Operation Baseline Science and Monitoring Needs

A memorandum summarizing the outcomes of a stakeholder workshop and surveys

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PREPARED FOR
Delta Science Program

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DELTA STEWARDSHIP COUNCIL
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Introduction

In May 2018, the Delta Science Program (DSP) and the San Francisco Estuary Institute-Aquatic Science Center (SFEI-ASC) held a stakeholder workshop to discuss the nutrient-related effects of an upcoming major upgrade to the Sacramento Regional County Sanitation District's Wastewater Treatment Plant (WWTP, hereafter Regional San). The purpose of the workshop was threefold: (1) to inform managers and scientists about scientific efforts underway to understand the impacts of the upgrade on water quality and the environment of the northern San Francisco Estuary (nSFE); (2) to solicit stakeholder input on a framework developed to identify and explore potential nutrient-related responses to the upgrade in downstream habitats; and (3) to capture data and knowledge gaps, and discuss the relative merits of potential studies that could inform nutrient-related management decisions. In order to encourage discussions on science and policy that is inclusive, responsive, transparent and mutually relevant, workshop participants included stakeholders, scientists, managers, decision-makers, and other interested parties. This memo describes the workshop and subsequent surveys, and summarizes key messages gathered about nutrient-related science priorities.

Upgrades to the Sacramento Regional Wastewater Treatment Plant and a Conceptual Framework for Understanding Potential Changes to Downstream Waterways

Excess inputs of the nutrients Nitrogen (N) and Phosphorus (P) from anthropogenic activities have created pervasive water quality problems in freshwater, estuarine, and coastal ecosystems worldwide (e.g., Cloern et al. 2001; Statham 2012; Pearl et al. 2014). Concerns about the contribution of these excess nutrients to several management challenges in the nSFE, including harmful algal blooms, food web alterations, and the spread of invasive aquatic vegetation (Dahm et al. 2016, National Research Council 2012, Bricker et al. 2008), have catalyzed efforts from managers, regulators, and stakeholders to understand the effects of nutrient enrichment in the nSFE, identify protective nutrient loads or concentrations, and pursue effective nutrient management strategies.

Upgrades to Regional San's WWTP, one of the largest current nutrient sources to the nSFE, and the largest ammonium (NH_4^+) point source to the Sacramento River (**Figure 1**; Jassby 2008; Saleh and Domagalski, 2015; Novick et al. 2015), are slated to be completed by the end of 2021. The upgrades will substantially reduce dissolved inorganic nitrogen (DIN) inputs to the Sacramento River and Sacramento River-influenced areas within the Delta, and alter the dominant chemical form of N from NH_4^+ to nitrate (NO_3^-). Effluent NH_4^+ concentrations are expected to decrease by over 95% year-round (from about 35 mg-N/L to <1 mg N/L). On average, Regional San's WWTP effluent DIN loads are expected to decrease more than 65%, from about 14,000 to about 4,700 kg N per day. Regional San's WWTP P inputs are not expected to change.

While it is reasonable to label many habitats throughout the nSFE as nutrient-enriched, it is nonetheless challenging to confidently predict how those habitats will respond to a new nutrient regime. The uncertainties surrounding potential ecosystem responses stem in large part from the fact that many nutrient-related processes are strongly regulated by physical and biological factors, such as physical connectivity, flow patterns, temperature, light availability, and foodweb interactions (Ward and Paerl 2017), which themselves vary seasonally, interannually, and spatially.

In 2016, the Delta Science Program (DSP) launched a set of pilot studies to track and analyze the changes expected due to the upgrade. The set of pilot studies, collectively called “Operation Baseline”, includes the development of a conceptual framework (Senn et al., *in preparation*) to 1) critically examine potential ecosystem responses to decreased nutrient loads; and 2) identify opportunities and constraints for science and monitoring (pre- and post-upgrade). The conceptual framework, which served as a basis for the Management Needs Workshop, summarizes the current understanding of ecosystem function related to nutrients; identifies key data and knowledge gaps related to predicting or observing ecosystem upgrade; and aims to support nSFE adaptive management by advancing our understanding of critical nSFE ecosystem functions. The other Operation Baseline studies are field-based, and target the collection of pre-upgrade baseline observations and method development, including: conducting nutrient transformation rate measurements; exploring wetland nutrient cycling and links to the lower foodweb; applying high-frequency methods for measuring nitrate, ammonium, phosphate, and phytoplankton community composition in space and time; and forensically investigating nutrient isotopes. Those studies, while targeting important knowledge and data gaps, only address a small portion of what will ultimately be needed to characterize and observe ecosystem responses to the upgrade work. More information on the Operation Baseline Initiative is available at: http://deltacouncil.ca.gov/operation-baseline-studying-effects-regional-san-treatment-plant-upgrade.

The conceptual framework considers nutrient-related processes that are directly and indirectly linked to several nutrient-related management priorities (e.g., Delta Nutrient Management Plan; CVRWQB 2018), including the health of the foodweb, the success of wetland restoration, drinking water quality, recreation, and navigation via ‘bottom-up’ pathways. The upgrade’s influence at the level of management priorities would occur through a series of biogeochemical processes and ecological responses, which are themselves regulated by multiple physical and biological factors.

Since multiple factors contribute to ecosystem condition, directly linking changes in ‘bottom-up’ factors such as nutrient condition to enhanced ecosystem function becomes challenging, especially at higher trophic levels. The conceptual framework thus focuses on opportunities for measuring responses to the upgrade that would be reliable indicators of change, as follows: 1) by identifying plausible pathways along which the upgrade could influence nutrient-related management priorities, with each pathway comprised of a series of responses linked in a stepwise fashion; 2) by identifying stages along those pathways at which measurable effects can be reliably detected.

Plausible responses to the upgrade are described in a set of linked response tiers (**Figure 2**), that cover both nutrient-linked ‘bottom-up’ processes, and ‘top-down’ management concerns. Changes to nutrient loads due to the Regional San WWTP upgrade sit at the base (Tier 0; T0), representing a large-magnitude and reasonably well-constrained change with relatively low uncertainty. Nutrient-related management priorities, identified by regulators, managers, and stakeholders (e.g., Delta Nutrient Research Plan 2018, CVRWQCB, 2018) serve as the endpoints motivating the analysis (Tier 4; T4). Intermediate Tiers 1-3 include:

- Tier 1 (T1): changes in the amount of nutrients in the water, i.e., ambient nutrient concentrations;
- Tier 2 (T2): direct biological responses to changes in nutrients in photosynthetic organisms at the lowest level of the foodweb, i.e., (primary production by phytoplankton and macrophytes) and the non-photosynthetic microbial community (heterotrophic, chemoautotrophic microbes); and
- Tier 3 (T3) higher-level biological responses, including foodweb interactions.

The tiers and potential responses therein are summarized in **Table 1**, organized first by response category and, within each category, by more specific responses.

Responses to the upgrade are likely to vary considerably in space and time, and this variation will inform when and where to look for changes due to the upgrade. The conceptual framework therefore presents a preliminary estimate of the 'Zone of Influence' for WWTP upgrade-related changes to DIN and NH_4^+ concentrations (**Figure 3**). The framework also identifies regions in which Tier 2 responses may be most evident, if they occur (**Figure 4**), as well as a guidance for considering how the responses may behave over time (**Figure 5**).

Further, the conceptual framework identifies key knowledge and data gaps related to responses in Tiers 1 and 2. Data needs and knowledge gaps for Tiers 3 and 4 were not articulated in the conceptual framework because nutrient-related effects on response Tiers 3 and 4 are currently uncertain. The data needs and knowledge gaps for Tiers 1 and 2 were discussed in the Management Needs Workshop and are listed in **Table 2**. The conceptual framework manuscript stops short of prioritizing these knowledge and data gaps, recognizing that developing priorities should involve a wider group of stakeholders — managers, scientists and others. Therefore, the DSP, in coordination with the San Francisco Estuary Institute-Aquatic Science Center (SFEI-ASC), convened a workshop to present the draft conceptual framework and to discuss potential research priorities in relation to the upgrade.

Regional San Upgrade Conceptual Framework and Management Needs Workshop and Survey

Upgrades to Regional San's WWTP represent a costly effort and a big opportunity to examine this major change in nutrient concentrations to understand system biogeochemistry. For this reason, it is important to conduct studies that emphasize management priorities and that leverage the expertise of managers, scientists, and stakeholders alike. Truly, the divide between these groups is often much narrower than perceived, since many natural resource management professionals are well-trained in the natural sciences, and many scientists actively pursue research that is highly relevant to management decisions. Therefore, collaboration and 'co-discovery' can be a very fruitful enterprise when addressing environmental management issues (Civitanovic et al 2016, Lemos and Morehouse 2005). Further, results from collaborative science efforts that include stakeholders are seen as more legitimate, easier to understand, and more useable than efforts that are generated within a narrower arena of participation

(Meyer et al 2015, Wyborn 2015, Dilling and Lemos 2011). There is also a recognition that resources are limited and that decision-makers and managers need priorities in order to allocate scarce resources.

Recognizing the need to involve the management community in prioritizing data needs, in May 2018, DSP and SFEI-ASC convened a workshop to gather managers, scientists, and stakeholders with expertise in nutrients and nutrient-related management issues to discuss science needs with regard to the Regional San upgrade (the workshop agenda is provided in **Appendix A**; for a list of attendees, see **Appendix B**). The goals of the workshop were to:

1. Inform the group on conceptual framework for the Sacramento Regional Wastewater Treatment Plant upgrade and related science knowledge gaps already identified within that framework.
2. Share an initial set of management questions that may have a direct or indirect nexus with the conceptual framework, discuss and add to list of management needs.
3. Identify additional key management questions related to expected outcomes of the WWTP upgrade that will serve to address management needs. Clarify areas of greatest uncertainty (i.e., key data gaps) and refine list of potential research, monitoring, and modeling efforts capable of reducing uncertainties associated with anticipated outcomes of the WWTP upgrade. For each topic or study, identify its: (a) Feasibility (in terms of cost, permitting, staffing, timing); (b) Importance (relevance to key management question or knowledge gap); (c) Broad application to multiple issues; and (d) Opportunity to leverage existing data collection.

To further solicit input, a post-workshop survey was sent to scientists and managers who attended, as well as those who could not attend. The goal of the survey was to gather additional feedback about the workshop and the conceptual framework. Survey questions are included as **Appendix C**.

Other Nutrient Planning Efforts in the nSFE

The work described in this memo is taking place in the context of several related nutrient science initiatives in the nSFE. Concurrent with the Operation Baseline studies, the Regional Water Quality Control Board, Central Valley Region (CVRWQCB) has developed a Delta Nutrient Research Plan to determine whether numeric water quality objectives for nutrients are warranted in order to protect water quality in the Delta (CVRWQCB 2018). The CVRWQCB process included the development of several white papers on Delta nutrient-related topics, as well as a stakeholder engagement process to identify research gaps and develop consensus on a Delta-wide research plan for management challenges related to nutrient enrichment. The Delta Regional Monitoring Program (DRMP) and the San Francisco Bay Nutrient Management Strategy (SFBNMS) have also developed stakeholder-derived nutrient-related research questions for the estuary (DRMP 2018, McKee et al. 2011).

The initiatives above are highly relevant to, and in some cases overlap with, studies identified in the conceptual framework for understanding the ecosystem responses to the Regional San WWTP upgrade. Studies related to the Regional San WWTP upgrade could help address a subset of these regional research needs. **Appendix D** compiles questions and knowledge gaps identified through these regional efforts that are also identified within the conceptual framework.

Goals of this report

The goals for this report are to relay the content of the workshop, and to present the outcomes of workshop discussions and post-workshop surveys. It should be noted that the 'priorities' identified at the workshop and through the surveys are preliminary in nature. Further coordination will be needed to make decisions about which studies to pursue ahead of Regional San's upgrade.

Figure 1. Map of the northern San Francisco Estuary (i.e., Sacramento-San Joaquin Delta). The orange triangle indicates the location of the Sacramento Regional Wastewater Treatment Plant (Regional San) along the Sacramento River.

Table 1 Summary of *potential* response scenarios related to the Regional San WWTP upgrade. Developed by considering plausible responses to the upgrade, the pathways by which the responses occur, and their relation to priority management issues. Note that this set of responses was developed to capture a wide range of proposed or hypothesized responses, including those hypothesized in other investigations (Table prepared for Senn et al. *in prep*).

