Monitoring Workplan

Fiscal Year 2023-2024

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Appendix III – Delta RMP CEC Year 1 and Year 2 Preliminary Data Summaries

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LIST OF ACRONYMS

ASC	Aquatic Science Center
ASTM	American Society for Testing and Materials
BOD	Board of Directors
CDFW	California Department of Fish and Wildlife
CEC	Constituent of Emerging Concern
CEDEN	California Environmental Data Exchange Network
CUP	Current Use Pesticides
CV RDC	Central Valley Regional Data Center
CVRWQCB	Central Valley Regional Water Quality Control Board
DCA	Dichloroaniline
Delta RMP	Delta Regional Monitoring Program
DMAC	Data Management Advisory Committee
DMCP	Delta Mercury Control Program
DMT	Data Management Team
DOC	Dissolved Organic Carbon
EDD	Electronic Data Deliverable
EPA	United States Environmental Protection Agency
FY 21-22	Fiscal Year 2021-2022
FY 22-23	Fiscal Year 2022-2023
FY 23-24	Fiscal Year 2023-2024
GRTS	Generalized Random-Tessellation Stratified
HAB	Harmful Algal Bloom
IEP	Interagency Ecological Program
MLML	Moss Landing Marine Laboratories
MTQ	Monitoring Trigger Quotients
NOAA	National Oceanic and Atmospheric Administration
OCRL	Organic Chemistry Research Laboratory
PCA	Pentachloroanisole
PCNB	Pentachloronitrobenzene
PER	Pacific EcoRisk
PFAS	Per- and Polyfluoroalkyl Substances
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctanesulfonic acid

POTW	Publicly Owned Treatment Works
PPCP	Pharmaceuticals and Personal Care Products
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
SC	Steering Committee
SCCWRP	Southern California Coastal Water Research Project
SEP	Supplemental Environmental Project
SFEI	San Francisco Estuary Institute
SSC	Suspended Sediment Concentration
SWAMP	State Board Surface Water Ambient Monitoring Program
SWRCB	State Water Resource Control Board
TAC	Technical Advisory Committee
TIE	Toxicity Identification Evaluation
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
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 (Delta RMP) is submitting the annual Monitoring Workplan for fiscal year 2023 – 2024 (FY 23-24) in accordance with Resolution R5-2021-0054. The purpose of this Monitoring Workplan is to identify the projects that will be implemented by the Delta RMP in the next fiscal year (July 1 through June 30). This Monitoring Workplan includes an initial draft budget estimate for each project; a final budget will be submitted by June 30 as a separate document. The Delta RMP 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 Delta RMP also funds work for planning, data management, and reporting in addition to monitoring.

Any deviations to the Workplan and/or Quality Assurance Project Plans (QAPPs) will be documented and reported to the Central Valley Regional Water Quality Control Board (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 State Water Resource Control Board (State Board or 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.

CURRENT USE PESTICIDES

During FY 23-24, the Current Use Pesticide (CUP) monitoring program will include monitoring according to Year 3 and Year 4 of the study design as outlined below. The original study design was approved on July 17, 2018, and began in October 2019. Monitoring is conducted on a water year (WY) and therefore the FY 23-24 will include monitoring for Event 5 and 6 of Year 3 and Event 1 – 4 of Year 4 of the study design.

Additional activities include CUP Technical Advisory Committee (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 QAPP.

CONSTITUENTS OF EMERGING CONCERN

The Year 3 Constituents of Emerging Concern (CEC) study design and associated QAPP are due on May 1, 2023. The study design was first submitted to the Steering Committee in February 2023 to be recommended for approval by the BOD. During the Steering Committee meeting held on February 16, 2023, it was agreed that the CEC Year 3 study design would be revised based on comments received and included in this Monitoring Workplan for final approval.

Sampling for Year 3 will be completed between August and October 2023. It is expected that the final results from the Year 3 data will be reviewed, loaded, and verified by February 2024. All CEC data are managed by MLJ Environmental through the CV RDC. A Year 3 Data Report will be developed by MLJ Environmental and MLML who will provide QA oversight and assessment. Additional activities in FY 23-24 include CEC TAC meetings to review data from Year 3 and finalize the Year 3 Data Report.

NUTRIENTS / HABS

For FY 23-24, the Delta RMP is continuing long-term planning for nutrients which includes Harmful Algal Blooms (HABs). The Steering Committee has provided direction to the Nutrient TAC to develop a multi-year study plan during the most recent Joint Steering Committee and Nutrient TAC meeting held on March 16, 2023. In addition to long-term planning, the Nutrient TAC will be working on reviewing and recommending for approval the United States Geological Survey (USGS) Cyanotoxin Study report.

MERCURY

The Steering Committee decided at its March 14, 2022, Steering Committee meeting to begin mercury long-term planning in 2023. 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 Delta RMP 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 by the Delta RMP from 2016 – 2022 and evaluate trends in aqueous and fish tissue mercury concentrations since 2000 in the context of water year type and subarea. The final report will be posted on the Delta RMP's website. The timeline for developing the Mercury Report is contingent on a SWRCB contract amendment with 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. It is anticipated that the contract amendment will be executed in November / December 2023.

Mercury TAC 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 23-24 Budget Executive Summary.

Budget Category / Monitoring Sector	Expenses Estimate
Operational Costs	$16,025
General Administration	$64,000
Collaboration	$81,000
Governance Documentation	$5,000
Resolution Requirements	$83,000
Current Use Pesticides	$715,000
Constituents of Emerging Concern	$215,000
Nutrients	$105,00
Mercury	$115,00
Data Management & Quality Assurance (QA)	$20,000
Expenses Total	**$1,419,025**

INTRODUCTION

The Delta Regional Monitoring Program (Delta RMP) is submitting the annual Monitoring Workplan for fiscal year 2023 – 2024 (FY 23-24) in accordance with Resolution R5-2021-0054. The purpose of this Monitoring Workplan is to identify the projects that will be implemented by the Delta RMP in the next fiscal year (July 1 through June 30). This Monitoring Workplan includes an initial draft budget estimate for each project; a final budget will be submitted by June 30 as a separate document. The Delta RMP 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 Delta RMP also funds work for planning, data management, and reporting in addition to monitoring.

This document describes the work to be funded by the Delta RMP for planning, monitoring, data management, and reporting for the next fiscal year (FY 23-24) including initial budget estimates.

BACKGROUND

DELTA RMP STRUCTURE AND ORGANIZATION

The purpose of the Delta RMP 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 for the Delta RMP is a nonprofit public benefit corporation under which the Board of Directors (BOD) oversees operations of the program.

The Delta RMP 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 Delta RMP is implemented with stakeholder participation at the Steering Committee and TAC levels which are open to various coordinated monitoring, resource, regulatory, and regulated entities. These groups give technical and program policy recommendations to the 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**.

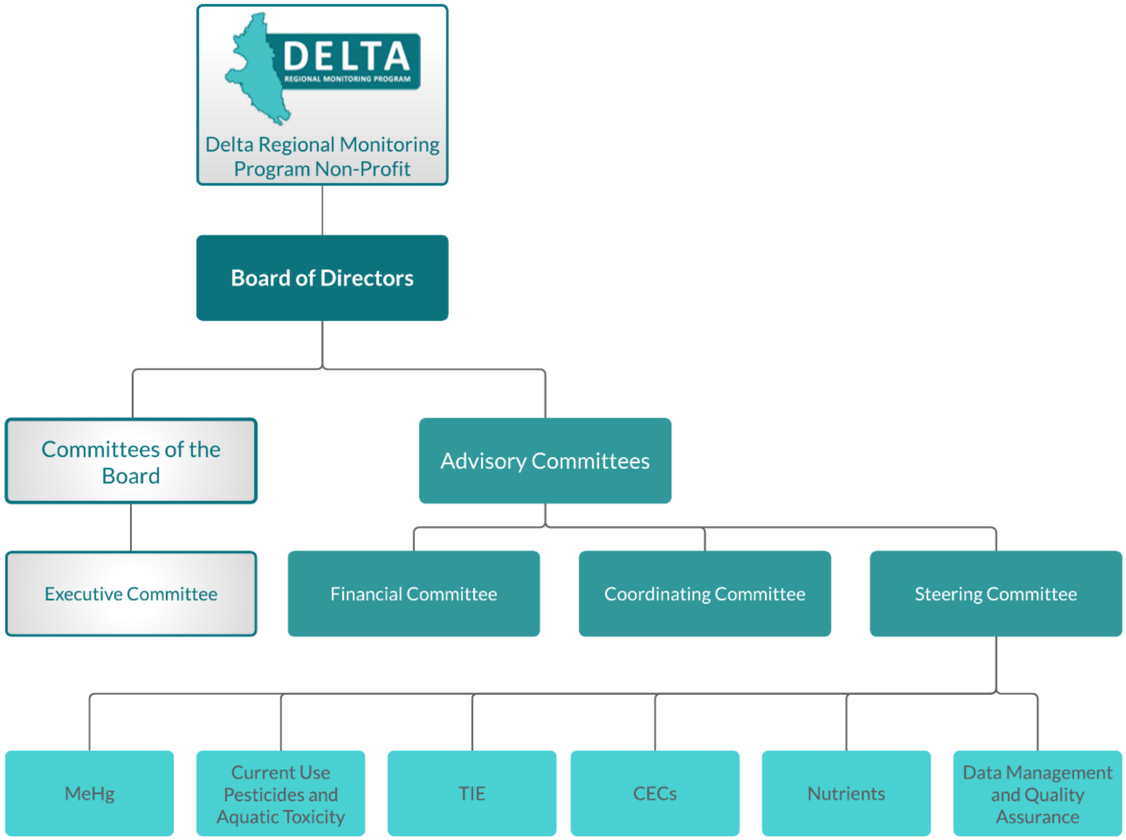
The implementation of the Delta RMP is done in close coordination with the Central Valley Regional Water Quality Control Board (CVRWQCB) and participating dischargers. Other stakeholders who may be involved with this program who are not dischargers include State Water Resources Control Board (State Board or SWRCB), United States Environmental Protection Agency (EPA), California Department of Fish and Wildlife (CDFW), National Oceanic and Atmospheric Administration (NOAA), Interagency Ecological Program (IEP), and State Water Contractors. The expectations of the discharger requirements to participate in the program as well as the expectations of the Implementing Entity are outlined in Resolution R5-2021-0054.

The funds contributed to the Delta RMP 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 Delta RMP 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 Delta RMP is implemented by the Delta Regional Monitoring Program, a California nonprofit public benefit corporation, and guided by a governing board and advisory committees, each of which contain representatives from the various agencies contributing to the Delta RMP. The makeup of the BOD, Executive Committee, Steering Committee, and TACs is described on the Delta RMP website.

Figure 1. Delta RMP Non-Profit Structure (as of March 2023).



RESOLUTION REQUIREMENTS

Though the Delta RMP is not a regulatory program, in 2013, the CVRWQCB passed R5-2013-0130 allowing dischargers to modify or reduce some of the requirements of their own permits in exchange for their contribution to the Program. As such, the close collaboration with the CVRWQCB is essential to ensure that the Delta RMP provides effective monitoring throughout the Delta and provides compliance of the Program participants in the protection of water quality throughout the Central Valley.

In October 2021, the CVRWQCB passed Resolution R5-2021-0054 approving the updated implementing entity governance structure as a vehicle for this modified monitoring to -continue. Future refinements to the Delta RMP 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. The EO will review any changes to ensure the effectiveness of regional monitoring and adequate monitoring and assessment of cumulative impacts that alter water. It is the responsibility of the Delta RMP 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 in order 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 Delta RMP 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 Delta RMP stakeholders met on December 8, 2021, to discuss an overall strategy for implementing a long-term monitoring program. The Delta RMP 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 this	Start planning earlier and develop meeting schedules earlier 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 Delta RMP based on this 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 Delta RMP agreed to begin long-term planning in 2022 starting with nutrients and then transitioning to mercury.

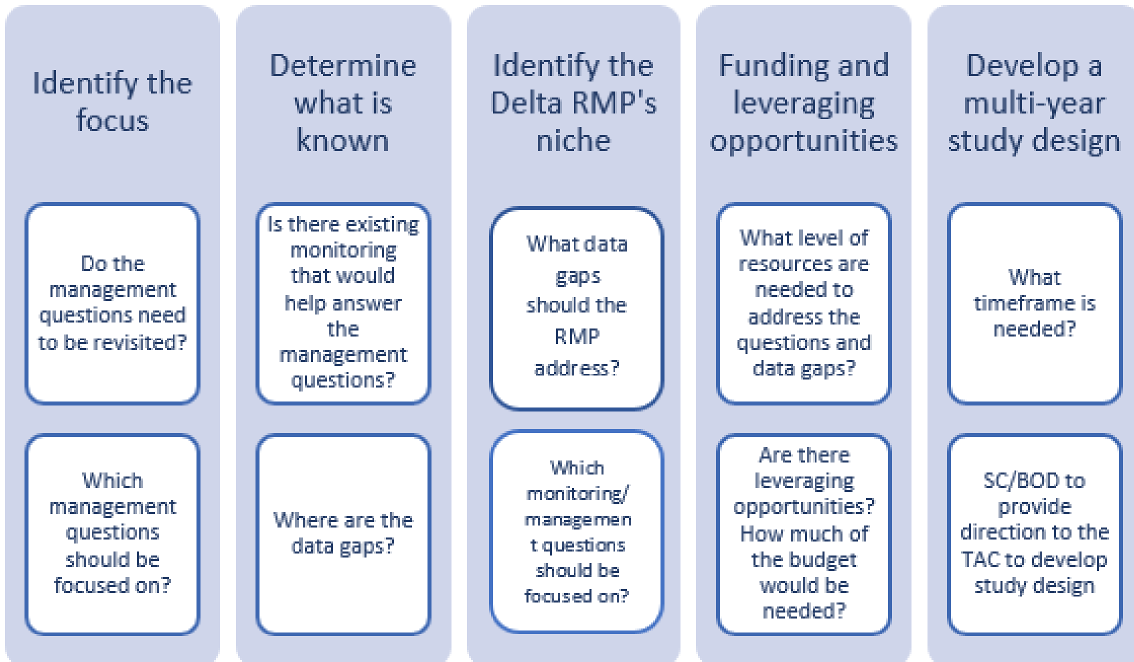
Figure 2 is an illustration of how the Delta RMP could plan across years to allocate resources across monitoring sectors and is adjusted annually. The Delta RMP is still working through the specifics of the staggered approach in terms of planning, monitoring, and reporting.

As the Delta RMP works through the second year of developing a long-term strategy (focusing on nutrients first), the Program has come up with a general strategy for guiding long term planning (**Figure 3**). The Delta RMP intends to refine this general strategy per monitoring sector as it moves through long-term planning across the Program focus areas.

Figure 2. Staggered approach for long-term planning across monitoring sectors.
This figure is an illustration of the strategy; specifics for years after FY 23-24 have not been decided upon by the Delta RMP.

FY	PESTICIDES	NUTRIENTS	CEC	MERCURY	PLANNING
22/23	CUP Monitoring	Monitoring / Nutrient Planning	CEC Data Analysis + Planning	Mercury Monitoring / Planning	Nutrient Symposium
23/24	CUP Monitoring	Planning	CEC Year 3 Monitoring	Interpretive Report / Planning	
24/25	CUP Data Analysis	Nutrient Monitoring	CEC Data Analysis / Final Report	Planning	Mercury Symposium / Pesticide Symposium
25/26	CUP Planning	Nutrients Monitoring	CEC Planning	Planning	CEC Symposium
26/27	CUP Monitoring	Nutrients Monitoring	CEC Planning	Mercury Monitoring	Pulse of the Delta
27/28	CUP Monitoring	Nutrient Data Analysis	CEC Monitoring	Mercury Monitoring	Nutrient Symposium

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



FY 23-24 OVERVIEW

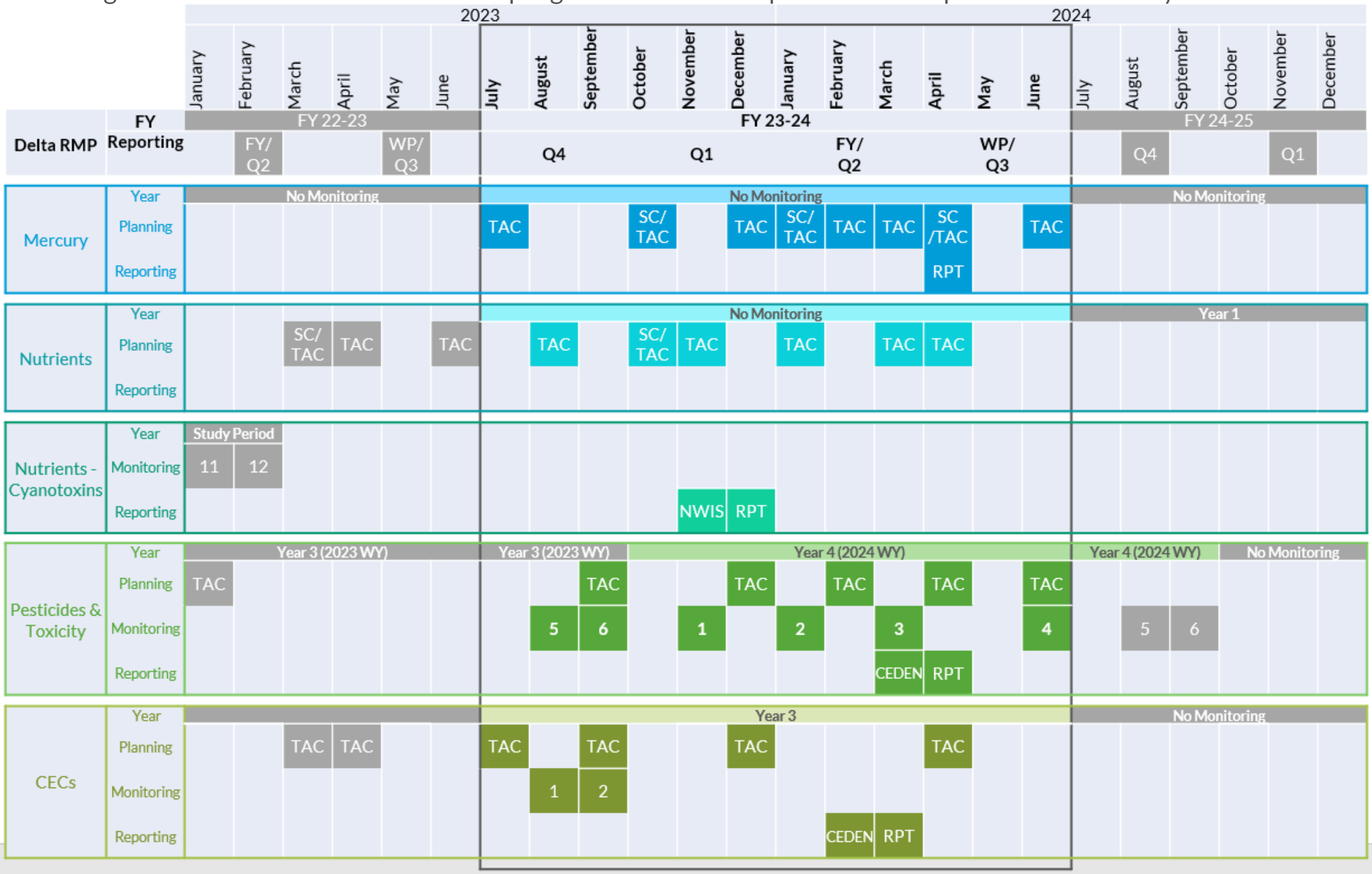
For FY 23-24, the Delta RMP is continuing to implement existing monitoring designs, perform data synthesis and reporting, and conduct planning for multi-year projects. **Table 3** and **Figure 4** include an overview of the monitoring sectors and what will occur in terms of planning, monitoring, and 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 23-24 work to be performed in the four Delta RMP monitoring sectors.

Monitoring Sector	Planning	Monitoring	Data Synthesis / Reporting
Current Use Pesticides	--	Water Year 2023 and 2024 Monitoring	Water Year 2023 Data Report
Constituents of Emerging Concern Pilot Study	Planning for an Interpretive Report	Year 3 Study	Year 3 Data Report
Nutrients / Harmful Algal Blooms (HABs)	Multi Year Nutrient Study Plan	--	--
Mercury	Long Term Planning Mercury Symposium	--	Mercury Interpretive Report and Factsheet [a]

[a] The Mercury Interpretive Report and Factsheet may not be completed in FY 23-24 pending contract execution dates.

Figure 4. Summary of anticipated Delta RMP planning, monitoring, and reporting activities for FY 23-24.
Monitoring events associated with storm sampling are estimated. 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
SYM: Symposium Reports

SUMMARY OF BUDGETS

The FY 23-24 Monitoring Workplan includes a preliminary budget reflecting estimated expenses for the upcoming fiscal year. The Delta RMP will provide an updated budget for the program by June 30, 2023. The current estimates do not include in-kind contributions, matching funds, or contributions from the Surface Water Ambient Monitoring Program (SWAMP) funds from the CVRWQCB (maximum of $205,600 of in-kind contributions). The June 30, 2023, budget will include in-kind contributions and updated estimates in preparation for FY 23-24.

For FY 23-24, 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 Co-Chairs to implement the program.

Table 4. FY 23-24 budget for expenses.

Monitoring Sector	Planning	Monitoring	Data Management	Deliverables	Expenses Estimate
Operational Costs	--	--	--	--	$16,025
General Administration	Yearly planning, communication between stakeholders	--	Droplet - File Sharing	Website	$64,000
Collaboration	BOD meetings, EC meetings, SC meetings, RB Coordination	--	--	--	$81,000
Governance Documentation	--	--	--	Policies and Procedures	$5,000
Resolution Requirements	FY Workplan	--	Data Management Plan	Quarterly Report, Quarterly SEP Reports, Annual Report, Workplan, Data Management Plan	$83,00
Current Use Pesticides	TAC meetings	WY 2023 and 2024 Monitoring	WY 2023 and WY 2024 Data Review, Loading, and Verification; Deviations	WY 2023 Data Report	$715,000
Constituents of Emerging Concern	TAC meetings, Interpretive Report Planning	Year 3 Monitoring	Year 3 Data Review, Loading, and Verification; Deviations	Year 3 Data Report	$215,000
Nutrients	TAC meetings		NWIS Tableau	Nutrient Study Plan, QAPP	$105,000
Mercury	TAC meetings		SWAMP - CEDEN	Mercury Report [a]	$115,000

Monitoring Sector	Planning	Monitoring	Data Management	Deliverables	Expenses Estimate
Data Management & Quality Assurance (QA)	--	--	QA Oversight and Policy Updates	--	$20,000
				Expenses Total	**$1,419,025**

[a] The Mercury Interpretive Report and Factsheet may not be completed in FY 23-24 pending contract execution dates.

DATA MANAGEMENT PLAN

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

As required by 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 Delta RMP 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 Delta RMP submitted a second extension letter to allow for time needed to focus on the Annual Monitoring Workplan and QAPP deadlines of May 1, 2023, and resume discussion regarding the Data Management Plan in July 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 QAPP Template was finalized in March 2022 and was used to develop the Current Use Pesticide (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. The QAPP Template is also being used to develop the Constituents of Emerging Concern (CEC) QAPP for Year 3 monitoring.

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 Delta RMP 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 Delta RMP 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 Delta RMP projects and studies is conducted in coordination with the CVRWQCB QA Representative, Selina Cole. The SWRCB QA Officer, Andrew Hamilton, will also be consulted to ensure consistency with SWRCB data management policies.

The Delta RMP expects that there will be data management items, policies, and procedure updates to be discussed and addressed during FY 23-24 including the finalization of the Data Management Plan by December 23, 2023. The Delta RMP will have draft language prepared for discussion with the CVRWQCB in September 2023 in advance of a meeting. The revised Data Management Plan will be reviewed by the Steering Committee and the Data Management Advisory Committee in a joint meeting in October 2023 and the final revised Data Management Plan will be submitted by December 23, 2023.

Budget has been allocated for these discussions and potential updates to the Data Management Plan with an estimated cost of $83,000 (**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 23-24, the Current Use Pesticide (CUP) monitoring program will include monitoring according to Year 3 and Year 4 of the study design as outlined below. The original study design was approved on July 17, 2018, and began in October 2019 (**Appendix I**). Monitoring is conducted on a water year (WY) and therefore the FY 23-24 will include monitoring for Event 5 and 6 of Year 3 and Event 1 – 4 of Year 4 of the study design.

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 QAPP.

Monitoring for Year 3 and Year 4 of the monitoring design is being conducted under CUP QAPP version 1.3 (approved on January 23, 2023). An amendment to this QAPP will be submitted by May 1, 2023, 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 Delta RMP 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 Delta RMP 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 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. The fixed sites, Ulatis Creek at Brown Road and San Joaquin River at Buckley Cove, are locations where aquatic toxicity was consistently 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.

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 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). 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 the California Environmental Data Exchange Network (CEDEN).

The FY 23-24 monitoring will include the last two events of Year 3 of monitoring (Event 5 and 6, WY 2023) and Event 1-4 of Year 4 of the four-year design (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 Delta RMP 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 23-24 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. Due to delays and hydrologic conditions that occurred during the 2022 WY, sampling for the third year of pesticide monitoring picked back up with the 2023 WY which began on October 1, 2022. Events 5 and 6 will be conducted in FY 23-24. Year 4 will begin with the 2024 WY on October 1, 2023. Events 1 through 4 will be 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 23-24 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
2023 WY	Event 5	4. South Delta	Sout-017	38.04166	-121.49771
		4. South Delta	Sout-018	37.88673	-121.4445
		4. South Delta	Sout-019	38.05089	-121.46503
		4. South Delta	Sout-020	38.10563	-121.48937
		5. Central Delta	Cent-009	37.99109	-121.57778
		5. Central Delta	Cent-010	37.97646	-121.51462
2023 WY	Event 6	4. South Delta	Sout-021	37.81977	-121.52646
		4. South Delta	Sout-022	38.05065	-121.41834
		4. South Delta	Sout-023	37.9959	-121.36884
		4. South Delta	Sout-024	38.06388	-121.49817
		5. Central Delta	Cent-011	38.03492	-121.60047
		5. Central Delta	Cent-012	38.0232	-121.51372
2024 WY	Event 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	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	5. Central Delta	Cent-017	37.92026	-121.556
		5. Central Delta	Cent-018	37.99156	-121.515

Water Year	Sampling Event	Site Subregion	Sampling Site	Latitude	Longitude
		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	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 [1]	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
		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 [1]	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 WY	Oversample Point 1	4. South Delta	Sout-025	37.91663	-121.32144
2023 WY	Oversample Point 2	4. South Delta	Sout-026	38.00774	-121.45576
2023 WY	Oversample Point 3	4. South Delta	Sout-027	37.80179	-121.31318
2023 WY	Oversample Point 4	4. South Delta	Sout-028	38.08441	-121.5025
2023 WY	Oversample Point 5	4. South Delta	Sout-029	37.95635	-121.29327
2023 WY	Oversample Point 6	4. South Delta	Sout-030	38.01117	-121.45969
2023 WY	Oversample Point 7	4. South Delta	Sout-031	37.81982	-121.47719
2023 WY	Oversample Point 8	4. South Delta	Sout-032	38.08585	-121.4327
2023 WY	Oversample Point 9	4. South Delta	Sout-033	38.03779	-121.48623

Water Year	Sampling Event	Site Subregion	Sampling Site	Latitude	Longitude
2023 WY	Oversample Point 10	4. South Delta	Sout-034	38.01175	-121.37018
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
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

Water Year	Sampling Event	Site Subregion	Sampling Site	Latitude	Longitude
2024 WY	Oversample Point #10	6. Confluence	Conf-034	38.07157	-121.852

[1] The 2024 WY Events 5 and 6 may occur during FY 23-24; not all sites identified in this table will be sampled during FY 23-24.

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 23-24 is anticipated to include the remainder of the events from Year 3 (two of six) and a subset (four of six) of the sampling events planned for the fourth monitoring year. All events planned for FY 23-24 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
2023 WY Event 5	Irrigation/ Baseflow	2	1	1	4
2023 WY Event 6	Irrigation/ Baseflow	2	1	1	4
2024 WY Event 1	Storm Sampling	2	1	1	4
2024 WY Event 2	Storm Sampling	2	1	1	4
2024 WY Event 3	Storm Sampling	2	1	1	4
2024 WY Event 4	Irrigation/ Baseflow	2	1	1	4
Total Samples		**12**	**6**	**6**	**24**

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 183 pesticide constituents. The dissolved fraction is reported for all 183 constituents, while the particulate fraction is reported for 178. This list of constituents has been updated from previous year's testing due to updates to the analytical methodology and the reporting of which pesticides are currently in use.

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 23-24 CUP monitoring.

