Draft CyanoHAB Knowledge Gap Document[1]

In 2013 the Delta Stewardship Council adopted the Delta Plan. The Plan identified a number of water quality problems that might be the result of excessive nutrient levels in the Delta. One of these was the increase in the magnitude and frequency of cyanobacterial (cyanoHAB) blooms in summer. The Plan recommended that the Central Valley Regional Water Quality Control Board develop and implement a research plan to determine whether nutrient management might reduce these problems. The Central Valley Water Board commissioned a white paper to:

- *Review the biological and ecological factors that influence the prevalence of cyanobacteria and cyanotoxin production.*
- *Summarize observations of cyanobacterial blooms and associated toxin levels in the Delta.*
- *Synthesize the literature to provide an understanding of the factors, including nutrients, promoting cyanobacterial blooms in the Delta.*

The Central Valley Water Board also assembled a Science Work Group composed of cyanobacteria experts (Appendix A) to review and comment on the white paper[2]. White paper comments and group discussions were used to identify areas of agreement and important knowledge gaps about the state of cyanoHAB knowledge in the Delta. These discussions were the basis for this document. An important consideration for Regional Board staff was to determine whether the observed increase in the magnitude and frequency of cyanobacteria blooms in the Delta is the result of long term changes in nutrient concentrations and whether management of nutrient loads can ameliorate the problems associated with cyanobacteria. Areas of agreement and knowledge gaps have been assembled into a series of tables to inform a Nutrient Research Plan. The Research Plan will be presented to the Regional Water Board and, if requested, the Delta Stewardship Council. The white paper, knowledge gaps report and Nutrient Research Plan are intended to provide the rationale and roadmap for future research to resolve management questions, including whether nutrient management might help control maximum cyanoHAB biomass and toxin levels.

Table 1 lists areas of agreement among Science Work Group members about CyanoHABs in the Delta. The consensus of the group is that CyanoHABs represent a serious emerging

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[1] This document was developed after discussions among the Cyanobacteria Science Work Group and represents their opinion on what is known about cyanobacteria and what are critical knowledge gaps that should be the focus of research in the next three to five year time period.

[2] M. Berg and M. Sutula, 2015. Factors affecting growth of Cyanobacteria with special emphasis on the Sacramento-San Joaquin Delta. Southern California Coastal Water Research Project Technical Report No. 869 April 2015.
http://www.waterboards.ca.gov/centralvalley/water_issues/delta_water_quality/delta_nutrient_research_plan/science_work_groups/2015_08_cyano_wp_final.pdf

toxicological problem warranting additional research. All the work conducted to date in the Delta has consisted of a series of one-time special studies. These have been valuable to help define the problem but are insufficient to address emerging issues. Important management questions that both the Stakeholders and Science Work Group identified for follow up are listed in Table 2. Rapid progress may occur if a strong, coordinated cyanobacteria program were established to answer the management questions and researchers were required to coordinate field activities and share special study, monitoring and modeling results at annual meetings.

Important findings to date are that cyanoHABs in the Delta, while not present each year, have become an established phenomenon in the Central Delta and perhaps at other unmonitored locations. *Microcystis* sp. is the most common cyanoHAB in the Delta although a number of other genera have been observed. The concern is that *Microcystis* and other cyanoHAB species produce metabolic byproducts that are central nervous system, liver and kidney toxins for both people, dogs, cattle and aquatic wildlife. The most toxic *Microcystis* byproduct is microcystin LR which has consistently been measured in the Delta.

Insufficient information exists to characterize the risk that microcystin concentrations pose to people and wildlife in the Delta and in downstream waters. There are several reasons for this. First, there is no comprehensive monitoring program to detect cyanoHABs and measure toxin levels in the Delta. Future monitoring locations should cover a range of locations and habitat types including natural and restored wetlands, drinking water intakes, and recreational areas and beaches where human contact is known to occur. A second problem is that while the U.S. EPA, California Office of Environmental Health Hazard Assessment (OEHHA), and World Health Organization (WHO) have published human health guidelines, the recommended method for collecting water samples to assess compliance with these recommendations has not always been employed. Future monitoring should include measurement of *Microcystis* abundance and toxin levels in surface water scum. A third problem is that insufficient research has occurred nationally to establish the most sensitive wildlife life species and to determine no and low effect levels to protect them. In spite of these limitations, observations in 2012 indicated that concentrations in the San Joaquin River's Stockton ship channel exceeded the OEHHA action level and the WHO guideline. Microcystin in fish tissue has also occasionally been measured at concentrations that OEHHA suggests could cause sub lethal effects. These findings suggest that more extensive surveillance is warranted to evaluate the severity of the human and wildlife health problem and determine how the magnitude of the impairment changes over time and in different regional habitats in the Delta. Information of this type will be needed in the future to balance the cost of cyanoHAB management against the risk of environmental damage from cyanoHABs.

