat for aquatic life. We utilized the thermal preferences and critical maximum temperatures for three species: 1) Southern California steelhead (*Oncorhynchus mykiss*), 2) California Chorus Frog (*Peudacris hypochondriaca*), and 3) Mosquitofish *(Gambusia affinis)* to illustrate an example of climate effects on potential changes to thermal habitat for aquatic species. The Chorus Frog and Mosquitofish did not show discriminatory power relative to the range of predicted water temperature changes (i.e., would not likely be affected by predicted water temperature changes) and thus, analyses and discussion of effects focus on the Southern California steelhead.

Uncertainty in future climate predictions was evaluated through use of three global climate models (GCMs) that represent a range of potential future local conditions in precipitation and air temperature (Pierce et al. 2018). Statistically downscaled GCM data were used as inputs to the HSPF watershed models to predict effects on streamflow, water temperature, and nutrient concentrations. HSPF climate analyses were conducted with and without CWRMA flow augmentation to investigate the effect of the release on eutrophication and biointegrity outcomes in the river. Thus, a total of six HSPF model runs were conducted (3 GCMs with and without CWRMA releases). Each run consisted of the historic baseline (i.e., GCM predicted hindcast climate) and the predicted future condition from mid- to late-21st century. Outputs from the HSPF models were applied as boundary conditions for the mainstem WASP model and used for flow ecology and thermal tolerance analyses.

Regional flow ecology and thermal tolerance analyses were conducted on the full suite of six HSPF model runs. However, WASP water quality runs are computationally intensive and, as such, we chose to use representative runs to explore the variability in predicted climate and the associated consequences for eutrophication outcomes. Five future years (i.e., GCM and year scenario) were run in WASP (Table 3.1). Average annual air temperature and annual precipitation totals were computed for all GCM-year combinations run in the HSPF models, and the 10^{th}, 50^{th} and 90^{th} percentile of the variability was evaluated based on those parameters. Based on this assessment, five scenarios were selected to capture the following conditions 1) warmer and wetter, 2) warmer and drier, 3) cooler and wetter, 4) cooler and drier, and 5) moderate conditions. Results were analyzed for nutrients, water temperature, benthic chlorophyll-a, and dissolved oxygen.

Table 3.1. Climate scenarios for WASP modeling.

Description	Average Air Temperature **°C** (°F)	Annual Precipitation (in/yr)	GCM-Year
Cooler, drier	Near 10^{th} percentile, 19.1 (66.4)	Near 10^{th} percentile, 7.7	HadGEM-ES365,
Cooler, wetter	Near 10^{th} percentile, 19.0 (66.2)	Near 90^{th} percentile, 26.8	CNRM-CM5, 2050
Moderate	Near 50^{th} percentile, 20.7 (69.2)	Near 50^{th} percentile, 11.3	MIROC5, 2068
Warmer, drier	Near 90^{th} percentile, 22.5 (72.5)	Near 10^{th} percentile, 6.8	HadGEM2-
Warmer, wetter	Near 90^{th} percentile, 22.4 (72.4)	Near 90^{th} percentile, 29.4	CNRM-CM5, 2094

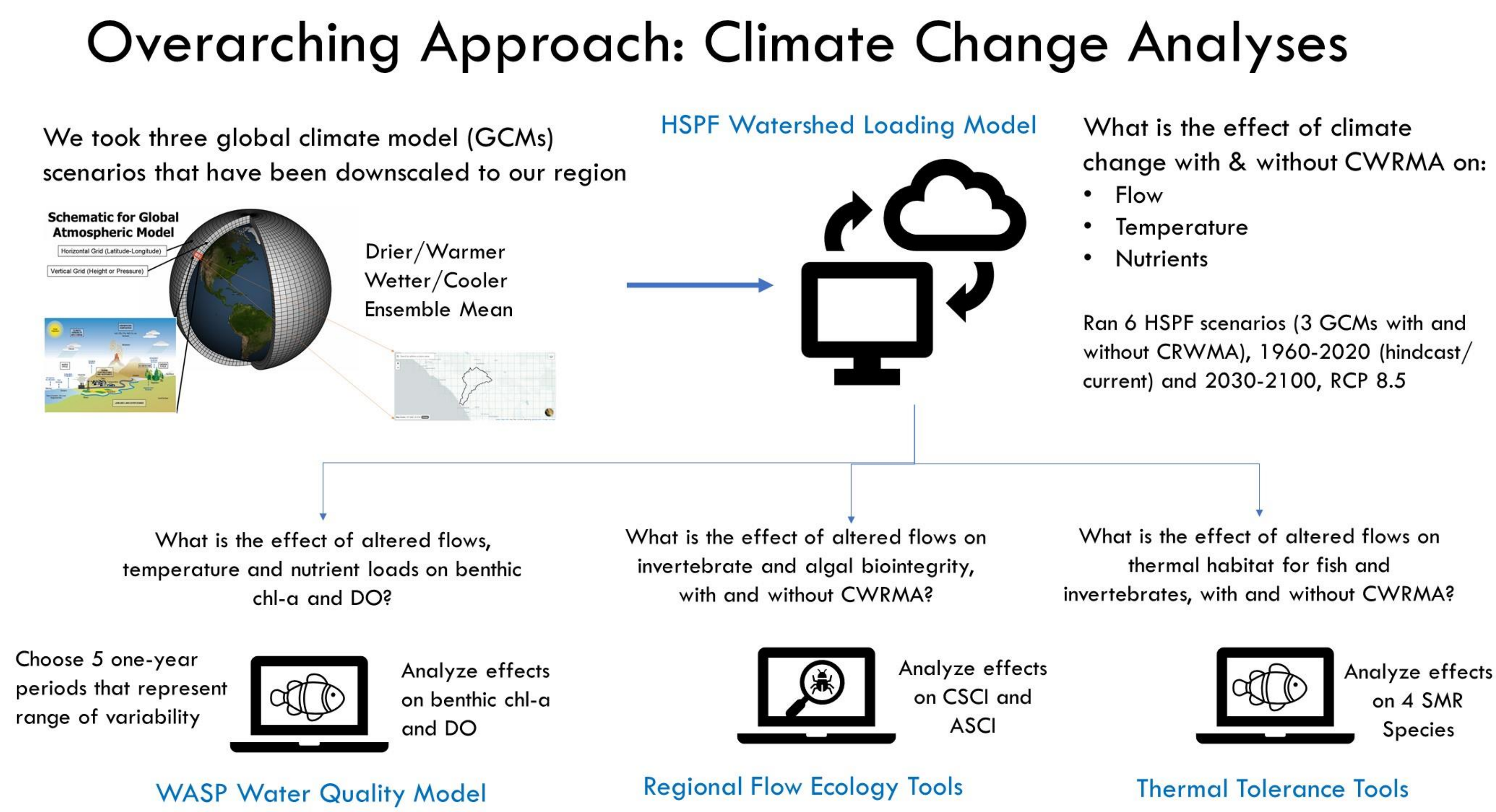


Figure 3.1. Overview of conceptual approach to SMR climate analyses and linkage to biostimulatory conditions (flow, temperature, nutrients) and eutrophication and biological integrity effects.

3.2.2 Future Climate Data

The SMR models use hourly meteorological forcing data. Weather variable outputs from spatially downscaled and bias-corrected GCMs were used to derive the watershed and receiving water model input time series for two periods – a hindcast period spanning 1960 through 2005 and a future period spanning 2030 through 2099; these periods were selected to represent climatic conditions over multiple decades, with the future period covering the mid- and late-21st century. Results from the hindcast and potential future climate conditions from individual GCMs were used to evaluate relative, or proportional, change in conditions due to climate. Use of hindcast and forecast data from the same GCM helps cancel out spatial biases that may be specific to a given GCM.

Downscaling and Climate Data Processing

The GCM output needs to be downscaled in space and in time to provide hourly input to the watershed and receiving water models. GCMs generate output at a large spatial scale (typically about 1°x1° [equivalent to 111 km x 94 km for San Diego] or coarser) that does not consider details of local geography and topography. To be useful for watershed studies at the local scale it is necessary to undertake spatial downscaling. Downscaling can be done either through the use of a smaller-scale regional climate model (RCM) or through statistical methods. RCMs are difficult and expensive to run, so only a limited number of GCMs have been downscaled in this way. In contrast, there are many different varieties of statistically downscaled products now available. Most of these work with the general design of using spatial statistical corrections of GCM monthly output to local spatial scales with bias correction based on analysis of GCM ability to replicate historical climatology, followed by temporal downscaling to a daily time step.

There are various sources of statistically downscaled and bias-corrected climate model daily output for precipitation and temperature; however, many of these do not provide the full suite of weather variables needed to estimate potential evapotranspiration (PET) by an energy balance method that accounts for simultaneous changes in temperature, humidity, and other factors. The Multivariate Adaptive Constructed Analogs (MACA) dataset includes statistically downscaled climate data (to a 4 km x 4 km scale) created by the University of Idaho. The MACA method (Abatzoglou and Brown 2012) has two advantages that make it preferable to other downscaling methods for continuous watershed simulation: (1) it provides simultaneous downscaling of precipitation, temperature maximum and minimum, humidity, wind, and solar radiation (rather than just precipitation and temperature), helping to ensure physical consistency in the outputs and providing a basis for estimation of PET, and (2) the method uses a historical library of observations to construct the downscaling using the constructed analogs approach such that future climate projections are distributed from the monthly to the daily scale by analogy to months that exhibit similar characteristics in the historical record. Daily, spatially downscaled, and bias corrected GCM output for the SMR watershed were obtained from the MACA website (http://maca.northwestknowledge.net/) for the three GCM (RCP 8.5) scenarios.

The MACA spatially downscaled data are available at a daily time step, while the model operates on an hourly time step. Standard methods are available for the disaggregation of variables such as temperature and solar radiation throughout the day; however, precipitation is more challenging. It is important to distribute daily precipitation events in a realistic way that reflects the intensity and duration of storms experienced in the area. To accomplish the temporal downscaling of precipitation, this study applied a random multiplicative cascade (RMC) method (Menabde et al. 1997; Molnar and Burlando 2005). The RMC approach is described in the middle SMR watershed HSPF modeling report (Tetra Tech 2020a) and ensures that the within-day precipitation follows a realistic pattern. Other variables were disaggregated from daily to hourly based on standard methods: Solar radiation above the atmosphere was distributed based on daylight hours based on latitude and time of year (Hamon et al. 1954). Air temperature was disaggregated on a daily pattern assuming that the minimum falls at 6 a.m. and the maximum occurs at 4 p.m. Wind is disaggregated using an empirical distribution applied in the SARA Timeseries Utility for HSPF models (RESPEC website).

MACA does not directly provide cloud cover (used to calculate effective solar radiation at the land surface and for longwave radiation exchanges), dew point temperature, or potential evapotranspiration (PET). Minimum and maximum daily dew point temperatures were computed with the August-Roche-Magnus formula then disaggregated using the same algorithm as air temperature (Alduchov and Eskridge 1997). Daily average cloud cover is first approximated with the Davis method and then it is disaggregated to hourly using the same method as applied for solar radiation (Davis 1997). Cloud cover for sun-down to sun-up is not estimated by this method, therefore, nighttime cloud cover was approximated using a linear interpolation over the night period. After the other required meteorological variables were assembled or calculated, potential evapotranspiration was calculated via the Penman Pan method (Penman 1948) based on air temperature, solar radiation, wind movement, and dew point, using the routines in the HSPF WDMUtil toolbox (RESPEC website). The baseline models use reference crop evapotranspiration from the California Irrigation Management Information System (CIMIS) monitoring network; however, the climate models apply Penman Pan evapotranspiration. A crop coefficient is applied in the EXT SOURCES block to translate Penman Pan evapotranspiration to reference evapotranspiration in the HSPF models. The coefficient (0.58) was derived by scaling the annual hindcast GCM-based Penman Pan evapotranspiration totals to the historic reference crop evapotranspiration implemented in the baseline models for the period of 1995-2018.

Time series from the MACA archive (and computed variables) were spatially averaged to create zonal weather input time series for the HSPF and WASP models, consistent with the existing watershed model setup (Tetra Tech 2020a, 2020b).

Climate Summary

A summary of hindcast and future air temperature and annual precipitation is provided in Table 3.2 for the three scenarios. Annual average air temperature is expected to rise between 3.0°C (5.4°F) to 3.9°C (7.1°F) from the hindcast period of 1960-2005 to the future period of 2030-2099. The highest predicted increase in average annual air temperature is for HadGEM2-ES365 scenario. Expected changes in annual average precipitation differ for the three GCMs. CNRM-CM5 is the wettest future condition, predicting a 27.2% increase in annual average precipitation. The HadGEM2-ES365 scenario predicts minimal change in annual average precipitation. MIROC5 is the driest scenario with annual average precipitation decreasing by about 17.7% in the future. Increasing air temperatures raise expected potential evapotranspiration between 8.3 to 12.6%. To examine variability, annual average air temperature and precipitation are plotted for each GCM-year (between 2030-2099) for the SMR watershed in Figure 3.2. The 10th, 25th, 50th

(median), 75th, and 90th percentiles of annual average air temperature and precipitation for future years across the three GCMs are shown in Table 3.3. This information was used to support selection of subsequent WASP receiving water model scenarios to evaluate biostimulatory responses in the river (Section 3.2.4). For example, selection of a GCM year that closely aligns with the 25th precipitation percentile and 75th air temperature percentile could be used to further evaluate dry and warm future conditions.

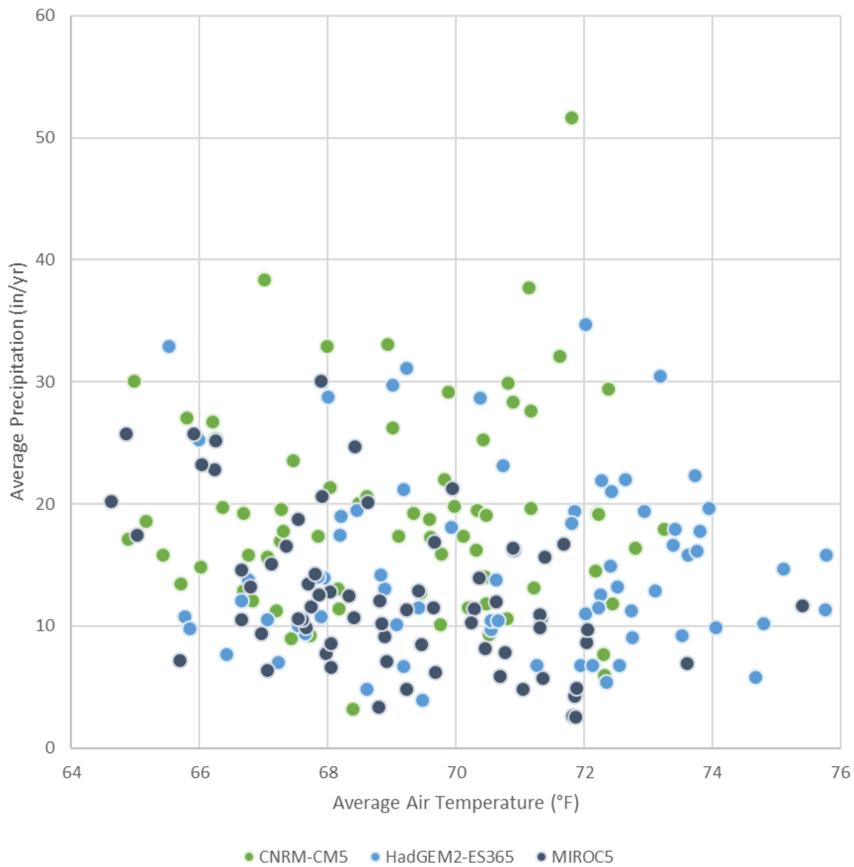


Figure 3.2. Predicted annual average air temperature and precipitation for SMR watershed for individual future years 2030 to 2099, CMIP5 RCP 8.5.

Table 3.2. Climate summary for hindcast (1960-2005) and future (2030-2099) periods in the Santa Margarita River watershed based on MACA downscaled projections.

Variable (Annual Average)	Period	CNRM-CM5	HadGEM2-ES365	MIROC5
Air Temperature °C (°F)	Hindcast	17.6 (63.7)	17.6 (63.6)	17.5 (63.5)
	Future	20.6 (69.1)	21.5 (70.7)	20.6 (69.0)
	Relative Change	17.0% (8.5%)	22.2% (11.2%)	17.7% (8.7%)
	Absolute Change	3.0 (5.4)	3.9 (7.1)	3.1 (5.5)
Precipitation (in/yr)	Hindcast	15.2	14.9	15.2
	Future	19.3	15.1	12.5
	Relative Change	27.2%	1.3%	-17.7%
	Absolute Change	4.1	0.2	-2.7
Potential Evapotranspiration (in/yr)	Hindcast	88.7	89.1	88.8
	Future	96.0	100.2	97.2
	Relative Change	8.3%	12.6%	9.4%
	Absolute Change	7.3	11.2	8.4

Table 3.3. Distribution of annual average air temperature and precipitation for SMR watershed for future years 2030 to 2099; results combine the CNRM-CM5, HadGEM2-ES365, and MIROC5 scenarios shown in 2.

Percentile	Air Temperature °C (°F)	Precipitation (in/yr)
10th	19.1 (66.3)	6.8
25th	19.8 (67.7)	10.2
50th	20.8 (69.5)	14.0
75th	22.1 (71.7)	19.5
90th	22.6 (72.7)	26.8

3.2.3 Constructing the HSPF Scenarios to Simulate Climate

Like most rivers in the Southwest, the SMR is extensively managed. These anthropogenic influences, which may change under future climate, need to be accounted for to develop realistic scenarios.

Irrigation

Irrigation of lawns and agricultural lands was represented in the baseline calibrated HSPF models for the lower and middle SMR watershed. Since historic application rates are imprecisely known, irrigation demands were estimated from precipitation and evaporation demands based on vegetation type (e.g., row crop, lawns; see CIMIS/WUCOLS guidance (cimis.water.ca.gov/Content/PDF/wucols00.pdf). A description of the methodology can be found in Section 2.5 of the modeling report (Tetra Tech 2020a). The same methodology was applied for the climate scenarios. Precipitation and evapotranspiration time series based on GCM outputs were used to approximate irrigation demands in the middle and lower SMR drainage areas. Unique series were generated for each GCM scenario and vegetation type (e.g., orchards) for the extended period of 1950 to 2099.

Reservoir Releases

There are three major water supply reservoirs in the SMR watershed, two of which (Diamond Valley and Lake Skinner) are used primarily to store Colorado River Project water. Reservoir releases in the middle SMR watershed are described in Section 2.4 of the HSPF model report (Tetra Tech 2020b). These include infrequent spills from Diamond Valley Lake, and Lake Skinner along with releases required by water rights settlements from Vail Lake. Releases from these reservoirs were extended by repeating the historic time series and not changed to reflect potential future climate.

Atmospheric Deposition

Atmospheric deposition of nitrogen is represented in the lower and middle SMR watershed HSPF models. See Section 4.3.1.1 of the middle watershed HSPF model report for additional information (Tetra Tech 2020b). Monthly average wet and dry atmospheric deposition concentrations and fluxes, respectively, were computed for the simulation period of the calibrated model – 1994 to 2018. The monthly averages were applied to the extended period simulated for the climate scenarios.

CWRMA Releases

The CWRMA specifies the releases of external sources water to the SMR to satisfy senior water rights of Camp Pendleton. The location is south of the confluence of the Murrieta and Temecula Creeks at the head of the SMR Gorge. Additional information can be found in the middle SMR watershed HSPF modeling report (Tetra Tech 2020b). Future CWRMA releases are assumed to follow flow augmentation requirements as described in the agreement and annual reports (SMR Watershed Watermaster 2007, 2012, and 2020; Cooperative Water Resource Management Agreement between Camp Pendleton and Rancho California Water District 2002). Based on this information, CWRMA releases were estimated as follows for the future climate scenarios:

- The daily precipitation series at Wildomar (corresponding with the precipitation location specified in the agreement) was obtained for each GCM from MACA.
- Monthly precipitation totals were computed for the extended simulation period.
- Natural streamflow in cubic feet per second (cfs) at Murrieta was estimated as a function of monthly rainfall at Wildomar for the months of October – April (i.e., based on polynomial equation described in the agreement, see Exhibit C, Equation 1 in Cooperative Water Resource Management Agreement between Camp Pendleton, and Rancho California Water District (2002)), and converted to units of acre-feet per month.
- The total flow volume between October and April was computed. Because the Hydrologic Index in the CWRMA agreement is determined by combining observed streamflow at Murrieta, Vail Lake, Aguanga, and Pauba and Wolf Valleys, some of which are not addressed in the existing watershed model covering the area downstream of the reservoirs, a regression relationship was developed to approximate the CWRMA Hydrologic Index solely from Murrieta natural flows: Hydrologic Index (acre-feet) = 1.3209 * m + 2,980.6, where m is the flow at Murrieta in acre-feet. The coefficient of determination (R^2) is 0.9784, indicating strong predictive power.
- The resulting Hydrologic Index flow was applied to determine the flow classification (critically dry, below normal, above normal, and very wet) for each water year based on specifications in the CWRMA agreement. These classifications determine basic release requirements.
- The agreement also includes adjustments based on the previous year. If the current year is below normal and the prior year is either normal or very wet, 2,200 acre-feet are added to the sum used to determine the Hydrologic Index. If the current year is above normal and the prior year was critically dry, then 10,000 acre-feet are subtracted. The flow class is adjusted accordingly.
- January to April releases are either 11.5 cfs or less after adjustment for credit if over-release occurred during the prior winter following specifications in the agreement.
- Required CWRMA releases for the months of May to December is determined based on

the flow classification (e.g., above normal) as specified in Table B-2 of the agreement. There is a minimum release requirement of 3 cfs.

- Following this step, the full time series was formatted for the extended simulation period and imported to the Watershed Data Management file (WDM) for the middle SMR HSPF model.

- Historic average observed concentrations in the CWRMA release water were applied to generate input water quality loading time series for the HSPF model.

3.2.4 Effects of flow alteration on algal and benthic invertebrate assemblages

Aquatic life beneficial uses in the SMR are defined based on the ability of the river and its tributaries to support characteristic aquatic plant and animal communities (i.e., biological integrity). The intent of this analysis is to evaluate the potential effects of alterations in flow on existing beneficial uses, focusing specifically on effects on benthic invertebrates and algae. This is appropriate since the San Diego Water Board has established biological objectives which established a REF10[8] thresholds for the California Stream Condition Index (CSCI; Mazor et al. 2016; San Diego Water Board 2020), which measures the stream condition using benthic invertebrate assemblages. The Water Board is also considering utilizing the Algal Stream Condition Index (ASCI; Theroux et al. 2020) as part of the suite of biostimulatory targets for SMR. For both indices, the site is scored as a deviation from the reference benchmark and reference is measured equivalently in all settings so that a given index score has the same ecological meaning across the entire region of interest.

Mazor et al. (2017) and Irving et al. (in prep) have previously created "flow-ecology" curves or models relating alterations in hydrologic conditions to the probability of decline in the condition of benthic invertebrates and algal communities using CSCI and ASCI as a proxy, respectively. In these analyses, flow alterations under the various climate change scenarios were determined based on the thresholds of probability of falling below the REF10 thresholds for CSCI and ASCI. This analysis was done for two sites: 1) the Gorge, just below CWRMA, and 2) Old Hospital site on Camp Pendleton, just above the point of diversion. Two steps were involved in this analysis:

1) Characterize hydrologic alteration based on deviation from reference.

2) Biological flow alteration based on CSCI and ASCI.

Characterize Hydrologic Alteration Based on Deviation from Reference. We characterized hydrologic alteration based on the deviation of current and projected future flow conditions under climate change from historic reference conditions in the absence of flow alterations associated with current land use practices, including dams and CWRMA. Reference, current, and modeled future hydrology were characterized by quantifying key components of the annual hydrograph that support a broad suite of ecological functions, referred to as functional flow metrics (FFM). An alteration assessment comparing FFM from reference to current or future conditions was

[8] REF10 refers to the 10th percentile of CSCI scores of minimally disturbed (reference) stream sites, such it represents a loss of 90 percent of the range of natural variability inherent in these reference sites. REF10 is the established biointegrity objective of the San Diego Water Board.

conducted to identify in which seasons (i.e., wet, or dry) and direction (i.e., augmented, or depleted) are flows likely altered. This analysis serves as context to evaluate the current alteration status of hydrology in SMR mainstem as it relates to the ability to support stream functions, habitats, and species.

The first step in this process is to assess flow alteration (Figure 3.3). This involved identifying the "minimally altered" reference flow conditions that serves as the basis to calculate flow alteration. In the case of SMR watershed, it was important to capture conditions before the installation of the dams in the upper watershed, the first of which was installed in 1945. USGS gauge data were available at the Temecula Gorge (USGS Gage 11044000) beginning in 1921 though anecdotal evidence exists that groundwater withdrawal from agriculture were already beginning to occur at that time. At the Old Hospital, Stetson et al. (2012) reconstructed the minimally impacted flow conditions as a time series 1931-1945 for the Southern CA Steelhead Passage Assessment and Conjunctive Use Project for Lower SMR. We chose to use the daily flow data from 1931 to 1945 from both these datasets to represent the minimally disturbed flow conditions.

The second step in the process involved calculation of functional flow metrics. Hydrology can be characterized by hundreds of flow metrics that span across variable timescales, flow characteristics, and seasons. In this study, we evaluated current and reference hydrology across a suite of 24 FFM that represent multiple aspects of the annual hydrograph, consistent with the California Environmental Flows Framework (CEFF; Yarnell et al. 2020, see Table 3.4 and Figure 3.4) (https://ceff.ucdavis.edu/). Functional flows are the components of the annual hydrograph that support a broad suite of ecological functions and support a characteristic set of aquatic and riparian plants and animals. In California, functional flow components include the fall pulse flow, winter baseflows, peak flows, spring recession flows, and summer baseflows. FFM are quantifiable flow characteristics that describe the timing, magnitude, duration, and frequency of these functional flow components and are calculated annually from daily flow timeseries.

Flow datasets reflecting reference conditions, simulated current, and projected future flow under the climate scenarios, each with and without CWRMA, were post-processed to mean daily flow and annual FFM were calculated using the functional flows calculator (https://eflows.ucdavis.edu/hydrology) and the interfacing R package (https://github.com/ceff-tech/ffc_api_client) developed for the CEFF. Additionally, the 10th, 25th, 50th, 75th, and 90th percentiles of FFM were summarized for current, mid-century and late century period. We then calculated the change in FFM percentiles from reference to current (Delta H) (Equation 1).

Eqn. 1: $Delta\ H = FFM_{current\ or\ future} - FFM_{reference}$

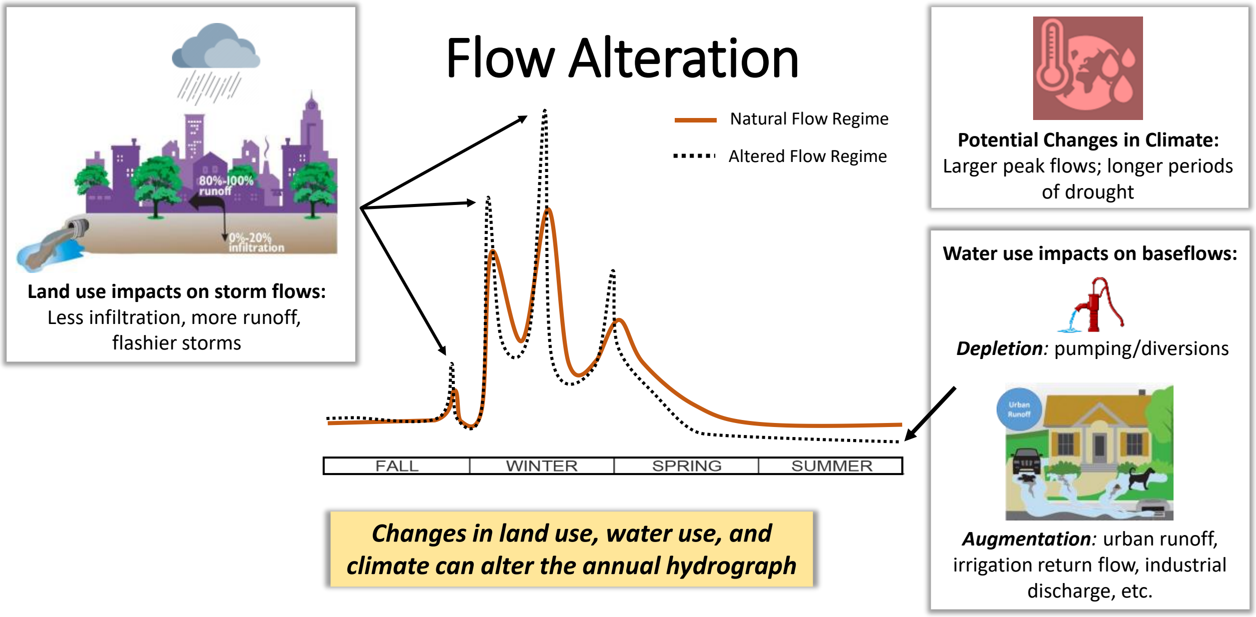


Figure 3.3. Conceptual diagram of the effects of flow alteration from land use, climate change, and water management on components of an annual stream hydrograph.

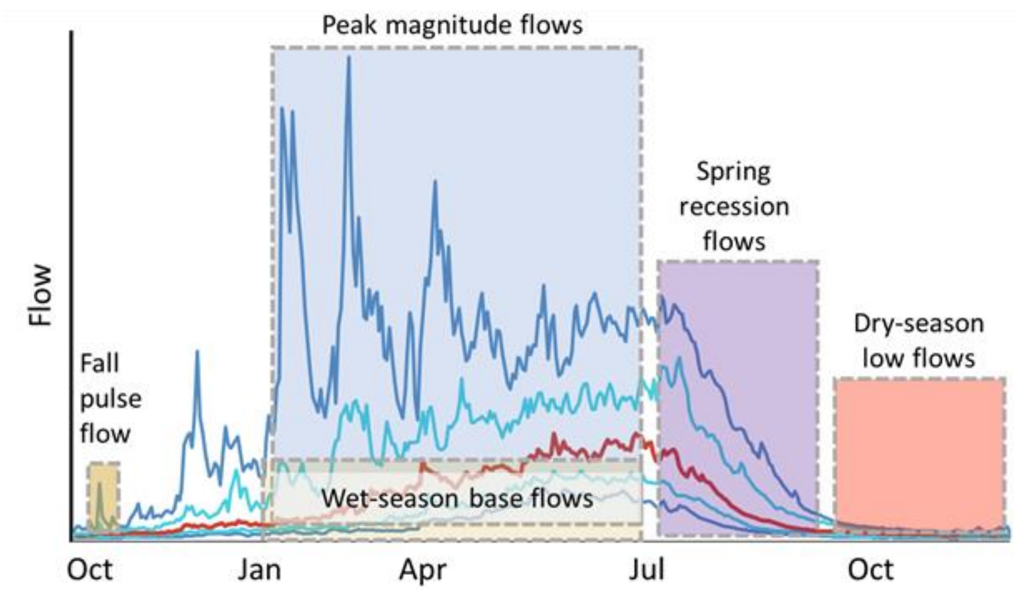


Figure 3.4. Components of the annual stream hydrograph that map specifically to flow characteristics and functional flow metrics established in the California Environmental Flows Framework (Yarnell et al. 2020). Colored lines represent different water years.

Table 3.4. From California Environmental Flows Framework (Yarnell et al. 2020). Definition of functional flow metrics related to different seasonal components of the hydrograph (designated by color, and linked to graphical view in Figure 3.5)

Flow Component	Flow Characteristic	Flow Metric
Fall pulse flow	Magnitude (cfs)	Peak magnitude of fall season pulse event (maximum daily peak flow during event)
	Timing (date)	Start date of fall pulse event
	Duration (days)	Duration of fall pulse event (# of days start-end)
Wet-season base flows	Magnitude (cfs)	Magnitude of wet season baseflows (10th and 50th percentile of daily flows within that season, including peak flow events)
	Timing (date)	Start date of wet season
	Duration (days)	Wet season baseflow duration (# of days from start of wet season to start of spring season)
Peak flow	Magnitude (cfs)	Peak-flow magnitude (50%, 20%, 10% exceedance values of annual peak flow --> 2-, 5-, and 10-year recurrence intervals)
	Duration (days)	Duration of peak flows over wet season (cumulative number of days in which a given peak-flow recurrence interval is exceeded in a year).
	Frequency	Frequency of peak flow events over wet season (number of times in which a given peak-flow recurrence interval is exceeded in a year).
Spring recession flows	Magnitude (cfs)	Spring peak magnitude (daily flow on start date of spring-flow period)
	Timing (date)	Start date of spring (date)
	Duration (days)	Spring flow recession duration (# of days from start of spring to start of summer base flow period)
	Rate of change (%)	Spring flow recession rate (Percent decrease per day over spring recession period)
Dry-season base flows	Magnitude (cfs)	Base flow magnitude (50th and 90th percentile of daily flow within summer season, calculated on an annual basis)
	Timing (date)	Summer timing (start date of summer)
	Duration (days)	Summer flow duration (# of days from start of summer to start of wet season)

Impact of Flow Alteration on Biological Condition. The final step involves determining the sites and scenarios in which flow alteration is sufficient to be associated with a decline in biological condition as indicated by the standard statewide biological indices, the CSCI (Mazor et al. 2016) for benthic invertebrates and the ASCI (Theroux et al. 2020) for benthic algae. Stein et al. (2017) and Irving et al. (in prep) modeled CSCI and ASCI bioassessment data from Southern California with the FFM. As a brief summary of this work, at each bioassessment site, reference and current flow conditions were modeled with an ensemble of regional HEC-HMS models developed for Southern California in a previous study (Sengupta et al. 2018). FFM were calculated and the change in flow metrics from reference to current were determined. The change value (hereafter referred to as Delta H) was applied in logistic regression to predict the probability of a healthy CSCI/ASCI score based on the currently accepted threshold values, providing relationships between the indices and FFM. These relationships were used to define Delta H limits and perform subsequent analysis in the biologically relevant alteration process (described below). The logistic regression process modelled each FFM individually, therefore, to understand the relative influence of all FFM on each biological index, Boosted Regression Trees (BRTs) were performed on the full set of FFM, and the relative importance determined and ranked. This ranking process aided the FFM filtering process outlined below.

To attain a manageable subset of the 24 FFM, the metrics were prioritized based on relevancy and amenability to management actions. The FFM were filtered based on the following criteria: 1) Can be modeled with confidence through the regional flow models, 2) Not highly correlated, 3) High relative importance from BRT assessment, 4) Strong relationship through logistic regression analysis, 5) High data density to ensure relationships not driven by only 1 or 2 points, and 6) Can be influenced through management.

Selected metrics for CSCI and their supported ecological functions include:

- Magnitude of largest annual storm (physical: encompasses maintenance and rejuvenation of physical habitat)
- Spring recession flow duration (biological: increases hydraulic habitat diversity and habitat availability resulting in increased algal productivity, macroinvertebrate diversity, arthropod diversity, fish diversity, and general biodiversity)
- Wet season baseflow duration (biological: supports algal growth and primary producers)

Selected metrics for ASCI and their supported ecological functions include:

- Magnitude of largest annual storm (physical function: scour of algae and substrate
- Dry season baseflow magnitude (biological: supports algal growth and primary producers)
- Wet season baseflow magnitude (biogeochemical: supports hyporheic exchange)

Defining biologically relevant flow alteration requires a series of decisions on thresholds and magnitudes of alteration. For each chosen FFM we identified Delta H limits based on 50 percent probability of achieving healthy CSCI/ASCI score, defined as a REF10 score greater than 0.79 for CSCI and 0.86 for ASCI, based on the precedent of Mazor et al. (2017). Applying these limits, the selected FFM were classified at each subbasin using the following criteria:

- **Biologically Altered**: if change in subbasin FFM falls *outside* of Delta H limits
- **Biologically Unaltered**: if change in subbasin FFM falls *within* Delta H limits

We then synthesized biologically relevant flow alteration across metrics as “likely altered” if two or more selected metrics met the thresholds for “biologically altered.”

3.2.5 Effects of flow and temperature alteration on thermal habitat for aquatic life

Most aquatic organisms, including fish and invertebrates, are ectotherms, which means that their body temperature is modulated by the temperature of the water. If water temperature varies, then so does their body temperature. Each species has an optimal or preferred water temperature (an ideal temperature for living and proper functioning, including metabolism, feeding, growth, reproduction, swimming speed, foraging) as well as a critical thermal maximum and minimum (loss of equilibrium: temperature beyond which vital bodily functions break down and that can lead to death). Elevated temperatures are especially challenging for many species because they increase the metabolic demand for oxygen while at the same time decreasing the saturation concentration of oxygen in water. Climate change is projected to increase air temperatures and decrease stream flow, both of which can increase water temperatures (Figure 3.5). In this component of the analyses, we identified preferred temperatures (T_{PREF}) and critical thermal maximum (CT_{Max}) and their associated duration corresponding to a suite of SMR Watershed aquatic species and applied these thresholds to current and future climate scenarios to assess the degree to which thermal habitat may be impacted. This process consisted of the following steps:

1. Decide on species of interest that have been historically present in the SMR Watershed.
2. Literature review to collate information on CT_{MAX} and T_{PREF}.
3. Define thresholds for each species.
4. Calculate change metrics and apply them to temperature time series to each of the hindcast and forecast with and without CWRMA.

Decisions of species of interest began with an initial list of species that are present in SMR, including native fish (both currently and historically present), amphibians and reptiles. We also included invasive fish, amphibians, and invertebrates to understand the degree to which invasive species might have temperature preferences which make them more tolerant to climate change.

From the initial list, we undertook a literature review of thermal tolerance data to identify both T_{PREF} and CT_{MAX}. Based on this list, we chose a subset of three species, two native and one invasive, based on the following criteria: 1) range of sensitivities to water temperature, from sensitive to tolerant, 2) species of special interest, and 3) data availability. The three species chosen include:

- Steelhead (*Oncorhynchus mykiss*)
- Baja California Chorus Frog (*Peudacris hypochondriaca*)
- Mosquitofish *(Gambusia affinis)*

CT_{MAX} data were the most common and standardized (Table 3.5), but due to the maximum temperature in the time series, especially at the Old Hospital (30-33°C), preference temperature thresholds were the most relevant for these analyses (Table 3.6).

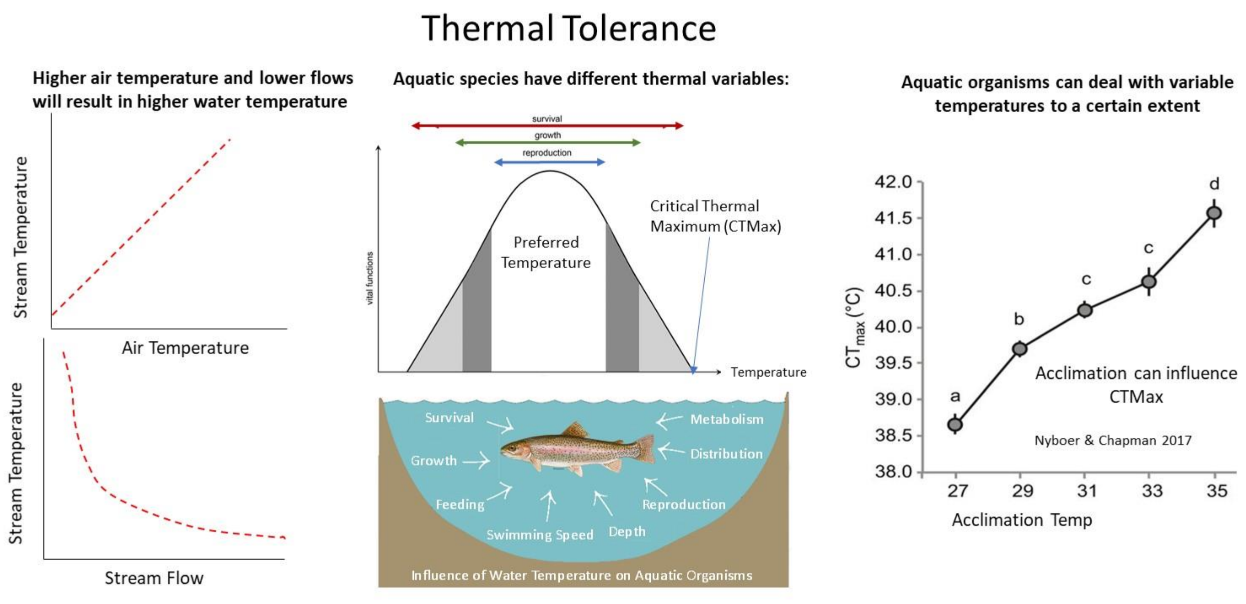


Figure 3.5. Conceptual view of how air temperature and flow effect water temperature and the impacts of that temperature on the thermal tolerance of fish. Preferred temperature range here is intended to capture effects on growth, feeding, swimming, speed, reproduction, and metabolism.

Table 3.5. Summary of CT_{MAX} data for three selected species. N is the number of CT_{MAX} values used in the calculation of the final CT_{MAX}.

Species	Scientific Name	Life stage	N	CTMax (°C)	Std Error	Acclimation Temps (°C)	Source
Baja Calif. Chorus Frog	*Peudacris hypochondriaca*	Larval	8	39.4	0.4	10-25	Mueller et al. 2019
Steelhead	*Oncorhynchus mykiss*	Juvenile	17	29.4	0.3	10-25	Lee and Rinne 1980, Myrick and Cech 2000, Cech and Myrick 1999
Mosquitofish	*Gambusia affinis*	Adult	15	38.7	0.6	5-25	Carveth et al. 2006, Otto 1973, Otto 1974

Table 3.6 Summary of T_{PREF} available data for selected species.

Species	Scientific Name	Life stage	Preference Range (°C)	Source
Baja California Chorus Frog	*Peudacris hypochondriaca*	Embryo, Larval, Adult	20-34	Brown 1975, Cunningham and Mullally 1956, Schechtman and Olson 1941, Brattstrom and Warren 1955
Steelhead	*Oncorhynchus mykiss*	Embryos, Adult	17.5-21	Brittany Struck (personal communication), Melendez and Mueller 2021, Spina 2007

The CT_{MAX} values and their acclimation temperatures are presented in Table 3.4 are the average of CT_{MAX} values (defined as the loss of equilibrium) found through the literature review. CT_{MAX} temperatures are generally dependent on acclimation of ambient water temperatures. In addition, only studies located in similar climates (i.e., Southern California and Arizona) were included.

The preference range presented in Table 3.5 includes a range of endpoints relating to optimal or preferred water temperature found in the literature review. The Baja California Chorus Frog range of endpoints includes a temperature limit for normal embryo development, the upper temperature at which tadpoles were observed, temperatures that led to 100% viability of eggs and the highest temperature at which singing behavior was observed in adults as based on studies conducted throughout California. The steelhead range includes temperature that hatchlings were deemed sensitive to (Mt. Shasta) and the 7-day max temperature of occupied ponds (Southern California).

Two temperature metrics were calculated from the hourly time series: 1) mean weekly maximum temperature (MWMT) calculated as a 7-day rolling mean of the daily maximum temperature, and 2) mean weekly average temperature (MWAT) calculated as 7-day rolling mean of the daily mean temperature.

Cumulative density functions (CDFs) of MWMT were created for each of the three climate scenarios, with and without CWRMA, for a selection of years. We report 1960, 2005, 2060 and 2099 to span a range of timepoints throughout the hindcast and forecast date ranges.

Two comparison metrics were derived to compare between scenarios. First, the proportion of time derived from hourly temperature time series and defined as the percentage of hours above CT_{MAX} or T_{PREF} for each year, second the number of days CT_{Max} or T_{PREF} were exceeded by the temperature metrics MWAT and MWMT.

The metrics and thresholds were applied to Gorge and Old Hospital for each of the three HSPF simulated GCMs for the current/historic hindcast, then mid-century through the end of century (2035-2100).

3.2.4 Effects of flow, nutrients, and temperature alteration on benthic algal biomass and dissolved oxygen

The impacts of future climate on streamflow, nutrients, and water temperature were refined from HSPF predictions with the SMR WASP receiving water model. The WASP model was then used to evaluate predicted changes in biostimulatory response variables - attached macroalgal biomass and dissolved oxygen concentrations. Outputs from the climate scenarios with the HSPF watershed models served as boundary condition inputs to the WASP model. The WASP model simulations apply a dynamic time-step that averaged about 30 seconds for the calibration model, which is a much finer temporal resolution compared to the hour time-step applied by HSPF. Thus, a subset of annual scenarios was completed from the extended future period simulated with the HSPF models (2030-2099). Note that the comparisons presented in this section assume that the rules for water releases specified by CWRMA will be present under future conditions, which results in substantial buffering of the effects of climate change on the SMR mainstem.

To support the WASP climate scenario selection process, the average annual air temperature and annual precipitation totals were plotted for each GCM-year combination included in the HSPF modeling analyses (Figure 3.3). The 10th, 50th (median), and 90th percentiles were computed for each metric. The WASP scenario set aimed to capture the potential range and bound expected conditions for the watershed between 2030-2099, excluding extreme outlier years. These include scenarios for 1) warmer and wetter, 2) warmer and drier, 3) cooler and wetter, 4) cooler and drier, and 5) moderate conditions. Note that these descriptions are relative within the full GCM-year set (i.e., cooler does not mean that the future air temperature is lower than the past, rather it is cooler compared to most of the GCM-year combinations from the period of 2030-2099). For the warm and wet scenario, for example, a GCM-year combination was selected from the upper right-hand of the plot around the 90th percentile air temperature (about 22.6°C (72.7°F)) and 90th percentile annual precipitation (about 26.8 in/yr). The selected GCM-year scenarios and associated air temperatures and precipitation totals are listed in Table 3.6 and shown in Figure 3.6. The period of October through December of the previous calendar year served as a spin-up period and results are quantified for the calendar year listed for the other ten GCMs studied.

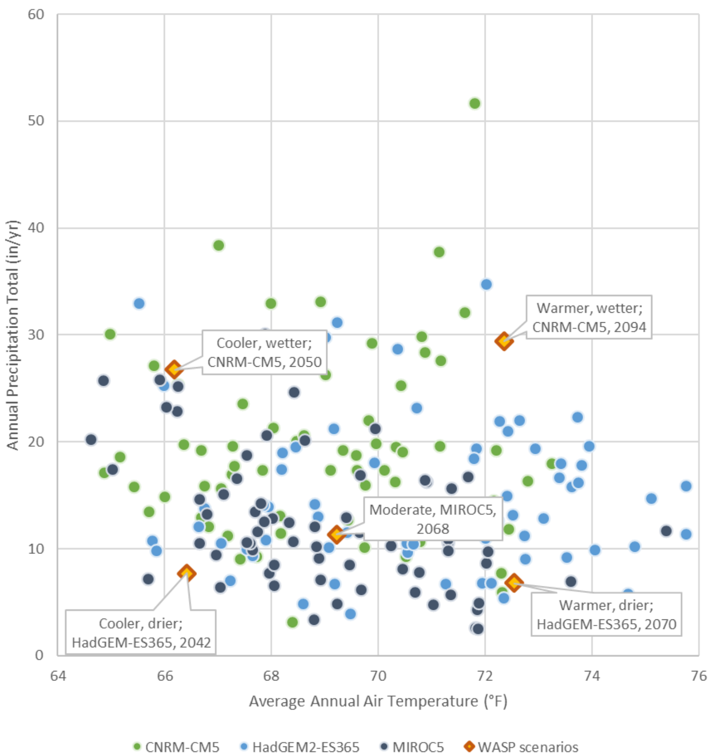


Figure 3.6. Average annual air temperature and precipitation by GCM-year and selected WASP scenarios.

3.3 Results

3.3.1 Potential Future Climate Effects on Hydrology and Water Temperature and Effects of Flow Augmentation

Changes in Streamflow

Changes to the summary annual hydrograph show augmented storm flows in CNRM-CM5 and HadGEM2-ES365, while MIROC5 predicts depleted storm flows (Figure 3.7 and 3.8). Median wet season baseflow duration was on average shorter at both Gorge and Old Hospital sites under CNRM-CM5 and HadGEM2-ES365 (Figure 3.9). However, the change in the 90th percentile of wet season baseflow duration was highly variable. CWRMA has no effect on peak flows nor wet season baseflow duration. Median wet season baseflow magnitude increased under CNRM-CM5 at both the Gorge and Old Hospital, but these gains were either much more modest at the Old Hospital under HADGEM2-ES365 or declined at the Gorge under HADGEM2-ES365 or at both sites under MIROC5 (Figure 3.10). CNRM-CM5 and HADGEM2-ES365 show increasingly depleted baseflows without CWRMA. The presence of CWRMA augments both the wet and dry season baseflow magnitude above reference (CMRM-CM5, HAD-GEMES365) or within reference (MIROC5; Figure 3.11). CWRMA had no effect on wet weather (storm flows) but had an important effect on wet and dry season baseflow (Figure 3.8-3.11).

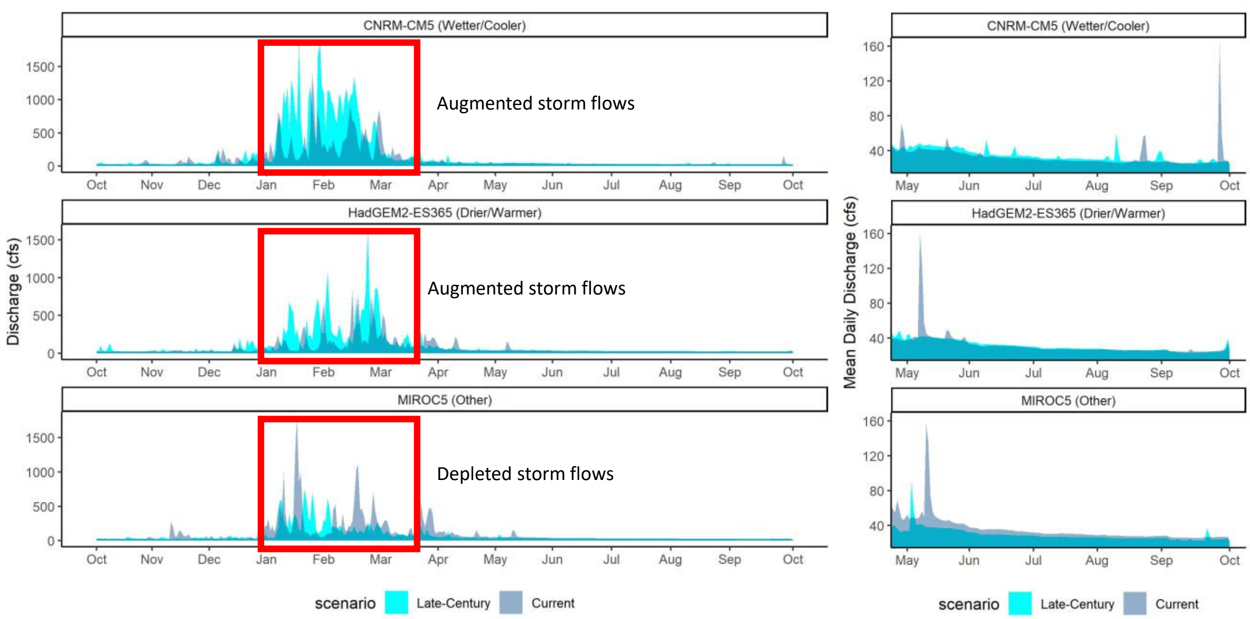


Figure 3.7. Summary annual hydrographs (left panel) and a zoom in on the dry season period by GCM for Old Hospital site.

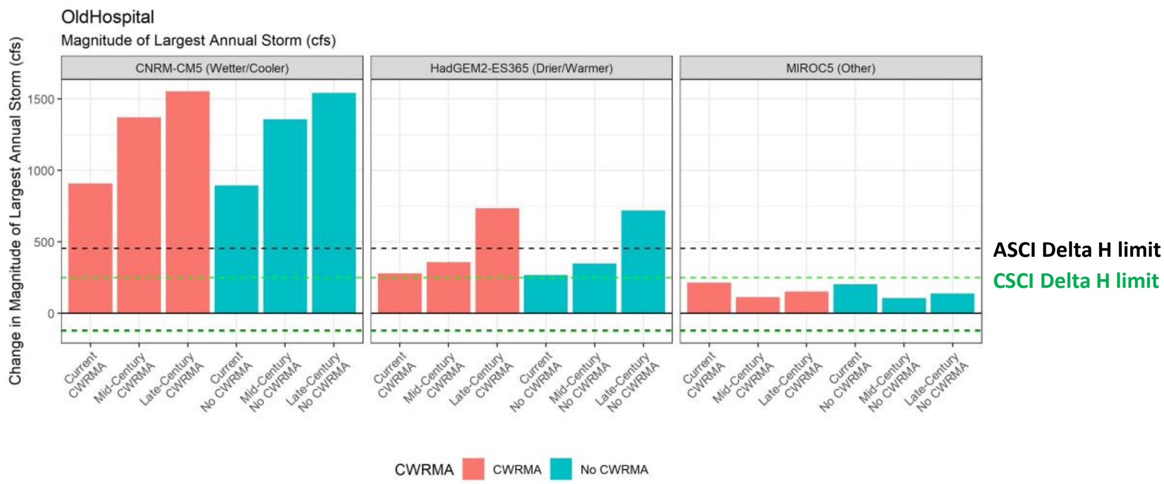


Figure 3.8. Change in median magnitude of largest annual storm, showing augmented peak flows at Old Hospital, relative to current day, with (in red) and without (in blue) CWRMA.

