SCIENCE PLAN TO SUPPORT THE DEVELOPMENT OF A NUTRIENT CONTROL PROGRAM FOR CALIFORNIA WADEABLE STREAMS

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INTRODUCTION AND GOAL OF DOCUMENT

The California State Water Resources Control Board (State Water Board) is developing nutrient objectives and a program of implementation for the state's surface waters. State Water Board staff has developed a Work Plan that describes an overarching strategy, process, and technical work elements that will govern the development of nutrient objectives for freshwater and estuarine habitats (SWRCB 2014). During the first phase, State Water Board staff intends to establish a narrative objective applicable to all water body types and numeric guidance specifically for wadeable streams. The Work Plan outlines six tasks to accomplish that goal (Table 1). Three of these, Tasks 2, 3, and 5, have technical elements. In addition, the State Water Board Work Plan provides guiding principles for nutrient objective development describing the paradigm within which the technical elements must be structured (Table 2).

Table 1. Descriptions of State Water Board tasks to complete the first phase of nutrient objective development (from SWRCB 2014)

No.	Task	Description
1	Outreach	Actively reaching out to technical, regulatory, regulated, and non-governmental stakeholders to ensure that their interests, ideas, suggestions, and concerns are fully considered
2	Conceptual Approaches, Water body Definition & Classification	Provides the problem statement, an overview of conceptual approaches to nutrient objective development, and definitions and classification of water bodies.
3	Conduct and Synthesize Science to Support Numeric Guidance in Wadeable Streams	Science to support policy decisions on numeric guidance (i.e. selection of abiotic and/or ecological response indicators, numeric endpoints, and use of models to establish linkage to nutrient management in wadeable streams).
4	Implementation Plan Development	Defines how nutrient objectives will be used in regulatory programs such as 303(d) listing, NPDES compliance, 401 certification, etc.
5	Implementation Plan Technical Support	Provides sufficient method standardization, data transfer formats, documentation, and education for widespread, consistent, effective implementation.
6	Rulemaking	The legislatively defined public process of developing, adopting, and implementing objectives

The purpose of this Science Plan is to develop technical information that can be utilized by the State Water Board in developing nutrient policy and management strategies. This document describes the background and context, the major scientific elements, the conceptual approach, and timeline for deliverables to Task 3 (Conduct and Synthesize Science to Support Numeric Guidance in Wadeable Streams) and Task 5 (Implementation Plan Technical Support). All elements include outreach to actively engage regulatory, stakeholder and science panel advisory groups to solicit critical review of technical work plans and products. This will be accomplished through distribution of relevant documents in advance of meetings and oral presentations and discussions at meetings.

Table 2. State Water Board staff guiding principles for development of nutrient objectives (from SWRCB 2014).

The State should develop nutrient objectives that address nutrient pollution and biostimulatory conditions (Fig. 1). Environmental variables such as hydrology, etc. can modify the ecosystem response to nutrients. Anthropogenic activities that alter these environmental variables can be biostimulatory (i.e. lead to increased eutrophication), even under low nutrient conditions. Therefore the policy should address both nutrient pollution and biostimulatory conditions.
The State should develop narrative nutrient objectives with numeric guidance. The addition of numeric guidance to narrative objectives provides two important benefits: 1) a framework for consistent quantitative assessments and interpretation; and 2) the potential to trigger enforcement and remedial actions that narrative objectives do not.
Numeric guidance should have a strong linkage to beneficial use. Nutrient pollution results in adverse ecological responses in a water body. These ecological responses are directly linked to beneficial uses. The State is considering the option that nutrient objectives may consist of a set of numeric endpoints for these biological and chemical indicators, plus models to establish water body specific nutrient numeric targets.
The State should have numeric guidance for all water body types. The State Water Board intends to develop numeric guidance that translates the narrative nutrient objective for all water body types.
There should be statewide consistency with regional flexibility. Statewide consistency is important for equity among stakeholders. However, the State has many different ecosystems, each of which has varying biological characteristics. Therefore, a defensible statewide program must accommodate the unique qualities of each ecoregion. Furthermore, our knowledge of the ecology of our water bodies varies throughout the State so the refinement of numeric guidance will likely proceed at different rates in different regions.

REGULATORY CONTEXT FOR PROPOSED SCIENCE

In 1999, the State Water Board began development of nutrient objectives, focused on streams and lakes. Pilot studies were conducted to analyze existing data and explore alternative approaches. Based on these pilot studies, in 2011 State Water Board staff proposed two options for nutrient objectives under consideration for CEQA scoping: 1) numeric guidance based on EPA ecoregional reference criteria (US EPA 2000a) and 2) the Nutrient Numeric Endpoint (NNE) approach (SWQCB Nutrient Policy CEQA Scoping 2011). Water Board staff has designated the NNE as their preferred option. EPA ecoregional reference criteria have been established for the xeric west (US EPA 2000a), so the technical elements proposed in this plan are focused on supporting the NNE approach.

The NNE is comprised of two components. First, it will include a suite of ecological response indicator (e.g., algal abundance and community metrics, dissolved oxygen) that have numeric endpoints linked to beneficial use protection (Figure 1). Second, it will include models to link the response indicator assessment endpoints to site-specific numeric nutrient targets and other potential management controls.

Previous work on the NNE framework for streams and lakes included a conceptual model and review of applicable indicators, recommended assessment endpoints, and a suite of models to translate assessment endpoints to nutrient targets (Tetra Tech 2006 Appendix 1). These models merit additional explanation.

