San Francisco Bay Nutrient Management Strategy
Detailed Modeling Workplan for FY15-FY21

- Draft -

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1. Introduction

San Francisco Bay has long been recognized as a nutrient-enriched estuary, but one that has exhibited resistance to some of the classic symptoms of nutrient overenrichment, such as high phytoplankton biomass and low dissolved oxygen. However, recent observations indicate that the Bay's resistance to high nutrient loads is weakening, leading regulators and stakeholders to collaboratively develop the San Francisco Bay Nutrient Strategy (SFBRWQCB, 2012). The Nutrient Strategy aims to address four overarching management questions (Table 1), and lays out an approach for building the scientific foundation to inform the related upcoming, and potentially costly, management decisions. Among its recommendations, the Nutrient Strategy calls for developing models to quantitatively characterize the Bay's response to nutrient loads; explore ecosystem response under future environmental conditions; and test the effectiveness of load reduction scenarios and other scenarios that mitigate or prevent impairment.

In January 2014, SFEI prepared a white paper with recommendations for developing and applying models to inform nutrient management decisions in San Francisco Bay[1] (Senn et al., 2014). The white paper recommended using the the Deltares suite of models and a phased approach to modeling. At its June 25, 2014 meeting, the Nutrient Steering Committee, the joint stakeholder and regulator decision-making body that oversees the Nutrient Strategy's implementation, approved funding to begin implementing that plan in FY15 .

The purpose of this report is to present a detailed workplan for modeling in FY15-FY21 based on the recommendations from Senn et al. (2014) and additional input from a team of technical advisors. Specifically, the objectives for this report are to:

- Outline the general approach for modeling, including quality assurance and peer review,
- Describe the specific tasks, deliverables and schedule for modeling, and how those tasks address key management questions,
- Identify the parties who will be responsible for modeling, and
- Calculate the overall budget for modeling.

This report will serve as a deliverable for Task 6.3 of the Nutrient Management Strategy ("Develop and Implement Modeling Strategy) (SFBRWQCB, 2012).

[1] http://www.sfei.org/sites/default/files/Nutrient_Modeling_Approach_draftFINAL_Jan212014.pdf

2. Approach

The nutrient modeling program will use a phased approach, quality assurance protocols, and an open-source modeling platform to promote efficiency, produce quality results, and maximize the value of the modeling investment.

<u>Phased Approach</u>

Work on water quality model development will proceed in a phased approach. For Phase 1, models will be simplified-domain (several boxes, with "real" hydrodynamics through grid aggregation of an existing hydrodynamic model), focused on South Bay/Lower South Bay and Suisun Bay. The simplified domain models will allow effort to be directed toward parameter sensitivity analysis, subembayment scale calibration, exploration of underlying causes of observed changes in ecosystem response, and identification of key data needs to prioritize among other research and monitoring activities in subsequent years. For Phase 2, work will gradually move toward higher degrees of spatial resolution, building toward a whole bay model and will provide preliminary answers to key management questions about the role of nutrients in the Bay. Phase 3 modeling will involve more complicated and/or multi-year scenarios to answer management questions with a higher degree of certainty.

At a two-day model planning development meeting in January 2014, SFEI's team of technical advisors strongly recommended pursuing this path of gradual development from simplified domain to more complex and larger-scale models. The rationale for pursuing this path is that sensitivity analysis becomes increasingly computationally-intensive, and data interpretation becomes much more complex, as a model becomes larger and more highly resolved. The Phase 1 focused studies will provide output that will ultimately help to reach the goal of a calibrated/validated model more rapidly, and, along the way, will provide preliminary answers to key management questions (Table 1), and will prioritize among additional data collection needs that will improve model calibration. The phased approach also allows the underlying hydrodynamic model to undergo continued development while work moves forward on the water quality models.

<u>Quality Assurance</u>

SFEI will follow widely accepted guidelines for quality assurance to produce accurate and transparent results. A recent U.S. Environmental Protection Agency guidance document recommended four specific practices for developers of environmental models used for regulatory decision-making (USEPA, 2009 at vii):

- Subject the model to credible, objective peer review;
- Assess the quality of the data used in the model;
- Corroborate the model by evaluating the degree to which it corresponds to the system being modeled; and
- Perform sensitivity and uncertainty analysis.

SFEI will conduct peer reviews, establish data quality objectives, and follow a structured modeling process to ensure that all four of these recommended best practices are completed.

Peer Review

The modeling process and products will be peer reviewed by a Modeling Advisory Team (MAT) and, if deemed necessary for the Nutrient Management Strategy process, additional peer review panels.

The MAT will consist of 3-4 national experts in relevant disciplines and will be responsible for reviewing all of the technical work products produced over the full length of this project. MAT members will not be involved with the modeling work directly to avoid conflict of interest. However, by being involved with the project over multiple years, the MAT members will be familiar with the project study area and goals. The MAT will meet in person at least once per year, with the first meeting to be held in FY15. The intent of this arrangement is to have a panel of high-quality, independent reviewers who can evaluate work products as they are produced and provide guidance to the program during yearly meetings.

Convening the MAT is intended to meet the Nutrient Management Strategy's need for detailed external peer review of highly technical work products. If deemed necessary for the Nutrient Management Strategy process, additional peer reviewers could also be convened at critical stages of the modeling process to provide an outside review of the work to date. The costs and time required to convene additional peer review panels are included in the budget and schedule, but these tasks are optional.

Data Quality Objectives

The Data Quality Objective Planning Process will be used to clearly define the purpose of the models or modeling activity, the quality of input data, and model performance objectives. USEPA (2006) offers useful guidance on this planning process, with self-evident benefits (see Figure 1). The level of detail and specificity in planning documents will match both the stage of modeling and management implications of the model results.