Constituent	CAS# [1]	Parameter Type	Agency	Matrix	Method	Units
Ceriodaphnia dubia (Reproduction)	NA	Water Column Toxicity	PER	Water	EPA 821/R-02-013	young/ female
Ceriodaphnia dubia (Survival)	NA	Water Column Toxicity	PER	Water	EPA 821/R-02-013	%
Hyalella azteca (Survival)	NA	Water Column Toxicity	PER	Water	EPA 821/R-02-012	%
Pimephales promelas (Larval biomass)	NA	Water Column Toxicity	PER	Water	EPA 821/R-02-013	mg/ original organisms exposed
Pimephales promelas (Larval survival)	NA	Water Column Toxicity	PER	Water	EPA 821/R-02-013	%
Selenastrum capricornutum (Growth)	NA	Water Column Toxicity	PER	Water	EPA 821/R-02-013	cells/mL
Chironomus dilutus (Growth)	NA	Water Column Toxicity	PER	Water	EPA 600/R-99-064M	mg/ surviving organisms
Chironomus dilutus (Survival)	NA	Water Column Toxicity	PER	Water	EPA 600/R-99-064M	%
Dissolved Organic Carbon (DOC)	NA	Ancillary Parameters	Babcock	Water	SM 5310 B	mg/L
Total Organic Carbon (TOC)	NA	Ancillary Parameters	Babcock	Water	SM 5310 B	mg/L
Nitrate + Nitrite as N	NA	Ancillary Parameters	Babcock	Water	EPA 353.2	mg/L
TKN	NA	Ancillary Parameters	Babcock	Water	EPA 351.2	mg/L
Total Suspended Solids (TSS)	NA	Ancillary Parameters	OCRL	Water	EPA 160.2	mg/L

Constituent	CAS# [1]	Parameter Type	Agency	Matrix	Method	Units
Hardness	NA	Ancillary Parameters	Babcock	Water	SM 2340 B	mg/L
Calcium	7440702	Ancillary Parameters	Babcock	Water	EPA 200.7	mg/L
Magnesium	7439954	Ancillary Parameters	Babcock	Water	EPA 200.7	mg/L
Copper	7440508	Trace Metals	Babcock	Water	EPA 200.8	µg/L
3,4-Dichloroaniline (3,4-DCA)	95-76-1	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
3,5-Dichloroaniline (3,5-DCA)	626-43-7	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Acetamiprid	135410-20-7	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Acetochlor	34256-82-1	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Acibenzolar-S-Methyl	135158-54-2	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Allethrin	584-79-2	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Atrazine	1912-24-9	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Atrazine, Desethyl	6190-65-4	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Atrazine, Desisopropyl	1007-28-9	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Azoxystrobin	131860-33-8	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Benefin (Benfluralin)	1861-40-1	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L

Constituent	CAS# [1]	Parameter Type	Agency	Matrix	Method	Units
Bentazon	25057-89-0	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Benzobicyclon	156963-66-5	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Benzovindiflupyr	1072957-71-1	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Bifenthrin	82657-04-3	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Boscalid	188425-85-6	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Boscalid Metabolite - M510F01 Acetyl	661463-87-2	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Broflanilide	1207727-04-5	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Bromuconazole	116255-48-2	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Butralin	33629-47-9	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Carbaryl	63-25-2	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Carbendazim	10605-21-7	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Carbofuran	1563-66-2	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Chlorantraniliprole	500008-45-7	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Chlorfenapyr	122453-73-0	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Chlorothalonil	1897-45-6	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L

Constituent	CAS# [1]	Parameter Type	Agency	Matrix	Method	Units
Chlorpyrifos	2921-88-2	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Chlorpyrifos Oxon	5598-15-2	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Clomazone	81777-89-1	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Clothianidin	210880-92-5	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Clothianidin Desmethyl	135018-15-4	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Coumaphos	56-72-4	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Cyantraniliprole	736994-63-1	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Cyazofamid	120116-88-3	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Cyclaniliprole	1031756-98-5	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Cycloate	1134-23-2	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Cyfluthrin	68359-37-5	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Cyhalofop-Butyl	122008-85-9	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Cyhalothrin	68085-85-8	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Cymoxanil	57966-95-7	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Cypermethrin	52315-07-8	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L

Constituent	CAS# [1]	Parameter Type	Agency	Matrix	Method	Units
Cyproconazole	94361-06-5	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Cyprodinil	121552-61-2	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
DCPA	1861-32-1	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
DCPMU	3567-62-2	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
DCPU	2327-02-8	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Deltamethrin	52918-63-5	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Desthio-Prothioconazole	120983-64-4	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Diazinon	333-41-5	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Diazinon Oxon	962-58-3	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Dichlorvos	62-73-7	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Difenoconazole	119446-68-3	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Dimethomorph	110488-70-5	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Dinotefuran	165252-70-0	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Dithiopyr	97886-45-8	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Diuron	330-54-1	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L

Constituent	CAS# [1]	Parameter Type	Agency	Matrix	Method	Units
EPTC	759-94-4	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Esfenvalerate	66230-04-4	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Ethaboxam	162650-77-3	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Ethalfluralin	55283-68-6	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Etofenprox	80844-07-1	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Etoxazole	153233-91-1	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Famoxadone	131807-57-3	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Fenamidone	161326-34-7	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Fenbuconazole	114369-43-6	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Fenhexamid	126833-17-8	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Fenpropathrin	39515-41-8	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Fenpyroximate	134098-61-6	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Fipronil	120068-37-3	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Fipronil Desulfinyl	205650-65-3	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Fipronil Desulfinyl Amide	1115248-09-3	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L

Constituent	CAS# [1]	Parameter Type	Agency	Matrix	Method	Units
Fipronil Sulfide	120067-83-6	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Fipronil Sulfone	120068-36-2	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Flonicamid	158062-67-0	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Florpyrauxifen-Benzyl	1390661-72-9	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Fluazinam	79622-59-6	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Fludioxonil	131341-86-1	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Flufenacet	142459-58-3	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Fluindapyr	1383809-87-7	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Flumetralin	62924-70-3	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Fluopicolide	239110-15-7	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Fluopyram	658066-35-4	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Fluoxastrobin	193740-76-0	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Flupyradifurone	951659-40-8	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Fluridone	59756-60-4	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Flutolanil	66332-96-5	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L

Constituent	CAS# [1]	Parameter Type	Agency	Matrix	Method	Units
Flutriafol	76674-21-0	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Fluxapyroxad	907204-31-3	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Halauxifen-Methyl Ester	943831-98-9	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Hexazinone	51235-04-2	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Imazalil	35554-44-0	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Imidacloprid	138261-41-3	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Imidacloprid Desnitro	115970-17-7	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Imidacloprid Olefin	115086-54-9	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Imidacloprid Urea	120868-66-8	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Imidacloprid, 5-Hydroxy	380912-09-4	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Indaziflam	950782-86-2	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Indoxacarb	173584-44-6	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Ipconazole	125225-28-7	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Iprodione	36734-19-7	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Isofetamid	875915-78-9	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L

Constituent	CAS# [1]	Parameter Type	Agency	Matrix	Method	Units
Kresoxim-Methyl	143390-89-0	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Malathion	121-75-5	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Malathion Oxon	1634-78-2	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Mandestrobin	173662-97-0	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Mandipropamid	374726-62-2	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Metalaxyl	57837-19-1	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Metalaxyl Alanine Metabolite	85933-49-9	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Metconazole	125116-23-6	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Methoprene	40596-69-8	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Methoxyfenozide	161050-58-4	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Metolachlor	51218-45-2	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Myclobutanil	88671-89-0	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Naled (Dibrom)	300-76-5	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Napropamide	15299-99-7	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Nitrapyrin	1929-82-4	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L

CONSTITUENT	CAS# [1]	PARAMETER TYPE	AGENCY	MATRIX	METHOD	UNITS
Novaluron	116714-46-6	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Oryzalin	19044-88-3	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Oxadiazon	19666-30-9	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Oxathiapiprolin	1003318-67-9	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Oxyfluorfen	42874-03-3	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
p,p'-DDD	72-54-8	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
p,p'-DDE	72-55-9	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
p,p'-DDT	50-29-3	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Paclobutrazol	76738-62-0	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Pendimethalin	40487-42-1	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Penoxsulam	219714-96-2	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Pentachloroanisole (PCA)	1825-21-4	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Pentachloronitrobenzene (PCNB)	82-68-8	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Penthiopyrad	183675-82-3	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Permethrin	52645-53-1	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L

Constituent	CAS# [1]	Parameter Type	Agency	Matrix	Method	Units
Phenothrin	26002-80-2	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Phosmet	732-11-6	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Picarbutrazox	500207-04-5	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Picoxystrobin	117428-22-5	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Piperonyl Butoxide	51-03-6	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Prodiamine	29091-21-2	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Prometon	1610-18-0	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Prometryn	7287-19-6	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Propanil	709-98-8	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Propargite	2312-35-8	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Propiconazole	60207-90-1	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Propyzamide	23950-58-5	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Pydiflumetofen	1228284-64-7	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Pyraclostrobin	175013-18-0	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Pyridaben	96489-71-3	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L

CONSTITUENT	CAS# [1]	PARAMETER TYPE	AGENCY	MATRIX	METHOD	UNITS
Pyrimethanil	53112-28-0	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Pyriproxyfen	95737-68-1	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Quinoxyfen	124495-18-7	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Sedaxane	874967-67-6	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Simazine	122-34-9	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Sulfoxaflor	946578-00-3	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Tebuconazole	107534-96-3	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Tebuconazole t-Butylhydroxy	212267-64-6	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Tebufenozide	112410-23-8	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Tebupirimfos	96182-53-5	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Tebupirimfos Oxon	1035330-36-9	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Tefluthrin	79538-32-2	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Tetraconazole	112281-77-3	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Tetramethrin	7696-12-0	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
t-Fluvalinate	102851-06-9	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L

Constituent	CAS# [1]	Parameter Type	Agency	Matrix	Method	Units
Thiabendazole	148-79-8	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Thiacloprid	111988-49-9	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Thiamethoxam	153719-23-4	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Thiamethoxam Degradate (CGA-355190)	902493-06-5	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Thiamethoxam Degradate (NOA-407475)	NA	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Thiobencarb	28249-77-6	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Tolfenpyrad	129558-76-5	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Triadimefon	43121-43-3	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Triadimenol	55219-65-3	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Triallate	2303-17-5	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Tribufos	78-48-8	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Trifloxystrobin	141517-21-7	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Triflumizole	68694-11-1	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Trifluralin	1582-09-8	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Triticonazole	131983-72-7	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L

Constituent	CAS# [1]	Parameter Type	Agency	Matrix	Method	Units
Valifenalate	283159-90-0	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L
Zoxamide	156052-68-5	Pesticides	OCRL	Water	OCRL-WATER-PEST_06	ng/L

[1] The CAS number for chemicals is associated with each constituent. Constituents that are not chemicals have an "NA" for Not Applicable associated with them.

Schedule of Deliverables

The overall schedule of deliverables for the FY 23-24 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 23-24 Monitoring Workplan (includes CUP Study Design)	May 1, 2023	July 1, 2023 – June 30, 2024	Per fiscal year
CUP QAPP v1.3 Amendment	May 1, 2023	WY 2024	Amended as needed
Final CUP Budget	June 30, 2023	July 1, 2023 – June 30, 2024	Per fiscal year
Preliminary CUP Data	60 calendar days	Sample analysis	Per event
Finalized CUP Data [1]	6 months	Sample analysis	Per event
Transfer of CUP Data to CEDEN	6 months	Final sampling event of the water year	Per water year
Delta RMP FY 22-23 Annual Report [2]	February 1, 2024	July 1, 2022 – June 30, 2023	Annually
Delta RMP FY 23-24 Annual Report [2]	February 1, 2025	July 1, 2023 – June 30, 2024	Annually
Additional Study Deliverable FY 23-24			
Year 3 Data Report and QC Assessment	April 2024	October 1, 2022 – September 31, 2023	Per water year

[1] 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.

[2] Associated metadata included in Annual Reports.

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 the CUP project (CUP QAPP v1.3) was approved by the CVRWQCB and State Board QA Officer on January 23, 2023, to encompass the monitoring planned for Year 3 (October 2022 – September 2023) and Year 4 (October 2023 – September 2024). Any necessary amendments to the CUP QAPP v1.3 will be submitted to the CVRWQCB and SWRCB on May 1, 2023, for FY 23-24.

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 Delta RMP 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 Resolution R5-2021-0054 requirement, a quality assurance assessment for samples collected in the previous fiscal year must be included in the Delta RMP 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.

Data Report and QC Report

The 2023 WY dataset will be assessed in a Data Report with an associated QA Report that will be submitted in FY 23-24. 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 2023 WY. This report is anticipated to be completed in April of 2024, following the end of the 2023 WY, or upon completion of the entire dataset (**Table 8**). The 2024 WY dataset will not be assessed in a report until FY 24-25.

FY Annual Report

The Delta RMP 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 Delta RMP 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, 2024. Samples collected between October 1, 2022 (beginning of the 2023 WY) through June of 2023 (end of FY 22-23) will be reported in the Annual Report submitted on February 1, 2024 (**Table 8**).

Budget

The high-level draft budget for tasks associated with the Delta RMP CUP project for FY 23-24 is provided in (**Table 4**). The CUP budget is estimated at $715,000. 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, 2023; it is anticipated that the budget amounts will vary by approximately 15% from actuals.

CONSTITUENTS OF EMERGING CONCERN

The Year 3 Constituents of Emerging Concern (CEC) Study Design and associated QAPP are due on May 1, 2023. The study design was first submitted to the Steering Committee in February 2023 to be recommended for approval by the BOD. During the Steering Committee meetings held on February 16, 2023, and April 10, 2023, it was agreed that the CEC Study Design would be revised based on comments received and included in this Monitoring Workplan for final approval.

Sampling for Year 3 will be completed between August and October 2023. It is expected that the final results from the Year 3 data will be reviewed, loaded, and verified by February 2024. All CEC data are managed by MLJ Environmental through the CV RDC. A Year 3 Data Report will be developed by MLJ Environmental and MLML who will provide QA oversight and assessment. Additional activities in FY 23-24 include CEC TAC meetings to review data from Year 3 and finalize the Year 3 Data Report.

BACKGROUND

A stakeholder group developed the Central Valley Pilot Study for Monitoring CECs Work Plan (**Appendix II**, referred to here as the Stakeholder Work Plan) outside of the Delta RMP. The stakeholder group consisted of several Delta RMP participants including publicly owned treatment works (POTW), municipal separate storm sewer systems (MS4s), the Central Valley Regional Water Quality Control Board (Regional Water Board), and the State Water Resources Control Board (State Water Board). The Delta RMP Technical Advisory Committee (TAC) under the previous governance structure reviewed and provided comments on the Stakeholder Work Plan.

The Delta RMP is implementing the Stakeholder Work Plan as the "CEC Pilot Study". **Table 9** summarizes the key documents in the development of the Stakeholder Work Plan and subsequent implementation by the Delta RMP. The Stakeholder Work Plan is based on the State Water Board CEC pilot study monitoring guidance that was directly informed by the result of a technical report prepared for the State Water Board by the Southern California Coastal Water Research Project (SCCWRP). The CEC TAC advises the Delta RMP Steering Committee on technical issues related to implementation of the Stakeholder Work Plan.

The Regional Water Board adopted Resolution R5-2021-0054 in October 2021 that specifies requirements for study design development and data deliverables. This "Delta RMP Resolution" was adopted after the Delta RMP approved the three-year CEC Pilot Study. Although the Delta RMP Steering Committee had previously approved the CEC

Pilot Study, the Delta RMP Resolution is addressed in this Year 3 Study Design as shown in **Table 10**.

Table 9: Central Valley CEC Pilot Study documents

KEY DOCUMENT	DATE	REFERENCE NAME
Monitoring Strategies for Chemicals of Emerging Concern (CECs) in California's Aquatic Ecosystems Recommendations of a Science Advisory Panel. submitted at the request of the California Water Resources Control Board by the Southern California Coastal Water Research Project. Technical Report 692	April 2012	SCCWRP Science Panel Recommendations
Monitoring of Constituents of Emerging Concern (CECs) in Aquatic Ecosystems – Pilot Study Guidance. Nathan G. Dodder, Alvine C. Mehinto, and Keith A. Maruya	March 2015	Pilot Study Design and QA/QC Guidance
Constituents of Emerging Concern (CECs) Statewide Pilot Study Monitoring Plan. State Water Board	January 2016	Statewide CEC Pilot Study Monitoring Plan
Central Valley Pilot Study for Monitoring Constituents of Emerging Concern (CECs) Work Plan. Larry Walker Associates on behalf of Stakeholder Group	July 2018	Stakeholder Work Plan
Quality Assurance Project Plan Pilot Study of Constituents of Emerging Concern in the Sacramento-San Joaquin Delta. Aquatic Science Center. Updated by MLJ Environmental	October 2021 (update)	CEC QAPP
Approval of Delta Regional Monitoring Program Governance Structure and Implementing Entity Resolution R5-2021-0054. Central Valley Regional Water Quality Control Board	October 2021	Delta RMP Resolution

Table 10: Delta RMP Resolution required study design requirements and associated Year 3 Study Design location.

DELTA RMP RESOLUTION REQUIREMENT	ASSOCIATED YEAR 3 STUDY DESIGN SECTION
Specific hypothesis to be tested (only study questions provided for this pilot study)	**CEC Gradient Study Questions**
Sample locations	**Sample Collection Locations**
Sample collection frequency	**Sample Collection Frequency and Timing**
Sample analytes	**Sample Analytes and Methods**
Analysis methods	**Sample Analytes and Methods**
Preliminary data deliverables	**Data Deliverables and Reports**
Planned reports to summarize results	**Data Deliverables and Reports**
Timeline and schedule for all of the study design elements to be completed	**Study Timeline and Schedule**

DELTA RMP CEC MONITORING

The Stakeholder Work Plan specifies collection of targeted chemistry analyses in aqueous, sediment, and tissue matrices over a three-year period with different elements in each year. The first two years of the CEC Pilot Study were completed in 2019-20 (Year 1) and 2020-21 (Year 2) as follows:

- Year 1 – ambient monitoring. The first year of monitoring included ambient monitoring to assess the presence of the targeted CECs at specific locations in the Delta.
- Year 2 – ambient and source monitoring. The second year of monitoring continued the ambient monitoring conducted during the first year and added source characterization sites to monitor POTW effluent and MS4 urban runoff.

Due to COVID-19 health and safety limitations, three site locations (Sacramento River at Hood, Sacramento River at Freeport, and San Joaquin River at Buckley Cove) were each not sampled during one event in Year 1; this equates to one event out of the eight total Year 1 and Year 2 events. As part of the Year 3 Study Design development the CEC TAC considered whether to collect the missed samples during Year 3. This is discussed further under Sample Locations.

The Delta RMP prepared the preliminary data summary (**Appendix III**) from the first two years of CEC monitoring to inform this Year 3 Study Design. The preliminary data summary includes CEC detection rates, monitoring site concentration plots, and an assessment of contamination issues.

Year 3 sample collection is scheduled for 2023-24. Both the FY 23-24 Workplan and the CEC Year 3 QAPP must be approved by the Regional Water Board prior to the Year 3 Study Design implementation. Delta RMP completion of the following Stakeholder Work Plan elements will complete the CEC Pilot Study:

- Year 3– gradient study and second year of source monitoring. The third year continues only the source monitoring from Year 2 and adds gradient studies upstream and downstream of POTWs.

The Year 3 gradient study evaluates POTW discharge CEC attenuation in Dry Creek in Roseville, CA and in Old Alamo Creek near Vacaville, CA. These receiving waters are consistent with effluent dominated inland waters (Scenario 1) identified in the Statewide CEC Pilot Study Monitoring Plan.[1] The Delta RMP CEC TAC reviewed the Year 1 and

[1] "Alamo Creek downstream of the Vacaville Easterly WWTP and Pleasant Grove downstream of the City of Roseville Pleasant Grove WWTP" is specified in the

Year 2 preliminary data summaries (**Appendix III**) and recommended including all Stakeholder Work Plan constituents in the Year 3 study. All constituents were detected in POTW source waters or immediately downstream. Bisphenol A was detected in method blanks and/or field blanks in each event at concentrations similar to environmental concentrations. Therefore, bisphenol A was recommended for Year 3 sample collection and analysis methods evaluation.

Delta RMP Management Questions

Table 11 summarizes the technical approaches to address the Statewide CEC Pilot Study Monitoring Plan. The CEC Pilot Study was designed based on study objectives and study questions from the Stakeholder Work Plan, which was developed outside of the Delta RMP. However, the CEC Pilot Study does begin to inform a Delta RMP management question:

> **Is there a problem or are there signs of a problem?**

The CEC Pilot Study will provide an initial assessment of conditions through consideration of the Statewide CEC Pilot Study Monitoring Plan monitoring questions that are identified in **Table 11**. This Year 3 Study Design addresses the bolded row in **Table 11:**

> **How quickly (i.e., at what distance) do the CECs attenuate once discharged?**

The Delta RMP will address the other **Table 11** study questions using the collective three-year data set.

Table 11: Monitoring questions for the CEC Pilot Study.

2016 Statewide Monitoring Plan Monitoring Questions	Technical Approach to Address Monitoring Questions
POTWs	
Which CECs are detected in freshwaters and in which California watersheds are they detected?	Monitor to determine detection of CECs at boundaries of the Delta and within the legal Delta over multiple years and conditions.
Can the CECs be shown to originate from the inland WWTP, or are they present at background concentrations?	Compare observed concentrations at upstream boundaries or locations and downstream monitoring locations.

Statewide CEC Pilot Study Monitoring Plan. However, Dry Creek in Roseville was recommended in the Stakeholder Work Plan as a more ideal study location with fewer outside sources.

2016 Statewide Monitoring Plan Monitoring Questions	Technical Approach to Address Monitoring Questions
How quickly (i.e., at what distance) do the CECs attenuate once discharged?	**Perform a gradient study to evaluate concentrations at multiple locations downstream from discharges to evaluate CEC attenuation over distance.**
What are the concentrations and loadings of target CECs in the dry vs. wet seasons?	Compare wet and dry season concentrations and loadings at individual source characterization and ambient sites.
Do the new occurrence data change the estimated monitoring trigger quotients (MTQs)?	Compare maximum detected ambient values to determine if site-specific MTQ is greater than or less than unity (1.0).
Which detected CECs have been found to accumulate in sediments and fish tissue?	Compare water column detected concentrations to paired sediment and tissue samples. Calculate average accumulation ratios.
MS4s	
Which CECs are detected in waterways dominated by stormwater?	Monitor to determine detection at the American River at Discovery Park monitoring location during wet weather conditions.
What are their concentrations and loadings in the dry vs. wet seasons?	Compare wet and dry season concentrations and loadings at individual source characterization sites.
What is the relative contribution of CECs in WWTP effluent vs. stormwater?	Compare wet and dry weather source characterization loading estimates for urban area runoff and POTW discharge relative to ambient flux.
What is the spatial and temporal variability in loadings and concentration (e.g., between storm variability during the wet season; in stream attenuation rate during low flow, dry season conditions)?	There is insufficient sample collection included in the Work Plan to perform a robust variability assessment; however, significant trends may be detectable when evaluated with other (external) data and work by MS4s (e.g., statistical loading models).

Note: Bolded question is addressed in this Year 3 Study Design

CEC Gradient Study Questions

The three-year Stakeholder Work Plan design was approved by the Delta RMP prior to the Regional Water Board Resolution that now requires a study hypothesis. The CEC Year 3 Study Design was developed based on the specified number of study areas (two POTWs and two receiving waters), sample collection locations (seven in total), and sample frequency (2 dry weather events). While study hypotheses could be developed to evaluate attenuation, the number of samples specified in the Stakeholder Work Plan would likely be insufficient to have statistical significance and the Stakeholder Work Plan study questions can be addressed without a specific hypothesis test. Moreover, the Stakeholder Work Plan is a pilot study intended to inform future monitoring design with initial data collection and evaluation.

This Year 3 Study Design includes testable study questions that inform the next steps, including future hypotheses development in regional CEC monitoring programs. The Year 3 study questions are as follows:

1. For each of the CEC constituents, what is the attenuation at distances downstream from the POTW discharge?
2. For each of the CEC constituents, can the relative magnitude of the type of attenuation (hydraulic or degradation/inputs) be quantified based on a simple mass balance with available flow, travel time, and concentration measurements or estimates?

The Year 3 gradient study will characterize the spatial distribution of CECs and hydraulic dilution of CECs. The study reaches are designed to be long enough to gather information about both the attenuation of CECs expected to attenuate rapidly and persistent CECs. The study will inform future studies on degradation rates and sample collection strategies and methods.

Sampling Strategy

To answer the CEC Pilot Study questions with a limited number of samples and expected lack of upstream flow at some targeted ambient monitoring sites, a site prioritization strategy is necessary. Prior to mixing with main stem[2] and tributary[3] confluences and absent new sources, changes in surface water CEC concentrations would occur due to degradation or partitioning into sediments or aquatic organisms. While each of the CECs may have different attenuation rates, these processes were assumed to follow an exponential decay[4] for this design strategy where the absolute magnitude of attenuation (decay) is higher where CECs exist at higher concentrations (i.e., near to the source signal). The downstream sites were chosen at increasing distances downstream from the POTW source to follow the expected exponential decay curve model for attenuation of CECs along the study reaches. If sites were located equidistant from each other, the absolute concentration difference between sites would get increasingly smaller. The smaller differences may be more difficult to measure at the expected low concentrations. First order decay is just one consideration in site selection in addition to access (logistical and safety) considerations that are discussed later.

The gradient study mass balance and point of attenuation schematics in **Figure** 5 identify the variables within the study system. **Figure** 5 identifies the study "flow path" which is the downstream path of POTW effluent where attenuation distance is measured. The Statewide CEC Pilot Study Monitoring Plan does not specify the definition of "point of attenuation" and whether it is 1) any decrease in concentration or 2) decrease to background concentration. For CEC Pilot Study question testing, this point is assumed to be the first downstream point after the source at which the concentration decreases and does not increase at the next downstream point on average for the two study events.

At each of the flow path sample locations a mass balance spatial boundary can be defined as shown in **Figure** 5. For each of these spatial boundaries (i.e., each flow path sample location) a mass flux balance can be performed where mass flux (mass per time) is the product of flow and concentration. A generalized mass balance equation would be:

$$mass\ flux_{in} = mass\ flux_{out} + unmeasured\ massflux + mass\ acumulation\ rate - mass\ decay\ rate + error$$

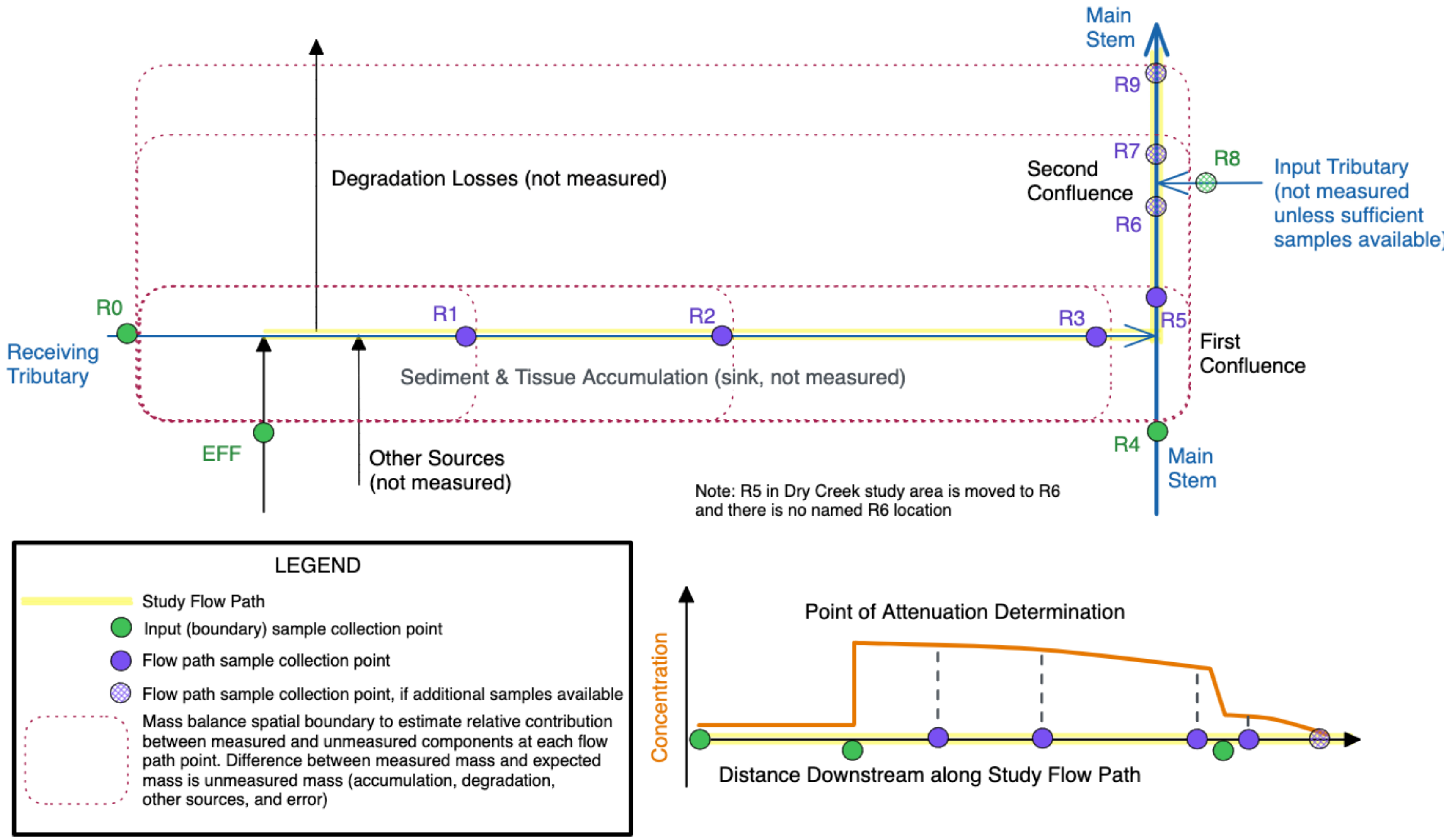
[2] "Main stem" is the named waterbody that continues downstream of the confluence (e.g., the tributary Dry Creek merges with the main stem Steelhead Creek).
[3] "Tributaries" are any waterbodies that flow to the main stem.
[4] dC/dt = -kC for a first order decay reaction. Where k is the decay rate and C is the concentration of the contaminant.

$$mass\ flux_{in} = mass\ flux_{out} + unmeasured\ massflux + mass\ acumulation\ rate - mass\ decay\ rate + error$$

In the case of this study design, the mass flux in and the mass flux out (blue terms in the above equation) are the only factors measured; the remaining factors are considered potential factors that would result in the mass flux in and the mass flux out being unequal.

Unmeasured mass flux are external inputs or outputs (e.g., storm drain) that are not measured in this Study Design but may be visually observed. Mass can accumulate within the spatial boundary in the sediments, uptake to plants, or uptake to aquatic life. Error may also be introduced through any of the flow or concentration measurements and collection timing. The Study Design specifies collection of mass flux in and out of the spatial boundary. When these values are not equal, the difference can be attributed to the other equation terms.

Figure 5: Gradient study mass balance schematic and flow path point of attenuation diagram.



Wherever possible, inputs to the study flow path will be measured upstream of the study flow path and immediately downstream to evaluate the effects of additional inputs on any observed attenuation. For each study area (i.e., "POTW 1" for Dry Creek and "POTW 2" for Old Alamo Creek), the three waterbodies evaluated are:

- **Receiving tributary** – the immediate receiving water for the effluent. The effluent input and, if applicable, any upstream inputs will be monitored as the input samples for this waterbody. Three study flow path samples will be collected from the first confluence with the main stem as shown in **Table 12**.
- **Main stem** – the larger waterbody into which the receiving tributary flows at the first confluence. If there is water upstream of the receiving tributary, the upstream input and immediately downstream of the confluence will be monitored. Includes the additional sites along the main stem leading up to the second confluence.
- **Input tributary** – an additional tributary which meets the main stem at the second confluence. The input tributary upstream and downstream of the main stem confluence will only be monitored when there are insufficient input sites on the receiving tributary and main stem to reach seven sample locations.

Table 12. Waterbodies assessed for each gradient study area.

Waterbody Type	Sites	Study Area POTW 1	Study Area POTW 2
Effluent	EFF	POTW1	POTW2
Receiving Tributary	R0, R1, R2, R3	Dry Creek	Old Alamo Creek
Main Stem	R4, R5, R6, R7, R9	Steelhead Creek	New Alamo Creek
Input Tributary	R8	Robla Creek	Ulatis Creek

Each study area will be sampled at seven sites according to the decision trees provided in **Figure 6** and **Figure 7**. The preferred sample locations would assess the effluent, an upstream input, and five downstream locations (R1-R5). Given the dry season conditions in which sampling will occur, up to four alternate sites (R6-R9) further downstream on the main stem and input tributaries have also been identified such that a total of seven samples can still be collected if the upstream input site (R0) and/or the main stem input site (R4) do not have flowing water to be sampled.

Any samples collected immediately downstream of a confluence with both waterbodies flowing should be collected as spatial (transect) composite samples (if safe to do so). All other samples will be collected as single grab samples as outlined below.

The sample collection strategy maximizes the limited number of Stakeholder Work Plan specified samples per study area ("1 effluent, 1 upstream receiving water, and 5 downstream receiving water") to answer the study questions. The strategy will result in one of four possible scenarios for the seven available samples per event per study area per event.

- The first scenario is if the upstream site is not dry, and the first confluence is not dry. In scenario one, the design includes all preferred sites including the upstream (1), effluent (2), R1 (3), R2 (4), R3 (5), R4 (6), and R5 (7) sites.
- The second scenario is if the upstream site is not dry but the first confluence is dry. In scenario two, the design includes 6 preferred locations and one alternate site, including the upstream (1), effluent (2), R1 (3), R2 (4), R3 (5), R5 (6), and R6 (7) sites.
- The third scenario is if the upstream site is dry, and the first confluence is not. In scenario three, the design also includes six preferred sites and one alternate site (similar to scenario two) including the effluent (1), R1 (2), R2 (3), R3 (4), R4 (5), R5 (6), and R6 (7) sites.
- The fourth scenario is if the upstream site is dry, and the first confluence is dry. In scenario four, the design includes five preferred sites and two alternate sites including the effluent (1), R1 (2), R2 (3), R3 (4), R5 (5), R6 (6) and R7 (7) sites.