Microcystin toxins are released when *Microcystis* cells lyse. The amount of toxin produced is a function of the final size of the bloom, larger biomass results in higher toxin levels. Factors that trigger the commencement of a bloom appear to be an increase in surface water temperature above 20^{O}C, increased seasonal irradiance (during the summer), and increased water clarity.

There is no research demonstrating that bloom initiation is the result of changes in nutrient concentrations, forms or ratios. Also, the factor(s) that arrest bloom development and determine final biomass are not well understood. Ascertaining the factors limiting cyanoHAB development is critical as toxin production and the risk to people and wildlife is a function of final bloom size. The Science Work Group does agree though, that when all other drivers remain favorable and the bloom has sufficient time to fully utilize the available nutrients that final bloom biomass should be a function of the magnitude of the available nutrient pool. Future research will need to determine the combination of factors routinely determining final bloom size. Permitted upgrades to sewage treatment plants are expected to decrease ammonium loads by over 80 percent in the Sacramento River dominated region of the Delta in the next 10-years and decrease dissolved inorganic nitrogen concentrations by 20 to 30 percent[3]. A combination of monitoring, special studies and modeling should be employed to evaluate whether present nutrient levels or the concentrations expected over the next 10-years will constrain bloom size and limit the risk posed to people and wildlife or whether the management of drivers other than nutrients may be necessary or desirable to adequately and cost-effectively prevent or control final bloom size.

The Cyanobacteria white paper had two main recommendations. These were to develop and fund a three to five year monitoring and special study program and to develop and employ an ecological model to understand the physical and chemical controls on primary production and phytoplankton community composition, including cyanobacteria, in the Delta. The Science Work Group agreed with these general recommendations and provided a list of specific management questions that the monitoring and special studies should address. These are summarized in Table 2. The Delta Stakeholder and Technical Advisory Group (STAG) also posed several management questions to the Science Work Group (Table 3). The Scientists responded by indicating what additional information would be required to answer the STAG's management questions. Questions in Table 2 and 3 include assessing the toxicological risk that present microcystin concentrations pose to people and wildlife in the Delta, identifying factors that control *Microcystis* bloom initiation, growth and maximum bloom size, and determining the role of nutrients in bloom initiation, growth and final bloom size.

Microcystins have been detected in Suisun and San Francisco Bay, presumably at least in part, by transport from the Delta. Therefore, blooms in the Delta may increase the risk and concentration of microcystins in Suisun and SF Bay. The San Francisco Bay Regional Water Quality Control Board, in coordination with the San Francisco Estuary Institute have been developing nutrient management and modeling strategies. It would be beneficial to coordinate research in both the Delta and Bay to develop a holistic understanding of the issue. The Science Work Group cautioned that their role was to identify the specific management questions and explain why addressing them was important but not to prescribe how the research should be

[3] Calculated from http://www.swrcb.ca.gov/centralvalley/board_decisions/adopted_orders/sacramento/r5-2010-0114-03_amend.pdf

conducted. The latter should be left to the science community to describe in their solicitation proposals.

An important element of a future monitoring and special study program is to insure the two are closely coordinated so that when the surveillance group detects the start of a *Microcystis* bloom, it is able to alert other research groups so they can mobilize, get into the field and make measurements to address specific questions. Onset of bloom identification will be critical for answering questions about how toxin levels change over time as the bloom matures, assessing the risk that the metabolic byproducts pose to people and wildlife, determining whether consistent relationships exist between chlorophyll a concentration and cyanoHAB cell abundance/toxin levels, and determining which factors limit growth and maximum bloom size. Of particular interest to the Central Valley Water Board is to ascertain whether nutrient concentrations decline during bloom development and whether nutrients limit final maximum bloom size at any time or location in the Delta. To successfully inform these questions will require close coordination between the surveillance monitoring and special study groups. Funding authorities should insure that such relationships exist when evaluating proposals.

