DELTA
Regional Monitoring Program

Monitoring Workplan

Fiscal Year 2024-2025

Submitted to the Central Valley Regional Water Quality Control Board on May 1, 2024

Prepared By:

MLJ ENVIRONMENTAL

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LIST OF ACRONYMS

ASC	Aquatic Science Center
CDFW	California Department of Fish and Wildlife
CEC	Constituent of Emerging Concern
CEDEN	California Environmental Data Exchange Network
chl-a	Chlorophyll a
CUP	Current Use Pesticides
CV RDC	Central Valley Regional Data Center
CVRWQCB	Central Valley Regional Water Quality Control Board
DRMP	Delta Regional Monitoring Program
DRMP BOD	Delta Regional Monitoring Program Implementing Entity Board of Directors
DRMP non-profit	Delta Regional Monitoring Program Implementing Entity
DIN	Dissolved Inorganic Nitrogen
DMAC	Data Management Advisory Committee
DMCP	Delta Mercury Control Program
DMT	Data Management Team
EDD	Electronic Data Deliverable
EO	Executive Officer
EPA	United States Environmental Protection Agency
FY 22-23	Fiscal Year 2022-2023
FY 23-24	Fiscal Year 2023-2024
FY 24-25	Fiscal Year 2024-2025
GRTS	Generalized Random-Tessellation Stratified
HAB	Harmful Algal Bloom
IEP	Interagency Ecological Program
MLML	Moss Landing Marine Laboratories
N	Nitrogen
NOAA	National Oceanic and Atmospheric Administration
nSFE-BGCM	northern San Francisco Estuary Biogeochemical Model
OCRL	Organic Chemistry Research Laboratory
P	Phosphorus
PER	Pacific EcoRisk
POTW	Publicly Owned Treatment Works
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control

SC	Steering Committee
SCCWRP	Southern California Coastal Water Research Project
SFEI	San Francisco Estuary Institute
SWAMP	State Board Surface Water Ambient Monitoring Program
SWRCB	State Water Resources Control Board
TAC	Technical Advisory Committee
TIE	Toxicity Identification Evaluation
TN	Total Nitrogen
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
WY	Water Year

LIST OF UNITS

L	liter
mg	milligram
mL	milliliter
ng	nanograms
µg	microgram

EXECUTIVE SUMMARY

The Delta Regional Monitoring Program (DRMP) is submitting the annual Monitoring Workplan for fiscal year 2024 – 2025 (FY 24-25) in accordance with Resolution R5-2021-0054. The purpose of this Monitoring Workplan is to identify the projects that will be implemented in the next fiscal year (July 1 through June 30). This Monitoring Workplan includes an initial draft budget estimate for each project (**Table 1**); a final budget will be submitted by June 30 as a separate document. The DRMP non-profit funds projects in the following monitoring sectors: Current Use Pesticides, Constituents of Emerging Concern, Nutrients (including harmful algal blooms), and Mercury. Projects to be implemented within each monitoring sector include a study design to address monitoring and assessment questions. Not all monitoring sectors will have monitoring projects funded during this fiscal year. The DRMP non-profit also funds work for planning, data management, and reporting in addition to monitoring.

This document describes the work to be funded by the DRMP non-profit for planning, monitoring, data management, and reporting for the next fiscal year (FY 24-25) including initial budget estimates.

CURRENT USE PESTICIDES

During FY 24-25, the Current Use Pesticide (CUP) monitoring program will include monitoring for the last events of Year 4 of the study design as outlined below. The study plan was approved on July 17, 2018, and monitoring began in October 2019 (**Appendix I**). Monitoring is conducted on a water year (WY) and therefore FY 24-25 will include monitoring for Events 5 and 6 of Year 4. Data from the previous events associated with Year 4 will also be undergoing submission and data review during this FY. The CUP Technical Advisory Committee (TAC) will work with the Steering Committee to discuss the possible scope and details of a CUP Interpretive Report.

Additional activities include CUP TAC meetings and Toxicity Identification Evaluation (TIE) TAC meetings. The TIE TAC meetings will be conducted when samples are toxic and the criterion for triggering a TIE occurs (greater than 50% effect). The TIE TAC will recommend which TIE procedures should be performed as outlined in the Quality Assurance Project Plan (QAPP).

CONSTITUENTS OF EMERGING CONCERN

The Constituents of Emerging Concern (CEC) monitoring program concluded the implementation of the Stakeholder Work Plan, referred to as the "CEC Pilot Study", in FY

23-24. Each of the three years of the CEC Stakeholder Work Plan had a Data Report with a data quality assessment included. Appropriate data have been loaded to the California Environmental Data Exchange Network (CEDEN); data not appropriate to load to CEDEN are available on the Delta RMP website. The CEC TAC will work with the Steering Committee to determine the scope and details of a CEC Interpretive Report.

The next step for CECs is to incorporate the information gained into an interpretive report and begin long-term planning. Planning for a CEC Interpretive Report will take place in FY 24-25.

NUTRIENTS / HABS

In FY 24-25, the DRMP non-profit will begin implementing the Nutrient Multi-Year Study Plan (**Appendix II**). The Steering Committee provided direction to the Nutrient TAC to develop a Multi-Year Study Plan at a Joint Steering Committee and Nutrient TAC meeting held on March 16, 2023. The Nutrient Multi-Year Study Plan includes three focus areas with funds allocated to each. During FY 24-25, modeling as part of Focus Area #1 will begin and development of a QAPP for the Focus Area #2 study design will occur. In addition, the DRMP non-profit will work with other monitoring groups to evaluate projects that meet the objectives of Focus Area #3 to determine if the DRMP non-profit should contribute funds. If a project under Focus Area #3 is identified and funded, the FY 24-25 Workplan will be amended to include the study design, deliverables, and project specific budget.

MERCURY

The Steering Committee decided at its March 14, 2022, Steering Committee meeting to begin mercury long-term planning in 2023. In December 2022, the Steering Committee created a Mercury Report Subgroup to outline the parameters for a mercury interpretive report. The Mercury Report will have a primary audience of the Central Valley Regional Water Quality Control Board (CVRWQCB) and Methylmercury Total Maximum Daily Load (TMDL) stakeholders with an objective to assess trends in fish tissue and aqueous methylmercury concentrations and evaluate other factors impacting trends in methylmercury concentrations. Data utilized in the report will include data generated from 2016 – 2022 and will evaluate trends in aqueous and fish tissue mercury concentrations since 2000 in the context of water year type and subarea. The timeline for developing the Mercury Report is contingent on a State Water Resources Control Board (State Board or SWRCB) contract amendment with the San Francisco Estuary Institute – Aquatic Sciences Center (SFEI-ASC); SFEI-ASC will be the entity developing the report and the CVRWQCB has allocated Surface Water Ambient Monitoring Program (SWAMP)

funds from SWRCB to be used to fund this work. The contract amendment was executed on April 30, 2024. The SFEI-ASC contract includes a timeline that is relative to the execution date. The DRMP non-profit will develop a specific timeline in coordination with SFEI-ASC to ensure that deliverables are completed within the timeframes outlined in the contract language. This will require coordination between schedules of CVRWQCB, SFEI-ASC, Steering Committee, and Mercury TAC members.

Mercury TAC meetings and Steering Committee meetings will be scheduled to review the deliverables associated with the Mercury Report (a compilation of mercury results and metadata, presentations to the Mercury TAC, a draft Factsheet and Mercury Report, and a final Factsheet and Mercury Report). Time is allocated for planning for a Mercury Symposium and scheduling meetings with the Mercury TAC and Steering Committee to develop a long-term plan for mercury monitoring.

SUMMARY BUDGET

Table 1. FY 24-25 Preliminary Budget Executive Summary.

BUDGET CATEGORY / MONITORING SECTOR	EXPENSES ESTIMATE
Operational Costs	$20,000
General Administration	$75,000
Collaboration	$120,000
Governance Documentation	$5,000
Resolution Requirements	$60,000
Current Use Pesticides	$145,000
Constituents of Emerging Concern	$35,000
Nutrients	$433,290
Mercury	$65,000
Data Management & Quality Assurance (QA)	$18,590
Expenses Total	**$976,880**

INTRODUCTION

The DRMP non-profit is submitting the annual Monitoring Workplan for fiscal year 2024 – 2025 (FY 24-25) in accordance with Resolution R5-2021-0054. The purpose of this Monitoring Workplan is to identify the projects that will be implemented in the next fiscal year (July 1 through June 30). This Monitoring Workplan includes an initial draft budget estimate for each project (**Table 1**); a final budget will be submitted by June 30 as a separate document. The DRMP non-profit funds projects in the following monitoring sectors: Current Use Pesticides, Constituents of Emerging Concern, Nutrients (including harmful algal blooms), and Mercury. Projects to be implemented within each monitoring sector include a study design to address monitoring and assessment questions. Not all monitoring sectors will have monitoring projects funded during this fiscal year. The DRMP non-profit also funds work for planning, data management, and reporting in addition to monitoring.

This document describes the work to be funded by the DRMP non-profit for planning, monitoring, data management, and reporting for the next fiscal year (FY 24-25) including initial budget estimates.

BACKGROUND

DRMP STRUCTURE AND ORGANIZATION

The purpose of the DRMP is to educate and inform decisions on how to protect and, where necessary, restore beneficial uses of water in the Sacramento-San Joaquin River Delta area of California by producing objective and cost-effective scientific information critical to understanding regional water quality conditions and trends. The Implementing Entity DRMP is a California nonprofit public benefit corporation (hereafter called the DRMP non-profit) under which the Board of Directors (BOD) oversees program operations.

The DRMP pursues the following objectives:

a) Improve the efficiency of water quality data collection and management in the Delta.

b) Generate information that informs and educates the public, agencies, and decision makers.

c) Raise awareness of Delta water quality conditions and how they impact beneficial uses.

d) Foster independent science, objective peer review, and a transparent review process.

The DRMP is implemented with stakeholder participation of various coordinated monitoring, resource, regulatory, and regulated entities. These groups give technical and program policy recommendations to the DRMP BOD through participation in the Steering Committee (SC) and various project-specific Technical Advisory Committees (TACs). The program structure is illustrated below in **Figure 1**.

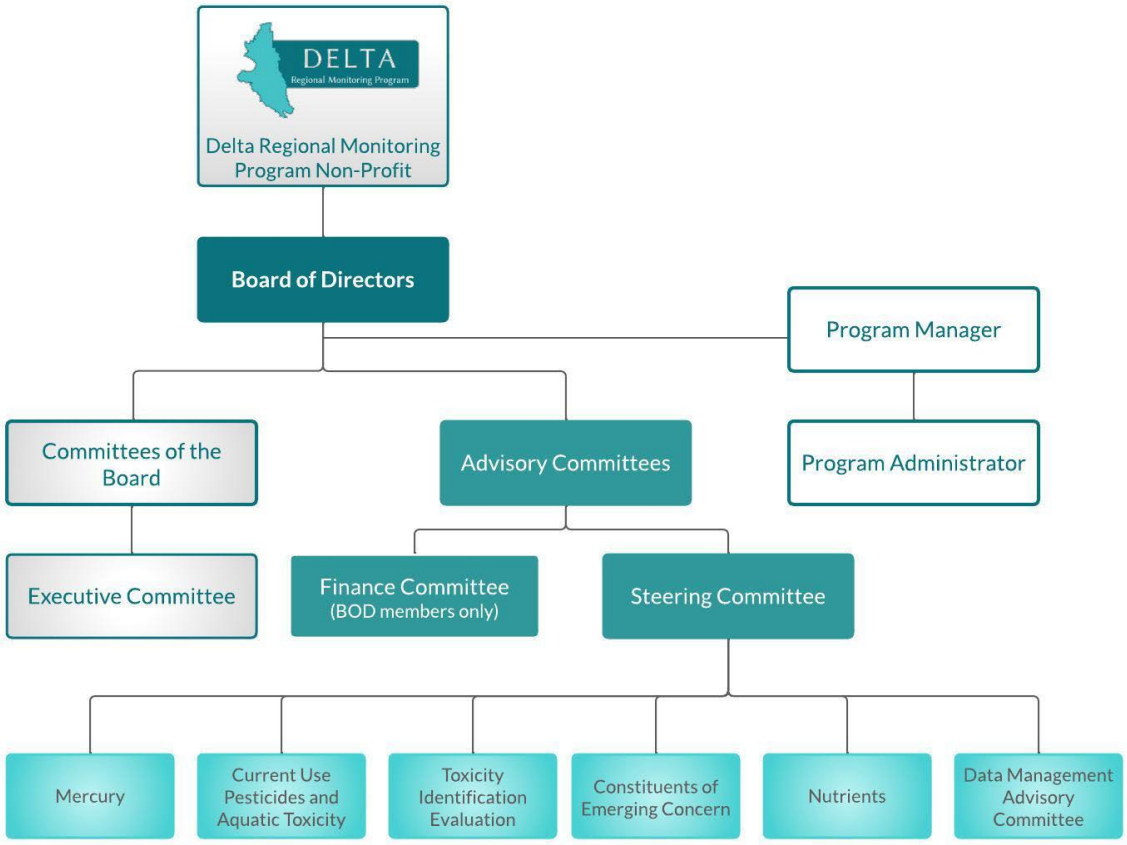
The implementation of the DRMP non-profit is done in close coordination with the CVRWQCB and permitted dischargers. Other stakeholders who may be involved with this program who are not dischargers include the SWRCB, United States Environmental Protection Agency (EPA), California Department of Fish and Wildlife (CDFW), National Oceanic and Atmospheric Administration (NOAA), Interagency Ecological Program (IEP), Delta Science Program, and State Water Contractors.

The funds contributed to the DRMP non-profit are used to support the collection of scientific data in the Delta region to support the goals of the Program. To ensure these goals are met, the data generated under the DRMP must be managed and governed in a consistent way and be of consistent quality such that the assessments and decisions made are effective at protecting and improving the water quality in the Delta.

ORGANIZATIONAL STRUCTURE AND GOVERNANCE

The program is implemented by the DRMP non-profit, a California nonprofit public benefit corporation, and guided by a governing board and advisory committees. The makeup of the DRMP BOD, Executive Committee, Steering Committee, and TACs is described on the DRMP website.

Figure 1. DRMP Non-profit Structure.



RESOLUTION REQUIREMENTS

A variety of permittees throughout the Central Valley, regulated by the CVRWQCB, contribute and participate in the DRMP non-profit. In 2013, the CVRWQCB passed Resolution R5-2013-0130 allowing DRMP participation in lieu of some receiving water monitoring/special study requirements. As such, the close collaboration with the CVRWQCB is essential to ensure the continued value and effectiveness of regional monitoring in lieu of individual monitoring and special studies that otherwise might be required by CVRWQCB for participating permittees.

In October 2021, the CVRWQCB passed Resolution R5-2021-0054 approving the updated DRMP non-profit governance structure as a vehicle for this modified monitoring to occur. Future refinements to the DRMP non-profit governance structure including changes to policy and procedure and foundational documents, must be reported to the CVRWQCB according to the reporting requirements of Attachment A of Resolution R5-2021-0054. The CVRWQCB Executive Officer (EO) will review any changes to ensure the

effectiveness of regional monitoring and adequate monitoring and assessment of cumulative impacts that alter water quality. It is the responsibility of the DRMP non-profit to submit the documents outlined in Attachment A according to the timelines and requirements therein to maintain approval by the CVRWQCB.

Attachment A of Resolution R5-2021-0054 outlines the reporting requirements of the implementing entity to the CVRWQCB to ensure added value of the coordinated efforts under the Program are adequate to investigate water quality issues in lieu of individual monitoring and special studies.

The requirements in Resolution R5-2021-0054 for the annual Monitoring Workplan are:

- Identify the projects the DRMP non-profit will implement over the next fiscal year (July 1 through June 30).
- Develop and provide the initial draft budget estimate for each project. The final budget shall be submitted as a separate document by June 30.
- Identify management, monitoring, and assessment questions to be addressed by each project in the Monitoring Workplan.
- Provide a study design to address monitoring and assessment questions. The study design shall include the following information:
    - Specific hypothesis to be tested
    - Sample locations
    - Sample collection frequency
    - Sample analytes
    - Analysis methods
    - Preliminary data deliverables
    - Planned reports to summarize results
    - Timeline and schedule

LONG TERM STRATEGIC PLANNING

The DRMP stakeholders met on December 8, 2021, to discuss an overall strategy for implementing a long-term monitoring program. The DRMP decided to move forward with a long-term planning strategy that allows for a staggered approach across monitoring sectors between planning, monitoring, and reporting with the goal of maximizing resources. Long-term planning is now focused on developing multiyear monitoring workplans for each focused monitoring sector.

The following key outcomes (**Table 2**) were identified during the December 8, 2021 meeting with agreement by the various participants. These outcomes are associated with implementation needs that were identified to improve the efficiency of the Program.

Table 2. Key outcomes from the December 8, 2021 Long-Term Planning Meeting.

KEY OUTCOME	KEY IMPLEMENTATION NEEDS
Support for long-term planning and for the Steering Committee to be responsible for directing such planning	Start planning earlier and develop meeting schedules earlier in the planning process Develop multi-year plans
Increased review time and increased emphasis on the importance of review time	Increased review time includes review of existing data, meeting preparation time, and determination of outstanding questions and needs
Synthesis of existing data in the Delta (including from other programs)	Identification of data gaps and what is known/unknown Determine future focus for DRMP based on this knowledge Further develop collaborations with other groups
Clear or new process for project implementation and identification of special studies	Ensure projects and special studies are linked to management questions

The DRMP agreed to begin long-term planning in 2022 starting with nutrients and then transitioning to mercury.

Figure 2 is an illustration of how the DRMP could plan across years to allocate resources across monitoring sectors and is adjusted annually. The DRMP is still working through the specifics of the staggered approach in terms of planning, monitoring, and reporting.

The Program has developed a general strategy for guiding long term planning (**Figure 3**). The DRMP intends to refine this general strategy per monitoring sector as it moves through long-term planning across the Program focus areas.

The DRMP continues to work with other monitoring programs such as the IEP and the Delta Science Program to identify areas where monitoring coordination can occur to maximize resources and fill data gaps.

Figure 2. Staggered approach for long-term planning across monitoring sectors.
This figure is an illustration of the strategy; specifics for years after FY 24-25 have not been decided upon by the DRMP.

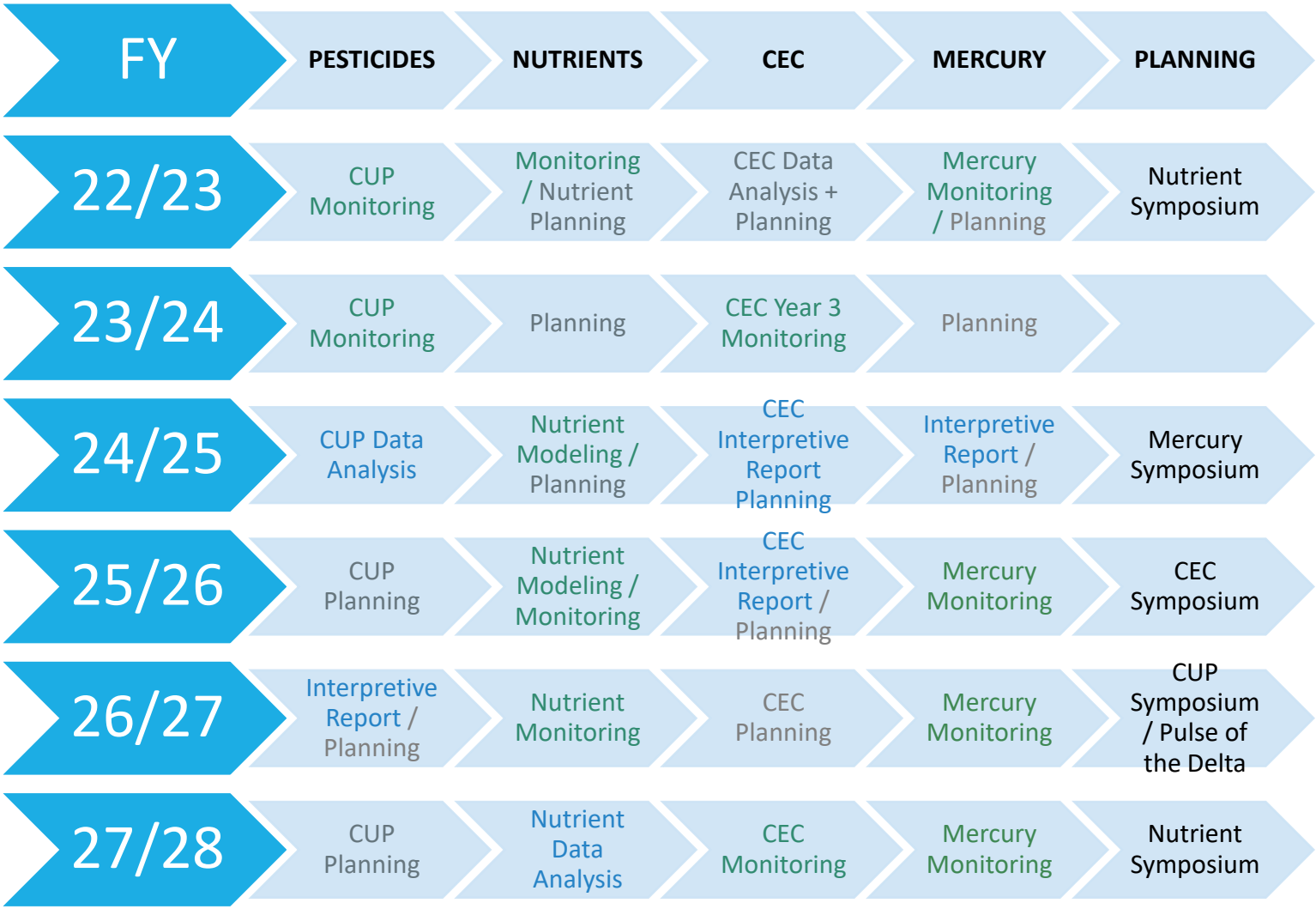
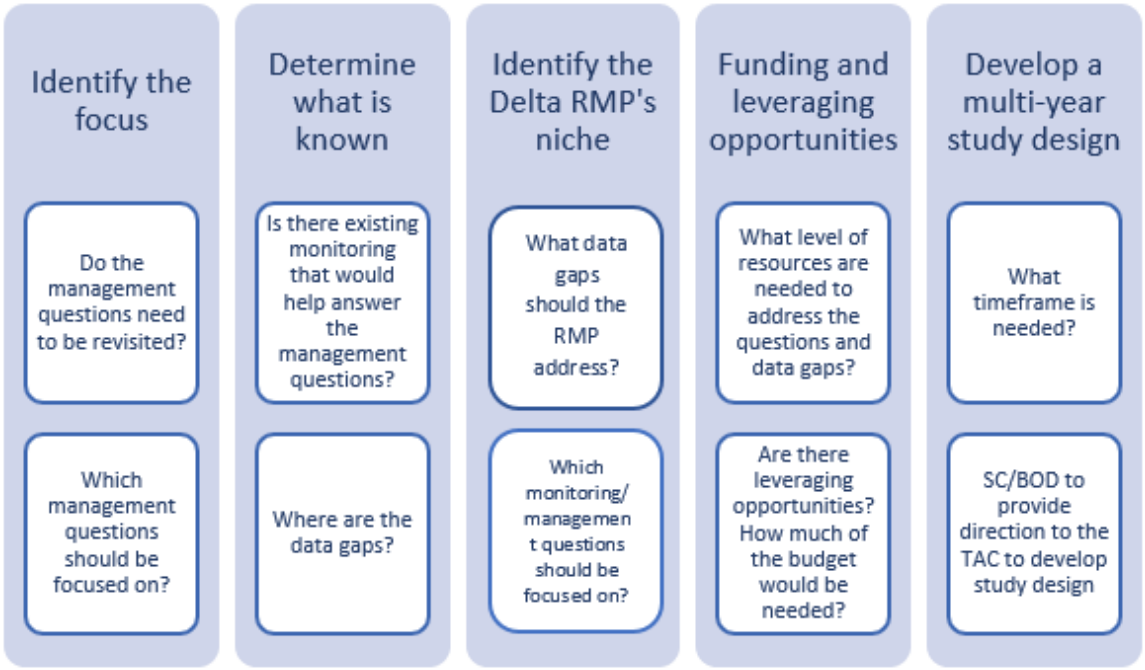


Figure 3. General strategy for developing multi-year study designs as part of the DRMP long term planning strategy.



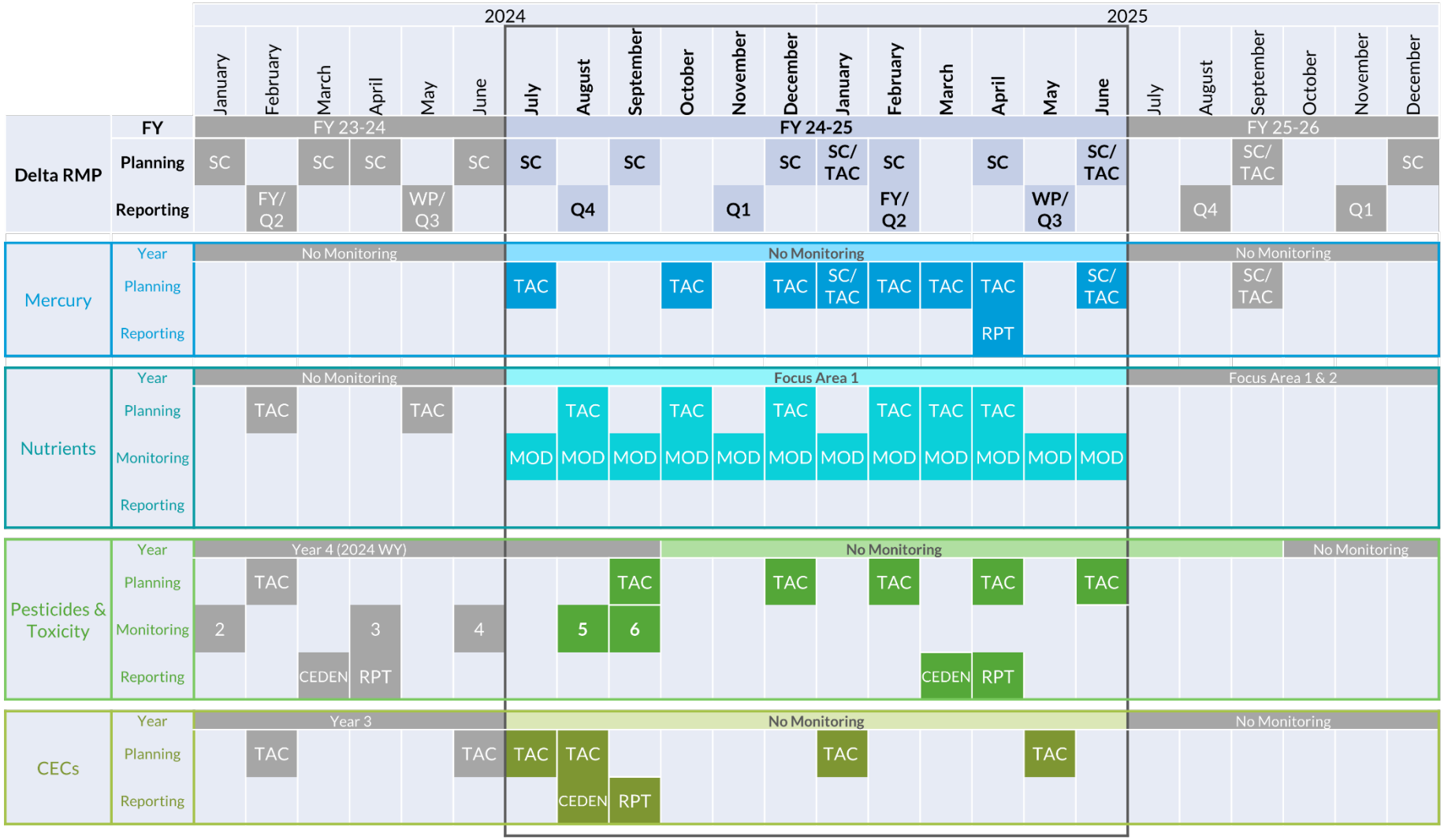
FY 24-25 OVERVIEW

For FY 24-25, the DRMP non-profit is continuing to implement existing monitoring designs, perform data synthesis and reporting, and conduct planning for multi-year projects. **Table 3** and **Figure 4** include an overview of the monitoring sectors and what will occur in terms of planning, monitoring, and data synthesis/reporting during the upcoming fiscal year. This is in addition to the deliverables identified within the Resolution which includes Quarterly and Annual Reports. The TAC meetings in **Figure 4** are estimates and not all of these meetings have been scheduled yet.

Table 3. FY 24-25 work to be performed in the four DRMP monitoring sectors.

MONITORING SECTOR	PLANNING	MONITORING	DATA SYNTHESIS / REPORTING
Current Use Pesticides	--	Water Year 2024 Monitoring	Water Year 2024 Data Report
Constituents of Emerging Concern Pilot Study	Planning for an Interpretive Report	--	--
Nutrients / Harmful Algal Blooms (HABs)	Focus Area #2 Study Design / QAPP Development	Biogeochemical Modeling	--
Mercury	Long Term Planning Mercury Symposium	--	Mercury Interpretive Report and Factsheet

Figure 4. Summary of anticipated DRMP planning, monitoring, and reporting activities for FY 24-25.
These are tentative timelines and milestones that will be adjusted as necessary to reflect direction from the Steering Committee. The timing of the Mercury Interpretive Report (draft and final) is pending contract execution; therefore, the timeframe included in the figure are estimations. Report and data upload deadlines may be estimated.



FY: FY Annual Report
Q: Quarterly Report
WP: Annual Workplan
TAC: TAC Meeting(s)
SC/TAC: Joint Meeting
RPT: Data or Study Report
CEDEN: Data upload to CEDEN
NWIS: Data upload to NWIS
MOD: Modeling

SUMMARY OF BUDGETS

The FY 24-25 Monitoring Workplan includes a preliminary budget reflecting estimated expenses for the upcoming fiscal year (**Table 4**). The DRMP non-profit will provide an updated budget for the program by June 30, 2024. The current estimates do not include in-kind contributions, matching funds, or contributions from SWAMP funds from the CVRWQCB (maximum of $205,600 of in-kind contributions). The June 30, 2024, budget will include in-kind contributions and updated estimates in preparation for FY 24-25.

For FY 24-25, Melissa Turner (MLJ Environmental) will be the Program Manager for the program with assistance from Jennifer Glenn (MLJ Environmental) as the Program Administrator. Their time is included in the cost estimate for General Administration, Collaboration, Governance Documentation, and Resolution Requirements. In addition, their responsibilities include scheduling Steering Committee and Technical Advisory Committee meetings and providing meeting notes. The Program Manager and Program Administrator work closely with the Board of Directors (including the Executive Committee) and Steering Committee Chair(s) to implement the program.

Table 4. FY 24-25 preliminary budget for expenses.

Monitoring Sector	Planning	Monitoring	Data Management	Deliverables	Expenses Estimate
Operational Costs	--	--	--	--	$20,000
General Administration	Yearly planning, communication between stakeholders	--	Droplet - File Sharing	Website	$75,000
Collaboration	BOD meetings, EC meetings, SC meetings, RB Coordination	--	--	--	$120,000
Governance Documentation	--	--	--	Updates to Policies and Procedures	$5,000
Resolution Requirements	FY Monitoring Workplan	--	--	Quarterly Report, Annual Report, Workplan, Data Management Plan Revisions	$60,000
Current Use Pesticides	TAC meetings	WY 2024 Monitoring	WY 2024 Data Review, Loading, and Verification; Deviations	WY 2024 Data Report	$145,000
Constituents of Emerging Concern	TAC meetings, Interpretive Report Planning	--	--	--	$35,000
Nutrients	TAC meetings, Study Design Development	Modeling	--	Focus Area #2 Study Design, QAPP	$433,290
Mercury	TAC meetings, Long Term Planning			Mercury Report	$65,000

Monitoring Sector	Planning	Monitoring	Data Management	Deliverables	Expenses Estimate
Data Management & Quality Assurance (QA)	DMAC meetings	--	QA Oversight and Policy Updates	QAPP Template Updates	$18,590
				Expenses Total	**$976,880**

DATA MANAGEMENT PLAN

The DRMP BOD formed a Data Management Advisory Committee (DMAC) on December 16, 2021, with a charge to develop a QAPP Template and Data Management Plan. Participation in the DMAC includes CVRWQCB staff, SWRCB staff, and representatives from the discharger groups.

As required by the Resolution R5-2021-0054, a Data Management Plan was submitted on October 3, 2022. However, based on comments at the Steering Committee on September 8, 2022, it was determined that the Data Management Plan would still require revisions and additional language to meet Water Boards' expectations. Therefore, the DRMP non-profit requested an extension on submitting the Data Management Plan to allow for time to work with the CVRWQCB and SWRCB to address outstanding comments and concerns. They granted an extension of the submittal date of the Data Management Plan to February 14, 2023. As a result of other workloads coinciding with this resubmittal date, the DRMP non-profit submitted a second extension letter to allow for time needed to focus on the Annual Monitoring Workplan and QAPP deadlines of May 1, 2023. On February 6, 2023, the CVRWQC granted the extension to submit the revised Data Management Plan from February 14, 2023, to December 23, 2023. The revised Data Management Plan was recommended by the Steering Committee on December 12, 2023, and approved by the DRMP BOD on December 12, 2023. The revised Data Management Plan (version 2.0) was submitted to the CVRWQCB Executive Officer (EO) on December 15, 2023 for approval.

The QAPP Template was finalized in March 2022 and was used to develop the CUP QAPP; during the process of finalizing the CUP QAPP some of the template language was adjusted to include additional recommendations from the CVRWQB and SWRCB. It is expected that the QAPP Template will be revised during the FY 24-25 to incorporate EPA updated requirements and ensure consistency with approved Data Management Plan language.

The QAPP Template outlines the role of the Program Quality Assurance (QA) Officer relative to the roles of the SWRCB QA Officer and the CVRWQCB QA Representative.

The Program QA Officer is Will Hagen from Moss Landing Marine Laboratories (MLML) and will provide quality assurance oversight for field and laboratory procedures, and final data review and assessment of completeness, accuracy, and precision of data generated by this project. The DRMP QA Officer is independent of any direct data generation, such as sample collection, field parameter recording, or laboratory analysis. In addition to procedural QA/Quality Control (QC), the Program QA Officer, in coordination with the Program Manager, is responsible for reviewing laboratory protocols to confirm laboratory compliance with the overall requirements of the DRMP and is ultimately responsible for reviewing project data both for accuracy and comparability with the SWRCB's SWAMP guidance. Quality assurance oversight for the implementation of DRMP projects and studies is conducted in coordination with the CVRWQCB QA Representative. The SWRCB QA Officer will also be consulted to ensure consistency with SWRCB data management policies.

The DRMP expects that there may be data management items, policies, and procedure updates to be discussed and addressed during FY 24-25. Therefore, budget has been allocated for these discussions as part of Collaboration, Governance Documentation, and Resolution Requirements (**Table 4**). As per Resolution R5-2021-0054, any changes or refinements to the Data Management Plan will require approval from the Executive Officer prior to implementation.

MONITORING STUDY DESIGNS

CURRENT USE PESTICIDES

During FY 24-25, the CUP monitoring program will include monitoring for the last events of Year 4 of the study design as outlined below. The study plan was approved on July 17, 2018, and monitoring began in October 2019 (**Appendix I**). Monitoring is conducted on a water year (WY) and therefore FY 24-25 will include monitoring for Events 5 and 6 of Year 4. Data from the previous events associated with Year 4 will also be undergoing submission and data review during this FY. The CUP TAC will work with the Steering Committee to discuss the possible scope and details of a CUP Interpretive Report.

Additional activities include CUP TAC meetings and TIE TAC meetings. The TIE TAC meetings will be conducted when samples are toxic and the criterion for triggering a TIE occurs (greater than 50% effect). The TIE TAC will recommend which TIE procedures should be performed as outlined in the QAPP.

Monitoring for Year 4 of the monitoring design is being conducted under CUP QAPP version 1.4 (approved on September 28, 2023). If necessary, an amendment to this QAPP will be submitted by May 1, 2024, to account for any updates to constituents and/or Standard Operating Procedures (SOPs). Any deviations to the Workplan and/or QAPP(s) will be documented and reported to the CVRWQCB as required in the Resolution. Any deviation to the QAPP(s) that can prevent project and data quality objectives from being met shall be described in the QAPP and must be approved by the CVRWQCB QA Representative, the SWRCB QA Officer, or the CVRWQCB QA Officer, prior to implementation. When prior approval is not possible, the deviations must be reported to the CVRWQCB within 7 calendar days of becoming aware of the deviation.

Study Design

The DRMP CUP monitoring includes the collection of samples for aquatic toxicity testing and the analysis of pesticide concentrations in water at multiple sample locations across the Delta over multiple monitoring years. Sample locations are randomly selected based on a rotating basin monitoring design. The DRMP has divided the Delta into 7 subregions based on the contribution of source waters as described in the 2018 report *Modeling to Assist Identification of Temporal and Spatial Data Gaps for Nutrient Monitoring* (Jabusch et al. 2018). The rotating basin monitoring design includes 6 of these 7 subregions, excluding the Suisun Bay subregion which is outside of the Legal Delta. Two of these areas are assessed each year on a set rotation cycle such that monitoring of the entire Delta region will be completed over the course of four years. The fixed sites, Ulatis Creek at Brown

Road and San Joaquin River at Buckley Cove, are locations where aquatic toxicity was frequently observed during the first two years of Delta RMP monitoring. These sites represent two entry points of discharges into the Delta from a mixture of urban and agricultural sources and allows for a more effective assessment of the temporal aspects of the management questions provided below than could be achieved by the rotating sampling design alone. The detailed CUP study design is provided as **Appendix I**.

The rotating basin design allows for the assessment of pesticide and toxicity conditions in individual subregions of the Delta and in the Delta as a whole. The goal of this design is to collect a minimum of 24 samples from 24 different locations in each subregion, allowing for an assessment of the conditions of all six subregions over a four-year period. In addition, samples are collected from two fixed sites during each event over the entire study period. These sites represent two entry points of discharges into the Delta from a mixture of urban and agricultural sources and allows for a more effective assessment of the temporal aspects of the management questions provided below than could be achieved by the rotating sampling design alone.

Specific sample collection locations for the rotating sites were randomly selected within each subregion from a pool of potential locations using the Generalized Random-Tessellation Stratified (GRTS) method which identifies monitoring sites based on a stratified random selection process. Additional oversample site locations were also identified as a part of this analysis to be used in the event that a location is inaccessible or impractical to reach. The GRTS site selection was also further stratified by water body type (i.e., large fast-flowing river channels to smaller creeks and sloughs), ensuring that the entire Delta is adequately represented in the sampling design and that assessments can be made regarding the characterization of different types of water bodies.

The CUP monitoring will be led by the United States Geological Survey (USGS) and includes field sampling by USGS, chemistry analysis for pesticides by USGS laboratories, ancillary parameters and copper by Babcock Laboratories, toxicity testing by Pacific EcoRisk (PER), and data management by MLJ Environmental through the Central Valley Regional Data Center (CV RDC). Moss Landing Marine Laboratories (MLML) will be responsible for QA oversight including end of year assessment of the quality of the data in a Data Report, consultation on QA issues throughout the year, and final review of data and associated flagging to ensure compliance with the QAPP prior to exporting to CEDEN.

The FY 24-25 monitoring will include the last two events of Year 4 of monitoring (Event 5 and 6, WY 2024).

Management and Assessment Questions

The overall purpose of this study is to characterize status and trends of pesticide concentrations and toxicity in the Delta.

The primary management question driving the implementation of this study is:

- Is water quality currently, or trending towards adversely affecting beneficial uses of the Delta?

More specifically to pesticides and aquatic toxicity, the assessment questions this study has the goal of answering are:

- Status & Trends 1 - To what extent do current use pesticides contribute to observed toxicity in the Delta?
    - Status & Trends 1.1 - If samples are toxic, do detected pesticides explain the toxicity?
    - Status & Trends 1.2 - What are the spatial and temporal extent of lethal and sublethal aquatic and sediment toxicity observed in the Delta?
- Status & Trends 2 - What are the spatial/temporal distributions of concentrations of currently used pesticides identified as possible causes of observed toxicity?

In order to answer these questions, the primary study objectives are defined as follows:

- Collect water samples from a variety of locations across Delta subregions and analyze them for a broad suite of current use pesticides and for toxicity to aquatic organisms.
- Test whether pesticides in ambient water samples exceed aquatic life benchmarks.
- Test for the co-occurrence of pesticides and observed aquatic toxicity.

Hypothesis

This study design was approved by the DRMP prior to the Board Resolution and hypotheses were not required at that time. Future study designs will include hypothesis.

Monitoring Locations

Samples are collected from within the legal boundaries of the Delta. The fixed sites, subregions, and the planned individual sites from which samples will be collected during FY 24-25 are outlined in **Table 5**. The monitoring years for this study occur on a WY basis, beginning on October 1 and continuing through the following September. Year 4 began with the 2024 WY on October 1, 2023. Events 1 through 4 were conducted in FY 23-24. All sites which are scheduled for Year 4 are provided below.

In addition to sample collection at the two fixed monitoring locations, the Year 4 monitoring will cover the second half (12 of 24) of sites from Subregion 5, the Central Delta. Due to the random site selection, the samplers may end up being unable to access one of the sites preselected for the subregion; in those cases, they will select another set of samples from predetermined "oversample" sites. **Table 5** includes both the scheduled and oversample sites.

Table 5. Site locations for FY 24-25 monitoring for pesticides and aquatic toxicity (Year 4).

Water Year	Sampling Event	Site Subregion	Sampling Site	Latitude	Longitude
All	All	Fixed Site	San Joaquin River at Buckley Cove	37.9718	-121.3736
All	All	Fixed Site	Ulatis Creek at Brown Road	38.307	-121.7942
2024 WY	Event 1[1]	5. Central Delta	Cent-013	37.94248	-121.559
		5. Central Delta	Cent-014	38.06307	-121.561
		6. Confluence	Conf-001	38.04107	-121.825
		6. Confluence	Conf-002	38.05926	-121.822
		6. Confluence	Conf-003	38.02936	-121.754
		6. Confluence	Conf-004	38.0217	-121.735
2024 WY	Event 2[1]	5. Central Delta	Cent-015	38.05692	-121.609
		5. Central Delta	Cent-016	38.1042	-121.593
		6. Confluence	Conf-005	38.02386	-121.816
		6. Confluence	Conf-006	38.06217	-121.843
		6. Confluence	Conf-007	38.07803	-121.683
		6. Confluence	Conf-008	38.04345	-121.709
2024 WY	Event 3[1]	5. Central Delta	Cent-017	37.92026	-121.556
		5. Central Delta	Cent-018	37.99156	-121.515
		6. Confluence	Conf-009	38.03502	-121.831
		6. Confluence	Conf-010	38.0252	-121.748
		6. Confluence	Conf-011	38.10005	-121.719
		6. Confluence	Conf-012	38.10961	-121.71
2024 WY	Event 4[1]	5. Central Delta	Cent-019	38.06157	-121.619
		5. Central Delta	Cent-020	38.02919	-121.583
		6. Confluence	Conf-013	38.07439	-121.773
		6. Confluence	Conf-014	38.04787	-121.795
		6. Confluence	Conf-015	38.02104	-121.704
		6. Confluence	Conf-016	38.13653	-121.687
2024 WY	Event 5	5. Central Delta	Cent-021	37.8893	-121.575
		5. Central Delta	Cent-022	38.00364	-121.529
		6. Confluence	Conf-017	38.04499	-121.802

Water Year	Sampling Event	Site Subregion	Sampling Site	Latitude	Longitude
		6. Confluence	Conf-018	38.05608	-121.807
		6. Confluence	Conf-019	38.05904	-121.678
		6. Confluence	Conf-020	38.0094	-121.72
2024 WY	Event 6	5. Central Delta	Cent-023	38.05159	-121.634
		5. Central Delta	Cent-024	38.03892	-121.57
		6. Confluence	Conf-021	38.02724	-121.811
		6. Confluence	Conf-022	38.07076	-121.837
		6. Confluence	Conf-023	38.08438	-121.71
		6. Confluence	Conf-024	38.03909	-121.725
2023 / 2024 WY	Oversample Point 1	5. Central Delta	Cent-025	38.00963	-121.54678
2023 / 2024 WY	Oversample Point 2	5. Central Delta	Cent-026	37.97532	-121.52924
2023 / 2024 WY	Oversample Point 3	5. Central Delta	Cent-027	38.02158	-121.60701
2023 / 2024 WY	Oversample Point 4	5. Central Delta	Cent-028	38.05344	-121.52894
2023 / 2024 WY	Oversample Point 5	5. Central Delta	Cent-029	37.97748	-121.57555
2023 / 2024 WY	Oversample Point 6	5. Central Delta	Cent-030	38.0854	-121.5748
2023 / 2024 WY	Oversample Point 7	5. Central Delta	Cent-031	38.05183	-121.61223
2023 / 2024 WY	Oversample Point 8	5. Central Delta	Cent-032	38.09282	-121.66764
2023 / 2024 WY	Oversample Point 9	5. Central Delta	Cent-033	37.91614	-121.57317
2023 / 2024 WY	Oversample Point 10	5. Central Delta	Cent-034	37.98716	-121.51273
2024 WY	Oversample Point #1	6. Confluence	Conf-025	38.06592	-121.793
2024 WY	Oversample Point #2	6. Confluence	Conf-026	38.03582	-121.777
2024 WY	Oversample Point #3	6. Confluence	Conf-027	38.05161	-121.692
2024 WY	Oversample Point #4	6. Confluence	Conf-028	38.1158	-121.685
2024 WY	Oversample Point #5	6. Confluence	Conf-029	38.08838	-121.74

Water Year	Sampling Event	Site Subregion	Sampling Site	Latitude	Longitude
2024 WY	Oversample Point #6	6. Confluence	Conf-030	38.02255	-121.8
2024 WY	Oversample Point #7	6. Confluence	Conf-031	38.01509	-121.695
2024 WY	Oversample Point #8	6. Confluence	Conf-032	38.14447	-121.692
2024 WY	Oversample Point #9	6. Confluence	Conf-033	38.0364	-121.807
2024 WY	Oversample Point #10	6. Confluence	Conf-034	38.07157	-121.852

[1] The 2024 WY Events 1 -4 occurred during FY 23-24; not all sites identified in this table will be sampled during FY 24-25.

Monitoring Events

A total of six sampling events are conducted each water year. Samples are collected over the course of two to three days during times of interest, namely, during periods with high agricultural and/or urban irrigation and during periods of high flows following storms when pollutants are flushed from land surfaces into waterways via overland flow and drains. The sample collection schedule for FY 24-25 is anticipated to include the remainder of the events from Year 4 (two of six). All events planned for the FY 24-25 are outlined below in **Table 6**.

Table 6. Schedule of CUP sample events anticipated for FY 23-24.

Sampling Event	Event Type	GRTS Sites in Subregion 5	Fixed Site 1	Fixed Site 2	Total
2024 WY Event 5	Irrigation/ Baseflow	2	1	1	4
2024 WY Event 6	Irrigation/ Baseflow	2	1	1	4
Total Samples		**4**	**2**	**2**	**8**

Monitoring Constituents

All samples collected for CUP monitoring are analyzed for the constituents identified in **Table 7.** Per the study design, samples are collected for both water chemistry and aquatic toxicity testing at each site. Water column toxicity testing is done using five different test species. Three of the five species are evaluated for both lethal and sublethal endpoints. The USGS Organic Chemistry Research Laboratory (OCRL) analyzes a suite of 178 pesticide constituents. The dissolved fraction is reported for all 178 constituents, while the particulate fraction is reported for 173.

In addition, ancillary parameters that can be used for further interpretation of the bioavailability and relative toxicity of the measured pesticide concentrations are analyzed by Babcock Analytical. Babcock Analytical will analyze for seven ancillary parameters and one trace metal.

Table 7. Constituents monitored for FY 24-25 CUP monitoring.

