FINAL ENVIRONMENTAL IMPACT REPORT

LOOKOUT SLOUGH TIDAL HABITAT RESTORATION AND FLOOD IMPROVEMENT PROJECT

State Clearinghouse No. 2019039136

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Date: October 2020

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CHAPTER 1
Introduction

1.1 Information on the Final Environmental Impact Report

The Department of Water Resources (DWR) circulated the Lookout Slough Tidal Habitat Restoration and Flood Improvement Project (Proposed Project) Draft Environmental Impact Report (EIR) for a 60-day public and agency comment period from December 16, 2019 through February 14, 2020. To facilitate public and agency review of the Draft EIR, DWR held a public meeting on January 22, 2020 in Dixon, California. At the end of the circulation period for the Draft EIR, a total of 19 written comment letters and e-mails were received. There were three commenters at the public meeting.

This document is the Final EIR for the Proposed Project. The Final EIR has been prepared in accordance with the California Environmental Quality Act (CEQA) and together with the Draft EIR (and appendices) constitutes the EIR for the Proposed Project. This Final EIR describes text changes made in response to comments and initiated by staff (see Chapter 2 of this Final EIR). It also contains written responses to all comments received by DWR from agencies and the public on the Draft EIR (see Chapter 3 of this Final EIR). Because multiple comments were received that addressed a number of key issues, DWR prepared comprehensive responses addressing these issues (master responses). Each master response provides background regarding the specific issue, how the issue was addressed in the Draft EIR, and additional clarification and explanation as appropriate to address the comments. In addition, individual responses to comments received were prepared. This Final EIR also includes a list of commenters, and comment letters received. This Final EIR, including text changes in Chapter 2 and responses to comments in Chapter 3, clarifies, amplifies, or makes insignificant changes to the Draft EIR and does not change the finding or conclusions of the Draft EIR. DWR has taken the comments into consideration in preparing the Final EIR.

1.2 Summary of Proposed Project

The Proposed Project would restore within the Proposed Project Site approximately 3,164 acres of tidal marsh that would partially fulfill DWR's obligations under Reasonable and Prudent Alternative (RPA) 4 of the 2008 United States Fish and Wildlife Service (USFWS) Delta Smelt Biological Opinion (BiOp) and is consistent with RPA I.6.1 of the 2009 National Marine Fisheries Service (NMFS) Salmonid BiOp for the coordinated operations of the State Water Project and the Central Valley Project. The Proposed Project Site is comprised of three properties totaling approximately 3,400 acres in size in unincorporated southeastern Solano County, California, with a small portion of work extending into Yolo County.

The 2008 USFWS BiOp RPA 4 and 2009 NMFS BiOp Reasonable and Prudent Alternative (RPA) I.6.1 were carried forward as baseline conditions in the USFWS *Biological Opinion for the Reinitiation of Consultation on the Coordinated Operations of the Central Valley Project and the State Water Project* and the NMFS *Biological Opinion on Long Term Operation of the Central Valley Project and the State Water Project*, both of which were issued on October 21, 2019. In addition, Section 9.1.1 of the *Incidental Take Permit for Long-Term Operation of the State Water Project in the Sacramento-San Joaquin Delta (2081-2019-066-00)* (2020 LTO ITP), issued by the California Department of Fish and Wildlife (CDFW) on March 31, 2020, carries forward the 8,000-acre tidal habitat restoration requirement as compensatory mitigation for activities under the 2020 LTO ITP.

The Proposed Project would create habitat that is beneficial to Delta Smelt (*Hypomesus transpacificus*) and other fish and wildlife species and widen a portion of the Yolo Bypass to increase flood storage and conveyance. When completed, the Proposed Project would provide habitat for Delta Smelt, Longfin Smelt (*Spirinchus thaleichthys*), Chinook Salmon (*Oncorhynchus tshawytscha*), Green Sturgeon (*Acipenser medirostris*), Steelhead (*Oncorhynchus mykiss*), giant garter snake (*Thamnophis gigas*), and other species. The Proposed Project is also designed to meet regional flood protection objectives in a manner consistent with the 2017 DWR Sacramento Basin-wide Feasibility Study.

The Proposed Project involves constructing a new setback levee along Duck Slough and Liberty Island Road. The existing levee at Shag Slough would be breached and partially degraded to provide tidal and flood connectivity between Duck Slough and Shag Slough. The existing Cache/Hass Slough Levee would be enhanced to increase stability and reduce long term maintenance cost. The Cache/Hass Slough Levee would continue to function to prevent increased water surface elevations in the Cache Slough Complex. Grading, placement of fill material, and revegetation would be used to restore and enhance upland, tidal, subtidal, and floodplain habitat.

1.3 Public Participation and Environmental Review Process

DWR notified all responsible and trustee agencies and interested groups, organizations, and individuals that the Draft EIR on the Proposed Project was available for review. The following list of actions took place during the preparation, distribution, and review of the Draft EIR:

- A Notice of Preparation (NOP), an Initial Study, and Notice of Completion (NOC) were filed with the State Clearinghouse (State Clearinghouse Number (SCH #) 2019039136) on March 21, 2019 for public review ending on April 22, 2019.
- The NOP and information on the scoping meeting was provided to: (1) State, local and federal agencies; (2) the Yolo County and Solano County Clerk offices; (3) public libraries in Davis, Dixon, Rio Vista, and Vacaville; (4) local newspapers; and (5) other interested parties.
- A public scoping meeting was held on April 10, 2019 at the Olde Vets Hall (231 N. First Street) in Dixon California from 6:00 to 8:00 pm.
- The NOC and copies of the Draft EIR were filed with the State Clearinghouse on December 16, 2019 with public review ending on February 14, 2020.
- Notices of Availability (NOA) of the Draft EIR and information on the public meeting was provided to: (1) State, local and federal agencies; (2) the Yolo County and Solano County Clerk offices; (3) public libraries in Davis, Dixon, Rio Vista, and Vacaville; (4) local newspapers; and (5) other interested parties. The NOA and the Draft EIR were also made available on DWR's website.
- A public meeting to receive comments on the Draft EIR was held on January 22, 2020 at the Olde Vets Hall (231 N. First Street) in Dixon, California from 5:30 to 7:30 pm.
- During the public review period, the Draft EIR was available for review on DWR's website at: https://water.ca.gov/Programs/Environmental-Services/Restoration-Mitigation-Compliance/Delta-Projects

1.4 CEQA Certification and Project Approval

Before DWR makes a decision with regard to the Proposed Project, CEQA Guidelines section 15090(a) requires that DWR first certify that the EIR has been completed in compliance with CEQA, that DWR has reviewed and considered the information in the EIR, and that the EIR reflects the independent judgment and analysis of DWR.

In the event DWR approves the Proposed Project, CEQA requires that it file a Notice of Determination (NOD) and adopt appropriate findings as set forth in CEQA Guidelines Section 15091. Under CEQA Guidelines Section 15092, a lead agency may only approve or carry out a project subject to an EIR if it determines that: (1) that project will not have a significant effect, or (2) that the agency has eliminated or substantially lessened all significant effects on the environment where feasible and any remaining significant effects on the environment that are found to be unavoidable are acceptable due to overriding considerations.

1.5 Organization of the Final EIR

The Final EIR is organized as follows:

- Chapter 1, Introduction.
- Chapter 2, Revisions to the Draft EIR: presents text changes to the Draft EIR that have been made in response to comments and/or DWR staff-initiated changes. Changes in the text are indicated by ~~strikeout~~ where text is removed and by double underline where text is added.
- Chapter 3, Responses to Comments: includes a list of commenters on the Draft EIR, all comment letters received during the public review period for the Draft EIR, transcript of the public meeting, and responses to comments. Additionally, this chapter presents "master responses" that have been prepared to address frequently raised comments, and to avoid repetition of responses and lengthy duplication of text.
- Appendices: Appendices include documents that provide additional information not included in the Draft EIR.

CHAPTER 2
Revisions to the Draft EIR

This chapter of the Final Environmental Impact Report (EIR) presents revisions to the Draft EIR, including those that have been made in response to comments (see Chapter 3 of this Final EIR) and/or California Department of Water Resources (DWR) staff-initiated changes. Changes in the text are indicated by ~~strikeout~~ where text is removed and by double underline where text is added. The text revisions are organized by the chapter, section, and page number that appear in the Draft EIR.

Chapter I, Introduction

- Page I-3. The text in the 1st full paragraph is revised as follows:

  "This Draft EIR was prepared by WRA, Inc. (WRA), an environmental consultant (CEQA Guidelines, Section 15084(d)(2)). DWR has the principal responsibility for approving and implementing the project and for certifying that CEQA requirements have been met, including exercising independent judgement and analysis. EIP is a contractor to DWR, and may implement mitigation measures for the Proposed Project that do not restrict DWR's discretion over the Project. The Proposed Project is intended to achieve DWR's stated goals and objectives. Lists of personnel who assisted in preparing the EIR as well as organizations and persons consulted on the EIR are provided in Section VIII (Preparers of the EIR and Persons Contacted)."

Chapter II, Executive Summary

- Page II-2. The text in the middle of the page is revised as follows:

  c. Project Objectives

  ~~The Proposed Project would create, restore, and maintain ideal habitat conditions to encourage the proliferation of Delta Smelt and other sensitive fish species associated with unrestricted tidal freshwater ecosystems in the Delta. Restoration activities would provide spawning and rearing habitat for Delta smelt, which is on the brink of extinction in its natural habitat1, and would serve to fulfil a portion of the Delta Smelt habitat mitigation required by the 2008 Delta Smelt Biological Opinion for the state Water Project and Central Valley Project (81420-2008-F-1481-5).[2]~~

  The goals and objectives of the Lookout Slough Tidal Habitat Restoration and Flood Improvement Project are listed below: …

- Page II-14. The text in Table II-1, Summary of Environmental Impacts that were Analyzed and Mitigation Measures, is revised as follows:

Impact #	Impact	Significance	Proposed Mitigation
AG-i.	Conversion of a substantial amount of prime farmland to nonagricultural use	Less than Significant with Mitigation	Mitigation Measure AG-1a: Off-Site Agricultural Improvements Prior to commencement of construction, improvements beneficial to agricultural productivity shall be installed to improve the irrigation capability and extent of the Zanetti property and improve drainage of the Wineman Property. Improvements shall include irrigation infrastructure with potential to convert all or part of the property to Prime Farmland; these may include, but are not limited to, power drops, pumps, and pipelines. Other improvements may include, but are not limited to, farm buildings such as barns, workshops, corrals and fencing, and worker housing with an associated septic system. Improvements would be selected in coordination with the property owner(s) and/or their agricultural lessees in a manner which best improves the agricultural viability and drainage in this part of Solano County. Mitigation Measure AG-1b: Agricultural Conservation Easement ~~The Applicant~~ DWR shall cause to be established an off-site agricultural preserve by placing a conservation easement ...

- Page II-16. The text in Table II-1, Summary of Environmental Impacts that were Analyzed and Mitigation Measures, is revised as follows:

Impact #	Impact	Significance	Proposed Mitigation
AIR-i.	Would the project conflict with implementation of the applicable air quality plan?	Less than Significant with Mitigation	Mitigation Measure AIR-1: Construction Equipment Standards b) Engine Requirements • ~~If commercially available, the~~All ~~engines of the~~ diesel off-road equipment shall have engines that meet the ~~USEPA or CARB~~ Tier 4 Final off-road emission standards, as certified by CARB. The equipment that shall use Tier 4 Final engines may include, but are not limited to: compactors, rollers, bulldozers, excavators, motor graders, scrapers equivalent to the Caterpillar 631K Wheel Tractor-Scraper model, and off-road haul vehicles~~truck~~. This requirement shall be verified through submittal of an equipment inventory that includes the following information: (1) Type of Equipment, (2) Engine Year and Age, (3) Number of Years Since Rebuild of Engine (if applicable), (4) Type of Fuel Used, (5) Engine HP, (6) Verified Diesel Emission Control Strategy (VDECS) information if applicable and other related equipment data. A Certification Statement by the Contractor shall be required to be submitted to the project director of EIP and DWR, for documentation of compliance and for future review by the air district upon request. The Certification Statement must state that the Contractor agrees to compliance and acknowledges that a violation of this requirement shall constitute a material breach of contract.

<table>
<tr><th>Impact #</th><th>Impact</th><th>Significance</th><th>Proposed Mitigation</th></tr>
<tr><td>AIR-i. (cont.)</td><td></td><td></td><td>
Equipment requirements above may be waived by the project director of EIP or DWR may waive the equipment requirement above, but only under any of the following unusual or emergency circumstances: if a particular piece of off-road equipment with Tier 4 Final standards or Tier 3 standards is not technically feasible or not commercially available; the equipment would not produce desired emissions reductions due to expected operating modes; use or installation of the equipment would create a safety hazard or impaired visibility for the operator; or there is a compelling emergency need to use other alternate off-road equipment. that does not meet the equipment requirements, above. If the project director of EIP or If DWR grants the waiver based on one or more of the above unusual circumstances, the contractor shall use the next cleanest piece of off-road equipment available, as detailed in Table M-AIR-1 below the following order: Tier 4 Interim, Tier 3, and then Tier 2 engines.
For purposes of this mitigation measure, “commercially available” shall mean the availability of Tier 4 Final engines similar to the availability for other large-scale construction projects in the region occurring at the same time and taking into consideration factors such as (i) potential significant delays to critical-path timing of construction for the project and (ii) geographic proximity to the Proposed Project Site of Tier 4 Final equipment.
The Contractor shall maintain records concerning its efforts to comply with this requirement.
Table M-AIR-1A details the off road compliance step down approach. If engines that comply with Tier 4 Final off-road emission standards are not commercially available, then the Contractor shall meet Compliance Alternative 1. If off-road equipment meeting Compliance Alternative 1 are not commercially available, then the Project sponsor shall meet Compliance Alternative 2. If off-road equipment meeting Compliance Alternative 2 are not commercially available, then the Project sponsor shall meet Compliance Alternative 3 as demonstrated below.
TABLE M-AIR-1
OFF ROAD EQUIPMENT COMPLIANCE STEP DOWN APPROACH
<table>
<tr><th>Compliance Alternative</th><th>Engine Emissions Standard</th><th>Emissions Control</th></tr>
<tr><td>1</td><td>Tier 4 Interim</td><td>N/A</td></tr>
<tr><td>2</td><td>Tier 3</td><td>ARB Level 3 VDECS</td></tr>
<tr><td>3</td><td>Tier 2</td><td>ARB Level 3 VDECS</td></tr>
</table>
In seeking a waiver from this requirement it must be demonstrated, to the satisfaction of DWR, that the total annual ROG and NOx emissions do not exceed a total of 10 tons per year. Additionally, it must also be demonstrated that the average daily PM10 emissions do not exceed 80 pounds per day for PM10 to meet YSAQMD’s significance thresholds as stated in Table IV.C-4 on the previous page.
Mitigation Measure AIR-2: Dust Control
Contractors for construction of the Proposed Project DWR shall implement all of the following applicable dust control measures:
</td></tr>
</table>

- Page II-18. The text in Table II-1, Summary of Environmental Impacts that were Analyzed and Mitigation Measures, is revised as follows:

Impact #	Impact	Significance	Proposed Mitigation
BIO-i	Substantial adverse effects on riparian habitat or other sensitive natural communities	Less than Significant with Mitigation	Mitigation Measure BIO-1. Re-Plant Riparian Vegetation at a ~~1.1:1~~ 3:1 Ratio for Riparian Woodland and 1.5:1 Ratio for Riparian Scrub To compensate for Proposed Project impacts to riparian habitat the Proposed Project shall: 1) Avoid a long-term net loss of riparian habitat, and 2) Mitigate for direct impacts to riparian woodland at a ~~1:1~~ 3:1 ratio, and for impacts to riparian scrub at a 1.5:1 ratio. Mitigation would be achieved through on-site planting of riparian woodland and scrub habitats. The condition of planted riparian habitats will be monitored for a minimum of 1-year after planting to ensure the successful establishment of habitat that is dominated by native riparian vegetation. If mortality of riparian plantings reduces the amount of established riparian habitat to less than what is required to achieve the above ratios, replanting will be implemented to ensure the successful establishment of native riparian habitats sufficient to achieve the required acreage.

- Page II-20. The text in Table II-1, Summary of Environmental Impacts that were Analyzed and Mitigation Measures, is revised as follows:

Impact #	Impact	Significance	Proposed Mitigation
BIO-iii	Substantial adverse effects on special-status plant species	Less than Significant with Mitigation	Mitigation Measure BIO-2. Special-Status Plant Avoidance, Preservation, and Re-Planting 5) Performance shall be monitored to evaluate success of replacement of special-status species habitat. Target replacement shall be at a minimum 1:1 ratio of impacted to established habitat acreage for each of the directly impacted special-status plant species. Success would be considered achieved when an equal area of habitat is occupied at a plant density similar to pre-project conditions. Monitoring shall be conducted for a minimum of three growing seasons following initial planting or until performance has been achieved. If individuals of Mason's lilaeopsis are newly detected during pre-construction surveys in areas to be impacted by Proposed Project activities and DWR determines that complete avoidance is not feasible, ~~EIP~~DWR shall consult with CDFW prior to the start of construction to obtain authorization for project implementation and develop an appropriate type and amount of compensatory mitigation. Mitigation shall be provided at a minimum 1:1 ratio of impacted individuals to replanted; final mitigation ratios and other specific compensatory requirements shall be determined through consultation with CDFW.

Impact #	Impact	Significance	Proposed Mitigation
BIO-iii (cont.)			6) If individuals of Mason's lilaeopsis are newly detected during preconstruction surveys in areas to be impacted by Proposed Project activities and DWR, determines that complete avoidance is not feasible, ~~the Applicant~~ DWR shall consult with CDFW prior to the start of construction to obtain authorization for project implementation and develop an appropriate type and amount of compensatory mitigation. Mitigation shall be provided at a minimum 1:1 ratio of impacted individuals to replanted; final mitigation ratios and other specific compensatory requirements shall be determined through consultation with CDFW.

- Page II-22. The text in Table II-1, Summary of Environmental Impacts that were Analyzed and Mitigation Measures, is revised as follows:

Impact #	Impact	Significance	Proposed Mitigation
BIO-iv	Substantial adverse effects on special-status wildlife species, either directly or through habitat modification	Less than Significant with Mitigation	7) Escape routes or coverings shall be provided at any temporary open excavations with steep-sided walls or open pipes that have potential to entrap wildlife. For excavations determined to be sufficiently steep that wildlife may become stranded, an escape ramp shall be installed, or an adjustment to the slope of the wall to be less steep shall be made in a location to allow escape, or the feature shall be completely covered to prevent entrapment of wildlife. If questions occur about excavations, a qualified biologist shall be available to determine if a ramp is necessary and advise on potential solutions for ramp design to allow animal escape. 8) Escape ramps do not apply to the cutoff wall excavation due to the combination of fencing, and bare ground which would be sufficient to deter wildlife from the vicinity. 9) Plastic, monofilament, jute netting, or similar temporary erosion control matting that could entangle snakes shall not be placed on the site. Possible substitutes include coconut coir or matting, burlap wrapped straw wattles, tackified hydroseeding compounds, or other materials. 10) To eliminate attraction of predators of special-status wildlife species, all food-related trash items, such as wrappers, cans, bottles, and food scraps, shall be disposed of in closed containers and hauled off-site on a regular basis. Mitigation Measure BIO-4. Invasive Plant Species Abatement Prior to the start of construction activities, protocols shall be developed for targeted invasive weed abatement, which shall include at a minimum, the following: 1) Identify target weeds that are rated High or Moderate for negative ecological impact in the California Invasive Plant Database (Cal-IPC) within the Proposed Project Site that have potential to spread off-site and/or sustain on-site following the Proposed Project's restoration actions. 2) Where determined necessary to control identified weed populations, target weed infestations shall be treated according to control methods and practices considered appropriate for those species. 3) Weed control treatments shall include all legally permitted herbicide, manual, and mechanical methods, approved for aquatic use by the U.S. Environmental Protection Agency and California Department of Pesticide Regulation. The application of herbicides shall be in compliance with all state and federal laws and regulations under the prescription of a Pest Control Advisor and implemented by a Licensed Qualified Applicator.

Impact #	Impact	Significance	Proposed Mitigation
BIO-iv (cont.)			4) The timing of weed control treatment shall be determined for each target plant species with the goal of controlling populations. During post-construction operation of the Proposed Project, DWR shall monitor for the presence of invasive aquatic plant species in accordance with BIO-4(1). Invasive aquatic plant species shall be removed in accordance with BIO-4(2) and (3). Post-construction monitoring shall occur following the implementation of any procedures used to remove invasive aquatic plants to ensure that the procedures are effective.

- Pages II-22 to II-26. The text in Table II-1, Summary of Environmental Impacts that were Analyzed and Mitigation Measures, is revised as follows:

Impact #	Impact	Significance	Proposed Mitigation
BIO-v	Substantial adverse effects on special-status wildlife species, either directly or through habitat modification	Less than Significant with Mitigation	Mitigation Measure BIO-5A. Nesting Birds The following measures shall be implemented prior to construction to avoid or minimize impacts to nesting birds: 1) Implement Mitigation Measure BIO-3 (WEAP). 2) To the extent feasible, vegetation removal and initial ground disturbance shall occur from September 1 through January 31 so that initial ground disturbing work occurs outside of the general nesting bird season. If vegetation removal and initial ground disturbance occurs during the general nesting bird season, DWR will consult with CDFW and implement necessary measures. 3) For vegetation removal and ground disturbance within the Proposed Project footprint that is conducted within the general nesting bird season (February 1 through August 31), pre-construction nesting bird surveys shall be conducted within an appropriate radius of vegetation removal or ground disturbance within 14 days of the initiation of these activities to avoid disturbance to active nests, eggs, and/or young. 4) All active nests of native birds found during the survey shall be protected by a no-disturbance buffer until all young from each nest fledge or the nest otherwise becomes inactive. The size of each buffer shall be determined by an agency- approved, qualified biologist dependent upon extant conditions, including individual bird behavior, baseline disturbance, level of construction, and physical factors such as visual obstruction and maywill require consultation with the CDFW. Buffers are typically a minimum of 50 feet for non-special-status birds and may be larger for special-status or raptor species. Mitigation Measure BIO-5B. Swainson's Hawk Nesting and Foraging Habitat ~~Due to the potential for adverse impacts to Swainson's hawk, consultation and permitting with CDFW may be required if reduced buffers during the nesting season are necessary for construction activities. If permitting for potential take of Swainson's hawk is determined to be necessary, EIP shall consult with CDFW and implement all avoidance and minimization measures as required in the Proposed Project Incidental Take Permit and Lake and Streambed Alteration Agreements. In addition, t~~The following measures shall be implemented prior to and during construction to avoid ~~or minimize~~ impacts to Swainson's hawk:

Impact #	Impact	Significance	Proposed Mitigation
BIO-v (cont.)			1) In each year that Proposed Project activities occur during Swainson's hawk nesting season, two surveys shall be conducted within each of nest season Phases II and III[1] as described below: a) In the first year of construction: (i) If Proposed Project activities ~~work has been initiated~~ begin prior to March 20 (prior to the nesting season for Swainson's hawk), two surveys each shall be conducted within Phases II (March 20-April 5) and Phase III of the nesting season (April 5 - May 20) to determine if nests have established during Proposed Project activities. (ii) If Proposed Project activities ~~work~~ begin~~s~~ between March 20 and April 5 (Phase II) at least one of the two surveys within Phase II shall be conducted prior to the start of ground disturbing activities. Two surveys shall also be conducted between April 5 – April 20 (Phase III). (iii)If Proposed Project activities ~~work~~ begin~~s~~ in Phase III, two surveys shall be conducted in Phase II and at least one survey in Phase III shall be conducted prior to start of ground disturbing activities. b) In the second or third year of Proposed Project activities ~~construction~~, two surveys shall be conducted within each of the Phases II and III windows identified above. c) Surveys shall be conducted within 0.~~2~~5-mile of planned work areas during the nesting season. (i) If a nest is determined to be active and ~~ground disturbance~~ work has not yet been initiated, an appropriate buffer up to a 0.~~2~~5-mile (~~1,320~~2,640-foot) radius shall be established in consultation with CDFW. If ~~ground disturbance~~work has been initiated and a Swainson's hawk establishes a nest after ~~construction~~ work has been initiated, a 500-foot buffer shall be established around the nest tree. d) Following surveys, monthly checks shall be conducted in May, June, and July to provide status updates on any active nests. If a nest is determined to have become inactive, the nest buffer would be removed. ~~e) If a smaller buffer is sought, CDFW shall be consulted and the methods described below (Item 2) shall be instituted in addition to any measures requested by CDFW in approving the reduced buffer.~~ ~~2) Reduced buffer: If construction will occur within 0.25-mile of an active Swainson's hawk nest site (and the nest was established prior to initial construction in the area) or within 500 feet of an active Swainson's hawk nest established during construction, the following additional measures shall be implemented:~~ ~~a) Staging areas for equipment, materials, and work personnel shall be located 0.25-mile away from active Swainson's hawk nest sites. These areas shall be flagged and identified to all work personnel during employee orientation.~~

1 California Department of Fish and Game, Swainson's Hawk Technical Advisory Committee, "Recommended Timing and Methodology for Swainson's Hawk Nesting Surveys in California's Central Valley" (Sacramento, May 31, 2000), https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=83990&inline.

Impact #	Impact	Significance	Proposed Mitigation
BIO-v (cont.)			~~b) For nests established during construction, if construction needs to occur within 500 feet of an active Swainson's hawk nest, no construction shall occur prior to 8:00 AM, and shall be discontinued by 5:00 PM each day.~~ ~~c) If work needs to occur temporarily within any buffer, a qualified biologist shall monitor active nests daily for signs of disturbance for the duration of the construction activity. If it is determined that Proposed Project-related activities are resulting in nest disturbance, then work in those sensitive areas shall cease immediately and the 0.25-mile buffer or 500-foot buffer (for nests in ongoing work areas) shall be re-established. CDFW shall then be contacted for further guidance.~~

- Page II-27 and II-28. The text in Table II-1, Summary of Environmental Impacts that were Analyzed and Mitigation Measures, is revised as follows:

Impact #	Impact	Significance	Proposed Mitigation
BIO-v	Substantial adverse effects on special-status wildlife species, either directly or through habitat modification	Less than Significant with Mitigation	~~4) Wildlife exclusion fencing (i.e. silt fencing) shall be installed surrounding the designated staging areas. Vehicles or equipment left overnight inside of fenced areas will not be required to be inspected prior to moving. Equipment left outside of staging areas shall be inspected for giant garter snake prior to moving. Operators and construction personnel may conduct vehicle inspections if they have received training on the inspections by the qualified biologist. The exclusion fence shall be inspected on a weekly basis by either a qualified biologist or trained construction personnel. See Mitigation Measure BIO-1A. Habitat Protection and Avoidance.~~ 4~~5~~) A speed limit of 15 mph shall be observed in areas within 200 feet of areas designated as suitable giant garter snake aquatic habitat by a qualified biologist. 5) If a giant gartersnake is observed in the construction area, all activities within the immediate area of the snake will cease, and the qualified biologist will be notified immediately. The qualified biologist will follow procedures for the relocation approved by USFWS and CDFW. 6) DWR will procure a conservation easement for 57 acres of GGS upland and winter refugia habitat in the vicinity of the Proposed Project Site or, if required as part of regulatory permitting, buy credits at a CDFW-approved conservation bank in an amount equal to 57 acres. ~~6) Escape routes or coverings shall be provided at any temporary open excavations with steep-sided walls that have potential to entrap giant garter snake. For excavations determined to be sufficiently steep that wildlife may become stranded, an escape ramp shall be installed, or an adjustment to the slope of the wall to be less steep shall be made in a location to allow escape, or the feature shall be completely covered to prevent entrapment of wildlife. If questions occur about excavations, a qualified biologist shall be available to determine if a ramp is necessary and advise on potential solutions for ramp design to allow animal escape.~~ ~~7) Escape ramps do not apply to the cutoff wall excavation due to the combination of fencing, and bare ground which would be sufficient to deter wildlife from the vicinity.~~

Impact #	Impact	Significance	Proposed Mitigation
BIO-v (cont.)			~~8) Plastic, monofilament, jute netting, or similar temporary erosion control matting that could entangle snakes shall not be placed on the site. Possible substitutes include coconut coir or matting, burlap wrapped straw wattles, tackified hydroseeding compounds, or other materials.~~ ~~9) To eliminate attraction of predators of giant garter snake, all food-related trash items, such as wrappers, cans, bottles, and food scraps, shall be disposed of in closed containers and hauled off-site on a regular basis.~~

- Page II-29. The text in Table II-1, Summary of Environmental Impacts that were Analyzed and Mitigation Measures for Mitigation Measure BIO-5E, is revised as follows:

Impact #	Impact	Significance	Proposed Mitigation
BIO-v	Substantial adverse effects on special-status wildlife species, either directly or through habitat modification	Less than Significant with Mitigation	4) Any viable western pond turtle nests encountered including those with eggs or hatchlings shall be flagged and a 100-ft buffer around the nest shall be designated. If construction activity cannot avoid the nest area, the nest shall be relocated either off site or to an appropriate wildlife care facility. <u>CDFW will be consulted prior to relocating the nest or eggs.</u>

- Page II-30 and II-31. The text in Table II-1, Summary of Environmental Impacts that were Analyzed and Mitigation Measures for Mitigation Measure BIO-5F, is revised as follows:

Impact #	Impact	Significance	Proposed Mitigation
BIO-v	Substantial adverse effects on special-status wildlife species, either directly or through habitat modification	Less than Significant with Mitigation	a) If the tree has no potential to support roosting bats (e.g. no large basal cavities, exfoliating bark<u>,</u> ~~or~~ interstitial spaces<u>, or suitable foliage</u>), the tree may be removed with no further measures required to protect roosting bats. b) If potential bat habitat is present, and work is occurring outside the maternity season, the qualified biologist may either 1.) Conduct an emergence survey to determine if the roost is occupied; or 2.) The tree may be felled using a two-phased cut. i) If the emergence survey confirms the roost is inactive, the tree may be felled normally. ii) If the roost is confirmed active, or is assumed to be active, a two-phased cut shall be employed to remove the tree. On day one the qualified biologist shall oversee removal of branches and small limbs not containing potential bat roost habitat <u>(including large basal cavities, exfoliating bark, interstitial spaces, and suitable foliage)</u> using hand tools such as chainsaws or handsaws only. The next day, the rest of the tree may be removed.

- Page II-31. The text in Table II-1, Summary of Environmental Impacts that were Analyzed and Mitigation Measures, is revised as follows:

Impact #	Impact	Significance	Proposed Mitigation
BIO-v	Substantial adverse effects on special-status wildlife species, either directly or through habitat modification	Less than Significant with Mitigation	Mitigation Measure BIO-5G. Valley Elderberry Longhorn Beetle Prior to Proposed Project Activities that would directly impact occupied elderberry shrubs ~~EIP~~ DWR shall implement the following to avoid impacts to Valley elderberry longhorn beetle (adapted from USFWS 2017[25]): 1) Avoidance and Minimization: To the extent feasible, as determined by DWR, project activities within 165 feet of occupied elderberry shrubs shall be avoided. For all activities that occur within 165 feet of occupied elderberry shrubs, the following measures shall be implemented to ensure that avoidance activities completely avoid impacting elderberry shrub habitat for valley elderberry longhorn beetle: … 2) Transplanting: Where occupied elderberry shrubs cannot be avoided or indirect impacts nearby would result in the death of stems or entire shrubs, ~~EIP~~ DWR shall transplant all elderberry shrubs with stems greater than 1 inch in diameter, where DWR, determines feasible, to protect potential valley elderberry longhorn beetle larvae. In addition, ~~EIP~~ DWR shall use the following guidelines when transplanting elderberry shrubs to a USFWS-approved location: …

- Page II-34 and II-35. The text in Table II-1, Summary of Environmental Impacts that were Analyzed and Mitigation Measures, is revised as follows:

Impact #	Impact	Significance	Proposed Mitigation
BIO-vi	Substantial adverse effects on special-status fish species, either directly or through habitat modification	Less than Significant with Mitigation	Mitigation Measure BIO-6 Special-Status Fish Species Due to the potential for adverse impacts to listed and special-status fish species, consultation and permitting with the USFWS, NMFS, and CDFW is required. As part of the permitting process, consultation with USFWS, NMFS, and CDFW shall be completed and ~~the Applicant/~~DWR shall implement all requirements in the Proposed Project Biological Opinions, Incidental Take Permit, Lake and Streambed Alteration Agreement, as well as water quality protection measures required in the Section 401 Water Quality Certification. The following measures shall be implemented prior to and during construction to avoid or minimize impacts to protected fish species: 1) Implement Mitigation Measure BIO-3 (WEAP). 2) In-water work outboard of the SPFC levees shall be completed between June 1 and October 31. In-water work on the outboard side of existing levees shall only occur outside the work window if a cofferdam separates the work area from the channel. 3) If sheet piles are used to construct a cofferdam, a vibratory hammer shall be used to start the installation of each pile and shall be used as long as geotechnical conditions permit. A vibratory hammer shall be used to remove the sheet pile. If an impact hammer is necessary to complete sheet pile installation, a "soft start" will be implemented. This method entails gradually increasing energy and frequency of impacts to permit wildlife to vacate the surrounding area. …

Impact #	Impact	Significance	Proposed Mitigation
BIO-vi (cont.)			7) Levee excavation shall be conducted in a manner to minimize erosion and excavated material from entering Shag Slough, Cache Slough, or Hass Slough. 8) All cofferdam installation, removal, and final breaching activity shall be limited to daylight hours (sunrise to sunset). 9) During the systematic dewatering of interior channels, an agency-approved biologist will inspect channels for stranded, native aquatic wildlife and fish. Should stranded, native aquatic wildlife or fish be detected, the approved biologist will use a net or other suitable gear to rescue the individual(s). Native fish and aquatic wildlife will be placed in a suitable container and kept in good condition until they can be relocated to the closest suitable aquatic habitat. CDFW will be consulted to determine how non-native fish and wildlife will be disposed of or relocated. 10) Before conducting any pond dewatering operations CDFW will be consulted regarding Wakasagi.

- Page II-34 and II-35. The text in Table II-1, Summary of Environmental Impacts that were Analyzed and Mitigation Measures, is revised as follows:

Impact #	Impact	Significance	Proposed Mitigation
CUL-i.	Substantial adverse changes in the significance of an archaeological resource pursuant to Section 15064.5	Less than Significant with Mitigation	~~No mitigation is proposed.~~ Mitigation Measure CULT-1A: Preconstruction Cultural Resource Sensitivity Training Prior to any ground disturbing activities, DWR shall require cultural sensitivity training be conducted for the construction crews, environmental monitors and other individuals conducting field activities and geological analysis to ensure awareness about cultural resources and tribal cultural resources, including identification of and proper protocol for handling any unexpected finds. Sensitivity training for tribal cultural resources will be administered by a member of the Yocha Dehe Wintun Nation. Mitigation Measure CULT-1B: Stop Work for Accidental Archaeological Discoveries If pre-contact or historic-era archaeological resources are encountered by construction personnel during project construction, all construction activities within 100 feet shall halt until a qualified archaeologist, defined as one meeting the Secretary of the Interiors Standards for Archeology, can assess the significance of the find. Pre-contact archaeological materials might include obsidian and chert flaked-stone tools (e.g., projectile points, knives, scrapers) or toolmaking debris; culturally darkened soil (midden) containing fire-affected rock, artifacts, or shellfish remains; and groundstone artifacts (e.g., mortars, pestles, handstones); battered stone tools, such as hammer stones and pitted stones. Historic-era materials might include stone, concrete, or adobe footings and walls; filled wells or privies; and deposits of metal, glass, and/or ceramic refuse. If it is determined that the Proposed Project could damage a unique archaeological resource, construction shall cease in an area determined by a qualified archaeologist until a mitigation plan has been prepared and implemented to the satisfaction of the qualified archaeologist, DWR, the lead federal agency as applicable, and, if the resource is indigenous, relevant Native American representatives. The mitigation plan shall recommend preservation in place, or, if preservation in place is not feasible, data recovery through excavation.

Impact #	Impact	Significance	Proposed Mitigation
CUL-i. (cont.)			If preservation in place is not feasible, a qualified archaeologist shall prepare and implement a detailed treatment plan to recover the scientifically consequential information from the resource prior to any excavation at the resource site. The treatment plan shall be prepared in consultation with DWR, the federal lead agency as applicable, and, if the resource is indigenous, relevant Native American representatives. Treatment for most resources would consist of (but would not necessarily be limited to) sample excavation, artifact collection, site documentation, and historical research, with the aim to target the recovery of important scientific data contained in the portion(s) of the significant resource to be impacted by the Proposed Project. The treatment plan shall include provisions for analysis of data in a regional context, reporting of results within a timely manner, curation of artifacts and data at an approved facility, and dissemination of reports to local and state repositories, libraries, and interested professionals.

- Page II-38. The text in Table II-1, Summary of Environmental Impacts that were Analyzed and Mitigation Measures, is revised as follows:

Impact #	Impact	Significance	Proposed Mitigation
HAZ-ii	Significant hazards to the public or the environment through reasonably foreseeable upset and accident conditions involving the release of hazardous materials into the environment	Less than Significant with Mitigation	**d. Mitigation Measure HAZ-1: Natural Gas Well and Pipeline Abandonment and Avoidance** Prior to the start of construction, ~~EIP~~ DWR shall develop plans and procedures for natural gas well and pipeline ~~abandonment and~~ avoidance and potential re-abandonment during construction, which may include but are not limited to re-abandonment, plugging, removal, or avoidance of on-site natural gas pipelines and wells. These procedures shall be incorporated into final construction plans provided to ~~DWR and~~ DOGGR prior to the start of ground disturbance and shall describe what work, if any, would be performed on each well and/or pipeline and which wells and/or pipelines would be avoided during site excavation. In addition, a Registered Petroleum Engineer would be on call during re-abandonment, plugging or removal of any pipelines.

- Page II-38. The text in Table II-1, Summary of Environmental Impacts that were Analyzed and Mitigation Measures, is revised as follows:

Impact #	Impact	Significance	Proposed Mitigation
HYDRO-i	Violation of water quality standards or waste discharge requirements or substantial degradation of surface or groundwater quality	Less than Significant with Mitigation	Mitigation Measure HYDRO-1: Project coverage shall be obtained under the National Pollutant Discharge Elimination System (NPDES) Construction General Permit, including preparation of a Stormwater Pollution Prevention Plan (SWPPP), prior to commencement of construction. ~~The contractor in charge of the Proposed Project construction shall obtain the NPDES permits required for construction and discharge of dewatering prior to the start of construction activities.~~

- Page II-43. The text in Table II-1, Summary of Environmental Impacts that were Analyzed and Mitigation Measures, is revised as follows:

Impact #	Impact	Significance	Proposed Mitigation
TCR-i	Adverse change in the significance of a tribal cultural resource that is listed or eligible for listing in the California Register of Historical Resources, or in a local register of...	Less than Significant with Mitigation	Mitigation Measure TCR-1A: ~~Preconstruction Cultural Resource Sensitivity Training~~ Implement Mitigation Measure CULT-1A. Mitigation Measure TCR-1~~A~~B: Stop Work for Accidental Discoveries… Mitigation Measure TCR-1~~B~~C: Tribal Cultural Resources Management Plan

Chapter III, Project Description

- Page III-6. The first full paragraph is revised as follows:

  In the Cache Slough Complex, levee maintenance responsibilities are shared among DWR~~, the Corps,~~ and local reclamation districts (RDs), with the CVFPB providing assurances to the Corps for operations and maintenance of SPFC levees. …

- Page III-34. The text at the top of the page is revised to clarify that the Proposed Project would not require relocating water utilities:

  … buildings, and storage units. The Proposed Project would not remove, cause to be removed, or otherwise relocate water infrastructure, including diversions, located on property outside of the Proposed Project Site. Approximate removal quantities are outlined in Table III-2.

- Page III-35. The first paragraph in the discussion on *Road Vacation and Movement of Private Utilities* is revised as follows:

  The Proposed Project Site is presently accessed via Liberty Island Road. Near the southeastern terminus of Liberty Island Road, the Shag Slough Bridge provides pedestrian access to ~~the Reserve~~ a small portion of the western shoreline of Shag Slough in the Reserve where bank fishing is allowed. The Proposed Project would vacate Liberty ~~Farm~~ Island Road from the ~~northwest~~ northeast corner of the project to the Shag Slough Bridge.

- Page III-35. The second paragraph in the discussion on *Road Vacation and Movement of Private Utilities* is revised as follows:

  The Proposed Project would provide non-public internal access to the Duck Slough Setback Levee, Cache/Hass Slough Training Levee, Cross Levee, and the northern section of the degraded Shag Slough Levee. A gate would be installed at the ~~northwest~~ northeast corner of the Project Site on the southern side of Liberty Island Road at Shag Slough in order to restrict public pedestrian and vehicular access to the Project Site. Internal access would include a network of internal roads along the top and toes of the levees and PG&E access peninsulas for maintenance, monitoring, and emergency services.

- Page III-39. The following text is added to describe construction methods for the installation of the Duck Slough setback levee cutoff wall:

    Duck Slough Setback Levee Cutoff Wall Construction

    A soil-bentonite shallow cutoff wall will be constructed under the Duck Slough Setback Levee to reduce nuisance seepage potential by intersecting intermittent, discontinuous higher permeable soil layers in the upper 20 feet of ground. In general, the soil conditions underlying the Duck Slough Setback Levee alignment consist of a relatively thick layer of clay which allows little to no groundwater movement, with some discontinuous permeable soils with limited localized shallow groundwater movement. This localized source of groundwater is not connected to a larger aquifer.

    The wall will extend only 35-feet-deep along the majority of the alignment, with an exception where it will extend to a 50-foot depth for about 2,000 feet of the alignment to address an anomalous, isolated shallow pervious layer. The wall will be constructed along the centerline of the Duck Slough Setback Levee, before construction of the Levee itself. The existing ground will be cleared, and an excavator with a long stick excavator boom will dig a 3-foot wide trench to the specified depth. A bentonite slurry will then be used to fill in the trench during trench excavation. The excavated soil will be mixed with bentonite slurry and then placed back in the trench. After a specified time-frame, approximately two weeks, the levee embankment will then be constructed. Prior to construction, the Spill Prevention Countermeasure and Control Plan (SPCC) will be in place to deal with any spills or erosion.

Chapter IV, Environmental Impact Analysis

Section A – Impacts Found to Be Less Than Significant

- Page IV.A-8. The following text is added after the last paragraph in item i:

    Land-use change was also considered in assessing potential impacts of the Proposed Project effect on GHGs. Under existing conditions, annual soil sequestration, CO2 emissions, and CH4 emissions result in 42,051 tonnes CO2 equivalents emitted per year from the Proposed Project site; a reduction of 38,701 tonnes CO2 equivalents than under existing conditions. Additionally, post-restoration biomass would be expected to increase by 16,127 tonnes CO2 equivalent, decreasing GHGs even more during Proposed Project operations.[2] Impacts would be less than significant.

- Page IV.A-19. The text in paragraph one is revised as follows:

    DWR~~EIP~~ proposes levee modifications, tidal channel excavation, and other activities which would restore tidal marsh complex and improve Yolo Bypass flood conveyance within the Proposed Project Site.

2 ESA. 2020. Memorandum from Linsey Sheehan, ESA to Erick Cooke, ESA. Subject: Lookout Slough Change in Operational GHG. April 28, 2020.

- Page IV.A-19. The text in paragraph five is revised as follows:

  i. *Direct and indirect inducement of substantial unplanned population growth*

  DWR ~~EIP~~ proposes levee modifications, tidal channel excavation, and other activities which would restore tidal marsh complex and improve Yolo Bypass flood conveyance within the Proposed Project Site.

Section B – Agriculture and Forestry

- Page IV.B-1. The last sentence in the 2nd paragraph is revised as follows:

  A Checklist was prepared for the Proposed Project and is included in Appendix ~~B~~ E of this Draft EIR.

- Page IV.B-6. The following text is added following the first paragraph:

  The Williamson Act requires that public agencies considering acquiring interests in land within an agricultural preserve, and that the interest or interests would be used for a public purpose, shall provide notice to the local government agency responsible for administering the preserve and to the Director of Conservation. (Cal. Gov. Code § 51291.)

- Page IV.B-12. The following text is added to Mitigation Measure AG-1a (Off-Site Agricultural Improvements):

  Improvements would be selected in coordination with the property owner(s) and/or their agricultural lessees in a manner which best improves the agricultural viability and drainage in this part of Solano County.

- Page IV.B-12. The following text in Mitigation Measure AG-1b (Agricultural Conservation Easement) is revised as follows:

  ~~The Applicant~~ DWR, shall cause to be established an off-site agricultural preserve by placing a conservation…"

Section C – Air Quality

- Page IV.C-13. The text in the fourth bulleted paragraph is revised as follows:

  Mitigation Measure AIR-1: Construction Equipment Standards

  b) Engine Requirements

  - ~~If commercially available, the~~All ~~engines of the~~ diesel off-road equipment shall have engines that meet the ~~USEPA or CARB~~ Tier 4 Final off-road emission standards, as certified by CARB. The equipment that shall use Tier 4 Final engines may include, but are not limited to: compactors, rollers, bulldozers, excavators, motor graders, scrapers equivalent to the Caterpillar 631K Wheel Tractor-Scraper model, and off-road haul vehicle~~truck~~s. This requirement shall be verified through submittal of an equipment inventory that includes the following information: (1) Type of Equipment, (2) Engine Year and Age, (3) Number of Years Since Rebuild of Engine (if applicable), (4) Type of Fuel Used, (5) Engine HP, (6) Verified Diesel Emission Control

Strategy (VDECS) information if applicable and other related equipment data. A Certification Statement by the Contractor shall be required to be submitted to DWR, for documentation of compliance and for future review by the air district upon request. The Certification Statement must state that the Contractor agrees to compliance and acknowledges that a violation of this requirement shall constitute a material breach of contract.

- TheEquipment requirements above may be waived by the project director of EIP orDWR may waive the equipment requirement above , but only under any of the following unusual or emergency circumstances: if a particular piece of off-road equipment with Tier 4 Final standards or Tier 3 standards is not technically feasible or not commercially available; the equipment would not produce desired emissions reduction due to expected operating modes; use or installation of the equipment would create a safety hazard or impaired visibility for the operator; or there is a compelling emergency need to use other alternate off-road equipment. that does not meet the equipment requirements, abovethe project director of EIP or If DWR grants the waiver based on one or more of the above unusual circumstances, the contractor shall use the next cleanest piece of off-road equipment available, as detailed in Table M-AIR-1 belowthe following order: Tier 4 Interim, Tier 3, and then Tier 2 engines.

For purposes of this mitigation measure, "commercially available" shall mean the availability of Tier 4 Final engines similar to the availability for other large-scale construction projects in the region occurring at the same time and taking into consideration factors such as (i) potential significant delays to critical-path timing of construction for the project and (ii) geographic proximity to the Proposed Project Site of Tier 4 Final equipment.

The Contractor shall maintain records concerning its efforts to comply with this requirement.

Table M-AIR-1A details the off road compliance step down approach. If engines that comply with Tier 4 Final off-road emission standards are not commercially available, then the Contractor shall meet Compliance Alternative 1. If off-road equipment meeting Compliance Alternative 1 are not commercially available, then the Project sponsor shall meet Compliance Alternative 2. If off-road equipment meeting Compliance Alternative 2 are not commercially available, then the Project sponsor shall meet Compliance Alternative 3 as demonstrated below.

TABLE M-AIR-1
OFF ROAD EQUIPMENT COMPLIANCE STEP DOWN APPROACH

Compliance Alternative	Engine Emissions Standard	Emissions Control
1	Tier 4 Interim	N/A
2	Tier 3	ARB Level 3 VDECS
3	Tier 2	ARB Level 3 VDECS

In seeking a waiver from this requirement, it must be demonstrated to the satisfaction of DWR that the total annual ROG and NOx emissions do not exceed a total of 10 tons per year. Additionally, it must also be demonstrated that the average daily PM_{10} emissions do not exceed 80 pounds per day for PM_{10} to meet YSAQMD's significance thresholds as stated in **Table IV.C-4 on the previous page.**

- Page IV.C-13. The text in Mitigation Measure AIR-2 (Dust Control) is revised as follows:

Contractors for construction of the Proposed Project DWR shall implement all of the following applicable dust control measures …

Section D – Biological Resources

- Page IV.D-43. The last paragraph is revised as follows:

…Among other things, CESA requires state agencies to coordinate with CDFW to ensure that state-authorized or state-funded projects or actions do not jeopardize a state-listed species. …

- Page IV.D-44. The first paragraph is revised as follows:

The beds and banks of rivers, sStreams, and lakes, and riparian vegetation as habitat for fish and wildlife, are subject to CDFW jurisdiction under Section 1602 of the California Fish and Game Code. A 1602 Lake and Streambed Alteration Agreement is generally required for any activity that will have one or more of the following effects:
(1) substantially obstruct or divert the natural flow of a river, stream, or lake;
(2) substantially change or use any material from the bed, channel, or bank of a river, stream, or lake; or (3) deposit or dispose of debris, waste, or other material containing crumbled, flaked, or ground pavement where it can pass into a river, stream, or lake. The term "stream", which includes creeks and rivers, is defined in the California Code of Regulations as follows: "a body of water that flows at least periodically or intermittently through a bed or channel having banks and supports fish or other aquatic life". This includes watercourses having a surface or subsurface flow that supports or has supported riparian vegetation" (California Code of Regulations Title 14, Section 1.72). In addition, the term stream can include ephemeral streams, dry washes, watercourses with subsurface flows, canals, aqueducts, irrigation ditches, and other means of water conveyance if they support aquatic life, riparian vegetation, or stream-dependent terrestrial wildlife.[15] Riparian is defined as "on, or pertaining to, the banks of a stream;" therefore, riparian vegetation is defined as, "vegetation which occurs in and/or adjacent to a stream and is dependent on, and occurs because of, the stream itself".[16] Removal of riparian vegetation also requires a Section 1602 Lake and Streambed Alteration Agreement from the CDFW.

- Page IV.D-46 after the first paragraph. The following text is added to the Draft EIR:

viii. Sacramento-San Joaquin Delta Mercury Control Program (DMCP) and Methylmercury Total Maximum Daily Load (TMDL)

The waterways in the Delta are subject to site-specific methylmercury fish tissue objectives, the DMCP, and monitoring provisions which apply to all Delta waterways, Yolo Bypass waterways within the Delta, and also those north of the Legal Delta boundary to which the commercial beneficial use applies. The DMCP is designed to protect people eating one meal/ week of trophic levels 3 and 4 Delta fish and some non-Delta commercial market fish. The

DMCP identifies the waterways in the legal Delta and Yolo Bypass, up to the Fremont weir, subject to the regulation. The amendment uses a phased, adaptive management approach. Among other actions, the first phase focuses on conducting control or characterization studies to identify potential control mechanisms participants of the DCMP can attain load and waste load allocations specified in the DMCP. The Delta Methylmercury TMDL was adopted by the Central Valley Water Board on April 22, 2010. Final approval by the USEPA was received on October 20, 2011.

- Page IV.D-51. Mitigation Measure BIO-1 is revised to include monitoring and performance of the planted areas as follows:

Mitigation Measure BIO-1. Re-Plant Riparian Vegetation at a ~~1.1:1~~ 3:1 Ratio for Riparian Woodland and 1.5:1 Ratio for Riparian Scrub

To compensate for Proposed Project impacts to riparian habitat the Proposed Project shall:

1) Avoid a long-term net loss of riparian habitat, and
2) Mitigate for direct impacts to riparian woodland at a ~~1:1~~ 3:1 ratio, and for impacts to riparian scrub at a 1.5:1 ratio. Mitigation would be achieved through on-site planting of riparian woodland and scrub habitats. The condition of planted riparian habitats will be monitored for a minimum of 1-year after planting to ensure the successful establishment of habitat that is dominated by native riparian vegetation. If mortality of riparian plantings reduces the amount of established riparian habitat to less than what is required to achieve the above ratios, replanting will be implemented to ensure the successful establishment of native riparian habitats sufficient to achieve the required acreage.

- Page IV.D-54. The text in Mitigation Measure BIO-2 (Special-Status Plant Avoidance, Preservation, and Re-Planting) is revised as follows:

5) Performance shall be monitored to evaluate success of replacement of special-status species habitat. Target replacement shall be at a minimum 1:1 ratio of impacted to established habitat acreage for each of the directly impacted special-status plant species. Success would be considered achieved when an equal area of habitat is occupied at a plant density similar to pre-project conditions. Monitoring shall be conducted for a minimum of three growing seasons following initial planting or until performance has been achieved. If individuals of Mason's lilaeopsis are newly detected during pre-construction surveys in areas to be impacted by Proposed Project activities and DWR determines that complete avoidance is not feasible, ~~EIP~~DWR shall consult with CDFW prior to the start of construction to obtain authorization for project implementation and develop an appropriate type and amount of compensatory mitigation. Mitigation shall be provided at a minimum 1:1 ratio of impacted individuals to replanted; final mitigation ratios and other specific compensatory requirements shall be determined through consultation with CDFW.

- Page IV.D-56. The text in Mitigation Measure BIO-4 (Invasive Plant Species Abatement) is revised as follows:

2) Where determined necessary to control identified weed populations, target weed infestations shall be treated according to control methods and practices considered appropriate for those species.

3) Weed control treatments shall include all legally permitted herbicide, manual, and mechanical methods, approved for aquatic use by the U.S. Environmental Protection Agency and California Department of Pesticide Regulation. The application of herbicides shall be in compliance with all state and federal laws and regulations under the prescription of a Pest Control Advisor and implemented by a Licensed Qualified Applicator.

4) The timing of weed control treatment shall be determined for each target plant species with the goal of controlling populations. During post-construction operation of the Proposed Project, DWR shall monitor for the presence of invasive aquatic plant species in accordance with BIO-4(1). Invasive aquatic plant species shall be removed in accordance with BIO-4(2) and (3). Post-construction monitoring shall occur following the implementation of any procedures used to remove invasive aquatic plants to ensure that the procedures are effective.

- Page IV.D-58. The text in Items 2 and 4 of Mitigation Measure BIO-5A (Nesting Birds**)** is revised as follows:

2) To the extent feasible, vegetation removal and initial ground disturbance shall occur from September 1 through January 31 so that initial ground disturbing work occurs outside of the general nesting bird season. If vegetation removal and initial ground disturbance occurs during the general nesting bird season, DWR will consult with CDFW and implement necessary measures.

4) All active nests of native birds found during the survey shall be protected by a no-disturbance buffer until all young from each nest fledge or the nest otherwise becomes inactive. The size of each buffer shall be determined by an agency-approved, qualified biologist dependent upon extant conditions, including individual bird behavior, baseline disturbance, level of construction, and physical factors such as visual obstruction and ~~may~~will require consultation with the CDFW. Buffers are typically a minimum of 50 feet for non-special-status birds and may be larger for special-status or raptor species.

- Page IV.D-59. The last sentence of the 2nd paragraph is revised as follows:

~~Typically, a 0.25-mile avoidance buffer around Swainson's hawk nests is sufficient to protect against nest abandonment when the species is exposed to stimuli such as construction-related noise, visual disturbance, and dust.~~

- Page IV.D-60. Mitigation Measure BIO-5B is revised as follows:

Mitigation Measure BIO-5B. Swainson's Hawk Nesting and Foraging Habitat

~~Due to the potential for adverse impacts to Swainson's hawk, consultation and permitting with CDFW may be required if reduced buffers during the nesting season are necessary for construction activities. If permitting for potential take of Swainson's hawk is determined to be necessary, EIP shall consult with CDFW and implement all avoidance and minimization measures as required in the Proposed Project Incidental Take Permit and Lake and Streambed Alteration Agreements. In addition, t~~The following measures shall be implemented prior to and during construction to avoid ~~or minimize~~ impacts to Swainson's hawk:

1) In each year that Proposed Project activities occur during Swainson's hawk nesting season, two surveys shall be conducted within each of nest season Phases II and III[3] as described below:

    a) In the first year of construction:

        (i) If Proposed Project activities ~~work has been initiated~~ begin prior to March 20 (prior to the nesting season for Swainson's hawk), two surveys each shall be conducted within Phases II (March 20-April 5) and Phase III of the nesting season (April 5 - May 20) to determine if nests have established during Proposed Project activities.

        (ii) If Proposed Project activities ~~work~~ begin~~s~~ between March 20 and April 5 (Phase II) at least one of the two surveys within Phase II shall be conducted prior to the start of ground disturbing activities. Two surveys shall also be conducted between April 5 – April 20 (Phase III).

        (iii) If Proposed Project activities ~~work~~ begin~~s~~ in Phase III, two surveys shall be conducted in Phase II and at least one survey in Phase III shall be conducted prior to start of ground disturbing activities.

    b) In the second or third year of Proposed Project activities ~~construction~~, two surveys shall be conducted within each of the Phases II and III windows identified above.

    c) Surveys shall be conducted within 0.~~2~~5-mile of planned work areas during the nesting season.

        (i) If a nest is determined to be active and ~~ground disturbance~~ work has not yet been initiated, an appropriate buffer up to a 0.~~2~~5-mile (~~1,320~~2,640-foot) radius shall be established in consultation with CDFW. If ~~ground disturbance~~work has been initiated and a Swainson's hawk establishes a nest after ~~construction~~ work has been initiated, a 500-foot buffer shall be established around the nest tree.

    d) Following surveys, monthly checks shall be conducted in May, June, and July to provide status updates on any active nests. If a nest is determined to have become inactive, the nest buffer would be removed.

    ~~e) If a smaller buffer is sought, CDFW shall be consulted and the methods described below (Item 2) shall be instituted in addition to any measures requested by CDFW in approving the reduced buffer.~~

~~2) Reduced buffer: If construction will occur within 0.25-mile of an active Swainson's hawk nest site (and the nest was established prior to initial construction in the area) or within 500 feet of an active Swainson's hawk nest established during construction, the following additional measures shall be implemented:~~

    ~~a) Staging areas for equipment, materials, and work personnel shall be located 0.25-mile away from active Swainson's hawk nest sites. These areas shall be flagged and identified to all work personnel during employee orientation.~~

3 California Department of Fish and Game, Swainson's Hawk Technical Advisory Committee, "Recommended Timing and Methodology for Swainson's Hawk Nesting Surveys in California's Central Valley" (Sacramento, May 31, 2000), https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=83990&inline.

~~b) For nests established during construction, if construction needs to occur within 500 feet of an active Swainson's hawk nest, no construction shall occur prior to 8:00 AM, and shall be discontinued by 5:00 PM each day.~~

~~c) If work needs to occur temporarily within any buffer, a qualified biologist shall monitor active nests daily for signs of disturbance for the duration of the construction activity. If it is determined that Proposed Project-related activities are resulting in nest disturbance, then work in those sensitive areas shall cease immediately and the 0.25-mile buffer or 500-foot buffer (for nests in ongoing work areas) shall be re-established. CDFW shall then be contacted for further guidance.~~

- Page IV.D-71. The following text changes are made to Mitigation Measure BIO-5D:

4~~5~~) A speed limit of 15 mph shall be observed in areas within 200 feet of areas designated as suitable giant garter snake aquatic habitat by a qualified biologist.

5) If a giant gartersnake is observed in the construction area, all activities within the immediate area of the snake will cease, and the qualified biologist will be notified immediately. The qualified biologist will follow procedures for the relocation approved by USFWS and CDFW.

6) ~~The applicant~~ DWR will procure a conservation easement for 57 acres of GGS upland and winter refugia habitat in the vicinity of the Proposed Project Site or, if required as part of regulatory permitting, buy credits at a CDFW-approved conservation bank in an amount equal to 57 acres.

- Page IV.D-72. The following text is added to the middle of the 2nd paragraph:

Under existing conditions, the Project Site has 246 acres of potential nesting habitat for WPT. This area represents the portion of non-native grassland habitat identified in Figure IV.D-1 of the DEIR which is not identified as managed wetland in Figure IV.D-2. Following project implementation, the Project Site would have 70 acres of potential nesting habitat for WPT, which is depicted as GGS winter refugia and unmanaged winter refugia on Figure IV.D-3. Additionally, the procurement of a 57-acre offsite conservation easement for GGS upland habitat, as required by Mitigation Measure BIO-5D, will increase the total amount of nesting habitat available to western pond turtle to 127 acres. Overall, the quantity of nesting habitat would be reduced based on exposure to winter flooding upon Proposed Project Site connection with the Yolo Bypass Floodplain. However, the quality of habitat would be improved through reduced human disturbance and through management activities that are expected to promote successful use of the area by western pond turtle for nesting activities. Road traffic mortality and detrimental~~,~~ habitat maintenance activities, including disking, mowing, ~~dredging and~~ berm maintenance, and ~~small mammal management~~ human disturbance, which have all been identified as key factors in the decline of wester pond turtles, would be reduced relative to ~~less than~~ current management regimes, making those habitats managed in the absence of such factors more suitable for western pond turtle nesting. Further, those upland habitats that will be available post-construction for western pond turtle nesting will be closer in proximity to aquatic habitats, allowing for more access by western pond turtles at multiple sites.

- Page IV.D-73. The text in Mitigation Measure BIO-5E is revised as follows:

    4) Any viable western pond turtle nests encountered including those with eggs or hatchlings shall be flagged and a 100-ft buffer around the nest shall be designated. If construction activity cannot avoid the nest area, the nest shall be relocated either off site or to an appropriate wildlife care facility. CDFW will be consulted prior to relocating the nest or eggs.

- Page IV.D-75. The text in Mitigation Measure BIO-5F is revised as follows:

    3) Prior to the removal of any large trees (DBH>16 inches) a bat roost assessment shall be conducted by a qualified biologist at least 30 days beforehand to determine if potential roost habitat is present.

        a) If the tree has no potential to support roosting bats (e.g. no large basal cavities, exfoliating bark, ~~or~~ interstitial spaces, or suitable foliage), the tree may be removed with no further measures required to protect roosting bats.

        b) If potential bat habitat is present, and work is occurring outside the maternity season, the qualified biologist may either 1.) Conduct an emergence survey to determine if the roost is occupied; or 2.) The tree may be felled using a two-phased cut.

            i) If the emergence survey confirms the roost is inactive, the tree may be felled normally.

            ii) If the roost is confirmed active, or is assumed to be active, a two-phased cut shall be employed to remove the tree. On day one the qualified biologist shall oversee removal of branches and small limbs not containing potential bat roost habitat (including large basal cavities, exfoliating bark, interstitial spaces, and suitable foliage) using hand tools such as chainsaws or handsaws only. The next day, the rest of the tree may be removed.

        c) If potential bat roosting habitat is present and work is occurring during the maternity season, the qualified biologist may either 1.) Conduct an emergence survey to determine if the roost is occupied; or 2.) Assume the roost is occupied and a buffer shall be implemented.

            i) If the roost assessment does not detect bats, the tree may be removed normally. If roosting bats are detected, or the tree is assumed to be an active roost, the tree shall be given a 100-foot buffer and shall be avoided until after the maternity roosting season is complete.

- Page IV.D-76. The text in Mitigation Measure BIO-5G (Valley Elderberry Longhorn Beetle) is revised as follows:

    Mitigation Measure BIO-5~~F~~G. Valley Elderberry Longhorn Beetle

    Prior to Proposed Project Activities that would directly impact occupied elderberry shrubs ~~EIP~~ DWR shall implement the following to avoid impacts to Valley elderberry longhorn beetle (adapted from USFWS 2017[25]):

    1) Avoidance and Minimization: To the extent feasible, as determined by DWR, project activities within 165 feet of occupied elderberry shrubs shall be avoided. For all activities that occur within 165 feet of occupied elderberry shrubs, the following

measures shall be implemented to ensure that avoidance activities completely avoid impacting elderberry shrub habitat for valley elderberry longhorn beetle: …

2) Transplanting: Where occupied elderberry shrubs cannot be avoided or indirect impacts nearby would result in the death of stems or entire shrubs, ~~EIP~~ DWR shall transplant all elderberry shrubs with stems greater than 1 inch in diameter, where DWR, determines feasible, to protect potential valley elderberry longhorn beetle larvae. In addition, ~~EIP~~ DWR shall use the following guidelines when transplanting elderberry shrubs to a USFWS-approved location: …

- Page IV.D-81. The first paragraph in Mitigation Measure BIO-6 (Special-Status Fish Species) is revised as follows:

As part of the permitting process, consultation with USFWS, NMFS, and CDFW shall be completed and DWR shall implement all requirements in the Proposed Project Biological Opinions, Incidental Take Permit, Lake and Streambed Alteration Agreement, as well as water quality protection measures required in the Section 401 Water Quality Certification ~~will be implemented~~. …

- Page IV.D-81. The text in Mitigation Measure BIO-6 is revised as follows:

3) If sheet piles are used to construct a cofferdam, a vibratory hammer shall be used to start the installation of each pile and shall be used as long as geotechnical conditions permit. A vibratory hammer shall be used to remove the sheet pile. If an impact hammer is necessary to complete sheet pile installation, a "soft start" will be implemented. This method entails gradually increasing energy and frequency of impacts to permit wildlife to vacate the surrounding area. …

- Page IV.D-82. The following sub-points are added to Mitigation Measure BIO-6:

8) All cofferdam installation, removal, and final breaching activity shall be limited to daylight hours (sunrise to sunset).

9) During the systematic dewatering of interior channels, an agency-approved biologist will inspect channels for stranded, native aquatic wildlife and fish. Should stranded, native aquatic wildlife or fish be detected, the approved biologist will use a net or other suitable gear to rescue the individual(s). Native fish and aquatic wildlife will be placed in a suitable container and kept in good condition until they can be relocated to the closest suitable aquatic habitat. CDFW will be consulted to determine how non-native fish and wildlife will be disposed of or relocated.

10) Before conducting any pond dewatering operations CDFW will be consulted regarding Wakasagi.

- Page IV.D-82. The text in the middle of the first full paragraph in the section on Noise Impediments to Fish Migration is revised as follows:

…This, and other measures specified by Mitigation Measure BIO-3 ~~4B~~, would minimize the likelihood of construction-related noise posing an impediment to fish migration…

- Page IV.D-87. The text in the last paragraph in the section on methylmercury is revised as follows:

  … Total mercury is not anticipated to change as a result of grading or construction.

  However, ~~there could be a short-term increase in methylmercury production during or immediately after construction within the Proposed Project Site, which could be transported to adjacent waterways[49]. A~~a localized increase in water column methylmercury could result in increased levels of mercury bioaccumulation in aquatic organisms, especially top predators like Striped Bass. DWR is conducting both tidal wetland and open water characterization studies to determine if tidal wetlands are a source or sink for mercury and methylmercury and further understanding of how methylmercury is produced in the Yolo Bypass under large flood events. DWR submitted a study of methylmercury flux of tidal wetlands to the CVRWQCB. The report, titled *Mercury Imports and Exports of Four Tidal Wetlands in the Sacramento-San Joaquin Delta, Yolo Bypass, and Suisun Marsh for Delta Mercury Control Program Compliance* (Lee and Manning, April 2020), concluded that the four tidal wetlands studied, which are like the Proposed Project, do not export methylmercury.[49] Therefore, impacts of the Proposed Project would not exceed the applicable threshold of significance related to a substantial adverse effect of methyl-mercury on water quality and food web accumulation and the Proposed Project's impact with regard to this threshold would be ***less than significant.*** ~~For further detail, please see Chapter IV.G, Hydrology and Water Quality.~~

  ~~49 *Valoppi, L., 2018, Phase 1 studies summary of major findings of the South Bay Salt Pond Restoration Project, South San Francisco Bay, California: U.S. Geological Survey Open-File Report 2018–1039, 58 p., plus appendixes, https://doi.org/10.3133/ofr20181039.*~~

  49 DWR. 2020. *Mercury Imports and Exports of Four Tidal Wetlands in the Sacramento-San Joaquin Delta, Yolo Bypass, and Suisun Marsh for Delta Mercury Control Program Compliance*. April 2020.

Section E – Cultural Resources

- Page IV.E-7. The text in the third paragraph is revised as follows:

  The reclaimed land established the Liberty Farms Company on an area spanning two ~~islands~~ areas– the western ~~island~~ Upper Liberty (which includes the current Proposed Project Site, but not the Bowlsbey Property) and the eastern island (Liberty Island, which now encompasses the Liberty Island Ecological Reserve).

- Page IV.E-7. The text in the fifth paragraph is revised as follows:

  However, this levee ~~continuously failed~~ experienced multiple instances of subsidence and sloughing through its history, as described above under "Levee Unit 109.

- Page IV.E-23. The following mitigation measure is added just prior to Mitigation Measure CULT-1: Stop Work for Accidental Archaeological Discoveries:

  Mitigation Measure CULT-1A: Preconstruction Cultural Resource Sensitivity Training

  Prior to any ground disturbing activities, DWR shall require cultural sensitivity training be conducted for the construction crews, environmental monitors and other individuals conducting field activities and geological analysis to ensure awareness about cultural resources and tribal cultural resources, including identification of and proper protocol for handling any unexpected finds. Sensitivity training for tribal cultural resources will be administered by a member of the Yocha Dehe Wintun Nation.

- Page IV.E.23. Mitigation Measure CULT-1 is re-numbered as follows:

Mitigation Measure CULT 1B: Stop Work for Accidental Archeological Discoveries

Section F – Hazards and Hazardous Materials

- Page IV.F-15. The text in the first full paragraph is revised as follows:

Prior to the start of construction, ~~EIP~~DWR shall develop plans and procedures for natural gas well and pipeline ~~abandonment and~~ avoidance and potential re-abandonment during construction, which may include but are not limited to re-abandonment, plugging, removal, or avoidance of on-site natural gas pipelines and wells. These procedures shall be incorporated into final construction plans provided to DOGGR prior to the start of ground disturbance and shall describe what work, if any, would be performed on each well and/or pipeline and which wells and/or pipelines would be avoided during site excavation. In addition, a Registered Petroleum Engineer would be on call during re-abandonment, plugging or removal of any pipelines.

Section G – Hydrology and Water Quality

- Page IV.G-7. The 3rd full paragraph is revised as follows:

Flood control operations and river flow play an important role in determining the flow of water through the Cache Slough Complex. During winter months the Yolo Bypass contributes flows through ~~design capacity of~~ the Cache Slough Complex up to 500,000 cubic feet per second (cfs) ~~flow contributing to the system~~. In contrast, during the summer, tidal forces and agricultural and municipal diversions (e.g., Barker Slough pumping plant) heavily influence the flow of the Cache Slough Complex, which tends to experience a net upstream flow~~. Diversions in the area further contribute, ultimately leading to a net flow of~~ up to 3,000 cfs~~ upstream~~. This may result in longer residence times and reduced mixing between regional and downstream waters.

- Page IV.G-7. The last paragraph is revised as follows:

Diversions near the Proposed Project Site include the nearby RD 2068 agricultural diversion, the State Water Project's Barker Slough Pumping Plant, the City of Vallejo's Cache Slough Pumping Plant, and private agricultural diversions.

- Page IV.G-16. The following text is added to the first incomplete sentence on the page:

of tidal wetlands and floodplains with respect to mercury and methylmercury production.[34,35,36] Please see Section IV.D, *Biological Resources* for analysis of impacts related to methylmercury.

- Page IV.G-17. The following text is added to the local regulatory setting:

  iii. Solano County Grading Ordinance

  The Solano County Code Chapter 31 was adopted to provide the means for controlling soil erosion, sedimentation, and increased rates of water runoff in order to protect downstream waterways and wetlands and to promote the safety, public health, convenience and general welfare of the community. The ordinance establishes standard methods to prevent off-site erosion.

- Page IV.G-20. Mitigation Measure HYDRO-1 is revised as follows:

  Mitigation Measure HYDRO-1: Project coverage shall be obtained under the National Pollutant Discharge Elimination System (NPDES) Construction General Permit, including preparation of a Stormwater Pollution Prevention Plan (SWPPP), prior to commencement of construction. ~~The contractor in charge of the Proposed Project construction shall obtain the NPDES permits required for construction and discharge of dewatering prior to the start of construction activities.~~

Section K – Tribal Cultural Resources

- Page IV.K-11. The following mitigation measure is added just prior to Mitigation Measure TCR-1A:

  Mitigation Measure TCR-1A: Preconstruction Cultural Resource Sensitivity Training.

  Implement Mitigation Measure CULT-1A.

- Page IV.K-11 and 12. Mitigation Measures TCR-1A and TCR-1B are renumbered as follows:

  Mitigation Measure TCR-1~~A~~B: Stop Work for Accidental Discoveries

  Mitigation Measure TCR-1~~B~~C: Tribal Cultural Resources Management Plan

Chapter V, Cumulative Impacts

- Page V-9. The text between the first and second paragraphs on this page is revised as follows:

  When combined with other related projects in the Delta, many of which would also be freshwater tidal restoration projects, the anticipated increased methylmercury production, export, and bioaccumulation resulting from the Proposed Project would be low. Given the less-than-significant Project-specific impact, and findings of the DWR (2020) report titled *Mercury Imports and Exports of Four Tidal Wetlands in the Sacramento-San Joaquin Delta, Yolo Bypass, and Suisun Marsh for Delta Mercury Control Program Compliance* that tidal wetlands are not exporting methylmercury, the cumulative impact of methylmercury is not significant and there would be no incremental contribution from the Proposed Project.

- Page V-9. The text in the middle of the last paragraph is revised as follows:

  Projects that ~~would~~may have an overlapping construction period with the Proposed Project include phase two of the Dutch Slough Tidal Habitat Restoration Project, the Prospect Island Restoration Project, and the Lower Yolo Ranch Restoration Project.

- Page V-10: The text at the top of the page is revised to include the following:

  The Proposed Project is designed to favor native fish species while discouraging establishment and colonization by non-native species. The Proposed Project also includes invasive species control during the construction stage, as discussed on Draft EIR pages III-23, III-29, and III-33. In addition, the Proposed Project would include post-construction monitoring of invasive aquatic plant species. Therefore, the Proposed Project would incorporate greater invasive species control than what is undertaken in surrounding sloughs under baseline conditions. Thus, the Proposed Project would not have a cumulatively considerable contribution to the proliferation of invasive aquatic species.

- Page V-13. The text immediately beneath the heading "Water Quality" is revised as follows:

  Current farming practices, under baseline conditions, use pesticides and fertilizers that can contribute residual levels of chemicals in irrigation and other site runoff which can adversely affect receiving water quality. Such practices would end prior to construction of the Proposed Project, decreasing potential inputs that might contribute to water quality issues over time as part of the cumulative scenario. Additionally, the emergence of increased concentrations of HABs is indicative of potential problems with water stagnation. The Proposed Project would reintroduce tidal influence to the Project Site, reducing water stagnation. Therefore, the Proposed Project is expected to have a positive influence on water quality by eliminating agricultural inputs and by reducing stagnation that contribute to the proliferation of HABs and other aquatic invasive species. As a result, the Proposed Project would not have a cumulatively considerable contribution to cumulative water quality effects, including the proliferation of HABs.

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CHAPTER 3
Responses to Comments

3.1 Introduction

This chapter contains written responses to all comments received by DWR from agencies and the public on the Draft EIR. The information included in responses to comments clarify, amplify, or make insignificant modifications to the Draft EIR. These responses do not identify any new significant effects on the environment or a substantial increase in the severity of an environmental impact requiring major revisions to the Draft EIR that would require recirculation. Table 3-1 lists all of the parties who submitted comments on the Draft EIR during the public comment period.

TABLE 3-1
LIST OF COMMENTERS

Letter #	Commenter
1	California Department of Toxic Substances Control
2	California Department of Fish and Wildlife, Bay Delta Region
3	Central Valley Flood Protection Board
4	Delta Protection Commission
5	Delta Stewardship Council
6	Central Valley Regional Water Quality Control Board
7	Yocha Dehe Wintun Nation
8	Contra Costa Water District, Solano County Water Agency, City of American Canyon, City of Vallejo
9	North Delta Water Agency
10	Central Delta Water Agency
11	Contra Costa Water District
12	Downey Brand on behalf of RD 2060, RD 2068, California Central Valley Flood Control Association, North Delta Water Agency
13	Solano County Department of Resource Management
14	Solano County Water Agency
15	Soluri Meserve on behalf of the Local Agencies of the North Delta and RD 501
16	City of Vallejo
17	West Sacramento Area Flood Control Agency
18	Westlands Water District
19	RD 2068
20	Transcript from January 22, 2020 Public Meeting

3.2 Master Responses

Because multiple comments were received that addressed a number of key issues, DWR prepared comprehensive responses addressing these issues (master responses). Each master response provides background regarding the specific issue, how the issue was addressed in the Draft EIR, and additional clarification and explanation as appropriate to address the comments. In addition, each master response includes a list of the individual responses that the master response addresses. The following master responses were prepared for this Final EIR:

1. Salinity and Bromide
2. Farmland
3. Local Water Diversions and Special-Status Fish Species
4. Piecemealing
5. Cumulative Impact Analysis
6. Methylmercury
7. Operation and Maintenance (O&M) of Levees
8. Dissolved Organic Carbon
9. Tidal Effects on Diversions
10. Recreation
11. Good Neighbor Checklist
12. Not a Comment on the Adequacy of the EIR and Economic and Social Impacts
13. Performance Standards and Deferred Mitigation
14. Invasive Plant Species and Harmful Algal Blooms

Master Response #1: Salinity and Bromide

This Master Response responds to the following comments: 5-5, 8-1, 8-2, 8-4, 9-1, 9-4, 9-5, 9-9, 10-2, 10-3, 10-5, 11-1, 11-2, 11-3, 12-2, 12-15, 12-16, 12-22, 12-23, 12-24, 12-25, 12-31, 13-3, 13-9, 13-22, 13-23, 13-24, 13-25, 13-26, 13-27, 13-28, 14-1, 14-3, 14-4, 14-5, 14-10, 15-1, 15-3, 15-4, 16-1, 16-2, 16-3, 16-4, 19-7, and 20-8.

Comments raised questions regarding the analysis for potential salinity impacts to water quality and the findings that the Proposed Project would have less than significant impacts as a result of salinity changes. Specifically, comments included: significance standards for analyzing impacts on water quality; modeling approach; model configuration and reporting; and the limitations of modeling. In addition, comments raised concerns about salinity in upper Cache Slough; representative years selected for modeling; water management; salinity at municipal drinking intakes; agricultural diversions and salinity in soils; bromides; sea level rise; and cumulative impacts.

A summary of the initial modeling and analysis to assess salinity impacts was included in the Draft EIR's Appendix S, *Lookout Slough Tidal Habitat Restoration and Flood Improvement*

Project – Potential Salinity Impacts Assessment. In response to comments on the Draft EIR, additional modeling and analysis was conducted for a range of hydrological conditions. The report which provides the additional modeling and analysis, *Lookout Slough Tidal Habitat Restoration and Flood Improvement Project: Modeling EC Impacts*, is added to the Final EIR as Appendix X.

The additional modeling and analysis completed in response to comments, described in Appendix X, do not change the conclusions of less than significant for salinity impacts on drinking water, agriculture, and fish and wildlife that were made in the Draft EIR Section IV.G, *Hydrology and Water Quality* (pages IV.G-22 to IV.G-24) or of less than cumulatively considerable made on pages V-13 to V-14 in Chapter V, *Cumulative Impacts* of the Draft EIR. No mitigation or consideration of alternatives is required under CEQA for potential adverse environmental impacts that are less than significant.

General Concerns

Analysis Objectives and Approach

The EIR's approach was to model existing salinity conditions to establish a baseline and then model salinity conditions with the Proposed Project. Predicted salinity values were then compared between the baseline and the Proposed Project conditions to assess if the Proposed Project would exceed the CEQA thresholds for a significant impact. The same approach was used to compare salinity values between existing conditions and those including the Proposed Project and all reasonably foreseeable projects affecting tidal exchanges to determine if the Proposed Project's contribution to cumulative salinity changes in the Delta were considerable.

CEQA Significance Standards for Salinity Impacts

As stated on page IV.G-17 in Section IV.G, *Hydrology and Water Quality* in the Draft EIR and Appendix G of the CEQA Guidelines, the significance of impacts was based on whether the Proposed Project would "[v]iolate any water quality standards or waste discharge requirements or otherwise substantially degrade surface or groundwater quality."

The applicable water quality standards for salinity are the San Francisco Bay/Sacramento-San Joaquin Delta Estuary Plan (Bay-Delta Plan) and California State Water Resources Control Board Decision 1641 (D-1641), as described in the Draft EIR (page IV.G-14 in Section IV.G, *Hydrology and Water Quality*). The Draft EIR analyzed whether the Proposed Project would result in non-compliance with the Bay-Delta Plan and D-1641.

Comments state that analyzing changes in salinity in relation to compliance with D-1641 is not sufficient to characterize potential impacts of the Proposed Project on salinity. As described below, the analysis showed that the Proposed Project is not predicted to cause non-compliance or make non-compliance with the D-1641 salinity standard more likely. The analysis considered whether D-1641 water quality standards were exceeded and whether beneficial uses would be unreasonably affected or would result in water quality of less quality than that prescribed in the policies such that D-1641 non-compliance would be more likely.

Modeling Objective and Approach

Potential impacts to existing beneficial uses of water within the Delta were analyzed using a hydrodynamic model of the Bay and Delta which simulates the flow of water and also predicts the concentration and transport of water quality constituents.

Analytical methods to measure salinity within the Delta are limited by temporal and logistical constraints that make direct physical measurements infeasible. As a result, when many salinity measurements are needed, electrical conductivity (EC), a physical property of water, based on the concentration of salt dissolved in the water, is usually measured instead. EC measurements are strongly correlated with salinity. EC measurements are commonplace and well-known surrogates for salinity, including specific regulatory standards and compliance monitoring requirements in D-1641 and the Bay-Delta Plan.

Hydrodynamic and EC modeling to analyze potential salinity impacts of the Proposed Project was conducted for the Draft EIR (as summarized in Appendix S of the Draft EIR) and additional modeling was then conducted to respond to comments on Draft EIR (Appendix X). The modeling used a two-dimensional (2D) hydrodynamic model of the San Francisco Bay and Delta region that has been applied to an extensive range of planning studies and CEQA water quality impact analyses over the last decade.

Following circulation of the Draft EIR, the model was further revised to improve its predictions of EC in the vicinity of the Proposed Project. The model was used to predict EC for three years (2009, 2010, and 2016) and these predictions were compared with observed EC at multiple locations in the Delta and Suisun Bay (see Appendix X). By comparing model results from the Base scenario,[1] representing existing conditions, to three hydrologic scenarios with the Proposed Project, the modeling was used to predict likely changes to EC. The predicted changes in EC were mapped for the Delta and Suisun Bay. In addition, EC model output at locations corresponding to D-1641 compliance stations and the Bay-Delta Plan's X2[2] metric were analyzed to predict whether the Proposed Project would change the frequency or duration of any periods of non-compliance with the regulatory standards. The D-1641 compliance stations selected for this analysis include stations to provide coverage near the Proposed Project area and to assess the potential for the Proposed Project to affect salinity intrusion in the Delta. Additional locations were modeled relevant to beneficial water uses. Documentation of this modeling is included in the Final EIR as Appendix X, as described in the next section.

Model Configuration and Reporting

Comments requested additional documentation about the development, assumptions, calibration, and results of the 2D hydrodynamic modeling of flow and EC. The Draft EIR included a summary of the modeling in Appendix S. The Final EIR has added Appendix X: *Lookout Slough*

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[1] The Base scenario refers to the model configuration that represents existing conditions in the Delta during the three years modeled, to the extent that data is available to describe these conditions. See Appendix X for additional details regarding the Base scenario configuration. The Base scenario is used as a reference point to compare the likely changes that would occur as a result of the Proposed Project under the specific hydrologic conditions in each year modeled.

[2] The Bay-Delta Plan X2 metric is defined as the distance, in kilometers, from the Golden Gate to a salinity concentration of two parts per thousand.

Tidal Habitat Restoration and Flood Improvement Project: Modeling EC Impacts to provide more details and information about model development, assumptions, calibration, and results. The additional modeling and analysis information for the Final EIR in Appendix X support the findings summarized for the Draft EIR in Appendix S.

Additional information about the modeling in Appendix X includes the following:

- Model configuration, including the domain extents, and data used for bathymetry and boundary conditions.
- Assumptions made in configuring the model to represent the bathymetry and hydrology of the Delta, Suisun Bay, and San Francisco Bay.
- Model calibration to EC observations in the vicinity of the Proposed Project for three different years, (2009, 2010, and 2016), covering a range of hydrologic conditions. Modeled EC is compared to observed EC at multiple locations across the Delta at multiple temporal resolutions using 15-minute intervals and tidally averaged intervals and compared with standard goodness-of-fit statistics. See below for additional discussion of predicted versus observed EC in upper Cache Slough near the Proposed Project Site.
- Evaluation of proposed conditions, both for the Proposed Project and for the Proposed Project with other cumulative regional restoration projects.
- Results of the model's predictions for the with-Proposed Project conditions are both daily and monthly averaged (as appropriate for the relevant standard or to provide additional temporal resolution), converted to chloride concentrations, and are mapped across the Delta. Results are also provided in granular detail for D-1641 compliance stations and key drinking water intakes.

Limitations of Modeling and Approach

Flows and salinity in the Delta are dynamic, with historic data indicating large fluctuations between seasons and between years due to variation in precipitation, water management practices, and other factors. While modeling can replicate a substantial fraction of these dynamics, there is a limit to their capacity to fully replicate observed conditions. The modeling used to analyze potential salinity impacts of the Proposed Project is a regional model of the Delta and San Francisco Bay. As such, calibration of this model may result in some tradeoffs in simulation quality at specific locations. In areas closer to the model's boundary, the model predictions are more sensitive to the model's boundary conditions and can only replicate observations within the Delta to the degree that is provided by existing available data. For example, at most locations, the coefficient of determination between predicted and observed EC is 0.9 or higher, indicating that the model's predictions replicate 90% or more of the variance in the observed EC. At a few locations in the vicinity of the Proposed Project, local watershed sources of EC play a larger role, but data to characterize these watershed sources is very limited. As a result, the model replicates 67-80% of the EC variance at some locations, which is still a high correlation. Further explanation and interpretation of these EC predictions with less agreement are provided in the Final EIR's Appendix X and discussed below in *Salinity in Upper Cache Slough*.

Conclusions

As described on pages IV.G-22 to IV.G-23 in Section IV.G, *Hydrology and Water Quality* of the Draft EIR, hydrodynamic modeling indicates that the Proposed Project is predicted to cause slight changes in the distribution of EC in the Delta. These changes would occur because the restoration of tidal flows created by the Proposed Project would increase the tidal exchange within the Proposed Project Site, the nearby vicinity, and slightly within the region. The predicted changes in salinity are considerably less than historical variations between seasons and between the same times in different years (Appendix X, Figures 18-45).

The salinity analysis includes reference to background concentrations and applicable water quality objectives. The standards for salinity in the Delta are set by D-1641. Modeling undertaken during restoration planning of the Proposed Project (Appendices S and X), did not indicate any instance of non-compliance with D-1641 standards. No violations of D-1641 chloride standards[3] are identified for any of the locations modeled, including the Contra Costa Water District (CCWD) intakes (Appendix X). During summer and fall when Delta outflows are lowest, results showed less than 5% increase in salinity for the majority of the modeled compliance locations. The Proposed Project is not predicted to cause non-compliance or make non-compliance with the D-1641 salinity standard more likely for agriculture, municipal, or fish and wildlife beneficial use. Thus, the Proposed Project would not violate any water quality standards or waste discharge requirements or otherwise substantially degrade surface or groundwater quality. Therefore, the impact of the Proposed Project with regard to site-specific salinity is less than significant and it is not necessary to consider mitigation.

Specific Concerns

Salinity in Upper Cache Slough

In response to comments about the quality of EC predictions in the vicinity of the Proposed Project, the model was revised to improve EC predictions in upper Cache Slough, as described in more detail in Appendix X. Model revisions consisted primarily of data updates including the most recent bathymetry data collected and estimates of watershed sources into the Cache Slough region that were revised to improve the model's EC predictions as compared to observed EC. In addition to the modeling of 2009 done for the first modeling iteration (Appendix S), the updated modeling (Appendix X) simulated two additional calendar years, 2010 and 2016.

As described above in the section *Limitations of Modeling and Approach*, the calibrated model replicates 90% of the observed EC variance in most of the Delta and replicates 67-80% of the variance at some of the stations in the Cache Slough, e.g. DWR California Data Exchange Center stations, Cache Slough (CCS) and Upper Cache Slough (UCS). As shown in Appendix X's Figure 112 for the CCS station in 2009-2010 and Figure 130 for the UCS station in 2016, the revised model predicts the magnitude and timing of seasonal variations in EC although it does not always predict some of the observed fluctuations in EC that occur at daily and weekly time scales. At the other nearby upper Cache Slough station, the Barker Slough Pumping Plant intake

3 State Water Resources Control Board. 2018. Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary.

(Figures 113 and 131 in Appendix X of the Final EIR), the model explains 90% or more of the observed EC variations.

This localized difference in the model's predictive capability for the upper Cache Slough (stations CCS and UCS) is due to locally-caused salinity dynamics in this specific area (Figure 61 in Appendix X) and the limited data to describe these dynamics. Because of the locally-caused differences, the upper Cache Slough area has observed EC conditions that are typically opposite of other areas in the Delta. For example, EC typically peaks in the Delta during the dry season when freshwater inflows are less, however in the upper Cache Slough observed EC peaks occur in the wet season. This is because local watershed sources of salinity are discharged into the upper slough by wet season runoff. In addition to this seasonal difference, EC values are typically higher in upper Cache Slough and lower at downstream locations, such as Rio Vista. This higher-to-lower gradient in upper Cache Slough is the opposite of the rest of the Delta, which has lower-to-higher salinity moving downstream toward San Francisco Bay, the primary source of EC. This reverse gradient is also a result of the locally-caused salinity dynamics.

The observed local EC dynamics in upper Cache Slough that differ from regional Bay-Delta seawater dynamics can only be replicated in the model using local boundary conditions representing the elevated EC inputs from local watershed runoff (Figure 7 in Appendix X). However, available data to inform the boundary conditions' magnitude and timing of watershed sources to upper Cache Slough are very limited. Due to this limited data and the assumptions required to represent these local sources in the boundary conditions, the model replicates approximate seasonal variations of EC in upper Cache Slough and does not as closely replicate daily or more frequent EC variations due to changes in local inflows and pumping. However, the model's overall ability to predict EC throughout the Delta indicates that the model can characterize the relative change in EC and provide a basis of comparison between existing conditions in upper Cache Slough to those likely to occur as a result of the Proposed Project.

These locally-driven factors affecting EC within the upper Cache Slough region, and the limited data available to inform boundary conditions provide context for the predictions at compliance station C19. Compliance station C19 is located in upper Cache Slough (Figure 17 in Appendix X), approximately a half mile upstream from the nearest observation station used to calibrate the model (station CCS). Station C19 is located next to a City of Vallejo intake which is currently not used. Since 1992,[4] the City now draws drinking water diversions from the Barker Slough Pumping Plant and does not currently rely on water from near C19 for any of its operations.[5]

At C19, EC increases by 4-5.5% from about May to October in each of the three years modeled and increases less than 3% for the rest of each year (Figures 25 and 39 in Appendix X). The Proposed Project reduces the tidal exchange in upper Cache Slough, which reduces the mixing of fresher flows into the upper portion of the slough and thus reduces dilution of locally sourced EC near C19. The Proposed Project is predicted to cause increased EC at compliance station C19 of up to 5.5% for about six months per year; however, this increase would not cause non-compliance

4 Denton., R.A. 2015. Delta Salinity Constituent Analysis. Prepared for State Water Project Contractors Authority.

5 RMC Water and Environment Inc. 2016. City of Vallejo 2015 Urban Water Plan.

with standards including non-compliance with D-1641 or make con-compliance more likely for agriculture, municipal, or fish and wildlife beneficial use.

Years Selected for Modeling

In response to comments that only one year was modeled and analyzed in the Draft EIR, DWR has expanded the hydrodynamic modeling analysis to include the analysis of potential impacts over three different calendar years (2009, 2010, and 2016) which represent Sacramento River watershed inflows ranging from below normal to dry hydrologic conditions. The modeled years all occur as part of multi-year droughts as shown in **Table 3-2**: 2009 is the second year, 2010 the third year, and 2016 is the fifth year of consecutive drought years. The modeled years include conditions when reservoir storage was depleted and less water was available for salinity management.

TABLE 3-2
WATER SUPPLY INDEX, 2006-2016

Year	Sacramento Valley	San Joaquin Valley
2006	Wet	Wet
2007	Dry	Critically Dry
2008	Critically dry	Critically Dry
2009	Dry	Below Normal
2010	Below Normal	Above Normal
2011	Wet	Wet
2012	Below Normal	Dry
2013	Dry	Critically Dry
2014	Critically Dry	Critically Dry
2015	Critically Dry	Critically Dry
2016	Below Normal	Dry

SOURCE: DWR California Cooperative Snow Surveys
http://cdec.water.ca.gov/reportapp/javareports?name=WSIHIST

Some comments requested consideration of a larger range of hydrologic conditions, such as critical dry year conditions or continuous multi-year analysis of more than a decade. For all of the modeled years, the salinity modeling represented dry year conditions which are defined as a minimum monthly flow rate of 4,000 cfs in October and 4,500 cfs in November and December in the lower Sacramento River at Rio Vista. For comparison, critically dry year conditions are defined as a minimum monthly flow rate of 3,000 cfs and 3,500 cfs for the same months at the same location (see Table 3 of SWRCB 2018). Water operations in critically dry years are not typical and D-1641 standards in critically dry years include elevated EC. The modeling for this analysis has shown Delta salinity levels are well within D-1641 compliance for dry year conditions and represents a reasonable variety of hydrologic conditions sufficient to analyze potential salinity impacts.

Consideration of Water Management

The modeling of the Proposed Project conditions used boundary conditions reflective of the historic State Water Project (SWP), Central Valley Project (CVP), and assumed local water management measures (e.g. increase reservoir releases, reduce diversions, or other mitigating offsets) that occurred across the three calendar years (2009, 2010, and 2016) analyzed. With local water management held as fixed boundary conditions, the modeling indicates no change in compliance with Bay-Delta Plan or D-1641 salinity standards. Since the Proposed Project was found to not exceed these standards and to not trigger Bay Delta Term 91 curtailment,[6] there would be no need to alter SWP, CVP, and/or local water management measures to address salinity levels as a result of the Proposed Project under the modeled range of conditions.

Salinity at Municipal Drinking Water Intakes

Overall, the changes in EC predicted to occur as a result of the Proposed Project are considerably less than the natural variations between seasons and between the same time in different years.

The general observations for the 2009 Proposed Project EC results are:

- Largest percent EC increases due to Proposed Project occur during the fall at Prisoners Point (3.3% relative to Base) and during the summer at C19 (5.5%).
- Other locations with EC increases, which are between about 1 - 2%, include West Canal at Clifton Court, DMC at Tracy Pumping Plant, Collinsville, Rio Vista and CCWD intakes at Rock Slough, Old River and Victoria Canal.
- Largest percent EC decreases due to Proposed Project occur during the summer at Emmaton (-4.6%) and Jersey Point (-3.7%) and during the fall at Antioch (-3.6%) and Rio Vista (-4.3%).

The general observations for the 2010 Proposed Project EC results are:

- Largest percent EC increases due to Proposed Project occur during the fall at Prisoners Point (2.1% relative to Base) and Victoria Canal (1.6%), and during the summer at C19 (5.1%).
- Largest percent EC decreases due to Proposed Project occur during the spring in Barker Slough (-4.3%), during the summer at Antioch (-3.3%) and Jersey Point (-2.9% / -2.6%), and during the fall at Emmaton (-4.4%) and Rio Vista (-2.7%).

The general observations for the 2016 Proposed Project EC results are:

- Largest percent EC increases due to Proposed Project occur during the fall at C19 (4.2%), Prisoners Point (3.5%) and Victoria Canal (2.2%).
- Other locations with EC increases, which are between about 1 - 2%, include West Canal at Clifton Court, DMC at Tracy Pumping Plant, Collinsville, CCWD intakes at Rock Slough and Old River and Rio Vista.

[6] Term 91 is a condition in State Water Resource Control Board permits and licenses that requires reduction in local diversions when the SWP and CVP have to release extra water to compensate for local diversions. Term 91 specifically states: *No diversion is authorized by this license when satisfaction of inbasin entitlements requires release of supplemental Project water by the Central Valley Project or the State Water Project.*

- Largest percent EC decreases due to Proposed Project occur during the summer at Antioch (-3.5%) and Jersey Point (-2.5%), and during the fall at Emmaton (-4.7%) and Rio Vista (-4.7%).

Additional details, including magnitude of the changes at the compliance locations, can be found in Appendix X as time series plots (Figures 18-45), EC change maps (Figures 49-61), and tabulated (Tables 3-5).

Overall, EC is predicted to decrease for all months modeled at the Barker Slough Pumping Plant intake for the North Delta Aqueduct. As noted above, the City of Vallejo is not currently using its intake in upper Cache Slough near Station C19 and now receives water from the Barker Slough intake. EC increases at CCWD intakes increase by up to about 1-2%, with the larger increases occurring in the fall.

D-1641 compliance at water intakes are based on chloride concentrations. Chloride concentrations with and without the Proposed Project were estimated as a function of modeled EC. Across the three dry years modeled, there was no change in the number of days meeting D-1641 compliance for any of the municipal drinking water intakes (Appendix X, Tables 8, 9, and 10) and the number of days in compliance remained well above the number of days required for compliance or well below the chloride concentration threshold.

In addition to analyzing compliance at D-1641 stations with EC or chloride-based standards, the modeling was also used to predict the change in X2 for the Proposed Project conditions as compared to the Base scenario. The Bay-Delta Plan X2 metric is defined as the distance, in kilometers, from the Golden Gate to a salinity concentration of two parts per thousand. Therefore, larger values of X2 indicate more inland penetration of salinity into the Bay and Delta. The modeling predicts that X2 will decrease with the Proposed Project by less than 0.2 kilometers (km) from its typical range of 60-80 km. As such, the Proposed Project will not result in any change in compliance for X2 objectives.

Salinity in Agricultural Diversions and Soils

Several comments expressed concerns that increases in irrigation water salinity can build up in Delta soils, damage crops, and impair agricultural productivity. As discussed above, the potential for salinity changes in the Delta channels, from which surface water is diverted for agriculture, has been analyzed for the Proposed Project conditions, and the modeling indicates no change in compliance with D-1641 EC standards. In addition to the salinity of the diverted water, salinity build-up in soils is also a function of water management (e.g., timing of diversions during low tides) and soil characteristics of a particular site, which is not related to the Proposed Project.

Bromides

No standards are in effect for bromide, although it has been recognized as a constituent of concern warranting additional study and evaluation.[7] As such, information about the potential

[7] Regional Water Quality Control Board, Central Valley Region. 2013. Amendment to the Water Quality Control Plan for the Sacramento and San Joaquin River Basins to Establish a Drinking Water Policy for Surface Waters of the Delta and its Upstream Tributaries. Resolution No. R5-2013-0098. State Water Resources Control Board. 2018. Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary.

changes in bromide concentrations at municipal drinking water intakes has been developed from hydrodynamic modeling and are reported in Appendix X.

The potential source of bromide, a precursor to disinfection byproducts which could be affected by the Proposed Project, is seawater that mixes from San Francisco Bay into the Delta via tidal exchange. As described above, hydrodynamic modeling was conducted for three years (2009, 2010, and 2016) to assess potential Proposed Project impacts on EC. Predicted EC was then converted to bromide using numerical relationships between EC and bromide concentration. These relationships depend on the fraction of EC attributed to San Francisco Bay water entering the Delta at Martinez as compared to water originating from the Delta's watersheds. Therefore, the modeling was also used to predict the distribution of a tracer which originated at Martinez, between the western side of the Delta and Suisun Bay. The concentration of the Martinez tracer, which is predicted at drinking water intakes, provides an indication of what fraction of EC can be attributed to Bay seawater originating west of the Delta and which relationship to use for estimating bromide concentrations. Predicted EC values and the fraction of water sourced from Martinez were used to estimate bromide concentrations at the drinking water intakes and compare how the bromide concentrations would likely change as a result of the Proposed Project. Additional details on the methods used to estimate bromide concentrations can be found in Appendix X.

Results of the hydrodynamic modeling (Appendix X) show the Proposed Project would result in relatively small increases and decreases in bromide. Overall, the modeling predicts the following changes in bromide concentrations at active drinking water intakes:

- Increases are highest during dry years' October through December at the CCWD intake at Victoria Canal (up to 4%; Appendix X, Figures 82 and 91)
- Increases are typically only 2% to 3% at other intakes outside of the north Delta (Appendix X, Figures 77, 78, 79, 86, 87, and 88)
- Largest percent bromide decreases due to Proposed Project occur at Antioch, where decreases of -3% to -4% are predicted from April through December (Appendix X, Figures 76 and 85)
- At the Barker Slough Pumping Plant intake, bromide concentrations are predicted to decrease for nearly all of 2009-2010 by as much as -7% (Appendix X, Figure 74). For January-April and November-December 2016, bromide concentrations are predicted to increase by up to 3% at the Barker Slough Pumping Plant intake (Appendix X, Figure 83).
- In upper Cache Slough, where the un-used City of Vallejo intake is located, bromide concentrations are predicted to increase by up to 8% during June through October (Appendix X, Figures 75 and 84). As discussed above, the City now draws Delta water from the Barker Slough Pumping Plant where bromide concentrations are predicted to decrease for much of the year and intermittent increases are lower than the increases predicted for upper Cache Slough.

Sea Level Rise

Recent evaluations of climate change impacts on Delta ecosystems and infrastructure indicate that salinity in the Delta could be affected by rising sea levels.[8] Sea level rise is predicted to increase salinity levels in the Delta. Below is an assessment of whether the Proposed Project would significantly exacerbate sea level rise-related increases of salinity.

As discussed below, modeling of the Proposed Project's predicted change in monthly average X2 is up to 0.2 km eastward and up to an incremental 10 to 15 uS/cm EC increase due to the Proposed Project. However, these predicted changes suggest that the response to future sea level rise would not result in non-compliance with D-1641 water quality standards nor result in instances where non-compliance is likely.

Using a probabilistic approach, the State of California Sea-Level Rise Guidance 2018 Update[9] recommends planning for 1.1 feet (ft) of sea level rise by 2050 as the upper end of the 'Likely Range' for management projects that pose low-risk or low consequences of flooding, such as the Proposed Project. In addition, 1.5 ft of sea level rise, consistent with other DWR project assessments, was also considered.

MacWilliams and Gross[10] used three-dimensional tidal hydrodynamic modeling to evaluate changes in flows and salinity intrusion over one annual hydrologic cycle using existing inputs for water year 2002 and five levels of sea level rise between 0.49 feet and 4.6 feet including a 1.1-foot sea level rise scenario. For the 1.1-foot scenario, the model projected that X2, the Bay-Delta Plan standard, would shift up to 2 km eastward for most of the year. For the 1.5-foot scenario, the model projected that X2 would shift up to 3 km eastward. The Proposed Project's predicted change in X2, up to 0.2 km, is relatively small, approximately 10% or less than the change predicted for sea-level rise. In the western and interior Delta locations, the modeling by MacWilliams and Gross also projected an increase of approximately 100 uS/cm due to 1.1 ft of sea level rise and an increase of approximately 150 uS/cm due to 1.5 ft of sea level rise. Again, the change due to the Proposed Project is relatively small, less than 10-15% as compared to the sea level rise related impacts. The predicted increase in EC in upper Cache Slough due to the Proposed Project is a larger fraction, about 25%, of the change predicted for sea level rise. However, as explained previously, EC in this location is a function of local watershed salinity sources, and therefore would not be affected to the same degree by sea level rise.

In sum, and based on the modeling summarized above, the Proposed Project would only result in small changes to salinity relative to the projected salinity increases caused by 1.1 ft to 1.5 ft of sea level rise. These small changes would not significantly exacerbate sea level rise-related impacts on salinity. Therefore, the Proposed Project itself would not result in salinity increases that would be the primary cause of D-1641 non-compliance for agriculture, municipal, or fish and wildlife beneficial use.

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8 Delta Stewardship Council. 2018. Climate Change and the Delta: A Synthesis. Public Review Draft 3/23/18.

9 Ocean Protection Council. 2018. State of California Sea-Level Rise Guidance, 2018 Update.

10 MacWilliams M.L., and E.S. Gross. 2010. UnTRIM San Francisco Bay–Delta Model sea level rise scenario modeling report. Delta Conservation Plan. Prepared for Science Applications International Corporation and the California Department of Water Resources. 562 p.

Cumulative Impacts

Hydrodynamic modeling described in Appendix X considered the cumulative impact of the Proposed Project in addition to 17 other regional restoration sites in the Delta and Suisun Marsh, as listed in the Draft EIR Chapter V, *Cumulative Impacts*. The regional restoration sites included three in the northwest Delta near the Proposed Project: Lower Yolo Ranch, Prospect Island, and Yolo Flyway Farms.

Two scenarios that included the regional projects were simulated with the hydrodynamic and EC modeling:

- all the regional projects *without* the Proposed Project
- all the regional projects *and* the Proposed Project

The results of these two scenarios were then evaluated for compliance with D-1641 and X2 for three years with below normal or dry conditions: 2009, 2010, and 2016. None of the scenarios modeled resulted in an increase in non-compliance with D-1641 or X2 standards for agriculture, fish and wildlife (Appendix X, Figures 62-73), or D-1641 standards for drinking water intakes (Appendix X, Tables 8-10).

While the cumulative effect of regional restoration with or without the Proposed Project results in small salinity increases in some portions of the Delta (Appendix X, Figures 49-60), these increases do not result in salinity levels that are in non-compliance due to the Proposed Project or are substantially more likely to cause D-1641 non-compliance for agriculture, fish and wildlife, or municipal beneficial uses. Even with the predicted change in salinity due to either of the regional restoration scenarios, a substantial buffer remains between the predicted salinity and the EC compliance thresholds for agriculture and wildlife (Appendix X, Figures 62-73). Similarly, a substantial buffer remains between predicted salinity and the EC compliance thresholds for municipal uses (Appendix X, Tables 8-10).

These scenarios meet the requirements of CEQA for cumulative impact analysis. The cumulative impact of the regional projects was assessed to reach a determination of the significance of the cumulative impact, prior to determining if the contribution of the Proposed Project's effects on the cumulative impact would be considerable. Cumulative impacts, therefore, would not be significant because they would not result in any additional water quality degradation that would cause any of the locations to approach D-1641 non-compliance for agriculture, fish and wildlife, or municipal drinking water beneficial use.

Master Response #2: Farmland

This Master Response responds to the following comments: 13-4, 12-20, 15-10, and 19-14.

The Draft EIR described the setting for agriculture within the footprint of the Proposed Project in Section IV.B, *Agriculture and Forestry,* on page IV.B-2 and in Figure IV.B-1 on page IV.B-3. The Proposed Project Site is comprised of three properties: The Vogel Property, Liberty Farms Property, and Bowlsbey Property. The relevant section of the CEQA statute defines "Agricultural land" as: "Prime Farmland, Farmland of Statewide Importance, or Unique Farmland, as defined by the United States Department of Agriculture land inventory and monitoring criteria, as modified for California" (Public Resources Code section 21060.1(a)). With regard to agricultural impacts, Appendix G of the CEQA Guidelines refers to categories of Prime Farmland, Unique Farmland or Farmland of Statewide Importance (called Important Farmland in the EIR). The Department of Conservation's Important Farmland Maps, and the underlying data giving rise to those maps, include other categories of land, including Farmland of Local Importance, urban land, other land, and grazing land, all of which are distinct in character from the discrete categories recognized within CEQA's definition. Affected land within those categories excluded from CEQA's definition of Important Farmland within the Proposed Project Site is examined as a land resource of lesser importance by reason of that exclusion, and the conversion of such land would need to be evaluated to determine whether it would result in uses that fall within the collective definition of open space (e.g., in Government Code sections 51201 (o), or 51205). In this Proposed Project, the new uses fall within the same general agricultural or other category and also fall within the expansive definition of open space use. The Vogel Property is classified as "other land" and the Liberty Farms Property is classified as "grazing land" and "other land." Agriculture (including grazing) is already a prohibited use on the Liberty Farms Property due to the Wetland Reserve Program (WRP), and therefore, conversion of the Vogel Property and Liberty Farms properties to tidal marsh and seasonal floodplain would not result in any conversion of Important farmland to non-agricultural use. There are, however, approximately 1,460 acres of Prime Farmland on the Bowlsbey Property that would be converted to non-agricultural use. The Draft EIR identifies this conversion as a potential significant impact and identifies mitigation measures to reduce the impact to less than significant.

The Proposed Project mitigation for agricultural impacts embodies a portfolio approach. As stated on pages IV.B-10 through IV.B-13 of the Draft EIR, Mitigation Measures AG-1a and AG-1b, the improvements and conservation measures required per Mitigation Measure AG-1 would result in the following:

Impact

- 1,460 acres of Prime Farmland converted to non-Prime Farmland

Mitigation

- Improved irrigation on 320 acres of Prime Farmland
- Conversion of 340 acres of Grazing Land that is currently not categorized as Prime Farmland to Prime Farmland through funding irrigation improvements
- Creation of 100 acres of new irrigated farmland that is currently designated as Grazing Land
- New and improved drainage for 960 acres of Grazing Land
- Long-term preservation of 1,000 acres of Prime-Farmland

This mitigation approach was developed through consultation with Solano County, area stakeholders, and adjacent landowners. The intent of these discussions was to identify mutually beneficial solutions to maintain agricultural and economic productivity in the area affected. The proposed mitigation measures are consistent with the Solano County General Plan policies and goals as described on pages IV.B-7 and IV.B-8 of the Draft EIR. DWR concludes that the combination of agricultural conservation easements, which would protect in perpetuity Prime Farmland that might otherwise be converted to non-Prime Farmland, plus the funding and implementation of measures to increase the agricultural capability of adjacent agricultural land, would reduce the impact on agricultural land to a less-than-significant level. Based on the evidence referenced in the Draft EIR, the Draft EIR concluded that the impacts on agriculture from the Proposed Project were less than significant with mitigation incorporated.

Master Response #3: Local Water Diversions and Special-Status Fish Species

This Master Response responds to the following comments: 4-3, 9-3, 9-8, 9-9, 10-8, 12-2, 12-3, 12-4, 12-5, 12-14, 12-15, 12-16, 12-17, 12-31, 13-9, 14-6, 14-10, 15-1, 16-5, 19-1, 20-4, and 20-6.

Some comments were received regarding potential effects of the Proposed Project on agricultural water users associated with increases in special-status fish species in the Delta. One of the main objectives and goals of the Proposed Project is to meet DWR's commitments to enhance the food web and habitat in the Delta to benefit Delta Smelt and juvenile salmonids. The Draft EIR described the setting on pages IV.D- 1 through IV.D-40 relative to the listed fish species. The Draft EIR analyzed the effects of the Proposed Project tidal marsh design and its benefits to listed fish species on pages IV.D-54 to IV.D-57 and IV.D-78 to IV.D-89 in Section IV.D, *Biological Resources,* and on pages V-8 to V-11 in Section V of the Draft EIR. In addition, Appendix H, *Fish Study Restoration Basis of Design,* of the Draft EIR documents the work of experts on Delta Smelt and the results to be expected from the Proposed Project design. Appendix H concludes that the Proposed Project would benefit Delta Smelt, and most likely other listed species, by providing more primary and secondary food web production, an increase in spawning and rearing habitat, and improved water quality.

Agricultural diversions in the region of the Proposed Project are currently located in critical habitat for several listed fish species, and thus they are already subject to compliance with the state and federal endangered species acts. Therefore, the potential outcome of increased numbers of listed fish species is not an adverse environmental effect of the Proposed Project that must be analyzed and mitigated by DWR in the EIR.

The effects of agricultural diversions on fish populations, especially listed species, are complex and continually being explored. Fish entrainment depends on the size, location, and timing of the diversion. Limited studies suggest that small irrigation diversions in the Delta may not have a large impact on listed species at all.[11,12] A number of studies indicate that local agricultural water

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[11] Nobriga, M. L., Z. Matica, and Z. P. Hymanson. 2004. Evaluating entrainment vulnerability to agricultural irrigation diversions: a comparison among open-water fishes. American Fisheries Society Symposium 39: 281-295.

[12] Moyle, P. B., and J. A. Israel. 2005. Untested assumptions. Fisheries 30: 20–28. DOI: https://doi.org/10.1577/1548-8446(2005)30[20:UA]2.0.CO;2

diversions in the waterways near the Proposed Project Site are likely to have minimal effects on listed fish species due to the limited overlap with regard to listed species seasonal abundance, their associated habitat use, and the irrigation season when most pumping at the various diversions occur.[13,14,15,16,17]

To help protect listed fish species from entrainment, safeguards such as screens could be used to physically prevent fish from entering a diversion. Per California Fish and Game Code sections 5980-6028, California Department of Fish and Wildlife (CDFW) can inspect conduits and require them to be screened if CDFW determines a screen is necessary to prevent fish passage into the conduit. If screens are ordered, CDFW must fund the screening of diversions under 250 cubic feet per second (cfs) and would share the cost with landowners on screens attached to conduits over 250 cfs. Program specifics may be discussed directly with CDFW. Some of the comments raised the question of whether diverters might be required to move their diversions to protect listed fish species. As far as DWR is aware, this is an action that has not been proposed by any regulatory agency and is not considered an environmental effect of the Proposed Project that must be considered for mitigation.

Some of the commenters suggested that DWR provide incidental take protection for local diverters as mitigation for the Proposed Project. Since the Proposed Project does not result in any significant adverse impact to listed species, there is no requirement under CEQA to consider mitigation.

See also Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts* for comments on social or economic impacts related to the topics in this master response.

Master Response #4: Piecemealing

This Master Response responds to the following comments: 10-1, 10-4, 13-24, 15-2, and 15-5.

Some comments suggest that DWR is piecemealing a larger Proposed Project that could or should include all of the restoration projects that any entity is proposing in the Delta (including pursuant to the 30,000-acre EcoRestore Initiative) or, at a minimum, the 8,000 acres that DWR is required to develop pursuant to regulatory requirements.

Where an individual project is a necessary precedent for action on a larger project, or commits the Lead Agency to a larger project, with significant environmental effect, an EIR must address itself

[13] NMFS. 2014. Recovery Plan for the Evolutionary Significant Units of Sacramento Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon and the Distinct Population Segment of California Central Valley Steelhead. Prepared by NMFS, California Central Valley Area Office, Sacramento, California. July.

[14] Sommer, T., F. H. Mejia, M. L. Nobriga, F. Feyrer, and L. Grimaldo. 2011. The spawning migration of Delta Smelt in the upper San Francisco Estuary. San Francisco Estuary & Watershed Science 9(2): 1-16. DOI:https://doi.org/10.15447/sfews.2011v9iss2art2

[15] Dege, M., and L. R. Brown. 2004. Effect of outflow on spring and summertime distribution and abundance of larval and juvenile fishes in the upper San Francisco Estuary. American Fisheries Society Symposium 39: 49-65.

[16] Merz, J. E., S. Hamilton, P. S. Bergman, and B. Cavallo. 2011. Spatial perspective for Delta Smelt: a summary of contemporary survey data. California Fish and Game 97: 164–189.

[17] Nobriga, M. L., Z. Matica, and Z. P. Hymanson. 2004. Evaluating entrainment vulnerability to agricultural irrigation diversions: a comparison among open-water fishes. American Fisheries Society Symposium 39: 281-295.

to the scope of the larger project. However, where a project is one of several similar projects of a public agency, but is not deemed a part of a larger undertaking or a larger project, the agency may prepare one EIR for all projects, or one for each project, but shall in either case comment upon the cumulative effects (CEQA Guidelines Section 15165).

CEQA does not require DWR to analyze, in one EIR, the Proposed Project, in combination with all the other potential projects that may be implemented to meet the 8,000-acre requirement in the U.S. Fish and Wildlife Service (USFWS) Delta Smelt Biological Opinion, or to meet other habitat restoration goals, because:

1. Although the Proposed Project and the other tidal restoration projects are related in that they are all projects designed to meet habitat restoration goals, future potential projects are not a reasonably foreseeable consequence of the Proposed Project and it is not, therefore, a necessary precedent to action on any other project.
2. The Proposed Project has significant independent utility, including independent benefits that do not depend on any other project.

DWR could have decided to prepare a Master EIR pursuant to Section 15169 of the CEQA Guidelines, or a Program EIR pursuant to Section 15168(a)(4) of the CEQA Guidelines, that included at least some of the potential regional tidal habitat restoration projects needed to meet the USFWS Delta Smelt Biological Opinion, or that met other restoration goals, but it was not required to do so. Preparing a project-level EIR for a project with independent utility, and which may be approved and carried out separately from any other project, does not constitute improper piecemealing pursuant to CEQA.

Master Response #5: Cumulative Impact Analysis

This Master Response responds to the following comments: 10-4, 13-21, 15-2, 15-3, 15-4, and 15-5.

Some comments stated that the Draft EIR either did not identify all cumulative impacts or that the impacts were not accurately described and/or adequately analyzed. Chapter V (page V-6 et seq.) of the Draft EIR provides an assessment of cumulative impacts. “Cumulatively considerable” means that the incremental effects of an individual project are significant when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects (CEQA Guidelines Sections 15065(a)(3)).

The Draft EIR uses a CEQA-recommended “List Approach” (CEQA Guidelines Section 13130), which involved developing a list of past, present, and probable future projects potentially producing related or cumulative impacts (the list is provided in Table V-2 of the Draft EIR). The Draft EIR included a comprehensive summary of all known, or likely anticipated, projects that existed at the time of the Notice of Preparation in 2019. This list included several tidal habitat restoration projects that would result in impacts that could potentially interact with those of the Proposed Project, and analyzed the cumulative impacts of implementing these projects within the cumulative geographical context as shown in Table V-1 of the Draft EIR. The data and analysis documented in the Draft EIR support the significance conclusions reached, i.e., that there are no cumulatively considerable impacts from the Proposed Project. In summary, DWR was required to, and did, discuss the cumulative effects of the Proposed Project and the Alternatives with other past, present, and reasonably foreseeable future restoration projects.

To satisfy comments on the potential for cumulative methylmercury impacts, DWR has expanded the discussion of cumulative water quality impacts in relation to methylmercury (see Text Changes in Master Response 6, *Methylmercury*). The clarifying information does not change the conclusion from the Draft EIR that the cumulative impact of methylmercury from restoration projects in the Delta is not significant.

Master Response #6: Methylmercury

This Master Response responds to the following comments: 6-2, 10-6, 12-27, 15-3, and 15-9.

Some comments were received regarding impacts related to methylmercury. The Draft EIR described the setting and current status of regulations regarding mercury and methylmercury in the Cache Slough Complex, where the Proposed Project is located, on pages IV.D-42 in Section IV.D Biological Resources, and on pages IV.G-5, IV.G-10, IV.G-15 and IV.G-16 in Section IV.G, *Hydrology and Water Quality*. Historic mining operations have resulted in large inputs of mercury to the Delta and subsequent uptake by fish, causing tissue concentrations in exceedance of local and national health guidelines for fish consumption. The Central Valley Regional Water Quality Control Board (Central Valley Water Board) promulgated the Delta Methylmercury Total Maximum Daily Load and through the TMDL, the Delta Mercury Control Program (DMCP), after the Delta was listed on the Clean Water Act 303(d) list. Fish methylmercury concentrations generally exceed the TMDL target for fish in several parts of the Delta and Yolo Bypass (see page IV.G.-5 of the Draft EIR). Waters of the Proposed Project Site are therefore considered impaired due to the presence of methylmercury (see page IV.G.-10).

Current mercury and methylmercury dynamics in tidal wetlands are not well understood, and until recently, few, if any studies existed that were able to collect mercury, methylmercury, and flow data with enough accuracy and precision to make realistic estimates of methylmercury dynamics in tidal wetlands. DWR participated in the DMCP Phase 1 workplan by conducting tidal wetland characterization studies in the Yolo Bypass, Suisun Marsh, and the Delta.[18,19] The tidal wetland study that DWR completed focused on methylmercury and total mercury imports and exports at four tidal wetlands: the Yolo Wildlife Area Tidal Wetland (Yolo) in the Yolo Bypass, Blacklock Tidal Wetland in Suisun Marsh, and in the Delta at North Lindsey Slough Tidal Wetland in the Cache Slough Complex, and the Westervelt Cosumnes River Tidal Wetland southeast of the confluence of the Cosumnes and Mokelumne Rivers.

Based on the collected data and analyses from the completed studies, it appears that tidal wetlands, such as the Proposed Project, do not export mercury or methylmercury in large amounts annually. None of the four wetlands studied appear to be significant sources of methylmercury to

[18] DWR. 2015. Progress Report – Delta Mercury Control Program: methylmercury import and export studies of tidal wetlands in the Sacramento-San Joaquin Delta, Yolo Bypass, and Suisun Marsh.

[19] DWR. 2020. *Mercury Imports and Exports of Four Tidal Wetlands in the Sacramento-San Joaquin Delta, Yolo Bypass, and Suisun Marsh for Delta Mercury Control Program Compliance*. April 2020.

adjacent waterbodies, nor are concentrations of methylmercury significantly higher leaving the wetlands than entering the wetlands, although seasonal differences may occur. Imports and exports are heavily influenced by flow, water source, and whether a wetland contains a floodplain within its boundaries. In some instances, tidal wetlands appear to be a sink with regard to methylmercury (see page IV-G-15 of the Draft EIR), but the study showed that there was not a measurable annual increase in methylmercury loads in receiving waters due to the tidal wetlands. The report and the data from the study was provided to the Central Valley Water Board in early 2020. This is the largest study to date of methylmercury imports and exports of tidal wetlands within the Delta and Yolo Bypass.[20]

The EIR has made use of the best available and up-to-date science in concluding that the Proposed Project was not a source of methylmercury and would have a less-than-significant impact on methylmercury concentrations in the Delta (see pages IV.D-87 to 88 in Section IV.D, *Biological Resources*). In addition, to clarify the regulatory setting on water quality and methylmercury bioaccumulation, the following text is added to the Draft EIR in Section IV.D, *Biological Resources* on page IV.D-46 after the first paragraph:

> *viii. Sacramento-San Joaquin Delta Mercury Control Program (DMCP) and Methylmercury Total Maximum Daily Load (TMDL)*
>
> The waterways in the Delta are subject to site-specific methylmercury fish tissue objectives, the DMCP, and monitoring provisions which apply to all Delta waterways, Yolo Bypass waterways within the Delta, and also those north of the Legal Delta boundary to which the commercial beneficial use applies. The DMCP is designed to protect people eating one meal/week of trophic levels 3 and 4 Delta fish and some non-Delta commercial market fish. The DMCP identifies the waterways in the legal Delta and Yolo Bypass, up to the Fremont weir, subject to the regulation. The amendment uses a phased, adaptive management approach. Among other actions, the first phase focuses on conducting control or characterization studies to identify potential control mechanisms so participants of the DCMP can attain load and waste load allocations specified in the DMCP. The Delta Methylmercury TMDL was adopted by the Central Valley Water Board on April 22, 2010. Final approval by the USEPA was received on October 20, 2011.

In addition, to clarify the analysis of impacts on water quality and bioaccumulation, the following text is added to the Draft EIR in Section IV.D, *Biological Resources* on page IV.D-87:

> … Total mercury is not anticipated to change as a result of grading or construction.
>
> However, ~~there could be a short-term increase in methylmercury production during or immediately after construction within the Proposed Project Site, which could be transported to adjacent waterways[49]. A~~a localized increase in water column methylmercury could result in increased levels of mercury bioaccumulation in aquatic organisms, especially top predators like Striped Bass. DWR is conducting both tidal wetland and open water characterization studies to determine if tidal wetlands are a source or sink for mercury and methylmercury and further understanding of how methylmercury is produced in the Yolo Bypass under large flood events. DWR submitted a study of methylmercury flux of tidal wetlands to the Central Valley Water Board. The

[20] DWR. 2020. *Mercury Imports and Exports of Four Tidal Wetlands in the Sacramento-San Joaquin Delta, Yolo Bypass, and Suisun Marsh for Delta Mercury Control Program Compliance*. April 2020.

report, titled *Mercury Imports and Exports of Four Tidal Wetlands in the Sacramento-San Joaquin Delta, Yolo Bypass, and Suisun Marsh for Delta Mercury Control Program Compliance* (Lee and Manning, April 2020), concluded that the four tidal wetlands studied, which are like the Proposed Project, do not export methylmercury.[49] Therefore, impacts of the Proposed Project would not exceed the applicable threshold of significance related to a substantial adverse effect of methyl-mercury on water quality and food web accumulation and the Proposed Project's impact with regard to this threshold would be ***less than significant.*** ~~For further detail, please see Chapter IV.G, Hydrology and Water Quality.~~

~~49 *Valoppi, L., 2018, Phase 1 studies summary of major findings of the South Bay Salt Pond Restoration Project, South San Francisco Bay, California: U.S. Geological Survey Open-File Report 2018–1039, 58 p., plus appendixes, https://doi.org/10.3133/ofr20181039.*~~

49 DWR. 2020. *Mercury Imports and Exports of Four Tidal Wetlands in the Sacramento-San Joaquin Delta, Yolo Bypass, and Suisun Marsh for Delta Mercury Control Program Compliance.* April 2020.

Regarding potential cumulative effects relating to methylmercury, the following text has been added between the first and second paragraphs on page V-9 in Section D, *Cumulative Impacts* of the Draft EIR:

When combined with other related projects in the Delta, many of which would also be freshwater tidal restoration projects, the anticipated increased methylmercury production, export, and bioaccumulation resulting from the Proposed Project would be low. Given the less-than-significant Project-specific impact, and findings of the DWR (2020) report titled *Mercury Imports and Exports of Four Tidal Wetlands in the Sacramento-San Joaquin Delta, Yolo Bypass, and Suisun Marsh for Delta Mercury Control Program Compliance* that tidal wetlands are not exporting methylmercury, the cumulative impact of methylmercury is not significant and there would be no incremental contribution from the Proposed Project.

CEQA does not require mitigation when the impact identified is less than significant. DWR will continue to work with the Central Valley Water Board on further studies of methylmercury dynamics.

Master Response #7: Operation and Maintenance (O&M) of Levees

This Master Response responds to the following comments: 2-18, 3-2, 9-1, 9-2, 9-9, 12-8, 12-10, 12-31, 13-13, 14-7, 14-8, 14-9, 14-10, 19-2, 20-4, and 20-7.

Some comments were received regarding impacts relating to operation and maintenance of levees. Questions regarding funding and management of levees relate to economic and social effects that may be required to be worked out during other regulatory processes with the Central Valley Flood Protection Board (CVFPB), the US Army Corps of Engineers (USACE) and relevant reclamation districts (RDs), but they are not comments on the adequacy of the EIR. See Master Response 12.

The EIR states that long-term operation and maintenance of the Duck Slough Setback Levee, which could include habitat management and rodent management activities, will be the responsibility of RD 2098. There is an existing statutory framework for the responsibilities of

RDs, funding, and even in the extreme situation, creation of a state-managed maintenance area to ensure continued function. RD 2098 will be entering into an updated Operation, Maintenance, Repair, Replacement, and Rehabilitation ("OMRR&R") Agreement with the CVFPB. Further, the USACE will conduct periodic inspections of the Cache/Hass Slough Training Levee. These periodic inspections will include on-site inspections of the levee access roads and slopes to ensure that vegetation is being maintained, roadways are being maintained, erosion and drilling on the slopes is addressed, and that rodent burrows do not threaten the integrity of the levee. These periodic inspections will be conducted to ensure flood control responsibilities are met, and to ensure flood impacts are not transferred to neighboring RDs.

To the extent that these operations and maintenance duties involve mitigation responsibilities, DWR would ultimately be responsible for making sure the mitigation is carried out. As part of the long-term considerations of the Proposed Project, DWR is engaging with RD 2098 to determine the various responsibilities of DWR and RD 2098. To the extent that approval by the CVFPB and USACE may require additional assurances regarding funding and operations changes will be handled through the appropriate regulatory processes.

Master Response #8: Dissolved Organic Carbon

This Master Response responds to the following comments: 8-3, 14-2, 14-10, and 16-4.

Some comments were received regarding the analysis of the Proposed Project's effects on dissolved organic carbon (DOC) content in the Delta, particularly with regard to the potential impact on the Barker Slough Pumping Plant intake of the North Bay Aqueduct (NBA). Dissolved organic carbon is part of the natural ecosystem in the Delta, as it typically originates from peat soils formed from algae and plant detritus and is an essential source for the base of the food chain. DOC is a concern with regard to drinking water diverted from the Delta because DOC can contribute to the formation of disinfection byproducts (DBPs). When chlorine and/or ozone are used to disinfect drinking water, these disinfectants may react with DOC to form DBPs, which are regulated constituents in drinking water. DBPs include a broad class of chemical compounds, which react differently to chemical processing, both within the Delta and in the drinking water treatment process. The type and amount of DBPs formed when DOC undergoes drinking water treatment is a function of the chemical composition of total DOC. Currently, the Central Valley Water Board has not identified DOC as a priority pollutant in the San Francisco Bay/Sacramento–San Joaquin Delta Estuary (Bay-Delta Plan) and has not established numerical water quality criteria with regard to DOC impacts to drinking water beneficial uses.

The Barker Slough Pumping Plant of the NBA, which is the closest drinking water intake to the Proposed Project Site, already experiences elevated DOC under existing (baseline) conditions. At the NBA intake, DOC concentrations are often higher than levels in the rest of the Delta.[21] The higher DOC values at the NBA intake are largely associated with upland sources that drain into the Delta via Barker Slough and other nearby drainage channels.[22]

[21] ESA PWA. 2010. Dissolved Organic Carbon (DOC) Literature Review and Evaluation of Liberty Island Conservation Bank Negative Declaration. Prepared for Solano County Water Agency.

[22] DWR. 2002. Water Quality Investigations of the Barker Slough Watershed, 1997-2001. Prepared by the Municipal Water Quality Investigations Unit. 161 p.

Wetland plants, such as those which are anticipated to populate large portions of the Proposed Project Site could also be potential sources of DOC. While some types of DBPs have a greater propensity to form when DOC is from tidal wetland vegetation, the changes in DBP in response to wetland-sourced DOC is uncertain. While the conversion of the agricultural land on the Proposed Project Site to tidal wetlands may increase the amount of DOC entering the Delta,[23] the amount and composition of DOC that is exported by tidal wetlands depends on many factors that are not completely understood.

Although there is no regulatory threshold and the current scientific understanding is not sufficient to make accurate predictions to determine the significance of direct, indirect, and cumulative impacts of the Proposed Project's effect on DOC, there is information related to Liberty Island that provides some indication on DOC from tidal wetlands. Liberty Island, just east of the Proposed Project Site, was accidentally breached and restored to tidal exchange in 1998. The restored area includes approximately 1,200 acres of tidal marsh. The largest breach at the south end of Liberty Island is closer to the NBA intake and the rest of the Delta than the Proposed Project. Despite the size and proximity of the Liberty Island tidal wetland to the NBA intake, DOC levels at the intake from 1998 to 2010 show no change or slight decreases.[24]

The Proposed Project breaches to the Shag Slough and Vogel Levees are the farthest from the NBA intake than the Liberty Island breach. Particle tracking with a hydrodynamic model was conducted to assess the trajectory of water originating in the Proposed Project Site.[25] The model domain only extended to the lower section of Lindsey Slough and does not go as far as the NBA intake on Barker Slough. The model indicated that only 1.3% of particles that started in the Proposed Project Site reached the model domain boundary in the lower section of Lindsey Slough. The NBA intake is more than five miles farther up Lindsey Slough and Barker Slough from the model domain boundary, so an even lower percentage of particles from the Proposed Project would be predicted to reach the NBA intake.

Further, the hydrodynamic modeling was also used to predict how long water remained within the Proposed Project Site and adjacent waterways. Much of the area within and adjacent to the Proposed Project Site was found to have water residence times of a week or more. These residence times mean that water that stays within the Proposed Project Site is released gradually and augments the longer residences times currently observed in Shag Slough. Kraus and others[26] found that DOC sourced from Shag Slough has undergone additional environmental processing due to longer residence times, which resulted in DOC precursors with a lower potential to form DBPs.

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[23] ESA PWA. 2010. Dissolved Organic Carbon (DOC) Literature Review and Evaluation of Liberty Island Conservation Bank Negative Declaration. Prepared for Solano County Water Agency.

[24] PWA. 2008. North Bay Aqueduct Organic Carbon Monitoring Plan. Prepared for Solano County Water Agency.

[25] ESA. 2019. Basis of Design Report – Tidal Hydrology and Hydraulic Analysis: Lookout Slough Restoration Project. Prepared for EIP. Appendix P in DEIR.

[26] Kraus TEC, Bergamaschi BA, Hernes PJ, Spencer RGM, Stepanauskas R, Kendall C, Losee RF, Fujii R. 2008. Assessing the contribution of wetlands and subsided islands to dissolved organic matter and disinfection byproduct precursors in the Sacramento-San Joaquin River Delta: A geochemical approach Organic Geochemistry 39(9):1302-1318.

The Draft EIR did not include an analysis of the Proposed Project effect on DOC because there is no regulatory standard to form a significant threshold to determine effects on DOC levels. However, because several comments were raised regarding DOC, DWR reconsidered the issue based on the above information. In summary, the Proposed Project would not raise DOC and affect the quality of water treated at water treatment plants for the following reasons: the lack of impact from the nearby Liberty Island restoration; the limited potential for water particles from the Proposed Project reaching the NBA intake; and the potential environmental processing of DOC on the Proposed Project Site. DWR has determined that additional analysis is not required.

Master Response #9: Tidal Effects on Diversions

This Master Response responds to the following comments: 4-3, 9-1, 9-3, 9-4, 9-9, 12-4, 12-14, 12-15, 12-16, 12-31, 13-9, 13-14, 14-6, 14-10, 15-1, 16-3, 18-3, 18-4, and 19-6.

Some comments raised issues relating to the Proposed Project's effect on tidal water levels and how that could adversely affect water diversions and drainage.

Lands adjacent to the Proposed Project Site use both pumps and gravity-driven diversions to irrigate agricultural land with water from Delta channels. Some of these lands also use pumps to drain agricultural land and discharge to Delta channels. Because of concerns regarding the potential for water level changes to adversely affect diversions and drainage, the comments request additional analysis and/or mitigation measures.

As described on page IV.G-25 in Section IV.G, *Hydrology and Water Quality* of the Draft EIR, based on hydraulic modeling and results summarized in Appendix T, *Lookout Slough Tidal Habitat Restoration and Flood Improvement Project – Potential Tidal Water Levels and Tidal Prism Impacts Assessment*, the analysis found that the Proposed Project may slightly change the range of water surface elevations influenced by the tides (page IV.G-25 of the Draft EIR). Near the Proposed Project Site, the anticipated muting of tidal range results in a decrease of water surface elevation by a maximum of -0.2 ft during the mean higher high water (MHHW) each day, and an increase of water surface elevation by a maximum of 0.1 ft during the mean lower low water (MLLW) each day. The amount of tidal muting decreases with distance from the Proposed Project Site, such that little to no change is predicted for areas outside of the northwest Delta. Even at their largest value of approximately 0.2 ft, the Proposed Project effects on water surface elevation are only a fraction of the total tide range and its natural variations during the entire tidal cycle. The average natural tide range between MHHW and MLLW for the areas adjacent to the Proposed Project is approximately 4 and 4.4 ft. Natural variations in the sun and moon's positions cause additional variations of approximately 1 foot in the mean tide range on a two-week cycle, known as the spring-neap cycle.

Gravity-driven diversions use hydraulic structures (e.g. siphons, culverts, tide gates) to convey water based only on the difference in water levels at either end of the structure. In some areas in the vicinity of the Project, the tide range fluctuates to exceed the land surface elevation on high tide and to drop below the land surface on low tide. This allows some diverters to use gravity-driven flow during high tide to irrigate and during low tide to drain. Since gravity-driven flow depends on just the tide range or a portion of the tide range, this type of flow can be more sensitive to changes in water levels. However, the gravity-driven systems already accommodate the average daily tidal range of about 4 to 4.4 ft and the spring-neap modulation of this range of about 1 foot.

While a decrease in MHHW of 0.2 ft could result in higher energy consumption and increased pumping costs, an increase of 0.1 ft in MLLW could result in lower energy consumption and decreased pumping costs. Given the capacity of both pumped and gravity-driven diversions and drainage systems to accommodate natural water level variability, the Proposed Project would not have significant effects on gravity-driven diversions or drainage capacity as determined in the analysis on pages IV.G-24 and IV.G-25 in Section IV.G, *Hydrology and Water Quality* of the Draft EIR.

Based on the evidence referenced in the Draft EIR, the Draft EIR concluded that there was not a physical environmental effect on water diversions and drainage. No new information has been presented that changes this conclusion. No mitigation is required under CEQA for adverse environmental impacts that are less than significant.

Master Response #10: Recreation

This Master Response responds to the following comments: 2-24, 4-2, 13-11, 13-16, 13-17, 19-8, and 19-13.

Some comments were received regarding impacts on access for recreation on the Liberty Island Ecological Reserve (Reserve) and shoreline fishing. As noted on page III-35 in Chapter III, *Project Description* of the Draft EIR, the portion of Liberty Island Road that provides access to the Shag Slough Bridge would be removed as a result of levee breaching, thus eliminating bridge access to the Reserve. Although the Proposed Project would result in the loss of bridge access to the Reserve, the Proposed Project would add more than 20 miles of new channels accessible by boats, kayaks, and paddleboards that would increase recreational opportunities for fishing, birdwatching, waterfowl hunting, and sightseeing in the project vicinity. While not a designated recreational area, both the Shag Slough Levee and the bridge are currently used for fishing. The Reserve is used for fishing, waterfowl hunting, and birdwatching, although there is no signage stating that the Reserve is a resource for public recreation. According to a Sacramento State University 2017 study of recreational boating use of the Delta, the Reserve and Proposed Project Site are not within an area of high boating use.[27] The Reserve would remain accessible by boat, as the Proposed Project does not propose any impediments within navigable waters, nor does it propose excluding access to navigable waters within the Proposed Project Site, and it is therefore consistent with California Constitution Article X, Section 4.

In the evaluation of the Proposed Project's impact on recreation, DWR used the recreation significance thresholds from the 2019 CEQA Guidelines Appendix G checklist and added a third threshold. This third threshold evaluated how loss of access to the bridge would affect regional shoreline fishing opportunities, including those on the Reserve. Based on the evidence referenced in

[27] Mikel, A., D. Rolloff, E. Erickson, and G. Shaw. 2017. *Recreational Boating Use of the Sacramento - San Joaquin Delta*. Prepared for the Delta Protection Commission.

on page IV.J-6 in Section IV.J, *Recreation* of the Draft EIR, the impact of the Proposed Project was determined to be less than significant. The site is currently not accessible by public transportation and requires vehicle or boat access to reach the area. There are many other opportunities with similar settings in the Delta region for shoreline fishing, including at least 28 informal fishing areas and 30 fishing piers as noted on page IV.J-3 of the Draft EIR, and for similar recreation provided by the Reserve. This impact was also considered to be less than significant due to the relatively small number of users that would be impacted from the Proposed Project's removal of vehicle access to the Reserve via Shag Slough Bridge (see page IV.J-6 of the Draft EIR). As explained on pages IV.J-5 and IV.J-6 in Section IV.J, *Recreation* of the Draft EIR, substantial or accelerated deterioration of recreational facilities would not occur due to the relatively small potential for increased use at other facilities, and the Proposed Project's impact would be less than significant. No new information has been presented that changes this conclusion of less than significant impacts. There is no requirement under CEQA that an EIR consider mitigation or alternatives for adverse environmental impacts that are less than significant. DWR recognizes that there is an opportunity to have a broader discussion on public access and recreational activities within the greater Delta region and will be convening a working group with state and local agencies, other stakeholders, and landowners.

Master Response #11: Good Neighbor Checklist

This Master Response responds to the following comments: 4-3, 4-5, 9-7, 9-9, 12-17, 12-19, 14-6, 15-1, 19-17, 20-2, and 20-3.

Some comments were received regarding DWR as a good neighbor. As discussed in the Draft EIR, DWR developed a Good Neighbor Checklist as part of the Agricultural and Land Stewardship Program (ALSP) Framework and Strategies posted online in July 2014: (now located at https://water.ca.gov/Programs/California-Water-Plan/Water-Resource-Management-Strategies/Agriculture-and-Land-Stewardship-Framework). The ALSP Framework and Strategies were developed, in consultation with the California Department of Agriculture, local landowners and other stakeholders, to identify a toolbox of ALSP strategies. The ALSP Framework for considering the strategies can help inform agricultural and land stewardship activities at all levels of planning and assist with funding decisions and provide project proponents and those affected by a proposed project with a collaborative approach to address protecting and changing uses of agricultural land, from mitigating its loss to valuing its multiple benefits. There is no correct or mandated action suggested, but DWR's project developers are encouraged to consider these measures, as appropriate, in developing their projects.

The Good Neighbor Checklist includes some of these measures and was developed to help project managers be aware of issues that local landowners and neighbors close to a Proposed Project may have regarding potential impacts. The Checklist includes several points that are not related to environmental impacts. A Checklist has been prepared for the Proposed Project (see Appendix E, *Good Neighbor Checklist* of the Draft EIR) and has been used to identify and consider potential issues affecting neighbors. This is not required by CEQA or any other law, but it has informed DWR of local considerations and aided the analysis in the Draft EIR. To the extent that the measures relate to potential significant environmental impacts, they are covered in the Draft EIR and Final EIR independent of the Checklist.

Outside of the CEQA process, DWR has agreed to participate in a variety of projects and studies, which it considers to be responsive to requests that DWR be a good neighbor. These measures were not included in the EIR since they are not considered mitigation measures under CEQA. Not including the measures helps to distinguish the impact analyses in the EIR from good neighbor policy actions. There is a discernable difference between Proposed Project mitigation and good neighbor actions. Pursuant to CEQA Section 15126.4, mitigation measures are introduced to feasibly minimize significant adverse impacts in proportion with the scale of the impact, and must be fully enforceable through permit conditions, agreements, or other legally binding agreements. Where effects are not found to be significant, mitigation measures are not required (CEQA Section 15126.4(a)(3)).

Good neighbor actions are separate from, and in addition to the analyses for the Proposed Project under CEQA. CEQA impacts are identified in the EIR and the analysis does not rely on any information in Appendix E. Some comments stated that the EIR must look at mitigation measures and alternatives for effects that the commenter considered significant. However, under CEQA where effects are found to be less than significant (Not Significant, Less Than Significant or Less than Significant if Mitigated), additional mitigation measures or alternatives do not need to be considered. Some comments stated that DWR should commit to monitoring or specific mitigation for impacts found to be less than significant because they disagreed with the conclusions of the EIR. The significance determinations in the EIR are based on substantial technical evidence and supported by the best available science. Pre-mitigation for speculative impacts that is not supported by scientific evidence is not fiscally responsible, and not required by CEQA.

Master Response #12: Not a Comment on the Adequacy of the EIR and Economic and Social Impacts

This Master Response responds to the following comments: 4-3, 5-2, 6-1, 6-2, 9-5, 9-9, 10-9, 12-5, 12-6, 12-15, 12-16, 12-19, 12-21, 12-31, 13-6, 14-6, 14-7, 14-8, 14-10, 15-1, 15-6, 18-3, 18-5, 19-2, 19-3, 19-8, 19-12, 19-14, 20-2, 20-3, 20-4, 20-6, and 20-7.

Not a Comment on the Adequacy of the EIR

Where this Master Response is referred to in response to comments, no issues related to the adequacy of the EIR are raised by the commenter.

DWR is required to comply with a variety of statutory and regulatory programs separate from CEQA, including programs administered by the CVFPB, the Delta Stewardship Council, USACE, CDFW and others. DWR and its contractors will comply with all applicable regulatory requirements; however, the EIR is not required to include all the information necessary to meet other regulatory program requirements. Similarly, questions of the Proposed Project's compliance with relevant contracts are beyond the scope of the CEQA analysis.

Since no relevant issues regarding adequacy of the environmental impact analysis are raised, these comments are not generally further addressed. In some cases, further information is given so that the public and decision makers can have a better understanding of these issues.

Social and Economic Impacts

Comments relating to social and economic impacts are often not comments about the adequacy of the EIR. Under CEQA, economic or social effects of a project shall not be treated as significant effects on the environment unless they cause a physical effect (CEQA Guidelines Section 15131). Lead agencies are only required to analyze potentially significant adverse impacts of a project to the physical environment. The term "environment" means "the physical conditions which exist within the area which will be affected by a proposed project including land, air, water, minerals, flora, fauna, ambient noise, and objects of historical or aesthetic significance… The "environment" includes both natural and man-made conditions" (CEQA Guidelines Section 15360).

Under CEQA, potential effects from implementing a project that are solely social or economic in nature would not constitute an impact to the physical environment. This could include effects such as reductions in property values, loss of property tax revenues, increases in energy costs, or relocation of infrastructure. The fact that additional screening for existing intakes or moving intakes, for example, may incur economic costs does not transform the issue of cost into a matter of CEQA concern where, as here, the Draft EIR considers the Proposed Project's potential physical changes to the environment on a resource-by-resource basis, including potential impacts to agricultural resources, fish, water quality, water supplies, and other environmental considerations.

Questions about how programs will be funded and managed are also social or economic in nature and would not constitute an impact to the physical environment. As long as an agency is obligated or has committed to carrying out specific measures, the source of funding or the way in which the project is managed is not considered a CEQA effect, although other regulatory agencies may require additional information.

Master Response #13: Performance Standards and Deferred Mitigation.

This Master Response responds to the following comments: 2-8, 10-10, 12-29, 13-6, and 15-6.

Section 15126.4 of the CEQA Guidelines states that the "[f]ormulation of mitigation measures shall not be deferred until some future time." The section then provides guidance for determining whether a mitigation action has been improperly deferred. Each mitigation measure in the Final EIR has been reviewed in the context of CEQA Guidelines Section 15126.4, and it has been determined that:

1. The formulation of the mitigation measure does not involve any deferral, or that;
2. The relevant mitigation measure involves compliance with a regulatory permit or other similar process where compliance would result in implementation of measures that would be reasonably expected, based on substantial evidence in the record, to reduce the significant impact to the specified performance standards, or that;
3. The relevant mitigation measure commits DWR to mitigating the impact, describes the performance standards incorporated in the mitigation measure and identifies the types of potential actions (sometimes called "best management practices" or BMPs) that can feasibly achieve the performance standard.

The following are examples reflecting the three items above: Mitigation Measure AG-1a, which would make improvements beneficial to agricultural productivity, prior to commencement of construction, to off-site land to convert that land to Prime Farmland to mitigate for on-site impacts of the Proposed Project on Prime Farmland (Item 1); the requirement from Mitigation Measure HYDRO-2 which requires (or restates) the Central Valley Regional Water Quality Control Board Basin Plan for the Delta Estuary turbidity monitoring thresholds (Item 2); Mitigation Measure AIR-1b, which states when DWR can waive a specific requirement and what it will do if the requirement is waived to meet the performance standard (Item 3).

The phrase "to the extent feasible" or "as appropriate" appears in several mitigation measures. However, in every instance, there is a "fall back" position that identifies specific activities that would be required to be implemented in the event of infeasibility in the first instance. For example, Mitigation Measure BIO-2(2) says to avoid new areas mapped "if feasible." In the event avoidance is determined to be infeasible, then compliance with Mitigation Measure BIO-2(3) would appropriately reduce the impact. Mitigation Measure BIO-2(3) which uses the term "as appropriate" does not differentiate between newly surveyed or previously surveyed plants, it applies to all special-status plants impacted. It requires that seed, propagules, and/or rhizomes to be collected from 50% of plants impacted. This measure is supported with specific performance standards and monitoring to ensure achievement of 1:1 area of habitat with similar density to pre-Project conditions. Mitigation Measure BIO-2(6) also includes language about feasibility. It is specific to one special-status plant, Mason's lilaeopsis, that could be adversely impacted by the Proposed Project. It calls for compensatory mitigation if new individuals are found during pre-construction surveys. Accordingly, the inclusion of the phrase "to the extent feasible" does not render identified mitigation measures impermissibly vague or otherwise insufficient for purposes of CEQA.

Master Response #14: Invasive Plant Species and Harmful Algal Blooms

This Master Response responds to the following comments: 12-11, 12-28, 13-7, 14-7, 14-10, 15-2, 15-6, 15-7, and 19-1.

DWR agrees with commenters that the control of invasive species and harmful algal blooms (HABs) is important to the long-term success of the Lookout Slough Tidal Habitat Restoration and Flood Improvement Project. Invasive species control, monitoring, adaptive management, and long-term management actions are included as part of the Proposed Project. It is expected that the Proposed Project will reduce overall cover of invasive species within the Proposed Project Site, resulting in improvements to water quality and habitat integrity.

As described on page III-49 in Chapter III, *Project Description* of the Draft EIR, the Proposed Project is located within the Cache Slough Complex, an area that currently supports various invasive species such as: common reed *(Phragmites australis*), pampas grass (*Cortaderia selloana*), giant reed (*Arundo donax*), Brazilian waterweed (*Egeria densa*), water hyacinth (*Eichhornia crassipes*), spongeplant (*Limnobium laevigatum*), red sesbania (*Sesbania punicea*), and water primrose (*Ludwigia* spp.). Currently, tidal sloughs surrounding the Project Site are monitored and maintained to minimize invasive species through the Department of Parks and

Recreation Division of Boating and Waterway (DBW)'s Submersed Aquatic Vegetation Control Program and Floating Aquatic Vegetation Control Program, and through the Delta Region Area-wide Aquatic Weed Project funding of invasive aquatic vegetation research, monitoring, and control in the Delta.[28,29] DWR currently has a contract with DBW specifically to monitor and treat invasive vegetation at DWR's Fish Restoration Program (FRP) restoration sites, which would include the Proposed Project Site. DBW engages in surveys of areas where invasive species plant control is needed at FRP sites and DWR conducts aerial photography of all FRP restoration sites to identify vegetation composition, including invasive species infestations, before and following levee breaching.

Invasive Plant Species Management

Several comments were received regarding the adequacy of the Draft EIR's analysis of invasive species impacts. As described in Chapter III, *Project Description* of the Draft EIR, the Proposed Project would not only control invasive species before initial ground disturbance, but would also manage invasive species post-construction through compliance monitoring and effectiveness monitoring that will track indicators of ecological status and function. Long-term management of aquatic invasive plant species is outlined in the Draft EIR on page III-49 and discussed further in Section IV.D, *Biological Resources* on pages IV.D-56 and IV.D-57 under Impact iv. *Substantial Adverse Effects on Special-Status Species through Habitat Modification*. Mitigation Measure BIO-4 *Invasive Species Abatement* (page IV.D-56 through IV.D-57) requires the implementation of weed control protocols prior to, during, and after construction to minimize the potential for habitat degradation due to spread of existing on-site invasive species and establishment of invasive species in the vicinity of the Proposed Project Site. In addition, Mitigation Measure BIO-4 requires use of legally permitted pesticides to prevent impacts on water quality. With implementation of this mitigation measure, impacts from invasive species would be less than significant.

Mitigation Measure BIO-4 sets performance standards and identifies types of potential actions that can achieve the performance standards. The mitigation measure requires identification of target invasive weeds and weed infestations based on the California Invasive Plant Council Database ratings. Weed control treatments and timing will be selected for each target plant species "with the goal of controlling populations." Therefore, treatments will be deemed necessary when required to control weed populations. Mitigation Measure BIO-4 also permits the use of legally permitted herbicides, manual and mechanical extractions, and the use of a licensed qualified applicator subject to established regulatory programs. Weed control is also greatly influenced by timing of eradication efforts, and Mitigation Measure BIO-4 obligates DWR to use the specified weed control treatments necessary to control invasive populations. Implementation of Mitigation Measure BIO-4 would also include the long-term management removal of invasive water hyacinth, thus preventing water quality degradation from this invasive species. While the

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28 Ta, J., Anderson, L. W, Christman, M. A, Khanna, S., Kratville, D., Madsen, J. D, Patrick J. Moran, and Joshua H. Viers. 2017. *Invasive Aquatic Vegetation Management in the Sacramento–San Joaquin River Delta: Status and Recommendations*. San Francisco Estuary and Watershed Science, 15(4). Available: https://escholarship.org/uc/item/828355w6.

29 Division of Boating and Waterways. 2020. Aquatic Invasive Species Programs. Available: https://dbw.parks.ca.gov/?page_id=28764. Accessed April 18, 2020.

BIO-4 requires the implementation of weed control protocols prior to construction, it applies to both during and after construction.

With regards to the impact of invasive species on mitigation plantings of special-status plant species, see Mitigation Measure BIO-2, *Special-Status Plant Avoidance, Preservation, and Re-Planting* pages IV.D-53 and IV.D-54. A Restoration Plan will be prepared to mitigate for impacts to special-status plant species. As an element of the Restoration Plan, the mitigation plantings will be monitored according to specific performance criteria to evaluate successful reestablishment for a minimum of three growing seasons following initial planting or until performance has been achieved.

With regards to successful revegetation of tidal marsh discussed in Chapter III, *Project Description* of the Draft EIR on page III-41, the control of invasive species would provide for reduced competition followed by natural recruitment of tidal marsh plants. Revegetation of tidal marsh will be addressed as part of post-construction monitoring, adaptive management, and long-term management activities to ensure successful establishment.

A comment was received about impacts to water supply as a result of the growth of invasive plant species that consume large amounts of water that is lost to the atmosphere due to evapotranspiration. It is expected that the Proposed Project will reduce overall cover of invasive species in both upland and aquatic habitats within the Project Site. As described on pages III-47 through III-50 in Chapter III, *Project Description* of the Draft EIR, levee maintenance and long-term management would remove and minimize upland and aquatic invasive vegetation on the Project Site. Levee vegetation management may include any or all the following: herbicide spraying, burning, mechanized equipment operations, hand clearing, goat grazing, and other possible methods. With implementation of invasive upland and aquatic plant species removal throughout the Project Site, monitoring and long-term management discussed, and with the implementation of Mitigation Measure BIO-4, the impact on water supply through evapotranspiration due to the proliferation of invasive plant species as a result of the Proposed Project would be less than significant.

In response to comments regarding the application of pesticides and potential impacts to surface water, species, and/or adjacent areas, existing agricultural operations currently apply pesticide within the Project Site (see Draft EIR Section IV.F, *Hazards and Hazardous Materials*, pages IV.F-2 and IV.F-13). Levels of pesticide or herbicide known to exist in local waterbodies under existing conditions are discussed in Section IV.G, *Hydrology and Water Quality*, pages IV.G-3 through IV.G-5 of the Draft EIR. Any future application must also be conducted in compliance with all state and federal laws and regulations under the prescription of a Pest Control Advisor and implemented by a Licensed Qualified Applicator (see Chapter II, Executive Summary page II-22 and Section IV.D Biological Resources page IV.D-56 of the Draft EIR).

To clarify invasive species control measures, Mitigation Measure BIO-4 is revised as follows:

Mitigation Measure BIO-4. Invasive Plant Species Abatement

Prior to the start of construction activities, protocols shall be developed for targeted invasive weed abatement, which shall include at a minimum, the following:

1) Identify target weeds that are rated High or Moderate for negative ecological impact in the California Invasive Plant Database (Cal-IPC) within the Proposed Project Site that have potential to spread off-site and/or sustain on-site following the Proposed Project's restoration actions.
2) Where determined necessary to control identified weed populations, target weed infestations shall be treated according to control methods and practices considered appropriate for those species.
3) Weed control treatments shall include all legally permitted herbicide, manual, and mechanical methods, approved for aquatic use by the U.S. Environmental Protection Agency and California Department of Pesticide Regulation. The application of herbicides shall be in compliance with all state and federal laws and regulations under the prescription of a Pest Control Advisor and implemented by a Licensed Qualified Applicator.
4) The timing of weed control treatment shall be determined for each target plant species with the goal of controlling populations. During post-construction operation of the Proposed Project, DWR shall monitor for the presence of invasive aquatic plant species in accordance with BIO-4(1). Invasive aquatic plant species shall be removed in accordance with BIO-4(2) and (3). Post-construction monitoring shall occur following the implementation of any procedures used to remove invasive aquatic plants to ensure that the procedures are effective.

Harmful Algal Blooms (HAB)

Several comments were received regarding the adequate analysis of water quality impacts associated with the proliferation of HABs. The Proposed Project will not create conditions that would give rise to HABs with regard to environmental factors including turbidity, salinity, temperature, or nutrients that would trigger the emergence and subsequent growth of HABs. The potential contribution of turbidity and nutrients related to water quality and algal blooms is discussed in Section IV.G *Hydrology and Water Quality*, of the DEIR, pages IV.G-4, IV.G-21, and IV.G-22. With regards to temperature, as stated on page IV.G-28: "Temperature decreases associated with marsh vegetation shading are therefore anticipated to roughly offset or decrease temperature increases associated with solar radiation due to shallow depth. Accordingly, changes to water temperature would be minimal and would not impact in-Delta water temperature criteria. Therefore, impacts would be less than significant." Thus, the Proposed Project would have minimal effect on water temperature that may influence the presence of HABs. With regards to salinity, as stated on page IV.G-23 through IV.G-25, the Proposed Project would not result in substantial adverse effects on the beneficial use of Delta waters as drinking water or exceed the applicable threshold of significance for agricultural operations or fish and wildlife populations post-construction. With regard to nutrients, current farming practices, under baseline conditions, use pesticides and fertilizers that can contribute residual levels of chemicals in irrigation and other site runoff which can adversely affect receiving water quality. Such practices would end prior to construction of the Proposed Project, decreasing potential inputs that might contribute to water quality issues over time as part of the cumulative scenario. Additionally, the emergence of increased concentrations of HABs is indicative of potential problems with water stagnation. The Proposed Project would reintroduce tidal influence to the Project Site, reducing water stagnation. Therefore, the Proposed Project is expected to have a positive influence on water quality by eliminating agricultural inputs that contribute to HABs and other aquatic invasive species. Thus, impacts to water quality would be less than significant.

Cumulative Impacts

Pertaining to the adequacy of the Draft EIR's analysis of cumulative impacts, including the potential proliferation of HABs and invasive aquatic species, as previously discussed, the Proposed Project includes invasive species control during the construction stage and post-construction. The Proposed Project is also designed to favor native fish species while discouraging establishment and colonization by non-native species, as explained on in Section IV.D, *Biological Resources*, page IV.D-84 of the Draft EIR. In summary, the Proposed Project and other restoration projects would not contribute to the proliferation of HABs or other invasive aquatic species. Accordingly, impacts would be less than cumulatively considerable. The following clarifying text has been added to Chapter V, Cumulative Impacts.

In the context of potential cumulative impacts to biological resources, the text at the top of page V-10 has been revised to clarify as follows:

> The Proposed Project is designed to favor native fish species while discouraging establishment and colonization by non-native species. The Proposed Project also includes invasive species control during the construction stage, as discussed on Draft EIR pages III-23, III-29, and III-33. In addition, the Proposed Project would include post-construction monitoring of invasive aquatic plant species. The Proposed Project would incorporate greater invasive species control than what exists in surrounding sloughs under baseline conditions. Therefore, the Proposed Project would not have a cumulatively considerable contribution to the proliferation of invasive aquatic species.

In the context of potential cumulative impacts to water quality, the text at the top of page V-13 has been revised to clarify as follows:

> Current farming practices, under baseline conditions, use pesticides and fertilizers that can contribute residual levels of chemicals in irrigation and other site runoff which can adversely affect receiving water quality. Such practices would end prior to construction of the Proposed Project, decreasing potential inputs that might contribute to water quality issues over time as part of the cumulative scenario. Additionally, the emergence of increased concentrations of HABs is indicative of potential problems with water stagnation. The Proposed Project would reintroduce tidal influence to the Project Site, reducing water stagnation. Therefore, the Proposed Project is expected to have a positive influence on water quality by eliminating agricultural inputs and by reducing stagnant water that contribute to the proliferation of HABs and other aquatic invasive species. As a result, the Proposed Project would not have a cumulatively considerable contribution to cumulative water quality effects, including the proliferation of HABs.

3.3 Responses to Comments

This section presents the comment letters received (see Table 2-1) and responses to the comments contained in each letter. The responses to comments are numbered consistent with the comment number for each letter and the order of the comment. For example, the response to the first comment in Comment Letter 1 is Response 1-1. For each comment, DWR responds to the full comment provided by the commenter. In some cases where multiple comment letters provided the same or similar comments, the comment may refer the reader to a similar response to another letter(s) or to a master response.

Letter 1
California Department of Toxic Substances Control

Letter 1

Department of Toxic Substances Control

Meredith Williams, Ph.D.
Acting Director
8800 Cal Center Drive
Sacramento, California 95826-3200

Jared Blumenfeld
Secretary for
Environmental Protection

Gavin Newsom
Governor

December 24, 2019

Ms. Heather Green
Department of Water Resources
3500 Industrial Boulevard
West Sacramento, California 95691

DRAFT ENVIRONMENTAL IMPACT REPORT FOR LOOKOUT SLOUGH TIDAL HABITAT RESTORATION AND FLOOD IMPROVEMENT PROJECT - DATED DECEMBER 2019
(STATE CLEARINGHOUSE NUMBER: 2019039136)

Dear Ms. Green:

The Department of Toxic Substances Control (DTSC) received a Draft Environmental Impact Report (EIR) for Lookout Slough Tidal Habitat Restoration and Flood Improvement Project.

The proposed project is designed to be a multi-benefit project to restore approximately 3,100 acres of tidal marsh, increase flood storage and conveyance in the Yolo Bypass, increase levee resilience, and decrease flood risk. Habitat restoration and flood improvement goals would be attained by excavating a network of tidal channels, constructing a new setback levee along Duck Slough, breaching and degrading the Shag Slough (Yolo Bypass West) Levee, breaching the Vogel Levee, and improving the Cache/Hass Slough Levee to function as a training levee.

DTSC recommends that the following issues be evaluated in the EIR, Hazards and Hazardous Materials section:

1. The EIR should acknowledge the potential for project site activities to result in the release of hazardous wastes/substances. In instances in which releases may occur, further studies should be carried out to delineate the nature and extent of the contamination, and the potential threat to public health and/or the environment should be evaluated. The EIR should also identify the mechanism(s) to initiate any required investigation and/or remediation and the government agency who will be responsible for providing appropriate regulatory oversight. 1-1

Response 1-1:

As described on Draft EIR pages IV.F-1 to IV.F-3 in Section IV.F, *Hazards and Hazardous Materials*, the analysis of the potential for project activities to result in the release of hazardous materials was based on a number of Phase I and Phase II Environmental Site Assessments that were included as Appendices J through N of the Draft EIR. The current landowner, as part of the purchase of the property, had the Phase I and Phase II Environmental Site Assessments prepared by firms certified in California to conduct hazardous materials and asbestos surveys, testing and removal. Remediation by the current landowner will be completed prior to initiation of Project construction activities and will include removal of contaminated soil associated with an underground storage tank and previous agricultural activities. As described on page IV.F-3, the current landowner will remediate hazardous materials identified in the Phase II Environmental Site Assessment in accordance with applicable state regulations and guidelines. Therefore, the remediation activities are not part of the Proposed Project analyzed in the Draft EIR. Once these hazardous materials are removed and remediated to applicable regulatory standards, there will be no known hazardous materials above applicable regulatory thresholds on the property.

DWR and its contractors will comply with all applicable regulatory requirements. Significant hazards to the public or the environment through the routine transport, use and disposal of hazardous materials is analyzed in Impact i on page IV.F-13. The analysis identifies a number of local, state and federal laws and regulations that apply to the Proposed Project, including best management practices required by the Solano County Certified Unified Program Agencies (CUPA) program, the state Unified Hazardous Waste and Hazardous Materials Management Regulatory Program required by Senate Bill 1082 and a Spill Prevention Containment and Countermeasure (SPCC) plan as required under Section 301 of the Clean Water Act to minimize the potential for, and effects from, spills of hazardous, toxic, and petroleum substances during construction and operation activities. In addition, Impact ii analyzes possible upset and accident conditions on pages IV.F-14 through IV.F-15. The analysis states that although natural gas wells and pipelines are well-documented and all available data indicate that they have been properly plugged and abandoned in compliance with applicable standards, this does not preclude the slight possibility of future leaks or accidental disturbance during construction. Mitigation Measure MINERAL-1 requires plans and procedures for natural gas well abandonment and avoidance to be incorporated into final construction plans to minimize the likelihood of such an occurrence. Therefore, with the implementation of these local, state and federal requirements, impacts of the Proposed Project would not exceed the applicable threshold of significance related to significant hazards to the public or the environment through the routine transport, use, or disposal of hazardous materials or significant hazards to the public or the environment through reasonably foreseeable upset and accident conditions involving the release of hazardous materials into the environment and the Proposed Project's impact with regard to these thresholds would be less than significant.

In addition, in the event that undocumented petroleum hydrocarbons are encountered during construction, as described on pages IV.F-7 through IV.F-8, a SPCC plan will be developed prior to construction, kept on site, and implemented that will include provisions to minimize the effects of unearthing previously undocumented hazardous materials.

Letter 1

2. If buildings or other structures are to be demolished on any project sites included in the proposed project, surveys should be conducted for the presence of lead-based paints or products, mercury, asbestos containing materials, and polychlorinated biphenyl caulk. Removal, demolition and disposal of any of the above-mentioned chemicals should be conducted in compliance with California environmental regulations and policies. In addition, sampling near current and/or former buildings should be conducted in accordance with DTSC's 2006 *Interim Guidance Evaluation of School Sites with Potential Contamination from Lead Based Paint, Termiticides, and Electrical Transformers* (https://dtsc.ca.gov/wpcontent/uploads/sites/31/2018/09/Guidance Lead Contamination 050118.pdf). 1-2

Response 1-2:

See Response 1-1 for a discussion of the environmental site assessments completed for the Proposed Project Site.

3. If any projects initiated as part of the proposed project require the importation of soil to backfill any excavated areas, proper sampling should be conducted to ensure that the imported soil is free of contamination. DTSC recommends the imported materials be characterized according to *DTSC's 2001 Information Advisory Clean Imported Fill Material* (https://dtsc.ca.gov/wp-content/uploads/sites/31/2018/09/SMP FS Cleanfill-Schools.pdf). 1-3

Response 1-3:

As described in Chapter III, *Project Description* on page III-36, the Proposed Project includes the excavation of approximately 5,255,000 cubic yards of soil. Excavated materials would be re-used on-site as appropriate based on soil types and beneficial re-use needs. No soil would be imported to backfill excavated areas.

4. If any sites included as part of the proposed project have been used for agricultural, weed abatement or related activities, proper investigation for organochlorinated pesticides should be discussed in the EIR. DTSC recommends the current and former agricultural lands be evaluated in accordance with DTSC's 2008 *Interim Guidance for Sampling Agricultural Properties (Third Revision)* (https://dtsc.ca.gov/wp-content/uploads/sites/31/2018/09/A-gGuidance-Rev-3-Augu$t-7-2008-2.pdf). 1-4

Response 1-4:

The DTSC guidance referenced in the comment is designed to evaluate sites for suitability as school use and to determine potential impacts on public health. The guidance is based on the assessment of exposure routes (inhalation, contact and ingestion) to humans. Use of the Proposed Project Site as a restoration project will not include public use.

As noted in Response 1-3, excavated soil would be re-used on site; therefore, the Proposed Project would not result in the export of soil. In addition, and as noted in Response 1-1, on pages IV.F-1 to IV.F-3,

Letter 1

Phase I and Phase II Environmental Site Assessments were conducted on the Project Site. These assessments included a soil sampling and testing program to identify the potential for hazardous materials associated with prior agricultural activities, such as pesticides, including organochlorinated pesticides. See also Response 1-1 for more information on the testing and clean-up of identified hazardous materials prior to the start of the Proposed Project.

DTSC appreciates the opportunity to review the EIR for Lookout Slough Tidal Habitat Restoration and Flood Improvement Project. Should you need any assistance with an environmental investigation, please submit a request for Lead Agency Oversight Application, which can be found at: https://dtsc.ca.gov/wp-content/uploads/sites/31/2018/09NCP App-1460.doc. Additional information regarding voluntary agreements with DTSC can be found at: https://dtsc.ca.gov/brownfields/.

If you have any questions, please contact me at (916) 255-3710 or via email at Gavin.McCreary@dtsc.ca.gov.

Sincerely,

Gavin McCreary
Project Manager
Site Evaluation and Remediation Unit
Site Mitigation and Restoration Program
Department of Toxic Substances Control

cc: (via email)

Governor's Office of Planning and Research
State Clearinghouse
State.clearinghouse@opr.ca.gov

Ms. Lora Jameson, Chief
Site Evaluation and Remediation Unit
Department of Toxic Substances Control
Lora.Jameson@dtsc.ca.gov

Mr. Dave Kereazis
Office of Planning & Environmental Analysis
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Dave.Kereazis@dtsc.ca.gov

Letter 2
California Department of Fish and Wildlife, Bay Delta Region

State of California
Department of Fish and Wildlife

Memorandum

Date: February 12, 2020

To: Ms. Heather Green
California Department of Water
Resources 3500 Industrial Boulevard
Sacramento, CA 95691

From: Mr. Greg Erickson, Regional Manager
California Department of Fish and Wildlife-Bay Delta Region, 2825 Cordelia Road, Suite 100, Fairfield, CA 94534

Subject: Lookout Slough Tidal Habitat Restoration and Flood Improvement Project, Draft Environmental Impact Report, SCH #2019039136, Solano County

The California Department of Fish and Wildlife (CDFW) has reviewed the above Lookout Slough Tidal Habitat Restoration and Flood Improvement Project (Project) draft Environmental Impact Report (EIR) as proposed by the lead agency, the California Department of Water Resources (DWR) pursuant the California Environmental Quality Act (CEQA) and CEQA Guidelines.[1] We appreciate the opportunity to provide comments regarding those aspects of the Project that CDFW, by law, may be required to carry out or approve through the exercise of its own regulatory authority under the Fish and Game Code.

CDFW ROLE

CDFW is California's Trustee Agency for fish and wildlife resources and holds those resources in trust by statute for all the people of the State. [Fish and Game Code, §§ 711.7, subd. (a) and 1802; Pub. Resources Code, § 21070; CEQA Guidelines § 15386, subd. (a)]. CDFW, in its trustee capacity, has jurisdiction over the conservation, protection, and management of fish, wildlife, native plants, and habitat necessary for biologically sustainable populations of those species *(Id.,* § 1802). Similarly, for purposes of CEQA, CDFW is charged by law to provide, as available, biological expertise during public agency environmental review efforts, focusing specifically on projects and related activities that have the potential to adversely affect fish and wildlife resources.

CDFW is also submitting comments as a Responsible Agency under CEQA (Pub. Resources Code, § 21069; CEQA Guidelines, § 15381). CDFW expects that it may need to exercise regulatory authority as provided by the Fish and Game Code. As proposed, for example, the Project may be subject to CDFW's lake and streambed alteration regulatory authority (Fish and Game Code, § 1600 et seq.). Likewise, to the extent implementation of the Project as proposed may result in "take", as defined by State law, of any species protected under the California Endangered Species Act (CESA) (Fish and Game Code, § 2050 et seq.), the Project proponent may seek related take authorization as provided by the Fish and Game Code.

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[1] CEQA is codified in the California Public Resources Code in section 21000 et seq. The "CEQA Guidelines" are found in Title 14 of the California Code of Regulations, commencing with section 15000.

REGULATORY REQUIREMENTS

California Endangered Species Act

Please be advised that a CESA Incidental Take Permit (ITP) must be obtained if the Project will result in "take" of plants or animals listed under CESA, either during construction or over the life of the Project. Issuance of a CESA ITP is subject to CEQA documentation; the CEQA document must specify impacts, mitigation measures, and a mitigation monitoring and reporting program. If the Project will impact CESA listed species, early consultation is encouraged, as significant modification to the Project and mitigation measures may be required in order to obtain a CESA ITP. 2-1

Response 2-1:

DWR and its contractors will comply with all applicable regulatory requirements, however the EIR is not required to include all the information necessary to meet other regulatory program requirements.

CEQA requires a Mandatory Finding of Significance if a project is likely to substantially restrict the range or reduce the population of a threatened or endangered species (Pub. Resources Code, §§ 21001, subd. (c), 21083; CEQA Guidelines, §§ 15380, 15064, and 15065). Impacts must be avoided or mitigated to less-than-significant levels unless the CEQA Lead Agency makes and supports Findings of Overriding Consideration (FOC). The CEQA Lead Agency's FOC does not eliminate the Project proponent's obligation to comply with CESA. 2-2

Response 2-2:

Please see Response 2-1. The Draft EIR did not find any impacts on biological resources to be significant and unavoidable.

Lake and Streambed Alteration

CDFW requires a Lake and Streambed Alteration (LSA) Notification, pursuant to Fish and Game Code section1600 et. seq., for Project activities affecting lakes or streams and associated riparian habitat. Notification is required for any activity that may substantially divert or obstruct the natural flow; change or use material from the bed, channel, or bank including associated riparian or wetland resources; or deposit or dispose of material where it may pass into a river, lake, or stream. Work within ephemeral streams, washes, watercourses with a subsurface flow, and floodplains are subject to notification requirements. CDFW will consider the CEQA document for the Project and may issue an LSA Agreement. CDFW may not execute the final LSA Agreement (or ITP) until it has complied with CEQA as a Responsible Agency. 2-3

Response 2-3:

Please see Response 2-1.

PROJECT DESCRIPTION SUMMARY

Proponent: California Department of Water Resources

Objective: The objective of the Project is to restore approximately 3,164 acres of tidal marsh and subtidal habitats and increase flood conveyance and storage within the Yolo Bypass. Primary Project activities include dewatering internal water features, remove existing infrastructure, vegetation clearing, invasive plant species control, creation of the Duck Slough Setback Levee, improvements to the Cache/ Hass Slough Levee, excavating internal ponds and channels, constructing access peninsulas, installing temporary cofferdams at breaches, excavating 11 breaches, degrading portions of the Shag Slough Levee, creating Delta Smelt spawning habitat, and ecosystem restoration compliance and effectiveness monitoring.

Location: The Project is located in the Cache Slough Complex, in unincorporated southeastern Solano County, with a small portion of work extending into Yolo County. The Project is bounded by Liberty Island Road to the north, Duck Slough to the northwest, Cache and Hass Sloughs to the south and southwest, and Shag Slough to the east.

Construction Timeframe: June 2020 – April 2022

COMMENTS AND RECOMMENDATIONS

CDFW offers the comments and recommendations below to assist DWR in adequately identifying and/or mitigating the Project's significant, or potentially significant, direct and indirect impacts on fish and wildlife (biological) resources.

Project Description and Related Impact Shortcoming

Comment 1: Duck Slough Setback Levee Construction, page 111-38. The draft EIR states that "The Duck Slough Setback Levee would include a soil-bentonite cutoffwall ranging in depth from 25 to 50 feet below the existing ground surface". No additional information is provided about the cutoff wall. Because of the lack of information about construction of the cutoff wall, CDFW cannot adequately evaluate potential environmental impacts associated with the cutoff wall. Furthermore, the draft EIR does not evaluate potential impacts from the cutoff wall to subsurface water flow in the Environmental Impacts section of the draft EIR. According to the draft EIR, groundwater in the Proposed Project is between 3 and 12 feet below the ground surface. Because of the shallow groundwater depth, CDFW has concerns that a 25- to 50-foot-deep cutoff wall could significantly impact local subsurface water flow between the wetlands and adjacent land. 2-4

CDFW recommends DWR provide additional construction methods (such as trenching, volume of soil-bentonite mixture, how and where it will be mixed, any potential water quality impacts, bentonite spill contingency plan) for the soil-bentonite cutoff wall in the draft EIR and analyze the potential impacts to subsurface water flow between the Project site and adjacent land.

Response 2-4:

Regarding impacts from the cutoff wall to subsurface water flow, in general, the soil conditions underlying the Duck Slough Setback Levee alignment consist of a relatively thick layer of clay which allows little to no groundwater movement. Potential water quality impacts from all aspects of the Proposed Project were considered in Section IV.G, *Hydrology and Water Quality* of the Draft EIR.

The following text is added to Draft EIR Chapter III, *Project Description* on page III-39 to describe construction methods for the installation of the Duck Slough setback levee cutoff wall:

> Duck Slough Setback Levee Cutoff Wall Construction
>
> A soil-bentonite shallow cutoff wall will be constructed under the Duck Slough Setback Levee to reduce nuisance seepage potential by intersecting intermittent, discontinuous higher permeable soil layers in the upper 20 feet of ground. In general, the soil conditions underlying the Duck Slough Setback Levee alignment consist of a relatively thick layer of clay which allows little to no groundwater movement, with some discontinuous permeable soils with limited localized shallow groundwater movement. This localized source of groundwater is not connected to a larger aquifer.
>
> The wall will extend only 35-feet-deep along the majority of the alignment, with an exception where it will extend to a 50-foot depth for about 2,000 feet of the alignment to address an

> anomalous, isolated shallow pervious layer. The wall will be constructed along the centerline of the Duck Slough Setback Levee, before construction of the Levee itself. The existing ground will be cleared, and an excavator with a long stick excavator boom will dig a 3-foot wide trench to the specified depth. A bentonite slurry will then be used to fill in the trench during trench excavation. The excavated soil will be mixed with bentonite slurry and then placed back in the trench. After a specified time-frame, approximately two weeks, the levee embankment will then be constructed. Prior to construction, the Spill Prevention Countermeasure and Control Plan (SPCC) will be in place to deal with any spills or erosion.

To the extent that other regulatory program requirements deal with this subject, DWR and its contractors will comply with all applicable regulatory requirements.

Comment 2: The Project description does not mention the fate of the Shag Slough Bridge. CDFW is concerned that the bridge could become a navigational hazard without a land-based route to maintain or remove the bridge. CDFW recommends DWR analyze the impacts associated with removing road access to the bridge and the potential impediments to maintenance or removal of the bridge. 2-5

Response 2-5:

As discussed in the Draft EIR on page IV.1-9 in Chapter IV.I, *Public Services* and on page V-16 in Chapter V, *Cumulative Impacts*, the Shag Slough Bridge would not be removed, although it would no longer be accessible by land. Closure of the bridge to traffic does not preclude maintenance or removal of the bridge by water. Removal of the bridge is not a part of the Proposed Project. Furthermore, the condition of the bridge is part of the existing environmental setting and baseline condition, and no changes to the structure or location of the bridge are part of the Proposed Project.

Regulatory Framework

Comment 3: California Endangered Species Act, page IV.D-43. The draft EIR description of CESA is misleading. The statement "CESA requires State agencies to coordinate with CDFW to ensure that State-authorized or State-funded actions do not jeopardize a state-listed species" implies that only State agencies are subject to CESA. However, CESA applies to agencies, groups, organizations, and individuals. 2-6

CDFW recommends revising this section of the draft EIR to better describe CESA and CDFW's role in working with agencies, organizations, and other interested parties to study, protect, and preserve CESA-listed species and their habitats. Additional information on CESA and ITPs can be found on our website (https://wildlife.ca.gov/Conservation/CESA).

Response 2-6:

Page IV.D-43 in Section IV.D, *Biological Resources* of the Draft EIR focuses on State agency action because DWR is a State lead agency. In response to this comment, the last paragraph on page IV.D-43 of the Draft EIR is revised as follows for clarification:

> …Among other things, CESA requires state agencies to coordinate with CDFW to ensure that ~~state-authorized or state-funded~~ projects or actions do not jeopardize a state-listed species.…

Comment 4: California Fish and Game Code 1600, page IV.D-44. The draft EIR states that "The term 'stream', which includes creeks and rivers, is defined in the California Code of Regulations as follows: 'a body of water that flows at least periodically or intermittently through a bed or channel having banks and supports fish or other aquatic life'. This includes watercourses having a surface or subsurface flow that supports or has supported riparian vegetation" (California Code of Regulations Title 14, Section 1.72)". However, California Code of Regulations Title 14, Section 1.72 does not apply to Fish and Game Code section 1602. CDFW recommends deleting this stream definition from the draft EIR.

The draft EIR also uses information and language from a 1994 CDFW document, *A Field Guide to Lake and Streambed Alteration Agreements.* This document is outdated is not used by CDFW. CDFW recommends deleting all information cited from *A Field Guide to Lake and Streambed Alteration Agreements,* specifically the following sentences from the draft EIR: 2-7

> "~~In addition, the term stream can include ephemeral streams, dry washes, watercourses with subsurface flows, canals, aqueducts, irrigation ditches, and other means of water conveyance if they support aquatic life, riparian vegetation, or stream-dependent terrestrial wildlife.~~[15] ~~Riparian is defined as "on, or pertaining to, the banks of a stream;" therefore, riparian vegetation is defined as, "vegetation which occurs in and/or adjacent to a stream and is dependent on, and occurs because of, the stream itself".~~[16] ~~Removal of riparian vegetation also requires a Section 1602 Lake and Streambed Alteration Agreement from the CDFW.~~"

Response 2-7:

The following text has been revised in the Draft EIR to reflect the comment:

> The beds and banks of rivers, s~~S~~treams, and lakes~~, and riparian vegetation as habitat for fish and wildlife,~~ are subject to CDFW jurisdiction under Section 1602 of the California Fish and Game Code. A 1602 Lake and Streambed Alteration Agreement is generally required for any activity that will have one or more of the following effects: (1) substantially obstruct or divert the natural flow of a river, stream, or lake; (2) substantially change or use any material from the bed, channel, or bank of a river, stream, or lake; or (3) deposit or dispose of debris, waste, or other material containing crumbled, flaked, or ground pavement where it can pass into a river, stream, or lake. ~~The term "stream", which includes creeks and rivers, is defined in the California Code of Regulations as follows: "a body of water that flows at least periodically or intermittently through a bed or channel having banks and supports fish or other aquatic life". This includes watercourses having a surface or subsurface flow that supports or has supported riparian vegetation" (California Code of Regulations Title 14, Section 1.72). In addition, the term stream can include ephemeral streams, dry washes, watercourses with subsurface flows, canals, aqueducts, irrigation ditches, and other means of water conveyance if they support aquatic life, riparian vegetation, or stream-dependent terrestrial wildlife.~~[15] ~~Riparian is defined as "on, or pertaining to, the banks of a stream;" therefore, riparian vegetation is defined as, "vegetation which occurs in and/or adjacent to a stream and is dependent on, and occurs because of, the stream itself".~~[16] ~~Removal of riparian vegetation also requires a Section 1602 Lake and Streambed Alteration Agreement from the CDFW.~~

Environmental Impacts

Comment 5: The draft EIR has several minimization and mitigation measures that are not strong enough or specific enough to be implemented. Wording such as "to the extent feasible" and portions of measures that will be determined at a later date such as buffer distances are not able to be implemented consistently during construction. The vague language used in the draft EIR provides no protections to the species. 2-8

To reduce the risk to species, CDFW suggests revising any minimization or mitigation measure that includes undefined areas, buffers, or other vague language to better define measures to be implemented.

Response 2-8:

As discussed in Master Response 13, *Performance Standards and Deferred Mitigation,* DWR has reviewed all of its mitigation measures and does not consider any of them to be improperly deferred. See the discussion below regarding Mitigation Measure BIO-5A, Nesting Birds, and Mitigation Measure BIO 5F, Valley Elderberry Longhorn Beetle (VELB), which both describe a circumstance where work will be performed to an extent feasible; and to the extent it is not feasible, then additional specific actions are required to be implemented, including seasonal restrictions or buffer distances.

Regarding Mitigation Measure BIO-5A, and as noted on page IV.D-58 in Section IV.D, *Biological Resources* of the Draft EIR, vegetation removal is limited to the non-nesting season (September 1 to January 31) to the extent feasible. To the extent vegetation removal is not feasible during this time period, the mitigation measure provides specific measures that must be followed, such as, nesting bird surveys must be conducted within 14 days prior to the start of any project-related work to assure disturbance to active nests (i.e. those with eggs and/or young) are avoided. With these measures, Mitigation Measure BIO-5A includes performance standards that are incorporated in the mitigation measure and identifies the types of potential actions that can feasibly achieve the performance standard. Based on these mitigation measures, the Draft EIR concluded on page IV.D-60 that impacts to nesting birds would be less than significant with mitigation incorporated.

Regarding Mitigation Measure BIO-5F, and as noted on page IV.D-76 of the Draft EIR, Proposed Project activities within 165 feet of occupied elderberry shrubs shall be avoided to the extent feasible. To the extent avoidance is not feasible within this 165-foot buffer, eight specific measures (a-h) would be implemented to avoid impacts to the VELB or its habitat (elderberry shrubs). In addition, any occupied shrubs that cannot be avoided would be transplanted as described in Point 2 of the same mitigation measure on page IV.D-77. Based on these mitigation measures, the Draft EIR concluded on page IV.D-76 that impacts to the VELB would be less than significant with mitigation incorporated. Mitigation Measure BIO-5F includes performance standards that are incorporated in the mitigation measure and identifies the types of potential actions that can feasibly achieve the performance standard.

Comment 6: The draft EIR does not predict the amount of time it will take for wetland or other habitats to naturally regenerate on-site post-construction. Post-construction acreages of habitat types are asserted but there is no discussion of the amount of time it will take to achieve those acreages. The draft EIR does not analyze the impacts related to loss of habitat and potential increase in turbidity prior to wetland and other habitat types colonizing the site. Depending on the length of time it takes for habitat to develop and post-construction conditions, there are potentially significant impacts to species, habitats, and water quality due to a lag in development of habitats. 2-9

Response 2-9:

Direct and indirect impacts to biological resources (including wetlands, habitats and species) are analyzed in Draft EIR Section IV.D, *Biological Resources* and direct and indirect impacts to water quality are analyzed in Draft EIR Section IV.G *Hydrology and Water Quality*. As discussed on page III-41in the Draft EIR Section III, *Project Description*, the Proposed Project will rely on natural regeneration of tidal marsh vegetation following construction. Additionally, riparian habitats will be planted and upland areas will be seeded with grasses.

Extensive research, including literature reviews and discussions with wetland experts, was conducted to understand rates of natural regeneration for tidal marsh vegetation, however an exact time frame for tidal marsh establishment is difficult to predict due to a lack of published reports on this topic. It is anticipated that colonization of freshwater tidal emergent marsh vegetation in the mid-intertidal zones across the Proposed Project Site may take 3-5 years. It is also anticipated to take 10-15 years for tidal marsh vegetation to establish at the upper and lower end of the intertidal zone following breaching.[1]

With regard to the amount of time it would take for the planted riparian habitats to become established after project construction, the Draft EIR did consider this timeframe and assessed the impacts thereof. Temporary impacts on riparian habitats during and immediately following construction are discussed on pages IV.D-51 to IV.D-52 in the Draft EIR. Page IV.D-57 and page IV.D-62 discuss that following restoration, revegetation of riparian areas would take several years to reach maturity. Further discussion on the length of time it will take riparian plantings to mature is included in Response 2-10 below.

The Proposed Project has the potential to cause temporary adverse impacts to listed and special-status fish species through construction-related injury or mortality, noise, turbidity, and stranding. A discussion of impacts of turbidity and mitigation on fish species is presented under the heading "Turbidity Impacts to Fish" on pages IV.D-82 and IV.D-83 of the Draft EIR and concludes impacts would be less than significant with mitigation incorporated. As discussed in Section IV.G, *Hydrology and Water Quality* of the Draft EIR, turbidity levels in the Delta are generally high due to sediment transport from the Sacramento River and San Joaquin River watersheds, especially during high flow periods. As stated on page IV.D-32 of the Draft EIR, Delta Smelt are strongly associated with turbid conditions, requiring turbidity gradients for spawning cues and concealment from predators. Following the removal of the cofferdams to connect the Proposed Project with tidal flows, turbidity levels are anticipated to be the highest. However, Mitigation Measure BIO-6 restricts breaching to the time between June 1 and October 31, or the period of time when most special-status fish are not present.

High levels of erosion are not anticipated to contribute to turbidity. Geotechnical and hydrologic and hydraulic investigation, modeling, and analysis performed for the Proposed Project indicate that the underlying soil provides stable soil conditions that would not be susceptible to erosion from the hydraulic shear stresses on the designed channels and levee breaches.[2,3] Areas with no ground disturbance outside of slough and levee construction would remain vegetated and provide habitat patches to facilitate revegetation and limit erosion after construction. Lastly, during construction of the

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1 Environmental Science Associates. 2020. *Freshwater Tidal Emergent Marsh Maturation Trends with Restoration at Lookout Slough Tidal Habitat Restoration and Flood Improvement Project*. Memo prepared for EIP. April 28, 2020.

2 Environmental Science Associates. 2019. *Lookout Slough Tidal Habitat Restoration and Flood Improvement Project – Draft Hydrologic and Hydraulic System Analysis.* September.

3 *Draft 65% geotechnical basis of design Report. 2019.* Blackburn Consulting. November 2019.

Proposed Project, turbidity levels will be monitored in accordance with the objectives of the Basin Plan for the Delta Estuary as described in Mitigation Measure HYDRO-2 on page IV.G-20.

In relation to the cumulative impact, the Draft EIR similarly concludes on pages V-9 to V-10 of Chapter,V, *Cumulative Impacts* of the Draft EIR that "[i]n the long-term, the Proposed Project and related projects would create habitat for species such as Delta Smelt, Chinook Salmon, Steelhead, Longfin Smelt, and Sacramento Splittail, creating a net beneficial effect on special-status and listed fish species." Besides the specific mitigation measures identified in the Draft EIR, a number of project monitoring programs that include CDFW involvement will occur, including a Restoration Plan, an Adaptive Management and Monitoring Plan, and a Long-Term Management Plan.

Comment 7: Loss of Riparian Habitat and Mitigation Measure BIO-1, page IV.D-51. The draft EIR states that the proposed Project "would result in impacts to approximately 24.8 acres of sensitive Great Valley mixed riparian forest..." and that "Implementation of Mitigation Measure BIO-1, which requires a minimum 1.1:1 replacement ratio for riparian vegetation removal, would result in an approximate 10% increase in riparian acreage." CDFW disagrees with the latter statement because a 10% increase would require 100% survival of the replanted riparian habitat. It is very unlikely that such a high survival rate would occur over 5 years, let alone 10 years, especially for riparian habitat planted on the access roads subject to periodic Yolo Bypass flooding. Prolonged flooding could erode or kill newly planted riparian vegetation. Additionally, a 1.1:1 ratio does not mitigate for the temporal loss of riparian habitat function because it could take as long as a decade for the replanted riparian habitat to grow into a mature mixed riparian forest. 2-10

To reduce the loss of riparian habitat to less-than-significant, CDFW recommends that the 1.1:1 riparian vegetation mitigation ratio in Mitigation Measure BIO-1 be replaced with a **3:1** ratio. A 3:1 ratio would mitigate for the direct loss and the temporal loss as the replanted riparian habitat matures and regain its biological and ecological functions. CDFW also recommends that DWR monitor and maintain the replanted riparian habitat for at least 5 years and maintain a minimum 75% survival rate at year 5.

Response 2-10:

The planting approach detailed on pages III-41 to III-42 in Chapter III, *Project Description* of the Draft EIR, assuming even a modest level of mortality of planted material, would likely result in a patchy habitat structure with openings in the canopy that is common and is consistent with the existing riparian habitats on-site, as described in section 4.1.2 of Appendix F, *Biological Resource Assessment (BRA): Lookout Slough Tidal Habitat Restoration and Flood Improvement Project* of the Draft EIR.

The commenter also suggests that a 1.1:1 replacement ratio would not mitigate for the temporal loss of riparian habitat function because it could take as long as a decade for the replanted riparian habitat to grow into a mature mixed riparian forest. This comment notes that the existing riparian habitats are comprised of mature mixed riparian forest and that the habitat function of the planted riparian habitat is dependent on the riparian habitat being mature. As stated on page 16 of Appendix F, *Biological Resource Assessment (BRA): Lookout Slough Tidal Habitat Restoration and Flood Improvement Project* of the Draft EIR, the existing great valley riparian forest has both closed canopy and open canopy components consisting of mixed stands of arroyo willow thickets and black willow thickets as well as valley oak woodlands. While habitats dominated by mature patches of riparian trees, such as valley oak woodlands, that are temporarily impacted by the Proposed Project may take 25 to 30 years to develop a sizeable tree canopy,[4] riparian scrub habitats such as arroyo willow thickets, black willow thickets, or open canopy areas would be expected to develop rapidly because of the fast growing nature of arroyo willow and black willow.[5] Stem cuttings of willows can grow to 6 feet tall within the first growing season.[6] The California Riparian Habitat Restoration Handbook suggests planting early successional species, like willows, along with later successional species, like valley oak, so that the rapidly growing species will first provide structure, while the slower growing species will become dominant as they mature.[7] Understory plantings as described in Chapter III, *Project Description* of the Draft EIR on pages III-41 and III-42 would also aid to speed development of these habitats by creating a multilayered, closed canopy within just a few years following installation. DWR and its contractors will comply with all applicable regulatory requirements related to replacement and monitoring of riparian habitat and vegetation, including those related to the Fish and Game Code Section 1602 process. Further, to compensate for temporal loss of riparian habitat, Mitigation Measure BIO-1 on page IV.D-51 in Section IV.D, *Biological Resources* of the Draft EIR has been revised to include a mitigation ratio of 3:1 for slower growing riparian woodland habitats dominated by trees, and a ratio of 1.5:1 for faster growing riparian scrub habitat dominated by willow thickets and shrubs (see below).

In addition, to ensure that successfully established riparian plantings compensate for temporal loss of riparian habitat and achieve the minimum ratios described above, of 3:1 for impacted riparian woodland and 1.5:1 for impacted riparian scrub, Mitigation Measure BIO-1 has been modified to include monitoring and performance of the planted areas as follows:

> **Mitigation Measure BIO-1. Re-Plant Riparian Vegetation at a ~~1.1:1~~ 3:1 Ratio for Riparian Woodland and 1.5:1 Ratio for Riparian Scrub**
>
> To compensate for Proposed Project impacts to riparian habitat the Proposed Project shall:
>
> 1) Avoid a long-term net loss of riparian habitat, and
> 2) Mitigate for direct impacts to riparian woodland at a ~~1:1~~ 3:1 ratio and for impacts to riparian scrub at a 1.5:1 ratio. Mitigation would be achieved through on-site planting of riparian woodland and scrub habitats. The condition of planted riparian habitats will be monitored for a minimum of 1-year after planting to ensure the successful establishment of habitat that is dominated by native riparian vegetation. If mortality of riparian plantings reduces the amount of established riparian habitat to less than what is required to achieve the above ratios, replanting will be implemented to ensure the successful establishment of native riparian habitats sufficient to achieve the required acreage.

Comment 8: Mitigation Measure BIO-2, page IV.D-54. The draft EIR states a restoration plan shall be prepared for avoidance and mitigation of special-status plants and will be provided to DWR prior to construction. The restoration plan for special-status plants should be submitted for CDFW for review and approval. 2-11

[4] Bernhardt, E. A., & Swiecki, T. J. 2001. Restoring oak woodlands in California: theory and practice. Phytosphere Research, 8(15), 2005.
[5] California Native Plant Society. 2020. A Manual of California Vegetation, Online Edition. http://www.cnps.org/cnps/vegetation/; California Native Plant Society, Sacramento, CA.
[6] Griggs, F. T. (2009). California Riparian Habitat Restoration Handbook. California: Riparian Habitat Joint Venture.
[7] Griggs, F. T. (2009). California Riparian Habitat Restoration Handbook. California: Riparian Habitat Joint Venture.

Response 2-11:

DWR and its contractors will comply with all applicable regulatory requirements, however the EIR is not required to include all the information necessary to meet other regulatory program requirements.

Comment 9: Mitigation Measure BIO-2, page IV.D-54 Number 4 and 5 of Mitigation Measure BIO-2 state that mitigation of special-status plants should be at least 1:1 ratio. A 1:1 ratio of seeds and propagules is unlikely to offset impacts to special-status plants. CDFW recommends mitigation of 3:1 for most special-status plants and 5:1 for Mason's lilaeopsis. 2-12

Response 2-12:

The ratio stated in the mitigation measure BIO-2 is a "minimum of 1:1" (see Draft EIR page IV.D-54 in Section IV.D, *Biological Resources*); therefore it may be higher than 1:1, and revegetation efforts would be monitored for three years to ensure this ratio is achieved. In support of a minimum 1:1 ratio, the Proposed Project will result in an increase of suitable habitat for special status plants. Page IV.D-53 of the Draft EIR discusses how the Proposed Project would re-establish emergent tidal marsh habitat with microhabitats suitable for future establishment and growth of Suisun Marsh aster, woolly rose-mallow, and Mason's lilaeopsis. Revegetation of emergent tidal marsh habitat is discussed in Responses 2-9 and 2-10. Suisun Marsh aster and Mason's lilaeopsis grow in unique microhabitats within freshwater marsh habitats similar to post-Project conditions. Suisun Marsh aster and Mason's lilaeopsis observed at the Proposed Project Site under existing conditions both grow at the toe of the outboard levee slopes between roughly the Mean Tide Line (MTL) and Mean Higher High Water (MHHW). Both prefer edge habitats where competition from dense tules is limited, therefore their habitat can best be understood in terms of length of appropriate edge habitats. Potential habitat for these species under existing conditions and post-Project is depicted in the following table.

Table 1. Potential Suisun Marsh Aster and Mason's lilaeopsis Habitat: tidally influenced edge habitats between MTL and MHHW

Habitat area	Existing	Post-Project
Shag Slough Levee	3.52 Miles	6.59 Miles
Cross Levee	0.5 Mile	1.0 Mile
Cache/Hass Levee	3.54 Miles	6.44 Miles
PG&E Access Peninsulas	0	4.35 Miles
Internal Slough Banks	0	40+ Miles
Total	**7.56 Miles**	**58+ Miles**

Wooly rose mallow was only observed in one location on the Proposed Project Site, growing among tules along the margins of Sycamore Slough; however, this species is known to grow in marshes and among riprap on sides of levees.[8] Potential habitat for this species will remain intact around Sycamore Slough and the habitats listed in the table above may also provide suitable habitat for this species post-Project.

[8] California Native Plant Society, Rare Plant Program. 2020. Inventory of Rare and Endangered Plants of California (online edition, v8-03 0.39). Website http://www.rareplants.cnps.org [accessed 02 September 2020].

Parry's rough tarplant is an annual species that is commonly observed in seasonally moist grassland areas and disturbed areas such as roadsides.[9] Within the Proposed Project area this species was observed exclusively along three dirt ranch roads at elevations just above the irrigated pastures. The upland habitat along the proposed PG&E access roads, the O&M access roads for Cache/Hass Slough Levee and the Duck Slough Setback Levee would provide similar habitat for Parry's rough tarplant to what currently exists on the Proposed Project Site. The Draft EIR concluded on page IV.D-53 that impacts would be less than significant with implementation of a minimum 1:1 replacement ratio.

Mitigation Measure BIO-2 on page IV.D-54 states final mitigation ratios and other specific compensatory requirements for Mason's lilaeopsis will be determined through consultation with CDFW. DWR and its contractors will comply with all applicable regulatory requirements regarding the mitigation of state listed species; however, the EIR is not required to include all the information necessary to meet other regulatory requirements.

Comment 10: Mitigation Measure BIO-2, page IV.D-54 In number 5 of Mitigation Measure BIO- 2, the draft EIR indicates that CDFW will be consulted if pre-construction surveys indicate Mason's lilaeopsis *(Ulaeopsis masonil),* State listed as rare, will be impacted by Project activities. Although the currently known locations of Mason's lilaeopsis are outside any earth disturbing footprint, an ITP will be required for transplanting any newly discovered plants from the construction footprint. If there is a likelihood of Mason's lilaeopsis newly colonizing in the construction footprint due to suitable habitat and a nearby population, CDFW recommends adding Mason's lilaeopsis to your ITP application. 2-13

Response 2-13:

DWR and its contractors will comply with all applicable regulatory requirements, including those relating to ITP applications.

Comment 11: Nesting Birds, Mitigation Measure BIO-5A, page IV.D-58. Number 4 of Mitigation Measure BIO-5A does not specify a buffer for special-status species. CDFW recommends a minimum work buffer of 250 feet for all nests of non-raptor, special-status species. A buffer of 500 feet is recommended for raptor species except those listed as threatened or endangered. If work must take place within the specified buffer, CDFW should be consulted. 2-14

Response 2-14:

As written, Mitigation Measure BIO-5A provides protection for all nesting birds, not just special-status species on a case-by-case basis as noted on page IV.D-58 (item 4) in Section IV.D, *Biological Resources* of the Draft EIR. The buffer for non-special-status species will be determined by an agency-approved, qualified biologist based on the species, nest location and other on-site factors including individual bird behavior, baseline disturbance, level of construction, and physical factors such as visual obstruction, and may require consultation with CDFW. The resulting site-specific, species-specific buffers may be less than, equal to, or greater than the distances recommended in this comment. Further, because a qualified biologist will determine the appropriate buffer using such factors, nests for all birds would be protected by this measure.

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9 California Native Plant Society, Rare Plant Program. 2020. Inventory of Rare and Endangered Plants of California (online edition, v8-03 0.39). Website http://www.rareplants.cnps.org [accessed 02 September 2020].

To ensure adequate protection for nesting birds, Mitigation Measure BIO-5A (items 2 and 4) has been modified as follows:

Mitigation Measure BIO-5A. Nesting Birds

The following measures shall be implemented prior to construction to avoid or minimize impacts to nesting birds:

1. Implement Mitigation Measure BIO-3: Habitat Protection and Avoidance,
2. To the extent feasible, vegetation removal and initial ground disturbance shall occur from September 1 through January 31 so that initial ground disturbing work occurs outside of the general nesting bird season. If vegetation removal and initial ground disturbance occurs during the general nesting bird season, DWR will consult with CDFW and implement necessary measures.
3. For vegetation removal and ground disturbance within the Proposed Project footprint that is conducted within the general nesting bird season (February 1 through August 31), pre-construction nesting bird surveys shall be conducted within an appropriate radius of vegetation removal or ground disturbance within 14 days of the initiation of these activities to avoid disturbance to active nests, eggs, and/or young.
4. All active nests of native birds found during the survey shall be protected by a no-disturbance buffer until all young from each nest fledge or the nest otherwise becomes inactive. The size of each buffer shall be determined by an agency-approved, qualified biologist dependent upon extant conditions, including individual bird behavior, baseline disturbance, level of construction, and physical factors such as visual obstruction and ~~may~~will require consultation with the CDFW. Buffers are typically a minimum of 50 feet for non-special-status birds and may be larger for special-status or raptor species.

DWR and its contractors will comply with all applicable regulatory requirements regarding the mitigation of state listed species; however, the EIR is not required to include all the information necessary to meet other regulatory requirements.

Comment 12: Swainson's Hawk Nesting and Foraging Habitat, Mitigation Measure BIO-5B, page IV.D-59. The proposed Project will result in the conversion of approximately 1,850 acres of Swainson's hawk *(Buteo swainson),* State listed as threatened under CESA, foraging habitat consisting of irrigated pasture and non-native grassland to tidal and subtidal marsh. DWR proposes to reduce this significant impact to less-than-significant through implementation of Mitigation Measure BIO-5B which requires "an establishment of an off-site easement and/or purchase of credits at a CDFW-approved mitigation bank. The mitigation shall permanently conserve a minimum of approximately 1,000 acres of Swainson's hawk foraging habitat of equal or greater forage quality than irrigated pasture (a 0.54:1 mitigation ratio)".

CDFW agrees that the loss of Swainson's hawk foraging habitat is significant and requires mitigation; 2-15
however, the proposed 0.54:1 ratio will result in a net loss of at least 850 acres of foraging habitat. CDFW considers the unmitigated loss of 850 acres of foraging habitat a significant impact. The primary threat to the Swainson's hawk population in California continues to be habitat loss, especially the loss of suitable foraging habitat, but also nesting habitat in some portions of the species' breeding range in the Central Valley.

CDFW strongly recommends that DWR use a minimum 1:1 mitigation ratio to reduce the loss of Swainson's hawk foraging habitat to less-than-significant. To reduce this impact to less-than-significant, DWR may either purchase 850 acres of Swainson's hawk foraging credits at a CDFW-approved conservation bank (see https://www.wildlife.ca.gov/Conservation/Planning/Banking/Approved-Banks) or by placing a conservation easement over lands providing 850 additional acres of foraging habitat, including funding an endowment for managing the lands for the benefit of Swainson's hawk in perpetuity, and preparation and implementation of a long-term management plan by the land manager. 2-15 Cont.

Response 2-15:

The foraging habitat on the Proposed Project Site will be converted from irrigated pasture and non-native grassland to tidal and subtidal marsh. To mitigate this loss, page IV.D-59 in Section IV.D, *Biological Resources* of the Draft EIR states that at minimum, approximately 1,000 acres would be placed under easement on lands of equal or greater foraging value for Swainson's hawk than irrigated pasture (e.g., grassland, alfalfa, tomato, or beets). DWR will procure a higher acreage of conservation easements totaling approximately 1,285 acres, which will be managed for prey production to optimize Swainson's hawk habitat values. A 2009 study done in Yolo County found that cover types like alfalfa and irrigated pasture have high prey accessibility through Swainson's Hawk breeding season.[10] Irrigated cropland has the highest prey densities, and the irrigation and mowing sequences often increases prey accessibility in these habitat types which are exploited by Swainson's hawk. With steady prey availability in these habitat types, Swainson's hawk foraging ranges were noted to be steady and similar to the breeding season home range, i.e. Swainson's hawks did not have to forage far from their nest in search of available prey items.[11] Insufficient prey resources or long-distance hunting from the nest site may result in reduced nesting success due to the energetics required by the foraging effort.[12] Active management of habitat for prey production provides higher quality foraging habitat because it provides an increase in the density of prey items and therefore provides a greater benefit to the species than agricultural lands not managed for prey production. CDFW's Staff Report Regarding Mitigation for Impacts to Swainson's hawks states that a 0.5:1 mitigation ratio is recommended for impacts to foraging habitat within 1 mile of a nest tree to reduce impacts to less than significant levels when mitigation lands are managed for prey production. Following this CDFW guidance document and the site-specific biological reports and recommendations for the Proposed Project Site in Appendix F, *Biological Resource Assessment (BRA): Lookout Slough Tidal Habitat Restoration and Flood Improvement Project* of the Draft EIR, the mitigation provided under these conservation easements equates to a 0.69:1 ratio, exceeding a 0.5:1 ratio, and permanently protects lands and provides for a higher quality of habitat, which supports the finding of less than significant.