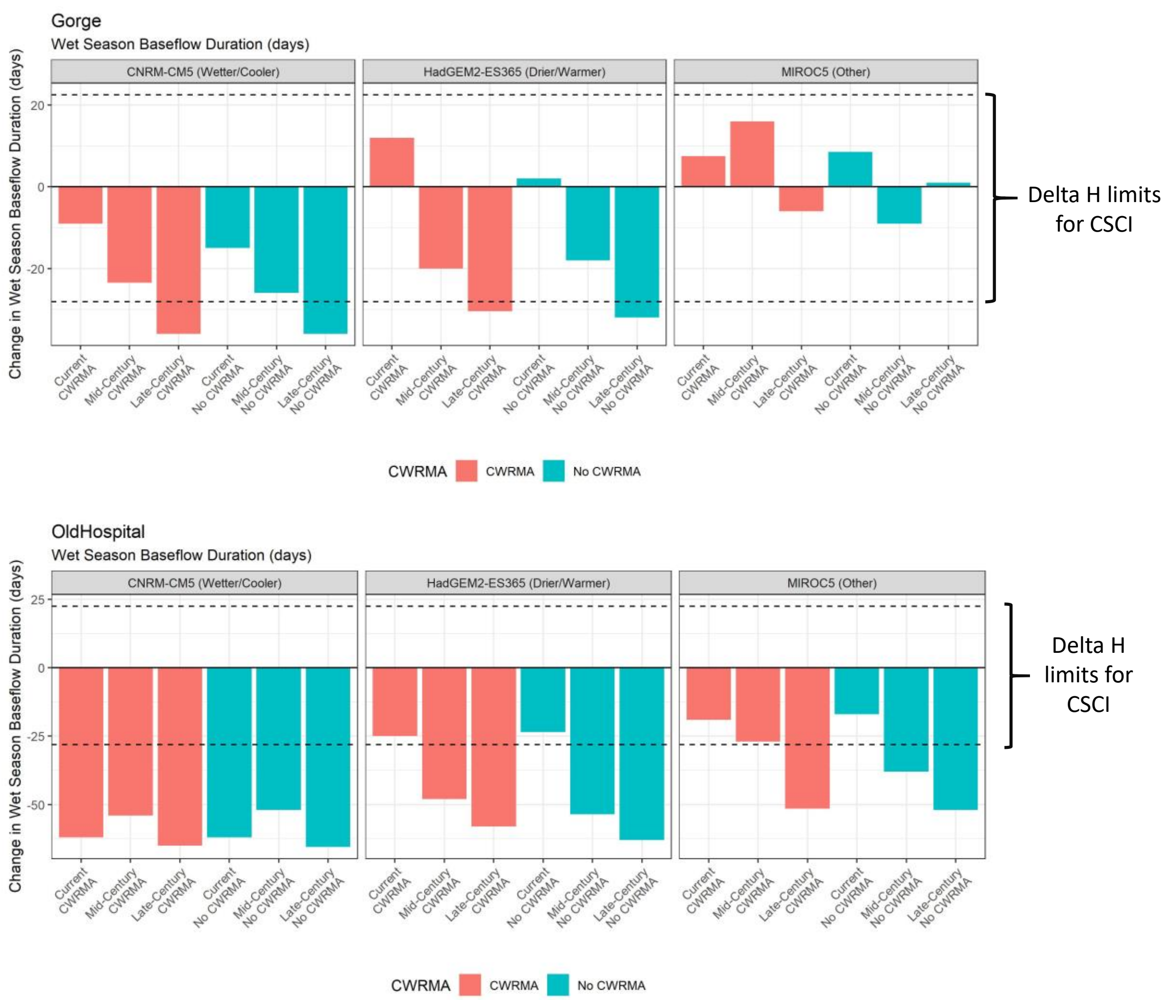


Figure 3.9. Change in median wet season baseflow duration, showing nearly all scenarios with shorter duration relative to reference at the Gorge (top panel) and Old Hospital (bottom panel).

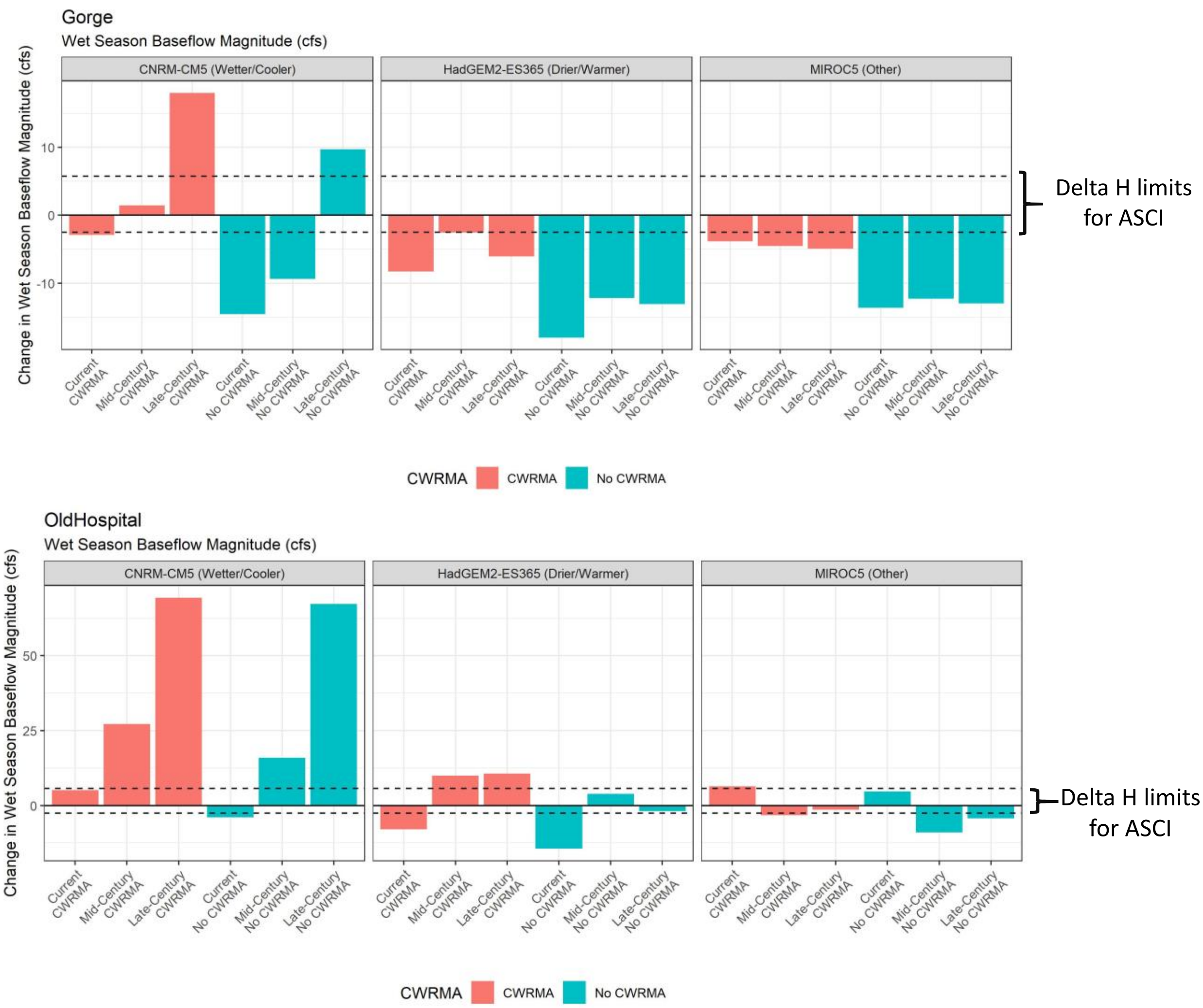


Figure 3.10. Change in median wet season baseflow magnitude at the Gorge (top panel) and Old Hospital (bottom panel), showing declining wet season baseflow magnitude with (in red) and without (in blue) CWRMA.

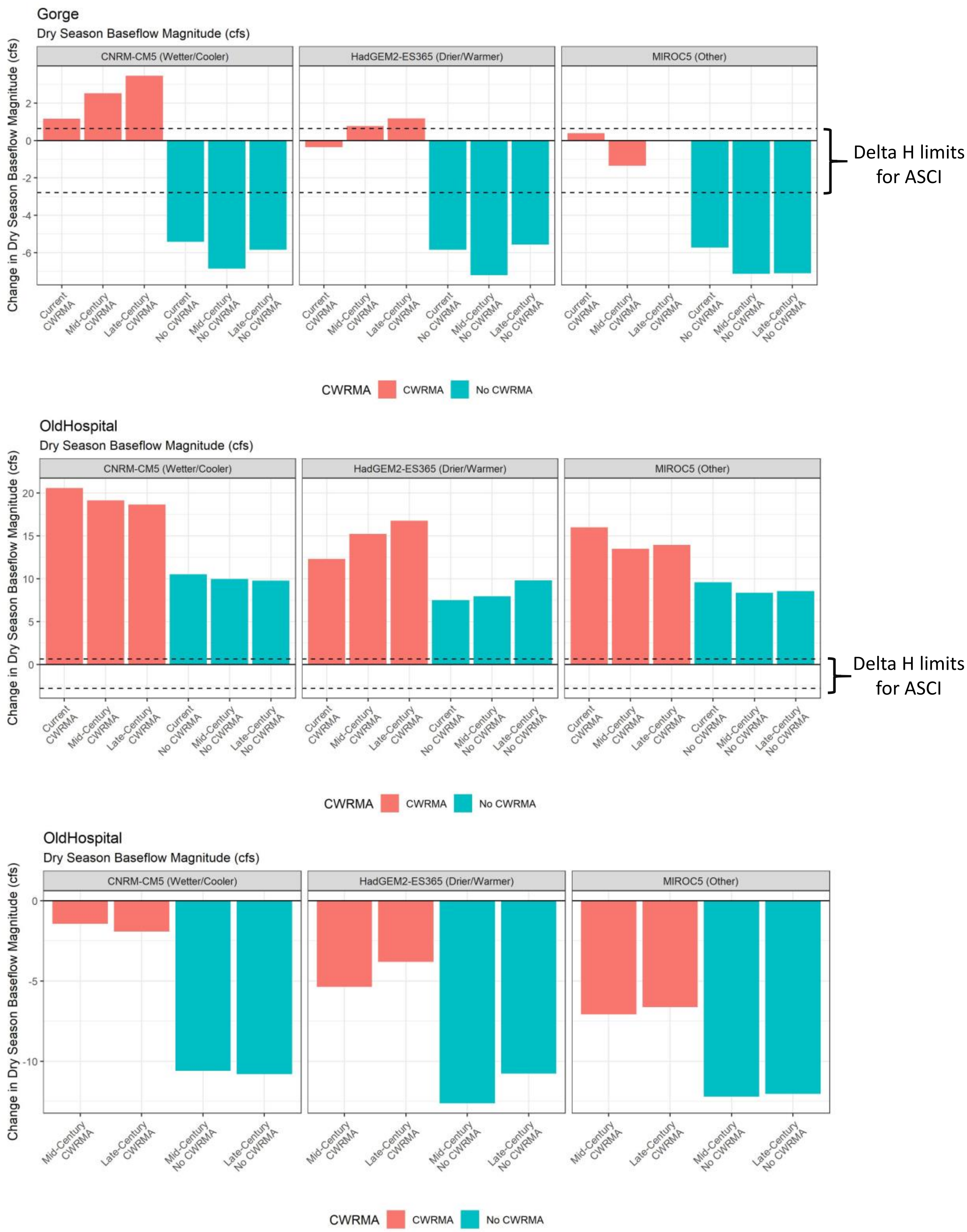


Figure 3.11. Change in median dry season baseflow magnitude at Gorge (top panel) and Old Hospital (middle panel). At the Old Hospital, dry season baseflow is augmented for all scenarios due to irrigation return flow. The bottom panel shows the Old Hospital relative to current conditions, illustrating that dry season baseflow is projected to decrease.

Effects on Temperature

The HSPF models were also used to evaluate potential impacts on stream temperature under potential future climate. The relative change in average monthly water temperature from the hindcast to the future period is shown in Figure 3.12. Across scenarios and locations water temperatures are expected to rise due, in part, to rising air temperatures into the 21st century. At the Gorge, water temperatures increase consistently across the year, generally ranging from about 0.3°C (0.5°F) to 0.7°C (1.25°F). Impacts to water temperature are shown to be more severe downstream near the Old Hospital, ranging from about 0.6°C (1.0°F) to 1.1°C (2.0°F). CWRMA helps to lower water temperatures in the river across the long-term HSPF climate scenarios; water temperatures are more than 10% higher at the Old Hospital without flow augmentation by CWRMA (Figure 3.13).

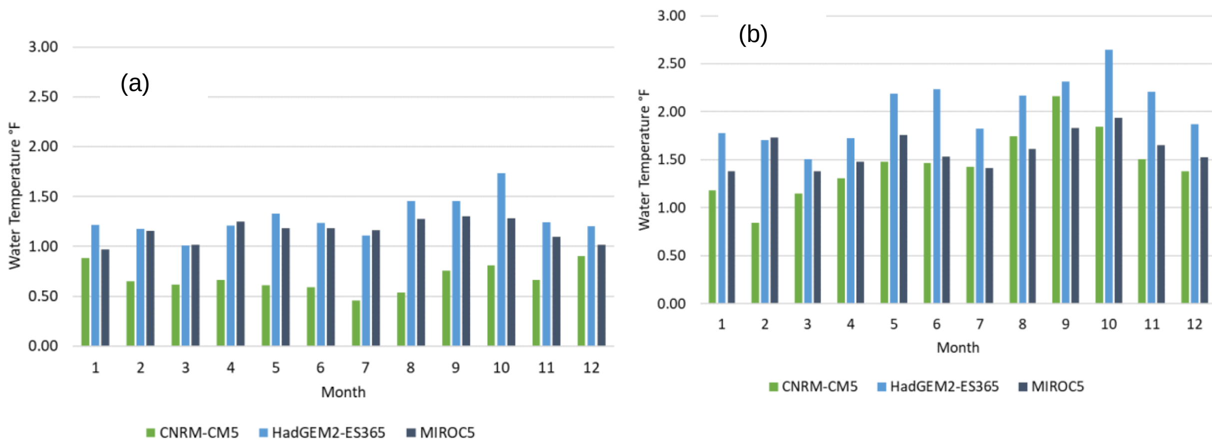


Figure 3.12. Relative change in average monthly water temperature from hindcast (1960-2005) to future (2030-2099) period at SMR Gorge (a) and the Old Hospital (b).

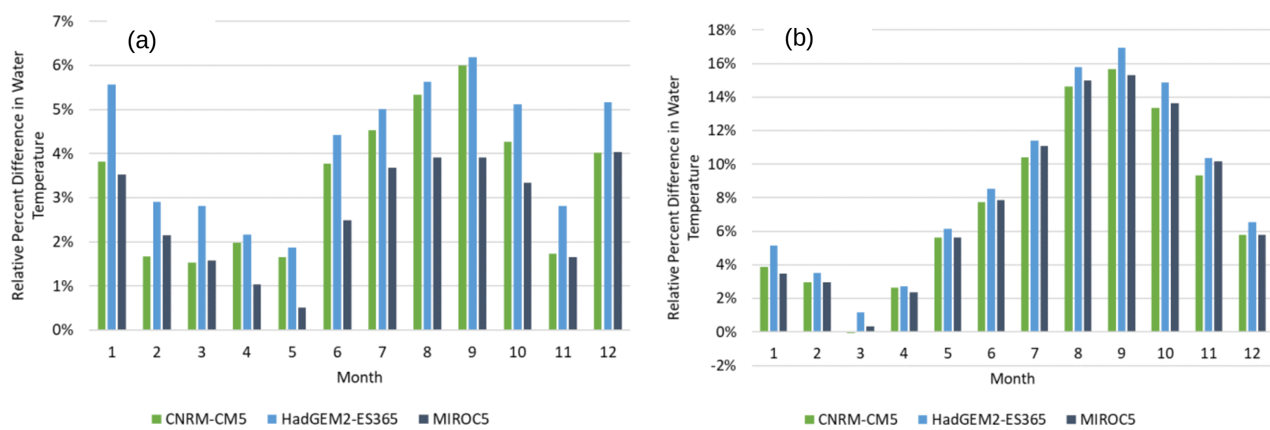


Figure 3.13. HSPF predicted relative difference in average monthly water temperature at SMR near Gorge (a) and Old Hospital (b) if flow augmentation is absent under future climate (2030-2099).

3.3.2 Effects of Altered Stream Flow and Temperature on Biological Integrity

Effects of Flow Alterations on Benthic Invertebrates and Algae

Regional flow ecology models for CSCI predicts effects of alterations in the magnitude of largest annual storm, spring recession flow duration, and wet season baseflow duration, while that of ASCI predicts the effect of the magnitude of largest annual storm, dry season baseflow magnitude, and wet season baseflow magnitude. CSCI regional flow ecology models applied to the GCMs illustrate that biological integrity appears to be robust at the Gorge, until late century (2065-2100), when two of three models predict that biotic integrity will likely be altered (Table 3.7, Figures 3.8-3.11). At the Old Hospital, these impacts are anticipated sooner, with two of three GCMs predicting alterations in biological integrity by mid-century (2030-2065), and more severe by late century (Figures 3.8-3.11). ASCI is sensitive to alterations in wet and dry weather baseflow conditions relative to the 1935-1941 “minimally disturbed” baseline and ASCI Delta H thresholds were triggered even for current conditions simulated by GCMs, such that ASCI Delta H thresholds had no discriminatory power to discern effects of climate change (Table 3.8).

Table 3.7. Effects of flow alteration on biological integrity, as measured by CSCI, which includes magnitude of largest annual storm, spring recession flow duration, and wet season baseflow duration.

Site	GCM	Current (2002-2020)		Mid-Century (2030-2065)		Late-Century (2065-2100)	
		CWRMA	No CWRMA	CWRMA	No CWRMA	CWRMA	No CWRMA
Gorge	CNRM-CM5	Likely Unaltered	Likely Altered	Likely Unaltered	Likely Unaltered	Likely Altered	Likely Altered
	HadGEM2-ES365	Likely Unaltered	Likely Unaltered	Likely Unaltered	Likely Unaltered	Likely Altered	Likely Altered
	MIROC5	Likely Unaltered	Likely Unaltered	Likely Unaltered	Likely Unaltered	Likely Unaltered	Likely Unaltered
Old Hospital	CNRM-CM5	Likely Altered	Likely Altered	Likely Altered	Likely Altered	Likely Altered	Likely Altered
	HadGEM2-ES365	Likely Unaltered	Likely Unaltered	Likely Altered	Likely Altered	Likely Altered	Likely Altered
	MIROC5	Likely Unaltered	Likely Unaltered	Likely Unaltered	Likely Unaltered	Likely Altered	Likely Altered

Table 3.8. Effects of flow alteration on biological integrity, as measured by ASCI, which includes magnitude of largest annual storm, spring recession flow duration, and wet season baseflow duration.

Site	GCM	Current (2002-2020)		Mid-Century (2030-2065)		Late-Century (2065-2100)	
		CWRMA	No CWRMA	CWRMA	No CWRMA	CWRMA	No CWRMA
Gorge	CNRM-CM5	Likely Altered	Likely Altered	Likely Altered	Likely Altered	Likely Altered	Likely Altered
	HadGEM2-ES365	Likely Unaltered	Likely Altered	Likely Altered	Likely Altered	Likely Unaltered	Likely Altered
	MIROC5	Likely Altered	Likely Altered	Likely Unaltered	Likely Altered	Likely Altered	Likely Altered
Old Hospital	CNRM-CM5	Likely Altered	Likely Altered	Likely Altered	Likely Altered	Likely Altered	Likely Altered
	HadGEM2-ES365	Likely Altered	Likely Altered	Likely Altered	Likely Altered	Likely Altered	Likely Altered
	MIROC5	Likely Altered	Likely Altered	Likely Altered	Likely Altered	Likely Altered	Likely Altered

Effects of Temperature and Flow Alterations on Thermal Habitat for Aquatic Organisms

At the Gorge, only CT_{Max} and T_{PREF} for *Oncorhynchus mykiss* (Steelhead; 29.4°C and 21°C, respectively) and T_{PREF} for *Peudacris hypochondriaca* (Baja California Chorus Frog; 34 °C) were relevant (Figure 3.15). We focused further analyses on T_{PREF} for Steelhead as this threshold had the most discriminatory power among the sites and scenarios analyzed.

The percent of time (Figures 3.14 and 3.15) and the number of days (Figure 3.16) with temperatures greater than the T_{PREF} for Steelhead increases steadily and consistently for all scenarios relative to the historic baseline. Increases were the most pronounced for HadGEM2-ES365 at the Gorge from 30% to 60% by the end of the century, while these increases were less pronounced at the Old Hospital (on the order of 10% increase). CWRMA had a modifying effect on these T_{PREF} exceedances at the Gorge, but not at the Old Hospital (Figure 3.15-3.16).

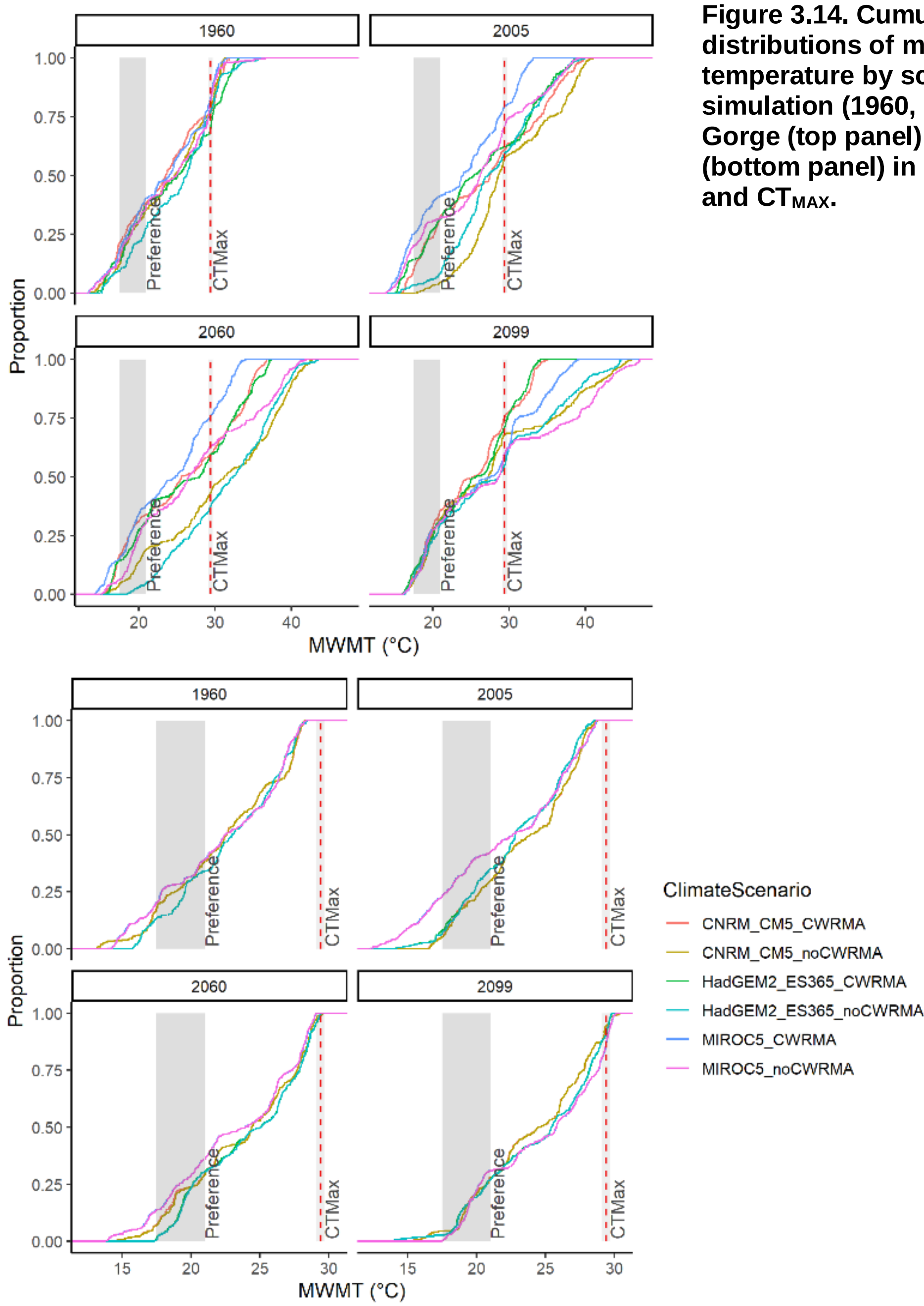


Figure 3.14. Cumulative frequency distributions of mean weekly maximum temperature by scenario for selected years in simulation (1960, 2005, 2060, 2099) for the Gorge (top panel) and the Old Hospital (bottom panel) in relation to Steelhead T_{PREF} and CT_{MAX}.

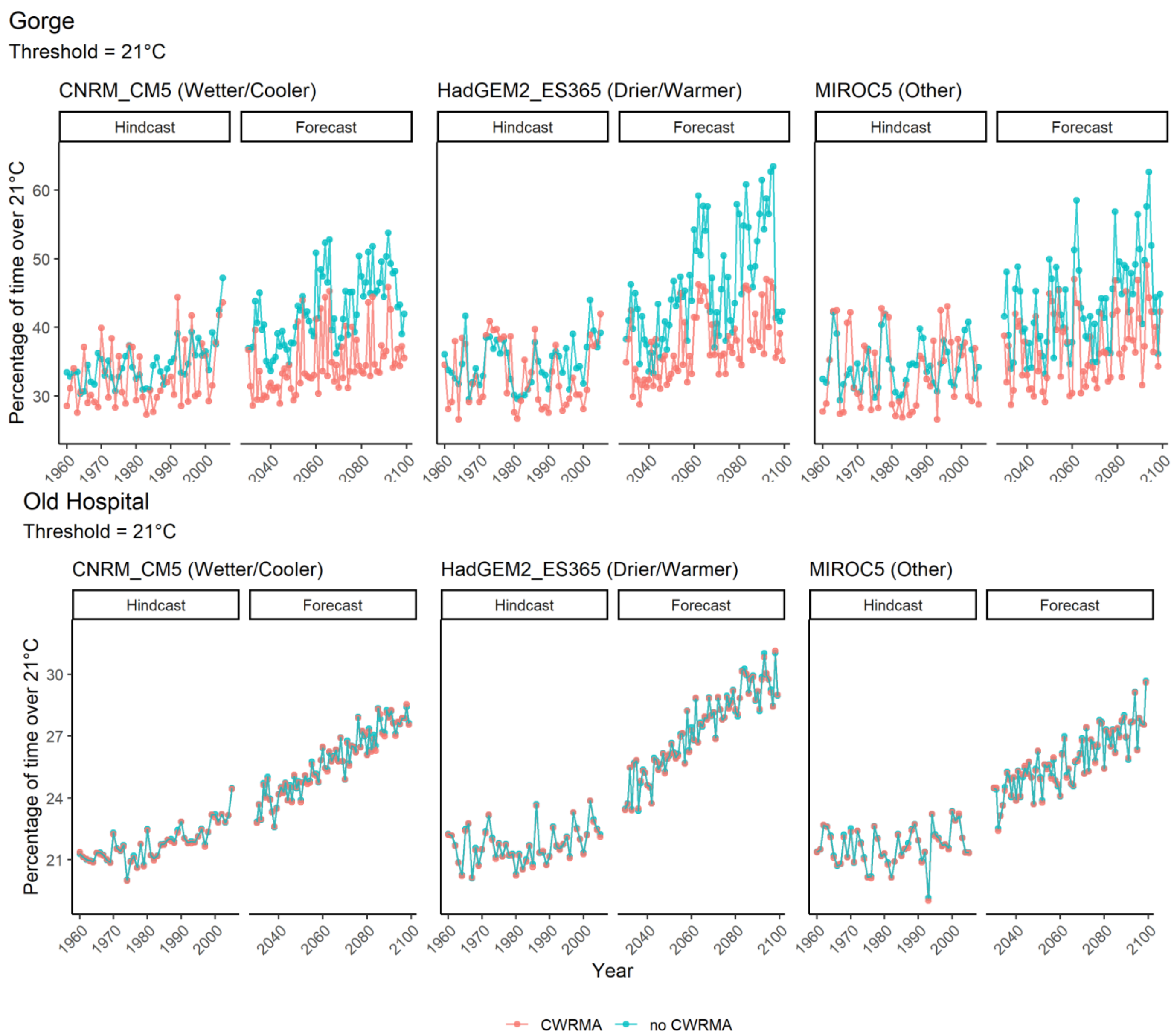


Figure 3.15. Percent of time that T_{PREF} (21°C) for Steelhead is exceeded by scenario for hindcast and forecast, with and without CWRMA.

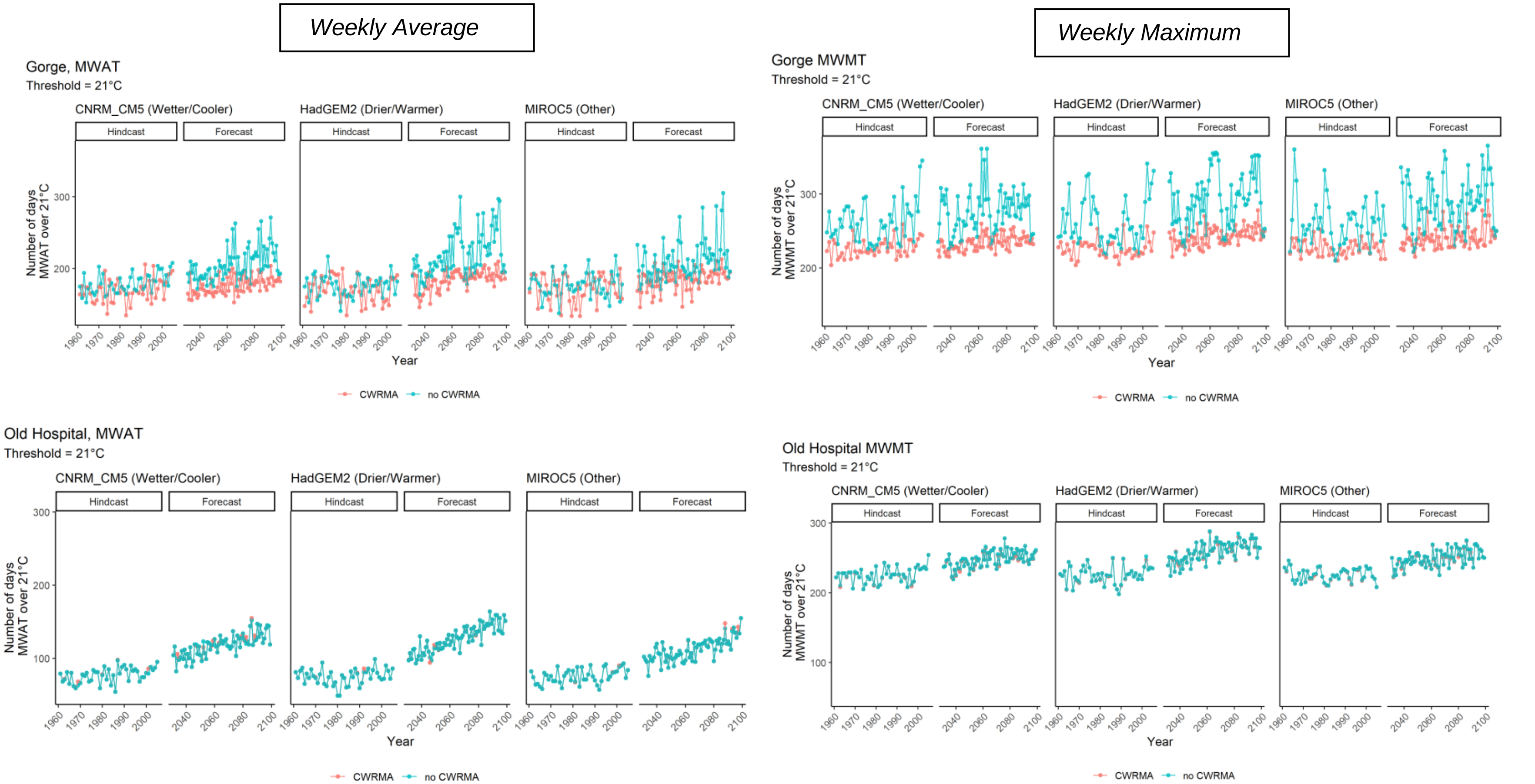


Figure 3.16. Plots of the number of days > T_{PREF} for Steelhead for the Gorge (top panel) and Old Hospital (bottom panel) as a weekly average (left panels) and weekly maximum (right panel). Results are shown with and without the augmentation by CWRMA.

3.3.2 Effects of Altered Streamflow, Nutrients, Temperature on Eutrophication Response

Streamflow and Water Temperature

For the five scenarios simulated in WASP (Figure 3.17), the differences between monthly average minimum and maximum water temperatures are larger at upstream locations such as at MWD and Rainbow compared to downstream locations such as at the Old Hospital (Figure 3.18). There is also a clear gradient in maximum temperature, from coastal increasing inland. Differences are also evident across the scenarios at the same location (e.g., MIROC5 2068 vs. CNRM-CM5 2050 at the Gorge), although seasonal patterns are generally consistent. Lack of flow augmentation has varied impacts on water temperature across the GCM-year scenarios and locations as shown in Figure 3.19. This differs from the HSPF predictions, which predict higher water temperatures under conditions without CWRMA. The HSPF simulations reflect a long-term future period from 2030 to 2099 whereas the WASP simulations capture conditions on a particular year for a GCM within that temporal period. In addition, WASP represents conditions with a finer spatial and temporal resolution.

Nutrients

Variability in future predicted HSPF-simulated annual total nitrogen (TN) and total phosphorus (TP) loads results for the 21st century is evident from simulations of 1950 through 2099 (Figure 3.20) and mostly stem from changes in flow (Figure 3.21), particularly for CNRM-CM5. There are significant differences in impacts to TN and TP loads across the GCMs (Table 3.9). For example, the CNRM-CM5 scenario estimates TN loads will increase by about 380% into the mid- and late-21st century, but MIROC5 predicts a decrease in average annual TN load of about 22%, corresponding to predicted flow alterations (Figure 3.21). However, median and average TN concentrations are shown to decrease (less than 10%) for both GCM scenarios at the Old Hospital location. While the load is higher for the CNRM-CM5 scenario, additional streamflow volume simultaneously dilutes the TN concentrations. Median TP concentrations for the future period are very similar to the hindcast period for all three scenarios near the Old Hospital. However, changes in load may have a bigger impact on nutrient concentrations in the Santa Margarita Estuary.

WASP-predicted average and median TN and TP concentrations and loads are provided for the GCM-year scenarios by location in Table 3.10. Concentrations tend to be somewhat similar across the scenarios while the loads vary significantly due to flow. At the Gorge, for example, TP loads for the two wet scenarios (CNRM-CM5 in 2050 and 2094) are 289,382 and 816,070 lb/yr, whereas the loads are 20,497 and 13,033 lb/yr for the drier scenarios (HadGEM2-ES365 in 2042 and 2070). Median TP concentrations are higher for the drier scenarios. Median and average TN and TP concentrations under future climate are consistently higher compared to current/historic conditions due to complex interacting upland and instream processes; these include, for example, storm severity and duration that influence flow pathways (e.g., infiltration, runoff) and landscape pollutant transport (e.g., sheet and rill erosion), irrigation water demands under future climate, instream biogeochemical dynamics (e.g., decomposition rates due to changes in water temperature, algal uptake of nutrients), and more.

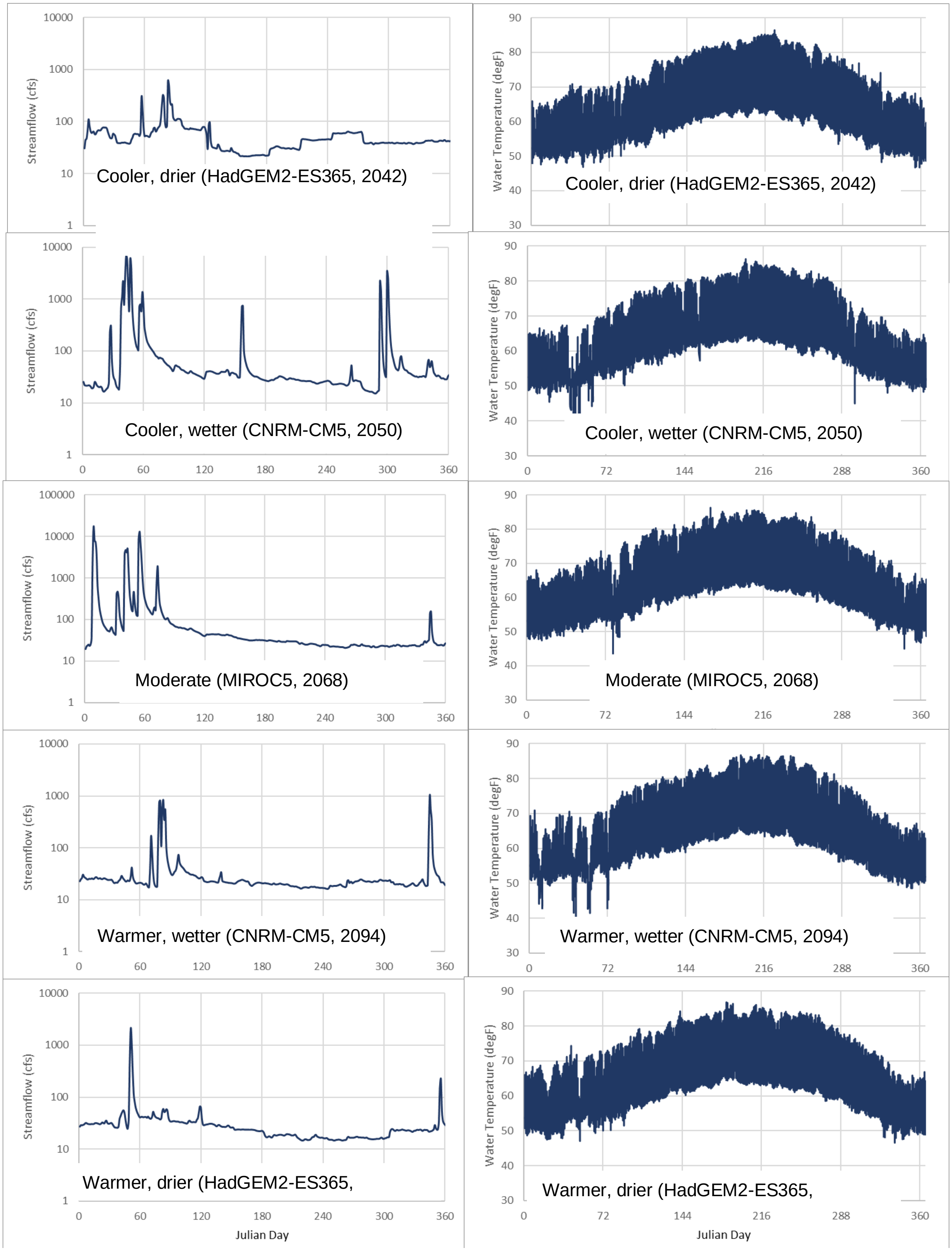
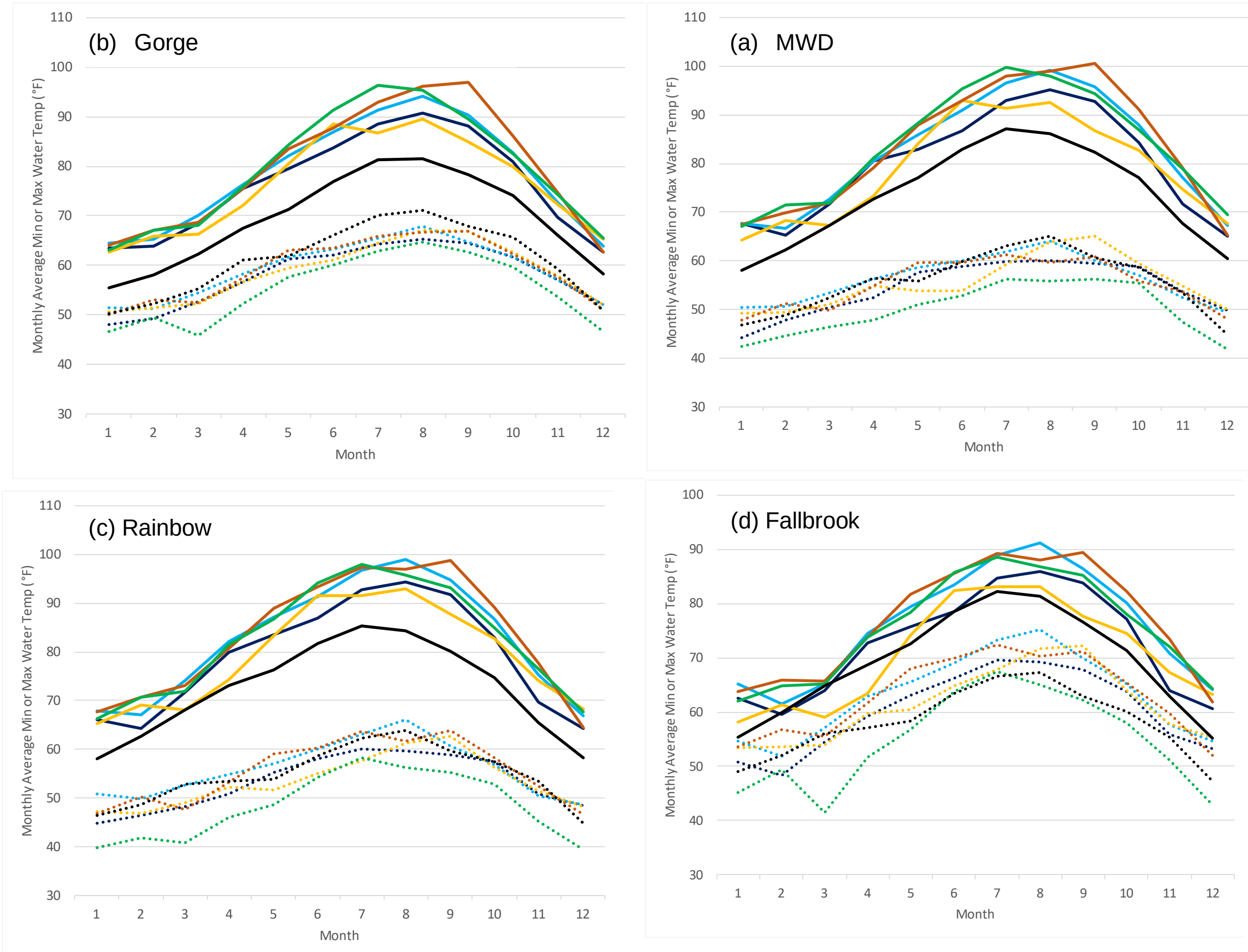


Figure 3.17. HSPF simulated streamflow and temperature for SMR near the Old Hospital for selected WASP climate scenarios.



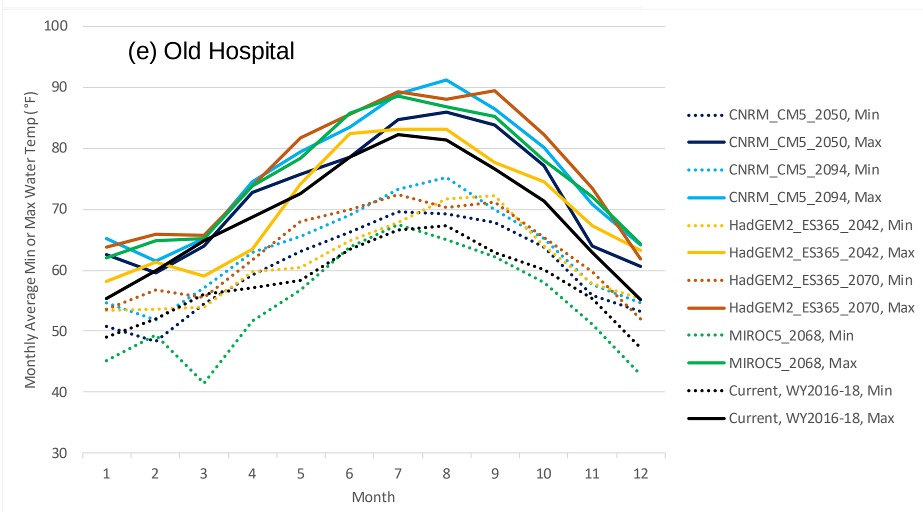


Figure 3.18. Monthly average minimum and maximum water temperature at Gorge. The black line shows current conditions from the 2016-2018 calibration run and a clear departure from the 10th, 50th, and 90th percentile of temperature extremes represented in the climate scenarios.

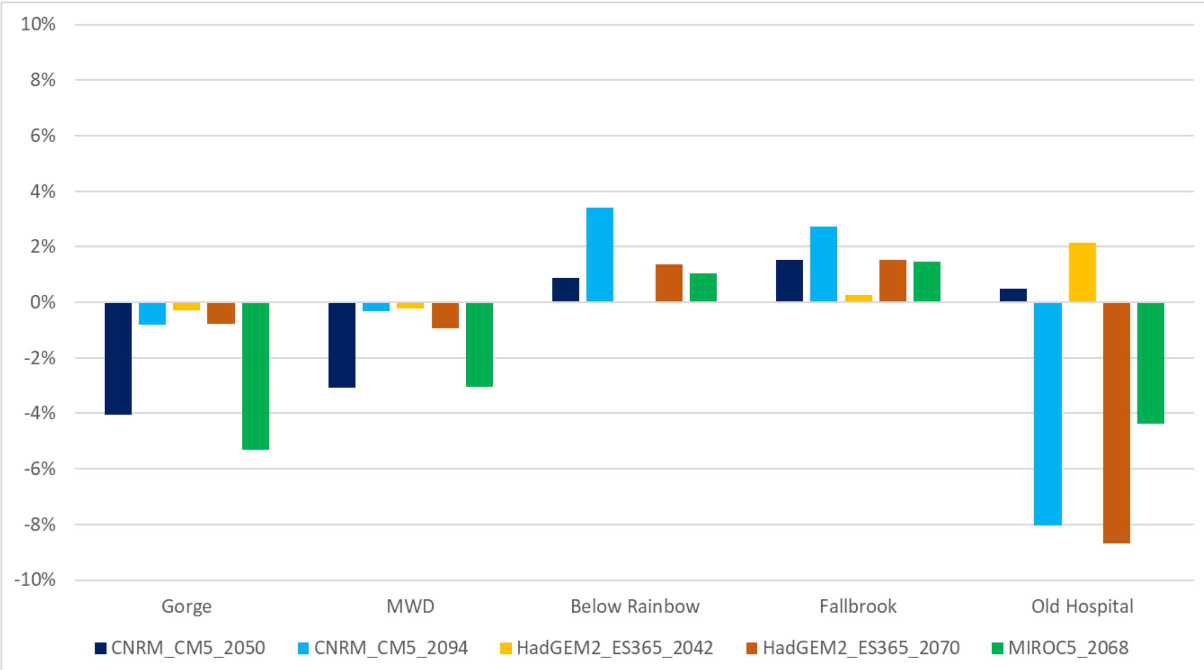


Figure 3.19. WASP predicted relative difference in average water temperature if flow augmentation is absent under future climate by GCM-year and location.

TN and TP loads decrease slightly in the absence of flow augmentation as the CWRMA releases contribute some nutrients. Due to decreased water volume in the stream reaches, however, median, and average TN and TP concentrations are higher in future climate scenarios without flow augmentation (Table 3.11). Therefore, simulations indicate the CWRMA releases dilute nutrients. WASP-predicted scenarios show the most pronounced impacts at the Gorge, MWD, and below the confluence with Rainbow Creek (Table 3.12). The lower watershed contributes runoff and subsurface flow to the river lessening the influence of the CWRMA release on nutrient concentrations in the river near Fallbrook and the Old Hospital. The relative changes to nutrient loads are significantly smaller compared to those for concentrations, indicating the presence of the CWRMA release dilutes nutrients concentrations in the river but loading is more largely attributed to other point and nonpoint sources in the watershed.

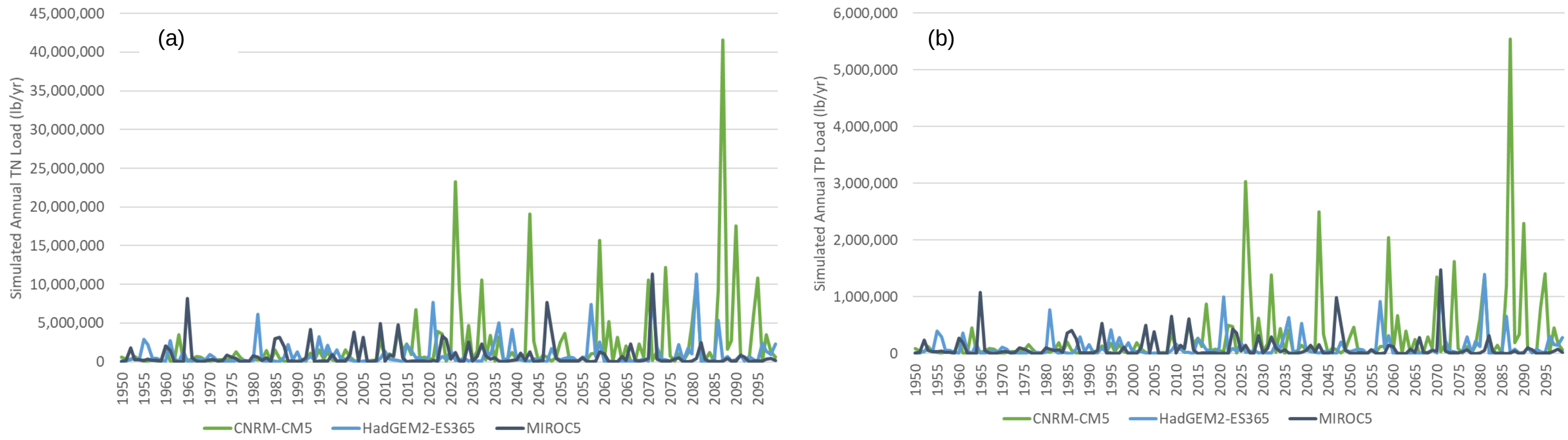


Figure 3.20 Predicted annual total nitrogen load (lb/yr) (a) and total phosphorus load (lb/yr) (b) from hindcast (1960-2005) to future (2030-2099) period at SMR Gorge.

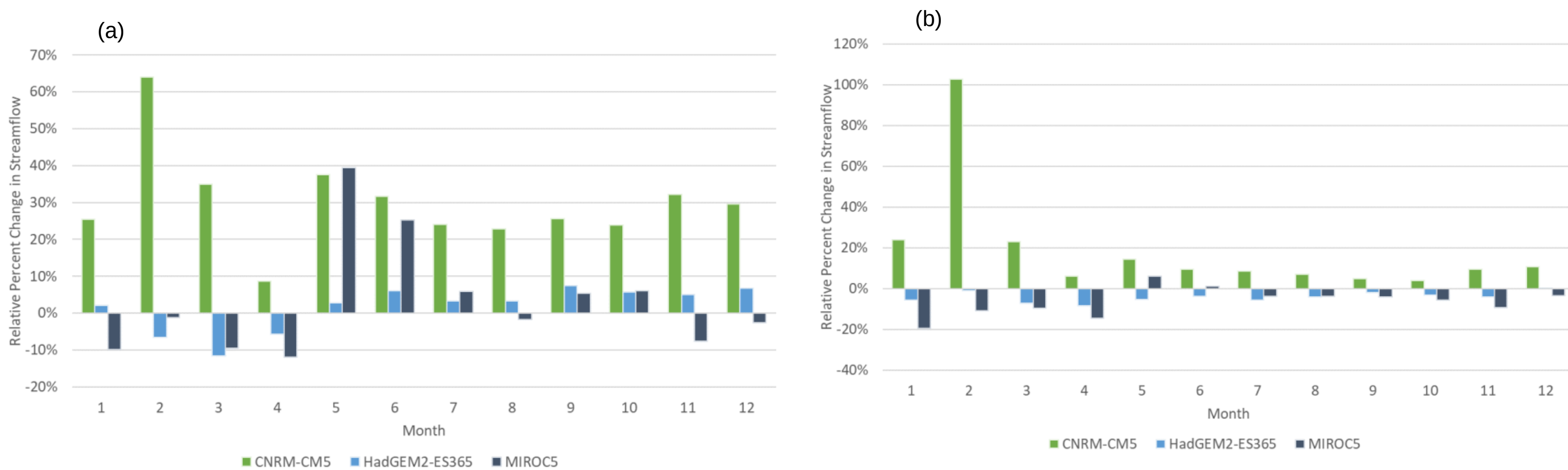


Figure 3.21. Relative percent change in median streamflow by month from hindcast (1960-2005) to future (2030-2099) period at SMR Gorge (a) and Old Hospital (b).