LAB	MATRIX	METHOD	ANALYTE	CAS NUMBER	FRACTION	UNIT
Babcock	Water	Calculated	Nitrogen, Total	Not Applicable	Dissolved	mg/L
Babcock	Water	Calculated	Nitrogen, Total	Not Applicable	Total	mg/L
Babcock	Water	EPA 200.7	Calcium	7440702	Dissolved	mg/L
Babcock	Water	EPA 200.7	Magnesium	7439954	Dissolved	mg/L
Babcock	Water	EPA 200.8	Copper	7440508	Dissolved	µg/L
Babcock	Water	EPA 351.2	Nitrogen, Total Kjeldahl	7727379	Dissolved	mg/L
Babcock	Water	EPA 351.2	Nitrogen, Total Kjeldahl	7727379	Total	mg/L
Babcock	Water	EPA 353.2	Nitrate + Nitrite as N	Not Applicable	Total	mg/L
Babcock	Water	SM 2340 B	Hardness as CaCO3	Not Applicable	Dissolved	mg/L
Babcock	Water	SM 5310 B	Dissolved Organic Carbon	Not Applicable	Dissolved	mg/L
Babcock	Water	SM 5310 B	Total Organic Carbon	Not Applicable	Total	mg/L
OCRL	Water	EPA 160.2	Total Suspended Solids	Not Applicable	Particulate	mg/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_GC/MS/MS	Acibenzolar-S-methyl	135158542	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_GC/MS/MS	Allethrin	584792	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_GC/MS/MS	Benfluralin	1861401	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_GC/MS/MS	Bifenthrin	82657043	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_GC/MS/MS	Chlorfenapyr	122453730	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_GC/MS/MS	Chlorothalonil	1897456	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_GC/MS/MS	Cyfluthrin, Total	68359375	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_GC/MS/MS	Cyhalofop-butyl	122008859	Dissolved, Particulate	ng/L

LAB	MATRIX	METHOD	ANALYTE	CAS NUMBER	FRACTION	UNIT
OCRL	Water	USGS-OCRL_WATER-PEST_06_GC/MS/MS	Cyhalothrin, Total	68085858	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_GC/MS/MS	Cypermethrin, Total	52315078	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_GC/MS/MS	Dacthal	1861321	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_GC/MS/MS	DDD(p,p')	72548	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_GC/MS/MS	DDE(p,p')	72559	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_GC/MS/MS	DDT(p,p')	50293	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_GC/MS/MS	Deltamethrin	52918635	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_GC/MS/MS	Dithiopyr	97886458	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_GC/MS/MS	Esfenvalerate	66230044	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_GC/MS/MS	Ethalfluralin	55283686	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_GC/MS/MS	Ethofenprox	80844071	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_GC/MS/MS	Fenpropathrin	39515418	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_GC/MS/MS	Methoprene	40596698	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_GC/MS/MS	Nitrapyrin	1929824	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_GC/MS/MS	Pentachloroanisole	1825214	Dissolved, Particulate	ng/L

LAB	MATRIX	METHOD	ANALYTE	CAS NUMBER	FRACTION	UNIT
OCRL	Water	USGS-OCRL_WATER-PEST_06_GC/MS/MS	Pentachloronitrobenzene	82688	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_GC/MS/MS	Permethrin, Total	52645531	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_GC/MS/MS	Phenothrin	26002802	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_GC/MS/MS	Tefluthrin	79538322	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_GC/MS/MS	Tetramethrin	7696120	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_GC/MS/MS	T-Fluvalinate	102851069	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_GC/MS/MS	Trifluralin	1582098	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Acetamiprid	135410207	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Atrazine	1912249	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Azoxystrobin	131860338	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Bentazon	25057890	Dissolved	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Benzobicyclon	156963665	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Benzovindiflupyr	1072957711	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Boscalid	188425856	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Boscalid-5-hydroxy	661463872	Dissolved, Particulate	ng/L

LAB	MATRIX	METHOD	ANALYTE	CAS NUMBER	FRACTION	UNIT
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Broflanilide	1207727045	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Bromuconazole	116255482	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Butralin	33629479	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Carbaryl	63252	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Carbendazim	10605217	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Carbofuran	1563662	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Chlorantraniliprole	500008457	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Chloro-N-(ethoxymethyl)-N-(2-ethyl-6-methylphenyl)acetamide, 2-	34256821	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Chlorpyrifos	2921882	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Chlorpyrifos oxon	5598152	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Clomazone	81777891	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Clothianidin	210880925	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Clothianidin-Desmethyl	135018154	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Coumaphos	56724	Dissolved, Particulate	ng/L

LAB	MATRIX	METHOD	ANALYTE	CAS NUMBER	FRACTION	UNIT
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Cyantraniliprole	736994631	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Cyazofamid	120116883	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Cyclaniliprole	1031756985	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Cycloate	1134232	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Cymoxanil	57966957	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Cyproconazole	94361065	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Cyprodinil	121552612	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Desethyl-Atrazine	6190654	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Desisopropyl-Atrazine	1007289	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Desnitro-imidacloprid	115970177	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Desthio-prothioconazole	120983644	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Diazinon	333415	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Diazoxon	962583	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Dichloroaniline, 3,5-	626437	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Dichlorobenzenamine, 3,4-	95761	Dissolved, Particulate	ng/L

LAB	MATRIX	METHOD	ANALYTE	CAS NUMBER	FRACTION	UNIT
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Dichlorophenyl Urea, 3,4-	2327028	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Dichlorophenyl-3-methyl Urea, 3,4-	3567622	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Dichlorvos	62737	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Difenoconazole	119446683	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Dimethomorph	110488705	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Dinotefuran	165252700	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Diuron	330541	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	EPTC	759944	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Ethaboxam	162650773	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Etoxazole	153233911	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Famoxadone	131807573	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Fenamidone	161326347	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Fenbuconazole	114369436	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Fenhexamid	126833178	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Fenpyroximate	134098616	Dissolved, Particulate	ng/L

LAB	MATRIX	METHOD	ANALYTE	CAS NUMBER	FRACTION	UNIT
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Fipronil	120068373	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Fipronil Desulfinyl	205650653	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Fipronil Desulfinyl Amide	1115248093	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Fipronil Sulfide	120067836	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Fipronil Sulfone	120068362	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Flonicamid	158062670	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Florpyrauxifen-Benzyl	1390661729	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Fluazinam	79622596	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Fludioxonil	131341861	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Flufenacet	142459583	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Fluindapyr	1383809877	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Flumetralin	62924703	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Fluopicolide	239110157	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Fluopyram	658066354	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Fluoxastrobin	193740760	Dissolved, Particulate	ng/L

LAB	MATRIX	METHOD	ANALYTE	CAS NUMBER	FRACTION	UNIT
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Flupyradifurone	951659408	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Fluridone	59756604	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Flutolanil	66332965	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Flutriafol	76674210	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Fluxapyroxad	907204313	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Halauxifen-methyl	943831989	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Hexazinone	51235042	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Hydroxy-Imidacloprid, 5-	380912094	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Imazalil	35554440	Dissolved	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Imidacloprid	138261413	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Imidacloprid olefin	115086549	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Imidacloprid urea	120868668	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Indaziflam	950782862	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Indoxacarb	173584446	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Ipconazole	125225287	Dissolved, Particulate	ng/L

LAB	MATRIX	METHOD	ANALYTE	CAS NUMBER	FRACTION	UNIT
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Iprodione	36734197	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Isofetamid	875915789	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Kresoxim-methyl	143390890	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Malaoxon	1634782	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Malathion	121755	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Mandestrobin	173662970	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Mandipropamid	374726622	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Metalaxyl	57837191	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Metalaxyl-hydroxymethyl	85933499	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Metconazole	125116236	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Methoxyfenozide	161050584	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Metolachlor	51218452	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Myclobutanil	88671890	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Naled	300765	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Napropamide	15299997	Dissolved, Particulate	ng/L

LAB	MATRIX	METHOD	ANALYTE	CAS NUMBER	FRACTION	UNIT
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Novaluron	116714466	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Oryzalin	19044883	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Oxadiazon	19666309	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Oxathiapiprolin	1003318679	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Oxyfluorfen	42874033	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Paclobutrazol	76738620	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Pendimethalin	40487421	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Penoxsulam	219714962	Dissolved	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Penthiopyrad	183675823	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Phosmet	732116	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Picarbutrazox	500207045	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Picoxystrobin	117428225	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Piperonyl Butoxide	51036	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Prodiamine	29091212	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Prometon	1610180	Dissolved, Particulate	ng/L

LAB	MATRIX	METHOD	ANALYTE	CAS NUMBER	FRACTION	UNIT
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Prometryn	7287196	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Propanil	709988	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Propargite	2312358	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Propiconazole	60207901	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Propyzamide	23950585	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Pydiflumetofen	1228284647	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Pyraclostrobin	175013180	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Pyridaben	96489713	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Pyrimethanil	53112280	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Pyriproxyfen	95737681	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Quinoxyfen	124495187	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Sedaxane	874967676	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Simazine	122349	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Sulfoxaflor	946578003	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Tebuconazole	107534963	Dissolved, Particulate	ng/L

LAB	MATRIX	METHOD	ANALYTE	CAS NUMBER	FRACTION	UNIT
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Tebuconazole-tert-Butylhydroxy	212267646	Dissolved	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Tebufenozide	112410238	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Tebupirimfos	96182535	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Tebupirimfos oxon	1035330369	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Tetraconazole	112281773	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Thiabendazole	148798	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Thiacloprid	111988499	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Thiamethoxam	153719234	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Thiamethoxam Degradate (CGA-355190)	--	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Thiamethoxam Degradate (NOA-407475)	--	Dissolved	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Thiobencarb	28249776	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Tolfenpyrad	129558765	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Triadimefon	43121433	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Triadimenol	55219653	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Triallate	2303175	Dissolved, Particulate	ng/L

LAB	MATRIX	METHOD	ANALYTE	CAS NUMBER	FRACTION	UNIT
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Tributyl Phosphorotrithioate, S,S,S-	78488	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Trifloxystrobin	141517217	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Triflumizole	68694111	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Triticonazole	131983727	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Valifenalate	283159900	Dissolved, Particulate	ng/L
OCRL	Water	USGS-OCRL_WATER-PEST_06_LC/MS/MS	Zoxamide	156052685	Dissolved, Particulate	ng/L

Schedule of Deliverables

The overall schedule of deliverables for the FY 24-25 CUP monitoring is defined in **Table 8** and outlined below.

Table 8. Schedule of Deliverables for CUP monitoring.

Deliverable	Deliverable Due Date	Activity Period or Trigger	Frequency
Resolution Deliverables			
FY 24-25 CUP Study Design	May 1, 2024	July 1, 2024 – June 30, 2025	Per fiscal year
CUP QAPP v1.5 Amendment	May 1, 2024	WY 2024	Amended as needed
Final CUP Budget	June 30, 2024	July 1, 2024 – June 30, 2025	Per fiscal year
Preliminary CUP Data	60 calendar days	Sample analysis	Per event
Finalized CUP Data	6 months	Sample analysis	Per event
Transfer of CUP Data to CEDEN	6 months	Final sampling event of the water year	Per water year
DRMP FY 23-24 Annual Report	February 1, 2025	July 1, 2023 – June 30, 2024	Annually
Additional Study Deliverable FY 24-25			
Year 4 Data Report and QC Assessment	April 2025	October 1, 2023 – September 31, 2024	Per water year

QAPP

QAPPs for the upcoming FY must be submitted to the CVRWQCB by May 1 of each year, per the requirements outlined in R5-2021-0054. The QAPP must:

- Meet guidance and requirements from both the Water Boards and EPA,
- Include a documentation process for deviations and an assessment of corrective action process, and
- Be reviewed and approved by the State Water Board QA Officer or the Central Valley Water Board's QA Officer before project implementation can occur.

A QAPP specific to the CUP project (CUP QAPP v1.3) was approved by the CVRWQCB and State Board QA Officer on January 23, 2023, which included monitoring planned for Year 4 (October 2023 – September 2024). An amendment to v1.3, i.e., v1.4, was approved on September 28, 2023, which included an updated method reference from the incorrect method OCRL-WATER-PEST_05 to the correct method OCRL-WATER-PEST_06. As part

of this amendment, forty pesticides had MDL and RLs updates for USGS Method v 6.0. Any necessary amendments to the CUP QAPP v1.4 will be submitted to the CVRWQCB and SWRCB on May 1, 2024, for FY 24-25.

Preliminary Data

According to the requirements outlined in Resolution R5-2021-0054, preliminary data in the form of unverified/raw results provided by the project laboratories will be submitted within 60 days of the sample analysis date for each sampling event. Raw data and laboratory reports (where applicable) are provided to the CUP TAC and CVRWQCB staff via upload to a shared file storage site. The DRMP will also email the following CVRWQCB staff with the preliminary data attached to the email when the files are uploaded to the file storage site: Executive Officer Patrick Pulupa, Program Manager Meredith Howard, and Environmental Scientists Selina Cole and Ryan Brown.

Final Data in CV RDC

Pesticide and toxicity data are processed by the CV RDC Data Management Team (DMT) and loaded into the CV RDC for storage and analysis prior to being published to CEDEN. The DMT is responsible for reviewing reports and electronic data deliverables (EDDs) to ensure completeness, assessing whether project MQOs were met, and ensuring CEDEN/SWAMP comparability. The DMT is responsible for uploading data to the CV RDC, performing final checks, and transferring data to CEDEN annually within 6 months of the last sampling date per Resolution R5-2021-0054. The CV RDC will track completion of monitoring events and data received; this information will be used to complete the QA Report at the end of the WY.

Stage 1 data are reviewed by DMT staff during the data loading process for each individual EDD received. Data verification by the CV RDC DMT according to the approved Data Management SOP occurs as close to receipt of the EDD as possible to ensure that any analytical issues identified during review can be communicated with laboratories and resolved in a timely manner. Once loaded into the CV RDC, an additional data verification is conducted by Program QA Officer (or a delegate) on a result and batch level for individual results sets. The QA Officer applies the appropriate compliance codes to each reviewed record, indicating the data are finalized on the result and batch level. These Stage 2 data are considered final data and are then exported and provided to the CUP TAC, stakeholders, and CVRWQCB staff. Per Resolution R5-2021-0054, this is done within six months of sample analysis.

Per the Resolution R5-2021-0054 requirement, a quality assurance assessment for samples collected in the previous fiscal year must be included in the DRMP Annual Report. This assessment will include all of the quality assurance section elements

identified in R5-2021-0054 and is considered an intermediate QA Assessment since not all samples will have been received, verified, and finalized for the WY. The Program QA Officer will conduct a final review and assessment of the data prior to transfer to CEDEN including a QA Report for data collected during the WY.

The DRMP is in discussions with the CVRWQCB and SWRCB regarding analytical data from USGS that was analyzed prior to submitting MDL and RL verification study data to the SWRCB QA Officer. Data in CEDEN will be flagged according to the outcomes from these discussions and used appropriately.

Data Report and QC Report

The 2024 WY dataset will be assessed in a Data Report with an associated QA Report that will be submitted in FY 24-25. This report will summarize the field activities that occurred, the field measurements collected, the chemistry and toxicity results provided, and will provide an assessment of completeness, precision, and accuracy for the final, verified dataset generated during the 2024 WY. This report is anticipated to be completed in April of 2025, following the end of the 2024 WY, or upon completion of the entire dataset (**Table 8**).

FY Annual Report

The DRMP Annual Report for the previous FY is due on February 1 of each year. According to the requirements outline in R5-2021-0054, for each project this report must include:

- A list and description of all deviations to the QAPP.
- The corrective action(s) taken to address the deviation(s).
- A description of how the DRMP monitors the effectiveness of any corrective actions and ensures any deviations do not occur frequently in the future.
- Summary of dataset completeness, precision, and accuracy.
- A list and description of sample comparisons or tests that did not meet minimum test acceptability criteria for analyses or were considered invalid.
- Results for all analyses completed during the reporting period and comparison of results to previous year's observations, if applicable.
- List of monitoring data (and associated metadata) that do not meet predetermined quality control measures and measurement quality objectives.

There will be CUP data included in the FY Annual Report due February 1, 2025. Samples collected between October 1, 2023 (beginning of the 2024 WY) through June of 2024

(end of FY 23-24) will be reported in the Annual Report submitted on February 1, 2025 (**Table 8**).

Long Term Planning

It is anticipated that planning discussions for a CUP Interpretive Report will begin between April and June 2025. The Steering Committee will be responsible for providing direction on requirements of an Interpretive Report to the CUP TAC.

Budget

The high-level draft budget for tasks associated with the DRMP CUP project for FY 24-25 is provided in (**Table 4)**. The CUP budget is estimated at $145,000. All budgets provided with this Workplan are considered preliminary, with a finalized budget to be submitted prior to the beginning of the FY by June 30, 2024; it is anticipated that the budget amounts will vary by approximately 15% from actuals.

CONSTITUENTS OF EMERGING CONCERN

A stakeholder group developed the Central Valley Pilot Study for Monitoring CECs Work Plan (referred to here as the Stakeholder Work Plan) outside of the DRMP. The stakeholder group consisted of several DRMP contributors including publicly owned treatment works (POTW), municipal separate storm sewer systems (MS4s), the CVRWQCB, and the SWRCB. The Stakeholder Work Plan was based on the State Water Board CEC pilot study (Tadesse 2016) monitoring guidance that was directly informed by the result of a technical report prepared for the SWRCB by the Southern California Coastal Water Research Project (SCCWRP).

The CEC monitoring program concluded the implementation of the Stakeholder Work Plan, referred to as the "CEC Pilot Study", in FY 23-24. Each of the three years of the CEC Stakeholder Work Plan had a Data Report with a data quality assessment included. Appropriate data have been loaded to CEDEN; data not appropriate to load to CEDEN are available on the DRMP website.

The next step for CECs is to incorporate the information gained into an interpretive report and begin long-term planning. Planning for a CEC Interpretive Report will take place in FY 24-25.

Long Term Planning

Development of an interpretive report is the first step of the long-term planning process for CECs. The CEC TAC will work with the Steering Committee to determine the scope and details of a CEC Interpretive Report. The Steering Committee will provide direction on the main audience, objectives, data to include, and management questions to address for the interpretive report. Additionally, the Steering Committee may decide to provide a report outline. It is anticipated that direction for the CEC Interpretive Report will be provided by the end of FY 24-25 and the report will be drafted and finalized in FY 25-26.

As part of the long-term planning process, there will be a joint Steering Committee and CEC TAC meeting to discuss goals and objectives for future monitoring and discuss how the interpretive report will help inform future monitoring hypotheses and study design. This will be an initial joint meeting to engage all stakeholders in the long-term planning process.

Budget

The FY 24-25 budget for CECs includes time for planning and preparing for TAC meetings, a joint Steering Committee and CEC TAC meeting, and planning for an interpretive report. The initial cost estimate for CECs is $35,000 (**Table 4**).

NUTRIENTS / HABS

In FY 24-25, the DRMP non-profit will begin implementing the Nutrient Multi-Year Study Plan (**Appendix II**). The Steering Committee provided direction to the Nutrient TAC to develop a Multi-Year Study Plan at a Joint Steering Committee and Nutrient TAC meeting held on March 16, 2023. The Nutrient Mult-Year Study Plan includes three focus areas with funds allocated to each. During FY 24-25, modeling as part of Focus Area #1 will begin and development of a QAPP for the Focus Area #2 study design will occur. Modeling progress as part of Focus Area #1 will include progress updates with the Nutrient TAC throughout the year and a summary of work performed in the FY 24-25 Annual Report due in the following FY (February 1, 2026). In addition, the DRMP non-profit will work with other monitoring groups to evaluate projects that meet the objectives of Focus Area #3 to determine if the DRMP non-profit should contribute funds. If a project under Focus Area #3 is identified and funded, the FY 24-25 Workplan will be amended to include the study design, deliverables, and project specific budget. Any deviations or amendments to the Workplan and/or QAPP(s) will be documented and reported to the CVRWQCB as required in the Resolution. The project specific budget will include costs for completing quality assurance documentation (e.g, a QAPP) as required by the Data Management Plan. Details and timelines for these specific requirements will be included in the study design.

The DRMP developed a Multi-Year Nutrient Study Plan to guide long-term studies of the effects of nutrients on the ecology of the Delta. After discussion between the DRMP Steering Committee and the Nutrient TAC, three primary questions (also referred to as focus areas) were developed to guide the development of the Study Plan.

1. Following a reduction in nutrient loading from different point and nonpoint sources, what ranges of nutrient concentrations are expected to occur throughout the Delta, and how might they be affected by climate change, wetland restorations, and water management and routing?
2. What are the thresholds for nutrients (nitrogen (N) and phosphorus (P) and their ratios) that can limit Harmful Algal Bloom (HAB) biomass and cyanotoxin accumulation to safe levels, limit the abundance and distribution of nuisance macrophytes, and support robust growth of desirable phytoplankton and macrophytes throughout the Delta?
3. How are the characteristics of harmful cyanobacteria blooms and cyanotoxins in the Delta changing (e.g., species, magnitude, geographic extent, and timing) and what factors contribute to these changes?

The Multi-Year Nutrient Study Plan addresses these three questions or focus areas using a combination of modeling, field/experimental studies, and monitoring. It is not the objective of this Multi-Year Nutrient Study Plan to completely address all three focus area

questions. The intent of the studies included in this Study Plan is to begin a multi-year process that begins to address these questions with a hypothesis driven approach and prioritizing data gaps identified by the Steering Committee and Nutrient TAC.

Study Design

Management and Assessment Questions

The DRMP has agreed upon a set of management questions that reflect specific concerns about multiple aspects of the Delta and the impacts of human activities.

Since each of the management questions is quite broad, it is important to first identify a set of more specific "assessment questions" to guide a future monitoring or special study design. **Table 9** lists the management questions that were developed by the Steering Committee and the assessment questions that were developed by the Nutrient Subcommittee in 2018. When the DRMP Steering Committee prioritized planning for a multi-year study plan, these questions were used as a starting point for the three primary questions or focus areas.

Biogeochemical (BGC) modeling efforts will be used to answer the following question by conducting a series of model scenarios based on hypothesis testing to address the following Focus Area #1 question:

- Following a reduction in nutrient loading, what ranges of nutrient concentrations are expected to occur throughout the Delta, and how might they be affected by climate change, wetland restorations, and water management and routing?

In pursuing the above question, the study targets a number of questions the DRMP has identified as priorities (**Table 9)**, including Management Questions 2a, 2b, 2c, 3a, and 3b; and Assessment Questions 2.1.A-F and 3.1.

Table 9. DRMP management and assessment questions for nutrients.

TYPE	CORE MANAGEMENT QUESTIONS	NUTRIENT ASSESSMENT QUESTIONS
1. Status & Trends	Is there a problem or are there signs of a problem? 1a. Is water quality currently, or trending towards, adversely affecting beneficial uses of the Delta? 1b. Which constituents may be impairing beneficial uses in subregions of the Delta? 1c. Are trends similar or different across different subregions of the Delta?	[1.1] How do concentrations of nutrients (and nutrient-associated parameters) vary spatially and temporally? A. Are trends similar or different across subregions of the Delta? B. How are ambient levels and trends affected by variability in climate, hydrology, and ecology? C. Are there important data gaps associated with particular water bodies within the Delta subregions?

Type	Core Management Questions	Nutrient Assessment Questions
2. Sources, Pathways, Loadings & Processes	Which sources and processes are most important to understand and quantify? 2a. Which sources, pathways, loadings, and processes (e.g., transformations, bioaccumulation) contribute most to identified problems? 2b. What is the magnitude of each source and/or pathway (e.g., municipal wastewater, atmospheric deposition)? 2c. What are the magnitudes of internal sources and/or pathways (e.g., benthic flux) and sinks in the Delta?	[2.1] 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? [2.2] 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?
3. Forecasting Scenarios	3a. How do ambient water quality conditions respond to different management scenarios. 3b. What constituent loads can the Delta assimilate without impairment of beneficial uses? 3c. What is the likelihood that the Delta will be water quality-impaired in the future?	[3.1] 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, water resource management changes, and climate change?

Type	Core Management Questions	Nutrient Assessment Questions
4. Effectiveness Tracking	4a. Are water quality conditions improving as a result of management actions such that beneficial uses will be met? 4b. Are loadings changing as a result of management actions?	[4.1] 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?

Hypothesis – Focus Area #1

The Nutrient TAC will work with the Modeling Team to identify the most relevant set of load reduction scenarios to simulate. Approaches for establishing reduction scenarios include i) identifying a set of percentage reductions to dissolved inorganic nitrogen (DIN) and total nitrogen (TN) from source areas and determine the relative impact on DIN, TN, and chlorophyll a (chl-a) concentrations at locations in the Delta, and/or ii) establishing target DIN/TN concentrations at specific locations in the Delta and determining the percentage reduction and the location of the reductions needed to achieve the target concentrations.

Below are four initial hypotheses (null and alternative) that can be used to build model scenarios for testing the hypotheses. The hypotheses use the terminology of substantial change as a way to test the hypotheses; the Nutrient TAC will work with the modelers to define substantial (e.g., larger than background variation) as modeling is implemented and include this definition in the interpretation and reporting of model results.

BGC Model Hypothesis 1

H_0: Reducing the nonpoint and point source inputs of N from the Sacramento River to the Delta will have no effect on the concentration of DIN, TN, P, or chl-a at any targeted location or region in the Delta at any time during the year.

H_1: At least one targeted location/region in the Delta will experience a substantial change in the concentration of DIN, TN, P, or chl-a after reductions from point and nonpoint sources in the Sacramento Valley at some time during the year.

BGC Model Hypothesis 2

H_0: Reducing the nonpoint and point source inputs of N from within the Delta will have no effect on the concentration of DIN, TN, P, or chl-a at any targeted location or region in the Delta at any time during the year.

H_1: At least one targeted location in the Delta will experience a substantial change in the concentration of DIN, TN, P, or chl-a for a sustained period (e.g., days to weeks) after reductions from point and nonpoint sources in the Delta at some time during the year.

BGC Model Hypothesis 3

H_0: Reducing the nonpoint and point source inputs of N from the San Joaquin Valley will have no effect on the concentration of DIN, TN, P, or chl-a at any targeted location or region in the Delta at any time during the year.

H_1: At least one targeted location in the Delta will experience a substantial change in the concentration of DIN, TN, P, or chl-a for a sustained period (e.g., days to weeks) after

reductions from point and nonpoint sources in the San Joaquin Valley at some time during the year.

BGC Model Hypothesis 4

H_0: Reducing the nonpoint and point source inputs of N simultaneously from the Sacramento River, the San Joaquin River, and internal Delta sources will have no effect on the concentration of DIN, TN, P, or chl-a at any targeted location or region in the Delta at any time during the year.

H_1: At least one targeted location/region in the Delta will experience a substantial change in the concentration of DIN, TN, P, or chl-a for a sustained period (e.g., days to weeks) after N reductions simultaneously from the Sacramento River, the San Joaquin River, and internal Delta sources at some time during the year.

To test Hypotheses 1-4, the northern San Francisco Estuary Biogeochemical Model (nSFE-BGCM) will be used to simulate a series of load reduction scenarios (**Table 10**) during two proposed water years, WY2016 and WY2022. In the central and south Delta, nutrient concentrations in the winter and spring can be higher than those in the summer and fall (Beck et al. 2018, Jabusch et al 2018). However, HABs typically occur in the summer through fall (Berg and Sutula 2015), so DIN reduction modeling scenarios were developed from IEP Environmental Monitoring Program (EMP) data collected July through October in 2022. The US EPA has recommended that states consider criteria of total N of 0.31 mg/L and total P of 0.047 mg/L for EcoRegion 1 which includes parts of Washington, Oregon, and California (EPA 2001). These concentrations are not directly related to the Delta but provide context for concentrations being evaluated for nutrient criteria in the Delta.

Internal nutrient concentrations were calculated as the difference in average DIN between Buckley Cove (1.1 mg/L-N) and Vernalis (0.36 mg/L-N) = 0.74 mg/L-N. The first two modeling scenarios reduce DIN from all sources to yield reduced concentrations (0.1 mg/L-N and 0.2 mg/L-N) that match those proposed in the DRMP N reduction bioassay study and reflect lowest observed concentrations detectable during the fall in the system (see section 3.3.2 in **Appendix II** of the Nutrient Multi-Year Study Plan for more specifics). Scenarios 3 to 6 test percent DIN loading reductions to understand the importance of individual sources vs. a standard 20% reduction from all sources. The final scenario(s) evaluates nutrient concentrations based on the feasible limit of reductions in N loading from individual loading sources such as POTWs, municipal stormwater, and agriculture. A set of feasible N load reduction scenarios will be developed by Nutrient TAC and Steering Committee members with assistance from SFEI-ASC.

Two potential phosphorus reduction scenarios may be added to the study. The Nutrient TAC will work with the modelers to identify scenario details and related hypotheses.

Table 10. Potential BGC modeling scenarios

DIN CONCENTRATIONS IN 2022 (JULY-OCT)	DIN (MG/L-N)	REDUCTION
Sacramento River (Hood)	0.26	0%
San Joaquin River (Vernalis)	0.36	0%
Internal sources	0.74	0%

Model Scenario 1	DIN (mg/L-N)	Reduction
Sacramento River (Hood)	0.1	61%
San Joaquin River (Vernalis)	0.1	72%
Internal sources	0.1	86%

Model Scenario 2	DIN (mg/L-N)	Reduction
Sacramento River (Hood)	0.2	22%
San Joaquin River (Vernalis)	0.2	45%
Internal sources	0.2	73%

Model Scenario 3	DIN (mg/L-N)	Reduction
Sacramento River (Hood)	0.13	50%
San Joaquin River (Vernalis)	0.36	0%
Internal sources	0.74	0%

Model Scenario 4	DIN (mg/L-N)	Reduction
Sacramento River (Hood)	0.26	0%
San Joaquin River (Vernalis)	0.18	50%
Internal sources	0.74	0%

Model Scenario 5	DIN (mg/L-N)	Reduction
Sacramento River (Hood)	0.26	0%
San Joaquin River (Vernalis)	0.36	0%
Internal sources	0.37	50%

Model Scenario 6	DIN (mg/L-N)	Reduction
Sacramento River (Hood)	0.21	20%
San Joaquin River (Vernalis)	0.29	20%
Internal sources	0.59	20%

Model Scenario 7 (or more)	DIN (mg/L-N)	Reduction
Sacramento River (Hood)	Lowest feasible	TBD
San Joaquin River (Vernalis)	Lowest feasible	TBD

DIN CONCENTRATIONS IN 2022 (JULY-OCT)	DIN (MG/L-N)	REDUCTION
Internal sources	Lowest feasible	TBD

Monitoring – Focus Area #2 and #3

Monitoring for Focus Area #2 will begin in FY 25-26 based on the details outlined in the Bioassay Study QAPP that will be developed in FY 24-25. The study design for Focus Area #2 will be detailed in the Bioassay Study QAPP and follow the Nutrient Multi-Year Study Plan for Focus Area #2 (**Appendix II**).

The DRMP is in the process of identifying potential studies that meet the objectives of Focus Area #3. The FY 24-25 Workplan will be amended to include specifics for any studies funded as part of Focus Area #3 once they are approved by the DRMP BOD.

Schedule of Deliverables

The overall schedule of deliverables for the FY 24-25 Nutrient monitoring is defined in **Table 11**, and outlined below.

Table 11. Schedule of deliverables for Nutrient monitoring.

DELIVERABLE	DELIVERABLE DUE DATE	ACTIVITY PERIOD OR TRIGGER	FREQUENCY
Resolution Deliverables			
FY 24-25 Nutrient Study Design – Focus Area #1	May 1, 2024	July 1, 2024 – June 30, 2025	Per fiscal year
Bioassay Study QAPP – Focus Area #2	May 1, 2025	July 1, 2025 – June 30, 2026 (two-year study)	Amended as needed
Final Nutrient Budget	June 30, 2024	July 1, 2024 – June 30, 2025	Per fiscal year

QAPP

QAPPs for the upcoming FY must be submitted to the CVRWQCB by May 1 of each year, per the requirements outlined in R5-2021-0054. The QAPP must:

- Meet guidance and requirements from both the Water Boards and EPA,
- Include a documentation process for deviations and an assessment of corrective action process, and

- Be reviewed and approved by the State Water Board Quality Assurance Officer or the Central Valley Water Board's Quality Assurance Officer before project implementation can occur.

A QAPP specific to Focus Area #2 of the Nutrient Multi-Year Study Plan will be developed in coordination with the Nutrient TAC during FY 24-25 for monitoring to begin in FY 25-26.

Data Management & Data Deliverables

Modeling work associated with Focus Area #1 is being conducted with open-source/public-domain tools, and all data, model output, and scripts.

Reporting

For Focus Area #1, the primary deliverable will be a Technical Report which is expected in FY 25-26.

Budget

The high-level draft budget for tasks associated with the DRMP Nutrient Focus Area #1 modeling project, the QAPP development for Focus Area #2, and funds allocated for potential studies under Focus Area #3 is provided in (**Table 4**). The Nutrient budget is estimated at $433,290. All budgets provided with this Workplan are considered preliminary, with a finalized budget to be submitted prior to the beginning of the FY by June 30, 2024; it is anticipated that the budget amounts will vary by approximately 15% from actuals.

MERCURY

The Steering Committee decided at its March 14, 2022, Steering Committee meeting to begin mercury long-term planning in 2023. In December 2022, the Steering Committee created a Mercury Report Subgroup to outline the parameters for a mercury interpretive report. The Mercury Report will have a primary audience of the CVRWQCB and DRMP regulated entities with an objective to assess trends in fish tissue and aqueous methylmercury concentrations and evaluate other factors impacting trends in methylmercury concentrations. Data utilized in the report will include data generated from 2016 – 2022 and will evaluate trends in aqueous and fish tissue mercury concentrations since 2000 in the context of water year type and subarea. The timeline for developing the Mercury Report is contingent on a SWRCB contract amendment with the SFEI-ASC; SFEI-ASC will be the entity developing the report and the CVRWQCB has allocated SWAMP funds from SWRCB to be used to fund this work. The contract amendment was executed on April 30, 2024. The SFEI-ASC contract includes a timeline that is relative to the execution date. The DRMP non-profit will develop a specific timeline in coordination with SFEI-ASC to ensure that deliverables are completed within the timeframes outlined in the contract language. This will require coordination between schedules of CVRWQCB, SFEI-ASC, Steering Committee, and Mercury TAC members.

Mercury TAC meetings and Steering Committee meetings will be scheduled to review the deliverables associated with the Mercury Report (a compilation of mercury results and metadata, presentations to the Mercury TAC, a draft Factsheet and Mercury Report, and a final Factsheet and Mercury Report). Time is allocated for planning for a Mercury Symposium and scheduling meetings with the Mercury TAC and Steering Committee to develop a long-term plan for mercury monitoring.

Study Design

The DRMP mercury monitoring study was completed in FY 22-23.

Final Data in CEDEN

The DRMP mercury data was finalized and confirmed to be available on CEDEN on October 2, 2023. There are no expected data deliverables in FY 24-25.

Data Report and QC Report

The Mercury Report will be developed by SFEI-ASC and will follow the Mercury Report Template that was developed by the Mercury Report Subgroup. The Mercury Report will integrate all DRMP mercury data and include an assessment of precision, accuracy, and

completeness of the data being evaluated including results through FY 22-23. There will not be a separate Data Report or QC Report developed.

FY Annual Report

The DRMP Annual Report for the previous FY is due on February 1 of each year. As monitoring is paused, there will not be any new data to address in the FY Annual Report due February 1, 2025.

Long Term Planning

The mercury long term planning strategy will be implemented similarly to the nutrient long-term monitoring strategy. The DRMP will refine the strategy based on what was learned with implementing the nutrient long term planning process and cater the process to the specifics associated with DRMP mercury monitoring priorities and other policies including the Mercury TMDL.

Long Term Planning & Milestones

The long-term planning for mercury in FY 24-25 includes efforts to identify the initial focus and determine what is known. There are two reports that have been identified as milestones for these first two steps of the long-term planning process: the Mercury Report to be developed by SFEI-ASC and the Delta Mercury Control Program (DMCP) Review Draft Staff Report. The goal of the Mercury Report is to help inform the DRMP stakeholders on the trends of aqueous and fish methylmercury concentrations in the Delta. A draft of the Mercury Report is anticipated seven months after the contract execution date of the contract with SFEI-ASC. The CVRWQCB is in the process of developing a draft staff report on the DMCP and will submit it for scientific peer review concurrently with releasing it to tribes and the public. Phase 2 of the DMCP began in late 2022 as required by the Methylmercury TMDL. Both the DMCP Review Draft Staff Report and the DRMP Mercury Report will inform the mercury monitoring priorities of the DRMP. Therefore, the timeline for the mercury long-term planning and multi-year study design has been developed to allow for these reports to be available during initial discussions with the Steering Committee regarding the initial focus and determining what is known (**Table 12**).

The Steering Committee and Mercury TAC will meet to discuss the initial focus of the mercury long-term planning and determine the objectives of the Mercury Symposium (**Table 12). Figure 5** includes additional activities anticipated as part of the long-term planning process; these are tentative timelines and may be adjusted per direction from the Steering Committee. In addition, the Mercury Report will be important for understanding trends of aqueous and fish methylmercury concentrations in the Delta and

informative for determining priorities for future mercury monitoring. There may be delays in the mercury planning process if the timing of the Mercury Report is altered.

Table 12. Mercury long-term planning activities and milestones (tentative).

General Planning Steps	FY 24-25 Activities	FY 24 -25 Milestones	Milestone Time Period
Identify the focus	Review mercury management and assessment questions	Identify Focus of Mercury Long-Term Planning Objectives for Mercury Symposium	October 2024 January 2025
Determine what is known	Review DMCP Review Draft Staff Report Develop Mercury Report Mercury Symposium Planning	DMCP Review Draft Staff Report Draft Mercury Report Mercury Symposium Agenda	TBD March 2025 June/July 2025
Prioritize Management & Assessment Questions	Not Applicable	Not Applicable	FY 25-26
Decide how much to budget	Not Applicable	Not Applicable	FY 25-26
Provide direction to the TAC	Not Applicable	Not Applicable	FY 25-26
Develop a multi-year study design	Not Applicable	Not Applicable	FY 26-27

Long Term Planning Schedule

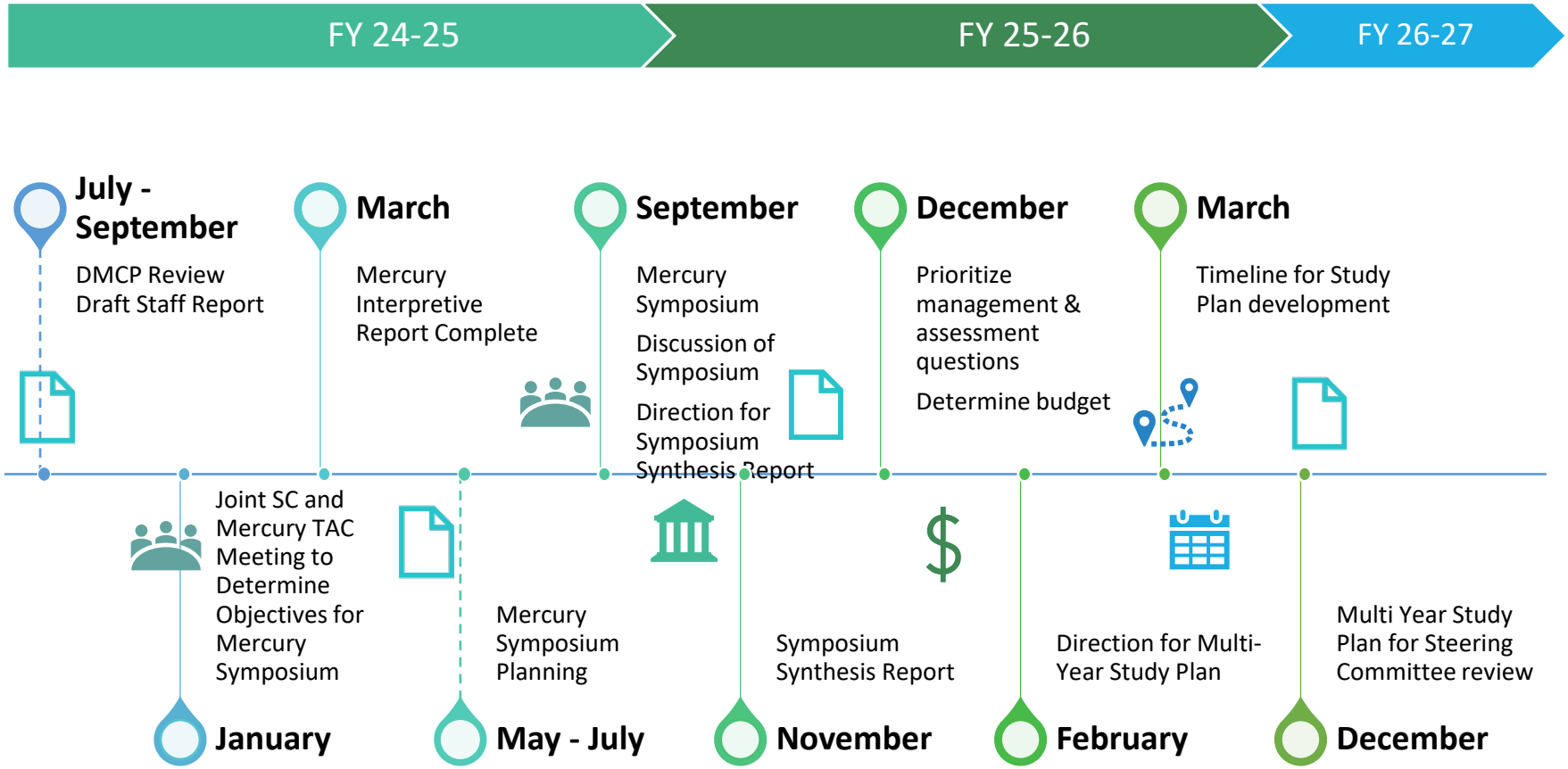
The DRMP will be working on mercury long-term planning during FY 24-25 with the goal of having direction to the Mercury TAC to develop a study plan for Steering Committee review in January 2026 (**Figure 5**). The DRMP will begin planning for mercury using lessons learned from the nutrient long term planning strategy. Joint Steering Committee and Mercury TAC meetings will be scheduled throughout FY 24-25 to determine the objectives of the Mercury Symposium (planned for September 2025). Future milestones for FY 24-25 include the DMCP Review Draft Staff Report and the Mercury Report. Both reports will be used to inform the objectives and priorities of the Mercury Symposium; a draft Mercury Symposium agenda is planned for summer 2025 (June or July) (**Figure 5**).

Budget

The FY 24-25 budget for mercury is estimated at $65,000 (**Table 4**). In-kind funds from CVRWQCB SWAMP funds will be used for the development of the Mercury Report; these

are not captured in the FY 24-25 budget but will be included in the final budget to be submitted on June 30, 2024.

Figure 5. Steering Committee and Mercury TAC long-term planning activities (FY 24-25, FY 25-26, and FY 26-27). These are tentative timelines and milestones that will be adjusted as necessary to reflect direction from the Steering Committee.



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Appendix I – Current Use Pesticide Study Design

Delta RMP Special Study Description for FY18/19 Workplan

Aquatic Toxicity and Current Use Pesticides Monitoring Using a Rotating Basin Probabilistic Design, Water Year 2019

Summary

The Delta RMP Steering Committee elected to fund the hybrid option (Option B) described in the monitoring proposal on the following pages. Funding was approved for Year 1 of the 5-year study.

Project Cost to the Delta RMP:	**$211,578**
In-Kind Contributions:	
State Water Resources Control Board, Surface Water Ambient Monitoring Program (SWAMP)	$328,040
U.S. Geological Survey	$13,704
US Army Corps of Engineers	$50,000
Total In-Kind Contributions	**$391,744**

Planned Deliverables:

- Amended QAPP, including detailed sampling and analysis plan
  - Draft Sept 2018
  - Final Oct 2018
- Year- end monitoring reports by USGS and AHPL
  - Draft: Nov 30, 2019
  - Final: Mar 31, 2020
- QA Officer Memo, dataset
  - Draft memo and dataset: Mar 31, 2020
  - Final memo and data uploaded to CEDEN: June 30, 2020

Scope Amendment

In approving the proposed workplan for pesticides and toxicity monitoring, the Steering Committee (at its meeting on July 17, 2018), specified that certain elements should be addressed as the program finalizes the Quality Assurance Program Plan prior to beginning monitoring. These required elements are described in a memo (dated July 17, 2018) by Regional San's SC member describing topics they wished to see addressed during QAPP development. The text of the memo is included below as an amendment to the scope of work.

Memo

To: Delta RMP Steering Committee

From: Rebecca Franklin, SC member, Regional San

Date: July 17, 2018

Re: QAPP topics for inclusion in: Aquatic Toxicity and Current Use Pesticides Monitoring Using a Rotating Basin Probabilistic Design, Water Year 2019 Work Group Discussions (Proposal; dated 7/3/18 for Delta RMP SC review)

The current draft Delta RMP Current Use Pesticide 2018-19 Monitoring Proposal identifies three topics that are not sufficiently described in the monitoring plan and will be discussed during QAPP development (Section: QAPP Modifications Needed; pages 33-34). Each of the three information gaps identified in the monitoring proposal are important and each will require effort to define and describe. Additional topics also need to be addressed in the QAPP so that data evaluation procedures are clear. These additional topics are listed below in blue as an addition to the three topics currently outlined on page 34 of the draft CUP Monitoring Proposal.

T**opics to be addressed during QAPP development:**

1) Sample location selection and pool of possible locations
2) Additional EC-based control and data interpretation protocols for Ceriodaphnia dubia toxicity tests
    a) Criteria for comparing samples with secondary controls – The Delta RMP should be able to develop program-specific data evaluation procedures to understand and agree on how data evaluation informs the program's goals.
    b) Criteria for evaluating data when secondary controls do not meet test acceptability criteria (TAC) - Delta RMP should understand and agree on how data evaluation informs the program goals.
    c) Criteria for evaluating data when secondary controls are significantly different (or not significantly different) from primary controls – The Delta RMP should develop program-specific data evaluation procedures to understand and agree on how data evaluation informs the program goals.
3) Toxicity test methods for Chironomus dilutes
4) Test termination criteria for Ceriodaphnia dubia - Testing should be complete when 60% or more of surviving control females have produced three broods of offspring as defined in EPA (2002) guidance.
5) Reporting and interpreting reference toxicity data - The reference toxicity warning and control limits should be calculated in accordance with EPA (2002) guidance.

6) Define a weight-of-evidence process to trigger retesting of toxicity samples or invalidate test results - Rather than developing hard rules, it may be best for the Delta RMP to identify triggers for the lab to notify the TAC (toxicity work group) when there are indications of potential concerns. Together, the lab and TAC can determine a path forward, rather than the lab making the decision alone. This is the same as the current approach used for go/no-go decisions for toxicity identification evaluations (TIEs).

Revised Detailed Budget

The project budget has been revised to take into account a $50,000 in-kind contribution by the US Army Corps of Engineers to directly fund work by the USGS. However, this contribution has only offset $44,356 in expenses by the Delta RMP due to federal contracting rules. The proposed workplan included a planned $19,344 cost share by the USGS. Under the revised budget, the USGS cost share will be $13,700, or $5,644 lower than we had originally anticipated. A more detailed explanation follows.

The Joint Funding Agreement between ASC and the USGS for pesticides monitoring includes an in-kind contribution on the part of USGS, in the form of a 10% federal cost share on labor and travel expenses. However, when USGS receives funding from another federal agency, there is no cost share available. In addition, the overhead rate on the Corps funds is a fraction of a percent higher than for USGS' funding agreement with ASC. As a result of these changes, the USGS Pesticide Fate Research Group (PFRG) gave us a revised budget for FY18/19 pesticide sampling. The total project cost is the same, however, the USGS cost share is lower than before:

	Old cost estimate	**Revised amount in joint funding agreement**
Delta RMP funding (via ASC)	$199,873	$155,517
USGS cost share	*$19,344*	*$13,700*
Army Corps contribution	-	$50,000
Total Project Cost	**$219,217**	**$219,217**

As noted, the total cost of the pesticides monitoring project is the same. The revised funding arrangement will provide the exact same amount of personnel hours, supplies, analytical costs, etc. as were originally planned. However, while the Delta RMP is **gaining** a $50,000 in-kind contribution from the Corps, in a sense we are **losing** an anticipated $5,644 in-kind contribution from the USGS. This can be thought of as a "cost of doing business." We still benefit greatly from this new indirect contribution to the program by the Army Corps.

A revised budget showing planned expenses is shown in the table on the following page.

Table Revised budget for approved FY18/19 Delta RMP monitoring of current-use pesticides and toxicity

(Revised budget to account for $50,000 direct contribution by the US Army Corps of Engineers.)

Contractor	Item	Number	Unit Cost	Total Cost
USGS	Field sample collection and lab analysis			
	Project oversight and reporting	1		$19,350
	Sample collection, labor	48		$19,673
	Sample collection, supplies	48		$7,445
	GC/MS Analyses	48		$45,233
	LC/MS/MS Analyses	48		$59,804
	NWQL Analyses	48		$11,025
	Reports	1		$6,691
	USGS Cost share			–$13,704
				$155,517
AHPL	Toxicity Reporting			
	Provisional Data			
	A) SWAMP Toxicity Transformers (no charge)	6	0	$0
	B) Bench Sheet Copies	6	$500	$3,000
	C) Reference Toxicant Control Charts	6	$875	$5,250
	D) Corrective Actions Table	6	$100	$600
	Attend meetings and present preliminary results	4	$800	$3,200
	Indirect costs (University mandated 25%)			$3,013
				$15,063
ASC	Data Management and Quality Assurance	(hours)	(rate)	
	DS Project Management and Coordination	70	$115	$6,900
	Data Receipt and Data Management	193	$105	$16,485
	Data Validation	88	$152	$7,904
	Data Storage and Release	46	$100	$4,600
	Toxicity data QA Summary	10	$152	$1,520
	10% contingency			$3,589
				$40,998
Total Cost to the Delta RMP……				$211,578

Revision Date: 7/3/2018

Delta RMP Special Study Proposal

Aquatic Toxicity and Current Use Pesticides Monitoring Using a Rotating Basin Probabilistic Design, Water Year 2019

Executive Summary

Estimated Cost:

Delta RMP Funds: $248,352 or $255,933 (depending on monitoring design chosen)

SWAMP Funds (in-kind contribution): $311,120

USGS In-kind contribution: $18,022

Oversight Group: Delta RMP Pesticides Subcommittee

Proposed by: SFEI-ASC, USGS

This proposal requests funding from the Delta RMP Steering Committee for Year 1 of a 4- to 5-year study of current-use pesticides and aquatic toxicity in the Sacramento-San Joaquin Delta. Two options are proposed: 1) a rotating basin monitoring design and 2) a hybrid design that adds monitoring at 2 fixed sites selected based on previous monitoring history. Both options include a statistical survey of subregions of the Delta and include analysis of the same constituents. Year 1 monitoring would begin in October 2018 and continue through September 2019 (2019 Water Year); years 2–4 would continue to be based on a water year. A key to the success of a status and trends monitoring program is that it be sustained over a long time. This proposal describes a 3 to 4 year monitoring program covering the Delta. During year 4, an interpretive report is planned, from which lessons may be drawn to adaptively manage and improve future monitoring.

Under this "rotating basin" monitoring design, the Delta is split into 6 subregions (established by prior analytical work by the Delta RMP) and 2 subregions are monitored each year. All 6 subregions are monitored over a 3-year cycle. Within each subregion, sampling points are randomly selected using the Generalized Random-Tessellation Stratified (GRTS) method. Subregions will be further stratified or divided into two water body types, representing 1) large river channels and open water lakes, and 2) smaller, shallower streams and sloughs. An advantage of this random or "probabilistic" design is that it allows the use of standard statistical methods to make inferences about Delta waterways as a whole, and to calculate the uncertainty for estimates in terms of confidence intervals. A key output of the study will be to determine what percent of Delta waterways exhibit toxicity to aquatic organisms or have concentrations of pesticides that exceed a water quality threshold or aquatic life benchmark.

During Year 1 of the study, 48 water samples will be collected by boat from 2 Delta subregions by field crews from the USGS California Water Science Center in Sacramento. Samples will be analyzed for a suite of 174 Current Use Pesticides (CUP) by the USGS Organic Chemistry Research Laboratory (OCRL). Compounds include fungicides, herbicides, insecticides, and their degradation products. In addition, crews will measure field parameters (water temperature, pH, conductivity, dissolved oxygen, turbidity), and document conditions at the field site. The USGS National Water Quality Laboratory will analyze samples for copper and ancillary parameters (total nitrogen, total particulate carbon, particulate organic carbon, and dissolved organic carbon).

The Aquatic Health Program Laboratory at UC Davis will analyze the toxicity of water samples for a suite of test organisms based on EPA (2002, 2000) and SWAMP (2008) methods:

- *Ceriodaphnia dubia*, a daphnid or water flea (survival, reproduction) – sensitive to organophosphate pesticides
- *Hyalella azteca*¸ an aquatic invertebrate (survival) – sensitive to pyrethroids
- *Selenastrum capricornutum* (also known as *Raphidocelis subcapitata*), a single-celled algae (growth) – sensitive to herbicides
- *Chironomus dilutus*, midge larvae (formerly *Chironomus tentans)* - sensitive to fipronil and more sensitive in chronic exposures to imidacloprid than *C. dubia.*
- *Pimephales promelas* (growth, survival) – chronic and acute effects on whole organism growth and survival

If toxicity exceeding a certain threshold is found in a water sample, we may instruct the lab to conduct follow-up investigations to determine the cause of toxicity, by performing a Toxicity Identification Evaluation (TIE). As in past years of monitoring, the discussion of whether to conduct a TIE will be triggered when significant toxicity is observed exceeding a pre-determined threshold, and decided upon by a subcommittee of stakeholders and technical experts.