Structured Modeling Process

Each model will be produced and documented following a three-step modeling process (Figure 2). The basic purpose and main components of the three steps are defined as (USEPA, 2009 at 6):

Model development: develop the conceptual model that reflects the underlying science of the processes being modeled, and develop the mathematical representation of that science and encode these mathematical expressions in a computer program.
Components: Conceptual Model, Code Verification, Model Calibration

Model evaluation: test that the model expressions have been encoded correctly into the computer program and test the model outputs by comparing them with empirical data.
Components: Model Corroboration (validation), Sensitivity Analysis, Uncertainty Analysis

Model application: run the model and analyze its outputs to inform a decision.
Components: Model Predictions, Assessments

By following this structured modeling process, SFEI will complete the corroboration and sensitivity/uncertainty analyses recommended for model quality assurance. The Deltares suite of models selected for the Bay nutrient modeling effort offer the advantage that they are widely-used, peer-reviewed, and open-source models. In that sense, the model development steps related to encoding mathematical expressions into a computer program and verifying that the encoding has been done correctly have already been largely completed through past efforts for the more widely-used and peer-reviewed model components. Model development and evaluation steps specific to San Francisco Bay model will, of course, still be required. In addition, there will undoubtedly be some need to verify and evaluate new modeled processes, or new approaches/parameterizations for a process, that are introduced during the Bay modeling effort.

SFEI will produce reports at key stages of the model development and application process for stakeholder review and peer review either by the MAT or external reviewers. For the whole bay models, a model development and evaluation report will be produced and reviewed first, before starting on lengthy and expensive model applications. For smaller, subembayment models, all of the modeling steps will be documented in one combined model development-evaluation-application report.

Open-Source Community Modeling Platform

While nutrient management decisions will remain the primary driver and focus behind model development, an additional goal is to facilitate the model's use as an open-source, community model for a broad range of applications to address both management questions and fundamental research questions. The current plan is for SFEI to serve as the hub for this model, in collaboration with USGS and Deltares. The corroborated base model will be shared freely with all interested users, and periodically updated to incorporate model refinements. The stipulation for all users will be that any refinements or improvements to the model will also be open-source and freely available, and archived at the model hub.

The "community model" approach will have benefits both for the nutrient science program and for other topics of interest to regional monitoring programs in both the Bay and the Delta, regulators, dischargers, and environmental managers/planners. Having a large user base will lower SFEI's marginal costs for model enhancements and model maintenance. Nutrient-related funding will be directed toward developing components that are essential for nutrients, and collaborators may pursue funding from other sources to develop additional model capabilities, ultimately expanding the user community.

SECTION 3: Detailed Modeling Workplan

In the following section, the major modeling tasks, deliverables and schedule have been outlined. Gantt charts that illustrate the timing of the tasks and when information will be available to answer management questions are provided in Figures 3 and 4. See Table 2 for major model evaluation questions at each stage. The modeling stages and the timing of low, medium, and highest confidence answers to management questions were designed considering three major factors: realistic timelines for model development; progress in other areas of the Nutrient Management Strategy implementation (assessment framework development; data collection through monitoring and special studies); and regulatory drivers, such as the timing of Nutrient Watershed Permit. Major work products will be reviewed by the MAT or external peer reviewers, as indicated in Figure 3. The project durations and deliverable dates are approximate, especially those beyond FY15, and will be updated periodically.

Phase 1 Tasks

1.1 Phase 1 Hydrodynamic Modeling

Description: As described in the modeling development plan (Senn et al., 2014), the USGS-led CASCaDE II project represents the best opportunity for developing and sustainably maintaining a hydrodynamic model of the necessary complexity to address the range of nutrient-related modeling needs. Therefore, SFEI will direct resources toward supporting and quality assuring this existing effort rather than creating a separate hydrodynamic model. Specific steps include:

- Select a readily available hydrodynamic model to serve as the platform for Phase 1 subembayment-scale water quality models. This model will not be the final hydrodynamic model. The goal is to have a sufficiently calibrated/validated hydrodynamic model upon which to develop the Phase 1 water quality models, which will be simplified-domain subembayment-scale models ranging from 3 boxes to 10s of boxes at the subembayment scale. The current plan is to use a 'beta' version of the CASCaDE II hydrodynamic model. If the CASCaDE II hydrodynamic model is delayed, other options will be considered (see Senn et al., 2014 for further discussion of other options).
- Calibrate and validate a single-year hydrodynamic model for the Bay-Delta. SFEI will contribute resources to the on-going model development, calibration, and validation effort with the goal of moving that project forward so a Phase 1 model is available when whole-Bay water quality modeling work is set to begin.

Deliverables and Schedule:

Task	Deliverable	Completion Date
1.1a	Select a readily available hydrodynamic model to serve as the platform for Phase 1 subembayment-scale water quality models.	12/31/14
1.1b	Collaborate with USGS and Deltares to develop the Phase 1 CASCaDE Hydrodynamic and Sediment Model (single-year)	6/30/16

1.2 Phase 1 Water Quality Modeling: Lower South Bay and South Bay Water Quality Model

Description: The goal of this task is to develop a subembayment-scale water quality/ phytoplankton/ grazing model for the South Bay and Lower South Bay. The standard DELWAQ code from Deltares contains the vast majority of the biogeochemical/ecological processes that need to be included in the base model. The goals of Task 1.2 are: (1) to develop models that produce results that are conceptually correct, internally consistent, and sufficiently accurate to carry out sensitivity analysis and hypothesis testing at subembayment scales (or in simplified space/time domains); and (2) to begin exploring several fundamental questions about factors that regulate ecosystem response (Figure 4) . Specific tasks include:

- Develop a Data Quality Objectives Project Plan that contains the study objectives and model design.
- Perform simplified domain experiments for sensitivity analysis and hypothesis testing/generating (e.g., 1-box, 2-box).
- Develop aggregated models (e.g., several grid cells up to 10s of grid cells) for Lower South Bay and South Bay and carry out sensitivity analysis, initial calibrations, and focused experiments that address high priority science questions. In these studies, water quality will be driven by realistic hydrodynamic input that has been aggregated to the same grid.
- Produce a combined model development-evaluation-application report. This report will contain details of the model development (calibration), evaluation (validation), and application. A preliminary list of model evaluation questions is shown in Table 2.