In addition, Swainson's hawk will benefit from additional sources of foraging habitat due to Proposed Project actions and associated easements. Displayed in Table IV.D-2 in Section IV.D, *Biological Resources* of the Draft EIR (page IV.D-6) and Table 2 shown below, the existing foraging habitat within the Proposed Project Site includes 1,364 acres of unprotected irrigated pasture. It also includes a total of 487 acres of non-native grassland, of which a subset of approximately 388 acres is protected in the northern extent of Liberty Farms by a Wetland Reserve Program easement, while the remaining 98 acres are non-eased, dry, non-native grassland. In combination, this equates to 1,850 acres of existing suitable foraging habitat.

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10 Estep, J. A. 2009. *The Influence of vegetation structure on Swainson's hawk (Buteo swainsoni) foraging habitat suitability in Yolo County, California*. Prepared for the Yolo Natural Heritage Program, Woodland, CA, USA.

11 Estep, J. A. (1989). *Biology, movements, and habitat relationships of the Swainson's Hawk in the Central Valley of California*, 1986-87.

12 CDFG. 1994. *Staff Report Regarding Mitigation for Impacts to Swainson's Hawks (Buteo swainsoni) in the Central Valley of California*. Available online: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=83992&inline.

The Proposed Project would maintain and protect (via a conservation easement) foraging habitat for Swainson's hawk through approximately 77 acres of unmaintained uplands and along the edges of marsh habitats within the Proposed Project Site. In addition, 57 acres of non-native grassland placed in easement for giant garter snake (*Thamnophis gigas*, GGS) mitigation will be managed for consistency to maintain additional foraging habitat for Swainson's hawk as part of Mitigation Measure BIO-5B. Lastly, as discussed on page IV.B-10 and IV.B-11 in Section IV.B, *Agriculture* of the Draft EIR, approximately 340 acres of existing dry pasture will be converted to irrigated pasture on the Zanetti property to offset a portion of the currently unprotected irrigated pasture in the Bowlsbey Property as part of Mitigaiton Measure AG-1. This habitat will provide the same foraging habitat values that the Bowlsbey Property currently provides. In summary, the above mentioned actions combined will result in approximately 1,759 acres of land available to Swainson's hawk, of which approximately 1,285 acres would be managed for prey production specifically for this species. However, due to the foraging value of lands managed specifically for Swainson's hawk and other eased lands, the weighted value (discussed in Table 2 below) of the protected habitat is 3,044 acres, which mitigates well above the 1,850 acres impacted by the Proposed Project.

As to nesting habitat, observed Swainson's hawk nesting trees within the Proposed Project Site would be maintained or removed outside of the nesting season and replaced per Mitigation Measure BIO-5B.

TABLE 2. PROPOSED PROJECT'S SWAINSON'S HAWK FORAGING HABITAT

Habitat Value / Security Scale	Existing Habitat		Proposed Mitigation		
	Habitat Type / *Location*	Area (acres)	Habitat Type / *Location*	Area (acres)	Weighted Area by Value (acres)[1,2]
Highest Value / Most Protection			Eased prey-producing irrigated pasture *Property 1 (agriculture easement)*	450	900
			Eased prey-producing irrigated pasture *Property 2 (portion for agriculture easement)*	835	1,670
	Eased non-native grassland *Liberty Farms WRP easement*	388	Eased non-native grassland *GGS conservation easement*	57	57
			Eased non-native grassland *Remaining within Proposed Project Site*	77	77
	Non-eased irrigated pasture *Bowlsbey Ranch*	1,364	Non-eased dry pasture converted to irrigated pasture *Zanetti Property*	340	340
Lowest Value / Least Protection	Non-eased dry non-native grassland *Vogel Property and Bowlsbey Ranch roads*	98			
	Total Existing Habitat	1,850	**Total Proposed Habitat**	1,759	3,044

1 CDFG. 1994. Staff Report Regarding Mitigation for Impacts to Swainson's Hawks (*Buteo swainsoni*) in the Central Valley of California. Available online: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=83992&inline.

2 CDFW's Staff Report states that a 0.5:1 mitigation ratio is recommended for impacts to foraging habitat to reduce impacts to less than significant levels when mitigation lands are managed for prey production; therefore, the eased areas managed for prey production are weighted at twice the value.

Comment 13: Mitigation Measure BIO-5B, page IV.D-60. In Mitigation Measure BIO-5B, the measure states that there is the "potential for adverse impacts to Swainson's hawk..." and "If permitting for potential take of Swainson's hawk is determined to be necessary…" This implies that there is a potential for take. CDFW agrees there is a potential for take and recommends that the lead agency include Swainson's hawk in their ITP application for this project. 2-16

Response 2-16:

See Response 2-17 below for text revisions to Mitigation Measure BIO-5B on page IV.D-60 in Section IV.D, *Biological Resources* of the Draft EIR. With implementation of Mitigation Measure BIO-5B as revised, potential for impacts to or take of Swainson's hawk will be avoided.

Comment 14: Mitigation Measure BIO-5B, page IV.D-60. Mitigation measure BIO-5B sets nests buffers of various distances. Nest buffers should be 0.5 miles from any active Swainson's hawk nest. Any reduction in buffers should be done only after consultation with CDFW which may require additional minimization and mitigation measures. 2-17

Response 2-17:

Mitigation Measure BIO-5B on page IV.D-60 in Section IV.D, *Biological Resources* of the Draft EIR has been modified as follows:

Mitigation Measure BIO-5B. Swainson's Hawk Nesting and Foraging Habitat

~~Due to the potential for adverse impacts to Swainson's hawk, consultation and permitting with CDFW may be required if reduced buffers during the nesting season are necessary for construction activities. If permitting for potential take of Swainson's hawk is determined to be necessary, EIP shall consult with CDFW and implement all avoidance and minimization measures as required in the Proposed Project Incidental Take Permit and Lake and Streambed Alteration Agreements. In addition, t~~The following measures shall be implemented prior to and during construction to avoid ~~or minimize~~ impacts to Swainson's hawk:

1) In each year that Proposed Project activities occur during Swainson's hawk nesting season, two surveys shall be conducted within each of nest season Phases II and III[13] as described below:

   a) In the first year of construction:

      i. If Proposed Project activities ~~work has been initiated~~ begin prior to March 20 (prior to the nesting season for Swainson's hawk), two surveys each shall be conducted within Phases II (March 20-April 5) and Phase III of the nesting season (April 5 – May 20) to determine if nests have established during Proposed Project activities.

      ii. If Proposed Project activities ~~work~~ begin~~s~~ between March 20 and April 5 (Phase II) at least one of the two surveys within Phase II shall be conducted prior to the start of ground disturbing activities. Two surveys shall also be conducted between April 5 – April 20 (Phase III).

      iii. If Proposed Project activities ~~work~~ begin~~s~~ in Phase III, two surveys shall be conducted in Phase II and at least one survey in Phase III shall be conducted prior to start of ground disturbing activities.

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13 California Department of Fish and Game, Swainson's Hawk Technical Advisory Committee, "Recommended Timing and Methodology for Swainson's Hawk Nesting Surveys in California's Central Valley" (Sacramento, May 31, 2000), https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=83990&inline.

b) In the second or third year of Proposed Project activities ~~construction~~, two surveys shall be conducted within each of the Phases II and III windows identified above.

c) Surveys shall be conducted within 0.~~2~~5-mile of planned work areas during the nesting season.

i. If a nest is determined to be active and ~~ground disturbance~~ work has not yet been initiated, an appropriate buffer up to a 0.~~2~~5-mile (~~1,320~~2,640-foot) radius shall be established in consultation with CDFW. If ~~ground disturbance~~work has been initiated and a Swainson's hawk establishes a nest after ~~construction~~ work has been initiated, a 500-foot buffer shall be established around the nest tree.

d) Following surveys, monthly checks shall be conducted in May, June, and July to provide status updates on any active nests. If a nest is determined to have become inactive, the nest buffer would be removed.

~~e) If a smaller buffer is sought, CDFW shall be consulted and the methods described below (Item 2) shall be instituted in addition to any measures requested by CDFW in approving the reduced buffer.~~

~~2) Reduced buffer: If construction will occur within 0.25-mile of an active Swainson's hawk nest site (and the nest was established prior to initial construction in the area) or within 500 feet of an active Swainson's hawk nest established during construction, the following additional measures shall be implemented:~~

~~a) Staging areas for equipment, materials, and work personnel shall be located 0.25-mile away from active Swainson's hawk nest sites. These areas shall be flagged and identified to all work personnel during employee orientation.~~

~~b) For nests established during construction, if construction needs to occur within 500 feet of an active Swainson's hawk nest, no construction shall occur prior to 8:00 AM, and shall be discontinued by 5:00 PM each day.~~

~~c) If work needs to occur temporarily within any buffer, a qualified biologist shall monitor active nests daily for signs of disturbance for the duration of the construction activity. If it is determined that Proposed Project-related activities are resulting in nest disturbance, then work in those sensitive areas shall cease immediately and the 0.25-mile buffer or 500-foot buffer (for nests in ongoing work areas) shall be re-established. CDFW shall then be contacted for further guidance.~~

Comment 15: Winter Refugia/Brumation discussion, page IV.D-68. The proposed Project draft EIR identifies approximately 127 acres of existing winter refugia habitat for giant garter snake *(Thamnophis gigas),* a State listed threatened species under CESA. Upon Project completion, approximately 24 acres of suitable winter refugia habitat would remain on Duck Slough and 46 acres of upland habitat would be available on the interior Pacific Gas and Electric Company access peninsulas, that are approximately at the 2-foot flood elevation, and along the remnant sections of the Shag Slough Levee. The draft EIR states that "The overall acreage of brumation habitat would decrease; however, the quality of this habitat is expected to increase…" and that "the loss of winter refugia is a less than significant impact". 2-18

The proposed Project includes nine breaches and degradation of two 1,500-foot segments of remnant levee which will provide up to 40,000 acre-feet of overbank water storage during large flood events in the Yolo Bypass. CDFW is concerned that increased flooding of the once suitable winter refugia habitat, including the overtopping of the proposed access peninsulas, could have a significant impact on giant garter snakes. The draft EIR does not fully discuss how levee maintenance activities such as rodenticides will be kept separate from the 24-acre Duck Slough winter refugia habitat nor whether a buffer has been set between the toe of the levee and the area designated for giant garter snake winter refugia. In order to reduce this potential impact to less-than-significant, CDFW recommends DWR fully mitigate the loss of 103 acres of winter refugia habitat on or adjacent to the Project site. If rodenticides could encroach upon the 24-acre Duck Slough winter refugia habitat, then the CDFW recommends mitigating for the loss of 127 acres of winter refugia habitat. For example, DWR could raise sections of the access roads to provide refugia habitat from a 5-year flood or put a conservation easement on suitable winter refugia habitat adjacent to the new Duck Slough Levee or purchase credits at a CDFW-approved conservation bank (see https://www.wildlife.ca.gov/Conservation/Planning/Banking/Approved-Banks). 2-18 Cont.

Response 2-18:

The post-construction levee maintenance will meet both state and federal standards. See Master Response 7, *Operation and Maintenance (O&M) of Levees*. Rodent control measures for levee maintenance, such as trapping or rodenticides, would not affect burrows for GGS use outside of 15 feet from the toe of the levee; therefore, these measures are not anticipated to indirectly affect the adjacent upland habitats for GGS winter use. Similar activities are currently performed along the Shag Slough Levee and Cache/Hass Slough Levee; therefore, maintenance along the new Duck Slough Setback Levee and Cache/Hass Slough Training Levee is likely to maintain a similar level of disturbance as is currently experienced. Overall length of maintained levees in the post-restoration condition would be relatively similar to pre-restoration conditions. Further, DWR and its contractors will comply with all applicable regulatory requirements, including those related to ITP applications.

The comment also describes that increased flood exposure of winter refugia, including overtopping of access peninsulas, could have a significant impact on GGS. An extant population of GGS is known to exist within the Yolo Bypass north of the Proposed Project Site, which occasionally floods in winter similar to the conditions anticipated for the Proposed Project Site. The post-construction habitat would result in variable water levels in the winter with burrow habitat available above typical winter flood levels, in contrast to the existing conditions of managed flooding elevations. Proposed Project flood levels over the 2-year flood elevation are anticipated to be short in duration and not result in the elimination of winter refugia on the access peninsulas. In addition, winter refugia outboard of the Duck Slough Setback Levee was only considered for areas at or above the 2-year flood elevation, of which some locations occur above the 4-year flood elevation. The post-restoration reduction in winter refugia habitat is not anticipated to restrict GGS winter survivorship in the Proposed Project Site based on the availability of 46 acres of upland habitat above 2- and 4-year flood levels outboard of the Duck Slough Setback Levee and 24 acres of flood-protected uplands inboard of the Duck Slough Setback Levee.

Although not a significant impact, in response to this comment, Mitigation Measure BIO-5D has been revised to reflect that DWR will procure an offsite easement for 57 acres of GGS upland habitat to obtain a net zero loss. A total of 70 acres of winter refugia habitat would be present within the Proposed Project Site for GGS post-restoration efforts, thus an offsite easement on 57 acres of upland habitat would total 127 acres and equal the existing habitat on the Proposed Project Site for winter refugia. The following language for Mitigation Measure BIO-5D on page IV.D-72 of the Draft EIR has been added:

6) DWR will procure a conservation easement for 57 acres of GGS upland and winter refugia habitat in the vicinity of the Proposed Project Site or, if required as part of regulatory permitting, buy credits at a CDFW-approved conservation bank in an amount equal to 57 acres.

Comment 16: Western Pond Turtle. BIO-5E, page IV.D-73. The draft EIR does not discuss the currently available nesting habitat on-site nor the quantity nor availability of nesting habitat post construction. Impacts to western pond turtle nesting should be analyzed. Additionally, the mitigation measure states western pond turtles or their nests may be relocated out of the work area or off-site. Prior to any western pond turtles being relocated, CDFW shall be consulted. 2-19

Response 2-19:

As discussed on page IV.D-72 in Section IV.D, *Biological Resources,* of the Draft EIR, the Proposed Project would cause temporary impacts to western pond turtle due to construction activities. In addition, the Proposed Project would reduce the quantity of nesting habitat available to western pond turtle. However, the Proposed Project would result in the creation of over 429 acres of freshwater tidal channels and eight acres of ponds as described on page IV.D-72, and the quality of habitat would be improved through reduced human disturbance and management activities. Together these actions, with the implementation of Mitigation Measure BIO-5E on page IV.D-73 of the Draft EIR, reduce potential impacts to western pond turtle to less than signficant. The following clarifying information is provided in response to CDFW's request for additional information regarding western pond turtle nesting habitat.

Under existing conditions, the Proposed Project Site has 246 acres of potential nesting habitat for western pond turtle, represented by the non-native grassland habitats identified in Figure IV.D-1 on page IV.D-7 in Section IV.D, *Biological Resources* of the Draft EIR that are not identified as managed wetland in Figure IV.D-2 on page IV.D-12 of the Draft EIR. These existing potential nesting habitats are concentrated (primarily) within the northern portion of Liberty Farms and are not necessarily directly adjacent to tidal sloughs, channels, or otherwise high-quality habitats. Therefore, the surrounding land use limits access to the extant nesting habitat, with managed wetlands to the south and existing roads and maintained levees to the west and north. Existing management activities within the potential nesting habitats include disking, which can impact and destroy western pond turtle eggs.

An assessment of current threats to western pond turtle concluded that habitat loss, including the loss of wetlands, has reduced the extent of aquatic habitat for western pond turtles.[14] Additional threats identified in that same study included: loss of nesting habitat resulting from flood control that reduced the extent and frequency of floods, limiting ephemeral open areas near aquatic habitat, agriculture (differentiated from grazing), road mortality, and recreational disturbances. Agricultural practices referenced primarily relate to ground crops that require tilling and disking (e.g., grass seed, berries, hops, and beans).[15] Such agricultural practices can destroy turtle nests through working of the soil if nests are present.[16] Mortality of turtles along existing roadways also poses a threat to the turtles when moving between aquatic and upland habitats (such roads currently exist between those areas of Liberty Farms and Shag Slough). Finally, recreational disturbances from the presence of people can limit turtles' thermoregulation and metabolic processes in sites with heavy disturbance.

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14 Rosenberg, D., Gervais, J., Vesely, D., Barnes, S., Holts, L., Horn, R., Swift, R., Todd, L. and Yee, C., 2009. Conservation assessment of the Western Pond Turtle in Oregon (*Actinemys marmorata*). Version 1.0.

15 Uhrich, M.A. and Wentz, D.A., 1999. Environmental setting of the Willamette basin, Oregon (Vol. 97). US Department of the Interior, US Geological Survey.

16 Rosenberg, D., Gervais, J., Vesely, D., Barnes, S., Holts, L., Horn, R., Swift, R., Todd, L. and Yee, C., 2009. Conservation assessment of the Western Pond Turtle in Oregon (*Actinemys marmorata*). Version 1.0.

Following implementation of the Proposed Project, the Proposed Project Site would have 70 acres of potential nesting habitat for western pond turtle, which is depicted as GGS winter refugia and unmanaged winter refugia on Figure IV.D-3 on page IV.D-65 of the Draft EIR. Post-construction management activities do not include disking of habitats in which western pond turtle may nest. Reduction of disturbance in grassland habitats (removal of agricultural, waterfowl, and upland game bird management and hunting-related disturbances) eliminates some of the key threats identified to western pond turtle.[17] Removing these disturbances can be expected to increase nest success and western pond turtle nest hatchling survival because hatchlings may stay in upland habitats for several days to weeks prior to entering the aquatic habitats.[18] The increased habitat complexity in the tidal marsh post-construction will also provide hatchlings greater protection from predators and may increase survival of hatchlings in the aquatic habitat. Additionally, the procurement of a 57-acre offsite conservation easement for GGS upland habitat, as required by Mitigation Measure BIO-5D discussed in Response 2-18, will increase the total amount of nesting habitat available to western pond turtle to 127 acres. As shown by Table 3 below, the overall quantity of nesting habitat would be decreased by the Proposed Project, but the quality of nesting and aquatic habitats would be greatly improved such that no additional habitat mitigation is determined to be necessary beyond the habitat improvements and management described in the Proposed Project.

TABLE 3. WESTERN POND TURTLE NESTING HABITAT

Western Pond Turtle Nesting Habitat					
Existing		Post Restoration		Proposed Mitigation	
Habitat Type	Area (acres)	Habitat Type	Area (acres)	Habitat Type	Area (acres)
Non-native grassland	246	Non-native grassland	70	Eased dry non-native grassland - *GGS CE*	57
				Total Potential Habitat	**127**

The following text addition has been added for clarification on page IV.D-72 of the Draft EIR:

> Under existing conditions, the Project Site has 246 acres of potential nesting habitat for WPT. This area represents the portion of non-native grassland habitat identified in Figure IV.D-1 of the Draft EIR which is not identified as managed wetland in Figure IV.D-2. Following project implementation, the Project Site would have 70 acres of potential nesting habitat for WPT, which is depicted as GGS winter refugia and unmanaged winter refugia on Figure IV.D-3. Additionally, the procurement of a 57-acre offsite conservation easement for GGS upland habitat, as required by Mitigation Measure BIO-5D, will increase the total amount of nesting habitat available to western pond turtle to 127 acres. Overall, the quantity of nesting habitat would be reduced based on exposure to winter flooding upon Proposed Project Site connection with the Yolo Bypass Floodplain. However, the quality of habitat would be improved through reduced human disturbance and through management activities that are expected to promote successful use of the area by western pond turtle for nesting activities. Road traffic mortality and detrimental habitat maintenance activities, including disking, mowing, ~~dredging and~~ berm

17 Rosenberg, D., Gervais, J., Vesely, D., Barnes, S., Holts, L., Horn, R., Swift, R., Todd, L. and Yee, C., 2009. Conservation assessment of the Western Pond Turtle in Oregon (*Actinemys marmorata*). Version 1.0.

18 Rosenberg, D.K. and R. Swift. 2013. Post-emergence behavior of hatchling western pond turtles (*Actinemys marmorata*) in Western Oregon. American Midland Naturalist 169:111-121.

maintenance, and ~~small mammal management~~human disturbance, which have all been identified as key factors in the decline of western pond turtles, would be reduced relative to ~~less than~~ current management regimes, making those habitats managed in the absence of such factors more suitable for western pond turtle nesting. Further, those upland habitats that will be available post-construction for western pond turtle nesting will be closer in proximity to aquatic habitats, allowing for more access by western pond turtles at multiple sites.

Per the commenters request, the additional statement has been added to Mitigation Measure BIO-5E under #4 to read:

Any viable western pond turtle nests encountered including those with eggs or hatchlings shall be flagged and a 100-ft buffer around the nest shall be designated. If construction activity cannot avoid the nest area, the nest shall be relocated either off site or to an appropriate wildlife care facility. CDFW will be consulted prior to relocating the nest or eggs.

Comment 17: Roosting Bats. Page IV.D-73. The draft EIR does not mention surveys for western red bat. Western red bat, including maternity colonies, are found in riparian habitat in the Project area. Surveys should be conducted for western red bat on the Project site. If western red bat are detected, the current roosting bat minimization and mitigation measures are insufficient as they are not building or cavity roosting bats. Additional measures will need to be implemented to protect western red bat. 2-20

Response 2-20:

Mitigation Measure BIO-5F has been modified as follows to clarify that the existing measure detailing a two-phase process for tree removal is sufficient to reduce impacts to foliage-roosting bats, including western red bat. This measure would be applied to all large trees as described, and if any potential roosts are identified, the subsequent measures implemented as described. This measure would protect all bat species including western red bat.

3) Prior to the removal of any large trees (DBH>16 inches) a bat roost assessment shall be conducted by a qualified biologist at least 30 days beforehand to determine if potential roost habitat is present.

   a) If the tree has no potential to support roosting bats (e.g. no large basal cavities, exfoliating bark, ~~or~~ interstitial spaces, or suitable foliage), the tree may be removed with no further measures required to protect roosting bats.

   b) If potential bat habitat is present, and work is occurring outside the maternity season, the qualified biologist may either 1.) Conduct an emergence survey to determine if the roost is occupied; or 2.) The tree may be felled using a two-phased cut.

      i) If the emergence survey confirms the roost is inactive, the tree may be felled normally.

      ii) If the roost is confirmed active, or is assumed to be active, a two-phased cut shall be employed to remove the tree. On day one the qualified biologist shall oversee removal of branches and small limbs not containing potential bat roost habitat (including large basal cavities, exfoliating bark, interstitial spaces, and suitable foliage) using hand tools such as chainsaws or handsaws only. The next day, the rest of the tree may be removed.

c) If potential bat roosting habitat is present and work is occurring during the maternity season, the qualified biologist may either 1.) Conduct an emergence survey to determine if the roost is occupied; or 2.) Assume the roost is occupied and a buffer shall be implemented.

i) If the roost assessment does not detect bats, the tree may be removed normally. If roosting bats are detected, or the tree is assumed to be an active roost, the tree shall be given a 100-foot buffer and shall be avoided until after the maternity roosting season is complete.

Comment 18: Noise Impediments to Fish Migration, page IV.D-82. The draft EIR indicates that construction equipment noise and vibrations could cause disruptions to special-status fish migrations and with implementation of Mitigation Measure BIO-6 and other measures specified in Mitigation Measure BIO-4B would reduce this impact to less-than-significant. However, there is no Mitigation Measure BIO-4B in the draft EIR. This mitigation measure is likely misnumbered.

To further reduce potential noise and vibration impacts to special-status fish, especially Delta Smelt that are present year-round in the waters adjacent to the Project, CDFW recommends implementing two additional measures to Mitigation Measure BIO-6 or as a new vibratory/pile driving mitigation measure: 2-21

1) Initiate a soft start to allow fish to leave the area prior to operating the vibratory hammer at full capacity. The hammer operatory shall initiate noise from the hammer for 15 seconds at reduced energy followed by a one-minute waiting period. This procedure shall be repeated two additional times before commencing hammering at full capacity.
2) Pile driving activities shall only occur between two hours after sunrise till two hours before sunset. If fish species are detected during pile driving activities, all piles shall cease until the fish leave the Project area.

Response 2-21:

The commenter correctly notes that Mitigation Measure BIO-4B was incorrectly numbered. The correct reference was to Mitigation Measure BIO-3. Therefore, the reference to Mitigation Measure BIO-4B in the first full paragraph on page IV.D-82 of the Draft EIR is revised as follows:

> …This, and other measures specified by Mitigation Measure BIO-3 ~~4B~~, would minimize the likelihood of construction-related noise posing an impediment to fish migration….

The comment does not suggest the existing levels of mitigation recommended in the Draft EIR would be insufficient but still recommends additional measures "to further reduce potential noise and vibration impacts to special-status fish." The Draft EIR concludes that "with the implementation of Mitigation Measure BIO-6 and other mitigation measures discussed in this section, impacts of the Proposed Project would not exceed the applicable threshold of significance related to a substantial adverse effect on special-status fish species and the Proposed Project's impact with regard to this threshold would be ***less than significant with mitigation incorporated***." (Draft EIR, page IV.D-82.) To clarify and assure the effectiveness of Mitigation Measure BIO-6, sub-point 4 (Draft EIR, page IV.D-82) that states that a qualified biologist shall monitor cofferdam installation, removal, and final breaching activity, the following sub-point is added to Mitigation Measure BIO-6:

> (8) All cofferdam installation, removal, and final breaching activity shall be limited to daylight hours (sunrise to sunset).

Because these activities must be monitored by a qualified biologist, by restricting these to "daylight hours" it will assure the biologist has adequate light to observe the operation.

To assure the effectiveness of Mitigation Measure BIO-6, sub-point 3 (Draft EIR, page IV.D-81), the following text has been added to Mitigation Measure BIO-6:

> 3) If sheet piles are used to construct a cofferdam, a vibratory hammer shall be used to start the installation of each pile and shall be used as long as geotechnical conditions permit. A vibratory hammer shall be used to remove the sheet pile. <u>If an impact hammer is necessary to complete sheet pile installation, a "soft start" will be implemented. This method entails gradually increasing energy and frequency of impacts to permit wildlife to vacate the surrounding area.</u>

Lastly, DWR is conducting formal consultation with CDFW and the USFWS (as disclosed on Draft EIR page IV.D-81) for potential effects to Delta Smelt. DWR and its contractors will comply with all applicable regulatory requirements regarding special-status fish species; however, the EIR is not required to include all the information necessary to meet other regulatory requirements.

Comment 19: Dewatering Fish Injury and Mortality, page IV.D-83. The draft EIR states that the interior aquatic features would be dewatered as part of excavation and channel creation. Although native and special-status fishes are not likely present or occur in low numbers in the interior aquatic features, nonnative sportfish and other fish species do occur in these water bodies. Dewatering the internal cannels and ponds could result in a fish kill and wanton waste of fish. 2-22

In order to reduce this impact to less-than-significant, CDFW recommends including a mitigation measure that implements a staged dewatering plan to chase fish down existing canals to the southern ponded area, which was discussed in our meeting on December 5, 2019 at the Stockton office. CDFW also recommends including a backup fish rescue plan in case fish become isolated in disconnected or poorly connected interior channels during the dewatering phase.

Response 2-22:

The Proposed Project proposes the phased dewatering approach described on pages III-29 and III-33 in Chapter III, *Project Description* of the Draft EIR for the benefit of GGS that would also be protective of fish. During site preparation, dewatering activities would systematically remove water across the site from north to south. This systematic dewatering process would allow fish as well as GGS to slowly relocate to more southerly habitats as the water is drawn down.

Part of the habitat elements of the relocation area are aquatic foraging habitats that would be maintained for GGS and fish. Using such a methodology to slowly draw water across the site will allow wildlife and any fish to move through the existing interconnected water conveyance system and into the GGS Temporary Relocation Area, which will have adequate water levels maintained throughout the Project term. Fish that move through the conveyance system during dewatering will end up within the GGS Temporary Relocation Area and can remain there without requiring rescue or relocation until the interior of the Proposed Project is reconnected to the adjacent sloughs and tidal influence returns. Dewatering in this manner is expected to take at least one construction season (approximately 8 months), but may be required throughout both construction seasons, thus the movement of water and fish through the Proposed Project area would be gradual. By utilizing this methodology it is anticipated that the vast majority of fish will be able to self-relocate avoiding any "fish kills" or "wanton waste" described in the comment.

Mitigation Measure BIO-6 (Draft EIR, Page IV.D-82) has been revised to include subpoint (9) which describes how if any native aquatic wildlife or fish are observed stranded, an agency-approved biological monitor will rescue the individual using the methods described in subpoint (9). The following text has been added to Mitigation Measure BIO-6:

(9) During the systematic dewatering of interior channels, an agency-approved biologist will inspect channels for stranded, native aquatic wildlife and fish. Should stranded, native aquatic wildlife or fish be detected, the approved biologist will use a net or other suitable gear to rescue the individual(s). Native fish and aquatic wildlife will be placed in a suitable container and kept in good condition until they can be relocated to the closest suitable aquatic habitat. CDFW will be consulted to determine how non-native fish and wildlife will be disposed of or relocated.

Comment 20: Dewatering Fish Injury and Mortality- Wakasagi, page IV.D-83. Wakasagi *(Hypomesus nipponensis),* a nonnative smelt that is known to hybridize with Delta Smelt *(Hypomesus transpacificus),* were identified during fish surveys of internal water features (draft EIR Appendix F-Biological Resources Assessment). If Wakasagi are in high abundance in certain agriculture ponds, CDFW may recommend measures to minimize their eventual release into the surrounding waterways that are inhabited by Delta Smelt. As part of the dewatering and fish rescue mitigation measure (see Comment #6), CDFW recommends that DWR first consult with CDFW regarding Wakasagi before conducting any pond dewatering operations. 2-23

Response 2-23:

DWR is open to conversations about the species, which could occur in the context of DWR's consultation with CDFW for an ITP. Mitigation Measure BIO-6 on page IV.D-82 of the Draft EIR has been modified as follows to address the comments concern by adding the following sub-point:

(10) Before conducting any pond dewatering operations CDFW will be consulted regarding Wakasagi.

Comment 21: Recreation; page IV.J-1. The Liberty Island Ecological Reserve (LIER), a CDFW managed property located east of the Project, is connected to the Project Site via the Shag Slough Bridge (Bridge). The draft EIR states that "there are no officially sanctioned public recreational facilities with the Proposed Project Site; though there are private facilities and access points to public areas with recreational opportunities" and that "the bridge provides pedestrian access to a small portion of the western shoreline of Shag Slough in the Reserve (LIER) where bank fishing is allowed". The proposed Project would eliminate pedestrian access to bank fishing along the shoreline of the LIER as well as fishing access along the Shag Slough Levee. The draft EIR goes on to conclude that impacts resulting from a decrease in opportunities to fish from the shoreline within the Delta regions would be less-than-significant. However, CDFW disagrees and believes the loss of public land-based access to LIER via the Bridge is a significant impact. 2-24

The draft EIR states that the Bridge only allows access to a small portion of the LIER; however, the Bridge provides access to more than three miles of shoreline along Shag Slough and the "stairstep" at the north end of the island. Although some portions of this bank are heavily vegetated and difficult to fish from, a large proportion of this bank is accessible to fishing. The draft EIR acknowledges that much of the interior of LIER is only accessible by kayak or shallow-water boats. Currently, the Bridge provides public access to hand-launch kayaks or small boats within LIER. Kayaking is very common on LIER foryear-round fishing and especially for hunting during the waterfowl season. From roughly the middle of October through the end of January, waterfowl hunting is open seven days a week on LIER for no access fee. While some hunters can boat the more than ten miles from the nearest launches, many only have access to kayaks or small watercraft and rely on the Bridge as the main access point to hand-launch onto LIER. Those that rely on the bridge and shoreline access are predominately from disadvantaged communities. The loss of foot-access to LIER via the Bridge will eliminate recreational opportunities for many hunters, anglers, and bird watchers who don't have the ability to purchase and maintain a boat capable of accessing the island from the nearest boat launches, making recreation impacts by the Project disproportionately affect lower income individuals and communities. Furthermore, public bank fishing is already very limited in the Cache Slough Complex as most of the levees are on private property or have restricted access. For these reasons, CDFW believes the proposed Project will have a significant impact on recreational opportunities on Shag Slough and at LIER. 2-24 Cont.

To reduce this impact to less-than-significant, CDFW recommends DWR provide a new public access point to Shag Slough and LIER. DWR could construct a small boat ramp for hand- launching small vessels and a fishing access point on the northeast comer of the Project, where Liberty Island Road meets Shag Slough. This would allow recreational users access lo Shag Slough and LIER. Alternatively, DWR could allow the public to hand-launch from the new agency ramp. CDFW recommends keeping the agency boat ramp to mitigate CDFW's loss of access to LIER but is willing to allow the public to hand-launch kayaks and small crafts from this ramp. If this alternative is used to mitigate the public's land-based access loss, CDFW recommends installing a gate on the access road to prevent public vehicles from launching boats on the agency ramp, i.e. the public would be restricted to launch small boats by hand only.

Response 2-24:

DWR has incorporated CDFW’s recommendation for the public agency boat ramp and gate into the project description, see DEIR, p. III-35. Please also see Master Response 10, *Recreation*.

Comment 22: Biological Resources-special-status fish, page V-9. The draft EIR indicates that based on available information on Project status, two projects within the Cache Slough Complex (phase two of Dutch Slough and Lower Yolo Ranch) could have overlapping construction schedules. However, the Dutch Slough Project, which is referenced in several paragraphs in this cumulative impact section, is not in the Cache Slough Complex. CDFW recommends replacing the Dutch Slough Project with the Prospect Island Tidal Habitat Restoration Project and reevaluate the potential cumulative impacts. The Prospect Island project is located in the Cache Slough Complex and the construction schedule would overlap with the proposed Project's schedule. If all three of these restoration projects are conducting in-water work during the same time, fish in the area could experience cumulative impacts from noises, vibrations, and decreased water quality from levee work and breaching activities. 2-25

Mitigation Measure 4A and 4B are mentioned in this cumulative impact section; however, these mitigation measures are not found in the document. These measures are likely misnumbered. CDFW recommends checking and cross-referencing mitigation numbering in the draft EIR.

Response 2-25:

The comment notes that a project was missing from the text of the cumulative impact analysis on page V-9 in Chapter V, *Cumulative Impacts* of the Draft EIR. The Prospect Island Restoration Project was analyzed along with the projects listed on page V-9 and the following text change has been made to correct this omission:

Projects that would have an overlapping construction period with the Proposed Project include phase two of the Dutch Slough Tidal Habitat Restoration Project, the Prospect Island Restoration Project, and the Lower Yolo Ranch Restoration Project.

The Prospect Island Restoration Project was included in the list of cumulative projects on page V-5 of the Draft EIR and was considered in the analysis of cumulative impacts on listed and special-status fish species. Further, see Response to Comment 2-21 regarding the correction to numbering of mitigation measure.

Comment 23: Biological Resources- Swainson's hawk foraging habitat, page V-9. The draft EIR indicates that the loss of Swainson's hawk foraging habitat is less than cumulatively considerable with implementation of Mitigation Measure BIO-3B and that nearby restoration projects, specifically Lower Yolo Ranch, loss of foraging habitat would not be cumulative considerable with implementation of their mitigation measure. However, the mitigation measures will only mitigate roughly half of the Swainson's hawk foraging habitat loss from Project activities (proposed Project mitigates at 0.54 to 1 ratio, Lower Yolo Ranch at 0.5 to 1 ratio). This could result in the loss of over 1,700 acres of Swainson's hawk foraging habitat between these two projects alone. CDFW considers this loss a cumulatively considerable impact. 2-26

To help reduce this impact to less than cumulatively considerable, CDFW recommends DWR mitigate the loss of Swainson's hawk foraging habitat at a minimum 1:1 ratio. Please see above Comment 6 for more details on mitigating Swainson's hawk foraging habitat.

Response 2-26:

The Draft EIR analyzes potential cumulative impacts on biological resources, including Swainson's hawk foraging habitat in Chapter V, *Cumulative Impacts* on page V-10. The effects of the Proposed Project have been found to be less than significant. See Response 2-15 for further details, including a table that specifies the acreage of conservation easements and relative foraging value, which shows that comparative value of mitigation lands, including onsite and additional offsite easements, will meet or exceed the 1:1 mitigation recommended in the comment. Of these conservation easements, approximately 1,285 acres will cover irrigated pasture that will be managed for prey production to optimize Swainson's hawk foraging habitat value. Response 2-15 further discusses the value and increased quality of lands protected and managed for prey production. The table shown in Response 2-15 weighs the relative value of the proposed acres of habitat which will be put under easement for conservation and supports that the extent of proposed easements would indeed provide higher value than is recommended by the CDFW Staff Report Regarding Mitigation for Impacts to Swainson's Hawks (0.5:1) and slightly over 1:1 as stated in the comment.

By mitigating with the conservation easements managed for prey production as described in Response 2-15 the Proposed Project's contribution to the cumulative impact would not only be less than considerable. Mitigating at such a ratio decreases any potential cumulative effects that may result from the Proposed Project when considered together with past, other present, and reasonably foreseeable future projects, including the Lower Yolo Ranch Restoration project noted in the comment.

Mitigation and Monitoring Program

CEQA requires that a draft Mitigation and Monitoring Reporting Program be prepared and submitted by the trustee agency to the lead agency for any proposed mitigation measures to mitigate significant impacts. The following table summarizes the revised or new mitigation measures, from the above comments on the draft EIR, for inclusion in the Project's Mitigation and Monitoring Reporting Program.

Comment Number	Mitigation Measure	Timing	Responsibility	Reporting Date/Initials
7	**Mitigation Measure BIO-1. Re-Plant Riparian Vegetation at a 3:1 ratio.** To mitigate the loss of riparian habitat, DWR shall replant permanently impacted riparian habitat on-site at a 3:1 ratio. DWR shall monitor and maintain the replanted habitat for a minimum of 5 years and ensure a minimum 75% survival rate at year 5,	During construction and post-construction	DWR	
8,9,10	**Mitigation Measure BIO-2. Special-Status Plant Avoidance, Preservation, and Replanting.** A Restoration Plan shall be prepared that includes the following elements to avoid and mitigate for potential impacts to Mason's lilaeopsis, woolly rose mallow, Suisun Marsh aster, and Parry's rough tarplant. The Plan shall be prepared and provided to CDFW for approval prior to the start of construction and may be included as part of the Proposed Project's Adaptive Management and Monitoring Plan or Long-Term Management Plan. 4) Seeds and propagules shall be planted into suitable habitat after restoration activities are complete. Planting areas shall be adequate to ensure a minimum of 3:1 replacement of occupied habitat for each of the impacted special-status species. Planted habitat shall be maintained and adaptively managed for five years to ensure successful species establishment. Performance shall be monitored to evaluate success of replacement of special-status species habitat. Target replacement shall be at a minimum 3:1 ratio of Impacted to established habitat acreage for each of the directly impacted special-status plant species. Success would be considered achieved when an equal area of habitat is occupied at a plant density similar to pre-project conditions. Monitoring shall be conducted for a minimum of five growing seasons following initial planting or until performance has been achieved. If individuals of Mason's lilaeopsis are newly detected during pre-construction surveys in areas to be impacted by Proposed Project activities and complete avoidance is not feasible, EIP shall consult with CDFW prior to the start of construction to obtain authorization for Project implementation and develop an appropriate type and amount of compensatory mitigation. Mitigation shall be provided at a minimum 5:1 ratio of impacted individuals to replanted; final mitigation ratios and other specific compensatory requirements shall be' determined through consultation with CDFW.	Pre-construction	DWR	
11	**Mitigation Measure BIO-SA. Nesting birds.** 4) All active nests of native birds found during the survey shall be protected by a no disturbance buffer until all young from each nest fledge or the nest otherwise becomes inactive. Special-status species shall have a minimum buffer of 250 feet (500 feet for raptors). CDFW shall be consulted prior to any work within the specified buffer area. Buffers are typically a minimum of 50 feet for non-special - status birds and may be larger for special-status or raptor species.	During construction	DWR	

2-27

Comment Number	Mitigation Measure	Timing	Responsibility	Reporting Date/Initials
12,13,14	**Mitigation Measure B10-5B. Swainson's Hawk Nesting and Foraging Habitat.** 1) and 2) A no disturbance buffer shall be created within ½ mile of any active Swainson's hawk nest. If work must occur in the buffer area during nesting season, CDFW shall be consulted prior to any work occurring in the buffer. At that time, CDFW may require additional minimization and mitigation measures. 5) The loss of approximately 1,850 acres of foraging habitat shall be mitigated through establishment of an off- site easement and/or purchase of credits at a CDFW- approved mitigation bank. The mitigation shall permanently conserve a minimum of approximately 1,850 acres of Swainson's hawk foraging habitat of equal or greater forage quality than irrigated pasture (a 1:1 mitigation ratio). This may include perennial grassland, tomatoes, alfalfa, beets, drvland pasture , or irriqated pasture.	Pre-construction and during construction	DWR	
15	**Mitigation Measure B10-5D. Giant Garter Snake.** 6) The loss of 103 acres of winter refugia habitat shall be mitigated at a 1:1 ratio through establishment of an off-site easement and/or purchase of credits at a CDFW-approved mitigation bank.	Pre-construction	DWR	
16	**Mitigation Measure BIO-5E. Western Pond Turtle.** 6) CDFW shall be consulted prior to any western pond turtle or western pond turtle nests being relocated	During construction	DWR	
18	**Mitigation Measure BIO-6 Special-Status Fish Species.** 8) Initiate a soft start to allow fish to leave the area prior to operating the vibratory hammer at full capacity. The hammer operatory shall initiate noise from the hammer for 15 seconds at reduced energy followed by a one-minute waiting period. This procedure shall be repeated two additional times before commencing hammering at full capacity. 9) Pile driving activities shall only occur between two hours after sunrise till two hours before sunset. If fish species are detected during pile driving activities, all piles shall cease until the fish leave the Project area.	During construction	DWR	
19 & 20	**Mitigation Measure BIO-6 Special-Status Fish Species.** 10) To prevent an unintentional fish kill, DWR shall develop and implement a staged dewatering plan to force fish to migrate through existing canals to the southern ponded area. This plan shall also include a backup plan to rescue any stranded fish during the dewatering phase. DWR shall consult with CDFW regarding Wakasagi prior to dewatering any ponds that contain a large number of Wakasagi.	Pre-construction and during construction	DWR	
21	**New Recreation Mitigation Measure. Agency and Public Access to Liberty Island Ecological Reserve and Shag Slough.** To mitigate the loss of CDFW staff access to Liberty Island Ecological Reserve (LIER) and public land-based recreational access to LIER and Shag Slough, DWR shall construct either 1) an agency only use boat ramp and a small public hand-launch boat ramp and fishing access point on Shag Slough or 2) provide restricted access to the agency ramp that would only allow the public to hand-launch kayaks ans small boats.	During construction	DWR	

2-27 Cont.

Response 2-27:

As described on page I-4 in Chapter I, *Introduction* of the Draft EIR, a Mitigation Monitoring and Reporting Program (MMRP) will be prepared and adopted as part of the project approval process. DWR will consider the proposed changes together with other comments received and all responses provided in preparing the MMRP for the Proposed Project.

ENVIRONMENTAL DATA

CEQA requires that information developed in environmental impact reports and negative declarations be incorporated into a database, which may be used to make subsequent or supplemental environmental determinations [Pub. Resources Code, § 21003, subd. (e)]. Accordingly, please report any special-status species and natural communities detected during Project surveys to the California Natural Diversity Database (CNDDB). The CNNDB field survey form can be found at the following link: https://www.wildlife.ca.gov/Data/CNDDB/Submitting-Data#44524420-pdf-field-survey-form. The completed form can be mailed electronically to CNDDB at the following email address: cnddb@wildlife.ca.gov. The types of information reported to CNDDB can be found at the following link: https://www.wildlife.ca.gov/Data/CNDDB/Plants-and-Animals. 2-28

Response 2-28:

Comment noted.

FILING FEES

The Project, as proposed, would have an impact on fish and/or wildlife, and assessment of filing fees is necessary. Fees are payable upon filing of the Notice of Determination by the Lead Agency and serve to help defray the cost of environmental review by CDFW. Payment of the fee is required in order for the underlying project approval to be operative, vested, and final. (Cal. Code Regs, tit. 14, § 753.5; Fish and Game Code, § 711.4; Pub. Resources Code, § 21089). 2-29

Response 2-29:

Comment noted.

CONCLUSION

Thank you for the opportunity to provide comments and recommendations regarding those activities involved in the Project that may affect California's fish and wildlife. Likewise, we appreciate the opportunity to provide comments regarding those aspects of the Project that CDFW, by law, may be required to carry out or approve through the exercise of its own regulatory authority under the Fish and Game Code.

Questions regarding this letter or further coordination should be directed to Mr. Andy Rockriver, Senior Environmental Scientist (Specialist), at (209) 234-3433 or Andy.Rockriver@wildlife.ca.gov; or Ms. Gina Van Klompenburg, Senior Environmental Scientist (Supervisory), at (209) 234-3432 or Gina.VanKlompenburg@wlidlife.ca.gov.

cc: State Clearinghouse #2019039136

Letter 3
Central Valley Flood Protection Board

STATE OF CALIFORNIA- CALIFORNIA NATURAL RESOURCES AGENCY **GAVIN NEWSOM,** GOVERNOR

CENTRAL VALLEY FLOOD PROTECTION BOARD
3310 El Camino Ave., Ste. 170
SACRAMENTO, CA 95821
(916) 574-0609 FAX: (916) 574-0682

February 14, 2020

Ms. Heather Green
California Department of Water Resources
3500 Industrial Boulevard
West Sacramento, California 95691

Subject: Lookout Slough Tidal Habitat Restoration and Flood Improvement Project, Draft Environmental Impact Report, State Clearinghouse No. 2019039136

Location: Solano and Yolo Counties

Dear Ms. Green,

Thank you for the opportunity to comment on the Lookout Slough Tidal Habitat Restoration and Flood Improvement Project Draft Environmental Impact Report (DEIR). The DEIR was prepared to disclose and address potential environmental impacts associated with the proposed Lookout Slough Project. The proposed project involves habitat restoration and flood control enhancement of an approximate 3,400-acre area into a self-sustaining tidal marsh and floodplain. This enhancement is required as part of U.S Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) issued Biological Opinions in 2008 and 2009, in which the California Department of Water Resources (DWR) must restore 8,000 acres of tidal marsh complex in the Delta to provide habitat for Delta Smelt and salmonids.

To restore and enhance upland, tidal, subtidal, and floodplain habitat designed to perform a range of habitat functions for targeted species, the project involves levee modifications, grading, fill placement, revegetation. The proposed project would construct a new setback levee along Duck Slough and Liberty Island Road (Duck Slough Setback Levee) to replace flood protection currently offered by the existing Shag Slough Levee, which would be breached at nine locations and degraded along two segments. The existing Cache/Hass Slough levee would be improved to reduce subsidence and prevent erosion and would function as a training levee to prevent increases in water surface elevations in Cache and Hass Sloughs. Proposed levee modifications would help meet regional flood protection objectives in a manner consistent with DWR's 2017 Sacramento Basin-wide Feasibility Study. This project is located within the Cache Slough Complex and is within the Central Valley Flood Protection Board's (Board) permitting authority, thereby requiring an encroachment permit.

The Board, as a Responsible Agency under the California Environmental Quality Act (CEQA), will review and consider the environmental effects of the proposed project identified in the Environmental Impact Report, and reach its own conclusions on whether and how to approve the project involved (14 CCR 15096, subd. (a)). Accordingly, the comments herein are intended to assist in the development of a robust CEQA document capable of supporting the Board's permitting process.

As a partner in the Yolo Bypass/Cache Slough Partnership, the Board supports this project. However, as a regulatory agency permitting this proposed project, the Board has the following concerns about the project. Page 111-6 of the DEIR describes Cache Slough Complex levee maintenance responsibilities as shared among DWR, the U.S. Army Corps of Engineers (USACE), and local reclamation districts. While DWR and local reclamation districts are responsible for levee maintenance, it is the Board who has provided assurances to the USACE of operation and maintenance of State Plan of Flood Control (SPFC) levees. The USACE does not share any levee maintenance responsibilities. 3-1

Response 3-1:

Comment noted. The first full paragraph on page III-6 in Chapter III, *Project Description* of the Draft EIR is revised as follows:

> In the Cache Slough Complex, levee maintenance responsibilities are shared among DWR~~, the Corps,~~ and local reclamation districts (RDs), with the CVFPB providing assurances to the Corps for operations and maintenance of SPFC levees.…

Page 111-20 of the DEIR states that Reclamation District (RD) 2098 would be responsible for maintaining the Duck Slough Setback Levee after project completion. Pages 111-47 through 111-49 of the DEIR describe the Post-Construction Operations and Maintenance of the proposed project. It states that RD 2098 would be responsible for implementing long-term operations and management of the Duck Slough Setback Levee and DWR would be responsible for implementing long-term management and monitoring activities of the remainder of the Proposed Project Site. The DEIR does not address whether it will be financially feasible for RD 2098 to provide long-term operation and maintenance for the Duck Slough Setback Levee. The Board is aware that the proposed project will create a reduction in revenue for RD 2098 to operate and maintain the Duck Slough Setback Levee in perpetuity. There is concern that RD 2098's lack of revenue would not allow the required operation and maintenance of the Duck Slough Setback Levee, potentially causing flood risk impacts to the surrounding property and flood facilities. 3-2

Response 3-2:

See Master Response 7, *Operation and Maintenance (O&M) of Levees*. To the extent that the CVFPB may have questions with regard to this and other issues, DWR and its contractors will comply with all applicable regulatory requirements; however, the EIR is not required to include all the information necessary to meet other regulatory programs and requirements.

Page IV.D.53 of the DEIR describes Mitigation Measure BIO-2 which requires a Restoration Plan that will be provided to DWR prior to the start of construction, and that it may be included as part of the proposed project's Adaptive Management and Monitoring Plan or Long-Term Management Plan. The Board will require a Long-Term Management Plan be submitted as part of its permitting process. This plan should include information regarding how the proposed project site will be managed and maintained in perpetuity, once restoration is deemed complete. In addition, detailed information regarding how RD 2098 will generate revenue to operate and maintain the Duck Slough Setback Levee in perpetuity should be included. 3-3

Response 3-3:

See Response 3-2.

The EIR should include language describing that there is sufficient funding and executed agreements between DWR, RD 2098, and Ecosystem Investment Partners (the project proponent) to facilitate the transfer of property and maintenance responsibilities to DWR. The EIR should also reference that the proposed project will be maintained in perpetuity, in compliance with the Board's Operation, Maintenance, Repair, Replacement and Rehabilitation resolution. In addition, RD 2098 will need to update its maintenance responsibilities to the Board through the Board's adoption of an assurance agreement prior to encroachment permit issuance. 3-4

Response 3-4:

See Response 3-2.

Thank you for the opportunity to provide comments. If you have any questions, please contact me at (916) 574-0332, or via email at Andrea.Buckley@CVFlood.ca.gov.

Sincerely,

An rea Buckley, Chief
Environmental Services and Land Management Branch

cc: Office of Planning and Research
P.O. Box 3044, Room 113 Sacramento, CA
95812-3044

ec: Heather Green
Heather.Green@wate.rca.gov
FRPA@wate r.ca.gov

Letter 4
Delta Protection Commission

Letter 4

STATE OF CALIFORNIA - NATURAL RESOURCES AGENCY — Gavin Newsom, *Gover.*

DELTA PROTECTION COMMISSION
2101 Stone Blvd., Suite 240 West
Sacramento, CA 95691
(916) 375 - 4800
www.delta.ca.gov

February 14, 2020

Heather Green
CA Department of Water Resources
3500 Industrial Blvd.
West Sacramento, CA 95691 (via email: frpa@water.ca.gov)

Subject: Lookout Slough DEIR (SCH# 2019039136)

Dear Ms. Green,

Thank you for providing the Delta Protection Commission (Commission) the opportunity to review and provide comments regarding the Lookout Slough (Project} Draft Environmental Impact Report (DEIR).

The Commission is a State agency charged wit h ensuring orderly, balanced conservation and development of Delta land resources and improved flood protection. The Commission' s authority over "development" project s in the primary zone (Public Resources Code Section 29723(a)} is based on the Commission's Land Use and Resource Management Plan for the Primary Zone of the Delta. Although this authority does not extend to State projects, we submit these comments on the DEIR for DWR's consideration.

We submitted a Notice of Preparation (NOP) comment letter requesting that the DEIR address the impact s of the project on water quality, surface water elevations and velocities, and aquatic endangered species. We also requested incorporation of the DWR " Good Neighbor Checklist".

We have reviewed the DEIR and provide the following comments:

Conversion of Farmland to Non-Agricultural Use: The DEIR identifies 1,460 acres of agricultural land that will be converted for habitat restoration. The Commission acknowledges the Memorandum of Understanding between DWR and Solano County regarding assurances for this project, and applauds the MOU provision related to farmland mitigation. Both the efforts to improve agricultural productivity on nearby parcels and the use of agricultural conservation easements to protect other farmland, as called for in the MOU, are appropriate mechanisms to mitigate for the loss of farmland. 4-1

Response 4-1:

Comment noted.

Recreation Access: The DEIR does not adequately address the loss of access for informal bank fishing that presently occurs on Shag Slough along Liberty Island Road. Relocating activities to suggested sites in Table IV.J-1. "Selected Shoreline and Pier Fishing Sites within a One Hour Drive of the Proposed Project Site" may not be a viable option for subsistence fisherman or those with limited means. Project proponents should work with Solano County to identify and enhance, as appropriate, a nearby area that can be designated a fishing site to reduce these impacts. As proponents design project features and levees, please also consider including public access opportunities for passive recreation such as hiking and bird watching, as well as opportunities for segments of the Great California Delta Trail. 4-2

Response 4-2:

See Master Response 10, *Recreation*.

Hydrology and Water Quality: The DEIR indicates that hydrologic modeling results show a less than significant impact to salinity, water levels, turbidity, wind-wave erosion, seepage, and tidal range. Modeling is a good first step to understand how the restoration project could change the Delta environment, but mitigation measures to require post-construction monitoring and remediation in the case of any unanticipated deleterious effects should be included. This includes measures to ensure that nearby landowners are not made to bear additional costs related to negative effects from changed hydrology as a result of the project. 4-3

Response 4-3:

The analysis of Proposed Project impacts on hydrology and water quality during and after construction were provided on pages IV.G-19 through IV.G-31 in Section IV.G, *Hydrology and Water Quality* of the Draft EIR. As the comment noted, the impact analysis concluded that the Proposed Project would result in less than significant impacts to hydrology and water quality, which do not require implementation of mitigation measures or post-construction monitoring in most cases. Mitigation is required for impacts related to erosion and sedimentation during construction (see Draft EIR pages IV.G-19 to IV.G-21). Mitigation Measure HYDRO-1 requires NPDES permits and Mitigation Measure HYDRO-2 requires the implementation of a Turbidity Monitoring Program. In addition, as described in Chapter III, *Project Description* on page III-49, upon completion of Proposed Project construction, a series of monitoring and adaptive management activities would ensure the long-term viability of the newly restored ecosystem. In keeping with the requirements of the Delta Plan, post-construction site monitoring and management is designed to be flexible and adaptive based on changing conditions in the Delta, using the best available science to inform decision-making. See also Master Response 11, *Good Neighbor Checklist;* Master Response 3, *Local Water Diversions and Special-status Fish Species*; Master Response 9, *Tidal Effects on Diversions;* and Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts*.

Aquatic Endangered Species: In its NOP comment letter, the Commission extended support to projects that protect the natural resources of the Delta and preserve agriculture as a critical part of the region's economy. The DEIR proposes reconnecting historic habitat and creating new habitat for listed and special-status fish species. The DWR-Solano County MOU calls for DWR to provide support for the development of a Habitat Conservation Plan. This could help ensure that neighboring agricultural operations can continue to operate without incidental taking of aquatic endangered species in nearby irrigation infrastructure. 4-4

Response 4-4:

Comment noted.

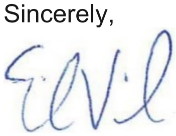
Good Neighbor Checklist: We commend the use of the DWR Good Neighbor Checklist and identifying a point of contact for neighboring landowners to reach out to with concerns. The Commission will continue to ask this of all habitat restoration project proponents in the Delta, and we appreciate the good example that DWR is setting. 4-5

Response 4-5:

Comment noted. DWR will consider identifying a point of contact for neighboring landowners to reach to with concerns. See also Master Response 11, *Good Neighbor Checklist.*

The Commission appreciates your consideration of these comments. Please contact Jeremy Terhune, Associate Environmental Planner, at (916) 375-4534 for any questions regarding the comments provided.

Sincerely,



Erik Vink
Executive Director

cc: Skip Thomson, Commission Member and Solano County Board of Supervisors

Letter 5
Delta Stewardship Council

DELTA STEWARDSHIP COUNCIL
A California State Agency

980 NINTH STREET, SUITE 1500
SACRAMENTO, CALIFORNIA 95814
HTTP://DELTACOUNCIL.CA.GOV
(916) 445-5511

February 14, 2020

Heather Green, Senior Environmental Scientist
California Department of Water Resources
3500 Industrial Blvd.
West Sacramento, CA 95691

Sent via email: FRPA@water.ca.gov

RE: Comments on Draft Environmental Impact Report for the Lookout Slough Tidal Habitat Restoration and Flood Improvement Project, SCH#2019039136

Dear Heather Green:

Thank you for the opportunity to review and comment on the Lookout Slough Tidal Habitat Restoration and Flood Improvement Project (project) Draft Environmental Impact Report (Draft EIR), released December 16, 2019. The project includes enhanced fish and wildlife habitat and improved flood control, and consists of restoration activities on approximately 3,164 acres within a 3,400-acre site located primarily in unincorporated Solano County with a small portion located within unincorporated Yolo County. The project area currently consists of agricultural lands, wetlands, and tidal marshlands within the Cache Slough complex and the Yolo Bypass.

The Delta Stewardship Council (Council) is an independent agency of the State of California, established by the Sacramento-San Joaquin Delta Reform Act of 2009, codified in Division 35 of the California Water Code, sections 85000-85350 (Delta Reform Act). The Delta Reform Act charges the Council with furthering California's coequal goals of achieving a more reliable water supply and restoring the Sacramento-San Joaquin River Delta (Delta) ecosystem, to be achieved in a manner that protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place. (Cal. Water Code section 85054.)

Pursuant to the Delta Reform Act, the Council has adopted the Delta Plan, a legally enforceable management framework for the Delta and Suisun Marsh for achieving the coequal goals. The Delta Reform Act grants the Council specific regulatory and appellate authority over certain actions that take place in whole or in part in the Delta and Suisun Marsh, referred to as "covered actions." (Cal. Water Code sections 85022(a) and 85057.5.) The Council exercises that authority through its regulatory policies (set forth in Title 23 of the California Code of Regulations, Sections 5001 through 5016) and recommendations incorporated into the Delta Plan. State and local agencies are required to demonstrate consistency with the Delta Plan when carrying out, approving, or funding a covered action (Cal. Water Code section 85057.5 and 85225).

Letter 5

Thank you for meeting with Council staff on January 29, 2020 to review and discuss the project. The Council previously submitted a comment letter on the Notice of Preparation of an Environmental Impact Report (NOP) for this project dated April 22, 2019. We appreciate that the comments offered in that letter appear to have been considered and addressed in the Draft EIR, including use of a reference table providing a high-level overview of potentially applicable Delta Plan policies and recommendations and corresponding sections of the Draft EIR (Table IV.A-1, DEIR p. IV.A-11 through IV.A-13).

Covered Action Determination and Certification of Consistency with the Delta Plan

Water Code section 85057.5(a) provides a multi-part test to define what activities would be considered covered actions. Based on the project location and scope, as described in the Draft EIR, the proposed project appears to meet the definition of a covered action because it:

1. Will occur in whole or in part within the boundaries of the Legal Delta (Water Code §12220) or Suisun Marsh (Public Resources Code §29101). The project would occur within the boundaries of the Legal Delta within the Cache Slough complex and the Yolo Bypass.
2. Will be carried out, approved, or funded by the State or a local public agency. DWR is the lead agency and would carry out, approve, and fund the project.
3. Will have a significant impact on the achievement of one or both of the coequal goals or the implementation of a government-sponsored flood control program to reduce risks to people, property, and State interests in the Delta. The project would restore tidal wetland habitat and provide enhanced flood protection, and therefore would have a significant impact on both ecosystem restoration and implementation of government- sponsored flood control. 5-1
4. Is covered by one or more of the regulatory policies contained in the Delta Plan (23 CCR section 5003-5015). Delta Plan regulatory policies that may apply to the project are discussed below.

It is the State or local agency approving, funding, or carrying out the project that must determine if that project is a covered action and, if so, file a Certification of Consistency with the Delta Plan prior to project implementation. (Cal. Water Code section 85225; 23 CCR section 5001(j)(3).)

Response 5-1:

DWR acknowledges that the Proposed Project is a covered action and plans to file a Certification of Consistency.

Comments Regarding Delta Plan Policies and Potential Consistency Certification

The following section describes regulatory Delta Plan policies that may apply to the proposed project based on the available information in the Draft EIR. This information is offered to assist DWR to prepare environmental documents that can be used to support the project's eventual Certification of Consistency. This information may also assist DWR to better describe the relationship between the proposed project and the Delta Plan in the Final EIR.

General Policy 1: Detailed Finding to Establish Consistency with the Delta Plan

Delta Plan Policy **G P1** (23 CCR section 5002) specifies what must be addressed in a certification of consistency for a covered action. The following is a subset of Policy G P1 requirements that a project must meet to be considered consistent with the Delta Plan:

Mitigation Measures

Delta Plan Policy **G P1, subsection (b)(2),** (23 CCR section 5002(b)(2)) requires that actions not exempt from CEQA and subject to Delta Plan regulations must include all applicable feasible mitigation measures adopted and incorporated into the Delta Plan as amended April 26, 2018, or substitute mitigation measures that are equally or more effective. Mitigation measures in the Delta Plan's Mitigation and Monitoring Report Program (Delta Plan MMRP) are available at: https://deltacouncil.ca.gov/pdf/delta- plan/2018-appendix-o-mitigation-monitoring-and-reporting-program.pdf. 5-2

The Draft EIR identifies potentially significant impacts requiring mitigation on Agricultural Resources, Air Quality, Biological Resources, Hazardous Materials, Hydrology and Water Quality, and Tribal Cultural Resources. Council staff recommend that DWR review the Delta Plan MMRP and implement applicable feasible mitigation measures identified in the Delta Plan or substitute mitigation measures that are equally or more effective.

Agriculture is a prominent land use in the Delta, including on the project site and in surrounding areas. The Delta Plan MMRP discusses mitigation for impacts to Agricultural Resources under Mitigation Measure 7-1. DWR describes corresponding mitigation measures for the project in the Draft EIR which minimize impacts to agriculture, including off-site agricultural improvements (Draft EIR Mitigation Measure AG-1a) and establishment of an off-site agricultural preserve by placing a conservation easement on a minimum of 1,000 acres of Prime Farmland (Draft EIR Mitigation Measure AG-1b).

The project will include construction activities adjacent to waterways and wetlands. The Draft EIR indicates that DWR will follow construction Best Management Practices (BMPs) during construction and maintenance (Draft EIR, p. IV.G-19). Since the final required BMPs are subject to approval by the Central Valley Water Resources Quality Control Board (Water Board), DWR should provide an updated list of BMPs to fulfill requirements set forth in Delta Plan mitigation measures 3-1 (Water Resources) and 4-1 (Biological Resources) in a future certification of consistency.

Chapter IV.D and Appendix F of the Draft EIR describe how the project will address invasive nonnative species. This chapter includes proposed mitigation measures to reduce potential invasive species to a less than significant level, including project *Mitigation Measure BIO-4. Invasive Species Abatement*. DWR should review the Delta Plan MMRP (https://deltacouncil.ca.gov/pdf/delta-plan/2018-appendix-o-mitigation- monitoring-and-reporting-program.pdf) to ensure that each proposed measure related to invasive nonnative species is equally or more effective than related Delta Plan mitigation measures. Specifically, in the Final EIR, DWR should describe how proposed project Mitigation Measure BIO-4 is equally or more effective than Delta Plan Mitigation Measure 4-1. Delta Plan Mitigation Measure 4-1 requires development and implementation of an invasive species management plan for any project whose construction or operation could lead to introduction or facilitation of invasive species establishment, and describes the required content of the management plan. 5-2 Cont.

Response 5-2:

DWR and its contractors will comply with all applicable regulatory requirements. This is not an issue relating to the adequacy of the environmental impact analysis under CEQA (see Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts*). DWR is planning to file a Certification of Consistency with the Delta Stewardship Council (DSC) and appreciates the DSC's identification of potential policies that may apply.

Best Available Science

Delta Plan Policy **G P1, subsection (b)(3),** (23 CCR section 5002(b)(3)) states that covered actions must document use of best available science as relevant to the purpose and nature of the project. The regulatory definition of "best available science" is provided in Appendix 1A of the Delta Plan (https://deltacouncil.ca.gov/pdf/delta- plan/2015-appendix-1a.pdf). Best available science is defined in the Delta Plan as the best scientific information and data for informing management and policy decisions. Six criteria are used to define best available science: relevance, inclusiveness, objectivity, transparency and openness, timeliness, and peer review. (23 CCR section 5001(f)) This policy generally requires that the lead agency clearly document and communicate the process for analyzing project alternatives, impacts, and mitigation measures of proposed projects, in order to foster improved understanding and decision making.

The Draft EIR for the project generally cites well-documented hydrodynamic models, invasive species best practices, and biological resource areas. The proposed restoration design strategies to provide habitat and a source of food for Delta smelt and other protected species is well supported by multiple numerous scientific studies that may meet the best available science criteria. In addition to using scientific literature cited throughout Draft EIR Appendix H (*Fish Study Restoration Basis of Design*), DWR consulted with experts on the species (Draft EIR Appendix H, p. 2). Appendix H includes a Delta smelt habitat conceptual model, explains the aspects of the model based on peer-reviewed literature, and relates these aspects to both the project site and proposed design. Appendix H also discusses the potential of the project to contribute to recovery of select protected fish species that may use the area. Appendix H considers key components of each species' life history and evaluates the potential for each species to occur within the project area following proposed restoration. DWR should more fully support the information in the Biological Resources Assessment and in Section IV.D of the Final EIR using additional references to supporting scientific literature. 5-3

Response 5-3:

See Response 5-2.

Adaptive Management

Delta Plan Policy **G P1, subsection (b)(4),** (23 CCR section 5002(b)(4)) requires that ecosystem restoration and water management covered actions include adequate provisions, appropriate to the scope of the action, to assure continued implementation of adaptive management. This requirement is satisfied through: a) the development of an adaptive management plan that is consistent with the framework described in Appendix 1 B of the Delta Plan (https://deltacouncil.ca.gov/pdf/delta-plan/2013-appendix-b-combined.pdf), and b) documentation of adequate resources to implement the proposed adaptive management plan. 5-4

Adaptive management is required for the project given its ecosystem restoration component. Council staff understand that an adaptive management plan is not available as part of the Draft EIR. An adaptive management plan consistent with the framework referenced above will be required as part of a certification of consistency with the Delta Plan for the project. Council staff in the Delta Science Program are available to provide early consultation on adaptive management upon request.

Response 5-4:

See Response 5-2.

Ecosystem Restoration Policy 1: Delta Flow Objectives

Delta Plan Policy **ER P1** (23 CCR section 5005) requires the State Water Resources Control Board's Bay Delta Water Quality Control Plan flow objectives to be used to determine consistency with the Delta Plan for a proposed action that could significantly affect flow in the Delta. This policy relates to the project because the project proposes modifications to Delta levees at several locations, which has potential to significantly affect flow.

The Draft EIR describes potential impacts to flood flow and conveyance as less than significant. The basis for this finding is described in several sections and appendices to the Draft EIR, and summarized on page IV.G-1. The Draft EIR describes a nested model approach utilizing one-dimensional HEC-RAS and two-dimensional TUFLOW models. Electrical conductivity modeling methods, a common proxy for salinity, are summarized in Appendix S. As described in the Draft EIR, these modeling methods appear to align with best current practices and would useful in describing compliance with current Bay-Delta Water Quality Control Plan (D-1641) flow objectives in a future certification of consistency. Modeling conducted for this project predicts slight reductions in electrical conductivity at two D-1641 compliance points: up to 5% reduction at Barker Slough North Bay Aqueduct intake, and up to 1.2% at the Contra Costa Water District Mallard Slough intake. Modeling simulates slight increases at all other locations, up to 1.6% for at least one month per year (Draft EIR, Appendix S, pp. 3-4). When considering the cumulative impacts of other proposed restoration sites in the Delta and Suisun Marsh, the compliance locations are simulated to remain in compliance with D-1641 standards (Draft EIR, Appendix S, pp. 5-6). Council staff notes that the salinity modeling used 2009 as a representative dry year. In the Final EIR, DWR should describe the basis for selecting 2009 as a representative year and how salinity conditions may vary across other water-year types and under anticipated climate change conditions relative to the State Water Board's Delta flow objectives. 5-5

Response 5-5:

See Response 5-2. Also see Master Response 1, *Salinity and Bromide* for discussion of the expanded hydrodynamic modeling analysis that includes analysis of potential impacts over three different calendar years (2009, 2010, and 2016) which represent Sacramento River watershed inflows ranging from below normal to dry hydrologic conditions.

Ecosystem Restoration Policy 2: Restore Habitats at Appropriate Elevations

Delta Plan Policy **ER P2** (23 CCR section 5006) requires habitat restoration to be consistent with Appendix 3 (https://deltacouncil.ca.gov/pdf/delta-plan/2013-appendix-b-combined.pdf), which describes the many ecosystem benefits related to restoring floodplains. The elevation map included as Figure 4-1 in Appendix 4 (https://deltacouncil.ca.gov/pdf/delta-plan/2013- appendix-b-combined.pdf) of the Delta Plan should be used as a guide for determining appropriate habitat restoration actions based on an area's elevation.

The Draft EIR analyzes the elevation of the project site in relation to the 1957 authorized design water surface and storm surge plus 1 foot to account for uncertainties associated with climate change and sea-level rise (Draft EIR Appendix D, section 4.1, p. 600). The project site ranges from approximately +3 feet to +8 feet in elevation. Based on this analysis, it appears that the project site is appropriate for tidal marsh restoration under current conditions, and provides capacity for tidal marsh to migrate as sea level increases. However, in the Final EIR DWR should further document how this analysis and project design aligns with Delta Plan policies ER P2 and G P1(b)(4) (best available science).[1] 5-6

FOOTNOTE 1 For example, by highlighting the project elevation profiles, appropriate sea-level projections, and overlay with Delta Plan Figure 4-1.

Response 5-6:

See Response 5-2.

Ecosystem Restoration Policy 4: Expand Floodplains and Riparian Habitats in Levee Projects

Delta Plan Policy **ER P4** (23 CCR section 5008) requires levee projects to evaluate and, where feasible, incorporate alternatives to increase floodplains and riparian habitats. This policy applies to the project because the project includes modifications to Delta levees.

The Draft EIR notes that flood improvement and floodplain expansion are primary objectives of the project and that the project will expand the Yolo Bypass in this area. As DWR finalizes specific levee setback designs, it should review the January 2016 Council report: "Improving Habitat along Delta Levees".[2] This report summarizes which habitat designs along levees may provide greater benefits to target native species with an emphasis on salmon and riparian birds. 5-7

FOOTNOTE 2 Available upon request by contacting accessibility@deltacouncil.ca.gov.

Response 5-7:

See Response 5-2.

Ecosystem Restoration Policy 5: Avoid Introductions of and Habitat Improvements for Invasive Nonnative Species

Delta Plan Policy **ER P5** (23 CCR section 5009) calls for avoiding introduction and habitat improvements for invasive, nonnative species or mitigating these potential impacts in a manner that appropriately protects the ecosystem.

Please refer to previous discussion regarding project Mitigation Measure BIO-4 and Delta Plan Mitigation Measure 4-1 under Delta Plan Policy G P1(b)(2) above[3]. 5-8

FOOTNOTE 3 Council staff note that the Draft EIR includes reference to two Delta Plan recommendations, ER R2 (Prioritize and Implement Projects that Restore Delta Habitat) and ER R7 (Prioritize and Implement Actions to Control Nonnative Invasive Species). As DWR is aware, these recommendations are not regulatory. However, the Council appreciates that the recommendations are referenced here, as they relate to the project and support achievement of the coequal goals.

Response 5-8:

See Response 5-2.

Delta as Place Policy 2: Respect Local Land Use when Siting Water or Flood Facilities or Restoring Habitats

Delta Plan Policy **DP P2** (23 CCR section 5011) reflects one of the Delta Plan's charges to protect the Delta as an evolving place by requiring the siting of project improvements/facilities to avoid or reduce conflicts with existing or planned future land uses when feasible. Given that the project's scope and location is within the Delta, DP P2 applies to this project. In the Final EIR, DWR should describe in detail the project process and anticipated outcomes that would avoid or reduce conflicts with existing or planned future land uses.

5-9

The Draft EIR states that conflict with existing agricultural land uses would be minimal after proposed mitigation and with implementation of aspects of the Good Neighbor Checklist (Draft EIR p. IV.B-15). These mitigation measures and the checklist are described in Chapter IV.B (p. IV.B-1) and Appendix E of the DEIR, respectively. The Council understands that in addition to these proposed mitigation measures, DWR has entered into a Memorandum of Understanding with Solano County that advances additional strategies to reduce impacts to agriculture. A certification of consistency for the project should describe any additional steps taken by DWR to minimize or offset the loss of agricultural land and promote compatibility of agricultural and ecosystem restoration uses.

The project area contains 3,400 acres of agricultural land and is surrounded by neighboring agricultural parcels. As the Draft EIR acknowledges, agriculture is an important land use in the project area and throughout the Delta. The Draft EIR notes that the three parcels comprising the project site are under Williamson Act contracts with Solano County, which limits their use to agricultural or open space. However, the Vogel and Liberty Farms properties are not designated as prime farmland and therefore would not result in conversion of prime farmland to non-agricultural use. The majority of one of the three remaining properties, Bowlsbey, is designated as prime farmland. The project would result in the loss of approximately 1,460 acres of prime farmland on the Bowlsbey property (Draft EIR pp. IV.B-10 - IV.B-15). Proposed project Mitigation Measure AG-1a would partially offset this loss by requiring funding for agricultural improvements (e.g., irrigation infrastructure) on a nearby property and at least one agricultural conservation easement for a minimum of 1,000 acres. Together, these measures would exceed the amount of prime farmland to be converted on the Bowlsbey property. It should be noted that not all of the mitigated area is currently of the same quality as land that would be converted, although the total proposed area aligns with Solano County General Plan implementation program AG.I-1, which requires mitigation for loss of agricultural land at a minimum of 1.5:1 (https://www.solanocounty.com/civicax/filebank/blobdload.aspx?BlobID=6493). In the Final EIR, DWR should add additional discussion regarding consistency with Solano County's General Plan. 5-9 Cont.

The Draft EIR highlights the Delta Plan in relation to agricultural land use, stating that the Delta Plan does not contain any regulatory policies focused specifically on agriculture. However, Delta Plan Policy DP P2's scope includes planned and existing land uses, which in the project area includes agricultural land. A certification of consistency for the project should include robust discussion regarding consistency of the project with adjacent existing and planned agricultural uses, in addition to other aspects of Delta as Place, including but not limited to recreation and cultural resources. As noted under Delta Plan Policy G P1(b)(2) above, the Delta Plan also includes mitigation measures specific to these items, which should be included in the Final EIR as applicable (or the Final EIR should include equally or more effective mitigation measures).[4]

FOOTNOTE 4 The Draft EIR also includes three Delta Plan recommendations specific to agriculture: Promote Value-added Crop Processing (DP R8), Encourage Agritourism (DP R9), and Encourage Wildlife-friendly Farming (DP R10). The Council appreciates reference to and recognition of these non-regulatory Delta Plan recommendations as applicable to the project.

Response 5-9:

See Response 5-2.

Risk Reduction Policy 1: Prioritization of State Investments in Delta Levees and Risk Reduction

Delta Plan Policy **RR P1** (23 CCR section 5012) calls for the prioritization of State investments in Delta flood risk management, including levee operation, maintenance and improvements.

Delta Plan Policy RR P1 provides interim priorities to guide discretionary State investments in Delta flood risk management, including levee operation, maintenance and improvements.

The project includes levee alterations and improvements to provide habitat and flood control enhancements. As described in the Draft EIR (p. I-2), the project would widen a portion of the Yolo Bypass to increase flood storage and conveyance, increase the resilience of levees, and reduce flood risk. The project involves constructing a new setback levee along Duck Slough and Liberty Island Road (Duck Slough Setback Levee) to replace flood protection currently offered by the existing Shag Slough Levee. A certification of consistency should explain, and provide supporting documentation to demonstrate, how the project is consistent with the priorities outlined in Policy RR P1. 5-10

Draft EIR Table IV.A-1 identifies the Council's draft proposed regulatory language for Policy RR P1 that is the subject of an ongoing rulemaking process, rather than the version of RR P1 currently in effect. The Final EIR, should refer to and analyze the priorities established by currently effective RR P1 regulatory requirements (23 CCR section 5012).

Response 5-10:

See Response 5-2.

Closing Comments

As DWR proceeds with development of a Final EIR for the project, the Council invites DWR staff to engage Council staff in early consultation, prior to submittal of a certification of consistency, to discuss project features and mitigation measures that would promote consistency with the Delta Plan. As part of the Council, the Delta Science Program's Adaptive Management Liaisons are also available to provide further consultation and guidance regarding appropriate application of best available science and adaptive management.

More information on covered actions, early consultation, and the certification process can be found on the Council website, http://deltacouncil.ca.gov/covered-actions. Council staff are available to discuss items discussed in this letter as you proceed in the next stages of your project and approval processes. Please contact Daniel Constable at (916) 322-9338 (daniel.constable@deltacouncil.ca.gov) with any questions.

Letter 5

Sincerely,

Jeff Henderson, AICP Deputy
Executive Officer Delta
Stewardship Council

Cc: You-Chen Chao, Department of Water Resources (youchen.chao@water.ca.gov)
Kristopher Jones, Department of Water Resources (kristopher.jones@water.ca.gov)

Letter 6
Central Valley Regional Water Quality Control Board

CALIFORNIA
Water Boards

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SECRETARY FOR
ENVIRONMENTAL PROTECTION

Central Valley Regional Water Quality Control Board

19 February 2019

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COMMENTS TO REQUEST FOR REVIEW FOR THE DRAFT ENVIRONMENTAL IMPACT REPORT, LOOKOUT SLOUGH TIDAL HABITAT RESTORATION AND FLOOD IMPROVEMENT PROJECT, SCH#2019039136, SOLANO COUNTY

Pursuant to the State Clearinghouse's 16 December 2019 request, the Central Valley Regional Water Quality Control Board (Central Valley Water Board) has reviewed the *Request for Review for the Draft Environmental Impact Report* for the Lookout Slough Tidal Habitat Restoration and Flood Improvement Project, located in Solano County.

Our agency is delegated with the responsibility of protecting the quality of surface and groundwaters of the state; therefore our comments will address concerns surrounding those issues.

I. Regulatory Setting

<u>Basin Plan</u>

The Central Valley Water Board is required to formulate and adopt Basin Plans for all areas within the Central Valley region under Section 13240 of the Porter-Cologne Water Quality Control Act. Each Basin Plan must contain water quality objectives to ensure the reasonable protection of beneficial uses, as well as a program of implementation for achieving water quality objectives with the Basin Plans. Federal regulations require each state to adopt water quality standards to protect the public health or welfare, enhance the quality of water and serve the purposes of the Clean Water Act. In California, the beneficial uses, water quality objectives, and the Antidegradation Policy are the State's water quality standards. Water quality standards are also contained in the National Toxics Rule, 40 CFR Section 131.36, and the California Toxics Rule, 40 CFR Section 131.38.

The Basin Plan is subject to modification as necessary, considering applicable laws, policies, technologies, water quality conditions and priorities. The original Basin Plans were adopted in 1975, and have been updated and revised periodically as required, using Basin Plan amendments. Once the Central Valley Water Board has adopted a Basin Plan amendment in noticed public hearings, it must be approved by the State Water Resources Control Board (State Water Board), Office

of Administrative Law (OAL) and in some cases, the United States Environmental Protection Agency (USEPA). Basin Plan amendments only become effective after they have been approved by the OAL and in some cases, the USEPA. Every three (3) years, a review of the Basin Plan is completed that assesses the appropriateness of existing standards and evaluates and prioritizes Basin Planning issues. For more information on the *Water Quality Control Plan for the Sacramento and San Joaquin River Basins*, please visit our website:
http://www.waterboards.ca.gov/centralvalley/water_issues/basin_plans/

Antidegradation Considerations

All wastewater discharges must comply with the Antidegradation Policy (State Water Board Resolution 68-16) and the Antidegradation Implementation Policy contained in the Basin Plan. The Antidegradation Implementation Policy is available on page 74 at:
https://www.waterboards.ca.gov/centralvalley/water_issues/basin_plans/sacsjr_201805.pdf

In part it states:

> *Any discharge of waste to high quality waters must apply best practicable treatment or control not only to prevent a condition of pollution or nuisance from occurring, but also to maintain the highest water quality possible consistent with the maximum benefit to the people of the State.*
>
> *This information must be presented as an analysis of the impacts and potential impacts of the discharge on water quality, as measured by background concentrations and applicable water quality objectives.*

The antidegradation analysis is a mandatory element in the National Pollutant Discharge Elimination System and land discharge Waste Discharge Requirements (WDRs) permitting processes. The environmental review document should evaluate potential impacts to both surface and groundwater quality. 6-1

Response 6-1:

DWR appreciates the Board's identification of potential regulatory requirements that may apply. DWR and its contractors will comply with all applicable regulatory requirements.

II. Permitting Requirements

Total Maximum Daily Load - Mercury

Central Valley Water Board staff recommends replacing all instances of 'characterization study' with 'control study' when referencing Phase 1 studies for the Delta Mercury Control Program.

The Draft Initial Study indicates that potential impacts from methylmercury may be significant. The Draft Environmental Impact Report indicates that potential impacts from methylmercury are less than significant. However, some tidal wetlands may be a source of methylmercury, thus posing a potential health risk for human and wildlife consumption of aquatic organisms within and beyond the wetland.

Please refer to the following references that indicate the potential for tidal wetlands to be a source of methylmercury:

1. Heim, W.A., M. Stephenson, B. Hughes, A. Bonnema, and K, Coale. 2008. “Methylmercury Loading Studies in Delta Wetlands--Sycamore Slough and Suisun Marsh.” Final Report submitted to the CALFED Bay-Delta Program for the Project “Transport, Cycling and Fate of Mercury and Monomethylmercury in the San Francisco Delta and Tributaries” Task 5.3a.
2. Gill, G.A. 2008. “Sediment-water Exchange.” Final Report submitted to the CALFED Bay-Delta Program for the Project “Transport, Cycling and Fate of Mercury and Monomethylmercury in the San Francisco Delta and Tributaries” Task 4.2. Pacific Northwest National Laboratory. 6-2
3. Fleck, J.A., G. Aiken, B.A. Bergamaschi, D. Latch. 2008. “Methylmercury Loading Studies in Delta Wetlands – Brown’s Island.” Final Report submitted to the CALFED Bay-Delta Program for the Project “Transport, Cycling and Fate of Mercury and Monomethylmercury in the San Francisco Delta and Tributaries” Task 5.3a.
4. Bergamaschi, B.A., J.A. Fleck, B.D. Downing, E. Boss, B. Pellerin, N.K. Ganju, D.H. Schoellhamer, A.A. Byington, W.A. Heim, M. Stephenson, and R. Fujii. 2011. “Methyl mercury dynamics in a tidal wetland quantified using in situ optical measurements.” Limnology and Oceanography 56(4): 1355-1371.
5. Mitchell, C.P.J, T.E. Jordan, A. Heyes, and C.C. Gilmour. 2012. “Tidal exchange of total mercury and methylmercury between a salt marsh and a Chesapeake Bay sub-estuary. Biogeochemistry”. Published online: January 1, 2012.doi: 10.1007/s10533-011-9691-y.
6. Lee, P., D. Bosworth, J. Manning. 2015. “Methylmercury Import and Export Studies of Tidal Wetlands in the Sacramento-San Joaquin Delta, Yolo Bypass, and Suisun Marsh.” Progress Report, Delta Mercury Control Program.
7. Turner, R.R., C.P.J. Mitchell, A.D. Kopec, R.A. Bodaly. 2018. “Tidal fluxes of mercury and methylmercury for Mendall Marsh, Penobscot River estuary, Maine.” Science of the Total Environment 637-638 (2018) 145-154.

The Delta, including the proposed project area, is subject to the Delta Mercury Control Program (also referred to as the Delta Methylmercury Total Maximum Daily Load). Several entities have conducted studies to develop management practices to minimize the production and bioaccumulation of methylmercury. If viable and feasible management practices are identified in the future, the project proponents will need to consider incorporating those practices during construction and future operations of wetlands on the proposed project area. 6-2 Cont.

The proposed project was included in Department of Water Resource's August 2018 Delta Regional Monitoring Program (RMP) Participation Plan. Currently the Delta RMP is monitoring methylmercury in fish and water at multiple locations within the Delta and future RMP monitoring efforts may focus on mercury monitoring near habitat restoration projects.

Response 6-2:

See Response 6-1. For additional information on the analysis of Proposed Project impacts related to methylmercury, see Master Response 6, *Methylmercury*.

The Delta Mercury Control Program has specific requirements for managing mercury-contaminated sediment in the Cache Creek Settling Basin. Pursuant to the Delta Mercury Control Program, the United States Army Corps of Engineers, Department of Water Resources and Central Valley Flood Protection Board are required to develop and submit to the Central Valley Water Board an implementation plan to decrease mercury loads discharged from the Cache Creek Settling Basin.

Please see the referenced requirements below, located on page 4-99 of the Basin Plan:

> ***4.5.4.3.5.7 <u>Cache Creek Settling Basin Improvement Plan and Schedule</u>***
>
> *Department of Water Resources, Central Valley Flood Protection Board, and USACE, in conjunction with any landowners and other interested stakeholders, shall implement a plan for management of mercury contaminated sediment that has entered and continues to enter the Cache Creek Settling Basin (Basin) from the upstream Cache Creek watershed. The agencies shall:* 6-3
>
> *1. By 20 October 2012, the agencies shall take all necessary actions to initiate the process for Congressional authorization to modify the Basin, or other actions as appropriate, including coordinating with the USACE.*
>
> *2. By 20 October 2013, the agencies shall develop a strategy to reduce total mercury from the Basin for the next 20 years. The strategy shall include a description of, and schedule for, potential studies and control alternatives, and an evaluation of funding options. The agencies shall work with the landowners within the Basin and local communities affected by Basin improvements.*
>
> *3. By 20 October 2015, the agencies shall submit a report describing the long term environmental benefits and costs of sustaining the Basin's mercury trapping abilities indefinitely.*

4. By 20 October 2015, the agencies shall submit a report that evaluates the trapping efficiency of the Cache Creek Settling Basin and proposes, evaluates, and recommends potentially feasible alternative(s) for mercury reduction from the Basin. The report shall evaluate the feasibility of decreasing mercury loads from the basin, up to and including a 50% reduction from existing loads.

5. By 20 October 2017, the agencies shall submit a detailed plan for improvements to the Basin to decrease mercury loads from the Basin. 6-3 Cont.

The agencies shall submit the strategy and planning documents described above to the Regional Water Board for approval by the Executive Officer. During Phase 1, the agencies should consider implementing actions to reduce mercury loads from the Basin. Beginning in Phase 2, the agencies shall implement a mercury reduction plan.

Response 6-3:

See Response 6-1.

Construction Storm Water General Permit

Dischargers whose project disturb one or more acres of soil or where projects disturb less than one acre but are part of a larger common plan of development that in total disturbs one or more acres, are required to obtain coverage under the General Permit for Storm Water Discharges Associated with Construction Activities (Construction General Permit), Construction General Permit Order No. 2009-009- DWQ. Construction activity subject to this permit includes clearing, grading, grubbing, disturbances to the ground, such as stockpiling, or excavation, but does not include regular maintenance activities performed to restore the original line, grade, or capacity of the facility. The Construction General Permit requires the development and implementation of a Storm Water Pollution Prevention Plan (SWPPP). For more information on the Construction General Permit, visit the State Water Resources Control Board website at: http://www.waterboards.ca.gov/water_issues/programs/stormwater/constpermits.shtml 6-4

Clean Water Act Section 404 Permit

If the project will involve the discharge of dredged or fill material in navigable waters or wetlands, a permit pursuant to Section 404 of the Clean Water Act may be needed from the United States Army Corps of Engineers (USACE). If a Section 404 permit is required by the USACE, the Central Valley Water Board will review the permit application to ensure that discharge will not violate water quality standards. If the project requires surface water drainage realignment, the applicant is advised to contact the Department of Fish and Game for information on Streambed Alteration Permit requirements. If you have any questions regarding the Clean Water Act Section 404 permits, please contact the Regulatory Division of the Sacramento District of USACE at (916) 557-5250.

<u>Clean Water Act Section 401 Permit – Water Quality Certification</u>

If an USACE permit (e.g., Non-Reporting Nationwide Permit, Nationwide Permit, Letter of Permission, Individual Permit, Regional General Permit, Programmatic General Permit), or any other federal permit (e.g., Section 10 of the Rivers and Harbors Act or Section 9 from the United States Coast Guard), is required for this project due to the disturbance of waters of the United States (such as streams and wetlands), then a Water Quality Certification must be obtained from the Central Valley Water Board prior to initiation of project activities. There are no waivers for 401 Water Quality Certifications. For more information on the Water Quality Certification, visit the Central Valley Water Board website at:
https://www.waterboards.ca.gov/centralvalley/water_issues/water_quality_certification/

<u>Waste Discharge Requirements – Discharges to Waters of the State</u>

If USACE determines that only non-jurisdictional waters of the State (i.e., “non- federal” waters of the State) are present in the proposed project area, the proposed project may require a Waste Discharge Requirement (WDR) permit to be issued by Central Valley Water Board. Under the California Porter-Cologne Water Quality Control Act, discharges to all waters of the State, including all wetlands and other waters of the State including, but not limited to, isolated wetlands, are subject to State regulation. For more information on the Waste Discharges to Surface Water NPDES Program and WDR processes, visit the Central Valley Water Board website at:
https://www.waterboards.ca.gov/centralvalley/water_issues/waste_to_surface_water/ 6-4 Cont.

<u>Dewatering Permit</u>

If the proposed project includes construction or groundwater dewatering to be discharged to land, the proponent may apply for coverage under State Water Board General Water Quality Order (Low Risk General Order) 2003-0003 or the Central Valley Water Board’s Waiver of Report of Waste Discharge and Waste Discharge Requirements (Low Risk Waiver) R5-2013-0145. Small temporary construction dewatering projects are projects that discharge groundwater to land from excavation activities or dewatering of underground utility vaults. Dischargers seeking coverage under the General Order or Waiver must file a Notice of Intent with the Central Valley Water Board prior to beginning discharge.

For more information regarding the Low Risk General Order and the application process, visit the Central Valley Water Board website at:
http://www.waterboards.ca.gov/board_decisions/adopted_orders/water_quality/2003/wqo/wqo2003-0003.pdf

For more information regarding the Low Risk Waiver and the application process, visit the Central Valley Water Board website at:
http://www.waterboards.ca.gov/centralvalley/board_decisions/adopted_orders/waivers/r5-2013-0145_res.pdf

Limited Threat General NPDES Permit
If the proposed project includes construction dewatering and it is necessary to discharge the groundwater to waters of the United States, the proposed project will require coverage under a National Pollutant Discharge Elimination System (NPDES) permit. Dewatering discharges are typically considered a low or limited threat to water quality and may be covered under the General Order for *Limited Threat Discharges to Surface Water* (Limited Threat General Order). A complete Notice of Intent must be submitted to the Central Valley Water Board to obtain coverage under the Limited Threat General Order. For more information regarding the Limited Threat General Order and the application process, visit the Central Valley Water Board website at: https://www.waterboards.ca.gov/centralvalley/board_decisions/adopted_orders/general_orders/r5-2016-0076-01.pdf

6-4 Cont.

NPDES Permit
If the proposed project discharges waste that could affect the quality of surface waters of the State, other than into a community sewer system, the proposed project will require coverage under a National Pollutant Discharge Elimination System (NPDES) permit. A complete Report of Waste Discharge must be submitted with the Central Valley Water Board to obtain a NPDES Permit. For more information regarding the NPDES Permit and the application process, visit the Central Valley Water Board website at: https://www.waterboards.ca.gov/centralvalley/help/permit/

If you have questions regarding these comments, please contact me at (916) 464-4812 or Jordan.Hensley@waterboards.ca.gov.

Response 6-4:

See Response 6-1.

If you have questions regarding these comments, please contact me at (916) 464-4812 or Jordan.Hensley@waterboards.ca.gov.

Original Signed By

Jordan Hensley
Environmental
Scientist

cc: State Clearinghouse unit, Governor’s Office of Planning and Research, Sacramento (via email)

Jennie Fuller
Central Valley Water Board
Jennifer.Fuller@waterboards.ca.gov

Letter 7
Yocha Dehe Wintun Nation

YOCHA **DEHE**
CUI TURAL RESOURCES

January23, 2020

California Department of Water Resources
Attn: Heather Green
3500 Industrial Boulevard
West Sacramento, CA 95691

RE: Lookout Slough Restoration Project

Dear Ms. Green:

Thank you for submitting the notification of availability dated, December 16, 2019, regarding cultural information on or near the proposed Lookout Slough Restoration Project, Solano County. We appreciate your effort to contact us and wish to respond.

The Cultural Resources Department has reviewed the project and concluded that it is within the aboriginal territories of the Yocha Dehe Wintun Nation. Therefore, we have a cultural interest and authority in the proposed project area.

Based on the information provided, Yocha Dehe Wintun Nation is not aware of any known cultural resources near this project site and a cultural monitor is not needed. However, if any new information is available or cultural items are found, please contact the Cultural Resources Department. In addition, we recommend cultural sensitivity training for any pre-project personnel. Please contact the individual listed below to schedule the cultural sensitivity training, prior to the start of the project. 7-1

Laverne Bill, Cultural Resources
Manager Yocha Dehe Wintun Nation
Phone: (530) 723-3891
Email: lbill@yochadehe-nsn.gov

Please refer to identification number YD-03252019-04 in any correspondence concerning this project.

Thank you for providing us the opportunity to comment.

Sincerely,

Tribal Historic Preservation Officer

Response 7-1:

The comment states that the Yocha Dehe Wintun Nation (YDWN) has an interest in the Proposed Project area. The comment acknowledges that no known tribal cultural resources exist on the Proposed Project Site. As described in Section IV.K, *Tribal Cultural Resources* on page IV.K-11 to IV.K-12, in the event previously unrecorded resources are uncovered during construction that could qualify as a tribal cultural resource, Mitigation Measures TCR-1A and 1B would be implemented. As described in Mitigation Measure TCR-1A, if indigenous archeological resources are encountered during project development or operation, all activity within 100 feet of the find shall cease, and a qualified archaeologist will be informed of and inspect the discovery. As described in Mitigation Measure TCR-1B, if a resource is identified that could be indigenous in origin, the YDWN will be consulted to develop and implement a Tribal Cultural Resources Management Plan.

In addition, in order to address comment that cultural resource sensitivity training be provided to construction crews prior to initiation of construction activities. The following mitigation is added to Section IV.E, *Cultural Resources*:

> Mitigation Measure CULT-1A: Preconstruction Cultural Resource Sensitivity Training
>
> Prior to any ground disturbing activities, DWR shall require cultural sensitivity training be conducted for the construction crews, environmental monitors and other individuals conducting field activities and geological analysis to ensure awareness about cultural resources and tribal cultural resources, including identification of and proper protocol for handling any unexpected finds. Sensitivity training for tribal cultural resources will be administered by a member of the Yocha Dehe Wintun Nation.

Mitigation Measure CULT-1 has been renumbered as follows:

> Mitigation Measure CULT-1B: Stop Work for Accidental Archeological Discoveries

The following mitigation measure is added to Section IV.K, *Tribal Cultural Resources*:

> Mitigation Measure TCR-1A: Preconstruction Cultural Resource Sensitivity Training
>
> Implement Mitigation Measure CULT-1A.

Mitigation Measures TCR-1A and TCR-1B have been renumbered as follows:

> Mitigation Measure TCR-1~~A~~B: Stop Work for Accidental Discoveries
>
> Mitigation Measure TCR-1~~B~~C: Tribal Cultural Resources Management Plan

Letter 8
Contra Costa Water District, Solano County Water Agency, City of American Canyon, City of Vallejo

Letter 8

February 13, 2020

Lookout Slough DEIR
Attn: Heather Green
California Department of Water Resources
3500 Industrial Blvd.
West Sacramento, CA 95691

Regional Comment Letter on Draft EIR for the Lookout Slough Restoration Project

Dear Ms. Green,

The purpose of this letter is to provide the California Department of Water Resources (DWR) consistent, regional comments vital to the agricultural and municipal water users in Napa, Solano, and Contra Costa Counties. Across the Tri-County region, the Sacramento – San Joaquin Delta is the primary source water for over one-million residents including large urban cities such as Concord, Martinez, Antioch, Pittsburg, Fairfield, Vacaville, Vallejo, Napa and others.

The Delta and specifically the North Bay Aqueduct (NBA) is also the primary municipal supply to the Travis Air Force Base, one of the largest employers and economic drivers in Solano County. While the agencies are supportive of habitat restoration in the Delta, projects should:

(A) Be done in a manner and sequence that does not degrade salinity and water quality for existing municipal and agricultural users in the Delta;
(B) Cumulative impacts should be minimized by implementing individual restoration projects in a sequence that also does not degrade salinity and water quality for existing municipal and agricultural users in the Delta; and
(C) Modeling tools should be used to find design alternatives that minimize salinity and water quality impacts.

This letter provides a summary of key regional water quality concerns that should be addressed in the Lookout Slough Restoration Project – Environmental Impact Report. The overlying concern for all of the agencies listed, is the importance and protection of reliable, high quality water for the communities in Napa, Solano, and Contra Costa Counties.

1.) Municipal Users (Page IV.G-7 & 8).

While the Draft Environmental Impact Report (DEIR) – Hydrology and Water Quality Section does identify diversions near the Project Site, including Reclamation District 2068 and the NBA, there is no reference to the City of Vallejo's Cache Slough Pumping Plant located 1.5 river miles from the proposed Project. In addition, the DEIR does not discuss the importance and sensitivity of Contra Costa Water District's (CCWD's) four municipal intakes located at Mallard Slough, Rock Slough, Old River and Victoria Canal which can be highly influenced by hydrodynamic changes in the Delta and Suisun Marsh. In addition, it should be noted that CCWD provides municipal water to over 500,000 residents in Contra Costa County and the NBA to 500,000 residents in Napa and Solano Counties. The City of Vallejo also has water rights that predate the State Water Project (SWP) on Cache Slough, and provides municipal drinking water to over 120,000 residents within the City as well as Travis Air Force Base. 8-1

Response 8-1:

The Draft EIR has been revised to include the City of Vallejo's Cache Slough water diversion pumping plant. DWR recognizes that municipal water quality is an important issue with regard to CCWD, the NBA and the City of Vallejo. See Master Response 1, *Salinity and Bromide*. Page IV.G-7 in Section IV.G, *Hydrology and Water Quality* of the Draft EIR is revised to clarify as follows:

> Diversions near the Proposed Project Site include the nearby RD 2068 agricultural diversion, the State Water Project's Barker Slough Pumping Plant, the City of Vallejo's Cache Slough Pumping Plant, and private agricultural diversions.

2.) Salinity & Bromide (Page IV.G-9).

The DEIR discussion on salinity is considerably sparse and lacking in sufficient detail, to protect the municipal and agricultural beneficial uses in the Delta. No analyses, modeling results, or data are provided in the DEIR or Appendices for agencies to proficiently assess the Project's Impacts. In addition, there is also no discussion, analysis, or modeling of Bromide which is of critical importance to municipal users in the Delta. When municipal water supplies are treated to meet drinking water standards, Bromide can form Bromate a known and regulated carcinogen, which can impact human health. Municipal water purveyors in the Central and South Delta, including CCWD, are highly sensitive to changes in Bromide concentration in the Delta. In the North Delta, the NBA municipal users do not currently have significant issues with Bromide. However, major land use changes such as Lookout Slough, have the potential to enhance sea water intrusion upstream of Rio Vista, and elevate Salinity and Bromide above baseline concentrations. Since many of the water purveyors utilize ozone (to deal with high levels of organics), they would be highly sensitive to changes in Bromide above baseline conditions. 8-2

A more significant analysis of Salinity and Bromide is needed to evaluate and protect existing municipal and agricultural beneficial uses in the Delta.

Response 8-2:

See Master Response 1, *Salinity and Bromide*.

3.) Organic Carbon (Not Included).

Section G (Hydrology and Water Quality) of the DEIR does not include any discussion or analysis of Organic Carbon. While Organic Carbon may have ecological benefits, it can also have significant impacts on municipal water quality. In the drinking water treatment process, Organic Carbon can react with Chlorine to form a variety of Disinfection Byproducts including Trihalomethanes (THMs) and Haloacetic Acids (HAAs) which are carcinogenic and harmful to human health. Throughout the Delta, municipal water purveyors are highly sensitive to changes in Organic Carbon, often measured as Total Organic Carbon (TOC) and Dissolved Organic Carbon (DOC). In the North Delta water purveyors are highly sensitive to Organic Carbon levels, as users will often need to blend or switch water sources, to maintain high water quality standards. However, some purveyors do not have the ability to blend or use alternative sources. Major land use changes such as Lookout Slough, have the potential to export Organic Carbon and/or modify hydrodynamic process that may further degrade municipal water quality. 8-3

Analysis of Organic Carbon is needed to evaluate and protect existing municipal water use in the Delta.

Response 8-3:

See Master Response 8, *Dissolved Organic Carbon*.

4.) Modeling Results for Salinity for the NBA & Mallard Slough Intakes (Page IV.G-22)

The DEIR states that the "*RMA modeling predicts reduced EC at the Barker Slough North Bay Aqueduct intake (reductions up to five percent) and Contra Costa Water District intake at Mallard Slough (reductions up to 1.2 percent). All the other stations are predicted to have increased EC of up to 1.6 percent for at least one month per year, with the largest increases typically occurring in the fall.*"

While the results seem encouraging, in reviewing the DEIR and Appendices, no additional analyses, figures, model results, tables, etc. can be found to substantiate these results. In Appendix S, a 6-page qualitative memorandum from ESA was provided summarizing the Potential Salinity Impacts, however no analyses, figures, model results, tables, etc. could be found to substantiate the Appendix S or DEIR conclusions pertaining to Salinity and Drinking Water. 8-4

DWR needs to provide a more detailed and transparent analyses of the Salinity Modeling results, corresponding Project Impacts, and conclusions reached in the DEIR.

5.) Modeling Analyses for Water Quality (General)

In reviewing the DEIR and Appendices related to water quality, little to no information is provided on the RMA Modeling, including calibration and validation efforts, boundary conditions, SWP-CVP operations, Delta agricultural extractions, and other key assumptions. This information is important in understanding how well the model is likely to simulate the Lookout Slough Restoration Project impacts and corresponding Cumulative Impacts analysis on water quality.
DWR needs to provide detailed information on the Water Quality Modeling used to analyze and assess both Project Impacts and Cumulative Impacts on water quality including Salinity, Bromide, and other constituents as needed.

6.) Modeling Confidence, Example (City of Vallejo P.P. at Cache Slough)

As part of the DEIR review, the Solano County Water Agency requested model output information from DWR. Only the model results from the City of Vallejo Pumping Plant will be discussed in this letter, due to its close proximity to the Lookout Slough project, and to illustrate regional concerns in regards to model confidence. Figure 1 is a time series plot for July-2009 showing measured and modeled EC data for the City of Vallejo's Pumping Plant at Cache Slough. Figure 2 is a Scatter Plot showing the Measured vs Modeled EC data for this same time period. The corresponding $R^2 = 0.09$, which indicates very poor correlation. The two figures illustrate the challenge of the RMA model to reasonably simulate EC during typical summer conditions at the City of Vallejo's Pumping Plant location. This is important, as the Lookout Slough project is located in close proximity to this node, and is an indication of poor model confidence. 8-4 Cont.
Additional model analyses, comparisons, and transparency on the model development is needed, to improve overall model confidence and ability to reasonably simulate Project Impacts on water quality.

7.) Violation of Salinity Quality – Drinking Water & Agriculture (Page IV.G-22 & 23)

In regards to Salinity Quality, the DEIR concludes that there are **"<u>less-than-significant</u>"** impacts on both municipal and agricultural water supplies. However, as discussed in points 1 through 6 above, significantly more detailed and transparent analyses are required by DWR, before any reasonable Project and Cumulative Impacts can be assessed.
The existing DEIR does not provide any detailed analyses, figures, model results, tables, etc. in regards to Salinity, to reach a reasonable conclusion of Project Impacts.

8.) Level of Significance after Mitigation (Page IV.G-31)

The DEIR concludes "With implementation of Mitigation Measured HYDRO-1 through HYDRO-2, the Proposed Project would have **<u>less-than-significant impacts</u>** on hydrology and water quality." Since the two mitigation measures (HYDRO-1 and HYDRO-2) only pertain to in-progress construction activities, DWR needs to address points 1 through 7 above, before any reasonable Project Impacts on Water Quality can be assessed.
The existing DEIR does not provide sufficient information as detailed above, to reach a reasonable conclusion of Project Impacts, including the DEIR assessment of "less-than-significant impacts" on water quality.

9.) Cumulative Impacts – Water Quality (Page V-14)

For Cumulative Impacts to Water Quality the DEIR concludes that the impacts are "**less than cumulatively considerable**." However, as discussed in the points above, no additional analyses, figures, model results, tables, etc. can be found in the DEIR or Appendices to substantiate these conclusions. 8-4 Cont.

The existing DEIR does not provide sufficient information as detailed above, to reach a reasonable conclusion of Cumulative Impacts, including the DEIR assessment of "less-than-cumulative considerable" impacts on water quality.

Response 8-4:

Regarding point 6, on the modeling results at the City of Vallejo Pumping Plant, see Response 16-2. Regarding points 4, 5, 7, 8, and 9, see Master Response 1, *Salinity and Bromide*.

Thank you for the opportunity to submit comments vital to the agricultural and municipal water users in Napa, Solano and Contra Costa Counties. Across the Tri-County region, the Sacramento – San Joaquin Delta is one of the most important water supplies for over one-million residents. Should DWR have any questions or seek additional clarification, please feel free to contact any of the lead wholesale agencies listed below. Thank you for taking the time to review our concerns.

Agency	Contact	E-Mail
Contra Costa Water District	Maureen Martin, Special Projects Manager	mmartin@ccwater.com
Napa County FC&WCD	Phillip Miller, Deputy Director	Phillip.Miller@countyofnapa.org
Reclamation District 2068	Bryan Busch, General Manager	busch@rd2068.com
Solano County Water Agency	Alex Rabidoux, Supervising W.R. Engineer	ARabidoux@scwa2.com

Sincerely,

Maureen Martin,
Special Projects Manager
Contra Costa Water District

Phillip M. Miller, PE
District Engineer,
Napa County Flood Control & Water Conservation District

Bryan Busch,
General Manager
Reclamation District 2068

Roland Sanford,
General Manager
Solano County Water Agency

Felix Hernandez III,
Deputy Public Works Director
City of American Canyon

Michael Kern,
City Engineer | Public Works Director
City of Calistoga

Felix Riesenberg,
Assistant Public Works Director
City of Fairfield

Philip Brun, PE
Utilities Director
City of Napa

Curtis Paxton,
Director of Utilities **City of Vacaville**

Michael Malone,
Director of Water
City of Vallejo

CC: California State Senator Bill Dodd
California State Senator Steve Glazer
Assembly Member Cecilia M. Aguiar-Curry
Assembly Member Jim Frazier
Assembly Member Timothy S. Grayson

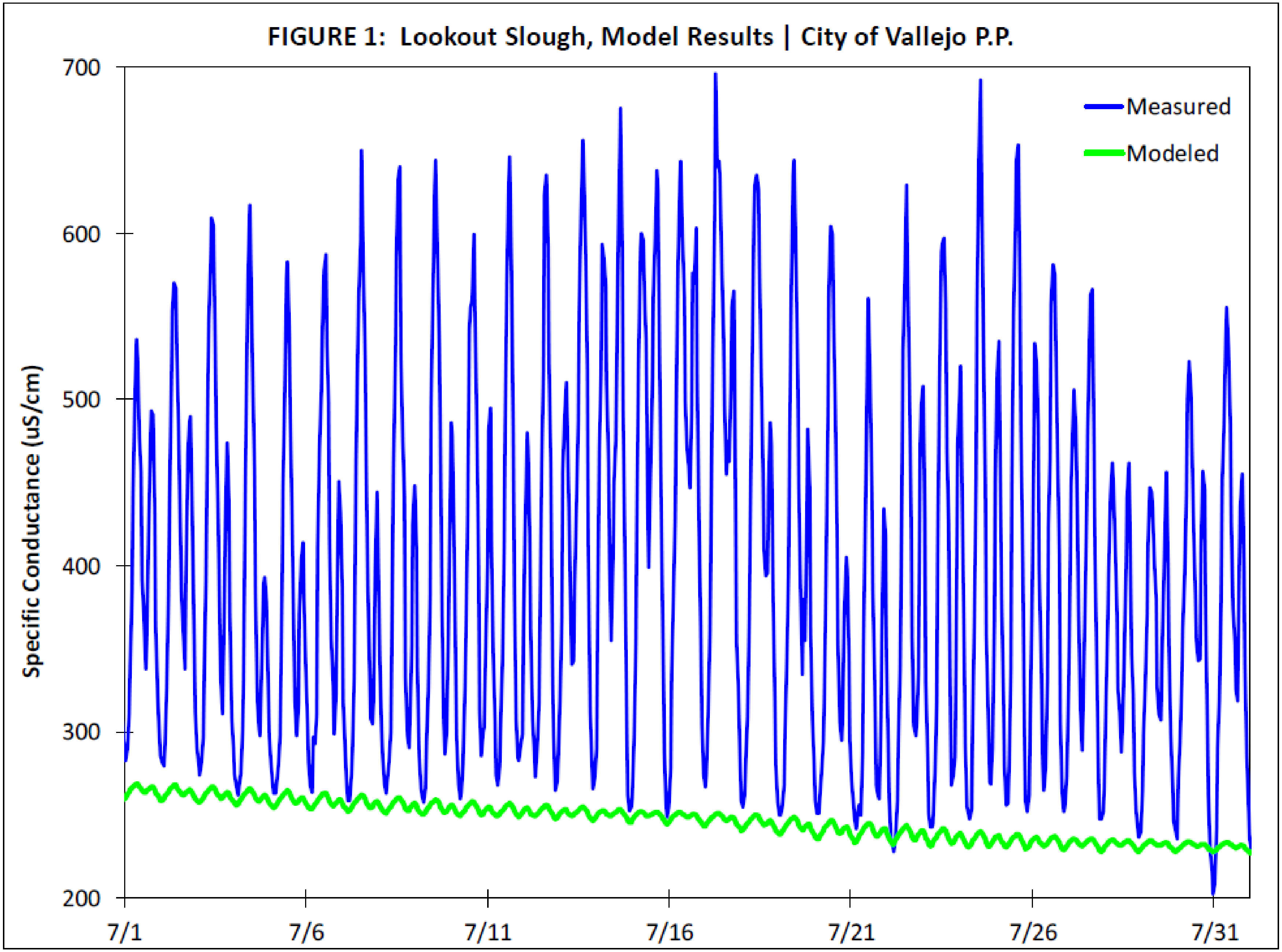
FIGURE 1: Lookout Slough, Model Results | City of Vallejo P.P.
Specific Conductance (uS/cm)
700
600
500
400
300
200
7/1
7/6
7/11
7/16
7/21
7/26
7/31
Measured
Modeled

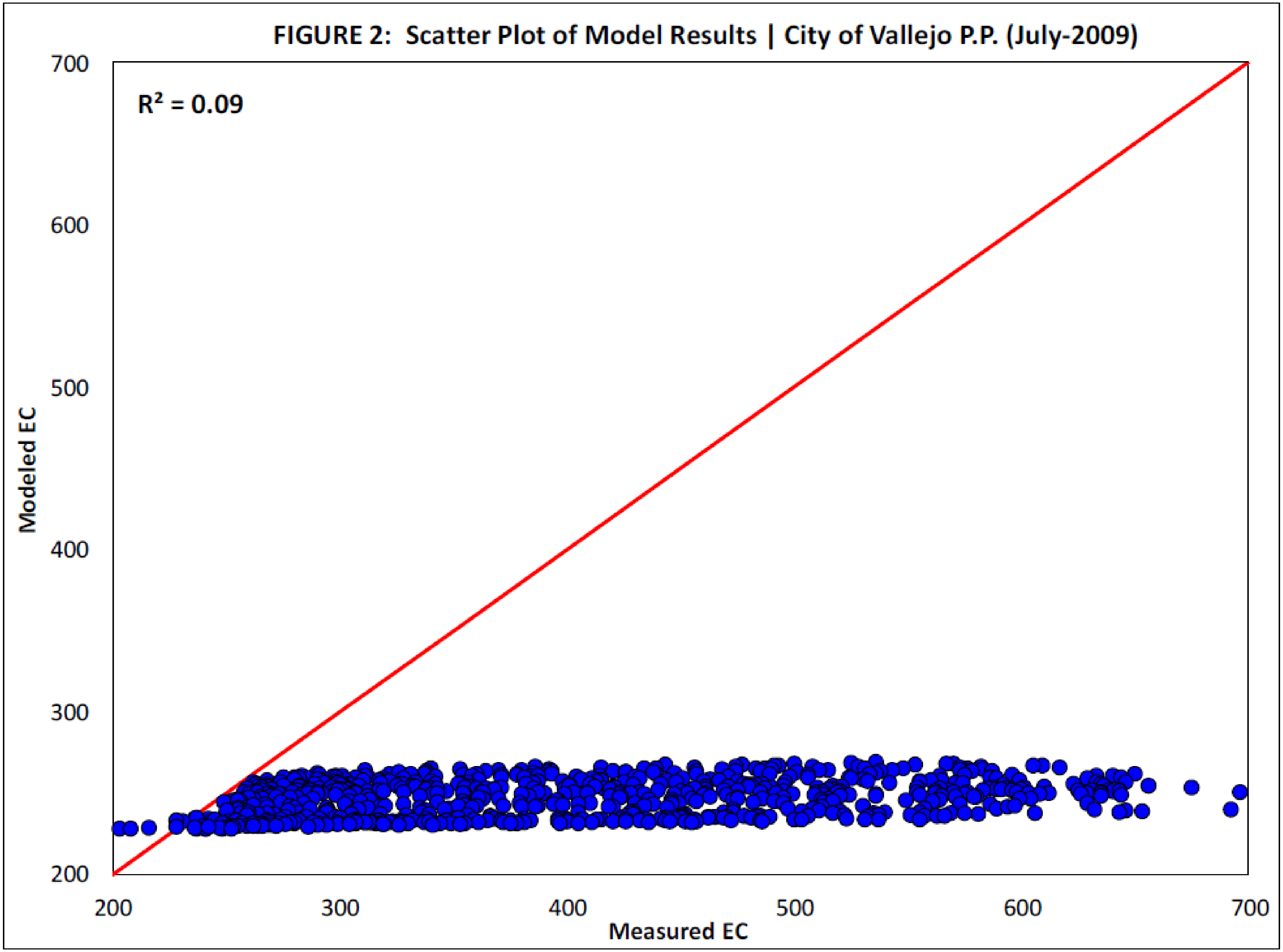
FIGURE 2: Scatter Plot of Model Results | City of Vallejo P.P. (July-2009)
R² = 0.09
700
600
500
400
300
200
Modeled EC
200
300
400
500
600
700
Measured EC

Letter 9
North Delta Water Agency

NDWA
NORTH DELTA WATER AGENCY

February 13, 2020

CA Department of Water Resources
3500 Industrial Blvd.
West Sacramento, CA 95691
ATTN: Heather Green
Delivered via email: FRPA@water.ca.gov

SUBJECT: Comments on Lookout Slough Restoration Project EIR

Dear Ms. Green:

The North Delta Water Agency (NDWA/Agency) submits these comments on the draft EIR for the Lookout Slough Tidal Habitat Restoration and Flood Improvement Project (Proposed Project), located in the Lower Yolo Bypass region of Solano County.

NDWA has a clear statutory mandate to assure that the lands within the North Delta have a dependable supply of water of suitable quality sufficient to meet present and future beneficial uses.[1] In 1981 the NDWA and the Department of Water Resources (DWR/Department) executed the *Contract for the Assurance of a Dependable Water Supply of Suitable Quality* (1981 Contract or Contract).

The 1981 Contract contains certain water quality criteria to be maintained year-round at seven monitoring locations. The Contract water quality criteria varies from month to month, and from year to year, based on the Four River Basin Index; with the criteria at each location based on the 14-day running average of mean daily electrical conductivity (EC). The Contract also contains provisions pertaining to physical changes that obligate DWR to avoid or repair damages from hydrodynamic changes, and if necessary, require limitations on the operations of the SWP pumps and reservoirs in order to maintain water quality compliance.

The Agency is concerned that the creation of tidal habitat through modification or breaching of levees as proposed in the Lookout Slough restoration project will affect water quality, surface water elevations and velocities, and individual water rights. Comments herein are intended to facilitate DWR's compliance with the 1981 Contract and to ensure that any significant adverse impacts to water users and Delta channels associated with the proposed project are properly described, analyzed, and mitigated in accordance with applicable law.

[1] North Delta Water Agency Act, Chapter 283, Special Statutes of 1973.

3050 Beacon Blvd., Ste 203, West Sacramento, CA 95691 TEL (916) 446 0197 FAX (916) 446 2404 northdeltawater.net

In addition, some levees located in the vicinity of the Proposed Project experienced erosion damage in the February 2017 storms and require repair and rehabilitation prior to any alteration of hydrodynamics in the area. Local landowners should not have to bear any costs associated with mitigating adverse water supply or quality impacts created by the Proposed Project.

Proposed Project

The overarching goal of the Proposed Project is to increase tidal action and inundation of more than 3,000 acres within RD 2098 by modifying existing levees in order to support recovery of endangered fish species by enhancing the productivity and food availability for Delta smelt; and creating juvenile salmonid rearing habitat.

The project as currently proposed entails constructing a setback levee along Duck Slough and Liberty Island Road and the existing Yolo Bypass west levee at Shag Slough would be breached and degraded to provide connectivity between Lookout and Shag Sloughs.

These proposed activities would alter hydrology, resulting in an increase of the tidal prism in the Cache Slough Complex, and, in turn, reduce tidal range, which could lower water elevations and reduce water quality due to greater salinity incursion. 9-1

Response 9-1:

See Master Response 1, *Salinity and Bromide*, Master Response 7, *Operation and Maintenance (O&M) of Levees*, and Master Response 9, *Tidal Effects on Diversions*. See also Response 19-6.

Large portions of the project site would become permanent, open water area with greater depths at high tides and winter high flow events. Therefore, channel banks would be subjected to more intensive wave-fetch forces leading to erosion of the levee slopes for reclamation districts in the vicinity, including, but not limited to RD 146, RD 501, RD 536, RD 1667, RD 2060, RD 2084, RD 2093, and RD 2104. A mitigation measure should be added, requiring Project Proponents to fund repair of these levee erosion sites. 9-2

Response 9-2:

As described in Section IV.G, *Hydrology and Water Quality*, the Draft EIR relies on hydraulic modeling and analysis to evaluate changes to velocity, shear stress, and wind-wave run up under the with-Project condition to assess the likelihood of erosion and scour of flood control facilities. As explained in the *Lookout Slough Setback Levee Wave Runup and Wind Setup Analysis TM*, attached as Appendix C to Appendix D, *Lookout Slough Tidal Habitat Restoration and Flood Improvement Project: 65% Basis of Design Report* of the Draft EIR, fetch sites were selected so that the transects delineated for each site align with the proposed breach locations in the Shag Slough Levee and maximize fetch properties.

Please see the figure on page 7 of the *Lookout Slough Tidal Habitat Restoration and Flood Improvement Project – Draft Hydrologic and Hydraulic System Analysis,* attached as Appendix A to Appendix D of the Draft EIR, which shows details on locations of reclamation districts that surround the Proposed Project Site. In addition, please see the *Lookout Slough Setback Levee Wave Runup and Wind Setup Analysis TM*, Attachments 3 and 4, for figures depicting fetch length and wind wave runup under current conditions and with the Proposed Project, respectively, in reference to the responses provided below:

- RD 146 is not located on local management planning databases as an active reclamation district.[1]
- RD 501 is downstream of the Proposed Project, and is located east of RD 1667. Based on location relative to the Proposed Project, a continuous wave fetch length does not exist between the Proposed Project and RD 501. Because the Proposed Project does not alter wave-fetch lengths for RD 501, the Proposed Project will not increase wave fetch or erosion to RD 501.
- RD 536 is located south of RD 2060. Based on location relative to the Proposed Project, a continuous wave fetch length does not exist between the Proposed Project and RD 536. Because the Proposed Project does not alter wave-fetch lengths for RD 536, the Proposed Project will not increase wave fetch or erosion to RD 536.
- RD 2084 is located south of the Proposed Project. Based on location relative to the Proposed Project, a continuous wave fetch length does not exist between the Proposed Project and RD 2084. Because the Proposed Project does not alter wave-fetch lengths for RD 2084, the Proposed Project would not increase wave fetch or erosion to RD 2084.
- The Proposed Project would not change wind fetch to RD 2060 since the existing Cache/Hass Slough Levees would continue to be maintained and are proposed to be armored to withstand wave action. (*Lookout Slough Setback Levee Wave Runup and Wind Setup Analysis TM*, page 8; Draft EIR, page III-39.) Therefore, the Proposed Project would not increase wave fetch or erosion to RD 2060.
- The Proposed Project would not change wind fetch to RD 2104 since the existing Cache/Hass Slough Levees would continue to be maintained and are proposed to be improved to withstand wind wave action. (*Lookout Slough Setback Levee Wave Runup and Wind Setup Analysis TM*, page 8; Draft EIR, page III-39.) Therefore, the Proposed Project would not cause a significant impact from an increase in wave fetch or erosion to RD 2104.
- RD 2093 is mostly open water because the Liberty Island levees were breached decades ago. The site is now owned by the California Department of Fish and Wildlife as the Liberty Island Ecological Reserve. The levees of RD 2093 that would experience increased wave fetch from the Proposed Project are no longer maintained, and therefore, the increased wave fetch associated with the Proposed Project would not cause a significant erosion impact or pose a related maintenance burden on RD 2093.

According to the *Lookout Slough Tidal Habitat Restoration and Flood Improvement Project – Draft Hydrologic and Hydraulic System Analysis,* the Proposed Project would increase wave fetch to RD 1667 from approximately 2.1 miles to approximately 4.2 miles. The corresponding wave runup would increase from approximately 3.3 feet to approximately 5.4 feet (see the *Lookout Slough Setback Levee Wave Runup and Wind Setup Analysis TM*, Attachments 3 and 4 for figures depicted fetch length and wind wave runup). This increase is below the design freeboard of the Yolo Bypass East Levee (6-feet). Therefore, this increase would not cause a significant erosion impact or result in increased O&M effort for RD 1667 and no mitigation is required. As indicated in Impact viii. Post-Construction Changes to Wind-Wave Generated Erosion (page IV.G-26 of the Draft EIR), the Proposed Project addresses the need to maintain the existing level of erosion protection of the new and existing levees to avoid impacts from wind waves. The wind wave analysis conducted for the 65% design presented in the *Lookout Slough Setback Levee Wave Runup and Wind Setup Analysis TM* demonstrates the feasibility of maintaining existing level of erosion protection through a combination of design parameters, including levee crest

[1] https://databasin.org/maps/new#datasets=8aee127380164046b32c2c85dee44d55

elevation and erosion protection measures, while also avoiding impacts to offsite location by waves transmitted across the Proposed Project Site. Some aspects of the wave erosion hazard have been further quantified as part of on-going Project design processes. This refined quantification confirms the wave erosion hazard analysis included in the *Lookout Slough Setback Levee Wave Runup and Wind Setup Analysis TM* and further supports the conclusion in the Draft EIR that impacts associated with post-construction changes to wind-wave generated erosion are less than significant and no mitigation measures are required. This refined quantification is included as Appendix Y of this Final EIR.

See also Master Response 7, *Operation and Maintenance (O&M) of Levees* regarding responsibilities to maintain existing and new levees, and Responses 17-1, 19-3, and 19-9.

In addition, there are probably about 30-40 diverters in the area that could experience lowered surface water elevations as well as regulatory restrictions and increased costs associated with a greater presence of endangered fish species in the vicinity of these local diversion intakes, including intakes maintained by agencies such as RD 2060 and RD 2068.

Potential Water Supply and Water Quality Impacts

Water diversions within NDWA occur by two principal methods: siphons and electric pumps. The siphon systems within NDWA were designed with historic landside and water surface elevations in north Delta channels as a base line. If the elevation differential between these two elevations (referred to as "head") is not sufficient, the siphon will not work. When water surface elevations in Delta channels are lowered, longer durations are necessary to apply the same amount of water under existing conditions.

If an electric pump is needed to replace a siphon, the costs are quite substantial. For example, if power lines are present at the landside base of the levee, the costs are $25,000 for the utility to put a transformer and string power to the new electric pump. In addition, a new pump column, impellor and motor of sufficient size to replace a 12-inch siphon's water flow costs an additional $25,000. The labor to install the pumping facility is an additional $8,000. Permit costs and timelines need to be factored in as well. 9-3

On many islands, power lines are not present at the land side base of the levee and there is not enough voltage to supply the power needed for new power draws on the existing utility company system. The cost of stringing new wires and poles are approximately $50,000 per quarter mile. New pumps would therefore necessitate improvements in the utility provider's electrical system, with those costs borne by the RD or landowner. A mitigation measure should be added to remediate any reductions in diversion flow capacity due to changes in water elevation.

Response 9-3:

See Draft EIR Section IV.G, *Hydrology and Water Quality* (pages IV.G-24 and -25) and Master Response 9, *Tidal Effects on Diversions,* regarding potential Proposed Project impacts on pumps and gravity diversions (e.g., siphons). See Draft EIR Section IV.D, *Biological Resources* (IV.D-78 to IV.D-85) and Master Response 3, *Local Water Diversions and Special-Status Fish Species*, regarding the potential for increased presence of endangered species as a result of the Proposed Project.

Freshwater flows from the Sacramento River that are conveyed through Miner and Sutter Sloughs and tidal action are the primary factors influencing water quality in the Cache Slough Complex, with local agricultural diversions having a greater effect during summer irrigation. In general, the river flow in Steamboat and Miner Sloughs is higher when the Delta Cross Channel (DCC) is closed, so tidal exchange varies with both Sacramento River flow and DCC operation. The altering or breaching of levees would alter the hydrodynamics in the vicinity, potentially resulting in greater salinity intrusion from increased tidal flux, amplitude, and range.

Increases in mean daily EC during the irrigation season or extreme salinity fluctuations occurring on an hourly basis, can be particularly harmful to crops under the altered tidal exchange created by proposed levee modifications and breaches. Further, longer diversion periods may be required due to reduced efficiency of irrigation siphons and pumps as a result of lowered surface water elevations from project implementation. Increases in mean daily EC during the irrigation season or extreme salinity fluctuations occurring on an hourly basis, can be particularly harmful to crops under the altered tidal exchange created by proposed levee modifications and breaches. Further, longer diversion periods may be required due to reduced efficiency of irrigation siphons and pumps as a result of lowered surface water elevations from project implementation. 9-4

In addition to immediate damage to planted crops, salt loading of soils can occur when water with high concentrations of salt compounds is used for irrigation of crops, even over a short period of time, degrading the long-term productivity of the ground. Permanent crops such as pears and wine grapes are especially intolerant of salt loading, resulting in reduced yields and long-term health issues for the trees and vines. Once permanent crops are lost or hurt due to salt loading in the soils, it will take a long time for the land to fully regain its productivity (if ever), and growing permanent crops may no longer be possible in some areas. A mitigation measure should be added, requiring Project Proponents to relocate existing water diversion intakes to site with water quality as good as available prior to installation of the Project and be designed to divert at same diversion capacity of existing facility.

Response 9-4:

See Draft EIR Section IV.G *Hydrology and Water Quality – c.iv. Violation of Salinity Quality Standards or Conflict with a Water Quality Control Plan during Post-Construction Operation – Agriculture*, Master Response 1, *Salinity and Bromide*, and Master Response 9, *Tidal Effects on Diversions* for more information on the Proposed Project's effects on salinity and agricultural water users.

Concluding Recommendations

In light of the aforementioned potential impacts to water users in the Project Area, the Project Proponents must provide modeling results with the details necessary to determine the location, severity, duration, and seasonal differences of water quality and availability impacts and ultimate compliance with the NDWA 1981 Contract. The EIR must include additional mitigation measures to relocate or install new diversion intakes in order to maintain existing water quality and diversion capacity. 9-5

Response 9-5:

See Master Response 1, *Salinity and Bromide*, for environmental impacts of the Proposed Project.

See also Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts*. As with applicable regulatory requirements, DWR must comply with existing contracts and agreements; however, CEQA does not require the EIR to include all the information necessary to show compliance with these contracts and agreements.

Changes in velocities may create scouring (erosion) of nearby levees that could exceed levee stability thresholds during high flow winter conditions and cause seepage on adjacent lands/crops. 9-6

Response 9-6:

Maximum flood velocities were reviewed for the without-Project and with-Project conditions, and are identified in the Basis of Design Report (See Draft EIR Appendix D, *Lookout Slough Tidal Habitat Restoration and Flood Improvement Project: 65% Basis of Design Report*). The most significant change in erosion potential caused by flow velocities that could affect neighboring levees would occur near the northeast corner of the site (See Draft EIR Appendix D, Page 26, Figure 3). Review of velocities and bed shear stresses computed at neighboring levees indicates that although there are some localized changes in hydraulic forces, they are below the threshold that would necessitate revetment and would not result in scour or underseepage of levees, and would therefore, not constitute a significant impact.

The EIR should include mitigation measures for installation of groundwater and surface water monitoring stations prior to implementation of the Proposed Project in order to determine baselines from which impacts can be measured, and add mitigation measures necessary to prevent and repair any seepage damage associated with altered hydrodynamics created by the project. 9-7

Response 9-7:

See Response 9-6. Based on the evidence referenced in the Draft EIR, the Draft EIR concluded that the impacts identified in the comment are less than significant. No new information has been presented that changes the conclusion in the Draft EIR. No mitigation is required under CEQA for adverse environmental impacts that are less than significant. See also Master Response 11, *Good Neighbor Checklist*.

Mitigation measures may also be necessary to screen or consolidate local intakes and provide incidental take coverage to local diversions if engendered species populations increase in the area. 9-8

Response 9-8:

See Master Response 3, *Local Water Diversions and Special-Status Fish Species*.

Utilization of funding provided in the Delta Levees Special Projects Program with a 100% State cost share could be used to improve and reinforce levees in the project vicinity, to screen or consolidate local intakes, to ensure efficiency of existing siphons by maintaining adequate water elevations or provide new pumps and electricity infrastructure, to provide incidental take coverage to local diversions, and to comply with water quality criteria and other channel obligations in the 1981 Contract. These mitigation measures should be funded and implemented by the State prior to installation of this habitat restoration project. 9-9

Response 9-9:

See Master Response 1, *Salinity and Bromide*; Master Response 3, *Local Water Diversions and Special-Status Fish Species*; Master Response 7, *Operation and Maintenance (O&M) of Levees*; Master Response 9, *Tidal Effects on Diversions*; Master Response 11, *Good Neighbor Checklist*; and Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts*.

Again, we request modification of the Lookout Slough EIR to add modeling results that disclose the severity of changes in EC levels resulting from the project, and add mitigation measures to fully mitigate adverse impacts that would affect the operation and maintenance of local water supply and flood control infrastructure in the project area. 9-10

Response 9-10:

Comment noted. See above responses.

Sincerely,

Melinda Terry, Manager

Letter 10
Central Delta Water Agency

CENTRAL DELTA WATER AGENCY
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February 14, 2020

Via Email Only to frpa@water.ca.gov

Attn: Heather Green
CA Dept. of Water Resources
3500 Industrial Blvd.
West Sacramento, CA 95691

Re: CDWA Comments on the Draft EIR for the Lookout Slough Tidal Habitat Restoration and Flood Improvement Project.

Dear Ms. Green:

The creation of tidal habitat, such as the proposed project, raises numerous questions and concerns. While the DEIR attempts to address many of those questions and concerns, the DEIR's discussion and analysis is lacking in numerous, significant respects, including those discussed herein.

1. Improper Peacemealing of the 8,000 Acre Tidal Habitat Restoration Obligation and the Broader 30,000 Acre EcoRestore Initiative.

According to the DEIR at page III-20:

> The Lookout Slough Tidal Habitat Restoration and Flood Improvement Project is proposed to help satisfy DWR's obligation to restore 8,000 acres of tidal marsh per the 2008 USFWS BiOp and the 2009 NMFS BiOp, and to increase flood storage and conveyance, increase the resiliency of levees, and reduce flood risk within the Yolo Bypass. The Proposed Project is part of the California EcoRestore Initiative, which seeks to restore and/or enhance 30,000 acres of habitat in the Delta and Suisun Marsh.

10-1

At the outset, the DEIR is continuing the trend to unlawfully piecemeal the environmental analysis of the entire 8,000-acre tidal habitat restoration obligation, as well as the broader 30,000 acre EcoRestore Initiative.

Under CEQA "'[p]roject' means <u>the whole of an action</u>, which has a potential for resulting in either a direct physical change in the environment, or a reasonably foreseeable indirect physical change in the environment . . . ." (Guidelines, § 15378, subd. (a), emphasis added.) As the court explains in <u>Orinda Assn v. Board of Supervisors</u> (1986) 182 Cal.App.3d 1145, at page 1171:

> A public agency is not permitted to subdivide a single project into smaller individual sub-projects in order to avoid the responsibility of considering the environmental impact of the project as a whole. "The requirements of CEQA, 'cannot be avoided by chopping up proposed projects into bite-size pieces which, individually considered, might be found to have no significant effect on the environment or to be only ministerial.' [Citation.]" [Citation]. 10-1 Cont.

Nearly the entire gamut of potentially significant environmental impacts resulting from this project has the potential to be cumulatively significant when similar impacts from all 8,000 acres of tidal habitat restoration, as well as all 30,000 acres of habitat restoration and/or enhancement, are evaluated as a whole. "Chopping up [these larger projects] into bite-size pieces" is exactly what DWR is doing.

Unless and until there is a programmatic or other analysis of the "whole" of the 8,000 acre obligation and 30,000 EcoRestore Initiative, the piecemealed analysis in the DEIR for this project is ineffective and cannot support the approval of this project.

Response 10-1:

See Master Response 4, *Piecemealing*.

2. The DEIR Fails to Properly Analyze and Mitigate the Project's Individual and Cumulative Impacts on Salinity.

a. The DEIR's Reliance on Compliance with D-1641 to Mitigate Salinity Impacts is Misplaced.

The DEIR acknowledges that the Project will individually and cumulative increase the tidal prism. However, the DEIR's analysis of the impacts from such an increase on Delta salinity is based on whether DWR and USBR will be able to meet and maintain the SWRCB's D-1641 salinity standards: 10-2

> [T]he determination of whether a change is considered "significant" depends on whether there would be an exceedance of a standard set forth in

> the State Water Resources Control Board's (SWRCB's) Bay-Delta Water Quality Control Plan (Bay-Delta Plan) and/or Water Rights Decision 1641 (D-1641).

(DEIR, App. S, pp. 2 & 3.) As the DEIR further explains:

> The combined effect of the Project on Delta EC in combination with other planned tidal wetland restoration project can at times of the year be appreciable for certain D-1641 monitoring compliance stations when compared to existing baseline conditions without these Delta restoration projects in place (e.g., greater than 8 percent increase in EC for an October 2009 scenario at Station D29); nevertheless, even with the combined effects of the Project with other restoration projects currently under planning, Delta salinities would remain in compliance with D-1641 requirements. Therefore, the Project's incremental effect on salinity in the Delta would not be considerable and the cumulative impact is less than significant.

(DEIR, App. S, p. 6.)

Compliance with D-1641 to mitigate the salinity impacts of the Project means that water will have to come from some source and, hence, be taken away from some other use, to offset the salinity degradation from this Project in order to maintain that compliance. DWR's obligation under CEQA is to thoroughly analyze the full range of potential environmental impacts from such a redirection of water use. For example, to the extent such offsetting will foreseeably come from reservoir releases, impacts to cold water pool storage, carryover storage, river flows, water quality, water available for senior water rights, etc., will be foreseeable and potentially significant. Thus far, DWR has made no attempt to investigate or analyze any such impacts in the DEIR. 10-2 Cont.

A further complication to the DEIR's reliance on DWR and USBR's compliance with D- 1641 to reduce the individual and cumulative impacts from the Project is the fact that whenever DWR or USBR release storage water to maintain the D-1641 standards, the State Water Board curtails all post-1914 appropriative water right holders within the Delta watershed that have "Term 91" in their water permits or licenses. Thus, to the extent this Project, individually or cumulatively, triggers the need for DWR or USBR to release storage water to maintain one or more of D-1641's salinity or other standards, a vast number of diverters within the Delta watershed, including the Delta itself, must cease diverting under their post-1914 appropriative water rights. Such cessation of diversions has the potential to cause substantial and widespread effects on numerous environmental resources including terrestrial species, air quality, groundwater recharge, etc. (Information on Term 91 is readily available on the State Water Board's website at: https://www.waterboards.ca.gov/water_issues/programs/delta_watermaster/term91.html

Accordingly, because the DEIR relies on DWR and USBR's compliance with the various D-1641 standards to mitigate the Project's individual or cumulative impacts on salinity, the DEIR must analyze the extent, and under what hydrological and other conditions, those impacts will trigger the need for DWR or USBR to the release storage water to bring those standards into compliance and analyze the entire host of environmental resources impacted by such releases, including the impacts on those resources from the widespread curtailment of post-1914 appropriative rights that contain Term 91.

If on the other hand DWR determines that it is not reasonably feasible that the Project, individually or cumulatively, will ever trigger the need for DWR or USBR to release storage water to offset impacts on any D-1641 standard under any reasonably foreseeable drought or other hydrological condition, then DWR must provide sufficient facts and analysis to support such a determination. As it stands, however, the DEIR concedes that the Project may, at least cumulatively, trigger the need for such releases, and, accordingly, the DEIR must perform a thorough analysis of the potential environmental impacts from such releases. 10-2 Cont.

Response 10-2:

See Master Response 1, *Salinity and Bromide*.

b. The Modeling Analysis of Impacts on Salinity is Grossly Inadequate.

The DEIR explains:

> Resource Management Associates, Inc. (RMA) was tasked with modeling the Project's effect on the Delta salinity regime using their RMA Bay-Delta model. This model simulates the flows in the Bay and Delta that are driven by ocean tides, riverine inputs, and water diversions. The model then uses these flows to predict the distribution of EC, as a surrogate for salinity. The modeling scenario for this study replicates all of 2009, which is representative of typical dry year conditions, when achieving Delta salinity standards is often a challenge.1 RMA conducted salinity simulations for four scenarios: 1) existing conditions, 2) existing conditions with Project, 3) proposed regional restoration projects without Project, and 4) proposed regional restoration projects with Project. By comparing these runs in pairs, the modeling provides predictions of the potential EC changes due to the Project, both relative to existing conditions and cumulatively with other restoration projects. 10-3

(DEIR, App. S, p. 2.)

There are numerous deficiencies in this modeling, including the following.

First, the fact that the analysis of only a single water year, 2009, was utilized has to be unprecedented in the realm of Delta water quality analysis. In light of the wealth of available information on water quality, water flows, the operations of DWR and USBR, not to mention numerous detailed and readily available models, there is no excuse to limit the individual and cumulative analysis of the Project's impacts on salinity to a single year. CEQA requires the performance of a degree of analysis that is reasonably feasible. Limiting the analysis to a single year comes nowhere close to meeting that burden.

Second, what is most important is an analysis of how this Project, both individually and cumulatively, will impact salinity (and all other environmental resources) during foreseeable droughts like the state has experienced numerous times in the past, including the very recent past. It is during times when hydrological conditions are the driest that projects, such as the instant Project, will likely have the most adverse impacts on salinity and when mitigation of those impacts is most critical. The data and tools are readily available to analyze the Project's individual and cumulative impacts under such conditions, and it is a substantial breach of DWR's duties under CEQA to omit such an analysis. 10-3 Cont.

Third, the CDWA was unable to locate the actual model results, and importantly, the modeling assumptions, anywhere in the DEIR or its Appendices. CEQA imposes a duty on DWR to provide the facts and analysis that support the conclusion in the DEIR. The omission of the model results and the various assumptions used in the model constitutes a breach of that duty.

Response 10-3:

See Master Response 1, *Salinity and Bromide*.

Forth, along the same lines, the DEIR provides no explanation or disclosure of what constitutes the "proposed regional restoration projects" that were included in the cumulative analysis of the project. The omission of this, and the foregoing information, is highly prejudicial and "'subverts the purposes of CEQA [because] it omits material necessary to informed decisionmaking and informed public participation.' [Citation.]" (Lighthouse Field Beach Rescue v. City of Santa Cruz, supra, 131 Cal.App.4th 1170, 1202.) 10-4

Response 10-4:

The "proposed regional restoration projects" considered in the cumulative effects analysis include "associated related ecosystem restoration and flood improvement projects in the Delta" (Draft EIR, page I-9) and are identified in DEIR Chapter V, *Cumulative Impacts*. See Table V-2. *Related Projects* (Draft EIR, pages V-4 through V-6), which lists plans and projects that were approved, proposed, or in-progress in the Delta at the time the Notice of Preparation for this DEIR was released (i.e., March 21, 2019). Appendix S lists the specific restoration projects included in the salinity modeling See also Master Response 4, *Piecemealing* and Master Response 5, *Cumulative Impact Analysis.*

c. The DEIR Fails to Properly Address the State and Federal Anti-degradation Laws.

The Federal Environmental Protection Agency ("EPA") requires all states to adopt an “antidegradation policy” similar to the State Water Resources Control Board’s (“SWRCB”) Resolution 68-16. (40 C.F.R. 131.12.) Resolution 68-16 is further intended to, and does, implement Water Code section 13000 which requires the SWRCB to regulate all “activities and factors which may affect the quality of the waters of the state” such that they “attain the highest water quality which is reasonable.”

The State Water Resources Control Board’s (“SWRCB”) "Resolution 68-16 [commonly referred to as the SWRCB's "Anti-Degradation Policy"] provides in pertinent part: 10-5

> Whenever the existing quality of water is better than the quality established in policies as of the date on which such policies become effective, such existing high quality will be maintained until it has been demonstrated to the State that any change will be consistent with maximum benefit to the people of the State, will not unreasonably affect present and anticipated beneficial use of such water and will not result in water quality less than that prescribed in the policies.

The DEIR fails to adequately discuss, address and implement these Anti-Degradation Policies in general, and in the context of its discussion and formulation of mitigation measures and alternatives. In particular, the DEIR’s dismissal of any impacts to salinity that do result in a violation of the SWRCB’s D-1641 standards constitutes a failure to properly consider and implement these policies.

Response 10-5:

The Draft EIR discusses the Sacramento and San Joaquin River Basin Plan (Basin Plan) on page IV.G-13, including the fact that the State’s anti-degradation policy is one of three main bases for the water quality controls included in the Basin Plan. Draft EIR Section IV.G, *Hydrology and Water Quality* analyzes whether the Proposed Project could result in degradation of surface water and groundwater quality. The analysis concludes that the potential impact would be less than significant with mitigation incorporated. See also Master Response 1, *Salinity and Bromide*.

3. The DEIR Fails to Properly Analyze and Mitigate the Project's Individual and Cumulative Impacts on Mercury and Methymercury.

The DEIR explains:

> Analysis for this DEIR is based on best available scientific information. As part of the first phase of the Delta Mercury Control Program, DWR is conducting both tidal wetland and open water characterization studies in the Yolo Bypass, the Delta and Suisun Marsh. The tidal wetland studies are examining whether tidal wetlands are a source or a sink of methylmercury. The open water characterization studies consist of the development of mercury models for the Delta and Yolo Bypass as well as a number of studies conducted to provide data to the Yolo Bypass Mercury model. . . . DWR is currently analyzing data from these studies to inform understanding of tidal wetlands and floodplains with respect to mercury and methylmercury production."

(DEIR, p. IV.G-15 & 16, emphasis added.) 10-6

From this passage in the DEIR it is clear that the instant Project, as well as the rest of the projects that make up the 8,000-acre tidal habitat restoration obligation and the broader 30,000 acre EcoRestore Initiative, are not ready to be approved. Specific and detailed modeling and analysis of impacts from such projects on mercury and methylmercury are currently underway: DWR "is currently analyzing data" from these pending studies. In light of the scope of acreage involved in the Project and the other related projects, none of these projects should be implemented until those pending studies are completed and the results of those studies are duly incorporated into the CEQA analysis for such projects.

There is no valid reason why the instant Project and its related tidal wetland and floodplain projects cannot wait until this analysis, which is specifically directed to such projects, is completed and duly processed. As with other omissions in the DEIR, the omission of this highly pertinent information is highly prejudicial and "'subverts the purposes of CEQA [because] it omits material necessary to informed decisionmaking and informed public participation.' [Citation.]" (Lighthouse Field Beach Rescue v. City of Santa Cruz, supra, 131 Cal.App.4th 1170, 1202.)

Response 10-6:

See Master Response 6, *Methylmercury*.

4. Lack of an Identified Water Right for the Project.

The DEIR does not appear to explain what water rights will be utilized to inundate the land within the Project's boundaries with tidal water. The DEIR should thoroughly explain those rights and, in particular, discuss the priority of those water rights and how diversions of tidal water under those rights will be halted in order to protect more senior water rights in the event the SWRCB curtails water rights based on priority as it did in 2014 and 2015. 10-7

Response 10-7:

Water that flows uncontrolled, such as through the proposed open-water breaches on Shag Slough, does not qualify as a diversion; therefore, implementation of the Proposed Project or any of the Alternatives would not need a water right.

5. The DEIR Fails to Properly Analyze and Mitigate the Project's Individual and Cumulative Impacts on Fish Species.

With respect to post-construction increased predation on native fish, the DEIR fails to adequately discuss and analyze impacts of fish predation by other piscivorous fish as well as many other species of wildlife that prey upon native fish including, but not limited to, Pelicans, Egrets, Cormorants, Herons, Grebes, Minks and Otters. (See attached photo of Pelicans and Egrets foraging for fish in a pond adjacent to the San Joaquin River in Middle Roberts Island.)

Moreover, important fishery studies appear to have been overlooked or not adequately addressed in the preparation of the Project and its CEQA analysis, including the following two studies.

The study by Ted R. Sommer, William C. Harrell and Matthew L. Lobriga titled "Habitat use and Stranding Risk of Juvenile Chinook Salmon on a Seasonal Floodplain" published online November 4, 2005, North American Journal of Fisheries Management 25: 193-1504, 2005 reflects uncertainty as to habitat benefits from flooded areas, including seasonal flooding of floodplains. (A copy of the study is attached hereto.) 10-8

The study concludes that "Floodplains appear to be a viable rearing habitat for Chinook Salmon, making Floodplain restoration an important tool for enhancing salmon production" and that "seasonal habitat should be considered as part of restoration plans for this species."

The survival data from the study is as follows:

Release Group	1998 (53,000)	1999 (105,000)	2000 (55,000)
Yolo Bypass	75	136	27
Sacramento River	35	138	47
Survival Ratio	2.14	0.99	0.57

Although the report finds that "The limited results suggest that fry-adult survival rates were at least comparable in the Yolo Bypass and Sacramento River" the data reflects that the positive results are related to higher flow and the negative results are related to lower flow through the bypass.

The subject management area although still located within the boundary of the lower bypass is in great part no longer "Floodplain" or seasonally flooded but rather is to be a permanently inundated area bordered by wetlands.

The April 2011 report by Dave Vogel titled "Insights into the Problems, Progress, and Potential Solutions for Sacramento River Basin Anadromous Fish Restoration" prepared for the Northern California Water Association and Sacramento Valley Water Users contains the results of studies which include the Liberty Island Ecological Reserve area. (The entire study can be viewed on the Northern California Water Association website by clicking on "Fisheries"; excerpts are attached hereto).

At pages 112 and 113 the report provides, with emphasis added:

> Subsequent, additional juvenile salmon telemetry studies were conducted by Natural Resource Scientists Inc. on behalf of the USFWS and CALFED in the north Delta (Vogel 2001, Vogel 2004). Triangulating radio-tagged fish locations in real time (Figure 61) clearly demonstrated how juvenile salmon move long distances with the tides and were advected into regions with very large tidal prisms, such as upstream into Cache Slough and into the flooded Prospect and Liberty Islands (Figure 62). During the studies, it was determined that some radio-tagged salmon were eaten by predatory fish in northern Cache Slough, near the levee breaches into flooded islands (discussed below).

10-8 cont.

At page 120 the report provides:

> During recent years, there has been an emphasis to reclaim or create shallow, tidal wetlands to assist in re-recreating the form and function of ecosystem processes in the Delta with the intent of benefitting native fish species (Simenstad *et al.* 1999). Amoung a variety of measures to create such wetlands, Delta island levees either have been breached purposefully or have remained unrepaired so the islands became flooded. A recent example is the flooding of Prospect Island which was implemented under the auspices of creating shallow water habitat to benefit native fish species such as anadromous fish (Christophel *et al.* 1999). Initial fish sampling of the habitat created in Prospect Island suggested the expected benefits may not have been realized due to an apparent dominance of non-native fish (Christophel *et al.* 1999). Importantly, a marked reduction of sediment load to the Delta in the past century (Shvidchenko *et al.* 2004) has implications in the long-term viability of natural conversion of deep water habitats on flooded Delta islands

into shallow, tidal wetlands. The very low rates of sediment accretion on flooded Delta islands indicate it would take many years to convert the present-day habitats to intertidal elevations which has potentially serious implications for fish restoration (Nobriga and Chotkowski (2000) due to likely favorable conditions for non-salmonid fish species that can prey on juvenile salmon. Studies of the shallow water habitats at flooded Delta islands showed that striped bass and largemouth bass represented 88 percent of the individuals amoung 20 fish species sampled (Nobriga *et al.* 2003).

There have likely been significant adverse, unintended consequences of breaching levees in the Delta. There is a high probability that site-specific conditions at the breaches have resulted in hazards for juvenile anadromous fish through the creation of favorable predator habitats. The breaches have changed the tidal prisms in the Delta and can change the degree in which juvenile fish are advected back and forth with the tides (Figure 61; previously discussed). Additionally, many of the breaches were narrow which have created deep scour holes favoring predatory fish. Sport anglers are often seen fishing at these sites during flood or ebb tides. Breaching the levees at Liberty Island is an example (Figure 72 and 73). Recent acoustic-tagging of striped bass in this vicinity confirmed a high presence of striped bass (Figure 74, D. Vogel, unpub. data.) 10-8 cont.

The evidence appears to be clear that the increased tidal prism and advection of juvenile salmon into the Project area will likely cause ongoing significant adverse impacts to juvenile salmon.

Response 10-8:

See Master Response 3, *Local Water Diversions and Special-status Fish Species*.

The Draft EIR analyzes direct and indirect impacts to biological resources, including fish predation by a variety of species, in Draft EIR Section IV.D, *Biological Resources* (pages IV.D-1through IV.D-90); cumulative impacts are analyzed in Section V.3.c (page V-8 through V-11). On page IV.D-85 of the Draft EIR, it was noted that the increase in wetland habitat was expected to increase native fish growth rates, thereby helping native fish grow past the “mouth gape” size of non-native predators. Additionally, page IV.D-84 of the Draft EIR states that the Project has been designed to favor native fish species while discouraging establishment and colonization by non-native species, which could prey on the special-status fish. While it was noted that the new habitat would also provide foraging areas for wildlife species that consume fish such as egrets, herons, and otters, page IV.D-85 of the Draft EIR concluded that the Proposed Project would have an overall benefit to native fish, and less-than-significant impacts to special-status fish species.

The Draft EIR Appendix H, *Fish Study Restoration Basis of Design*, includes a Project-specific study that discusses how the Proposed Project was designed and analyzed to provide the greatest potential benefit for native fish. Currently there is no accepted or workable approach in the region that would fully exclude harmful invasive and predatory species while still allowing Delta Smelt open access (Appendix H, page 6). While complete control and exclusion of harmful invasive species and non-native predators is not feasible, the best available science states that high levels of hydrologic connectivity and habitat heterogeneity should be targeted to promote native fish species (Moyle et al 2010; Appendix H, page 7). To help assure habitat connectivity and heterogeneity in accordance with the best available science, nine large breaches are designed along the Shag Slough Levee, ranging in width up to approximately 575 feet. Such large breaches allow water to slowly enter and exit the site. Numerous, enlarged breaches avoid creating high velocity funnels that can disorient fish as they enter or exit the site. Such channel geometry also favors native fish species with dendritic channels. Constructed channels have been designed to be large and allow for tidal exchange, maximizing primary productivity while minimizing the potential for non-native species establishment (page IV.D-85). Therefore, the best available science as well as the input from the area's leading scholars and agency staff have been consulted in order to assure the design is as beneficial as possible to native fish populations (Appendix H, page 2).

The information and analysis in the Sommer article were considered in the preparation of the Draft EIR: Footnote 37 on Draft EIR page IV.D-85 and Footnote 50 on page IV.D-88 cite this article, and a full reference for it is provided in Draft EIR Chapter IX, *References* (page IX-7). The Vogel article is not cited in the Draft EIR but was reviewed but not considered as relevant as the other studies cited since it contains results for a different geographic area and restored habitat.

6. Monitoring of the Project's Benefits.

Many of the purported benefits of the Project are highly questionable. The DEIR, however, is void of any measurable, quantifiable biological objectives or goals. There was seemingly no attempt to establish or evaluate the success/benefits or failure/detriment to listed species. Without a clearly delineated method to evaluate the success or failure of the project, and without a specific plan to address any failures, the DEIR is inadequate. Even mitigation measures themselves must be analyzed under CEQA, and to do that, measures such as the measures included in any plan to address any such failures, must be first identified which, in this respect, they are not. 10-9

Response 10-9:

The Draft EIR sets forth the Proposed Project goals and objectives in the Draft EIR Section III, *Project Description* on pages III-20 through III-22. Ratios for replanting and replacement of habitat or individuals are stated for various habitats and species, including riparian vegetation (Mitigation Measure BIO-1, Draft EIR, page IV.D-51) and special-status plants (Mitigation Measure BIO-2, Draft EIR, page IV.D-54). In addition, the analysis of the development of the Proposed Project going forward is further supported by a Restoration Plan, an Adaptive Management and Monitoring Plan, and Long-Term Management Plan (Draft EIR, page IV.D-53). Implementation of each of these plans would support the overall restoration goals and objectives. See also Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts* and Master Response 13, *Performance Standards and Deferred Mitigation*.

7. Additional Comments.

– The DEIR at page IV.G-20 provides the following mitigation measure: "Mitigation Measure HYDRO-1: The contractor in charge of the Proposed Project construction shall obtain the NPDES permits required for construction and discharge of dewatering prior to the start of construction activities." The DEIR fails to adequately discuss and analyze the potential contaminates in any such discharges and the measures that will be taken to address those contaminates. Such discussion and analysis of contaminates and any mitigate measures necessary to avoid any potential significant impacts from such discharges must be included within the DEIR and cannot be deferred and addressed, if at all, after DWR approves the Project. 10-10

Response 10-10:

Please refer to Response 1-1 for a discussion of the site cleanup activities to be completed prior to initiating construction activities. Please also refer to Draft EIR Section IV.F, *Hazards and Hazardous Materials* on page IV.F-15. Because the Proposed Project would not be located on a site which is included on a list of hazardous materials sites compiled pursuant to Government Code Section 65962.5, the Proposed Project would result in no hazards to the public or the environment.

Measures to address potential contamination include Mitigation Measures HYDRO-1 (the requirement to obtain the NPDES permits mentioned in this comment) and HYDRO-2 (a turbidity monitoring program). Regarding Mitigation Measure HYDRO-1, conditions of the Construction General Permit require the development of a Stormwater Pollution Prevention Plan (SWPPP) that would serve as a roadmap for how stormwater discharges from Project activities would be controlled, the installation and maintenance of erosion and sediment controls for the duration of construction so they operate effectively to control stormwater discharges, the implementation of pollution prevention controls to minimize the discharge of pollutants from spilled or leaked materials or stormwater, implementation of an inspection regimen, and an obligation to take corrective action to address any issues. These are not deferred mitigation measures. They involve compliance with a regulatory permit or other similar process where compliance would result in implementation of measures that would be reasonably expected, based on substantial evidence in the record, to reduce the significant impact to the specified performance standards. See Master Response 13, *Performance Standards and Deferred Mitigation*. Nonetheless, the language of Mitigation Measure HYDRO-1 has been clarified as follows:

> Mitigation Measure HYDRO-1: <u>Project coverage shall be obtained under the National Pollutant Discharge Elimination System (NPDES) Construction General Permit, including preparation of a Stormwater Pollution Prevention Plan (SWPPP), prior to commencement of construction.</u> ~~The contractor in charge of the Proposed Project construction shall obtain the NPDES permits required for construction and discharge of dewatering prior to the start of construction activities.~~

– The DEIR at page III-36 provides: "The Proposed Project would cumulatively necessitate excavation of approximately 5,255,000 cubic yards of soil. Excavated materials would be re-used on-site as appropriate based on soil types and beneficial re-use needs." The DEIR fails to adequate discuss and analyze what constitutes "appropriate" and "un-appropriate" uses of this voluminous material. Such discussion and analysis must also be included in the DEIR and such determinations of appropriateness likewise cannot be deferred and addressed, if at all, after DWR approves the Project. 10-11

Response 10-11:

As stated in Chapter I, *Introduction* of the Draft EIR, the Proposed Project is intended to restore approximately 3,164 acres of tidal marsh that would create habitat beneficial to Delta Smelt and other fish and wildlife species. Chapter II, *Executive Summary* of the Draft EIR, further explains that an objective of Goal 2 is to "promote suitable spawning habitat with appropriate water velocities and depths accessible for Delta Smelt within the Proposed Project and the immediate tidal sloughs surrounding the Project Site."

As discussed in Chapter III, *Project Description* and Appendix H, *Fish Study Restoration Basis of Design* of the Draft EIR, other suitable spawning habitat elements have been incorporated into the project design aside from the placement of sand, such as targeting appropriate water velocities and depths within constructed tidal channels. Further, Appendix H, *Fish Study Restoration Basis of Design* of the Draft EIR, explains how spawning for Delta Smelt has not been observed in the wild and what is known is inferred from the location of captures of post hatch larvae, laboratory culture, and from comparison to similar species. Suitable spawning habitat is believed to include sand or pebble-sized substrates. Results shown in Appendix D, *Lookout Slough Tidal Habitat Restoration and Flood Improvement Project – 65% Basis of Design Report* show potential sources of sand will be encountered during excavation and the Proposed Project would use the found sand to provide the substrate for spawning habitat. Should sand be placed within the tidal channels of the Project, this action would comply with all Proposed Project mitigation measures required during construction and would therefore not result in additional environmental impacts during construction. No impacts are anticipated to water quality from the potential introduction of sand excavated from the Proposed Project Site itself.

As described in Draft EIR Chapter III, *Project Description*, the Proposed Project would "[d]ispose of unused excavated soils within the interior of the site in a manner that is consistent with the ecological goals of the Proposed Project" (page III-23). As shown on Figure III-9 on page III-31 of the Draft EIR, soil that would not be used would be disposed at the locations identified in the figure as "soil sidecast re-use areas." No soil would be imported to backfill excavated areas. Pages III-36 through III-37 of the Draft EIR explain the Proposed Project includes the excavation of approximately 5,255,000 cubic yards of soil, the excavated material would be re-used on-site, and how the unused excavated soil from the channel system excavation would be deposited within the tidal marsh restoration area to minimize haul distances while achieving elevations suitable for tidal range as well as to construct elevated peninsulas to facilitate PG&E access.

Page III-39 describes how excavated material will be utilized to create the new Duck Slough Setback Levee and indicates that "[g]eotechnical investigations were completed to identify on-site borrow areas with soil that would be suitable for the construction of the Duck Slough Setback Levee." As shown on Figure III-9 on page III-31 of the Draft EIR, soil that would not be used would be disposed at the locations identified in the figure as "soil sidecast re-use areas." No soil would be imported to backfill excavated areas. The Geotechnical Basis of Design Report included as Appendix C to the Draft EIR discusses how on-site soils were evaluated and borrow areas identified for constructing the Duck Slough Setback Levee were determined to be suitable for this use. Additionally, pages IV.F-2 and IV.F-14 in Section IV.F, *Hazards and Hazardous Materials* detail the environmental testing program completed for the property, which included an evaluation of soil conditions for any potential on-site contamination requiring further due diligence or cleanup.

– As with other omissions of information, these omissions are likewise highly prejudicial and "'subvert[] the purposes of CEQA [because] [they] omits material necessary to informed decisionmaking and informed public participation.' [Citation.]" (Lighthouse Field Beach Rescue v. City of Santa Cruz, supra, 131 Cal.App.4th 1170, 1202.) 10-12

Response 10-12:

See Responses 10-10 and 10-11.

8. Conclusion.

As it stands the DEIR is not in compliance with CEQA. The above and another deficiencies must first be duly corrected and addressed prior to approval of the Project.

Respectfully submitted,

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February 14, 2020

Via Email Only to frpa@water.ca.gov

Attn: Heather Green
CA Dept. of Water Resources
3500 Industrial Blvd.
West Sacramento, CA 95691

Re: CDWA Comments on the Draft EIR for the Lookout Slough Tidal Habitat Restoration and Flood Improvement Project.

Dear Ms. Green:

The creation of tidal habitat, such as the proposed project, raises numerous questions and concerns. While the DEIR attempts to address many of those questions and concerns, the DEIR's discussion and analysis is lacking in numerous, significant respects, including those discussed herein.

1. **Improper Peacemealing of the 8,000 Acre Tidal Habitat Restoration Obligation and the Broader 30,000 Acre EcoRestore Initiative.**

According to the DEIR at page III-20:

> The Lookout Slough Tidal Habitat Restoration and Flood Improvement Project is proposed to help satisfy DWR's obligation to restore 8,000 acres of tidal marsh per the 2008 USFWS BiOp and the 2009 NMFS BiOp, and to increase flood storage and conveyance, increase the resiliency of levees, and reduce flood risk within the Yolo Bypass. The Proposed Project is part of the California EcoRestore Initiative, which seeks to restore and/or enhance 30,000 acres of habitat in the Delta and Suisun Marsh.

At the outset, the DEIR is continuing the trend to unlawfully piecemeal the environmental analysis of the entire 8,000-acre tidal habitat restoration obligation, as well as the broader 30,000 acre EcoRestore Initiative.

Under CEQA "'[p]roject' means the whole of an action, which has a potential for resulting in either a direct physical change in the environment, or a reasonably foreseeable indirect physical change in the environment . . . ." (Guidelines, § 15378, subd. (a), emphasis added.) As the court explains in Orinda Assn v. Board of Supervisors (1986) 182 Cal.App.3d 1145, at page 1171:

> A public agency is not permitted to subdivide a single project into smaller individual sub-projects in order to avoid the responsibility of considering the environmental impact of the project as a whole. "The requirements of CEQA, 'cannot be avoided by chopping up proposed projects into bite-size pieces which, individually considered, might be found to have no significant effect on the environment or to be only ministerial.' [Citation.]" [Citation].

Nearly the entire gamut of potentially significant environmental impacts resulting from this project has the potential to be cumulatively significant when similar impacts from all 8,000 acres of tidal habitat restoration, as well as all 30,000 acres of habitat restoration and/or enhancement, are evaluated as a whole. "Chopping up [these larger projects] into bite-size pieces" is exactly what DWR is doing.

Unless and until there is a programmatic or other analysis of the "whole" of the 8,000 acre obligation and 30,000 EcoRestore Initiative, the piecemealed analysis in the DEIR for this project is ineffective and cannot support the approval of this project.

2. **The DEIR Fails to Properly Analyze and Mitigate the Project's Individual and Cumulative Impacts on Salinity.**

a. **The DEIR's Reliance on Compliance with D-1641 to Mitigate Salinity Impacts is Misplaced.**

The DEIR acknowledges that the Project will individually and cumulative increase the tidal prism. However, the DEIR's analysis of the impacts from such an increase on Delta salinity is based on whether DWR and USBR will be able to meet and maintain the SWRCB's D-1641 salinity standards:

> [T]he determination of whether a change is considered "significant" depends on whether there would be an exceedance of a standard set forth in the State Water Resources Control Board's (SWRCB's) Bay-Delta Water Quality Control Plan (Bay-Delta Plan) and/or Water Rights Decision 1641 (D-1641).

(DEIR, App. S, pp. 2 & 3.) As the DEIR further explains:

> The combined effect of the Project on Delta EC in combination with other planned tidal wetland restoration project can at times of the year be appreciable for certain D-1641 monitoring compliance stations when compared to existing baseline conditions without these Delta restoration projects in place (e.g., greater than 8 percent increase in EC for an October 2009 scenario at Station D29); nevertheless, even with the combined effects of the Project with other restoration

projects currently under planning, Delta salinities would remain in compliance with D-1641 requirements. Therefore, the Project's incremental effect on salinity in the Delta would not be considerable and the cumulative impact is less than significant.

(DEIR, App. S, p. 6.)

Compliance with D-1641 to mitigate the salinity impacts of the Project means that water will have to come from some source and, hence, be taken away from some other use, to offset the salinity degradation from this Project in order to maintain that compliance. DWR's obligation under CEQA is to thoroughly analyze the full range of potential environmental impacts from such a redirection of water use. For example, to the extent such offsetting will foreseeably come from reservoir releases, impacts to cold water pool storage, carryover storage, river flows, water quality, water available for senior water rights, etc., will be foreseeable and potentially significant. Thus far, DWR has made no attempt to investigate or analyze any such impacts in the DEIR.

A further complication to the DEIR's reliance on DWR and USBR's compliance with D-1641 to reduce the individual and cumulative impacts from the Project is the fact that whenever DWR or USBR release storage water to maintain the D-1641 standards, the State Water Board curtails all post-1914 appropriative water right holders within the Delta watershed that have "Term 91" in their water permits or licenses. Thus, to the extent this Project, individually or cumulatively, triggers the need for DWR or USBR to release storage water to maintain one or more of D-1641's salinity or other standards, a vast number of diverters within the Delta watershed, including the Delta itself, must cease diverting under their post-1914 appropriative water rights. Such cessation of diversions has the potential to cause substantial and widespread effects on numerous environmental resources including terrestrial species, air quality, groundwater recharge, etc. (Information on Term 91 is readily available on the State Water Board's website at:
https://www.waterboards.ca.gov/water_issues/programs/delta_watermaster/term91.html)

Accordingly, because the DEIR relies on DWR and USBR's compliance with the various D-1641 standards to mitigate the Project's individual or cumulative impacts on salinity, the DEIR must analyze the extent, and under what hydrological and other conditions, those impacts will trigger the need for DWR or USBR to the release storage water to bring those standards into compliance and analyze the entire host of environmental resources impacted by such releases, including the impacts on those resources from the widespread curtailment of post-1914 appropriative rights that contain Term 91.

If on the other hand DWR determines that it is not reasonably feasible that the Project, individually or cumulatively, will ever trigger the need for DWR or USBR to release storage water to offset impacts on any D-1641 standard under any reasonably foreseeable drought or other hydrological condition, then DWR must provide sufficient facts and analysis to support such a determination. As it stands, however, the DEIR concedes that the Project may, at least cumulatively, trigger the need for such releases, and, accordingly, the DEIR must perform a thorough analysis of the potential environmental impacts from such releases.

b. The Modeling Analysis of Impacts on Salinity is Grossly Inadequate.

The DEIR explains:

> Resource Management Associates, Inc. (RMA) was tasked with modeling the Project's effect on the Delta salinity regime using their RMA Bay-Delta model. This model simulates the flows in the Bay and Delta that are driven by ocean tides, riverine inputs, and water diversions. The model then uses these flows to predict the distribution of EC, as a surrogate for salinity. The modeling scenario for this study replicates all of 2009, which is representative of typical dry year conditions, when achieving Delta salinity standards is often a challenge.1 RMA conducted salinity simulations for four scenarios: 1) existing conditions, 2) existing conditions with Project, 3) proposed regional restoration projects without Project, and 4) proposed regional restoration projects with Project. By comparing these runs in pairs, the modeling provides predictions of the potential EC changes due to the Project, both relative to existing conditions and cumulatively with other restoration projects.

(DEIR, App. S, p. 2.)

There are numerous deficiencies in this modeling, including the following.

First, the fact that the analysis of only a single water year, 2009, was utilized has to be unprecedented in the realm of Delta water quality analysis. In light of the wealth of available information on water quality, water flows, the operations of DWR and USBR, not to mention numerous detailed and readily available models, there is no excuse to limit the individual and cumulative analysis of the Project's impacts on salinity to a single year. CEQA requires the performance of a degree of analysis that is reasonably feasible. Limiting the analysis to a single year comes nowhere close to meeting that burden.

Second, what is most important is an analysis of how this Project, both individually and cumulatively, will impact salinity (and all other environmental resources) during foreseeable droughts like the state has experienced numerous times in the past, including the very recent past. It is during times when hydrological conditions are the driest that projects, such as the instant Project, will likely have the most adverse impacts on salinity and when mitigation of those impacts is most critical. The data and tools are readily available to analyze the Project's individual and cumulative impacts under such conditions, and it is a substantial breach of DWR's duties under CEQA to omit such an analysis.

Third, the CDWA was unable to locate the actual model results, and importantly, the modeling assumptions, anywhere in the DEIR or its Appendices. CEQA imposes a duty on DWR to provide the facts and analysis that support the conclusion in the DEIR. The omission of the model results and the various assumptions used in the model constitutes a breach of that duty

Forth, along the same lines, the DEIR provides no explanation or disclosure of what constitutes the "proposed regional restoration projects" that were included in the cumulative analysis of the project. The omission of this, and the foregoing information, is highly prejudicial and "'subverts the purposes of CEQA [because] it omits material necessary to informed decisionmaking and informed public participation.' [Citation.]" (Lighthouse Field Beach Rescue v. City of Santa Cruz, supra, 131 Cal.App.4th 1170, 1202.)

c. The DEIR Fails to Properly Address the State and Federal Anti-degradation Laws.

The Federal Environmental Protection Agency ("EPA") requires all states to adopt an "antidegradation policy" similar to the State Water Resources Control Board's ("SWRCB") Resolution 68-16. (40 C.F.R. 131.12.) Resolution 68-16 is further intended to, and does, implement Water Code section 13000 which requires the SWRCB to regulate all "activities and factors which may affect the quality of the waters of the state" such that they "attain the highest water quality which is reasonable."

The State Water Resources Control Board's ("SWRCB") "Resolution 68-16 [commonly referred to as the SWRCB's "Anti-Degradation Policy"] provides in pertinent part:

> Whenever the existing quality of water is better than the quality established in policies as of the date on which such policies become effective, such existing high quality will be maintained until it has been demonstrated to the State that any change will be consistent with maximum benefit to the people of the State, will not unreasonably affect present and anticipated beneficial use of such water and will not result in water quality less than that prescribed in the policies.

The DEIR fails to adequately discuss, address and implement these Anti-Degradation Policies in general, and in the context of its discussion and formulation of mitigation measures and alternatives. In particular, the DEIR's dismissal of any impacts to salinity that do result in a violation of the SWRCB's D-1641 standards constitutes a failure to properly consider and implement these policies.

3. The DEIR Fails to Properly Analyze and Mitigate the Project's Individual and Cumulative Impacts on Mercury and Methymercury.

The DEIR explains:

> Analysis for this DEIR is based on best available scientific information. As part of the first phase of the Delta Mercury Control Program, DWR is conducting both tidal wetland and open water characterization studies in the Yolo Bypass, the Delta and Suisun Marsh. The tidal wetland studies are examining whether tidal wetlands are a source or a sink of methylmercury. The open water characterization studies consist of the development of mercury models for the

> Delta and Yolo Bypass as well as a number of studies conducted to provide data to the Yolo Bypass Mercury model. . . . DWR is currently analyzing data from these studies to inform understanding of tidal wetlands and floodplains with respect to mercury and methylmercury production."

(DEIR, p. IV.G-15 & 16, emphasis added.)

From this passage in the DEIR it is clear that the instant Project, as well as the rest of the projects that make up the 8,000-acre tidal habitat restoration obligation and the broader 30,000 acre EcoRestore Initiative, are not ready to be approved. Specific and detailed modeling and analysis of impacts from such projects on mercury and methylmercury are currently underway : DWR "is currently analyzing data" from these pending studies. In light of the scope of acreage involved in the Project and the other related projects, none of these projects should be implemented until those pending studies are completed and the results of those studies are duly incorporated into the CEQA analysis for such projects.

There is no valid reason why the instant Project and its related tidal wetland and floodplain projects cannot wait until this analysis, which is specifically directed to such projects, is completed and duly processed. As with other omissions in the DEIR, the omission of this highly pertinent information is highly prejudicial and "'subverts the purposes of CEQA [because] it omits material necessary to informed decisionmaking and informed public participation.' [Citation.]" (Lighthouse Field Beach Rescue v. City of Santa Cruz, supra, 131 Cal.App.4th 1170, 1202.)

4. **Lack of an Identified Water Right for the Project.**

The DEIR does not appear to explain what water rights will be utilized to inundate the land within the Project's boundaries with tidal water. The DEIR should thoroughly explain those rights and, in particular, discuss the priority of those water rights and how diversions of tidal water under those rights will be halted in order to protect more senior water rights in the event the SWRCB curtails water rights based on priority as it did in 2014 and 2015.

5. **The DEIR Fails to Properly Analyze and Mitigate the Project's Individual and Cumulative Impacts on Fish Species.**

With respect to post-construction increased predation on native fish, the DEIR fails to adequately discuss and analyze impacts of fish predation by other piscivorous fish as well as many other species of wildlife that prey upon native fish including, but not limited to, Pelicans, Egrets, Cormorants, Herons, Grebes, Minks and Otters. (See attached photo of Pelicans and Egrets foraging for fish in a pond adjacent to the San Joaquin River in Middle Roberts Island.)

Moreover, important fishery studies appear to have been overlooked or not adequately addressed in the preparation of the Project and its CEQA analysis, including the following two studies.

The study by Ted R. Sommer, William C. Harrell and Matthew L. Lobriga titled "Habitat use and Stranding Risk of Juvenile Chinook Salmon on a Seasonal Floodplain" published online November 4, 2005, North American Journal of Fisheries Management 25: 193-1504, 2005 reflects uncertainty as to habitat benefits from flooded areas, including seasonal flooding of floodplains. (A copy of the study is attached hereto.)

The study concludes that "Floodplains appear to be a viable rearing habitat for Chinook Salmon, making Floodplain restoration an important tool for enhancing salmon production" and that "seasonal habitat should be considered as part of restoration plans for this species."

The survival data from the study is as follows:

Release Group	1998 (53,000)	1999 (105,000)	2000 (55,000)
Yolo Bypass	75	136	27
Sacramento River	35	138	47
Survival Ratio	2.14	0.99	0.57

Although the report finds that "The limited results suggest that fry-adult survival rates were at least comparable in the Yolo Bypass and Sacramento River" the data reflects that the positive results are related to higher flow and the negative results are related to lower flow through the bypass.

The subject management area although still located within the boundary of the lower bypass is in great part no longer "Floodplain" or seasonally flooded but rather is to be a permanently inundated area bordered by wetlands.

The April 2011 report by Dave Vogel titled "Insights into the Problems, Progress, and Potential Solutions for Sacramento River Basin Anadromous Fish Restoration"prepared for the Northern California Water Association and Sacramento Valley Water Users contains the results of studies which include the Liberty Island Ecological Reserve area. (The entire study can be viewed on the Northern California Water Association website by clicking on "Fisheries"; excerpts are attached hereto).

At pages 112 and 113 the report provides, with emphasis added:

> Subsequent, additional juvenile salmon telemetry studies were conducted by Natural Resource Scientists Inc. on behalf of the USFWS and CALFED in the north Delta (Vogel 2001, Vogel 2004). Triangulating radio-tagged fish locations in real time (Figure 61) clearly demonstrated how juvenile salmon move long distances with the tides and were advected into regions with very large tidal prisms, such as upstream into Cache Slough and into the flooded Prospect and Liberty Islands (Figure 62). During the studies, it was determined that some

radio-tagged salmon were eaten by predatory fish in northern Cache Slough, near the levee breaches into flooded islands (discussed below).

At page 120 the report provides:

> During recent years, there has been an emphasis to reclaim or create shallow, tidal wetlands to assist in re-recreating the form and function of ecosystem processes in the Delta with the intent of benefitting native fish species (Simenstad *et al.* 1999). Amoung a variety of measures to create such wetlands, Delta island levees either have been breached purposefully or have remained unrepaired so the islands became flooded. A recent example is the flooding of Prospect Island which was implemented under the auspices of creating shallow water habitat to benefit native fish species such as anadromous fish (Christophel *et al.* 1999). Initial fish sampling of the habitat created in Prospect Island suggested the expected benefits may not have been realized due to an apparent dominance of non-native fish (Christophel *et al.* 1999). Importantly, a marked reduction of sediment load to the Delta in the past century (Shvidchenko *et al.* 2004) has implications in the long-term viability of natural conversion of deep water habitats on flooded Delta islands into shallow, tidal wetlands. The very low rates of sediment accretion on flooded Delta islands indicate it would take many years to convert the present-day habitats to intertidal elevations which has potentially serious implications for fish restoration (Nobriga and Chotkowski (2000) due to likely favorable conditions for non-salmonid fish species that can prey on juvenile salmon. Studies of the shallow water habitats at flooded Delta islands showed that striped bass and largemouth bass represented 88 percent of the individuals amoung 20 fish species sampled (Nobriga *et al.* 2003).
>
> There have likely been significant adverse, unintended consequences of breaching levees in the Delta. There is a high probability that site-specific conditions at the breaches have resulted in hazards for juvenile anadromous fish through the creation of favorable predator habitats. The breaches have changed the tidal prisms in the Delta and can change the degree in which juvenile fish are advected back and forth with the tides (Figure 61; previously discussed). Additionally, many of the breaches were narrow which have created deep scour holes favoring predatory fish. Sport anglers are often seen fishing at these sites during flood or ebb tides. Breaching the levees at Liberty Island is an example (Figure 72 and 73). Recent acoustic-tagging of striped bass in this vicinity confirmed a high presence of striped bass (Figure 74, D. Vogel, unpub. data.)

The evidence appears to be clear that the increased tidal prism and advection of juvenile salmon into the Project area will likely cause ongoing significant adverse impacts to juvenile salmon.

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6. **Monitoring of the Project's Benefits.**

Many of the purported benefits of the Project are highly questionable. The DEIR, however, is void of any measurable, quantifiable biological objectives or goals. There was seemingly no attempt to establish or evaluate the success/benefits or failure/detriment to listed species. Without a clearly delineated method to evaluate the success or failure of the project, and without a specific plan to address any failures, the DEIR is inadequate. Even mitigation measures themselves must be analyzed under CEQA, and to do that, measures such as the measures included in any plan to address any such failures, must be first identified which, in this respect, they are not.

7. **Additional Comments.**

– The DEIR at page IV.G-20 provides the following mitigation measure: "Mitigation Measure HYDRO-1: The contractor in charge of the Proposed Project construction shall obtain the NPDES permits required for construction and discharge of dewatering prior to the start of construction activities." The DEIR fails to adequately discuss and analyze the potential contaminates in any such discharges and the measures that will be taken to address those contaminates. Such discussion and analysis of contaminates and any mitigate measures necessary to avoid any potential significant impacts from such discharges must be included within the DEIR and cannot be deferred and addressed, if at all, after DWR approves the Project.

– The DEIR at page III-36 provides: "The Proposed Project would cumulatively necessitate excavation of approximately 5,255,000 cubic yards of soil. Excavated materials would be re-used on-site as appropriate based on soil types and beneficial re-use needs." The DEIR fails to adequate discuss and analyze what constitutes "appropriate" and "un-appropriate" uses of this voluminous material. Such discussion and analysis must also be included in the DEIR and such determinations of appropriateness likewise cannot be deferred and addressed, if at all, after DWR approves the Project.

– As with other omissions of information, these omissions are likewise highly prejudicial and "'subvert[] the purposes of CEQA [because] [they] omits material necessary to informed decisionmaking and informed public participation.' [Citation.]" (Lighthouse Field Beach Rescue v. City of Santa Cruz, supra, 131 Cal.App.4th 1170, 1202.)

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8. **Conclusion.**

As it stands the DEIR is not in compliance with CEQA. The above and another deficiencies must first be duly corrected and addressed prior to approval of the Project.

Respectfully submitted,

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Enclosures

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Habitat Use and Stranding Risk of Juvenile Chinook Salmon on a Seasonal Floodplain

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Abstract.—Although juvenile Chinook salmon *Oncorhynchus tshawytscha* are known to use a variety of habitats, their use of seasonal floodplains, a highly variable and potentially risky habitat, has not been studied extensively. Particularly unclear is whether a seasonal floodplain is a net "source" or a net "sink" for salmonid production. To help address this issue, we studied salmon habitat use in the Yolo Bypass, a 24,000-ha floodplain of the Sacramento River, California. Juvenile salmon were present in the Yolo Bypass during winter–spring; fish were collected in all regions and substrates of the floodplain in diverse habitats. Experimental releases of tagged hatchery salmon suggest that the fish reared on the floodplain for extended periods (mean = 33 d in 1998, 56 d in 1999, and 30 d in 2000). Floodplain rearing and associated growth are also supported by the significantly larger size of wild salmon at the floodplain outlet than at the inlet during each of the study years. Several lines of evidence suggest that although the majority of young salmon successfully emigrated from the floodplain, areas with engineered water control structures had comparatively high rates of stranding. Adult ocean recoveries of tagged hatchery fish indicate that seasonal floodplains support survival at least comparable with that of adjacent perennial river channels. These results indicate that floodplains appear to be a viable rearing habitat for Chinook salmon, making floodplain restoration an important tool for enhancing salmon production.

A large downstream movement of fry to provide dispersal to rearing areas is typical of ocean-type Chinook salmon *Oncorhynchus tschawytcha* (Healey 1991). Rearing areas include channel and off-channel habitat in natal and nonnatal streams and their estuaries (Bjornn 1971; Kjelsen et al. 1982; Levy and Northcote 1982; Swales et al. 1986; Swales and Levings 1989; Healey 1991; Shreffler et al. 1992). Recently, Sommer et al. (2001b) observed that juvenile Chinook salmon also live on seasonal floodplains. Large rivers and streams typically have dynamic floodplains varying in size from several to thousands of hectares, unless their channels are heavily confined by topography (e.g., streams at high elevation or confined by canyons or levees). Floodplains are known to be of major importance to aquatic ecosystems in most regions; large rivers typically favor the development of a fauna adapted to colonize this habitat (Welcomme 1979; Junk et al. 1989; Sparks 1995). As a result, it is reasonable to expect dispersing salmonid fry show some ability to use seasonal habitat. In support of this hypothesis, Sommer et al. (2001b) reported that food resources and water temperatures on the seasonal floodplain of a large river were superior to those in an adjacent perennial channel, resulting in enhanced growth rates of young salmon. Despite some evidence that enhanced growth on the floodplain improved fry–smolt survival in the estuary, Sommer et al. (2001b) did not address any effects on adult production.

Intuitively, rearing in seasonal floodplains or intermittent streams seems risky because these habitats are among the most dynamic on earth (Power et al. 1995). It is still unknown whether seasonally dewatered habitats are a net "source" or a "sink" for salmonid production relative to production in permanent stream channels (Brown 2002). In particular, the high degree of seasonal flow fluctuation characteristic of floodplain habitat could cause major stranding events and increase mortality rates of young salmon (Bradford 1997; Brown 2002). For resident taxa in intermittent streams, the benefits of very large flow fluctuations appear to outweigh costs associated with a variable environment (Spranza and Stanley 2000). This issue continues to be a key concern for regulatory agencies that evaluate off-channel restoration projects or proposed flow fluctuations for possible effects on fishes (Brown 2002; Bruce Oppenheim, NOAA Fisheries, personal communication).

Here, we describe spatial and temporal trends in juvenile Chinook salmon habitat use and stranding in a large California river floodplain. Our study was conducted in the Yolo Bypass, the primary floodplain of the Sacramento River, the major pro-

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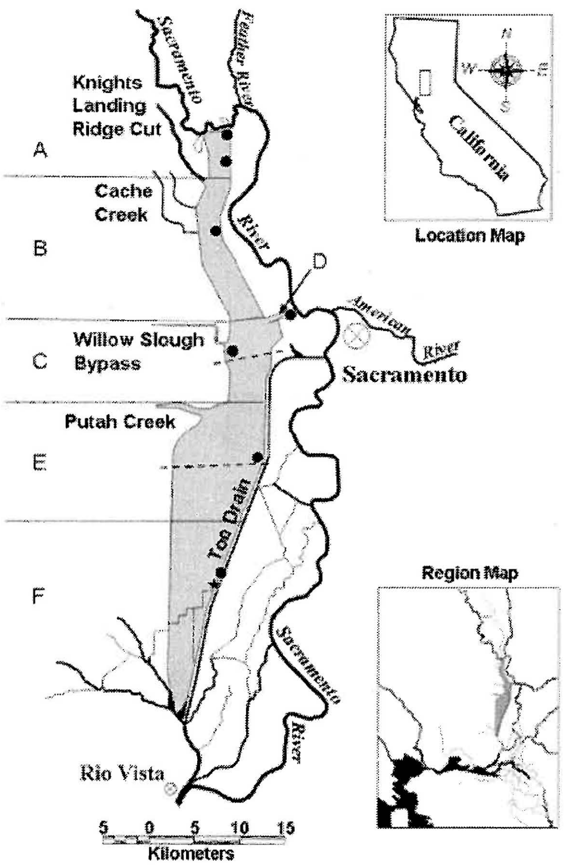


FIGURE 1.—Location of Yolo Bypass in relation to the San Francisco Bay–Delta and its tributaries. Fremont Weir is the upper (northern) edge of the Yolo Bypass. The major regions of the floodplain are delineated from north to south and correspond to the following codes: (**A**) Fremont Weir; (**B**) Cache Creek sinks; (**C**) Yolo Bypass Wildlife Area; (**D**) Sacramento Bypass; (**E**) Putah Creek Sinks; and (**F**) Liberty Island. The sampling locations are identified as follows: beach seine sites (solid circles); screw trap (star); and purse seine transects (dotted lines).

ducer of salmon in the San Francisco estuary (Figure 1). Because the Yolo Bypass can convey 75% or more of the total flow from the Sacramento River basin (Sommer et al. 2001a), this floodplain can be expected to be a migratory pathway for a substantial number of juvenile Chinook salmon. A major objective of our study was to collect basic information about the timing, duration, and habitat use of salmon on floodplains. We hoped that these data would provide insight into whether a floodplain is a net source (i.e., with rearing benefits) or a net sink (i.e., with high mortality because of stranding or predation) for salmon populations. The major hypotheses evaluated were as follows: (1) salmon occur in all major habitat types and geographic regions; (2) floodplains provide rearing habitat for salmon and are not simply a migration corridor; and (3) stranding of juvenile salmon does not have a major population-level effect on survival of the fish that use floodplain habitat. We addressed these hypotheses by sampling wild fish throughout the floodplain, experimentally releasing tagged fish, and using hydrologic modeling and measurements of physical conditions to describe how habitat varied over the study period.

Study Area

The San Francisco Estuary and its two component regions, Sacramento–San Joaquin Delta and downstream bays (Figure 1), make up one of the largest estuaries on the Pacific coast of North America. Major changes to the system have included diking and isolation of about 95% of the wetlands, introduction of exotic species, channelization, sediment inputs from hydraulic mining, and discharge of agricultural and urban chemicals (Nichols et al. 1986; Kimmerer 2002). The Estuary receives most freshwater via the Delta, which drains approximately 100,000 km^2. Most precipitation occurs upstream of the Delta during winter and spring, resulting in a greater than 10-fold seasonal range of daily freshwater flow into the estuary. However, the hydrograph is substantially altered by dams on each of the major rivers. Peak flow pulses typically occur during winter, but dam operations can reduce the magnitude of the pulses, particularly in dry years, when much of the inflow is captured behind reservoirs (Mount 1995; Kimmerer 2002). The historically prominent spring flow pulse from snowmelt is at present muted except during heavy, late-season storms. For the past several decades, much of the spring snowmelt has been stored in reservoirs and released during summer and autumn, periods of historically lower flow. As much as 65% of the net Delta flow during summer and autumn is diverted from the channels by two large water diversions (the State Water Project and the Central Valley Project); additional water is diverted by 2,200 pumps and siphons for irrigation (Kimmerer 2002).

The 24,000-ha Yolo Bypass is the primary floodplain of the Delta (Sommer et al. 2001a). The majority of the floodplain is leveed to protect surrounding cities from floodwaters, but levees confine flow through the bypass only under very high flow events. The Yolo Bypass currently floods an average of every other year, typically under high-flow periods in winter and spring. The Yolo Bypass has a complex hydrology, with inundation possible from several different sources. The floodplain typically has a peak inundation period during January–March but can flood as early as October and as late as June. The primary input to the Yolo Bypass is through Fremont Weir in the north, which conveys floodwaters from the Sacramento and Feather rivers. During major storm events (e.g., >5,000 m^3/s), additional water enters from the east via the Sacramento Weir, adding flow from the American and Sacramento rivers. Flow also enters the Yolo Bypass from several small streams on its western margin, including Knights Landing Ridge Cut, Cache Creek, and Putah Creek. During much of the winter, water-suspended sediment levels in the Yolo Bypass and Sacramento River are high, generally resulting in secchi depths of less than 0.25 m. However, hydraulic residence times are typically longer in the Yolo Bypass than in the Sacramento River (Sommer et al. 2004). Floodwaters recede from the northern and western portions of the bypass along relatively even elevation gradients of 0.09% west–east and 0.01% north–south into a perennial channel on the eastern edge of the Bypass; they then rejoin the Sacramento River near Rio Vista. The majority of the Yolo Bypass is at present managed for wildlife in a mosaic that includes riparian, wetland, upland, and perennial pond habitats; however, a dominant land use during the past two decades, agriculture has decreased in recent years because of habitat restoration activities.

Our data collection focused on the fall-run juvenile Chinook salmon, currently the numerically dominant race in the Sacramento Valley (Yoshiyama et al. 2000). There are four races of Chinook salmon in the Sacramento Valley: winter, spring, late-fall, and fall-run. Like many other native fish, Chinook salmon in the San Francisco estuary and its tributaries have been adversely affected by such factors as habitat loss, water diversions, and species introductions (Bennett and Moyle 1996); as a result, the Sacramento River winter and spring run Chinook salmon are protected under the Federal Endangered Species Act. The typical life history pattern is for young fall-run salmon fry (approximately 35–70 mm fork length) to migrate from the tributaries during winter and spring to the estuary (Brandes and McLain 2001).

Methods

Physical habitat.—Because seasonal hydrologic variability is a key characteristic of floodplain habitat, we reasoned that detailed data on changes in physical habitat would be necessary to evaluate the responses of young salmon. Daily flow data were obtained from gauging stations in the floodplain, and temperature data were collected using continuous temperature recorders (Sommer et al. 2001b). However, the vast area of Yolo Bypass made it impractical to directly measure other parameters, such as depth and surface area. As an alternative, we used a hydrologic model to estimate these parameters (Sommer et al. 2004). To summarize, the model treated Yolo Bypass as a "reservoir" described by (1) basin geometry and (2) flow and stage time series. The Yolo Bypass floodplain geometry was developed from 200 cross-sections with data collected at 300-m intervals by standard rod and level survey techniques. Mean daily stage and flow data were obtained from five gauging stations in the Yolo Bypass. For each date in the time series, we used linear interpolation between the gauging stations to estimate the stage at each cross-section. The estimated stage value was then used to calculate conveyance characteristics of each cross-section: area, width, and wetted perimeter. The daily results for each cross-section were used to estimate total surface area and mean depth. The large scale of the study reach did not allow validation of the depth estimates. As a partial validation of the model, Sommer et al. (2004) estimated total inundated area for the Yolo Bypass by using aerial photographs on days when the floodplain was inundated (February 8 and March 2, 1998) and when the floodplain was draining (April 28, 1998). To provide additional information about areas where fish stranding and consequent losses could occur, we estimated the portion of the area that was isolated ponds versus inundated area that was actively draining to the Delta (i.e., perennial channels and adjacent inundated area) on April 28, 1998.

Fish habitat use.—We used beach seine sampling to examine which regions and substrates of the floodplain were used by young salmon (hypothesis 1). During January through April of each year, a 15-m seine (3.2-mm mesh) was used to sample six regions of the Yolo Bypass (Figure 1). Fixed stations were used in each region during flooded periods. After floodplain drainage, samples were collected randomly within each region. For all periods, the primary substrate type of the habitat (sand, mud, gravel, pavement, or vegetation), fish species and size, and an estimate of the surface area swept by the seine were recorded. Habitat use during flood events was summarized in terms of the percentage of samples that contained salmon for each region and substrate type.

To provide additional information about habitat use, we conducted purse seine sampling along two transects (Figure 1). This sampling, performed in 1998 when the Yolo Bypass flow was relatively high (>850 m^3/s), used purse seines (30.5 m × 4.6 m, 4.75-mm mesh) set from a jet boat. Purse seining was conducted at 1–2 transects up to five times weekly, depending on hydrology. Hauls were made at random points in each of three habitat types (riparian, agricultural fields, and wetlands), the boundaries of which were established from aerial photographs taken before the Bypass was inundated. In the case of riparian habitat, hauls were made in clearings adjacent to trees to avoid snagging. We also recorded transect side (east or west half) for each haul because the western side of the Yolo Bypass was shallower and flow was dominated by inputs from westside streams rather than from Fremont or Sacramento weirs (Sommer et al. 2004). Most of these hauls were performed in areas exposed to at least a modest current. Additional limited paired sampling was conducted to examine possible differences between areas with and without velocity refuges. Low-velocity habitats sampled included downstream edges of levees, islands, and clusters of trees. Water velocities in randomly selected areas were approximately 0–0.05 m/s compared with greater than 0.33 m/s in adjacent exposed areas. Water depths were similar for each sampling pair. Differences in salmon densities for each habitat type were examined by using a Kruskal–Wallace test. A randomization t-test with 1,000 iterations (Haddon 2001) was used to compare salmon density on the east and west sides of the floodplain.

Migration trends.—To examine temporal trends in salmon migration through the floodplain (hypotheses 2 and 3), we operated a rotary screw trap (EG Solutions, Corvallis, Oregon) near the base of the Yolo Bypass during each study year. This technique was intended to provide an indication of the timing and duration of migration, rather than an absolute measure of the number of salmon emigrating the floodplain. During much of the sampling period the inundated width of the floodplain was 1–5 km, an area we considered too large for the traditional mark–recapture evaluations required to measure trap efficiency and total emigration (Roper and Scarnecchia 1996). A 1.5-m-diameter trap was used for the first 3 weeks of sampling in February 1998, after which a 2.4-m trap was used for all other sampling. We operated traps as often as 7 days each week, the daily effort varying from 1 to 24 h, depending on debris load and safety considerations. Fish number and size were recorded in all years. In 1998, young salmon were classified as fry (prominent parr marks) or transitional fish/smolts (faded parr marks, silver appearance).

Floodplain residence time and growth.—We used experimental releases of salmon with coded wire tags (CWTs) as our primary method to evaluate fish residence time on the floodplain (hypothesis 2). Fry (mean size = 57 mm fork length) from the Feather River Fish Hatchery (Figure 1) were tagged by using coded-wire half tags (Northwest Marine Technologies) and released in the Yolo Bypass below the Fremont Weir on March 2, 1998 (53,000 fry); February 11, 1999 (105,000 fry); and February 22, 2000 (55,000 fry). We assessed residence time in the Yolo Bypass from recoveries of tagged fish in the screw trap at the base of the floodplain.

We also examined, using the previously described beach seine data, whether there was evidence of long-term rearing of wild salmon in the floodplain. We compared the slopes of weekly fork length measurements for the two northern beach seine regions ("North") to the southernmost region ("South"), using a generalized linear model (GLM) with a Poisson distribution and log link variance function. We reasoned that major significant differences between the sizes of fish in the two areas provided evidence of extended rearing and growth of fish in the floodplain.

Salmon survival and stranding.—We used several independent data sources to examine whether salmon successfully emigrated from the floodplain (hypothesis 3). First, we compared survival of each of the Yolo Bypass CWT hatchery-reared salmon release groups with the survival of parallel CWT groups containing the same number of fish released into the Sacramento River (Sommer et al. 2001b). Recapture rates at the smolt stage of the 1998 and 1999 release groups had previously been analyzed by Sommer et al. (2001b); in the present study, we evaluated adult recoveries in the commercial and recreational ocean fisheries through 2003. Second, we examined stranding by using beach seine data (described previously) collected within a few weeks after the Sacramento River stopped flowing into the Yolo Bypass. Densities of salmon were compared with a randomization t-test (Haddon 2001) for (1) isolated earthen ponds (2) perennial channels, and any sites immediately adjacent to these water sources. The results for all years were pooled because of relatively low sample sizes for individual years. Data for each year

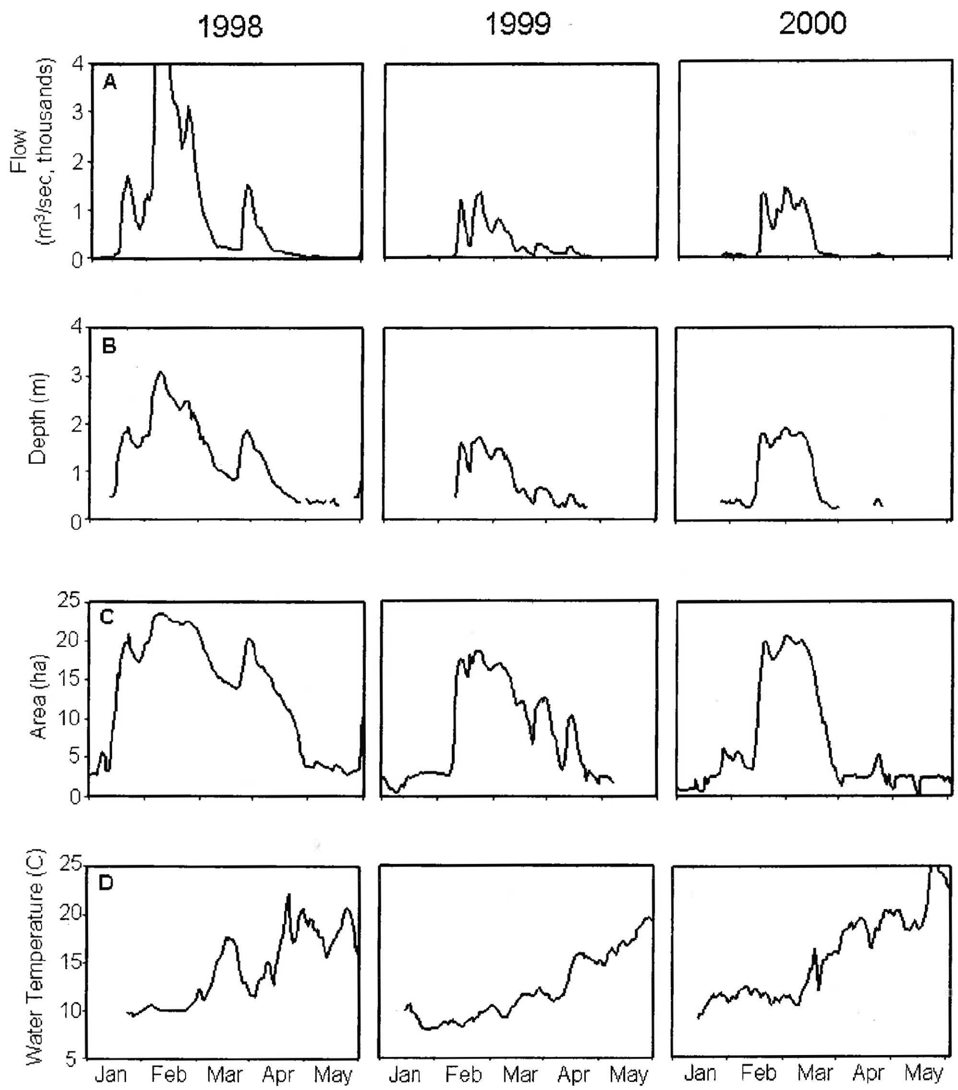


FIGURE 2.—Trends in physical variables for January–June 1998–2000: (**A**) mean daily flow in the Yolo Bypass; (**B**) simulated mean daily depth; (**C**) surface area; and (**D**) daily mean water temperature. The surface area data for 1998 and 2000 are from Sommer et al. (2004).

were first standardized for possible annual differences in abundance by conversion to *z*-scores; we then ran the randomization analysis using 1,000 iterations. We hypothesized that abundance of salmon would be equal in isolated ponds and contiguous water sources; that is, they would show no distinct "preferences." Our reasoning was that similar abundance levels would indicate successful emigration, because most of the water drains from the floodplain. To further understand factors that could affect stranding, we also used a randomization *t*-test to compare densities of fish in two types of isolated ponds: isolated earthen ponds and concrete weir scour ponds at Fremont and Sacramento weirs (Figure 1). Sampling effort was much greater in the isolated earthen ponds, so the randomization *t*-test was performed after randomly subsampling the earthen pond data from throughout the floodplain to provide equal sample sizes. We predicted that flood control structures would cause higher stranding than "natural" ponds. In addition, we examined trends in the catch of salmon in the screw trap data. We predicted that salmon catch would increase substantially during drainage because fish successfully emigrated the floodplain.

Results

Physical Habitat

The hydrographs varied substantially during the years of study (Figure 2A). In 1998 the hydrology was wet (4.4-year recurrence flood event) and the Yolo Bypass was inundated during mid-January through mid-April and again in early June. The flow was lower in the other 2 years, when inundation occurred between mid-February and mid-March, peak flood events being at the 1.7-year recurrence interval in 1999 and at the 2.4-year recurrence interval in 2000. Surface area in the Yolo Bypass closely followed the flow peaks, the amounts of inundated area being successively smaller in each of the study years (Figure 2C). For the April 28, 1998, photographs, the total surface area of 5,050 ha was slightly lower than the model estimate of 6,700 ha. Based on the aerial photographs, we estimated that only 600 ha of the 5,050 ha comprised isolated ponds, the remainder being water that drained to the Delta. For all but peak flood events, mean water depth remained less than 1 m (Figure 2B). During peak flood events, mean depths did not exceed 2 m except in February 1998. Water temperature showed gradual increases throughout each study year (Figure 2D).

Fish Habitat Use

We captured salmon in all regions of the floodplain and on all substrate types. During 1998–2000 flood events, salmon were captured in a high percentage of samples in each region (Figure 1) of the floodplain: (1) Fremont Weir (100%, n = 13 samples); (2) Cache Creek Sinks (50%, n = 16 samples); (3) Yolo Bypass Wildlife Area (77%, n = 22 samples); (4) Sacramento Bypass (100%, n = 7 samples); (5) Putah Creek Sinks (94%, n = 11 samples); and (6) Liberty Island (100%, n = 7 samples). Similarly, during 1998–2000 flood events we collected salmon on a high percentage of substrate types: (1) mud (70%, n = 47 samples); (2) sand (100%, n = 3 samples); (3) pavement (100%, n = 8 samples); (4) vegetation (97%, n = 32 samples); and 5) gravel (89%, n = 9 samples).

Salmon densities as estimated by purse seine sampling were not significantly different between riparian (mean abundance = 46.9/ha, SE = 10.4, n = 23), agricultural (mean abundance = 20.9/ha, SE = 6.1, n = 35), or natural vegetated habitat types (mean abundance = 27.5/ha, SE = 5.6, n = 31) based on a Kruskal–Wallis test (H = 4.38, df = 2, P = 0.112). There was also no statistically significant difference between the east (mean abundance = 29.5/ha, SE = 6.0, n = 53) and west (mean abundance = 29.9/ha, SE = 6.7, n = 36) sides of the Bypass as shown by a randomization t-test (P = 0.95). Salmon were collected in six hauls in low-velocity habitat (mean abundance = 189/ha, SE = 24/ha), but none were collected in adjacent areas exposed to a current.

Floodplain Migration Trends

Salmon migration as indicated by trends in screw trap catch was highly variable over the course of the study, but there were prominent peaks in Chinook salmon catch coincident with floodplain drainage during late March–April (Figure 3B). Additional smaller peaks in salmon catch also paralleled flow, mostly during February and March. The life history stage of salmon during 1998 was exclusively parr through the end of March, after which the majority showed signs of smoltification.

Floodplain Residence Time

Based on recoveries of tagged fish in the screw trap, the mean residence time of CWT salmon was 33 d (range, 16–46 d; n = 10) in 1998, 56 d (range, 4–76 d; n = 49) in 1999, and 30 d (range, 28–37 d; n = 25) in 2000. The size of fish was significantly larger (P<0.001; GLM) at the outlet of the floodplain than at the top (Figure 3C) during each of the study years.

Salmon Survival and Stranding

The numbers of CWT fish recovered for the Yolo Bypass were higher than in the Sacramento River in 1998, similar in 1999, and lower in 2000 (Table 1). Densities of wild Chinook salmon were highly variable during floodplain drainage events, with no statistically significant difference between densities in isolated earthen ponds and contiguous water sources (Table 2). However, densities of salmon were significantly higher (P < 0.0001; randomization t-test) in concrete weir scour ponds than in isolated earthen ponds (Table 3).

