Nutrient Management Strategy for San Francisco Bay

Draft Version March 2012

1. Purpose of the Nutrient Strategy

This document presents a draft strategy for developing the science needed to make informed decisions about assessing nutrient impacts on water quality, protecting beneficial uses, and managing nutrient loads to San Francisco Bay. The document first provides relevant background, after which management decisions related to nutrients are highlighted. The document then lays out a plan, developed collaboratively by the San Francisco Regional Water Quality Control Board (Water Board) and Bay stakeholders, for the technical studies required to support decisions regarding nutrient management. This version of the document is intended as a "strawman" strategy to focus input from the stakeholder, regulatory, and regional scientific communities, and will be revised to incorporate input over the subsequent months.

2. Background

San Francisco Bay has long been recognized as a nutrient-enriched estuary. Nonetheless, dissolved oxygen concentrations found in the Bay's subtidal habitats are much higher, and phytoplankton biomass and productivity are substantially lower than would be expected in an estuary with such high nutrient enrichment, implying that eutrophication is controlled by processes other than straightforward nutrient-limitation of primary production. The published literature suggests that phytoplankton growth and accumulation are limited by a combination of factors, including strong tidal mixing, light limitation due to high turbidity, and grazing pressure by clams, although the relative importance of these individual factors is not well-established.

There is a growing body of evidence that suggests the historic resilience of San Francisco Bay to the harmful effects of nutrient enrichment is weakening. Since the late 1990's, regions of the Bay have experienced significant increases in phytoplankton biomass (30- 105% from Suisun to South Bay) and significant declines in DO concentrations (2% and 4% in Suisun Bay and South Bay, respectively; J. Cloern, unpublished data). In addition, an unprecedented autumn phytoplankton bloom in October of 1999, and increased frequency of cyanobacteria and dinoflagellate (2004 red tide event) blooms occurring in the North Bay, further signal changes in the Estuary.

The indications of decreased Bay resilience have come to the fore at a time when the availability of resources to continue assessing the Bay's condition is uncertain. Since 1969, a USGS research program has supported water-quality sampling in the San Francisco Bay. This USGS program collects monthly samples between the South Bay and the lower Sacramento

River to measure salinity, temperature, turbidity, suspended sediments, nutrients, dissolved oxygen and chlorophyll a. The USGS data, along with sampling conducted by the Interagency Ecological Program, provide coverage for the entire San Francisco Bay –Delta system. The San Francisco Bay Regional Monitoring Program (RMP) has no independent nutrient-related monitoring program, but instead contributes approximately 20% of the USGS data collection cost. Thus, there is currently an urgent need to lay the groundwork for a locally-supported, long-term monitoring program to provide information that is most needed to support management decisions in the Bay.

The timing also coincides with a major state-wide initiative, led by the California State Water Resources Control Board (State Water Board), for developing nutrient water quality objectives for the State's surface waters, using an approach known as the Nutrient Numeric Endpoint (NNE) framework. The NNE establishes a suite of numeric endpoints based on the ecological response of a waterbody to nutrient over-enrichment and eutrophication (e.g. excessive algal blooms, decreased dissolved oxygen). In addition to numeric endpoints for response indicators, the NNE framework must include models that link the response indicators to nutrient loads and other management controls. The NNE framework is intended to serve as numeric guidance to translate narrative water quality objectives.

Since San Francisco Bay is the State's largest estuary, and one for which there is currently a relative wealth of data, it is a primary focus of a state-wide effort to develop NNEs for estuaries. As part of the state-wide effort, the Water Board is working with State Water Board to develop an NNE framework specific to the Bay. This effort was initiated by a literature review and data gaps analysis to recommend indicators to assess eutrophication and other adverse effects of anthropogenic nutrient loading in San Francisco Bay (McKee et al., 2011). The review made five major recommendations: 1) develop an NNE assessment framework for the Bay, 2) quantify external nutrients loads, 3) develop a suite of models that link NNE response indicators to nutrient loads and other co-factors, 4) implement a monitoring program, and 5) coordinate development of the Bay NNE workplan with nutrient management activities in Sacramento and San Joaquin Delta.

At an RMP-sponsored workshop on nutrient management in the Bay (June 29-30, 2011), participants engaged in monitoring activities in the Bay-Delta were convened on day two to discuss elements of a monitoring strategy. They agreed that development of a NNE assessment framework and funding of a monitoring program were priorities, but that these efforts must begin with spatially-explicit conceptual models of the linkages between nutrient loads, ecological response indicators and Bay beneficial uses.