Tier	Category	Specific response or effect
T1	Ambient Nutrient concentrations (N)	N1: Decreased concentrations of dissolved inorganic nitrogen (↓ [DIN])
		N2: Decreased concentration of ammonium (↓ [NH4])
		N3: Gradual decrease of labile N in sediments
T2	Phytoplankton (P)	P1: Decreased phytoplankton primary production or biomass, due to ↓ [DIN]
		P2: Increased phytoplankton primary production, relaxation of NH4-inhibition due to ↓ [NH4]
		P3a: Changes in assemblage due to inter-taxa differences in growth-limiting N concentrations, ↓ [DIN] P3b: Changes in phytoplankton assemblage (toward better food quality) due to ↓ [NH4] (relaxation of negative impacts of [NH4] on 'healthy' taxa)
		P4A-B: Decrease in occurence of harmful algal blooms (HABs) and a decrease in cyanotoxin production (see Tier 2 HAB Summary for more specific response categories) due to ↓ [DIN] and ↓ [NH4] P4C: Recycled nutrients from sediments are sufficient to sustain large and toxic Microcystis blooms; blooms will only decrease once sediment N levels N flux from sediments drop substantially
	Microbial community (M)	M1: Changes to nitrifier community (abundance, assemblage) due to ↓ [NH4]
		M2: Changes to denitrifier community (abundance, assemblage) due to ↓ [DIN]
		M3: Other changes to the heterotrophic microbial community due to ↓ [DIN]
	Aquatic Vegetation (AV)	AV1: Reduction in plant biomass due to ↓ [DIN]
		AV2: Shift in AV community composition due to ↓ [DIN] and/or ↓ [NH4]
		AV3: Change in distribution of AV if there are substantial decreases in sediment N pools and fluxes.
T3	Food Web (FW)	FW1a: Improved food resources reaching species of interest (e.g., production rates or quantity; quality; alignment in space/time with resource needs) and/or evidence of favorable responses (e.g., abundances) FW1b: Lower food resources reaching species of interest
		FW2: Lower toxicity exposure to intermediate food resources from HABs, or evidence of increasing abundances
		FW3: Alterations (improvements) to physical habitat that indirectly influence species of interest within the food web (e.g., decrease of invasive predator habitat), or evidence of changing abundances.
T4	Consumptive Water Use (CW)	CW1: Improvements to water operations due to decreased invasive aquatic vegetation
		CW2: Lower human exposure to HAB toxins, lower production of taste and odor compounds, lower production of disinfection byproduct precursors.
	Recreation and Navigation (RN)	RN1: Fewer issues with physical obstructions due to reduction in invasive aquatic vegetation (recreational boating, transport, fishing)
		RN2: Fewer concerns about dermal contact to HAB toxins (recreational boating, swimming, fishing)
	Habitat (H)	H1: Improved physical habitat due to lower presence of invasive aquatic vegetation (e.g., more suitable spawning habitat, higher turbidity for predator avoidance, poorer conditions for invasive predators)
		H2: Decreased impacts to biota from direct exposure to HAB toxins that impact reproductive success or other individual or population-level responses
		H3: Improved food supply, in particular for pelagic fish, due to changes in phytoplankton primary production (quantity and quality) and aquatic vegetation
		H4: Improved DO conditions, resulting from decreased primary production and subsequent metabolism

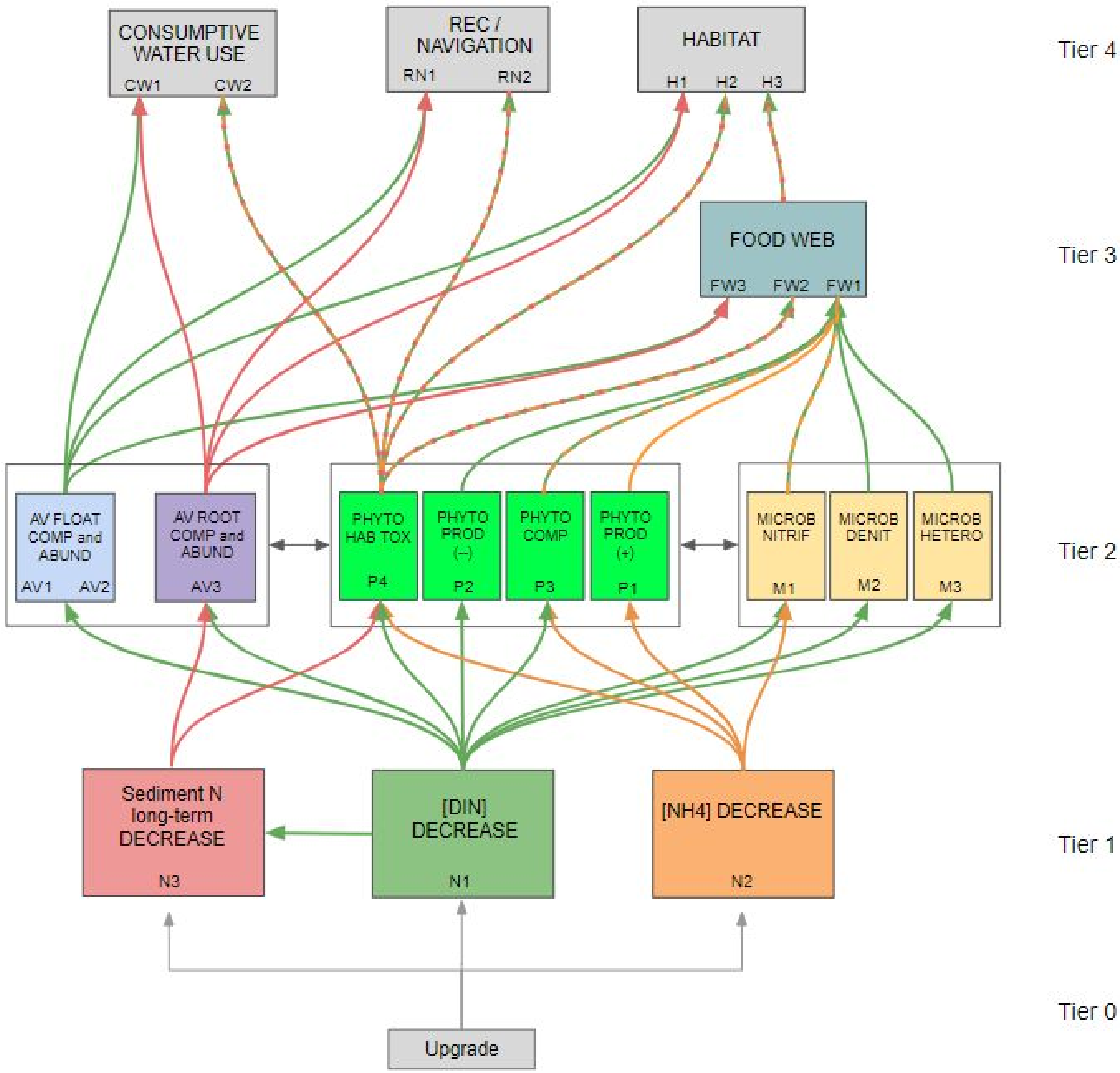

Figure 2. Plausible mechanistic pathways developed for the conceptual framework. Arrows between tiers indicate plausible pathways that have been hypothesized or proposed in Bay-Delta scientific literature or management considerations. Arrow colors extending from T2 to T3 or T4 indicate whether the continued path is related originally to N1 (green), N2 (orange), or both. ↔ denotes interactions/feedbacks between T2 responses, P↔M, AV↔P, and AV↔M. See Table 1 for a more detailed description of the potential responses (Figure prepared for Senn et al. *in prep*).

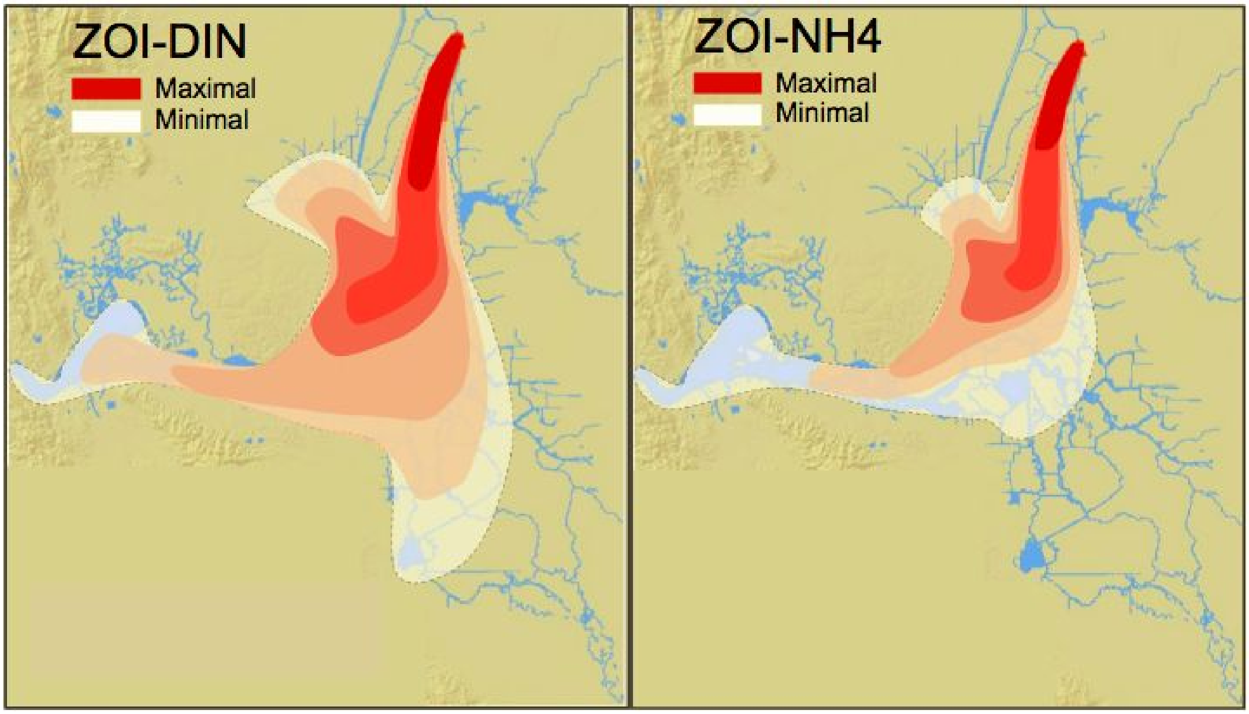

Figure 3. Conceptual depiction of Regional San WWTP's effluent Zone of Influence (ZOI) for DIN and NH_4^+ in summer. Changes between pre- and post-upgrade nutrient concentrations are expected to be highly variable in space and time. The area indicated on the map combines water age (**τ**) and source tracer estimates to identify Regional San's Zone of Influence (ZOI). The primary goal of this analysis was to begin identifying the characteristics of the ZOI, not to predict nutrient concentrations. Contours are approximations based on model simulations (hydrodynamic + simplified biogeochemistry), and provide a qualitative depiction of the predicted change in DIN concentration for mid-August. Being able to predict where, and by how much, nutrient concentrations are expected to change is critical for designing robust studies. In addition, some hypotheses or pathways are related to specific N forms (i.e., NH_4^+). Since ZOI-NH_4^+ may differ considerably from ZOI-DIN, ideal study sites may differ for exploring DIN and NH_4^+ - related issues. Also note that changes in water management may have a substantial influence on the ZOI spatial extent (Figure prepared for Senn et al. *in prep*).