Discussion

Research on migratory fishes reveals that these species frequently have alternative life histories that may be influenced by habitat use at early life stages (Clark 1968; Secor 1999). Under Clark's (1968) "contingent hypothesis," migratory taxa have divergent migration pathways that could help the species deal with environmental variability and heterogeneity. This theory is consistent with our understanding of Chinook salmon, which are adapted to the extreme hydrologic variability in western North America and show a range of life histories (Healey 1991; Bottom et al. 2005). In this context, the use of multiple habitats—including natal and nonnatal streams (Bjornn 1971; Scriv-

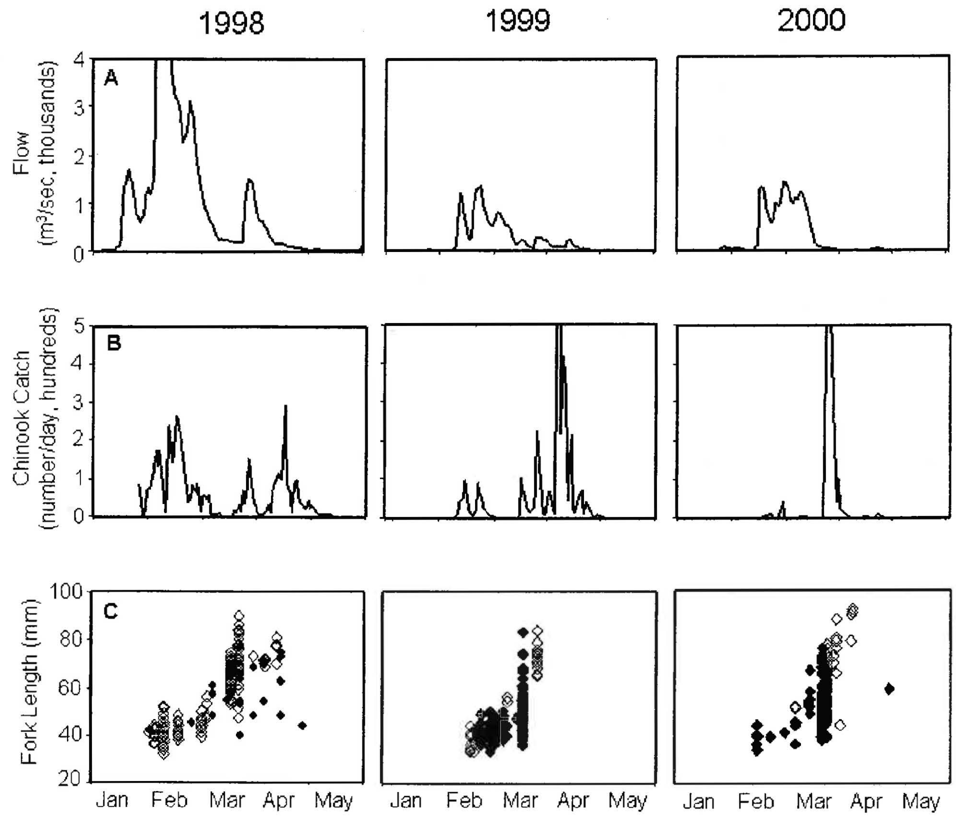


FIGURE 3.—Chinook salmon results during winter and spring 1998–2000: (A) mean daily flow; (B) salmon catch rates in screw trap sampling; and (C) salmon size for beach seine samples near the Yolo Bypass intake (solid symbols) and outlet (clear symbols).

ener et al. 1994), side channels and off-channel ponds (Swales et al. 1986; Swales and Levings 1989), low-elevation rivers (Kjelsen et al. 1982; Brown 2002), and estuaries (Healey 1991; Shreffler et al. 1992)—can be considered as part of an overall "bet-hedging" strategy that spreads risk across a variable environment. Despite the fact that seasonal floodplain represents perhaps the single most variable habitat available to salmon, our study suggests that floodplains are a viable rearing location for young fish.

TABLE 1.—Number of coded wire tags recovered in the ocean and commercial fisheries for Chinook salmon released in the Yolo Bypass and Sacramento River. The total number of tagged fish released in each location for each year is shown in parentheses. The survival ratio is calculated as the number of Yolo Bypass recoveries divided by the number of Sacramento River recoveries.

Release group	1998 (53,000)	1999 (105,000)	2000 (55,000)
Yolo Bypass	75	136	27
Sacramento River	35	138	47
Survival ratio	2.14	0.99	0.57

At the beginning of our study, our conceptual model for floodplain habitat use was that young salmon move into the floodplain during high-flow events and spread throughout the broad expanse of seasonally inundated habitat. Among the wide variety of suitable substrates and habitat types for rearing, young salmon appear to seek out low-velocity areas. Moreover, floodplain habitat apparently is not simply a migration corridor; many young salmon actively rear on the highly productive floodplain habitat for extended periods of time, resulting in high growth rates. Our findings suggest that salmon emigrate from the seasonally inundated habitat both during flood events and during drainage. Juvenile Chinook salmon do not appear to be especially prone to stranding mortality; indeed, survival may actually be enhanced by floodplain rearing in some years. Our conceptual model was supported by our results and has a variety of management implications.

Salmon were present in a broad range of habitat and substrate types and were collected in all regions and sides of the Yolo Bypass floodplain. The

TABLE 2.—Densities of Chinook salmon (number/ha ± SE, with sample size in parentheses) collected in beach seine sampling during drainage events in 1998–2000. The sample locations are divided into isolated earthen ponds and contiguous water sources. Density differences were not statistically significant between the two pond types based on a randomization t-test of the pooled data for all years ($P = 0.79$; $n = 43$ for isolated ponds; $n = 59$ for contiguous water sources).

Location type	1998	1999	2000
Isolated ponds	206 ± 112 (30)	890 ± 491 (8)	126 ± 65 (5)
Contiguous water sources	167 ± 79 (33)	310 ± 104 (13)	463 ± 123 (13)

fact that they were present on the western half of the Bypass, where flows are dominated by Knights Landing Ridge Cut and Cache and Putah creeks, suggests that salmon spread throughout the floodplain after entering the basin by way of Fremont and Sacramento weirs. A few of these fish may have originated from a modest spawning population in Putah Creek (Marchetti and Moyle 2001). The fact that salmon were present in a wide range of habitat and substrate types and in different regions of the Yolo Bypass indicates that many areas of habitat were suitable, although this does not mean that there were no habitat preferences. Like many young fishes, much of the distribution of juvenile Chinook salmon can be explained by their association with shallow depths and low velocities (Everest and Chapman 1972; Roper et al. 1994; Bradford and Higgins 2001). The physical modeling indicated that mean depths were generally 1 m or less during all but peak flood periods, so much of the thousands of hectares of inundated habitat was probably within the shallow range typically preferred by young Chinook salmon (Everest and Chapman 1972). Our limited purse seine sampling suggested that young salmon were most abundant in low-velocity areas, which is consistent with previous studies in river and stream habitat (Everest and Chapman 1972; Roper et al. 1994; Bradford and Higgins 2001). We did not directly simulate water velocity in the present study; however, the relatively shallow water depth during flood events reflects the broad area of low-velocity rearing habitat created during flood events. We expect that this increase in rearing habitat in the Yolo Bypass provides foraging opportunities (Sommer et al. 2001b), reduced energy expenditure, and perhaps reduced probability of encounter with a predator (Ward and Stanford 1995).

Our results also suggest that fish rear in the system for extended periods rather than simply using it as a migration corridor. The mean residence time of 30–56 d for the 44-km reach between the floodplain release location and the screw trap is substantially longer than one would expect, given that (1) fingerlings are capable of migrating at rates of at least 6–24 km/d in low-elevation reaches of other large rivers (Healey 1991) and (2) one of our 1999 CWT fish was recovered just 4 days after being released, having traveled an estimated rate of 11 km/d. The fish were significantly larger at the base of the Yolo Bypass, suggesting that their period of residence in the floodplain was long enough to support substantial growth. Similarly, Sommer et al. (2001b) found that salmon showed higher growth rates in the Yolo Bypass than in the adjacent Sacramento River, primarily because of higher levels of invertebrate prey in the floodplain. A long period of rearing is also supported by the screw trap data, which showed that the densities of salmon were greatest during drainage of the floodplain. We believe that these peaks are a result of rearing salmon being forced off of the floodplain by receding flows. Temperature and salmon life history stage do not provide good alternative explanations for the emigration trends. In 1998, for example, water temperatures were relatively high by late March and salmon began smoltification shortly thereafter; yet the screw trap data indicate

TABLE 3.—Densities of Chinook salmon (number/ha ± SE, with sample size in parentheses) collected in beach seine sampling for earthen ponds and adjacent concrete weir ponds. Density differences were statistically significant between the two pond types based on a randomization t-test of the pooled data for all years ($P < 0.0001$; $n = 26$ for each pond type). Note that we used a randomly sampled subset of the earthen pond data to provide equal sample sizes for the comparison.

Location type	1998	1999	2000
Earthen ponds	186 ± 67 (63)	531 ± 200 (21)	369 ± 97 (18)
Concrete weir ponds	2,717 ± 1,115 (14)	14,208 ± 3,898 (12)	4,181 ± 1,275 (3)

that emigration did not peak until the end of April, when the floodplain drained. Perhaps the emigration trends are partially confounded by seasonal variation in salmon abundance. In the absence of trap efficiency data, we cannot estimate the proportion of the population that emigrated in winter versus spring events.

Several lines of evidence suggest that the majority of fish successfully emigrated from the floodplain. One important observation was that the area of isolated ponds was small relative to the overall area of the floodplain during both peak flood and drainage periods. As an example, in 1998, the wettest year we studied, the peak area of inundation was 24,000 ha, but the total inundated area dropped to 5,000 ha by late April. Of the 5,000 ha remaining at this point, our estimates from aerial photographs showed that isolated ponds took up only 600 ha. Put another way, isolated ponds represented just 12% of the wetted area in April and only 2.5% of the peak inundated area in winter. The same trend is evident in the area simulations for 1999 and 2000, when the peak area was 20,000 ha, but dropped to about 2,000 ha within a month. These results demonstrate that the Yolo Bypass drains fairly efficiently, leaving little isolated area where stranding can occur. This finding was somewhat unexpected, because many parts of the Yolo Bypass have natural topographic features or agricultural levees that could potentially impede drainage and fish emigration. Even if the area of isolated ponds is low, stranding could still be a substantial source of mortality if densities of fish in the remaining ponds were very high. However, we found no evidence that densities of fish stranded in isolated ponds were significantly higher than those in contiguous water sources that were draining to the Delta. The key point here is that most of the water drains from the floodplain and apparently the majority of the fish are leaving with the receding floodwaters. To help illustrate this issue, if we assume that mean densities of fish observed in Table 2 were representative of the entire wetted area of floodplain in April 1998, then the total number of fish in the 600 ha of isolated ponds would have been 123,600 salmon, lower than an estimate of 835,000 fish in the 5,000 ha of contiguous water sources. This conservative estimate also does not include the large numbers of fish that emigrated from the floodplain before April.

In addition to the beach seine and surface area data, we believe that trends in screw trap data support the hypothesis that stranding is not consistently a major problem on the floodplain. The screw trap data are somewhat ambiguous, because the large area of the floodplain makes it unreasonable to measure the efficiency of the trap. Therefore, we cannot accurately estimate the absolute number of salmon emigrating from the floodplain. However, we can at least examine the patterns of trap catch to evaluate likely mechanisms. Some of the possible patterns that we would expect to see for different factors are summarized in Figure 4. First, under the "trap efficiency" model, we would have expected dual peaks in the earliest and latest portions of flood events, when the screw trap would be sampling the highest portion of total flow (Figure 4A). If young salmon follow the "go with the flow" model, catch and flow peaks should be well-correlated (Figure 4B). Alternatively, if floodplains represent an important rearing habitat, we would expect catch trends to follow the "loitering" model, in which catch does not increase until drainage, when fish are forced from their rearing habitat by receding floodwaters (Figure 4C). Finally, if stranding were a major factor controlling catch trends, we would expect an early increase in catch as fish moved through the floodplain during inundation, but then catch should drop earlier than flow as young salmon became isolated from draining floodwaters (Figure 4D; "bathtub" model). Of these patterns, our data for the Yolo Bypass provide the strongest support for both the "go with the flow" and "loitering" models. In each year we saw obvious screw trap catch peaks associated with flow events, and additional prominent peaks associated with drainage. To summarize, apparently some of the fish move

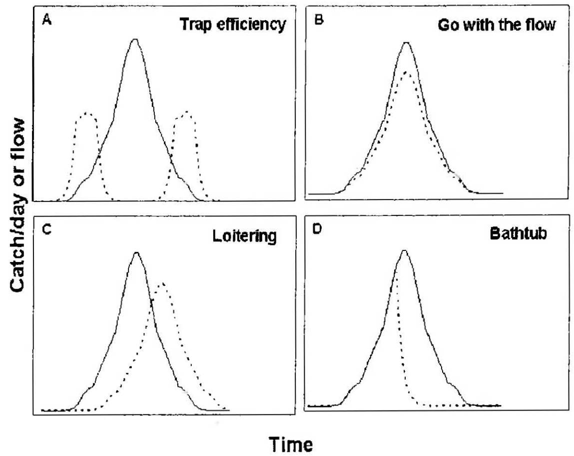


FIGURE 4.—Four conceptual models of expected screw trap catch (dotted line) relative to flow (solid line). See the Discussion for further details about each model.

through the floodplain in direct association with flow, whereas others remain as long as possible to rear on the floodplain. The screw trap trends show no evidence that stranding had a major influence on patterns of emigration.

Relatively low stranding rates on the Yolo Bypass floodplain are supported by observations from other seasonal floodplain habitat in the San Francisco estuary (Peter Moyle, University of California–Davis, personal communication) and other studies. Higgins and Bradford (1996) and Bradford (1997) report that juvenile salmonids are relatively mobile and that most avoid being stranded during moderate rates of stage change. Higgins and Bradford (1996) state that maximum recommended stage reduction levels for gravel bars of regulated rivers are typically 2.5–5 cm/h, much more than the 1 cm/h or less rates of change in mean water depth we observed during drainage in the present study. In his review of the ecology of fishes in floodplain rivers, Welcomme (1979) noted that the majority of fish emigrate from floodplain habitat during drainage.

Even if stranding is not a major source of mortality, this does not necessarily mean that floodplains are not sinks for salmon production. Of the possible sources of mortality, birds and piscivorous fishes may have benefited from stranded salmon (Brown 2002). As noted by Sommer et al. (2001a), major avian predation is unlikely because densities of wading birds are low relative to the thousands of hectares of rearing habitat available during flood events. We did not measure densities of fish predators, but believe that the creation of large areas of rearing habitat should create more refuges for young fish and decrease the probability of encounter with a predator.

Ultimately, it is survival data that allow us to differentiate source from sink habitat. The size and complexity of the San Francisco estuary made it very difficult to directly measure survival rates with statistical rigor (Newman and Rice 2002); however, our CWT release studies at least provide an indication of whether survival rates in the Yolo Bypass were substantially different from those in the Sacramento River, the adjacent migration corridor. The limited results suggest that fry–adult survival rates were at least comparable in the Yolo Bypass and the Sacramento River. Moreover, the 1998 results suggest that in some years, survival may actually be substantially higher for salmon that migrate through the floodplain. Although none of these CWT releases were replicated, the fact that Sommer et al. (2001b) reported similar results for fry-to-smolt survival for the same releases in 1998 and 1999 increases our confidence that the survival data are not spurious.

Our data indicate that floodplains are a viable rearing habitat for juvenile Chinook salmon. Hence, the most important management implication of our study is that seasonal habitat should be considered as part of restoration plans for this species. Despite frequent concerns that off-channel habitat could increase stranding mortality (Brown 2002; Bruce Oppenheim, NOAA Fisheries, personal communication), our results for a hydrologically variable seasonal floodplain suggest that one should be able to design restoration projects that do not create a population sink because of excessive mortality. This is not to say, however, that stranding mortality is never an issue on floodplain habitat. For example, in the Yolo Bypass we saw significantly higher stranding rates in the concrete weir scour ponds of Fremont and Sacramento weirs than in earthen ponds. This finding suggests that artificial water control structures can create unusual hydraulics that promote stranding. However, the total area of these concrete weir ponds was only 3 ha, much smaller than our estimate of 600 ha for total isolated pond area for April 1998 and insignificant compared with the peak inundated area of 24,000 ha area. Fixing the poor hydraulics at these water-control structures may, nonetheless, be an attractive option, particularly if the cost of the solution is relatively low or if it helps to address other fisheries issues such as adult fish passage. In the Yolo Bypass, the concrete weirs not only create stranding problems for juveniles but also frequently block upstream passage of adult salmon, sturgeon, and steelhead trout (Sommer et al. 2001a), thus creating an incentive to resolve both issues simultaneously.

Finally, we wish to acknowledge that even natural floodplain or well-designed restored floodplain habitat could at least occasionally be a population sink because of stranding or predation losses. Our study was conducted over 3 years for a single, large floodplain; we cannot rule out the possibility that floodplains may not have net benefits in other years or locations. As an example, fish densities in the Yolo Bypass were relatively low compared with those reported in some other studies (Levy and Northcote 1982; Swales et al. 1986; Swales and Levings 1989); perhaps young salmon behavior could be different at higher densities. However, the potential for such losses can still be consistent with effective management of salmon populations. Diverse life history strategies provide bet-hedging for salmon populations in the highly variable environment of coastal tributaries (Secor 1999; Bottom et al. 2005). We therefore expect that young salmon will not thrive in all habitats in every year. In the case of highly variable seasonal environments such as floodplains, stranding losses might cause excessive mortality in some years, but the risks may be offset by increased rearing habitat and food resources in other years (Sommer et al. 2001b; Brown 2002).

Acknowledgments

This study would not have been successful without the contributions of staff from the Interagency Ecological Program, which includes the California Department of Water Resources, California Department of Fish and Game, and U.S. Fish and Wildlife Service. The field assistance of W. Batham, R. Kurth, C. Messer, K. Malchow, F. Feyrer, and L. Grimaldo is gratefully acknowledged. This manuscript was substantially improved by the comments of P. Moyle, B. Herbold, F. Feyrer, T.G. Brown, and two anonymous reviewers. Funding was provided by the Interagency Ecological Program and CALFED.

References

Bennett, W. A., and P. B. Moyle. 1996. Where have all the fishes gone?: interactive factors producing fish declines in the Sacramento–San Joaquin Estuary. Pages 519–542 *in* J. T. Hollibaugh, editor. San Francisco Bay: the ecosystem. Pacific Division of the American Association for the Advancement of Science, San Francisco.

Bjornn, T. C. 1971. Trout and salmon movements in two Idaho streams as related to temperature, food, streamflow, cover, and population density. Transactions of the American Fisheries Society 100:423–438.

Bottom, D. L., C. A. Simenstad, J. Burke, A. M. Baptiste, D. A. Kay, K. K. Jones, E. Casillas, and M. H. Schiewe. 2005. Salmon at river's end: the role of the estuary in the decline of Columbia River salmon. NOAA Technical Memorandum NMFS-NWFSC-68.

Bradford, M. J. 1997. An experimental study of stranding of juvenile salmonids on gravel bars and in side channels during rapid flow decreases. Regulated Rivers 13(5):95–401.

Bradford, M. J., and P. S. Higgins. 2001. Habitat-, season-, and size-specific variation in diel activity patterns of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*Oncorhynchus mykiss*). Canadian Journal of Fisheries and Aquatic Sciences 58:365–374.

Brandes, P. L., and J. S. McLain. 2001. Juvenile Chinook salmon abundance, distribution, and survival in the Sacramento–San Joaquin Estuary. California Department of Fish and Game Fish Bulletin 179(2): 39–138.

Brown, T. G. 2002. Floodplains, flooding, and salmon rearing habitats in British Columbia: a review. Canadian Science Advisory Secretariat, Research Document 2002/007. Available: http://www.dfo-mpo.gc.ca/Library/274333.pdf. (May 2005)

Clark, J. 1968. Seasonal movements of striped bass contingents of Long Island Sound and the New York Bight. Transactions of the American Fisheries Society 97:320–343.

Everest, F. H., and D. W. Chapman. 1972. Habitat selection and spatial interaction by juvenile Chinook salmon and steelhead trout in two Idaho streams. Journal of the Fisheries Research Board of Canada 29(1):91–100.

Haddon, M. 2001. Modelling and quantitative methods in fisheries. Chapman and Hall–CRC, Boca Raton, Florida.

Healey, M. C. 1991. Life history of Chinook salmon. Pages 311–394 *in* C. Groot and L. Margolis, editors. Pacific salmon life histories. UBC Press, Vancouver.

Higgins, P. S., and M. J. Bradford. 1996. Evaluation of a large-scale fish salvage to reduce the impacts of controlled flow reduction in a regulated river. North American Journal of Fisheries Management 16: 666–673.

Junk, W. J., P. B. Bayley, and R. E. Sparks. 1989. The flood pulse concept in river–floodplain systems. Canadian Special Publication of Fisheries and Aquatic Sciences 106:110–127.

Kimmerer, W. J. 2002. Physical, biological, and management responses to variable freshwater flow into the San Francisco estuary. Estuaries 25:1275–1290.

Kjelsen, M. A., P. F. Raquel, and F. W. Fisher. 1982. Life history of all-run juvenile Chinook salmon, *Oncorhynchus tshawytscha*, in the Sacramento–San Joaquin Estuary, California. Pages 393–411 *in* V. S. Kennedy, editor. Estuarine comparisons. Academic Press, New York.

Levy, D. A., and T. G. Northcote. 1982. Juvenile salmon residence in a marsh area of the Fraser River estuary. Canadian Journal of Fisheries and Aquatic Sciences 39:270–276.

Marchetti, M. P., and P. B. Moyle. 2001. Effects of flow regime on fish assemblages in a regulated California stream. Ecological Applications 11:530–539.

Mount, J. F. 1995. California's rivers and streams: the conflict between fluvial process and land use. University of California Press, Berkeley.

Newman, K. B., and J. Rice. 2002. Modeling the survival of Chinook salmon smolts out-migrating through the lower Sacramento River system. Journal of the American Statistical Association 97:983–993.

Nichols, F. H., J. E. Cloern, S. N. Luoma, and D. H. Peterson. 1986. The modification of an estuary. Science 231:567–573.

Power, M. E., A. Sun, G. Parker, W. E. Dietrich, and J. T. Wootton. 1995. Hydraulic food-chain models: an approach to the study of food-web dynamics in larger rivers. Bioscience 45:159–167.

Roper, B., D. L. Scarnecchia, and T. J. La Marr. 1994.

Summer distribution of and habitat use by Chinook salmon and steelhead within a major basin of the South Umpqua River, Oregon. Transactions of the American Fisheries Society 123(3):298–308.

Roper, B., and D. L. Scarnecchia. 1996. A comparison of trap efficiencies for wild and hatchery age-0 Chinook salmon. North American Journal of Fisheries Management 16:214–217.

Scrivener, J. C., T. G. Brown, and B. C. Anderson. 1994. Juvenile Chinook salmon (*Oncorhynchus tshawytscha*) utilization of Hawks Creek, a small and nonnatal tributary of the upper Fraser River. Canadian Journal of Fisheries and Aquatic Sciences 41:1139–1146.

Secor, D. H. 1999. Specifying divergent migrations in the concept of stock: the contingent hypothesis. Fisheries Research 43:13–34.

Shreffler, D. K., C. A. Simenstad, and R. M. Thom. 1992. Juvenile salmon foraging in a restored estuarine wetland. Estuaries 15:204–213.

Sommer, T. R., W. C. Harrell, A. Mueller-Solger, B. Tom, and W. J. Kimmerer. 2004. Effects flow variation on the channel and floodplain biota and habitats of the Sacramento River, California, USA. Aquatic Conservation: Marine and Freshwater Ecosystems 14:247–261.

Sommer, T. R., W. C. Harrell, M. Nobriga, R. Brown, P. B. Moyle, W. J. Kimmerer, and L. Schemel. 2001a. California's Yolo Bypass: evidence that flood control can be compatible with fish, wetlands, wildlife, and agriculture. Fisheries 26(8):6–16.

Sommer, T. R., M. L. Nobriga, W. C. Harrell, W. Batham, and W. J. Kimmerer. 2001b. Floodplain rearing of juvenile Chinook salmon: evidence of enhanced growth and survival. Canadian Journal of Fisheries and Aquatic Sciences 58:325–333.

Sparks, R. E. 1995. Need for ecosystem management of large rivers and their floodplains. Bioscience 45: 168–182.

Spranza, J. J., and E. H. Stanley. 2000. Condition, growth, and reproductive styles of fishes exposed to different environmental regimes in a prairie drainage. Environmental Biology of Fishes 59(1): 99–109.

Swales, S., and C. D. Levings. 1989. Role of off-channel ponds in the life cycle of coho salmon (*Oncorhynchus kisutch*) and other juvenile salmonids in the Coldwater River, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 46:232–242.

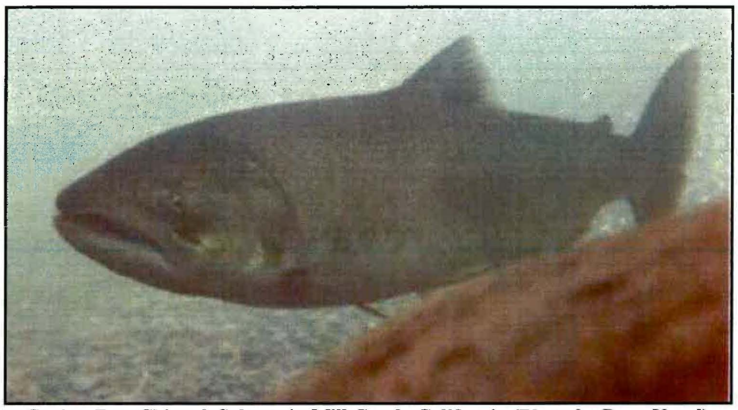
Swales, S., R. B. Lauzier, and C. D. Levings. 1986. Winter habitat preferences of juvenile salmonids in two interior rivers in British Columbia. Canadian Journal of Zoology 64:1506–1514.

Ward, J. V., and J. A. Stanford. 1995. Ecological connectivity in alluvial river ecosystems and its disruption by flow regulation. Regulated Rivers: Research and Management 11:105–119.

Welcomme, R. L. 1979. Fisheries ecology of floodplain rivers. Longman Group Limited, London.

Yoshiyama, R. M., E. R. Gerstung, F. W. Fisher, and P. B. Moyle. 2000. Chinook salmon in the California Central Valley: an assessment. Fisheries 25(2):6–20.

Insights into the
Problems, Progress, and Potential Solutions
for Sacramento River Basin Native Anadromous Fish Restoration



Spring-Run Chinook Salmon in Mill Creek, California (Photo by Dave Vogel)

April 2011

Prepared for:

Northern California Water Association
and
Sacramento Valley Water Users

Prepared by:

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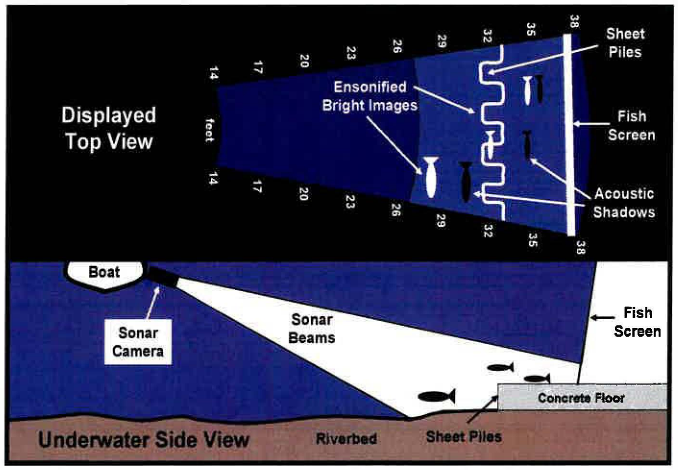

Figure 60. Schematics of DIDSON™ imaging at the base of a flat-plate fish screen. Bottom diagram shows orientation of sonar beams from the acoustic camera off the side of a boat and submerged objects at the fish screens. Top diagram shows the resultant corresponding sonar imaging of objects ensonified with acoustic shadows from the objects. (from Vogel 2008b)

From 1996 through 2010, Natural Resource Scientists, Inc. conducted 22 separate research projects on juvenile salmon (including four studies of predatory fish) in the Delta using acoustic or radio telemetry as a means to gain an improved understanding of fish movements and mortality (Vogel 2010a). The reason juvenile salmon telemetry studies were initiated in the Delta was to acquire detailed data on fish behavior, fish route selection through complex channels, and estimate fish survival in discrete reaches. Past efforts using traditional coded-wire tagging could not answer those critically important questions. Research findings from the telemetry investigations indicate that smolt survival assumptions and models must incorporate these new conclusions to avoid misinterpretation of data and improve quantitative estimates of fish survival and movements (Vogel 2010a).

The first successful use of telemetry on juvenile salmon in the Central Valley was conducted by Natural Resource Scientists, Inc. on behalf of EBMUD in 1996 and 1997. At that time, the specific behavior of juvenile salmon in the Delta was largely unknown. The initial studies quickly determined that the fish did not move as a school, but instead, dispersed, exhibiting a wide range in migratory behaviors in the complex Delta environment. Salmon moved many miles back and forth each day with the ebb and flood tides and the side channels (where flow was minimal) were largely unused. Site-specific hydrodynamic conditions present at flow splits when the fish arrived had a major affect in initial route selection. Importantly, some of the salmon were believed to have been preyed upon based on very unusual behavior patterns (Vogel 2010a).

Subsequent, additional juvenile salmon telemetry studies were conducted by Natural Resource Scientists Inc. on behalf of the USFWS and CALFED in the north Delta (Vogel 2001, Vogel 2004). Triangulating radio-tagged fish locations in real time (Figure 61) clearly demonstrated how juvenile salmon move long distances with the tides and were advected into regions with very large tidal prisms, such as upstream into Cache Slough and into the flooded Prospect and Liberty Islands (Figure 62). During the studies, it was determined that some radio-tagged salmon were eaten by predatory fish in northern Cache Slough, near the levee breaches into flooded islands (discussed below). Also, monitoring telemetered fish revealed that higher predation occurred in Georgiana Slough as compared to the lower Sacramento River (Figure 63). As discussed previously, past coded-wire tagging studies found that salmon released into northern Georgiana Slough were found to have a higher mortality rate than fish released downstream of the slough in the Sacramento River (Brandes and McLain 2001).

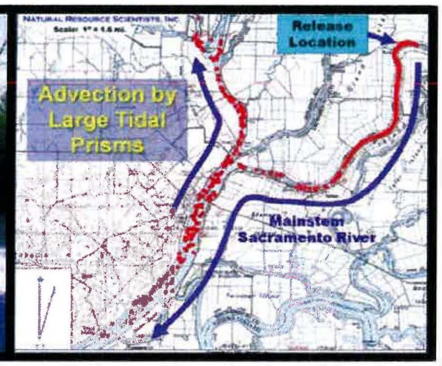

Figure 61. Left picture, mobile telemetry conducted in the north Delta. Photo by Dave Vogel.
Figure 62. Right picture, telemetered locations of approximately 100 radio-tagged salmon smolts released in the lower Sacramento River near Ryde (data from Vogel 2001 and Vogel 2004).

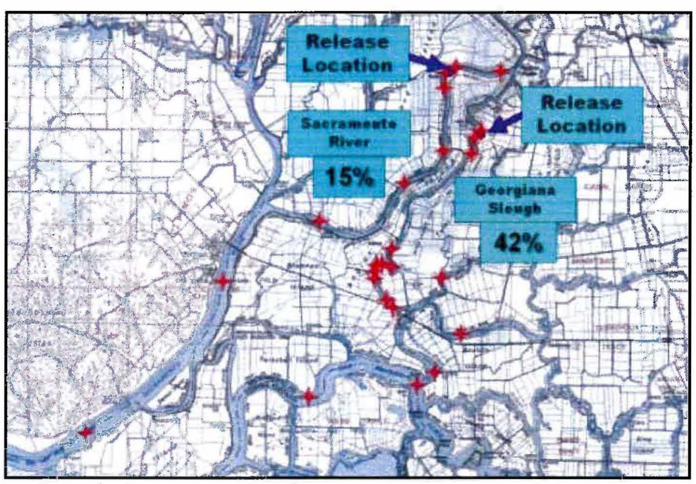

Figure 63. Estimated mortality rate for groups of radio-tagged salmon released at two locations in the north Delta and locations where radio-tagged salmon smolts were detected to have been preyed upon (Vogel 2001, Vogel 2004).

More recently, a 2007 study conducted by releasing acoustic-tagged juvenile salmon in the San Joaquin River found 116 motionless juvenile salmon transmitters in the lower San Joaquin River near the Stockton Waste Water Treatment Plant and a nearby bridge (Figure 64) (Vogel 2007b). This was an all-time record for the largest number of dead radio- or acoustic-telemetered juvenile vegetation at some sites in the Delta and water clarity. Increased water clarity for sight predators such as black bass and striped bass would presumably favor predatory fish over prey (*e.g.*, juvenile salmon). Fewer native fish species are found in *Egeria* stands compared to introduced fish species (Grimaldo and Hymanson 1999). Additionally, it has been hypothesized that high densities of *Egeria* in portions of the Delta may restrict juvenile salmon access to preferred habitats, forcing salmon to inhabit deep water or channel areas where predation risks may be higher (Grimaldo *et al.* 2000).

During recent years, there has been an emphasis to reclaim or create shallow, tidal wetlands to assist in re-recreating the form and function of ecosystem processes in the Delta with the intent of benefitting native fish species (Simenstad *et al.* 1999). Among a variety of measures to create such wetlands, Delta island levees either have been breached purposefully or have remained unrepaired so the islands became flooded. A recent example is the flooding of Prospect Island which was implemented under the auspices of creating shallow water habitat to benefit native fish species such as anadromous fish (Christophel *et al.* 1999). Initial fish sampling of the habitat created in Prospect Island suggested the expected benefits may not have been realized due to an apparent dominance of non-native fish (Christophel *et al.* 1999). Importantly, a marked reduction of sediment load to the Delta in the past century (Shvidchenko *et al.* 2004) has implications in the long-term viability of natural conversion of deep water habitats on flooded Delta islands into shallow, tidal wetlands. The very low rates of sediment accretion on flooded Delta islands indicate it would take many years to convert the present-day habitats to intertidal elevations which has potentially serious implications for fish restoration (Nobriga and Chotkowski (2000) due to likely favorable conditions for non-salmonid fish species that can prey on juvenile salmon. Studies of the shallow water habitats at flooded Delta islands showed that striped bass and largemouth bass represented 88 percent of the individuals among 20 fish species sampled (Nobriga *et al.* 2003).

There have likely been significant adverse, unintended consequences of breaching levees in the Delta. There is a high probability that site-specific conditions at the breaches have resulted in hazards for juvenile anadromous fish through the creation of favorable predator habitats. The breaches have changed the tidal prisms in the Delta and can change the degree in which juvenile fish are advected back and forth with the tides (Figure 61; previously discussed). Additionally, many of the breaches were narrow which have created deep scour holes favoring predatory fish. Sport anglers are often seen fishing at these sites during flood or ebb tides. Breaching the levees at Liberty Island is an example (Figure 72 and 73). Recent acoustic-tagging of striped bass in this vicinity confirmed a high presence of striped bass (Figure 74, D. Vogel, unpub. data).

Figure 72. Liberty Island in the north Delta before and after flooding.

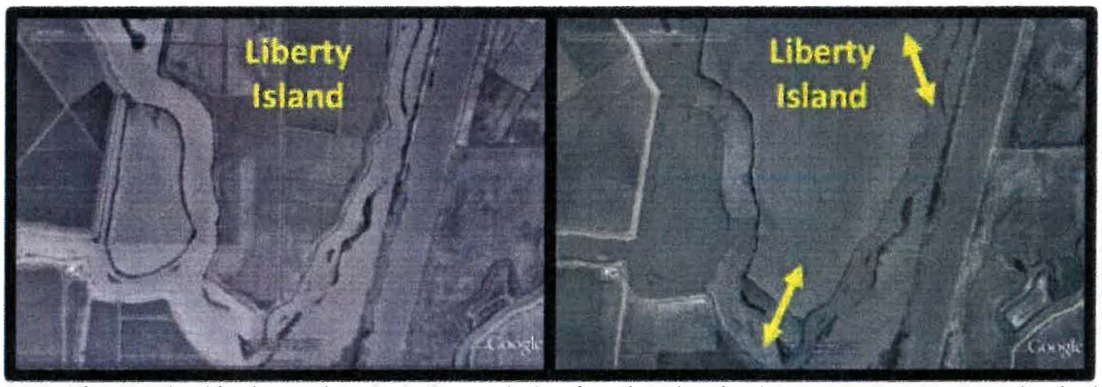

Figure 73. Liberty Island in the north Delta before and after flooding showing locations of narrow breaches in the levee.

Figure 74. Locations (squares) where predatory striped bass were acoustic-tagged with transmitters during the winter of 2008 – 2009 in the north Delta near Liberty Island (D. Vogel, unpublished data).

Letter 11
Contra Costa Water District

CONTRA COSTA
WATER DISTRICT

February 14, 2020

Heather Green
Senior Environmental Scientist
California Department of Water Resources
3500 Industrial Blvd.
West Sacramento, CA 95691

Subject: Comments on the Lookout Slough Tidal Habitat Restoration and Flood Improvement Project Draft Environmental Impact Report.

Dear Ms. Green:

Contra Costa Water District (CCWD) appreciates the opportunity to provide comments on the Draft Environmental Impact Report (DEIR) for the Lookout Slough Tidal Habitat Restoration and Flood Improvement Project (Project). CCWD is concerned that the environmental impacts of the Project have not been fully and properly evaluated.

CCWD provides water diverted at its four intakes in the Sacramento-San Joaquin Delta to approximately 500,000 people in Contra Costa County. Changes in water quality at CCWD intakes, even in the absence of exceedances of State Water Resources Control Board Decision 1641 water quality objectives, can impact CCWD's water supply and the water quality served to our customers.

Since 2011, CCWD has written comment letters on at least seven other habitat restoration projects in the Delta,[1] many of which have been managed by the Department of Water Resources. As we have stated in the past, CCWD supports habitat restoration in the Delta, but such projects must be planned and implemented in such a way as to minimize and mitigate impacts to other water users and beneficial uses in the Delta. In order to ensure that impacts are minimal and avoided, we continue to advocate for the following approach for this Project and other habitat restoration projects:

[1] The projects CCWD has commented on include:
2011 Suisun Marsh Habitat Management, Preservation, and Restoration Plan Environmental Impact Statement/ Environmental Impact Report
2013 Notice of Preparation for the Prospect Island Tidal Habitat Restoration Project
2013 Initial Study/Mitigated Negative Declaration for the Mallard Farms Conservation Bank
2014 Dutch Slough Tidal Marsh Restoration Project Supplemental Environmental Impact Report
2014 Initial Study/Mitigated Negative Declaration for the Honker Bay Conservation Bank
2015 Tule Red Addendum to the Suisun Marsh Habitat Management, Preservation, and Restoration Plan Environmental Impact Statement/Environmental Impact Report
2016 Decker Island Restoration Project Initial Study/Mitigated Negative Declaration

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1. Evaluate potential salinity impacts on drinking water intakes in the Delta by simulating the Project alternatives under a range of hydrologic conditions using an appropriate hydrodynamic model such as the RMA model.
2. Evaluate the cumulative salinity impacts of the preferred alternative with other planned habitat restoration projects in the Delta using an appropriate hydrodynamic model such as the RMA model.
3. Refine design configuration of the preferred alternative (levee breach location, habitat type, depth of channels, etc.) to minimize potential salinity impacts.
4. Disclose the potential impacts and the modeling analyses used to substantiate the determinations of the impact analyses in the environmental document. 11-1
5. Include appropriate measures, when necessary, to mitigate for salinity impacts on an individual and cumulative basis as is required under CEQA. A commitment to implement individual projects in such a manner (location, design, and phasing) such that the net cumulative salinity impacts are minimized could be one such measure.

The assessment of the potential water quality impacts of the Project in the DEIR is not adequate, so the DEIR does not fully disclose the environmental impacts of the Project and does not offer appropriate mitigation. The deficiencies in the DEIR that are described in the attachment to this letter must be corrected.

Response 11-1:

See Master Response 1, *Salinity and Bromide*.

CCWD would be happy to meet with you to discuss these comments further. If you have any questions or comments, please contact me at (925) 688-8323 or mmartin@ccwater.com.

Sincerely,

Maureen Martin

Maureen Martin
Special Projects Manager SR/MM:wec
Attachment

Inadequacies of the Lookout Slough Tidal Habitat Restoration and Flood Improvement Project Draft EIR

The DEIR states on Page IV. G-22 that modeling conducted by RMA predicts that the Project reduces salinity, as measured in monthly averaged electrical conductivity (EC), at CCWD's Mallard Slough Intake by up to 1.2 percent, and that salinity at all other CCWD intakes is predicted to increase by up to 1.6 percent for at least one month per year, particularly in the fall. This increase in monthly-averaged salinity has the potential to significantly impact CCWD real-time operations. Almost all of CCWD's diversions occur at the Rock Slough Intake, Old River Intake, and Middle River Intake at Victoria Canal, and CCWD uses the Mallard Slough Intake infrequently due to high salinity, so the improvement in Mallard Slough salinity does not offset the salinity impacts at CCWD's other intakes.

More detailed discussion and analysis of the results of the hydrodynamic modeling at CCWD's intakes were not provided in the DEIR. CCWD appreciates that the RMA modeling results for salinity at CCWD's intakes were shared upon request to allow CCWD to conduct our own further analysis. However, analysis and discussion such as on the validity of the model, modeling assumptions, and modeled water quality impacts, should have been included in the DEIR to disclose potential water quality impacts. 11-2

Upon examination of the modeling data provided, CCWD noted two inadequacies:

- The modeled baseline (existing conditions) salinity at CCWD intakes is biased lower (7.8 percent) at Mallard Slough and biased higher at the Rock Slough, Old River (7.1 percent) and Victoria Canal (4.5 percent) intakes compared to actual salinity measurements (see attached Figure 1). This model bias should be corrected, or at least explained.

- The modeled period was 2009, a dry year. It is not clear that the full range of potential water quality impacts are represented in a single dry year. Additional modeling over a range of water year types should be conducted and analysis of water quality impacts provided.

Response 11-2:

The RMA hydrodynamic and electrical conductance (EC) modeling was revised and extended in response to comments on the Draft EIR and the revised modeling is documented in Appendix X of this Final EIR. As shown in Appendix X, Table 1, the coefficients of determination between predicted and observed EC for the four locations cited by CCWD (Mallard Slough, Rock Slough, Old River, and Victoria Canal) are 0.91 or higher, indicating that the model's predictions replicate 91% or more of the variance in the observed EC. Details about the models calibration can be found in Appendix B of Appendix X. This level of replication of observed variance is deemed to be sufficient for the overall modeling approach. This approach is to characterize the potential impacts of the Proposed Project on EC, salinity, and bromide by comparing the differences between modeling with and without the Proposed Project. As shown in Figure 1 of this letter and as shown in the revised model figures evaluating water quality impacts at the CCWD compliance stations (Appendix X, Figures 21, 28, 29, 30, 35, 42, 43, and 44), the differences between with and without the Proposed Project are typically smaller than the differences between observed and predicted conditions that are raised in the comment. Therefore, the conclusions drawn from the modeling are sufficient for the significance conclusion of less than significant in the Draft EIR.

Regarding the years selected for modeling, as well as for additional detail on the EC modeling approach, calibration, and accuracy, see Master Response 1, *Salinity and Bromide*.

In addition, the cumulative effect of the Project on Delta salinity in combination with other planned tidal wetland restoration projects is at times an increase of greater than 8 percent in EC, as stated on page 6 of Appendix S. This cumulative increase by itself and in the context of future climate change and projected sea level rise has the potential to significantly impact CCWD operations. There was no analyses conducted to evaluate future climate change and projected sea level rise with the Project and cumulative impacts which must be analyzed and reported. 11-3

Response 11-3:

See Master Response 1, *Salinity and Bromide* for clarification and addition information on cumulative impacts and sea level rise effects related to EC.

The Project considered a "No Channel Design" Alternative, which entails not constructing over 20 miles of tidal channel network throughout the Project interior. The DEIR states that the No Channel Alternative was not selected because this does not meet the goal of habitat creation (Page VII-13), even though the DEIR acknowledges this as the environmentally superior alternative (Page VII-33). The DEIR states the No Channel Alternative design would have minimal impacts on salinity (Page VII-20), but the No Channel Alternative was not among those evaluated in the water quality modeling in Appendix S of the DEIR, so it is not possible to validate this claim. If the No Channel Alternative has a lower impact on salinity compared to the proposed project, then a fuller evaluation of this alternative, or a modification of this alternative that would meet the habitat creation goals of this Project, should be included in the DEIR. 11-4

Response 11-4:

The goals and objectives of this Proposed Project are set forth beginning on page III-21 in Chapter III, *Project Description* of the Draft EIR. Two of the three overarching goals relate to habitat: the first is to "[c]reate and maintain a diverse landscape of intertidal and associated subtidal habitat that supports habitat elements for native species and improved food productivity within the Project area" and the second is to "[d]esign and implement a Project that also supports viable populations of special-status aquatic and terrestrial species." The No Channel Alternative was found to only partially meet four of the Proposed Project's objectives. In addition, habitat creation is a fundamental purpose of the Proposed Project, and the No Channel Alternative would not "[p]romote suitable spawning habitat with appropriate water velocities and depths accessible for Delta Smelt within the Proposed Project Site and the immediate tidal sloughs surrounding the Proposed Project Site," as discussed on page VII-16 of the Draft EIR. For these reasons, DWR did not carry the potential "No Channel Design" Alternative forward for more detailed consideration.

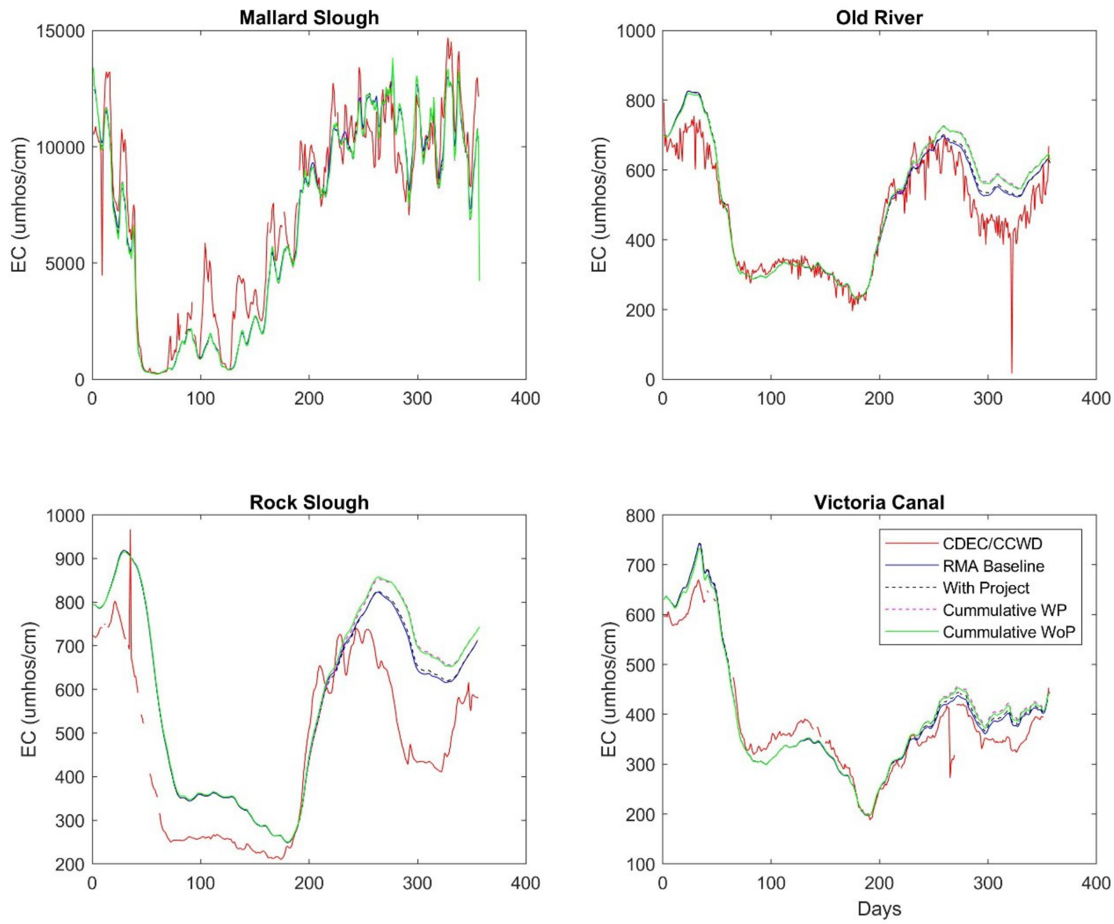

Figure 1. Comparison of RMA baseline (existing conditions) with CDEC/CCWD 2009 EC. RMA with project, cumulative with project (WP) and cumulative without project (WoP) are also displayed.

Letter 12
Downey Brand on behalf of RD 2060, RD 2068, California Central Valley Flood Control Association, North Delta Water Agency

Letter 12

DOWNEYBRAND

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February 14, 2020

VIA E-MAIL

Attn: Heather Green
California Department of Water Resources
3500 Industrial Blvd
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E-Mail: FRPA@water.ca.gov

Re: Comments on Lookout Slough Draft Environmental Impact Report

Dear Ms. Green:

On behalf of Reclamation District No. 2060 (RD 2060), Reclamation District No. 2068 (RD 2068), the California Central Valley Flood Control Association (Association), and the North Delta Water Agency (NDWA), I am submitting comments on the California Department of Water Resources' (DWR) Draft Environmental Impact Report (DEIR) for the Lookout Slough Tidal Habitat Restoration and Flood Improvement Project (Project). While we are supportive of the Project's dual goals of habitat restoration and flood control enhancement, we have serious concerns regarding the DEIR's evaluation of the Project's environmental impacts under the California Environmental Quality Act (CEQA), in particular the Project's acknowledged impacts on the operations and maintenance (O&M) practices of the reclamation districts and agricultural diversions that are within the vicinity of the proposed Project.

NDWA has a statutory responsibility to ensure that the lands within its boundaries in the North Delta have a dependable supply of quality water. The Association represents over 75 agencies with the mission of promoting rural and urban flood management issues in the Central Valley. RD 2060 and RD 2068 provide flood control services to landowners within their respective districts and RD 2068 also provides water service. All four agencies are located in close proximity to the Project area, and thus are concerned about the impacts the Project will have on their own operations and the local environment.

A. The DEIR Contains Inconsistent Statements Concerning Whether the Project Is a Public DWR Project or a Private EIP Project.

The Project Description states that DWR is "the state agency carrying out the Proposed Project" and that DWR obligated to restore tidal marsh acreage as directed by Biological Opinions (BiOps) issued by the U.S. Fish and Wildlife Service and National Marine Fisheries Service in 2008 and 2009, respectively. (DEIR, pp. I-2, III-20-21.) However, the EIR identifies Ecosystem Investment Partners (EIP), as the "Applicant" carrying out the Project. (DEIR, p. VIII-2.) In this way, the DEIR is internally inconsistent as to which entity is the project proponent, for what is inarguably a public project. This foundational flaw in the DEIR not only deprives the public of an understanding of who is carrying out the project, but also infects other portions of the DEIR related to required mitigation.

A lead agency is defined as "the public agency which has the principal responsibility for carrying out or approving a project." (Guidelines, § 15367.)[1] A "'private project' means a project which will be carried out by a person other than a governmental agency, but the project will need a discretionary approval from one or more governmental agencies." (Guidelines, § 15377.) An applicant is defined as "a person who proposes to carry out a project which needs a lease, permit, license, certificate, or other entitlement for use or financial assistance from one or more public agencies when that person applies for the governmental approval or assistance." (Guidelines, § 15351.) If EIP is simply the entity hired by DWR to carry out a DWR project, that does not mean EIP is carrying out the project for purposes of CEQA analysis and mitigation responsibility. The distinction is important.

It is the lead agency that must "adopt a program for monitoring or reporting," and the "the lead agency remains responsible for ensuring that implementation of the mitigation measures occurs in accordance with the program." (Guidelines, § 15097.) DWR "may delegate reporting or monitoring responsibilities to a ... private entity which accepts the delegation," but it cannot transfer responsibility over mitigation to that party. (*Id.*) Mitigation Measures AG-1b, AIR-1, AIR-2, BIO-2, BIO-5B, BIO-5G, BIO-6, and HAZ-1 improperly place responsibility on third parties (i.e., construction contractors, EIP, or an unspecified entity) to implement mitigation measures. While DWR can contract with EIP or other entities to carry out or perform work required in mitigation measures, DWR remains responsible for mitigation of its own public project under CEQA. The EIR must be revised to clearly define the roles of DWR and EIP, and revise all mitigation measures to clarify that DWR is responsible for ensuring such mitigation measures are carried out. 12-1

Similarly, as the lead agency under CEQA, DWR must make decisions regarding the feasibility of specific mitigation measures. (See Pub. Resources Code, § 21002; Guidelines, § 15126.4(a).) The DEIR delegates authority for determining feasibility to EIP in certain mitigation measures. For example, Mitigation Measure AIR-1(b) allows either DWR or EIP to waive equipment requirements under unusual circumstances, including if it is technically infeasible to find a piece of off-road equipment that meets those requirements. (DEIR, p. II-16.) In BIO-5G, EIP is to implement avoidance activities for Valley Elderberry Longhorn Beetle "to the extent feasible." (DEIR, p. II-31.) This puts the responsibility to determine feasibility of a particular part of a mitigation measure in EIP's hands rather than DWR. The DEIR, and its mitigation measures, should be revised to ensure that DWR as lead agency and the project proponent, not EIP, has sole responsibility for determining whether a mitigation measure is feasible.

FOOTNOTE 1 The CEQA Guidelines are found in title 14 of the California Code of Regulations, beginning at section 15000.

Response 12-1:

On page I-1 in Chapter I, *Introduction*, the Draft EIR states that DWR is the Lead Agency under CEQA for the Proposed Project. The Final EIR makes it clear that the Proposed Project is a “project” under Public Resources Code Section 21065, which is an activity that may cause a direct physical change in the environment and would be undertaken by DWR, a public agency. As such DWR is responsible for determining the adequacy of the EIR and providing that mitigation measures are fully enforceable. DWR’s role has been clarified in the EIR. EIP is the current owner of the Proposed Project property. Agreements that DWR may or will have with EIP or other entities with regard to planning or carrying out the Proposed Project are not relevant to the environmental analysis in the EIR. Mitigation Measures AIR-1(b), BIO-5(g), and additional clarifying text in the Draft EIR have been revised.

In response to the comment, the text in paragraph five on page I-2 and paragraph 1 on page I-3 in Chapter I, *Introduction*, has been revised to state:

> “This Draft EIR was prepared by WRA, Inc. (WRA), an environmental consultant (CEQA Guidelines, Section 15084(d)(2)). DWR has the principal responsibility for approving and implementing the project and for certifying that CEQA requirements have been met, including exercising independent judgement and analysis. EIP is a contractor to DWR, and may implement mitigation measures for the Proposed Project that do not restrict DWR’s discretion over the Project. The Proposed Project is intended to achieve DWR’s stated goals and objectives. Lists of personnel who assisted in preparing the EIR as well as organizations and persons consulted on the EIR are provided in Section VIII (Preparers of the EIR and Persons Contacted).”

The following text in paragraph five on page IV.A-19 and paragraph 1 on page IV.A-20 in Chapter IV.A, *Impacts Found to be Less than Significant*, of the Draft EIR has been revised to state:

> “DWR~~EIP~~ proposes levee modifications, tidal channel excavation, and other activities which would restore tidal marsh complex and improve Yolo Bypass flood conveyance within the Proposed Project Site.”

The following text in paragraph five on page IV.A-19 in Chapter IV.A, *Impacts Found to be Less than Significant*, of the Draft EIR has been revised to state:

> “i. *Direct and indirect inducement of substantial unplanned population growth*
>
> DWR ~~EIP~~ proposes levee modifications, tidal channel excavation, and other activities which would restore tidal marsh complex and improve Yolo Bypass flood conveyance within the Proposed Project Site.”

The following text on page IV.B-12 in Section IV.B, Agriculture and Forestry of the Draft EIR has been revised to state:

> “Mitigation Measure AG-1b: Agricultural Conservation Easement
>
> ~~The Applicant~~ DWR, shall cause to be established an off-site agricultural preserve by placing a conservation…”

The following text in fourth bulleted paragraph on page IV.C-13 in Section IV.C, *Air Quality*, of the Draft EIR has been revised to state:

Mitigation Measure AIR-1: Construction Equipment Standards

b) Engine Requirements

- ~~If commercially available, the~~All ~~engines of the~~ diesel off-road equipment shall have engines that meet the ~~USEPA or CARB~~ Tier 4 Final off-road emission standards, as certified by CARB. The equipment that shall use Tier 4 Final engines may include, but are not limited to: compactors, rollers, bulldozers, excavators, motor graders, scrapers equivalent to the Caterpillar 631K Wheel Tractor-Scraper model, and off-road haul vehicle~~truck~~s. This requirement shall be verified through submittal of an equipment inventory that includes the following information: (1) Type of Equipment, (2) Engine Year and Age, (3) Number of Years Since Rebuild of Engine (if applicable), (4) Type of Fuel Used, (5) Engine HP, (6) Verified Diesel Emission Control Strategy (VDECS) information if applicable and other related equipment data. A Certification Statement by the Contractor shall be required to be submitted to DWR, for documentation of compliance and for future review by the air district upon request. The Certification Statement must state that the Contractor agrees to compliance and acknowledges that a violation of this requirement shall constitute a material breach of contract.

- ~~Equipment requirements above may be waived by the project director of EIP or~~DWR may waive the equipment requirement above ~~, but~~ only under ~~any of~~ the following unusual or emergency circumstances: if a particular piece of off-road equipment with Tier 4 Final standards ~~or Tier 3 standards~~ is not technically feasible or not commercially available; the equipment would not produce desired emissions reductions due to expected operating modes; use or installation of the equipment would create a safety hazard or impaired visibility for the operator; or there is a compelling emergency need to use other alternate off-road equipment. ~~that does not meet the equipment requirements, abovethe project director of EIP or~~ If DWR grants the waiver based on one or more of the above unusual circumstances, the contractor shall use the next cleanest piece of off-road equipment available, as detailed in Table M-AIR-1 below~~the following order: Tier 4 Interim, Tier 3, and then Tier 2 engines~~.

For purposes of this mitigation measure, "commercially available" shall mean the availability of Tier 4 Final engines similar to the availability for other large-scale construction projects in the region occurring at the same time and taking into consideration factors such as (i) potential significant delays to critical-path timing of construction for the project and (ii) geographic proximity to the Proposed Project Site of Tier 4 Final equipment.

The Contractor shall maintain records concerning its efforts to comply with this requirement.

Table M-AIR-1A details the off road compliance step down approach. If engines that comply with Tier 4 Final off-road emission standards are not commercially available, then the Contractor shall meet Compliance Alternative 1. If off-road equipment meeting Compliance Alternative 1 are not commercially available, then the Project sponsor shall meet Compliance Alternative 2. If off-road equipment meeting Compliance Alternative 2 are not commercially available, then the Project sponsor shall meet Compliance Alternative 3 as demonstrated below.

TABLE M-AIR-1
OFF ROAD EQUIPMENT COMPLIANCE STEP DOWN APPROACH

Compliance Alternative	Engine Emissions Standard	Emissions Control
1	Tier 4 Interim	N/A
2	Tier 3	ARB Level 3 VDECS
3	Tier 2	ARB Level 3 VDECS

In seeking a waiver from this requirement it must be demonstrated to the satisfaction of DWR, that the total annual ROG and NOx emissions do not exceed a total of 10 tons per year. Additionally, it must also be demonstrated that the average daily PM10 emissions do not exceed 80 pounds per day for PM10 to meet YSAQMD's significance thresholds as stated in **Table IV.C-4 on the previous page**.

The following text on page IV.C-13 in Section IV.C, *Air Quality*, of the Draft EIR has been revised to state:

> "Mitigation Measure AIR-2: Dust Control
>
> ~~Contractors for construction of the Proposed Project~~ DWR shall implement all of the following applicable dust control measures:…"

The following text in the final paragraph in the fourth column on page II-16 and continuing onto page II-17 in Chapter II, *Executive Summary*, of the Draft EIR has been revised to state:

Impact #	Impact	Significance	Proposed Mitigation
AIR-i.	Would the project conflict with implementation of the applicable air quality plan?	Less than Significant with Mitigation	Mitigation Measure AIR-1: Construction Equipment Standards b) Engine Requirements • ~~If commercially available, the~~All ~~engines of the~~ diesel off-road equipment shall have engines that meet the ~~USEPA or CARB~~ Tier 4 Final off-road emission standards, as certified by CARB. The equipment that shall use Tier 4 Final engines may include, but are not limited to: compactors, rollers, bulldozers, excavators, motor graders, scrapers equivalent to the Caterpillar 631K Wheel Tractor-Scraper model, and off-road haul vehicles~~truck~~. This requirement shall be verified through submittal of an equipment inventory that includes the following information: (1) Type of Equipment, (2) Engine Year and Age, (3) Number of Years Since Rebuild of Engine (if applicable), (4) Type of Fuel Used, (5) Engine HP, (6) Verified Diesel Emission Control Strategy (VDECS) information if applicable and other related equipment data. A Certification Statement by the Contractor shall be required to be submitted to the project director of EIP and DWR, for documentation of compliance and for future review by the air district upon request. The Certification Statement must state that the Contractor agrees to compliance and acknowledges that a violation of this requirement shall constitute a material breach of contract.

Impact #	Impact	Significance	Proposed Mitigation
			(continued below)

- ~~Equipment requirements above may be waived by the project director of EIP or~~ DWR may waive the equipment requirement above ~~, but~~ only under ~~any of~~ the following unusual or emergency circumstances: if a particular piece of off-road equipment with Tier 4 Final standards ~~or Tier 3 standards~~ is not technically feasible or not commercially available; the equipment would not produce desired emissions reduction due to expected operating modes; installation of the equipment would create a safety hazard or impaired visibility for the operator; or there is a compelling emergency need to use other alternate off-road equipment. ~~that does not meet the equipment requirements, above~~. If ~~the project director of EIP or~~ If DWR grants the waiver based on one or more of the above unusual circumstances, the contractor shall use the next cleanest piece of off-road equipment available, as detailed in Table M-AIR-1 below~~the following order: Tier 4 Interim, Tier 3, and then Tier 2 engines~~.

For purposes of this mitigation measure, “commercially available” shall mean the availability of Tier 4 Final engines similar to the availability for other large-scale construction projects in the region occurring at the same time and taking into consideration factors such as (i) potential significant delays to critical-path timing of construction for the project and (ii) geographic proximity to the Proposed Project Site of Tier 4 Final equipment.

The Contractor shall maintain records concerning its efforts to comply with this requirement.

Table M-AIR-1A details the off road compliance step down approach. If engines that comply with Tier 4 Final off-road emission standards are not commercially available, then the Contractor shall meet Compliance Alternative 1. If off-road equipment meeting Compliance Alternative 1 are not commercially available, then the Project sponsor shall meet Compliance Alternative 2. If off-road equipment meeting Compliance Alternative 2 are not commercially available, then the Project sponsor shall meet Compliance Alternative 3 as demonstrated below.

TABLE M-AIR-1
OFF ROAD EQUIPMENT COMPLIANCE STEP DOWN APPROACH

Compliance Alternative	Engine Emissions Standard	Emissions Control
1	Tier 4 Interim	N/A
2	Tier 3	ARB Level 3 VDECS
3	Tier 2	ARB Level 3 VDECS

In seeking a waiver from this requirement it must be demonstrated, to the satisfaction of DWR, that the total annual ROG and NOx emissions do not exceed a total of 10 tons per year. Additionally, it must also be demonstrated that the average daily PM10 emissions do not exceed 80 pounds per day for PM10 to meet YSAQMD’s significance thresholds as stated in **Table IV.C-4 on the previous page**.

Mitigation Measure AIR-2: Dust Control

~~Contractors for construction of the Proposed Project~~ DWR shall implement all of the following applicable dust control measures:

In response to the comment, the following text in paragraph two on page IV.D-54 in Chapter IV.D, *Biological Resources*, has been revised as follows:

> **Mitigation Measure BIO-2. Special-Status Plant Avoidance, Preservation, and Re-Planting**
>
> "5) Performance shall be monitored to evaluate success of replacement of special-status species habitat. Target replacement shall be at a minimum 1:1 ratio of impacted to established habitat acreage for each of the directly impacted special-status plant species. Success would be considered achieved when an equal area of habitat is occupied at a plant density similar to pre-project conditions. Monitoring shall be conducted for a minimum of three growing seasons following initial planting or until performance has been achieved. If individuals of Mason's lilaeopsis are newly detected during pre-construction surveys in areas to be impacted by Proposed Project activities and DWR determines that complete avoidance is not feasible, ~~EIP~~DWR shall consult with CDFW prior to the start of construction to obtain authorization for project implementation and develop an appropriate type and amount of compensatory mitigation. Mitigation shall be provided at a minimum 1:1 ratio of impacted individuals to replanted; final mitigation ratios and other specific compensatory requirements shall be determined through consultation with CDFW.

In response to the comment, the following text in paragraph two in the fourth column on page II-20 in Chapter II, *Executive Summary*, has been revised to state:

Impact #	Impact	Significance	Proposed Mitigation
BIO-iii	Substantial adverse effects on special-status plant species	Less than Significant with Mitigation	Mitigation Measure BIO-2. Special-Status Plant Avoidance, Preservation, and Re-Planting 5) Performance shall be monitored to evaluate success of replacement of special-status species habitat. Target replacement shall be at a minimum 1:1 ratio of impacted to established habitat acreage for each of the directly impacted special-status plant species. Success would be considered achieved when an equal area of habitat is occupied at a plant density similar to pre-project conditions. Monitoring shall be conducted for a minimum of three growing seasons following initial planting or until performance has been achieved. If individuals of Mason's lilaeopsis are newly detected during pre-construction surveys in areas to be impacted by Proposed Project activities and DWR determines that complete avoidance is not feasible, ~~EIP~~DWR shall consult with CDFW prior to the start of construction to obtain authorization for project implementation and develop an appropriate type and amount of compensatory mitigation. Mitigation shall be provided at a minimum 1:1 ratio of impacted individuals to replanted; final mitigation ratios and other specific compensatory requirements shall be determined through consultation with CDFW. 6) If individuals of Mason's lilaeopsis are newly detected during preconstruction surveys in areas to be impacted by Proposed Project activities and DWR, determines that complete avoidance is not feasible, ~~the Applicant~~ DWR shall consult with CDFW prior to the start of construction to obtain authorization for project implementation and develop an appropriate type and amount of compensatory mitigation. Mitigation shall be provided at a minimum 1:1 ratio of impacted individuals to replanted; final mitigation ratios and other specific compensatory requirements shall be determined through consultation with CDFW.

See Response 2-17 for text changes to Mitigation Measure BIO-5B.

The following text in paragraph five on page IV.D-76 and paragraph 8 on page IV.D-77 in Chapter IV.D, *Biological Resources*, of the Draft EIR has been revised to state:

> **Mitigation Measure BIO-5~~F~~G. Valley Elderberry Longhorn Beetle**
>
> "Prior to Proposed Project Activities that would directly impact occupied elderberry shrubs ~~EIP~~ DWR shall implement the following to avoid impacts to Valley elderberry longhorn beetle (adapted from USFWS 201725):
>
> 1) Avoidance and Minimization: To the extent feasible, as determined by DWR, project activities within 165 feet of occupied elderberry shrubs shall be avoided. For all activities that occur within 165 feet of occupied elderberry shrubs, the following measures shall be implemented to ensure that avoidance activities completely avoid impacting elderberry shrub habitat for valley elderberry longhorn beetle:…
> 2) Transplanting: Where occupied elderberry shrubs cannot be avoided or indirect impacts nearby would result in the death of stems or entire shrubs, ~~EIP~~ DWR shall transplant all elderberry shrubs with stems greater than 1 inch in diameter, where DWR, determines feasible, to protect potential valley elderberry longhorn beetle larvae. In addition, ~~EIP~~ DWR shall use the following guidelines when transplanting elderberry shrubs to a USFWS-approved location: …"

The following text in the final paragraph in the fourth column on page II-31 and the final paragraph page II-32 in the fourth column, and continuing onto page II-33 in Chapter II, *Executive Summary*, of the Draft EIR has been revised as follows:

Impact #	Impact	Significance	Proposed Mitigation
BIO-v	Substantial adverse effects on special-status wildlife species, either directly or through habitat modification	Less than Significant with Mitigation	Mitigation Measure BIO-5G. Valley Elderberry Longhorn Beetle Prior to Proposed Project Activities that would directly impact occupied elderberry shrubs ~~EIP~~ DWR shall implement the following to avoid impacts to Valley elderberry longhorn beetle (adapted from USFWS 2017[25]): 1) Avoidance and Minimization: To the extent feasible, as determined by DWR, project activities within 165 feet of occupied elderberry shrubs shall be avoided. For all activities that occur within 165 feet of occupied elderberry shrubs, the following measures shall be implemented to ensure that avoidance activities completely avoid impacting elderberry shrub habitat for valley elderberry longhorn beetle: … 2) Transplanting: Where occupied elderberry shrubs cannot be avoided or indirect impacts nearby would result in the death of stems or entire shrubs, ~~EIP~~ DWR shall transplant all elderberry shrubs with stems greater than 1 inch in diameter, where DWR, determines feasible, to protect potential valley elderberry longhorn beetle larvae. In addition, ~~EIP~~ DWR shall use the following guidelines when transplanting elderberry shrubs to a USFWS-approved location: …

Regarding the comment that Mitigation Measure BIO-5G uses the language "to the extent feasible," regarding avoidance and minimization measures for Valley Elderberry Longhorn Beetle, Mitigation Measure BIO-5G further states on page IV.D-78, that "…if direct impacts cannot be avoided to elderberry shrubs or transplanting is not feasible, elderberry shrubs shall be replaced at a 3:1 ratio…" Therefore, Mitigation Measure BIO-5G meets the requirements of CEQA Guidelines Section 15126.4

The following text in paragraph three on page IV.D-81 in Chapter IV.D, *Biological Resources*, of the Draft EIR has been revised to state:

> **Mitigation Measure BIO-6. Special-Status Fish Species**
>
> "As part of the permitting process, consultation with USFWS, NMFS, and CDFW shall be completed and DWR shall implement all requirements in the Proposed Project Biological Opinions, Incidental Take Permit, Lake and Streambed Alteration Agreement, as well as water quality protection measures required in the Section 401 Water Quality Certification ~~will be implemented~~.

The following text in paragraph two in the fourth column on page II-34 in Chapter II, *Executive Summary*, of the Draft EIR has been revised as follows:

Impact #	Impact	Significance	Proposed Mitigation
BIO-vi	Substantial adverse effects on special-status fish species, either directly or through habitat modification	Less than Significant with Mitigation	Mitigation Measure BIO-6 Special-Status Fish Species Due to the potential for adverse impacts to listed and special-status fish species, consultation and permitting with the USFWS, NMFS, and CDFW is required. As part of the permitting process, consultation with USFWS, NMFS, and CDFW shall be completed and ~~the Applicant/~~DWR shall implement all requirements in the Proposed Project Biological Opinions, Incidental Take Permit, Lake and Streambed Alteration Agreement, as well as water quality protection measures required in the Section 401 Water Quality Certification.

The following text on page IV.F-15 in Section IV.F, *Hazards and Hazardous Materials* of the Draft EIR has been revised to state:

> "**d. Mitigation Measure HAZ-1: Natural Gas Well and Pipeline Abandonment and Avoidance**
>
> Prior to the start of construction, ~~EIP~~ DWR shall develop plans and procedures for natural gas well…"

B. The DEIR Does Not Fully Disclose, Analyze, or Mitigate Impacts Related to Agricultural Diversion and Reclamation District Water Supply Operations.

According to the DEIR, the Project would "create, restore, and maintain ideal habitat conditions to encourage the proliferation of Delta Smelt and other sensitive fish species associated with unrestricted tidal freshwater ecosystems in the Delta" and would also "[p]romote suitable spawning habitat with appropriate water velocities and depths accessible for Delta Smelt within the Proposed Project and the immediate tidal sloughs surrounding the Project Site." (DEIR, pp. II-2, III-22.) The DEIR, however, significantly downplays conflicts this will generate with O&M practices of the surrounding Reclamation Districts and agricultural diversions. 12-2

First, the DEIR's discussion concerning salinity and bromide does not reflect a reasonable, good faith disclosure and analysis as required by CEQA. (*Laurel Heights Improvement Assn. v. Regents of Univ. of Cal.* (1988) 47 Cal.3d 376 ("*Laurel Heights I*").) Changes in salinity and bromide will impact operation of agricultural users and the drinking water supply of municipal water suppliers in the vicinity of the Project. The DEIR's conclusion that impacts to municipal and agricultural water suppliers are less than significant is not supported by data, modeling, or analysis. (Guidelines, § 15384(b) [substantial evidence is defined as "facts, reasonable assumptions predicated upon facts, and expert opinion supported by facts."].) Additional discussion of the deficiencies in the DEIR's water quality analysis is provided in Section F below. 12-2 Cont.

Response 12-2:

The Lookout Slough Tidal Habitat Restoration and Flood Improvement Project is designed to achieve the three goals and associated objectives that are presented on Draft EIR page III-21. Goal 1 is to "[c]reate and maintain a diverse landscape of intertidal and associated subtidal habitat that supports habitat elements for native species and improved food productivity within the Project area." Objective 1.c. is to "[p]romote suitable spawning habitat with appropriate water velocities and depths accessible for Delta Smelt within the Proposed Project Site and the immediate tidal sloughs surrounding the Proposed Project Site."

The text on Draft EIR page II-2 in Chapter II, *Executive Summary* is revised as follows:

> **c. Project Objectives**
> ~~The Proposed Project would create, restore, and maintain ideal habitat conditions to encourage the proliferation of Delta Smelt and other sensitive fish species associated with unrestricted tidal freshwater ecosystems in the Delta. Restoration activities would provide spawning and rearing habitat for Delta smelt, which is on the brink of extinction in its natural habitat[1], and would serve to fulfil a portion of the Delta Smelt habitat mitigation required by the 2008 Delta Smelt Biological Opinion for the state Water Project and Central Valley Project (81420-2008-F-1481-5)[2].~~
>
> The goals and objectives of the Lookout Slough Tidal Habitat Restoration and Flood Improvement Project are listed below: …
>
> Please see also Master Response 1, *Salinity and Bromide*.

Second, it is unclear how the Project will account for impacts to fish species, including special status species, related to increasing endangered fish population density in an area with existing agricultural and municipal water diversions. Specifically, the DEIR does not analyze how the Project would make fish vulnerable to take via entrainment at longstanding water diversion facilities operated by other agencies, and whether this result in a need to relocate water facilities. As fish density increases, the risk of entrainment increases, and more individual fish may be subject to take water diversions than under existing conditions. However, the analysis in the DEIR is limited to the impacts that construction might have on fish species, and fails to acknowledge that the Project is proposing to increase fish habitat and population in an area where entrainment hazards exist—i.e., operational impacts. 12-3

Response 12-3:

Please see Master Response 3, *Local Water Diversions and Special-Status Fish Species*.

The threshold of significance for impacts to utilities and service systems under Appendix G of the Guidelines—the threshold applied in the DEIR—requires evaluation of "[r]elocation . . . of water . . . facilities." (DEIR, p. IV.A-21; Guidelines, Appx. G, XIX.) The DEIR's analysis of impacts under this threshold, *provides no analysis whatsoever* regarding the potential for the Project to result in a need to relocate existing water diversion facilities of surrounding agricultural and municipal water users. (DEIR, pp. IV.A-21-22.) Instead, the analysis only focuses on the other portion of the threshold related to the need for new or expanded facilities. (*Id.*) 12-4

Response 12-4:

See Master Response 3, *Local Water Diversions and Special-status Fish Species*. See also Master Response 9, *Tidal Effects on Diversions*.

The following text has been added to the Draft EIR on page III-34 to clarify that the Proposed Project would not require relocating water utilities:

> "… buildings, and storage units. <u>The Proposed Project would not remove, cause to be removed, or otherwise relocate water infrastructure, including diversions, located on property outside of the Proposed Project Site.</u> Approximate removal quantities are outlined in Table III-2."

The DEIR also fails to impose feasible mitigation measures to address both sets of impacts— impacts to fish at the Project site resulting from existing water diversion facilities, and impacts related to the need to relocate existing water facilities to avoid impacts to fish. Moreover, there are significant economic costs associated with either adjusting operations at these water intakes, adding screening devices to existing intakes, moving intakes to be further from endangered fish populations, or otherwise mitigating impacts to fish. These costs are not trivial and must be carefully considered when identifying and evaluating potential *feasible* mitigation measures. Where a Project's physical changes to the environment *cause* the economic or social impact, these impacts can be used to determine the significance of the physical change. (Guidelines, § 15131(b); see also *Christward Ministry v. Superior Court* (1986) 184 Cal.App.3d 180, 197.) CEQA also requires lead agencies to disclose and evaluate social or economic impacts of a project when such effects "directly or indirectly will lead to adverse physical changes in the environment." (*Bakersfield Citizens for Local Control v. City of Bakersfield* (2004) 124 Cal.App.4th 1184, 1205.) Analysis on both fronts is required here: how the Project's physical effects to the environment will cause economic or social impacts to agricultural and municipal water supplies, and how the Project will result in a need for agricultural and municipal water suppliers to modify operations, which in turn could lead to physical changes in the environment. Because impacts on local diverters were not disclosed or mitigated in the current DEIR, the DEIR must be revised and recirculated to disclose, evaluate, and mitigate these impacts. (Guidelines, § 15088.5; *Laurel Heights Improvement Assn. of San Francisco, Inc. v. Regents of the Univ. of Cal.* (1993) 6 Cal.4th 1112, 1130 ("*Laurel Heights II*").) 12-5

Response 12-5:

See Master Response 3, *Local Water Diversions and Special-Status Fish Species* and Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts*.

C. The DEIR Does Not Fully Disclose, Analyze, or Mitigate Increased Risks Associated with Flood Operations.

1. The DEIR fails to evaluate the Project's impacts on flooding, flood storage, and emergency access.

A project has the potential to cause environmental impacts where it may "[r]esult in inadequate emergency access" or "impede or redirect flood flows." (Guidelines, Appx. G, XVII, X.) The DEIR is essentially silent about the risks to flooding and changes in emergency access associated with the Project's construction and operation. The Project will result in the conversion of a county road (Liberty Island Road) into a full-height Federal Project Levee. This new levee is proposed to be capped by a gravel road; not by a road equipped for normal driving conditions. 12-6 This change imposes new risks on the adjoining district, RD 2068. First, the existing operations plan for RD 2068 provides that in the event of high water which outflanks the RD 2068 levee, the District will cut the Liberty Island Road embankment, allowing water to flow down into RD 2098, at which point another relief cut is made to allow water to flow back into the Delta. Such a cut reduces the backwater effect in the District, allowing more time for evacuation and reduced damages. The Project will directly impact these operations, increasing the time required to evacuate people in an emergency, and more challenging to evacuate the thousands of cattle in this portion of the District. These impacts must be disclosed, analyzed, and mitigated in the DEIR.

Response 12-6:

Please see Response 13-16.

The Project also proposes to make significant modifications to the flood storage capacity of U.S. Army Corps of Engineers Unit 109, which could result in the permanent loss of 40,000 acre-feet of storage. (DEIR, p. II-39.) The DEIR does not propose solutions to replace the potential loss of Unit 109 storage potential, nor does it propose mitigation for the removal of a potential 40,000 acre-foot loss of storage. 12-7 This represents a permanent and irreversible modification in the Unit 109 operation, performance and level of flood protection afforded Unit 109. This is a significant impact, but is not disclosed, analyzed, or mitigated in the DEIR.

Response 12-7:

Page II-39 in Chapter II, *Executive Summary* of the Draft EIR contains no reference to flood storage. It is not clear to what statement the comment is referring. The Unit 109 levee system is designed to protect 13,000 acres of land from flooding originating from the Yolo Bypass, Cache Slough, and Hass Slough. The interior of Unit 109 was not designed to be a flood storage system and therefore any incidental volume in this basin is not counted in the regional calculations for flood protection. The Draft EIR, however, makes it clear that the Proposed Project would *create* approximately 40,000 acre-feet or more of transitory flood storage in the Yolo Bypass through building a new improved Unit 109 levee, decreasing local flood elevations and improving reliability of the system (see page III-23 in Chapter III, *Project Description* of the Draft EIR). As such, the proposed modification would result in no adverse impacts to flood storage capacity.

2. The DEIR ignores the potential infeasibility of charging RD 2098 with responsibility for long-term operations and management of the Duck Slough Setback Levee.

The DEIR anticipates that RD 2098 would be responsible for implementing long-term operations and management of the Duck Slough Setback Levee, while DWR would be responsible for implementing long-term management and monitoring activities of the remainder of the Project site. It is unclear whether it is or will be feasible in the long run for RD 2098 to take over maintenance responsibility. The Project will reduce the acreage of farmable land in RD 2098, leaving little acreage and few landowners to meet the OMRR&R[2] obligations of RD 2098. DWR created a Levee Maintenance Agreement (LMA) budget spreadsheet as part of the supporting documents to the 2017 update to the Central Valley Flood Protection Plan. This spreadsheet is a tool to develop a budget for a LMA that addresses all of the things that should be considered to adequately budget for OMRR&R. The OMRR&R costs for the reconstituted RD 2098 should be calculated using this tool and it demonstrated that that residual property owners can bear that cost on a per acre basis. The DEIR should carefully consider whether RD 2098 will be capable, in the long term, of adequately implementing the mitigation set forth in the DEIR. (Guidelines, § 15364 ["'Feasible' means capable of being accomplished in a successful manner within a reasonable period of time, taking into account *economic*, environmental, legal, social, and technological factors"] [emphasis added].) It is important to note that failure to properly maintain this levee has consequences beyond Reclamation District No. 2098, as this key levee also provides protection to adjoining areas such as Reclamation District No. 2068. 12-8

If RD 2098 is not capable of conducting the required operation and management of Duck Slough Setback Levee, then the flood risk impacts this levee is intended to address remain significant and unavoidable. The DEIR must evaluate this risk. Alternatively, DWR might retain operation and management responsibility, which would ensure that the levee remains a viable mitigation measure. In that instance, the DEIR should be revised to clarify that DWR will retain responsibility for O&M on the Duck Slough Setback Levee. While it appears that certain modifications to the project or mitigation measures could address this issue, currently the DEIR is completely silent as to whether the issue even exists.

FOOTNOTE 2 OMRR&R stands for Operation, Maintenance, Repair, Replacement, and Rehabilitation.

Response 12-8:

See Master Response 7, *Operation and Maintenance (O&M) of Levees*.

3. The Project will remove the sole means of access to the RD 2068 pumping plant.

A related impact to flood operations is the Project's abandonment of Liberty Island Road and reduction of its capacity for truck and equipment traffic. According to Solano County, Liberty Island Road is a county road that cannot be removed as a public road unless properly abandoned under the law. The road is also the only route for trucks and equipment to reach a RD 2068 pumping plant as well as certain PG&E transmission equipment. The new gravel levee road is not designed to handle a significant level of truck or equipment traffic. No ramps have been proposed to allow truck traffic to get to key equipment. And the levee road would be particularly impassable for large equipment, such as a crane truck, during flood events when attention to the pumping plant or PG&E facilities could be urgent. 12-9

Response 12-9:

The Proposed Project would preserve emergency access for RD 2068 personnel during construction and operation via the existing Liberty Island Road alignment and via the proposed crown road of the Duck Slough Setback Levee. There are proposed access ramps up to the crown of the levee shown on sheets C313, C318, and C320 in Appendix D, *Lookout Slough Tidal Restoration and Flood Improvement Project – 65% Basis of Design Report* of the Draft EIR. Sheet C320 also illustrates a proposed ramp from the levee access road down to the RD 2068 levee north of the Project, which could be used to access the RD 2068 pumping plant. Furthermore, the proposed access roads, as well as any access road on top of the constructed levee, would be designed in accordance with U.S. Army Corps of Engineers (USACE) standards in order to support typical flood-fight and pump station maintenance vehicles. See also Responses 13-16, 13-17 and 19-8.

4. The DEIR identifies threats to levees from rodents, but fails to provide any mitigation reduce impacts.

The Project Description section of the DEIR identifies impacts from rodents such as ground squirrels and nutria, which “pose a threat to levee integrity.” (DEIR, p. III-48.) The DEIR states that “[a]n appropriate rodent and damage repair program would minimize impacts to levee integrity,” yet the DEIR does not provide any detail concerning such a program, nor is such program required as mitigation. Other sections of the DEIR similarly refer to a “rodent abatement” program being undertaken either by DWR or RD 2098, but nothing further is provided. (DEIR, p. IV.G-27, III-47.) Nutria in particular require attention in in the DEIR, and yet they receive no analysis whatsoever. The California Department of Fish and Wildlife provides information on the destruction that nutria cause to wetland habitats, agriculture, flood protection infrastructure, and native plant communities.[3] “Potential levee and dike failures due to nutria burrowing have serious implications for flood protection, water delivery, and agricultural irrigation in California.”[4] The DEIR failed to evaluate impacts associated with nutria and other rodents, both to levees and to habitat. While CEQA does not require evaluation of effects of the *environment* on the Project, the lead agency must evaluate the Project’s potential to increase rodents within the vicinity of the Project, as well as the potential for failure of the habitat and infrastructure being built as part of the Project based on known existing conditions. 12-10

FOOTNOTE 3 https://wildlife.ca.gov/Conservation/Invasives/Species/Nutria/Infestation

FOOTNOTE 4 *Id.*

Response 12-10:

The Proposed Project will not result in an increase in burrowing animals, including nutria. Nutria are not known to exist in the Cache Slough Complex or the North Delta.[1,2]

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[1] CDFW. 2020a. California’s Invaders: Nutria. *Myocastor coypus.* Available: https://wildlife.ca.gov/Conservation/Invasives/Species/Nutria. Accessed April 2020.

[2] CDFW. 2020b. Discovery of invasive nutria in California. Available: https://wildlife.ca.gov/Conservation/Invasives/Species/Nutria/Infestation. Accessed April 2020.

Maintenance activities prescribed for levees currently in existence surrounding the Proposed Project are defined under USACE Unit 109, West Levee of Yolo Bypass, and East Levee of the Cache Slough O&M Manual, as well as the U.S. Code of Federal Regulations, Title 33, Section 208.10 – Local flood protection works; maintenance and operation of structures and facilities (page III-47 of the Draft EIR). Both the maintenance plan and federal regulation outline or require "exterminate[ing] burrowing animals" as part of required levee maintenance due to the potential detrimental effects posed by burrowing animals (CFR, § 208.10, Section (b), Sub-section 1).

See also Master Response 7, *Operation and Maintenance (O&M) of Levees*.

D. The DEIR Does Not Adequately Disclose and Evaluate the Project's Impacts to Biological Resources.

1. The Project fails to evaluate or mitigate impacts associated with invasive species after initial Project construction.

The DEIR states that construction activities may encourage establishment of invasive species in the Project area, but fails to evaluate impacts associated with *the operational phase* of the Project, and how increases in invasive species after Project construction might affect fish species, water quality, and the ecosystem. The only mitigation measure proposed to address these impacts, Mitigation Measure BIO-4, is focused *solely* on protocols *prior to* the start of construction. (DEIR, p. IV.D-56.) There is no discussion of how invasive aquatic weeds, like water hyacinth, whose presence in the Delta is widely known, might increase once the Project is complete and additional tidal channels formed. Water hyacinth "plants propagate by budding and by setting abundant seed -- and those seeds fall to the bottom of the water, where they can stay *viable in the muck for many years*. Even if they didn't set seed, the plants would be a menace: they can form floating mats six feet thick, shutting off light and depriving native organisms of nutrients, then turning the local water quite acidic when they decompose."[5] 12-11

FOOTNOTE 5 https://www.kcet.org/redefine/5-invasive-plants-currently-messing-up-californias-delta

For example, the DEIR must disclose and evaluate how DWR will manage invasive species during the operational phase of the Project, performance criteria for such removal, such as potential impacts to water quality (oxygen levels) or habitat function for special status fish. In the Project Description, the DEIR mentions briefly that the Project includes long-term management of aquatic invasive species through spraying or mechanical removal, but no detail is provided whatsoever. (DEIR, p. III-49.) This is not sufficient. The DEIR must evaluate whether the Project will make the Project site more amenable to aquatic invasive species, disclose any impacts associated with increases on and in the vicinity of the Project site, adopt *as mitigation* a program to monitor and remove invasive species based on objective success criteria, and evaluate impacts to fish and other sensitive species resulting from the mitigation technique selected.

In addition, the DEIR's analysis of Project impacts to special-status plant species—which identifies impacts to four special status plants and imposes a mitigation ratio of 1:1 under Mitigation Measure BIO-2—contains *no analysis* of how invasive species may impact the mitigation plantings of sensitive species *after* Project construction. (DEIR, p. IV.D-53.) The

DEIR concludes that any impacts to special status species attributable to invasive species are addressed through Mitigation Measure BIO-4, but again this only relates to pre-construction work and does not address post-construction success of mitigation plants to compensate for the loss of sensitive plant species.

The DEIR should be recirculated to identify and analyze operational impacts associated with invasive aquatic species and propose feasible mitigation and monitoring for the management of invasive species during project operation. In such mitigation, DWR should evaluate the potential impacts of aquatic herbicides on fish and other native species rather than proposing to use all legally permitted herbicides, as Mitigation Measure BIO-4 does. 12-11 Cont.

Response 12-11:

See Master Response 14, *Invasive Plant Species and Harmful Algal Blooms*.

2. Mitigation for impacts to riparian forest are inadequate.

The Project will result in 24.8 acres to sensitive Great Valley mixed riparian forest, and the DEIR recommends imposition of Mitigation Measure BIO-1 to mitigate losses to riparian habitat at a mitigation ratio of 1.1:1 for "temporarily impacted" riparian habitat. There is no discussion, however, of the biological equivalency of the mitigation relative to the functions and values of the riparian impacts. The DEIR also does not provide *any discussion* of the success rate of new riparian vegetation plantings, nor any success criteria or monitoring of riparian mitigation. Mitigation Measure BIO-1 states DWR should "[a]void a long-term net loss of riparian habitat" but this falls short of providing clear, objective, success criteria for the riparian vegetation, nor does it provide any monitoring period for which the success criteria will be reviewed and applied. Further, typical projects mitigate losses to native riparian habitat at *no less than* a 3:1 ratio. If this ratio is not possible on-site, off-site mitigation should be provided. The DEIR must explain what the success criteria are for the mitigation and should explain why a higher, more typical, mitigation ratio was rejected from consideration. Below are proposed revisions to this mitigation measure. 12-12

REVISED Mitigation Measure BIO-1: Prior to commencement of Project construction, DWR shall obtain all necessary permits for impacts to riparian resources. Impacts to riparian habitat shall be mitigated at a minimum of a 3:1 ratio. Mitigation shall be accomplished by one or more of following options: on- or off-site habitat restoration; purchase of credits from an in-lieu fee program; and/or purchase of credits from a mitigation bank. A habitat mitigation and monitoring plan shall be prepared and shall include, at a minimum, the following information:

- Location and detailed maps of the mitigation and revegetation areas.
- An evaluation of the existing function and values, and a description of the function and values to be achieved through compensatory mitigation.
- Detailed plant and seed mix requirements.
- Detailed planting plan.
- Specific and measurable three-year success criteria.
- Three-year maintenance and monitoring requirements.

As it stands, the DEIR fails as an informational document and does not adequately disclose and mitigate for impacts to riparian vegetation. (See *Concerned Citizens of South Central Los Angeles v. Los Angeles Unified School Dist.* (1994) 24 Cal.App.4th 826, 841.) Instead, it states a conclusion that a small ratio of riparian habitat mitigation will reduce the Project's impacts, but does not support that conclusion with facts or analysis, which is inconsistent with CEQA's requirements for adequate mitigation. (*Sierra Club v. County of Fresno* (2018) 6 Cal.5th 502, 522.) 12-12 Cont.

Response 12-12:

Please see Response 2-10.

3. The DEIR fails to mitigate for permanent impacts to Western Pond Turtle nesting habitat.

As acknowledged in the DEIR, Western Pond Turtles "prefer to nest on unshaded upland slopes" and that the Project site currently contains "suitable basking sites and friable soils capable of supporting reproduction for this species." (DEIR, p. IV.D-37.) The DEIR confirms that the Project will result in a reduction in the "quantity of nesting habitat" based on "exposure to winter flooding." (DEIR, p. IV.D-72.) Despite this conclusion, the DEIR does not provide *any calculation* of the total loss of nesting habitat, does not evaluate how this loss of habitat might impact the species, and does not evaluate the need for or impose *mitigation* for the loss of nesting habitat. The only mitigation imposed addresses temporary impacts during construction, a completely separate impact. Given these substantial deficiencies in analysis and mitigation, recirculation is required. (Guidelines, § 15088.5; *Laurel Heights II*, 6 Cal.4th at 1130.) 12-13

Response 12-13:

Please see Response 2-19.

E. The DEIR Does Not Adequately Evaluate Project Impacts to Agriculture.

1. The DEIR must evaluate the Project's impacts to agricultural water diversions.

As stated previously, the DEIR fails to consider the impacts that the Project will have on existing water diversions in the vicinity of the Project site. Many of these water diversions provide water supplies for local agricultural uses. Although the DEIR recognizes several Delta Protection Commission (DPC) and Solano County policies governing the support and maintenance of agricultural production in the Delta, including the avoidance of conflicts between agricultural and non-agricultural uses, the local water purveyors might be required to adjust their operations in order to avoid negative impacts on fish species. 12-14

Response 12-14:

See Master Response 3, *Local Water Diversions and Special-status Fish Species*. See also Master Response 9, *Tidal Effects on Diversions*.

Additionally, water quality and water level impacts resulting from the Project might reduce the ability for local agricultural entities to meet their water needs. This, in turn, could reduce agricultural productivity in the area. The potential impacts to agriculture from changed operations at water intakes are directly foreseeable impacts on the physical environment due to the Project. (*Bakersfield Citizens for Local Control,* 124 Cal.App.4th at 1205.) These impacts have not been analyzed or mitigated in the DEIR. The DEIR should consider the impacts of the Project on local water diverters and analyze how those impacts might have adverse effects on the physical environment. In proposing potential mitigation, DWR should remember that it cannot unilaterally require action of these local diverters, and should consider the economic feasibility of any proposed mitigation measure. 12-15

Response 12-15:

See Master Response 1, *Salinity and Bromide*; Master Response 3, *Local Water Diversions and Special-Status Fish Species*; Master Response 9, *Tidal Effects on Diversions*; and Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts*.

As explained in Section B, the DEIR lacks any analysis concerning impacts related to relocation of water facilities. (DEIR, p. IV.A-21-22; Guidelines, Appx. G, XIX.) Because the impacts on agriculture via the Project's effects on local water diversions have not been identified, analyzed, or mitigated in the DEIR, the DEIR must be recirculated to adequately inform the public of the analysis and provide an opportunity for the public to weigh in on these impacts and proposed mitigation. (Guidelines, § 15088.5; *Laurel Heights II*, 6 Cal.4th at1130.) 12-16

Response 12-16:

See Master Response 1, *Salinity and Bromide*; Master Response 3, *Local Water Diversions and Special-Status Fish Species*; Master Response 9, *Tidal Effects on Diversions*; and Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts*.

2. The "Good Neighbor" checklist hides potential impact areas.

The DEIR states that DWR evaluated the Project's potential impacts on agriculture through the use of its "Good Neighbor" checklist. The DEIR states this is located in Appendix B to the DEIR (it is actually found in Appendix E). The analysis in the checklist, however, is insufficient to establish whether the identified Project effects could rise to a level of significance. Specifically, Appendix E is the only location where potential impacts on agricultural diversions in the Project area related to increased abundance of fish species are mentioned. (DEIR, Appx. E, p. 5.) CEQA requires that the information and data underlying an EIR must be presented in a way that is sufficient to inform the public about the project. (*Vineyard Area Citizens for Responsible Growth, Inc. v. City of Rancho Cordova* (2007) 40 Cal.4th 412, 442 (*Vineyard*).) Thus, "information 'scattered here and there in EIR appendices' or a report 'buried in an appendix,' is not a substitute for 'a good faith reasoned analysis.'" (*Ibid.*, quoting *California Oak Found. v. City of Santa Clarita* (2005) 133 Cal.App.4th 1219, 1239.) 12-17

Moreover, the analysis of the potential impacts to agricultural diversions in the Project area due to increased fish abundance is cursory, merely stating that "[l]imited studies suggest that small irrigation diversions in the Delta *may not have a large impact* on listed species and that small local agricultural water diversions in the waterways surrounding the Proposed Project are likely to have minimal effects on listed fish species . . .” (DEIR, Appx. E, p. 5 (emphasis added).) These limited studies are not identified, nor is the conclusion that diversions “may not have a large impact” on fish presented in a way that allows comparison to the relevant thresholds for significance. 12-17 Cont.

Response 12-17:

See Master Response 3, *Local Water Diversions and Special-status Fish Species* and Master Response 11, *Good Neighbor Checklist*. The text in paragraph two on page IV.B-1 in Section IV.B, *Agriculture and Forestry* in the Draft EIR has been changed to show that the Checklist is included in Appendix E:

> A Checklist was prepared for the Proposed Project and is included in Appendix ~~B~~E of this Draft EIR.

The DEIR does not disclose or evaluate whether the Project will attract more birds to the area through creation of the tidal habitat, and how this may harm nearby agricultural operations. A significant increase in certain bird species (e.g., Canadian Geese and starlings) would damage nearby crops, specifically Winter Wheat or other winter forage crops. Birds already cause extensive damage to crops in California and the Delta specifically.[6] The DEIR must evaluate whether the Project will attract increasing numbers of birds to the area, evaluate the potential environmental and related economic impacts to adjacent farmland, and mitigate for those impacts. (See Guidelines, § 15131(b); *Christward Ministry*, 184 Cal.App.3d at 197; *Bakersfield Citizens for Local Control*, 124 Cal.App.4th at 1205.) 12-18

FOOTNOTE 6 https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1045&context=icwdmbirdcontrol

Response 12-18:

See Section IV.D, *Biological Resources* of the Draft EIR for a discussion on baseline conditions in the Proposed Project area. The Cache Slough Complex is located within the Pacific Flyway, and a substantial portion of the Proposed Project Site is currently managed as waterfowl habitat. Under baseline conditions, waterfowl currently have the ability to use the entirety of the existing Proposed Project Site, and the Proposed Project Site is adjacent to large tracts of conservation land and open water areas (e.g. Liberty Island Ecological Reserve). The Proposed Project would not result in new or greater bird populations in the area compared to the existing bird populations that currently use the region for foraging and nesting habitat. While the Proposed Project would provide additional tidal wetland habitat, the Project Site would no longer be managed as waterfowl habitat and the planting of waterfowl friendly crops would cease.

The Proposed Project is not anticipated to change the overall quantity of birds; increased crop damage is therefore not anticipated to occur due to changes in species composition or abundance as a result of the Proposed Project.

The checklist also introduces the potential impact that the neighboring landowners' use of pesticides might impact the functioning of the Project itself. It is critical that the Project not result in a future restriction on existing agricultural users application of legally permissible pesticides and herbicides to maintain their crops and economic viability of their lands. Appendix E states that the use of pesticides will not impact fish, despite the fact that Cache Slough is listed on the 303(d) list as impaired for several pesticides. There is no evidence provided to support this conclusion. Impact conclusions must be supported by substantial evidence, which is defined as "facts, reasonable assumptions predicated upon facts, and expert opinion supported by facts." (Guidelines, § 15384(b); *Santiago County Water Dist. v. County of Orange* (1981) 118 Cal.App.3d 818, 831.) Mere conclusory statements and unsubstantiated narrative will not suffice. 12-19

Response 12-19:

See Master Response 11, *Good Neighbor Checklist*, and Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts*. The Proposed Project would not change the use of pesticides by others and DWR would not be responsible for the reduction of pesticides in the Cache Slough Complex or other waterways in the Delta that receive pesticide input from the watersheds that drain into the Delta.

3. Mitigation Measure AG-1a lacks objective performance standards and criteria.

CEQA requires that all mitigation measures include "specific criteria or standard of performance," rather than a generalized goal. (*San Joaquin Raptor Rescue Center v. County of Merced* (2007) 149 Cal.App.4th 645, 670; see also *Communities for a Better Environment v. City of Richmond* (2010) 184 Cal.App.4th 70, 95 (*CBE*).) Mitigation Measure AG-1a states that DWR will install irrigation infrastructure to convert "all or part" of a specific property to Prime Farmland. This mitigation measure is vague and does not commit DWR to a measurable criteria or performance standard. Additionally, the DEIR fails to analyze impacts of the proposed mitigation, including the proposed construction of the irrigation infrastructure and farm buildings and housing on the property. 12-20

Response 12-20:

The commenter has provided a partial description of Mitigation Measure AG-1a. As noted on page IV.B-10 in Section IV.B, *Agriculture and Forestry* of the Draft EIR, the main action of this mitigation measure is to provide for agricultural improvements that would convert or restore land with existing limits to its productive capacity to Prime Farmland. As noted on page IV.B-12 of the Draft EIR, there is a range of possible actions that would achieve the improvements associated with Mitigation Measure AG-1a; Mitigation for impacts to agriculture should be viewed in the context of the portfolio approach of Mitigation Measures AG-1a and AG-1b. Although DWR and EIP have some of the details on agricultural improvements at this time, those improvements do not require analysis in addition to what was presented in the Draft EIR. Further, the CEQA Guidelines Section 15145 indicates that if after thorough investigation, impacts are found to be too speculative for evaluation, they should not be analyzed further. This is the case for Mitigation Measure AG-1a. See Master Response 2, *Farmland*.

In addition, the DEIR should include an analysis of the other impacts associated with conversion of privately-owned farmland to habitat uses in this Project. Specifically, DWR might be responsible for compensating landowners whose properties are damaged by the construction and operation of this government-backed Project. In this context, it is imperative that the mitigation measures adopted are adequate and include clear performance standards. 12-21

Response 12-21:

All lands to be converted to habitat uses are within the Proposed Project Site. No other property of private landowners will be damaged by the construction and operation of the Proposed Project. See also Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts*.

F. The DEIR Does Not Adequately Evaluate Water Quality Impacts.

The EIR states that the Project site was selected based on the "salinity, turbidity, and water temperatures that are known to support all life stages of Delta Smelt." (DEIR, p. III-35.) Yet, the EIR provides very little analysis of how the Project could result in changes to salinity, turbidity, and water temperatures as a result of Project construction and operation.

1. The DEIR does not adequately analyze Project impacts related to salinity, bromide, and water temperature.

The DEIR acknowledges that "[s]alinity for municipal, agricultural and fish and wildlife uses is of particular concern in the tidally influenced Delta" and that "[a]ny failure of Delta levees and subsequent island flooding draws saline water into the Delta." (DEIR, p. IV.G-4.) The DEIR also concedes that the Project could "alter the salinity regime in the Delta" and that increased "salinity could negatively impact drinking water quality." (DEIR, p. IV.G-22.) Here, the Project is proposing to purposefully breach levees and flood current dry areas, and yet the analysis of Project impacts to salinity changes is slim. 12-22

The DEIR evaluates the Project's impacts on salinity using results from a simulation for 2009, but the selection of a single year does not account for uncertainties and variations found in the hydrologic conditions in the Delta. (DEIR, p. IV.G-22.) The standard technical analyses for CALFED storage projects involve a longer simulation period (either 1922-2003 or 1976-1991) that covers a wide variety of hydrological conditions to evaluate the potential consequences of a project that would change Delta hydrodynamics. Specifically, these longer simulation periods include droughts and wet-year periods of varying magnitude and length to better demonstrate existing conditions in the Delta. A proper impact analysis requires a longer simulation of the project under varying hydrologic conditions to better understand how the Project will impact salinity over time. (*Communities for a Better Environment v. South Coast Air Quality Dist.* (2010) 48 Cal.4th 310, 321 [the relevant environmental setting, or baseline, against which to evaluate a project's impacts is the "real conditions on the ground"].)

Response 12-22:

Although the Draft EIR recognized the potential for the Proposed Project to negatively impact drinking water quality, it concluded that the impact of the Proposed Project with regard to salinity was less than significant. See Master Response 1, *Salinity and Bromide*.

Additionally, the DEIR states the predicted net increase in electrical conductivity (EC), a common measure of salinity, is "very slight," although the DEIR does not explain how the net increase was calculated, nor whether the data used to calculate the net increase was based on EC measurements taken on a daily, monthly, or other time interval. (DEIR, p. IV.G-23.) The DEIR refers to salinity objectives set forth in applicable water quality control plans and water rights decision D-1641, but never states what that objective is nor what the current salinity levels in the Project area are. Without this information, the public cannot follow the line of reasoning from the data to DWR's conclusion that the impacts to agriculture based on salinity would be less than significant. CEQA requires further explanation such that the public can follow "the analytic route the agency traveled from evidence to action." (*Laurel Heights I*, 47 Cal.3d at 404.)

The analysis is even thinner when it comes to the DEIR's evaluation of the Project's impacts on salinity for drinking water purposes. The analysis fails to demonstrate whether the Project would have adverse impacts to salinity with regard to drinking water standards. Both the agricultural and drinking water salinity impact discussions are conclusory, and neither refer to supporting information or reports in a way that facilitates a reader locating this information. CEQA requires that relevant information related to potential impacts on the environment be presented in the EIR itself, not hidden away in an appendix or report, in order to fulfill the goals of CEQA as a means of agency accountability. (*Vineyard*, 40 Cal.4th at p. 442.) 12-23

The Project creates tidal marshland, which has the effect of widening the Yolo Bypass floodplain in the Project area. The DEIR correctly states that salinity increases in areas with shallower water and less shade, where more evaporation occurs. However, the DEIR does not discuss the potential salinity impacts of the changed hydrology of the Project area, specifically whether evaporation will increase at the Project site, which would increase salinity in the area.

Response 12-23:

See Master Response 1, *Salinity and Bromide*. This comment notes that the potential for the Proposed Project to increase salinity by increasing evaporation is not discussed in the Draft EIR. As discussed on page IV.D-85 of section IV.D, *Biological Resources,* in the Draft EIR, data from similar sites as the Proposed Project indicates tidal marsh restoration will result in a net decrease in water temperature. Since water temperature will not increase as a result of the Proposed Project, the Proposed Project will not increase salinity via the mechanism of increased evaporation.

The DEIR also does not mention whether the Project would result in increased seawater intrusion into the Project area, which would bring with it increased levels of salinity and other constituents such as bromide. Bromide salts are rarely found in typical fresh surface waters, but do appear in seawater. As a result, coastal groundwater and soils have higher bromide concentrations due to seawater intrusion.[7] When drinking water purveyors disinfect water higher in bromide with ozone, the treatment can result in the creation of carcinogenic compounds, including bromate. Many drinking water purveyors in the Project vicinity use ozone as a disinfectant, and thus are very sensitive to changes in bromide concentrations. The Project's impacts on bromide levels in the Project area, and whether those changes might cause water suppliers to change their treatment systems should be disclosed, analyzed, and properly mitigated. 12-24

FOOTNOTE 7 Davis, S. N., J. T. Fabryka-Martin, et al. (2004). "Variations of bromide in potable ground water in the United States." Ground Water 42(6): 902-909. http://onlinelibrary.wiley.com/doi/10.1111/j.1745-6584.2004.t01-8-.x/abstract

Response 12-24:

See Master Response 1, *Salinity and Bromide*.

Similarly, the DEIR states that groundwater levels of Total Dissolved Solids (TDS), an alternative measure of salinity, in the Project area exceed the current objectives for drinking water and/or agricultural use. If surface water salinity increases, this could increase TDS levels in groundwater such that the water is no longer suitable for current uses due to the interconnectedness between groundwater quality and surface water quality in the Project vicinity. (See DEIR, p. IV.G-6.) 12-25

Response 12-25:

The comment is correct that the current levels of Total Dissolved Solids (TDS) in groundwater in the local groundwater basin exceeds water quality criteria for drinking water or agricultural use. As analyzed on pages IV.G-19 to IV.G-20, IV.G-22 to IV.G-23, and IV.G-29 of Section IV.G, *Hydrology and Water Quality* of the Draft EIR, the Proposed Project would have less-than-significant impacts on groundwater quality and quantity. Therefore, the Proposed Project would not result in a significant increase in TDS and would not change or worsen the current status of the exceedance of water quality criteria for drinking water or agricultural use. See also Master Response 1, *Salinity and Bromide*.

As to water temperature, DEIR includes a conclusory assertion that the Project will not cause significant impacts in the Project area, stating that the increased solar radiation under the Project would be offset by shade from marsh vegetation. The DEIR does not include any data on the potential increase in temperature due to increased solar radiation, nor does it quantify how much effect vegetation will have on reducing any temperature increases. The DEIR also lacks any information about whether the purported offset is sufficient to satisfy Basin Plan temperature objectives. The EIR must include facts and analysis, not mere conclusions. (Guidelines, § 15384(b); *Santiago County Water Dist.,* 118 Cal.App.3d at 831.) 12-26

Response 12-26:

As described on page IV.G-28 in Section IV.G in the Draft EIR, the Water Quality Control Plan for the Sacramento and San Joaquin River Basins temperature objective calls for no increase in water temperatures greater than 5 degrees Fahrenheit from the receiving water body's natural temperature (page IV.G-28). After describing the primary processes that affect water temperature in tidal marshes, the Draft EIR references a study (page IV.G-28, footnote 41) of two sites in the Suisun Marsh, which is located in the same estuary as the Proposed Project. Water temperature and related physical data were collected at both sites, which have similar tidal hydrology and slough channels as the Proposed Project. Based on the outcomes of the study, temperature decreases associated with marsh vegetation shading are anticipated to roughly offset or decrease temperature increases associated with solar radiation due to shallow water depth. Therefore, data from these sites supports the Draft EIR's finding of a less-than-significant impact relative to the Basin Plan objective of not increasing water temperature.

2. The DEIR fails to adequately evaluate mercury or methylmercury as a potential water quality impact.

The DEIR acknowledges that methylmercury exists in sufficiently high concentrations in the Cache Slough Complex to have triggered a Federal Clean Water Act Section 303(d) listing for this pollutant. "Waters of the Proposed Project Site are therefore considered impaired due to the presence of methylmercury." (DEIR, p. IV.G.-10). The DEIR also notes that a total maximum daily load (TMDL) for mercury and methylmercury has been established, and that current fish tissue concentrations of methylmercury are above the level set in the TMDL. (DEIR, p. IV.G-5.) These acknowledgments suggest a need for a reasonable analysis of the potential of the proposed project to exacerbate this impairment. The DEIR appears to take a step in this direction, claiming that its analysis of methylmercury is based on "best scientific information" (DEIR, p. IV.G.-14). But there is no analysis of the mechanisms that contribute to mercury methylation or the potential of the landscape changes proposed by the Project to affect these mechanisms. Instead, the DEIR simply reports that DWR is conducting ongoing studies to determine whether tidal wetlands "are a source or a sink of methylmercury." (DEIR, p. IV.G-15), and concludes that these studies show "that tidal wetlands do not export mercury or methylmercury in large amounts, although seasonal differences occur and imports and exports are heavily influenced by flow and whether a wetland is associated with a floodplain." (DEIR, p. IV.G-15.) 12-27

This is the extent of the analysis. The DEIR stops short of applying what has been learned by the referenced DWR studies to the landscape changes being proposed for the Project site. Without this exercise, the DEIR falls well short of the reasoned analysis required under CEQA to dismiss methylmercury as a water quality impact of concern. CEQA requires that EIRs include an informed discussion of potential impacts. "The fact that precision may not be possible, however, does not mean that no analysis is required. . . an agency must use its best efforts to find out and disclose all that it reasonably can." (*Laurel Heights I*, 47 Cal.3d at p. 399 [internal quotations omitted]; see also *Banning Ranch Conservancy v. City of Newport Beach* (2017) 2 Cal.5th 918, 938.)

Response 12-27:

See Master Response 6, *Methylmercury*.

3. The DEIR does not evaluate water quality impacts associated with water hyacinth and other invasive aquatic plants.

In the Sacramento-San Joaquin Delta, water hyacinth is a major invasive species that has modified ecosystem functioning and vegetation communities.[8] In recent years, the impacts on the Delta from water hyacinth have increased.[9] Floating aquatic vegetation increased from 323 hectares in 2004 to over 2590 hectares in 2014 (a change from 1.3 to 10.6% of the area of the Delta) due to recent droughts, milder winters, and delays in implementing control programs. Control efforts are crucial to maintaining the ecological functions of the system.[10] In addition, water hyacinth prefer slower-moving water velocities. Water hyacinth colonies have demonstrated negative impacts on temperature, dissolved oxygen, and turbidity, both of which negatively impact fish species such as Delta Smelt and Chinook salmon.[11]

Despite the well-known impacts on water quality as a result of the presence of water hyacinth, the DEIR fails to note this as a potential water quality impact of the Project. To the extent that the Project, either during construction or during Project operation, creates more habitat suitable for colonization by water hyacinth, it is reasonably foreseeable that this colonization will negatively impact water quality in the Project area. This impact should be discussed, analyzed, and properly mitigated to avoid adverse water quality impacts, particularly to parameters crucial to fish survival, such as temperature and dissolved oxygen. Because the impacts of invasive aquatic plant species on water quality was not identified or analyzed in the DEIR, the DEIR must be recirculated and mitigation proposed for these impacts. Recirculation is required to inform the public of the true potential impacts and proposed mitigation related to invasive species' impacts on water quality. (Guidelines, § 15088.5; *Laurel Heights II*, 6 Cal.4th at 1130.) 12-28

FOOTNOTES 8-11 Tobias, V.D., Conrad, J.L., Mahardja, B. et al. *Biol Invasions* (2019) 21: 3479. https://doi.org/10.1007/s10530- 019-02061-2 (citing Khanna et al. 2012).

Response 12-28:

See Master Response 14, *Invasive Plant Species and Harmful Algal Blooms*.

G. The DEIR's Mitigation for Air Quality Impacts Improperly Allows Unilateral Waiver of Mitigation Requirements Based on Undefined "Unusual Circumstances."

Mitigation Measure AIR-1 states "[e]quipment requirements may be waived by the project director of EIP or DWR" based on unknown "unusual circumstances." (DEIR, p. IV.C-13.) This standard is not sufficiently clear and objective to constitute adequate mitigation. (*San Joaquin Raptor Rescue Center*, 149 Cal.App.4th at p. 670; see also *CBE*, 184 Cal.App.4th at p. 95.) The specific conditions under which a waiver may be issued should be clearly set forth in the mitigation measure. Furthermore, it is unclear whether the air quality impacts associated with the Project would actually be mitigated below the level of significance if the equipment requirements were waived. The DEIR should analyze this potential impact and explain whether waiver changes the determinations of whether construction equipment will have a significant effect on the environment. Finally, as stated above, EIP cannot have control over determining whether or not mitigation is feasible as DWR must make this determination as the lead agency. 12-29

Response 12-29:

Please see Response 12-1 for a discussion regarding Mitigation Measure AIR-1(b), which includes clarification of unusual or emergency circumstances that would result in a waiver of Tier 4 Final off-road emissions standards and requires use of the next cleanest available equipment. See also Master Response 13, *Performance Standards and Deferred Mitigation.*

H. Critical Attributes of the Proposed Project Remain Vague, Contributing Further to the DEIR's Failure to Evaluate the Project's Impacts.

CEQA is premised on the need for an accurate, stable, and consistent description of the proposed project. (Guidelines, § 15124.) Consequently, "project" is defined broadly as "an activity which may cause either a direct physical change in the environment, or a reasonably foreseeable indirect physical change in the environment" and that is "directly undertaken by any public agency." (Pub. Res. Code, § 21065; *Laurel Heights I,* 47 Cal.3d at 396.) The reason for this broad interpretation is simple—without an accurate project description, decision-makers and the public cannot undertake "an intelligent evaluation of the potential environmental effects of a proposed activity." (*McQueen v. Bd. of Directors* (1988) 202 Cal.App.3d 1136, 1143.)

Several aspects of the Project remain vague, which causes the project description to be defective and results in an inadequate analysis of environmental impacts. For example, the DEIR states that sand will only be placed "if feasible." (DEIR, p. III-36.) There is no information provided concerning how DWR will evaluate if sand placement is feasible, what impacts would result with or without the sand as it pertains to impacts on water quality and the success of the project in creating suitable habitat for Delta Smelt. The DEIR notes that "[t]he only known structural feature used by Delta Smelt are sandy substrates required for spawning" and that the species requires "open, unvegetated, shallow, subtidal (less than 9 feet) waters with sand or pebble-sized substrate within freshwater sloughs." (DEIR, p. 12-30
IV.D-32.) Given the necessity of sandy substrates to Delta Smelt, the DEIR must provide a clear statement of when sand will be placed, and disclose, evaluate, and mitigate environmental impacts stemming from an inability to place sand.

The DEIR also contains extremely little information concerning the placement of soil excavated from the Project site. Cumulatively, the Project will "necessitate excavation of approximately 5,255,000 cubic yards of soil." (DEIR, p. III-36.) The DEIR states that this material "would be re-used on site *as appropriate* based on soil types and beneficial re-use needs" and that "[*s*]*ome* of the material from the degradation of the Shag Slough Levee and the excavation of the tidal channels would be placed within proposed marsh plain to eliminate hauling the material over long distances." (DEIR, p. III-36 [emphasis added].) Other sections also call into question how much of the excavated soil will be able to be placed on site. (DEIR, p. IV.A-13 ["some of the material . . . would be placed within the proposed marsh plain to eliminate hauling the material over long distances].) Thus, it is entirely unclear whether placement on-site is feasible or how DWR will go about determining whether placement is "appropriate," or what volume of material will need to be off-hauled. While certain portions of the DEIR reference placement of certain amounts of fill taken from the excavated soil (e.g., 712,000 cubic yards of tidal channel excavations will be used for the Duck Slough Setback Levee), placement of the bulk of the 5.255 million cubic yards is not identified.

Given that the purpose of the Project is to inundate areas and excavate new channels, it is entirely unclear how this volume of excavated soil will be utilized solely on-site, without any need for off-hauling. There is also no statement concerning soil testing prior to re-placement of the soil. If there is a possibility that DWR will have to off-haul some (or most) of this material, the EIR must evaluate impacts associated with increased material movement as it relates to air quality and greenhouse gases. Currently, the Air Quality section assumes *no removal of excavated soil whatsoever*, it only evaluates off-hauling of other construction debris and materials. (DEIR, p. IV.C-11.) 12-30 Cont.

Response 12-30:

Please see Response 10-11.

I. The DEIR Improperly Concludes Several Impacts Are Less than Significant Without Mitigation.

Section IV.A of the DEIR lists those impact categories for which DWR screened from further analysis in the Initial Study based on the conclusion that the impacts were less than significant without mitigation. In discussing several categories of impacts, however, the DEIR relies on mitigation adopted in other sections of the DEIR to conclude that the impacts are less than significant, or rely on "project features" that are in fact mitigation measures in violation of *Lotus v. Department of Transportation* (2014) 223 Cal.App.4th 645, 655-656. For example, in discussing impacts related to "substantial soil erosion or loss of topsoil," the DEIR relies on future "O&M measures to minimize the impact of erosion on the Cache/Hass Slough Training Levee and assure long-term stability." (DEIR, p. IV.A-6.) The O&M measures, however, are not identified, evaluated, or imposed as mitigation. The DEIR's analysis of consistency with the Delta Plan also repeatedly relies upon mitigation measures to make a finding of consistency. (See, e.g., DEIR, p. IV.A-13 [referencing Mitigation Measure AG-1], p. IV.A-14 [referencing invasive plant species mitigation and Mitigation Measure AG-1].) As discussed in Sections B and E, the DEIR also completely avoids analysis of whether the Project will result in the need to relocate nearby water facilities due to both changes in water quality as well as the potential for water facilities to entrain fish that are attracted to the Project site. 12-31

It is clear that many impacts that were "screened from further analysis" should indeed be fully evaluated, and many require mitigation measures to remain less than significant.

Response 12-31:

Section IV.A, *Impacts Found to be Less Than Significant* of the Draft EIR explains why the interior of the Proposed Project Site is not at substantial risk for erosion. See pages IV.G-21 and IV.G-22 in Section IV.G, *Hydrology and Water Quality* for an analysis regarding the potential for erosion. As reported in Draft EIR Appendix D, *Lookout Slough Tidal Habitat Restoration and Flood Improvement Project – 65% Basis of Design Report*, Appendix Q, *Draft Hydrologic and Hydraulic System Analysis*, and Draft EIR Appendix R, *Hydrologic and Hydraulic Risk and Uncertainty Analysis*, soil within the Proposed Project Site provides stable soil conditions that would not be susceptible to erosion from the hydraulic shear stresses on the designed channels and levee breaches. Further, the design of the Duck Slough Setback Levee would meet State and federal levee design criteria, including criteria for prevention of erosion through a standard operations and maintenance plan as required by State and federal minimum criteria.

The Draft EIR does not analyze consistency with the Delta Plan and makes no findings regarding consistency. Mitigation measures mentioned in the Draft EIR are analyzed in terms of compliance with CEQA and do not rely on consistency with the Delta Plan. DWR will consider Delta Plan consistency when it submits a certification of consistency with the DSC. See also Master Response 7, *Operation and Maintenance (O&M) of Levees*; Master Response 1, *Salinity and Bromide*; Master Response 3, *Local Water Diversions and Special-Status Fish Species*; Master Response 9, *Tidal Effects on Diversions*; and Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts*.

Conclusion

DWR's focus on accelerating the timeline for Project implementation is coming at the expense of adequate environmental analysis and engagement with adjacent reclamation districts, agricultural operators, and other local stakeholders. We urge DWR to revise and recirculate the Draft EIR to address the areas of concern and unaddressed impacts identified above. 12-32

Response 12-32:

Comment noted. CEQA review for the Proposed Project has been conducted under DWR's standard timeline and has not been accelerated. The responses to comments in the Final EIR clarify, amplify, or make insignificant modifications to the Draft EIR. These responses to comments do not identify any new significant effects on the environment or a substantial increase in the severity of an environmental impact requiring major revisions to the Draft EIR that would require recirculation.

Sincerely,

DOWNEY BRAND LLP

Arielle O. Harris

cc: Lower Sacramento/Delta North Regional Planning Area

1606152v8

Letter 13
Solano County Department of Resource Management

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February 14, 2020

California Department of Water Resources
Attn: Heather Green
3500 Industrial Blvd
West Sacramento, CA 95691
Via email FRPA@wate.rca.gov

Subject: Solano County comments on Lookout Slough Tidal Habitat Restoration and Flood Improvement Project DEIR

Dear Ms. Green;

Solano County appreciates this opportunity to comment on the Lookout Slough Tidal Habitat Restoration and Flood Improvement Project Draft Environmental Impact Report (DEIR) that was released for 60-day public review on December 16, 2019. According to the California Department of Water Resources, the DEIR describes the Proposed Project and provides DWR's assessment of potential environmental impacts and includes proposed measures to avoid, mitigate, or offset those environmental impacts, as required under the California Environmental Quality Act (CEQA).

The Lookout Slough Restoration Project is proposed in the unincorporated portion of Solano County and includes converting approximately 3,400 acres of agricultural lands to tidal marsh and other wetlands.

Project Description
Section 21065 of the Public Resources Code defines the term "project" as "an activity which may cause either a direct physical change in the environment, or a reasonably foreseeable indirect physical change in the environment, and which is any of the following: (a) An activity directly undertaken by any public agency; (b) An activity undertaken by a person which is supported, in whole or in part, through contracts, grants, subsidies, loans, or other forms of assistance from one or more public agencies; [or] (c) An activity that involves the issuance to a person of a lease, permit, license, certificate, or other entitlement for use by one or more public agencies."

Letter 13

The DEIR, at page Vlll-2, identifies Ecosystem Investment Partners ("EIP") as the project applicant, which implies that the Lookout Slough Project ("Project") is not an activity directly undertaken by the Department of Water Resources ("DWR") for purposes of subdivision (a) of section 21065. Instead, the DEIR's identification of EIP as the project applicant and DWR as the lead agency implies one of two things: either the Project will be undertaken by EIP with financial support from DWR in the form of contracts, grants, subsidies, loans, or other forms of assistance; or the Project involves the issuance by DWR to EIP of a lease, permit, license, certificate, or other entitlement for use.

Section 15124 of the CEQA Guidelines[1] requires that the project description portion of an EIR include a list of permits and other approvals required to implement the project, to the extent such information is known by the lead agency. If a public agency must make more than one decision on a project, all its decisions subject to CEQA should be listed, preferably in the order in which they will occur. The Governor's Office of Planning and Research will assist a lead agency or responsible agency in identifying state permits required for a project.

FOOTNOTE 1 The CEQA Guidelines are located at 14 C.C.R. § 15000, *et seq.*

The DEIR, at page 111-50, describes Table 111-4 as identifying federal, state, regional, and local agencies that may have jurisdiction over aspects of the Project and may require "certain permits and approval that include but are not necessarily limited to those outlined in Table 111-4." This level of non-specificity is inadequate for purposes of Section 15124. As described above, the DEIR describes the Project as being undertaken by EIP rather than by DWR, and thereby acknowledges that the Project will be undertaken by EIP only after DWR approves a contract, grant, subsidy, loan, or other form of financial assistance, or issues a lease, permit, license, certificate, or other entitlement for use. To the extent DWR will be approving financial assistance or issuing an entitlement for use for the Project, it is incumbent on DWR to acknowledge those project-approval actions and identify them with specificity on Table 111-4. CEQA compliance is not a project approval action such as the approval of financial assistance or issuance of an entitlement for use. The lead agency must certify that the final EIR has been completed in compliance with CEQA *before* it approves the project. (CEQA Guidelines, § 15090.) When an EIR has been prepared for a project, the lead agency shall not approve or carry out the project until after the EIR has been certified and considered by the agency. (CEQA Guidelines, §§ 15091 & 15092.) "With private projects, approval occurs upon the earliest commitment to issue or the issuance by the public agency of a discretionary contract, grant, subsidy, loan, or other form of financial assistance, lease, permit, license, certificate, or other entitlement for use of the project." (CEQA Guidelines, § 15352, subd. (b).) 13-1

Agreement Number 4600012583, executed by DWR on October 2, 2018, provides that prior to commencement of construction of the Project, fee title to the Project property will be transferred to DWR. Following transfer of title, EIP will implement and complete construction of the Project as DWR's contractor. The description of the Project provided in Agreement Number 4600012583 is inconsistent with the project description provided in the DEIR. The Agreement describes the Project as being undertaken by DWR, while the DEIR describes the Project as being undertaken by EIP after approval by DWR.

The distinction made in Section 21065 between project directly undertaken by a public agency, pursuant to subdivision (a), and a project approved by a public agency through approval of financing or issuance of entitlements, pursuant to subdivisions (b) or (c), is significant to the adequacy of the DEIR for two reasons, either of which causes both the project description and agricultural impact analysis in the DEIR to be inadequate.

If the Project will be undertaken by EIP following the approval of financing or issuance of entitlements by DWR, then the County will have jurisdiction over EIP's development and use of the Project. Under the Solano County Zoning Regulations, the Project is a permittable use on the property and within the A-80 zoning district, provided a discretionary use permit is approved by the County. In addition, grading and other construction activities on the property would be subject to County jurisdiction and would require County permits, including permits for removal of any hazardous materials storage containers (such as underground or above ground storage tanks). These County permits must be identified in Table 111-4 and the County must be identified in the DEIR as a Responsible Agency for the Project. In addition, the analysis of compatibility with existing zoning in Chapter IV.B should be revised to reflect that a County use permit will be required for the Project.

On the other hand, if the Project will be directly undertaken by DWR, with EIP possibly acting as DWR's contractor or contract manager as described in Agreement Number 4600012583, then the project description in the DEIR must be revised to clarify that role of DWR. Due to its status as a state agency, a project directly undertaken by DWR is not subject to County land use regulation. The Williamson Act, however, imposes strict requirements limiting a public agency's ability to acquire land within an agricultural preserve. See Government Code section 51290 and following. Section 51293 relaxes these strict requirements somewhat when the acquisition is for purposes of flood control works or public works for fish and wildlife enhancement and preservation, by the notification and consultation requirements of Section 51291 and related sections are still applicable to such projects. For land within an agricultural preserve that is subject to a Williamson Act contract, the contract is null and void when the public agency acquires the land. If the Project will be directly undertaken by DWR, Chapter IV.B should be revised to describe the notification and consultation requirements, and to identify both the Department of Conservation and Solano County as responsible agencies in this consultation process. That chapter should also indicate that the Williamson Act contracts will be terminated upon acquisition of the Project property by DWR. 13-1 Cont.

Response 13-1:

See Response 12-1 regarding DWR’s role as the CEQA Lead Agency carrying out the Proposed Project.

To clarify the notice requirements described in Government Code section 51291 for acquisition of the Project Site, the following text is added following the first paragraph on page IV.B-6 in Section IV.B, Agriculture and Forestry:

> <u>The Williamson Act requires that public agencies considering acquiring interests in land within an agricultural preserve, and that the interest or interests would be used for a public purpose, shall provide notice to the local government agency responsible for administering the preserve and to the Director of Conservation. (Cal. Gov. Code § 51291.)</u>

A notice was prepared pursuant to DWR’s responsibilities under Cal. Gov. Code §51291, and delivered to the County and the Director of Conservation in June, 2020. Also, DWR has held numerous in-person meetings with the County for over two years specifically to discuss the Proposed Project, its location and impacts, including Williamson Act and agricultural issues.

As described in pages IV.B-13 to IV.B-14 in Chapter IV.B, Agriculture and Forestry, the Proposed Project meets the principals of compatibility contained in the Williamson Act, and would not conflict with the applicable Williamson Act contracts. The Williamson Act contracts covering the Proposed

Project Site were adopted in 1970, 1979, and 1984. Each contract contains a compatibility provision for open space use pursuant to Government Code section 51205. More specifically, all three Williamson Act contracts identify Open Space as an allowed use independent of the separate and equally allowed use for agricultural purposes, and nothing in the language of the contracts prevents the open space use from occupying all of the contracted parcels. As an example, the Liberty Williamson Act Contract, paragraph 11, cites "Watershed and Conservation or Marsh Preservation zoning" as compatible zones, with attendant uses being compatible with the purposes of the Contract.

To put this another way, all three properties can be fully committed to Open Space as a primary use, just as they can also be fully used for agriculture, and uses compatible with agriculture. Finally, even if Open Space were not a fully authorized use for these properties, as in this case, the provisions of the principles of compatibility that limit approval of new compatible uses that displace agriculture do not apply to these properties. Because the contracts were executed prior to June 7, 1997, and open space uses defined by Gov. Code 51205 were and are specifically permitted within the four corners of the contracts without exception, Gov. Code subsection 51238.3 exempts properties such as these from the provisions of either Gov. Code subsections 51283.1 or 51238.2.

National Environmental Policy Act (NEPA) review

NEPA review is required yet is not considered with CEQA at this time. The Project consists of ecosystem development of agricultural land and significant change to federal flood control elements requiring permits which should not be bifurcated. The effects of the entire Lookout Project should be considered together. 13-2
The Project as described will breach State and Federal flood system levees, construct additional State-Federal Project levees and change the hydrology of the Yolo Bypass and Cache Slough region.

Response 13-2:

NEPA applies to projects which are carried out, financed, or approved in whole or in part by a federal agency. In the case of the Proposed Project, there are several federal agencies that may require certain permits and approvals, including the US Army Corps of Engineers (USACE), US Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), and US Department of Agriculture (USDA). See Table III-4 in the Draft EIR for a full list of permitting agencies. CEQA encourages the use of a previously prepared EIS and the development of joint EIR/EIS documents but does not mandate joint federal/state environmental documents. The federal agencies will conduct their own NEPA analysis in support of their permit action as part of their permit processes. DWR is working closely with the federal permit agencies to assure coordination.

DEIR Water Quality Modeling Data Not Made Readily Available

Despite several requests, all of the relevant water quality electrical conductivity (EC) and hydraulic modeling data was not made available to Solano County, with relevant data not arriving until as late as February 5 and February 11, 2020. Of particular concern are seasonal data and data that break down monthly and daily averages (which often do not reflect changes of significance) into smaller increments. As mandated in Section 15147 of the CEQA Guidelines, supporting technical data must be made readily available for public examination. Unless all of the relevant data is made available the commentator cannot independently determine the significance of impacts summarized in the DEIR. This is important in determination of effects the variety of projects and water operations will have within the County and the Delta. Most notably, data for only one water year was simulated in the model (discussed in Appendix A) which is not enough to determine full long-term impacts. In not making such data readily available, DWR has not proceeded in the manner required by law. 13-3

Response 13-3:

Hydrologic and hydraulic modeling conducted and used to support the analyses and conclusions in Chapter IV, *Environmental Impact Analysis* of the Draft EIR is included in Appendices D, as well as O through T, and are therefore, available for review and are part of the public record. See Master Response 1, *Salinity and Bromide*, for more information on issues raised in this comment.

Agricultural Sustainability

The continued viability of agricultural lands in the region with the introduction of habitat restoration projects, especially such large-scale projects such as this, is something Solano County takes very seriously. The County appreciates inclusion of the Good neighbor checklist on page p IV A-12 and IV B-1 and would like to work with DWR and relevant State agencies to develop a more comprehensive Checklist for State use for this Project and in the future. Although agricultural mitigation is accounted for at the Zanetti and Wineman properties, as identified on pages IV B-12 et. sec., we strongly encourage the state and the project proponent to work very closely with the County to ensure that this mitigation is effective. Furthermore, we are not clear on the drainage benefits to Wineman and request additional information and/or direction to the background information in the DEIR and the appropriate appendices. As a reminder, Solano County requires a minimum of 1000 acres of agricultural conservation and Swainson Hawk conservation easements within the County. The location of such conservation easements shall be in close consultation with Solano County. 13-4

Response 13-4:

The implementation of Mitigation Measures AG-1a and AG-1b will be enforced and monitored by DWR through the Mitigation Monitoring and Reporting Plan.

In response to the comment requesting additional information on the drainage benefits to the Wineman Property, the new infrastructure is to improve drainage and agricultural viability of 960 acres of non-irrigated rangeland would consist of, but is not limited to: improved ditching for irrigation and drainage, pumps for irrigation, pipelines, and power drops.

The following text is added to Mitigation Measure AG-1a:

> Improvements would be selected in coordination with the property owner(s) and/or their agricultural lessees in a manner which best improves the agricultural viability and drainage in this part of Solano County.

Regarding the reminder about conservation easements for agriculture and Swainson's hawk, page IV.B-12 of the Draft EIR describes Mitigation Measure AG-1b, which requires DWR to establish one or more off-site conservation easements on a minimum of 1,000 acres of Prime Farmland. DWR intends to establish the easements in-county. Also, pages IV.D-59 through IV.D-61 describe Mitigation Measure BIO-5b, which requires that a minimum of 1,000 acres be placed under easement on lands of equal or greater foraging value for Swainson's hawk (e.g., grassland, alfalfa, tomato, or beets). There may be some overlap with regard to these two requirements. See also Master Response 2, *Farmland* and Responses 2-15, 2-17, and 2-26.

Hazards and Hazardous Materials

Haz-ii - Natural Gas Wells and Pipelines - Page 111-34: The site is within the Maine Prairie Gas field which is an active dry gas field. According to the Department of Conservation Well Finder GIS maps, approximately 40 abandoned, plugged, or cancelled natural gas wells are located within the project site. The project description (page 111-34) indicates that decommissioned wells will not be disturbed except in areas of proposed grading. Page IV.F-2 indicated that during a Phase I ESA, a pipe was identified as being associated with *an abandoned gas well/pipe network*. Overall the project includes breaching and removing levees, creating over 20 miles of interior tidal channels, and additional excavation totaling approximately 5,255,000 cubic yards of soil moved within the site. Since most of the site will include some surface grading, it is likely that abandoned, or previously decommissioned wells and associated piping will be exposed. Removal or alternating the surface material surrounding sealed natural gas wells may also impact the integrity of surface seals on these wells which could pose pathway risks for hydrocarbons or other contaminants to migrate into the surface water or groundwater. Article 4.2 of the Public Resources Code requires re-abandonment of previously abandoned gas wells if deemed to pose potential risk or hazard. Mitigation measure HAZ-1: Natural Gas Well and Pipeline Abandonment and Avoidance, page IV.F-15 indicated that EIP shall develop plans and procedures *for natural gas well and pipeline abandonment and avoidance during construction, which may include but are not limited to re-abandonment, plugging, removal, or avoidance of on-site natural gas pipelines and wells.* These procedures should include assessing the long-term integrity of the abandoned well and pipeline seals located in and near inundated areas against risk of impacts to the environment and water quality. The Department of Conservation may require re-decommissioning at-risk or partially plugged natural gas wells that are exposed during site work. Geologic Energy Management Division (CalGEM, formerly DOGGR) administers regulations and procedures pertaining to all oil and gas wells on public and private land. Operators must obtain permits for permanently sealing and closing-also known as plugging and abandoning-wells. 13-5

Response 13-5:

As stated on page IV.F-3 in Section IV.F, *Hazards and Hazardous Materials* of the Draft EIR, according to available records from the California Department of Conservation's Division of Oil, Gas, and Geothermal Resources (DOGGR), all natural gas extraction and transportation infrastructure such as wells and pipelines within the Proposed Project Site have been plugged and properly abandoned in compliance with all applicable regulations. The location of natural gas infrastructure within the Proposed Project Site is depicted in Figure IV.F-1. The location of the plugged and abandoned gas wells and pipelines have been mapped and the restoration design has been developed to avoid disturbance of the abandoned gas wells and pipelines as much as possible. Two portions of lines will be cut and removed as part of levee improvements in accordance with DOGGR regulations. As described in Mitigation Measure HAZ-1, well and pipeline considerations must be integrated into construction plans to minimize the risk of accident or upset conditions involving unknown abandoned natural gas infrastructure. Additional measures include (1) consultation with PG&E to physically test the abandoned pipeline infrastructure on the Proposed Project site to make sure it does not pose a potential risk or hazard, and (2) a requirement to contract with a Registered Petroleum Engineer who will be on-call should it be deemed necessary to re-abandon, plug or remove any pipelines, who can consult with CalGEM regarding any requirements for unknown infrastructure relating to oil and gas wells on the Proposed Project Site. Therefore, procedures are in place for pipeline abandonment testing and avoidance during construction consistent with existing state and federal protocols. The following revisions have been made to Mitigation Measure HAZ-1 on page IV.F-15 of the Draft EIR regarding the plan and procedures that would be put in place:

> Prior to the start of construction, ~~EIP~~ DWR shall develop plans and procedures for natural gas well and pipeline ~~abandonment and~~ avoidance and potential re-abandonment during construction, which may include but are not limited to re-abandonment, plugging, removal, or avoidance of on-site natural gas pipelines and wells. These procedures shall be incorporated into final construction plans provided to DWR and DOGGR prior to the start of ground disturbance and shall describe what work, if any, would be performed on each well and/or pipeline and which wells and/or pipelines would be avoided during site excavation. In addition, a Registered Petroleum Engineer would be on call during re-abandonment, plugging or removal of any pipelines.

Dewatering and Revegetation: Impacts to Species, Adjoining Lands

Dewatering of the site is discussed on Pages 111-29, 30. Will there be impacts to adjacent properties or groundwater wells from dewatering? Impacts to species occupying the site (other than Giant Garter Snake (GGS)) from dewatering, use of heavy construction equipment and earth movement are not discussed in the DEIR. How reasonable is it to assume GGS will voluntarily move to the southeast corner of the property or move offsite and how are these impacts addressed? What are the impacts to other species on the site? What are the impacts to adjacent agriculture and residences in the area from vectors, and other displaced terrestrial species? 13-6

Response 13-6:

Dewatering activities described on page III-29 and III-33 in Chapter III, *Project Description* of the Draft EIR identify that water would be pumped to prepare the Proposed Project Site for construction activities. The dewatering would be for any water in collecting canals or other depressions on the Proposed Project Site. Dewatering activities associated with construction of the Proposed Project were analyzed in the Draft EIR. As described on page IV.G-29 in Section IV.G, *Hydrology and Water Quality*, the Proposed Project would result in temporary dewatering in areas where groundwater is perched or where surface water has collected. This dewatering would be temporary and would not affect neighboring landowners, agriculture, or residences. As a result, it was determined that dewatering activities associated with the Proposed Project would not result in a significant impact.

The Draft EIR also includes analyses of the Proposed Project effects (from dewatering and other construction and operational activities) on special-status species, including GGS, western pond turtle, birds, fish, roosting bats, and special-status plants, on pages IV.D-50 through IV.D-90 in Section IV.D, *Biological Resources* of the Draft EIR. Impacts to GGS and other special-status species from use of heavy construction equipment or earth movement are not anticipated, as these species are expected to vacate the area upon dewatering and before construction equipment enter the area.

Dewatering is a standard measure for avoidance and minimization of impacts to GGS from regulatory agency guidance. The diet of GGS is restricted to aquatic species (tadpoles, fish, frogs), and by dewatering in the active season, GGS naturally relocate from the dewatered habitats to follow prey items. The measure, as described in the Draft EIR, is to dewater and have the area remain dry for 15 days to allow time for GGS to relocate to on-site suitable habitat in search of food. On-site refugia would then be fenced to keep GGS from entering the active portions of the construction area. Based on experience with other projects and guidance from the USFWS and CDFW, dewatering is anticipated to reduce the numbers of GGS in work areas that are dry and distant from suitable aquatic habitat. The standard measure for dewatering has been incorporated into the project description to promote GGS self-migration out of the work areas, and as described in BIO-5D, a qualified biologist will be present for work within 200 feet of suitable aquatic habitat. Suitable aquatic habitat includes areas that have not been dewatered for 15 days. Furthermore, Mitigation Measure BIO-3 includes protection and avoidance measures, and Mitigation Measure BIO-5D would require additional protection for GGS. The Draft EIR concluded that potential Proposed Project impacts on species, including GGS, would be less-than-significant with mitigation incorporated. The mitigation measures identified are consistent with currently-applied state and federal wildlife agency requirements regarding impacts to rare and endangered species such as the western pond turtle and GGS. DWR and its contractors will comply with all applicable regulatory requirements, however the EIR is not required to include all the information necessary to meet other regulatory program requirements. See also Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts* and Master Response 13, *Performance Standards and Deferred Mitigation*.

In response to the comment on vectors, pages IV.A-11 and IV.A-12 in Section IV.A, *Impacts Found to Be Less Than Significant* of the Draft EIR provides and analysis of the Proposed Project effects on vectors (i.e., mosquitoes). As discussed in the analysis, current conditions on the Proposed Project Site result in breeding conditions for mosquitoes due to prolonged periods of flooding resulting in standing water, the presence of emergent vegetation, and the absence of predaceous fish. The Proposed Project would result in a decrease in mosquito breeding habitat compared to current conditions through the creation of open water channels subject to tidal circulation, an increase in water turbidity, and the creation of more favorable habitat for fish. Therefore, the Proposed Project would not result in an increase in vectors.

In response to the comment on displaced terrestrial species, Section IV.D, *Biological Resources* of the Draft EIR analyzed impacts of the Proposed Project on terrestrial species on pages IV.D-64 through

IV.D-73. As stated above, GGS would relocate during dewatering activities to on-site suitable habitat and would be fenced off from entering the construction area. In regard to post-Project impacts on GGS, on page IV.D-71 the Draft EIR finds that, "The Proposed Project would lead to a substantial increase in the total amount and quality of giant garter snake foraging habitat in the Proposed Project Site." Also, as discussed on page IV.D-72, the implementation of Mitigation Measure BIO-5E would relocate western pond turtle away from active construction areas to on-site suitable habitat and protect this species during construction. See also Response 2-19 for a discussion of post-Project habitat for western pond turtle. Displaced terrestrial species would be relocated to suitable habitat on the Proposed Project Site, outside of the active construction area, and would not be placed on adjacent privately owned lands. Areas not undergoing active construction would still be available to individuals of these species, and post-Project high quality habitat is anticipated to attract such species back to the Proposed Project Site.

Invasive Species: The Project would convert agricultural land to tidal marshland which may result in new invasive species that can impact surrounding agricultural land uses. Page 111-33 notes that target invasive plant species would be mechanically removed and /or sprayed as part of the land clearing process. No evaluation was presented regarding potential impact from spraying to surface water, species, and/or adjacent agricultural areas?

An active Revegetation Plan is needed. Page 111-41 specifies that tidal marsh areas are anticipated to revegetate with tule and cattail through "natural recruitment". Natural recruitment, or revegetation can take many years (or even decades) and is usually unsuccessful due to the favorable environment for invasive plant species that may already exist on the site and throughout the area if not carefully managed. Should the Project wish to get credit for the functional habitat it develops and creates habitat that assists aquatic species and food web production, an ongoing, active and managed revegetation program is strongly encouraged. 13-7

Response 13-7:

See Master Response 14, *Invasive Plant Species and Harmful Algal Blooms*.

Water Rights and Water Intakes

The proposed project includes abandonment of intake piping along various levees that were previously utilized for agricultural and residential property. Will the existing water entitlements and place of use be transferred? If not, will the water right owners be compensated, or water right licenses be replaced/ reestablished. 13-8

Response 13-8:

The Proposed Project does not propose changing or transferring existing water rights. Current water rights that exist for the Proposed Project site will transfer with ownership.

In addition, there are a number of agricultural intakes near the Project in the Cache Slough region that will be affected to an as yet unknown degree by the tidal restoration and flood project. Agriculture depends on the continued availability of water of sufficient quality and quality. The ecosystem projects will change water quality and, possibly will bring aquatic species near and potentially into intakes. The DEIR does not evaluate the potential impacts to the ongoing use of water intakes in the area and likelihood of the effects of intake infrastructure or operations and endangered species. Furthermore, no mitigation is identified in the DEIR that could feasibly address such impacts. In fact, DWR, the County and others are working on incidental take protections through developing and permitting a focused habitat conservation plan - an effort that is completely unaddressed by the DEIR. Lastly, there will be economic and social effects associated with the impact on intakes, which, in accordance with Section 15131(b) of the CEQA Guidelines, should be used to determine the significance of physical changes caused by the Project. 13-9

Response 13-9:

Potential changes to water quality are addressed in Master Response 1, *Salinity and Bromide*. Potential changes to water levels are addressed in Master Response 9, *Tidal Effects on Diversions*. Potential changes as a result of increased endangered species are addressed in Master Response 3, *Local Water Diversions and Special-status Fish Species*.

Impacts to Housing and Surrounding Communities

According to the DEIR, Page IV.A-20 mentions only *three* housing units are on the project site. The DEIR project indicated *"The loss of three housing units does not represent a significant number of displaced persons or housing units, and no replacement housing would need to be constructed."* However, the Environmental Assessment report prepared by Blackburn (October 31, 2017) identified nine single family residences on the Liberty Island Ranch Property. An accurate accounting of the number of housing units that will be lost due to the project is needed to evaluate full impacts of such loss. 13-10

In addition, the DEIR does not identify mitigation for the loss of these housing units

Response 13-10:

When the current owner purchased the properties, there were nine single-family units on the property, only one of which was inhabited. The other eight units were un-inhabitable, with no sewage facilities, no windows, and in decrepit condition. The current owner obtained demolition permits from the County and has been in the process of demolishing those homes. At the time of the circulation of the Draft EIR, three of the nine houses remained, one of which was inhabited. The remaining houses will be removed before construction of the Proposed Project commences.

Furthermore, severing access for the public to lower Liberty Island Road, Liberty Island Road Bridge, and Liberty Island would degrade, limit, and significantly impact the public views of these features and create division for the fishing, hunting, and naturalist communities that are currently available to the public. As such, the Project should consider alternatives that would allow continued public right of way and access to these locations. 13-11

Response 13-11:

As described on pages IV.A-2 through IV.A-3 in Section IV.A, *Impacts Found To Be Less Than Significant* of the Draft EIR, the Proposed Project's visual impacts during construction would be minimal due to the temporary nature of construction, the limited availability of public views of the site (including from Liberty Island Road), and because some of the visual character within the project vicinity would be replicated. Therefore, the Proposed Project would not substantially degrade the existing visual character or quality of the site or its surroundings and the impact would be less than significant.

Potential for loss of fishing and hunting opportunities are discussed in Master Response 10, *Recreation*.

Utilities, page IV.A-21 discusses the relocation of utilities (electric power service) onto a neighboring property. Is this relocation being done with the permission of the adjacent property owner? Through easement or other means? Will this service be extended to other users? 13-12

Response 13-12:

As described in the Draft EIR on pages IV.A-22 and 23 in Section IV.A, *Impacts Found To Be Less Than Significant*, implementation of the Proposed Project would result in the relocation or removal of a series of local electrical distribution lines and this impact was found to be less than significant. The existing power line alignment runs east to west on the south side of Liberty Island Road and within the existing County Road Right of Way and currently provides electrical service to the neighboring Rasmussen property, RD 2068's pump #5, and to a pump on Westland's property east of Shag Slough Levee. The Proposed Project would relocate the power lines from the south side to the north side of Liberty Island Road within the existing County Road Right of Way and per the franchise agreement in place between PG&E and Solano County. Electrical service would continue to be provided to existing users. Any impacts as a result of these activities were described in the Draft EIR on pages IV.A-22 and 23 in Section IV.A, *Impacts Found To Be Less Than Significant*.

Impacts on Levees surrounding the Project site

Geology/Soils Page IV.A-4 of the DEIR indicates that proposed project would not cause substantial adverse effects involving strong seismic ground shaking. *"The Proposed Project would alter levees and other facilities on-site that could be exposed to potential adverse impacts during ground shaking; but the modified levee system would be more resilient to earthquakes than the current levees..."* The project intends to remove portions of existing levees and construct the Duck Slough Setback levee. Only the new structure (Duck Slough Setback Levee) and the Cache/Hass Slough Training Levee, and remaining portion of Shag Slough levees that are surrounding the project site are proposed to be strengthened or modified to withstand seismic shaking or other erosion measures. However, removing existing levees or portions thereof could impact levees that surround existing valuable agricultural lands, making these levees susceptible to erosion, wind waves, scouring, and tidal action, and therefore more vulnerable during seismic shaking events if not mitigated and strengthened to current US Army Corp of Engineering standards. 13-13

Furthermore, substantial subsidence and/or collapse of nearby levees are likely with regular inundation of the Project land and without maintenance by public agencies (public right of way interests, public water conveyance interests, and levee maintenance/reclamation district(s)). As such, resultant removal and modification of existing levees could significantly impact surrounding levees protecting valuable agricultural lands if not mitigated.

Response 13-13:

As described in Chapter III, *Project Description* of the Draft EIR on page III-22, Goal 3 of the Proposed Project is to provide additional flood storage and conveyance within the Yolo Bypass to reduce the chance of catastrophic flooding and protect existing nearby infrastructure (e.g., agriculture, power, and human habitation). More specifically, one of the stated Project Objectives is to protect existing nearby infrastructure surrounding the Proposed Project Site and avoid any adverse flood-related impacts in the region. Therefore, the Proposed Project has been designed so that it would not transfer flood risk to adjoining districts. As a result, the seismic loading would be the same for the adjoining areas under the pre and post project conditions, and the Proposed Project would not make adjoining areas or infrastructure more vulnerable during seismic events. The Draft EIR includes some specific information on levee stability as follows:

- As described on page IV.G-30 in Section IV.G, *Hydrology and Water Quality* of the Draft EIR, the Proposed Project was constrained to prevent increases of flood stages in Cache and Hass Slough to no more than 0.01 foot. The Cache/Hass Slough Levee would also remain in place as a training levee and provide a wind-wave buffer for an additional layer of safety for levees on the opposite side of Cache Slough and Hass Slough. Therefore, the Proposed Project's potential to transfer risk from one part of the system to another is less than significant.
- As described on page IV.G-27 in Section IV.G, *Hydrology and Water Quality* of the Draft EIR, the Cache/Hass Slough Training Levee would be reconstructed to have a 16-foot wide levee crown and uniform 4H:1V side slope. These measures would make the east/Proposed Project-facing side of the Cache/Hass Slough Training Levee more resilient in comparison to its existing condition even with the potential for larger wind- generated waves. The modeled wave run-up with the Proposed Project ranges from 2.3 to 3.4 feet and, therefore, the Cache/Hass Slough Training Levee would continue to have insufficient freeboard to completely contain total wave run-up. However, the Cache/Hass Slough Training Levee would be protected at the crest using rock slope protection, articulated concrete block, a turf reinforcing mat, or other similar erosion control measures, as needed. This crest protection would effectively break all waves emanating from the Proposed Project Site such that waves would not continue to propagate towards the Cache Slough and Hass Slough west levees. See also Response to 17-1.
- In addition to these improvements, the Cache/Hass Slough Training Levee and Cross Levee would undergo long term O&M activities. DWR will take over O&M of the Cache/Hass Slough Training Levee and Cross Levee from RD 2098 and would implement maintenance activities such as regular inspections, repairs following flood conditions, and rodent abatement, among others. See also Master Response 7, *Operation and Maintenance (O&M) of Levees*, for a further discussion of maintenance of the levees.
- As described on page IV.G-29 in Section IV.G, *Hydrology and Water Quality* of the Draft EIR, to assure long-term levee stability and minimize risk to adjacent properties, geotechnical investigations at the 65% design phase examined both under-seepage, and through-seepage of groundwater and floodwaters. These investigations found the design is projected to be stable for steady-state slope stability, rapid drawdown slope stability, and end-of-construction slope stability, and have no through seepage. A soil-bentonite cutoff wall is included in the proposed Duck Slough Setback Levee design to provide a seepage barrier within the levee foundation and to tie together the underlying clay blanket. The Duck Slough Setback Levee would therefore not be at risk for under-seepage. Similarly, based on review of historic geotechnical explorations, a thick clay blanket underlies properties across Cache and Hass Sloughs and there is no shallow aquifer present which could elevate groundwater exit

gradients and result in seepage. Off-site levees across Cache and Hass Sloughs would therefore not be at risk for underseepage.

Please see Response 13-14 for additional discussion on levee protection aspects of the Proposed Project.

Lands north and west of project will also be susceptible to greater inundation. As such, flood plain mapping needs to be studied to assess impacts that the Project may create to the local and regional flood plains as well as to the FEMA 100-year flood plain (i.e. increase base flood elevations). Project needs to study and include drainage improvements and mapping to determine the potential impacts for these issues. 13-14

Response 13-14:

In designing the Duck Slough Setback Levee, a series of flooding and habitat considerations were accounted for. Chief among these was the need to maintain the existing level of flood protection for lands north and west of the Proposed Project Site. Compared to baseline conditions, water elevations during the 100-year event would decrease in most upstream and downstream locations. These results indicate that the Proposed Project would improve local flood control and conveyance, and that the Proposed Project would not substantially alter the drainage pattern of the area in a way that would result in flooding; see Draft EIR page IV.G-30 and IV.G-31 in Section IV.G, *Hydrology and Water Quality*.

The lands located north and west of the Proposed Project are currently protected by levees of the State Plan of Flood Control. Through its Non-Urban Levee Evaluation (NULE) Program, investigations by the DWR have identified a number of potential hazards with this levee system.[A] These levees are uncertified and FEMA has mapped these areas within a Special Flood Hazard Area (SFHA).

The Proposed Project would convert land within RD 2098 to tidal marsh habitat. If the Proposed Project is implemented, lands north and west of the Proposed Project Site would benefit from the improved levee protection afforded by the Proposed Project through construction of the new setback levee along Duck Slough and Liberty Island Road. The other levees that would be protecting lands north and west of the Proposed Project are the same ones protecting these lands in the No Project condition, but there are fewer miles of them. Most of these levees (RD 2098 Unit 1 and RD 2098 Unit 4) are considered vulnerable due to freeboard deficiencies, or have a record of issues related to stability, underseepage, or erosion, that are unrelated to the Proposed Project (see **Table 1**, below). Although lands north and west of the Proposed Project Site would remain in a SFHA, their overall exposure to flood risk would be reduced by construction of the Proposed Project, and would represent an improvement relative to existing conditions.

FOOTNOTE A URS. 2011. Geotechnical Assessment Report – North NULE Project Study Area, Volume 6 of 6: Appendix G – Area 5 Levee Segments. Prepared on behalf of California Department of Water Resources.

TABLE 1
LEVEE HAZARD SUMMARY (URS, 2011)

Levee Unit	NULE Unit ID	Scenario	Levee Length (miles)	NULE GAR Hazard Extent (miles)			
				Freeboard Less Than Design	Stability	Under-seepage	Erosion
RD 2068 Unit 1	152	without-Project	5.5	2.8	0.3	2.8	2.2
		with-Project	5.5	2.8	0.3	2.8	2.2
RD 2068 Unit 2	311	without-Project	3.3	No Hazards Identified*			
		with-Project	3.3				
RD 2098 Unit 1	153	without-Project	4.2	3.5	3.8	3.8	1.6
		with-Project	0.0	0.0	0.0	0.0	0.0
RD 2098 Unit 2	313	without-Project	1.9	0.1	0.4	1.9	0.6
		with-Project	0.0	0.0	0.0	0.0	0.0
RD 2098 Unit 3	312	without-Project	1.9	0.1	1.2	0.0	1.0
		with-Project[1]	0.8	0.0	0.5	0.0	0.4
RD 2098 Unit 4	249	without-Project	2.9	0.0	0.9	0.0	0.0
		with-Project	2.9	0.0	0.9	0.0	0.0
Proposed Setback Levee	N/A	without-Project	0.0	0.0	0.0	0.0	0.0
		with-Project	2.9	0.0	0.0	0.0	0.0
Total		**without-Project**	**19.7**	**6.5**	**6.5**	**8.5**	**5.3**
		with-Project	**15.5**	**2.8**	**1.7**	**2.8**	**2.6**

NOTE:
1 Although performance record suggests majority of issues have occurred south of Duck Slough, analysis assumes deficiencies are uniform on a per mile basis north of this location in the with-Project condition

SOURCE: URS. 2011. Geotechnical Assessment Report – North NULE Project Study Area, Volume 6 of 6: Appendix G – Area 5 Levee Segments. Prepared on behalf of California Department of Water Resources.

The Proposed Project Site is currently mapped within a SFHA, and implementation of the Proposed Project would not change the hazard classification of these lands. Typically, FEMA does not require remapping an area unless changes in water surface are greater than 0.5 feet. As described on page IV.G-25 in Section IV.G, *Hydrology and Water Quality* of the Draft EIR, based on hydraulic modeling, the analysis found that the Proposed Project may decrease the range of water surface elevations influenced by the tides (page IV.G-25). As the project lowers flood stages in the region, and does not enlarge the area at risk, updates to the FEMA floodplain maps to reflect the Proposed Project improvements would not be required.

Please see Master Response 9, *Tidal Effects on Diversions*, for additional discussion on the Proposed Project's effect on tidal water levels.

The resultant project will incur a substantial soil erosion and loss of topsoil due to conversion of these land during grading operations without best management practices. Long term soil erosion into Shag Slough may be significant without runoff control measures. Grading, drainage, and erosion control plan must be reviewed and permitted by Solano County Department of Resource Management in accordance with Solano County Ordinance Chapter 31. Post-construction water flows from the Project through the new tidal marshes may increase the rate of erosion and sedimentation into Shag Slough. 13-15

Response 13-15:

With regard to erosion issues during construction, as described on pages IV.G-19 through IV.G-20 in Section IV.G, *Hydrology and Water Quality* of the Draft EIR, if the Proposed Project is approved, an NPDES permit from the Central Valley Water Board would require that a Stormwater Pollution Prevention Plan (SWPPP) be prepared, and applicable best management practices would be implemented during construction in compliance with necessary permit requirements and stipulations as approved by the Board. The SWPPP is required to describe all of the construction site operator's activities to prevent stormwater contamination, control sediment and erosion, and comply with the requirements of the Clean Water Act.

Solano County Ordinance 31 deals with means for controlling soil erosion, sedimentation and increased rates of water runoff and the standard methods set forth in the ordinance are similar to or the same as those that would be included in the SWPPP. Reference to the ordinance has been added to the regulatory setting in Section IV.G, of the Draft EIR.

With regard to erosion issues post construction, flood-basin deposits in this region are typically firm to stiff silty clay, clayey silt, and silt.[B] Velocities computed across the marsh plain for both high (flood) and normal tidal flow conditions are generally below the threshold for which these types of soils would erode. Over time, as vegetation colonizes the site, erosion potential would be further reduced, as tules and other marsh plants would provide a buffer against wind and water forces. Once vegetation is established, sediment and plant litter transported by freshwater and tidal flows will likely accrete, gradually building marsh elevation in opposition to erosion.[C] Further, as described on page IV.G-X in Section IV.G, *Hydrology and Water Quality* of the Draft EIR, the soil underlying the Proposed Project Site provides stable soil conditions that would not be susceptible to erosion from the hydraulic shear stresses on the designed channels and levee breaches.

FOOTNOTE B Atwater, B. 1982. *Geologic Maps of the Sacramento-San Joaquin Delta California*. U.S. Geological Survey; MF-1401.

FOOTNOTE C U.S. Fish and Wildlife Service (USFWS). 2013. Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California. Sacramento, California.

With regard to Solano County Ordinance 31, the following text has been added to the regulatory setting on page IV.G-17:

> Solano County Grading Ordinance
>
> The Solano County Code Chapter 31 was adopted to provide the means for controlling soil erosion, sedimentation, and increased rates of water runoff in order to protect downstream

waterways and wetlands and to promote the safety, public health, convenience and general welfare of the community. The ordinance establishes standard methods to prevent off-site erosion.

Although the Proposed Project is a State-sponsored project that for most purposes is exempt from local ordinances and policies, the Proposed Project incorporates design elements to prevent soil erosion, sedimentation, and increased rates of water runoff in order to protect downstream waterways and wetlands, including a NPDES permit from the Central Valley Water Board and mandatory implementation of BMPs. (Draft EIR pages IV.G-19 to IV.G-22.)

Public and Emergency Access and Conflicts with Existing Easements

The Project proposes to breach the levee under Liberty Island Road and vacate the public easement that serves Liberty Island Road, Shag Slough Bridge, and Liberty Island. A Road Vacation process subject to Solano County Board of Supervisors approval is required for Liberty Island Road. However, no mitigation is proposed since the proposed project description on page IV.A-21 indicates that emergency and public access will not be impacted because the property and remaining access will not serve populated areas. Severing access to Liberty Island Road, Shag Slough Bridge, and Liberty Island will impact emergency response and public access to these locations. In addition, PG&E transmission towers will remain and will be accessible via peninsulas. Removal of existing and supporting roadway access to the PG&E towers may curtail response time to these towers in an emergency; especially with locked gates and use of levees for access. Furthermore, these changes as proposed in the Project will result in substantial impairment of adopted emergency response plans and emergency evacuation plans. The Project should consider alternatives, including culverts, bridges, or other accessible drainage ways, that would allow continued public right of way and emergency access to these locations 13-16

Severing and vacating the public right of way and access to Liberty Island Road, Shag Slough Bridge, and Liberty Island will conflict with the Solano County General Plan goal for improving agricultural, pedestrian, and general public access and circulation to eastern Solano County. It is also inconsistent with the California Constitution itself. (See Cal. Const., Art. X, § 4.) The Project may also significantly impact and degrade the condition of connecting roadways through importation (trucking) of soils over Solano County's roads.

Response 13-16:

DWR and its contractors will comply with all applicable requirements with regard to the Proposed Project vacation of, and relating to the Liberty Island Road no longer being available for public use; however, the EIR is not required to include all the information necessary to meet other regulatory program requirements. The Draft EIR considers the following with regard to the breach and its relationship to the use of the Liberty Island Road and Shag Slough Bridge for emergency access and public use not relating to recreation.

Emergency access to and within the Proposed Project Site will be maintained as described on page III-35 in Chapter III, *Project Description* of the Draft EIR. Roads for internal project access will be closed to the general public, but they would be open to utility and emergency service providers. Internal access would support inspection and maintenance activities associated with the levees and would provide access to the proposed boat ramp, which would be used by DWR and CDFW to monitor the long-term success of the restoration goals of the Proposed Project. Access to PG&E transmission towers would be maintained via the setback levee road, as described on page III-35 in Chapter III, *Project Description*, and as depicted in

Figure 1. As noted in Response 19-8, these levee roads would be graveled, all-weather roads. Therefore, there would be no significant impact from the Proposed Project with regard to emergency access and use not relating to recreation.

With regard to other access, the Proposed Project would not affect any roadways that provide community connectivity, as described on page IV.A-8 in Chapter IV.A. Provisions for access for the neighbor to the north of the property is being made by moving driveway access to the new proposed terminus of Liberty Island Road. The following text changes have been made in Chapter III, *Project Description* on page III-35 to reflect a change in the location of the gate on Liberty Island Road and clarify access to entities for maintenance and emergency services:

> The Proposed Project would provide non-public internal access for emergency and non-recreational uses to the Duck Slough Setback Levee, Cache/Hass Slough Training Levee, Cross Levee, and the northern section of the degraded Shag Slough Levee. A gate would be installed at the ~~northwest~~ northeast corner of the Project Site on the southern side of Liberty Island Road at Shag Slough in order to restrict public pedestrian and vehicular access to the Project Site. Internal access would include a network of internal roads along the top and toes of the levees and PG&E access peninsulas for maintenance, monitoring, and emergency services.

Liberty Island Road presently dead ends on the western side of the Liberty Farms Property and does not serve any populated areas that require emergency access. The only property where emergency access could be potentially affected is the Liberty Island Ecological Reserve (LIER), where direct road access would no longer be available following breaching along the Shag Slough Levee. The Proposed Project would not necessitate the construction or expansion of emergency services or impact emergency response. As discussed in Section IV.I, *Public Services* of the Draft EIR, the Shag Slough Bridge cannot currently support emergency vehicles because of its damaged condition. However, fire and police protection for the LIER is currently provided by boat access from entities with emergency marine services such as the Solano County Sherriff Marine Patrol Division or the Coast Guard, and this would continue after implementation of the Proposed Project. In addition, the boat ramp proposed as part of the Proposed Project will be open to emergency service providers. Therefore, as described on page IV.A-21 in Section IV.A, *Impacts Found To Be Less Than Significant* of the Draft EIR, the Proposed Project would not physically or permanently alter publicly accessible roadways in a manner that might result in inadequate emergency access.

See also Master Response 10, *Recreation*.

With regard to construction traffic, as described on page IV.A-20 in Section IV.A, *Impacts Found To Be Less Than Significant* of the Draft EIR, haul and commute trips would lead to greater road usage than baseline levels. However, extra vehicle trips would be temporary and would be spread out throughout the construction period, making the likelihood of road damage low. This is especially true given that roads in the vicinity of the Proposed Project Site are designed for and regularly accommodate agricultural equipment and operations, which may include large trucks and farm equipment. Therefore, the Proposed Project would not interfere with agricultural, pedestrian, and general public access and circulation, and the impact of the Proposed Project would be less than significant with regard to public access not related to recreation.

Changes to the levees will require approvals from other agencies including the Central Valley Flood Control Board and the US Army Corps of Engineers. As discussed in Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts,* DWR and its contractors will comply with all applicable regulatory requirements, including alteration to the RD 2098/2068 Emergency Operation plan at the appropriate time. Please also see Responses 12-9. However, the EIR is not required to include all the information necessary to meet other regulatory program requirements. As explained on Draft EIR page IV.F-17, the Proposed Project would increase flood resilience relative to baseline conditions. Thus, the Proposed Project would locally decrease the likelihood of damaging flooding.

Recreation

The document does not address negative impacts to public access, offers no alternatives to recreation in the area, and does not acknowledge the suite of problems that will arise from the public's continued use of this area despite gates and other obstructions. For these reasons, we also disagree with the assertion on page IV 1-9 that emergency vehicle and Marine Patrol interaction will be reduced in this area. These impacts must be addressed in the document. The assumption on page IV.J-5 that most Californians travel an hour for recreation is not relevant in this context and inadequate justification for not addressing the impacts described above. Severing and vacating the public right of way for Liberty Island Road, Shag Slough Bridge, and Liberty Island as proposed will significantly impact the shoreline fishing and other recreational opportunities for the public in the Delta, which is already relatively limited.

Does the Project suggest leaving the Liberty Island/Shag Slough Bridge in place despite the intention to vacate all access to it? The commentary on page IV.A-21, IV.I-9 would indicate this is the case. The Project should consider alternatives, including culverts, bridges, or other accessible drainage ways, that would allow continued public right of way and access to these locations. We also suggest modification of the Project to leave the road in place, do not degrade the Shag Slough levee up to the bridge and instead culvert necessary levee breaches in that section. This would allow continued use of the road by those needing access, as well as continued public access to the area and adjacent Liberty Island. Road vacation requires a lengthy process and permits are required. The document is incorrect in that it mentions only one neighbor to the north requiring road access. This road is used by the public, landowners to the north, as well as RD 2068, to access its facility located just to the north of the project.

13-17

Response 13-17:

See response to Comment 13-16 with regard to access for emergency and non-recreational uses. For comments regarding potential impacts related to recreation see Master Response 10, *Recreation*. The assumption about anglers traveling one hour to seek alternate fishing opportunities is based on information contained in a study referenced on page IV.J-6 of in Section IV.J, *Recreation* of the Draft EIR and is included as background and context for the analysis. However, this study was not cited in the Draft EIR as justification for not addressing potential impacts to recreation. If there is unauthorized use of the area despite gates and other obstructions, there is adequate emergency access to deal with potential problems. Shag Slough Bridge is discussed on page III-35 in Chapter III, *Project Description* of the Draft EIR, which states that as part of the Proposed Project, access on Liberty Island Road would be vacated from the northeast corner of the project to the Shag Slough Bridge. The Proposed Project does not include any action regarding the bridge. Page III-35 in Chapter III, *Project Description* of the Draft EIR will be revised to reflect this information as follows:

> The Proposed Project Site is presently accessed via Liberty Island Road. Near the southeastern terminus of Liberty Island Road, the Shag Slough Bridge provides pedestrian access to ~~the Reserve~~ a small portion of the western shoreline of Shag Slough in the Reserve where bank fishing is allowed. The Proposed Project would vacate Liberty ~~Farm~~ Island Road from the ~~northwest~~ northeast corner of the project to the Shag Slough Bridge.

Regarding the suggestion to culvert levee breaches, the use of culverts in the place of breaches is inconsistent with FRP restoration guidelines, as stated in the FRP Implementation Strategy and does not meet the Proposed Project objectives.

Please see Responses 13-16 and 12-9 regarding access for RD 2068.

Environmental Setting, i. Environmental Site Assessments

Two Phase I Environmental Site Assessments (ESAs) (Appendixes J, K, L and M) were conducted for the project site which identified potential areas of concern. Subsequent Phase II ESAs were conducted at each the Bowlsbey and Liberty Farms properties which included collecting shallow soil samples at each property. Laboratory analysis of the shallow site soil identified elevated concentrations of volatile organic compounds, petroleum hydrocarbons, organic pesticides, and metals. The Phase II reports compared the analytical results to the USEPA Regional Screening Levels and the San Francisco Bay Regional Water Quality Control Board Environmental Screening levels (ESLs) for residential site use. However, the reported concentrations were not compared to Water Quality Objectives for the Central Valley Region, of which the site is located; nor for potential leaching or impacting surface and drinking water or risks to the environment including bioaccumulation and fish ingestion. Furthermore, the DEIR indicated that samples collected near a waste collection area exhibited elevated levels of Chromium reported *"at levels low enough to be safe if the soils are left undisturbed"*. However, the proposed project includes massive grading, reuse of onsite soils, and inundation of the project to tidal fresh water. As such, impacted soil are likely to be disturbed and may result in unauthorized releases to surface water. Overall, findings of elevated concentrations identified at the site warrant reporting of potential unauthorized release(s) (Heath and Safety Code § 25501 through 25510, CCR § 2703, and Water Code § 13271) and further assessment for possible mitigation. At minimum the findings should be reported to the Solano County Certified Unified Program Agency (CUPA), the Central Valley Regional Water Quality Control Board and the Department of Toxics Substance Control. Any hazardous materials and/or storage including fuel storage tanks may require permitting by the CUPA prior to removal. All impacts identified should be assessed and mitigated as required under the oversight of the Central Valley Region Water Quality Control Board and/or Department of Toxics Substance Control. 13-18

Response 13-18:

As described in Response 1-1, remediation of hazardous materials identified in Appendix K, *Phase II Environmental Site Assessment (Phase II ESA): Cache Slough Project Property [Bowlsbey and Vogel Properties]* of the Draft EIR, will be completed before the initiation of any Proposed Project-related earth disturbing activities. Once these hazardous materials are removed and remediated to applicable regulatory standards, there will be no known hazardous materials above applicable regulatory thresholds on the Proposed Project Site.

While chromium was detected on the Proposed Project Site, results were well below the regional screening levels and were not detected during testing for soluble fraction of chromium; therefore, remediation for chromium in the soils, including soils tested around the waste collection area (see Figure 2 in Appendix K of the Draft EIR) is not required. In addition, as discussed in Response 1-1, a Spill Prevention Containment and Countermeasure (SPCC) plan will be developed and implemented, as required under Section 301 of the Clean Water Act, to minimize the potential for, and effects from, spills of hazardous, toxic, and petroleum substances during construction and operation activities, as well as minimize the effects of unearthing previously undocumented hazardous materials. DWR and its contractors will comply with all applicable regulatory requirements regarding hazardous materials removal and remediation.

For general context, the regulatory settings for Section IV.D, *Biological Resources* and Section IV.G, *Hydrology and Water Quality* of the Draft EIR on pages IV.D-42, IV.D-45 to IV.D-46, and IV.G-11 through IV.G-14 provide details on the requirements for water quality, including stormwater pollution prevention during construction and dewatering. DWR and its contractors will comply with all applicable regulatory requirements regarding water quality.

Conversion of agricultural lands to tidal marsh wetlands may create significant releases of atmospheric methane, with potential for other emissions, which will significantly increase the Greenhous Gas (GHG) emissions from the Project acreage. This directly conflicts with the Solano County General Plan and Climate Action Plan goal of reducing GHG emissions. The Project needs to consider alternatives to address this impact or incorporate mitigations for these impacts. 13-19

Response 13-19:

Greenhouse gas emissions (GHGs) associated with implementation of the Proposed Project, including the conversion of agricultural lands to tidal marsh wetlands were analyzed and are included in Section IV.A, *Impacts Found To Be Less Than Significant* of the Draft EIR on pages IV.A-7 and IV-A-8. Discussion on these pages explains why the GHG emissions of the project are less than significant. Although not discussed in the Draft EIR, some data show that operation of the Proposed Project would result in fewer GHG emissions compared to existing land uses which include cattle grazing and farming practices that emit GHG's.

The following text is added to page IV.A-8 in item 'i' of the GHG emissions discussion of the Draft EIR:

> Land-use change was also considered in assessing potential impacts of the Proposed Project effect on GHGs. Under existing conditions, annual soil sequestration, CO2 emissions, and CH4 emissions result in 42,051 tonnes CO2 equivalents emitted per year from the Proposed Project site; a reduction of 38,701 tonnes CO2 equivalents than under existing conditions. Additionally, post-restoration biomass would be expected to increase by 16,127 tonnes CO2 equivalent, decreasing GHGs even more during Proposed Project operations.[D] Impacts would be less than significant.
>
> FOOTNOTE D ESA. 2020. Memorandum from Linsey Sheehan, ESA to Erick Cooke, ESA. Subject: Lookout Slough Change in Operational GHG. April 28, 2020.

Because the impacts associated with GHG emissions from the Proposed Project were determined to be less than significant, GHG emissions would not conflict with the Solano County General Plan and Climate Action Plan goal of reducing GHG emissions or any other local, regional or state climate action plans.

Alternatives

The range of alternatives to the Project described in Chapters II and VII are very narrowly defined, consisting of minor variations of the project on the site, including a flood-only alternative that does not meet the objectives of the Project. The DEIR should evaluate a broad range of alternatives to the project, including other options outside of the proposed Project boundaries. This could include a project to develop functional habitat at the partially flooded Liberty Island site, already owned by the State. 13-20

Response 13-20:

The range of alternatives evaluated in Chapter VII, *Alternatives* of the Draft EIR represent a reasonable range of alternatives that could feasibly attain most of the basic objectives of the project. An alternative consisting of developing functional habitat at the partially flooded Liberty Island site would not meet most of the Project Objectives, including: providing additional flood storage and conveyance within the Yolo Bypass; improving primary and secondary productivity and food availability for Delta Smelt and other native fishes, compared to existing conditions; increasing on-site diversity of foraging, breeding, and refuge habitat conditions for wetland-dependent species, compared to existing conditions. The Draft EIR includes a discussion of this alternative, which would replace existing tidal wetland habitat with new tidal wetland habitat for a zero net gain, in the alternatives rejected section.

Cumulative Effects of the Project with others in the region

Page V-5 to V-7 list many projects in the Yolo Bypass/Cache Slough region, Suisun Marsh and the Delta. However, the document is silent on the fact that many of these projects are elements of larger plans for flood control, ecosystem restoration and fish recovery, all implemented as separate projects with little or no comprehensive modeling and research of cumulative effects. For example, the larger Yolo Bypass region has been the focus of a number of the projects listed, that together (and with climate change) will allow the Bypass to be flooded more frequently and for a longer duration than it is today. This would establish necessary flood capacity to help address climate change and to bolster salmonid survival by allowing fish into the Bypass to rest and feed. The cumulative effects of this project, along with others such as the Fremont and Lisbon Weir Projects and the Yolo Bypass Salmonid & Fish Passage Projects as well as the ecosystem projects need to be modeled so that cumulative impacts can be identified and disclosed. 13-21

Response 13-21:

As explained in Chapter V, *Cumulative Impacts*, the Draft EIR relies on a list approach for the cumulative impacts analysis and uses an accepted qualitative, rather than quantitative (or modeling) analysis (see page V-1 in the Draft EIR). However, the cumulative analysis did model other tidal marsh restoration options in the Delta. Modeling results indicate that the primary driver of changes to salinity distribution is tidal prism during dry season. The fish passage measures in the Yolo Bypass will only affect wet season flows, when complying with salinity standards will not be an issue. So while those projects were not considered in the modeling, they are not anticipated to affect salinity distribution.

Please see Master Response 5, *Cumulative Impacts Analysis*, for additional discussion of cumulative impact analysis in the Draft EIR.

Thank you for the opportunity to review and comment on the DEIR.

Sincerely,

Bill Emlen
Director of Resource Management

CC: Board of Supervisors
Birgitta Corsello, County Administrator
Bernadette Curry, County Counsel

Attachment - Appendix A: Water Quality

APPENDIX A: Water Quality

The Draft EIR misinterprets the CEQA Guidelines for Water Quality significant impacts

The DEIR in Appendix S, Potential Salinity Impacts Assessment, on page 2, states:

With regard to assessing effects of changes in salinity for CEQA, the most important significance criteria "result in substantial adverse effects on beneficial uses of water" and "violate existing water quality standards, waste discharge requirements or otherwise substantially degrade water quality." Based on how DWR has recently analyzed the impacts of tidal wetland restoration projects on salinity (e.g., Prospect Island, Winter Island, Decker Island), the determination of whether a change is considered "significant" depends on whether there would be an exceedance of a standard set forth in the State Water Resources Control Board's (SWRCB's) Bay-Delta Water Quality Control Plan (Bay-Delta Plan) and/or Water Rights Decision 1641 (D-1641.)

The reference to "otherwise substantially degrade water quality" is from CEQA Appendix G, Environmental Checklist Form, under VIII. Hydrology and Water Quality, term (f). This term acknowledges that there can still be significant adverse water quality impacts when water quality is well below any regulatory standard such as those in the SWRCB's D-1641.

For example, farmers in the north Delta choose crop types and irrigation practices based on their expectation of salinities that are well below the agricultural EC and urban chloride concentration standards in D-1641. 13-22

Similarly, there is no D-1641 chloride standard at either CCWD 's Old River intake or Victoria Canal intake. That does not however allow for degradation of water quality in those two locations. CCWD constructed Los Vaqueros Reservoir based on a historical availability of water of 50 mg/L chloride concentration or better at those two central Delta intakes. A project that causes increases in salinity and reduced availability of 50 mg/L water in those locations can cause significant adverse impacts.

DWR's method for analyzing the significance of adverse impacts of tidal wetland restoration projects on salinity (e.g., Prospect Island, Winter Island, Decker Island) which was based on whether a change would be an exceedance of a D-1641 standard was inadequate.

As discussed below, the Lookout Slough EIR must also use a significance criteria based on a percentage increase in salinity, whether or not a standard is exceeded.

Response 13-22:

See Master Response 1, *Salinity and Bromide*, including additional discussion of impacts associated with salinity related to exceedance of the D-1641.

The Draft EIR fails to define acceptable Significance Criteria for identifying significant adverse impacts

As discussed in Solano County's April 22, 2019 comments on the Notice of Preparation for Proposed Lookout Slough Restoration Project, the EIR for the Lookout Slough project must include a detailed analysis of the adverse impacts of the proposed restoration of approximately 3,000 acres of tidal marsh habitat on water quality in the full Sacramento-San Joaquin Delta. The Lookout Slough DEIR fails to use accepted Bay-Delta water quality significance criteria of 5 mg/l chloride or 5% increase, whichever is greater. In the case of specific conductance (EC) the corresponding criterion should be the greater of 20 µSiem or 5% increase.

California Water Code Section 85020 also states that the policy of the State of California is to achieve the following objectives that the Legislature declares are inherent in the coequal goals for management of the Delta, including:

(e) Improve water quality to protect human health and the environment consistent with achieving water quality objectives in the Delta.

It would be inconsistent with this law to implement Bay-Delta projects that fail to mitigate for degradation of their significant water quality impacts.

According to the modeling results provided to Solano County by DWR, the EcoRestore Projects, including the proposed Lookout.Slough project would increase salinities at CCWD's Rock Slough intake off Old River in the central Delta by as much as 9.2%. Key excerpts from the DWR water quality modeling data are presented in the table below. Significant adverse water quality impacts (salinity increases greater than 5%) occur in October, November and December for the very limited simulation period of January 10, 2019 through January 31, 2019 (less than one year). 13-23

This is a significant adverse impact on Bay-Delta stakeholders and must be fully disclosed and mitigated. CCWD and other urban water agencies are operated to meet regulatory water quality requirements for drinking water and industrial water use on a daily basis. Disclosing impacts only as long-term averages is not acceptable.

CCWD Intake at Rock Slough
Daily-averaged Specific Conductance (EC as µSiem)

Date	Existing Base EC	Existing with Lookout Slough EC	Regional Projects Base EC	Regional Projects with Lookout Slough EC	Cumulative Adverse Impact in EC	% Increase in EC
10/30/09	692	702	750	755	63	**9.10**
10/31/09	682	692	739	744	63	**9.17**
11/1/09	672	681	728	733	62	**9.19**
11/2/09	663	672	718	723	61	**9.17**
11/3/09	655	664	710	715	60	**9.11**
11/4/09	648	658	702	707	59	**9.03**

According to a RMA Report provided to Solano County by DWR (file: LookoutSloughSalinityImpactsD1641_06May201.p9df), significant adverse water quality impacts (greater than 5%) also occur at Prisoners Point. These data were monthly-averaged EC so the percentage increase in EC for daily EC data is expected to be even larger than the 8.9% in the table below. Data very recently provided by DWR show the maximum daily increase is 11.2%.

 Letter 13

Monthly-average computed Base EC, Base EC with Lookout Slough, Regional Restoration EC and Regional Restoration with Lookout Slough EC (µSiem) and relative (%) **EC change due to the Regional and Lookout Slough projects at D29 - San Joaquin River at Prisoners Point**

Month	Existing base EC µSiem	With Lookout Slough EC µSiem	Regional restoration base EC µSiem	Regional with Lookout EC µSiem	Total EC Change µSiem	Total EC % Change
Jan-2009	542.7	544.6	531.3	532.9	-9.8	-1.8
Feb-2009	456.2	459.5	443.7	446.0	-10.2	-2.2
Mar-2009	220.3	220.3	217.2	217.2	-3.1	-1.4
Apr-2009	219.2	219.7	217.5	217.9	-1.3	-0.6
May-2009	211.3	211.9	209.4	209.9	-1.4	-0.7
Jun-2009	193.2	193.9	192.4	193.0	-0.2	-0.1
Jul-2009	223.6	222.9	225.3	224.4	0.8	0.4
AuQ-2009	360.3	362.9	371.9	372.2	**11.9**	3.3
Sep-2009	413.0	421.8	434.2	438.8	**25.8**	**6.2**
Oct-2009	323.6	333.1	344.8	352.4	**28.8**	**8.9**
Nov-2009	322.3	328.9	337.5	343.5	**21.2**	**6.6**
Dec-2009	402.9	406.8	411.2	414.9	**12.0**	3.0

The DEIR on page 6 of Appendix S states: 13-23 Cont.

The combined effect of the Project on Delta EC in combination with other planned tidal wetland restoration project can at times of the year be appreciable for certain D-1641 monitoring compliance stations when compared to existing baseline conditions without these Delta restoration projects in place (e.g., greater than 8 percent increase in EC for an October 2009 scenario at Station D29); nevertheless, even with the combined effects of the Project with other restoration projects currently under planning, Delta salinities would remain in compliance with D-1641 requirements. Therefore, the Project's incremental effect on salinity in the Delta would not be considerable and the cumulative impact is less than significant.

This is not accurate. The increase of 8.9% in the monthly-averaged EC at Prisoners Point is significant because it exceeds the 5% significance criteria generally used for Bay-Delta projects.

SWRCB D-1641 includes a fish and wildlife standard of 440 µSiem (maximum 14-day running average) for April and May for all but critical water years. However, significant adverse impacts to salinity in this region, at any time of the year, will affect all beneficial uses of Delta water and must be fully mitigated.

The simulated daily increases in salinity (EC) at Prisoners Point, CCWD's Rock Slough and Old River intakes and the State Water Project's Clifton Court Forebay intake are shown as a times series for 2009 in the graph below. Some of these data were provided by DWR on February 11, just before the comment deadline. Not only are there significant adverse water quality impacts well in excess of the 5% significance criteria but they persist for much of the one-year simulation period. This also points to the need for a longer simulation period. Will the salinity increases be larger and occur more often in critical years? Will exceedances of 5% occur every year?

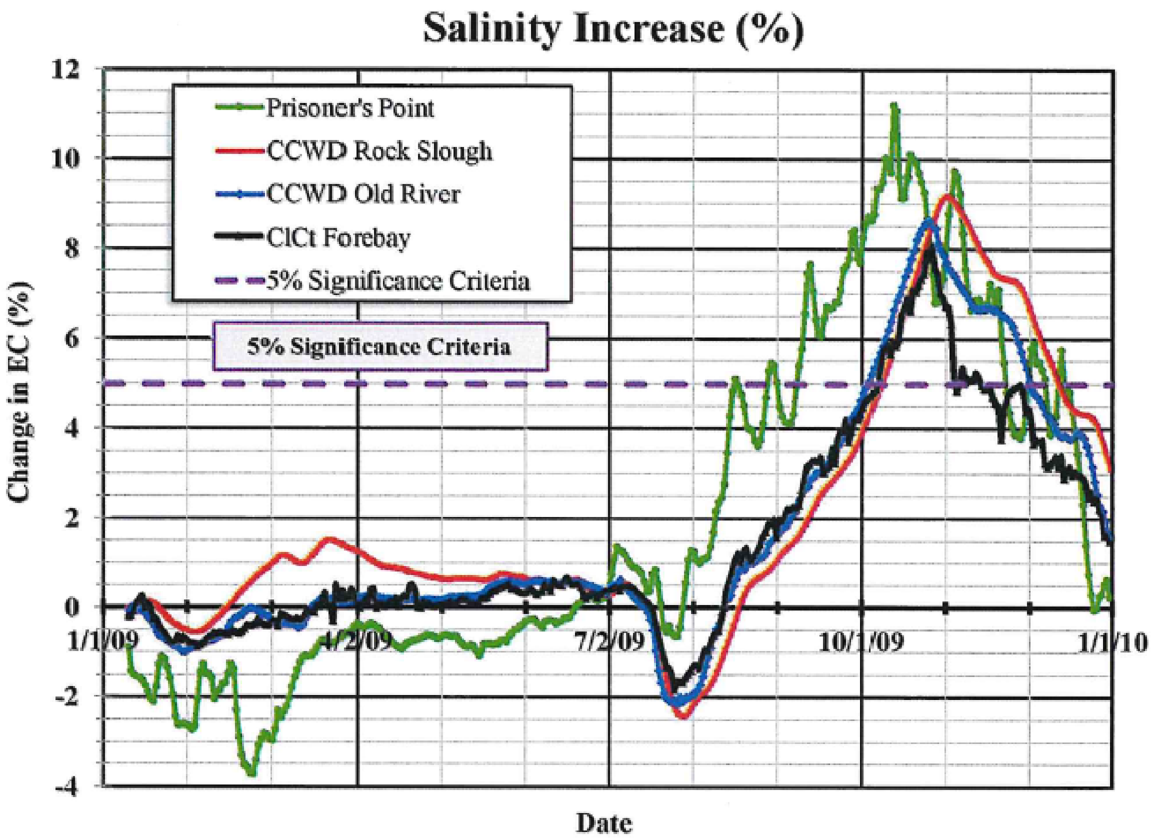


Figure: Time series plot of percentage increases in salinity at Prisoners Point, CCWD's Rock Slough and Old River intakes and the State Water Project 's Clifton Court Forebay intake for January-December 2009.

The EIR must fully analyze and disclose all these significant water quality impacts, as daily averages, and commit to actions to avoid or fully mitigate these impacts. 13-23 Cont.

Response 13-23:

Please see Master Response 1, *Salinity and Bromide* for detailed information on salinity and bromide modeling. Issues specific to this comment from Solano County are further addressed below in regards to the significance standard, the adequacy of the modeling, and the potential change in EC due to the Proposed Project.

<u>*Significance Standard*</u>

The comment requests that the analysis of effects of the Proposed Project on salinity use a significance criterion of "5 mg/l chloride or 5% increase, whichever is greater" and for specific conductance use "the greater of 20 µSiem or 5% increase." The standard proposed by the comment was developed by Contra Costa Water District (CCWD) for its 1993 Los Vaqueros Proposed Project Final EIR/EIS and also used by East Bay Municipal Utility District for its 2003 Freeport Regional Water Proposed Project EIR/EIS. As discussed in more detail in Master Response 1, *Salinity and Bromide*, salinity standards from the San Francisco Bay/Sacramento-San Joaquin Delta Estuary Plan (Bay-Delta Plan) and State Water Board Decision 1641 (D-1641) were used as thresholds for analysis of the Proposed Project's effects on water quality and are generally accepted. The 2008 EIR analyzing Solano County's General Plan used standards from the San Francisco Bay Regional and Central Valley Regional Water Quality Control Board's basin plans and other statewide water quality regulations for analysis of impacts.[E] In relation to these standards, even though there are small increases above 5% EC in some locations for some limited periods of time, the Proposed Project does not result in any additional water quality degradation that would cause any of the locations in the comment to approach D-1641 non-compliance for agriculture, fish and wildlife, or municipal drinking water beneficial use.

FOOTNOTE E Draft Environmental Impact Report – Solano County 2008 Draft General Plan (SCH #2007122069) p. 4.5-37, https://www.solanocounty.com/civicax/filebank/blobdload.aspx?BlobID=15179.

Adequacy of Modeling

The comment raises concern about the need for longer simulation periods, consideration of critical years, and disclosing impacts as daily averages. As explained in Master Response 1, *Salinity and Bromide*, all of these concerns have been addressed by revising the modeling and documenting the revised modeling in Appendix X. This additional modeling indicates that the Proposed Project does not result in any additional water quality degradation that would cause any of the locations in the comment to approach D-1641 non-compliance for agriculture, fish and wildlife, or municipal drinking water beneficial use.

Potential Change in EC due to the Proposed Project

The County tabulates results from the salinity modeling of 2009 conditions and calculates the potential magnitude of change as up to 28.8 µSiemens/cm or 8.9% for monthly averaged EC and up to 63 µSiemens/cm or 11.2% for daily maximum EC. The County's calculations of total change in EC are the result of subtracting the existing base scenario from the Regional Restoration with Proposed Project scenario. By comparing these two scenarios, this calculation overstates the potential impact from the Proposed Project, as compared to the impact analysis conducted for this EIR, as described in the next paragraph.

The Draft EIR analyzed the immediate potential impact of the Proposed Project by subtracting the existing base scenario from the existing base scenario with the Proposed Project. For the cumulative impact analysis, the Draft EIR explained why the combined impact of the Proposed Project and other Regional Projects is not significant and determined that the Proposed Project's incremental impact on EC is not cumulatively significant. To analyze the potential incremental effect of the Proposed Project, the EIR analyzes the change by subtracting the Regional Restoration scenario from the Regional Restoration scenario with the Proposed Project.

The model results in the table in this comment are from an earlier iteration of the modeling in Appendix S of the Draft EIR, and have been superseded by refined modeling in Appendix X of this Final EIR. Using the same table as the comment does not change the substance of the response or findings of the EIR as demonstrated in the EIR's comparison of scenarios result in lower absolute change in EC and percent change in EC compared to the County's calculations and as shown in Appendix X.

Additional discussion of cumulative impacts can be found in Master Response 1, *Salinity and Bromide*.

The Lead Agency has Improperly Piecemealed the Full Proposed Project

The Lookout Slough proposed project is one of a number of Regional Projects that are part of California EcoRestore, such as Decker Island, Dutch Slough, Lower Yolo, McCormack Williamson, Prospect Island, and Tule Red. As is apparent from the table above, the cumulative impact of all these projects, even if individually they might increase salinity by less than 5%, will be significant.

By piecemealing these projects and carrying out separate environmental analyses, DWR is failing to fully analyze and disclose the full adverse impacts of the habitat restoration projects. Such piecemealing is impermissible. *(See East Sacramento Partnership for a Livable City v. City of Sacramento* (2016) 5 Cal.App.5th 281, 293.) 13-24

Response 13-24:

Please see Master Response 4, *Piecemealing*. Please see Master Response 1, *Salinity and Bromide*, for additional discussion on the analysis of the site specific and cumulative impacts of the Proposed Project on salinity in the Delta.

The DEIR fails to analyze and disclose the impacts of the Lookout Slough project due to climate change and sea level rise.

Among the goals and objectives listed in the DEIR is objective (e): *To the greatest extent practical, preserve existing topographic variability to allow for habitat succession and resilience against future climate change. (e.g.,* pages 11-3 and 111-22)

The DEIR does argue on page VII-26 that this objective will be met for the project because:

> *The existing topography does contain a significant amount of land at elevations that would convert to tidal marsh habitat with rising sea levels. The Duck Slough Setback Levee would be designed to be resilient to rising sea levels. This alternative and the Project address this goal to the greatest extent practical.* 13-25

However, the DEIR fails to analyze and disclose the significant adverse water quality impacts of the project due to future climate change and sea level rise. Other environmental analyses prepared for DWR assumed a sea level rise at the Golden Gate Bridge of 15 cm (0.5 feet) by 2025 and a projected sea level rise of 45 cm (1.5 feet) by 2060.

The DEIR should also include modeling of tidal hydrodynamics, flows and water quality after 1.5 feet of sea level rise.

Response 13-25:

CEQA does not require a lead agency to consider the effects of future environmental conditions on a project's future users or residents unless these changes could be exacerbated by project-related impacts. Climate change could cause changes in the tidal hydrodynamics, flows, and water quality. As discussed in Master Response 1, *Salinity and Bromide*, changes to tidal hydrodynamics, flows, and salinity as a result of sea level rise of 1.1 ft and 1.5 ft were modeled as part of another DWR study. Comparing the results of sea level rise from that previous DWR study with the predicted changes from the Proposed Project indicate that the potential changes due to sea level rise are substantially greater than the incremental effect of the Proposed Project. Therefore, the Proposed Project's impacts on tidal hydrodynamics, flows, and salinity will not exacerbate the changes from sea level rise.

Climate change will likely also increase Delta water temperatures. However, the Proposed Project could offset or result in a net decrease in temperature relative to the adjacent waterways (see response to Comment 12-26). Therefore, the Proposed Project will generally help offset increased water temperatures causes by climate change.

The DEIR does not analyze and disclose the impacts of the necessary reoperation on the SWP and CVP to compensate for the effects of the Lookout Slough project and other Regional projects

The DEIR discloses that the Lookout Slough restoration project will result in changes to EC and chloride concentrations within the north, central and south Delta and will change the location of the estuarine habitat standard X2. The modeling appears to have been carried out using the historical Delta inflows and export unchanged for each alternative.

In future operations, Delta operations may need to change to offset the cumulative effects of the Regional Projects and Lookout Slough. The one year of model of each alternative gives no indication of how much federal Central Valley Project (CVP) will be needed to offset water quality impacts or how much the CVP exports from the Delta would need to be reduced. 13-26

The EIR should include analysis of these impacts and a commitment to fully mitigate these impacts on the CVP.

Response 13-26:

Please see Master Response 1, *Salinity and Bromide*.

The DEIR is inadequate because it only analyses project impacts for a single dry year

In Solano County 's April 22, 2019 scoping comments, we requested that the Lookout Slough DEIR disclose and fully mitigate the significant adverse impacts of the proposed project on salinity in the Delta under the full range of hydrologic conditions (especially critically-dry years). Specifically, Solano County requested Central Valley and Delta operations modeling and Delta water quality modeling over the full historical 82-year modeling period (water years 1922-2003).

Merely analyzing a calendar dry year is insufficient to fully disclose the range of possible significant adverse environmental impacts of the project.

The DEIR in Appendix S on page 6 states: *The modeling scenario for this study replicates all of 2009, which is representative of typical dry year conditions, when achieving Delta salinity standards is often a challenge.* In footnote 1, the DEIR argues that: *In wet years, salinity issues are generally not considered a problem; in critically dry years, freshwater supplies are often so limited that they constrain the ability to achieve salinity standards through management actions.* 13-27

The SWRCB requires that its salinity standards be met in all water year types, even critical years. In critical years when flows are lowest and salinities are typically highest, the significant adverse impacts of the proposed project are likely to be even higher than in dry years, The DEIR must disclose the effects of the project over a range of many different water year types, not just one dry water year.

Response 13-27:

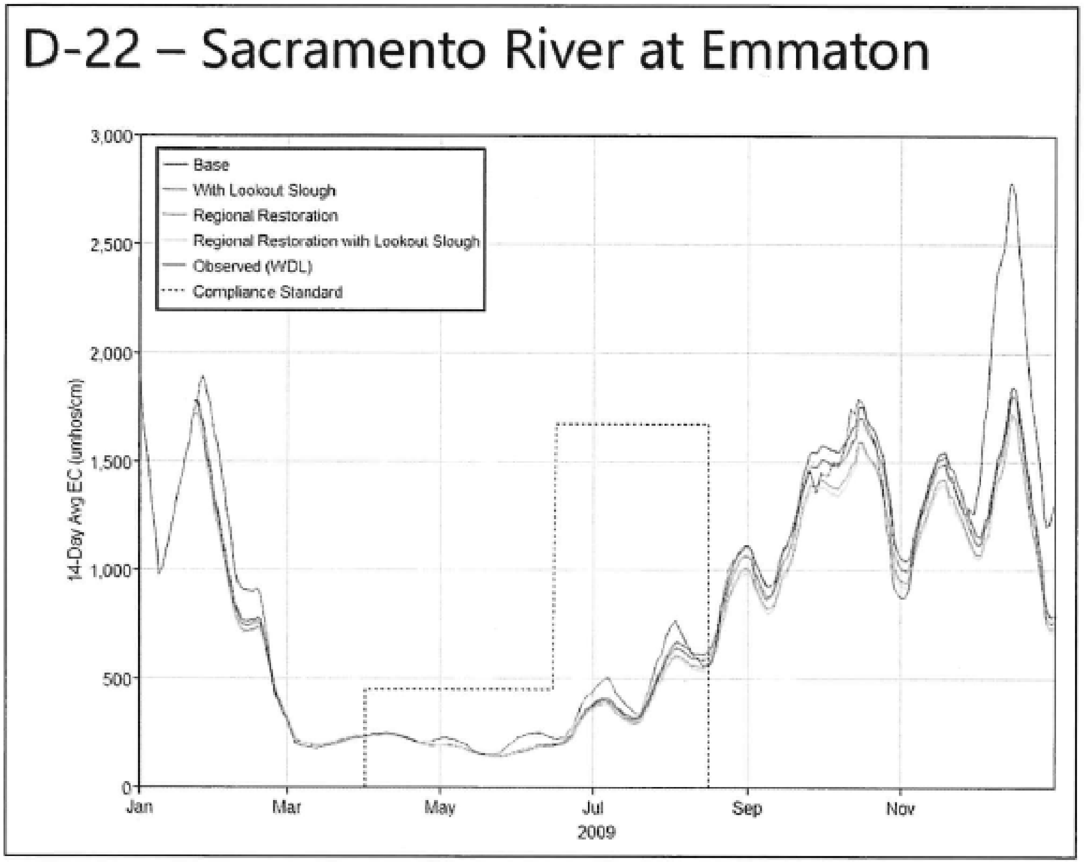
Please see Master Response 1, *Salinity and Bromide*.

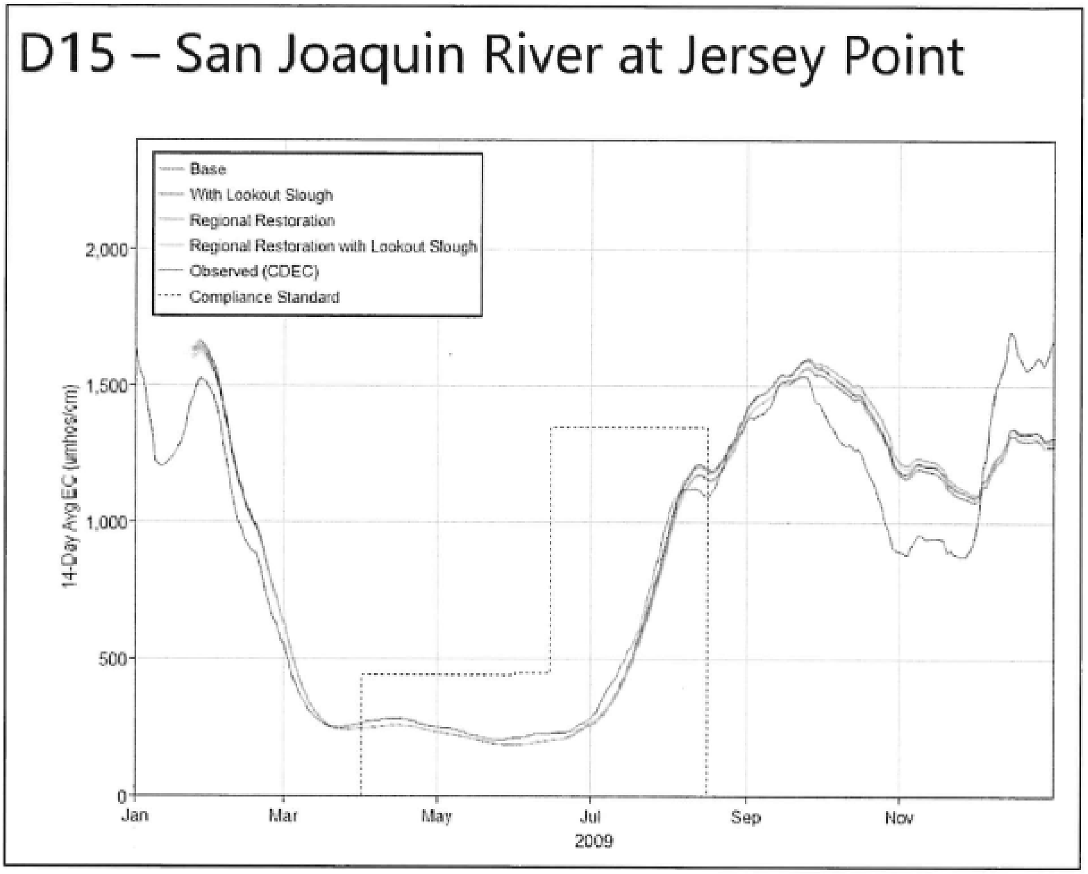
The DEIR modeling does not accurately simulate the existing historical base case

The 6 May 2019 RMA slide show, titled Lookout Slough Restoration: Modeling of EC and Hydrodynamic Impacts contained graphs that compared the RMA model simulations of EC for January-December 2019 with the historical field EC measurements. The graph for D22 - Sacramento River at Emmaton is reproduced below. In December 2019, the historical Emmaton EC peaks at about 2,800 µSiem whereas the simulated existing base case only peaks at about 1,800 µSiem (only two-thirds as much).

Similarly, the corresponding graph for D15 - San Joaquin River at Jersey Point shows big differences between the simulated and historical EC data for October through December.

The significant differences between actual and simulated EC data brings into question the accuracy of the Draft EIR analysis of adverse water quality impacts. 13-28





13-28 Cont.

Response 13-28:

To improve upon the accuracy and extent of the salinity modeling presented in the Draft EIR, the initial modeling conducted in 2019 was revised and extended in 2020. As described in Appendix X, the extended modeling included two additional years, for a total of three years simulated. By extending the simulation periods to three years, the accuracy of the model can be assessed over a broader range of hydrologic conditions. For the three years that were modeled, differences between measurements and predicted EC occurred for about 17% of the time (four months from October 2009 to January 2010 at Emmaton, Jersey Point and Prisoner's Point; two months from October to November 2016 at Emmaton). Over the course of the three years that were modeled, the coefficient of determination between predicted and observed EC is 0.8 or higher at the Emmanton, Jersey Point, and Prisoner's Point compliance stations. This performance metric indicates that the model's predictions replicate 80% or more of the variance in the measured EC. The additional analysis confirms the conclusions in the Draft EIR that water quality impacts are less than significant.

For additional details on the revised salinity modeling, please also see Master Response 1, *Salinity and Bromide*.

Letter 14
Solano County Water Agency

Letter 14

SOLANO COUNTY WATER AGENCY

February 14, 2020

Lookout Slough DEIR Attn: Heather Green
California Department of Water Resources 3500 Industrial Blvd.
West Sacramento, CA 95691

SCWA Comment Letter on Draft EIR for the Lookout Slough Restoration Project

Dear Ms. Green,

The purpose of this letter is to provide the California Department of Water Resources (DWR) comments on behalf of the Solano County Water Agency (SCWA). SCWA provides wholesale water supply to cities, special districts and State agencies in Solano County. Our agency boundary encompasses all of Solano County including portions of the legal Delta. The North Bay Aqueduct (NBA) portion of the State Water Project (SWP) delivers source water directly from the Cache Slough Complex (CSC) of the Delta to over 500,000 residents in Napa and Solano Counties includes the communities of Vacaville, Fairfield, Vallejo, Benicia, Napa, American Canyon, Calistoga, and Travis Air Force Base. While the NBA is owned and operated by DWR, SCWA has a longstanding interest in the Delta to ensure the NBA and other water supplies can provide reliable and high-quality water to the agricultural and municipal water users in Solano County.

While SCWA is supportive of habitat restoration in the Delta, the Agency is concerned that the Draft Environmental Impact Report (DEIR) for the Lookout Slough Restoration Project does not adequately address regional water quality concerns, biological impacts, and flood control impacts associated with the Project. Below is a more detailed summary of the Water Agency's concerns. The Agency is also a participant in the regional Water Quality letter for Napa, Solano, and Contra Costa counties, which also provides detailed water quality comments for the entire Tri-County region.