In addition to these four scenarios, if any of the sites cannot be sampled alternate sites R8 and R9 would be sampled to ensure that seven samples are collected. In the case of the POTW 1 study area, R6 does not have a sample location since R5 and R7 are so close together. In this case, the sequence in **Figure 7** skips R6 and goes directly to R7 depending on the scenario.

"Preferred sites" are those that would be sampled if flow is measured at R0 and R4 and "alternate sites" are pre-designated sites that would be sampled based on the observed conditions as follows (site types are listed in **Table 13** and specified in the **Sample Collection Methods** section.

Preferred Sites:

- Collect the upstream of POTW discharge (Upstream) ambient sample at mid-stream and mid-depth in the morning (before 9AM) and measure upstream flow. If upstream flow is zero, no sample will be collected. If no upstream sample is collected, an additional downstream sample will be collected (for a total of six downstream samples).
- Collect grab effluent sample (Effluent) in the morning just after the upstream sample collection (9AM).

- Collect the three (R-1, R-2, and R-3) mid-stream and mid-depth[5] downstream samples to the first confluence. Begin downstream sample collection closest to the discharge point, and end sample collection at the site furthest from the discharge point. Samplers will be instructed to minimize sediment disturbance as much as possible.
- If there is main stem upstream flow at the first confluence with Steelhead Creek or Old Alamo Creek main stems, collect samples in the main stem upstream and downstream of the tributary confluence. If wadable, the upstream sample should be taken as a grab sample at mid-stream, mid-depth. If wadable, the site immediately downstream of the first confluence should be collected as an approximate transect composite sample to account for incomplete mixing of the two waterbodies. For locations immediately downstream from a confluence a transect composites are collected by filling the sample bottle one-third for each of three mid-third, mid-depth locations in a transect across the main stem (i.e., near third, middle third, and far third). If not wadable, a shore grab as far into the stream as possible is acceptable.

Alternate Sites:

- If there is no main stem upstream flow at the Steelhead Creek or Old Alamo Creek confluence with the receiving water tributary, collect a mid-stream, mid-depth grab sample on the main stem downstream of the confluence (R5) and on the main stem at the next downstream location above the next flowing tributary confluence R6 (if applicable). Shore samples can be taken if the main stem is not wadable. Continue this approach at each confluence between the main stem and a tributary input until the total sample collection points reaches seven. If it is not possible to sample at a location as described in **Figure 6** and the **Sample Collection Methods** section of this document, continue to the next downstream main stem location (upstream of the next input tributary confluence).
- If there is no flow at either the upstream Dry Creek site (R0) or the upstream Steelhead Creek site (R4), samplers will proceed directly from the flow path main stem site (R5) to the Steelhead Creek site downstream of the second confluence with Robla Creek (R7). There is no R6 site identified for Steelhead Creek because the distance along the main stem between the first confluence (terminus of Dry Creek) and the second confluence (terminus of Robla Creek) is relatively short compared to the scale of the overall study area (500 meters compared to > 20 kilometer study area) with no known inputs between those two confluences. Therefore, there is not likely an appreciable difference in attenuation between a

[5] In low flow conditions, mid-stream, mid-depth samples should be collected from the portion of the waterbody with the swiftest current.

sample collected immediately downstream of Dry Creek and a sample collected immediately upstream of Robla Creek and an additional sample (R6) along this section of the main stem would be redundant. The R5 site on Steelhead Creek will serve the purpose of evaluating the sample flow path as influenced by any upstream inputs from Steelhead Creek, as well as establishing the main stem conditions prior to the input tributary of Robla Creek. If there is flow at the upstream main stem site (R4), then a transect composite will be collected at R5 to account for potential mixing occurring at that confluence. If an additional sample is required after the main stem (R5) site, sampling crews will proceed to the site downstream of the second confluence (R7), followed by R8 and R9, if needed.

- Though considered a “main stem” waterbody for the purposes of this study, New Alamo Creek is a tributary to Ulatis Creek. If this confluence is reached (i.e., samples are added beyond the five to six downstream receiving water samples), the New Alamo Creek terminus (R6) sample and downstream (composite) confluence (R7) samples should be collected. If needed to reach a total of seven samples, field crews will collect an additional grab sample from Ulatis Creek, upstream of the New Alamo Creek confluence (R8). If the five (or six) receiving water samples have already been collected the sample collection priority order is: New Alamo Creek terminus, main stem downstream of the confluence, and main stem upstream of the confluence.
- If for any reason seven total samples have not been reached, then a sample should be collected from the final alternate site (R9).

At all ambient (non-effluent) locations the following data should be collected:

- Water depth at mid-stream
- Mid-stream flow measurement parameters (see section **Flow Measurement Methodologies** for details).
- Photographs of site location and surrounding conditions
- Field measurements for specific conductance, pH, and temperature
- Atmospheric temperature and weather conditions
- Latitude and longitude coordinates

Table 13 is a summary of the expected gradient sample locations including priority numbering based on the monitoring strategy. The **Sample Collection Locations** section below contains specific details about the locations.

Figure 6: Gradient study sample collection strategy.

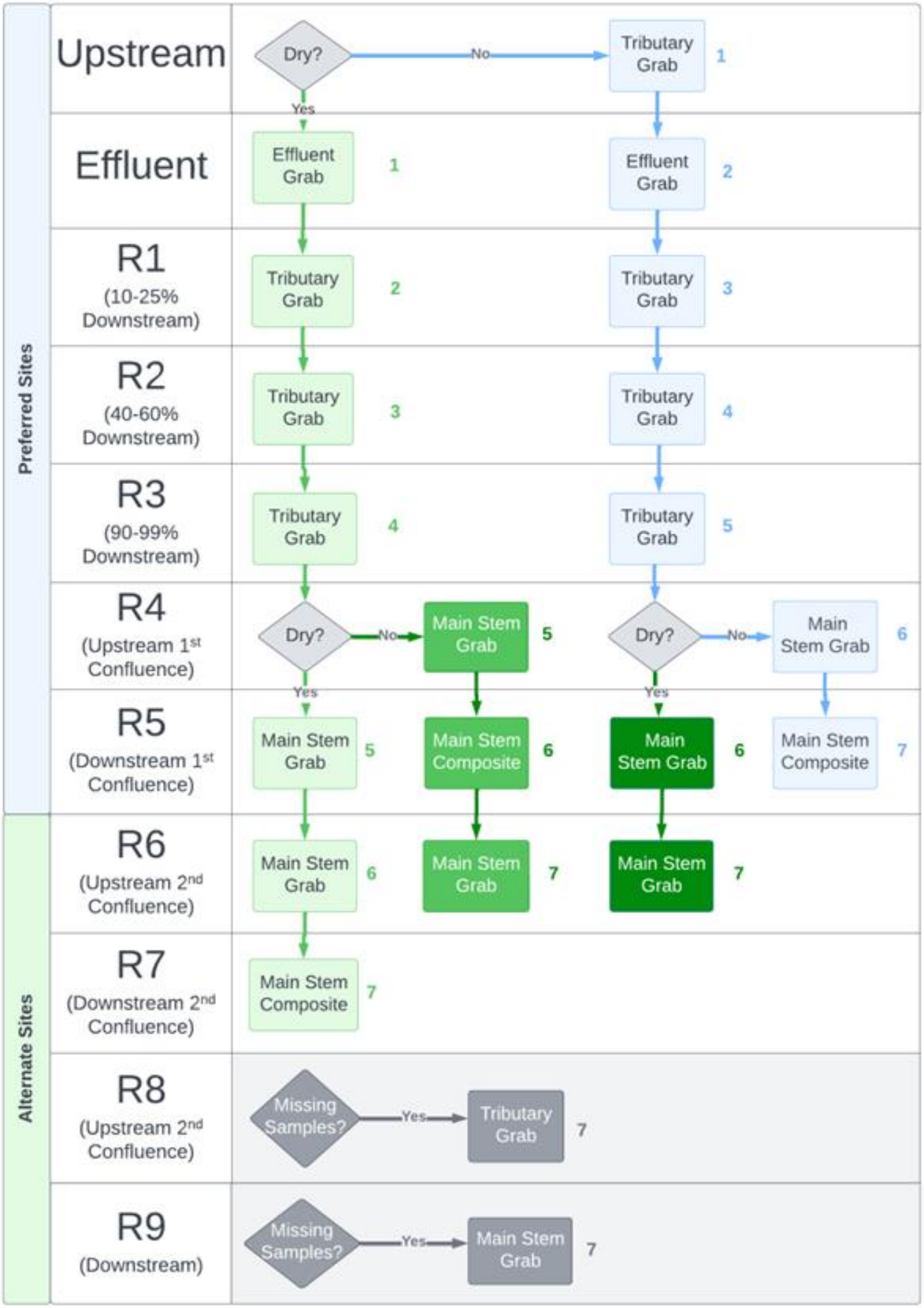
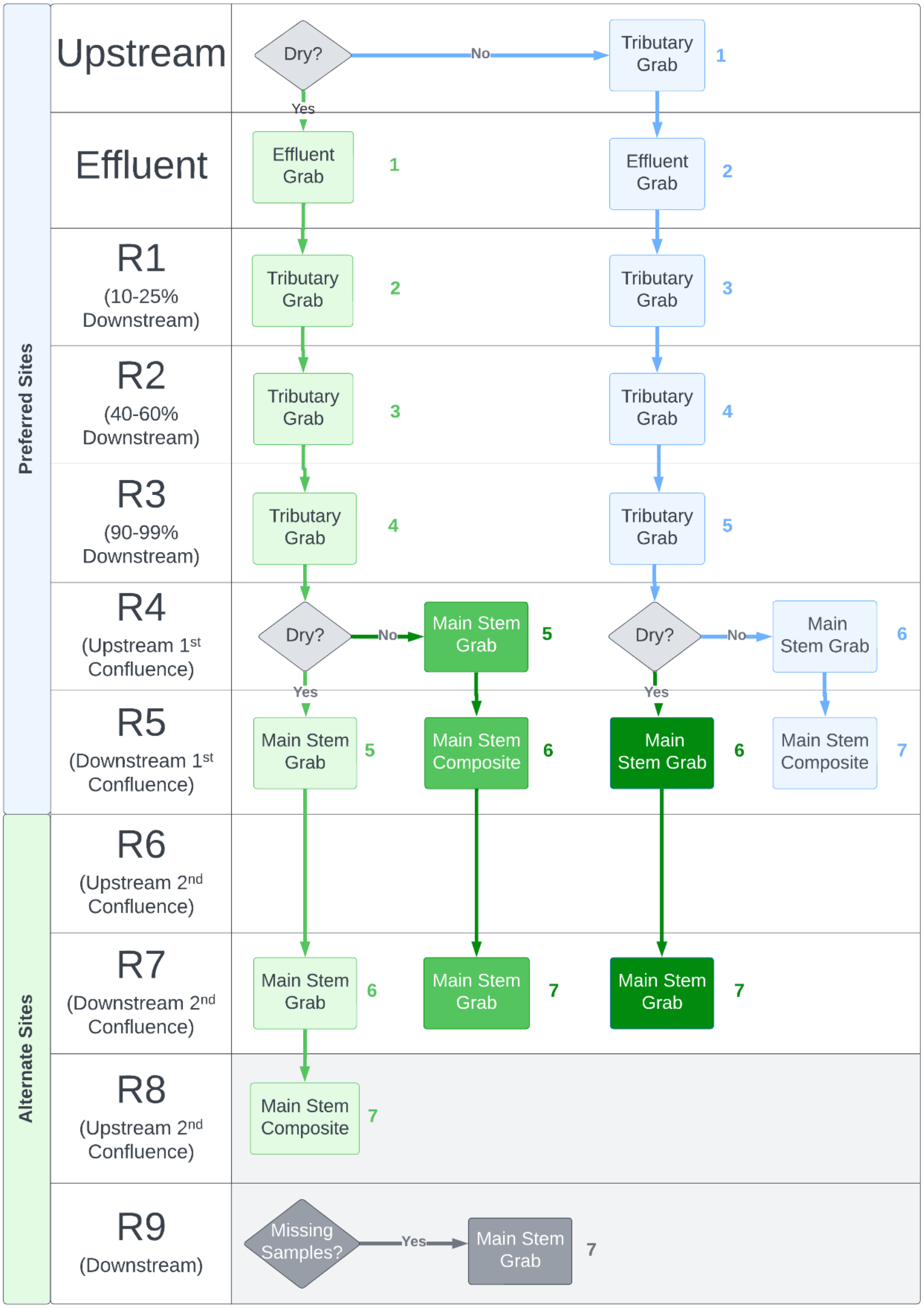


Figure 7. Adjusted gradient sample collection strategy for the POTW 1 study area.



An R6 monitoring site is not identified for the POTW 1 study area because the relatively short distance (500 meters) between the first and second confluence would result in redundant data collection. If necessary, samplers will proceed from R5 (downstream of the first confluence) to R7 (downstream of the second confluence) for the POTW 1 study area.

Table 13: Gradient sample types, descriptions, and sampling priority for additional sites.

Gradient Sample Type	Waterbody	Sample Type	Site Location Description
Preferred Sites			
R0	Receiving Tributary	Input	Upstream location in NPDES permit. If site has no upstream flow, do not collect sample and add a downstream location.
EFF	NA	Input	Effluent sample at NPDES permit location as a grab sample.
R1	Receiving Tributary	Flow Path	First receiving water (tributary) downstream location.
R2	Receiving Tributary	Flow Path	Second receiving water (tributary) downstream location.
R3	Receiving Tributary	Flow Path	Third receiving water (tributary) downstream location.
R4	Main Stem	Input	Upstream of confluence on main stem, if flow is not measurable, move to R6.
R5	Main Stem	Flow Path	Downstream of confluence on main stem if flow is measurable at R4.
Alternate Sites			
R6	Main Stem	Flow Path	Main stem upstream of next flowing tributary confluence.
R7	Main Stem	Flow Path	Main stem downstream of next flowing tributary confluence.
R8	Input Tributary	Input	Tributary upstream of confluence with main stem.
R9	Main Stem	Flow Path	Main stem gradient site not associated with a confluence

Sample Collection Locations

This Year 3 gradient study will evaluate two POTW effluent gradients, each consisting of one upstream site, one POTW effluent site, and up to five downstream sites in Old Alamo Creek and Dry Creek. Municipal separate storm sewer systems (MS4) urban runoff monitoring sites will be sampled in Roseville and Sacramento that do not directly inform the gradient study but are part of the full three-year CEC study. For each of the two events, the Delta RMP will collect water or effluent samples at a total of sixteen site locations. Other ambient locations sampled in Year 1 and Year 2 will not be sampled in Year 3.

In December 2021, the Steering Committee discussed whether additional sampling should occur during FY 22-23 to capture the missed samples from Year 1. In the Delta RMP FY 22-23 Workplan the Steering Committee referred the issue to the CEC TAC to evaluate the merit of collecting the missed samples during FY 23-24 as part of the Year 3 Study Design.

As discussed in the Year 2 Data Report, the CEC TAC did not recommend collecting additional samples from the three sites where one sample was missed during Year 1 of the CEC Pilot Study. The Year 2 Data Report also did not recommend re-sampling sites where samples did not meet measurement quality objectives, but did recommend the addition of laboratory split and travel blanks for bisphenol A.

Urban Runoff Source Characterization Monitoring Sites

The Year 3 MS4 stormwater monitoring sites are existing MS4 sites located in Roseville and Sacramento (**Table 14**).

Table 14: MS4 stormwater monitoring sites, CEDEN station code, latitude, and longitude.

Station Description	CEDEN Station Code	Latitude	Longitude
Sacramento Urban Runoff 3; Sump 111	519SACUR3	38.60127	-121.49296
Roseville Urban Runoff	519PGC010	38.80477	-121.32733

Gradient Monitoring Locations

The gradient monitoring locations described in the **Sampling Strategy** section include POTW effluent, upstream receiving water, and downstream receiving water locations. In cases where an upstream main stem or tributary does not have flow (and a sample cannot be taken) the sample is shifted downstream as described in the **Sampling Strategy** section. Gradient study areas are shown in the **Figure 8** and **Figure 9.** maps for Dry Creek and Old Alamo Creek, respectively. The maps show the additional potential locations if flow is not present upstream of POTW discharge or upstream at the first main stem (Steelhead Creek and New Alamo Creek) or if sampling cannot be conducted at any other preferred locations.

The gradient study receiving water sites were selected to determine the distance at which CECs attenuate downstream of the POTW effluent discharges.[6] Based on the monitoring strategy, field crews verified likely sites' accessibility, safety concerns and dry weather conditions using aerial imagery and follow-up site visits.

POTW Effluent

The effluent monitoring sites for POTW discharges to Dry Creek and Old Alamo Creek effluent are existing monitoring sites from Years 1 & 2, shown in **Table 15** and in **Figure 8** and **Figure 9**.

Table 15: POTW effluent monitoring locations, CEDEN station codes, latitude, and longitude

Station Description	Gradient Sample Type	CEDEN Station Code	Latitude	Longitude
POTW Source 1 effluent discharge to Dry Creek	EFF	519POTW01	38.73402	-121.32185
POTW Source 2 effluent discharge to Old Alamo Creek	EFF	511POTW02	38.34664	-121.90156

Upstream Locations

The upstream receiving water monitoring locations for Old Alamo Creek and Dry Creek gradients are shown in **Figure 8** and **Figure 9** and listed in **Table 16.** The upstream receiving water site in Dry Creek is an established monitoring site from Years 1 & 2.

[6] LWA, et al. July 2018. *Central Valley Pilot Study for Monitoring Constituents of Emerging Concern (CECs) Work Plan.*

Table 16: Upstream receiving tributary monitoring locations, CEDEN station codes, latitude, and longitude.

Station Description	Gradient Sample Type	CEDEN Station Code	Latitude	Longitude	Distance Upstream From Discharge (meters)
Dry Creek before POTW Source 1	R0	519DRYCRK	38.7341	-121.31444	60
Old Alamo Creek Before POTW Source 2	R0	511OACUPS	38.34741	-121.90507	320

Downstream Receiving Water Locations

The Delta RMP will collect samples at five POTW receiving water and downstream sites, and up to six locations if the upstream receiving water location is dry.

POTW1 Downstream Receiving Water Locations

Downstream receiving water monitoring sites through the first confluence (R1-R5) and additional receiving water monitoring sites (R7-R9) for the POTW1 gradient are shown in **Figure** 8 and listed in **Table** 17, **Table** 18, and **Table 19**. An R6 monitoring site is not identified for the POTW 1 study area because the relatively short distance (500 meters) between the first and second confluence would result in redundant data collection. For the POTW 1 study area, the R5 sample serves as the sample that will be representative of water downstream of the first confluence and upstream of the input from the second confluence.

Additional sampling sites were pre-determined from the confluence between Magpie Creek and Steelhead Creek until the confluence between Steelhead Creek and the Sacramento River at Discovery Park.

During Year 3 Study Design development, Delta RMP field crews could not access the main stem Steelhead and Magpie Creek terminus confluence, or the main stem Steelhead Creek and Arcade Creek terminus confluence. Field crews will scout the area again to determine if there is a feasible access point for the farthest downstream alternate site (R9) that is closer to the other gradient study sites. Any changes to monitoring locations will require CVRWQCB and State Board QA Officer approval prior to implementation.

Figure 8: Dry Creek and downstream gradient monitoring locations.

An R6 monitoring site is not identified for the POTW 1 study area because the relatively short distance (500 meters) between the first and second confluence would result in redundant data collection. For this study area, the R5 sample will represent water downstream of the first confluence and upstream of the input from the second confluence.

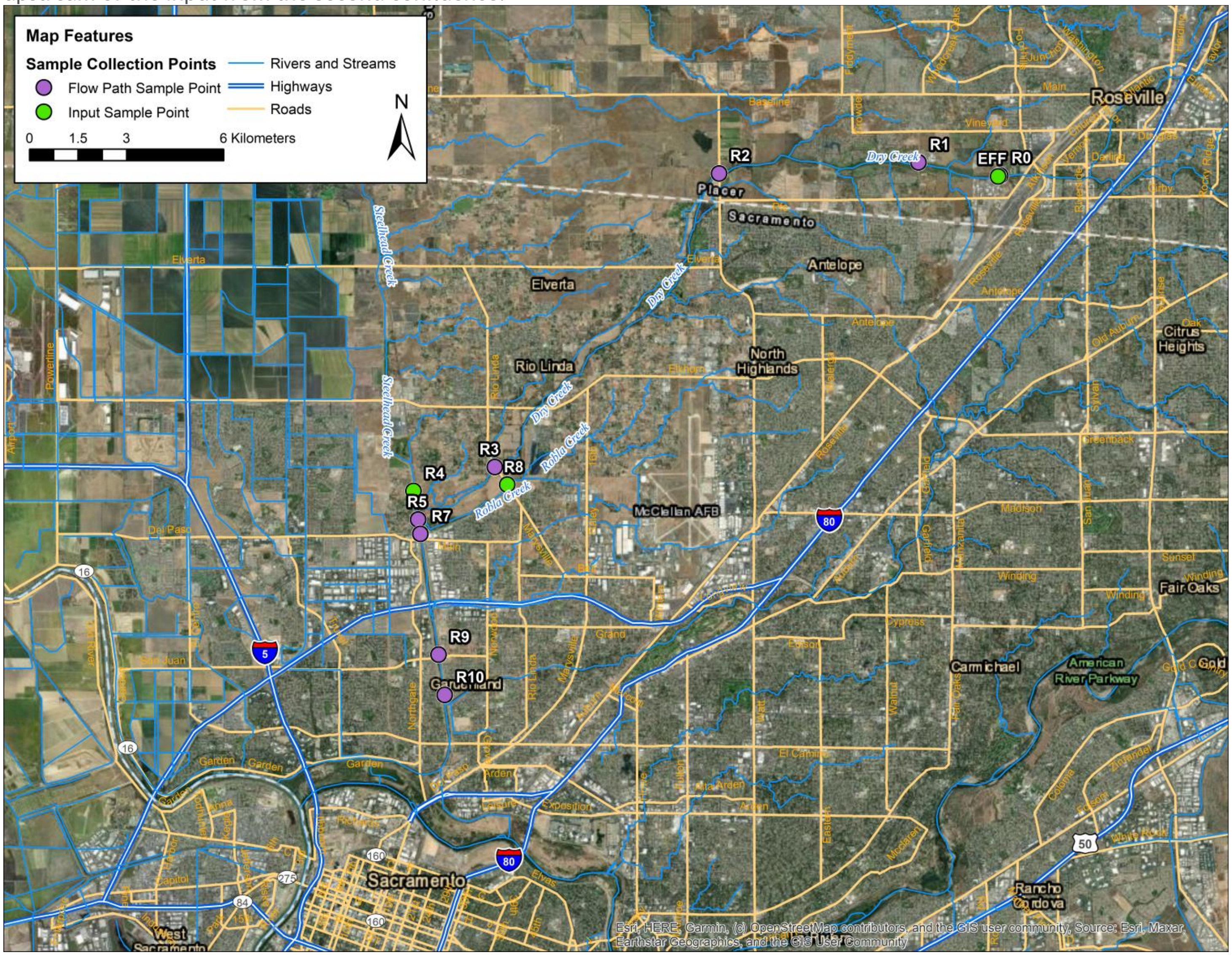


Table 17: POTW 1 study area receiving tributary flow path monitoring locations.

Station Description	Gradient Sample Type	CEDEN Station Code	Latitude	Longitude	Distance From Discharge (meters)	Site Location Basis
Dry Creek at Cook Riolo Rd bridge	R1	519DRYCRB	38.73672	-121.33670	2,200	Accessible from roadway
Dry Creek at Watt Ave bridge	R2	519DRYWAB	38.73456	-121.39290	7,300	Accessible from roadway; increasing distance from previous location
Terminus of Dry Creek at Rio Linda Blvd	R3	519DRYRLB	38.67109	-121.45415	17,000	Accessible from roadway; increasing distance from previous location

Table 18: POTW 1 study area preferred main stem monitoring locations.

Station Description	Gradient Sample Type	CEDEN Station Code	Latitude	Longitude	Distance From Discharge (meters)	Site Location Basis
Steelhead Creek main stem Upstream of confluence with Dry Creek	R4	519SHCUDC	38.665806	-121.477325	NA	Accessible upstream on main stem
Steelhead Creek main stem Downstream of confluence with Dry Creek	R5	519HCDDC	38.66407	-121.47720	19,700	Accessible downstream on main stem.

Table 19: POTW 1 study area alternate monitoring locations.

Station Description	Gradient Sample Type	CEDEN Station Code	Latitude	Longitude	Distance From Discharge (meters)	Site Location Basis
NA	R6 [1]	NA	NA	NA	NA	NA
Steelhead Creek main stem downstream of Robla and Steelhead Creek confluence	R7	519SHCDRC	38.6565	-121.475453	20,600	Closest accessible downstream of Robla Creek
Terminus of Robla Creek at Rio Linda Blvd	R8	519RCARLB	38.66811	-121.45018	NA	Closest accessible location to terminus of Robla Creek
Steelhead Creek main stem upstream of San Juan Rd overpass	R9	519SHCUSJ	38.63031	-121.47053	23,600	Closest accessible downstream location with minimal additional influence.
Steelhead Creek main stem upstream of Arcade and Steelhead Creek confluence	R10	519SHCUAC	38.62185	-121.46890	24,600	Additional accessible downstream location.

[1] An R6 monitoring site is not identified for the POTW 1 study area because the relatively short distance (500 meters) between the first and second confluence would result in redundant data collection.

POTW2 Downstream Receiving Water Locations

Downstream receiving water monitoring (R1-R5) and additional receiving water monitoring (R6-R8) sites for the POTW2 gradient are shown in **Figure 9** and listed in **Table 20**, **Table 21**, and **Table 22**. Access to locations is limited based on unpaved road conditions, private land ownership, and fencing. Locations were then selected primarily based on roadway accessibility. Some locations are known to have hydraulic structures (e.g., weirs, check dams, etc.) where flow can be measured accurately.

An additional site not associated with a confluence (R9) was identified for the POTW2 gradient before the gradient stream system enters a tidal slough (**Table 22**). This additional site (R9) is the furthest downstream site that should be sampled if there are dry conditions along the POTW2 gradient during sample collection.

Figure 9: Old Alamo Creek and downstream gradient monitoring locations.

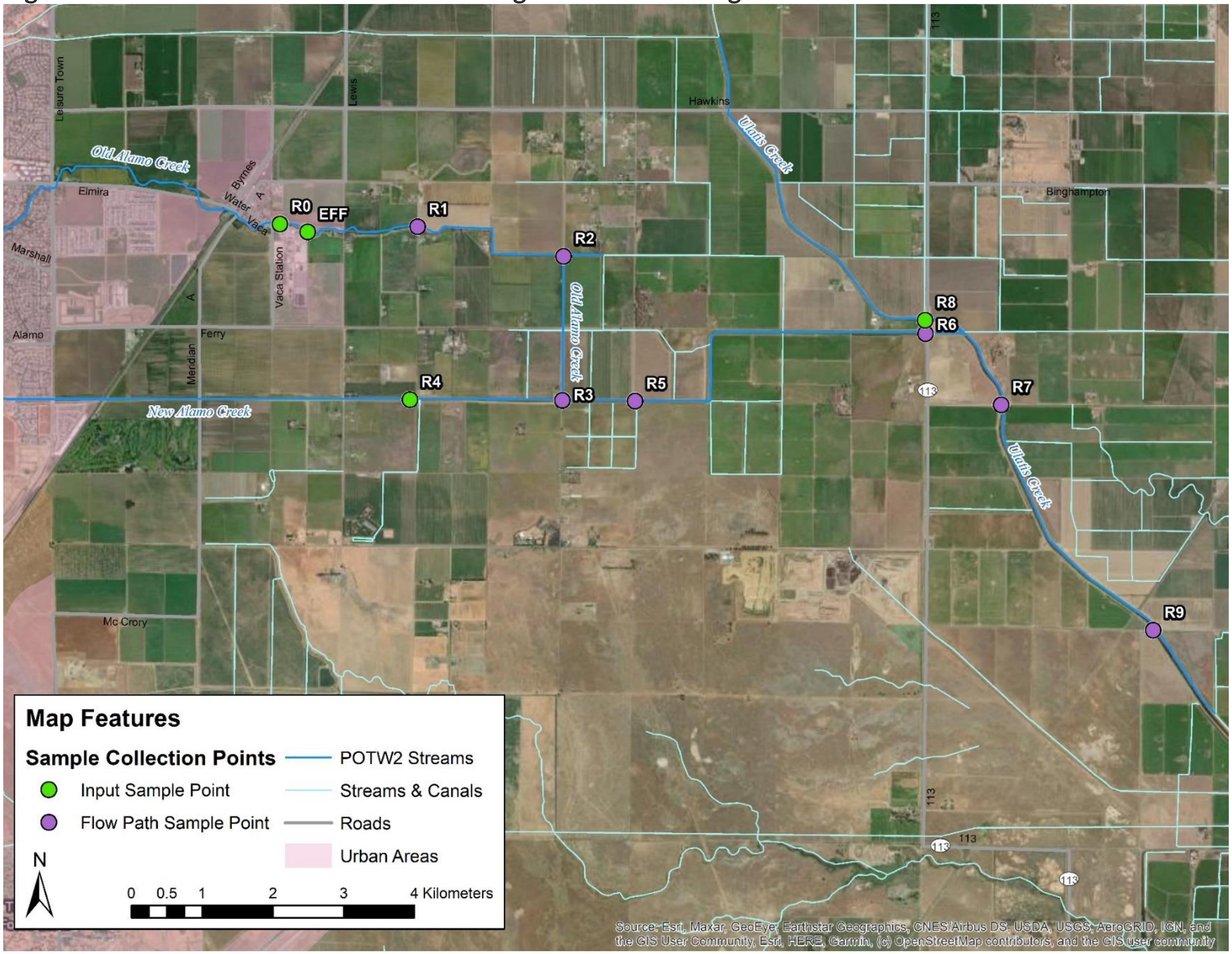


Table 20: POTW 2 study area receiving tributary flow path monitoring locations.

Station Description	Gradient Sample Type	CEDEN Station Code	Latitude	Longitude	Distance From Discharge (meters)	Site Location Basis
Old Alamo Creek at Chicorp Ln.	R1	511OACCLN	38.347147	-121.887617	1,300	Accessible location used as part of other study
Old Alamo Creek at Sunnybrook Ln.	R2	511OACSBL	38.344197	-121.869089	3,200	Accessible location used as part of other study. Samples to be collected upstream of ag drains
Terminus of Old Alamo Creek upstream of confluence with New Alamo Creek	R3	511OACUNA	38.329869	-121.869231	4,800	Furthest downstream accessible location prior to confluence. Available flow measurement structure

Table 21: POTW 2 study area preferred main stem monitoring locations.

Station Description	Gradient Sample Type	CEDEN Station Code	Latitude	Longitude	Distance From Discharge (meters)	Site Location Basis
New Alamo Creek upstream of confluence with Old Alamo Creek	R4	511NACUO	38.329939	-121.888569	NA	Available flow measurement structure
New Alamo Creek downstream of confluence between New and Old Alamo Creeks	R5	511NACDOA	38.329789	-121.860019	5,500	Available flow measurement structure

Table 22: POTW 2 study area alternate monitoring locations.