Dr. Alex Parker reported at the cyanobacteria science work group meeting on unpublished *Microcystis* grow out experiments. *Microcystis* collected from the Delta and grown in laboratory bioassays amended with ammonium had a significantly faster growth rate than controls held in the same media but with different forms of nitrogen. These findings may be important because ammonium concentrations at some locations in the Delta are expected to decline by up to 80-percent over the next decade as a result of sewage plant upgrades. If correct, the results suggest that changes in the form of nitrogen in the Delta may result in a slower *Microcystis* growth rate and a longer time period before maximum bloom biomass is achieved. The Science Work Group found these results intriguing but did not recommend that they be included in Table 1 as they had not yet been published. Once published, the *Microcystis* ammonium results should be replicated by a second laboratory over multiple days using several growth related metrics, including cell counts, chlorophyll-a, and nutrient uptake, in both laboratory and field experiments.

The white paper also recommended development of an ecosystem computer model to synthesize and provide information on phytoplankton primary production rates and cyanoHAB occurrences in the Delta. Specific management issues that the model might inform are:

- Identification of key factors controlling primary production rates and biomass accumulation (phytoplankton and cyanoHABs),
- Quantifying phytoplankton food quality and transfer of carbon to higher trophic levels,
- Assessing relative importance of environmental factors such as benthic and zooplankton grazing, flow, residence time, light penetration (water clarity), water column stability, temperature and salinity on phytoplankton and cyanoHAB production and maximum bloom size,

- Developing and evaluating hypotheses regarding conditions needed to initiate and curtail cyanoHABs, including the redirected effect of reduced nutrient levels on the remainder of the phytoplankton community (including periods with and without large phytoplankton blooms).

A Modeling Science Work Group has been formed to provide advice on how a suite of water quality models might be linked through one or more hydrodynamic models. The Modeling Science Work Group is to provide advice on model selection criteria, the characteristics of the institution(s) where the hydrodynamic model(s) and water quality modules would be housed and how development of the models should be phased. The deliberations and recommendations of the work group will be captured in a white paper. The white paper will not recommend the preferred suite of models nor the institution responsible for housing and maintaining the models. Instead, the Work Group will identify criteria that should be considered in selecting models and institutions. Selection of the preferred models and institution(s) would be left to the funding authorities to determine in a competitive bid process. Figure 1 is a conceptual model on how a suite of water quality models might be linked with one or more hydrodynamic models to predict pelagic primary production and cyanoHAB biomass in the Delta. More information can be obtained by reading the modeling charge[4].

The Cyanobacteria Science Work Group recommended that monitoring and special studies also include the collection of information needed by modelers to develop, calibrate and validate phytoplankton models. Likewise, the modelers should consult with nutrient managers and cyanobacteria researchers to determine high priority management questions for evaluation. This exchange will require active collaboration between the cyanoHAB research and ecosystem modeling communities. Funding authorities should look for ways to encourage this exchange, including requiring periodic annual workshops where each group informs the other of their findings and research needs. The funding authorities should set aside money to fund high priority follow up studies as identified by both groups.

In conclusion, the Cyanobacteria Science Work Group's research recommendations for the next three to five year time period are listed in Table 2. An important issue for the Central Valley Water Board was to determine whether nutrient management might be employed to significantly reduce the frequency and magnitude of cyanoHABs. No research has been conducted on the effect of nutrient concentrations, forms or ratios on bloom initiation although most members of the science work group thought that nutrients were not likely to be important. Instead, they surmised that bloom initiation was caused by increasing water temperature, clarity, and/or residence time. Moreover, it is not clear what factor(s) are responsible for arresting cyanobacterial growth and controlling maximum bloom biomass. A future research topic will be to determine whether present nutrient levels or the reduced

[4]http://www.waterboards.ca.gov/centralvalley/water_issues/delta_water_quality/delta_nutrient_research_plan/science_work_groups/modeling_swg_charge.pdf/

concentrations that are expected to occur over the next 10 years will decrease the magnitude and frequency of blooms and reduce the risk that cyanoHABs pose to people and wildlife. If studies indicate that the predicted nutrient reductions will not reduce cyanoHABs to an acceptable level to protect people and wildlife, then additional studies may be required to evaluate if further nutrient control could be effective in achieving these goals or if a different form of CyanoHAB management is necessary. It is also important to predict how nutrient reductions would affect the overall phytoplankton community, and ultimately the entire Delta ecosystem. A judicious combination of monitoring, directed special studies, and modeling should inform this and other important cyanobacteria issues.