A hybrid option (Option B) is included in this proposal. It reduces the number of probabilistic samples collected each year in order to continue monitoring at two fixed sites (Ulatis Creek at Brown Road and San Joaquin River at Buckley Cove) where aquatic toxicity has been observed in the past. This "hybrid" option includes the capability of detecting trends at these two sites over a longer period of continuous data and may provide additional opportunities to test for association s between pesticides and toxicity at these locations. However, under Option B we would collect fewer random samples in each subregion each year, requiring one extra year to obtain the number of samples estimated for the desired statistical power of the study.

This proposal was developed with the collaboration of the Delta RMP Pesticides Subcommittee and with the input of a consulting statistician. During the proposal development process, we sought to follow the recommendations of the 2016 Independent Panel Review (Raimondi et al. 2016). The key recommendations were to: (1) engage the services of a professional

environmental statistician, (2) consider a random sampling to expand beyond monitoring at fixed sites only and expand capability to draw inferences about more areas of the Delta, and (3) clearly define quantities to be observed or estimated from measurements. We have responded to the first two recommendations during the planning of this monitoring design by engaging an environmental statistician with experience in randomized sampling design to analyze the first two years of Delta RMP pesticides and toxicity data, perform power analyses, and advise us on the monitoring design. A report by our consulting statistician is provided in Appendix 3. We responded to (3) by following the EPA's Data Quality Objectives (DQO) process, stating *a priori* the information to be collected, the analytical approach to be used to evaluate data, and tolerable limits on decision errors. More information on this is provided in the section Data Analysis and Presentation on page 35.

There are tradeoffs involved in designing a monitoring program due to budget and practical constraints. The strengths and limitations of the proposed monitoring designs are listed in more detail on page 24.

The Steering Committee is being asked to commit funding for the first year of this 4-year plan. However, this proposal is not intended to lock us into an inflexible program. The program should be open to "adaptively manage" and make changes to the monitoring design. For instance, we have recently hired a contractor to analyze the data on pesticides and toxicity from the first two years of monitoring from 2015 to 2017. We may wish to make changes to the monitoring design based on the results of data analysis and interpretation, and as our knowledge and priorities change over time.

Contents

Tables

Figures

Acronyms and Abbreviations

AHPL	Aquatic Health Program Laboratory at UC Davis
ASC	Aquatic Science Center
BLM	biotic ligand model
BPA	Basin Plan Amendment
CAWSC	USGS California Water Science Center
CC	chief chemist
CDF	cumulative distribution function
CEDEN	California Environmental Data Exchange Network
CUP	Current Use Pesticides
CVRWQCB	Central Valley Regional Water Quality Control Board
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
DM	Database manager
DMS	Data management staff
DQO	Data quality objectives
DWR	Department of Water Resources
EC	electrical conductivity
EPA	Environmental Protection Agency
FY	Fiscal year (July 1 – June 30)
GC/MS	Gas chromatography/mass spectrometry
GIS	Geographic Information System
LC50	Lethal concentration (that kills 50% of the test organisms during the observation period)
GRTS	Generalized Random-Tessellation Stratified (sampling method)
LC/MS	Liquid chromatography/mass spectrometry
MDL	Method detection limit
MQO	Measurement quality objective
NA	Not applicable
NHD	National Hydrography Dataset
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NWIS	USGS National Water Information System
NWQL	National Water Quality Laboratory
NWQMC	National Water Quality Monitoring Council
OCRL	Organic Chemistry Research Laboratory
OFR	USGS Open File Report
OPP	USEPA Office of Pesticides Programs
PD	Project director
PTI	Pesticide Toxicity Index
QA	Quality Assurance
QAO	Quality assurance officer

QAPP	Quality Assurance Program Plan
QC	Quality control
RL	Reporting limit
RMA	Resource Management Associates
RMP	Regional Monitoring Program
S&T	Status & Trends
SFEI	San Francisco Estuary Institute
SJR	San Joaquin River
SWAMP	Surface Water Ambient Monitoring Program
TAC	Technical Advisory Committee
TIE	Toxicity identification evaluation
TMDL	Total Maximum Daily Load
USGS	U.S. Geological Survey

Background and Motivation

A better understanding of the effects of contaminants in the apparent decline of Delta ecosystems is a priority for regulators and stakeholders. Pesticide use in the Delta and Central Valley generally is one of the potential drivers of these effects. Constantly changing pesticide use presents a challenge for environmental scientists, resource managers, and policy makers trying to understand whether these contaminants are impacting aquatic systems and if so, which pesticides appear to be the biggest problem. Less than half of the pesticides currently applied in the Central Valley are routinely analyzed in monitoring studies and new pesticides are continually being registered for use. Therefore, baseline monitoring of ambient surface water for both aquatic toxicity and a broad list of current use pesticides is needed to understand whether current use pesticides contribute to observed toxicity in the Delta.

Regulatory Drivers

The proposed monitoring is intended to provide useful information to state and federal water quality regulators. Important regulatory drivers are described below.

Water Quality Control Plan for the Central Valley Basin (Basin Plan)

According to the State Water Board, the Basin Plan is "the Board's master water quality control planning document. It designates beneficial uses and water quality objectives for waters of the State, including surface waters and groundwater. It also includes programs of implementation to achieve water quality objectives."

The Central Valley Basin Plans states that, "in addition to numerical water quality objectives for toxicity, the Basin Plan contains a narrative water quality objective that requires all surface waters to '...be maintained free of toxic substances in concentrations that are toxic to or that produce detrimental physiological responses to human, plant, animal, and aquatic life.' To check for compliance with this objective, the Regional Water Board initiated a biotoxicity monitoring program to assess toxic impacts from point and nonpoint sources in FY 86-87" (CVRWQCB 2016, IV-32.08). The plan states that the Regional Board "will continue to impose toxicity testing monitoring requirements in National Pollutant Discharge Elimination System (NPDES) permits. The focus of ambient toxicity testing will continue to be the Delta and major tributaries." In other words, the Board is interested in verifying that there are "no toxics in toxic amounts" in waterways, and will continue to require aquatic toxicity testing as a key means of making this determination.

Organophosphate TMDL

In 2006, the Central Valley Water Board identified Delta waterways as impaired under the federal Clean Water Act Section 303(d) due to elevated concentrations of the organophosphate pesticides diazinon and chlorpyrifos and created a plan for their allowable discharge to the Delta referred to as the Total Maximum Daily Load (TMDL). Under this plan (CVRWQCB 2006), the board put in place a number of new rules and requirements. One of these stated that

new discharge permits (or WDRs) for runoff from fields and orchards draining to Delta Waterways must contain monitoring to meet a number of goals, the most relevant being:

- Determine attainment of the diazinon and chlorpyrifos water quality objectives and Load Allocations (additivity target).
- Determine whether alternatives to diazinon and chlorpyrifos are causing surface water quality impacts.
- Determine whether the discharge causes or contributes to a toxicity impairment due to additive or synergistic effects of multiple pollutants

In addition are nearly identical requirements for agricultural dischargers to the Sacramento and San Joaquin River under those TMDLs, respectively (Daniel McClure, personal communication).

Control Program for Diazinon and Chlorpyrifos

In 2014, the Central Valley Water Board published an additional amendment to the Basin Plan containing a control program for discharges of diazinon and chlorpyrifos (CVRWQCB 2014). The control plan created new pollution control requirements for waterways designated as supporting both warm and cold freshwater habitats. Under these requirements, agricultural, municipal stormwater, and wastewater dischargers in the Sac -SJR basins below major reservoirs are required to monitor in order to:

- Determine compliance with established water quality objectives applicable to diazinon and/or chlorpyrifos.
- Determine whether alternatives to diazinon and/or chlorpyrifos are being discharged at concentrations which have the potential to cause or contribute to exceedances of applicable water quality objectives.

In addition, agricultural dischargers are also required to monitor water quality in order to:

- Determine whether the discharge causes or contributes to a toxicity impairment due to additive or synergistic effects of multiple pollutants

Pyrethroids Basin Plan Amendment

In 2017, the regional board determined that more than a dozen waterways are impaired due to elevated concentrations of pyrethroid pesticides under Clean Water Act section 303(d). In response, the regional board adopted a Basin Plan Amendment (CVRWQCB 2017) which includes a pyrethroid pesticide control program for the Sacramento and San Joaquin River Basins. This Basin Plan Amendment was adopted by the regional board in June 2017 and it is expected to be fully approved by Stater Water Board, the Office of Administrative Law, and EPA by the end of 2018.

The amendment contains requirements for monitoring of pyrethroids, pyrethroid alternatives, and aquatic toxicity to the invertebrate *Hyalella* in discharges and/or receiving water in order to:

- Determine If the pyrethroid concentration goals are being attained through monitoring pyrethroids either the discharge (POTWs) or discharge or receiving water (MS4s and Ag dischargers)
- Determine whether pyrethroid pesticides are causing or contributing to exceedances of the narrative water quality objective for toxicity – through toxicity testing with Hyalella in water column of receiving waters (POTWs) or receiving waters water column and bed sediments (Ag and MS4s)

This monitoring must be completed two years from the effective date of the Basin Plan Amendment (BPA), expected December 2018. In the long term after that two-year period, dischargers will also be required to monitor for alternative insecticides that could be having water quality impacts.

Objectives of the Delta RMP Current Use Pesticides Monitoring Program

The overall objectives of the Delta Regional Monitoring Program's (Delta RMP's) Current Use Pesticide (CUP) monitoring program are to collect ambient surface water samples to answer the Program's Management and Assessment Questions (Table 1). The management and assessment questions are broad and the Delta is large, so addressing them will require a correspondingly large effort over the course of several years. The current proposed study design was developed to make the best use of available funding to answer the highest priority Management and Assessment Questions in an initial effort to characterize status and trends of pesticide concentrations and toxicity in the Delta.

Proposed Delta RMP CUP monitoring includes the collection of samples for aquatic toxicity testing and analyzing pesticide concentrations in water samples at multiple randomly-chosen sampling locations within subregions of the Delta. One or more of these areas would be assessed each year over the rotation cycle.

Applicable Management and Assessment Questions

Table 1 shows the Delta RMP Management and Assessment Questions that this study can help answer. The table also shows the objectives of the project and examples of how the information collected by the project can be used by water managers and water quality regulators.

Table 1 Delta Regional Monitoring Program Management and Assessment Questions

Relevant Management and Assessment Questions	Study Objectives	Example Information Application
Management Question Is water quality currently, or trending towards adversely affecting beneficial uses of the Delta? **Assessment Questions** S&T 1 - To what extent do current use pesticides contribute to observed toxicity in the Delta? S&T 1.1 - If samples are toxic, do detected pesticides explain the toxicity? S&T 1.2 - What are the spatial and temporal extent of lethal and sublethal aquatic and sediment toxicity observed in the Delta? S&T 2 - What are the spatial/temporal distributions of concentrations of currently used pesticides identified as possible causes of observed toxicity?	Collect water samples from a variety of locations across Delta subregions and analyze them for a broad suite of current use pesticides and for toxicity to aquatic organisms. Test whether pesticides in ambient water samples exceed aquatic life benchmarks. Test for the co-occurrence of pesticides and observed aquatic toxicity.	The Delta RMP can use this information to determine what percentage of Delta waters exhibit toxicity to aquatic organisms or have concentrations of pesticides that exceed thresholds. State water quality regulators may use this information to help evaluate if waterways should be classified as impaired under section 303(d) of the Clean Water Act. Regulators will be able to evaluate particular stream segments and parameters for signs of impairment, and, after several years of monitoring, may be able to track changes in impairment over time. If certain compounds are found to be having adverse impacts on aquatic environment that prevent the obtainment of beneficial uses, regulators may require the development of a management plan to prevent or mitigate pesticide contamination of waterways, or when warranted, adopt restrictions to further protect surface water from contamination.

Technical Approach

The Delta RMP will collect ambient surface water samples to be analyzed for pesticide concentrations and toxicity to established aquatic test species during multiple sampling events in the Sacramento-San Joaquin Delta from October 2018 to September 2019. The sampling program is based on a "rotating basin" monitoring design. This design is widely used to assess water bodies on a large geographic scale, repeated at regular intervals, while allowing resources to be focused on smaller geographic areas in any given year (NWQMC 2017). To implement the

design, the resource (in our case, Delta waterways) is divided into smaller geographic areas, referred to in this proposal as "subregions," and one or more of these areas is assessed each year over the rotation cycle. A rotation cycle is typically five or more years in length. In our case, we have divided the Delta into 6 subregions, and propose to monitor 2 subregions per year over a cycle of 3 or 4 years.

The rotating basin design allows us to assess pesticide and toxicity conditions in individual subregions of the Delta and in the Delta as a whole. The goal is to collect a minimum of 24 samples from 24 different locations in each subregion. This will allow for an assessment of the condition of the subregions over a 3- to 4-year period. Due to the constraints of the budget is it not possible to monitor all subregions within a single year. The proposed monitoring design allows for spatial representation and increases the statistical power to be able to detect differences among the subregions.

Further stratifying regions by water body type ensures that the entire Delta is adequately represented in the sampling design and that we can draw inferences about different types of water bodies, such as large fast-flowing river channels to smaller creeks and sloughs. More details on when and where we propose to monitor, and how the sampling locations will be chosen, are provided in the following section.

Adaptive management of the study design – The TAC has discussed whether it makes sense to commit to a multi-year project before the Pesticides and Toxicity interpretive report and analysis is complete. The TAC concluded that we should plan to "adaptively manage" and change our monitoring design based on the results of data gathering and interpretation. This is in fact, a key expected outcome of the interpretive report that is currently underway by Deltares; the scope of work for the study says that the analysis should "inform decisions about future monitoring for pesticides and toxicity in the Delta." Therefore, this proposal is not intended to lock us into an inflexible program. On the contrary, the program should remain open to make changes as our knowledge and priorities change over time.

Geographic and Temporal Scope

Delta Subregions

Samples will be collected from within the legal boundaries of the Delta. Previous efforts by both the Delta RMP and the Central Valley Regional Water Quality Control Board (CVRWQCB) have divided the Delta into roughly similar regions based on hydrology and management practices.

The Delta RMP has divided the Delta into 7 regions based on the contribution of source waters, as described in the 2018 report *Modeling to Assist Identification of Temporal and Spatial Data Gaps for Nutrient Monitoring* (Jabusch, Trowbridge, Heberger, and Guerin 2018). The CVRWQCB has also identified regions within the Legal Delta which it uses for the 303(d) list. The boundaries of the subregions are shown in Figure 1. Other monitoring efforts by the Delta RMP are utilizing

the subregions identified in Jabusch et al. 2018 (Delta RMP subregions) including the nutrient monitoring design; therefore, this proposal includes assessing the subregions defined by this effort rather than the 303(d) waterways. The rotating basin monitoring design includes monitoring 6 of the 7 subregions shown in Figure 1, excluding the Suisun Bay subregion, which is outside of the Legal Delta. (Note that the numbers on this figure are only placeholders and are not intended to dictate the order in which subregions are monitored.)

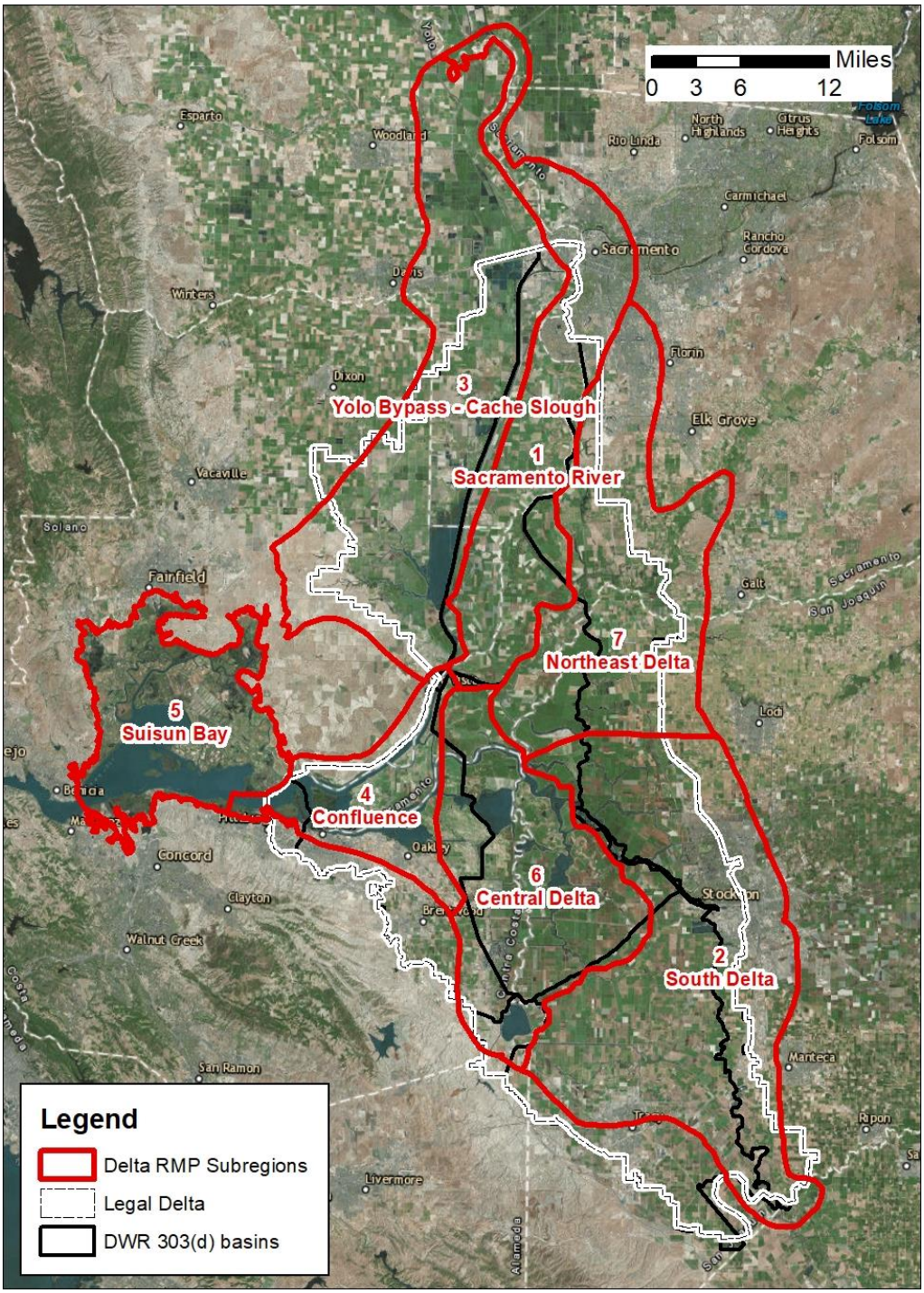

Figure 1 Map of Delta RMP subregions

Temporal Scope

In this proposal, we are requesting the first year of funding for a proposed monitoring design that will last for 4-5 years depending on the option selected. Year 1 of this effort would begin in October 2018 and end in September 2019.

We propose 6 sampling events during each water year. Samples will be collected over the course of 2 to 3 days at the following during times of interest (high agricultural and/or urban irrigation). Other sampling will occur during periods of high flow or following storms when pollutants are flushed from land surfaces into waterways via overland flow and drains. These events may include the fall "first flush," a second winter storm, and a period of high flow during spring runoff (snowmelt). Storm triggers are perhaps one of the most significant elements of stormwater sampling.

The specific timing will be planned in collaboration with the Delta RMP Pesticides Subcommittee and our science advisors and will be documented in detail in the Quality Assurance Program Plan (QAPP). This planning will occur from July to September of 2018, and the deliverable will be the detailed sampling and analysis plan included in the revised QAPP. Table 2 shows the sampling event triggers in the Delta RMP 2016 QAPP, which can be adapted or expanded upon for proposed monitoring program. Furthermore, special consideration may be needed in the event of a drought year. We will work with the Pesticides Subcommittee of the TAC to determine a course of action if the storm trigger conditions are not met by a particular date.

Table 2 Sampling event triggers in the Delta RMP 2016 QAPP, to be adapted for proposed monitoring program

Event	Sampling Triggers	Criteria	Notes
Wet			
1st seasonal flush (Water Year)	• Guidance plots project significant increase (~25%) in flow at four sites: lower Sacramento River, lower American River, San Joaquin River at Vernalis, and Mokelumne River.	• Preceded by ≥30 days dry weather (Sacramento R. stormwater criteria).	• *Sample events to hit all sites in 1 to 2 days.* • *When favorable storm conditions and runoff are forecast coordinate directly with AHP lab.* • *Alert AHPL 7 days in advance of upcoming storm for organism preparation and 2 days in advance about likelihood of adequate precipitation*
Significant winter storm	• Guidance plots project significant increase (~25%) at four sites: lower Sacramento River, lower American River,	• Minimum 2 weeks since 1st flush sample event.	• *If collect more than 1 event sample in the same month, do not sample in following month.*

Event	Sampling Triggers	Criteria	Notes
	San Joaquin River at Vernalis, and Mokelumne River.		• *When favorable storm conditions and runoff are forecast coordinate directly with AHP lab.* • *Alert AHPL 7 days in advance of upcoming storm for organism preparation and 2 days in advance about likelihood of adequate precipitation*
Dry			
Early Spring	• No triggers, can sample in a particular month (March-April).	• None	• *Meant to capture snowmelt but recognize significant impact of upstream dams.* • *Coordinate sampling schedule with AHP lab 7 or more days in advance.*
1st irrigation season sampling (late spring/ early summer)	• No triggers, can sample in a particular month (May-June).	• None	• *Meant to capture late winter and spring pesticide applications (post storms).* • *Account for planting/ pesticide application timing.* • *Coordinate sampling schedule with AHP lab 7 or more days in advance.*
2nd irrigation season sampling (late summer)	• No triggers, can sample a particular month (August).	• None	• *Meant to capture summer pesticide applications (rice, etc.).* • *Account for planting/ pesticide application timing.* • *Coordinate sampling schedule with AHP lab 7 or more days in advance.*

Monitoring Design

The two monitoring design options are presented in Table 3. The options involve collecting 48 ambient surface water samples under Option A, or 57 samples under Option B in Water Year 2019. Both monitoring design options would result in 30 samples from each of the 6 Delta subregions after 3 or 4 years of monitoring depending on the design selected. This will allow us to draw conclusions about water quality conditions across the Delta, as well as differences among the subregions.

There were several constraints on designing a pesticides monitoring program in 2018/19. Based on the available budget and laboratory costs, a maximum of around 60 samples can be collected and analyzed per year. Due to logistical constraints involving the toxicity testing laboratory, no

more than 15 samples can be analyzed for planned toxicity tests per sampling event. This number is based on the proposed suite of test organisms, and is based on available bench space, refrigeration, labor to initiate tests, etc.

Option A, the "rotating basin" probabilistic monitoring design, is excellent for the purpose of understanding the spatial extent of toxicity and pesticide concentrations. In this instance, the "basins" are our 6 Delta subregions. The rotating basin approach will allow for enough samples in each subregion to characterize the variance of concentrations in the subregion. A weakness of the approach is that subregions will be sampled in different years under different weather conditions. Therefore, comparisons between subregions will be compromised. With Option A, after 3 years, we will have collected data for the whole Delta. Further, we will have collected 30 samples in each of the subregions, which allows us to make statistical comparisons between subregions with a reasonably small margin of error.

Under **Option B**, the "hybrid" design, we keep the rotating basin design but reduce the number of probabilistic samples in order to continue monitoring 6 times per year at two fixed sites. Both sites, Ulatis Creek at Brown Road and San Joaquin River at Buckley Cove, are locations where aquatic toxicity has been observed by Delta RMP monitoring in the past (Figure 2). For more information on the first year of Delta RMP pesticides monitoring, see recent reports by the USGS (De Parsia et al. 2018) and SFEI-ASC (Jabusch, Trowbridge, Heberger, Orlando, et al. 2018). This "hybrid" option includes the capability of detecting temporal trends at these two sites and an analysis of the correlation between pesticide concentrations and toxicity. By sampling at the same location repeatedly, we are holding more factors constant, which may provide additional opportunities to test for the association between pesticides and toxicity at these locations. However, because of the limited budget, there is a trade-off of collecting fewer random samples in each subregion each year, which means it will take us an additional year to reach the desired 30 samples in each subregion.

Table 3 Rotating Probabilistic Monitoring Design Options with/without 1 fixed site per subregion

Option	**Option A (Rotating Basin)**	**Option B (Hybrid)**
Number of random sample locations per subregion	24	24 in first region 12 in second subregion
Subregions evaluated per year	2	2
Number of repeated sample locations per subregion	0	0
Number of fixed sites sampling locations	0	2
Sampling events per year	6	6
Total samples per year	48	36 samples at random locations; 12 samples at 2 fixed sites; 48 samples total
Time (years) to collect 30 samples in all subregions covering the Delta	2 regions evaluated in any given year. 3 years to cover whole Delta with desired margin of error.	One subregion fully evaluated (n = 24) in any given year. Second subregion will be sampled at half the intensity (n=12) with sampling to be continued over two subsequent years to reach the desired number of samples. Based on the lower intensity of sampling, it will take 4 years rather than 3 in order to obtain 24 samples in each subregion and cover the whole Delta with the desired margin of error.

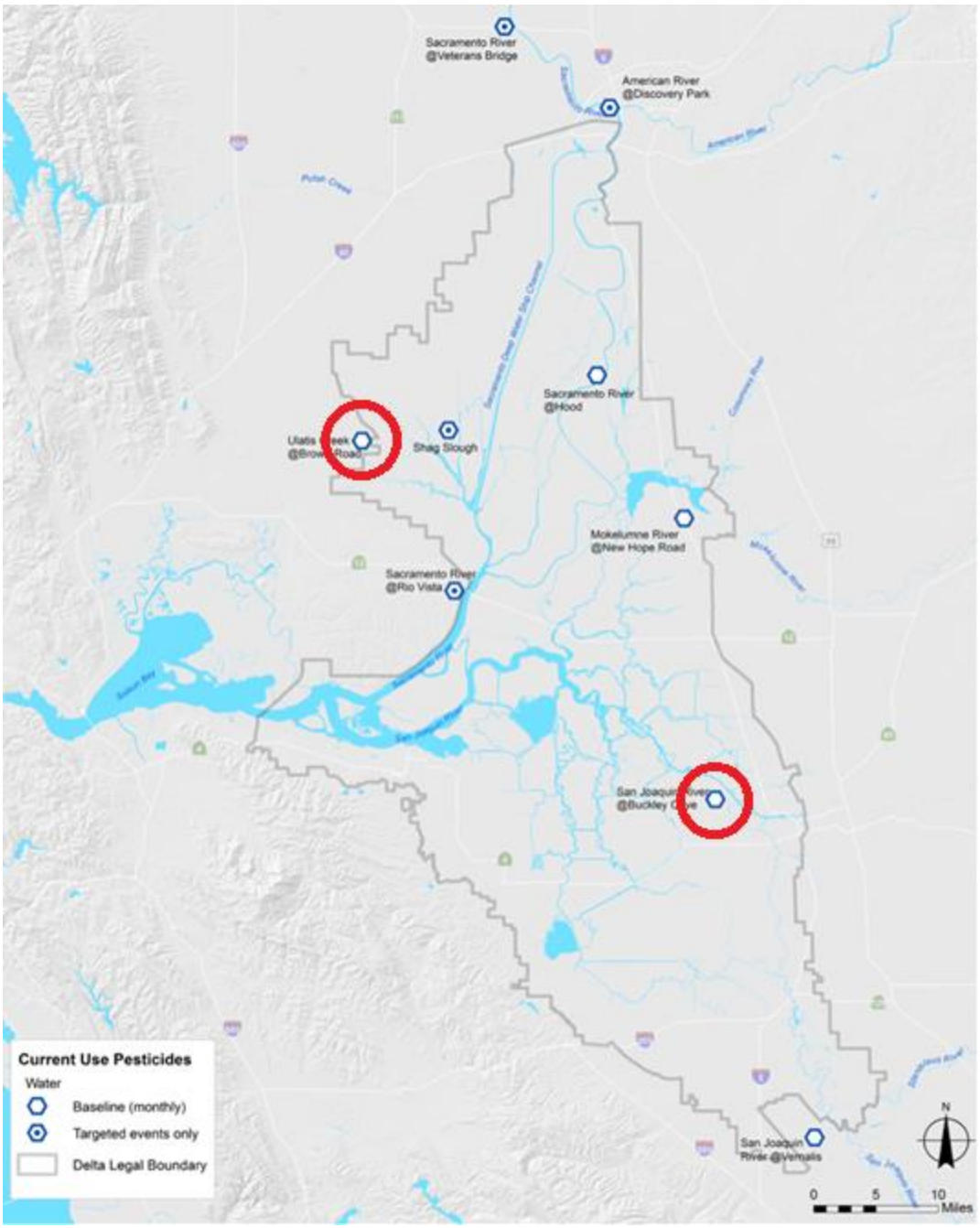

Figure 2 Map of Delta RMP integrator sites monitored 2015-2017, highlighting the two fixed stations where continued monitoring is proposed.

Table 4 shows a schedule of monitoring and deliverables for years 1 through 5 of the proposed monitoring designs. Under both options, sampling will be conducted in two out of six subregions each year. At the end of the 3-year cycle, we will analyze the collected data and determine whether it makes sense to continue the existing monitoring design or to reevaluate. Under Option B, we will continue monitoring into Year 4 in order to obtain our target of 30 samples in each of the 6 subregions.

In terms out reporting and deliverables, the Annual Field Sampling Report will document sample collection methods, target sampling sites, actual sampling sites, how many samples were collected, measurements made using field instruments, and any deviations from the QAPP for field sampling methods. After 3 years of data collection, we will have sampled the entire Delta. In Year 4, a Summary and Interpretive Report will be prepared. Under option B, this report would be prepared in Year 5. This interpretive report will answer the program's management and assessment questions to the extent possible. Namely, the analysis will determine whether, and to what extent, pesticides contribute to observed toxicity in the Delta. The report will show where and when pesticides and toxicity are observed, prioritize which pesticides should be monitored in the future, and describe gaps in current monitoring programs that limit answering other important management questions.

Table 4 Schedule of monitoring and deliverables for years 1 – 5 of the proposed monitoring designs.

Option A Rotating Basin Design only

	Year 1 FY18/19	**Year 2 FY19/20**	**Year 3 FY20/21**	**Year 4 FY 21/22**
Monitoring	24 samples each in Subregions 1, 2 (48 samples total)	24 samples each in Subregions 3, 4 (48 samples total)	24 samples each in Subregions 5, 6 (48 samples total)	
Reporting/ Deliverables	Annual Field Report	Annual Field Report	Annual Field Report	**Summary and Interpretive Report**

Option B Hybrid design: Rotating Basin + 2 fixed sites

	Year 1 FY18/19	**Year 2 FY19/20**	**Year 3 FY20/21**	**Year 4 FY 21/22**	**Year 5 FY22/23**
Monitoring	24 samples in subregion 1; 12 samples in subregion 2 *(50% of n = 24 needed, complete in year 2)* 6 samples at each of 2 fixed sites (48 samples total)	12 samples in subregion 2; 24 samples in subregion 3; 6 samples at each of 2 fixed sites (48 samples total)	24 samples in subregion 4; 12 samples in subregion 5 *(50% of n = 24 needed, complete in year 4)* 6 samples at each of 2 fixed sites (48 samples total)	12 samples in subregion 5; 24 samples in subregion 6; 6 samples at each of 2 fixed sites (48 samples total)	
Reporting/ Deliverables	Annual Field Report	Annual Field Report	Annual Field Report	Annual Field Report	**Summary and Interpretive Report**

Rotating Basin - Stratified Probabilistic Sampling Design

The main advantage to using a random sampling design is that it allows us to analyze the data with lower chances of errors. Statisticians have developed procedures for assessing the margin of error or confidence interval of estimates. It lets us draw conclusions about the population we are interested in (in this case, water quality in the Delta) and understand the uncertainty associated with these estimates. By further subdividing the Delta into subregions, it lets us assess whether there are differences in water quality within the Delta, i.e. between one subregion and others.

A pool of potential sample locations will be developed for sample collection. Sample collection locations will be randomly selected from within each of the subregions. Each subregion will be sampled at the frequency and number of samples described below at locations randomly selected from a pool of potential sampling locations. Sampling locations within a subregion will be selected using the Generalized Random-Tessellation Stratified (GRTS) method which identifies monitoring sites based on a stratified random selection process (NPS 2017). These locations will be selected and mapped during the development of the Quality Assurance Project Plan (QAPP) before the beginning of sampling. As is typical with randomized trials, we will "oversample," identifying more sampling locations than needed in the event where a location is inaccessible or impractical to reach.

Further Stratification by Hydrographic Features

Stratifying the population helps to ensure that the sampling program is representative of the Delta. Therefore, Delta subregions will be further stratified based on hydrography and water body characteristics. The random sampling algorithm (GRTS) is based on area, and is biased towards placing more sample points in larger water bodies, simply because of their larger surface area. Stratifying by hydrographic characteristics will help ensure that not all of the samples are in large channels and that we also collect samples from smaller sloughs and creeks. Our working hypothesis is that the smaller sloughs and creeks are often closer to sources and have less initial dilution, and less tidal flushing, and thus have the potential for higher pesticide concentrations. These smaller water bodies may also have high habitat value. The sample frame and strata will be planned in collaboration with the Delta RMP Pesticides Subcommittee and field sampling crews and outlined in the Quality Assurance Program Plan (QAPP) from July to September 2018.

In order to draw conclusions with reasonable statistical confidence, we would like to have approximately 30 samples within each of the strata. Therefore, in order to make conclusions about conditions in any of the strata such as "shallow water," we should collect at least 20% of the samples from within that strata. The Pesticide Subcommittee has had a preliminary discussion where it was suggested to split the number of samples would be 50% in open water (wide river channels and lakes) and 50% in shallow regions (sloughs, tributaries, and backwater reaches). Others have suggested that a ratio like 60/40 or 70/30 would be preferable. This ratio could be based on the available surface area of each water body type in a subregion, their linear

distance, or water volume. Such details will be worked out during the development of the detailed sampling plan and documented in the project QAPP.

One proposed method has been to split Delta waterways into "open water" vs. "shallow water." A preliminary stratification is shown in Figure 3. The potential sample frame in Figure 3 is based on a GIS datalayer developed by DWR for a similar purpose, to draw sampling points for benthos monitoring (Elizabeth Wells, DWR, personal communication). The data is a polygon layer representing Delta waterways. It was based on the National Hydrography Dataset (NHD) created by the USGS. DWR technicians refined the basic hydrology and also broke the overall areas into Bay-Large, Bay, River, River-Large, Lake, and Slough, in addition to Island (non-target) and identified other inaccessible areas. The data layer was further refined by removing areas that boat captains deemed inaccessible because of hazards or emergent vegetation that makes sampling impractical. To add depth to this datalayer, and SFEI geographer/GIS technician merged this with data that was compiled from a variety of sources previously for the study *A Delta Transformed* (Robinson et al. 2014). Here, we defined "deep water" as greater than as deeper than 2m (6.6 feet). We divided channels where appropriate, but did not cut channels longitudinally. Further refinement of the sample frame will be made in consultation with the USGS field crews, who may be using a smaller boat than the vessel used by DWR and may be able to reach shallower waters.

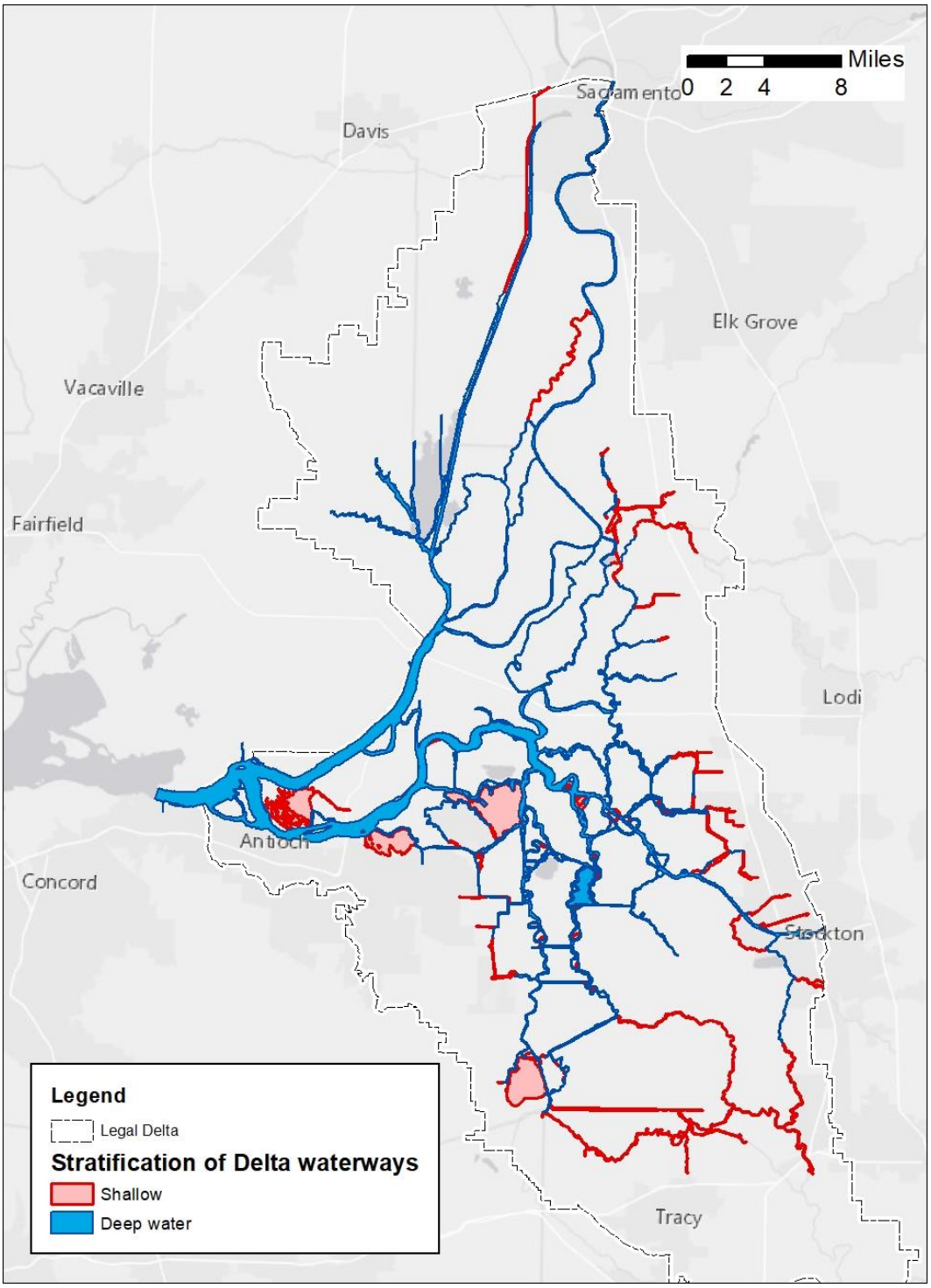

Figure 3 Stratification of Delta waterways into shallow and deep water (>2m)

Another method of stratifying Delta waterways has been proposed related to hydrologic connectivity, flow-through and circulation. The working hypothesis is that channel edges can have high habitat value and be areas of high pesticide concentrations due to localized drain inputs. We have not yet gotten to the level of detail in the sampling plan to develop this

datalayer. We may be able to do this using hydrodynamic model outputs that were developed as a part of recent Delta RMP nutrients studies (Guerin 2015). For example, Figure 4 shows the water "age" or exposure time. These data are based on model results by RMP subcontractor Resource Management Associates (RMA). Note that this particular map represents a simulation of June 2011 under a particular set of circumstances (e.g. Delta Cross Channel open, Old River Barrier closed for part of month). We have access to dozens of maps (and the underlying data) for similar simulations, under periods of low, high, and average flow. These data could be used to stratify the Delta into areas of "high" and "low" connectivity. This will require a number of assumptions and requires us to set some arbitrary cutoff for the difference between high and low connectivity. This stratification can be done in collaboration with the Delta RMP's Technical Advisory Committee and Pesticides Subcommittee who have significant amount of local knowledge of the Delta.

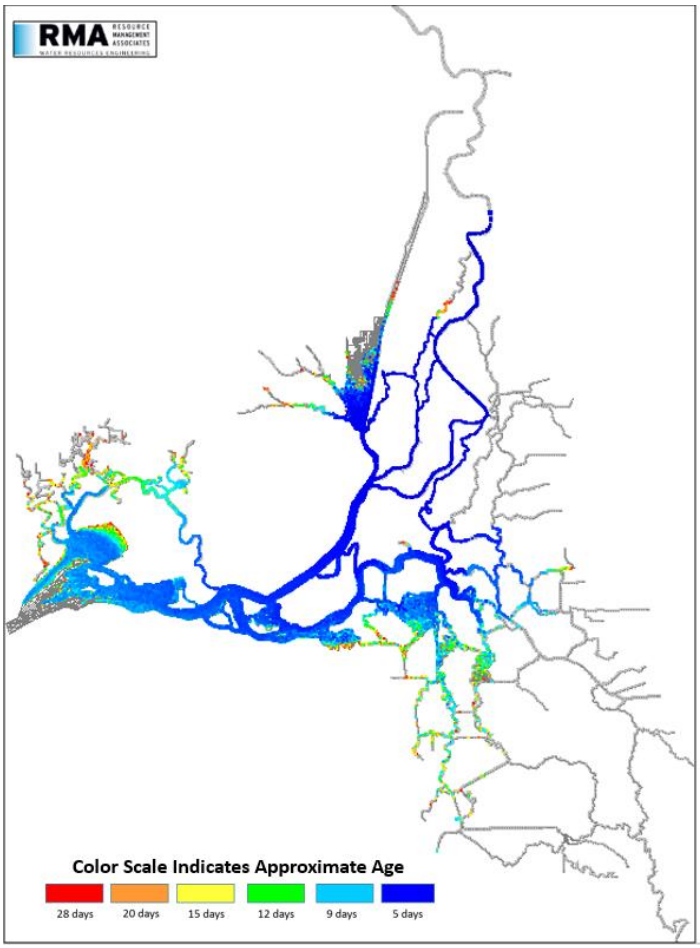

Figure 4 Example fate and age/exposure time map produced by RMA for the Delta RMP 2018 nutrients modeling study.

Fixed Sites

Option B, the hybrid option, includes sampling at two fixed sites. Some pesticides subcommittee members expressed a strong preference for continuing to monitor at fixed sites. These are "critical to being able to characterize the pesticides in the Delta in terms of the frequency and timing of toxicity, detections and exceedances. All of this is essential to answer Management and Assessment Questions S&T 1.1 and S&T1.2 and the temporal aspect of question S&T2. [See Table 1 on page 11.] The fixed sites proposed are good representatives of areas that receive a mix of urban and agricultural discharges at concentrations of concern in Delta Receiving waters."

The first of the two sites, San Joaquin River at Buckley Cove is on the main stem of the San Joaquin River, below the influence of the Stockton urban area. It is an integrator site with a variety of land uses upstream. The second site, Ulatis Creek at Brown Road represents agricultural and urban influences in the North Delta discharging to the ecologically significant Cache/Prospect Slough complex. The rationale behind selecting peripheral "integrator" sites is to characterize the spatial and temporal variations in loadings to the inner Delta as a first step. A monitoring design to measure loads of pesticides to the Delta is an appropriate first step toward understanding conditions in the inner Delta.

Strengths and Limitations of the Proposed Monitoring Designs

Table 5 describes the strengths and limitations of the rotating basin probabilistic design (adapted from NWQMC 2017). Table 6 covers the advantages and disadvantages of fixed site monitoring.

Table 5 Strengths and limitations of the rotating basin probabilistic design (included in both Option A and Option B).

Strengths	Limitations
Estimates the extent and proportion of the population in condition classes (i.e. meeting or not meeting standards) with known levels of precision and documented margin of error. Identifies patterns as well as associations between indicators to broad analysis of stressor/response signals. Focused approach in a smaller geographic areas allowing for a more robust characterization in the years when the subregion is sampled. Travel time to sites during each sampling event is reduced through selection of rotational areas. Smaller geographic scale allows for more detailed analysis of potential sources. Rotating basin designs paired with long-term trend monitoring at "integrator" sites overcome the lack of ongoing data between rotations. The approach is flexible regarding within-basin study designs, and adaptable to a variety of monitoring questions.	Not designed for localized or site specific characterizations, though data at sites sampled supports detailed characterizations. Generally not applied to characterize local, site specific effectiveness assessments (e.g. Total Maximum Daily Loads, TMDLs, Best Management Practices, BMPs). As with all designs, changes detected by repeat surveys must consider hydrologic and other variable factors. It will take 3 years or more to monitor the entire Delta. Annual changes in weather, stream flow, and other variables make it challenging to compare assessments between subregions. Detecting trends within a subregion will take longer with data collected on three-year intervals than it would if samples were collected annually.

Table 6 Strengths and limitations of fixed site monitoring (included in Option B only).

Strengths	Limitations
Provides long-term, in-depth water quality information at specific locations. Supports conclusions about conditions at specific sites or areas or concern. Because it is holding other variables constant by repeatedly sampling the same location, increased power for trend detections at the fixed sampling locations. Ability to determine frequency of exceedance of water quality thresholds, how conditions vary by season or flow regime, and, possibly, the effectiveness of regulatory actions.	Usually biased sites that provide specific information that cannot be extrapolated to make conclusions about the condition of the entire Delta. Under this proposal's Option B, adding fixed sites reduces the number of samples per year under the rotating basin probabilistic design, meaning this component of the study will take longer and cost more money to complete (4 years rather than 3 years to cover the whole Delta).

Data Collected

Samples will be collected by boat by crews from the USGS Organic Chemistry Research Laboratory (OCRL). The water quality parameters to be analyzed are described below. Additional samples (around 20% of samples) will be analyzed for quality assurance and quality control purposes. This will include lab and field replicates, matrix spikes, matrix spike replicates, field blanks, filter blanks, method blanks, continuous calibration blanks, initial blanks, and laboratory control samples. Table 13 in Appendix 1 shows the analysis method, reporting limit, and method detection limits for all parameters.

Conventional Parameters

Basic field measures of water chemistry (dissolved oxygen, pH, temperature, specific conductivity, turbidity) will be made at each monitoring site during each event. Other conventional water quality parameters are analyzed in the lab, including total alkalinity, ammonium as N, hardness.

Habitat Parameters

The field crew will make a number of observations about the sampling location, and record these on a field sampling data sheet. These observations are somewhat confusingly referred to (by USGS, SWAMP and others) as "habitat parameters," even though we are not specifically monitoring wildlife habitat. Table 7 shows the elements captured in this form. In the past, Delta RMP CUP monitoring visited the same 5 sites monthly, and therefore, each site was well known to us, and there was not much to be gained from these observations. However, as we will be monitoring dozens of new, randomly-selected locations, it will be important to record

conditions at each site, particularly anything out of the ordinary. These observations may be useful for interpreting the pesticide and toxicity results for that station.

We may wish to collect additional information to help understand factors affecting each sampling location more than the standard field form describes. This may include upland land use (e.g., urban, ag, native), cover, submerged or emergent aquatic vegetation presence/absence. This data collection element will be discussed by the TAC during the development of the detailed sampling and analysis plan and documented in the QAPP. This is important as it is typically a much greater effort – and more prone to error - to describe each site 1 to 2 years after sample collection when writing an interpretive report, if data are not collected at the time of sampling or soon after.

Table 7 Habitat parameters recorded by field crews at each sampling location.

Parameter	**Possible responses**
Site odor	None, Sulfides, Sewage, Petroleum, Smoke, Other
Sky code	Clear, Partly cloudy, Overcast, Fog, Smoky, Hazy
Other presence	Vascular, Nonvascular, Oily Sheen, Foam, Trash, Other
Dominant substrate	Bedrock, Concrete, Cobble, Boulder, Gravel, Mud, Unknown, Other
Water clarity	Clear (see bottom), Cloudy (>4" visibility), Murky (<4" visibility)
Water odor	None, Sulfides, Sewage, Petroleum, Mixed, Other
Water color	Colorless, Green, Yellow, Brown
Overland runoff (last 24 hours)	None, light, moderate/heavy, unknown
Observed flow	NA, Dry Waterbody bed, No Observed Flow, Isolated Pool, Trickle (<0.1 cfs), 0.1 - 1 cfs, 1-5cfs, 5-20 cfs, 20-50cfs, 50-200cfs, >200cfs
Wadeability	Yes, No, Unknown
Wind speed (Beaufort scale)	
Wind direction	
Precipitation (at time of sampling)	None, Fog, Drizzle, Rain, Snow
Precipitation (last 24 hours)	Unknown, <1", >1"
Occupation Method	Walk-in, Bridge, Other
Starting bank	
Distance from bank	
Stream width	
Water depth	
Location	Bank Thalweg, Mid-channel, Open Water
Hydromodification	None, Bridge, Pipes, Concrete channel, Grade control, Culvert, Aerial zipline, Other

Current Use Pesticides

Pesticide chemistry analysis will be performed by the USGS Organic Chemistry Research Laboratory (OCRL) in Sacramento. Samples will be analyzed for total and dissolved pesticide concentrations for 174 current use pesticides and degradates. Compounds include fungicides, herbicides, insecticides, degradation products, and "other." Examples of compounds classified as "other" include pyriproxyfen which is a hormone and insect growth regulator, and piperonyl butoxide, which is a "synergist" which increases the potency of certain other pesticides. Water samples will be processed and analyzed by liquid chromatography tandem mass spectrometry (LC/MSMS) or gas chromatography mass spectrometry (GC/MS. These analysis methods are have been previously described in the Delta RMP's FY15/16 data report (Jabusch, Trowbridge, Heberger, Orlando, et al. 2018). A full list of analytes, methods, and reporting limits is given in Appendix 1.