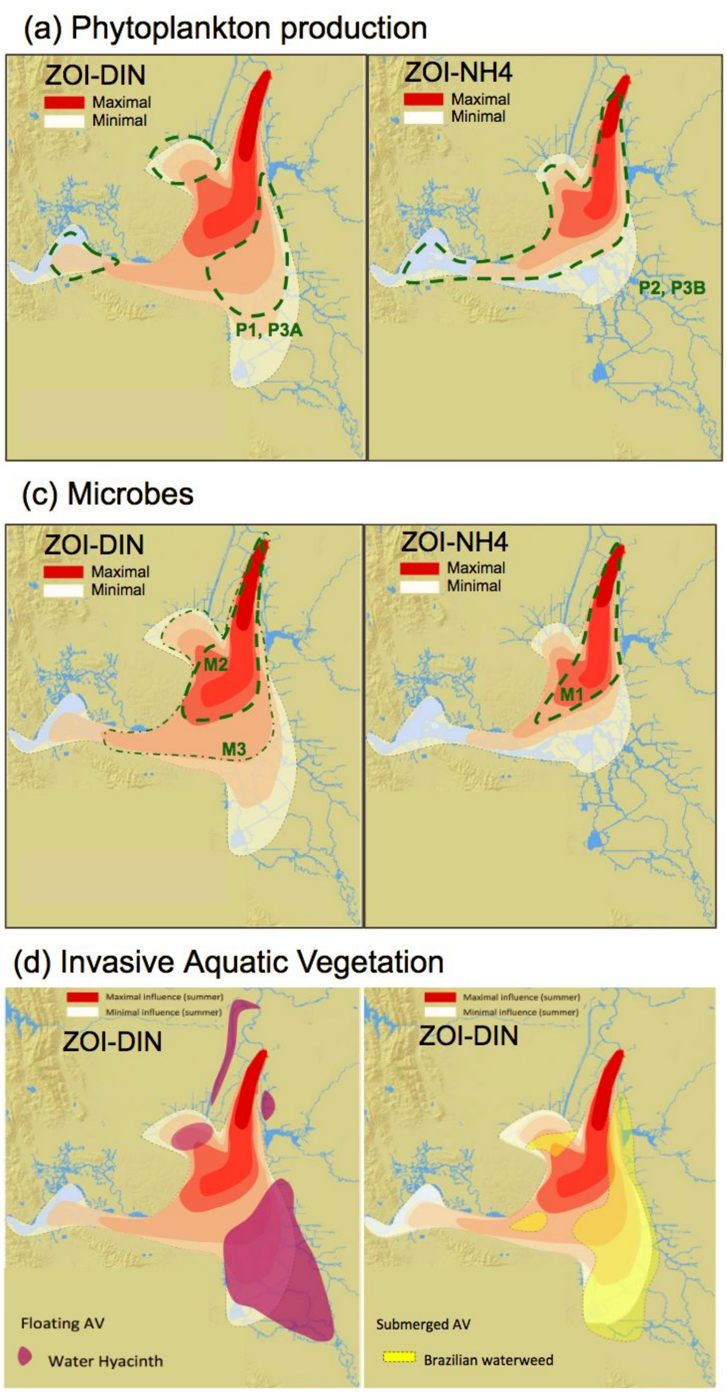

Figure 4. Conceptual illustrations of zones in which Tier 2 responses to the Regional San upgrade could be most effectively studied (summer months), for (a) phytoplankton production, (b) HABs, (c) microbial production, and (d) invasive aquatic vegetation. Overlap between the overlays and ZOI contours indicates zones with greatest likelihood of detecting T2 responses, if those responses occurred. Some responses are specifically related to changes in NH_4^+ concentrations, and are thus depicted relative to ZOI-NH_4^+; ideal study sites may differ for exploring some DIN and NH_4^+- related issues. For phytoplankton responses P2 and P3B, and microbial assemblage, the overlays fall entirely within the ZOI-DIN or ZOI-NH_4^+. For phytoplankton responses P1 and P3A, areas where phytoplankton may respond to DIN limitation are indicated. For HAB, SAV, and FAV responses, the full extents of the overlays depict regions where negative impacts are currently most pronounced for each. While portions of the HAB-, SAV-, and FAV-affected areas overlap with zones in which some change to DIN and NH_4^+ concentrations may occur, substantial portions of the affected areas are in zones where limited changes to N concentrations may occur, highlighting the need for careful selection of study sites related to the ZOI. It is important to emphasize that the ZOIs and the T2 response areas are intended as coarse, conceptual depictions. Within each of these overlapping areas, multiple other factors will influence the likelihood of detecting responses, such as channel geometry and water velocities. Determining locations for field studies would require finer-spatial-resolution considerations (Figure prepared for Senn et al. *in prep*).

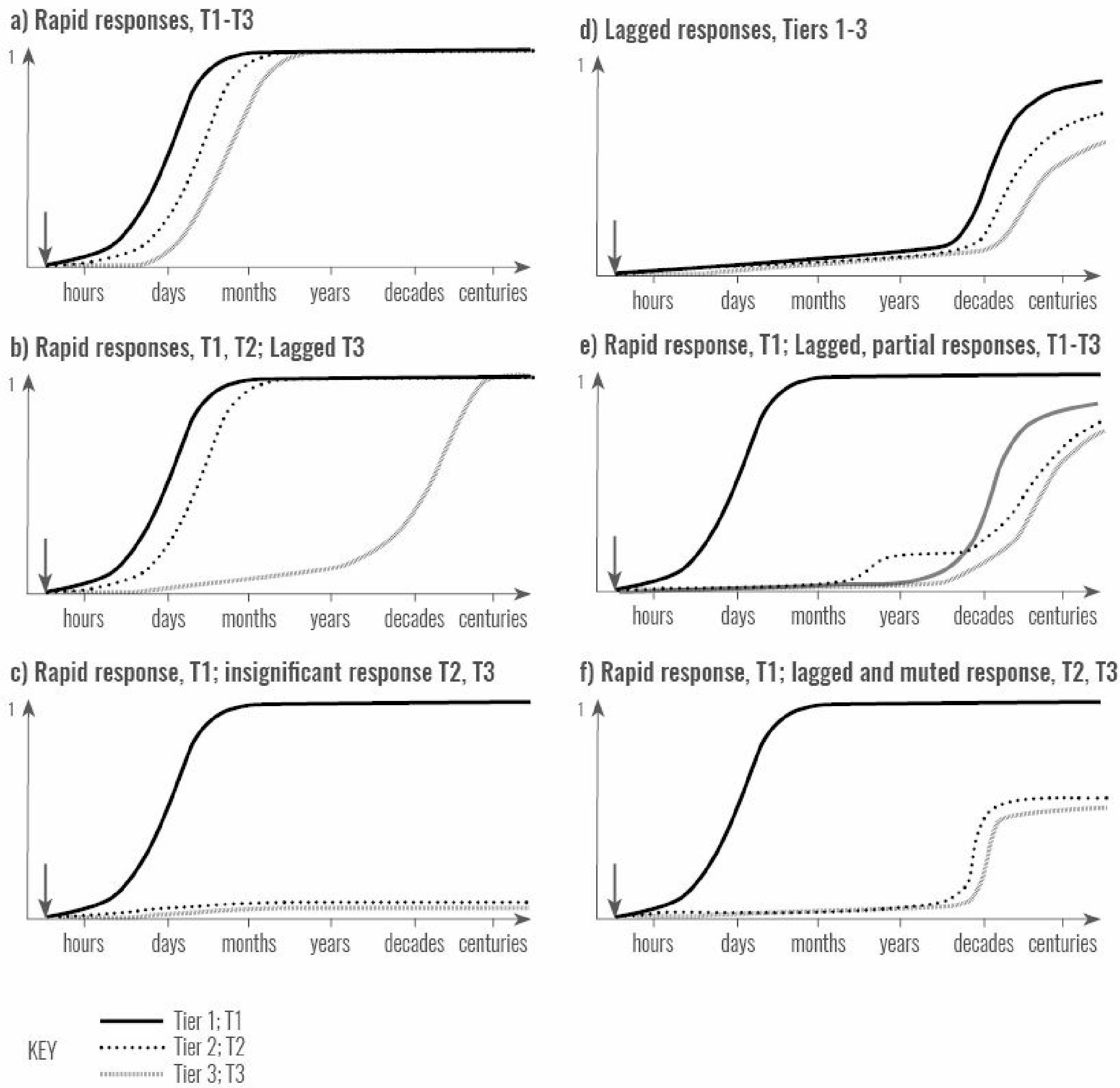

Figure 5. Conceptual differences in potential responses to Regional San's WWTP upgrade over time. Tier 1 includes potential changes in nutrient loading, Tier 2 responses relate to potential changes in primary production, and Tier 3 responses relate to potential foodweb-related changes (Figure prepared for Senn et al. *in prep*).

	very high
	high
	moderate
	not relevant

Table 2 Key data needs and knowledge gaps identified in the conceptual framework for potential nutrient-related responses to the Regional San WWTP upgrade. Cell color indicates the relevance of the data need, knowledge gap to each response. Note that data needs and knowledge gaps were identified for Tiers 1 and 2 only, because nutrient-related effects on response Tiers 3 and 4 are uncertain.

		Tier 1			Tier 2									
		Nutrients			Phytoplankton (beneficial, HABs)				Microbes			Aquatic Vegetation			
	Data Need, Knowledge Gap	N1	N2	N3	P1	P2	P3	P4	M1	M2	M3	AV1	AV2	AV3	AV4
1	Quantify ambient nutrient concentration (higher spatial and temporal resolution, additional habitats)														
2	Measure transport parameters (e.g., water sources, residence time)														
3	Quantify nutrient transformation rates across space and time (e.g., mineralization, nitrification, denitrification, biotic uptake)														
4	Quantify sediment nutrient pools, availability and fluxes														
5	Characterize links between water column and sediment nutrient pools														
6	Phytoplankton Biomass: Additional discrete (Chl-a) and high frequency mooring, mapping; biomass data linked to measurement of nutrients and other drivers														
7	Phytoplankton Community: High and low resolution (space,time) of phytoplankton community composition, densities, and biovolume														
8	Quantify phytoplankton growth rates and nutrient requirements in relation to other drivers (e.g., temperature, light, salinity) for relevant phytoplankton taxa														
9	Quantify phytoplankton and HAB loss rates to planktonic and benthic grazers, including size-selective grazing														
10	Quantify toxin concentrations in relation to the nutrient field and other drivers														
11	Characterize microbial assemblage in relation to the nutrient field and other drivers														
12	Quantify contribution of microbial community to the foodweb.														
13	Quantify relationships between microbial assemblage and nutrient transformations, or use as indicators of condition and/or function														
14	Trace the fate of nutrients taken up by primary producers (AV, phytoplankton)														
15	Identify nutrient thresholds affecting growth of AV, by species (including nutrient concentrations, form, timing, and duration of minimum supply)														
16	Quantify nutrient demand by AV to determine effects on water column nutrient concentrations														
17	Ascertain whether AV growth rates differ under NH4 vs. NO3, and whether the form of N effects competition between species														
18	Monitor AV biomass and species composition over space and time, quantify feedbacks between AV in relation to nutrient demand and cycling														
19	Quantify nutrient demand of and transformation rates in restored wetlands														
20	Develop and apply coupled hydrodynamic and biogeochemistry models														
21	Enhance monitoring of key physical factors (e.g., temperature, light, salinity, water depth)														
22	Maximize coordination: data collection and analysis across various entities, including between monitoring, special studies, and modeling efforts														

Methods

Participation in this stakeholder workshop was open to a wide range of interested stakeholder representatives following a broad invitation circulated to some 5,700+ stakeholder contacts encompassing a broad range of agencies, researchers, general public, and professional organizations. Considerable attempts, including targeted outreach, were made to have the key stakeholder groups represented.

Priority data needs and knowledge gaps were ranked by workshop participants in a group exercise. Participants were divided into four groups of roughly equal size, with each group composed of participants with different backgrounds and perspectives, and asked to come to agreement on how the different data needs identified in Table 2 should be ranked along two axes - importance and feasibility. Each group repeated this ranking exercise four separate times, each time considering the data needs through the lens of one of the four management priorities identified in the conceptual framework: Foodweb, Consumptive Use, Habitat, and Recreation/Navigation. To facilitate this process, the groups used a board with the two axes drawn and a set of printed cards with the 22 data needs on them to aid in the discussion and ranking (**Figure 6**). Additional, blank 'wild cards' were also provided so participants could contribute additional ideas. Participants were given 20 minutes to rank data needs for each of the four management topics.

Figure 6. Workshop participants rank data needs along two axes, one for feasibility and another for importance.

For this exercise, importance related to the relevance of data gaps to addressing key management questions. Feasibility included consideration of available methods, logistical constraints, permitting, and cost. Comparisons among groups were complicated by slightly different definitions of feasibility and importance within and among groups. For example, the extent to which feasibility was defined by cost varied by group. Other important considerations that likely impacted ranking included: not all groups were able to rank all of the data needs in the 20 minutes allotted for each round, and prioritization was influenced by the particular expertise within each group. The highest priority data needs identified in the workshop are summarized here by tallying the data needs that ranked highest in both importance and feasibility across all groups and management priority topics, as well as within topics.