Station Description	Gradient Sample Type	CEDEN Station Code	Latitude	Longitude	Distance From Discharge (meters)	Site Location Basis
Terminus of New Alamo Creek at Rio Dixon Rd before confluence with Ulatis Creek	R6	511NACARD	38.336511	-121.823136	9,500	Available flow measurement structure
Ulatis Creek at Maine Prairie Rd downstream of confluence with Alamo Creek	R7	511UCAMPR	38.329431	-121.813564	10,800	Nearest accessible downstream location
Ulatis Creek at Rio Dixon Rd upstream of confluence with Alamo Creek	R8	511ULCABR	38.337831	-121.823219	NA	Nearest accessible upstream (Ulatis) location
Ulatis Creek additional downstream site not associated with a confluence	R9	511ULCABR	38.3070	-121.7942	13,900	Furthest downstream additional location

Sample Collection Frequency and Timing

The Delta RMP will collect gradient and MS4 urban runoff samples during two dry weather events as part of the Year 3 study. It is recommended that the two events be separated by at least two weeks. The Delta RMP Resolution specifies annual deadlines for planning and reporting. It is expected that the Delta RMP will complete Year 3 CEC gradient monitoring by October 2023. However, field conditions may require event rescheduling to avoid wet weather as the gradient study is intended to assess effluent-dominated receiving waters. As prescribed in the Delta RMP Resolution, sampling and monitoring results will be submitted within six months from the date of sample analysis. Details regarding the timing of data verification, loading in the Central Valley Regional Data Center (CV RDC) database, and migration to an approved publicly available database (e.g., CEDEN) will be documented in the Year 3 QAPP.

During dry weather, the most significant hydrologic difference at the gradient monitoring locations will be the presence of irrigation water, which will be evident based on the upstream main stem flows in Steelhead Creek, Old Alamo Creek, New Alamo Creek, and Ulatis Creek. Upstream irrigation return flows may provide hydraulic attenuation or additional CEC mass inputs. Upstream flows will not be considered in event targeting (i.e., events will not be rescheduled based on upstream flow conditions). The Delta RMP will collect flow measurements at all monitoring locations wherever flow is present and flow measurements are feasible during both events. See the Flow Measurements section for further information.

The Stakeholder Work Plan does not specify whether wet weather samples are required for the Year 3 MS4 urban runoff samples. To simplify sample collection logistics, the Delta RMP will collect MS4 urban runoff samples concurrently within three days of gradient sample collection. Dry weather urban runoff occurs in much smaller volumes than wet weather. MS4 agencies implement dry weather control and diversion programs, but there are sources of permitted non-stormwater flows in MS4 discharges.

Sample Analytes and Methods

The CEC Pilot Study Work Plan recommends that the CEC analytes monitored in Year 3 of the CEC Pilot Study depend on those CECs detected in Year 2 source monitoring. The Delta RMP monitored aqueous samples for CECs listed in **Table 23**. The **Appendix III** Year 1 and Year 2 data show that each of the analytes was detected at one of the source monitoring locations or immediately downstream at receiving water locations. At multiple CEC TAC meetings (August 29, 2022, October 18, 2022, and November 17, 2022) there were no CEC TAC member objections to include the complete list of **Table 23** CECs in Year 3 monitoring events. Additional constituents included in the method used will be reported in the data deliverable (CEDEN and appendix of results), but not included in the data report body.

Table 23: Analytes and methods for Year 3 of CEC water column monitoring. Additional constituents included in the method used will be reported in the data deliverable (CEDEN and appendix of results), but not included in the data report body.

Analyte Category	Analyte	Analyte Type	Year 1 and Year 2 Lab	Method	Units
PFAS	Perfluorooctanesulfonic acid (PFOS)	Required	Enthalpy [d]	EPA 537M	ng/L
PFAS	Perfluorooctanoic acid (PFOA)	Required	Enthalpy [d]	EPA 537M	ng/L
Physical and Conventional Parameters	Suspended Sediment Concentration (SSC)	Ancillary	Weck	ASTM D3977M	mg/L
Physical and Conventional Parameters	Total organic carbon	Ancillary	Weck	EPA 9060M	mg/L
Physical and Conventional Parameters	Turbidity	Ancillary	NA [a]	SM 2130 B	NTU
Pharmaceuticals and Personal Care Products (PPCPs)	Bisphenol A [c]	Required	Weck	EPA 1694M	ng/L
PPCPs	Bisphenol A [c]	Required	Physis	EPA 625.1M	ng/L
PPCPs	Diclofenac	Required	Weck	EPA 1694M	ng/L
PPCPs	Estradiol, 17beta-	Required	Weck	EPA 1694M	ng/L
PPCPs	Estrone	Required	Weck	EPA 1694M	ng/L
PPCPs	Galaxolide	Required	Physis	EPA 625.1M	ng/L

Analyte Category	Analyte	Analyte Type	Year 1 and Year 2 Lab	Method	Units
PPCPs	Ibuprofen	Required	Weck	EPA 1694M	ng/L
PPCPs	Triclocarban	Required	Physis	EPA 625.1M	ng/L
PPCPs	Triclosan	Required	Weck	EPA 1694M	ng/L
PPCPs	Ethynylestradiol, 17alpha-	Additional	Weck	EPA 1694M	ng/L
PPCPs	Gemfibrozil	Additional	Weck	EPA 1694M	ng/L
PPCPs	Iopromide	Additional	Weck	EPA 1694M	ng/L
PPCPs	Naproxen	Additional	Weck	EPA 1694M	ng/L
PPCPs	Progesterone	Additional	Weck	EPA 1694M	ng/L
PPCPs	Salicylic Acid	Additional	Weck	EPA 1694M	ng/L
PPCPs	Testosterone	Additional	Weck	EPA 1694M	ng/L
Physical and Conventional Parameters	Flowrate	Required	NA [b]	USGS methods	m^3/s
Physical and Conventional Parameters	Midstream Depth	Required	NA [b]	NA	m
Physical and Conventional Parameters	Specific Conductance	Required	NA [b]	EPA 120.1	µS/cm
Physical and Conventional Parameters	pH	Required	NA [b]	EPA 150.1	PH units
Physical and Conventional Parameters	Temperature	Required	NA [b]	NA	°C

Note: Based on the findings of the State Water Board *Monitoring Strategies for Constituents of Emerging Concern (CECs) in California's Aquatic Ecosystems Recommendations of a Science Advisory Panel* report that is expected to be finalized in early 2023, the Steering Committee may direct the TAC to discuss modifications to analytical methods or the analytical list. Any changes to the QAPP must be approved prior to implementation.

[a] Turbidity was collected as a field measure during years 1 and 2.

[b] Parameter will be measured in the field and recorded by field crews during year 3.
[c] Bisphenol A will be analyzed twice for each sample and event by two separate laboratories and methods per recommendations based on Years 1 and 2 sample results. Both sets of results will be used indiscriminately and submitted to CEDEN.
[d] Enthalpy Analytical Laboratory purchased Vista Analytical Laboratory; previous data were reported under Vista.

Sample Collection Methods

During both dry weather monitoring events, the Delta RMP will collect sufficient sample volume for analysis of the CEC constituents in **Table 23** according to the strategy specified in **Table 13** and **Figure 6** and as specified in the **Gradient Monitoring Locations** section. Urban runoff source monitoring protocols will follow the Year 2 sample collection and methods, in addition to any recommended modifications identified in the Year 2 Data Report.

Pre-Monitoring Event Site Visits

Before each monitoring event, Delta RMP field crews should visit all gradient study downstream receiving water monitoring sites no less than two days and no more than three days before samples are collected. There will be at least one full day between the pre-monitoring visit and the day of sample collection to allow sufficient time to communicate the list of anticipated sample locations and for field crews to prepare sampling materials. Pre-event site visits will allow field staff to determine if any of the sites do not have measurable flow (are dry) or have safety concerns that make sampling infeasible at that location. The Delta RMP field crews will then generate a list of monitoring sites to collect samples from during the upcoming monitoring event based on the field conditions they observed during the pre-monitoring event site visits and the collection strategy outlined in **Figure 6**. The Project Manager and CVRWQCB QA Representative will review and approve the list of sites prior to monitoring. Actual sampling locations may deviate +/- 50-m from the Study Design latitude and longitude coordinates if required by site conditions.

Collection Methods

The Year 3 sample collection methods will be the same as those specified in the CEC QAPP v2 and approved deviations. The Delta RMP will collect mid-stream, mid-depth ambient grab samples, unless otherwise specified (i.e., cross sectional composites). The samples will be collected as close to mid-stream as possible considering conditions and safety concerns. Delta RMP field crews will collect one effluent grab sample following collection of the upstream sample and before the first downstream sample. Delta RMP crews then collect ambient samples moving down the **Figure 5** flow path. If receiving water flows are estimated at one foot per second, the total travel distance in 18 hours is just over 12 miles. It is expected that the downstream locations can be sampled in a 6–8-hour period by one Delta RMP field crew. If measured velocities are slower than one foot per second, Delta RMP field crews may want to decrease the pace of downstream sample collection. While the goal is to best capture the attenuation of the measured discharge concentration and mass, this Year 3 Study Design is not designed or expected to track a single parcel of sampled effluent as it moves downstream.

Quality Control Samples

The Delta RMP will collect quality control samples as described in the forthcoming Year 3 CEC QAPP based on this Year 3 Study Design, the CEC QAPP v2, and any approved deviations and amendments. It is recommended that the Year 3 CEC QAPP specify collection of a field blank and field duplicate for each event. Laboratories should be required to perform laboratory blanks and laboratory control samples consistent with the CEC QAPP v2 specifications. Based on the CEC Year 2 Data Report and the **Appendix III** data from Years 1 and 2, it is recommended that the Delta RMP collect and analyze a field duplicate at a secondary lab and collect travel blanks for at least bisphenol A for each event.

Flow Measurements

Flow measurements are necessary to estimate mass flux of constituents and to answer study Question 2: "For each of the CEC constituents, can the relative magnitude of the type of attenuation (hydraulic or degradation/inputs) be quantified based on a simple mass balance with available flow, travel time, and concentration measurements or estimates?"

At monitoring sites without in-stream gauges or other existing methods for measuring flow, Delta RMP field crews will measure flow using one of the methods described in the **Flow Measurement Methodologies** section. A determination or measurement of "dry" means that there was no water present at the site, water was only present in isolated pools, or that a positive water velocity was not present (i.e., measured as zero flow). A determination of "unmeasurable flow" means that site conditions did not allow flow measurement and the flow was estimated based on wetted perimeter measurement and an average velocity estimate.

FLOW MEASUREMENT METHODOLOGIES

Delta RMP field crews will make all in-stream flow measurements to calculate discharge (volumetric flow in cfs) according to USGS methodologies[7] wherever possible. The preferred methods for field flow measurements are methods 1 and 2 listed below. In-stream velocity measurements will be collected using rotating-element mechanical,

[7] USGS (2010). Discharge Measurements at Gauging Stations. Chapter 8 of Book 3, Section A. Techniques and Methods 3-8A

electromagnetic, acoustic doppler, or acoustic digital current point velocity current meters.

1. At any monitoring location where there is measurable stream flow velocity and a wadable channel deep enough to measure velocity using a current meter, field crews will estimate volumetric flow using the current-meter midsection method. Data will be collected using the USGS current meter measurements by wading protocol. The USGS current-meter midsection method is an accurate method of measuring volumetric flow in the field and is the preferred field flow measurement method for the CEC gradient study. Field staff will select a cross section for current meter midsection flow measurements according to the USGS site selection methodology.[7]
2. At monitoring locations with culverts or weirs, field staff will collect the necessary data about culvert or weir geometry, flow depth, and in-stream velocity to calculate volumetric flow rates in cfs.
3. Field staff will decide if there are “unmeasurable flow” conditions at monitoring locations where in-stream velocities and stream depths are below the specified limits of current meters in all accessible cross sections at the monitoring site. When a site has unmeasurable flow, field staff will use a surface float method to estimate volumetric flow rates if possible. The cross-sectional area of the stream will be measured in the field and a surface float will be used with a stopwatch to estimate velocity.
4. If any monitoring location lacks a wadable cross section (i.e., stream is too deep and current is too strong to safely wade across the channel), field staff will follow the USGS discharge measurement of deep, swift streams with a mechanical current meter. If there is a bridge located near the monitoring site, depth and velocity measurements should be taken from the bridge if safe to do so.

Data Deliverables and Reports

The Delta RMP Resolution requires that the study design specify the "Planned reports to summarize results". Data collected through Delta RMP implementation of this Year 3 Study Design will be evaluated according to the Year 3 QAPP and applicable Delta RMP data management practices and schedules. The Year 3 Data Report will be the primary data deliverable for the Year 3 Study Design and will present the CEC gradient study analytical results.

The primary data deliverables and data products associated with Year 3 Data Report are:

1. CEDEN submitted ambient water quality results and quality assurance quality control data.
2. Summary of any deviations to the QAPP or any other project deviations that impacted the quality of the Delta RMP data in order to ensure data of known and documented quality including corrective action(s).
3. Summary of dataset completeness, precision, and accuracy.
4. A list and description of all sample comparisons or tests that did not meet minimum test acceptability criteria for analyses or were considered invalid.
5. POTW and MS4 urban runoff source results and quality assurance quality control data in CEDEN reporting format.
6. Concentration vs. distance from discharge data plots for each gradient location and each constituent.
7. Mass flux vs. distance from discharge data plots for each gradient location and each constituent.
8. Evaluate mass balance and in cases where inputs are not equal to outputs, provide an estimate of the error and unmeasured sources and sinks.
9. Identification of the monitoring location where attenuation is observed for each constituent. Two metrics will be used to identify this location: a) where receiving water concentrations return to background concentrations or b) where a negative change in concentration is observed from the previous monitoring locations. Additionally, there may be a finding that attenuation was not observed in the study area. The Statewide CEC Pilot Study Monitoring Plan does not specify how the point of attenuation is determined so these two approaches provide a means to make an assessment. Additional attenuation determination methodologies may be developed.
10. Estimate of the contribution of attenuation caused by hydraulic dilution in study area, if any.
11. Provide a list and brief description of the unmeasured variables, field observations, and/or potential conditions that may influence CEC attenuation.

The Delta RMP Steering Committee and Board of Directors may further specify preparation of an overall CEC Pilot Study report for all three years of data collection.

This may include more detailed assessment and interpretation of the data and data summaries provided in the Year 3 Data Report.

Data Management

Study implementation will be overseen by the Delta RMP Program Manager in coordination with the CVRWQCB QA Representative. Data will be processed and managed in a CEDEN-comparable format in the CV RDC. The review of project data for compliance with the QAPP will be overseen by the Delta RMP QA Officer in accordance with the procedures reviewed and approved by the CVRWQCB QA Representative and SWRCB QA Officer which are outlined in the Data Management Standard Operating Procedures to be submitted with the QAPP.

Study Timeline and Schedule

The schedule of CEC Year 3 deliverables for FY 22-23 in **Table 24** assumes that the Delta RMP Board of Directors approve the Year 3 study design based on a recommendation from the Steering Committee including funding for FY 23-24 and that the Regional Water Board approves the FY 23-24 Workplan and CEC Year 3 QAPP in August 2023 which would allow for the first sampling event to occur in September.

Table 24: CEC schedule of deliverables.

Deliverable / Milestone	Deliverable Due Date
Resolution Deliverables	
FY 23-24 Monitoring Workplan including the CEC Year 3 study design [a]	May 1, 2023
CEC QAPP	May 1, 2023
Year 3 Data Report and CEDEN Deliverable [c]	February 2024
Study Design Milestones	
Year 3 Study Design Finalized by TAC	January 23, 2023
Year 3 Study Design Recommended to SC	January 23, 2023
Year 3 Study Design Recommended to BOD	April 10, 2023
EC Approved Year 3 Study Design	April 24, 2023
Recommended Implementation Schedule	
Regional Water Board-Approved FY 23-24 Monitoring Workplan and QAPP	August 2023
Year 3 Study Finalized Budget	June 30, 2023
Year 3 Event No. 1 [b]	August 2023 – September 2023
Year 3 Event No. 2 [b]	September 2023 – October 2023

Notes: [a] The CEC Year 3 study design was submitted to the Regional Water Board as part of the FY 23-24 Monitoring Workplan due May 1, 2023.
[b] Preliminary raw data and monitoring results will be provided to the Central Valley Water Board within 60 calendar days from the date of sample analysis.
[c] Sampling and monitoring results shall be submitted within 6 months from the date of sample analysis, in a format described in the approved Data Management Plan or QAPP, and the data must go through primary quality verification and corrective actions completed, if applicable.

Budget

Initial cost estimates for the CEC Pilot Study tasks and deliverables are estimated at $215,000 (**Table 4**). The budgeted amounts provided in this table are draft values that may be further refined after the submission of this Workplan. Further information regarding the FY 23-24 Delta RMP budget is provided in **Summary of Budgets**.

NUTRIENTS / HABS

For FY 23-24, the Delta RMP is continuing long-term planning for nutrients which includes Harmful Algal Blooms (HABs). The Steering Committee has provided direction to the Nutrient TAC to develop a multi-year study plan during the most recent Joint Steering Committee and Nutrient TAC meeting held on March 16, 2023. In addition to long-term planning, the Nutrient TAC will be working on reviewing and recommending for approval the USGS Cyanotoxin Study report.

USGS Cyanotoxin Study

The USGS Cyanotoxin Study was added to the FY 21-22 Workplan as an amendment approved by the BOD on January 24, 2022. Monitoring funded by the Delta RMP includes collecting samples at the Middle River station from March 2022 through February 2023. The study objectives and management questions are outlined in **Table 25**. Data will be available through the USGS tableau site. The final report is expected in FY 23-24.

Table 25. USGS Cyanotoxin study objectives and questions relevant to Delta RMP management questions.

CORE MANAGEMENT QUESTION	STUDY OBJECTIVES/QUESTIONS
Status & Trends Is there a problem or are there signs of a problem? a. Is water quality currently, or trending towards, adversely affecting beneficial uses of the Delta? b. Which constituents may be impairing beneficial uses in subregions of the Delta? c. Are trends similar or different across different subregions of the Delta?	**How do harmful algal blooms and cyanotoxin concentrations vary spatially and temporally year-round?** **How are ambient concentrations and trends in HABs and cyanotoxins affected by variability in water quality conditions, particularly nutrients?** Collect cyanotoxin data and associated phytoplankton and water quality variables year-round from MDM to complement sampling occurring at other Delta monitoring stations. Year-round data collection will enable a more comprehensive assessment of the variation of HABs and cyanotoxins and how they are impacted by water quality conditions, flow (i.e., drought) including nutrient concentration.

CORE MANAGEMENT QUESTION	STUDY OBJECTIVES/QUESTIONS
Sources, Pathways, Loadings, and Processes Which sources and processes are most important to understand and quantify? a. Which sources, pathways, loadings, and processes (e.g., transformations, bioaccumulation) contribute most to identified problems? b. What is the magnitude of each source and/or pathway (e.g., municipal wastewater, atmospheric deposition)? c. What are the magnitudes of internal sources and/or pathways (e.g., benthic flux) and sinks in the Delta?	**Which areas of the Delta are cyanotoxins produced and how are they transported? Which sources and levels of nutrients are more closely linked to HAB and toxin formation?** Provide online access to data and spatial and temporal trend plots of nutrient concentrations, associated water quality conditions, phytoplankton abundance and cyanotoxins for managers and scientists.
Forecasting scenarios a. How do ambient water quality conditions respond to different management scenarios b. What constituent loads can the Delta assimilate without impairment of beneficial uses? c. What is the likelihood that the Delta will be water quality-impaired in the future?	**Are cyanotoxin concentrations linked with nutrient concentrations, forms and ratios? How will changes to nutrient inputs to the Delta (e.g., WWTP upgrades) affect the development of HABs and cyanotoxins?** Improving understanding of linkages between environmental drivers (nutrients, flow, temperature) on HAB formation, initiation, and duration will assist modeling and targeted data analyses.
Effectiveness Tracking a. Are water quality conditions improving as a result of management actions such that beneficial uses will be met? b. Are loadings changing as a result of management actions?	Data collected by this study can be used to help determine whether cyanotoxins are at concentrations of concern in the Delta and will help managers develop future monitoring programs.

Long Term Planning

Management & Assessment Questions

As part of the long-term planning process, the Steering Committee and Nutrient TAC reviewed the management and assessment questions (**Table 26**) in relation to the Delta Nutrient Research Plan. The Steering Committee provided direction regarding the focus of monitoring for generally the next three to five years.

Table 26. Delta RMP management and assessment questions for nutrients (revised May 30, 2018).

TYPE	CORE MANAGEMENT QUESTIONS	NUTRIENTS
Status & Trends	Is there a problem or are there signs of a problem? Is water quality currently, or trending towards, adversely affecting beneficial uses of the Delta? Which constituents may be impairing beneficial uses in subregions of the Delta? Are trends similar or different across different subregions of the Delta?	How do concentrations of nutrients (and nutrient-associated parameters) vary spatially and temporally? Are trends similar or different across subregions of the Delta? How are ambient levels and trends affected by variability in climate, hydrology, and ecology? Are there important data gaps associated with particular water bodies within the Delta subregions?
Sources, Pathways, Loadings & Processes	Which sources and processes are most important to understand and quantify? Which sources, pathways, loadings, and processes (e.g., transformations, bioaccumulation) contribute most to identified problems? What is the magnitude of each source and/or pathway (e.g., municipal wastewater, atmospheric deposition)? What are the magnitudes of internal sources and/or pathways (e.g., benthic flux) and sinks in the Delta?	Which sources, pathways, and processes contribute most to observed levels of nutrients? How have nutrient or nutrient-related source controls and water management actions changed ambient levels of nutrients and nutrient-associated parameters? What are the loads from tributaries to the Delta? What are the sources and loads of nutrients within the Delta? What role do internal sources play in influencing observed nutrient levels? What are the types and sources of nutrient sinks within the Delta? 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? 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? Which factors in the Delta influence the effects of nutrients on the water quality concerns listed above?

Type	Core Management Questions	Nutrients
Forecasting Scenarios	How do ambient water quality conditions respond to different management scenarios? What constituent loads can the Delta assimilate without impairment of beneficial uses? What is the likelihood that the Delta will be water quality-impaired in the future?	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?
Effectiveness Tracking	Are water quality conditions improving as a result of management actions such that beneficial uses will be met? Are loadings changing as a result of management actions?	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?

Long Term Planning Strategy & Milestones

Planning for a multi-year nutrient study design began in January and February 2022. As outlined in **Figure 3**, a general approach was developed for long-term planning. The Steering Committee and Nutrient TAC have customized this approach for nutrients/HABs, and the Steering Committee provided direction in March 2023 to the Nutrient TAC to develop a multi-year study design. The Nutrient TAC will continue to meet throughout 2023 to develop a multi-year study plan.

The FY 22-23 Workplan included milestones and deliverables for the nutrient long-term planning strategy. All milestones and deliverables have been met except for the study plan development which is planned for 2023. It is anticipated that the multi-year Nutrient Study Plan will be completed by December 2023. Below is a recap of the activities that have occurred to date as part of the long-term planning process.

To narrow the focus of the nutrient/HAB long-term planning, a Nutrient Symposium was held on September 27, 2022 with the goals of informing upcoming Delta RMP long-term nutrient planning efforts, informing Delta RMP stakeholders on recent nutrient activities in the Delta including an assessment of data gaps and an evaluation of management questions, and improving understanding of management activities associated with water quality problems identified in the Delta Nutrient Research Plan. In preparation of Day 2 of the Nutrient Symposium, the Nutrient TAC developed a report out of Day 1 with the key takeaways from the symposium provided as a summary of Delta RMP funded research (What do we know?), data gaps (What do we need to know about nutrients in the Delta?), and next steps (What can we get in the next 3-5 years from the research, special studies, and/or modeling?). As part of the summary of next steps, a table of 19 study questions was created associating Core Management and Assessment questions to more specific study questions with research methods and information gained. Day 2 of the Nutrient Symposium was held on November 30, 2022, and additional discussion occurred at the Steering Committee meeting held on December 15, 2022. Based on the feedback from the Steering Committee regarding priorities, the Nutrient TAC narrowed down the 19 potential study plan questions into two study plan questions; a third study plan question was added based on continued discussion at the Joint Steering Committee and Nutrient TAC meeting held on March 16, 2023.

The Nutrient Study Plan questions revolve around three priority focus areas: 1) management of nutrient concentrations, 2) understanding the ecological effects of nutrient reductions, and 3) status and trends of harmful cyanobacteria blooms with a primary question under each priority area. The primary questions have been adjusted based on feedback from the Steering Committee and are associated with options for research methods and tied to information gained. The specifics associated with each focus area are still being developed as part of the multi-year Nutrient Study Plan development process; the language associated with the research method and information gained for each focus area may be adjusted during this process.

Focus Area 1: Capability to Predict Nutrient Concentrations

Primary Question: Following a reduction in nutrient loading from different point and non-point 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?

Research Method: Use a hydrodynamic biogeochemical model to estimate N and P concentrations (and their ratios) in different regions of the Delta under multiple nutrient management scenarios. Evaluate how differing river discharges (precipitation and reservoir releases), and water management operations (export pumping, Delta Cross Channel Gate closures, and Suisun Marsh Salinity Control Gates tidal closures), might affect nutrient concentrations (N and P, and their ratios) throughout different regions of the Delta. Create maps of predicted ranges in nutrient concentrations under reduced nutrient loading from river inflows and potentially internal sources.

Information Gained: Modeling the level of nutrient reduction that could be achieved by reducing nutrient loading from river tributaries would help identify the minimum feasible nutrient concentrations in the Delta and quantify the effort required to establish and maintain low nutrient concentrations.

Reductions in nutrient loading from different sources would have differing effects throughout the Delta, due to hydrodynamics and biogeochemical processes. Therefore, it is helpful to model how reductions in nutrient loading from particular sources, or a combination of sources, could affect nutrient concentrations in specific regions of interest (such as regions where Harmful Algal Blooms (HABs) are common). It is also important to understand how changes in water operations can change water flows and possibly the distribution of nutrient concentrations and biogeochemical processing.

Focus Area 2: Understanding the Ecological Effects of Nutrient Reductions

Primary 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?

Research Method: Many research options could inform this question.
Perform a literature review of previous research investigating reductions of nitrogen, phosphate, and the N:P ratio in controlling the growth, biomass, and distribution of harmful cyanobacteria, nuisance aquatic plants, and beneficial phytoplankton. What phytoplankton and aquatic plant species inhabit other estuaries following significant nutrient reductions? At low nutrient concentrations, would phytoplankton and aquatic plant growth be affected differently by water temperature, turbidity, water depth, tidal flows, stratification, nutrient cycling, and invertebrate grazing?
Testing nutrient thresholds for cyanobacteria, phytoplankton, taste and odor, and aquatic plant growth and biomass in replicated mesocosms. Methods to reduce initial nutrient concentrations might include diluting Delta surface water with low nutrient (filtered) water and adding back nutrients and major ions to experimental concentrations, creating laboratory culture water at specific nutrient concentrations, or allowing biological nutrient drawdown to occur before starting experiments to test low nutrient loading. Many important factors need to be controlled and potentially used as variables in mesocosm experiments, such as initial nutrient concentrations, nutrient loading rates, light levels, temperature, water mixing, sediment volume and properties, DO, pH, salinity, POC, starting species composition and biomass (pelagic, epiphytic, and periphytic phytoplankton and cyanobacteria and aquatic plants), species and biomass of invertebrate grazers, river conditions occurring prior to sample collection, experimental duration, and sampling frequency.
Trends in growth and biomass of phytoplankton, cyanobacteria, and aquatic plant communities can be monitored along nutrient gradients in the Delta that decline to low levels, such as those occurring in terminal sloughs. Monitoring studies should collect data on factors affecting phytoplankton growth, such as water velocity and mixing, water depth and light, turbidity, salinity, pH, DO, invertebrate grazing pressure, aquatic weed

control programs, connectivity to other waterways, and local nutrient inputs (groundwater and island discharge).

Information Gained: Nutrient concentrations in most major Delta channels were replete during past studies, so ecological responses to low nutrient concentrations in the Delta are not well understood. The reduction of concentration and loading rate of nutrients necessary to prevent cyanobacteria and aquatic plants from growing to harmful concentrations in the Delta has not been determined. Correlations between HABs and nutrient concentrations are of limited use because cyanobacteria populations may persist by recycling nutrients when concentrations are low and HABs do not form in all regions of the Delta where nutrient concentrations are high, likely due to suppression by other physical or biological factors. A literature review would be informative but should be focused on the outcomes of nutrient reduction programs in other estuaries, as lakes and rivers that are naturally oligotrophic are unlikely to represent the processes occurring in managed and highly urbanized estuary systems.

Mesocosm experiments that control nutrient concentrations and other physical factors can be useful in evaluating phytoplankton and aquatic plant growth and other ecological interactions at low nutrient concentrations. These experiments can be initiated with water samples collected from the Delta to help identify species that are competitively dominant at low nutrient concentrations (N, P, or their ratios). Mesocosms can also be used to estimate the biomass of desirable phytoplankton produced at low nutrient concentrations and/or other scenarios that may not currently occur.

Some terminal channels in the Delta have been shown to have gradients in nutrient concentrations, with low concentrations present at their distal ends. Monitoring phytoplankton species occurring at different nutrient concentrations within these sloughs may help identify species expected to occur elsewhere at reduced nutrient loads. However, due to the lack of tidal flows through the distal end of these habitats, they might be dominated by phytoplankton that inhabit lentic (non-flowing) waters, which would not represent the majority of the Delta.

Focus Area 3: Status and Trends of Harmful Cyanobacteria Blooms

Primary Question: 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?

Research Method: Monitor cyanobacteria blooms and toxins by collaborating with or augmenting other data collection efforts or funding future Supplemental Environmental Project (SEP) studies. 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 chlorophyll-a, phytoplankton community composition, and genetic analyses for cyanotoxin production potential. Ideally, factors potentially affecting HAB blooms should be measured concurrently during sample collection or obtained in parallel, such as water temperature, salinity, depth, light availability, turbidity, water column mixing and flows, dissolved oxygen, pH, and nutrient concentrations.

Information Gained: 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 or sites to studies led by others (e.g., passive sampler media deployment by USGS).

Long Term Planning Schedule

In FY 23-24, the Nutrient TAC will develop a multi-year Nutrient Study Plan based on direction received from the Steering Committee in early 2023. The Nutrient TAC will come up with a timeline for study plan development to present to the Steering Committee and agree upon the timeline for developing and implementing the study plan. It is anticipated that the study plan will be completed in December 2023 and implemented in FY 24-25. The Nutrient TAC will work with the Steering Committee to report on progress and continue to get feedback and direction. The study design will include all the required elements of Resolution R5-2021-0054 including hypothesis testing.

Budget

The FY 23-24 budget for nutrients is includes time for planning and preparing for TAC meetings (including joint meetings with the Steering Committee), and time to prepare the multi-year Nutrient Study Plan and associated quality assurance documentation in anticipation for inclusion in the FY 24-25 Monitoring Workplan. There is also a budget set aside in case the Delta RMP decides to hire an additional nutrient expert to assist with the development of the Nutrient Study Plan. The cost estimate for Nutrients is $105,000 (**Table 4**).

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 Delta RMP 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 by the Delta RMP from 2016 – 2022 and evaluate trends in aqueous and fish tissue mercury concentrations since 2000 in the context of water year type and subarea. The final report will be posted on the Delta RMP's website. The timeline for developing the Mercury Report is contingent on a SWRCB contract amendment with San Francisco Estuary Institute – Aquatic Sciences Center (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. It is anticipated that the contract amendment will be executed in November / December 2023. The contract will be executed through the SWRCB. The SFEI-ASC contract includes a timeline that is relative to the execution date. The Delta RMP would develop a specific timeline once the contract is executed to ensure that deliverables are completed within the timeframes outlined in the contract language. This will require coordination between schedules of SFEI-ASC, Steering Committee, and Mercury TAC members.