These analytes are the same as those previously monitored during the first phase of the CUP program in 2015 and 2016, plus the addition of 19 new analytes for which the lab has recently developed a method. The new analytes are the following:

Acetochlor	Herbicide
Benzovindiflupyr	Fungicide
Carboxin	Fungicide
Chlorfenapyr	Insecticide
Dichlorvos	Insecticide
Etoxazole	Insecticide
Flubendiamide	Insecticide
Fluopyram	Fungicide
Flupyradifurone	Insecticide
Imidacloprid urea	Insecticide
Isofetamid	Fungicide
Oxathiapiprolin	Fungicide
Penthiopyrad	Fungicide
Pyriproxyfen	Other
Sulfoxaflor	Insecticide
Tebufenozide	Insecticide
Thiamethoxam Degradate (NOA-407475)	Insecticide
Thiamethoxam Degradate (CGA-355190)	Insecticide
Tricyclazole	Fungicide

Some compounds are highly water soluble, while others tend to be adhere to sediments and other particles. In order to gain a full picture of pesticides in the environment, OCRL will measure both the dissolved fraction in water and the fraction associated with suspended sediments. (Note that we are not proposing to measure pesticides in bedded sediment at this

time.) Measuring pesticides that are both dissolved in water and on suspended sediments can help give greater insight into the fate and transport of different compounds. The way chemicals move through and impact the environment can depend strongly on their physical and chemical properties – some are highly soluble in water, while others tend to adsorb strongly to sediments particles. Of the 174 compounds measured in water, the lab is able to analyze 139 compounds in suspended sediment.

Copper

Copper is an ingredient used in herbicides, and is used in the cultivation of rice, as well as to control aquatic plants and algal blooms, and has been previously suggested as a possible cause of aquatic-biota toxicity in the Delta. However, it is also a natural occurring and ubiquitous trace element that may originate from other sources.

Samples will be sent to the USGS National Water Quality Laboratory (NWQL) in Denver for analysis for copper. Copper will be analyzed at the NWQL using the method described in Techniques and Methods Book 5-B1 (Garbarino, Kanagy, and Cree 2006). It is also important to measure other ancillary parameters in order to interpret whether copper is bioavailable and potentially toxic. Copper has a complex chemistry and its toxicity can vary widely from place to place due to local conditions (e.g., pH, ionic composition, presence of natural organic matter). Hardness-adjusted thresholds provide a simplified approach to address water chemistry and bioavailability but they do not directly consider other water chemistry parameters (e.g., pH and DOC) that affect bioavailability and toxicity of dissolved copper. More complex methods for evaluating copper toxicity take into account additional water quality parameters to estimate bioavailability. For example, EPA's National Recommended Water Quality Criteria (2017) considers how various water quality parameters affect copper toxicity using the Biotic Ligand Model (BLM). Lab analysis of water samples additional ancillary parameters will help us to interpret the copper measurements using the methods described above.

Ancillary Parameters

To assist with interpreting the bioavailable fraction of pyrethroid pesticides, samples will also be analyzed for ancillary parameters by the USGS National Water Quality Laboratory (NWQL). Other parameters measured by NWQL are:

Fraction	**Water Quality Parameter**
Dissolved	Dissolved Organic Carbon
Particulate	Carbon, Total
Particulate	Nitrogen, Total
Particulate	Particulate Organic Carbon
Particulate	Total Inorganic Carbon
Particulate	Total Suspended Solids

Dissolved organic carbon will be analyzed at the NWQL using the method described in OFR 92-480 (Brenton and Arnett 1993). Particulate organic carbon, total particulate inorganic carbon, total particulate nitrogen, and total particulate carbon will be analyzed at the NWQL using EPA method 440.0 (Zimmerman, Keefe, and Bashe 1997).

Aquatic Toxicity Testing

Under the proposed monitoring design, we plan to test ambient surface water samples for acute and chronic aquatic toxicity with five different organisms shown in Table 8 below. Test organisms were selected based on updated SWAMP guidance (Anderson et al. 2015), past Delta RMP monitoring experience, and input by stakeholders and technical experts.

The use of midge larvae (*Chironomus dilutus*) is new to the Delta RMP. *Chironomus dilutus* has been listed as a valid alternate species for over a decade in EPA's freshwater acute toxicity test manual (USEPA 2002). EPA and USGS developed species-specific methods that are currently out for review within these agencies. *Chironomus* toxicity data (SWAMP-funded) could support method validation efforts. More information about *Chironomus* is included in Appendix 4. Detailed information on the test methods for the other 4 organisms can be found in the *Delta RMP Current Use Pesticides Year 1 Data Report* (Jabusch, Trowbridge, Heberger, Orlando, et al. 2018).

Table 8 Proposed aquatic toxicity tests

Test organism	**Endpoints**	**Rationale for including**
Ceriodaphnia dubia, a daphnid or water flea	survival, reproduction	Sensitive to organophosphate pesticides
Hyalella azteca, an aquatic invertebrate	survival	Sensitive to pyrethroids
Selenastrum capricornutum, a single-celled algae (also known as *Raphidocelis subcapitata)*	growth	Sensitive to herbicides
Chironomus dilutus (formerly *Chironomus tentans*), midge larvae	growth, survival	Sensitive to fipronil and more sensitive in chronic exposures to imidacloprid than *C. dubia.*
Pimephales promelas, fathead minnow	growth, survival	Chronic and acute effects on whole organism growth and survival

Stakeholders have asked questions about how results from Chironomus toxicity data could be used by regulators. Currently all existing Chironomus toxicity data in CEDEN is flagged as "screening." This may change in the upcoming year if the State Water Board publishes method quality objectives (MQOs) for certified labs to follow.

Any data can be used by state regulators to list a water body as impaired under section 303(d) of the Clean Water Act. It is the Regional Board's decision whether or not to use data for a particular purpose. Staff may use any and all data, regardless of whether it is flagged as "screening" "survey" or has any other QA flag attached. If a group (i.e. regulated entity) wants to invalidate data for some reason, it would be incumbent upon them to contact the 303(d) unit at the appropriate Regional Board and make the case that data should not be used. In brief, anything in CEDEN may be used for regulatory purposes, regardless of flags/QA codes, and it is up to the Regional Board to make the decision what they use. Also, some Regions have begun using data from sources other than CEDEN.

Rainbow trout - It has been suggested to add rainbow trout (*Oncorhynchus mykiss*) to the suite of test organisms. This would be a useful test organism as it is more closely related to threatened and endangered species in the Delta. However, this test is not covered under the SWAMP contract with the testing lab. We have held discussions with NOAA fisheries, who have indicated that they will consider funding beginning in the *next* fiscal year, FY19/20.

Toxicity Identification Steps

Consistent with monitoring and assessment question S&T1.1A ("If samples are toxic, do detected pesticides explain the toxicity?"), a Toxicity Identification Evaluation (TIE) s triggered when the sample experiences a 50% reduction in the endpoint (e.g., survival) compared to the control. A TIE is an investigative process that uses laboratory modifications of test sample chemistry and resulting changes in toxicity to identify the constituent group (e.g., organophosphates) that are the likely cause(s) of toxicity.

This proposal includes a budget to conduct up to 4 TIEs during the water year. The decision to conduct a TIE is based upon consideration of multiple factors such as the magnitude of toxicity. magnitude of toxicity present in the sample matrix is an important consideration because a moderate to high level of toxicity typically yield results that are more successful.

Data Management and Quality Assurance

Data will be reviewed for overall quality/usability according to SWAMP and EPA data validation procedures. SWAMP program staff will be responsible for managing the toxicity data and performing quality assurance. SWAMP is working to identify additional QA or Corrective Actions that will be done in 2018/19 to address past deviations or errors. This may include, for example, performing an independent QC check on 10% of toxicity bench sheet calculations that would trigger a more thorough audit and corrective actions by the lab if errors are found.

SWAMP's QA program is described in its *Quality Assurance Program Plan* (2017). SWAMP has created measurement quality objectives (MQOs) establishing requirements and recommendations for the various tests and measurements used for SWAMP's water-quality monitoring projects. SWAMP's MQOs can be found on the SWAMP Wiki and the SWAMP webpage.

SWAMP managers have indicated that they will *not* be providing data analysis, reporting services, or QA summary/narratives for this project. We have added a small amount of budget (10 hours total) for ASC staff to review the toxicity data and prepare a brief QA summary of the toxicity data. To prepare the toxicity QA summary, ASC staff will download the toxicity data from CEDEN, run standard QA/QC analyses, and write a short memo describing whether the measurement quality objectives (MQOs) described in the Quality Assurance Program Plan (QAPP) were met, and describing any deviations from the QAPP. ASC will not be adding any new QA flags to the data, nor will we describe deficiencies identified by the SWAMP Quality Assurance Officer, or corrective actions that were taken.

Delta RMP stakeholders have expressed a strong interest in receiving detailed updates regarding any deficiencies by the laboratories, communications, and corrective actions. The SWAMP QA Officer has indicated that SWAMP staff are able to provide us with a "simple summary statement from SWAMP including the following: 'issues were detected, a correction action report was completed and approved, and laboratory performance will be assessed regularly.' Discussing the details of what steps were taken with stakeholders is not appropriate. Nor will we allow for additional requests to be made of our Contractor [the UC Davis toxicity lab]" (Melissa Morris, personal communication, June 27, 2018).

In addition, we have arranged for AHPL to submit provisional electronic data and documentation of their processes and controls after each and every monitoring round. These submittals will be in lieu of an annual lab report, which they have provided in years 1 and 2 of pesticide monitoring. ASC's Data Management and Quality Assurance team will do a brief review of the submitted data, and we will distribute the information to TAC and Pesticides subcommittee members so that those who are interested can review this information.

The Aquatic Science Center (ASC)'s Data Services team (DS) will be responsible for handling and reviewing data generated by field crews and for chemical analyses by the USGS labs. The staff of the OCRL performs certain QA checks on the data before submitting it to ASC. For more information about QA performed by the USGS lab, see Appendix 2. ASC's Quality Assurance Officer (QAO) and staff independently recalculate any QC metrics reported by the lab, as an additional layer of verification of the results.

The review process consists of ASC's DS team checking that results are received for all samples collected and that the lab reported results for the analytes requested in the contracts. Staff will check in the data as it arrives, and perform a partial analysis of the data to verify that it is complete and meets certain minimum acceptability criteria. This will help us to identify any potential problems in a timely manner and make any necessary corrective actions. For more information, see the *Delta RMP Data Management and Quality Assurance Standard Operating Procedures* (Franz et al. 2018).

Data is standardized by ASC's DS team using California Environmental Data Exchange Network (CEDEN) templates, controlled vocabulary, and business rules. Data is reviewed by

ASC's QA officer or designee (under the supervision of the QA Officer) to ensure sufficient laboratory control samples are analyzed in order to evaluate whether samples are meeting Measurement Quality Objectives (MQO) as stipulated in the Quality Assurance Project Plan (QAPP). These processes are necessary to ensure data are usable by project staff, regulatory agencies and members of the public.

Five evaluations make up the core of the QA-review process:

1. **Data completeness:** Has the lab submitted all expected data, including the correct number of QA samples? Were contract and QAPP expectations met?
2. **Sensitivity**: Were the analytical methods sensitive enough to get detectable results?
3. **Contamination**: Was there contamination present in any of the sample batches?
4. **Accuracy**: Did the lab reliably measure known concentrations?
5. **Precision**: Was the lab able to consistently obtain the same result in its analysis of replicate or duplicate samples?

Deliverables for this step include a tabular summary of the data (typically in an Excel spreadsheet), and a memo from ASC's QA officer summarizing the quality assurance (QA) review. The QA review will begin after we receive final dataset from the laboratories, typically about 3 months after the last samples are collected, planned for December 2019. The QA memo will be written in the spring of 2020 and sent to TAC members in the first quarter of 2020. A timeline of planned deliverables is shown in Table 10 on page 44.

QAPP Modifications Needed

Several important details have been left open-ended, to be developed in the future. It is important that these details be set before monitoring begins in October 2018. This proposal follows a similar process that SEFI-ASC scientists have used successfully over the last 20 years: first we draft a proposal that outlines a monitoring program, and then develop a more detailed "sampling and analysis plan" after funding is approved. This is appropriate because developing this plan requires an investment of time and money that would not be well spent in the proposal stage. Because the Delta RMP has a detailed Quality Assurance Program Plan (QAPP), it is appropriate to add these details to this document. Some of the important details to be included in the QAPP are described below.

The QAPP will include measurement quality objectives for all parameters. The current Delta RMP Quality Assurance Program Plan (QAPP version 3.5, dated March 14, 2018) does not include a description of monitoring of pesticides and toxicity, as the program took a hiatus from monitoring these parameters in FY17/18. Previous versions of the QAPP (version 2.2, dated September 30, 2016) described pesticides and toxicity monitoring. Much of this information is still useful and relevant; however, certain updates and modifications will need to be made to the QAPP following approval of this monitoring plan. We expect to draw heavily on the QAPP from FY16/17, and to update it as necessary.

Budget to update the QAPP was approved by the Steering Committee as part of the FY18/19 Workplan. The sampling and analysis plan will rely heavily on standardized methods for data/sample collection and analysis. A QAPP will describe these specific activities and be sufficiently robust to achieve the study goals. As shown in the schedule of deliverables (Table 10 on page 44), QAPP updates will be done from July to September 2018.

ASC staff will work closely with the pesticides subcommittee and our science advisors as we develop additional guidance and documentation to include in the QAPP. In addition, the draft QAPP will be made available to the TAC and external stakeholders for review (planned for August 2018), and their comments and input solicited. At least two meetings with the pesticides subcommittee will be held from July to September to discuss the detailed sampling plan and QAPP amendments. New elements to be added to the QAPP include the following items:

Sample location selection and pool of possible locations - Development of the final geographic datalayer of Delta waterways to form the basis of our population or the "sample frame" from which random sampling locations will be drawn. Stratification of Delta waterways, as described above on page 20. Selection of sample locations using the GRTS method.

Additional EC-based control and data interpretation protocols for *Ceriodaphnia dubia* toxicity tests - In the first two years of Delta RMP monitoring, it was noted by technical reviewers that there may be an interference with toxicity testing of C. dubia when sample water had had unusually low levels of salinity/conductivity, as indicated by measurements of electrical conductivity (EC). *C. dubia* reproduction is known to be sensitive to low conductivity. The Delta RMP Pesticides subcommittee has been discussing this issue with the SWAMP QA team and the UC Davis aquatic toxicity lab manager. Our goal is to put in place revised procedures in the form of Measurement Quality Objectives (MQOs) that will increase the reliability of the test in low-EC waters, most likely by adding an additional control batch when EC is in the range of 100 – 200 μS/cm, and establishing protocols for performing statistical comparisons to the most appropriate control. It is our current understanding that Bryn Phillips of the UC Davis Granite Canyon lab is currently drafting a tech memo for SWAMP that will provide guidance on this issue. For additional information on this issue, see the tech memo from the Jan 9, 2018 Pesticides Subcommittee meeting (available upon request or on the TAC workspace website.)

Toxicity test methods for *Chironomus dilutus* – There are at present no standardized test methods for water-only testing with midge larvae (*Chironomus dilutus*). We will work with the lab, SWAMP and our technical advisors to determine the most appropriate methods with a view to making test results reliable, repeatable, and comparable with results obtained by others. For more detailed information on method development for water-only toxicity testing with *Chironomus*, see Appendix 4.

Data Analysis and Presentation

The goal of Delta RMP monitoring is to help answer the management and assessment questions shown in Table 1. As a part of the Data Quality Objectives (DQO) process, the Pesticide Subcommittee has worked to convert these questions into hypotheses, or specific, quantitative decisions to be made based on the data collected. The next step in the DQO process is to "Specify tolerable limits on decision errors." Data quality objectives (DQOs) for the monitoring program are shown in Table 9. The decision rules in Table 9 anticipate that parametric statistical methods will be used. If data are non-normally distributed or regression residuals are non-normal, there may be a need to use nonparametric statistical analysis methods. Non-parametric methods may require larger sample sizes to answer the assessment questions listed in Table 1.In the table, we set the parameters for tolerable limits on decision errors (referred to by statisticians as *alpha* and *beta*) based on commonly used assumptions in science. We chose a significance level (alpha) of 0.05 for a one-tailed hypothesis test. For example, suppose we are testing whether more than 1% of river miles have a pesticide concentration exceeding a threshold. With alpha = 0.05, there is a 5% chance of a false positive with hypothesis testing (incorrectly concluding that concentrations in these river miles exceeds the threshold.) The choice of beta of 0.2 is the probability of a false negative. Statistical power is 1 – beta or 0.8. This means, for example, that we have only a 20% chance of incorrectly concluding that a predicted pesticide concentration does not exceed a threshold.

Water quality thresholds – The simplest and most straightforward way of determining whether a chemical may be causing an adverse impact on a waterway is to compare observed concentrations to a water quality threshold or benchmark. When a threshold has the force of law, it is referred to as a standard, or in California, a water quality objective. However, state and federal regulators have written standards for only a few current use pesticides. For example, the Central Valley Regional Water Quality Control Board has established water quality objectives for chlorpyrifos and diazinon that cover much of the Central Valley including the Delta.[1] For the hundreds of other current use pesticides, there are neither national water quality criteria recommended by the EPA, nor are there state water quality objectives.

Comparing ambient concentrations to benchmarks is a useful first step in the process for interpreting pesticide data and evaluating relative risk. The choice of a threshold is important. If our monitoring shows that concentrations exceed a threshold, the implication is that there is a problem. Yet, the choice of a threshold is a complicated technical question. *We have not explicitly defined thresholds in this proposal,* in part because this work is ongoing, as part of an analysis of pesticides and toxicity data contracted by the Delta RMP to the firm Deltares.

[1] See *Amendments to the 1994 Water Quality Control Plan for the Sacramento River and San Joaquin River Basins* (Central Valley Regional Water Quality Control Board, 2016), Table III-2A, Specific Pesticide Objectives, on page III-6.01. Chronic toxicity is based on the average concentration over a 4-day period.

Options for setting thresholds include aquatic life (AL) benchmarks published by the US EPA Office of Pesticide Programs (OPP). OPP benchmarks were developed by the U.S. EPA for use in the agency's risk assessments conducted as part of the decision-making process for pesticide registration. The OPP benchmark values are based on the most sensitive species tested within taxonomic groups (fish, invertebrates, vascular and non-vascular plants). They represent the lowest toxicity values available from peer-reviewed data with transparent data quality standards. OPP benchmarks may or may not be useful for interpreting Delta RMP toxicity data. However, these thresholds are broadly relevant to protecting aquatic life. It has also been suggested by TAC members that it may be appropriate to divide OPP aquatic life benchmarks by a safety factor of 5 or 10. This would in line with the precautionary principle, and consistent with the CVRWQCB's Basin Plan, which states that standards will be based on the lowest LC50 divided by 10.[2]

Handling of non-detects – In the first two years of pesticide monitoring by the Delta RMP, many of the pesticide chemistry results were non-detects. Statistical methods should be chosen carefully for handling "censored data" (Helsel 2010). Common methods used in the past, such as substitution of zero or one-half the detection limit for non-detects is known to introduce bias in data analyses. One of our science advisors has recommended the use of the "Nondetects and Data Analysis (NADA)" package in R created by D. Helsel (USGS). We anticipate that useful guidance will also be developed as a part of the Delta RMP-funded interpretive report underway by Deltares.

[2] See Amendments to the 1994 Water Quality Control Plan for the Sacramento River and San Joaquin River Basins (2016), page IV-35: "Where valid testing has developed 96 hour LC50 values for aquatic organisms (the concentration that kills one half of the test organisms in 96 hours), the Board will consider one tenth of this value for the most sensitive species tested as the upper limit (daily maximum) for the protection of aquatic life. Other available technical information on the pesticide (such as Lowest Observed Effect Concentrations and No Observed Effect Levels), the water bodies and the organisms involved will be evaluated to determine if lower concentrations are required to meet the narrative objectives."

Table 9 Analytic approach, decision rule, and data quality objectives

Spatial extent of pesticides and toxicity (included in Options A and B)

Questions to Answer with Delta RMP Pesticide Data	Analytic Approach	Decision Rule	Data Quality Objectives	Power Analysis
Spatial extent of pesticide, toxicity occurrence For what percent of the subregion was aquatic toxicity and co-occurrence of pesticides greater than risk-based thresholds observed? Over what percentage of the subregion does a pesticide concentration exceed a threshold? Secondary objective that can be evaluated qualitatively: Identify spatial patterns in aquatic toxicity and pesticide concentrations within the subregion to inform decisions about sensitive habitats, sources, and strata for future designs.	1. Metric for toxicity: Binary variable (0/1 or True/False) indicating whether toxicity was observed, by species (as determined by a statistically significant reduction in an endpoint compared to control, to be described in greater detail in the QAPP). 2. Metric for pesticides: -Individual pesticide concentrations in water and suspended sediment - Individual pesticide frequency of exceedance of aquatic life benchmark. - Cumulative frequency of exceedance 3. Metric for determining cause of toxicity: outcome of Toxicity Identification Evaluations (TIEs)	Population estimates will be made using open source R software ('spsurvey').[3] Population estimates are not a statistical test. There is no null hypothesis. The result will be a percent of subregion water area meeting a certain condition such as: -Percent of subregion with statically significant aquatic toxicity -Percent of subregion with pesticide concentrations above risk based thresholds -Percent of subregion with significant toxicity AND pesticide concentrations above risk based thresholds	The sample size for each subregion should be large enough to be able to estimate the percent of subregion's water area with a certain condition with error bars of ±10%. Assume a Type 1 error of <0.05 and a Type 2 error of <0.2 (80% statistical power).	Because we are employing a random sampling design, a standard probability distribution known as the binomial distribution can be used to estimate of the upper and lower bounds of confidence intervals. The relationship between sample size and the confidence intervals around the cumulative distribution function are shown in Appendix 3 Figure 7 (see notes for assumptions). A sample size of n = 24 gives a 90% confidence interval of around ±13%. (This is acceptably close to our objective of ±10%.) More details on the power analysis presented in Appendix 3.

[3] https://cran.r-project.org/web/packages/spsurvey/spsurvey.pdf

Co-Occurrence of Pesticides and Toxicity (included in both Options A and B)

Questions to Answer with Delta RMP Pesticide Data	Analytic Approach	Decision Rule	Data Quality Objectives	Power Analysis
Causes of toxicity Evaluate the co-occurrence of aquatic toxicity and pesticides.	**Metrics for toxicity:** 1. Binary variable (0/1, or True/False) indicating whether significant toxicity was observed (stratified by species, and possibly by endpoint) 2. Continuous variable - Percent effect observed for individual toxicity tests: reduction in organism survival, reproduction, or growth compared to control. **Metrics for pesticides:** 1. Continuous variable: Observed concentration of individual pesticides, in ng/L 2. Binary variable (0/1 or True/False) Individual pesticide observations exceeding a risk threshold. 3. Frequency with which individual pesticides exceed a threshold. 4. Cumulative frequency of exceedance (for one or all pesticides) 5. Cumulative frequency of exceedance for classes of pesticides grouped by type or mode of action (organophosphate and pyrethroids) 6. Pesticide Toxicity Index*	**Statistical Test:** -Logistic Regression -Multivariate linear regression All data from all sites will be pooled for the test if and/or sites to be analyzed individually based on a statistical analysis of their similarity using Generalized Linear Models or Principal Components Analysis. Null hypotheses: Ho: Toxicity is not related to exposure to pesticides. (There is no relationship between pesticide levels and toxicity.) Ha: There exists a relationship between pesticide exposure and the toxicity.	The test should be able to detect a 5% effect** of pesticide exposure with a Type 1 error of <0.1 and a Type 2 error of <0.2 (80% power).	For the site on the San Joaquin River at Buckley Cove, to detect an effect size = 0.03 would require around 60 samples. In this context, an effect size of 0.03 is equivalent to a 3% increase in toxicity to macroinvertebrates for each unit increase in the Pesticide Toxicity Index (PTI). Requires 36 new samples at each site, or 6 years (i.e., collecting 6 samples per year at this fixed location). See Appendix 3 for more details on the power analysis.

* The Pesticide Toxicity Index (PTI) is a screening tool to assess potential aquatic toxicity of complex pesticide mixtures by combining measures of pesticide exposure and acute toxicity in an additive toxic-unit model. For more information, see "Pesticide Toxicity Index—A tool for assessing potential toxicity of pesticide mixtures to freshwater aquatic organisms" (Nowell et al. 2014).

** An effect size of 5% means that a unit increase of the PTI would result in a 5% reduction in a toxicity endpoint such as reproduction, survival, or growth. In general, large effect sizes (e.g. 50% reduction in survival) are easier to detect with smaller sample sizes, while small effect sizes (5% reduction in survival) are more difficult to differentiate from random chance and need a much larger number of samples to detect.)

Co-Occurrence of Pesticides and Toxicity (included in both Options A and B)

A goal of the proposed program is to better understand the role that contaminants play in contributing to toxicity in the Delta.[4] A statistical analysis of the first two years of Delta RMP monitoring data, described in more detail in Appendix 3, included an evaluation of power to detect statistical relationships between pesticide concentrations and toxicity across a range of sample sizes. In brief, an examination of data from the first two years of sampling did not find a statistically significant relationship between pesticide concentrations and observed toxicity. However, with two years of monthly data, collected under a variety of flow conditions, we now have a better estimate of the variability in predictor variables (pesticide concentrations) and response variables (toxicity endpoints such as percent reductions in survival or reproduction compared to a control).

The variability of these parameters is a key input into the power analysis. What the power analysis allows us to say is, if there is a relationship among these variables of a certain strength (or "effect size"), how many samples would be needed to recognize this relationship statistically, given a certain risk tolerance for a false conclusion? It was concluded that, based on the historically measured variability, and certain assumptions on the effect size we wish to detect and desired statistical power, that a total of 60 samples would be required. As we already have 24 samples at each fixed site to date, we need 36 additional samples giving us the ability to detect a correlation between pesticide concentrations and toxicity. Under this proposal, we would collect 6 samples per year at each of the fixed stations. Therefore, we would be able to detect such a correlation after another 6 years of sampling. For more details on the statistical power analysis, see Appendix 3.

Both monitoring design options can test for the co-occurrence of aquatic toxicity at measured pesticide concentrations using samples collected throughout the Delta. While toxicity might be found at any sample location in the Delta, the fixed sampling locations included in Option B had elevated toxicity in the past sampling years. Therefore, a similar frequency of toxicity is expected from the fixed monitoring stations under Option B to inform the co-occurrence analysis over the long term. The stratified probabilistic design would include surface water samples from areas with less dilution of pesticides (i.e., small tributaries), which could result in samples with a higher magnitude of toxicity than previously encountered. This would potentially allow for more TIEs to identify the causes of observed toxicity than was done in 2015-2017 Delta RMP sampling.

[4] Note however that under the "independent applicability policy" in water quality regulation, the cause of toxicity does not need to be demonstrated in order for regulators to list a water body as impaired. The toxicity water quality objective is a separate standard. However, it is desirable to determine which toxicant(s) are contributing to or causing toxicity.

Spatial Extent of Pesticides and Toxicity (Included in Options A and B)

With the data from the probabilistic design, we would like to know the percentage of each subregion where a pesticide concentration exceeds a benchmark, has observed toxicity, or where elevated concentrations of pesticides and toxicity co-occur. Using sample data from each of the subregions, we can construct cumulative distribution functions (CDFs) that show the distribution of a variable within that region. The CDF shows the percentage of stream miles that are less than or equal to each possible value of a variable. A hypothetical example is shown in Figure 5. In this case, the CDF could describe the concentration of a particular pesticide, the value of the Pesticide Toxicity Index (PTI), or the value of a toxicity endpoint. The CDF is useful for describing the overall condition of the resource being sampled, and lets you answer a number of questions, some of which are of interest to us. The important point is that with a larger number of samples, we will have smaller confidence intervals around the empirical CDF. We cannot do a conventional power analysis for the probabilistic design. However we can *a priori* estimate the size of the confidence intervals around the CDF, using the binomial distribution, and making some assumptions. Having "tighter" error bounds around the CDF is desirable for when we'll use it as a tool to make any kind of estimation.

A recent report from Oregon (DeGasperi and Stolnack 2015) which used GRTS to evaluate the status and trends of aquatic habitats describes how CDFs derived from sample data can be used to make inferences about the sampled populations:

> A CDF plot for a particular target sample population sampled in a particular year establishes a baseline against which future surveys (using the same probabilistic design) can be compared. Change over time (or between subpopulations of the target sample frame) can be detected not only in some measure of central tendency such as the mean or median value of a particular metric, but in certain portions of the CDF via visual comparison of the two (or more) CDF plots. Depending on the expected response of a particular metric to environmental stressors or to restoration measures, the CDF will be expected to shift to the left or right. Confidence intervals for each CDF provide a statistical basis for assessing change.

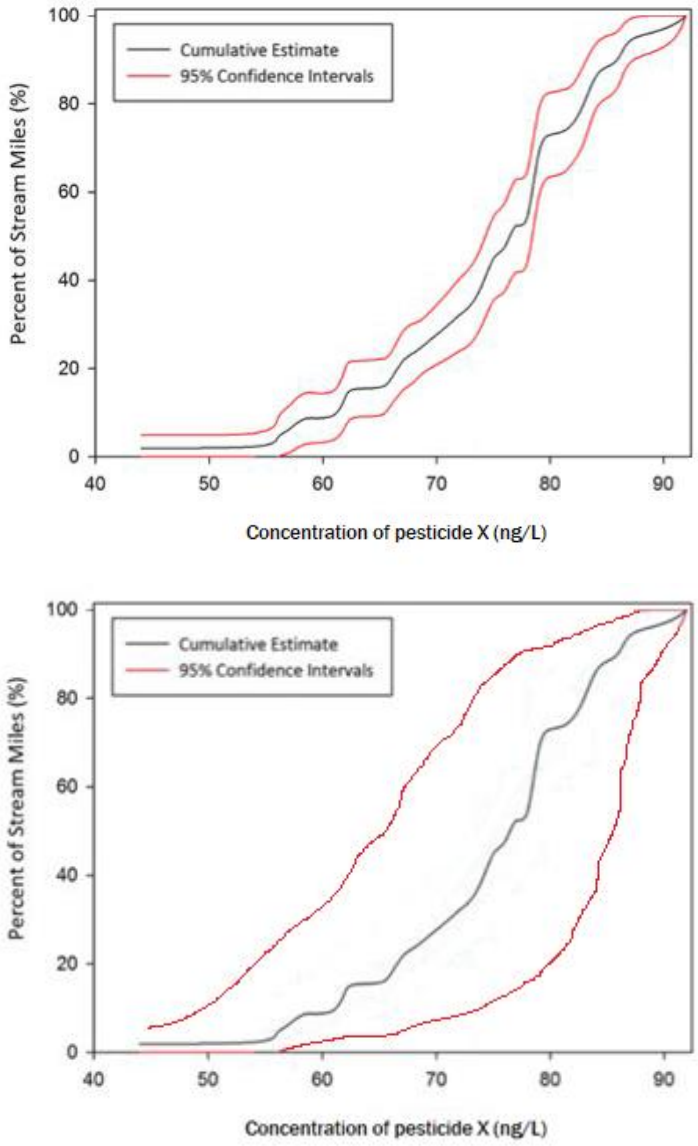

Figure 5 Hypothetical cumulative distribution functions for pesticide concentration in a Delta subregion.

In the hypothetical example in Figure 5, suppose we are seeking to answer the question, what percent of stream miles have a pesticide concentration < 75 ng/L. In the top figure, with more samples and smaller confidence intervals, the answer is 30% to 40%. In the bottom figure, with fewer samples and large confidence intervals, the answer is 15% to 80%. This is a made-up example, but it demonstates that a larger number of samples lets us make better estimations about the condition of the waterway.

In other words, we wish to make the confidence intervals as small as possible in order to make more reliable estimates about the sampled population. This means collecting a larger the number of samples, however there are constraints in terms of budget. No explicit guidance on the recommended sample size for GRTS survey designs exists. Budgetary and logistical

constraints of individual study designs often dictate the level of effort employed. That said, probabilistic designs incorporating GRTS often aim to determine an estimate of a proportional extent, and thus refer to the binomial distribution to evaluate precision. In the scenarios analyzed in Appendix 3, a sample size of 30 would result in an estimated confidence interval of ±12%. A sample size of 24 gives only a slightly larger confidence interval of around ±13%. Increasing the sample size would not significantly impact on the size of the confidence interval, while fewer than 24 samples would increase the confidence interval substantially. Consequently, a sample size of 30 can be considered an "industry standard", and has, in the experience of our consulting statistician, been selected as a default sample size in order to make statistical inferences about condition, with a relatively low degree of error. A sample size o f24 is only slightly worse, and fits within available budget. Under Option A, this target sample size of 24 will be reached after 3 years. Under Option B, the number will be reached after 4 years. For more details, see the power analysis in Appendix 3.

Option B, which includes fewer random samples to add sampling at 2 fixed sites, can answer all of the same questions, although it may take longer to achieve the desired level of statistical power due to the smaller number of samples collected each year. However, it also adds the ability to detect trends at two locations in the Delta by repeatedly sampling at these two fixed sites. Further, fixed site sampling can be better at identifying associations among different water quality parameters, as we are holding more potentially confounding factors constant by sampling repeatedly at the same location.

Monitoring data can also be used to identify spatial patterns in aquatic toxicity and pesticide concentrations within the subregion to inform decisions about sensitive habitats, sources, and strata for future designs. The goal of most sample surveys is to estimate the proportion of a resource that is degraded. In this case, we will be able to estimate the percentage of each subregion in which a pesticide concentration exceeds a threshold.[5]

Numeric water quality standards exist for only a few current use pesticides. Therefore, we will compare observed pesticide concentrations to U.S. Environmental Protection Agency aquatic life (AL) benchmarks.[6] Benchmark values will be used as a first step in a process for interpreting

[5] Not all Pesticide Subcommittee members agreed on the usefulness of assessing differences in water quality within or among subregions of the Delta. One member wrote, "I am less interested in the variation of pesticide concentration from one subregion to another sub region. There may be underlying reasons like different crop, climatic change, and pest patterns and therefore different pesticides used from one year to the next year. The overarching management question, 'Is there a problem or are there signs of a problem?" and the rotating basin design does not help to answer this. Especially, since we are only evaluating 2 subregions each year. If we find there is a problem, we will not return to that that sub-region again until another 3 years, and that is problematic."

[6] OPP benchmarks were developed by the U.S. EPA for use in the agency's risk assessments conducted as part of the decision-making process for pesticide registration. The OPP benchmark values are based on the most sensitive species tested within taxonomic groups (fish, invertebrates, vascular and non-vascular

pesticide data and evaluating relative risk. Aquatic life benchmarks may or may not be useful determining the cause of toxicity. However, these thresholds are broadly relevant to protecting aquatic life. The USGS OCRL's reporting limits are lower than the lowest benchmark for every analyte, as shown in Appendix 1. This appendix has a table showing all of the analytes to be measured, and lists the analysis method, method detection limit, and lowest aquatic life benchmark.

plants). They represent the lowest toxicity values available from peer-reviewed data with peer-reviewed data quality objectives.

Proposed Deliverables and Timeline

Table 10 Timeline of proposed activities and deliverables.

	2018						2019												2020				2021				2022			
	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Task 0: QAPP Update		d	f																											
Task 1A: Year 1 Sampling																	d		f											
Task 1B: Year 1 Data mgmt and QA																			d	f										
Task 2A: Year 2 Sampling																						d	f							
Task 2B: Year 2 Data mgmt and QA																						d	f							
Task 3A: Year 3 Sampling																										d	f			
Task 3B: Year 3 Data mgmt and QA																										d	f			
Task 4: Analysis and interpretation																													d	f

D = Draft deliverable
f = Final deliverable
■ = Activity

Deliverables:

- Task 0: Amended QAPP, including detailed sampling and analysis plan
- Tasks 1A, 2A, and 3A: Year- end monitoring reports by USGS and AHPL
- Tasks 1B, 2B, 3B: QA Officer Memo, data uploaded to CEDEN
- Task 4: Detailed interpretive report including findings of 3-year sampling program and recommendations for future monitoring

Note: Option B (hybrid design) looks similar but adds a 4th year of monitoring from Oct. 2021 – Sept. 2022 and delays interpretive report by 1 year to 2023.

Budget and Principal Investigators

The budget for proposed monitoring in Table 11 below covers year 1 of the proposed 4-year study.

Table 12 shows a multi-year planning budget. Note that the Option B extends over 4 years of monitoring. Even though monitoring activities remain essentially the same from year to year, we assumed a cost escalation of 3% per year. We also assume that the Option B data analysis and interpretation would require somewhat more effort, as it involves analyzing two classes of data from separate sampling designs, and could include an analysis of pesticide and toxicity trends over time. The average annual cost of Option A (not adjusted for inflation) is $218K per year, while Option B averages $238K per year.

Participants in the study include:

- San Francisco Estuary Institute – Aquatic Science Center (ASC)
- Aquatic Health Program Laboratory at UC Davis (AHPL)
- U.S. Geological Survey Organic Chemistry Research Laboratory (OCRL)
- USGS National Water Quality Laboratory (NWQL)

All field work will be done by staff of the USGS OCRL at Sacramento State. They will also perform the pesticides chemical analyses. The USGS lab has a unique capability to test 170+ analytes, low detection limits, and a competitive cost when compared to commercial labs. In addition, the USGS has offered a 10% cost share on labor and travel. Water samples will be processed and analyzed by liquid chromatography tandem mass spectrometry (LC/MSMS) or gas chromatography mass spectrometry (GC/MS). These analysis methods are documented in a series of USGS reports and have been previously described in the Delta RMP's FY15/16 data report. See Appendix 1 for the planned analysis method for each analyte.

USGS OCRL will produce an informal data report for the Delta RMP. After some discussion, the project PI and staff agreed it was not worth the extra effort and expense to produce a formal USGS Open File Report, as we did in Years 1 and 2. A report like this would not add a great deal of new information to the literature. Further, a formal report would be less timely, as it typically takes several extra months to publish due to the USGS' editing and approval process. The report will contain describe sample collection and analysis methods, monitoring results, and a summary of data quality assurance.

Toxicity analyses are funded as an in-kind contribution by the State Water Resources Control Board, through the SWAMP program. SWAMP has a contract with AHPL, the UC Davis toxicity lab, which covers toxicity testing and reporting of results, but nothing else. In the past, lab staff have provided us with a number of *pro bono* "extras," such as participation in meetings, presentations of preliminary results, and a detailed year-end report. The contract manager at SWAMP has indicated that they are not willing to pay for these extras under their contract,

which is to cover lab analyses only. If we would like to continue having these extra services, we will need to pay for them out of the Delta RMP budget.

The estimated cost of these extra services from AHPL is $15,063. This covers preparing and sending provisional data and information on the labs internal processes and controls, in addition to having the lab manager attend Delta RMP meetings to give updates. Note that we have not budgeted for a formal year-end report as in years past in order to reduce costs. However, the lab manager understands that there may be substantive comments on the data, and that staff may need to prepare a detailed response to comments and make revisions to deliverables.

The first task in the list should be considered essential. Provisional results of toxicity testing is required for the Delta RMP TAC to identify samples on which to perform TIEs.

The budget for data management and quality assurance is $40,998, as shown in Table 11. This budget is somewhat more than was budgeted in years 1 and 2 of Delta RMP pesticides monitoring, but more in line with actual expenses. This task was budgeted in FY16/17 at $37,400 and projected to go over budget by approximately $5,000. The previous budgets were not adequate for the task. In brief, we encountered problems with missing and incorrect data that has required a great deal of troubleshooting and correspondence with the labs. In addition, some work has had to be repeated with corrected data, for example the database queries that we run as a part of the QA process. For this proposal, the level of effort and budgets have been adjusted to meet these expectations. ASC and USGS have assessed the “lessons learned” from the first two years of CUP monitoring and are confident that previous data management challenges will be minimized.

Table 11 Budget for proposed Delta RMP Monitoring of Current-Use Pesticides and Toxicity

Contractor	Item	Number	Unit Cost	Option A Cost	Option B Cost
USGS	**Field sample collection and lab analysis**				
	Project oversight and reporting			$19,350	$19,350
	Sample collection, labor			$22,659	$30,993
	Sample collection, supplies			$7,445	$7,445
	GC/MS Analyses			$82,587	$82,587
	LC/MS/MS Analyses			$59,804	$59,804
	NWQL Analyses			$11,025	$11,025
	Reports			$6,691	$6,691
	USGS Cost share (10% of labor and travel			-$17,269	-$18,022
				$217,645	**$192,292**
AHPL	**Toxicity Reporting**				
	Provisional Data				
	A) SWAMP Toxicity Transformers (no charge)	6	0	$0	
	B) Bench Sheet Copies	6	$500	$3,000	
	C) Reference Toxicant Control Charts	6	$875	$5,250	
	D) Corrective Actions Table	6	$100	$600	
	Attend meetings and present preliminary results	4	$800	$3,200	
	Indirect costs (University mandated 25%)			$3,013	
				$15,063	**$15,063**
ASC	**Data Management and Quality Assurance**				
	DS Project Management and Coordination	70	$115	$6,900	
	Data Receipt and Data Management	193	$105	$16,485	
	Data Validation	88	$152	$7,904	
	Data Storage and Release	46	$100	$4,600	
	Toxicity data QA Summary	10	$152	$1,520	
	10% contingency			$3,589	
				$40,998	**$40,998**
			Total	**$248,352** (Option A)	**$255,933** (Option B)

Toxicity Analysis Budget (in-kind contribution by SWAMP)

AHPL	Toxicity Lab Analysis	Number	Unit Cost	Total Cost
	Ceriodaphnia 7-day test	60	$1,160	$69,600
	Hyalella 10-day test	60	$1,160	$69,600
	Selenastrum (algae) 96-hr test	60	$960	$57,600
	Chironomus (midge larvae) 10-day test	60	$1,160	$69,600
	Pimephales (fathead minnow) 7-day test	60	$1,200	$72,000
				$270,720
	Toxicity Identification Evaluations (TIEs)*			
	Phase I TIE	4	$6,600	$26,400
	Phase II TIE	1	$14,000	$14,000
				$40,400
	Toxicity testing total (same for Option A & B)			**$311,120**

*May not be necessary, pending results of initial toxicity testing

Table 12 Multi-year planning budget for pesticides and toxicity monitoring in the Delta.

Item	Option A	Option B
Year 1 Monitoring	$250K	$256K
Year 2 Monitoring	$258K	$264K
Year 3 Monitoring	$265K	$272K
Year 4 monitoring	-	$280K
Interpretive Report	$100K	$120K
Project Total	**$873K**	**$1,190K**

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Appendix 1 Water Quality Measurements, Methods and Reporting Limits

In Table 13 below, methods are referred to by the following codes.

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2	Hladik, M.L., Smalling, K.L., and Kuivila, K.M., 2008, A multi-residue method for the analysis of pesticides and pesticide degradates in water using Oasis HLB solid phase extraction and gas chromatography-ion trap mass spectrometry: Bulletin of Environmental Contamination and Toxicology, v. 80, p. 139–144.
3	Hladik, M.L., and Calhoun, D.L., 2012, Analysis of the herbicide diuron, three diuron degradates, and six neonicotinoid insecticides in water—Method details and application to two Georgia streams: U.S. Geological Survey Scientific Investigations Report 2012–5206, 10 p. https://pubs.usgs.gov/sir/2012/5206/pdf/sir20125206.pdf
4	Hladik, M.L., and McWayne, M.M., 2012, Methods of analysis—Determination of pesticides in sediment using gas chromatography/mass spectrometry: U.S. Geological Survey Techniques and Methods 5–C3, 18 p. Available at http://pubs.usgs.gov/tm/tm5c3
EPA 440	Zimmerman, C. F., Keefe, C. W., Bashe, J. 1997. Method 440.0 Determination of Carbon and Nitrogen in Sediments and Particulates of Estuarine/Coastal Waters Using Elemental Analysis. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-15/00. https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=309418
NFM-A6	Chapter A6, *Field Measurements* in: Wilde, F. D., D. B. Radtke, Jacob Gibs, and R. T. Iwatsubo. *National Field Manual for the Collection of Water-Quality Data: US Geological Survey Techniques of Water-Resources Investigations*. Handbooks for Water-Resources Investigations, Book 9. Reston, VA: U.S. Geological Survey, 2005. https://water.usgs.gov/owq/FieldManual/.
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The numbers and letters after "SM" refer to the method number in *Standard Methods*. Readers are referred to either the print edition, or individual chapters can be purchased online.

TM-5-B1 Garbarino, J.R., Kanagy, L.K., Cree, M.E. 2006. Determination of Elements in Natural Water, Biota, Sediment and Soil Samples Using Collision/Reaction Cell Inductively Coupled Plasma-Mass Spectrometry, U.S. Geological Survey Techniques and Methods, 88p. (Book 5, Sec. B, Chap.1). https://pubs.usgs.gov/tm/2006/tm5b1/

Table 13 Summary of method, Reporting Limits (RL) and Method Detection Limits (MDL) for monitored constituents.