After the workshop, surveys were sent out to all workshop invitees, including those that were unable to attend the workshop in person. Invitees who had not attended the workshop were asked to fill out a slightly different version of the survey (both surveys are included in **Appendix C**). Both versions of the survey included the following:

i. Questions about data need/knowledge gaps
ii. Questions about potential responses
iii. Feedback on usefulness of conceptual framework
iv. Information about respondents

Survey participants were asked to consider both importance and feasibility together in ranking priority data needs and potential responses. Surveys completed by workshop participants also asked for feedback on the workshop itself. Eleven workshop attendees and four invitees who did not attend responded to the surveys. Results of the surveys are discussed qualitatively.

Results and Discussion

The workshop and subsequent survey highlighted the challenges of prioritizing the studies necessary to understand the impact of the Regional San upgrade on management priorities of interest. There are many pathways by which changes in nutrient inputs can affect management priorities, and many unknowns within this system. The conceptual framework which underpinned this workshop identified 22 data needs (Table 2) and 28 potential responses (Table 1) of the system to the upgrade, and workshop and survey participants ranked most of those data needs and potential responses to be between moderate and high priority.

Despite the fact that most of the data needs and responses were identified as valuable to participants, through the group exercise and survey, they were still able to arrive at a group of data needs that ranked higher than the others. These higher ranked data needs are discussed below. It is important to note that these rankings are not intended to convey final priorities, but rather to inform future decision-making processes.

The workshop offered an opportunity for discussion, which participants reported was informative and affected their personal prioritization. Some participants appreciated the opportunity to consider the data needs from multiple perspectives of the management priority categories. Others stated that the prioritization exercise benefitted from group discussion (as opposed to individuals making independent rankings). A common theme that emerged at the workshop and in the surveys was that group coordination and discussion were deemed extremely valuable.

Summary of Key Points from Workshop and Survey Results

Though the workshop discussions and survey results do not represent a definitive ranking of priorities, certain general observations can be made about which data needs and knowledge gaps were deemed more important and feasible than others. The **highest ranking data needs and knowledge gaps** that emerged from the exercise and discussions were those that **are applicable to many of the plausible responses** to the Regional San WWTP upgrade. Specifically, these were: to expand/reconfigure the quantification of ambient nutrient conditions (1); to measure transport parameters (2); to enhance monitoring of phytoplankton biomass (6); to enhance monitoring of key physical factors (21); and to maximize coordination (22). **Additional high-ranking data needs were those relating to fundamental questions** about phytoplankton, modeling, and nutrient transformation rates — in other words, participants valued additional studies addressing topics in Tier 1 (ambient nutrient concentrations) and Tier 2 (primary producers), as opposed to those more closely related to Tiers 3 (foodwebs) and 4 (management priorities). This would indicate that a holistic program that builds on efforts currently in place, and that adds special studies to fill in knowledge gaps, would be valuable. This was also a major recommendation of the Delta Independent Science Board's water quality review (Delta ISB 2018).

When asked to assess the value of investigating the potential responses to the Regional San upgrade that were identified in the conceptual framework, the majority of the plausible responses were deemed of medium or high importance (scoring 2 and above out of possible high of 3 in the survey responses). Only two of the plausible responses received an average score below 2. This could indicate that there was agreement that **measuring most of the responses identified in the framework is important to the group**.

The value of enhanced coordination and increased collaboration was highly emphasized by the group, and some considered this the key to successfully addressing science needs not only related to the upgrade, but to Delta science in general; one respondent stated that "Coordination across scientific disciplines is of utmost importance". Related to this general point, **many studies will be much more meaningful if they are done together,** because some of the data needs and knowledge gaps are linked. For example, measurements of nutrient concentrations (Data Need #1 in Table 2) on their own are not very informative without information about change over time (#3), and their relation to environmental factors like temperature, light, and transport (#2, #8 in Table 2). Several participants noted that the monitoring of data needs should be coordinated (e.g. the importance of measuring toxins at same time as measuring temperature).

It should be noted that **some of the data needs fall under the umbrella of basic research rather than directly relating to management priorities or management questions**, and may have been ranked lower for this reason. For example, one area that would fall under basic research at this time includes questions dealing with microbial community structure, abundance, and function. As one survey respondent put it, "We know very little about the importance of dissolved organic matter quality to microbial food webs; or how this will be changing at different locations". Research into this topic would likely reveal valuable insights about nutrient cycling, among other things, but clear management linkages are difficult to make *a priori* in these cases. This does not diminish their intrinsic value to fundamental research, and may reveal important management strategies in the future.

The **definitions of importance and feasibility varied by group**. Groups applied a number of criteria to determine feasibility and importance that included cost, technical feasibility, importance to environmental goals, potential for data need to inform adaptive management, degree of possible coordination, and public visibility of the topic. For example, some groups considered cost highly in the feasibility definition, but others ignored cost in order to focus on the technical or scientific importance of a given data need. Additionally, the application of importance and feasibility criteria also **varied within each group**, changing from topic to topic. Participants reported that it was sometimes difficult to 'take off the hat' of a previous topic and dive into the next. This highlighted that **prioritization depends on what you care most about in terms of outcomes**. It should also be noted that the **groups' choices were heavily influenced by the expertise of people at the table**; for example, data needs or topics that group members were relatively uninformed about tended to be deprioritized. Additionally, **the form of the exercise**, as well as **interpersonal dynamics**, likely **affected the outcome of the rankings**. For example, groups learned how to do the exercise over the course of moving to the four tables, such that groups that had been unable to get through all the data needs for the first round were able to complete the exercise by the end. In terms of group dynamic, it was notable that some groups were able to quickly come to consensus, while others spent more time discussing data needs in-depth. All these factors likely affected the groups' choices.

A more detailed summary of workshop and survey feedback follows.

Specific Feedback on Data Needs / Knowledge Gaps

As noted above, workshop participants were asked to prioritize the data needs and knowledge gaps identified in the conceptual framework by their feasibility and importance four times, each time taking the perspective of a different management category. Across all groups, the numbered data needs / knowledge gaps that received the highest rank both during the workshop and from the post workshop surveys were 'ambient nutrients' (data need, knowledge gap #1 in Table 2), 2 (transport parameters' (#2), 'enhanced phytoplankton monitoring' (#6), 'enhanced monitoring of physical factors (#21), and 'maximize coordination' (#22) (**Table 3**). Notably, these data needs were also identified as highly important in the conceptual framework because they address many of the responses across Tiers 1 and 2. Several attendees remarked that 'maximize coordination' was particularly important, indeed, key to the success of any effort.

Table 3. Top Five Data Needs, Knowledge Gaps as 'ranked' during workshop and surveys

#	Data Need, Knowledge Gap
1	Quantify ambient nutrient concentration (higher spatial and temporal resolution, additional habitats)
2	Measure transport parameters (e.g., water sources, residence time)
6	Phytoplankton Biomass: Additional discrete (Chl-a) and high frequency mooring, mapping; phytoplankton biomass data linked to measurement of nutrients and other drivers
21	Enhance monitoring of key physical factors (e.g., temperature, light, salinity, water depth)
22	Maximize coordination: data collection and analysis across various entities, including between monitoring, special studies, and modeling efforts

Survey respondents were asked to indicate their level of agreement that these top five data needs identified at the workshop were indeed worthy of rising to the top. Taken together, respondents 'mostly' agreed, with an averaged rating of 3.1 out of 4 [0 to 4 scale; 0=not at all agree; 4=very much agree].

When we look at the rankings within the groups, a slightly more nuanced picture arrives. This is not surprising, considering that priorities can shift when the focus of the ranking is on different outcomes. Reflecting the general rankings, the **Consumptive Water Use** groups ranked the following the highest: ‘ambient nutrients’ (#1), ‘transport parameters’ (#2), ‘develop models’ (#20), and ‘maximize coordination (#22). The **Recreation/Navigation** groups ranked ‘transport parameters’ (#2) highest, followed by ‘ambient nutrients’ (#1) and ‘phytoplankton biomass measurements’ (#6). In addition to ‘ambient nutrients’ (#1), ‘transport parameters’ (#2), ‘phytoplankton biomass measurements’ (#6), and ‘monitoring of key physical factors’ (#21), the **Foodweb** groups also highly ranked ‘nutrient transformation rates’ (#3), ‘sediment nutrient pools’ (#4), ‘phytoplankton community measures’ (#7), ‘phytoplankton growth rates vs. other drivers for certain taxa’ (#8) and ‘coupled hydrodynamic and biogeochemistry modeling’ (#20). The **Habitat** groups each defined habitat differently, which may have had a bearing on the rankings within each group: some emphasized pelagic habitat, others marshes; some included foodwebs, while others did not. For Habitat, the highest ranked data needs were ‘ambient nutrients’ (#1), ‘AV biomass over space and time’ (#18) and ‘monitoring of key physical factors’ (#21); while ‘transport parameters’ (#2), ‘phytoplankton biomass measurements’ (#6), #21, and ‘maximize coordination (#22) were each chosen by two of the groups to be highly feasible and important. See **Appendix C** for complete tallies.

In addition to the top five data needs from the workshop, survey respondents were asked to identify additional data needs not included in the top five that they considered important and feasible (**Table 4**). They ranked data needs ‘phytoplankton community measures’ (#7), ‘coupled hydrodynamic and biogeochemistry modeling’ (#20), ‘nutrient transformation rates’ (#3), ‘phytoplankton growth rates vs. other drivers for certain taxa’ (#8), ‘HAB toxin concentrations’ (#10), and ‘nutrient thresholds affecting AV’ (#15) as very important / feasible.

Table 4. Additional Data Needs, Knowledge Gaps ranked as important in surveys

#	**Data Need, Knowledge Gap**
7	Phytoplankton Community: High and low resolution (space, time) of phytoplankton community composition, densities, and biovolume
20	Develop and apply coupled hydrodynamic and biogeochemistry models
3	Quantify nutrient transformation rates across space and time (e.g., mineralization, nitrification, denitrification, biotic uptake)
8	Quantify phytoplankton growth rates and nutrient requirements in relation to other drivers (e.g., temperature, light, salinity) for relevant phytoplankton taxa
10	Quantify toxin concentrations in relation to the nutrient field and other drivers
15	Identify nutrient thresholds affecting growth of AV, by species (including nutrient concentrations, form, timing, and duration of minimum supply)

Workshop participants provided ideas for several additional data needs and knowledge gaps that had not been included in the conceptual framework. These were then evaluated by survey respondents, and are presented here with the ideas that were chosen by multiple respondents as important / feasible listed first:

e. Measure phytoplankton, nutrients upstream of WWTP
f. What stops HAB production? Track blooms from start to finish
a. What is the wetland contribution to the detrital foodweb?
g. Quantify taste and odor (cyanobacteria) compounds
c. Zooplankton biomass, community composition
d. Lab study or cage studies with cultured fish for zooplankton consumption
b. Quantify physical sediment parameters

Specific Feedback on Potential Responses to the Upgrade

The 28 Tier 1 through Tier 4 "potential responses" (see Table 1) were not critically evaluated during the workshop, though there was discussion about the importance of reviewing them. The follow-up survey asked respondents to consider the importance of investigating the responses, by assigning a ranking to each response on an importance scale of 1 to 3 (1=low, 2=medium, 3=high). Out of the 28 responses, 26 were ranked an average 'medium' or higher, with no obvious breaks in averaged scores, indicating that the bulk of the responses are about equally important to those surveyed (**Figure 6**). Nevertheless, interest was greatest for:

1. 'Decreased phytoplankton primary production or biomass, due to decreased [DIN]' (P1),
2. 'Decreased concentrations of dissolved inorganic nitrogen (↓ [DIN])' (N1),
3. 'Reduction in plant biomass due to ↓ [DIN]' (AV1),
4. 'Improved food supply, in particular for pelagic fish, due to changes in phytoplankton primary production (quantity and quality) and aquatic vegetation' (H3), and
5. 'Shift in AV community composition due to ↓ [DIN] and/or ↓ [NH4]' (AV2).

Please see Table 1 for the complete list of potential responses and **Appendix C** for additional survey data on the responses.