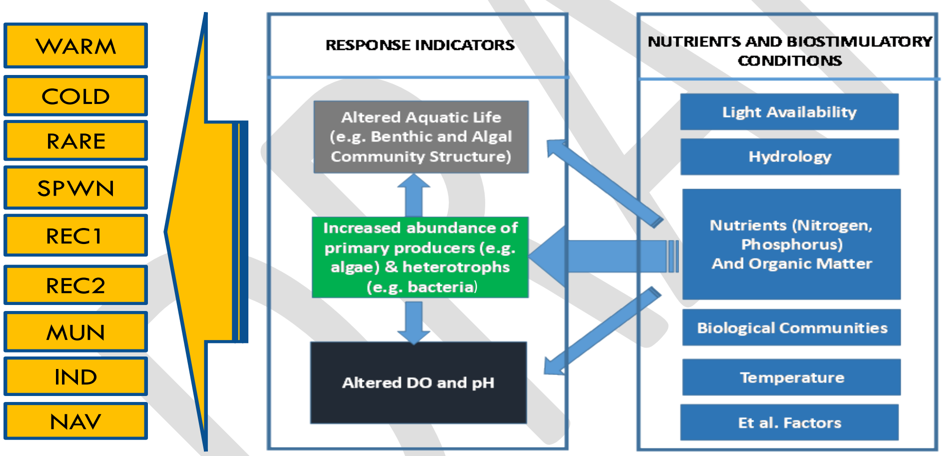

Figure 1. Conceptual model underlying the Nutrient Numeric Endpoints (NNE) approach. Assessment endpoints would be based on response indicators such as algal abundance and algal community metrics, dissolved oxygen and pH, which are linked to ecosystem services and beneficial uses. Statistical or process models could be developed to link those assessment endpoints back to management of nutrient and stream co-factors (which include biostimulatory conditions).

Models that could be used to develop and evaluate numeric nutrient targets fall into two general types that bracket a range of possible models: 1) Reach- or watershed- specific mechanistic or process models; these models require extensive data to develop, are more temporally and spatially explicit, and can be used for scenario analyses; and 2) regional or statewide statistical models, which have less flexibility for evaluation of site-specific management scenarios, but they are less resource intensive to develop for a region and can also provide a direct measure of uncertainty. Statewide, it is impractical to develop site-specific process models for all water bodies. Therefore, the State Water Board staff is interested in offering statistical models that can be used in establishing "default" nutrient targets for a water body, with the intent to allow stakeholders the flexibility to work with their respective Regional Boards to develop a mechanistic or process model for a watershed or site-specific water body, supported by adequate data. These process models could be used to explore alternative targets and identify implementation options involving management of nutrients and biostimulatory conditions.

A set of statewide models for streams has previously been developed and are packaged in a Benthic Biomass Spreadsheet Tool (BBST, Tetra Tech 2006). Two types of models are included in the BBST: 1) a statistical model based on empirical field data that was developed by Dodds et al. (1998) for temperate streams in North America and 2) simplified versions of the QUAL2K, an EPA-supported steady state, mechanistic model.

Originally, the development of the BBST models occurred without an abundance of data from California wadeable streams. Due to a substantial investment in stream bioassessment by State and local agencies over the past 10 years, a dataset containing variables such as nutrients, stream and landscape environmental measures, algal abundance, and algal and benthic macroinvertebrate community structure is now available for California wadeable streams. In addition, the amount of peer-reviewed literature on nutrients in wadeable streams has increased substantially over the last decade. State Water Board staff are interested in technical analyses and synthesis of newly available science to support policy decisions on the implementation of nutrient objectives.

WADEABLE STREAM SCIENCE PLAN ELEMENTS AND APPROACH

This Science Plan to support nutrient policy development and management strategies in California wadeable streams consists of two major elements:

Element 1: Conduct and Synthesize Science Supporting Development of Numeric Guidance for Wadeable Streams

Element 2: Provide Technical Support for Implementation Plan Development

Several terms used throughout this document merit defining: 1) "**objectives**" refer to, in this case, narrative regulatory requirements; 2) "**endpoints**" refer to numeric guidance for response indicators that assist in the translation of a narrative objective; 3) "**targets**" refer to numeric guidance for nutrient concentrations or loads established as statewide or regional "default" values or as targets derived for specific sites based on watershed-specific analysis and management strategies; and 4) "**thresholds**" reflect statistically detectable inflection points in biotic response (e.g., in terms of some measure of instream community composition) along a stressor (biomass or nutrient) gradient. Thresholds are derived strictly analytically based on available data, and do not involve interpretation or value judgments, but they may constitute a line of evidence in the formulation of nutrient objectives.

Element 1. Conduct and Synthesize Science Supporting Development of Numeric Guidance for Wadeable Streams

The wadeable stream Science Plan has three major goals that are intended to support the development of numeric response indicator endpoints and statewide or regional "default" nutrient targets:

1. Identify response indicators representative of wadeable stream beneficial uses;
2. Determine the numeric range of response indicators that correspond to varying levels of protection of beneficial uses, relative to the gradient of "natural background" and ambient concentrations found in wadeable streams statewide;
3. Develop statistical models linking response indicators to nutrients and, to the extent possible, other site-specific factors, in wadeable streams in order to identify nutrient concentrations and other site-specific conditions that correspond to the numeric response values identified in goal 2.

Progress has been made towards these goals above, through a recently completed research study conducted in partnership with EPA-ORD through the EPA Regional Ecosystem Services Research Grant Program (REServe; Fetscher et al. 2014a). The study utilized existing data available through State and regional wadeable stream bioassessment programs to accomplish the following objectives:

1. Estimate the natural background and ambient concentrations of nutrients and indicators of primary producer abundance and algal community metrics;
2. Explore relationships and identify thresholds of adverse effects of nutrient concentrations and primary producer abundance on indicators of aquatic life (benthic macroinvertebrate and algal community structure) in California wadeable streams;
3. Evaluate the Benthic Biomass Spreadsheet Tool (BBST) for California wadeable streams using available data and recommend avenues for refinement.