Table 3.9. HSPF-predicted relative change in annual load, median concentration, and average concentration for Total Nitrogen and Total Phosphorus from hindcast (1960-2005) to future (2030-2099) period at SMR Gorge, including the influence of CWRMA.

	CNRM-CM5	HadGEM2-ES365	MIROC5
OLD HOSPITAL			
Annual Average Load			
Total Nitrogen	530.9%	71.7%	-21.6%
Total Phosphorus	539.0%	67.3%	-22.7%
Median Concentration			
Total Nitrogen	-3.9%	2.0%	6.9%
Total Phosphorus	-9.1%	-1.4%	4.8%
Average Concentration			
Total Nitrogen	8.8%	4.5%	2.1%
Total Phosphorus	6.2%	0.1%	-6.8%
GORGE			
Annual Average Load			
Total Nitrogen	530.9%	71.7%	-21.6%
Total Phosphorus	539.0%	67.3%	-22.7%
Median Concentration			
Total Nitrogen	-3.9%	2.0%	6.9%
Total Phosphorus	-9.1%	-1.4%	4.8%
Average Concentration			
Total Nitrogen	8.8%	4.5%	2.1%
Total Phosphorus	6.2%	0.1%	-6.8%

Table 3.10. WASP predicted average and median total nitrogen and total phosphorus concentrations and loads at SMR Mainstem Sites.

Nutrient Measure (concentration-mg/L or load-lb/yr)	Current (WY2016-18)	CNRM-CM5, 2050	CNRM-CM5, 2094	HadGEM2 - ES365, 2042	HadGEM2-ES365, 2070	MIROC 5, 2068
Gorge						
Average TN	0.92	1.54	1.56	1.64	1.56	1.68
Median TN Conc.	0.66	1.03	0.98	1.44	1.37	1.42
TN Load	67,095	2,427,80	6,328,461	125,281	115,726	85,065
Average TP Conc.	0.061	0.117	0.137	0.242	0.129	0.117
Median TP Conc.	0.032	0.059	0.060	0.221	0.116	0.119
TP Load	8,455	289,382	816,070	20,497	13,033	8,025
MWD						
Average TN	1.03	1.89	1.79	1.75	1.76	1.97
Median TN Conc.	0.83	1.38	1.22	1.24	1.47	1.54
TN Load	70,718	2,437,01	6,350,104	123,832	120,934	91,242
Average TP	0.058	0.121	0.134	0.233	0.121	0.114
Median TP Conc.	0.031	0.061	0.057	0.217	0.104	0.097
TP Load	8,259	284,633	808,196	19,569	12,665	7,782
Rainbow						
Average TN	1.19	2.84	2.53	2.18	2.51	2.85
Median TN Conc.	1.03	2.45	2.00	1.42	2.31	2.16
TN Load	85,859	2,499,64	6,374,174	141,311	151,152	124,101
Average TP Conc.	0.056	0.149	0.155	0.232	0.147	0.145
Median TP Conc.	0.040	0.098	0.081	0.210	0.127	0.120
TP Load (lb/yr)	8,445	277,744	785,825	19,114	13,314	8,735
Fallbrook						
Average TN	1.28	3.75	3.40	2.68	3.28	3.65
Median TN Conc.	1.09	3.58	2.96	1.95	3.15	3.21
TN Load	113,588	2,685,99	6,576,971	224,116	238,460	226,134
Average TP Conc.	0.056	0.138	0.144	0.195	0.121	0.117
Median TP Conc.	0.039	0.101	0.092	0.186	0.117	0.103
TP Load	8,746	278,155	783,548	20,034	14,593	10,278
Old Hospital						
Average TN	1.30	3.68	3.31	2.73	3.31	3.55
Median TN Conc.	1.08	3.54	2.63	1.79	3.09	2.94
TN Load	127,968	2,825,51	6,737,677	254,545	278,795	269,661
Average TP	0.060	0.138	0.137	0.181	0.124	0.114
Median TP Conc.	0.042	0.111	0.101	0.175	0.123	0.085
TP Load	8,889	272,864	761,102	19,807	15,328	10,840

Table 3.11. HSPF predicted relative difference in annual load, median concentration, and average concentration for Total Nitrogen and Total Phosphorus at SMR Gorge and Old Hospital if flow augmentation is absent under future climate (2030-2099).

	CNRM-CM5	HadGEM2-ES365	MIROC5
	Gorge		
Annual Average Load			
Total Nitrogen	-0.3%	-0.7%	-1.0%
Total Phosphorus	-0.1%	-0.3%	-0.4%
Median Concentration			
Total Nitrogen	186%	209%	211%
Total Phosphorus	235%	255%	231%
Average Concentration			
Total Nitrogen	352%	463%	505%
Total Phosphorus	218%	288%	305%
	Old Hospital		
Annual Average Load			
Total Nitrogen	-0.5%	-1.2%	-1.6%
Total Phosphorus	-0.2%	-0.5%	-0.8%
Median Concentration			
Total Nitrogen	14.1%	13.5%	12.6%
Total Phosphorus	11.7%	10.3%	8.7%
Average Concentration			
Total Nitrogen	15.6%	16.2%	15.7%
Total Phosphorus	8.2%	8.6%	8.1%

Table 3.12. WASP predicted relative difference in annual load, median concentration, and average concentration for Total Nitrogen and Total Phosphorus if flow augmentation is absent under future climate by GCM-year by SMR mainstem site.

Nutrient Measure	CNRM-CM5, 2050	CNRM-CM5, 2094	HadGEM2 -ES365, 2042	HadGEM2-ES365, 2070	MIROC5, 2068
		Gorge			
Average TN Conc. (mg/L)	318.3%	271.6%	69.4%	137.7%	290.6%
Median TN Conc. (mg/L)	232.9%	300.1%	17.8%	60.5%	150.7%
TN Load (lb/yr)	-0.5%	-0.1%	-4.8%	-6.7%	-17.5%
Average TP Conc. (mg/L)	210.1%	146.3%	60.5%	102.4%	201.1%
Median TP Conc. (mg/L)	240.9%	260.1%	52.8%	76.7%	120.0%
TP Load (lb/yr)	-0.2%	-1.6%	10.1%	-3.9%	-6.8%
		MWD			
Average TN Conc. (mg/L)	328.9%	276.8%	92.1%	124.2%	277.6%
Median TN Conc. (mg/L)	317.9%	350.7%	13.6%	65.2%	223.1%
TN Load (lb/yr)	-0.5%	0.0%	-2.6%	-7.2%	-17.8%

Average TP Conc. (mg/L)	216.5%	141.9%	67.9%	86.5%	201.7%
Median TP Conc. (mg/L)	258.2%	233.6%	48.2%	71.1%	133.4%
TP Load (lb/yr)	-0.3%	-1.5%	11.2%	-5.0%	-8.4%
Rainbow					
Average TN Conc. (mg/L)	176.3%	163.9%	67.0%	79.5%	142.6%
Median TN Conc. (mg/L)	192.1%	202.2%	17.9%	57.4%	127.2%
TN Load (lb/yr)	-0.6%	0.0%	0.7%	-6.2%	-13.3%
Average TP Conc. (mg/L)	149.2%	131.2%	63.3%	74.0%	139.5%
Median TP Conc. (mg/L)	216.6%	299.2%	44.7%	81.8%	130.1%
TP Load (lb/yr)	-0.3%	-1.3%	13.4%	-4.9%	-7.2%
Fallbrook					
Average TN Conc. (mg/L)	49.2%	56.7%	25.2%	33.6%	44.0%
Median TN Conc. (mg/L)	54.1%	67.6%	18.9%	39.1%	64.9%
TN Load (lb/yr)	-0.6%	-0.1%	1.0%	-4.2%	-7.6%
Average TP Conc. (mg/L)	34.0%	34.7%	38.5%	27.5%	36.2%
Median TP Conc. (mg/L)	51.9%	62.6%	35.9%	33.8%	44.1%
TP Load (lb/yr)	-0.3%	-1.3%	13.2%	-4.3%	-5.9%
Old Hospital					
Average TN Conc. (mg/L)	30.7%	35.4%	20.4%	24.9%	30.3%
Median TN Conc. (mg/L)	32.6%	44.3%	22.9%	31.1%	46.8%
TN Load (lb/yr)	-0.7%	-0.1%	1.6%	-3.8%	-6.6%
Average TP Conc. (mg/L)	24.3%	23.6%	36.9%	22.1%	24.5%
Median TP Conc. (mg/L)	26.3%	25.4%	30.4%	24.3%	44.7%
TP Load (lb/yr)	-0.7%	-1.3%	15.1%	-3.7%	-5.4%

Dissolved Oxygen

Simulated dissolved oxygen at the five key mainstem locations illustrate key differences across scenarios (Figures 3.22 and 3.23, Table 3.13). At the Gorge location warm season 7DADMin differs significantly across the scenarios and tends to be better (i.e., higher water column dissolved oxygen concentrations with less excursions of the water quality objective (WQO) under wetter conditions (both CNRM-CM5 scenarios). Higher 7DADMin concentrations correspond with a narrower diel range. Interestingly, results in the cooler season from about November through late March are very similar across the five scenarios and differences are attributed to conditions in the warm season at this location. Below the confluence with Rainbow Creek and at Fallbrook, sites that are more influenced by higher nutrient concentrations, daily dissolved oxygen variability is much larger. Excursions of the WQO occur between about 40% to 53% of the time year-round under future climate. This is worse compared to current conditions; for Water Year (WY) 2016-2018 the WASP predicted frequency of year-round 7DADMin excursions is 38.7%. At the Old Hospital site, where temperatures are buffered by proximity to ocean, exceedances of about 20.8% were predicted under current conditions compared to about 18% to 40% under future climate. These results suggest that attainment of the dissolved oxygen WQO will be more difficult to achieve in the mid to late 21st century compared to now.

As shown in Table 3.14, the frequencies of 7DADMin (the 7-day rolling average of daily minima) excursions are consistently predicted to be higher without CWRMA as are dissolved oxygen diel variabilities.

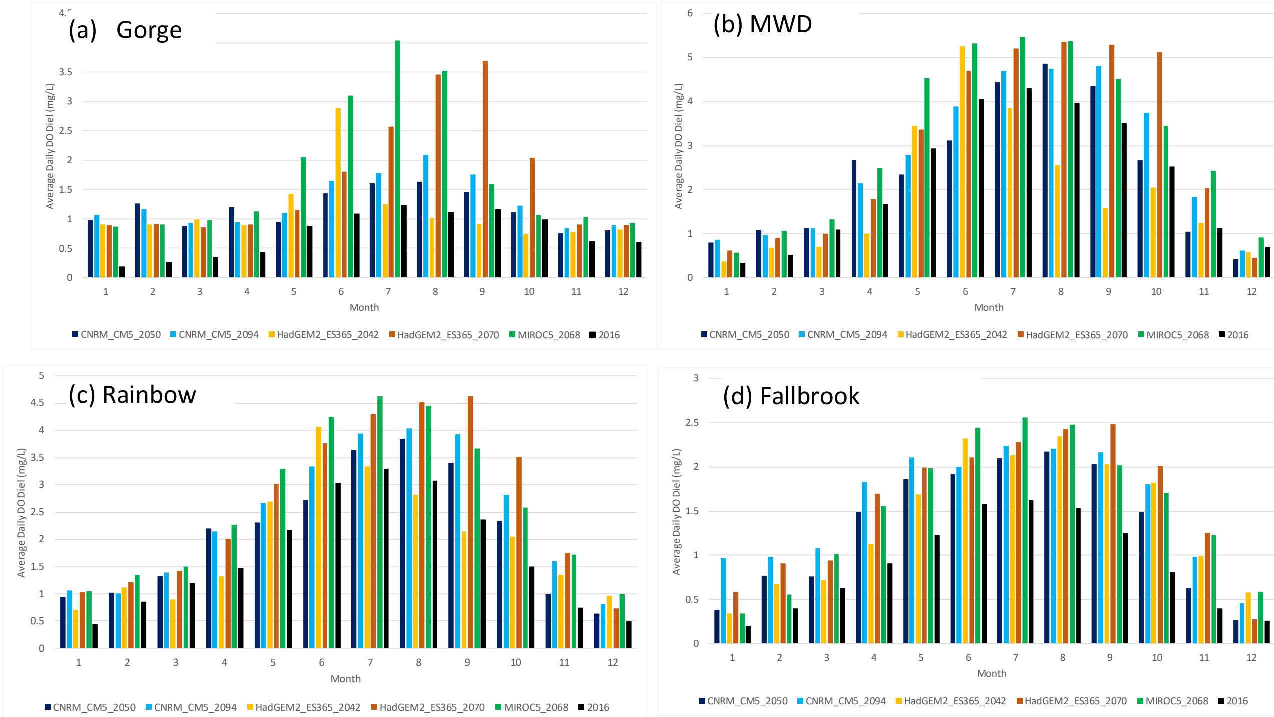
Table 3.13. WASP predicted frequency of 7DADMin excursions (< 6mg/L) at Gorge.

Period	Current (WY2016-18)	COOLER, WETTER	WARMER, WETTER	COOLER, DRIER	WARMER, DRIER	MODERATE
		CNRM-CM5,	CNRM-CM5, 2094	HadGEM2-ES365,	HadGEM2-ES365,	MIROC5, 2068
			Gorge			
Year-round	16.5%	10.7%	17.8%	8.8%	33.2%	34.8%
April to September	32.8%	21.3%	35.5%	17.5%	56.3%	69.4%
October to March	0.0%	0.0%	0.0%	0.0%	9.9%	0.0%
			MWD			
Year-round	43.5%	49.6%	55.6%	39.2%	55.1%	58.6%
April to September	76.5%	89.1%	91.3%	71.0%	88.0%	91.3%
October to March	10.0%	9.9%	19.8%	7.1%	22.0%	25.8%
			Rainbow			
Year-round	38.7%	44.7%	53.2%	39.7%	54.0%	52.9%
April to September	72.7%	80.9%	89.1%	74.3%	88.5%	90.2%
October to March	4.3%	8.2%	17.0%	4.9%	19.2%	15.4%
			Fallbrook			
Year-round	21.7%	45.2%	54.0%	41.1%	54.8%	49.9%
April to September	43.2%	81.4%	92.3%	74.9%	90.7%	89.1%
October to March	0.0%	8.8%	15.4%	7.1%	18.7%	10.4%
			Old Hospital			
Year-round	20.8%	27.1%	34.2%	17.8%	40.3%	35.3%
April to	41.3%	50.8%	66.1%	35.5%	73.8%	69.4%
October to March	0.0%	3.3%	2.2%	0.0%	6.6%	1.1%

Table 3.14. WASP predicted relative difference in frequency of 7DADMin excursions (< 6mg/L) and DO diel variability if flow augmentation is absent under future climate by GCM-year and location.

Location	CNRM-CM5,	CNRM-CM5, 2094	HadGEM2 - ES365, 2042	HadGEM2-ES365, 2070	MIROC5, 2068
Frequency of 7DADMin excursions					
Gorge	359.0%	267.7%	100.0%	33.1%	52.0%
MWD	23.2%	34.0%	4.2%	14.9%	28.0%
Below Rainbow	18.4%	32.0%	2.8%	6.1%	25.4%
Fallbrook	8.5%	13.2%	3.3%	6.0%	12.1%
Old Hospital	40.4%	30.4%	30.8%	9.5%	13.2%
DO diel variability					
Gorge	223.7%	263.0%	15.8%	58.2%	137.0%
MWD	99.4%	116.8%	12.7%	42.8%	82.6%
Below Rainbow	34.1%	56.5%	6.7%	16.1%	36.2%
Fallbrook	29.3%	34.7%	1.2%	12.4%	33.1%
Old Hospital	52.7%	49.8%	22.1%	31.8%	40.8%

Figure 3.22. Predicted 7DADMin and daily mean dissolved oxygen concentration at SMR mainstem sites.



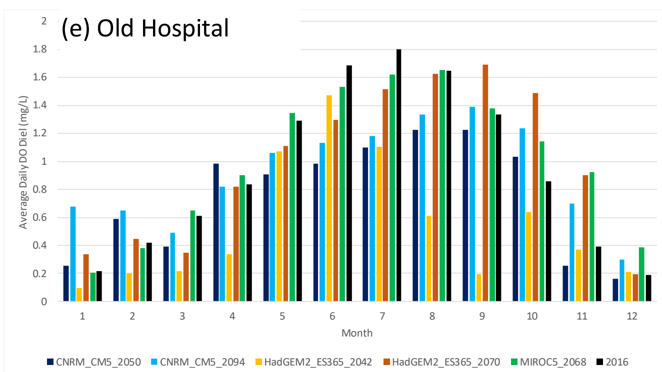


Figure 3.23. Predicted mean monthly dissolved oxygen diel variability at the five SMR main stem sites from climate change relative to the variability predicted during the 2016 calibration run.

Algae

As discussed in the WASP model development and calibration report (Tetra Tech 2020b), two forms of attached algae present in the river are simulated – these include benthic (i.e., low mat) and submersed (i.e., vegetative canopy forming) macroalgae. Results are presented collectively for the two forms as macroalgal biomass expressed as milligrams of chlorophyll-*a* per square meter. Average and median attached algae chlorophyll-*a* density metrics (Table 3.15) are provided for each location. Cooler conditions, wetter or drier, produced more variable results, depending on the site. The moderate scenario (MIROC5) and warmer conditions, wetter or drier, consistently produced higher biomass. Wetter conditions produced less biomass than drier conditions, presumably because of impacts to stream temperature, water column light attenuation, and turbidity. Algal scour is not represented in the model.

Predicted algal biomass is reduced in the absence of flow augmentation (Table 3.16). Streamflow in the warm season is significantly reduced without CWRMA under potential future climate. This reduces the attached algal chlorophyll-*a* biomass even under higher nutrient concentration conditions. This may be due to either increased volume of habitat (by virtue of increased flow and water level) or increased overall loading.

Table 3.15 Predicted average and median instream chlorophyll-a (mg/m2) for attached algae at SMR mainstem sites (current) and the percent change predicted from that value for the five climate scenarios.

Metric	Current (WY2016-18)	COOLER, WETTER CNRM-CM5, 2050	WARMER, WETTER CNRM-CM5, 2094	COOLER, DRIER HadGEM2 - ES365, 2042	WARMER, DRIER HadGEM2-ES365, 2070	MODERATE MIROC5, 2068
			Gorge			
Average	568	3%	4%	2%	8%	9%
Median	593	8%	8%	10%	13%	12%
			MWD			
Average	491	-3%	4%	-3%	4%	7%
Median	511	1%	6%	4%	9%	10%
			Rainbow			
Average	521	4%	7%	4%	9%	8%
Median	573	10%	11%	13%	14%	14%
			Fallbrook			
Average	403	-2%	15%	-3%	15%	7%
Median	414	0%	18%	-10%	27%	11%
			Old Hospital			
Average	387	-8%	9%	-15%	10%	2%
Median	403	-5%	16%	-16%	23%	9%

Table 3.16 WASP predicted relative difference in macroalgae biomass density if flow augmentation is absent under future climate by GCM-year and location.

Location	CNRM-CM5, 2050	CNRM-CM5, 2094	HadGEM2 - ES365, 2042	HadGEM2-ES365, 2070	MIROC5, 2068
			Average		
Gorge	-14.0%	-15.4%	-3.0%	-5.1%	-11.6%
MWD	-20.6%	-16.8%	-3.9%	-9.3%	-15.6%
Below	-6.3%	-6.1%	-1.3%	-2.9%	-6.0%
Fallbrook	-5.0%	-7.0%	-0.4%	-3.7%	-6.4%
Old Hospital	-3.7%	-3.3%	-1.7%	-2.6%	-4.1%
			Median		
Gorge	-14.4%	-22.6%	-2.9%	-3.5%	-16.9%
MWD	-20.8%	-25.3%	-3.1%	-5.4%	-16.9%
Below	-6.3%	-10.7%	-0.2%	-3.3%	-6.7%
Fallbrook	-4.1%	-9.6%	-0.4%	-5.4%	-5.6%
Old Hospital	-3.0%	-4.4%	-1.2%	-2.1%	-2.8%

3.4 Discussion

Rising temperature, changes in seasonality, frequency and magnitude of precipitation and its impacts on the hydrologic cycle will shift riverine ecosystem diversity, communities process rates and core functions. These changes will be strongly linked to pollutant transport, ecosystem productivity, food-chain relationships, and climate feedbacks, all of which will have important societal consequences (Grimm et al. 2013). Riverine ecosystems are particularly vulnerable to climate change because (1) aquatic organisms and communities are strongly shaped by water temperatures and flow, (2) water temperatures and flow are strongly climate-dependent, (3) at the interface with altered land use, they are typically directly exposed to numerous human-induced pressures (Woodward et al. 2010), and (4) many of these human pressures, including water quality and eutrophication, act on the same drivers and therefore have interactive, co-varying effects with climate change.

Few studies have looked mechanistically at the interactive effects of climate change on eutrophication potential of stream ecosystems (Lemm et al. 2021) and the effect that flow augmentation has to modify those effects as was done in this study. We further integrated assessments of how these same flow and temperature alterations impacted biological integrity. We found that simulations of the effects of all three GCMs consistently predicted a suite of drivers that exacerbated symptoms of eutrophication in the SMR main stem and degraded biological integrity (Table 3.17). Increased water temperature, declining wet season duration and wet/dry season baseflow (Figure 3.24), and increased nutrient concentrations produced variable but consistent declines in daily oxygen minima and increased diel variability. Projected increases in climate extremes (including peak flows (Gershunov et al. 2019), declining magnitude, and duration of wet and dry season baseflow) adversely impacted biological integrity, as measured by invertebrate and algal indices of biological condition, with increasingly severe effects consistent across two of three GCMs. Optimal thermal habitat for Southern California Steelhead, already compressed in this watershed, showed projected declines. However, flow augmentation from the CWRMA release, which was established to support the water resource requirements of lower watershed land owners (and did not consider environmental flows), is already having a nearly overwhelmingly positive effect to remediate the effects of eutrophication and improving biointegrity by reversing flow alteration.

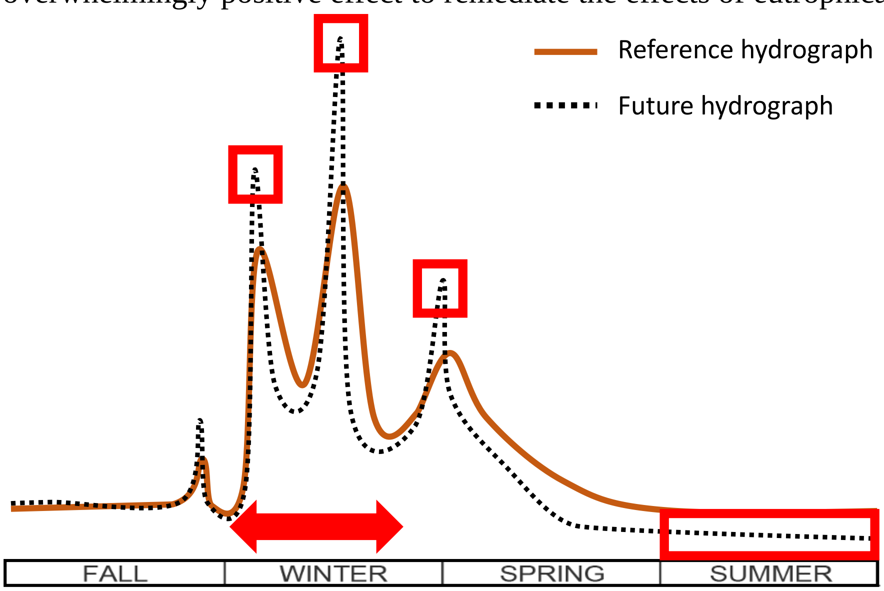


Figure 3.24. Conceptual view of climate change effects on functional flows. CWRMA partially addresses diminished wet and dry season baseflows but had no effect on peak storm flows. Red boxes denote changes in the peak or base flow. Red arrows indicates change in the timing or duration of seasonal flows.

Table 3.17. Summary of effects of climate change (based on CNRM-5, HadGEM2-ES365 and MIROC5). A red arrow signifies a negative environmental effect while a blue arrow signifies a mitigating or positive environmental effect. The direction of the arrow signifies whether the variable increased (up) or decreased (down).

Ecosystem Attribute	Effect of Climate Change (Based on Three GCMs)	Effect of Baseflow Augmentation (CWRMA Release)
Eutrophication Drivers (Biostimulatory Substances/Conditions)		
Water Temperature	↑	↓
Flow Alteration		
Peak flow	↑↓	No effect
Wet season baseflow	↓↑	↑
Wet season flow duration	↓↑	↑
Dry season baseflow	↓	↑
Nutrients		
Nutrient Concentrations	↑	↓
Nutrient Loads	↑	↑
Eutrophication Responses		
Dissolved oxygen		
Daily minima	↓	↑
Diel variability	↑	
Algal biomass	↑↓	↑
Biological Integrity		
Biological integrity, invertebrates and algae	↓	↑
Thermal habitat, for Steelhead	↓	↑

Clearly, uncertainty exists in these predictions. Pierce et al. (2018) noted that confidence is highest in climate projections of air temperature and all three GCMs showed consistent projected increases over time. The greatest uncertainty is in projected precipitation and thus while the mean state of baseflow and wet season flow duration is declining, uncertainty and extreme variability exists. Since thermal habitat and dissolved oxygen effects are strongly linked to temperature, these predicted impacts are ones in which we have the most uncertainty. Prediction in biological outcomes is the most uncertain because WASP and statistical biointegrity models imperfectly capture the non-linear feedbacks and responses of ecosystem physics, chemistry, and food web interactions.

3.4.1 Effects on Eutrophication and Effect of Flow Augmentation

For eutrophication, the magnitude of climate change effects on declining oxygen minima differed predictably by chosen scenario year and the range of temperature/flow conditions represented, with warmer/drier extremes showing a more pronounced effect than cooler/wetter. Overall, these effects were more pronounced for sites on the extreme end of the eutrophication gradient (e.g., below Rainbow), illustrating the synergistic nature of climate change with local stressors (Woodard et al. 2010). CNRM-CM5 (cooler/wetter) and HadGEM2-ES365 (warmer/drier) predicted more extreme precipitation and extreme heat events are already occurring and are projected to become increasingly intense towards the mid-late century (Pierce et al. 2018). We can speculate that these extreme climate events could have an even greater effect than what the HSPF and WASP models can mechanistically reproduce in our simulations. In addition to bringing higher nutrients loads, these peak flows events will cause more erosion of habitat that can rip out riparian and floodplain vegetation and reduce shade, a key factor found in model sensitivity analyses to control water temperatures and therefore DO solubility. In addition, extreme heat and low humidity is expected to increase the frequency of fires, which can burn through riparian habitat, increasing light availability and releasing nutrients, further exacerbating eutrophication.

Similar to peak flow, simulations of algal biomass were responsive to variability in both flow and temperature, which can be understood as the balance between scour and heightened biomass accumulation through higher nutrient concentrations or loading, as well as changes to flow depth that influence water column light attenuation. Uncertainty in algal biomass predictions and effects of climate change is greater than that of dissolved oxygen because the model does not mechanistically account for scour and because there is significant lateral and longitudinal variability in biomass observations in the river that are not fully replicated due to segment scale and microhabitat characteristics. In addition, the model cannot represent the habitat destruction or modifications that come with extreme flow events and fires, which would likely great increase light and temperature and, in the case of fires, nutrient supply. However, because respiration from algal biomass only accounts for 30 percent of the DO budget, variability in the algal biomass accumulation did not detract from the consistency in predicted declines in DO minima.
CWRMA flow augmentation has an important effect on eutrophication currently and those effects are magnified with climate change. CWRMA dilutes nutrients in the water column and without the CWRMA release, nutrient concentrations are higher and water temperatures are elevated. Dissolved oxygen diel variability widens and 7DADMin excursions are more frequent with removal of the CWRMA release under future conditions. Algal biomass is reduced without flow augmentation, particularly in the Gorge and MWD sites, which is likely more a factor of total load and habitat volume than nutrient concentrations per se. With higher flows, the river can support a greater volume of algal biomass. Because the concentrations of nutrients in both CWRMA and upstream inputs are above the critical minimum for algal uptake, and macroalgae have the ability to uptake excess nitrogen and store it in their tissues to support later growth, then the enhanced flows of CWRMA are providing a subsidy that fuels algae growth in the river by roughly ~20%. On the other hand, it also cools water temperatures, dilutes nutrients, and greatly improves oxygen levels.

3.4.2 Effects on Biological Integrity and Effect of Flow Augmentation

River flow and temperature regimes determine fundamental processes that shape and organize the physical and chemical habitat and associated biotic communities (Carlisle et al. 2017; Yarnell et al. 2020). Altered flows have important effects on benthic invertebrate and algal community composition including (Mazor et al. 2017; Irving et al. in prep): 1) peak flows (maintenance and rejuvenation of physical habitat, scour of algae and substrate), 2) spring recession flow duration (increases hydraulic habitat diversity and habitat availability resulting in increased algal productivity, macroinvertebrate diversity, arthropod diversity, fish diversity, and general biodiversity), and 3) wet and dry season baseflow duration (supports algal growth and primary producers and hyporheic exchange). Climate change model results showed that biologically relevant flow alteration based on the invertebrate CSCI emerged by mid-century and progressively worsened, particularly downstream of watershed development. In contrast, biologically relevant flow alteration predicted by the algal ASCI showed important flow alterations have already occurred in the historic record due to dams, groundwater withdrawals and other land use modifications (particularly in wet and dry season baseflow) and the alterations are projected to become more severe over time.

Other studies have noted that trajectories of alteration of biological communities will be highly non-random with climate change, with certain taxa, especially those higher in the food web, typically being more vulnerable to local extirpation or extinction (Woodard et al. 2010; Ings et al. 2009). The Southern California Steelhead is a prime example of this. Exceedance of "preference" thermal tolerance thresholds that support physiological functions such as growth, reproduction, foraging, etc. are already occurring at a base rate of ~20-30% of the time as of 1960. Climate scenarios consistently predicted steady increases in water temperatures that further reduces optimal thermal habitat by about an additional 10-30% of the year by end of century. These findings are consistent with other climate change studies in stream ecosystems that showed reduction in the quantity of habitat based on limits to thermal tolerance to salmonids (Rogers et al. 2020).

Though not specifically targeting environmental flows, baseflow augmentation from CWRMA releases are already mitigating biologically relevant effects of flow alteration in the SMR watershed. This augmentation appears to be sufficient to counteract CSCI (invertebrate)-derived flow alteration thresholds. This baseflow augmentation continues to mitigate the effects of climate change until late century. However, baseflow augmentation is insufficient to meet ASCI (algal)-derived flow alteration thresholds currently, and climate change predictions of further reductions in baseflow are expected to further exacerbate this problem.

3.5. Conclusions and Recommendations for Management

This study documented the impacts of climate change on eutrophication and biological integrity in stream ecosystems and how baseflow augmentation alleviated those impacts. Here we provide some recommendations on what actions storm water managers could take to mitigate these impacts, namely: 1) watershed restoration and 2) policies to ease compliance with biostimulatory targets. These recommendations are intended to be more broadly applicable than SMR watersheds. Such recommendations must be considered in a "climate" of increasing uncertainty. Our analyses illustrated a range of possible futures, but inherent in climate science is the reality that we do not know which ones are most likely. The underlying philosophy of "Robust Decision-making" (RDM; Marchau et al. 2019) are relevant here. Rather than agreeing on what future is most likely, we can attempt to envision what strategies are most likely to produce benefits (and co-benefits) under a range of possible futures. It is with this philosophy that we make the following recommendations below.

1. Restore natural hydrograph

CWRMA release showed the potential power of hydrologic restoration to counter effects of climate change. The analysis demonstrated CWRMA baseflow augmentation, although not specifically intended to support environmental flows, designed to approximate 2/3 of natural flows and was countered the effects of both eutrophication and degradation of biological integrity. Assuring adequate summer time baseflow to provide an abundance of deep pools that are appropriate thermal habitat for Steelhead and other temperature-sensitive species. Opportunities to enhance groundwater infiltration to buffer temperatures and maintain baseflow should be considered. Climate change is increasing the frequency of extreme events, so management actions that are already intended to decrease peak flows through best management practices and low impact development are a key part of the strategy.

2. Restore floodplain and channel habitat

Floodplain and in channel habitat provide important ecosystem functions, including slowing and storing flood waters, reducing summertime peak temperatures, recharging groundwater, enhanced recycling and retention of land-based nutrients inputs and provision of shade that controls water temperatures. Floodplain restoration is therefore a key strategy to counter the effects of climate change—one that goes hand-in-hand with hydrologic restoration. Establishing buffer setbacks to restore nutrient cycling functions in the tributaries is critical. Channel habitat restoration, removal of impediments to flow (Arizona crossings) and planting of riparian habitat will improve physical habitat that protects biological integrity and increase shade—all of which will reduce eutrophication and protect dissolved oxygen.

3. Reduce nutrient concentrations and loads

Climate change will exacerbate eutrophication by making more severe many of the principal drivers (temperature, nutrient concentrations, and loads). Projections of declining DO with climate change were more egregious in regions of the SMR mainstems with greater anthropogenic nutrient loads (e.g., below confluence with Rainbow Creek). To reduce the effects of climate change on stream ecosystems, an important strategy is to lower the eutrophication potential by reducing nutrient concentrations and loads.

4. Consider future changes to biointegrity and biostimulatory objectives and targets.

This study showed that climate change will degrade biological integrity, as measured by CSCI and ASCI the management endpoints that the suite of biostimulatory targets is intended to protect. Excursions of the 7DADMin dissolved oxygen water quality standard are more frequent and of longer duration under future climate compared to current conditions (WY 2016-2018) based on WASP predictions. Results of this study suggest that attainment of current biointegrity, biostimulatory and DO objectives will be more challenging to achieve in the future. We recommend that more consideration be given to how both biological integrity and biostimulatory targets can structured in the future to offer flexibility in compliance. One way to do this in the future is to through "natural sources exclusion," in which the rate of non-compliance with targets in reference sites is also applied to non-reference sites (Tiefenthaler et al. 2018).

San Diego Water Board's biological objectives are based on attainment of CSCI. Because CSCI is formulated using an observed/expected reference approach (Mazor et al. 2016), you could expect the index to incorporate a “shifting baseline” as the biological integrity at reference sites are also impacted. However, the rate at which reference sites are monitored and can incorporate change is an issue, as currently only ~30 sites per year are measured. Moreover, climate impacts are likely to have a great deal of watershed site specificity, so the degree to which other reference sites around the region or state account for this is also problematic and will contribute to the precision with which the biointegrity tools can be used to assess condition.

DO objectives should be refined to incorporate explicit considerations of how temperature is considered in DO compliance. DO concentration-based targets ignore the effects of temperature and flow. Using percent saturation targets that scale with temperature would help to address this issue. In addition, seasonal exclusion, be they for high temperature or low flow, would also help to ease issues with compliance.

Nutrient load allocations are strongly affected by extreme events. If wet weather load allocations are in place, establishing criteria to exclude extreme events from load allocation may be appropriate. Concentration-based versus load-based TMDLs may be preferable, or a hybrid approach with appropriate exclusions in place.

4. Analyses of Maximum Allowable Loads and Load Allocations in the SMR Watershed

4.1 Introduction

The Santa Margarita River (SMR) exhibits eutrophic conditions with periods of significant algal blooms and low levels of dissolved oxygen. To support water quality improvement activities, the San Diego Regional Water Quality Control Board (Water Board) established nutrient concentrations intended to achieve biostimulatory targets and restore water quality in the SMR and its tributaries. This memorandum provides total nitrogen (TN) and total phosphorus (TP) allocations for the Santa Margarita River Alternative Restoration Plan based on the Water Quality Control Plan for the San Diego Region (Basin Plan) target concentrations.

The Water Board worked with entities in the Santa Margarita River watershed and established MS4 responsible areas for Municipal Separate Storm Sewer Systems (MS4) for the County of San Diego, the County of Riverside, United States Marine Corps (USMC) Camp Pendleton, and the California Department of Transportation (CALTRANS), as well as non-MS4 areas that were also considered in the calculations presented in this memorandum (Figure 4.1). Consistent with the approach used for the Santa Margarita River Estuary (Tetra Tech, 2017b), target loads and allocations were calculated based on "at-source" loads for dry and wet weather conditions. Dry and wet weather days were defined based on the MS4 permit which states weather is considered dry if the preceding 72 hours has been without measurable precipitation (> 0.1 inch). Wet weather includes all other days that do not meet this criterion. Note that depending on the timing of storms and the length of time needed to return to baseflow conditions, dry weather loads may be influenced by wet weather conditions in some cases.

Existing loads for jurisdictions and land uses/covers within the watershed were established from Hydrologic Simulation Program - FORTRAN (HSPF) models; two HSPF models have been developed and calibrated for the middle and lower Santa Margarita River watershed. Most recently, the middle watershed HSPF model was updated, extended in time through Water Year (WY) 2018, and calibrated for flow, sediment, nutrients, dissolved oxygen, water temperature, and algae as is discussed in the model report (Tetra Tech 2020). The middle watershed HSPF model extent spans from Diamond Valley Reservoir, Lake Skinner, and Vail Lake down to the Santa Margarita River gorge. The middle watershed HSPF model is linked to the lower watershed HSPF model, which spans from the gorge down to the Old Hospital for the simulation period through WY 2018. Note the full HSPF model of the lower watershed extends down to the Santa Margarita River Estuary, but the simulation period of that version ends in WY 2016 (Tetra Tech 2017a). Updating the portion of the lower model below the Old Hospital involves extending groundwater exchanges characterized by the Camp Pendleton MODFLOW model. The project scope did not include a full extension of the lower watershed model; however, the portion above the Old Hospital was extended through WY 2018 to support the development of a receiving water model using WASP (Tetra Tech 2021) and the allocations presented in this memorandum.

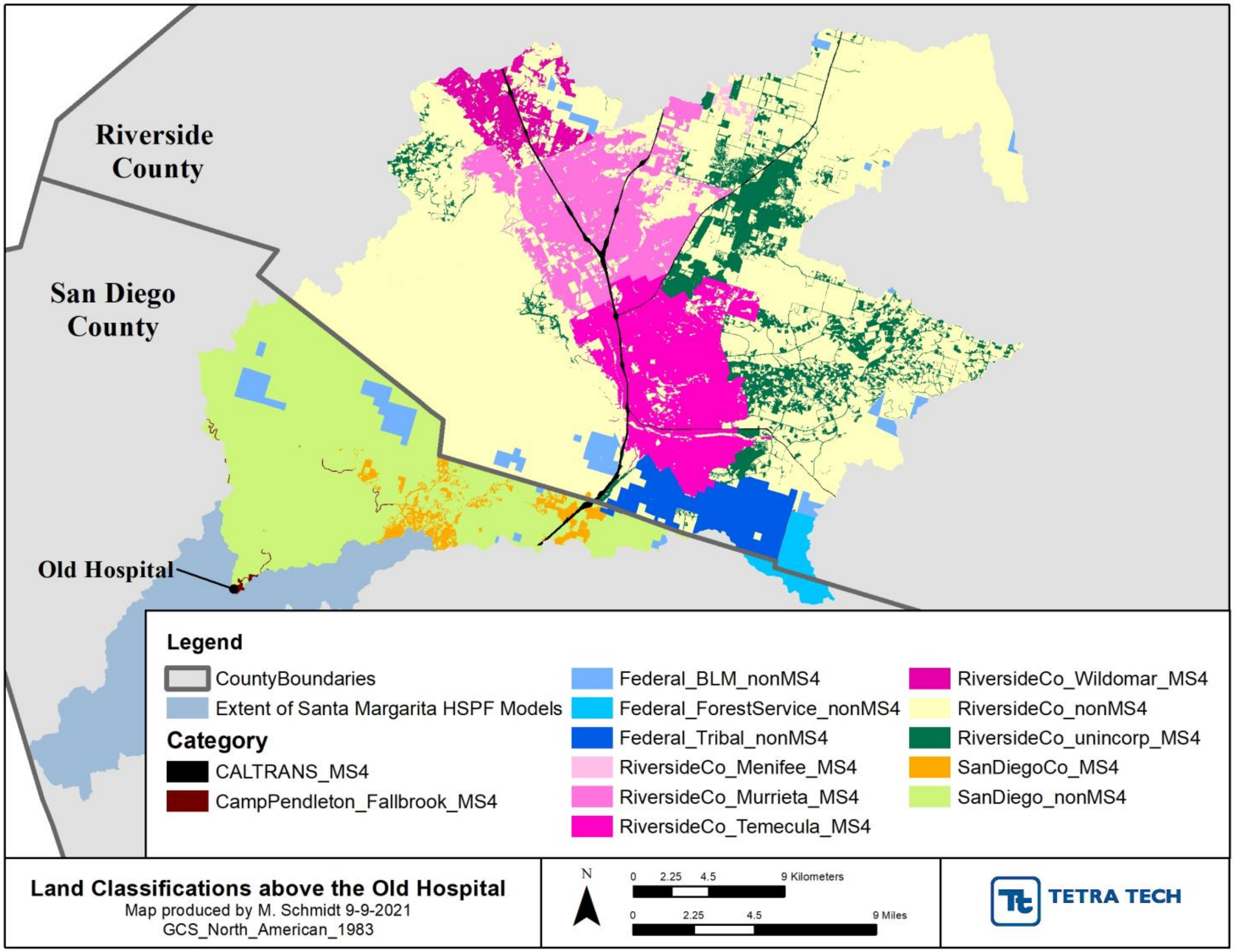


Figure 4.1. Jurisdictions above the Old Hospital within the Santa Margarita River watershed.

4.2 Delivered Loading Targets

The Water Board established instream nutrient concentrations for the Santa Margarita River and its tributaries that are equivalent to the Basin Plan Objectives of 1 mg/L for TN and 0.1 mg/L for TP. The Water Board selected seven locations within the drainage area of the Santa Margarita River for explicit assignment of loading targets and associated allocations, which are listed in Table 4.1 and shown in Figure 4.2. Four of the sites are located on the SMR tributaries, Devils Creek, Rainbow Creek, Sandia Creek, and De Luz Creek, and three of the sites are below the gorge along the mainstem at SCCWRP monitoring locations including MWD2, MLS, and near the Old Hospital. Figure 4.2 also depicts the drainage area of each site. Modeled flows from the calibrated HSPF models of the middle and lower Santa Margarita River watershed were combined with the Basin Plan TN and TP concentrations to establish delivered loading targets for each site for dry weather.

The Water Board requested that a 10% explicit Margin of Safety (MOS) be applied to the target loads to account for uncertainty. To do so, the delivered loading targets were reduced by 10 percent (e.g., a delivered loading target of 1,000 lb/yr was reduced by 10% equaling 900 lb/yr after application of the 10 percent MOS).

Instream processes (e.g., deposition of particulate phosphorus) and transformations (e.g., nitrification) that influence the loads and concentrations at the allocation sites are accounted for in delivered loads. Existing, or current condition, delivered nutrient loads were also tabulated for each site from the HSPF outputs. Both the existing and allowable nutrient loads were computed for the period of Water Year (WY) 2009 to WY 2018 to capture a range of hydrologic conditions in the watershed. The percent reductions required to meet the allowable loads (i.e., relative to existing loads) were established for each site and are listed in Table 4.1.

Table 4.1. Percent reductions for delivered loads needed to meet average annual dry weather loading targets with a 10% margin of safety

Allocation Site	TN	TP
Devils Creek	70%	46%
MWD2	0%	0%
Rainbow Creek	83%	52%
Sandia Creek	76%	0%
SMR-MLS	54%	56%
De Luz Creek	71%	0%
Old Hospital	12%	0%

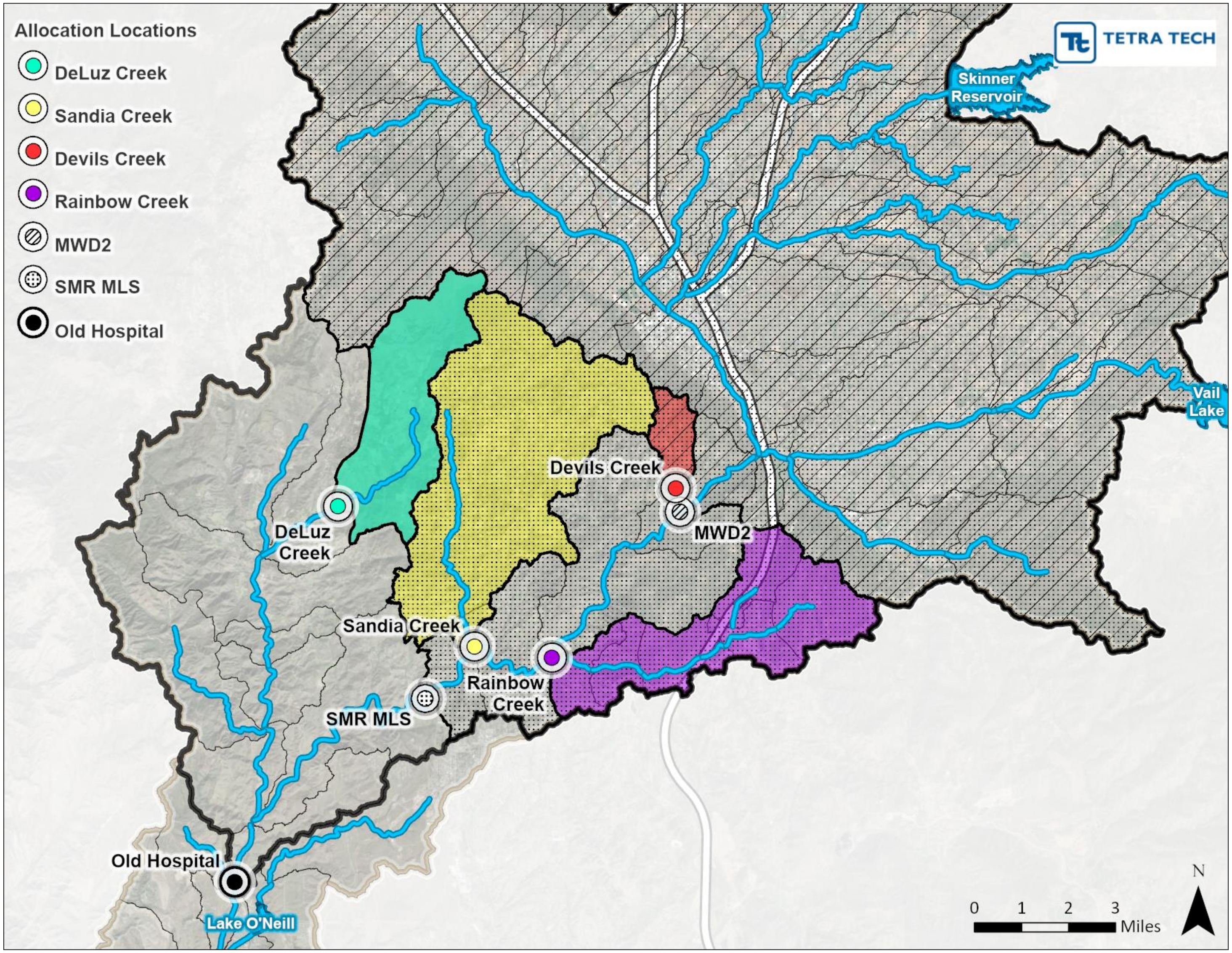


Figure 4.2. Allocation sites and their contributing drainage areas in the Santa Margarita River watershed.

4.3 Existing At-source Loads

The Water Board requested that allocations be specified as at-source loads as opposed to delivered loads, which is consistent with the strategy applied for the Santa Margarita River Estuary allocations. At-source loads are edge-of-stream loads that have not yet been subjected to instream transport and transformation processes that are reflected in delivered loads. Dry weather at-source loads simulated by the HSPF models were tabulated by jurisdiction and land use for WY 2009-2018 (Figure 4.1). Table 4.2 through Table 4.15 list the dry weather at-source TN and TP loads at each site under existing conditions (wet weather at-source loads are detailed in

Figure 4.5. Conceptual schematic diagram of nested wet weather TN allocations with a 10% margin of safety.

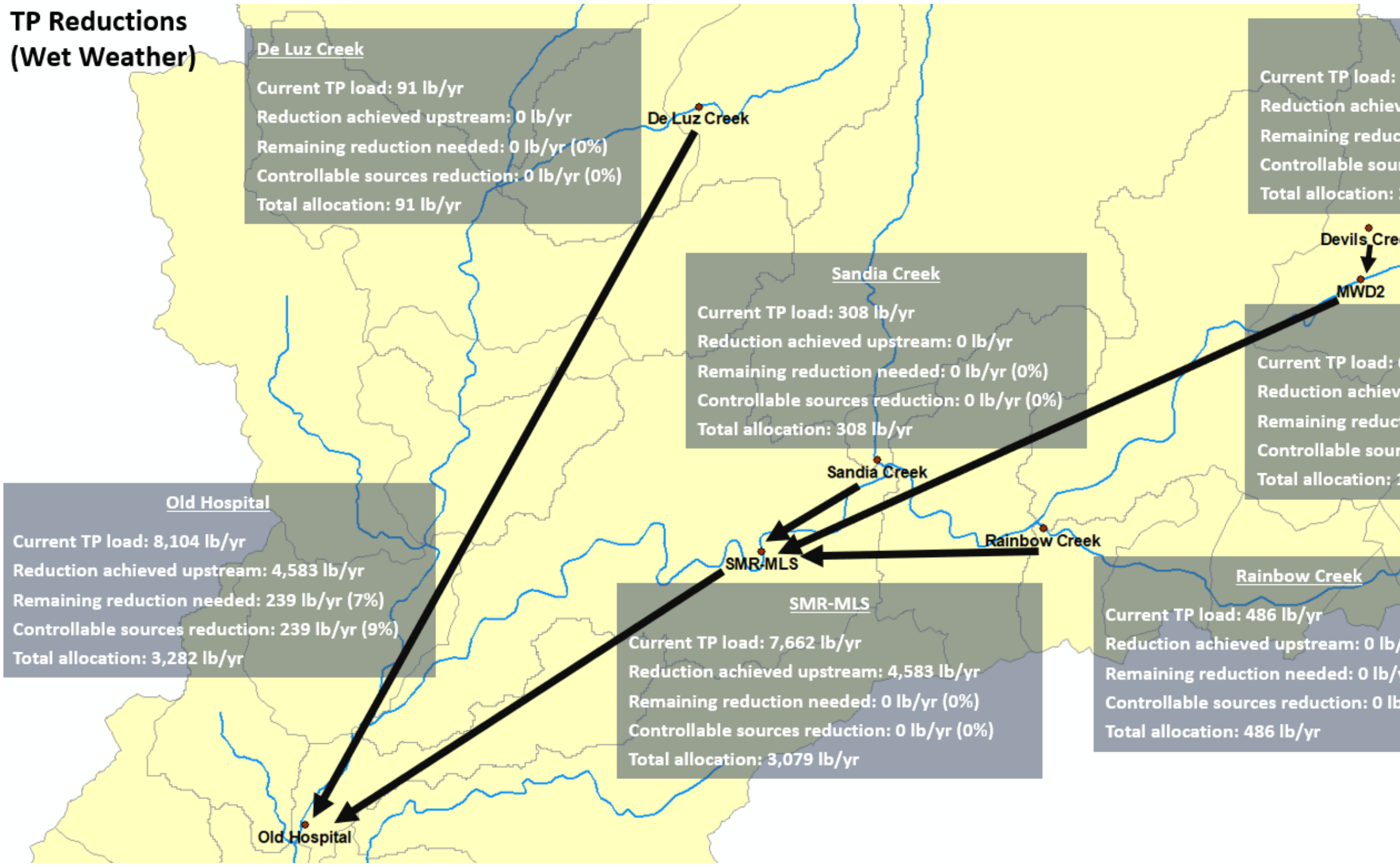


Figure 4.6. Conceptual schematic diagram of nested wet weather TP allocations with a 10% margin of safety.