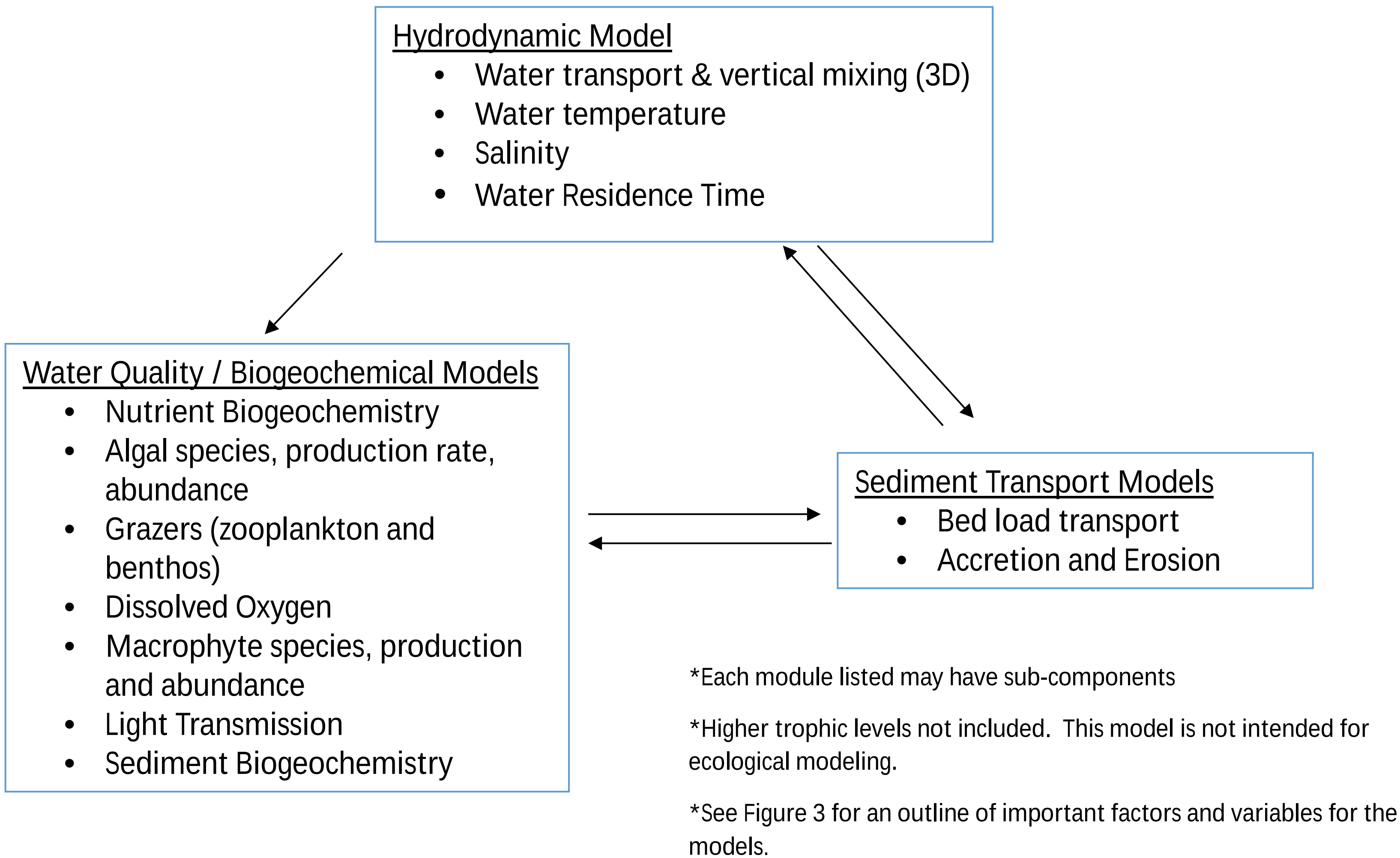

Figure 1. Preliminary framework for the hydrodynamic, water quality/biogeochemical, and sediment transport models and sub-models needed to inform nutrient related questions. Other researchers may use the model to investigate non-nutrient related issues. (Figure is from the charge to the modeling science work group).