To accomplish these objectives, Fetscher et al. (2014a) compiled existing data from State and regional wadeable stream bioassessment programs and augmented the dataset with meteorological data and GIS-derived variables that provide additional landscape context for inclusion in statistical analyses (see summary, Appendix 1). Findings contributed by Fetscher et al. (2014a) will be summarized as needed in each of the elements to provide context for the proposed work.

ELEMENT 1.1 IDENTIFY RESPONSE INDICATORS REPRESENTATIVE OF WADEABLE STREAM BENEFICIAL USES

The purpose of this task is to identify response indicators representative of wadeable stream beneficial uses.

Background and Previous Work. Adverse effects of nutrient enrichment in streams generally fall into one of three types: 1) increases in the amount of algae and macrophytes as well as live and dead organic matter, 2) changes in the community structure of stream algae and fauna (e.g. benthic macroinvertebrate, fish, etc.) and 3) alterations in water chemistry, including increased diel fluctuations in water column dissolved oxygen and pH (Figure 1; EPA 2013).

Tetra Tech (2006) reviewed response indicators relevant for assessment of eutrophication in streams and rivers. Since then, additional science related to this topic has been published. In 2013, EPA sponsored a workshop to achieve consensus among experts on appropriate indicators for assessment of eutrophication in wadeable streams. In California, Fetscher et al. (2014a) screened algal abundance indicators currently included in the California wadeable stream algal bioassessment protocol (Fetscher et al. 2009) for the nature and strength of relationships with benthic macroinvertebrate and algal community structure metrics (representative of aquatic life).

Proposed Work. This element will: 1) provide a conceptual model to communicate “the problem” of potential adverse effects of nutrients and biostimulatory conditions in wadeable streams and how they link to beneficial uses and 2) will summarize available literature on wadeable stream response indicators to evaluate them vis-à-vis five suitability criteria:

- The indicator has a clear link to conditions influencing one or more beneficial uses (WARM, COLD, etc);
- Has a predictive relationship with causal factors such as nutrient concentrations/loads and other factors known to regulate response to eutrophication (hydrology, etc.). This relationship could be empirical (modeled as a statistical relationship between load/concentration and response, or modeled mechanistically through process models);
- Has a scientifically sound and practical measurement process;
- Shows a trend either towards increasing or/and decreasing in response to eutrophication with an acceptable signal:noise ratio; and
- Entails data types that are either already routinely collected by State programs, or can be added relatively easily.

Some indicators may be more appropriate or meaningful to address some beneficial uses than others. The synthesis will attempt to identify which indicators reflect the designated beneficial uses for streams.

Deliverables for this element include: 1.1) a draft and final report chapter on appropriate NNE response indicators in the Wadeable Streams Nutrient Objective Scientific Synthesis Report.

ELEMENT 1.2. Determine the numeric range of stream nutrient and response indicators that correspond to levels of protection of beneficial uses.

The purpose of this element is to conduct analyses and synthesize literature to quantify the numeric range of stream eutrophication stressors (nutrient, algal abundance or organic matter accumulation indicators) that correspond to varying levels of beneficial use protection. The synthesis of this information should be placed within the context of the distribution of concentrations at minimally disturbed reference and ambient monitoring sites across the state. The outcome of this task will support policy decisions on regulatory endpoints for response indicators (assessment endpoints). It can also be used to support decisions on statewide or regional numeric nutrient targets, should the State Water Board choose to do so. "Levels" and "thresholds" refer to the outcome of scientific analyses, while "endpoints" and "targets" refer to numeric guidance to assist in the interpretation of narrative objectives.

Background and Previous Work. The "biological condition gradient" (BCG) is a conceptual model that describes the changes in aquatic communities, measured by aquatic life indicators (e.g., benthic macroinvertebrate or algal community structure), as a function of stress (e.g. algal abundance and community metrics, nutrients; Davies and Jackson 2006; Figure 2). This model describes the predictable transition of biotic communities as a function of increasing stress, from pristine, to slightly modified ecological condition, then moderate, and finally, very modified ecological condition. The stressor gradients, in the context used here, can be represented by nutrient concentrations or response indicators such as algal abundance and community metrics, organic matter accumulation, or levels of DO and pH.

Existing field data that capture this gradient can be used to explore the quantitative relationships between nutrients, ecological responses, and desired levels of narrative beneficial use support. This can be informed by exploring approaches that relate responses to stress and characterizing those responses in terms of beneficial use measures so various response conditions can be identified and used to guide further analysis. Stages of change will be identified along the BCG response surface that correspond with specific beneficial use impairments. Analytical approaches to determine the ranges at which a stream ecosystem transitions from no apparent effects to increasing effects in response to increasing stress (*e.g.*, from low to high nutrient levels) have typically involved one or more of the following (US EPA 2010, Figure 3):

1. Use of statistical methods to determine breakpoints or abrupt changes (henceforth referred to as "thresholds") in an aquatic life indicator measures as a function of increasing stressor levels and relating such changes to desired beneficial use goals;
2. Use of conditional probability or predictive regression models to estimate stressor "levels" that are linked to a quantitative target for an indicator representative of beneficial use support (*e.g.*, an established benthic macroinvertebrate index of biological integrity (IBI) score); and/or
3. Use of scientific expert consensus to interpret the range of response indicator values corresponding to levels of condition along the BCG, such that thresholds and levels

identified in the previous two approaches can be synthesized for their relevance to levels of beneficial use attainment.