Table 4.33 through

Table 4.46). Note that TN values are reported with two significant digits and TP values are reported with three significant digits given the magnitudes of the current loads and allocations. Thus, a value of 0.00 or 0.000 lb/yr indicates a non-zero value.

Table 4.2. Dry weather at-source TN loads (lb/year) by land use category and jurisdiction at Devils Creek (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	-	-	-
Chaparral, scrub	-	-	0.00	4.79	-	-	-	0.00	4.79
Commercial, institutional	-	-	-	0.02	-	-	-	-	0.02
Forest	-	-	0.00	0.25	-	-	-	0.00	0.25
Grassland, herbaceous	-	-	-	1.95	-	-	-	-	1.95
High density residential	-	-	-	-	-	-	-	-	-
Dairy, livestock, horse ranches	-	-	-	-	-	-	-	-	-
Industrial	-	-	-	-	-	-	-	-	-
Irrigated agriculture	-	-	-	7.65	-	-	-	-	7.65
Low density residential	-	-	0.03	5.05	-	-	-	0.03	5.08
Non-irrigated agriculture	-	-	-	-	-	-	-	-	-
Nurseries	-	-	-	-	-	-	-	-	-
Open and recreation	-	-	-	-	-	-	-	-	-
Orchard, vineyard	-	-	-	260.53	-	-	-	-	260.53
Parks and recreation	-	-	-	-	-	-	-	-	-
Road, freeway	-	-	0.00	2.93	-	-	-	0.00	2.93
Transitional	-	-	0.01	0.01	-	-	-	0.01	0.02
Water	-	-	-	-	-	-	-	-	-
Total	-	-	0.04	283.19	-	-	-	0.04	283.23

Note for all tables: CALTRANS freeways and right-of-way areas are not included in the "Road, freeway" land use category. There is no double-counting or overlap of CALTRANS areas with other roads.

Table 4.3. Dry weather at-source TP loads (lb/year) by land use category and jurisdiction at Devils Creek (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	-	-	-
Chaparral, scrub	-	-	0.000	0.723	-	-	-	0.000	0.723
Commercial, institutional	-	-	-	0.002	-	-	-	-	0.002
Forest	-	-	0.000	0.031	-	-	-	0.000	0.031
Grassland, herbaceous	-	-	-	0.274	-	-	-	-	0.274
High density residential	-	-	-	-	-	-	-	-	-
Dairy, livestock, horse ranches	-	-	-	-	-	-	-	-	-
Industrial	-	-	-	-	-	-	-	-	-
Irrigated agriculture	-	-	-	0.220	-	-	-	-	0.220
Low density residential	-	-	0.003	0.397	-	-	-	0.003	0.399
Non-irrigated agriculture	-	-	-	-	-	-	-	-	-
Nurseries	-	-	-	-	-	-	-	-	-
Open and recreation	-	-	-	-	-	-	-	-	-
Orchard, vineyard	-	-	-	13.426	-	-	-	-	13.426
Parks and recreation	-	-	-	-	-	-	-	-	-
Road, freeway	-	-	0.000	0.239	-	-	-	0.000	0.239
Transitional	-	-	0.001	0.001	-	-	-	0.001	0.002
Water	-	-	-	-	-	-	-	-	-
Total	-	-	0.004	15.313	-	-	-	0.004	15.317

Table 4.4. Dry weather at-source TN loads (lb/year) by land use category and jurisdiction at MWD2 (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	8.33	8.33	8.33
Chaparral, scrub	-	0.20	0.00	87.14	-	39.98	-	0.00	127.32
Commercial, institutional	-	-	17.44	1.19	-	0.19	-	17.44	18.83
Forest	-	0.00	0.00	2.79	-	0.80	-	0.00	3.60
Grassland, herbaceous	-	-	0.00	3.59	-	0.06	-	0.00	3.65
High density residential	-	-	11.14	0.45	-	-	-	11.14	11.59
Dairy, livestock, horse ranches	-	-	-	97.63	-	0.01	-	-	97.64
Industrial	-	-	29.11	5.18	-	-	-	29.11	34.29
Irrigated agriculture	-	-	0.01	65.17	-	19.75	-	0.01	84.93
Low density residential	-	-	416.94	26.45	-	10.66	-	416.94	454.05
Non-irrigated agriculture	-	-	-	0.72	-	0.03	-	-	0.76
Nurseries	-	-	0.00	48.26	-	-	-	0.00	48.27
Open and recreation	-	-	49.09	5.18	-	1.50	-	49.09	55.78
Orchard, vineyard	-	-	0.02	802.84	-	-	-	0.02	802.86
Parks and recreation	-	-	45.26	8.99	-	2.32	-	45.26	56.57
Road, freeway	-	0.00	72.11	7.18	-	0.29	-	72.11	79.58
Transitional	-	-	3.51	3.51	-	-	-	3.51	7.02
Water	-	-	-	16.50	-	0.24	-	-	16.74
Total	-	0.21	644.63	1182.79	-	75.83	8.33	652.96	1911.79

Table 4.5. Dry weather at-source TP loads (lb/year) by land use category and jurisdiction at MWD2 (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	0.660	0.660	0.660
Chaparral, scrub	-	0.011	0.000	7.520	-	2.470	-	0.000	10.002
Commercial, institutional	-	-	1.002	0.075	-	0.009	-	1.002	1.086
Forest	-	0.000	0.000	0.296	-	0.087	-	0.000	0.383
Grassland, herbaceous	-	-	0.000	0.429	-	0.003	-	0.000	0.431
High density residential	-	-	0.913	0.050	-	-	-	0.913	0.963
Dairy, livestock, horse ranches	-	-	-	1.672	-	0.000	-	-	1.672
Industrial	-	-	2.166	0.362	-	-	-	2.166	2.527
Irrigated agriculture	-	-	0.000	2.213	-	0.445	-	0.000	2.659
Low density residential	-	-	26.291	1.816	-	0.527	-	26.291	28.634
Non-irrigated agriculture	-	-	-	0.124	-	0.003	-	-	0.126
Nurseries	-	-	0.000	2.934	-	-	-	0.000	2.934
Open and recreation	-	-	2.756	0.402	-	0.071	-	2.756	3.228
Orchard, vineyard	-	-	0.001	37.768	-	-	-	0.001	37.769
Parks and recreation	-	-	2.769	0.863	-	0.107	-	2.769	3.738
Road, freeway	-	0.000	4.136	0.574	-	0.013	-	4.136	4.724
Transitional	-	-	0.230	0.230	-	-	-	0.230	0.461
Water	-	-	-	1.616	-	0.019	-	-	1.635
Total	-	0.011	40.265	58.942	-	3.753	0.660	40.925	103.631

Table 4.6. Dry weather at-source TN loads (lb/year) by land use category and jurisdiction at Rainbow Creek (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	28.94	28.94	28.94
Chaparral, scrub	3.60	22.88	0.01	10.93	-	14.33	-	3.60	51.75
Commercial, institutional	1.15	0.77	0.81	0.00	-	0.00	-	1.96	2.73
Forest	0.04	0.68	0.05	0.70	-	1.60	-	0.08	3.07
Grassland, herbaceous	0.16	18.30	0.00	0.42	-	0.99	-	0.16	19.87
High density residential	-	10.69	-	-	-	0.01	-	-	10.69
Dairy, livestock, horse ranches	-	-	-	-	-	-	-	-	-
Industrial	1.08	10.40	1.86	0.01	-	0.11	-	2.93	13.45
Irrigated agriculture	11.28	38.52	0.00	0.06	-	0.06	-	11.28	49.92
Low density residential	11.79	92.45	4.58	0.03	-	0.09	-	16.37	108.94
Non-irrigated agriculture	0.15	0.35	0.00	0.00	-	-	-	0.15	0.51
Nurseries	330.89	706.96	-	-	-	-	-	330.89	1037.85
Open and recreation	-	-	-	-	-	-	-	-	-
Orchard, vineyard	49.58	629.06	-	-	-	-	-	49.58	678.63
Parks and recreation	0.36	0.00	-	-	-	-	-	0.36	0.37
Road, freeway	3.02	11.89	1.22	0.00	-	0.16	-	4.24	16.29
Transitional	0.01	0.01	0.02	0.02	-	-	-	0.03	0.06
Water	-	-	-	-	-	-	-	-	-
Total	413.11	1542.9 6	8.53	12.17	-	17.36	28.94	450.58	2023.06

Table 4.7. Dry weather at-source TP loads (lb/year) by land use category and jurisdiction at Rainbow Creek (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	1.628	1.628	1.628
Chaparral, scrub	0.421	2.721	0.001	1.274	-	1.671	-	0.422	6.087
Commercial, institutional	0.076	0.052	0.053	0.000	-	0.000	-	0.129	0.182
Forest	0.003	0.073	0.002	0.079	-	0.182	-	0.005	0.339
Grassland, herbaceous	0.019	2.218	0.000	0.049	-	0.120	-	0.019	2.407
High density residential	-	0.723	-	-	-	0.000	-	-	0.723
Dairy, livestock, horse ranches	-	-	-	-	-	-	-	-	-
Industrial	0.077	0.760	0.135	0.001	-	0.008	-	0.211	0.980
Irrigated agriculture	0.430	1.229	0.000	0.002	-	0.002	-	0.430	1.663
Low density residential	0.798	6.282	0.313	0.002	-	0.006	-	1.111	7.401
Non-irrigated agriculture	0.018	0.041	0.000	0.000	-	-	-	0.018	0.059
Nurseries	31.895	68.144	-	-	-	-	-	31.895	100.039
Open and recreation	-	-	-	-	-	-	-	-	-
Orchard, vineyard	2.421	30.452	-	-	-	-	-	2.421	32.873
Parks and recreation	0.024	0.000	-	-	-	-	-	0.024	0.024
Road, freeway	0.202	0.806	0.081	0.000	-	0.011	-	0.283	1.100
Transitional	0.000	0.000	0.001	0.001	-	-	-	0.002	0.003
Water	-	-	-	-	-	-	-	-	-
Total	36.384	113.50 2	0.586	1.409	-	2.001	1.628	38.598	155.509

Table 4.8. Dry weather at-source TN loads (lb/year) by land use category and jurisdiction at Sandia Creek (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	-	-	-
Chaparral, scrub	0.00	8.15	0.00	44.15	-	4.19	-	0.00	56.49
Commercial, institutional	-	-	-	0.37	-	-	-	-	0.37
Forest	0.00	0.96	0.00	2.03	-	0.99	-	0.00	3.98
Grassland, herbaceous	0.00	0.82	0.00	1.47	-	0.22	-	0.00	2.50
High density residential	-	-	-	-	-	-	-	-	-
Dairy, livestock, horse ranches	-	-	-	5.20	-	-	-	-	5.20
Industrial	-	-	0.00	0.61	-	-	-	0.00	0.61
Irrigated agriculture	0.00	24.91	0.00	77.92	-	0.45	-	0.00	103.28
Low density residential	0.27	16.14	0.04	75.54	-	0.02	-	0.32	92.02
Non-irrigated agriculture	0.00	0.44	-	0.14	-	-	-	0.00	0.58
Nurseries	-	4.61	-	-	-	-	-	-	4.61
Open and recreation	-	-	-	-	-	-	-	-	-
Orchard, vineyard	0.00	668.47	0.01	2823.09	-	1.53	-	0.01	3493.10
Parks and recreation	-	-	-	10.97	-	-	-	-	10.97
Road, freeway	0.13	2.15	0.00	14.28	-	0.01	-	0.14	16.58
Transitional	-	-	0.29	0.29	-	-	-	0.29	0.58
Water	-	-	-	-	-	-	-	-	-
Total	0.41	726.64	0.35	3056.08	-	7.41	-	0.76	3790.89

Table 4.9. Dry weather at-source TP loads (lb/year) by land use category and jurisdiction at Sandia Creek (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	-	-	-
Chaparral, scrub	0.000	1.369	0.000	7.154	-	0.714	-	0.000	9.237
Commercial, institutional	-	-	-	0.031	-	-	-	-	0.031
Forest	0.000	0.159	0.000	0.244	-	0.169	-	0.000	0.573
Grassland, herbaceous	0.000	0.138	0.000	0.225	-	0.037	-	0.000	0.400
High density residential	-	-	-	-	-	-	-	-	-
Dairy, livestock, horse ranches	-	-	-	0.106	-	-	-	-	0.106
Industrial	-	-	0.000	0.054	-	-	-	0.000	0.054
Irrigated agriculture	0.000	0.607	0.000	1.954	-	0.011	-	0.000	2.572
Low density residential	0.022	1.372	0.003	6.247	-	0.002	-	0.026	7.647
Non-irrigated agriculture	0.000	0.067	-	0.020	-	-	-	0.000	0.087
Nurseries	-	0.492	-	-	-	-	-	-	0.492
Open and recreation	-	-	-	-	-	-	-	-	-
Orchard, vineyard	0.000	37.111	0.000	156.545	-	0.085	-	0.001	193.742
Parks and recreation	-	-	-	0.841	-	-	-	-	0.841
Road, freeway	0.012	0.185	0.000	1.183	-	0.001	-	0.012	1.381
Transitional	-	-	0.027	0.027	-	-	-	0.027	0.055
Water	-	-	-	-	-	-	-	-	-
Total	0.034	41.501	0.032	174.632	-	1.019	-	0.066	217.218

Table 4.10. Dry weather at-source TN loads (lb/year) by land use category and jurisdiction at SMR-MLS (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	37.27	37.27	37.27
Chaparral, scrub	3.68	51.72	0.01	203.16	0.02	68.44	-	3.72	327.04
Commercial, institutional	1.33	0.81	18.24	1.75	-	0.20	-	19.58	22.33
Forest	0.04	2.59	0.05	9.14	0.01	3.74	-	0.10	15.56
Grassland, herbaceous	0.20	41.06	0.00	6.88	0.03	1.27	-	0.23	49.44
High density residential	0.27	10.69	11.14	0.45	-	0.01	-	11.41	22.55
Dairy, livestock, horse ranches	-	-	-	102.84	-	0.01	-	-	102.84
Industrial	1.65	10.40	30.97	6.52	-	0.11	-	32.61	49.65
Irrigated agriculture	11.50	92.95	0.01	163.93	-	20.26	-	11.50	288.64
Low density residential	141.05	113.39	421.53	109.86	0.15	10.77	-	562.73	796.75
Non-irrigated agriculture	0.16	1.05	0.00	0.87	-	0.03	-	0.16	2.10
Nurseries	331.15	761.96	0.00	48.26	-	-	-	331.15	1141.38
Open and recreation	0.33	0.07	49.09	5.18	-	1.50	-	49.42	56.18
Orchard, vineyard	55.15	2221.24	0.02	4287.52	-	1.53	-	55.17	6565.46
Parks and recreation	0.37	0.01	45.26	19.97	-	2.32	-	45.63	67.92
Road, freeway	11.67	15.74	73.32	27.84	0.04	0.46	-	85.03	129.08
Transitional	0.01	0.01	3.81	3.81	-	-	-	3.82	7.64
Water	-	-	-	16.50	-	0.24	-	-	16.74
Total	558.55	3323.69	653.45	5014.48	0.25	110.88	37.27	1249.53	9698.58

Table 4.11. Dry weather at-source TP loads (lb/year) by land use category and jurisdiction at SMR-MLS (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	2.288	2.288	2.288
Chaparral, scrub	0.432	6.767	0.001	24.457	0.004	6.221	-	0.437	37.882
Commercial, institutional	0.088	0.055	1.055	0.121	-	0.009	-	1.143	1.328
Forest	0.003	0.334	0.002	1.089	0.001	0.482	-	0.006	1.912
Grassland, herbaceous	0.024	5.340	0.000	0.936	0.006	0.160	-	0.030	6.466
High density residential	0.018	0.723	0.913	0.050	-	0.000	-	0.932	1.705
Dairy, livestock, horse ranches	-	-	-	1.778	-	0.000	-	-	1.778
Industrial	0.123	0.760	2.300	0.480	-	0.008	-	2.423	3.672
Irrigated agriculture	0.437	2.687	0.000	4.675	-	0.458	-	0.437	8.257
Low density residential	9.812	8.002	26.606	8.688	0.013	0.535	-	36.430	53.655
Non-irrigated agriculture	0.018	0.139	0.000	0.144	-	0.003	-	0.018	0.304
Nurseries	31.920	73.503	0.000	2.934	-	-	-	31.920	108.357
Open and recreation	0.022	0.005	2.756	0.402	-	0.071	-	2.778	3.255
Orchard, vineyard	2.695	114.082	0.001	230.939	-	0.085	-	2.696	347.802
Parks and recreation	0.024	0.000	2.769	1.704	-	0.107	-	2.792	4.603
Road, freeway	0.820	1.116	4.217	2.227	0.003	0.025	-	5.041	8.409
Transitional	0.000	0.000	0.258	0.258	-	-	-	0.259	0.517
Water	-	-	-	1.616	-	0.019	-	-	1.635
Total	46.437	213.513	40.879	282.497	0.027	8.184	2.288	89.631	593.825

Table 4.12. Dry weather at-source TN loads (lb/year) by land use category and jurisdiction at De Luz Creek (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	-	-	-
Chaparral, scrub	-	2.96	-	23.73	-	2.19	-	-	28.88
Commercial, institutional	-	-	-	0.35	-	-	-	-	0.35
Forest	-	0.43	-	0.74	-	0.93	-	-	2.10
Grassland, herbaceous	-	0.10	-	5.21	-	0.03	-	-	5.34
High density residential	-	-	-	-	-	-	-	-	-
Dairy, livestock, horse ranches	-	-	-	-	-	-	-	-	-
Industrial	-	-	-	0.49	-	-	-	-	0.49
Irrigated agriculture	-	15.17	-	30.16	-	0.00	-	-	45.33
Low density residential	-	3.00	-	6.40	-	0.28	-	-	9.68
Non-irrigated agriculture	-	0.15	-	-	-	0.01	-	-	0.16
Nurseries	-	5.63	-	-	-	-	-	-	5.63
Open and recreation	-	-	-	-	-	-	-	-	-
Orchard, vineyard	-	60.69	-	955.11	-	-	-	-	1015.80
Parks and recreation	-	-	-	-	-	-	-	-	-
Road, freeway	-	1.21	-	3.45	-	0.36	-	-	5.01
Transitional	-	-	0.12	0.12	-	-	-	0.12	0.23
Water	-	-	-	-	-	-	-	-	-
Total	-	89.33	0.12	1025.75	-	3.81	-	0.12	1119.00

Table 4.13. Dry weather at-source TP loads (lb/year) by land use category and jurisdiction at De Luz Creek (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	-	-	-
Chaparral, scrub	-	0.451	-	3.580	-	0.367	-	-	4.397
Commercial, institutional	-	-	-	0.028	-	-	-	-	0.028
Forest	-	0.071	-	0.112	-	0.155	-	-	0.338
Grassland, herbaceous	-	0.015	-	0.779	-	0.006	-	-	0.800
High density residential	-	-	-	-	-	-	-	-	-
Dairy, livestock, horse ranches	-	-	-	-	-	-	-	-	-
Industrial	-	-	-	0.040	-	-	-	-	0.040
Irrigated agriculture	-	0.376	-	0.758	-	0.000	-	-	1.135
Low density residential	-	0.243	-	0.520	-	0.024	-	-	0.787
Non-irrigated agriculture	-	0.022	-	-	-	0.001	-	-	0.023
Nurseries	-	0.600	-	-	-	-	-	-	0.600
Open and recreation	-	-	-	-	-	-	-	-	-
Orchard, vineyard	-	3.270	-	50.905	-	-	-	-	54.176
Parks and recreation	-	-	-	-	-	-	-	-	-
Road, freeway	-	0.097	-	0.274	-	0.031	-	-	0.403
Transitional	-	-	0.008	0.008	-	-	-	0.008	0.017
Water	-	-	-	-	-	-	-	-	-
Total	-	5.147	0.008	57.005	-	0.585	-	0.008	62.745

Table 4.14. Dry weather at-source TN loads (lb/year) by land use category and jurisdiction at Old Hospital (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	37.27	37.27	37.27
Chaparral, scrub	3.69	212.14	0.01	256.91	0.42	78.27	-	4.11	551.43
Commercial, institutional	1.33	1.21	18.24	2.10	1.80	0.20	-	21.38	24.88
Forest	0.04	13.74	0.05	10.78	0.05	6.16	-	0.14	30.82
Grassland, herbaceous	0.20	166.59	0.00	25.10	0.59	6.32	-	0.79	198.80
High density residential	0.36	10.69	11.14	0.45	-	0.01	-	11.50	22.64
Dairy, livestock, horse ranches	-	-	-	102.84	-	0.01	-	-	102.84
Industrial	2.18	12.57	30.97	7.22	0.36	0.11	-	33.51	53.41
Irrigated agriculture	11.53	293.15	0.01	205.85	-	20.30	-	11.53	530.84
Low density residential	156.46	233.60	421.53	131.30	4.07	11.19	-	582.06	958.16
Non-irrigated agriculture	0.16	4.44	0.00	0.87	-	0.04	-	0.16	5.50
Nurseries	331.21	969.08	0.00	48.26	-	-	-	331.21	1348.55
Open and recreation	0.33	0.71	49.09	5.21	-	1.50	-	49.42	56.84
Orchard, vineyard	55.45	3699.59	0.02	5450.31	-	3.15	-	55.47	9208.52
Parks and recreation	0.37	0.79	45.26	19.97	-	2.32	-	45.63	68.70
Road, freeway	12.85	43.31	73.32	43.56	1.51	0.97	-	87.68	175.52
Transitional	0.04	0.04	4.05	4.05	-	-	-	4.08	8.17
Water	-	0.00	-	16.50	-	0.24	-	-	16.74
Total	576.18	5661.64	653.69	6331.27	8.80	130.78	37.27	1275.94	13399.64

Table 4.15. Dry weather at-source TP loads (lb/year) by land use category and jurisdiction at Old Hospital (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	2.288	2.288	2.288
Chaparral, scrub	0.432	30.331	0.001	32.512	0.059	7.792	-	0.492	71.127
Commercial, institutional	0.088	0.083	1.055	0.149	0.125	0.009	-	1.268	1.509
Forest	0.003	2.035	0.002	1.325	0.003	0.878	-	0.009	4.247
Grassland, herbaceous	0.024	23.247	0.000	3.662	0.091	0.918	-	0.116	27.942
High density residential	0.024	0.723	0.913	0.050	-	0.000	-	0.938	1.711
Dairy, livestock, horse ranches	-	-	-	1.778	-	0.000	-	-	1.778
Industrial	0.170	0.942	2.300	0.538	0.026	0.008	-	2.496	3.984
Irrigated agriculture	0.438	7.682	0.000	5.728	-	0.459	-	0.438	14.307
Low density residential	11.006	17.528	26.606	10.397	0.294	0.570	-	37.905	66.400
Non-irrigated agriculture	0.018	0.632	0.000	0.144	-	0.004	-	0.018	0.798
Nurseries	31.926	95.884	0.000	2.934	-	-	-	31.926	130.745
Open and recreation	0.022	0.054	2.756	0.404	-	0.071	-	2.778	3.306
Orchard, vineyard	2.711	192.301	0.001	292.215	-	0.167	-	2.712	487.394
Parks and recreation	0.024	0.061	2.769	1.704	-	0.107	-	2.792	4.664
Road, freeway	0.910	3.308	4.217	3.459	0.113	0.069	-	5.241	12.077
Transitional	0.002	0.002	0.273	0.273	-	-	-	0.275	0.551
Water	-	-	-	1.616	-	0.019	-	-	1.635
Total	47.799	374.812	40.894	358.887	0.711	11.072	2.288	91.692	836.463

4.4 Allocations

The TN and TP percent reductions required to meet the delivered loading targets shown in Table 4.1 were applied to the sum of the existing at-source loads (i.e., the loads in Table 4.2 through Table 4.15) for each allocation site to determine the total at-source (i.e., edge-of-stream) loading targets. This approach has the underlying assumption that a certain required percent reduction in delivered load can be achieved with an equivalent reduction in the total at-source load within the site drainage area. After total at-source loading targets were computed, TN and TP allocations were established by land use category and jurisdiction for each site.

Within the Santa Margarita River watershed, there are land uses where nutrient load reductions are feasible (e.g., with the implementation of Best Management Practices), as well as natural land covers where reductions are not possible or more difficult to achieve from a management perspective (i.e., chaparral, scrub/shrub, forest, grassland, herbaceous and water). Per Water Board direction, allocations for these natural land covers were held at their current loading levels. Loading from certain land uses, such as residential and commercial properties, are subject to potential reductions needed to meet the targets. The transitional land use category is split as 50 percent MS4 responsible land and 50 percent non-MS4 land as determined by the Water Board. Being that nutrient loading from some sources is reducible, the percent reductions for these land uses must be greater to achieve the overall percent reductions listed in Table 4.1. If, for example, the existing total at-source load is 2,000 lb/yr at site Z, the total at-source TN loading target is 1,000 lb/yr (i.e., a 50 percent reduction), and 300 lb/yr originate from natural land covers, the percent reduction required for the controllable sources is about 59 percent (i.e., controllable sources have an existing load of 1,700 lb/yr and target load of 700 lb/yr because 300 lb/yr is allocated to natural land cover sources).

Wasteload allocations (WLA) and Load allocations (LA) are assigned to point sources and non-point sources, respectively.

Table 4.16 outlines the Water Board's categorization of WLA/LA specification by land use/cover.

Table 4.16. Relationship between land use and WLA/LA categories provided by the Water Board.

Model Land Use	WLA/LA
CALTRANS	WLA
Chaparral, scrub	LA
Commercial, institutional	WLA
Forest	LA
Grassland, herbaceous	LA
High density residential	WLA
Horse ranches	LA
Industrial	WLA
Irrigated agriculture	LA
Low density residential	WLA
Non-irrigated agriculture	LA
Nurseries	LA
Open and recreation	LA
Orchard, vineyard	LA
Parks and recreation	LA
Road, freeway	WLA
Transitional	WLA/LA
Water	LA

Three of the site drainage areas are nested, thus allocations were assigned upstream to downstream to account for benefits achieved within drainages upstream. Allocations assigned at MWD2, MLS, and Old Hospital are impacted by upstream load reductions, where the reductions achieved upstream were applied to the at-source loads at the downstream sites. Any further reductions (if needed) were computed for the reducible sources within the remaining drainage area of the site.

Figure 4.3 and Figure 4.4 provide a conceptual schematic of the nested allocation strategy approach for TN and TP, respectively. Note that the values listed in the schematics are rounded to the nearest whole number (original values were used in the calculations). Table 4.1Table 4.17 lists the total existing and target at-source loads at each site; it also lists the percent reductions for controllable land uses to meet the targets after accounting for reductions achieved upstream. Note that a jurisdiction may have allocations applicable at multiple locations (e.g., Riverside County MS4 has allocations applicable to MWD2, MLS, and the Old Hospital and will need to meet all three collectively). The resulting dry weather at-source allocations are provided in Table 4.18 through Table 4.31. For informational purposes, wet weather at-source allocations are presented in Table 4.48 through Table 4.61.

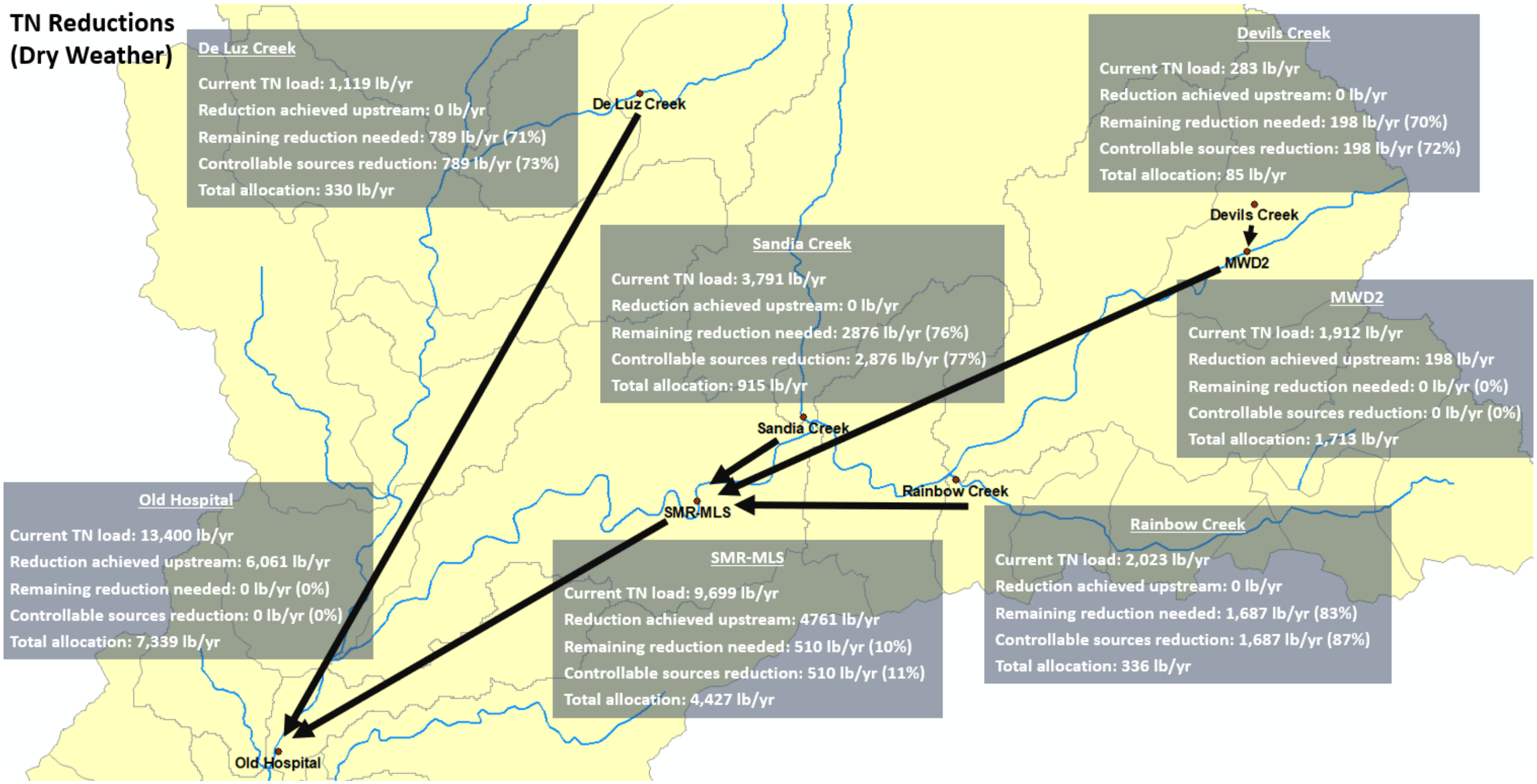


Figure 4.3. Conceptual schematic diagram of nested TN allocations with a 10% margin of safety.

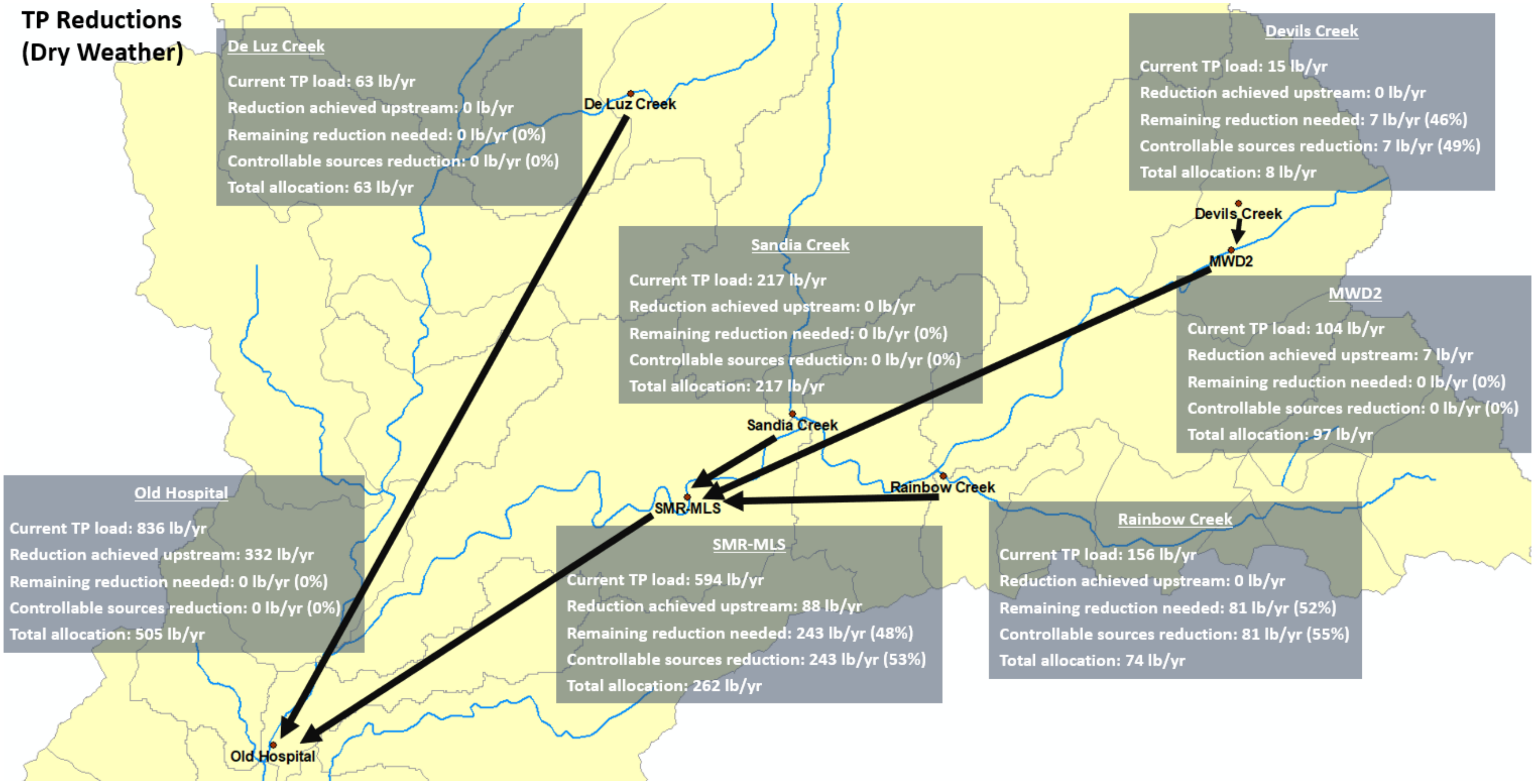


Figure 4.4. Conceptual schematic diagram of nested TP allocations with a 10% margin of safety.

Table 4.17. Summary table: existing and target at-source loads and percent reductions for controllable sources with 10 percent margin of safety.

Site	TN				TP			
	Existing total at-source load (lb/yr)	Existing load after upstream reductions (lb/yr)	Total at-source loading targets (lb/yr)	Percent reduction for controllable sources within the remaining drainage area	Existing total at-source load (lb/yr)	Existing load after upstream reductions (lb/yr)	Total at-source loading targets (lb/yr)	Percent reduction for controllable sources within the remaining drainage area
Devils Creek	283	283	85	72%	15	15	8	49%
MWD2	1912	1714	1912	0%	104	97	104	0%
Rainbow Creek	2023	2023	336	87%	156	156	74	55%
Sandia Creek	3791	3791	915	77%	217	217	217	0%
SMR-MLS	9699	4937	4427	11%	594	506	262	53%
De Luz Creek	1119	1119	330	73%	63	63	63	0%
Old Hospital	13400	7339	11823	0%	837	505	837	0%

Note: The values in this Table 4.are rounded and were not used in allocation calculations

Table 4.18. Dry weather at-source TN allocations (lb/year) by land use category and jurisdiction at Devils Creek with 10 percent margin of safety (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	-	-	-
Chaparral, scrub	-	-	0.00	4.79	-	-	-	0.00	4.79
Commercial, institutional	-	-	-	0.01	-	-	-	-	0.01
Forest	-	-	0.00	0.25	-	-	-	0.00	0.25
Grassland, herbaceous	-	-	-	1.95	-	-	-	-	1.95
High density residential	-	-	-	-	-	-	-	-	-
Dairy, livestock, horse ranches	-	-	-	-	-	-	-	-	-
Industrial	-	-	-	-	-	-	-	-	-
Irrigated agriculture	-	-	-	2.16	-	-	-	-	2.16
Low density residential	-	-	0.01	1.42	-	-	-	0.01	1.43
Non-irrigated agriculture	-	-	-	-	-	-	-	-	-
Nurseries	-	-	-	-	-	-	-	-	-
Open and recreation	-	-	-	-	-	-	-	-	-
Orchard, vineyard	-	-	-	73.47	-	-	-	-	73.47
Parks and recreation	-	-	-	-	-	-	-	-	-
Road, freeway	-	-	0.00	0.83	-	-	-	0.00	0.83
Transitional	-	-	0.00	0.00	-	-	-	0.00	0.01
Water	-	-	-	-	-	-	-	-	-
Total	-	-	0.01	84.88	-	-	-	0.01	84.90

Table 4.19. Dry weather at-source TP allocations (lb/year) by land use category and jurisdiction at Devils Creek with 10 percent margin of safety (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	-	-	-
Chaparral, scrub	-	-	0.000	0.723	-	-	-	0.000	0.723
Commercial, institutional	-	-	-	0.001	-	-	-	-	0.001
Forest	-	-	0.000	0.031	-	-	-	0.000	0.031
Grassland, herbaceous	-	-	-	0.274	-	-	-	-	0.274
High density residential	-	-	-	-	-	-	-	-	-
Dairy, livestock, horse ranches	-	-	-	-	-	-	-	-	-
Industrial	-	-	-	-	-	-	-	-	-
Irrigated agriculture	-	-	-	0.112	-	-	-	-	0.112
Low density residential	-	-	0.001	0.202	-	-	-	0.001	0.203
Non-irrigated agriculture	-	-	-	-	-	-	-	-	-
Nurseries	-	-	-	-	-	-	-	-	-
Open and recreation	-	-	-	-	-	-	-	-	-
Orchard, vineyard	-	-	-	6.832	-	-	-	-	6.832
Parks and recreation	-	-	-	-	-	-	-	-	-
Road, freeway	-	-	0.000	0.122	-	-	-	0.000	0.122
Transitional	-	-	0.001	0.001	-	-	-	0.001	0.001
Water	-	-	-	-	-	-	-	-	-
Total	-	-	0.002	8.298	-	-	-	0.002	8.300

Table 4.20. Dry weather at-source allocations for TN loads (lb/year) by land use category and jurisdiction at MWD2 with 10 percent margin of safety (WY 2009-2018)

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	8.33	8.33	8.33
Chaparral, scrub	-	0.20	0.00	87.14	-	39.98	-	0.00	127.32
Commercial, institutional	-	-	17.44	1.18	-	0.19	-	17.44	18.81
Forest	-	0.00	0.00	2.79	-	0.80	-	0.00	3.60
Grassland, herbaceous	-	-	0.00	3.59	-	0.06	-	0.00	3.65
High density residential	-	-	11.14	0.45	-	-	-	11.14	11.59
Dairy, livestock, horse ranches	-	-	-	97.63	-	0.01	-	-	97.64
Industrial	-	-	29.11	5.18	-	-	-	29.11	34.29
Irrigated agriculture	-	-	0.01	59.68	-	19.75	-	0.01	79.44
Low density residential	-	-	416.92	22.83	-	10.66	-	416.92	450.40
Non-irrigated agriculture	-	-	-	0.72	-	0.03	-	-	0.76
Nurseries	-	-	0.00	48.26	-	-	-	0.00	48.27
Open and recreation	-	-	49.09	5.18	-	1.50	-	49.09	55.78
Orchard, vineyard	-	-	0.02	615.78	-	-	-	0.02	615.80
Parks and recreation	-	-	45.26	8.99	-	2.32	-	45.26	56.57
Road, freeway	-	0.00	72.11	5.07	-	0.29	-	72.11	77.48
Transitional	-	-	3.50	3.50	-	-	-	3.50	7.00
Water	-	-	-	16.50	-	0.24	-	-	16.74
Total	-	0.21	644.60	984.48	-	75.83	8.33	652.93	1713.45

Table 4.21. Dry weather at-source allocations for TP loads (lb/year) by land use category and jurisdiction at MWD2 with 10 percent margin of safety (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	0.660	0.660	0.660
Chaparral, scrub	-	0.011	0.000	7.520	-	2.470	-	0.000	10.002
Commercial, institutional	-	-	1.002	0.074	-	0.009	-	1.002	1.085
Forest	-	0.000	0.000	0.296	-	0.087	-	0.000	0.383
Grassland, herbaceous	-	-	0.000	0.429	-	0.003	-	0.000	0.431
High density residential	-	-	0.913	0.050	-	-	-	0.913	0.963
Dairy, livestock, horse ranches	-	-	-	1.672	-	0.000	-	-	1.672
Industrial	-	-	2.166	0.362	-	-	-	2.166	2.527
Irrigated agriculture	-	-	0.000	2.105	-	0.445	-	0.000	2.551
Low density residential	-	-	26.290	1.621	-	0.527	-	26.290	28.437
Non-irrigated agriculture	-	-	-	0.124	-	0.003	-	-	0.126
Nurseries	-	-	0.000	2.934	-	-	-	0.000	2.934
Open and recreation	-	-	2.756	0.402	-	0.071	-	2.756	3.228
Orchard, vineyard	-	-	0.001	31.175	-	-	-	0.001	31.176
Parks and recreation	-	-	2.769	0.863	-	0.107	-	2.769	3.738
Road, freeway	-	0.000	4.136	0.457	-	0.013	-	4.136	4.606
Transitional	-	-	0.230	0.230	-	-	-	0.230	0.460
Water	-	-	-	1.616	-	0.019	-	-	1.635
Total	-	0.011	40.263	51.926	-	3.753	0.660	40.923	96.614

Table 4.22. Dry weather at-source allocations for TN loads (lb/year) by land use category and jurisdiction at Rainbow Creek with 10 percent margin of safety (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	3.88	3.88	3.88
Chaparral, scrub	3.60	22.88	0.01	10.93	-	14.33	-	3.60	51.75
Commercial, institutional	0.15	0.10	0.11	0.00	-	0.00	-	0.26	0.37
Forest	0.04	0.68	0.05	0.70	-	1.60	-	0.08	3.07
Grassland, herbaceous	0.16	18.30	0.00	0.42	-	0.99	-	0.16	19.87
High density residential	-	1.43	-	-	-	0.00	-	-	1.43
Dairy, livestock, horse ranches	-	-	-	-	-	-	-	-	-
Industrial	0.14	1.39	0.25	0.00	-	0.01	-	0.39	1.80
Irrigated agriculture	1.51	5.17	0.00	0.01	-	0.01	-	1.51	6.69
Low density residential	1.58	12.40	0.61	0.00	-	0.01	-	2.20	14.61
Non-irrigated agriculture	0.02	0.05	0.00	0.00	-	-	-	0.02	0.07
Nurseries	44.37	94.81	-	-	-	-	-	44.37	139.18
Open and recreation	-	-	-	-	-	-	-	-	-
Orchard, vineyard	6.65	84.36	-	-	-	-	-	6.65	91.01
Parks and recreation	0.05	0.00	-	-	-	-	-	0.05	0.05
Road, freeway	0.40	1.59	0.16	0.00	-	0.02	-	0.57	2.18
Transitional	0.00	0.00	0.00	0.00	-	-	-	0.00	0.01
Water	-	#N/A	-	-	-	-	-	-	-
Total	58.68	243.17	1.19	12.07	-	16.98	3.88	63.76	335.98

Table 4.23. Dry weather at-source allocations for TP loads (lb/year) by land use category and jurisdiction at Rainbow Creek with 10 percent margin of safety (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	0.727	0.727	0.727
Chaparral, scrub	0.421	2.721	0.001	1.274	-	1.671	-	0.422	6.087
Commercial, institutional	0.034	0.023	0.024	0.000	-	0.000	-	0.058	0.081
Forest	0.003	0.073	0.002	0.079	-	0.182	-	0.005	0.339
Grassland, herbaceous	0.019	2.218	0.000	0.049	-	0.120	-	0.019	2.407
High density residential	-	0.323	-	-	-	0.000	-	-	0.323
Dairy, livestock, horse ranches	-	-	-	-	-	-	-	-	-
Industrial	0.034	0.339	0.060	0.000	-	0.004	-	0.094	0.437
Irrigated agriculture	0.192	0.549	0.000	0.001	-	0.001	-	0.192	0.742
Low density residential	0.356	2.804	0.140	0.001	-	0.003	-	0.496	3.303
Non-irrigated agriculture	0.008	0.018	0.000	0.000	-	-	-	0.008	0.026
Nurseries	14.236	30.416	-	-	-	-	-	14.236	44.652
Open and recreation	-	-	-	-	-	-	-	-	-
Orchard, vineyard	1.081	13.592	-	-	-	-	-	1.081	14.673
Parks and recreation	0.011	0.000	-	-	-	-	-	0.011	0.011
Road, freeway	0.090	0.360	0.036	0.000	-	0.005	-	0.126	0.491
Transitional	0.000	0.000	0.001	0.001	-	-	-	0.001	0.002
Water	-	#N/A	-	-	-	-	-	-	-
Total	16.485	53.436	0.263	1.405	-	1.985	0.727	17.475	74.301

Table 4.24. Dry weather at-source allocations for TN loads (lb/year) by land use category and jurisdiction at Sandia Creek with 10 percent margin of safety (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	-	-	-
Chaparral, scrub	0.00	8.15	0.00	44.15	-	4.19	-	0.00	56.49
Commercial, institutional	-	-	-	0.08	-	-	-	-	0.08
Forest	0.00	0.96	0.00	2.03	-	0.99	-	0.00	3.98
Grassland, herbaceous	0.00	0.82	0.00	1.47	-	0.22	-	0.00	2.50
High density residential	-	-	-	-	-	-	-	-	-
Dairy, livestock, horse ranches	-	-	-	1.19	-	-	-	-	1.19
Industrial	-	-	0.00	0.14	-	-	-	0.00	0.14
Irrigated agriculture	0.00	5.69	0.00	17.81	-	0.10	-	0.00	23.60
Low density residential	0.06	3.69	0.01	17.26	-	0.01	-	0.07	21.03
Non-irrigated agriculture	0.00	0.10	-	0.03	-	-	-	0.00	0.13
Nurseries	-	1.05	-	-	-	-	-	-	1.05
Open and recreation	-	-	-	-	-	-	-	-	-
Orchard, vineyard	0.00	152.77	0.00	645.18	-	0.35	-	0.00	798.30
Parks and recreation	-	-	-	2.51	-	-	-	-	2.51
Road, freeway	0.03	0.49	0.00	3.26	-	0.00	-	0.03	3.79
Transitional	-	-	0.07	0.07	-	-	-	0.07	0.13
Water	-	#N/A	-	-	-	-	-	-	-
Total	0.09	173.72	0.08	735.19	-	5.86	-	0.18	914.94

Table 4.25. Dry weather at-source allocations for TP loads (lb/year) by land use category and jurisdiction at Sandia Creek with 10 percent margin of safety (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	-	-	-
Chaparral, scrub	0.000	1.369	0.000	7.154	-	0.714	-	0.000	9.237
Commercial, institutional	-	-	-	0.031	-	-	-	-	0.031
Forest	0.000	0.159	0.000	0.244	-	0.169	-	0.000	0.573
Grassland, herbaceous	0.000	0.138	0.000	0.225	-	0.037	-	0.000	0.400
High density residential	-	-	-	-	-	-	-	-	-
Dairy, livestock, horse ranches	-	-	-	0.106	-	-	-	-	0.106
Industrial	-	-	0.000	0.054	-	-	-	0.000	0.054
Irrigated agriculture	0.000	0.607	0.000	1.954	-	0.011	-	0.000	2.572
Low density residential	0.022	1.372	0.003	6.247	-	0.002	-	0.026	7.647
Non-irrigated agriculture	0.000	0.067	-	0.020	-	-	-	0.000	0.087
Nurseries	-	0.492	-	-	-	-	-	-	0.492
Open and recreation	-	-	-	-	-	-	-	-	-
Orchard, vineyard	0.000	37.111	0.000	156.545	-	0.085	-	0.001	193.742
Parks and recreation	-	-	-	0.841	-	-	-	-	0.841
Road, freeway	0.012	0.185	0.000	1.183	-	0.001	-	0.012	1.381
Transitional	-	-	0.027	0.027	-	-	-	0.027	0.055
Water	-	#N/A	-	-	-	-	-	-	-
Total	0.034	41.501	0.032	174.632	-	1.019	-	0.066	217.218

Table 4.26. Dry weather at-source allocations for TN loads (lb/year) by land use category and jurisdiction at SMR-MLS with 10 percent margin of safety (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	10.84	10.84	10.84
Chaparral, scrub	3.68	51.72	0.01	203.16	0.02	68.44	-	3.72	327.04
Commercial, institutional	0.30	0.13	15.57	1.28	-	0.17	-	15.87	17.46
Forest	0.04	2.59	0.05	9.14	0.01	3.74	-	0.10	15.56
Grassland, herbaceous	0.20	41.06	0.00	6.88	0.03	1.27	-	0.23	49.44
High density residential	0.24	1.27	9.88	0.40	-	0.00	-	10.12	11.80
Dairy, livestock, horse ranches	-	-	-	87.70	-	0.00	-	-	87.70
Industrial	0.63	1.24	26.05	5.37	-	0.01	-	26.69	33.31
Irrigated agriculture	1.53	35.83	0.01	87.21	-	17.63	-	1.54	142.20
Low density residential	115.92	18.53	370.50	42.54	0.13	9.47	-	486.55	557.09
Non-irrigated agriculture	0.02	0.36	0.00	0.67	-	0.03	-	0.02	1.08
Nurseries	39.61	129.78	0.00	42.83	-	-	-	39.61	212.22
Open and recreation	0.29	0.06	43.56	4.60	-	1.33	-	43.86	49.86
Orchard, vineyard	10.84	1030.13	0.01	1706.07	-	0.31	-	10.85	2747.36
Parks and recreation	0.04	0.00	40.17	10.21	-	2.06	-	40.21	52.48
Road, freeway	7.95	3.36	64.13	13.06	0.03	0.28	-	72.11	88.81
Transitional	0.00	0.00	3.16	3.16	-	-	-	3.16	6.32
Water	-	-	-	16.50	-	0.24	-	-	16.74
Total	181.30	1316.08	573.10	2240.76	0.23	104.99	10.84	765.47	4427.30

Table 4.27. Dry weather at-source allocations for TP loads (lb/year) by land use category and jurisdiction at SMR-MLS with 10 percent margin of safety (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	0.650	0.650	0.650
Chaparral, scrub	0.432	6.767	0.001	24.457	0.004	6.221	-	0.437	37.882
Commercial, institutional	0.022	0.012	0.480	0.056	-	0.004	-	0.502	0.575
Forest	0.003	0.334	0.002	1.089	0.001	0.482	-	0.006	1.912
Grassland, herbaceous	0.024	5.340	0.000	0.936	0.006	0.160	-	0.030	6.466
High density residential	0.009	0.151	0.428	0.023	-	0.000	-	0.436	0.611
Dairy, livestock, horse ranches	-	-	-	0.833	-	0.000	-	-	0.833
Industrial	0.038	0.159	1.043	0.225	-	0.002	-	1.080	1.466
Irrigated agriculture	0.093	0.940	0.000	2.139	-	0.214	-	0.093	3.386
Low density residential	4.389	2.119	12.381	3.978	0.006	0.249	-	16.777	23.123
Non-irrigated agriculture	0.004	0.055	0.000	0.067	-	0.001	-	0.004	0.127
Nurseries	6.681	16.758	0.000	1.375	-	-	-	6.681	24.813
Open and recreation	0.010	0.002	1.291	0.188	-	0.033	-	1.301	1.525
Orchard, vineyard	0.635	45.542	0.000	105.091	-	0.040	-	0.635	151.309
Parks and recreation	0.005	0.000	1.297	0.798	-	0.050	-	1.302	2.150
Road, freeway	0.332	0.314	1.955	0.988	0.002	0.009	-	2.288	3.599
Transitional	0.000	0.000	0.120	0.120	-	-	-	0.120	0.241
Water	-	-	-	1.616	-	0.019	-	-	1.635
Total	12.675	78.493	18.999	143.980	0.019	7.485	0.650	32.342	262.300

Table 4.28. Dry weather at-source allocations for TN loads (lb/year) by land use category and jurisdiction at De Luz Creek with 10 percent margin of safety (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	-	-	-
Chaparral, scrub	-	2.96	-	23.73	-	2.19	-	-	28.88
Commercial, institutional	-	-	-	0.10	-	-	-	-	0.10
Forest	-	0.43	-	0.74	-	0.93	-	-	2.10
Grassland, herbaceous	-	0.10	-	5.21	-	0.03	-	-	5.34
High density residential	-	-	-	-	-	-	-	-	-
Dairy, livestock, horse ranches	-	-	-	-	-	-	-	-	-
Industrial	-	-	-	0.13	-	-	-	-	0.13
Irrigated agriculture	-	4.11	-	8.17	-	0.00	-	-	12.29
Low density residential	-	0.81	-	1.73	-	0.08	-	-	2.62
Non-irrigated agriculture	-	0.04	-	-	-	0.00	-	-	0.04
Nurseries	-	1.53	-	-	-	-	-	-	1.53
Open and recreation	-	-	-	-	-	-	-	-	-
Orchard, vineyard	-	16.45	-	258.86	-	-	-	-	275.31
Parks and recreation	-	-	-	-	-	-	-	-	-
Road, freeway	-	0.33	-	0.93	-	0.10	-	-	1.36
Transitional	-	-	0.03	0.03	-	-	-	0.03	0.06
Water	-	-	-	-	-	-	-	-	-
Total	-	26.76	0.03	299.64	-	3.33	-	0.03	329.76

Table 4.29. Dry weather at-source allocations for TP loads (lb/year) by land use category and jurisdiction at De Luz Creek with 10 percent margin of safety (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	-	-	-
Chaparral, scrub	-	0.451	-	3.580	-	0.367	-	-	4.397
Commercial, institutional	-	-	-	0.028	-	-	-	-	0.028
Forest	-	0.071	-	0.112	-	0.155	-	-	0.338
Grassland, herbaceous	-	0.015	-	0.779	-	0.006	-	-	0.800
High density residential	-	-	-	-	-	-	-	-	-
Dairy, livestock, horse ranches	-	-	-	-	-	-	-	-	-
Industrial	-	-	-	0.040	-	-	-	-	0.040
Irrigated agriculture	-	0.376	-	0.758	-	0.000	-	-	1.135
Low density residential	-	0.243	-	0.520	-	0.024	-	-	0.787
Non-irrigated agriculture	-	0.022	-	-	-	0.001	-	-	0.023
Nurseries	-	0.600	-	-	-	-	-	-	0.600
Open and recreation	-	-	-	-	-	-	-	-	-
Orchard, vineyard	-	3.270	-	50.905	-	-	-	-	54.176
Parks and recreation	-	-	-	-	-	-	-	-	-
Road, freeway	-	0.097	-	0.274	-	0.031	-	-	0.403
Transitional	-	-	0.008	0.008	-	-	-	0.008	0.017
Water	-	-	-	-	-	-	-	-	-
Total	-	5.147	0.008	57.005	-	0.585	-	0.008	62.745

Table 4.30. Dry weather at-source allocations for TN loads (lb/year) by land use category and jurisdiction at Old Hospital with 10 percent margin of safety (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	10.84	10.84	10.84
Chaparral, scrub	3.69	212.14	0.01	256.91	0.42	78.27	-	4.11	551.43
Commercial, institutional	0.30	0.53	15.57	1.38	1.80	0.17	-	17.67	19.75
Forest	0.04	13.74	0.05	10.78	0.05	6.16	-	0.14	30.82
Grassland, herbaceous	0.20	166.59	0.00	25.10	0.59	6.32	-	0.79	198.80
High density residential	0.33	1.27	9.88	0.40	-	0.00	-	10.21	11.88
Dairy, livestock, horse ranches	-	-	-	87.70	-	0.00	-	-	87.70
Industrial	1.17	3.41	26.05	5.71	0.36	0.01	-	27.58	36.71
Irrigated agriculture	1.56	224.97	0.01	107.14	-	17.67	-	1.57	351.35
Low density residential	131.33	136.56	370.50	59.31	4.05	9.68	-	505.88	711.45
Non-irrigated agriculture	0.02	3.64	0.00	0.67	-	0.03	-	0.02	4.36
Nurseries	39.67	332.80	0.00	42.83	-	-	-	39.67	415.30
Open and recreation	0.29	0.70	43.56	4.62	-	1.33	-	43.86	50.51
Orchard, vineyard	11.15	2464.23	0.01	2172.61	-	1.93	-	11.16	4649.93
Parks and recreation	0.04	0.79	40.17	10.21	-	2.06	-	40.21	53.26
Road, freeway	9.12	30.05	64.13	26.27	1.51	0.53	-	74.76	131.60
Transitional	0.03	0.03	3.31	3.31	-	-	-	3.34	6.68
Water	-	0.00	-	16.50	-	0.24	-	-	16.74
Total	198.93	3591.46	573.25	2831.44	8.78	124.41	10.84	791.80	7339.11

Table 4.31. Dry weather at-source allocations for TP loads (lb/year) by land use category and jurisdiction at Old Hospital with 10 percent margin of safety (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	0.650	0.650	0.650
Chaparral, scrub	0.432	30.331	0.001	32.512	0.059	7.792	-	0.492	71.127
Commercial, institutional	0.022	0.040	0.480	0.084	0.125	0.004	-	0.627	0.756
Forest	0.003	2.035	0.002	1.325	0.003	0.878	-	0.009	4.247
Grassland, herbaceous	0.024	23.247	0.000	3.662	0.091	0.918	-	0.116	27.942
High density residential	0.015	0.151	0.428	0.023	-	0.000	-	0.442	0.617
Dairy, livestock, horse ranches	-	-	-	0.833	-	0.000	-	-	0.833
Industrial	0.085	0.340	1.043	0.282	0.026	0.002	-	1.154	1.778
Irrigated agriculture	0.094	5.935	0.000	3.192	-	0.215	-	0.094	9.436
Low density residential	5.583	11.645	12.381	5.687	0.287	0.285	-	18.251	35.868
Non-irrigated agriculture	0.004	0.548	0.000	0.067	-	0.002	-	0.004	0.621
Nurseries	6.687	39.139	0.000	1.375	-	-	-	6.687	47.201
Open and recreation	0.010	0.051	1.291	0.190	-	0.033	-	1.301	1.576
Orchard, vineyard	0.650	123.761	0.000	166.367	-	0.122	-	0.651	290.901
Parks and recreation	0.005	0.061	1.297	0.798	-	0.050	-	1.302	2.211
Road, freeway	0.422	2.506	1.955	2.220	0.111	0.053	-	2.488	7.267
Transitional	0.002	0.002	0.135	0.135	-	-	-	0.137	0.274
Water	-	-	-	1.616	-	0.019	-	-	1.635
Total	14.037	239.792	19.014	220.370	0.703	10.373	0.650	34.403	504.939

4.5 Wet Weather

Wet weather reductions and allocations were calculated using the methods applied for dry weather though for wet weather days; these are listed below in Tables 32-61. Figure 4.5 and Figure 4.6 illustrate the nested reduction process for wet weather. Weather is considered wet up to 72 hours after a storm event greater than or equal to 0.1 inches. These results are included for informational purposes given the current strategy is to focus on dry weather reductions for the first 5 years. At that point, if measurable improvements are not being seen, wet weather reductions will be implemented as noted by Water Board staff during stakeholder meetings. Wet weather targets and reductions may be calculated using a different method, depending upon the Water Board's review (Table 4.33-4.46). Note that TN values are reported with two significant digits and TP values are reported with three significant digits given the magnitudes of the current loads and allocations. Thus, a value of 0.00 or 0.000 lb/yr indicates a non-zero value.