Table 1. The areas of agreement about cyanoHABs in the Delta were developed by the Science Work Group after review and discussion of the white paper.

Issue #	Topic	Agreement
1	Cyanoblooms	*Microcystis* is the most common cyanoHAB genus in the Delta although cyanoblooms of *Aphanizomenon* and *Anabaena* have also been documented.
2	Toxicity	CyanoHABs can cause adverse impacts for people, livestock and wildlife because the metabolic byproducts are liver and nerve toxins. Humans and livestock concerns include degradation of drinking water and contact recreation. Impacts to aquatic wildlife include acute and chronic toxicity and bioconcentration of toxins in the food chain.
3	Toxins	Microcystin is the primary toxic cyanoHAB byproduct detected in the Delta. There are numerous microcystin congeners. Microcystin LR is believed to be the most toxic congener variant and is consistently measured in the Delta during blooms.
4	Risk	The risk of microcystin exposure to people and wildlife has not been well quantified in the Delta although potentially toxic concentrations to both people and wildlife have been detected. Additional monitoring will be needed to ascertain the extent, magnitude, duration and frequency of these episodes.
5	Toxicological guidelines	The California Office of Health Hazard Assessment, World Health Organization and the U.S. EPA have published human and domesticated animal health guidelines for some microcystin congeners. These congeners have been measured in water and organisms in the estuary. No toxicological guidelines are available for wildlife, making a robust aquatic life risk assessment difficult without additional toxicological studies to establish no effect and low effect levels.
6	Hot Spots	The San Joaquin River in the Central Delta has experienced reoccurring cyanoHABs. High concentrations may also have occurred in other unmonitored locations in the Delta.
7	Trends	Visible *Microcystis* blooms were first observed in the late 1990s and are now commonly observed in various Delta locations during the summer and fall.
8	Drivers	Seven water quality drivers have been identified that likely control the initiation and production of *Microcystis* biomass in the Delta. These are temperature, high irradiance, water clarity, flushing time, a stratified water column, salinity, and nutrients.

Table 1. Continued.

Issue #	Topic	Agreement
9	Delta Heterogeneity	The absolute magnitude of the drivers may change independently of each other in different areas of the Delta resulting in changes in their relative importance and in the probability of *Microcystis* blooms.
10	Bloom initiation	Published studies provide evidence that bloom initiation may be triggered by higher water temperatures, increased residence time and/or increased water clarity in the Central Delta. Published studies that evaluate whether nutrient concentrations, forms or ratios trigger bloom initiation in the Delta do not exist.
11	Bloom size	It is uncertain which driver(s) limits maximum *Microcystis* bloom biomass and toxin concentration in Delta waterways.
12	Maximum potential bloom size	If other drivers do not limit production, *Microcystis* growth will continue until the available nutrient pool is exhausted.
13	Nutrient Limitation	Further research is necessary to evaluate whether *Microcystis* bloom growth reduces ambient nutrient concentrations and whether final biomass is currently or could in the future with reduced nutrient loading be constrained by the available nutrient pool.

Table 2. Management questions were identified by the Cyanobacteria Science Work Group after review and discussion of the white paper. Many of the management questions can only be answered by a combination of surveillance monitoring and special laboratory and field studies. A robust field surveillance program is needed to identify where and when blooms are forming. This information will be essential for mobilizing other research groups to make the detailed measurements needed to answer specific management questions.

Topic	Management Question	Knowledge Gap	Recommendation
1	Have the major hotspots where cyanoHABs occur and/or where people, domesticated animals & wildlife are at greatest risk from exposure been identified?	Uncertainty exists whether the location & magnitude of hotspots in the Delta have been identified because of a lack of a comprehensive surveillance program.	Institute a robust field surveillance program for three to five years to identify where, when, and under what physical and biological conditions the blooms are forming. Use that information to measure toxin levels.
2	What risk do cyanoHAB toxin levels pose for human drinking water & contact recreation in the Delta?	The risk of exposure has not been adequately characterized because there is no monitoring program in the Delta measuring bloom formation and toxin levels in a manner appropriate for determining human health impacts and also because relevant exposure thresholds such as Maximum Contaminant Level Goals for cyanotoxins in drinking water have not been developed.	The surveillance monitoring program should include both surface water and scum monitoring to evaluate human health contact recreation and drinking water risks. Criteria to protect human health should be developed by the US EPA and others.
3	What risk do cyanoHAB toxin levels pose for aquatic wildlife in the Delta?	The risk to aquatic wildlife has not been adequately characterized because of the absence of a Delta-wide monitoring program. In addition, there are no accepted aquatic life criteria for comparing toxin levels against to ascertain the risk to wildlife.	The surveillance monitoring program and associated special studies should measure dissolved & particulate cyanoHAB toxin concentrations and an appropriate suite of aquatic wildlife biometrics including tissue concentrations. US EPA and others should develop criteria to protect aquatic wildlife.