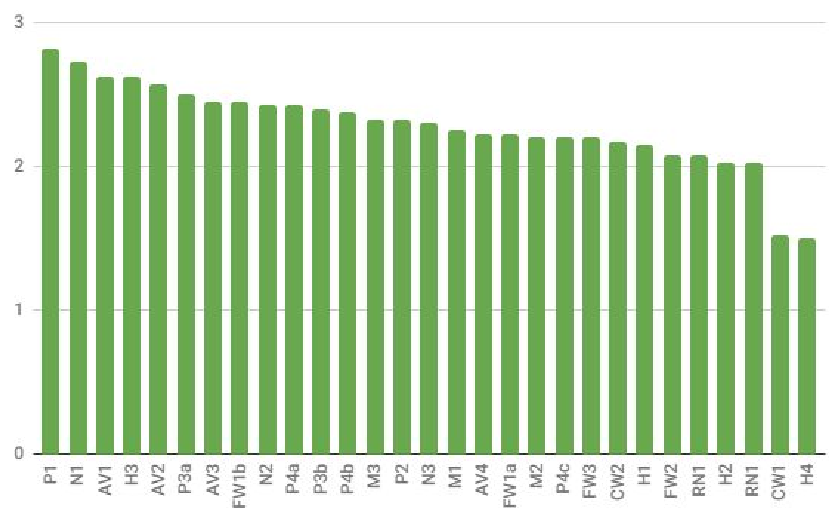

Figure 6. Survey rankings of the importance of investigating responses, ordered from highest to lowest average rank. Scale of importance was 1 to 3 (1=low, 2=medium, 3=high).

Feedback on the Conceptual Framework in General

Participants who provided feedback on the conceptual framework reported it to be comprehensive, gathering the important pieces together without making the diagrams and tables overly complex. This was also reflected in the survey comments that generally indicated that most responses and data needs were important. Workshop attendees and respondents had a few suggestions and comments for improving the conceptual framework.

In listing the data needs and knowledge gaps, and tying them to the potential responses, the conceptual framework does not currently address the varying scope of the different questions, and thus the effort needed to pursue the various needs and gaps. Addressing some of the needs, gaps would require a large effort that may well be worth doing, while addressing others could require smaller special studies to reveal whether they are indeed important to system function; addressing still others would supplement current efforts. Parsing the needs and gaps in this way may help to narrow down to a set of questions that could be addressed by future studies.

Some respondents emphasized that the research will be more valuable if stronger ties can be made between the research and management priorities, for example, through the use of biogeochemical models:

> "The conceptual model focuses on changes in plankton production and nitrification rates, which are likely where the largest ecological changes can be measured, but the translation up food web to other secondary effects is what people are most concerned about. Therefore, the Operation Baseline research program should try to connect their measured rate changes, such as phytoplankton production, nitrification, and mineralization, with data from other agencies monitoring system-wide ecological patterns (by using biogeochemical models) to help evaluate if reduced nitrogen loading in the Sacramento River might have contributed to a change in Delta species assemblages, including zooplankton, benthic invertebrates, invertebrate communities sustained by macrophytes, and fishes." --survey respondent

> "The conceptual model framework will only be helpful to managers if it can connect regulated constituents to large-scale, measureable ecosystem outcomes." --survey respondent

The desire for data to support decisions about large-scale outcomes is understandable, but must be weighed against the realities and limitations of the data we are actually able to gather as a result of the changes due to the upgrade. It is more likely that studies pursued for Operation Baseline, and other potential studies as suggested through the conceptual framework, will provide a valuable piece to the overall puzzle of ecosystem health in the nSFE. For full responses about the conceptual framework, see **Appendix C**.

Feedback on the Value of the Discussion and Workshop Process

Feedback about the workshop itself was generally positive, with some conflicting reviews. Several commenters related that they valued the opportunity to collaborate. One reviewer stated that the workshop “helped to set expectations for future nutrient reductions in the Delta” and valued the presentations about theorized ecological changes that might occur.

Participants expressed a desire for more opportunities to collaborate in the future, and for more information about how this effort connects to other ongoing efforts. Participants stated that they valued learning from each other, and from the information exchange about the upgrade and the system. There was a mixed response as to the value of the group exercise, with some participants reporting that it lasted too long, while others perceived it to be too short.

People who were able to attend the meeting mainly described themselves as scientists, with fewer people describing themselves as managers. Several participants noted that ensuring the participation of a range of stakeholders is important, and that future meeting formats should be tailored so that more people can attend and participate.

Collaboration and the Way Forward

Collaborative decision making processes take time and funding to achieve their full potential for creating more optimal environmental outcomes. Many nutrient-related collaborative groups are already active, including: the Delta Nutrient Stakeholder and Technical Advisory Group (STAG), the Delta Regional Monitoring Program (Delta RMP), the San Francisco Bay Regional Monitoring Program (RMP), the San Francisco Bay Nutrient Management Steering Committee (NMS), the IEP Data Utilization Work Group, the IEP Nutrient Project Work Team, the CCHAB Work group, CV-SALTS, and Operation Baseline stakeholder meetings. Integration among these and other nutrient-related efforts in the Delta will be needed to avoid duplication of effort and ensure that the Operation Baseline studies are viewed in the proper context.

Though increased collaboration and coordination was seen as highly valuable, participants noted several barriers to effective collaboration that they have experienced. These included: a) the ad-hoc nature of organizing groups, where organizers and participants alike are not funded to collaborate and therefore participate on a voluntary basis; b) the tendency of collaborative groups to delve into specialized topics, therefore diminishing the scope of participation; c) the tendency for groups to cease reaching out to new members.

Participants discussed effective modes of information sharing as a means to collaboration. People want to know what work is going on, and who is doing it. Annual work plans are one way to discover what agencies are prioritizing, but these are not collected in a central location. Several people mentioned that a web-based tracking system for science activities would be helpful. Tracking systems such as CEDEN have proven successful due to employing a hybrid of centralization and dispersion; however, this requires someone to manage the repository, and everyone needs to contribute to it, with ease of upload and use, as well a data compatibility, being keys to success. The Delta Science Plan (specifically Action 2.3) calls for a web-based tracking system of science activities (research projects, monitoring, modeling, data management, synthesis, peer review, and other science activities) and the Delta Science Program is actively pursuing a platform that can meet the needs of scientists, decision-makers, and stakeholders in the nSFE.

Nutrients and nutrient-related management issues continue to be of great scientific and management interest regionally and in the nSFE, due in part to the fundamental role they play in ecosystem functioning. Continued research and collaboration in this field will be needed to build on past research and to determine viable and successful management alternatives for nutrient management in the future. Though tackling a complex, multi-faceted topic, workshop participants were able to come to a surprising amount of agreement and convergence on important future directions, with maximized collaboration as one of the most highly valued next steps. This workshop represented one step in what ideally should be an ongoing collaboration effort that will continue to foster interactions along the science - policy interface.

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Appendices

Appendix A. Workshop Agenda

Regional San Upgrade
Conceptual Model and Management Needs Workshop
Workshop Agenda

May 18, 2018
UC Davis Extension Sutter Square Galleria
2901 K Street
Sacramento, CA 95816

Project's overarching question: How are the changes to Regional San's WWTP expected to affect nutrient biogeochemistry and ecosystem responses in the Delta? How can the conceptual model inform short-, intermediate-, and longer-term management decisions?

Meeting Goals:

1. Inform group on conceptual model framework for the Sacramento Regional Wastewater Treatment Plant upgrade and related science knowledge gaps already identified within that framework.
2. Share initial set of management questions that may have a direct or indirect nexus with the conceptual model, discuss and add to list of management needs.
3. Identify additional key management questions related to expected outcomes of the WWTP upgrade that will serve to address management needs. Clarify areas of greatest uncertainty (i.e., key data gaps) and refine list of potential research, monitoring, and modeling efforts capable of reducing uncertainties associated with anticipated outcomes of the WWTP upgrade. For each topic or study, identify its: (a) Feasibility (in terms of cost, permitting, staffing, timing); (b) Importance (relevance to key management question or knowledge gap); (c) Broad application to multiple issues; and (d) Opportunity to leverage existing data collection.

Meeting Outcomes:

1. Shared understanding of upgrade's effect on nutrient inputs and conceptual framework for understanding the effects of this change. (e.g., shifts in primary producer classes; effects on invasive macrophytes; extent, frequency, and duration of harmful algal blooms and production of associated cyanotoxins; effects on food web; implications for habitat restoration designs; drinking water quality; wetlands management, etc.)

2. Workshop summary that synthesizes upgrade-related management questions, related uncertainties, and research efforts to reduce uncertainty discussed at the meeting.

3. Provide an opportunity for post-meeting feedback for people who cannot attend or who have thoughts after the meeting.

Agenda

Item		Time
1	**Welcome** (coffee/tea/nametags)	9:15
2	**Goals and Introductions** (10 min) **What We are Doing Today and What Success Looks Like** (5 mins) *John Callaway (DSC), Jessica Law (DSC)*	9:30
3	**Context: Concurrent Nutrient Efforts in the Estuary** (20 min) *Janis Cooke (CVRWQCB), Tom Mumley (SFRWQCB)*	9:35
Overview of Regional San Nutrients Conceptual Model		
4	**Conceptual Model** (30 min) *David Senn (SFEI)* *Goal: group understanding of upgrade and of conceptual model work*	9:55
5	**Question and Answer Period: Conceptual Framework** (35 mins) *Jessica Law (DSC), Participants* *Goal: Answer questions on conceptual model, start identifying key uncertainties*	10:25
Identifying Key Management Issues		
6	**Present Draft Initial Management Concerns** (10 mins) *Rainer Hoeneke (DSC)*	11:00
7	**Group Discussion of Management Concerns** (40 mins) Questions for participants during the discussion: -What are your needs with regard to nutrient management? -What are the most important management challenges today? In the next 10 years? In the next 20 years? -How does this upgrade intersect with your management needs? *Participants, Jessica Law (DSC)* *Goal: Refine list of management concerns*	11:10
Lunch At area restaurants, or bring your own. (60 mins)		11:50

8	**Charge for Breakout Sessions** (5 mins) *Jessica Law (DSC)*	12:50
Breakout Sessions How can study of the Regional San Upgrade address management knowledge gaps? (4, 20 mins each)		
9	**Breakout Session One** (20 mins) *Participants, Jessica Law (DSC), "Minders" Assigned to Record at Sessions* *Goal: Refine and elaborate on management concerns.*	1:00 - 1:20
10	**Breakout Session Two** (20 mins)	1:20 - 1:40
11	**Breakout Session Three** (20 mins)	1:40 - 2:00
12	**Breakout Session Four** (20 mins)	2:00 - 2:20
13	**Report-Out from Breakout Sessions** (30 mins) *Jessica Law (DSC), Minders (TBD), Participants* *Goal: Group understanding of refined management concerns*	2:20
Break (10 mins)		2:50
14	**Plenary Discussion on how to Rank Management Priorities** (45 mins) *Jessica Law (DSC)* *Goal: Gather feedback on list of science concerns to address management problems, and rank the priorities*	3:00
15	**Wrap Up and Next Steps** (15 mins) *Dave Senn (SFEI), Jessica Law (DSC)* *Goal: Group understanding of what to expect by way of reporting and opportunity for additional comment*	3:45
Adjourn		4:00

Appendix B. List of Workshop Attendees

First Name, Last Name	Affiliation	Attendee Status
Brian Bergamaschi	United States Geological Survey	Attending
Gabrielle Boisrame	Delta Science Program	Attending
Larry Brown	United States Geological Survey	Attending
Russ Brown	Private Consultant	Attending
John Callaway	Delta Science Program	Attending
Mike Chotkowski	United States Geological Survey	Attending
Janis Cooke	Central Valley Regional Water Quality Control Board	Attending
Steve Culberson	Delta Stewardship Council	Attending
Dick Dugdale	San Francisco State University	Attending
Daniel Ellis	California Department of Fish and Wildlife	Attending
Mary Lou Esparza	Central Contra Costa Sanitary District	Attending
Stephanie Fong	State and Federal Contractors Water Authority	Attending
Rebecca Franklin	Regional San	Attending
Tom Grovhoug	Private Consultant	Attending
Yumiko Henneberry	Delta Science Program	Attending
Rainer Hoenicke	Delta Science Program	Attending
Carol Kendall	United States Geological Survey	Attending
Shruti Khanna	California Department of Fish and Wildlife	Attending
Martina Koller	Delta Science Program	Attending
Tamara Kraus	United States Geological Survey	Attending
Kenneth Kundargi	California Department of Fish and Wildlife	Attending
Sarah Lesmeister	Central Valley Regional Water Quality Control Board	Attending
Qinqin Liu	Central Valley Regional Water Quality Control Board	Attending
Stephen Louie	California Department of Fish and Wildlife	Attending
Terrie Mitchell	Regional San	Attending
Thomas Mumley	San Francisco Regional Water Quality Control Board	Attending
Tim Mussen	Regional San	Attending
Tim Otten	Private Consultant	Attending
Jason Peltier	Sustainable Delta	Attending
Erik Porse	California State University - Stanislaus	Attending
Mary Repine, PhD		Attending
Amy Richey	San Francisco Estuary Institute	Attending
April Robinson	San Francisco Estuary Institute	Attending
Sam Safi	Regional San	Attending
Dave Senn	San Francisco Estuary Institute	Attending
Lynda Smith	Metropolitan Water District	Attending