Table 4.32. Percent reductions for delivered loads needed to meet average annual wet weather loading targets with a 10 percent margin of safety.

Allocation Site	TN	TP
Devils Creek	72%	26%
MWD2	60%	70%
Rainbow Creek	49%	0%
Sandia Creek	78%	0%
SMR-MLS	48%	14%
De Luz Creek	78%	0%
Old Hospital	56%	60%

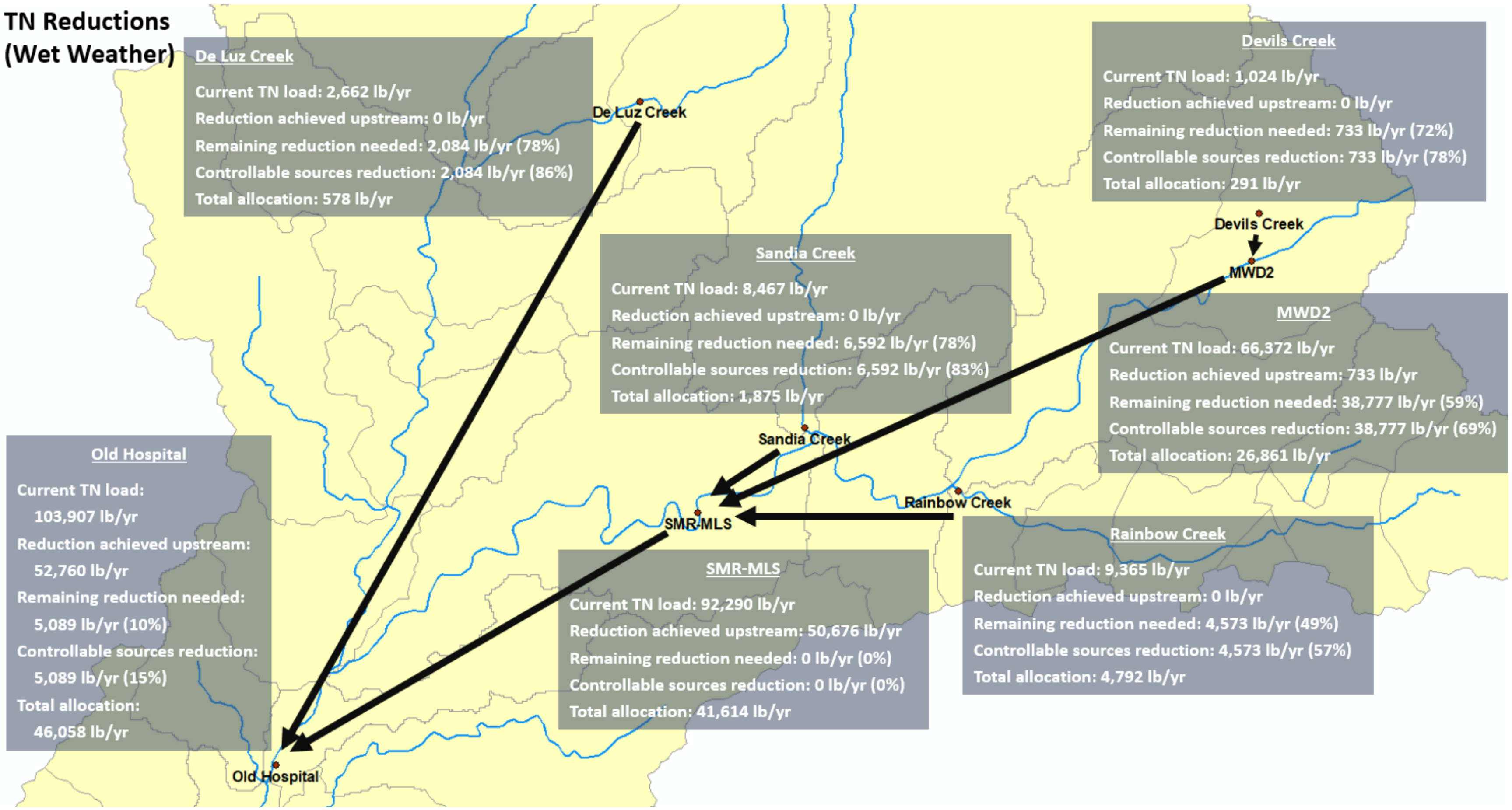


Figure 4.5. Conceptual schematic diagram of nested wet weather TN allocations with a 10% margin of safety.

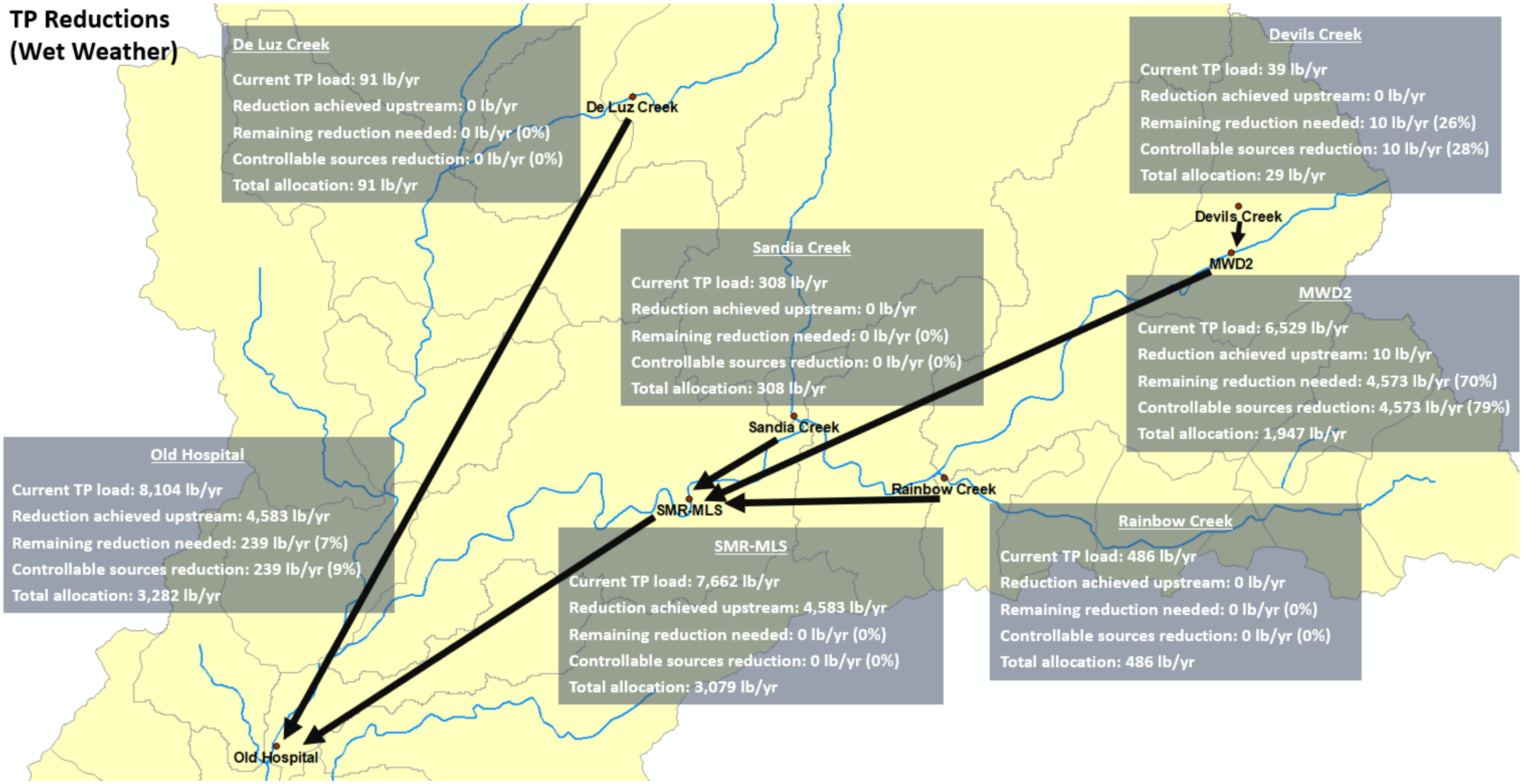


Figure 4.6. Conceptual schematic diagram of nested wet weather TP allocations with a 10% margin of safety.

Table 4.33. Wet weather at-source TN loads (lb/year) by land use category and jurisdiction at Devils Creek (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	-	-	-
Chaparral, scrub	-	-	0.00	52.67	-	-	-	0.00	52.67
Commercial, institutional	-	-	-	0.51	-	-	-	-	0.51
Forest	-	-	0.00	6.30	-	-	-	0.00	6.30
Grassland, herbaceous	-	-	-	26.67	-	-	-	-	26.67
High density residential	-	-	-	-	-	-	-	-	-
Dairy, livestock, horse ranches	-	-	-	-	-	-	-	-	-
Industrial	-	-	-	-	-	-	-	-	-
Irrigated agriculture	-	-	-	67.58	-	-	-	-	67.58
Low density residential	-	-	0.24	43.44	-	-	-	0.24	43.68
Non-irrigated agriculture	-	-	-	-	-	-	-	-	-
Nurseries	-	-	-	-	-	-	-	-	-
Open and recreation	-	-	-	-	-	-	-	-	-
Orchard, vineyard	-	-	-	799.51	-	-	-	-	799.51
Parks and recreation	-	-	-	-	-	-	-	-	-
Road, freeway	-	-	0.00	22.39	-	-	-	0.00	22.39
Transitional	-	-	2.50	2.50	-	-	-	2.50	4.99
Water	-	-	-	-	-	-	-	-	-
Total	-	-	2.74	1021.57	-	-	-	2.74	1024.31

Table 4.34. Wet weather at-source TP loads (lb/year) by land use category and jurisdiction at Devils Creek (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	-	-	-
Chaparral, scrub	-	-	0.000	2.058	-	-	-	0.000	2.058
Commercial, institutional	-	-	-	0.056	-	-	-	-	0.056
Forest	-	-	0.000	0.647	-	-	-	0.000	0.647
Grassland, herbaceous	-	-	-	1.070	-	-	-	-	1.070
High density residential	-	-	-	-	-	-	-	-	-
Dairy, livestock, horse ranches	-	-	-	-	-	-	-	-	-
Industrial	-	-	-	-	-	-	-	-	-
Irrigated agriculture	-	-	-	1.971	-	-	-	-	1.971
Low density residential	-	-	0.020	2.931	-	-	-	0.020	2.952
Non-irrigated agriculture	-	-	-	-	-	-	-	-	-
Nurseries	-	-	-	-	-	-	-	-	-
Open and recreation	-	-	-	-	-	-	-	-	-
Orchard, vineyard	-	-	-	28.997	-	-	-	-	28.997
Parks and recreation	-	-	-	-	-	-	-	-	-
Road, freeway	-	-	0.000	1.045	-	-	-	0.000	1.045
Transitional	-	-	0.068	0.068	-	-	-	0.068	0.135
Water	-	-	-	-	-	-	-	-	-
Total	-	-	0.088	38.844	-	-	-	0.088	38.932

Table 4.35. Wet weather at-source TN loads (lb/year) by land use category and jurisdiction at MWD2 (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	825.57	825.57	825.57
Chaparral, scrub	-	7.67	0.12	7116.05	-	2035.70	-	0.12	9159.54
Commercial, institutional	-	-	1922.25	50.00	-	37.07	-	1922.25	2009.32
Forest	-	0.01	0.11	62.49	-	12.66	-	0.11	75.28
Grassland, herbaceous	-	-	0.00	46.77	-	0.10	-	0.00	46.87
High density residential	-	-	447.59	10.50	-	-	-	447.59	458.08
Dairy, livestock, horse ranches	-	-	-	496.69	-	0.02	-	-	496.72
Industrial	-	-	1610.63	132.49	-	-	-	1610.63	1743.11
Irrigated agriculture	-	-	0.06	948.99	-	178.28	-	0.06	1127.33
Low density residential	-	-	14002.55	512.84	-	112.22	-	14002.55	14627.60
Non-irrigated agriculture	-	-	-	80.79	-	3.81	-	-	84.59
Nurseries	-	-	0.02	880.79	-	-	-	0.02	880.81
Open and recreation	-	-	1156.37	289.38	-	3.41	-	1156.37	1449.16
Orchard, vineyard	-	-	0.05	5965.13	-	-	-	0.05	5965.17
Parks and recreation	-	-	1676.56	1303.71	-	58.98	-	1676.56	3039.25
Road, freeway	-	0.04	5698.74	207.29	-	9.04	-	5698.74	5915.10
Transitional	-	-	8991.88	8991.88	-	-	-	8991.88	17983.76
Water	-	-	-	466.16	-	18.66	-	-	484.82
Total	-	7.72	35506.92	27561.95	-	2469.94	825.57	36332.49	66372.09

Table 4.36. Wet weather at-source TP loads (lb/year) by land use category and jurisdiction at MWD2 (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	177.382	177.382	177.382
Chaparral, scrub	-	0.265	0.008	586.427	-	103.624	-	0.008	690.325
Commercial, institutional	-	-	399.592	10.209	-	8.705	-	399.592	418.507
Forest	-	0.001	0.014	4.881	-	0.587	-	0.014	5.482
Grassland, herbaceous	-	-	0.000	2.295	-	0.007	-	0.000	2.302
High density residential	-	-	67.610	1.408	-	-	-	67.610	69.018
Dairy, livestock, horse ranches	-	-	-	17.808	-	0.000	-	-	17.809
Industrial	-	-	294.582	22.593	-	-	-	294.582	317.175
Irrigated agriculture	-	-	0.002	46.146	-	7.750	-	0.002	53.897
Low density residential	-	-	1772.478	54.229	-	13.603	-	1772.478	1840.310
Non-irrigated agriculture	-	-	-	16.858	-	0.589	-	-	17.447
Nurseries	-	-	0.002	63.457	-	-	-	0.002	63.459
Open and recreation	-	-	116.938	32.263	-	0.295	-	116.938	149.496
Orchard, vineyard	-	-	0.002	349.289	-	-	-	0.002	349.290
Parks and recreation	-	-	180.983	151.560	-	5.822	-	180.983	338.365
Road, freeway	-	0.002	825.848	13.034	-	1.040	-	825.848	839.924
Transitional	-	-	589.147	589.147	-	-	-	589.147	1178.295
Water	-	-	-	0.709	-	0.006	-	-	0.715
Total	-	0.268	4247.205	1962.313	-	142.029	177.382	4424.587	6529.196

Table 4.37. Wet weather at-source TN loads (lb/year) by land use category and jurisdiction at Rainbow Creek (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	376.69	376.69	376.69
Chaparral, scrub	63.10	393.42	0.11	192.72	-	252.27	-	63.21	901.62
Commercial, institutional	16.84	13.62	20.11	0.04	-	0.01	-	36.95	50.62
Forest	1.54	14.32	2.44	12.00	-	26.53	-	3.98	56.82
Grassland, herbaceous	2.86	316.44	0.02	7.57	-	17.13	-	2.88	344.01
High density residential	-	111.32	-	-	-	0.06	-	-	111.38
Dairy, livestock, horse ranches	-	-	-	-	-	-	-	-	-
Industrial	12.56	129.64	25.80	0.07	-	1.50	-	38.36	169.58
Irrigated agriculture	175.97	440.97	0.00	0.75	-	0.55	-	175.97	618.25
Low density residential	150.50	1184.23	62.38	0.30	-	1.17	-	212.88	1398.58
Non-irrigated agriculture	2.73	6.10	0.00	0.00	-	-	-	2.73	8.84
Nurseries	721.84	1542.24	-	-	-	-	-	721.84	2264.08
Open and recreation	-	-	-	-	-	-	-	-	-
Orchard, vineyard	211.86	2567.23	-	-	-	-	-	211.86	2779.09
Parks and recreation	6.13	0.05	-	-	-	-	-	6.13	6.18
Road, freeway	56.43	191.18	19.80	0.05	-	2.40	-	76.22	269.86
Transitional	1.09	1.09	3.72	3.72	-	-	-	4.81	9.62
Water	-	-	-	-	-	-	-	-	-
Total	1423.46	6911.85	134.37	217.23	-	301.62	376.69	1934.51	9365.21

Table 4.38. Wet weather at-source TP loads (lb/year) by land use category and jurisdiction at Rainbow Creek (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	32.644	32.644	32.644
Chaparral, scrub	2.848	21.426	0.006	8.171	-	10.761	-	2.854	43.212
Commercial, institutional	1.361	1.193	2.194	0.003	-	0.001	-	3.555	4.751
Forest	0.202	1.149	0.347	0.580	-	1.196	-	0.548	3.474
Grassland, herbaceous	0.132	14.993	0.001	0.331	-	0.806	-	0.132	16.261
High density residential	-	5.117	-	-	-	0.002	-	-	5.120
Dairy, livestock, horse ranches	-	-	-	-	-	-	-	-	-
Industrial	0.731	6.133	1.981	0.004	-	0.061	-	2.712	8.910
Irrigated agriculture	19.773	25.363	0.000	0.020	-	0.012	-	19.773	45.168
Low density residential	8.765	61.022	4.178	0.017	-	0.064	-	12.943	74.046
Non-irrigated agriculture	0.138	0.362	0.000	0.000	-	-	-	0.138	0.500
Nurseries	41.951	89.631	-	-	-	-	-	41.951	131.582
Open and recreation	-	-	-	-	-	-	-	-	-
Orchard, vineyard	8.149	96.238	-	-	-	-	-	8.149	104.387
Parks and recreation	0.414	0.003	-	-	-	-	-	0.414	0.417
Road, freeway	3.980	10.281	1.156	0.003	-	0.117	-	5.136	15.536
Transitional	0.029	0.029	0.098	0.098	-	-	-	0.127	0.254
Water	-	-	-	-	-	-	-	-	-
Total	88.471	332.939	9.960	9.227	-	13.020	32.644	131.075	486.261

Table 4.39. Wet weather at-source TN loads (lb/year) by land use category and jurisdiction at Sandia Creek (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	-	-	-
Chaparral, scrub	0.00	66.16	0.01	323.31	-	35.28	-	0.01	424.76
Commercial, institutional	-	-	-	7.15	-	-	-	-	7.15
Forest	0.00	8.31	0.11	50.12	-	7.49	-	0.11	66.03
Grassland, herbaceous	0.01	6.56	0.00	7.95	-	1.84	-	0.01	16.36
High density residential	-	-	-	-	-	-	-	-	-
Dairy, livestock, horse ranches	-	-	-	12.81	-	-	-	-	12.81
Industrial	-	-	0.03	3.69	-	-	-	0.03	3.72
Irrigated agriculture	0.00	151.77	0.00	434.78	-	2.74	-	0.00	589.29
Low density residential	1.22	58.79	0.37	342.82	-	0.08	-	1.58	403.27
Non-irrigated agriculture	0.00	3.16	-	0.57	-	-	-	0.00	3.72
Nurseries	-	3.79	-	-	-	-	-	-	3.79
Open and recreation	-	-	-	-	-	-	-	-	-
Orchard, vineyard	0.00	1277.94	0.01	5388.12	-	2.99	-	0.01	6669.06
Parks and recreation	-	-	-	48.90	-	-	-	-	48.90
Road, freeway	0.75	11.65	0.04	87.80	-	0.05	-	0.79	100.30
Transitional	-	-	59.14	59.14	-	-	-	59.14	118.27
Water	-	-	-	-	-	-	-	-	-
Total	1.98	1588.13	59.70	6767.16	-	50.47	-	61.68	8467.44

Table 4.40. Wet weather at-source TP loads (lb/year) by land use category and jurisdiction at Sandia Creek (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	-	-	-
Chaparral, scrub	0.000	2.062	0.000	10.489	-	1.072	-	0.000	13.622
Commercial, institutional	-	-	-	0.777	-	-	-	-	0.777
Forest	0.000	0.384	0.013	5.383	-	0.233	-	0.013	6.013
Grassland, herbaceous	0.000	0.207	0.000	0.286	-	0.057	-	0.000	0.549
High density residential	-	-	-	-	-	-	-	-	-
Dairy, livestock, horse ranches	-	-	-	0.163	-	-	-	-	0.163
Industrial	-	-	0.003	0.293	-	-	-	0.003	0.296
Irrigated agriculture	0.000	3.919	0.000	14.924	-	0.056	-	0.000	18.900
Low density residential	0.066	2.568	0.033	20.152	-	0.003	-	0.099	22.822
Non-irrigated agriculture	0.000	0.110	-	0.024	-	-	-	0.000	0.134
Nurseries	-	0.226	-	-	-	-	-	-	0.226
Open and recreation	-	-	-	-	-	-	-	-	-
Orchard, vineyard	0.000	45.000	0.000	188.533	-	0.104	-	0.001	233.637
Parks and recreation	-	-	-	2.128	-	-	-	-	2.128
Road, freeway	0.028	0.454	0.003	4.912	-	0.002	-	0.031	5.399
Transitional	-	-	1.601	1.601	-	-	-	1.601	3.202
Water	-	-	-	-	-	-	-	-	-
Total	0.095	54.930	1.654	249.663	-	1.527	-	1.749	307.869

Table 4.41. Wet weather at-source TN loads (lb/year) by land use category and jurisdiction at SMR-MLS (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	1202.26	1202.26	1202.26
Chaparral, scrub	64.54	679.01	0.21	8456.27	0.21	2461.68	-	64.96	11661.92
Commercial, institutional	21.71	15.25	1942.36	62.76	-	37.08	-	1964.07	2079.17
Forest	1.67	42.86	2.55	171.60	0.08	51.55	-	4.30	270.31
Grassland, herbaceous	3.44	627.21	0.02	74.86	0.29	19.10	-	3.75	724.91
High density residential	3.65	111.36	447.59	10.50	-	0.06	-	451.24	573.15
Dairy, livestock, horse ranches	-	-	-	509.51	-	0.02	-	-	509.53
Industrial	17.67	129.66	1636.33	140.16	-	1.50	-	1654.01	1925.33
Irrigated agriculture	178.26	854.74	0.06	1499.14	-	181.57	-	178.32	2713.77
Low density residential	1617.22	1295.32	14065.20	911.98	0.62	113.48	-	15683.04	18003.82
Non-irrigated agriculture	2.75	12.65	0.00	81.36	-	3.81	-	2.75	100.56
Nurseries	722.40	1654.76	0.02	880.79	-	-	-	722.41	3257.96
Open and recreation	4.95	1.09	1156.37	289.38	-	3.41	-	1161.33	1455.21
Orchard, vineyard	231.99	6795.34	0.05	12601.56	-	2.99	-	232.04	19631.93
Parks and recreation	6.27	0.25	1676.56	1352.61	-	58.98	-	1682.83	3094.66
Road, freeway	175.60	221.91	5718.51	365.65	0.23	11.46	-	5894.34	6493.37
Transitional	1.09	1.09	9052.79	9052.79	-	-	-	9053.88	18107.76
Water	-	-	-	466.16	-	18.66	-	-	484.82
Total	3053.22	12442.50	35698.62	36927.07	1.43	2965.34	1202.26	39955.53	92290.44

Table 4.42. Wet weather at-source TP loads (lb/year) by land use category and jurisdiction at SMR-MLS (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	210.026	210.026	210.026
Chaparral, scrub	2.910	34.461	0.013	637.590	0.006	121.082	-	2.930	796.063
Commercial, institutional	1.866	1.379	401.786	11.626	-	8.706	-	403.652	425.363
Forest	0.219	3.371	0.361	12.376	0.005	2.236	-	0.586	18.569
Grassland, herbaceous	0.160	29.070	0.001	3.337	0.009	0.870	-	0.169	33.447
High density residential	0.148	5.119	67.610	1.408	-	0.002	-	67.758	74.288
Dairy, livestock, horse ranches	-	-	-	17.972	-	0.000	-	-	17.972
Industrial	1.088	6.134	296.553	23.175	-	0.061	-	297.640	327.011
Irrigated agriculture	19.905	39.738	0.002	63.827	-	7.819	-	19.907	131.290
Low density residential	87.107	66.379	1776.684	77.624	0.031	13.670	-	1863.823	2021.495
Non-irrigated agriculture	0.139	0.650	0.000	16.882	-	0.589	-	0.139	18.260
Nurseries	41.984	96.177	0.002	63.457	-	-	-	41.985	201.619
Open and recreation	0.200	0.044	116.938	32.263	-	0.295	-	117.138	149.740
Orchard, vineyard	8.899	251.356	0.002	581.559	-	0.104	-	8.901	841.921
Parks and recreation	0.433	0.033	180.983	153.687	-	5.822	-	181.417	340.959
Road, freeway	10.901	11.605	827.002	20.793	0.010	1.157	-	837.914	871.469
Transitional	0.029	0.029	590.794	590.794	-	-	-	590.823	1181.645
Water	-	-	-	0.709	-	0.006	-	-	0.715
Total	175.988	545.543	4258.731	2309.080	0.062	162.421	210.026	4644.806	7661.851

Table 4.43. Wet weather at-source TN loads (lb/year) by land use category and jurisdiction at De Luz Creek (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	-	-	-
Chaparral, scrub	-	14.83	-	148.14	-	17.88	-	-	180.84
Commercial, institutional	-	-	-	1.14	-	-	-	-	1.14
Forest	-	3.40	-	5.31	-	6.70	-	-	15.42
Grassland, herbaceous	-	0.50	-	35.55	-	0.28	-	-	36.33
High density residential	-	-	-	-	-	-	-	-	-
Dairy, livestock, horse ranches	-	-	-	-	-	-	-	-	-
Industrial	-	-	-	1.39	-	-	-	-	1.39
Irrigated agriculture	-	49.76	-	144.45	-	0.03	-	-	194.24
Low density residential	-	10.34	-	20.59	-	1.02	-	-	31.96
Non-irrigated agriculture	-	0.81	-	-	-	0.06	-	-	0.88
Nurseries	-	4.64	-	-	-	-	-	-	4.64
Open and recreation	-	-	-	-	-	-	-	-	-
Orchard, vineyard	-	105.69	-	2032.30	-	-	-	-	2137.99
Parks and recreation	-	-	-	-	-	-	-	-	-
Road, freeway	-	6.31	-	16.91	-	2.06	-	-	25.28
Transitional	-	-	16.13	16.13	-	-	-	16.13	32.26
Water	-	-	-	-	-	-	-	-	-
Total	-	196.29	16.13	2421.90	-	28.03	-	16.13	2662.35

Table 4.44. Wet weather at-source TP loads (lb/year) by land use category and jurisdiction at De Luz Creek (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	-	-	-
Chaparral, scrub	-	0.548	-	5.058	-	0.548	-	-	6.153
Commercial, institutional	-	-	-	0.042	-	-	-	-	0.042
Forest	-	0.150	-	0.300	-	0.219	-	-	0.669
Grassland, herbaceous	-	0.018	-	1.162	-	0.009	-	-	1.188
High density residential	-	-	-	-	-	-	-	-	-
Dairy, livestock, horse ranches	-	-	-	-	-	-	-	-	-
Industrial	-	-	-	0.054	-	-	-	-	0.054
Irrigated agriculture	-	1.260	-	3.694	-	0.001	-	-	4.955
Low density residential	-	0.420	-	0.880	-	0.038	-	-	1.337
Non-irrigated agriculture	-	0.030	-	-	-	0.002	-	-	0.032
Nurseries	-	0.276	-	-	-	-	-	-	0.276
Open and recreation	-	-	-	-	-	-	-	-	-
Orchard, vineyard	-	3.731	-	70.955	-	-	-	-	74.687
Parks and recreation	-	-	-	-	-	-	-	-	-
Road, freeway	-	0.276	-	0.731	-	0.081	-	-	1.088
Transitional	-	-	0.435	0.435	-	-	-	0.435	0.870
Water	-	-	-	-	-	-	-	-	-
Total	-	6.709	0.435	83.310	-	0.896	-	0.435	91.350

Table 4.45. Wet weather at-source TN loads (lb/year) by land use category and jurisdiction at Old Hospital (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	1202.26	1202.26	1202.26
Chaparral, scrub	64.56	2053.20	0.21	8791.65	1.46	2535.41	-	66.23	13446.50
Commercial, institutional	21.71	21.84	1942.36	63.90	33.11	37.08	-	1997.18	2120.00
Forest	1.69	156.86	2.55	185.78	2.52	67.63	-	6.75	417.02
Grassland, herbaceous	3.47	2143.93	0.02	207.83	3.82	57.73	-	7.30	2416.79
High density residential	4.84	111.36	447.59	10.50	-	0.06	-	452.43	574.35
Dairy, livestock, horse ranches	-	-	-	509.51	-	0.02	-	-	509.53
Industrial	19.75	136.26	1636.33	143.21	8.70	1.50	-	1664.79	1945.76
Irrigated agriculture	178.41	1611.05	0.06	1697.13	-	181.79	-	178.46	3668.44
Low density residential	1728.78	1885.32	14065.20	985.18	37.32	114.98	-	15831.30	18816.78
Non-irrigated agriculture	2.75	30.38	0.00	81.36	-	3.87	-	2.75	118.35
Nurseries	722.45	1825.52	0.02	880.79	-	-	-	722.46	3428.78
Open and recreation	4.95	4.19	1156.37	289.50	-	3.41	-	1161.33	1458.42
Orchard, vineyard	232.49	9829.59	0.05	15083.34	-	6.82	-	232.54	25152.29
Parks and recreation	6.27	3.89	1676.56	1352.63	-	58.98	-	1682.83	3098.32
Road, freeway	186.72	386.24	5718.51	448.03	15.11	14.37	-	5920.34	6768.98
Transitional	3.85	3.85	9078.91	9078.91	-	-	-	9082.76	18165.53
Water	-	114.11	-	466.16	-	18.66	-	-	598.92
Total	3182.68	20317.60	35724.75	40275.40	102.04	3102.30	1202.26	40211.72	103907.02

Table 4.46. Wet weather at-source TP loads (lb/year) by land use category and jurisdiction at Old Hospital (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	210.026	210.026	210.026
Chaparral, scrub	2.911	88.032	0.013	648.904	0.072	123.398	-	2.996	863.330
Commercial, institutional	1.866	1.968	401.786	11.668	4.171	8.706	-	407.823	430.165
Forest	0.221	11.893	0.361	13.470	0.314	2.770	-	0.896	29.029
Grassland, herbaceous	0.161	94.042	0.001	7.603	0.138	2.095	-	0.299	104.040
High density residential	0.196	5.119	67.610	1.408	-	0.002	-	67.806	74.336
Dairy, livestock, horse ranches	-	-	-	17.972	-	0.000	-	-	17.972
Industrial	1.200	6.430	296.553	23.389	1.109	0.061	-	298.862	328.742
Irrigated agriculture	19.913	59.494	0.002	68.906	-	7.824	-	19.914	156.138
Low density residential	93.890	94.705	1776.684	80.802	4.036	13.725	-	1874.611	2063.843
Non-irrigated agriculture	0.139	1.321	0.000	16.882	-	0.591	-	0.139	18.933
Nurseries	41.987	106.373	0.002	63.457	-	-	-	41.988	211.819
Open and recreation	0.200	0.151	116.938	32.267	-	0.295	-	117.138	149.851
Orchard, vineyard	8.918	358.127	0.002	668.312	-	0.238	-	8.919	1035.596
Parks and recreation	0.433	0.192	180.983	153.690	-	5.822	-	181.417	341.120
Road, freeway	11.590	19.163	827.002	24.433	1.458	1.269	-	840.050	884.915
Transitional	0.102	0.102	591.496	591.496	-	-	-	591.598	1183.197
Water	-	0.000	-	0.709	-	0.006	-	-	0.715
Total	183.726	847.113	4259.433	2425.368	11.298	166.803	210.026	4664.483	8103.768

Table 4.47. Summary table: wet weather existing and target at-source loads and percent reductions for controllable sources with 10 percent margin of safety.

Site	TN				TP			
	Existing total at-source load (lb/yr)	Existing load after upstream reductions (lb/yr)	Total at-source loading targets (lb/yr)	Percent reduction for controllable sources within the remaining drainage area	Existing total at-source load (lb/yr)	Existing load after upstream reductions (lb/yr)	Total at-source loading targets (lb/yr)	Percent reduction for controllable sources within the remaining drainage area
Devils Creek	1024	1024	291	78%	39	39	29	28%
MWD2	66372	65639	26861	69%	6529	6519	1947	79%
Rainbow Creek	9365	9365	4792	57%	486	486	486	0%
Sandia Creek	8467	8467	1875	83%	308	308	308	0%
SMR-MLS	92290	41614	48219	0%	7662	3079	6612	0%
De Luz Creek	2662	2662	578	86%	91	91	91	0%
Old Hospital	103907	51147	46058	15%	8104	3521	3282	9%

Note: The values in this table are rounded; unrounded values were used in calculations.

Table 4.48. Wet weather at-source TN allocations (lb/year) by land use category and jurisdiction at Devils Creek with 10 percent margin of safety (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	-	-	-
Chaparral, scrub	-	-	0.00	52.67	-	-	-	0.00	52.67
Commercial, institutional	-	-	-	0.11	-	-	-	-	0.11
Forest	-	-	0.00	6.30	-	-	-	0.00	6.30
Grassland, herbaceous	-	-	-	26.67	-	-	-	-	26.67
High density residential	-	-	-	-	-	-	-	-	-
Dairy, livestock, horse ranches	-	-	-	-	-	-	-	-	-
Industrial	-	-	-	-	-	-	-	-	-
Irrigated agriculture	-	-	-	14.78	-	-	-	-	14.78
Low density residential	-	-	0.05	9.50	-	-	-	0.05	9.55
Non-irrigated agriculture	-	-	-	-	-	-	-	-	-
Nurseries	-	-	-	-	-	-	-	-	-
Open and recreation	-	-	-	-	-	-	-	-	-
Orchard, vineyard	-	-	-	174.84	-	-	-	-	174.84
Parks and recreation	-	-	-	-	-	-	-	-	-
Road, freeway	-	-	0.00	4.90	-	-	-	0.00	4.90
Transitional	-	-	0.55	0.55	-	-	-	0.55	1.09
Water	-	-	-	-	-	-	-	-	-
Total	-	-	0.60	290.32	-	-	-	0.60	290.92

Table 4.49. Wet weather at-source TP allocations (lb/year) by land use category and jurisdiction at Devils Creek with 10 percent margin of safety (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	-	-	-
Chaparral, scrub	-	-	0.000	2.058	-	-	-	0.000	2.058
Commercial, institutional	-	-	-	0.040	-	-	-	-	0.040
Forest	-	-	0.000	0.647	-	-	-	0.000	0.647
Grassland, herbaceous	-	-	-	1.070	-	-	-	-	1.070
High density residential	-	-	-	-	-	-	-	-	-
Dairy, livestock, horse ranches	-	-	-	-	-	-	-	-	-
Industrial	-	-	-	-	-	-	-	-	-
Irrigated agriculture	-	-	-	1.413	-	-	-	-	1.413
Low density residential	-	-	0.014	2.101	-	-	-	0.014	2.115
Non-irrigated agriculture	-	-	-	-	-	-	-	-	-
Nurseries	-	-	-	-	-	-	-	-	-
Open and recreation	-	-	-	-	-	-	-	-	-
Orchard, vineyard	-	-	-	20.780	-	-	-	-	20.780
Parks and recreation	-	-	-	-	-	-	-	-	-
Road, freeway	-	-	0.000	0.749	-	-	-	0.000	0.749
Transitional	-	-	0.048	0.048	-	-	-	0.048	0.097
Water	-	-	-	-	-	-	-	-	-
Total	-	-	0.063	28.906	-	-	-	0.063	28.969

Table 4.50. Wet weather at-source allocations for TN loads (lb/year) by land use category and jurisdiction at MWD2 with 10 percent margin of safety (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	252.59	252.59	252.59
Chaparral, scrub	-	7.67	0.12	7116.05	-	2035.70	-	0.12	9159.54
Commercial, institutional	-	-	588.14	15.18	-	11.34	-	588.14	614.66
Forest	-	0.01	0.11	62.49	-	12.66	-	0.11	75.28
Grassland, herbaceous	-	-	0.00	46.77	-	0.10	-	0.00	46.87
High density residential	-	-	136.95	3.21	-	-	-	136.95	140.16
Dairy, livestock, horse ranches	-	-	-	151.97	-	0.01	-	-	151.98
Industrial	-	-	492.79	40.54	-	-	-	492.79	533.33
Irrigated agriculture	-	-	0.02	274.20	-	54.55	-	0.02	328.76
Low density residential	-	-	4284.19	146.53	-	34.33	-	4284.19	4465.05
Non-irrigated agriculture	-	-	-	24.72	-	1.17	-	-	25.88
Nurseries	-	-	0.01	269.49	-	-	-	0.01	269.49
Open and recreation	-	-	353.81	88.54	-	1.04	-	353.81	443.39
Orchard, vineyard	-	-	0.01	1633.98	-	-	-	0.01	1633.99
Parks and recreation	-	-	512.96	398.89	-	18.05	-	512.96	929.89
Road, freeway	-	0.01	1743.60	58.07	-	2.77	-	1743.60	1804.45
Transitional	-	-	2750.58	2750.58	-	-	-	2750.58	5501.16
Water	-	-	-	466.16	-	18.66	-	-	484.82
Total	-	7.69	10863.29	13547.35	-	2190.37	252.59	11115.88	26861.29

Table 4.51. Wet weather at-source allocations for TP loads (lb/year) by land use category and jurisdiction at MWD2 with 10 percent margin of safety (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	38.024	38.024	38.024
Chaparral, scrub	-	0.265	0.008	586.427	-	103.624	-	0.008	690.325
Commercial, institutional	-	-	85.658	2.185	-	1.866	-	85.658	89.709
Forest	-	0.001	0.014	4.881	-	0.587	-	0.014	5.482
Grassland, herbaceous	-	-	0.000	2.295	-	0.007	-	0.000	2.302
High density residential	-	-	14.493	0.302	-	-	-	14.493	14.795
Dairy, livestock, horse ranches	-	-	-	3.817	-	0.000	-	-	3.818
Industrial	-	-	63.148	4.843	-	-	-	63.148	67.991
Irrigated agriculture	-	-	0.000	9.772	-	1.661	-	0.000	11.434
Low density residential	-	-	379.954	11.447	-	2.916	-	379.954	394.317
Non-irrigated agriculture	-	-	-	3.614	-	0.126	-	-	3.740
Nurseries	-	-	0.000	13.603	-	-	-	0.000	13.603
Open and recreation	-	-	25.067	6.916	-	0.063	-	25.067	32.046
Orchard, vineyard	-	-	0.000	73.113	-	-	-	0.000	73.114
Parks and recreation	-	-	38.796	32.489	-	1.248	-	38.796	72.533
Road, freeway	-	0.000	177.032	2.731	-	0.223	-	177.032	179.986
Transitional	-	-	126.288	126.288	-	-	-	126.288	252.576
Water	-	-	-	0.709	-	0.006	-	-	0.715
Total	-	0.266	910.460	885.432	-	112.328	38.024	948.484	1946.510

Table 4.52. Wet weather at-source allocations for TN loads (lb/year) by land use category and jurisdiction at Rainbow Creek with 10 percent margin of safety (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	163.05	163.05	163.05
Chaparral, scrub	63.10	393.42	0.11	192.72	-	252.27	-	63.21	901.62
Commercial, institutional	7.29	5.90	8.71	0.02	-	0.00	-	15.99	21.91
Forest	1.54	14.32	2.44	12.00	-	26.53	-	3.98	56.82
Grassland, herbaceous	2.86	316.44	0.02	7.57	-	17.13	-	2.88	344.01
High density residential	-	48.19	-	-	-	0.02	-	-	48.21
Dairy, livestock, horse ranches	-	-	-	-	-	-	-	-	-
Industrial	5.44	56.11	11.17	0.03	-	0.65	-	16.61	73.40
Irrigated agriculture	76.17	190.87	0.00	0.33	-	0.24	-	76.17	267.61
Low density residential	65.14	512.59	27.00	0.13	-	0.51	-	92.14	605.37
Non-irrigated agriculture	1.18	2.64	0.00	0.00	-	-	-	1.18	3.82
Nurseries	312.45	667.55	-	-	-	-	-	312.45	980.00
Open and recreation	-	-	-	-	-	-	-	-	-
Orchard, vineyard	91.70	1111.22	-	-	-	-	-	91.70	1202.92
Parks and recreation	2.65	0.02	-	-	-	-	-	2.65	2.68
Road, freeway	24.42	82.75	8.57	0.02	-	1.04	-	32.99	116.81
Transitional	0.47	0.47	1.61	1.61	-	-	-	2.08	4.16
Water	-	-	-	-	-	-	-	-	-
Total	654.43	3402.49	59.61	214.42	-	298.39	163.05	877.09	4792.39

Table 4.53. Wet weather at-source allocations for TP loads (lb/year) by land use category and jurisdiction at Rainbow Creek with 10 percent margin of safety (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	32.644	32.644	32.644
Chaparral, scrub	2.848	21.426	0.006	8.171	-	10.761	-	2.854	43.212
Commercial, institutional	1.361	1.193	2.194	0.003	-	0.001	-	3.555	4.751
Forest	0.202	1.149	0.347	0.580	-	1.196	-	0.548	3.474
Grassland, herbaceous	0.132	14.993	0.001	0.331	-	0.806	-	0.132	16.261
High density residential	-	5.117	-	-	-	0.002	-	-	5.120
Dairy, livestock, horse ranches	-	-	-	-	-	-	-	-	-
Industrial	0.731	6.133	1.981	0.004	-	0.061	-	2.712	8.910
Irrigated agriculture	19.773	25.363	0.000	0.020	-	0.012	-	19.773	45.168
Low density residential	8.765	61.022	4.178	0.017	-	0.064	-	12.943	74.046
Non-irrigated agriculture	0.138	0.362	0.000	0.000	-	-	-	0.138	0.500
Nurseries	41.951	89.631	-	-	-	-	-	41.951	131.582
Open and recreation	-	-	-	-	-	-	-	-	-
Orchard, vineyard	8.149	96.238	-	-	-	-	-	8.149	104.387
Parks and recreation	0.414	0.003	-	-	-	-	-	0.414	0.417
Road, freeway	3.980	10.281	1.156	0.003	-	0.117	-	5.136	15.536
Transitional	0.029	0.029	0.098	0.098	-	-	-	0.127	0.254
Water	-	-	-	-	-	-	-	-	-
Total	88.471	332.939	9.960	9.227	-	13.020	32.644	131.075	486.261

Table 4.54. Wet weather at-source allocations for TN loads (lb/year) by land use category and jurisdiction at Sandia Creek with 10 percent margin of safety (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	-	-	-
Chaparral, scrub	0.00	66.16	0.01	323.31	-	35.28	-	0.01	424.76
Commercial, institutional	-	-	-	1.23	-	-	-	-	1.23
Forest	0.00	8.31	0.11	50.12	-	7.49	-	0.11	66.03
Grassland, herbaceous	0.01	6.56	0.00	7.95	-	1.84	-	0.01	16.36
High density residential	-	-	-	-	-	-	-	-	-
Dairy, livestock, horse ranches	-	-	-	2.20	-	-	-	-	2.20
Industrial	-	-	0.01	0.63	-	-	-	0.01	0.64
Irrigated agriculture	0.00	26.08	0.00	74.71	-	0.47	-	0.00	101.26
Low density residential	0.21	10.10	0.06	58.91	-	0.01	-	0.27	69.30
Non-irrigated agriculture	0.00	0.54	-	0.10	-	-	-	0.00	0.64
Nurseries	-	0.65	-	-	-	-	-	-	0.65
Open and recreation	-	-	-	-	-	-	-	-	-
Orchard, vineyard	0.00	219.60	0.00	925.90	-	0.51	-	0.00	1146.02
Parks and recreation	-	-	-	8.40	-	-	-	-	8.40
Road, freeway	0.13	2.00	0.01	15.09	-	0.01	-	0.14	17.24
Transitional	-	-	10.16	10.16	-	-	-	10.16	20.32
Water	-	-	-	-	-	-	-	-	-
Total	0.35	340.01	10.35	1478.73	-	45.62	-	10.70	1875.06

Table 4.55. Wet weather at-source allocations for TP loads (lb/year) by land use category and jurisdiction at Sandia Creek with 10 percent margin of safety (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	-	-	-
Chaparral, scrub	0.000	2.062	0.000	10.489	-	1.072	-	0.000	13.622
Commercial, institutional	-	-	-	0.777	-	-	-	-	0.777
Forest	0.000	0.384	0.013	5.383	-	0.233	-	0.013	6.013
Grassland, herbaceous	0.000	0.207	0.000	0.286	-	0.057	-	0.000	0.549
High density residential	-	-	-	-	-	-	-	-	-
Dairy, livestock, horse ranches	-	-	-	0.163	-	-	-	-	0.163
Industrial	-	-	0.003	0.293	-	-	-	0.003	0.296
Irrigated agriculture	0.000	3.919	0.000	14.924	-	0.056	-	0.000	18.900
Low density residential	0.066	2.568	0.033	20.152	-	0.003	-	0.099	22.822
Non-irrigated agriculture	0.000	0.110	-	0.024	-	-	-	0.000	0.134
Nurseries	-	0.226	-	-	-	-	-	-	0.226
Open and recreation	-	-	-	-	-	-	-	-	-
Orchard, vineyard	0.000	45.000	0.000	188.533	-	0.104	-	0.001	233.637
Parks and recreation	-	-	-	2.128	-	-	-	-	2.128
Road, freeway	0.028	0.454	0.003	4.912	-	0.002	-	0.031	5.399
Transitional	-	-	1.601	1.601	-	-	-	1.601	3.202
Water	-	-	-	-	-	-	-	-	-
Total	0.095	54.930	1.654	249.663	-	1.527	-	1.749	307.869