Another issue of importance to the Water Board and stakeholders is that of the potential impact of ammonia/ammonium on Bay beneficial uses. While the USGS has documented a loss of resiliency throughout San Francisco Bay, additional factors may influence productivity in

Suisun Bay compared with South Bay. Dugdale et al (submitted) argue that elevated levels of ammonium actually limit primary productivity in Suisun Bay, and perhaps elsewhere in the Estuary. There is currently disagreement within the scientific community about the potential role ammonium plays in limiting primary productivity, and this issue needs to be resolved. To help resolve the issue, the Water Board supported studies in Suisun Bay in 2010 that showed a strong relationship between ammonium concentrations and impacts on phytoplankton biomass and in the spring of 2011 the Water Board initiated a two-year follow-up study. Additional follow-up studies include toxicity tests and TIE method development to identify the cause of inhibition of diatom growth in Suisun, studies to evaluate copepod toxicity due to ammonium, investigations into the potential influence of nutrient ratios on system response, and the importance of nutrient fluxes from sediments. These data and information from additional studies being conducted in the Delta should be reviewed and a process should be developed to resolve these outstanding questions and concerns about ammonium.

In addition, given that several factors (light-limitation/turbidity; grazing pressure by clams; tidal mixing) contribute to maintaining phytoplankton biomass at relatively low levels in this otherwise nutrient-rich estuary, improved understanding is needed with regards to the relative importance of these factors, including temporal and spatial considerations, and regarding susceptibility to future changes in the level of control they exert (e.g., decreases in suspended sediment loads).

Considering the compelling evidence of changing conditions in San Francisco Bay, uncertainty about future monitoring programs, and new nutrient policies on the horizon, there is a strong need for a coherent nutrient science and management strategy for the Bay. Section 3 identifies upcoming management decisions related to nutrient overenrichment and eutrophication. Section 4 lays out the goals of the nutrient strategy and a plan, developed collaboratively by the Water Board and Bay stakeholders, for the technical studies required to support decisions regarding nutrient management. The current version of the strategy focuses on priority work elements within a five-year planning horizon, with the recognition that this work will extend beyond that time period and will build upon these foundational early efforts. Some commitments have already been made by various groups to fund or undertake priority tasks. These are summarized in Appendix 1.

3. Key Nutrient Management Decisions, Questions

Several key management decisions and questions provide the context for the San Francisco Bay nutrient management strategy. The primary anticipated management decisions include:

1) Establishing Bay nutrient objectives
2) Evaluating the need for revised objectives for dissolved oxygen (in sub-habitats) and ammonium/ammonia
3) Developing and implementing a nutrient monitoring program
4) 303(d) listing decisions for the adverse effects of nutrients or ammonium – whether impairment exists currently or is forecast in the future
5) Specifying nutrient limits in NPDES permits (e.g. POTW and MRP) as well as determining additional data collection needs
6) Determining whether management actions are necessary to prevent or address nutrient enrichment impacts and if so, the schedule, and nature for POTW treatment plant upgrades and stormwater treatment

Nutrient management issues may be influenced by, or can influence to some degree, decisions on other issues, such as the regulation of freshwater flow from the Delta, a regional sediment management strategy, recycling of wastewater, management of nutrient loading to the Delta, and nutrient watershed TMDLs, e.g., Sonoma Creek and Napa River.

These upcoming decisions are the foundation for five key management questions that, in turn, drive the elements of the nutrient strategy, and correspond to the recommendations laid out in a recent literature review and data gap analysis that was conducted as an early step in the NNE process (Table 1; McKee et al., 2011).

4. Nutrient Strategy Goals and Work Elements

Generating the scientific understanding needed to fully support all of the management decisions and questions will likely take a decade or more, and will require a significant investment of resources. Therefore, it is imperative that a well-reasoned and cost-effective nutrient strategy be adopted that identifies logical first steps, leverages existing resources, and incorporates elements of adaptive management.

With this philosophy in mind, we propose that the five-year strategy have six principal goals:

1. Define the problem
2. Establish guidelines (water quality objectives; i.e., assessment framework) for nutrients, including ammonium, focusing on the endpoints of eutrophication and other adverse effects of nutrient overenrichment;
3. Implement a monitoring program that supports regular assessments of the Bay;

4. Develop and utilize nutrient-load response models to support nutrient management decisions;
5. Evaluate control strategies to reduce nutrient inputs from wastewater treatment plants and other sources; and
6. Consider alternative regulatory scenarios for how to move forward with nutrient management in SF Bay.

Work elements and a list of major tasks associated with each goal are detailed in the sections below. The phasing and timeframe of these work elements and major tasks is provided in Table 2.