Elizabeth Stumpner	United States Geological Survey	Attending
Erwin van Nieuwenhuyse	United States Bureau of Reclamation	Attending
Debbie Webster	Central Valley Clean Water Association	Attending
Frances Wilkerson	San Fransisco State University	Attending
Jessica Law	Delta Science Program	Facilitator
Eli Ateljevich	California Department of Water Resources	Invited
Shakoora Azimi-Gaylon	Delta Conservancy	Invited
Kathy Boyer	San Fransisco State University	Invited
Louise Conrad	California Department of Water Resources	Invited
Philip Crader	Central Valley Regional Water Quality Control Board	Invited
Rebecca Fitzgerald	Central Valley Regional Water Quality Control Board	Invited
Pat Glibert	University of Maryland Center for Environmental Science	Invited
Eddie Hard	California Department of Parks and Recreation	Invited
Thomas Jabusch	Delta Conservancy	Invited
Gardner Jones	California Department of Water Resources	Invited
Kristopher Jones	California Department of Water Resources	Invited
Wim Kimmerer	San Fransisco State University	Invited
Raphe Kudela	University of California - Santa Cruz	Invited
Peggy Lehman	California Department of Fish and Wildlife	Invited
Zhimin Lu	Central Valley Regional Water Quality Control Board	Invited
Nicholas Martorano	Central Valley Regional Water Quality Control Board	Invited
Lori Schectel	Central Contra Costa Sanitary District	Invited
Stacy Sherman	California Department of Fish and Wildlife	Invited
Martha Sutula	Southern California Coastal Water Research Project	Invited
Jan Thompson	United States Geological Survey	Invited
Laura Valoppi	State and Federal Contractors Water Authority	Invited
Carl Wilcox	California Department of Fish and Wildlife	Invited
Hwaseong Jin	Central Valley Regional Water Quality Control Board	Probably

Appendix C. Post-Workshop Survey Questions and Analysis

Two surveys were created, one for attendees at the workshop, and another for people who were not able to attend. Survey questions are provided below.

Survey Questions for Attendees

Sit back, relax and think of your time at the workshop...
1. What was your main take-away that you gained from the workshop?

2. What comments on the conceptual model framework would you like to provide?

The **top 5 'data gaps, research needs'** identified during the breakout groups were:

#1. Quantify ambient nutrient concentration (higher spatial and temporal resolution, additional habitats)
#2. Measure transport parameters (e.g., water sources, residence time)
#6. Phytoplankton Biomass: Additional discrete (Chl-a) and high frequency mooring, mapping; phytoplankton biomass data linked to measurement of nutrients and other drivers
#21. Enhance monitoring of key physical factors (e.g., temperature, light, salinity, water depth)
#22. Maximize coordination: data collection and analysis across various entities, including between monitoring, special studies, and modeling efforts

3. **Do you agree that this group represents the most important needs and gaps?**

4. Do you think a **'data gap, research need' is missing** from the top 5 list that you would prioritize higher based on **feasibility and importance**?

None
3. Quantify nutrient transformation rates across space and time (e.g. mineralization, nitrification, denitrification, biotic uptake)
4. Quantify sediment nutrient pools, availability and fluxes
5. Characterize links between water column and sediment nutrient pools
7. Phytoplankton Community: high and low resolution (space, time) of phytoplankton community composition, densities, and biovolume
8. Quantify phytoplankton growth rates and nutrient requirements in relation to other drivers (e.g. temperature, light, salinity) for relevant phytoplankton taxa
9. Quantify phytoplankton and HAB loss rates to planktonic and benthic grazers, including size-selective grazing
10. Quantify HAB toxin concentrations in relation to the nutrient field and other drivers
11. Characterize microbial assemblage in relation to the nutrient field and other drivers
12. Quantify contribution of microbial community to the foodweb
13. Quantify relationships between microbial assemblage and nutrient transformations, or use as indicators of condition and/or function
14. Trace the fate of nutrients taken up by primary producers (Aquatic vegetation, phytoplankton)
15. Identify nutrient thresholds affecting growth of AV, by species (including nutrient concentrations, form, timing, and duration of minimum supply)
16. Quantify nutrient demand by AV to determine effects on water column nutrient concentrations
17. Ascertain whether AV growth rates differ under NH4 vs. NO3 , and whether the form of N effects competition between species

18. Monitor AV biomass and species composition over space and time, quantify feedbacks between AV in relation to nutrient demand and cycling
19. Quantify nutrient demand of and transformation rates in restored wetlands
20. Develop and apply coupled hydrodynamic and biogeochemistry models

Additional data gaps, research needs identified during the breakout groups were:

a. What is the wetland contribution to the detrital foodweb?
b. Quantify physical sediment parameters
c. Zooplankton biomass, community composition
d. Lab study or cage studies with cultured fish for zooplankton consumption
e. Measure phytoplankton, nutrients upstream of WWTP
f. What stops HAB production? Track blooms from start to finish
g. Quantify taste and odor (cyanobacteria) compounds

5. **Do you have any feedback on these? Which of these are most feasible/important?**

6. When you were considering importance and feasibility, **what criteria did you use** (i.e. cost, technical ability, visibility, etc.)?

7. How would you rate your overall workshop experience?

8. Please provide any overall comments regarding the workshop. Were the right people there? Was this a good use of your time? How could it have been improved?

9. A number of potential responses to the WWTP upgrade were identified...

As a stakeholder in the Bay-Delta system, how important is it to investigate the following potential <u>responses</u> in **nutrients**? (1=low, 2=medium, 3=high)

Lower concentrations of dissolved inorganic nitrogen will occur in the river [N1]

Lower concentrations of ammonium will occur in the river [N2]

Gradual decrease of labile (easily broken down physically, chemically or biologically) nitrogen will occur in sediments [N3]

As a stakeholder in the Bay-Delta system, how important is it to investigate the following potential <u>responses</u> in **aquatic vegetation (AV)?**

(1=low, 2=medium, 3=high)

Reduced floating aquatic vegetation or submerged aquatic vegetation density will occur, or shifts in spatial distribution/coverage will occur due to decreased nitrogen [AV1]

Shifts in floating aquatic vegetation or submerged aquatic vegetation community composition will occur due to decreased nitrogen (and/or ammonium) [AV2]

Recycled nutrients from sediments are sufficient over the near-term to partially or fully support aquatic vegetation densities and distribution. Major changes await substantial decreases in sediment nitrogen pools and fluxes [AV3]

Over a 5-20 year + period, aquatic vegetation abundance (density, distribution) and assemblage will undergo further shifts as bioavailable sediment nitrogen levels decrease [AV4]

As a stakeholder in the Bay-Delta system, how important is it to investigate the following potential <u>responses</u> in **microbial community?** (1=low, 2=medium, 3=high)

Changes to the nitrifier microbial community will occur (abundance, assemblage) due to decreased ammonium [M1]

Changes to the denitrifier microbial community will occur (abundance, assemblage) due to decreased dissolved inorganic nitrogen [M2]

Other changes to the heterotrophic microbial community will occur due to decreased dissolved inorganic nitrogen [M3]

As a stakeholder in the Bay-Delta system, how important is it to investigate the following potential responses in **phytoplankton and HABs (harmful algal blooms)?** (1=low, 2=medium, 3=high)

- Decreased phytoplankton primary production or biomass will occur due to decreased dissolved inorganic nitrogen [P1]
- Increased phytoplankton primary production and relaxation of the ammonium inhibition will occur due to decreased ammonium [P2]
- Changes in phytoplankton assemblage due to inter-taxa differences in growth-limiting nitrogen concentrations will occur, due to decreased dissolved inorganic nitrogen [P3a]
- Changes in phytoplankton assemblage (toward better food quality) due to decreased ammonium concentrations (relaxation of negative impacts of ammonium on 'healthy' phytoplankton taxa) [P3b]
- Decrease in occurrence of harmful algal blooms (HABs) and a decrease in cyanotoxin production will occur due to decreased dissolved inorganic nitrogen [P4a]
- Decrease in occurrence of harmful algal blooms (HABs) and a decrease in cyanotoxin production will occur due to decreased ammonium [P4b]
- Recycled nutrients from the sediments are sufficient to sustain large and toxic *Microcystis* blooms; blooms will only decrease once sediment nitrogen levels and nitrogen flux from sediments drop substantially [P4c]

As a stakeholder in the Bay-Delta system, how important is it to investigate the following potential responses in **food webs?** (1=low, 2=medium, 3=high)

- Improved food resources will reach species of interest (e.g. production rates or quantity, quality, alignment in space/time with resource needs) and/or evidence of favorable responses (e.g., abundances) [FW1a]
- Lower quality/quantity of food resources will reach species of interest [FW1b]
- Lower toxicity exposure to intermediate food resources from HABs, or evidence of increasing abundances, will occur [FW2]
- Alterations (improvements) to physical habitat that indirectly influence species of interest within the food web (e.g. decrease of invasive predator habitat), or evidence of changing abundances will occur [FW3]

As a stakeholder in the Bay-Delta system, how important is it to investigate the following potential responses in **habitat?** (1=low, 2=medium, 3=high)

- Improved physical habitat will occur due to lower presence of invasive aquatic vegetation (e.g., more suitable spawning habitat, higher turbidity for predator avoidance, poorer conditions for invasive predators) [H1]
- Decreased impacts to biota from direct exposure to HAB toxins that impact reproductive success or other individual or population-level responses will occur [H2]
- Improved food supply, in particular for pelagic fish will occur due to changes in phytoplankton primary production (quantity and quality) and aquatic vegetation [H3]
- Improved dissolved oxygen levels will result from decreased primary production and subsequent metabolism [H4]

As a stakeholder in the Bay-Delta system, how important is it to investigate the following potential responses in **Recreation and Navigation?** (1=low, 2=medium, 3=high)

- Fewer issues with physical obstructions will occur due to reduction in invasive aquatic vegetation (for recreational boating, transportation, fishing) [RN1]
- Fewer concerns about dermal contact to HAB toxins will occur (recreational boating, swimming, fishing) [RN2]

As a stakeholder in the Bay-Delta system, how important is it to investigate the following potential responses in **Consumptive Water Use?** (1=low, 2=medium, 3=high)

- Improvements to water operations will occur due to decreased invasive aquatic vegetation [CW1]
- Lower human exposure to HAB toxins, lower production of taste and odor compounds, and lower production of disinfection byproduct precursors will occur [CW2]

10. What is your personal **area of expertise** and **what types of projects** are you involved in currently?

- Water supply
- Flow and hydrodynamics
- Water quality (e.g., HAB toxins, contaminants, temperature, salinity, dissolved oxygen)
- Drinking water quality (e.g., algae, toxins, taste and odor, disinfection byproducts)
- Sediment supply, fate and transport
- Habitat restoration
- Recreation (e.g., boating, swimming, aesthetics)
- Native species protection
- Invasive species
- Foodweb
- Other

11. What is your primary role at your job?

- Manager
- Scientist
- Policy Maker
- Data Manager
- Journalist

12. Please indicate if you participate in any of the following collaborative meetings:

- Delta Nutrient Stakeholder and Technical Advisory Group (STAG)
- Delta Regional Monitoring Program (RMP)
- Delta RMP Nutrient subcommittee
- SF Bay Nutrient Management Steering Committee
- IEP Data Utilization Work Group
- CCHAB Work group
- SF Bay RMP
- CV-SALTS
- Operation Baseline Stakeholder meetings
- Intend to attend: IEP Nutrient Project Work Team
- None of the above
- Other

13. Please indicate your affiliation.

- Academic/University
- Federal Agency
- Local Agency
- Non Governmental Organization
- Other
- Private/Consulting
- Public Water Agency
- State Agency

14. If you're interested in attending future Operation Baseline-related events, **enter your email address** and we'll let you know about it.