Table 4.56. Wet weather at-source allocations for TN loads (lb/year) by land use category and jurisdiction at SMR-MLS with 10 percent margin of safety (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	415.64	415.64	415.64
Chaparral, scrub	64.54	679.01	0.21	8456.27	0.21	2461.68	-	64.96	11661.92
Commercial, institutional	12.16	7.53	596.84	21.99	-	11.35	-	609.00	649.86
Forest	1.67	42.86	2.55	171.60	0.08	51.55	-	4.30	270.31
Grassland, herbaceous	3.44	627.21	0.02	74.86	0.29	19.10	-	3.75	724.91
High density residential	3.65	48.23	136.95	3.21	-	0.02	-	140.59	192.06
Dairy, livestock, horse ranches	-	-	-	154.17	-	0.01	-	-	154.18
Industrial	10.55	56.14	503.84	45.11	-	0.65	-	514.39	616.28
Irrigated agriculture	78.46	478.96	0.02	463.86	-	55.26	-	78.48	1076.55
Low density residential	1530.86	574.99	4311.17	261.59	0.62	34.86	-	5842.65	6714.09
Non-irrigated agriculture	1.20	6.57	0.00	24.82	-	1.17	-	1.20	33.75
Nurseries	313.00	776.93	0.01	269.49	-	-	-	313.01	1359.43
Open and recreation	4.95	1.09	353.81	88.54	-	1.04	-	358.76	449.43
Orchard, vineyard	111.84	4280.99	0.01	3808.20	-	0.51	-	111.84	8201.55
Parks and recreation	2.79	0.23	512.96	407.29	-	18.05	-	515.75	941.31
Road, freeway	142.97	103.80	1752.11	143.69	0.23	3.79	-	1895.32	2146.59
Transitional	0.47	0.47	2760.40	2760.40	-	-	-	2760.88	5521.75
Water	-	-	-	466.16	-	18.66	-	-	484.82
Total	2282.55	7685.00	10930.89	17621.24	1.43	2677.69	415.64	13630.51	41614.44

Table 4.57. Wet weather at-source allocations for TP loads (lb/year) by land use category and jurisdiction at SMR-MLS with 10 percent margin of safety (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	70.668	70.668	70.668
Chaparral, scrub	2.910	34.461	0.013	637.590	0.006	121.082	-	2.930	796.063
Commercial, institutional	1.866	1.379	87.852	3.602	-	1.867	-	89.718	96.566
Forest	0.219	3.371	0.361	12.376	0.005	2.236	-	0.586	18.569
Grassland, herbaceous	0.160	29.070	0.001	3.337	0.009	0.870	-	0.169	33.447
High density residential	0.148	5.119	14.493	0.302	-	0.002	-	14.641	20.064
Dairy, livestock, horse ranches	-	-	-	3.981	-	0.000	-	-	3.981
Industrial	1.088	6.134	65.119	5.425	-	0.061	-	66.206	77.827
Irrigated agriculture	19.905	39.738	0.000	27.453	-	1.730	-	19.906	88.827
Low density residential	87.107	66.379	384.161	34.841	0.031	2.983	-	471.299	575.502
Non-irrigated agriculture	0.139	0.650	0.000	3.638	-	0.126	-	0.139	4.553
Nurseries	41.984	96.177	0.000	13.603	-	-	-	41.984	151.763
Open and recreation	0.200	0.044	25.067	6.916	-	0.063	-	25.267	32.290
Orchard, vineyard	8.899	251.356	0.000	305.384	-	0.104	-	8.900	565.744
Parks and recreation	0.433	0.033	38.796	34.617	-	1.248	-	39.230	75.127
Road, freeway	10.901	11.603	178.186	10.489	0.010	0.340	-	189.098	211.531
Transitional	0.029	0.029	127.934	127.934	-	-	-	127.963	255.927
Water	-	-	-	0.709	-	0.006	-	-	0.715
Total	175.988	545.542	921.985	1232.199	0.062	132.720	70.668	1168.703	3079.164

Table 4.58. Wet weather at-source allocations for TN loads (lb/year) by land use category and jurisdiction at De Luz Creek with 10 percent margin of safety (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	-	-	-
Chaparral, scrub	-	14.83	-	148.14	-	17.88	-	-	180.84
Commercial, institutional	-	-	-	0.16	-	-	-	-	0.16
Forest	-	3.40	-	5.31	-	6.70	-	-	15.42
Grassland, herbaceous	-	0.50	-	35.55	-	0.28	-	-	36.33
High density residential	-	-	-	-	-	-	-	-	-
Dairy, livestock, horse ranches	-	-	-	-	-	-	-	-	-
Industrial	-	-	-	0.20	-	-	-	-	0.20
Irrigated agriculture	-	7.08	-	20.54	-	0.00	-	-	27.62
Low density residential	-	1.47	-	2.93	-	0.14	-	-	4.54
Non-irrigated agriculture	-	0.12	-	-	-	0.01	-	-	0.12
Nurseries	-	0.66	-	-	-	-	-	-	0.66
Open and recreation	-	-	-	-	-	-	-	-	-
Orchard, vineyard	-	15.03	-	288.99	-	-	-	-	304.02
Parks and recreation	-	-	-	-	-	-	-	-	-
Road, freeway	-	0.90	-	2.40	-	0.29	-	-	3.59
Transitional	-	-	2.29	2.29	-	-	-	2.29	4.59
Water	-	-	-	-	-	-	-	-	-
Total	-	43.99	2.29	506.51	-	25.31	-	2.29	578.10

Table 4.59. Wet weather at-source allocations for TP loads (lb/year) by land use category and jurisdiction at De Luz Creek with 10 percent margin of safety (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	-	-	-
Chaparral, scrub	-	0.548	-	5.058	-	0.548	-	-	6.153
Commercial, institutional	-	-	-	0.042	-	-	-	-	0.042
Forest	-	0.150	-	0.300	-	0.219	-	-	0.669
Grassland, herbaceous	-	0.018	-	1.162	-	0.009	-	-	1.188
High density residential	-	-	-	-	-	-	-	-	-
Dairy, livestock, horse ranches	-	-	-	-	-	-	-	-	-
Industrial	-	-	-	0.054	-	-	-	-	0.054
Irrigated agriculture	-	1.260	-	3.694	-	0.001	-	-	4.955
Low density residential	-	0.420	-	0.880	-	0.038	-	-	1.337
Non-irrigated agriculture	-	0.030	-	-	-	0.002	-	-	0.032
Nurseries	-	0.276	-	-	-	-	-	-	0.276
Open and recreation	-	-	-	-	-	-	-	-	-
Orchard, vineyard	-	3.731	-	70.955	-	-	-	-	74.687
Parks and recreation	-	-	-	-	-	-	-	-	-
Road, freeway	-	0.276	-	0.731	-	0.081	-	-	1.088
Transitional	-	-	0.435	0.435	-	-	-	0.435	0.870
Water	-	-	-	-	-	-	-	-	-
Total	-	6.709	0.435	83.310	-	0.896	-	0.435	91.350

Table 4.60. Wet weather at-source allocations for TN loads (lb/year) by land use category and jurisdiction at Old Hospital with 10 percent margin of safety (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	353.92	353.92	353.92
Chaparral, scrub	64.56	2053.20	0.21	8791.65	1.46	2535.41	-	66.23	13446.50
Commercial, institutional	10.35	12.02	508.21	18.86	28.19	9.66	-	546.75	587.30
Forest	1.69	156.86	2.55	185.78	2.52	67.63	-	6.75	417.02
Grassland, herbaceous	3.47	2143.93	0.02	207.83	3.82	57.73	-	7.30	2416.79
High density residential	4.12	41.07	116.61	2.73	-	0.02	-	120.73	164.55
Dairy, livestock, horse ranches	-	-	-	131.28	-	0.01	-	-	131.28
Industrial	10.75	53.42	429.02	39.99	7.41	0.55	-	447.18	541.14
Irrigated agriculture	66.93	1015.47	0.02	458.05	-	47.22	-	66.94	1587.69
Low density residential	1398.50	984.43	3670.93	270.03	31.78	30.22	-	5101.21	6385.89
Non-irrigated agriculture	1.02	20.10	0.00	21.13	-	1.00	-	1.02	43.25
Nurseries	266.56	803.57	0.00	229.47	-	-	-	266.57	1299.60
Open and recreation	4.22	3.56	301.26	75.50	-	0.89	-	305.48	385.43
Orchard, vineyard	95.65	6151.68	0.01	3871.46	-	3.70	-	95.66	10122.49
Parks and recreation	2.37	3.29	436.79	346.82	-	15.37	-	439.16	804.63
Road, freeway	131.21	223.71	1491.91	180.14	12.86	4.19	-	1635.98	2044.03
Transitional	2.76	2.76	2360.92	2360.92	-	-	-	2363.68	4727.36
Water	-	114.11	-	466.16	-	18.66	-	-	598.92
Total	2064.17	13783.16	9318.45	17657.81	88.04	2792.25	353.92	11824.57	46057.79

Table 4.61. Wet weather at-source allocations for TP loads (lb/year) by land use category and jurisdiction at Old Hospital with 10 percent margin of safety (WY 2009-2018).

Land Use Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		Other CALTRANS	SMR Watershed	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
CALTRANS	-	-	-	-	-	-	63.968	63.968	63.968
Chaparral, scrub	2.911	88.032	0.013	648.904	0.072	123.398	-	2.996	863.330
Commercial, institutional	1.689	1.781	79.523	3.299	3.776	1.690	-	84.988	91.758
Forest	0.221	11.893	0.361	13.470	0.314	2.770	-	0.896	29.029
Grassland, herbaceous	0.161	94.042	0.001	7.603	0.138	2.095	-	0.299	104.040
High density residential	0.178	4.634	13.119	0.273	-	0.002	-	13.297	18.206
Dairy, livestock, horse ranches	-	-	-	3.603	-	0.000	-	-	3.603
Industrial	1.087	5.820	58.945	5.104	1.004	0.055	-	61.036	72.016
Irrigated agriculture	18.025	53.854	0.000	29.448	-	1.570	-	18.025	102.897
Low density residential	84.989	85.727	347.741	34.415	3.653	2.750	-	436.384	559.276
Non-irrigated agriculture	0.125	1.196	0.000	3.293	-	0.116	-	0.126	4.731
Nurseries	38.006	96.289	0.000	12.313	-	-	-	38.007	146.608
Open and recreation	0.181	0.137	22.691	6.264	-	0.057	-	22.872	29.330
Orchard, vineyard	8.072	324.176	0.000	354.961	-	0.215	-	8.073	687.424
Parks and recreation	0.392	0.173	35.118	31.337	-	1.130	-	35.510	68.151
Road, freeway	10.491	17.345	161.294	12.790	1.320	0.409	-	173.105	203.649
Transitional	0.093	0.093	116.441	116.441	-	-	-	116.534	233.068
Water	-	0.000	-	0.709	-	0.006	-	-	0.715
Total	166.621	785.191	835.249	1284.229	10.277	136.265	63.968	1076.115	3281.800

5. References Cited

Abatzoglou, J.T. and T.J. Brown. 2012. A comparison of statistical downscaling methods suited for wildfire applications. International Journal of Climatology, 32: 772-780, doi:10.1002/joc.2312.

Alduchov, O. and R. Eskridge. 1997. Improved Magnus' Form Approximation of Saturation Vapor Pressure, NOAA, doi:10.2172/548871.

Alexander, R.B., R.A. Smith, and G.E. Schwarz. 2000. Effect of stream channel size on the delivery of nitrogen to the Gulf of Mexico. Nature, 403.6771:758.

Baker, M.E. and R.S. King. 2010. A new method for detecting and interpreting biodiversity and ecological community thresholds. Methods in Ecology and Evolution 1, 25–37. https://doi.org/10.1111/j.2041-210X.2009.00007.x

Bicknell, B.R., J.C. Imhoff, J.L. Kittle, Jr., T.H. Jobes, P.B. Duda, and A.S. Donigian, Jr. 2014. HSPF Version 12.4 User's Manual. National Exposure Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Athens, GA.

Biggs, B.J.F. 2000. Eutrophication of streams and rivers: dissolved nutrient-chlorophyll relationships for benthic algae. Journal of the North American Benthological Society 19.1:17-31.

Black, R.W., P.W. Moran, and J.D. Frankforter, J.D., 2011. Response of algal metrics to nutrients and physical factors and identification of nutrient thresholds in agricultural streams. Environ Monit Assess 175, 397–417. https://doi.org/10.1007/s10661-010-1539-8

Brattstrom, B.H. and J.W. Warren. 1955. Observations on the ecology and behavior of the Pacific treefrog, Hyla regilla. Copeia, 1955(3), pp.181-191.

Brown, H.A. 1975. Embryonic temperature adaptations of the Pacific treefrog, Hyla regilla. Comparative Biochemistry and Physiology Part A: Physiology, 51(4), pp.863-873.

California State Water Resources Control Board (SWRCB). 2005. A process for addressing impaired waters in California. State of California S.B. 469 TMDL Guidance. Sacramento, CA.

Carleton, J.N., R.A. Park, and J.S. Clough. 2009. Ecosystem Modeling Applied to Nutrient Criteria Development in Rivers. Environmental Management 44, 485–492. https://doi.org/10.1007/s00267-009-9344-2

Carlisle, D.M., T.E. Grantham, K. Eng, and D.M. Wolock. 2017. Biological relevance of streamflow metrics: Regional and national perspectives. Freshwater Sci. 2017; 36(4):927–40.

Carveth, C.J., A.M. Widmer, and S.A. Bonar. 2006. Comparison of upper thermal tolerances of native and nonnative fish species in Arizona. Transactions of the American Fisheries Society, 135(6), pp.1433-1440.

Caskey, B.J., A.R. Bunch, M.E. Shoda, J.W. Frey, S. Selvaratnam, and R.J. Miltner. 2013. Identifying Nutrient Reference Sites in Nutrient-Enriched Regions: Using Algal, Invertebrate, and Fish-Community Measures to Identify Stressor-Breakpoint Thresholds in Indiana Rivers and

Streams, 2005-9 (No. Geological Survey Scientific Investigations Report 2012–5243).

Cayan, D., M. Tyree, K. E. Kunkel, C. Castro, A. Gershunov, J. Barsugli, A. J. Ray, J. Overpeck, M. Anderson, J. Russell, B. Rajagopalan, I. Rangwala, and P. Duffy. 2013. “Future Climate: Projected Average.” In Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment, edited by G. Garfin, A. Jardine, R. Merideth, M. Black, and S. LeRoy, 101–125. A report by the Southwest Climate Alliance. Washington, DC: Island Press.

Cech Jr, J.J. and C.A. Myrick. 1999. Steelhead and Chinook salmon bioenergetics: temperature, ration, and genetic effects.

Cuffney, T.F., R.A. Brightbill, J.T. May, and I.R. Waite. 2010. Responses of benthic macroinvertebrates to environmental changes associated with urbanization in nine metropolitan areas. Ecological Applications 20:1384-1401.

Cunningham, J.D. and D.P. Mullally. 1956. Thermal factors in the ecology of the Pacific treefrog. Herpetologica, 12(1), pp.68-79.

Davis, R.F. 1997. Comparison of modeled to observed global irradiance. Journal of Applied Meteorology, 35: 192-201.

Dodds, W.K. 2007. Trophic state, eutrophication, and nutrient criteria in streams. Trends in Ecology & Evolution 22, 669–676. https://doi.org/10.1016/j.tree.2007.07.010

Dodds, W.K., J.R. Jones, and E.B. Welch. 1998. Suggested classification of stream trophic state: distributions of temperate stream types by chlorophyll, total nitrogen, and phosphorus. Water Research 32, 1455–1462. https://doi.org/10.1016/S0043-1354(97)00370-9

Duffy, J.E. 2009. Why biodiversity is important to the functioning of real-world ecosystems. Frontiers in Ecology and the Environment, 7: 437-444. https://doi.org/10.1890/070195

Duffy, J.E., B.J. Cardinale, K.E. France, P.B. McIntyre, E. Thébault, and M. Loreau. 2007. The functional role of biodiversity in ecosystems: incorporating trophic complexity. Ecology letters 10.6:522-538.

Evans-White, M.A., W.K. Dodds, D.G. Huggins, and D.S. Baker. 2009. Thresholds in macroinvertebrate biodiversity and stoichiometry across water-quality gradients in Central Plains (USA) streams. Journal of the North American Benthological Society 28, 855–868. https://doi.org/10.1899/08-113.1

Fetscher, A.E., L. Busse, and P. Ode. 2009. Standard Operating Procedures for Collecting Stream Algae Samples and Associated Physical Habitat and Chemical Data for Ambient Bioassessments in California (No. Bioassessment SOP 002). California State Water Resources Control Board Surface Water Ambient Monitoring Program (SWAMP).

Fetscher, A.E., M. Sutula, A. Sengupta, and N. Detenbeck. 2014. Linking nutrients to alterations in aquatic life in California wadeable streams. EPA/600/R-14/043. US

Fetscher, A.E., M.A. Sutula, L.B. Busse, and E.D. Stein. 2013. Condition of California perennial, wadeable streams based on algal indicators. California

Fovet, O., G. Belaud, X. Litrico, S. Charpentier, C. Bertrand, P. Dollet, C. Hugodot. 2012. A model for fixed algae management in open channels using flushing flows. River Research and Applications 28:960–972.

Gasith A. and V. Resh. 1999. Streams in Mediterranean Climate Regions: Abiotic Influences and Biotic Responses to Predictable Seasonal Events Annual Review of Ecology and Systematics 1999 30:1, 51-81

Gershunov, A., T. Shulgina, R.E.S. Clemesha, K. Guirguis, D.W. Pierce, M.D. Dettinger, D.A. Lavers, D.R. Cayan, S.D. Polade, J. Kalansky, and F. Martin Ralph. 2019. Precipitation regime change in Western North America: The role of Atmospheric Rivers. Sci Rep 9, 9944. https://doi.org/10.1038/s41598-019-46169-w

Gillett D., R. Mazor, M. Sutula, and A. Holt. In Prep. Reach-scale models show heterogeneity of stream benthic invertebrate response to eutrophication stress. In prep for submission to Freshwater Science.

Gillett D., R. Mazor, and S. Norton. 2019. Selecting comparator sites for ecological causal assessment based on expected biological similarity. Freshwater Science. 38. 000-000. 10.1086/704926.

Grimm, N.B., F.S. Chapin III, B. Bierwagen, P. Gonzalez, P.M. Groffman, Y. Luo, F. Melton, K. Nadelhoffer, A. Pairis, P.A. Raymond, J. Schimel, and C.E. Williamson. 2013. The impacts of climate change on ecosystem structure and function. Frontiers in Ecology and the Environment, 11: 474-482. https://doi.org/10.1890/120282

Hamon, R.W., L.L. Weiss, and W.T. Wilson. 1954. Insolation as an empirical function of daily sunshine duration. Monthly Weather Review, 82(6):141-146.

Heiskary, S.A. and R.W. Bouchard Jr. 2015. Development of eutrophication criteria for Minnesota streams and rivers using multiple lines of evidence. Freshwater Science 34.2:574-592.

Ings, T.C., J.M. Montoya, J. Bascompte, N. Blüthgen, L. Brown, C.F. Dormann, F. Edwards, D. Figueroa, U. Jacob, J.I. Jones, R.B. Lauridsen, M.E. Ledger, H.M. Lewis, J.M. Olesen, F.J. Frank van Veen, P.H. Warren, and G. Woodward. 2009. Ecological networks: beyond food webs. J. Anim. Ecol. 78, 253–269 (doi:10.1111/j.1365-2656.2008.01460.x)

IPCC. 2014. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 688.

Irving, K., K. Taniguchi-Chan, D. Shultz, R. Mazor, F. De Santos, M. Sutula, J. Butcher, M. Schmidt, and C. Boschen. Effects of climate change on thermal habitat and flow ecology of a

Mediterranean stream ecosystem, U.S.A. in prep for Submission to Freshwater Science.

Jakus, P.M., N. Nelson, and J. Ostermiller. 2017. Using Survey Data to Determine a Numeric Criterion for Nutrient Pollution. Water Resources Research 53, 10188–10200. https://doi.org/10.1002/2017WR021527

Jennings, M.K., D. Cayan, J. Kalansky, A.D. Pairis, D.M. Lawson, A.D. Syphard, U. Abeysekera, R.E.S. Clemesha, A. Gershunov, K. Guirguis, J.M. Randall, E.D. Stein, and S. Vanderplank. (San Diego State University). 2018. San Diego County ecosystems: ecological impacts of climate change on a biodiversity hotspot. California’s Fourth Climate Change Assessment, California Energy Commission. Publication number: CCCA4-EXT-2018-010

Jessup, B. 2015. New Mexico Nutrient Thresholds for Perennial Wadeable Streams (Final Report). Tetra Tech, New Mexico Environment Department and U.S. EPA Region 6 and the N-STEPS Program.

Lee, R.M. and J.N. Rinne. 1980. Critical thermal maxima of five trout species in the southwestern United States. Transactions of the American Fisheries Society, 109(6), pp.632-635.

Lembi, C.A. 2003. Control of nuisance algae. In: Wehr, J.D., Sheath, R.G. (eds). Freshwater Algae of North America Ecology and Classification pp. 805-834. Academic Press, New York.

Lemm, J.U., M. Venohr, L. Globevnik, K. Stefanidis, Y. Panagopoulos, J. van Gils, L. Posthuma, P. Kristensen, C.K. Feld, J. Mahnkopf, D. Hering, and S. Birk. 2021. Multiple stressors determine river ecological status at the European scale: Towards an integrated understanding of river status deterioration. Glob. Change Biol., 27: 1962-1975. https://doi.org/10.1111/gcb.15504

LWA. 2015. Santa Margarita River Watershed Nutrient Management Initiative: Process Plan

Marchau V., W.E. Walker, P. Bloemen and S. Popper (eds). 2019. Decision Making under Deep Uncertainty: From Theory to Practice. Springer Verlag. https://doi.org/10.1007/978-3-030-05252-2

Mazor, R., M. Sutula, and S. Theroux. In Prep. Concentrations of nutrient associated with protection of algal and benthic macroinvertebrate protection endpoints. For Submission to Journal of Freshwater Science.

Mazor, R.D., A.C. Rehn, P.R. Ode, M. Engeln, K. Schiff, E.D. Stein, D.J. Gillett, D.B. Herbst, and C.P. Hawkins. 2016. Bioassessment in complex environments: designing an index for consistent meaning in different settings. Freshwater Science 35:249–271.

McLaughlin, K., M. Sutula, J. Cable. and P. Fong. 2013 (a) Eutrophication and Nutrient Cycling in Santa Margarita River Estuary: A Summary of Baseline Data for Monitoring Order R9-2006-0076. Costa Mesa, CA, Southern California Coastal Water Research Project.

Melendez, C.L. and C.A. Mueller. 2021. Effect of increased embryonic temperature during developmental windows on survival, morphology, and oxygen consumption of rainbow trout (Oncorhynchus mykiss). Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology, 252, p.110834.

Menabde, M., D. Harris, A. Seed, G. Austin, and D. Stow. 1997. Multiscaling properties of rainfall and bounded random cascades. Water Resources Research, 33(12): 2823-2830.

Miltner, R.J. 2010. A Method and Rationale for Deriving Nutrient Criteria for Small Rivers and Streams in Ohio. Environmental Management 45, 842–855. https://doi.org/10.1007/s00267-010-9439-9

Molnar, P. and P. Burlando. 2005. Preservation of rainfall properties in stochastic disaggregation by a simple random cascade model. Atmospheric Research, 77:137-151, doi:10.1016/j.amosres.2004.10.024.

Mote, P., L. Brekke, P.B. Duffy, and E. Maurer. 2011. Guidelines for constructing climate scenarios. EOS, Transactions of the American Geophysical Union, 92(31): 257-258.

Mueller, C.A., J. Bucsky, L. Korito, and S. Manzanares. 2019. Immediate and persistent effects of temperature on oxygen consumption and thermal tolerance in embryos and larvae of the Baja California chorus frog, Pseudacris hypochondriaca. Frontiers in physiology, 10, p.754.

Myrick, C.A. and J.J. Cech. 2000. Temperature influences on California rainbow trout physiological performance. Fish Physiology and Biochemistry, 22(3), pp.245-254.

Nijboer, R.C. and P.F.M Verdonschot. 2004. Variable selection for modelling effects of eutrophication on stream and river ecosystems. Ecological Modelling 177, 17–39.

Nixon, S.W. 1995. Coastal marine eutrophication: a definition, social causes, and future concerns. Ophelia 41.1:199-219.

Ode, P.R., A.C. Rehn, R.D. Mazor, K.C. Schiff, E.D. Stein, J.T. May, L.R. Brown, D.B. Herbst, D. Gillett, K. Lunde, and C.P. Hawkins. 2016. Evaluating the adequacy of a reference-site pool for ecological assessments in environmentally complex regions. Freshwater Science 35.1:237-248.

Otto, R.G. 1973. Temperature tolerance of the mosquitofish, Gambmia affinis (Baird and Girard). Journal of fish biology, 5(5), pp.575-585.

Otto, R.G. 1974. The effects of acclimation to cyclic thermal regimes on heat tolerance of the western mosquitofish. Transactions of the American Fisheries Society, 103(2), pp.331-335.

Pachauri, R. K. , Allen, M. R. , Barros, V. R. , Broome, J. , Cramer, W. , Christ, R. , Church, J. A. , Clarke, L. , Dahe, Q. , Dasgupta, P. , Dubash, N. K. , Edenhofer, O. , Elgizouli, I. , Field, C. B. , Forster, P. , Friedlingstein, P. , Fuglestvedt, J. , Gomez-Echeverri, L. , Hallegatte, S. , Hegerl, G. , Howden, M. , Jiang, K. , Jimenez Cisneroz, B. , Kattsov, V. , Lee, H. , Mach, K. J. , Marotzke, J. , Mastrandrea, M. D. , Meyer, L. , Minx, J. , Mulugetta, Y. , O'Brien, K. , Oppenheimer, M. , Pereira, J. J. , Pichs-Madruga, R. , Plattner, G. K. , Pörtner, H. O. , Power, S. B. , Preston, B. , Ravindranath, N. H. , Reisinger, A. , Riahi, K. , Rusticucci, M. , Scholes, R. , Seyboth, K. , Sokona, Y. , Stavins, R. , Stocker, T. F. , Tschakert, P. , van Vuuren, D. and van Ypserle, J. P. 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change / R. Pachauri and L. Meyer (editors) , Geneva, Switzerland, IPCC, 151 p., ISBN: 978-92-9169-143-2 .

Paerl, H.W., N.S. Hall, and E.S. Calandrino. 2011. Controlling harmful cyanobacterial blooms in a world experiencing anthropogenic and climatic-induced change. Sci Total Environ. 15;409(10):1739-45. doi: 10.1016/j.scitotenv.2011.02.001. Epub 2011 Feb 23. PMID: 21345482.

Paul, M. and L. Zheng, L. 2007. Development of Nutrient Endpoints for the Northern Piedmont Ecoregion of Pennsylvania: TMDL Application. Tetra Tech, Owing Mills, MD.

Paul M., B. Jessup, L.R. Brown, J.L. Carter, M. Cantonati, D.F. Charles, J. Gerritsen, D.B. Herbst, R. Stancheva, J. Howard, B. Isham, R. Lowe, R. Mazor, P.K. Mendez, P. Ode, A. O'Dowd, J. Olson, Y. Pan, A.C. Rehn, S. Spaulding, M. Sutula, and S. Theroux. 2020. Characterizing benthic macroinvertebrate and algal Biological Condition Gradient models for California wadeable streams, USA. Ecol. Ind., 117 (2020), Article 106618, 10.1016/j.ecolind.2020.106618

Penman, H.L. 1948. Natural evaporation from open water, bare soil, and grass. Proceedings of the Royal Society of London, A. 193:120-145.

Pierce, D.W., J.F. Kalansky, and D.R. Cayan, (Scripps Institution of Oceanography). 2018. Climate, Drought, and Sea Level Rise Scenarios for California's Fourth Climate Change Assessment. California's Fourth Climate Change Assessment, California Energy Commission. Publication Number: CNRA-CEC-2018-006.

Qian, S.S., R. King, and C.J. Richardson. 2003. Two statistical methods for the detection of environmental thresholds. Ecological Modelling 166:87-97.

Quinn, J.M. and B.W. Gilliland. 1989. The Manawatu River cleanup - Has it worked? Transactions of the Institution of Professional Engineers, New Zealand 16:22-26.

Quinn, J.M. and C.W. Hickey. 1990. Characterization and classification of benthic invertebrate communities in 88 New Zealand rivers in relation to environmental factors. New Zealand Journal of Marine and Freshwater Research 24:387–409.

Richardson, C.J., R.S. King, S.S. Qian, P. Vaithiyanathan, R.G. Qualls, and C.A. Stow. 2007. Estimating Ecological Thresholds for Phosphorus in the Everglades. Environ. Sci. Technol. 41, 8084–8091. https://doi.org/10.1021/es062624w

Rogers, J.B., E.D. Stein, M.W. Beck, and R.F. Ambrose. 2020. The impact of climate change induced alterations of streamflow and stream temperature on the distribution of riparian species. PLoS ONE 15(11): e0242682. https://doi.org/10.1371/journal.pone.0242682

San Diego Regional Water Quality Control Board (SDRWQCB). 1994. Water Quality Control Plan for the San Diego Basin (9). California Regional Water Quality Control Board, San Diego Region, 8.

Schechtman, A.M. and J.B. Olson. 1941. Unusual temperature tolerance of an amphibian egg (Hyla regilla). Ecology, 22(4), pp.409-410.

Sengupta, A., S.K. Adams, B.P. Bledsoe, E.D. Stein, K.S. McCune, and R.D. Mazor. 2018. Tools for managing hydrologic alteration on a regional scale: Estimating changes in flow characteristics at ungauged sites. Freshwater Biol. 2018; 63: 769– 785. https://doi.org/10.1111/fwb.13074

Smith, A.J., R.W. Bode, and G.S. Kleppel. 2007. A nutrient biotic index (NBI) for use with benthic macroinvertebrate communities. Ecological Indicators 7, 371–386. https://doi.org/10.1016/j.ecolind.2006.03.001

Smith, A.J. and C.P. Tran. 2010. A weight-of-evidence approach to define nutrient criteria protective of aquatic life in large rivers. Journal of the North American Benthological Society 29, 875–891. https://doi.org/10.1899/09-076.1

Smith, J., M. Sutula, K. Bouma-Gregson, and M. Van Dyke. 2021. California State Water Boards' Framework and Strategy for Freshwater Harmful Algal Bloom Monitoring: Full Report with Appendices. SCCWRP Technical Report #1141.B. Southern California Coastal Water Research Project. Costa Mesa, CA. http://www.sccwrp.org/

Smucker, N.J., M. Becker, N.E. Detenbeck, and A. Morrison. 2013. Using Algal Metrics and Biomass to Evaluate Multiple Ways of Defining Concentration-Based Nutrient Criteria in Streams and their Ecological Relevance. Ecological Indicators 32, 51–61.

Spina, A.P. 2007. Thermal ecology of juvenile steelhead in a warm-water environment. Environmental Biology of Fishes, 80(1), pp.23-34.

SSC-PAC. 2016. Calibration of a linked hydrodynamic and water quality model for Santa Margarita Lagoon. Prepared for Camp Pendleton Marine Corps Base.

Stein, E.D., A. Sengupta, R.D. Mazor, K. McCune, B.P. Bledsoe, and S. Adams. 2017. Application of regional flow-ecology relationships to inform watershed management decisions: application of the ELOHA framework in the San Diego River watershed, California, USA. Ecohydrology. 2017; 10:e1869. https://doi.org/10.1002/eco.1869

Steinman, A.D. 1996. Effects of grazers on freshwater benthic algae. In: Stevenson R.J., M.L. Bothwell, and R.L. Lowe (eds). Algal ecology: freshwater benthic ecosystems pp. 341-373. Academic Press, New York.

Stevenson, R.J., B.H. Hill, A.T. Herlihy, L.L. Yuan, and S.B. Norton. 2008. Algae–P relationships, thresholds, and frequency distributions guide nutrient criterion development. Journal of the North American Benthological Society 27, 783–799. https://doi.org/10.1899/07-077.1

Suplee, M.W., V. Watson, M. Teply, and H. McKee. 2009. How green is too green? Public opinion of what constitutes undesirable algae levels in streams. JAWRA Journal of the American Water Resources Association 45.1:123-140.

Suplee, M.W., V. Watson, W.K. Dodds, and C. Shirley. 2012. Response of Algal Biomass to Large-Scale Nutrient Controls in the Clark Fork River, Montana, United States1. JAWRA Journal of the American Water Resources Association 48, 1008–1021. https://doi.org/10.1111/j.1752-1688.2012.00666.x

Sutula, M., J. Butcher, M. Schmidt, and C. Boschen. Effects of climate change on the eutrophication responses of a Mediterranean stream ecosystem, U.S.A. in prep-a for Submission to Freshwater Science.

Sutula, M., R. Mazor, A. Rehn, and S. Theroux. 2022. Synthesis of Science Supporting Decisions on Biostimulatory Numeric Guidance for California Wadeable Streams. Southern California Coastal Water Research Project.

Sutula, M. 2011. Review of Indicators for Development of Nutrient Numeric Endpoints in California Estuaries. Technical Report 646. Southern California Coastal Water Research Project. Costa Mesa, CA.

Sutula, M. 2021. Scientific Foundation for Assessment of Biostimulatory Impacts to California Estuaries, Enclosed Bays, and Inland Waterbodies. Technical Report 871. Southern California Coastal Water Research Project. Costa Mesa, CA.

Sutula, M. and D. Shultz. 2022. Status of eutrophication in the Upper (2016-2017) and Lower Main Stem (2015-2016) of the Santa Margarita River, San Diego County, California. Southern California Coastal Water Research Project Technical Report #1184. Costa Mesa, CA. www.sccwrp.org.

Sutula, M., J. Butcher, C. Boschen, and M. Molina. 2016. Application of Watershed Loading and Estuary Water Quality Models to Inform Nutrient Management in the Santa Margarita River Watershed. Technical Report 933. Southern California Coastal Water Research Project. Costa Mesa, CA.

Tetra Tech. 2018. Santa Margarita River Watershed Model and Lower River Nutrient Response Models. Prepared for County of San Diego Watershed Planning Program by Tetra Tech, Inc.

Tetra Tech. 2020a. Santa Margarita River Upper Watershed HSPF Model. Prepared for County of San Diego Watershed Planning Program by Tetra Tech, Inc.

Tetra Tech. 2020b. Santa Margarita River WASP Nutrient Response Model. Prepared for Southern California Coastal Water Research Project by Tetra Tech, Inc.

Tetra Tech. 2019. Rainbow Creek TMDL Compliance – Required MS4 Load Reductions. Prepared for San Diego County by Tetra Tech, Inc., San Diego, CA.

Tetra Tech. 2017a. Santa Margarita River Watershed Model – San Diego County Update (DRAFT). Prepared for the County of San Diego Watershed Planning Program, San Diego, CA, by Tetra Tech., Inc., Research Triangle Park, NC.

Tetra Tech. 2017b. At-Source and Delivered MS4 Loads for WY 2008 (DRAFT). Prepared for San Diego County, San Diego, CA, by Tetra Tech, Inc., Research Triangle Park, NC.

Tetra Tech. 2014. Santa Margarita River Watershed, Phase II – Sediment and Nutrient Calibration Memorandum. Prepared for U.S. Environmental Protection Agency, Region IX by Tetra Tech, Inc., San Diego, CA.

Tetra Tech. 2013. Santa Margarita River Watershed, Phase I – Hydrology Update and Re-calibration Memorandum. Prepared for U.S. Environmental Protection Agency, Region IX by Tetra Tech, Inc., San Diego, CA.

Theroux, S., R.D. Mazor, M.W. Beck, P.R. Ode, E.D. Stein, and M. Sutula. 2020. Predictive biological indices for algae populations in diverse stream environments. Ecological Indicators DOI:10.1016/j.ecolind.2020.106421.

USEPA. 2010. Using Stressor-response Relationships to Derive Numeric Nutrient Criteria (No. EPA-820-S-10-001). U.S. Environmental Protection Agency, Office of Water, Office of Science and Technology, Washington, DC.

USEPA. 2009. WASP7 Stream Transport – Model Theory and User's Guide. Supplement to Water Quality Analysis Simulation Program (WASP) User Documentation. U.S. Environmental Protection Agency, Athens, Georgia

Wang, L., D.M. Robertson, and P.J. Garrison. 2007. Linkages Between Nutrients and Assemblages of Macroinvertebrates and Fish in Wadeable Streams: Implication to Nutrient Criteria Development. Environmental Management 39, 194–212. https://doi.org/10.1007/s00267-006-0135-8

Weigel, B.M. and D.M. Robertson. 2007. Identifying Biotic Integrity and Water Chemistry Relations in Nonwadeable Rivers of Wisconsin: Toward the Development of Nutrient Criteria. Environmental Management 40, 691–708. https://doi.org/10.1007/s00267-006-0452-y

Woodward, G., D.M. Perkins, and L.E. Brown. 2010. Climate change and freshwater ecosystems: impacts across multiple levels of organization Phil. Trans. R. Soc. B3652093–2106. http://doi.org/10.1098/rstb.2010.0055

Worcester, K.R., D.M. Paradies, and M. Adams. 2010. Interpreting Narrative Objectives for Biostimulatory Substances for California Central Coast Waters. Surface Water Ambient Monitoring Program Technical Report.

Yarnell, S.M., G.E. Petts, J.C. Schmidt, A.A. Whipple, E.E. Beller, C.N. Dahm, P. Goodwin, and J.H. Viers. 2015. Functional Flows in Modified Riverscapes: Hydrographs, Habitats and Opportunities. Bioscience. 65(10):963–72.

Yarnell, S.M., E.D. Stein, J.A. Webb, T. Grantham, R.A. Lusardi, J. Zimmerman, R.A. Peek, B.A. Lane, J. Howard, and S. Sandoval-Solis. 2020. A functional flows approach to selecting ecologically relevant flow metrics for environmental flow applications. River Res Applic. 36: 318– 324. https://doi.org/10.1002/rra.3575

APPENDIX 1 SUPPLEMENTAL TABLES

Table A1. 2018 303(d) listing of Santa Margarita River Segments.

Waterbody Name	Waterbody ID	Waterbody Counties	Decision ID	Pollutant	Final Listing Decision
De Luz Creek	CAR9022100020010924135442	Riverside, San Diego	69042	Nitrogen	List on 303(d) list (TMDL required list)
De Luz Creek	CAR9022100020010924135442	Riverside, San Diego	69042	Nitrogen	List on 303(d) list (TMDL required list)
Long Canyon Creek (tributary to Murrieta Creek)	CAR9028300020011025112509	Riverside, San Diego	77747	Nitrogen	List on 303(d) list (TMDL required list)
Murrieta Creek	CAR9023200020010924152136	Riverside	77052	Nitrogen	List on 303(d) list (TMDL required list)
Murrieta Creek	CAR9023200020010924152136	Riverside	77052	Nitrogen	List on 303(d) list (TMDL required list)
Rainbow Creek	CAR9022200019980803102333	Riverside, San Diego	68853	Nitrogen	Do Not Delist from 303(d) list (being addressed with USEPA approved TMDL)
Rainbow Creek	CAR9022200019980803102333	Riverside, San Diego	68853	Nitrogen	Do Not Delist from 303(d) list (being addressed with USEPA approved TMDL)
Rainbow Creek	CAR9022200019980803102333	Riverside, San Diego	68853	Nitrogen	Do Not Delist from 303(d) list (being addressed with USEPA approved TMDL)
Rainbow Creek	CAR9022200019980803102333	Riverside, San Diego	68853	Nitrogen	Do Not Delist from 303(d) list (being addressed with USEPA approved TMDL)
Rainbow Creek	CAR9022200019980803102333	Riverside, San Diego	68853	Nitrogen	Do Not Delist from 303(d) list (being addressed with USEPA approved TMDL)
Rainbow Creek	CAR9022200019980803102333	Riverside, San Diego	68853	Nitrogen	Do Not Delist from 303(d) list (being addressed with USEPA approved TMDL)
Rainbow Creek	CAR9022200019980803102333	Riverside, San Diego	68853	Nitrogen	Do Not Delist from 303(d) list (being addressed with USEPA approved TMDL)

Rainbow Creek	CAR9022200019980803102333	Riverside, San Diego	68853	Nitrogen	Do Not Delist from 303(d) list (being addressed with USEPA approved TMDL)
Sandia Creek	CAR9022200019991117132333	Riverside, San Diego	76741	Nitrogen	List on 303(d) list (TMDL required list)
Sandia Creek	CAR9022200019991117132333	Riverside, San Diego	76741	Nitrogen	List on 303(d) list (TMDL required list)
Sandia Creek	CAR9022200019991117132333	Riverside, San Diego	76741	Nitrogen	List on 303(d) list (TMDL required list)
Sandia Creek	CAR9022200019991117132333	Riverside, San Diego	76741	Nitrogen	List on 303(d) list (TMDL required list)
Sandia Creek	CAR9022200019991117132333	Riverside, San Diego	76741	Nitrogen	List on 303(d) list (TMDL required list)
Sandia Creek	CAR9022200019991117132333	Riverside, San Diego	76741	Nitrogen	List on 303(d) list (TMDL required list)
Sandia Creek	CAR9022200019991117132333	Riverside, San Diego	76741	Nitrogen	List on 303(d) list (TMDL required list)
Sandia Creek	CAR9022200019991117132333	Riverside, San Diego	76741	Nitrogen	List on 303(d) list (TMDL required list)
Sandia Creek	CAR9022200019991117132333	Riverside, San Diego	76741	Nitrogen	List on 303(d) list (TMDL required list)
Santa Gertrudis Creek	CAR9024200020080825001546	Riverside	76007	Nitrogen	List on 303(d) list (TMDL required list)
Santa Margarita River (Lower)	CAR9021100019980911161346	San Diego	76241	Nitrogen	List on 303(d) list (TMDL required list)
Santa Margarita River (Lower)	CAR9021100019980911161346	San Diego	76241	Nitrogen	List on 303(d) list (TMDL required list)
Santa Margarita River (Lower)	CAR9021100019980911161346	San Diego	76241	Nitrogen	List on 303(d) list (TMDL required list)
Santa Margarita River (Lower)	CAR9021100019980911161346	San Diego	76241	Nitrogen	List on 303(d) list (TMDL required list)

Santa Margarita River (Upper)	CAR9022200020011001141050	Riverside, San Diego	76379	Nitrogen	List on 303(d) list (TMDL required list)
Warm Springs Creek (Riverside County)	CAR9023300020080825005933	Riverside	76477	Nitrogen	List on 303(d) list (TMDL required list)
Long Canyon Creek (tributary to Murrieta Creek)	CAR9028300020011025112509	Riverside, San Diego	76024	Phosphorus	List on 303(d) list (TMDL required list)
Murrieta Creek	CAR9023200020010924152136	Riverside	69236	Phosphorus	Do Not Delist from 303(d) list (TMDL required list)
Murrieta Creek	CAR9023200020010924152136	Riverside	69236	Phosphorus	Do Not Delist from 303(d) list (TMDL required list)
Murrieta Creek	CAR9023200020010924152136	Riverside	69236	Phosphorus	Do Not Delist from 303(d) list (TMDL required list)
Rainbow Creek	CAR9022200019980803102333	Riverside, San Diego	77191	Phosphorus	Do Not Delist from 303(d) list (being addressed with USEPA approved TMDL)
Rainbow Creek	CAR9022200019980803102333	Riverside, San Diego	77191	Phosphorus	Do Not Delist from 303(d) list (being addressed with USEPA approved TMDL)
Rainbow Creek	CAR9022200019980803102333	Riverside, San Diego	77191	Phosphorus	Do Not Delist from 303(d) list (being addressed with USEPA approved TMDL)
Rainbow Creek	CAR9022200019980803102333	Riverside, San Diego	77191	Phosphorus	Do Not Delist from 303(d) list (being addressed with USEPA approved TMDL)
Rainbow Creek	CAR9022200019980803102333	Riverside, San Diego	77191	Phosphorus	Do Not Delist from 303(d) list (being addressed with USEPA approved TMDL)
Rainbow Creek	CAR9022200019980803102333	Riverside, San Diego	77191	Phosphorus	Do Not Delist from 303(d) list (being addressed with USEPA approved TMDL)
Rainbow Creek	CAR9022200019980803102333	Riverside, San Diego	77191	Phosphorus	Do Not Delist from 303(d) list (being addressed with USEPA approved TMDL)
Rainbow Creek	CAR9022200019980803102333	Riverside, San Diego	77191	Phosphorus	Do Not Delist from 303(d) list (being addressed with USEPA approved TMDL)

Santa Gertrudis Creek	CAR9024200020080825001546	Riverside	76980	Phosphorus	List on 303(d) list (TMDL required list)
Santa Margarita River (Lower)	CAR9021100019980911161346	San Diego	76863	Phosphorus	List on 303(d) list (TMDL required list)
Santa Margarita River (Lower)	CAR9021100019980911161346	San Diego	76863	Phosphorus	List on 303(d) list (TMDL required list)
Santa Margarita River (Upper)	CAR9022200020011001141050	Riverside, San Diego	68819	Phosphorus	Do Not Delist from 303(d) list (TMDL required list)
Santa Margarita River (Upper)	CAR9022200020011001141050	Riverside, San Diego	68819	Phosphorus	Do Not Delist from 303(d) list (TMDL required list)
Santa Margarita River (Upper)	CAR9022200020011001141050	Riverside, San Diego	68819	Phosphorus	Do Not Delist from 303(d) list (TMDL required list)
Santa Margarita River (Upper)	CAR9022200020011001141050	Riverside, San Diego	68819	Phosphorus	Do Not Delist from 303(d) list (TMDL required list)
Santa Margarita River (Upper)	CAR9022200020011001141050	Riverside, San Diego	68819	Phosphorus	Do Not Delist from 303(d) list (TMDL required list)
Temecula Creek	CAR9025100020011025111323	Riverside, San Diego	69685	Phosphorus	Do Not Delist from 303(d) list (TMDL required list)
Temecula Creek	CAR9025100020011025111323	Riverside, San Diego	69685	Phosphorus	Do Not Delist from 303(d) list (TMDL required list)
Warm Springs Creek (Riverside County)	CAR9023300020080825005933	Riverside	68293	Phosphorus	List on 303(d) list (TMDL required list)

Table A2. Beneficial Uses of Inland Surface Waters in the Santa Margarita River Watershed.

Waterbody[1,2]	Hydrologic Unit Basin Number	MUN	AGR	IND	PROC	GWR	FRSH	POW	REC-1	REC-2	BIOL	WARM	COLD	WILD	RARE	SPWN
Santa Margarita River	2.22	●	●	●					●	●		●	●	●	●	
Murrieta Creek	2.31	●	●	●	●				○	●		●		●		
Bundy Canyon	2.31	●	●	●	●				○	●		●		●		
Slaughterhouse Canyon	2.31	●	●	●	●				○	●		●		●		
Murrieta Creek	2.32	●	●	●	●				○	●		●		●		
Murrieta Creek	2.52	●	●	●	●	●			○	●		●		●		
Cole Canyon	2.32	●	●	●	●				○	●	●	●		●		
Miller Canyon	2.32	●	●	●	●				○	●		●		●		
Warm Spring Creek	2.36	●	●	●	●				○	●		●		●		
Diamond Valley	2.36	●	●	●	●				○	●		●		●		
Goodhart Canyon	2.36	●	●	●	●				○	●		●		●		
Pixley Canyon	2.36	●	●	●	●				○	●		●		●		
Warm Spring Creek	2.35	●	●	●	●				○	●		●		●		
Domenigoni Valley	2.35	●	●	●	●				○	●		●		●		
Warm Spring Creek	2.34	●	●	●	●				○	●		●		●		
Warm Spring Creek	2.33	●	●	●	●				○	●		●		●		
French Valley	2.33	●	●	●	●				○	●		●		●		
Santa Gertrudis Creek	2.42	●	●	●	●	○			●	●		●		●		
Long Valley	2.42	●	●	●	●	○			●	●		●		●		
Glenoak Valley	2.42	●	●	●	●	○			●	●		●	●	●		
Tucalota Creek	2.43	●	●	●	●	○			●	●		●	●	●		
Willow Canyon	2.44	●	●	●	●	○			●	●		●	●	●		

Waterbody[1,2]	Hydrologic Unit Basin Number	MUN	AGR	IND	PROC	GWR	FRSH	POW	REC-1	REC-2	BIOL	WARM	COLD	WILD	RARE	SPWN
Tucalota Creek	2.41	●	●	●	●	○			●	●		●		●		
Crown Valley	2.41	●	●	●	●	○			●	●		●	●	●		
Rawson Canyon	2.41	●	●	●	●	○			●	●		●	●	●		
Tucalota Creek	2.42	●	●	●	●	○			●	●		●		●		
Santa Gertrudis Creek	2.32	●	●	●	●				○	●		●		●		
Long Canyon	2.32	●	●	●	●				○	●		●		●		
Temecula Creek	2.93	●	●	●	●	●			○	●		●		●		
Kohler Canyon	2.93	●	●	●	●	●			○	●		●	●	●		
Rattlesnake Creek	2.93	●	●	●	●	●			○	●		●	●	●		
Temecula Creek	2.92	●	●	●	●	●			○	●		●		●		
Chihuahua Creek	2.94	●	●	●	●	●			○	●		●		●		
Chihuahua Creek	2.92	●	●	●	●	●			○	●		●		●		
Cooper Canyon	2.92	●	●	●	●	●			○	●		●		●		
Iron Spring Canyon	2.92	●	●	●	●	●			○	●		●		●		
Temecula Creek	2.91	●	●	●	●	●			○	●		●		●		
Culp Valley	2.91	●	●	●	●	●			○	●		●		●		
Temecula Creek	2.84	●	●	●	●	●			●	●		●	●	●		●
Tule Creek	2.84	●	●	●	●	●			●	●		●	●	●		
Million Dollar Canyon	2.84	●	●	●	●	●			●	●		●	●	●		
Cottonwood Creek	2.84	●	●	●	●	●			●	●		●	●	●		●
Temecula Creek	2.83	●	●	●	●	●			●	●		●	●	●		●
Long Canyon	2.83	●	●	●	●	●			●	●		●	●	●		●
Wilson Creek	2.63	●	●	●	●	●			○	●		●		●		

Waterbody[1,2]	Hydrologic Unit Basin Number	MUN	AGR	IND	PROC	GWR	FRSH	POW	REC-1	REC-2	BIOL	WARM	COLD	WILD	RARE	SPWN
Wilson Creek	2.61	●	●	●	●	●			○	●		●		●		
Cahuilla Creek	2.73	●	●	●	●	●			○	●		●		●		
Hamilton Creek	2.74	●	●	●	●	●			○	●		●		●		
Hamilton Creek	2.73	●	●	●	●	●			○	●		●		●		
Cahuilla Creek	2.72	●	●	●	●	●			○	●		●		●		
Cahuilla Creek	2.71	●	●	●	●	●			○	●		●		●		
Elder Creek	2.71	●	●	●	●	●			○	●		●		●		
Cahuilla Creek	2.61	●	●	●	●	●			○	●		●		●		
Wilson Creek	2.81	●	●	●	●	●			●	●		●	●	●		
Lewis Valley	2.62	●	●	●	●	●			○	●		●		●		
Arroyo Seco Creek	2.81	●	●	●	●	●			●	●		●	●	●		
Arroyo Seco Creek	2.82	●	●	●	●	●			●	●		●	●	●		●
Kolb Creek	2.81	●	●	●	●	●			●	●		●	●	●		
Temecula Creek	2.81	●	●	●	●	●			●	●		●	●	●		●
Temecula Creek	2.51	●	●	●	●	●			○	●		●		●		
Temecula Creek	2.52	●	●	●	●	●			○	●		●		●		
Pechanga Creek	2.52	●	●	●	●	●			○	●		●		●		
Rainbow Creek	2.23	●	●	●					●	●		●	●	●		●
Rainbow Creek	2.22	●	●	●					●	●		●	●	●		●
Sandia Canyon	2.22	●	●	●					●	●		●	●	●		●
Walker Basin	2.22	●	●	●					●	●		●	●	●		
Santa Margarita River	2.21	●	●	●					●	●		●	●	●	●	
De Luz Creek	2.21	●	●	●					●	●		●	●	●	●	●

Waterbody[1,2]	Hydrologic Unit Basin Number	MUN	AGR	IND	PROC	GWR	FRSH	POW	REC-1	REC-2	BIOL	WARM	COLD	WILD	RARE	SPWN
Cottonwood Creek	**2.21**	●	●	●					●	●		●	●	●		
Camps Creek	**2.21**	●	●	●					●	●		●	●	●		●
Fern Creek	**2.21**	●	●	●					●	●		●	●	●		●
Roblar Creek	**2.21**	●	●	●					●	●		●	●	●		
Santa Margarita River	**2.13**	●	●	●	●				●	●		●	●	●	●	
Wood Canyon	**2.13**	●	●	●	●				●	●		●		●		
Santa Margarita River	**2.12**	●	●	●	●				●	●		●	●	●	●	
Santa Margarita River	**2.11**	●	●	●	●				●	●		●	●	●	●	
Pueblitos Canyon	**2.11**	●	●	●	●				●	●		●		●	●	
Newton Canyon	**2.11**	●	●	●	●				●	●		●		●		

Notes:
● Existing Beneficial Use
○ Potential Beneficial Use
1. Water bodies are listed multiple times if they cross hydrologic area or sub area boundaries.
2. Beneficial use designations apply to all tributaries to the indicated water body, if not listed separately.