Table 1 - Summary of management questions developed with input from the Nutrient Workgroup, and corresponding recommendations from the San Francisco Bay NNE literature review (McKee et al. 2011).

Type	Management Question	Recommendation From McKee et al. 2011 Review
Status and trends	Is there a problem or are there signs of a problem? Are trends spatially the same or different in San Francisco Bay? a. Is eutrophication currently, or trending towards, adversely affecting beneficial uses of the Bay? b. Are beneficial uses in segments of San Francisco Bay impaired by any form of nutrients (e.g. ammonium)? c. Are trends spatially the same or different in San Francisco Bay?	Implement a monitoring program to support regular assessments of nutrient support for the Bay beneficial uses. Coordinate with Delta nutrient monitoring and management.
Objectives	What are appropriate guidelines for identifying a nutrient-related problem?	Establish a NNE framework for the Bay
Sources and Pathways	Which sources, pathways, (and processes) of nutrients are of most concern? (Get the loads right!) a. What is the relative contribution of each loading pathway (POTW, Delta inputs, NPS, etc.)? b. What are contributions of internal sources (e.g. benthic fluxes) from sediments and sinks (e.g. denitrification) to the Bay nutrient budgets?	Quantify external sources of nutrients to the Bay and develop a spatially-explicit budget of the Bay.
Fore-casting	What nutrient loads can the Bay assimilate without impairment of beneficial uses?	Develop load-response models
	What is the likelihood that the Bay will be impaired by nutrient overenrichment/eutrophication in the future?	

WORK ELEMENT 1: DEFINE THE PROBLEM

The goal of this task is to develop conceptual models for Bay segments that characterize important processes linking nutrient and organic matter loading, biological responses, and indicators of adverse effects of nutrient over-enrichment. Because of the large differences in hydrography and nutrient dynamics between regions of the Bay, the Bay will be divided into a manageable number of segments and habitat-types, and individual conceptual models will be developed for each.

The NNE assessment framework being developed for San Francisco Bay proposes the use of models to assist with determining the capacity of the Bay to assimilate nutrient loads based on beneficial use protection. The conceptual models developed in this task are needed to help frame the questions that may eventually be explored through quantitative modeling efforts, and to identify the key drivers/factors that need to be incorporated into models. The conceptual model development should provide us with an understanding of the beneficial uses to be protected, an assessment of impairment defined by bay segment or other spatial scale, and identify any temporal aspects to impairment. The conceptual model will be used to visualize all potential and suspected sources of impairment, the species of nutrients associated with potential impairment, as well as pathways and transformations of nutrients (e.g., internal processes of biogeochemical cycling of nutrients and carbon, including important internal sources and sinks, and interactions between nutrients and other stressors). It should be framed in terms of the indicators identified in the literature review and should discuss the linkage between sources and the indicators.

With these conceptual models as a foundation, and with input from stakeholders and regional scientists, a list of plausible future scenarios for the Bay will also be developed. Two broad categories of scenarios are envisioned: i) changes in management actions (e.g., increases or decreases in nutrient loads via various sources, changes in the timing or quantity of freshwater flows); and ii) changes in environmental factors outside of human control (e.g., changes in suspended sediment load and water clarity, changes in temperature, interannual variability in freshwater flow, large-scale climate forcings and climate change). The incorporation of possible future scenarios into the conceptual model will help build our understanding of the Bay ecosystem.

Based on the evaluation of the conceptual model and scenarios, a consensus statement will be developed about the present or future state of the estuary and concerns regarding nutrients and beneficial uses. This task will also identify major data and knowledge gaps, and identify priorities for additional scientific investigation (e.g., Special Studies) that will be required in order to adapt conceptual models into quantitative models (Work Element 4).

WORK ELEMENT 2. ESTABLISH GUIDELINES

The purpose of this work element is to develop the technical foundation and make the policy decisions to establish nutrient-related water quality objectives. This strategy assumes that the development of nutrient related water quality objectives would be accomplished under the umbrella of creation of the “nutrient numeric endpoint framework”—the numeric guidance that would serve as a means to translate narrative water quality objectives.