Survey Questions for Non-Attendees

If you did not attend the **Regional San WWTP Upgrade Conceptual Model and Management Needs Workshop,** on May 18, 2018, this is your opportunity to provide input!

Please take some time to review the event handouts:
http://deltacouncil.ca.gov/event-detail/15633

Changes will occur in the north San Francisco Estuary after the Regional Sanitation District wastewater treatment plant upgrade...
Please review the PowerPoint slides:
http://deltacouncil.ca.gov/docs/may-18-2018-nutrient-workshop-handoutpdf

1. Were all of the important potential ecosystem responses identified? If not, please describe.

2. Provide any additional or general feedback about the conceptual framework.

3. A number of potential responses to the WWTP upgrade were identified...

    As a stakeholder in the Bay-Delta system, how important is it to investigate the following potential responses in **nutrients?** (1=low, 2=medium, 3=high)

        <nutrient responses listed as in attendee survey>

    As a stakeholder in the Bay-Delta system, how important is it to investigate the following potential responses in **aquatic vegetation (AV)?** (1=low, 2=medium, 3=high)

        <AV responses listed as in attendee survey>

    As a stakeholder in the Bay-Delta system, how important is it to investigate the following potential responses in **microbial community?** (1=low, 2=medium, 3=high)

        <microbial responses listed as in attendee survey>

    As a stakeholder in the Bay-Delta system, how important is it to investigate the following potential responses in **phytoplankton and HABs (harmful algal blooms)?** (1=low, 2=medium, 3=high)

        <phytoplankton and HABs responses listed as in attendee survey>

    As a stakeholder in the Bay-Delta system, how important is it to investigate the following potential responses in **food webs?** (1=low, 2=medium, 3=high)

        <food web responses listed as in attendee survey>

    As a stakeholder in the Bay-Delta system, how important is it to investigate the following potential responses in **habitat?** (1=low, 2=medium, 3=high)

        <habitat responses listed as in attendee survey>

    As a stakeholder in the Bay-Delta system, how important is it to investigate the following potential responses in **Recreation and Navigation?** (1=low, 2=medium, 3=high)

        <recreation and navigation responses listed as in attendee survey>

    As a stakeholder in the Bay-Delta system, how important is it to investigate the following potential responses in **Consumptive Water Use?** (1=low, 2=medium, 3=high)

        <consumptive water use responses listed as in attendee survey>

4. Of the following data need, knowledge gaps identified below, which ones would you rank the **most important and feasible? (Please limit to 5)**

        <data need, knowledge gaps listed as in Table 2>

5. Comments on your choices?

6. Additional data gaps and research needs identified by workshop participants included:
   a. What is the wetland contribution to the detrital foodweb?
   b. Quantify physical sediment parameters
   c. Zooplankton biomass, community composition
   d. Lab study or cage studies with cultured fish for zooplankton consumption
   e. Measure phytoplankton, nutrients upstream of WWTP
   f. What stops HAB production? Track blooms from start to finish
   g. Quantify taste and odor (cyanobacteria) compounds

Do you have any feedback on these topics? Which of these are most feasible/important? Would you add any?

7. When you were considering importance and feasibility above, **what criteria did you use** (i.e. cost, technical ability, visibility, critical path, etc.)?

8. What is your personal **area of expertise** and **what types of projects** are you involved in currently?
- Water supply
- Flow and hydrodynamics
- Water quality (e.g., HAB toxins, contaminants, temperature, salinity, dissolved oxygen)
- Drinking water quality (e.g., algae, toxins, taste and odor, disinfection byproducts)
- Sediment supply, fate and transport
- Habitat restoration
- Recreation (e.g., boating, swimming, aesthetics)
- Native species protection
- Invasive species
- Foodweb
- Other

9. What is your primary role at your job?
- Manager
- Scientist
- Policy Maker
- Data Manager
- Journalist
- Other

10. Please indicate your affiliation.
- Academic/University
- Federal Agency
- Local Agency
- Non Governmental Organization
- Other
- Private/Consulting
- Public Water Agency
- State Agency

11. Please indicate if you participate in any of the following collaborative meetings:
- Delta Nutrient Stakeholder and Technical Advisory Group (STAG)
- Delta Regional Monitoring Program (RMP)
- Delta RMP Nutrient subcommittee

· SF Bay Nutrient Management Steering Committee
· IEP Data Utilization Work Group
· CCHAB Work group
· SF Bay RMP
· CV-SALTS
· Operation Baseline Stakeholder meetings
· Intend to attend: IEP Nutrient Project Work Team
· None of the above
· Other

12. How can coordination be maximized among connected efforts? Do you see gaps in collaborative groups?

13. If you're interested in attending future Operation Baseline-related events, **enter your email address** and we'll let you know about it. The Operation Baseline website has more information: http://deltacouncil.ca.gov/operation-baseline-studying-effects-regional-san-treatment-plant-upgrade

Summary of Feedback on Data Needs and Knowledge Gaps

The following table tallies the rankings for data need, knowledge gaps from the workshop as well as from the surveys. The top five data need, knowledge gaps as ranked at the workshop and in the survey results are indicated in green.

		Number of times the data need, knowledge gap was in the upper right quadrant of prioritization 'game board' at workshop					Survey Results	Total
	Data Need, Knowledge Gap	Foodweb	Consumptive Use	Recreation / Navigation	Habitat	**Tally from workshop**	Importance/feasibility rankings by not-present respondents (4 respondents)	**Total tally from workshop and survey**
1	Quantify ambient nutrient concentration (higher spatial and temporal resolution, additional habitats)	3	4	2	3	**12**	2	14
2	Measure transport parameters (e.g., water sources, residence time)	2	2	3	2	**9**	2	11
3	Quantify nutrient transformation rates across space and time (e.g., mineralization, nitrificaiton, denitrification, biotic uptake)	1	1			**2**	1	3
4	Quantify sediment nutrient pools, availability and fluxes	1				**1**		1
5	Characterize links between water column and sediment nutrient pools							

6	Phytoplankton Biomass: Additional discrete (Chl-a) and high frequency mooring, mapping; phytoplankton biomass data linked to measurement of nutrients and other drivers	3	1	2	2	**8**	2	10
7	Phytoplankton Community: High and low resolution (space,time) of phytoplankton community composition, densities, and biovolume	1	1		2	**4**		4
8	Quantify phytoplankton growth rates and nutrient requirements in relation to other drivers (e.g., temperature, light, salinity) for relevant phytoplankton taxa	1	1		1	**3**	1	4
9	Quantify phytoplankton and HAB loss rates to planktonic and benthic grazers, including size-selective grazing							
10	Quantify toxin concentrations in relation to the nutrient field and other drivers		2	1		**3**		3
11	Characterize microbial assemblage in relation to the nutrient field and other drivers							
12	Quantify contribution of microbial community to the foodweb.							
13	Quantify relationships between microbial assemblage and nutrient transformations, or use as indicators of condition and/or function							
14	Trace the fate of nutrients taken up by primary producers (AV, phytoplankton)	1				**1**		1
15	Identify nutrient thresholds affecting growth of AV, by species (including nutrient concentrations, form, timing, and duration of minimum supply)			2		**2**		2
16	Quantify nutrient demand by AV to determine effects on water column nutrient concentrations							
17	Ascertain whether AV growth rates differ under NH4 vs. NO3, and whether the form of N effects competition between species			1		**1**		1
18	Monitor AV biomass and species compositon over space and time, quantify feedbacks between AV in relation to nutrient demand and cycling			2	3	**5**		5

19	Quantify nutrient demand of and transformation rates in restored wetlands							
20	Develop and apply coupled hydrodynamic and biogeochemistry models	2			2	**4**	1	5
21	Enhance monitoring of key physical factors (e.g., temperature, light, salinity, water depth)	2	1	2	3	**8**	1	9
22	Maximize coordination: data collection and analysis across various entities, including between monitoring, special studies, and modeling efforts	1	3		2	**6**	2	8

Summary of Feedback for Data Needs/Knowledge Gaps beyond the Top Five

The following table orders additional data need, knowledge gaps beyond the top five that were identified in the survey as important to respondents. The survey question was: ‘Do you think a 'data gap, research need' is missing from the top 5 list that you would prioritize higher based on feasibility and importance?’

Data Need/Knowledge Gap* *note that the data need / knowledge gap number is taken from the Conceptual Framework	**Number of Respondents indicating the data need/ knowledge gap should be higher priority**
7. Phytoplankton Community: high and low resolution (space, time) of phytoplankton community composition, densities, and biovolume	6
20. Develop and apply coupled hydrodynamic and biogeochemistry models	5
3. Quantify nutrient transformation rates across space and time (e.g. mineralization, nitrification, denitrification, biotic uptake)	4
8. Quantify phytoplankton growth rates and nutrient requirements in relation to other drivers (e.g. temperature, light, salinity) for relevant phytoplankton taxa	4
10. Quantify HAB toxin concentrations in relation to the nutrient field and other drivers	4
15. Identify nutrient thresholds affecting growth of AV, by species (including nutrient concentrations, form, timing, and duration of minimum supply)	4
4. Quantify sediment nutrient pools, availability and fluxes	3
5. Characterize links between water column and sediment nutrient pools	3

9. Quantify phytoplankton and HAB loss rates to planktonic and benthic grazers, including size-selective grazing	3
12. Quantify contribution of microbial community to the foodweb	2
14. Trace the fate of nutrients taken up by primary producers (Aquatic vegetation, phytoplankton)	2
18. Monitor AV biomass and species composition over space and time, quantify feedbacks between AV in relation to nutrient demand and cycling	2
19. Quantify nutrient demand of and transformation rates in restored wetlands	2
None	1
13. Quantify relationships between microbial assemblage and nutrient transformations, or use as indicators of condition and/or function	1
16. Quantify nutrient demand by AV to determine effects on water column nutrient concentrations	1
11. Characterize microbial assemblage in relation to the nutrient field and other drivers	0
17. Ascertain whether AV growth rates differ under NH4 vs. NO3 , and whether the form of N effects competition between species	0
Other	0

Summary of Feedback on Potential Responses to the Upgrade

Survey Question: As a stakeholder in the Bay-Delta system, how important is it to investigate the following potential responses? 1=low, 2=medium, 3=high

Potential Response to Regional San Upgrade	**Survey Combined Average Importance Ranking**
Decreased phytoplankton primary production or biomass will occur due to decreased dissolved inorganic nitrogen [P1]	2.825
Lower concentrations of dissolved inorganic nitrogen will occur in the river [N1]	2.725
Reduced floating aquatic vegetation or submerged aquatic vegetation density will occur, or shifts in spatial distribution/coverage will occur due to decreased nitrogen [AV1]	2.625
Improved food supply, in particular for pelagic fish will occur due to changes in phytoplankton primary production (quantity and quality) and aquatic vegetation [H3]	2.625