Joint Mercury TAC 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 Delta RMP mercury monitoring study was completed in FY 22-23. Data collected in FY 22-23 will be incorporated into the Mercury Report.

Final Data in CEDEN

Mercury sample collection and data processing for FY 22-23 (and all other data collected as part of the FY 21-22 Workplan) was funded by CVRWQCB SWAMP funds through a SWRCB contract and data are managed directly by the SWRCB SWAMP. Interim data deliverable deadlines are therefore not managed or controlled by the Delta RMP data managers. Fish tissue and water chemistry analysis data are submitted directly to SWRCB staff, where they are reviewed and verified according to the SWAMP requirements. Delta RMP staff coordinate with SWCRB data managers to ensure that Delta RMP stakeholders and participants are notified once data have been finalized and published to CEDEN. It is expected that SWRCB SWAMP will have Delta RMP mercury data finalized by July 1, 2023. Therefore, there are no expected data deliverables in FY 23-24.

Data Report and QC Report

The Mercury Report will be developed by SFEI-ASC. The Mercury Report will integrate all Delta RMP mercury data and include an assessment of precision, accuracy, and completeness of the data being evaluated including results from FY 22-23. There will not be a separate Data Report or QC Report developed.

FY Annual Report

The Delta RMP Annual Report for the previous FY is due on February 1 of each year. Information and data generated during the fall 2022 event, which occurred during FY 22-23, will be addressed in the FY Annual Report due February 1, 2024.

Long Term Planning

The mercury long term planning strategy will be implemented similarly to the nutrient long-term monitoring strategy. The Delta RMP 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 Delta RMP mercury monitoring priorities and other policies including the Mercury total maximum daily load (TMDL).

Long Term Planning & Milestones

The long-term planning for mercury in FY 23-24 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 Delta RMP stakeholders on the trends of aqueous and fish methylmercury concentrations in the Delta. A draft of the Mercury Report is anticipated in April 2024 but is contingent on the execution data 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. The CVRWQCB will host meetings to discuss proposed findings and modifications in fall of 2023. Phase 2 of the DMCP began in late 2022 as required by the Methylmercury TMDL. Both the DMCP Review Draft Staff Report and the Delta RMP Mercury Report will inform the mercury monitoring priorities of the Delta RMP. 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 27**).

The Steering Committee and Mercury TAC will meet to discuss the initial focus of the mercury long-term planning (October) and determine the objectives of the Mercury Symposium (**Table 27). Figure 10** 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, if the Mercury Report work cannot begin until December 2023, there may be delays in the mercury planning process since 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.

Table 27. Mercury long-term planning activities and milestones (tentative). The milestone time periods are approximate due to their dependency on the DMCP Staff Report and the Mercury Interpretive Report.

General Planning Steps	FY 23-24 Activities	FY 23 -24 Milestones	Milestone Time Period
Identify the focus	Review mercury management and assessment questions	Identify Focus of Mercury Long-Term Planning Objectives for Mercury Symposium	Within 3 months of the DMCP Staff Report Within 3 months of identifying the focus of the Mercury Long-Term Planning
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	August – October 2023 7 months after contract amendment date Within 6 months of identifying the Mercury Symposium objectives
Prioritize Management & Assessment Questions	Not Applicable	Not Applicable	FY 24-25
Decide how much to budget	Not Applicable	Not Applicable	FY 24-25
Provide direction to the TAC	Not Applicable	Not Applicable	FY 24-25
Develop a multi-year study design	Not Applicable	Not Applicable	FY 25-26

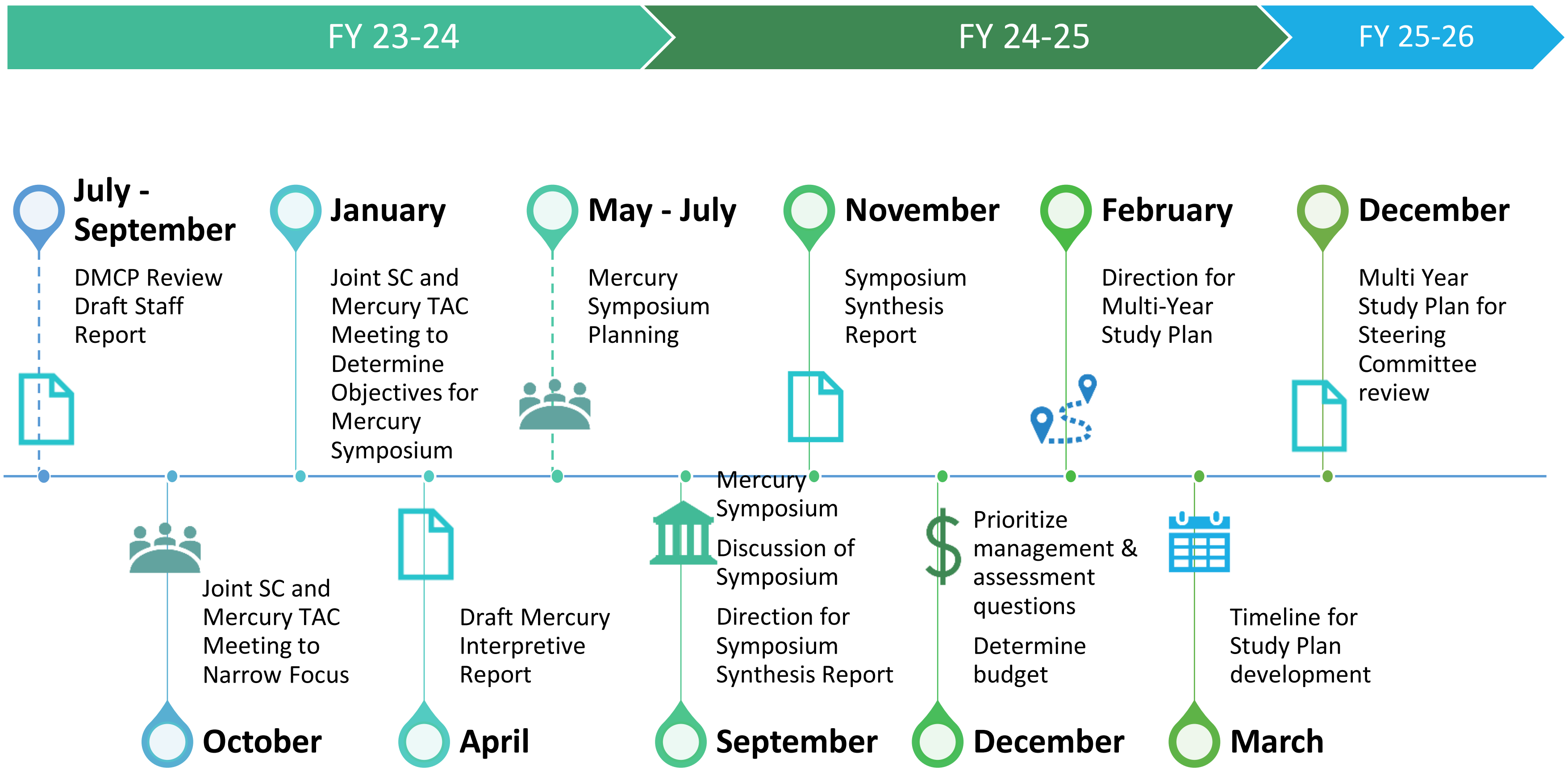
Long Term Planning Schedule

The Delta RMP will be working on mercury long-term planning during 2024 with the goal of having direction to the Mercury TAC to develop a study plan in February 2025 (**Figure 10**). The Delta RMP will begin planning for mercury using lessons learned from the nutrient long term planning strategy. A Joint Steering Committee and Mercury TAC meeting will be scheduled in January 2024 to determine the objectives of the Mercury Symposium (planned for September 2024). Future milestones for FY 23-24 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 June 2024 (**Figure 10**).

Budget

The FY 23-24 budget for mercury is estimated at $115,000 (**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 23-24 budget but will be included in the final budget to be submitted on June 30, 2023.

Figure 10. Steering Committee and Mercury TAC long-term planning activities (FY 23-24, FY 24-25, and FY 25-26). 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.



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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

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.

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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.)

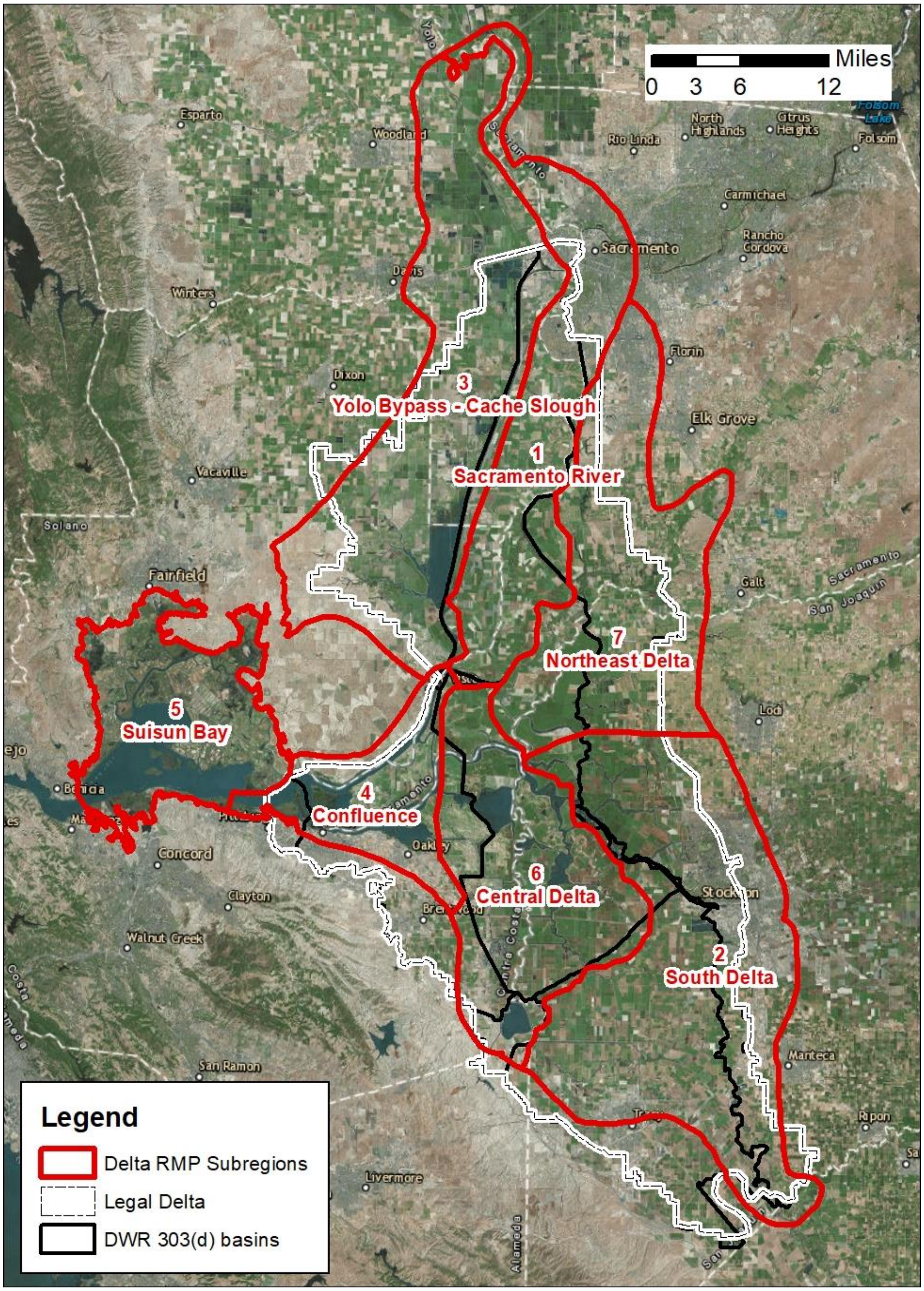

Figure 1 Map of Delta RMP subregions

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.

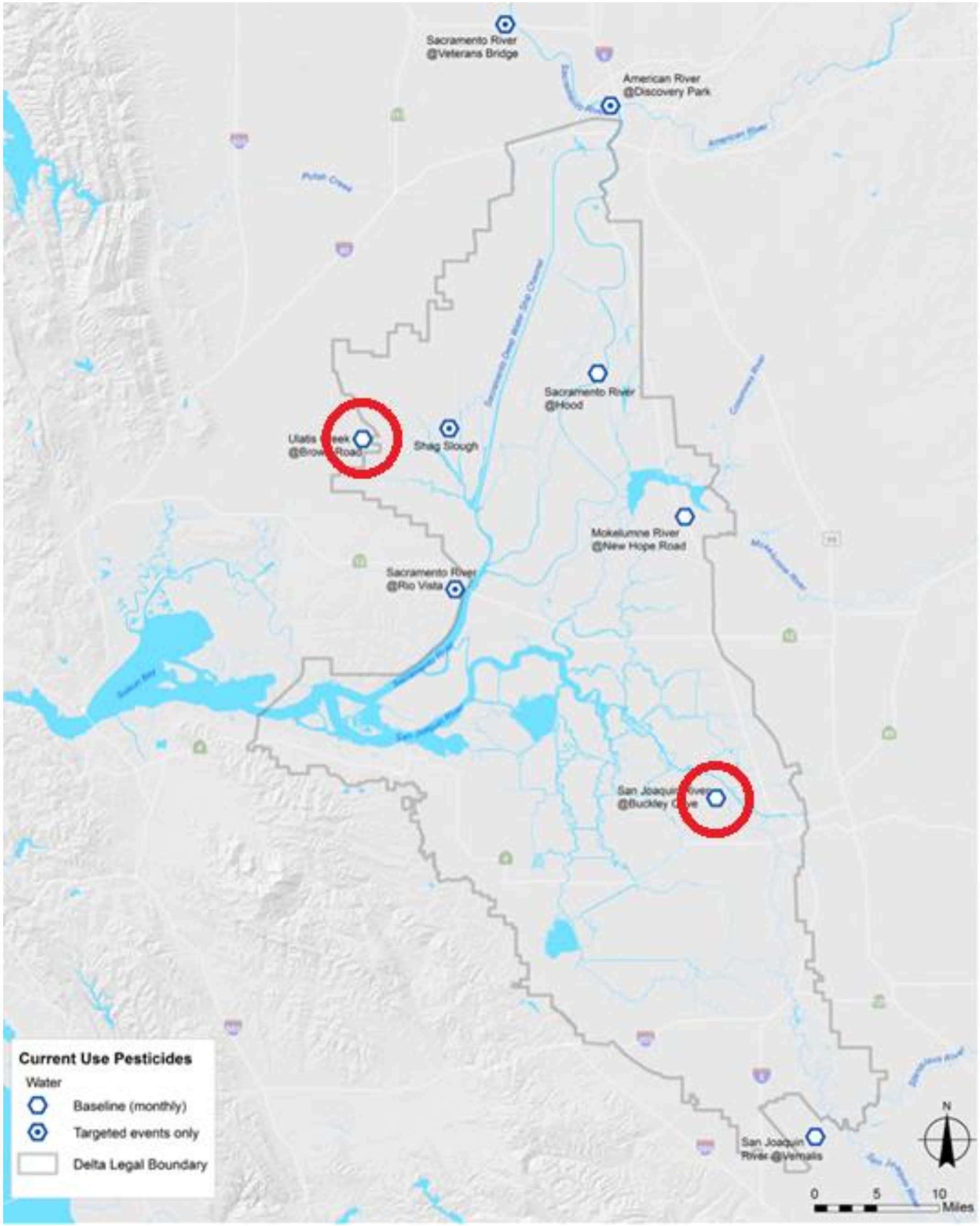

Figure 2 Map of Delta RMP integrator sites monitored 2015-2017, highlighting the two fixed stations where continued monitoring is proposed.

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.

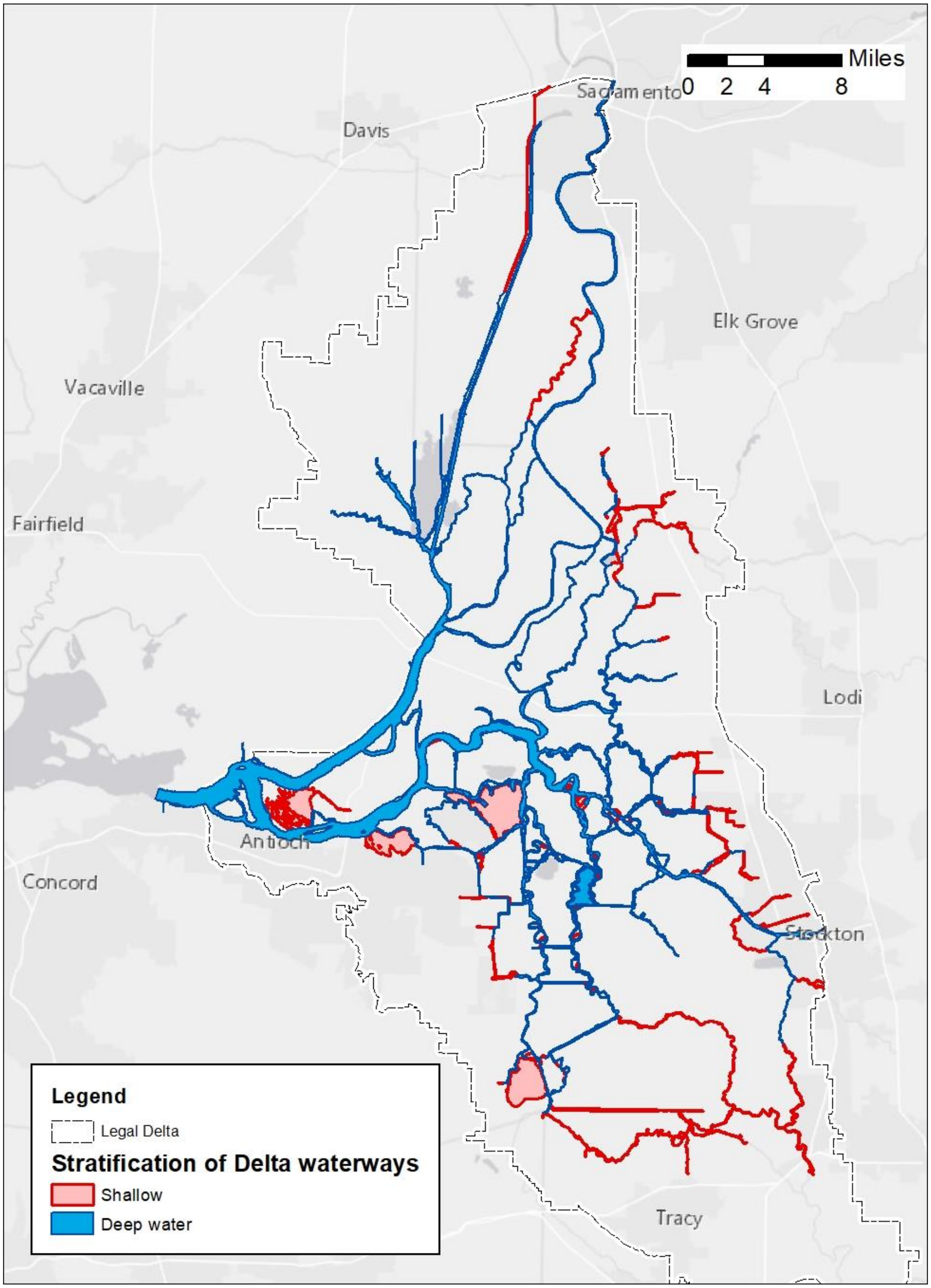

Figure 3 Stratification of Delta waterways into shallow and deep water (>2m)

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.

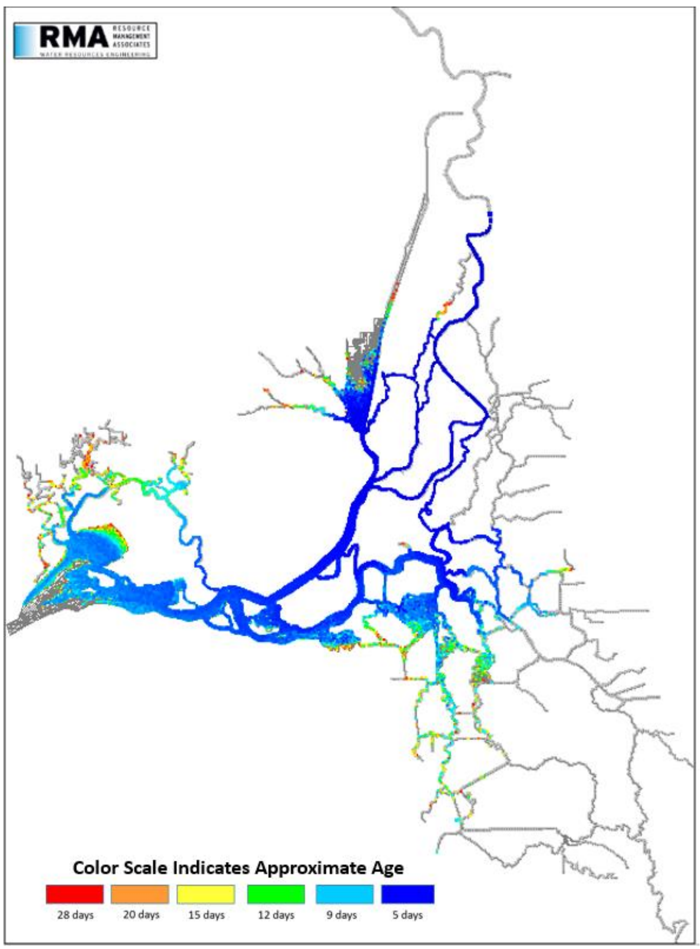

Figure 4 Example fate and age/exposure time map produced by RMA for the Delta RMP 2018 nutrients modeling study.

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.

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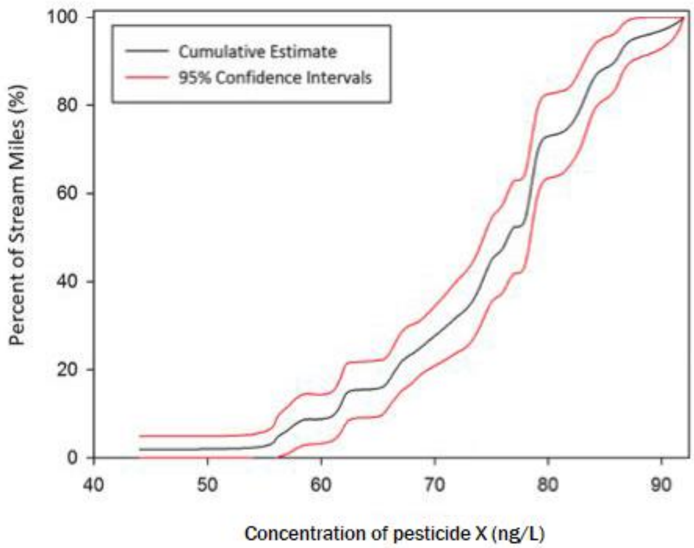
[4] Note however that under the "independent applicability policy" in water quality regulation, the cause of toxicity does not need to be demonstrated in order for regulators to list a water body as impaired. The toxicity water quality objective is a separate standard. However, it is desirable to determine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



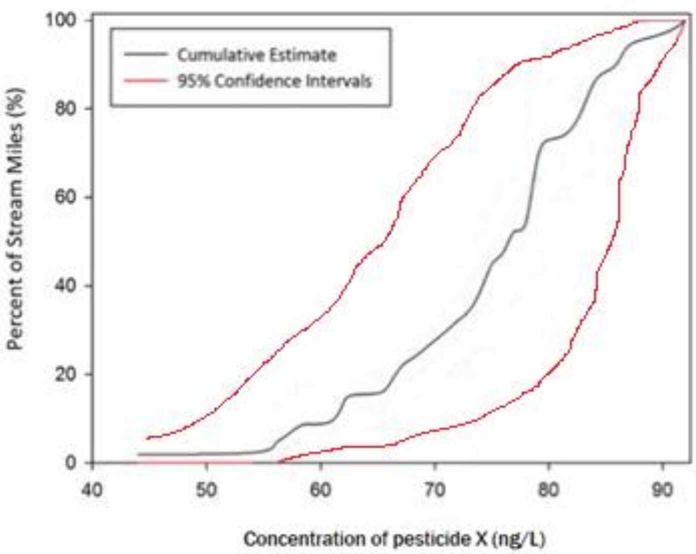


Figure 5 Hypothetical cumulative distribution functions for pesticide concentration in a Delta subregion.

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

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[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.

1	Hladik, M.L., Smalling, K.L., and Kuivila, K.M., 2009, Methods of analysis—Determination of pyrethroid insecticides in water and sediment using gas chromatography/mass spectrometry: U.S. Geological Survey Techniques and Methods 5–C2, 18 p. https://pubs.usgs.gov/tm/tm5c2/tm5c2.pdf
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/.
OFR-92-480	Brenton, R.W., Arnett, T.L. 1993. Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory--Determination of dissolved organic carbon by UV-promoted persulfate oxidation and infrared spectrometry: U.S. Geological Survey Open-File Report 92-480, 12 p. https://nwql.usgs.gov/rpt.shtml?OFR-92-480
SM […]	Rice, E.W., R.B. Baird, A.D. Eaton, and L.S. Clesceri. *Standard Methods for the Examination of Water and Wastewater*. Water Environmental Federation, American Water Works Association, American Public Health Association, 2005. https://www.standardmethods.org/

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).

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[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

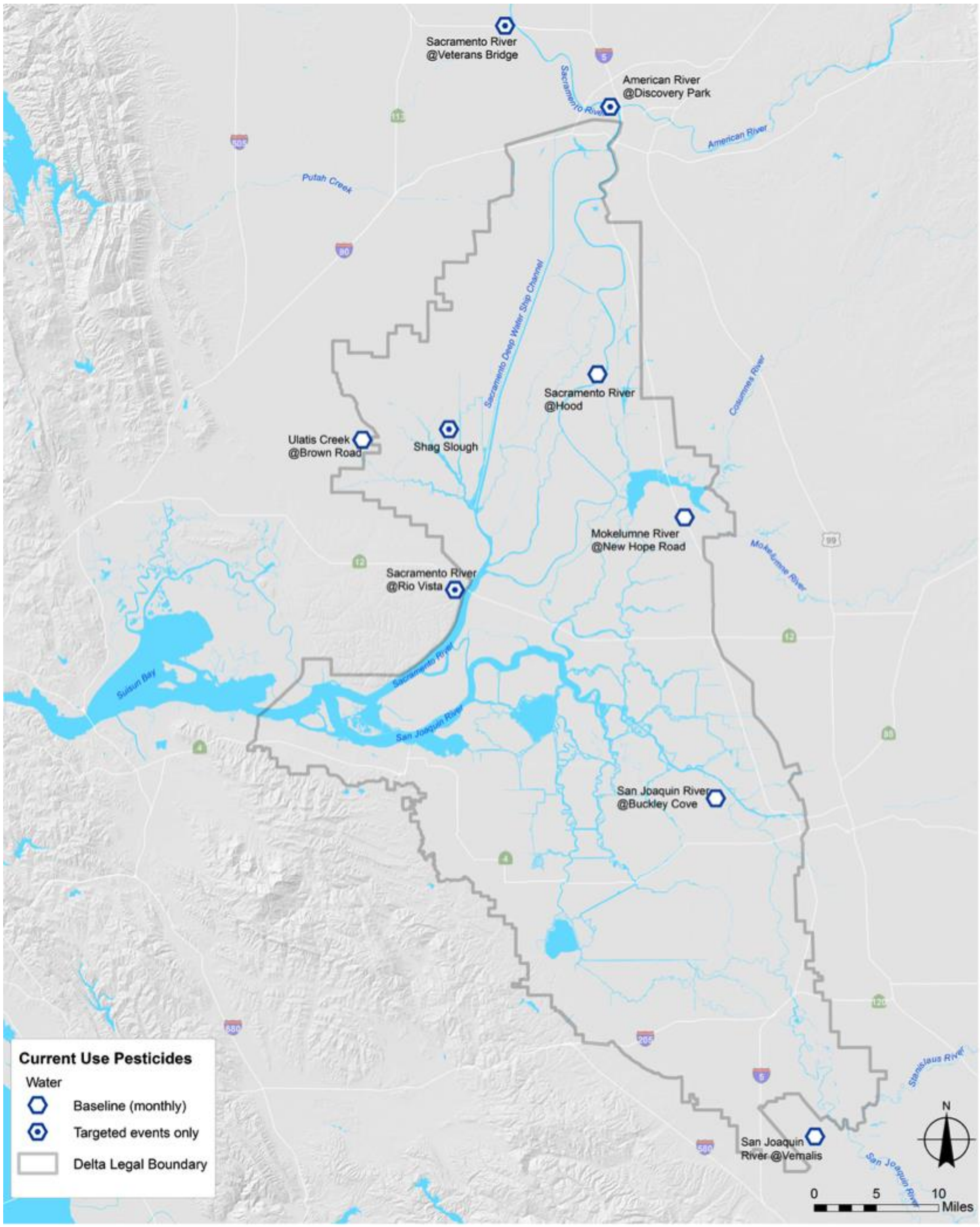


Figure 1. Map of Delta RMP integrator sites for pesticides sampling

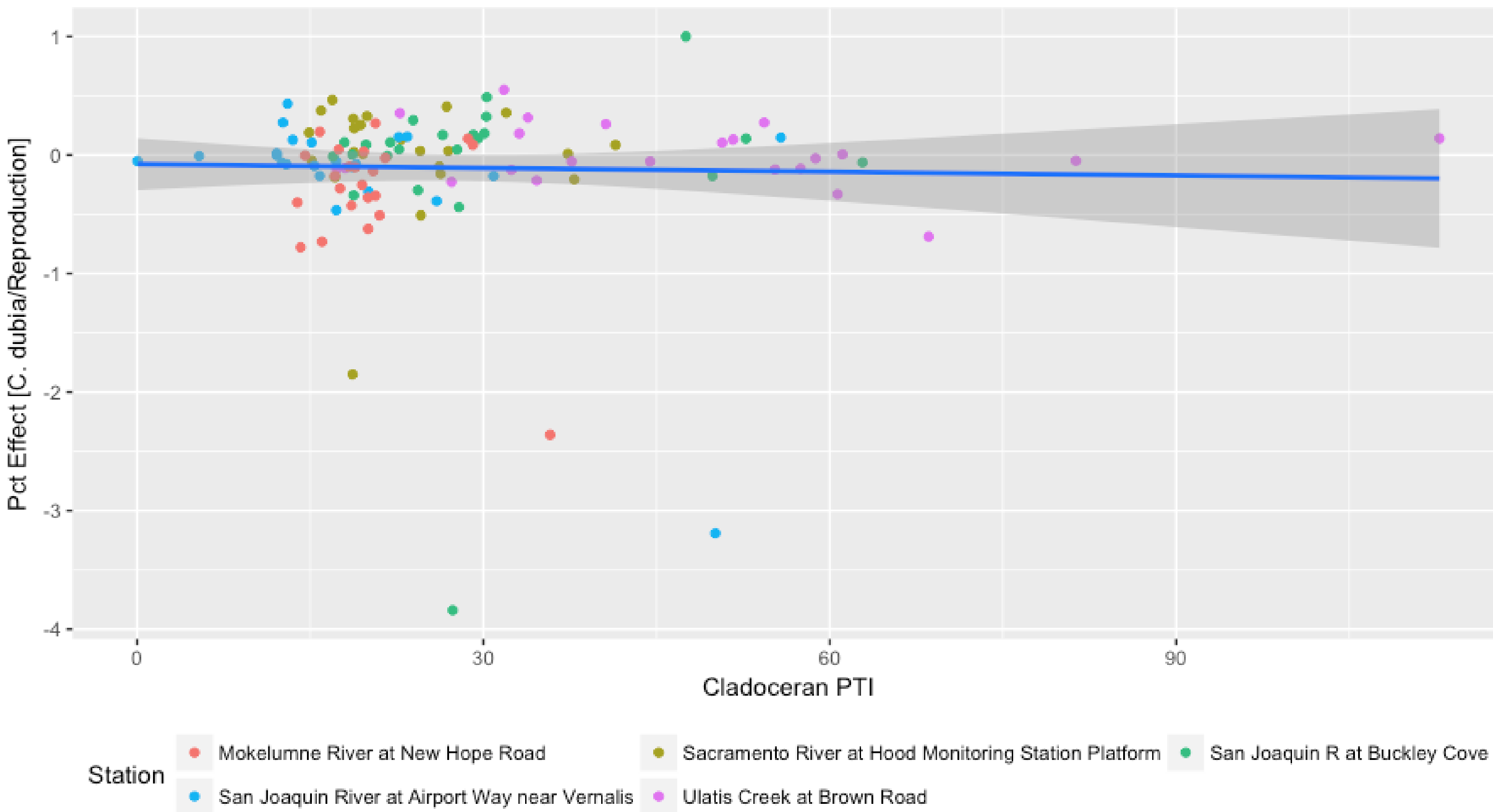


Figure 2. Pesticide Toxicity Index (PTI, Cladoceran) plotted against Percent Toxic Effect in *Ceriodaphnia dubia* / Reproduction test. Colors designate each site. The trend line indicates there is no clear relationship between the two variables.