The Bay NNE literature review and data gaps analysis proposed a suite of primary and supporting indicators appropriate to assess the effects of eutrophication and other adverse effects of nutrients on Bay beneficial uses (McKee et al. 2011). Indicators were proposed for three principal habitat types: 1) subtidal unvegetated habitat, 2) vegetated subtidal (seagrass and other SAV), and 3) intertidal mudflat. The review proposes specific tasks to develop the NNE assessment framework for each habitat types. These tasks are given in Table 3. An initial rank of high, medium and low priority was assigned to each by the Water Board, pending feedback by Bay stakeholders. Prioritization of work elements reflects: 1) percentage of habitat type represented in the Bay and 2) best professional judgment as to whether an indicator represents the most sensitive assessment of potential impacts to beneficial uses. Based on these two criteria, phytoplankton and dissolved oxygen were the primary NNE indicators of interest in subtidal unvegetated habitat. Determination of the utility of ammonium as an indicator is pending the completion of funded studies and synthesis by a working group of scientists. Indicators representative of other habitat types such as intertidal flats and seagrass are of high interest in the Bay as well as other estuaries around the state. Several studies are ongoing to support decision on NNE thresholds in California estuaries outside of the Bay. Thus, the strategy was to designate these work elements as moderate priority, with the intention of evaluating the applicability of these studies to assessment of these habitats in San Francisco Bay.

Five tasks were designated as high priority and as such they are components of planned activities during the first four years.

Task 2.1 Phytoplankton NNE Assessment Framework

The purpose of this task is to develop a phytoplankton assessment framework. This will be done by choosing the precise indicators (e.g. biomass, phytoplankton assemblage, etc.), specifying how & when they will be measured, and creating decision rules for how the indicators will be combined in order to classify Bay segments into categories. Existing phytoplankton data will be used to graphically illustrate options with respect to how to use data to make an assessment.

Task 2.2 Evaluate the Need to Revise Objectives for Ammonium

The purpose of this task is to synthesize available data on factors known to control primary productivity in different regions in the Bay, and to develop consensus on the relative importance of ammonium inhibition of phytoplankton primary production Bay-wide and specifically in Suisun Bay, and potential toxicity of ammonium to copepods. Work under this task will include gathering and synthesizing existing data, and may include the use of biogeochemical models (e.g., Task 4.2.a) to assess the relative importance of ammonium's inhibitory role in primary production. In addition, this task will identify data gaps or studies that may still need to be conducted, working toward a determination of whether or not there is a need to control ammonium discharge. It would also be important to determine the need for and approach to next steps with respect to incorporating ammonium into the NNE assessment framework for the Bay.

Task 2.3 Review of Dissolved Oxygen Objectives

2.3.a Synthesis of Existing Dissolved Oxygen Data

This task will synthesize existing dissolved oxygen data Bay-wide and for specific habitats, such as tidal sloughs, estuarine diked Baylands and shallow subtidal areas. This topic was not covered in the Bay NNE literature review and data gaps analysis (McKee et al. 2011). The synthesis effort will include analysis of data currently being collected (since 2011) at 6 USGS moored stations (DO, chlorophyll, and fluorescence), as well as other data sources. This synthesis will assess status and trends of dissolved oxygen relative to Basin plan standards, and will assess whether objectives are being met and whether there is evidence of impairment.

2.3.b Evaluate the Adequacy of the Dissolved Oxygen Objectives and the Need for Site-specific Objectives

Building on the synthesis in subtask *2.3.a*, the adequacy of dissolved oxygen objectives will be evaluated. The potential for site-specific dissolved oxygen objectives will also be considered.

2.3.c Recommendations for Additional Data Collection and Monitoring Program

Based on the synthesis in subtask *2.3.a*, data gaps will be identified and, if necessary, recommendations for additional data collection will be made, either as part of informing spatial elements of the monitoring program (Work Element 3) or as special studies.

Task 2.4 Macroalgal NNE Assessment Framework

The objectives of this task are: 1) to document baseline abundance of macroalgae in a variety of habitat types and regions of the Bay and 2) participate in statewide effort to develop an assessment framework for eutrophication in intertidal flats and shallow subtidal habitat, based on macroalgae. The intent is that progress on this work element would be monitored for applicability to the Bay, while progress is made on Tasks 1-1 through 1-3.

WORK ELEMENT 3. MONITORING PROGRAM DEVELOPMENT AND IMPLEMENTATION

The purpose of this work element is to develop the San Francisco Bay monitoring program. Targeted habitats include unvegetated and vegetated subtidal and mudflat habitat in the Bay. Managed pond habitats will be excluded, as this habitat type will be addressed in a separate work element in the strategy. Two major tasks are associated with this work element.

Task 3.1 Develop a Monitoring Program

3.1.a Recommend Elements of a core SF Bay Monitoring Program to Assess Status and Trends of Loads and Bay Response.