Table 2. (Continued)

Topic	Management Question	Knowledge Gap	Recommendation
4	Chlorophyll a is the most common measurement of algal abundance in the Delta. Relationships have been observed elsewhere between chlorophyll a & toxin levels. Do similar relationships exist in the Delta? Could these relationships be used to predict health impacts to humans and aquatic wildlife?	It is uncertain whether there is a consistent relationship between surface-collected chlorophyll a concentrations and cell abundance/toxin levels in different seasons and locations in the Delta. It is also unclear whether the relationship changes during bloom initiation, development and senescence and as a function of water depth.	Once surveillance monitoring has identified the formation of a bloom, then special studies should measure chlorophyll, cell abundance and toxin levels in scum, surface water, and at mid-water depth to ascertain whether predicable relationships exist. These relationships should be compared with continuous DWR and USGS sensor data to determine whether the continuous data can be used to predict toxin levels.
5	What factor(s) limits initiation, growth rate, maximum bloom size, and toxin concentration? Are any of these factors controllable in the Delta?	Limited information exists on which factor(s) limits initiation of cyanoHABs, control growth rates, final bloom biomass and maximum toxin levels in the Delta (see white paper, Summary section 5.2, Table 5.1); the present information is inadequate for management decisions. It is also not known whether these factors differ by season and location.	Use the surveillance monitoring program to identify and routinely observe multiple blooms at different stages of development in different locations in the Delta to determine what controls growth rate, maximum biomass & toxin level. The monitoring should include all drivers identified in the white paper, across a range of values for each driver. At selected locations evaluate the importance of other hypothesized factors (like herbicides, grazing). "Control" sampling should also be performed in adjacent locations in which no bloom is observed. Confirm the importance of key drivers with controlled laboratory and field studies.

Table 2. (Continued)

Topic	Management Question	Knowledge Gap	Recommendation
6	Can management of other drivers (temperature, flow, turbidity, residence time) reduce the magnitude and frequency of blooms and their associated risk?	We lack information on how the magnitude and frequency of cyanoHABs could be affected by regional water conditions, such as turbidity, mixing rates, and outflow rates (causing wash-out). It is important to consider conducting studies investigating management of these factors to control cyanobacteria blooms.	Conduct field and laboratory studies to investigate whether turbidity (influenced by TSS inflow and wind re-suspension), flow rates (washout, outflow), and/or mixing (related to tidal flow velocities, outflow velocity water depth, and wind waves) can be controlled through flow management (such as flow routing and outflow volumes), habitat restoration (water depth and residence time), or turbidity input (sediment runoff), to help limit future bloom formations. An ecosystem model would help evaluate the management potential of these factors on watershed and regional scales.
7	Can nutrient management reduce the magnitude & frequency of blooms and the risk of elevated toxin levels anywhere in the Delta?	We lack information on whether nutrient concentrations decline as blooms develop and whether a lack of nutrients arrest bloom growth & determine final bloom biomass. We lack information on what concentrations and forms of nutrients may constrain bloom biomass below a level that poses a risk to people and wildlife. We lack information on whether these factors have different effects in different areas of the Delta. We lack information on whether limiting nutrient concentrations would affect the growth of other beneficial phytoplankton species.	Conduct high frequency temporal monitoring to determine whether different forms and concentrations of nitrogen and phosphorus are correlated with maximum bloom biomass & toxin level. Monitoring and evaluations should also include all other potential drivers of cyanobacteria growth. Confirm results with special laboratory and field studies.