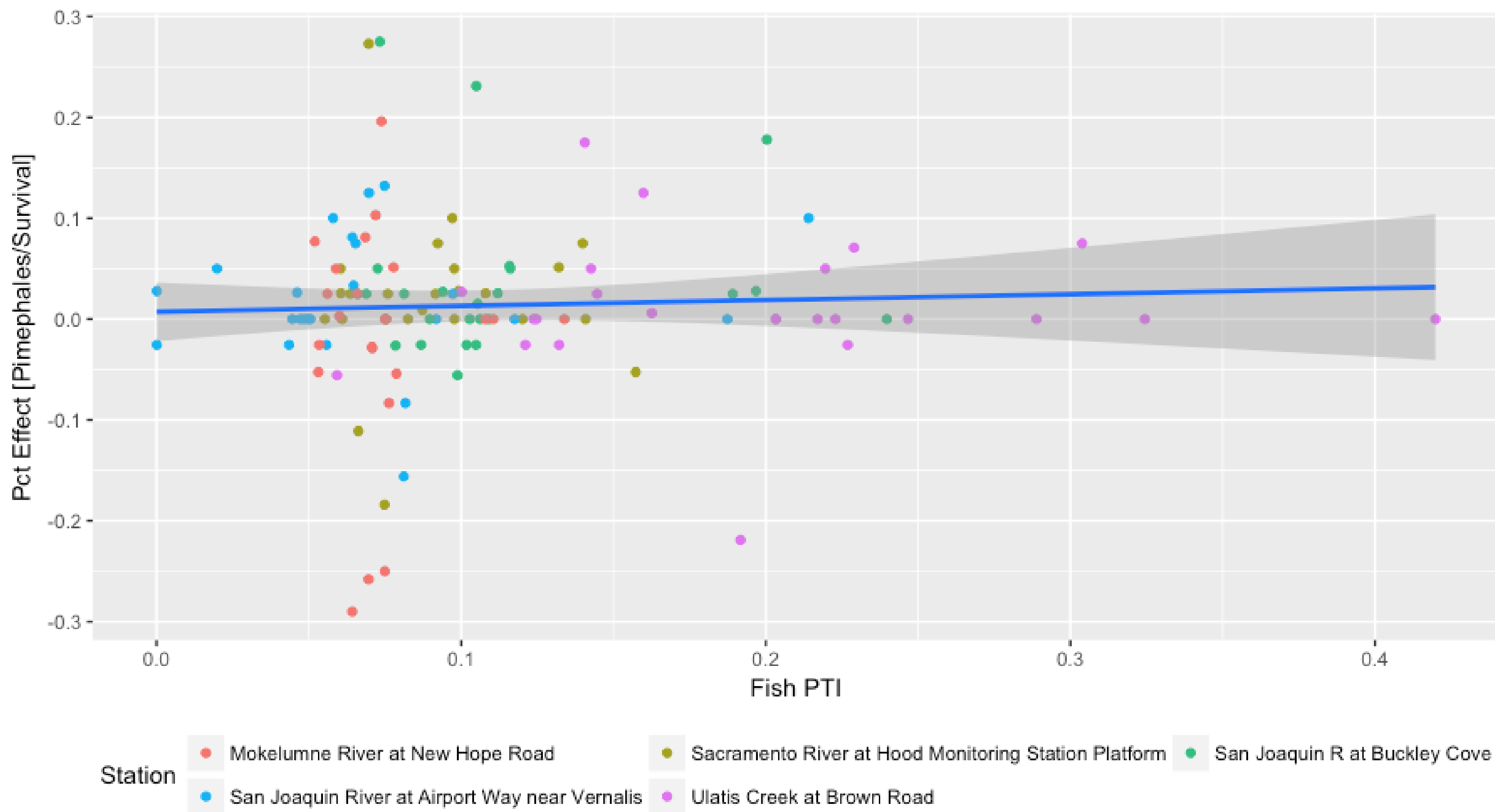


Figure 3. Pesticide Toxicity Index (PTI, Fish) plotted against Percent Toxic Effect in *Pimephales promelas* / Survival test. Colors designate each site. The trend line indicates there is no clear relationship between the two variables.

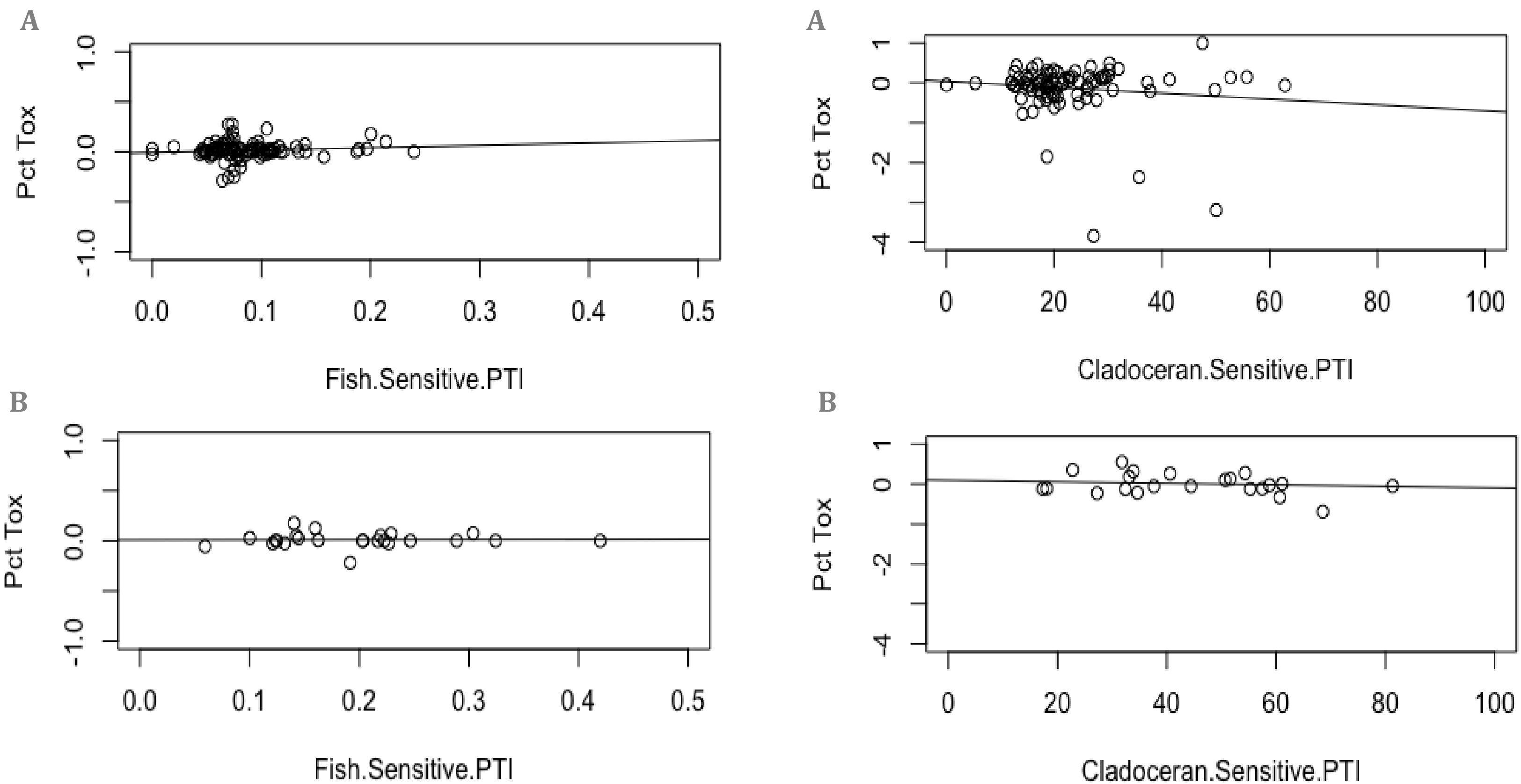


Figure 4. Pesticide Toxicity Index (PTI) plotted against Percent Toxic Effect for scenario A and B. Fish PTI data were plotted against *Pimephales promelas* / Survival test (left plots) and Cladoceran PTI were plotted against *Ceriodaphnia dubia* / Reproduction test (right plots). The trend line close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

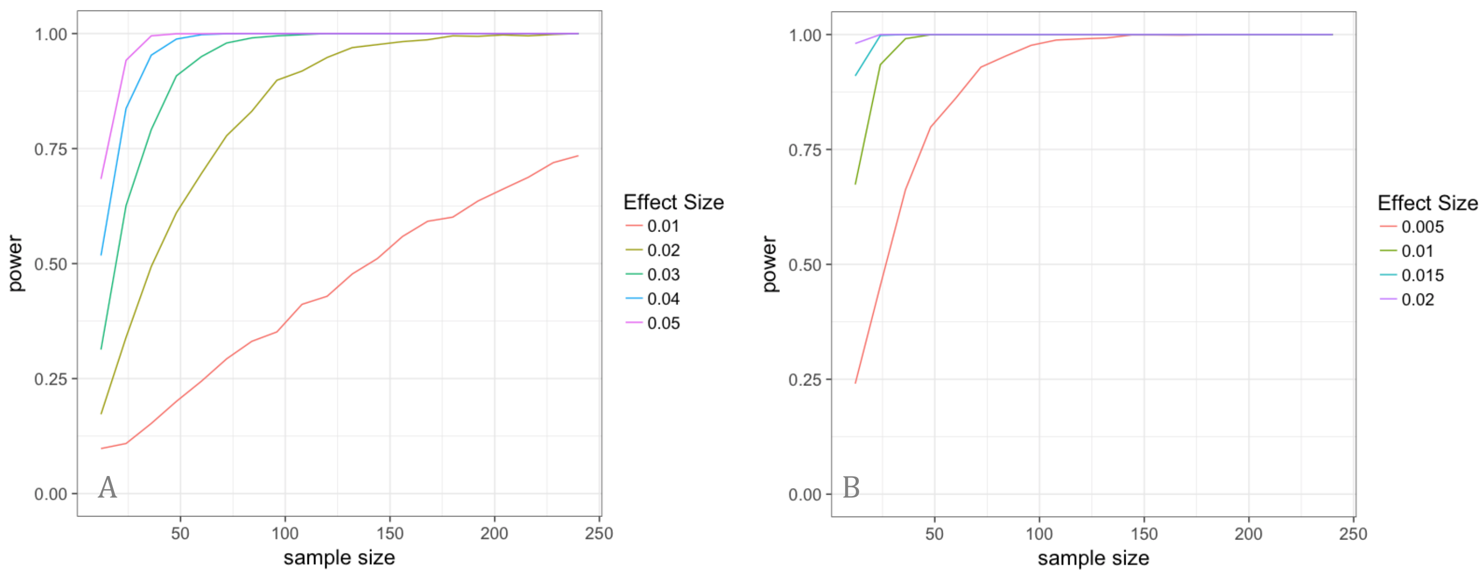
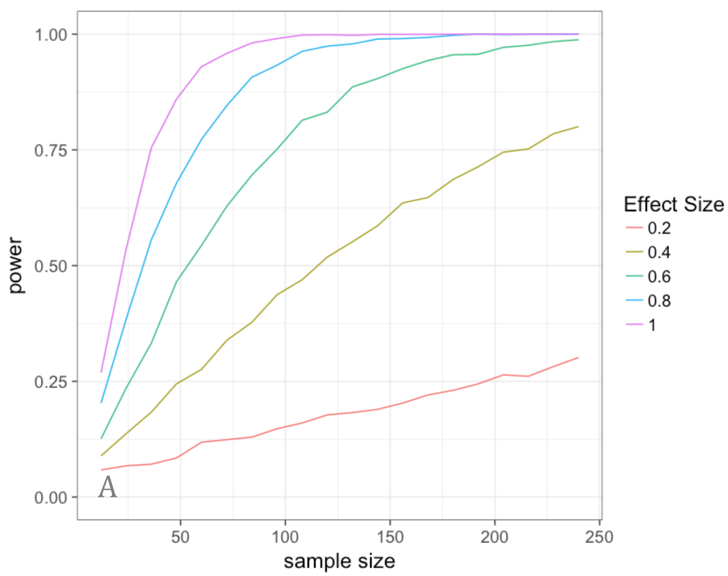


Figure 5. Power curve for scenarios A (left) and B (right) based on Cladoceran Sensitive PTI vs. *Ceriodaphnia* toxicity



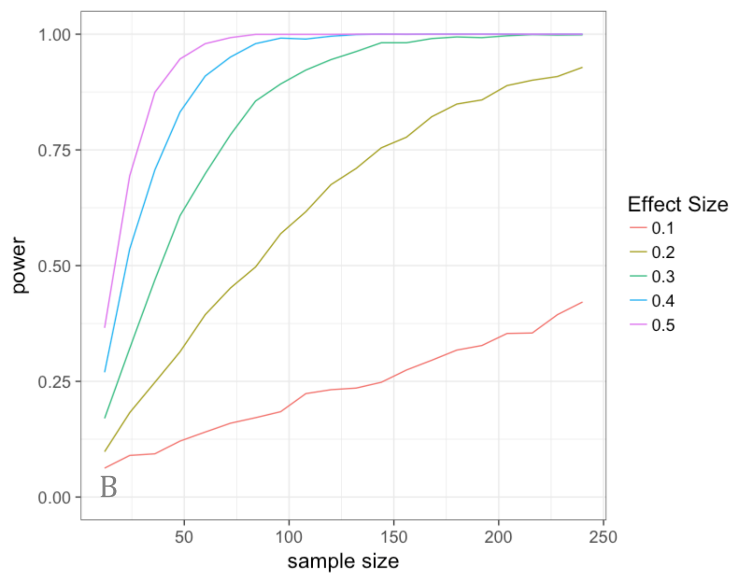


Figure 6. Power curve for scenarios A (left) and B (right) based on Fish Sensitive PTI vs. *Pimephales* toxicity

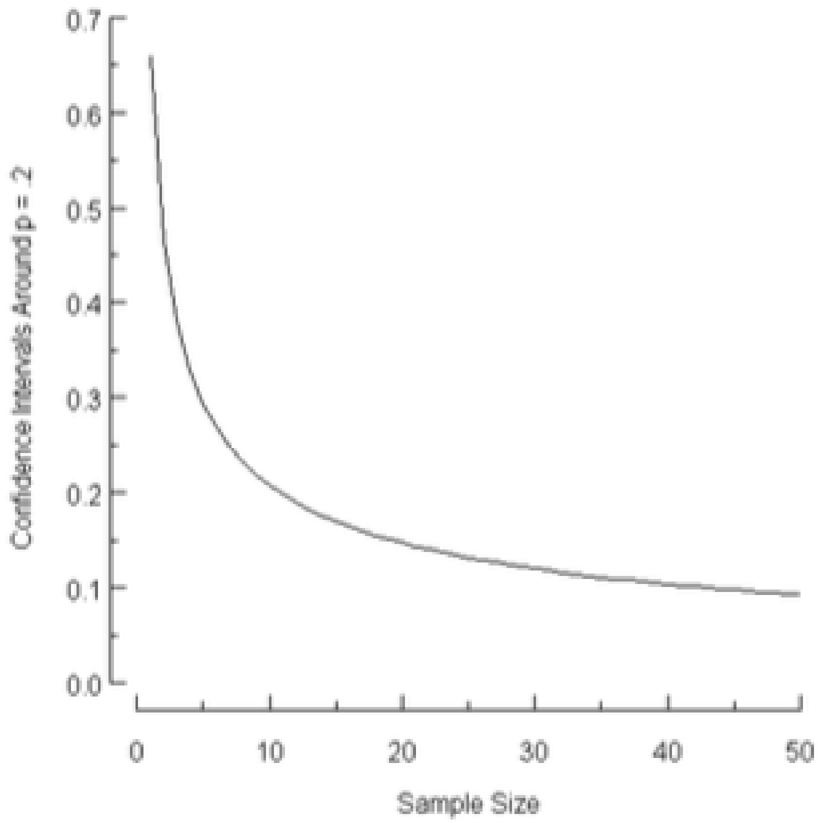


Figure 7. Sample size and size of confidence interval for a binomial distribution (p = 0.2)

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).

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[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.

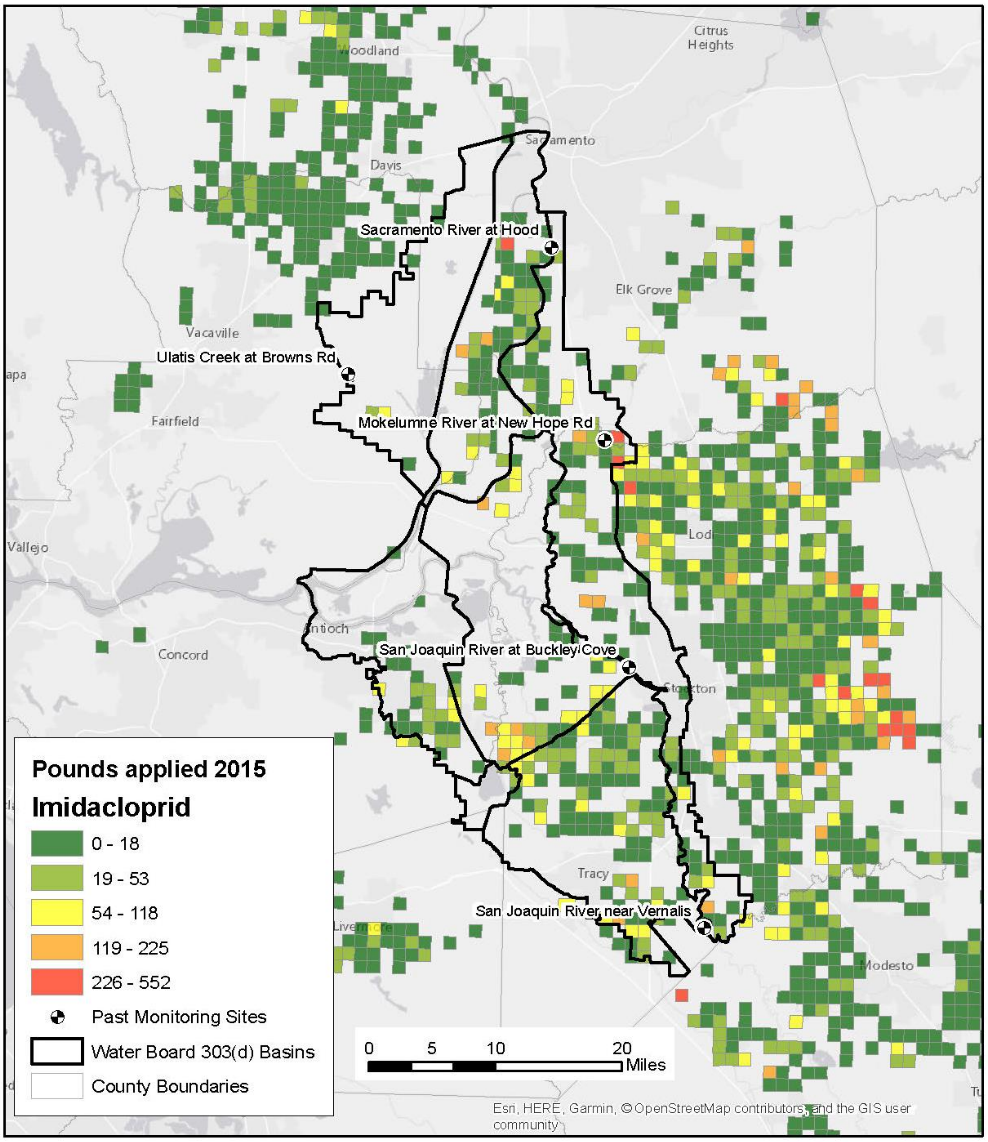

Figure 1 Application of imidacloprid near the Delta in 2015. Map by SFEI-ASC using data from DPR's pesticide use reporting database, http://www.cdpr.ca.gov/docs/pur/purmain.htm

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

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[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 – Central Valley CEC Pilot Study Work Plan

REVISED
JULY 2, 2018

Central Valley Pilot Study for Monitoring Constituents of Emerging Concern (CECs) Work Plan

Prepared by:

Larry Walker Associates for the Central Valley Clean Water Association, Sacramento County Regional Sanitation District, Sacramento Stormwater Quality Partnership, and City of Stockton – San Joaquin County Stormwater Partnership

In consultation with:

Other participating agencies including the City of Vacaville, City of Roseville, Central Valley Regional Water Quality Control Board, and State Water Resources Control Board

1 Introduction

At the request of the Central Valley Regional Water Quality Control Board (Central Valley Water Board) and the State Water Resources Control Board (State Water Board), the Central Valley Clean Water Association (CVCWA) and several[1] Central Valley Municipal Separate Storm Sewer System (MS4) representatives (collectively "Stakeholders") developed this Pilot Study for Monitoring Constituents of Emerging Concern (CECs) Work Plan (Work Plan), to be implemented through the Delta Regional Monitoring Program (Delta RMP), to monitor CECs in the Central Valley on a pilot basis, primarily in and around the Sacramento-San Joaquin Delta (Delta). If this Work Plan is not implemented through the Delta RMP, revisions would be necessary.

This Work Plan has been developed to address the targeted CEC study elements as described in the CECs Statewide Pilot Study Monitoring Plan developed by the State Water Board (2016 Statewide Monitoring Plan)[2]. The 2016 Statewide Monitoring Plan was created as part of a statewide effort to address CEC monitoring needs in reaction to public interest in this topic and employs a beneficial use protection assessment approach. CEC monitoring has already been implemented differently in several regions through regional monitoring programs, Surface Water Ambient Monitoring Program (SWAMP) funding, and individual discharger funded programs.

In addition to requests from the State Water Board and the Central Valley Water Board, the development and implementation of a pilot CEC monitoring program in the Delta will also address one of the Delta Stewardship Council's Priority Science Actions recommended in the 2017 Science Action Agenda of the Delta Stewardship Council[3].

A suggested list of CECs is described in the 2016 Statewide Monitoring Plan. This Work Plan has been adapted for the Central Valley to address most of the key CECs identified by the State Water Board. Exceptions include those CECs that are currently monitored in the Central Valley under separate programs or regulations, including a number of current-use pesticides, among them pyrethroids.

The State Water Board, Central Valley Water Board, and other California Regional Water Quality Control Boards convened a workshop on May 1 and 2, 2017 to share information regarding CEC monitoring completed to date in other regions in the State. Information presented and discussed at this workshop aided in the development of this Work Plan.

While the analytical methods necessary for this Work Plan can be performed by research laboratories and a select few commercial laboratories, any data collected in the program should

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[1] Approximately nine (9) out of a total of 143 MS4 agencies voluntarily participated in the Work Plan development that is intended to satisfy the Central Valley region-wide effort.

[2] Dawitt Tadesse, Office of Information Management and Analysis, State Water Resources Control Board. "Statewide Monitoring Plan. Constituents of Emerging Concern (CECs) Statewide Pilot Study Monitoring Plan." January 2016. https://www.waterboards.ca.gov/water_issues/programs/swamp/cec_aquatic/docs/oima_sw_cec_mon_plan.pdf

[3] Delta Stewardship Council, Delta Science Program. "Science Action Agenda: 2017-2021 A Collaborative Road Map for Delta Science." September 2017. http://scienceactionagenda.deltacouncil.ca.gov/sites/default/files/2017-2021-SAA-final-Sept2017.pdf

be specifically evaluated to demonstrate or measure the extent the data are reliable (accuracy against a known standard), reproducible (precision of duplicates between multiple laboratories), and repeatable (precision by primary laboratory) before they are used for source management and regulatory enforcement decision making. Moreover, effects thresholds are not well known at the expected low concentrations with respect to additive or mitigating effects, and an established process should be developed when assessing beneficial use protection. Based on discussions with Central Valley Water Board staff during the coordination meeting held on September 18, 2017, the data gathered during this pilot study will be used to inform the statewide and Central Valley Water Board's CEC programs and will not be used for regulatory purposes.

The State Water Board and the Central Valley Water Board conditionally approved[4] the previous version of this Work Plan on February 16, 2018. The conditional approval requires the Work Plan to address seven comments in order to be deemed a final approved work plan. These comments have been addressed as part of this submittal.

1.1 DELTA REGIONAL MONITORING PROGRAM

During early discussions, the use of the Delta Regional Monitoring Program (RMP) to implement the pilot study was favored and supported by publicly owned treatment works (POTW) and MS4 representatives and Central Valley Water Board management for numerous reasons, including the following:

- It capitalizes on the ongoing Delta RMP stakeholder-based process, including technical and peer review;
- It provides a better understanding of CEC presence in Central Valley waters than isolated receiving water data;
- It is consistent with the stated mission of the Delta RMP;
- It supports the growth of the Delta RMP, including enhancement of data assessment and communications; and
- It addresses one of the Delta Stewardship Council's Priority Science Actions to improve understanding of interactions between stressors and managed species and their communities (Action 4). Specifically, the CEC pilot monitoring program will provide the opportunity to develop initial information on the potential impacts of CECs on aquatic species in the Central Valley.

Ideally, the Central Valley CEC pilot monitoring program would begin in fiscal year 2018-2019, after July 1, 2018. This Work Plan should be implemented as a Delta RMP "Special Study" without extensive revision. While the Delta RMP does not have a specific process for approving special studies, the previously performed Pathogen Study[5] is an analogous approach whereby a

[4] Creedon, Pamela, Central Valley Regional Water Quality Control Board and Greg Gearheart, State Water Board Office of Information Management and Analysis. *Conditional Approval of Central Valley Pilot Study for Monitoring Constituents of Emerging Concern (CECs) Work Plan*. Letter communication to MS4 and POTW Permittees (distribution list not specified). February 16, 2018.

[5] Delta Regional Monitoring Program. "Monitoring Design Summary." Prepared for the Delta RMP Steering Committee. November 3, 2014. Revised June 16, 2015. https://www.waterboards.ca.gov/centralvalley/water_issues/delta_water_quality/delta_regional_monitoring/wq_monitoring_plans/drmp_monitoring_design.pdf

specific monitoring and assessment need was identified through a stakeholder process which was then addressed through the Delta RMP with active involvement by the stakeholder group. Because this Work Plan was developed for a specific purpose by the Stakeholders and was specifically approved by the Central Valley Water Board and the State Water Board, no significant changes to the scope of the effort are intended. The Delta RMP Steering Committee[6] agreed to implement the Work Plan, pending funding appropriation and directed the Delta RMP Technical Advisory Committee (TAC) to proceed as follows:

- Form a CEC Technical Workgroup based on the Stakeholder group and other interested members
- Review the Work Plan to identify collaboration opportunities that would reduce cost or provide significant technical benefit
- Identify any significant sample collection method improvements that can be implemented without changes to the overall level of effort or increase in budget

[6] Delta Regional Monitoring Program Steering Committee meeting, March 2, 2018.

2 Purpose

The proposed Central Valley CEC pilot study would provide preliminary information to begin to address the Delta RMP management question, "Is there a problem or are there signs of a problem" through the stated question[7], "Are CECs impacting Beneficial Uses in the Central Valley?". This Work Plan will not directly answer this question, which would require significant science development and consideration of factors not included in this Work Plan. However, this Work Plan will provide incremental assessment of conditions through consideration of the 2016 Statewide Monitoring Plan monitoring questions that are compiled in **Table 1**.

Consistent with the current direction of the Delta RMP, the proposed Central Valley CEC pilot study is focused on development of information to understand the presence of a specific list of CECs in ambient waters, sediments, and, to a limited extent, tissues of locally gathered fish and bivalves. Evaluation of contributions from urban sources is also consistent with the "Sources and Pathways" Delta RMP Management Question.

A clear need exists to develop an understanding of the presence/absence and potential risks (i.e., a need for water quality standards for determination of beneficial use impairment) posed by CECs in the Central Valley. This will require significant expansion of effects research. This is best addressed at a national or statewide level and is not recommended as an element of the Central Valley CEC pilot monitoring effort.

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[7] Assessment question as stated by Regional Water Board staff at the December 7, 2017 Central Valley Regional Water Quality Control Board hearing.

Table 1. Technical Approaches to Address Assessment Questions

2016 Statewide Monitoring Plan Monitoring Questions	Technical Approach to Address Monitoring Questions
POTWs	
1. Which CECs are detected in freshwaters and in which California watersheds are they detected?	• Monitor to determine detection of CECs at boundaries of the Delta and within the legal Delta over multiple years and conditions.
2. Can the CECs be shown to originate from the inland WWTP, or are they present at background concentrations?	• Compare observed concentrations at upstream boundaries or locations and downstream monitoring locations.
3. How quickly (i.e., at what distance) do the CECs attenuate once discharged?	• Perform a gradient study to evaluate concentrations at multiple locations downstream from discharges to evaluate CEC attenuation over distance.
4. What are the concentrations and loadings of target CECs in the dry vs. wet seasons?	• Compare wet and dry season concentrations and loadings at individual source characterization and ambient sites.
5. Do the new occurrence data change the estimated monitoring trigger quotients (MTQs)?	• Compare maximum detected ambient values to determine if site-specific MTQ is greater than or less than unity (1.0).
6. Which detected CECs have been found to accumulate in sediments and fish tissue?	• Compare of water column detected concentrations to paired sediment and tissue samples. Calculation of average accumulation ratios.
MS4s	
1. Which CECs are detected in waterways dominated by stormwater?	• Monitor to determine detection at the American River at Discovery Park monitoring location during wet weather conditions.
2. What are their concentrations and loadings in the dry vs. wet seasons?	• Compare wet and dry season concentrations and loadings at individual source characterization sites.
3. What is the relative contribution of CECs in WWTP effluent vs. stormwater?	• Compare wet and dry weather source characterization loading estimates for urban area runoff and POTW discharge relative to ambient flux.
4. What is the spatial and temporal variability in loadings and concentration (e.g. between storm variability during the wet season; in stream attenuation rate during low flow, dry season conditions)?	• There is insufficient sample collection included in the Work Plan to perform a robust variability assessment; however, significant trends may be detectable when evaluated with other (external) data and work by MS4s (e.g. statistical loading models).