The purpose of this task is to recommend specific indicators and methods, spatial and temporal density of sampling that should be included in a "core" monitoring program to make regular assessments of the status of the Bay with response indicators and to assess trends in external nutrient loads and response. An evaluation of existing monitoring activities in the Bay will be considered, along with the potential for maximizing synergies and leveraging resources. The product of Task 3.1.a. will be used to develop a detailed nutrient monitoring program for the Bay (3.1.b).

3.1.b Develop San Francisco Bay Nutrient Monitoring Program Work Plan and QAPP.

The purpose of this work element is to develop the work plan and quality assurance project plan (QAPP) for the Bay nutrient monitoring program. The work plan and QAPP covers monitoring to assess status and trends in external nutrient loads and ecosystem response of the Bay to those loads. This task includes development of field, sampling handling, laboratory analyses, data management and reporting procedures for data collection.

Task 3.2 Implement the San Francisco Bay Nutrient Monitoring Program

WORK ELEMENT 4. DEVELOP LOAD-RESPONSE MODELS

The purpose of this work element is develop models to simulate the nutrient and carbon sources, pathways and loads to SF Bay and forecast the ecological response to changes in loads and changes in other environmental factors in the Bay. These models will be used to engage stakeholders in discussion of options for nutrient management under a variety of different scenarios. Previous work elements will define conceptual models and scenarios of interest (Work Element 1), and management endpoints of concern (Work Element 2).

Task 4.1 Modeling of External Sources

Task 4.1.a Synthesize existing data on external nutrient loads and data gaps analysis

The purpose of this task is to synthesize existing information to develop, to the extent possible, spatially and temporally explicit estimates of nutrient and organic carbon external loads via the major pathways. This task will also identify major data gaps that contribute to current uncertainty in total loads, speciation of those loads, and the relative importance of various sources. A conceptual model for external loads will first be developed that considers major sources and pathways through the watershed, airshed, and oceanic sources.

A summary of external loads to the South Bay has already estimated by SFEI (McKee and Gluchowski, 2011). Task 4.1 will expand that loading work into the Central and North Bay, develop temporally-explicit load estimates (e.g., monthly, annually), and explore the importance of uncertainties in loading and nutrient speciation. The nutrient sources considered will include: POTW discharges; stormwater discharges; flows from the San Joaquin and Sacramento Rivers entering through the Delta, along with other smaller downstream tributaries; exchange across the Golden Gate; and direct atmospheric deposition. Nutrient fluxes from Bay sediments to the water column will also be considered.

Initial estimates of POTW loads will be based on individual treatment technologies employed and the expected effluent nutrient speciation and concentrations (based on consultation with wastewater experts and the literature) and flow. In addition, the Water Board is requiring a two year effluent characterization data collection effort by Bay area municipal and industrial wastewater dischargers that should begin generating data in the second half of 2012. This data will be used to refine load estimates.

This task will also identify high-priority monitoring activities and special studies designed to better constrain nutrient load estimates.

Task 4.1.b Review Models to Simulate Nutrient/ Organic Carbon Loads and Test Management Scenarios

This task will review existing models or types of models that can be used to simulate the sources and pathways of nutrient load to the Bay and summarize the data requirements. The task will begin by identifying the types of questions that the model(s) or empirical data must answer. The intent is to review models and tools that can assist in decision-making on nutrient management strategies and test the cost-effectiveness of implementation scenarios. This work element will feed into the development of a modeling strategy.

Task 4.1.c Monitoring Elements

This task will recommend specific monitoring elements (as core monitoring or special studies) either in support of empirical estimates and/or model development for key within-Bay sources, sinks and rates of transformation. Key findings from Task 3.2 will inform Task 3.5, and recommendations made in Task 3.5 will in turn feed into Task 1.5 and 1.6.

Task 4.2 Modeling of Load-Response

Task 4.2.a Basic Numeric Modeling and Scenario Analysis

The purpose of this task is to develop and apply basic numeric biogeochemical models, as an early step in modeling efforts, to inform future model development and data collection. The models will be used to quantitatively synthesize existing data; develop nutrient budgets; support evaluation of proposed indicators as part of the NNE; test appropriate management endpoints; determine how key processes should be modeled and assess the relative importance of and uncertainty related to those processes; and identify major data gaps at an early stage to inform the monitoring program and the need for special studies. In addition, these models will be used to evaluate biological responses under future scenarios (e.g., decreased nutrient loads, changes in flow from the Delta, changes in nitrogen speciation due to potential addition of a nitrification step at wastewater treatment plants, continued decreases in suspended sediment loads, etc).