APPENDIX 2 NATURAL CONDITIONS SCENARIO ANALYSES

TETRA TECH INC.

MEMO

To:	Matt Yeager, Riverside County Flood Control and Water Conservation District; Ryan Jensen, San Diego County, Watershed Protection Program
Cc:	Martha Sutula, Southern California Coastal Water Research Project
From:	Michelle Schmidt, Jon Butcher, and Clint Boschen, Tetra Tech
Date:	December 15, 2021
Subject:	Simulation of Natural Conditions within the Santa Margarita River Watershed [Final]

1.0 Introduction

This memorandum describes a natural conditions modeling scenario for the Santa Margarita River and watershed. It applies three linked models – a Hydrologic Simulation Program – FORTRAN (HSPF) watershed model of the middle Santa Margarita River watershed, a HSPF model of the lower Santa Margarita River watershed above the Old Hospital, and a Water Quality Analysis Simulation Program (WASP) receiving water model. The development and calibration of these models are discussed in past reports (Tetra Tech, 2021; Tetra Tech, 2020; Tetra Tech, 2018).

The objective of the natural conditions modeling analyses is to examine the streamflow regime and water quality conditions in the river under the absence of anthropogenic activities below the major water supply dams (Diamond Valley Lake, Vail Lake, and Skinner Lake) and above Camp Pendleton where urbanization and agricultural lands are concentrated in Riverside and San Diego Counties.

Section 2.0 describes the approach to model natural conditions in the watershed. Results for the scenarios are presented and discussed in Section 3. Natural conditions source loads are tabulated for jurisdictions in Section 0. Note that the terms "baseline" and "current condition" are used interchangeably throughout this memo.

2.0 Natural Conditions Approach

The natural conditions scenarios for the Santa Margarita River cover the middle watershed (from the reservoir dams to the head of the Santa Margarita Gorge near Temecula) and a portion of the lower watershed (from the head of the Gorge down to the Camp Pendleton water diversion near the Old

Hospital). The part of the lower watershed downstream of the Old Hospital is not included because a natural conditions scenario would involve substantial changes to water management on Camp Pendleton including diversions, infiltration, and pumping of alluvial groundwater that would require a revised groundwater model for that region.

This study evaluates predicted runoff, pollutant loading, water temperature, dissolved oxygen, and macroalgae under natural land use for the portion of the Santa Margarita watershed that is downstream of the major water supply dams (Diamond Valley Lake, Vail Lake, and Skinner Lake). A primary purpose of the scenario is to estimate what nutrient loads and concentrations would likely be present in the perennial mainstem Santa Margarita River absent anthropogenic changes to the landscape. The reservoir operations are not changed in this scenario due to the low probability that these reservoirs that supply drinking and irrigation water to Riverside and San Diego Counties would be removed. The HSPF and WASP models are calibrated for current conditions, which serves as the baseline. The natural condition scenarios are conducted both with and without the Comprehensive Water Rights Agreement (CWRMA) discharge active. The CWRMA release at the head of the Santa Margarita Gorge is not natural but is required by a court settlement.

3.0 Land Cover

Existing land use is represented in the HSPF models to reflect current conditions. Existing land uses related to anthropogenic activities (e.g., residential, agriculture, roads, etc.) were reconfigured to represent natural, or pre-settlement, vegetation in the watershed. Natural vegetation characteristics were informed by LANDFIRE's biophysical settings (BPS) coverage that depicts vegetation that was dominant on the landscape prior to Euro-American settlement. The LANDFIRE Biophysical Settings (BPS) layer was used to estimate the vegetation systems that likely existed in the Santa Margarita River watershed before human settlement. The BPS layer contains the vegetation system name, a generalized vegetation group, as well as historical disturbance regime information (Fire Return Intervals (FRI)). The BPS categories represented in the natural conditions models are summarized in Table 1.

Table 62. LANDFIRE biophysical settings categories represented in the natural conditions scenario

BPS Code	BPS Name	Vegetation Group	Fire Return Interval		
			Replacement (High)	Mixed (Medium)	Surface (Low)
11	Open Water	Open Water	NA	NA	NA
31	Barren-Rock/Sand/Clay	Barren-Rock/Sand/Clay	NA	NA	NA
10140	Central and Southern California Mixed Evergreen Woodland	Hardwood	335	34	10
10270	Mediterranean California Dry-Mesic Mixed Conifer Forest and Woodland	Conifer	150	35	17

BPS Code	BPS Name	Vegetation Group	Fire Return Interval		
			Replacement (High)	Mixed (Medium)	Surface (Low)
10820	Mojave Mid-Elevation Mixed Desert Scrub	Shrubland	399	NA	NA
10870	Sonora-Mojave Creosotebush-White Bursage Desert Scrub	Shrubland	329	NA	NA
10920	Southern California Coastal Scrub	Shrubland	150	NA	NA
10970	California Mesic Chaparral	Shrubland	79	NA	NA
11050	Northern and Central California Dry-Mesic Chaparral	Shrubland	50	NA	NA
11080	Sonora-Mojave Semi-Desert Chaparral	Shrubland	81	NA	NA
11100	Southern California Dry-Mesic Chaparral	Shrubland	51	NA	NA
11130	California Coastal Live Oak Woodland and Savanna	Hardwood	175	31	27
11180	Southern California Oak Woodland and Savanna	Hardwood	173	43	30
11290	California Central Valley and Southern Coastal Grassland	Grassland	4	NA	NA
11520	California Montane Riparian Systems	Riparian	100	76	NA
10960	California Maritime Chaparral	Shrubland	124	NA	NA
11630	Pacific Coastal Marsh Systems	Riparian	15	35	NA

The LANDFIRE BPS data were used as the primary source for natural conditions land cover representation. The translation, or reclassification, between BPS and model land use/cover was accomplished using the BPS Vegetation Group (Table 63). The numeric hydrologic response unit (HRU) codes representing land use/cover were retained from the existing models. No new land uses were added to the model, rather existing land uses were reclassified into representative natural categories as shown in Table 63.

Table 63. LANDFIRE biophysical settings categories mapped to model land uses/covers

BPS Vegetation Group	Lower Watershed		Middle Watershed	
	Land Cover Category	Base Model HRU Code	Land Cover Category	Base Model HRU Code
Open Water	Water	16	Water	15
Barren-Rock/Sand/Clay	Transitional	17	Transitional	16
Hardwood	Forest	13	Forest	12
Conifer	Forest	13	Forest	12
Shrubland	Chaparral/Scrub	14	Chaparral/scrub	13
Shrubland	Chaparral/Scrub	14	Chaparral/scrub	13
Shrubland	Chaparral/Scrub	14	Chaparral/scrub	13
Shrubland	Chaparral/Scrub	14	Chaparral/scrub	13
Shrubland	Chaparral/Scrub	14	Chaparral/scrub	13
Shrubland	Chaparral/Scrub	14	Chaparral/scrub	13
Shrubland	Chaparral/Scrub	14	Chaparral/scrub	13
Hardwood	Forest	13	Forest	12
Hardwood	Forest	13	Forest	12
Grassland	Grassland/Herbaceous	15	Grassland/herbaceous	14
Riparian	Grassland/Herbaceous	15	Grassland/herbaceous	14
Shrubland	Chaparral/Scrub	14	Chaparral/scrub	13
Riparian	Grassland/Herbaceous	15	Grassland/herbaceous	14

In addition to the pre-settlement vegetation system, the BPS layer includes historic disturbance regime information – namely natural fire intensity and frequency. Each BPS type contains a Fire Return Interval, which is the number of years between fires. These are further divided into three intensity categories: Replacement, Mixed, and Surface. To simplify modeling, and because of the potential hydrologic effects of different fire intensities, only the Replacement level fires were considered. Incomplete burns are less likely to impact hydrology in significant ways. As fire occurrence is not spatially explicit in the BPS, the amount of burned land was calculated outside of GIS in Excel. For each BPS, the likelihood that the land area has been burned in any given year was calculated as 1/Replacement FRI. This ratio was then used to calculate the area was then assigned to the Transitional (Barren) land class. Only the first year of a fire was incorporated into this calculation, as re-vegetation would likely begin the following year, and the area would begin to reflect the hydrologic properties of vegetated land.

The model HRUs also incorporate soil types because these alter infiltration, susceptibility to erosion, and other processes that influence watershed hydrology and water quality. The SSURGO soil polygons for the hydrologic soil groups (HSG) are distinguished in the model HRUs. In contrast to the existing conditions models, the dual-class HSGs (e.g., “A/D”), which represent the potential HSG if soils are artificially drained, were assumed to be in the undrained state. Therefore, an “A/D” soil was under natural conditions was classified as a “D” type HSG.

Effective impervious areas that are part of the upland land use scheme in the existing conditions models (i.e., IMPLNDS) were reclassified to a natural cover for the scenario.

Each HRU was analyzed to determine the average slope and soil erodibility (K-factor) to inform parameterization in the HSPF model. The K-factor represents the soil’s susceptibility to erosion as well as the rate of runoff. The slope values were calculated from the National Elevation Dataset 30-meter (lower watershed) and 10-meter (middle watershed) datasets applied in model development, while K-factor was calculated from the SSURGO dataset.

Landscape processes (infiltration, pollutant build-up/wash-off) that influence hydrology and water quality from these natural covers were calibrated during model development and were not altered for the natural condition scenario. These were calibrated to be consistent with literature values, including SCCWRP estimates of natural background loading rates, and simultaneously with calibration of instream water quality based on available monitoring data. Results are provided in Table 4-5 of the technical report for the middle watershed HSPF model (October 2020), for example.

4.0 Drainage Network

The natural conditions scenario applied the same representation of stream network linkages and hydraulics as contained in the current conditions models. While human disturbances have resulted in changes to drainage pathways, there is not a firm basis for characterizing pre-settlement channel morphology and there are few hardened concrete channels within current developed areas. Releases from the three major dams that provide boundary conditions to the middle watershed model (i.e., for outflows from Diamond Valley Lake, Lake Skinner, and Vail Lake) were maintained; as described in the model report, the drainage areas to Lake Skinner and Vail Lake are not represented in the middle watershed HSPF model.

5.0 Best Management Practices

Best management practices (BMPs) that detain, retain, or infiltrate urban stormwater are included in the HSPF models representing current conditions in the middle and lower watersheds. As discussed in the model development reports, it was not possible to determine or represent the exact location and number of development and lot-scale BMPs in the existing conditions model; instead, prorated adjustments were applied based on the fraction of development that had occurred in a subbasin since new development/redevelopment requirements were in place. Removal of the urban BMPs occurred automatically with the removal of urban land uses for the natural conditions scenario.

6.0 Irrigation

The current conditions watershed models represent irrigation on urban and agricultural lands; both of these land uses are replaced with natural covers and, thus, irrigation is removed for the natural conditions scenario. The effects of groundwater pumping on upland water balance was also removed from the model by turning off the fraction of shallow groundwater that was assumed to percolate to deeper aquifers as a result of pumping. The effects of groundwater pumping on losses from the stream network are not simulated directly by HSPF but rather are transmitted as boundary conditions from the MODFLOW groundwater model; the groundwater exchanges were refined to approximate natural conditions as is described in Section 8.0.

7.0 CWRMA Discharge

As discussed in the HSPF model report for the middle Santa Margarita River watershed (Tetra Tech, 2020), the Comprehensive Water Rights Management Agreement (CWRMA) regulates the discharge of water delivered to the Santa Margarita River at the head of the Gorge from Lake Skinner to satisfy water rights obligations. As discussed in Section 2.4.4 of the HSPF model development and calibration report, a CWRMA flow release time series was derived from provided flow records. The natural conditions scenario was run both with and without the CWRMA discharge present in the middle watershed HSPF model and WASP receiving water model. The historic release time series was maintained for the with-CWRMA scenario. Results for the alternative natural condition scenarios are provided in Section 3.

8.0 Groundwater

Interactions between surface streams and underlying aquifers were quantified based on the Geoscience MODFLOW model and represented in the middle watershed HSPF model (Tetra Tech, 2020). At this time, Geoscience has not completed a natural condition groundwater model run. Furthermore, sufficient data are not available to fully characterize how the surface-groundwater interactions along the stream network under natural conditions differed from existing conditions. Therefore, an approach was developed to approximate natural conditions for groundwater exchanges.

Current surface-groundwater exchanges in the middle watershed are influenced by irrigation pumping from the aquifer. The pumping reduces resurfacing groundwater that feeds streams in the vicinity of the Gorge and conversely, imported irrigation water and infiltration basins facilitate recharge to the local surficial aquifer. The natural conditions scenario reduces percolation to the deep aquifer that is in part driven by pumping, leading to more natural outflow from shallow ground water. The natural conditions scenario also removes irrigation activities in the watershed and human-built recharge basins.

Under natural conditions, pumping wells would not exist. This would reduce the losses from streams, but also raise the water table so that larger natural discharges from groundwater would occur at the head of the Gorge at approximately the same location as the CWRMA discharge.

Water rights have been litigated in the Santa Margarita since 1928, at which time there were already concerns about over-pumping from the aquifer. Determining the natural baseflow in the system is thus challenging. Fortunately, work to resolve this issue was undertaken to establish the 2002 CWRMA specifications. The CWRMA technical document (available on the Santa Margarita Watermaster web site at (https://smrwm.org/wp-content/uploads/2020/08/1.10-More-Legible-Copy-CWRMA-Agreement.pdf) developed both a groundwater model (MODFLOW) and a surface water model (HSPF) to estimate total natural streamflow at the Gorge over the period of 1935 through 1994. The two models were said to be in close agreement regarding total monthly flow volume and median flows. The median flows (flows that are exceeded 50 percent of the time) are indicative of baseflows and remove the influence of surface runoff events, including most runoff from the areas now upstream of dams. As CWRMA is a binding agreement that has been accepted by the courts it is prudent to use this analysis to develop the revised natural condition modeling analysis.

The original models, developed in 2000 by Geoscience and Stetson, do not appear to be available; however, details on their application and results are provided in Exhibit B attached to the CWRMA agreement.

The CWRMA modeling was used to set flow augmentation targets based on the natural flows. Specifically, the CWRMA flow targets are described as 2/3 of the median natural flow. These are developed on a monthly basis for four different annual hydrologic conditions ranging from "critically dry" to "very wet." (This guarantees that the CWRMA discharge follows the pattern of natural base flows.) The annual median flows, which should provide a good estimate of baseflow at the Gorge, are summarized in Table 64.

Table 64. Annual median flows at the Gorge by hydrologic condition provided in CWRMA documentation

Hydrologic Condition	Median Discharge Requirement (cfs)	Natural Median Flow (cfs)
Critically Dry	3.6	5.4
Below Normal	5.8	8.7
Above Normal	11.8	17.7
Very Wet	15.6	23.4

Note: Discharge requirements are from Table B-2 in Exhibit B attached to the 2002 CWRMA. The natural median flow is 1.5 times the discharge requirement.

Methods for describing the hydrologic condition of a given year are somewhat complex and are described in Exhibit C of CWRMA. Fortunately, the annual Watermaster reports describe the hydrologic condition for each year from 2002 onward. These suggest the following approach for specifying deep groundwater exchanges (independent of CWRMA releases) in the natural condition scenario, which was applied:

1. The natural conditions HSPF model was run with no CWRMA discharge, no losses to deep groundwater, and no resurfacing groundwater. The median predicted streamflow from 2002 through 2018 was calculated.

2. Iteratively a fraction of groundwater discharge at the head of the Gorge was restored to sufficiently match the modeled median streamflow to the median streamflow estimated from Table 64 for 2002 through 2018. This was done in the model by restoring a fraction of the current CWRMA flow amounts because the CWRMA discharges are designed to follow the natural seasonal cycle and are adjusted to match the hydrologic condition of each year. Nutrient concentrations associated with this seepage were specified at levels representative of natural groundwater concentrations prior to European settlement.[9]

[9] Specifically, total N = 0.31 mg/L and total P = 0.039 mg/L, which are the 90th percentile values of reference site concentrations for the South Coast ecoregion as summarized in Sutula, M., R. Mazor, S. Theroux et al. October 2018 Draft. Scientific Bases for Assessment, Prevention, and Management of Biostimulatory Impacts in California Wadeable Streams. Technical Report Number

The natural conditions scenario also includes the portion of the lower watershed HSPF model that drains to the Santa Margarita River upstream of the Old Hospital for WASP receiving water model simulations. This area is upstream of Camp Pendleton where there are complex diversions and groundwater exchanges, thus, no changes were made to the groundwater exchanges that occur downstream of the Camp Pendleton diversion in the full lower watershed HSPF model because that area was not being simulated for the natural conditions scenario.

9.0 Weather

The hourly weather forcing series in the HSPF and WASP models were derived from gridded datasets, including PRISM and NLDAS. Weather variables represented in the models collectively include precipitation, air temperature, dew point temperature, wind, cloud cover, solar radiation, and potential evapotranspiration. The weather input time series from the calibrated current conditions models were maintained for the natural conditions scenario.

10.0 Existing Conditions without CWRMA

Natural conditions scenarios were completed with and without the CWRMA discharge. Baseline conditions for the recent past include the CWRMA discharge. To examine the influence of the CWRMA discharge on river hydrology and water quality, the baseline conditions were also run in WASP without CWRMA. Results are provided in Section 3.0 alongside the natural conditions scenario results for WASP.

3 RESULTS

11.0 Hydrology

The natural conditions scenarios result in significant changes to predicted hydrology in the watershed. Hydrology in the middle watershed is substantially altered by the reduction in impervious surfaces, absence of well pumping and irrigation, and conversion of developed and agricultural land back to natural covers such as chaparral and forest. Comparisons below focus on two locations. The first is HSPF Reach 390 in the middle watershed model, representing the headwaters of the Santa Margarita River below the confluence of Murrieta and Temecula Creeks and at the head of the Santa Margarita River gorge. The second location is HSPF Reach 118 in the lower watershed model, coincident with the USGS flow gage at Fallbrook PUD. Time series for the two natural condition scenarios and the current condition baseline are shown in Figure 7 and Figure 8. Flow duration curves are presented in Figure 9 through Figure 12, with the first for each location showing low to moderate streamflow (i.e., exceedance probabilities between 10 percent to 100 percent) and the second plot for each location showing very high streamflow (i.e., exceedance probabilities between <1 percent to 10 percent). Flow statistics are summarized in Table 65 and Table 66.

The current condition or baseline run (in dark blue) has the strongest response in regard to peak storm runoff events (Figure 7 and Figure 10), reflecting the presence of extensive impervious surface areas;

1048. Southern California Coastal Water Research Project. Costa Mesa, CA. https://www.waterboards.ca.gov/water_issues/programs/biostimulatory_substances_biointegrity/stakeholder_advisory/docs/sutula_et_al_assessment_biostimulatory_impacts_wadeable_streams.docx, accessed 4/23/2020.

relatively high flows are exhibited during the summer dry period due to flow augmentation at the head of the gorge via the CWRMA discharge. The natural conditions run (without CWRMA; green series) exhibits a muted storm peak response and the lowest predicted flows due to the absence of both CWRMA and irrigation (e.g., streamflow is less than five cubic feet per second (cfs) more than half of the time at the head of the gorge as shown in Figure 9). Adding the CWRMA discharge back to the natural conditions (yellow series) results in higher summer flows compared to the baseline; this is partially attributed to reduced losses to the deep aquifer driven by pumping that occurs under current conditions.

Duration of dry periods

For the three HSPF scenarios, which include natural conditions with CWRMA, natural conditions without CWRMA, and baseline conditions with CWRMA, there are no true intermittent dry periods as there is always some, though at times small, streamflow in the mainstem. The duration of completely dry periods is thus zero days per year for all three scenarios. Near Fallbrook, the 99th percentile simulated streamflow (i.e., exceeded nearly all of the time) is about 1.004 cubic meters per second (cms) for existing conditions, 0.176 cms for natural conditions with CWRMA, and 0.161 cms for natural conditions without CWRMA.

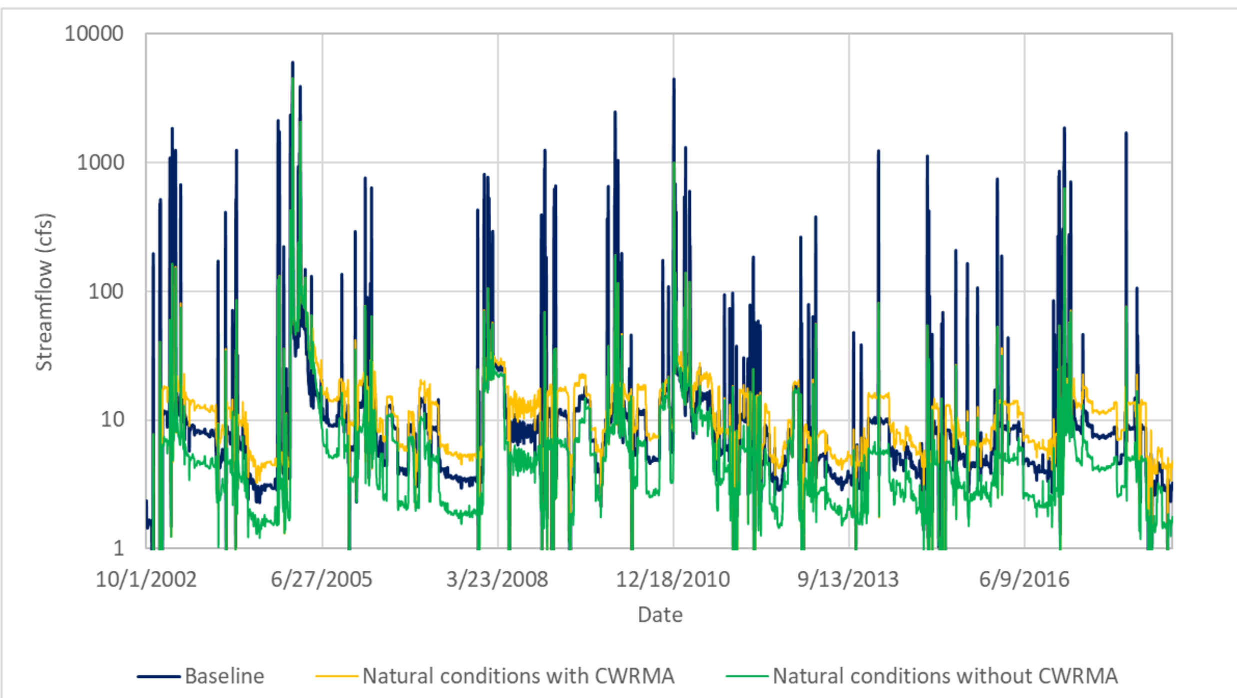


Figure 7. HSPF simulated daily flow for Santa Margarita River at the head of the gorge

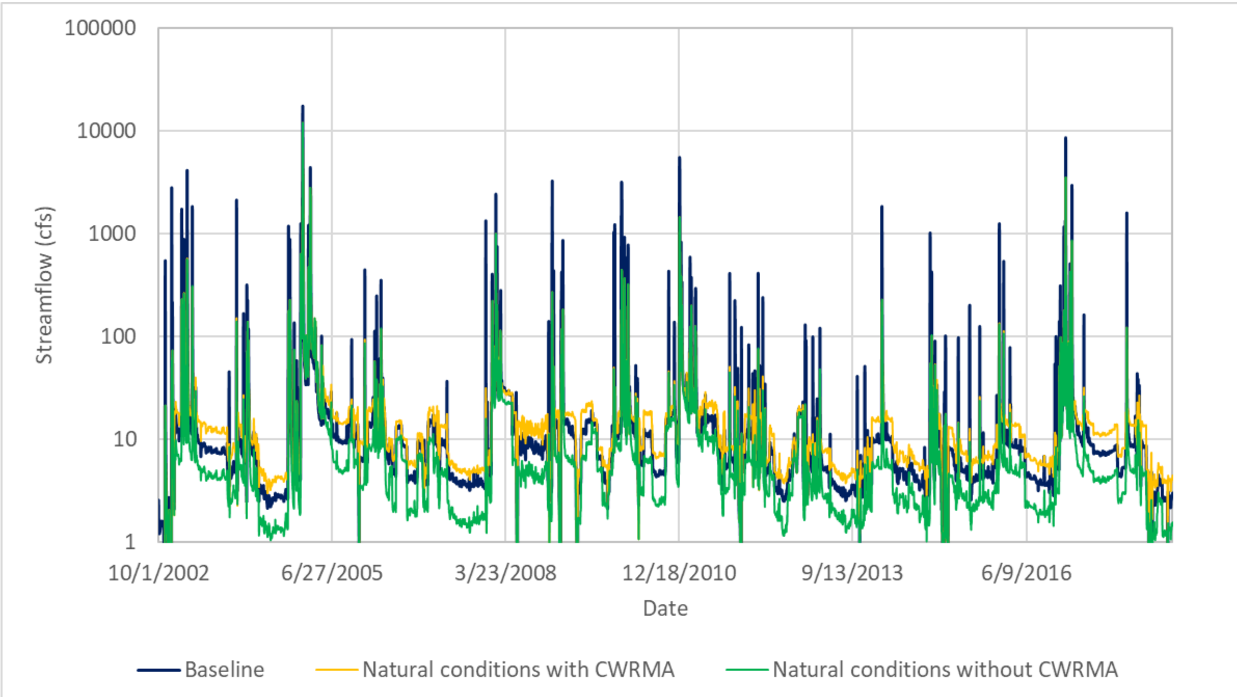


Figure 8. HSPF simulated daily flow for Santa Margarita River at Fallbrook PUD

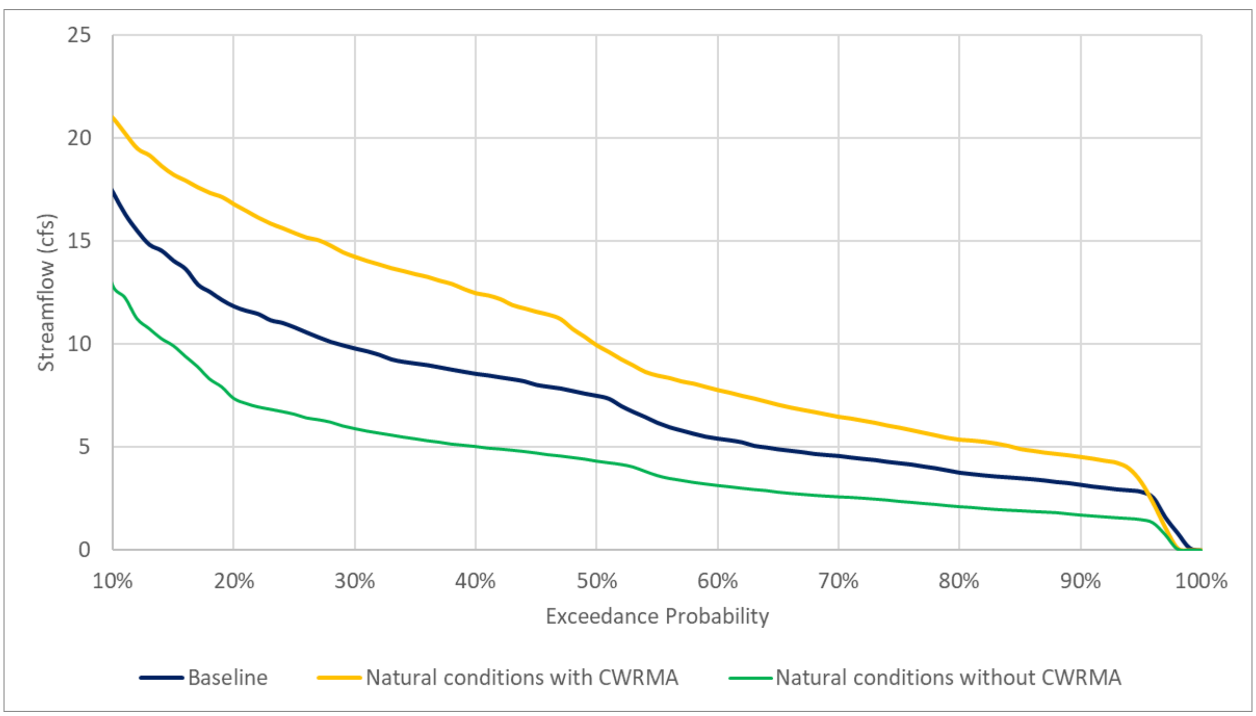


Figure 9. HSPF predicted flow duration curve for Santa Margarita River at head of the gorge (low to moderate flows)

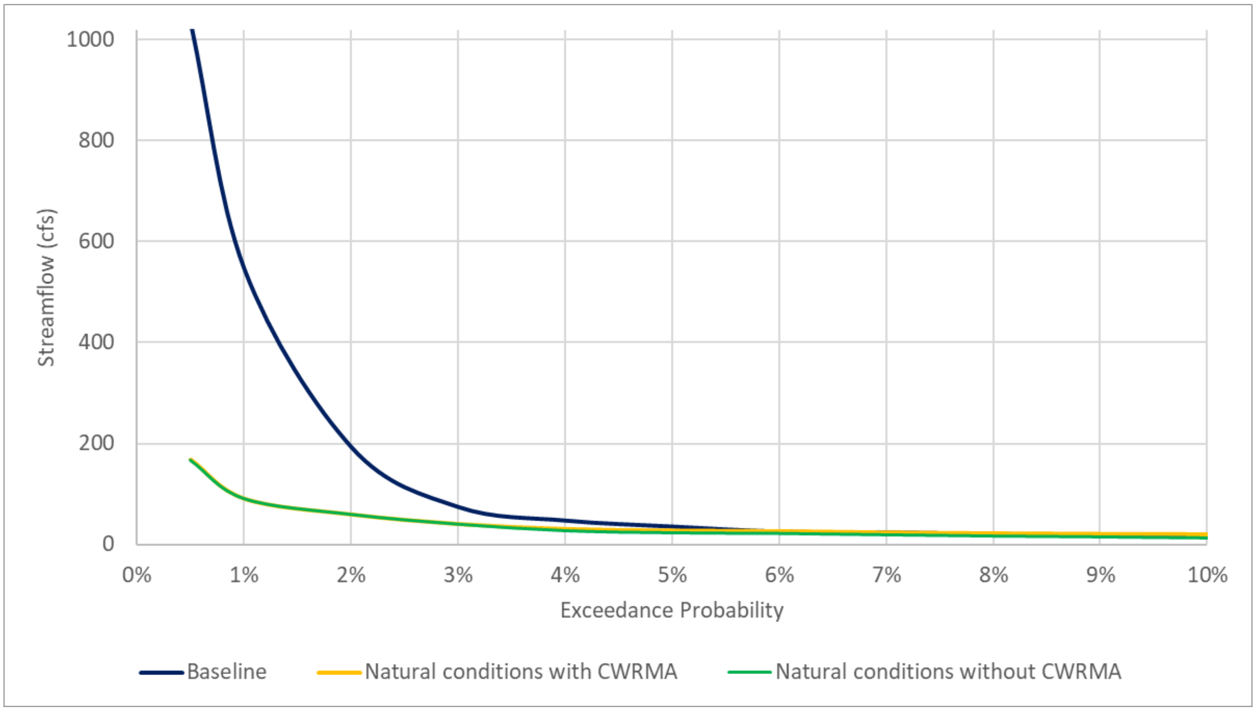


Figure 10. HSPF predicted flow duration curve for Santa Margarita River at head of the gorge (very high flows)

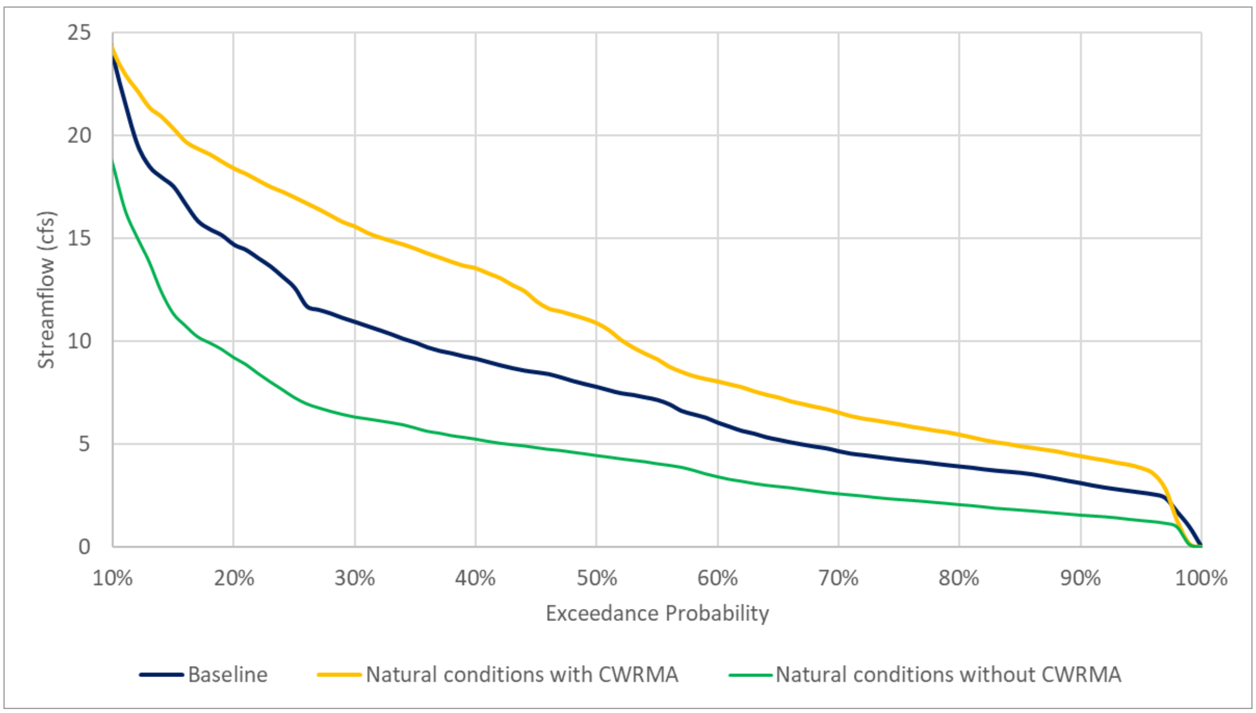


Figure 11. HSPF predicted flow duration curve for Santa Margarita River at Fallbrook PUD (low to moderate flows)

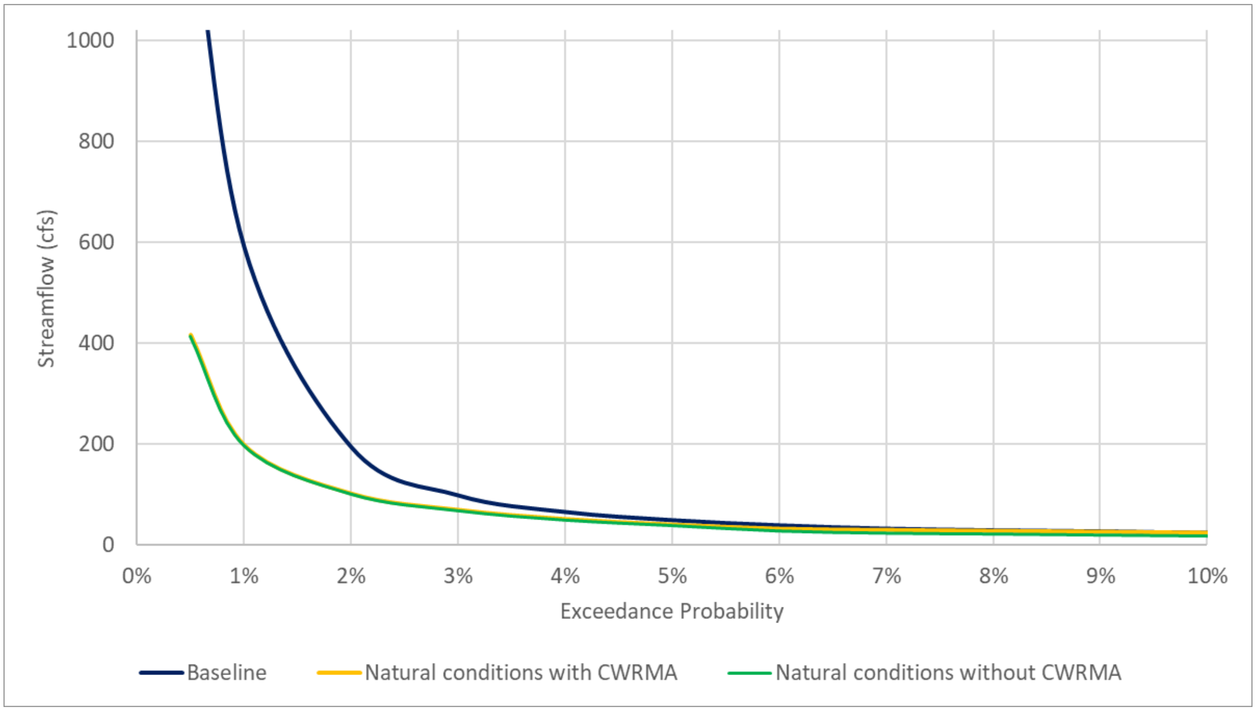


Figure 12. HSPF predicted flow duration curve for Santa Margarita River at Fallbrook PUD (very high flows)

Table 65. Summary of HSPF simulated flows for Santa Margarita River at head of gorge (cfs), water year 2003-2018

	Baseline	Natural Conditions without CWRMA	Natural Conditions with CWRMA
		Whole Year	
Maximum	5,802	4,436[1]	4,436[1]
Average	27.3	10.9	16.3
Median	7.5	4.3	9.9
		May-September	
Average	7.0	4.4	10.0
Median	5.3	3.1	7.7

Note: the CWRMA release predominately impacts low and moderate flows, not high flows. Thus, the maximum simulated flows with and without CWRMA at the two locations are equivalent.

Table 66. Summary of HSPF simulated flows for Santa Margarita River at Fallbrook PUD (cfs), water year 2003-2018

	Baseline	Natural Conditions without CWRMA	Natural Conditions with CWRMA
		Whole Year	

Maximum	17,486	11,908[1]	11,908[1]
Average	35.9	18.2	23.6
Median	7.8	4.5	10.9
May-September			
Average	7.2	4.0	9.7
Median	5.0	2.9	7.4

Note: the CWRMA release predominately impacts low and moderate flows, not high flows. Thus, the maximum simulated flows with and without CWRMA at the two locations are equivalent.

12.0 Nutrients

The linked HSPF models provide a convenient summary of pollutant loads over a longer period compared to the WASP receiving water model, although results differ due to different representations of the algal growth cycle (e.g., two forms of macroalgae are simulated in WASP), reach scale, timestep (i.e., hourly for HSPF and about 30-seconds for WASP), interactions with the sediment, and more. The HSPF results are provided for weather experienced in water years 2003 through 2018. Although the model simulation begins in 1994, water year 2003 was chosen as the start because that is the first year in which the CWRMA discharge was present. Results for total phosphorus and total nitrogen loads are shown in Table 67 and Table 68 and concentrations are shown in Table 69 and

Table 70.

The natural condition scenario without CWRMA results in a reduction of nutrient loads relative to current conditions. Adding the CWRMA discharge to the natural condition increases loads, but the nutrient loads still remain below current rates. However, results for instream concentrations are more complex as the natural conditions scenario changes both the water balance and pollutant loads, in different ways. The natural condition scenario (without the CWRMA release) results in lower loads but tends to result in higher nutrient concentrations because flow is predicted to decline by a greater proportion than pollutant loads, especially for phosphorus, thus, concentrating nutrients in the river. Most notably, the predicted growing season median concentration of total phosphorus at Fallbrook is higher under the natural condition scenario (without CWRMA) than under the current baseline. The associated biostimulatory impacts of this phenomenon are discussed in subsequent sections. It is also the case that adding the CWRMA discharge on top of naturally discharging groundwater at the head of the gorge (which would be restored under the natural condition scenario) tends to decrease average concentrations because the additional flow provided by CWRMA dilutes concentrations naturally present in the river.

Unit area loads for natural land covers, which were developed during the calibrations of the middle and lower watershed HSPF models based on the literature and local data (e.g., nutrient grab samples collected at multiple locations), are listed in Table 71 (Tetra Tech, 2020; Tetra Tech, 2018).

Table 67. Summary of HSPF simulated total phosphorus loads (lb/day), water year 2003-2018

	Baseline	Natural Conditions without CWRMA	Natural Conditions with CWRMA

Santa Margarita River at Head of the Gorge (R390)			
	Whole Year		
Average	46.3	25.8	26.6
Median	1.66	1.32	2.23
	May-September		
Average	3.17	2.33	3.40
Median	1.76	1.31	2.41
Santa Margarita River at Fallbrook PUD (R118)			
	Whole Year		
Average	50.0	26.3	27.1
Median	1.96	1.01	1.73
	May-September		
Average	2.91	1.59	2.60
Median	1.69	0.90	1.62

Table 68. Summary of HSPF simulated total nitrogen loads (lb/day), water year 2003-2018

	Baseline	Natural Conditions without CWRMA	Natural Conditions with CWRMA
Santa Margarita River at Head of the Gorge (R390)			
	Whole Year		
Average	349.1	219.7	234.5
Median	26.7	12.3	30.5
	May-September		
Average	32.8	17.2	32.1
Median	21.9	11.8	24.2
Santa Margarita River at Fallbrook PUD (R118)			
	Whole Year		
Average	418.5	229.3	238.0
Median	32.2	11.5	21.5
	May-September		
Average	32.9	13.9	21.7
Median	24.1	10.2	17.9

Table 69. Summary of HSPF simulated total phosphorus concentration (mg/L), water year 2003-2018

	Baseline	Natural Conditions without CWRMA	Natural Conditions with CWRMA
Santa Margarita River at Head of the Gorge (R390)			

Whole Year			
Average	0.128	0.184	0.132
Median	0.033	0.049	0.036
May-September			
Average	0.082	0.102	0.066
Median	0.051	0.067	0.048
Santa Margarita River at Fallbrook PUD (R118)			
Whole Year			
Average	0.079	0.075	0.057
Median	0.051	0.045	0.031
May-September			
Average	0.069	0.074	0.049
Median	0.051	0.057	0.037

Table 70. Summary of HSPF simulated total nitrogen concentration (mg/L), water year 2003-2018

	Baseline	Natural Conditions without CWRMA	Natural Conditions with CWRMA
Santa Margarita River at Head of the Gorge (R390)			
Whole Year			
Average	1.23	2.05	1.62
Median	0.67	0.57	0.55
May-September			
Average	0.84	0.80	0.61
Median	0.73	0.64	0.55
Santa Margarita River at Fallbrook PUD (R118)			
Whole Year			
Average	0.99	0.84	0.66
Median	0.78	0.55	0.41
May-September			
Average	0.79	0.72	0.44
Median	0.67	0.64	0.41

Table 71. HSPF predicted total nitrogen and total phosphorus unit area loads (UALs) for natural covers in the middle and lower watersheds

	TN UAL (lb/ac/yr)	TP UAL (lb/ac/yr)

Land Cover (Aggregated)	Middle Watershed	Lower Watershed	Middle Watershed	Lower Watershed
Water	NA	NA	NA	NA
Forest	0.07	0.46	0.02	0.13
Chaparral/Scrub	0.21	0.99	0.13	0.20
Grassland/Herbaceous	0.02	0.41	0.02	0.16
Barren/Transitional	2.33	2.06	0.24	0.81

WASP receiving water model simulations are being used to inform target development to address biostimulatory impacts in the SMR. Compared to HSPF, the WASP model segmentation is finer and so is the temporal resolution as predictions are computed based on a dynamic time-step averages about 30-seconds (Tetra Tech, 2021). The simulation period of the WASP model is therefore shorter, covering water years 2016 through 2018, and results are presented for this period.

Average and median total nitrogen and total phosphorus concentrations predicted by WASP at Santa Margarita River near the Old Hospital, marking the downstream end of the perennial section of the river, are provided in Table 72 and Table 73. Similar to the HSPF results, the total phosphorus concentrations are elevated compared to the baseline for natural conditions without CWRMA; this occurs for year-round and growing season average and median total phosphorus concentrations due to the interwoven relationship between changes in streamflow and nutrients (i.e., lower streamflow concentrates nutrients in the river). Median year-round total nitrogen is also higher under natural conditions without CWRMA and there are minor reductions in the other total nitrogen concentration metrics. Total nitrogen and total phosphorus concentrations are reduced somewhat under natural conditions with CWRMA. Within the river, the flow augmentation dilutes natural concentrations of nutrients as well as nutrients attributed to the discharge, cumulating in lower total nitrogen and total phosphorus concentrations under natural conditions with CWRMA. The same is true for baseline conditions; with removal of the CWRMA discharge nutrient concentrations are about doubled for both TN and TP compared to baseline conditions with CWRMA and are higher compared to both natural conditions scenarios.

WASP predicted TN and TP loads at the Old Hospital, corresponding to the most downstream point in the WASP model, are shown for all four scenarios in Table 74.

Table 72. Summary of WASP simulated total phosphorus concentration (mg/L), water year 2016-2018

	Baseline with CWRMA	Baseline without CWRMA	Natural Conditions with CWRMA	Natural Conditions without CWRMA
	Santa Margarita River near Old Hospital			
	Whole Year			
Average	0.060	0.123	0.052	0.071
Median	0.042	0.089	0.038	0.052
	May-September			
Average	0.089	0.188	0.077	0.111

Median	0.068	0.124	0.066	0.093

Table 73. Summary of WASP simulated total nitrogen concentration (mg/L), water year 2016-2018

	Baseline with CWRMA	Baseline without CWRMA	Natural Conditions with CWRMA	Natural Conditions without CWRMA
	Santa Margarita River near Old Hospital			
	Whole Year			
Average	1.30	2.57	0.084	1.16
Median	1.08	2.16	0.082	1.15
	May-September			
Average	1.61	3.52	1.02	1.49
Median	1.48	2.58	1.01	1.45

Table 74. Summary of WASP simulated total phosphorus and total nitrogen annual average loads, water year 2016-2018, at Santa Margarita River near Old Hospital

	Baseline with CWRMA	Baseline without CWRMA	Natural Conditions with CWRMA	Natural Conditions without CWRMA
Total nitrogen	127,966	122,419	67,083	63,432
Total phosphorus	8,889	8,832	4,317	4,105

13.0 Water Temperature

Water temperature under natural conditions with and without the CWRMA release based on WASP simulations is summarized for Santa Margarita River near the Gorge, Rainbow Creek, Fallbrook, and near the Old Hospital (Table 75 to Table 78 and Figure 13 to Figure 16). The figures show the range in water temperature by month and the tables summarize the water temperature exceedance probability, or percent of time that a given water temperature level is equaled or exceeded. The difference between the current conditions and natural conditions without CWMRA scenarios quantify changes in water temperature due to all human activities whereas the difference between the scenarios with and without CWRMA (either baseline or natural conditions) quantify the impacts of the CWRMA release. The ranges in water temperature during most months of the year (e.g., March and May) at Rainbow Creek are wider under natural conditions without CWRMA compared to current conditions, reflecting more variability. However, the ranges in water temperatures under current conditions and natural conditions with CWRMA are similar at Rainbow Creek (e.g., in August, September, and November). This indicates that the CWRMA release is more influential in affecting water temperatures compared to other current human activities in the watershed. In the warm months of June through September, water temperatures are similar across the natural conditions scenarios and baseline at the Old Hospital, which is less directly influenced by the CWRMA release compared to upstream locations. Without CWRMA under current/baseline conditions there is less streamflow in the river; the water column is more susceptible to air temperature fluctuations, so the simulated water temperature range widens across months and locations.