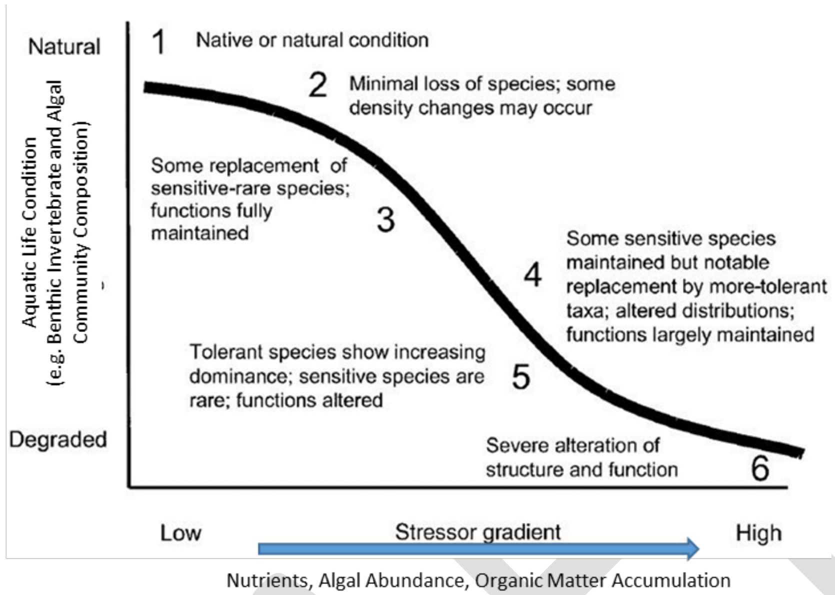

Figure 2. Conceptual model of the biological condition gradient (BCG) depicting stages of change in biological conditions in response to increasing levels of stress. Reproduced from Davies and Jackson (2006). In this context, the stressor gradient can include nutrients or response indicators such as algal abundance and community metrics, organic matter accumulation, DO and pH.

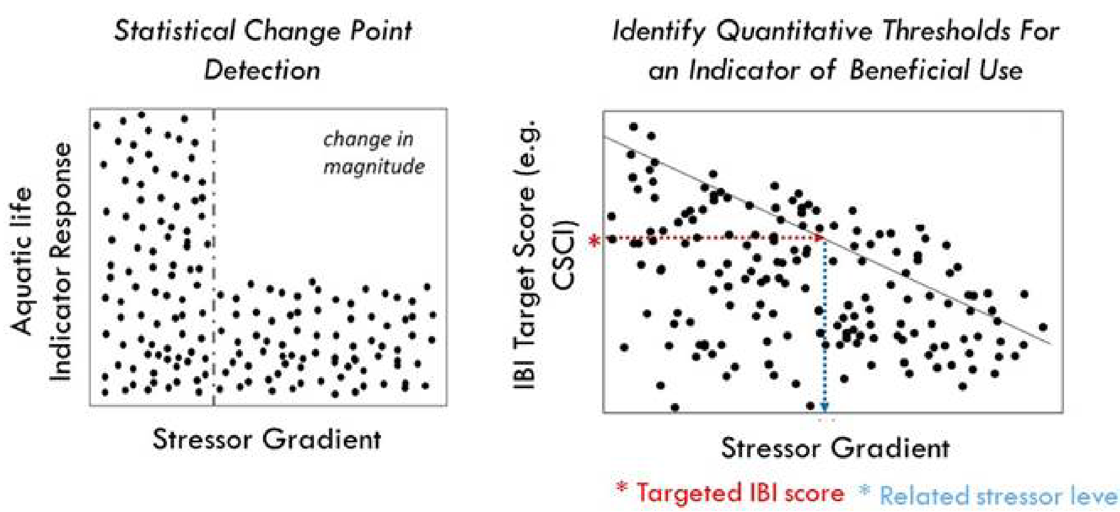

Figure 3. Examples of statistical approaches to determining the point along stressor gradient where ecosystem response shifts from no-effect to adverse-effects. The left panel illustrates a "step function" in the relationship between stressor and ecological response; here statistical methods can be used to identify the level of stress (or threshold, as indicated by the dashed

line) at which an aquatic life indicator value changes abruptly. The right panel illustrates a quantile regression in which a target value for a benthic macroinvertebrate or algal IBI score is used to interpolate the level of stressor (e.g., in terms of nutrient concentrations or algal biomass) that should not be exceeded in order to protect biotic integrity.

Existing data for California wadeable streams set the stage for exploration of the relationship between stressors (nutrients, algal abundance and community metrics, organic matter accumulation), stream co-factors (site-specific and landscape) and aquatic life response (algal and benthic macroinvertebrate community structure). It does not include comprehensive measures of dissolved oxygen and pH.

Fetscher et al. (2014a) investigated thresholds in ecological responses to nutrient and algal abundance gradients in California wadeable streams using a variety of statistical methods (Approach 1; Figure 3, left panel). They found a narrow range of thresholds of aquatic life responses along water-column nutrient and benthic algal concentration gradients (Fetscher et al. 2014a); they also demonstrated relationship between algal community metrics and nutrients. They interpreted these results within the context of statewide and regional reference and ambient distributions of biomass and nutrient concentrations. This work is being repeated using only South Coast data to determine whether identified thresholds would be different at a regional scale (Fetscher and Sutula, in prep). No additional work is proposed using this threshold-oriented approach.

Proposed Work. The goals of this element are two-fold:

- Estimate levels of stressors (nutrient concentrations, algal abundance and community metrics, organic matter accumulation, nutrient- and eutrophication-algal community metrics) that are correlated to condition levels representative of beneficial use support (Approach 2 above; Fig. 3, right panel).
- Conduct a BCG expert exercise (Approach 3, above) to evaluate the ecological relevance of 1) statistically-derived thresholds of response to stress (Fetscher et al. 2014a), 2) stressor levels linked to quantitative targets (Approach 2), and 3) existing literature, to assessment of different levels of beneficial use support.

Estimate Levels of Stressors, Algal Abundance, Algal Community Metrics and Nutrient Concentrations, Associated with Attainment of Varying Condition Levels. Two types of condition are applicable for this analysis, given the existing statewide stream bioassessment data: 1) quantitative targets for the benthic macroinvertebrate and stream algal indices of biotic integrity relative to levels of algal abundance and algal community metrics, organic matter accumulation and 2) algal percent cover (a metric of aesthetics) relative to levels of algal abundance and nutrients.