Model development would focus on Suisun Bay and South Bay. A technical advisory group consisting of regional and national experts would be convened to develop a modeling study plan. A key task of this group will be to identify the main questions to be addressed through the modeling work, approaches for incorporating key processes into the model, and the appropriate model platform(s). Options for model structure range from 1-2 boxes per Bay segment up to coupling a biogeochemical model with an existing 1-D (e.g., Uncles-Peterson model) or 2-D hydrodynamic model within each segment. The ultimate choice for model structure will be determined by the level of detail needed to address the main study questions and sufficiently capture physical forcings (tides, flow, salinity). It should be emphasized that the model(s) developed and used in this task are not intended to be the final models that may ultimately be required for the Bay (which may be more complex and computationally intensive), but rather as scoping tools.

Task 4.2.b Review of Existing Models to Predict the Ecological Response of the Bay to Nutrient Loads and other Co-factors

This task will produce a review of available models and/or modeling platforms that will be the basis for developing a modeling strategy for the Bay. A working group will identify the management questions and endpoints (indicators) of concern and relevant spatial and temporal scales, focusing on hydrodynamic, water quality (dissolved oxygen, nutrients, carbon) and a phytoplankton-zooplankton production and phytoplankton speciation models. A review will be conducted of existing Bay and Delta hydrodynamic and water quality models or other applicable types of models, from simple spreadsheet to complex dynamic simulation models, their data needs, and advantages and disadvantages. Deliverables for this work element include a powerpoint presentation and a technical report. Conceptual models will be developed or cited as needed beyond those already created in Work Element 1 or available in model documentation.

Task 4.3 Modeling Strategy

The purpose of this task is to synthesize information generated from previous tasks to develop a monitoring strategy for the Bay. The strategy would identify questions to be answered by the models, types of models needed (e.g. external loads, bay hydrodynamic and water quality), identify modeling platforms, amount of data required and funding required, schedule, and what policy decisions will be informed. Information should be presented as cost/benefits of model options with trade-offs in terms of what indicators can be modeled at varying levels of accuracy/precision or timescales.

Task 4.4 Begin Implementing Modeling Strategy

WORK ELEMENT 5: CONTROL STRATEGIES

This work element will explore the various approaches available (e.g., technological) to reduce nutrient loads to the Bay. The goal would be to consider these approaches in parallel with the other activities above so that an implementation plan can be developed and evaluated that would support any proposed objectives or nutrient assessment framework.

[Note: This work element will be developed further in subsequent revisions of the strategy]

WORK ELEMENT 6: REGULATORY APPROACHES

This work element will include an analysis of potential approaches to regulating nutrients, and consideration of their applicability to the San Francisco Bay setting. As with Work Element 5, this work element will be carried in parallel with other tasks so that, should nutrient regulations be necessary, a range of options will already have been explored in some depth to streamline decision-making.

[Note: This work element will be developed further in subsequent revisions of the strategy]

Table 2 - GANTT chart of approximate timing of work elements and tasks associated with 5-yr nutrient plan.

Task No.	Brief Task Description	Yr1	Yr2	Yr3	Yr4	Yr5
Element 1: Define the Problem						
1.1	Nutrient/Water Quality Conceptual Model and Scenario Building	■				
Element 2: Establish Guidelines						
2.1	Phytoplankton NNE Assessment Framework	■	■			
2.2	Evaluate the Need to Revise Objectives for Ammonium	■	■	■		
2.3	Review of Dissolved Oxygen Objectives	■	■	■		
2.3a	Synthesis of existing dissolved oxygen data	■	■			
2.3.b	Evaluate the adequacy of the dissolved oxygen objectives, need for site- specific objectives		■	■		
2.3.c	Recommendations for additional data collection and monitoring program		■	■		
2.4	Macroalgal NNE Assessment Framework.	■	■	■		
Element 3: Monitoring Program Development and Implementation						
3.1	Develop a Monitoring Program		■	■	■	
3.1.a	Recommend elements of a core SF Bay monitoring program		■	■		
3.1.b	Develop the Bay nutrient monitoring program Work Plan and QAPP			■	■	
3.2	Implement the Bay nutrient monitoring program					■
Element 4: Modeling Strategy						
4.1	Modeling of External Sources	■	■	■		
4.1.a	Synthesize existing data on external nutrient loads and data gaps analysis	■	■			
4.1.b	Review Models to simulate Nutrient/ Organic Carbon Loads and Test Management Scenarios		■	■		

4.1.c	Monitoring Elements					
4.2	Modeling of Load-Response					
4.2.a	Basic Numeric Modeling and Scenario Analysis					
4.2.b	Review of existing models/platforms to model Bay hydrodynamics & water quality					
4.3	Develop Modeling strategy					
4.4	Begin implementing modeling strategy					

Table 3 - Specific recommendations for science to support development of habitat-type specific NNE assessment frameworks. Priority designation of "high", "medium" or "low" is a preliminary designation, pending feedback by Bay stakeholders.