Deliverables and Schedule:

Task	Deliverable	Completion Date
1.2a	Data Quality Objectives Project Plan	12/31/14
1.2b	Combined Model Development-Evaluation-Application Report	9/30/15

1.3 Phase 1 Water Quality Modeling: Suisun Bay Water Quality Model

Description: The goal of this task is to develop a subembayment-scale water quality/ phytoplankton/ grazing model for Suisun Bay. Task 1.3 is similar to Task 1.2 in approach and broad goals, with the effort focused on Suisun Bay, bringing lessons learned from the South Bay/Lower South Bay work and addressing issues specific to Suisun Bay. Specific steps to include:

- Develop a Data Quality Objectives Project Plan that contains the study objectives and model design.
- Perform simplified domain experiments for sensitivity analysis and hypothesis testing/generating (e.g., 1-box, 2-box).

- Develop aggregated models (e.g., several grid cells up to 10s of grid cells) for Suisun Bay and carry out sensitivity analysis, initial calibrations, and focused experiments that address high priority science questions. In these studies, water quality will be driven by real hydrodynamic input that has been aggregated to the same grid.
- Produce a combined model development-evaluation-application report. This report will contain details of the model development (calibration), evaluation (validation), and application. A preliminary list of model evaluation questions is shown in Table 2.

Deliverables and Schedule:

Task	Deliverable	Completion Date
1.3a	Data Quality Objectives Project Plan	6/30/15
1.3b	Combined Model Development-Evaluation-Application Report	3/31/16

1.4 Feasibility Studies for Modeling Tidal Sloughs and Phytoplankton Community Composition

Description: The tidal sloughs in South Bay are very small features compared to the whole bay. However, they may represent disproportionately valuable habitat for aquatic organisms, and data evaluated to date suggests that some sloughs experience frequent low DO events (Senn et al., 2013). Moreover, these systems may contribute nontrivial amounts of phytoplankton biomass to the open Bay, which may need to be accounted for in the open-Bay models. For those reason, some degree of modeling is needed in the sloughs, with the ultimate amount of effort slough modeling receives still to be determined. While the whole bay model can provide boundary conditions for sloughs, it cannot be used to model dissolved oxygen dynamics of phytoplankton production in the sloughs. Therefore, a separate set of models will be needed for tidal sloughs, potentially including individual models for each slough of management interest.

Phytoplankton community composition, and conditions that may favor the proliferation of harmful or nuisance algae species, is considered a priority issue in the Nutrient Management Strategy. Developing and applying models that can yield valuable insights to this issue are expected to be a challenging undertakings, and appropriate modeling approaches need to be considered in more detail.

For this task, SFEI will explore the feasibility of and data requirements for using models to understand dissolved oxygen and phytoplankton biomass in tidal sloughs, and the feasibility of and data requirements for using models to understand factors that regulate phytoplankton community composition. If feasible, models for these parameters will be developed during Phase 2. Specific steps to include:

- Research available models for tidal sloughs, outline the strengths and weaknesses of each in a report, conduct simplified modeling of sloughs, and present recommendations for the modeling approach for Phase 2. It is possible that the Deltares suite of models remains the best choice.

However, there may be more suitable models, depending on the necessary level of hydrodynamic complexity and resolution. Deltares is currently collaborating with USGS on hydrodynamic and sediment transport studies in Alviso Slough, and it is likely that DELWAQ can be scaled to simulate water quality in this habitat. However, the data requirements, both in terms of hydrodynamics and water quality, for developing a reasonable model are not known.
- Research available models for phytoplankton community composition, outline the strengths and weaknesses of each in a report, conduct simplified modeling of subembayments, and present recommendations for the Phase 2 modeling approach.

Deliverables and Schedule:

Task	Deliverable	Completion Date
1.4a	Tidal Slough Model Feasibility Study Report	6/30/16
1.4b	Phytoplankton Composition Model Feasibility Study Report	6/30/16

1.5 Second Peer Review of Phase 1 Modeling Products

Description: If deemed necessary for the Nutrient Management Strategy, the Phase 1 modeling products could be subjected to an external peer review by experts not on the MAT. Alternatively, the time allocated to this task could be used by the MAT for a deeper review of the modeling program or to move ahead with modeling activities at an accelerated rate. Specific steps to include:
- Develop charge questions for the review panel.
- Compile reports and technical products that document Phase 1 modeling activities.
- Identify and enter into contracts with external peer reviewers who have expertise related to the charge questions.
- Convene panel and provide administrative support.
- Communicate panel findings to stakeholders.

Deliverables and Schedule:

Task	Deliverable	Completion Date
1.5	External Peer Review Findings Report (optional)	12/31/16

1.6 Update Model Development Plan

Description: Based on findings from Phase 1 modeling, peer reviews by the MAT, and potentially another external peer review, SFEI will update the Model Development Plan before starting on Phase 2 modeling. Specific steps to include:

- Update the Model Development Plan. This update will include identifying priority monitoring or research needs for Phase 2 models, revisiting the priority science questions, and developing a refined list and schedule of prioritized modeling studies.

Deliverables and Schedule:

Task	Deliverable	Completion Date
1.6	Update to Model Development Plan	3/31/17

Phase 2 Tasks

2.1 Phase 2 Hydrodynamic Modeling

Description: As in Phase 1, SFEI will direct resources toward supporting and quality assuring the existing USGS-led CASCaDE II project. Specific steps include:

- Following the peer review, adopt the revised hydrodynamic model as the driver for the Phase 2 whole bay water quality model.
- Optimize computational methods to reduce model processing time.

Deliverables and Schedule:

Task	Deliverable	Completion Date
2.1a	Collaborate with USGS and Deltares to develop the Phase 2 CASCaDE Hydrodynamic and Sediment Model (multi-year, fine-scale)	6/30/19

2.2 Phase 2 Water Quality Modeling: Whole Bay Water Quality Model

Description: The goal of this task is to develop a coarse-scale whole bay water quality/ phytoplankton/ grazing model building upon the experience gained through the subembayment-scale models developed during Phase 1. The peer-reviewed CASCaDE II hydrodynamic model will be the hydrodynamic model used to drive the water quality model. Water quality parameters for nutrients, phytoplankton, and dissolved oxygen will be modeled by refining and scaling-up the DELWAQ-based model that was developed during Phase 1.