Constituent	Matrix	Reporting group	RL	MDL	Unit	Lab	Note	Method	Min. OPP Aquatic Life Benchmark (ng/L)	Benchmark Category
Oxygen, Dissolved	Water	Field Parameters	0.5	0.5	mg/L	USGS Field crew		NFM-A6		
pH	Water	Field Parameters	NA	NA	NA	USGS Field crew		NFM-A6		
Specific Conductivity	Water	Field Parameters	10.0	10.0	uS/cm	USGS Field crew		NFM-A6		
Temperature	Water	Field Parameters	NA	NA	NA	USGS Field crew		NFM-A6		
Turbidity	Water	Field Parameters	1.0	1.0	FNU	USGS Field crew		NFM-A6		
Alkalinity as $CaCO_3$	Water	Conventional	12.0	4.0	mg/L	AHPL		SM 2320B		
Ammonia as N	Water	Conventional	0.2	0.1	mg/L	AHPL		SM 4500-NH3F		
Hardness as $CaCO_3$	Water	Conventional	6.0	2.0	mg/L	AHPL		SM 2340C		
Dissolved Organic Carbon	Water	Conventional	0.2	0.2	mg/L	USGS NWQL		OFR-94-480		
Particulate Organic Carbon	Water	Conventional	0.1	0.1	mg/L	USGS NWQL		EPA 440		
Copper, dissolved	Water	Trace Metals	0.8	0.8	ug/L	USGS NWQL		TM-5-B1		
3,4-Dichloroaniline	Water	Herbicide	3.2	3.2	ng/L	OCRL		3	--	--
3,4-Dichloroaniline	Suspended Sediment	Herbicide	8.3	8.3	ng/L	OCRL		2	--	--
3,5-Dichloroaniline	Water	Herbicide	7.6	7.6	ng/L	OCRL		3	--	--
3,5-Dichloroaniline	Suspended Sediment	Herbicide	7.6	7.6	ng/L	OCRL		2	--	--
Acetamiprid	Water	Insecticide	3.3	3.3	ng/L	OCRL		2	2,100	Invertebrates - Chronic
Acetochlor	Water	Herbicide	1.5	1.5	ng/L	OCRL		2	1,430	Nonvascular plants - Acute
Acetochlor	Suspended Sediment	Herbicide	1.5	1.5	ng/L	OCRL		1	1,430	Nonvascular plants - Acute
Acibenzolar-S-methyl	Water	Fungicide	3.0	3.0	ng/L	OCRL		2	--	--
Acibenzolar-S-methyl	Suspended Sediment	Fungicide	3.0	3.0	ng/L	OCRL		2	--	--
Alachlor	Water	Herbicide	1.7	1.7	ng/L	OCRL		2	1,640	Nonvascular plants - Acute
Alachlor	Suspended Sediment	Herbicide	1.7	1.7	ng/L	OCRL	New in 2018	2	1,640	Nonvascular plants - Acute

Constituent	Matrix	Reporting group	RL	MDL	Unit	Lab	Note	Method	Min. OPP Aquatic Life Benchmark (ng/L)	Benchmark Category
Allethrin	Water	Insecticide	1.0	1.0	ng/L	OCRL		2	1,050	Invertebrates - Acute
Allethrin	Suspended Sediment	Insecticide	1.0	1.0	ng/L	OCRL		2	1,050	Invertebrates - Acute
Atrazine	Water	Herbicide	2.3	2.3	ng/L	OCRL		1	1,000	Nonvascular plants - Acute
Atrazine	Suspended Sediment	Herbicide	2.3	2.3	ng/L	OCRL		2	1,000	Nonvascular plants - Acute
Azinphos-methyl	Water	Insecticide	9.4	9.4	ng/L	OCRL		2	80.0	Invertebrates - Acute
Azinphos-methyl	Suspended Sediment	Insecticide	9.4	9.4	ng/L	OCRL		2	80.0	Invertebrates - Acute
Azinphos-methyl oxon	Water	Insecticide	9.4	9.4	ng/L	OCRL		2	11.0	Invertebrates - Chronic
Azinphos-methyl oxon	Suspended Sediment	Insecticide	9.4	9.4	ng/L	OCRL		2	11.0	Invertebrates - Chronic
Azoxystrobin	Water	Fungicide	3.1	3.1	ng/L	OCRL		2	8,000	Invertebrates - Chronic
Azoxystrobin	Suspended Sediment	Fungicide	3.1	3.1	ng/L	OCRL		3	8,000	Invertebrates - Chronic
Benefin (Benfluralin)	Water	Herbicide	2.0	2.0	ng/L	OCRL		2	1,900	Fish - Chronic
Benefin (Benfluralin)	Suspended Sediment	Herbicide	2.0	2.0	ng/L	OCRL		3	1,900	Fish - Chronic
Benzovindiflupyr	Water	Fungicide	3.4	3.4	ng/L	OCRL	New in 2018	3	950	Fish - Chronic
Benzovindiflupyr	Suspended Sediment	Fungicide	3.4	3.4	ng/L	OCRL	New in 2018	2	950	Fish - Chronic
Bifenthrin	Water	Insecticide	0.7	0.7	ng/L	OCRL		2	1.3	Invertebrates - Chronic
Bifenthrin	Suspended Sediment	Insecticide	0.7	0.7	ng/L	OCRL		2	1.3	Invertebrates - Chronic
Boscalid	Water	Fungicide	2.8	2.8	ng/L	OCRL		2	116,000	Fish - Chronic
Boscalid	Suspended Sediment	Fungicide	2.8	2.8	ng/L	OCRL		2	116,000	Fish - Chronic
Bromoconazole	Water	Fungicide	3.2	3.2	ng/L	OCRL		3	--	--
Bromoconazole	Suspended Sediment	Fungicide	3.2	3.2	ng/L	OCRL		2	--	--
Butralin	Water	Herbicide	2.6	2.6	ng/L	OCRL		3	--	--
Butralin	Suspended Sediment	Herbicide	2.6	2.6	ng/L	OCRL		3	--	--
Butylate	Water	Herbicide	1.8	1.8	ng/L	OCRL		2	105,000	Fish - Acute
Butylate	Suspended Sediment	Herbicide	1.8	1.8	ng/L	OCRL		1	105,000	Fish - Acute
Captan	Water	Fungicide	10.2	10.2	ng/L	OCRL		2	105	Invertebrates - Acute
Captan	Suspended Sediment	Fungicide	10.2	10.2	ng/L	OCRL		1	105	Invertebrates - Acute
Carbaryl	Water	Insecticide	6.5	6.5	ng/L	OCRL		3	500	Invertebrates - Chronic
Carbaryl	Suspended Sediment	Insecticide	6.5	6.5	ng/L	OCRL		1	500	Invertebrates - Chronic
Carbendazim	Water	Fungicide	4.2	4.2	ng/L	OCRL		2	990	Fish - Chronic
Carbofuran	Water	Insecticide	3.1	3.1	ng/L	OCRL		2	860	Fish - Chronic
Carbofuran	Suspended Sediment	Insecticide	3.1	3.1	ng/L	OCRL		2	860	Fish - Chronic
Carboxin	Water	Fungicide	4.5	4.5	ng/L	OCRL	New in 2018	3	370,000	Nonvascular plants - Acute

Constituent	Matrix	Reporting group	RL	MDL	Unit	Lab	Note	Method	Min. OPP Aquatic Life Benchmark (ng/L)	Benchmark Category
Chlorantraniliprole	Water	Insecticide	4.0	4.0	ng/L	OCRL		3	6,360,000	Fish - Chronic
Chlorfenapyr	Water	Insecticide	3.3	3.3	ng/L	OCRL	New in 2018	1	20,000	Nonvascular plants - Acute
Chlorfenapyr	Suspended Sediment	Insecticide	3.3	3.3	ng/L	OCRL	New in 2018	3	20,000	Nonvascular plants - Acute
Chlorothalonil	Water	Fungicide	4.1	4.1	ng/L	OCRL		2	2,400	Nonvascular plants - Acute
Chlorothalonil	Suspended Sediment	Fungicide	4.1	4.1	ng/L	OCRL		2	2,400	Nonvascular plants - Acute
Chlorpyrifos	Water	Insecticide	2.1	2.1	ng/L	OCRL		2	800,000	Invertebrates - Chronic
Chlorpyrifos	Suspended Sediment	Insecticide	2.1	2.1	ng/L	OCRL		2	800,000	Invertebrates - Chronic
Chlorpyrifos oxon	Water	Insecticide	5.0	5.0	ng/L	OCRL		2	--	--
Chlorpyrifos oxon	Suspended Sediment	Insecticide	5.0	5.0	ng/L	OCRL		2	--	--
Clomazone	Water	Herbicide	2.5	2.5	ng/L	OCRL		2	167,000	Nonvascular plants - Acute
Clomazone	Suspended Sediment	Herbicide	2.5	2.5	ng/L	OCRL		3	167,000	Nonvascular plants - Acute
Clothianidin	Water	Insecticide	3.9	3.9	ng/L	OCRL		2	1,100	Invertebrates - Chronic
Coumaphos	Water	Insecticide	3.1	3.1	ng/L	OCRL		3	33.7	Invertebrates - Chronic
Coumaphos	Suspended Sediment	Insecticide	3.1	3.1	ng/L	OCRL		2	33.7	Invertebrates - Chronic
Cyantraniliprole	Water	Insecticide	4.2	4.2	ng/L	OCRL		1	6,560	Invertebrates - Chronic
Cyazofamid	Water	Fungicide	4.1	4.1	ng/L	OCRL		3	8,700	Invertebrates - Chronic
Cycloate	Water	Herbicide	1.1	1.1	ng/L	OCRL		2	1,200,000	Invertebrates - Acute
Cycloate	Suspended Sediment	Herbicide	1.1	1.1	ng/L	OCRL		2	1,200,000	Invertebrates - Acute
Cyfluthrin	Water	Insecticide	1.0	1.0	ng/L	OCRL		2	7.4	Invertebrates - Chronic
Cyfluthrin	Suspended Sediment	Insecticide	1.0	1.0	ng/L	OCRL		2	7.4	Invertebrates - Chronic
Cyhalofop-butyl	Water	Herbicide	1.9	1.9	ng/L	OCRL		2	47,400	Invertebrates - Chronic
Cyhalofop-butyl	Suspended Sediment	Herbicide	1.9	1.9	ng/L	OCRL		2	47,400	Invertebrates - Chronic
Cyhalothrin (all isomers)	Water	Insecticide	0.5	0.5	ng/L	OCRL		2	101,000	Fish - Chronic
Cyhalothrin (all isomers)	Suspended Sediment	Insecticide	0.5	0.5	ng/L	OCRL		2	101,000	Fish - Chronic
Cymoxanil	Water	Fungicide	3.9	3.9	ng/L	OCRL		1	--	--
Cypermethrin	Water	Insecticide	1.0	1.0	ng/L	OCRL		2	69.0	Invertebrates - Chronic
Cypermethrin	Suspended Sediment	Insecticide	1.0	1.0	ng/L	OCRL		2	69.0	Invertebrates - Chronic
Cyproconazole	Water	Fungicide	4.7	4.7	ng/L	OCRL		2	--	--
Cyproconazole	Suspended Sediment	Fungicide	4.7	4.7	ng/L	OCRL		2	--	--
Cyprodinil	Water	Fungicide	7.4	7.4	ng/L	OCRL		2	11.0	Invertebrates - Chronic
Cyprodinil	Suspended Sediment	Fungicide	7.4	7.4	ng/L	OCRL		3	11.0	Invertebrates - Chronic

Constituent	Matrix	Reporting group	RL	MDL	Unit	Lab	Note	Method	Min. OPP Aquatic Life Benchmark (ng/L)	Benchmark Category
DCPA	Water	Herbicide	2.0	2.0	ng/L	OCRL		2	110	Invertebrates - Chronic
DCPA	Suspended Sediment	Herbicide	2.0	2.0	ng/L	OCRL		2	110	Invertebrates - Chronic
DCPMU	Water	Herbicide	3.5	3.5	ng/L	OCRL		2	37.0	Invertebrates - Chronic
DCPU	Water	Herbicide	3.4	3.4	ng/L	OCRL		2	3,000,000	Invertebrates - Chronic
Deltamethrin	Water	Insecticide	0.6	0.6	ng/L	OCRL		2	4.1	Invertebrates - Chronic
Deltamethrin	Suspended Sediment	Insecticide	0.6	0.6	ng/L	OCRL		2	4.1	Invertebrates - Chronic
Desthio-prothioconazole	Water	Fungicide	3.0	3.0	ng/L	OCRL		2	--	--
Desulfinylfipronil	Water	Insecticide	1.6	1.6	ng/L	OCRL		2	590	Fish - Chronic
Desulfinylfipronil	Suspended Sediment	Insecticide	1.6	1.6	ng/L	OCRL		3	590	Fish - Chronic
Desulfinylfipronil amide	Water	Insecticide	3.2	3.2	ng/L	OCRL		3	--	--
Desulfinylfipronil amide	Suspended Sediment	Insecticide	3.2	3.2	ng/L	OCRL		2	--	--
Diazinon	Water	Insecticide	0.9	0.9	ng/L	OCRL		2	105	Invertebrates - Acute
Diazinon	Suspended Sediment	Insecticide	0.9	0.9	ng/L	OCRL		2	105	Invertebrates - Acute
Diazoxon	Water	Insecticide	5.0	5.0	ng/L	OCRL		2	--	--
Diazoxon	Suspended Sediment	Insecticide	5.0	5.0	ng/L	OCRL		2	--	--
Dichlorvos	Water	Insecticide	5.1	5.1	ng/L	OCRL	New in 2018	2	5.8	Invertebrates - Chronic
Dichlorvos	Suspended Sediment	Insecticide	5.1	5.1	ng/L	OCRL	New in 2018	3	5.8	Invertebrates - Chronic
Difenoconazole	Water	Fungicide	10.5	10.5	ng/L	OCRL		3	860	Fish - Chronic
Difenoconazole	Suspended Sediment	Fungicide	10.5	10.5	ng/L	OCRL		2	860	Fish - Chronic
Dimethomorph	Water	Fungicide	6.0	6.0	ng/L	OCRL		2	110,000	Invertebrates - Chronic
Dimethomorph	Suspended Sediment	Fungicide	6.0	6.0	ng/L	OCRL		2	110,000	Invertebrates - Chronic
Dinotefuran	Water	Insecticide	4.5	4.5	ng/L	OCRL		2	480,000	Fish - Chronic
Dithiopyr	Water	Herbicide	1.6	1.6	ng/L	OCRL		2	--	--
Dithiopyr	Suspended Sediment	Herbicide	1.6	1.6	ng/L	OCRL		2	--	--
Diuron	Water	Herbicide	3.2	3.2	ng/L	OCRL		2	2,400	Nonvascular plants - Acute
EPTC	Water	Herbicide	1.5	1.5	ng/L	OCRL		3	800,000	Invertebrates - Chronic
EPTC	Suspended Sediment	Herbicide	1.5	1.5	ng/L	OCRL		2	800,000	Invertebrates - Chronic
Esfenvalerate	Water	Insecticide	0.5	0.5	ng/L	OCRL		2	--	--
Esfenvalerate	Suspended Sediment	Insecticide	0.5	0.5	ng/L	OCRL		2	--	--
Ethaboxam	Water	Fungicide	3.8	3.8	ng/L	OCRL		2	7,000	Nonvascular plants - Acute
Ethalfluralin	Water	Herbicide	3.0	3.0	ng/L	OCRL		3	--	--
Ethalfluralin	Suspended Sediment	Herbicide	3.0	3.0	ng/L	OCRL		2	--	--

Constituent	Matrix	Reporting group	RL	MDL	Unit	Lab	Note	Method	Min. OPP Aquatic Life Benchmark (ng/L)	Benchmark Category
Etofenprox	Water	Insecticide	2.2	2.2	ng/L	OCRL		2	10.0	Invertebrates - Chronic
Etofenprox	Suspended Sediment	Insecticide	2.2	2.2	ng/L	OCRL		2	10.0	Invertebrates - Chronic
Etoxazole	Water	Insecticide	4.2	4.2	ng/L	OCRL	New in 2018	2	130	Invertebrates - Chronic
Etoxazole	Suspended Sediment	Insecticide	4.2	4.2	ng/L	OCRL	New in 2018	2	130	Invertebrates - Chronic
Famoxadone	Water	Fungicide	2.5	2.5	ng/L	OCRL		2	75,000	Invertebrates - Chronic
Famoxadone	Suspended Sediment	Fungicide	2.5	2.5	ng/L	OCRL		3	75,000	Invertebrates - Chronic
Fenamidone	Water	Fungicide	5.1	5.1	ng/L	OCRL		2	4,700	Fish - Chronic
Fenamidone	Suspended Sediment	Fungicide	5.1	5.1	ng/L	OCRL		3	4,700	Fish - Chronic
Fenarimol	Water	Fungicide	6.5	6.5	ng/L	OCRL		2	120,000	Invertebrates - Acute
Fenarimol	Suspended Sediment	Fungicide	6.5	6.5	ng/L	OCRL		2	120,000	Invertebrates - Acute
Fenbuconazole	Water	Fungicide	5.2	5.2	ng/L	OCRL		2	--	--
Fenbuconazole	Suspended Sediment	Fungicide	5.2	5.2	ng/L	OCRL		2	--	--
Fenhexamid	Water	Fungicide	7.6	7.6	ng/L	OCRL		2	101,000	Fish - Chronic
Fenhexamid	Suspended Sediment	Fungicide	7.6	7.6	ng/L	OCRL		2	101,000	Fish - Chronic
Fenpropathrin	Water	Insecticide	0.6	0.6	ng/L	OCRL		2	60.0	Fish - Chronic
Fenpropathrin	Suspended Sediment	Insecticide	0.6	0.6	ng/L	OCRL		3	60.0	Fish - Chronic
Fenpyroximate	Water	Insecticide	5.2	5.2	ng/L	OCRL		2	16.0	Fish - Chronic
Fenpyroximate	Suspended Sediment	Insecticide	5.2	5.2	ng/L	OCRL		2	16.0	Fish - Chronic
Fenthion	Water	Insecticide	5.5	5.5	ng/L	OCRL		3	13.0	Invertebrates - Chronic
Fenthion	Suspended Sediment	Insecticide	5.5	5.5	ng/L	OCRL		1	13.0	Invertebrates - Chronic
Fipronil	Water	Insecticide	2.9	2.9	ng/L	OCRL		1	100,000	Invertebrates - Chronic
Fipronil	Suspended Sediment	Insecticide	2.9	2.9	ng/L	OCRL		2	100,000	Invertebrates - Chronic
Fipronil sulfide	Water	Insecticide	1.8	1.8	ng/L	OCRL		2	110	Invertebrates - Chronic
Fipronil sulfide	Suspended Sediment	Insecticide	1.8	1.8	ng/L	OCRL		2	110	Invertebrates - Chronic
Fipronil sulfone	Water	Insecticide	3.5	3.5	ng/L	OCRL		2	37.0	Invertebrates - Chronic
Fipronil sulfone	Suspended Sediment	Insecticide	3.5	3.5	ng/L	OCRL		2	37.0	Invertebrates - Chronic
Flonicamid	Water	Insecticide	3.4	3.4	ng/L	OCRL		2	3,000,000	Invertebrates - Chronic
Fluazinam	Water	Fungicide	4.4	4.4	ng/L	OCRL		2	6,300	Invertebrates - Chronic
Fluazinam	Suspended Sediment	Fungicide	4.4	4.4	ng/L	OCRL		2	6,300	Invertebrates - Chronic
Flubendiamide	Water	Insecticide	6.2	6.2	ng/L	OCRL	New in 2018	2	140	Invertebrates - Acute
Flubendiamide	Suspended Sediment	Insecticide	6.2	6.2	ng/L	OCRL	New in 2018	2	140	Invertebrates - Acute
Fludioxonil	Water	Fungicide	7.3	7.3	ng/L	OCRL		2	1,000	Invertebrates - Chronic

Constituent	Matrix	Reporting group	RL	MDL	Unit	Lab	Note	Method	Min. OPP Aquatic Life Benchmark (ng/L)	Benchmark Category
Fludioxonil	Suspended Sediment	Fungicide	7.3	7.3	ng/L	OCRL		2	1,000	Invertebrates - Chronic
Flufenacet	Water	Herbicide	4.7	4.7	ng/L	OCRL		2	--	--
Flufenacet	Suspended Sediment	Herbicide	4.7	4.7	ng/L	OCRL		2	--	--
Flumetralin	Water	Other	5.8	5.8	ng/L	OCRL		2	830,000	Nonvascular plants - Acute
Flumetralin	Suspended Sediment	Other	5.8	5.8	ng/L	OCRL		1	830,000	Nonvascular plants - Acute
Fluopicolide	Water	Fungicide	3.9	3.9	ng/L	OCRL		2	1,100,000	Fish - Chronic
Fluopicolide	Suspended Sediment	Fungicide	3.9	3.9	ng/L	OCRL		2	1,100,000	Fish - Chronic
Fluopyram	Water	Fungicide	3.8	3.8	ng/L	OCRL	New in 2018	3	--	--
Fluopyram	Suspended Sediment	Fungicide	3.8	3.8	ng/L	OCRL	New in 2018	1	--	--
Fluoxastrobin	Water	Fungicide	9.5	9.5	ng/L	OCRL		2	13,000	Vascular plants - Acute
Fluoxastrobin	Suspended Sediment	Fungicide	9.5	9.5	ng/L	OCRL		3	13,000	Vascular plants - Acute
Flupyradifurone	Water	Insecticide	3.0	3.0	ng/L	OCRL	New in 2018	2	5,200	Nonvascular plants - Acute
Fluridone	Water	Herbicide	3.7	3.7	ng/L	OCRL		2	480,000	Fish - Chronic
Flusilazole	Water	Fungicide	4.5	4.5	ng/L	OCRL		1	290	Nonvascular plants - Acute
Flusilazole	Suspended Sediment	Fungicide	4.5	4.5	ng/L	OCRL		2	290	Nonvascular plants - Acute
Flutolanil	Water	Fungicide	4.4	4.4	ng/L	OCRL		2	220,000	Fish - Chronic
Flutolanil	Suspended Sediment	Fungicide	4.4	4.4	ng/L	OCRL		1	220,000	Fish - Chronic
Flutriafol	Water	Fungicide	4.2	4.2	ng/L	OCRL		3	310,000	Invertebrates - Chronic
Flutriafol	Suspended Sediment	Fungicide	4.2	4.2	ng/L	OCRL		3	310,000	Invertebrates - Chronic
Fluxapyroxad	Water	Fungicide	4.8	4.8	ng/L	OCRL		3	--	--
Fluxapyroxad	Suspended Sediment	Fungicide	4.8	4.8	ng/L	OCRL		3	--	--
Hexazinone	Water	Herbicide	8.4	8.4	ng/L	OCRL		3	7,000	Nonvascular plants - Acute
Hexazinone	Suspended Sediment	Herbicide	8.4	8.4	ng/L	OCRL		2	7,000	Nonvascular plants - Acute
Imazalil	Water	Fungicide	10.5	10.5	ng/L	OCRL		2	--	--
Imazalil	Suspended Sediment	Fungicide	10.5	10.5	ng/L	OCRL		3	--	--
Imidacloprid	Water	Insecticide	3.8	3.8	ng/L	OCRL		2	5,200	Nonvascular plants - Acute
Imidacloprid urea	Water	Insecticide	4.0	4.0	ng/L	OCRL	New in 2018	2	3,000	Vascular plants - Acute
Indoxacarb	Water	Insecticide	4.9	4.9	ng/L	OCRL		2	75,000	Invertebrates - Chronic
Indoxacarb	Suspended Sediment	Insecticide	4.9	4.9	ng/L	OCRL		2	75,000	Invertebrates - Chronic
Ipconazole	Water	Fungicide	7.8	7.8	ng/L	OCRL		3	180,000	Fish - Chronic
Ipconazole	Suspended Sediment	Fungicide	7.8	7.8	ng/L	OCRL		2	180,000	Fish - Chronic
Iprodione	Water	Fungicide	4.4	4.4	ng/L	OCRL		2	120,000	Invertebrates - Acute
Iprodione	Suspended Sediment	Fungicide	4.4	4.4	ng/L	OCRL		2	120,000	Invertebrates - Acute

Constituent	Matrix	Reporting group	RL	MDL	Unit	Lab	Note	Method	Min. OPP Aquatic Life Benchmark (ng/L)	Benchmark Category
Isofetamid	Water	Fungicide	2.0	2.0	ng/L	OCRL	New in 2018	2	86,000	Fish - Chronic
Isofetamid	Suspended Sediment	Fungicide	2.0	2.0	ng/L	OCRL	New in 2018	2	86,000	Fish - Chronic
Kresoxim-methyl	Water	Fungicide	4.0	4.0	ng/L	OCRL		3	299,200	Vascular plants - Acute
Kresoxim-methyl	Suspended Sediment	Fungicide	4.0	4.0	ng/L	OCRL		2	299,200	Vascular plants - Acute
Malaoxon	Water	Insecticide	5.0	5.0	ng/L	OCRL		3	--	--
Malaoxon	Suspended Sediment	Insecticide	5.0	5.0	ng/L	OCRL		2	--	--
Malathion	Water	Insecticide	3.7	3.7	ng/L	OCRL		2	49.0	Invertebrates - Acute
Malathion	Suspended Sediment	Insecticide	3.7	3.7	ng/L	OCRL		2	49.0	Invertebrates - Acute
Mandipropamid	Water	Fungicide	3.3	3.3	ng/L	OCRL		1	30,000	Invertebrates - Chronic
Metalaxyl	Water	Fungicide	5.1	5.1	ng/L	OCRL		2	1,500	Invertebrates - Chronic
Metalaxyl	Suspended Sediment	Fungicide	5.1	5.1	ng/L	OCRL		2	1,500	Invertebrates - Chronic
Metconazole	Water	Fungicide	5.2	5.2	ng/L	OCRL		2	--	--
Metconazole	Suspended Sediment	Fungicide	5.2	5.2	ng/L	OCRL		2	--	--
Methidathion	Water	Insecticide	7.2	7.2	ng/L	OCRL		2	1,040	Nonvascular plants - Acute
Methidathion	Suspended Sediment	Insecticide	7.2	7.2	ng/L	OCRL		2	1,040	Nonvascular plants - Acute
Methoprene	Water	Insecticide	6.4	6.4	ng/L	OCRL		1	9,100	Fish - Chronic
Methoprene	Suspended Sediment	Insecticide	6.4	6.4	ng/L	OCRL		2	9,100	Fish - Chronic
Methoxyfenozide	Water	Insecticide	2.7	2.7	ng/L	OCRL		2	299,200	Vascular plants - Acute
Methyl parathion	Water	Insecticide	3.4	3.4	ng/L	OCRL		2	21,000	Nonvascular plants - Acute
Methyl parathion	Suspended Sediment	Insecticide	3.4	3.4	ng/L	OCRL		2	21,000	Nonvascular plants - Acute
Metolachlor	Water	Herbicide	1.5	1.5	ng/L	OCRL		2	1,000	Invertebrates - Chronic
Metolachlor	Suspended Sediment	Herbicide	1.5	1.5	ng/L	OCRL		2	1,000	Invertebrates - Chronic
Molinate	Water	Herbicide	3.2	3.2	ng/L	OCRL		3	105,000	Fish - Acute
Molinate	Suspended Sediment	Herbicide	3.2	3.2	ng/L	OCRL		2	105,000	Fish - Acute
Myclobutanil	Water	Fungicide	6.0	6.0	ng/L	OCRL		3	830,000	Nonvascular plants - Acute
Myclobutanil	Suspended Sediment	Fungicide	6.0	6.0	ng/L	OCRL		3	830,000	Nonvascular plants - Acute
Napropamide	Water	Herbicide	8.2	8.2	ng/L	OCRL		2	20,000	Fish - Chronic
Napropamide	Suspended Sediment	Herbicide	8.2	8.2	ng/L	OCRL		2	20,000	Fish - Chronic
Novaluron	Water	Insecticide	2.9	2.9	ng/L	OCRL		2	30.0	Invertebrates - Chronic
Novaluron	Suspended Sediment	Insecticide	2.9	2.9	ng/L	OCRL		2	30.0	Invertebrates - Chronic
Oryzalin	Water	Herbicide	5.0	5.0	ng/L	OCRL		2	13,000	Fish - Chronic
Oxadiazon	Water	Herbicide	2.1	2.1	ng/L	OCRL		3	5,200	Nonvascular plants - Acute

Constituent	Matrix	Reporting group	RL	MDL	Unit	Lab	Note	Method	Min. OPP Aquatic Life Benchmark (ng/L)	Benchmark Category
Oxadiazon	Suspended Sediment	Herbicide	2.1	2.1	ng/L	OCRL		2	5,200	Nonvascular plants - Acute
Oxathiapiprolin	Water	Fungicide	3.2	3.2	ng/L	OCRL	New in 2018	3	140,000	Nonvascular plants - Acute
Oxyfluorfen	Water	Herbicide	3.1	3.1	ng/L	OCRL		3	2,240	Nonvascular plants - Acute
Oxyfluorfen	Suspended Sediment	Herbicide	3.1	3.1	ng/L	OCRL		2	2,240	Nonvascular plants - Acute
p,p'-DDD	Water	Insecticide	4.1	4.1	ng/L	OCRL		1	--	--
p,p'-DDD	Suspended Sediment	Insecticide	4.1	4.1	ng/L	OCRL		2	--	--
p,p'-DDE	Water	Insecticide	3.6	3.6	ng/L	OCRL		1	--	--
p,p'-DDE	Suspended Sediment	Insecticide	3.6	3.6	ng/L	OCRL		3	--	--
p,p'-DDT	Water	Insecticide	4.0	4.0	ng/L	OCRL		1	--	--
p,p'-DDT	Suspended Sediment	Insecticide	4.0	4.0	ng/L	OCRL		2	--	--
Paclobutrazol	Water	Fungicide	6.2	6.2	ng/L	OCRL		2	8,000	Vascular plants - Acute
Paclobutrazol	Suspended Sediment	Fungicide	6.2	6.2	ng/L	OCRL		2	8,000	Vascular plants - Acute
Pebulate	Water	Herbicide	2.3	2.3	ng/L	OCRL		3	230,000	Nonvascular plants - Acute
Pebulate	Suspended Sediment	Herbicide	2.3	2.3	ng/L	OCRL		3	230,000	Nonvascular plants - Acute
Pendimethalin	Water	Herbicide	2.3	2.3	ng/L	OCRL		1	5,200	Nonvascular plants - Acute
Pendimethalin	Suspended Sediment	Herbicide	2.3	2.3	ng/L	OCRL		3	5,200	Nonvascular plants - Acute
Penoxsulam	Water	Herbicide	3.5	3.5	ng/L	OCRL		2	3,000	Vascular plants - Acute
Pentachloroanisole	Water	Insecticide	4.7	4.7	ng/L	OCRL		2	190,000	Invertebrates - Chronic
Pentachloroanisole	Suspended Sediment	Insecticide	4.7	4.7	ng/L	OCRL		2	190,000	Invertebrates - Chronic
Pentachloronitrobenzene	Water	Fungicide	3.1	3.1	ng/L	OCRL		2	13,000	Fish - Chronic
Pentachloronitrobenzene	Suspended Sediment	Fungicide	3.1	3.1	ng/L	OCRL		2	13,000	Fish - Chronic
Penthiopyrad	Water	Fungicide	3.2	3.2	ng/L	OCRL	New in 2018	2	100,000	Fish - Chronic
Permethrin	Water	Insecticide	0.6	0.6	ng/L	OCRL		2	42,000	Invertebrates - Chronic
Permethrin	Suspended Sediment	Insecticide	0.6	0.6	ng/L	OCRL		3	42,000	Invertebrates - Chronic
Phenothrin	Water	Insecticide	1.0	1.0	ng/L	OCRL		2	470	Invertebrates - Chronic
Phenothrin	Suspended Sediment	Insecticide	1.0	1.0	ng/L	OCRL		3	470	Invertebrates - Chronic
Phosmet	Water	Insecticide	4.4	4.4	ng/L	OCRL		2	17,500	Invertebrates - Acute
Phosmet	Suspended Sediment	Insecticide	4.4	4.4	ng/L	OCRL		1	17,500	Invertebrates - Acute
Picoxystrobin	Water	Fungicide	4.2	4.2	ng/L	OCRL		3	1,000	Invertebrates - Chronic
Picoxystrobin	Suspended Sediment	Fungicide	4.2	4.2	ng/L	OCRL		2	1,000	Invertebrates - Chronic
Piperonyl butoxide	Water	Other	2.3	2.3	ng/L	OCRL		2	30,000	Invertebrates - Chronic
Piperonyl butoxide	Suspended Sediment	Other	2.3	2.3	ng/L	OCRL		2	30,000	Invertebrates - Chronic

Constituent	Matrix	Reporting group	RL	MDL	Unit	Lab	Note	Method	Min. OPP Aquatic Life Benchmark (ng/L)	Benchmark Category
Prodiamine	Water	Herbicide	5.2	5.2	ng/L	OCRL		2	1,500	Invertebrates - Chronic
Prodiamine	Suspended Sediment	Herbicide	5.2	5.2	ng/L	OCRL		2	1,500	Invertebrates - Chronic
Prometon	Water	Herbicide	2.5	2.5	ng/L	OCRL		2	1,000	Invertebrates - Chronic
Prometon	Suspended Sediment	Herbicide	2.5	2.5	ng/L	OCRL		2	1,000	Invertebrates - Chronic
Prometryn	Water	Herbicide	1.8	1.8	ng/L	OCRL		2	1,040	Nonvascular plants - Acute
Prometryn	Suspended Sediment	Herbicide	1.8	1.8	ng/L	OCRL		1	1,040	Nonvascular plants - Acute
Propanil	Water	Herbicide	10.1	10.1	ng/L	OCRL		2	9,100	Fish - Chronic
Propanil	Suspended Sediment	Herbicide	10.1	10.1	ng/L	OCRL		2	9,100	Fish - Chronic
Propargite	Water	Insecticide	6.1	6.1	ng/L	OCRL		2	7,000	Invertebrates - Acute
Propargite	Suspended Sediment	Insecticide	6.1	6.1	ng/L	OCRL		2	7,000	Invertebrates - Acute
Propiconazole	Water	Fungicide	5.0	5.0	ng/L	OCRL		2	21,000	Nonvascular plants - Acute
Propiconazole	Suspended Sediment	Fungicide	5.0	5.0	ng/L	OCRL		3	21,000	Nonvascular plants - Acute
Propyzamide	Water	Herbicide	5.0	5.0	ng/L	OCRL		2	224,000	Fish - Chronic
Propyzamide	Suspended Sediment	Herbicide	5.0	5.0	ng/L	OCRL		2	224,000	Fish - Chronic
Pyraclostrobin	Water	Fungicide	2.9	2.9	ng/L	OCRL		2	1,500	Nonvascular plants - Acute
Pyraclostrobin	Suspended Sediment	Fungicide	2.9	2.9	ng/L	OCRL		2	1,500	Nonvascular plants - Acute
Pyridaben	Water	Insecticide	5.4	5.4	ng/L	OCRL		2	2,760	Invertebrates - Chronic
Pyridaben	Suspended Sediment	Insecticide	5.4	5.4	ng/L	OCRL		2	2,760	Invertebrates - Chronic
Pyrimethanil	Water	Fungicide	4.1	4.1	ng/L	OCRL		2	20,000	Fish - Chronic
Pyrimethanil	Suspended Sediment	Fungicide	4.1	4.1	ng/L	OCRL		2	20,000	Fish - Chronic
Pyriproxyfen	Water	Other	5.2	5.2	ng/L	OCRL	New in 2018	3	15.0	Invertebrates - Chronic
Pyriproxyfen	Suspended Sediment	Other	5.2	5.2	ng/L	OCRL	New in 2018	3	15.0	Invertebrates - Chronic
Quinoxyfen	Water	Fungicide	3.3	3.3	ng/L	OCRL		2	13,000	Fish - Chronic
Quinoxyfen	Suspended Sediment	Fungicide	3.3	3.3	ng/L	OCRL		2	13,000	Fish - Chronic
Resmethrin	Water	Insecticide	1.0	1.0	ng/L	OCRL		2	140	Fish - Acute
Resmethrin	Suspended Sediment	Insecticide	1.0	1.0	ng/L	OCRL		2	140	Fish - Acute
Sedaxane	Water	Fungicide	5.2	5.2	ng/L	OCRL		2	--	--
Sedaxane	Suspended Sediment	Fungicide	5.2	5.2	ng/L	OCRL		2	--	--
Simazine	Water	Herbicide	5.0	5.0	ng/L	OCRL		3	2,240	Nonvascular plants - Acute
Simazine	Suspended Sediment	Herbicide	5.0	5.0	ng/L	OCRL		3	2,240	Nonvascular plants - Acute
Sulfoxaflor	Water	Insecticide	4.4	4.4	ng/L	OCRL	New in 2018	2	24,500	Invertebrates - Acute
tau-Fluvalinate	Water	Insecticide	0.7	0.7	ng/L	OCRL		2	64.0	Fish - Chronic
tau-Fluvalinate	Suspended Sediment	Insecticide	0.7	0.7	ng/L	OCRL		2	64.0	Fish - Chronic

Constituent	Matrix	Reporting group	RL	MDL	Unit	Lab	Note	Method	Min. OPP Aquatic Life Benchmark (ng/L)	Benchmark Category
Tebuconazole	Water	Fungicide	3.7	3.7	ng/L	OCRL		2	11,000	Fish - Chronic
Tebuconazole	Suspended Sediment	Fungicide	3.7	3.7	ng/L	OCRL		2	11,000	Fish - Chronic
Tebufenozide	Water	Insecticide	3.0	3.0	ng/L	OCRL	New in 2018	2	29,000	Invertebrates - Chronic
Tebupirimfos	Water	Insecticide	1.9	1.9	ng/L	OCRL		2	299,200	Vascular plants - Acute
Tebupirimfos	Suspended Sediment	Insecticide	1.9	1.9	ng/L	OCRL		3	299,200	Vascular plants - Acute
Tebupirimfos oxon	Water	Insecticide	2.8	2.8	ng/L	OCRL		2	--	--
Tebupirimfos oxon	Suspended Sediment	Insecticide	2.8	2.8	ng/L	OCRL		2	--	--
Tefluthrin	Water	Insecticide	0.6	0.6	ng/L	OCRL		2	4.0	Fish - Chronic
Tefluthrin	Suspended Sediment	Insecticide	0.6	0.6	ng/L	OCRL		2	4.0	Fish - Chronic
Tetraconazole	Water	Fungicide	5.6	5.6	ng/L	OCRL		3	190,000	Invertebrates - Chronic
Tetraconazole	Suspended Sediment	Fungicide	5.6	5.6	ng/L	OCRL		2	190,000	Invertebrates - Chronic
Tetradifon	Water	Insecticide	3.8	3.8	ng/L	OCRL		2	--	--
Tetradifon	Suspended Sediment	Insecticide	3.8	3.8	ng/L	OCRL		2	--	--
Tetramethrin	Water	Insecticide	0.5	0.5	ng/L	OCRL		2	1,850	Fish - Acute
Tetramethrin	Suspended Sediment	Insecticide	0.5	0.5	ng/L	OCRL		2	1,850	Fish - Acute
Thiabendazole	Water	Fungicide	3.6	3.6	ng/L	OCRL		2	42,000	Invertebrates - Chronic
Thiacloprid	Water	Insecticide	3.2	3.2	ng/L	OCRL		3	970	Invertebrates - Chronic
Thiamethoxam	Water	Insecticide	3.4	3.4	ng/L	OCRL		2	17,500	Invertebrates - Acute
Thiamethoxam Degradate (CGA-355190)	Water	Insecticide	3.5	3.5	ng/L	OCRL	New in 2018	3	--	--
Thiamethoxam Degradate (NOA-407475)	Water	Insecticide	3.4	3.4	ng/L	OCRL	New in 2018	2	--	--
Thiazopyr	Water	Herbicide	4.1	4.1	ng/L	OCRL		2	--	--
Thiazopyr	Suspended Sediment	Herbicide	4.1	4.1	ng/L	OCRL		2	--	--
Thiobencarb	Water	Herbicide	1.9	1.9	ng/L	OCRL		2	1,000	Invertebrates - Chronic
Thiobencarb	Suspended Sediment	Herbicide	1.9	1.9	ng/L	OCRL		2	1,000	Invertebrates - Chronic
Tolfenpyrad	Water	Insecticide	2.9	2.9	ng/L	OCRL		2	81.5	Fish - Acute
Triadimefon	Water	Fungicide	8.9	8.9	ng/L	OCRL		2	52,000	Invertebrates - Chronic
Triadimefon	Suspended Sediment	Fungicide	8.9	8.9	ng/L	OCRL		3	52,000	Invertebrates - Chronic
Triadimenol	Water	Fungicide	8.0	8.0	ng/L	OCRL		2	--	--
Triadimenol	Suspended Sediment	Fungicide	8.0	8.0	ng/L	OCRL		2	--	--
Triallate	Water	Herbicide	2.4	2.4	ng/L	OCRL		3	14,000	Invertebrates - Chronic
Triallate	Suspended Sediment	Herbicide	2.4	2.4	ng/L	OCRL		1	14,000	Invertebrates - Chronic
Tribufos	Water	Herbicide	3.1	3.1	ng/L	OCRL		1	1,560	Invertebrates - Chronic

Constituent	Matrix	Reporting group	RL	MDL	Unit	Lab	Note	Method	Min. OPP Aquatic Life Benchmark (ng/L)	Benchmark Category
Tribufos	Suspended Sediment	Herbicide	3.1	3.1	ng/L	OCRL		2	1,560	Invertebrates - Chronic
Tricyclazole	Water	Fungicide	4.1	4.1	ng/L	OCRL	New in 2018	2	--	--
Trifloxystrobin	Water	Fungicide	4.7	4.7	ng/L	OCRL		2	2,760	Invertebrates - Chronic
Trifloxystrobin	Suspended Sediment	Fungicide	4.7	4.7	ng/L	OCRL		2	2,760	Invertebrates - Chronic
Triflumizole	Water	Fungicide	6.1	6.1	ng/L	OCRL		2	33,000	Fish - Chronic
Triflumizole	Suspended Sediment	Fungicide	6.1	6.1	ng/L	OCRL		2	33,000	Fish - Chronic
Trifluralin	Water	Herbicide	2.1	2.1	ng/L	OCRL		2	1,900	Fish - Chronic
Trifluralin	Suspended Sediment	Herbicide	2.1	2.1	ng/L	OCRL		2	1,900	Fish - Chronic
Triticonazole	Water	Fungicide	6.9	6.9	ng/L	OCRL		2	--	--
Triticonazole	Suspended Sediment	Fungicide	6.9	6.9	ng/L	OCRL		2	--	--
Zoxamide	Water	Fungicide	3.5	3.5	ng/L	OCRL		2	3,480	Fish - Chronic
Zoxamide	Suspended Sediment	Fungicide	3.5	3.5	ng/L	OCRL		2	3,480	Fish - Chronic

Appendix 2 USGS PFRG Data Review Process

This information applies to all analytical results generated by the Pesticide Fate Research Group (PFRG) Organic Chemistry Research Laboratory (OCRL).

Following sample analysis at the OCRL all analytical results are reviewed by the USGS Project Director (PD) responsible for submitting the samples for analysis. Results are reviewed as they become available from the laboratory. The PD reviews each sample for completeness to ensure that all requested analytes have been quantitated, and reviews each analytical result for unexpected presence/absence or unexpectedly high or low result values (based on previous results and/or known trends in pesticide use and occurrence). If quality control samples were analyzed the PD reviews these samples to ensure that project measurement quality objectives, as outlined in the project Quality Assurance Project Plan (QAPP), have been met. During these review processes the PD flags any suspect results which are then sent back to the OCRL Chief Chemist (CC) for review. The CC then reviews the quantitation for any flagged results to verify the initial result or make corrections as appropriate. If questions persist as to the quality of the data, sample extracts may be reanalyzed. Additionally, samples with high results which fall outside the instrument calibration curve, may be diluted and reanalyzed at this time. The CC then returns the final, verified results to the PD for review. If questions regarding the data persist, the USGS California Water Science Center (CAWSC) Water Quality Specialist will be consulted to review the data and make any suggestions for corrective actions and/or proper coding of the data. If the PD has no further questions or comments about the data they are entered in the project specific data reporting spreadsheet.

At the end of the project, or at an earlier date as specified in the project QAPP or data management plan, the finalized data reporting spreadsheet is provided to the PFRG database manager (DM). The DM then enters the laboratory analytical results in the OCRL Access database which also contains field sample collection and laboratory sample tracking information. The DM then performs a semi-automated process to format the analytical results and necessary field collection information for entry into the USGS National Water Information System (NWIS) database. Once formatted, the data are uploaded to NWIS using a batch process. All data are uploaded to NWIS with a "Data Quality Indicator" code of "Provisional". At this point the data are publicly viewable.

Prior to publication in any USGS series report the data undergo an additional, extensive review process. During this process the CAWSC Water Quality Specialist reviews the draft publication and data to ensure that they meet USGS accuracy and reporting standards. CAWSC data management staff (DMS) also review the data to verify that the data in the publication match the data stored in NWIS. Once the publication and data have been approved by the Water Quality Specialist and DMS the PFRG DM will switch the data quality indicator codes for all data results to "Reviewed and Accepted".

In rare instances where OCRL data are not reported in a USGS series report or scientific journal the data will be reviewed and approved by the CAWSC Water Quality Specialist prior to the PFRG DM switching the data quality indicator codes to "Reviewed and Accepted".

The following information applies to results from the USGS National Water Quality Laboratory (NWQL), produced for projects managed by PFRG personnel.

Some research projects may require that samples be submitted to the NWQL for analysis. Analytical results produced by the NWQL are reviewed by the PD as they become available from the laboratory. The PD reviews each sample for completeness to ensure that all requested analytes have been reported, and reviews each analytical result for unexpected presence/absence or unexpectedly high or low result values (based on previous results and/or known trends in pesticide use and occurrence). If quality control samples were analyzed the PD reviews these samples to ensure that specific project measurement quality objectives as outlined in the project Quality Assurance Project Plan (QAPP) have been met. During these processes the PD flags any suspect results and may request a rerun of the sample if possible, or work with laboratory personnel to better understand/evaluate unexpected results. The PD also manually queries NWQL laboratory QC data for relevant analytical batches. These data are evaluated by the PD to determine if any environmental or field QC samples need to be coded in NWIS to reflect laboratory QC problems. All NWQL environmental, field QC, and laboratory QC data are entered in a project specific data reporting spreadsheet.

Environmental and field QC data produced by the NWQL are automatically flagged for some laboratory quality control issues as described in the NWQL's Quality Assurance and Quality Control Manual available at (http://wwwnwql.cr.usgs.gov/qas/QCM_v1.0.pdf). Data are automatically uploaded to the USGS NWIS database with a "Data Quality Indicator" code of "Provisional" At this point the data are publicly viewable.

Prior to publication in any USGS series report the data undergo an additional, extensive review process. During this process the CAWSC Water Quality Specialist reviews the draft publication and data to ensure that they meet USGS accuracy and reporting standards. CAWSC data management staff (DMS) also review the data to verify that the data in the publication match the data stored in NWIS. Once the publication and data have been approved by the Water Quality Specialist and DMS the PFRG DM will switch the data quality indicator codes for all data points to "Reviewed and Accepted".

In rare instances where PFRG project data produced by the NWQL are not reported in a USGS series report or scientific journal the data will be reviewed and approved by the CAWSC Water Quality Specialist prior to the PFRG DM switching the data quality indicator codes to "Reviewed and Accepted."

The following information applies to analytical results produced by the OCRL or USGS National Water Quality Laboratory (NWQL), which are submitted to non-USGS environmental databases (for example CEDEN).

Some research projects may require that analytical results be submitted to non-USGS environmental databases, in addition to NWIS, for storage. In addition to the data quality review procedures described earlier in this document, data destined for non-USGS databases undergo additional data formatting and review prior to submittal. After the data have been entered into the PFRG Access database the PFRG DM performs a semi-automated process to format the analytical results and necessary field collection information for entry into the external database using that database's coding and required fields. The formatted upload files are then provided to two USGS PFRG personnel for review. Each reviewer performs an independent review comparing analytical results, field collection information and method detection limits to data contained in the PFRG Access and USGS NWIS databases. Any discrepancies are flagged by the reviewers and the DM is notified. The DM makes any necessary corrections to the upload files which are then resubmitted to the reviewers to verify the corrections. Once this internal review process is completed the data are submitted to the non-USGS database and undergo any review processes pertinent to that database.

Appendix 3 Statistical Power Analysis

APPLIED marine SCIENCES

Technical Memorandum

TO: Matthew Heberger (Aquatic Science Center)

FROM: Aroon Melwani (Applied Marine Sciences, Inc.)

DATE: April 26, 2018

SUBJECT: Statistical Analysis to Support the Delta Regional Monitoring (DRMP) Program FY 2018 Pesticide Monitoring Designs

Background

The Delta Regional Monitoring Program (DRMP) includes evaluation of current-use pesticides and the extent to which they contribute to observed aquatic toxicity in the Delta. Between July 2015 and June 2017 (FY 2015-2016 and FY 2016-17), the DRMP collected baseline monthly water samples at five integrator sites that were analyzed for pesticides and paired toxicity analysis of 4-5 different species/endpoints (Figure 1). The DRMP is now undertaking an evaluation of these data to optimize the sampling design for future pesticides monitoring, with the specific goal of detecting a significant relationship between aquatic concentrations and toxicity.

On behalf of the DRMP Pesticides Subcommittee, the Aquatic Science Center contracted with Dr. Aroon Melwani (Applied Marine Sciences, Inc.) to conduct a power analysis and provide technical guidance towards employing a targeted or probabilistic sampling design for pesticides monitoring. The scope of work consisted of three tasks: 1) a preliminary analysis of variability in pesticide concentrations to inform stratification of baseline data, 2) evaluation of power to detect statistical relationships between pesticide concentrations and toxicity across a range of sample sizes, and 3) guidance on sampling effort and bias associated with probabilistic monitoring designs. This memorandum summarizes the results from these evaluations. This information is being used by the DRMP Pesticide Subcommittee to facilitate further discussions about an appropriate monitoring study design to address DRMP priorities.

Methods

A two-year dataset of 152 pesticides (including degradates) analyzed monthly between June 2015 – July 2017 at five integrator sites in the Delta were the basis for all statistical analyses discussed herein. Only dissolved pesticide concentrations were used.

Based on initial discussions with the Pesticides Subcommittee, these data were summarized for analysis using the Pesticide Toxicity Index (PTI) values, following the methods of Munn and Gilliom (2001) and Nowell et al. (2014). The PTI is an index that combines the measured concentrations of any number of pesticides into a single value, to assess the potential toxicity of pesticide mixtures to freshwater aquatic organisms. It is

based on the concept of additive toxic units, well known in the field of risk assessment. TUs were calculated for individual compounds that were measured above the method detection limits, and summed for each location and sampling event using a database query in MS Access. The spreadsheet and database are available upon request from Matthew Heberger (matth@sfei.org).

Application of the PTI calculation to the pesticide concentration data resulted in a single index value for each analyzed sample (n = 24 per site; N = 120 total). It should be noted that several calculation assumptions exist for summarizing pesticide concentration into the PTI. To provide the most relevant and conservative calculation methodology for integration with the DRMP toxicity data, the Fish Sensitive and Cladoceran Sensitive calculations were used. Methods to represent an invertebrate endpoint or less conservative assumptions also exist.

Two chronic toxicity tests were selected for statistical evaluations based on recommendations from the Pesticides Subcommittee. For comparison to the Cladoceran Sensitive PTI, the *Ceriodaphnia dubia* reproductive test was selected (Figure 2), while for the Fish Sensitive PTI, the *Pimephales promelas* survival test was used (Figure 3). All toxicity results (as % effect) were included, irrespective if the result was statistically significant or not.

Task 1. PTI Variability

The PTI data were initially assessed for patterns in variability to generate appropriate simulated data for power analysis. Summary statistics of the PTI results for the five sites are provided for context (Tables 1 and 2).

An analysis of variance test was used to determine significant differences in the PTI data. Due to the lack of temporal resolution and replication (1 sample per site per month for two years; n = 2 per group), temporal effects could not be tested with this analysis. The analysis of variance thus focused on spatial variability.

Based on the ANOVA results, two variance groups were identified by pooling sites that were not statistically different ($p < 0.05$). Significance of groups was established through the use of 'dummy' variables for each site in the ANOVA tests. Subsequently, the mean, standard deviation, and coefficient of variation were calculated by stratifying the data into the respective groups ("A" and "B").

Task 2. Power Analysis

A power analysis simulation was designed to evaluate the necessary sample size to make statistical associations between PTI data and toxicity. The power analysis procedure simulated 2000 datasets, based on estimates of arithmetic mean and variability (standard deviation) in PTI for each variance group and sample size scenario. It assumed for each scenario that the modeled level of variation remains constant during the monitoring period. Sample size was varied from n = 12 to n = 240.

The statistical model for examining the PTI vs. toxicity relationship was:

$$y_i = y_o + r(PTI) + \varepsilon \qquad \textit{(Equation 1)}$$

Where, y_i = a simulated toxic effect value, y_o = the initial toxic effect value (intercept), r = slope of toxic effect vs. PTI (the effect size), PTI = individual pesticide toxicity index value, and ε (model error) is a normally distributed error term. The error term estimate was calculated as the standard deviation of the regression model error (i.e., sigma, δ). In employing this methodology, it is acknowledged that the model error estimate (ε) consists of the unexplained temporal variance as well as other potential driving factors.

Linear regression analysis was performed on each simulated dataset to determine statistical significance (p-value). The proportion of results that exhibited statistically significant slopes ($p < 0.05$) estimated the statistical power. The results of the power analysis were summarized in power curves (sample size vs. power) at varying effect sizes. The effect sizes selected were approximately an order of magnitude higher than the current size of the slope in the PTI: toxicity endpoint relationships.

Task 3. Probabilistic Monitoring

To address the final task in the scope of work, a technical review of the main concepts and recommendations for designing an ambient monitoring design was presented to the DRMP Pesticides Subcommittee. A summary of the design concepts discussed with the group is provided below.

Results

Task 1. PTI Variability

Two PTI datasets were assessed for spatial differences. Tables 1 and 2 summarize the mean PTI and variance for each site.[1] For either calculation model (Fish or Cladoceran), Ulatis Creek exhibited average PTI and standard deviation that was twice that of the other sites. As a result, two variance scenarios were developed (A and B) to represent the range in future pesticide distributions.

Task 2. Power Analysis

Summary statistics of the two groups (Table 3) indicate that the coefficient of variation in each group was similar, but Group B (only Ulatis Creek) exhibited higher pesticide concentrations (and thus higher PTI values) than Group A. No significant relationship was apparent in the baseline data for either scenario or toxicity endpoint (Figure 4).

[1] In general, TU values approaching 1 are cause for concern. However, According to Nowell et al. (2004), PTIS is "not necessarily appropriate as a sensitive tool for predicting whether pesticide mixtures in water samples are likely to be toxic to aquatic organisms." Rather, it was originally designed to be an indicator of relative toxicity. PTI values for samples, seasons, or sites have been used as explanatory variables in multivariate analyses designed to determine the environmental variables that best explain spatial patterns in the structure of a biological community."

Power curves employing the Cladoceran PTI using the Group A scenario indicated that to detect an effect size = 0.03 with > 80% power would require ~ 60 samples (Figure 5). For an effect size = 0.02, the same variance scenario would require > 75 samples.

Due to higher concentrations under the Group B scenario, power indicated that smaller effect sizes could be detected with similar levels of effort to Group A (Figure 6). For example, where an effect size = 0.03 would require a minimum of 60 samples to achieve > 80% power in Group A, a similar level of effort could detect an effect size < 0.01.

In the scenarios to test the relationship between the Fish PTI and *Pimephales* toxicity, similar patterns were evident to the *Ceriodaphnia* results. Generally, the scenarios using Group B (Ulatis Creek) indicated 80% power could be achieved with similar levels of effort of Group A and 50% smaller effect sizes. This is important observation given the current lack of significant relationships at any of the sites. For example, an effect size of 0.3 with 60 samples would have > 80% power in Group B, as would an effect size of 0.6 with 60 samples in Group A.

Task 3. Probabilistic Designs

A probability sample is one where every element of the target population has a known likelihood of being selected. Two important features of a probability sample are that the site selection mechanism safeguards against selection bias, and is the basis for inference to characteristics of the entire target population. Good sampling designs tend to spread out the sample points more or less regularly.

U.S. EPA's Generalized Random Tessellation Stratified (GRTS) survey design methodology is a probabilistic sampling method for implementing a spatial survey (Stevens and Olsen, 2004), which has been adopted in many regional surveys in California and nationwide. GRTS incorporates several design concepts important for making inferences across a population with unbiased estimates of condition (Kincaid and Olsen, 2016), these include: 1) Stratified sampling; 2) Unequal probability sampling; 3) Panel sampling; 4) Over-sample selection.