No policy decisions on quantitative targets for benthic macroinvertebrate-based bioassessment tools (e.g., the California Stream Condition Index, or “CSCI”; Mazor et al., under review) nor algal community measures (e.g., the “hybrid” algae IBI, or “H20”; Fetscher et al. 2014b) have been established to date. Therefore, we propose to use various percentiles of reference sites distributions (e.g. 75^{th}, 95^{th}, and 99^{th}) for CSCI and H20 scores to explore the sensitivity of percentile used on the stressor target levels derived.

Similarly, no targets for algal percent cover have been established by the State. However, we will review ranges of percent cover proposed as assessment endpoints in other State programs as a basis to explore the sensitivity of algal abundance and community metrics levels to percent cover targets.

Conduct a BCG Expert Synthesis. Currently the State is moving forward with a wadeable stream biological integrity policy that does not have numeric objectives for benthic macroinvertebrate or algal community condition. As such, the purpose of this element is to use the consensus of wadeable stream experts to interpret the range of response indicator values corresponding to categories of algal community composition as an indicator of condition along the BCG. The levels and thresholds identified in Fetscher et al. (2014a) and in the work proposed under bullet #2 under "Background and Previous Work", above, can be then be synthesized for their ecological significance in BCG bins and their relevance to different levels of beneficial use attainment. <u>Funding is currently available to conduct this synthesis for algal community composition; benthic macroinvertebrate community composition can be included, if additional resources are leveraged.</u>

The approach for this element will be described in a separate work plan, but is summarized briefly here. The work will be accomplished through a series of workshops. Approximately 6-10 experts in stream algal ecology and, pending availability of additional funding, stream benthic macroinvertebrates, will be identified. During the first workshop, these experts will identify the methodology they will use and the site data necessary to independently categorize selected sites into bins of BCG condition (e.g., 1-6, Figure 2). Methods may include utilizing raw community composition data and/or metric and index data from the California IBI data sets. Following the first workshop, the experts will independently score the sites. Differences will be reconciled and consensus achieved, to the extent possible, through subsequent workshop(s). This expert BCG categorization of algal community composition attributes will then be used to interpret and synthesize the thresholds for nutrient, algal abundance, and algal community metrics (Fetscher et al. 2014a) and levels correlating to quantitative aquatic life targets (bullet #2) for their relevance to the BCG. Ranges of reference and ambient concentrations of algal metrics, and nutrients will be used to put the synthesis into context.

Deliverables for this subtask include: 1.2) oral presentations and draft and final report chapter(s) summarizing findings of BCG expert synthesis, 1.3) oral presentations and a draft and final report chapter on additional statistical analyses linking quantitative thresholds for aquatic life or other beneficial use indicators to stressors (nutrients, algal metrics, and organic matter accumulation);

ELEMENT 1.3. DEVELOP BASIC STATISTICAL MODELS LINKING INDICATORS OF ALGAE AND ORGANIC MATTER ACCUMULATION TO NUTRIENTS IN WADEABLE STREAMS.

The purpose of this element is to develop statistical models that link response indicators to nutrients and, to the extent possible, other co-factors in wadeable streams for use in site-specific NNE modeling or for derivation of regional numeric nutrient targets. In the previous work element (1.2), statistical analyses were used to explore the quantitative linkage between measures of aquatic life (e.g. algal or benthic macroinvertebrate community condition) and nutrients, algal metrics and organic matter accumulation (as stressors). In this element, we focus on developing statistical models of the relationship between nutrients, landscape, and site-scale stream co-factors with indicators of algal abundance, algal community response to nutrients and eutrophication, and organic matter accumulation (Figure 1).

This task places major emphasis on modeling the linkage between nutrients and algal abundance/ organic matter accumulation indicators in the event that the State Water Board chooses to establish numeric endpoints for these response indicators. We note that the State Water Board has the option to use the outputs of Fetscher et al. (2014a) and work performed in bullet #2 under element 1.2 in setting default nutrient numeric targets, in lieu of the models developed in this element.

Background and Previous Work. Fetscher et al. (2014a) evaluated the performance of the existing models in the Nutrient Numeric Endpoint Benthic Biomass Spreadsheet Tool (BBST; Tetra Tech 2006). The BBST models showed model fits of R^2 = 0.15-0.26 in predicting benthic chlorophyll *a* when validated against the statewide stream bioassessment dataset. This relatively modest outcome is understandable, given that the BBST was optimized for North American temperate streams and that the model predicts maximum algal abundance, a value not captured by the current California stream bioassessment "index period", when sampling is conducted. Nonetheless, the validation exercise provided several insights into factors that could be compromising model predictive capacity. In particular, it was determined that classification of stream types within the model was likely necessary, presumably because it is difficult to adequately optimize model parameters over the wide range of natural gradients spanning a State as large as California.

Fetscher et al. (2014a) conducted a preliminary exploration of potential alternative modeling approaches, including boosted regression trees and Bayesian classification and regression trees (B-CART) analyses. Of these B-CART showed the most promise. B-CART is an approach to the development of Regression Trees that is informed by the analyst's prior knowledge of tree form and distribution of potential model coefficients. For our purposes, it assigns sites to environmentally defined groups based on a set of classification variables and then optimizes the fit of regression models within each final group of stream types (rather than optimizing the difference in mean values of the response variable among groups). The approach is advantageous in that it allows incorporation of mechanistic elements as needed (e.g. effect of shading, temperature), but the classification process also allows for incorporation of factors that cannot be modelled mechanistically. This has advantages over relying on a purely mechanistic approach (such as QUAL2K), because California is characterized by a broad latitudinal range that translates to broad environmental gradients, presenting major challenges to optimization of a single mechanistic model statewide.