Shifts in floating aquatic vegetation or submerged aquatic vegetation community composition will occur due to decreased nitrogen (and/or ammonium) [AV2]	2.575
Changes in phytoplankton assemblage due to inter-taxa differences in growth-limiting nitrogen concentrations will occur, due to decreased dissolved inorganic nitrogen [P3a]	2.5
Recycled nutrients from sediments are sufficient over the near-term to partially or fully support aquatic vegetation densities and distribution. Major changes await substantial decreases in sediment nitrogen pools and fluxes [AV3]	2.45
Lower quality/quantity of food resources will reach species of interest [FW1b]	2.45
Lower concentrations of ammonium will occur in the river [N2]	2.425
Decrease in occurrence of harmful algal blooms (HABs) and a decrease in cyanotoxin production will occur due to decreased dissolved inorganic nitrogen [P4a]	2.425
Changes in phytoplankton assemblage (toward better food quality) due to decreased ammonium concentrations (relaxation of negative impacts of ammonium on 'healthy' phytoplankton taxa) [P3b]	2.4
Decrease in occurrence of harmful algal blooms (HABs) and a decrease in cyanotoxin production will occur due to decreased ammonium [P4b]	2.375
Other changes to the heterotrophic microbial community will occur due to decreased dissolved inorganic nitrogen [M3]	2.325
Increased phytoplankton primary production and relaxation of the ammonium inhibition will occur due to decreased ammonium [P2]	2.325
Gradual decrease of labile (easily broken down physically, chemically or biologically) nitrogen will occur in sediments [N3]	2.3
Changes to the nitrifier microbial community will occur (abundance, assemblage) due to decreased ammonium [M1]	2.25
Over a 5-20 year + period, aquatic vegetation abundance (density, distribution) and assemblage will undergo further shifts as bioavailable sediment nitrogen levels decrease [AV4]	2.225
Improved food resources will reach species of interest (e.g. production rates or quantity, quality, alignment in space/time with resource needs) and/or evidence of favorable responses (e.g., abundances) [FW1a]	2.225
Changes to the denitrifier microbial community will occur (abundance, assemblage) due to decreased dissolved inorganic nitrogen [M2]	2.2
Recycled nutrients from the sediments are sufficient to sustain large and toxic Microcystis blooms; blooms will only decrease once sediment nitrogen levels and nitrogen flux from sediments drop substantially [P4c]	2.2

Alterations (improvements) to physical habitat that indirectly influence species of interest within the food web (e.g. decrease of invasive predator habitat), or evidence of changing abundances will occur [FW3]	2.2
Lower human exposure to HAB toxins, lower production of taste and odor compounds, and lower production of disinfection byproduct precursors will occur [CW2]	2.175
Improved physical habitat will occur due to lower presence of invasive aquatic vegetation (e.g., more suitable spawning habitat, higher turbidity for predator avoidance, poorer conditions for invasive predators) [H1]	2.15
Lower toxicity exposure to intermediate food resources from HABs, or evidence of increasing abundances, will occur [FW2]	2.075
Fewer issues with physical obstructions will occur due to reduction in invasive aquatic vegetation (for recreational boating, transportation, fishing) [RN1]	2.075
Decreased impacts to biota from direct exposure to HAB toxins that impact reproductive success or other individual or population-level responses will occur [H2]	2.025
Fewer concerns about dermal contact to HAB toxins will occur (recreational boating, swimming, fishing) [RN2]	2.025
Improvements to water operations will occur due to decreased invasive aquatic vegetation [CW1]	1.525
Improved dissolved oxygen levels will result from decreased primary production and subsequent metabolism [H4]	1.5

Survey Responses: General Feedback on the Conceptual Framework

Attendees

1) "The conceptual framework appears to capture the different hypothesized responses in the tiers, including hypotheses from different publications and studies, which is appropriate. It is not clear from the meeting materials what modeling studies were used to estimate the zone of influence. If the biogeochemical model that is being developed by SFEI and collaborators is the model, it is currently only modeling one historical year - 2011. Any effort to estimate the zone of influence needs to consider a range of water year types and the different times of year, since existing regulations require different operations at different times of the year. Water year type and Delta operations have a large influence on Delta water quality and mixing, etc., which will affect the ZOI."

2) "The conceptual framework represents a snapshot of our knowledge and understanding of the Delta system as it relates to the problems that generically may be associated with nutrients in the Delta. I think it helps organize our thinking and provides a framework for stakeholder interaction. It helps to establish expectations regarding the effects to be observed through the Operation Baseline research.

Ultimately, the conceptual model framework is most helpful if it provides the linkage between scientific understanding, management actions, and policy drivers. These connections are needed to address key questions regarding the effectiveness of alternative management actions (or bundles of actions) in resolving or ameliorating existing problems."

3) "The conceptual model framework will only be helpful to managers if it can connect regulated constituents to large-scale, measureable ecosystem outcomes."

4) "The conceptual framework includes many large-scale research questions that would be expensive and challenging to answer. The Delta Science Program studies to support Operation Baseline are being conducted in wetland habitats where gradients in nutrient concentrations might be present. Shifts in ecological patterns due to a reduction in nutrients are more likely to be observed in these protected wetland areas, but we also need to consider how localized changes in these regions would translate out to changes in the larger river channels (where most of the Delta's water volume is located).

The conceptual model focuses on changes in plankton production and nitrification rates, which are likely where the largest ecological changes can be measured, but the translation up food web to other secondary effects is what people are most concerned about. Therefore, the Operation Baseline research program should try to connect their measured rate changes, such as phytoplankton production, nitrification, and mineralization, with data from other agencies monitoring system-wide ecological patterns (by using biogeochemical models) to help evaluate if reduced nitrogen loading in teh Sacramento River might have contributed to a change in Delta species assemblages, including zooplankton, benthic invertebrates, invertebrate communities sustained by macrophytes, and fishes."

5) "It is clear a lot of thought has been put into it."

6) "Needs to emphasize the major and measurable effects of the WWTP upgrade rather than all the effects."

7) "Seems a reasonable compromise between complex and simple."

8) "This is a good way to summarize and visualize effects."

9) "Workable in present form. Do not overly complicate."

10) "I'm impressed they were able to "simplify" it to this extent."

11) "All essential pieces are there without making the graphic too complex."

Non-Attendees

1) "The conceptual model will be most useful if it helps to guide us conduct practical tests of the potential mechanisms affecting phytoplankton production in the Delta, and the transfer of energy further up the food web. These tests will also need to be related to actual potential management actions

that managers could choose to enact. Some of these actions may go beyond nutrient management (e.g., decrease in non-native predator biomass). Also, the conceptual model would be improved by more detail regarding the spatio-temporal expectations of the various hypotheses. Figure 7 in the handout is a start, but the X-axes (time) and Y-axes have no units. We should be able to use existing data and numerical models to predict how far downstream of SRWTP a particular effect would be expected, and with what time lags (e.g., based on transport time; reproductive rates of phytoplankton, zooplankton, clams, and fish)."

2) "Good easy to follow one-line drawing"

3) "The conceptual model visualization is simple and corresponds to Table 1 well (even if Table 1 seems upside down to me)." [n.b., the Table 1 was re-ordered for this memo in response to this, and other, comments]

Appendix D. Management Questions Identified through Concurrent Nutrient Management Processes

The lists of questions on subsequent pages have been excerpted from the Draft Delta Nutrient Research Plan (5/16/2018); the DRMP Assessment Questions for Nutrients (3/2/2018); and the SF Bay Nutrient Management Strategy (n.d.). They are meant as a starting place for conversation about how research related to the upcoming Regional San WWTP upgrade could help address these questions.

Subset of Delta Nutrient Research Plan management questions that studies related to Regional San upgrade could help answer

This list reflects questions as proposed May 16, 2018 (https://www.waterboards.ca.gov/rwqcb5/water_issues/delta_water_quality/delta_nutrient_research_plan/public_involvement_stag_meetings/2018_0516_stagmtg_ag_item_04.pdf).
* Note that the numbering system is included here for reference during conversation; original list is bulleted.

A. Do we have a water quality problem? (*see Status and Trends in SFBNMS*)
   1. What are the location, timing, duration and extent of the nutrient-related effects in the Delta (*see 2a in Delta RMP*)
      a. Diatom blooms and adequate primary production
      b. Cyanobacteria blooms and toxins
      c. Biomass of aquatic macrophytes
   2. What are the spatial and temporal trends in cyanobacteria blooms and toxins in downstream conveyance and storage facilities?

B. Are nutrients contributing to the problem?
   3. What is the relative importance of nutrients versus other factors in promoting cyanobacteria dominance and/or cyanotoxin production in in the San Francisco Bay-Delta?
   4. Do nutrient concentrations contribute to the problems with aquatic macrophytes?
   5. What are the main factors affecting potential nutrient-related effects and how does the relative importance of these factors vary with space and time?
   6. What are the magnitudes of external sources and internal sources and sinks of nutrients in the Delta, including various nitrogen and phosphorous forms? (*see Sources and Pathways in SFBNMS*)
   7. Have within-Delta nutrient sources been quantified adequately? (*see Sources and Pathways #1 in SFBNMS*)
   8. How significant is recycling of N and P from decaying macrophytes and other organic matter In the Delta?

C. Can nutrient management address or ameliorate the problem?

9. Can nutrient management limit the occurrence or severity (frequency, magnitude, and/or toxin concentrations) of harmful algal blooms?
10. Can nutrient management reduce the severity (density of plants and/or spatial coverage of beds) of macrophyte growth?
11. Can nutrient management in the northern Delta (e.g., Yolo Bypass, Sacramento River) increase abundance or nutritional quality of pelagic phytoplankton?
12. What are potential unintended consequences of nutrient management to address any of the water quality issues?
13. What is the level and type of change in nutrients needed to affect change in HABs, macrophytes, or phytoplankton abundance?

D. Are particular hydrologic, biological, meteorological, or biogeochemical conditions needed for nutrient management to be effective?

14. Is nutrient management alone sufficient to limit cyanobacteria bloom frequency, magnitude and/or toxin levels?
15. Is nutrient management alone sufficient to control density and areal extent of macrophytes?
16. What combinations of nutrient management and other management actions are likely to achieve equal levels of benefit with regard to macrophyte management?

E. What management of nutrients is needed to meet beneficial uses now and / or in the future?

17. What level of nutrient management is needed to support control of harmful algal blooms and algal toxin production?
18. What level of nutrient management is needed to support control of invasive aquatic macrophytes?
19. What nutrient levels are needed to support adequate primary production and a healthy food web, particularly for endangered fish species?
20. What nutrient loads can the Delta assimilate without impairment of beneficial uses? (*see Forecasting #1 in SFBNMS*)

Subset of Delta Regional Monitoring Program Questions that studies related to Regional San Upgrade could help answer

DRMP Assessment Questions for Nutrients (adopted by steering committee 3/2/2018), available at: https://www.waterboards.ca.gov/rwqcb5//water_issues/delta_water_quality/delta_regional_monitoring/meetings/2018_0302_drmp_scmtg_ag.pdf

Note that the numbering system is taken from the DRMP's original list

Status and Trends

ST2. How are nutrients linked to water quality concerns such as harmful algal blooms, low dissolved oxygen, invasive aquatic macrophytes, low phytoplankton productivity, and drinking water issues? (*see 1A of NRP*)

A. Which factors in the Delta influence the effects of nutrients on the water quality concerns listed above? (*see 3B of NRP*)

Sources, Pathways, Loadings and Processes

SPLP1. Which sources, pathways, and processes contribute most to observed levels of nutrients?

A. How have nutrient or nutrient-related source controls and water management actions changed ambient levels of nutrients and nutrient-associated parameters?
B. What are the loads from tributaries to the Delta?
C. What are the sources and loads of nutrients within the Delta?
D. What role do internal sources play in influencing observed nutrient levels?
E. What are the types and sources of nutrient sinks within the Delta?
F. What are the types and magnitudes of nutrient exports from the Delta to Suisun Bay and water intakes for the State and Federal Water Projects?

SPLP2. How are nutrients linked to water quality concerns such as harmful algal blooms, low dissolved oxygen, invasive aquatic macrophytes, low phytoplankton productivity, and drinking water issues?

A. Which factors in the Delta influence the effects of nutrients on the water quality concerns listed above?

Forecasting Scenarios
FS1. How will nutrient loads, concentrations, and water quality concerns from Sources, Pathways, Loadings & Processes Question 2 respond to potential or planned future source control actions, restoration projects, and water resource management changes, and climate change?

Effectiveness Tracking
ET1. How did nutrient loads, concentrations, and water quality concerns from Sources, Pathways, Loadings & Processes Question 2 respond to source control actions, restoration projects, and water resource management changes?

Subset of San Francisco Bay Nutrient Management Strategy questions that that studies related to Regional San Upgrade could help answer

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), available at: http://sfbaynutrients.sfei.org/books/key-nutrient-management-decisions-and-questions

Status and Trends
Is there a problem or are there signs of a problem?
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?

Sources and Pathways
Which nutrient sources, pathways, and cycling processes are most important to understand and quantify? (Get the loads right!)

1. What is the relative contribution of each loading pathway (POTW, Delta inputs, NPS, etc.)?
2. What are contributions of internal sources (e.g. benthic fluxes) from sediments and sinks (e.g. denitrification) to the Bay nutrient budgets?

Forecasting
1. What nutrient loads can the Bay assimilate without impairment of beneficial uses?