<u>**Concerns:**</u>

1.) Water Quality – Salinity & Bromide (Page IV.G-9)

As mentioned in the regional water quality letter, the DEIR discussion on salinity is sparse and lacking in sufficient detail to protect the municipal and agricultural beneficial uses in the Delta. No analyses, modeling results, or data are provided in the DEIR or Appendices for SCWA or our member agencies to proficiently assess the Project's Water Quality Impacts. 14-1

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95688 Phone (707) 451-6090 • Fax (707) 451-6099

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• WASTE NOT • WANT NOT •

In addition, there is also no discussion, analyses, or modeling of Bromide which is of critical importance to the NBA. In the North Delta, the NBA municipal users do not currently have significant issues with Bromide. However, major land use changes such as Lookout Slough, have the potential to enhance sea water intrusion upstream of Rio Vista, and elevate Salinity and Bromide above baseline concentrations. When municipal water supplies are treated (particularly with ozone) to meet drinking water standards, Bromide can form Bromate a known and regulated carcinogen, which can impact human health. Since most of the NBA water purveyors utilize ozone (to deal with high levels of organics), they would be highly sensitive to changes in Bromide above baseline conditions. 14-1 Cont.

A more significant analysis of Salinity and Bromide is needed to evaluate and protect existing municipal and agricultural beneficial uses in the Delta, including the NBA, City of Vallejo's Pumping Plant, and Reclamation District 2068.

Response 14-1:

See Master Response 1, *Salinity and Bromide*.

2.) Water Quality – Organic Carbon (Not Included).

Section G (Hydrology and Water Quality) of the DEIR does not include any discussion or analysis of Organic Carbon. While Organic Carbon may have ecological benefits, it can also have significant impacts on municipal water quality. In the drinking water treatment process, Organic Carbon can react with Chlorine to form a variety of Disinfection Byproducts including Trihalomethanes (THMs) and Haloacetic Acids (HAAs) which are carcinogenic and harmful to human health. The NBA water purveyors are highly sensitive to Organic Carbon levels, as users will often need to blend or switch water sources (if possible), or aggressively treat NBA source water to maintain safe high-quality municipal drinking water standards. Additionally, the NBA currently experiences the poorest water quality throughout the entire SWP in regards to Total Organic Carbon (TOC) levels, as illustrated by Figure 1. Major land use changes such as Lookout Slough, have the potential to export Organic Carbon and/or modify hydrodynamic process that may further degrade NBA municipal water quality. 14-2

Analysis of Organic Carbon is needed to evaluate and protect existing municipal water use in the Delta, including the NBA.

Response 14-2:

See Master Response 8, *Dissolved Organic Carbon*.

3.) Water Quality – Modeling Results
In reviewing the DEIR and Appendices related to water quality, little to no information is provided on the RMA Water Quality Modeling, including calibration and validation efforts, boundary conditions, SWP-CVP operations, Delta agricultural extractions, and other key assumptions. Additionally, the DEIR makes several conclusions in regards to Salinity at the NBA and other Delta Intakes, but no additional analyses, figures, model results, tables, etc. can be found in either the DEIR or Appendix S to substantiate these results. 14-3

DWR needs to provide more transparent and detailed information on the Water Quality Modeling used to analyze and assess Project Impacts and Cumulative Impacts on water quality including Salinity, Bromide, and other constituents as needed.

Response 14-3:

See Master Response 1, *Salinity and Bromide*, and Appendix X in this Final EIR for the full modeling report.

4.) Water Quality – Modeling Confidence (City of Vallejo P.P.)
As part of the DEIR review, SCWA requested model output information from DWR. To determine model confidence, measured EC data was compared to modeled EC data. Figure 2 is a time series plot for July-2009 showing measured and modeled EC data for the City of Vallejo's Pumping Plant at Cache Slough. Figure 3 is a Scatter Plot showing the Measured vs Modeled EC data for the same time period. The corresponding R^2 = 0.09, which indicates very poor correlation. The two figures illustrate the challenge of the RMA model to reasonably simulate EC during summer (i.e. baseline) conditions at the City of Vallejo's Pumping Plant location. This is important, as the Lookout Slough project is located in close proximity to this node, and is an indication of poor model confidence. 14-4

Additional model analyses, comparisons, and transparency on the model development is needed, to improve overall model confidence and ability to reasonably simulate Project Impacts and Cumulative Impacts on water quality, particularly in the CSC.

Response 14-4:

See Master Response 1, *Salinity and Bromide*, especially the section titled 'Salinity in Upper Cache Slough'. Please also see Response 11-2.

5.) Water Quality – BDCP Modeling Results on Cumulative Impacts
In 2015 extensive water quality modeling was conducted by DWR as part of the Bay Delta Conservation Plan (BDCP) – Recirculated DEIR (RDEIR). In Section 5.2.2.4 (Cumulative Impacts, Water Quality) of the RDEIR, Impact WQ-3 identifies the NBA as being negatively impacted by Bromide associated primarily with habitat restoration projects, as described below (excerpt from page 5-77 of the RDEIR).

"The primary driver of the adverse cumulative condition was the assumed amount and location of tidal habitat restoration to be implemented as part of the alternative. The amount of tidal habitat restoration assumed for Alternatives 4A, 2D, and 5A is substantially less than assumed for Alternative 4, such that it is not expected to significantly affect Delta hydrodynamics and source water fractions.

However, a substantial amount of tidal habitat restoration is still anticipated to occur in the future as part of separate actions (e.g., the California Water Action Plan/EcoRestore), which could result in a greater portion of higher-bromide concentration water in the restored areas, thus contributing to elevated long-term average and drought period bromide concentrations in those areas. Thus, the cumulative condition for bromide is still considered adverse." 14-5

Since this was the conclusion in 2015 after extensive modeling efforts by DWR, this directly conflicts with DWR's more recent assessment on Cumulative Impacts on the Lookout Slough Project as "less than cumulatively considerable."

Since DWR was the lead applicant for both Projects, SCWA specifically requests that DWR address this major discrepancy between the BDCP and Lookout Slough Cumulative Impact assessments on the NBA.

Response 14-5:

The current location and configuration of the Proposed Project was not known at the time of the 2015 Recirculated Draft EIR for the BDCP, and therefore, was not analyzed in it. The Draft EIR for the Proposed Project includes more accurate and current analysis of the Proposed Project's impacts to the North Bay Aqueduct intake, as well as of cumulative water quality impacts including the Proposed Project and other restoration projects, because it contains the Proposed Project design and location rather than theoretical locations and designs as was assumed in the BDCP Recirculated Draft EIR. As discussed in Master Response 1, *Salinity and Bromide*, and presented in EIR Appendices S and X, bromide concentrations at the Barker Slough Pumping Plant are predicted to decrease in a representative dry year (2009) and a below normal water year (2010) by as much as -7% and increase by up to +3% in a year of normal hydrology (outside of the dry season; 2016), even when regional restoration projects are considered. These results support the determination that impacts at the Barker Slough Pumping Plant resulting from the Proposed Project and regional restoration projects, would be less than cumulatively considerable.

6.) Biological Impacts - Endangered Species (Local Diversions)
One of the primary and worthwhile objectives of the Lookout Slough Restoration Project (Goals 1 & 2) is to improve food availability, rearing habitat, spawning habitat, and habitat elements for special status species such as Delta Smelt, salmonids, and other native fish. However, the DEIR and Appendices do not include any analysis, assessment, potential impacts, or recommended solutions to minimize impacts to existing agricultural and municipal users in the Delta and specifically within the CSC. Within the CSC, several public agencies including SCWA and Napa County Flood Control and Water Conservation District (via the NBA), City of Vallejo, and Reclamation District 2068 have major diversion facilities, as well as numerous private agricultural intakes. Figure 4 is a map showing the multitude of existing agricultural and municipal diversions within the CSC. Additionally, as part of Appendix E (Good Neighbor Checklist), DWR has not adequately addressed one of the key elements, which is "…are species on the project site expected to increase markedly in abundance and move from the site to neighboring lands or waterways?" 14-6

DWR needs to adequately and transparently address the Project Impacts to Local Diversions including the NBA, City of Vallejo, RD 2068, as well as private agricultural diversions. Additional support and funding is necessary for regional projects such as the NBA Alternate Intake Project and other regional solutions, to support and achieve co-equal goals for the entire Sacramento – San Joaquin Delta including the CSC.

Response 14-6:

With respect to comments on impacts to existing diversions, see Master Response 3, *Local Water Diversions and Special-Status Fish Species* and Master Response 9, *Tidal Effects on Diversions*. See also Master Response 11, *Good Neighbor Checklist* and Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts* for issues not relating to the adequacy of the EIR.

7.) Biological Impacts – Invasive Species

One of the primary Goals of the Lookout Slough Restoration Project (Goal 1-F) is "to the greatest extent practical, avoid promoting conditions adverse to Proposed Project biological objectives, such as those that would favor establishment or spread of invasive exotic species." However, the DEIR does not provide any Post-Project solutions, mitigation strategies, or funding mechanisms to prevent the spread of invasive species. Additionally, at the January 22, 2020 public meeting neither EIP or DWR laid out a strategy of how to mitigate invasive species. For invasive plant species, DWR and EIP suggested that the Division of Boating and Waterways (DBW) could manage these species. However, DBW is currently overtaxed and responsible for managing Aquatic Invasive Species throughout the entire Sacramento – San Joaquin Delta. The California Department of Fish & Wildlife (CDFW) Lindsey Slough Restoration Project, is a great example of a "build and leave" project within the CSC, where consistent and dedicated Operation & Maintenance (O&M) funding and on-site personnel is critical for the project to succeed. Figure 5 is a photograph of the Restored Project 4-years after completion, which is choked with invasive floating Water Hyacinth as well as submerged Brazilian Waterweed. 14-7

Without adequate O&M funding and availability of on-site personnel, the long-term outlook is likely to be similar for the Lookout Slough Restoration Project.

DWR needs to layout a detailed and transparent plan to provide dedicated O&M funding and on-site personnel to manage invasive species throughout the Project Site and meet the specified Project Goals. There should also be periodic accountability by an independent party, to ensure Project Goals are met.

Response 14-7:

See Master Response 14, *Invasive Species*; Master Response 7, *Operation and Maintenance (O&M) of Levees*; and Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts*.

In addition, the goals and objectives of the Proposed Project (Draft EIR, pages III-20 through III-22) going forward are supported by a Restoration Plan, an Adaptive Management and Monitoring Plan, and Long-Term Management Plan which include management of invasive plant species mentioned by the comment (Draft EIR, page IV.D-53 in Section IV.D, *Biological Resources*). Implementation of each of these plans would support achievement of the overall restoration goals and objectives of the Proposed Project. In relation to accountability within the CEQA process, DWR, as Lead Agency, is responsible for determining the adequacy of the EIR and providing that CEQA mitigation measures are fully enforceable.

8.) Flood Control – Levee Protections and Long-Term Funding

Another primary Goal of the Lookout Slough Restoration Project (Goal 3) is to "provide additional flood storage and conveyance within the Yolo Bypass to reduce the chance of catastrophic flooding and protect existing nearby infrastructure." In the DEIR and Appendices, many assumptions are made in regards to levee impacts including tidal dampening, wave runup reductions, benefits of emergent marsh vegetation, benefits of the PG&E access roads in reducing waves, roughness coefficients, etc.

However, the DEIR does not provide any details on funding mechanisms, site repairs, and/or remedies if any of the assumptions are incorrect. Additionally, some of the core aspects of Yolo Bypass levee management are (a) continuous annual maintenance and (b) immediate repairs during and post Yolo Bypass Flood Events. However, the DEIR does not provide specific details on the funding mechanisms, including annual O&M Funding, Capital Funding when larger repairs are needed, and accountability of potential impacts to neighboring Reclamation Districts including RDs 2068, 2098, and 2060. 14-8

DWR needs to layout a detailed and transparent plan to provide dedicated O&M Funding, Capital Funding, and on-site personnel to meet core flood control and levee maintenance responsibilities as part of the Project. Similar to above, there should also be periodic accountability by an independent party, to ensure flood control responsibilities are met and ensure flood impacts are not translated to neighboring Reclamation Districts.

Response 14-8:

See Master Response 7, *Operations and Maintenance of Levees* and Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts*. See also Response 14-7.

9.) Flood Control – Wind-Wave Generated Erosion (Page IV.G-26 to 28)

In regards to Wind-Wave Generated Erosion, the DEIR concludes that there are **"<u>less-than-significant</u>"** impacts, and indicates that DWR will take over O&M activities of the Cache/Hass Slough Training Levee and Cross Levee. However, DWR does not layout a detailed and transparent plan in regards to dedicated O&M Funding, Capital Funding, and accountability of potential impacts to neighboring Reclamation Districts.

As stated above, DWR needs to layout a detailed and transparent plan to provide dedicated O&M Funding, Capital Funding, and on-site personnel to meet core flood control and levee maintenance responsibilities. There should also be periodic accountability by an independent party, to ensure flood control responsibilities are met and ensure flood impacts are not translated to neighboring Reclamation Districts, to meet the "less-than-significant" impact stated in the DEIR. 14-9

Response 14-9:

See Master Response 7, *Operations and Maintenance of Levees*. See also Response 14-7.

Mitigation Measures:

As both a supportive and impacted public agency by the Lookout Slough Restoration Project, the Solano County Water Agency highly recommends that DWR consider the following measures, to help mitigate Project Impacts, develop regional collaboration, and move the Project forward.

A.) Water Quality Modeling, General – A more detailed and transparent analysis should be done to improve the RMA Water Quality Model for the Cache Slough Complex region. Modeling confidence needs to be improved, to allow for a more accurate, transparent, and reasonable assessment of Project Impacts and Cumulative Impacts by all interested parties.

B.) Water Quality, Organic Carbon – A detailed and transparent analysis on Organic Carbon should be done in regards to Project Impacts and Cumulative Impacts on municipal water quality. If uncertainties exist, they should be clearly stated and acknowledged in the final EIR.

C.) Water Quality, Salinity – A more detailed and transparent analysis on Salinity should be done in regards to Project Impacts and Cumulative Impacts on both agricultural and municipal water quality.

D.) Water Quality, Bromide – A detailed and transparent analysis on Bromide should be done in regards to Project Impacts and Cumulative Impacts on municipal water quality. In addition, detailed and transparent analyses are needed to identify why there are different outcomes associated with Cumulative Impacts from the BDCP vs the current Lookout Slough Restoration Project. 14-10

E.) Biological Impacts, Local Diversions – A detailed and transparent analysis is needed to reasonably assess both Project Impacts and Cumulative Impacts on local diversions including the NBA, RD 2068, City of Vallejo Pumping Plant, and other local agricultural diversions. *It is important to note that while the NBA represents about 2% of the SWP, the vast majority of SWP Biological Opinions and Eco Restore implementation is focused in the CSC and Suisun Marsh regions, directly impacting the NBA and Napa-Solano water purveyors.*

F.) Biological Impacts, Regional Solutions – DWR as well as other State and Federal stakeholders, should help fund and commit tangible resources (including bond funds) to support regional multi- benefit projects such as the NBA Alternate Intake Project and others, to achieve <u>and</u> sustain co- equal goals for the Sacramento – San Joaquin Delta.

G.) Long-term Funding – DWR needs to provide specific details on long-term O&M Funding, Capital Funding, and On-Site personnel to provide both flood control and invasive species management.

H.) Independent Accountability – DWR needs to provide specific details on how to achieve periodic and independent accountability to meet both flood control and ecosystem Project Goals, as outlined in the DEIR.

Response 14-10:

The above comments (14-10 A-H) are recommending revisions to the Draft EIR analysis and do not propose any identifiable mitigation measures. Each comment is addressed below.

A.) See Master Response 1, *Salinity and Bromide*.

B.) See Master Response 8, *Dissolved Organic Carbon*.

C.) See Master Response 1, *Salinity and Bromide*.

D.) See Master Response 1, *Salinity and Bromide*. See also Response 14-5 above.

E.) See Master Response 3, *Local Water Diversions and Special-status Fish Species*, and Master Response 9, *Tidal Effects on Diversions*.

F.) The NBA Alternative Intake Project and other regional multi-benefit projects are the subject of other multi-agency discussions in which DWR is participating and not part of the Proposed Project. See Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts*; this is not a comment on the adequacy of the DEIR.

G.) See Master Response 7, *Operation and Maintenance (O&M) of Levees*, and Master Response 14, *Invasive Species*.

H.) See Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts*. See also Responses 10-8 and 14-7.

Thank you for the opportunity to submit comments vital to the agricultural and municipal water users in Solano County. As mentioned above, SCWA has a longstanding interest in the Delta to ensure the NBA and other water supplies can provide reliable and high-quality water to the many agricultural and municipal water users in Solano County. The Water Agency looks forward to working collaboratively with DWR, to protect and sustain the Co-Equal Goals for the Sacramento – San Joaquin Delta, including the Cache Slough Complex and Yolo Bypass region. Should you have any questions, please don't hesitate to contact me by e-mail at RSanford@scwa2.com or by phone (707) 455-1103.

Sincerely,

Roland Sanford, General Manager

CC: Phillip M. Miller, District Engineer • Napa County Flood Control & Water Conservation District Bryan Busch, General Manager • Reclamation District 2068 Michael Malone, Director of Water • City of Vallejo

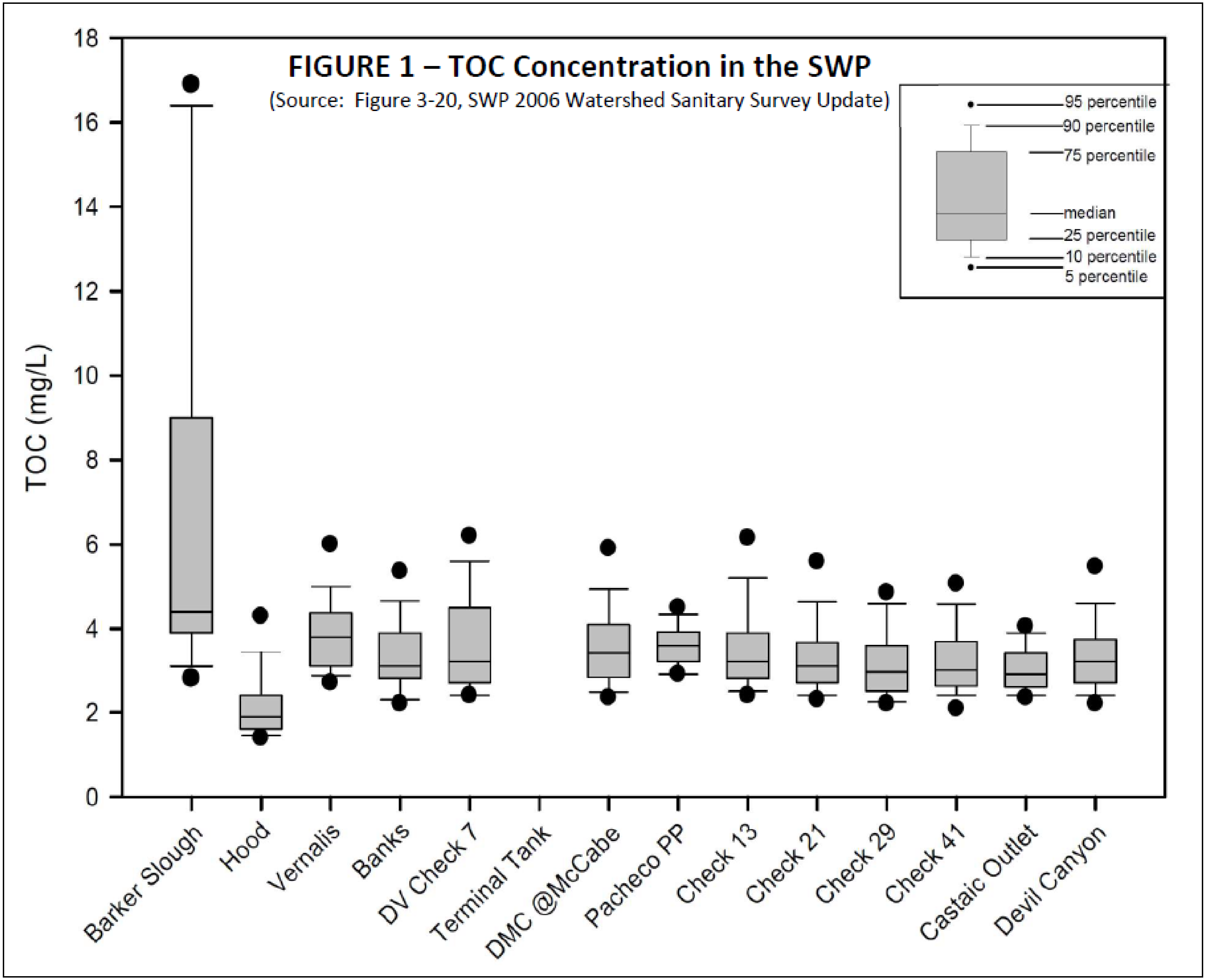

FIGURE 1 – TOC Concentration in the SWP
(Source: Figure 3-20, SWP 2006 Watershed Sanitary Survey Update)
95 percentile
90 percentile
75 percentile
median
25 percentile
10 percentile
5 percentile
TOC (mg/L)
0
2
4
6
8
10
12
14
16
18
Barker Slough
Hood
Vernalis
Banks
DV Check 7
Terminal Tank
DMC @McCabe
Pacheco PP
Check 13
Check 21
Check 29
Check 41
Castaic Outlet
Devil Canyon

Letter 14

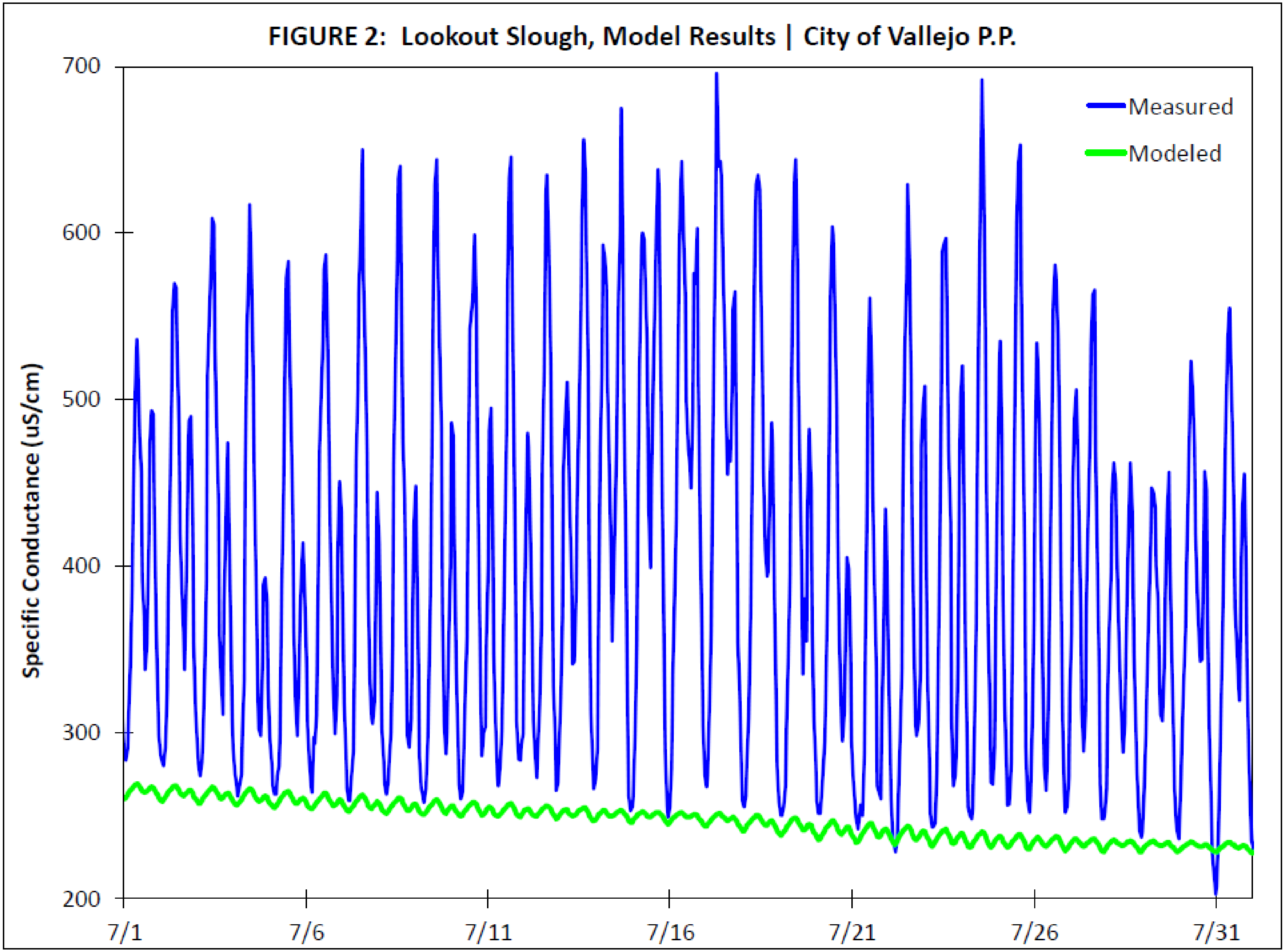
FIGURE 2: Lookout Slough, Model Results | City of Vallejo P.P.
Specific Conductance (uS/cm)
700
600
500
400
300
200
7/1
7/6
7/11
7/16
7/21
7/26
7/31
Measured
Modeled

Letter 14

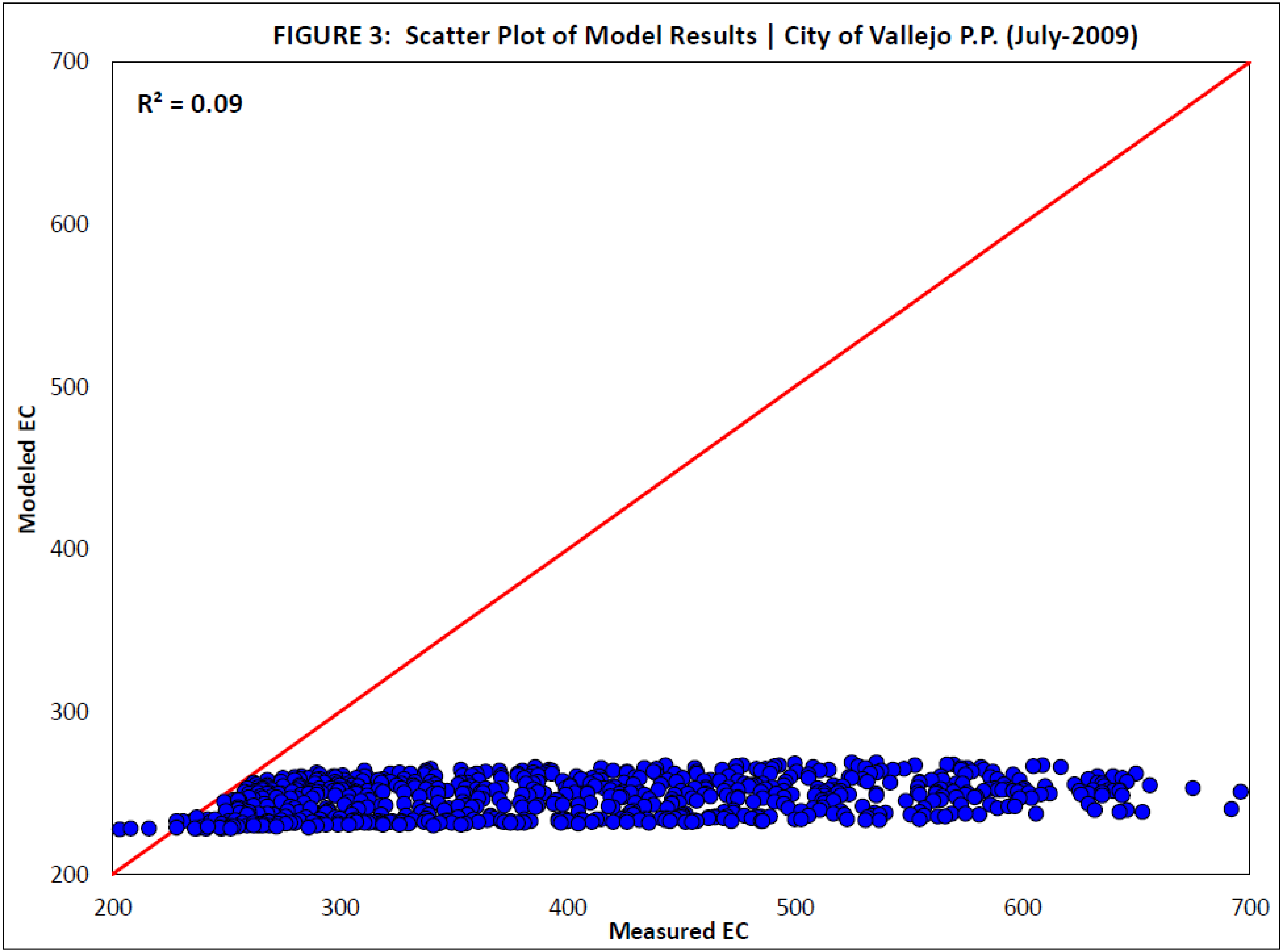

FIGURE 3: Scatter Plot of Model Results | City of Vallejo P.P. (July-2009)
R² = 0.09
700
600
500
400
300
200
Modeled EC
200
300
400
500
600
700
Measured EC

FIGURE 4: Existing Municipal and Agricultural Diversions in the Cache Slough Complex

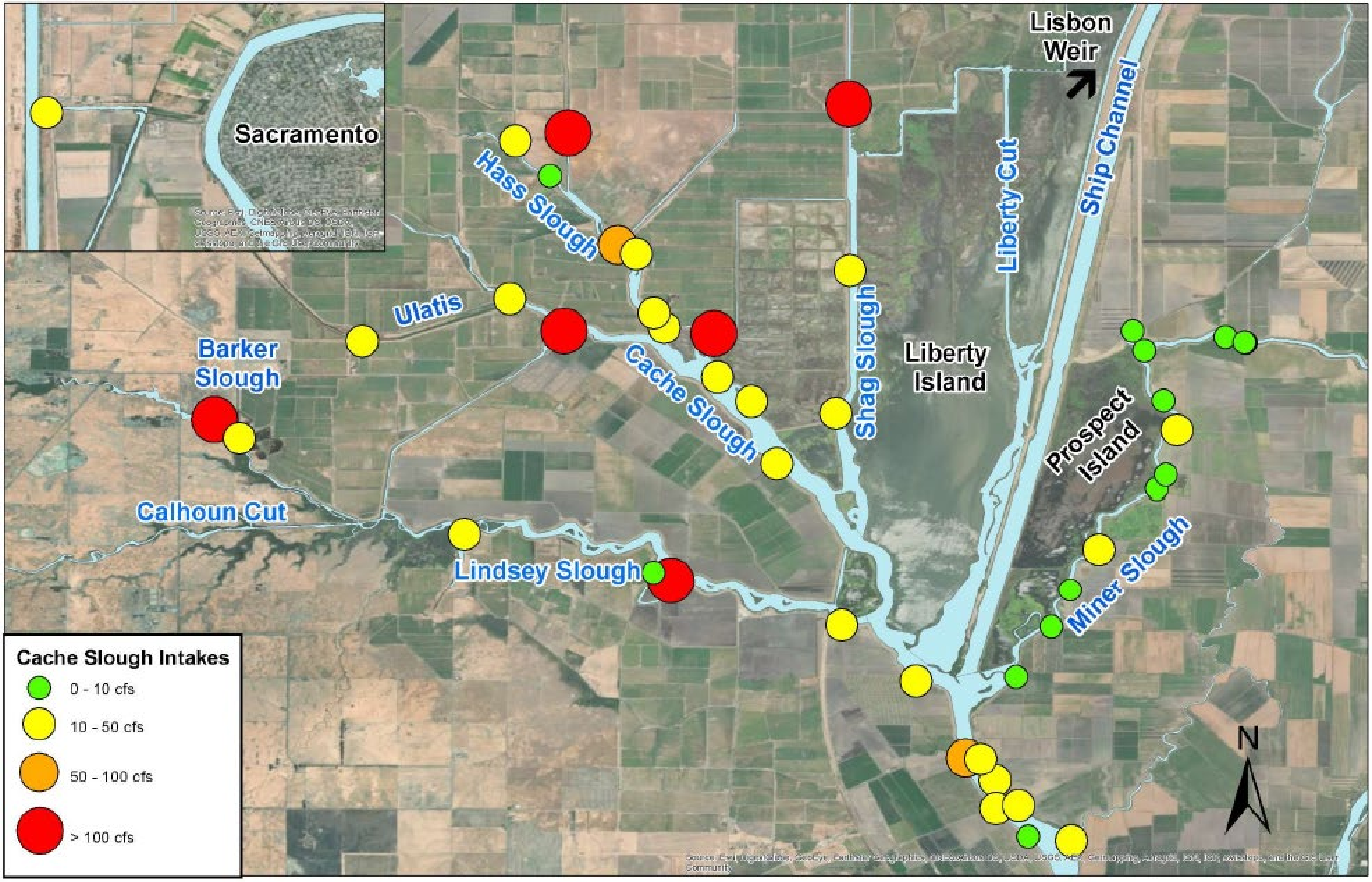

FIGURE 5 – DFW Lindsey Slough Restoration Project
(Photo taken 11/8/2018, Water Hyacinth in Foreground)

Letter 15
Soluri Meserve on behalf of the Local Agencies of the North Delta and RD 501

SOLURI MESERVE
a law corporation

tel: 916.455.7300 · fax: 916.244.7300
510 8th Street · Sacramento, CA 95814

February 14, 2020

SENT VIA EMAIL (FRPA@water.ca.gov)

Heather Green
California Department of Water Resources
3500 Industrial Blvd
West Sacramento, CA 95691

RE: Comments on the Draft EIR for the Lookout Slough Tidal Habitat Restoration and Flood Improvement Project

Dear Ms. Green:

These comments on the December 2019 Draft Environmental Impact Report ("DEIR") for the Lookout Slough Tidal Habitat Restoration and Flood Improvement Project ("Project") prepared by the California Department of Water Resources ("DWR") are submitted on behalf of Local Agencies of the North Delta ("LAND") and Reclamation District 501 ("RD 501"), (collectively "LAND"). LAND supports Delta restoration activities, but the impacts on the environment and adjacent land and water uses must be fully disclosed and fully mitigated in the context of CEQA, and effective coordination with adjacent landowners must continue throughout the life of the project. Responsible restoration, with a focus on disclosure, analysis and mitigation of system-wide impacts of all restoration projects in the Delta, complies with CEQA while minimizing adverse effects on stakeholders.

The Project Must Include Good Neighbor Policies and Adequate Mitigation Measures

DWR's good neighbor checklist, while requiring some level of transparency and disclosure of the Project's impacts, needs more attention to detail and actions to prevent future negative offsite impacts and engender stakeholder support. (DEIR, Appendix E.) LAND has developed its own, more robust, good neighbor checklist, attached as Exhibit 1. LAND's good neighbor actions expand on DWR's checklist by including ongoing monitoring, preventative measures, and responsive mitigation across key impacts common to restoration projects. 15-1

LAND's good neighbor actions also call for establishing an ombudsman office and claims process for affected stakeholders. Such a process would provide a needed alternative to the inefficient Tort Claims Act (Gov. Code, § 810 et seq.). DWR should consider incorporating these enforceable measures not just in the Project, but in all restoration projects moving forward.

Additional attention to implementation of a robust good neighbor approach would also assist in the Project's consistency with Delta Plan Policy DP P2, which requires projects to be sited to avoid or reduce conflicts with existing uses or uses described in local general plans, considering comments from local agencies and the Commission. (DEIR, p. V.A-12.) DP P2 is mentioned only once in the DEIR, and the DEIR does not include sufficient information to conclude that the Project is in fact consistent with Delta Plan Policy DP P2 (Cal. Code Regs., tit. 23, § 5011). 15-1 Cont.

Impacts from restoration projects require ongoing monitoring, maintenance and management, whether in the form of good neighbor policies or formal mitigation measures. Despite LAND's consistent efforts to work with DWR to create viable long- term solutions to the issues posed by the project, DWR has in the past failed to adequately address these concerns. We hope the Lookout Slough project will be an opportunity to make progress on this issue, which is existential to the success of restoration efforts in the Delta.

Response 15-1:

See Master Response 11, *Good Neighbor Checklist* and Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts*. With respect to comments regarding Potential Project impacts on neighboring properties, please also see Master Response 1, *Salinity and Bromide*, Master Response 3, *Local Water Diversions and Special-status Fish Species*, and Master Response 9, *Tidal Effects on Diversions*.

The Draft EIR discussed all environmental impacts, including impacts to agriculture and land use. In addition, DWR's "Good Neighbor Checklist" was used to discuss potential effects on neighboring properties, outside the context of CEQA. See also, the response to comments in Letter 5 from the Delta Stewardship Council on consistency with the Delta Plan. DWR and its contractors will comply with all applicable regulatory requirements. This is not an issue relating to the adequacy of the environmental impact analysis under CEQA.

Cumulative Impacts are Potentially Significant

The DEIR includes an expanded list of cumulative projects, as compared to that included in the Prospect Island Tidal Habitat Restoration Project Environmental Impact Report ("Prospect Island EIR"). However, the DEIR does not describe the full extent of the cumulative impacts of planned restoration projects. Important potential cumulative impacts, such as proliferation of harmful algal blooms ("HABs") and invasive aquatic species, are not disclosed or analyzed at all. Other impacts are not adequately discussed, providing a limited view of the system-wide changes that would be caused by the cumulative restoration projects. 15-2

Response 15-2:

See Master Response 5, *Cumulative Impact Analysis*; Master Response 4, *Piecemealing*; and Master Response 14, *Invasive Plant Species and Harmful Algal Blooms*.

For example, the cumulative water quality impact discussion does not substantively address methylmercury bioaccumulation. (DEIR, pp. V-13 to V-14.) While methylmercury bioaccumulation is mentioned, the analysis only cites to D-1641 salinity standards, which require averages to be met and do not address instantaneous salinity. (*Ibid*.) Cumulative methylmercury bioaccumulation from the project, is a potentially significant cumulative water quality impact. 15-3

Response 15-3:

See Master Response 1, *Salinity and Bromide*, Master Response 5, *Cumulative Impact Analysis*, and Master Response 6, *Methylmercury*.

Further, the discussion of salinity impacts ignores the reality that incremental increases in irrigation water salinity can build up in Delta soils and impair agricultural productivity. (See, e.g., Exhibit 2, Michelle Leinfelder-Miles Testimony, pp. 4-5.) The project, in combination with other restoration projects, would change the tidal range, and increase the incursion of salinity into the region. Moreover, D-1641 salinity standards are averages and do not address instantaneous salinity levels. Reliance on D-1641 alone precludes full analysis of cumulative salinity impacts, which are potentially significant. 15-4

Response 15-4:

See Master Response 1, *Salinity and Bromide* including a discussion of D-1641 standards and salinity in soils. See also Master Response 5, *Cumulative Impact Analysis*.

The Delta is a complex system, and additional analysis is required to address the cumulative impacts of all the restoration projects in the region. Since DWR has not attempted to analyze all of the restoration projects on a programmatic level, project-level EIRs must include robust cumulative impact analyses. While this EIR improves upon past efforts, it still does not provide adequate disclosure and discussion under CEQA. 15-5

Response 15-5:

See Master Response 4, *Piecemealing*, and Master Response 5, *Cumulative Impact Analysis*.

Significant Invasive Weed Growth Impacts

The DEIR fails to disclose the impacts of weed growth on total water supply.

Studies show that exotic invasive plant species can consume more water than naturally occurring species, impacting water available for agriculture. (See Exhibit 3, Pitcairn et al., Yellow Starthistle continues its spread in California (2006).)

Water hyacinth is a well-documented Delta invasive plant that uses a considerable amount of water which is lost to the atmosphere due to transpiration. Weeds in arid regions compete for water with native plant or commodity crops, and the weeds can also compete for nutrients, and diminish crop values. (Exhibit 4, Abouziena et al., Water loss by weeds: a review (2014) 7 Int. Journal of ChemTech Research 1, pp. 323-336.) Aquatic weeds cause water loss in canals due to extensive root systems and high transpiration rates, in addition to physically blocking the canals. (*Id*. at 326.)

Environmental impacts from weed proliferation are potentially significant to the Delta. (See Exhibit 5, Ali & Khedr, Estimation of water losses through evapotranspiration of aquatic weeds in the Nile River (2018) 32 Water Science, pp. 259-275.) For example, water loss through evapotranspiration from water hyacinth was 3.7 times that from open water. (Exhibit 6, Timmer & Weldon, Evapotranspiration and Pollution of Water by Water Hyacinth (1966).) A study on the Nile River supported the doubling of evaporation as a result of hyacinth, and "...concluded that the main problem of water losses through evapotranspiration of aquatic weeds in the Nile River (Rosetta Branch) represented in water hyacinth, according to the present study more than 90% of water losses were from water hyacinth." (Exhibit 5, p. 274.) Given the Project's potential exacerbation of invasive weeds, and inadequate mitigation, the potential impacts on water consumption must be disclosed and analyzed. 15-6

Mitigation Measure BIO-4, Invasive Species Abatement fails to include any enforceable performance measures or standards, and is thus an improperly deferred mitigation measure. (See DEIR, p. II-22.) All BIO-4 does is require at some point before construction, that protocols be established to identify what invasive weed species are present, treat those species "According to control methods and practices appropriate to those species" including herbicide, and determine timing of treatment. (*Ibid*.) If DWR defers formulation of the weed abatement protocols, it must describe the potential treatments it would use and establish performance standards. (*Sacramento Old City Association v. City Council* (1991) 229 Cal.App.3d 1011, 1029; see also *Defend the Bay City of Irvine* (2004) 119 Cal.App.4th 1261, 1275 (agency must "commit[] itself to mitigation and list[] the alternatives to be considered, analyzed, and possibly incorporated in the mitigation plan.").) The DEIR fails to provide any of the information necessary for legal deferral of mitigation, and therefor the deferral of the weed abatement plan violates CEQA.

In addition, to be consistent with the Delta Plan, invasive species must be addressed. Under Delta Plan Policy ER P5 (Cal. Code Regs., tit. 23, § 5009.), the project must Avoid Introductions of and Habitat Improvements for Invasive Nonnative Species. (See DEIR, p. III-51.) Delta Plan Program EIR Mitigation Measure 4-1 requires advanced mitigation planning for ecological restoration, implementation of construction best management practices, and restoration of areas affected by construction impacts, among other sub-measures. Delta Plan Measure 4-1 also states in part that, "an invasive species management plan shall be developed and implemented for any project whose construction could lead to introduction or facilitation of invasive species establishment." (Appendix O, Mitigation and Monitoring Reporting Program, Delta Plan MMRP, Table 2.[1]) Mitigation Measure BIO-4 does not meet these requirements. 15-6 Cont.

FOOTNOTE 1 Available at: https://deltacouncil.ca.gov/pdf/delta-plan/2018-appendix-o-mitigation-monitoring-and-reporting-program.pdf.

Response 15-6:

See Master Response 14, *Invasive Species*; Master Response 13, *Performance Standards and Deferred Mitigation*; and Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts*. With regard to compliance with the Delta Plan, see Responses 5-2 and 15-1; DWR and its contractors will comply with all applicable regulatory requirements.

<u>Significant Harmful Algal Blooms Impacts</u>

The DEIR fails to disclose or analyze the Project's HABs impacts. The DEIR only discloses the potential for proliferation of HABs in the context of increased turbidity. (DEIR, p. IV.G-4.) Acknowledging that "[t]he emergence of increased concentrations of harmful algal blooms is indicative of potential problems with water stagnation" and then failing to analyze whether this Project would cause water stagnation sufficient to exacerbate the "increasing" problem is inadequate. (DEIR, p. IV.G-4.) According to DWR's expert on HABs at the California WaterFix water rights hearing: 15-7

There are five primary environmental factors that trigger the emergence and subsequent growth of Microcystis in the water column of Delta waters, which are:

1. Water temperatures >19°C (66.2°F),
2. Low flows and channel velocities resulting in low turbulence and long residence times,
3. Water column irradiance and clarity >50 micromoles per square meter per second (µmoles/m2/s),
4. Sufficient nutrient availability (nitrogen and phosphorus), and
5. Salinity below 10 ppt.

(Exhibit 7, Robertson-Bryan, Inc., Report on The Effects of the California WaterFix on Harmful Algal Blooms in the Delta (2017).) Thus, turbidity is only one of at least five major factors triggering HABs in the Delta environment where the Project is proposed.

The DEIR's limited discussion, which considered only turbidity, with no consideration of other major factors and no analysis, is inadequate. The DEIR admits, HABs concentrations are increasing. (*Ibid*.) The DEIR's failure to actually address how the Project could itself cause increased HABs concentrations or proliferations does not meet the informational disclosure requirements of CEQA. 15-7 Cont.

Past technical analysis for Prospect Island under the Fish Restoration Program Agreement demonstrated that 3-5 days of water retention begin to create risk of HABs, with increased risk as residence time goes up.[2] The potential increase in water residence time and temperature (DEIR, p. IV.G-28) combine to increase the likelihood the Project increases HABs proliferation (see Exhibit 9, Berg & Sutula, Factors Affecting Growth of Cyanobacteria (2015)). This potentially significant impact must be disclosed and analyzed.

FOOTNOTE 2 See Prospect Island Tidal Restoration Project Analysis of Primary Productivity Enhancement and Export for Phase 2 Alternatives Evaluation. Resource Management Associates (February 2014), pp. 2-10. This document was previously posted (e.g., http://www.water.ca.gov/environmentalservices/frpa_prospect_restoration.cfm) and was relied upon by the Prospect Island EIR but is no longer available online. See also, Exhibit 8, Phase 2 Modeling Synthesis Report Prospect Island Tidal Habitat Restoration Project (July 2014).

Response 15-7:

See Master Response 14, *Invasive Plant Species and Harmful Algal Blooms*.

Significant Impacts from Invasive Asian Clam Food Web Alterations

As the DEIR admits, the Project would create colonization opportunities for invasive Asian clams. (DEIR, p. IV.D-86.) Thus, the conclusion that the Project would have a less than significant impact is confounding. An invasive clams and mussels monitoring and response plan or actionable performance standards should be included in Mitigation Measure BIO-4 Invasive Species Abatement to mitigate any potential export of Asian Clam facilitated by the Project. Currently, BIO-4 only addresses invasive weeds, but it should apply the same framework to invasive animal species by establishing target species, enforcement triggers, and possible treatments. 15-8

Response 15-8:

See Page IV.D-87 in Section D, *Biological Resources,* of the Draft EIR which states that "Asian clam growth, density, and survival depend on numerous factors, including substrate, water quality, and flow, but how these factors contribute to the current structure of Asian clam populations in the Delta is not well understood. Various studies concerning the distribution and spread of Asian clam were summarized by Kramer-Wilt but provided unclear results regarding habitat types within which Asian clams successfully establish. Acknowledging this lack of clarity in the literature about the factors contributing to the distribution and spread of Asian clam, the Draft EIR concluded that "the extent to which this species would colonize within the restored Proposed Project Site is purely speculative".

The analysis then goes on to explain that "the Proposed Project Site currently supports land uses that do not export primary productivity to the surrounding sloughs. However, following restoration, the Proposed Project Site would likely support primary and secondary productivity similar to that of surrounding waterways, which would be expected to be exported to the surrounding systems. Even in the presence of Asian clam, there would be a net increase in export of primary and secondary productivity to surrounding sloughs compared with existing conditions, wherein no primary or secondary productivity is exported from the site. Therefore, impacts of the Proposed Project would not exceed the applicable threshold of significance related to potential invasion of the Asian clam and its impact on the food web for special-status fish species and the Proposed Project's impact with regard to this threshold would be ***less than significant impact".***

Significant Impacts from Methylmercury Accumulation

Methylmercury is a bioaccumulating neurotoxin subject to the SWRCB's regulation and under a Total Maximum Daily Load;[3] however, the DEIR dismisses methylmercury impacts without any basis. The DEIR's discloses that the Project could cause short-term increases in methylmercury production during or immediately after construction, leading to transportation to adjacent waterways. (DEIR, p. IV.D-87.) Yet this localized increase in bioaccumulation of the toxin is dismissed with a reference to yet unfinished research. (*Ibid.*) Relying on unfinished research to reach a significance determination as to a dangerous toxin violates CEQA's basic disclosure requirements. Moreover, the conclusion that any increase in methylmercury bioaccumulation would essentially be *di minimis* is belied by DWR's own prior conclusions on other Delta projects.

FOOTNOTE 3 See https://www.waterboards.ca.gov/centralvalley/water_issues/tmdl/central_valley_projects/delta_hg/.

The extent of the potential increase in bioaccumulation from the Project is never quantified, nor are the subsequent effects of such an increase. This approach contrasts starkly with DWR's previous analysis of restoration actions in the California WaterFix Final EIR/S ("CWF FEIR/S"). As described in the summary of the Delta tunnels' impacts, restoration actions are known sources of methylmercury: "[U]ptake of mercury from water and/or methylation of inorganic mercury may increase in localized areas as part of the creation of new, marshy, shallow, or organic-rich restoration areas. Although not quantifiable, on a local level, increases in methylmercury concentrations may be measurable." (Exhibit 9, CWF FEIR/S, p. 8-949.) 15-9

The DEIR does not describe any effort to measure increases in methylmercury accumulation from the Project. The CWF FEIR/S further identifies "the potential for increases in methylmercury concentrations in the Delta result in this potential impact being considered significant because, as described in the Discussion column *any potential* measurable increase in methylmercury concentrations would make existing mercury-related impairment measurably worse." (Exhibit 9, CWF FEIR/S, p. 8-950 [italics added].) This impact was found to be significant and unavoidable. (See *ibid*.) Thus, any potential increase in methylmercury concentrations makes impairment measurably worse, and the DEIR's conclusion is not supported by substantial evidence.

Response 15-9:

Please see Master Response 6, *Methylmercury*. The Draft EIR and Master Response 6 present more up-to-date information on methylmercury production, export, and bioaccumulation than was available at the time of the California WaterFix 2016 Final EIR/EIS.

Agricultural Impacts are Potentially Significant

The DEIR claims that the conversion of 1,460 acres of prime farmland is less than significant with mitigation. (DEIR, p. IV.B-10 to -12.) Regardless of the improvements to or conservation of other farmland, the Project would still result in a net loss of prime farmland in the Delta. (*Ibid*.) This is a significant and unavoidable impact according to the DEIR's own significance threshold. Moreover, the cumulative impact is significant as "planned and completed ecosystem restoration projects in the Cache Slough Complex … would convert farmland to non-agricultural use … including over 2,000 acres of important farmland." (DEIR, p. V-7.) The DEIR only claims that the cumulative impact is incremental because of the flawed conclusion that the project-level impact is less than significant. (*Ibid*.) 15-10

Response 15-10:

See Master Response 2, *Farmland.* See also pages V-6 through V-7 in Chapter V, *Cumulative Impacts* of the Draft EIR for this analysis.

Williamson Act Impacts are Potentially Significant

The Williamson Act "was enacted to curb 'the rapid and virtually irreversible loss of agricultural land to residential and other developed uses. . . .'" (*Honey Springs Homeowners Assn. v. Bd. of Supervisors* (1984) 157 Cal.App.3d 1122, 1139; see also Sierra Club v. City of Hayward (1981) 28 Cal.3d 840, 850–853.) The Williamson Act includes specific provisions addressing whether proposed uses are consistent with specified "principles of compatibility." (Gov. Code, § 51238.1.) "The provision for 'compatible uses' allows local governments familiar with the particular circumstances of each preserve to define other uses that will not compromise or impair the agricultural capability or operations on the parcels." (*Cleveland National Forest Foundation v. County of San Diego* (2019) 37 Cal.App.5th 1021, 1044, citing Gov. Code, §§ 51231, 51238, 51238.1.)

The DEIR's significance threshold for the Project considers whether the proposed Project would conflict with a Williamson Act contract. (DEIR, p. IV.B.9; see also CEQA Guidelines, App. G, section II(b).) The DEIR claims that because the site Williamson Act contracts list open space as a compatible use, the Project would be a compatible use. This is a logical fallacy unsupported by law. The proposed Project does not allow public access, and converts prime and other valuable agricultural lands and accessible open space to flooded tidal marsh with restricted access. Therefore, the Project's change in land use is not comparable to the Williamson Act "open space" nor consistent with the purpose of Williamson Act. As a result, the EIR fails to identify any potentially feasible mitigation measures or project alternatives that could reduce the significance of these impacts, which violates CEQA. (See *Banning Ranch* v. City of Newport Beach (2017) 2 Cal.5th, 918, 938 (failure to analyze impacts to environmentally sensitive habitat areas resulted in inadequate discussion of appropriate mitigation measures).) 15-11

Response 15-11:

The Draft EIR properly disclosed potential impacts regarding the Williamson Act and concluded that the impacts would be less than significant. See Response 13-1.

CONCLUSION

The DEIR must be revised and recirculated to address the deficiencies identified in this letter. Please contact me with any questions about these comments. 15-12

Response 15-12:

The responses to comments in the Final EIR clarify, amplify, or make insignificant modifications to the Draft EIR. These responses to comments do not identify any new significant effects on the environment or a substantial increase in the severity of an environmental impact requiring major revisions to the Draft EIR that would require recirculation.

Very truly yours,

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ORM:mre

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Exhibits

Exhibit 1 – Good Neighbor Checklist for Restoration Projects.

Exhibit 2 – Testimony of Michelle Leinfelder-Miles, State Water Resources Control Board Hearing on the California WaterFix Water Rights Change Petition.

Exhibit 3 – Pitcairn et al., Yellow Starthistle continues its spread in California (2006).

Exhibit 4 – Abouziena et al., Water loss by weeds: a review (2014) 7 Int. Journal of ChemTech Research 1, pp. 323-336.

Exhibit 5 – Ali & Khedr, Estimation of water losses through evapotranspiration of aquatic weeds in the Nile River (2018) 32 Water Science, pp. 259-275.

Exhibit 6 – Timmer & Weldon, Evapotranspiration and Pollution of Water by Water Hyacinth (1966).

Exhibit 7 – Robertson-Bryan, Inc., Report on The Effects of the California WaterFix on Harmful Algal Blooms in the Delta (2017).

Exhibit 8 – Phase 2 Modeling Synthesis Report Prospect Island Tidal Habitat Restoration Project (July 2014).

Exhibit 9 – Berg & Sutula, Factors Affecting Growth of Cyanobacteria (August 2015).

Exhibit 10 – California WaterFix Final EIR/S (2016) (excerpt).

EXHIBIT 1

Good Neighbor Checklist for Restoration Projects

Restoration projects can have many benefits, but can also cause impacts to neighboring properties, agriculture, infrastructure (particularly roads and levees) and water resources. These impacts can be social, economic, and environmental. In many cases, these impacts are not adequately addressed in environmental review and permitting processes. Inclusion of Good Neighbor policies in restoration projects supports agricultural communities, reinforces the benefits of conservation partnerships, reduces conflicts and delay, and helps achieve sustainable conservation. Restoration planners and project managers should use the following checklist to ensure that they comprehensively consider and address the impacts of their project on neighbors.

Goal: Increase value and resilience of restoration projects by addressing and appropriately limiting negative impacts on neighboring property and infrastructure. Avoid economic, social and environmental costs of unmitigated offsite impacts and continued controversies.

Good Neighbor Restoration Projects:

Siting and Planning

☒ Are completed on public lands, or where private property is required, rely on willing sellers and do not use condemnation or eminent domain to acquire land.

☒ Do not conflict with existing agricultural or conservation easements.

☒ Do not fragment or divide existing farms or communities.

☒ Engage neighbors and stakeholders constructively at each major phase of plan development, including early planning, with special attention to changes to local drainage, irrigation and levee/flood infrastructure.

☒ Establish and maintain at least baseline conditions for roads, bridges and levees used by the project.

☒ Are sited to avoid interfering with other beneficial water uses such as existing water diversions, boating, fishing and recreation.

☒ Are designed to prevent damage to nearby flood control facilities, and include preventative levee strengthening and ongoing repairs as needed.

☒ Provide buffers so that surrounding lands can remain in agricultural and other uses without interference.

☒ Include safe harbor or other protections (e.g., take coverage) for neighboring land and water uses if listed wildlife species are expected to increase in abundance on neighboring lands or waterways.

☒ Carefully design any public access to be compatible with (or ideally benefit) local businesses, landowners and residents.

Good Neighbor Checklist for Restoration Projects

Construction, Operation and Maintenance

☒ Reduce or avoid project dust, traffic, vibration, noise and lighting impacts.

☒ Minimize project traffic during commute and harvest periods.

☒ Include invasive species protection plans and long-term abatement funding to:

- Protect against proliferation of mosquitos to protect against arboviruses, which can lead to injury and mortality of wildlife and humans.
- Monitor and treat terrestrial and aquatic weeds and set specific triggers for action.

☒ Monitor and mitigate project-related changes to local water quality and quantity to:

- Protect beneficial water uses from harmful algal blooms, nitrates, phosphorous, and methylmercury.
- Avoid excess drainage, seepage or changes in water the table that impair neighboring agricultural activities.

☒ Provide mitigation for conversion of productive agricultural land in the form of conservation easements or other measures to enhance local agricultural productivity.

☒ Include a detailed operation and maintenance plan, and as adequate personnel to maintain site security, prevent trespass, manage any publicly accessible areas, and control flooding and weeds.

Accessible Community Interface

☒ Provide an Ombudsman Office to:

- Facilitate stakeholders and affected landowners and local agency discussions regarding offsite impacts and options to address them.
- Provide an alternative dispute resolution process to the inefficient Government Claims Act process.
- Provide project updates to the affected public and incorporate input into the project during project planning and operation.

References

Department of Water Resources 2014, Agricultural and Land Stewardship Strategies. https://water.ca.gov/programs/california-water-plan/water-resource-management-strategies/agriculture-and-land-stewardship-framework).

Delta Conservancy 2019, Delta Public Lands Strategy http://deltaconservancy.ca.gov/wp-content/uploads/2019/01/Delta_Public_Lands_Strategy_Final_1-22-19.pdf

Department of Fish and Wildlife 2018, Delta Conservation Framework 2018-2050 https://www.wildlife.ca.gov/Conservation/Watersheds/DCF

EXHIBIT 2

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BEFORE THE

CALIFORNIA STATE WATER RESOURCES CONTROL BOARD

HEARING IN THE MATTER OF CALIFORNIA DEPARTMENT OF WATER RESOURCES AND UNITED STATES BUREAU OF RECLAMATION REQUEST FOR A CHANGE IN POINT OF DIVERSION FOR CALIFORNIA WATER FIX

REBUTTAL TESTIMONY OF MICHELLE LEINFELDER-MILES

Joint Rebuttal: Local Agencies of the North Delta, Delta Watershed Landowner Coalition, Bogle Vineyards, Diablo Vineyards, Stillwater Orchards, and Islands, Inc.

I, Michelle Leinfelder-Miles, do hereby declare:

I. INTRODUCTION

I am the Delta Crops Resource Management Advisor with the University of California Cooperative Extension, based in San Joaquin County. I have five years of experience working in this capacity and fourteen total years of research experience in agricultural cropping systems, which includes work in grains and forages, vegetable crops, and tree and vine fruit crops. I received my B.S. in Crop Science and Management from UC Davis (2001), my M.S. in Horticulture from Cornell University (2005), and my Ph.D. in Horticulture from Cornell University (2010). As the Delta Crops Resource Management Advisor, I conduct an applied science, multidisciplinary research and outreach program on agricultural production and resource stewardship. My research projects center on row crops and the management of water and soil resources in those agricultural systems. I conduct research projects in cooperation with Delta growers, on their farms, in order to gain an understanding of how scientific principles apply in the field. A description of my research projects is included in my statement of qualifications (II-12). My outreach program is directed toward agricultural producers, allied industry representatives, and natural resource managers. I conduct instructional meetings and demonstration field meetings where I communicate research results from my own program and those of my UC colleagues to the agricultural community. These are the major roles of a UC Cooperative Extension farm advisor—to conduct applied research and to extend the findings of research to the local community.

II. EVALUATING SALINITY IN DELTA AGRICULTURAL SYSTEMS

I have dedicated considerable time to assessing soil salinity conditions in the Delta because salinity has the potential to impact crop productivity and soil resource management. I have led several field projects over the last few years where we have monitored irrigation water salinity and investigated soil salinity in the north and south Delta under various cropping and irrigation regimes. These projects were developed with the source of irrigation water, soil series, crop, and irrigation system in mind, in order to understand baseline conditions at various locations throughout the Delta and, in the case of the alfalfa project, how the irrigation water salinity and soil salinity changed over time.

In a scenario where asked to evaluate how water salinity may impact soil salinity and crop yield, I would identify sampling locations with the following criteria in mind:

- Water quality. I would select sampling locations where water salinity ranges from low to high and/or has daily or seasonal fluctuations. I have used information from the California Data Exchange Center[1] to assist in cursory selection, but I also value land owners' understanding for water quality and how it can vary across different points of diversion on the same farm. My procedures would then involve monitoring water quality over the course of the irrigation season, preferably taking water samples as it is applied to fields, or at least taking samples at points of diversion onto Delta islands of interest. Documents submitted by protestants, and other available information, demonstrate the locations of water diversions and water uses that could potentially be injured by the Project as petitioned, including LAND-62, Exhibit C [Water Rights within LAND Area]; LAND-5 and LAND-75 [Bogle water rights protest to Petition, Exhibits A and B], LAND-6 and LAND-76 [Diablo water rights protest to Petition, Exhibits A and B], LAND-7 and LAND-77 [Elliot/Stillwater water rights protest to Petition, Exhibits A and B][2], and II-38 [Ryer Island diversions]; see also SWRCB-2, DWR and Reclamation's September 11, 2015 Joint Change Petition Addendum and Errata, Attachment C [list of all diversions within Project area].
- Soil series. I would sample fields with soil series that are representative of large areas of the Delta. This information is available from the Natural Resources Conservation Service SSURGO database, accessible from the CA Soil Resource interface.[3]

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[1] Available at http://cdec.water.ca.gov/.
[2] These exhibits include reliable listings and/or maps with an accurate and undisputed description of the water rights associated with these protestants.
[3] Available at: http://casoilresource.lawr.ucdavis.edu/drupal/node/902.

- <u>Cropping patterns and crop salinity tolerance</u>. Crop acreage is available from the offices of the county Agricultural Commissioners and can be parsed out for the Delta region. I would use established salinity thresholds (II-15; Ayers and Westcot, 1985) to determine what crops are most sensitive to salinity. I would then concentrate my sampling efforts on crops that are sensitive or moderately sensitive to salinity, widely planted in the Delta, and/or high value.
- <u>Irrigation method</u>. My previous testimony (II-13) and an updated project report, which is identified as exhibit LAND-79 [Leinfelder-Miles (2016)] describe how sampling methods should vary based on drip, sprinkler, and flood irrigation programs. The methods capture how soil salinity varies with how water is applied to the field.

I would follow previously described procedures for monitoring applied water salinity, soil salinity, groundwater depth and salinity, and crop yield, as described for border check flood irrigated alfalfa fields, a drip irrigated vineyard, and a sprinkler irrigated pear orchard (II-13, II-14, and LAND-79 [Leinfelder-Miles, 2016].)

For applied water salinity, I emphasize the importance of sampling water as it was being applied to the field and from as many irrigations as possible during the growing season (generally April-October) in order to characterize the salinity of the water available to the crop. In contrast, the Petitioners failed to consider injuries that the Petition may cause to individual water rights. In testimony and cross examination, a DWR witness stated that she relied on regulatory Water Quality Control Plan compliance requirements rather than individual diversions in evaluations of how the Project could injure water users. (DWR-53, Testimony of Maureen Sergent, pp. 4:9-16, 13:7-20; see also September 23, 2016, Meserve Cross Examination of Maureen Sergent, p. 36:7-25; September 23, 2016, Meserve Cross Examination of Maureen Sergent, pp. 41:4-42:1 ["Let's note that to everyone. They did not investigate individual diversions."].)

The salinity of water in surface waterways is not an accurate representation of what the crop takes up. Additionally, monthly averages of salinity in surface waterways do not accurately represent what the crop takes up. Monthly averages of surface waterway salinity should not be used as a substitute for the seasonal average applied water salinity to a field.

Irrigation water salinity influences soil salinity because irrigation water carries salts, and when it is applied to fields, salts are added to the soil. Salts accumulate in the soil at higher concentrations than they existed in the irrigation water because evaporation and plant uptake extract water from the soil leaving the salts behind. Salts may accumulate disproportionately in the soil profile depending on soil properties, irrigation systems, groundwater depth, or other reasons. For these reasons, soil sampling procedures must be thorough enough to understand salt distribution with soil depth and across variations in the field based on soil, cropping pattern, and/or irrigation program. This could represent a two-dimensional grid pattern, as described for a drip irrigated vineyard; random sampling across an area but at specific depth increments, as described for a sprinkler irrigated pear orchard; or in field sections (e.g., top, middle, and bottom), as described for border check flood irrigated alfalfa fields. It would also be important to measure groundwater depth and salinity to better understand how groundwater may be influencing soil salinity.

III. CHARACTERIZING SALINITY INJURIES TO DELTA AGRICULTURAL SYSTEMS AS A RESULT OF INCREASES IN SURFACE WATER SALINITY

Increases in applied water salinity may injure Delta agricultural systems by degrading soil conditions or decreasing yield. Unleached salts have the potential to injure current crops and future cropping. Fluctuating groundwater depth, crop rotations and associated tillage, and changes in irrigation regimes are all reasons that unleached salts can be redistributed in the rooting zone and injure future cropping—either by reducing cropping choices or by reducing yields. In evaluating yield impacts, I would measure yields at the field because county Agricultural Commissioner reports will tally crop yields for the entire county, and those yields may not accurately reflect crop yields for the Delta.

It can be difficult to establish statistical relationships between water quality, soil salinity, and crop yields using surveying procedures, but soil salinity thresholds have been established for various crops (II-15, Ayers and Westcot, 1985), which relate soil salinity to yield potential.

We can plot these values for salinity and yield potential to understand how salinity may reduce yields. This is presented for alfalfa and grapes in Figures 1-2, attached hereto as Exhibit A. For alfalfa, we would not expect yield to be impacted until soil salinity (ECe) reaches the threshold 2.0 dS/m. Beyond this level, we would expect to see a roughly 7% decline in yield potential with each 1 dS/m increase in ECe. For grapes, the ECe threshold is 1.5 dS/m. Beyond this level, we would expect to see a roughly 9.5% decline in yield potential with each 1 dS/m increase in ECe. While absolute tolerances may vary depending on climate, soil conditions, and cultural practices, these numbers serve as a guide for understanding how soil salinity impacts crop yields.

In cross examination, a DWR witness stated that a change in water quality that is less than 5% is not an impact. (August 25, 2016 John Herrick Cross Examination of Parviz Nader-Tehrani, pp. 11:21-12:8.) This is a hasty and unfounded assumption. First, based on crop salinity tolerances (II-15, Ayers and Westcot, 1985), even a small change in water salinity could reduce yield if that change resulted in an increase in soil salinity that exceeded the crop tolerance threshold. Nevertheless, if a grower must change practices to adapt to increases in water salinity in order to prevent reaching the soil salinity threshold, then another potential injury is the cost associated with these changes in practices (e.g., soil amendments, applying more water, changing crops). For example in previous testimony (II-13 and II-14), I illustrated how salinity is distributed in a Ryer Island vineyard and how average root zone salinity has reached a level that has the potential to impact yield. A small increase in applied water salinity could injure yields and soil quality through evapoconcentration of salts. A change in practices, such as applying more water, could negatively impact fruit quality by reducing the soluble solids of the grapes.

I have heard the argument that growers should grow salt-tolerant crops or plant varieties with higher salt tolerance in response to higher salinity conditions, but my response is that the choice of what crop to grow is an economic decision that takes many factors into account, and plant breeding is not a substitute for soil salinity management. For all of these reasons, it is my opinion that it is inaccurate to conclude that injury would not result to Delta agricultural water uses and users from changes in water quality that Petitioners may characterize as small.

VII. CONCLUSIONS

My experiences in monitoring soil and applied water salinity in Delta agricultural systems have elucidated the complexity of managing salinity in these systems. My understanding of salinity comes from sampling field conditions in the north and south Delta, with varying water quality, soil types, cropping systems, and irrigation regimes. An increase in water salinity has the potential to injure agricultural water users by decreasing yields or increasing soil salination. The Petitioners failed to characterize these injuries in their modeling of water quality, disregarded individual diversions/water users, and improperly assumed that small changes would not cause injury, without considering crop salinity tolerances and other site-specific considerations. For these reasons, the analysis presented by the Petitioners is inadequate to conclude no injury to Delta agricultural water users.

I declare under penalty of perjury under the laws of the State of California that the foregoing statements are true and correct.

Executed on the 23rd day of March 2017, at Stockton, California.

Michelle Leinfelder-Miles

REFERENCES

II-15, Ayers, R. S. and D. W. Westcot. 1985. Water Quality for Agriculture. FAO Irrigation and Drainage Paper 29 Rev. 1. FAO, United Nations, Rome. 174 p.

Leinfelder-Miles, M. 2016. Leaching fractions achieved in South Delta soils under alfalfa culture. Project Report Update December 2016. UC Cooperative Extension, San Joaquin County, Stockton, CA.

EXHIBIT A

EXHIBIT A – Yield potential as a function of soil salinity for alfalfa and grapes (From Ayers and Westcot, 1985).

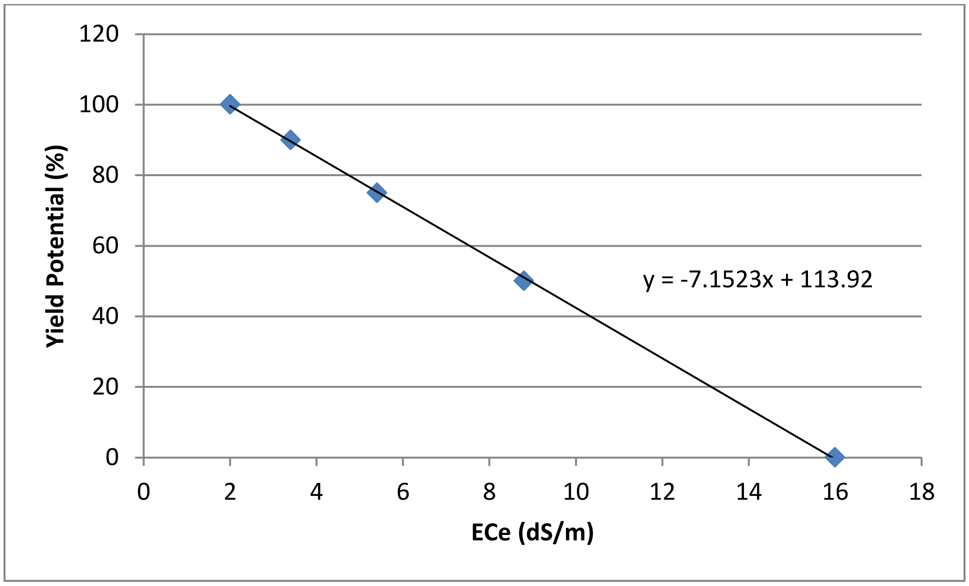

Figure 1. Yield potential of alfalfa as a function of soil salinity (ECe).

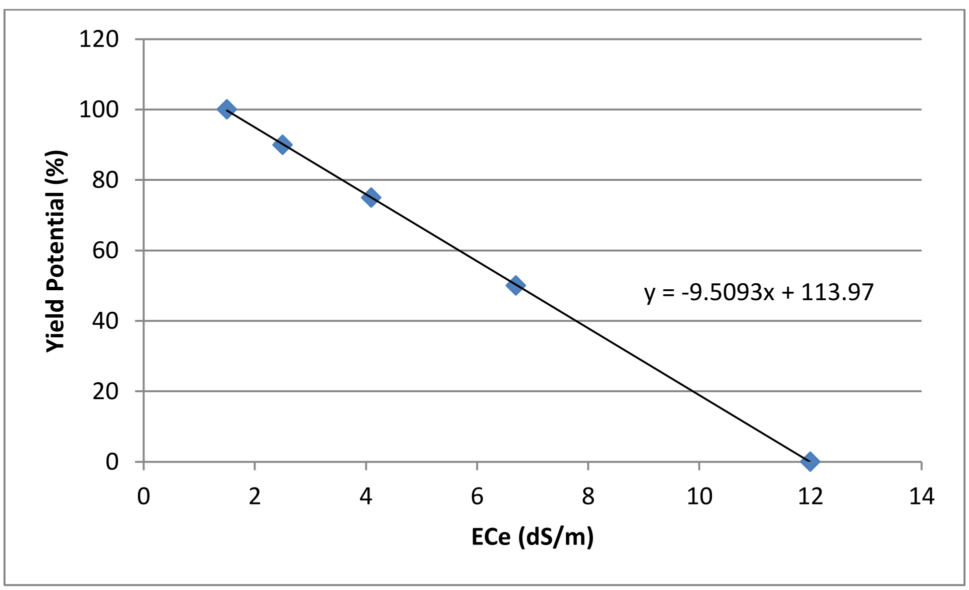

Figure 2. Yield potential of grapes as a function of soil salinity (ECe).

EXHIBIT 3

Title
Yellow starthistle continues its spread in California

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Yellow starthistle continues its spread in California

by Michael J. Pitcairn, Steve Schoenig,
Rosie Yacoub and John Gendron

Yellow starthistle is an exotic invasive weed that is estimated to infest over 14 million acres in California and is considered the most common exotic weed statewide. We reviewed several previous studies and conducted a township survey to provide an up-to-date analysis of the weed's rapid spread throughout the state. A county-by-county comparison between 1985 and 2002 showed increases in yellow starthistle in all regions of the state except for northeast California and the southeast desert region. Currently, most infestations occur in Northern California, but future invasions and spread will likely occur in the coastal counties of Southern California.

Baldo Villegas/CDFA

Yellow starthistle is the fastest-moving and most-widespread invasive, nonnative plant in California history. Dale Woods of the California Department of Food and Agriculture and Bill Bruckart of the U.S. Department of Agriculture examine the weed in Placer County.

Yellow starthistle is an exotic, noxious weed commonly found in rangelands and along roadsides and walking trails throughout California. Approximately 1-inch-long spines extend from the flower heads in a star-like pattern, giving rise to its common name of "starthistle." These spines are a bane to hikers and discourage feeding by grazing animals. Although not toxic to most animals, yellow starthistle (*Centaurea solstitialis* L. [Asteraceae]) is poisonous to horses and can cause brain lesions that may eventually kill them (Cordy 1978). Yellow starthistle favors disturbed soils but is also capable of invading undisturbed areas. Once this weed gains a foothold, it can build up dense populations that displace native and other desirable vegetation. Yellow starthistle is native to the Mediterranean climates of southern Europe and northern Africa and was first recorded in California near Oakland (Alameda County) in 1869. It is now considered the most common weed in the state.

Yellow starthistle was likely introduced many times to California as a contaminant of alfalfa seed (DiTomaso and Gerlach 2000). In the late 1800s, alfalfa seed from Europe, Asia and South America was imported for planting in the Sacramento Valley, and early records show that yellow starthistle was a frequent contaminant in these shipments. By 1917, this weed was common along roads, trails, ditches and railroad tracks throughout the Sacramento Valley (DiTomaso and Gerlach 2000). Yellow starthistle's primary means of spread is through human activity. The weed's seed can be transported over long distances by automobiles and earth-moving equipment, and in contaminated soil, crop seed and hay. More locally, the seed can be carried on animal fur and hiking boots and clothing, and by moving water. Wind does not appear to be an effective dispersal method.

Previous infestation estimates

Since the late 1950s, three estimates of the number of acres infested by yellow starthistle in California have been undertaken (Maddox and Mayfield 1985). The first, by the California Department of Food and Agriculture (CDFA), used responses from a questionnaire sent to county agricultural commissioners in 1958; the infested acreage of yellow starthistle was estimated at approximately 1.2 million acres (486,000 hectares). A similar survey undertaken by CDFA in 1965 found an estimated 1.9 million infested acres (769,000 hectares).

Donald Maddox and Aubrey Mayfield performed the third estimate 20 years later, in 1985. They also distributed questionnaires to the county agricultural commissioners but included UC Cooperative Extension farm advisors and other interested parties as well. Maddox and Mayfield estimated the number of acres infested with yellow starthistle at approximately 7.9 million acres (3.2 million hectares), a four-fold increase from 1965.

Unlike the previous two surveys, Maddox and Mayfield (1985) also reported the infested acreage by county and identified those with high and low infestation levels. High infestation counties had at least 1,000 acres (405 hectares) of yellow starthistle. In 1985, 38 of California's 58 coun-

Baldo Villegas/CDFA

A native plant of southern Europe and northern Africa, yellow starthistle was first recorded in California near Oakland in 1869.

Starthistle abundance guidelines

The following descriptions were provided to cooperators in the township survey to provide guidance in scoring yellow starthistle abundance.

Low:

- Only a single plant was found in the township.
- The only plants found were scattered plants and confined to the roadsides.
- Plants were scattered throughout the township, but did not occur in high densities.
- No dense patches or a few small, dense patches (< 10 acres) were observed.

High:

- Plants occurred primarily along roadsides, and quite dense for several miles.
- Plants not confined to roadsides, but observed throughout neighboring fields.
- Dense patches of plants > 10 acres found in at least three sections.
- Everywhere you looked you saw yellow starthistle plants.

ties had high infestation levels, with Lake County the highest, followed by Siskiyou, Humboldt and Trinity counties. Six counties reported no infestations: Alpine, Imperial, Inyo, Mono, Orange and San Francisco. In addition, Maddox and Mayfield grouped the county estimates into seven regions that represented the state's major drainage areas. The Sacramento and North Coast drainages had the highest infestation acreage, representing over 76% of the total reported acreage of yellow starthistle for the state.

Maddox and Mayfield's survey showed that the invasion and spread of yellow starthistle in California differed regionally. Northern California had more areas with high infestation levels and Southern California had fewer invaded areas, especially in the South Coast and San Joaquin drainages. This difference was attributed to the Northern California infestations having been in place longer than those in Southern California. Other regions with low infestation levels, such as the higher elevations of the Sierra Nevada and the Sonora and Mojave deserts, were believed to have climates that limit population growth and resist invasion by yellow starthistle.

Knowing the distribution of an invasive weed is of direct importance to its management. If an uninfested area is climatically unsuitable for yellow starthistle, then control efforts may not be necessary. However, if an area susceptible to yellow starthistle has not yet been infested, it might be feasible to control this noxious weed before it becomes abundant and impractical to manage. Studies have shown that controlling exotic weeds at the early stages of invasion is the most successful and cost-effective strategy (Randall 1996; Rejmanek and Pitcairn 2002).

Planning and prioritizing control measures at the regional level requires detailed knowledge of the target weed's distribution. For example, the U.S. Department of Agriculture and CDFA are implementing a statewide distribution effort of several biological control insects for yellow starthistle. For this effort to be successful, it is critical to know where yellow starthistle occurs so that all infestations are targeted for releases (Villegas 2001a, 2001b; Woods and Villegas 2005).

Surveying occurrence by township

To provide a more detailed and more recent assessment of the spread of yellow

Joe DiTomaso

Human activity, such as the use of automobiles and agricultural equipment, is the primary means of dispersal for yellow starthistle seeds. While nontoxic to most animals, it causes neurological diseases in horses. High densities crowd out native vegetation, discourage grazing and annoy hikers.

starthistle statewide, we performed a survey of its occurrence by township. A legal township in the Federal Public Lands Survey is a 6-mile-by-6-mile square (9.6-kilometers-by-9.6-kilometers). Early land surveyors throughout much of California established townships in the late 1800s. We purchased county maps and used markers to highlight the grid of township borders printed on them. For areas where townships were not established, such as many of the early Spanish land grants, we used markers to extend the grid into those areas.

These marked-up county maps were distributed to CDFA's Weed and Vertebrate Program biologists, who coordinate the eradication of noxious weeds throughout the state. We asked that each township be given a score of "0" for no yellow starthistle plants, "1" for low abundance and "2" for high abundance. Guidelines were provided as to what constituted low and high abundance (see box, page 84). Some program biologists completed the maps themselves, while others distributed them to the county agricultural commissioners in their districts. The township grid survey was performed in 1996 and 1997. All information collected during the survey was transferred into a geographic information system (GIS) database and a preliminary map of yellow starthistle in California was produced (Pitcairn et al. 1998).

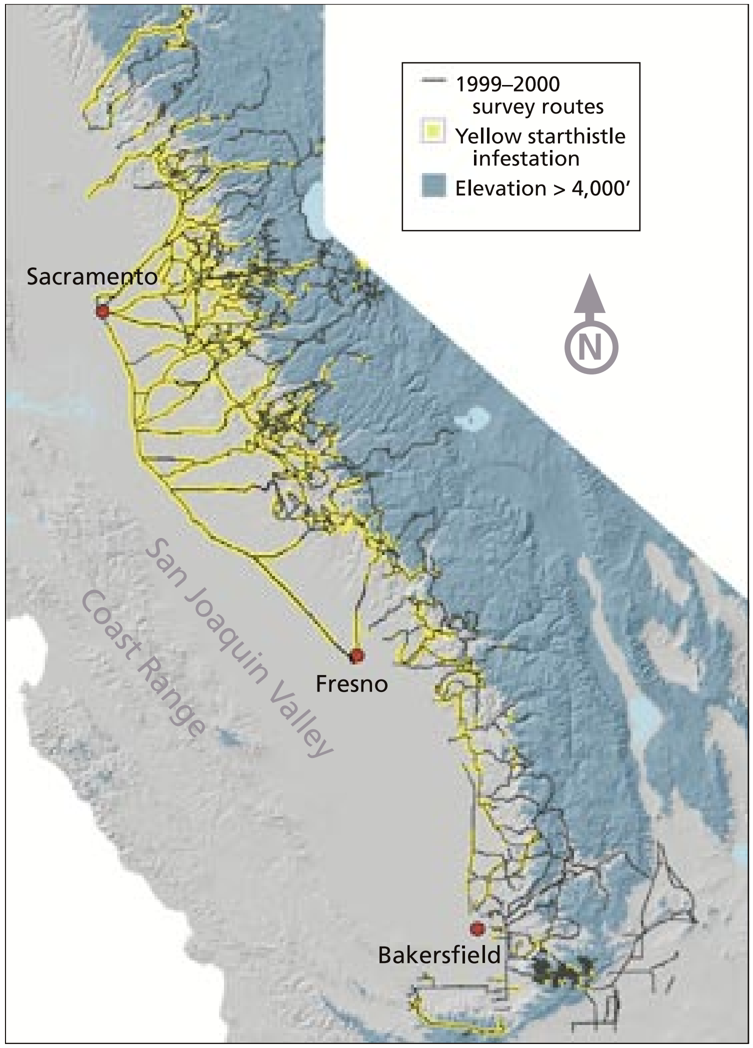

Fig. 1. Surveys of roads in the Sierra Nevada in 1999 and 2000 showed yellow starthistle to be less common at elevations above 4,000 feet (1,220 meters).

Sierra Nevada and Kern County. In compiling the township grid data, we learned that knowledge of the occurrence of yellow starthistle was particularly weak or missing in the mid-elevations of the Sierra Nevada and throughout Kern County. Both areas are important transitions from the Central Valley to the mountains in the east and the desert in the southeast, respectively. Before a final map of yellow starthistle in California was produced, we examined these two areas more closely. Information on the occurrence of yellow starthistle in Kern County was provided by the agricultural commissioner's office, which performed a local noxious weed survey in 2000.

In cooperation with the California Department of Transportation, in 1999 we surveyed for yellow starthistle along 14 major roads crossing the Sierra Nevada as well as along many of the smaller roads in between them. The objective was to identify how far yellow starthistle had spread into the higher elevations. If control efforts were focused on local eradication of new, incipient populations, large tracts of important public and private land might be protected from invasion. In addition, the infested acreage along the advancing front of the invasion might be relatively small and control costs low, especially compared to the value of the area to be protected.

The survey was broken into three phases: a general survey of the highway roadsides, a survey of areas beyond the right-of-way to determine how far yellow starthistle extended away from the roadside, and a resurvey of the upper elevations to determine if plants that germinated later in the season were missed during the survey's first phase. Surveyors used global positioning systems (GPS) to mark yellow starthistle locations, and all data were entered into a GIS database.

In 2000, we coordinated a survey over the same geographic area, taking advantage of the recently formed Weed Management Areas to acquire contacts from many different private and public landowners throughout the region. Weed Management Areas are local coalitions of public and private landowners that work on invasive weeds. They typically include representatives from state and federal agencies with land in the area, land managers from local park districts, large private landowners and concerned citizens. We incorporated

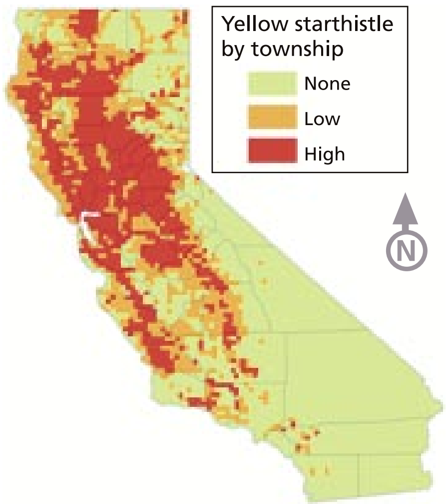

Fig. 2. Occurrence of yellow starthistle by township, incorporating information from all surveys through 2002.

into our database any information on areas surveyed for yellow starthistle or incidental finds collected by cooperators. This included GPS positions, GIS-digitized locations, road descriptions and paper maps. Additionally, we resurveyed some of the highways that were surveyed in 1999 and many of the smaller mountain roads, again using GPS units to record locations.

The results of these two road surveys showed an edge to the spread of yellow starthistle into the Sierra Nevada (fig. 1). When mapped with elevation contours, yellow starthistle was generally not common above elevations of 4,000 feet (1,220 meters). While major highways in the northern Sierra Nevada (such as Interstate 5 and Highway 50) had infestations well above this elevation, yellow starthistle was much less frequent or absent above 4,000 feet (1,220 meters) in the central and southern portion of the mountain range. In addition, while yellow starthistle was common along some roads in the Tehachapi mountains, almost none was observed on the eastern side of mountains in the Mojave Desert.

Modoc County, statewide surveys. Two more yellow starthistle surveys also became available and were incorporated into our township grid database. First, Modoc County performed a noxious weed survey in 2002, and this information was used to update the township grid data they

TABLE 1. Yellow starthistle infestation totals reported by county agricultural commissioners, 2002

County	Total county acres*	1985 gross†	2002 gross	Increase	Portion county infested	2002 net	Net/gross ratio
		······· acres ·······		%	%	acres	% cover
Alameda	528,270	20,000	200,000	900	38	15,000	7.5
Alpine	465,030	0	250	—	< 1	11	4.4
Amador	384,810	243,000	243,000	0	63	33,000	13.6
Butte	1,065,490	463,000	463,000	0	43	50,000	10.8
Calaveras	663,290	100,000	400,000	300	60	150,000	37.5
Colusa	739,740	246,000	265,000	8	36	50,000	18.9
Contra Costa	510,680	470,400	310,000	–34	61	44,000	14.2
Del Norte	641,920	4	1,000	24,900	< 1	1	0.1
El Dorado	1,155,040	5,000	650,000	12,900	56	129,000	19.8
Fresno	3,838,820	3,000	925,000	30,733	24	303,000	32.8
Glenn	844,160	10,000	400,000	3,900	47	175,000	43.8
Humboldt	2,303,690	686,000	250,000	–64	11	50,000	20.0
Imperial	2,942,340	0	0	0	0	0	0.0
Inyo	6,462,640	0	10	—	< 1	2	20.0
Kern	5,229,000	100	4,500	4,400	< 1	2,500	55.6
Kings	918,790	10	120	1,100	< 1	100	83.3
Lake	848,960	800,000	500,000	–38	59	176,000	35.2
Lassen	3,001,780	500	1,000	100	< 1	500	50.0
Los Angeles	2,610,730	2	415	20,650	< 1	125	30.1
Madera	1,374,160	300	10,000	3,233	< 1	5,000	50.0
Marin	376,300	2,000	2,200	10	< 1	1,500	68.2
Mariposa	938,690	200,000	250,000	25	27	200,000	80.0
Mendocino	2,246,840	250,000	1,000,000	300	45	400,000	40.0
Merced	1,284,930	1,000	600,000	59,900	47	120,000	20.0
Modoc	2,777,870	120	500	317	< 1	210	42.0
Mono	1,985,950	0	1	—	< 1	1	100.0
Monterey	2,127,430	6,000	1,650,000	27,400	78	56,000	3.4
Napa	510,010	242,560	242,560	0	48	85,120	35.1
Nevada	635,010	200,000	248,000	24	39	75,000	30.2
Orange	502,440	0	0	0	0	0	0.0
Placer	964,140	274,000	360,000	31	37	145,000	40.3
Plumas	1,675,780	800	13,000	1,525	< 1	3,300	25.4
Riverside	4,635,540	251+	2,080	729	< 1	920	44.2
Sacramento	649,780	320,000	320,000	0	49	25,000	7.8
San Benito	894,150	72,000	80,000	11	9	8,000	10.0
San Bernardino	12,905,960	2,890	1,500	–48	< 1	58	3.9
San Diego	2,739,560	15	26	73	< 1	8	30.8
San Francisco	58,300	0	1,000	—	2	12	1.2
San Joaquin‡	919,180	72,000	333,143	363	36	38,883	11.7
San Luis Obispo	2,128,800	10,000	60,000	500	3	15,000	25.0
San Mateo§¶	339,690	27	5,000	18,419	1	5,000	100.0
Santa Barbara	1,756,580	3,000	5,720	91	< 1	3,000	52.4
Santa Clara	842,160	5,000	7,307	46	< 1	7,040	96.3
Santa Cruz	281,360	75	250	233	< 1	100	40.0
Shasta	2,464,140	400,000+	500,000	25	20	333,000	66.6
Sierra	613,500	5	364	7,180	< 1	73	20.1
Siskiyou	4,043,710	768,000	1,010,000	32	25	252,500	25.0
Solano#	558,210	20,000+	95,794	379	17	24,906	26.0
Sonoma	1,022,460	100,000	100,000	0	10	10,000	10.0
Stanislaus	973,580	227,000	227,000	0	23	45,050	19.8
Sutter	388,480	200,000	199,324	0	51	65,450	32.8
Tehama	1,904,640	40,000	789,267	1,873	41	137,934	17.5
Trinity	2,062,500	612,672	200,000	–67	10	50,000	25.0
Tulare	3,100,710	10,000	20,000	100	< 1	6,000	30.0
Tuolumne§	1,467,320	212,818	40,000	–81	3	40,000	100.0
Ventura	1,192,680	5	250,000	4,999,900	21	100,000	40.0
Yolo	661,760	198,600	660,760	233	100	165,440	25.0
Yuba	409,020	407,680	407,680	0	100	80,000	19.6
Total	101,563,500	7,905,834	14,305,771	81	14	3,682,744	25.7

* Source: Hornbeck et al. 1983.
† Source: Maddox and Mayfield 1985.
‡ No estimate submitted; gross and net values were estimated as the average of values reported by Sacramento and Stanislaus counties.
§ Only net acreage provided.
¶ Value provided by San Mateo Weed Management Area.
# Only gross acreage provided; net acreage was estimated as 26% of gross acreage (based on the average ratio between total net and gross acreage for the other counties reporting both values).

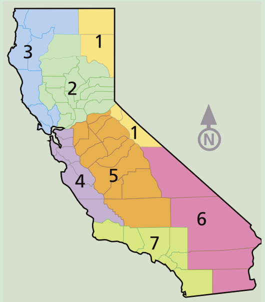

TABLE 2. Comparison of yellow starthistle infestations for major California drainage areas, 1985 and 2002

Drainage area	Gross acreage 1985*	Gross acreage 2002	% of total 1985	% of total 2002	Net acreage 2002	Net acreage % of total	Net/gross ratio
1. Northeast interior basins	58,219	1,751	0.7	< 0.1	722	< 0.1	41.2
2. Sacramento drainage	3,235,035	5,872,189	40.9	41.0	1,635,103	44.4	27.8
3. North Coast drainage	2,792,186	2,805,760	35.3	19.6	849,121	23.1	30.3
4. Central Coast drainage	355,042	2,313,557	4.5	16.2	150,152	4.1	6.5
5. San Joaquin drainage	1,458,300	3,052,763	18.4	21.3	943,533	25.6	30.9
6. Southeast desert basins	2,796	10	< 0.1	< 0.1	2	< 0.1	20.0
7. South Coast drainage	4,256	259,741	< 0.1	1.8	104,111	2.8	40.1
Total	7,907,819	14,305,771	100.0	100.0	3,682,744	100.0	

*Source: Maddox and Mayfield 1985.

had submitted in 1997. Second, CDFA conducted a statewide survey in 2001 and 2002 of biological control agents released against yellow starthistle (Pitcairn et al. 2003). This survey consisted of collecting yellow starthistle plants from 421 locations throughout California and examining them for the presence of four insects known to attack the seed heads. We overlaid the yellow starthistle collection locations on the township map, and then updated the map accordingly.

Final map. The information from all surveys through 2002 was compiled into a final map of yellow starthistle occurrence by township (fig. 2). Of the 6,389 townships statewide, 3,010 had yellow starthistle (1,441 had low abundance and 1,569 had high abundance). These infested townships account for approximately 47% of the surface area of California. The high-abundance townships occurred primarily in the Sacramento Valley and Sierra Nevada foothills, but were also reported for several coastal valleys from San Luis Obispo County to Humboldt County. The northeast interior and desert basins had few infestations of yellow starthistle.

Number of infested acres

The township grid map provides our best estimate of the extent to which yellow starthistle has spread, but provides no information on the amount of actual acres infested. To address this question, in 2002 we repeated the questionnaire survey of infested acres performed by Maddox and Mayfield (1985). In contrast to the previous three questionnaires, we requested two estimates of yellow starthistle infestations: gross acreage and net acreage. Gross acreage is the amount of land over which yellow starthistle populations are distributed. This is how the acreage of plant infestations is usually estimated, and how the results from the previous three surveys were reported.

Net acreage is the amount of land actually covered by the yellow starthistle plant canopy. For example, if one 10-acre (4-hectare) plot had 100 yellow starthistle plants while another 10-acre plot had 10,000 plants, the gross acreage in both cases is still 10 acres (4 hectares). However, the net acreage for the plot with 100 plants may be only 1 acre (0.4 hectares), while the net acreage for the plot with 10,000 plants may be 6 acres (2.4 hectares). The ratio of net acres to gross acres multiplied by 100 provides an estimate of the percentage cover of the infestation.

The total gross acreage of yellow starthistle in California is now estimated at 14.3 million acres (5.8 million hectares), an increase of over 80% from 1985 (table 1). Monterey County had the highest reported gross acres of yellow starthistle in the state, at 1.65 million acres (668,000 hectares). This was followed by Siskiyou County with just over 1 million acres (405,000 hectares), Mendocino County with 1 million acres (405,000 hectares) and Fresno County with 925,000 acres (374,000 hectares). In addition, four of the six counties previously reporting no yellow starthistle reported some infestations in 2002; only Orange and Imperial counties still reported none in 2002.

Eight counties reported no change since 1985 in the number of gross acres infested with yellow starthistle, and six counties reported a decrease in infested acres. All other counties reported an increase in infested gross acreage. The largest increase was reported by Monterey County, which jumped from only 6,000 acres (2,430 hectares) in 1985 to 1.65 million acres (668,000 hectares) in 2002. The largest proportional increase was reported for Ventura County, which jumped from just 5 acres (2 hectares) in 1985 to 250,000 acres (101,000 hectares).

Per Maddox and Mayfield (1985), we grouped the county infestation acreages by region (table 2). Although our grouping boundaries were not identical to those used by Maddox and Mayfield, they are similar. The differences are due to our grouping of counties as a whole instead of partitioning the estimates according to drainage area. The exception was the reported acreage for Riverside and San Bernardino counties, which occurred entirely within the South Coast drainage area; consequently, estimates from these counties were combined with the South Coast counties.

Our 2002 survey showed that the Sacramento Valley continued to have the largest amount of yellow starthistle gross acreage, with over 5.8 million acres (2.3 million hectares). The San Joaquin Valley followed with just over 3 million acres (1.2 million hectares), then the North Coast drainage with 2.8 million acres (1.1 million hectares) and the Central Coast drainage with 2.3 million acres (0.9 million hectares). These four regions represent over 98% of the total yellow starthistle gross acreage statewide.

Comparing the proportional amounts of the total yellow starthistle infestation located within each region for 1985 and 2002 showed little change except for the Central Coast drainage, which increased from 4.5% to 16.2% of the total gross acreage, and the North Coast drainage, which decreased from 35.3% to 19.6% of the total gross acreage (table 2). Interestingly, the amount of canopy cover of yellow starthistle (as estimated by the ratio between net and gross acreages) was similar among regions (rang-

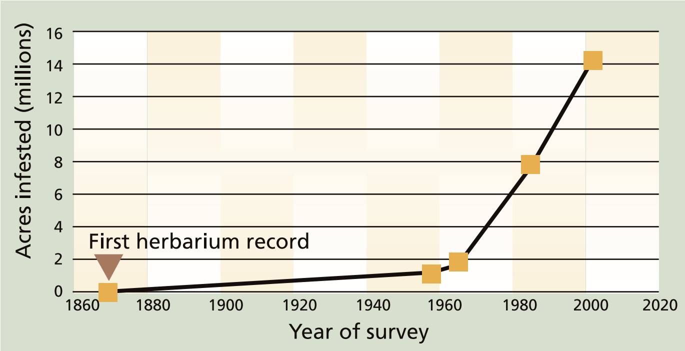

Fig. 3. Number of acres infested by yellow starthistle by year of survey. Sources: Maddox and Mayfield 1985, this report (2002).

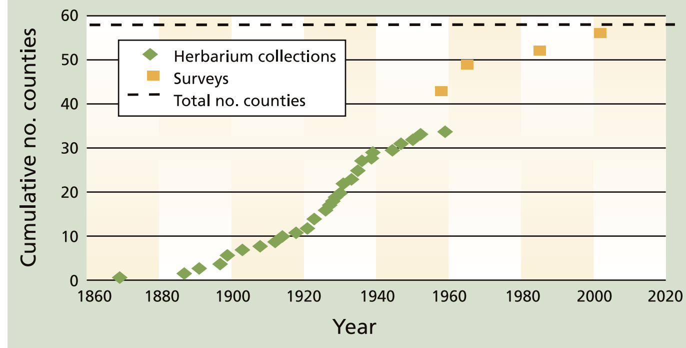

Fig. 4. Cumulative number of counties with yellow starthistle from 1869 through 2002. Data from the herbarium collections compiled by Doug Barbe, CDFA botanist (retired), for 1869 through 1960 (Calflora 2005). Survey data is from questionnaires from 1959 through 1985 (Maddox and Mayfield 1985) and this report (2002).

ing from 20% to 41%) except for the Central Coast drainage, which reported an estimated canopy cover of 6.5%. This suggests that, although the gross acreage was high, yellow starthistle cover was actually lower in the Central Coast drainage than elsewhere.

It must be emphasized that our estimates of yellow starthistle acreage are subjective and rely on the judgment of the county biologists. However, an acre-by-acre survey would be economically unfeasible. County biologists are trained to identify yellow starthistle and have good firsthand knowledge of the infestations in their county, so a subjective estimate may be our best estimate of infested acreage for an exotic weed that occurs over millions of acres.

Township levels vs. infested acres

The county survey of infested acres and the abundance of yellow starthistle by township were performed separately. However, we expected that the results of the two surveys were correlated, so to quantify this we summed the amount of acres identified as low or high in the township survey and compared the totals for each county with their estimate of infested acres. There was a significant correlation between the two data sets ($r = 0.61$, $P < 0.05$) when we assumed that the high-abundance townships were 45% infested with yellow starthistle (10,400 out of 23,040 acres [4,211 out of 9,328 hectares]) and the low-abundance townships were 17% infested (4,000 out of 23,040 acres [1,619 out of 9,328 hectares]). This suggests that the township abundance survey and the infested acres survey both yielded similar patterns of high and low abundance for yellow starthistle.

History of starthistle's spread

The invasion of California by yellow starthistle shows two phases of spread: a long initial period of slower spread prior to 1960 and a period of rapid spread after 1960 (fig. 3). An initial lag phase has been observed for other exotic weeds and is thought to be due to the weed's genetic adjustment to the new environment and the initiation of enough new founder populations to promote rapid spread (Weber 1998). Some insight into the early invasion dynamics of yellow starthistle may be obtained from the examination of early herbarium records. Doug Barbe, CDFA botanist (retired), visited the main herbaria throughout California and compiled a list of the locations and years of collection for yellow starthistle specimens collected through 1959. A total of 58 localities were obtained and the data were posted on the Internet by Fred Hrusa, the current CDFA botanist (Calflora 2005).

We used these records to examine the patterns of first yellow starthistle occurrence by county and the expansion of the weed's range throughout California (fig. 4). In addition to the herbarium data, we included the numbers of counties reporting infestations in the four surveys between 1959 and 2002. The data shows a logistic curve with the highest rate of increase between 1920 and 1940. There was a decline in new county collections after 1940, when yellow starthistle was no longer considered unusual. Once a species is widely recognized as a common weed, the collection of herbarium specimens often declines. However, the addition of the data from the county surveys after 1958 suggests a steady increase in spread from 1920 through 1965.

It appears that during the lag phase of the invasion, yellow starthistle gradually increased in abundance until around 1920, when the rate of spread increased. The earliest herbarium collections occurred within the Sacramento River and North Coast drainage areas (Calflora 2005), but beginning in the 1920s yellow starthistle was collected for the first time in San Bernardino and Santa Barbara counties in Southern California. This was a significant expansion of range.

Gerlach (1997) suggested that invasion of California by yellow starthistle occurred in a multiple-step process. Prior to 1900, yellow starthistle was likely introduced as a contaminant of alfalfa seed brought from Chile. The original source of alfalfa in Chile was Spain, so the yellow starthistle that was initially introduced to California may have been of Spanish origin. After 1900, California received contaminated alfalfa seed directly from several locations throughout Europe and Asia, including Spain, Italy, France, Turkey and "Turkestan" (an area consisting of parts of Turkmenistan, Uzbekistan and Kazakhstan) (Gerlach 1997). This suggests that different biotypes of yellow starthistle may have been introduced during this period.

Individual introductions of a species are only a sample of the genetic diversity of the original source popula-

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Prior to 1960, yellow starthistle's rate of spread through California was about 13,500 acres annually; between 1965 and 2002 the rate escalated to more than 334,000 acres annually. ***Above*****, tall yellow starthistle plants in a pasture near Quincy.**

Fig. 5. Historical distribution of yellow starthistle in California, 1941. Source: Robbins et al. 1941.

tion, and the lack of genetic diversity may limit a weed's ability to adjust and overcome biotic and abiotic barriers to establishment in its new habitat. The occurrence of multiple introductions and the subsequent hybridization of plants from formerly separated source populations may provide the necessary genetic material to allow a species to become successful in its new environment (Ellstrand and Schierenbeck 2000). The occurrence of multiple introductions of yellow starthistle into California suggests that local hybridization was possible, but its role in the invasion biology of this weed has not been examined.

Gerlach (1997) suggested that a second invasion began in the 1930s or 1940s, when yellow starthistle became associated with the grazing system being developed for the foothill grasslands. This second invasion was facilitated by changes in cropping practices from 1920 to 1940. Prior to 1920, early reports of yellow starthistle were associated with the irrigated alfalfa fields and dry-land crops (wheat and barley) located near the Sacramento River and its tributaries (Gerlach 1997). Later, with motorized vehicles becoming more common, the cropping systems and harvesting equipment began to move away from the watercourses.

Prior to the 20th century, agricultural production was concentrated near the Sacramento and San Joaquin rivers. Later, with the expansion of the state's irrigation system and the increased use of motorized vehicles, farming expanded away from the river system and into the foothills. The development of new roads into the foothills and the movement of large numbers of grazing animals between the valley and foothills provided an efficient method for yellow starthistle to spread into new areas.

The increase in rate of first occurrence by county (fig. 4) after 1920 is consistent with Gerlach's hypothesis. The movement of yellow starthistle into the foothill grazing system and assistance in its dispersal by the movement of infested agricultural products, animals and machinery, may have been the stimulus that allowed yellow starthistle to move into the second phase of its invasion statewide.

After 1960, the rate of spread of yellow starthistle increased dramatically. The slope of the linear regression of the amount of infested acres between 1965 and 2002 shows that the spread rate was 334,377 acres (135,400 hectares) per year (fig. 3). In contrast, prior to 1960 the rate of spread averaged only 13,500 acres (5,500 hectares) per year. A spread rate of 334,377 acres per year is quite high compared to other exotic invasive plants, as most are reported to spread at rates less than 250,000 acres (100,000 hectares) per year (Weber 1998; Smith et al. 1999). Moreover, since 1960 the rate of spread of yellow starthistle in California has been steady, almost linear, and there is no indication of it slowing down. Eventually, however, the rate of spread will decrease as maximum coverage is approached and more aggressive management programs are employed.

The expansion of yellow starthistle throughout California appears to have occurred in two ways: a steady diffusion away from existing population centers, and a disjunctive establishment of multiple satellite populations that were originally separated by great distances but eventually expanded and coalesced. Robbins et al. (1941) produced an early distribution map of yellow starthistle in California (fig. 5) that showed a high concentration of the weed within the Sacramento Valley; several small, scattered populations throughout the remainder of Northern California; and a few small populations in the San Joaquin Valley and the coastal counties of Southern California. This map, along with the early herbarium records, suggests that the initial population center for yellow starthistle was the Sacramento River drainage area. This area continues to have the highest number of infested acres today.

Baldo Villegas/CDFA

A statewide township survey conducted in 2002 identified more than 14 million gross acres infested with yellow starthistle, nearly double the level of a 1985 survey. *Above,* U.S. Department of Agriculture scientist Sharon Anderson collects leaf samples along an infested trail in Fresno County.

From 1985 to 2002, increases of infested acres occurred in all areas of the state except the Interior Great Basin and the desert regions. The increases in Southern California likely resulted from new founder populations as well as from the expansion of small existing populations, and these areas showed the highest proportional increases of this weed. However, yellow starthistle infestations in the Sacramento Valley continued to increase, indicating a filling in of the gaps in this area.

Future increases in abundance

Because this weed has a strong affinity for roadsides and can be transported on machinery and in feed and hay, it is likely that human activity accelerated the scattering of new founder populations and contributed to its high rate of spread. It is not certain how far east and southeast yellow starthistle will spread in the future because environmental factors that may limit its distribution (such as low annual rainfall) are not yet known. However, we anticipate yellow starthistle continuing to increase its density and distribution in both Northern and Southern California, with the highest rates of increase in the southern coastal counties.

Future increases in yellow starthistle abundance may be significant for land managers of areas not currently infested. To stop the spread, new infestations should be eradicated when populations are small and easy to control, taking into account biological control efforts already under way.

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References

Calflora. 2005. The Calflora Database, Berkeley, CA. www.calflora.org/index0.html (accessed March 25, 2005).

Cordy DR. 1978. Centaurea species and equine nigropallidal encephalomalacia. In: Keeler RF, Van Kampen KR, James LF (eds.). *Effects of Poisonous Plants on Livestock*. Academic Pr. p 327–36.

DiTomaso JM, Gerlach JD. 2000. *Centaruea solstitialis* L. In: Bossard CC, Randall JM, Hoshovsky M (eds.). *Invasive Plants of California's Wildlands*. Berkeley, CA: UC Pr. p 101–6.

Ellstrand NC, Schierenbeck, KA. 2000. Hybridization as a stimulus for the evolution of invasiveness in plants? Proc Nat Acad Sci 97(13):7043–50.

Gerlach JD. 1997. How the west was lost: Reconstructing the invasion dynamics of yellow star-thistle and other plant invaders of western rangelands and natural areas. In: Kelly M, Wagner E, Werner P (eds.). Proc California Exotic Pest Plant Council Symposium, Vol 3. p 67–72.

Hornbeck D, Kane P, Fuller D. 1983. *California Patterns: A Geographical and Historical Atlas*. Palo Alto, CA: Mayfield Publ. 117 p.

Maddox DM, Mayfield A. 1985. Yellow starthistle infestations on the increase. Cal Ag 39(6):10–2.

Pitcairn MJ, O'Connell RA, Gendron JM. 1998. Yellow starthistle: Survey of statewide distribution. In: Woods DM (ed.). Biological Control Program Annual Summary, 1997. California Department of Food and Agriculture, Plant Health and Pest Prevention Services, Sacramento, CA. p 64–6.

Pitcairn MJ, Villegas B, Woods DM, et al. 2003. Statewide survey of yellow starthistle biological control agents. In: Woods DM (ed.). Biological Control Program Annual Summary, 2002. California Department of Food and Agriculture, Plant Health and Pest Prevention Services, Sacramento, CA. p 45–9.

Randall JM. 1996. Weed control for the preservation of biological diversity. Weed Technol 10:370–83.

Rejmanek M, Pitcairn MJ. 2002. When is eradication of exotic pest plants a realistic goal? In: Veitch CR, Clout MN (eds.). *Turning the Tide: the Eradication of Invasive Species*. IUCN SSC Invasive Species Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK. p 249—53.

Robbins WW, Bellue MK, Ball WS. 1941. *Weeds of California* (1st ed.). California State Department of Agriculture, Sacramento, CA. p 395.

Smith HA, Johnson WS, Shonkwiler JS, Swanson SR. 1999. The implications of variable or constant expansion rates in invasive weed infestations. Weed Sci 47:62–6.

Villegas B. 2001a. Releases of the flower weevil, *Larinus curtus,* for the biological control of yellow starthistle in California in 2000. In: Woods DM (ed.). Biological Control Program Annual Summary, 2000. California Department of Food and Agriculture, Plant Health and Pest Prevention Services, Sacramento, CA. p 47.

Villegas B. 2001b. Releases of the hairy weevil, *Eustenopus villosus,* in California during 2000. In: Woods DM (ed.). Biological Control Program Annual Summary, 2000. California Department of Food and Agriculture, Plant Health and Pest Prevention Services, Sacramento, CA. p 48–9.

Weber E. 1998. The dynamics of plant invasions: A case study of three exotic goldenrod species *(Solidago* L.) in Europe. J Biogeogr 25:147–54.

Woods DM, Villegas B. 2005. Field releases of the rust, *Puccinia jaceae* var. *solstitialis,* in California. In: Woods DM (ed.). Biological Control Program Annual Summary, 2004. California Department of Food and Agriculture, Plant Health and Pest Prevention Services, Sacramento, CA. p 25–6.

EXHIBIT 4

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Water loss by weeds: a review

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Abstract : Water losses caused by weeds were and remain important constraints, worldwide, in raising the plant productivity and crop production. Thus, the objectives of this paper are to review the water loss caused by weeds and to discuss the potential of some applications for cutting these losses. Depending on the available literature review it could concluded that weeds need more water than many crops and many weeds are known to be "water wasters". Therefore, proper weed control raises available soil water for crop production. Some common annual weeds growing with crops transpires about four times more water than a crop plant and use up to three times as much water to produce a pound of dry matter as do the crops. Under water stress condition weeds can cut crop yields more than 50% through moisture competition alone. The competition between weeds and crops are depending on weed density, the plant's physical characteristics rather than the aboveground biomass. So, perennial weeds can be less affected by drought than annual weeds. Evaporation from the soil accounts 25–50% of the total water used, therefore a layer of mulch can cut evaporation by as much as 75%. Any weed management measure that leads to cut the loss water is important for the sustainable agricultural development. Soil mulching raise soil water storage (up to 41%), raised grain water use efficiency by 14% and cut water loss from 0 to 30cm soil depth. Water saving under plastic mulching was more than 50% compared to herbicides or hoeing treatments and the benefits of mulching to crop performance are raised under water stress
Keywords: *Water Loss, Mulching, Evapotranspiration, Aquatic Weeds.*

Introduction

One of the biggest challenges in agriculture is the management of water, widely considered the greatest limiting resource for crops[1]. This limitation is especially important in the arid environments. In the field, the cultivated plants and weeds take share in influencing the water balance[2]. Agriculture is responsible for 70% of all water use globally and water use efficiency (WUE) in this sector is low, not exceeding 45%[3]. The annual freshwater withdrawals for agriculture in 2001 amounted to 83 percent[4]. In Egypt, agricultural sector consumes about 85% of Egypt's freshwater[5,6], the cultivated land area was 3,277 ha in August 2013 and many irrigation water applied to farm land is consumed by evapotranspiration (ET)[7].

Weeds compete for water, cut water availability, and contribute to crop water stress[8]. Knowledge of weed transpiration (T) is important in assessing the competition of weeds against cultivated plants[9].

Weeds directly compete with crops for water leading to less water available for crops, where weeds are potentially responsible for 34 percent of crop loss worldwide[10]. Weeds consume water intended for crops, cause water loss by seepage through root channels, transpire water, and cut water flow in irrigation ditches, leading to higher consumption by weeds and more evaporative water loss[8].

About 10% of all plant species are weeds, or a total of some 30,000 weed species. Of these, 1,800 cause serious economic losses in crop production, and about 300 species plague cultivated crops worldwide[11].

Weeds are a major competitor for available soil water in crops or during fallow periods[12]. Therefore, proper weed control raises available soil water for crop production.

Water extraction pattern of weeds are more close to the root zone volume of a species rather than the aboveground biomass[13]. Also, plants with a deeper rooting system are less affected by drought than plants with shallower rooting systems, because they can more readily explore soil profiles for water[14]. For this reason, perennial weeds can be less affected by drought than annual weeds.

Water conservation is defined as minimizing the loss or waste, care and protecting water resources and the efficient use of water. There are many ways to conserve water. A layer of mulch can cut down evaporation by as much as 75 percent[15].

Knowledge of weed transpiration is important in assessing the competition of weeds against cultivated plants[9].

Competition for water occurs below ground between roots. The ability to absorb water is is related to rooting volume. But, not only are the dimensions (breadth and depth) of rooting zones important: so is water extraction[16].

To produce a unit of dry matter, weeds transpire more water than do most of our crop plants. In weedy fields, the soil moisture may be exhausted by the time the crop reaches the fruiting stage, which is often the peak.

Water requirement for the growth of weeds is mainly of interest from the stand-point of competition with the crop plant for the available moisture[17]. Weeds, like other plants, consume large quantities of water, and most of it is lost by transpiration to the atmosphere. He came to conclusion that weeds are need more water than many crops[18,19]. Weed control is even more important during years of water shortage. When moisture is in short supply, weeds can cut crop yields more than 50% through moisture competition alone. Some common annual weeds growing with cultivated crops use up to three times as much water to produce a pound of dry matter as do the crops[19].

Weeds caused high evapotranspiration (ET) rates comparable with the ET rates of com during its early development stage[20].

Using some applications such as soil mulching with plant wastes which are excellent alternative to synthetic mulches, bed planting method, transplanting rather than direct seed sowing method, and so on, can be used as measures to cut the water losses in agriculture.

Therefore the present review has covered a great deal about the reduction of water losses caused by weeds and shows the potential of some agricultural practices for cutting the water losses. Further investigation and research are needed in this concern.

1. Weeds and Water

Many investigators have reported a great loss in the water caused by weed infestation from different parts of the world. Weeds are potentially responsible for 34 percent of crop losses worldwide[10]. Fourteen of the world's worst weeds are C_4 plants, while 76% of the harvested crop area is with C_3 crops[21]. In drought situations C_4 weeds might also have advantages over C_3 crops under elevated CO_2. Water requirement for the growth of weeds is mainly of interest from the stand-point of competition with the crop plant for the available moisture[17]. It was reported that wild mustard weed transpires about four times more water than a crop plant[18].

The amount of water used varies among plant species because of differences in root characteristics and distribution in the soil[22]. Many weeds are known to be water wasters[23]. These plants are less sensitive to the much available water and they transpire or use much water each day. Weeds are a major competitor for available soil water in crops or during fallow periods. Therefore, proper weed control raises available soil water for crop production.

Cutting unnecessary evaporation and unwanted transpiration, particularly by weeds and other non-cropped biomass in waterlogged parts of irrigated fields, along water supply ditches and canals and in and along irrigation drainage pathways could conserve water beyond the farm[24].

Some annual weeds can emerge and produce seeds in less than 6 weeks [25]. With regard to water retention, timely control is essential because weeds may daily use 5 mm of water from a soil[26].

During a normal growing season, evaporation from the soil surface may reach up to 50% of ET [27]. High proper evaporation to ET, roughly amounted by 50% in crops such as *Z. mays*[22]. The E/ET ratio was 40.7% in the growing period for the control, and it was only 17.8–25.0% for treatments mulched with sand and gravel. Soil evaporation with non-mulching was reduced by 78.0–93.7 mm when plastic film was mulched on the gravel surface and by 16.9–26.3 mm with gravel mulching only[28].

2. Competition between Weeds and Crops on Water

In the framework of phytocoenosis, the cultivated plants and weeds take share in influencing the water balance[2]. Some annual weeds can emerge and produce seeds in less than 6 weeks[25]. Several factors contribute to the water loss that occurs in water-limiting environments, including weed density, weed species, weed root structure, weed physiology, and duration of weed growth[12].

For example, the consumptive use of water for lambsquarters weed(*Chenopodium album*) was estimated by 550 mm against 479 mm for wheat crop. It is attributable to weed can remove moisture from deeper depth of soil than crops[16]. In another study, common lambsquarters requires 658 pounds of water to produce one pound of dry matter, common sunflower requires 623 pounds, and common ragweed 912 pounds, compared with 349 pounds for corn and 557 pounds for wheat[19].

The physiology of a weed also is important in WUE and thus total water loss from the soil system. C_3 plants (i.e., wheat, barley and mustards) are estimated to be half as water-use efficient as C4 plants (i.e., sorghum, corn, and shatercane) [29]. Plants of the C_4 category contain an extra carbon-fixing step in the leaves that allow it to close its stomata during times of few water supply[30]. By regulating stomata, plants conserve water internally and continue biomass production under water-limiting environments. Weed C_4 plants produce two to three times as much high dry matter production for unit of water used, compared to weed C_3 plants[8]. The same figures can be expressed in gallons of water required to produce one pound of dry matter. Lambsquarters requires nearly 79 gallons of water to produce one pound of dry matter, and ragweed 109 gallons as compared with only 42 gallons for corn and 67 for wheat[19].

Lambsquarters, if it were conserved through adequate weed control practices, could produce a new 1.9 tons for acre of corn and 1.2 tons for acre of wheat. One common mustard weed uses as much moisture as four wheat plants[19].

Researchers and growers experience clearly points out a good weed control program in all crops when adequate water is available. One can imagine the seriousness under meager irrigation water[19].

Table 1. Transpiration ratio (T: R1) of various Crops and weed species[31].

Crops	**T:R1**	**Crops**	**T:R1**	**Crops**	**T:R1**	**Crops**	**T:R1**
Sorghum	304	Cotton	568	Sugar beets	377	Wheat	528
Corn	349	Sunflower	630	Soybeans	646	Dry beans	700
Weeds	**T:R1**	**Weeds**	**T:R1**	**Weeds**	**T:R1**	**Weeds**	**T:R1**
Pigweed	287	Lambsquarters	801	Gumweed	608	Ragweed	948

T:R1: Pounds of water transpired per pound of above-ground dry matter produced. Water weighs 8.34 pounds $gallon^{-1}$.

Weeds caused high ET rates, as shown in Table (1), comparable with the ET rates of corn during its early development stage[20]. Also, there was a gain in water storage above field capacity when the ground surface was mulched or weeds covered, while important decrease in water storage occurred duringthe corn growing season[20].

3. Weeds and Water Losses under Dry Land Condition

Weed control was important under dry land condition. Under dry land conditions, weeds usually cause the most severe reduction in yield the first two or three weeks of crop growth. Good pre-plant or pre-emergence weed control and early post-emergence weed control seem to be essential for maintaining or increasing yields[19].

4. Plant Factors Affecting Water Use Efficiency

4.1. *Weed Density*

Weed density is important in depletion of soil moisture and has significant negative effects on the WUE of crops. Raising weed density decreases soil water and crop yields, the competitive ability of different weed species at similar densities may not have the same influence on water use[32].

The competition between Palmer amaranth (*Amaranthuspalmeri* S. Wats.) weed and irrigated corn were evaluated[33], and they found that total water use by *A.palmeri* continually rose as densities rose from 0 to 8 plants per meter of corn row[33]. Therefore, WUE of corn continued to decrease withraising*A.palmeri* density resulting in corn yield losses from 11 to 91% as densityraise from 0.5 to 8 plants per meter, respectively. Although raising weed density decreases soil water, the competitive ability of different weed species at similar densities may not have the same influence on water use. The similar found was recorded with *Solanumnigrum*L. when growing with tomatoes, it cut significantly the soil water, while*S.nigrum*at a density of 1.6 plants per square meter did not reduce soil water[34].

4.2. *Plants Physical Characteristics*

The ability of a specific weed species to affect crop yield under few soil water may depend on the plant's physical characteristics, such as rooting structure and depth[12]. Also, plants with a deeper rooting system are less affected by drought than plants with shallower rooting systems because they can more readily explore soil profiles for water[14]. For this reason, perennial weeds can be less affected by drought than annual weeds.

4.3. *Root Zone Volume*

Water extraction by weeds is more closely related of root zone volume of a species rather than the aboveground biomass[13].

5. Aquatic Weeds

Many problem weeds that occur on the canals have the potential to use excessive quantities of water through extensive root systems and high transpiration rates. Plants on canal banks that have extensive root systems and transpire continually will cut the water available for irrigation. Weeds present in the canals and ditches also can obstruct water flow[35]. The total length of Egyptian networks (canals and drains) exceeds 47000 km, 31000 km canals and 16000 km drains[36], and the total ratio of infested canals with all types of weeds was 86.9% and drains had a ratio of 73.6%[37]. Reducing flow rate caused by excessive growth of submerged weeds was determined by 80% in some small canals[37]. Also, in Egypt the total water loss by ET from water hyacinth infested areas was estimated to be 3.5 billion m^3per year. This amount is enough to irrigate about a further 432km^2 (43200 ha) every year[38].

Water hyacinth causes 4 billion m^3 losses of water every year in Egypt, enough to sustain Cairo with water[39]. The total infested area is estimated to be 487 km^2 covering most of the drainage and irrigation canals in different governorates of Egypt, and about 151 km^2 covering lakes. It was estimated, for example, that a pond infested with one hectare of water hyacinth will produce up to 1.8 tons of dry mass a day. That rate of reproduction alone makes the weed almost impossible to control[40]. Water hyacinths grow will in hot water and in hot climate[8].

5.1. *Aquatic Weeds in Cultivated Plants*

The rice crop suffers severely from competition when infested by aquatic weeds during the first stage of growth. The losses may range from 30 to 60%[41].

5.2. Evaporation or Transpiration is the Main Problem in Water Loss

The aquatic weeds pose a big problem in water loss because it have higher transpiration rate. Indeed, several recent studies have shown that such water losses are 2, 3 or even 6 times higher in reservoirs covered in weeds than they are in open waters[42]. The water loss (evapotranspiration) caused by water hyacinth weed was estimated by about to be 2.5 and 13 times evaporation from that of a free water surface and the flow of water in canals is reduced drastically was 40 to 90% .

6. Weed Control Management

Proper weed management can be used to cut the water losses in agriculture. Therefore, in this section we will discuss with a great deal the potential of some agricultural practices for cutting the water losses. Further investigation and research are needed in this concern.

6.1. Time of Weed Control Management

From the jointing to the milking stage of winter wheat, retaining definite amounts of weeds, no matter which tillage method was adopted, could significantly increase the 0-20 cm soil water content, suggesting the soil water conservation effect of retaining weeds[44].

6.2. Mulching

Mulching soil with plant wastes or synthetic mulches is one of the management practices for cuttingsoil evaporation, raises water retention, rising water use efficiency (WUE) and weed control in crop fields. Mulching soil with plant wastes or synthetic mulches cut soil evaporation loss and raised WUE of crops[45]. Mulching is one of the management practices for rising WUE and weed control in crop fields[46].

6.2.1. Soil mulching Effects on Water Conservation

Evaporation from the soil makes up 25–50% of the total quantity of water used[47]. So, soil mulching prevents soil water evaporation, and thus helps retain soil moisture, raising water use efficiency and weed control in crop fields[46,48]. Mulch raised grain yield by 17%, aboveground biomass by 19% and grain water use efficiency by 14% compared with bare soil treatments[49]. The amount of moisture stored in the profile to a soil depth of 90 cm was significantly greater under polythene and straw mulch over bare and chemically mulched soil [48]. Ramakrishna et al.[48] added that at 30 days after sowing, the polythene mulch plots contained more water (67 mm in autumn–winter and 47 mm in spring) than the un-mulched plots, while straw mulched plots recorded more profile water 43 mm in autumn–winter and 37 mm in spring. Use of vertical mulching substantially raised soil water storage (up to 41%) under some conditions [50].

Mulching treatments significantly cut water loss from 0 to 0.30 m soil depth [46]. Also soil salinity (0–0.30 m) gradually increased through accumulation of salts in the surface layer after sowing regardless of mulching, but not-mulched soil seemed to accumulate more salts than mulched soil. Mulching is more beneficial to crop performance when there is water stress[51]. The less moisture depletion under the mulches was a result of prevention of contact between the soil and dry air, which reduced water loss into the atmosphere through evaporation[51].

6.2.2. Effects of Mulch Type on Water Save

Several types of mulches such as rice straw or husk, grasses, sedges, banana leaves, pseudo stems, shrubs such as Lantana, weeds, soybean, black gram, rice husks, sawdust, wheat straw, plastic film, wood, sand and oil layer have shown to be beneficial in cutting the water losses by weeds.

6.2.3. Organic Mulches

Mulching soil with plant wastes or synthetic mulches is one of the management practices for cuttingsoil evaporation; rising water retention, WUE and weed control in crop fields [45,48,50,52,53,54]. This also ensures a more even moisture distribution throughout the soil profile, which further improves water use.Organic mulches also improve WUE indirectly. As the mulch decomposes, humus is added to the soil, which raised its water holding capacity[54]. A mulch layer prevents weed seedling growth by inhibiting light penetration to the soil surface. Lower weed prevalence significantly improves WUE[55].

Rice straw mulch raise WUE; where Zhang[45] observed that mulching with straw cut soil evaporation loss and raised WUE of winter wheat in northern China. They also showed remarkable higher grain yield of wheat when grown along with irrigation. Favorable soil environment, lower weed infestation and higher groundnut yield were got by using straw mulch compared to no mulched treatment in Vietnam [48].

In Egypt, soil mulching with rice straw was useful and not expensive especially if the material was available in the farm to cut transportation cost[52]. Although cost of weed control with plastic mulching is apparently high, about L.E 600 feddan^{-1}, against L.E 500 for herbicides and L.E 300 for hoeing, it can be used for two seasons if handled. Water saving is most important in the desert areas especially in the vineyards using drip irrigation from deep wells, and water becomes the most expensive factor of production in such areas. It could be recommended to use plastic mulching in the infected vineyards for its economy, control of weeds, to protect the environment from pollution and most important to save water and raised the net income of the grower[52].

6.2.4. Mulching with Sand and Gravel

Mulching with sand or gravel reduce the E/ET ratio, where the E/ET ratio was 40.7% in the growing period for the control, and it was only 17.8–25.0% for treatments mulched with sand and gravel[28]. At the size of gravel; a12 mm gravel mulch had greater effect on water savings, by preventing evaporation, than a 6 mm layer, but water conservation rose no further with a 25 mm layer [56]. Soil evaporation with non-mulching was reduced by 78.0–93.7 mm when plastic film was mulched on the gravel surface and by 16.9–26.3 mm with gravel mulching only[28].

6.2.5. Synthetic Mulch

Plastic films, which are probably the most commonly used mulching materials other than crop residues, are highly effective for controlling evaporation[50]. With a 100% plastic cover on soil to prevent evaporation and rainwater infiltration, grain sorghum yielded 6.3 Mg ha^{-1} with 178 mm water use from soil. Ungeret al.[50] concluded that plastic film mulches control evaporation and improve crop production.

Water saving under plastic mulching was more than 50% compared to herbicides or hoeing treatments[52].

Conserve soil moisture through mulching is one of the important purposes. When soil surface is covered with mulch helps to prevent weed growth, cut evaporation and raise infiltration of rain water during growing season. Plastic mulch helps prevent soil water loss during dry years and sheds excessive water away from the crop root zone during periods of excessive rain fall. This can reduce irrigation frequency and amount of water[58].

In 0- 10 cm soil depth, the transparent polythene mulch apparently showed highest moisture (21.1%), followed by black (20.4%) and blue (19.2%) polythene mulch[59]. The lowest moisture (14.6%) was recorded in the control plot. Increased moisture retention capacity caused by mulching with polythene could be attributed to less evaporation from the soil. Because of vapours, the water was further trapped in the mulches, resulting in fog which again dropped into the upper soil layer.

6.2.6. Effects of Mulch Thickness on Water Save

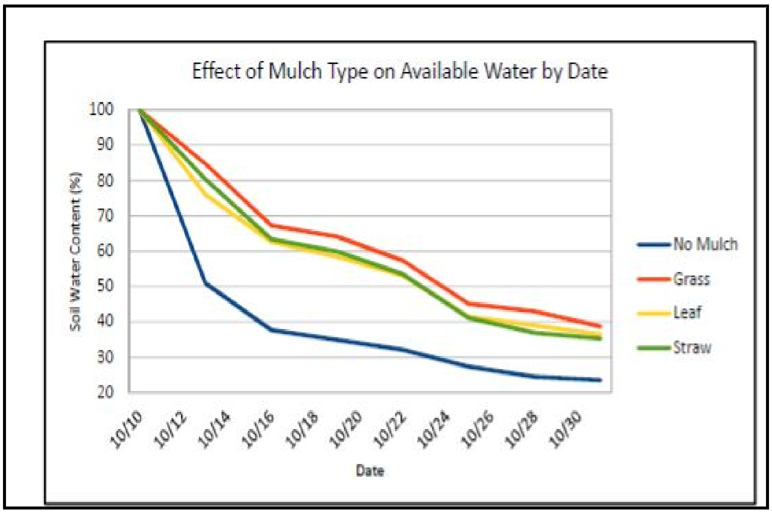

Figure 1.The effect of the three different mulch types on the soil water content[57].

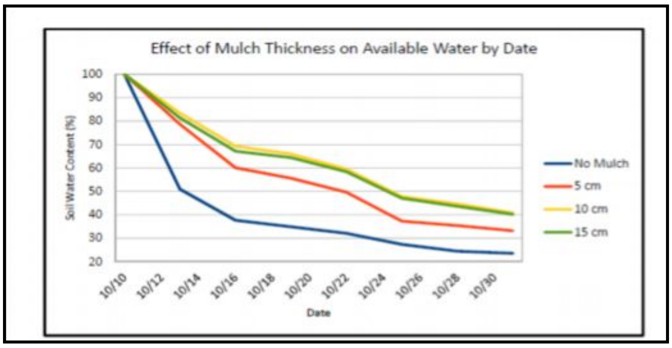

Figure 2.The effect of the three different mulch thicknesses on the soil water content[57].

Mulch thickness affected the water loss rate as shown in Figs. (1 and 2)[57], where doubling the mulching (Wheat straw, grass clippings, and leaf debris) rate from 5cm to 10 cm maintained soil moisture 10% higher. But, rising the mulch depth to 15 cm didn't significantly cut evaporation further[57]. They added that even a fairly thin layer of plant debris can conserve a considerable amount of water, especially right after an irrigation. In the first 3 days, bare soil lost half the moisture content, but soil covered with mulch layer of 5 cm lost only 20%.

That extra 30% would considerably improve the irrigation efficiency in a cropping situation, especially with shallow rooting plants such as vegetables and berries. Furthermore, the moisture is the soil is at a much lower tension, so it is much more easily absorbed by the crop.

The reduction in evaporation and maintains the humidity right at the soil surfacecaused by mulch may because of that mulch cut the amount of sunlight hitting the soil and prevents airflow which keeps the moisture in the soil [57].

The maximum mean percent soil moisture contents were observed at mulch treatment applied at 8 t ha^{-1}[60]as shownin Table (2). They added that rising the mulch rates from zero to 2, 4, 6 and 8 t/ha resulted in corresponding raises in dry stover yield by 19.0, 34.3, 63.4 and 83.5% respectively.

Table 2.Effect of mulch on average oil moisture content (%) in the top 0-15cm in experimental plots during 2007-2009 dry seasons [60].

Mulch treatments (t ha^{-1})	Soil moisture content (%)				Weed infestation (t ha^{-1})	Grain yield (t ha^{-1})
	3 WAS*	5 WAS	7 WAS	9 WAS		
0	12.5	7.6	10.1	11.9	2.09	2.16
2	14.8	9.5	13.0	12.9	1.01	3.48
4	16.4	10.9	14.1	14.0	0.89	4.05
6	19.3	13.1	17.8	15.2	0.31	5.52
8	21.9	14.8	19.6	16.8	0.18	5.69
LSD (0.05)	2.1	1.67	2.17	1.48	0.74	1.248

WAS: weeks after sowing.

6.3. Tillage

Tillage is common practice to control weeds, but tillage results in raises need for irrigation because of considerable water loss from the soil caused by evaporation from each tillage operation[61]. Thus, soil water content at plantings 50 percent higher in the herbicide plots compared to the tillage plots[62]. When tillage is used, exposing moist soil to the atmosphere may cause losses of 5 to 8 mm for each operation[63].

6.3.1. Tillage Effects on Water Conservation

Tillage practices that maintain crop residue on the soil surface were shown to raise maize yields in many studies and the yield raises were credited to raise water contents in the soil caused by cut evaporation [49].

Residue cuts evaporation of soil water mainly by shading the soil surface from the sun. Soils with stubble cover here cut wind velocities at the surface and temperatures, cutting evaporation from the soil surface.

Experiments at Akron, Colorado suggest that water losses were 1.5 times greater on bare soil compared to soils with 3,000 pounds of wheat straw[31]as shown in Table (3).

Table 3.Water losses from different operations 1 and 4 days after tillage[31].

Operation	1 day	4 days
	--- inches of water ---	
One way	0.33	0.51
Chisel	0.29	0.48
Sweep plow	0.09	0.14
Rod weeder	0.04	0.22

Tillage results in rising need for irrigation because of considerable water loss from the soil caused by evaporation from each tillage operation. Of the seven technologies, conservation tillage was the least costly through raising the cost per acre-foot of water saved. It is 80 times less costly than changing to irrigation equipment[62].

Raising conservation tillage practices yielded water savings of 2.0% of total irrigation water pumped[64]. Comparing moldboard, disk, rotary, sweep, and no-tillage treatments, soil water content rose during a fallow period following wheat averaged 3.50, 4.29, 3.35, 4.49 and 5.55 inches for the respective tillage treatments and averaged 3.82 and 4.65 inches for low and high residue treatments[65]. A water savings of 1.75 inches an acre per year was estimated from shifting an acre from conventional to conservation tillage with herbicide applications substituting for tillage operations. Raising conservation tillage from 50 percent of all irrigated acres in 2000 to 72 percent by 2060 was estimated to lead to a cumulative water savings over the 60 year period of 2.1 million acre-feet (682 billion gallons)[64].

6.3.2. No-Tillage

No-tillage considered one of agronomic practices used by farming for weed control and raising waterconservation. The ultimate conservation tillage system is *no-tillage*, which is a procedure so that a crop is planted directly into the soil with no primary or secondary tillage since harvest of the previous crop; usually a special planter is needed to prepare a narrow, shallow seedbed immediately surrounding the seed being planted[66]. The available soil water content in the soil 15- and 46-cm depths was greater each year in dryland grain sorghum [*Sorghum bicolor* (L.) Moench] with no-tillage compared to conventional tillage[67].

Shallow tillage had three advantages contained; control weeds and retain plant residues on the surface to protect the soil from erosion. A third goal was to retain surface residues to cut runoff, cut evaporative soil water losses, and conserve more water for the following crop[50].

6.4. Cultivar Selectivity

Use of aggressive cultivars one of the cultural practice for weed growth suppression [8,68]. Also some cultivars had a positive effect on water saving, however there is no available literature on the relationship between competitor cultivars with weeds and its potentiality to produce high yield with less water irrigation.

Depending on cultivar, SRI cultivar used 15–19% less water than CMP cultivar, a result of the system's intermittent irrigation regime[69]. Short-duration cultivars require less irrigation, and the lowest water use under SRI was with NERICA 1 (783 mm), followed closely by S108 (785 mm) [69]. In CMP, these cultivars also had the lowest water use, though they received 170 and 195 mm more water, respectively, than in SRI.

6.5. Raised Bed Planting and Ridges Technique

Raised bed plantingand ridges systems have been used for weed control, increased WUE and plant productivity[70,71,72](Table 4). Raised bed planting helped in saving of 27% irrigation water and raising crop yield by 16.6% compared to flat planting under precision land leveling[67].

Table4.Effect of laser land leveling and planting techniques on water productivity of wheat[70].

Treatments	Average of total number of irrigations applied year^{-1}	Irrigation waterUse ($m^3 \cdot ha^{-1}$)	Irrigation water productivity ($kg \cdot grain \cdot m^{-3}$ water)
Precision leveling with raised bed planting*	4.5	2.403	2.15
Traditional leveling with raised beds *	4.5	3.103	1.57
Precision leveling with flat beds*	4.5	3.293	1.44
Traditional leveling with flat beds*	4.5	4.790	0.93
Traditional leveling with flat beds with o fertilizer as control	4.5	4.790	0.56
SE ±	—	13.88	0.04

* With recommended balanced nutrients (N120 + P26 + K50).

The minimum water use was observed in raised broad bed sowing[71]. In maize crop, after 4 years of experimental in farmers' fields, there were raises of 30%, 32% and 65% in grain yield, water saving and water productivity, respectively, under permanent raised beds compared to basins[71]. Similarly, permanent raised beds showed 13%, 36% and 50% higher grain yield, water saving and water productivity, respectively, for the wheat crop.

Weed infestation was also 24% and 31% lower for maize and wheat crops, respectively, under permanent raised beds, which maintained lower soil bulk density and high infiltration rates. Partial budgeting showed that raised beds generated 54% and 35% rose net benefit for maize and wheat, respectively. District farmers' experience with raised beds showed similar results, with 34% water saving, and 32% and 19% higher yields for maize and wheat, respectively. Raised bed and ridge sowing methods of wheat plantation saved 22.47 and 13.26% irrigation water, and significant higher wheat yield by 24.5 and 20.9%, respectively over flat sowing either by drilling or broadcasting[73]. The cost of cultivation was lower and net benefit cost ratio was higher in bed planting than conventional method of wheat plantation.

6.6. Role of Cover Crops in Weed Management and Water Quality

Some cover crops can improve weed control by raising mulch and allelopathically suppressing weed growth and may improve environmental quality, especially through protecting the surface water and groundwater, by cutting or in some cases ending the need for pre-emergence herbicides[74].

Cover crops are not classified as weeds, but they use water. Thus, their management about water retention is important, especially in drier regions where a delay in ending their growth may result in meager soil water retention for a following crop[75]. As a result, cover crops are not recommended for use under dry land conditions.

6.7. Effects of Chemical Weed Control on Water Conservation

Soil acting herbicides prevent some weed seeds from germinating and, therefore, cutout water use by such weeds, thus good water management contributed to lesser weed growth resulting in lesser weed density and biomass irrespective of treatment[76].

The soil water content at plantings 50 percent higher in the herbicide plots relative to the tillage plots[61,62]. Using herbicides to remove weeds without any tillageimproved soil water storage to 40 percent[61,62,77]. In minimum-tillage systems, herbicides are an important tool to control weeds and increase yields. Drier environments that rely on cut tillage systems to conserve water are often challenging environments in which to reach effective weed control[77].

With regard to water retention, timely control is essential because weeds may daily use 5 mm of water from a soil[26].

For the ET and water salvage (water available for other ecological operates), it was found that seasonal stand-level saltcedar water loss at an untreated control site ranged from 0.42 to 1.18 m/yr[78]. Seasonal water savings following application of imazapyr ranged from 31% 4 yr after treatment to 82% 2 yr after treatment.

Significant water savings may be reached by chemical saltcedar control, dependent on water use by replacement vegetation and saltcedar re-growth[78].

6.7.1. Disadvantages of Herbicides

Detectable residues of atrazine and alachlor in a small percentage were found in water wells[79]. Use of herbicides was effective in cutting the percentage of weeds but not recommended because environmental pollution and water loss from the barren soils is high. Repeated hoeing rose weed cover percentage, damage the fibrous roots and rose water loss[52]. With chemical weed control the need for tillage was cut and this resulted in accumulation of surface crop residues and leading to cut in soil erosion, raised conservation of water, and crop yields[80,81]. Weed populations are often cut in no-till systems because of less soil disturbance and more suppression of germination by accumulation of crop residues[80].

6.8. Pre-Planting Weed Management and Planting Date

Early planting of barley for forage can be an excellent addition to cropping systems as part of a multitactic approach for improved weed and water management[82]. Lenssen[82] added that early planting of zero tillage (ZT) barley resulted in excellent forage yields (7.3 kg ha^{-1}), small accumulation of weed biomass, averaging 76 kg ha^{-1}, and no weed seed production regardless of pre-plant weed management system. Early planting resulted in higher WU than delayed planting, averaging 289 and 221 mm, respectively.

7. Climatic Changes and water Loss by Weeds

Over the coming decades, global change will affect weeds. As mentioned before that 14 of the world's worst weeds are C_4 plants, while 76% of the harvested crop area is C_3 plants[21]. In drought situations C_4 weeds might also have advantages over C_3 crops under elevated CO_2. Elevated CO_2increase plant growth (above-and belowground) and improve plant water relations (reduces transpiration and increases WUE) [82]. Prior et al.[83] added that weeds often show greater growth responses to elevated CO_2 than do crop plants, which may be the result of weeds having greater genetic diversity and physiological plasticity than managed plants[84]. How rising CO_2 will impact weed management in horticultural systems is unknown. More knowledge in this area is required to develop best management strategies to deal with these potentially serious threats to productivity and profitability not only in horticulture, but for agriculture and forestry as well[82].

Conclusion

From the previous review it could be concluded that:

- The weeds are the major competitors for soil water with crops.
- The water amount used by an infestation of weed, if it were conserved through adequate weed control practices, could produce a more yield of each acre.
- Weed control is essential for water conservation purposes because weeds present before crop planting use soil water that could be later used by the crop.
- It is important to prevent or reduce unnecessary evaporation and unwanted transpiration by weeds in fields, irrigated fields, watercourse, canals and in and along irrigation drainage pathways.
- Improving water efficient use with using mulches that reduces evaporation and so conserves moisture for the crop. The organic mulches improve organic matter content and soil moistures status.
- Improving water efficient use through using bed planting techniques.
- Enhancing water flow in fields through sowing most crops (such as wheat) in holes on ridges.
- Adoption of nonchemical weed control application methods has been and will be an important part for improving water quality and the environment.
- Develop techniques for controlling the weeds before crop sowing or at early stage without using synthetic herbicides.

It might reasonably be argued that integration of approaches rather than single one could solve the water loss caused by weed infestation problem in substantially leading to satisfactory yield.

References

1. Lenssen,A.W., Johnson,G.D. and Carlson,G.R., "Cropping sequence and tillage system influences annual

crop production and water use in semiarid Montana", USA, Field Crops Res., 2007, 100, 32-43.
2. Pivec,J. and Brant,V., "The Actual consumption of water by selected cultivated and weed species of plants and the actual values of evapotranspiration of the stands as determined under field conditions", Soil & Water Res., 2009,4,S39–S48
3. Zhang,X., Friedl,M.A., Schaaf,C.B. and Strahler,A.H., "Climate Controls on Vegetation Phenological Patterns in Northern Mid and High Latitudes Inferred from MODIS Data", Glob. Change, 2004, 10, 1133-1145.
4. UN CCA, "United Nation's Common Country Assessment-Egypt", Cairo, Egypt.
5. Gohar,A.A. and Ward,F.A., "Gains from improved irrigation water use efficiency in Egypt, Intern J Water Res Development", 2011, 1, 1-22.
6. Hassanien,M.K. Abdrabbo,M.A., Hashem,F.A. Khalil, A.A., and Refay, K.M.,"Deficit irrigation management for the main crops in Egypt under current and future conditions" (in Arabic), Climate Change Risk Management Program (CCRMP) in Egypt. Ministry of Agriculture and Land Reclamation, Central Laboratory for Agricultural Climate (CLAC), 2013, pp: 178.
7. El-Shirbeny,M., Ali,A., and Saleh,N., "Crop water requirements in Egypt using remote sensing techniques", J AgricChem and Environ, 2014,3, 57-65.
8. Zimdahl,R.L., "Fundamentals of Weed Science", 4th ed. Academic Press, San Diego, San Diego, California, USA, 2013. P. 31.
9. Pivec,J., Brant,V. and Hamouzová,K., "Evapotranspiration and Transpiration Measurements in Crops and Weed Species by the Bowen Ratio and Sapflow Methods Under the Rainless Region Conditions, Evapotranspiration - From Measurements to Agricultural and Environmental Applications", Dr. Giacomo Gerosa (Ed.), ISBN: 978-953-307-512-9,2011.In Tech, Availablefrom:http://www.intechopen.com/books/ evapotranspiration-from-measurements-to-agricultural-and-nvironmentalapplications/evapotranspiration-and-ranspiration -measurments-in-crops-and-weed-species-by-the-bowenratio-and-s
10. Oerke,E.C., "Crop losses to pests", J AgricSci, 2006,144, 31-43.
11. Ware G.W., and Whitacre D.M., "An Introduction to Herbicides, (2nd edition) Extracted from The Pesticide Book, 6th edition), 2004, http://ipmworld.umn.edu/chapters/whitacreherb.htm
12. Shoup,D. and Holman,J., "Controlling Weeds to Conserve Water". In: Efficient Crop Water Use In Kansas (Presley, De., D. Shoup, J. Holman and A. Schlegel (ed.): Water Conservation- Increased Efficiency in Usage (2010-34296-20702), of the U. S. Department of Agriculture-National Institute of Food and Agriculture. Efficient Crop Water Use in Kansas, Kansas State University, August 2012. Kansas State University Agricultural Experiment Station and Cooperative Extension Service.
13. Davis,R.G., Wiese,A.F. and Pafford,J.L., "Root moisture extraction profiles of various weeds", Weeds, 1965, 13, 98-100.
14. Maganti,M., Weaver,S. and Downs,M., "Response of spreading Orach (*Atriplexpatula*) and common lambsquarters (*Chenopodium album*) to soil compaction, drought, and waterlogging", Weed Sci., 2005, 53,90-96.
15. Bell,N., "Prevent weeds, improve soil and save water by mulching your garden", July 2, 2007. Oregon State University Extension Service. http://extension.oregonstate.edu/gardening/node/960
16. Hasanuzzaman,M., "Crop-Weed Competition", 2008, 6pp. http://hasanuzzaman.weebly.com/ uploads/ 9/3/4/0/934025/crop-weed_competetion.pdf
17. Gibson,L.R., "Plant Competition", Agronomy Department, Iowa State University, 2000.
18. Thakur,C., "Weed Science" (Ed.): B.V. Gupta. Book Co. Pvt. Ltd. 1, Netajisubhash Marg, New Delhi, 110002, India, 1984. p. 37-47.
19. Parker, R. "Water Conservation, Weed Control Go Hand in Hand",2003, http://cru.cahe.wsu.edu /CEPublications/em4856/em4856.pdf
20. Villagra,M.M., Gabriels,D., Verplancke,H. and Hartmann,R., "Estimating crop coefficients for corn during an evapotranspiration experiment on an OXISOL IN Brazil soil. Sci. Agric. Piracicaba, 1994, 51, 2, 270-278.
21. Holm,L.G., PlucknettD.L., PanchoJ.V., and HerbergerJ.P., The World's Worst Weeds- Distribution and Biology, University of Hawaii Press, Honolulu,1977.
22. Radosevich,S., Holt J., and GhersaC., "Weed Ecology", 2nd edition. John Wiley and Sons, New York. 1997. P.589.
23. Patterson,D.T., "Effects of environmental stress on weed/crop interactions", Weed Sci., 1995, 43,483-490.
24. Schaible,G.D., and AilleryM.P., "Water Conservation in Irrigated Agriculture: Trends and Challenges in the Face of Emerging Demands", United States Department of Agriculture, Economic Research Service, Economic Information Bulletin Number 99, September 2012. P. 67.

25. Aldrich,R.J., and Kremer R.J., "Principles in Weed Management", 2nd edition. Iowa State University Press, Ames. 1997. P.455.
26. Wicks,G.A., and SmikaD.E., "Chemical fallow in a wheat-fallow rotation", J Weed SciSoc Am, 1973, 21, 97–102.
27. Peters,D.B., "Relative magnitude of evaporation and transpiration", Agron J, 1960, 52, (9)536-538.
28. Xie,Z., Wang Y., Jiang W., and Wei X., "Evaporation and evapotranspiration in a watermelon field mulched with gravel of different sizes in northwest China, Agric Water Management, 2006, 81(1-2), 173-184.
29. Lovelli,S., PerniolaM., Ferrara A., Amato M., and TommasoT. Di, "Photosynthetic response to water stress of pigweed (*Amaranthusretroflexus*) in a southern-Mediterranean area, Weed Sci, 2010, 58:126-131.
30. Long, S.P., "C_4 photosynthesis – environmental responses, 1998, pp: 215-249 in R. F. Sage and R. K Monson, Eds. The Biology of C4 Photosynthesis. San Diego, CA.: Academic
31. Croissant,R.L., Peterson G.A., and Westfall D.G., "Dryland Cropping Systems,2014, http://www.ext. colostate.edu /pubs/crops/00516.html#top
32. Dalley,C.D., BernardsM.L., and J.J. Kells, "Effect of weed removal timing and row spacing on soil moisture in corn (*Zea mays*), Weed Tech, 2006, 20:399-409.
33. Massinga,R.A., Currie R.S., and TrooienT.P., "Water use and light interception under Palmer amaranth (*Amaranthuspalmeri*) and corn competition, Weed Sci, 2003, 51:523-531.
34. McGiffen,M.E., MasiunasJ.B., and Huck M.G., "Tomato and night shade (*Solanumnigrum* L. and *S. ptycanthum* Dun.) effects on soil water content, J Am SocHorticSci, 1992, 117, 730-735.
35. Schroeder,J., Sanderson and R., "Identification and detection of problem and noxious weeds on irrigation canals will lead to effective weed management programs and increase water for irrigation, USDA Special Grants, Rio Grande Basin Initiative. Water Task Force, Report 157, 2004. http://riogrande-conference.tamu.edu/wrapup/2005/presentations/session_5B/Task6_Ulery.pdf
36. Mashaly,I.A., El-HalawanyE.F., and Omar G., Vegetation analysis along irrigation and drain canals in Damietta province, Egypt J BioloSci, 2001, 1(12), 1183-1189.
37. El-Shinnawy,I.A., Abdel-MeguidM., NourEldinM.M., and BakryM.F., "Impact of aswan high dam on the aquatic weed ecosystem/ICEHM2000, Cairo University, Egypt, September, 2000, page 534- 541.
38. Fayad,Y.H., Ibrahim A.A., El-ZoghbyA.A., and ShalabyF.F., "Ongoing activities in the biological control of water hyacinth in Egypt. In: Julien, M.H., Hill, M.P., Center, T.D. and Ding Jianqing, ed. 2001. Biological and Integrated Control of Water Hyacinth, *Eichhorniacrassipes*. Proceedings of the Second Meeting of the Global Working Group for the Biological and Integrated Control of Water Hyacinth, Beijing, China, 9–12 October 2000. ACIAR Proc. No. 102, 152p
39. El-Shahawy,T.A.I., "Aquatic weeds and their management. A State of the Art. Botany Department, Agric. and Biological Research Division, National Research Centre, Egypt (Personal communication), 2013.
40. Goldsmith,E., and HildyardN., "Water losses: exceeding gains? Published as Chapter 5 of The Social and Environmental Effects of Large Dams: Vol. 1. Overview. Wadebridge Ecological Centre, Worthyvale Manor Camelford, Cornwall PL32 9TT, UK, 1984. By Edward Goldsmith and Nicholas Hildyard.
41. Jayan,P.R., and SathyanathanN., "Aquatic weed classification, environmental effects and the management technologies for its effective control in Kerala, India Int J Agric&BiolEng, 2012, 5(1), 76－91.
42. PenfoundW.T., and T.T. Earle, "The Biology of Water Hyacinth", *Ecological Monographs*, 1948, 18, 447-472.
43. Yirefu,F., TafesseA., GebeyehuT., and TessemaT., "Distribution, Impact and Management of Water Hyacinth at Wonji-Shewa Sugar Factory", Eth J Weed Mgt, 2007, 1(1), 41 – 52.
44. Han,H.F., NingT.Y., Li Z.J., Tian S.Z., Wang Y., ZhongW.L., and Tian X.X., "Effects of conservation tillage and weed control on soil water and organic carbon contents in winter wheat field", Ying Yong Sheng Tai XueBao, 2011, 22(5), 1183-1188.
45. Zhang,X., Chen S., Liu M., Pei D., and Sun H., "Improved water use efficiency associated with cultivars and agronomic management in the north China plain", Agron J, 2005, 97,783–790.
46. Dong,H., Li W., Tang W., and Zhang D., "Early plastic mulching increases stand establishment and lint yield of cotton in saline fields", Field Crops Res, 2009, 111,269–275.
47. Liu,C.M., Zhang X.Y., and Zhang Y.Q., "Determination of daily evaporation and evapotranspiration of winter wheat and maize by Large-Scale Weighing Lysimeter and Microlysimeter", Agric and Forest Meteorology, 2002, 111, 109–120.
48. Ramakrishna,A., Tam H.M., WaniS.P., and Long T.D., Effect of mulch on soil temperature, moisture,

weed infestation and yield of groundnut in northern Vietnam, Field Crops Res, 2006, 95, 115–125.
49. Tolk,J.A., Howell T.A., and EvettS.R., "Effect of mulch, irrigation, and soil type on water use and yield of maize", Soil & Tillage Res, 1999, 50: 137-147.
50. Unger, P.W., Kirkham M.B., and Nielsen D.C., "Water Conservation for Agriculture, Soil and Water Conservation Advances in the United States. SSSA Special Publication 60. T.M. Zobeck and W.F. Schillinger, editors. 2010. SSSA, 677 S. Segoe Rd., Madison, WI 53711, USA, 2010.pp:46.
51. Awodoyin,R.O., OgbeideF.I., and OluwoleO., "Effects of three mulch types on the growth and yield of tomato (*Lycopersiconesculentum* Mill.) and weed suppression in Ibadan, Rainforest-savanna Transition Zone of Nigeria", Tropical Agric Res &Exten., 2007,10, 53-60.
52. Hegazi, A., "Plastic mulching for weed control and water economy in vineyards", Acta Hort. ISHS) 536 (XIVth Intern Symp on Horticultural Economics, 2000, pp. 245-250.
53. Kar, G. and Singh, R., "Soil water retention—transmission studies and enhancing water use efficiency of winter crops through soil surface modification", Indian J Soil Conservation, 2004, 8, 18–23.
54. Unger,P., 1974. "Crop residue management", Proceedings, 15, 45-56.
55. Ossom,E.M., Pace P.F., RhykerdR.L., and RhykerdC.L., "Effect of mulch on weed infestation, soil temperature, nutrient concentration, and tuber yield in *Ipomoea batatus* (L.) Lam. in Papua New Guinea", Tropical Agric, Trinidad, 2001, 78, 144–151.
56. Corey,A.T., and Kemper W.D., "Conservation of soil water by gravel mulches, Hydrol", Pap. No. 30. Colorado State University, Fort Collins, CO, 1968. p. 23.
57. McMillen,M., "The effect of mulch type and thickness on the soil surface evaporation rate, Horticulture and Crop Science Department California Polytechnic State University San Luis Obispo, June 2013.
58. Kumar,S.D., and LalB.R., "Effect of Mulching On Crop Production under Rainfed Condition: A Review, Intern J Res in Chem and Environ, 2012, 2(2), 8-20.
59. Ashrafuzzaman,M., AbdulhamidM., Ismail M.R., and SahidullahS.M., "Effect of plastic mulch on growth and yield of chilli (*Capsicum annuum* L.), Brazilian ArshivesBiol and Technol, 2011, 54 (2), 321-330.
60. Uwah,D.F., and Iwo G.A., "Effectiveness of organic mulch on the productivity of maize (*Zea mays* L.) and weed growth, Plant Sci, 2011, 21(3), 525-530.
61. Gianessi,L., and Williams A., "Herbicide Use Benefits Water Conservation Efforts U.S. Pesticide Benefits Case Study No. 2, May2011.
62. Unger,P.W., Allen R.R., and Wiese A.F., "Tillage and herbicides for surface residue maintenance, weed control, and water conservation, J Soil and Water Conserv, 1971, 26,147-150.
63. Good,L.G., and SmikaD.E., "Chemical fallow for soil and water conservation in the Great Plains, J Soil Water Conserv, 1978, 33, 89–90.
64. Amosson,S.H., Almas L. K., BretzF., Gaskins D., Guerrero B., Jones D., Marek T., New L. and Simpson N., 2006. "Water Management Strategies for Reducing Irrigation Demands in Region A. Available at: http://www.panhandlewater.org/2006_reg_plan/Plan/Appendix%20Q%20WMS%20for%20reducing%20Irrigation%20Demands.pdf
65. Unger,P.W., "Tillage and residue effects on soil water and crop factors in a winter wheat-sorghum-sunflower rotation, Soil SciSoc Am J, 1984, 48,885-891.
66. SSSA (Soil Science Society of America), "Glossary of soil science terms, SSSA, Madison, WI, 2001
67. Shear,G.M., Introduction and history of limited tillage, In: A.F. Wiese (ed.). Weed control in limited - tillage systems, Weed Sci. Soc. Am., Champaign, IL. 1985, pp. 1–14.
68. Abouziena,H.F., Ahmed M.A., EldabaaM.A.T. and Abd El WahedM.S.A., "A Comparative study on the productivity of two yellow maize cultivars grown under various weed control management", Middle East Journal of Agriculture Research, 2(2): 56-67, 2013
69. Krupnik,T.J., RodenburgJ., MbayeS., and Haden V.R., "Trade-offs between rice yield, weed competition and water use in the Senegal River Valley, Second Africa Rice Congress, Bamako, Mali, 22–26 March 2010: Innovation and Partnerships to Realize Africa's Rice Potential, 2010.
70. Jat,M.L., Gupta R., SaharawatY.S., and KhoslaR., "Layering precision land leveling and furrow irrigated raised bed planting: Productivity and input use efficiency of irrigated bread wheat in Indo-Gangetic Plains, Am J Plant Sci, 2011, 2, 578-588.
71. Ram, H., Singh G., Aggarwal N. and Kaur J., Soybean (*Glycine max*) growth, productivity and water use under different sowing methods and seeding rates in Punjab, Indian J Agron, 2011, 56 (4), 377-380.
72. Abouziena,H.F., El-DesokiE.R., Sharma S., Omar A.A., and Singh M., "Evaluation of wheat sowing in hills on ridges as a new technique for enhancement of wheat (*Triticumaestivum*, L) productivity under weed control treatments", Egypt J Agron, 2007, 27, 85-100.
73. Ali,M., Ali L., WaqarM.Q. and Ali M.A., "Bed planting: A new crop establishment method for wheat (*Triticumaestivum* L.) in cotton -wheat cropping system of southern Punjab, Int J AgricApplSci, 2012,

4(1), 8-14.

74. Worsham,A.D., “Weed and Disease Management. In: W.L. Hargrove, Ed., Role of cover crops in weed management and water quality Cover crops for clean water”. The proceedings of an international conference West Tennessee Experiment Station, April 9-11, 1991, Jackson, Tennessee, 1991,
75. Locke,M.A., Tyler D.D., and Gaston L.A., “Soil and water conservation in the mid-south United States: Lessons learned and a look to the future.” In: T.M. Zobeck and W.F. Schillinger (ed.) Soil and Water Conservation Advances in the United States. ASA, Madison, WI, 2010, pp. 201-236.
76. Kabir,M.H., Bari M.N., HaqueM.M., Ahmed G.J.U., and Islam A.J.M.S., “Effect of water management and weed control treatments on the performance of transplanted aman rice”, Bangladesh J. Agri. Res., 2008, 33(3) 399-408.
77. Peterson,G.A., and Westfall D.G., “Managing precipitation use in sustainable drylandagroecosys terms”, Annals of Applied Biology, 2004, 144,127-138.
78. Hatler,W.L. and Hart C.R., “Water Loss and Salvage in Saltcedar (*Tamarix spp*.) Stands on the Pecos River, Texas. Invasive Plant Science and Management, 2009, 2 (4): 309-317.
79. Williams,W., Holden P., Parsons D., and CorberM., “Pesticides in Groundwater Data Base”: 1988, 1nterim Report. US, Environ. Protection Agency, Washington, D.C., 1988.
80. Anderson,R.L., “Impact of subsurface tillage on weed dynamics in the central Great Plains”. Weed Tech., 2004, 18:186-192.
81. Sarkar,S., and Singh S.R., “Interactive effect of tillage depth and mulch on soil temperature, productivity and water use pattern of rainfed barley (*Hordiumvulgare* L.)”, Soil & Tillage Res, 2007, 92, 79–86.
82. Lenssen,A.W., “Planting date and preplant weed management influence yield, water use, and weed seed production in herbicide-free forage barley”, Weed Techn, 2008, 22(3), 486–492.
83. Prior,S.A., RunionG.B., Marble S.C., Rogers H.H., Gilliam C.H. and TorbertH.A., “A Review of Elevated Atmospheric CO_2 Effects on Plant Growth and Water Relations: Implications for Horticulture”, HortSci, 2011, 46(2), 158-162.
84. Ziska,L.H., and RunionG.B., “Future weed, pest, and disease problems for plants”, In: Newton, P.C.D., CarranR.A., Edwards G.R., and NiklausP.A. (eds). Agroecosystems in a changing climate. CRC Press, Boca Raton, FL, 2007, pp. 61– 287.

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EXHIBIT 5

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Research Article

Estimation of water losses through evapotranspiration of aquatic weeds in the Nile River (Case study: Rosetta Branch)

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Abstract

Aquatic weeds management and estimation of water losses from evapotranspiration must be taken into consideration in order to reduce water losses. The objective of this research is estimating the water losses through evapotranspiration of aquatic weeds in the Rosetta Branch in order to identify the quantities of water that could be saved when applying appropriate maintenance programs for aquatic weeds. To achieve the objective of this research, the research team identify areas of infection of the aquatic weeds using field visits, determine its coordinates using GPS and Satellite imagery (Landsat-8) and estimate of water losses through evapotranspiration of aquatic weeds by using the following evapotranspiration equation: ETc = ETo × Kc. The result for estimation of the average annual water losses through evapotranspiration of aquatic weeds in the Rosetta Branch during one year (from December 2015 to November 2016) were 21.3 million m^3/year, 0.7 million m^3/year and 1.1 million m^3/year for water hyacinth, Common Reed and Torpedo grass, respectively.

Keywords: Water losses; Evapotranspiration; Aquatic weeds; Nile River

1. 1 Introduction

After constructing Aswan High Dam, a series of barrages have been built across the river and its Branches; regulate the water level in the Nile River to meet Egyptian demands for cultivation, industrial, navigation, hydroelectric power and domestic water supply. This regulation allows a gradual rise and drop down in the water level creating a favorable habitat for many aquatic weeds to spread in huge amount. Khattab and El-Gharably (1984) mentioned that there are three aquatic weeds forms which are floating weeds, emergent and ditch bank weeds and submerged weeds. The

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high aquatic weed infestations caused a lot of problems by causing water losses, retardation of flow, obstruction of gates and intakes, interference with navigation, health hazards and alteration in the physic-chemical characteristics of both water and hydro soil (El-Samman and Abou EL-Ella, 2009). Also, the Nile River system has been subjected to several ecological changes: silt free water running downstream and the consequent excessive use of fertilization, permanent presence of water throughout the year, low current velocity in the Nile and decrease the water flow to the Mediterranean. These factors have encouraged fast growth of aquatic weeds such as water hyacinth *(Eichhornia crassipes*) within the Egyptian Nile River even at the end of the growing season, which extends from the end of March to October (El-Shinnawy et al., 2000). *Eichhornia crassipes* is the most notorious aquatic weed; it is listed as one of the top ten world's worst weeds. Peninah et al. (2013) stated that Lake Victoria, Kenya, which is the largest freshwater body in the tropics, has undergone serious ecological changes including invasion by the water hyacinth, *Eichhornia crassipes*, the presence of the weeds in the lake has led to many problems including blockage of water pumps, reduced fishing activities and increase in water borne diseases such as schistosomiasis. The need for improving monitoring and reporting of aquatic weeds problems is stressed. Advances in the technology of remote sensing, coupled with the increasingly widespread availability of cheap computer databases can provide the means for such improvements (Murphy, 1988).

Water losses increase through evapotranspiration and considered as one of the most important weed problems in water bodies, which require tools to reduce water losses. Thus, estimating water losses through evapotranspiration of aquatic weeds is very important for preparation of both canals maintenance and weeds removal programs in order to reduce water losses. Florentina et al. (2016) results indicated that in 2014, the open water evaporation was in average of 4.3 mm/day and the aquatic plants evapotranspiration was in average of 7.8 mm/day on the Căldăruşani Lake. The two processes generated a water loss of 34% of lake's volume. In lack of vegetation, the water volume lost by evaporation would have been lower, than the aquatic plants transpiration (i.e., reed associations). Angela et al. (2014) stated that the average annual water loss of Common Reed of six seasons between 2005 and 2011 ranged from 566 to 1008 mm but depended on the weather, especially on net radiation. The average evapotranspiration (ET) of Common Reed was 779 mm for the entire study period while the average Kc value was 1.23. Seasonal mean Kc values for Common Reed ranged from 0.73 to 1.37. In cool weather (seasonal mean air temperatures <17 °C), annual mean crop coefficient (K_c) and ET were 0.73 and 385 mm respectively, while in hot weather (seasonal mean temperatures above 18 °C), Kc and ET were 1.37 and 875.4 mm respectively. Brezny et al. (1973) stated that evapotranspiration of water hyacinth (*Eichornia crassipes* Mart Solms.) was 30–40% higher, that of narrow leaf cattail (*Typha augustifolia* L.) was 60–70% higher, and that of purple nutsedge (*Cyperus rotundus* L.) was 130–150% higher than evaporation from a free water surface under equivalent conditions. Rosa et al. (2009) proved that the colonization of the aquatic weeds increased the water losses in the mesocosms, with the highest losses being observed in those colonized by *Typha latifolia*, between 3.54 to 4.71 times the water surface without aquatic weeds. The losses in the mesocosms colonized by *Myriophyllum aquaticum*, *Brachiaria subquadripara*, *Echinochloa polystachya*, and *Pontederia lanceolata* were statistically similar and promoted increases between 1.54 to 2.21 times the free surface. The results showed that aquatic weeds control is important to prevent water losses in reservoirs used for water storage. Timmer and Weldon (1966) proved that water loss through evapotranspiration from water hyacinth was 3.7 times that from open water. El-Shinnawy et al. (2000) stated that comparing water lost by tubes of water covered by *Eichhornia crassipes* with similar tubes of open water for a period of five weeks showed that the ratio of evapotranspiration to evaporation varied from 1.5:1 to 3.2:1 in winter and summer respectively. Also, it was reported that phreatophytes (excluding beneficial species) cover about 6.5 million ha in the seventeen western states of the United States of America losing annually 30.65 km^3 of water. Victor et al. (1987) stated that evapotranspiration of water hyacinth, water lettuce, Salvinia and water fern, should represent 196,000; 84,000; 87,000 and 71,000 l/ha/day, respectively. Wherefore, this research objective to estimating the water losses through evapotranspiration of aquatic weeds in the Rosetta Branch, in order to identify the quantities of water could be saved when applying appropriate maintenance programs for the different types of aquatic weeds.

2. Materials and methods

2.1. Rosetta Branch study area

The southern beginning of the Delta head is at the intersection of latitude 30°10 26.57 North with longitude 31°8 19.56 East is the starting point of Rosetta Branch, which runs northeast to 239,035 km to pour in the Mediter-

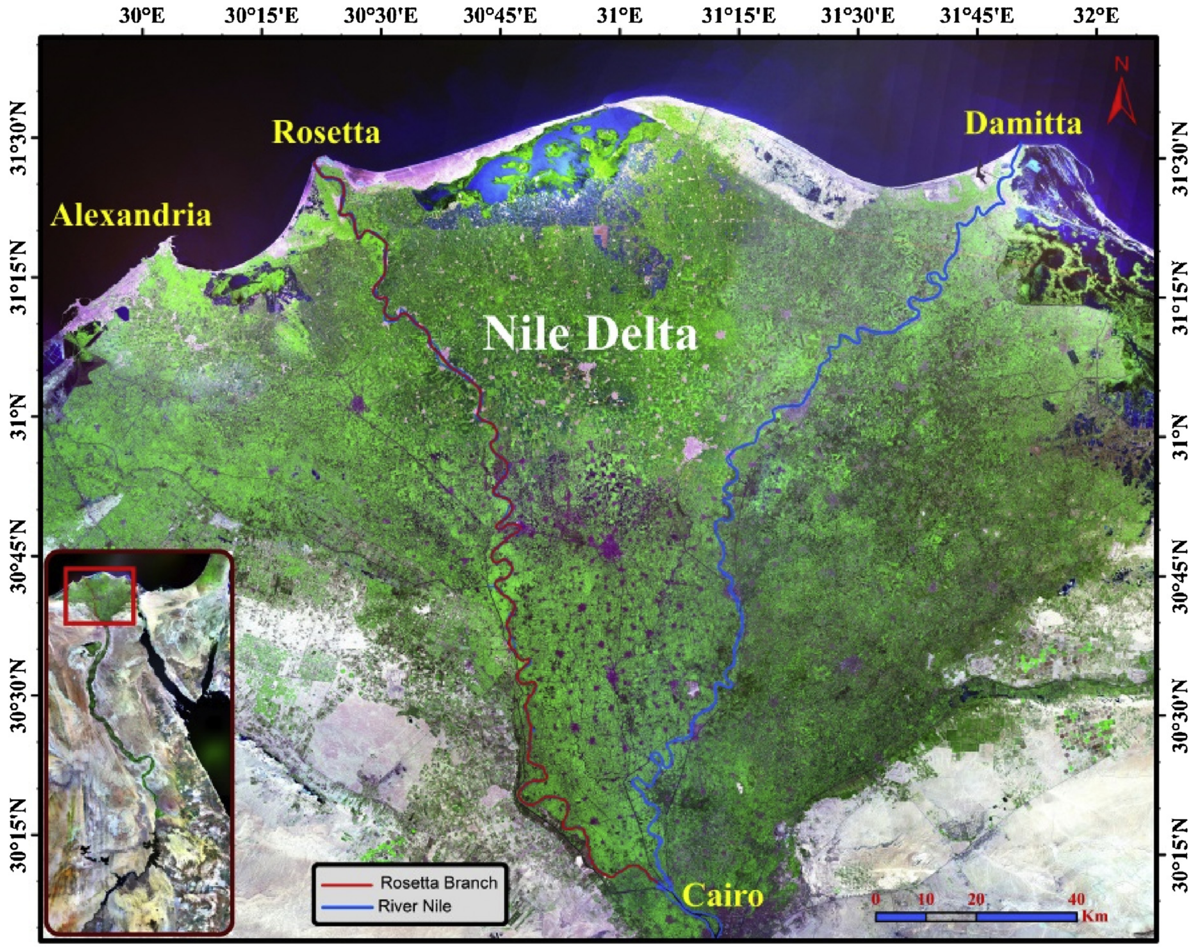


Fig. 1. Nile Delta showing Rosetta Branch (study area).

ranean Sea at Rashid city at intersection of latitude 31°28 15.39 North with longitude 30°21 53.19 East, as shown in Fig. 1. The average width of Rosetta Branch ranged between 132 to 485 m. Rosetta Branch has 44 islands that could be classified between permanent and seasonal islands, with a combined area of 1872.6 feddan (feddan = 4200 m^2), including eight permanent islands with extensive land use in agriculture. The total sum of the water area without islands in the Rosetta Branch during research period ranged between 13,943–15,239 feddan, depending on rise and drop down in the water level.

2.2. *Determination of the areas and infestation percentages for the aquatic weeds types*

Rosetta Branch was divided into three reaches (reach 1: from km. 0.0 to km. 79.0, reach 2: from km. 79.0 to km. 162.5 and reach 3: from km. 162.5 to km. 235.6) to facilitate the inventory and classification of aquatic weeds with determination of the areas and infestation rates of the aquatic weeds (water hyacinth especially). Also, there are three meteorological stations covers those three reaches on Rosetta Branch, which facilitate the estimation of water losses through evapotranspiration of aquatic weeds in Rosetta Branch.

Determination of the areas and infestation percentages for aquatic weed types during the period from December 2015 to November 2016 were done by using two complementary ways to each other. The first way depend on field visits for five days during each season of the four seasons to inventory and classify of the aquatic weeds types in Rosetta Branch by using GPS to determine the coordinates of the area infested by different types of aquatic weeds. The second way was done by analysis of satellite images available to the Rosetta Branch for the same period. Satellite imagery analysis has been intensified during the aquatic weeds boom in the spring and summer (from March to October). 10 satellite images were used, including 2 images dated 06 Dec. 2015 and 07 Jan. 2016 represent winter season, 2 images dated 11 Mar. 2016 and 14 May 2016 represent spring season, 4 images dated 15 Jun. 2016, 01 Jul. 2016, 17 Jul. 2016 and 19 Sep. 2016 represent summer season (two of them were taken before the intensification of the mechanical control and the other two were taken during and after the intensification of the mechanical control which implemented by the Ministry of Water Resources and Irrigation) and 2 image dated 15 Oct. 2016 and 16 Nov. 2016 represent the autumn season.

2.3. Satellite imagery analysis

Methodology of satellite imagery analysis relied on the following:

- Download the satellite imagery (Landsat-8) from the website (https://lv.eosda.com), for two Scenes (Path & Row: 039/177 and 038/138), during dates starting from December 2015 to November 2016, and used layer stack tools from ERDAS IMAGINE Software for band combination, and Mosaic the images for each date.
- Applied Enhancements tools on the images such as Contrast and Stretching Histogram.
- Digitizing the water body and the outline bank border for Rosetta Branch, and used it for subset the river boundary.
- Using the NDVI index for highlighting the plants (weeds), on each date by below equation:

$$Normalized\ Difference\ Vegetation\ Index\,(NDVI) = \frac{(NIR - RED)}{(NIR + RED)} = \frac{(Band\,5 - Band\,4)}{(Band\,5 + Band\,4)} \quad (1)$$

- Used the Unsupervised Classification for classifying the output of NDVI to three classes (Water, Land and Plants) based on the histogram curve.
- Use the river boundary for creating buffer zone based on distance 10 m towards the inside (it is the estimate distance for ditch weeds growing), that aims to detect and select the aquatic weeds on the near shoreline (−10 m) and classified it as a ditch weeds class.
- Convert the thematic layer from the raster to vector format in shape file extension (Shp) to classify the weeds based on the buffer zone (−10 m) to ditch and floating or submerged weeds.
- Field checking for five days during each season of the four seasons, which aimed to recognize the types of aquatic weeds on Rosetta Branch, and saved GPS points for accuracy assessment.
- Extraction of coordinates table, for 15th random points to calculate the accuracy assessment by the field truth, that aim to accepted the results of satellite imagery classification.
- Extraction the areas table, for each type of image classes (Water, Weeds and Lands), and another table for areas of each type of weeds (Ditch or Floating), and create the layouts.

Also, data collection for the infection percentages of the floating aquatic weeds in the Nile River and its branches through reports issued by Channel Maintenance Research Institute (CMRI), National Water Research Center (NWRC), during the period from 1985/1986 to 2013/2014, were considered in the present research.

2.4. Meteorological data and reference evapotranspiration, (ET_O)

The collected meteorological data which cover the entire Rosetta Branch was obtained from 3 stations, Rashid 1 (Latitude: 30.25 N, Longitude: 30.75 E), Rashid 2 (Latitude: 30.75 N, Longitude: 30.75 E) and Rashid 3 (Latitude: 31.25 N, Longitude: 30.50 E). Meteorological data collected from 3 stations were used in the program Cropwat 8 for calculating the reference evapotranspiration (ET_o) from average monthly weather stations variables.

2.5. Crop coefficient (K_c)

Values of crop coefficient (Kc) of aquatic weeds which were used in this research derived from research papers for each Meleha (2005) and Rashed (2014) that conducted on almost similar areas in the climatic conditions of the Rosetta Branch. The monthly average value was used of water hyacinth coefficient (K_c) which has been calculated by

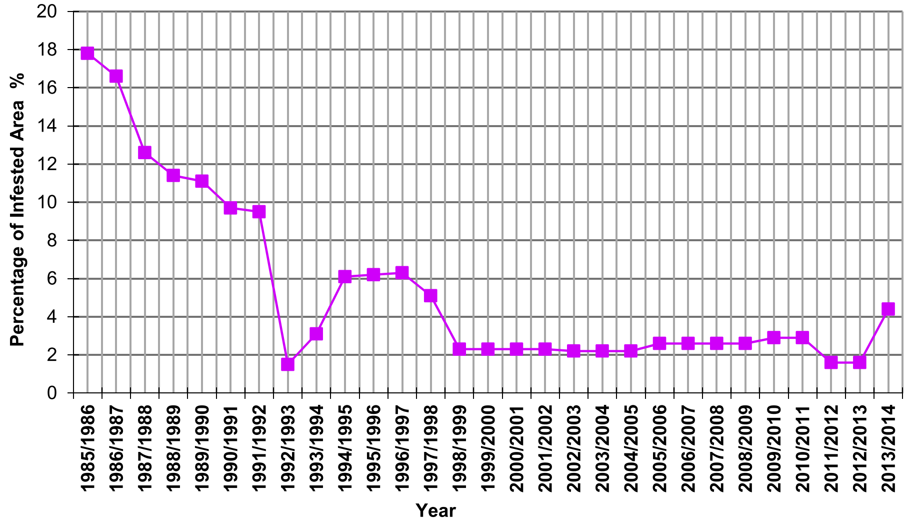


Fig. 2. Percentage of infested areas by floating weeds (water hyacinth) in the Nile River.

Meleha (2005) who estimated the monthly average of crop coefficient (K_c) for water hyacinth of the average value by many empirical formulas were 1.48, 1.54, 1.38, 1.42, 1.96, 2.27, 2.41, 2.31, 2.20, 1.97, 1.62, 1.34 and 1.30 in the months from Nov., 2004 till Nov., 2005 respectively. While, the monthly average was used of Common Reed and Torpedo Grass coefficient which has been calculated by (Rashed, 2014) who estimated the monthly average of crop coefficient (K_c) for each of the Common Reed and Torpedo grass to open water evaporation, values ranged between 1.19–1.33 and 1.25–1.35 mm/d respectively, during months from Nov. 2008 till Aug. 2009. It has been using Common Reed coefficient values that was recorded 1.08, 0.69, 0.60, 1.24, 1.27, 1.28, 1.98, 1.63 and 1.55, while Torpedo grass coefficient values was recorded 1.21, 0.80, 0.56, 1.28, 1.32, 1.32, 1.82, 1.71 and 1.65 for the months same of satellite images were used in this research.

2.6. Calculation of evapotranspiration (ET_c) of aquatic weeds in Rosetta Branch

Average daily of water losses of evapotranspiration (ET_c) for each of water hyacinth, Common Reed and Torpedo Grass is calculated by equation as follows:

$$ET_c = ET_o \times K_c \quad (2)$$

where: ET_c: evapotranspiration, ET_o: reference evapotranspiration, K_c: crop coefficient.

3. Results and discussion

In Nile River and its branches, water hyacinth is the most common type of floating weeds. It represents more than 90% of the floating weeds in the river. Thus, it is considered representative for all types of floating weeds in the Nile River. Data were collected for the infestation percentages of the floating weeds (water hyacinth) in the Nile River and its branches from eleven public Nile protection directorates that covered the entire length of Nile River from High Aswan Dam to Mediterranean Sea through reports issued by CMRI (Channel Maintenance Research Institute), 2014, this monitoring of infestation was carried out for 29 consecutive years during the period from 1985/1986 to 2013/2014 as shown in Fig. 2. The total percentage of infested area by floating weeds (water hyacinth) in Nile reached 17.8% in season 1985/1986 (the maximum rate of infestation), after this year, the infestation decreased gradually with increasing time and reached the minimum level in season 1992/1993 which was 1.5%, then, increased to reach about 6.3% in season 1996/1997, then, decreased to range between 2.1–4.4% during the period from 1998/1999 to 2013/2014 as shown in Fig. 2. The infestation percentages of the floating weeds (water hyacinth) in the Nile River during the inventory years concentrated in Rosetta and Damietta branches.

3.1. The infestation of aquatic weeds

Rosetta Branch was divided into three reaches in order to facilitate the inventory and classification of aquatic weeds with determination of the areas and infestation percentages of the aquatic weeds during the period from December 2015 to November 2016 using two methods. The first method by depends on the field visits to observe the aquatic weeds types for inventory of the types aquatic weeds and using GPS to determine the coordinates of infestation sites from them to use it in determining the extracted infestation areas from satellite imagery for each type accurately. The second method depends on the analysis of 10 satellite imagery available to calculate the areas and infestation percentages for the aquatic weeds types that have been monitored for the same period.

3.2. Inventory and classification of aquatic weeds through field visits

The results of the inventory and classification of aquatic weeds for five days during each season of the four seasons in December 2015, May 2016, July 2016 and October 2016, showed four main life forms of aquatic weeds which related to the plants position in the Rosetta Branch. These four forms are floating weeds represented in water hyacinth *"Eichornia crassipes"*, ditch-bank weeds represented in Common Reed *"Phragmites australis"* emergent weeds represented in Torpedo grass *"Echinochloa stagninum"*, submerged weeds represented in Eurasian Water-Milfoil *"Myriophyllum spicatum"* and Curlyleaf Pondweed *"Potamogeton crispus"*. Water hyacinth is the most common type in the three reaches, it is the main problem of aquatic weeds in Rosetta Branch, followed by Common Reed and Torpedo grass, while, submerged weeds are the least common and monitored in the first reach only. Infection area does not exceed 2–10 feddan during four seasons. The areas and infestation percentages of the aquatic weeds has been determined on Rosetta Branch in three reaches. These weeds are water hyacinth *"Eichornia crassipes",* Common Reed *"Phragmites australis"* and Torpedo grass *"Echinochloa stagninum"*.

Through field observations, it has been monitored that the increase in the spread of aquatic weeds during the summer season from the rest of seasons and the spread of aquatic weeds during the seasons could be arranged in the following order: summer > spring > autumn > winter. This arrangement corresponds to the period of weed boom that starts from March to October each year.

3.3. Areas and infestation percentages of aquatic weeds using satellite imagery

The results of analysis 10 satellite imagery available for the areas and infestation percentages for the aquatic weeds in Rosetta Branch during the period from December 2015 to November 2016 are shown in Tables 1 and 2. The following could be shown:

- Total infestation areas of aquatic weeds ranged between 679.30–3179.37 feddan of the total water surface area in Rosetta Branch (three reaches) which is equivalent to injury percentage ranged between 5.07–20.86%. The highest infestation of aquatic weeds recorded in 01 Jul. 2016 and lowest infestation in 07 Jan. 2016.
- Infestation areas of water hyacinth ranged between 542.15–2935.55 feddan of the total water surface area which is equivalent to infestation percentage 4.04–19.26%. The infestation areas existed in the highest value in summer season "01-Jul-2016" and the lowest value was accompanied with winter season "07 Jan. 2016".
- Infestation areas of Common Reed ranged between 36.98–103.29 feddan of the total water surface area which is equivalent to infestation percentage 0.24–0.74%. The infestation areas were existed in the highest value in spring season "14 May 2016" and the lowest value was accompanied with autumn season "19 Sep. 2016".
- Infestation areas of Torpedo grass ranged between 66.07–168.65 feddan of the total water surface area which is equivalent to infestation percentage 0.44–1.20%. The infestation areas were existed in the highest value in summer season "17 Jul. 2016" and the lowest value was accompanied with autumn season "19 Sep. 2016".

Figs. 3–6 show the spread of aquatic weeds in the distance from South of Desouq city at kilometer 170.900 to Fuwah city at kilometer 185.800, as an example of some areas of aquatic weeds infection during the four seasons.

The previous results in tables and figures, show the highest infestation of aquatic weeds during summer season (May and July 2016) due to the availability of weed growth factors which help aquatic weeds boom in this period. Also, drains that flow untreated drainage on Rosetta Branch (such as Al-Rahawi drain, Sibal drains and others), this

Table 1
Infestation areas of aquatic weeds in the Rosetta Branch.

No.	Reaches From (km)	Reaches To (km)	Total Water surface area (feddan = 4200 m^2)	Infested areas of water hyacinth	Infested areas of Common Reed	Infested areas of Torpedo grass	Total infested area of aquatic weeds	Date
1	0.000	79.000	2649.30	280.38	44.80	74.37	399.55	**06 Dec. 2015**
2	79.000	162.500	4705.41	483.75	16.64	26.88	527.27	
3	162.500	235.600	6919.91	190.92	30.15	19.32	240.39	
	Total infestation		**14,274.62**	**955.05**	**91.59**	**120.57**	**1167.21**	
1	0.000	79.000	2610.35	112.55	21.32	54.14	188.01	**07 Jan. 2016**
2	79.000	162.500	4618.22	294.15	13.81	19.15	327.11	
3	162.500	235.600	6180.36	135.45	16.62	12.11	164.18	
	Total infestation		**13,408.93**	**542.15**	**51.75**	**85.40**	**679.30**	
1	0.000	79.000	2646.73	277.53	50.93	73.66	402.12	**11 Mar. 2016**
2	79.000	162.500	5515.51	430.13	20.86	36.08	487.07	
3	162.500	235.600	6966.56	158.64	10.85	15.09	184.58	
	Total infestation		**15,184.28**	**866.3**	**82.64**	**124.83**	**1073.77**	
1	0.000	79.000	2753.68	328.99	42.09	56.51	427.6	**14 May 2016**
2	79.000	162.500	4777.69	974.50	33.99	49.32	1057.81	
3	162.500	235.600	6412.27	577.54	27.2	31.87	636.61	
	Total infestation		**13,943.64**	**1881.03**	**103.29**	**137.69**	**2122.02**	
1	0.000	79.000	2732.54	312.44	33.49	70.38	416.31	**15 Jun. 2016**
2	79.000	162.500	5244.4	911.92	30.55	57.28	999.76	
3	162.500	235.600	6232.32	830.17	19.69	28.98	878.84	
	Total infestation		**14,209.26**	**2054.53**	**83.73**	**156.64**	**2294.91**	
1	0.000	79.000	2755.74	331.95	28.81	53.76	414.53	**01 Jul. 2016**
2	79.000	162.500	5395.6	962.97	35.98	57.54	1056.49	
3	162.500	235.600	7088.36	1640.63	29.33	38.39	1708.35	
	Total infestation		**15,239.70**	**2935.55**	**94.13**	**149.68**	**3179.37**	
1	0.000	79.000	2843.3	210.19	31.29	53.48	294.96	**17 Jul. 2016**
2	79.000	162.500	5341.12	606.38	37.75	62.43	706.56	
3	162.500	235.600	5876.05	1148.7	26.73	52.75	1228.18	
	Total infestation		**14,060.47**	**1965.27**	**95.77**	**168.65**	**2229.69**	
1	0.000	79.000	2983.39	130.61	11.44	23.4	165.45	**19 Sep. 2016**
2	79.000	162.500	5338.53	459.43	14.18	26.7	500.31	
3	162.500	235.600	6805.29	452.75	11.36	15.97	480.08	
	Total infestation		**15,127.21**	**1042.79**	**36.98**	**66.07**	**1145.84**	
1	0.000	79.000	2870.31	169.53	43.12	57.16	269.81	**15 Oct. 2016**
2	79.000	162.500	5100.34	314.93	38.26	43.61	396.8	
3	162.500	235.600	6868.97	184.78	14.82	15.26	214.86	
	Total infestation		**14,839.62**	**669.24**	**96.2**	**116.03**	**881.47**	
1	0.000	79.000	2855.85	135.22	34.85	46.52	216.59	**16 Nov. 2016**
2	79.000	162.500	5043.28	278.35	29.65	35.55	343.55	
3	162.500	235.600	6741.35	155.53	15.74	16.32	187.59	
	Total infestation		**14,640.48**	**569.10**	**80.24**	**98.39**	**747.73**	

Table 2
Infestation percentages of aquatic weeds in the Rosetta Branch.

No.	Reaches		Total Water surface percent	Infestation percent of water hyacinth	Infestation percent of Common Reed	Infestation percent of Torpedo grass	Total infestation percent of aquatic weeds	Date
	From (km)	To (km)	(%)					
1	0.000	79.000	100	10.58	1.69	2.81	15.08	**06 Dec. 2015**
2	79.000	162.500	100	10.28	0.35	0.57	11.20	
3	162.500	235.600	100	2.75	0.44	0.28	3.47	
	Total infestation		**100**	**6.69**	**0.64**	**0.84**	**8.17**	
1	0.000	79.000	100	4.31	0.82	2.07	7.20	**07 Jan. 2016**
2	79.000	162.500	100	6.37	0.30	0.41	7.08	
3	162.500	235.600	100	2.19	0.27	0.20	2.66	
	Total infestation		**100**	**4.04**	**0.39**	**0.64**	**5.07**	
1	0.000	79.000	100	10.48	1.92	2.78	15.18	**11 Mar. 2016**
2	79.000	162.500	100	7.80	0.38	0.65	8.83	
3	162.500	235.600	100	2.28	0.15	0.22	2.65	
	Total infestation		**100**	**5.71**	**0.54**	**0.82**	**7.07**	
1	0.000	79.000	100	11.95	1.53	2.05	15.53	**14 May 2016**
2	79.000	162.500	100	20.40	0.71	1.03	22.14	
3	162.500	235.600	100	9.01	0.42	0.50	9.93	
	Total infection		**100**	**13.49**	**0.74**	**0.99**	**15.22**	
1	0.000	79.000	100	11.43	1.23	2.58	15.24	**15 Jun. 2016**
2	79.000	162.500	100	17.39	0.58	1.09	19.06	
3	162.500	235.600	100	13.32	0.32	0.46	14.10	
	Total infestation		**100**	**14.46**	**0.59**	**1.10**	**16.15**	
1	0.000	79.000	100	12.05	1.04	1.95	15.04	**01 Jul. 2016**
2	79.000	162.500	100	17.85	0.67	1.06	19.58	
3	162.500	235.600	100	23.15	0.41	0.54	24.10	
	Total infestation		**100**	**19.26**	**0.62**	**0.98**	**20.86**	
1	0.000	79.000	100	7.39	1.10	1.88	10.37	**17 Jul. 2016**
2	79.000	162.500	100	11.35	0.71	1.17	13.23	
3	162.500	235.600	100	19.55	0.45	0.90	20.90	
	Total infestation		**100**	**13.98**	**0.68**	**1.20**	**15.86**	
1	0.000	79.000	100	4.38	0.38	0.78	5.54	**19 Sep. 2016**
2	79.000	162.500	100	8.61	0.26	0.50	9.37	
3	162.500	235.600	100	6.65	0.17	0.23	7.05	
	Total infestation		**100**	**6.89**	**0.24**	**0.44**	**7.57**	
1	0.000	79.000	100	5.91	1.50	1.99	9.40	**15 Oct. 2016**
2	79.000	162.500	100	6.17	0.75	0.86	7.78	
3	162.500	235.600	100	2.69	0.22	0.22	3.13	
	Total infestation		**100**	**4.51**	**0.65**	**0.78**	**5.94**	
1	0.000	79.000	100	4.73	1.22	1.63	7.58	**16 Nov. 2016**
2	79.000	162.500	100	5.52	0.59	0.70	6.81	
3	162.500	235.600	100	2.31	0.23	0.24	2.78	
	Total infestation		**100**	**3.88**	**0.56**	**0.67**	**5.11**	

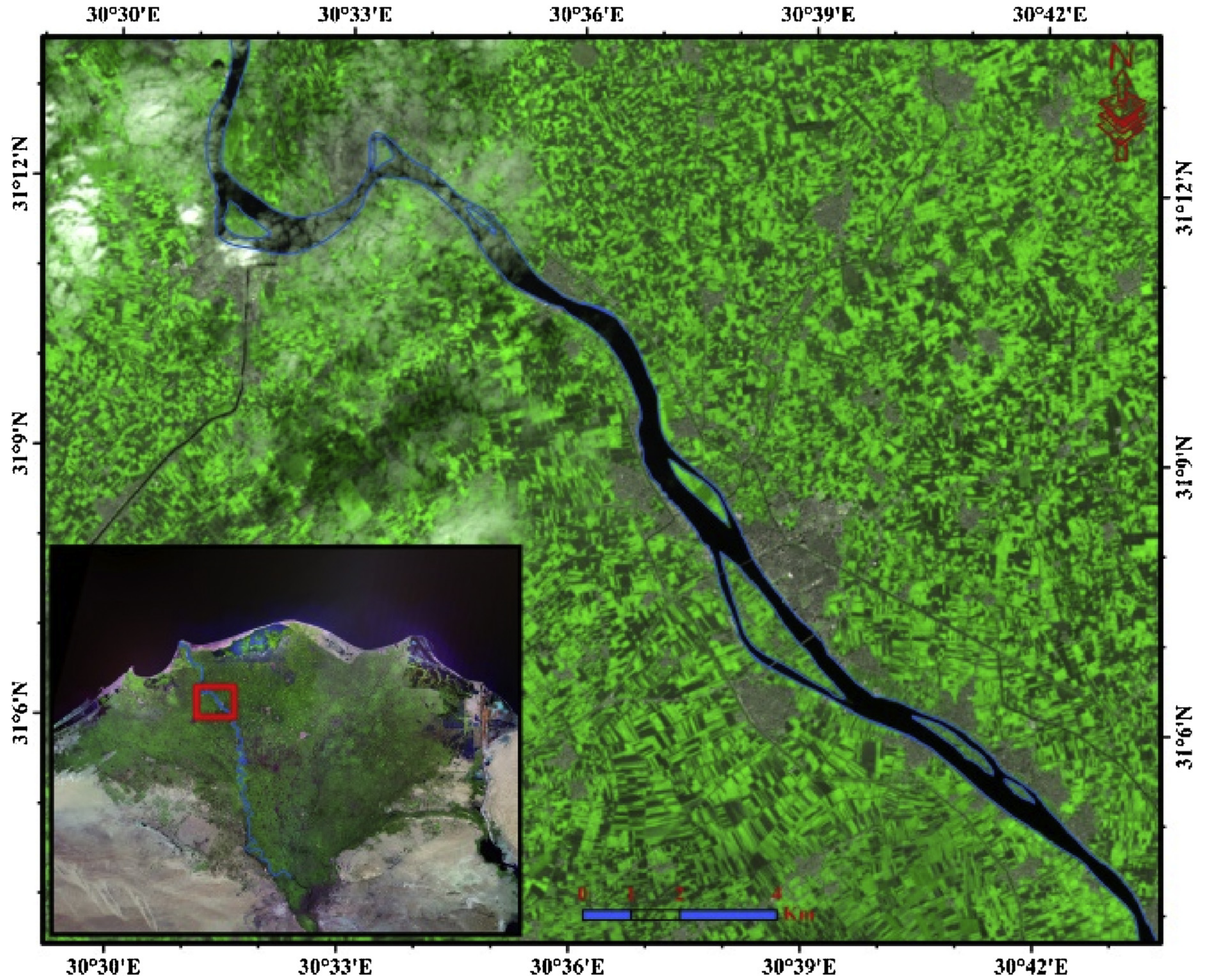


Fig. 3. Aquatic weeds from Desouq city to Fuwah city in 06 Dec. 2015.

drainage carries with it nutrients that help the aquatic weeds growth and expansion (water hyacinth especially) and very weak method to manage and control aquatic weeds mechanical control. While, infestation decreased of aquatic weeds during autumn season (September and October 2016) as a result of the intensive maintenance work to control the weeds with increased equipment used in weed control and prepare a good maintenance plan during July and August 2016. Whereas, the lowest infection of aquatic weeds was during winter season especially in Jan. 2016 because the factors that help to grow weeds were weak.

Table 3 presents average monthly weather stations variables which have been calculated from meteorological data that were collected from the three meteorological stations "Rashid 1, Rashid 2 and Rashid 3". This data included maximum and minimum temperature, relative humidity (%), wind speed (km/d) and sun shine (hours). Reference evapotranspiration (ETo) was calculated from average monthly weather stations variables by entering the data on program Cropwat 8. The highest values of reference evapotranspiration were recorded during summer season (Jun. 2016 and Jul. 2016), while, the lowest values of reference evapotranspiration were recorded during winter season (Dec. 2015 and Jan. 2016).

Water losses that calculated by evapotranspiration from aquatic weeds on Rosetta Branch were depended on meteorological station Rashid 1 covers the distance from principle to km. 79,000. While, Rashid 2 covers a reach from km. 79,000 to km. 162,500, whereas, Rashid 3 covers a reach from km. 162,500 to km. 235,600 on Rosetta Branch.

Table 4 presents average water losses through evapotranspiration that was calculated for water hyacinth compared to evaporation of free surface for the same infested area from Rosetta Branch during the period from December 2015

Table 3
Average monthly weather stations variables and evapotranspiration reference (ETo) on Rosetta Branch.

Date	Station	Temperature		Humidity	Wind	Sun Shin	ETo
		Min. (°C)	Max. (°C)	%	km d^{1}	Hours	mm d^{1}
Dec. 2015	Rashid 1	11.2	20.5	64.0	85.44	8.2	1.88
	Rashid 2	12.0	19.4	75.0	96.12	8.0	1.73
	Rashid 3	13.3	19.9	66.7	92.88	8.4	1.86
Jan. 2016	Rashid 1	9.8	18.2	58.4	109.92	7.2	1.93
	Rashid 2	8.3	17.5	67.0	100.2	8.4	1.81
	Rashid 3	9.6	17.6	67.9	105.36	7.8	1.72
Mar. 2016	Rashid 1	15.9	26.6	43.9	117.84	8.7	3.96
	Rashid 2	11.6	22.2	66.3	111.84	8.2	3.09
	Rashid 3	13.2	22.8	60.2	113.04	8.8	3.32
	Rashid 1	20.8	33.2	40.5	121.44	11	6.05
May 2016	Rashid 2	16.9	28.3	58.5	111.36	10.6	5.03
	Rashid 3	18.7	28.8	54.7	110.64	11.2	5.30
	Rashid 1	24.2	37.1	43.2	113.04	11.5	6.64
Jun. 2016	Rashid 2	21.4	31.9	64	112.08	11.8	5.83
	Rashid 3	22.5	31.9	57.6	108.24	12.2	6.03
	Rashid 1	25	35.5	54.4	106.08	11.1	6.26
Jul. 2016	Rashid 2	22.9	30.7	70.8	111.12	11.6	5.65
	Rashid 3	24.4	31.3	61.7	118.32	11.6	5.94
	Rashid 1	23.7	33.8	54.4	108.96	10.1	5.14
Sep. 2016	Rashid 2	22.0	29.2	70.3	91.44	9.8	4.31
	Rashid 3	22.9	30.8	56.9	102.96	10.1	4.72
	Rashid 1	21.3	30.7	62.2	104.16	9.2	3.87
Oct. 2016	Rashid 2	20.2	27.8	70.8	86.16	8.7	3.29
	Rashid 3	21.1	28.1	59.4	96.24	8.9	3.53
	Rashid 1	16.5	25.6	55.9	93.84	8.3	2.73
Nov. 2016	Rashid 2	16.2	23.4	73	104.76	8.8	2.41
	Rashid 3	16.3	24.8	57.2	97.44	8.5	2.63

Table 4
Average water losses through evapotranspiration of water hyacinth and evaporation of water surface for the same infected area in the Rosetta Branch from December 2015 to November 2016.

Date	Reach	ETo	Kc average	$Et = Et_o \times Kc$	Infection areas	Water losses of water hyacinth	Water losses of water surface
	From (km) To (km)	mm/d		mm/d	feddan	m^3/d	m^3/d
06 Dec. 2015	0.000–79.000	1.88	1.54	2.89	280.38	3403	2213
	79.000–162.500	1.73	1.54	2.66	483.75	5404	3514
	162.500–235.600	1.86	1.54	2.86	190.92	2293	1491
Water losses of evapotranspiration and evaporation in 6 Dec. 2015					**955.05**	**11101**	**7220**
07 Jan. 2016	0.000–79.000	1.93	1.38	2.66	112.55	1259	912
	79.000–162.500	1.81	1.38	2.49	294.15	3085	2236
	162.500–235.600	1.72	1.38	2.37	135.45	1350	978
Water losses of evapotranspiration and evaporation in 07 Jan. 2016					**542.15**	**5695**	**4126**
11 Mar. 2016	0.000–79.000	3.96	1.96	7.76	277.53	9045	4615
	79.000–162.500	3.09	1.96	6.06	430.13	10947	5582
	162.500–235.600	3.32	1.96	6.51	158.64	4337	2212
Water losses of evapotranspiration and evaporation in 11 Mar. 2016					**866.30**	**24330**	**12410**
14 May 2016	0.000–79.000	6.05	2.41	14.58	328.99	20146	8359
	79.000–162.500	5.03	2.41	12.12	974.50	49605	20587
	162.500–235.600	5.3	2.41	12.77	577.54	30975	12856
Water losses of evapotranspiration and evaporation in 14 May 2016					**1881.03**	**100727**	**41802**
15 Jun. 2016	0.000–79.000	6.64	2.31	15.34	312.44	20129	8713
	79.000–162.500	5.83	2.31	13.47	911.92	51590	22329
	162.500–235.600	6.03	2.31	13.93	830.17	48570	21024
Water losses of evapotranspiration and evaporation in 15 Jun. 2016					**2054.53**	**120290**	**52067**
01 Jul. 2016	0.000–79.000	6.26	2.2	13.77	331.95	19198	8727
	79.000–162.500	5.65	2.2	12.43	962.97	50272	22851
	162.500–235.600	5.94	2.2	13.07	1640.63	90060	40930
Water losses of evapotranspiration and evaporation in 01 Jul. 2016					**2935.55**	**159531**	**72509**
17 Jul. 2016	0.000–79.000	6.26	2.2	13.77	210.19	12156	5526
	79.000–162.500	5.65	2.2	12.43	606.38	31656	14389
	162.500–235.600	5.94	2.2	13.07	1148.7	63056	28657
Water losses of evapotranspiration and evaporation in 17 Jul. 2016					**1965.27**	**106869**	**48573**
19 Sep. 2016	0.000–79.000	5.14	1.62	8.33	130.61	4569	2819
	79.000–162.500	4.31	1.62	6.98	459.43	13468	8316
	162.500–235.600	4.72	1.62	7.65	452.75	14546	8975
Water losses of evapotranspiration and evaporation in 19 Sep. 2016					**1042.79**	**32585**	**20111**
15 Oct. 2016	0.000–79.000	3.87	1.34	5.19	169.53	3695	2755
	79.000–162.500	3.29	1.34	4.41	314.93	5833	4351
	162.500–235.600	3.53	1.34	4.73	184.78	3670	2739
Water losses of evapotranspiration and evaporation in 15 Oct. 2016					**669.24**	**13199**	**9846**
16 Nov. 2016	0.000–79.000	2.73	1.39	3.79	135.22	2155	1550
	79.000–162.500	2.41	1.39	3.35	278.35	3916	2817
	162.500–235.600	2.63	1.39	3.66	155.53	2388	1717
Water losses of evapotranspiration and evaporation in 16 Nov. 2016					**569.10**	**8459**	**6085**
Average water losses through evapotranspiration of water hyacinth and evaporation of water surface (m^3/day)						**58279**	**27475**
Average water losses through evapotranspiration of water hyacinth and evaporation of water surface (million m^3/year)						**21.3**	**10.0**

Kc average: calculated by Meleha (2005).