No explicit guidance on the recommended sample size for GRTS survey designs exists. Budgetary and logistical constraints of individual study designs often dictate the level of effort employed. That said, probabilistic designs incorporating GRTS often aim to determine an estimate of a proportional extent, and thus refer to the binomial distribution to evaluate precision. Figure 7 depicts the binomial relationship between sample size and size of confidence interval for determining the likelihood that a sample estimate is within 80% of the population. In this scenario, a sample size of 30 would result in an estimated confidence interval of ~ 12%. Increasing the sample size would not significantly impact on the size of the confidence interval, while fewer than 30 samples would increase the confidence interval substantially. Consequently, a sample size of 30 can be considered an "industry standard", and has, in my experience, been selected as a default sample size in order to make statistical inferences about condition, with a relatively low degree of error. Ultimately, deciding upon an appropriate sample size for GRTS for the DRMP will require

consideration of the monitoring objectives, precision desired, and the expected variability in the resource being sampled.

Conclusions

The take-home points from the power analysis simulations are:

- The Pesticide Toxicity Index does not exhibit a significant relationship with baseline DRMP toxicity results
- Ulatis Creek simulations indicate the highest probability of detecting small effect sizes in PTI-toxicity relationships in the future, due to the presence of some higher concentrations and toxic hits
- Using the Fish PTI, effect size would need to increase by 4-20x to detect significant relationship in the next 5-10 years (assuming n = 6-12/yr)

Overall, the baseline integrator site data set appears to only have captured a handful of high concentrations, which do not currently associate with toxicity results. The lack of extreme concentrations or frequently toxic samples in these short-term data sets does not necessarily mean that such events would not occur had a longer period been monitored. Though, it might just be as equally probable to spend continued effort to sample high concentrations / toxicity that are simply not present. Conversely, where high concentrations have been found (such as at Ulatis Creek), it is difficult to evaluate how common or rare such occurrences are, and what the underlying factors that are driving these variations. Therefore, the DRMP could benefit from implementing a probabilistic sampling approach, which incorporates spatial and temporal sampling to distinguish sites and seasons with sufficiently elevated concentrations to make associations with toxicity due to the presence of likely sources/runoff patterns. At a minimum, expanding upon the baseline resolution of pesticides sampling is a necessary next step for the Program.

References

Kincaid, T. M. and Olsen, A. R. (2016). spsurvey: Spatial Survey Design and Analysis. R package version 3.3.

Stevens, D.L., Jr., and Olsen, A.R. (2004). Spatially-balanced sampling of natural resources. Journal of the American Statistical Association 99: 262-278.

Figures

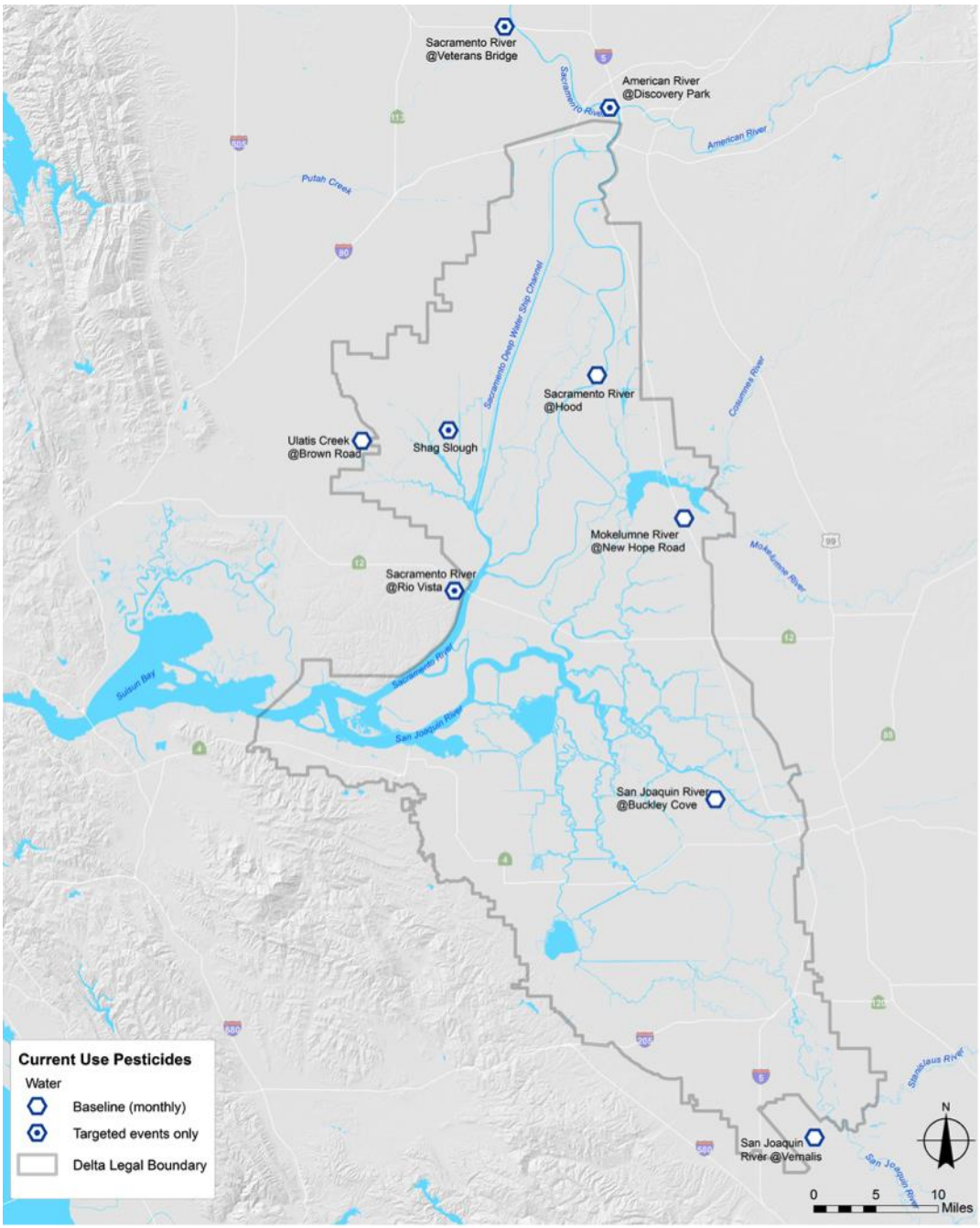

Figure 1. Map of Delta RMP integrator sites for pesticides sampling

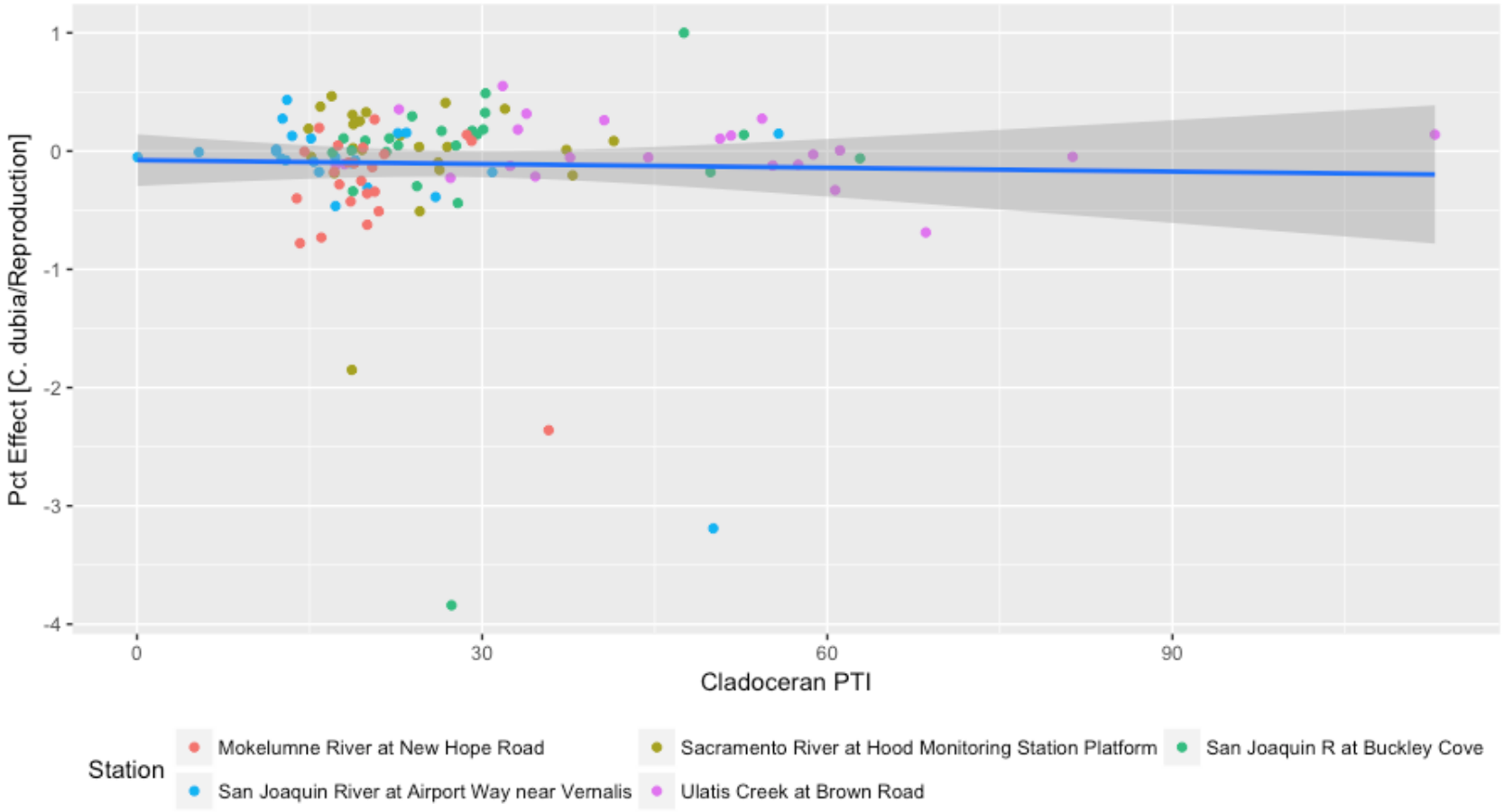

Figure 2. Pesticide Toxicity Index (PTI, Cladoceran) plotted against Percent Toxic Effect in *Ceriodaphnia dubia* / Reproduction test. Colors designate each site. The trend line indicates there is no clear relationship between the two variables.

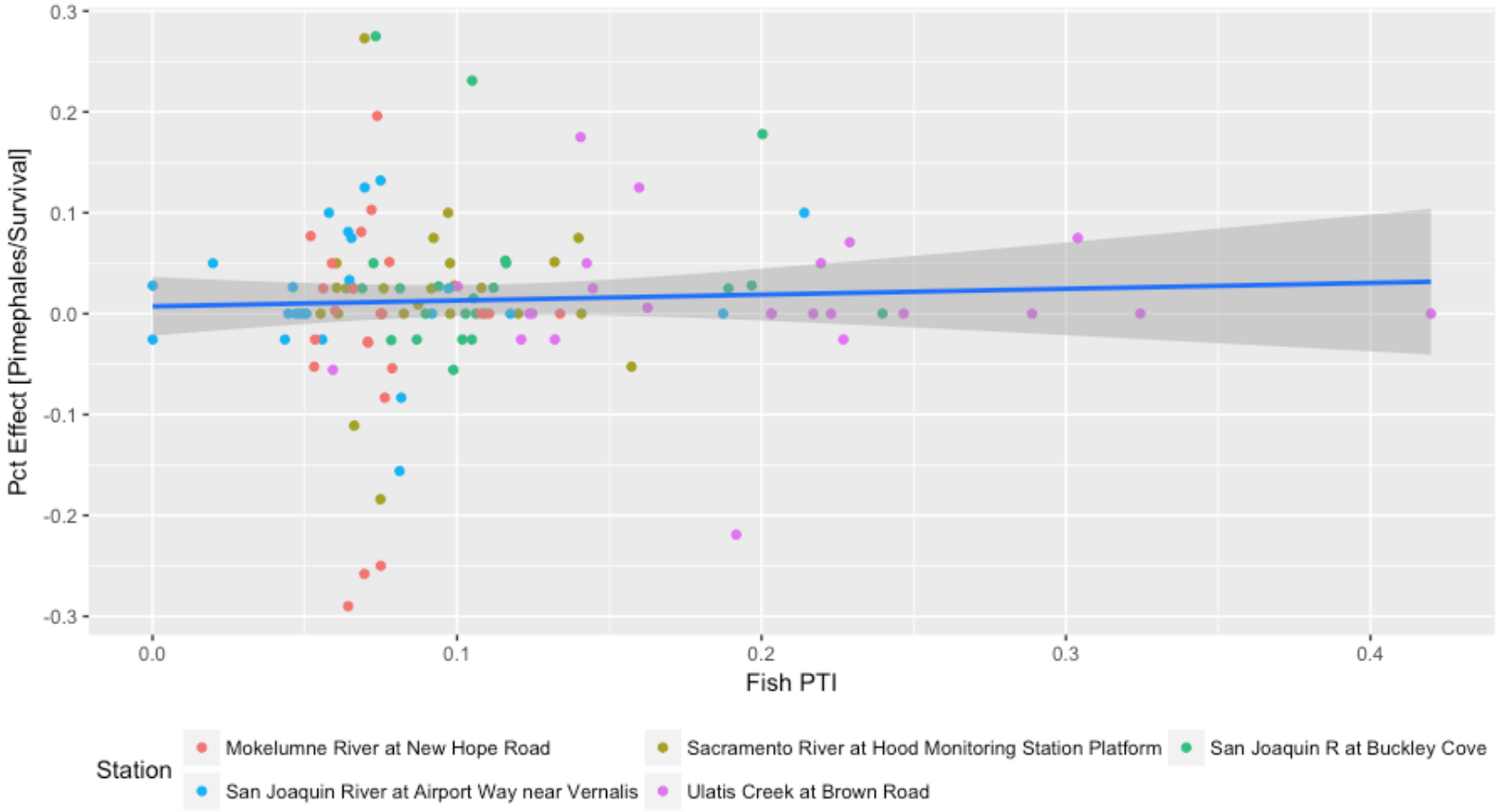

Figure 3. Pesticide Toxicity Index (PTI, Fish) plotted against Percent Toxic Effect in *Pimephales promelas* / Survival test. Colors designate each site. The trend line indicates there is no clear relationship between the two variables.

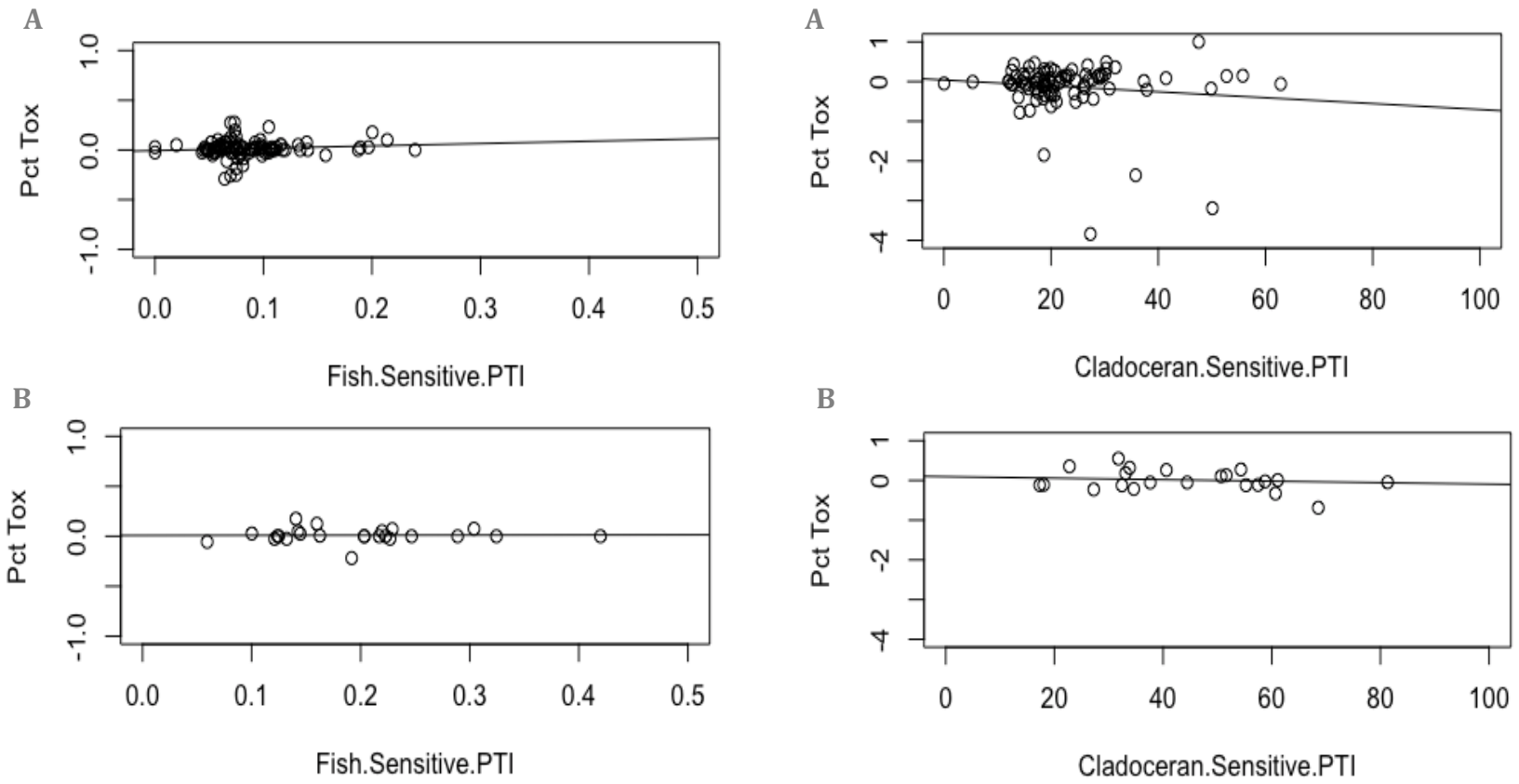

Figure 4. Pesticide Toxicity Index (PTI) plotted against Percent Toxic Effect for scenario A and B. Fish PTI data were plotted against *Pimephales promelas* / Survival test (left plots) and Cladoceran PTI were plotted against *Ceriodaphnia dubia* / Reproduction test (right plots). The trend line close to zero indicates there is no relationship between the two variables in any of the scenarios.

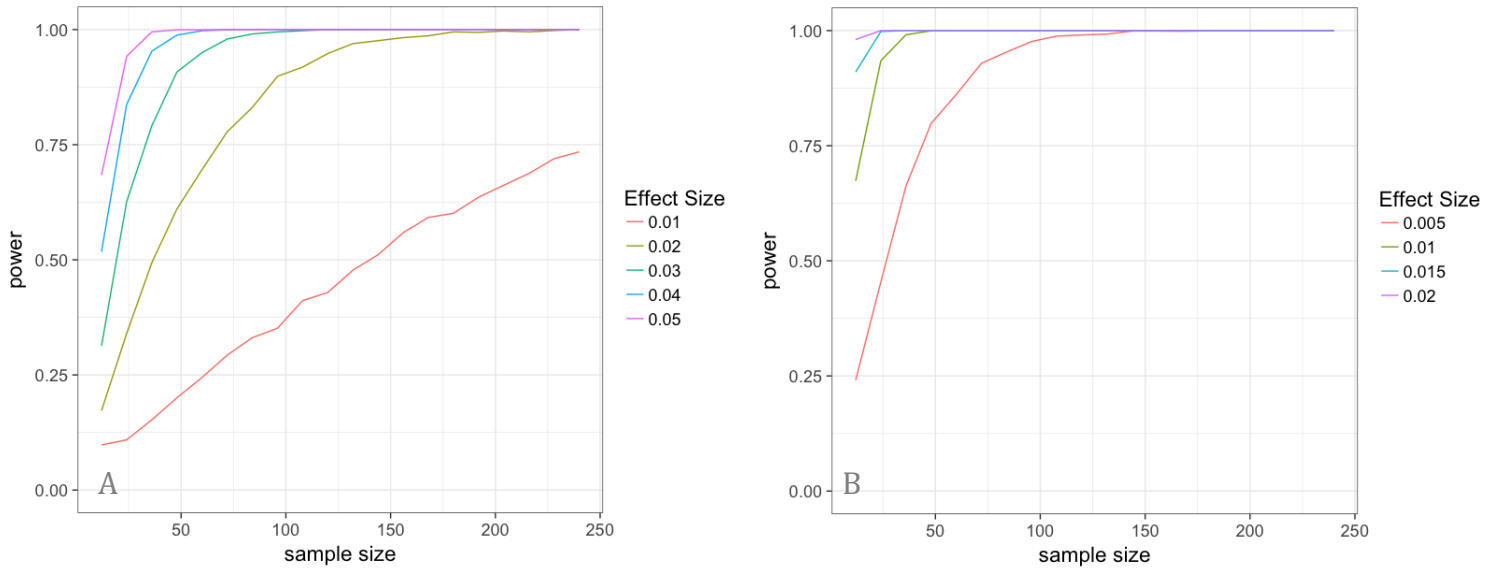

Figure 5. Power curve for scenarios A (left) and B (right) based on Cladoceran Sensitive PTI vs. *Ceriodaphnia* toxicity

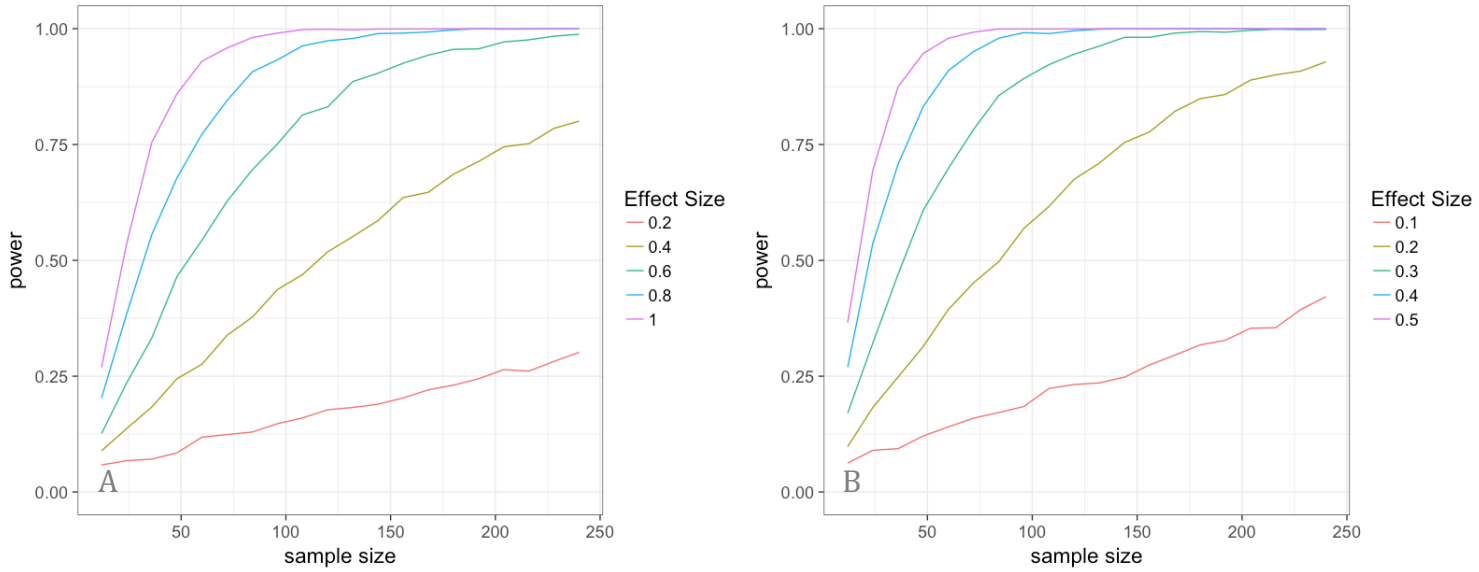

Figure 6. Power curve for scenarios A (left) and B (right) based on Fish Sensitive PTI vs. *Pimephales* toxicity

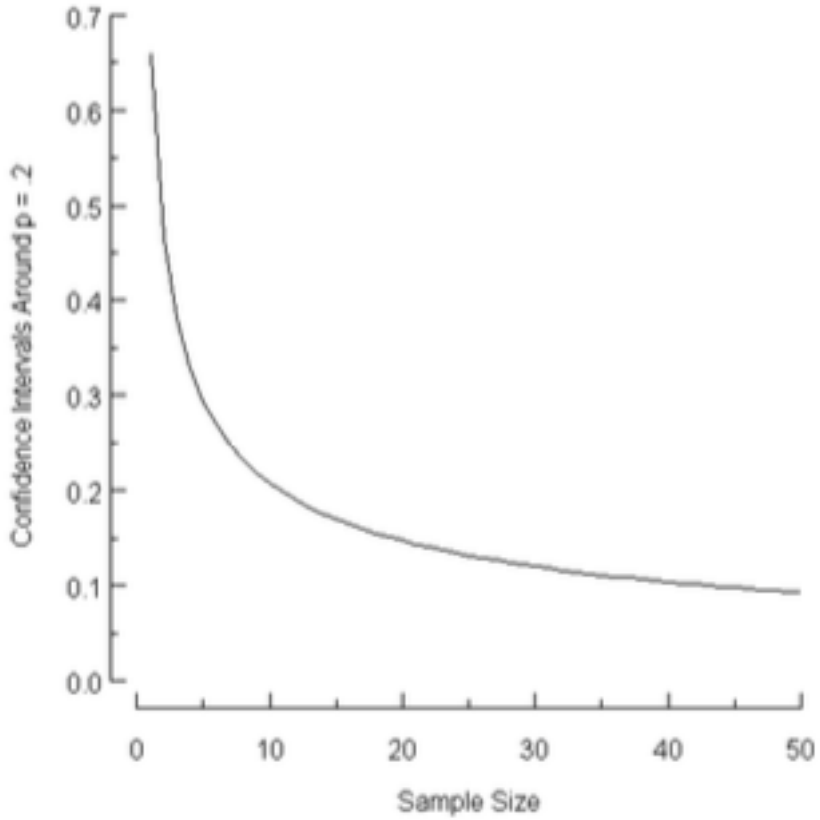

Figure 7. Sample size and size of confidence interval for a binomial distribution (p = 0.2)

Table 1. Mean, coefficient-of-variation, and result of ANOVA test on Pesticide Toxicity Index (Cladoceran-Sensitive)

PTI - Cladoceran Sensitive	Mean +/ SD	Coefficient of Variation	Statistical Difference
Mokelumne River at New Hope Road	20 +/- 5	26%	A
Sacramento River at Hood Monitoring	24 +/- 7	31%	A
San Joaquin R at Buckley Cove	29 +/- 12	40%	A
San Joaquin River at Airport Way near	18 +/- 13	69%	A
Ulatis Creek at Brown Road	47 +/- 22	46%	B

Table 2. Mean, coefficient-of-variation, and result of ANOVA test on Pesticide Toxicity Index (Fish-Sensitive)

PTI - Fish Sensitive	Mean +/ SD	Coefficient of Variation	Statistical Difference
Mokelumne River at New Hope Road	0.07 +/- 0.02	26%	A
Sacramento River at Hood Monitoring	0.09 +/- 0.03	31%	A
San Joaquin R at Buckley Cove	0.11 +/- 0.05	41%	A
San Joaquin River at Airport Way near	0.07 +/- 0.05	70%	A
Ulatis Creek at Brown Road	0.20 +/- 0.08	42%	B

Table 3. Variability estimates used for power analysis scenarios

Variance Group	**A**		**B**	
Station Composition	Hood, Buckley Cove, Mokelumne, Vernalis		Ulatis	
Predictor	Fish PTI	Cladoceran PTI	Fish PTI	Cladoceran PTI
N	96	96	24	24
Mean	0.09	23	0.20	47
SD	0.04	11	0.08	22
CV (%)	47%	46%	41%	46%

Appendix 4 Aquatic Toxicity Testing with *Chironomus dilutus*

Memo

To: Delta RMP Technical Advisory Committee and Steering Committee

From: Matthew Heberger, Aquatic Science Center

Date: June 19, 2018 (third revision)

Re: Information on aquatic toxicity testing with the midge larvae *Chironomus dilutus*

Delta RMP scientists have suggested adding the midge larvae *Chironomus dilutus* to our suite of test species for toxicity testing. This memo compiles some basic information about aquatic toxicity testing with this species. This memo includes information and text contributed by:

- Marie Stillway, Aquatic Health Program Laboratory at UC Davis
- Cameron Irvine, Robertson Bryan Inc.
- Stephanie Fong, State and Federal Contractors Water Agency
- Armand Ruby, Armand Ruby Consulting
- Danny McClure, Central Valley Regional Water Quality Control Board

Motivation for adding Chironomus

We are proposing adding *Chironomus* to our suite of test organisms in order to keep pace with changing use patterns of pesticides and aquatic toxicity in California. According to a 2015 memorandum from the Surface Water Ambient Monitoring Program (SWAMP):[1]

> As patterns of urban and agricultural pesticide use change in California, the species used to monitor water and sediment toxicity in SWAMP programs should be selected to properly evaluate these variations. While past data showed that much of the surface water toxicity was due to organophosphate pesticides such as diazinon and chlorpyrifos, these have largely been replaced by pyrethroids in most watersheds. In addition, recent data suggest new classes of pesticides are increasing in use, including phenylpyrazoles such as fipronil, and neonicotinoids such as imidacloprid. Decisions regarding toxicity monitoring for these pesticides should be based on their use patterns, and their relative toxicity to different test species and protocols.

Data show that *Chironomus* is more sensitive to fipronil and more sensitive in chronic exposures

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[1] Brian Anderson et al., "Updated Recommendations for Monitoring Current-Use Pesticide Toxicity in Water and Sediment in the Surface Water Ambient Monitoring Program," SWAMP Technical Memorandum (Sacramento, California: State Water Resources Control Board, Surface Water Ambient Monitoring Program, 2015), https://www.waterboards.ca.gov/water_issues/programs/swamp/docs/workplans/tox_recs_tech_memo.pdf.

to neonicotinoids such as imidacloprid than the invertebrate *Ceriodaphnia dubia*, which has been the only invertebrate species tested by the Delta RMP in the past. According to UC Davis toxicologist Bryn Philips, "we are observing increasing sediment toxicity to *Chironomus* in urban SPoT samples over the last three years, whereas sediment toxicity to *Hyalella* has been decreasing at the same sites." This will be the subject of a forthcoming publication (in press).

Fipronil is recognized as a concern in the Delta, present in stormwater and wastewater effluent.[2]

Imidacloprid was one of our more frequently detected pesticides during the first 2 years of Delta RMP monitoring, often at levels above aquatic life benchmarks. As of 1999, imidacloprid was the most widely used pesticide in the world, and data from the California Department of Pesticide Regulation (DPR) confirms that it is widely used in an around the Delta and its watershed (Figure 1).

[2] Akash M. Sadaria et al., "Passage of Fiproles and Imidacloprid from Urban Pest Control Uses through Wastewater Treatment Plants in Northern California," *Environmental Toxicology and Chemistry*, 2016, http://onlinelibrary.wiley.com/doi/10.1002/etc.3673/full.

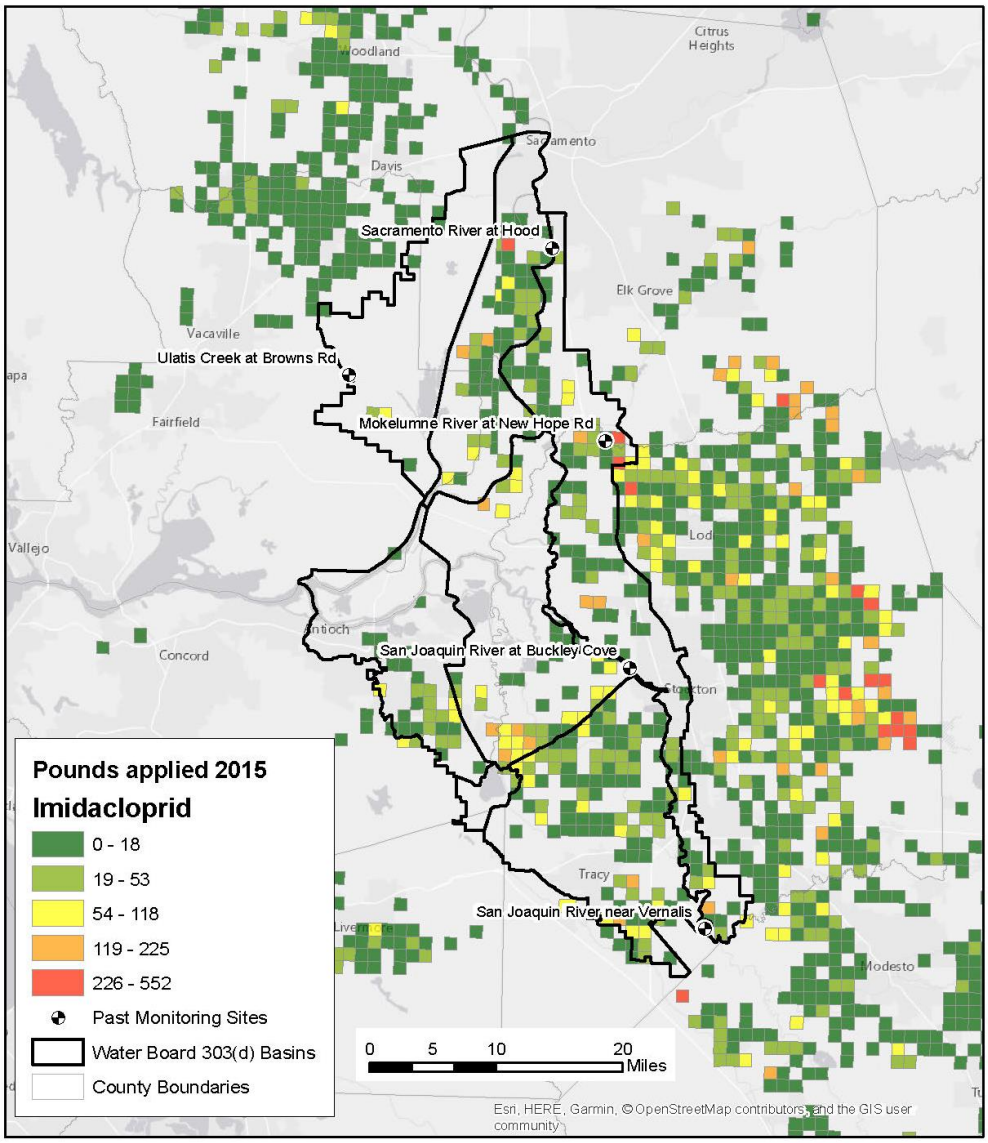

Figure 1 Application of imidacloprid near the Delta in 2015. Map by SFEI-ASC using data from DPR's pesticide use reporting database, http://www.cdpr.ca.gov/docs/pur/purmain.htm

About the species

Chironomus dilutus is the scientific name for a midge, a flying insect which has a global distribution.[3] The species was formerly known as *Chironomus tentans.* Midges are "informally known as chironomids, nonbiting midges, or lake flies" which superficially resemble mosquitoes.[4] Figures 2 and 3 show the larval and adult stages. In the last century, it was

[3] SWAMP, "SWAMP Toxicity Test Species Highlight: Midge Larvae – Chironomus Dilutus," *SWAMP Newsletter*, no. 1 (2016), https://www.waterboards.ca.gov/water_issues/programs/swamp/newsletter/winter2016/test_species.pdf.
[4] "Chironomidae," *Wikipedia*, May 20, 2018, https://en.wikipedia.org/w/index.php?title=Chironomidae&oldid=842162410.

thought that adult midges did not feed, however, it has been found that many adults do feed. In general, the "larval stages of the Chironomidae form an important fraction of the macrozoobenthos of most freshwater ecosystems."[5] They are an important food source for a variety of fish and other aquatic organisms. Larval midges in the genus *Chironomus* typically inhabit the lower zone of water bodies. While they can tolerate low dissolved oxygen, they have also been described as an important indicator species, with their presence/absence a useful indicator of contaminant pollution.

Figure 2 Chironomus dilutus *(midge) larvae.*
Photo courtesy of U.S. Geological Survey

Figure 3 Adult midge, Chironomus dilutus.
Photo © 2011 John F. Carr.

[5] "Chironomidae."

Use of Chironomus in aquatic toxicity testing

Chironomus has been referred to as a "commonly-used test species" and "widely used in standardized methods for testing with whole sediments measuring lethal as well as sublethal endpoints."[6] According to the USEPA, "many investigators have successfully used *C. tentans* to evaluate the toxicity of freshwater sediments."[7] The authors cite over a dozen examples from the literature spanning the years from 1977 to 1994. However, its use as a water-only test species is more recent and the test methods are not completely standardized.

Use at AHPL

The Aquatic Health Program Laboratory at UC Davis (AHPL) has been using *Chironomus* for water-only toxicity testing to analyze ambient water samples for the California Department of Pesticide Regulation (DPR). AHPL has recently been conducting water-only toxicity tests that evaluate organism survival over 96-hrs. This is an acute toxicity test; the lab has not yet run the chronic 10-day test. AHPL has used this method since 2017 and has run approximately eight samples and two reference toxicant tests to date, with seven more samples to be tested in June 2018.

The manager of the lab has offered to run some preliminary tests prior to the start of the project in order to gain extra experience with the 10-day test protocol.

A water-only protocol was developed by the UC Davis Granite Canyon Laboratory for survival and growth over 10-days, and is based on the EPA (2000) sediment toxicity test method. In place of an environmental sediment sample, clean sand is added to the bottom of the test chamber. The sand is important for the heath (i.e., reduced stress) of the organism, which likes to burrow and makes a case comprised of the substrate to live inside. Differences between the current UC Davis Granite Canyon lab test method and other potential test methods include the number of replicates, number of organisms per replicate, endpoints, feeding, and test acceptability criteria (**Table 1**). The Granite Canyon Lab supported updating their protocols to be consistent with pending updates to EPA (2000).

Use in Stormwater Sampling

It is becoming more common for *Chironomus* to be required as a test species in California municipal stormwater NPDES permits. As part of the statewide STORMS urban pesticides/ toxicity project, State Water Board staff worked with Regional Water Board staff in 2017 to compile statewide NPDES permit monitoring requirements for pesticides and toxicity testing (in water and sediment).

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[6] Guilherme Lotufo et al., "Assessing Biological Effects," 2014, 131–75, https://doi.org/10.1007/978-1-4614-6726-7_6.

[7] USEPA, *Methods for Measuring the Toxicity and Bioaccumulation of Sediment-Associated Contaminants with Freshwater Invertebrates Second Edition*, EPA 600/R-99/064 (US Environmental Protection Agency, 2000), https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=30003SBA.TXT.

Per the results of that unpublished survey (2017), it turns out that only the SF Bay area (incorporating Region 2 and a small section of Region 5 in eastern Contra Costa County) requires municipal stormwater (MS4) agencies to include toxicity testing for *Chironomus* in water. The required sample numbers are small, and limited (annual) dry weather monitoring began last year; very limited wet weather monitoring occurred this past winter (all 10 samples required regionally during the five-year permit term were collected this wet season). Both the SF Bay area and Orange County (Region 8) require limited sediment toxicity testing using Chironomus.

The Bay Area toxicity testing is being done by Pacific EcoRisk, a commercial lab in Fairfield, California. The *Chironomus* method is a 96-hour survival test, using a water exposure test protocol based on modification of the US EPA guidelines.[8]

The fact that more California agencies do not require toxicity testing with *Chironomus* is not surprising, as the NPDES permit monitoring requirements are often dated, and permits are slow to address changes in pesticide use patterns. Many permits are still requiring monitoring for long-banned pesticides, and failing to include monitoring for the most problematic current-use pesticides. For instance, *Hyalella azteca* is an amphipod species sensitive to pyrethroid pesticides, yet *Hyalella* testing in water is only required for MS4s in Orange County and the SF Bay area. (*Hyalella* testing in sediment is more widely required, but still not universal.)

Two SF Bay area wet weather urban creek water samples from January 2018 both showed potentially toxic levels of bifenthrin, fipronil, and imidacloprid (estimated toxic unit equivalents >1.0 for each pesticide), and both samples were significantly toxic to *Hyalella*; however, neither sample was toxic to *Chironomus* (Armand Ruby, personal communication).

Test Methods

The specific test method to be used in testing will need to be identified. There is not yet a standard SWAMP (2008) method or measurement quality objectives (MQOs) for testing midge, and EPA guidance only includes a water-only method evaluating survival over 96-hrs (reference tox for the sediment test). However, the EPA and ASTM methods are being updated and are expected to include water-only test methods (Table 1). Drafts of these updates are currently available.

EPA (2000) sediment toxicity testing guidance describes a 96-hr water-only reference toxicity test with midge evaluating survival. Sediment tox testing methods for *Chironomus dilutus* evaluate survival and growth over 10-days, and a 60-65-day life-cycle test

SWAMP (2008) MQOs describe several sediment toxicity testing methods but none for the midge. Data developed without SWAMP MQOs cannot be validated and are flagged as

[8] USEPA.

"screening" when reported in the California Environmental Data Exchange Network (CEDEN).

EPA (2000), and the corresponding ASTM method, are being updated and will more explicitly include water-only test guidance (described below). Drafts of both documents were distributed for limited external review in August-2017 and are currently being revised. Reviewers were given the following charge:

> "For the 1st and 2nd editions of the USEPA freshwater sediment test methods, considerable effort was directed to keeping the USEPA methods and the parallel methods described by ASTM (E1706 and E1688) consistent with one another. Toward that end, Chris Ingersoll of ASTM Sub-Committee E50.47 on Biological Effects and Environmental Fate (formerly Committee E47) has organized a simultaneous review of revisions to the ASTM versions of the *Hyalella azteca, Chironomus dilutus,* and *Lumbriculus variegatus* test methods that match those in the draft USEPA revision. Response to reviews of the USEPA method and the ASTM methods are being coordinated, so if you are contacted about both reviews, you may respond to either one and your comments will be considered under both."

According to the ASTM document lead author, an updated draft – at least for the ASTM method – is expected this fall. Delta RMP TAC member Cameron Irvine is the chair of the ASTM subcommittee responsible for this review and balloting and has promised to keep us posted on its status. The EPA version is being updated in parallel.

Test Repeatability / Lab intercalibration

One way to check the validity and repeatability of a method is to perform a laboratory intercalibration. When a single sample is split and sent to multiple labs, it is sometimes referred to as a "round robin."

At the present time, the water-only method with *Chironomus* is not performed widely. Nonetheless, a round-robin-style laboratory intercalibration would be very informative in describing the reliability and reproducibility of test methods among labs. While the water-only method would be new to most labs, it is common for EPA-led round robin testing to include labs that are both experienced and inexperienced with proposed test methods.

Interlaboratory comparison testing is an appropriate and important step to take when developing and using new methods, even if only among a few labs, but it was not considered by the TAC toxicity workgroup (5/24/18 meeting) to be a requirement for the draft 2018 Delta RMP Pesticide monitoring plan and no funding seems to be currently available. In the future, when funding is identified, it would be appropriate to participate in or help organize a round-robin-style laboratory intercalibration study with *Chironomus* in water-only toxicity testing.

SWAMP has suggested that it could include a *Chironomus* water-only laboratory intercalibration study in their budget planning in 2019. It has also been suggested that the Delta RMP could seek funding for a *Chironomus* toxicity intercalibration study via Supplemental Environmental

Project (SEP) funding, an alternative to penalties paid by dischargers for permit violations. However, an intercalibration study is probably not a good candidate for SEP funding. Projects are supposed to be connected to the area in which the fine is associated. While lab studies help inform all future studies, the link is not strong, and thus this may not be attractive to potential funders.

Conclusions

- *Chironomus* sp. have been widely used for four decades to test 96-hr water-only (survival) and sediment toxicity.
- The TAC toxicity workgroup recommends using a 10-day test method to evaluate survival and growth (weight and biomass) over the 96-hour test method (survival) to take advantage of midge sensitivity to some current use pesticides.
- A specific test protocol will need to be identified.
- Standardized midge test methods are currently being updated by SWAMP, ASTM, and the USEPA that will include water-only testing, and both 10-d and 96-h test durations.
- The Delta RMP is not a regulatory program, but data produced by the Delta RMP are intended for use by regulators and for regulatory decisions. Therefore, it would be appropriate for the program to develop high-quality data based on reproducible and reliable methods that are technically defensible.
- We should strive to make our testing methods be consistent with the draft update to EPA methods that are expected to be finalized in the near future.

Table 1. Current *Chironomus riparius* toxicity test method summary in water-only exposures.

Parameter	EPA (2000) (96-hour ref tox) single organism per chamber	EPA (2000) (96-hour ref tox) multiple organism per chamber	EPA / ASTM (10-day) (update in progress)	Granite Canyon Lab (10-day)	U.C. Davis AHPL (96-hour toxicity test and ref tox)
Test Duration (days)	4		10	10	4
Test vessel	30-mL plastic cups	250-mL glass	300 mL glass	300 mL glass	300-mL glass
Volume of test solution (mL)	20	100	175 mL	200	200
Number of organisms per replicate	1	10	10	12	12
Number of replicates per treatment	10	3	8 (min 4)	4	4
Feeding	0.25 mL Tetrafin® (4 g/L stock) on Day 0 and 2	1.25 mL Tetrafin® (4 g/L stock) on Day 0 and 2	Feed a suspension of fine fish-food flakes (not blended) at a rate of 6 mg for test day -1, 2 mg/day for test days 0 to 3, 4 mg/d for days 4 to 6, and 6 mg/d for days 7 to 9.	0.5 mL of 4 g/L Tetramin® slurry for the first 4 days, 1.0 mL the middle 3 days, and 1.5 mL the final 3 days of the test.	0.5 mL of 4 g/L Tetramin® slurry at test initiation, and at 48-hr water renewal
Water Renewals	none		2 volume additions/d (e.g., one volume addition every 12 h).	50% every other day	60% at 48-hrs
Control/dilution water	Culture water, well water, surface water, site water, or reconstituted water			Granite Canyon well water	Reconstituted water
Organism age (days)	second- to third-instar larvae (about 10-d-old larvae)[1]		From a single culture cohort, 7-10 day old & within 24 h age, and ≤ 0.12 mg/individual at the start of test.	7-day post hatch with all organisms from the same culture (2-3 instar)	
Substrate	sand (monolayer)		5 – 10 mL neutral substrate such as clean quartz sand	Clean sand (5 mL)	
Number of ref tox concentrations	Control + 5 test concentrations		-	-	NA for tox test / Control + 5 test concentrations for RT
Temperature	23 ± 1 ° C		23 ± 1 ° C	23 ± 1 ° C	23 ± 1 ° C
Lighting	About 100 to 1000 lux			10 – 20 µE/m2/s or 50 – 100 ft-c	
Photoperiod	16L:8D			16L:8D	
Oxygen/aeration	None		If DO < 2.5 mg/L	If DO < 2.5 mg/L	
Endpoints[7]	Survival (LC50)		Survival, growth (AFDW), biomass	Survival and growth (AFDW)	Survival
Test acceptability criteria (Controls)	≥ 90% control survival		≥ 90% control survival; AFDW ≥ 0.60 mg/individual.	≥ 70% control survival; AFDW ≥ 0.48 mg/ individual	≥ 90% control survival

Table 1. Current *Chironomus riparius* toxicity test method summary in water-only exposures.

Parameter	EPA (2000) (96-hour ref tox) single organism per chamber	EPA (2000) (96-hour ref tox) multiple organism per chamber	EPA / ASTM (10-day) (update in progress)	Granite Canyon Lab (10-day)	U.C. Davis AHPL (96-hour toxicity test and ref tox)
Water Quality	Hardness, alkalinity, conductivity, DO, and pH at the beginning and end of a test. Temperature daily		Temperature daily and hardness, alkalinity, conductivity, pH, and ammonia in each treatment at the beginning and end of a test. DO three times per week in each treatment (more often if DO < 2.5 mg/L)	DO, pH, conductivity, and ammonia are measured at the beginning and end of the exposure. Temperature is measured continuously, and hardness and alkalinity are measured at the beginning of the test.	DO, pH, conductivity and temperature are measured at the beginning and end of the exposure. Temperature is monitored continuously. DO and pH are measured in new renewal water and in 48-hr old water. Hardness alkalinity and ammonia are measured at the beginning of the test.

Notes:

Highlights indicate relevant information differs among tests.

AFDW – ash free dry weight

DO – dissolved oxygen

LC50 – lethal concentrations for 50 percent of test organisms

[1] Age requirement: All animals must be third or second instar with at least 50% of the organisms at third instar.

Appendix II – Nutrient Multi-Year Study Plan

Nutrient Multi-Year Study Plan

Version 1.0
Approved on March 18, 2024

Prepared By:

MLJ ENVIRONMENTAL

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ACRONYM	DEFINITION
ANOVA	Analysis of Variance
ASC	Aquatic Science Center
BGC	Biogeochemical
chl-a	Chlorophyll-a
CSC	Cache Slough Complex
CVRWQCB	Central Valley Regional Water Quality Control Board

DCC	Delta Cross Channel
Delta RMP	Delta Regional Monitoring Program
DICU	Delta Island Consumptive Use
DIN	Dissolved Inorganic Nitrogen
DO	Dissolved Oxygen
DWR	Department of Water Resources
EMP	Environmental Monitoring Program
HAB	Harmful Algal Bloom
HPLC	High-Performance Liquid Chromatography
IAV	Invasive Aquatic Vegetation
IEP EMP	Interagency Ecological Program's Environmental Monitoring Program
N	Nitrogen
NH_4	Ammonium
NO_3	Nitrate
nSFE-BGCM	northern San Francisco Estuary Biogeochemical Model
O_2	Oxygen
P	Phosphorus
PO_4	Phosphate
POTW	Publicly Owned Treatment Works
RMA	Resource Management Associates
RMSE	Root Mean Square Error
SC	Steering Committee
SEP	Supplemental Environmental Project
SFE	San Francisco Estuary
SFEI	San Francisco Estuary Institute
Si	Silicon
TAC	Technical Advisory Committee
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
USGS	United States Geological Survey
WY	Water Year

LIST OF UNITS

cm	centimeter
L	liter
m	meter
mg	milligram
mL	milliliter
µg	microgram
µmol	micromole
s	second

1 INTRODUCTION

1.1 BACKGROUND

The Delta Regional Monitoring Program (Delta RMP) is developing a Multi-Year Nutrient Study Plan to guide long-term studies of the effects of nutrients on the ecology of the Delta. After discussion between the Delta RMP Steering Committee (SC) and the Nutrient Technical Advisory Committee (TAC), three primary questions (also referred to as focus areas) were developed to guide the development of the Study Plan.