Due to its size and complexity, we anticipate the whole bay model will be developed in stages, although the sequencing proposed here may change based on observations from Phase 1. Specific steps to include:

- Develop a Data Quality Objectives Project Plan or Quality Assurance Project Plan that contains the study objectives and model design.
- Combine the CASCaDE hydrodynamic model for the whole bay with a water quality model for nutrient cycling (without phytoplankton) and carry out model sensitivity analysis, initial calibrations, and focused experiments that address science questions The first step will involve assuming nutrients behave conservatively, and assessing, under this assumption, the relative contributions of individual nutrient sources to different areas of the Bay over an annual cycle. From there, non-phytoplankton nutrient transformations/reactions will be added. Neglecting phytoplankton would be done for practical reasons to speed the pace of nutrient model development, since calibrating phytoplankton production is itself likely to be a challenging and time-consuming stage of model development. That said, initially neglecting phytoplankton-related reactions may be a reasonable first approximation since a large portion of nitrogen and phosphorus appear to go unutilized by phytoplankton during much of the year.

Moreover, if the model can reproduce typical nutrient concentrations without modeling phytoplankton, that would be useful information about how important phytoplankton are (or are not) to nutrient cycling in the Bay.

- Produce a combined model development-evaluation report, focused on nutrient cycling . This report will contain details of the model development (calibration), evaluation (validation). Table 2 presents a preliminary list of related model evaluation questions.
- Develop the phytoplankton (and potentially benthic algae) and dissolved oxygen components of the model and carry out sensitivity analysis, calibrations, and focused experiments to answer science questions.
- Produce a combined model development/evaluation report, focused on phytoplankton, and dissolved oxygen. This report will contain details of the model development (calibration), evaluation (validation). Table 2 presents a preliminary list of model evaluation questions.
- Perform model simulations to answer key management questions related to current conditions (see Table 1). Initially, the model will be run for single-year simulations. The model simulations will grow in complexity to cover multiple years at finer spatial resolution, as needed, in Phase 3. The model applications will be documented in a model application report.

Task	Deliverable	Completion Date
2.2a	Data Quality Objectives Project Plan or Quality Assurance Project Plan	9/30/17
2.2b	Model Development and Evaluation Report for Nutrient Cycling	6/30/18
2.2c	Model Development and Evaluation Report for Phytoplankton and Dissolved Oxygen	3/31/19
2.2d	Model Application Report for Single-Year Whole Bay Simulations	6/30/20

2.3 Phase 2 Water Quality Modeling: Slough Water Quality Models

Description: The feasibility of modeling dissolved oxygen in tidal sloughs will be evaluated in Phase 1. If deemed feasible, and necessary (based on other components of the Nutrient Management Strategy), a separate set of models will be needed for sloughs, potentially including individual models for each slough of management interest. In Task 2.3, models for tidal sloughs will be developed and applied toward exploring management questions related to the relationship between nutrients, phytoplankton (or benthic) production, dissolved oxygen, and other factors that regulate water quality (e.g., stratification, salt pond exports). This task has been assigned a long timeline to allow for workflow flexibility around the labor-intensive whole bay water quality modeling, and recognizing that the rate of progress on slough modeling may be limited by available funds. Specific steps include:

- Prepare a Data Quality Objectives Project Plan that contains the study objectives and model design.
- Develop and evaluate models for one or more individual sloughs (e.g., Alviso Slough). Similar to the approach for modeling open-area regions of the Bay, slough modeling will likely also

proceed in a step-wise fashion, starting with aggregated models with simplified hydrodynamics and adding complexity as needed.
- Produce a combined model development and evaluation report. This report will contain details of the model development (calibration) and evaluation (validation). A preliminary list of model evaluation questions is shown in Table 2.
- Perform model runs to partially answer key management questions (see Table 1). The model applications will be documented in a model application report.

Deliverables and Schedule

Task	Deliverables	Completion Date
2.3a	Data Quality Objectives Project Plan	9/30/17
2.3b	Model Development and Evaluation Report	12/31/18
2.3c	Model Application Report	6/30/20

2.4 Phase 2 Water Quality Modeling: Phytoplankton Community Composition Models

Description: The feasibility of developing phytoplankton community composition models will be evaluated in Phase 1. If deemed feasible, and necessary (based on other components of the Nutrient Management Strategy), a separate set of models will be needed for phytoplankton community composition. In Task 2.4, models for phytoplankton community composition will be developed and applied toward exploring management questions related to the relationship phytoplankton community composition, nutrients, and other influential factors (temperature, light, etc.). Similar to Task 2.3, this task has been assigned a long timeline to allow for workflow flexibility around the labor-intensive whole bay water quality modeling, and recognizing that the rate of progress on phytoplankton composition models be limited by available funds and the complexity of the task. Specific steps include:
- Prepare a Data Quality Objectives Project Plan that contains the study objectives and model design.
- Develop and evaluate models for one or more subembayments (e.g., Suisun Bay). Similar to the approach for modeling open-area regions of the Bay, phytoplankton community modeling will likely also proceed in a step-wise fashion, starting with aggregated models with simplified hydrodynamics and adding complexity as needed.
- Produce a combined model development and evaluation report. This report will contain details of the model development (calibration) and evaluation (validation). A preliminary list of model evaluation questions is shown in Table 2.
- Perform model runs to partially answer key management questions (see Table 1). The model applications will be documented in a model application report.

Deliverables and Schedule

Task	Deliverables	Completion Date
2.4a	Data Quality Objectives Project Plan	9/30/17
2.4b	Model Development and Evaluation Report	12/31/18
2.4c	Model Application Report	6/30/20

2.5 Second Peer Review of Phase 2 Modeling Products

Description: If deemed necessary for the Nutrient Management Strategy, the Phase 2 modeling products could be subjected to external peer review by experts not on the MAT. Alternatively, the time allocated to this task could be used by the MAT for a deeper review of the modeling program or to move ahead with modeling activities at an accelerated rate. Specific steps to include:

- Develop charge questions for the review panel.
- Compile reports and technical products that document Phase 2 modeling activities.
- Identify and enter into contracts with external peer reviewers who have expertise related to the charge questions.
- Convene panel and provide administrative support.
- Communicate panel findings to stakeholders.