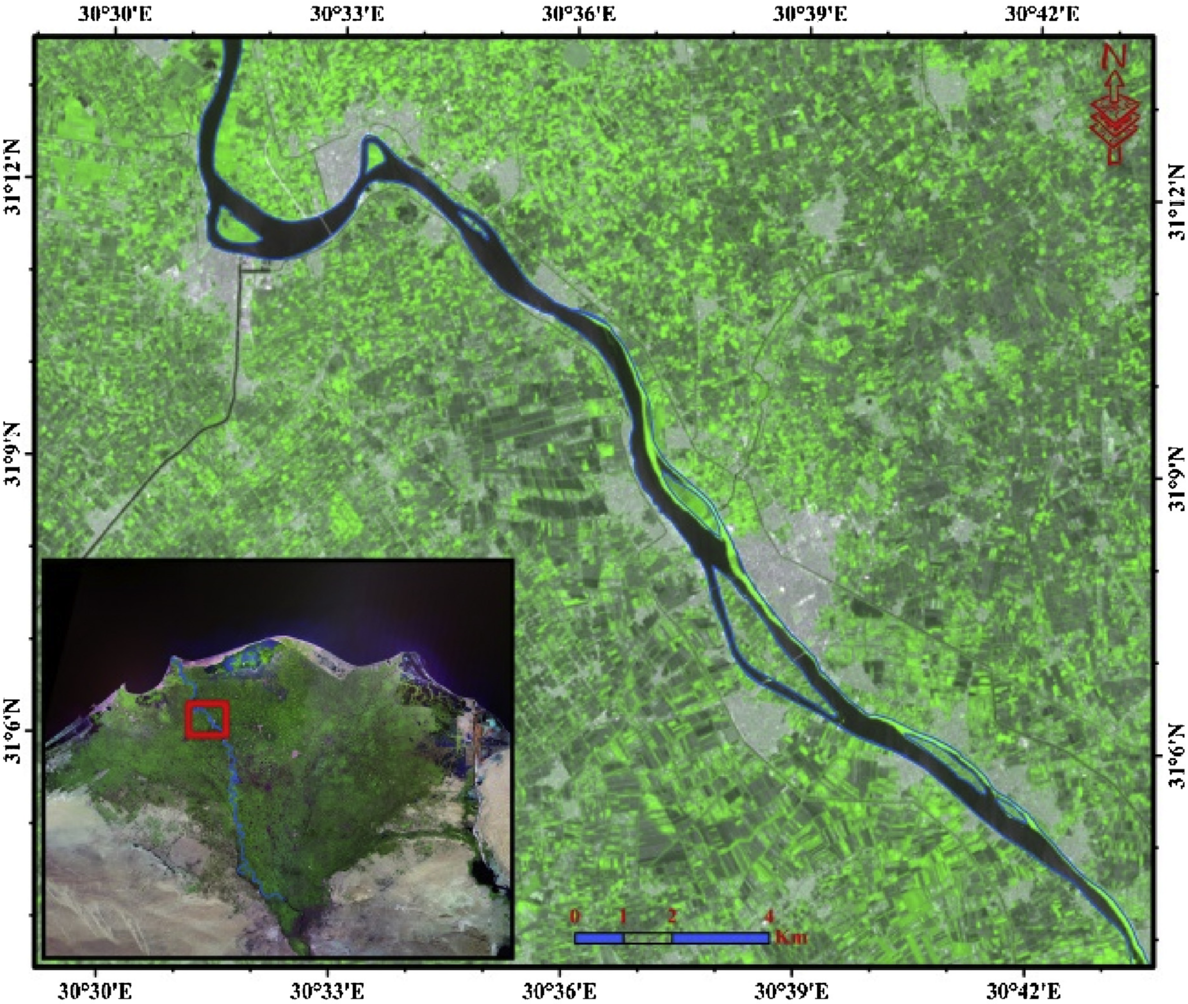


Fig. 4. Aquatic weeds from Desouq city to Fuwah city in 14 May. 2016.

to November 2016. Average daily evapotranspiration rate of water hyacinth was 58,279 m^3/d, while, evaporation of free surface for the same infested area was 27,475 m^3/d. Average annual of water losses of evapotranspiration of water hyacinth was 21.3 million m^3/y and evaporation of free surface for the same infested area was 10.0 million m^3/y. Evapotranspiration of water hyacinth reached 2.13 fold that found in evaporation of free surface for the same infested area, these results agree with both El-Shinnawy et al. (2000) and Brezny et al. (1973), while, disagree with the results obtained by Victor et al. (1987) which was recorded values of evapotranspiration of water hyacinth higher than the values obtained in this research. The highest values of water losses from water hyacinth reached 159,531 m^3/d which recorded in 01 Jul. 2016, while, the lowest values of water losses reached 5695 m^3/d which recorded in 07 Jan. 2016.

Tables 5 and 6 present average water losses through evapotranspiration that were calculated for both of Common Reed and Torpedo grass compared to evaporation of water surface for the same infested area from Rosetta Branch during the period of this research. The results show average daily evapotranspiration rate for both of Common Reed and Torpedo grass was 1875 and 2938 m^3/d, while, evaporation of water surface for the same infested area was 1473 and 2251 m^3/d, respectively. Average annual of water losses of evapotranspiration for both of Common Reed and Torpedo grass was 0.68 million and 1.07 million m^3/y respectively, while, evaporation of water surface for the same infested area was 0.54 million and 0.82 million m^3/y, respectively. Evapotranspiration for both of Common Reed and Torpedo grass reached 1.27 and 1.30 fold that found in evaporation of free surface for the same infested area respectively. These results agree with Angela et al. (2014), while, the results obtained in this research recorded values of evapotranspiration

Table 5
Average water losses through evapotranspiration of Common Reed and evaporation of water surface for the same infected area in the Rosetta Branch from December 2015 to November 2016.

Date	Reach From (km) – To (km)	ETo mm/d	Kc average	$Et = Et_o \times Kc$ mm/d	Infection areas feddan	Water losses of Common Reed m^3/d	Water losses of water surface m^3/d
06 Dec. 2015	0.000–79.000	1.88	1.08	2.03	44.80	382	354
	79.000–162.500	1.73	1.08	1.87	16.64	131	121
	162.500–235.600	1.86	1.08	2.01	30.15	254	235
Water losses of evapotranspiration and evaporation in 6 Dec. 2015					**91.59**	**767**	**710**
07 Jan. 2016	0.000–79.000	1.93	0.69	1.33	21.32	119	173
	79.000–162.500	1.81	0.69	1.25	13.81	73	105
	162.500–235.600	1.72	0.69	1.19	16.62	82	120
Water losses of evapotranspiration and evaporation in 07 Jan. 2016					**51.75**	**274**	**398**
11 Mar. 2016	0.000–79.000	3.96	0.60	2.37	50.93	508	847
	79.000–162.500	3.09	0.60	1.85	20.86	162	271
	162.500–235.600	3.32	0.60	1.99	10.85	91	151
Water losses of evapotranspiration and evaporation in 11 Mar. 2016					**82.64**	**761**	**1269**
14 May 2016	0.000–79.000	6.05	1.24	7.50	42.09	1326	1070
	79.000–162.500	5.03	1.24	6.24	33.99	891	718
	162.500–235.600	5.3	1.24	6.57	27.2	750	605
Water losses of evapotranspiration and evaporation in 14 May 2016					**103.29**	**2967**	**2393**
15 Jun. 2016	0.000–79.000	6.64	1.27	8.43	33.49	1186	934
	79.000–162.500	5.83	1.27	7.40	30.55	950	748
	162.500–235.600	6.03	1.27	7.66	19.69	633	498
Water losses of evapotranspiration and evaporation in 15 Jun. 2016					**83.73**	**2769**	**2180**
01 Jul. 2016	0.000–79.000	6.26	1.28	8.01	28.81	971	757
	79.000–162.500	5.65	1.28	7.23	35.98	1092	854
	162.500–235.600	5.94	1.28	7.60	29.33	936	732
Water losses of evapotranspiration and evaporation in 01 Jul. 2016					**94.13**	**2999**	**2343**
17 Jul. 2016	0.000–79.000	6.26	1.28	8.01	31.29	1053	823
	79.000–162.500	5.65	1.28	7.23	37.75	1146	896
	162.500–235.600	5.94	1.28	7.60	26.73	854	666
Water losses of evapotranspiration and evaporation in 17 Jul. 2016					**95.77**	**3053**	**2385**
19 Sep. 2016	0.000–79.000	5.14	1.98	10.17	11.44	489	247
	79.000–162.500	4.31	1.98	8.53	14.18	508	257
	162.500–235.600	4.72	1.98	9.35	11.36	446	225
Water losses of evapotranspiration and evaporation in 19 Sep. 2016					**36.98**	**1443**	**729**
15 Oct. 2016	0.000–79.000	3.87	1.63	6.31	43.12	1142	701
	79.000–162.500	3.29	1.63	5.36	38.26	862	529
	162.500–235.600	3.53	1.63	5.75	14.82	358	220
Water losses of evapotranspiration and evaporation in 15 Oct 2016					**96.20**	**2362**	**1450**
16 Nov. 2016	0.000–79.000	2.73	1.55	4.23	34.85	619	399
	79.000–162.500	2.41	1.55	3.74	29.65	466	300
	162.500–235.600	2.63	1.55	4.08	15.74	269	174
Water losses of evapotranspiration and evaporation in 16 Nov. 2016					**80.24**	**1354**	**873**
Average water losses through evapotranspiration of Common Reed and evaporation of water surface (m^3/day)						**1875**	**1473**
Average water losses through evapotranspiration of Common Reed and evaporation of water surface (million m^3/year)						**0.68**	**0.54**

Kc average: calculated by Rashed, 2014.

Table 6
Average water losses through evapotranspiration of Torpedo grass and evaporation of water surface for the same infected area in the Rosetta Branch from December 2015 to November 2016.

Month	Reach	ETo	Kc average	Et = $Et_o \times Kc$	Infection areas	Water losses of Torpedo grass	Water losses of water surface
	From (km) To (km)	mm/d		mm/d	feddan	m^3/d	m^3/d
	0.000–79.000	1.88	1.21	2.27	74.37	710	587
06 Dec. 2015	79.000–162.500	1.73	1.21	2.09	26.88	236	195
	162.500–235.600	1.86	1.21	2.25	19.32	183	151
Water losses of evapotranspiration and evaporation in 06 Dec. 2015					**120.57**	**1129**	**933**
	0.000–79.000	1.93	0.8	1.54	54.14	351	439
07 Jan. 2016	79.000–162.500	1.81	0.8	1.45	19.15	116	145
	162.500–235.600	1.72	0.8	1.38	12.11	70	87
Water losses of evapotranspiration and evaporation in 07 Jan. 2016					**85.40**	**537**	**671**
	0.000–79.000	3.96	0.56	2.22	73.66	686	1225
11 Mar. 2016	79.000–162.500	3.21	0.56	1.80	36.08	272	486
	162.500-235.600	3.32	0.56	1.86	15.09	118	210
Water losses of evapotranspiration and evaporation in 11 Mar. 2016					**124.83**	**1076**	**1921**
	0.000–79.000	6.05	1.28	7.74	56.51	1838	1436
14 May 2016	79.000–162.500	3.21	1.28	4.11	49.32	851	665
	162.500–235.600	5.3	1.28	6.78	31.87	908	709
Water losses of evapotranspiration and evaporation in 14 May 2016					**137.69**	**3597**	**2810**
	0.000–79.000	6.64	1.32	8.76	70.38	2591	1963
15 Jun. 2016	79.000–162.500	5.83	1.32	7.69	57.28	1851	1402
	162.500–235.600	6.03	1.32	7.96	28.98	969	734
Water losses of evapotranspiration and evaporation in 15 Jun. 2016					**156.64**	**5411**	**4099**
	0.000–79.000	6.26	1.32	8.26	53.76	1866	1413
01 Jul. 2016	79.000–162.500	5.65	1.32	7.46	57.54	1802	1365
	162.500–235.600	5.94	1.32	7.84	38.39	1264	958
Water losses of evapotranspiration and evaporation in 01 Jul. 2016					**149.68**	**4932**	**3736**
	0.000–79.000	6.26	1.32	8.26	53.48	1856	1406
17 Jul. 2016	79.000–162.500	5.65	1.32	7.46	62.43	1955	1481
	162.500–235.600	5.94	1.32	7.84	52.75	1737	1316
Water losses of evapotranspiration and evaporation in 17 Jul. 2016					**168.65**	**5548**	**4203**
	0.000–79.000	5.14	1.82	9.35	23.4	919	505
19 Sep. 2016	79.000–162.500	4.31	1.82	7.84	26.7	880	483
	162.500–235.600	4.72	1.82	8.59	15.97	576	317
Water losses of evapotranspiration and evaporation in 19 Sep. 2016					**66.07**	**2375**	**1305**
	0.000–79.000	3.87	1.71	6.62	57.16	1589	929
15 Oct 2016	79.000–162.500	3.29	1.71	5.63	43.61	1030	603
	162.500–235.600	3.53	1.71	6.04	15.26	387	226
Water losses of evapotranspiration and evaporation in 15 Oct. 2016					**116.03**	**3006**	**1758**
	0.000–79.000	2.73	1.65	4.50	46.52	880	533
16 Nov. 2016	79.000–162.500	2.41	1.65	3.98	35.55	594	360
	162.500–235.600	2.63	1.65	4.34	16.32	297	180
Water losses of evapotranspiration and evaporation in 16 Nov. 2016					**98.39**	**1771**	**1073**
Average water losses through evapotranspiration of Torpedo grass and evaporation of water surface (m^3/day)						**2938**	**2251**
Average water losses through evapotranspiration of Torpedo grass and evaporation of water surface (million m^3/year)						**1.07**	**0.82**

Kc average: calculated by Rashed (2014).

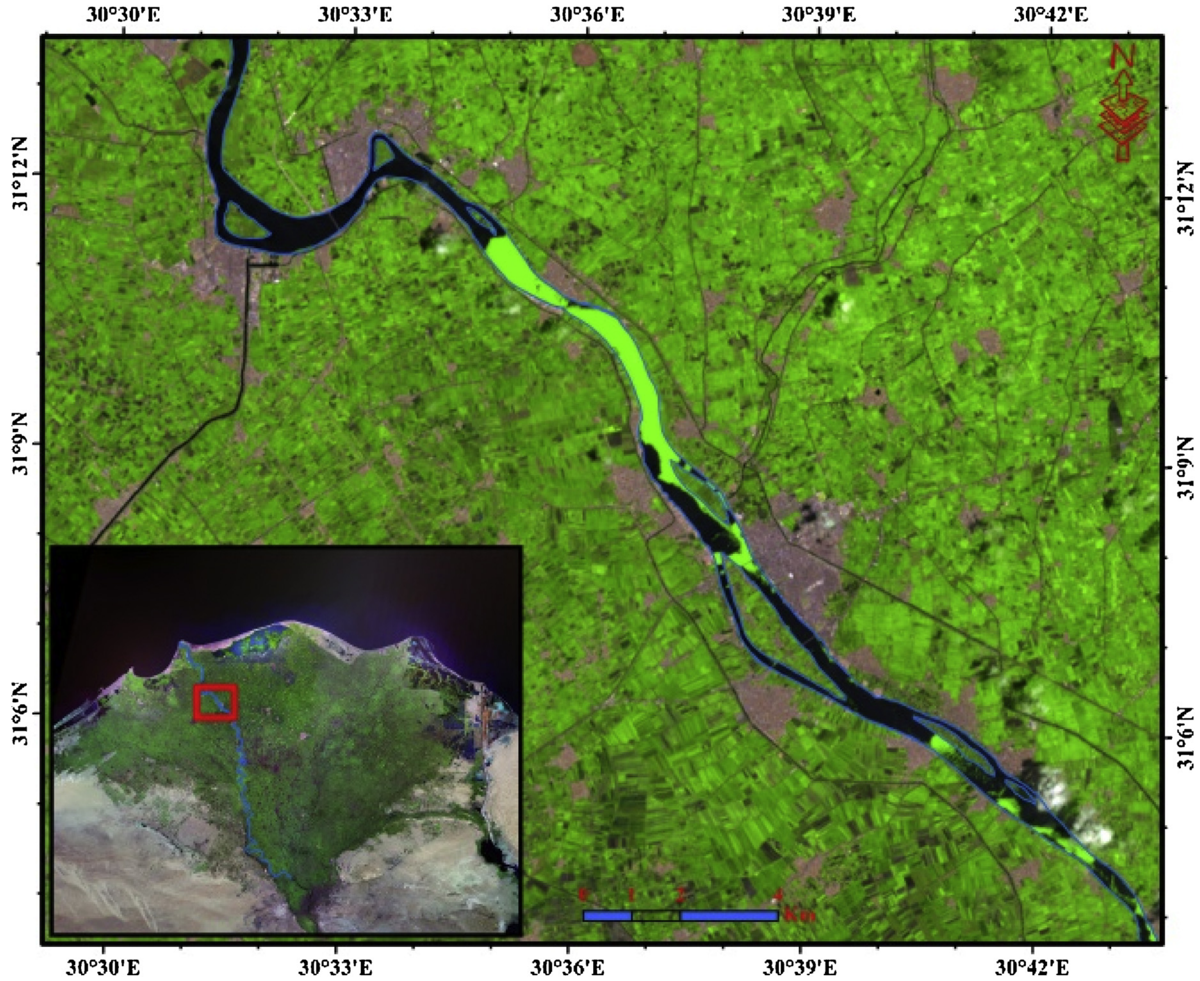


Fig. 5. Aquatic weeds from Desouq city to Fuwah city in 17 Jul. 2016.

for both Common Reed and Torpedo grass less than the values obtained by Florentina et al. (2016) and Rosa et al. (2009) for plants similar to the same species. The highest value of water losses for both of Common Reed and Torpedo grass reached 3053 and 3006 m^3/d respectively which recorded in 17 Jul. 2016 and 15 Oct. 2016, while, the lowest value of water losses reached 274 and 537 m^3/d which recorded in 07 Jan. 2016 for both of them, respectively.

4. Conclusions

Growth of aquatic weeds (water hyacinth especially) in Rosetta Branch causes many serious problems. Wherefore, it must be managed and controlled to a minimum infestation level. Field visits to Rosetta Branch for inventory and classification of various types of aquatic weeds and using of satellite imagery to identify areas and percentages of infestation by the aquatic weeds has been done. Meteorological data collected from meteorological stations located in the Rosetta Branch were analyzed using the program Cropwat 8. The water losses through evapotranspiration of aquatic weeds in the Rosetta Branch during the study period were estimated. It can be concluded that:

- The monitoring of aquatic weeds in Rosetta Branch during the period from December 2015 to November 2016 showed that the infestation areas by different types of weeds, ranged between 679.30–3179.37 feddan of water surface area which is equivalent to infestation percentage ranged between 5.07–20.86%. Infestation areas of water hyacinth, Common Reed and Torpedo grass ranged between 542.15–2935.55, 36.98–103.29 and 66.07–168.85 feddan which

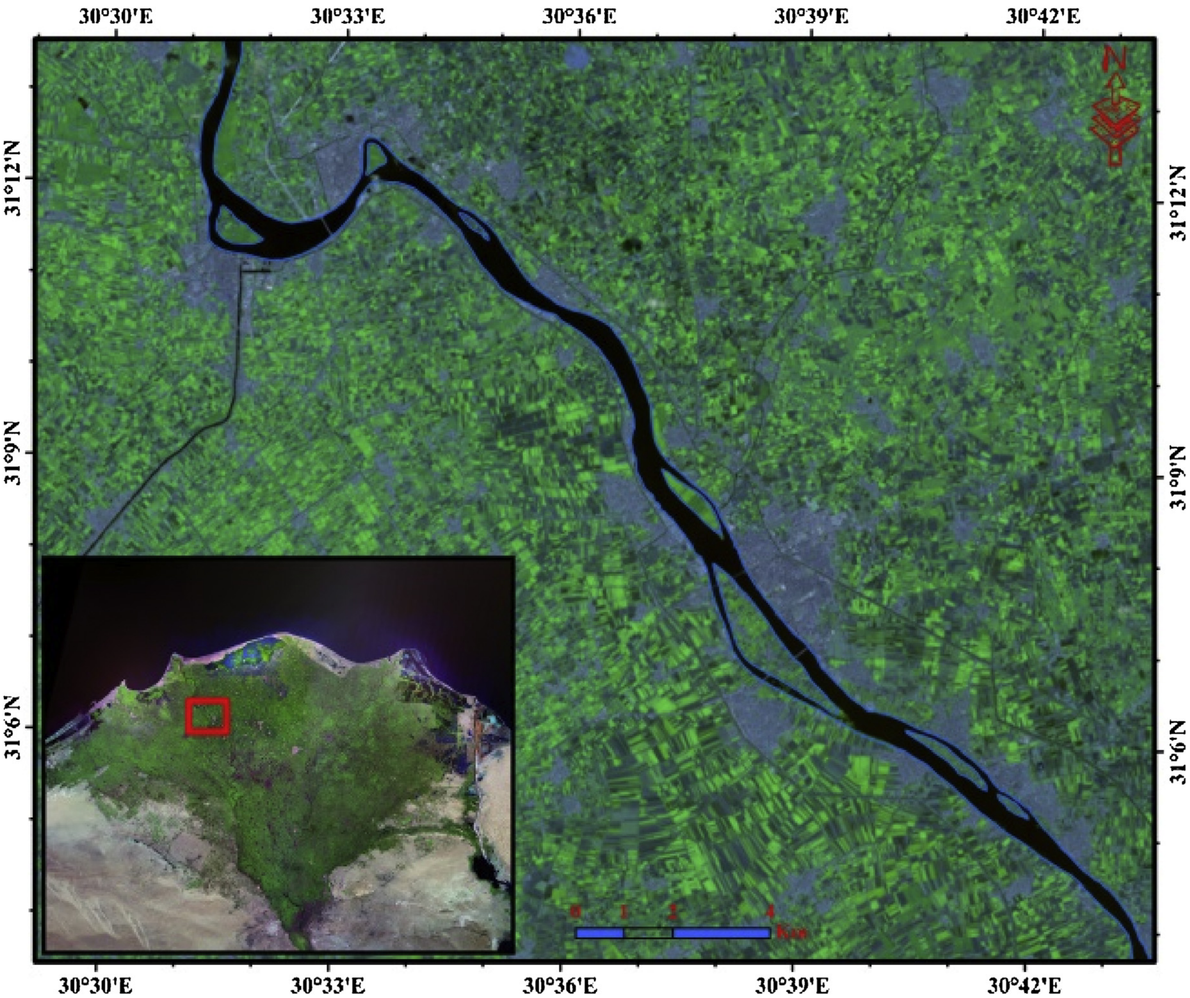


Fig. 6. Aquatic weeds from Desouq city to Fuwah city in 15 Oct. 2016.

is equivalent to infestation percentage ranged between 4.04–19.26, 0.24–0.74 and 0.44–1.20% respectively of the total water surface area of Rosetta Branch.

- In Rosetta Branch, average annual evapotranspiration rate of water hyacinth, Common Reed and Torpedo grass was 21.3 million m^3/y, 0.7 million m^3/y and 1.1 million m^3/y, which represent about 92%, 3%, 5% of evapotranspiration from those weeds respectively. While, evapotranspiration of water hyacinth, Common Reed and Torpedo grass reached 2.12, 1.27 and 1.30 fold that found in evaporation of free surface for the same infected area, respectively.

Thus, it could be concluded that the main problem of water losses through evapotranspiration of aquatic weeds in the Nile River (Rosetta Branch) represented in water hyacinth, according to the present study more than 90% of water losses were from water hyacinth.

5. Recommendations

From the result of this paper, it can be recommended that:-

- Monitoring of aquatic weeds by using geographic information system and remote sensing to estimate the aquatic weeds infestation in irrigation and drainage networks and Nile River (Rosetta Branch especially) is strongly recommended, in order to prepare the maintenance programs for different types of aquatic weeds.

- Id entify a management strategy to reduce the excessive growth of aquatic weeds in Rosetta Branch in order to control the weeds as well as prepare a good maintenance plan and raise the technical capacity of the working teams who are responsible for the maintenance work.
- Removal of aquatic weeds, especially water hyacinth accumulated upstream the barriers with appropriate mechanical equipment for this.
- Do not leave the aquatic weeds, especially water hyacinth on the edges of the waterway to prevent renewed infection as a result of re-falling in the waterway and growth and spread of these weeds.
- Provision of trained technical employment for the operation and maintenance of mechanical equipment used in weed removal.

References

Angela, A., Jaime, A.T.S., Gabor, S., 2014. Evapotranspiration and crop coefficient of common reed at the surroundings of Lake Balaton, Hungary. Aquat. Bot. 116, 01–08.

Brezny, O., Mehta, I., Sharma, R.K., 1973. Studies on evapotranspiration of some aquatic weeds. Weed Sci. Soc. Am. 21, 197–204.

CMRI (Channel Maintenance Research Institute), 2014. Classification and Survey the Aquatic Weeds Infested the Irrigation and Drainage Channels and Nile River during period from 1980 to 2014. Technical Report. Channel Maintenance Research Institute, National Water Research Center, Cairo, Egypt.

El-Samman, T.A., Abou EL-Ella, Salwa M., 2009. Aquatic weeds monitoring and associated problems in Egyptian channels. In: Thirteenth International Water Technology Conference, IWTC 13, Hurghada, Egypt.

El-Shinnawy, A.I., Abdel-Meguid, M., Nour Eldin, M.M., Bakry, M.F., 2000. Impact of Aswan High Dam on the Aquatic Weed Ecosystem. ICEHM2000. Cairo University, Egypt, pp. 534–540, September, 2000.

Florentina, I.S., Neculau, G., Zaharia, L., Toroimac, G.I., Sorin, M., 2016. Study on the evaporation and evapotranspiration measured on the Căldăruşani Lake (Romania). International Conference — Environment at a Crossroads: SMART Approaches for a Sustainable Future.

Khattab, A.F., El-Gharably, Z., 1984. The problem of aquatic weeds in Egypt and methods of management. In: Proc. EWRS 3rd. Symp. on Weed Problems in the Mediterranean Area, Lispona, Protugal, pp. 335–344.

Meleha, M.E., 2005. Calculation of water consumptive use of hayacinth *Elchhornia Crasslpes*. Water Sci. 38, 69–76.

Murphy, K.J., 1988. Aquatic weed problems and their management: a review I. The worldwide scale of the aquatic weed problem. Crop Protect. 7, 232–248.

Peninah, A., Ojwang, W., Omondi, R., Njiru, J.M., Dalmas, O., 2013. A review of the impacts of invasive aquatic weeds on the bio-diversity of some tropical water bodies with special reference to Lake Victoria (Kenya). Biodivers. J. 4, 471–482.

Rashed, A.A., 2014. Assessment of aquatic plants evapotranspiration for secondary agriculture drains (case study: Edfina drain, Egypt). Egypt. J. Aquat. Res. 40, 117–124.

Rosa, C.S., Antunes, R.D., Pitelli, R.A., Pitelli, R.L.C.M., 2009. Comparative evaluation of water losses by evapotranspiration in mesocosms colonized by different aquatic weeds. Planta Daninha Viçosa-MG 27, 441–445.

Timmer, C.E., Weldon, L.W., 1966. Evapotranspiration and pollution of water by water hyacinth. Annual report. In: Soil and Water Conservation. Research Division. Southern Branch, Florida.

Victor, H.L., Rafael, A.S., Maria, D.L., 1987. Evapotranspiration from *Eichhornia Crassipes, Pistia Stratiotes*, *Salvinia Herzogll* and *Azolla Caroliniana* during summer in Argentina. Aquat. Plant Manage. 25, 48–50.

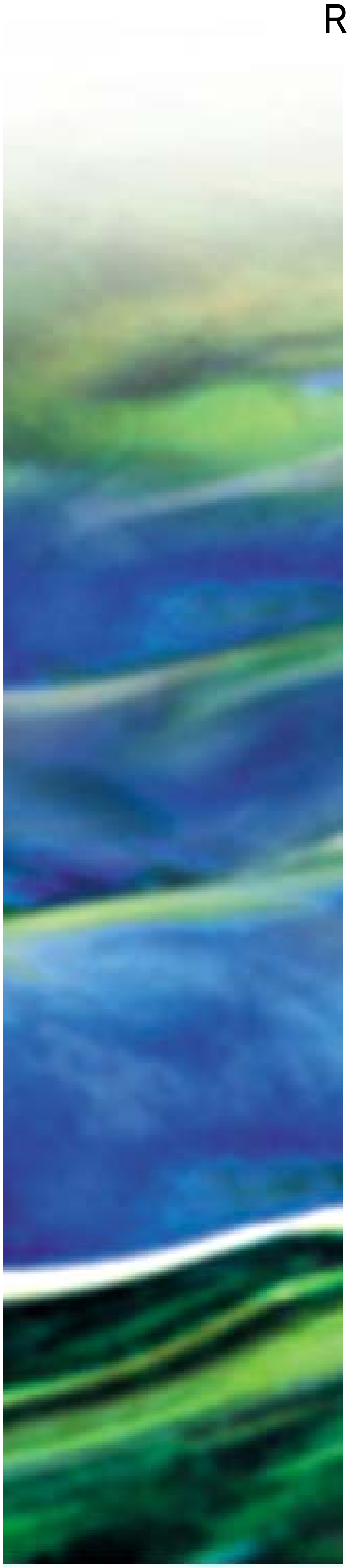
EXHIBIT 6

This attachment is available upon request from DWR at FRPA@water.ca.gov.

EXHIBIT 7

Exhibit DWR-653

REPORT ON THE EFFECTS OF THE CALIFORNIA WATERFIX ON HARMFUL ALGAL BLOOMS IN THE DELTA



Prepared for:

CALIFORNIA DEPARTMENT OF WATER RESOURCES

Prepared by:

ROBERTSON - BRYAN, INC.
Solutions for Progress

March 2017

EXHIBIT DWR-653

REPORT ON THE EFFECTS OF THE CALIFORNIA WATERFIX ON HARMFUL ALGAL BLOOMS IN THE DELTA

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March 2017

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ACRONYMS AND ABBREVIATIONS

BDCP	Bay Delta Conservation Plan
C	Celsius
CEQA	California Environmental Quality Act
cfs	cubic feet per second
CWF	California WaterFix
Delta	Sacramento-San Joaquin Delta
DWR	California Department of Water Resources
EIR/EIS	Environmental Impact Report/Environmental Impact Statement
F	Fahrenheit
ft/s	feet per second
HABs	harmful algal blooms
NAA	No Action Alternative
NEPA	National Environmental Policy Act
N:P	nitrogen:phosphorus
RBI	Robertson-Bryan, Inc.
RDEIR/SDEIS	Recirculated Draft Environmental Impact Report/Supplemental Draft Environmental Impact Statement
USGS	United State Geological Survey

1 QUALIFICATIONS

My name is Dr. Michael Bryan. I am a Principal Scientist and Managing Partner at Robertson-Bryan, Inc. (RBI). I received a Bachelor of Science degree in Fisheries Biology from the University of Wisconsin-Stevens Point in 1986, a Master of Science degree in Fisheries Biology from Iowa State University in 1989, and a Doctor of Philosophy degree in Toxicology and Fisheries Biology from Iowa State University in 1993.

I have 23 years of experience in assessing impacts of water resource projects on water quality and aquatic biological resources in California. My expertise includes assessing measured and modeled data developed to characterize the environmental effects of projects for determining impacts to beneficial uses of waters throughout northern California, with a focus on Central Valley water bodies from Shasta Reservoir to the Sacramento-San Joaquin Delta (Delta). I have worked closely with the Central Valley Regional Water Quality Control Board over the past two decades to assist in developing and adopting eight new water quality objectives for the Central Valley Water Quality Control Plan (Basin Plan). For the California WaterFix (CWF), I led a team of scientists and engineers at RBI in the preparation of the Water Quality Chapter of the Environmental Impact Report/Environmental Impact Statement (EIR/EIS).

My responsibilities at RBI include serving as the Firm’s Managing Partner and technical lead for the practice areas of water quality, fisheries biology, and California Environmental Quality Act/National Environmental Policy Act documentation. Prior to my work at RBI, I was employed by Surface Water Resources, Inc., where I used modeling output from hydrologic models (e.g., PROSIM and CALSIM), temperature models (e.g., Bureau of Reclamation’s [Reclamation] lower Sacramento River and lower American River temperature models), and salmon early life stage mortality models (e.g., Reclamation’s mortality models for the lower Sacramento and American rivers) along with other studies and monitoring data to assess the potential impacts of water diversion and reservoir and dam re-operation projects on water quality and fish resources in the State Water Project and Central Valley Project reservoirs, rivers and Delta. My expertise also includes designing and implementing field and modeling studies to evaluate the impacts of wastewater treatment plant discharges on receiving water beneficial uses. A copy of my statement of qualifications has been submitted as Exhibit DWR-33.

2 PURPOSE AND ORGANIZATION OF REPORT

Testimony provided primarily by Mr. Erik Ringelberg on behalf of the County of San Joaquin, San Joaquin County Flood Control and Water Conservation District and Mokelumne River Water and Power Authority, and Local Agencies of the North Delta, South Delta Water Agency and Central Delta Water Agency [Exhibit SJC 004], and more generally reiterated by Janet McCleary [Exhibit SCDA-62-errata, Frank Morgan [Exhibit SCDA-61-errata], Michael Broadsky [Exhibit SCDA-60-errata], and Tom Burke [Exhibit SCDA-35; Exhibit SDWA-76], Tim Stroshane [Exhibit RTD-10-rev2] and Barbara Barrigan-Parrilla [Exhibit RTD-20], and Fred Lee [Exhibit CSPA-6-Revised] raised concerns regarding the potential for the CWF to result in more frequent harmful algal blooms (HABs) within the Delta. Testimony regarding

HABs provided by Mr. Ringelberg focused primarily on the cyanobacteria *Microcystis aeruginosa*.

This report has been prepared as the technical basis for the expert opinions that I present in my rebuttal testimony regarding the degree to which the CWF would affect HABs within the Delta, with emphasis on *Microcystis aeruginosa* blooms. Specific claims being rebutted by this testimony are quoted under various sections below, followed by evidence supporting my expert opinions on the issues addressed.

Section 3 provides an overview on the environmental factors that trigger the emergence of the most commonly studied HAB genera in Central California – *Microcystis*. Section 4 provides a rebuttal of claims that the CWF would cause an increase in HABs in the Delta, due to increased water temperatures, nutrient effects, decreased flows and turbulence and associated increased residence time, and decreased turbidity. In this section, I provide a detailed assessment of how the CWF could affect river water temperature, river velocity, and turbidity and how such changes in these physical parameters could, in turn, affect HABs in the Delta. In addition, this section provides rebuttal to Mr. Ringelberg's claims that the CWF EIR/EIS should have used models to assess the effects of the project on Delta HABs, that the EIR/EIS analysis should have discussed genera of cyanobacteria other than *Microcystis*, and that the spring is an important time-period for HABs in the Delta.

Since *Microcystis aeruginosa* generally dominates cyanobacteria blooms in the Delta, and cyanotoxins are primarily associated with *Microcystis* (Lehman et al. 2010, 2017; Kudela et al. 2015), most Delta research has focused on *Microcystis aeruginosa* (Kurobe et al. 2013, Lehman et al. 2013, Berg and Sutula 2015) Thus this technical report primarily focuses on *Microcystis*, but will reference other cyanobacteria genera when appropriate.

3 ENVIRONMENTAL FACTORS AFFECTING HARMFUL ALGAE BLOOMS

Cyanobacteria (also commonly called blue-green algae) are a phylum of bacteria that obtain their energy through photosynthesis. The name "cyanobacteria" comes from their color (Greek: "kyanós" meaning "blue"). Cyanobacteria perform photosynthesis in folds within the outer membrane of the cell, rather than within chloroplasts like many other eukaryotic algae. The term cyanoHABs refers to cyanobacteria such as *Microcystis*, *Anabaena*, *Aphanizomenon*, *Oscillatoria* and other genera that can produce harmful algal blooms. The most common and well studied cyanoHAB in the Delta is due to *Microcystis*.

This section is included in this report to provide an overview of the scientific understanding of the primary environmental factors that trigger the emergence and subsequent growth of *Microcystis*. Although focused on *Microcystis spp*., based on the abundance of scientific study of this genera of cyanobacteria, much of the information pertaining to this genera also pertains to *Anabaena* and other cyanobacteria. The information presented here is used as the technical basis from which I rebut the claims regarding effects of the CWF on cyanoHABs within the Delta.

3.1.1 Life History

Toxin producing cyanobacteria have been observed in the Delta since 1999 (Lehman et al. 2005). These blooms are primarily comprised of *Microcystis aeruginosa*. In the Delta, scums are primarily composed of the colonial form of Microcystis, but single cells are also present (Baxa et al. 2010). Other pelagic cyanobacteria including *Aphanizomenon* spp., *Anabaena* spp. (recently renamed Dolichospermum) and *Oscillatoria* have also been detected in the Delta, although generally to a lesser extent than *M. aeruginosa* (Lehman et al. 2010, Spier et al. 2013, Mioni et al. 2012, Berg and Sutula 2015). From August through October 2011, *Aphanizomenon* was identified as the most common cyanobacteria genus in the Delta (Mioni et al. 2012); however, the species of *Aphanizomenon* that has been shown to occur in the Delta is typically not toxic, so when this species is present, it is considered more of a nuisance than harmful to humans and wildlife (Kudela et al. 2015).

Microcystis has an annual life cycle characterized by two phases. The first is a benthic phase, during which cysts overwinter in the sediment. In the second planktonic phase, which occurs during the summer and early fall months, *Microcystis* enters the water column and begins to grow. When environmental conditions, such as sufficiently warm water temperatures, trigger *Microcystis* recruitment from the sediment, the organism is resuspended into the water column (Verspagen et al. 2004, Mission and Latour 2012).

There are five primary environmental factors that trigger the emergence and subsequent growth of *Microcystis* in the water column of Delta waters, which are:

1. Water temperatures >19°C (66.2°F),
2. Low flows and channel velocities resulting in low turbulence and long residence times,
3. Water column irradiance and clarity >50 micromoles per square meter per second (µmoles/m^2/s),
4. Sufficient nutrient availability (nitrogen and phosphorus), and
5. Salinity below 10 ppt.

Although the factors listed above are positively related to *Microcystis* abundance throughout the Delta (Jassby 2005, Lehman et al. 2013, Berg and Sutula 2015, Preece et al. 2017), substantial uncertainty exists with regards to how interaction of these factors result in blooms. To determine the exact processes and interactions of factors that affect development of *Microcystis* blooms in the Delta, additional studies that investigate hydraulic processes and water quality are required (Lehman et al. 2015).

Compared to other phytoplankton species, *Microcystis*, has a relatively slow growth rate (Mur et al. 1999). *Microcystis* blooms typically develop over a period of several weeks after cells emerge from the benthic state (Marmen et al. 2016). Because environmental conditions and benthic recruitment drive *Microcystis* formation within the water column, it is common for many *Microcystis* cells to enter the water column at the same time. Like many cyanobacteria species, *Microcystis* possess specialized intracellular gas vesicles that enable the organism to regulate its buoyancy (Reynolds 1981, as cited in Paerl et al. 2014). This buoyancy allows *Microcystis* to take advantage of near surface areas with optimal growth conditions (e.g., light). Cells collect at the water surface to form colonies and the collection of colonies come together to form a mat or "scum layer," primarily in calm waters, because turbulent waters prevent this phenomenon from occurring. The collection of cells and colonies at the water surface in calm water environments allows *Microcystis* to sustain a competitive advantage over other phytoplankton species by optimizing their photosynthetic needs for light (by being at the water surface) while shading out other algal species that they compete with for nutrients and light via the formation of mats or "scum layers" at the surface (Huisman et al. 2004). Once in the water column, and when environmental conditions are favorable, *Microcystis* multiplies. One study found the doubling time of 32 *Microcystis aeruginosa* strains ranged from 1.5 to 5.2 days, with an average doubling time of 2.8 days (Wilson et al. 2006).

3.1.2 Temperature

Cyanobacteria usually bloom during the summer and early fall when water temperatures are warm. Several studies have found 20°C was the threshold for cyanobacterial growth (Dupuis and Hann 2009, Neuheimer and Taggart 2007 as cited in Rolland et al. 2013). The only available regional temperature threshold information for cyanobacteria is for *Microcystis* (Lehman et al. 2008, 2013), which is 19°C (66.2°F). Temperature is considered the primary factor that typically restricts *Microcystis* development to the summer and early fall months in water bodies of the region (Lehman et al. 2013). Cyanobacteria generally require temperatures above 25°C (77°F) to be competitive with diatoms and temperatures above 20°C (68°F) for growth rates to compete with other algae species (Berg and Sutula 2015). In temperate latitudes, optimal cyanobacteria growth usually occurs between temperatures of 25°C (77°F) and 35°C (95°F) (Reynolds 2006, Lürling et al. 2013). Evidence suggests cyanobacteria growth rates double when temperatures increase from 20°C (68°F) to 27°C (80.6°F) (Lürling et al. 2013, Berg and Sutula 2015).

3.1.3 Flows and Residence Time

Because *Microcystis* has a relatively slow growth rate long residence times are required for cells to accumulate and form significant blooms (Reynolds 1997 as cited in Lehman et al. 2008, Lehman et al. 2013, 2015). Wind and tides can also enhance the aggregation of *Microcystis* cells in slow moving waters (Baxa et al. 2010). Since flushing rates determine residence time, lower channel velocities increase residence time and decrease cyanobacteria loss rates (Romo et al. 2013). Several studies have found longer residence times are positively related to cyanobacteria abundance (Elliott 2010, Romo et al. 2013, Lehman et al. 2017). For example, in the extreme drought year of 2014, Lehman et al. (2017) found long residence times were one factor affecting the magnitude of *Microcystis* blooms within the Delta. Other studies demonstrate that long residence time alone does not cause cyanobacteria blooms to form, even when other environmental conditions are suitable for a bloom. This was exemplified in the Stockton Deep Water Ship Chanel, where there are long summer residence times. Here, a three year study documented a large persistent *Microcystis* bloom in 2012 but not in 2009 or 2011 (Spier et al. 2013). Environmental conditions were similar in 2012 and 2009 and *Microcystis* cells were present in 2009, yet no bloom formed in 2009. No specific environmental factor could be attributed to the 2012 bloom (Spier et al. 2013). This suggests *Microcystis* ecology and competition with other algae is complex, and longer residence times do not necessarily indicate that a bloom will form.

In faster moving, turbulent waters, the ability of *Microcystis* to maintain its positive buoyancy is reduced (Visser et al. 1996). Therefore, higher flow rates (and associated higher channel velocities and turbulence) make it difficult for *Microcystis* to form dense collections of colonies at the water surface. Turbulence affects metabolic processes and cell division (Koch 1993, Thomas et al. 1995, as cited in Li et al. 2013) and thus can be a negative growth factor (Paerl et al. 2001). Moreover, turbulent water mixes all algae throughout the photic zone of the water column and reduces light through turbidity which allows faster growing chlorophytes (green algae) and diatoms to outcompete the slower growing cyanobacteria, including *Microcystis* (Wetzel et al. 2001, Huisman et al. 2004, Li et al. 2013). The magnitude of water velocity required to disrupt *Microcystis* blooms varies substantially by system. Although this information is not specifically available for Central Valley waters, a number of studies report critical velocity rates that disrupt *Microcystis* blooms to be in the 0.1 to 1.3 ft/s range (Mitrovic et al. 2003, Zhang et al. 2007, Long et al. 2011, as cited in Zhang et al. 2015, Mitrovic et al. 2011, Li et al. 2013). For example, in the lower Darling River, Australia, velocities above 1.0 ft/s were shown to quickly disrupt an established cyanobacteria bloom (Mitrovic et al. 2011). In the Zhongxin Lake system China, flow velocities of 0.2 to 1.0 ft/s disrupted *Microcystis* blooms and shifted the dominant phytoplankton species to green algae and diatoms (Li et al. 2013, Zhang et al. 2015). This information from the scientific literature is consistent with what we see in the Central Valley regarding where *Microcystis* blooms often occur (i.e., in calm, low velocity, non-turbulent aquatic environments) (Lehman et al. 2005, 2008, 2013; Berg and Sutula 2015), and where they typically do not occur (i.e., in riverine channels having higher velocities and turbulent flow) (Lehman et al. 2013).

3.1.4 Irradiance

Irradiance plays a critical role in cyanobacteria buoyancy control (Walsby et al. 2004), growth rates, and triggering vertical migration of over-wintering cyanobacteria cells from the sediment. Relatively high irradiances (>50 µmol photons m-2 s-1) have been found to promote maximal cyanobacteria growth rates in the Delta (Berg and Sutula 2015) and are considered a prerequisite for *Microcystis* and *Anabaena* bloom formation (Tsujimura and Okubo 2003, Lehman et al. 2013). Cyanobacteria generally grow ineffectively in well mixed, low light waters, although certain genera (i.e. *Anabaena* and *Cylindrospermopsis*), can grow well in constant low light conditions (Litchman 1998). Other genera, such as *Microcystis* have high light requirements and, thus cannot become dominant in light limited conditions (Huisman 1999). Diatoms are generally more adapted to low light conditions and dominate phytoplankton communities during periods of low average irradiance with high light fluctuations (Reynolds 1994 as cited in Litchman 1998, Litchman 1998). For example, diatoms keep near maximal growth rates in irradiances less than 50 µmol photons m^{-2} s^{-1} (Berg and Sutula 2015). Since cyanobacteria have poor light absorption efficiency in well mixed environments (Reynolds 2006), fluctuating light levels in turbulent waters, conditions often present in spring months, favor diatoms (Reynolds 1983, Kiorboe 1993 as cited in Litchman 1998, Reynolds 2006). Green algae and cyanobacteria can both dominate in high light conditions; however, *Microcystis* and *Anabaena* can use their buoyancy to migrate to the water surface where light is available and utilize high irradiance levels that inhibit other phytoplankton species (Wu et al. 2011 as cited in Lehman et al. 2013).

3.1.5 Nutrients

Nutrients (nitrogen and phosphorus) within the Delta are available annually at levels that are non-limiting to the growth of *Microcystis* (Lehman et al. 2017). With optimal temperatures, flows and residence time, and irradiance, *Microcystis* (and other cyanobacteria) biomass is proportional to nutrient (i.e., nitrogen and phosphorus) availability in the water column (Berg and Sutula 2015). However, recent literature suggests that levels of nitrogen, phosphorus, or their N:P ratio do not control the seasonal or inter-annual bloom variation within the Delta (Lehman et al. 2005, 2008, 2013, 2017; Berg and Sutula 2015). In fresh water bodies, cyanobacteria growth is often associated with excessive phosphorus loading and growth is generally limited by phosphorus rather than nitrogen (Schindler et al. 2008). However, some studies have found total nitrogen alone is the limiting nutrient for algal growth in freshwater bodies (Levine and Whalen 2001). Thus, both phosphorus and nitrogen are important in promoting cyanobacteria growth and subsequent blooms, as is the case with other algae. In general, nutrients typically become limiting to phytoplankton when concentrations fall below 0.07 mg/L dissolved inorganic nitrogen (nitrite, nitrate and ammonia) and 30 µg/L dissolved phosphorus (orthophosphate or soluble reactive phosphorus, Jassby 2005). The amount of total phosphorus in a water body is a fundamental basis for cyanobacteria growth, but concentrations below 100 µg/L are unlikely to cause mass cyanobacteria blooms (Chorus and Cavalieri 2000, World Health Organization 2011). In reviews of stream ecosystems, lakes and reservoirs, total nitrogen concentrations of 0.7-1.5 mg/L were found to support cyanobacteria growth (Dodds et al. 1998).

3.1.6 Toxins

The cyanobacteria toxin, microcystin, was first documented in the Delta in 2003 (Lehman et al. 2005) and has been detected on numerous occasions since (Lehman et al. 2008, 2010, 2013, 2015, 2017; Spier et al. 2013) with increased toxin concentrations generally associated with higher *Microcystis* abundances (Lehman et al. 2013). During the 2014 drought microcystin concentrations were the highest on record for the Delta, frequently exceeding both the World Health Organization (1 µg/L) and Environmental Protection Agency (0.3 µg/L for children under the age of 6) drinking water guidelines (Lehman et al. 2017). Cyanobacteria produce a number of cyanotoxins. In Central California, toxins other than microcystins are not frequently detected (Gibble and Kudela 2014, Berg and Sutula 2015). Like other regions where *Microcystis* occurs, a mix of toxigenic and non-toxigenic strains occurs in the Delta (Baxa et al. 2010). Toxigenic strains and appropriate environmental conditions must be present for microcystin to occur (Marmen et al. 2016). Production of microcystins associated with *Microcystis* blooms is highly variable and not well understood. Nevertheless, *Microcystis* blooms often produce microcystin (Lehman et al. 2015).

4 HABS WITHIN THE DELTA

Mr. Erik Ringelberg, and the others mentioned in the beginning of the report, made numerous statements in their written [e.g. Exhibit SJC-004] or oral testimony [e.g. 11-17-16 and 11-30-16 Transcripts] pertaining to the effect of the CWF on HABs in the Delta that are not based on analyses or independent studies. Thus, his claims that the CWF would cause temperatures and flows to be more conducive to harmful algae bloom formation in the Delta are unsupported. This section provides information and assessment that serve as the technical basis for my rebuttal of key statements from Mr. Ringelberg's testimony.

4.1 ASSESSMENT OF HABS IN EIR/EIS

4.1.1 Use of Models for Delta HAB Formation

In his written and oral testimony, Mr. Ringelberg claims the project proponents should have used models to assess the effects of the CWF on Delta HABs. For example, he stated: "*…it's not rocket science to produce flow-bloom relationships, and it should be done*." [Transcript vol. 29, pg. 50, Ln. 8–12]. In his written testimony, Mr. Ringelberg states: "*Given the wide range of uncertainty regarding the ultimate climate change trajectory, and the temporal difference between when the project is proposed and the more significant impacts of that change in the Delta, the project should use or develop a model for HABs and their formation processes in the Delta, and then provide model support to demonstrate how it will not induce HABs through its operations over the next 20 years*." [Exhibit SJC-004, pg. 13, Ln. 19–23]. Mr. Ringelberg also states: "*There is a detailed Delta food web model, as well as predictive models used for the Potomac and Lake Erie*[1]*. (SJC-046 Durand, 2008, SJC-047 Tango 2009) The project failed to apply any of those models to this project*."[SJC-004, pg. 3, Ln. 7-10].

> ***At this time there is no model to predict Microcystis blooms in the Delta. It will take years of work to develop such a model because there is not sufficient information available currently to develop a predictive, environmental parameter-driven Microcystis model for the Delta. Consequently, the project proponents did not error by not using a model to predict the effects of the CWF on HABs in the Delta because no such model is available to do so.***

A substantial amount of field data are required to develop, calibrate, and verify flow-bloom relationships, and such relationships would be expected to vary by site within the Delta due to complex hydrodynamics and how flows affect channel velocity, turbulence, and residence time, and interact with nutrients, turbidity, and temperature, which also affect HABs. At this time there is not sufficient information available to develop a flow-bloom model. For example, C. Mioni has been attempting to develop hydrodynamic models to predict harmful algal bloom occurrences (Berg and Sutula 2015). Mioni has determined there are no clear physical drivers related to cell or cyanotoxin abundance and that further monitoring and modeling is necessary to develop a complex model to predict HABs development (Berg and Sutula et al. 2015). Furthermore, the Central Valley Regional Water Quality Control Board, the California Environmental Protection Agency, and State Water Resources Control Board have proposed developing a work plan for a modeling strategy, model data requirements, and an implementation strategy for HABs within the Delta (Berg and Sutula 2015). Hence, based on the current state of the science regarding HABs in the Delta, it was not possible for DWR/Reclamation to develop and use a calibrated and verified model to evaluate flow-bloom relationships within the Delta. Such models were not available at the time the CWF EIR/EIS was prepared, they are not available presently, and will not likely be available for years to come.

Later in his testimony, Mr. Ringelberg contradicts his own statements cited above by stating that the development of a flow-HAB model for the Delta would be complex and that much work needs to be done to develop such a model. Specifically, he stated: *"Algae dynamics are literally dynamic. They change spatially; they change temporally; there's lots of moving parts in terms of the actual variables on that. We need to spend a lot more time, a lot more energy, setting up monitoring, looking at a couple factors, developing models, testing those models, working those models out so we can catch up with places like the Potomac, because we have the ability to do so."* [Transcript vol. 29, pg. 58–59, Ln. 21–25, 1–2]. Further, he agrees that the data currently does not exist to develop these models. This is illustrated in his conversation with Ms. Ansley: "*MS. ANSLEY: So this model doesn't specifically provide any information regarding the level of flows that were initiated or maintain a microcystis bloom in the Delta. WITNESS RINGELBERG: To the best of my knowledge, those data don't exist.*" [Transcript vol. 29, pg. 90–91, Ln. 21–25, 1]. Hence, Mr. Ringelberg acknowledges here that models are not currently available to predict HABs in the Delta, and that substantial efforts are required to develop such models. Moreover, by the above-cited statement, he also acknowledges that we cannot simply apply a model developed for the Potomac River to the Delta, but rather have to develop Delta-specific models. Mr. Ringelberg referenced additional models of Durand, 2008 and Tango 2009, which are not applicable to the Delta. Efforts are ongoing by DWR, the Central Valley Regional Water Quality Control Board, the California Environmental Protection Agency, the State Water Resources Control Board and others to collect the field data necessary to develop such models.

Mr. Ringelberg's use of DRERIP (or Delta Food Web Model) is inappropriate because it does not address cyanobacteria. Mr. Ringelberg acknowledges in his oral testimony that the DREIP model does not apply to cyanobacteria. This is illustrated in his conversation with Ms. Ansley. "*WITNESS RINGELBERG: Well, it actually breaks out phytoplankton to finer scales, but it does not, I think to your next question, identify specific blue-green algae. MS. ANSLEY: Correct. It focuses on diatoms and microflagellates? WITNESS RINGELBERG: That's correct.*" [Transcript vol. 29, pg. 89, Ln. 5-11]. Mr. Ringelberg also agrees that the DRERIP model does not provide any information related to flows and *Microcystis* blooms. "*MS. ANSLEY: So this model doesn't specifically provide any information regarding the level of flows that were initiated or maintain a microcystis bloom in the Delta. WITNESS RINGELBERG: To the best of my knowledge, those data don't exist*." Mr. Ringelberg also incorrectly states the United States Geological Survey (USGS) has completed or is working on a modeling exercise for HABs. *"There are other elements to algal growth that I talked about, lights and different nutrient ratios. That's a more sophisticated modeling exercise. That can also readily be done with the information we have today. The USGS is doing that."* [Transcript vol. 29, pg. 50, Ln. 13–17]. Although the USGS is currently collecting water quality and hydrodynamic data to develop a more complete understanding of changes in the Delta's physical, chemical and biological environment, to the best of my knowledge, the agency is not developing a model to predict HABs.

At this time there is no model to predict *Microcystis* blooms in the Delta (Berg and Sutula 2015), and it will take years of work to develop such a model. Consequently, the project proponents did not error by not using a model to predict the effects of the CWF on HABs in the Delta because no such model is available to do so. Without a model being available, the CWF Recirculated Draft EIR/Supplemental Draft EIS (and Final EIR/EIS published in December 2016) identified what is known about the key drivers of *Microcystis* blooms in the Delta, and evaluated how the CWF could affect those drivers and thus how the CWF would be expected to affect *Microcystis* blooms in the Delta.

4.1.2 Microcystis vs. Other HABs

Mr. Ringelberg also claims the project proponents should not have looked at only a single HAB genera (*Microcystis*): "*Where there is any project analysis regarding HABs, the project impacts are largely ignored, and, instead, what limited analysis exists is solely and incorrectly focused on the nutrient data, and their relationship to the blooms of a single species, Microcystis aeruginosa.* (SCWRB-3 RESIRC 2622 Pg. 14-20)" [Exhibit SJC-004, pg. 5, Ln. 15–18]. Mr. Ringelberg also claims; "*The--the focus on a single, readily understood organism, microcystis is a diversion away from the other microcystin and other algal toxin creating blue-green algae or microbacteria and have the potential of creating multiple kinds of algal blooms with different kinds of toxicity, different rations, different mixes of different toxins*." [Transcript vol. 29, pg. 100, Ln. 1-8].

As discussed above in Section 3, HABs in the Delta and its tributaries are primarily comprised of *Microcystis aeruginosa.* Although *Aphanizomenon spp*. and *Anabaena spp*. (recently renamed *Dolichospermum* spp.), and *Oscillatoria* spp. have also been detected in the Delta (Lehman et al. 2010, Mioni et al. 2012), there is limited information available on these genera. Therefore, most Delta research has focused on annual *Microcystis* blooms (Kurobe et al. 2013, Lehman et al. 2013). For example, in their report titled: "Factors Affecting Growth of Cyanobacteria with Special Emphasis on the Sacramento-San Joaquin Delta," Berg and Sutula (2015) state (p. 35, paragraph 3): "*Because Aphanizomenon and Anabaena densities have only been documented for two time points, the following sections will focus on Microcystis biomass and microcystin toxin concentrations.*" Furthermore, cyanotoxins other than microcystin are not frequently encountered in the Delta. Hence, because most of the HAB data available for the Delta is associated with *Microcystis*, and because *Microcystis* is the cyanobacteria genera of greatest concern in the Delta, it was appropriate for the CWF EIR/EIS to focus on assessing the harmful algae genera *Microcystis*.

4.1.3 Spring as an Important Bloom Period

Mr. Ringelberg claims in his written testimony that spring is now an important period for blooms. He states, *"Moreover, because of the current drought conditions, spring is now an important period for bloom formation. (SJC-048 Glibert et al. 2014)"* [Exhibit SJC-004, pg. 4, Ln. 9–11]. Mr. Ringelberg used incorrect information to support this statement by using the

Glibert et al. (2014) paper, which refers to diatoms and green algae and does not mention cyanobacteria occurring during spring months. Mr. Rinbelberg admitted on cross examination that the Glibert et al. (2014) did not refer to cyanobacteria. "*MS. ANSLEY: And isn't it true that the bloom observed in 2014 was, depending on location, dominated by chlorophytes and diatoms but not microcystis; is that correct? WITNESS RINGELBERG: (Nodding head.)*" [Transcript vol. 29, pg. 102, Ln. 5–9]. Mr. Ringelberg goes on to explain in his oral testimony that he used the Glibert et al. (2014) paper to illustrate that the bloom formation was novel. Mr. Ringelberg states: "*The intent of the study was not a synoptic study to identify algal blooms, it was to look at algal blooms that they were able to identify in the field recon and provide samples of those.*" [Transcript vol. 29, pg. 103, Ln. 10-13]." Glibert et al. (2014) used cell counts to identify a variety of phytoplankton species, but did not mention a single cyanobacteria species. Instead, the paper highlights the positive aspects of the dominant spring diatom and green algae bloom by highlighting the importance of community composition. Specifically, results from the research suggest the importance of diatoms and green algae to the Delta food-web, particularly delta smelt prey items. In comparison, cyanobacteria have poor nutritional value and are not beneficial to the food web. Thus, Mr. Ringelberg is incorrect to assume that the presence of a spring phytoplankton bloom is correlated to being an important period for cyanobacteria formation.

Compared with other phytoplankton genera, cyanobacteria have lower growth rates in colder temperatures. In the Delta, *Microcystis* blooms are generally restricted to summer months between June and November when water temperatures are greater than 19°C (Lehman et al. 2013). Although other factors (nutrients, surface irradiance) generally become sufficient for *Microcystis* growth between March and June, water temperature is generally the limiting factor that prevents *Microcystis* formation in the Delta until water temperatures exceed 19°C, which typically does not happen until June (Lehman et al. 2013). Although water temperature during the spring months is often too cold to support *Microcystis* or other cyanobacteria (e.g., *Aphanizomenon* and *Anabaena*) blooms (Msagati et al. 2006 as cited in Mioni et al. 2012, Berg and Sutula 2015), in the extreme drought year of 2014, elevated spring water temperatures in the Delta extended the *Microcystis* bloom by at least two months in the spring and another two months in the fall. This resulted in an increased duration (eight months) of the *Microcystis* bloom, twice as long as previous bloom seasons (Lehman et al. 2017). This information suggests blooms can form in spring months under severe droughts and when water temperatures are sufficiently high in the spring months, but spring blooms of *Microcystis* have historically been rare in the Delta. The CWF will not result in extreme drought-like conditions in the Delta, relative to the NAA [see also Exhibits DWR-514; DWR-86], and thus spring cyanobacteria blooms are not expected to occur as a result of the CWF.

4.2 River Flows and Velocity Effects of the CWF

Mr. Ringelberg claims the CWF would increase harmful algae blooms in the Delta due to decreased flows. He states: "*The proposed project influences flow and water quality within Sacramento San Joaquin Delta as a result of this diversion, and those factors further influence the formation of Harmful Algal Blooms ("HABs" or cyanoHABs).*" [Exhibit SJC-004, pg. 1, Ln 24–27]. Mr. Ringelberg provides only unsubstantiated claims and he completed no analysis of how the CWF would alter flows at specific locations, or how such flow changes would influence the formation of HABs, based on the scientific literature.

Mr. Ringelberg, Mr. Burke, and Mr. Lee claim the CWF would increase harmful algae blooms in Discovery Bay due to decreased flows, diversions and/or reductions of flows from the Sacramento River. Mr. Ringelberg states: "*The Petition completely fails to identify or analyze the potential for the project to create or to exacerbate impacts to human health and the environment from blue-green algae (cyanobacteria) and their toxins, within Discovery Bay*." [Exhibit SCDA_33, pg. 2, Ln. 1–3]. He also states: "*Although not addressed at all in the Petition (DWR 1-3) the project is likely to create localized flow conditions that are likely to significantly exacerbate algal and aquatic weed growth. Toxic (and non-toxic) aquatic invasive plants can lead to many potential environmental problems created by the project both in the near-term and cumulatively. Reducing the flow of Sacramento River water through the Delta and concentrating the drainage of the San Joaquin River affects the dilution and the mixing of nutrients*." [Exhibit SCDA_33, pg. 2, Ln. 9–14].

Mr. Burke states: "*If diversions are shifted to the proposed NDD, this dilution effect will be reduced or eliminated. This will result in a higher nutrient loads for waters in and around Discovery Bay. All things being equal, higher nutrient loads can lead to algal blooms which reduce dissolved oxygen and lead to degradation of water quality*." [Exhibit SCDA-35, pg. 2, Ln. 22–25].

Mr. Lee states: "*The proposed WaterFix project's diversion of Sacramento River water will reduce the amount of Sacramento River water that enters the Central Delta and thereby impact the phosphorus input to the Central Delta and the phytoplankton population in that area of the Delta. The reduction in dilution of phosphorus concentration in the Central Delta leads to impaired water quality and adverse impacts/injuries to the public/users of Central Delta waters*." [Exhibit CSPA-6-Revised, pg. 17].

See also Mr. Stroshane [RTD 10-Rev 2] generally stating that increased residence time would increase *Microcystis* blooms.

Mr. Ringelberg, Mr. Burke, Mr. Lee and Mr. Shroshane did not provide any evidence to support their claims that the CWF would decrease flows and associated channel velocity and thus turbulence and mixing, and increase residence time, in the Delta. Likewise, Mr. Ringelberg, Mr. Burke and Mr. Lee did not provide any evidence to support their claim that the CWF would increase nutrients in the Discovery Bay area by magnitudes that would affect *Microcystis* blooms. Consequently, their claims are speculative and unsupported. To rebut such unsubstantiated claims, the following analysis is provided.[1]

[1] For a response to Mr. Ringelberg, Mr. Burke and Mr. Lee's comments regarding nutrients, see Section 4.6 of this report.

Based on the nine Delta locations assessed below with regards to daily maximum and absolute 15-minute channel velocities (regardless of direction of flow), modeling shows that the CWF would not substantially increase the frequency with which low channel velocities would occur, relative to the NAA. Consequently, the CWF will not create hydrodynamic conditions that would be substantially more conducive to the occurrence of Microcystis blooms in the Delta relative to the NAA.

Flow (measured in cubic feet per second (cfs)) is a measure of the volume of water passing a specified location within a channel, whereas velocity (measured in feet per second (ft/s)) is the measure of how rapidly the water is moving within a channel. Channel velocity is the primary driver of channel turbulence and mixing, in-channel generated turbidity, and hydraulic residence time – all of which can affect cyanoHABs. If a channel is large and has substantial cross-sectional area, the channel may have a relatively high flow (cfs) despite having a relatively low velocity (ft/s). Conversely, if a channel has a small cross-sectional area, it may have a relatively low flow (cfs), but a relatively high velocity (ft/s). The distinction between flow and velocity is important when evaluating cyanobacteria because it is not the volume of water moving through a channel, but rather the velocity with which the water moves that most affects the ability of cyanobacteria to out-compete other algae, as discussed further below. Consequently, this assessment compared modeled channel velocity for the CWF and NAA scenarios to determine the hydrodynamic effects of the CWF on cyanoHABs in the Delta, with an emphasis on *Microcystis* blooms.

In calm waters, *Microcystis* cells can move to the water surface through the control of their buoyancy via gas vesicles within the cells (Reynolds 2006). Cells come together to form colonies and then colonies join together to form mats or "scum" layers at the water's surface. Here, the dense mats of *Microcystis* shade-out the other algal species and thus out-compete the other algae for light and nutrients which fuel their bloom. In higher velocity, turbulent waters, this life history strategy is disrupted. Higher velocity, turbulent water mixes all algae throughout the photic zone of the water column and reduces light through turbidity which allows faster growing chlorophytes (green algae) and diatoms to out-compete the slower growing cyanobacteria, including *Microcystis* (Wetzel et al. 2001, Huisman et al. 2004, Li et al. 2013). Because all algae present are mixed from the channel surface to bottom in turbulent flowing water, *Microcystis* cells cannot control their location in the water column and thus cannot as readily, if at all, form the dense collection of cells and colonies at the water's surface as occurs in calm waters.

As stated in Section 3.1.3, the channel velocity required to disrupt *Microcystis* blooms varies by system, with studies reporting critical velocity rates of 0.1 to 1.3 ft/s (Mitrovic et al. 2003, Zhang et al. 2007, Long et al. 2011 as cited in Zhang et al. 2015, Mitrovic et al. 2011, Li et al. 2013). For example, in the lower Darling River, Australia, velocities above 1.0 ft/s were shown to quickly disrupt an established cyanobacteria bloom (Mitrovic et al. 2011). In the Zhongxin Lake system China, flow velocities of 0.2 to 1.0 ft/s disrupted *Microcystis* blooms and shifted the dominant phytoplankton species to green algae and diatoms (Li et al. 2013, Zhang et al. 2015).

Channel velocity also dictates residence time within a channel reach because velocities dictate the flushing rate for the reach. Hence, to assess the effects of flow changes caused by the CWF on cyanobacteria, this assessment evaluates channel velocity because velocity is the primary driver of channel turbulence and mixing, in-channel generated turbidity, and residence time – all of which can affect cyanobacteria and its ability to produce blooms.

The velocities are from the Delta Simulation Model II (DSM2) modeling that was conducted in support of DWR's water right petition and case-in-chief for Alternative 4A, operations scenarios 4A-H3 and 4A-H4 (called 4A-H3 and 4A-H4 herein), and Boundary 1 and Boundary 2 scenarios, as well as the No Action Alternative (NAA) scenario.

The analysis presented below focuses on how the CWF would affect daily maximum velocity and 15-minute absolute velocity (regardless of direction) in channels of the Delta. Daily maximum velocity is assessed because the Delta channels are tidal and thus flows are slowed, and can reverse direction in most channels daily, on the tidal cycle. As such, mathematical daily average velocity may approach zero when flows on the tidal cycle move in opposite directions, and thus is not very useful for determining how channel velocity affects cyanobacteria. In such tidally influences channels, daily maximum velocity and 15-minute absolute velocity (regardless of direction) are the parameters that best characterize the degree of channel mixing that occurs daily. Hence, this analysis determines how the CWF would affect daily maximum and 15-minute absolute velocity, relative to the NAA. Once CWF-driven reductions in channel velocity were determined, the effect that such reductions could have on *Microcystis* blooms in the Delta channels was then determined, based on the scientific literature.

Microcystis blooms have historically been observed in the south and central Delta channels where channel velocities can be low and thus more conducive to bloom formation. Based on studies by Lehman et al. 2008, 2013, Mioni et al. 2012 and Spier et al. 2013, the areas of the Delta that have most often experienced substantial blooms of *Microcystis* are in the Central Delta, between Antioch and Mildred Island. In 2012, substantial *Microcystis* blooms were also observed in the Southeast Delta within the Stockton Deepwater Ship Channel (Spier et al. 2013). *Microcystis* abundance decreases moving west from Antioch to Suisun Bay and it is almost non-detectable by Chipps Island (Lehman et al. 2005, 2008, 2010). *Microcystis* abundance also substantially decreases moving north from Antioch. The locations assessed below for velocity were chosen because they represent: 1) key locations where channel velocities may change due to the proposed north Delta diversions, and 2) areas of the Delta (south and central Delta channels) that have historically experienced *Microcystis* blooms.

Sacramento River at Freeport

At Freeport on the lower Sacramento River, included in this assessment to evaluate river velocities upstream of the proposed north Delta diversions, DSM2 modeling output shows that daily maximum velocity would be above 1.0 ft/s all the time. The frequency with which any given velocity above 1.0 ft/s would be exceeded for the CWF scenarios modeled (i.e., 4A-H3, 4A-H4, BNDY 1 and BNDY 2) would be similar to or greater than that for the NAA (**Figure 1**). Hence, the CWF would not decrease, but rather would often increase, daily maximum velocity at

Freeport, relative to that which would occur for the NAA. Consequently, the CWF would maintain similar or somewhat greater turbulent flow conditions in the lower Sacramento River at Freeport, relative to the NAA, which would not provide more favorable flow conditions for *Microcystis* blooms in the river. In fact, based on the scientific literature cited above and the daily maximum velocities shown in Figure 1, one would not expect cyanobacteria to outcompete diatoms and green algae in the lower Sacramento River at Freeport under the CWF or NAA scenarios. Water temperature and nutrient levels have been adequate to support *Microcystis* in the river near Freeport during the summer, annually, but the river's velocities, turbulent flow, and turbidity have prevented *Microcystis* blooms from occurring here in the past. This would be expected to continue in the future under the CWF.

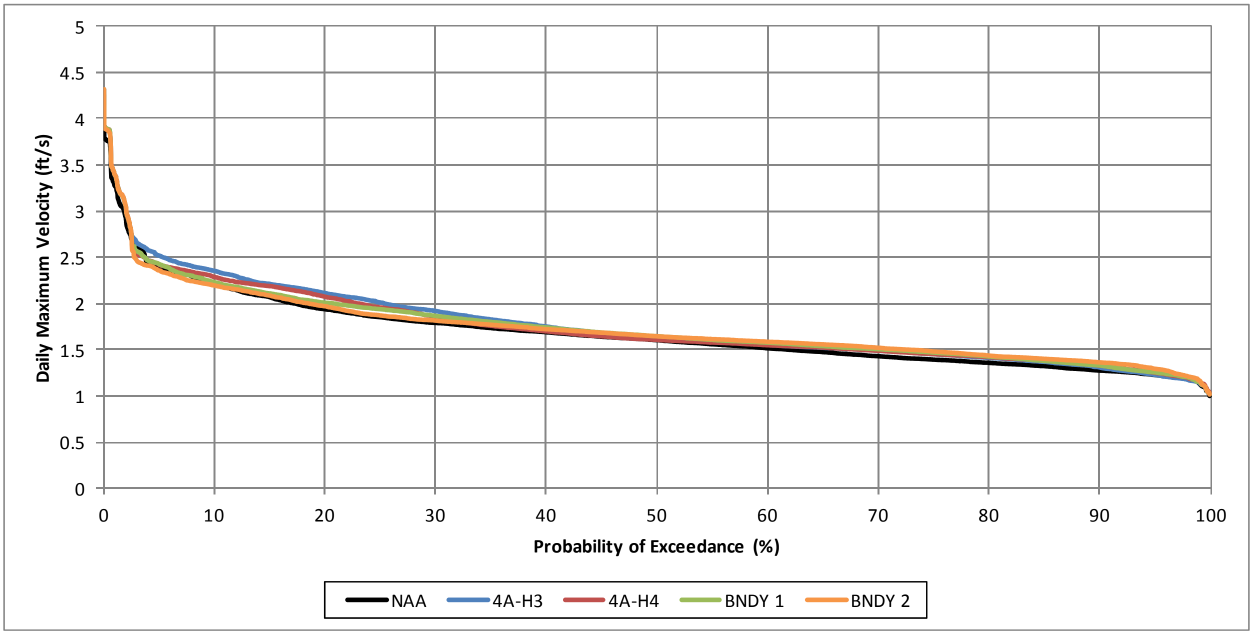


Figure 1. Probability of exceedance of daily maximum velocity in the lower Sacramento River at Freeport for the 1976–1991 period of record modeled.

Lower Sacramento River at Rio Vista

The lower Sacramento River at Rio Vista was assessed because it is downstream of the proposed north Delta diversions and Delta Cross Channel located at Walnut Grove, and upstream of the river's confluence with the San Joaquin River. DSM2 modeling output shows that the frequency with which any given daily maximum velocity would occur in the lower Sacramento River at Rio Vista, downstream of the new north Delta intakes, would be virtually the same for the CWF scenarios, relative to the NAA (**Figure 2**). The same is true when looking at the absolute value of channel velocities (regardless of direction), as modeled by DSM2 on a 15-minute time-step at this location during the months June through November (**Figure 3**). Consequently, from a flow velocity and associated river turbulence, mixing, and residence time perspective, the CWF would not increase the potential for *Microcystis* blooms to occur in the lower Sacramento River, in the vicinity of Rio Vista, relative to that for the NAA.

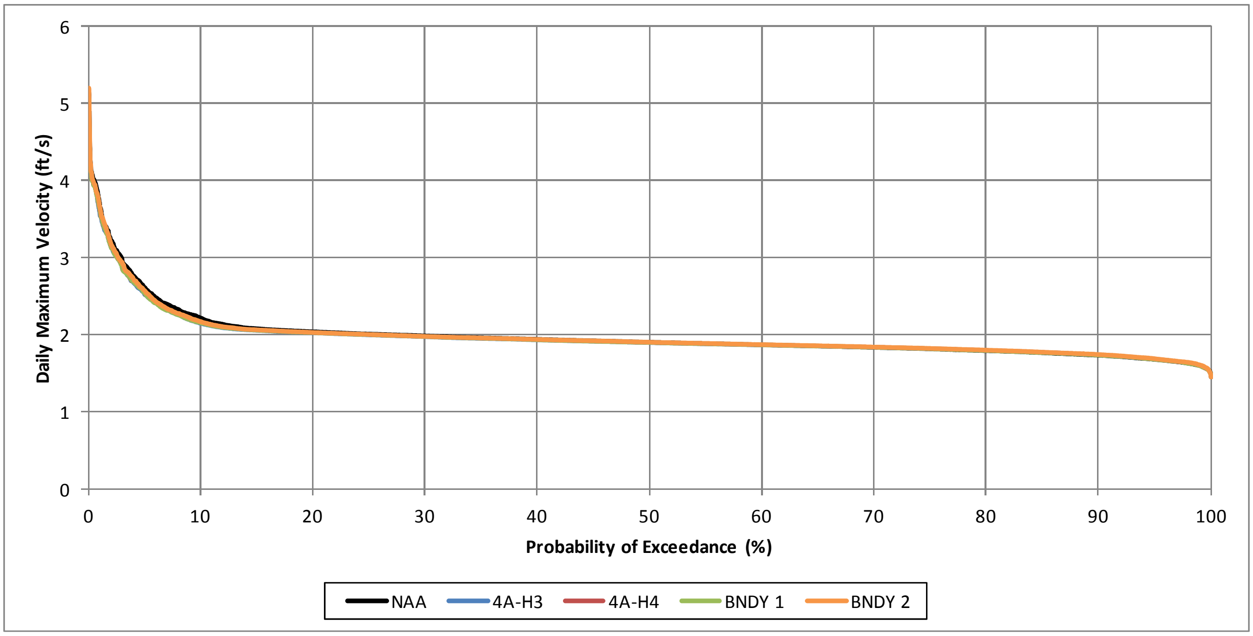


Figure 2. Probability of exceedance of daily maximum velocity in the lower Sacramento River at Rio Vista for the 1976–1991 period of record modeled.

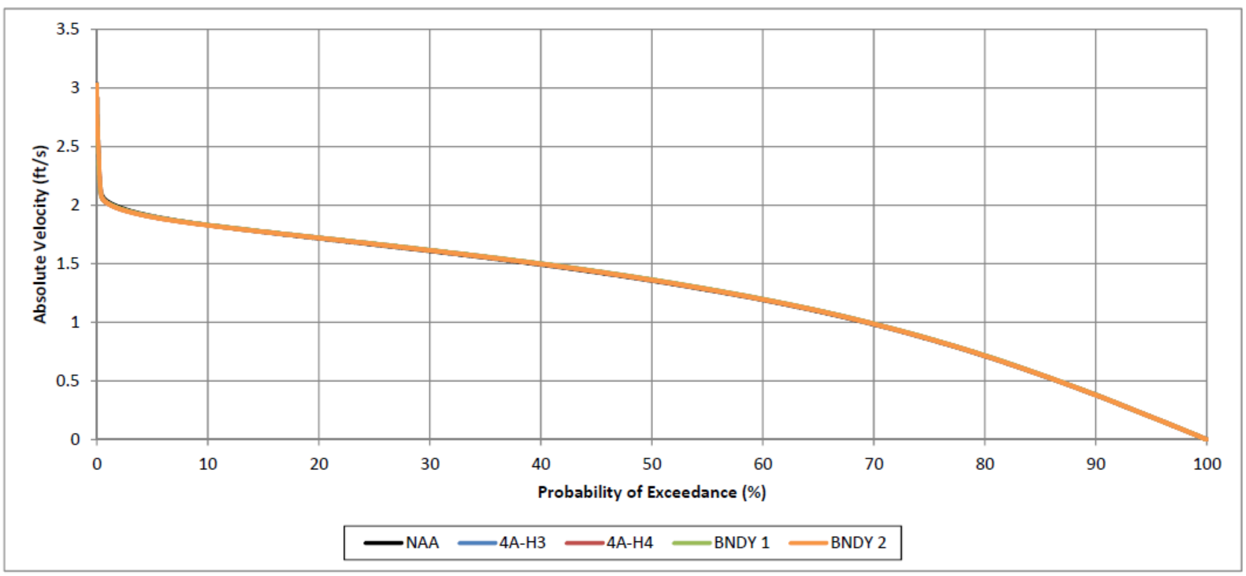


Figure 3. Probability of exceedance of absolute values of daily velocities, on a 15-minute time-step, in the lower Sacramento River at Rio Vista during the months June through November for the 1976–1991 period of record modeled.

San Joaquin River at Brandt Bridge and Antioch

These locations were selected because they book-end the San Joaquin River, across the central Delta, from east to west. The frequency with which any given daily maximum velocity would be exceeded in the San Joaquin River at Brandt Bridge (**Figure 4**) and Antioch (**Figure 6**) for the CWF scenarios would be the same or greater than that for the NAA. The same is true when looking at the absolute value of channel velocities (regardless of direction), as modeled by DSM2 on a 15-minute time-step at these locations during the months June through November (**Figure 5** and **Figure 7**). Consequently, the CWF would maintain similar to somewhat greater turbulent flow, mixing, and resident time conditions in the San Joaquin River, relative to the NAA, which would not provide more favorable flow conditions for *Microcystis* blooms in the river. Because velocities above 1.0 ft/s were shown to quickly disrupt an established cyanobacteria bloom (Mitrovic et al. 2011) and flow velocities of 0.2–1.0 ft/s disrupted *Microcystis* blooms and shifted the dominant phytoplankton species to green algae and diatoms (Li et al. 2013, Zhang et al. 2015), because daily maximum velocities at Brandt Bridge and Antioch would always be at or above 1 ft/s based on modeling output, and because the frequency with which any given velocity would occur would be about the same or greater for the CWF, relative to the NAA, at both locations for the months June through November (Figure 5 and Figure 7), one would not expect cyanobacteria to outcompete diatoms and green algae in the San Joaquin River in the vicinity of Brandt Bridge or Antioch under the CWF or NAA scenarios. Based on the similarity in channel velocities between the scenarios, turbulence and mixing and resident time conditions would not be expected to be substantially more favorable for cyanobacteria for the CWF scenarios, relative to the NAA scenario. Hence, the potential for cyanobacteria blooms to occur at these river locations would not be substantially increased by the CWF channel velocities, relative to channel velocities that would occur for the NAA.

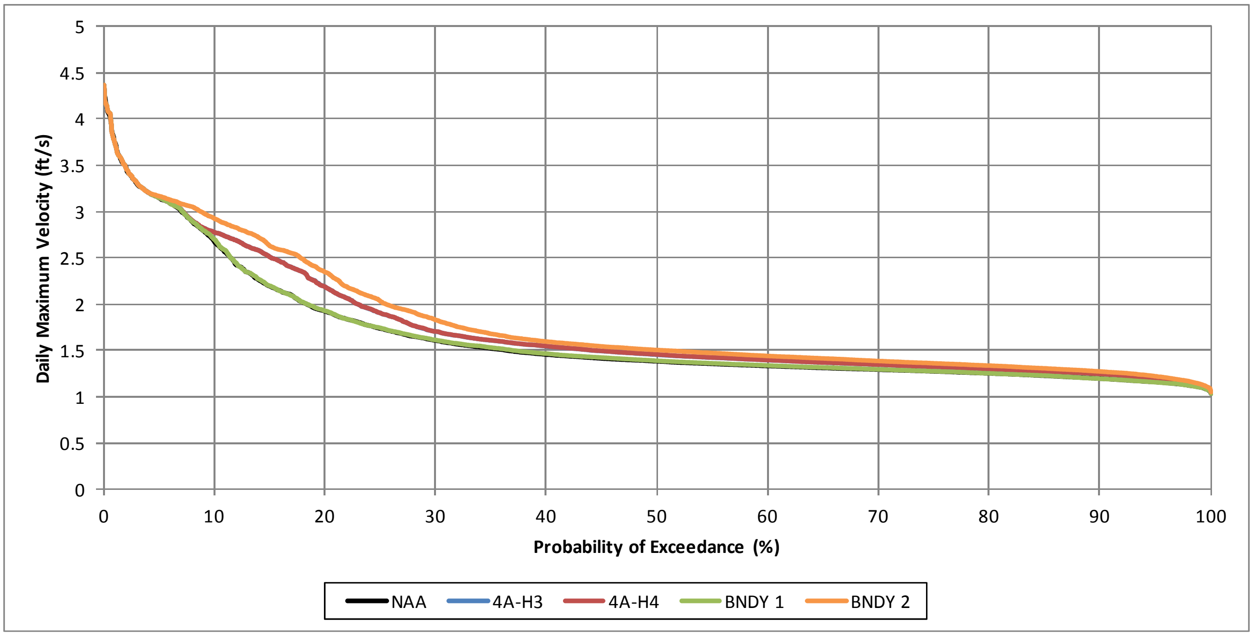


Figure 4. Probability of exceedance of daily maximum velocity in the San Joaquin River at Brandt Bridge for the 1976–1991 period of record modeled.

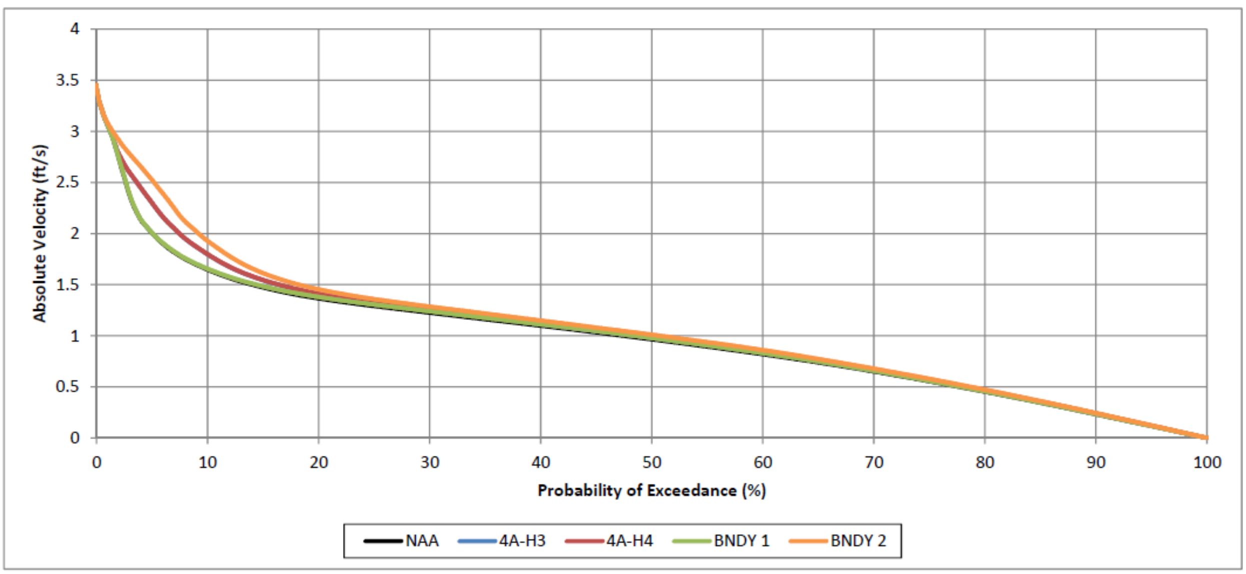


Figure 5. Probability of exceedance of absolute values of daily velocities, on a 15-minute time-step, in the San Joaquin River at Brandt Bridge during the months June through November for the 1976–1991 period of record modeled.

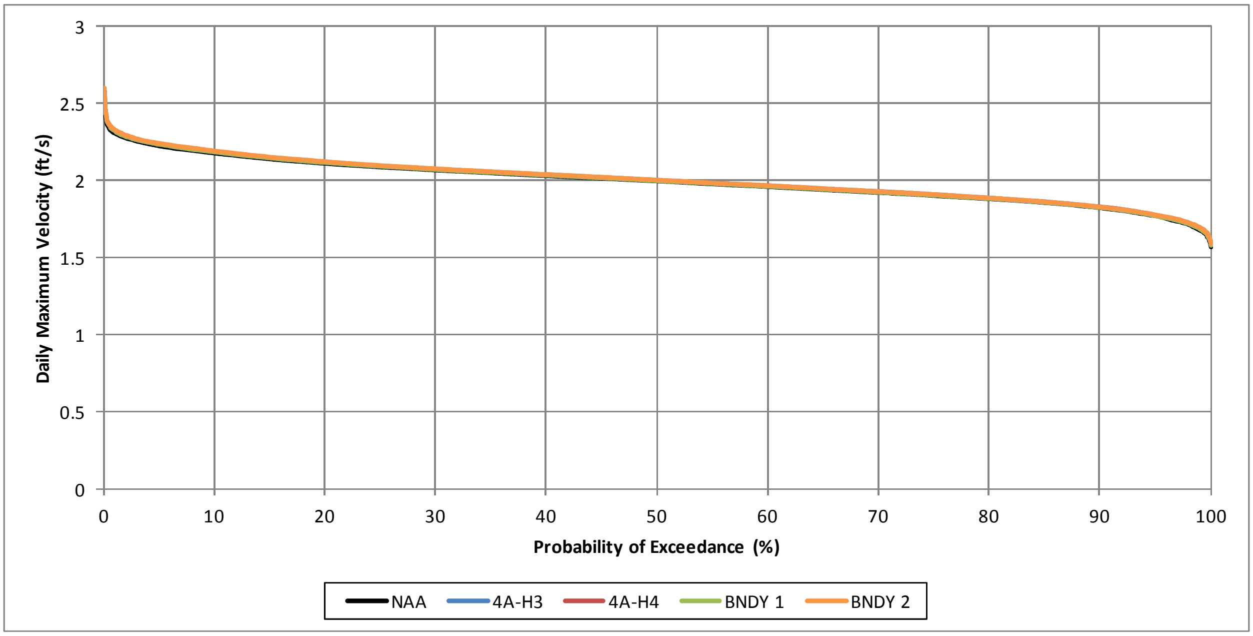


Figure 6. Probability of exceedance of daily maximum velocity in the San Joaquin River at Antioch for the 1976–1991 period of record modeled.

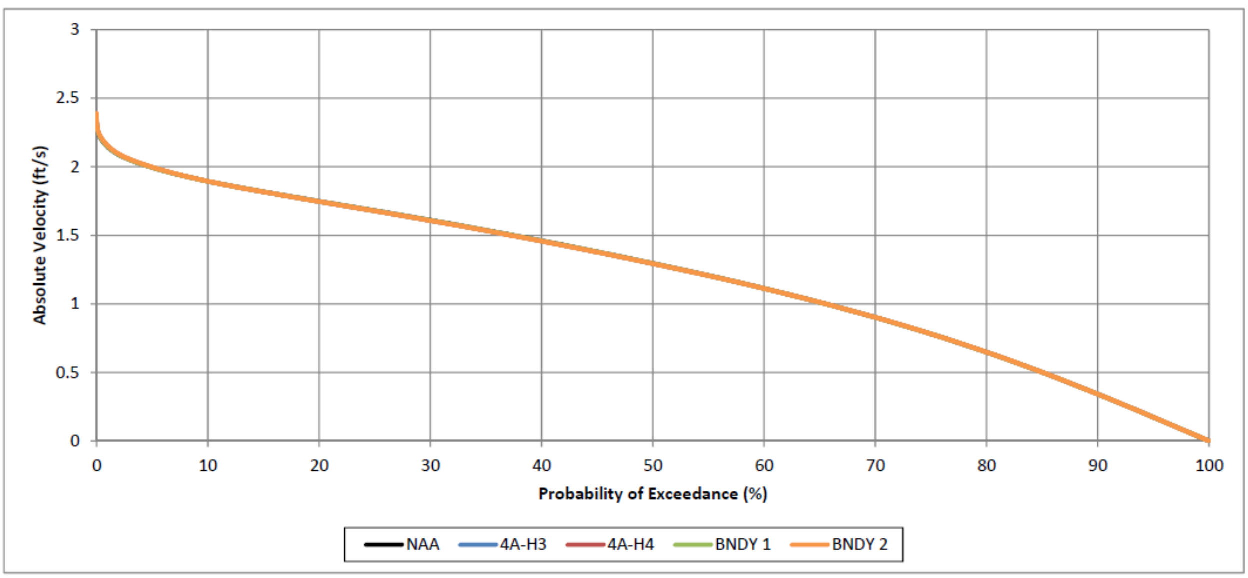


Figure 7. Probability of exceedance of absolute values of daily velocities, on a 15-minute time-step, in the San Joaquin River at Antioch during the months June through November for the 1976–1991 period of record modeled.

San Joaquin River at Buckley Cove

Buckley Cove on the San Joaquin River was chosen for assessment because it was a water quality assessment location for Chapter 8 of the EIR/EIS, and because it is within the Stockton Deep Water Ship Channel. In the San Joaquin River at Buckley Cove, daily maximum velocity would be below 1 ft/s about 93% of the time for both the CWF scenarios and the NAA (**Figure 8**). For the 50% of the time when daily maximum velocities would be lowest for this location, the frequency with which any given velocity would be exceeded would be the same for the CWF and the NAA. Likewise, the absolute value of channel velocities (regardless of direction), as modeled by DSM2 on a 15-minute time-step, would be the same for the CWF as for the NAA during the months June through November (**Figure 9**).The frequency with which absolute channel velocities would be below 0.2 ft/s during these months would be the same for the CWF and the NAA scenarios, which would be about 22% of the time.

Because flow velocities of 0.2–1.0 ft/s disrupted *Microcystis* blooms and shifted the dominant phytoplankton species to green algae and diatoms (Li et al. 2013, Zhang et al. 2015), because daily maximum velocities at Buckley Cove would always be at or above 0.4 ft/s based on modeling output, and because the absolute value of channel velocities on a 15-minute time-step (regardless of flow direction within the channel) would be above 0.2 ft/s about 78% of the time for both the CWF and NAA scenarios, one would not expect cyanobacteria to outcompete diatoms and green algae in the San Joaquin River in the vicinity of Buckley Cove much of the time under the CWF or NAA scenarios. However, there is the potential for *Microcystis* blooms to develop in this reach of the river when all conditions for blooms are met, including low velocities. That said, the CWF would not cause lower daily maximum velocities, or reduce the frequency with which any given velocity would occur when velocities are low during the months June through November, relative to the NAA and thus would not create hydraulic conditions that would be more conducive to *Microcystis* blooms at this location, relative to the NAA.

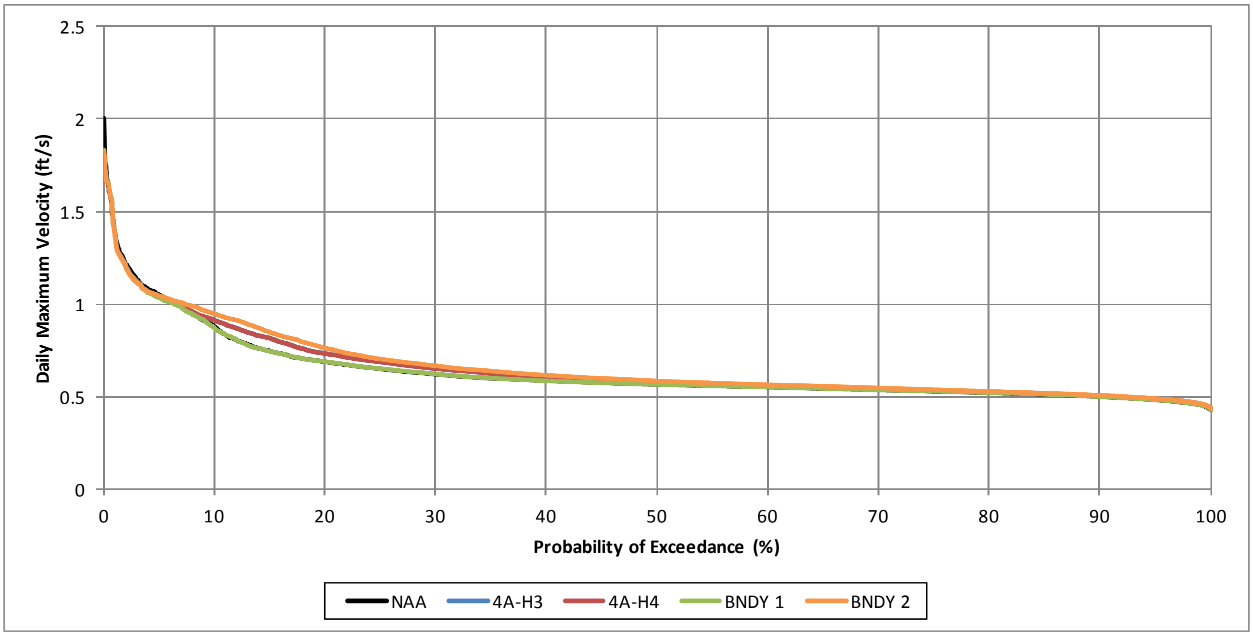


Figure 8. Probability of exceedance of daily maximum velocity in the San Joaquin River at Buckley Cove for the 1976–1991 period of record modeled.

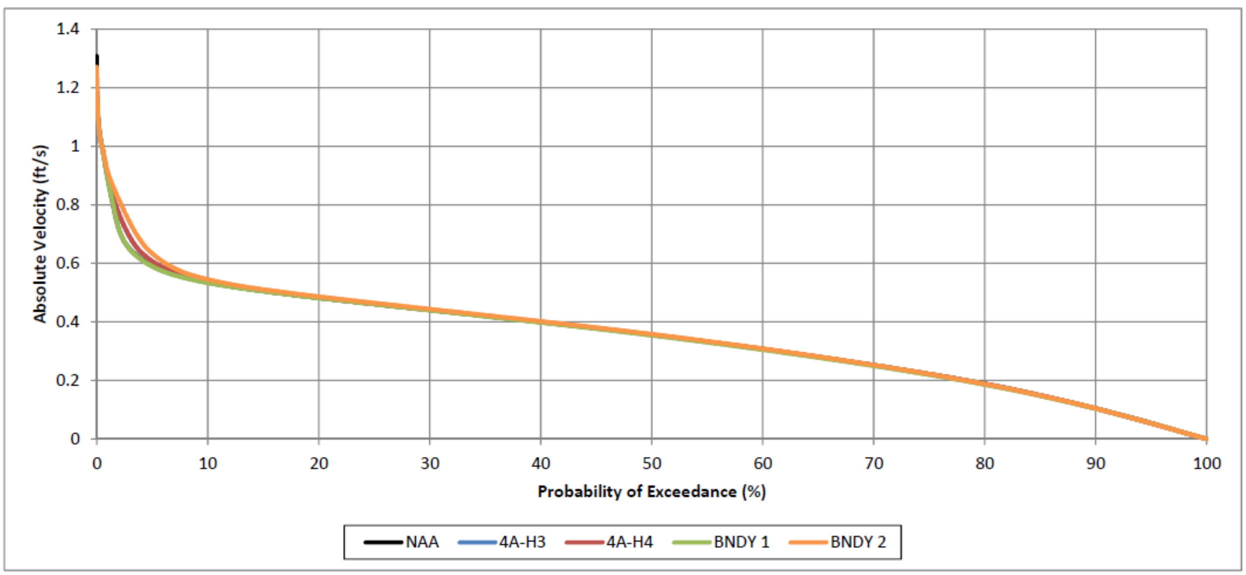


Figure 9. Probability of exceedance of absolute values of daily velocities, on a 15-minute time-step, in the San Joaquin River at Buckley Cove during the months June through November for the 1976–1991 period of record modeled.

Old River at Tracy Road

Old River at Tracy Road was selected to represent a location in the south Delta that may experience *Microcystis* blooms. Looking at Old River at Tracy Road (**Figure 10**), modeling output shows that the frequency with which any given daily maximum velocity would occur for the CWF scenarios would differ negligibly from that modeled for the NAA. Likewise, the absolute value of channel velocities (regardless of direction), as modeled by DSM2 on a 15-minute time-step, would be the same for the CWF as for the NAA during the months June through November (**Figure 11**).

In Old River at Tracy Road, the frequency with which daily maximum velocity would be at levels less than 0.5 ft/s would be nearly the same for the CWF scenarios and the NAA, and would be identical for the 30% of the time when daily maximum velocities would be the lowest (0.2–0.3 ft/s) at this location. It is at times when daily velocities would be lowest during the summer months that *Microcystis* blooms would be most likely to occur here. Nevertheless, modeling shows that the CWF rarely cause lower daily maximum velocities and would not reduce the frequency with which any given velocity would occur when velocities are below about 0.4 ft/s during the months June through November (Figure 11), and thus would not create hydraulic conditions that would be more conducive to *Microcystis* blooms at this location, relative to the NAA. Although *Microcystis* blooms may occur in Old River near Tracy Road in the future due to its relatively low channel velocities, modeling shows that channel velocities at this location would not be made more conducive to *Microcystis* blooms for the CWF, relative to that which would occur for the NAA.

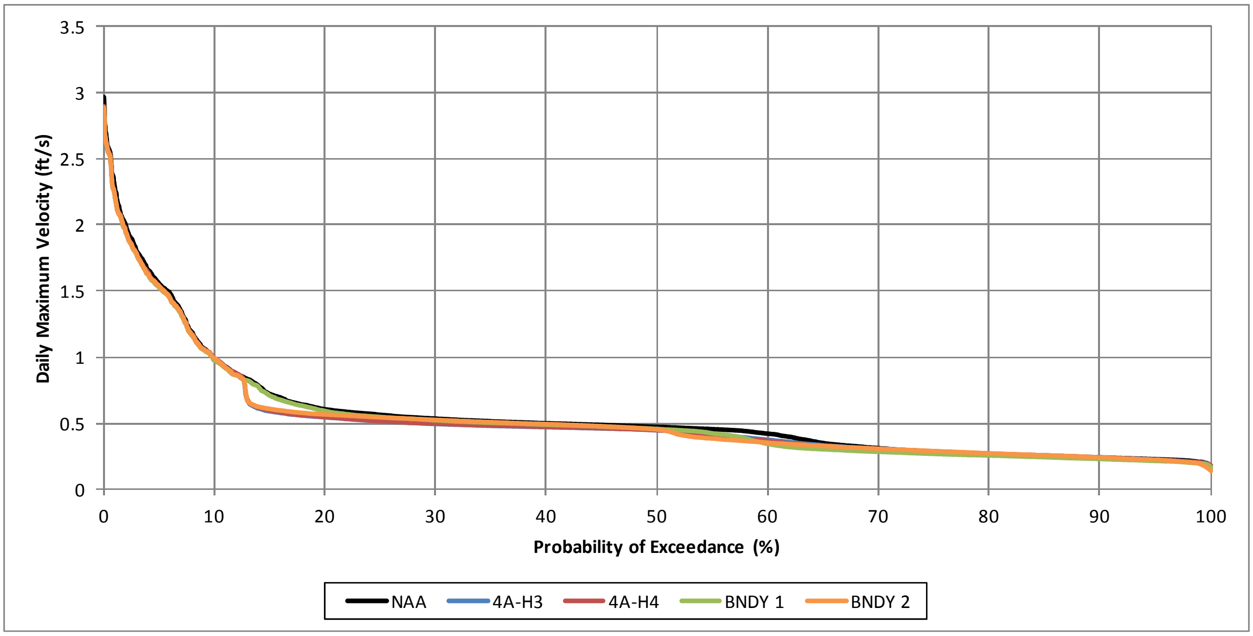


Figure 10. Probability of exceedance of daily maximum velocity in the Old River at Tracy Road for the 1976–1991 period of record modeled.

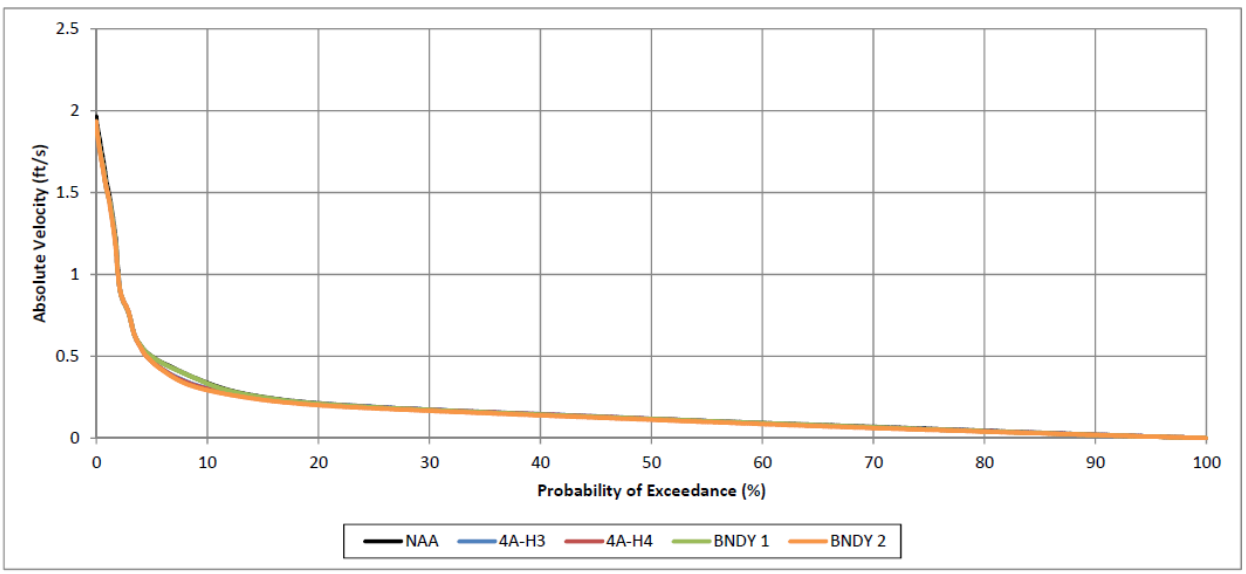


Figure 11. Probability of exceedance of absolute values of daily velocities, on a 15-minute time-step, in Old River at Tracy Road during the months June through November for the 1976–1991 period of record modeled.

Grant Line Canal

Grant Line Canal was selected to represent a location in the south Delta that may experience *Microcystis* blooms. Modeling output shows that daily maximum velocities in Grant Line Canal (**Figure 12**) would always remain above 0.5 ft/s for the CWF scenarios and the NAA. Although the frequency that any given daily maximum velocity above 1.25 ft/s would be exceeded for the CWF would be somewhat less than for the NAA, *Microcystis* blooms are not expected to occur when daily maximum channel velocities are above 1.25 ft/s. For the 40% of the time when daily maximum velocity is the lowest at this location (i.e., below 1 ft/s), the frequency of exceeding any given velocity would be the same for the CWF and the NAA.

Likewise, the frequency with which any given absolute value of channel velocities (regardless of direction), as modeled by DSM2 on a 15-minute time-step, would occur would be about the same for the CWF as for the NAA in Grant line Canal during the months June through November. The frequency with which absolute channel velocities would be below 0.2 ft/s during these months would be somewhat lesser for the CWF than for the NAA (**Figure 13**).

Because flow velocities of 0.2–1.0 ft/s disrupted *Microcystis* blooms and shifted the dominant phytoplankton species to green algae and diatoms (Li et al. 2013, Zhang et al. 2015), and because daily maximum velocities at Grant Line Canal would always be at or above 0.6 ft/s based on modeling output (Figure 12), one would not expect cyanobacteria to outcompete diatoms and green algae in Grant Line Canal much of the time under the CWF or NAA scenarios. However, there is some chance that *Microcystis* blooms could develop in the canal when all conditions for blooms are met, including low daily velocities. That said, the CWF would have minimal effects on maximum daily velocities and would not reduce the frequency with which any given velocity would occur during the months June through November, relative to the NAA and thus would not create hydraulic conditions that would be more conducive to *Microcystis* blooms at this location, relative to the NAA. Hence, the frequency with which *Microcystis* blooms could form in Grant Line Canal, with regards to hydraulic conditions, would not be greater for the CWF than for the NAA.

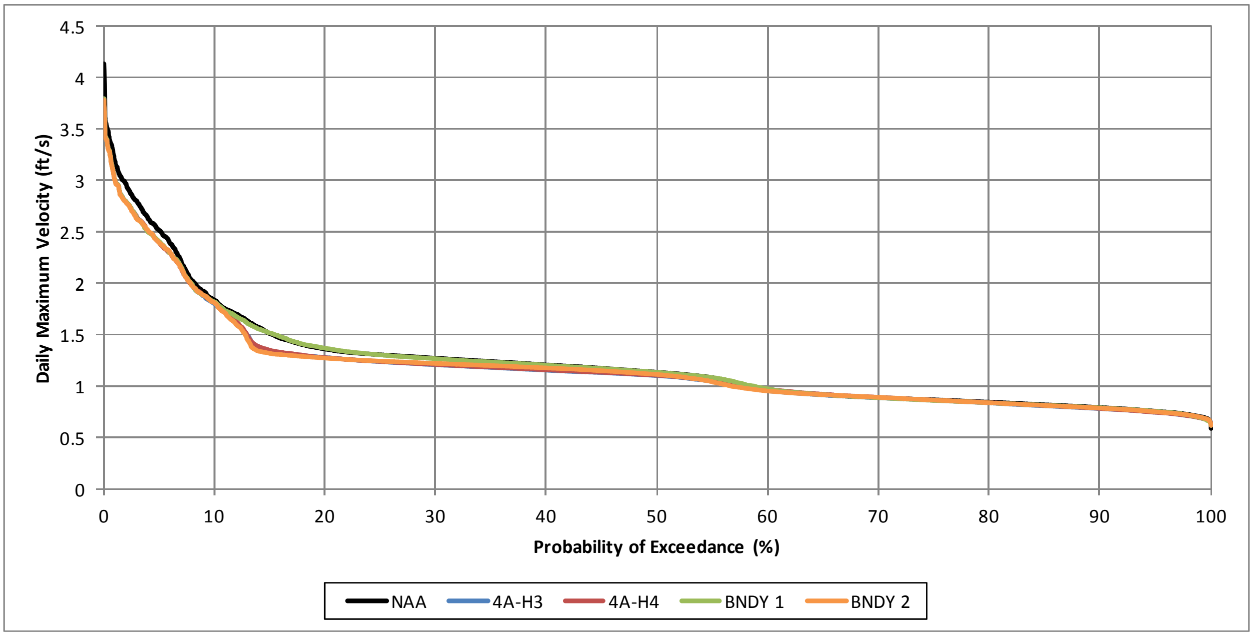


Figure 12. Probability of exceedance of daily maximum velocity in the Grant Line Canal for the 1976–1991 period of record modeled.

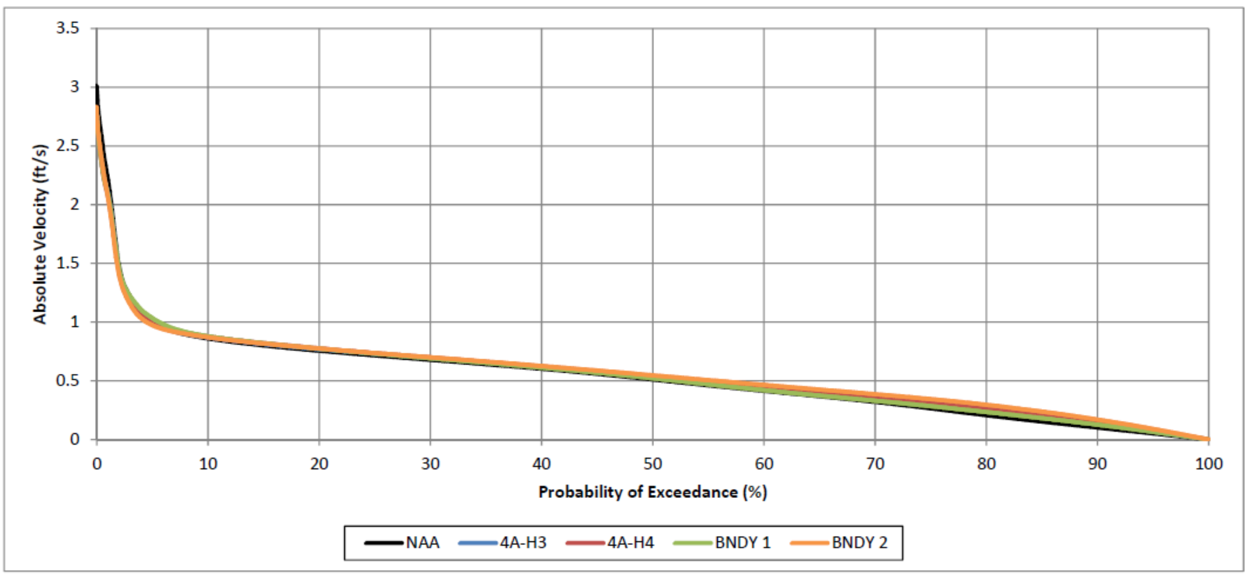


Figure 13. Probability of exceedance of absolute values of daily velocities, on a 15-minute time-step, in Grant Line Canal during the months June through November for the 1976–1991 period of record modeled.

Middle River at Bacon Island

Middle River at Bacon Island was selected to represent a location within Middle River and the central Delta that may experience *Microcystis* blooms. Modeling output shows that daily maximum velocities in Middle River at Bacon Island would nearly always remain above 0.6 ft/s for the CWF scenarios and the NAA. Daily maximum velocity would exceed 0.8 ft/s about 70% of the time for the CWF and about 80% of the time for the NAA. The frequency with which any given daily maximum velocity above 0.6 ft/s would be exceeded for the CWF would be somewhat less than for the NAA (**Figure 14**).

The frequency with which any given absolute value of channel velocities (regardless of direction), as modeled by DSM2 on a 15-minute time-step, would occur would be similar or greater for the CWF, relative to the NAA, when velocities are about 0.5 ft/s or lower during the months June through November. The frequency with which absolute velocities would exceed 0.5 ft/s, as modeled on a on a 15-minute time-step, would be somewhat lower for the CWF during these months, relative to the NAA (**Figure 15**).

Because flow velocities of 0.2–1.0 ft/s disrupted *Microcystis* blooms and shifted the dominant phytoplankton species to green algae and diatoms (Li et al. 2013, Zhang et al. 2015), because daily maximum velocities in Middle River at Bacon Island would nearly always be at or above 0.6 ft/s based on modeling output (Figure 14), and because the frequency with which any given absolute value of channel velocities (regardless of direction) would occur would be similar or greater for the CWF, relative to the NAA, when velocities are about 0.5 ft/s or lower, cyanobacteria would not be expected to outcompete diatoms and green algae at this location much of the time for either the CWF or NAA scenarios. However, there is some chance that *Microcystis* blooms would develop in the river when all conditions for blooms are met, including low daily velocities. That said, the CWF would not cause more frequent occurrence of velocities below about 0.5 ft/s and thus would not create hydraulic conditions that would be substantially more conducive to *Microcystis* blooms at this location, relative to the NAA.

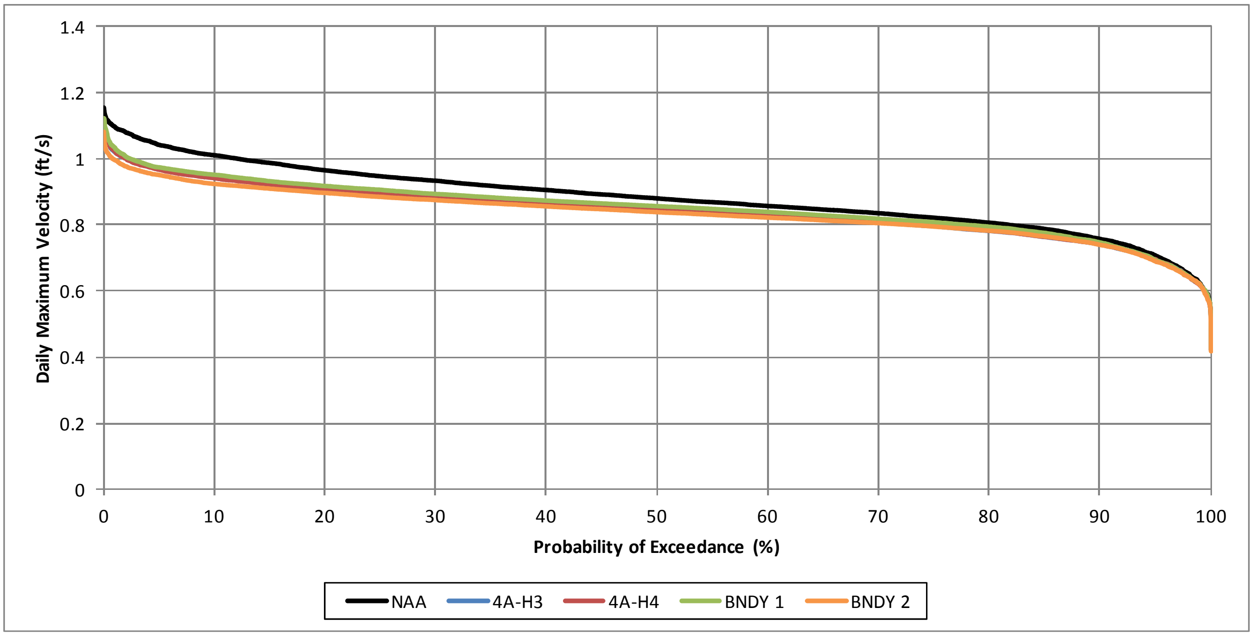


Figure 14. Probability of exceedance of daily maximum velocity in the Middle River at Bacon Island for the 1976–1991 period of record modeled.

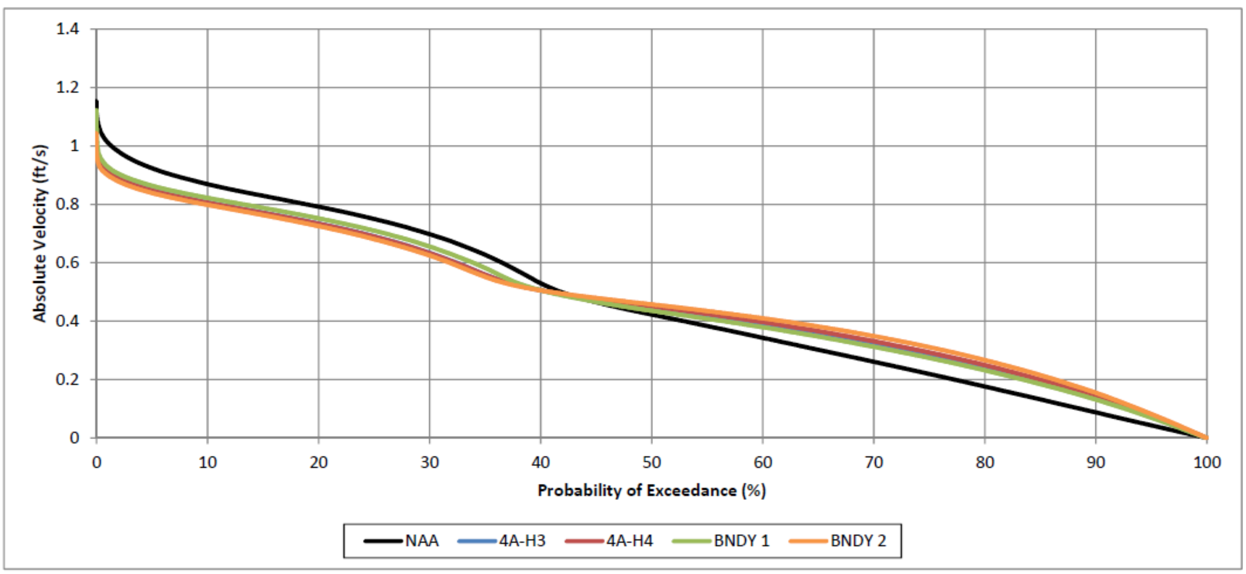


Figure 15. Probability of exceedance of absolute values of daily velocities, on a 15-minute time-step, in Middle River at Bacon Island during the months June through November for the 1976–1991 period of record modeled.

Old River at Rock Slough

Old River at Rock Slough was selected to represent a location within Old River and the central Delta that may experience *Microcystis* blooms, and because it is a main river channel that provides flow to the Discovery Bay area. Modeling output shows that daily maximum velocities in Old River at Rock Slough would nearly always remain above 0.8 ft/s for the CWF scenarios and the NAA. Although the frequency with which any given daily maximum velocity above 1.0 ft/s for the CWF would be somewhat less than for the NAA, *Microcystis* blooms are not expected to occur when daily maximum channel velocities are above 1.0 ft/s. For the 40% of the time when daily maximum velocity is the lowest at this location (i.e., below 1 ft/s), the frequency of exceeding any given velocity would be nearly the same for the CWF and the NAA.

The frequency with which any given absolute value of channel velocities (regardless of direction), as modeled by DSM2 on a 15-minute time-step, would occur would be similar or greater for the CWF, relative to the NAA, when velocities are about 0.8 ft/s or lower during the months June through November. The frequency with which absolute velocities would exceed 0.8 ft/s, as modeled on a on a 15-minute time-step, would be similar or somewhat lower for the CWF during these months, relative to the NAA (Figure 17).

Because flow velocities of 0.2–1.0 ft/s disrupted Microcystis blooms and shifted the dominant phytoplankton species to green algae and diatoms (Li et al. 2013, Zhang et al. 2015), and because daily maximum velocities in Old River at Rock Slough would always be at or above 0.8 ft/s based on modeling output (Figure 16), one would not expect cyanobacteria to outcompete diatoms and green algae in Old River at Rock Slough most of the time under the CWF or NAA scenarios. However, there is some chance that *Microcystis* blooms could develop in the channel when all conditions for blooms are met, including low daily maximum velocities. That said, the CWF would have little effect on daily maximum velocities and would either have no effect or increase the frequency with which velocities below 0.8 ft/s would occur and thus would not create hydraulic conditions that would be more conducive to *Microcystis* blooms at this location, relative to the NAA.

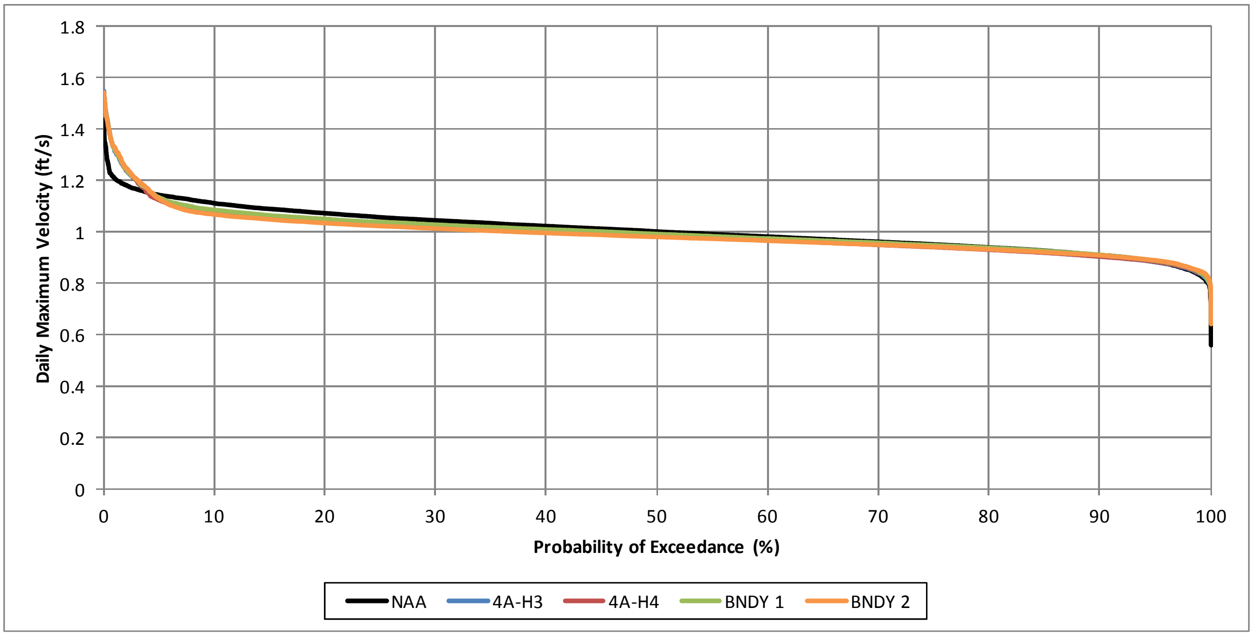


Figure 16. Probability of exceedance of daily maximum velocity in the Old River at Rock Slough for the 1976–1991 period of record modeled.

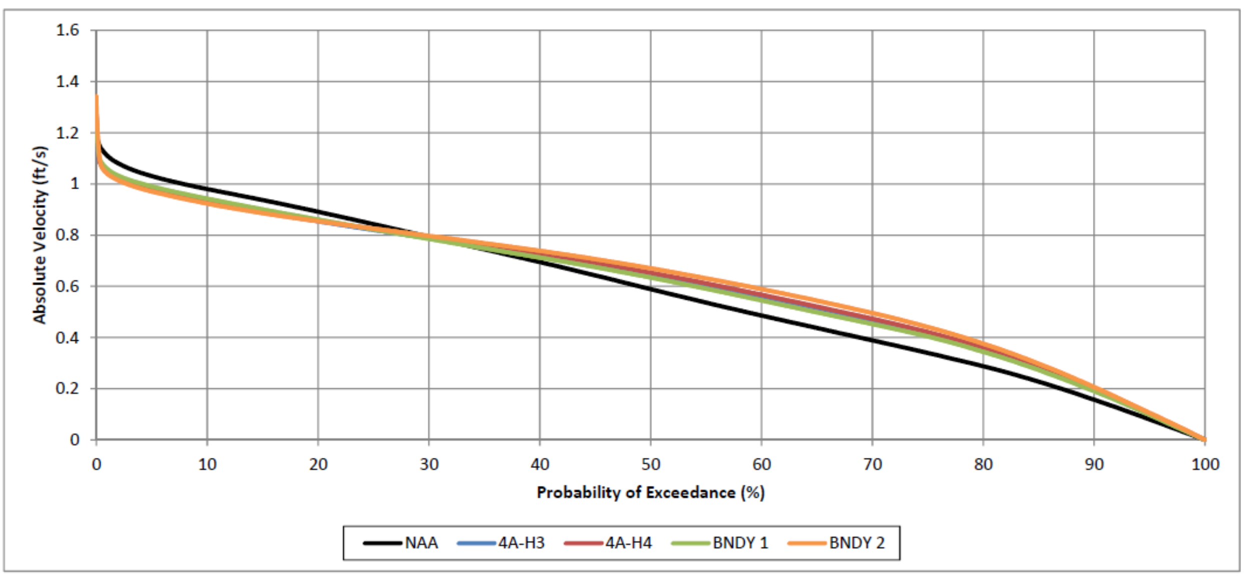


Figure 17. Probability of exceedance of absolute values of daily velocities, on a 15-minute time-step, in Old River at Rock Slough during the months June through November for the 1976–1991 period of record modeled.

Old River at Highway 4

Old River at Hwy 4 was selected to represent a location within Old River and the south Delta that may experience *Microcystis* blooms, and because it is just south of Discovery Bay and thus serves as a second location, along with Old River at Rock Slough, to address Mr. Ringelberg, Mr. Burke, and Mr. Lee's claims that the CWF would exacerbate cyanobacteria blooms within Discovery Bay. Old River is a primary river channel providing water to the Discovery Bay area. Modeled velocity data were not available for locations closer to or within Discovery Bay.

As shown in **Figure 18**, the frequency with which any given maximum daily channel velocity below 2.0 ft/s would be exceeded would be lower for the CWF, relative to the NAA. The frequency that velocities above 2.0 ft/s would occur at this location for the CWF would be similar or higher than that for the NAA. Maximum daily channel velocities would remain at or above 1 ft/s about 98% of the time for the CWF compared to nearly 100% of the time for the NAA. These modeled daily maximum velocity data indicate that the site would experience sufficiently high velocities, on a daily time-step, to maintain a well mixed channel, and to prevent extended periods (i.e., many days or weeks) with little to no water movement.

The frequency with which absolute channel velocities (in either direction) would exceed about 0.75 ft/s would be lower for the CWF, relative to the NAA. Conversely, the frequency with which absolute channel velocities would exceed levels between zero and 0.75 ft/s would be the same or greater for the CWF, relative to the NAA. Hence, for the 50% of the time when Old River channel velocities at Hwy 4 are at their lowest, the CWF would typically have channel velocities equal to or slightly greater than those for the NAA.

Because daily maximum channel velocities would be maintained at or above about 1.0 ft/s for both the CWF and NAA scenarios, and because for the 50% of the time when Old River channel velocities at Hwy 4 are at their lowest, the CWF would typically have channel velocities equal to or slightly greater than those for the NAA, I would not expect the channel velocities modeled to occur for this location for the CWF to cause an increase in the frequency that *Microcystis* blooms occur here.

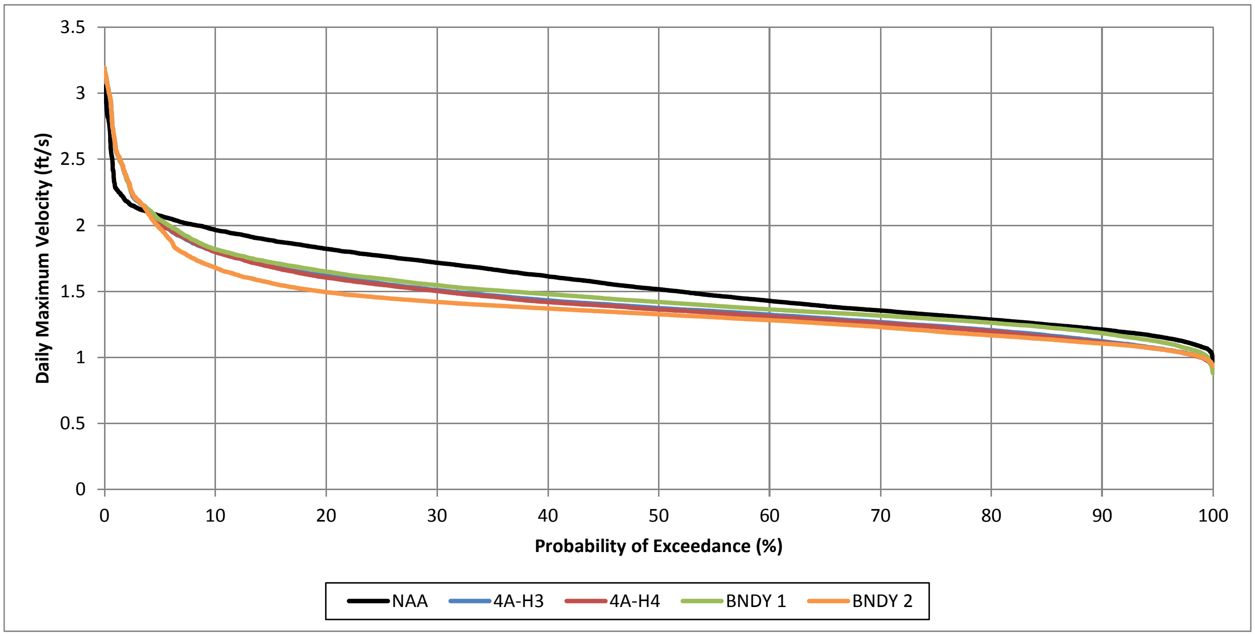


Figure 18. Probability of exceedance of daily maximum velocity in Old River at Hwy 4 for the 1976–1991 period of record modeled.

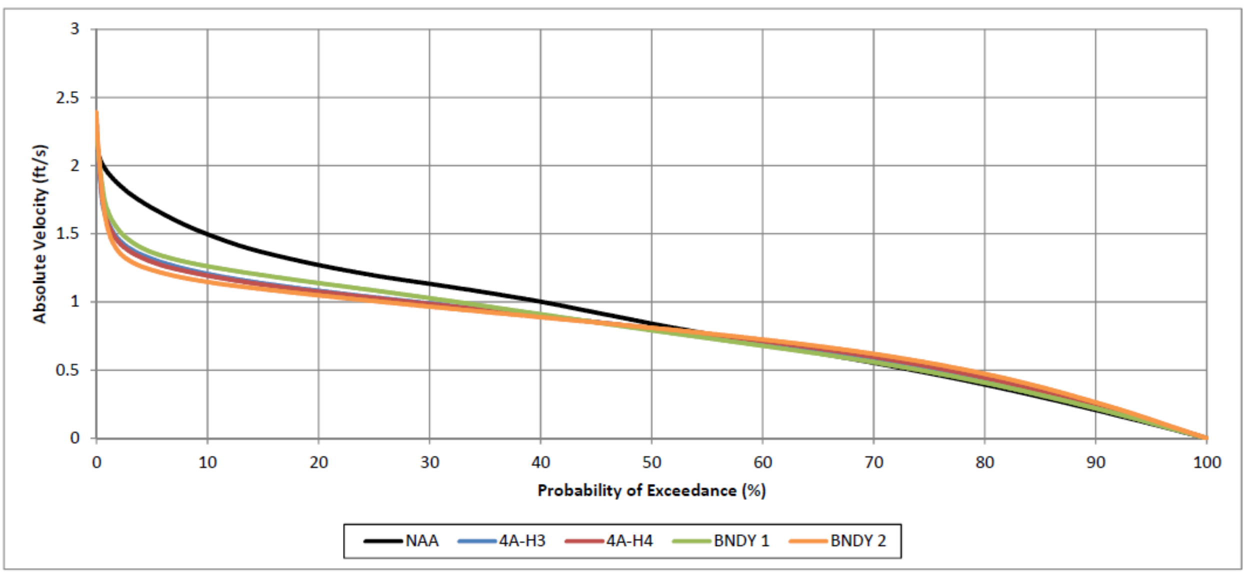


Figure 19. Probability of exceedance of absolute values of daily velocities, on a 15-minute time-step, in Old River at Hwy 4 during the months June through November for the 1976–1991 period of record modeled.

4.3 Residence Time Effects of the CWF

Mr. Burke and Mr. Ringelberg claim the CWF would increase residence time in the Delta thereby allowing cyanobacteria to increase. Mr. Burke states: "*A decrease in the volume of water that is flushed through the system can result in a buildup of nutrients, increased water temperatures, and an increase in algal growth.*" [Exhibit-SDWA—76 ERRATA, paragraph 16, Ln. 10-12]. Mr. Ringelberg states: "*If the conveyance facility is built, the north-to-south draw of water across the delta that has existed for decades would likely be reduced as a result of compensatory reductions in pumping from the south delta, creating much longer average residence times. Longer residence times are associated with higher rates of algal growth, which could fuel eutrophication in some regions, including increased blooms of nuisance algae, such as Microcystis, which is toxic to humans and other organisms (Lehman and others, 2013).*" [Exhibit SJC-004, pg. 12, Ln. 9-15]. Further Mr. Ringelberg states: "*Removing significant fractions of the flow of the Sacramento River and concentrating that effect in a river corridor profoundly changes the downstream channel flow (velocity). The flow-related dilution and water column mixing, as well as the induction of flow reversals which serve to lengthen residence time, are further exacerbating conditions that lead to HAB formation and maintenance.*" [Exhibit SJC-004, pg. 14, Ln. 19-23].

Mr. Burke provided insufficient information and Mr. Ringelberg did not provide any evidence to support their respective claims that residence times will increase due to the CWF, and thus the frequency and magnitude of cyanoHABs will be made worse by increased residence times. As such, their claims are either largely or completely unsupported.

> ***Hydraulic residence times may increase in parts of the southern and central Delta for the CWF, relative to the NAA. Increased residence time provides the opportunity for cyanobacteria to accumulate in areas. However, other factors such as daily in-channel absolute velocities, turbulence, and mixing; competition with other algal species; and grazing losses to zooplankton, fish, and clams exert their own effects on cyanobacteria accumulation, and thus a given magnitude increase in residence time will not always equate to a given magnitude increase in bloom size, or an increase in bloom size at all. Because of the many factors involved beyond residence time alone, relationships between bloom size and residence time are expected to be highly variable both spatially and temporally in the Delta. Additional Microcystis research would be needed before definitive determinations regarding how modeled changes in residence time caused by the CWF would affect the magnitude of Microcystis blooms in the Delta can be made.***

The current science on Microcystis in the Delta indicates that factors such as water temperature, channel velocity and turbulence, irradiance, nutrient availability primarily dictate whether Microcystis can out-compete other algae for available resources and produce a bloom at a given location. Because Microcystis is relatively slow growing compared to other algal species, sufficient residence time (due to low channel velocities) is needed to enable a bloom to become established. Insufficient residence time (due to high channel velocities) results in what cells are produced being flushed from the area before a "bloom" can form, and high velocities result in turbulent, well mixed channel flows where cyanobacteria generally cannot out-compete green algae or diatoms. Hence residence times beyond the minimum required for bloom initiation (e.g., increased residence times in areas where blooms have historically occurred) primarily affects how much biomass a bloom can accumulate in an area after a bloom has initiated.

Long residence time does not always translate into large *Microcystis* blooms. This was exemplified in the Stockton Deep Water Ship Channel, where long summer residence times occur annually. Here, a three year study documented a large persistent *Microcystis* bloom in 2012 but not in 2009 or 2011 (Spier et al. 2013). Environmental conditions were similar in 2012 and 2009 and *Microcystis* cells were present in 2009, yet no large bloom occurred in 2009. No specific environmental factor could be attributed to the 2012 bloom (Spier et al. 2013). This suggests *Microcystis* ecology and competition with other algae is complex, and longer residence times do not necessarily indicate that a bloom will form.

When considering how any given residence time (modeled in days) or increase in residence time may affect *Microcystis* bloom formation and persistence, it is also important to distinguish between areas that have higher residence times because they are truly lake-like with little water movement (e.g., a back-water slough) versus those more tidally influenced where a particle may move long distances upstream on the flood tide and long distances back downstream on the ebb tide. Two such environments could have nearly the same estimated hydraulic residence times. For the former example, channel velocities and turbulence would be low and water column stability high. In the latter example, daily channel velocities and turbulence would be relatively high and thus water column stability low. Hydrodynamic conditions would be more favorable to *Microcystis* in the former, versus the latter example, despite the fact that their estimated residence times may be nearly the same.

Lehman et al. (2017) states that high residence time was a factor that contributed to the magnitude of the 2014 *Microcystis* bloom in the Delta. The high residence time allows *Microcystis* colonies to accumulate in areas of the Delta, without getting flushed from the area. There is no evidence in the scientific literature to indicate that higher residence time result in higher algal growth rates, as claimed by Mr. Ringelberg. Algal species, availability of nutrients, and temperature primarily control algal growth rates, not residence time *per se*. Accumulation of Microcystis cells and colonies (via longer residence times) is an important mechanism affecting controlling the magnitude of *Microcystis* blooms, because *Microcystis* has a slow growth rate compared to other algae. Lehman et al. (2017) reported that relatively small *Microcystis* blooms occurred in the 2004 and 2005 wet years when San Joaquin River flow was 28.32-35.40 m^3s^{-1}. A San Joaquin River flow of 9.1 m^3s^{-1}, a factor of three lower compared to 2004 and 2005 flows, produced the large 2014 *Microcystis* bloom. This is an important finding to put the flow and associated residence time effects of the CWF into context.

The Lehman et al (2017) study shows that very large reductions in flow (i.e., a factor of three lower) and associated very large increases in residence times can contribute to increased magnitude and duration of *Microcystis* blooms because the cells and colonies are not being flushed from the area as rapidly as would occur with lower residence times, and thus they accumulate in an area over time. As shown in Section 4.2 of this report, the effects of the CWF on channel velocities in the Delta is small compared to the large three-fold reduction in flow and commensurate effects to velocity and residence time observed between 2014 and other years, where large effects on *Microcystis* were observed.

Other factors such as daily in-channel absolute velocities, turbulence, and mixing; competition with other algal species under the channel velocity conditions; and grazing losses to zooplankton, fish, and clams exert influences on blooms that will affect the amount of biomass that can accumulate over time for any given residence time, or increase in residence time for a site. Hence, greater residence time provides the opportunity for cyanobacteria to accumulate in areas of the Delta, without getting flushed from the area, but because of the other factors identified above that also affect the ability of cyanobacteria to accumulate in areas, a given magnitude increase in residence time will not always equate to a given magnitude increase in bloom size, or an increase in bloom size at all. The relationship between residence time (or increases in residence time at a location) and the size of *Microcystis* blooms (should a bloom occur at the site) would be expected to vary substantially by location within the Delta and by year due to how the factors listed above and other environmental factors vary temporally and spatially. Additional *Microcystis* research would be needed before definitive determinations regarding how changes in estimated residence time caused by the CWF would affect the magnitude of *Microcystis* blooms in the Delta can be made.

4.4 Temperature Effects of the CWF

Mr. Ringelberg claims the CWF would increase water temperatures due to loss of dilution. In his oral testimony Mr. Ringelberg states [Transcript vol. 29, pg. 53, Ln. 1–4], "…*you take significant fractions of the coldest, highest quality of water out of the system, Sacramento River water, you're reducing the dilution effect and ultimately the assimilation capacity of this particular watershed*." [See also others who raise generalized temperature concerns, Mr. Stroshane RTD-10-rev2 p.38, ln.4–11; Ms. McCleary SCDA-62-errata p.3, ln.5–22.]

Mr. Ringelberg specifically claims water temperature in the Delta will increase. He states: "*The project will cause changes to water operations and creation of project-required tidal and floodplain restoration areas that change water residence times within Delta channels, and increases in Delta water temperatures.*" [Exhibit SJC-004, pg. 10, Ln. 21-23]. The only evidence he uses to support this claim regarding increased water temperatures is the testimony provided by Ms. Starr that addresses water temperature upstream of the Delta. In his oral testimony, he specifically relies on Ms. Starr as the source of his conclusion regarding temperature effects, stating: "*The quite extensive illustrations of the effects of operational changes and priorities to Folsom Dam and the consequential effects of temperature and clarity on what they believed to be significant impacts on their beneficial uses of water. We could go line by line through that, if you'd like.*

> *MS. ANSLEY: And would this be -- Just for my knowledge, would this be the testimony of Pravani Vandeyar and Bonny Starr?*
>
> *WITNESS RINGELBERG: That's correct." [Transcript vol. 29, pg. 104–105, Ln. 20–25, 1–5].*

Ms. Starr's testimony [Exhibit CITYSAC-8] was incorrect and is rebutted in Exhibit DWR-651. Mr. Ringelberg provides no assessment of any type to support his claim that the CWF would increase water temperatures in the Delta. As stated in the USFWS (2008b:194) OCAP BiOP, and as cited in the Final EIR/EIS, Chapter 8, p. 8-172.

> The [state and federal] water projects have little if any ability to affect water temperatures In the Estuary (Kimmerer 2004). Estuarine and Delta water temperatures are driven by air temperature. Water temperatures at Freeport can be cooled up to about 3°C by high Sacramento River flows, but only by very high river flows that cannot be sustained by the projects. Note also that the cooling effect of the Sacramento River is not visible in data from the west Delta at Antioch (Kimmerer 2004) so the area of influence is limited.

While air temperature is the primary factor that drives Delta water temperatures, not Central Valley Project/State Water Project operations, I nevertheless provide the following assessment of how the CWF could potentially affect Delta water temperatures, based on modeling in the comparative mode to rebut Mr. Ringelberg's unsubstantiated claims about the effects of the CWF on Delta water temperatures.

The small differences in water temperature between the CWF and NAA scenarios modeled for various locations across the Delta would not substantially increase the frequency or magnitude of cyanobacteria blooms within the Delta.

This analysis compares modeled temperatures for the CWF to that modeled for the NAA as presented in the CWF Biological Assessment. The tables and figures supporting the analysis are provided in **Appendix A**. The nine locations selected for this analysis were based primarily on the availability of modeled temperature data, and thus they are not one-and-the-same with the nine locations assessed for velocity.

The CWF Biological Assessment provides temperature data for four locations in the Delta, which are: 1) lower Sacramento River at Rio Vista, 2) San Joaquin River at Prisoners Point, 3) San Joaquin River near Stockton Deep Water Ship Channel, and 4) San Joaquin River at Brant Bridge. The months of the year for which water temperatures at the four locations listed above exceed the 19°C (66.2°F) threshold below which *Microcystis* blooms have not been observed in the Delta are May through October. Consequently, this assessment will be limited to the months May through October, because cyanobacteria blooms are not expected to occur in the Delta during other months of the year, in most years, including most dry and critical years.

Lower Sacramento River at Rio Vista

Modeling shows that for the full simulation period (1922–2003), the period mean temperatures in the lower Sacramento River at Rio Vista for the CWF would be up to 0.1°C (0.18°F) higher than that modeled for the NAA for each month of the May through October period of the year. Likewise, the mean temperature for each month, by water year type, would not be more than 0.1°C (0.18°F) higher for the CWF, relative to the NAA. The frequency with which any given temperature above 19°C (66.2°F) would occur for the CWF would be very similar to that for the NAA (i.e., within about 5% or less) (Appendix A). The minor differences in river temperatures at Rio Vista for the CWF, relative to the NAA, would not affect the frequency or magnitude of cyanobacteria blooms in this reach of the lower Sacramento River, relative to that which could occur for the NAA. It should also be noted that historical *Microcystis* abundance has substantially decreased moving north from Antioch. Hence, not only have *Microcystis* blooms not been a problem in the mainstem lower Sacramento River near Rio Vista historically, they are not expected to be a problem at this location for the CWF.

San Joaquin River at Prisoners Point

Modeling shows that for the full simulation period (1922-2003), the period mean temperatures in the San Joaquin River at Prisoners Point for the CWF would be up to 0.1°C (0.18°F) higher than that modeled for the NAA for each month of the May through October period of the year. Likewise, the mean temperature for each month, by water year type, would not be more than 0.1°C (0.18°F) higher for the CWF, relative to the NAA. The frequency with which any given temperature above 19°C (66.2°F) would be exceeded for the CWF would be very similar to that for the NAA (i.e., within about 5% or less). In September, the modeled maximum mean monthly temperature for the CWF would be about 0.3°C (0.6°F) higher than that modeled for the NAA (Appendix A). The minor differences in river temperature at Prisoners Point for the CWF, relative to the NAA, would not adversely affect the frequency or magnitude of cyanobacteria blooms in this reach of the San Joaquin River, relative to that which could occur for the NAA.

San Joaquin River near Stockton Deep Water Ship Channel

Modeling shows that for the full simulation period (1922–2003), the period mean temperatures in the San Joaquin River near the Stockton Deep Water Ship Channel for the CWF would be -0.1°C to 0.2°C (-0.18°F to 0.36°F) different than that modeled for the NAA, or for each month of the May through October period of the year. Likewise, the mean temperature for each month, by water year type, would not be more than 0.3°C (0.5°F) higher for the CWF, relative to the NAA, and would occasionally be up to 0.2°C (0.36°F) colder than the NAA. The frequency with which any given temperature above 19°C (66.2°F) would be exceeded for the CWF would be similar to that for the NAA (i.e., within about 7% or less) (Appendix A). In October, the maximum mean monthly temperature never exceeds the 19°C (66.2°F) for any of the scenarios, with 19°C (66.2°F) being the threshold below which problem-level *Microcystis* blooms have not been observed in the Delta. The minor differences in river temperature near the Stockton Deep Water Ship Channel for the CWF, relative to the NAA, would not affect the frequency or magnitude of cyanobacteria blooms in this reach of the San Joaquin River, relative to that which could occur for the NAA.

San Joaquin River at Brandt Bridge

Modeling shows that for the full simulation period (1922–2003), the period mean temperatures in the San Joaquin River at Brandt Bridge for the CWF would be within 0.1°C (0.18°F) of that modeled for the NAA, for each month of the May through October period of the year. Likewise, the mean temperature for each month, by water year type, would not be more than 0.1°C (0.18°F) higher for the CWF, relative to the NAA. The frequency with which any given temperature above 19°C (66.2°F) would be exceeded for the CWF would be nearly identical to that for the NAA (Appendix A). The minor differences in river temperature at Brandt Bridge for the CWF, relative to the NAA, would not affect the frequency or magnitude of cyanobacteria blooms in this reach of the San Joaquin River, relative to that which could occur for the NAA.

In addition to the main-stem lower Sacramento and San Joaquin River locations presented above, DSM2-QUAL temperature modeling was conducted for five interior Delta locations, which are: Middle River at Middle River, Middle River at Bacon Island, Victoria Canal near Bryon, Old River at Holland Cut, and Old River at Clifton Court Ferry. Temperature probability exceedance plots for each location for the CWF (4A-H3+) and the NAA are presented in **Appendix A**, p. 9-11. This temperature modeling was not presented in either the Final EIR/EIS or the CWF Biological Assessment. These temperature exceedance plots show little to no difference in the frequency with which any given temperature would be exceeded for the CWF, relative to the NAA, for each of the five locations. This modeling provides additional evidence that the CWF would have minimal effects on Delta water temperatures.

Attachment 4 in Appendix 5B of the CWF Biological Assessment provides a detailed description of the assumptions and limitations for the DSM2 temperature modeling. The evaluation of DSM2 temperature modeling output described herein, conducted through a comparison of probability of exceedance with the CWF versus the NAA, is consistent with the temperature analysis approach in the Biological Assessment. This analysis did not rely upon the absolute results of the DSM2 temperature modeling, but rather used the modeling output in a comparative mode to determine the relative degree to which the CWF may affect Delta temperatures, relative to NAA, consistent with the appropriate use of this modeling.

Temperature modeling shows only very minor temperature changes (both increases and decreases) that could occur in the lower Sacramento River, San Joaquin River, and interior Delta locations due to the CWF, relative to temperatures that would occur for the NAA. A key reason the temperature changes are very small at these locations within the Delta is because by the time water released from upstream reservoirs reaches the Delta, it is typically at or close to equilibrium with ambient air temperatures. As such, flow differences between the CWF and the NAA that can have greater temperature effects in the rivers closer to the reservoir release locations generally result in minor temperature difference within the Delta. The minor differences in temperature in the lower Sacramento River at Rio Vista, San Joaquin River at Prisoners Point, San Joaquin River near Stockton Deep Water Ship Channel, San Joaquin River at Brant Bridge, Middle River at Middle River, Middle River at Bacon Island, Victoria Canal near Bryon, Old River at Holland Cut, and Old River at Clifton Court Ferry between the CWF and NAA scenarios would not be expected to substantially affect the frequency or magnitude of cyanobacteria blooms in these water bodies within the Delta, relative to that which would occur for the NAA.

4.5 TURBIDITY EFFECTS OF THE CWF

Mr. Ringelberg claims the CWF will reduce turbidity, which will allow more light to enter the water column and cause greater problems with HABs. Mr. Ringelberg states, "*The significant reduction of sediment, thus influencing turbidity, results in greater sunlight penetration of the* *water column. This light is likely to support phytoplankton, which get their energy from sunlight, and is understood to be one of the key controlling factors for HAB formation in the Delta.*" [Exhibit SJC-004, pg. 13, Ln. 4–7]. No evidence is provided to support this statement. Instead, the only evidence Mr. Ringelberg provides to support his claim that reduced turbidity will affect phytoplankton growth is a figure showing how the marine diatom, *Chaetoceros*, is affected by varying light levels [Exhibit SJC-004, SJC-066, pg. 19].

As stated in the Final EIR/EIS, Chapter 8, p. 8-971-972, the operation of the water conveyance facilities for the CWF is expected to have a minimal effect on total suspended solids (TSS) and turbidity levels in the Delta, relative to the NAA. This is because the factors that would affect TSS and turbidity within the Delta would remain the same. Turbidity and TSS levels in Delta waters are affected by TSS concentrations and turbidity levels of inflows (and associated sediment load), as well as fluctuation in flows within the channels due to the tides, with sediments depositing as flow velocities and turbulence are low at periods of slack tide, and sediments becoming suspended when flow velocities and turbulence increase when tides are near the maximum. Turbidity and TSS variations can also be attributed to phytoplankton, zooplankton and other biological material in the water. These factors would be similar under the CWF and the NAA.

The conclusion in the Final EIR/EIS is further confirmed by the analysis contained herein. The discussion provided in Section 4.2, above, indicated from DSM2 modeling output that daily maximum and 15-minute absolute channel velocities throughout the Delta for the CWF would not differ sufficiently from that which would occur for the NAA to result in hydrodynamics conditions substantially more favorable to cyanobacteria. It is the daily velocities in Delta channels, regardless of direction of flow, that generate much of the turbidity at any given site. Because channel velocities between the CWF and NAA scenarios differ little at the Delta locations assessed, in-channel, velocity driven turbidity also would be expected to differ little between these scenarios.

Further, cyanobacteria in the Delta are not light limited during the period of the year (May–October) when temperatures are warm enough to support cyanobacteria growth. For *Microcystis* in the Delta, the surface irradiance threshold is reached three months earlier than the water temperature threshold. Thus, temperature, not light, is the factor that limits cyanobacteria growth in the Delta (Lehman et al. 2013). In drought year of 2014, when *Microcystis* blooms were large in magnitude and duration, light levels in the euphotic zone were no greater than they were in previous years during the peak of the bloom (Lehman et al. 2017). In fact, Mr. Ringelberg contradicts his written testimony cited above in his oral testimony by stating that cyanobacteria in the Delta are not light limited. In his oral testimony, he stated: "*And since we have essentially full sunlight most of the year, during -- certainly during the growing period for algae, they are not light limited*." [Transcript vol. 29, pg. 47, Ln. 1–3]. Because cyanobacteria are not light limited from June through November (Lehman et al. 2013) when other conditions are suitable for blooms, any minor change in turbidity that may occur from the CWF would not substantially affect the frequency or magnitude of cyanoHABs in the Delta.

4.6 NUTRIENT EFFECTS OF THE CWF

Mr. Ringelberg, Mr. Burke, and Mr. Lee claim the CWF would increase nutrients in that Delta thereby causing cyanoHABs to become worse. [See also claims generally stated by Mr. Stroshane RTD-10-Rev2, p. 46:12-26, Mr. Broadksy SCDA-60 errata, p. 12:1- 18]

Mr. Ringelberg states: "*Reducing the flow of Sacramento River water through the Delta and concentrating the drainage of the San Joaquin River affects the dilution and the mixing of nutrients.*" [Exhibit SCDA_33, pg. 2, Ln. 9–14].

Mr. Burke states: "*If diversions are shifted to the proposed NDD, this dilution effect will be reduced or eliminated. This will result in a higher nutrient loads for waters in and around Discovery Bay. All things being equal, higher nutrient loads can lead to algal blooms which reduce dissolved oxygen and lead to degradation of water quality.*" [Exhibit SCDA-35, pg. 2, Ln. 22–25].

Mr. Lee states: "*The proposed WaterFix project's diversion of Sacramento River water will reduce the amount of Sacramento River water that enters the Central Delta and thereby impact the phosphorus input to the Central Delta and the phytoplankton population in that area of the Delta. The reduction in dilution of phosphorus concentration in the Central Delta leads to impaired water quality and adverse impacts/injuries to the public/users of Central Delta waters.*" [Exhibit CSPA-6-Revised, pg. 17].

Mr. Ringelberg, Mr. Burke and Mr. Lee (as well as Mr. Shroshane and Mr. Broadsky) did not provide any evidence to support their claims cited above. Consequently, their claims suggesting that the CWF would increase nutrients in areas of the Delta that would then cause greater cyanoHABs are speculative and unsupported.

The small increases in nutrients in portions of the Delta due to the CWF would not be expected to increase the frequency, magnitude, or duration of cyanoHAB in the Delta, relative to that which would occur for the NAA.

Based on the modified system operations, the CWF scenarios would increase the amount of San Joaquin River water and decrease the amount of Sacramento River water at various central Delta locations. Because the San Joaquin River generally has higher concentrations of total nitrogen compounds (N) and total phosphorus compounds (P) compared to the lower Sacramento River, it is expected that total N and P levels in the central Delta would increase somewhat for the CWF scenarios.

There are three forms of nitrogen that are commonly measured in water bodies, which are: ammonia, nitrates and nitrites. Total nitrogen (total N) is the sum of total kjeldahl nitrogen (ammonia, organic and reduced nitrogen) and nitrate and nitrite. Total N is available in non-limiting amounts for *Microcystis* in the Delta (Lehman et al. 2008, 2017; Berg and Sutula 2015). Lehman et al. (2017) found that although Delta nitrate concentrations were always above analytical detection limits and dominated the dissolved inorganic nitrogen pool, ammonium

(NH_4^+) was the primary source of nitrogen for the *Microcystis* bloom in 2014. *Microcystis* favored ammonium, even when ammonium was low to below detection limits and nitrate was available in excess (Lehman et al. 2017).

Orthophosphate or soluable reactive phosphorus (SRP) – the form directly taken up by plant cells – also is available in non-limiting amounts in the Delta (Lehman et al. 2008, 2017; Berg and Sutula 2015). Moreover, Lehman et al. (2017) reported that there was no clear link between the large increase in orthophosphate (referred to by Lehman as SRP) in the 2014 drought condition and elevated *Microcystis* biomass or chlorophyll *a* concentration in the Delta in 2014. Bioassays have shown that the addition of only orthophosphate does not enhance growth in *Microcystis* blooms in the Klamath River, Oregon; Lake Taihu, China; or Lake Erie, Michigan (Moisander et al. 2009, Xu et al. 2010, Chaffin et al. 2013 as cited in Lehman et al. 2017).

The maintenance of *Microcystis* blooms requires the availability of the macronutrients nitrogen and phosphorus but there was no suggestion from study data that these nutrients or their ratio controlled the seasonal or inter-annual variation in the bloom (Lehman et al. 2013). Based on their comprehensive review of the available literature to provide insight into cyanobacteria blooms in the Delta, Berg and Sutula (2015) found that nutrient concentrations and N:P ratios do not change sufficiently among years to explain inter-annual variation in *Microcystis* biomass or occurrence. They further stated: "*Therefore, the initiation of Microcystis blooms and other cyanoHABs are probably not associated with changes in nutrient concentrations or their ratios in the Delta*." Nutrient ratios also do not vary between pre- and post-bloom in the Delta, indicating that nutrients are in excess of phytoplankton demand for the entire summer season (Berg and Sutula 2015). Total N and orthophosphate (SRP) concentrations were well in excess during the *Microcystis* bloom in 2014 and the N:P ratio was not correlated with *Microcystis* biovolume (Lehman et al. 2017).

5 REFERENCES

Baxa, D.V., Kurobe, T., Ger, K.A., Lehman, P.W., Teh, S.J. 2010. Estimating the abundance of toxic *Microcystis* in the San Francisco Estuary using quantitative real-time PCR. Harmful Algae. 9:342-349.

Berg, M., Sutula, M. 2015. Factors affecting the growth of cyanobacteria with special emphasis on the Sacramento-San Joaquin Delta. Southern California Coastal Water Research Project Technical Report 869. August 2015.

Chorus, I., Cavalieri, M. 2000. Cyanobacteria and Algae. In J. Bartram and G. Rees (eds): Monitoring Bathing Waters. Published on the behalf of World Health Organization by Spon/Chapman & Hall, London. 337, 219 – 271.

Dodds, W.K., Jones, J.R., Welch, E.B. 1998. Suggested classification of stream trophic states: distributions of temperate stream types by chlorophyll, total nitrogen, and phosphorus. 32(5):1455-1462.

Elliott, J.A. 2010. The seasonal sensitivity of cyanobacteria and other phytoplankton to changes in flushing rate and water temperature. *Global Change Biology* 16:864-876.

Gibble, C.M., Kudela, R.M. 2014. Detection of persistent microcystin toxins at the land-sea interface in Monterey Bay, California. Harmful Algae. 39:146-153.

Glibert, P.M, Dugdale, R.C., Wilkerson, F., Parker, A.E., Alexandar, J., Antell, E., Blaser, S., Johnson, A., Lee, J., Lee, T., Murasko, S., Strong, S. 2014. Major –but rare- spring blooms in 2014 in San Francisco Bay Delta, California, a result of the long-term drought, increased residence time and altered nutrient loads and forms. 460:8-18.

Huisman, J., Jonker, R.R., Zonneveld, C., Weissing, F.J. 1999. Competition for light between phytoplankton species: Experimental tests of mechanistic theory. Ecology. 80(1):211-222.

Huisman, J., Sharples, J., Stroom, J.M., Visser, P.M., Kardinaal, W.E.A., Verspagen, J.M.H., Sommeijer, B., 2004. Changes in turbulent mixing shift competition for light between phytoplankton species. Ecology. 85(11):2960-2970.

Jassby, A.D., 2005. Phytoplankton regulation in a eutrophic tidal river (San Joaquin River, California). San Francisco Estuary & Watershed Science. 3(1):1-22.

Kudela, R.M., Palacios, S.L., Austerberry, D.C., Accorsi, E.K., Guild, L.S., Torres-Perez, J. 2015. Application of hyperspectral remote sensing to cyanobacterial blooms in inland waters. Remote Sensing Env. 167:196-205.

Kurobe, T., Baxa, D.V., Mioni, C.E., Kudela, R.M., Smythe, T.R., Waller, S., Chapman, A.D., Teh, S.J. 2013. Identification of harmful cyanobacteria in the Sacramento-San Joaquin Delta and Clear Lake, California by DNA barcoding. SpringerPlus. 2:491. DOI: 10.1186/2193-1801-2-491.

Lehman, P.W., G. Boyer, C. Hall, S. Waller and K. Gehrts. 2005. Distribution and toxicity of a new colonial *Microcystis aeruginosa* bloom in the San Francisco Bay Estuary, California. Hydrobiologia 541:87-99.

Lehman, P.W., G. Boyer, M. Satchwell and S. Waller. 2008. The influence of environmental conditions on the seasonal variation of *Microcystis* cell density and microcystins concentration in San Francisco Estuary. Hydrobiologia 600:187-204.

Lehman, P.W., S.J. Teh, G.L. Boyer, M.L. Nobriga, E. Bass and C. Hogle. 2010. Initial impacts of *Microcystis aeruginosa* blooms on the aquatic food web in the San Francisco Estuary. Hydrobiologia 637:229-248.

Lehman, P.W., Marr, K., Boyer, G.L., Acuna, S., Teh, S.J. 2013. Long-term trends and causal factors associated with *Microcystis* abundance and toxicity in San Francisco Estuary and implications for climate change impacts. Hydrobiologia. 718:141-158.

Lehman, P.W., Kendall, C., Guerin, M.A., Young, M.B., Silva, S.R., Boyer, G.L., Teh, S.J. 2015. Characterization of the *Microcystis* bloom and its nitrogen supply in San Francisco Estuary using stable isotopes. Estuaries and Coasts. 38:165-178.

Lehman, P.W., Kurobe, T., Lesmeiseter, S., Baxa, D., Tung, A., Teh, S.J. 2017. Impacts of the 2014 severe drought on the Microcystis bloom in San Francisco Estuary. Harmful Algae. 63:94-108.

Li, F., Zhang, H., Zhu, Y., Yihua, Z., Ling, C. 2013. Effect of flow velocity on phytoplankton biomass and composition in a freshwater lake. Science of the total environment. 447:64-71.

Litchman, E. 1998. Population and community responses of phytoplankton to fluctuating light. Oecologia. 117:247-257.

Lürling, M., Eshetu, F., Faassen, E.J., Kosten, S., Huszar, V.L.M. 2013. Comparison of cyanobacterial and green algal growth rates at different temperatures. Freshwater Bio. 58:552-559.

Marmen, S., Aharonovich, D., Grossowicz, M., Blank, L., Yacobi, Y.Z., Sher, D.J. 2016. Distribution and habitat specificity of potentially-toxic *Microcystis* across climate, land, and water use gradients. Frontiers in Microbiology. doi: 10.3389/fmicb.2016.00271

Mioni, C., R. Kudela and D. Baxa. 2012. Harmful cyanobacteria blooms and their toxins in Clear Lake and the Sacramento-San Joaquin Delta (California). Surface Water Ambient Monitoring Program Report 10-058-150.

Mission, B., Latour, D. 2012. Influence of light, sediment mixing, temperature and duration of the benthic life phase on the benthic recruitment of *Microcystis*. Journal of Plankton Research. 34(2):113-119.

Mitrovic, S.M., Hardwick, L. Dorani, F. 2011. Use of flow management to mitigate cyanobacterial blooms in the Lower Darling River, Australia. J. Plankton Research. 33(2):229-241.

Mur, L.R., Skulberg, O.M., Utkilen, H. 1999. Cyanobacteria in the environment. *In* Toxic cyanobacteria in water. Edited by Chorus, I., Bartram, J. E&FN Spon, London, UK. pp.15–40.

O'Brien, K.R., Meyer, D.L., Waite, A.M., Ivey, G.N., Hamilton, D.P. 2004. Disaggregation of *Microcystis aeruginosa* colonies under turbulent mixing: laboratory experiments in a grid-stirred tank. Hydrobiologia. 519:143-152.

Paerl, H.W., Fulton, R.S., Moisander, P.H., Dyble, J. 2001. Harmful freshwater algal blooms, with an emphasis on cyanobacteria. The Scientific World. 1:76-113.

Paerl, H.W., Xu, H., Hall, N.S., Zhu, G., Qin, B., Wu, Y., Rossignol, K.L., Dong, L., McCarthy, M.J., Joyner, A.R. 2014. Controlling cyanobacterial blooms in hypereutrophic lake Taihu, China: will nitrogen reductions cause replacement of non-N_2 fixing by N_2 fixing taxa. PlosONE. http://dx.doi.org/10.1371/journal.pone.0113123

Preece, E.P., Bryan, M., Hardy, F.J., Moore, B.C. 2017. A review of microcystin detections in Estuarine and Marine waters: environmental implications and human health risk. Harmful Algae. 61:31-45.

Reynolds, C.S. 1983. A physiological interpretation of the dynamic responses of populations of a planktonic diatom to physical variability of the environment. New Phytol. 95:41-53.

Reynolds, C.S. 2006. Ecology of Phytoplankton (Ecology, Biodiversity and Conservation). Cambridge University Press, Cambridge, UK.

Rolland, D.C., Bourget, S., Warren, A., Laurion, I., Vincent, W.F. 2013. Extreme variability of cyanobacterial blooms in an urban drinking water supply. J. Plankton Res. 35(4):744-758.

Romo, A., J. Soria, F. Fernandez, Y. Ouahid and A. Baron-Sola. 2013. Water residence time and the dynamics of toxic cyanobacteria. Freshwater Biology 58:513-522.

Schindler, D.W., R.W. Hecky, D.L. Findlay et al. 2008. Eutrophication of lakes cannot be controlled by reducing nitrogen input: results of a 37 year whole ecosystem experiment. Proceedings of the National Academy of Sciences USA 105:11254-11258.

Spier, C., W. Stringfellow, J. Hanlon, M. Estiandan, T. Koski and J. Kaaria. 2013. Unprecedented bloom of toxin-producing cyanobacteria in the Southern Bay-Delta Estuary and its potential negative impact on the aquatic food web. University of the Pacific Ecological Engineering Research Program Report 4.5.1.

Tsujimura, S., Okubo, T. 2003. Development of Anabaena blooms in a small reservoir with dense sediment akinete population, with special reference to temperature and irradiance.

Verspagen, J.M.H. 2004. Recruitment of benthic *Microcystis* (cyanophyceae) to the water column: internal buoyancy changes or resuspension? Journal of Phycology. 40:260-270.

Visser, P.M., Ibelings, B.W., Van der Veer, B., Koedoods, J., Mur, L.R. 1996. Artificial mixing prevents nuisance blooms of the cyanobacterium *Microcystis* in Lake Nieuwe Meer, the Netherlands. Freshwater Biology. 36:435-450.

Visser, P.M., Ibelings, B.W., Bormans, M., Huisman, J. 2016. Artificial mixing to control cyanobacterial blooms: a review. Aquat. Ecol. 50:423-441.

Walsby, A.E., Gabrielle, N., Dunn, C., Davis, P.A. 2004. Comparison of the depth where *Plantothrix rubescens* stratifies and the depth where the daily insolation supports its neutral buoyancy. New Phytologist. 162:133-145.

Wetzel, R.G. 2001. Limnology, 3rd ed. Academic Press.

Wilson, A.E., Wilson, W.A., Hay, M.E. 2006. Intraspecific variation in growth and morphology of the bloom-forming cyanobacterium *Microcystis aeruginosa.* Applied and Environ. Microbio. 72(11):7386-7389.

World Health Organization. 2011. Management of cyanobacteria in drinking- water supplies: Information for regulators and water suppliers. Geneva, Switzerland. Available at: http://www.who.int/water_sanitation_- health/dwq/cyanobacteria_in_drinking-water.pdf (Accessed March 3, 2016)

Zhang, H., Chen, R., Li, F., Chen, L. 2015. Effect of flow rate on environmental variables and phytoplankton dynamics: results from field enclosures. Chinese J. of Oceanology and Limno. 33(2):430-43

Appendix A

Delta Monthly Mean Temperatures at Nine Locations for the CWF and NAA

Sacramento River at Rio Vista, Monthly Temperature

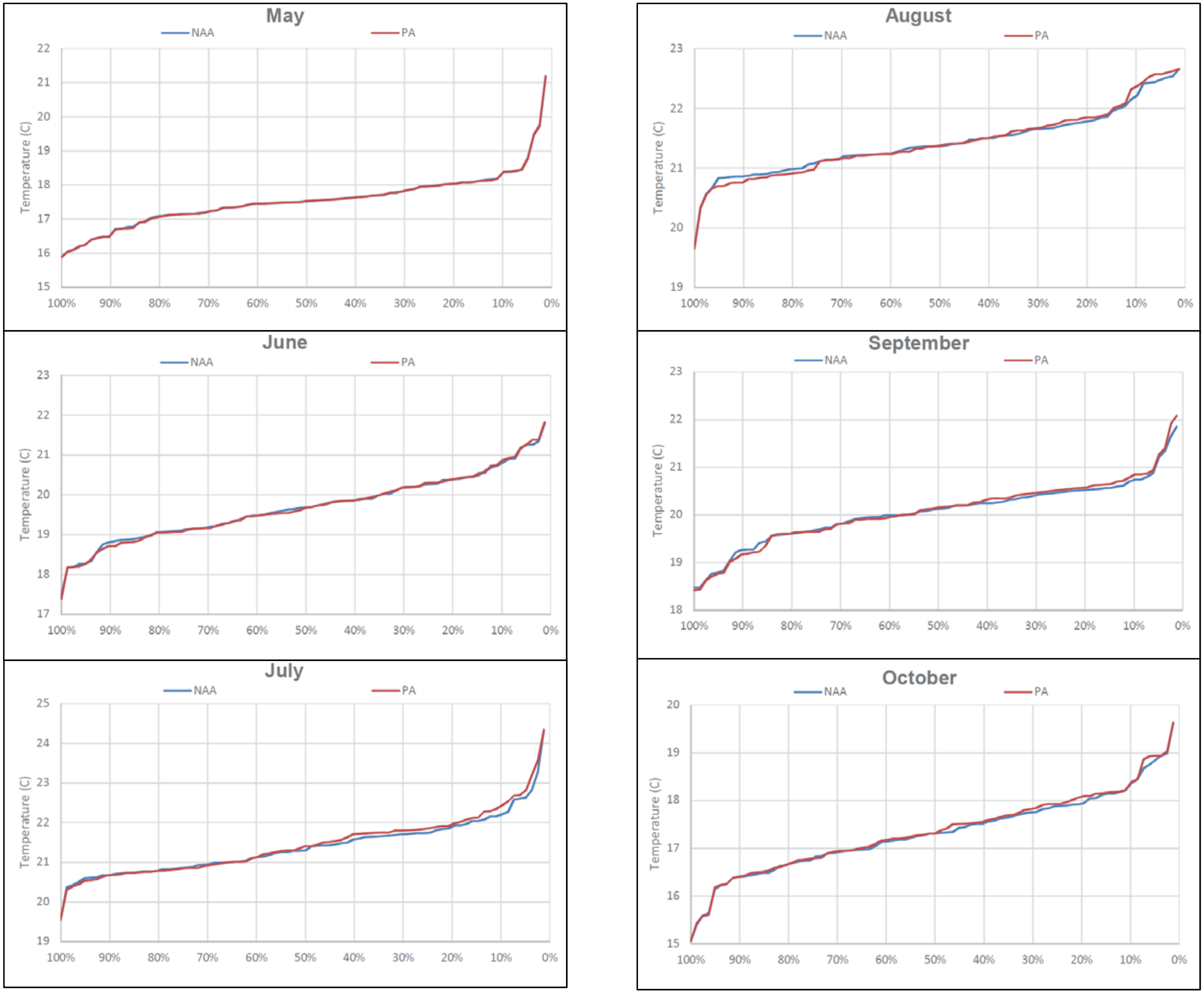
Statistic	Monthly Temperature (Deg-C)																							
	October				November				December				January				February				March			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																								
10%	18.2	18.2	0.0	0%	14.9	15.0	0.1	1%	10.7	10.7	0	0%	9.7	9.7	0.0	0%	11.1	11.1	0.0	0%	14.2	14.2	0.0	0%
20%	17.9	18.1	0.1	1%	14.5	14.7	0.2	2%	10.5	10.5	0	0%	9.5	9.5	0.0	0%	11.0	11.0	0.0	0%	13.7	13.8	0.0	0%
30%	17.8	17.8	0.1	0%	14.4	14.4	0.0	0%	10.4	10.4	0	0%	9.2	9.3	0.1	1%	10.9	10.9	0.0	0%	13.4	13.5	0.1	1%
40%	17.5	17.5	0.0	0%	14.2	14.3	0.0	0%	10.2	10.2	0	0%	9.1	9.1	0.0	0%	10.7	10.8	0.0	0%	13.3	13.3	0.0	0%
50%	17.3	17.3	0.0	0%	14.0	14.1	0.1	0%	10.1	10.1	0	0%	9.0	9.0	0.0	0%	10.6	10.6	0.0	0%	13.0	13.0	0.1	0%
60%	17.1	17.2	0.0	0%	13.8	13.8	0.0	0%	10.0	10.0	0	0%	8.9	8.9	0.0	0%	10.4	10.4	0.0	0%	12.7	12.8	0.0	0%
70%	16.9	16.9	0.0	0%	13.6	13.7	0.1	0%	9.8	9.8	0	0%	8.8	8.8	0.0	0%	10.3	10.3	0.0	0%	12.6	12.6	0.0	0%
80%	16.6	16.7	0.0	0%	13.3	13.3	0.0	0%	9.7	9.7	0	0%	8.4	8.4	0.0	0%	10.1	10.2	0.0	0%	12.4	12.5	0.1	1%
90%	16.4	16.4	0.0	0%	12.9	12.9	0.0	0%	9.4	9.5	0	0%	8.1	8.0	0.0	0%	10.0	10.0	0.0	0%	12.0	12.0	0.0	0%
Long Term																								
Full Simulation Period[b]	17.3	17.3	0.0	0%	13.9	14.0	0.1	0%	10.1	10.1	0	0%	9.0	9.0	0.0	0%	10.6	10.6	0.0	0%	13.0	13.1	0.1	0%
Water Year Types[c]																								
Wet (32%)	17.3	17.4	0.1	0%	13.9	14.0	0.1	1%	10.1	10.1	0	0%	9.1	9.1	0.0	0%	10.5	10.5	0.0	0%	12.7	12.7	0.1	0%
Above Normal (16%)	15.7	15.8	0.0	0%	12.5	12.6	0.1	1%	9.2	9.2	0	0%	9.3	9.3	0.0	0%	10.6	10.7	0.0	0%	13.0	13.0	0.0	0%
Below Normal (13%)	17.4	17.4	0.0	0%	14.1	14.2	0.1	1%	10.0	10.0	0	0%	8.8	8.8	0.0	0%	10.4	10.4	0.0	0%	13.0	13.1	0.1	0%
Dry (24%)	17.3	17.3	0.0	0%	14.0	14.1	0.1	0%	10.2	10.3	0	0%	8.7	8.7	0.0	0%	10.6	10.6	0.0	0%	13.0	13.1	0.1	0%
Critical (15%)	17.6	17.6	0.0	0%	14.1	14.1	0.0	0%	10.1	10.2	0	0%	8.8	8.8	0.0	0%	10.7	10.8	0.0	0%	13.8	13.8	0.0	0%

Statistic	Monthly Temperature (Deg-C)																							
	April				May				June				July				August				September			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																								
10%	15.9	15.9	0.0	0%	18.2	18.2	0.0	0%	20.7	20.8	0	0%	22.2	22.3	0.2	1%	22.1	22.3	0.2	1%	20.7	20.8	0.1	0%
20%	15.5	15.5	0.0	0%	18.0	18.0	0.0	0%	20.4	20.4	0	0%	21.9	21.9	0.1	0%	21.8	21.8	0.1	0%	20.5	20.6	0.0	0%
30%	15.2	15.2	0.0	0%	17.8	17.8	0.0	0%	20.2	20.2	0	0%	21.7	21.8	0.1	0%	21.7	21.7	0.0	0%	20.4	20.5	0.1	0%
40%	14.9	15.0	0.0	0%	17.6	17.6	0.0	0%	19.9	19.9	0	0%	21.5	21.7	0.1	1%	21.5	21.5	0.0	0%	20.2	20.3	0.1	0%
50%	14.7	14.7	0.0	0%	17.5	17.5	0.0	0%	19.7	19.6	0	0%	21.3	21.4	0.1	0%	21.4	21.4	0.0	0%	20.1	20.1	0.0	0%
60%	14.5	14.5	0.0	0%	17.5	17.4	0.0	0%	19.5	19.5	0	0%	21.1	21.1	0.0	0%	21.2	21.2	0.0	0%	20.0	19.9	0.0	0%
70%	14.4	14.4	0.0	0%	17.2	17.2	0.0	0%	19.2	19.2	0	0%	20.9	20.9	0.0	0%	21.2	21.2	0.0	0%	19.8	19.8	0.0	0%
80%	14.2	14.2	0.0	0%	17.1	17.1	0.0	0%	19.1	19.0	0	0%	20.8	20.8	0.0	0%	21.0	20.9	-0.1	0%	19.6	19.6	0.0	0%
90%	14.1	14.1	0.0	0%	16.5	16.5	0.0	0%	18.8	18.7	0	-1%	20.7	20.7	0.0	0%	20.9	20.8	-0.1	0%	19.3	19.2	-0.1	0%
Long Term																								
Full Simulation Period[b]	14.8	14.8	0.0	0%	17.5	17.5	0.0	0%	19.7	19.7	0	0%	21.4	21.4	0.1	0%	21.4	21.4	0.0	0%	20.1	20.1	0.0	0%
Water Year Types[c]																								
Wet (32%)	14.5	14.5	0.0	0%	17.5	17.5	0.0	0%	19.4	19.4	0	0%	21.3	21.4	0.1	0%	21.5	21.5	0.0	0%	20.2	20.3	0.0	0%
Above Normal (16%)	14.8	14.8	0.0	0%	17.6	17.6	0.0	0%	20.0	20.0	0	0%	21.4	21.4	0.0	0%	21.2	21.2	0.0	0%	20.0	20.0	0.0	0%
Below Normal (13%)	15.2	15.2	0.0	0%	17.4	17.4	0.0	0%	19.7	19.7	0	0%	21.4	21.5	0.1	0%	21.3	21.3	0.0	0%	19.9	19.9	0.1	0%
Dry (24%)	15.0	15.0	0.0	0%	17.6	17.6	0.0	0%	20.1	20.1	0	0%	21.5	21.5	0.1	0%	21.4	21.4	0.0	0%	20.1	20.1	0.0	0%
Critical (15%)	15.0	15.0	0.0	0%	17.5	17.5	0.0	0%	19.3	19.3	0	0%	21.5	21.5	0.0	0%	21.4	21.4	0.0	0%	19.9	19.9	0.0	0%

a Exceedance probability is defined as the probability a given value will be exceeded in any one year.
b Based on the 82-year simulation period.
c As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999); projected to Year 2030. WYT for a given water year is applied from Feb through Jan consistent with CALSIM II.
d There are 26 wet years, 13 above normal years, 11 below normal years, 20 dry years, and 12 critical years projected for 2030 under Q5 climate scenario.

Source: Biological Assessment, Appendix 5.B, DSM2 Modeling and Results

Sacramento River at Rio Vista, Monthly Temperature



Source: Biological Assessment, Appendix 5B, Figure 5.B.5.40-1

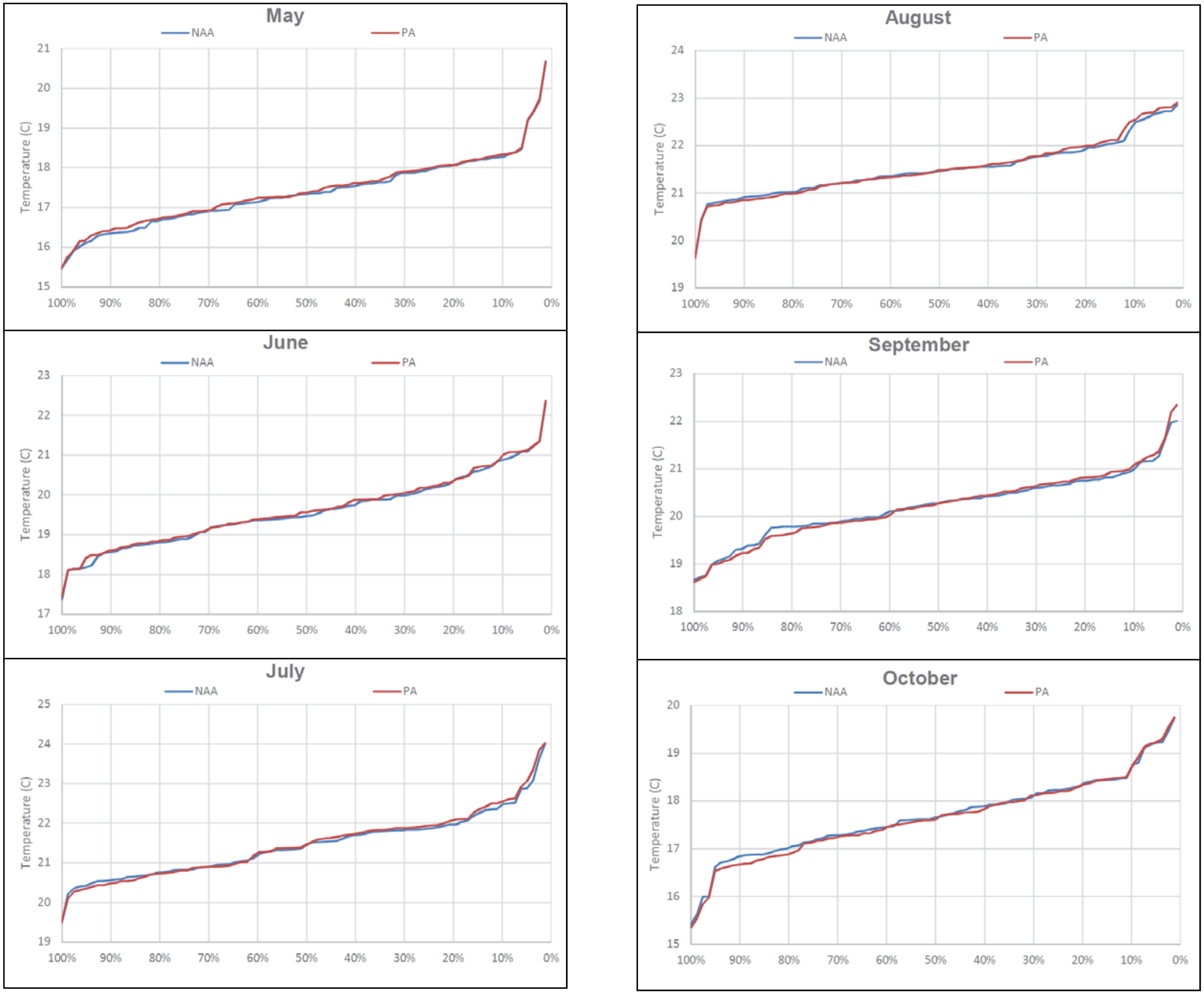
San Joaquin River at Prisoners Point, Monthly Temperature

Statistic	Monthly Temperature (Deg-C)																							
	October				November				December				January				February				March			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																								
10%	18.5	18.5	0.0	0%	15.5	15.5	0.0	0%	11.6	11.6	0	0%	10.4	10.6	0.1	1%	11.9	12.1	0.1	1%	14.6	15.0	0.4	3%
20%	18.3	18.3	0.0	0%	15.2	15.2	0.0	0%	11.3	11.3	0	1%	10.0	10.0	0.1	1%	11.6	11.9	0.2	2%	14.3	14.6	0.3	2%
30%	18.0	18.1	0.0	0%	14.9	14.9	0.1	0%	11.1	11.1	0	1%	9.7	9.8	0.1	1%	11.4	11.6	0.2	2%	14.0	14.3	0.3	2%
40%	17.9	17.8	-0.1	-1%	14.7	14.7	0.1	0%	11.0	11.0	0	0%	9.4	9.5	0.1	1%	11.2	11.3	0.1	1%	13.8	14.0	0.2	1%
50%	17.6	17.6	0.0	0%	14.5	14.6	0.1	0%	10.8	10.8	0	0%	9.3	9.3	0.0	0%	11.0	11.1	0.2	1%	13.6	13.7	0.2	1%
60%	17.4	17.4	-0.1	0%	14.4	14.2	-0.2	-1%	10.6	10.7	0	0%	9.0	9.1	0.1	1%	10.8	11.0	0.2	2%	13.3	13.7	0.3	2%
70%	17.3	17.2	-0.1	0%	14.1	14.0	0.0	0%	10.5	10.6	0	1%	8.8	8.9	0.1	1%	10.6	10.8	0.1	1%	13.1	13.4	0.3	2%
80%	17.0	16.9	-0.1	-1%	13.9	13.8	-0.1	0%	10.3	10.4	0	1%	8.5	8.5	0.0	0%	10.2	10.3	0.1	1%	13.0	13.2	0.2	2%
90%	16.8	16.7	-0.1	-1%	13.2	13.1	-0.1	0%	9.9	9.9	0	0%	8.0	8.0	0.0	0%	9.9	10.0	0.1	1%	12.7	12.9	0.2	2%
Long Term																								
Full Simulation Period[b]	17.5	17.4	0.0	0%	14.3	14.3	0.0	0%	10.7	10.7	0	0%	9.3	9.3	0.1	1%	10.9	11.1	0.2	2%	13.6	13.9	0.3	2%
Water Year Types[c]																								
Wet (32%)	17.8	17.7	-0.1	0%	14.5	14.4	-0.1	-1%	10.8	10.8	0	0%	9.6	9.7	0.1	1%	11.4	11.6	0.3	2%	13.7	14.0	0.3	2%
Above Normal (16%)	16.1	16.0	-0.1	0%	13.0	12.9	-0.1	0%	9.7	9.8	0	1%	9.8	9.9	0.1	1%	11.1	11.3	0.2	2%	13.7	14.2	0.5	3%
Below Normal (13%)	17.6	17.6	0.0	0%	14.6	14.6	0.0	0%	10.7	10.8	0	0%	9.0	9.1	0.1	1%	10.5	10.6	0.1	1%	13.3	13.7	0.3	2%
Dry (24%)	17.6	17.6	0.0	0%	14.6	14.6	0.1	0%	11.1	11.1	0	0%	8.8	8.9	0.1	1%	10.7	10.8	0.1	1%	13.4	13.6	0.2	1%
Critical (15%)	17.9	17.8	0.0	0%	14.7	14.6	0.0	0%	10.9	10.9	0	0%	8.8	8.8	0.0	0%	10.6	10.7	0.0	0%	14.0	14.1	0.1	1%

Statistic	Monthly Temperature (Deg-C)																							
	April				May				June				July				August				September			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																								
10%	16.4	16.4	0.0	0%	18.3	18.3	0.0	0%	20.8	20.8	0	0%	22.4	22.5	0.1	1%	22.3	22.5	0.2	1%	20.9	21.0	0.1	0%
20%	15.9	16.0	0.1	1%	18.0	18.1	0.0	0%	20.3	20.3	0	0%	22.0	22.0	0.1	0%	21.9	22.0	0.1	0%	20.7	20.8	0.1	0%
30%	15.6	15.7	0.1	1%	17.9	17.9	0.0	0%	20.0	20.0	0	0%	21.8	21.9	0.1	0%	21.8	21.8	0.0	0%	20.6	20.6	0.0	0%
40%	15.3	15.3	0.1	0%	17.5	17.6	0.1	0%	19.7	19.8	0	1%	21.7	21.7	0.0	0%	21.6	21.6	0.0	0%	20.4	20.4	0.0	0%
50%	15.0	15.1	0.1	0%	17.3	17.4	0.0	0%	19.5	19.6	0	1%	21.4	21.4	0.0	0%	21.5	21.5	0.0	0%	20.3	20.2	0.0	0%
60%	14.8	14.9	0.2	1%	17.1	17.2	0.1	1%	19.4	19.4	0	0%	21.2	21.2	0.0	0%	21.4	21.3	0.0	0%	20.1	20.0	-0.1	0%
70%	14.6	14.8	0.1	1%	16.9	16.9	0.0	0%	19.1	19.1	0	0%	20.9	20.9	0.0	0%	21.2	21.2	0.0	0%	19.9	19.9	0.0	0%
80%	14.4	14.5	0.2	1%	16.7	16.7	0.0	0%	18.8	18.8	0	0%	20.8	20.7	0.0	0%	21.0	21.0	0.0	0%	19.8	19.6	-0.2	-1%
90%	13.7	13.9	0.2	1%	16.3	16.4	0.1	0%	18.6	18.6	0	0%	20.6	20.5	-0.1	0%	20.9	20.9	-0.1	0%	19.3	19.2	-0.1	0%
Long Term																								
Full Simulation Period[b]	15.1	15.2	0.1	1%	17.4	17.4	0.1	0%	19.6	19.6	0	0%	21.4	21.5	0.0	0%	21.5	21.5	0.0	0%	20.2	20.2	0.0	0%
Water Year Types[c]																								
Wet (32%)	14.9	15.0	0.1	1%	17.4	17.4	0.0	0%	19.4	19.5	0	1%	21.4	21.4	0.0	0%	21.6	21.7	0.0	0%	20.4	20.4	0.0	0%
Above Normal (16%)	15.0	15.1	0.1	1%	17.4	17.4	0.1	0%	19.9	20.0	0	0%	21.4	21.4	0.0	0%	21.4	21.4	0.0	0%	20.1	20.0	0.0	0%
Below Normal (13%)	15.3	15.4	0.1	1%	17.3	17.4	0.0	0%	19.5	19.5	0	0%	21.5	21.5	0.0	0%	21.4	21.4	0.0	0%	20.1	20.1	0.0	0%
Dry (24%)	15.2	15.3	0.1	1%	17.4	17.5	0.0	0%	20.0	20.0	0	0%	21.5	21.6	0.0	0%	21.5	21.5	0.0	0%	20.2	20.2	0.0	0%
Critical (15%)	15.1	15.2	0.0	0%	17.3	17.3	0.0	0%	19.1	19.1	0	0%	21.4	21.4	0.0	0%	21.5	21.5	0.0	0%	20.1	20.1	0.0	0%

a Exceedance probability is defined as the probability a given value will be exceeded in any one year.
b Based on the 82-year simulation period.
c As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999); projected to Year 2030. WYT for a given water year is applied from Feb through Jan consistent with CALSIM II.
d There are 26 wet years, 13 above normal years, 11 below normal years, 20 dry years, and 12 critical years projected for 2030 under Q5 climate scenario.

San Joaquin River at Prisoner's Point, Monthly Temperature



Source: Biological Assessment, Appendix 5B, Figure 5.B.5.41-1

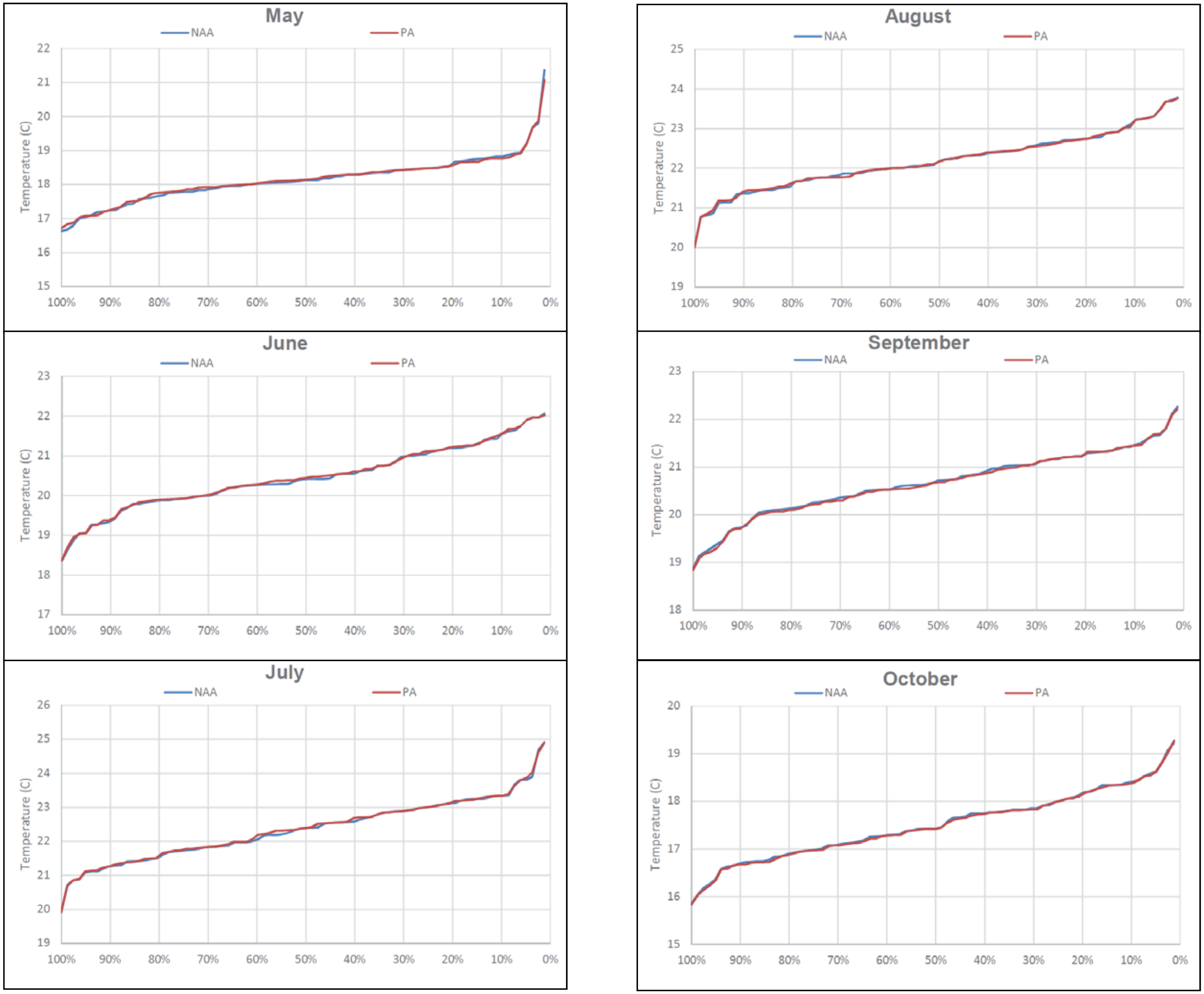
San Joaquin River at Brandt Bridge, Monthly Temperature

Statistic	Monthly Temperature (Deg-C)																							
	October				November				December				January				February				March			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																								
10%	18.4	18.4	0.0	0%	14.7	14.6	0.0	0%	11.0	11.0	0	0%	10.7	10.7	0.0	0%	12.7	12.6	0.0	0%	15.6	15.4	-0.2	-1%
20%	18.1	18.1	0.0	0%	14.3	14.3	0.0	0%	10.7	10.7	0	0%	10.4	10.4	0.0	0%	12.5	12.4	0.0	0%	15.2	15.2	0.0	0%
30%	17.8	17.8	0.0	0%	14.1	14.1	0.0	0%	10.3	10.3	0	0%	10.3	10.3	0.0	0%	12.3	12.3	0.0	0%	14.9	14.8	-0.1	-1%
40%	17.8	17.7	0.0	0%	14.0	14.0	0.0	0%	10.2	10.2	0	0%	10.1	10.1	0.0	0%	12.1	12.1	0.0	0%	14.5	14.5	0.0	0%
50%	17.4	17.4	0.0	0%	13.8	13.7	0.0	0%	10.0	10.0	0	0%	10.0	10.0	0.1	1%	12.0	12.0	0.0	0%	14.3	14.3	0.0	0%
60%	17.3	17.2	0.0	0%	13.6	13.6	0.0	0%	9.9	9.9	0	0%	9.8	9.8	0.1	1%	11.8	11.9	0.0	0%	14.1	14.1	0.0	0%
70%	17.1	17.1	0.0	0%	13.4	13.4	0.0	0%	9.7	9.7	0	0%	9.5	9.6	0.1	1%	11.7	11.7	0.0	0%	14.0	14.0	0.0	0%
80%	16.9	16.9	0.0	0%	13.1	13.1	0.0	0%	9.6	9.6	0	0%	9.1	9.2	0.1	1%	11.6	11.6	0.0	0%	13.7	13.7	0.0	0%
90%	16.6	16.7	0.0	0%	12.6	12.5	0.0	0%	9.2	9.2	0	0%	8.7	8.9	0.2	2%	11.4	11.4	0.0	0%	13.3	13.4	0.0	0%
Long Term Full Simulation Period[b]	17.3	17.3	0.0	0%	13.6	13.5	0.0	0%	10.0	10.0	0	0%	9.8	9.9	0.1	1%	12.0	12.0	0.0	0%	14.4	14.4	0.0	0%
Water Year Types[c]																								
Wet (32%)	17.6	17.6	0.0	0%	13.9	13.8	0.0	0%	10.2	10.2	0	0%	10.1	10.2	0.0	0%	12.0	12.0	0.0	0%	14.2	14.2	0.0	0%
Above Normal (16%)	15.9	15.9	0.0	0%	12.4	12.3	0.0	0%	9.2	9.2	0	0%	10.2	10.3	0.0	0%	12.1	12.1	0.0	0%	14.5	14.5	0.0	0%
Below Normal (13%)	17.5	17.5	0.0	0%	13.8	13.8	0.0	0%	9.9	9.9	0	0%	9.6	9.7	0.1	1%	11.8	11.8	0.0	0%	14.3	14.3	0.0	0%
Dry (24%)	17.4	17.4	0.0	0%	13.7	13.7	0.0	0%	10.3	10.3	0	0%	9.5	9.6	0.1	1%	12.0	12.0	0.0	0%	14.5	14.5	0.0	0%
Critical (15%)	17.6	17.6	0.0	0%	13.7	13.7	0.0	0%	10.0	10.0	0	0%	9.6	9.7	0.1	1%	12.0	12.0	0.0	0%	15.0	14.9	-0.1	-1%

Statistic	Monthly Temperature (Deg-C)																							
	April				May				June				July				August				September			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																								
10%	16.9	16.9	0.0	0%	18.8	18.8	-0.1	0%	21.4	21.5	0	0%	23.3	23.3	0.0	0%	23.1	23.0	-0.1	0%	21.4	21.4	0.0	0%
20%	16.5	16.5	0.0	0%	18.5	18.5	0.0	0%	21.2	21.2	0	0%	23.1	23.1	0.0	0%	22.7	22.7	0.0	0%	21.2	21.2	0.0	0%
30%	16.3	16.3	0.0	0%	18.4	18.4	0.0	0%	20.9	20.9	0	0%	22.9	22.9	0.0	0%	22.6	22.5	0.0	0%	21.0	21.1	0.0	0%
40%	16.1	16.1	0.0	0%	18.3	18.3	0.0	0%	20.5	20.6	0	0%	22.6	22.6	0.1	0%	22.4	22.4	0.0	0%	20.9	20.9	0.0	0%
50%	15.7	15.8	0.0	0%	18.1	18.1	0.0	0%	20.4	20.4	0	0%	22.4	22.4	0.0	0%	22.1	22.1	0.0	0%	20.7	20.7	0.0	0%
60%	15.6	15.6	0.0	0%	18.0	18.0	0.0	0%	20.3	20.3	0	0%	22.0	22.1	0.1	0%	22.0	22.0	0.0	0%	20.5	20.5	0.0	0%
70%	15.4	15.4	0.0	0%	17.8	17.9	0.1	0%	20.0	20.0	0	0%	21.8	21.8	0.0	0%	21.8	21.8	-0.1	0%	20.3	20.3	0.0	0%
80%	15.2	15.2	0.0	0%	17.7	17.8	0.1	1%	19.9	19.9	0	0%	21.5	21.5	0.0	0%	21.6	21.6	0.1	0%	20.1	20.1	0.0	0%
90%	14.9	14.9	0.0	0%	17.2	17.2	0.0	0%	19.3	19.4	0	0%	21.3	21.3	0.0	0%	21.4	21.4	0.0	0%	19.7	19.7	0.0	0%
Long Term Full Simulation Period[b]	15.8	15.8	0.0	0%	18.1	18.1	0.0	0%	20.4	20.5	0	0%	22.4	22.4	0.0	0%	22.2	22.2	0.0	0%	20.7	20.6	0.0	0%
Water Year Types[c]																								
Wet (32%)	15.6	15.6	0.0	0%	18.2	18.2	0.0	0%	20.5	20.5	0	0%	22.9	22.9	0.0	0%	22.7	22.7	0.0	0%	21.1	21.1	0.0	0%
Above Normal (16%)	15.8	15.8	0.0	0%	18.2	18.2	0.0	0%	20.8	20.8	0	0%	22.3	22.3	0.0	0%	22.0	22.0	0.0	0%	20.7	20.7	0.0	0%
Below Normal (13%)	16.2	16.3	0.1	0%	17.8	17.8	0.1	0%	20.4	20.5	0	0%	22.2	22.2	0.0	0%	21.9	21.9	0.0	0%	20.5	20.5	0.0	0%
Dry (24%)	15.9	15.9	0.0	0%	18.2	18.2	0.0	0%	20.6	20.7	0	0%	22.0	22.1	0.1	0%	22.0	22.0	0.0	0%	20.5	20.5	0.0	0%
Critical (15%)	15.9	15.9	0.0	0%	18.1	18.1	0.0	0%	19.6	19.6	0	0%	22.0	22.0	0.0	0%	21.8	21.8	0.0	0%	20.2	20.2	0.0	0%

a Exceedance probability is defined as the probability a given value will be exceeded in any one year.
b Based on the 82-year simulation period.
c As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999); projected to Year 2030. WYT for a given water year is applied from Feb through Jan consistent with CALSIM II.
d There are 26 wet years, 13 above normal years, 11 below normal years, 20 dry years, and 12 critical years projected for 2030 under Q5 climate scenario.

San Joaquin River at Brandt Bridge, Monthly Temperature



Source: Biological Assessment, Appendix 5B, Figure 5.B.5.42-1

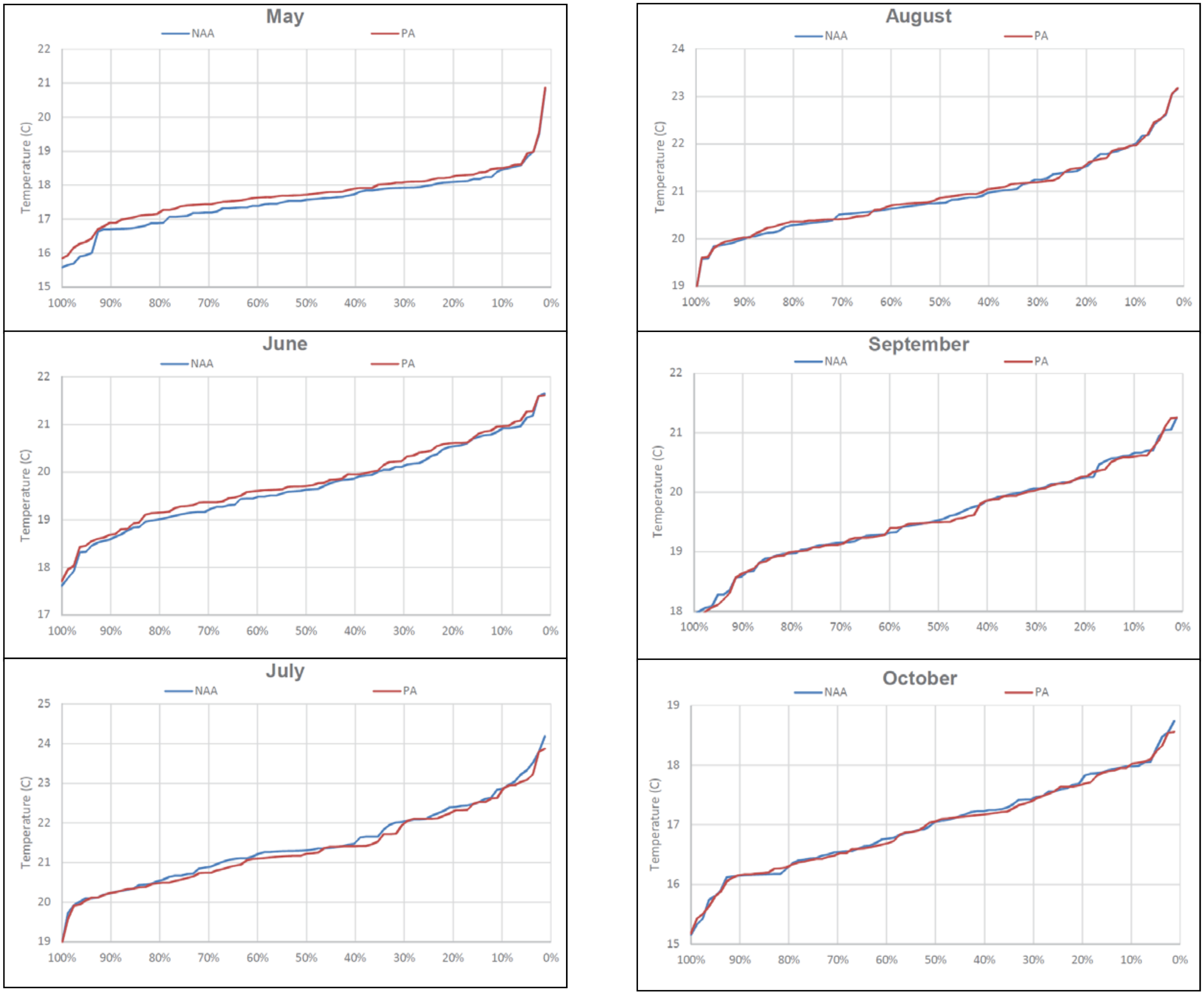
San Joaquin River near Stockton DWSC, Monthly Temperature

Statistic	Monthly Temperature (Deg-C)																							
	October				November				December				January				February				March			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																								
10%	18.0	18.0	0.0	0%	14.4	14.4	0.0	0%	10.9	10.9	0	-1%	10.3	10.5	0.2	2%	12.2	12.3	0.1	1%	15.1	15.2	0.2	1%
20%	17.7	17.7	0.0	0%	14.0	14.0	0.0	0%	10.4	10.4	0	0%	10.0	10.1	0.2	2%	11.9	12.1	0.2	2%	14.8	15.0	0.1	1%
30%	17.4	17.4	0.0	0%	13.8	13.8	0.0	0%	9.9	9.9	0	0%	9.7	10.0	0.3	3%	11.7	12.0	0.3	2%	14.4	14.5	0.1	1%
40%	17.2	17.2	-0.1	0%	13.6	13.6	0.0	0%	9.6	9.6	0	0%	9.4	9.7	0.3	3%	11.6	11.8	0.2	1%	14.1	14.3	0.2	1%
50%	16.9	17.0	0.0	0%	13.5	13.5	0.0	0%	9.5	9.5	0	0%	9.1	9.5	0.3	4%	11.4	11.7	0.2	2%	13.8	14.0	0.2	1%
60%	16.7	16.7	-0.1	0%	13.3	13.3	0.0	0%	9.4	9.4	0	0%	8.9	9.3	0.4	5%	11.4	11.5	0.2	2%	13.7	13.9	0.2	1%
70%	16.5	16.5	0.0	0%	13.1	13.1	0.0	0%	9.2	9.2	0	0%	8.5	9.1	0.6	7%	11.1	11.4	0.3	3%	13.6	13.7	0.1	1%
80%	16.2	16.3	0.1	1%	12.7	12.7	0.0	0%	9.0	9.0	0	0%	8.1	8.7	0.6	7%	10.9	11.3	0.3	3%	13.3	13.6	0.3	2%
90%	16.1	16.1	0.0	0%	12.3	12.3	0.0	0%	8.7	8.7	0	0%	7.6	8.2	0.6	8%	10.5	10.9	0.5	5%	12.9	13.2	0.3	2%
Long Term																								
Full Simulation Period[b]	16.8	16.8	0.0	0%	13.3	13.3	0.0	0%	9.5	9.5	0	0%	9.0	9.4	0.4	4%	11.4	11.6	0.3	2%	14.0	14.1	0.2	1%
Water Year Types[c]																								
Wet (32%)	17.2	17.2	0.0	0%	13.6	13.6	0.0	0%	9.7	9.7	0	0%	9.7	9.9	0.2	2%	11.8	11.9	0.1	1%	14.0	14.1	0.1	0%
Above Normal (16%)	15.5	15.5	0.0	0%	12.1	12.1	0.0	0%	8.7	8.7	0	0%	9.6	9.9	0.3	3%	11.6	11.8	0.2	2%	14.2	14.3	0.1	1%
Below Normal (13%)	17.0	16.9	-0.1	0%	13.5	13.5	0.0	0%	9.5	9.4	0	0%	8.7	9.2	0.4	5%	11.0	11.4	0.3	3%	13.8	14.0	0.2	1%
Dry (24%)	16.9	16.9	0.0	0%	13.5	13.5	0.0	0%	9.9	9.9	0	0%	8.5	9.0	0.5	6%	11.1	11.5	0.4	4%	13.7	14.0	0.3	2%
Critical (15%)	17.0	16.9	-0.1	0%	13.3	13.3	0.0	0%	9.5	9.4	0	0%	8.3	8.9	0.6	7%	11.0	11.4	0.5	4%	14.1	14.4	0.3	2%

Statistic	Monthly Temperature (Deg-C)																							
	April				May				June				July				August				September			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																								
10%	16.2	16.4	0.2	1%	18.4	18.5	0.1	1%	20.8	21.0	0	1%	22.8	22.6	-0.2	-1%	21.9	22.0	0.0	0%	20.6	20.6	0.0	0%
20%	16.1	16.2	0.1	1%	18.1	18.2	0.1	1%	20.5	20.6	0	0%	22.4	22.2	-0.2	-1%	21.5	21.5	0.0	0%	20.2	20.3	0.0	0%
30%	15.8	15.9	0.1	1%	17.9	18.1	0.2	1%	20.1	20.2	0	1%	22.0	21.9	-0.1	-1%	21.2	21.2	0.0	0%	20.1	20.0	0.0	0%
40%	15.5	15.6	0.1	1%	17.7	17.9	0.2	1%	19.9	20.0	0	1%	21.5	21.4	0.0	0%	20.9	21.0	0.1	0%	19.8	19.8	0.0	0%
50%	15.3	15.5	0.2	1%	17.6	17.7	0.2	1%	19.6	19.7	0	0%	21.3	21.2	-0.1	0%	20.7	20.8	0.1	0%	19.5	19.5	0.0	0%
60%	15.1	15.3	0.2	1%	17.4	17.6	0.2	1%	19.5	19.6	0	1%	21.2	21.1	-0.1	0%	20.6	20.7	0.1	0%	19.3	19.3	0.0	0%
70%	14.9	15.1	0.1	1%	17.2	17.4	0.3	1%	19.2	19.4	0	1%	20.9	20.7	-0.1	-1%	20.5	20.4	-0.1	0%	19.2	19.1	0.0	0%
80%	14.6	14.8	0.2	1%	16.9	17.2	0.3	2%	19.0	19.1	0	1%	20.5	20.5	-0.1	0%	20.3	20.4	0.1	0%	19.0	19.0	0.0	0%
90%	14.3	14.6	0.3	2%	16.7	16.9	0.2	1%	18.6	18.7	0	1%	20.2	20.2	0.0	0%	20.0	20.0	0.0	0%	18.6	18.6	0.0	0%
Long Term																								
Full Simulation Period[b]	15.3	15.5	0.2	1%	17.5	17.7	0.2	1%	19.7	19.8	0	1%	21.4	21.4	-0.1	0%	20.9	20.9	0.0	0%	19.6	19.6	0.0	0%
Water Year Types[c]																								
Wet (32%)	15.3	15.4	0.1	1%	17.9	17.9	0.0	0%	19.9	20.0	0	0%	21.8	21.8	0.0	0%	21.4	21.5	0.1	0%	20.1	20.0	0.0	0%
Above Normal (16%)	15.3	15.5	0.2	1%	17.7	17.9	0.2	1%	20.0	20.2	0	1%	21.3	21.2	0.0	0%	20.6	20.6	0.1	0%	19.5	19.5	0.0	0%
Below Normal (13%)	15.7	15.9	0.2	2%	17.2	17.5	0.3	2%	19.5	19.7	0	1%	21.3	21.1	-0.2	-1%	20.6	20.6	0.0	0%	19.4	19.4	0.0	0%
Dry (24%)	15.3	15.5	0.2	1%	17.4	17.7	0.3	2%	19.8	19.9	0	1%	21.4	21.1	-0.2	-1%	20.7	20.7	0.0	0%	19.5	19.4	0.0	0%
Critical (15%)	14.9	15.2	0.3	2%	17.0	17.3	0.3	2%	18.9	18.9	0	0%	21.2	21.1	-0.1	0%	20.7	20.7	-0.1	0%	19.1	19.0	-0.1	0%

a Exceedance probability is defined as the probability a given value will be exceeded in any one year.
b Based on the 82-year simulation period.
c As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999); projected to Year 2030. WYT for a given water year is applied from Feb through Jan consistent with CALSIM II.
d There are 26 wet years, 13 above normal years, 11 below normal years, 20 dry years, and 12 critical years projected for 2030 under Q5 climate scenario.