1. Following a reduction in nutrient loading from different point and nonpoint sources, what ranges of nutrient concentrations are expected to occur throughout the Delta, and how might they be affected by climate change, wetland restorations, and water management and routing?
2. What are the thresholds for nutrients (nitrogen (N) and phosphorus (P) and their ratios) that can limit Harmful Algal Bloom (HAB) biomass and cyanotoxin accumulation to safe levels, limit the abundance and distribution of nuisance macrophytes, and support robust growth of desirable phytoplankton and macrophytes throughout the Delta?
3. How are the characteristics of harmful cyanobacteria blooms and cyanotoxins in the Delta changing (e.g., species, magnitude, geographic extent, and timing) and what factors contribute to these changes?

The Multi-Year Nutrient Study Plan addresses these three questions or focus areas using a combination of modeling, field/experimental studies, and monitoring. It is not the objective of this Multi-Year Nutrient Study Plan to completely address all three focus area questions. The intent of the studies included in this Study Plan is to begin a multi-year process that begins to address these questions with a hypothesis driven approach and prioritizing data gaps identified by the Steering Committee and Nutrient TAC.

1.2 DELTA RMP MANAGEMENT QUESTIONS

The Delta RMP has agreed upon a set of management questions that reflect specific concerns about multiple aspects of the Delta and the impacts of human activities.

Since each of the management questions is quite broad, it is important to first identify a set of more specific "assessment questions" to guide a future monitoring or special study design. **Table 1** lists the management questions that were developed by the SC and the assessment questions that were developed by the Nutrient Subcommittee in 2018. When the Delta RMP SC prioritized planning for a multi-year study plan, these questions were used as a starting point for the three primary questions or focus areas.

Table 1. Delta RMP management and assessment questions for nutrients.

TYPE	CORE MANAGEMENT QUESTIONS	NUTRIENT ASSESSMENT QUESTIONS
1. Status & Trends	Is there a problem or are there signs of a problem? 1a. Is water quality currently, or trending towards, adversely affecting beneficial uses of the Delta? 1b. Which constituents may be impairing beneficial uses in subregions of the Delta? 1c. Are trends similar or different across different subregions of the Delta?	1.1. How do concentrations of nutrients (and nutrient-associated parameters) vary spatially and temporally? A. Are trends similar or different across subregions of the Delta? B. How are ambient levels and trends affected by variability in climate, hydrology, and ecology? C. Are there important data gaps associated with particular water bodies within the Delta subregions?

Type	Core Management Questions	Nutrient Assessment Questions
2. Sources, Pathways, Loadings & Processes	Which sources and processes are most important to understand and quantify? 2a. Which sources, pathways, loadings, and processes (e.g., transformations, bioaccumulation) contribute most to identified problems? 2b. What is the magnitude of each source and/or pathway (e.g., municipal wastewater, atmospheric deposition)? 2c. What are the magnitudes of internal sources and/or pathways (e.g., benthic flux) and sinks in the Delta?	2.1. 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? 2.2. 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?

Type	Core Management Questions	Nutrient Assessment Questions
3. Forecasting Scenarios	3a. How do ambient water quality conditions respond to different management scenarios. 3b. What constituent loads can the Delta assimilate without impairment of beneficial uses? 3c. What is the likelihood that the Delta will be water quality-impaired in the future?	3.1. 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, water resource management changes, and climate change?
4. Effectiveness Tracking	4a. Are water quality conditions improving as a result of management actions such that beneficial uses will be met? 4b. Are loadings changing as a result of management actions?	4.1. 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?

1.3 THREE-YEAR PLANNING BUDGET

This section presents a comprehensive three-year planning budget. A nutrient budget of roughly $500,000 is allocated for each fiscal year (FY), for a total budget of $1,500,000 (FY 24-25, FY 25-26, FY 36-27). **Table 2** outlines how funds will be spent for each of the three focus areas over the course of three fiscal years. The planning budget allows for a 10% contingency ($150,000) as scopes and contracts are finalized in preparation of project implementation. The Delta RMP Annual Monitoring Workplan and final budget will include actual allocated funds for the upcoming fiscal year.

Table 2. Three-year budget for the Nutrient Multi-Year Study Plan focus areas.

Fiscal Year	Focus 1	Focus 2	Focus 3	FY Budget	FY Allocated Funds	Difference
FY 24-25	$167,500	$50,000	$150,000	$367,500	$500,000	$132,500
FY 25-26	$232,500	$265,252	$150,000	$647,752	$500,000	-$147,752
FY 26-27	$0.00	$225,252	$150,000	$375,252	$500,000	$124,748
Totals	**$400,000**	**$490,504**	**$450,000**	**$1,349,500**	**$1,500,000**	**$109,496**

2 FOCUS AREA #1

Biogeochemical (BGC) modeling efforts will be used to answer the following question by conducting a series of model scenarios based on hypothesis testing to address the following Focus Area #1 question:

- Following a reduction in nutrient loading, what ranges of nutrient concentrations are expected to occur throughout the Delta, and how might they be affected by climate change, wetland restorations, and water management and routing?

In pursuing the above question, the study targets a number of questions the Delta RMP has identified as priorities (**Table 1**), including: Management Questions 2a, 2b, 2c, 3a, and 3b; and Assessment Questions 2.1.A-F and 3.1.

2.1 PROJECT SUMMARY AND OBJECTIVES

The proposed project's high-level goals and approaches are summarized below, with details covered in subsequent sections.

High-Level Project Goals

1. Quantify the effects of nutrient source load reductions on nutrient concentrations throughout the Delta, including how those effects vary spatially, temporally (seasonally, interannually), and as a function of water management or flow-routing.
2. Evaluate in greater detail and provide visualizations of changes in nutrient concentrations within, or nutrient delivery to, regions of the Delta that are impacted by HABs and invasive aquatic vegetation (IAV).
3. Investigate additional priority hypotheses, including one or more of the following: a) Quantify the importance of remaining nutrient sources (beyond those included in scenarios) within HAB- and IAV- prone regions, including Delta non-point sources; b) Assess the relative importance of IAV on nutrient concentrations and cycling; and/or c) Characterize the relative importance of factors regulating phytoplankton biomass or productivity, including potential effects of decreased nutrient availability due to load reductions on 'beneficial production'.

Approach

To address these goals, the project will:

- Simulate hydrodynamics and biogeochemistry during water year 2022 (WY2022) and water year 2016 (WY2016), using actual nutrient loads during those years ('Base'), to predict nutrient transport, cycling, and concentrations throughout the Delta. The Base conditions include the nutrient loading rate that occurred in 2022 for both water years; see section **Model Updates, Calibration, and Validation** for more details.
- Re-simulate WY2022 and WY2016 biogeochemistry for a priority set of load reduction scenarios to forecast nutrient concentrations under each of those conditions.
- Quantify differences in nutrient concentrations between the Base and Scenario simulations, including their variability spatially (map-view concentrations), temporally (time-series at specific locations), and interannually.
- Test additional priority hypotheses (Project Goal #3) by undertaking targeted analyses of model output, including through, e.g., mass-budgets/control-volume analyses, numerical tracers (source-tracking, age/travel-time tracers), or sensitivity analyses.

Early work will include a set of tasks to extend hydrodynamic and biogeochemical simulations to WY2022 and improve model performance during low-flow conditions and reduced-load scenarios. The hydrodynamic and biogeochemical models will then be calibrated and validated for WY2022 and WY2016, and the updated model used for Base and Scenario simulations.

2.2 WHY IS THIS A PRIORITY?

Potential future regulation of N discharges could set allowable concentrations at levels meant to reduce or eliminate the proliferation of cyanobacteria and the production of cyanotoxins that are harmful to humans, companion animals, and wildlife. It is also anticipated that reductions of nutrients will lead to reductions in the growth of nuisance aquatic macrophytes. The desire is to determine if the anticipated outcomes will be realized without any adverse impacts such as decreases in the growth of desirable phytoplankton.

The goal of the modeling element of the Multi-Year Nutrient Study Plan is to identify the effects of changing Dissolved Inorganic Nitrogen (DIN) and Total Nitrogen (TN) concentrations from source areas inside and outside the Delta on the DIN and TN concentrations and chlorophyll-a (chl-a) concentrations at targeted areas in the Delta. The targeted areas include:

- Locations where beneficial algal production occurs, which can support zooplankton growth (an important food resource for zooplankton and native fishes, such as Delta Smelt) locally or distally through advection and dispersion including but not limited to:
    - Liberty Island and the North Delta
- Locations where Harmful Algal Blooms occur including but not limited to:
    - Stockton Waterfront
    - Discovery Bay
    - Franks Tract
    - Old and Middle Rivers

This project will model reductions in DIN and TN inputs to the Delta from various sources to determine if and how these reductions can affect the delivery of DIN and TN to or concentrations within regions of the Delta, in particular regions that experience HABs or IAV, and/or locations that are critical to the survival of pelagic fish in the Delta (primarily the north Delta). In pursuing the Focus Area #1 question, the study targets a number of Delta RMP priority Management Questions (2a, 2b, 2c, 3a, 3b) and Assessment Questions (2.1.A-F, 3.1) (Table 1) . The proposed work focuses in particular on the first half of the Focus Area #1 question, addressing knowledge gaps related to the relative contributions, or zones of influence, of nutrient sources within the Delta and the degree to which nutrient management options (individually, or in combination) could affect nutrient concentrations within or mass fluxes to priority management regions. There is also the potential for the modeling results to complement findings from the Focus Area #2 field studies in addressing the Focus Area #2 question. The proposed work will not directly investigate how load reduction scenario results would be influenced by factors like climate change, wetland restoration, or water management. Pursuing those topics would

require investigating additional layers of scenarios (e.g, climate change scenarios could include changes in temperature, sunlight (i.e., cloud-cover), flow, and sea-level-rise changes to flooded areas). However, some of those factors could be pursued through follow-up work that builds on this project's scenario results.

2.3 HYPOTHESES AND MODELING QUESTIONS

Nitrogen enters the Delta from point and nonpoint sources in the Sacramento Valley, San Joaquin Valley, and internal Delta from such sources as atmospheric deposition, agricultural discharges, urban runoff, and Public Owned Treatment Works (POTWs). Although regulatory actions are being considered to further reduce these inputs, it is currently unknown what the ecological responses of reduced N inputs will be. Decreased occurrences of HABs and IAV have been identified as plausible or hypothesized beneficial ecosystem responses to decreased Delta nutrient loads (Senn et al. 2020). However, thus far few studies (field or modeling) have directly investigated these potential responses. Since modules for mechanistically simulating cyano-HABs or IAV have not yet been incorporated into the northern San Francisco Estuary Biogeochemical Model (nSFE-BGCM), this project will focus on quantifying nutrient delivery to or predicted concentrations within priority management areas, and changes to those deliveries and concentrations in response to load reduction scenarios. Through continued discussions with Delta RMP stakeholders, additional priority hypotheses or management questions will be identified (example options summarized under **Analysis & Interpretation** below). Coupled with other studies and monitoring funded by the Delta RMP, it may be possible to estimate the amount of harmful cyanobacteria and cyanotoxins produced at low N concentrations throughout the Delta. These studies hopefully will access if the Delta responds similarly to other waterbodies and inform the development of nutrient regulation.

The Nutrient TAC will work with the Modeling Team to identify the most relevant set of load reduction scenarios to simulate. Approaches for establishing reduction scenarios include i) identifying a set of percentage reductions to DIN and TN from source areas and determine the relative impact on DIN, TN, and chl-a concentrations at locations in the Delta, and/or ii) establishing target DIN/TN concentrations at specific locations in the Delta and determining the percentage reduction and the location of the reductions needed to achieve the target concentrations.

Below are four initial hypotheses (null and alternative) that can be used to build model scenarios for testing the hypotheses. The hypotheses use the terminology of substantial change as a way to test the hypotheses; the Nutrient TAC will work with the modelers to define substantial (e.g., larger than background variation) as modeling is implemented and include this definition in the interpretation and reporting of model results.

2.3.1 BGC Model Hypothesis 1

H_0: Reducing the nonpoint and point source inputs of N from the Sacramento River to the Delta will have no effect on the concentration of DIN, TN, P, or chl-a at any targeted location or region in the Delta at any time during the year.

H_1: At least one targeted location/region in the Delta will experience a substantial change in the concentration of DIN, TN, P, or chl-a after reductions from point and nonpoint sources in the Sacramento Valley at some time during the year.

2.3.2 BGC Model Hypothesis 2

H_0: Reducing the nonpoint and point source inputs of N from within the Delta will have no effect on the concentration of DIN, TN, P, or chl-a at any targeted location or region in the Delta at any time during the year.

H_1: At least one targeted location in the Delta will experience a substantial change in the concentration of DIN, TN, P, or chl-a for a sustained period (e.g., days to weeks) after reductions from point and nonpoint sources in the Delta at some time during the year.

2.3.3 BGC Model Hypothesis 3

H_0: Reducing the nonpoint and point source inputs of N from the San Joaquin Valley will have no effect on the concentration of DIN, TN, P, or chl-a at any targeted location or region in the Delta at any time during the year.

H_1: At least one targeted location in the Delta will experience a substantial change in the concentration of DIN, TN, P, or chl-a for a sustained period (e.g., days to weeks) after reductions from point and nonpoint sources in the San Joaquin Valley at some time during the year.

2.3.4 BGC Model Hypothesis 4

H_0: Reducing the nonpoint and point source inputs of N simultaneously from the Sacramento River, the San Joaquin River, and internal Delta sources will have no effect on the concentration of DIN, TN, P, or chl-a at any targeted location or region in the Delta at any time during the year.

H_1: At least one targeted location/region in the Delta will experience a substantial change in the concentration of DIN, TN, P, or chl-a for a sustained period (e.g., days to weeks) after N reductions simultaneously from the Sacramento River, the San Joaquin River, and internal Delta sources at some time during the year.

2.3.5 BGC Model Scenarios

To test Hypotheses 1-4, the nSFE-BGCM will be used to simulate a series of load reduction scenarios (**Table 3**) during two proposed water years, WY2016 and WY2022. In the central and south Delta, nutrient concentrations in the winter and spring can be

higher than those in the summer and fall (Beck et al. 2018, Jabusch et al 2018). However, HABs typically occur in the summer through fall (Berg and Sutula 2015), so DIN reduction modeling scenarios were developed from Interagency Ecological Program (IEP) Environmental Monitoring Program (EMP) data collected July through October in 2022. The US EPA has recommended that states consider criteria of total N of 0.31 mg/L and total P of 0.047 mg/L for EcoRegion 1 which includes parts of Washington, Oregon, and California (EPA 2001). These concentrations are not directly related to the Delta but provide context for concentrations being evaluated for nutrient criteria in the Delta.

Internal nutrient concentrations were calculated as the difference in average DIN between Buckley Cove (1.1 mg/L-N) and Vernalis (0.36 mg/L-N) = 0.74 mg/L-N. The first two modeling scenarios reduce DIN from all sources to yield reduced concentrations (0.1 mg/L-N and 0.2 mg/L-N) that match those proposed in the Delta RMP N reduction bioassay study and reflect lowest observed concentrations detectable during the fall in the system (see section **3.3.2 N and P Reduction Bioassay Treatments** for more specifics). Scenarios 3 to 6 test percent DIN loading reductions to understand the importance of individual sources vs. a standard 20% reduction from all sources. The final scenario(s) evaluates nutrient concentrations based on the feasible limit of reductions in N loading from individual loading sources such as POTWs, municipal stormwater, and agriculture. A set of feasible N load reduction scenarios will be developed by Nutrient TAC and SC members with assistance from San Francisco Estuary Institute-Aquatic Science Center (SFEI-ASC).

Two potential phosphorus reduction scenarios may be added to the study. The Nutrient TAC will work with the modelers to identify scenario details and related hypotheses.

Table 3. Potential BGC modeling scenarios.

DIN CONCENTRATIONS IN 2022 (JULY-OCT)	DIN (MG/L-N)	REDUCTION
Sacramento River (Hood)	0.26	0%
San Joaquin River (Vernalis)	0.36	0%
Internal sources	0.74	0%

Model Scenario 1	DIN (mg/L-N)	Reduction
Sacramento River (Hood)	0.1	61%
San Joaquin River (Vernalis)	0.1	72%
Internal sources	0.1	86%

Model Scenario 2	DIN (mg/L-N)	Reduction
Sacramento River (Hood)	0.2	22%
San Joaquin River (Vernalis)	0.2	45%
Internal sources	0.2	73%

DIN CONCENTRATIONS IN 2022 (JULY-OCT)	DIN (MG/L-N)	REDUCTION

Model Scenario 3	DIN (mg/L-N)	Reduction
Sacramento River (Hood)	0.13	50%
San Joaquin River (Vernalis)	0.36	0%
Internal sources	0.74	0%

Model Scenario 4	DIN (mg/L-N)	Reduction
Sacramento River (Hood)	0.26	0%
San Joaquin River (Vernalis)	0.18	50%
Internal sources	0.74	0%

Model Scenario 5	DIN (mg/L-N)	Reduction
Sacramento River (Hood)	0.26	0%
San Joaquin River (Vernalis)	0.36	0%
Internal sources	0.37	50%

Model Scenario 6	DIN (mg/L-N)	Reduction
Sacramento River (Hood)	0.21	20%
San Joaquin River (Vernalis)	0.29	20%
Internal sources	0.59	20%

Model Scenario 7 (or more)	DIN (mg/L-N)	Reduction
Sacramento River (Hood)	Lowest feasible	TBD
San Joaquin River (Vernalis)	Lowest feasible	TBD
Internal sources	Lowest feasible	TBD

2.4 APPROACH

2.4.1 Model Overview

The core Modeling Team will consist of hydrodynamic and biogeochemical modelers from SFEI and Resource Management Associates (RMA).

Modeling work will be pursued using the nSFE-BGCM, a 3-D coupled hydrodynamic-biogeochemical model capable of simulating nutrient transport, nutrient cycling, and an array of relevant ecosystem responses (e.g., phytoplankton production). The hydrodynamic and biogeochemical models are described in detail elsewhere (SFEI 2019, 2020, 2021a), and are summarized briefly here. The SFE-BGCM uses the public-domain/open-source models D-Flow Flexible Mesh (DFM, Deltares 2019a) to simulate hydrodynamics; D-Water Quality (DWAQ; Deltares 2019b) to simulate water quality; and a suite of Python-based utilities to facilitate model setup and postprocessing. Two branches of the SFE-BGCM are maintained, emphasizing different regions of the San Francisco Estuary (SFE): the San Francisco Bay (SFB-BGCM); and the northern San Francisco Estuary (Delta, Suisun; nSFE-BGCM). The biogeochemical modules for each of the regional models have similar baseline capabilities, and refinements implemented within one regional model have been routinely transferred to other branches when relevant. For this Delta-Suisun focused analysis, the nSFE-BGCM model will be used. The model domain includes the Delta and San Francisco Bay, and extends into the Pacific Ocean to approximately Point Reyes to the north and Half Moon Bay to the south (**Figure 1**). The model has ~75,000 horizontal cells and 10 vertical layers (sigma layers). The nSFE-BGCM incorporates flows and nutrient loads from all known point sources (POTWs, refineries), along with flows and loads from upstream watersheds.

The nSFE-BGCM was developed to simulate the array of biogeochemical processes and state variables depicted in **Figure 2**, and summarized in the extended figure caption. Through recent Delta-Suisun focused projects (SFEI 2021a, 2021b) a number of substantial improvements were made, including (see also **Figure 3**): water column transformations and sediment diagenesis; adjustments to clam and zooplankton initial conditions and grazing rates informed by comparisons with biomass and grazing data from a complementary modeling effort; refining boundary conditions for nutrient loading from both freshwater sources and POTWs; developing spatially varying initial conditions for nutrient concentrations; calculating space-time varying light-attenuation coefficients using the network of high frequency turbidity sensors throughout the Delta; and developing a “global” calibration that performed well at predicting N, P, and silica (Si) concentrations across two water years with strongly differing physical conditions (WY2011, wet; WY2016, dry) and biogeochemical responses. Through those projects the Modeling Team have expanded capacity for processing model output, including establishing regional and sub-regional control volumes and quantifying mass budgets over

relevant time periods (**Figure 4**). Using this modeling framework, it is also possible to introduce several types of numerical 'tracer' techniques (conservative tracers, age tracers, habitat exposure tracers) and track their movement over space and time. These tracers can provide valuable information about, e.g., a point-source's zone of influence, and recent tracer applications in the Delta have demonstrated great promise at, for example, estimating rates of N loss in regions with dense growth of IAV, and detecting and tracking signals of ag-return-flow waters.

An important limitation of the prior version of the nSFE-BGCM also emerged during the WY2016 simulation, with results indicating that transport was under-resolved within the Cache Slough Complex (CSC) which affected the reliability of nutrient concentration predictions in the upper CSC. That issue will be remedied during this project by incorporating an improved bathymetry dataset and model grid within the CSC that were recently implemented as part of another related project (see below in section **Model Updates, Setup, and Calibration for WY2022 and WY2016**).

Model Updates, Calibration, and Validation

For this project, two water years will be simulated, WY2016 and WY2022. Of the two years that were previously calibrated (WY2016, WY2011), WY2016 is recommended because of the ample water quality monitoring data available for model calibration and validation (water quality moorings, high-resolution mapping, in addition to monthly discrete data). Key reasons for simulating WY2022 include: i) comparable or greater water quality monitoring as WY2016; and ii) the EchoWater Resource Recovery Facility's upgrades were completed and online during WY2022, allowing for a post-upgrade time-period to be included in model calibration/validation.

Model Updates, Setup, and Calibration for WY2022 and WY2016

Initial work will include incorporating several major improvements to the model grid and bathymetry (CSC, Suisun Bay, and portions of the Sacramento River, near the Delta Cross Channel (DCC)) (**Figure 5**). The grid and bathymetry improvements were developed through a recent project and have already been merged with the broader nSFE-BGCM domain. Remaining steps include updating model set-up scripts (re-plumbing boundary conditions or inputs into appropriate new grid cells) and post-processing scripts (analysis, plotting) to align with the altered grid, and incorporating any minor refinements that emerge during early test runs.

Hydrodynamic runs will be set up for WY2022 and WY2016, using the new grid and bathymetry. Hydrodynamic input files (boundary conditions, forcings) will be developed for WY2022, including river flows, point source flows, meteorological data, and gate and pump operations (WY2016 data already compiled). Model setup for WY2022 will also

require incorporating flow alterations at the Old River Drought Barrier (trial runs, iterations to fine-tune), During dry and critically dry years like WY2016 and WY2022, interior-Delta water withdrawals/returns (i.e., 'ag return flows', Delta Island Consumptive Use (DICU)) can affect both flow routing and biogeochemistry. The influence of interior-Delta flow withdrawals/returns will be estimated by incorporating spatially distributed daily flows from the Delta Channel Depletion dataset (DCDv1.0; CA DWR 2018). A major focus of the hydrodynamic calibration work will be on accurately representing discharge and water elevations at structures/drought-barriers, within the CSC, and within regions affected by HABs and IAV.

Biogeochemical model input files will be developed for WY2022, including (see SFEI 2021b): nutrient concentrations at model boundaries for estimating loads entering the Delta (e.g., Battey and Perry 2023); spatially and temporally (hourly to daily) varying light attenuation coefficients, estimated through interpolating turbidity data from the Delta's network of continuous turbidity sensors (DWR and USGS networks); and abundances of benthic (clam) (e.g., Wells et al., 2023; Zierdt et al. 2021); and pelagic (zooplankton) grazers (Burdi et al., 2023). Additional information on model boundary condition and forcing data can be found in SFEI 2021b. The Delta-focused biogeochemical model will be updated with relevant improvements made through recent Bay modeling work, including refinements to the sediment biogeochemical module (nutrient fluxes), and phytoplankton production and grazing modules. A major focus of effort will then be on developing an updated global biogeochemical calibration for water years 2022 and 2016.

Model Validation

The hydrodynamic model will be validated for WY2016 and WY2022 by comparing time series of modeled and observed discharge, gauge height, salinity, and temperature at approximately 60 measurement stations across the Delta and Suisun Bay, and assessing performance using a suite of validation statistics (e.g., bias, root mean square error (RMSE), skill, r^2, tidal amplitude ratio, lag) (see SFEI 2019).

The biogeochemical model will be validated for WY2022 and WY2016 by comparing model-predicted concentrations of priority water quality parameters (e.g., nitrate, ammonium, phosphate, silica, chl-a) with observed data. For the above parameters, discrete monthly and semi-monthly data are available from 10-15 sites across the Delta and Suisun Bay (see **Figure 4**; Battey and Perry 2023]. Modeled nitrate and chl-a concentrations will be compared with the USGS's extensive network of moored monitoring stations in this region. Lastly, modeled nitrate and chl-a values will also be compared with data from USGS high-speed mapping surveys conducted during 2016 and 2022. Additional information on data sources for model validation can be found in SFEI 2021b.

2.4.2 Load Reduction Scenario Simulations

As noted in Section 2.3.1, the calibrated biogeochemical model will be used to simulate load reduction scenarios to assess the influence of load reductions on nutrient availability within the Delta. The final set of scenarios will be identified through consultation with the Nutrient TAC. In addition to the nitrogen-focused scenarios in **Table 3** at least one phosphorus reduction scenario will also be simulated.

Load reduction scenarios will be simulated and compared with 'Base' conditions. Two Base Cases will be established:

- $WY2022_{base}$: results from the WY2022 biogeochemical simulation, using actual loads during WY2022.
- $WY2016_{base}$: After model calibration (using actual WY2016 loads), WY2016 biogeochemistry will be re-simulated using post-upgrade loads at the EchoWater Facility, along with other upgrade-related changes to Delta point-source loads, with those model results serving as $WY2016_{base}$ (For nonpoint-source loads, WY2016 loads will be used).

Load reduction scenarios will be set-up and simulated as follows (for each scenario):

- *Scenario Load Estimates*: For each source that will be changed, nutrient concentrations or loads will be translated into a daily time-series.
- *Scenario Simulations:*
    - The updated load time-series will be substituted for the actual load time-series used for the Base case.
    - WY2022 and WY2016 biogeochemistry will be re-simulated using the scenario loads, with all other model inputs/boundary conditions/forcings the same as the base case, except as noted below.
    - Changes in nutrient concentrations will be quantified by comparing scenario conditions ($WY2022_{scenario}$, $WY2016_{scenario}$) with either $WY2022_{base}$ or $WY2016_{base}$.
- *Other Model Adjustments for Scenario Runs*: As needed, water column initial conditions (i.e., starting concentrations assigned throughout the domain) will be adjusted from the Base Case values. In some cases, adjustments to sediment conditions (and/or nutrient flux rates) may also be relevant to consider. The proposed approach to sediment-adjustments will involve: i) Assess the importance of sediment fluxes to water column nutrient concentrations or budgets (for Base case); ii) When necessary (i.e., flux is both quantitatively important and may overestimate fluxes under the scenario), a basic proportional adjustment to

sediment fluxes will be implemented. *Note*: More nuanced sediment-flux adjustments may be warranted for some cases, including considering the zones of influence of the altered sources, or the contribution of particulate nutrients from upstream (allochthonous organic matter) to the sediment nutrient pool.

The current budget is based on an assumption that four (4) load reduction scenarios will be explored, with each scenario simulated for WY2022 and WY2016 (8 year-scenario simulations).

2.4.3 Analysis & Interpretation

One of the primary outputs from this work will be the quantification of pre-/post-Scenario differences in N concentrations or fluxes (spatially, temporally), as described above. Where relevant, changes in P concentrations and fluxes will also be evaluated. Analysis of model output for the scenarios will include (for each scenario and water year):

- Delta-wide map-views of nutrient concentrations, at relevant times of the year:
    - Base concentrations, Scenario concentrations, Difference = Base-Scenario
    - Time period: plots can be developed for e.g., weekly- or monthly averages for representative times of the year, or daily average examples.
- For high-priority regions (e.g., HAB- or IAV-prone regions), changes in nutrient availability will also be investigated in greater detail.
    - Time-series of nutrient concentrations at specific stations or spatially averaged within areas of interest (Base, Scenario, Difference = Base-Scenario).
    - Changes in nutrient transport (mass flux, kg/d) into an area of interest (e.g., difference in the kg/d of DIN entering a region between $WY2022_{base}$ and $WY2022_{scenario}$).

Five of the seven priority regions (HAB- or IAV-prone regions) highlighted in **Section 2.2 Why is this a priority?** (Franks Tract, Old River, Middle River, Liberty Island, North Delta) are in the interior of the model domain, and are well-resolved by the grid. For each of these regions, load reduction scenarios will be examined by comparing DIN concentrations within, and mass fluxes into, the region. Both the Stockton Waterfront and Discovery Bay are positioned at or near the boundary of the model domain. For the Stockton Waterfront, the model grid extends along the majority of the Stockton Ship Channel (~2.8 km), but the region is not gridded at high-resolution, and data are relatively sparse for biogeochemical model validation. Discovery Bay is connected to the model grid at the boundary; however, the grid does not extend into Discovery Bay. For the Stockton Waterfront and Discovery Bay, the influence of load reduction scenarios will be examined primarily by characterizing changes in DIN mass fluxes into these regions (relative to the

Base simulations). These regions and relevant scenarios could be investigated further in follow-up modeling studies, informed by the results from this project.

The final technical report will include relevant graphics along with descriptive analysis of results. The current budget is based on the assumption that four load reduction scenarios will be simulated and analyzed for each water year (8 year-scenario simulations).

A second central aim of this work is to investigate one or more additional priority nutrient-related hypotheses, leveraging the same simulations, through using mass-budgets/control-volume analyses, numerical tracers, or other approaches. Examples include:

- Characterizing the relative importance of physical/biological/biogeochemical factors regulating phytoplankton biomass or productivity, including potential effects of lower nutrient availability due to load reductions.

Quantifying the importance of remaining nutrient sources (beyond those included in scenarios) within HAB- and IAV- prone regions, including Delta non-point sources; and/or assessing the relative importance of IAV on nutrient concentrations and cycling. This work could focus on regions where beneficial algal production occurs (Liberty Island, North Delta); or regions where HABs and/or IAV impact water quality and habitat quality (Stockton Waterfront; Franks Tract; Old and Middle Rivers). The specific combination of techniques used to investigate these issues will vary by topic, and may include some or all of the following: analysis of additional model output within regions of interest (e.g., changes to primary productivity or evidence of nutrient-limited growth rates within regions of interest); quantification of nutrient source contributions or additional nutrient losses within a region, using mass balance and various tracer approaches, The specific focus of this component of the project will be finalized with input from the Nutrient TAC. The current project cost estimate includes budget to pursue one of the above analysis-directions, with the potential to pursue additional hypotheses depending on their depth of analysis.

2.5 DATA DELIVERABLES AND REPORTS

2.5.1 Data Management & Data Deliverables

Modeling work is being conducted with open-source/public-domain tools, and all data, model output, and scripts.

2.5.2 Reporting

The primary deliverable will be a Technical Report, presenting the following:

1. Hydrodynamic and biogeochemical model validation, along with description of the model and relevant model updates.

2. Results of Base-Case and Scenario simulations, with the current budget based on an assumption of four scenarios (simulated during both water years). Analyses will include:
    a. Delta/Suisun-wide: analysis/interpretation of differences in nutrient concentrations, over space and time (seasonal, interannual).
    b. Additional focus or depth of analysis within priority regions, i.e., regions that are considered HAB-prone, IAV-prone, or where fostering beneficial production is a management priority.
3. Analysis/Interpretation of additional priority hypotheses or science/management questions.
4. For #3 (and potentially other components), the technical report may be written in the form of manuscript (time-permitting) for submission to a peer-reviewed journal, with additional analyses/figures/documentation that are relevant to the Delta RMP included in appendices as needed.

2.6 STUDY TIMELINE AND SCHEDULE

Project work will begin in July 2024, aligned with the start of the Delta RMP's FY2025. Assuming a 2-year project, work would proceed as follows (approximate):

- *0-6 months* hydrodynamic model setup and initial calibration work, initial biogeochemical model setup;
- *7-12 months* finalize hydrodynamic calibration and validation, setup/calibrate/validate biogeochemical model, and initial scenario/analysis work;
- *13-18 months* complete scenario simulations/visualizations and analysis;
- *19-24 months* report preparation.

2.7 BUDGET ESTIMATE

The cost estimates below (**Table 4**) are approximate and may vary depending on decisions related to the number of scenarios, and the breadth and depth of additional hypotheses to pursue.

Table 4. Cost estimates for hydrodynamic and biogeochemical modeling, and subsequent analysis, interpretation, and writing of a final technical report.

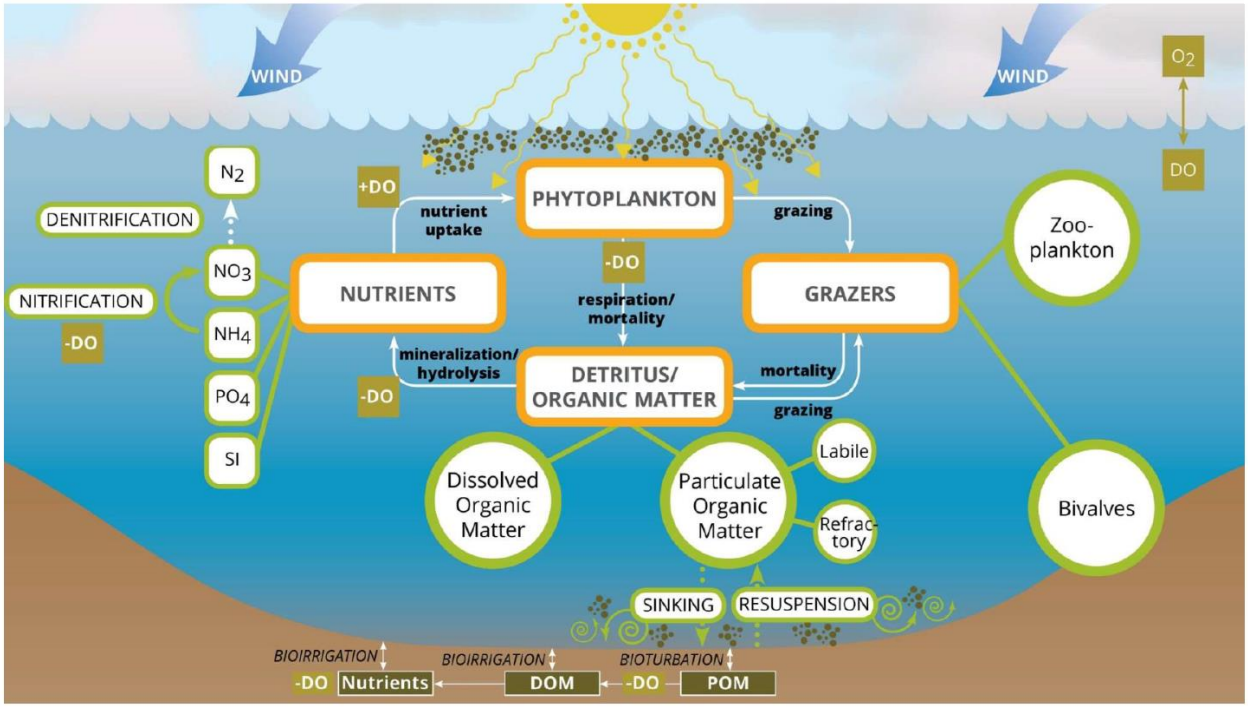
TASK	COST
1. Hydrodynamic: model updates, setup, calibration & validation	$90,000
2. Biogeochemical: model updates, setup, calibration & validation	$135,000
2a. Optional Phosphorus reduction scenarios	*$20,000*

TASK	COST
3. Analysis, Interpretation, Write-up	$155,000
Total	**$380,000**
Total with Optional Phosphorus reduction scenarios	***$400,000***

The above budget (**Table 4**) is based on an estimate of eight load reduction scenarios (8 scenarios simulated for two years each) being explored in depth, as opposed to all seven in **Table 3**, considering that there may be substantial information-overlap among some of the scenarios and not all will be required. Scenarios can be added as needed, at an estimated cost of $7,000-$10,000/scenario (for example, if only four scenarios are needed the cost would be reduced by approximately $30,000).

Figure 1. Model domain of the current nSFE-BGCM.

Figure 2. Schematic of state variables and processes simulated by the nSFE-BGCM.



Important water column and sediment-compartment processes include:

Water Column Processes

- Microbial: nitrification; respiration (dissolved oxygen [DO] consumption) and remineralization of organic matter (converting organic forms of nutrients, including dead phytoplankton, to inorganic forms).
- Phytoplankton: growth (production of new biomass), uptake/assimilation of nutrients, respiration, mortality.
- Grazers: grazing (consumption of phytoplankton), excretion of nutrients, growth (increased biomass), respiration, mortality
- Oxygen (O2) exchange between the water column and atmosphere.
- Light attenuation by suspended sediment and phytoplankton.

Sediment Processes

- Microbial: nitrification, denitrification, aerobic respiration (DO consumption), and mineralization of organic matter (converting organic forms of nutrients to inorganic forms).
- Benthic grazing: filtration/consumption of phytoplankton and detritus, excretion of nutrients, growth (increased biomass), reproduction, and death.
- Accumulation of organic matter (settling from the water column) and mixing/bioturbation of sediments.
- Sediment←→ Water: flux of Ammonium (NH4), Nitrate (NO3), Phosphate (PO4), and Si from the sediments to the water column, flux of NO3 and O2 from the water column to the sediments (denitrification and oxygen consumption, respectively, at the sediment-water interface).

Figure 3. Summary of major updates and improvements to the nSFE-BGCM incorporated during recent projects, including the recent DRMP-funded modeling project.
Additional biogeochemical model refinements (developed through on-going Bay modeling work) will be incorporated into the nSFE-BGCM during this project and applied to WY2022 and WY2016 simulations.

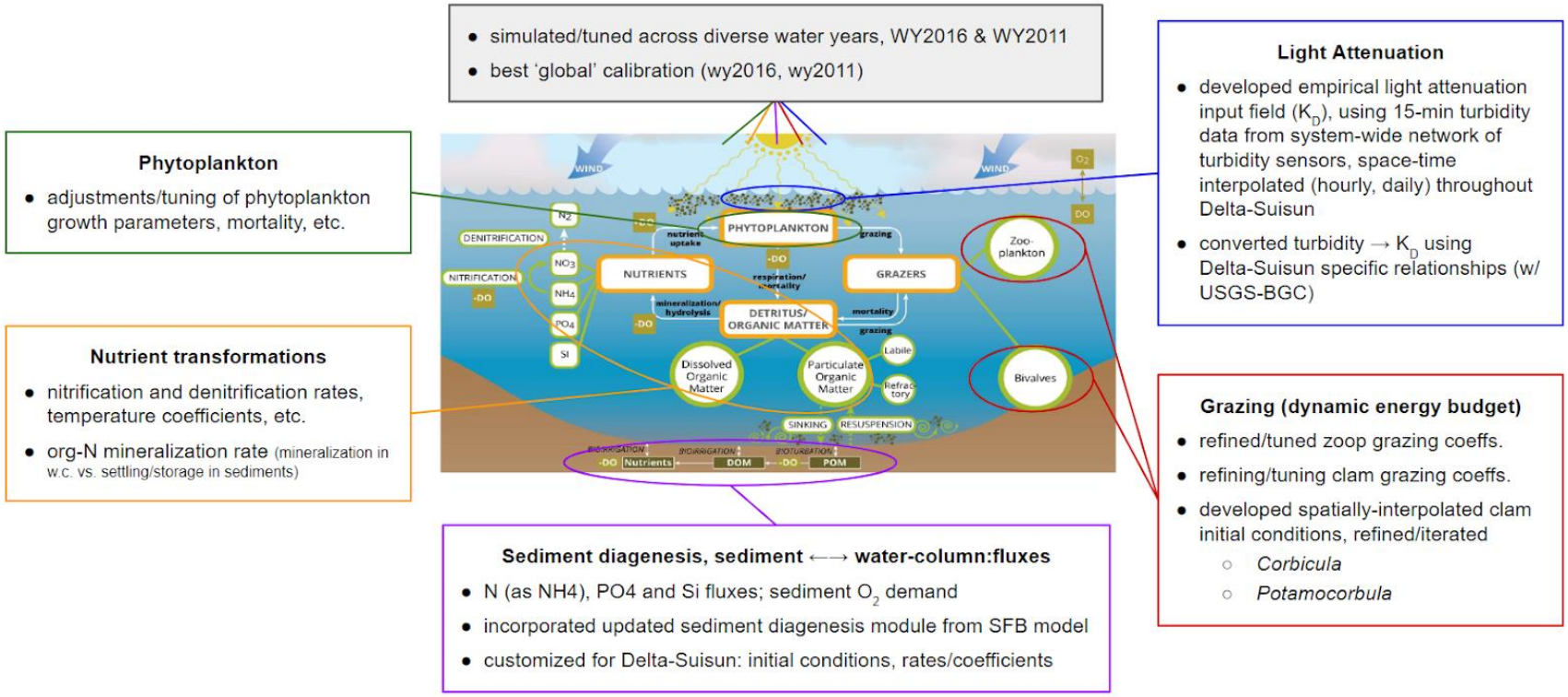


Figure 4. Regional control volumes used in nSFE-BGCM simulation for WY2016.
A set of finer resolution control volumes was also established (5-20 per region), allowing for more targeted analyses and interpretations. Simulations are run at full-spatial and full-temporal resolutions, and internal transformation rates are daily-integrated and spatially averaged. (Red circles indicate the locations of some of the monthly discrete monitoring stations used for model validation).

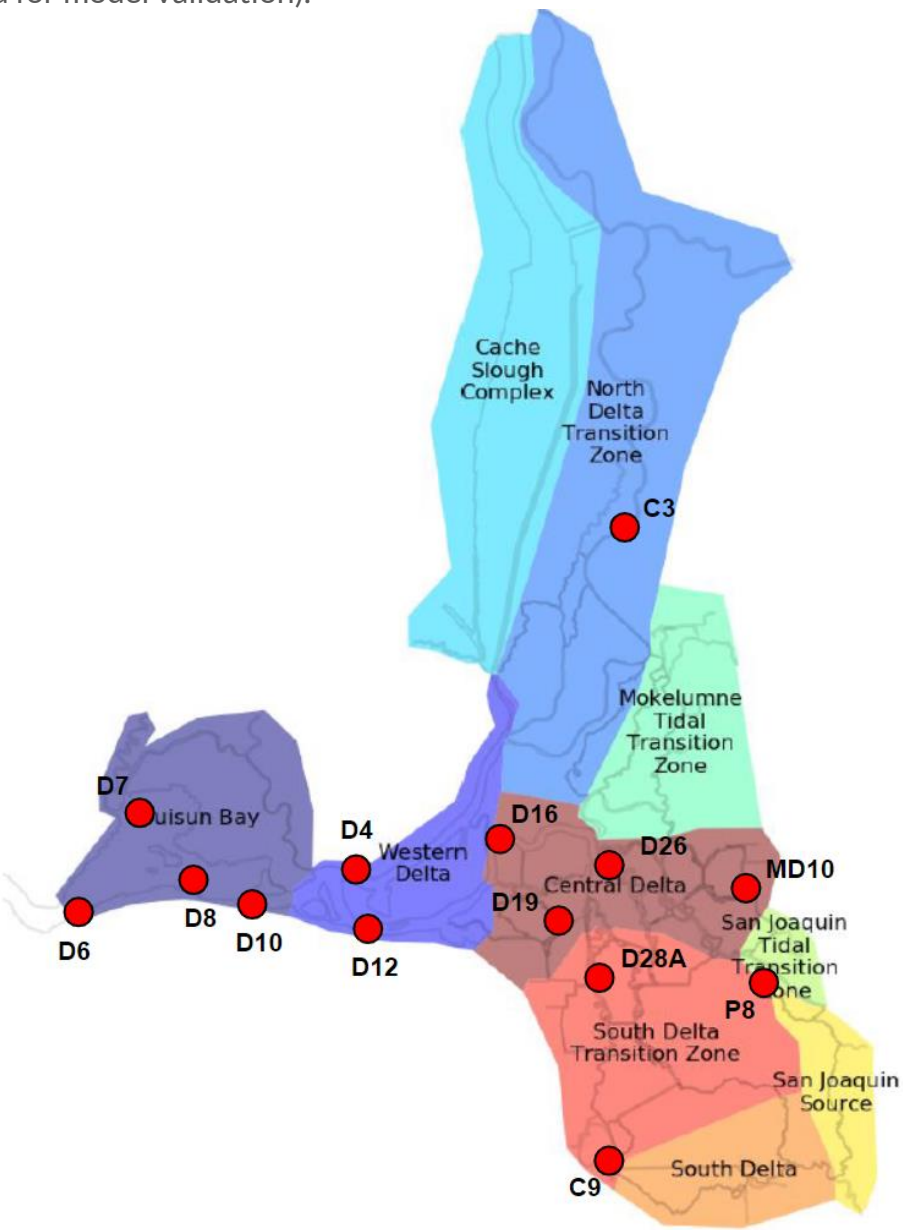
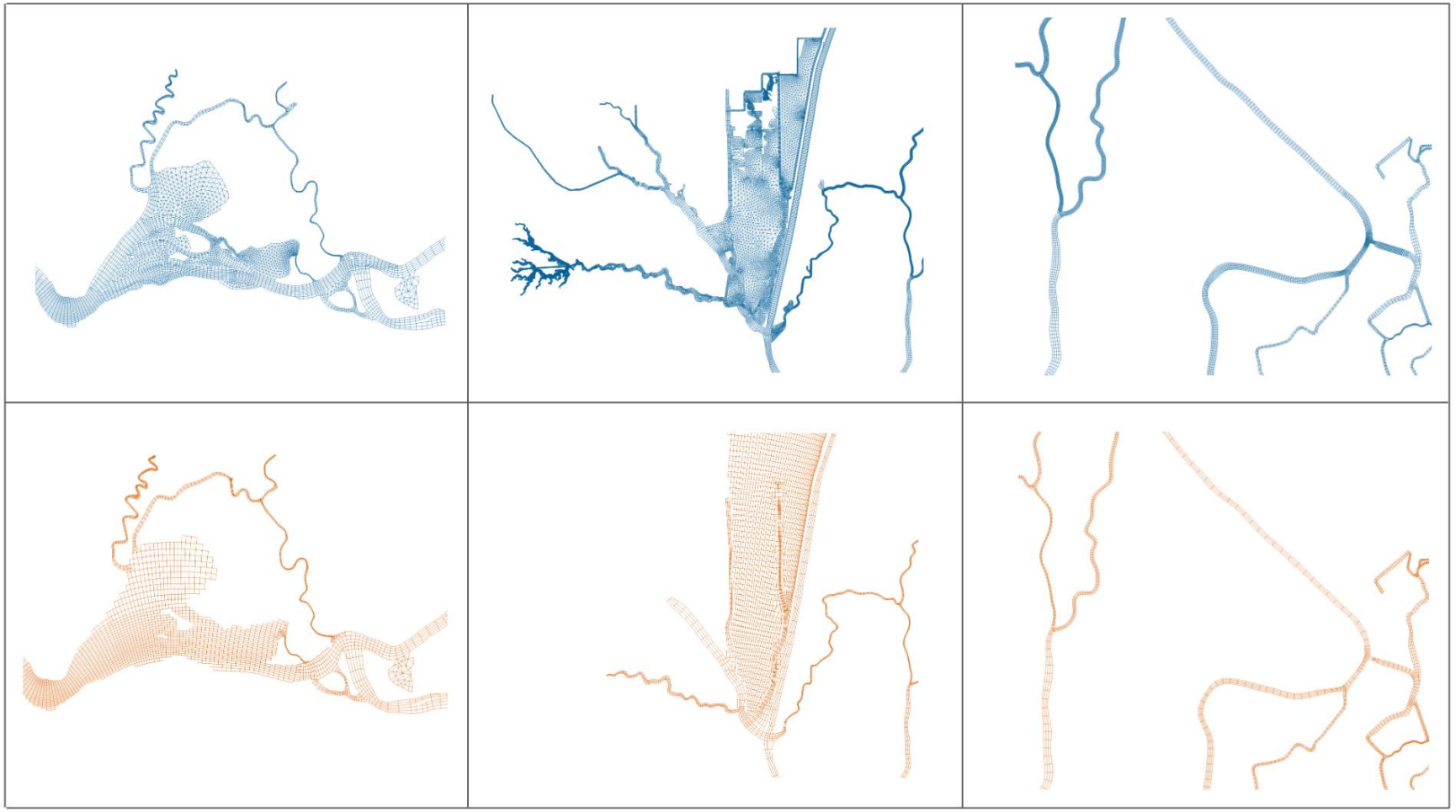


Figure 5. Current and new nSFE-BGCM grids.
Bottom: Subsets of grid used for prior nSFE-BGCM work; Top: Updated grid (Holleman, et al., in prep.), to be used for the proposed project. The grid updates have already been merged with the rest of the domain in **Figure 1**. The remaining work includes 're-plumbing' boundary conditions/forcings, and updating model set-up (control-volume or transect boundaries) and post-processing scripts (analysis, plotting), etc.



3 FOCUS AREA #2

To assist with understanding the ecological effects of nutrient reductions, a bioassay study will be used to answer the following Focus Area #2 question:

- What are the thresholds for nutrients (N and P and their ratios) that can limit HAB biomass and cyanotoxin accumulation to safe levels, limit the abundance and distribution of nuisance macrophytes, and support robust growth of desirable phytoplankton and macrophytes throughout the Delta?

3.1 STUDY OBJECTIVES

The study objective is to understand how reductions in N and P concentrations might affect phytoplankton species composition, biomass, and cyanotoxin production in the Delta and to identify if other environmental factors will influence phytoplankton growth at low N or P concentrations (potentially altering the outcomes of nutrient reduction actions). This study is designed to partially inform one of the management questions identified as a high priority by the Delta RMP SC. "What are the thresholds for nutrients (N and P and their ratios) that can limit HAB biomass and cyanotoxin accumulation to safe levels, limit the abundance and distribution of nuisance macrophytes, and support robust growth of desirable phytoplankton and macrophytes throughout the Delta?" It also follows a research recommendation in the Delta Nutrient Research Plan (Cooke et al. 2018), to perform a "Study of potential for changes in nutrients or physical drivers to reduce frequency and magnitude of harmful cyanobacteria blooms and toxins".

This study will use controlled and replicated bioassay experiments to investigate how phytoplankton sourced from the south Delta responds to limited N or P availability. Bioassay experiments simplify complex natural processes by controlling specific factors and can be used to test a hypothesis in a similar but controlled environment. However, there are limitations to bioassay experiments focused on phytoplankton communities, including unintended impacts of the study design such as: deleterious impacts of the enclosure on physiological performance of phytoplankton, potential changes in species composition, and the potential of inducing the limitation of other nutrients when adding another macronutrient (Beardall et al 2001). Results of these types of studies should be used in context of the limitations of the study design recognizing that they will not be a perfect representation of the Delta. More details regarding limitations of the bioassay design are included in section **Limitations of the Bioassay Design**.