3 Pilot Study Scope

The Central Valley CEC pilot study is proposed over a three-year period with phased study components and some (albeit limited) adaptive management elements. **Table 1** summarizes the technical approaches to address the State Water Board's 2016 Statewide Monitoring Plan monitoring questions. Year 1 includes ambient monitoring to assess the presence of the targeted CECs at specific locations in the Delta. After the first year of ambient monitoring, subsequent elements of the proposed CEC monitoring plan include continued ambient monitoring and source monitoring (POTW effluent and urban runoff characterization) during Year 2, and continuation of Year 2 source monitoring in addition to gradient studies upstream and downstream of POTWs and other identified sources during Year 3. Year 3 studies will be focused on those CECs detected at levels of interest. Sample collection during Year 3 may be modified to better address information needs based on the first two years of monitoring but will at least include the second year of source monitoring. Changes to the monitoring elements will be agreed upon by the Stakeholders through a Delta RMP technical review and budgeting process. It is recommended that the Stakeholders establish a CEC Technical Workgroup, as a Delta RMP Technical Advisory Committee (TAC) subcommittee, to implement the Work Plan through the Delta RMP.

The ambient sampling locations include entry points into the Delta, in-Delta waters, and ambient locations in the vicinity of POTW discharges and within the influence from urban runoff. Ambient monitoring to characterize background conditions was suggested in the State Water Board's 2016 Statewide Monitoring Plan.

The proposed Central Valley CEC pilot study will not address several other elements of the 2016 Statewide Monitoring Plan, including non-targeted assessment, bioanalytical or toxicity components. These components may be added to the Work Plan if additional external funding is available to support this work.

During the development of this Work Plan, preliminary evaluations were performed to identify and confirm appropriate sampling, sample extraction, analytical, sample handling, and quality assurance/quality control (QA/QC) methods to be used for each of the CECs on the target list to maintain consistency with other elements of the 2016 Statewide Monitoring Plan. The Delta RMP Quality Assurance Project Plan (QAPP) should be updated to address data quality and provide data usage qualification for the constituents included in this proposed pilot study. A sample collection plan should also be developed, either as an attachment to the QAPP or as a standalone Delta RMP document.

3.1 TARGET CECS

The list of CECs shown in **Table 2** will be monitored as part of this Work Plan, consistent with the list proposed in the State Water Board's 2016 Statewide Monitoring Plan and/or recommended during the May 2017 workshop.

Table 2. Target CECs and Matrices to Be Monitored During the Central Valley CEC Pilot Study

	Matrix		
Analyte [1]	**Water Column [2]**	**Sediment [3]**	**Tissue [4]**
Estrone	✓	---	---
Ibuprofen	✓	---	---
Bisphenol A	✓	---	---
17-beta-estradiol	✓	---	---
Galaxolide (HHCB)	✓	---	---
Diclofenac	✓	---	---
Triclosan	✓	---	---
Triclocarban	✓	---	---
PBDE-47	---	✓	✓
PBDE-99	---	✓	✓
PFOS	✓	✓	✓ [5]
PFOA	✓	✓	✓ [5]

Notes:

[1] Sites may be modified to optimize logistics or costs. Any changes to the monitoring proposal will be approved by the Stakeholders under the Delta RMP. Additional constituents included in the method used will be reported in the data deliverable (CEDEN and appendix of results), but not included in the data report body.

[2] Filtered samples will be used to estimate the aqueous concentration

[3] Sediment sample collection may only be performed at wadeable streams or otherwise be coordinated with the State Water Board's Stream Pollution Trends Monitoring Program (SPoT) or other programs with deeper water sediment collection.

[4] Tissue sample collection to be coordinated with Delta RMP mercury monitoring efforts, the Department of Water Resources (DWR), and other historic monitoring efforts. Sites may be modified based on logistical optimization and may not be coincidental with water column (aqueous) samples.

[5] Fish tissue only based on known limited concentrations in bivalves.

3.2 AMBIENT MONITORING – YEARS 1, 2 AND 3

The targeted list of CECs will be monitored at six (6) to eight (8) ambient sites located in the Delta and vicinity in water column, sediment and/or tissue matrices, according to the matrix shown in **Table 2** of this Work Plan. Tissues used in the Central Valley CEC pilot study will be fish and bivalve tissue samples obtained as part of the Delta RMP mercury monitoring efforts in 2018 or will be fish and bivalve tissues available from other tissue collection efforts in the Delta from the sites specified in **Table 3**.

Proposed in-Delta ambient monitoring sites are a subset of monitoring sites monitored by the Delta RMP for other parameters, consistent with Delta RMP efforts to leverage ongoing sampling efforts wherever possible. Proposed in-Delta sites include the Sacramento River at Hood and San Joaquin River at Vernalis. Should funds allow, the San Joaquin River at Buckley

Cove and Sacramento River at Freeport sites are also recommended as lower priority in-Delta locations.

The Sacramento River at Veterans Bridge, San Joaquin River at Vernalis, and American River at Discovery Park sites will be used as boundary sites to provide information on "background" levels of CECs in waters entering the Delta.

The locations of proposed ambient sites are summarized in **Table 3** and shown in **Figure 1**. Monitoring of ambient sites will be performed for three years, during both wet and dry seasons. The proposed frequency of ambient monitoring during each year is described in **Table 4** of this Work Plan. The frequency of ambient monitoring during Year 3 is contingent on interpretation of detected results and priority information needs from the first two years of monitoring.

Table 3. Monitoring Locations for Central Valley CEC Pilot Study and Possible Coordination Opportunities

Location Description	Approximate Latitude/Longitude	Sample Collection	Sample Coordination Opportunities
Ambient Locations			
Sacramento River at Veterans Bridge	38.680922, -121.626422	WC, FISH, BIV	BIV [2]
Sacramento River at Freeport [5]	38.457345, -121.504589	WC, FISH, BIV	WC, FISH, BIV [1,2]
Sacramento River at Hood	38.367116, -121.520419	WC, BIV	WC, BIV [2]
American River at Discovery Park	38.602103, -121.497311	WC, BIV, SED	WC, SED [4]
San Joaquin River at Vernalis	37.679107, -121.263181	WC, FISH, BIV	WC, FISH [1, 4]
San Joaquin River at Buckley Cove [5]	37.978041, -121.383336	WC, FISH, BIV	WC [6], BIV [3]
Dry Creek	38.733852, -121.315722 [7]	WC, SED	[8]
Old Alamo Creek	38.346428, -121.896835 [7]	WC, SED	[8]
Source Locations			
POTW Source No. 1	38.733899, -121.315051	WC	[8]
POTW Source No. 2	38.346617, -121.901601	WC	[8]
Sacramento Urban Runoff (UR3)	38.601271, -121.492956	WC	[8]
Roseville Urban Runoff	[7]	WC	[7]

Notes:

WC – water column, FISH – sport fish, BIV – bivalve, SED – sediment

[1] Delta RMP Methylmercury plans to collect water column (8-10 times annually) and largemouth bass (annually).

[2] Historic samples collected and frozen by Sacramento Regional County Sanitation District (SRCSD) may be available and substituted for some samples. Other historic preserved samples are available.

[3] DWR ERM Benthic Site (also, Old River Upstream Clifton Court, Old River Upstream of Rock Slough, San Joaquin River at Bradford Island, Sacramento River Downstream of Rio Vista, Sacramento River at Sherman Island)

[4] SPoT sediment and water column monitoring location. Samples are also collected at Sacramento River at Clarksburg Marina between Freeport and Hood (approximates Hood downstream of SRCSD and Sacramento urban area)

[5] Identified as lower priority site

[6] Delta RMP Pesticide may include water column monitoring.

[7] CDPR historic location in Pleasant Grove Creek watershed to be field verified based on presence of urban runoff flow in storm drains. Possible locations include 38.80477, -121.32733; 38.802707, -121.338524; and 38.802599 -121.338787.

[8] Coordination with existing permit collection may be possible

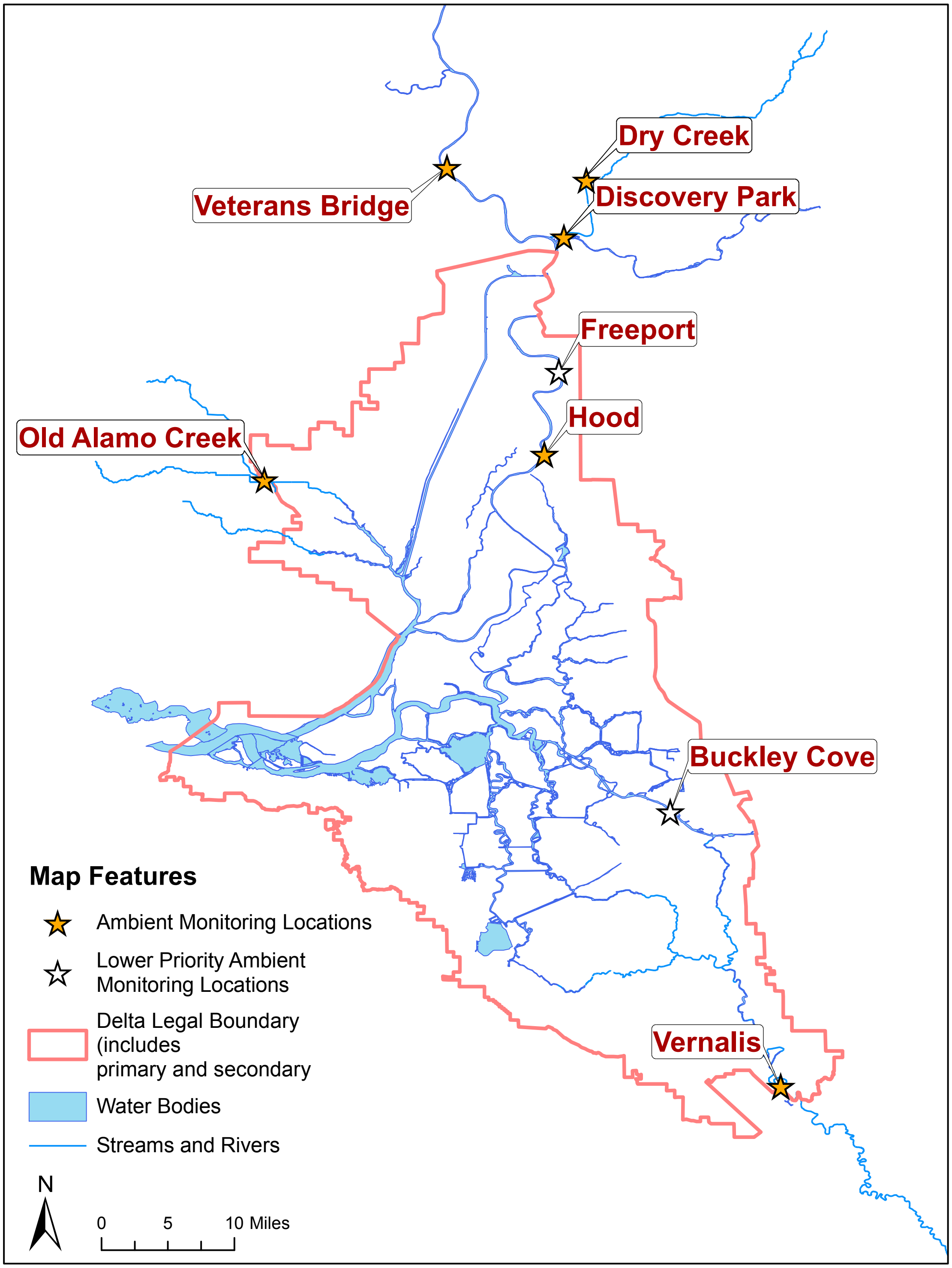

Figure 1. Central Valley CEC Pilot Study Ambient Monitoring Locations

Table 4. Monitoring Frequency Proposed for Central Valley CEC Pilot Study

Year	Matrix	No. of Monitoring Sites	Samples/Year	Total Samples [1,3]
1	Water (ambient)	6-8	4	24-32
	Water (POTW)	0	0	0
	Water (MS4)	0	0	0
	Sediment (ambient) [2]	2-4	2	4-8
	Tissue (fish)	2-4	1-2	2-8
	Tissue (bivalve)	2-4	1-2	2-8
2	Water (ambient)	6-8	4	24-32
	Water (POTW)	2	4	8
	Water (MS4)	2	4	8
	Sediment (ambient) [2]	2-4	2	4-8
	Tissue (fish)	2-4	1-2	2-8
	Tissue (bivalve)	2-4	1-2	2-8
3	Water (ambient) [2]	10-18	2	20-36
	Water (POTW)	2	2	4
	Water (MS4)	2	2	4
	Sediment (ambient)	0	0	0
	Tissue (fish)	0	0	0
	Tissue (bivalve)	0	0	0

Notes:

[1] Total samples shown in this table do not include field-collected QA/QC samples (i.e., field blanks, field duplicates, and inter-laboratory split samples) that will be collected at some frequency for each monitoring event during the 3-year pilot study.

[2] Sediment sample collection limited based on recommendation in conditional approval letter (February 16, 2018). Receiving water monitoring includes gradient monitoring at one location upstream and up to five locations downstream of two POTW discharges.

[3] Ranges of the number of monitoring locations and samples per year reflect the expected optimization effort to identify and use samples from existing efforts by the Delta RMP and others noted in the Coordination section of this Work Plan.

3.3 POTW EFFLUENT AND URBAN RUNOFF CHARACTERIZATION MONITORING – YEARS 2 AND 3

In Year 2, in addition to ambient monitoring, two POTW effluent(s) and two urban runoff characterization locations will be monitored. Because of the limited urban area within the Delta, upstream out-of-Delta urban runoff and POTW characterization locations may be monitored and are intended to generally characterize these sources throughout the Central Valley.

3.4 GRADIENT STUDIES – YEAR 3

In Year 3, two POTW gradients will be monitored. CECs monitored in the gradients will depend on those CECs detected in Year 2 POTW source monitoring. The gradient monitoring will consist of one upstream station and up to five downstream stations, as suggested in the State

Water Board's 2016 Statewide Monitoring Plan. The decisions on the specific locations and number and spacing of gradient sites will be made during Year 2. After consultation with the Stakeholders, including the Central Valley Water Board and State Water Board, the gradient study may be reduced in scope or omitted if other information needs are higher priority given the available Delta RMP funding.

3.5 ANALYTICAL AND SAMPLE COLLECTION METHODS

Research and commercial analytical methods are available for the targeted list of CECs in this Work Plan. Because of the low concentrations and potentially low effect levels, sample collection and analysis methods must be robust to avoid or otherwise quantify contamination and other systematic method biases. The possible laboratories and proposed analytical methods are shown in **Table 5**. These methods and laboratories were identified to optimize both logistics and cost to the program. Quality control samples should be collected to evaluate method and laboratory performance.

3.5.1 Sample Collection and Handling

The sampling methods, sample containers, holding times, and sample preservation methods for the proposed Central Valley CEC pilot study should be specified in a sample collection and analysis plan (SAP). Procedures and equipment specified in that plan should follow the recommendations provided in the 2015 Southern California Coastal Water Research Project (SCCWRP) QA/QC guidance document[8] and be consistent with Surface Water Ambient Monitoring Program (SWAMP) standards. The sample collection plan can be incorporated into the QAPP, this Work Plan, or as a standalone document. Specific sample collection methods (i.e., sample collection plan) will be developed by the CEC Technical Workgroup and should include the following considerations:

- Minimize sample contamination - direct bottle sample collection is likely necessary for some analytes to minimize contact with plasticizers and Teflon (PFOA and PFOS). Composite samples may not be possible through typical equipment currently used by POTWs and MS4s and the SAP should include equipment specifications.
- Sample compositing periods, if applicable, should be representative of typical conditions. Guidance for grab sample timing and methods should also be provided.
- Analytical laboratories selected for this study should be consulted as to sample containers, holding times, and sample preservation methods, as the SCCWRP QA/QC guidance on this topic may not be standard practice or suitable for all analytes and matrices included in this Work Plan
- All water column (aqueous) samples should be field filtered
- Tissue sample collection and preparation methods should be specified to detail size compositing and tissue type

[8] Nathan G. Dodder, Alvine C. Mehinto, and Keith A. Maruya, "Monitoring of Constituents of Emerging Concern (CECs)in Aquatic Ecosystems – QA/QC Guidance" (Southern California Coastal Water Research Project Authority, 2015), https://www.waterboards.ca.gov/water_issues/programs/swamp/cec_aquatic/docs/qaqc_guidance_final.pdf.

Table 5. Target CECs Laboratories and Analytical Methods

Constituent	Primary Laboratory Method [1]	Primary Laboratory [1]	Secondary Laboratory [1]
Water Column Aqueous Only			
Estrone 17-beta-estradiol	EPA 1694M-APCI -LCMSMS-APCI+	WECK	AXYS
Ibuprofen Bisphenol A Diclofenac Triclosan	EPA 1694M-ESI- LCMSMS-ESI	WECK	AXYS
Galaxolide (HHCB)	EPA 1694M-ESI+ LCMSMS-ESI+	WECK	USGS NWQL
Triclocarban	AXYS MLA-075	AXYS	TBD
PFOS PFOA [2]	EPA 537M - LCMS/MS	WECK	AXYS
Sediment and Tissue Only			
PBDE-47 PBDE-99	EPA 1614M - GC/MS SIM	WECK	AXYS
PFOS PFOA [2]	EPA 537M - LCMS/MS	WECK	AXYS

Notes: [1] Primary and secondary laboratories identified for preliminary budgeting purposes. The California Department of Fish and Wildlife (CDFW) analytical laboratory and the USGS National Water Quality Laboratory (NWQL) may be considered during sampling and analysis plan development and as funding is available. Other qualified laboratories may be identified.
[2] PFOS and PFOA will not be analyzed in bivalves.

3.5.2 Quality Assurance/Quality Control

The CEC Technical Workgroup will implement the QA/QC methods for the proposed Central Valley CEC pilot study that will follow the methods outlined in the SCCWRP QA/QC guidance document and the QAPP. Field blank, field duplicate, and inter-laboratory duplicate samples will be included in the quality control sample collection schedule.

4 Data Analysis and Reporting

Data collected through implementation of this Work Plan implementation will be evaluated according to the Delta RMP Communication Plan and associated schedule. Pilot study ambient data (along with its associated QA/QC data) will be uploaded to the California Environmental Data Exchange Network (CEDEN). Source monitoring locations (POTW effluent and urban runoff characterization) will be identified within reports based on latitude and longitude but are not required to be designated as characterization of a specific POTW or MS4. Level of treatment and land uses may be attributed to the sites. Source monitoring data will not be uploaded to CEDEN. Electronic reporting of source monitoring data will be consistent permit provisions, if applicable.

The elements of the Work Plan will be adaptively managed during the three year study through the Delta RMP CEC Technical Workgroup, TAC review, and annual budget review process. This will be necessary both due to budgetary considerations and new information acquired through the Pilot Study and will be based on technical justification agreed upon by the Stakeholders.

The interpretation of results by the Delta RMP will be performed after a process is established that considers the adequacy of the Work Plan technical assessment tools and known system variability to determine appropriate threshold values to assess beneficial use impacts. A draft interpretive report summarizing the work performed, methods, data analysis and conclusions will be prepared after the completion of the proposed Central Valley CEC pilot study. The draft report will follow adopted Delta RMP processes for report preparation. A final interpretive report will be prepared which addresses comments received by the Delta RMP TAC and Steering Committee on the draft report.

The ability to interpret data developed under the proposed pilot study is limited by the lack of available information for the target CECs regarding environmental effects. Threshold values in water, sediment and/or tissues largely do not exist or are not of sufficient quality to determine answers to the management question, “Is there a problem or signs of a problem?” This limitation must be clearly stated in the communication plan for this Work Plan monitoring effort. Care must be taken to avoid the use of “detection” as an indication of “problems” in the aquatic environment.

During and following Year 2 of this pilot study, the overall scope of Year 3 efforts will be adaptively managed based on a prioritization of information needs and agreement by the Stakeholders as informed by the CEC Technical Workgroup. The Delta RMP Steering Committee approves and allocates funds ultimately needed to implement this Work Plan.

5 Identified Coordination Opportunities

The coordination opportunities below should be evaluated to reduce costs and provide consistency through common sample collection protocols. It may be possible with additional funding to have these programs expand or modify their activities to better match this Work Plan. Because this Work Plan is an initial pilot and screening effort, it should also consider modifications to locations and frequencies to leverage these coordination opportunities, especially if funding sources are not sufficient. A more detailed coordination plan will be developed as part of the QAPP.

- **Delta RMP Mercury Study** includes water column and fish tissue sample collection:
    - Water column sample collection eight to ten times per year
    - Annual fish tissue sample collection (largemouth bass)
    - Sacramento River at Freeport and San Joaquin River at Vernalis are only sites in common
    - May be possible to add locations or fish tissue events
    - Additional water quality samples could be collected in lieu of fish tissue samples
- **Delta RMP Pesticide Study** is under development for FY18-19 and may be able to accommodate water column sample collection.
- **Department of Water Resources Environmental Monitoring Program** benthic sample collection includes bivalve sample collection at one of the proposed Work Plan sites and may be able to provide additional in-kind funded services.
- **Stream Pollution Trends Monitoring Program (SPoT)** collects sediment samples statewide with historical locations at American River at Discovery Park, Sacramento River at Clarksburg, and San Joaquin River at Vernalis. Sample collection included sediment toxicity monitoring as well as contaminant concentration in sediments, including PBDE. These sites were anticipated in the 2018-2020 SPoT work plan[9].
- **Source monitoring** may be coordinated with other sample collection through in-kind participation and if the schedules and locations coincide.

Sample collection protocols should be coordinated and adequately evaluated through quality control samples and adequate documentation of any variances from sample collection or handling protocols.

[9] Email communication from Bryn Phillips, Department of Environmental Toxicology, University of California, Davis, Granite Canyon Laboratory (February 16, 2018). SPoT work plan development will not be confirmed until May 2018 and program development includes an April 4, 2018 SPoT Science Committee meeting.

6 Estimated Costs

It is expected that the Delta RMP will fund the sample collection and analysis effort for all ambient waters, sediments, and tissues through existing participation fees and the addition of new ongoing and special study participating Delta RMP members. The Delta RMP may also leverage in-kind services from other monitoring programs. Stakeholders are actively seeking external fund sources. The scope of this proposed pilot study may be reduced, as necessary and agreed upon by the Stakeholders, to match available funding. The cost estimate includes data reporting and compilation costs, but not overall interpretative assessment reports. The planning level estimated costs for the proposed CEC pilot monitoring program are detailed in **Appendix A Table A-1** through **Table A-5** of this Work Plan.

6.1 ESTIMATED COST REDUCTIONS WITH ADDITIONAL COLLABORATION

The Cost estimates in **Appendix A Table A-1** through **Table A-5** assume minimal additional in-kind support by Delta RMP participants or other monitoring programs referenced in **Section 5** of this Work Plan.

The following are potential project modifications and the estimated change in total costs and are presented as planning assumptions to evaluate whether collaboration is feasible:

- Coordinate all ambient water column sample collection with Delta RMP Mercury and Pesticide sample collection, which would result in a reduction of monitoring locations and sample collection labor costs. These other Delta RMP efforts may need additional funding to offset labor costs, especially if sites are added to their efforts. It is assumed the additional funding would be provided for analytical costs. Cost reductions could exceed $20,000 annually.
- Coordinate all fish tissue and bivalve tissue sample collection with historic Delta RMP Mercury, SRCSD historic, and DWR collection efforts. It may be necessary to add a fish collection cruise to augment the annual event or to add a location. There are limited number of 2016 frozen bivalve samples at Regional San. Cost reductions could exceed $8,000 annually in both Year 1 and Year 2 depending on collaboration or reductions to the Work Plan.
- Coordinate river sediment and water column sample collection with the SWAMP SPoT program, which includes American River at Discovery Park and potentially other locations if identified through the SPoT 2018-2020 work plan development. Cost reductions could exceed $10,000 annually in Year 1 and Year 2.
- Coordinate source characterization monitoring with California Depart of Pesticide Regulation (DPR) Surface Water Protection Program monitoring in the Roseville urban area. Cost reductions could exceed $5,000 annually.

While these and other opportunities to coordinate activities leverage resources, the overall sample collection approach should not be modified without Stakeholder review and Water Board input. Collaboration could introduce differences in sample collection methods, analytical methods, laboratories, and sample handling approaches. In this case, a more robust quality control program would be helpful to measure differences in methods. Additionally, a high level of collaboration will require additional program management costs and potentially delay data availability.

Through review by other Delta RMP potential collaborators, additional study components and modifications were identified that are outside the conditionally approved Work Plan. For the purpose of future study development and tracking, these technical comments are compiled in **Appendix B**.

Appendix A. Planning Cost Estimates

Table A-1. Analytical Methods, Method Detection Limits, and Cost Based on Laboratory Selection

Constituents	Laboratory Analytical Grouping	Lab	Method	Cost/ Sample	MDL	Units	Notes
			Water Column				
Estrone	Hormones	Weck	EPA 1694M-APCI - LCMSMS-APCI+	$ 200	0.2	ng/L	Additional constituents would be included in data deliverable.
17-beta-estradiol					0.31	ng/L	
Ibuprofen	Pharmaceuticals and Personal Care Products (PPCP)	Weck	EPA 1694M-ESI- LCMSMS-ESI-	$ 200	0.39	ng/L	Additional constituents would be included in data deliverable.
Bisphenol A					0.27	ng/L	
Diclofenac					0.26	ng/L	
Triclosan					1.2	ng/L	
Galaxolide (HHCB)		Weck	EPA 1694M-ESI+ LCMSMS-ESI+	$ 250	3.0	ng/L	Additional constituents would be included in data deliverable.
Triclocarban		AXYS	AXYS MLA-075	$ 350	36	ng/L	Ibuprofen, Bisphenol A, and Triclosan also included
Total Suspended Solids	Ancillary	Weck		$ 25	5	mg/L	
			Sediment and Tissue				
PBDE-47	Polybrominated Diphenyl Ethers	Weck	EPA 1614M - GC/MS SIM	$ 225	2.5	µg/kg	Additional constituents would be included in data deliverable.
PBDE-99					2.5	µg/kg	
PFOS	Perfluorinated Compounds	Weck	EPA 537M - LCMS/MS	$ 250	2.5	µg/kg	
PFOA					2.5	µg/kg	
Total Organic Carbon	Ancillary	Weck		$ 95	200	mg/kg	Sediment only
Total Moisture	Ancillary	Weck		$ 20	0.10	% w/w	Tissue only
Total Lipid Content	Ancillary	Weck		$ 95	0.05	% w/w	Tissue only

Table A-2. Year 1 Program Cost Estimate

Annual Costs								
Year 1								
Number of Sites				**Labor**	**Direct**	**Laboratory**	**Total**	**Notes**
Ambient water column	8		Pre-Project	$ 24,000	$ 150	$ -	$ 24,150	ASC estimate $23K for QAPP
Source water column	0		Preparation	$ 9,600	$ 640	$ -	$ 10,240	Equipment and coordination
Sediment	4		Ambient samples	$ 35,200	$ 9,600	$ 41,000	$ 85,800	Grab sample collection
Tissue	4		Source samples	$ -	$ -	$ -	$ -	
Number of Events			Sediment samples	$ 8,800	$ 2,400	$ 6,850	$ 18,050	Wadeable sample collection
Ambient water column	4		Tissue samples	$ 13,200	$ 400	$ 6,850	$ 20,450	
Source water column	0		Compilation & Reporting	$ 28,800	$ -	$ -	$ 28,800	Data report only
Sediment	2		TOTAL	**$ 119,600**	**$ 13,190**	**$ 54,700**	**$ 187,490**	
Tissue	2							

Notes:
•Costs are estimates based on expected level of effort and interpretation of work plan and document guidance.
•Costs include total program costs, and some labor may be provided in-kind or as part of other programs.

Assumed Unit Rates
Field Scientist $175/hour
Field Technician $125/hour
Monitoring Manager $200/hour
QC rate 25% (one QC sample for every four environmental samples)

Table A-3. Year 2 Program Cost Estimate

Year 2								
Number of Sites				**Labor**	**Direct**	**Laboratory**	**Total**	**Notes**
Ambient water column	8		Preparation	$ 18,000	$ 640	$ -	$ 18,640	Equipment and coordination
Source water column	4		Ambient samples	$ 35,200	$ 9,600	$ 41,000	$ 85,800	Grab sample collection
Sediment	4		Source samples	$ 17,600	$ 2,800	$ 20,500	$ 40,900	Grab samples
Tissue	4		Sediment samples	$ 8,800	$ 2,400	$ 6,850	$ 18,050	Wadeable sample collection
Number of Events			Tissue samples	$ 13,200	$ 400	$ 6,850	$ 20,450	
Ambient water column	4		Compilation & Reporting	$ 38,400	$ -	$ -	$ 38,400	Data report only
Source water column	4		TOTAL	**$ 131,200**	**$ 15,840**	**$ 75,200**	**$ 222,240**	
Sediment	2							
Tissue	2							

Notes:
•Costs are estimates based on expected level of effort and interpretation of work plan and document guidance.
•Costs include total program costs, and some labor may be provided in-kind or as part of other programs.

Assumed Unit Rates
Field Scientist $175/hour
Field Technician $125/hour
Monitoring Manager $200/hour
QC rate 25% (one QC sample for every four environmental samples)

Table A-4. Year 3 Program Cost Estimate

Year 3								
Number of Sites				**Labor**	**Direct**	**Laboratory**	**Total**	**Notes**
Ambient water column	18		Preparation	$ 6,600	$ 720	$ -	$ 7,320	Equipment and coordination
Source water column	4		Ambient samples	$ 39,600	$ 2,800	$ 46,125	$ 88,525	May reduce number of sites
Sediment	0		Source samples	$ 8,800	$ 1,400	$ 10,250	$ 20,450	Grab samples
Tissue	0		Sediment samples	$ -	$ -	$ -	$ -	
Number of Events			Tissue samples	$ -	$ -	$ -	$ -	
Ambient water column	2		Compilation & Reporting	$ 26,400	$ -	$ -	$ 26,400	Data report only
Source water column	2		TOTAL	**$ 81,400**	**$ 4,920**	**$ 56,375**	**$ 142,695**	
Sediment	0							
Tissue	0							

Notes:
•Costs are estimates based on expected level of effort and interpretation of work plan and document guidance.
•Costs include total program costs, and some labor may be provided in-kind or as part of other programs.

Assumed Unit Rates
Field Scientist $175/hour
Field Technician $125/hour
Monitoring Manager $200/hour
QC rate 25% (one QC sample for every four environmental samples)

Table A-5. Total Program Cost Estimate

TOTAL ESTIMATED COST					
	Labor	Direct	Laboratory	Total	Notes
Pre-Project	$ 24,000	$ 150	$ -	$ 24,150	QAPP/SAP
Preparation	$ 34,200	$ 2,000	$ -	$ 36,200	Logistics and mobilization
Ambient samples	$ 110,000	$ 22,000	$ 128,125	$ 260,125	Includes boat rental
Source samples	$ 26,400	$ 4,200	$ 30,750	$ 61,350	
Sediment samples	$ 17,600	$ 4,800	$ 13,700	$ 36,100	
Tissue samples	$ 26,400	$ 800	$ 13,700	$ 40,900	Collected with ambient
Compilation & Reporting	$ 93,600	$ -	$ -	$ 93,600	Data report only
TOTAL	**$ 332,200**	**$ 33,950**	**$ 186,275**	**$ 552,425**	

Notes:
•Costs are estimates based on expected level of effort and interpretation of work plan and document guidance.
•Costs include total program costs, and some labor may be provided in-kind or as part of other programs.