Habitat Type	Recommended Action	Priority
All subtidal	Sponsor a series of expert workshops to develop a draft assessment framework based on indicators of phytoplankton (biomass, productivity, assemblage, cyanobacteria cell counts and toxin concentrations) and dissolved oxygen	High
	Form a working group of Bay scientists to synthesize available data on factors known to control primary productivity in different regions in the Bay, developing consensus on relative importance of ammonium inhibition of phytoplankton blooms to Baywide primary productivity, and determining next steps with respect to incorporating ammonium into the NNE assessment framework for the Bay.	High
	Consider a review of the Bay dissolved oxygen objectives, either Bay-wide or for specific habitat types such as tidally muted areas (tidal sloughs, estuarine diked Baylands)	High
Un-vegetated Subtidal	Utilize IEP-EMP data to explore use of macrobenthos to assess eutrophication in oligohaline habitats. Consider including biomass in the protocol to improve diagnosis of eutrophication. Determine whether combination of indicators can be used reliably to diagnose eutrophication distinctly from other stressors.	Low
Submerged Aquatic Vegetation	Conduct studies to establish light requirements for the Bay seagrass species;	Low
	Collect baseline data to characterize prevalence of macroalgal blooms and other stressors on seagrass beds	Moderate
	Evaluate the findings of statewide NNE studies characterizing effects of macroalgae on seagrass for applicability to the Bay	Moderate
	Participate in statewide group to develop an assessment framework for eutrophication in seagrass, based on phytoplankton biomass, macroalgae, and epiphyte load.	High

Habitat Type	**Recommended Action**	**Priority**
Intertidal Flats	Evaluate the findings of studies characterizing effects of macroalgae on intertidal flats for applicability to the Bay	Moderate
	Participate in statewide group to develop an assessment framework for eutrophication in intertidal flats, based on macroalgae and other supporting indicators.	High
Tidally muted habitats - managed ponds	Synthesize existing DO oxygen data for tidally muted areas and collect baseline data primary and supporting indicators (macroalgal biomass and cover and phytoplankton biomass, taxonomic composition, and HAB toxin concentrations) in these habitats needed to make a full assessment of status of eutrophication.	High

APPENDIX 1

List of additional planned data collection efforts – updated from June 30, 2011 Nutrient Strategy Session Minutes

- Diagnostic pigments (CHEMTAX)
    - Raphe Kudela is pursuing an alternative method to microscopy for measuring phytoplankton composition, HPLC with CHEMTAX, which uses pigment ratios to determine the main taxonomic groups present.
    - This study will begin to answer the question of whether this method can be used in San Francisco Bay for monitoring the phytoplankton composition. It is much less expensive than microscopy and will allow more samples to be collected throughout the system. At this time the extent of phytoplankton composition sampling is limited by funds.
    - Alex Parker is preparing to test a flow cytometer and fluoroprobe
    - A pilot study for 2012 is underway, under Tara Schraga's lead to fund Raphe Kudela's HPLC/CHEMTAX analysis and compare it to years of the microscopic counts USGS has funded a taxonomist to complete. Alex Parker will be adding the flow cytometer and fluoroprobe to this year-long study to test their viability for accurate determination of phytoplankton groups. USGS will also fund Raphe analyzing some HPLC/CHEMTAX samples for Alex from other stations in the North Bay not on the Polaris track. This project will bring together these efforts and include a summary analysis at the end.
- Urea
    - A pilot study measuring urea in the Bay, led by Tara Schraga and Jim Cloern, is scheduled for monthly sampling (5 stations) for one year (2012).
    - Parker and Dugdale also have five stations that they are sampling annually.
- Algal Toxins
    - In 2012 the USGS is conducting a pilot study collecting samples for phycotoxin analysis throughout the Bay on 1 cruise each month. Raphe Kudela will analyze the samples. Jim Cloern indicated that he needed assistance filtering on the USGS monthly cruises since they are adding this analysis and the CHEMTAX samples .

  - Raphe proposed deploying SPATT collectors at various sites throughout the Bay as a pilot study. The bags integrate the toxins they are exposed to over the period of time deployed.