Dilution bioassay studies allow the effects of low nutrient concentrations on phytoplankton to be evaluated in waterways where low nutrient concentrations rarely

occur. A recent bioassay testing Sandusky Bay water from Western Lake Erie determined that a 40% P reduction prevented the increase of microcystin concentrations in 3-day experiments compared to undiluted treatments where Microcystin concentrations roughly doubled (Barnard et al. 2021). These bioassay experiments also determined that in August low N concentrations limited chl-a production and production of the cyanotoxin anatoxin in Sandusky Bay water.

It is also important to recognize that the Delta is a complex ecosystem and many factors other than nutrient concentrations can influence phytoplankton growth, such light limitation, salinity, water temperature, nutrient competition with macrophytes, grazing losses to clams, and differences in water residence times. Therefore, a second set of mesocosm studies is proposed to examine how phytoplankton respond to nutrient reductions in combination with some of these other common environmental variables that can be manipulated in the bioassay containers (additional details are provided in the methods section). The goal for the second set of treatments is to determine if other environmental factors can have a large influence on phytoplankton community responses at low N concentrations. It is recommended that all of the multiple-factor treatments be conducted at a single low nitrate (DIN) concentration, such as 0.1 mg/L-N, allowing direct comparisons between treatments and control. If one of these environmental factors shows a strong effect on phytoplankton biomass, HAB biomass, or cyanotoxin production, compared to that of the low N concentration control, then the factor should be tested further in separate (future) sets of experiments across a range of low N concentrations. Future studies would be necessary to further understand how phytoplankton responses to a range of low nutrient reduction might differ in the presence of other common environmental factors.

This study is a first step in understanding how phytoplankton communities in the Delta can respond to low nutrient concentrations. It is currently unknown which species will dominate phytoplankton communities grown at low nutrient concentrations. The findings from this study will guide future research investigating the potential ecological effects of reduced nutrient loading into the Delta. Additional manipulative studies, comparisons to samples collected in the waterway, and biogeochemical and hydrological modeling are also needed to continue the development of nutrient objectives for the Delta and Suisun Bay.

The bioassay experiment is an exploratory study that seeks to inform the broad questions listed below using nutrient dilution assays.

- Would N or P reduction reduce HAB growth in the Delta? If so, what level of N or P reduction is needed to significantly reduce HAB growth and cyanotoxin concentrations to acceptable levels in the Delta?

- Would N or P reduction reduce the biomass of desirable phytoplankton in the Delta? If so, is the reduction significant and meaningful?
- Would N or P reduction significantly alter the growth of specific cyanobacteria that cause taste and odor problems for drinking water systems?
- How do other environmental factors, such as light limitation, aquatic plant growth, or clam grazing, alter the effects of N or P reductions on HABs and/or phytoplankton populations?

3.1.1 Why is this a priority?

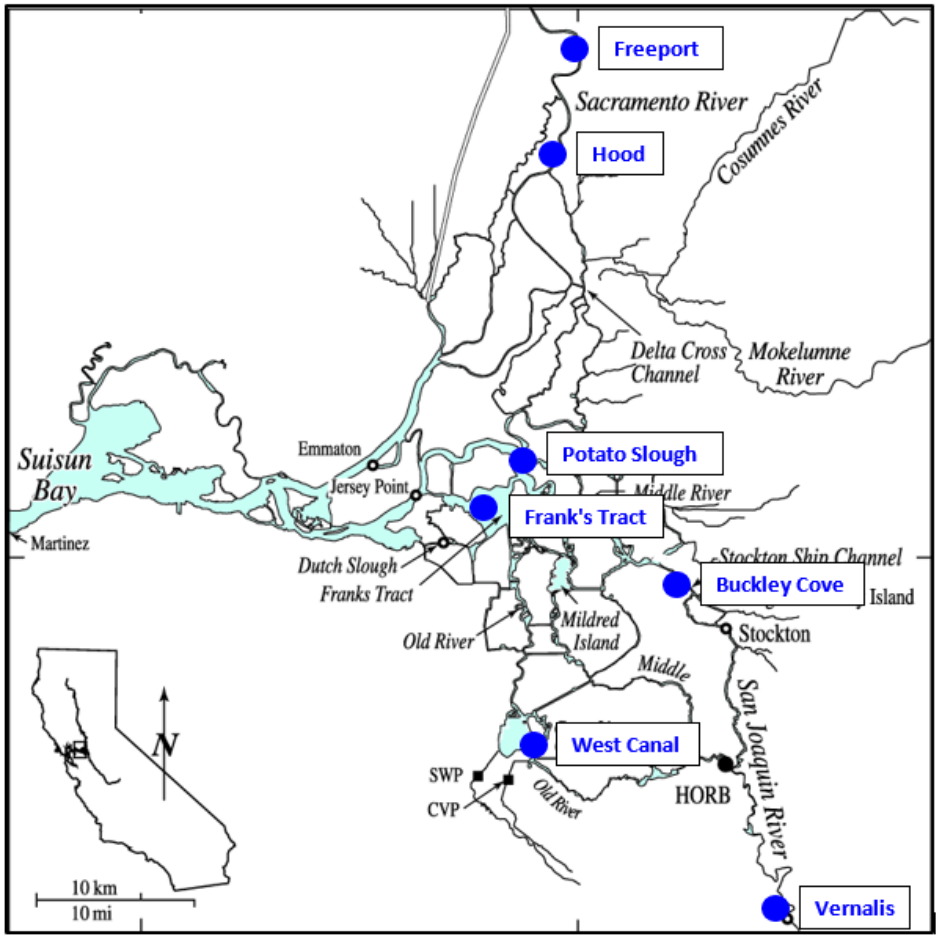
The Central Valley Regional Water Quality Control Board's (CVRWQCB or Central Valley Water Board) Delta Nutrient Research Plan identified research recommendations for further research to better address nutrient management questions in the Sacramento-San Joaquin Delta (Delta) (Cooke et al. 2018). The top-ranking special study recommendation was to determine the roles of nutrients and other drivers in controlling the growth rate, maximum biomass, and toxin production of HABs. The Central Valley Water Board noted that they anticipate the possible development of nutrient benchmarks and/or reduction goals during the Delta Nutrient Research Plan implementation. Accordingly, the Delta RMP Nutrient TAC has developed a study to evaluate the potential effects of nutrient reductions on phytoplankton in the Delta. Reduced nutrient concentrations in the Delta might help control the occurrence and severity of HABs, such as *Microcystis* sp., *Aphanizomenon* sp., and *Dolichospermum* sp. and reduce cyanotoxin concentrations, such as microcystin, anatoxin, saxitoxins, and cylindrospermopsin. However, nutrient reduction also has the potential to reduce the growth of desirable phytoplankton species, such as diatoms, which provide an important base to the Delta's pelagic food web.

Low concentrations of nutrients, including N and P, can limit phytoplankton and cyanobacteria growth. In the summer and fall periods of 2022, the average ratio of N:P in the Delta ranged from 6:1 to 24:2 (Battey and Perry 2023, Error! Reference source not found.), indicating that N supply might become depleted before P during phytoplankton blooms at some stations. If N is depleted in the early stages of a bloom, it might reduce the HAB biomass, shorten the HAB duration, and decrease the cyanotoxin concentration produced. Limiting nitrogen concentrations might also allow N-fixing cyanobacteria to become more prevalent in the Delta phytoplankton community, although N-fixing cyanobacteria can also supply N to other cyanobacteria species when they die (Molot et al. 2017).

Table 5. Average monthly N and P concentrations and standard errors at Delta locations measured by the IEP Environmental Monitoring Program between June and October 2022.
Samples with concentrations below the analytical minimum detection level were averaged using the detection limit. The less than symbol indicated that all sample concentrations in the data set are less than the analytical minimum detection level. Values are concentrations +/- (1 standard error). Standard errors were not calculated for stations where all values were below the analytical minimum detection level and are marked with "n/a".

Location	Station ID	Latitude	Longitude	DIN mg/L-N	Ortho-P mg/L-P	Total N mg/L-N	Total P mg/L-P	Total N µmol/L	Total P µmol/L	TN:TP molar ratio
Vernalis	C10A	37.679	-121.265	0.33 (0.07)	< 0.05 (n/a)	0.43 (0.08)	0.04 (0.004)	31.1 (5.8)	1.3 (0.1)	24.2
Hood	C3A	38.367	-121.521	0.24 (0.02)	< 0.05 (n/a)	0.31 (0.02)	0.03 (0.002)	22.3 (1.4)	1.0 (0.1)	23.1
West Canal	C9	37.830	-121.554	0.16 (0.03)	0.08 (0.007)	0.40 (0.07)	0.09 (0.009)	28.8 (4.9)	3.0 (0.3)	9.5
Buckley Cove	P8	37.978	-121.382	1.60 (0.51)	0.35 (0.03)	2.08 (0.51)	0.35 (0.03)	148.6 (36.7)	11.4 (1.0)	13.0
Frank's Tract	D19	38.043	-121.615	< 0.1 (n/a)	0.05 (0.002)	0.25 (0.01)	0.06 (0.003)	17.6 (0.7)	1.9 (0.1)	9.1
Potato Slough	D26	38.076	-121.567	0.13 (0.01)	0.05 (0.003)	0.26 (0.02)	0.10 (0.04)	18.7 (1.6)	3.1 (1.2)	6.1

Figure 6. A map of selected IEP EMP Monitoring Program station locations.



3.1.2 Background

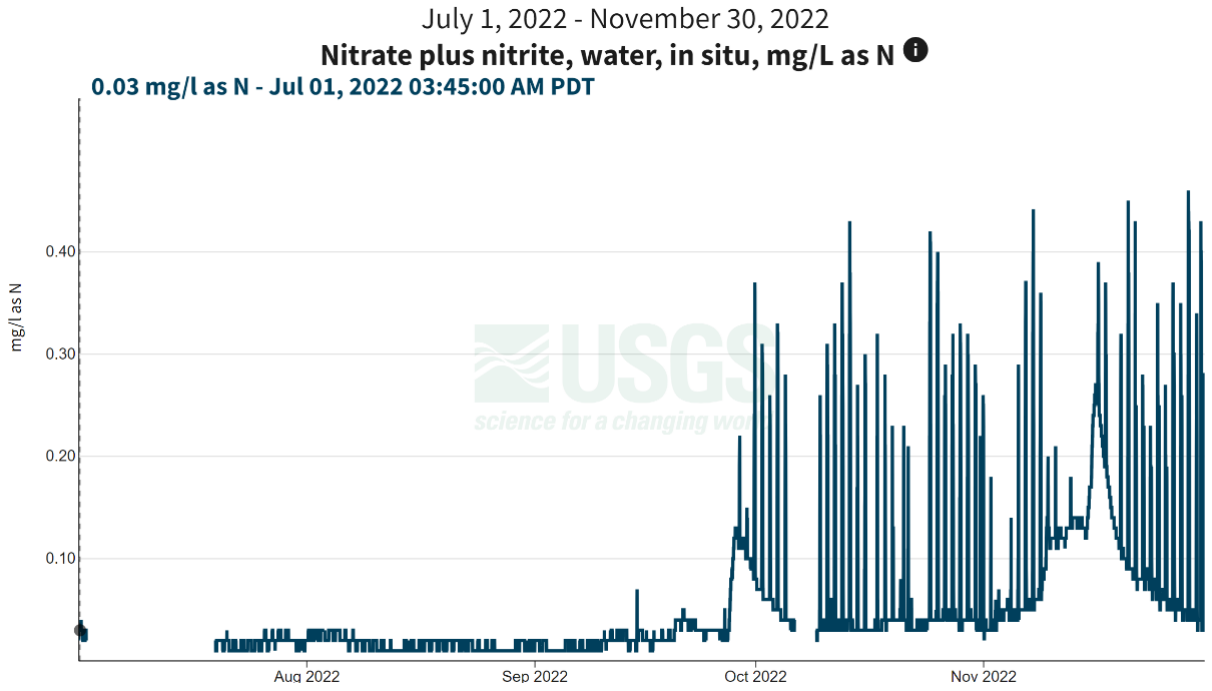
During 2022, California was in a prolonged drought and *Microcystis* sp. blooms were common in the South Delta from June to October (Battey and Perry 2023). Phytoplankton grew using the dissolved fraction of N in the water (DIN), which was mostly in the form of nitrate from June to October of 2022 (Battey and Perry 2023). Water quality monitoring (IEP EMP) in the Delta (at the stations indicated in **Figure 6**) determined that ammonium was often below the detection limit of 0.05 mg/L-N from June to October in 2022, with the only detectable ammonium concentrations of 0.06 and 0.07 occurring at Buckley Cove in September and October, respectively (Battey and Perry 2023).

In general, the average DIN concentrations were lower in stations receiving Sacramento River water compared to those receiving San Joaquin River water (Error! Reference source not found.). Potato Slough N concentrations were lower than that supplied by Sacramento or San Joaquin Rivers, suggesting that nutrient drawdown had occurred before the water reached this station. The average concentration of N in July through August 2022 at Freeport Bridge in the Sacramento River was < 0.05 mg/L-N (**Figure 7**,

USGS 2023). The Freeport monitoring station is located just upstream of the Sacramento Area Sewer District's (SacSewer) discharge location, so reverse flows occurring in late September and November created short-term spikes in N. At the Hood monitoring station, which is downstream of SacSewer's discharge location, the effluent was well mixed with Sacramento River water and the average N was approximately 0.2 mg/L-N (Error! Reference source not found.). Therefore, the range in DIN occurring throughout the Delta in 2022, from 0.05 mg/L-N to 1.0 mg/L-N, provides a good range of DIN concentrations to evaluate phytoplankton response to differing N availability.

During this same period, the average of total P observed at monitored sites ranged from 0.03 to 0.35 mg/L-P, which serves as a benchmark for identifying a range of potential P reductions and N:P ratios suitable for evaluation along with DIN in nutrient reduction experiments.

Figure 7. Nitrate plus Nitrite concentrations at the USGS Freeport monitoring station on the Sacramento River from 7/1/2022 to 11/30/2022.
Concentration spikes in October and November are caused by Sacramento River flow reversals briefly transporting wastewater effluent to the Freeport Station.



3.2 HYPOTHESES

This study tests multiple N and P concentrations that occurred throughout the Delta during the 2022 drought when nutrient dilution was likely minimal. *Microcystis sp.* was common in the south Delta during this time (Battey and Perry 2023). The findings from this study should be compared to nutrient, chl-a, HAB, and phytoplankton enumerations

data collected from the Delta in 2022 to determine if similar chl-a concentrations and phytoplankton species occur in Delta locations with matching environmental parameters. Particularly strong interacting factors should be further investigated across a range of low N concentrations in future experiments.

The bioassay addresses an important question for nitrogen management; which phytoplankton species and how much phytoplankton biomass are likely to grow in the Delta at low N and P concentrations under ideal growing conditions? Phytoplankton (and HAB) management strategies also need to identify expected nutrient concentrations throughout the Delta under reduced nutrient loading (investigated by Focus Area 1) and how other factors known to reduce phytoplankton growth might interact with low dissolved inorganic nitrogen (DIN) to affect phytoplankton species biomass and occurrence.

Other important factors that should be studied in combination with nutrient limitation include light or silica limitation, reduced growth periods due to increased flows, temperature effects, herbicide effects, salinity effects, stratification, competition with macrophytes, grazing by herbivores, and mortality from disease and parasites. If a model can combine all the known outcomes of these interacting factors on phytoplankton growth, and estimate the biogeochemical nitrogen cycle, it should provide reasonable predictions for how phytoplankton would respond to nutrient loading reductions in the Delta.

The proposed bioassay study provides a useful first step by identifying the upper limit of phytoplankton biomass that might occur in the Delta at different low DIN and P concentrations in the absence of these other regulating factors. The study will also help evaluate if light limitation, competition with a submerged macrophyte, or grazing by clams might have substantial impacts on phytoplankton growth at low nutrient concentrations.

The findings from this study will help California State regulators and stakeholders estimate the upper limit of cyanobacteria biomass and cyanotoxins that can be produced at low N or P concentrations, under conditions promoting phytoplankton growth. This information will help California State regulators and stakeholders evaluate the level of nutrient reduction that might result in material reductions in cyanobacteria populations. The findings will also help determine if low N or P concentrations might limit the biomass of beneficial phytoplankton produced in the Delta. Chlorophyll-a concentrations above 10 µg/L have been shown to support maximal zooplankton growth rates (Müller-Solger et al. 2002). The study also provides an initial investigation into potential interactions between low N concentrations and other factors known to affect phytoplankton biomass in the Delta, including light limitation, nutrient competition with macrophytes, and grazing losses to clams, to assess the importance of combined effects. Detailed descriptions of these multi-factor treatments are provided in the methods section.

The proposed hypotheses to be tested are:

1. Low N or low P concentrations will prevent cyanobacteria from growing to nuisance concentrations and producing harmful concentrations of cyanotoxins.
2. Low N or low P concentrations will prevent beneficial phytoplankton species from growing to concentrations that support robust zooplankton growth (i.e., 10 µmol chl-a).
3. Low N or low P concentrations will reduce the biomass of specific planktonic cyanobacteria to concentrations that may not cause taste and odor problems for drinking water systems.
4. Phytoplankton species grown at a low N concentration and low light levels will differ from those grown at a low N concentration with moderate light levels.
5. At a low N concentration, nutrient competition with *Egeria densa* and its associated periphyton will result in lower cyanobacteria biomass, cyanotoxin concentrations, and beneficial phytoplankton biomass.
6. At a low N concentration, the presence of clams will reduce the accumulation of cyanobacteria, cyanotoxins, and beneficial phytoplankton biomass compared to phytoplankton grown at a low N concentration without clams.

3.3 MONITORING STRATEGY

The methods described here are provided for discussions of the study design which will be adjusted and refined by the Principal Investigator in close coordination with the Nutrient TAC members. All parameters and procedures will be adjusted to best evaluate the research questions and hypotheses. The final study design will be included in the Delta RMP Monitoring Workplan.

3.3.1 Pilot Scoping Studies

An initial set of pilot studies, testing different variables of the project design, such as sampling locations, water volumes, incubation duration, dilution water chemistry, N and P concentrations, salinities, light levels, clam biomass, and macrophyte biomass, should be performed prior to running the fully replicated study.

3.3.2 N and P Reduction Bioassay Treatments

Bioassay Treatments 1-8

Target N and P concentrations in the N reduction and P reduction bioassays (Treatments #1-8, **Table 6**) were selected to represent the range of average DIN and P concentrations occurring from June to October at different stations in the Delta in 2022. The highest average DIN and P concentrations occurred at Buckley Cove (roughly 1.6 mg/L-N and 0.35 mg/L-P, Error! Reference source not found.). The lowest DIN concentration occurred at Freeport (roughly 0.05 mg/L-N, **Figure 7**), while the lowest P concentration occurred at Hood (0.03 mg/L-P, Error! Reference source not found.). The N and P concentrations used in treatments #1-8 represent different levels of nutrient change, reduction or increase, at comparative stations across the Delta (**Table 7**). For example, a DIN value of 0.1 mg/L-N (treatment #3) would represent a 22% reduction at Potato Slough, a 58% reduction in average DIN at Hood, a 69% reduction at Vernalis, and a 94% reduction at Buckley Cove (**Table 7**). Similarly, a total P value of 0.03 mg/L-N (treatment #7) would represent a 70% reduction at Potato Slough, a 0% reduction in total P at Hood, a 25% reduction at Vernalis, and a 91% reduction at Buckley Cove (Table 6). The nitrate concentration in treatment #4 (0.05 mg/L-N) is representative of DIN concentrations in the Sacramento River from July through August upstream of SacSewer's discharge (**Figure 7**).

Treatment 9 is a river control treatment. Water will be collected directly from the source water location in the Delta during all three days of the experiment. This treatment will compare changes in phytoplankton biomass and assemblage occurring in the Delta waterway during the experimental period to those occurring in each of the bioassay treatments.

Treatment 10 is an ambient nutrient control treatment. Source water will be filtered with 100-200 µm Nitex screening, to remove large zooplankton and larval clams, and then be poured directly into the bioassay cubitainers without dilution or the addition of supplemental nutrients. This treatment will evaluate phytoplankton growth in the cubitainer environment at the ambient nutrient concentrations present in the source water.

Table 6. Treatments, bioassay descriptions, and target nitrate concentrations used in nitrogen reduction (#1-4), phosphorus reduction (#5-8), controls (9-11), and multi-factor (#12-14) bioassays. All treatments are tested in triplicate.

Treatment #	Treatment Category	Treatment Description	Nitrate (mg/L-N) or Phosphorus (mg/L-P)	Nitrate or Phosphorus (µmol/L)
1	N Reduction Bioassay	Nitrogen reduction, Unlimited P	0.4	29
2	N Reduction Bioassay	Nitrogen reduction, Unlimited P	0.2	14
3	N Reduction Bioassay	Nitrogen reduction, Unlimited P	0.1	7
4	N Reduction Bioassay	Nitrogen reduction, Unlimited P	0.05	4
5	P Reduction Bioassay	P reduction, Unlimited N	0.12	4
6	P Reduction Bioassay	P reduction, Unlimited N	0.06	2
7	P Reduction Bioassay	P reduction, Unlimited N	0.03	1
8	P Reduction Bioassay	P reduction, Unlimited N	0.015	0.5
9	Control	River control treatment	TBD	TBD
10	Cubitainer Control	Ambient nutrient control treatment	TBD	TBD
11	Duplicate Control	Duplicate of treatment 4 (control)	0.1	7
12	Multi-factor Bioassay	50% light reduction + nutrient reduction	0.1	7
13	Multi-factor Bioassay	*Egeria densa* addition + nutrient reduction	0.1	7
14	Multi-factor Bioassay	*Corbicula fluminea* addition + nutrient reduction	0.1	7

Table 7. The percent change in nutrient concentration reductions (negative values are reductions) per treatment (#1-8) based on average DIN and TP concentrations in the Delta from June to October in 2022 (Error! Reference source not found.**).**

Location	DIN Reduction				TP Reduction			
	Treatment							
	1	2	3	4	5	6	7	8
Frank's Tract	300%	100%	0%	-50%	100%	0%	-50%	-75%
Potato Slough	213%	57%	-22%	-61%	20%	-40%	-70%	-85%
West Canal	157%	28%	-36%	-68%	33%	-33%	-67%	-83%
Hood	68%	-16%	-58%	-79%	300%	100%	0%	-50%
Vernalis	23%	-39%	-69%	-85%	200%	50%	-25%	-63%

Location	DIN Reduction				TP Reduction			
	Treatment							
	1	2	3	4	5	6	7	8
Buckley Cove	-75%	-88%	-94%	-97%	-66%	-83%	-91%	-96%

Multiple-Factor Bioassay Treatments

The Delta is a complex ecosystem and many factors other than DIN and total phosphorus concentrations are known to influence phytoplankton growth, such as light limitation, nutrient competition with macrophytes, grazing losses to clams, and differences in residence times. This second set of mesocosm studies investigates how phytoplankton might respond to nutrient reductions in combination with other common environmental variables (summarized in **Table 6**). These experiments are intended to evaluate if other factors with the potential to regulate phytoplankton biomass and species composition might cause substantial changes to the experimental results. If these factors significantly impact phytoplankton growth in the bioassay, they also need to be considered in future phytoplankton management strategies.

- In low light, phytoplankton growth may be slower, but low light might also support phytoplankton species that are better adapted to living at low light levels.
- If nutrients are taken up by aquatic vegetation, then higher nutrient concentrations might be required to reach desirable levels of beneficial phytoplankton growth.
- Clam grazing might exclude some phytoplankton species, allowing a different phytoplankton assemblage to be dominant under nutrient-limited conditions in regions where clam grazing is common.

If phytoplankton in the multi-factor bioassays show substantial differences from the control, it is an indication that additional research on these factors will be necessary before the effects of nutrient reductions on phytoplankton biomass can be estimated for the Delta.

The goal is to determine if interactions between low N concentrations and any of these factors might significantly alter the outcome of nutrient reductions in phytoplankton communities. It is recommended that all multiple-factor cubitainer studies be conducted at the low nitrate concentration of 0.1 mg/L-N. A control treatment duplicating the conditions present in Treatment #4 should be conducted and used for comparisons in the multiple-factor studies. If one of these factors shows a strong effect on phytoplankton biomass, HAB biomass, or cyanotoxin production, then the interaction should be tested to a greater extent in a separate (future) sets of experiments across a range of low N concentrations.

The multiple-factor bioassay treatments will require 18 cubitainers per day, so the full study (Treatments 1 through 14) will use 42 cubitainers per day. The sampling frequency and test parameters used in the multiple-factor bioassay treatments will follow those listed in **Table 8**.

CONTROL (TREATMENT #11)

This treatment is a duplicate of treatment #4 and will be used for statistical comparisons with the other treatments in the multifactor bioassay treatments. Comparing the multifactor treatment results with treatment #4 would require a Bonferroni correction to be used in the Analysis of Variance (ANOVA) tests for each study.

LIGHT REDUCTION (TREATMENT #12)

Insufficient light is known to limit phytoplankton growth in the main channels of the Delta (Cloern 1987), where the water column is often turbid, deep, and well-mixed. The PAR levels in other treatments are intended to simulate the light available within the first meter of water depth and should be sufficient for rapid phytoplankton growth. However, it is important to also understand the combined effects of reduced N concentrations and limited light on phytoplankton growth. Lower light may allow slower-growing phytoplankton to become the competitively dominant species in the bioassays. Cubitainers in this treatment should be wrapped with an extra layer of neutral density screening to reduce light levels so they are at 50% of the PAR received in other treatments.

EGERIA DENSA ADDITION (TREATMENT #13)

Egeria densa (*E. densa*, also known as Brazilian waterweed) is an invasive submerged aquatic plant that is common throughout the Delta. *E. densa* stalks have whorls of leaves that create a bottle-brush appearance and can live free-floating (without roots) by absorbing nutrients directly from the water. The competition between *E. densa* and phytoplankton for scarce levels of nutrients has not been tested in the Delta. Periphyton can also grow on the surface of *E. densa* and take up additional nutrients. The study will not attempt to differentiate between the nutrients utilized by *E. densa* or its associated periphyton because they regularly occur together, and the goal is to understand their combined effect on phytoplankton biomass and species composition. It is also possible that some periphyton on *E. densa* stalks might propagate out into the suspended algae during the experiments.

E. densa stems will be harvested from the Delta and trimmed to a length of 25 cm from the stem tip. Stems should be gently rinsed with river water to remove built-up sediments. Stems should be visually inspected, and all macroinvertebrates removed (such as snails and insects). Non-branching stems that include at least one double node should be

selected to allow the cutting to grow into a new plant (GISD 2023). A double node consists of two single nodes separated by a greatly shortened internode. Two 25 cm-long *E. densa* stems (tip to cutting) should be added to each cubitainer in this treatment and moved between cubitainers during the daily water transfers. At the end of the experiment, the length of the cutting should be remeasured as an indicator of growth (measuring plant weights and marking the top leaves at the start of the experiment might also help measure and visualize plant growth, respectively). Under ideal light and nutrient conditions, *E. densa* can grow up to 3 cm per day.

CORBICULA FLUMINEA ADDITION (TREATMENT #14)

Small *Corbicula fluminea* (*C. fluminea*, 10-mm shell width) can be collected from the Delta using clam dredges (or by hand) the day preceding the experiment and transported to the collection site in chilled coolers, using an approved California Department of Fish and Wildlife scientific collecting permit. *C. fluminea* is resilient to brief periods of air exposure. In the 10L cubitainers, a single clam of this size represents a moderately-high clam biomass-to-water volume ratio for the Delta. The clam's filtering range will cover a larger proportion of the cubitainer than it would in a deep Delta channel, therefore the treatment only simulates phytoplankton growth in shallow water habitats inhabited by clams. *C. fluminea* frequently targets diatoms for consumption and may avoid ingesting cyanobacteria, which could promote cyanobacteria abundance in the phytoplankton community (Bolam et al. 2019). Diatoms might also sink to the bottom of the cubitainer in the relatively still water and be more easily grazed by clams compared to positively buoyant cyanobacteria, such as *Microcystis* sp. This would also promote a taxonomic shift to cyanobacteria in the bioassays.

3.4 SAMPLE COLLECTION FREQUENCY AND TIMING

Samples will be collected during each day of the study for each treatment as outlined in **Table 8**.

Table 8. Sample collection days for each test parameter. The initial day is listed as day 0 and will be evaluated with six replicate samples collected from the source water.

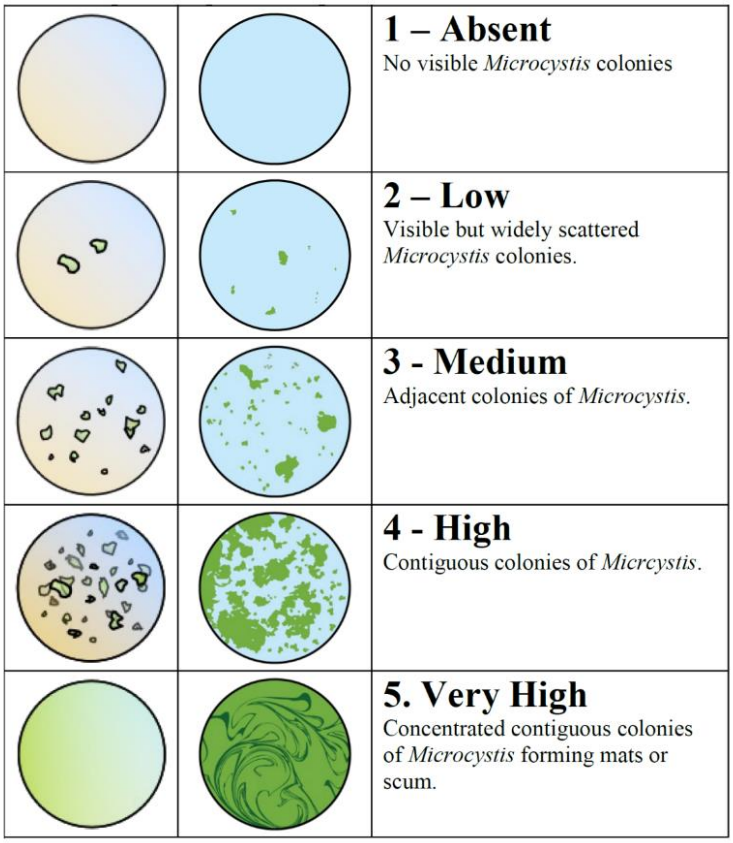
PARAMETER	MEASUREMENTS DAYS			
	0	1	2	3
Temperature	x	x	x	x
Dissolved oxygen	x	x	x	x
pH	x	x	x	x
Specific conductivity	x	x	x	x
Turbidity	x	x	x	x
Pesticides	x			
Nitrate + nitrite	x	x	x	x
Ammonium	x	x	x	x
Unfiltered Total Kjeldahl Nitrogen (TKN)	x	x	x	x
Dissolved TKN	x	x	x	x
Total phosphate	x	x	x	x
Dissolved Silica	x	x	x	x
Chlorophyll-a	x	x	x	x
High-Performance Liquid Chromatography (HPLC) phytoplankton pigment concentrations	x	x	x	x
Cyanotoxin concentrations	x			x
Taste and odor compounds	x			x
Phytoplankton enumeration	x			x

3.5 SAMPLING LOCATIONS AND METHODS

Water will be collected from one location in the south Delta where HABs are known to occur. Two collections will be made, the first occurring during the spring (March-April) before HABs develop and the second during the summer/fall, with water sources from an actively growing HAB bloom (July-August). If a bloom is not present in the late summer, then the second round of the study will be postponed, potentially until the following year. As these bioassay experiments are influenced by the starting conditions at the sampling location, it is recommended that the full experiment be repeated during the following year to evaluate how phytoplankton responses to N and P reductions change under different starting conditions.

Water samples will be collected from the Delta by boat, 0.5 m below the surface, at midday, at a location where *Microcystis* sp. populations are known to occur. If there is low cyanobacteria biomass, it is likely the experiment will be postponed. Sampling will be coordinated with Division of Boating and Waterways to avoid time periods when spraying is occurring within the Delta. Samples will also be collected in triplicate for pesticide analysis to understand background pesticide concentrations of the source water. During the late summer/fall collection, researchers should visually ensure that *Microcystis* sp. is at medium to high concentration at the time of collection based on the DWR visual assessment methodology (**Figure 8**, Flynn et al. 2022) or using another analytical method. All surface water samples should be collected from the same location on the same day during each sampling event. Source water should be filtered with 100-200 µm Nitex screening to prevent large zooplankton and clam veligers from being added to cubitainers. However, phagotrophic protists are likely to pass through the Nitex screening, due to their small cell sizes, and are expected to consume a substantial proportion phytoplankton's daily production in all treatments (Nogueira et al. 2014).

Figure 8. Microcystis scale for visual index of Microcystis sp., Aphanizomenon sp., and Dolichospermum sp. used by monitoring programs in the Delta (Flynn et al. 2022).



Surface water will be diluted to achieve the lowest N and P concentrations that are to be tested in the experiment (0.05 mg/L-N and 0.015 mg/L-P), using deionized water supplemented with other essential nutrients and major ions to match the initial river concentrations, following the methods of Barnard et al. (2021). Diluted river water should be mixed gently (to ensure that *Microcystis* sp. and other floating or sinking phytoplankton species are well distributed throughout the sample) and transferred to individual 10L containers. Nitrate and/or potassium dihydrogen phosphate (KH_2PO_4) will be added to cubitainers to achieve the initial target nitrate and phosphorus concentrations in each treatment (**Table 6**). Sodium bicarbonate ($NaHCO_3$) and Silica (Na_2SiO_3) should be added to the source water to prevent carbon or Si limitation from occurring during the incubation in the sealed containers. Cubitainers will also receive any other amendments required when they are filled, such as clams or macrophyte cuttings, as discussed below, in the Multiple-Factor bioassay treatments section. Cubitainers will be placed in flowing water baths for temperature control, either by utilizing laboratory water baths or by using floating enclosures attached to a dock located within the Delta waterway (**Figure 9**). Neutral-density screening should be used as enclosure covers to ensure there is moderate

illumination for phytoplankton growth. Light levels should approximately match the light present at 0.5 m depth at the collection location during the time of sampling (likely near 120 µmol photons m^{-2} s^{-1}) to prevent photo-inhibition. Measurements of photosynthetically active radiation (PAR) should be made using an underwater quantum sensor.

Figure 9. Example of 10L containers housed in floating encloses attached to a dock in the Delta. A neutral-density screening cover is shown on the right (Mussen et al., unpublished study).

3.5.1 Bioassay Monitoring Methods

The source water will be sampled (six times) prior to filling individual cubitainers, to avoid unnecessary duplication of samples. Triplicate samples should be collected from the water source on the following days of the experiment for comparison with the phytoplankton incubated in the cubitainers. Source water measurements should follow those shown in **Table 8**. The source water concentrations can be compared to those in the ambient treatment to understand how phytoplankton growth was affected by the cubitainer environment.

Initial nitrate and phosphorus levels in the cubitainers should match the concentrations outlined in **Table 6.** The ambient treatment will measure phytoplankton growth of filtered source water without any dilution, to determine how phytoplankton growth in the cubitainers compares throughout the experiment to the growth happening in the source water throughout the experiment. Three replicate cubitainers will be tested for each treatment. Water quality parameters should be measured during each day of the experiment, including temperature, dissolved oxygen, pH, specific conductivity, and turbidity. At low N concentrations, it is predicted that most of the available N will be taken up by phytoplankton after three days. Phytoplankton in treatments receiving higher N

concentrations are expected to have higher phytoplankton biomass at the conclusion of the experiment.

Measurements will also include discrete samples for nitrate + nitrite, ammonium, unfiltered total Kjeldahl nitrogen (TKN), dissolved TKN, total P, dissolved silica, and chl-a (**Table 8**). Water samples for phytoplankton enumeration (taxonomy, cell count, and biovolume) and cyanotoxins (microcystin, anatoxin, saxitoxins, and cylindrospermopsin) concentrations should be collected from the source water at the start of the experiment and from each cubitainer at the end of the experiment. Total N concentration can be calculated from TKN plus nitrate and nitrite. Each day, cubitainers will be mixed by turning them upside down and gently shaking, repeated three times, prior to sampling.

3.6 DATA DELIVERABLES AND REPORTS

3.6.1 Predictions and Evaluation Methods

Analysis of Variance (ANOVA) will be used to identify significant differences in the final chl-a concentrations, the biovolume of specific phytoplankton (such as HAB species, species producing taste and odor compounds, and diatom species), and cyanotoxin concentrations among the various treatments. Chlorophyll a is expected to reach relatively stable concentrations by the end of the experiment, with higher biomass occurring in treatments with higher N concentrations and P concentrations. Zooplankton population sizes are not expected to increase dramatically during the 3-day experiments. The final biovolume of HABs and cyanotoxins can be compared to established national and state thresholds. The final biovolume of diatoms, chlorophytes, and other desirable phytoplankton species should be compared to chl-a restoration targets in the Delta, which are intended to increase zooplankton populations as a food source for fish. The biomass of cyanobacteria known to cause drinking water taste and odor challenges (or taste and odor compounds such as geosmin and 2-methylisoborneol (MIB)) should be evaluated against known benchmarks of impairment (DNDWW 2017). However, many taste and odor-causing cyanobacterial species are epibenthic or periphytic, so they are unlikely to grow to high pelagic biomass in this experiment.

The multifactor cubitainer treatments will provide initial insight into understanding how other environmental factors might alter phytoplankton responses to nutrient reductions. Analysis of Variance (ANOVA) will be used to identify significant differences among the treatments in final chl-a concentrations, the biovolume of specific phytoplankton (such as HAB and diatom species), and cyanotoxin concentrations among treatments. Phytoplankton biomass is expected to be lower in treatments with lower nutrient concentrations. Reduced light levels might reduce the increase in phytoplankton biomass over time or allow a different phytoplankton species to dominate the bioassay. The

presence of *E. densa* has the potential to reduce phytoplankton growth due to nutrient competition, shading, and the release of allelochemicals. *C. fluminea* is expected to have a strong grazing effect on the phytoplankton in the test chambers. These clams can deplete diatom abundance while potentially excluding cyanobacteria through selective filtration or consumption (Bolam et al. 2019). A refuge from clam grazing may also be established at the top of the cubitainer for motile or positively buoyant phytoplankton species (including *Microcystis* sp) because the filtering range of *C. fluminea* is unlikely to extend to the top of the 10L cubitainers. This study is intended to provide a starting point for understanding how phytoplankton in the Delta would respond to low N or to low P concentrations. Low N concentrations were rare in the system historically so the phytoplankton species that grow at low N concentrations are unknown. The study can inform how cyanobacteria in the Delta respond relative to low N concentrations, which might suppress the magnitude and duration of HABs and cyanotoxins production, and the growth of cyanobacteria causing taste and odor issues. The results also help evaluate if beneficial phytoplankton species biomass will grow to sufficient levels to support the Delta's food web at low N concentrations. Importantly, this study helps to determine if other environmental factors might significantly alter phytoplankton responses to nutrient reductions and if they should be included in nutrient management strategies. It is believed that the results from this study will guide future research questions and models predicting the outcome of N and P reduction management strategies in the Delta. However, it is not expected that the study findings will directly establish thresholds for nutrient benchmarks because other environmental effects, such as water flow rates (residence times), temperature, light availability (influenced by water and water depth), nutrient competition with macrophytes, and grazing effects from invertebrates should all be accounted for in the development of nutrient thresholds.

3.6.2 Limitations of the Bioassay Design

The findings from this study should be interpreted cautiously as many environmental conditions in cubitainers are different from those present in the Delta waterways. Cubitainers are beneficial for isolating and evaluating mechanistic effects of environmental factors, but they may not accurately represent phytoplankton growth under natural conditions in the Delta. Additionally, phytoplankton responses to N and P reductions are likely to differ due to interactions with other organisms and environmental variables. Future field monitoring studies may be needed to investigate and verify the bioassay findings of this proposed study.

It is assumed that the phytoplankton community is healthy at the start of the bioassay and that the water does not contain high levels of herbicides or other contaminants that can

inhibit phytoplankton growth. It is particularly important that all essential nutrients and major ions required for phytoplankton growth are included in the constructed dilution and exchange water. High phytoplankton production should be confirmed in pilot studies using constructed dilution water and tested using a high nitrate addition (and non-limiting P) prior to running the full bioassay testing low N and low P concentrations. Water in Delta channels is frequently turbid, well-mixed, and unlikely to stratify compared to that in the containers. Heavy particulate matter is likely to settle out of suspension in the cubitainers, increasing water clarity and potentially allowing the water to thermally stratify. Frequent rotation of the cubitainers should reduce the potential for stratification. Relatively stable water conditions in the cubitainers might select for the growth of motile phytoplankton species that are adapted to calmer environments than are typical for Delta channels. Tidal currents in the Delta also exchange water with shallow wetlands, which likely affects phytoplankton growth, grazing losses, and residence time in the waterway.

This experiment does not evaluate the taxonomy and biomass of invertebrates that develop when phytoplankton are grown at low N and low P concentrations, so the effects of N and P reduction on other trophic levels must be estimated using other techniques. Zooplankton can reduce phytoplankton biomass through grazing and zooplankton grazing might promote cyanotoxin production. The bioassay design also does not fully account for shading or nutrient competition with floating macrophytes, which are likely to impact phytoplankton growth at low N and/or P concentrations in the Delta.

This bioassay does not evaluate salinity effects on phytoplankton growth, but salinity can be a highly regulating factor for many phytoplankton and cyanobacteria species. Salinity is elevated in the Delta where river water mixes with Pacific Ocean water, and also in some backwater sloughs with minimal tidal exchange, where salinity is elevated due to evaporation. Water temperature also regulates phytoplankton growth and community composition. Therefore, the findings from this study will only represent phytoplankton growth at the salinity and water temperature that were present in the bioassay which generally are more ideal growth environments than the actual conditions outside of a cubitainer.

Effective nutrient management strategies need to be based on a strong scientific understanding of the mechanisms regulating phytoplankton growth and biomass in the Delta. Identifying the phytoplankton species, and predicted biovolumes, that will grow at different low N and P concentrations, the quantity of cyanotoxin or food resources generated, and interactions with other common environmental factors, will provide a solid foundation for future nutrient management discussions.

3.7 STUDY TIMELINE AND SCHEDULE

It is anticipated that the pilot study will be conducted in late summer / early fall of 2024 to allow for the first bioassay experiment to occur in spring of 2025 and the second bioassay experiment to occur in fall of 2025.

3.8 COST ESTIMATE

This experiment will require approximately 2,400 discrete samples to be collected and analyzed, plus those included in the pilot study. A rough estimate of the study's total cost is $490,504 as described in **Table 9**, which includes the costs of discrete sample analysis, field sampling and monitoring equipment, labor for conducting the experiment and reporting the findings, and overall project management and interactions with the Delta RMP Nutrient TAC and SC. The list of samples from each set of experiments and the total number of samples are shown in **Table 10**.

Table 9. Estimated nutrient reduction bioassay study costs (this estimate is for a pilot study in 2024 and two experiments conducted in the spring and late summer of 2025).

TASK	COST
Pilot Study	$40,000
Discrete samples	$262,080
Materials and equipment	$8,424
Operations	$90,000
Reporting	$60,000
Project management	$30,000
Total	**$490,504**

Table 10. Discrete analyte counts for one bioassay in one season. Treatments share initial data for the water source, with six replicates collected per analyte.

Discrete samples	Sample days	Treatments	Replicates	Initial	Total
Nitrate + nitrite	3	14	3	6	132
Ammonium	3	14	3	6	132
Unfiltered TKN	3	14	3	6	132
Dissolved TKN	3	14	3	6	132
Total phosphorus	3	14	3	6	132
Dissolved silica	3	14	3	6	132
HPLC phytoplankton pigment concentrations	3	14	3	6	132
Chlorophyll-a	3	14	3	6	132
Cyanotoxin concentrations	1	14	3	6	48
Taste and odor compounds	1	14	3	6	48
Phytoplankton enumeration	1	14	3	6	48

4 FOCUS AREA #3

The Delta RMP will look for opportunities to collaborate or leverage funding to address the question for Focus Area #3:

- How are characteristics of harmful cyanobacteria blooms in the Delta changing over time including the status of cyanobacteria blooms and cyanotoxins in the Delta and factors that affect their magnitude, geographic extent, and timing?

The Delta RMP will explore partnerships and funding opportunities with existing monitoring programs such as Department of Water Resources for Environmental Monitoring Program's discrete phytoplankton monitoring and regular fixed monitoring station maintenance crews, California Department of Fish and Wildlife for Interagency Ecological Program fish trawls and the Fish Restoration Program, and USGS Water Science Center studies. The Delta RMP is receptive to providing funds toward sample supplies, laboratory analyses, and shipping to add cyanotoxins and cyanobacteria to existing efforts.

4.1 STUDY OBJECTIVES

The study objective is to support the collection of data to better understand changes in cyanobacteria status and risks in the Delta. There is no comprehensive monitoring of cyanotoxins currently in place in the Delta. The Delta RMP has effectively contributed to HABs science by adding funding to studies led by others. The Delta RMP has added Focus

Area #3 into the Nutrient Multi-Year Study Plan with the objective to monitor cyanobacteria blooms and toxins by collaborating with, and/or augmenting other data collection efforts, or funding Supplement Environmental Project (SEP) studies (pending the ability for Delta RMP to use SEP funds in the future). Cyanotoxin analyses are relatively expensive and bloom conditions vary significantly over space and seasons. Therefore, leveraging Delta RMP funds by collaborating with other efforts is important to expand the scope of information that will be gained. Likely methods include collecting water and/or passive sampler media for analyses of cyanotoxins. Other analytes (water samples) could include chl-a, phytoplankton community composition, and genetic analyses for cyanotoxin production potential. An ideal study would measure multiple factors potentially affecting HAB blooms such as water temperature, salinity, depth, light availability, turbidity, water column mixing and flows, dissolved oxygen, pH, nutrient concentrations, and zooplankton abundance and assemblage. These are desirable factors to be measured but may not always be included in a study design; the Delta RMP may decide to fund studies to supplement factors measured to better understand HAB bloom mechanics.

4.1.1 Why is this a priority?

The Delta RMP SC identified status and trends of HABs as a priority area as part of the long-term planning process. This priority aligns with the Central Valley Water Board Delta Nutrient Research Plan special study recommendations to determine the roles of nutrients and other drivers in controlling the growth rate, maximum biomass, and toxin production of HABs, as mentioned above. Focus Area #3 works to address status and trends questions outlined by the Delta RMP in a set of management and assessment questions for nutrients (Table 1). The priority is to support studies looking to gain additional information to help understand what can be done to prevent and/or minimize harmful algal blooms.

4.2 HYPOTHESIS

There is no predetermined hypothesis for Focus Area #3. Hypothesis testing will be determined based on the specific project(s) funded for study.

4.3 MONITORING STRATEGY

Monitoring strategies could include but are not limited to collection of water, sediment, biota, and/or passive sampler media for analysis of cyanotoxins. Priority study areas include the impact of sediment resuspension, light and turbidity effects, HAB cyanotoxin concentrations and potential impacts, and transport (such as residence time effect on

HAB growth or movement of HABs across locations). Studies could focus on genetic analysis of cyanotoxin production potential, molecular assays, phytoplankton community compositions, and chl-a concentrations.

4.4 MONITORING STUDY PLAN REQUIREMENTS

Following the Delta RMP Data Management Plan and proposal or study plan requirements established by the Delta RMP, each project must include details specific to the monitoring design, including hypotheses to be tested, sample collection locations, sampling frequency, sample collection and analytical methods, data deliverables and data management, project schedule, and budget. Study plans approved by the Delta RMP will be incorporated into the Annual Monitoring Workplan which requires the following study design information:

a. Specific hypothesis(es) to be tested;
b. Sample locations;
c. Sample collection frequency;
d. Sample analytes;
e. Analysis methods;
f. Preliminary data deliverables;
g. Planned reports to summarize results;
h. Timeline and schedule for all the study design elements to be complete.

As described in the Data Management Plan, associated data management and quality assurance documentation will also be required and approved prior to implementation. The components of the study design should be implemented in a timeline that compliments the other studies included within this Study Plan and meets the objectives of Focus Area #3.

4.5 SAMPLE COLLECTION METHODS, ANALYTES AND ANALYTICAL METHODS

Specific sample collection methods, analytes, and analytical methods will be included with the study plan and/or proposal and evaluated to ensure that the study plan meets the objectives of Focus Area #3. Analytes for Focus Area #3 could include factors potentially affecting HAB blooms such as water temperature, salinity, depth, light availability, turbidity, water column mixing and flows, dissolved oxygen, pH, and nutrient concentrations. Analytes could also include chl-a, phytoplankton community composition, and genetic analyses for cyanotoxin production potential.

4.6 DATA DELIVERABLES AND REPORTS

4.6.1 Data Management

Data management associated with the study plan or proposal must follow the outlined requirements for Collaborative Studies in the Delta RMP Data Management Plan.

4.6.2 Data Deliverables and Reporting

Data deliverables and reporting must meet the requirements of Resolution R5-2021-0054 and the Data Management Plan. This includes data being publicly available and reporting of data within the timelines prescribed by Resolution R5-2021-0054.

4.7 STUDY TIMELINE, SCHEDULE, AND BUDGET

The study plan or proposal must include a project timeline, schedule, and budget. There is no prescribed timeline for project completion for Focus Area #3 and studies may range from months up to 3 years. It is most likely that these collaborative studies will be funded on an annual basis to correspond with the Delta RMP fiscal year Annual Monitoring Workplan timeline; however, it is possible that the Delta RMP would commit to multiple years of collaborative funding depending on the project, if the project's objectives align with the overall Nutrient Multi-Year Study Plan.

4.8 PROJECT APPROVAL PROCESS

The Delta RMP's Data Management Plan outlines the current proposal process which will be followed when reviewing project proposals. The process includes review of the initial proposal with the entity proposing the project and the Delta RMP Program Manager to ensure that the project meets the objectives of Focus Area #3, the overall Nutrient Multi-Year Study Plan objectives, is consistent with the Data Management Plan, and includes enough details to meet the Delta RMP study design requirements. The next step is for the Nutrient TAC to review the proposal using the proposal process outlined in the Data Management Plan. The Nutrient TAC review of the proposal will be provided to the Steering Committee for review and recommendation to the DRMP Board of Directors (BOD). The DRMP BOD will decide if they wish to fund the project. Once the project is funded, it will be integrated into the Annual Monitoring Workplan and associated data management documentation will be developed.

In cases where multiple proposals are being presented, the Steering Committee may ask to review pre-proposals to determine which projects should move forward into a complete proposal for review by the Nutrient TAC. This may require a joint discussion of the Steering Committee and Nutrient TAC.

The DRMP BOD is allocating approximately $150,000 a year for projects that fall within Focus Area #3 with a total amount of $450,000 over three years (**Table 2**).

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