Deliverables and Schedule:

Task	Deliverable	Completion Date
2.4	External Peer Review Findings Report (optional)	12/31/20

Phase 3: Out-Year Modeling Plans

This modeling workplan covers the first six years with the goal of (1) addressing critical management questions about nutrients in the estuary during the development phase and (2) building a robust platform capable of simulating conditions under multiple future scenarios.

In the out-years, the whole bay model will be applied toward answering more complicated management questions related to ecosystem response under future scenarios (e.g., changes in flows from the Delta due to withdrawals and rerouting; decreasing suspended sediments; climate change) and exploring the effectiveness of various nutrient load reduction scenarios.

The out-years will also likely be needed for refining tidal slough and phytoplankton community models, if such models are deemed both important and feasible.

Finally, in the out-years, the Bay-Delta model could be linked to near-shore coastal models to answer questions that are being asked about the the effects of nutrient exports from the Golden Gate on coastal eutrophication and harmful algal blooms, such as:

- What is the magnitude of nutrients exported to the coastal ocean, and what are the fate(s) of nutrients once exported coastal ocean?
- What are the impacts of nutrients exported to the coastal ocean?

The modeling tasks for the out-years are beyond the scope of this workplan, and so are not described in depth here. They will be developed through subsequent planning activities as the specific needs for those modeling activities become clearer.

4. Modeling Team

Phase 1 work will be carried by Core Team members (Table 3), consisting of SFEI staff and close external collaborators from academic institutions, research institutions (e.g., USGS, Deltares), and consulting firms.The expertise of the Core Team covers the major technical areas (e.g., hydrodynamics, biogeochemistry, phytoplankton dynamics), and will be complemented by individuals with specific expertise as needed. Full-time modeling staff at SFEI will carry out much of the hands-on work, although some specific hands-on technical work may be conducted by non-SFEI Core Team members The non-SFEI Core Team will serve three primary functions, with individuals contributing differently based on expertise and availability:

- Technical guidance during project planning stages and project start-up, and periodic meetings for regular project updates;
- In-depth, hands-on support from some individuals on specific topics, as needed; and
- On-going technical review of progress and major work products.

For Phase 2 and Phase 3, individual projects will be completed by the Core Team, external collaborators, or a combination of the two. The approach for selecting teams to work on specific projects will vary by project, and may depend on several factors, including the required expertise, time-sensitivity of the final product, and available budget. In some cases, the Core Team may be well-positioned to carry out the work; in other cases, sole-sourcing to a specific group or putting out a request for proposals may be the best route.

5. Budget

This model development workplan has been crafted to maintain a consistent level of effort over a six-year period. Major deliverables are typically spaced 6 months apart. The only variable costs are the optional second external peer reviews which will occur during FY17 and FY20. The total cost to implement this workplan is $3.7M over six years or approximately $620K per year (the peer review in FY21 not treated as a full year). This total cost does not include the cost of nutrient monitoring and research.

Line Item	FY15	FY16	FY17	FY18	FY19	FY20	FY21
SFEI Staff	$300,000	$309,000	$318,270	$327,818	$337,653	$347,782	
Contractors	$200,000	$206,000	$212,180	$218,545	$225,102	$231,855	
MAT Honoraria	$40,000	$41,200	$42,436	$43,709	$45,020	$46,371	
Second Peer Review (optional)			$100,000				$120,000
Total	$540,000	$556,200	$672,886	$590,073	$607,775	$626,008	$120,000
FY15-FY21 Total							$3,712,941

Budget Justification:

- SFEI staff: 1 new FTE modeler @ $240K plus contributions from existing SFEI staff @ $60K.
- Contractors: SFEI needs to hire contractors with specialized expertise to advise on model development and application, and assist on some technical topics. These contractors will be part of the Core Team. In 2015, $100,000 is being directed toward the collaboration with USGS and Deltares ($50,000: hydrodynamic model development/calibration; $50,000: BLOOM model development and benthic:pelagic coupling). Technical assistance from Deltares on water quality model set-up, hydrodynamics, grid aggregation, etc., was estimated at $50,000/yr. Additional specialized support will be needed during detailed modeling years.
- MAT Honoraria: MAT members will be paid an annual honorarium and will have travel expenses reimbursed. This budget assumes total expenses per MAT member to be $10,000 per year and that there will be 4 members of the MAT.
- External Peer Reviews: A payment of $25,000 per reviewer would be necessary to obtain thorough and detailed reviews from outside experts. A four person panel would, therefore, cost $100,000. The schedule of deliverables and reviews has been carefully aligned to minimize the number of times a second external panel would need to be convened (once in FY17 and once in FY21). The cost in FY21 was assumed to be $120,000.
- Costs for FY14 have been projected to future values using 3% discount rate for FY15-FY20.

6. References

Senn, D., and E. Novick. 2013. San Francisco Bay Nutrient Conceptual Model. San Francisco Estuary Institute, Richmond, CA. Draft for Review - May 1, 2013. Published online: http://sfbaynutrients.sfei.org/sites/default/files/Nutrients_CM_DRAFT_May12013_small.pdf.

Senn, D., D. Yee, C. Jones, E. Novick, and J. Davis. 2014. Model Development Plan to Support Nutrient Management Decisions in San Francisco Bay. San Francisco Estuary Institute, Richmond, CA. January 21, 2014. Published online: http://sfbaynutrients.sfei.org/sites/default/files/Nutrient_Modeling_Approach_draftFINAL_Jan212014.pdf.