San Joaquin River near Stockton DWSC, Monthly Temperature



Source: Biological Assessment, Appendix 5B, Figure 5.B.5.43-1

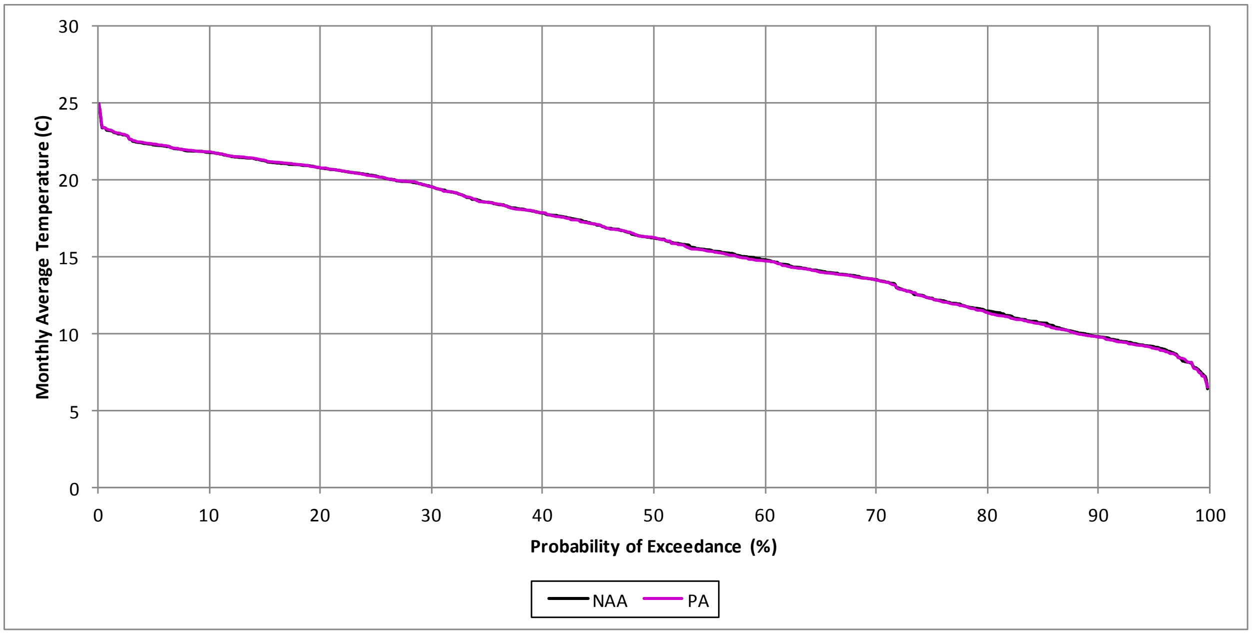


Figure 1. Middle River at Middle River Monthly Average Temperature for Period of Record WY1922-2002.

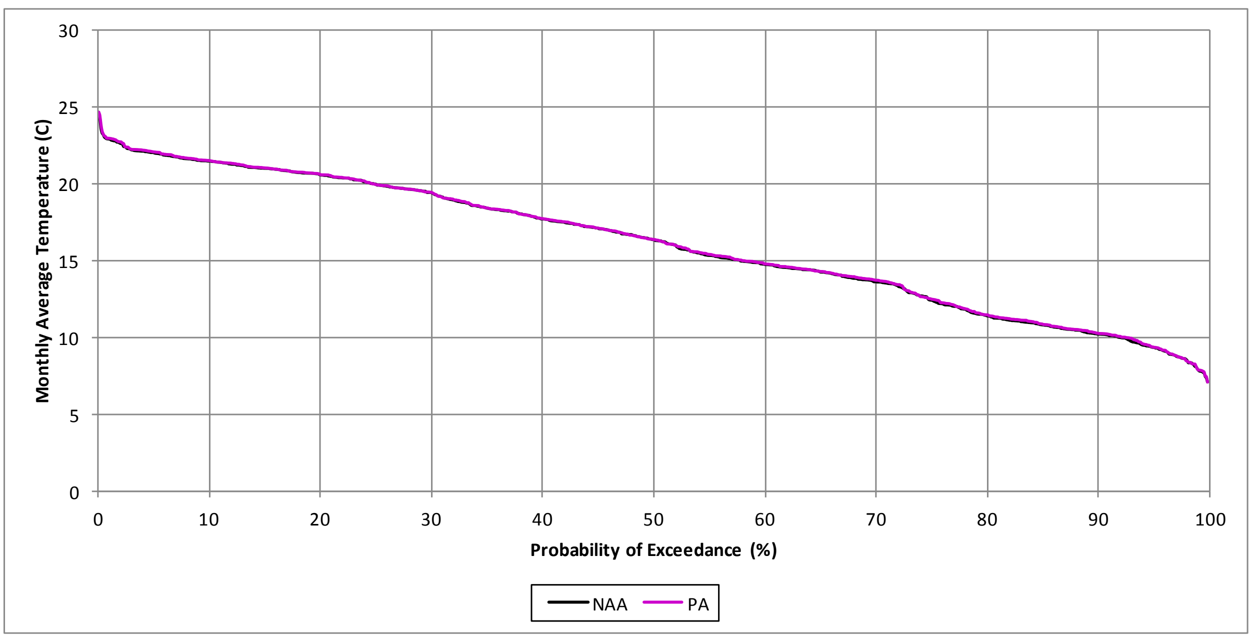


Figure 2. Middle River at Bacon Island Monthly Average Temperature for Period of Record WY1922-2002.

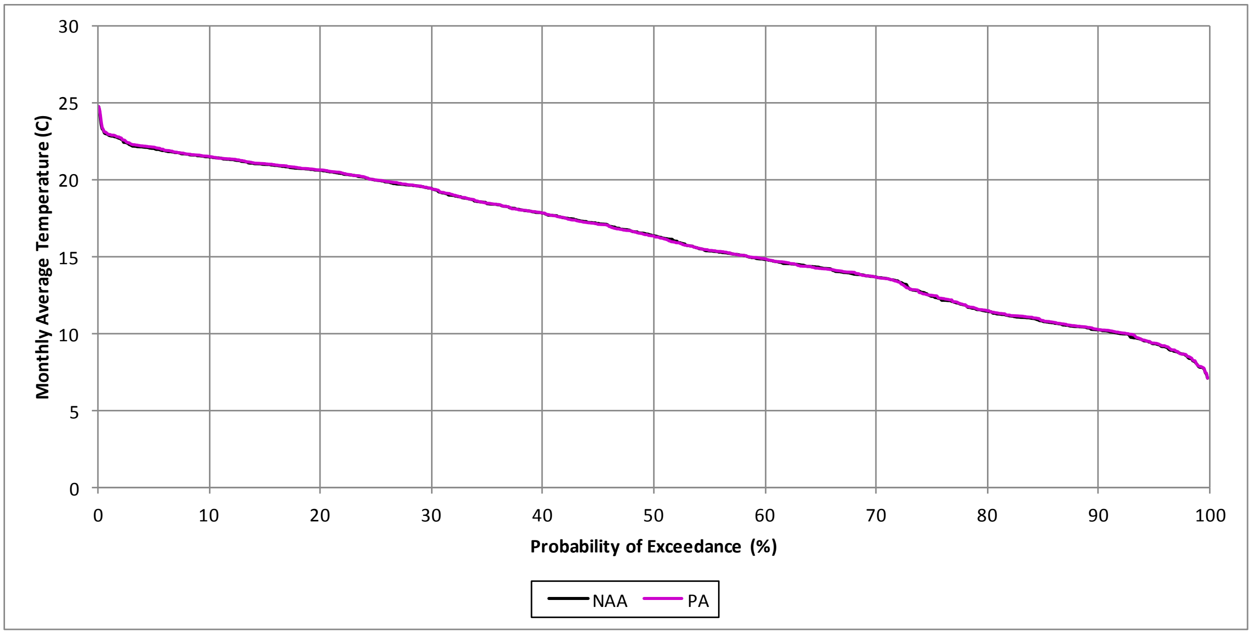


Figure 3. Victoria Canal near Bryon Monthly Average Temperature for Period of Record WY1922-2002.

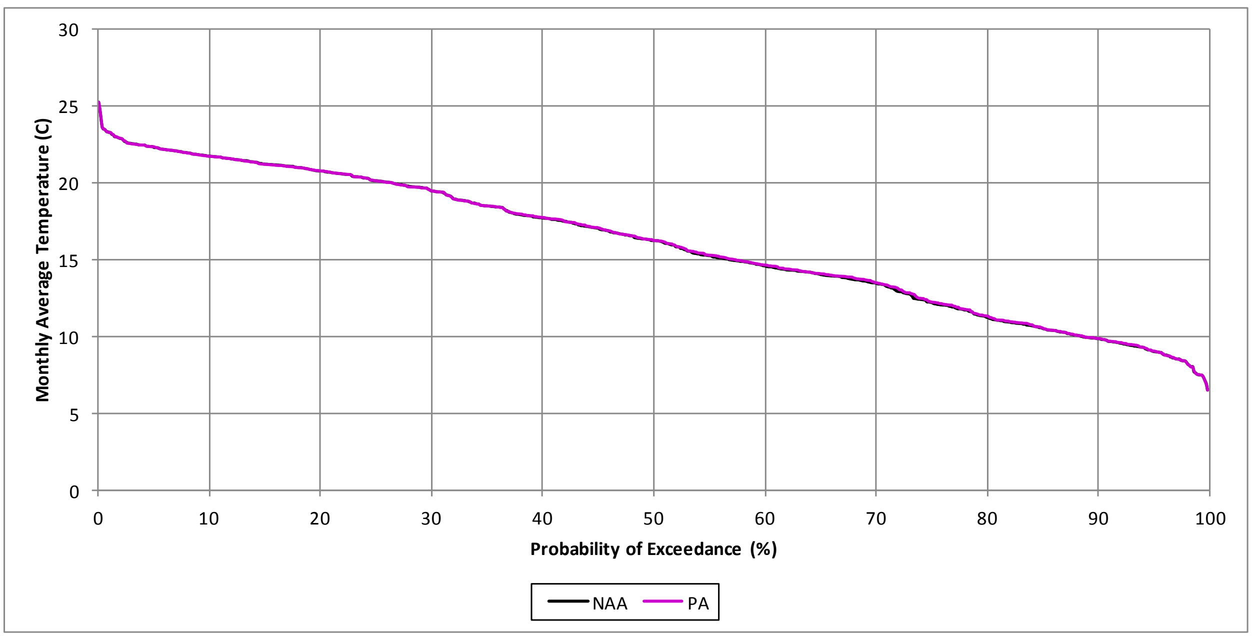


Figure 4. Old River at Holland Cut Monthly Average Temperature for Period of Record WY1922-2002.

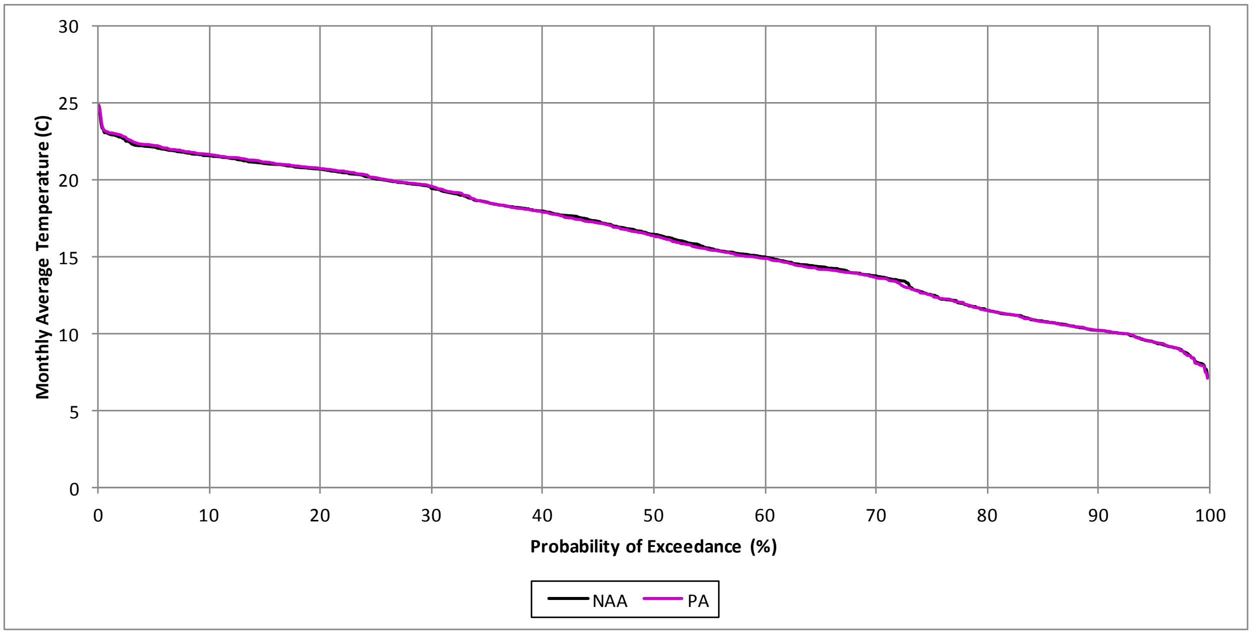


Figure 5. Old River at Clifton Court Ferry Monthly Average Temperature for Period of Record WY1922-2002.

<u>EXHIBIT 8</u>

DEPARTMENT OF WATER RESOURCES
AGREEMENT # 4600009291

FINAL REPORT ◦ JULY 2014

Phase 2 Modeling Synthesis Report Prospect Island Tidal Habitat Restoration Project

WETLANDS AND WATER RESOURCES
Stillwater Sciences
JOINT VENTURE

Suggested Citation:

Wetlands & Water Resources and Stillwater Sciences (WWR-Stillwater Sciences). 2014. Phase 2 Modeling Synthesis Report. Prospect Island Tidal Habitat Restoration Project. Final Report. Prepared for Department of Water Resources, West Sacramento, CA. Contract No. 4200009291. Prepared by Wetlands and Water Resources, Inc., San Rafael, CA and Stillwater Sciences, Davis, CA, with assistance from Resource Management Associates, Fairfield, CA, and Delta Modeling Associates, San Francisco, CA. July.

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1 INTRODUCTION

The Prospect Island Tidal Habitat Restoration Project (Project) includes levee breaches and other actions to restore tidal connection of diked lands within an approximately 1,600-acre property located in Solano County, in the northern portion of the Sacramento-San Joaquin River Delta (Delta) (Figure 1-1 and Figure 1-2). The Project is being cooperatively implemented under the Fish Restoration Program Agreement (FRPA) between the California Department of Water Resources (DWR) and Department of Fish and Wildlife (CDFW) to partially fulfill the 8,000-acre tidal restoration obligations contained within the Reasonable and Prudent Alternative (RPA) 4 of the U.S. Fish and Wildlife Service Delta Smelt Biological Opinion (USFWS 2008) and referenced in RPA I.6.1 of the National Marine Fisheries Service Salmonid Biological Opinion (NMFS 2009), for long-term coordinated operations of the State Water Project (SWP) and the federal Central Valley Project (CVP). Project planning was initiated by the Fish Restoration Program (FRP) in 2011 using a two-phased approach to develop alternatives for consideration, select the preferred Project alternative for design and construction, and to support assessment of potential environmental impacts. DWR (2013a) established six objectives for the Project consistent with the FRPA and RPAs identified in the above-referenced biological opinions (BiOPs) including:

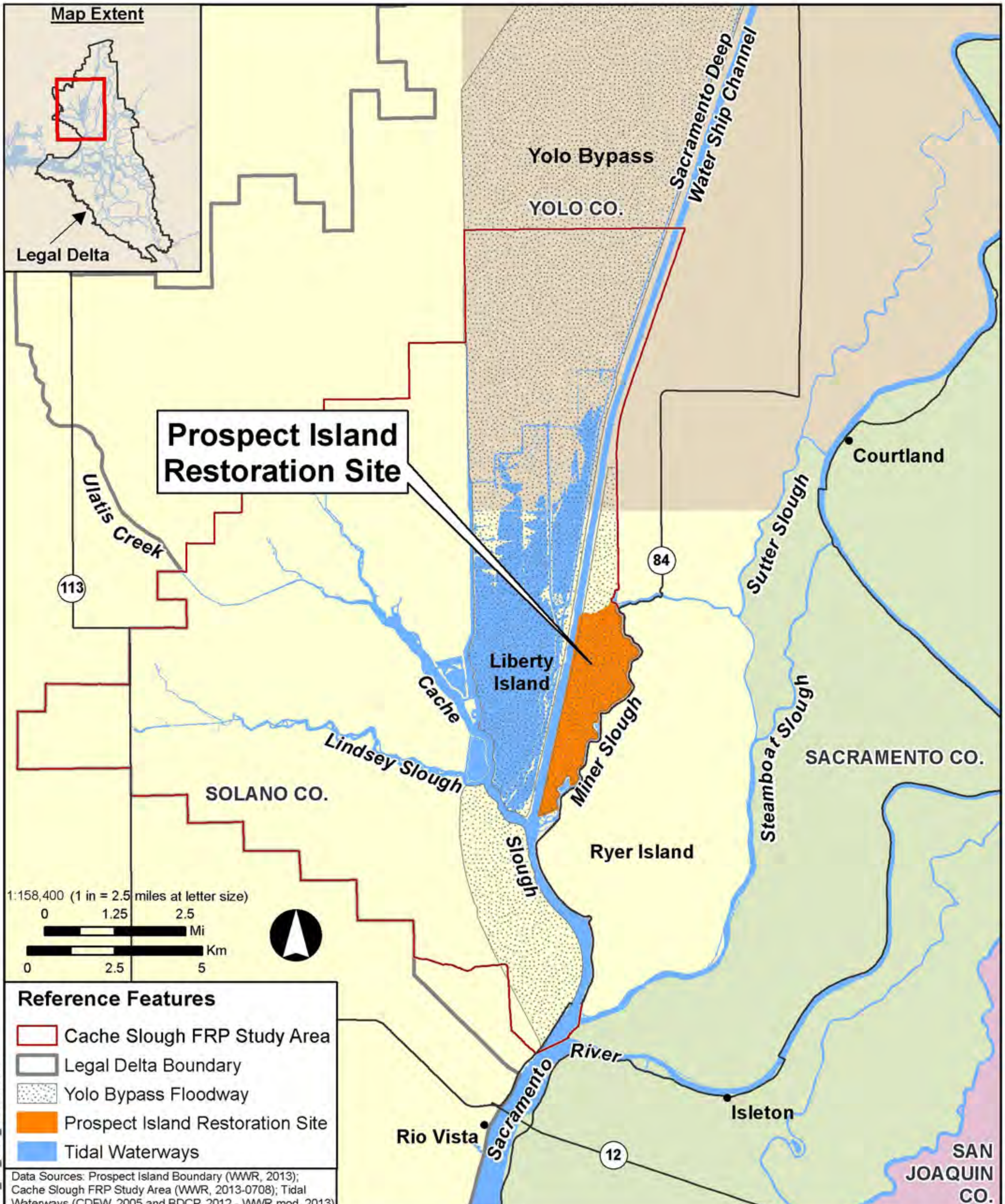
1. Enhance primary and secondary productivity and food availability for native fishes within Prospect Island and surrounding Delta waterways;
2. Increase the quantity and quality of salmonid rearing habitat within and in the areas surrounding Prospect Island;
3. Increase the amount and quality of habitats to support other listed species, to the extent they can be supported by site conditions and natural processes;
4. Provide other ecosystem benefits associated with increased Delta freshwater tidal marsh habitat, including water quality enhancement, recreation, and carbon sequestration;
5. To the greatest extent practical, promote habitat resiliency to changes in future Delta conditions, such as land use conversions, climate change, sea level rise, and invasive species; and
6. Avoid promoting conditions adverse to Project biological objectives, such as those which would favor establishment or spread of invasive exotic species.

Phase 1 of the two-phased approach included the identification and screening level modeling of fifteen alternatives out of thirty conceptual alternatives initially developed for the Project (Stillwater Sciences-WWR 2012). Modeling results were then evaluated using a suite of screening-level evaluation criteria (WWR 2012) with the purpose of determining which design alternatives would be carried forward into the second phase of Project planning (Stillwater Sciences-WWR 2012, WWR-Stillwater Sciences 2013a). Phase 1 analyses included application of the Delta Ecosystem Restoration Implementation Plan (DRERIP) conceptual models in review of the alternatives and Phase 1 modeling results. The October 2012 DRERIP review produced recommendations to the FRP regarding refinement of alternatives as well as follow-up analyses to be conducted in Phase 2 (ERP 2013).

Phase 2 modeling was conducted to support selection of final restoration alternatives for the Project, to inform environmental impact assessments, and to inform engineering design of the selected alternative. To accomplish these purposes, Phase 2 modeling included a broader range of evaluation criteria, which were applied to a subset of the restoration alternatives evaluated in Phase 1.

The purpose of this report is to present a synthesis of the Phase 2 modeling results in a format that compares and contrasts the modeled alternatives relative to the Phase 2 evaluation criteria. The remaining sections of this report are organized in the following manner:

- **Section 2** summarizes the Phase 2 evaluation criteria and their associated threshold(s), and describes how these criteria relate to restoration objectives and restoration alternatives selection.
- **Section 3** presents a brief description of each alternative modeled.
- **Section 4** summarizes the modeling findings presented in the modeling results reports. Readers are directed to Appendices A through D for the complete modeling results reports.
- **Section 5** presents a comparative analysis and discussion of the modeled alternatives relative to the evaluation criteria and thresholds. Readers are directed to this section preferentially for key comparative findings. Overall evaluation and ranking of alternatives was completed by FRP staff in a separate process that utilized these findings, among others.



File: Project-Location-Synthesis_AP_1149_2014-0624srb

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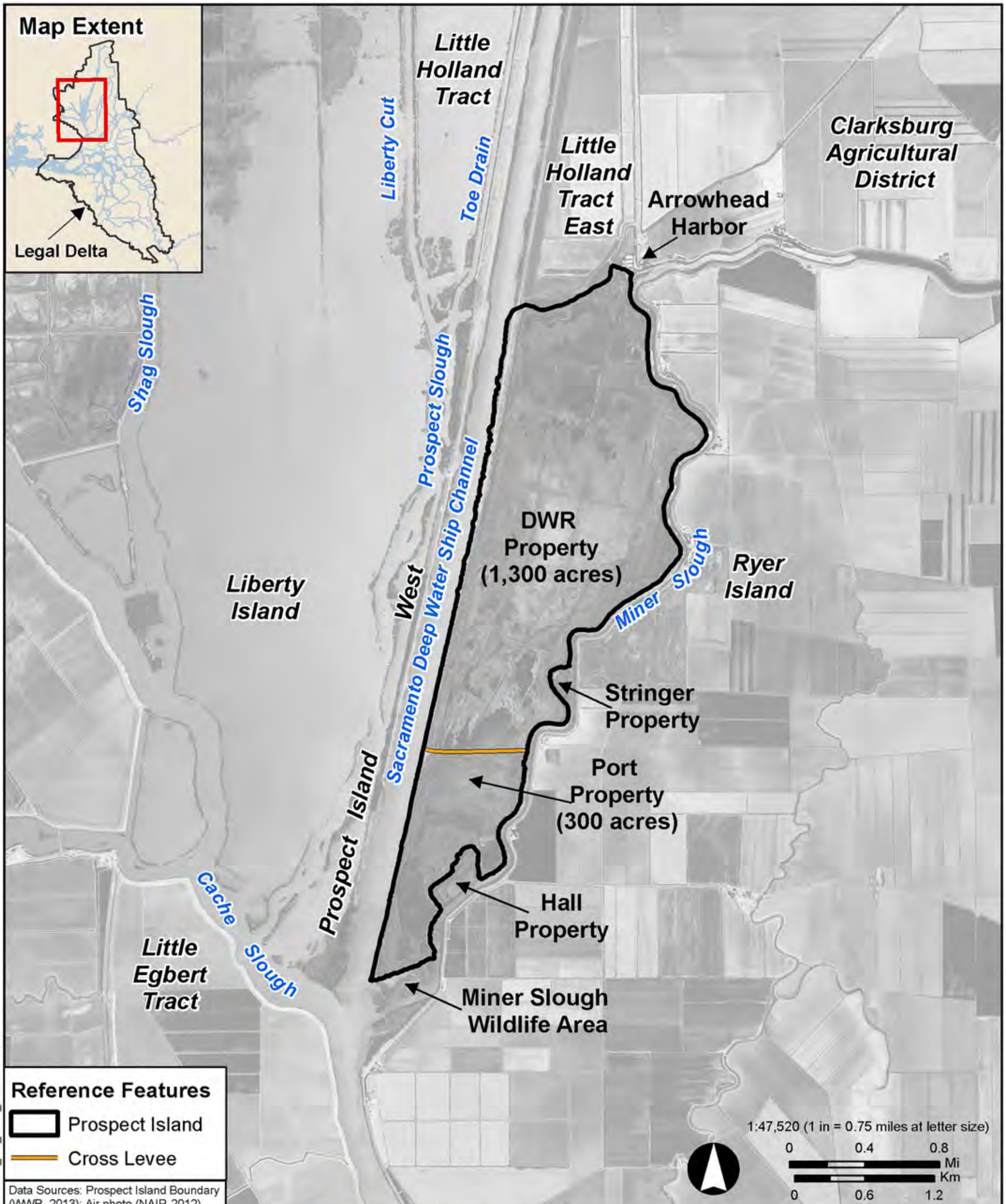
Project Location

Prospect Island Tidal Habitat Restoration Project

June 2014	Project 1149	**Figure 1-1**



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Prospect Island Site and Surrounding Features

Prospect Island Tidal Habitat Restoration Project

June 2014 | Project 1149 | **Figure 1-2**

2 PHASE 2 EVALUATION CRITERIA

Establishment of the appropriate Phase 2 modeling evaluation criteria was based upon the Phase 1 screening level modeling results (Stillwater Sciences-WWR 2012, WWR-Stillwater Sciences 2013a), recommendations from the October 2012 DRERIP evaluation (ERP 2013), and information derived from recent conferences and workshops, as well as FRP technical team meetings. Contributions from these sources informed the review and elimination of some criteria originally identified for use in Phase 2 analysis, where screening-level modeling results showed these criteria produced no substantive effects, nor served to demonstrate significant differences between alternatives (WWR-Stillwater Sciences 2014).

2.1 Relationship between Project Objectives and Evaluation Criteria

Table 2-1 summarizes the relationships between modeling evaluation criteria, potential benefits (B), impacts (I), and design considerations (D) of the Project. Table 2-2 presents the relationships between the Phase 2 modeling criteria and Project objectives (Section 1),which are intended both to meet the requirements of the BiOPs and to avoid and/or minimize potential impacts (DWR 2013a).

Table 2-1. Relationship between Modeling Evaluation Criteria and Potential Project Benefits, Impacts, and Design Considerations.

Potential Benefit (B) or Impact (I) Designation	Evaluation Criterion	Phase 1 Analysis	Phase 2 Analysis
B-1	Pelagic Food Web Productivity within the Restoration Site	✓	B
B-2	Tidal Mixing of Exported Productivity	✓	B
B-3, I-4	Temperature Changes in Adjacent Water Bodies	Deferred to Phase 2	B*,I
B-4	Interior Constructed Channel Velocity	Deferred to Phase 2	I,D
I-2	Turbidity Effects	Deferred to Phase 2	B*, I
I-3	Salinity Changes at D-1641 Compliance Stations	Deferred to Phase 2	B*, I
I-8	Regional Flow Alterations	Deferred to Phase 2	B*
I-10	Predatory Fish Refuges	Deferred to Phase 2	D
I-11	Scour Potential to Ryer Island Miner Slough Levee from Cross Currents	✓	I
I-12	Scour Potential to Ryer Island Miner Slough Levee from Increased Tidal Prism	✓	I
I-13	Arrowhead Marina Boating Access	Identified in Supplemental Phase 1 Analysis	I,D

Criterion Key:

B = primary basis for alternatives selection, criterion provides key distinctions between alternatives by meeting restoration objectives, or avoiding/minimizing potential adverse impacts; criteria marked by a star (*) used for primary selection if modeling results indicate substantial differences between alternatives

I = criterion applied primarily to environmental impact analyses

D = criterion applied primarily to restoration design approaches

Table 2-2. Relationship between Hydrodynamic Modeling Evaluation Criteria and Project Objectives and Impact Avoidance or Minimization.

Project Objective (defined in DWR 2013a)	Evaluation Criteria									
	B-1	B-2	B-3, I-4	B-4	I-2	I-3	I-8	I-10	I-11, I-12	I-13
	Pelagic Food Web Productivity	Tidal Mixing of Exported Productivity	Temperature Changes in Adjacent Water Bodies	Interior Constructed Channel Velocity	Turbidity Effects	Salinity Changes at D-1641 Compliance Stations	Regional Flow Alterations	Predatory Fish Refuges	Scour Potential to Ryer Island Miner Slough Levee	Arrowhead Marina Boating Access
Enhance primary and secondary productivity and food availability for native Delta fishes within Prospect Island and surrounding Delta waterways	X	X	X					X		
Increase the quantity and quality of salmonid rearing habitat within and in the areas surrounding Prospect Island	X	X	X	X				X		
Increase the amount and quality of habitats to support other listed species, to the extent they can be supported by site conditions and natural processes			X		X			X		
Provide other ecosystem services associated with increased Delta freshwater tidal marsh habitat, including water quality enhancement, recreation, and carbon sequestration						X	X			X
To the greatest extent practical, **promote habitat resiliency** to changes in future Delta conditions, such as land use conversions, climate change, sea level rise, and invasive species			X	X	X	X	X			
Avoid promoting conditions adverse to Project biological objectives, such as those which would favor establishment or spread of invasive exotic species			X	X	X	X	X			X

2.2 Evaluation Criteria used for Alternatives Selection

For the purposes of alternatives selection, a total of three “benefits” criteria and four “potential impact” criteria were evaluated with Phase 2 hydrodynamic modeling. The criteria below are summarized in Section 2.2.

- Pelagic Food Web Productivity within the Restoration Site (B-1)
- Tidal Mixing of Exported Productivity (B-2)
- Temperature Changes in Adjacent Water Bodies (B-3, I-4)
- Turbidity Effects (I-2)
- Salinity Changes at D-1641 Compliance Stations (I-3)
- Regional Flow Alterations (I-8)

2.2.1 Pelagic food web productivity within the restoration site (B-1)

Pelagic food web support within the restoration site was evaluated based upon particle tracking simulations (Appendix A) that used an exposure time (ET) metric. This modeling tracked the length of time simulated particles remained within the Prospect Island interior in either open water or vegetated habitats (WWR-Stillwater Sciences 2014). Particles tracked within open water habitats were used to evaluate each alternative’s potential contribution of on-site phytoplankton growth to the aquatic food web (i.e., the phytoplankton-zooplankton-fish food web pathway). Particle tracking simulations of vegetated zones was used to represent relative contributions to marsh-generated productivity pathways (i.e., epiphytic and detrital pathways to insects and fish). Appendix A modeling simulations were used to provide spatial estimates of ET across nine categories: <1 day, 1–3 days, 3–5 days, 5–7 days, 7–10 days, 10–15 days, 15–20 days, 20–25 days, and >25 days. Sensitivity analyses, described in Section 3.5 of this document, were used to determine the effects of vegetation and channel network extent on three broad ET evaluations (Section 4 and Section 4.2).

1. Open water-dominated ET ranges that are either faster or slower than typical algal growth rates were used to indicate the potential for selection of desirable algal species as well as avoidance of undesirable species. Evaluation of Project alternatives focused upon ET results within the preferred 1–3 days and 3–5 days range categories (Section 4). Modeling results for other ET categories (Appendix A) may be used for future assessments.

2. Vegetated zone-dominated ET was used to inform site hydrodynamics and to examine potential differences in marsh productivity export between various Project alternatives (Section 4.2).
3. The full range of ET modeling results (Appendix A) may be used to examine spatial variations in site hydrodynamics as a basis of future comparisons with ET modeling conducted at other sites in the region, such as Liberty Island (Brennan et al. 2013) and Mildred Island (Monsen and Cloern 2002).

2.2.2 Tidal mixing of exported productivity (B-2)

Estimates of exported productivity were based on regional simulations that tracked particles and reported their locations after two days and after seven days (Appendix A). Analysis of exported productivity focused on examination of the comparative contributions to total export of particles that spent the majority of time in open water- or vegetation-dominated zones of the Project site (WWR-Stillwater Sciences 2014). Particles that spent the majority of the simulation period in open water habitats were used to assess potential pelagic food web contributions by algae, and particles that spent the majority of time in vegetated zones were used to assess potential marsh-based productivity contributions to the food web in waters surrounding Prospect Island. Project alternatives having greater rates of particle export were ranked higher than those with greater on-site particle retention.

2.2.3 Temperature changes in adjacent water bodies (B-3, I-4)

Using the RMA Delta model for water temperature results (Appendix B), average daily water temperatures were categorized based on suitability for Delta Smelt spawning and rearing, and for juvenile Chinook Salmon rearing (with 15–20°C suitable, 20–25°C sub-optimal, and >25°C lethal) (WWR-Stillwater Sciences 2014). Changes in average daily water temperatures from the no-project baseline during March through September were then used as a basis for comparison between alternatives.

2.2.4 Turbidity effects (I-2)

The potential for adverse reduction of turbidity was identified as an evaluation criterion for the Project as related to habitat use by Delta Smelt (*Hypomesus transpacificus*) within the Cache Slough region (WWR 2012). Three dimensional suspended sediment and turbidity modeling was used to examine the effects of breach locations, vegetation extent, and channel network extent on turbidity levels within the site and adjacent water bodies (Appendix C). Modeling results were used to compare relative reduction in turbidity levels within a representative simulation period of October 1, 2012 through December 31, 2012, to capture a range of representative low and high turbidity conditions (WWR-Stillwater Sciences 2014). This window also captured an extended period during October and November, when observed turbidity in the Sacramento Deep Water Ship Channel (DWSC) and Cache Slough were elevated relative to that in Miner Slough, followed by a large outflow event in December 2012, when turbidity in Miner Slough was significantly elevated.

2.2.5 Salinity changes at D-1641 compliance stations (I-3)

Salinity changes at seven Delta locations used for compliance monitoring of SWRCB D-1641 (Table 2-3) were modeled to examine whether Project alternatives have the potential to result in non-compliance with water quality objectives, and to evaluate potential regional effects of the Project on Delta salinity levels (Appendix D). Emmaton (D22) and Jersey Point (D15) locations were chosen for the evaluation based on their proximity to the Project site and as an indication of how the Project may affect salinity levels in the Sacramento and San Joaquin river systems. These monitoring stations were also used to indicate the potential for salinity intrusion into the north and central Delta, as they are located just east of the low salinity zone. Prisoner's Point (D29), Emmaton, and Jersey Point stations were used to evaluate potential salinity effects to agriculture and fish and wildlife beneficial uses. Contra Costa Canal (C5), West Canal (C9), Delta Mendota Canal (DMC1), and Barker Slough NBA intake (SLBAR3) were chosen for use in analyzing potential impacts to municipal and industrial uses by the State Water Project, Central Valley Project, and Contra Costa Water District. Salinity modeling results for additional D-1641 compliance stations not used for alternatives selection are presented in Appendix D.

Table 2-3. D-1641 Compliance Location Used for Alternatives Comparison.

D-1641 Station ID	Location	Associated Beneficial Use
D22	Sacramento at Emmaton	Agriculture
D15	San Joaquin at Jersey Point	Agriculture, Fish and Wildlife
D29	San Joaquin at Prisoners Point	Fish and Wildlife
C5	Contra Costa Canal at Pumping Plant 1	Municipal and Industrial
C9	West Canal at mouth of Clifton Court Forebay	Municipal and Industrial
DMC1	Delta-Mendota Canal at Tracy Pumping Plant	Municipal and Industrial
SLBAR3	Barker Slough NBA intake	Municipal and Industrial

Table 2-4 summarizes the water quality objectives for salinity (as measured by electrical conductivity) for agricultural and fish and wildlife beneficial uses, and Table 2-5 summarizes water quality objectives for municipal and industrial uses (as measured by chloride). Conversion between EC and chloride concentration is generally accomplished using site-specific empirical relationships developed by Kamyar Guivetchi (DWR 1986). Additional details about this conversion are presented in Appendix D.

Table 2-4. D-1641 Station Electrical Conductivity Water Quality Objectives—Fish and Wildlife and Agriculture.

Station	Water Year Type[1]	Fish and Wildlife		Agriculture			
		Value[2]	Time Period	Value[2]	Time Period	Value[2]	Time Period
Sacramento at Emmaton	Wet	not applicable		0.45	Apr 1 - Aug 15	not applicable	
	Above Normal			0.45	Apr 1 - Jun 30	0.63	Jul 1 - Aug 15
	Below Normal			0.45	Apr 1 - Jun 19	1.14	Jun 20 - Aug 15
	Dry			0.45	April 1 - June 14	1.67	Jun 15 - Aug 15
	Critical			2.78	Apr 1 - Aug 15	not applicable	
San Joaquin at Jersey Point	Wet	0.44	Apr 1 - May 31	0.45	Apr 1 - Aug 15	not applicable	
	Above Normal	0.44	Apr 1 - May 31	0.45	Apr 1 - Aug 15	not applicable	
	Below Normal	0.44	Apr 1 - May 31	0.45	Apr 1 - Jun 19	0.74	Jun 20 - Aug 15
	Dry	0.44	Apr 1 - May 31	0.45	April 1 - June 14	1.35	Jun 15 - Aug 15
	Critical	not applicable		2.20	Apr 1 - Aug 15	not applicable	
San Joaquin at Prisoners Point	Wet, Above Normal, Below Normal, Dry	0.44	Apr 1 - May 31	not applicable			

Notes

1. Sacramento Valley Water Year Hydrologic Classification
2. Maximum 14-day running average of mean daily EC (mmhos/cm)

Table 2-5. D-1641 Station Chloride Water Quality Objectives—Municipal and Industrial.

Station	Water Year Type[1]	Municipal and Industrial	
		(Cl^-) Value[2]	Days of the Calendar Year
Contra Costa Canal at Pumping Plant 1	Wet	less than or equal to 150	240
	Above Normal		190
	Below Normal		175
	Dry		165
	Critical		155
Contra Costa Canal at Pumping Plant 1	All	250	365
West Canal at mouth of Clifton Court Forebay			
Delta-Mendota Canal at Tracy Pumping Plant			
Barker Slough NBA intake			
Cache Slough at City of Vallejo Intake			

1. Sacramento Valley Water Year Hydrologic Classification
2. Maximum mean daily value in mg/L

2.2.6 Regional flow alterations (I-8)

Regional flow alterations were modeled to inform potential changes to salinity and to identify potential compliance issues in relation to flow requirements on the Sacramento River at Rio Vista (D-1641 Station D24). These flow requirements summarized in Table 2-6 are designed to maintain a sufficient net downstream flow in the Lower Sacramento River to support salmon migration (SWRCB 2006). Below normal conditions and dry conditions were modeled to determine if and/or how Project alternatives could affect flow compliance at the Rio Vista station (WWR-Stillwater Sciences 2014).

Table 2-6. Rio Vista Minimum Monthly Average Flow Rate (cfs).

Month	Water Year Types					
	All	Wet	Above Normal	Below Normal	Dry	Critically Dry
September	3,000					
October		4,000	4,000	4,000	4,000	3,000
November-December		4,500	4,500	4,500	4,500	3,500

Source: SWRCB 2006

For the Prospect Island restoration, regional channels of interest include the Delta Cross Channel, Georgiana Slough, the Lower Sacramento River, and Threemile Slough (Appendix D, Figure 8). Fresh water flow through the Delta Cross Channel and down Georgiana Slough is important in maintaining a net outward flow on the lower San Joaquin River to repel salinity from Suisun Bay.

The net flow of fresher water from the Sacramento River to the San Joaquin River through Threemile Slough is also import to control salinity intrusion into the central Delta, although this water is less fresh as compared to water flowing through Georgiana Slough. Increases and decreases in net flows were documented, with changes of 10% and greater considered significant (WWR-Stillwater Sciences 2014).

2.3 Evaluation Criteria Potentially Useful for Impact Analysis and Design

The following evaluation criteria may be used in analyzing potential Project impacts during the environmental review process and/or for Project design, rather than for selection of alternatives.

2.3.1 Interior constructed channel velocity (B-4)

Modeled velocities within the Prospect Island interior channel network may be used to support analysis of the potential for colonization by invasive submerged aquatic vegetation and of potential scour effects. Preliminary modeling results showed little difference in interior channel velocities between alternatives (Figure 2-1). As the results showed no significant differences, this criterion was deemed ill-suited for use in alternatives selection. Instead, information from velocity modeling may be used in evaluation of potential impacts during the environmental review process, and in determination of potential SAV prevention/management options.

2.3.2 Predatory fish refuges (I-10)

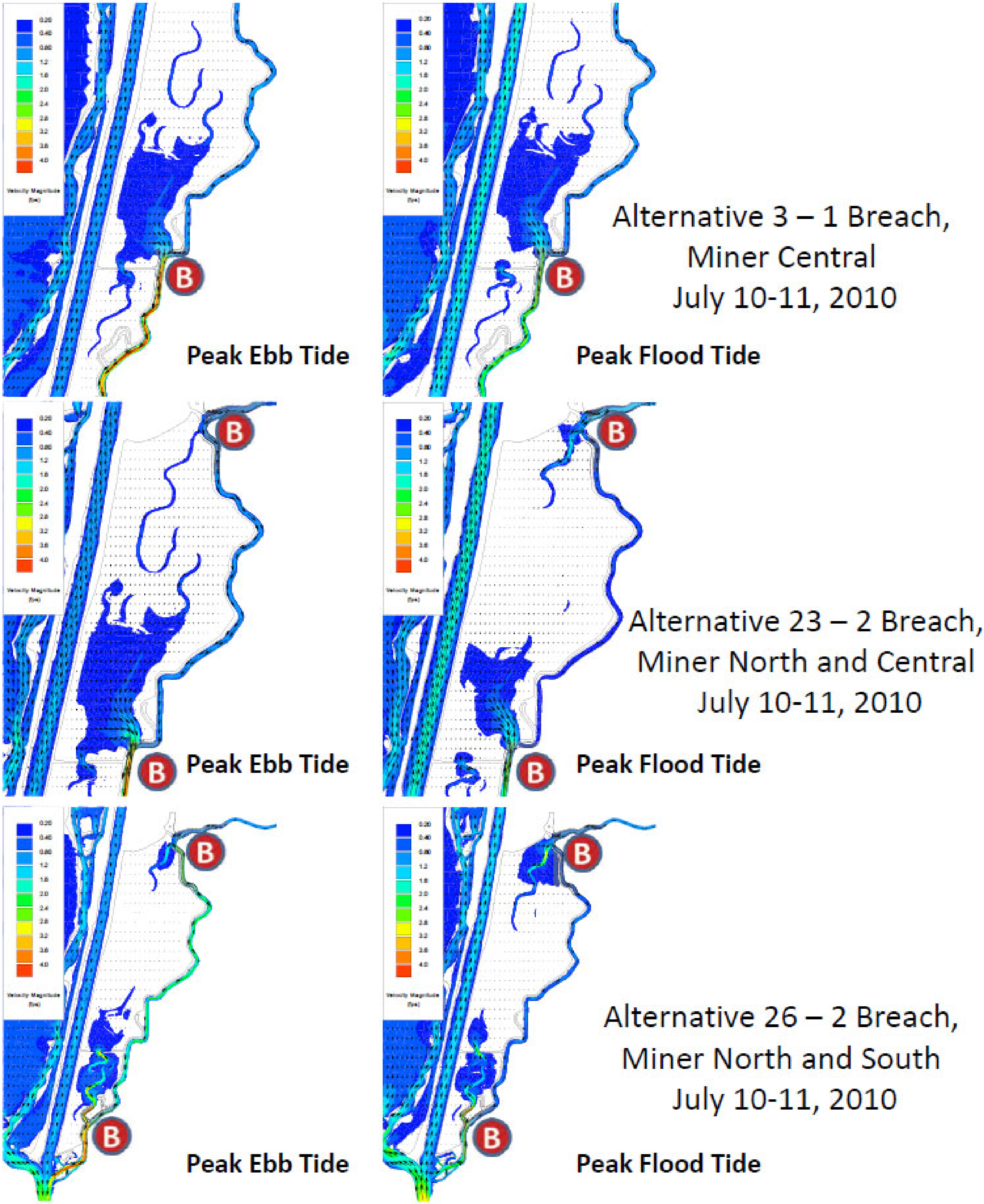
Localized velocity gradients at breach locations occur during flood tides, where high velocity inflows from outside tidal waters mix with low velocity waters just inside the breached site. Predatory fish have been observed to congregate at such localized velocity gradients. Two engineering design approaches are anticipated to minimize or potentially eliminate these conditions through flow dissipation: (1) creation of large levee breaches, and (2) placement of moderate-gradient earthen slopes on the restored island interior at breach locations. As these approaches can be applied to any alternative, this evaluation criterion may be utilized primarily for refining engineering design elements.

2.3.3 Potential scour of Ryer Island Miner Slough levee (I-11 and I-12)

Phase 1 modeling of scour potential in Miner Slough showed increases in long-channel velocities across all alternatives that were moved forward for Phase 2 analysis. As modeling showed that all alternatives have similar potential for scour, this criterion does not provide a means for comparison or selection. Modeling results regarding scour potential may, however, be used in Project environmental impacts analysis.

2.3.4 Arrowhead Harbor boating access (I-13)

Arrowhead Harbor marina is located just north of Prospect Island, along Miner Slough. The entrance to the marina is located immediately adjacent to the proposed location of the north Miner Slough breach. Modeling results showed that alternatives that included a breach to Miner Slough at this location would result in a shift of velocity and flow direction in Miner Slough, near the entrance of Arrowhead Harbor, from a north-south orientation (in line with the marina entrance) to a more east-west direction (orthogonal to the harbor entrance). This shift could potentially create a navigation hazard for recreational boaters (WWR-Stillwater Sciences 2013b). A decision to relocate the breach farther south along Miner Slough was made during subsequent alternatives selection discussions by FRP staff.



Data Source: RMA 2013

Preliminary Interior Velocity Modeling Results for Alternatives 3, 23, and 26

Prospect Island Tidal Habitat Restoration Project

June 2014	Project 1149	**Figure 2-1**

File: Fig2-1_Velocity-Modeling_RMA_1149_2014-0624srb

2.4 Summary of Modeling Completed to Date

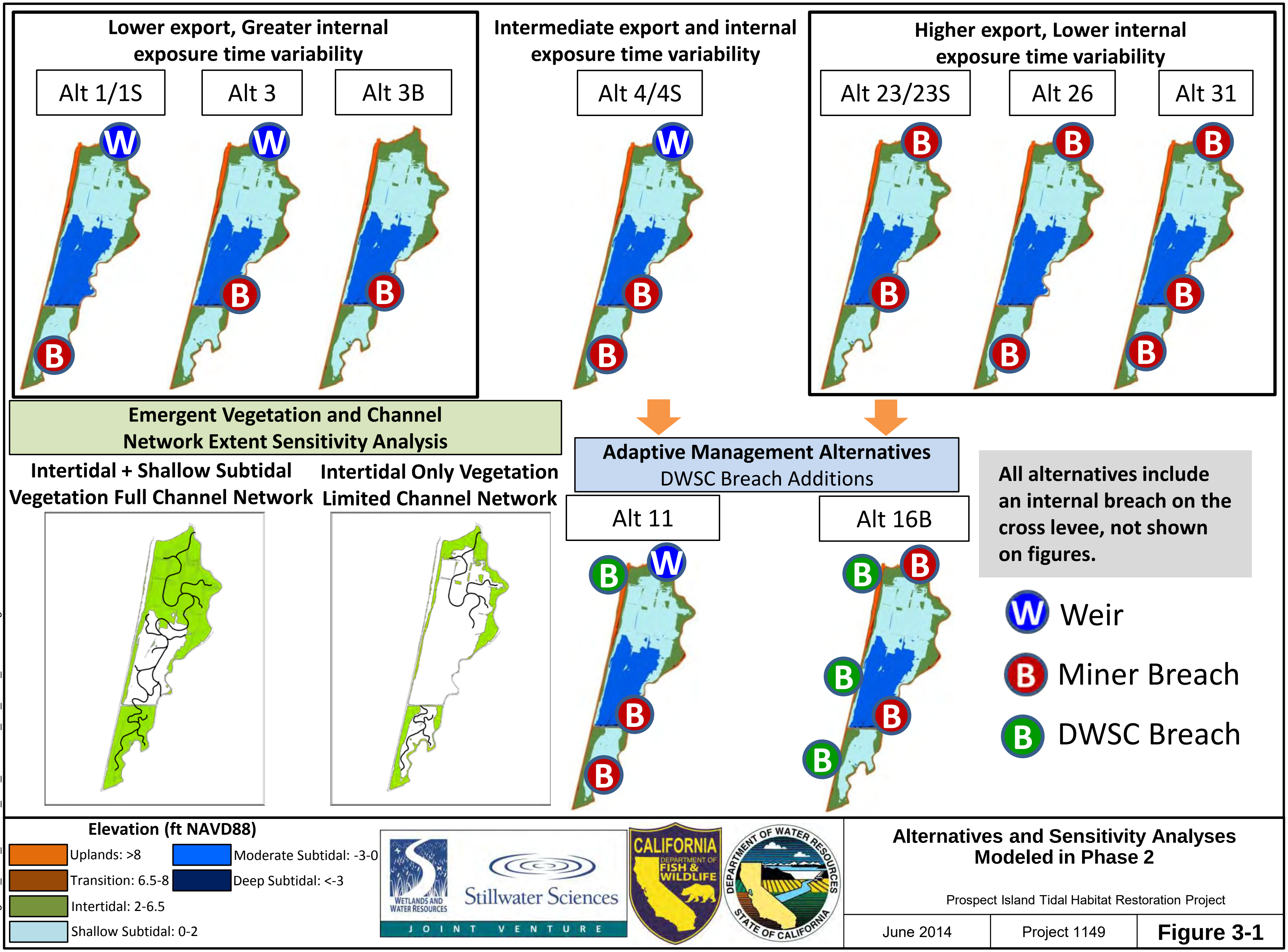
In addition to the modeling results presented here, additional work was completed under Phase I to evaluate the Project alternatives. The table below provides a list of Phase I modeling documents and the criteria they addressed. All of these reports are available for review upon request.

Table 2-7. Phase I Modeling Reports Produced to Date for Prospect Island.

Report Title	Date	Criteria Addressed
Modeling Results for Primary Productivity Enhancement and Export	September 2012	• On-site Food Web Productivity • Tidal Mixing of Exported Productivity
Modeling Results for DOC Impacts at Barker Slough Pumping Plant	October 2012	• DOC Impacts at Barker Slough
Modeling Results for Flood Conveyance	September 2012	• Flood Conveyance Impacts in the Yolo Bypass • Flood Conveyance Impacts in Miner Slough
Modeling Results for Tidal Range Impacts	August 2012	• Tide Range
Modeling Results for Deep Water Ship Channel Cross Currents	September 2012	• DWSC Navigation
Modeling Results for Scour Potential to Ryer Island Miner Slough Levee	September 2012	• Scour Potential in Miner Slough
Prospect Island Tidal Restoration Supplemental Phase 1 Screening-Level Modeling Results Memorandum	March 2013	• On-site Food Web Productivity • Tidal Mixing of Exported Productivity • Arrowhead Marina Access

3 ALTERNATIVES FOR PHASE 2 MODELING AND ANALYSIS

A total of twelve (12) conceptual design alternatives were modeled under Phase 2: seven with breaches along Miner Slough only, two with levee breaches along the DWSC for potential implementation in the future as an adaptive management measure, and three sensitivity model simulations combining reduced vegetation and channel network extents (Figure 3-1). y FRP staff selected from alternatives modeled in Phase 1 (WWR-Stillwater Sciences 2013a) based upon DRERIP recommendations (ERP 2013), results of refined on-site and exported productivity analyses (WWR-Stillwater Sciences 2013b), feasibility issues associated with private property access (i.e., adjacent Stringer property), and consideration of regulatory constraints associated with breaching the DWSC (i.e. lengthy permitting processes and potential navigation impacts). The seven Miner Slough-only breach alternatives were further sorted into three groupings, based on refined Phase 1 productivity modeling results (WWR-Stillwater Sciences 2013b). Each of these groups of alternatives is shown in Figure 3-1 and briefly described in the sections below.



File: Fig-3-1_Final_Revised_Alts_Selection_AP_1149_2014-0630gal

3.1 Lower Export and Greater Internal Exposure Time Variability Alternatives (Alternatives 1, 3, and 3B)

The first alternative group consists of Alternatives 1 and 3, both of which are single breach alternatives that would maintain access to the Stringer property by including an overflow weir at the north Miner Slough location, near Arrowhead Harbor. A modification of Alternative 3 (Alternative 3B) includes no weir at this location, for the purposes of examining the effect of the weir upon regional turbidity levels (Figure 3-1). The presence of only one external breach for alternatives in this group limits tidal connectivity, and results in lower exports of productivity to the surrounding waters and greater internal exposure time variability (WWR-Stillwater Sciences 2013b). Each of these alternatives includes an internal breach through the internal cross-levee, connecting the DWR- and Port-owned portions of the island.

3.2 Intermediate Export and Intermediate Exposure Time Variability Alternative (Alternative 4)

The second alternative group consists of a single alternative (Alternative 4). This is a two-breach alternative, with an overflow weir at the north Miner Slough location, and an internal breach through the internal cross-levee, connecting the DWR- and Port-owned portions of the property (Figure 3-1). The presence of two external breaches increases the tidal connectivity in this alternative as compared to the single breach alternatives, results in intermediate levels of productivity export to the surrounding waterways, and produces intermediate internal exposure time variability as compared to other alternatives modeled. This alternative configuration also maintains access to the Stringer property.

3.3 Higher Export and Lesser Internal Exposure Time Variability Alternatives (Alternative 23, 26, and 31)

The third group of alternatives consists of Alternatives 23, 26, and 31 (Figure 3-1). Alternatives 23 and 26 are flow-through, two-breach alternatives, and Alternative 31 is a three-breach alternative. All of these alternatives include a breach, rather than an overflow weir, at the north Miner Slough location, and all have an internal breach connecting the DWR- and Port-owned portions of the property. The presence of multiple breaches in these alternatives maximizes tidal connectivity, results in higher productivity exports to the surrounding waterways, and lower internal exposure time variability. None of the alternatives in this group maintain access to the Stringer property.

3.4 Adaptive Management Alternatives (Alternative 11 and 16B)

All of the alternatives recommended for additional modeling by the 2012 DRERIP evaluation (Alternatives 11, 16 [with addition of northeast Miner Slough breach], 25, 27 [with suggested addition of operable weir], and 29) included breaches to or partial removal of the DWSC levee. However, it was later determined that the lengthy regulatory process and potential for navigation problems associated with such project elements rendered these alternatives infeasible. Two of these alternatives were retained for Phase 2 modeling as future adaptive management alternatives. Alternative 11 includes a breach along the DWSC and was originally recommended for Phase 2 evaluation because this configuration performed well in Phase 1 productivity modeling (ERP 2013). Alternative 16B is a modification of Alternative 23 with three breaches added along the DWSC (Figure 3-1). This new configuration was recommended during the DRERIP evaluation process (WWR-Stillwater Sciences 2013b). Both adaptive management alternatives would produce higher export and lower internal exposure time variability. However, only Alternative 11 would maintain access along the DWSC levee to the Stringer property.

3.5 Vegetation and Channel Network Sensitivity Analysis (Alternative 1S, 4S, and 23S)

For each of the nine alternatives discussed above, the baseline hydrodynamic modeling condition assumed presence of vegetation at intertidal and shallow subtidal elevations (vegetation to 0 feet NAVD88) and full channel network extent (Figure 3-1). To determine the sensitivity of the alternatives to these design variations, one alternative from each groups described above was modeled again, in this instance using a reduced vegetated extent (vegetation at intertidal elevations only) and limited channel network extent condition (Figure 3-1). Alternative 1 was modeled from the lower export-greater internal exposure time variability group, Alternative 4 was modeled from the intermediate export and internal exposure time variability group, and Alternative 23 was modeled from the higher export-lower internal exposure time variability group. This approach was intended to provide a “bookend” view of the combined effects of channel network and vegetation extents, comparing maximum vegetation coverage and channel extent with minimal vegetation coverage and channel extent. This approach did not allow for differentiation between effects due to channel extent and those due to vegetation extent variations.

4 MODELING RESULTS SUMMARY

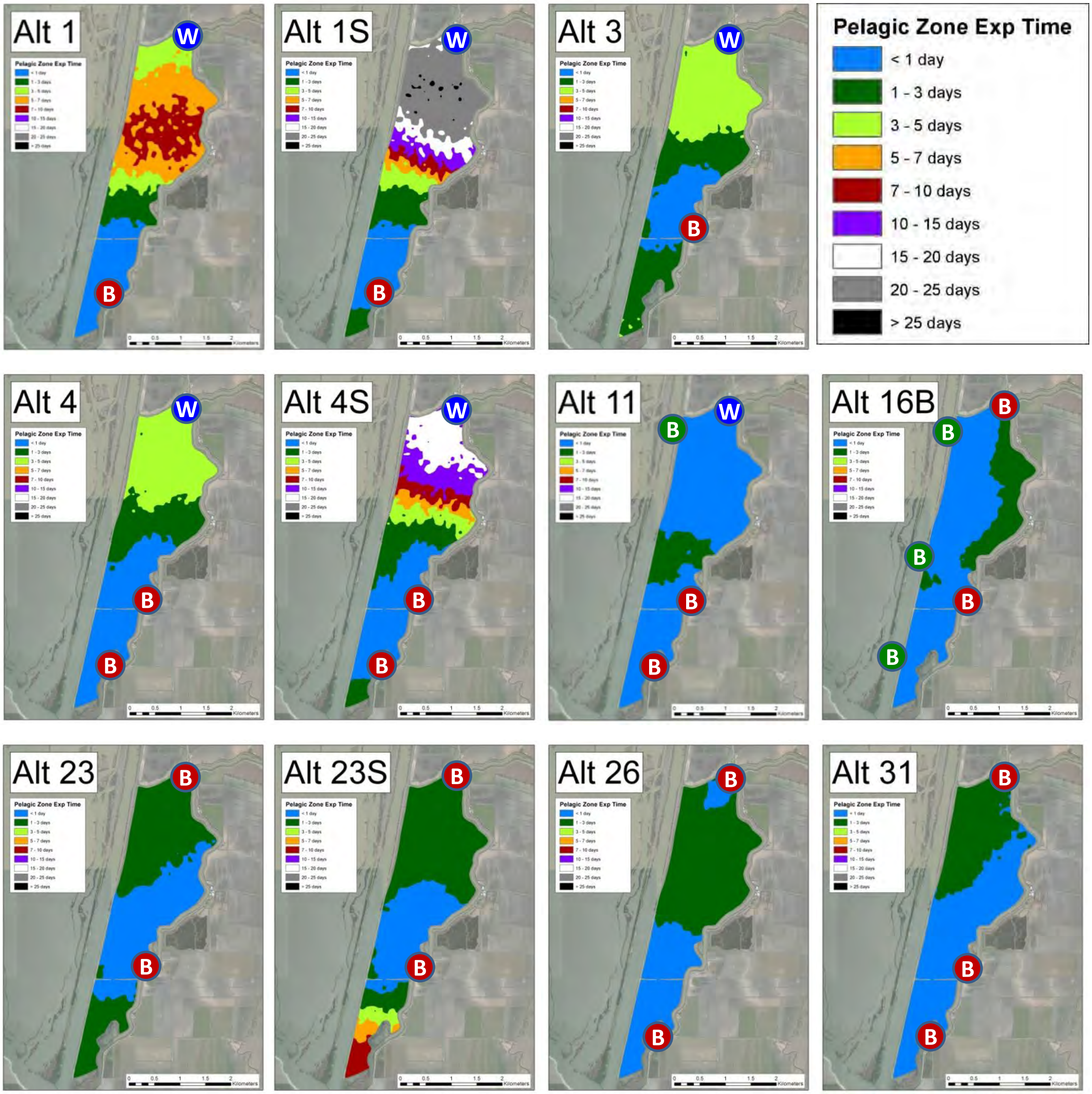
4.1 Pelagic Food Web Productivity within the Restoration Site (B-1)

The calibrated RMA Delta model with computational grid modifications within the restoration site and surrounding waterways was used to evaluate hydrodynamics within the restoration site (Appendix A). The RMA Delta model is a 2-D depth averaged / 1-D cross-sectionally averaged model extending from Martinez at the west end of Suisun Bay to the Sacramento River above the confluence with the American River, and to the San Joaquin River near Vernalis.

For each of the alternatives selected for continued evaluation in Phase 2 (Section 3), hydrodynamic modeling was used to simulate and compare particle movements within the interior of Prospect Island in response to tidal mixing (Appendix A). Relative differences in potential pelagic food web production were assessed by tracking the ET of particles within open water areas of the Prospect Island interior (i.e., areas conducive to phytoplankton growth). For modeling purposes, open water areas were defined as un-vegetated subtidal habitat deeper than 0 ft (NAVD 88, Figure 3-1). Appendix A presents results of a 26-day particle tracking simulation conducted to estimate the percentage of particles in each of nine ET classes, ranging from less than 1 day to maximums in excess of 25 days (Section 2.2.1). The full modeling results presented in Appendix A are summarized for open water zone ET in Figure 4-1 and discussed in the sections below:

- Alternative 1 and 3—Lower export, greater ET variability
- Alternative 4—Intermediate export, ET variability
- Alternative 23, 26, and 31—Higher export, lower ET variability
- Alternative 11 and 16B—adaptive management DWSC breach additions
- Alternative 1S, 4S, and 23S—alternative configurations for sensitivity analysis

For off-site comparison, Liberty Island modeling results showed ET variations between 0 and 25 days (Brennan et al. 2013). As habitat conditions in Liberty Island have been found to be beneficial for native fish (BREACH III, etc.), comparison of modeling results on the basis of the ET classes used for Prospect Island should be limited to alternatives selection and general productivity effects.



Design Symbol

W Weir

B Miner Slough Breach

B DWSC Breach

Data Source:
RMA 2013

Particle Pelagic Exposure Time within Prospect Island for Model Simulations between June 20 and July 31, 2010

Prospect Island Tidal Habitat Restoration Project

June 2014	Project 1149	**Figure 4-1**

File: Fig-4-1_Particle-Exposure-Time_RMA_1149_2014-0624srb

The results presented in (Table 4-1) and the sections below are focused on six ET classes (<1 day, 1–3 days, 3–5 days, 5–7 days, 7–25 days, and >25 days). At ET <1 day, removal by tidal flushing is expected to exceed algal growth rates, and therefore to limit productivity within the site. The target ET for diatom based productivity is in the 1–3 day range; the 3–5 days range is considered close to optimal. At longer ET, represented by the 5–7 days, 7–25 days, and >25 days classes, low rates of tidal exchange create risk of domination of the algal community by slower growing blue-green algae. To indicate the dominance of various ET classes, class percentages greater than 20% are highlighted in Table 4-1 for ease of interpretation, with blue highlighting ET of <1 day, dark green highlighting ET of 1–3 days, light green highlighting ET of 3–5 days, and gray highlighting ET of >25 days. The 20% threshold for highlighting guides focus on dominance but does not represent any absolute factors.

Table 4-1. Particle Exposure Time within Open Water Areas of Prospect Island for Model Simulations between June 20 and July 31, 2010.

Alternative Description		Alt. No.	Percent of Total Particles within Prospect Island Open Water Zone Exposure Time Classes [%]					
			< 1 day	Target 1–3 days	3–5 days	5–7 days	7–25 days[1]	> 25 days
Base Alternative Configuration	Lower export, greater ET variability	1	23	16	16	14	1–15	0
		3	27	32	21	12	0–6	0
	Intermediate export, ET variability	4	39	27	18	10	0–5	0
	Higher export, lesser ET variability	23	50	43	5	1	0	0
		26	39	52	9	0	0	0
		31	64	36	1	0	0	0
	DWSC breach additions	11	85	14	1	0	0	0
		16B	72	26	2	0	0	0
Sensitivity Alternative Configuration		1S	18	14	7	4	5–11	24
		4S	30	19	8	5	6–9	7
		23S	34	48	9	3	1–3	0

[1] Percent ranges for time classes 7–10 days, 10–15 days, 15–20 days, and 20–25 days.

4.1.1 Lower export and greater exposure time variability (Alternatives 1 and 3)

Results for Alternative 1 indicated long open water exposure times that could potentially favor slow-growing blue green algae growth. Of the total particles within Prospect Island, 45% of them were classified with ETs >5 days for this alternative (Table 4-1). Modeling results for Alternative 3 showed a more optimal exposure time distribution, with 32% of total particles having the target ET class of 1–3 days and 77% experiencing ETs <5 days. In this case, the location of the breach appears to have affected the amount of time particles spent in the open water zone and the quantity that was available for pelagic food web productivity (Figure 3-1).

4.1.2 Intermediate export and intermediate exposure time variability (Alternative 4)

For Alternative 4, model results showed higher proportions of particles within the <1 day ET class (39%) and the optimal ET classes (1–3 days = 27% and 3–5 days = 18%) (Table 4-1). Only 16% of particles were exposed to the open water zone for >5 days. These results indicate that Alternative 4 may produce high rates of primary productivity with favorable species composition.

4.1.3 Higher export and lesser exposure time variability (Alternative 23, 26, and 31)

Alternative 23, 26, and 31 resulted in the highest proportions of particles within the target 1–3 days open water zone ET class and the lowest proportions of particles with ET classes >5 days (Table 4-1). Of the three, Alternative 26 exhibited the highest proportion of particles in the target 1–3 days ET class (52%) and Alternative 31 exhibited the lowest proportion (36%). The presence of the open water adjacent breaches in Alternative 23 and 31 resulted in shorter ETs. Model results indicate that all three alternatives may produce high primary productivity with favorable phytoplankton species composition.

4.1.4 Adaptive management alternatives (Alternative 11 and 16B)

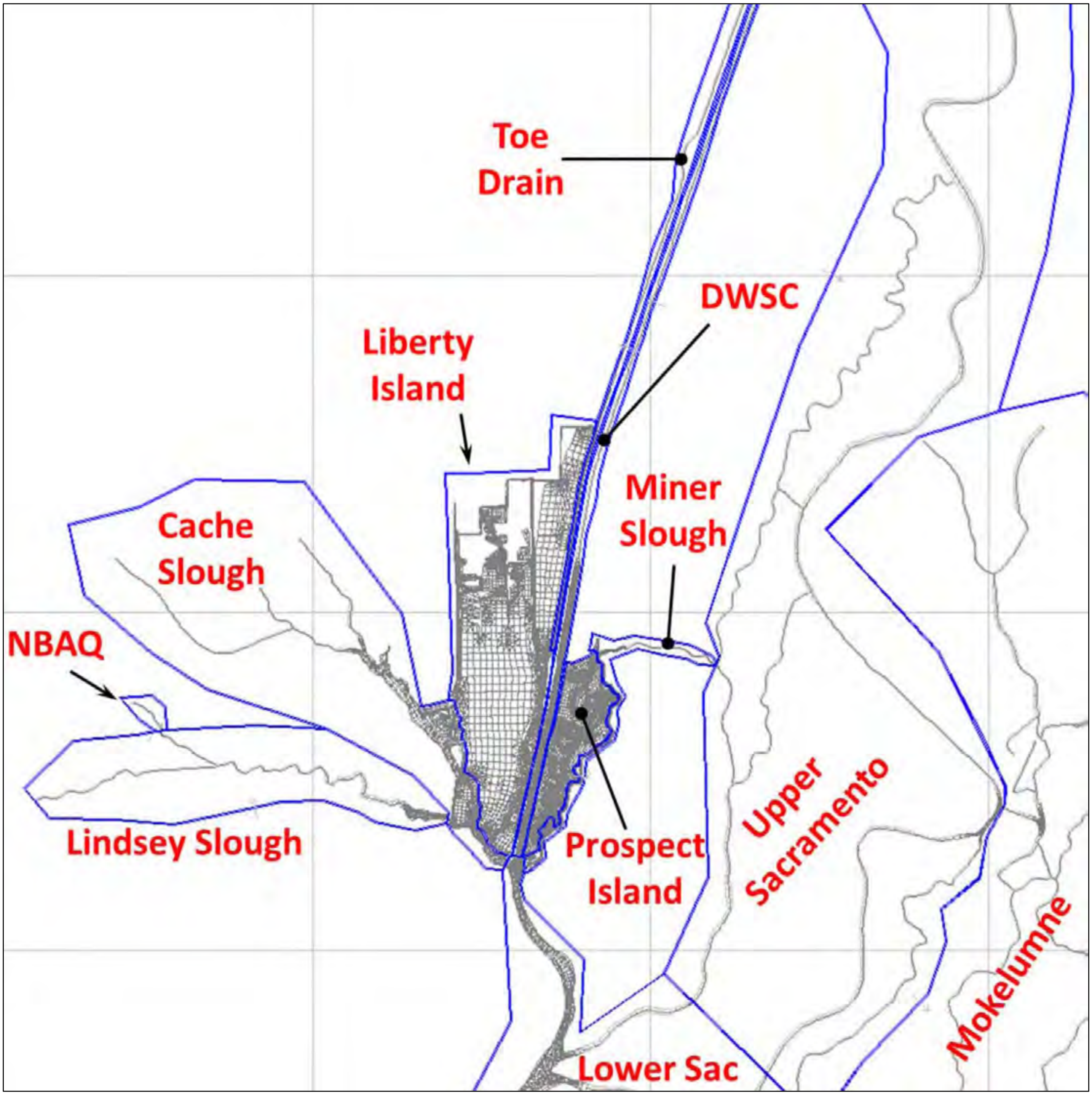
The addition of DWSC breaches in alternatives 11 and 16B resulted in the highest proportions of particles within the <1 day open water zone ET class (Alternative 11 = 85%, Alternative 16B = 72%) and low to intermediate proportions with the target 1–3 days ET class (Alternative 11 = 14%, Alternative 16B = 26%) (Table 4-1). Particles tracked in Alternative 16B experienced longer exposure times than Alterative 11, and no particles spent more than 7 days within the Prospect Island open water zone. These results indicate Alternative 11 may exhibit low primary productivity due to frequent tidal flushing in excess of maximum algal growth rates. Alternative 16B may exhibit high primary productivity with favorable phytoplankton species composition.

4.1.5 Vegetation and channel network sensitivity analysis (Alternative 1S, 4S, and 23S)

Sensitivity simulations exhibited variable increases in the representation of the longest ET classes (Table 4-1). Decreased vegetation and channel network extent translated to an increase in the extent of open water habitat under the sensitivity analysis configurations. This caused a shift towards longer open water zone hydraulic residence times commensurate to longer ET classes, relative to the base run. This effect was most pronounced for the single breach Alternative 1S, which showed approximately 57% of all particles within open water zone ET classes in excess of 7 days. Alternative 23S showed an increased representation in particles within the optimal 1–3 days class (43 to 48%) and a decreased representation in the lowest <1 day ET class (50 to 34%).

4.2 Tidal Mixing of Exported Productivity (B-2)

The calibrated RMA Delta model was used to track the regional transport of particles that spent the majority of time in either open water or vegetated habitats of Prospect Island (Appendix A). Figure 4-2 shows the regional boundaries used for particle tracking. Particles that spent the majority of time within the open water habitats of Prospect Island were used to assess potential export of phytoplankton to regional locations after 2 and 7 days (Table 4-2). Recognizing the potential importance of marsh-based productivity, a parallel assessment was conducted by tracking particles that spent the majority of time within the vegetated habitats of Prospect Island (Table 4-3). Project alternatives having the greatest combined export of all (both open water- and vegetation-dominated) were ranked higher than those with the majority of modeled particles remaining on-site at the end of the simulation.



Data Source: RMA 2013

Regional Boundaries for Particle Transport Simulations of Exported Productivity

Prospect Island Tidal Habitat Restoration Project

June 2014	Project 1149	**Figure 4-2**

File: Fig-4-2_Regional-Boundaries-Transport_RMA_1149_2014-0624srb

Table 4-2. Percentage of Open Water Zone Dominant Particles Remaining On Site and Exported to Other Locations in the Project Region after 2 and 7 Days.

Alternative grouping	Alt. No.	Percent of total particles (% of open water zone dominant)			Percent of total particles (% of open water zone dominant) transported to regional locations						
		Open water zone dominant	Remaining On-Site	Exported Off-Site	Lower Sac	DWSC	Liberty Island	Cache Slough	Lindsey Slough	Miner	Other Regions
OPEN WATER ZONE DOMINANT PARTICLES AFTER **2 DAYS** OF MODEL SIMULATION											
Lower export, higher ET variability	1	36	26 (73)	10 (27)	3 (9)	2 (5)	2 (6)	1 (4)	0 (1)	1 (3)	0 (0)
	1S	83	62 (75)	21 (25)	8 (10)	4 (5)	5 (6)	3 (3)	0 (0)	2 (2)	0 (0)
	3	34	12 (36)	22 (64)	7 (21)	3 (10)	5 (14)	3 (8)	0 (1)	3 (10)	0 (0)
Intermediate export, ET variability	4	31	13 (42)	18 (57)	7 (21)	3 (8)	4 (12)	2 (8)	0 (1)	2 (7)	0 (0)
	4S	81	49 (61)	32 (39)	13 (16)	4 (5)	7 (8)	4 (5)	1 (1)	4 (4)	0 (0)
Higher export, lesser ET variability	23	52	12 (23)	40 (78)	14 (27)	6 (12)	8 (15)	5 (10)	1 (1)	7 (13)	0 (0)
	23S	87	35 (40)	52 (60)	18 (21)	8 (9)	10 (11)	6 (7)	1 (1)	10 (11)	0 (0)
	26	48	27 (56)	21 (45)	8 (17)	3 (7)	4 (8)	3 (5)	0 (1)	3 (6)	0 (0)
	31	48	14 (29)	34 (71)	13 (27)	5 (10)	7 (14)	4 (9)	1 (1)	5 (11)	0 (0)
DWSC breach additions	11	19	10 (52)	9 (49)	3 (16)	3 (17)	1 (7)	1 (5)	0 (1)	1 (4)	0 (0)
	16B	36	8 (21)	28 (79)	10 (28)	10 (28)	4 (12)	3 (8)	0 (1)	1 (3)	0 (0)
OPEN WATER ZONE DOMINANT PARTICLES AFTER **7 DAYS** OF MODEL SIMULATION											
Lower export, higher ET variability	1	35	15 (42)	20 (57)	10 (28)	3 (7)	3 (8)	2 (6)	1 (1)	1 (2)	2 (6)
	1S	86	51 (59)	35 (41)	17 (20)	4 (5)	5 (5)	3 (4)	1 (1)	1 (1)	5 (5)
	3	35	3 (8)	32 (92)	16 (46)	3 (9)	4 (10)	3 (8)	1 (2)	1 (3)	4 (13)
Intermediate export, ET variability	4	30	3 (9)	28 (92)	14 (47)	3 (8)	3 (11)	3 (8)	1 (2)	1 (2)	4 (13)
	4S	85	34 (40)	51 (60)	26 (31)	4 (5)	6 (7)	4 (5)	1 (1)	2 (2)	8 (9)
Higher export, lesser ET variability	23	55	1 (1)	55 (100)	28 (51)	5 (9)	6 (11)	5 (9)	1 (2)	1 (2)	8 (16)
	23S	91	8 (9)	82 (90)	43 (47)	8 (9)	9 (10)	7 (8)	2 (2)	2 (3)	11 (12)
	26	56	1 (2)	55 (97)	29 (52)	6 (10)	7 (12)	5 (9)	1 (2)	1 (2)	6 (10)
	31	48	0 (1)	47 (99)	25 (52)	4 (9)	5 (11)	4 (8)	1 (2)	1 (2)	8 (16)
DWSC breach additions	11	14	0 (3)	14 (96)	6 (42)	4 (24)	1 (9)	1 (6)	0 (1)	0 (1)	2 (12)
	16B	38	1 (2)	37 (99)	20 (53)	3 (8)	4 (9)	3 (7)	1 (2)	0 (1)	7 (18)

Table 4-3. Percentage of Vegetation Zone Dominant Particles Remaining On Site and Exported to Other Locations in the Project Region after 2 and 7 Days.

Alternative grouping	Alt. No.	Percent of total particles (% of vegetation zone dominant)			Percent of total particles (% of vegetation zone dominant) transported to regional locations						
		Vegetation zone-dominant	Remaining On-Site	Exported Off-Site	Lower Sac	DWSC	Liberty Island	Cache Slough	Lindsey Slough	Miner	Other Regions
VEGETATION ZONE DOMINANT PARTICLES AFTER **2 DAYS** OF MODEL SIMULATION											
Lower export, higher ET variability	1	64	52 (81)	12 (19)	5 (8)	2 (3)	3 (4)	2 (3)	0 (0)	1 (1)	0 (0)
	1S	18	15 (84)	3 (16)	1 (6)	1 (3)	1 (3)	0 (2)	0 (0)	0 (1)	0 (0)
	3	66	60 (91)	6 (9)	2 (3)	1 (1)	1 (2)	1 (1)	0 (0)	1 (2)	0 (0)
Intermediate export, ET variability	4	70	51 (73)	19 (27)	8 (12)	2 (3)	4 (5)	2 (3)	0 (0)	2 (3)	0 (0)
	4S	19	14 (72)	5 (28)	3 (13)	1 (4)	1 (5)	1 (4)	0 (0)	1 (3)	0 (0)
Higher export, lesser ET variability	23	49	37 (76)	12 (24)	4 (8)	2 (3)	2 (4)	1 (2)	0 (0)	3 (7)	0 (0)
	23S	13	9 (69)	4 (31)	2 (14)	1 (5)	1 (5)	1 (4)	0 (0)	1 (4)	0 (0)
	26	51	30 (59)	21 (41)	9 (17)	3 (6)	4 (8)	3 (6)	0 (1)	2 (4)	0 (0)
	31	52	26 (50)	26 (50)	11 (21)	3 (6)	5 (9)	3 (6)	0 (1)	4 (8)	0 (0)
DWSC breach additions	11	80	23 (29)	57 (72)	11 (14)	36 (45)	5 (6)	3 (4)	0 (0)	2 (2)	0 (0)
	16B	65	23 (35)	42 (64)	17 (26)	15 (23)	5 (8)	3 (5)	0 (1)	1 (2)	0 (0)
VEGETATION ZONE DOMINANT PARTICLES AFTER **7 DAYS** OF MODEL SIMULATION											
Lower export, higher ET variability	1	65	48 (74)	17 (26)	8 (12)	2 (3)	2 (3)	2 (2)	0 (1)	0 (1)	3 (4)
	1S	13	9 (68)	4 (32)	2 (15)	1 (4)	1 (5)	0 (3)	0 (0)	0 (1)	1 (5)
	3	65	48 (74)	17 (26)	8 (12)	2 (3)	2 (4)	2 (3)	0 (1)	2 (3)	1 (2)
Intermediate export, ET variability	4	70	40 (57)	30 (43)	15 (21)	3 (4)	4 (5)	3 (4)	1 (1)	1 (2)	5 (7)
	4S	15	8 (52)	7 (48)	4 (25)	1 (4)	1 (5)	1 (4)	0 (0)	0 (1)	1 (9)
Higher export, lesser ET variability	23	45	10 (22)	35 (77)	18 (40)	4 (9)	4 (10)	3 (7)	1 (2)	2 (3)	3 (7)
	23S	9	2 (22)	7 (79)	4 (40)	1 (8)	1 (10)	1 (7)	0 (0)	0 (3)	1 (11)
	26	44	5 (12)	39 (88)	20 (45)	4 (9)	5 (11)	3 (8)	1 (2)	1 (2)	5 (11)
	31	52	2 (3)	51 (97)	27 (52)	4 (9)	6 (11)	4 (8)	1 (2)	1 (2)	7 (13)
DWSC breach additions	11	86	4 (4)	82 (96)	33 (39)	26 (30)	7 (9)	5 (6)	1 (1)	1 (1)	8 (9)
	16B	63	3 (5)	59 (95)	31 (49)	7 (11)	5 (8)	4 (6)	1 (2)	1 (1)	11 (17)

4.2.1 Lower export, greater exposure time variability (Alternative 1 and 3)

Model results for Alternative 1 and 3 indicated a low proportion of open water zone dominant particles, and relatively low export of those particles after 2- and 7-days simulation (Table 4-2). For both ET classes, 34–36% of all particles spent the majority of time in the open water zone with 57–92% of those exported by the end of the 7-day simulation. The location of the breach affected the proportion of total open water zone particles exported by each alternative. For example, Alternative 3 had a greater proportion of exported open water zone particles than Alternative 1, due to the location of the breach adjacent to the open water area of Prospect Island (Figure 3-1, Table 4-2).

In terms of potential marsh contributions to productivity export, the potential export of vegetation zone dominant particles was relatively low. For both alternatives, the majority of particles remained on site (Table 4-3). Of all the particles generated during the simulation period, 64–66% spent the majority of time in the vegetated zone and approximately 26% of those were exported by both alternatives by the end of the 7-day simulation.

4.2.2 Intermediate export and intermediate exposure time variability (Alternative 4)

Model results for Alternative 4 indicated a low proportion of open water zone dominant particles and higher export of those particles after 2- and 7-days (Table 4-2). Approximately 30% of the total particles generated during the simulation spent the majority of time in the open water zone, and 92% of those were exported after 7 days.

Approximately 70% of total particles simulated for Alternative 4 spent the majority of time in the vegetated zone (Table 4-3). As compared to the lower export 1 and 3), the additional breach improved the proportion of particles exported from the vegetated zone (Table 4-3). After 7 days, 43% of the vegetation zone dominant particles were exported off of Prospect Island.

4.2.3 Higher export and lesser exposure time variability (Alternative 23, 26, and 31)

Model results for Alternative 23, 26, and 31 indicated a moderate proportion of open water zone dominant particles, but relatively higher export of those particles after 2 and 7 days (Table 4-2). Open water zone particles composed approximately 48–56% of the total particles during the simulation, and 97–100%

of those were exported after 7 days. Alternative 23 and 31 showed slightly higher production and algal export potential than Alternative 26.

All three alternatives exhibited moderate proportions of vegetation dominant particles with moderate to high export of those particles after 2- and 7- days (Table 4-3). Alternatives 26 and 31, having breaches situated near vegetated zones, were able to export more particles from vegetated habitats (88% and 97%) among the three alternatives (Figure 3-1).

4.2.4 Adaptive management alternatives (Alternative 11 and 16B)

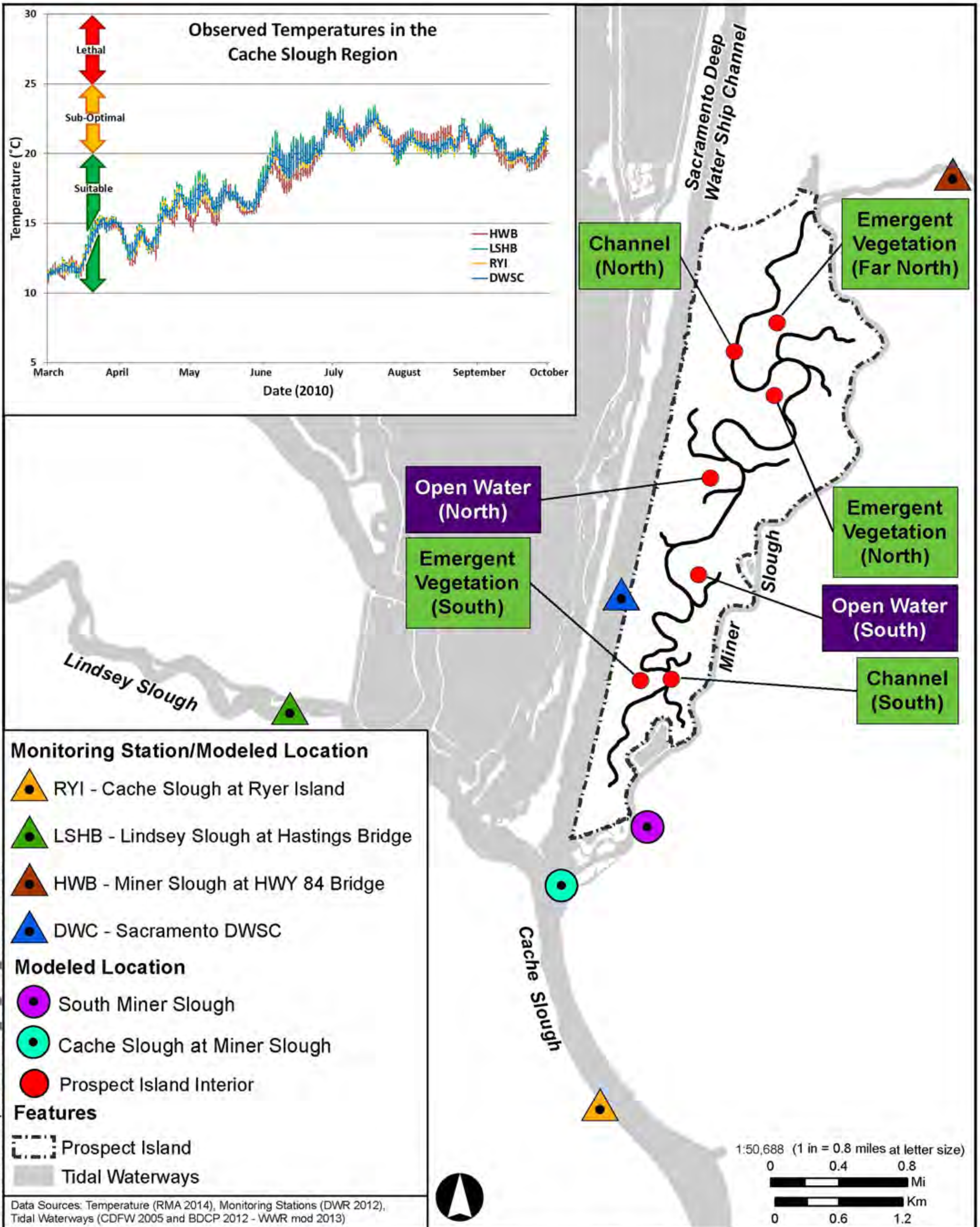
With the addition of DWSC breaches, results for Alternative 11 and 16B indicated a low proportion of open water zone dominant particles, but generally high export of all particles after 2- and 7- days (Table 4-2, Table 4-3). Of all particles simulated, 14–38% spent most of the time in the open water zone and 96–99% of those were exported after 7 days. Most simulated particles remained in vegetated areas for both alternatives. Vegetation zone dominant particles comprised 86% (Alternative 11) and 63% (Alternative 16B) of the total, and 95–96% were exported after 7 days.

4.2.5 Vegetation and channel network sensitivity analysis (Alternative 1S, 4S, and 23S)

Sensitivity simulations generally exhibited greater proportions of open water vs. vegetation zone dominant particles (Table 4-2, Table 4-3). Consistent with the increased extent of open water habitats, 7-day simulations for all three sensitivity alternative configurations (Alternative 1S, 4S, and 23S) resulted in much higher proportions of on-site and exported open water zone dominant particles than the corresponding alternatives with greater vegetation extents (Alternative 1, 4, and 23). The export of vegetation zone dominant particles was substantially decreased under the sensitivity alternative configurations.

4.3 Temperature Changes in Adjacent Water Bodies (B-3 and I-4)

The RMA Delta water model was used to model hydrodynamic (RMA2) and water quality (RMA11) parameters to predict temperature conditions within Prospect Island and in the adjacent water bodies (Appendix B and RMA 2013). The water temperature model (RMA11) considered heat sources and sinks at both the air-water and sediment-water interfaces. Meteorological inputs included air temperature, wind speed, relative humidity, and cloud cover. The model was also calibrated to include the effects of sun shading and wind sheltering related to the presence of vegetation. Additional details can be found in Appendix B. The year 2010 was chosen for evaluation as it represented the most recent year having less than extreme hydrologic classifications—above normal conditions for the San Joaquin Valley and below normal conditions for the Sacramento Valley (DWR 2013b). For this analysis, seven locations were selected to track temperature in adjacent water bodies, and seven locations were selected to track temperature within Prospect Island: two in open water (north and south), two in channel (north and south), and three in emergent vegetation (far north, north, and south) (Figure 4-3).



Wetlands and Water Resources Joint Venture
Stillwater Sciences

Modeled Temperature Locations and Existing Temperature Conditions in Project Area (March-Sept 2010)

Prospect Island Tidal Habitat Restoration Project

June 2014	Project 1149	**Figure 4-3**

4.3.1 Existing water temperature conditions

Under existing conditions, water temperatures in the Project area ranged from suitable (less than 20°C) to sub-optimal (between 20°C and 25°C) during the period of interest (from March through September 2010) (Figure 4-3). From March through May, temperatures were always in the suitable range for juvenile salmonids and Delta Smelt, varying from 11°C to 19°C. June temperatures reflected the transition from the cooler winter/spring temperatures to warmer summer/fall temperatures. Most of the channels exhibited suitable temperatures for a majority of the month, but temperatures in some areas increased to sub-optimal conditions for Delta Smelt. July and August were dominated by sub-optimal conditions for Delta Smelt, followed by transitional cooling in September to more suitable temperatures. Observed and modeled water temperatures did not approach or exceed lethal temperatures (greater than 25°C) at any time during the analysis period.

4.3.2 Modeled water temperatures within Prospect Island

The temperature modeling results for the Prospect Island interior are presented in Table 4-4. Average water temperatures ranged from approximately 11–12°C during March up to 21–22°C during July and August (Appendix B). For ease of interpretation, months with all days having suitable temperatures are highlighted in green; months exhibiting a majority of days with suitable temperatures, but also including sub-optimal temperatures, are highlighted in yellow; months with an even split between suitable and sub-optimal are shown in white; and months with a majority of days with sub-optimal temperatures are highlighted in pink. The values shown for each location type (emergent vegetation, channel, and open water) are the average of the sample locations by type (Appendix B). For example, the open water values are the average of the open water north and open water south locations seen in Figure 4-3.

In general, water temperatures within Prospect Island reflected the temperature trends in the surrounding water bodies with suitable temperatures from March through May, increasing temperatures in June, sub-optimal temperatures in July and August, and cooling temperatures in September. There were no days in the lethal temperature range for any of the alternatives. Though following the general trends observed in the adjacent water bodies, water temperatures within the island tended to be in the suitable range for longer periods of time than in the surrounding water bodies. This condition was best seen in July and August when temperatures in Miner Slough and the DWSC were fully in the sub-optimal range, whereas in Prospect Island, across all alternatives, temperature conditions were within both suitable and sub-optimal ranges for the target species.

There was little temperature difference by location within the island. Areas with emergent vegetation tended to have slightly more days in the suitable range compared to the channelized areas, which in turn had slightly more days in the suitable range compared to the open water areas. Although potential biological effects would require more extensive modeling (e.g., species specific bioenergetics), some benefits of the emergent vegetation and full channel network alternatives (1S, 4S, and 23S) upon water temperature are shown in Table 4-4. Reducing the extent of emergent vegetation (and channels in the deep area) increased the number of days temperatures fell within the sub-optimal ranges. This pattern is replicated in the channel and open water comparison locations (Table 4-4).

Table 4-4. Modeled Prospect Island Interior Temperatures by Alternative (March–September 2010).

Comparison Locations	Month	Days per Month Temperatures Fall within Each of the Temperature Range Classes *Temperature Range Class: suitable (<20 °C) /sub-optimal (20-25°C)/lethal (>25°C)*										
		1	1S[1]	3	4	4S[1]	23	23S[1]	26	31	11	16B
Emergent Vegetation[1]	Mar	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0
	Apr	30 / 0 / 0	30 / 0 / 0	30 / 0 / 0	30 / 0 / 0	30 / 0 / 0	30 / 0 / 0	30 / 0 / 0	30 / 0 / 0	30 / 0 / 0	30 / 0 / 0	30 / 0 / 0
	May	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0
	Jun	17 / 13 / 0	8 / 22 / 0	17 / 13 / 0	16 / 14 / 0	9 / 21 / 0	22 / 8 / 0	14 / 16 / 0	22 / 8 / 0	21 / 9 / 0	15 / 15 / 0	18 / 12 / 0
	July	6 / 25 / 0	3 / 28 / 0	5 / 26 / 0	5 / 26 / 0	2 / 29 / 0	4 / 27 / 0	2 / 29 / 0	4 / 27 / 0	4 / 27 / 0	3 / 28 / 0	2 / 29 / 0
	Aug	16 / 15 / 0	4 / 27 / 0	13 / 18 / 0	10 / 21 / 0	3 / 28 / 0	9 / 22 / 0	3 / 28 / 0	8 / 23 / 0	7 / 24 / 0	6 / 25 / 0	6 / 25 / 0
	Sep	20 / 10 / 0	7 / 23 / 0	20 / 10 / 0	17 / 13 / 0	7 / 23 / 0	20 / 10 / 0	8 / 22 / 0	19 / 11 / 0	18 / 12 / 0	15 / 15 / 0	17 / 13 / 0
Channel	Mar	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0
	Apr	30 / 0 / 0	30 / 0 / 0	30 / 0 / 0	30 / 0 / 0	30 / 0 / 0	30 / 0 / 0	30 / 0 / 0	30 / 0 / 0	30 / 0 / 0	30 / 0 / 0	30 / 0 / 0
	May	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0
	Jun	18 / 12 / 0	9 / 21 / 0	17 / 13 / 0	16 / 14 / 0	9 / 21 / 0	20 / 10 / 0	13 / 17 / 0	22 / 8 / 0	20 / 10 / 0	16 / 14 / 0	18 / 12 / 0
	July	6 / 25 / 0	3 / 28 / 0	5 / 26 / 0	4 / 27 / 0	2 / 29 / 0	4 / 27 / 0	2 / 29 / 0	4 / 27 / 0	4 / 27 / 0	3 / 28 / 0	2 / 29 / 0
	Aug	13 / 18 / 0	3 / 28 / 0	12 / 19 / 0	9 / 22 / 0	3 / 28 / 0	9 / 22 / 0	3 / 28 / 0	8 / 23 / 0	7 / 24 / 0	6 / 25 / 0	6 / 25 / 0
	Sep	19 / 11 / 0	8 / 22 / 0	20 / 10 / 0	17 / 13 / 0	7 / 23 / 0	20 / 10 / 0	8 / 22 / 0	18 / 12 / 0	18 / 12 / 0	14 / 16 / 0	16 / 14 / 0
Open Water	Mar	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0
	Apr	30 / 0 / 0	30 / 0 / 0	30 / 0 / 0	30 / 0 / 0	30 / 0 / 0	30 / 0 / 0	30 / 0 / 0	30 / 0 / 0	30 / 0 / 0	30 / 0 / 0	30 / 0 / 0
	May	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0	31 / 0 / 0
	Jun	14 / 16 / 0	10 / 20 / 0	18 / 12 / 0	18 / 12 / 0	15 / 15 / 0	18 / 12 / 0	15 / 15 / 0	15 / 15 / 0	19 / 11 / 0	19 / 11 / 0	19 / 11 / 0
	July	5 / 26 / 0	3 / 28 / 0	3 / 28 / 0	3 / 28 / 0	2 / 29 / 0	4 / 27 / 0	2 / 29 / 0	4 / 27 / 0	3 / 28 / 0	1 / 30 / 0	2 / 29 / 0
	Aug	9 / 22 / 0	4 / 27 / 0	3 / 28 / 0	2 / 29 / 0	2 / 29 / 0	6 / 25 / 0	2 / 29 / 0	8 / 23 / 0	4 / 27 / 0	0 / 31 / 0	2 / 29 / 0
	Sep	16 / 14 / 0	8 / 22 / 0	14 / 16 / 0	14 / 16 / 0	10 / 20 / 0	15 / 15 / 0	8 / 22 / 0	15 / 15 / 0	15 / 15 / 0	12 / 18 / 0	14 / 16 / 0

Green = All suitable temperatures, Yellow = Majority suitable, White = Even suitable, sub-optimal split, Pink = Majority sub-optimal
Note 1 - Alternatives 1S, 4S, and 23S have no emergent vegetation in the emergent vegetation location

4.3.3 Modeled temperature changes in adjacent water bodies

To determine the Project's potential effects on water temperature in the adjacent water bodies, six locations were chosen for evaluation: Miner Slough at the Highway 84 bridge, Miner Slough south of the most southern breach, Cache Slough at the confluence with Miner Slough and the DWSC, DWSC near the cross levee, Lindsey Slough near Hastings bridge, and Cache Slough at Ryer Island (Figure 4-3). The baseline daily average water temperatures at each location were tallied by month for each defined temperature bin (suitable, sub-optimal, and lethal). This process was repeated for each alternative and the bin counts for alternatives were differenced from the baseline conditions. Positive values in the suitable bin indicated a greater number of days within the suitable temperature range, negative values in the suitable bins indicated the opposite (Table 4-5). Increases of two days or more in the number suitable water temperature days are highlighted in green, 2-day decreases in the number of suitable days are highlighted in yellow, and decreases greater than two days are highlighted in pink. No-change results are shown in white and 1 day changes are highlighted in grey. Changes of one day are likely insignificant for the purposes of evaluation, but are called out to separate them from the no-change months.

Overall, no lethal conditions (temperatures above 25°C) were present under any alternative, under any month, at any location. In addition, there were no changes from base conditions at any location for March, April, or May under any alternative. Changes that did occur tended to be very small, in the 1- to 2-day range.

Miner Slough at the Highway 84 Bridge

- No changes from base conditions under any alternative, during any month.

Miner Slough south of the southern – most breach location

- Increase in number of suitable days in July by two days (Alternative 3, 4S, 23S, 11, and 16B) and three days (Alternative 4, 23, 26, and 31).
- Decrease in number of suitable days in September across all alternatives (two days - Alternative 1, 1S, 3, 4, 23, 26, 31, 11, and 16B; three days - Alternative 4S and 23S).

Cache Slough at the confluence with Miner Slough and the DWSC

- No changes from base for any other months besides June that only shows 1 day changes.

DWSC near the cross levee

- Largest beneficial changes are seen in the adaptive management alternatives, which include breaches to the DWSC. Increases in number of suitable days in July by two (Alternative 11, 16B) and in September by two (Alt 16B).
- Decrease in number of suitable days in June across all Miner-only, multi-breach alternatives (two days - Alternative 4, 4S, 23, 26, 31; five days - Alternative 23S). The five day change under Alternative 23S is the largest change under any alternative during any month.

Lindsey Slough near Hastings Bridge

- Decrease in number of suitable days in June by two days (Alternative 1S, 4S, and 23S). These alternatives have limited emergent vegetation and a reduced channel network
- Increase in number of suitable days in September by two days (Alternative 26, 31, 11, and 16B).

Cache Slough at Ryer Island

- Decrease in number of suitable days in June by two days (Alternative 23, 23S, 31, and 16B)
- Increase in number of suitable days in July by two days across all alternatives

Table 4-5. Changes in Temperature in Adjacent Water Bodies by Alternative.

Comparison Locations	Baseline Temperature Days Per Month (<20/20-25/>25°C)	Changes in Days per Month from Baseline Temperatures Fall within Each of the Temperature Range Classes *Temperature Range Class: suitable (<20°C)/sub-optimal (20-25°C)/lethal (>25°C)*										
		1	1S	3	4	4S	23	23S	26	31	11	16B
Miner Slough at HWY 84 Bridge (HWB)	Mar (31 / 0 / 0)	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	Apr (30 / 0 / 0)	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	May (31 / 0 / 0)	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	Jun (24 / 6 / 0)	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	Jul (0 / 31 / 0)	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	Aug (0 / 31 / 0)	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	Sep (19 / 11 / 0)	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
Miner Slough (South)	Mar (31 / 0 / 0)	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	Apr (30 / 0 / 0)	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	May (31 / 0 / 0)	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	Jun (22 / 8 / 0)	1 / -1 / 0	0 / 0 / 0	1 / -1 / 0	0 / 0 / 0	-1 / 1 / 0	-1 / 1 / 0	-3 / 3 / 0	0 / 0 / 0	0 / 0 / 0	1 / -1 / 0	0 / 0 / 0
	Jul (0 / 31 / 0)	0 / 0 / 0	0 / 0 / 0	2 / -2 / 0	3 / -3 / 0	2 / -2 / 0	3 / -3 / 0	2 / -2 / 0	3 / -3 / 0	3 / -3 / 0	2 / -2 / 0	2 / -2 / 0
	Aug (0 / 31 / 0)	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	1 / -1 / 0	0 / 0 / 0	2 / -2 / 0	0 / 0 / 0	1 / -1 / 0	2 / -2 / 0	0 / 0 / 0	0 / 0 / 0
	Sep (17 / 13 / 0)	-2 / 2 / 0	-2 / 2 / 0	-2 / 2 / 0	-2 / 2 / 0	-3 / 3 / 0	-2 / 2 / 0	-3 / 3 / 0	-2 / 2 / 0	-2 / 2 / 0	-2 / 2 / 0	-2 / 2 / 0
Cache Slough (at Miner Slough and DWSC confluence)	Mar (31 / 0 / 0)	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	Apr (30 / 0 / 0)	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	May (31 / 0 / 0)	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	Jun (20 / 10 / 0)	1 / -1 / 0	0 / 0 / 0	1 / -1 / 0	1 / -1 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	1 / -1 / 0	0 / 0 / 0
	Jul (3 / 28 / 0)	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	Aug (0 / 31 / 0)	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	Sep (13 / 17 / 0)	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
DWSC (DWC)	Mar (31 / 0 / 0)	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	Apr (30 / 0 / 0)	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	May (31 / 0 / 0)	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	Jun (18 / 12 / 0)	-1 / 1 / 0	-1 / 1 / 0	-1 / 1 / 0	-2 / 2 / 0	-2 / 2 / 0	-2 / 2 / 0	-5 / 5 / 0	-2 / 2 / 0	-2 / 2 / 0	1 / -1 / 0	1 / -1 / 0
	Jul (1 / 30 / 0)	1 / -1 / 0	0 / 0 / 0	1 / -1 / 0	1 / -1 / 0	1 / -1 / 0	1 / -1 / 0	1 / -1 / 0	1 / -1 / 0	1 / -1 / 0	2 / -2 / 0	2 / -2 / 0
	Aug (0 / 31 / 0)	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	1 / -1 / 0	1 / -1 / 0
	Sep (12/ 18 / 0)	1 / -1 / 0	1 / -1 / 0	1 / -1 / 0	1 / -1 / 0	1 / -1 / 0	1 / -1 / 0	-1 / 1 / 0	1 / -1 / 0	1 / -1 / 0	1 / -1 / 0	2 / -2 / 0
Lindsey Slough near Hasting Bridge (LSHB)	Mar (31 / 0 / 0)	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	Apr (30 / 0 / 0)	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	May (31 / 0 / 0)	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	Jun (12 / 18 / 0)	0 / 0 / 0	-2 / 2 /0	-1 / 1 / 0	0 / 0 / 0	-2 / 2 /0	-1 / 1 / 0	-2 / 2 /0	-1 / 1 / 0	-1 / 1 / 0	-1 / 1 / 0	0 / 0 / 0
	Jul (3 / 28 / 0)	0 / 0 / 0	0 / 0 / 0	1 / -1 / 0	1 / -1 / 0	0 / 0 / 0	1 / -1 / 0	1 / -1 / 0	1 / -1 / 0	1 / -1 / 0	1 / -1 / 0	1 / -1 / 0
	Aug (0 / 31 / 0)	1 / -1 / 0	1 / -1 / 0	1 / -1 / 0	1 / -1 / 0	1 / -1 / 0	1 / -1 / 0	1 / -1 / 0	1 / -1 / 0	1 / -1 / 0	1 / -1 / 0	1 / -1 / 0
	Sep (11 / 19 / 0)	1 / -1 / 0	1 / -1 / 0	1 / -1 / 0	1 / -1 / 0	1 / -1 / 0	1 / -1 / 0	1 / -1 / 0	2 / -2 / 0	2 / -2 / 0	2 / -2 / 0	2 / -2 / 0
Cache Slough at Ryer Island (RYI)	Mar (31 / 0 / 0)	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	Apr (30 / 0 / 0)	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	May (31 / 0 / 0)	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	Jun (22 / 8 / 0)	1 / -1 / 0	-1 / 1 / 0	0 / 0 / 0	0 / 0 / 0	-1 / 1 / 0	-2 / 2 / 0	-2 / 2 / 0	-1 / 1 / 0	-2 / 2 / 0	0 / 0 / 0	-2 / 2 / 0
	Jul (1 / 30 / 0)	2 / -2 / 0	2 / -2 / 0	2 / -2 / 0	2 / -2 / 0	2 / -2 / 0	2 / -2 / 0	2 / -2 / 0	2 / -2 / 0	2 / -2 / 0	2 / -2 / 0	2 / -2 / 0
	Aug (0 / 31 / 0)	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	Sep (13 / 17 / 0)	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	1 / -1 / 0	0 / 0 / 0

4.4 Turbidity Effects (I-2)

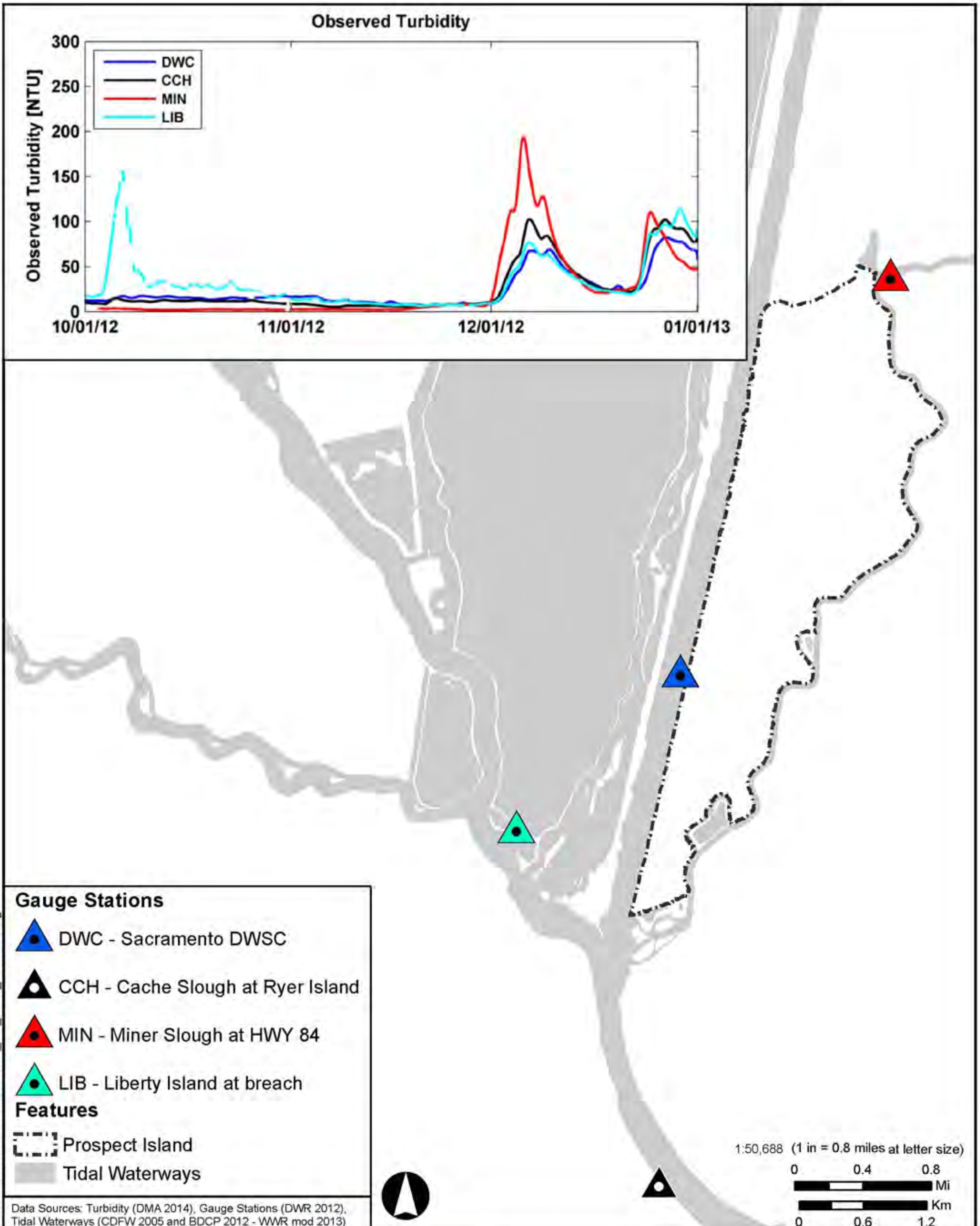
An analysis period of October 1, 2012 through December 31, 2012 was selected to evaluate the potential turbidity effects of the Project (Figure 4-4). This period captured a range of representative low and high turbidity conditions. October and November represented lower-wind conditions outside of storm periods that typically reflect very low Miner Slough turbidity and lower turbidity in the DWSC and Cache Slough versus winter time periods. December included a first flush storm sediment load in Miner Slough. This time period also included flow high enough to activate the proposed overflow weir in December, although for a relatively short duration.

Turbidity analysis examined both conditions external and internal to Prospect Island. The sedimentation and erosion potential both inside and outside of the Island was also simulated. Evaluation of regional effects focused on the following four locations (CDEC monitoring station ID shown in parentheses):

- Miner Slough north of Prospect Island at Highway 84 (HWB);
- Cache Slough downstream of the confluence with Miner Slough and the DWSC (CCH);
- DWSC near the internal Prospect cross levee (DWC); and
- Liberty Island at the breach to Cache Slough (LIB).

Overall, modeling indicated that the restoration of Prospect Island would reduce turbidity somewhat in the Cache Slough region. During low Delta outflow conditions, sediment was transported from Cache Slough, up Miner Slough, and sediment was deposited in Prospect Island. During high Delta outflow conditions, sediment from Miner Slough was transported into Prospect Island, where some deposition occurred. Deposition within Prospect Island would increase site elevations, improve long-term ecological resiliency, and promote natural tidal marsh function. Turbidity within open water areas would provide cover to Delta Smelt, aiding in predator avoidance.

The interaction of tides, winds, waves, and sediments results in complex physical processes which need to be simplified and parameterized in order to be represented in a numerical model (Appendix C). The interpretation of the model results must therefore take into account how these assumptions influence both the model predictions and any conclusions drawn from the model predictions. The largest uncertainty was associated with evaluations based on absolute turbidity thresholds, while relative comparisons between scenarios were less affected by model uncertainty. The modeling results presented here are relative comparisons between alternatives and not absolute comparisons. For further information on the details, uncertainties, and usage limitations of this analysis, please see Appendix C.



File: Observed-Turbidities-CSC_AP_1149_2014-0630gal

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Observed Turbidities in the Cache Slough Region

Prospect Island Tidal Habitat Restoration Project

June 2014	Project 1149	**Figure 4-4**

4.4.1 Turbidity changes in the Cache Slough region

The results of the turbidity modeling in the Cache Slough region are presented by groupings based on connectivity. Table 4-6 provides a summary of the average predicted monthly percent changes in tidally averaged turbidity at the four locations of interest. All alternatives resulted in a reduction of turbidity in the Cache Slough region in at least one location during one of the evaluated months. Sensitivity testing results of emergent vegetation and channel network extent indicated that turbidity outside Prospect Island was not sensitive to differences in combined vegetation and channel network extent. When vegetation was limited to the intertidal zone and the channel network was reduced (Alternative 1S, 4S, and 23S), predicted turbidities were almost always within 1 Nephelometric Turbidity Unit (NTU) of the predicted turbidity for the corresponding intertidal and shallow subtidal vegetation and full channel network alternatives (Alternative 1, 3, and 23).

4.4.1.1 Lower connectivity alternatives (Alternative 1, 1S, 3, and 3B)

As stated above, Alternative 1 and 1S behaved almost identically and generally exhibited the smallest reductions in the adjacent water bodies of all the alternatives across all months (Table 4-6). In Miner Slough, percent reductions are higher in October and November when turbidities are lower and lower during December when turbidities were higher. Percent changes remained consistent in Cache Slough regardless of time of year and gradually increased in the DWSC from October through November. At the Liberty Island breach, percent reductions slightly increased from October through November, and then decreased in December.

Alternative 3 and 3B differ from each other in structure in that Alternative 3 includes an overflow weir at the northern-most connection location on Miner Slough and Alternative 3B does not. The overflow weir was activated in the model during December for Alternative 3; however the inundation time was relatively short and did not result in a measurable difference with Alternative 3B. Alternative 3 and 3B have slightly larger reductions in turbidity as compared to Alternatives 1 and 1S (Table 4-6). .Alternative 3 and 3B follow the same trends as seen in Alternatives 1 and 1S, except with slightly greater reductions across all months and locations.

4.4.1.2 Intermediate connectivity alternatives (Alternative 4 and 4S)

Alternative 4 and 4S behaved almost identically, as discussed above (Table 4-6). In Miner Slough, percent reductions were higher in October and November when turbidities were lower and lower during December when turbidities were higher. Percent changes gradually increased in both Cache Slough and the DWSC from October to December. At the Liberty Island breach, percent reductions slightly increased from October through November, and then decreased in December.

4.4.1.3 Higher connectivity alternatives (Alternative 23, 23S 26, and 31)

The higher connectivity alternatives had larger percent reductions in turbidity than the lower and intermediate connectivity alternatives, but unlike the other groupings, also exhibited percent increases. These alternatives exhibited larger differences in effects depending on whether turbidity is higher in the DWSC and Cache (October and November) or Miner Slough (December).

As with the other sensitivity alternatives, Alternative 23 and 23S behave almost identically to each other (Table 4-6). In Miner Slough, percent reductions decrease from October and November when turbidities are lower. During December when turbidities are higher, Alternative 23 and 23S show percent increases in turbidity compared to baseline. In Cache Slough, the DWSC, and at the Liberty Island breach percent reductions increase slightly from October to November, and then double or more in value in December. While these increases are large, it is useful to keep in mind that turbidities are significantly higher during much of December as compared to October and November and larger percent reductions in may not be important when examining absolute values well above critical values for Delta smelt.

Alternative 26 has similar, but slightly smaller impacts and slightly larger benefits as compare to Alternative 23 and 23S and follows the same percent reductions and increases patterns across all months and locations (Table 4-6).

Alternative 31 followed the same patterns in percent reductions and increases as the other higher connectivity alternatives across all months and locations (Table 4-6). The magnitude of the changes, both positive and negative, under Alternative 31 was the greatest of the higher connectivity alternatives.

4.4.1.4 Adaptive management alternatives (Alternative 11 and 16B)

The adaptive management alternatives had the smallest percent decreases and largest percent increases in turbidity in Cache and Miner Sloughs, while conversely having the largest percent decrease in turbidity in the DWSC.

Model results for Alternative 11 showed reduced turbidity in Miner Slough during both October and November when turbidities were low, and then increased turbidity in December when turbidities were high (Table 4-6). In Cache Slough, there was a small percent increase in October and no effect in November. The percent increase was likely due to Prospect acting like a shortcut between the DWSC and the lower portion of Cache Slough, via Miner Slough. Conversely, a percent reduction was predicted in December, when turbidities and flows were higher. At both the DWSC and Liberty Island stations, percent reductions increased slightly from October to November, and then doubled or more in value in December, similar to the trends observed in the higher connectivity alternatives.

Alternative 16B is the only alternative that increased turbidity in Miner Slough in all the modeled months (Table 4-6). These increases were paired with relatively large percent decreases in the DWSC. These changes were likely due to the change in flow patterns described above. In Cache Slough, Alternative 16B exhibited minor percent increases in October and decreases in November, followed by larger percent decreases in December when turbidities were higher overall. At the Liberty Island station, percent reductions increased slightly from October through December.

In examining these alternatives, it should also be noted that turbidity in the DWSC increased downstream of breaches along the DWSC and decreased upstream of the breaches. The values described above and in Table 4-6 only reflect changes in monthly averaged turbidities at the monitoring location, which is located downstream of the DWSC breach in Alternative 11 and between DWSC breaches in Alternative 16B.

Table 4-6. Average Predicted Monthly Percent Change in Tidally Averaged Turbidity.

Averaging Period	Grouping	Alt	Station			
			Miner Slough	Cache Slough	DWSC	Liberty Island
October 2012	Lower Connectivity	Alt 1	-14	-6	-12	-10
		Alt 1SA	-15	-6	-12	-10
		Alt 3	-19	-5	-15	-11
		Alt 3B	-19	-5	-15	-11
	Intermediate Connectivity	Alt 4	-15	-5	-16	-12
		Alt 4SA	-15	-5	-16	-12
	Higher Connectivity	Alt 23	-16	-6	-16	-12
		Alt 23SA	-16	-6	-16	-12
		Alt 26	-18	-5	-13	-10
		Alt 31	-13	-5	-17	-12
	Adaptive Management (DWSC breaches)	Alt 11	-4	3	-13	-7
		Alt 16B	36	1	-22	-10
November 2012	Lower Connectivity	Alt 1	-13	-6	-13	-11
		Alt 1SA	-13	-6	-13	-11
		Alt 3	-15	-7	-16	-12
		Alt 3B	-15	-7	-16	-12
	Intermediate Connectivity	Alt 4	-12	-7	-18	-14
		Alt 4SA	-12	-7	-18	-14
	Higher Connectivity	Alt 23	-12	-7	-17	-13
		Alt 23SA	-12	-7	-17	-13
		Alt 26	-11	-6	-14	-11
		Alt 31	-10	-8	-19	-15
	Adaptive Management (DWSC breaches)	Alt 11	-4	0	-18	-10
		Alt 16B	30	-3	-28	-14
December 2012	Lower Connectivity	Alt 1	-2	-5	-15	-8
		Alt 1SA	-2	-6	-15	-8
		Alt 3	-5	-7	-19	-10
		Alt 3B	-5	-7	-19	-10
	Intermediate Connectivity	Alt 4	-2	-8	-22	-11
		Alt 4SA	-2	-8	-22	-11
	Higher Connectivity	Alt 23	8	-18	-36	-23
		Alt 23SA	8	-18	-35	-22
		Alt 26	10	-14	-28	-18
		Alt 31	11	-19	-37	-24
	Adaptive Management (DWSC breaches)	Alt 11	3	-10	-38	-16
		Alt 16B	17	-11	-31	-15

4.4.2 Sediment deposition and erosion potential within Prospect Island

Prospect Island is subsided, with elevations ranging from shallow subtidal (2.5 to 0 ft NAVD88) to moderate subtidal (0 to -2.5 ft NAVD88). Sediment accretion will help reverse subsidence, build marsh plain elevations, and provide adaptability for the site in terms of long-term sea level rise. The potential for sediment deposition within Prospect Island followed an inverse pattern as compared to that seen in the regional turbidity analysis: alternatives with greater connectivity accreted more sediment, thereby decreasing regional turbidity more, and alternatives with lesser connectivity accreted less sediment, thereby decreasing regional turbidity less. Deposition within the island was not uniform, but rather was concentrated near the breach locations and the deeper central area of the site (Appendix C). Alternatives are described by connectivity grouping below, while Table 4-7 provides a summary of accumulated sediment mass by alternative for the three-month period of October – December 2012 and Figure 4-5 provides insight into temporal accretion patterns.

Table 4-7. Prospect Island Modeled Cumulative Sediment Accretion (October–December 2012).

Grouping	Alternative	Sediment Mass (kilograms x10^7)
Lower Connectivity	1	1.12
	1S	1.15
	3	1.68
	3B	1.68
Intermediate Connectivity	4	2.07
	4S	2.02
Higher Connectivity	23	4.39
	23S	4.34
	26	3.31
	31	4.59
Adaptive Management	11	3.04
	16B	4.60

Erosion potential was uniform across the alternatives with some scour predicted within all breach locations. Higher sheer stresses were predicted at the cross levee breach, especially in alternatives that include the southern Miner Slough breach (Alternative 1, 4, 26, and 31). The associated erosion potential at the cross levee breach indicates that the breach should be resized to wider than 200 feet, especially for the alternatives with the southern breach.

4.4.2.1 Lower connectivity alternatives (Alternatives 1, 1S, 3, and 3B)

Alternative 1 had the smallest modeled cumulative accretion of all the alternatives (Table 4-7). Most deposition was seen near the breach in the southern portion of the property as the cross levee breach limited flow and transport between the northern and southern portion of the site, trapping sediment mostly in the south (Appendix C). Alternative 1S had slightly more sediment accretion than Alternative 1. The smaller vegetation extent and reduced channel network in Alternative 1S resulted in greater sediment dispersal in the northern part of the island, which was then trapped in the low energy subtidal area of the northern portion of the site. The southern portion of Alternative 1S had less accretion than Alternative 1. Alternative 3 and 3B accreted the same amount of sediment with the presence or absence of the overflow weir having no effect. Deposition was concentrated near the breach (Miner central location) and in the deeper central portion of the site (Appendix C).

4.4.2.2 Intermediate connectivity alternatives (Alt 4, 4S)

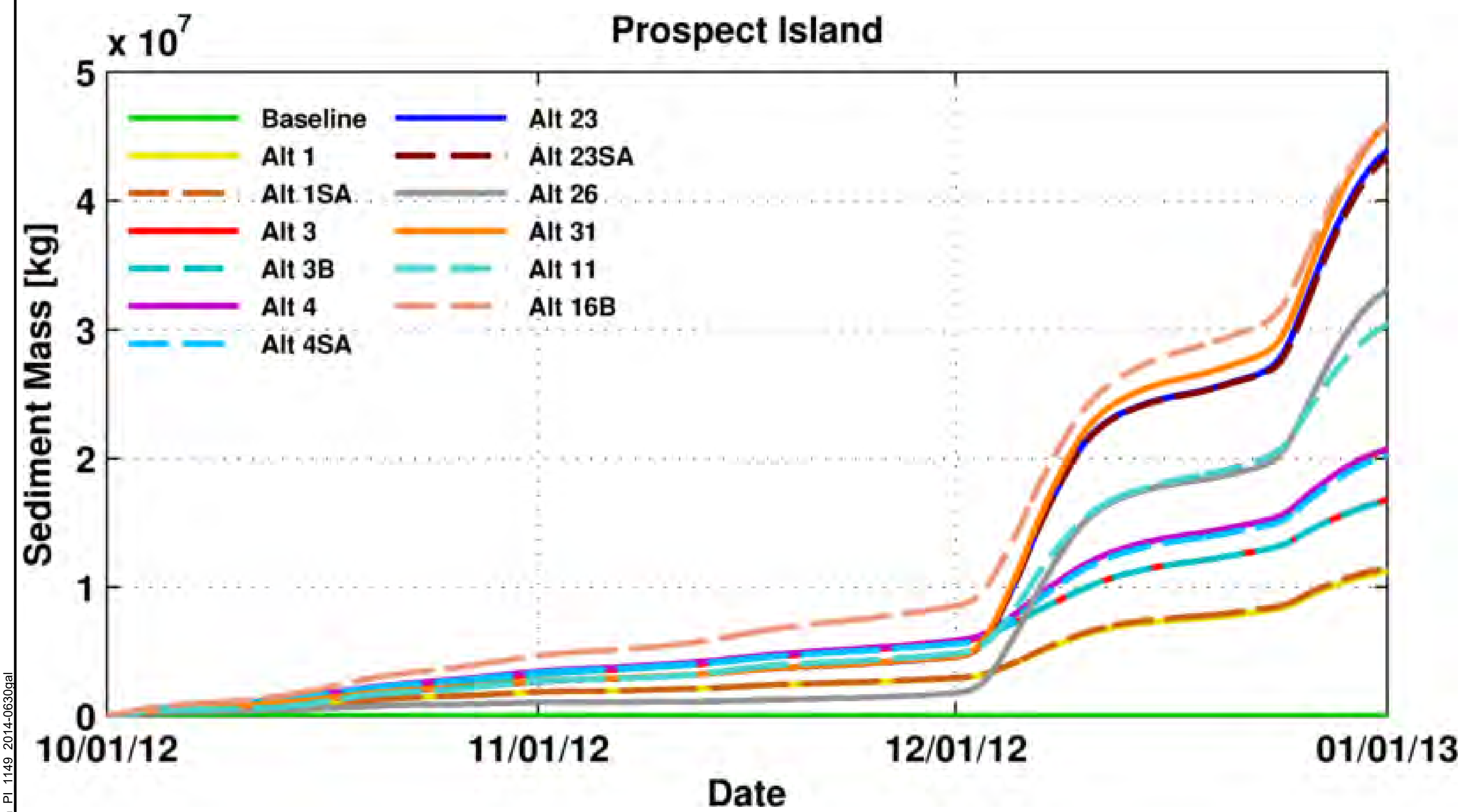
The increase in connectivity results in slightly higher sediment accumulation for Alternatives 4 and 4S as compared to the lower connectivity alternatives (Table 4-7). In Alternative 4, deposition is concentrated in the southern property, near breaches, and in deeper central portion of northern property. There is little deposition in most northern portions of the site. Alternative 4S has less accretion than Alternative 4, following expectation that less vegetation results in less sediment trapping. Deposition patterns are similar to those seen in Alternative 4.

4.4.2.3 Higher connectivity alternatives (Alternatives 23, 23S 26, and 31)

The higher connectivity alternatives accreted the highest levels of sediment of the non-DWSC breach alternatives (Table 4-7). Alternative 23 had deposition concentrated in the northern property, with very little in the southern property, due to the restriction caused by the cross-levee breach (Appendix C). Alternative 23S accreted slight less than Alternative 23, but both showed similar deposition patterns. Alternative 26 produced the most accretion during high flows (December) (Figure 4-5), with relatively low accretion, as compared to the other alternatives, during the lower flow times of October and November. Alternative 31 produced the most accretion and broader deposition than all other alternatives.

4.4.2.4 Adaptive management alternatives (Alternatives 11 and 16B)

The adaptive management alternatives accreted sediment at levels equal to the higher connectivity alternatives. The presence of breaches on the DWSC resulted in accretion of more sediment in the northern portion of the site and more uniform distribution of sediment throughout the site (Appendix C).



Source: DMA 2014

DELTA MODELING ASSOCIATES

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Department of Water Resources, State of California

Cumulative Sediment Accretion within Prospect Island for All Alternatives

Prospect Island Tidal Habitat Restoration Project

June 2014	Project 1149	**Figure 4-5**

File: Fig 4-5 Sediment-Accretion PI 1149 2014-0630gal

4.4.3 Additional turbidity observations

Under existing conditions, turbidity in Miner Slough is lower than Cache Slough and the DWSC in October and November. This low turbidity forms a movement barrier for Delta Smelt, preventing them from traveling up Miner Slough from Cache Slough. Depending on the alternative, the model predicted increases in Miner Slough turbidity from the confluence with Cache Slough to the southern or central breach, forming a turbidity “bridge” that connected Cache Slough to Prospect Island. This increase was due to the increased tidal prism from the Project, which transported sediment from Cache Slough into Miner Slough and into the Project site via the breaches (Appendix C). North of the breaches, turbidity was predicted to decrease. Graphical representations of this can be seen in Appendix C, Figures 5.2-23 and 5.2-24. This increase in turbidity may allow Delta Smelt to travel into Miner Slough and Prospect Island.

4.5 Salinity Changes at D-1641 Compliance Stations (I-3)

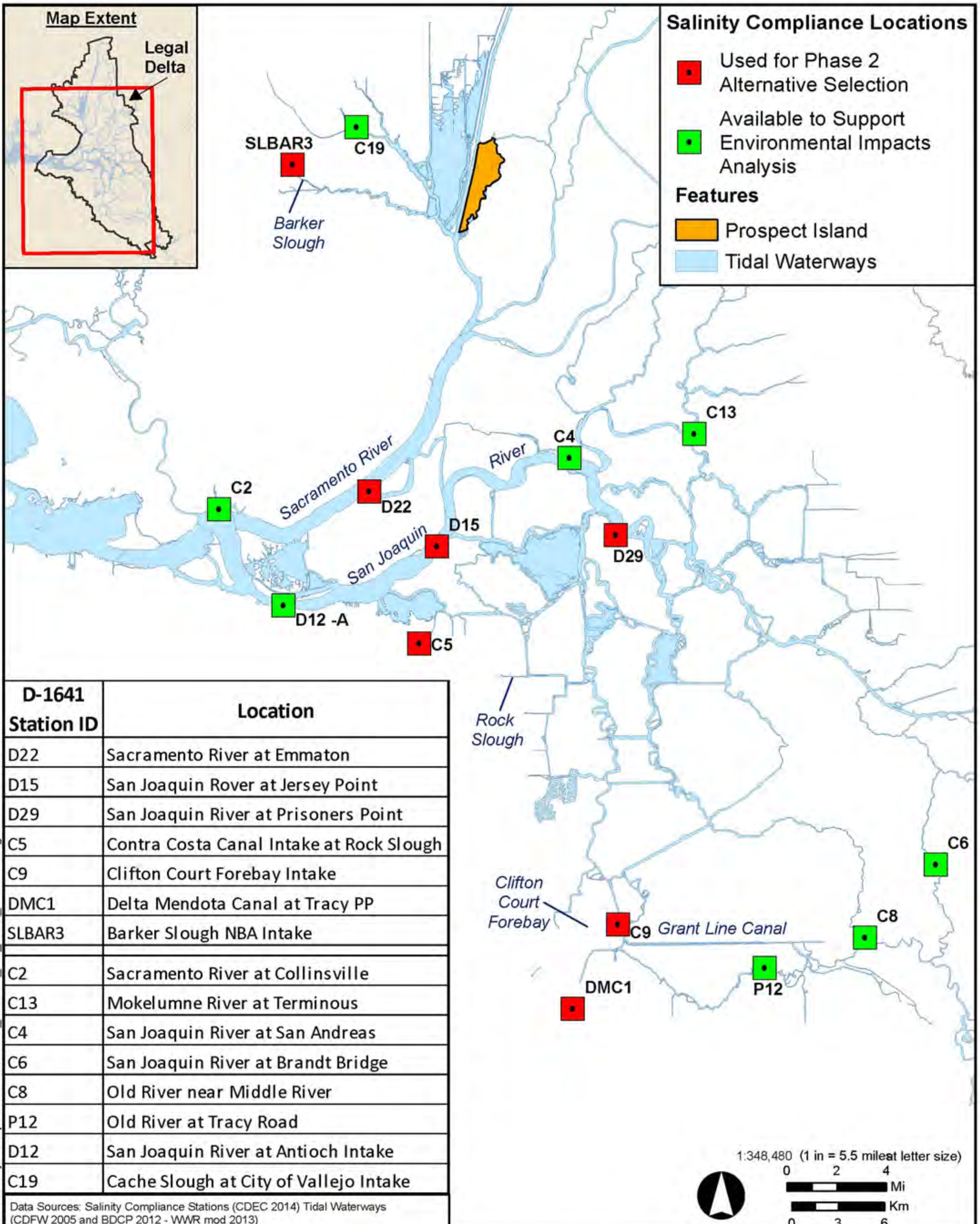
The RMA Delta model was used to evaluate potential changes in salinity for the Project (Appendix D). Electrical conductivity (EC) was modeled as a surrogate for salinity for 2009 and 2010. EC was used as a stand-in for the more precise term of Specific Conductance (SC) for the electrical conductance corrected to 25°C. The primary goal of the salinity model evaluation was to determine the potential for a Project alternative to be non-compliant with the D-1641 water quality objectives. These compliance results are presented first, followed by a general description of changes in salinity seen at different locations of interest in the Delta. Figure 4-6 shows the locations of the representative compliance stations used for alternatives comparison. Figure 4-6 also shows additional compliance stations modeled to support environmental impact analyses in the EIR, but not used for alternatives selection.

4.5.1 Agricultural and fish and wildlife compliance

Seasonal EC standards apply to the three representative Agriculture and Fish and Wildlife compliance stations: the Sacramento River at Emmaton (D22), and the San Joaquin River at Jersey Point (D15), and Prisoners Point (D29). Compliance was examined from April 1 – August 15 at Emmaton (D22) and Jersey Point (D15) and from April 1 – May 31 for Prisoners Point (D29). No potential compliance issues were identified at any location, under any alternative.

4.5.2 Municipal and industrial compliance

Year round chloride concentration limits apply to the four representative water export locations: the North Bay Aqueduct Intake at Barker Slough (SLBAR3), the Contra Costa Canal Intake at Rock Slough (C5), the Clifton Court Forebay Intake (C9), and the Delta Mendota Canal at the Tracy Pumping Plant (DMC1). There was little difference between computed base chloride concentrations and alternative chloride concentrations. All were within the D-1641 water quality compliance limits.



D-1641 Station ID	Location
D22	Sacramento River at Emmaton
D15	San Joaquin Rover at Jersey Point
D29	San Joaquin River at Prisoners Point
C5	Contra Costa Canal Intake at Rock Slough
C9	Clifton Court Forebay Intake
DMC1	Delta Mendota Canal at Tracy PP
SLBAR3	Barker Slough NBA Intake
C2	Sacramento River at Collinsville
C13	Mokelumne River at Terminous
C4	San Joaquin River at San Andreas
C6	San Joaquin River at Brandt Bridge
C8	Old River near Middle River
P12	Old River at Tracy Road
D12	San Joaquin River at Antioch Intake
C19	Cache Slough at City of Vallejo Intake

Data Sources: Salinity Compliance Stations (CDEC 2014) Tidal Waterways (CDFW 2005 and BDCP 2012 - WWR mod 2013)

File: Salinity-Compliance-Locations_D-1641_AP_1149_2014-0630gal

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D-1641 Salinity Compliance Locations

Prospect Island Tidal Habitat Restoration Project

June 2014	Project 1149	**Figure 4-6**

4.5.3 General trends in salinity changes

While modeling results did not show the potential for non-compliance with D-1641 salinity standards, they did show that alternatives produce both decreases and increases in computed EC both seasonally and spatially (Figure 4-7). Summaries of maximum and minimum absolute and percent changes can be seen in Table 4-8 and Table 4-9.

4.5.3.1 North Delta

In the northern Delta, at Barker Slough North Bay Aqueduct Intake (SLBAR3), EC decreased year round, with greater decreases in the spring (up to 7%), when salinities were higher, and smaller decreases in the summer though winter (between 1 and 2%), when salinities were lower. Alternative 16B exhibited the greatest decreases in salinity, while Alternative 1 exhibited the smallest decreases in salinity.

4.5.3.2 West Delta

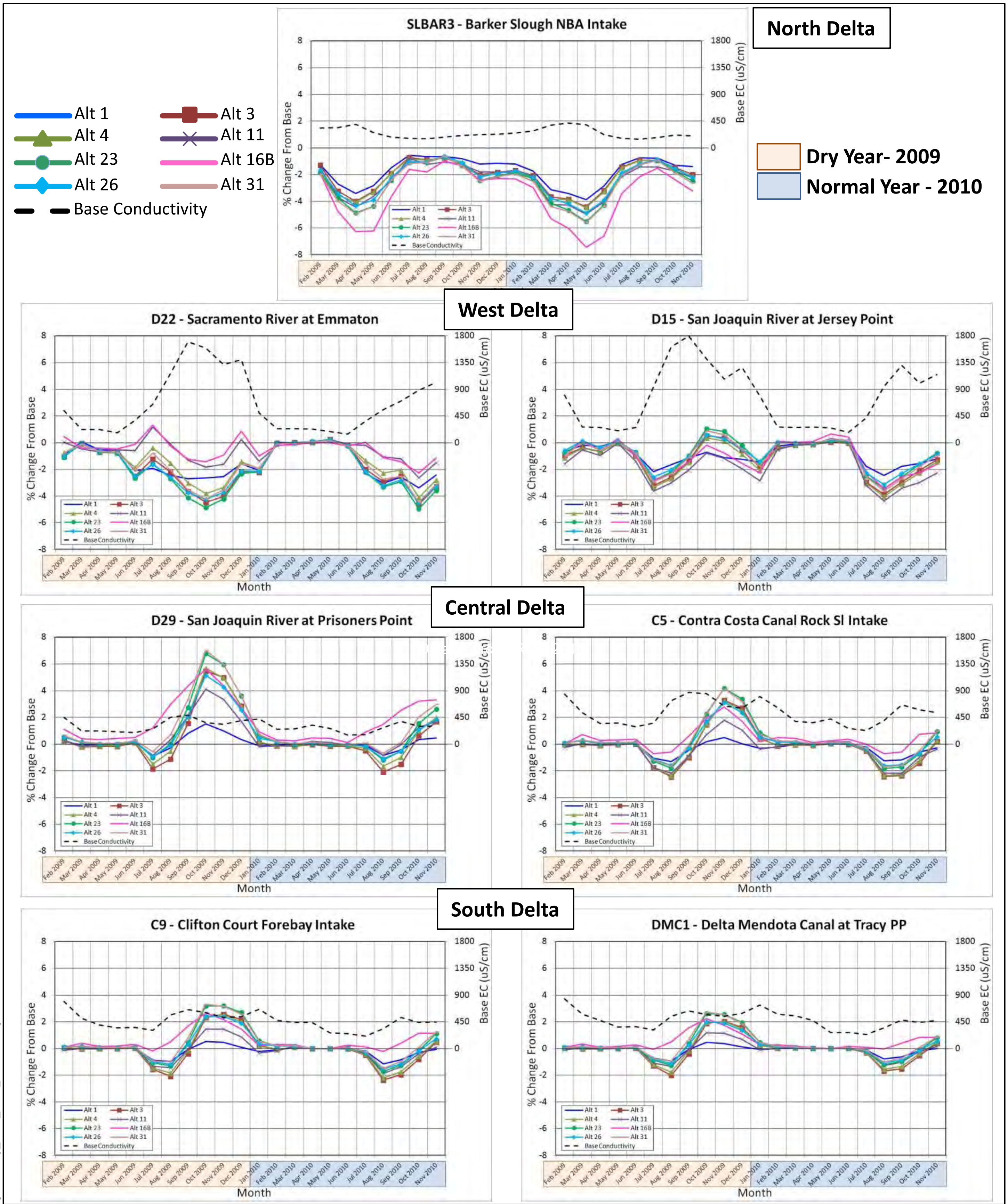
All alternatives generally decreased salinity in the western Delta. At the Sacramento River at Emmaton (D22), Alternative 1, 3, 4, 23, 26, and 31 decreased salinity in the summer and fall, when salinities were higher, and had no effect in the winter and spring, when salinities were lower. Alternative 11 and 16B also had no effect on salinity in the winter and spring, but both exhibited smaller decreases and some increases (≤ 1%) during the summer and fall months. All alternatives showed little effect on salinity at the San Joaquin River at in the winter and spring when salinities are low and decreases in salinity in the summer as salinities begin to increase under existing conditions. In the fall of the dry year, Alternative 3, 4, 23, 26, and 31 all exhibited increases in salinity of ≤ 1%

4.5.3.3 Central Delta

In the central Delta at the San Joaquin River at Prisoners Point (D29) and the Contra Costa Canal Rock Slough Intake (C5), the alternatives generally followed the same pattern of little to no change in the winter and spring (existing salinities low), followed by small decreases in summer (existing salinities increasing), and increases in the fall (peak existing salinities). Increases in salinity at Prisoners Point ranged from a high of 7% under Alternative 23 and 31 to a low of 1.5% under Alternative 1. Increases at Rock Slough Intake followed the same trend with a high of 4% under Alternative 23 and 31 to a low of 0.5% under Alternative 1.

4.5.3.4 South Delta

Changes in the southern Delta at the Clifton Court Forebay (C9) and the Delta Mendota Canal at the Tracy Pumping Plant (DMC1) followed the trends seen in the central Delta, but with slightly less magnitude. Results for all alternatives modeled generally showed little to no change in the winter and spring (existing salinities lower), followed by small decreases in summer (existing salinities increasing), and increases in the fall (peak existing salinities). Increases in salinity at both Clifton Court and Delta Mendota Canal ranged from a high of around 3% under Alternative 23 and 31 to a low of 0.5% under Alternative 1. Decreases in salinity were ≤ 2%.



Data Source:
RMA 2013

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Stillwater Sciences
Joint Venture
RMA Resource Management Associates
California Department of Fish & Wildlife
Department of Water Resources, State of California

Percent Change of Electrical Conductivity From Base Salinity D-1641 Compliance Stations

Prospect Island Tidal Habitat Restoration Project

June 2014	Project 1149	**Figure 4-7**

File: Fig-4-7_Percent-Change-Salinity_RMA_1149_2014-0630gal

Table 4-8. Minimum and Maximum Computed Absolute and Percentage Change from Base Condition Monthly Averaged EC in 2009

D1641 Station	Monthly Avg Base EC uS/cm		Change from Base EC (uS/cm and %): Feb 2009 - Dec 2009																																
			Alt 1				Alt 3				Alt 4				Alt 11				Alt 23				Alt 16B				Alt 26				Alt 31			
	min	max	min		max		min		max		min		max		min		max		min		max		min		max		min		max		min		max	
			uS/cm	%	uS/cm	%	uS/cm	%	uS/cm	%	uS/cm	%	uS/cm	%	uS/cm	%	uS/cm	%	uS/cm	%	uS/cm	%	uS/cm	%	uS/cm	%	uS/cm	%	uS/cm	%	uS/cm	%	uS/cm	%
D22	167	1700	-46	-2.7	0.1	0.1	-71	-4.5	-0.1	0.0	-61	-3.8	-0.2	-0.1	-29	-1.8	8	1.2	-78	-4.9	-0.1	0.0	-23	-1.4	11.9	1.3	-68	-4.2	-0.1	0.0	-67	-4.2	-0.2	-0.1
D15	203	1793	-27	-2.2	0.2	0.1	-42	-3.2	7	0.5	-44	-3.4	5	0.4	-49	-3.6	-0.1	0.0	-36	-2.8	15	1.0	-38	-2.8	1	0.3	-33	-2.6	8	0.6	-38	-2.9	12	0.9
D29	192	486	-2	-0.9	5	1.5	-5	-1.9	20	5.5	-4	-1.5	20	5.7	-2	-0.8	15	4.1	-3	-1.0	24	6.8	1	0.3	21	5.6	-2	-0.9	19	5.1	-1	-0.6	25	7.0
DMC1	308	833	-5	-0.9	3	0.4	-11	-2.0	11	2.0	-10	-1.8	11	2.0	-7	-1.3	7	1.2	-7	-1.3	15	2.6	-0.2	-0.1	13	2.2	-6	-1.1	11	2.0	-5	-0.9	16	2.7
C9	303	794	-6	-1.0	3	0.5	-12	-2.1	14	2.6	-10	-1.8	14	2.5	-8	-1.4	9	1.4	-7	-1.3	19	3.2	-1	-0.2	16	2.7	-7	-1.2	15	2.4	-6	-1.0	20	3.3
C5	287	868	-10	-1.3	3	0.5	-18	-2.5	21	3.3	-17	-2.4	21	3.2	-16	-2.2	12	1.8	-13	-1.8	27	4.2	-4	-0.7	18	2.8	-12	-1.6	20	3.1	-12	-1.7	26	4.1
SLBAR3	148	397	-14	-3.4	-1	-0.6	-16	-4.0	-1	-0.7	-16	-4.1	-1	-0.7	-18	-4.4	-1	-0.8	-19	-4.9	-1	-0.7	-25	-6.3	-2	-1.0	-17	-4.3	-1	-0.6	-20	-4.9	-1	-0.6

Table 4-9. Minimum and Maximum Computed Absolute and Percentage Change from Base Condition Monthly Averaged EC in 2010

D1641 Station	Monthly Avg Base EC uS/cm		Change from Base EC (uS/cm and %): Feb 2010 - Dec 2010																																
			Alt 1				Alt 3				Alt 4				Alt 11				Alt 23				Alt 16B				Alt 26				Alt 31			
	min	max	min		max		min		max		min		max		min		max		min		max		min		max		min		max		min		max	
			uS/cm	%	uS/cm	%	uS/cm	%	uS/cm	%	uS/cm	%	uS/cm	%	uS/cm	%	uS/cm	%	uS/cm	%	uS/cm	%	uS/cm	%	uS/cm	%	uS/cm	%	uS/cm	%	uS/cm	%	uS/cm	%
D22	147	1018	-30	-3.4	0.4	0.2	-41	-4.6	0.4	0.2	-36	-4.1	0.3	0.2	-23	-2.6	0.0	0.0	-44	-5.0	0.4	0.2	-20	-2.3	0.1	0.0	-40	-4.5	0.4	0.2	-40	-4.5	0.3	0.1
D15	172	1303	-23	-2.5	0.3	0.1	-39	-3.9	0.5	0.0	-40	-4.0	0.4	0.1	-44	-4.4	0.7	0.3	-33	-3.4	1	0.1	-33	-3.5	2	0.6	-30	-3.1	0.6	0.2	-35	-3.6	0.9	0.3
D29	155	422	-2	-0.8	1	0.5	-6	-2.1	5	1.7	-5	-1.7	6	2.0	-2	-0.9	5	1.7	-3	-1.2	8	2.6	0.2	0.1	10	3.3	-3	-1.1	6	1.8	-2	-0.7	9	3.0
DMC1	237	728	-3	-0.8	0.1	0.0	-7	-1.7	2	0.4	-6	-1.6	2	0.4	-5	-1.3	0.7	0.1	-5	-1.2	4	0.8	-0.2	-0.1	4	0.8	-4	-1.1	3	0.5	-4	-1.0	4	0.9
C9	208	657	-4	-1.1	0.3	0.1	-10	-2.4	2	0.5	-9	-2.2	3	0.6	-7	-1.9	0.6	0.1	-7	-1.7	5	1.1	-0.7	-0.2	5	1.1	-6	-1.5	3	0.7	-5	-1.5	5	1.2
C5	225	799	-8	-1.2	0.1	0.0	-16	-2.4	4	0.5	-15	-2.4	3	0.4	-14	-2.2	0.6	0.2	-11	-1.8	7	0.9	-4	-0.7	4	0.8	-10	-1.6	4	0.6	-11	-1.7	6	1.0
SLBAR3	145	414	-15	-3.9	-1	-0.7	-17	-4.4	-1	-0.9	-17	-4.5	-1	-0.9	-19	-5.0	-2	-1.4	-21	-5.5	-2	-0.9	-29	-7.5	-3	-1.5	-19	-4.9	-2	-0.9	-22	-5.6	-2	-0.9

4.6 Regional Flow Alterations (I-8)

The RMA Delta model was also used to estimate potential changes to the existing regional flow (Appendix D). The evaluation period spanned from February 1, 2009 to November 30, 2010, covering generally dry and below normal hydrologic conditions in the Sacramento Valley and dry and above normal conditions in the San Joaquin Valley (DWR 2013b)

4.6.1 Compliance with D-1641 flow requirements

The primary objective of the regional flow change analysis was to determine the potential for non-compliance with the D-1641 minimum flow requirements for the Sacramento River at Rio Vista. Analysis of flow at Rio Vista for all alternatives showed no potential for non-compliance with the D-1641 minimum monthly average flow requirements. All alternatives were predicted to slightly increase the net flow at Rio Vista (Table 4-10).

Table 4-10. Monthly Average Flow Rates at Rio Vista by Alternative.

Year	Month	Required Minimum	Monthly Averaged Flow (cfs)								
			Base	Alt 1	Alt 3	Alt 4	Alt 11	Alt 23	Alt 16B	Alt 26	Alt 31
2009	September	3,000	5,591	5,711	5,814	5,833	5,827	5,850	5,884	5,807	5,871
	October	4,000	5,493	5,593	5,741	5,750	5,718	5,771	5,751	5,716	5,782
	November	4,500	5,083	5,154	5,297	5,298	5,262	5,319	5,284	5,264	5,321
	December	4,500	7,252	7,303	7,367	7,372	7,359	7,387	7,391	7,363	7,394
2010	September	3,000	8,610	8,652	8,641	8,677	8,745	8,682	8,858	8,671	8,723
	October	4,000	6,386	6,507	6,584	6,605	6,647	6,618	6,709	6,578	6,674
	November	4,500	7,706	7,798	7,865	7,889	7,909	7,898	7,980	7,862	7,925

Source: Appendix D

4.6.2 General trends in regional and net tidal flow changes

To analyze regional and net tidal flow changes, three differing conditions of north Delta flow were examined within the full evaluation period: 1) July–September 2010, with inflow of 16,865 cfs at Freeport (representing summer months during below normal conditions for the Sacramento Valley and above normal conditions for the San Joaquin Valley) ; 2) July–September 2009, with inflow of 15,013 cfs at Freeport (representing summer months during dry conditions for the Sacramento and San Joaquin Valleys); and 3) October – November 2009, with inflow of 9,378 cfs at Freeport (representing fall months during dry conditions for the Sacramento and San Joaquin Valleys). Results are presented in Table 4-11, Table 4-12, and Table 4-13, respectively.

Generally, the breaching of Prospect Island levees increased net flow in Miner Slough, which in turn increased net flow in the Sacramento River at Rio Vista. The increase in flow in Miner Slough corresponded with decreases in flow through both the Delta Cross Channel and Georgiana Slough from the Sacramento River towards the San Joaquin River. Maintaining flows through the Delta Cross Channel and Georgiana Slough from the Sacramento River towards the San Joaquin River is important to help control salinity intrusion into the Central Delta from Suisun Bay via the San Joaquin River. The flow magnitude decreased in the Delta Cross Channel but increased in Georgiana Slough as Sacramento River inflow decreased (i.e. there were larger decreases in the fall months when flow at Freeport was lower than in summer when flow at Freeport was higher). The decreases in Delta Cross Channel and Georgian Slough flow were partially compensated by increases in flow from the Sacramento River to the San Joaquin River through Threemile Slough. The combined effect of the increases in Miner Slough flow, decreases in Delta Cross Channel and Georgiana Slough flow, and increases in Threemile Slough flow was a net increase of flow in the San Joaquin River at Jersey Point in the flood flow direction. As discussed above, increases in net flow in the flood direction could result in salinity changes in the Delta. Potential salinity changes are analyzed in Section 4.5.

Table 4-11. Computed Net Flow Change for July–September 2010

Station ID	Location Name	Base Net Q (cfs)	Alternative Net Flow - Base Net Flow (cfs)							
			Alt 1	Alt 3	Alt 4	Alt 11	Alt 23	Alt 16B	Alt 26	Alt 31
FPT	Sacramento River at Freeport	16,865	—	—	—	—	—	—	—	—
CACHE-CMPLX	Cache Sl above DWSC	-735	—	—	—	—	—	—	—	—
HWB	Miner Sl at Hwy 84 Bridge	2,289	33	-111	-41	72	93	493	57	189
SRV	Sacramento River at Rio Vista	8,589	60	46	82	150	89	263	79	130
DLC+GSS	Delta Cross Chan + Georgiana Sl	7,138	-61	-47	-83	-150	-90	-264	-80	-131
TMS	Threemile Slough	-2,329	-1	-4	-29	-76	-21	-119	-9	-48
EMM	Sacramento R at Emmaton	6,197	59	42	54	74	69	144	70	83
SJJ	San Joaquin R at Jersey Pt	-562	-56	-39	-51	-70	-65	-137	-66	-78

Table 4-12. Computed Net Flow Change for July–September 2009

Station ID	Location Name	Base Net Q (cfs)	Alternative Net Flow - Base Net Flow (cfs)							
			Alt 1	Alt 3	Alt 4	Alt 11	Alt 23	Alt 16B	Alt 26	Alt 31
FPT	Sacramento River at Freeport	15,013	—	—	—	—	—	—	—	—
CACHE-CMPLX	Cache Sl above DWSC	-760	—	—	—	—	—	—	—	—
HWB	Miner Sl at Hwy 84 Bridge	1,964	78	6	65	115	177	455	132	258
SRV	Sacramento River at Rio Vista	7,217	82	109	138	174	151	265	129	184
DLC+GSS	Delta Cross Chan + Georgiana Sl	6,631	-81	-109	-138	-175	-151	-266	-129	-184
TMS	Threemile Slough	-2,268	-6	-25	-47	-84	-42	-119	-26	-66
EMM	Sacramento R at Emmaton	4,896	76	84	91	91	109	146	104	118
SJJ	San Joaquin R at Jersey Pt	-584	-68	-75	-82	-84	-99	-137	-94	-107

Table 4-13. Computed Net Flow Change for October–November 2009

Station ID	Location Name	Base Net Q (cfs)	Alternative Net Flow - Base Net Flow (cfs)							
			Alt 1	Alt 3	Alt 4	Alt 11	Alt 23	Alt 16B	Alt 26	Alt 31
FPT	Sacramento River at Freeport	9,378	—	—	—	—	—	—	—	—
CACHE-CMPLX	Cache Sl above DWSC	-95	—	—	—	—	—	—	—	—
HWB	Miner Sl at Hwy 84 Bridge	1,177	112	247	260	163	322	305	244	345
SRV	Sacramento River at Rio Vista	5,037	92	239	241	203	265	227	210	268
DLC+GSS	Delta Cross Chan + Georgiana Sl	4,015	-89	-233	-236	-199	-260	-224	-205	-264
TMS	Threemile Slough	-1,392	-8	-62	-68	-67	-72	-75	-47	-80
EMM	Sacramento R at Emmaton	3,609	84	178	174	137	193	153	164	189
SJJ	San Joaquin R at Jersey Pt	1,490	-76	-162	-159	-124	-177	-140	-150	-174

5 ALTERNATIVES COMPARISON

This section presents a comparison of the six base alternatives along with additional comparisons of the two adaptive management and three sensitivity analysis configurations on the basis of Phase 2 modeling criteria (Section 2.2). Table 5-1 provides a comparative summary of the modeled alternatives relative to the evaluation criteria (Section 2). In the Sections below, individual modeling criteria to be used for alternatives selection (Section 2.2) by FRP staff are discussed with reference to modeling results summaries (Section 4) and supporting modeling reports (Appendices A through D).

5.1 On-site Productivity (B-1)

The top three alternatives that resulted in the greatest proportion of modeled particles within the preferred open water zone dominant ET classes (1–3 days and 3–5 days to represent selection for diatom species) are (Table 4-1 and Figure 4-1):

1. Alternative 26: A two-breach, flow-through alternative with an internal breach of the cross-levee connecting the DWR and Port-owned properties.
2. Alternative 3: A single breach alternative along Miner Slough providing connectivity to deeper open water portions of the site north of the internal cross-levee.
3. Alternative 23: A two-breach, shorter-distance flow-through design along Miner Slough connecting northeast Miner Slough to deeper open water portions of the site north of the internal cross-levee.

Because Alternative 3 and other single breach alternatives have lower hydraulic connectivity than Alternative 26 and 23, a greater proportion of the modeled particles were found to have longer exposure times potentially associated with selection for undesirable algae, such as *Microcystis*. However, it should be noted that the large overlap in growth rates of many algal species, effects of wind, light and nutrient availability, interactions of benthic algae, as well as potential grazing pressures from filter feeding organisms (e.g., *Corbula amurensis*) may alter phytoplankton population dynamics. For example, ET modeling conducted for Liberty Island (Brennan et al. 2013) found high spatial variability with ET well in excess of 20–25 days in some locations. Because food web conditions on Liberty Island appear to support Delta Smelt and other fish species, the ET classes used for Phase 2 modeling may be considered as reasonable proxies for, but not absolute determinants of, phytoplankton species composition or productivity export.

5.1.1 Effects of reduced vegetation and channel extent

Modeling sensitivity evaluations that included reduced vegetation and channel extent resulted in increased representation of preferred ET classes (e.g., 1–3 and 3–5 days) for the two-breach Alternative 23/23S, but reduced representation of these classes for the alternatives with a weir at the northern end of Miner Slough (Alternatives 1/1S and 4/4S). Considering only the effects upon pelagic productivity, these results suggest that increased open water extent will not necessarily result in greater production or export of pelagic productivity unless it is coupled with breaches providing tidal exchange with open water habitats.

5.1.2 Potential future adaptive management breaches to the Sacramento DWSC

These adaptive management alternatives are modifications of Alternatives 4 and 23 (Figure 3-1). When compared to Alternatives 4 and 23, the additional breaches on the Sacramento DWSC by Alternatives 11 and 16B is accompanied by a reduced ET for particles. These alternatives also exhibited large increases in the shortest ET class (< 1-day) (Table 4-1), indicating flushing rates in excess of algal doubling times. The lower proportion of particles within preferred ET classes (e.g., 1–3 and 3–5 days) under these alternatives suggests lower production and export of diatom-based phytoplankton than for other alternatives analyzed. However, depending upon the observed species composition following implementation of the preferred alternative, the results here suggest that additional breaches along the DWSC represent an effective means of manipulating algal productivity within Prospect Island.

5.2 Productivity Export (B-2)

Selection of alternatives maximizing the tidal export of productivity generated within Prospect Island to the Project vicinity, and especially toward the Cache Slough region, meets primary objectives of the Project (Section 1). Although particle modeling simulations of on-site productivity and export conducted for Phase 1 considered phytoplankton-based productivity (Stillwater Sciences-WWR 2012), it was recognized that productivity generated within marsh vegetation (e.g., epiphytic algae, detritus, and invertebrates) may supplement the food-web of pelagic and littoral species. This section highlights alternatives with the greatest relative export of modeled particles dominated by exposure to open water and vegetated habitats within Prospect Island.

For the short-term (2-day) export of open water-zone dominant particles, Alternative 23, 31, and 26 provided the greatest export (Table 4-2) in combination with the majority of these particles arising from preferred ET classes for the selection of diatom species (Table 4-1). For longer-term (7-day) export of both open water zone dominant particles (Table 4-2) and vegetation zone dominant particles (Table 4-3), the following are top three alternatives ranked in order of total export:

1. Alternative 31: A three-breach alternative along Miner Slough connecting northeast Miner Slough to deeper open water portions of the site on both sides of the internal cross-levee.
2. Alternative 26: A two-breach, flow-through alternative with an internal breach of the cross levee connecting the DWR and Port-owned properties.
3. Alternative 23: A two-breach, shorter-distance flow-through design along Miner Slough connecting northeast Miner Slough to deeper open water portions of the site north of the internal cross levee.

The potential linkages of marsh productivity exports to the pelagic food web have not been well studied in the Delta (see Howe and Simenstad 2011 as one example). However, the alternatives above also represent the greatest export of open water zone dominant particles (Table 4-2) and lowest representation of ET classes representing selection of undesirable algal species.

5.2.1 Effects of reduced vegetation and channel extent

Modeling sensitivity evaluations that included reduced extent of marsh vegetation and channel on the interior of Prospect Island resulted in minor increases in total particles exported and large increases in particles dominated by open water zone exposure (Table 4-2 and Table 4-3). For directly comparable alternatives, Table 4-2 shows that open water-zone dominant particle export for all low-vegetation alternatives (Alternative. 1S, 4S, and 23S) was substantially higher than for the vegetated base alternative counterparts (Alternative 1, 4, and 23). Because elevations at Prospect Island comprise a mix of shallow sub-tidal (up to about 4 feet below mean lower low water) and low intertidal habitats, if existing vegetation is removed and not re-established prior to breaching, the Project would support primarily open water tidal and subtidal aquatic habitat. Under an assumption of retaining existing marsh vegetation or its pre-breach re-establishment, or after successional processes increase marsh extent, these results suggest that the export of phytoplankton-based productivity may be partially replaced by marsh-based productivity in the long term.

5.2.2 Potential future adaptive management breaches to the Sacramento DWSC

When compared to Alternative 4 and 23, the additional breaches on the DWSC by Alternative 11 and 16B is accompanied by reduced exposure of particles to the open water zone within Prospect Island, as well as reduced export of open water zone dominant particles (Table 4-2). This appears to be the result of locating the additional levee breaches along the DWSC adjacent to vegetated habitats within Prospect Island (Figure 3-1). The increased connectivity to vegetated habitats increased the proportion of vegetation zone dominant particles as well as export of these particles (Table 4-3). Alternative 11 and 16B resulted in a greater percentage of both open water and vegetation zone dominant particle export into the DWSC, an area known to support Delta Smelt, than for Alternative 4 and 23 (Table 4-2 and Table 4-3).

5.3 Temperature Changes in Adjacent Water Bodies (B-3, I-4)

Water temperature conditions within Prospect Island and in the sloughs and channels adjacent to Prospect Island were modeled to determine the potential effects of the project on spawning and rearing of Delta Smelt and juvenile rearing and smolt emigration for Chinook Salmon.

5.3.1 Water temperatures within Prospect Island

Water temperature conditions within Prospect Island under most alternatives reflected general trends in existing water temperatures in the Project region, with suitable temperatures from March through May, temperatures transitioning from suitable to sub-optimal in June, sub-optimal temperature dominating in July and August, and temperatures transitioning back toward suitable, but still dominantly sub-optimal dominant in September. Exceptions to this behavior are alternatives with intertidal vegetation only (Alternative 1S, 3S, and 23S). These alternatives have longer periods of sub-optimal from June through September and have sub-optimal majorities in June and September, which is warmer than conditions seen in adjacent water bodies under existing conditions. Differences between alternatives with both intertidal and shallow subtidal vegetation are very minor (generally 2 to 3 days differences), with no alternative clearly providing greater benefits. As alternatives without shallow subtidal vegetation provide less suitable conditions and there is little difference between the remaining alternatives, any of the intertidal and shallow subtidal alternatives, Alternative 1, 2, 3B, 4, 23, 26, 31, 11 or 16B, could be chosen.

5.3.2 Water temperatures changes in adjacent water bodies

No lethal conditions (temperatures above 25°C) are present under any alternative, under any month, at any location. In addition, there were no changes from base conditions at any location for March, April, or May under any alternative. Changes that did occur tended to be small, in the 1- to 2-day range. As differences between alternatives across all locations were negligible or equivalent, alternatives should not be selected based on this criterion.

5.4 Turbidity in the Cache Slough Region (I-2)

Modeling of turbidity in the Cache Slough Region examined periods with both low and high turbidity conditions. Alternatives are compared and contrasted by these two conditions separately below.

During the months of October and November, turbidity conditions in Cache Slough, the DWSC, and Liberty Island, while relatively low, vary between suitable to less than suitable for Delta Smelt. Predicted reductions in turbidity across the alternatives at these locations were relatively constant: reductions at Cache Slough between 5–8%, at the DWSC between 12–19%, and at the Liberty Island breach between 10–15%. Conditions in Miner Slough during this time are not expected to support Delta Smelt. That being said, predicted reductions in Miner Slough were also relatively consistent between alternatives and varied from 10–19%.

The two alternatives, 11 and 16B, did not follow these patterns. In contrast to the other alternatives, Alternative 11 increased or had no effect on turbidity in Cache Slough and only slightly decreased turbidity in Miner Slough (i.e. by 4%). Turbidity reductions in the DWSC and at the Liberty Island breach were similar to the other alternatives, varying between 13–18% and 7–10%. Alternative 16B produced even more pronounced differences as compared to the other alternatives. Alternative 16B increased turbidity in Cache Slough in October by 1% and decreased turbidity in November by 3%. In the DWSC, Alternative 16B showed far greater reductions than any other alternative, between 22–28%, but exhibited similar reductions at the Liberty Island breach (10–14%). The biggest difference between Alternative16B and the other alternatives was seen in Miner Slough, where Alternative 16B increased turbidity by 30–36%.
Based on the discussion above, the alternatives are listed below by smallest to largest potential percent reductions in turbidity during times of lower turbidity.

Alternatives by potential percent turbidity reduction (Oct-Nov), smallest to largest

1. Alternative 11
2. Alternative 1, 1S, 3, 3B, 4, 4S, 23, 23S, 26, and 31—little variation
3. Alternative 16B—twice the percent reduction in the DWSC compared to other alternatives

During the month of December, predicted reductions in turbidity varied between alternatives, with lower connectivity alternatives having lesser reductions and higher connectivity alternatives having greater reductions. The lower connectivity alternatives had percent reductions between 5–7% in Cache Slough, 15–19% in the DWSC, 8–10% in Liberty Island, and 2–5% in Miner Slough. The intermediate connectivity alternatives had percent reductions of 8% in Cache Slough, 22% in the DWSC, 11% in Liberty Island, and 2% in Miner Slough. The higher connectivity alternatives had percent reductions between 14–19% in Cache Slough, 28–37% in the DWSC, 18–24% in Liberty Island, and increases of 8–10% in Miner Slough. The adaptive management alternatives had percent reductions between 10–11% in Cache Slough, 31–38% in the DWSC, 15–16% in Liberty Island, and increases of 3–17% in Miner Slough. Though these turbidity changes were generally larger than those seen in October and November, the higher turbidity during this period (greater than 18 NTU, with long periods of time they have less potential to be impacting as the turbidity levels in the water bodies during December are comparatively high (greater than 18 NTU, with long periods of time greater than 50NTU). Based on this, the alternatives are listed below by smallest to largest potential impacts.

Alternatives by impacts during higher turbidities (Dec), smallest to largest

1. Lower Connectivity—Alternative 1, 1S, 3, 3B
2. Intermediate Connectivity—Alternative 4, 4S
3. Adaptive Management—Alternative 11, 16B
4. Higher Connectivity—Alternative 23, 23S, 26, 31

Prospect Island is subsided, with elevations ranging from shallow to moderate subtidal. Sediment accretion will help reverse subsidence, build marsh plain elevations, and provide adaptability for site in terms of long-term sea level rise. As expected, sediment accretion at the site directly corresponds with the connectivity of the alternative. Alternatives with higher connectivity have higher predicted sediment accumulation and alternatives with lower connectivity have lower predicted sediment accumulation. There is little variation between alternatives by grouping. Based on this, the alternatives are listed below by grouping from highest to lowest sediment accumulation potential.

Alternatives ranked by sediment accumulation potential

1. Higher Connectivity—Alternative 23, 23S, 26, 31 and Adaptive Management—Alternative 11 and 16B
2. Intermediate Connectivity—Alternative 4 and 4S
3. Lower Connectivity—Alternative 1, 1S, 3, 3B

5.5 Salinity Changes at D-1641 Compliance Stations (I-3)

Prospect Island alternatives were modeled to determine the potential for non-compliance with both agricultural, fish and wildlife beneficial uses, and municipal and industrial beneficial uses under D-1641 standards. All alternatives were shown to be in compliance with all D-1641 standards. There are no recommended alternatives based on this criterion as there were no differences between the alternatives.

Although below threshold levels, both increases and decreases in salinity were observed at all of the compliance stations. These changes were relatively small (less than 8%), followed the same trends across all alternatives, and varied little between alternatives. The relative uniformity of the changes did not allow for differentiation between the alternatives; however, the results may be useful in evaluating potential water quality impacts from the project in the environmental review process.

5.6 Regional Flow Alterations (I-8)

Maintaining minimum flow rates to support fish and wildlife beneficial uses is required by Water Rights Decision D-1641. Modeling indicated that all alternatives increased net flow in the Sacramento River at Rio Vista and therefore none of the alternatives showed the potential for non-compliance with the flow requirement. There are no recommended alternatives based on this criterion as there were no differences between the alternatives.

All alternatives increased flows in the lower Sacramento River. The mechanism for this change was increasing flows from the Sacramento River through Miner Slough and decreasing flows from the Sacramento River through the Delta Cross Channel and Georgiana Slough. Some of this decrease was compensated by increases in flow from the Lower Sacramento River to the San Joaquin River through Threemile Slough, however all alternatives resulted in increased net flow in the flood direction in the San Joaquin River at Jersey Point, which in turn could alter salinity conditions. The magnitude of change in net flow increased with the number of breaches, although these changes were too small to allow for differentiation between alternatives. The modeling results may be useful in evaluating potential impacts due to the Project during the environmental review process.

Table 5-1. Prospect Island Evaluation Criteria Summary by Alternative

Details	Alternatives											
	Low Export, High Internal Exposure Time Variability				Intermediate Export and Internal Exposure Time Variability		High Export, Low Internal Exposure Time Variability				Adaptive Management (DWSC breaches)	
	1	1S	3	3B	4	4S	23	23S	26	31	11	16B
Pelagic Food Web Productivity within the Restoration Site												
Pelagic Zone exposure time (ET)	**Long** Pelagic Zone ET; Potential blue-green algae growth	**Long** Pelagic Zone ET; Potential blue-green algae growth	**Optimal** Pelagic Zone ET (1-3 day >20%)		**Optimal** Pelagic Zone ET (1-3 day >20%)	**Long** Pelagic Zone ET; Potential blue-green algae growth	**Optimal** Pelagic Zone ET (1-3 day >20%)	**Optimal** Pelagic Zone ET (1-3 day >20%)	**Optimal** Pelagic Zone ET (1-3 day >20%)	**Optimal** Pelagic Zone ET (1-3 day >20%)	**Short** Pelagic Zone ET	**Optimal** Pelagic Zone ET (1-3 day >20%)
Tidal Mixing of Exported Productivity (Results presented for 7 day model simulation)												
Pelagic Zone Dominant Particle Export (2-day)	**Low** Pelagic Zone Export (<30%)	**Low** Pelagic Zone Export (<30%)	**High** Pelagic Zone Export (>50%)		**High** Pelagic Zone Export (>50%)	**Intermediate** Pelagic Zone Export	**High** Pelagic Zone Export (>50%)	**High** Pelagic Zone Export (>50%)	**Intermediate** Pelagic Zone Export	**High** Pelagic Zone Export (>50%)	**Intermediate** Pelagic Zone Export	**High** Pelagic Zone Export (>50%)
Total Export (7-day)	**Low** Total Export (<50%)	**Low** Total Export (<50%)	**Low** Total Export (<50%)		**Intermediate** Total Export	**Intermediate** Total Export	**High** Total Export (>80%)	**High** Total Export (>80%)	**High** Total Export (>80%)	**High** Total Export (>80%)	**High** Total Export (>80%)	**High** Total Export (>80%)
On-Site Temperature Conditions and Changes in Adjacent Water Bodies												
On-site Temperatures	Reflects existing trends in adjacent water body temps; No lethal conditions	Temps slightly warmer for longer periods, especially in June and September	Reflects existing trends in adjacent water body temps; No lethal conditions		Reflects existing trends in adjacent water body temps; No lethal conditions	Temps slightly warmer for longer periods, especially in June and September	Reflects existing trends in adjacent water body temps; No lethal conditions	Temps slightly warmer for longer periods, especially in June and September	Reflects existing trends in adjacent water body temps; No lethal conditions	Reflects existing trends in adjacent water body temps; No lethal conditions	Reflects existing trends in adjacent water body temps; No lethal conditions	Reflects existing trends in adjacent water body temps; No lethal conditions
Changes in Adjacent Water Bodies	Differences between alternatives across all locations are negligible or equivalent. No lethal conditions are induced.											

Table 5-1. Prospect Island Evaluation Criteria Summary by Alternative

Details		Alternatives											
		Low Export, High Internal Exposure Time Variability				Intermediate Export and Internal Exposure Time Variability		High Export, Low Internal Exposure Time Variability				Adaptive Management (DWSC breaches)	
		1	**1S**	**3**	**3B**	**4**	**4S**	**23**	**23S**	**26**	**31**	**11**	**16B**
Turbidity in the Cache Slough Region													
% Turbidity change at **Miner Slough**	October	-14	-15	-19	-19	-15	-15	-16	-16	-18	-13	-4	36
	November	-13	-13	-15	-15	-12	-12	-12	-12	-11	-10	-4	30
% Turbidity change at **Cache Slough**	October	-5	-6	-5	-5	-5	-4	-6	-6	-5	-5	3	1
	November	-6	-6	-7	-7	-7	-7	-7	-7	-6	-8	0	-3
% Turbidity change at **Sacramento DWSC**	October	-12	-12	-15	-15	-16	-16	-16	-16	-13	-17	-13	-22
	November	-13	-13	-16	-16	-18	-18	-17	-17	-14	-19	-18	-28
% Turbidity change at **Liberty Island** (breach)	October	-10	-10	-11	-11	-12	-12	-12	-12	-10	-12	-7	-10
	November	-11	-11	-12	-12	-14	-14	-13	-13	-11	-15	-10	-14
% Turbidity change at **Miner Slough**	December	-2	-2	-5	-5	-2	-2	8	8	10	11	3	17
% Turbidity change at **Cache Slough**	December	-5	-6	-7	-7	-8	-8	-18	-18	-14	-19	-10	-11
% Turbidity change at **Sacramento DWSC**	December	-15	-15	-19	-19	-22	-22	-36	-35	-28	-37	-38	-31
% Turbidity change at **Liberty Island (breach)**	December	-8	-8	-10	-10	-11	-11	-23	-22	-18	-24	-16	-15
Prospect Island Cumulative Sediment Accretion (kilograms x 10^7)		1.12	1.15	1.68	1.68	2.07	2.02	4.39	4.34	3.31	4.59	3.04	4.60
Salinity Changes at D-1641 Compliance Stations													
D-1641 Compliance		No alternatives show potential for non-compliance with D-1641 water quality requirements for fish and wildlife, agricultural, or municipal and industrial objectives.[1]											
Regional Flow Alterations													
D-1641 Compliance		No alternatives show potential for non-compliance with D-1641 flow requirements at Rio Vista.[1]											
Notes: 1. Evaluation not performed for Alts 1S, 3B, 4S, and 23S													

6 REFERENCES

Brennan, M., E. Divita, M. Orr, and S. Crooks. 2013. Hydrodynamic, Wind-Wave, and Suspended Sediment Transport Modeling: Implications for Geomorphic Change and Restoration. Presentation prepared for BREACH III Final Products Meeting, June 2013. Available on-line at: https://sites.google.com/a/uw.edu/breach-iii/emerging-products/presentations

California Department of Water Resources (DWR). 1986. Salinity unit conversion equations. State of California Memorandum. Kamyar Guivetchi to Peter Lee, Dick Kretsinger, and James McDaniel. June. Available on-line at: http://www.water.ca.gov/suisun/facts/salin/index.cfm

California Department of Water Resources (DWR). 2013a. Notice of Preparation of a Draft Environmental Impact Report on the Prospect Island Tidal Habitat Restoration Project. California Department of Water Resources, Fish Restoration Program Agreement Office. May.

California Department of Water Resources (DWR). 2013b. California Data Exchange Center. Chronological Reconstructed Sacramento and San Joaquin Valley Water Year Hydrologic Classification Indices. December. Available on-line at: http://cdec.water.ca.gov/water_supply.html

Ecosystem Restoration Program (ERP). 2013. DRERIP Evaluation for Prospect Island Restoration Alternatives. Sacramento, CA. CA Department of Fish and Wildlife, Water Branch, Ecosystem Restoration Program. February.

Howe, E.R. and C.A. Simenstad. 2011. Isotopic Determination of Food Web Origins in Restoring and Ancient Estuarine Wetlands of the San Francisco Bay and Delta. Estuaries and Coasts (2011) 34:597–617

Monsen, N. E., J. E. Cloern, et al. 2002. A comment on the use of flushing time, residence time, and age as transport time scales. Limnology and Oceanography 47(5): 1545-1553.

Resource Management Associates (RMA). 2013. Prospect Island Tidal Restoration Project Calibration and Verification of Water Temperature Model Used for Phase 2 Alternatives Evaluation. Technical Memorandum. Prepared for Department of Water Resources, West Sacramento, CA.

Contract No. 4200009291. Prepared by Resource Management Associates, Fairfield, CA. December.

National Marine Fisheries Service (NMFS). 2009. Endangered Species Act – Section 7 Consultation Biological Opinion and Conference Opinion on the Long-term Operations of the Central Valley Project and State Water Project. National Marine Fisheries Service Southwest Region. June 4.

State Water Resources Control Board (SWRCB). 2006. Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. Resources Agency, Sacramento, CA.

Stillwater Sciences and Wetlands & Water Resources (Stillwater Sciences-WWR). 2012. Prospect Island Tidal Restoration: Synthesis of Phase 1 Screening-Level Modeling Evaluation of Conceptual Restoration Alternatives. Final Report. Prepared for Department of Water Resources, West Sacramento, CA. Contract No. 4200009291. Prepared by Stillwater Sciences, Davis, CA, and Wetlands and Water Resources, Inc., San Rafael, CA, with assistance from Resource Management Associates, Fairfield, CA, and cbec eco-engineering, West Sacramento, CA. September.

U. S. Fish and Wildlife Service (USFWS). 2008. Formal Endangered Species Act Consultation on the Proposed Coordinated Operations of the Central Valley Project (CVP) and State Water Project (SWP). Memorandum from Regional Director, Fish and Wildlife Service, Region 8, Sacramento, California, to Operation Manager, Bureau of Reclamation, Central Valley Operations Office Sacramento, California. December 15.

Wetlands and Water Resources (WWR). 2012. Phase One Screening Criteria. Prospect Island Tidal Wetland Restoration Project. Final Memorandum. Prepared for the Department of Water Resources, Division of Environmental Services, West Sacramento, CA. Prepared by Wetlands and Water Resources, San Rafael, CA. April 23.

Wetlands and Water Resources and Stillwater Sciences (WWR-Stillwater Sciences). 2013a. Prospect Island Tidal Restoration: Final Alternatives Selection for Phase 2 Modeling Memorandum. Prepared for Department of Water Resources, West Sacramento, CA. Contract No. 4200009291.

Prepared by Wetlands and Water Resources, Inc., San Rafael, CA and Stillwater Sciences, Davis, CA, August 2013

_____. 2013b. Prospect Island Tidal Restoration: Supplemental Phase 1 Screening-Level Modeling Results Memorandum. Final Report. Prepared for Department of Water Resources, West Sacramento, CA. Contract No. 4200009291. Prepared by Stillwater Sciences, Davis, CA, and Wetlands and Water Resources, Inc., San Rafael, CA, with assistance from Resource Management Associates, Fairfield, CA. March 2013

_____. 2014. Phase 2 Modeling Evaluation Criteria. Prospect Island Tidal Wetland Restoration Project. Final Report. Contract No. 4200009291. Prepared by Wetlands and Water Resources, Inc., San Rafael, California and Stillwater Sciences, Berkeley, California for Department of Water Resources, West Sacramento, California. January.

Appendices

Appendix A

Phase 2 Analysis for Primary Productivity Enhancement and Export

Appendix B

Phase 2 Alternatives Modeling Evaluation for Water Temperature Changes

Appendix C

Evaluation of Effects of Prospect Island Restoration on Sediment Transport and Turbidity: Phase 2 Alternatives

Appendix D

Phase 2 Alternatives Modeling Evaluation for Flow and Salinity Changes

<u>EXHIBIT 9</u>

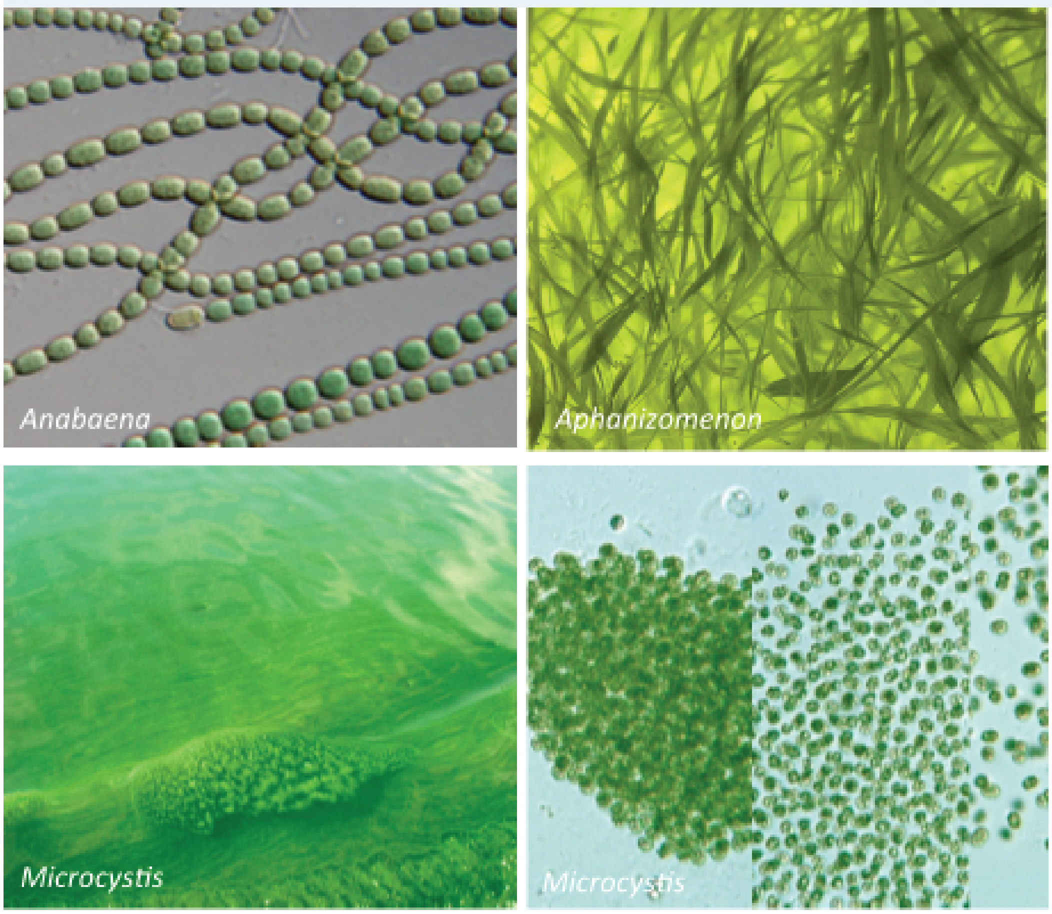
DWR-703

Factors Affecting Growth of Cyanobacteria

With Special Emphasis on the Sacramento-San Joaquin Delta

APPLIED marine SCIENCES

SCCWRP Established 1969



Mine Berg
Martha Sutula

Southern California Coastal Water Research Project

SCCWRP Technical Report 869

Factors Affecting the Growth of Cyanobacteria with Special Emphasis on the Sacramento-San Joaquin Delta

Prepared for:
The Central Valley Regional Water Quality Control Board
and
The California Environmental Protection Agency
State Water Resources Control Board
(Agreement Number 12-135-250)

Mine Berg
Applied Marine Sciences

Martha Sutula
Southern California Coastal Water Research Project

August 2015
Technical Report 869

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EXECUTIVE SUMMARY

A world-wide increase in the incidence of toxin-producing, harmful cyanobacterial blooms (cyanoHABs) over the last two decades has prompted a great deal of research into the triggers of their excessive growth. Massive surface blooms are known to decrease light penetration through the water, cause depletion of dissolved oxygen following bacterial mineralization of blooms, and cause mortality of aquatic life following ingestion of prey with high concentrations of toxins. Additionally, humans coming in contact with the water may develop digestive and skin diseases, and it may affect the drinking water supply.

The Central Valley Regional Water Quality Control Board (Water Board) is developing a science plan to scope the science needed to support decisions on policies governing nutrient management in the Delta. Blooms of cyanoHABs are one of three areas, identified by the Water Board, that represent pathways of potential impairment that could be linked to nutrients. The Water Board commissioned a literature review of the factors that may be contributing to the presence of cyanoHABs in the Delta. The literature review had three major objectives:

1) Provide a basic review of biological and ecological factors that influence the prevalence of cyanobacteria and the production of cyanotoxins;
2) Summarize observations of cyanobacterial blooms and associated toxins in the Delta;
3) Synthesize literature to provide an understanding of what ecological factors, including nutrients, may be at play in promoting cyanobacterial blooms in the Delta.

This review had four major findings:

#1. Five principal drivers emerged as important determinant of cyanobacterial blooms in a review of the global literature on factors influencing cyanobacteria blooms and toxin production. These include: 1) Water temperature, 2) Water column irradiance and water clarity, 3) Stratified water column coupled with long residence times, 4) Availability of N and P in non-limiting amounts; scientific consensus is lacking on the importance of N: P ratios as a driver for cyanoHABs, and 5) Salinity regime.

#2. Existing information is insufficient to fully characterize the threat of CyanoHABs to Delta ecosystem services because cyanoHABs are not routinely monitored. Based on existing data, the current risk to Delta aquatic health is of concern and merits a more thorough investigation. This observation is based total microcystin levels found in Delta fish tissues that are within the range of sublethal effects to fish as recently reviewed by the California Office of Environmental Health Hazards (OEHHA 2009), and dissolved toxin concentrations that occasionally exceed both the OEHHA action level and the World Health Organization (WHO) guideline of 1000 ng L^{-1} in certain “hotspots” of the Delta.

#3. Comprehensive understanding of the role of nutrients vis-à-vis other environmental factors in influencing cyanoHAB presence in the Delta is severely hampered by the lack of a routine monitoring program. Drawing on available information on the five factors influencing cyanoHABs, we can conclude the following:

- Temperature and irradiance appear to exert key roles in the regulation of the onset of blooms. Cyanobacteria require temperatures above 20°C for growth rates to be competitive with eukaryotic phytoplankton taxa, and above 25°C for growth rates to be competitive with diatoms. In addition, they require relatively high irradiances to grow at maximal growth rates.
- It appears that N and P are available in non-limiting amounts in the Delta; moreover, concentrations, or ratios, do not change sufficiently from year–to–year in order to explain year–to–year variation *Microcystis* biomass or occurrence. Therefore the initiation of *Microcystis* or other cyanoHAB blooms are probably not associated with changes in nutrient concentrations or their ratios in the Delta. However, as with all phytoplankton blooms, once initiated, cyanoHABs cannot persist without an ample supply of nutrients.
- Salinity is controlling the oceanward extent of cyanobacteria blooms in the Delta, but salinity gradients do not explain the spatial distribution of cyanoHABs in the Delta. Notably, salinity regime is not a barrier to toxin transport, as cyanotoxins have been detected in SF Bay.
- Turbidity, low temperatures, and higher flows during most of the year are likely restricting cyanobacteria blooms to the July-August time period.

#4. Climate change and anthropogenic activity associated with land use changes have the potential to alter cyanoHAB prevalence in the future. Climate change will likely result in warmer temperatures and increased drought, the latter of which could result in reduced flows, increased residence time and water column stability leading to higher light availability in the Delta. Both temperature and reduced flows would presumably result in a greater prevalence of cyanoHABs. It's noteworthy that phytoplankton biomass and primary productivity are depressed relative to available nutrients in the Delta, so it's unclear what the effect of modifying nutrient loads will have on frequency and intensity of cyanoHAB occurrence in the future.
Given these findings, two major science recommendations are proposed:

R1: Implement Routine Monitoring of CyanoHABs. DWR is currently conducting a monitoring program which routinely samples many of the variables of interest known to influence cyanoHABs. Comprehensive cyanoHAB monitoring should be added as a component to this program. To begin, a work plan should be developed which specifically scopes the needed changes in the program to comprehensively monitor cyanoHABs. This report details specific components that should be considered in this workplan. The workplan should also consider monitoring needed to develop and calibrate an ecosystem model to further investigate controls on primary productivity and phytoplankton assemblage (see R2 below). The workplan should be peer-reviewed by subject matter experts. After an initial period of 3-5 years, the monitoring data should be used to comprehensively report on the status and trends of cyanoHABs and the factors that favor bloom occurrence in the Delta.

R2: Develop an Ecosystem Model of Phytoplankton Primary Productivity and HABs Occurrence to further Inform Future Risk and Hypotheses on Factors Controlling CyanoHABs. Because nutrients are not currently limiting cyanobacterial blooms, it is critical that an improved understanding is gained of the factors that are controlling phytoplankton primary productivity in the Delta, since increased phytoplankton growth could lead to increased risk of cyanoHAB blooms. To inform management action moving into the future, an ecosystem model of phytoplankton primary productivity and HABs occurrence should be developed. This model should have the capability to provide information on primary productivity and biomass as well as planktonic food quality and transfer of carbon to higher trophic levels. To step into model development, three actions should be taken: 1) examine existing models already available to determine suitability for this task, 2) utilize existing data to explore, to the extent possible, the relationships between chlorophyll a, phytoplankton composition, climate variables *et al.* factors. This analyses should inform hypotheses that can be tested through model development as well as potential future scenarios, and 3) a work plan should be developed that lays out the modeling strategy, model data requirements, and implementation strategy.

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1. INTRODUCTION, PURPOSE AND ORGANIZATION OF THE REVIEW

1.1 Background and Context

The Sacramento–San Joaquin River Delta, is an inland river delta and estuary approximately 1300 square miles in size, found in Northern California. Formed at the western edge of the Central Valley by the confluence of the Sacramento and San Joaquin Rivers, the Delta is a key component of the State's water resource infrastructure and a region that is rapidly urbanizing, yet serves as critical habitat or fish, birds and wildlife. Water from the 45,000 square mile Delta watershed fuels both local and statewide economies, including important agricultural commodities. The Delta is widely recognized as in "crisis" because of human effects on the environment and competing demands for the Delta's resources. The consequences of these competing demands include point and non-point discharges, habitat fragmentation and loss, modified flow regimes, introduction of non-native species, all of which combine to threaten ecosystem health, including the continued decline of threatened and endangered species

In 2009 the California legislature passed the Delta Reform Act creating the Delta Stewardship Council. The mission of the Council is to implement the coequal goals of the Reform Act and provide a more reliable water supply for California while protecting, restoring, and enhancing the Delta ecosystem. The Council wrote and adopted a Delta Plan in 2013 to implement these goals. Chapter 6 of the Delta Plan deals with water quality and contains recommendations to implement the coequal goals of the Delta Reform Act. Recommendation # 8 states, in part, "…the State Water Resources Control Board and the San Francisco Bay and Central Valley Regional Water Quality Control Boards (Water Board) should prepare and begin implementation of a study plan for the development of objectives for nutrients in the Delta … by January 1, 2014. Studies needed for development of Delta… nutrient objectives should be completed by January 1, 2016. The Water Boards should adopt and begin implementation of nutrient objectives, either narrative or numeric, where appropriate, in the Delta by January 1, 2018. Potential nutrient related problems identified in the Delta Plan for evaluation are:

1) Decreases in algal abundance and shifts in algal species composition,
2) Increases in the abundance and distribution of macrophytes, including water hyacinth and Brazilian waterweed,
3) Increases in the magnitude and frequency of cyanobacterial blooms

To provide better scientific grounding for the study plan, the Water Board commissioned two literature reviews centered on these three potential areas of impairment. This document provides a synthesis of literature on cyanobacterial blooms in the Delta. Technical Adivory Group and Stakeholder comments on the review are provided in Appendices B and C, respectively.

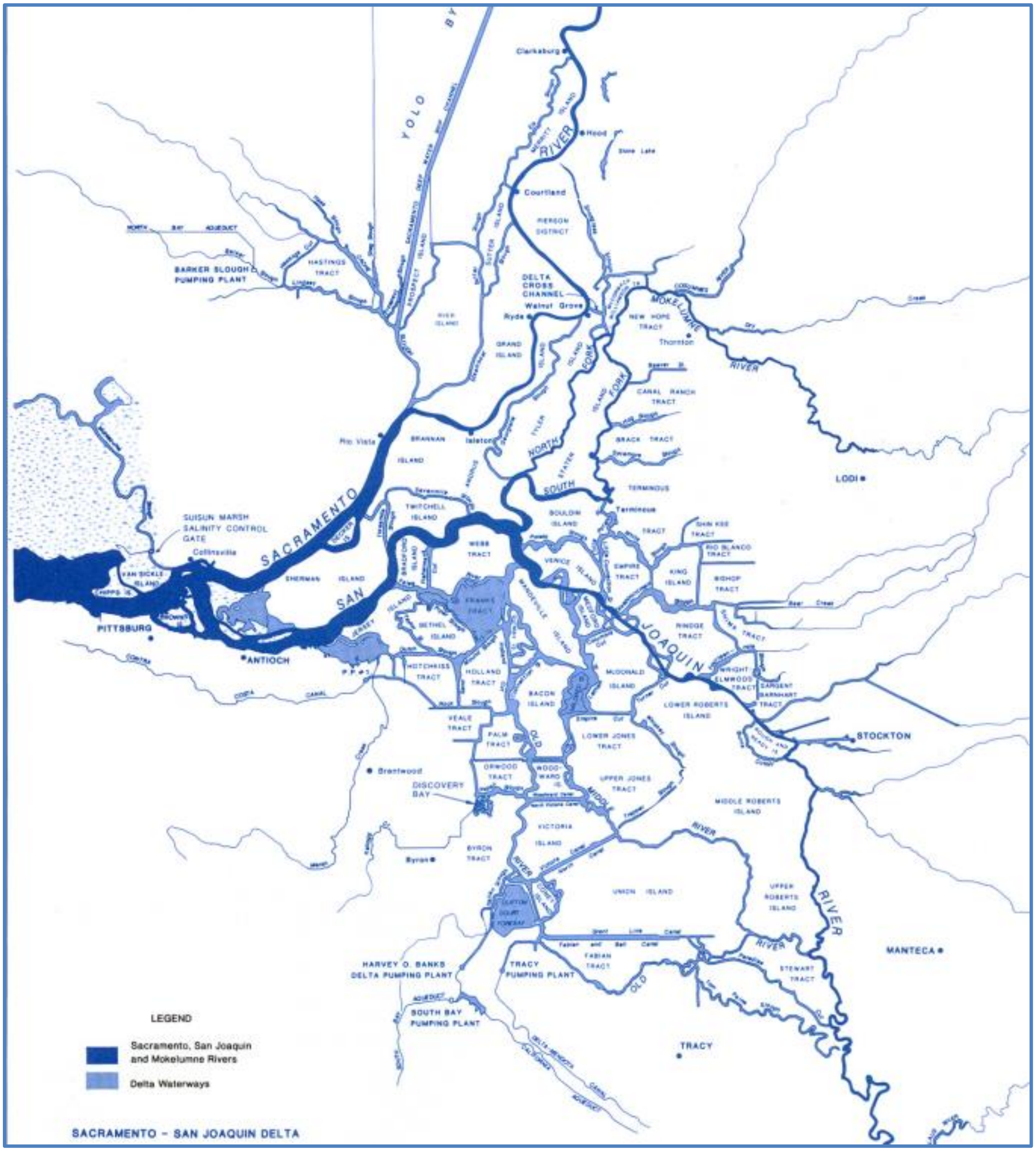


Figure 1.1. The Sacramento-San Joaquin Delta Region.

1.2 Goal and Organization of Cyanobacterial Literature Review

The goal of the cyanobacterial literature review is to synthesize available information to provide insight into cyanobacterial blooms in the Delta. The review had three major objectives:

1) Provide a basic review of biological and ecological factors that influence the prevalence of cyanobacteria and production of cyanotoxins;
2) Summarize observations of cyanobacteria blooms and associated toxins in the Delta;
3) Synthesize literature to provide an understanding of what ecological factors, including nutrients, may be at play in promoting cyanobacteria blooms in the Delta.

This review, and the recommended next steps, will contribute to a science plan to determine whether or how to proceed with the development of nutrient objectives for the Delta. The document is organized as follows:

Section 1: Introduction, Purpose and Organization of the Review

Section 2: Basic Biology and Ecology of Cyanobacteria

Section 3: Factors Influencing Cyanobacterial Blooms and Toxin Production

Section 4: Prevalence of CyanoHABs and Potential for Effects on Ecosystem Services in the Delta

Section 5: Synthesis of Factors Influencing CyanoHABs Presence and Toxin Production in the Delta

Section 6: Recommendations

Section 7: Literature Cited

2. Basic Biology and Ecology of Cyanobacteria

2.1 Overview

Cyanobacteria are a versatile group of bacteria that were the ancient colonizers of Earth and the photosynthetic ancestors of chloroplasts in eukaryotes such as plants and algae. As pioneers of photosynthesis, cyanobacteria were responsible for oxygenating Earth's atmosphere 2.5 billion years ago. In addition to being photosynthetic, cyanobacteria can differentiate into specialized cell types called heterocysts and fix nitrogen (N), exhibit gliding mobility, and tolerate a wide range of temperatures as evidenced by their ability to thrive in hot springs and ice-covered Antarctic lakes. Cyanobacteria also produce an array of bioactive compounds, some of which possess anti-microbial, anti-cancer and UV protectant properties. However, a subset of these bioactive compounds is highly toxic to humans and wildlife.

Blooms of cyanobacteria that produce these toxins, collectively known as harmful cyanobacterial algal blooms (cyanoHABs), has garnered a great deal of attention due to their increased occurrence in recent decades (Chorus and Bartram 1999, Carmichael 2008, Paerl and Huisman 2008, Hudnell 2010). The geographical distribution of these blooms has also increased with blooms appearing in areas previously unaffected (Lehman *et al.* 2005, Lopez *et al.* 2008). CyanoHABs can have major negative impacts on aquatic ecosystems. Toxins produced by cyanobacteria can lead to mortality in aquatic animals, waterfowl and domestic animals (Havens 2008, Miller *et al.* 2010). Moreover, toxins in drinking water supplies can pose a variety of adverse health effects and therefore require expensive treatment options such as filtration, disinfection, and adsorption with activated carbon (Cheung *et al.* 2013). In addition to the threat of toxins, oxygen depletion due to organic matter decomposition following the die-off of blooms can result in massive fish kills. CyanoHABs can also lead to revenue losses and impact local economies by reducing business in affected water bodies during the peak of tourism season. Considerable costs are associated with mitigation of blooms and lake restoration (Dodds *et al.* 2009).

The San Francisco Bay Delta is an area where cyanoHABs were previously undetected but have become commonplace since early 2000 (Lehman *et al.* 2005). In addition to providing a home for several species of pelagic fish and other wildlife, the Delta serves as a critical source of drinking water, and freshwater for irrigation of farms, to communities locally as well as farther south including the Los Angeles Metropolitan Water District. In concert with the occurrence of cyanoHABs, concentrations of the toxins they produce have been detected in the water and in higher trophic levels including zooplankton and fish (Lehman *et al.* 2010). The purpose of the following sections summarizes the basic biology of cyanobacteria beginning with classification, light harvesting, carbon metabolism, buoyancy regulation, nitrogen metabolism, cellular N:P ratios and toxin production, in order to build fundamental concepts that are later utilized in the review.

2.2 General Characteristics

2.2.1 Classification, Distribution and Akinete Production

<u>Classification</u>

Traditionally, morphological traits have been used to subdivide the cyanobacteria into five sub-groups (Rippka *et al*. 1979). The major division is between cyanobacteria that are single celled and/or colonial and those that grow filaments (Table 2.1). Each category contains a mixture of marine and freshwater species. In the former category are the Group I Croococcales including the freshwater *Microcystis* and *Synechocystis*, and the marine *Synechococcus* and *Prochlorococcus*. Group II Pleurocapsales include *Pleurocapsa* and *Xenococcus* (Table 2.1). The filamentous algae, Groups III, IV, and V, are further subdivided into the Oscillatoriales that produce only vegetative cells, including the freshwater planktonic *Planktothrix* species, the benthic *Oscillatoria* and *Lyngbya* species, as well as the marine *Trichodesmium* sp. (Table 2.1). Group IV, the Nostocales, contain filamentous algae that differentiate into heterocysts and fix N_2. This group includes *Aphanizomenon*, *Anabaena*, *Nostoc* and *Cylindrospermopsis* (Table 2.1). Additionally, the Nostocales is known for differentiation into resting cells called akinetes during unfavorable conditions. Group V, the Stigonematales include species with filaments that grow in complex branching patterns.

Table 2.1. Cyanobacterial groupings based on morphological traits. Adapted from Rippka *et al.* 1979.

<table>
<tr><td colspan="3">Croococcales
Unicellular, reproduce by binary fission
GROUP 1</td><td>Gloeothece (N)
Microcystis
Prochlorococcus
Prochloron
Synechococcus
Synechocystis</td></tr>
<tr><td colspan="3">Pleurocapsales
Unicellular, reproduce by multiple fission
GROUP 2</td><td>Pleurocapsa
Staniera (N)
Xenococcus (N)</td></tr>
<tr><td rowspan="3">Filamentous chain (trichome) forming; reproduce by random trichome breakage, hormogonia, germination of akinetes</td><td>Trichome composed of vegetative cells</td><td>Oscillatoriales
1 plane division
GROUP 3</td><td>Lyngbya (N)
Oscillatoria (N)
Phormidium
Prochlorothrix
Trichodesmium (N)</td></tr>
<tr><td rowspan="2">In the absence of fix d N, trichome contains heterocysts; some produce akinetes</td><td>Nostocales
1 plane division
GROUP 4</td><td>Aphanizomenon
Anabaena
Cylindrospermum
Nodularia
Nostoc</td></tr>
<tr><td>Stigonematales
Divisien in more than 1 plane
GROUP 5</td><td>Chlorogleopsis
Fisherella</td></tr>
</table>

It was originally thought that N_2 fixation primarily existed in the Nostocales which had the ability to differentiate into heterocyst cells. More recent investigations tracking the *nifD* and *nifH* gene diversity has uncovered that N_2 fixation occurs in a range of unicellular, non-filamentous cyanobacteria dispersed throughout the five original groups first proposed by Rippka *et al.* (1979). These species are indicated by an (N) after their name in Table 2.1. Depending on which functionality of the cyanobacteria is emphasized, recent gene-based groupings of cyanobacteria have created as many as ten different sub-categories (Turner *et al.* 1999, Tomatini *et al.* 2006). However, there appears to exist no general consensus over the best manner in which to categorize the cyanobacteria based on functionality and marker genes. Most cyanobacteria are planktonic and are dispersed throughout the five groups. The benthic cyanobacteria are found mainly in the Oscillatoriales subgroup. The toxic cyanoHAB-forming cyanobacteria are mostly freshwater planktonic species dispersed throughout groups I, III and IV and include the N_2 fixing genera *Anabaena*, *Aphanizomenon*, *Cylindrospermopsin*, and *Nodularia*; the benthic N_2 fixing genera *Lyngbya* and some *Oscillatoria*; and the non-N_2 fixing genera *Microcystis* and *Planktothrix* (Paerl and Paul 2012).

Akinete formation

Akinetes are the resting cells produced by the Nostocales in order to survive adverse environmental conditions such as cold and desiccation (Tomatini *et al.* 2006). Akinete cells maintain low levels of metabolic activity (Thiel and Wolk 1983, Sukenik *et al.* 2007), are dispersed in sediments (Baker 1999, Kim *et al.* 2005, Rucker *et al.* 2009), and are distinguishable from vegetative cells by their larger size (Figure 2.1). They germinate in response to improved environmental conditions such as light and temperature (Baker and Bellifemine 2000, Karlsson-Elfgren *et al.* 2004, Yoshimasa and Nakahara 2005, Kaplan-Levy *et al.* 2010) and provide an inoculum of Nostocales vegetative cells to the water column from the sediments where the akinete “seed bank” may remain viable for decades (Stockner and Lund 1970, Livingstone and Jaworski 1980). Therefore, eradication of Nostocales from a system once it has become “infected” is very difficult.

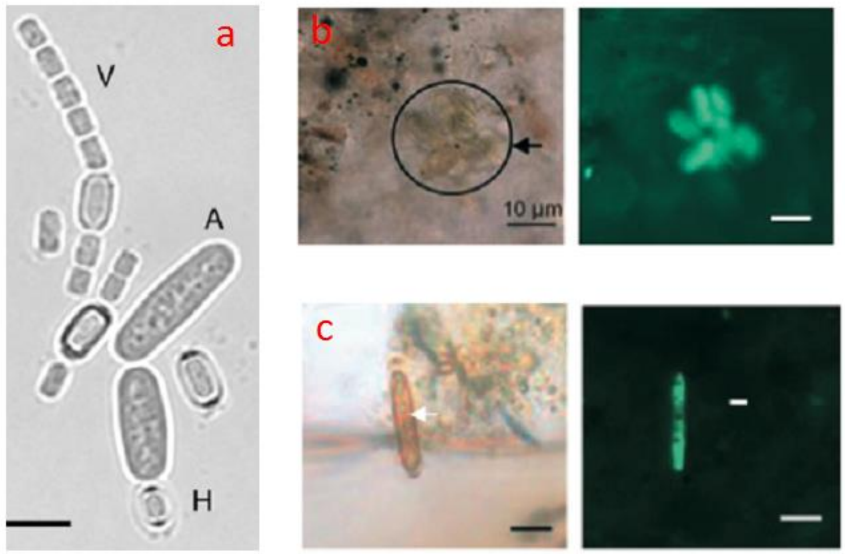


Figure 2.1. Akinetes of a) Anabaena cylindrica culture grown in medium without nitrogen; A=akinete; H=heterocyst; V=vegetative cell (picture from Tomatini *et al*. 2006), b) Anabaena lemmermanni, and c) Cylindrospermopsis raciborskii in lake sediments under light microscopy and hybridized with probe under fluorescence microscopy; scale bar is 10µm (pictures from Ramm *et al*. 2012).