Proposed Work. We propose to develop statistical models linking nutrient concentrations and site-specific and landscape factors to algal abundance indicators (i.e. benthic chlorophyll *a*, ash-free dry mass, and macroalgal percent cover). We propose to first use B-CART to develop statistical nutrient-algal abundance regression models. To build on the preliminary work of Fetscher et al. (2014a), we will test alternative regression tree models based on selection of classification variable sets and selection of regression variable sets. We will also calculate metrics of model fit for final (site-class-specific) regression models relating predicted to observed values to summarize the percent variation explained in each regression tree node. Alternative model approaches may be considered in the event that B-CART is not satisfactory.

Deliverables for this subtask include: 1.4) oral presentation and a draft and final chapter on development of statistical nutrient-algal abundance models, including the classification scheme and regression equations, in a wadeable streams synthesis report; 1.5) final report including executive summary, technical chapters, recommendations

ELEMENT 2 IMPLEMENTATION PLAN TECHNICAL SUPPORT.

The purpose of this task is to identify technical elements needed to support the implementation of nutrient objectives in wadeable streams (State Water Board Nutrient Objectives Workplan, Task 5). These technical elements may come in multiple forms such as, but not limited to:

1. Technical guidance and materials to provide sufficient method standardization, data transfer formats, documentation and education for widespread, consistent, effective implementation of policy across Regional Boards (see State Water Board Work Plan Task 5).
2. Technical information to guide site-specific decisions on nutrient management to meet the policy (i.e. source-dependent assessment of capabilities of available technologies to attain ambient nutrient concentrations, cost-effectiveness of a range of point and non-point source treatment technologies, methodologies to assess ability to attain biological endpoints in specific watersheds/water bodies)
3. Science and/or data and/or "guidance documents" needed to continue the improvement of statistical statewide/regional or site-specific mechanistic models.

These technical elements will be identified and prioritized during discussions with the State Water Board staff and its advisory groups (Stakeholder, Regulatory, and Science Panel) and compiled into a draft technical memo. This task is not currently funded; the Technical Team will work with advisory groups to identify funding opportunities for high-priority items as they are identified.

Deliverables for this task include: 2.1) a draft memo identifying technical elements needed support implementation.

Schedule of Deliverables

Task No.	Description of Deliverable	Estimated Schedule for Completion
Element 1. Conduct and Synthesize Science Supporting Numeric Guidance for Wadeable Streams		
1.1	Oral presentations and draft report chapter on appropriate NNE indicators in a wadeable streams synthesis report	July 2015
1.2	Oral presentations and draft report chapter(s) on BCG expert synthesis	July 2016
1.3	Oral presentation and draft report chapter(s) in a wadeable streams synthesis report on statistical analyses linking quantitative thresholds for aquatic life or other beneficial use indicators to stressors (nutrients, algal abundance)	January 2016
1.4	Draft chapter on development of statistical nutrient-algal abundance models in a wadeable streams synthesis report.	January 2016
1.5	Final report including executive summary, technical chapters (Deliverables 1.1-1.4), summary and recommendations	October 2016
ELEMENT 2 IDENTIFY KEY TECHNICAL ELEMENTS ADDRESSING IMPLEMENTATION		
2.1	Memo identifying technical elements needed to support implementation	October 2016

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APPENDIX 1 DESCRIPTION OF WADEABLE STREAM BIOASSESSMENT DATA TO BE USED IN SUPPORT OF SCIENCE PLAN

Wadeable stream bioassessment data that was used for the REServe report (Fetscher et al. 2014) analyses and that will support proposed analyses were compiled from several California wadeable stream monitoring programs:

- Statewide Perennial Stream Assessment (PSA),
- Statewide Reference Condition Management Program (RCMP), and
- Southern California Stormwater Monitoring Coalition (SMC)

Taken together, the available data represent 938 wadeable, perennial[1] stream reaches throughout the State (Figure A1), which were sampled from 2007 through 2011. Sampling was largely conducted as one-time site visits within the time frame spanning late spring to early fall, with the majority occurring in May through August. Factors affecting instream benthic algal growth and biomass accrual include nutrients, solar radiation, temperature, shading from riparian cover, incised stream channels, local topography, mean stream velocity, substratum type, abundance of grazers, and frequency of droughts or scouring flows. Therefore, the dataset to be used for modeling algal biomass response to nutrients will include the variables listed in Table A1, which have been separated into "response" variables (i.e., algal biomass) and explanatory variables, which include a variety of nitrogen and phosphorus species, as well as environmental co-factors in the form of landscape-level and local stream habitat variables that may modulate biomass response to nutrients.

The types and distribution of algal biomass indicators across channel habitats can widely vary among stream types. For this reason, it is important to assess biomass within a stream in a number of different ways, because each individual indicator captures this distribution differently. For example, both benthic chlorophyll *a* and ash-free dry mass (AFDM) measure algal biomass, but chlorophyll *a* is a proxy for the measurement of live algal biomass, while AFDM measures both live and dead biomass, as well as organic matter imported into the survey site. Furthermore, algae can occupy different "compartments" within the stream (i.e., floating on the surface, attached to cobbles/boulders, interstitially distributed within the upper layer of gravel and fine sediments), all of which are included across the sample types we will use as response variables.

[1] We use the PSA operational definition of "perennial", i.e., those stream reaches with surface flow during the index period for sampling. A "wadeable" reach was defined as that which is <1m deep for at least 50% of its length.