SFBRWQCB. 2012. Nutrient Management Strategy for San Francisco Bay. Published collaboratively by the San Francisco Bay Regional Water Quality Control Board, San Francisco Estuary Institute, and Southern California Coastal Water Resources Project. Published online: http://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/planningtmdls/amendments/estuarineNNE/Nutrient_Strategy%20November%202012.pdf

USEPA. 2006. Guidance on Systematic Planning Using the Data Quality Objectives Process EPA QA/G-4. EPA/240/B-06/001. Office of Environmental Information, U.S. Environmental Protection Agency, Washington, DC. February 2006. Published online: http://www.epa.gov/QUALITY/qs-docs/g4-final.pdf

USEPA. 2009. Guidance on the Development, Evaluation, and Application of Environmental Models. EPA/100/K-09/003. Council for Regulatory Environmental Modeling, U.S. Environmental Protection Agency, Washington, DC. March 2009. Published online: http://www.epa.gov/crem/library/cred_guidance_0309.pdf

Table 1: Priority Management Questions and Associated Modeling Questions

Management Question	Science Questions for Modeling
1. Is San Francisco Bay currently experiencing nutrient-related impairment, or is impairment likely in the future?	Not Applicable. Questions about impairment will be addressed through the assessment framework and monitoring components of the Nutrient Management Strategy.
2. If nutrient-related impairment is occurring, or future impairment is likely, what are the relative contributions of different nutrient sources to impairment, and how do these contributions vary spatially or temporally?	How much do nutrient loads from known sources contribute to ambient nutrient concentrations in: (1) each subembayment of the Bay by season; and (2) South Bay sloughs by season? How much do nutrient loads from known sources contribute to phytoplankton blooms and low dissolved oxygen in: (1) each subembayment of the Bay by season; and (2) South Bay sloughs by season? Do the models indicate that all the major sources of nutrients to the Bay are accurately being measured? What is the relative importance of ammonia inhibition of primary production on phytoplankton biomass compared to other factors? What is the relative importance of nutrient concentrations or ratios relative to harmful algal blooms compared to other factors?
3. What nutrient loads can the Bay assimilate without impairment of beneficial uses?	Under what future conditions would adverse impacts be expected? *Scenarios*:prolonged stratification, loss of clams, increased water clarity, stochastic introduction(s) of opportunistic harmful phytoplankton species, changes in nutrient load mass or speciation, water diversions.
4. What load reductions or other management strategies may be effective at mitigating current problems or preventing future problems from occurring?	What potential effects would different control measures have on mitigating current or future problems at the subembayment (or finer) scale? Scenarios: Changes in wastewater treatment, habitat restoration, water management, etc