2.2.2 Light Harvesting, Photosynthesis and Carbon Fixation

Cyanobacteria are distinct from all other algae in that most of them possess two light harvesting systems (as opposed to one). Maintaining two light harvesting system is costly in terms of protein and N requirements and manifests strongly in their cell biology. For example, the extra protein requirement means that cyanobacteria have a high tissue nitrogen:phosphorus (N:P) ratio and a high N requirement for growth (discussed below). Despite this, light harvesting is necessary in photosynthetic organisms to 1) collect light energy from the sun and 2) convert it to chemical energy in the form of electrons and ATP that can be used to power carbon fixation.

Light harvesting pigments and photosynthesis

Light harvesting is performed by chlorophyll *a* (Chl *a*) pigment molecules that are associated with two photosystems (PSI and PSII) that comprise the centers of the photosynthetic process which starts with the liberation of an electron from the splitting of water and ends with the production of ATP. Sitting in each of the photosystems is a specialized Chl *a* molecule that initiates the flow of electrons through the electron transport chain that eventually powers ATP synthesis. The other Chl *a* molecules, 40 and 90, together with 12 and 22 carotenoid pigment molecules, in PSI and PSII respectively, funnel light energy to the reaction core (DeRuyter and Fromme 2008). This complex of Chl *a* and carotenoid pigment molecules, coordinated by a large number of proteins, is very similar in its structure to the light-harvesting complex (LHC) embedded into the thylakoid membranes of vascular plants and eukaryotic phytoplankton (Fromme *et al.* 2001, 2002).

What makes the cyanobacteria unique is that they have a second light harvesting antenna complex peripheral to the thylakoid membrane that is water soluble (e.g. not membrane bound). This pigment complex, comprised of pigmented proteins arranged in rods fanning out from a core attached to the thylakoid membrane, called the phycobilisome (PBS), is what gives cyanobacteria their name (Grossman *et al.* 1993, Grossman 2003). Similar to the carotenoid pigments mentioned above, the PBS chromophores absorb light inbetween the Chl *a* absorption peaks of 440nm and 670nm (Grossman *et al.* 1993). Interestingly, the PBS proteins are not exclusive to cyanobacteria; they also occur in photosynthetic eukaryotes.

Up to 50% of cyanobacterial cellular protein content is bound in the PBS complex taking a large proportion of the cell's resources, particularly its nitrogen (N) allocation. Therefore, under stress condition such as N starvation, the entire PBS can be degraded within a few hours and the N can become reused within the cell (Sauer *et al.* 1999). When conditions improve, the PBS will be re-synthesized and re-assembled (Collier and Grossman 1994, Grossman *et al.* 2001).

Carbon fixation

The ATP produced and the electrons liberated during photosynthesis are used to power the fixation of carbon into sugars in the Calvin Cycle. They are also used to reduce oxidized sources of N to ammonia during N assimilation (discussed below). The primary and rate-limiting enzyme in carbon fixation is Rubisco which catalyzes the first step in the Calvin Cycle. To deal with the rate-limiting nature of Rubisco, cyanobacteria have evolved specialized structures called carboxysomes. In addition to housing Rubisco, the carboxysomes contain a number of other enzymes that help concentrate CO_2 in its vicinity to speed its reaction rate (Kaplan and Reinhold 1999). Cyanobacteria fix carbon to provide the skeletons needed to assimilate N into amino acids and build protein and cellular biomass; fixed carbon can also be used to accumulate carbohydrate storage products (carbohydrate ballasting) in order to make the cell heavier during buoyancy regulation.

2.2.3 Buoyancy Regulation

One distinct advantage of many cyanobacterial genera such as *Microcystis*, *Planktothrix*, *Anabaena* and *Aphenizomenon* is their ability to regulate their buoyancy by a combination of producing gas vesicles and carbohydrate storage products (Oliver 1994, Beard *et al.* 1999, Brookes *et al.* 1999). The former renders them positively buoyant whereas the latter does the opposite (Walsby 1994, 2005). The carbohydrate storage products are derived from C-fixation and the amount produced varies depending on the species and on irradiance (Howard *et al.* 1996, Visser *et al.* 1997, Wallace and Hamilton 1999). At an irradiance that is specific to each species and strain, the amount of carbohydrate storage product will perfectly balance the upward lift created by the gas vesicles and the cyanobacteria will become neutrally buoyant (Walsby *et al.* 2004). In addition to producing and storing the carbohydrates, cyanobacteria also consume the storage products to produce energy.

By regulating the amount of carbohydrate storage products consumed, cyanobacteria control their vertical position in the water column (Thomas and Walsby 1985, Konopka *et al.* 1987, Wallace and Hamilton 1999). Models demonstrate that filamentous cyanobacteria can sink or float at speeds up to 0.3 m per day in order to position them at a depth where irradiance is such that it maximizes their growth potential (Walsby 2005). These speeds are only achievable for filaments of a certain size and weight; picocyanobacteria and small filaments do not have enough momentum to respond by vertical repositioning to changes in irradiance (Walsby 2005). Of course, carbohydrate production, therefore buoyancy regulation, is affected by nutrient availability; nitrogen starved cells have excess carbohydrate stores and tend to lose buoyancy more easily than nutrient sufficient cells (Klemer *et al.* 1982, Brookes *et al.* 1999, Brookes and Ganf 2001).

2.2.4 Nitrogen Metabolism

Cyanobacteria use a wide variety of N sources for growth including ammonium (NH_4^+), nitrate (NO_3^-), nitrite (NO_2^-), urea, amino acids, cyanate, and several species are also capable of dinitrogen gas (N_2) fixation to satisfy their cellular N demand. Below we discuss the pathways of N transport, metabolism and assimilation, and their regulation.

Ammonium transport and assimilation of N into amino acids

Being a charged molecule, NH_4^+ cannot diffuse freely into the cell and has to be transported via active transport. Transport of NH_4^+ into cyanobacteria (as well as in eukaryotic algae) occurs via the Amt family of transporters. These transporters are either expressed constitutively or differentially depending on external N concentrations. At environmental concentrations, most of the NH_4^+ is transported into the cell via the high-affinity transporter Amt1 encoded by the gene *amt1* (Muro-Pastor *et al.* 2005).

Before it can be assimilated, all N sources, whether N_2, NO_3^- or organic N containing molecules, first have to be converted to NH_4^+. The NH_4^+ is then assimilated into amino nitrogen through the GS/GOGAT pathway. The primary NH_4^+ assimilating enzymes in cyanobacteria (as well as in vascular plants and eukaryotic algae) are glutamine synthetase (GS) and glutamate synthase (also called glutamine-2-oxogluterate-amido transferase, GOGAT) acting in concert to aminate 2-oxogluterate (2-OG). Photosystem I (PSI)-reduced ferredoxin (Fd_{red}) is typically used as a reductant in this reaction:

GS: Glutamate + NH_3 + ATP → Glutamine +ADP +P_i
GOGAT: Glutamine + 2-OG + 2[H] → 2 Glutamate
GS/GOGAT: 2-OG + NH_3 + ATP + 2[H] → Glutamate + ADP +P_i

An alternate route of NH_4^+ assimilation involves the enzyme glutamate dehydrogenase (GDH) but it's postulated that this occurs only during select conditions such as stationary growth:

GDH: 2-OG + NH_3 + 2[H] → Glutamate + H_2O

In all photosynthetic cells the link between the carbon (C) and N cycles in the cell occurs at the GS/GOGAT reactions because the two key ingredients in N assimilation is 1) 2-OG derived from carbon fixation, and 2) Fd_{red} derived from PSI. GOGAT (and also GDH) will not proceed without their presence, which avoids wasteful consumption of glutamine, and ensures that even in the presence of excess N, assimilation will not proceed unless an adequate supply of C skeletons is available (Flores and Herrero 2005, Muro-Pastor *et al.* 2005).

Nitrate transport and reduction to NH_4^+

As NO_3^- is also a charged molecule it's transported into the cell via active transport. Cyanobacteria use two different transport systems. Most freshwater species, including *Anabaena*, *Synechocystis* and *Gloebacter*, use the high affinity ATP-binding cassette (ABC) transporter NrtABCD (Flores *et al.* 2005). Most marine species (*Synechococcus* and others) take up NO_3^- and NO_2- via the major facilitator superfamily transporter NrtP, also a high-affinity transporter (Flores *et al.* 2005). Some species also have a NO_2^--specific transporter NIT (Maeda *et al.* 1998). Nitrate uptake is tightly regulated by the external concentration of NH_4^+; when NH_4^+ becomes available, cells cease NO_3^- uptake and switch to use NH_4^+ which is preferred. This process is regulated at the level of NO_3^- uptake (Flores and Herrero 1994). In addition, CO_2-fixation (regulated by irradiance) is required to maintain active NO_3^- uptake, a regulatory link that ensures that the product of NO_3^- reduction (ammonium) can be incorporated into carbon skeletons (Luque and Forchhammer 2008).

Reduction of NO_3^- to NH_4^+ is a two-step process catalyzed by the enzymes nitrate reductase (NR) and nitrite reductase (NiR). The power for the reduction reaction, in the form of 2 electrons for NR and 6 electrons for NiR, is provided by Fd_{red} via PSI providing a strong link between the light reactions and NO_3^- use by the cell (Flores *et al.* 2005).

In cyanobacteria, the genes encoding NR, narB, and Nir, nirA, and the NO_3^- transporter NrtP, are typically clustered in the same operon. An operon is a unit that tells the cells to transcribe a sequence of genes simultaneously. In cyanobacteria, the transcription of operons associated with N metabolism is tightly regulated by the transcription factor NtcA (discussed below).

The only cyanobacteria discovered to date that is not able to use NO_3^- is *Prochlorococcus* which lives in the open ocean. While it was initially thought that some species could assimilate NO_2^-, sequencing of their genomes demonstrates that they all lack the *nirA* genes and therefore cannot reduce NO_2^- (Garcia-Fernandez *et al.* 2004).

Urea transport and metabolism

Many, but not all, cyanobacteria can use urea as a source of N for growth. Because urea is not a charged molecule it diffuses freely into the cell; however, environmental concentration are not such that diffusion can supply the needed concentration of urea for the urease enzyme (based on its K_m). Both in freshwater and marine cyanobacteria, an ABC-type active transport system specific for urea has been identified (Valladares *et al.* 2002). The subunits of this transporter are encoded by the five genes urtA-E. In *Anabaena*, the urea transporter genes are in the same NtcA-activated promoter and subject to metabolic repression by NH_4^+ (Valladares *et al.* 2002).
Urea is metabolized to two molecules of NH_3 and CO_2 by the enzyme urease, also called urea amidohydrolase (Mobeley *et al.* 1995). The urease enzyme is well-conserved throughout the bacteria and eukaryotic organisms and consists of two small and one large subunit encoded by at least seven genes, three which encode the structural subunits (*ureA*, *ureB*, *ureC*) and the other four (*ureD*, *ureE*, *ureF*, *ureG*) encoding accessory polypeptides required for the assembly of the nickel metallocenter (Collier *et al.* 1999, Palinska *et al.* 2000).

Amino acid transport

All cyanobacteria tested to date have at least one transport system for amino acids. These transporters appear to have broad specificity (i.e. they can transport more than one type of amino acid) and different species have different combinations of transporters (Herrero and Flores 1990, Montesinos *et al.* 1997). For example, freshwater *Synechocystis* sp. has four different amino acid transporters, including the ABC transporter Nat for glutamine and histidine, the ABC transporter Bgt for basic amino acids, and two glutamate-specific transporters GHS and Gtr (Quintero *et al.* 2001). Once in the cell, cyanobacteria possess a variety of deaminase enzymes that can deaminate the amino acids to NH_3 which then enters the GS/GOGAT pathway.

Cyanate transport and metabolism

Cyanobacteria, including freshwater and marine species, can use cyanate (a toxin) as a N source for growth since they have the genes encoding a transporter (*cynA*, *cynB*, *cynC*) and the gene encoding the cyanase enzyme (*cynS*) which hydrolyzes cyanate to NH_3 and CO_2 (Kamennaya and Post 2011). In freshwater cyanobacteria, these genes are repressible by NH_4^+ suggesting that they are under NtcA regulation.

Nitrogen fixation

Arguably the most expensive (energetically speaking) source of N for cyanobacteria is molecular dinitrogen gas (N_2). Nitrogen fixation, the process of reducing N_2 to NH_3, is catalyzed by the nitrogenase enzyme. The nitrogenase has two subunits. The first is the dinitrogenase subunit which catalyzes the reduction of N_2 to NH_4^+, composed of the NifD and NifK polypeptides encoded by the *nifD* and *nifK* genes. The dinitrogenase contains an iron-molybdate active site and two iron-sulfur clusters. The second is the dinitrogenase reductase subunit (NifH polypeptide encoded by the *nifH* gene) which contains a central iron-sulfur cluster whose function it is to donate electrons derived from ferredoxin to dinitrogenase. Reduction of N_2 to NH_3 requires 8 electrons and 15 molecules of ATP in the following reaction:

$$N_2 + 8[H] + 16ATP \rightarrow 2\ NH_3 + H_2 + 16ADP + 16P_i$$

It was recently discovered that under conditions of molybdate limitation, some *Anabaena* species express an alternative nitrogenase containing a vanadium-iron cofactor instead of the molybdate-iron cofactor (Thiel 1993, Boison *et al.* 2006). Both these variants require iron cofactors to function and N_2 fixation cannot proceed under iron-limiting conditions.

The nitrogenase enzyme is very sensitive to oxygen (O_2), and O_2 is evolved as a byproduct of the water-splitting reactions at photosystem II (PSII), requiring the nitrogenase enzyme to be kept separate from PSII. Accordingly, freshwater cyanobacteria have evolved heterocysts (Wolk *et al.* 1994). These are specialized cells where PSII is inactivated, the PBS antenna proteins are degraded, and energy to power the cell is derived from cyclic electron flow around PSI. Rates of respiration in these cells are also high to scavenge any O_2. The ATP and reductant needed for N_2 reduction is generated by carbohydrate metabolism inside the heterocyst. The carbohydrate is synthesized in the non-heterocyst, vegetative cells flanking the heterocyst and transported inside. In turn, NH_3 produced inside the heterocyst is exported to the vegetative cells in the form of amino acids (Wolk *et al.* 1994). However, many species of cyanobacteria that fix N_2 do not form heterocysts; these species either separate N_2 fixation from photosynthesis in time (e.g. by fixing N_2 at night such as *Lyngbya aestuarii* and *Crocosphaera watsonii*) or in different regions of filaments as is hypothesized to be the case for *Trichodesmium* sp. (Frederiksson and Bergman 1997).

Because nitrogen fixation is such an energy expensive process, from the formation of the heterocysts to the reduction of N_2, it is tightly regulated by NtcA and is only induced under N starvation and in the absence of any other fixed N source (Herrero *et al.* 2004).

Regulation of nitrogen metabolism

As evident from the preceeding sections, the transcription factor NtcA (encoded by the gene *ntcA*) regulates most of the cyanobacterial genes associated with nitrogen uptake and assimilation, and is therefore considered the master regulator of N metabolism (Herrero et al 2004). NtcA binds to and activates the operons for heterocyst differentiation, N_2 fixation, NO_3^- uptake and reduction, urea uptake and hydrolysis, and glutamine synthetase to mention a few. In other words, none of the genes related to N metabolism are transcribed and their enzymes synthesized unless NtcA binds to their promoter in the genome (Luque *et al.* 1994, Wei *et al.* 1994, Forchammer 2004, Luque and Forchammer 2008). The exception to this rule are some NH_4^+ transport proteins which are not under NtcA control and are transcribed constitutively, i.e.

always “on” (Herrero *et al.* 2001). NtcA also controls signaling proteins that fine-tune cellular activities in response to fluctuating C/N conditions (Herrero *et al.* 2001).

NtcA is under negative control by NH_4^+, meaning that when NH_4^+ is detectable by the cell, *ntcA* gene transcription is repressed (Herrero *et al.* 2001, Lindell and Post 2001). There is an inverse relationship between NH_4^+ concentration and *ntcA* expression in all cyanobacteria tested to date, with basal levels of *ntcA* expression observed in the presence of high external NH_4^+ concentrations and maximal levels of *ntcA* expression observed under N starvation (Frias *et al.* 1994, Lindell *et al.* 1998, Lee *et al.* 1999, Sauer *et al.* 1999, Lindell and Post, 2001). Ammonium regulates expression of *ntcA* via 2-OG which is synthesized in the Calvin cycle and consumed in the GS/GOGAT cycle. Thus 2-OG is at the crossroads between C and N metabolism and is ideally suited to “sense” NH_4^+ concentrations (Vazquez-Bermudez *et al.* 2002, Tanigawa *et al.* 2002, Forchammer 2004).

The repression of *ntcA* expression by NH_4^+ places NH_4^+ at the top of the hierarchy of N substrates utilized and assimilated by cyanobacteria. The order in which N substrates other than NH_4^+ is assimilated differs depending on species. For example, in N_2 fixing cyanobacteria, NH_4^+ represses both N_2 fixation and NO_3^- assimilation. Nitrate, in turn, represses N_2 fixation. Therefore N_2 fixation is at the bottom of the hierarchy in some cyanobacteria (Ramasubramanian *et al.* 1994). But in others such as marine *Trichodesmium* sp., NO_3^- does not repress N_2 fixation genes and the process of N_2 fixation is on a more even footing with NO_3^- assimilation (Post *et al.* 2012).

2.2.5 Cellular Nitrogen:Phosphorus (N:P) Requirement

In 1958 Redfield published his discovery that phytoplankton particulate matter was composed of N and P in a molar ratio of 16, similar to the ratio of dissolved N:P in the water (Redfield 1958). Redfield suggested that the ratio of dissolved N:P in the ocean was driven by the remineralization of phytoplankton particulate matter, a theory which has since taken hold (Falkowski 2000, Geider and LaRoche 2002). Given that the average N:P ratio was discovered to be 16 in phytoplankton, it was deduced that under nutrient limiting conditions phytoplankton would become limited by N at dissolved N:P less than 16 and limited by P at dissolved N:P ratios greater than 16.

Shortly after Redfield’s discovery of the universality of the N:P ratio of 16, investigators turned to phytoplankton cultures to examine how closely phytoplankton cellular N:P ratios varied around 16. Parsons *et al.* (1961) published the first investigation demonstrating variability in cellular N:P ratios depending on the phytoplankton species. Subsequent investigations noted that diatoms and dinoflagellates tended to have cellular N:P ratios below 16 whereas chlorophytes and cyanobacteria typically had ratios above 25 (Geider and LaRoche 2002; Ho *et al.* 2003; Quigg *et al.* 2003; Klausmeier *et al.* 2004; Hillebrand *et al.* 2013; Figure 2.2). This difference among the taxa stems from slight variations in macromolecular composition of the phytoplankton, principally in their ratio of protein, the largest store of N in the cell, to nucleic acids, the largest store of P in the cell (Terry *et al.* 1985, Falkowski 2000, Elser *et al.* 2000, Geider and LaRoche 2002). As mentioned above in section 2.2.2, cyanobacteria have two light-harvesting complexes requiring a greater association of proteins with the light-harvesting pigments compared with eukaryotic cells which only have one light harvesting complex (Raven 1984, Geider and LaRoche 2002). The "excess" protein associated with the peripheral phycobilisomes substantially increase the cellular N:P ratios of cyanobacteria. Once it was realized that that there were significant departures in the cellular N:P ratio depending on taxa, it also became clear that the ratio of N:P uptake differed with respect to taxa and that this was a major basis of resource-based competition among taxa (Rhee 1978). That phytoplankton take up N:P in proportion to their tissue composition was subsequently confirmed in culture experiments (Droop 1974, Elrifi and Turpin 1985, Tett *et al.* 1985, Quigg *et al.* 2003, Leonardos and Geider 2004). In other words, phytoplankton do not take up nutrients according to the ratio that occurs in water, but rather the ratio dictated by the macromolecular composition of their tissues.

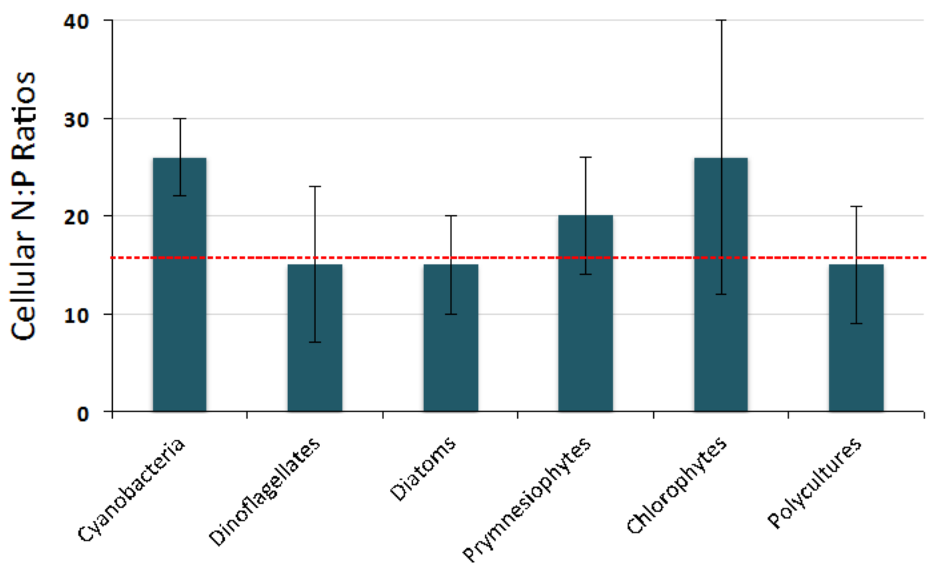


Figure 2.2. Cellular N:P ratios (mole:mole) in different phytoplankton taxa. Dashed red line indicates the average phytoplankton cellular N:P ratio of 16, also called the Redfield ratio. Data from Hillebrand *et al.* 2013.

Tissue N:P composition is not a fixed trait and phytoplankton are able to adjust it, within certain limits, in order to keep growing when environmental conditions change for the suboptimal. When limited for a nutrient, uptake of the non-limiting nutrient can proceed for a while skewing cellular ratios. But, severe limitation by one nutrient will eventually prevent the uptake of the other, non-limiting nutrient, even when the other is present in excess. This quirk of nature constrains the extent to which cellular ratios vary (Droop 1974, Tett *et al.* 1985, Leonardos and Geider 2004, Hillebrand *et al.* 2013). For example, a summary of nearly 50 phytoplankton studies demonstrates that the N:P ratio of P-limited phytoplankton converge around 28 and the N:P ratio of N-limited phytoplankton converges around 16 (Hillebrand *et al.* 2013).

Irradiance may also change the cellular N:P ratio through its influence on the cellular protein content (LaRoche and Geider 2002). Pigments (Chl *a* and light harvesting antenna pigments) are bound in pigment-protein complexes rich in N that increase as irradiance decreases, and decrease under high light as cells reduce the size of the light harvesting complex to avoid photodamage (Wynne and Rhee 1986, Falkowski and LaRoche 1991, Nielsen 1992, Leonardos and Geider 2004). The irradiance-dependent change in N:P ratios is even more pronounced among cyanobacteria due to the greater association of protein with the phycobilisome than in the eukaryotic light harvesting complex (Raven 1984, Geider and LaRoche 2002).

In contrast with limiting nutrient concentrations or changes in irradiance, changes in the medium N:P ratio when nutrient concentrations are in excess of demand was found not to affect cellular N:P ratios in phytoplankton in early experiments (i.e. Tilman *et al.* 1982, Tett *et al.* 1985, Reynolds 1999, Roelke *et al.* 2003, Sunda and Hardison 2007) and has not been pursued by the scientific community.

2.2.6 Toxin Production

Cyanobacteria produce a large variety of toxins with a number of different actions in animals and humans leading to significant health risks and drinking water issues globally (c.f. Chorus and Bartram 1999, Chamichael 2008, Cheung *et al.* 2013). The toxin-producing cyanobacteria, and the suite of different toxins that each species produces, is discussed below.

Toxin-producing taxa

The cyanobacterial toxins were named according to the species that they were originally discovered in and isolated from. For example, microcystin was discovered in *Microcystis aeruginosa* and anatoxin was originally isolated from *Anabaena*. However, most cyanobacteria produce several different types of toxins, with the exception of nodularin which is only produced by *Nodularia spumigena*.

The toxin most widely produced by different cyanobacterial taxa is the recently discovered neurotoxin Beta-N-methylamino-L-alanine (BMAA, Cox *et al.* 2005). This is followed by the microcystins which are produced by nine different taxa (Table 2.2). Chief among the microsystin producing taxa are *Microcystis* (the toxin was originally isolated from *Microcystis aeruginosa*), followed by *Planktothrix* and *Anabaena*. Another widely distributed toxin is anatoxin-a, which is produced by eight different cyanobacterial taxa, principally *Anabaena*, the genus from which the toxin was originally isolated.

Table 2.2.Toxins produced by cyanobacteria. Based on data from Cox *et al.* 2005, Sivonen and Borner 2008, Cheung *et al.* 2013.

	Microcystin	Nodularin	Cylindro spermopsin	Anatoxin a	Anatoxina(S)	Saxitoxin	Dermatotoxin	BMAA
Microcystis	X							X
Planktothrix	X			X		X		X
Anabaena	X		X	X	X	X		X
Nostoc	X							X
Anabaenopsis	X							
Radiocystis	X							X
Synechococcus	X							X
Phormidium	X			X				X
Oscillatoria limosa	X			X				
Oscillatoria				X			X	
Nodularia		X						X
Cylindro-spermopsis			X			X		X
Aphanizo-menon			X	X		X		X
Raphidiopsis			X	X				X
Cylindro-spermum				X				X
Lyngbya						X	X	X
Shizothrix							X	
Umezakia natans			X					

Anabaena species, including *flos-aquae*/ *lemmermannii*/ *circinalis*, may be the most toxically versatile of all the cyanobacteria as they can produce all the toxins, including BMAA, microcystins, cylindrospermopsin, anatoxin-a, anatoxin-a(S) and saxitoxins, save nodularin (Table 2.2). Nodularin is only produced by *Nodularia spumigena*. Another versatile toxin producer is *Aphanizomenon flos-aquae* which produces BMAA, cylindrospermopsin, anatoxin-a and saxitoxins (Table 2.2). *Planktothrix* also produces four different toxins including BMAA, microcystins, anatoxin-a and saxitoxins. The cyanobacteria *Cylindrospermopsis raciborskii* from whence cylindrospermopsin was originally isolated also produces saxitoxins (Table 2.2). Benthic cyanobacteria are also versatile when it comes to toxin production. For example, *Oscillatoria limosa* can produce microcystins as well as anatoxin-a while *Lyngbya wollei* can produce saxitoxins and dermatotoxins (Table 2.2).

Toxin types and their biosynthetic pathways

The toxins produced by cyanobacteria can be divided into three main groups: hepatotoxins that damage the liver of the organisms ingesting them, neurotoxins that cause respiratory arrest, and dermatoxins that cause rashes and inflammations. Each is discussed separately below.

Hepatotoxins. The most well-known hepatotoxins are microcystins and nodularin which are serine/threonine protein phosphatase inhibitors (Table 2.3). A large variety of different microcystins (close to 80) have been identified, with the most toxic being microcystin-LR. These cyclic heptapeptides contain seven amino acids, including a unique beta amino acid ADDA (MacKintosh *et al.* 1990, Yoshizawa *et al.* 1990). In contrast with microcystins, only a few varieties of nodularin have been identified (Yoshizawa *et al.* 1990). The toxicity of cyanobacterial toxins is typically measured by injecting them into mice and calculating the lethal dosage to half the population (LD_{50}; Table 2.3).

Biosynthesis of the microcystis and nodularin peptides occurs by non-ribosomal peptide synthases (NRPS) and polyketide synthases (PKS) found mainly in bacteria (Welker and von Dohren 2006). Both of these enzyme classes are needed for both the microcystin and nodularin biosynthesis pathways which have been sequenced from a number of cyanobacterial species including *Microcystis*, *Planktothrix* and *Anabaena* (Borner and Dittman 2005). For example, the *mcyA*, *mcyB* and *mcyC* genes encode the NRPS that synthesize the pentapeptide portion of microcystins. The *mcyD*, *mcyE*, *mcyF* genes encode the PKS which synthesize the ADDA amino acid unique to microcystins. Finally, the *mcyF*, *mcyG*, *mcyH*, *mcyI*, *mcyJ* genes encode the proteins that tailor and transport specific microcystins (Table 2.3). Similarly, the *nda* gene cluster specific to nodularin encode the NRPS and PKS synthases as well as the tailoring and transport proteins (Table 2.3). Although not verified through functional investigations, the cylindrospermopsin gene cluster, encoding the genes *cyrA*, *cyrB*, *cyrC*, has recently been characterized in *Aphanizomenon flos-aquae* (Stuken and Jakobsen 2010).

Table 2.3. Common cyanobacterial toxins. ND: Not determined.

Toxin	Chemical Class	Action	Effect	LD_{50}	Reference	Gene Name	Gene Reference
Micro-cystins	Cyclic heptapeptides; 80 variants; microcystin-LR is most toxic	Serine/threonine protein phosphatase (1 and 2A) inhibitors	Hepatotoxin; damages liver	50 µg kg^{-1}	MacKintosh *et al.* 1990, Yoshizawa *et al.* 1990	*mcyA-I*	Tillett *et al.* 2000, Christiansen *et al.* 2003
Nodularin	Cyclic pentapeptide; only a few variants identified	Serine/threonine protein phosphatase 1 and 2A inhibitor	Hepatotoxin; damages liver	50 µg kg^{-1}	Yoshizawa *et al.* 1990	*ndaA-I*	Moffitt and Neilan 2004
Cylindro-spermopsin	Cyclic guanidine alkaloid	Protein synthesis inhibitor	Hepatotoxin/Cytotoxin; affects liver as well as kidney, spleen, thymus and heart	200 µg kg^{-1} at 6 days 2000 µg kg^{-1} at 24 hrs	Runnegar *et al.* 1994, Terao *et al.* 1994, Ohtani *et al.* 1992	*cyrA-C*	Stuken and Jakobsen 2010
Anatoxin-a	Alkaloid	Competitive inhibitor of acetyl choline	Neurotoxins: causes death by respiratory arrest	200-250 µg kg^{-1}	Devlin *et al.* 1977, Carmichael *et al.* 1990, Skulberg *et al.* 1992	*ana*	Mejean *et al.* 2010
Anatoxin-a(S)	Phosphate ester of cyclic N-hydroxyguanine	Anticholin-esterase	Neurotoxins: causes death by respiratory arrest	20 µg kg^{-1}	Carmichael *et al.* 1990	*ana*	Mejean *et al.* 2010
Saxitoxins	Carbamate alkaloids; the most potent are saxitoxins and neosaxitoxins	Sodium channels blocker	Neurotoxin	10 µg kg^{-1}	Sivonen and Jones 1999	*stxA-Z*	Kellmann *et al.* 2008
BMAA	Non-protein amino acid		Neurotoxin: linked with neuro-degenerative diseases (e.g. Parkinson’s Dementia Complex)	ND	Cox *et al.* 2005	ND	
Dermato-toxins	Aplysiatoxins	Protein kinase C activators	Dermatotoxin: tumor promoters; dermatitis and oral/ gastrointestinal inflammations	ND	Mynderse *et al.* 1977, Fujiki *et al.* 1990	ND	

Neurototoxins. By far the most potent toxins are the neurotoxin saxitoxin that causes paralytic shellfish poisoning (PSP) syndrome and respiratory arrest in humans and animals. This neurotoxin is produced both by cyanobacteria and dinoflagellates and is an alkaloid that acts as a sodium channel blocker. Another alkaloid neurotoxin, anatoxin-a, competitively inhibits acetyl choline, and a variant, anatoxin-a(S), acts as an anti-cholinesterase (Devlin *et al.* 1977, Myderse *et al.* al 1977, Carmichael *et al.* 1990, Sivonen and Jones 1999). The LD_{50} of these toxins vary from 200-250 µg kg^{-1} in the case of anatoxin-a, 20 µg kg^{-1} in the case of anatoxin-a(S), to 10µg kg^{-1} in the case of saxitoxins (Table 3). The gene clusters encoding the saxitoxin biosynthesis and anatoxin biosynthesis pathways were very recently elucidated via functional homology and each contains 20 or more genes (Kellmann *et al.* 2008, Mejean *et al.* 2010). The recently discovered neurotoxin BMAA, a non-protein amino acid that is potentially linked to neurogenerative diseases such as Parkinson Dementia Complex (PDC), is produced in almost all cyanobacteria tested to date (Cox *et al.* 2005).

Dermatotoxins. Benthic cyanobacteria, including *Lyngbya*, *Oscillatoria* and *Schizothrix*, produce a number of different toxins including aplysiatoxins, debromoaplysiatoxins and lyngbyatoxin-a. These toxins are protein kinase C activators that cause dermatitis and oral and gastrointestinal inflammations, and can also promote tumor formation (Mynderse *et al.* 1977, Cardellina *et al.* 1979, Fujiki *et al.* 1990). The pathways and genes involved with the production of the dermatotoxins have yet to be elucidated.

Potential functions of toxin production

Interestingly, researchers have not been able to determine the purpose of toxin production in cyanobacteria, or under what conditions toxins are most likely to be produced (Sivonen and Borner 2008). Moreover, under environmental conditions cyanobacteria that produce toxins co-exist with cyanobacteria of the same genus that do not produce toxins; it's unclear whether the possession of, or lack of, the toxins confers an ecological advantage (Sivonen and Borner 2008, Baxa *et al.* 2010).

Despite these complications, several explanations for the potential function of toxin production exist. Originally it was thought that cyanotoxins acted as allelochemicals and that their secretion into the surrounding water would suppress the growth of competitors (Keating 1977, Keating 1978, Flores and Wolk 1986, Klein *et al.* 1995). But, when the distribution of toxins, such as microcystins, was compared between cells and the surrounding medium using immunodetection combined with electron microscopy, most of the toxin was found to be cell-bound (Rapala *et al.* 1997, Wiedner *et al.* 2003, Tonk *et al.* 2005, Gerbersdorf 2006). Because, live (i.e. non-lysed) cyanobacteria do not secrete the toxins they produce it is doubtful that they act as allelopathic chemicals. Consistent with this notion, most investigations that demonstrate allelopathic effects do so at concentrations of extracted toxins far above what is ecologically relevant, leading investigators to conclude that the ability of cyanobacterial toxins to work as allelophathic chemicals appears unlikely (Babica *et al.* 2006, Berry *et al.* 2008, Holland and Kinnear 2013).

One explanation that is gaining ground is that the primary role of toxins is probably not to be toxic (Llewellyn 2006). Rather, investigators are hypothesizing that toxins may be produced to protect the cells from abiotic stresses. For example, microcystins are produced during all phases of growth but the greatest accumulation typically occurs under conditions that support optimal growth, including growing under optimal light levels (Sivonen and Jones 1999, Wiedner *et al.* 2003). Several lines of evidence point towards increases in irradiance as being a trigger for microcystin production. These include accumulation of intraceullular microcystin-LR with increased irradiance, the association of intracellular microcystins with the thylakoid membranes, and increased microcystis gene expression with increased irradiance (Kaebernick *et al.* 2000, Tonk *et al.* 2005, Borner and Dittman 2005, Gerbersdorf 2006). As such, it makes sense that microcystins are produced across a number of cyanobacterial taxa, such as *Microcystis*, *Anabaena*, and *Planktothrix*, that grow well in high-light environments (Paerl and Paul 2012).

Microcystins may also be implicated in preventing iron-stress by acting as siderophores to scavenge iron (Utkilen and Gjolme 1995, Lyck *et al.* 1996), an idea supported by the discovery that the iron-regulator factor Fur binds to the genes that produce microcystins in cyanobacteria (Martin-Luna *et al.* 2006). As such, microcystin production may provide an advantage to cyanobacteria in early stages of iron-limiting conditions (Alexova *et al.* 2011, Holland and Kinnear 2013) vis-à-vis eukaryotic competitors (Molot *et al.* 2014).

Another potential role for cyanotoxins is to act as a grazing deterrent (Burns 1987, Gilbert 1996). However, recent research using *Microcystis aeruginosa*, has demonstrated that it's not the toxic microcystins that deters Daphnia from grazing *M. aeruginosa* but other substances it produces. In other words, the substances causing toxicity and deterrence are not identical and the non-toxic substances may be much important in terms of grazing deterrence (Rohrlack *et al.* 1999, 2003).

While the toxic substances are by far the most well-known, there are hundreds of other, secondary metabolites similar in structure to the toxins that are produced by cyanobacteria. Just as the toxins, these cyclic or linear peptides may not be needed for growth but may serve protective functions. For example, the grazing deterrents discussed above belong to a class of depsipeptides called microviridins (originally isolated from *Microcystis viridis*) and has since their isolation been found in a range of cyanobacteria (Rohrlack *et al.* 2003). These secondary metabolites may also have important pharmacological applications. An alkaloid produced by *Nostoc*, called nostocarboline, is a cholinesterase inhibitor which has an effect comparable to galanthamine, a drug approved for Alzheimer's disease (Becher *et al.* 2005). Also isolated from *Nostoc* is a compound called cyanovirin-N which has antiviral activity and is under development as an antiviral agent against HIV (Boyd *et al.* 1997, Bolmstedt *et al.* 2001).

3. FACTORS INFLUENCING CYANOBACTERIAL BLOOMS AND TOXIN PRODUCTION

The world-wide increase in the incidence of cyanoHABs such as the N_2 fixing genera *Anabaena*, *Aphanizomenon, Cylindrospermopsin*, and *Nodularia*; the benthic N_2 fixing genera *Lyngbya* and some *Oscillatoria*; and the non-N_2 fixing genera *Microcystis* and *Planktothrix* has prompted a great deal of research into the conditions that favor the growth of these species (Chorus and Bartram 1999; Carmichael 2008; Paerl and Huisman 2008; Hudnell 2008, 2010; O'Neill *et al*. 2012; Paerl and Paul 2012). These conditions typically include favorable salinity, ample supply of nutrients, calm water and stratified conditions, plenty of irradiance and warm water temperatures (Figure 3.1). In contrast, the most successful strategies to mitigate blooms of cyanoHABs include reducing the supply of nutrients, increasing the flow of water to promote mixing and destratify the water column (Figure 3.1). In the following sections, we will focus on the conditions that are favorable for the growth of the cyanoHAB genera.

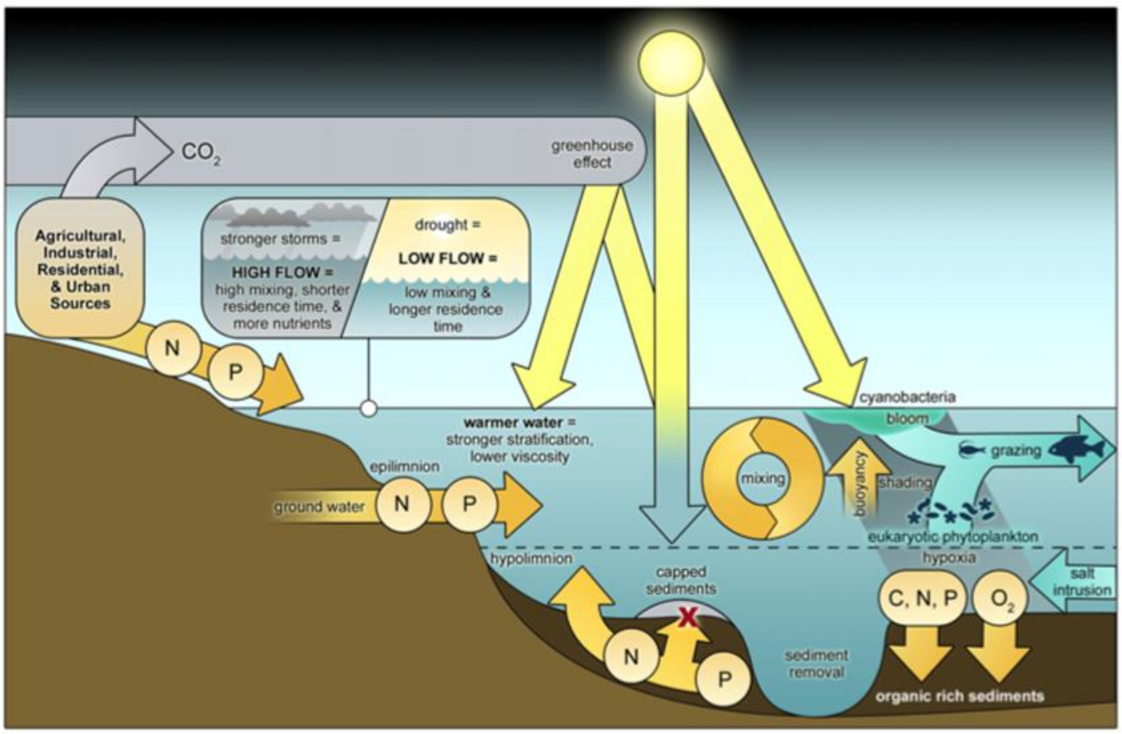


Figure 3.1. Conceptual model of factors affecting cyanobacteria blooms including warmer water, drought and decreased flow, decreased mixing, increased residence time, and increased N and P inputs from agricultural, industrial and urban sources. From Paerl *et al*. 2011.

3.1 Salinity

Most harmful algal bloom-forming and toxin-producing cyanobacteria (cyanoHABs) are freshwater species. In contrast, marine cyanobacteria such as *Prochlorococcus*, *Synechococcus* sp. and *Trichodesmium* sp. are not toxic and do not form cyanoHABs. However, laboratory investigations of freshwater cyanoHAB species demonstrate that these have quite wide salinity tolerance ranges. For example, the least tolerant, *Cylindrospermopsis* only thrives up to 2.5 ppt salinity, but the most tolerant, *Anabaenopsis* and *Nodularia* spp., thrive at salinities from 5-20 ppt (Moisander *et al.* 2002). *Microcystis aeruginosa* tolerates up to 10 ppt salinity without a change in its growth rate compared to that on freshwater (Tonk *et al.* 2007). What these studies suggest is that given optimal growth conditions, these species could also bloom in brackish-water regions. Indeed, recent decades have witnessed a spread in the geographical extent of these species into the mesohaline (5-15 ppt) reaches of coastal systems (Paerl and Paul 2012). For example, blooms of *Microcystis aeruginosa* have occurred in the Baltic Sea (Maestrini *et al.* 1999) and the San Francisco Estuary (Lehman *et al.* 2013) suggesting 1) that factors other than salinity are regulating their geographical distribution and that 2) those factors are currently changing to allow cyanoHAB growth to occur in regions where they previously did not exist. In summary, salinity may not be the strongest "barrier" in terms of restricting the occurrence and geographical distribution of toxic cyanoHABs.

3.2 Nutrient Concentrations and Ratios

As with other photosynthetic phytoplankton, given optimal temperatures and irradiance, cyanobacterial biomass accumulation is directly proportional to the amount of nutrients (N and P) available in the water column. Therefore, strategies to reduce the accumulation of cyanoHAB biomass and severity of their blooms frequently focus on reductions of nutrient concentrations (Paerl 2008).

3.2.1 Influence of N and P Loadings and Concentrations in Stimulating Cyanobacterial Growth

Cyanobacterial growth in freshwater systems (rivers and lakes), which tend to become limited by P sooner than by N, is frequently linked with excessive P loading (Likens 1972, Schindler 1977, Edmondson and Lehman 1981, Elmgren and Larsson 2001, Paerl 2008, Schindler *et al.* 2008). In contrast with freshwater systems, estuarine and marine systems tend to be more sensitive to N loading (Figure 3.2), and eutrophication due to cyanobacterial growth is frequently linked with excessive N loading (Ryther and Dunstan 1971, Nixon 1986, Suikkanen *et al.* 2007, Paerl 2008, Conley *et al.* 2009, Ahn *et al.* 2011).

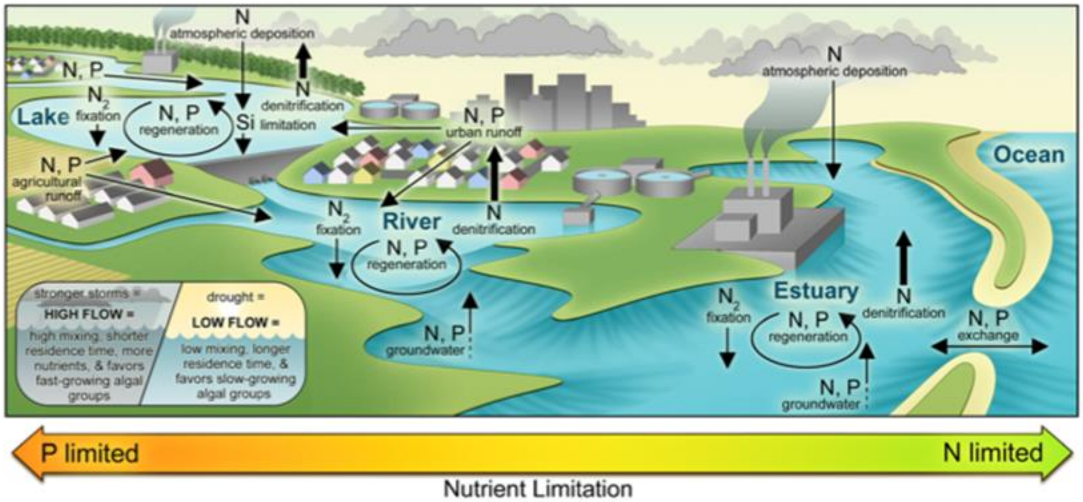


Figure 3.2. Conceptual diagram of interaction of nutrient inputs, cycling processes, and limitation of primary production along the freshwater to marine continuum. From Pearl *et al.* 2014b.

However, both non-point and point source nutrient contributions, such as agriculture and wastewater effluent, tend to increase N and P concentrations simultaneously (Paerl and Paul 2012, Paerl *et al.* 2014b). For example, human population growth-induced intensification of wastewater discharge and agriculture has led to hypereutrophication of China's third largest lake, Taihu (Qin *et al.* 2007). Increased nutrient loads, combined with low water column depth and increased water temperatures, has led to an explosive growth of cyanobacteria and a change in total phytoplankton community composition from being mainly diatom-dominated to being dominated by *Microcystis aeruginosa* (Qin *et al.* 2010, Paerl *et al.* 2014a). Bioassay experiments during summer months when cyanobacterial biomass is at its maximum, and nutrient concentrations at a minimum, demonstrate that N and P exert equal control over biomass accumulation in this system (Paerl *et al.* 2014a).

In general, dominance of both N_2-fixing and non-N_2 fixing cyanobacteria such as *Aphenizomenon flos aquae*, *Nodularia spumigena*, *Microcystis aeruginosa* and *Cylindrospermopsin raciborskii*, have increased world-wide in concert with increased loads of both N and P (Chapman and Schelske 1997, Jacoby *et al.* 2000, Gobler *et al.* 2007, Burford *et al.* 2006, Burford and O'Donahue 2006, Hong *et al.* 2006, Suikkanen *et al.* 2007, O'Neill *et al.* 2012).

3.2.2 Influence of Changes in N:P Ratios on Stimulation or Limitation of Cyanobacterial Growth

At low and intermediate nutrient loadings, reduction in only N or P may be sufficient to control blooms of cyanobacteria. But with elevated loadings of both N and P, reduction of only one type of nutrient can lead to an imbalance in the N:P ratio of the water column potentially leading to a worsening of the cyanoHAB problem, or even lead to a eukaryotic HAB problem (Smith 1983; Paerl 2008; Pearl *et al.* 2011, 2014b).

Low nutrient concentrations

Pioneering studies by Smith (1983, 1990) predicted that phytoplankton community composition would be dominated by cyanobacteria when N:P ratios were < 15, and by eukaryotic phytoplankton when N:P ratios > 20. This was because many nuisance freshwater cyanobacteria that fix N_2 were hypothesized to thrive at very low ambient concentrations of fixed N, therefore at N:P < 15. In comparison, growth rates of eukaryotic phytoplankton that could not fix N_2 were predicted to slow down at N- limiting concentrations, resulting in eukaryotic species becoming outcompeted at N:P < 15. At N:P > 20, growth rates of eukaryotic phytoplankton would not be limited by N and therefore they could dominate phytoplankton community composition (Smith 1983, 1990). These predictions suggested that one could control growth of cyanobacteria by increasing the dissolved N:P ratio above 20. Consequently, many investigators who study lakes with low to intermediate nutrient loadings advocate for reductions in "P only" as a way to control cyanobacterial growth (Schindler 1977, Schindler *et al.* 2008). However, increasing the dissolved N:P ratio >15 becomes less important as a way to control cyanobacterial growth at high concentrations of nutrients, for a number of reasons, including: 1) nutrient concentrations are high relative to biomass and non-limting; 2) the prevalence of N_2 fixation in N_2-fixing cyanobacteria is not as great as initially hypothesized; 3) the cellular N:P ratio of cyanobacteria, and their N requirement, is high; 4) analysis of lake data by several investigators have demonstrated that absolute concentrations of N and P are more important in supporting blooms of N_2 fixing cyanobacteria rather than specific ratios of dissolved N:P.

High and non-limiting nutrient concentrations

In order for changes in nutrient ratios to affect phytoplankton growth, nutrient concentrations must be so low (relative to the phytoplankton biomass) that either P or N will eventually limit their growth rates. In the last decades, both N and P loadings have increased to the point that they exceed the assimilative capacity of the resident phytoplankton in many systems (Chapman and Schelske 1997, Jacoby *et al.* 2000, Burford *et al.* 2006, Burford and O'Donahue 2006, Hong *et al.* 2006, Gobler *et al.* 2007, Suikkanen *et al.* 2007, Paerl 2008, Paerl *et al.* 2011, Dolman *et al.* 2012, O'Neill *et al.* 2012, Paerl and Paul 2012, Paerl *et al.* 2014a). Therefore, changes in the N:P ratio have little effect on the growth of any of the phytoplankton taxa present in the water column (Paerl 2008, Davidson *et al.* 2012, but see also Glibert *et al.* 2011 with respect to diatoms).

Prevalence of N_2 fixation

An assumption that must be met in order that N_2 fixing cyanobacteria dominate the community at low N:P ratios (and N limiting conditions) is that they mostly use N_2 gas rather than fixed N for growth. However, investigations demonstrate that the proportion of the N demand of N_2

fixers that is met by N_2-fixation is typically less than 25% (Levine and Lewis 1987, Findlay *et al.* 1994, Laamanen and Kuosa 2005). For example, in Baltic Sea phytoplankton communities dominated by the N_2 fixers *Aphanizomenon flos aquae* and *Nodularia spumigena*, less than 20% of N utilization is due to N_2 fixation under N-limiting conditions (Sorensson and Sahlsten 1987; Berg *et al.* 2001, 2003; Laamanen and Kuosa 2005). As mentioned in section 2.2.4, N_2 fixation is repressed in the presence of NH_4^+; culture studies of the N_2 fixing cyanobacterium *Cylindrospermopsis raciborskii* demonstrate that N_2 fixation is shut down in the presence of NH_4^+ and that it's competitive for fixed N (Sprosser *et al.* 2003, Moisander *et al.* 2008). Based on a wide range of investigations, the assumption that most of the N demand of cyanobacteria is met by N_2 fixation does not hold.

Cellular N:P composition

As discussed above (Section 2.2.5), the cellular N:P requirement of cyanobacteria is greater than any other eukaryotic group due to the large protein demand of the peripheral light harvesting antennae. At N-limiting conditions, cyanobacteria would need to provide most, if not all, of their N demand by N_2 fixation in order to meet their high tissue N demand. This would lead to a sharp divide in the distribution of genera that fix N_2 from those that do not; the latter group would be much better suited to dominate high N:P ratio (>25) than low N:P ratio environments. On the flip side, many genera of eukaryotic phytoplankton, such as diatoms and dinoflagellates, have relatively high tissue P requirements and have cellular N:P ratios <16 (Geider and LaRoche 2002, Quigg *et al.* 2003, Hillebrand *et al.* 2013) rendering them better suited for environments with N:P <16 (Arrigo *et al.* 1999, Mills and Arrigo 2010). Based on their cellular N:P ratios, cyanobacteria are better suited to dominate high N:P ratio systems (>25) and some eukaryotes low N:P ratio systems (<16) which is opposite of the conclusions reached by Smith (1983).

Confounding factors

Because the height of a phytoplankton bloom, including blooms of N_2 fixers, frequently coincides with a depletion in N and N:P <15, it is often assumed that the major control on the cyanobacteria is the nutrient ratio, rather than the other way around. Additionally, there may be time lags between nutrient uptake and increased biomass such that a correlation between the two variables at a given point in time may not imply causality. Blooms of N_2 fixers also coincide with a warm, stratified water column coupled with adequate or high irradiance. Because all these parameters (warm water, high irradiance, stratification, depletion of N, overall increase in Chl *a*) occur in concert, it's difficult to separate out the impact of nutrients from other co-occurring environmental variables in order to quantify the most important effect on increases in cyanobacterial biomass. Investigations that separate out the effect of changes in absolute concentrations from ratios, find that changes in absolute concentrations of nutrients, or changes in total Chl *a* biomass, are more strongly related to changes in cyanobacterial biomass than changes in the ratio of N:P (Trimbee and Prepas 1987, Downing *et al.* 2001, Dolman *et al.* 2012).

Meta analyses of Lake Studies

Consistent with the problems of assigning shifts in phytoplankton community composition to changes in N:P ratios described above, Trimbee and Prepas (1987) and Downing *et al.* (2001) demonstrated that changes in cyanobacterial biomass was more strongly associated with changes in the absolute concentrations of N and P than with changes in the dissolved N:P ratio in 99 different freshwater systems. In a study of 102 lakes in Germany, Dolman *et al.* (2012) found that the more enriched in both N and P the lakes were, the greater was their total cyanobacterial biomass. The cyanobacterial taxa that responded most to nutrient enrichment included *Planktothrix agardhii*, *Microcystis* and *Anabaenopsis*. Moreover, differences between cyanobacterial taxa were not consistent with the hypothesis that N fixing taxa were favored in low N:P conditions as the greatest biomass of *Aphaenizomenon* and *Cylindrospermopsis raciborskii* were found lakes with the greatest N:P ratios (Dolman *et al.* 2012).

3.2.3 Influence of Type of N on Growth of Cyanobacteria

As previously mentioned, NtcA is central in cyanobacterial N regulation and is under negative control by NH_4^+ (Section 2.2.4). Other than NH_4^+-transporters, transcription of all N related enzymes requires binding of the NtcA transcription factor in order to be transcribed. Therefore, uptake and metabolism of sources other than NH_4^+ does not take place unless NH_4^+ is at limiting concentrations (Lindell and Post 2001, Lindell *et al.* 2005). In contrast, NH_4^+ transporters are constitutively expressed, or always "on", regardless of external concentration of NH_4^+ (Berg *et al.* 2011). In addition, the *amt1* NH_4^+ transporter gene is one of the most highly expressed in cyanobacterial genomes. In the marine cyanobacteria *Synechococcus* and *Prochlorococcus*, *amt1* is expressed on par with, or at a greater level, respectively, than the gene encoding the C-fixation enzyme Rubisco (Berg *et al.* 2011). Considering the countless other critical processes happening within cells, it is noteworthy that the protein responsible for NH_4^+ uptake is one of the most abundant proteins in cyanobacteria.

Given that NH_4^+ exerts such a strong control over the use of other N sources in cyanobacteria, is the preference for NH_4^+ reflected in different rates of growth on different N sources? There is no clear answer to this question. From a theoretical perspective it should not be the case because the magnitude of reductant and ATP needed for carbon fixation dwarfs the energetic costs of N assimilation, even assimilation of "expensive" sources such as NO_3^- or N_2 gas (Turpin 1991). The type of N should not affect the rate of growth other than under conditions of very low irradiance where assimilation of NO_3^- may compete with carbon fixation for reductant and ATP, thereby lowering the growth rate (Turpin 1991). Culture investigations appear to bear this out as faster rates of growth are typically not observed when cyanobacteria are grown on NH_4^+ versus NO_3^- (i.e. Berman and Chava 1999, Hawkins *et al.* 2001, Post *et al.* 2012, Saker and Neilan 2001, Solomon *et al.* 2010). Differences in growth rates when growing on NO_3^- versus on NH_4^+ are frequently detected for individual strains (i.e. Saker and Neilan 2001), but there is no pattern that can be generalized with respect to cyanobacteria as a whole. Even within the same species, some strains may be growing faster on NH_4^+ and some on NO_3^-, but the difference with N source in most cases is smaller than the difference in growth rate among different strains (Figure 3.3). Therefore, observations of fast growth of cyanobacteria using NH_4^+ in the field are most likely due to 1) factors that promote fast growth of cyanobacteria generally (i.e. high temperature and high irradiance) combined with 2) high enough availability of NH_4^+ such that NtcA is repressed and only NH_4^+ is taken up and utilized by the cell.

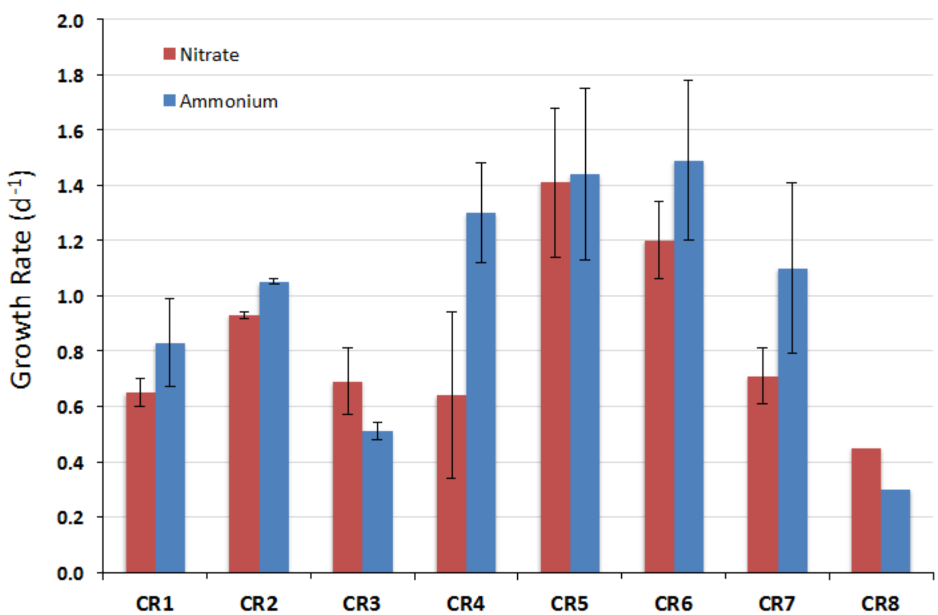


Figure 3.3. Difference in growth rates of *Cylindrospermopsin raciborskii* when growth on NO_3^- (red bars) versus NH_4^+ (blue bars) for eigth different strains. Data from Saker and Neilan 2001 and Stucken *et al.* 2014.

3.3 Irradiance and Water Clarity

Cyanobacteria have a distinct advantage with respect to other photosynthetic organisms in the amount of carotenoid pigments per cell volume (Section 2.2.2). These pigments serve a photoprotective function by dissipating excess light energy when required allowing cyanobacteria to be exposed to high irradiances without experiencing photoinhibition (Paerl *et al.* 1983, 1985). Recent investigations also demonstrate that the toxic peptides produced by cyanoHAB species accumulate in the thylakoid membranes potentially serving a role in photoprotection of the cells (Kaebernick *et al.* 2000, Borner and Dittman 2005, Gerbersdorf 2006). Interestingly, many cyanoHAB species are not strong competitors for light in a well-mixed environment due to their poor light absorption efficiency (Huisman *et al.* 1999, Reynolds 2006). Among the cyanoHAB species tested to date, *Microcystis* appears to possess the least efficient rate of photosynthesis for a given light intensity (Figure 3.4). The upshot of these traits is that cyanobacteria grow ineffectively at low and mixed light, but very effectively when exposed to high light, particularly the toxic peptide-producing varieties (Huisman *et al.* 2004, Reynolds 2006, Carey *et al.* 2012).

Aided by their positive buoyancy, cyanobacteria such as *Microcystis*, can grow very close to the surface by tolerating irradiance levels that are inhibitory to other members of the phytoplankton community. As a result, these cyanobacteria can increase their cell densities past the point where they would ordinarily become light-limited by self-shading. Growing close to the surface can also help cyanobacteria avoid light limitation if there is a high concentration of suspended sediment matter in the water. In contrast, phytoplankton than are not positively buoyant can become shaded by the cyanobacteria growing at the surface (Carey *et al.* 2012).

In contrast with *Microcystis* and *Aphanizomenon*, other cyanoHAB species such as *Cylindrospermopsis raciborskii* and *Planktothrix* sp. are good competitors at low light. Cultures of *C. Raciboskii* can grow at optimal rates at very low irradiances (Briand *et al.* 2004, Dyble *et al.* 2006, Wu et al. 2009) and it grows well in deep water columns where it's exposed to fluctuating light levels as it mixes from the surface to the bottom (McGregor and Fabbro 2000, Burford and Donohue 2006, O'Brien *et al.* 2009). Not only is the rate of photosynthesis in *C. raciborskii* efficient at low irradiances, it's also efficient at high irradiances, making this a very versatile cyanoHAB species (Figure 3.4).

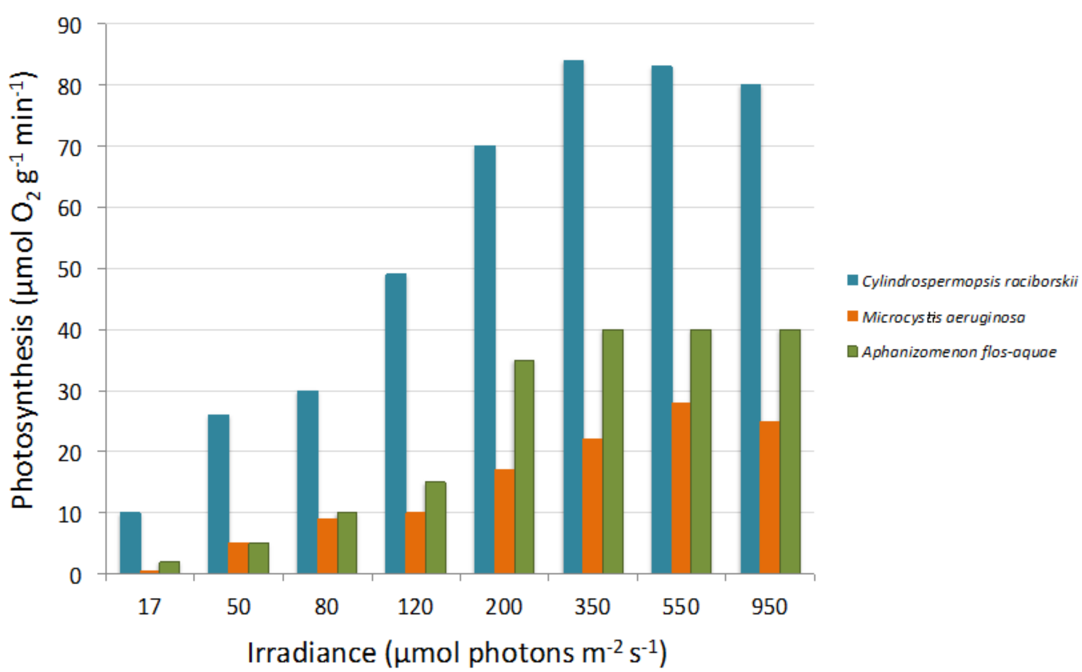


Figure 3.4. Photosynthesis as a function of irradiance in three cyanoHAB species. Data from Wu *et al.* 2009.

3.4 Factors Impacting Toxin Production and Degradation

While a large number of different toxins are produced by cyanoHAB species, the literature is heavily tilted towards investigations of factors impacting the production and degradation of microcystins. Therefore the information presented here is focused on microcystin-LR.

3.4.1 Toxin Production

Just as there is substantial discussion surrounding the purpose of toxin production in cyanobacteria, the conditions under which toxin production is enhanced is also vigorously debated. Previous studies have concluded that the greatest intracellular toxin concentrations are detected under favorable growth conditions, including high irradiance as discussed above, with maximal toxin production occurring at maximal rates of cell division and in late log phase (Watanabe and Oishi 1985, Orr and Jones 1998, Sivonen and Jones 1999, Van Der Westhuizen and Eloff 1985).

Investigations specifically focused on changes in nutrient concentrations and ratios, demonstrate that microcystin content reaches a maximum under maximum growth rates, regardless of medium N:P ratio, but that the microcystin content of the cells correlates with total cellular N and protein content (Lee *et al.* 2000, Vezie *et al.* 2002, Downing *et al.* 2005). These results make sense as the toxins, being peptides, require ample N in order to be synthesized. Consistent with this, total toxin production per cell decreases at N-limiting concentrations (Tonk *et al.* 2008).

Not only does toxin concentration per cell vary in strains that produce toxins (i.e. are toxigenic), but natural populations are typically comprised of a mix of toxigenic and non-toxigenic strains of the same species. It is also of interest to know whether the proportion of toxigenic:non-toxigenic strains within a population changes with nutrient concentrations or ratios. Laboratory culture investigations comparing growth of toxigenic and non-toxigenic strains of *Microcystis* demonstrated that toxigenic strains of *Microcystis* grew faster than non-toxigenic strains at N concentrations of 6000 µmoles L^{-1} and at N:P ratios >> 200 (Vezie *et al.* 2002). The reason for this is not clear, but could include microcystin conferring protection from NO_3^- toxicity in the toxin-producing strains at such unnaturally high concentrations of NO_3^-.

While results obtained with unnaturally high nutrient concentrations and ratios do not easily translate to natural systems, a nutrient enrichment bioassay investigation has demonstrated that toxigenic strains within a *Microcystis* population were promoted to a greater degree with N (and P) additions than non-toxigenic strains (Davis *et al.* 2010). However, the pattern of selective stimulation of toxigenic strains with increased nutrient concentrations is not evident in natural communities which typically exhibit a high degree of variability across small spatial scales in the proportion of toxigenic:non-toxigenic strains within a population. This variability appears not to be related to nutrient concentrations or ratios which do not exhibit the same spatial variability (Vezie *et al.* 1998, Baxa *et al.* 2010, Mbedi *et al.* 2005, Dolman *et al.* 2012).

3.4.2 Toxin Degradation

Together with labile dissolved organic carbon, toxins are rapidly degraded by the natural microbial community following sedimentation (and subsequent release of cellular material) of a cyanobacterial bloom (Jones *et al.* 1994, Rapala *et al.* 2005). In addition to non-specific degradation by the whole community, specific degradation of toxin peptides occurs due to bacteria belonging to the *Sphingomonadaceae* family (Bourne *et al.* 1996, 2001), and other more recently discovered families (Rapala *et al.* 2005, Yang *et al.* 2014). Bacteria that degrade microcystins may also degrade nodularin (Rapala *et al.* 2005). The predominance of these specialized bacteria in the microbial community may determine the length of time it takes (i.e. lag period) before bacterial degradation of toxins takes place. For example, Rapala *et al.* (1994) found the lag time decreased in waters with previous cyanobacterial blooms, compared with no previous cyanobacterial blooms, presumably due to a greater proportion of toxin-degradading bacteria in the former environment. Once degradation of toxin commences, it proceeds rapidly and toxin concentrations typically decrease in an exponential fashion (Figure 3.5), with a loss rate of 0.5 to 1 d^{-1}, corresponding to a half-life of only one day (Christoffersen *et al.* 2002, Jones and Orr 1994). While 95% of the toxins may be degraded within the first 3 days, a more recalcitrant fraction may remain for 20 days or more (Jones and Orr 1994). Other sinks for microcystin-LR include UV degradation (Tsuji *et al.* 1995), and adsorbtion onto clay particles (Morris *et al.* 2000). In the absence of bacteria, clay particles and UV light, microcystins are very stable in the environment and degrade slowly. At temperatures below 40°C the half-life of microcystin toxin increases to 10 weeks; this conservative estimate is used by the Office of Environmental Health Hazard Assessment to determine the risk of the toxin to wildlife (OEHHA 2009). Because there probably exists a great deal of variation in the relative importance of biological, chemical and physical processes in the degradation of microcystins depending on location, accounts in the literature regarding the half-life and recalcitrance of cyanoHAB toxins tend to be conflicting (i.e. Jones and Orr 1994, Gibble and Kudela 2014). Added to this uncertainty is the difference in toxin concentrations obtained using different methods of measurements (See Section 4.2.3 below).

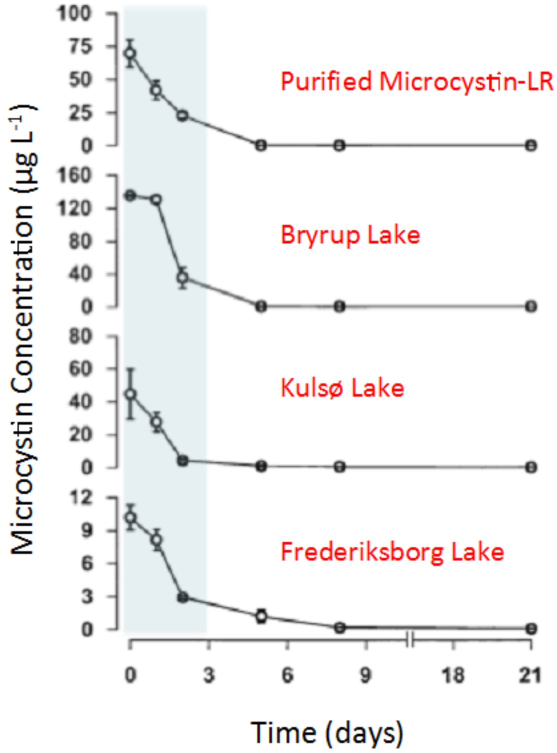


Figure 3.5. Concentration of dissolved microcystin-LR equivalents in bioassays as a function of time after addition of purified microcystin (top panel) or lysed bloom material (bottom 3 panels) to lake water containing natural microbial assemblages. Shaded area corresponds with time period of degradation of 95% of original microcystin concentration. Data from Christoffersen *et al.* 2002.

3.5 Temperature

Perhaps one of the most important factors in controlling the growth rate of cyanobacteria is temperature (Robarts and Zohary 1987, Butterwick *et al.* 2005, Reynolds 2006, Paerl and Huisman 2008). Cyanobacteria isolated from temperate latitudes (i.e. excluding polar regions) typically have temperature growth optima between 25 and 35°C (Reynolds 2006, Lurling *et al.* 2013). For example, in a survey of eight cyanobacteria the growth optima of two *Microcystis aeruginosa* strains were 30-32.5°C and that of *Aphanizomenon gracile* was 32.5°C. Lower growth temperature optima were observed in *Cynlindrospermopsis raciborskii* and *Planktothrix agardhii*, both at 27.5°C while *Anabaena* sp had an optimum of 25°C (Lurling *et al.* 2013). The optima of these freshwater HAB-forming cyanobacteria are greater than for marine cyanobacteria which typically have growth temperature optima ranging from 20-27.5°C (Breitbarth *et al.* 2007, Boyd *et al.* 2013).

Compared with other phytoplankton taxa, cyanobacteria typically demonstrate lower growth rates at colder temperatures and higher growth rates at higher temperatures. For example, diatoms typically have a 6-fold higher growth rate at 15°C, 3-fold higher growth rate at 20°C and a similar growth rate at 25°C, compared with cyanobacteria (Figure 3.6). Growth rates of dinoflagellates typically peak at 25°C. Above 25°C both chlorophytes and cyanobacteria have faster growth rates than diatoms and dinoflagellates (Figure 3.6). The difference in the optimum growth temperatures of the various phytoplankton taxa is hypothesized to become increasingly important in determining phytoplankton community composition as global temperatures continue to increase above 20°C (Lehman *et al.* 2005, Paerl and Huisman 2008). For example, the acceleration of growth rate with a 10°C increase in temperature (Q_{10}) commonly varies from 1-4 for cyanobacteria and 1-3 for chlorophytes (Reynolds 2006). However, it varies from 4-9 for *M. aeruginosa*, the highest recorded for any phytoplankton (prokaryotic or eukaryotic) species (Reynolds 2006). These data suggest that in a mixed phytoplankton assemblage, all else being equal, cyanobacteria will be able to grow faster and outcompete other phytoplankton taxa as the temperature increases. With continued climate change and global warming, there's an increased risk that cyanoHABs will become increasingly competitive vis-à-vis diatoms which often dominate community composition in temperate regions.

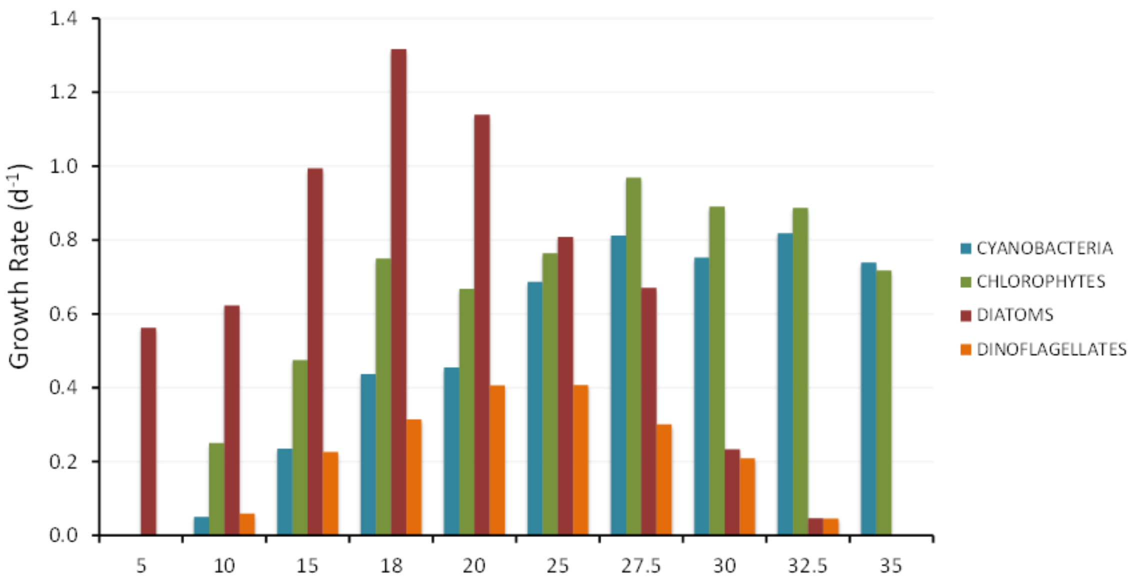


Figure 3.6. Changes in growth rate with temperature for diatoms (red ± 0.35 d^{-1}, T_{opt}= 20 ± 1.8 °C), Chlorophytes (green ± 0.21 d^{-1}, T_{opt}= 29 ± 3.8), Cyanobacteria (cyan ± 0.13 d^{-1}, T_{opt}=29 ± 4.5) and dinoflagellates (orange ± 0.1 d^{-1}, T_{opt}= 21 ± 2.8). Data from Kudo *et al.* 2000, Butterwick *et al.* 2005, Yamamoto and Nakahara 2005, Boyd *et al.* 2013, Lurling *et al.* 2013.

3.6 Stratification and Residence Time

3.6.1 Stratification

CyanoHAB blooms tend to occur during times of calm, stratified water columns (Huber *et al.* 2012). The degree of statification and water column stability increases with increased temperature, therefore stratification and temperature are closely linked (Paerl and Huisman

2008). The reasons that stratified conditions promote blooms of cyanobacteria are at least three-fold. First, growth rates will increase as a result of the increase in the temperature in the top layer of the water column. Second, cyanobacteria will remain in the top layer of the water column where irradiance is greater, and not become mixed down to the bottom and into lower light, allowing them to maintain higher growth rates. Third, stratification may be a sign of increased residence times (reduced flushing rates), which minimizes loss of cyanobacterial biomass from the system and allows cyanobacteria to use all the nutrients available in the water column (Jeppesen *et al.* 2007). In other words, it's likely that stratification does not directly promote cyanobacterial blooms, but rather it promotes blooms indirectly through increased temperatures, irradiance and reduced loss rates (Elliott 2010).

3.6.2 Residence Time

Because residence time is determined by the flushing rate, the direct effect of increased residence time is to decrease the loss rate of cyanobacteria (Romo *et al.* 2013). Indirect effects of residence time are the same as those for stratification; this is because residence time and stratification typically covary such that stratification is maximal when residence time is minimal, and vice versa. Studies that report on the effect of residence time suggest that cyanobacterial abundance, cell size and toxin concentration are positively related to increased residence time (Elliott 2010, Romo *et al.* 2013).

3.7 Other Factors

Additional to the above-mentioned factors, a number of others may influence cyanobacterial blooms including grazing by higher trophic levels and exposure to toxic compounds such as herbicides and pesticides. Grazing in the Delta region is dominated by *Corbicula fluminea* (Jassby 2008). It is not known to what extent *C. fluminea* impacts cyanoHAB species versus the rest of the phytoplankton community in the Delta. The same is true for grazing by zooplankton. Another factor that may differentially impact cyanoHAB species versus the rest of the phytoplankton community is resistance to herbicides and pesticides. Investigations demonstrate substantial variability in sensitivity to herbicides of cyanobacteria compared with other phytoplankton such as green algae and diatoms (Peterson *et al.* 1997, Lurling and Roessink 2006)

4. Prevalence of CyanoHABs and Potential for Effects on Ecosystem Services in the Delta

The Sacramento-San Joaquin Delta (hereafter Delta) is formed at the intersection of two of California's largest rivers, the Sacramento and the San Joaquin Rivers, and contains 700 miles of sloughs and waterways that drain 47% of the runoff in the State of California (Figure 1.1). The land surrounding the waterways is composed of 57 leveed island tracts, many of which provide wildlife habitat. In the Delta, freshwater from the rivers mix with saltwater from the San Francisco Bay; together the Bay and the Delta form the West Coast's largest estuary.

4.1 Ecosystem Services

The Delta region has many ecosystem services including agriculture, drinking water supplies, and wildlife habitat, all of which translate directly to the beneficial uses designated in the Water Board Basin Plan (Appendix A). The population surrounding the Delta region, numbering 500,000 people, is principally engaged in agriculture and produce crops that bring in revenues exceeding $500 million annually. While there is some local demand on the water from the Delta, most of the water is distributed via the State Water Project and Federal Central Valley Projects to the Central Valley to irrigate farmland and to provide drinking water to Southern California (http://www.water.ca.gov/swp/delta.cfm). According to the California Department of Water Resources, about two thirds of Californians and millions of acres of irrigated farmland rely on the Delta for their water. Besides acting as a source of drinking water, the Delta is a popular recreation spot and many people use it for sport fishing.

In addition to the human demand, the Delta supplies critical habitat to a large wildlife ecosystem and intersects migration paths for several fish species, including salmon, traveling between the Pacific Ocean and the Sacramento River and beyond. This habitat is in a fragile state with close to 20 of its endemic species listed as endangered. A recent and unexpected decline in four pelagic fish species including the endangered Delta Smelt and the Longfin Smelt, as well as juvenile-Striped Bass and Threadfin Shad, has caused concern among resource managers and renewed calls for conservation of the fragile Delta ecosystem (Sommer *et al.* 2007).

Set against this backdrop of competing resource use by human populations and wildlife, a new threat to Delta ecosystem services and designated beneficial uses is emerging in the form of toxic cyanoHABs. The impact of toxic cyanobacteria on the aquatic ecosystem differs widely depending on whether their density is low or high. At low concentrations, they are not dense enough to affect light penetration or dissolved O_2 concentration; therefore, they do not affect the growth of other members of the aquatic community. However, even at low concentrations toxins released (upon death and cell lysis, or by grazing) can accumulate in tissues of higher trophic levels (Lehman *et al.* 2010). At high densities, cyanoHABs increase the turbidity of the water column to the point where light penetration is severely restricted suppressing the growth of other phytoplankton, macrophytes, and benthic microalgae (Jeppesen *et al.* 2007, Paerl and Paul 2012). CyanoHABs also can cause night-time dissolved oxygen depletion via bacterial decomposition and respiration of dense blooms which results in fish kills and loss of benthic fauna (Paerl 2004, Paerl and Fulton 2006). At dense concentrations, mortality to aquatic animals such as sea otters, birds and seals may result from liver failure following ingestion of prey with high concentrations of toxin, or coming into physical contact with the toxin (Jessup *et al.* 2009, Miller *et al.* 2010). Humans coming in contact with the water may develop digestive and skin diseases (Section 2.2.6) and it may affect the drinking water supplies (Cheung *et al.* 2013). In the following sections, cyanoHAB abundance and toxin levels in the Delta vis-à-vis published guidance on alert levels are summarized in order to place the threat of cyanoHABs in the Delta into context.

4.2 Prevalence and Trends of CyanoHABs in the Delta

Since 1999 blooms of the toxin producing cyanobacteria *Microcystis aeruginosa* in the Delta have been observed by the Department of Water Resources (DWR), and have been reported in the scientific literature. In the beginning, only blooms of *Microcystis* were observed; these were documented visually appearing as little flakes of lettuce in the water (Lehman and Waller 2003). Later investigations (post 2005) employing microscopic enumeration and molecular characterizations have documented blooms comprised of a mix of *Aphanizomenon* sp. and *Microcystis*, with *Anabaena* sp. also present in much smaller densities (Lehman *et al.* 2010, Mioni *et al.* 2012).

While environmental indicators such as salinity, turbidity, temperature, total phytoplankton biomass (as Chl *a*), and phytoplankton species composition are monitored on a monthly basis by DWR, surface concentrations of cyanobacteria and cyanotoxins, which require special sampling, are not routinely monitored. As such, the information on the chronology of cyanoHAB occurrences presented here is taken from a handful of publications and reports, and varies somewhat in geographical extent according to where the authors sampled. Because *Aphanizomenon* and *Anabaena* densities have only been documented for two time points, the following sections will focus on *Microcystis* biomass and microcystin toxin concentrations. Additionally, these sections will focus on aquatic health rather than human health whose risks may be better evaluated from sampling of surface scums.

4.2.1 Spatial Distribution of Microcystis throughout the Delta

The Central Delta, between Antioch and Mildred Island, is typically the region with the highest surface *Microcystis* and *Aphanizomenon* concentrations. In 2003, the stations with the greatest recorded abundance of Chl *a* due to *Microcystis* (as determined by horizontal surface tows with a 75-µm mesh plankton net) were Jersey Point (D16), Mokelumne River Mouth and Navigation Marker 13 in the San Joaquin River, followed by San Mound Slough, Mildred Island, (D29) and Rancho del Rio (D28) in Old River (Figure 4.1). In following years, greatest abundance of

Microcystis has repeatedly occurred in the same areas in the San Joaquin and Old Rivers (Lehman *et al.* 2008, Mioni *et al.* 2012, Lehman *et al.* 2013). In 2012, abundant *Microcystis* colonies were also observed in the South-East Delta region in the Turning Basin of the Stockton Shipping Channel (Spier *et al.* 2013). Moving west from Antioch into Suisun Bay, *Microcystis* abundance decreases substantially to almost non-detectable by Chipps Island (Lehman *et al.* 2005, 2008, 2010). The same holds true when moving north where abundances detected at Antioch decline to almost zero by Collinsville at the entrance of the Sacramento River (Figure 4.1).

Whether or not the spatial distribution of *Microcystis* and other cyanoHAB species is affected favorably or unfavorably by concentrations of herbicides entering the Delta as run-off, or from the Sacramento and San Joaquin Rivers is not known. Recent reports suggest that a broad swath of herbicides and fungicides associated with agriculture is present at concentrations high enough to affect aquatic life (Orlando *et al.* 2014). As such, the impact of herbicides common to the Delta in selectively promoting certain phytoplankton species, including possibly cyanoHAB species, may deserve greater attention.

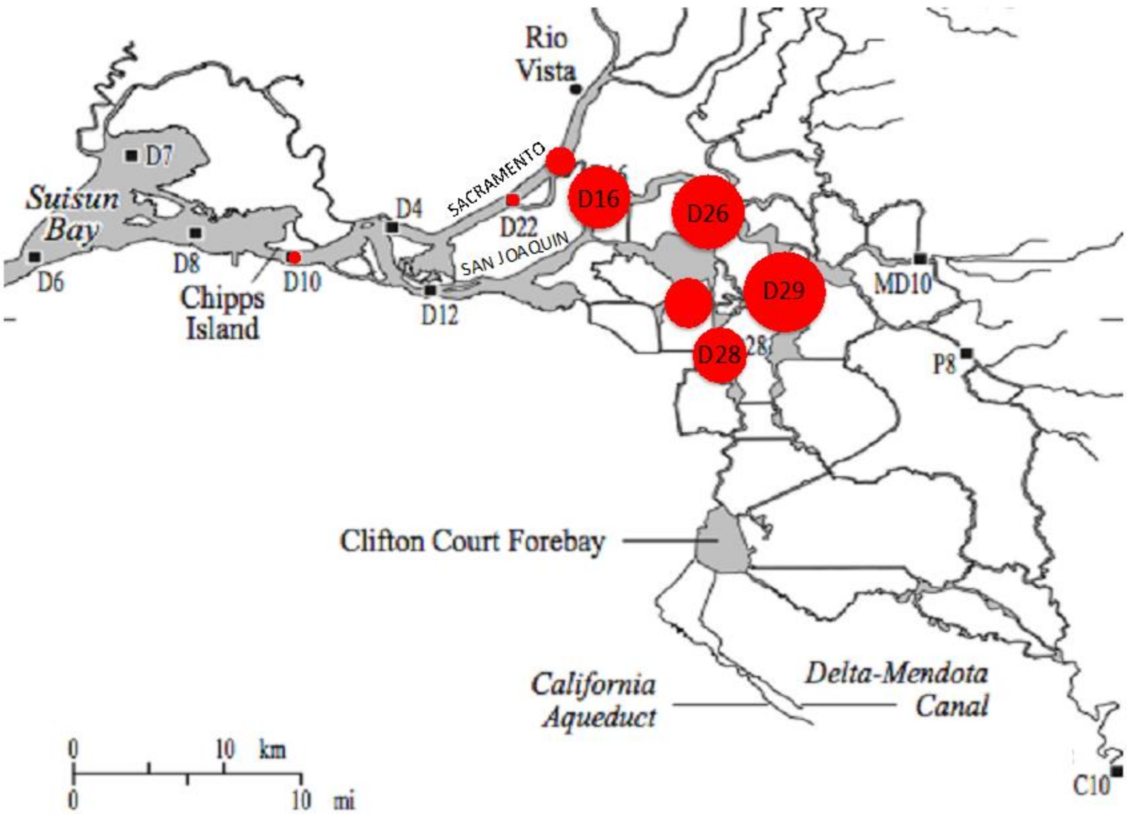


Figure 4.1. The Sacramento-San Joaquin Delta Region. Red bubbles mark locations with greatest Microcystis-associated surface Chl a concentrations (largest bubble=0.55 µg Chl a L^{-1}). Data from Lehman *et al.* 2005.

4.2.2 Interannual variability in Microcystis biomass in the Delta

Since 2003, *Microcystis* cell abundance in depth-integrated surface waters has varied from 4-40×10^3 cells mL^{-1} in the Delta (Lehman *et al.* 2008. The biomass (as surface Chl *a*) has also varied approximately 10-fold (Figure 4.2). Not only is *Microcystis* biomass patchy between years, its distribution in the years that it blooms is also variable. Even within a station, the distribution of *Microcystis* colonies is patchy, as evidenced by the low concentration of surface Chl *a*, sampled with horizontal net-tows normalized to total towed volume, which to date has not been above 0.6 µg Chl a L^{-1} (Figure 4.2). In the years following 2005, *Microcystis* was also present in the phytoplankton community together with *Aphanizomenon flos-aqua*, and to a lesser extent *Anabaena* sp. (Lehman *et al.* 2008, Mioni *et al.* 2012).

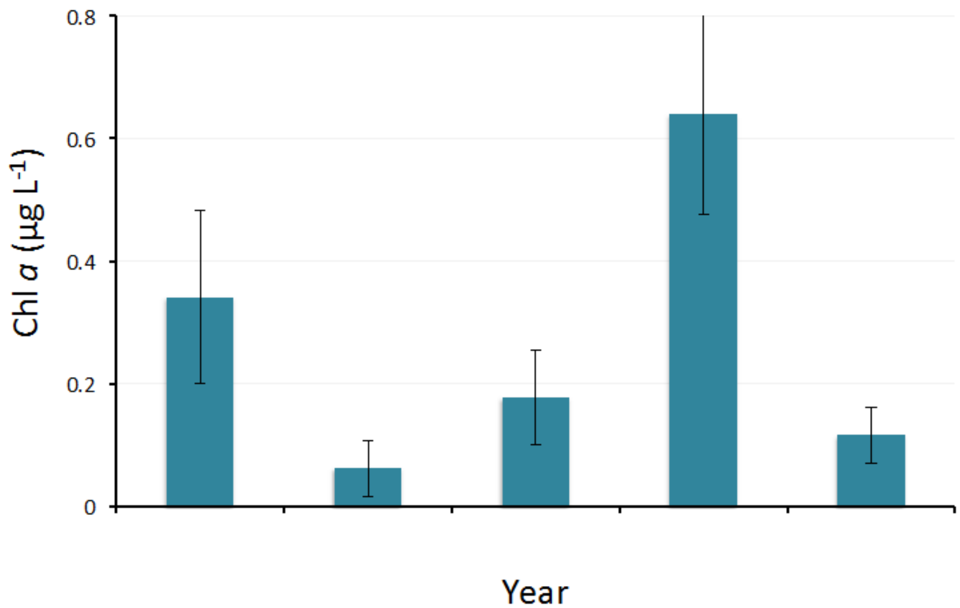


Figure 4.2. Interannual changes in surface Chl a due to abundance of Microcystis colonies. Means and standard deviations of 9 different stations in the San Joaquin River (Antioch (D12), Jersey Point (D16), Frank's Tract (D19), Potato Point (D26), Prisoners Point (D29), San Joaquin River at Turner Cut, Sand Mound Slough, Mildred Island, and Old River at Rancho del Rio (D28). Data from Lehman *et al.* 2005, 2013.

In addition to a high degree of horizontal variability, *Microcystis* cell densities and biomass also varies vertically in the water column, decreasing from the surface to almost zero at 1 m depth. The density of *Microcystis* in surface waters at the Central Delta Stations does not affect phytoplankton community composition in a measurable way. For example, at four stations where *Microcystis* dominated abundance of phytoplankton at the surface, the communities at 1m depth was a variable mix of different species of phytoplankton that was equally variable at stations containing no *Microcystis* in the surface. Rather than decreasing, the biomass of other phytoplankton taxa increased in tandem with increasing *Microcystis* biomass (Lehman *et al.* 2010).

Compared with lakes widely recognized for severe CyanoHAB problems, *Microcystis* (and other cyanoHAB species) biomass appears low. For example, in Clear Lake spring and early summer Chl *a* concentrations average 11.5±8 µg Chl *a* L^{-1} but increase to 352±295 µg Chl a L^{-1} in the summer once *Microcystis* starts to bloom (Figure 4.4). Here, *Microcystis*-associated Chl *a* concentration is a factor of 100 to 1000 greater than it is in the Delta (Figure 4.4). One important caveat with respect to determining surface Chl *a* concentrations is that it depends on the method used to collect the surface Chl *a*. The difference between using a surface net tow (akin to what is used in Lehman *et al.* 2013) and a grab sample from the middle of a patch (akin to Mioni *et al.* 2012) can be close to be 100-fold, i.e. 0.2 µg Chl a L^{-1} versus 20 µg Chl a L^{-1}, respectively. This is because the former is an integrated measure and the latter is not, suggesting that the "coverage" of *Microcystis* colonies in surface waters of the Central Delta is around 1%. This is in sharp contrast with Clear Lake where surface Chl *a* is uniformly high (above 150 µg Chl a L^{-1}) at all stations during a bloom (Richerson 1994, Mioni *et al.* 2012).

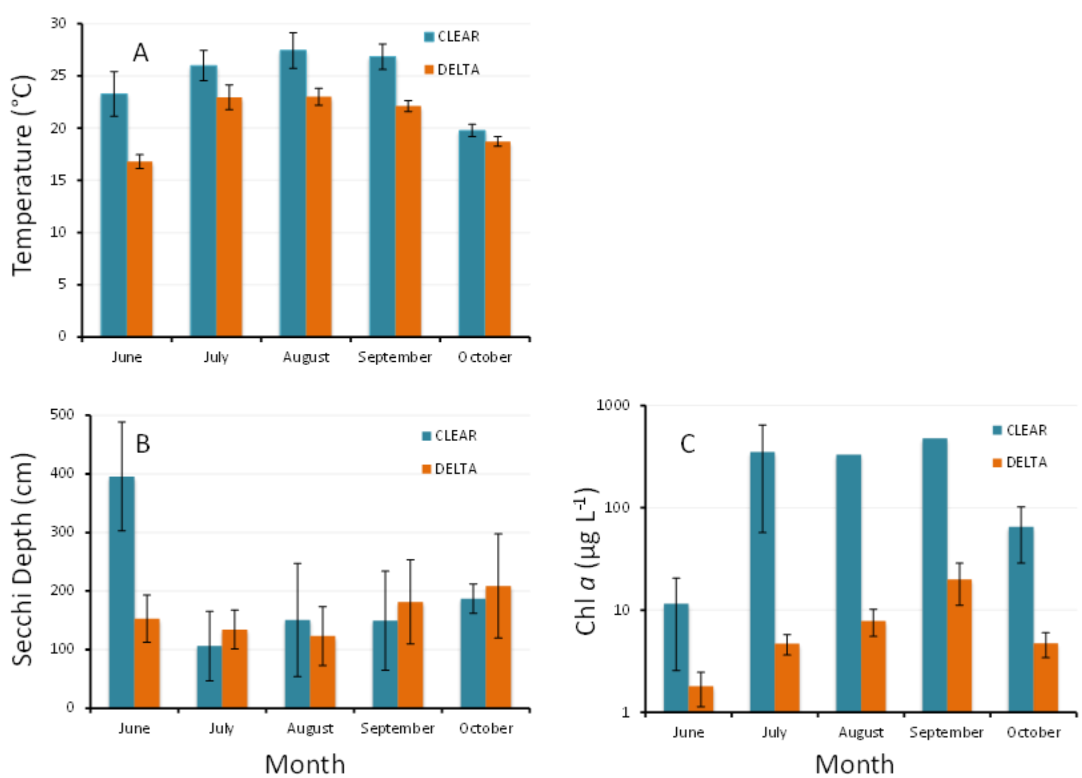


Figure 4.3. Comparison of environmental variables and Chl a in Clear Lake (Cyan) and the Delta (orange) using in-patch grab samples during the summer months of 2011. (A) Temperature, (B) Secchi disk depth, (C) Chl a. Data from Mioni *et al.* 2012.

4.2.3 Microcystin toxin concentrations in the Delta and San Francisco Bay

Given the number of different toxins produced by each cyanoHAB species, and the number of different genera present in Central California, one would expect a number of different toxins to be present in the water column. However, toxins other than microcystin are not frequently encountered (Kudela pers. com, Gibble and Kudela 2014). Based on the data available for the Delta, this section describes total microcystin concentrations and how they relate to *Microcystis* cell abundance.

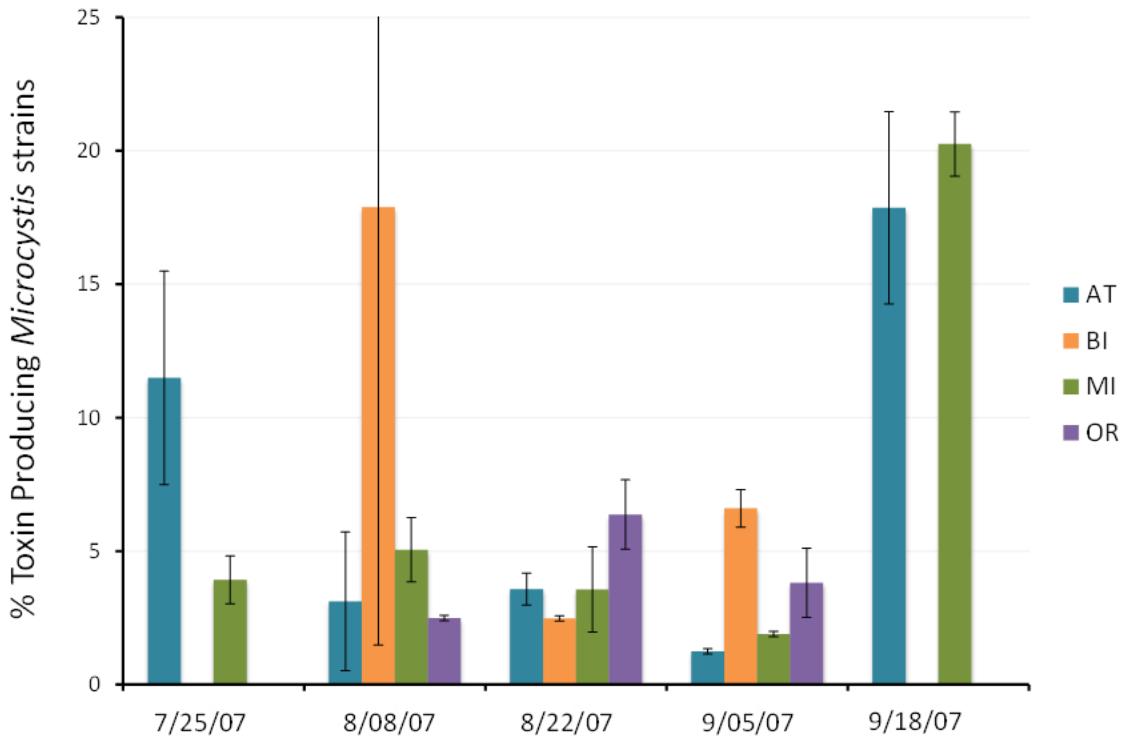


Figure 4.4. Percent toxin-producing strains in Microcystis assemblage at stations AT, Antioch (D12); BI, Brannan Island (D23); MI, Mildred Island; and OR, Old River at Rancho del Rio (D28). Data from Baxa *et al.* 2010.

Microcystis produces approximately 100-400 ng microcystin per µg Chl *a* in toxin producing strains (Sivonen and Jones 1999). Just as with other regions where *Microcystis* occurs, the strains that occur in the Delta are a mix of toxigenic and non-toxigenic strains (Baxa *et al.* 2010). Toxigenic strains generally comprise 2-20% of the total number of *Microcystis* strains present. This variation in the proportion of toxigenic strains is observed everywhere (i.e. at every station) and at all times (Figure 4.4). No single station stands out as consistently producing a greater proportion of toxigenic strains compared with other stations (Figure 4.4). Accordingly, total microcystin concentrations reflect total *Microcystis* cell abundance, typically varying from 10-50 ng L^{-1} (Lehman *et al.* 2008). However, in 2012 concentrations approaching 2000 ng L^{-1} were detected in the Stockton shipping channel during a *Microcystis* event (Spier *et al.* 2013).

In the Sacramento River, intermediate concentrations of total microcystins have been detected at a station close to Rio Vista (Brannon Island) where *Microcystis* cell abundance is low to non-detectable (Lehman *et al.* 2008, 2010). This station is connected via a channel to the San Joaquin River and the Frank's Tract area. Physical mixing of water directly from the San Joaquin River with brackish water at this station situated at the entrance to the Sacramento River may bring toxins but establishment of *Microcystis* populations may be prevented by the conditions in the Sacramento River including colder water, greater flow rates, mixing down to the bottom, and lower water clarity (Lehman *et al.* 2008).

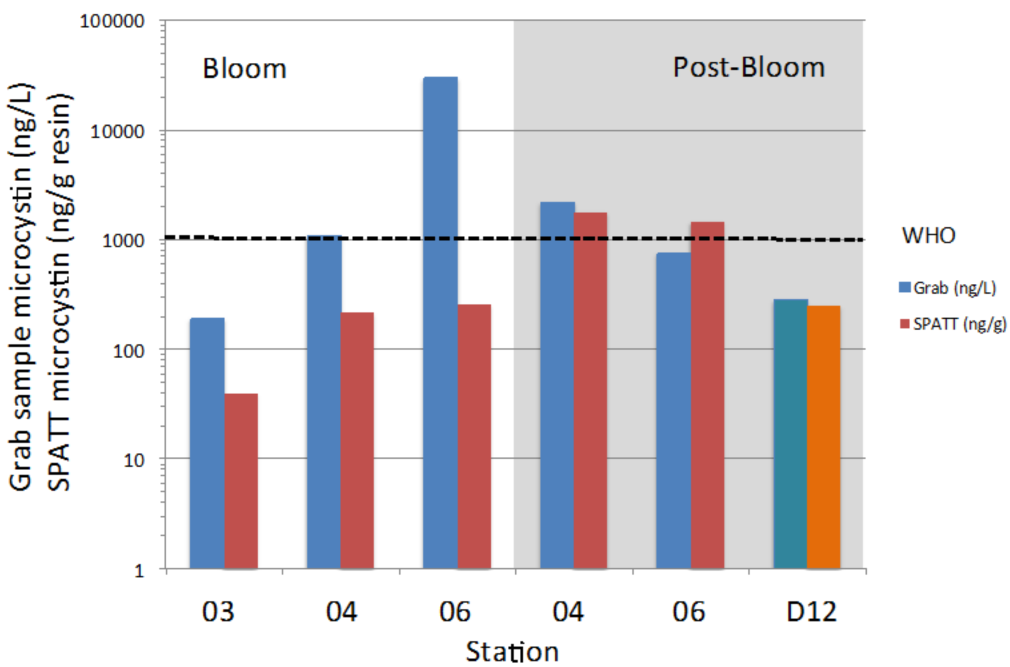


Figure 4.5. Microcystin toxin concentrations determined with grab samples (blue/cyan) and with SPATT resin (red/orange) at three stations in Clear Lake, during and after a Microcystis bloom, and at one station (D12, Antioch) in the Delta. Data from Mioni *et al.* 2012.

Microcystin toxin has also been detected at low concentrations throughout the Delta and the San Francisco Estuary using the novel Solid Phase Adsorption Toxin Tracking (SPATT) technique which integrates exposure of dissolved toxins over longer time spans (Kudela 2011). While valuable to indicate a potential for exposure to cyanotoxins, the comparison of SPATT to existing guidelines for human and aquatic health is problematic because SPATT detected concentrations are not directly comparable to traditional, instantaneous grab samples. For example, in Clear Lake microcystin detected with SPATT (ng/g resin) was 5-115 times lower than grab samples (ng/L) taken the last day of the SPATT deployment during the height of a *Microcystis* bloom (Figure 4.5). Post bloom, microcystin detected with SPATT was either comparable to, or double, levels measured in grab samples (Figure 4.5). While microcystin was detectable both with SPATT and with grab samples in Clear Lake, microcystin was detectable with SPATT in the Delta, at similar levels as in Clear Lake, but not with grab samples. In the former system *Microcystis* was very abundant and in the latter it was not. The above example illustrates that given longer equilibration times, SPATT becomes more senstitive than grab samples at lower concentrations of toxins. Although difficult to “translate” directly into effects on aquatic life (i.e. Echols *et al.* 2000), SPATT detection may be a very useful system for identifying regions at risk for harm to aquatic life from toxin exposure (Gibble and Kudela 2014).

4.2.4 Potential for CyanoHAB Risk to Delta Beneficial Uses

Characterization of the risk of cyanoHABs to Delta beneficial uses is generally poor. While no guidelines for toxicity of cyanotoxins to aquatic life have been established for California, total microcystin levels found in the Delta are within the range of potential impacts to aquatic health, as recently reviewed by the California Office of Environmental Health Hazards (OEHHA 2009). For example, microcystins are acutely toxic to fish at concentrations as low as a fraction of a microgram per liter (OEHHA 2009). Chronic exposures can also be problematic; embryos and larval fish appear to be very sensitive to chronic exposures to microcystins, resulting in oxidative stress, reduced growth, developmental defects, and lethality; exposures as low as 0.25 µg/L resulted in oxidative stress to zebrafish embryos (OEHHA 2009).

Consumption of prey items with body burdens of cyanotoxins can also be a potential pathway of impact. Lehman *et al.* (2010) traced increasing concentrations of microcystins from the water (25-50 ng L^{-1}) to zooplankton (0.4-1.5 µg g dry wt^{-1}) to striped bass muscle tissue (1-3.5 µg g dry wt^{-1}) at Central Delta Stations. These values are within the range of sublethal microcystin doses to fish (2.5 µg g dry wt^{-1}; OEHHA 2009). The striped bass caught at stations where *Microcystis* cells comprised 100% of the surface Chl *a* had tumor lesions in their liver tissue, consistent with the sublethal effects caused by microcystin-LR toxin (OEHHA 2009, Lehman *et al.* 2010). This is consistent with fish feeding studies which demonstrate that microcystin-LR spiked diets result in lesions of the liver (Deng *et al.* 2010; Acuna *et al.* 2012a,b). Zooplankton are also acutely sensitive to *Microcystis aeruginosa* cells; diets consisting of 50% toxigenic and non-toxigenic *Microcystis* strains result in 100% mortality in the copepods *Eurytemora affinis* and *Pseudodiaptomus forbesi* (Ger *et al.* 2010). Interestingly, when fed diets containing only 10-25% *Microcystis* cells, both copepods demonstrate significantly greater survival on the toxigenic strain than the non-toxigenic strain, suggesting that bioactive compounds other than the microcystin toxin exert a greater adverse impact on the zooplankton (Ger *et al.* 2010). This is consistent with a number of the studies of the effect of cyanoHABs on zooplankton mentioned in Section 2.2.6.

Determination of risk to human health in the Delta is problematic because cyanoHABs monitoring has been focused on aquatic health (depth-integrated sampling) rather than human health (via surface-scum sampling). With this caveat, toxin concentrations of 10-50 ng L^{-1} (Lehman *et al.* 2008) are 16-80 times lower than the Office of Environmental Health Hazard Assessment (OEHHA) Action Level for human health (Table 4.1), but the 2012 concentrations approaching 2000 ng L^{-1} in the Stockton shipping channel (Spier *et al.* 2013) exceed both the OEHHA Action level and the WHO guideline of 1000 ng L^{-1} (Table 4.1).

Table 4.1. Action levels developed by OEHHA (2009) for human health exposure to cyanotoxins compared with the WHO guidance level for microcystins and the EPA 10-day average exposure threshold.

Toxin	OEHHA Recreational Use (µg/L water)	OEHHA Consumption Level (ng/g fish)	WHO recreational Use (µg/L water)	EPA 10-day average (µg/L)
Microcystins	0.8	10	1.0	0.3
Cylindrospermopsin	4	70		
Anatoxin-a	90	5000		

4.2.5 Summary of Potential for Adverse Effects on Delta Beneficial Uses

A thorough characterization of the risks for adverse effects on Delta beneficial uses is hindered by the fact that cyanoHAB prevalence and toxin concentrations are currently not routinely monitored in the Delta; moreover, sampling has been focused on aquatic health and does not include sampling for human health risks. Determination of risk to human health is not possible at this time because surface scums are not currently being monitored. The current risk to Delta aquatic health is of concern and merits a more thorough investigation. This observation is based on total microcystin levels found in Delta fish tissues that are within the range of sublethal effects to fish as recently reviewed by the California Office of Environmental Health Hazards (OEHHA 2009). In addition, dissolved toxin concentrations (10- 50 ng L^{-1}) that are generally 16-80 times below the OEHHA action level, occasionally exceed both the OEHHA action level and the WHO guideline of 1000 ng L^{-1} in certain “hotspots” of the Delta. Whether or not these hotspots are expanding is currently not known and merits further investigation and monitoring.

5.0 Synthesis of Factors Influencing CyanoHABs presence and Toxin Production in the Delta

The charge of the cyanobacterial workgroup, as outlined in the Delta Nutrient Management Charter, is to “assess whether observed increases in the magnitude and frequency of cyanobacterial blooms in the Delta is the result of long-term changes in nutrient concentrations and whether management of nutrient loads can remedy the problems associated with cyanobacteria.” The best way to characterize the relationship between the extent and frequency of bloom occurrence and nutrient concentrations is by regression analysis. Ideally, this type of analysis ought to be performed in multiple locations for longer time scales. Given that temperature, irradiance and water column clarity are such powerful triggers of blooms, stepwise multiple regression analysis to test the influence of several environmental indicators simultaneously on cyanoHAB cell densities would be even more useful in order to ascertain key triggers of the blooms in the Delta region.

While environmental indicators such as salinity, turbidity, temperature, total phytoplankton biomass (as Chl *a*), and phytoplankton species composition are monitored on a monthly basis by DWR, surface concentrations of phytoplankton, which requires special sampling, are not routinely monitored in this program. Therefore, the statistical analyses needed to answer the charge of the cyanobacterial working group cannot be performed at this time. Instead, this section focuses on summarizing factors known to favor cyanobacterial prevalence (from Section 2) and synthesizing available literature on the extent to which those factors may also be at play in the Delta.

5.1 Present and Future Factors associated with cyanoHAB prevalence in the Delta

5.1.1 Flow and mixing

Environmental and population drivers that promote growth of cyanoHABs in freshwater bodies around the world also play key roles in regulating growth of cyanoHABs in the Delta (Table 5.1). Chief among these is low flow. For example, Lehman *et al.* (2013) noted that increased abundance of *Microcystis* is associated with up to a 50% reduction in flow of water in the San Joaquin River. In 2004, *Microcystis* only appeared in the Central Delta when stream flow was 1-35 $m^3 s^{-1}$ (Lehman *et al.* 2008). In addition to direct effects of decreased flow such as increased stratification of the water column, changes in flow and mixing also impart indirect effects that may influence cyanobacterial growth. These include changes in turbulence, sediment resuspension (therefore turbidity), chemical consitutents, and water temperature to mention a few. Changes in these parameters typically cannot be separated from that of flow to determine their relative importance. For example, in the Delta, reduction in flow is accompanied by a 50% reduction in turbidity and volatile suspended solids. Decreased flow also leads to increased water temperatures. Conditions of decreased flow occur more predictably in dry years (Lehman *et al.*

2013). Within the summer season, reduced flows typically occur in the July-August time frame (Figure 5.1) and set the stage for the two factors necessary for bloom initiation, including increased water column temperature and water column clarity (decreased turbidity). While decreased flow may increase the abundance of *Microcystis*, increasing rates of flow decrease its abundance because of the negative effects of water column mixing, such as light limitation, on its growth. Artificial mixing is even used as a strategy to mitigate blooms of harmful cyanobacteria in lakes and reservoirs (Reynolds *et al.* 1983, Burford and O'Donohue 2006). In the Delta, natural mixing rates may be sufficient to restrict the abundance of *Microcystis* to 10-15% of the total phytoplankton community.

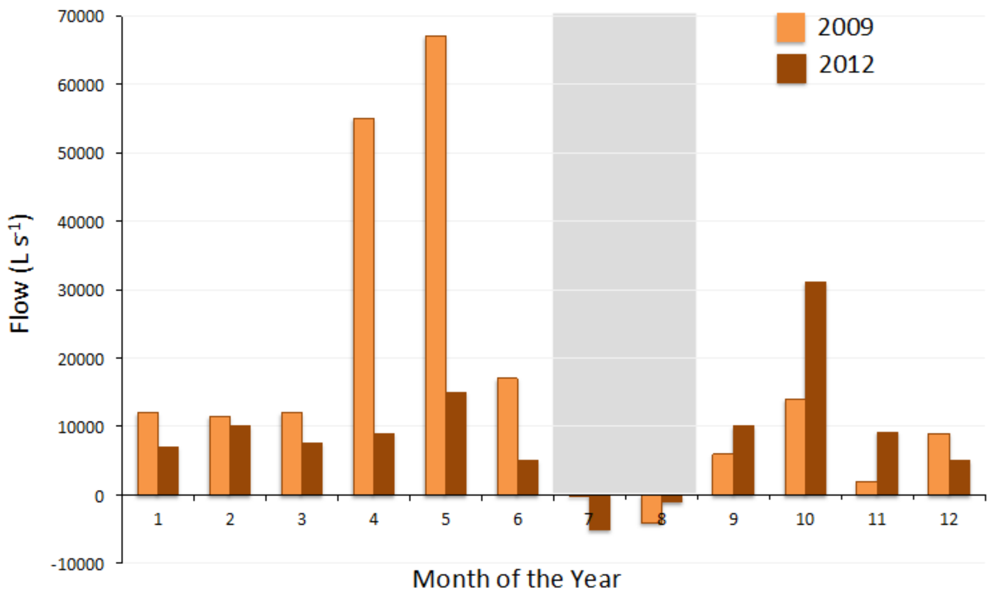


Figure 5.1. Variation in flow at Brandt Bridge in the Delta (years 2009 and 2012) illustrating the low- and reverse-flow window in July-August (shaded grey). Data and plot from Spier *et al.* 2013.

5.1.2 Temperature

Aside from the rate of water flow, water temperatures have increased globally over the last few decades as a result of global warming (Gille 2002, Hansen *et al.* 2005). In the Central Delta, a change from mainly negative deviations in the water temperature from the long-term mean to positive deviations occurred in 1999 (Figure 5.2). This local change in the water temperature may be part of the larger-scale global patterns and/or the Pacific Decadal Oscillation weather pattern which also changed sign in the same year (Cloern *et al.* 2007).

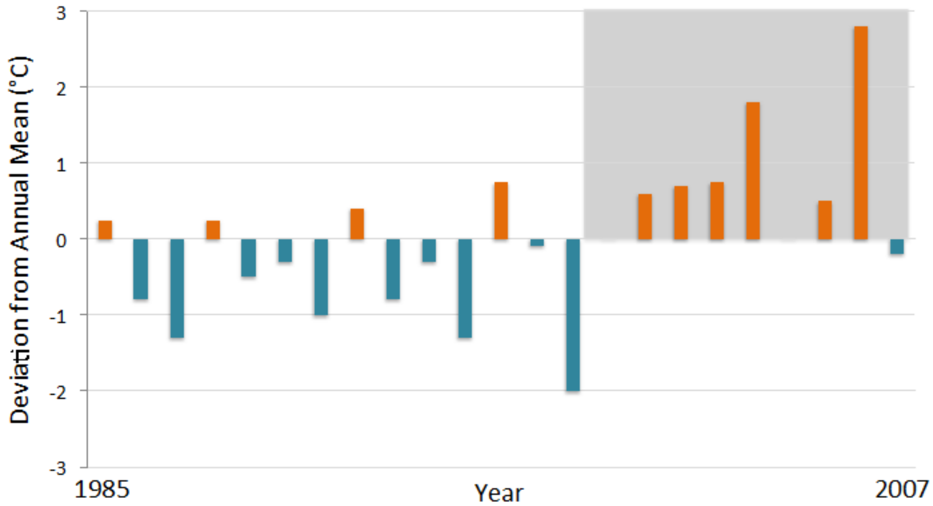


Figure 5.2. Deviation from the annual mean of maximum water temperatures at Stockton in the Central Delta. Grey shaded area indicates period from 1999 onwards with increased positive temperature deviations. Data from Brooks *et al.* 2011.

The interesting question with respect to changes in water temperatures is whether they are great enough to affect competition between cyanobacteria and other members of the phytoplankton community in the Central Delta. Presently, 40-75% of the phytoplankton community in the Delta is comprised of diatoms, followed by chlorophytes (15-30%), cyanobacteria (15-40%), cryptophytes (5-10%) and flagellates (0-10%), including dinoflagellates (Lehman 2007). In order for cyanoHAB species to to grow faster than diatoms and displace diatoms as the dominant member of the phytoplankton community, they would have to be able to accelerate their growth rates upto 2-3 fold. Alternatively, a scenario where the growth rate of diatoms would decrease and cyanobacteria would increase is necessary. Examining variation in growth rates with changes in environmental data, temperature appears the most likely candidate for bringing about such a change. Data from Figure 3.6 indicates that a doubling in cyanobacterial growth rates occurs with an increase in temperature from 20-27°C, whereas diatom growth rates decrease over the same temperature range. Therefore, a rise in temperature is a scenario under which cyanobacteria are able to outcompete diatoms.

This scenario is consistent with differences in temperature between a system, such as Clear Lake, where cyanoHABs dominate community composition, and the Delta. Comparing the 2011 environmental variables from Clear Lake and the Central Delta, two pre-bloom (June) differences become immediately clear. One is that the water temperature in Clear Lake is 7°C degrees warmer than the Delta (Figure 4.3). The other is that the Secchi disk depth is 2.6-fold greater in Clear Lake compared with the Delta (Figure 4.3). This difference in water clarity disappears in July when the *Microcystis* bloom takes off in Clear Lake, increasing Chl *a* 35-fold and decreasing the water clarity (Figure 4.3). Lehman *et al.* (2013) also predicted that the two factors that potentially would make the greatest impact on accelerating the growth of *Microcystis*, and increase the frequency and duration of blooms in the Delta, would be increased water temperatures and increased water column clarity. The earlier in the growth season that these increases would occur the greater the window of opportunity for growth would become (see also Peeters *et al.* 2007).

5.1.3 Water Clarity

The Central Delta is highly turbid due to large amounts of sediments transported into the upper estuary via the Sacramento River as well as due to sediment resuspension. However, as more and more of the sediment load is being caught behind dams, sediment transport is on the decline and the upper estuary is becoming less turbid (Schoellhamer *et al.* 2012). Since 1975, turbidity at Stations D26 and D28 has declined by on average 2 and 4% per year, respectively (Jassby 2008). These average declines are accentuated by declines in turbidity of up to 50% during the low flow months (Lehman *et al.* 2013). If these present declines in turbidity in the Central Delta continue into the future, they may substantially promote growth of cyanoHAB species.

5.1.4 Nutrient Concentrations

If water temperatures did not increase above the summer-time average of 18-20°C, could there be a 2-fold acceleration in cyanobacterial growth rates with changes in N source, or with N:P ratio, at non-limiting nutrient concentrations that would enable them to outcompete diatoms and become dominant? To answer this question, we can 1) look to growth results from culture investigations and 2) investigate how nutrient ratios differ between a system that is overwhelmed by *Microcystis* (such as Clear Lake) compared with the Delta.

1) Culture investigations demonstrate that there is no significant, or consistent, change in growth rates with change in N source, or N:P ratios, at nutrient concentrations in excess of demand (Tilman *et al.* 1982, Tett *et al.* 1985, Reynolds 1999, Saker and Neilan 2001, Roelke *et al.* 2003, Sunda and Hardison 2007).
2) Comparing the ratios of dissolved N:P between the Delta and Clear Lake, 3.6±0.6 and 2.9±0.8, respectively, it's clear that these are essentially the same (Mioni *et al.* 2012). Nutrient ratios also do not vary from pre-bloom to bloom in the Delta, indicating that nutrients are in excess of phytoplankton demand for the entire summer season (Lehman *et al.* 2008, Mioni *et al.* 2012). Moreover, nutrient concentrations, or ratios, do not change sufficiently from year–to–year in order to explain year–to–year variation *Microcystis* biomass or occurrence. For example, since 1994 there has been no change in concentrations or ratios of nutrients in the Cental Delta (Appendix A).

Therefore, the initiation of *Microcystis* blooms around 1999 in the Delta was probably not associated with changes in nutrient concentrations or their ratios. However, as with all phytoplankton blooms, once initiated, cyanoHABs cannot persist without an ample supply of nutrients. It is important to keep in mind that while nutrient reduction may not limit the onset or frequency of bloom occurrence, it will limit bloom duration, intensity and possibly also geographical extent. If, in the future, nutrient concentrations were to decrease to the point where they start to limit phytoplankton biomass, then the magnitude of the nutrient pool, as well as seasonal changes in the magnitude, would impact cyanoHAB concentration, distribution and bloom duration.

Interestingly, the long-term record for station D26 demonstrates that a decline in Chl *a* and corresponding increases in nitrogen concentrations (NH_4^+ and NO_3^-) and N:P ratios occurred in the period from 1985-1994 (Appendix A). Jassby (2008) reported similar changes in Chl *a* (decrease) and nitrogen (increase) at Central Delta Stations D16 and D28 between the years 1985 and 1994. Van Nieuwenhuyse (2007) hypothesized that the changes in N:P ratios and Chl *a* were driven by a decrease in phosphorus loadings to the Sacramento River that occurred in 1994; however the step change in P loading that year does not explain the gradual decrease in Chl *a* that started prior to 1994 (Appendix A).

Gradual decreases in Chl *a* concentrations may have been brought about by relative changes in flow and benthic grazing, leading to a new and lower Chl *a* equlibrium by the mid-1990's (Lucas and Thompson 2012). According to Lucas and Thompson (2012) the areas of the Delta where benthic grazing typically overwhelms phytoplankton growth rates are the same as those where *Microcystis* tends to bloom (Figure 4.1; Lehman *et al.* 2005). Because *Microcystis* floats at the very surface, it may avoid being grazed by clams in contrast with other phytoplankton that are distributed throughout the water column. It's important to bear in mind that large-scale (temporal and spatial) variation in environmental factors such as flow and grazing by clams may have a more profound impact on phytoplankton standing stocks, and competition among different phytoplankton taxa, compared with many of the autecological adaptations discussed in this review.

5.2 Summary

In the review of the global literature on factors influencing cyanobacterial blooms and toxin production, five principal drivers emerged as important determinants:

1) Water temperatures above 19°C
2) High irradiance and water clarity
3) Availability of N and P in non-limiting amounts; scientific consensus is lacking on the importance of N:P ratios and nutrient forms (e.g. ammonium) as a driver for cyanoHABs
4) Long residence times and stratified water column
5) Low salinity (<10 ppt) waters

Comprehensive understanding of the role of nutrients vis-à-vis other environmental factors in influencing cyanoHAB presence in the Delta is severely hampered by the lack of a routine monitoring program. The DWR monitoring program currently measures many of the environmental factors of interest, except cyanobacterial abundance and toxin concentration, which require a different approach than that used in standard phytoplankton monitoring. Drawing on the five factors influencing cyanoHABs, we can conclude the following:

- Because of the large effects of temperature and irradiance on accelerating, and decelerating, the growth rates of cyanoHABs, these two factors appear to exert key roles in the regulation of the onset of blooms. Cyanobacteria require temperatures above 20°C for growth rates to be competitive with eukaryotic phytoplankton taxa, and above 25°C for growth rates to be competitive with diatoms (Table 5.1). In addition, they require relatively high irradiance to grow at maximal growth rates. This is in contrast with diatoms that are able to keep near-maximal growth rates at irradiances limiting to cyanoHABs in the Delta, e.g., 50 µmol phot m^{-2} s^{-1} (Table 5.1).
- It appears that N and P are available in non-limiting amounts in the Delta; moreover concentrations, or ratios, do not change sufficiently from year-to-year to explain year-to-year variation in Microcystis biomass or occurrence. Therefore, the initiation of *Microcystis* blooms and other cyanoHABs are probably not associated with changes in nutrient concentrations or their ratios in the Delta. However, as with all phytoplankton blooms, once initiated, cyanoHABs cannot persist without an ample supply of nutrients. As long as temperatures, flow rates and irradiance remain favorable for growth, the size of the nutrient pool will determine the magnitude and extent of cyanoHAB blooms.
- Salinity is controlling the oceanward extent of cyanobacterial blooms in the Delta, but salinity gradients do not explain the spatial distribution of cyanoHABs in the Delta (Table 5.1). Notably, salinity regime is not a barrier to toxin transport, as cyanotoxins have been detected in San Francisco Bay.
- Higher flows, turbidity and lower temperatures during most of the year are likely restricting cyanobacterial blooms to the July-August time period.

Climate change and anthropogenic activity associated with land use changes have the potential to alter cyanoHAB prevalence in the future. Climate change will likely result in warmer temperatures and increased drought, the latter of which could result in reduced flows, increased residence time and water column stability leading to higher light availability in the Delta. Both higher temperatures and reduced flows would presumably result in a greater prevalence of cyanoHABs. It’s noteworthy that phytoplankton biomass and primary productivity are depressed relative to available nutrients in the Delta, so it’s unclear what the effect of modifying nutrient loads will have on frequency and intensity of cyanoHAB occurrence in the future.

Table 5.1. Summary of general physiological drivers of cyanobacterial growth, how they are manifested in population growth and competition with diatoms, and how they compare with environmental drivers observed to be operating in the Delta.

Physiological Driver	Population Driver	Observations in the Delta
Growth significantly slower below 20°C, and greater above 25°C, compared with eukaryotic phytoplankton taxa	Requires temperatures above 25°C for growth rates to be competitive with diatoms	Not observed at temperatures <19°C
Cyanobacteria have greater cellular N:P ratios than diatoms due to two light harvesting systems and peptide toxin production	At non-limiting nutrient concentrations, changes in ratios of nitrogen substrates or N:P does not affect competition among species or taxa	Nutrient concentrations, nitrogen speciation, and dissolved N:P ratios have not changed in the Delta over the last 25 years
Production of bioactive peptide compounds (toxic and non-toxic) results in high N demand of cells	Toxin production per cell is greatest at maximal growth rates; linked with external N concentrations and decrease at N limiting conditions; cyanoHABs do not secrete toxin	Inorganic N and P concentrations are at non-limiting concentrations for growth and toxin production; Variation in toxin produced per cell or in number of toxigenic vs non-toxigenic strains is not related to any specific environmental condition
Inefficient photosynthesis, low alpha; efficient at dissipating excess light energy via high concentration of carotenoid pigments in photosystems (*Microcystis*, *Anabaena* and *Aphanizomenon*)	CyanoHABs (*Microcystis*, *Anabaena* and *Aphanizomenon*) require high irradiance to grow; diatoms able to keep near-maximal growth rates at irradiances limiting to cyanoHABs (e.g. 50 μmol phot m^{-2} s^{-1})	High rate of water flow and mixing most of the growing season restricting blooms to low-flow periods (July-August), when turbidity is < 50 NTU, flow is <30 m^3 s^{-1} and irradiance > 50 μmol phot m^{-2} s^{-1} (Central Delta 2004-2008)
Growth optimal at salinities <10 ppt for most cyanoHAB species	CyanoHABs generally restricted to freshwater habitats and estuaries with salinities <10 ppt (Baltic Sea, San Francisco Delta, North Carolina)	Does not proliferate outside the Delta in the Sacramento River (freshwater) or Suisun Bay (mesohaline) suggesting that the primary agent restricting its spread is not salinity

6.0 RECOMMENDATIONS

The goal of this review is to synthesize available information to provide insight into cyanobacterial bloom occurrence in the Delta. The review has three major objectives:

1) Provide a basic review of biological and ecological factors that influence the prevalence of cyanobacteria and the production of cyanotoxins;
2) Summarize observations of cyanobacterial blooms and associated toxins in the Delta;
3) Synthesize literature to provide an understanding of what ecological factors, including nutrients, may be at play in promoting cyanobacterial blooms in the Delta.

This review found that the lack of a routine monitoring of cyanoHAB occurrence in the Delta greatly hindered our ability to summarize, with confidence, the status and trends of cyanoHABs in the Delta (Objective 2), and to what extent nutrients versus other factors were controlling their occurrence (Objective 3). Given this finding, our recommendations are focused on two principal actions:

1) Strengthening routine monitoring; and
2) Development and use of an ecosystem model, coupled with routine monitoring and special studies, to 1) understand controls on primary productivity and phytoplankton assemblage in the Delta and 2) test hypotheses regarding factors promoting or curtailing growth of cyanobacteria.

R1: Implement Routine Monitoring of CyanoHABs

DWR is currently conducting a monitoring program that routinely samples many of the variables of interest known to influence cyanoHABs. Comprehensive cyanoHAB monitoring should be added as a component to this program to fully evaluate risk to human and aquatic health as well as better understand linkages to factors that may be promoting or maintainting blooms.
To begin, a work plan should be developed which specifically scopes the needed changes in the program to comprehensively monitor cyanoHABs. Monitoring should include enumeration of major cyanobacterial species (e.g. *Microcystis*, *Aphanizomenon* and *Anabaena*). Sampling of toxins should include water column concentrations as well as mussel tissue concentrations or other important taxa that represent sentinels for bioaccumulation in the food web. Analyses of toxin concentrations should be expanded to include the six major cyanotoxins of concern identified in the OEHHA guidance in year 1 then adjusted based on the most commonly encountered toxins thereafter. In addition, selective sampling for analysis of concentrations of herbicides and fungicides commonly encountered in the Delta should be considered. The workplan should also consider monitoring needed to develop and calibrate an ecosystem model to further investigate controls on primary productivity and phytoplankton assemblage (see R2 below).

After an initial period of 3-5 years, the monitoring data should be used to comprehensively report on the status and trends of cyanoHABs and the factors that favor bloom occurrence in the Delta.

R2: Develop an Ecosystem Model of Phytoplankton Primary Productivity and HAB Occurrences to further Inform Future Risk and Hypotheses on Factors Controlling CyanoHABs

The Delta is at an advantage with respect to management of cyanoHABs in that naturally occurring high rates of flow and turbulence act to keep cyanobacteria in check. Despite this, future increases in temperature and residence time associated with climate change, increasing the degree and duration of stratification events, may substantially degrade the effectiveness of the Delta's breaking mechanism and increase the risk of cyanoHAB occurrences. Because nutrients are not currently limiting cyanobacterial blooms, it is critical that an improved understanding is gained of the factors that are controlling phytoplankton primary productivity in the Delta, since a relaxation of those factors followed by increased growth of phytoplankton could lead to increased risk of cyanoHABs.

To inform management actions moving into the future, an ecosystem model of phytoplankton primary productivity and HAB occurrences should be developed. This model should have the capability to provide information on primary productivity and biomass as well as planktonic food quality and transfer of carbon to higher trophic levels. Moreover, such a model could be used to assess the relative importance of environmental factors such as benthic grazing, flow, water column stability, temperature, to mention a few, at various times and locations in the Delta, on cyanobacterial growth. To step into model development, four steps should be taken: 1) examine existing models already available to determine suitability for this task, 2) utilize existing data from the Central Delta to explore, to the extent possible, the relationships between Chl *a*, phytoplankton composition, climate variables and other factors at stations where cyanoHABs are known to occur (e.g. D26, D28 and turning basin in the Stockton Shipping Channel). 3) Develop hypotheses regarding the environmental conditions in those areas that promote cyanoHABs. In addition, develop hypotheses regarding conditions needed to curtail cyanoHABs; including the effect of reducing nutrient loads on the entire phytoplankton community (including cyanobacteria) and on the transfer of carbon to higher trophic levels. These hypotheses can subsequently be tested through model development as well as potential future scenarios, and 4) a work plan should be developed that lays out the modeling strategy, model data requirements, and implementation strategy.

7.0 Literature Cited

Acuna, S., D. Baxa and S. Teh. 2012a. Sublethal dietary effects of microcystin producing *Microcystis* on threadfin shad, Dorosoma petenense. *Toxicon* 60:1191-1202.

Acuna, S., D.F. Deng, P. Lehman and S. Teh. 2012b. Sublethal dietary effects of *Microcystis* on Sacramento splittail, *Pogonichthys macrolepidotus*. *Aquatic Toxicology* 110-111:1-8.

Ahn, C.Y., H.M. Oh and Y.S. Park. 2011. Evaluation of environmental factors on cyanobacterial bloom in eutrophic reservoir using artificial neural networks. *Journal of Phycology* 47:495-504.

Alexova, R., M. Fujii, D. Birch, J. Cheng, T.D. Waite, B.C. Ferrari and B.A. Neilan. 2011. Iron uptake and toxin synthesis in the bloom-forming *Microcystis aeruginosa* under iron limitation. *Environmental Microbiology* 13:1064-1077.

Arrigo, K.R., D.H. Robinson, D.L. Worthen, R.B. Dunbar, G.R. DiTullio, M. VanWoert and M.P. Lizotte. 1999. Phytoplankton community structure and the drawdown of nutrients and CO_2 in the Southern Ocean. *Science* 283:265-367.

Babica, P., L. Blaha and B. Marsalek. 2006. Exploring the natural role of microcystin – a review of effects on photoautotrophic organisms. *Journal of Phycology* 42:9-20.

Baker, P.D. 1999. Role of akinetes in the development of cyanobacterial populations in the lower Murray River, Australia. *Marine & Freshwater Research* 50:265-279.

Baker, P.D. and D. Bellifermine. 2000. Environmental influences on akinete germination of *Anabaena circinalis* and implications for management of cyanobacterial blooms. *Hydrobiologia* 427:65-73.

Baxa, D., T. Kurobe, K.A. Ger, P.W. Lehman and S.J. Teh. 2010. Estimating the abundance of toxic *Microcystis* in the San Francisco Estuary using quantitative real-time PCR. *Harmful Algae* 9:342-349.

Beard, S.J., B.A. Handley, P.K. Hayes and A.E. Walsby. 1999. The diversity of gas vesicle genes in *Planktothrix rubescens* from Lake Zurich. *Microbiology* 145:2757-2768.

Becher, P.G., J. Beuchat, K. Gademann and F. Juttner. 2005. Nostocarboline: isolation and synthesis of a new cholinesterase inhibitor from *Nostoc* 78-12A. *Journal of Natural Products* 68:1793-1795.

Berg, G.M., P.M. Glibert, N.O.G. Jorgensen, M. Balode and I. Purina. 2001. Variability in inorganic and organic nitrogen uptake associated with riverine nutrient input in the Gulf of Riga, Baltic Sea. *Estuaries* 24:204-214.

Berg, G.M., M. Balode, I. Purina, S. Bekere, C. Bechemin and S.Y. Maestrini. 2003. Plankton community composition in relation to availability and uptake of oxidized and reduced nitrogen. *Aquatic Microbial Ecology* 30:263-274.

Berg, G.M., J. Shrager, G. van Dijken, M.M. Mills, K.R. Arrigo and A.R. Grossman. 2011. Responses of *psbA*, *hli*, and *ptox* genes to changes in irradiance in marine *Synechococcus* and *Prochlorococcus*. *Aquatic Microbial Ecology* 65:1-14.

Berman, T. and S. Chava. 1999. Algal growth on organic compounds as nitrogen sources. *Journal of Plankton Research* 21:1423-1437.

Berry, J.P., M. Gantar, M.H. Perez, G. Berry and F.G. Noriega. 2008. Cyanobacterial toxins as allelochemicals with potential applications as algicides, herbicides and insecticides. *Marine Drugs* 6:117-146.

Boison, G., C. Steingen, L.J. Stal and H. Bothe. 2006. The rice field cyanobacteria *Anabaena azotica* and *Anabaena* sp. CH1 express vanadium-dependent nitrogenase. *Archives of Microbiology* 186:367-376.

Bolmstedt, A.J., B.R. O'Keefe, R.S. Shenoy, J.B. Memahon and M.R. Boyd. 2001. Cyanoviridin-N defines a new class of antiviral agent targeting N-linked, high-mannose glycans in an oligosaccharide-specific manner. *Molecular Pharmacology* 59:949-954.

Borner, T. and E. Dittmann. 2005. Molecular biology of cyanobacterial toxins. pp. 25-40 *in*: J. Huisman, H.C.P. Matthijs and P.M. Visser (eds.), Harmful Cyanobacteria. Springer. New York, NY.

Boyd, M.R., K.R. Gustafson, J.B. McMahon, R.H. Shoemaker, B.R. O'Keefe, T. Mori, R.J. Gulakowski, L. Wu, M.I. Rivera, C.M. Laurencot, M.J. Currens, J.H. Cardellina, R.W. Buckheit, Jr., P.L. Nara, L.K. Pannell, R.C. Sowder and L.E. Hendersong . 1997. Discovery of cyanovirin-N, a novel human immunodeficiency virus-inactivating protein that binds viral surface envelope glycoprotein gp 120: potential applications to microbicide development. *Antimicrobial Agents Chemotheraphy* 42:1521-1530.

Boyd, P.W., T.A. Rynearson, E.A. Armstrong, F. Fu, K. Hayashi, Z. Hu, D.A. Hutchins, R.M. Kudela, E. Litchman, M.R. Mulholland, U. Passow, R.F. Strzepek, K.A. Whittaker, E. Yu and M.K. Thomas. 2013. Marine phytoplankton temperature versus growth responses from polar to tropical waters – outcome of a scientific community-wide study. *PLoS ONE* 8(5): e63091 doi:10.1371/journal.pone.0063091.

Bourne, D.G., G.J. Jones, R.L. Blakely, A. Jones, A.P. Negri and P. Riddles. 1996. Enzymatic pathway for the bacterial degradation of the cyanobacterial cyclic peptide toxin microcystin LR. *Applied Environmental Microbiology* 62:4086-4094.

Bourne, D.G., P. Riddles, G.J. Jones, W. Smith, R.L. Blakely. 2001. Characterisation of a gene cluster involved in bacterial degradation of the cyanobacterial toxin microcystin LR. *Environmental Toxicology* 16:523-524.

Breitbarth, E., A. Oschlies and J. LaRoche. 2007. Physiological constraints on the global distribution of *Trichodesmium* – effect of temperature on diazotrophy. *Biogeosciences* 4:53-61.

Briand, J.F., C. Leboulanger, J.F. Humbert, C. Bernard and P. Dufour. 2004. *Cylindrospermopsis raciborskii* (cyanobacteria) invasion at mid-latitudes: selection, wide physiological tolerance, or global warming. *Journal of Phycology* 40:231-238.

Brookes, J.D. and G.G. Ganf. 2001. Variations in the buoyancy response of *Microcystis aeruginosa* to nitrogen, phosphorus and light. *Journal of Plankton Research* 23:1399-1411.

Brookes, J.D., G.G. Ganf, D. Green and J. Whittington. 1999. The influence of light and nutrients on buoyancy, filament aggregation and flotation of *Anabaena circinalis*. *Journal of Plankton Research* 21:327-341.

Brooks, M.L., E. Fleishman, L.R. Brown, P.W. Lehman, I. Werner, N. Scholz, C. Mitchelmore, J.R. Lovvorn, M.L. Johnson, D. Schlenk, S. van Drunick, J.I. Drever, D.M. Stoms, A.E. Parker and R. Dugdale. 2011. Life histories, salinity zones, and sublethal contributions of contaminants to pelagic fish declines illustrated with a case study of San Francisco Estuary, California, USA. *Estuaries and Coasts* DOI 10.1007/s12237-011-9459-6.

Burford, M.A., K.L. McNeale and F.J. McKenzie-Smith FJ 2006. The role of nitrogen in promoting *Cylindrospermopsis raciborskii* in a subtropical water reservoir. *Freshwater Biology* 51:2143-2153.

Burford, M.A. and M.J. O’Donohue. 2006. A comparison of phytoplankton community assemblages in artificial and naturally mixed subtropical water reservoirs. *Freshwater Biology* 51:973-982.

Burns, W.C. 1987. Insights into zooplankton-cyanobacteria interactions derived from enclosure studies. *New Zealand Journal of Marine and Freshwater Research* 21:477-482.

Butterwick, C., S.I. Heaney and J.F. Talling. 2005. Diversity in the influence of temperature on the growth rates of freshwater algae, and its ecological relevance. *Freshwater Biology* 50:291-300.

Cardellina, J.H., F.J. Marner and R.E. Moore. 1979. Seaweed dermatitis, structure of lyngbyatoxin-A. *Science* 204:193-195.

Carey, C.C., B.W. Ibelings, E.P. Hoffmann, D.P. Hamilton and J.D. Brookes. 2012. Eco-physiological adaptations that favour freshwater cyanobacteria in a changing climate. *Water Research* 46:1394-1407.

Carmichael, W.W. 2008. A world overview one-hundred-twenty seven years of research on toxic cyanobacteria – Where do we go from here? *in*: H.K.Hudnell (ed.), Cyanobacterial Harmful Algal Blooms: State of the Science and Research Needs. Advances in Experimental Medicine & Biology, 619. Springer. New York, NY.

Carmichael, W.W., N.A. Mahmood and E.G. Hyde. 1990. Natural toxins from cyanobacteria (blue-green algae). pp. 87-106 *in*: S. Hall and G. Strichartz (eds.), Marine Toxins, Origin, Structure and Molecular Pharmacology, vol. 418. American Chemical Society USA. Boston, MA.

Chapman, A.D. and C.L. Schelske. 1997. Recent appearance of *Cylindrospermopsis* (Cyanobacteria) in five hypereutrophic Florida lakes. *Journal of Phycology* 33:191-195.

Cheung, M.Y., S. Liang and J. Lee. 2013. Toxin-producing cyanobacteria in freshwater: a review of the problems, impact on drinking water safety, and efforts for protecting public health. *Journal of Microbiology* 51:1-10.

Chorus, I. and J. Bartram. 1999. Toxic Cyanobacteria in Waters: a Guide to Public Health. Significance, Monitoring and Management, London: The World Health Organiziation E and FN Spon.

Christiansen, G., J. Fastner, M. Erhard, T. Borner and E. Dittmann. 2003. Microcystin biosynthesis in *Planktothrix*: genes, evolution, and manipulation. *Journal of Bacteriology* 185:564-572.

Christoffersen, K., S. Lyck and A. Winding. 2002. Microbial activity and bacterial community structure during degradation of microcystins. *Aquatic Microbial Ecology* 27:125-136.

Cloern, J.E., A.D. Jassby, J.K. Thompson and K.A. Hieb. 2007. A cold phase of the East Pacific triggers new phytoplankton blooms in San Francisco Bay. *Proceedings of the National Academy of Sciences USA* 104:18561-18565.

Collier, J.L. and A.R. Grossman. 1994. A small polypeptide triggers complete degradation of light-harvesting phycobiliproteins in nutrient-deprived cyanobacteria. *The EMBO Journal* 13:1039-1047.

Collier, J.L., B. Brahamsha and B. Palenik. 1999. The marine cyanobacterium *Synechococcus* sp. WH7805 requires urease (urea amidohydrolase, EC 3.5.1.5) to utilize urea as a nitrogen source: molecular-genetic and biochemical analysis of the enzyme. *Microbiology* 145:447-459.

Conley, D.J., H.W. Paerl and R.W. Howarth, D.F. Boesch S.P. Seitzinger, K.E. Havens, C. Lancelot and G.E. Likens 2009. Controlling eutrophication: nitrogen phosphorus. *Science* 323:1014-1015.

Cox, P.A., S.A. Banack, S.J. Murch, *et al.* 2005. Diverse taxa of cyanobacteria produce b-N-methylamino-L-alanine, a neurotoxic amino acid. *Proceedings of the National Academy of Sciences USA* 102:5074-5078.

Davidson, K., R.J. Gowen, P. Tett, E. Bresnan, P.J. Harrison, A. McKinney, S. Milligan, D.K. Mills, J. Silke and A.M. Crooks. 2012. Harmful algal blooms: how strong is the evidence that nutrient ratios and forms influence their occurrence? *Estuarine, Coastal and Shelf Science* 115:339-413.

Davis, T.W., M.J. Harke, M.A. Marcoval, J. Goleski, C. Orano-Dawson, D.L. Berry and C.J. Gobler. 2010. Effects of nitrogenous compounds and phosphorus on the growth of toxic and non-toxic strains of *Microcystis* during bloom events. *Aquatic Microbial Ecology* 61:149-162.

Deng, D.F., K. Zheng, F.C. Teh, P.W. Lehman and S.J. Teh. 2010. Toxic threshold of dietary microcystin (-LR) for quart medaka. *Toxicon* 55:787-794.

DeRuyter, Y.S. and P. Fromme. 2008. Molecular structure of the photosynthetic apparatus. pp. 217-269 *in*: A. Herrero and E. Flores (eds.), The Cyanobacteria Molecular Biology, Genomics and Evolution. Caister Academic Press. Norfolk, UK.

Devlin, J.P., O.E. Edwards, P.R. Gorham, M.R. Hunter, R.K. Pike and B. Stavric. 1977. Anatoxin-a, a toxic alkaloid from *Anabaena flos-aquae* NCR-44h. *Canadian Journal of Chemistry* 55:1367-1371.

Dodds WK, Bouska WW, Eitzmann JI et al. (2009) Eutrophication of U.S. freshwaters: Analysis of potential economic damages. Environ Sci Technol 43:12-19

Dolman, A.M., J. Rucker, F.R. Pick, J. Fastner, T. Rohrlack, U. Mischke and C. Wiedner. 2012. Cyanobacteria and cyanotoxins: the influence of nitrogen versus phosphorus. *PLoS ONE* 7(6):e38757. doi:10.1371/journal.one.0038757.

Downing, T.G., C.S. Sember, M.M. Gehringer and W. Leukes. 2005. Medium N:P ratios and specific growth rate comodulate microcystin and protein content in *Microcystis aeruginosa* PCC7806 and *M. aeruginosa* UV027. *Microbial Ecology* 49:468-473.

Downing, J.A., S.B. Watson and E. McCauley. 2001. Predicting cyanobacteria dominance in lakes. *Canadian Journal of Fisheries and Aquatic Sciences* 58:1905-1908.

Droop, M.R. 1974. The nutrient status of algal cells in continuous culture. *Journal of the Marine Biological Association of the United Kingdom* 55:541-555.

Dyble, J., P.A. Tester and R.W. Litaker. 2006. Effects of light intensity on cylindrospermopsin production in the cyanobacterial HAB species *Cylindrospermopsis raciborskii*. *African Journal of Marine Science* 28:309-312.

Echols, K.R., R.W. Gale, T.R. Schwartz, J.N. Huckins, L.L. Williams, J.C. Meadows, D. Morse, J.D. Petty, C.E. Orazio and D.E. Tillitt. 2000. Comparing Polychlorinated Biphenyl Concentrations and patterns in the Saginaw River using sediment, caged fish, and semipermeable membrane devices. *Environmental Science & Technology* 34:4095-4102.

Edmondson, W.R. and J.T. Lehman. 1981. The effect of changes in the nutrient income on the condition of Lake Washington. *Limnology and Oceanography* 26:1-29.

Elliott, J.A. 2010. The seasonal sensitivity of cyanobacteria and other phytoplankton to changes in flushing rate and water temperature. *Global Change Biology* 16:864-876.

Elmgren, R. and U. Larsson. 2001. Nitrogen and the Baltic Sea: managing nitrogen in relation to phosphorus. *The Scientific World* (1S2):371-377.

Elrifi, I.R. and D.H. Turpin. 1985. Steady-state luxury consumption and the concept of optimum nutrient ratios: a study with phosphate and nitrate limited *Selenastrum minutum* Chlorophyta). *Journal of Phycology* 21:592-602.

Elser JJ, Sterner RW, Gorokhova E et al. (2000) Biological stoichiometry from genes to ecosystems. *Ecological Letters* 3:540-550

Falkowski, P.G. 2000. Rationalizing elemental ratios in unicellular algae. *Journal of Phycology* 36:3-6.

Falkowski P.G. and J. LaRoche. 1991. Acclimation to spectral irradiance in algae. *Journal of Phycology* 27:8-14.

Findlay, D.L., R.E. Hecky, L.L. Hendzel, M.P. Stainton and G.W. Regehr. 1994. Relationships beween N2-fixation and heterocyst abundance and its relevance to the nitrogen budget of Lake 227. *Canadian Journal of Fisheries and Aquatic Sciences* S1:2254-2266.

Flores, E. and A. Herrero. 1994. Assimilatory nitrogen metabolism and its regulation. pp. 488-517 *in*: D.A. Bryant (ed.), The Molecular Biology of Cyanobacteria. Kluwe Academic Publishers. New York, NY.

Flores, E. and A. Herrero. 2005. Nitrogen assimilation and nitrogen control in cyanobacteria. *Biochemical Society Transactions*s 33:164-167.

Flores, E. and C.P. Worlk. 1986. Production, by filamentous, nitrogen-fixing cyanobacteria, of a bacteriocin and of other antibiotics that kill related strains. *Archives of Microbiology* 145:215-219.

Flores, E., J.E. Frias, L.M. Rubio and A. Herrero. 2005. Photosynthetic nitrate assimilation in cyanobacteria. *Photosynthesis Research* 83:117-133.

Forchammer, K. 2004. Global carbon/nitrogen control by PII signal transduction in cyanobacteria: from signals to targets. *FEMS Microbiology Reviews* 28:319-333.

Frederiksson, C. and B. Bergman. 1997. Ultrastructural characterization of cells specialized for nitrogen fixation in a non-heterocystous cyanobacterium, Trichodesmium spp. *Protoplasma* 197:76-85.

Frias, J.E., E. Flores and A. Herrero. 1994. Requirement of the regulatory protein NtcA for the expression of nitrogen assimilation and heterocyst development genes in the cyanobacterium Anabaena sp. PC 7120 *Molecular Microbiology* 14:823-832.

Fromme, P., P. Jordan and N. Krauss. 2001. Structure of photosystem I. *Biochimica et Biophysica Acta* 1507 5-31.

Fromme, P., J. Kern, B. Loll, J. Biersiadka, W. Saenger, H.T. Witt, N. Krauss and A. Zouni. 2002. Functional implications on the mechanism of the function of photosystem II including water oxidation based on the structure of Photosystem II. *Philosophical Transactions of the Royal Society of London. Series B-Biological Sciences* 357:1337-1344.

Fujiki, H., M. Suganuma, H. Suguri *et al.* 1990. New tumor promoters from marine natural products. pp. 232-240 *in*: S. Hall and G. Strichartz (eds.), Marine Toxins, Origin, Structure and Molecular Pharmacology, vol. 418. American Chemical Society USA. Boston, MA.

Garcia-Fernandez, J.M., N. Tandeau De Marsac and J. Diez. 2004. Streamlined regulation and gene loss as adaptive mechanisms in Prochlorococcus for optimized nitrogen utilization in oligotrohpic environments. *Microbiology and Molecular Biology Reviews* 68:630-638.

Geider, R. and J. La Roche. 2002. Redfield revisited: variability of C:N:P in marine microalgae and its biochemical basis. *European Journal of Phycology* 37:1-17.

Gerbersdorf, S.U. 2006. An advanced technique for immuno-labelling of microcystins in cryosectioned cells of Microcystis aeruginosa PCC 7806 (cyanobacteria): Implementations of an experiment with varying light scenarios and culture densities. *Toxicon* 47:218-228.

Ger, K.A., S.J. Teh, D.V. Baxa, S. Lesmeister and C.R. Goldman. 2010. The effect of dietary Microcystis aeruginosa and microcystin on the copepods of the upper San Francisco Estuary. *Freshwater Biology* doi:10.1111/j.1365-2427.2009.02367.x.

Gibble, C.M. and R.M. Kudela. 2014. Detection of persistent microcystin toxins at the land-sea interface in Monterey Bay, California. *Harmful Algae* 39:146-153.

Gilbert, J.J. 1996. Effect of temperature on the response of planktonic rotifers to a toxic cyanobacterium. *Ecology* 77:1174-1180.

Glibert, P.M., D. Fullerton, J.M. Burkholder, J.C. Cornwell and T.M. Kana. 2011. Ecological stoichiometry, biogeochemical cycling, invasive species, and aquatic food webs: San Francisco Estuary and comparative systems. *Reviews in Fisheries Science* 19:358-417.

Gille, S.T. 2002. Warming of the Southern ocean since the 1950s. *Science* 295:1275-1277.

Gobler, C.J., Davis, T.W., Coyne, K.J., and G.L. Boyer. 2007. The interactive influences of nutrient loading and zooplankton grazing on the growth and toxicity of cyanobacteria blooms in a eutrophic lake. *Harmful Algae* 6, 119–133.

Grossman, A.R. 2003. A molecular understanding of complementary chromatic adaptation. *Photosynthesis Research* 76:207-215.

Grossman, A.R., M.R. Schaefer, G.G. Chiang and J.L. Collier. 1993. The phycobilisome, a light-harvesting complex responsive to environmental conditions. *Microbiology Reviews* 57:725-749.

Grossman, A.R., D. Bhaya and Q. He. 2001. Tracking the light environment by cyanobacteria and the dynamic nature of light harvesting. *Journal of Biological Chemistry* 276:11449-11452.

Hansen, J., L. Nazaernko, R. Ruedy, M. Sato, J. Willis, A. Del Genio, D. Koch, A. Lacis, K. Lo, S. Menon, T. Novakav, J. Perlwitz, G. Russell, G.A. Schmidt and N. Tausnev. 2005. Earth's energy imbalance: confirmation and implications. *Science* 308:1431-1435.

Havens, K.E. 2008. Cyanobacteria blooms: effects on aquatic ecosys- tems. Cyanobacterial Harmful Algal Blooms: State of the Science and Research Needs, EPA, Adv. Exp. Med. Biol. 619, Springer Press, NY Chapter 33:733-747.

Hawkins, P.R., E. Putt, I. Falconer and A. Humpage. 2001. Phenotypical variation in a toxic strain of the phytoplankter *Cylindrospermopsis raciborskii* (Nostocales, Cyanophyceae) during batch culture. *Environmental Toxicology* 16:460-467.

Herrero, A. and E. Flores. 1990. Transport of basic amino acids by the dinitrogen-fixing cyanobacerium *Anabaena* PCC 7120. *Journal of Biological Chemistry* 265:3931-3935.

Herrero, A., A.M. Muro-Pastor and E. Flores. 2001. Nitrogen control in cyanobacteria. *Journal of Bacteriology* 183:411-425.

Herrero, A., A.M. Muro-Pastor, A. Valladares and E. Flores. 2004. Cellular differentiation and the NtcA transcription factor in filamentous cyanobacteria. *FEMS Microbiology Reviews* 28:469-487.

Hillebrand H, Steinert G, Boersma M, Malzahn A, Meunier CL, Plum C, Ptacnik R 2013. Goldman revisited: faster-growing phytoplankton has lower N:P and lower stoichiometric flexibility. *Limnology and Oceanography* 58:2076-2088.

Ho, T.Y., A. Quigg, Z.V. Finkel, A.J. Milligan, K. Wyman, P.G. Falkowski and M.M. Morel. 2003. The elemental composition of some marine phytoplankton. *Journal of Phycology* 39:1145-1159

Holland, A. and S. Kinnear. 2013. Interpreting the possible ecological role(s) of cyanotoxins: compounds for competitive advantage and/or physiological aide? *Marine Drugs* 11:2239-2258.

Hong, Y.A., R.R. Jonker, A. Inman, B. Biddanda, R. Rediske and G. Fahnenstiel. 2006. Occurrence of the toxin-producing cyanobacterium *Cylindrospermospsis raciborskii* in Mona and Muskegon Lakes, Michigan. *Journal of Great Lakes Research* 32:645-652.

Howard A, Irish AE, Reynolds CS. 1996. A new simulation of cyanobacterial underwater movement (SCUM′96). *Journal of Plankton Research* 18: 1373–1385.

Huber, V., C. Wagner, D. Gerten and R. Adrian. 2012. To bloom or not to bloom: contrasting responses of cyanobacteria to recent heat waves explained by critical thresholds of abiotic drivers. *Oecologia* 169:245-256.

Hudnell, H.K. (ed.). 2008. Cyanobacterial Harmful Algal Blooms: State of the Science and Research Needs. Advances in Experimental Medicine & Biology, 619. Springer. New York, NY.

Hudnell, H.K. 2010. The state of U.S. freshwater harmful algal blooms assessments, policy and legislation. *Toxicon* 55:1024-1034.

Huisman, J., R.R. Jonker, C. Zonneveld and F.J. Weissing. 1999. Competition for light between phytoplankton species: experimental tests of mechanistic theory. *Ecology* 80:211-222.

Huisman, J., J. Sharples, J.M. Stroom, P.M. Visser, W.E.A. Kardinaal, J.M.H. Verspagen and B. Sommeijer. 2004. Changes in turbulent mixing shift competition for light between phytoplankton species. *Ecology* 85:2960-2970.

Jacoby, J.M., Collier, D.C., Welch, E.B., Hardy, F.J., and M. Crayton,. 2000. Environmental factors associated with a toxic bloom of *Microcystis aeruginosa*. *Can. J. Fish. Aquat. Sci*. 57, 231–240.

Jassby, A. 2008. Phytoplankton in the upper San Francisco Estuary: Recent biomass trends, their causes and their trophic significance. *San Francisco Estuary and Watershed Science* 6(1) https://escholarship.org/uc/item/71h077r1.

Jeppesen, E., B. Kronvang, M. Meerhoff, M. Sondergaard, K.M. Hansen, H.E. Andersen, T.L. Lauridsen, L. Liboriussen, M. Beklioglu, A. Ozen and J.E. Olesen. 2007. Climate change effects on runoff, catchment phosphorus loading and lake ecological state, and potential adaptations. *Journal of Environmental Quality* 38:1930-1941.

Jessup D.A., Miller M.A., Ryan J.P. et al. 2009. Mass stranding of marine birds caused by a surfactant-producing Red Tide. PLoS One 4(2): e4550. doi:10.1371/journal.pone.0004550

Jones, G.J., D.G. Bourne, R.L. Blakely and H. Coelle. 1994. Degradation of the cyanobacterial hepatotoxin microcystin by aquatic bacteria. *Natural Toxins* 2:228-235.

Jones, G.J. and P.T. Orr. 1994. Release and degradation of microcystin following algicide treatment of a *Microcystis aeruginosa* bloom in a recreational lake, as determined by HPLC and protein phosphatase inhibition assay. *Water Research* 28:871-876.

Kaebernick, M., B.A. Neilan, T. Borner and E. Dittmann. 2000. Light and the transcriptional response of the microcystin gene cluster. *Applied Environmental Microbiology* 66:3387-3392.

Kamennaya N.A. and A.F. Post. 2011. Characterization of cyanate metabolism in marine *Synechococcus and Prochlorococcus* spp. *Applied and Environmental Microbiology* 77:291-301

Kaplan, A. and L. Reinhold. 1999. The CO_2 concentrating mechanisms in photosynthetic microorganisms. *Annual Review of Plant Physiology and Plant Molecular Biology* 50:539-570.

Kaplan-Levy, R.N., O. Hadas, M.L. Summers, J. Rucker and A. Sukenik. 2010. Akinetes: Dormant cells of cyanobacteria. pp. 5-28 *in*: E. Lubzens, J. Cerda and M. Clark (eds.), Dormancy and Resistance in Harsh Environments. Topics in Current Genetics. Vol. 21. Springer-Verlag. Heidelberg, GE.

Karlsson-Elfgren, I., K. Rengefors and S. Gustafsson. 2004. Factors regulating recruitment from the sediment to the water column in the bloom-forming cyanobacterium Gloeotrichia echinulata. *Freshwater Biology* 49:265-273.

Keating, K.I. 1977. Allelopathic influence on blue-green bloom sequence in a eutrophic lake. *Science* 196:885-887.

Keating, K.I. 1978. Blue-green algal inhibition of diatom growth: transition from mesotrophic to eutrophic community structure. Science 199:971-973.

Kellmann, R., T.K. Mihali, Y.J. Jeon, R. Pickford, F. Pomati and B.A. Neilan. 2008. Biosynthetic intermediate analysis and functional homology reveal a saxitoxin gene cluster in cyanobacteria. *Applied Environmental Microbiology* 74:4044-4053.

Kim, B.H., W.S. Lee, Y.O. Kim, H.O. Lee and M.S. Han. 2005. Relationship between akinete germination and vegetative population of *Anabaena flos-aquae* (Nostocales, Cyanobacteria) in Seokchon reservoir (Seoul, Korea). *Archiv fur Hydrobiologie* 163:49-64.

Klausmeier, C.A., E. Litchman, T. Daufresne and S.A. Levin. 2004. Optimal nitrogen-to-phosphorus stoichiometry of phytoplankton. *Nature* 429:171-174.

Klein, D., D. Daloze, J.C. Braekman, L. Hoffmann and V. Demoulin. 1995. New hapaindoles from the cyanophyte *Hapalasiophon laingii*. *Journal of Natural Products* 58:1781-1785.

Klemer, A.R., J. Feuillade and M. Feuillade. 1982. Cyanobacterial blooms: carbon and nitrogen limitation have opposite effects on the buoyancy of *Oscillatoria*. *Science* 2158:1629-1631.

Konopka, A., J. Kromkamp and L.R. Mur. 1987. Regulation of gas vesicle content and buoyancy in light- or phosphate-limited cultures of *Aphanizomenon flos-aquae* (Cyanophyta). *FEMS Microbial Ecology* 45:135-142.

Kudela, R.M. 2011. Characterization and deployment of Solid Phase Adsorption Toxin Tracking (SPATT) resin for monitoring of microcystins in fresh and saltwater. *Harmful Algae* 11:117-125.

Kudo, I., M. Miyamoto, Y. Noiri and Y. Maita. 2000. Combined effects of temperature and iron on the growth and physiology of the marine diatom *Phaeodactylum tricornutum* (Bacillariophyceae). *Journal of Phycology* 36:1096-1102.

Laamanen M, Kuosa H 2005. Annual variability of biomass and heterocysts of the N2-fixing cyanobacterium *Aphanizomenon flos-aquae* in the Baltic Sea with reference to *Anabaena* spp. and *Nodularia spumigena*. *Boreal Environment Research* 10:19-30.

Lee, S.J., M.H. Jang, H.S. Kim, B.D. Yoon and H.M. Oh. 2000. Variation of microcystin content of *Microcystis aeruginosa* relative to medium N:P ratio and growth stage. *Journal of Applied Microbiology* 89:323-329.

Lee, H.M., M.F. Vazquez-Bermudez and N. Tandeau de Marsac. 1999. The global nitrogen regulator NtcA regulates transcription of the signal trasducer PII (GlnB) and influences its phosphorylation level in response to nitrogen and carbon supplies in the cyanobacterium *Synechococcus* sp. strain PCC 7942. *Journal of Bacteriology* 181:2697-2702.

Lehman, P. W. 2007. The influence of phytoplankton community composition on primary productivity along the riverine to freshwater tidal continuum in the San Joaquin River, California. *Estuaries and Coasts* 30: 82-93.

Lehman, P.W. and S. Waller. 2003. Microcystis blooms in the Delta. *IEP Newsletter* 16:18-19.

Lehman, P.W., G. Boyer, C. Hall, S. Waller and K. Gehrts. 2005. Distribution and toxicity of a new colonial *Microcystis aeruginosa* bloom in the San Francisco Bay Estuary, California. *Hydrobiologia* 541:87-99.

Lehman, P.W., G. Boyer, M. Satchwell and S. Waller. 2008. The influence of environmental conditions on the seasonal variation of *Microcystis* cell density and microcystins concentration in San Francisco Estuary. *Hydrobiologia* 600:187-204.

Lehman, P.W., S.J. Teh, G.L. Boyer, M.L. Nobriga, E. Bass and C. Hogle. 2010. Initial impacts of *Microcystis aeruginosa* blooms on the aquatic food web in the San Francisco Estuary. *Hydrobiologia* 637:229-248.

Lehman, P.W., K. Marr, G.L. Boyer, S. Acuna and S.J. Teh. 2013. Long-term trends and causal factors associated with *Microcystis* abundance and toxicity in San Francisco Estuary and implications for climate change impacts. *Hydrobiologia* 718:141-158.

Leonardos, N. and R.J. Geider. 2004. Responses of elemental and biochemical composition of *Chaetoceros muelleri* to growth under varying light and nitrate:phosphate supply ratios and their influence on critical N:P. *Limnology and Oceanography* 49:2105-2114.

Levine, S.N. and W.M. Lewis. 1987. A numerical model of nitrogen fixation and its application to Lake Valencia, Venezuela. *Freshwater Biology*l 17:265-274.

Lewellyn, L.E. 2006. Saxitoxin, a toxic marine natural product that targets a multitude of receptors. *Natural Products Report* 23:200-220.

Likens, G.E., 1972. Eutrophication and aquatic ecosystems. In: Nutrients and Eutrophication: The Limiting-Nutrient Controversy, *Limnology and Oceanography Special Symposium*, vol. 1. pp. 3–13.

Lindell, D. and A.F. Post. 2001. Ecological aspects of *ntcA* gene expression and its use as an indicator of the nitrogen status of marine *Synechococcus* spp. *Applied Environmental Microbiology* 67:3340-3349.

Lindell, D., E. Padan and A.F. Post. 1998. Regulation of *ntcA* expression and nitrite uptake in the marine *Synechococcus* sp. Strain WH7803. *Journal of Bacteriology* 180:1878-1886.

Lindell, D., S. Penno, M. Al-Qutob, E. David, T. Rivlin, B. Lazar and A.F. Post. 2005. Expression of the N-stress response gene *ntcA* reveals N-sufficient *Synechococcus* populations in the oligotrophic northern Red Sea. *Limnology and Oceanography* 50:1932-1944.

Livingstone, D. and G.H.M. Jaworski. 1980. The viability of akinetes of blue-green algae recovered from the sediments of Rostherne Mere. *European Journal of Phycology* 15:357-364.

Lopez, C.B., Jewett, E.B., Dortch, Q., Walton, B.T., Hudnell, H.K. 2008. Scientific Assessment of Freshwater Harmful Algal Blooms. Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Human Health of the Joint Subcommittee on Ocean Science and Technology. Washington, DC.

Lucas, L.V. and J.K. Thompson. 2012. Changing restoration rules: exotic bivalves interact with residence time and depth to control phytoplankton productivity. *Ecosphere* 3(12):117.

Luque, I. and K. Forchammer. 2008. Nitrogen assimilation and C/N sensing. pp 334-382 *in*: A. Herrero and E. Flores (eds.), The Cyanobacteria Molecular Biology, Genomics and Evolution. Caister Academic Press. Norfolk, UK.

Luque, I., E. Flores and A. Herrero. 1994. Molecular mechanisms for the operation of nitrogen control in cyanobacteria. *The EMBO Journal* 13:2862-2869.

Lurling, M., F. Eshetu, E.J. Faassen, S. Kosten and V.M. Huszar. 2013. Comparison of cyanobacterial and green algal growth rates at different temperatures. *Freshwater Biology* 58:552-559.

Lurling, M. and I. Roessink. 2006. On the way to cyanobacterial blooms: Impact of the herbicide metribuzin on the competition between a green alga (*Scenedesmus*) and a cyanobacterium (*Microcystis*). *Chemosphere* 65:618-626.

Lyck, S., N. Gjølme and H. Utkilen. 1996. Iron starvation increases toxicity of *Microcystis aeruginosa* CYA 228/1 (Chroococcales, Cyanophyceae). *Phycologia* 35:120-124.

MacKintosh, C., K.A. Beattie, S. Klumpp, P. Cohen and G.A. Codd. 1990. Cyanobacterial microcystin-LR is a potent and specific inhibitor of protein phosphatase 1 and 2A from both mammals and higher plants. *FEBS Letters* 264:187-192.

Maeda, S.I., M. Okamura, M. Kobayashi and T. Omata. 1998. Nitrite-specific active transport system of the cyanobacterium *Synechococcus* sp. Strain PCC 7942. *Journal of Bacteriology* 180:6761-6763.

Martin-Luna, B., E. Sevilla, J.A. Hernandez, M.T. Bes, M.F. Fillat and M.L. Peleato. 2006. Fur from *Microcystis aeruginosa* binds in vitro promoter regions of the microcystin biosynthesis gene cluster. *Phytocheistry* 67:876-881.

Mbedi, S., M. Welker, J. Fastner and C. Wiedner. 2005. Variability of the microcystin synthetase gene cluster in the genus *Planktothrix* (Oscillatoriales, Cyanobacteria). *FEMS Microbiology Letters* 245:299-306.

McGregor GB, Fabbro LK 2000. Dominance of *Cylindrospermopsis raciborskii* (Nostocales, Cyanoptokaryota) in Queensland trophical and subtropical reservoirs: implications for monitoring and management. *Lakes and Reservoirs: Research and Managemen* 5:195-205.

Mejean, A., R. Mazmouz, S. Mann, A. Calteau, C. Medigue and O. Ploux. 2010. The genome sequence of the cyanobacterium *Oscillatoria* sp. PCC 6506 reveals several gene clusters responsible for the biosynthesis of toxins and secondary metabolites. *Journal of Bacteriology* 192:5264-5265.

Miller, M.M., R.M. Kudela, A. Mekebri, D. Crane, S.C. Oates, M.T. Tinker, M. Staedler, W.A. Miller, S. Toy-Choutka, C. Dominik, D. Hardin, G. Langlois, M. Murray, K. Ward and D.A. Jessup. 2010. Evidence for a novel marine harmful algal bloom: cyanotoxin (microcystin) transfer from land to sea otters. *PLoS ONE* 5(9):e12576. Doi:10.1371/journal.pone.0012576.

Mills, M.M. and K.R. Arrigo. 2010. Magnitude of oceanic nitrogen fixation influenced by the nutrient uptake ratio of phytoplankton. *Nature Geoscience* DOI: 10.1038/NGEO856.

Mioni, C., R. Kudela and D. Baxa. 2012. Harmful cyanobacteria blooms and their toxins in Clear Lake and the Sacramento-San Joaquin Delta (California). Surface Water Ambient Monitoring Program Report 10-058-150.

Mobeley, H.I., M.D. Island and R.P. Hausinger. 1995. Molecular biology of microbial ureases. *Microbiological Reviews* 59:451-480.

Moffitt, M.C. and B.A. Neilan. 2004. Characterization of the nodularin synthetase gene cluster and proposed theory of the evolution of cyanobacterial hepatotoxins. *Applied Environmental Microbiology* 70:6353-6362.

Moisander, P.H., E. McClinton and H.W. Paerl. 2002. Salinity effects on growth, photosynthetic parameters, and nitrogenase activity in estuarine planktonic cyanobacteria. *Microbial Ecology* 43:432-442.

Moisander, P.H., H.W. Paerl and J.P. Zehr. 2008. Effects of inorganic nitrogen on taxa-specific cyanobacterial growth and *nifH* expression in a subtropical estuary. *Limnology and Oceanography* 53:2519-2522.

Molot L.A., Watson S.B., Creed I.F. et al. 2014. A novel model for cyanobacteria bloom formation: the critical role of anoxia and ferrous iron. *Freshwater Biology* 59:1323-1340

Morris, R.J., D.E. Williams, H.A. Luu, C.F.B. Holmes, R.J. Andersen and S.E. Calvert. 2000. The adsorption of microcystin-LR by naural clay particles. *Toxicon* 38:303-308.

Montesinos, M.L., A. Herrero and E. Flores. 1997. Amino acid transport in taxonomically diverse cyanobacteria and identification of two genes encoding elements of a neutral amino acid permease putatively involved in recapture of leaked hydrophobic amino acids. *Journal of Bacteriology* 179:853-862.

Muro-Pastor, M.I., J.C. Reyes and F.J. Florencio. 2005. Ammonium assimilation in cyanobacteria. *Photosynthesis Research* 83:135-150

Mynderse, J.S., R.E. Moore, M. Kashiwagi and T.R. Norton. 1977. Antileukemia activity in the Oscillatoriaceae, isolation of debromoaplysiatoxin from *Lyngbya*. *Science* 196:538-540.

Nielsen, M.V. 1992. Irradiance and daylength effects on growth and chemical composition of *Gyrodinium aureolum* Hulburt in culture. *Journal of Plankton Research* 14:811-820.

Nixon, S.W. 1986. Nutrient dynamics and the productivity of marine coastal waters. pp. 97-115 in R. Halwagy, D. Clayton and M. Behbehani (eds). Marine Environment and Pollution. The Alden Press. Oxford, UK.

O'Brien, K.R., M.A. Burford and J.D. Brookes. 2009. Effects of light history on primary productivity in a *Cylindrospermopsis raciborskii*-dominated reservoir. *Freshwater Biology* 54:272-282.

OEHHA 2009. Microcystins: A brief overview of their toxicity and effects, with special reference to fish, wildlife, and livestock. Integrated Risk Assessment Branch. Office of Environmental Health Hazard Assessment. Ecotoxicology Program. California Environmental Protection Agency. January 2009.

Ohtani, I., R.E. Moore and M.T.C. Runnegar. 1992. Cylindrospermopsin, a potent hepatotoxin from the blue-green alga *Cylindrospermopsis raciborskii*. *Journal of the American Chemical Society* 114:7941-7942.

Oliver, R.L. 1994. Floating and sinking in gas-vacuolate cyanobacteria. *Journal of Phycology* 30:161-173.

O'Neill, J., T.W. Davis, M.A. Burford and C.J. Gobler CJ 2012. The rise of harmful cyanobacteria blooms: the potential roles of eutrophication and climate change. *Harmful Algae* 14:313-334.

Orlando, J.L., M. McWayne, C. Sanders and M. Hladik. 2014. Dissolved pesticide concentrations entering the Sacramento–San Joaquin Delta from the Sacramento and San Joaquin Rivers, California, 2012–13: U.S. Geological Survey Data Series 876, 28 p., http://dx.doi.org/10.3133/ds876.

Orr, P.T. and G.J. Jones. 1998. Relationship between microcystin production and cell division rates in nitrogen-limited *Microcystis aeruginosa* cultures. *Limnology and Oceanography* 43:1604-1614.

Paerl HW 2004. Estuarine eutrophication, hypoxia and anoxia dynamics: causes, consequences and controls. In: Rupp GL, White MD (eds) Proceedings of the 7th International symposium on fish physiology, toxicology and water quality. EPA Office of Research and Development, Athens, Georgia, USA EPA/600/R-04/049.

Paerl, H.W. 2008. Nutrient and other environmental controls of harmful cyanobacterial blooms along the freshwater-marine continuum. *Advances in Experimental Medicine and Biology* 619:216-241.

Paerl, H.W., P.T. Bland, N.D. Bowles and M.E. Haibach. 1985. Adaptation to high-intensity, low wavelength light among surface blooms of the cyanobacterium *Microcystis aeruginosa*. *Applied Environmental Microbiology* 49:1046-1052.

Paerl, H.W. and R.S. Fulton III. 2006. Ecology of harmful cyanobacteria. pp. 95-107 *in*: E. Graneli and J. Turner (eds.), Ecology of Harmful Marine Algae. Springer-Verlag, Berlin.

Paerl, H.W., N.S. Hall and E. Calandrino. 2011. Controlling harmful cyanobacterial blooms in a world experiencing anthropogenic and climatic-induced change. *Science of the Total Environment* 40:1739-1745.

Paerl, H.W., N.S. Hall, B.L. Peierls, and K.L. Rossignol. 2014b. Evolving paradigms and challenges in estuarine and coastal eutrophication cynamics in a culturally and climatically stressed world. *Estuaries and Coasts* 37:243-258.

Paerl, H.W. and J. Huisman. 2008. Blooms like it hot. *Science* 320:57-58.

Paerl, H.W. and V.J. Paul. 2012. Climate change: links to global expansion of harmful cyanobacteria. *Water Research* 46:1349-1363.

Paerl, H.W., J. Tucker and P.T. Bland. 1983. Carotenoid enhancement and its role in maintaining blue-green algal (*Microcystis aeruginosa*) surface blooms. *Limnology and Oceanography* 28:847-857.

Paerl, H.W., H. Xu, N.S. Hall, G. Zhu, B. Qin, Y. Wu, K.L. Rossignol, L. Dong, M.J. McCarthy and A.R. Joyner. 2014a. Controlling cyanobacterial blooms in hypertrophic Lake Taihu, China: will nitrogen reductions cause replacement of non-N_2 fixing by N_2 fixing taxa? *PLoS ON*E 9(11):e113123 doi:10.1371/journal.one.0113123.

Palinska, K.A., T. Jahns, R. Rippka and N. Tandeau De Marsac. 2000. *Prochlorococcus marinus* strain PCC 9511, a picoplanktonic cyanobacterium, synthesizes the smallest urease. Microbiology 146:3099-3107.

Parsons, T.R., K. Stephens and J.D.H. Strickland. 1961. On the chemical composition of eleven species of marine phytoplankters. *Journal of the Fisheries Research Board of Canada* 18:1001-1016.

Peeters, F., D. Straile, A. Lorke and D.M. Livingstone. 2007. Earlier onset of the spring phytoplankton bloom in lakes of the temperate zone in a warmer climate. *Global Change Biology* 13:1898-1909.

Peterson, H.G., C. Boutin, K.E. Freemark and P.A. Martin. 1997. Toxicity of hexazinone and diquat to green algae, diatoms, cyanobacteria and duckweed. *Aquatic Toxicology* 39:111-134.

Post, A.F., B. Rihtman and Q. Wang. 2012. Decoupling of ammonium regulation and ntcA transcription in the diazotrophic marine cyanobacterium *Trichodesmium* sp. IMS101. *The ISME Journal* 6:629-637.

Qin, B.Q., P.Z. Xu, Q.L. Wu, L.C. Luo and Y.L. Zhang. 2007. Environmental issues of Lake Taihu, China. *Hydrobiologia* 581:3-14.

Qin, B., G. Zhu, G. Gao, Y. Zhang, W. Li, H.W. Paerl and W.W. Carmichael WW 2010. A drinking water crisis in Lake Taihu China: linkage to climatic variability and Lake management. *Environmental Management* 45:105-112.

Quigg, A., Z.V. Finkel, A.J. Irwin Y. Rosenthal, T.-Y. Ho, J.R. Reinfelder, O. Schofield, F.M.M. Morel and P.G. Falkowski . 2003. The evolutionary inheritance of elemental stoichiometry in marine phytoplankton. *Nature* 425:291-294.

Quintero, M.J., M.L. Montesinos, A. Herrero and E. Flores. 2001. Identification of genes encoding amino acid permeases by inactivation of selected ORFs from the *Synechocystis* genomic sequence. *Genome Research* 11:2034-2040.

Ramasubramanian, T.S., T.F. Wei and J.W. Golden. 1994. Two *Anabaena* sp. strain PCC 7120 DNA-binding factors interact with vegetative cell- and heterocyst-specific genes. *Journal of Bacteriology* 176:1214-1223.

Ramm, J., A. Lupu, O. Hadas, A. Ballot, J. Rucker, C. Wiedner and A. Sukenik. 2012. A CARD-FISH protocol for the identification and enumeration of cyanobacterial akinetes in lake sediments. *FEMS Microbiology Ecology* 82:23-36.

Rapala J., Lahti K., Sivonen K., and S.I. Niemelä. 1994. Biodegradability and absorption on lake sediments of cyanobacterial hepatotoxins and anatoxin-a. *Letters in Applied Microbiology* 19: 423 – 426

Rapala J., Berg K.A., Lyra C. et al. 2005. *Paucibacter toxinivorans* gen. nov., sp. nov., a bacterium that degrades cyclic cyanobacterial hepatotoxins microcystins and nodularin. *International Journal of Systematic and Evolutionary Microbiology* 55:1563-1568.

Rapala, J., K. Sivonen, C. Lyra and S.I. Niemela. 1997. Variation of microcystins, cyanobacterial hepatotoxins, in *Anabaena* spp. as a function of growth stimuli. *Applied Environmental Microbiology* 63:2206-2012.

Raven, J.A. 1984. A cost-benefit analysis of photon absorption by photosynthetic cells. *New Phytologis* 98:593-625.

Redfield, A.C. 1958. The biological control of chemical factors in the environment. Am Sci 46:205-221.

Reynolds, C.S. 1999. Non-determinism to probability, or N:P in the community ecology of phytoplankton. *Archiv fur Hydrobiologie* 146:23-35.

Reynolds, C.S. 2006. Ecology of Phytoplankton. Cambridge University Press. Cambridge, UK.

Reynolds, C.S., S.W. Wiseman, B.M. Godfrey and C. Butterwick. 1983. Some effects of artificial mixing on the dynamics of phytoplankton populations in large limnetic enclosures. *Journal of Plankton Research* 5:203-232.

Rhee, G.Y. 1978. Effects of N:P atomic ratios and nitrate limitation on algal growth, cell composition, and nitrate uptake. *Limnology and Oceanography* 23:10-25.

Richerson, P.J., Suchanek, T.H. and Why, S.J. 1994. *The causes and control of algal blooms in Clear Lake.* Final report, July 28, 1994. Clean Lake Diagnostic/Feasibility Study for Clear Lake, California. pp.182.

Rippka R., Deruelles J., Waterbury J. B., Herdman M. and R. Y. Stanier. 1979. Generic assignments, strain histories and properties of pure cultures of cyanobacteria. *Journal of General Microbiology* 111:1-61

Robarts, R.D. and T. Zohary. 1987. Temperature effects on photosynthetic capacity, respiration and growth rates of phytoplankton of bloom-forming cyanobacteria. *New Zealand Journal of Marine and Freshwater Research* 21:391-401.

Roelke, D.L., S. Augustine and Y. Buyukates. 2003. Fundamental predictability in multispecies competition: The influence of large disturbance. *The American Naturalist* 162:615-623.

Rohrlack, T., K. Christoffersen, P.E. Hansen, W. Zhang, O. Csarnecki, M. Henning, J. Fastner, M. Erhard, B.A. Neilan and M. Kaebernick. 2003. Isolation, characterization, and quantitative analysis of microviridin J, a new *Microcystis* metabolite toxic to *Daphnia*. *Journal of Chemical Ecology* 29:1757-1770.

Rohrlack, T., E. Dittmann, M. Henning, T. Borner and J.G. Kohl. 1999. Role of microcystins in poisoning and food ingestion inhibition of Daphnia galeata caused by the cyanobacterium *Microcystis aeruginosa*. *Applied Environmental Microbiology* 65:737-739.

Romo, A., J. Soria, F. Fernandez, Y. Ouahid and A. Baron-Sola. 2013. Water residence time and the dynamics of toxic cyanobacteria. Freshwater Biology 58:513-522.

Rucker, J., E.I. Tingwey, C. Wiedner, C.M. Anu and B. Nixdorf. 2009. Impact of the inoculum size on the population of Nostocales cyanobacteria in a temperate lake. *Journal of Plankton Research* 31:1151-1159.

Runnegar, M.T., S.M. Kong, Y.Z. Zhong, J.E. Ge and S.C. Lu. 1994. The role of glutathione in the toxicity of a novel cyanobacterial alkaloid cylindrospermopsin in cultured rat hepatocytes. *Biochemical and Biophysical Research Communications* 201:235-241.

Ryther, J.H. and W.M. Dunstan. 1971. Nitrogen, phosphorus and eutrophication in the coastal marine environment. *Science* 171:1008-1112.

Saker, M.L. and B.A. Neilan. 2001. Varied diazotrophies, morphologies, and toxicities of genetically similar isolates of *Cylindrospermopsis raciborskii* (Nostocales, Cyanophyceae) from northern Australia. *Applied Microbiology* 67:1839-1845.

Sauer, J., M. Gorl and K. Forchammer. 1999. Nitrogen starvation in *Synechococcus* PCC 7942: involvement of glutamine synthetase and NtcA in phycobiliprotein degradation and survival. *Archives of Microbiology* 172:247-255.

Schindler, D.W. 1977. Evolution of phosphorus limitation in lakes. *Science* 195:260-262.

Schindler, D.W., R.W. Hecky, D.L. Findlay *et al.* 2008. Eutrophication of lakes cannot be controlled by reducing nitrogen input: results of a 37 year whole ecosystem experiment. *Proceedings of the National Academy of Sciences USA* 105:11254-11258.

Schoellhamer, D.H., S.A. Wright and J. Drexler. 2012. A conceptual model of sedimentation in the Sacramento-San Joaquin Delta. *San Francisco Estuary and Watershed Science* 10(3): https://escholarship.org/uc/item/2652z8sq.

Sivonen, K. and T. Borner. 2008. Bioactive compounds produced by cyanobacteria. pp. 159-197 *in*: A. Herrero and E. Flores (eds.), The Cyanobacteria Molecular Biology, Genomics and Evolution. Caister Academic Press. Norfolk, UK.

Sivonen K. and G.J. Jones. 1999. Cyanobacterial toxins. pp. 41-111 *in*: I. Chorus and J. Bertram (eds.), Toxic Cyanobacteria in Water: Guide to Public Health Consequences, Monitoring and Management. The World Health Organiziation E & FN Spon. London, UK.

Skulberg, O.M., W.W. Carmichael, R.A. Anderson, S. Matsunaga, R.E. Moore and R. Skulberg. 1992. Investigations of a neurotoxic Oscillatorialean strain (cyanophyceae) and its toxin. Isolation and characterization of homo-anatoxin-a. *Environmental Toxicology and Chemistry* 11:321-329.

Smith, V.H. 1983. Low nitrogen to phosphorus ratios favor dominance by blue-green algae in lake phytoplankton. *Science* 221:669-671.

Smith, V.H. 1990. Nitrogen, phosphorus, and nitrogen fixation in lacustrine and estuarine ecosystems. *Limnology and Oceanography* 35:1852-1859.

Solomon, C.M., J.L. Collier, G.M. Berg and P.M. Glibert. 2010. Role of urea in microbial metabolism in aquatic systems: a biochemical and molecular review. *Aquatic Microbial Ecology* 59:67-88.

Sommer, T., C. Armor, R. Baxter, R. Breuer, L. Brown, M. Chotkowski, S. Culberson, F. Feyrer, M. Gingras, B. Herbold, W. Kimmerer, A. Mueller-Solger, M. Nobriga and K. Souza. 2007. The collapse of pelagic fishes in the upper San Francisco Estuary. *Fisheries* 32:270-277.

Sorensson, F. and E. Sahlsten. 1987. Nitrogen dynamics of a cyanobacterial bloom in the Baltic Sea: new versus regenerated production. Mar Ecol Prog Ser 37:277-284.

Spier, C., W. Stringfellow, J. Hanlon, M. Estiandan, T. Koski and J. Kaaria. 2013. Unprecedented bloom of toxin-producing cyanobacteria in the Southern Bay-Delta Estuary and its potential negative impact on the aquatic food web. University of the Pacific Ecological Engineering Research Program Report 4.5.1.

Sprosser, P., H.M. Shafit, M. Presing, A.W. Kovacs and S. Herodek. 2003. Nitrogen uptake and fixation in the cyanobacterium *Cylindrospermopsis raciborskii* under different nitrogen conditions. Hydrobiologica 506-509:169-174.

Stockner, J.G. and J.W.G. Lund. 1970. Live algae in postglacial lake deposits. *Limnology and Oceanography* 15:41-58.

Stucken K., John U., Cembella A., Soto-Liebe K. and M. Vasquez. 2014. Impact of nitrogen sources on gene expression and toxin production in the diazotroph *Cylindrospermopsis raciborskii* CS-505 and non-diazotroph *Raphidiopsis brookii* D9. *Toxins* 6:1896-1915.

Stuken, A. and K.S. Jakobsen. 2010. The cylindrospermopsin gene cluster of *Aphanizomenon* sp. strain 10E5: Organization and recombination. *Microbiology* 156:2438-2451.

Suikkanen, S., M. Laamanen and M. Huttunen. 2007. Long-term changes in summer phytoplankton communities of the open northern Baltic Sea. *Estuarine, Coastal and Shelf Science* 71:580-592.

Sukenik, A., J. Beardall and O. Hadas. 2007. Photosynthetic characterization of developing and mature akinetes of *Aphanizomenon ovalisporum* (Cyanoprokaryota). *Journal of Phycology* 43:780-788.

Sunda, W.G. and D.R. Hardison. 2007. Ammonium uptake and growth limitation in marine phytoplankton. *Limnology and Oceanography* 52:2496-2506.

Tanigawa, R., M. Shirokane, S.S. Maeda, T. Omata, K. Tanaka and H. Takahashi. 2002. Transcirptional activation of NtcA-dependent promoters of *Synechococccus* sp. PCC 7942 by 2-oxogluterate in vitro. *Proceedings of the National Academy of Sciences USA* 99:4251-4255.

Terao, K., S. Ohmori, K. Igarashi, I. Ohtani, M.F. Watanabe, K.I. Harada, E. Ito and M. Watanabe. 1994. Electron microscopic studies on experimental poisoning in mice induced by cylindrospermopsin isolated from the blue-green alga *Umezakia natans*. *Toxicon* 32:833-843

Terry KL, Laws EA, Burns DJ (1985) Growth rate variation in the N:P requirement ratio of phytoplankton. *Journal of Phycology* 21:323-329

Tett, P., S.I. Heaney and M.R. Droop. 1985. The Redfield ratio and phytoplankton growth rate. *Journal of the Marine Biological Association of the United Kingdom* 65:487-504.

Thiel, T. 1993. Characterization of genes for an alternative nitrogenase in the cyanobacterium *Anabaena variabilis*. *Journal of Bacteriology* 175:6276-6286.

Thiel, T. and C.P. Wolk. 1983. Metabolic activities of isolated akinetes of the cyanobacterium *Nostoc spongiaforme*. *Journal of Bacteriology* 156:369-374.

Thomas RH, Walsby AE. 1985. Buoyancy regulation in a strain of *Microcystis. Journal of General Microbiology* 131: 799–809.

Tillett, D., E. Dittmann, M. Erhard, H. von Dohren, T. Borner and B.A. Neilan. 2000. Structural organization of microcystin biosynthesis in *Microcystis aeruginosa* PCC 7806: an integrated peptide-polyketide synthase system. *Chemical Biology* 7:753-764.

Tilman, D., S.S. Kilham and P. Kilham. 1982. Phytoplankton community ecology: the role of limiting nutrients. *Annual Review of Ecology, Evolution, and Systematics* 13:349-372.

Tomatini, A., A.H. Knoll, C.M. Cavanaugh and T. Ohno. 2006. The evolutionary difersification of cyanobacteria: Molecular-phylogenetic and paleontological perspectives. *Proceedings of the National Academy of Sciences USA* 103:5442-5447.

Tonk, L., K. Bosch, P.M. Visser and J. Huisman. 2007. Salt tolerance of the harmful cyanobacterium *Microcystis aeruginosa*. *Aquatic Microbial Ecology* 46:117-123.

Tonk, L., D.B. van de Waal, P. Slot, J. Huisman, H.C. Matthijs and P.M. Visser. 2008. Amino acid availability determines the ratio of microcystin variants in the cyanobacterium *Planktothrix agardhii*. *FEMS Microbiology Ecology* 65:383-390.

Tonk, L., P.M. Visser, G. Christiansen, E. Dittmann, E.O.F.M. Snelder, C. Wiedner, L.R. Mur and J. Huisman. 2005. The microcystin composition of the cynobacterium *Planktothrix agardhii* changes toward a more toxic variant with increasing light intensity. *Applied Environmental Microbiology* 71:5177-5181.

Trimbee, A.M. and E.E. Prepas. 1987. Evaluation of total phosphorus as a predictor of the relative biomass of blue-green algae with emphasis on Alberta lakes. *Canadian Journal of Fisheries and Aquatic Sciences* 44:1337-1342.

Turner S., Pryer K.M., Miao V.P. and J.D. Palmer. 1999. Investigating deep phylogenetic relationships among cyanobacteria and plastids by small subunit rRNA sequence analysis. *Journal of Eukaryotic Microbiology* 46:327-338.

Turpin, D.H. 1991. Effects of inorganic N availability on algal photosynthesis and carbon metabolism. *Journal of Phycology* 27:14-20.

Tsuji, K., T. Watanuki, F. Kondo, M.F. Watanabe, S. Suzuki, H. Nakazawa, M. Suzuki, H. Uchida, and K.-I. Harada. 1995. Stability of microcystins from cyanobacteria II. Effect of UV light on decomposition and isomerization. *Toxicon* 33:1619-1631.

Utkilen, H. and N. Gjølme. 1995. Iron-stimulated toxin production in *Microcystis aeruginosa*. *Applied Environmental Microbiology* 61:797-800

Valladares, A., M.L. Montesinos, A. Herrero and E. Flores. 2002. An ABC-type, high-affinity urea permease identified in cyanobacteria. *Molecular Microbiology* 43:703-715.

Van Der Westhuizen, A.J. and J.N. Eloff. 1985. Effect of temperature and light on the toxicity and growth of the blue-green alga *Microcystis aeruginosa* (UV006). *Planta* 163:55-59.

Van Nieuwenhuyse, E.E. 2007. Response of summer chlorophyll concentration to reduced total phosphorus concentration in the Rhine River (Netherlands) and the Sacramento-San Joaquin Delta (California, USA). *Canadian Journal of Fisheries and Aquatic Sciences* 64:1529-1542.

Vazquez-Bermudez, M.F., A. Herrero and E. Flores. 2002. 2-Oxogluterate increases the binding affinity of the NtcA (nitrogen control) transcription factor for the *Synechococcus* glnA promoter. *FEBS Letters* 512:71-74.

Vezie, C., L. Brient, K. Sivonen G. Bertru, J.-C. Lefeuvre and M. Salkinoja-Salonen. 1998. Variation of microcystin content of cyanobacterial blooms and isolated strains in Lake Grand-Lieu (France). *Microbial Ecology* 35:126-135.

Vezie, C., J. Rapala, J. Vaitomaa, J. Seitsonen and K. Sivonen. 2002. Effect of nitrogen and phosphorus on growth of toxic and nontoxic *Microcystis* strains and on intracellular microcystin concentrations. *Microbial Ecology* 43:443-454.

Visser, P.M., J. Passarge and L.R. Mur. 1997. Modelling vertical migration of the cyanobacterium *Microcystis*. Hydrobiologia 349-99-109.

Walsby, A.E. 1994. Gas vesicles. *Microbiological Reviews* 58:94-144.

Walsby, A.E. 2005. Stratification by cyanobacteria in lakes: a dynamics buoyancy model indicates size limitations met by Planktothrix rubescens filaments. *New Phytologist* 168:365-376.

Walsby, A.E., G. Ng, C. Dunn and P.A. Davis. 2004. Comparison of the depth where Planktothrix rubescens stratifies and the depth where the daily insolation supports its neutral buoyancy. *New Phytologist* 162:133-145.

Wallace, B.B. and D.P. Hamilton. 1999. The effect of variation in irradiance on buoyancy regulation in *Microcystis aeruginosa*. *Limnology and Oceanography* 44:273-281.

Watanabe, M.F. and S. Oishi. 1985. Effects of environmental factors on toxicity of a cyanobacterium (*Microcystis aeruginosa*) under culture conditions. *Applied Environmental Microbiology* 49:1342-1344.

Wei, T.F., T.S. Ramasubramanian and J.W. Golden. 1994. *Anabaena* sp. strain PCC 7120 ntcA gene required for growth on nitrate and heterocyst development. *Journal of Bacteriology* 176:4473-4482..

Welker, M. and H. von Dohren. 2006. Cyanobacterial peptides – Nature's own combinatorial biosynthesis. *FEMS Microbiology Reviews* 30:530-563.

Wiedner, C., P.M. Visser, J. Fastner, J.S. Metcalf, G.A. Codd and L.R. Mur. 2003. Effects of light on the microcystin content of *Microcystis* strain PCC 7806. *Applied Environmental Microbiology* 69:1475-1481.

Wolk, C.P., A. Ernst and J. Elhai. 1994. Heterocyst metabolism and development. pp. 769-823 *in*: D.A. Bryant (ed.), The Molecular Biology of Cyanobacteria. Kluwe Academic Publishers. New York, NY.

Wu, Z., J. Shi and R. Li. 2009. Comparative studies on photosynthesis and phosphate metabolism of Cylindrospermospsis raciborskii with Microcystis aeruginosa and Aphanizomenon flos-aquae 2009. *Harmful Algae* 8:910-915

Wynne, D. and G.Y. Rhee. 1986. Effects of light intensity and quality on the relative N and P requirement (the optimum N:P ratio) of marine planktonic algae. *Journal of Plankton Research* 8:91-103

Yamamoto Y. and H. Nakahara. 2005. The formation and degradation of cyanobacterium *Aphanizomenon flos-aquae* blooms: the importance of pH, water temperature, and day length. *Limnology* 6:1-6.

Yang, F., Y. Zhou, L. Yin, G. Zhu, G. Liang and Y. Pu. 2014. Microcystin-degrading activity of an indigenous bacterial strain *Stenotrophomonas acidaminiphila* MC-LTH2 isolated from Lake Taihu. *PLoS ONE* 9(1): e86216. doi:10.1371/journal.pone.0086216

Yoshimasa, Y. and H. Nakahara. 2005. The formation and degradation of cyanobacterium *Aphanizomenon flos-aquae* blooms: the importance of pH, water temperature, and day length. *Limnology* 6:1-6.

Yoshizawa, S., R. Matsushima, M.F. Watanabe, K. Harda, A. Ichihara, W.W. Carmichael and H. Fujiki. 1990. Inhibition of protein phosphatases by microcystin and nodularin associated with hepatotoxicity. *Journal of Cancer Research and Clinical Oncology* 116:609-614.