Assumed Unit Rates
Field Scientist $175/hour
Field Technician $125/hour
Monitoring Manager $200/hour
QC rate 25% (one QC sample for every four environmental samples)

Appendix B. Technical Considerations for Additional Work Outside of Work Plan Scope [revised July 2, 2018]

Throughout the Pilot Study for Monitoring Constituents of Emerging Concern (CECs) Work Plan (Work Plan) development and review, additional program elements were identified by Stakeholders and external reviewers as potentially beneficial. In general, these suggestions broadened the intended focus of the pilot study and required additional funding. CECs are a broad class of constituents with complex effects on aquatic life such that the research and study areas are dynamic, and the assessment methods are evolving quickly. Comments are summarized below for planning future studies beyond this Work Plan:

- Addition of non-targeted analysis (NTA) as included in the State Water Board Monitoring Plan in sections outside of the MS4 and POTW specific tasks and monitoring questions. NTA can provide a broad range scan of tentatively identified compounds, but not quantitative values of individual concentrations. NTA can capture a snapshot of transitory conditions for many compounds and the degradates. NTA can be useful when paired with bioanalytical, toxicity, and other exposure assessments, however, in isolation of other information NTA does not inform exposure effects or threshold conditions for beneficial use assessments. The Science Advisory Panel convened by the State Water Board[10] recently concluded that "NTA remains highly complex, labor and capital cost intensive" and recommended that NTA "be attempted and/or applied with clear goals (e.g. as guided by the responses from bioanalytical tools) on a voluntary basis as part of investigative type studies". The cost per sample can exceed $2,000 when considering follow-up interpretation, reporting, and the level of detail (range)of the NTA. NTA could be performed in future studies or as funding is available but was not part of the Conditional Approval.
- Addition of bioanalytical and toxicity testing as included in the State Water Board Monitoring Plan in sections outside of the MS4 and POTW specific tasks and monitoring questions. Bioanalytical methods can be useful but are not readily performed by commercial laboratories and are more appropriate for research activities for most all of the marker types. If funding and sample administration support became available, bioanalytical work could be considered to be added to the Pilot Study but was not part of the Conditional Approval.
- Addition of a wider range of constituents, including microplastics and constituents with more urban runoff considerations based on other study reports (SFEI and TAC comment). Though not included in this Work Plan, a number of additional constituents could be analyzed as part of the specified analytical methods, including the chlorinated phosphates, caffeine, and other hormones, personal care products, and pharmaceuticals. The Work Plan includes CECs based on the State Water Board Monitoring Plan and SCCRWP Guidance Document. Significant

[10] Jörg E. Drewes1, Paul Anderson, Nancy Denslow, Walter Jakubowski, Adam Olivieri, Daniel Schlenk, and Shane Snyder. Science Advisory Panel convened by the State Water Resources Control Board. Monitoring Strategies for Constituents of Emerging Concern (CECs) in Recycled Water Recommendations of a Science Advisory Panel. April 2018 Southern California Coastal Water Research Project Technical Report 1032

deviations change the narrower focus of this pilot study. However, findings from this and other studies could be used to inform future CEC work plan development.

- Addition of a downstream site that aggregates Delta flows would be valuable to any future modeling efforts as a downstream boundary (SFEI comment).
- Addition of PFOA/PFOS in water column which have previously been found in Bay Area work, while removing PFOA/PFOS in bivalve tissue because it is infrequently detected (SFEI comment). The Work Plan was annotated to include this modification.
- Addition or replacement of a site with the Marsh Creek at East Cypress Crossing location that is included in the SPoT Work Plan. This site represents a tributary to the Delta with influence from both agricultural and urban runoff sources. Consideration of this site was suggested by the State Board (Dawit Tadesse).

Appendix III – Delta RMP CEC Year 1 and Year 2 Preliminary Data Summaries

Cyanotoxin Monitoring in the Delta: Leveraging existing USGS and DWR field efforts to assess cyanotoxin status, trends, and drivers

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Problem Statement

One major impediment to improved understanding and prediction of harmful algal blooms (HABs) and the cyanotoxins they produce is the dearth of systematic collection of observational data across both space and time. HABs, which in freshwater comprise mostly cyanobacteria (cyanoHABs), are distributed worldwide and are a growing concern because they can adversely affect drinking water supplies, interfere with water transfers, harm aquatic organisms, and potentially harm humans and wildlife. Worldwide, the distribution and abundance of cyanoHABs are intensified by increased nutrient loads from agriculture and urban runoff, atmospheric deposition, global warming, and droughts. It is most often the cyanotoxins produced by these organisms that are the hazard rather than the organisms themselves – which may or may not produce toxins – so improved monitoring efforts seek to combine cyanobacterial detection with measurement of the toxins themselves.

Identifying drivers of cyanoHABs and their associated toxins requires an understanding of the conditions that foster their growth as well as hydrologic drivers that then transport them through the ecosystem. Environmental factors that have been attributed to the occurrence of cyanoHABs and the toxins they produce include nutrient concentrations, light conditions, water temperature, hydrologic conditions, water residence time, and meteorological conditions. These factors change rapidly in aquatic systems, particularly in hydrologically complex and tidal estuaries like the Delta (Kraus et al., 2017). Thus, a robust monitoring program for cyanoHABs and cyanotoxins requires investing in collection of a wide array of parameters. Unfortunately, there has been limited and sporadic cyanotoxin sampling in the Delta to date (Lehman et al. 2005, 2008, 2017; Otten et al. 2017). However, we do know from this work that cyanoHABs occur each year and negatively impact aquatic species at multiple trophic levels in the estuary (Lehman et al. 2010, 2017, 2020, 2021).

Another challenge for monitoring cyanotoxins is that the occurrence of these compounds can be episodic. Thus, discrete sampling programs that occur on a monthly or even bimonthly interval can miss key events and underestimate cyanotoxin risk, or if they capture a high-concentration event can give a false impression that cyanotoxins are a widespread health hazard. The use of SPATT (Solid Phase Adsorption Toxin Tracking) samplers helps address this issue by providing a temporally integrated signal of dissolved cyanotoxin concentrations (Kudela, 2017; Howard et al, 2017; Peacock et al., 2018, Howard et al., 2018). SPATT samplers have been used as a compliment to traditional monitoring programs and can elucidate toxin dynamics and environmental drivers. SPATT samplers have detected cyanotoxins when simultaneous “grab” samples of water have failed to detect the same cyanotoxins . SPATT captures ephemeral cyanotoxin events that may be missed by discrete water sampling, and exhibits more sensitivity compared with grab samples (Lane et al., 2010, Kudela, 2011; Howard et al., 2017; Kudela, 2017; Peacock et al., 2018). A timeseries of water (particulate fraction) and SPATT samples were collected in San Francisco Bay (SFB) from 2011 to 2016 and analyzed for both cyanotoxins and marine toxins (Peacock et al., 2018). The SPATT results indicated ubiquitous toxins throughout SFB, however, the particulate water samples only captured toxins during some timepoints and generally indicated toxins were not very prevalent. Both particulate and dissolved toxins are concentrated by shellfish (Miller et al., 2010; Gibble et al., 2016) and additional studies found multiple toxins were routinely present in mussels indicating a potential for transfer of toxins throughout the food web (Gibble et al., 2016; Peacock et al., 2018). Therefore, using SPATT samplers as a monitoring tool provided insight into the toxin detections in mussel samples, and the potential for transfer to the food web that the grab samples did not capture (Peacock et al., 2018).

Background

The Sacramento-San Joaquin Delta (Delta) serves as critical aquatic habitat and as a vital drinking water resource for almost 30 million Californians. It is also a physically, biologically, and hydrologically complex system, receiving flows from the Sacramento and San Joaquin Rivers, which drain approximately 40% of California and then move through and merge within the Delta, a maze-like network of interconnected channels and sloughs (Figure 1). Analysis of long-term observational data demonstrate that the Delta is in a state of severe ecological decline (Sommer et al. 2007; Thomson et al. 2010). In particular, the structure and function of habitats and the lower trophic levels has been transformed through invasive aquatic macrophytes, localized issues with low dissolved oxygen, excessive anthropogenic nutrients, and cyanoHABs.

Information about cyanoHABs and cyanotoxins in the Delta are available for the summer and fall months (Lehman et al. 2005, 2008, 2010, 2017; Otten et al. 2017). However, with warmer conditions due to climate change and extended droughts, blooms are starting earlier and lasting longer, suggesting that more extensive temporal sampling is needed to determine the current bloom impact (Lehman et al. 2017). The spatial extent of cyanoHABs is also changing; while these organisms have been detected in the Central and Southern Delta for many years, they have more recently been observed in the northern Delta including the Cache Slough Complex (Figure 1).

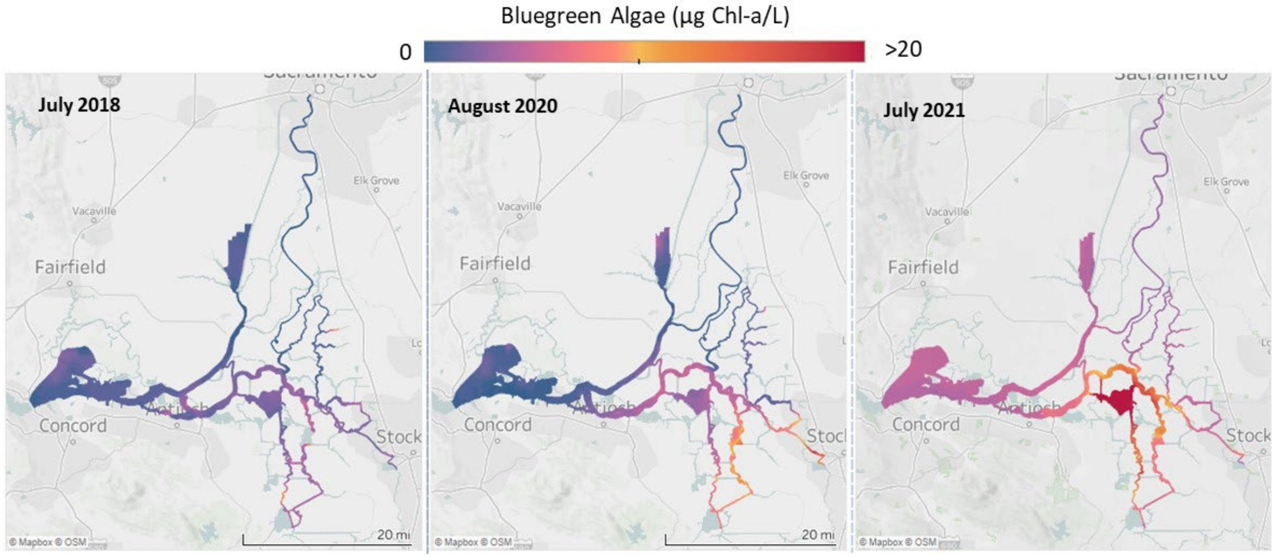


Figure 1. Data collected in July 2018, August 2020 and July 2021 during high resolution boat-based mapping surveys of the study area (Sacramento-San Joaquin Delta, California). Color gradient shows variation in the chlorophyll-a pool attributed to blue green algae (i.e.cyanobacteria) measured using a bbe Fluoroprobe (FP).

In the fall of 2019, the USGS received internal funding to collect cyanotoxins at two USGS continuous monitoring stations in the Delta (Jersey Point (JPT) and Decker (DEC), Figure 2). Then in 2020 the Delta Regional Monitoring Program (DRMP) funded the collection of samples for cyanotoxin analyses at four additional stations: two run by the USGS and two run by DWR (Figure 2). With the internal USGS and DRMP funding in 2020-2021 USGS was able to monitor cyanotoxins in 6 sites, however, both these funding sources expire in early 2022. Fortunately, in 2021 the USGS received funding from the Delta Science Program (DSP) to continue cyanotoxin collection at 5 of these sites. This funding will begin in Spring 2022, but funding was not sufficient enough to cover all previous 6 sites. Without additional funding, cyanotoxins will have to be dropped from one of the monitoring stations – Middle River (MDM).

In addition to cyanoHAB specific projects, the U.S. Geological Survey (USGS) California Water Science Center (CAWSC) and the California Department of Water Resources (CDWR) operate a network of continuous flow and water quality monitoring stations across the Delta (Figure 2). Stations are instrumented with multiparameter sondes that measure water temperature, specific conductance, turbidity, pH, dissolved oxygen (DO), fluorescence of "total" chlorophyll (fCHL), as well as a sensor that measures nitrate (Table 1). These stations are serviced approximately monthly, and at the same time interval discrete water samples are collected to validate and calibrate these instruments (e.g., chlorophyll-a, nitrate) as well as to collect samples for laboratory analyses (e.g., phosphorus, ammonium, dissolved organic nitrogen, phytoplankton identification and enumeration). Most stations report flow, water velocity, and stage, allowing for calculation of constituent fluxes.

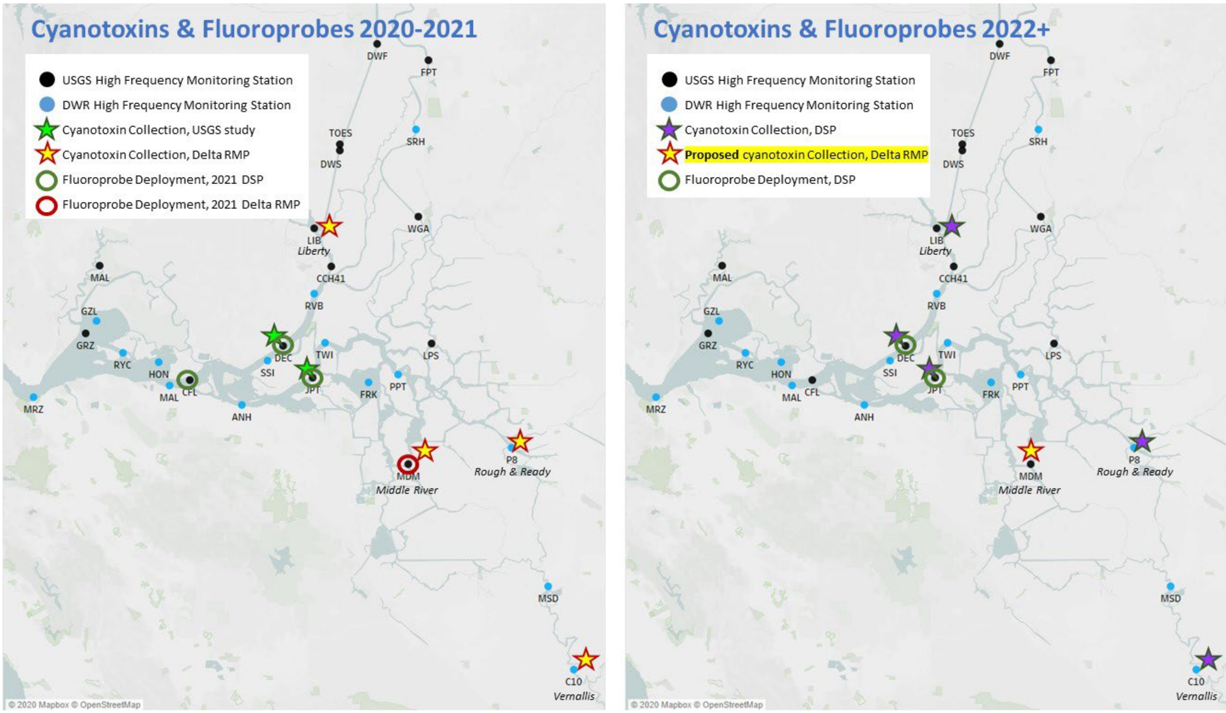


Figure 2. Map of the Delta showing locations of USGS (black circles) and DWR (blue circles) continuous monitoring stations. LEFT panel shows cyanotoxin and fluoroprobe monitoring in 2020-2021 funded by Delta RMP, Delta Science Program (DSP), and internal USGS funds. Funding for all these projects ends in early 2022. RIGHT panel shows cyanotoxin and fluoroprobe monitoring funded by DSP beginning in 2022. The yellow star in the right panel shows the MDM location for cyanotoxin monitoring proposed in this study.

Table 1. Configuration of USGS and DWR continuous monitoring stations.

Type	Description
ADCP, Pressure Sensors	Flow, Discharge, Gauge Height
Infrastructure	Data Collection Platform (Enclosure, Datalogger, wire and cable, telemetry, solar panels, regulators and batteries)
YSI EXO	Temp/Cond sensor
	pH sensor
	D.O. sensor
	Turbidity sensor
	fDOM sensor*
	Total algae sensor (Total chlorophyll (fCHL) and Phycocyanin (PC)
	Central Wiper
	signal output adaptors
SUNA Nitrate Analyzer*	SUNA Nitrate Analyzer*
bbe Fluoroprobe**	chlorophyll attributed to four phytoplankton classes (cyanobacteria, diatoms, green algae, chlorophytes)

*USGS stations only; **planned for MDM, JPT, DEC, CFL stations

Study Objectives

To provide a more comprehensive picture of the seasonal variation of HABs and their associated toxins in the Delta, this study would:

> Collect a full year of measurements of cyanotoxins (March 2022-Februrary 2023) at one station (Middle River, MDM) in the Delta that already have existing, robust monitoring programs, to supplement DSP funding and maintain a network of 6 cyanotoxin monitoring stations in the Delta.

Relevance to RMP Management Questions

The data gathered will provide important information to help stakeholders engaged in the Delta Nutrient Research Plan to determine whether nutrient concentrations and future management of nutrient concentrations could affect the initiation, duration, and source of cyanobacterial species and toxins in the Delta. Simultaneous collection of nutrients, phytoplankton and cyanotoxin data along with other water quality parameters (temperature, specific conductance, DO, pH) also will allow researchers to investigate how the suite of conditions along with nutrient concentrations contribute to HABs. The objectives of the project and how the information will be used relative to the RMP's high-level management questions are summarized in Table 2.

Table 2. Study objectives and questions relevant to RMP management questions.

Core Management Question	Study Objectives/Questions
Status & Trends Is there a problem or are there signs of a problem? a. Is water quality currently, or trending towards, adversely affecting beneficial uses of the Delta? b. Which constituents may be impairing beneficial uses in subregions of the Delta? c. Are trends similar or different across different subregions of the Delta?	**How do harmful algal blooms and cyanotoxin concentrations vary spatially and temporally year-round?** **How are ambient concentrations and trends in HABs and cyanotoxins affected by variability in water quality conditions, particularly nutrients?** Collect cyanotoxin data and associated phytoplankton and water quality variables year-round from MDM to complement sampling occurring at other Delta monitoring stations. Year-round data collection will enable a more comprehensive assessment of the variation of HABs and cyanotoxins and how they are impacted by water quality conditions, flow (i.e., drought) including nutrient concentration.
Sources, Pathways, Loadings, and Processes Which sources and processes are most important to understand and quantify? a. Which sources, pathways, loadings, and processes (e.g., transformations, bioaccumulation) contribute most to identified problems? b. What is the magnitude of each source and/or pathway (e.g., municipal wastewater, atmospheric deposition)? c. What are the magnitudes of internal sources and/or pathways (e.g. benthic flux) and sinks in the Delta?	**Which areas of the Delta are cyanotoxins produced and how are they transported?** **Which sources and levels of nutrients are more closely linked to HAB and toxin formation?** Provide online access to data and spatial and temporal trend plots of nutrient concentrations, associated water quality conditions, phytoplankton abundance and cyanotoxins for managers and scientists.

Core Management Question	Study Objectives/Questions
Forecasting scenarios a. How do ambient water quality conditions respond to different management scenarios b. What constituent loads can the Delta assimilate without impairment of beneficial uses? c. What is the likelihood that the Delta will be water quality-impaired in the future?	**Are cyanotoxin concentrations linked with nutrient concentrations, forms and ratios?** **How will changes to nutrient inputs to the Delta (e.g., WWTP upgrades) affect the development of HABs and cyanotoxins?** Improving understanding of linkages between environmental drivers (nutrients, flow, temperature) on HAB formation, initiation, and duration will assist modeling and targeted data analyses.
Effectiveness Tracking a. Are water quality conditions improving as a result of management actions such that beneficial uses will be met? b. Are loadings changing as a result of management actions?	Data collected by this study can be used to help determine whether cyanotoxins are at concentrations of concern in the Delta and will help managers develop future monitoring programs.

Study Approach

Cyanotoxin monitoring at Middle River (MDM) for 12 months

We will continue to measure cyanotoxins at the Middle River site (MDM). Cyanotoxins will be measured with discrete water samples and solid phase adsorption toxin tracking (SPATT) samplers. The MDM station is currently equipped with a YSI EXO (water temperature, specific conductance, turbidity, pH, dissolved oxygen, chlorophyll-a/BGA), a SUNA nitrate analyzer, and a bbe Fluoroprobe (Table 1).

Previous studies suggest that cyanotoxin concentrations in the Delta are higher in the summer and fall and lower in the winter and spring, thus we will collect samples approximately every 4 weeks (monthly) in the winter and spring, and approximately every 2 weeks in the summer and fall, for a total of 18 sample dates at MDM. Monthly (12 per year) water samples are collected at these stations under existing USGS and DWR programs, so additional samples for nutrients, phytoplankton enumeration, and picoplankton counts only are needed under this study for the 6 additional sampling dates (Table 3).

SPATT samples: The use of SPATT samplers (Figure 3) has recently been refined as a monitoring tool to compliment traditional discrete sampling programs by providing a time-integrated indicator of dissolved toxin presence (Lane et al., 2010; Kudela, 2011; Howard et al., 2017; Kudela, 2017, Peacock et al., 2018; Roue and others, 2018). SPATT samplers will be constructed in the USGS laboratory following methods described in Howard and others (2018). SPATTs will be deployed adjacent to sonde measurements. Each SPATT will be deployed for approximately two weeks; when one sampler is removed from the station a new one will immediately be deployed in its place. SPATT bags will be placed in ziplock bags, placed immediately on dry ice in the field, kept frozen (-80° C), and then sent to the laboratory (Lumigen Instrument Center, http://chem.wayne.edu/lumigen/director.html) for extraction and analysis. All (100%) SPATTs will undergo analysis via the method of liquid chromatography with tandem mass spectrometry (LCMS-MS) for the detection of cyanotoxins listed in Table 2. Upon review of LCMS-MS data – a subset of samples (~20%) will be selected for analysis via the method of enzyme-linked immunosorbent assay (ELISA) by BSA Environmental Services (https://www.bsaenv.com/), which is limited to the detection of four cyanotoxins (Table 3). Cyanotoxin methods of analysis differ by state and federal entities – analyses of SPATTs from this study using both analytical methods allow for data and method comparability across different HABs-funded studies.

Discrete water samples: In addition to collecting SPATTs, we will collect discrete whole water samples concurrent with the removal/placement of SPATTs (approx.18 times per year), which is concurrent with sample collection for analytes listed in Table 3. Whole water samples will be placed immediately on dry ice in the field, kept frozen (-80° C), and then sent to the laboratory (Lumigen Instrument Center) for analysis. All (100%) whole water samples will undergo analysis via LCMS-MS and – upon review of LCMS-MS data – a subset of samples (~20%) will be selected for analysis via ELISA (BSA Environmental Services). Again, analysis of discrete water samples from this study using both analytical methods allows for data and method comparability across different HABs-funded studies.

Figure 3. Photo showing the planned system for deploying SPATT at fixed locations.

The goal of implementing SPATT into this proposed study is as a monitoring tool to provide a robust, comprehensive approach to determining toxin patterns and dynamics within the Delta that traditional water grab samples alone can miss. We are very much aware of all the confounding factors that make SPATT cyanotoxin collection challenging to interpret compared to whole water samples, particularly because relating cyanotoxin data obtained from SPATT samplers to a health advisory threshold is not straightforward. The study objective is <u>not</u> to relate SPATT results to human health regulations, but rather to use SPATT as a separate, complementary sampling tool with water grabs to elucidate the prevalence of toxins and to capture ephemeral events that water grab samples can miss. That is why we are collecting SPATT only in conjunction with the more traditional whole water method, which is more easily applicable to health advisories.

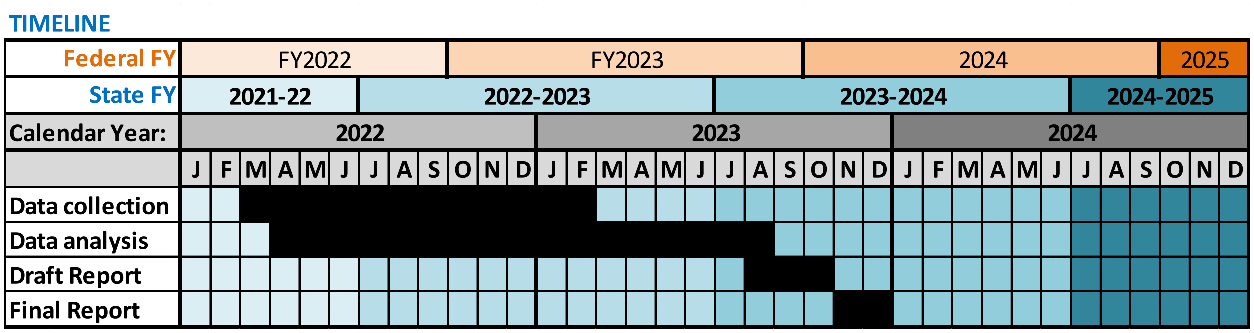
Table 3. List of parameters determined approximately monthly at the proposed monitoring station at Middle River (MDM). Funding from this proposal will cover cyanotoxin analysis for 18 sampling dates (18 dates, plus replicates and blanks), and analyses of other parameters not covered by other efforts.

Parameter	Approx. # Samples ($ this study)	*Approx. # Samples ($ other)*	Information Provided
Nitrate (NO3-N) (µM) **Nitrite (NO2-N)** (µM)	8	*14*	nitrogen as nitrate available for biological uptake; laboratory measurement to verify and calibrate in-situ data, increases due to nitrification or new inputs, decreases due to uptake and denitrification
Ammonium (µM)	8	*14*	nitrogen as ammonium available for biological uptake; tracer of wastewater source; shown to impact phytoplankton abundance, species composition, and primary production; increases due to mineralization or inputs decreases due to nitrification and uptake
Total Dissolved Nitrogen (TDN) (µM)	8	*14*	total nitrogen in the dissolved phase used to track the total N budget
Dissolved Organic Nitrogen (DON) (µM)	8	*14*	includes only the dissolved organic nitrogen fraction, used to track the total N budget; tracer of water source: Calculated as TDN-NO3-NO2-NH4
soluble reactive phosphate (SRP, PO4) (µM)	8	*14*	required nutrient for phytoplankton; has been shown to be inhibitory at high concentrations; tracer of water source
Chlorophyll-*a* & Phaeophytin (mg L^{-1})	0 (*no mid-month chla collection because have continuous chla data from sonde*)	*14*	laboratory measurements to verify and calibrate in-situ fCHLA data; phaeophytin to chlorophyll-a ratio provides information about algal growth versus senescence; tracer of water source
Phytoplankton Enumeration (cells L-1 and cm^3 L-1 by species)	8	*14*	microscope analysis for phytoplankton species identification, counts and biovolume; provides information about phytoplankton abundance and species composition; identifies whether the phytoplankton pool is made up of beneficial or harmful species; indicator of nutritional quality of the phytoplankton pool
Picocyanobaceria (cells L^{-1} and cm^3 L^{-1})	8	*14*	epifluorescence analysis that identifies picocyanobacteria (< 2 microns); identifies fraction of the phytoplankton pool that is made up of small cyanobacteria that are believed to be less favorable to the health of the food web
Cyanotoxins Whole Water (µg L^{-1}) SPATTs (ng g^{-1} day^{-1})	20 20	--	**LCMS-MS** analysis for the detection of Anabaenopeptins, Anatoxin-a, BMAA, Cylindrospermopsin, Microcystins, Nodularins, and Saxitoxins
Cyanotoxins Whole Water (µg L^{-1}) SPATTs (ng g^{-1} day^{-1})	5 5	--	**ELISA** analysis for the detection of microcystins, anatoxins, cylindrospermopsins, and saxitoxins

Project Timeline

- **Project Start-End Dates**
    - March 1, 2022 through December 31, 2023
- **State FY21-22 (March 2022 – June 2022)**
    - Collect and analyze samples March 2022 – June 2022 (4 months of data)
    - Updates to RMP and data sharing upon request
- **State FY22-23 (July 2022 – June 2023)**
    - Collect and analyze samples July 2022 – February 2023 (8 months of data)
    - Updates to RMP, data sharing upon request, initial data analysis
- **FY23-24 (July 2023 – June 2024)**
    - Public release of final data
    - Final report to RMP due December 2023

Table 4. Timeline for data collection, analysis and reporting



Deliverables

- Cyanotoxin and other data will be made available within 6 months following receipt of data from laboratory via the USGS database systems (NWIS and/or ScienceBase), or upon request. These data will also be made available using online visualization tools (e.g., https://tableau.usgs.gov/views/Bay_Delta_Portal/Portal?:embed=yes)
- Results will be reported to the Delta RMP, local conferences (e.g. Bay Delta, IEP), and upon request.
- A report that describes the approach and methods, summarizes any issues or lessons learned that occurred during data collection, provides tabular and/or graphical summaries of the spatial and temporal patterns in the data, evaluates the data quality, and relates study findings to the Delta RMP management questions will be provided at the end of the agreement. The report will also include comparison between the whole water and SPATT data and between the LCMS-MS and ELISA data.
- We anticipate data from this study along with other relevant data collected by the USGS and DWR through other funded cyanoHAB projects will be incorporated into a journal article, IEP Newsletter article, and/or USGS report.

Budget

This budget will cover USGS staff time and associated costs (e.g., boats, vehicles, fuel, supplies, instrument costs, travel, chlorophyll and nutrient analyses, phytoplankton enumeration, data analysis, presentations, data release, and report writing). This budget assumes the Delta RMP will contract directly with BSA Environmental and/or Lumigen Laboratories to cover analytical costs for cyanotoxins.

The total amount requested from the Delta RMP under this agreement is **$103,912**

USGS will contribute $18,106 in cooperative match dollars to this study.

In Kind Contributions: Well over $400,000 in equipment and annual cost sharing will be provided by the USGS to support monthly field visits (staff time, boats, vehicles, fuel, sampling equipment), analytical costs associated with samples listed in Table 2 that are collected monthly at MDM and collection of in situ continuous monitoring data at MDM.

Budget Breakdown

	DRMP Contribution	USGS Match
Cyanotoxin Analysis, Direct*	$23,580	$0
USGS data collection	$60,230	$12,991
USGS reporting	$20,102	$5,026
TOTAL, by entity	**$103,912**	**$18,016**
Project total		$121,928

*Cyanotoxin analytical costs will be paid directly to Lumigen Laboratories and/or BSA Environmental. If these samples are routed through the USGS the cost will increase to $33,720.

Analytical Costs associated with cyanotoxin analysis*					
ANALYTICAL COSTS	**Lab Cost per sample (2022)**	**Samples per year/ site**	**TOTAL Costs**	**Lumigen Lab**	**BSA Env. Lab**
Whole Water - LCMS-MS	$400	18	$7,200	$7,200	$0
SPATT samplers - LCMS-MS	$475	18	$8,550	$8,550	$0
Whole Wate - ELISA	$400	4	$1,600	$0	$1,600
SPATT samplers - ELISA	$575	4	$2,300	$400	$1,900
TOTAL/yr, without QAQC			$19,650	$16,150	$3,500
TOTAL/yr, ~20% QA/QC			**$23,580**	$19,380	$4,200

**As noted above, this assumes a contract can be signed directly with Lumigen Labs and/or BSA Environmental. If these analyses are instead routed through a USGS agreement, the cost will increase to $33,720.*

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