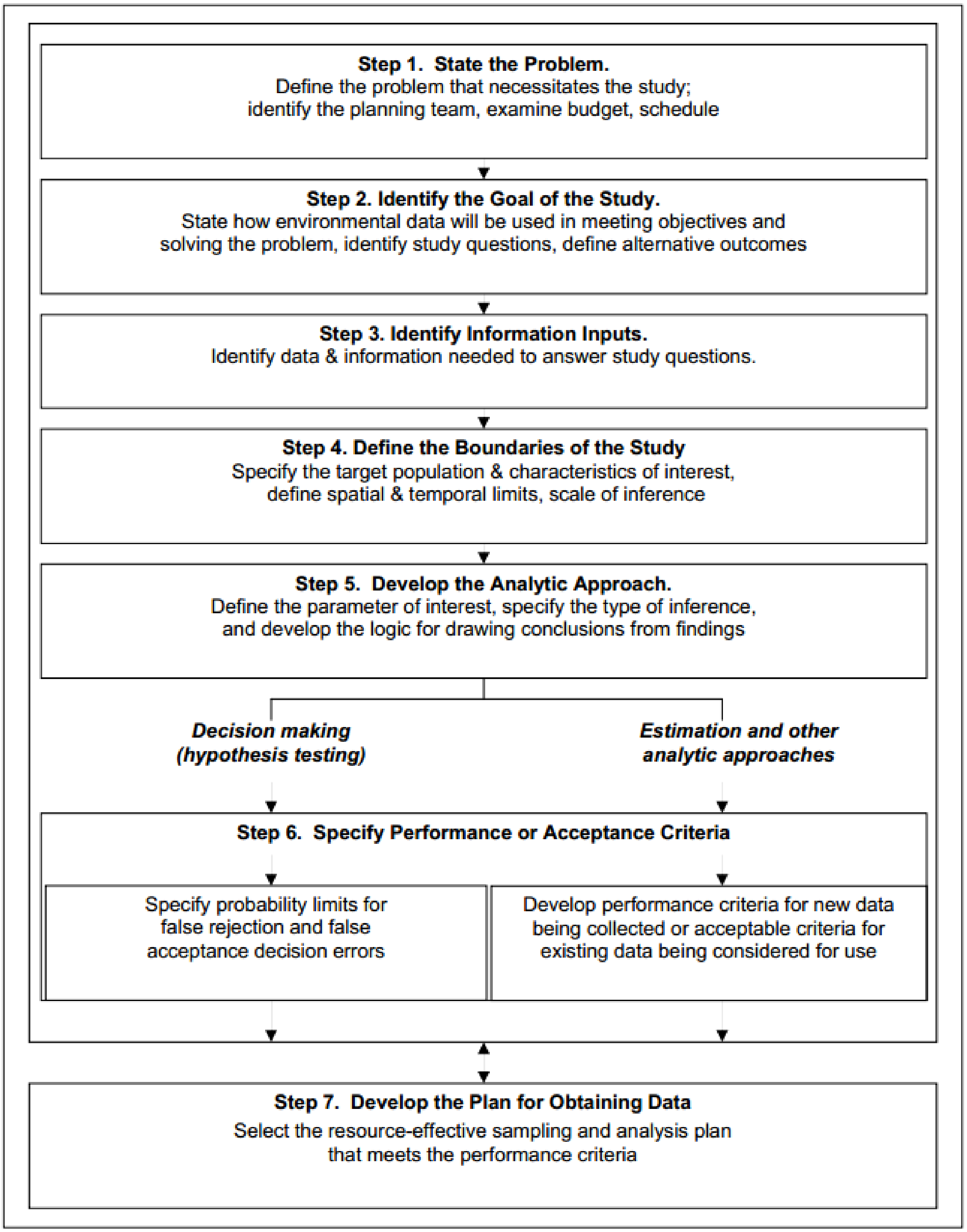
Table 2: Model Evaluation Questions

Model	Model Evaluation Questions
Phase 1 South Bay Water Quality Model	Can the parameterized model reproduce a similar (approximately three-fold) increase in phytoplankton biomass that has been observed in South Bay and Lower South Bay during summer and fall months since 1998? Can the parameterized model reproduce fall phytoplankton blooms that have been observed in South Bay and Lower South Bay after 1998? Can the parameterized model reproduce improvements in dissolved oxygen that were observed following wastewater treatment plant upgrades in the 1970s? What are the important mechanisms and highest priority data needs to improve model performance and decrease uncertainty?
Suisun Bay Water Quality Model	Can the parameterized model reproduce a decrease in phytoplankton biomass that has been observed in Suisun Bay post-1987, and a gradual increase in biomass in Suisun Bay since the late 1990s? What are the important mechanisms and highest priority data needs to improve model performance and decrease uncertainty?
Whole Bay Model	Can the parameterized model predict the diurnal and seasonal variability in nitrogen and phosphorus that has been observed in deep water areas of each of the five subembayments of San Francisco Bay. Can the parameterized model predict the diurnal and seasonal variability in dissolved oxygen that has been observed in deep water areas of each of the five subembayments of San Francisco Bay? Can the parameterized model predict the diurnal and seasonal variability in phytoplankton biomass and composition that has been observed in deep water areas of each of the five subembayments of San Francisco Bay? What are the important mechanisms and highest priority data needs to improve model performance and decrease uncertainty?
Tidal Slough Models	Can the parameterized model predict the diurnal and seasonal variability in nitrogen and phosphorus that has been observed in South Bay sloughs? Can the parameterized model predict the diurnal and seasonal variability in dissolved oxygen that has been observed in South Bay sloughs? Can the parameterized model predict the diurnal and seasonal variability in phytoplankton biomass that has been observed South Bay sloughs? What are the important mechanisms and highest priority data needs to improve model performance and decrease uncertainty?
Phytoplankton Community Composition Model	Can the parameterized model reproduce the changes in phytoplankton community composition that have been observed in Suisun Bay post-1987?

Table 3: Core Modeling Team Members (draft)

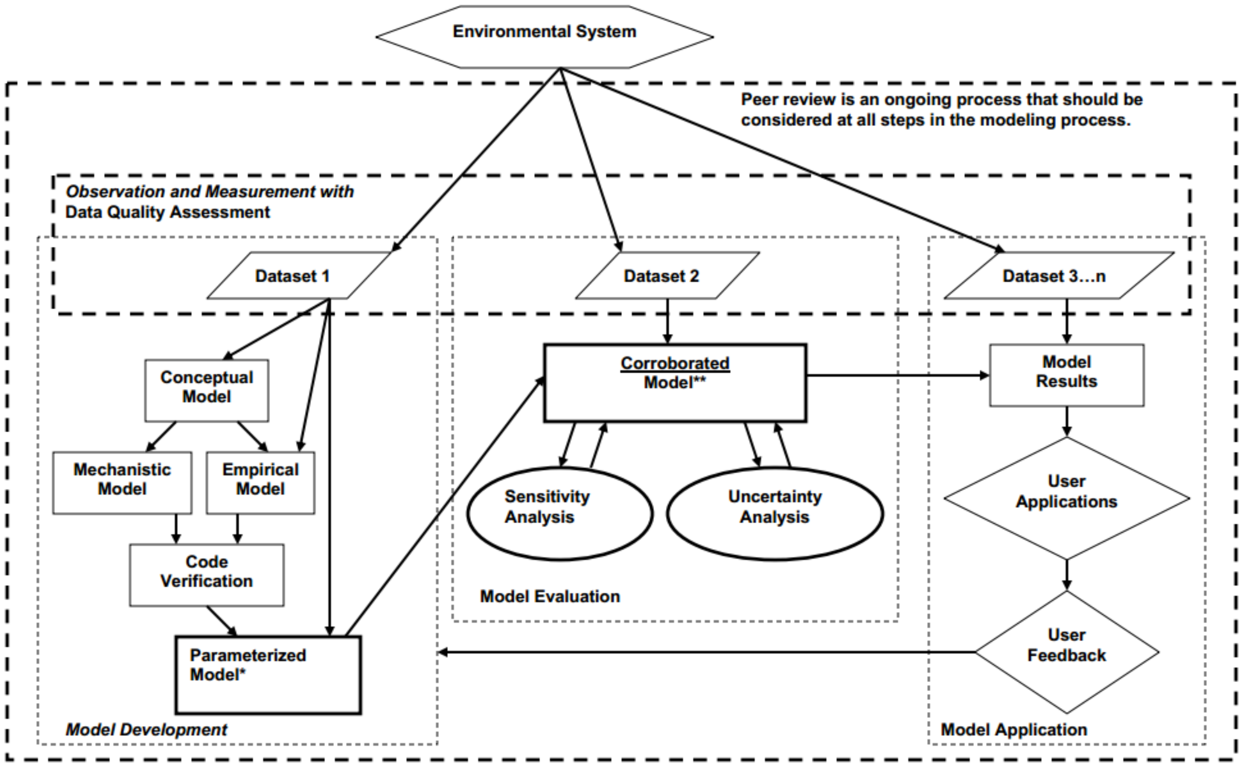
Name	Affiliation	Expertise
Mark Stacey	UC Berkeley	hydrodynamics
Lisa Lucas	USGS	hydrodynamics and phytoplankton productivity, benthic-pelagic coupling
Mick van der Wegen	Deltares, UNESCO-IHE	hydrodynamic modeling, sediment transport modeling
Ed Gross	UC Davis, RMA	hydrodynamic modeling
Craig Jones	Integral Consulting	sediment transport modeling
Jim Fitzpatrick	HDR-Hydroqual	water quality modeling
Johannes Smits	Deltares	water quality modeling
James Cloern	USGS	phytoplankton ecology, nutrients
Wim Kimmerer	SFSU-RTC	estuarine ecology, benthic and pelagic grazing
Oliver Fringer	Stanford	hydrodynamics, hydrodynamic modeling

Figure 1: Diagram of the Data Quality Objectives Planning Process



Source: USEPA (2006) at 8

Figure 2: Diagram of the Three-Step Modeling Process



Source: USEPA (2009) at 61

Figure 3: Gantt Chart for Model Development Tasks (Note: The current POTW Watershed Permit expires after FY19)