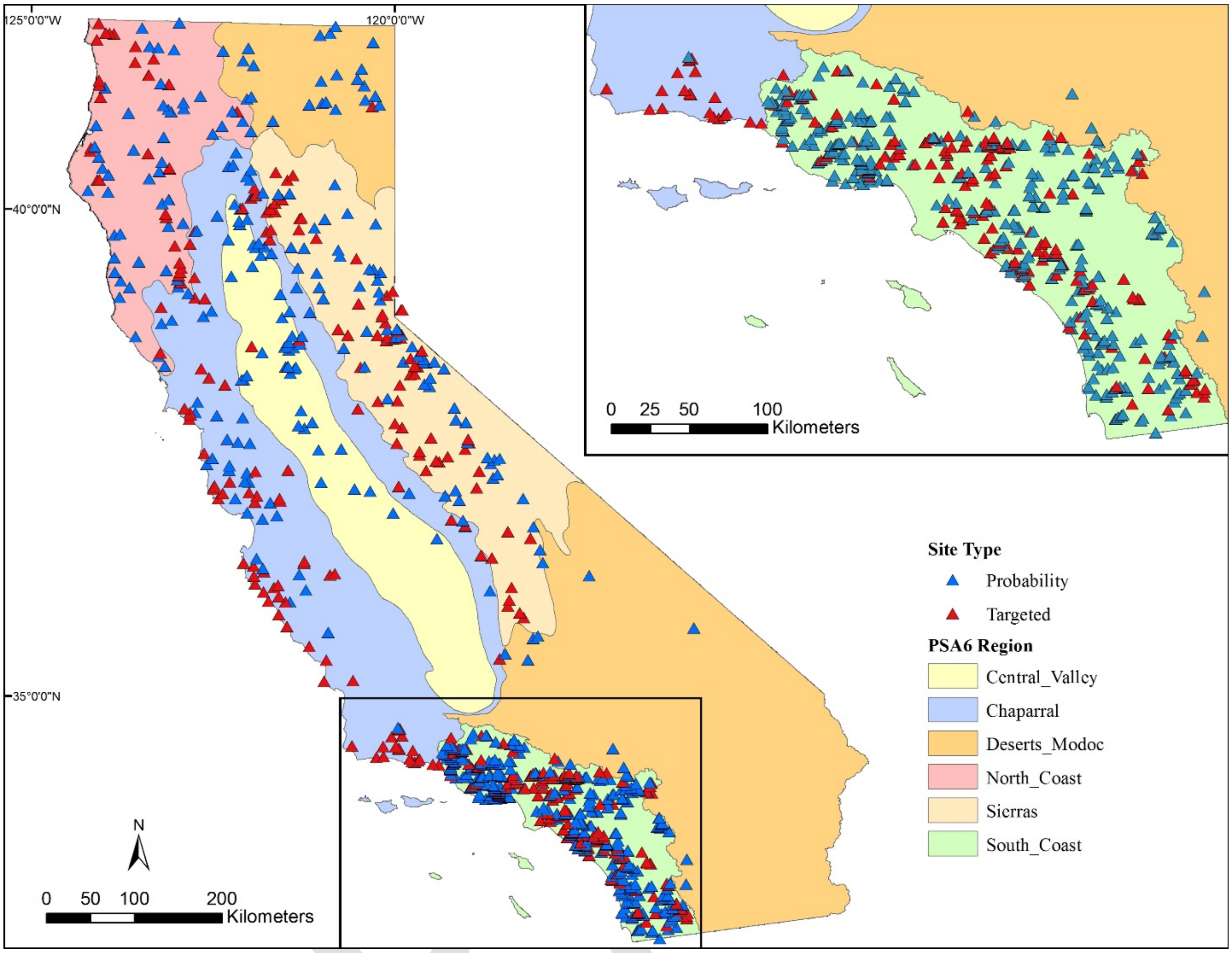

Figure A1. Sampling sites for which data are available, shown by the Perennial Stream Assessment (PSA) ecoregion in which they occur. State bioassessment programs use a combination of Omernik (1995) ecoregions and Regional Water Quality Control Board boundaries to partition the State for assessment purposes. "PSA6" refers to the version of the classification scheme that encompasses six ecoregions.

Table A1. Response and explanatory variables available for inclusion in the nutrient-response models.

- **RESPONSE VARIABLES** (algal biomass indicators of eutrophication)
  - benthic chlorophyll *a*
  - benthic ash-free dry mass (AFDM)
  - macroalgal percent cover (PCT_MAP)
- **EXPLANATORY VARIABLES**
  - **Nutrients**
    - total nitrogen (TN)
    - total phosphorus (TP)
    - nitrate + nitrite (NO_x)
    - orthophosphate (PO_4)
    - ammonium (NH_4)
  - **Landscape - geographic**
    - site elevation
    - watershed area
    - percent sedimentary geology in the catchment
    - modeled atmospheric deposition
  - **Landscape - meteorological**
    - mean monthly % cloud cover (3-mo antecedent mean)
    - mean monthly max temperature (3-mo antecedent mean)
    - mean monthly solar radiation (3-mo antecedent mean)[2]
    - total precipitation (3-mo antecedent total)
    - degree days from onset of growing season to sampling date

[2] These modeled data provide an estimate of how much sun may reach the stream (barring blockage by canopy, which is measured separately) based on geographic position (latitude), and hillslope shading from surrounding topography.

- **Local physical habitat ("PHab")**
  - percent cover of coarse particulate organic matter in streambed
  - percent cover of fine substrata in streambed
  - percent sand + fines in streambed
  - percent canopy cover
  - estimated days of accrual (i.e., number of days since last scour event)
  - mean stream depth
  - mean stream width
  - slope, reach-level
  - stream discharge
  - stream temperature
- **Water chemistry (general)**[3]
  - alkalinity
  - conductivity
  - turbidity

To collect data, a "multi-habitat" method was employed to quantitatively collect benthic algae at each sampling site. This method, SWAMP's Standard Operating Procedures (Fetscher et al. 2009), is based largely on the procedures of EPA's Environmental Monitoring and Assessment Program (EMAP; Peck et al. 2006) and is analogous to SWAMP's method for collecting benthic macroinvertebrates (Ode 2007). It involves objectively collecting from a known surface area specimens from a variety of stream substrata, in proportions aligning with substratum type relative abundances in the stream. Specifically, eleven subsamples are collected at predetermined locations, one from each of 11 transects that are spaced equidistantly from one another, across the 150-m sampling reach. The subsamples are then combined into a single "composite" sample for laboratory analyses. As such, a given composite sample may have been collected from any combination of cobbles, gravel, sand, and other substratum types. The goal is to achieve a representative sample of the benthic algae from each sampling reach, in terms of both community composition and biomass.