Table 2. Continues

Topic	Management Question	Knowledge Gap	Recommendation
8	Can models help evaluate the relative importance of different cyanoHAB drivers, test management scenarios & evaluate additional ecological effects of nutrient management?	Algal and cyanoHab ecosystem models are not available for the Delta although a Modeling Science Work Group is being formed to make recommendations on model development.	Develop an ecosystem model that includes a cyanoHAB component. All cyanoHAB monitoring and special studies should be coordinated with model development to inform model calibration and validation. Use model to predict the magnitude and frequency of cyano blooms in the Delta with the predicted future reductions in anthropogenic nutrient loads to the Delta, under a range of future possible water export scenarios.

Table 3. Management questions were identified by STAG members after review and discussion of the white paper. These management questions were posed to the Cyanobacteria Science Work Group. The Science Work Group responded with information on knowledge gaps and suggested research to answer the management question.

Topic	Management Question	Knowledge Gap	Recommendation
1	Do different nutrient forms increase the growth rate of *Microcystis* and the frequency of blooms? Do ammonium concentrations, within the range observed in the Delta, influence cyanobacteria growth rates or the frequency of blooms?	Dr. Parker summarized the results of unpublished laboratory ammonium grow out experiments for the Science Work Group. *Microcystis* grew faster on ammonium than on any other form of nitrogen. A duplicate study by a separate lab is needed to confirm these results, using the range of ammonium concentrations observed in the Delta.	Once published, the *Microcystis* ammonium results should be confirmed by a second investigator using multiple growth related metrics, including cell counts, chlorophyll-a, and nutrient uptake, in both laboratory and field experiments.
2	What drivers have been found to limit maximum *Microcystis* bloom biomass and toxin levels elsewhere in the world? Can this information be used to inform a management plan for the Delta?	Cyanobacteria blooms are a worldwide phenomenon. The white paper focused primarily on drivers influencing bloom formation and size in the Delta. More information may be available elsewhere that could inform management options for the Delta.	Conduct a second literature review summarizing successful cyanobacterial control programs elsewhere in the world. Compare the magnitude of responsible drivers at these locations with those in the Delta to determine whether nutrients or another management practice might be a viable option for the Estuary.

Table 3 (Continued)

Topic	Management Question	Knowledge Gap	Recommendation
3	What will be the effect of climate change on the frequency and size of cyanoHABs?	Climate change is predicted to result in higher water temperatures and increased drought in California. The latter should reduce flow and increase water residence time and water column stability in the Delta. The white paper predicts that these factors will result in an increase in the magnitude and frequency of cyanoHABs.	Use an ecosystem model to predict the relative increase in the frequency and magnitude of cyanoHABs in the Delta as a result of climate change.
4	The City of Stockton waterfront, among other areas utilized for non-contact recreation, is known to be impaired annually during the dry months from dense Microcystis surface scums that create not only unsafe conditions for contact recreation (REC-1), but objectionable odors and aesthetics that result in impairment of non-contact recreation uses (REC-2). Do the mechanisms that control open water Microcystis blooms differ from those that control and promote formation of surface scums? What are the various measures that are available and effective at addressing impairments of marinas, waterfronts, and other waterways from cyanobacteria surface scums? Will nutrient management enhance these control efforts?	The white paper focused primarily on aquatic life and contact recreation beneficial use impairments. The current extent of REC-2 beneficial use impairments is unknown and efforts to address these impairments were not reviewed for the white paper. It is not known whether the factors controlling Microcystis blooms in open water differ from those that promote surface scums.	As part of a robust field surveillance program, areas known to be impaired with regard to non-contact recreation should be identified. Waterfront, waterway, marina, and port managers should be solicited for information regarding measures that have been effective at addressing the impairments. The ecosystem model should determine whether the various factors that control open water Microcystis blooms differ from those promoting surface scums.

Appendix A

Table 1. List of Cyanobacteria Science Work Group members and their affiliation.

Individual	Affiliation
David Senn	San Francisco Estuary Institute
Lisa Thompson	Sacramento Regional County Sanitation District
Tim Mussen	Sacramento Regional County Sanitation District
Alex Parker	California Maritime Academy
Stephanie Fong	State and Federal Contractors Water Agency
Peggy Lehman	Department of Water Resources
Rafael Kudela	U.C. Santa Cruz
Mine Berg	Applied Marine Sciences
Martha Sutula (Facilitator)	Southern California Coastal Water Research Project
Karen Taberski	San Francisco Regional Water Quality Control Board
Kim Ward	State Water Resources Control Board
Daniel Orr	California Department of Fish and Wildlife