Task Name	Peer Review By
Modeling Workplan	
Phase 1: Pilot-Scale Water Quality Modeling and Feasibility Studies	
1.1 Hydrodynamic Modeling	
1.1a Readily-Available Model to support Phase 1 WQ Modeling	
1.1b Single-Year, Coarse-Scale Hydrodynamic Model for Whole Bay	MAT
1.2 South Bay Water Quality Model	
1.2a. Data Quality Objectives Project Plan	MAT
1.2b. Combined Model Development-Evaluation-Application Report	MAT
1.3 Suisun Bay Water Quality Model	
1.3a. Data Quality Objectives Project Plan	MAT
1.3b. Combined Model Development-Evaluation-Application Report	MAT
1.4 Feasibility Studies	
1.4a Tidal Slough Model Feasibility Study Report	MAT
1.4b Phytoplankton Composition Model Feasibility Study Report	MAT
1.5 Second Peer Review of Phase 1 (optional)	Reviewers not on MAT
1.6 Update Model Development Plan	MAT
Phase 2: Whole Bay Water Quality Modeling and Slough/Phytoplankton Model Development	
2.1 Hydrodynamic Modeling	
2.1a Multi-Year, Fine-Scale Hydrodynamic Model for Whole Bay	MAT
2.2 Whole Bay Water Quality Model	
2.2a Data Quality Objectives Project Plan or QAPP	MAT
2.2b Model Development and Evaluation Report for Nutrient Cycling	MAT
2.2c Model Development and Evaluation Report for Phytoplankton and Dissolved Oxygen	MAT
2.2d Model Application Report for Single-Year, Whole Bay Simulations	MAT
2.3 Tidal Slough Water Quality Model(s) [If Feasible]	
2.3a Data Quality Objectives Project Plan	MAT
2.3b Model Development and Evaluation Report	MAT
2.3c Model Application Report	MAT
2.4 Phytoplankton Community Model(s) [If Feasible]	
2.4a Data Quality Objectives Project Plan	MAT
2.4b Model Development and Evaluation Report	MAT
2.4c Model Application Report	MAT
2.5 Second Peer Review of Phase 2 (optional)	Reviewers not on MAT
Phase 3: Out-Year Model Applications	
3.1 Model Application Report for Multi-Year Simulations	MAT
3.2 Tidal Slough Water Quality Model Refinement	MAT
3.3 Phytoplankton Community Model Refinement	MAT
3.4 Linkage to Coastal Models	MAT

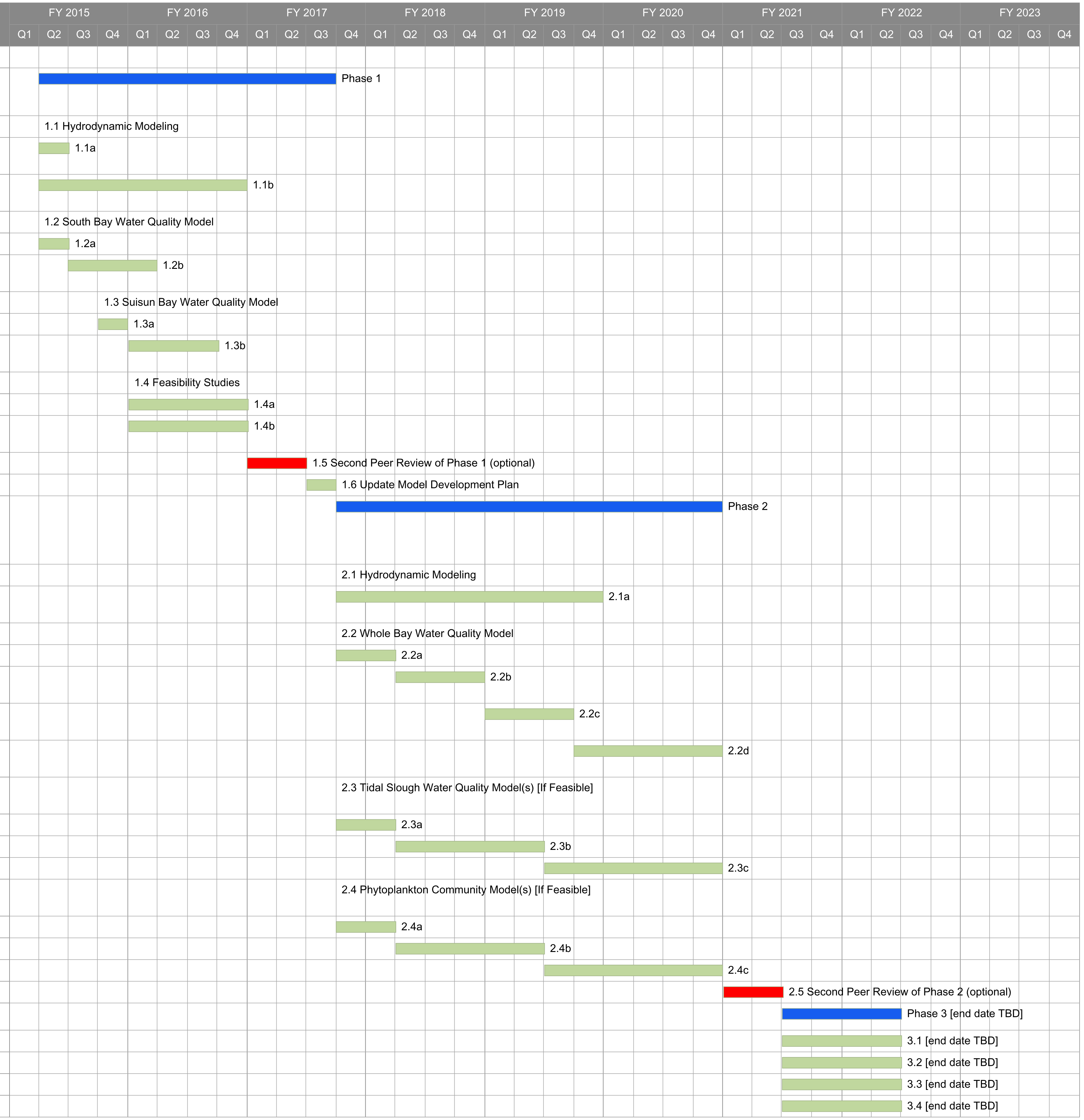


Figure 4: Gantt Chart of Management Questions, Modeling Questions, Tasks, and Quality of Information Expected by Certain Dates (Note: The current POTW Watershed Permit expires after FY19)