Percent macroalgal cover data were collected according to the methods outlined in Fetscher et al. (2009). This involved recording point-intercept presence/absence of macroalgae at each of 105 points objectively positioned (in a pre-determined grid) throughout each stream reach. The algal/macrophyte field metrics were calculated as percent cover estimates based on the percentage of sampling points at which the type of algae/macrophyte was observed. The variables to be used for this study are: Percent Presence of Macroalgae ("PCT_MAP") and Percent Presence of Macrophytes ("PCT_MCP").

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[3] Note that while dissolved oxygen and pH are recognized to be important factors influenced by stream nutrients, and they have great potential to affect beneficial uses relating to aquatic life, they are no included here due to lack of appropriate data on these parameters for use in the modeling exercise.

For algal biomass, filtered aliquots of quantitatively sampled algal material were analyzed for chlorophyll *a* content using EPA 445.0, and for AFDM using WRS 73A.3. Chlorophyll *a* and AFDM concentrations measured in the laboratory were transformed into mass per area of stream bottom sampled (e.g., mg/m^2).

Sites may be grouped into "disturbance classes" for some analyses. To assign sites to disturbance classes, we will use the same set of screening criteria as that employed by the State of California's Biological Objectives initiative (Ode et al., under review). Under this approach, sites are classified according to the degree of anthropogenic disturbance they are exposed to, based on surrounding land uses and local riparian disturbance measures. Table A2 provides a list of the factors that were used for classifying sites into one of the three disturbance classes: "Reference", or those sites that are exposed to the lowest levels of anthropogenic disturbance based on the variables considered, "Stressed", or those sites exposed to the highest levels, and "Intermediate", or those sites falling between the "Reference" and "Stressed" groups.

Table A2. Variables used for assigning sites to "site disturbance classes" per the state's bio-objectives process (adapted from Ode et al., under review). WS: Watershed. 5K: Watershed clipped to a 5-km buffer of the sample point. 1K: Watershed clipped to a 1-km buffer of the sample point. W1_HALL: proximity-weighted human activity index (Kaufmann et al. 1999). In order to be considered "Reference" condition, all criteria listed in the "Threshold" column for "Reference" must be met. If any of the criteria in the "Stressed" column apply, that site is considered "Stressed". Sites not falling into either of these categories default to "Intermediate". Data sources are as follows: A: National Landcover Data Set (2006, http://www.epa.gov/mrlc/nlcd-2006.html). B: Custom roads layer (P. Ode, pers. comm.). C: National Hydrography Dataset Plus (v2, http://www.horizon-systems.com/nhdplus/). D: National Inventory of Dams. E: Mineral Resource Data System (MRDS 2014). F: Field-measured variables (Fetscher et al. 2009).

Variable	Scale*	Threshold (Reference)	Threshold (Stressed)	Unit	Source
% Agriculture	1k, 5k, WS	3	50	%	A
% Urban	1k, 5k, WS	3	50	%	A
% Ag + % Urban	1k and 5k	5	50	%	A
% Code 21[4]	1k and 5k	7	50	%	A
	WS	10	50	%	A
Road density	1k, 5k, WS	2	5	km/km^2	B
Road crossings	1k	5	-	crossings/ km^2	B, C
	5k	10	-	crossings/ km^2	B, C
	WS	50	-	crossings/ km^2	B, C
Dam distance	WS	10	-	km	D
% canals and pipelines	WS	10	-	%	C
Instream gravel mines	5k	0.1	-	mines/km	C, E
Producer mines	5k	0	-	mines	E
W1_HALL	reach	1.5	5	NA	F

* For variables in which multiple spatial scales are used for determining site classification, in the case of the "Reference" boundary, the value indicated must apply to all spatial scales listed, whereas for the "Stressed" boundary, the indicated value need only apply for one of the listed spatial scales.

Secondary data for watershed characterization (to serve as environmental co-factors, among the explanatory variables) will be derived from the sources described in Table A3.

[4] "Code 21" encompasses a wide range of land uses primarily characterized by heavily managed vegetation (e.g., low-density residential development, parks, golf courses, highway medians)

Table A3. Sources of data for landscape, meteorological, and geological explanatory variables used in predictive models.

Data Type/Variable	Data Source	Description or Download
Minimum and maximum air temperature per month (2007-2012)	PRISM	http://www.prism.oregonstate.edu/products/matrix.phtml, http://www.prism.oregonstate.edu/docs/index.phtml
Solar Radiation (for topographic shading)	ArcMap 10 tool Solar Radiation using DEM data from NHDPlus	http://www.horizon-systems.com/nhdplus/
Cloud cover, mean percent per month (2007-2012)	MODIS Cloud data from NASA	http://ladsweb.nascom.nasa.gov/data/
Land cover/land use	National Landcover Data Set, 2006	http://www.epa.gov/mrlc/nlcd-2006.html
Hydrology	National Inventory of Dams and NHD Plus	http://geo.usace.army.mil/pgis/f?p=397:1:0; http://www.horizon-systems.com/nhdplus/index.php
Elevation	National Elevation Dataset	http://ned.usgs.gov/
Drainage area (from DEM)	NHDPlus	http://www.horizon-systems.com/nhdplus/
Geology maps	USGS	http://mrdata.usgs.gov/geology/state/
Total precipitation per month (2007-2012)	PRISM	http://www.prism.oregonstate.edu/products/matrix.phtml, http://www.prism.oregonstate.edu/docs/index.phtml
Basin slope (from DEM)	NHDPlus	http://www.horizon-systems.com/nhdplus/