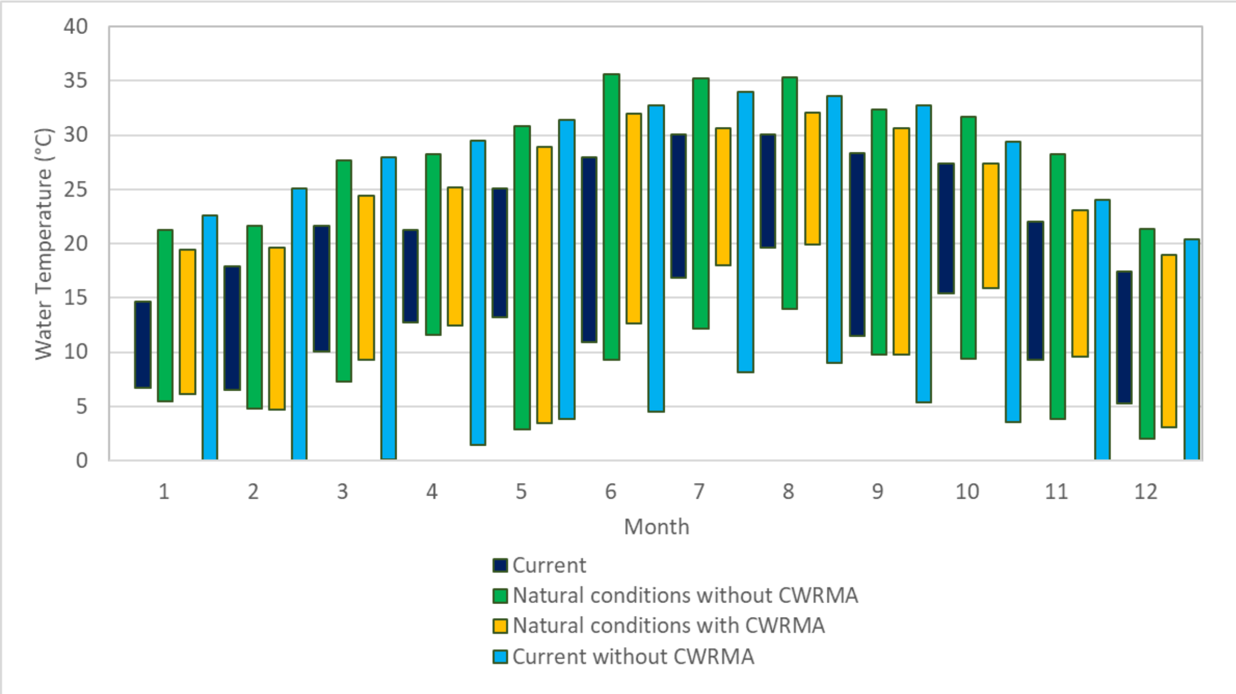


Figure 13. Water temperature range by month at Gorge

Table 75. Water temperature exceedance probability summary at Gorge

Exceedance Probability	Baseline with CWRMA	Baseline without CWRMA	Natural Conditions with CWRMA	Natural Conditions without CWRMA
10%	24.4	24.4	24.6	25.7
25%	22.1	19.5	21.2	21.6
50%	18.4	15.0	17.9	17.5
75%	14.0	11.1	13.7	13.2
90%	11.9	7.9	11.5	10.7

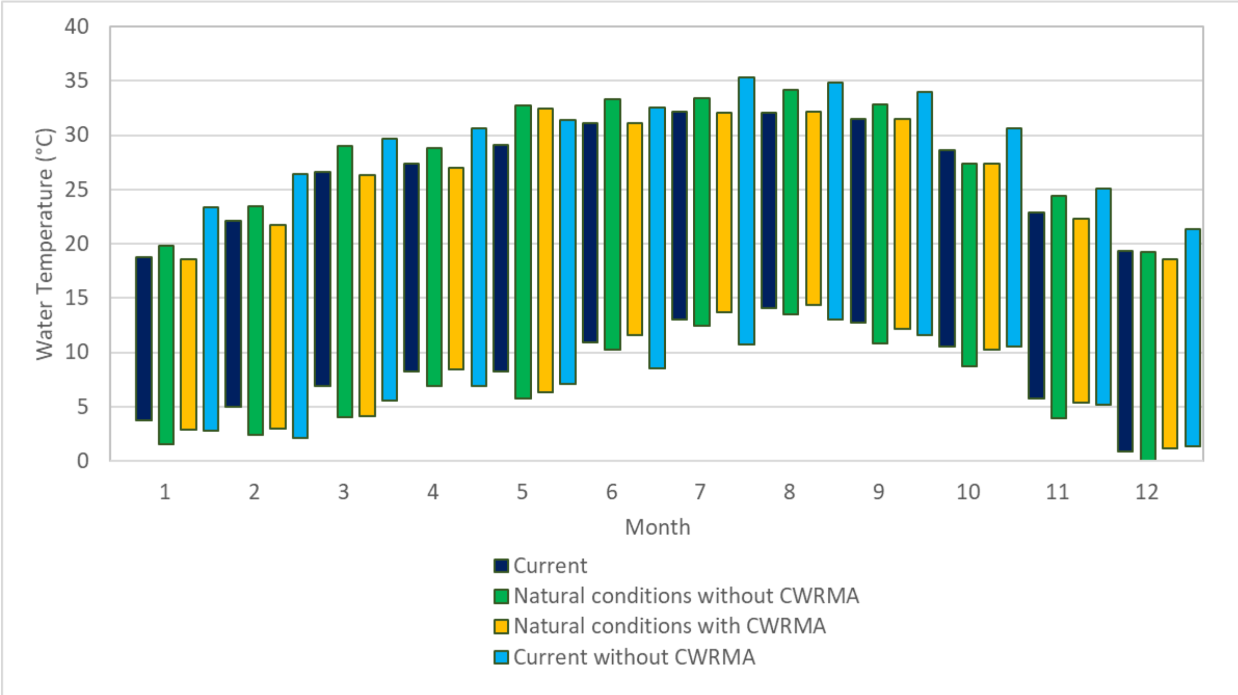


Figure 14. Water temperature range by month at Rainbow Creek

Table 76. Water temperature exceedance probability summary at Rainbow Creek

Exceedance Probability	Baseline with CWRMA	Baseline without CWRMA	Natural Conditions with CWRMA	Natural Conditions without CWRMA
10%	24.7	25.4	24.9	25.3
25%	20.8	20.5	20.8	20.7
50%	16.6	16.2	16.4	16.1
75%	13.0	12.5	12.8	12.4
90%	10.3	10.0	10.0	9.7

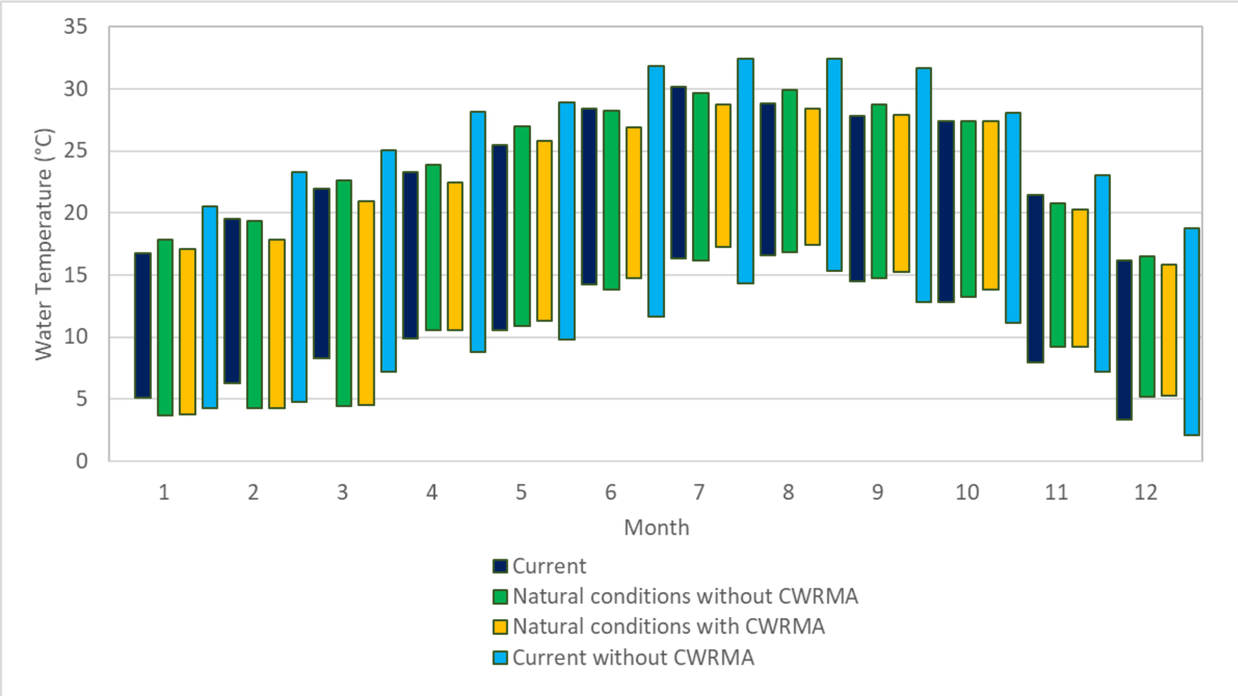


Figure 15. Water temperature range by month at Fallbrook

Table 77. Water temperature exceedance probability summary at Fallbrook

Exceedance Probability	Baseline with CWRMA	Baseline without CWRMA	Natural Conditions with CWRMA	Natural Conditions without CWRMA
10%	23.9	24.7	23.7	24.0
25%	20.9	21.0	20.8	20.6
50%	17.4	17.0	17.2	17.0
75%	13.8	13.6	13.7	13.7
90%	11.2	11.1	11.2	11.3

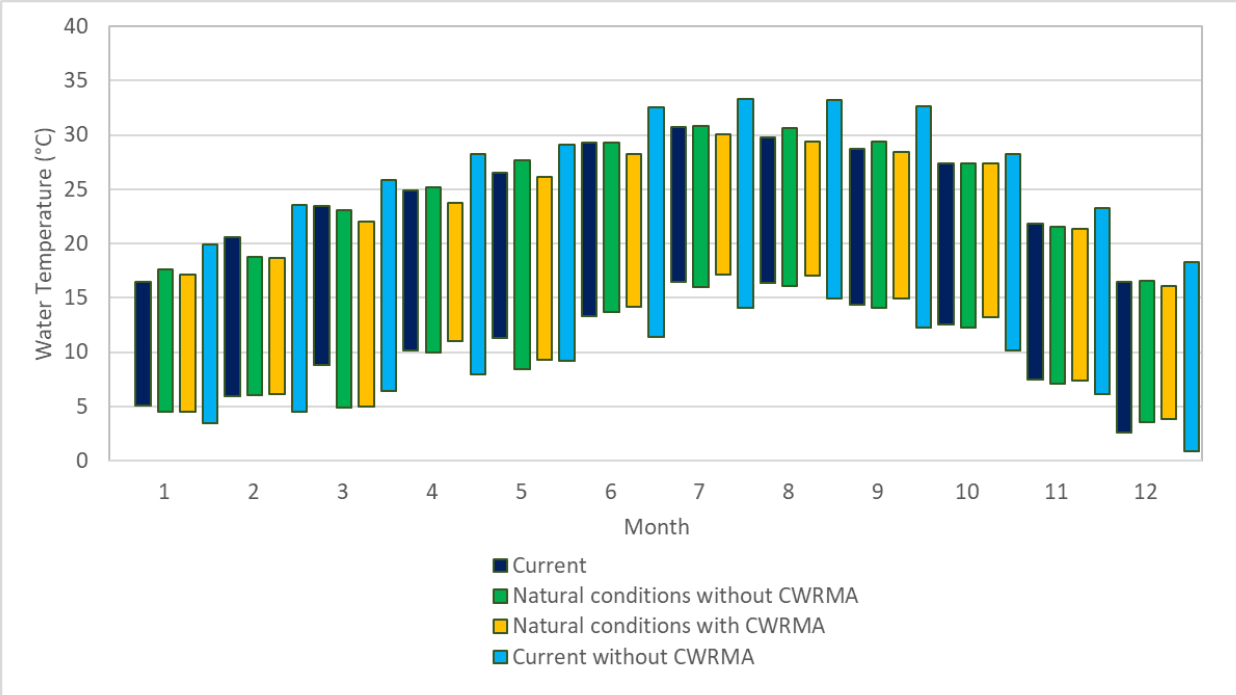


Figure 16. Water temperature range by month at Old Hospital

Table 78. Water temperature exceedance probability summary at Old Hospital

Exceedance Probability	Baseline with CWRMA	Baseline without CWRMA	Natural Conditions with CWRMA	Natural Conditions without CWRMA
10%	24.5	25.2	24.3	24.7
25%	21.3	21.2	21.1	21.1
50%	17.4	17.0	17.2	17.0
75%	13.6	13.2	13.4	13.3
90%	11.0	10.7	10.9	10.8

14.0 Dissolved Oxygen

Dissolved oxygen levels under natural conditions with and without the CWRMA release were evaluated with the WASP receiving water model. The predicted seven-day average of daily minima (7DADMin) dissolved oxygen concentration was computed using six-hour rolling average WASP output (i.e., consistent with the method being applied for target development). The frequencies of excursions, equal to the percent of time that the 7DADMin is less than 6 mg/L, are listed in

Location	Baseline with CWRMA	Baseline without CWRMA	Natural Conditions with CWRMA	Natural Conditions without

				CWRMA
Gorge	6.5%	70.6%	4.2%	25.4%
Below Rainbow Creek confluence	28.7%	60.5%	22.5%	31.2%
Below Fallbrook	11.7%	18.1%	9.6%	16.6%
Near Old Hospital	10.8%	22.3%	0.0%	14.9%

Table 79 for Santa Margarita River at the Gorge, Rainbow Creek, Fallbrook, and near the Old Hospital for current conditions and natural conditions, both with and without CWRMA. The values in

Table 79 incorporate a 10% allowable exceedance, in which excursions below 6 mg/L were allowed 10% of the time. Note that the plots in Figures 11-14 do not take the 10% allowable exceedance into account,

Location	Baseline with CWRMA	Baseline without CWRMA	Natural Conditions with CWRMA	Natural Conditions without CWRMA
Gorge	6.5%	70.6%	4.2%	25.4%
Below Rainbow Creek confluence	28.7%	60.5%	22.5%	31.2%
Below Fallbrook	11.7%	18.1%	9.6%	16.6%
Near Old Hospital	10.8%	22.3%	0.0%	14.9%

and thus, the values in

Table 79 and the figures do not match. Excursions are less frequent compared to current conditions for natural conditions if the CWRMA release was maintained. However, without the CWRMA release, the

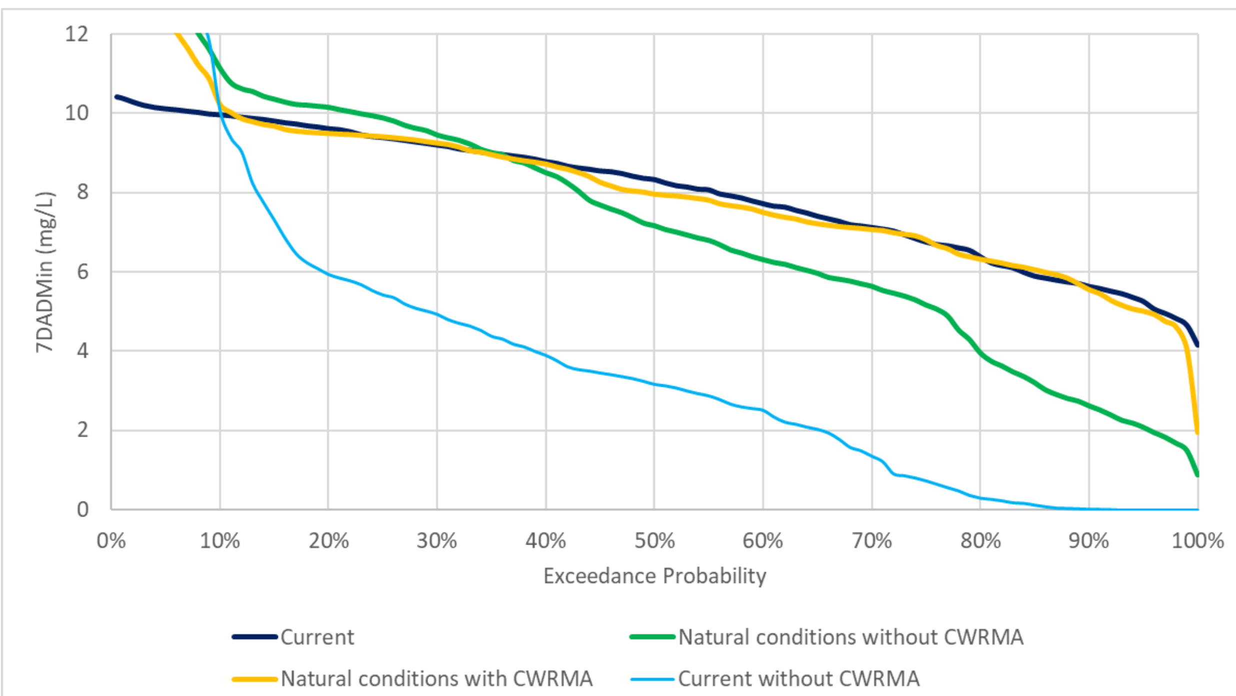
Location	Baseline with CWRMA	Baseline without CWRMA	Natural Conditions with CWRMA	Natural Conditions without CWRMA
Gorge	6.5%	70.6%	4.2%	25.4%
Below Rainbow Creek confluence	28.7%	60.5%	22.5%	31.2%
Below Fallbrook	11.7%	18.1%	9.6%	16.6%
Near Old Hospital	10.8%	22.3%	0.0%	14.9%

frequency of excursions is higher under natural conditions compared to current conditions. This is, in part, attributed to the higher water temperatures being further elevated (e.g., see maximum of range by month shown in Figure 14 and 10th percentile exceedance probabilities for water temperature listed in Table 76), which decreases oxygen saturation concentration in water. In addition to the direct effects of the water temperature of CWRMA release water, the CWRMA discharge alters streamflow and flow depth. Under natural conditions with CWRMA, the average flow depth at Santa Margarita River near Rainbow Creek, for example, is about 25 percent deeper compared to current conditions. Conversely, without the CWRMA release, the average flow depth at this location under natural conditions is about 8 percent shallower than current conditions. The solar heat load is distributed over this shallower depth, making the river more susceptible to 7DADMin excursions. Furthermore, total phosphorus and total nitrogen concentrations during the growing season are similar to current conditions under natural conditions without CWRMA whereas these are notably reduced with the CWRMA release added back in (i.e., in part due to the dilution caused by the augmented flow, see Table 69 and

Table 70). Without CWRMA under baseline conditions, 7DADMin exceedances are also more common compared to current conditions with CWRMA. Exceedance probability plots for 7DADMin are shown in Figure 17 to Figure 20. Curves, or parts of the curves, that shift upward and rightward indicate improvements in the 7DADMin. Predicted year-round average dissolved oxygen concentrations are higher under natural conditions compared to current conditions with CWRMA, which exhibits the poorest DO response across the scenarios (Table 80).

Table 79. Predicted frequency of 7DADMin excursions (<6 mg/L) for COLD beneficial use, year-round, with 10 percent allowable exceedances

Location	Baseline with CWRMA	Baseline without CWRMA	Natural Conditions with CWRMA	Natural Conditions without CWRMA
Gorge	6.5%	70.6%	4.2%	25.4%
Below Rainbow Creek confluence	28.7%	60.5%	22.5%	31.2%
Below Fallbrook	11.7%	18.1%	9.6%	16.6%
Near Old Hospital	10.8%	22.3%	0.0%	14.9%



Note: The frequencies of excursions below 6 mg/L listed in this table include a 10% allowable exceedance.

Figure 17. Exceedance probability for 7DADMin at Gorge

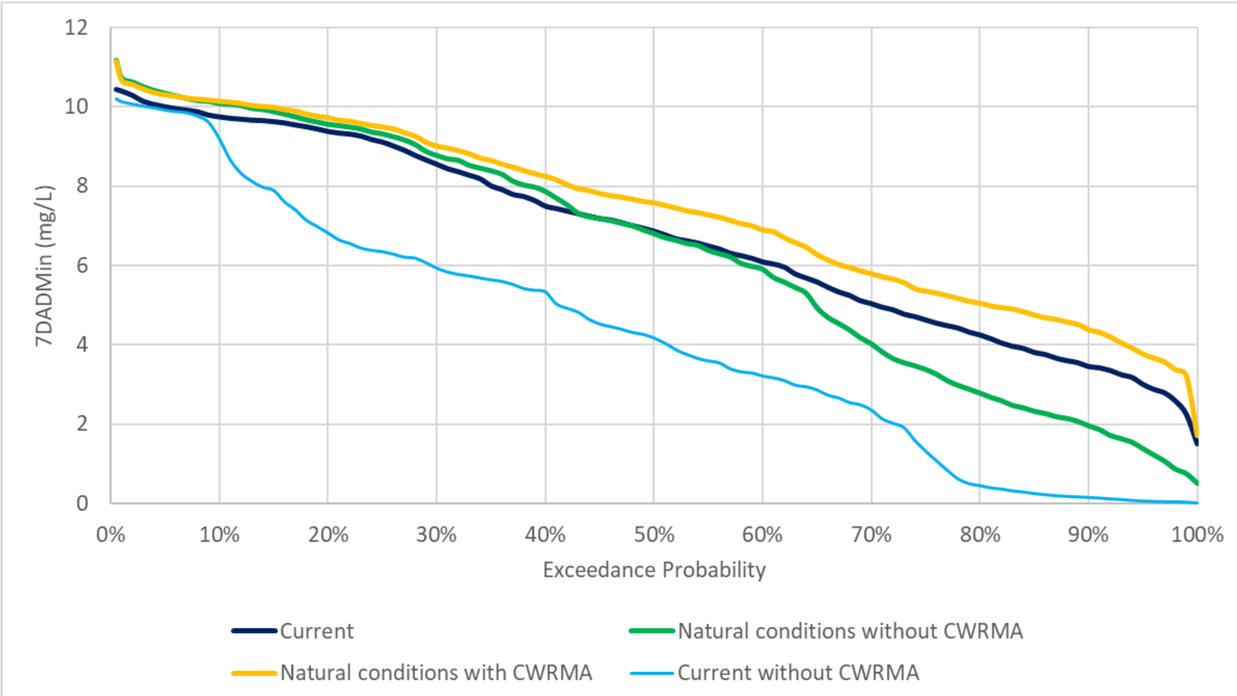


Figure 18. Exceedance probability for 7DADMin at Rainbow

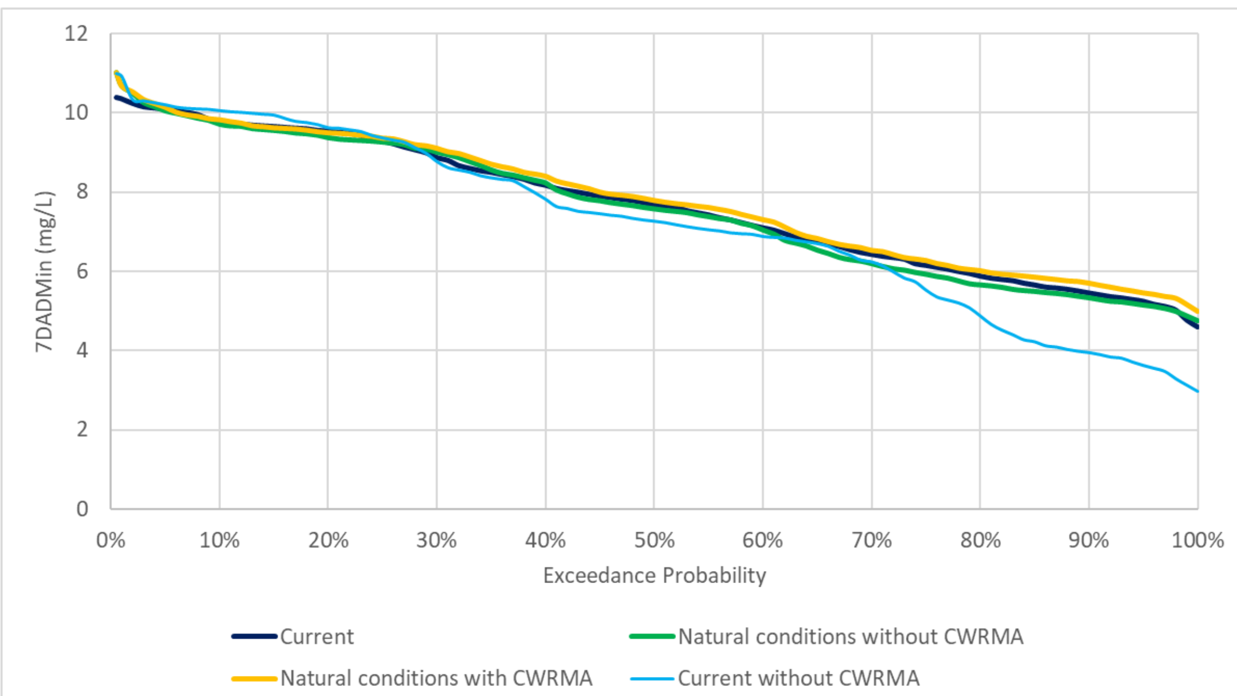


Figure 19. Exceedance probability for 7DADMin at Fallbrook

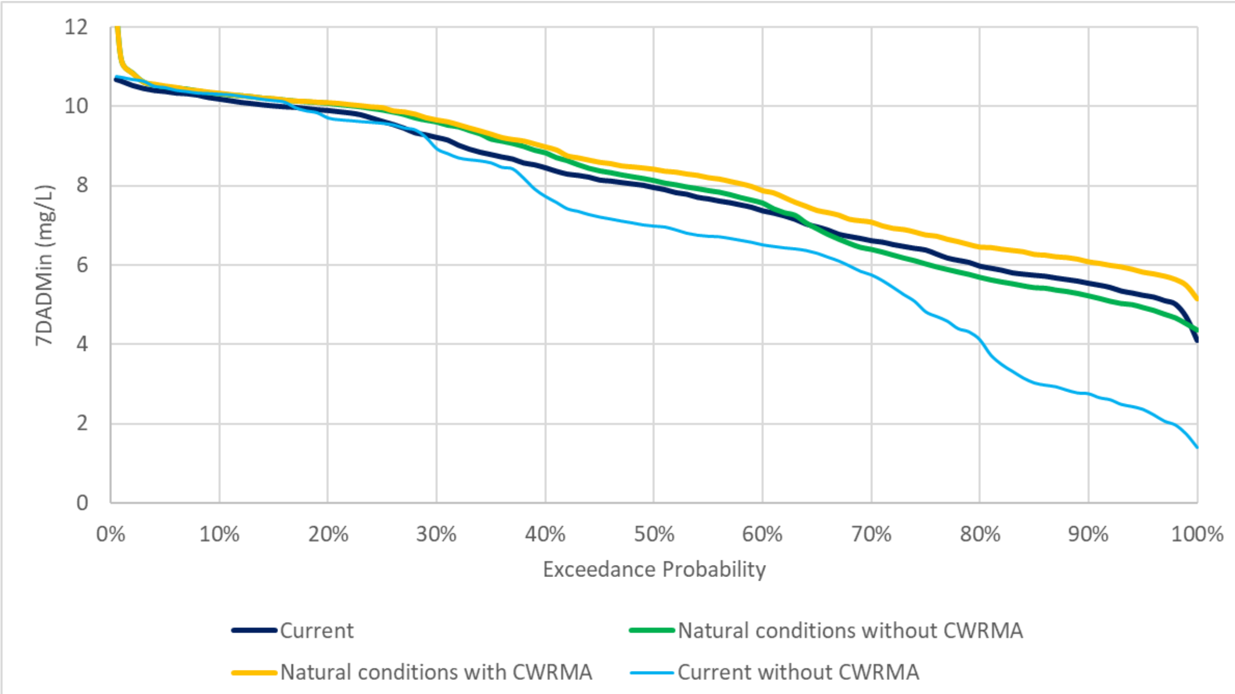


Figure 20. Exceedance probability for 7DADMin near Old Hospital

Table 80. Predicted average dissolved oxygen concentration (mg/L), year-round

Location	Baseline with CWRMA	Baseline without CWRMA	Natural Conditions with CWRMA	Natural Conditions without CWRMA
Gorge	8.58	8.90	9.33	9.56
Below Rainbow Creek confluence	8.41	6.46	8.95	8.56
Below Fallbrook	8.49	8.48	8.58	8.56
Near Old Hospital	8.73	8.31	9.00	8.90

The mean diel variability, equal to the absolute difference from the daily mean dissolved oxygen concentration, is plotted by month in Figure 21 through Figure 24. For warm months, the diel variability tends to be higher under natural conditions without CWMRA compared to current conditions with CWRMA whereas it tends to be lower under natural conditions with CWRMA releases maintained. This indicates that the CWRMA discharge is facilitating the beneficial narrowing of the DO diel range (or worsening it in the case of the removal of the discharge); this is also evidenced in the differences between the current conditions with and without CWRMA runs. The differences between current conditions and natural conditions with the CWRMA release isolate the impacts of the watershed (i.e., removal of human influence) on diel variability. At most locations, the natural watershed condition notably reduces diel variability. Near the Old Hospital, for example, diel variability is about 1.6 mg/L under current conditions and 1.2 mg/L under natural conditions (with CWRMA).

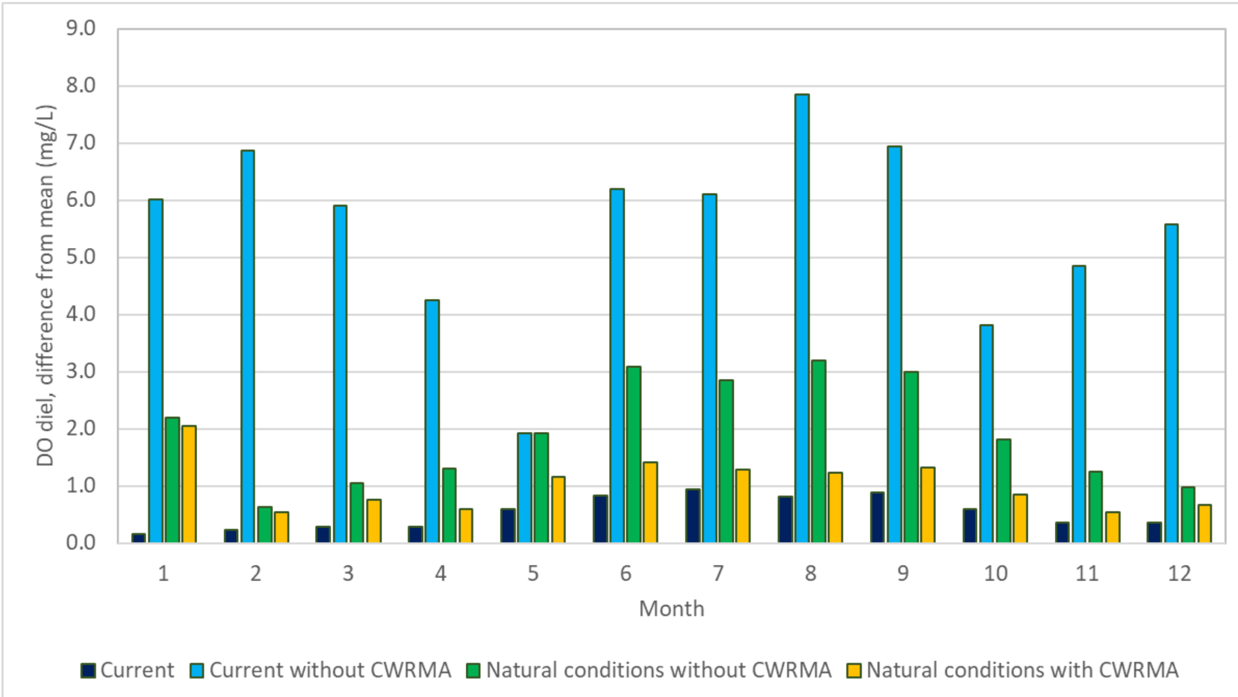


Figure 21. Mean monthly dissolved oxygen diel variability (deviation from mean) at Gorge

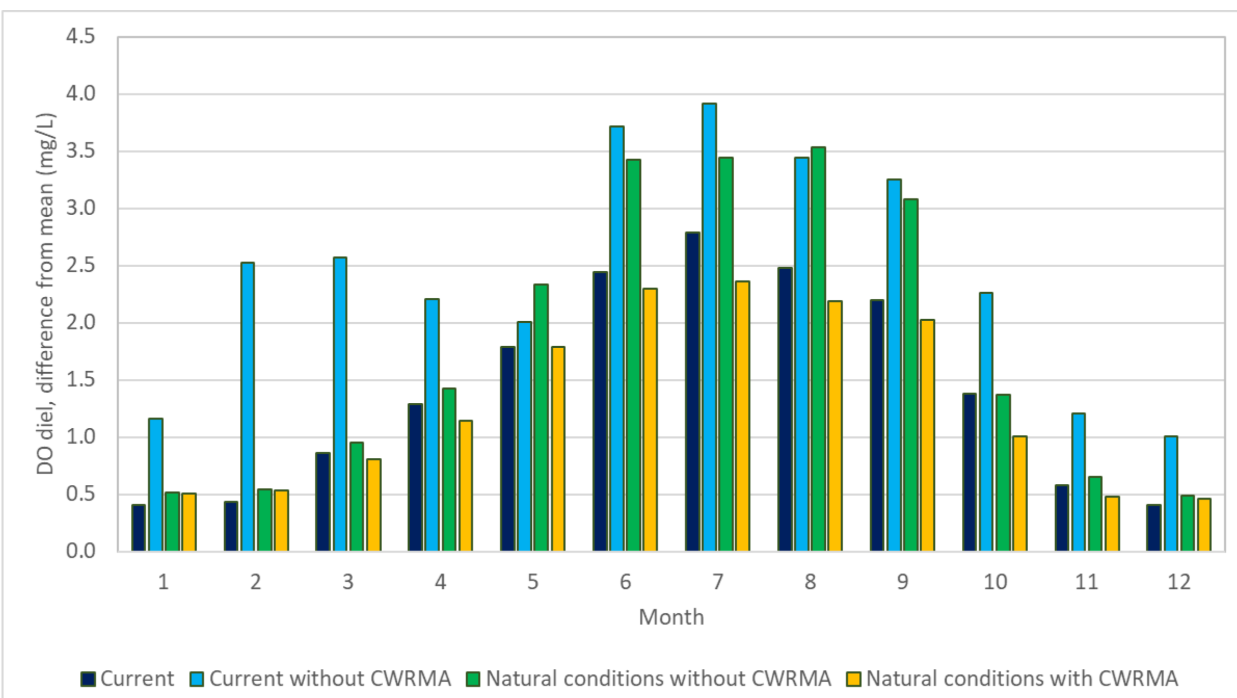


Figure 22. Mean monthly dissolved oxygen diel variability (deviation from mean) at Rainbow Creek

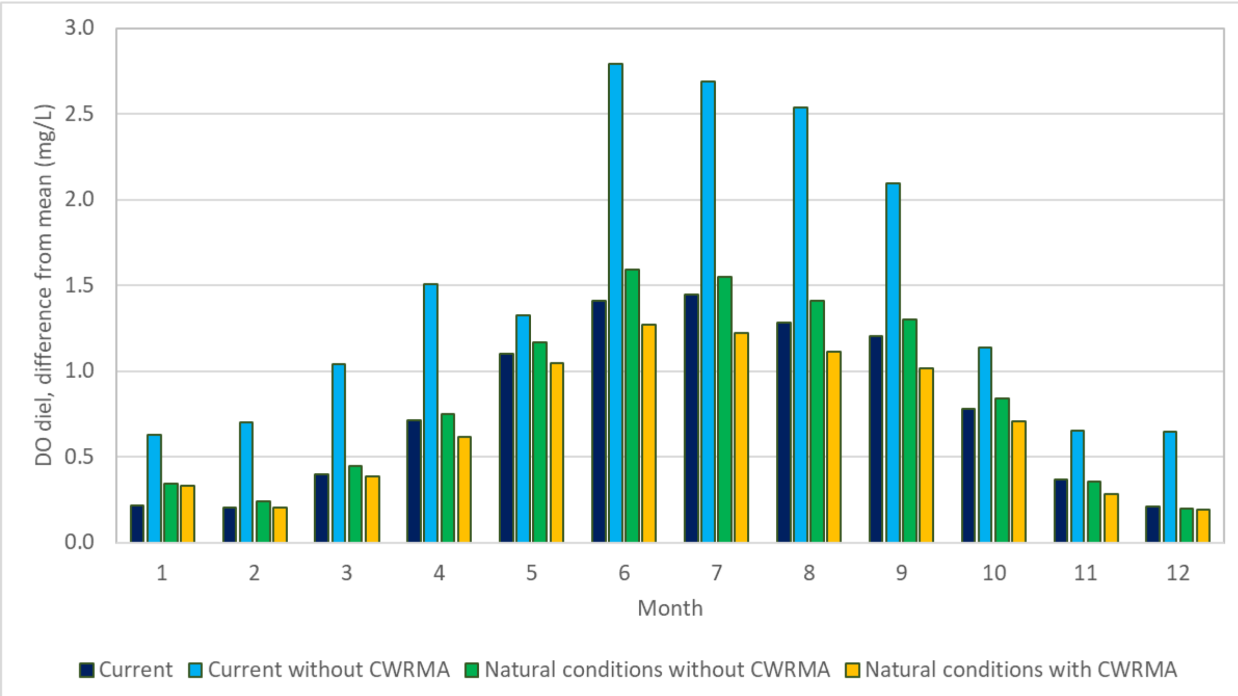


Figure 23. Mean monthly dissolved oxygen diel variability (deviation from mean) at Fallbrook

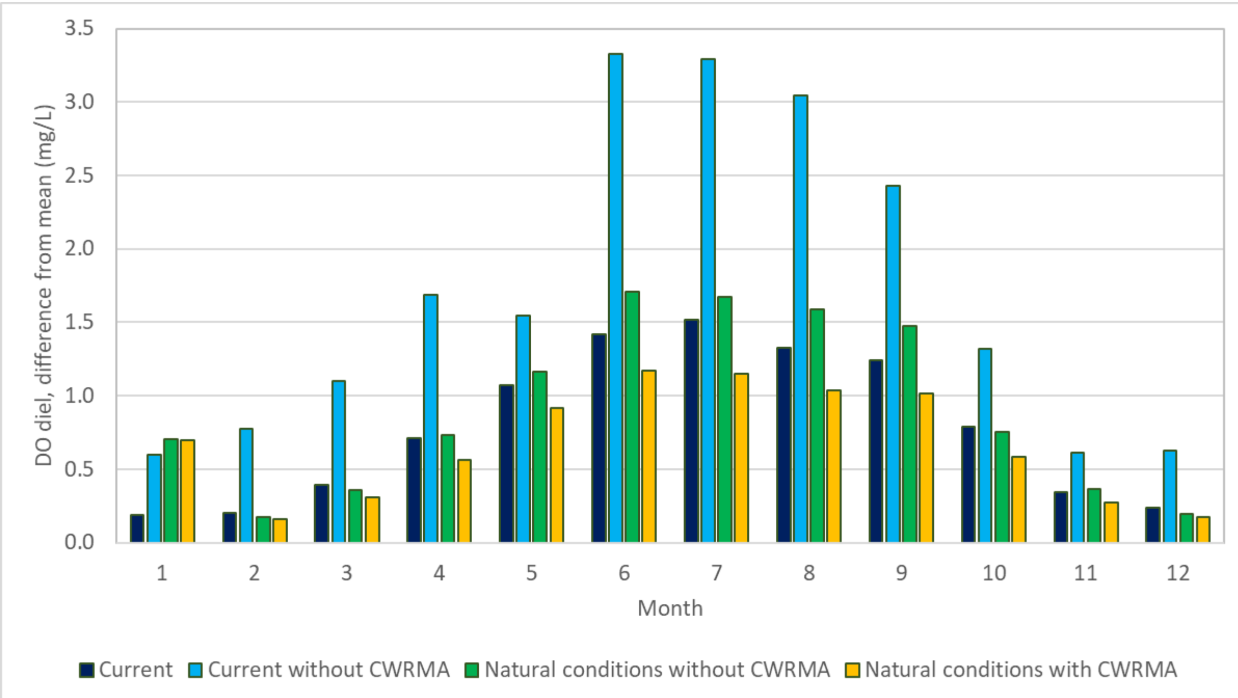
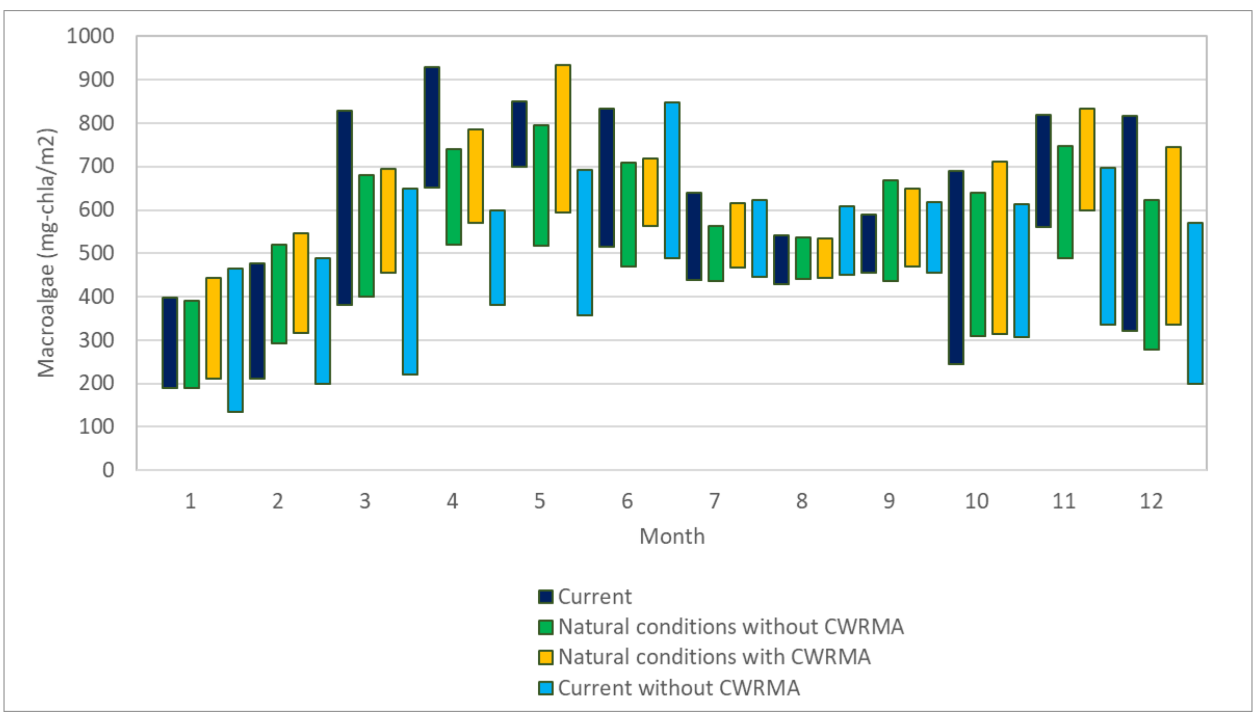


Figure 24. Mean monthly dissolved oxygen diel variability (deviation from mean) near Old Hospital

15.0 Macroalgae

Impacts of natural conditions on predicted macroalgae density, in terms of chlorophyll-*a* (i.e., mg-chl-*a*/m^2), were quantified with the WASP receiving water model. Figure 25 to Figure 28 show the range in macroalgae by month for current conditions and natural conditions with and without the CWRMA



release. Year-round average macroalgae densities are listed in Table 81. Collectively, the changes to streamflow, water temperature, and nutrient loads and concentrations alter macroalgae some, but do not show significant reductions in macroalgae under natural conditions. As discussed in Section 12.0., total phosphorus concentrations during the growing season are higher under the natural conditions without CWRMA (Table 72). While the total phosphorus load is lower, streamflow is also reduced, concentrating total phosphorus in the water column. Growing season total nitrogen concentrations are reduced, although not by a significant amount (Table 73). Due to these complex interactions, algal presence is only minorly effected. Nutrient concentrations are reduced slightly under natural conditions with CWRMA; median growing season total phosphorus near the Old Hospital is reduced from 0.068 to 0.066 mg/L and total nitrogen is reduced from 1.48 mg/L to 1.01 mg/L. Nevertheless, these nutrient levels are sufficient to support macroalgal growth and activity at levels similar to current conditions.

Figure 25. Macroalgae at chlorophyll-*a* density (mg-chl-*a*/m^2) range by month at Gorge

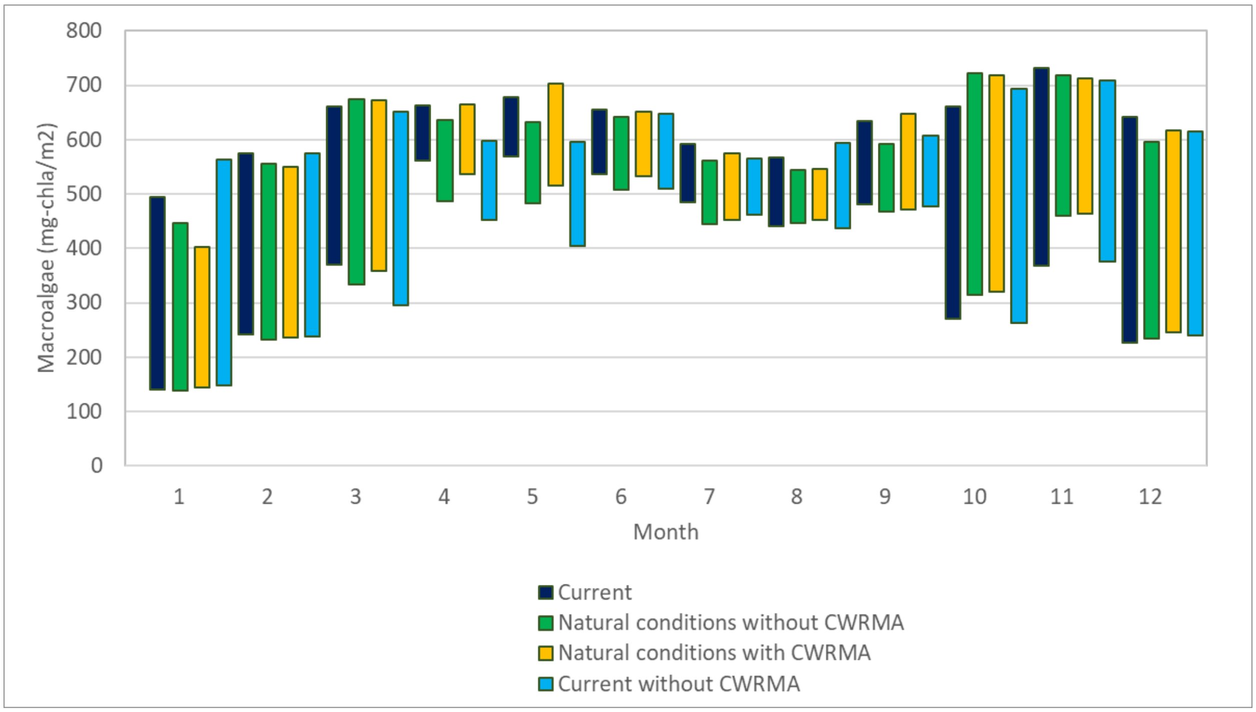


Figure 26. Macroalgae as chlorophyll-*a* density (mg-chl-*a*/m^2) range by month at Rainbow

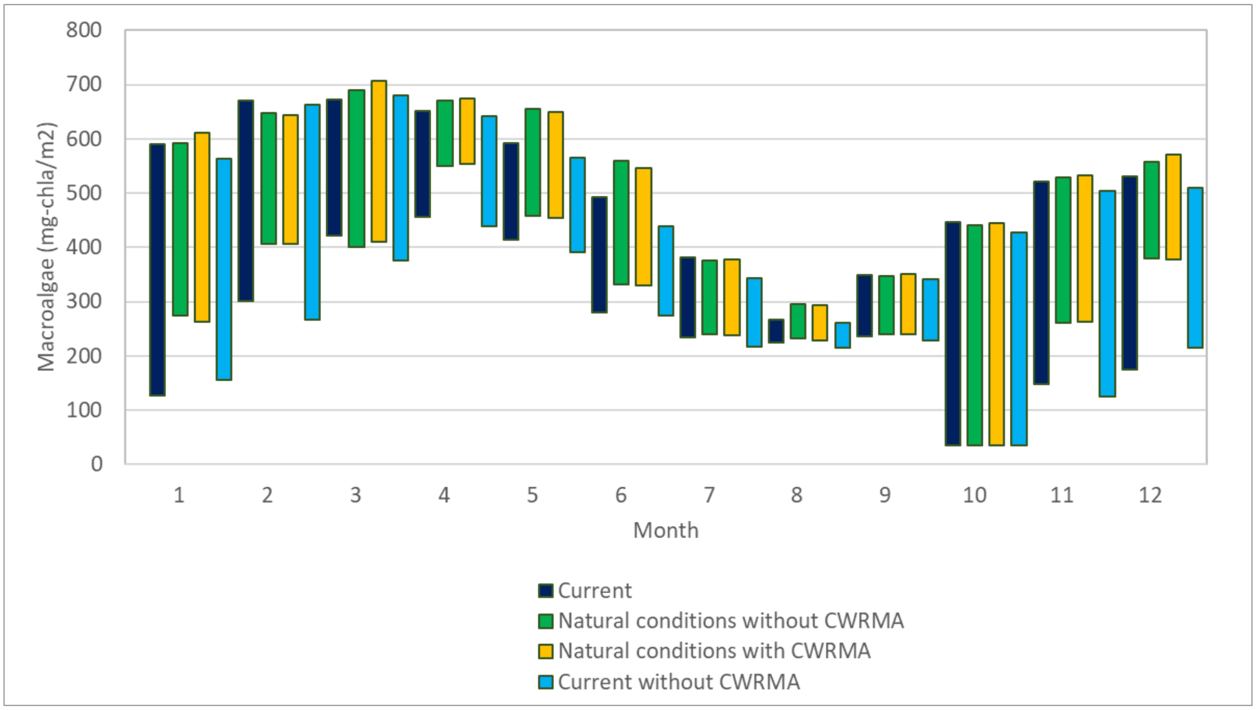


Figure 27. Macroalgae as chlorophyll-*a* density (mg-chl-*a*/m^2) range by month at Fallbrook

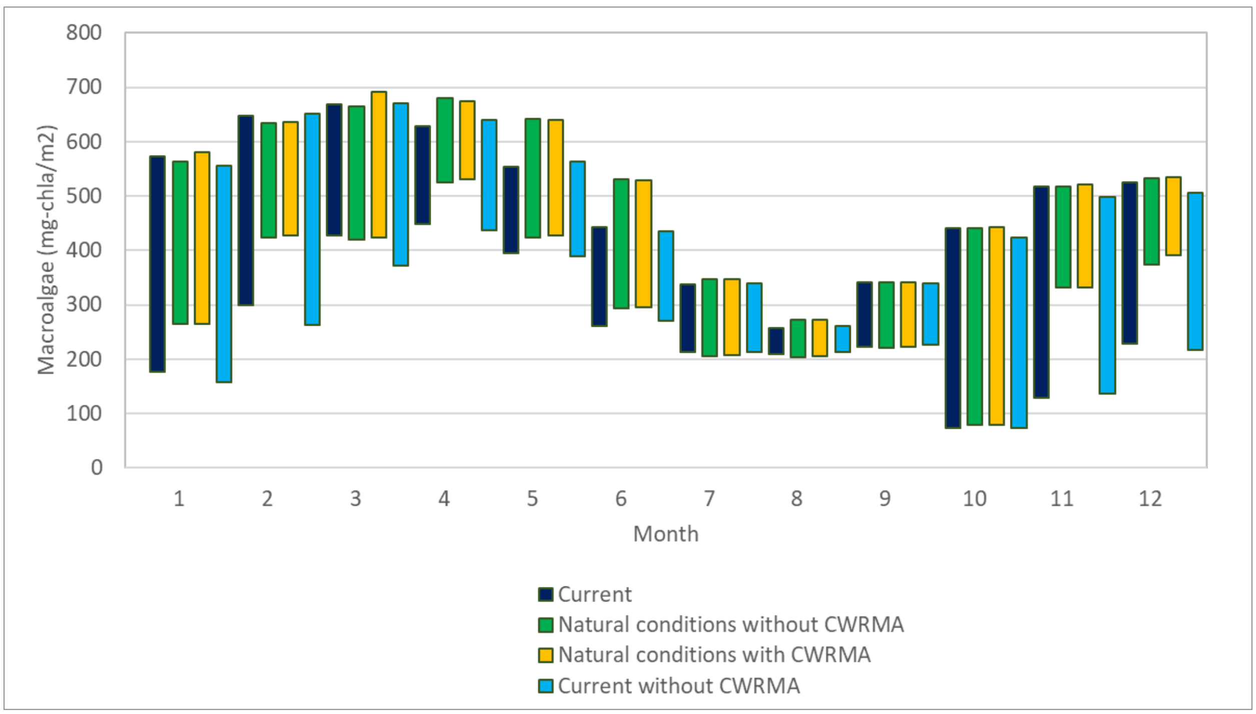


Figure 28. Macroalgae as chlorophyll-*a* density (mg-chl-*a*/m^2) range by month near Old Hospital

Table 81. Predicted average chlorophyll-*a* concentration (mg-chl-*a*/m^2), year-round

Location	Baseline with CWRMA	Baseline without CWRMA	Natural Conditions with CWRMA	Natural Conditions without CWRMA
Gorge	568	491	566	519
Below Rainbow Creek confluence	521	510	513	499
Below Fallbrook	403	385	443	442
Near Old Hospital	387	382	431	428

16.0 Source Loads

The jurisdictional areas being applied in the development of allocations for the Santa Margarita River (above the Old Hospital) were used to tabulate and apportion the natural condition loads. Both the allocations and the natural conditions loads are tabulated below the Old Hospital and represent at-source, year-round, dry weather loads. The baseline, or current condition (i.e., no reduction), total at-source, year-round, dry weather TN load above the Old Hospital is about 59,975 lbs/yr whereas the comparable natural conditions load is 15,228 lbs/yr. Thus, about 25 percent of the current load is attributed to natural loading. Similarly, the current condition total TP load is 2,782 lbs/yr and the natural conditions load is 730 lbs/yr, meaning about 26 percent of the current load is attributed to natural loading.

Table 82. At-source total nitrogen loads (lbs/yr) for year-round dry weather (WY 2009-2018) under natural conditions

Land use/cover Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		CALTRANS	SMR Watershed (above Old Hospital)	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
Chaparral/Scrub	632	5,584	204	3,800	11	806	103	950	11,140
Forest	110	745	7	364	0	79	0	118	1,305
Grassland/Herbaceous	85	746	4	349	2	24	3	93	1,211
Transitional	303	303	282	282	3	71	4	591	1,247
Water	7	284	0	30	1	3	0	8	325
Total	1,137	7,662	497	4,825	17	982	109	1,760	15,228

Table 83. At-source total phosphorus loads (lbs/yr) for year-round dry weather (WY 2009-2018) under natural conditions

Land use/cover Category	San Diego County		Riverside County		Camp Pendleton, Other Federal Land		CALTRANS	SMR Watershed (above Old Hospital)	
	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Total MS4	Total Upland Load
Chaparral/Scrub	34.5	291.3	14.5	179.7	0.8	37.8	5.3	55.1	563.8
Forest	5.6	38.4	0.4	18.3	0.0	3.8	0.0	6.1	66.6
Grassland/Herbaceous	4.5	39.9	0.2	17.6	0.1	1.1	0.1	5.0	63.6
Transitional	8.1	8.1	7.7	7.7	0.1	1.9	0.1	16.0	33.9
Water	0.0	0.0	0.0	2.3	0.0	0.1	0.0	0.0	2.4
Total	52.7	377.8	22.9	225.6	1.0	44.7	5.5	82.2	730.2

4. References

Tetra Tech. 2021. Santa Margarita River WASP Nutrient Response Model. Prepared for Southern California Coastal Water Research Project by Tetra Tech, Inc.

Tetra Tech. 2020. Santa Margarita River Upper Watershed HSPF Model. Prepared for County of San Diego Watershed Planning Program by Tetra Tech, Inc.

Tetra Tech. 2018. Santa Margarita River Watershed Model and Lower River Nutrient Response Models.

Prepared for County of San Diego Watershed Planning Program by Tetra Tech, Inc.