- Moored sensors
  - Dave Schoellhamer noted that there is funding (50K) from USGS to add sensors at the 6 moored stations, including DO, chlorophyll, fluorescence, and telemetery. Bottom DO will be monitored at San Mateo Bridge, Richmond Bridge, Carquinez Bridge, Benicia Bridge, Corte Madera Creek, Alviso Slough, and a new Central Bay site that will be deeper than their Alcatraz site in 2012. USGS already has a sensor at the Dumbarton bridge that is collecting data.

  - The pilot study still needs additional funding for processing and data analysis, so Dave Schoellhamer will put together a proposal for this funding from the RMP.

- Productivity method
  - Tara Schraga proposed performing in-water productivity measurements and comparing it to output from a productivity sensor. If there is agreement, the in-water instrument can collect productivity samples. If the methods are comparable, the in-water method would increase the temporal resolution and be less expensive (both in cost of samples and labor, and in time needed). The Cloern project uses the DO productivity measurement method while Alex Parker prefers C13/N15 labeling.
  - This pilot study is not currently planned for 2012 due to lack of trained staff and funds for staff or instrument.

Funded Projects within the Context of Nutrient Strategy

A. Conceptual Model development and Scenario Analysis (addressing Task 1; RMP – $80k in 2012)

B. Synthesize existing data on external nutrient loads and data gaps analysis (addressing Task 4.1.a; RMP - $20k in 2012 and provisionally $30k in 2013)

C. Phytoplankton Assessment Framework and Oxygen Objectives (addressing Task 2.1 and Task 2.3.a; State Water Board – $100k, Task 2.4 15k 2012-2013)

D. Suisun Bay Synthesis Report and Study Plan (addressing aspects of Task 2.2; BACWA - $80k in 2012) Summarize existing knowledge related to beneficial use impairment from ammonium in Suisun Bay and develop a study plan that articulates key questions and addresses persistent knowledge gaps. Includes describing the life cycles of diatoms and copepods shown or suspected to be adversely impacted by ammonium; summarizing available information regarding the potential impacts of ammonium on these biological resources; exploring the potential role of nutrients and other stressors in the system; and identify remaining critical information gaps and studies to address these gaps.

E. Numeric models and budgets: Suisun Bay and South Bay (addressing Task 4.3.a – 2 year project, initial funding of $80k for first half year from BACWA). Develop and apply numeric biogeochemical models for Suisun Bay and South Bay to serve as an early step in modeling efforts to inform future model development and data collection.

F. Effluent characterization from POTWs and other Bay dischargers (addressing Task 4.1.a; 2012-2014, POTWs, BACWA and refineries paying for sample analysis and initial reporting; there is an additional cost for data analysis/synthesis.)

G. Suisun Bay Ammonium Studies (addressing aspects of Task 2.2; SWAMP-funded 2010-2012, with work carried about by SFSU-RTC). Document relationships between nutrients (especially ammonium), chl a and phytoplankton species composition during spring/summer in Suisun Bay.

H. Toxicity study, Toxicity Identification Evaluation (TIE; focus on phytoplankton) and Pesticide and Trace Metal Measurements in Suisun Bay (addressing aspects of Task 2.2; funded jointly by SFCWA and CCCSD, 2010-2012)

Other Selected On-going Studies with Relevance to Nutrient Strategy

A. The Role of Microcystis in the foodweb of the San Francisco Estuary: A Functional Approach (addressing aspects of Work Elements 1 and 2; funded by Bay-Delta Science Program, 2012-2015; work carried out by SFSU-RTC). Identify what environmental conditions are key in bloom development, characterize spatial and temporal patterns in the presence of toxic strains of Microcystis and their toxins, and understand how zooplankton respond to the presence of Microcystis.

B. Understanding the Effects of Nutrient Forms, Nutrient Ratios and Light Availability on the Lower Food Web of the Delta (addressing aspects of Work Elements 1 and 2; funded by Bay-Delta Science Program, 2012-2015; work carried out by University of Maryland and SFSU-RTC) conducting experimental manipulations with different ambient communities from different sites and seasons and enriched with different combinations of nitrogen and phosphorus in different chemical forms

C. Ongoing nutrient and phytoplankton research by USGS (addressing aspects of Work Elements 1, 2, and 3; field work and analysis funded 20% by RMP; work carried by J Cloern et al.)

D. Ongoing sediment dynamics studies by USGS (addressing aspects of Work Elements 1 and 3; field work and analysis funded in part by RMP; work carried out by D Schoellhamer et al.)

E. Ongoing work by the Interagency Ecological Program in Suisun Bay and Delta

F. Hydrodynamic, water quality, and ecological modeling in the Delta and Suisun Bay (addressing aspects of Work Element 3; funded by USACE 2009-2012, work carried out by Dynamic Solutions)