APPENDIX A

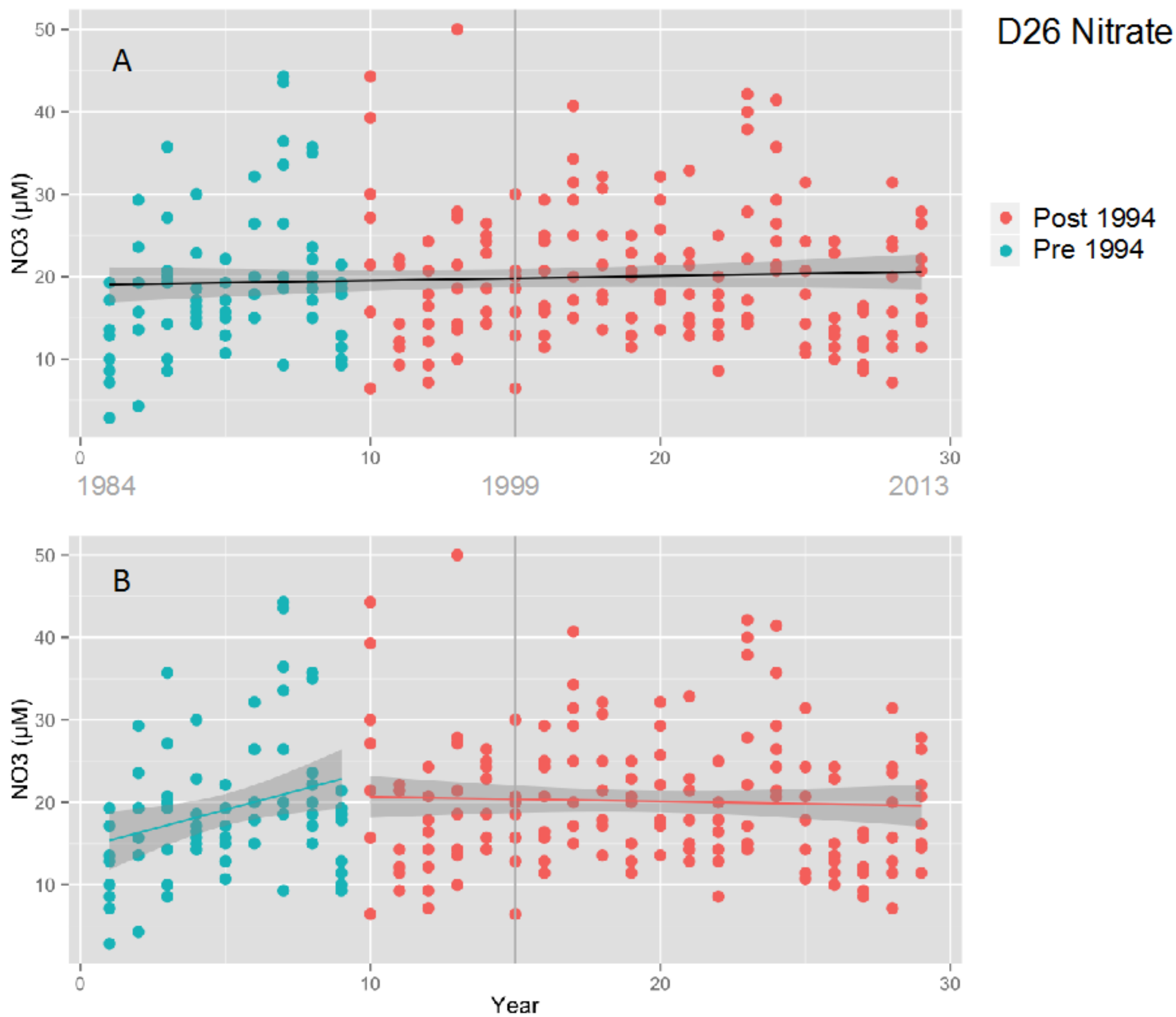


Figure A-1. Changes in the concentration of nitrate (NO_3^-) over time (1985-2013) at station D26 in the Delta. Green filled circles denote period before 1994 and red filed circles denote the period after 1994. Vertical grey line denotes the year 1999 when Microcystis started occurring. A) Regression of NO_3^- versus time for the period 1985-2013 (black line) with 95% confidence interval in grey. B) Regression of NO_3^- versus time for the period 1985-1994 (green line) and the period 1994-2013 (red line). Slopes significantly different from zero in bold in regression table:

Nitrate	1985-2013	1985-1994	1994-2013
Slope	0.09066	**1.374**	-0.02962
Probability	0.226	0.00149	0.832
multi- R^2	0.00424	0.09127	0.0001988

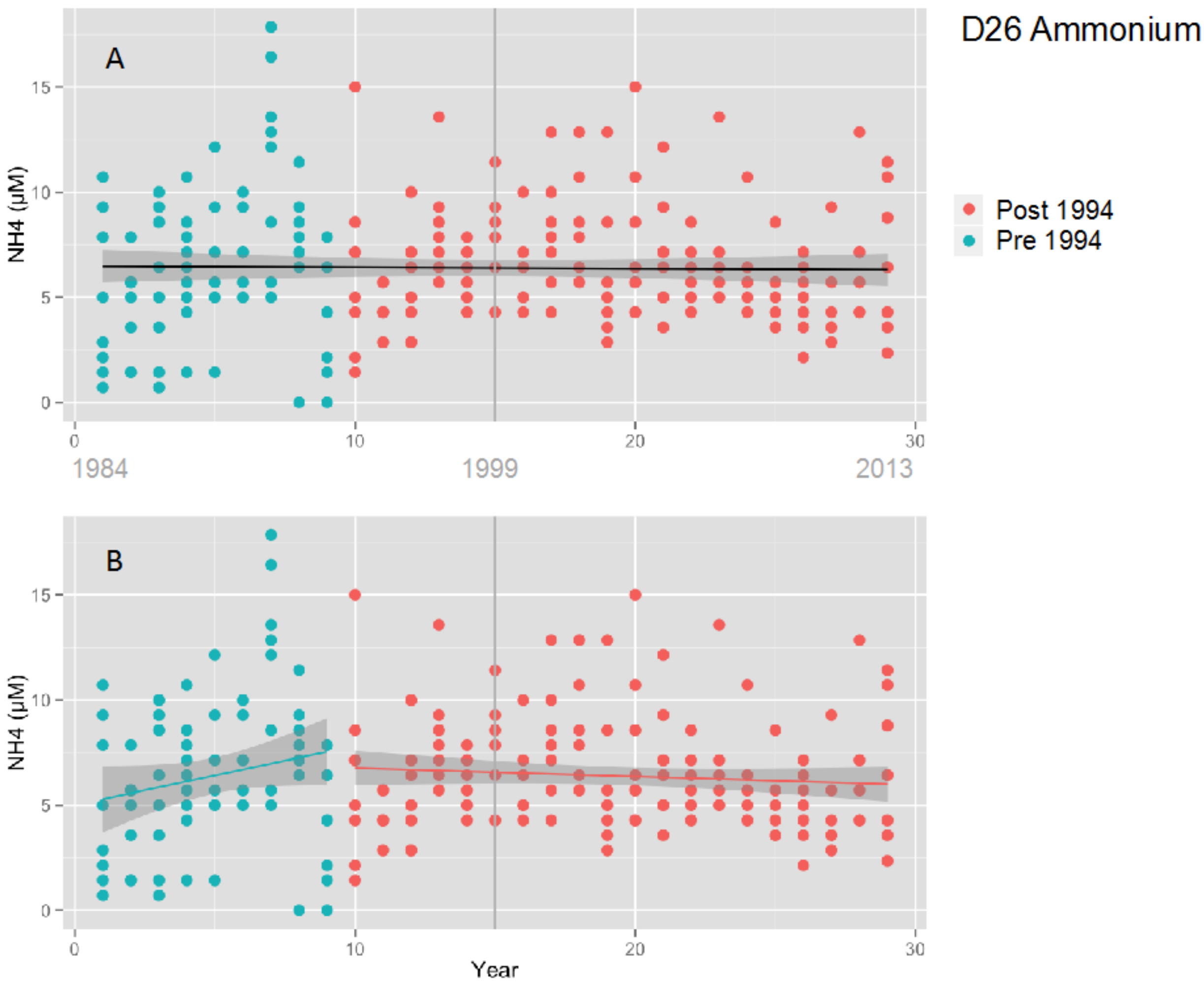


Figure A-2. Changes in the concentration of ammonium (NH_4^{+-}) over time (1985-2013) at station D26 in the Delta. Green filled circles denote period before 1994 and red filed circles denote the period after 1994. Vertical grey line denotes the year 1999 when Microcystis started occurring. A) Regression of NH_4^+ versus time for the period 1985-2013 (black line) with 95% confidence interval in grey. B) Regression of NH_4^+ versus time for the period 1985-1994 (green line) and the period 1994-2013 (red line). Slopes significantly different from zero in bold in regression table:

Ammonium	1985-2013	1985-1994	1994-2013
Slope	-0.038	**0.3801**	-0.03525
Probability	0.108	0.023	0.358
multi- R^2	0.007448	0.04779	0.00374

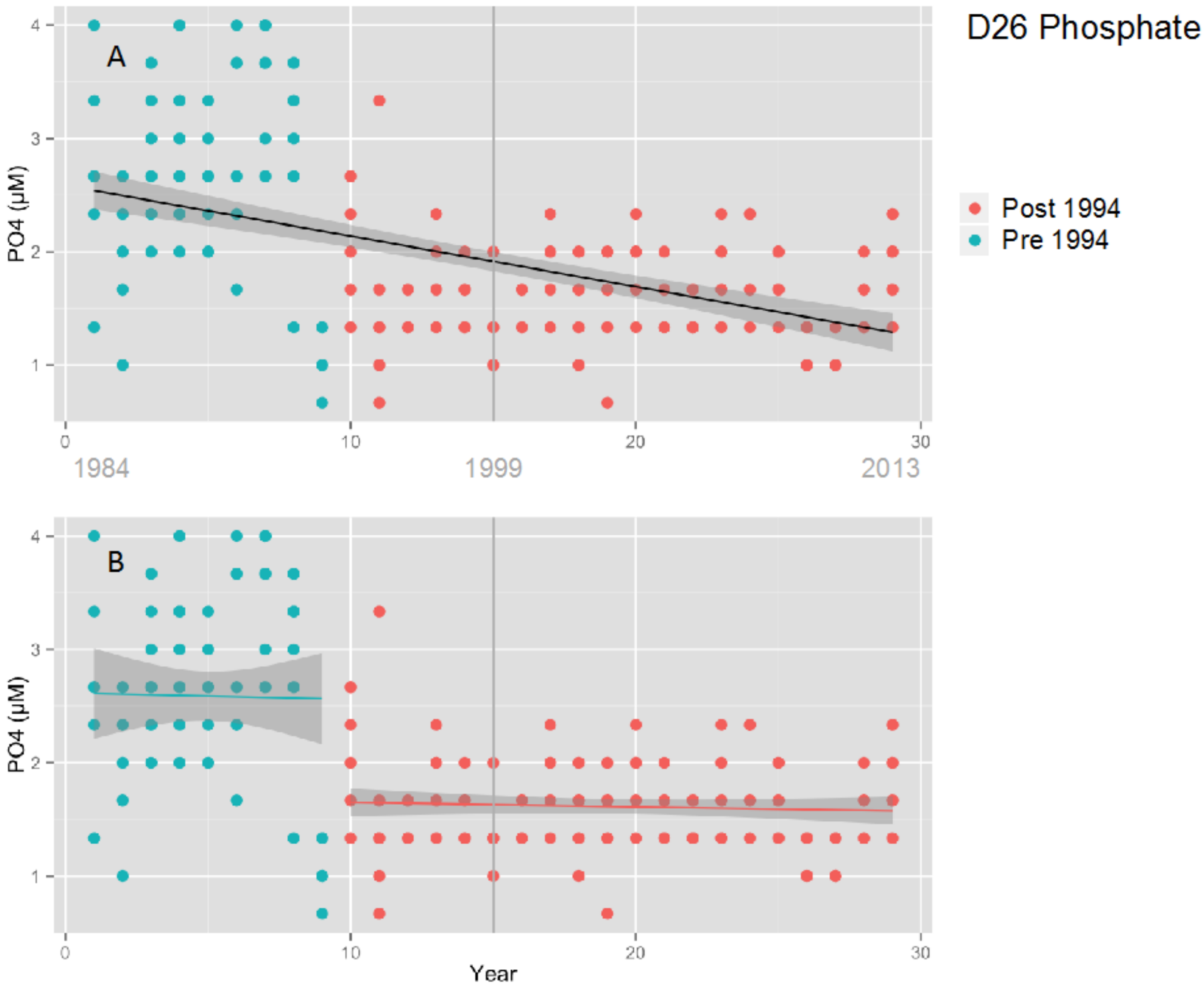


Figure A-3. Changes in the concentration of phosphate (PO_4^{3-}) over time (1985-2013) at station D26 in the Delta. Green filled circles denote period before 1994 and red filed circles denote the period after 1994. Vertical grey line denotes the year 1999 when Microcystis started occurring. A) Regression of PO_4^{3-} versus time for the period 1985-2013 (black line) with 95% confidence interval in grey. B) Regression of PO_4^{3-} versus time for the period 1985-1994 (green line) and the period 1994-2013 (red line). Slopes significantly different from zero in bold in regression table:

Phosphate	1985-2013	1985-1994	1994-2013
Slope	**-0.048906**	0.03673	-0.008772
Probability	2.00E-16	0.263	0.157
multi- R^2	0.2594	0.01183	0.008855

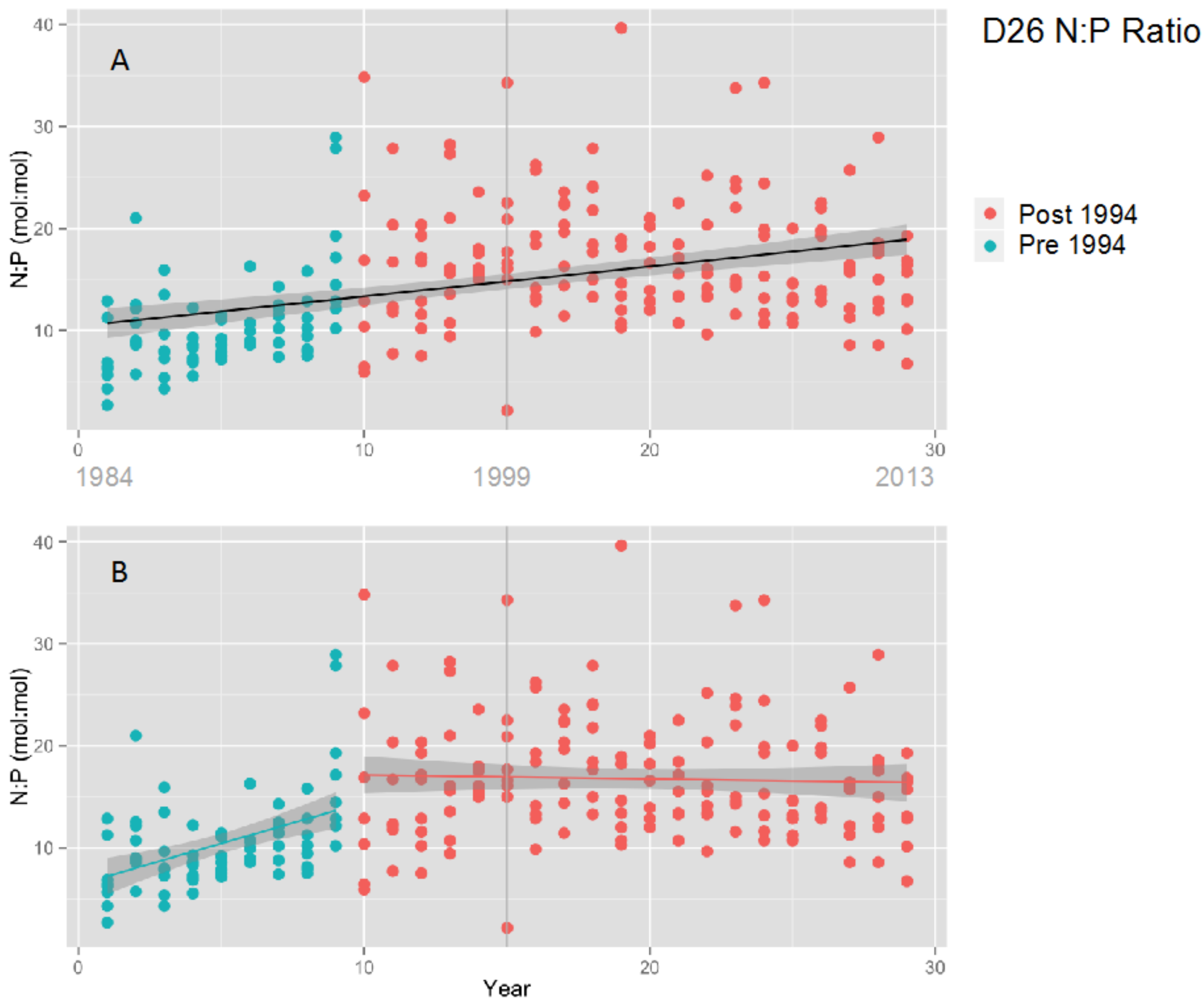


Figure A-4. Changes in the N:P ratio (mol:mol) over time (1985-2013) at station D26 in the Delta. Green filled circles denote period before 1994 and red filed circles denote the period after 1994. Vertical grey line denotes the year 1999 when Microcystis started occurring. A) Regression of N:P ratio versus time for the period 1985-2013 (black line) with 95% confidence interval in grey. B) Regression of N:P ratio versus time for the period 1985-1994 (green line) and the period 1994-2013 (red line). Slopes significantly different from zero in bold in regression table:

N:P Ratio	1985-2013	1985-1994	1994-2013
Slope	**0.3726**	**0.6236**	0.02932
Probability	3.79E-16	0.000572	0.736
multi- R^2	0.1747	0.1064	0.0005047

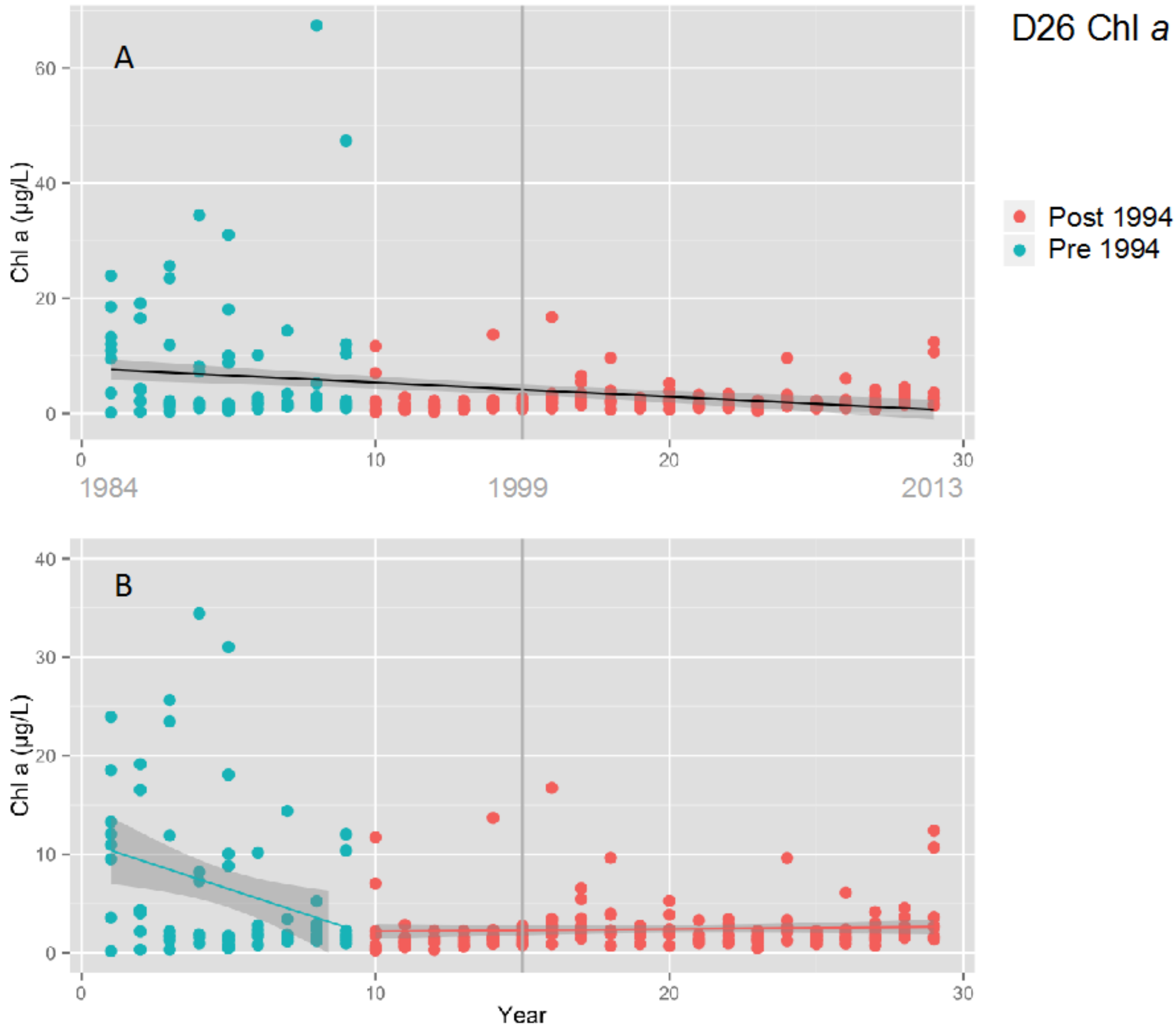


Figure A-5. Changes in the concentration of Chlorophyll a (Chl a) over time (1985-2013) at station D26 in the Delta. Green filled circles denote period before 1994 and red filed circles denote the period after 1994. Vertical grey line denotes the year 1999 when Microcystis started occurring. A) Regression of Chl a versus time for the period 1985-2013 (black line) with 95% confidence interval in grey. B) Regression of Chl a versus time for the period 1985-1994 (green line) with two of the high values from 1994 removed, and the period 1994-2013 (red line). Slopes significantly different from zero in bold in regression table:

Chl *a*	**1985-2013**	**1985-1994**	**1994-2013**
Slope	**-0.1676**	-0.7386	0.03936
Probability	2.87E-05	0.00759	0.1148
multi- R^2	0.05143	0.07266	0.01116

APPENDIX B

Comments from the Scientific Working Group and responses from the authors.

Author	Page	Comment	Response
Anonymous	iii	Under Finding #3, second bullet, regarding ratios of Nand P in Delta: I'm reading this to mean ratios of total N and total P (including various forms of each). I don't know that enough research has been done to determine if the ratios of the different forms can be an important driver.	Ratios of N:P are important drivers when one nutrient is in limiting supply and slows the growth rate down. Ratios of different forms of the same nutrient are important if a certain form produces a lower growth rate than the other; research on this topic is discussed under section 3.2.3 p24.
Foe	11	Under section 2.2.5, first paragraph, last sentence: Add something like this to last sentence on page 11, "it was deduced that *under nutrient limiting conditions*phytoplankton would become …"	Done
Foe	19	On pages 19, 22, and 38 you note that nutrient concentrations are one factor constraining the accumulation of cyanoHAB biomass. Can you estimate either from information from the delta or other waterbodies what range of N and P concentrations would be needed to limit cyanoHAB biomass and toxin levels below a low or moderate probability of human and wildlife health effects? Presumably there are a number of complicating factors including the fact that cyanoHABs co occur with blooms of other algal species which would also pull down nutrient levels. I understand that your estimate is likely to be fairly gross. Would it be possible to refine the range through a series of laboratory and/or field experiments? Could this be considered an information gap? Maybe discuss this somewhere around page 37?	I tried to do this in the original version where based on measurements of microcystin toxin that was harmful to aquatic life (0.8 µg/L) I calculated the amount of Microcystis-associated surface Chl a needed to produce that amount (7 µg/L). Because the science group did not like this estimation I've removed it from the paper. However, using 7 µg/L surface Chl a as a rough estimate, you would need greater or equal to 7 moles N/L to sustain such a level; this is not discussed in the current version
Foe	29	Second paragraph: You might note that Ger *et al.*, 2010 found that both toxin producing and non-toxin producing strains of Microcystis reduced the survival of both Eurytemora affinis and Pseudodiaptomus forbesi in 10 day lab bioassays. This suggests that the presence of other microcystis metabolites also contribute to overall toxicity.	A new section (4.2.4) on p39 entitled "Potential for CyanoHAB Risk to Delta Beneficial Uses" has been where the Ger (2010) paper and additional papers mentioned by Peggy Lehman are discussed
Foe	32	Under section 4.2.3, second paragraph: Brannan Island is located inside the legal boundary of the delta.	This sentence has been changed to read "Sacramento River" instead
Foe	35	Under section 4.2.4 under potential adverse effects on Delta beneficial uses: What can be concluded about the potential toxicity of cyanoHABs to aquatic organisms including zooplankton and larval fish in the Delta? Presumably there is the possibility of both direct and indirect effects. See Ger et al 2010 for an example of direct toxicity and Acuna et al (2012) and Deng et al (2010) for examples of bioaccumulation related effects. Peggy gave citations for all these papers. If uncertainty exists about the extent of	These effects and papers are discussed in a new section (4.2.4) on p39 entitled "Potential for CyanoHAB Risk to Delta Beneficial Uses". I think uncertainty exists regarding 1) whether the organisms reflect concentrations that are in the water column or 2) they bioaccumulate the toxin 3) what affects the zooplankton - toxic or non-toxic cells

		potential toxicity, then should this be listed as an information gap? What information is most important to collect first?	
Foe	38	Figure 5.2 shows nutrient trends at station D26 in the delta between 1994 and 2014. The conclusion is that nutrients concentrations are not changing. Longer term nutrient analysis suggest otherwise. Nutrient concentrations, N speciation, and dissolved N:P ratios have changed in the delta over the last 40 years. More DIN, more NH4, less SRP and an increase in the N:P ratio (Jassby 2008; Glibert, 2010[3] ; Van Nieuwenhuyse, 2007[4]) [3] Reviews in Fishery Science, 18:211-232 [4] Canadian journal of fisheries and aquatic science 64:1529-1542	I reanalyzed the nutrient data going back to 1985. My new interpretation is in section 5.1.4 on p43. I included the Van Nieuwenhuyse and Jassby citations. Appendix A provides plots of NO3, NH4, PO4, N:P, and Chl a from station D26. I demonstrate that one can draw different conclusions from these data depending on whether they are broken into separate time periods or analyzed as one long time course.
Foe	39	Around page 39. You note that cyanoHAB growth rates are a positive function of water clarity. The Delta has become clearer. The delivery of suspended sediment from the Sacramento River to the Delta has decreased by about half during the period between 1957 and 2001 (Wright and Schoellhamer (2004)[1] and this has resulted in a statistically significant -2 to -6 percent decrease per year in SPM between 1975 and 2005 (Jassby, 2008)[2]. Of course, it is uncertain whether the trend will continue. Might this increase in clarity also increase the frequency and magnitude of cyano blooms in Delta and make other factors like nutrients more important? [1] San Francisco Estuary and Watershed Science, 2004 volume 2, issue 2 [2] San Francisco Estuary and Watershed Science, 2006 volume 6, issue 1	This is true and I've added a new section (5.1.3) entitled Water Clarity (p 43) where this additional information is discussed.
Joab	ii	Second paragraph, second sentence. Add "the" between "by" and "Water Board".	Done
Joab	ii	Under Finding #2, item 1), change "e,g." to e.g.,"	Removed
Joab	1	Under section 1.1, first sentence. Add "in" between "found" and "Northern California".	Done
Joab	1	Last paragraph, first sentence regarding the commissioning of literature reviews: Actually we only commissioned two white papers (to date) on cyano	Changed to "two"

		and macrophytes. We are working on commissioning the third.	
Joab	4	Under section 2.1, first paragraph, fourth sentence. In sentence, "Cyanobacteria also produce and array…" Change "and" to "an".	Done
Joab	5	In Table 2.1, under the Nostocales (Group 4), is Cylindrospermum the correct name?	It is the correct name; however, I could just as easily have mentioned Cylindrospermopsin which is a more recognizable species.
Joab	6	Second paragraph, second sentence. You identify Group 5 as having toxic cyanoHAB-forming cyanobacteria: Don't you mean Group 4 based on the species identified in Table 2.1? Also, which group is Planktothrix in? I did not see them identified in the table - can they be added?	I did mean Group 4; it's been changed. I've also indicated in the text which subgroup Planktothrix belongs to
Joab	8	Under Ammonium transport section, third paragraph. Change "alterate" to "alternate".	Done
Joab	8	Under Nitrate transport and reduction section, last sentence regarding nitrate uptake: What concentrations of ammonia are relevant? Are these concentrations in the cells or the water column?	External; sentence changed to reflect this
Joab	9	First paragraph, first sentence: Carbon fixation seems to be very important in the nutrient uptake process. What controls carbon fixation? Is there someway to reduce their carbon fixation?	Irradiance controls CO2 fixation; this has been mentioned
Joab	9	Fourth paragraph, last sentence. Remove "have" between "their genomes" and "demonstrates".	Done
Joab	10	Under Nitrogen fixation, second paragraph, last sentence relating to n2 fixation under iron-limiting conditions: What is the iron-limiting condition? Do we know?	Where iron is not enough to support cell division
Joab	10	Under nitrogen fixation, last paragraph, seventh sentence. Correct the spelling of "heterocyst".	Done
Joab	11	First paragraph: What are the conditions for N starvation?	When N concentration is not enough to support cell division of available biomass
Joab	19	In Figure 3.1, step 6 states to add grazers: Are their cyanobacteria grazing fish and zooplankton?	This figure was very busy and included many processes not discussed in the White Paper; I've substituted a new and simpler figure
Joab	38	Under section 5.2, first paragraph, first sentence: This citation is now 8 years old. Is there any recent information to suggest if these percentages have changed significantly?	Not that I'm aware
Joab	39	First paragraph: Correct the spelling of "cyanHABs" to "cyanoHABs". Do global search in document to check spelling of cyanoHAB.	Done
Joab	39	Second full paragraph: In sentence, "In Clear Lake, Both N and P…" delete capital B and make lowercase.	Sentence changed

Joab	41	In Table 5.1, Observations in the Delta "temperatures above 25° C rarely occur." - Temperatures in the San Joaquin River near Stockton have over the past 3 years (2012-2014) reached over 25°C from June through October, most likely due to this persistent drought and overall increase in temperature.	Sentence has been removed
Kudela	31	Figure 4.2. I think this is an issue with Peggy's original figure, because I remember seeing it before, but the chlorophyll units don't make much sense. 0.1 ng/L is barely detectable under the best of circumstances.	Y-axis corrected to µg/L
Kudela	N/A	The toxin table is very thorough, but it might be worth pointing out that, based on available information, Central California seems to be dominated by microcystins. We have all of those genera present but we don't very often see saxitoxins or anatoxin-a. Admittedly we don't look that often either, but we have tested some samples from Clear Lake, SF Bay, and Pinto Lake. We very rarely get low levels of STX, and one low hit for anatoxin-a in Clear Lake. We did see low levels of anatoxin-a in Lake Chabot also, and if you go further north, anatoxin-a becomes dominant in the Eel River basin. This supports Mine's decision to focus on microcystins in the report, but the implication of that section is that we could see a wide variety of toxins, and we usually don't.	This has been pointed out in the first paragraph of section 4.2.3
Kudela	N/A	Temperature. While I completely agree with Mine's summary, bear in mind that we do see toxin at low temperatures (this is documented in Kudela 2012 and Gibble and Kudela 2014). We were not tracking species, but it seems likely that it's related to a shift in composition to more cold-tolerant species such as Planktothrix. We tend to get two peaks of toxicity—one at lower biomass and cooler temperatures, and the second (larger) when Microcystis is dominant.	I was not aware of the Gibble Kudela paper; would like to add appropriate discussion
Kudela	N/A	Marine toxins. I'm not sure I completely believe it but there is a recent article (which I can't find right now—looking for it) that documents presence of microcystins in marine waters, from marine cyanobacteria.	Noted

Kudela	N/A	I'd be very supportive of developing an ecosystem model, but for CHABs in particular you probably need a fairly complex model that can parameterize both end-members (riverine and marine). A good hydrodynamic model would be a great place to start. I'm not sure how easy or difficult it would be to add a biological model on top of that, or whether you'd need two models, etc. It's probably my own bias but I would start with assembling all the available data and run statistical analyses on that (Peggy's done quite a bit of this already) to see what variables emerge as most important. Cecile Mioni has been attempting that with the Bay/Delta data and it's been interesting, in that there are no clear physical drivers related to cell abundance or toxicity. She looked at all the usual ones, temperature, salinity, nutrients, etc. suggesting that either there's not enough data (a real possibility) or that it's not a simple relationship. That of course leads back to the need for more monitoring and modeling.	Noted
Mussen	iii	Under Finding #4, third sentence regarding increased nutrient loading: With continued regluatory controls on nutrient loads into the system, we should not necessarily expect nutrient loading to increase substantially in the future.	This has been removed
Mussen	1	Under section 1.1, in fourth sentence "The Delta is widely recognized as in "crisis" because of competing demands…" Add "human effects on the environment and" between "because of" and "competing".	Done
Mussen	4	Last paragraph, second sentence. Add "in local communities" between "irrigation of farms" and "as well as". Plus, remove the words "drinking water to" after the words "as well as".	Sentence has been revised
Mussen	7	Under Carbon Fixation, fifth sentence. Add "near" between "concentrate CO2" and "its vicinity".	Sentence has been revised
Mussen	28	Under section 4.1 Ecosystem Services, second paragraph, third sentence: Change "Striped Bass" to "juvenile-Striped Bass".	Done
Mussen	29	First paragraph, fourth sentence: "At high densities…(Paerl 2004, Paerl and Fulton 2006)" is a repeat from text in the paragraph above on page 28.	Noted; the repeat text has been removed
Mussen	29	First paragraph, sixth sentence "At dense concentrations…" - If low nutrient concentrations can be used to limit the magnitude of future cyanoHAB blooms, the effects of lower nutrient concentrations must also be considered for all other plant and algae species growing in the system (this is especially important for the period followin onset of a future cyanoHAB blooms where nutrients in the area would be fully depleted).	Noted; this point has been brought up in the recommendations section (6.0) in conjunction with hypotheses development

Mussen	38	Under section 5.2, second paragraph, first sentence refering to growth of cyanoHABs versus diatoms: Without nutrient limitation, growth rates may not determine which phytoplanktong species is dominant in the system. Other factors such as light availability, buoyancy, temperature, salinity and grazing pressure may determine the dominant species.	This sentence, presently in section (5.1.4) has been revised to clarify point
Mussen	40	Under second bullet, third sentence concerning blooms not persisting without ample supply of nutrients: Once a bloom consumes the available nutrients, would nutrient remineralization be able to sustain some lower concentration of cyanoHABs presence throughout the remainder of the growth season? Could cyanoHABs persist at harmful levels in this manner?	I think typically not; harmful levels require a certain level of biomass to be sustained
Mussen	40	Under second bullet, third sentence: Add "flow rates," between "temperatures," and "and irridiance".	Done
Mussen	40	Under second bullet, third sentence: Remove "s" from word "remains".	Done
Mussen	40	Last paragraph, fourth sentence starting with "Increase nutrient loading…": Please see my comment above on increased nutrient loading.	This has been removed
Mussen	42	Under R1, second paragraph discussing enumeration of cell counts: What about the inclusion of "and average biomass?"	Controversy regarding how it is to be measured; could be discussed under recommendations
Mussen	43	Under R2, first paragraph, second sentence: Replace "higher chlorophyll a" with "increased phytoplankton growth in the Delta".	Done
Mussen	43	Last paragraph, first sentence concerning informing management actions: It is also important to model expected nutrient levels with levels of reduced loading. The time required for a reduction and the amount of nutrient regeneration in a system can be highly variable.	Section expanded in order to note this point
Mussen	43	Last paragraph, first sentence. Add "s" to "action" making it "actions".	Done
Mussen	43	Last paragraph, second sentence regarding modeling primary productivity and biomass: CyanoHAB growth rates under ideal conditions (which may be used as the basis for a model design) can be quite different from their growth rates at near-limiting nutrient conditions. Do we know what low nutrient concentrations (thresholds) would be necessary to prevent the overgrowth of different cyanoHABs? How would other plants and algae in the system be affected by low nutrient concentrations? With limited nutrients, can we predict which phytoplankton species would be dominant in the system, and how the dominant species may change with climatic factors such as temperature, flow, and turbidity, or with differing grazing rates?	Section expanded in order to note this point

Orr	iii	Under #3, first bullet - During the last meeting lower temperatures (18°C) were discussed. Are there references for the blooms at lower temperatures in the delta?	None that I'm aware of
Orr	28	For the last sentence on page 28 under section 4.1. Ecosystem Services, "CyanoHABs also can cause night-time dissolved oxygen depletion via bacterial decomposition and respiration of dense blooms which results in fish kills and loss of benthic fauna (Paerl 2004, Paerl and Fulton 2006) - Does this occur in the Delta or is flow mixing sufficient to prevent the issue?	This is an example of an adverse effect noted in other systems
Orr	29	In the second paragraph, the sentences starting with "At low concentrations…(Lehman *et al.* 2010)" are already in the preceding paragraph. Consider removing.	This has been removed
Orr	29	Regarding the thrid sentence at the top of the page, "However, even at low concentrations, toxins released (upon death and cell lysis, or by grazing) can bioaccumulate in higher trophic levels (Lehman *et al.* 2010) - There is some disagreement on this topic in the literature. Based on the Lehman paper alone it seems unclear whether the toxins bioaccumulate or simply occur in tissue at concentrations that are not greater than the surrounding environment. In other systems it depends on the particular toxin and species in question. I recommend removing the "even at low concentrations" to make a more conservative statement. Another option would be to state they have been observed in higher trophic levels in the delta and leave the bioaccumulation to be addressed in recommendations or further research.	This sentence has been modified
Orr	32	Under section 4.2.3, last sentence in first paragraph "Using the relationship 115 ng microcystin µg surface Chl a^{-1} (Figure 4.4), *Microcystis*-associated surface Chl a concentration of 7 µg L^{-1} (sampled using a horizontal net tow) would produce enough microcystin (800 ng L^{-1}) to reach the OEHHA Action Level, and constitute an action level for the Delta." I am concerned with the concept of using Chl a to determine actions levels. While Chl a and microcystin levels are related the correltation is not linear and does not take other cyanotoxins into account. Whether or not chl a correlates with other toxins would be an interesting question.	This can be discussed further; to be on the safe side I removed Figure 4.4 and the calculation of a surface Chl a level that could potentially constitute an action level

Orr	36	Under section 5.1, last half of paragraph relating to flow and turbidity - Is there data to suggest that increased turbidity reduces risk of HABs in the delta that is independent of flow rate or temperature? HABs are common in other water bodies with high turbidity. The observation the HABs are controlled by turbidity may be an artifact of higher flows and lower temps. In low flows and turbid water could buoyancy regulating species stay near the surface to receive the necessary light intensity?	Yes, I do think that the effect of turbidity cannot be separated from the effect of flows in the Delta; whether turbidity alone has the same effect is not clear. I have revised this statement to reflect that the two covary
Orr	42	Under R1, second paragraph discussing monitoring - Consider not listing species. If the plan is long term the species of concern may change or expand.	Adaptive management strategies should take care of that; the species are listed as an example
Orr	42	Under R1, last sentence in first paragraph, correct the misspelling of "calibrate".	Done
Orr	N/A	The introductory sections have a broad perspective regarding toxigenic algal species. However, the discussion of factors influencing cyanobacterial blooms appears to focus on microcystins as a model for all blooms. I think the dicussion of other species should be increased.	The literature is heavily tilted towards microcystins therefore the white paper as well. However, Kudela noted in his comments that cyanobacterial toxins other than microcystins are almost not detected in the Delta; a statement to this effect has been added in the first paragraph of section 4.2.3
Orr	N/A	I am concerned about how tubidity is discussed. If data is available I recommend discussing it separately from flow and temperature. If turbidity related data is not available avoid general assumptions regarding its influence on blooms.	I have repeated previously published statements regarding turbidity and Microcystis in the Delta; the assumptions in the published work are stated. A new section (5.1.3) on water clarity in the Delta has been added.
Orr	N/A	It was unclear to me what the end goal of the monitoring program is. If a clearer question(s) can be developed I encourage adding a more specific monitoring plan.	To be discussed at the next meeting
Orr	N/A	I heard some monitoring questions from the group and am interested in how common these questions are among the group. I suspect there will be some disagreement about the hypothesized answers but the questions seemed shared. (See 4 questions below)	Noted
Orr	N/A	1. When and where do we reach the required surface temperatures for a bloom? (microcystis exclusively?) a. What is the appropriate depth to measure temperature?	Noted
Orr	N/A	2. Do nutrient limited conditions occur during blooms in the delta? Presumed not to. a. Does this occur in some areas but not others? b. Are we close enough for this to occur in near future? c. Is this question species or nitrogen source dependent in a non-limited system?	Noted
Orr	N/A	3. Spatially where are both temperature and nutrients high and do we need more spatial resolution?	Noted

Orr	N/A	4. Is chlorophyll a the right parameter to be measuring? a. Does it correlate with microcystin concentrations?	Noted
Taberski	iii	Delete "already exists" under the section R1, first sentence.	Done
Taberski	1	Add "of" under section 1.1, 4th sentence "…Delta is widely recognized as in "crisis" because *of* competing demands…"	Done
Taberksi	1	Delete "d" in word "declined" under section 1.1, last sentence "…including the continued decline~~d~~ of …"	Done
Taberski	22	The paragraph under sub-section "Confounding factors:" is not clear, particularly the last sentence is confusing.	This sentence has been revised
Taberski	29	In the 5th sentence at the top of the page, insert a space in the word "watercolumn".	Done
Taberski	32	In table 4.1, I think you should also include the OEHHA thresholds.	Table below has OEHHA thresholds
Taberski	39	Under the last paragraph for section 5.2, the last sentence "…nutrients are unlikely to play a role in the onset or frequency of bloom occurrence in the Delta." - I agree. Nutrient concentrations would play a role, though, in the magnitude (concentration) and duration of a bloom. If nutrients were lower, they would be depleted more quickly and the bloom would crash. This was stated in the Summary bullet #2. That clarification should be added to this paragraph.	This has been added
Taberski	40	Under the second bullet, in the third sentence, correct the misspelling of "initiated".	Done
Taberski	40	In the last paragraph, in the second sentence, put a space in the word "watercolumn".	Done
Taberksi	40	In the last paragraph, in the third sentence, change the sentence to read as "Both *higher* temperature*s* and reduced …"	Changed
Taberksi	42	Under R1, first sentence, delete the wording "already exists".	Done
Taberski	N/A	A section should be added on risk to aquatic life.	Done
Taberski	N/A	Historical data should be analyzed based on driving factors to evaluate risk (areas with high temperatures/low turbidity/long residence time)	Example analysis of nutrient concentrations at station D26 performed; included in Appendix A
Taberski	N/A	Recommended monitoring should be based on specific management questions related to status and trends, hotspots, risks to humans, animals and aquatic life, and directing management actions.	Noted
Taberski	N/A	Monitoring information should be collected on processes and projections needed for modeling cyanoHABs and directing management actions. The SF Bay RMP's management questions could be used as a model for developig management questions for cyanoHABs. The RMP's management questions are:	Noted

Taberski	N/A	1. Are chemical concentrations in the Estuary at levels of potential concern and are associated impacts likely? a. Which chemicals have the potential to impact humans and aquatic life and should be monitored? b. What potential for impacts on humand and aquatic life exists due to contaminants in the Estuary ecosystem? c. What are appropriate guidelines for protection of beneficial uses? d. What contaminants are responsible for observed toxic responses?	Noted
Taberski	N/A	2. What are the concentrations and masses of contaminants in the Estuary and its segments? a. Do spatial patterns and long-terms trends indicate particular regions of concern?	Noted
Taberski	N/A	3. What are the sources, pathways, loadings, and processes leading to contaminant-related impacts in the Estuary? a. Which sources, pathways, and processes contribute most to impacts? b. What are the best opportunities for management intervention for the most important contaminant sources, pathways, and processes? c. What are the effects of management actions on loads from the most important sources, pathways, and processes?	Noted
Taberski	N/A	4. Have the concentrations, masses, and associated impacts of contaminants in the Estuary increased or decreased? A. What are the effects of management actions on the concentrations and mass of contaminants in the Estuary? B. What are the effects of management actions on the potential for adverse impacts of humans and aquatic life due to Bay contamination?	Noted
Taberski	N/A	5. What are the projected concentrations, masses, and associated impacts of contaminants in the Estuary? A. What patterns of exposire are forecast for major segments of the Estuary under various management scenarios? B. Which contaminants are predicted to increase and potentially cause impacts in the Estuary?	Noted
Thompson	ii	You only have four, not five, major findings identified in the Executive Summary section	Corrected
Thompson	iii	Under Finding #3, first bullet, second sentence relating to temperature for growth: Should we specifiy the time frame over which the temperature is measured? e.g., instantaneous, daily average, daily max or min. This will matter more when we get to modeling phytoplankton dynamics.	Save for the modeling

Thompson	19	Under section 3, first sentence: Correct spelling of word "prompted" by adding a "p" between "m" and "t".	Done
Thompson	20	Under section 3.1, in sentence "Indeed, recent decades has witnessed…" Replace word "has" with "have".	Done
Thompson	20	Under section 3.2.1, first paragraph, reference Edmondson and Lehman 1981 was not included in the reference section.	Done
Thompson	21	Under Cellular N:P compostion section: Reference Mills *et al.* was not included in the reference section and date missing in citation.	Corrected; citation added
Thompson	22	Under Confounding Factors, third sentence: Should we introduce the concept that there may be time lags between nutrient uptake and increased biomass, such that a correlation between two variables at a given point in time may not imply causality?	Good idea; sentence added under confounding factors on page 23 of revised manuscript.
Thompson	22	Under Confounding Factors, third sentence discussing parameters: Is there a diagram from a paper or textbook that we could borrow and reference, that shows the patterns of these variables over time before, during and after a bloom? (e.g., temperature, nutrient concentration, nutrient uptake rate, phytoplankton biomass). Something to show phytoplankton biomass peaking as nutrients draw down.	I found one diagram that showed a dinoflagellate peaking as nutrients were drawn down but nothing for cyanobacteria; after looking for the same pattern for cyanobacteria for half day I gave up
Thompson	27	Last paragraph under section 3.6 on stratification and residence time: Suggest adding a brief discussion of the potential role of ferrous iron. See Molot *et al.* 2014. A novel model for cyanobacteria bloom formation: the critical role of anoxia and ferrous iron. Freshwater Biology 59:1323-1340. The article mainly deals with lakes but there is a section on page 1330 that mentions shallow, nearshore regions of lakes, including harbors, inshore areas of Lake Erie, and embayments of Georgian Bay (Lake Huron). [**Text from Introduction shown on next line**.]	The potential role of toxins acting as siderophores and aiding cyanobacteria with iron uptake providing an advantage in competition with eukaryotes is discussed in a new expanded paragraph on p. 19 and the Molot *et al.* citation has been added to this section.

Thompson	27	**Here's some text from the Introduction**: "We cannot predict with any certainty when a cyanobacteria bloom will begin once temperatures are warm enough to support growth or the duration of a bloom except through empirical observations from previous years. Nor do we know why the problem is worsening in some mesotrophic systems." "Clearly, the predictive state of cyanobacteria science is unsatisfactory. This dissatisfaction may have contributed to the recent debate challenging he supremacy of the P paradigm in eutrophication management. Wurtsbaugh, Lewis, Paerl, and their colleagues argue that N plays a major role alongside P in promoting cyanobacteria blooms and that both N and P should be controlled (refs). This argument has been vigorously challenged in return by Schindler and his colleagues who claim that controlling N to control cyanobacteria will not work because N-fixation by cyanobacteria will compensate to a large extent for induced N shortages (refs). The outcome of this on-going debate can be expected to influence the direction of billions of dollars in public expenditures to remedy nutrient loading." "Our purpose here is to present a novel model that does not supplant the important roles of P and N as major macronutrients, but instead weaves additional ideas into older ones to create a novel and more comprehensive conceptual framework with much more explanatory power that spans the range of conditions where cyanobacteria blooms have been observed."	Noted
Thompson	28	Under section 4.1 Ecosystem Services, second paragraph, Reference Sommer *et al.* 1997 not included in reference section.	Citation added
Thompson	30	Figure 4.1 - Can we get a higher resolution version of this map? It was blurry in the original Word version, prior to becoming a Google doc.	Will investigate
Thompson	36	Under section 5.0, first paragraph, last sentence: Should we specify that the variables may need to be time-lagged in order for the correlations to be apparent?	I actually prefer to be vague in case entirely different statistics are needed
Thompson	38	Under section 5.2, first paragraph, second sentence referring to Microcystis and Aphanizomenon becoming more common: Is the reference for this statement the Lehman 2007 paper? I think it would be worth referencing it again at the end of this sentence, or adding an additional reference as necessary.	This is based on Lehman's 2008 paper and the Mioni *et al.* 2012 report; thesecitations have been added
Thompson	38	Under section 5.2, second paragraph, second and fourth sentence refering to Figure 2: I think this is now [Figure] 3.3. Check Figure number.	Corrected: now figure 3.6

Thompson	39	Second full paragraph, reference to Figure 4.5: This information is not shown in this figure. Check your Figure number.	Correct, the reference to this figure has been deleted
Thompson	39	Second full paragraph, last sentence related to culture investigations: It would strengthen the point to reference (re-reference) some key papers here.	Done
Thompson	41	In Table 5.1, Observations in the Delta "when turbidity is <50 NTU, flow is <30 m^3s^{-1} and irradiance >50 µmol phot $m^{-2}s^{-1}$": Please briefly state where in the Delta this was measured, and over what spatial and temporal scale.	Done
Ward	N/A	**Comment 1:** Of the five questions the Work Group is tasked with answering, the first is to determine whether the principal physical and biological factors promoting cyanobacteria blooms and toxin production in the Delta have been identified. My reading of the current work in this area leads me to conclude that these factors have not yet been adequately characterized. More importantly, the critical task of accurately gauging the relative weight of various factors that are known to influence/control the formation of toxigenic (or other) blooms still seems beyond our capability at present, whether in the Delta or in other waterbodies for which some relevant data is available. These deficiencies are particularly problematic for the development of a model that has practical utility. The field work and laboratory studies on Delta water quality and Delta species involved with the Pelagic Organism Decline that were cited in the draft white paper and/or distributed to the Work Group are largely "Microcystis-centric" and "microcystin-centric". There is, in my view, a very large risk in attributing (1) all significant microcystin production to Microcystis in the Delta, and; (2) focusing on microcystin(s) to the exclusion of the effects of other possible toxigenic genera and other cyanotoxins. Dr. Berg's draft white paper duly notes the existence of many other toxigenic genera and other cyanotoxins, but it seems the Delta-specific research on these possibilities may not yet be available for review.	Noted; Please see new comment under section 4.2.3 on toxin data available from Central California demonstrating that very few detections of toxins other than microcystins have been made in the Delta

Ward	N/A	**Comment 1 continued:** This is not a trivial point: for example, various Aphanizomenon strains can produce saxitoxin, microcystin(s), cylindrospermopsin, BMAA, and anatoxin-a (Paerl & Otten, 2013), and Lehman *et al.* have noted the presence of this genus in the estuary, bay and/or Delta. Though it is quite possible that I have overlooked Delta-specific studies on Aphanizomenon strains which examined the possibility that one or more of these toxins is present, if it is true that these studies have not been conducted yet, it would be ill-advised to presume that microcystin(s) are some sort of "model" toxin that can be regarded as a generic equivalent of all of the others in a subsequent modeling exercise, especially given their chemical and toxicological heterogeneity. Similarly, the diazotrophic cyanobacteria such as Aphanizomenon may respond rather differently to "nutrient limitation" (of nitrogen) than the non-diazotrophic genera such as Microcystis. If both genera produce microcystins, then microcystin production per se may continue in a water body as nitrogen becomes more limiting for Microcystis. Comparisons of diazotrophic cyanobacteria with non-nitrogen fixing cyanobacteria to nitrogen-limited conditions tend to show the following pattern: diazotrophs (e.g., Aphanizomenon) tend to produce toxins such as microcystin under nitrogen-limited conditions, whereas non-nitrogen fixers such as Microcystis and Planktothrix increase toxin production under non-limiting conditions.	Not necessarily; please see Dolman 2012 citation for patterns of abundance of various species and toxin production in over 100 lakes in Germany under different N:P scenarios described in "Meta analyses of Lake Studies" on page 24.
Ward	N/A	**Comment 1 continued (references):** Holland, A., Kinnear, S. Interpreting the possible ecological role(s) of cyanotoxins: compounds for competitive advantage and/or physiological aide? Marine Drugs 2013, 11(7), 2239-2258 http://www.mdpi.com/1660-3397/11/7/2239 Paerl, H. Otten, T. Harmful Cyanobacterial Blooms: Causes, Consequences, and Controls. Microbial Ecology 2013 May;65(4):995-1010 http://www.unc.edu/ims/paerllab/research/cyanohabs/me2013.pdf Leao, P. *et al.* The chemical ecology of cyanobacteria. Natural Products Reports, 2012 Mar;29(3):372-91 http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4161925/pdf/nihms-599340.pdf	
Ward	N/A	**Comment 2:** Given my time limitations for reviewing more recent work on how/whether nutrient management can reduce the magnitude and frequency of cyanobacteria blooms and toxin formation, I was unable to conduct the review I had originally anticipated on this question.	Noted

Ward	N/A	**Comment 3:** I believe the draft white paper correctly examines and compares the relative significance of various factors in controlling the growth and development of toxigenic blooms based on the limited data now available on this subject that is "Delta-specific". However, as stated in answer to Question 1 (above), I also believe the factors considered, while appropriate, are nevertheless an incomplete list. At our meeting I mentioned the apparent role of competition for iron as a factor in bloom formation and dominance in freshwater ecosystems, and provided a citation for this. Other factors which should be considered include the differences in sensitivity to herbicides between cyanobacteria and other phytoplankton that are being reported in studies conducted elsewhere, and the role of allelopathy in bloom formation, dominance, and senescence. Allelopathy is also discussed in references provided in answer to Question 1. For pesticides – in this case, I focused on herbicides – please refer to references provided below.	Allelopathy was dicussed in the original version of the White paper under "Potential Functions of toxin production" on page 18. Two new references have been added to the previous references on allelophathy in this section.
Ward	N/A	**Comment 3 continued (references):** The USGS maintains an online geo-referenced database which charts the most commonly-used pesticides in CA as they have continued to change in recent years that is current through 2012: http://water.usgs.gov/nawqa/pnsp/usage/maps/compound_listing.php Lurling, M., Roessink, I.On the way to cyanobacterial blooms: Impact of the herbicide metribuzin on the competition between a green alga (Scenedesmus) and a cyanobacterium (Microcystis). Chemosphere, 2006, 65:4, 618-626. Peterson, H. *et al.* Toxicity of hexazinone and diquat to green algae, diatoms, cyanobacteria and duckweed. Aquatic Toxicology, 1997, 39(2), 111-134. Arunakumara, K. *et al.* Metabolism and degradation of glyphosate in aquatic cyanobacteria: a review African Journal of Microbiology Research, 2013 Vol. 7(32), pp. 4084-4090. http://www.academicjournals.org/article/article1380269900_Arunakumara%20et%20al.pdf	The potentially important influence of herbicides and fungicides on the prevalence of cyanobacteria vis-à-vis other phytoplankton is discussed in a new Section 3.7 on p. 31 and again under Section 4.2.1 p 33. Because concentrations of herbicides in the Delta have been demonstrated to be quite high, a recommendation has been added that selective sampling for herbicides and pesticides be instituted in the Delta.
Ward		**Comment 4**: In answer to this question, please see the additional references supplied in answer to Questions (1) and (3).	A citation by Holland and Kinnear (2013) has been added on the benefits of toxin production under iron limiting conditions as mentioned in previous comments.

Ward	N/A	**Comment 5:** Overall, I agree with the draft recommendation put forward regarding monitoring of CyanoHABs (Recommendation 1), but would place more emphasis on monitoring for more immediate threats to public health e.g., intakes for drinking water treatment plants either within the bloom-prone areas of the Delta. The waterboard's drinking water program staff has informed me that some public water supply systems are struggling to successfully contend with this issue elsewhere in California, and this may also be a recurrent problem for smaller communities in the Delta. With perennially limited resources, public health protection should be given the highest priority, followed closely by protection of beneficial uses such as threatened/endangered species already impacted by the Pelagic Organism Decline, and a (seasonal?) surveillance program for areas of the Bay/Delta which experience periods of frequent and prolonged recreational uses water-contact uses, fishing, etc. With respect to Recommendation 2, I am unclear as to what the model being described is intended to accomplish: will it, if properly deployed, facilitate successful toxigenic bloom "forecasting"? Will use of whatever model results from this development process be of assistance, say, to managers of local public water supplies whose intakes are situated in the Delta? Having worked on this issue for ten years, I am concerned that our scarce resources are not being directed at immediate (& often seasonally recurrent) cyanotoxin hazards, and that local public health officials and water system managers have too few resources to respond effectively, and in a timely manner, when these episodes occur.	Noted

Ward	N/A	**Comment 5 continued:** As an example, last year the public water supply system for 400,000 people in the greater Toledo area were shut down, causing a public emergency and immediate potable water shortage for the entire population, when a microcystin-producing Microcystis bloom swamped the treatment plant's capacity to remove it in the "finished" drinking water. The National Guard was called-up to help deliver potable to this large urban population, and the problem did not abate for several days. Prior to this episode, NOAA had been doing quite a bit of modeling, bloom-forecasting, and other scientific investigations on these recurrent toxigenic blooms on western portion of Lake Erie where Toledo area residents obtain their public water supplies. The NOAA investigations remain on-going, and no doubt have provided much useful information on the role of various environmental factors in bloom formation: their "mission", however, is not to protect specific public water supplies from catastrophic events such as this episode. http://www.washingtonpost.com/news/post-nation/wp/2014/08/04/toledos-water-ban-and-the-sensitivity-of-our-drinking-systems/	Noted

APPENDIX C

Comments from the Stakeholder and Technical Advisory Group (STAG) members and responses from the authors.

Author	Page	Comment	Response
Lee	N/A	Overall Comment: The findings expressed in the draft white papers are consistent with our many years of experience investigating nutrient-related water quality, our findings in investigating Delta nutrient impacts and control of excessive aquatic plants, as well as with the findings expressed in presentations made at the CWEMF Delta Nutrient Modeling Workhop discussed below.	Noted
Lee	N/A	There remains little ability to quantitatively and comparatively describe the role of nutrients (N and P) in controlling the excess fertilization of the Delta waters.	Noted
Lee	N/A	There is considerable misinformation in the professional arena on the relative roles of N and P concentrations and loads, and the ratios of N to P in affecting water quality in the Delta; some of the information presented on nutrient/water quality issues is biased toward preconceived positions.	Noted
Lee	N/A	Based on the results of the US and international OECD eutrophication study and our follow on studies of more than 600 waterbodies worldwide (lakes, reservoirs, estuarine systems) the planktonic chlorophyll levels in the Central Delta are well-below those that would be expected based on the phosphorus loads to the Delta.	Noted
Lee	N/A	There is a lack of understanding of the quantitative relationship between nutrient loads and fish production in the Delta.	Noted
Lee	N/A	The Delta Stewardship Council's timetable for developing Delta nutrient water quality objectives by January 1, 2016, and to adopt and begin implementation of nutrient objectives, either narrative or numeric as appropriate, in the Delta by January 1, 2018 is unrealistically short.	Noted
Lee	N/A	There is need for substantial well-funded, focused, and intelligently guided research on Delta nutrient water quality issues over at least a 10-yr period in order to develop the information needed to generate a technically sound and cost-effective nutrient management strategy for the Delta.	Noted
Lee	N/A	As discussed in our writings, some of which are noted below, it will be especially dfficult to develop technically valid and cost-effective nutrient control programs for excessive growths of macrophytes in the Delta.	Noted

Mioni	3	#2: pH may also be important (I see some correlations and I think Raphe mentioned a report). I believe some cyanobacteria can be more competitive when pH increases due to CO2 concentrating mechanism. I think Alex Parker did some research on the Delta pH... Also, the residence time may be affected by the pumping station located near the EMP Old River D28 station (a station with typically high Microcystis abundance).	Noted
Mioni	13	last paragraph: Please talk to Anke Mueller-Solger. I believe Microcystis was there before 2000 but was simply not monitored as closely or did not cause such bloom.	Noted
Mioni	16	Carbon fixation: I would include a few reference to the cyanobacteria carbon concentrating mechanism.	Noted
Mioni	16	Table 2.3: Microcystin LD50 varies depending on the variant	Noted
Mioni	20	typo "preceding"	Noted
Mioni	21	N:P ratio: I would cite Hans Paerl as well. I believe he has shown (in Lake Taihu?) that the N:P ratios were not so fixed for cyanobacteria.	Noted
Mioni	29	Salinity: I think Pia Moissander did phylogenetic studies in the SFBD and has shown that there were two types of Microcystis, one of those was associated with higher salinity.	Noted
Mioni	31	I agree that absolute concentrations of nutrients is more relevant than N:P ratios with regards to cyanobacteria. I believe Hans Paerl also demonstrated this (Nature paper? I can't recall the exact source).	Noted
Mioni	37	last paragraph: typo "water column"	Noted
Mioni	39	Old River stn (D28) usually has the highest abundance based on my monitoring. Antioch also has a high abundance of Microcystis. Pia Moisander's paper show that there may be two different strains (different requirements?) between antioch and other stations. It varies between years at other stations (see attached examples but please do not use as this is for the paper I am writing...)	Noted

Mioni	40	It really depends on the year. Aphanizomenon was very sporadic before 2011 and I focused on enumerating Microcystis which was the dominant cyanoHAB. But in 2011, Aphanizomenon was pretty significant. The tricky part here is that the Aphanizomenon cells are much larger than Microcystis so even if Aphanizomenon doesn't reach the cell density of Microcystis, it doesn't mean they are not dominating the bloom (e.g. 2011, it would clog my filters pretty quickly at some stations)... In 2012, Microcystis abundance was higher than in 2011 but Apha was still pretty abundant. I think that the "bloom" classification based on cell density should be revised to take into account the biovolume... Cell counts can be misleading.	Noted
Mioni	44	There is definitely variations explained by the method but there are also variations due to heterogeneity, patchiness and temporal variation. In Clear lake, while on station (within maybe 30min or less), we could see the scum moving very quickly with the wind. Also, the two net samples mostly applies to colonial forms of Microcystis although it occurs also as single cells and microcolonies. Another bias is the cell count. Prior to do my cell counts, I was homogenizing the samples by dislocating the colonies physically (based on prior research and comparison). I suspect that not dislocating the colonies prior to do the cell count may result in bias as the person enumerating the cells may not be able to count accurately as colonies can be more 3D than 2D (I hope it makes sense)... Although there is a bias in all methods, I do not think I ever collected samples in the same time than Peggy and at the same location. Thus, the comparison is a little puzzling to me. We never did intercomparison of the cell enumeration from the same samples. It would be more relevant to compare methods for the toxicology work since we did intercomparison of methods for the same samples.	Noted
Mioni	48	"colonial Microcystis have been more common", see my comments regarding the bias of tow net sampling versus grad raw water samples...	Noted

Mioni	4 & 35	#3 and page 35, temperature: Lenny Grimaldo generated a logistic model based on my CALFED data (see attached) which shows that Microcystis bloom probability raises to 50% when surface water temperature reaches 25C. Also, I suspect there is a minimum temperature that would need to be sustained for several days if not week for a bloom to initiate.	Noted
Mioni	42-43	I think the SWAMP report could be cited, especially for the SPATT results.	Noted
Mioni	Fig 4.5	Figure 4.5: the axis are not labelled and I have trouble understanding this figure.	Noted
Mioni	48	I could not find the figure 2 mentioned here…	Noted

<u>EXHIBIT 10</u>

mercury by frequency, magnitude, and geographic extent such that the affected environment would be expected to have measurably higher body burdens of mercury in aquatic organisms, thereby substantially increasing the health risks to wildlife (including fish) or humans consuming those organisms. Based on these findings, this impact is considered to be less than significant. No mitigation is required.

Impact WQ-14: Effects on Mercury Concentrations Resulting from Implementation of Environmental Commitments 3, 4, 6–12, 15, and 16

NEPA Effects: The potential types of effects on mercury resulting from implementation of the Environmental Commitments under Alternative 4A would be generally similar to those described under Alternative 4 (see Section 8.3.3.9). However, the magnitude of effects on mercury and methylmercury at locations upstream of the Delta, in the Delta, and the SWP/CVP Export Service Areas related to habitat restoration would be considerably lower than described for Alternative 4. This is because the amount of habitat restoration to be implemented under Alternative 4A would be very low compared to the total proposed restoration area that would be implemented under Alternative 4. The small amount of habitat restoration to be implemented under Alternative 4A may occur on lands in the Delta formerly used for irrigated agriculture. Habitat restoration proposed under Alternative 4A has the potential to increase water residence times and increase accumulation of organic sediments that are known to enhance methylmercury bioaccumulation in biota in the vicinity of the restored habitat areas. Design of restoration sites would be guided by Environmental Commitment 12, which requires development of site-specific mercury management plans as restoration actions are implemented. The effectiveness of minimization and mitigation actions implemented according to the mercury management plans is not known at this time, although the potential to reduce methylmercury concentrations exists based on current research. Although Environmental Commitment 12 would be implemented with the goal to reduce this potential effect, there remain uncertainties related to site-specific restoration conditions and the potential for increases in methylmercury concentrations in the Delta in the vicinity of the restored areas. Therefore, the effect of Environmental Commitments 3, 4, 6–12, 15, and 16 on mercury and methylmercury is considered to be adverse.

CEQA Conclusion: There would be no substantial, long-term increase in mercury or methylmercury concentrations or loads in the rivers and reservoirs upstream of the Delta or the waters exported to the SWP/CVP Export Service Areas due to implementation of Environmental Commitments 3, 4, 6–12, 15, and 16 relative to Existing Conditions. However, in the Delta, due to the small amount of tidal restoration areas proposed, relative to Existing Conditions, uptake of mercury from water and/or methylation of inorganic mercury may increase in localized areas as part of the creation of new, marshy, shallow, or organic-rich restoration areas. Although not quantifiable, on a local level, increases in methylmercury concentrations may be measurable. Methylmercury is CWA Section 303(d)-listed within the affected environment, and therefore any potential measurable increase in methylmercury concentrations would make existing mercury-related impairment measurably worse. Because mercury is bioaccumulative, increases in water-borne mercury or methylmercury that could occur in some areas could bioaccumulate to somewhat greater levels in aquatic organisms and would, in turn, pose health risks to fish, wildlife, or humans. Design of restoration sites would be guided by Environmental Commitment 12, which requires development of site-specific mercury management plans as restoration actions are implemented. The effectiveness of minimization and mitigation actions implemented according to the mercury management plans is not known at this time, although the potential to reduce methylmercury concentrations exists based on current research. Although Environmental Commitment 12 would be implemented with the goal to reduce this potential effect, the uncertainties related to site specific restoration conditions and the potential for increases in methylmercury concentrations in the Delta result in this potential impact being considered significant because, as described above, any potential measurable increase in methylmercury concentrations would make existing mercury-related impairment measurably worse. No mitigation measures would be available until specific restoration actions are proposed. Therefore, this impact is considered significant and unavoidable.

Impact WQ-15: Effects on Nitrate Concentrations Resulting from Facilities Operations and Maintenance

Upstream of the Delta

As described for Alternative 4 (in Section 8.3.3.9), nitrate levels in the major rivers (Sacramento, Feather, American) are low, generally due to ample dilution available in the reservoirs and rivers relative to the magnitude of the point and non-point source discharges, and there is no correlation between historical water year average nitrate concentrations and water year average flow in the Sacramento River at Freeport. Consequently, any modified reservoir operations and subsequent changes in river flows under Alternative 4A, relative to Existing Conditions or the No Action Alternative (ELT), are expected to have negligible, if any, effects on average reservoir and river nitrate-N concentrations in the Sacramento River watershed upstream of the Delta.

In the San Joaquin River watershed, nitrate concentrations are higher than in the Sacramento River watershed, owing to use of nitrate based fertilizers throughout the lower watershed. The correlation between historical water year average nitrate concentrations and water year average flow in the San Joaquin River at Vernalis is a weak inverse relationship—that is, generally higher flows result in lower nitrate concentrations, while low flows result in higher nitrate concentrations (linear regression r^2=0.49; Figure 2 in Appendix 8J, *Nitrate*). Under Alternative 4A, long-term average flows at Vernalis would decrease an estimated 1% relative to Existing Conditions and would remain virtually the same relative to the No Action Alternative (ELT). Given the relatively small decreases in flows and the weak correlation between nitrate and flows in the San Joaquin River, it is expected that nitrate concentrations in the San Joaquin River would be minimally affected, if at all, by anticipated changes in flow rates under the No Action Alternative (ELT).

In the LLT, the Delta source water fractions may be different from those occurring in the ELT due to changes in upstream hydrology and Delta hydrodynamics from additional climate change and sea level rise. These effects would occur independent of the alternative and, thus, the alternative-specific effects on nitrate in the LLT are expected to be similar to those described above.

Any negligible changes in nitrate concentrations that may occur under Alternative 4A in the water bodies of the affected environment located upstream of the Delta would not be of frequency, magnitude and geographic extent that would adversely affect any beneficial uses or substantially degrade the quality of these water bodies, with regard to nitrate.

Delta

Mass balance calculations indicate that under Alternative 4A relative to Existing Conditions and the No Action Alternative (ELT), nitrate concentrations throughout the Delta are anticipated to remain low (<1.4 mg/L-N) relative to adopted objectives (Appendix 8J, *Nitrate*, Table 34). Although changes at specific Delta locations and for specific months may be substantial on a relative basis (Appendix

Letter 16
City of Vallejo

City of VALLEJO California
Water Department · 202 Fleming Hill Road · Vallejo · CA · 94589 · 707.648.4307

Delivered via email (frpa@water.ca.gov)

February 14, 2020

Lookout Slough Public Comment
California Department of Water Resources Senior Environmental Scientist
Heather Green 3500 industrial Blvd.
West Sacramento, CA 95691

Subject: City of Vallejo Lookout Slough Restoration Project Draft Environmental Impact Report Comment Letter
File: Lookout Slough Dear Ms. Green,

Thank you for providing the City of Vallejo (the City) with the opportunity to comment on the Lookout Slough Restoration Project Draft Environmental Impact Report, which proposes to restore approximately 3,400 acres of tidal marsh at Lookout Slough. The purpose of this letter is to provide the California Department of Water Resources (DWR) comments the City deems vital to Vallejo citizens and Vallejo's regional water customers.

In addition to the regional comments submitted by Solano County Water Agency (SCWA) on Vallejo's behalf (see letter entitled, "Regional Comment Letter on Draft EIR for the Lookout Slough Restoration Project," dated February 13, 2020, where Vallejo is one signatory out of ten organizations in Napa, Solano, and Contra Costa counties), the City of Vallejo is submitting this separate letter with more specific comments relating to Vallejo's historic water right and Vallejo's historic Cache Slough Pumping Plant facility (Cache Slough PP). While the City supports habitat restoration, our concern is this project could negatively impact our ability to use our historic water right in Cache Slough, as well as significantly impact our ability to treat degraded water quality.

The Delta is the primary source of water for the City and the City's regional customers. The City has water rights that pre-date the State Water Project (SWP) on Cache Slough. In addition to the over 120,000 residents of Vallejo, Vallejo's Water Department serves Travis Air Force Base (one of the largest employers and economic drivers in Solano County), and areas of rural Solano County (Green Valley and Gordon Valley). During times of drought, and through good-neighbor agreements, Vallejo also periodically provides water to the City of American Canyon, Napa, Benicia, and Fairfield. The importance of the City's historic water right to the Solano County region cannot be overstated.

This letter provides a summary of Vallejo's key concerns, that need to be addressed in the Lookout Slough Restoration Project – Environmental Impact Report. The overlying concern for the City is the importance and protection of reliable, high quality water for the City and our surrounding region.

Concerns:

1.) Municipal Users
In our comment letter for the Notice of Preparation (dated April 22, 2019), we indicated our concern that the project would impact our ability to divert water from Cache Slough PP (to which we did not receive a response).

The EIR currently has no reference to the City's Cache Slough PP located directly upstream of the proposed project. The location of the City's Cache Slough PP, located at Hastings Cut, is very near to the TUFLOW Model Boundary (Appendix Q-Figure 12 identified as "Cache Slough RM"). This location is approximately 1,000 feet downstream of our pumping plant. Figure 1, previously provided in the NOP Comment Letter, identifies the location of the pumping plant. 16-1

A response should be provided on our NOP comment letter on how Vallejo's Cache Slough PP will be better analyzed in the EIR, and how our historic water right will be protected. The City reserves its right to reactivate the Cache Slough PP at any point in the future, at our historic water right rate of 35.52 cubic foot per second (cfs).

Response 16-1:

All comments received on the NOP were taken into consideration during the development of the Draft EIR.

The following text changes have been made to page IV.G-7 in Section IV.G, *Hydrology and Water Quality* of the Draft EIR to eflect the location of the City of Vallejo's Cache Slough water diversion pumping plant approximately 1.5 river miles from the Proposed Project Site:

> Diversions near the Proposed Project Site include the nearby RD 2068 agricultural diversion, the State Water Project's Barker Slough Pumping Plant, the City of Vallejo's Cache Slough Pumping Plant, and private agricultural diversions.

DWR recognizes that municipal water quality is an important issue with regard to Contra Costa Water District (CCWD), the North Bay Aqueduct (NBA), and the City of Vallejo.

As part of the Draft EIR analysis, the hydrodynamic model was used to assess changes to flows into and out of upper Cache Slough. The model used for this was the Resource Management Associates (RMA) model, which is described in more detail in Master Response 1, *Salinity and Bromide* and Appendix X of this Final EIR. This model's domain extends over the entire Delta and San Francisco Bay, including Cache Slough to its terminus approximately one mile upstream of the City's Cache Slough intake and the lower four miles of Ulatis Creek upstream of the City's Cache Slough intake (Appendix X, Figure 7). Estimated diversions from Cache Slough and Ulatis Creek, as well inflows to Ulatis Creek from its watershed and the Vacaville wastewater treatment plant are all represented in the model. Using this model, the tidal exchange for existing conditions and with the Proposed Project were both modeled and the results of these simulations compared to assess changes due to the Proposed Project. This modeling demonstrated that tidal exchange to upper Cache Slough decreased by less than 10%. For a channel with the conveyance capacity of upper Cache Slough, a decrease in tidal exchange of 10% will not impair the diversion of 35.52 cfs, should the City choose to exercise its historic water diversion rate in the future. Currently, the City of Vallejo takes its water from the Barker Slough pumping plant of the North Bay Aqueduct. The potential impact of the Proposed Project on both locations (current and historic) on water quality are discussed further in Master Response 1, *Salinity and Bromide*, and on water levels in Master Response 9, *Tidal Effects on Diversions*.

2.) Modeling Confidence
As part of the DEIR review, the Solano County Water Agency requested model output information from DWR. SCWA then forwarded that model output to City of Vallejo staff for review. City staff concurs and will expand on SCWA's concerns in regards to model confidence.

Figure 2 is the time series plot for July-2009 showing measured and modeled EC data for the City of Vallejo's Pumping Plant at Cache Slough. Figure 3 is a Scatter Plot showing the Observed (i.e. measured) Data vs Modeled EC data for this same time period. The corresponding R^2 value was calculated to be = 0.09, which indicates very poor correlation (good correlation is generally above 0.85). The two figures illustrate the challenge of the RMA model to reasonably simulate EC during typical summer conditions at the City of Vallejo's Pumping Plant location. This is important, as the Lookout Slough project is located in close proximity to this node, and is an indication of poor model confidence. 16-2

Further analysis of the time series data identifies several areas of significant inconsistencies in the RMA model (Figures 4-15), particularly as it pertains to the Cache Slough PP. The actual data exhibits high variability that is inconsistently captured, or completely void, from the model output.

Additional model analyses, comparisons, and transparency on the model development is needed, to improve overall model confidence and ability to reasonably simulate Project Impacts on water quality.

The City does not accept or agree with any water quality conclusions made using this model in its present state.

Response 16-2:

The RMA hydrodynamic and electrical conductance (EC) modeling was revised and extended in response to comments on the Draft EIR and the revised modeling is documented in Appendix X of this Final EIR. As shown in Appendix X, Table 1, the revised model's coefficient of determination (R^2) between predicted and observed EC for the currently unused City of Vallejo's Pumping Plant is substantially improved. For the Cache Slough monitoring station "CCS" located closest to the City's Pumping Plant, R^2 equals 0.67 for 2009 to 2010. For the upper Cache Slough monitoring station "UCS" located about a mile upstream from the City's Pumping Plant, R^2 equal 0.80 for 2016. (EC data were not available at CCS for 2016 and not available for UCS for 2009 to 2010.) This indicates that the model's predictions replicate 67% to 80% of the variance in the observed EC over three years with a range in natural seasonal and inter-annual variability. Details about the models calibration can be found in Appendix B, Figure 112 and Figure 130 of Appendix X. This level of replication of observed variance is deemed to be sufficient for the overall modeling approach. This approach is to characterize the potential impacts of the Proposed Project on EC, salinity, and bromide by comparing the differences between modeling with and without the Proposed Project. As shown in the revised model figures evaluating water quality impacts at the City's Pumping Plant (Appendix X, Figures 25 and 39), the differences between with and without the Proposed Project are typically smaller than the differences between observed and predicted conditions that are raised in the comment. Therefore, the conclusions drawn from the modeling are sufficient for the significance conclusion of less than significant in the Draft EIR.

See Master Response 1, *Salinity and Bromide*, for more information on the modeling of salinity and bromide, including how the model was revised to improve EC predictions in upper Cache Slough.

3.) Hydraulics
In Appendix T (Potential Tidal Water Levels and Tidal Prism Impacts Assessment), it states the Project has the potential to cumulatively alter tidal hydraulics in the Delta, and specifically states the Project has the potential to affect the capacity of agricultural water supply intakes. Given that the City's municipal supply intake was not taken into consideration during the modeling of this project, and due to Vallejo's intake being extremely close to the RD2068 agricultural intake, we are concerned our intake will be negatively affected by this project. Although the hydraulic model indicates minimal impacts in the Cache Slough reach, given the significant errors witnessed in the water quality model results, the City lacks confidence in the veracity of the hydraulic model. 16-3

The City's Cache Slough PP should be specifically included in the hydraulic modeling analysis, and analysis needs to be provided that shows the model has excellent correlation and is representative of actual conditions.

Response 16-3:

See Response 16-1, Master Response 1, *Salinity and Bromide*, and Master Response 9, *Tidal Effects on Diversions*.

4.) Water Quality
The City concurs with the opinion and concerns expressed in the SCWA-authored regional letter, dated February 13, 2020, as well as SCWA's individual letter, dated February 14, 2020. The NBA water source provides a consistent high quality source water, allowing the City of Vallejo to have reduced monitoring requirements for organic carbon, total trihalomethane (TTHMs), haloacetic acids (HAAs), and bromate/bromide. The Draft EIR currently indicates there are no direct project impacts to the Barker Slough pumping plant (the current intake for Vallejo's NBA water), but the DEIR needs to study indirect impacts to source water treatability.

The City lacks confidence in the assertion of no direct impacts with the model in its current state. Any small impact to Barker Slough's water quality resulting in a small increase in organics or bromide, would cause huge impacts to Vallejo's water quality and treatability. Of largest concern is the potential increase in disinfection by products (DBPs) if increased ozone and chlorine is required to treat source waters. Therefore, any small change in water quality (organics or bromide) may lead to Vallejo losing their reduced monitoring status, and result significant financial impact to the City. Such changes would also lead to higher chemical usage, which would also increase costs, and could have further negative effects on the water quality of Vallejo's treated water. There are many other possible effects that are not yet determined. 16-4

The EIR and modeling analyses must clearly show that the project will not increase precursors to disinfectant by-products, which would significantly increase the City's treatment and monitoring costs, and could degrade treated water quality and effect public health.

Response 16-4:

See Section IV.G, *Hydrology and Water Quality* of the Draft EIR. See also Master Response 1, *Salinity and Bromide,* and Master Response 8, *Dissolved Organic Carbon*. As discussed in Section IV.G, *Hydrology and Water Quality*, of the Draft EIR, the Proposed Project would have less than significant post-construction impacts on water quality and the additional modeling and analysis supports this conclusion.

5.) Habitat Improvement
Though the City supports habitat improvement in the delta, the City is concerned that mitigations needed due to degradation of the entire delta, are being concentrated upon historic water users in the Lookout Slough region. Should increased biological activity occur in the area surrounding our Cache Slough PP, this may affect the City's ability to operate our Cache Slough PP at our discretion. 16-5

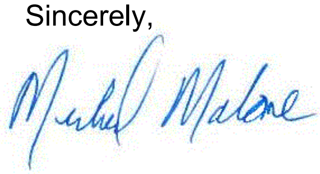
The EIR should indicate if future biological activity, including the increase of invasive species, could hamper the City's ability to pump its historic water right.

Response 16-5:

See Master Response 3, *Local Water Diversions and Special-status Fish Species*.

Thank you for taking the time to review our concerns.

Sincerely,



Mike Malone
Water Department Director

Cc: Roland Sanford, General Manager of Solano County Water Agency Beth Schoenberger, Water Department Operations Manager Randy Risner, Interim City Attorney
Shannon Eckmeyer, Assistant City Attorney Danielle Bonham, Water Quality Manager Mark Quady, Engineering Manager Melissa Cansdale,

Associate Engineer Attachments

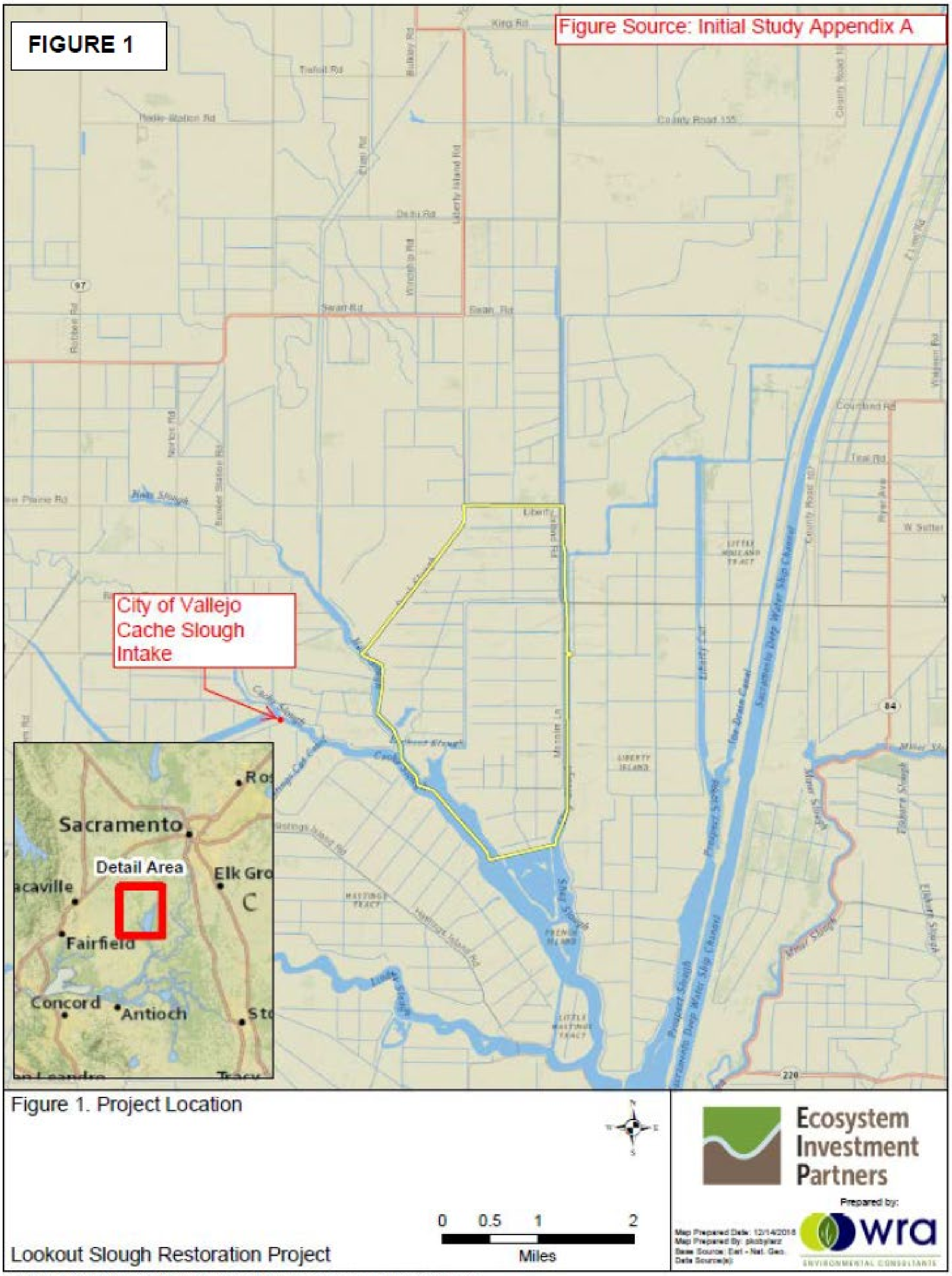


Figure 1. Project Location

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FIGURE 2

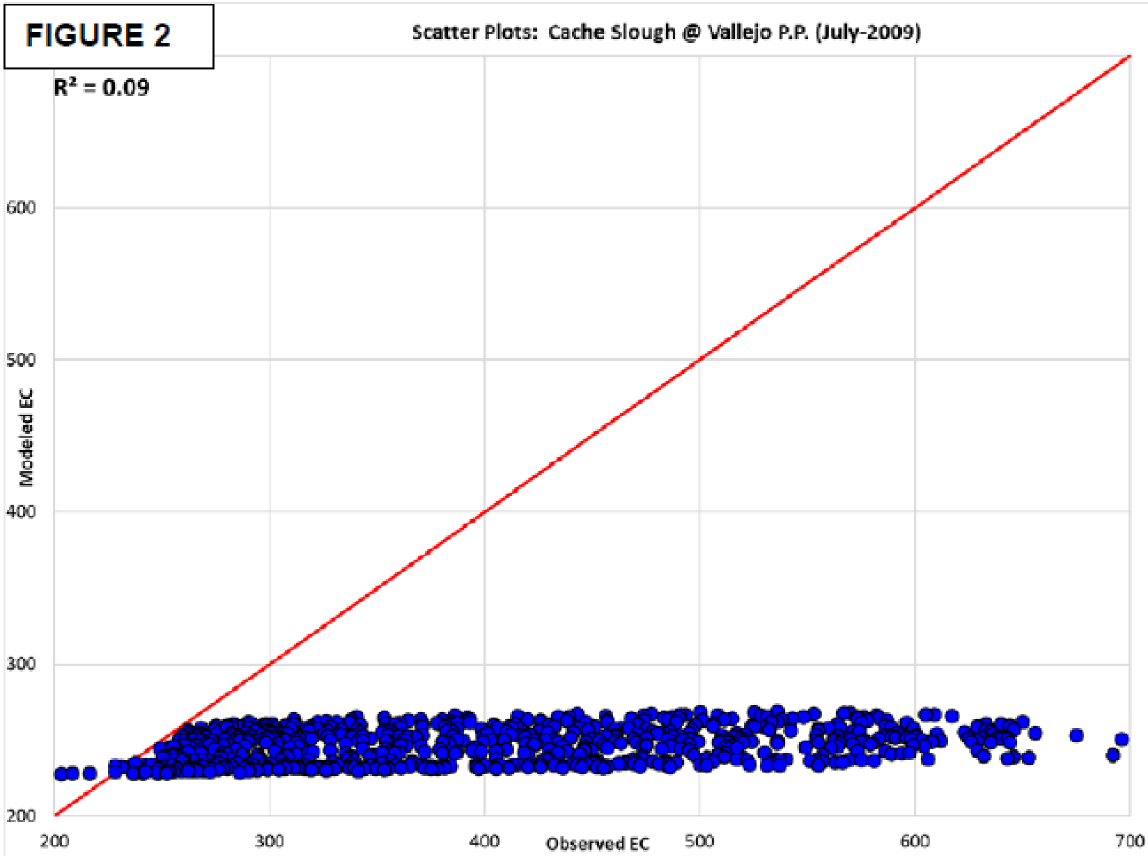


FIGURE 3

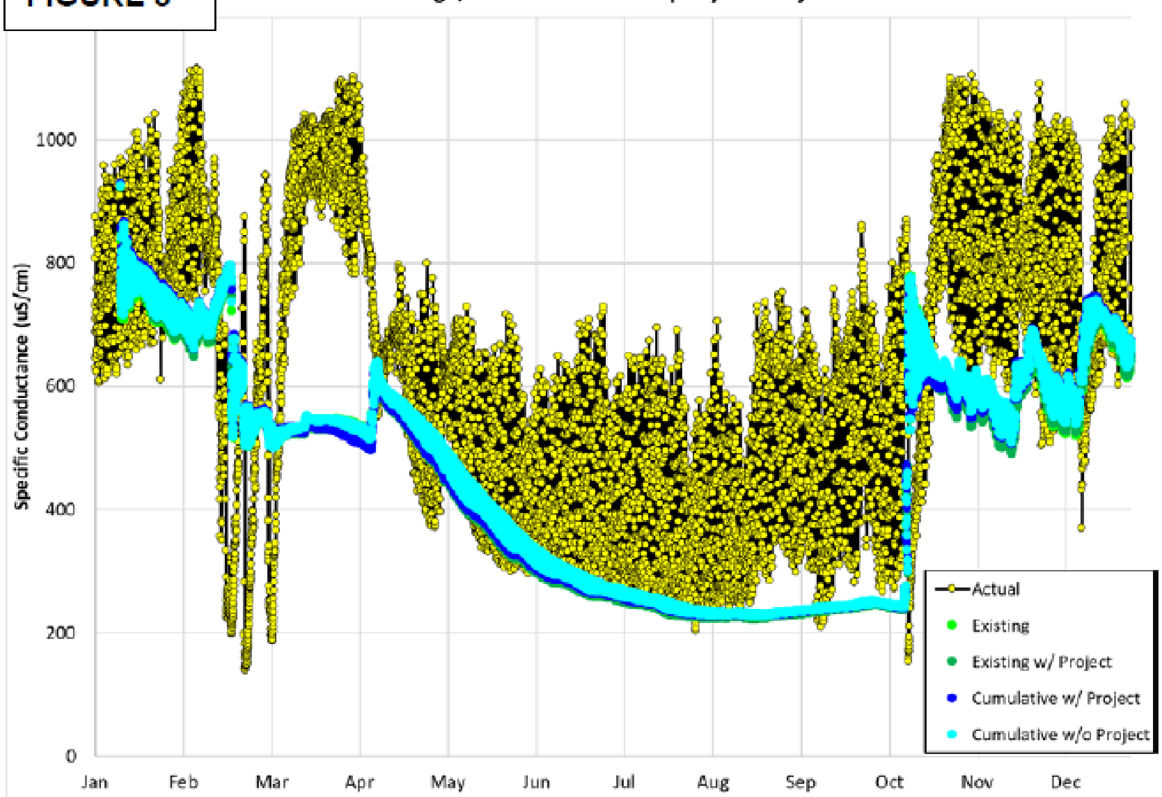


FIGURE 4 Lookout Slough, RMA Model Results | City of Vallejo P.P.

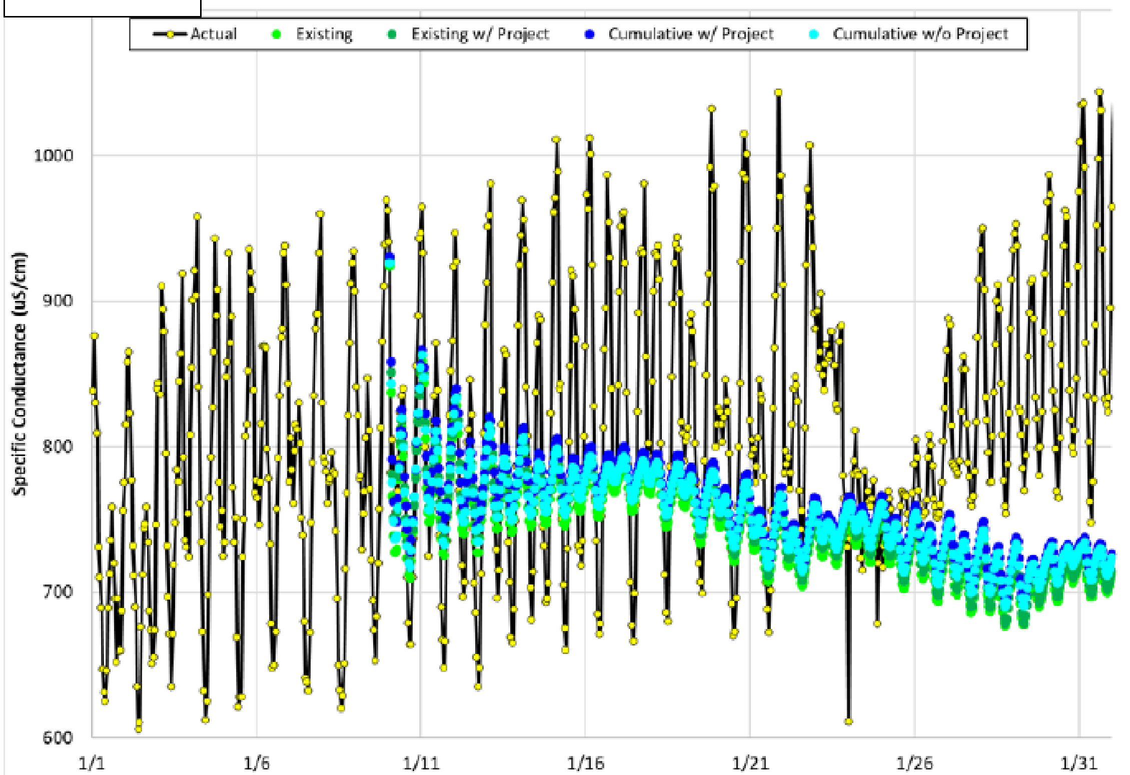


FIGURE 5 Lookout Slough, RMA Model Results | City of Vallejo P.P.

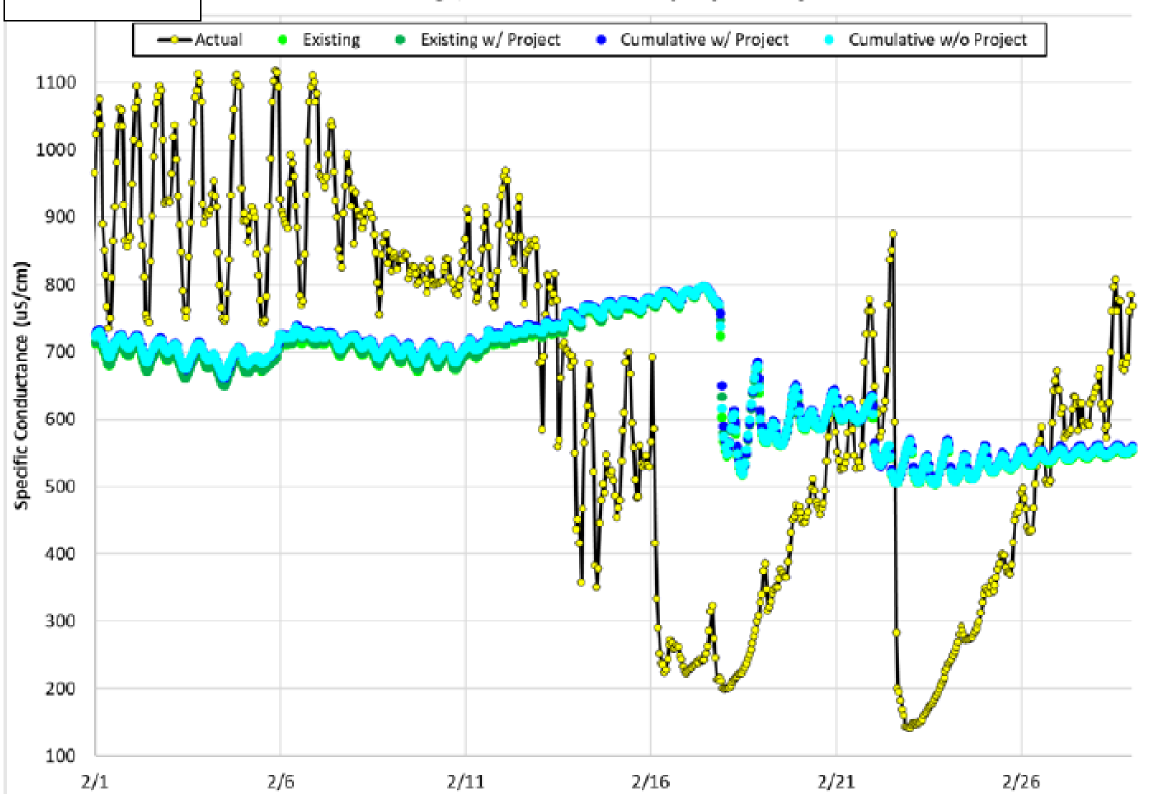


FIGURE 6

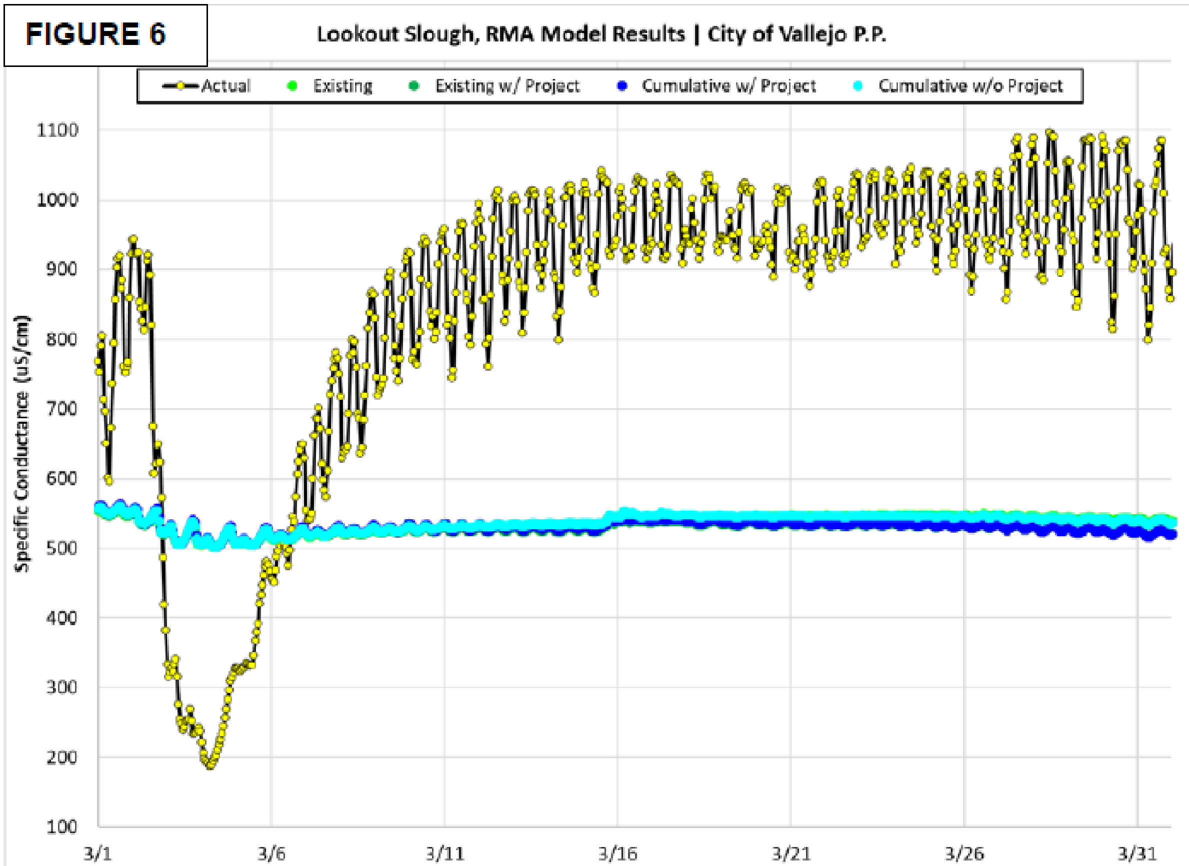


FIGURE 7

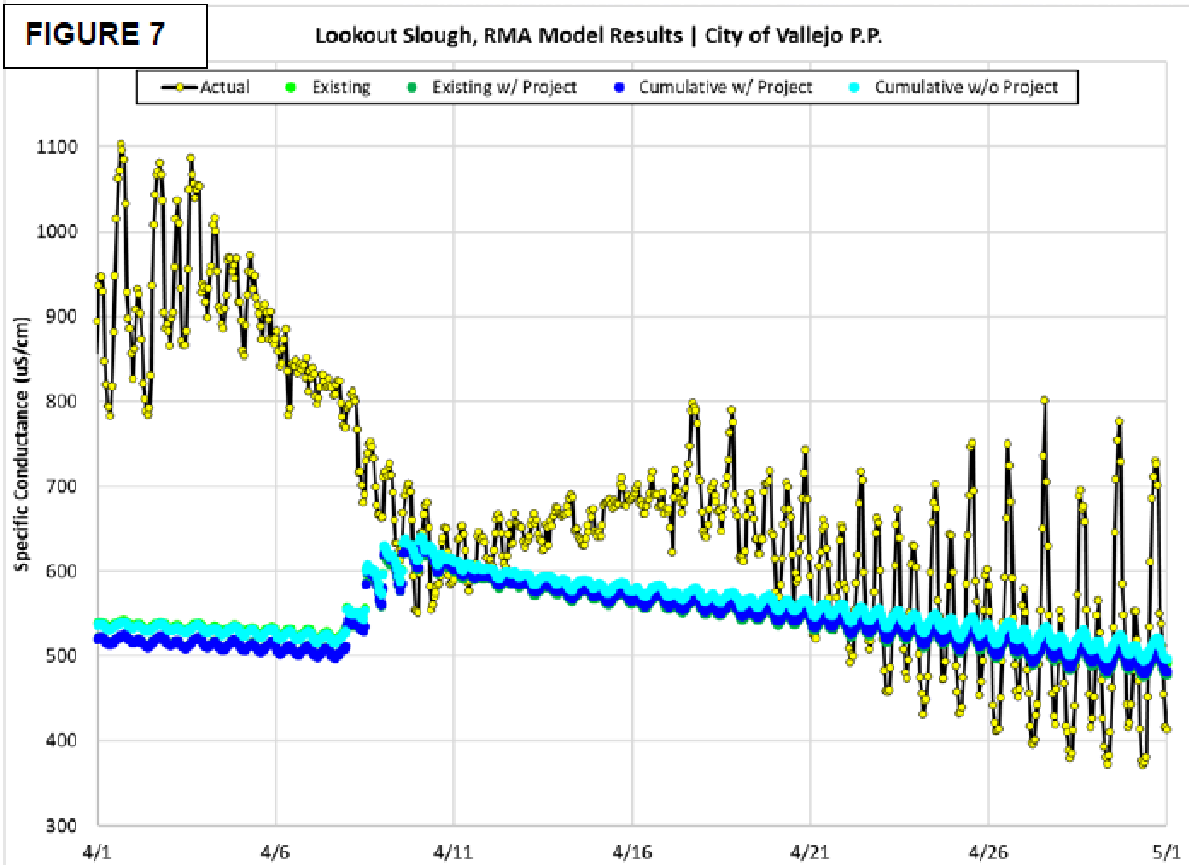


FIGURE 8

Lookout Slough, RMA Model Results | City of Vallejo P.P.

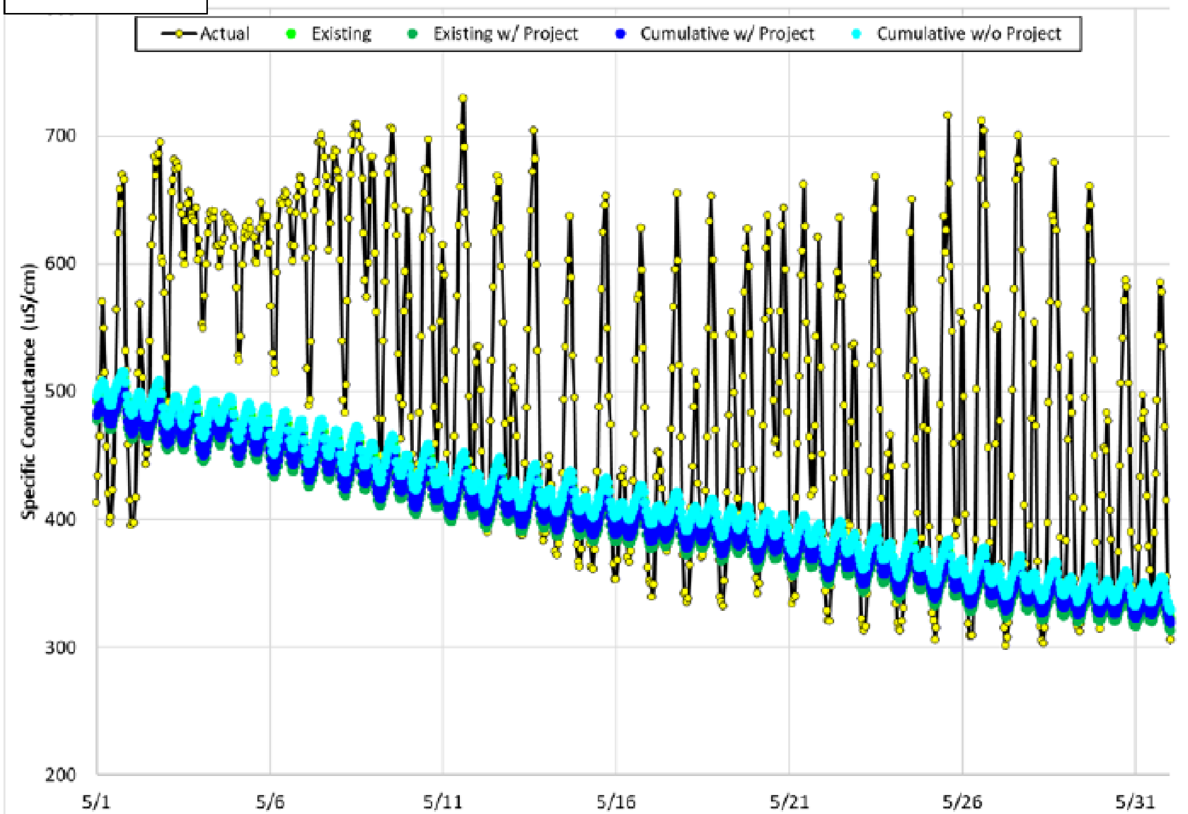


FIGURE 9

Lookout Slough, RMA Model Results | City of Vallejo P.P.

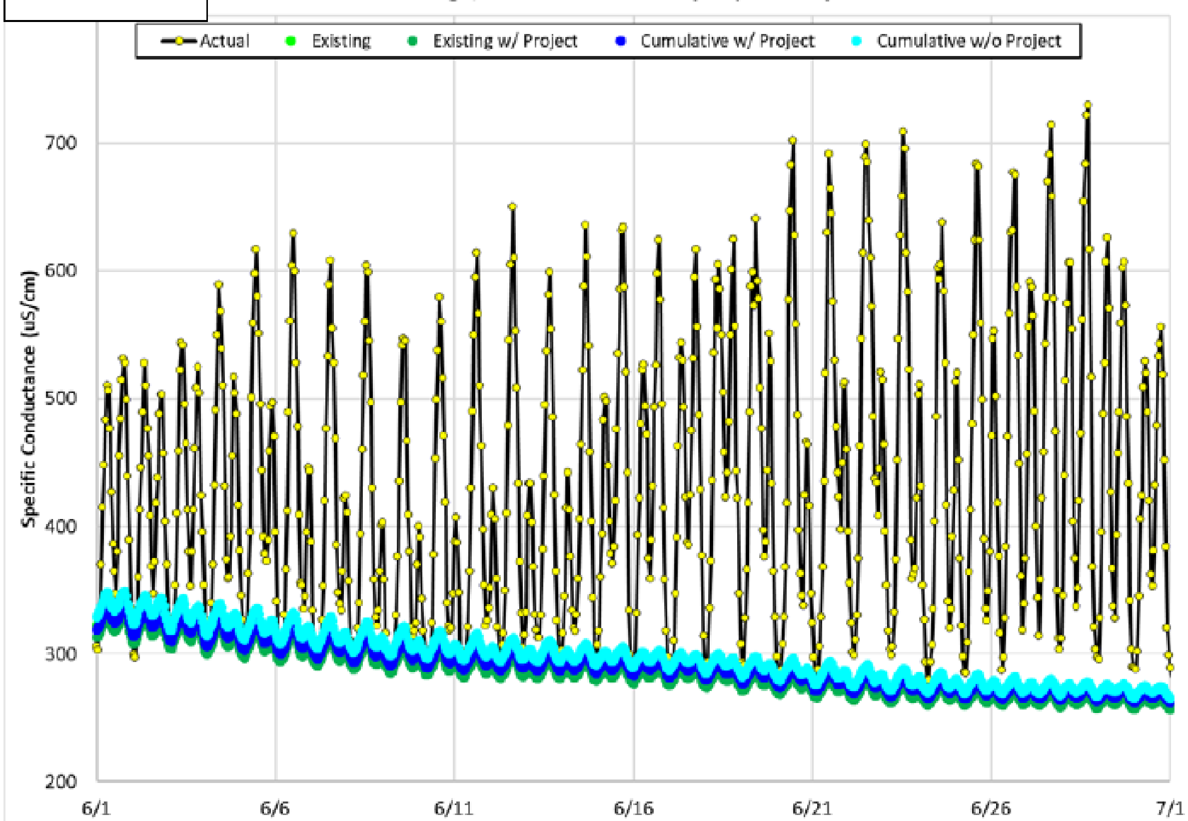


FIGURE 10

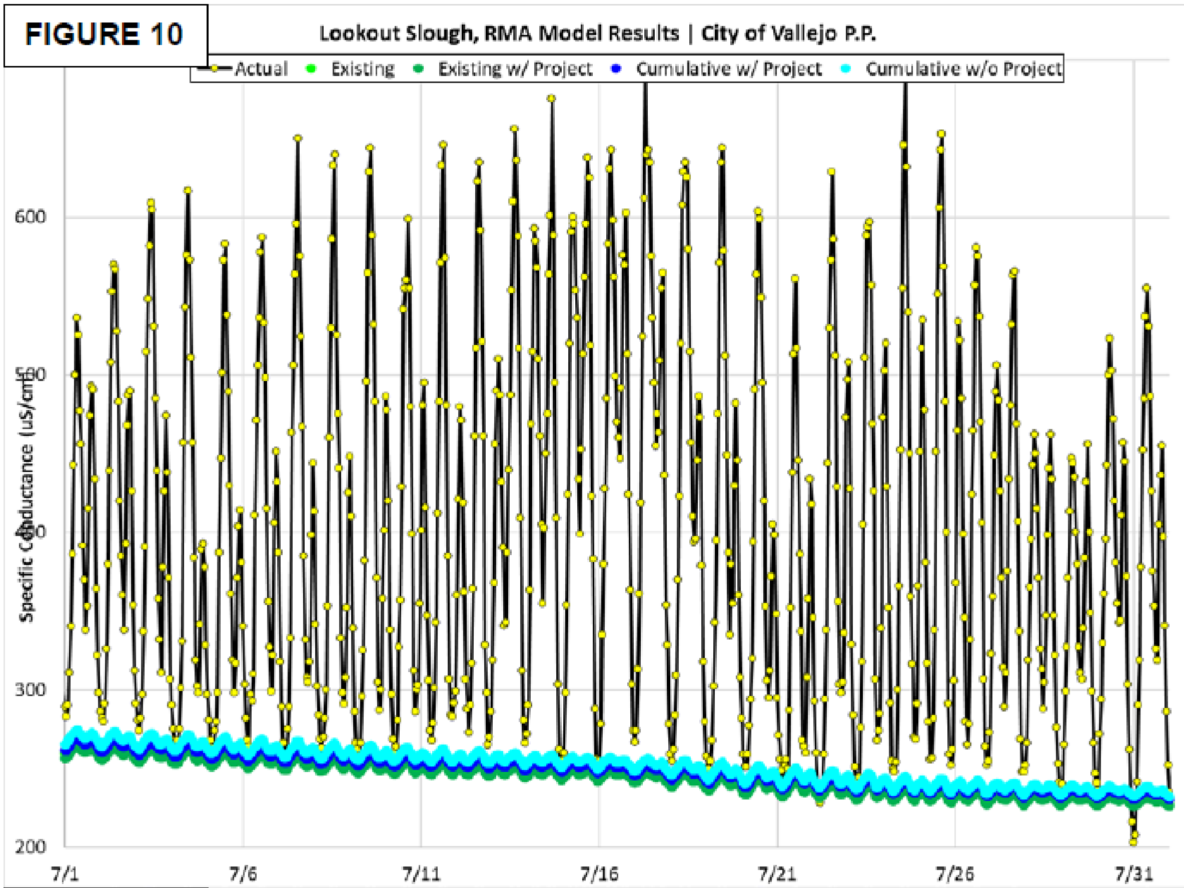


FIGURE 11

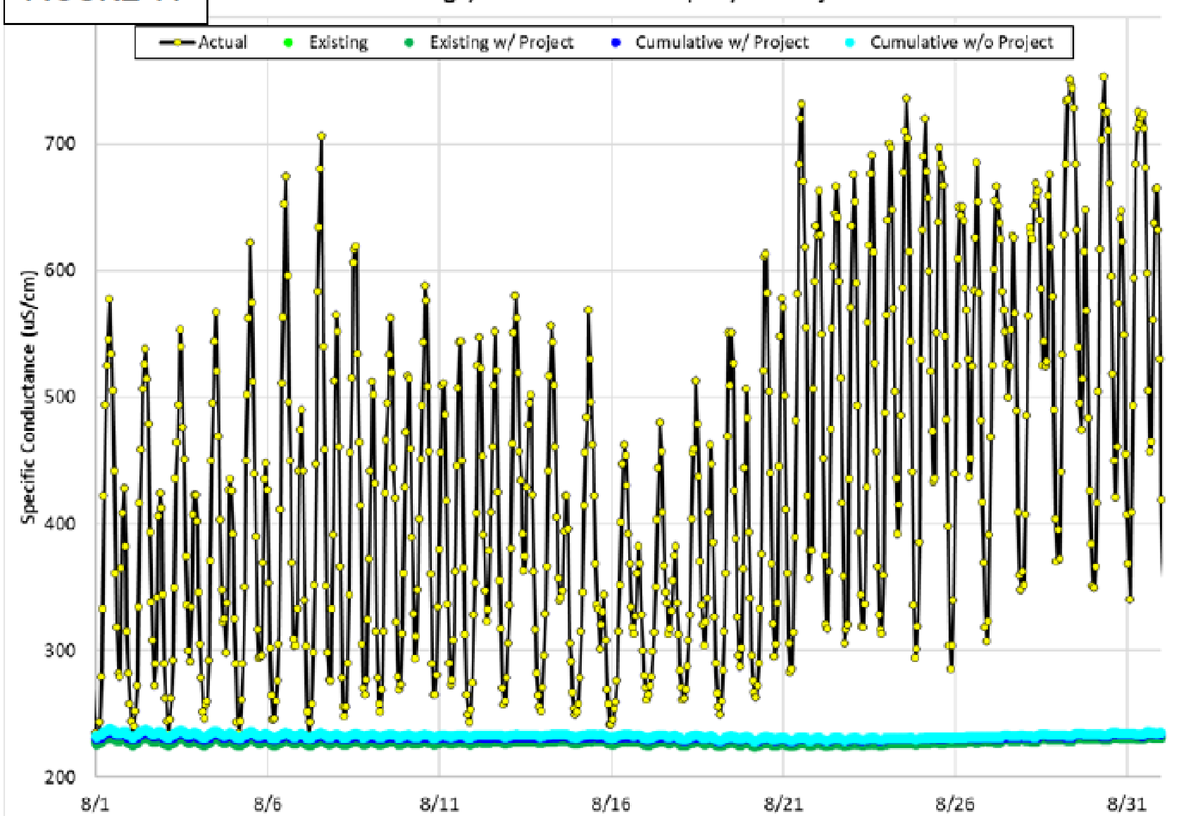


FIGURE 12

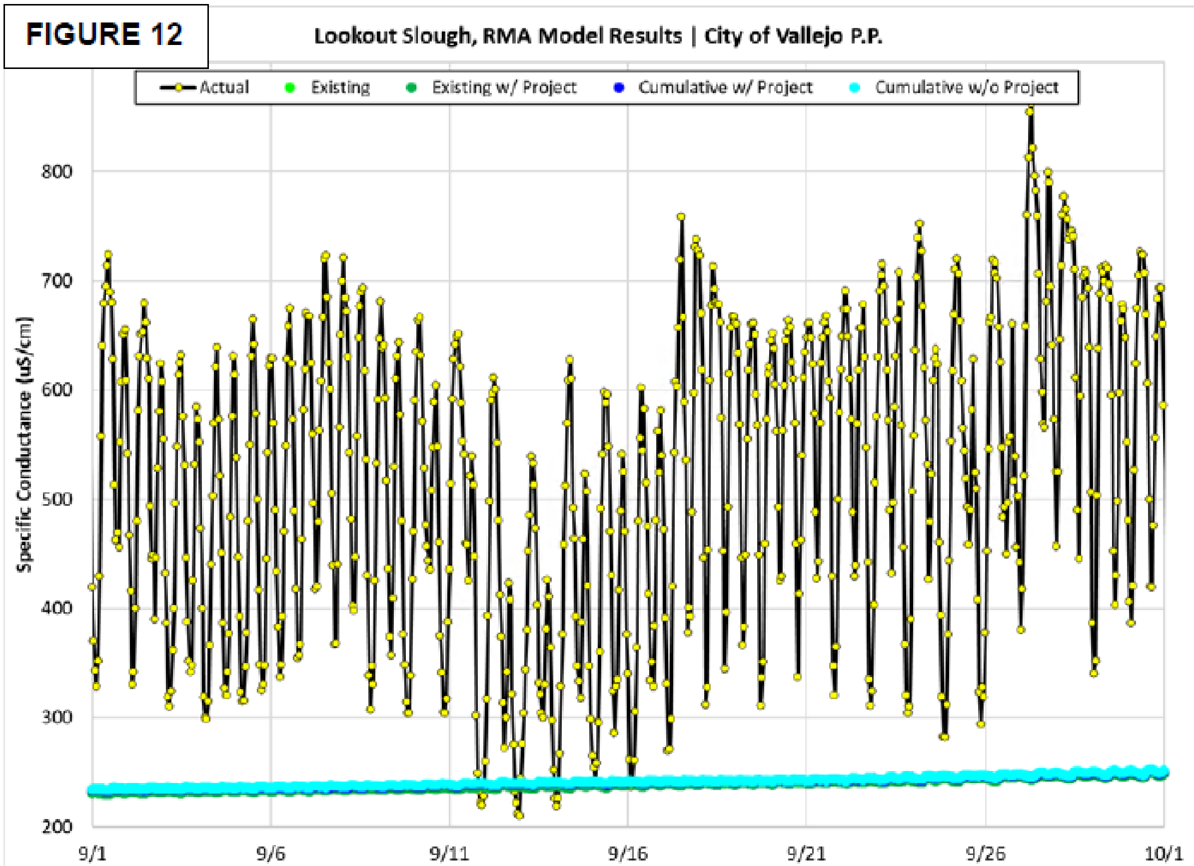


FIGURE 13

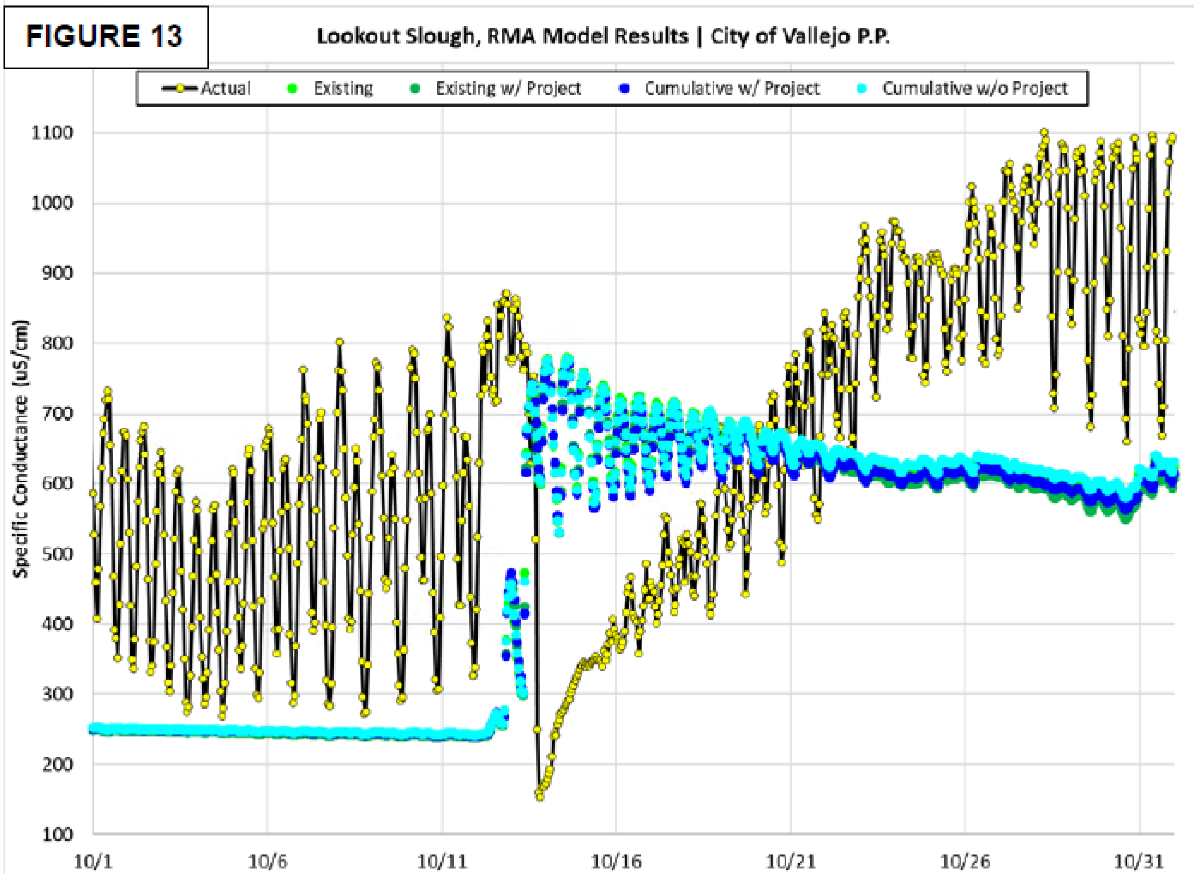


FIGURE 14

Lookout Slough, RMA Model Results | City of Vallejo P.P.

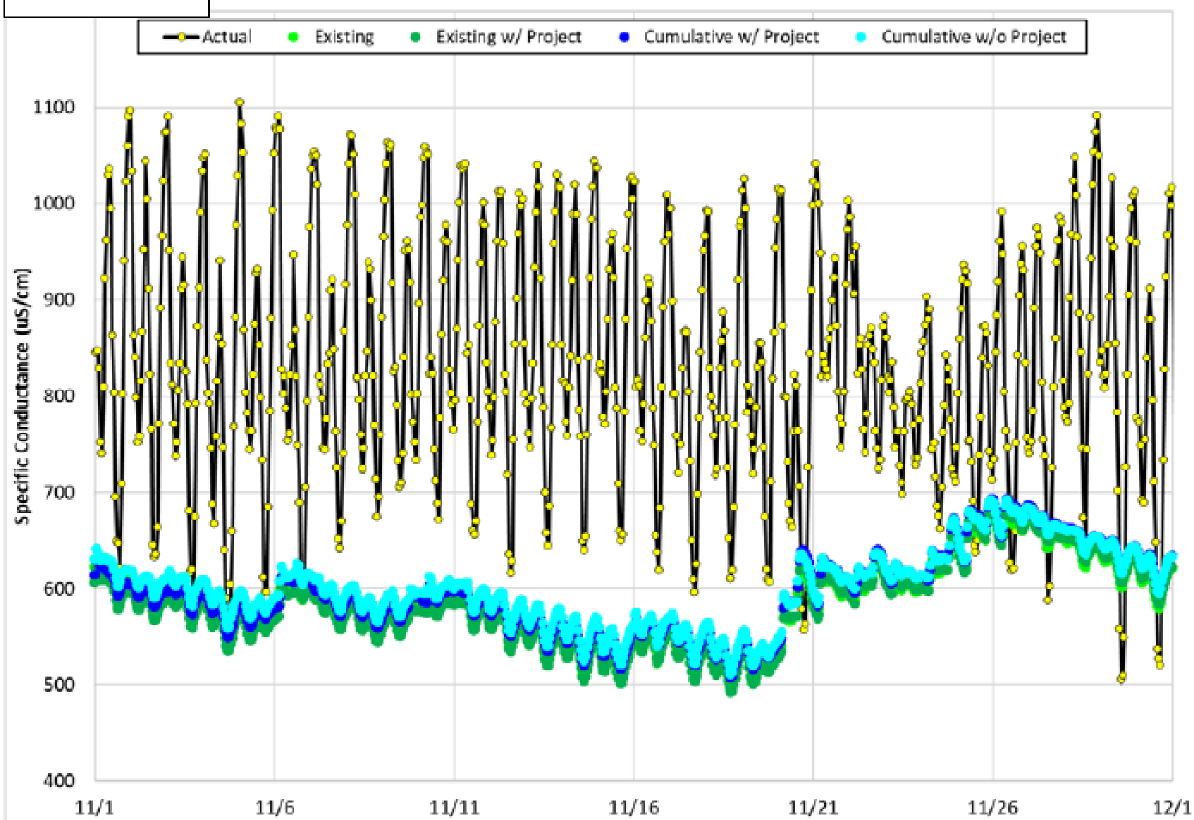
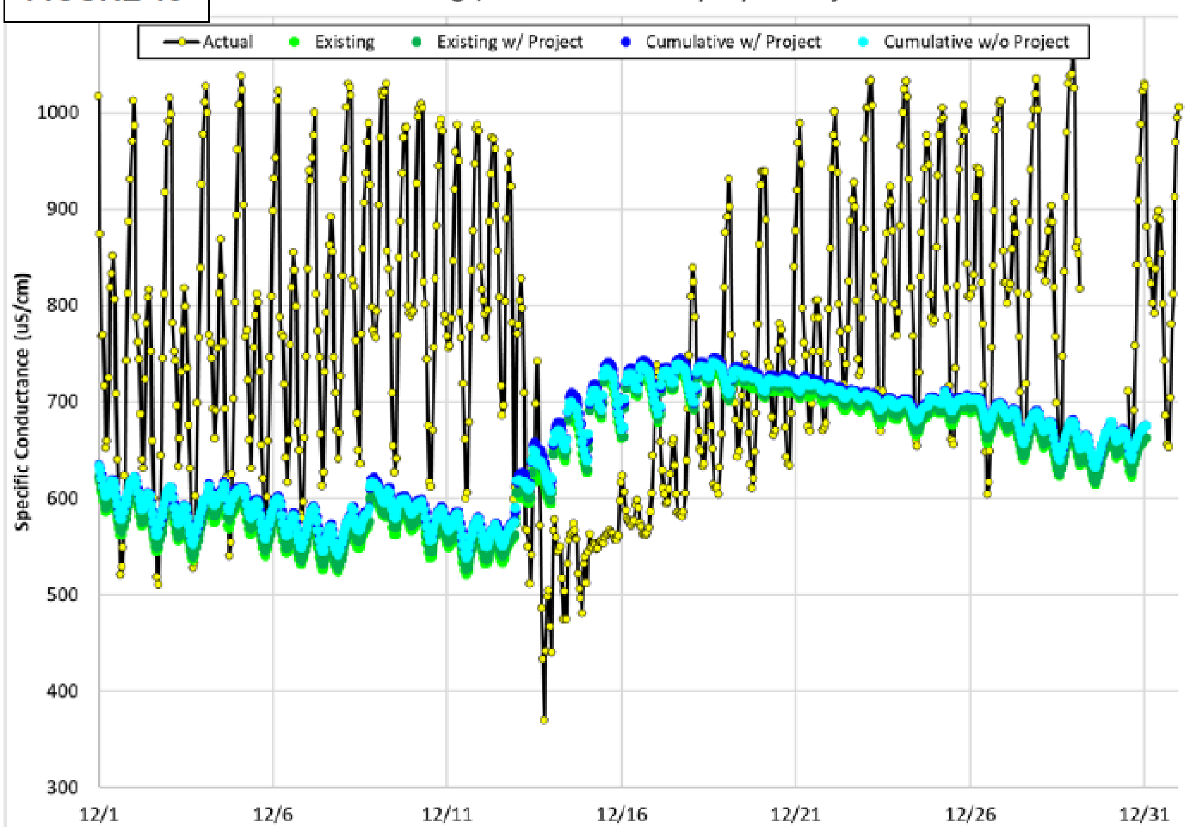


FIGURE 15

Lookout Slough, RMA Model Results | City of Vallejo P.P.



Letter 17
West Sacramento Area Flood Control Agency

Letter 17

WSAFCA
West Sacramento Area Flood Control Agency

CITY OF WEST SACRAMENTO

PORT of WEST SACRAMENTO

February 14, 2020

California Department of Water Resources Attn: Heather Green
3500 Industrial Blvd
West Sacramento, CA 95691

Subject: **Comments on Lookout Slough Draft Environmental Impact Report (EIR)**

Dear Ms. Green:

The West Sacramento Area Flood Control Agency (WSAFCA), The City of West Sacramento (City), and The Port of West Sacramento (Port) appreciate the opportunity to review and provide comments on the Draft EIR for the Lookout Slough Tidal Habitat Restoration and Flood Improvement Project. All three agencies representing the West Sacramento area support multi- benefit projects that enhance habitat for fish and wildlife while improving flood control infrastructure.

WSAFCA, in partnership with the California Department of Water Resources, recently completed the Southport Levee Improvement Project that demonstrates and implements these very same values. This project greatly reduces flood risk to the City of West Sacramento through the construction of nearly 4 miles of setback levee along the Sacramento River. This significant levee setback created the opportunity to reconnect over 150 acres of floodplain to the river in the urban core greatly improving riparian, shaded streamside and adjacent upland habitats.

Based on this and other experience collaborating with other agencies, the agencies representing West Sacramento community provide the following comments for your consideration.

17-1

1. Based upon a cursory review of the Appendix D in the Draft EIR, the source for wind speed is the Sacramento Executive Airport, which is inland and upstream of the project site. Winds near the project site are noted to be greater than those more inland and upstream of the project site. The runup heights seem small for the fetch distances compared to other studies elsewhere in the Yolo Bypass.

2. The with-project condition increases wind-wave runup with a commensurate increase of erosive effect against the east side of the Yolo Bypass, thereby increasing levee failure risk. If the levee were to fail, floodwaters from the bypass would enter the Deep Water Ship Channel (DWSC), increasing the flood risk to communities upstream, including the City of West Sacramento. Additionally, the DWSC would likely be rendered useless for commerce.

3. The City, WSAFCA, and Port request a review of the calculations to ensure that proper and adequate assumptions are used to quantify the effects of wind-wave runup on the DWSC levee. It is important that the effects are analyzed accurately so that potential unintended consequences of this very desirable project can be avoided.

Response 17-1:

As described in Section IV.G, *Hydrology and Water Quality*, the Draft EIR relies on hydraulic modeling and wave analysis to evaluate changes to velocity, shear stress, and wind-wave runup associated with the Proposed Project. While not identified directly in Section IV.G, changes in wave runup along the Sacramento River Deep Water Ship Channel West Levee were analyzed in the *Lookout Slough Setback Levee Wave Runup and Wind Setup Analysis TM*, attached as Appendix C to Appendix D, *Lookout Slough Tidal Habitat Restoration and Flood Improvement Project: 65% Basis of Design Report* of the Draft EIR. As noted on Pages 12 and 13, *Lookout Slough Setback Levee Wave Runup and Wind Setup Analysis TM,* in the locations analyzed, either design freeboard of six feet is greater than the runup with the Proposed Project or the levee was overtopped by runup in the without-Project condition, indicating that wind wave runup would not be exacerbating the existing condition of overtopping under those conditions.

In addition, the *Lookout Slough Setback Levee Wave Runup and Wind Setup Analysis TM* provides the procedures and calculations used to determine potential wind wave impacts. DWR acknowledges the receipt of information from WSAFCA presenting a review of the *Lookout Slough Setback Levee Wave Runup and Wind Setup Analysis TM.* As described in Response 9-2, some aspects of the wave erosion hazard have been further quantified as part of the Project design processes. This refined quantification confirms the wave erosion hazard analysis included in the *Lookout Slough Setback Levee Wave Runup and Wind Setup Analysis TM* and further supports the conclusion in the Draft EIR that impacts associated with post-construction changes to wind-wave generated erosion are less than significant, and that no mitigation measures are required. This refined quantification is included as Appendix Y of this Final EIR. See also Responses 9-2, 19-3, and 19-9.

Thank you in advance for your consideration of these comments and recommendations. Sincerely,

Greg Fabun
General Manager
West Sacramento Area Flood Control Agency

Rick Toft
Chief Operations Officer
Port of West Sacramento

Amanda Berlin Assistant
City Manager
City of West Sacramento

Letter 18
Westlands Water District

Westlands Water District

3130 N. Fresno Street, P.O. Box 6056, Fresno, California 93703-6056, (559) 224-1523, FAX: (559) 241-6277

LOOKOUT SLOUGH TIDAL HABITAT RESTORATION AND FLOOD IMPROVEMENT PROJECT
DRAFT ENVIRONMENTAL IMPACT REPORT
STATE CLEARINGHOUSE NO. 2019039136
DECEMBER 2019

COMMENTS PREPARED BY WESTLANDS WATER DISTRICT
FEBRUARY 14, 2020

Westlands Water District (Westlands) owns the approximately 3,427-acre Yolo Ranch, which is at the southern end of the Yolo Bypass and directly northeast of and bordering Lookout Slough. Current activities include cattle grazing that relies on tide gates to surcharge irrigation canals from Shag Slough and the Toe Drain, whereby water is lifted to flood irrigate improved pastures. Planned activities include construction of the Lower Yolo Restoration Project (LYRP) in summer 2020 on approximately 2,150 acres with the remaining acres to continue in cattle grazing. The following items were reviewed in preparation of these comments relative to current and planned activities on Yolo Ranch:

- DEIR (December 2019)
- DEIR Appendix D (65% Basis of Design Report; December 2019)
- Appendix A to DEIR Appendix D (Draft Hydrologic and Hydraulic System Analysis; December 2019)
- DEIR Appendix S (Potential Salinity Impacts Assessment; April 2019)
- DEIR Appendix T (Potential Tidal Water Levels and Tidal Prism Impacts Assessment; June 2019)

The following environmental impacts identified in the DEIR are discussed further:

Impact #	Impact	Significance	Proposed Mitigation
HYDRO-iv.	Violation of salinity standards for agriculture during post-construction operation	Less than Significant	No mitigation proposed
HYDRO-vi.	Post-construction changes to tidal range that could affect in-Delta agricultural water supplies and drainage	Less than Significant	No mitigation proposed
HYDRO-vii.	Post-construction changes to tidal range that could affect in-Delta wetland and wetland riparian habitats	Less than Significant	No mitigation proposed
HYDRO-xii.	Changes to flood flow and conveyance that could result in a potential increase to flood risk	Less than Significant	No mitigation proposed

It is our understanding that the Shag Slough Levee will be breached at nine locations to provide primary tidal connectivity via subtidal breaches ranging in width from 300 to 575 feet, as well as degraded at two locations to provide flood benefits via two 1,500-foot sections, with the northern section degraded to 14.7 feet NAVD88 and the southern section degraded to 11.8 feet NAVD88 (DEIR page III-40 and Figure III-10). The latter would allow floodwaters during a significant flood event (larger than a 6-year flood) to be conveyed through Lookout Slough, resulting in approximately 0.5 feet of water surface elevation (WSE) reduction in the vicinity of the northern breach (Index Point 4) and approximately 0.1 feet at County Road 155 (Index Point 1) for the range of floods analyzed (Appendix A to DEIR Appendix D Table 8).

18-1

In review of Appendix D, it is our understanding that the northern levee degrade / inlet weir will not be protected with erosion protection measures because it will not serve a flood protection purpose in the future (Appendix D page 12). While the remnant Shag Slough Levee will not perform as a federal facility, it does provide a specific flood benefit that would otherwise change from the design condition should the inlet weir become compromised due to erosion via repeat overtopping. As shown by Appendix D Table 2, Figure 2, and Figure 3, there will be an increase in hydraulic stresses on the Shag Slough Levee upstream of Lookout Slough. The waterside levee slope is owned by Westlands and maintained by RD 2068. The waterside slope of the levee presently experiences hydraulic stresses that have scoured the levee toe as flood flows are funneled towards the levee in part due to the restricted height levees on Liberty Island, known as the Stair Step. Further, the Westlands tide gate on Shag Slough was completely compromised in the March/April 2011 flood, but was subsequently permitted and rebuilt in summer 2013. If the inlet weir becomes compromised, it has the potential to further increase hydraulic stresses on the Shag Slough Levee immediately upstream of Lookout Slough, beyond the increases identified in Table 2, thereby impacting waterside levee toe scour and/or the integrity of the tide gate. As clearly demonstrated by Figure 2, the modeled shear stresses exceed 5 lb/sf, which exceeds what is considered permissible for 12-inch riprap. **In response to HYDRO-xii, Westlands recommended that the Lookout Slough design include armoring of the inlet weir to protect the weir at its design elevation against scour from repeat overtopping events and that the integrity of levee and tide gate upstream of the inlet weir be monitored.**

Response 18-1:

As described in Section G, *Hydrology and Water Quality*, of the Draft EIR, hydraulic modeling was used to evaluate changes to velocity and shear stress under the with-project condition to assess the likelihood of erosion and scour of flood control facilities in the vicinity of the Proposed Project. As stated on page 3 in Appendix D, *Lookout Slough Tidal Habitat Restoration and Flood Improvement Project: 65% Basis of Design Report* of the Draft EIR, the degraded portions of the west levee of the Yolo Bypass would not be maintained, and would be anticipated to gradually degrade over time. This would result in incremental changes in localized hydraulic stresses at and near the Proposed Project Site. However, as described in Section IV.G, *Hydrology and Water Quality*, on page IV.G-30 of the Draft EIR, "Flood protection previously offered by the Shag Slough Levee would now be provided by a newly constructed Duck Slough Setback Levee, which would become a part of the SPFC levee system upon Proposed Project completion." Also, the Proposed Project will include armoring of the Shag Slough Levee inlet weir to protect that portion of the weir at its design elevation against scour from repeat overtopping events. Additional supplemental analysis, completed since the release of the Draft EIR and at the request of the Project's Safety Assurance Review panel, confirmed the modeling results and assumptions in the Draft EIR associated with the potential waterside levee toe scour and integrity of the tide gate at Shag Slough Levee.[1] As stated in the supplemental analysis, review of velocities and bed shear stresses computed at the levee north of the Proposed Project Site indicates that although there are some localized changes in velocity and bed shear stress, they are below the threshold that would necessitate revetment (less than 0.5 lbs/sf), even under conditions where the levee and northern inlet degrade beyond what is shown in the design.

As noted in the comment, the gate failed completely and the entire structure washed out during the March/April 2011 storm event. Water levels measured at DWR's Yolo Bypass at Liberty Island stream gauge (California Data Exchange Center stream gauge ID Yolo Bypass at Liberty Island) during this event are lower than computed water levels for a 6-year storm event, and it is noted that the structure had withstood several larger flood events prior to this. Based on review of historic imagery, the structure may have experienced a number of issues not related to flood flows prior to the March/April 2011 event that may have exposed the headwalls on both sides of the structure and made them more vulnerable when that storm arrived. The tide gate was subsequently rebuilt in 2013, and is now armored on both the upstream and downstream sides. Modeling results indicate that hydraulic forces would increase slightly in the vicinity of the tide gate after the Proposed Project is constructed, and continue to increase slightly if the remnant levee along Shag Slough degrades and evolves over time. However, the increases in hydraulic stress are considered minor, and would not necessitate mitigation or modification of the tide gate structure. As discussed on page IV.G-18 and page IV.G-26 of the Draft EIR, the Proposed Project would not change wind-wave run-up potential at this location, nor would erosion occur as a result of shear stress at the Shag Slough Levee inlet weir.

As described on page III-20 of Section III, *Project Description*, of the Draft EIR, DWR would be responsible for maintaining the Shag Slough Levee north of the northernmost breach on the Proposed Project Site.

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[1] Environmental Science Associates (ESA). 2020. *Lookout Slough Tidal Habitat Restoration and Flood Improvement Project - Supplemental Risk Analysis of Adjacent Cache Slough Levee System*. Prepared for EIP Credit Co. III.

Based on the evidence referenced in the Draft EIR, the Draft EIR concluded that the impact identified in the comment was not significant and no mitigation is required under CEQA. Further analysis completed after the circulation of the Draft EIR provides additional support for the conclusion and no new information has been presented that changes the conclusion in the Draft EIR. The supporting analysis has been shared with the commenter.

In review of Appendix S relative to Yolo Ranch, **Westlands concurs that impacts to the salinity standards for agriculture are less than significant (HYDRO-iv).** 18-2

Response 18-2:

Comment noted.

In review of Appendix T, it is our understanding that the tide range will generally be compressed whereby MHHW will drop by approximately 0.2 feet and MLLW will rise by approximately 0.1 feet. Regarding irrigation, the tide gates on Shag Slough and the Toe Drain tidally charge irrigation canals on Westlands property, which will remain after construction of LYRP. If MHHW drops approximately 0.2 feet, five (5) lift pumps serviced by Shag Slough and four (4) lift pumps (two for Westlands, two for Mound Farms) serviced by the Toe Drain will cumulatively require greater energy to pump the same amount of water. **In response to HYDRO-vi, Westlands acknowledges that there is the potential for increased pumping costs for its grazing tenant. The Lookout Slough design should consider implementing vegetation removal within the Yolo Ranch irrigation canals to improve conveyance and offset the drop in MHHW.** 18-3

Response 18-3:

See Master Response 9, *Tidal Effects on Diversions* and regarding economic impacts and Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts*.

Further, construction of LYRP to restore tidal marsh habitat generally requires limited channel grading and very minimal mass grading to reconnect the adjacent waterways with the very gently sloped Yolo Ranch interior, where typical interior elevations are high intertidal and above 5 feet NAVD88. Reductions in MHHW by 0.2 feet has the potential to delay the establishment of approximately 130 acres of restored perennial emergent marsh habitat in the short-term due to tidal muting. **In response to HYDRO-vii, Westlands understands the cumulative habitat benefits within the Cache Slough Complex afforded by multiple constructed and planned restoration projects. Westlands recommends that DWR and DFW consider the effects of regional tidal muting during their restoration monitoring activities within the region when evaluating project-specific performance.** 18-4

Response 18-4:

Comment noted. As noted in Master Response 9, *Tidal Effects on Diversions*, the Proposed Project effect of tidal muting in the area during the highest high tide cycle would only last for approximately 4-percent of the entire tidal cycle, which is about one hour. This very low change in highest high tides is not likely to result in affecting nearby tidal marsh vegetation growth. However, DWR will consider this issue restoration monitoring activities.

Finally, it should be noted that the northern levee degrades includes degradation of lands owned by Westlands within Yolo County (DEIR Figure III-10 Section D-D). Westlands has not been notified by the Lookout Slough project proponents of the intent to degrade levees on lands owned by Westlands.

We look forward to receiving responses to our comments. If you have questions, please contact me at 559.241.6215 or jgutierrez@wwd.ca.gov.

Response 18-5:

As shown on page III-31 in Section III, *Project Description*, the levee degrade locations would occur on land that will be owned by DWR and within the jurisdiction of RD 2098, as depicted in Figure III-8, *Proposed Habitat Concept*. Changes to the levees will require approvals from other agencies including the Central Valley Flood Control Board and the U.S. Army Corps of Engineers. As discussed in Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts*, DWR and its contractors will comply with all applicable regulatory requirements, including easement notifications; however, the EIR is not required to include all the information necessary to meet other regulatory program requirements.

Sincerely,

Jose Gutierrez, P.E. Chief Operating Officer

Letter 19
RD 2068

TELEPHONE
(707) 678-5412

7178 YOLANO ROAD
DIXON, CA 95620

IRRIGATION DRAINAGE

RECLAMATION DISTRICT NO. 2068

February 14, 2020

California Department of Water
Resources Attn: Heather Green
3500 Industrial Blvd
West Sacramento, CA 95691

Subject: Public Comments on the Draft Environmental Impact Report for the Lookout Slough Restoration Project.

Dear Heather Green,

Reclamation District No. 2068 ("District") is a reclamation district formed under the laws of the State of California pursuant to Division 15 section 50000 et seq. of the California Water Code. The District provides irrigation, drainage, and flood control to over 13,200 acres. The District is adjacent to the northern boundary of the proposed Lookout Slough Project (Project), and the Project is fully within Reclamation District No. 2098 (RD 2098). The two reclamation districts make up Unit No. 109 (West Levee of Yolo Bypass and East Levee of Cache Slough) of the Sacramento River Flood Control Project; therefore, are intrinsically connected.

The District is supportive of the Lookout Slough Project (Project) dual goals of habitat restoration and flood control enhancement; however, we have serious concerns regarding the DEIR's evaluation of the Project's environmental impacts on the operations and maintenance (O&M) practices of the reclamation districts and agricultural diversions that are within the vicinity of the proposed Project. In addition, the Draft Environmental Impact Report (DEIR) and its appendices makes assumptions and generalizations of the project area that are incorrect. Below is a summary of the District's comments on the Project's DEIR.

1. Endangered Species. The main goal of the Project is to increase the population of endangered species including delta smelt and salmon. If the Project is successful the number of endangered fish species will increase in the vicinity of the District's diversion intakes and drainage outlets. An increased population of endangered species in the project area would cause increased regulatory restrictions and costs for the District to comply with environmental requirements. The Project provides open water space and emergent marsh which may allow non-native species like water hyacinth or water primrose to proliferate, increasing their presence in the region. The presence of non-native species would impair the ability of the Project to increase the population of native species and increase the cost of the District's maintenance activities. The DEIR is silent on these impacts. 19-1

Response 19-1:

See Master Response 3, *Local Water Diversions and Special-Status Fish Species,* and Master Response 14, *Invasive Plant Species and Harmful Algal Blooms*.

2. RD 2098 Solvency. The Project will flood approximately two-thirds of RD 2098. Since Reclamation District are funded by landowner assessments and have to adhere to the Proposition 218 requirements, the operations and maintenance costs of the remaining RD 2098 levees will be spread over fewer acres. Currently, RD 2098 has minimal funding due to the limited ability to generate adequate assessments from low profit land uses. The DEIR should carefully consider whether RD 2098 will be capable, in the long term, of adequately implementing the mitigation set forth in the DEIR. As Reclamation District No. 2068 shares levees with RD 2098 as part of a hydrologic basin, this is very concerning. 19-2

Response 19-2:

See Master Response 7, *Operation and Maintenance of Levees* and Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts*.

3. Hydraulics. The Project proposes to set back the Yolo Bypass Levee from the constructed segment of Shag Slough and breach a section of the Project Levee on Cache Slough. This proposed activity would alter the hydraulics in the Cache Slough region at high flow events causing increased water levels and flooding pressure on State Plan of Flood Control levees that have documented erosion, stability and freeboard deficiencies. The inundation of currently levee protected lands of RD 2098 would subject the remaining channel banks and levees to increased wave fetch and erosion. 19-3

Response 19-3:

As described in Chapter I, *Project Description*, the Proposed Project includes improvements to the stability of the Cache/Hass Slough Training Levee and does not include breaching a section of the Cache Slough Levee. The improved levee would function to maintain stage differences between the Proposed Project Site and waters in Cache/Hass Slough during bypass flooding events. As described in Section IV.G, *Hydrology and Water Quality*, hydraulic models were utilized to assess the potential for increased stages in Cache and Hass Sloughs. The model analysis indicates that there would be no change to water levels in Cache and Hass Sloughs, and that the Proposed Project would generally result in localized stage reductions in the Yolo Bypass and would not result in upstream or downstream stage increases. Stage decreases would have modest but positive impacts on flood-related public services by reducing demand on levees.

Hydraulic modeling was also used to evaluate changes to velocity and shear stress under the with-project condition to assess the likelihood of erosion and scour of flood control facilities. These models indicate that shear stress would slightly increase (+0.1 pounds/sq. ft.) upstream of the Proposed Project Site in Shag Slough, but that existing rock slope protection would be sufficient to manage the shear stress. In addition, see Appendix D, *Lookout Slough Tidal Habitat Restoration and Flood Improvement Project: 65% Basis of Design Report*, of the Draft EIR, which includes a Cache/Hass Slough Levee Impact Assessment.

As described in Section IV.G, *Hydrology and Water Quality*, of the Draft EIR, wave runup analysis was modeled to analyze potential effects of wave runup on the Proposed Project's levees and adjacent levees, including Cache/Hass Slough Training Levee. This analysis indicated that the Proposed Project would not create significant changes to wind-wave generated erosion and that adjacent properties would not be subject to increased wind wave run-up. See Appendix D, *Lookout Slough Tidal Habitat Restoration and Flood Improvement Project: 65% Basis of Design Report* of the Draft EIR regarding modifications and maintenance proposed for the Cache/Hass Slough Training Levee. The remaining levees would also continue to be maintained regularly by DWR, thereby further addressing any other erosion that may occur. See also Responses 9-2 and 17-1. Some aspects of the wave erosion hazard have been further quantified as part of on-going Project design and permitting (e.g. USACE Section 408 application) processes. This refined quantification confirms the wave erosion hazard analysis included in the *Lookout Slough Setback Levee Wave Runup and Wind Setup Analysis TM,* attached as Appendix C to Appendix D*, Lookout Slough Tidal Habitat Restoration and Flood Improvement Project: 65% Basis of Design Report* of the Draft EIR, and further supports the conclusion in the Draft EIR that impacts associated with post-construction changes to wind-wave generated erosion are less than significant and no mitigation measures are required. This refined quantification is included as Appendix Y of this Final EIR.

The inundation of current levee-protected lands of RD 2098 will not subject the remaining channel banks and levees to increased wave fetch and erosion. Changes to the levees will require approvals from other agencies including the Central Valley Flood Control Board and the US Corps of Army Engineers and coordination with relevant reclamation districts. As discussed in Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts,* DWR and its contractors will comply with all applicable regulatory requirements, however the EIR is not required to include all the information necessary to meet other regulatory program requirements. See also Responses 9-2, 17-1, and 19-9.

The 65% Design Basis of Design Report Figures 2 and 3 show increases pre and post project for shear stress and velocities of 1.4 to 1.8 pounds per square foot and 2.5 to 5.6feet per second to immediately north of the Project along Reclamation District NO. 2068's Yolo Bypass Levee. The analysis and figure say the "Existing RSP is sufficient to mitigate erosion form increase shear stresses approximately 60' from water side slope" and "Existing RSP is sufficient to mitigate erosion from the increased velocities approximately 60' from water side slope." However, there is no existing Reinforced Slope Protection along the Bypass levee in that location, which will see the same increases in shear stress and velocity. In addition, that location of the levee has experienced erosion in the last two high water events in 2017 and 2006. The increases in erosion force will dramatically increase erosion and stability damage if it is not mitigated. 19-4

Response 19-4:

The Proposed Project design includes the addition of new reinforced slope protection along the waterward side of the Yolo Bypass West Levee from the northern boundary of the Proposed Project south to the first breach location. Refer to sheet C101 in Appendix D, *Lookout Slough Tidal Habitat Restoration and Flood Improvement Project: 65% Basis of Design Report* of the Draft EIR for additional information. As shown on Figure 2 of Appendix D of the Draft EIR, the peak shear stresses computed during the 1% AEP (100-year) flood event are 0.1 pound per square foot (lb/sf) in the without-Project condition, and 0.2 lb/sf in the with-Project condition (here velocities are 2.7 feet per second (fps) and 3.9 fps for the without- and with-Project conditions, respectively). Although there are some localized changes in velocity and bed shear stress at this location, they are below the threshold that would necessitate revetment (less than 0.5 lb/sf).

The region shown on Figure 2 north of the Proposed Project where computed shear stress values are somewhat higher (1.4 lb/sf in the without-Project condition, and 1.8 lb/sf in the with-Project condition) is located on the opposite bank of Shag Slough at the proposed Lower Yolo Ranch Restoration Project, and is not part of the levee. At this location, velocities are in the range of 2.5 fps in the without-Project condition, and 5.6 fps in the with-Project condition. See also Response 18-1.

Based on the evidence referenced in the Draft EIR, the Draft EIR concluded that increases in erosion force were less than significant and would not significantly increase erosion and stability damage. No new information has been provided which changes the conclusion in the Draft EIR. No mitigation is required under CEQA for adverse environmental impacts that are less than significant.

<u>4. Hydrology.</u> Errors in the setting description are found starting on Page IV.G-6, as described as follows. Diversions are stated as "leading to a net flow of up to 3,000 cfs upstream" a statement attributed to DWR and DFW as footnote 21. This number cannot be justified as the Cache Slough Complex as stated on Page IV.G-6 is 53,000 acres and 3,000 cfs is approximately 6,000 acre-feet per day, which equates to about 41.3 feet of water applied per acre annually for the entire area. This level of combined diversion does not exist in this area to support the statement. The reference to the "design capacity of the Cache Slough Complex is 490,000" cfs is in fact the capacity of the Yolo Bypass flood conveyance system in the Lower Yolo Bypass region. The Cache Slough Complex as a term of regional identification is not the same as the Yolo Bypass Flood conveyance system. 19-5

Response 19-5:

The comment is correct that the setting description on page IV.G-7 in Section IV.G, *Hydrology and Water Quality* of the Draft EIR contains an error. The following clarifying text changes have been made to correct the setting description:

> During winter months the <u>Yolo Bypass contributes flows through</u> ~~design capacity of~~ the Cache Slough Complex up to 500,000 cubic feet per second (cfs) ~~flow contributing to the system~~. In contrast, during the summer, tidal forces <u>and agricultural and municipal diversions (e.g., Barker Slough pumping plant)</u> heavily influence the flow of the Cache Slough Complex, which tends to experience a net upstream flow~~. Diversions in the area further contribute, ultimately leading to a net flow of~~ up to 3,000 cfs ~~upstream~~. This may result in longer residence times and reduced mixing between regional and downstream waters.

The Project activities would alter hydrology resulting in an increase of the tidal prism and reduced tidal range, as described and analyzed in Appendix T of the DEIR. The intertidal zone of the Delta, where the Project is being developed, is unique in that lands can be both irrigated and drained passively using tidal gates (check valves). Tidal gates only allow water to flow one way either into irrigation canals or flow out of drainage canals. During irrigation, tidal gates store water in large channels during high tide and that stored water is slowly diverted passively or pumped during low tides. High tides are used to lift water into irrigation channels and tidal gates hold the water level during diversions at low tide. Tidal gates depend on high tide only for 19-6 irrigation and there are no benefits of a higher low tide; therefore, reductions in the high tide and increases in the low tide are not offsetting, as assumed in Appendix T.

Similarly, in drainage ditches tidal gates allow water to be drained to near peak low tide elevations and once the tide increases, tidal gates keep the high tide water out of drainage ditches. Water levels do increase in the drainage ditches due to irrigation runoff; however, the runoff is stored in large drain ditches during high tide, normally keeping the water level in drains below the average tidal elevation. Appendix T of the DEIR, assumes drainage is by pumping only and that is factually false. Although the District has a drainage pumping facility, the District diverts approximately 55,000 AF of water annually for irrigation and has not had to run its drainage pumps during the irrigation season in more than 30 years. Appendix T uses general assumptions for an area within the Delta lowlands; however, the Project is in the intertidal zone and Reclamation District 2068 is within the delta uplands. Therefore, the determination in Appendix T of less than significant impact is flawed and needs to be re-analyzed. 19-6 Cont.

Response 19-6:

Please see Master Response 9, *Tidal Effects on Diversions*.

To assess changes in tidal datums and range, the hydrodynamic model used recent topographic and hydrologic data to represent the intertidal zone and Delta uplands that straddle the Proposed Project site and RD 2068. The changes in tidal water levels were then predicted by the model using standard equations governing fluid mechanics to describe the local physical processes.

Therefore, the analysis is based on the best available data and understanding of physical processes. While Appendix T did not assess tidal prism effects on gravity and pump driven irrigation or drainage diversions directly, Master Response 9, *Tidal Effects on Diversions* amplifies and clarifies information relative to these kinds of diversions. Additional details regarding the hydrodynamic modeling can be found in Appendix X of this Final EIR.

5. **Water Quality.** Altering the tidal flux by breeching levees and changing tidal conditions has the potential to impair water quality near the District's point of diversion due to changes in Cache Slough salinities. Comments on the analysis of water quality impacts is extensively covered in a Regional Comment Letter with RD 2068 as a signatory. 19-7

Response 19-7:

See Master Response 1, *Salinity and Bromide.*

6. **Emergency Response.** The project will alter the RD 2068/2098 Emergency Response plan and the DEIR does not include any mitigation for a redesign of the Plan. The Project removes the levee section identified as an emergency breach location and removes flood water storage at the bottom of the leveed area. This changes flood response time and pre-developed flood responses during an emergency. Also, facilities labeled on the emergency response maps will be moved or eliminated, DWR needs to provide mitigation for these changes. 19-8

Response 19-8:

Changes to the levees will require approvals from other agencies including the Central Valley Flood Control Board and the US Corps of Army Engineers and coordination with relevant reclamation districts. As discussed in Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts,* DWR and its contractors will comply with all applicable regulatory requirements, including alteration to the RD2098/2068 Emergency Response plan at the appropriate time.

The Proposed Project would preserve emergency access for RD 2068 personnel during construction and operation via the existing Liberty Island Road alignment and via the proposed crown road on the Duck Slough Set Back Levee. As described on pages III-37 and III-48 in Chapter III, *Project Description* in the Draft EIR, the Proposed Project proposes to surface the roadways with crushed gravel, recycled concrete, or gravel which would provide for year-round "all-weather" access. This is consistent with the types of levee roads utilized by various entities throughout California, including the majority of Reclamation District 2098 on many of its levees. Access to the RD 2068 pumping plant #5 would be provided as described in Response 12-9. Furthermore, the proposed access roads, as well as any access road on top of the constructed levee, would be designed in accordance with USACE standards in order to support typical flood-fight and pump station maintenance vehicles. Please see also Response 13-16.

7. Wind Erosion. The Project analyzes wave runup and wind analysis in appendix D as part of the 65% Basis of Design Report. This is an example of confusing appendices and the appendices also includes unnecessary drafts of the same document. DWR should remove all unnecessary Drafts from the document and give each attached document an Appendix number. The Runup analysis seems to be analyzed with a very simple model. Existing conditions cause wind erosions problems, especially if there are no rip-rap reinforcement of the levee. Also, comparing the draft and final wind runup analysis shows that different average water depths were used for the same transect. How did this change? There was no analysis to find the transect or wind direction that created the max runup on the levee system, only random transects were used. Also, the analysis only looked at overtopping due to wind runup and damage due to wind erosion was not analyzed comparing pre and post project. If an increase in wind runup causes more wind erosion the Project should mitigate for that effect and native grasses do not protect from wind erosion. 19-9

Response 19-9:

Page viii of the Draft EIR lists all technical appendices referenced in the Draft EIR. The referenced documents used to support a technical appendix are listed in the Table of Contents for that particular appendix and a supporting document may include an earlier version of a report.

As described in Section IV.G, *Hydrology and Water Quality* of the Draft EIR, wave run-up analysis was modeled to analyze potential effects of wave run-up on the Proposed Project's levees and adjacent levees. See the *Lookout Slough Setback Levee Wave Runup and Wind Setup Analysis TM*, attached as Appendix C to Appendix D, *Lookout Slough Tidal Habitat Restoration and Flood Improvement Project: 65% Basis of Design Report* of the Draft EIR regarding the wave runup and wind analysis. The wave runup was estimated using the procedures outlined in the Coastal Engineering Manual (EM 1110-2-1100) (USACE 2008) and Shore Protection Manual (USACE 1984). These methods are consistent with the procedures used in prior wave runup and wind setup studies conducted in the region, such as the Wave Runup and

Erosion Analysis for West Sacramento Levee System General Reevaluation Report and the Lower Elkhorn Basin Levee Setback Project.

A range of water depths were used to represent the average depth along each of the transects in Table 2 on page 5 and 6 of the *Lookout Slough Setback Levee Wave Runup and Wind Setup Analysis TM*. The transects were selected such that they aligned with proposed breach locations in the Shag Slough Levee and maximized fetch properties and thus would maximize total runup. This approach is believed to be conservative as these are the only transects that would increase wave runup from the Proposed Project for the foreseeable future. See also Responses 9-2, 17-1, and 19-3.

8. Easements. The Project's northern levee is proposed to be built adjacent to Liberty Island Road (LIR) and the Central Valley Flood Protection Board will require a minimum twenty-foot easement from the toe of the levee prism landward. The District has an irrigation and drainage canal parallel and adjacent to LIR, and the District's easement for the canal extends approximately to the midpoint of LIR. If the setback levee's easement is co-located with the District's canal maintenance easement it will diminish the ability to perform maintenance due to regulatory restrictions on levees. The regulatory restrictions will also impact maintenance performed by Solano County on LIR. The DEIR is silent on this impact. 19-10

The creation of a new setback levee parallel to Liberty Island Road will cause an increase in drainage area into Reclamation District No. 2068 of approximately 10 acres. The additional drainage has to be conveyed in District Drains and during times the Yolo Bypass is flowing needs to be pumped out of the District. The Project needs to mitigate for this increase in drainage area into the Reclamation District No. 2068.

Response 19-10:

Changes to the levees will require approvals from other agencies including the Central Valley Flood Control Board and the U.S. Army Corps of Engineers. As discussed in Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts*, DWR and its contractors will comply with all applicable regulatory requirements, including easement notifications; however, the EIR is not required to include all the information necessary to meet other regulatory program requirements.

The Project's northern levee is proposed to be built adjacent to Liberty Island Road (LIR), with the levee toe approximately at the southern edge of LIR at the western end and 15 feet south of the edge of LIR at the eastern end. Title 23 CCR requires a 10-foot easement adjacent to the landward levee toe (Article 2, Section 4). This means the easement will lie at most approximately 10 feet north of the southern edge of LIR at the western end. LIR is approximately 16 feet wide from edge to edge in this vicinity, and the irrigation channel in question lies with its top of bank several feet to the north of the northern edge of LIR. At minimum there will be at least 6 feet of LIR pavement plus the shoulder between the Title 23 required easement and the southern top of bank of the irrigation channel providing sufficient clearance for any work required for the irrigation canal.

The approximate existing drainage area tributary to the RD2068 pumping plant is estimated to be approximately 1,585 acres. The increase of approximately 10 acres to this tributary area caused by the new levee represents an approximately 0.63% increase in the drainage area. This increased drainage area isn't expected to significantly increase the peak amount of runoff discharged to the RD2068 pump, but the overall volume discharged could be increased up to approximately 0.63%. This increase is considered negligible because it falls within the margin of error for the drainage area and operation parameters of RD 2068's pumping plant.

The DEIR is silent on easements held by Solano County for public roads. These roads may not have a deeded title, but clearly have a prescriptive right. The Project proposes to end Liberty Island Road before it reaches the Districts Pumping Plant, which provides the only all-weather access to the Pumping Plant. The Pumping Plant provides protection to over 6,000 acres of land and all-weather access is crucial to operate and maintain the facility. As with relocation of the all-weather road being a problem for the District Pumping Plant operation and maintenance, the same issue occurs due to the relocation of power lines into agriculture fields with no all-weather access. The DEIR is silent on these impacts and DWR needs to analyze potential mitigation measures. 19-11

Response 19-11:

See Responses 19-8, 12-9 and 13-16. See also pages IV.A-21 and IV.A-22 in Section IV.A, *Impacts Found to Be Less Than Significant* in the Draft EIR regarding relocation of power lines associated with the Proposed Project. The relocation of power lines for the Rasmussen property would be in coordination with PG&E to ensure all weather access is provided for their power lines.

9. Utilities. The Project will inundate a large number of acres of lands which may have active or inactive buried gas lines and above ground power lines. Maintenance or replacement of these lines will be impaired or impossible if they are under water. Further, any future power or gas transmission needs by local landowners in the region will be limited due to the Project area being covered in water. The DEIR relies on a statement from a Geologist that determined gas is not feasible in the Project area. However, this is under the current gas market, if the price of gas increases enough it would be feasible to further explore in the region. The DEIR needs to identify at what price would gas be feasible in the area to determine the impact of the gas fields being covered by water. 19-12

Response 19-12:

As described in Appendices U, *Mineral Report and Remoteness Opinions: Bowlesby and Vogel Properties*, and V, *Mineral Report and Remoteness Opinions: Liberty Farms*, the gas lines on the Proposed Project site have all been properly de-commissioned, purged and abandoned per DOGGR regulations years ago and prior to the Proposed Project site's current ownership. The underlying Maine Prairie Gas Field is known to be depleted. Only five unplugged gas wells remain in the entirety of the field, none of which are located on the Proposed Project Site, and of those five, only one is still deemed "active". This "active" well has not produced any gas since 2009. As a result of this, and other factors, the possibility of petroleum or other valuable minerals on the site "is so remote as to be negligible," as described in Appendixes U and V of the Draft EIR. See Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts*.

<u>10. Recreation.</u> The proposed Project is located at one of the few spots in the Cache Slough region where the public has access to the delta waterways and is used extensively by the public for recreational fishing and water sports. The Project also proposes to eliminate the only land access to lower Liberty Island by eliminating the bridge. The DEIR justifies not mitigating the loss of recreation by saying "There are no officially sanctioned, public recreational facilities within the Propose Project Site;" however, it contradicts itself and says the "the Shag Slough Bridge provides pedestrian access to the Liberty Island Ecological Reserve which provides recreational opportunities." Few alternative public access opportunities exist in the Project area and most of the areas identified are near the arbitrary one-hour distance to be considered a nearby alternative. A finding of less-than-significant impact was found even though a clear impact was identified and the Project could provide public access to mitigate for it. 19-13

Response 19-13:

See Master Response 10, *Recreation*.

<u>11. Agriculture.</u> The mitigation measures proposed for impacts to agriculture are not sufficient. The DEIR assumes that restoring non-irrigated agriculture to agriculture previously irrigated mitigates for loss of irrigated agriculture. This is insufficient because restoring irrigation is low cost compared to developing new irrigated agriculture and non-irrigated agriculture lands are still lost. Also, agriculture easements provide no benefit unless the easements are placed where agriculture conversions are likely to happen, either adjacent to expanding towns or at locations where habitat project can be foreseeable. The DEIR needs to analyze the change in the gross agriculture production or economic activity and not a value such as acres that does not look at production differences. 19-14

Response 19-14:

The Proposed Project's mitigation measures for agricultural impacts are described on pages IV.B-10 through IV.B-13 in Section IV.B, *Agriculture and Forestry* in the Draft EIR. Under CEQA, the sufficiency of mitigation is based on how effective it would be in avoiding or reducing a potential impact on the physical environment. Please see Master Response 2, *Farmland*, for further detail regarding how the criteria required for agricultural conservation easements outlined in Mitigation Measure AG-1b, along with the funding of measures to increase the agricultural capability of adjacent lands, would ensure that the Proposed Project's impacts on agricultural land would be less than significant. See also Response 12-1 for text changes to Mitigation Measure AG-1b.

Analysis of economic issues is not required by CEQA; please see Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts* for more detail.

The project will increase the habitat for waterfowl and eliminates irrigated pasture between the project and Reclamation District No. 2068. There is no analysis on the impact of greater number of geese and waterfowl on agriculture fields adjacent to the Project. 19-15

Response 19-15:

See Response 12-18.

12. RD 2098 History. The DEIR contains errors in the History section of the document starting on Page IV.E-4 as described below. Liberty Farms, the proposed project site is wholly contained in the area that became known as Upper Liberty (RD 2098) and in the DEIR is referred to as the "western island". This area was not and to this day is not an island. Reference is made of frequent flooding between 1918 and 1973. This is the flooding of the Liberty Island (RD 2093) or "lower Liberty" and not the levees of the SPFC in RD 2098 that protected "upper Liberty". The statement indicating "this levee continuously failed" is not referring the Proposed Project area, but rather the lands currently on the east side of the Shag Slough bridge, "Liberty Island". There is no record of a failure of the SPFC levee protecting the lands of RD 2098.

19-16

As written, this section conveys a grossly inaccurate portrayal of the Liberty Farms story. At its worst, it misrepresents the written history (Dickman, A.I., 1981. "The Story of Robert K. Malcolm, Founder."). It confuses the facts related to this area and success of the previous owners and RD 2098 in operating and maintaining a viable and robust levee system for the long-term protection of the proposed project site. It also misleads the reader to assume that the "Liberty Island" experience is describing the proposed project area experience and that is not true. All references to that portion of the Malcolm holdings on those lands not included in the proposed project site should be eliminated or separated and included clearly as a historical reference to the adjacent properties, unrelated to the proposed project.

Response 19-16:

The information gathered for the historical setting was obtained from historical documents and other written contexts, including meeting minutes from the Liberty Farms Board of Directors, levee maintenance reports from USACE, and other archival materials. Please also see Appendix I, *Lookout Slough Tidal Habitat Restoration and Flood Improvement Project – Cultural Resources Inventory and Evaluation Report* of the Draft EIR for supporting information obtained in researching the historical context of the Proposed Project Site and vicinity.

Maintenance documentation from USACE indicate that the levees within the Proposed Project area experienced multiple instances of subsidence and sloughing, requiring ongoing repair throughout their history. For clarity, the language on page IV.E-7 of the Draft EIR was changed to reflect this specific type of ongoing damage:

> However, this levee ~~continuously failed~~ experienced multiple instances of subsidence and sloughing through its history, as described above under "Levee Unit 109."

The discussion of both Liberty Island and the western island/Upper Liberty refers specifically to both components as part of Liberty Farms, which is the important larger historic context of the cultural resource analysis of the site. The two are interconnected and contextually should be discussed together to provide a comprehensive picture of the history. The text on page IV.E-7 has been changed to clarify this as follows:

> The reclaimed land established the Liberty Farms Company on an area spanning two ~~islands~~ areas– the western ~~island~~ Upper Liberty (which includes the current Proposed Project Site, but not the Bowlsbey Property) and the eastern island (Liberty Island, which now encompasses the Liberty Island Ecological Reserve).

The reference to "Western Island" was not removed in Appendix I, *Lookout Slough Tidal Habitat Restoration and Flood Improvement Project – Cultural Resources Inventory and Evaluation Report,* as it provides contextual historical information within the report

Further clarification or changes suggested by the comment would not change the analysis of impacts to historic resources provided in the Draft EIR which found in Draft EIR Section IV.E, *Cultural Resources,* that no historic resources were identified on the Proposed Project Site.

13. Conclusion. The Project is developed as mitigation for the 2008 and 2009 Biological Opinions for the Central Valley and State Water Projects Pumping Facilities, and only has incidental marginal flood improvements to a levee that has never had a failure and creates new flood issues that are not addressed in the DEIR for the Project area. DWR's focus on accelerating the timeline for Project implementation to satisfy the Biological Opinions is coming at the expense of adequate environmental analysis and engagement with adjacent reclamation districts, agricultural operators, and other local stakeholders. We urge DWR to revise and recirculate the Draft EIR to address the areas of concern and unaddressed impacts identified above. 19-17

Response 19-17:

Please see pages IV.G-29 to IV.G-31 in Section IV.G, *Hydrology and Water Quality* of the Draft EIR for the analysis of impacts related to flooding. As discussed on these pages, the Proposed Project would improve local flood control and conveyance, and the Proposed Project's potential to significantly increase flood risk would be less than significant.

CEQA review for the Proposed Project has been conducted under DWR's standard timeline. In addition, these responses to comments clarify, amplify, or makes insignificant modifications to the Draft EIR. These responses to comments do not identify any new significant effects on the environment or a substantial increase in the severity of an environmental impact requiring major revisions to the Draft EIR that would require recirculation.

Please see pages I-3 to I-5 in Chapter I, *Introduction* of the Draft EIR for a discussion on public engagement regarding the proposed project. See also Master Response 11, *Good Neighbor Checklist*. DWR will also have to comply with a variety of other regulatory programs, including programs administered by the Central Valley Flood Control Board, the Delta Stewardship Council, the US Army Corps of Engineers, the Department of Fish and Wildlife and others. DWR and its contractors will comply with all applicable regulatory requirements, however the EIR is not required to include all the information necessary to meet other regulatory program requirements.

Reclamation District No. 2068 appreciates the California Department of Water Resources commitment to protecting local water users and land owners in the Cache Slough region and following CEQA requirements. Please contact me busch@rd2068.com if we can be of assistance to clarify any of our concerns for this proposed habitat restoration project.

Sincerely,

Bryan Busch, General Manager

Letter 20
Transcript from January 22, 2020 Public Meeting

WEDNESDAY, JANUARY 22, 2020

LOOKOUT SLOUGH TIDAL HABITAT RESTORATION AND FLOOD IMPROVEMENT PROJECT

PUBLIC HEARING

CERTIFIED COPY

LOCATION OF HEARING:

Olde Vets Hall

231 North 1st Street

Dixon, California 95620

REPORTED BY: BRIANNA RUDD, CSR NO. 13668

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A P P E A R A N C E S

Charlotte Biggs, Hearing Facilitator

---o0o---

I N D E X

---o0o---

Dixon, California;
Wednesday, January 22, 2020
7:04 p.m.
---o0o---

MS. BIGGS: We have a court reporter that's ready to go, and she'll be taking notes and capturing your full comment verbatim. And it will become part of the public record, and we will respond to it as part of the final EIR. So I just want everybody to be aware of that.

We have three people who are interested in speaking, so we'll have time to accommodate a couple more as well. The only other kind of note I wanted to make, or reminder, is we have a lot of really good conversations going on between the project staff and folks that are attending here tonight. I do want to remind you that by having that interaction, that doesn't really count as a public comment. If you did have a comment or a concern or something that you wanted to make sure it gets entered, please do still submit your comment by the 14th. So just a reminder on that.

And I'm first gonna call John McManus. John and I talked earlier. I think he was going to hold the mike; is that right?

MR. McMANUS: Yeah, that's fine. Thank you.

I'm John McManus. I'm the president of the Golden State Salmon Association. We represent commercial and sports salmon fishermen and related businesses. We have about 4,500 members. And I've come today to voice support for this project. We think it'll be really good for salmon in a whole bunch of ways. I just want to cover a few things.

There's four species of king salmon in the Central Valley. Two of them are listed under the Federal Endangered Species Act. That includes winter run and spring run. The winter run originate in the far northern reaches of Sacramento Valley, and they've lost most of their spawning habitat. They've lost most of their rearing habitat. They come out of the gravel as early as September, October, November. And quite often by December, we're actually seeing juvenile winter run down in the Delta. Historically, they would have stayed in the upper Sac, except they just don't have the rearing habitat. 20-1

So here they are, down in the Delta, and they've got to make a living for about three months until they generally start to exit for the ocean around March. And making a living means finding stuff to eat and not being eaten. And the amount of rearing habitat available to them is not great. And this represents, I think, a real valuable chunk of real estate that would be used by winter run. We know already that the winter run, they're coming down the river, and they're already in this general vicinity. If they wander into the interior or the south Delta, they're dead -- game over. They get drawn into the pumps. They get eaten by predators. So the winter run that we see survive are all moving out towards Suisun Bay.

We also know that fall run, which is the run that we fish on -- fall run, king salmon -- are also down in this part of the Delta at different times of the year. They'll sometimes come down, depending upon the water year type, and they'll hang out until April, May, and even into June before they'll go out to the ocean. 20-1 Cont.

Another thing is -- my understanding -- and I'm not positive about this -- but my understanding is the elevation of this ground is good. As sea level rises, I believe this'll remain a productive area for decades to come -- and that matters. If you look at a bunch of other Delta properties, especially in the interior Delta, they've subsided. They just don't lend themselves to the type of habitat restoration that this place has, which is really special.

And finally, I just want to say that if this is restored as proposed, we can imagine there could be some nearby areas that divert, that might need streams. My experience in dealing with other diversions throughout the Central Valley is there's plenty of public money around to pay for streams, either from state or federal sources. And I can tell you our organization would strongly support public funding for any streams that may be needed. 20-1 Cont.

So again, I just want to say that this looks to us like a really valuable project. We highly support it.

Response 20-1:

Comment Noted.

MS. BIGGS: Thank you, John.

Next I'll invite up Jack. He told me I didn't have to say his last name.

MR. KUECHLER: Thank you very much.

My name is Jack Kuechler. I'm with Reclamation District 2060, Hastings Island Land Company, which is located directly across from this project.

I want to say, first and foremost, I think this is potentially an important project for the state. I think there's been a lot of discussion with DWR about that. Clearly, the state has requirements that meet the biological opinion to be able to ship water south, and creating more habitat is going to allow that to happen. As a local landowner, I don't have a problem with that conceptually, but that's kind of another conversation for another time. But if this project is going to happen, I think it's very important that, if there are gonna be benefits to people throughout our state, that the local landowners aren't having the burden of that project placed on them. 20-2

Response 20-2:

Comment Noted. See also Master Response 11, *Good Neighbor Checklist* and Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts.*

A lot of what we see here tonight, in terms of the description of the project, really focuses just on the project footprint itself. And one of the things I'm very concerned about are all of the impacts that are going to happen to landowners in the surrounding area, whether they be an individual landowner like myself, or additional costs that they're putting on, you know, the local maintaining agencies, the reclamation districts. 20-3

Response 20-3:

See Master Response 11, *Good Neighbor Checklist* and Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts*.

So two things that I'm very concerned about that I don't really see being addressed well or at all in this Draft EIR are: (1) -- and the gentleman who spoke just before me talked about it -- take issues. I know there's been a discussion going on about that, but we don't see anything in this document about that. We don't really know, at the end of the day, how those issues are going to be addressed. And they just cannot financially be on the backs of the locals. I just don't think it's appropriate. And it's probably not financially feasible for a lot of people. And then there's a lot of levee maintenance that needs to be done in that area. It's maintenance that isn't specific to the project, but this project will continue to have impacts on it, and we're hoping that'll happen.

So as the project is presented today, I think it's a worthwhile project, but I could not support it in its present form. And I hope things will change so we can support it in the future. Anyway, thank you.

20-4

Response 20-4:

See Master Response 3, *Local Water Diversions and Special-status Fish Species*; Master Response 7, *Operation and Maintenance (O&M) of Levees;* and Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts*.

MS. BIGGS: Thank you, Jack.

So next I'll call up Garrick Chang.

MR. CHANG: Hi. Good evening. My name is Garrick Chang. I'm a physician that's been practicing in Sacramento for the last 25 years or so. I also grew up in this area and have lived here for over almost 55 years or so, or 53 years. And I grew up hunting, fishing and all there is in the valley. But also, this exact spot, we used to launch a jon boat off the levee that's being proposed to be breached, and we used to hunt up in Shag -- or the slough that zigzags, makes a right turn.

But at any rate, I think for anyone here who has hunted and fished in this area for as long as I have, they have seen a tremendous decline in our fisheries. All the fisheries are in trouble. Some of the fisheries are on the brink of extinction, if not already extinct. And so I think that any project such as this, and other ones in the bypass that may prevent those loss of resources, are really important. 20-5

And I also founded a group called Putah Creek Trout. We're a nonprofit that works on the upper stretches of Putah Creek. And Putah Creek is also becoming more important as a salmon fishery. And so we would definitely be in favor of anything that increases the number of salmon and other fish. So thank you.

Response 20-5:

Comment Noted.

MS. BIGGS: Was there anyone else that was interested in speaking? Those were the speaker cards that we had. Thank you, for those of you that we did. We appreciate your comments. And for everyone else that might have given us comments here in writing tonight or are thinking about submitting their comments by the 14th, thank you very much for your interest and coming out tonight.

So we're gonna go ahead and adjourn, but we'll be packing up. If anyone has questions, we'll be here. And please help yourself. We have a lot of water that's left over. It's a long drive -- yeah, sure.

MR. HARDESTY: Good evening. I'm Mike Hardesty. I am mostly retired, but I have 43 years of operating in this area as the general manager of Reclamation District 2068, which is immediately north of this project. And actually it's connected to this project area by a common levee system, so -- and rather than get into the details, I want to mention three things that I think that generically are important to this region.

And Jack raised one of the issues -- and I think it is under-addressed at this point -- is that projects like this, while they may be good and they may be warranted, potentially put landowners and the agencies like District 2068, which operates as principally an irrigation operation, at risk of increased regulatory

20-6

compliance issues. And it's not that they have been ignored in the past; it's just that this sort of focuses on this region.

Particularly with regard to endangered species, the Cache Slough region has about something in the vicinity of 50 or 60 irrigation diversions. And I think from 2068's perspective, historic perspective, from my perspective as -- at the agency, is that the number one issue is dealing with the regulatory issues that are occasioned by the development of projects on your border or even within the boundaries.

So I would say that's the number one thing, and that's the thing that's going to drive a lot of landowners to be concerned about projects like this, is that if it is successful, they potentially have to pay a price in the regulatory environment.

20-6 Cont.

Response 20-6:

See Master Response 3, *Local Water Diversions and Special-status Fish Species* and Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts.*

The second one is issues regarding the flood control system. The two districts, 2098, which is part and parcel of what's being developed, and 2068, share a common levee system. And it has been operated as one unit, continues to be one unit. It's, of course, Unit 109. And that I think the -- without getting into the details, I'm pretty sure that all of the issues related to the interrelationship between the two agencies, agency lands have not been thoroughly vetted and, to some degree, not even recognized. 20-7

Response 20-7:

See Response 12-7 regarding flood storage capacity at Unit 109. See also Master Response 7, *Operation and Maintenance (O&M) of Levees* and Master Response 12, *Not a Comment on the Adequacy of the EIR and Economic and Social Impacts.*

And the third one is a more general one, and it's maybe not quite so much related to this project, and that is the issues of water quality and changing water-quality type regulations in the region as it becomes environmentally more sensitive.

Those are -- so I would characterize my concerns, and hopefully I'm sort of channeling some of my colleagues and neighbors in the region to say that: (1) water supply is paramount in terms of protecting the flood control of hundreds; (2) but equally important; and (3) is the prospect for changes in water quality, water elevations and those things from the alterations in the land form. 20-8

Response 20-8:

See Master Response 1, *Salinity and Bromide*.

So with that, I will have extensive comments, I'm sure, written comments, to add to that.

MS. BIGGS: Thank you, Mike.

Okay. Is there anyone else? We do have a few more minutes.

Okay. Well, thank you again for coming. And we will respond to all the comments that we received tonight, and in writing, in the final EIR. And I know we'll get a lot more, so we'll see that in the final EIR.

So thank you again. Have a good night.

(Whereupon the hearing concluded at 7:17 p.m.)

REPORTER'S CERTIFICATE

I, BRIANNA RUDD, a Shorthand Reporter, State of California, do hereby certify:

That said proceedings were taken before me at said time and place, and were taken down in shorthand by me, a Certified Shorthand Reporter of the State of California, and were thereafter transcribed into typewriting, and that the foregoing transcript constitutes a full, true and correct report of said proceedings that took place.

IN WITNESS WHEREOF, I have hereunto subscribed my hand this 12th day of February 2020.

Brianna Rudd, CSR NO. 13668

Appendix S

Lookout Slough Tidal Habitat Restoration and Flood Improvement Project – Potential Salinity Impacts Assessment

Appendix S – Lookout Slough Tidal Habitat Restoration and Flood Improvement Project – Potential Salinity Impacts Assessment, Environmental Science Associates, April 2019.

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memorandum

date	April 19, 2019
to	David Urban, Ecosystem Investment Partners
from	Matt Brennan, PE; Daniel Huang
subject	Lookout Slough Tidal Habitat Restoration and Flood Improvement Project – Potential Salinity Impacts Assessment

The proposed Lookout Slough Tidal Habitat Restoration and Flood Improvement Project (Project) will restore approximately 3,000 acres of freshwater tidal marsh in the Cache Slough Complex of the Sacramento-San Joaquin River Delta (Delta). The purpose of this memorandum (memo) is to briefly summarize the effects of the Project on the salinity regime in the Delta predicted by hydrodynamic modeling results and to interpret the potential implications of those modeling results for the Environmental Impact Report (EIR) to be prepared for the Project.

The Delta is a tidal estuary which is influenced by salt from the Pacific Ocean, conveyed through San Francisco Bay and into the Delta because of the continuous tidal exchange. Diverters of water from the Delta – which include the State Water Project (SWP), Central Valley Project (CVP), the Contra Costa Water District (CCWD), and local agricultural users – depend on freshwater flows from the Sacramento and San Joaquin River to offset the extent of saltwater intrusion into the Delta. Flows in the Delta are managed via upstream reservoir releases, export pumping, and in-channel control structures (e.g., the Delta Cross Channel), in part to meet various water quality objectives, including salinity. Delta salinity levels are important to various Delta users: municipal, industrial, agricultural, and fish and wildlife. Salinity extends further into the Delta during drier seasons and years since low freshwater inflows into the Delta are diminished and less water is available to release from reservoirs to offset the salinity intrusion.

At Lookout Slough, the proposed Project would involve breaching and lowering existing levees and excavating a tidal channel network, thereby re-introducing daily tidal flows to the Project site. This restored tidal exchange would also change flow patterns in the Delta channels outboard of the Project site. Because these tidal flows also distribute salinity within the Delta, these alterations in flow patterns could affect salinity levels in the Delta. Salinity increases are a concern to various municipalities, industries, agricultural interests, and resources agencies that depend on the availability of freshwater to maintain existing beneficial uses.

As described in more detail below, salinity modeling predicts that the effects of the Project on salinity would be less than significant. This finding applies to impact analyses for drinking water quality, irrigation water quality for Delta agricultural users, and fish and wildlife habitat conditions from changes in salinity resulting from the

Project. Furthermore, the incremental impact of the Project on salinity would not be cumulatively significant when also considering other tidal marsh projects in the Delta being planned concurrently with the Project.

OVERVIEW OF SALINITY MODELING

Salinity is evaluated as the measure of total dissolved solids (TDS) concentration in water determined by passing a sample through a filter, evaporating the water, and determining the mass of the salts left behind. Because the analytical methods used to measure salinity are time-consuming and expensive when many samples are needed, direct electrical conductivity (EC) measurements coupled with region-specific relationships between EC and TDS are often used in place of direct salinity sampling. Delta water quality management regulations and compliance monitoring are based on EC. Because EC is the operational surrogate used for regulation and monitoring, Bay and Delta modeling typically provide predictions of EC, not salinity, as outputs.

Resource Management Associates, Inc. (RMA) was tasked with modeling the Project's effect on the Delta salinity regime using their RMA Bay-Delta model. This model simulates the flows in the Bay and Delta that are driven by ocean tides, riverine inputs, and water diversions. The model then uses these flows to predict the distribution of EC, as a surrogate for salinity. The modeling scenario for this study replicates all of 2009, which is representative of typical dry year conditions, when achieving Delta salinity standards is often a challenge.[1] RMA conducted salinity simulations for four scenarios: 1) existing conditions, 2) existing conditions with Project, 3) proposed regional restoration projects without Project, and 4) proposed regional restoration projects with Project. By comparing these runs in pairs, the modeling provides predictions of the potential EC changes due to the Project, both relative to existing conditions and cumulatively with other restoration projects.

In the next sections, after describing the likely CEQA thresholds of significance, the modeling results are interpreted in terms of CEQA impacts analysis.

CEQA THRESHOLDS OF SIGNIFICANCE

For CEQA purposes, a threshold of significance is an identifiable quantitative, qualitative or performance level of a particular environmental effect. An effect will normally be determined to be "significant" by the CEQA lead agency when a project results in non-compliance with this threshold. Compliance means the effect normally will be determined to be "less than significant." As the CEQA lead agency, DWR can develop and publish their own thresholds of significance. However, DWR typically uses a slightly re-phrased version of the standard checklist questions included in Appendix G of the CEQA guidelines, by converting the language from Appendix G from interrogative sentences to declarative sentences. As such, with regards to assessing the effects of changes in salinity for CEQA, the most important significance criteria are "result in substantial adverse effects on beneficial uses of water" and "violate existing water quality standards, waste discharge requirements, or otherwise substantially degrade water quality." Based on how DWR has recently analyzed the impacts of tidal wetland restoration projects on salinity (e.g., Prospect Island, Winter Island, Decker Island), the determination of whether

1 Note: In wet years, salinity issues are generally not considered a problem; in critically dry years, freshwater supplies are often so limited that they constrain the ability to achieve salinity standards through management actions.

a change is considered "significant" depends on whether there would be an exceedance of a standard set forth in the State Water Resources Control Board's (SWRCB's) Bay-Delta Water Quality Control Plan (Bay-Delta Plan) and/or Water Rights Decision 1641 (D-1641)[2].

CEQA IMPACT ANALYSIS

The approach for how the salinity effects of the Project will be presented in the EIR will be influenced by public input received during public scoping meetings and via comment letters. This memo assumes that the EIR water quality section will include a discussion regarding how the Project's effects on salinity will affect drinking water quality and agricultural water use – and that the EIR biological resources section will include a discussion regarding how changes in salinity would affect Delta aquatic species. The following provides brief summaries of the RMA's salinity modeling results and its implications for these three topics. (Note that these summaries include some repetition, because we assume that they may be the basis for different, non-continuous sections of CEQA documentation).

Degradation of Drinking Water Quality Due to Alteration in Salinity Levels in Delta Waters

As a result of the restoration of tidal wetland habitat at the Lookout Slough Project site, the Project site will experience greater tidal exchange, and flows in the outboard Delta channels will be altered. These changes could alter the salinity regime in the Delta. Increased Delta salinities could negatively impact drinking water quality.

RMA analyzed the potential salinity impacts of the Project, using a modeling scenario based on calendar year 2009, representative of a dry year. By comparing EC for the existing conditions scenario with the Project conditions, the modeling provides a quantitative evaluation of the salinity changes.

D-1641 established multiple compliance monitoring stations to protect drinking water beneficial uses, which include: Contra Costa Canal at Pumping Plant 1 (C5), Clifton Court Forebay (C9), the Delta Mendota Canal entrance (DMC1), the North Bay Aqueduct at Barker Slough (SLBAR3), the City of Vallejo intake at Cache Slough (C19). Additionally RMA analyzed changes in salinity at the CCWD intakes at Mallard Slough, Old River, and Victoria Canal.

Given the dynamic nature of a tidal system, the effects of restoration on salinity at Delta drinking water intakes were expected to be small compared to other factors such as precipitation, Delta inflow, and tides. The RMA modeling backs up this assessment. The modeling predicts reduced EC at Barker Slough NBA intake (reductions up to 5 percent) and CCWD intake at Mallard Slough (reductions up to 1.2 percent). All the other stations are predicted to have increased EC of up to 1.6 percent for at least one month per year, with the largest increases

---

2 Water Rights Decision 1641 (D-1641) (SWRCB 2000) is part of SWRCB's implementation of the 1995 Bay-Delta Water Quality Control Plan (Bay-Delta Plan) and is considered the relevant water quality standards to assess salinity impacts. In D-1641, the State Water Board concluded that the exports in the south Delta were partially responsibility for salinity problems in the Delta as a result of hydrologic changes caused by export pumping. D-1641 includes water right permit terms and conditions to implement water quality objectives to protect beneficial uses. D-1641 contains flow and water quality objectives that must be measured at various compliance monitoring stations through the Delta.

typically occurring in the fall. The RMA modeling indicates that even for sites that would experience a slight increase in salinity as a result of the Project, the level of salinity would still be in compliance with D-1641 standards.

Therefore, based on the RMA modeling results, Project salinity changes would not result in substantial adverse effects on the beneficial use of Delta waters as a drinking water source; and there would be a less than significant effect on the degradation of water quality for drinking water due to alteration in salinity levels.

Degradation of Water Quality for in-Delta Agricultural Water Users Due to Alteration in Salinity Levels

The Project has the potential to affect water quality for in-Delta agricultural irrigation users by increasing salinity concentrations at their agricultural diversion intakes. Irrigation water that is more saline can negatively impact crop yields.

RMA analyzed the potential salinity impacts of the Project, using a modeling scenario based on calendar year 2009, representative of a dry year. By comparing EC for the existing conditions scenario with the Project conditions, the modeling provides a quantitative evaluation of the salinity changes.

The D-1641 stations for agricultural beneficial uses include Sacramento at Emmaton (D22) and San Joaquin at Jersey Point (D15).

The RMA modeling results for stations D22 and D15 indicate that under the 2009 modeling scenario, EC levels would be slightly reduced for most of the year compared to existing conditions. These slight EC reductions are largest during the months of August through October, when the reductions are still less than 5 percent. The only predicted increases in EC with the Project at D-1641 stations designated for agricultural beneficial uses occur in March for the D22 station and in May for station D15, although the net increases were very slight (<0.5 percent). Furthermore, these net short-term increases would not exceed any D-1641 compliance requirements that protect agricultural beneficial uses.

Therefore, based on the RMA modeling results, there would be a less than significant effect on the degradation of water quality for agricultural irrigation purposes due to the Project.

Degradation of Water Quality for Fish and Wildlife Due to Alteration in Salinity Levels

D-1641 includes salinity standards as a part of suite of water quality conditions intended to protect a more natural distribution of species composition and wildlife habitats across the Suisun Marsh and Delta. These standards are intended to maintain water quality conditions to prevent the following: a) loss of biodiversity, b) conversion of brackish marsh to salt marsh habitat; c) decreased population abundance of wildlife species and/or loss of habitat from increased salinity, and d) significant reductions in plant stature or percent cover from soil salinity or other water quality issues.

RMA analyzed the potential salinity impacts of the Project using a modeling scenario based on calendar year 2009, representative of a dry year. By comparing EC for the existing conditions scenario with the Project conditions, the modeling provides a quantitative evaluation of the salinity changes.

The D-1641 stations for fish and wildlife beneficial uses are: D15 (San Joaquin at Jersey Point), D29 (San Joaquin at Prisoners Point), and C2 (Sacramento at Collinsville).

Based on the RMA modeling results, salinity at these three stations would change with the Project by at most 3 percent as compared to existing conditions. The largest changes are predicted to be decreased EC at D15 of about 3 percent during July and August. The largest EC increases, of about 2-3 percent, are predicted for D29 during September through November. The salinity changes projected for Station C2 include both increases and decreases, depending on the month, but remain less than 1 percent. When these changes are considered relative to D-1641 standards, the Project would not result in any exceedance of the EC standards that are protective of fish and wildlife beneficial uses.

X2 represents the distance, measured in kilometers upstream from the Golden Gate Bridge, to where salinity measured one meter off the estuary's bed is 2 parts per thousand (ppt). In the past, X2 has averaged around 74 kilometers inland from the Golden Gate, although when tides are stronger and/or downstream flows weaker, X2 may extend as far inland as Rio Vista. X2 demarcates the low salinity zone where freshwater transitions into brackish water. This zone is historically associated with higher primary productivity, zooplankton populations, and abundances of native estuarine species. When X2 is more inland, the low salinity zone is smaller due to the constriction at the confluence of the Sacramento and San Joaquin River channels. When X2 is more seaward, the low salinity zone is larger because it can spread out over more of the Suisun Bay and Marsh region. When X2 is lower in value, and hence more seaward, the populations of many aquatic species, such as fish, typically have increased abundances. D-1641 requires the location of X2 to be west of certain specific locations for a specified number of days each month (specifically, Collinsville, Chipps Island, and Port Chicago at 81 km, 75 km, and 64 km, respectively, from the Golden Gate).

Based on the salinity modeling RMA conducted, the Project would very slightly shift the position of X2 seaward for all months of 2009, as compared to existing conditions. The largest shift, less than 0.2 km (650 ft) seaward, is predicted for an October 2009 scenario with the Project in place. The shifts in X2 from the Project are seaward, the direction of X2 shift that is correlated with improved habitat conditions for many native Delta species. These shifts in X2 position are so slight they are unlikely to cause meaningful beneficial or adverse impacts for fish and wildlife habitat.

Overall, based on the RMA modeling results, there would be a less than significant effect on the degradation of water quality for fish and wildlife due to alteration in salinity levels from the Project.

Cumulative Impacts

CEQA requires an evaluation of a project's contribution to cumulative impacts, which are two or more individual effects that, when considered together, are considerable or increase other environmental impacts. The Project, when combined with other planned tidal wetland restoration projects in the Delta and Suisun Marsh, has the potential to cumulatively alter salinity patterns in the Delta.

As described previously, based on salinity modeling conducted by RMA, the Project would result in minor alterations in salinity under dry year conditions (modelled using calendar year 2009) at the vast majority of D-1641 monitoring compliance stations. At certain stations for specific months of the year, salinity may increase up to 3 percent with implementation of the Project (at station D29), however no compliance issues with D-1641 requirements are projected to occur.

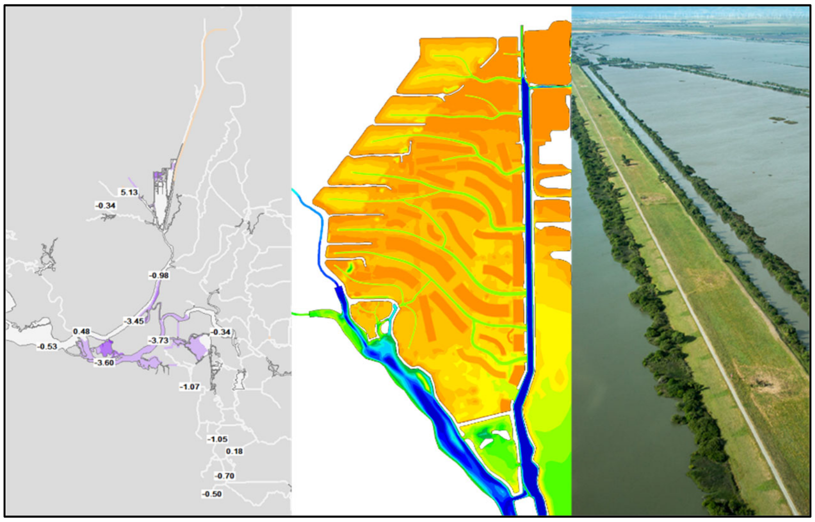
Planned tidal wetland restoration efforts have the potential to collectively make changes in salinity more prominent. To account for these effects, RMA analyzed the effects of over a dozen other tidal wetland restoration projects in the Delta and Suisun Marsh planned for restoration concurrently with the proposed Project, including Winter Island, Wings Land, Tule Red, McCormack Williamson Tract, Lower Yolo, Dutch Slough, and Prospect Island. The combined effect of the Project on Delta EC in combination with other planned tidal wetland restoration project can at times of the year be appreciable for certain D-1641 monitoring compliance stations when compared to existing baseline conditions without these Delta restoration projects in place (e.g., greater than 8 percent increase in EC for an October 2009 scenario at Station D29); nevertheless, even with the combined effects of the Project with other restoration projects currently under planning, Delta salinities would remain in compliance with D-1641 requirements. Therefore, the Project's incremental effect on salinity in the Delta would not be considerable and the cumulative impact is less than significant.

Appendix X

Resource Management Associates Lookout Slough Tidal Habitat Restoration and Flood Improvement Project Modeling

RMA RESOURCE MANAGEMENT ASSOCIATES
WATER RESOURCES ENGINEERING

Lookout Slough Tidal Habitat Restoration and Flood Improvement Project: Modeling EC Impacts



TECHNICAL MEMORANDUM

July 2020

Prepared For:
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RESOURCE MANAGEMENT ASSOCIATES
WATER RESOURCES ENGINEERING

Executive Summary

The RMA Bay-Delta model was applied to evaluate the Lookout Slough Tidal Habitat Restoration and Flood Improvement Project salinity impacts relative to Base (existing) condition and to proposed Regional Restoration. Restoration was represented in sufficient detail to achieve the modeling goal of assessing regional salinity impacts.

The RMA Bay-Delta model is a widely accepted tool that has been shown to be effective at predicting salinity distribution throughout the Delta. The model has been applied to flow and salinity impacts analysis for numerous tidal marsh restoration projects throughout the Bay-Delta.

The evaluation periods were January 10, 2009 to December 31, 2010 and January 1 to December 31, 2016. These periods cover a dry year hydrology (2009) and a below normal year hydrology (2010) as well as a below normal year hydrology following four years of below normal to critically dry conditions (2016). Periods were selected to reflect some of the historical salinity variation, including yearly and seasonal fluctuations in the dynamic Bay-Delta system.

The RMA Bay-Delta model is a 2-D depth averaged / 1-D cross-sectionally averaged model extending from the Golden Gate to the Sacramento River above the confluence with the American River, and to the San Joaquin River near Vernalis. The 2-D elements are employed to represent areas of open water and large channels (e.g. Suisun Bay, Cache Slough Complex, Cache Slough, the lower Sacramento River and restoration areas) while the 1-D elements are used to represent the channelized portions of the Delta.

The hydrodynamic model predicts depth and velocity throughout the model domain. These results are used to drive salt transport in the water quality model. In the model, Electrical Conductivity (EC) is used as a surrogate for salinity similar to other Delta models such as DWR DSM2.

The model was previously calibrated for the 2008 – 2013 period during the Regional Salinity modeling effort (RMA, 2017). For the current effort, further calibration was performed in the Cache Slough Complex (CSC) for the 2009-2010 and 2016 periods. Due to a dearth of boundary condition data in this region, some inflow, withdrawal and EC boundary conditions had to be estimated to bring modeled results into closer agreement with observed data. Minor adjustments to the water quality model calibration throughout the model domain were also

made. Overall, the model performed well for reproducing observed EC, with R^2 values at most stations at 0.9 or greater. The model underpredicts EC for periods of the winter of 2009-2010 in the central Delta and confluence area, however, these periods are not when compliance standards apply. Results in Upper Cache Slough are improved but the quality of the results still reflects the lack of data to characterize local watershed sources of salinity. In spite of these times when the model has some discrepancies as compared with observed conditions, the model is still sufficient to quantify the relative change in EC likely to result from the Lookout Slough and Regional restoration.

Salinity Evaluation

Electrical conductivity (µmhos/cm or µSiemens/cm), or EC, was modeled as a surrogate for salinity. EC is used as a stand-in for the more precise term of Specific Conductance (SC) for the electrical conductance corrected to 25° C. The RMA Bay-Delta model computes depth-averaged EC. EC is directly correlated with salinity, such that increases in EC correspond to increases in salinity. EC can also be used to estimate concentrations of particular forms of salt such as chlorides and bromides.

Salinity impacts were evaluated for select D-1641 compliance locations and Contra Costa Water District intake locations:

D-1641 Station ID	Location	Beneficial Use
D22	Sacramento at Emmaton	Agriculture
D15	San Joaquin at Jersey Point	Agriculture, Fish and Wildlife
D29	San Joaquin at Prisoners Point	Fish and Wildlife
C5	Contra Costa Canal at Pumping Plant 1	Municipal and Industrial
C9	West Canal at mouth of Clifton Court Forebay	Municipal and Industrial
DMC1	Delta-Mendota Canal at Tracy Pumping Plant	Municipal and Industrial
SLBAR3	Barker Slough NBA Intake	Municipal and Industrial
C19	City of Vallejo Intake (Abandoned) Cache Slough	Municipal and Industrial
C2	Sacramento at Collinsville	Fish and Wildlife
D12	San Joaquin at Antioch	Municipal and Industrial
	CCWD Intake at Mallard Slough	
	CCWD Intake at Old River	
	CCWD Intake at Victoria Canal	
D24	Sacramento at Rio Vista	

The locations were selected to assess the potential for the Lookout Slough restoration to affect salinity intrusion in the Delta.

The objectives of the model salinity evaluation were twofold:

1) Evaluate the salinity impacts by quantifying the change from the existing conditions.
2) Examine if the Lookout Slough restoration has the potential to result in non-compliance with the D-1641 water quality objectives for select locations.

The modeling results showed that Lookout Slough is predicted to cause both decreases and increases in computed EC both seasonally and spatially.

The first objective of the water quality evaluation was to quantify salinity changes from the Base and Regional Restoration conditions arising with Lookout Slough. Daily and monthly averaged EC for all modeled scenarios were compared for select D-1641 compliance locations and water intakes. Lookout Slough generally decreases EC in the lower Sacramento River and in the lower San Joaquin River below Threemile Slough. Some increases in EC are predicted in the south Delta with the Lookout Slough restoration, particularly from July through October. In the Cache Slough Complex, Lookout Slough restoration tends to reduce EC in Barker Slough and increase EC in upper Cache Slough. The increase in upper Cache Slough is the result of reduced mixing and dilution of local-source salinity.

The general observations are:

- Largest percent EC increases due to Lookout Slough restoration occur during the fall at Prisoners Point (as much as 3.5% relative to Base / 2.9% relative to Regional Restoration) and during the fall and summer at C19 (as much as 5.5% / 5.4%).
- Other locations with EC increases greater than 1% include West Canal at Clifton Court, DMC at Tracy Pumping Plant, Collinsville, Rio Vista and CCWD intakes at Rock Slough, Old River and Victoria Canal.
- Largest percent EC decreases due to Lookout Slough occur during the spring in Barker Slough (as much as -4.3% / -4.2%), during the summer at Emmaton (as much as -4.7% / -2.3%) and Jersey Point (as much as -3.7% / -3.2%), during the summer and fall at Antioch (as much as -3.6% / -3.0%) and during the fall at Rio Vista (as much as -4.7% / -2.0%).

One of the primary mechanisms impacting modeled salinity is a decreased tidal range in the north Delta resulting from Lookout Slough restoration. This tidal range decrease results in slightly less flow through the Delta Cross Channel and Georgiana Slough and slightly more flow down Sutter and Steamboat Sloughs and the Sacramento River below Georgiana Slough. This shift of freshwater flow results in decreased salinity in the Sacramento River and western Delta as well as the corresponding increased salinity in the central Delta when the Delta Cross Channel is open, typically late June through October.

The Regional Restoration shifts even more flow toward the Sacramento River. The Lookout Slough flow shift relative to the Regional Restoration flows is smaller and therefore the % EC changes are smaller than the changes from Base.

The second goal of the salinity model evaluation was to determine the potential for Lookout Slough restoration to result in non-compliance with the D-1641 water quality objectives. The compliance analysis considered seasonal agriculture, fish and wildlife EC standards for the Sacramento River at Emmaton and Collinsville, and the San Joaquin River at Jersey Point and Prisoners Point and chloride standards at the water intakes. At Emmaton, Jersey Point and Prisoner Point there were no new compliance issues resulting from Lookout Slough, nor did the Lookout Slough project make non-compliance substantially more likely. Where historical standards non-compliance occurred, Lookout Slough slightly decreased EC, thereby making non-compliance less likely. At Collinsville the same was true except for February 2009, where Lookout Slough resulted in slight EC increases when a historical non-compliance occurred.

Modeled EC results were converted to chloride to assess compliance at the water intakes. No non-compliance with water quality objectives occurred at any of the intakes under any of the modeled configurations or time periods and, relative to Base and Regional Restoration, Lookout Slough restoration had almost no impact on the maximum mean daily chloride values used to determine compliance.

Evaluation of changes to X2, a Bay-Delta Plan compliance standard, indicates that Lookout Slough restoration would generally decrease monthly averaged X2 by 0.2 km or less and cause no changes in compliance.

Bromide concentrations were estimated from modeled EC and Martinez volumetric source fraction. Lookout Slough was found to increase bromide at south Delta water intakes by as much as 1 to 3% and decrease bromide at Antioch and the CCWD intake at Mallard by 1 to 4%.

Although results based on published relationships between EC and bromide predict increases in bromide at C19 and at times in Barker Slough, there is uncertainty in the magnitude of these changes because the EC to bromide conversion equations were not developed specifically for the conditions occurring in this area, where local inflows are the primary source of salinity.

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Introduction and Purpose

The Lookout Slough Tidal Habitat Restoration and Flood Improvement Project is an approximately 3400-acre site located in the northern Sacramento–San Joaquin Delta, bounded by Cache Slough, Hass Slough and Duck Slough on the west and Shag Slough on the east (Figure 1). Proposed restoration includes excavation of interior channels, construction of interior berms, followed by breaching levees to Shag Slough to restore tidal influence.

Hydrodynamic and water quality model simulations were performed to assess potential project impacts on salinity at water intakes and salinity compliance standards. Impacts were considered relative to existing conditions and relative to anticipated Regional Restoration conditions.

Background

The RMA Bay-Delta model was applied to assess salinity impacts for the Lookout Slough Tidal Habitat Restoration and Flood Improvement Project. The RMA Bay-Delta model is a widely accepted tool that is effective at predicting EC throughout the Delta (see Appendix B: Water Quality Model Calibration). The model has been applied to flow and salinity impacts analysis for numerous restoration projects in the Bay-Delta system, including BDCP, Regional Salinity, Suisun Marsh PEIR/EIS, Prospect Island, Little Egbert Tract, McCormack-Williamson Tract, Decker Island, Winter Island, Dutch Slough, Chipps Island, Mallard Farms, Tule Red, Grizzly King, Potrero Marsh, Bradmoor Island, Arnold Slough, Hill Slough and Wings Landing (see for example RMA, 2009, 2012, 2013, 2015a and 2015b). The RMA Bay-Delta model has undergone continual development over more than 20 years to reflect currently available data and meet project needs. Similarly, since their original development in the 1970's, the RMA2 and RMA11 computational models have been updated over the years to best utilize the latest scientific knowledge and technology, and to meet new project needs.

Methods

The model evaluation was conducted using the RMA Bay-Delta model for flow and salinity. The model utilizes the finite element method to simulate 2-D depth averaged / 1-D cross-sectionally averaged flow and salinity for a 7.5-minute computational time step.

Hydrodynamic and EC (Electrical Conductivity, modeled as a surrogate for salinity) simulations were performed for the period of January 2009 – December, 2010 and January – December 2016. According to DWR's hydrologic classification index, the 2009 water year was classified as dry. The 2010 and 2016 water years were classified as below normal.

To assess potential impacts associated with the Project, simulations were performed for four scenarios examining existing conditions, implementation of the Project and potential cumulative impacts with and without consideration of other projects in the Delta that may be constructed in the future:

- Base (existing condition)
- Base with Lookout Slough Restoration
- Regional Restoration (no Lookout Slough)
- Regional Restoration with Lookout Slough

Results were post-processed to evaluate potential for violation of D-1641 standards and impacts on X2, the location along the primary axis of the estuary where tidally averaged bottom salinity is two parts per thousand which is a Bay-Delta Plan standard. Daily and monthly average salinity changes were assessed at D-1641 standards locations and water export locations. Spatial plots of relative salinity change were provided for select months.

EC results were converted to chloride for analysis of D-1641 standards at the water intakes.

Additionally, bromide impacts were assessed based on conversion of modeled EC to bromide.

Simulations of Martinez volumetric source fraction were performed to provide additional information for estimation of chloride and bromide concentrations at the water intakes.

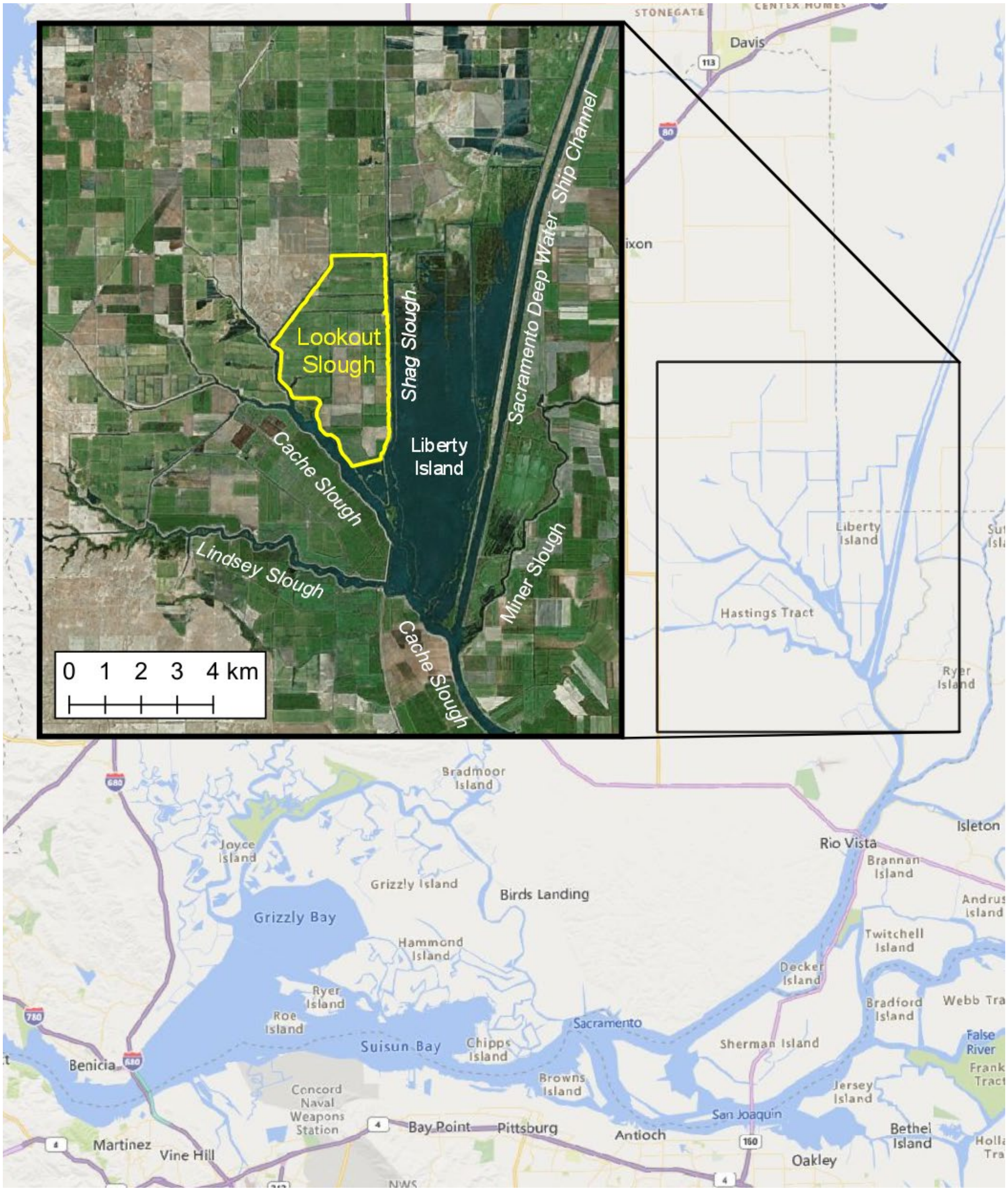

Figure 1 Location of the Lookout Slough restoration site in the Cache Slough Complex.

Model Configuration

Geometric Extents

RMA's San Francisco Bay, Sacramento–San Joaquin Delta network was developed using an in-house GIS-based graphical user interface program (RMA, 2003) and the Janet commercial grid generation program (developed by smile consult GmbH). The programs allow for development of the finite element mesh over layers of bathymetry points and bathymetry grids, GIS shapefiles and aerial images.

The RMA Bay-Delta model, shown in Figure 2, extends from Golden Gate up the Sacramento River above the confluence with the American River, and up the San Joaquin River near Vernalis. A two-dimensional depth-averaged approximation is used to represent the San Francisco Bay, Suisun Bay region, portions of Suisun Marsh, the Sacramento-San Joaquin confluence area, Sherman Lake, the Sacramento River up to Rio Vista, Cache Slough, Liberty Island, Shag Slough, portions of Lindsey Slough, the Sacramento River Deep Water Ship Channel (DWSC) and Miner Slough, Big Break, the San Joaquin River up to its confluence with Middle River, False River, Franks Tract and surrounding channels, Mildred Island, Old River south of Franks Tract, and the Delta Cross Channel area. The model has undergone continuous development through dozens of projects since 1997 (e.g. RMA, 2012, 2015b).

The other Delta and Suisun Marsh channels and tributary streams are represented using a one-dimensional cross-sectionally averaged approximation. A detail view of the Cache Slough Complex (CSC) is shown in Figure 3.

The Base model network used for model calibration does not include any restoration in Lookout Slough. The Lookout Slough restoration model network includes the detailed representation of the Lookout Slough restoration.

A second pair of model geometries include planned regional restorations, with and without Lookout Slough restoration.

The size and shape of elements are dictated by changes in bottom elevation and other hydraulic and salinity considerations. Wetting and drying of the tidal mudflats has been represented in sufficient detail to provide a good definition of change in the tidal prism with change in tidal stage.

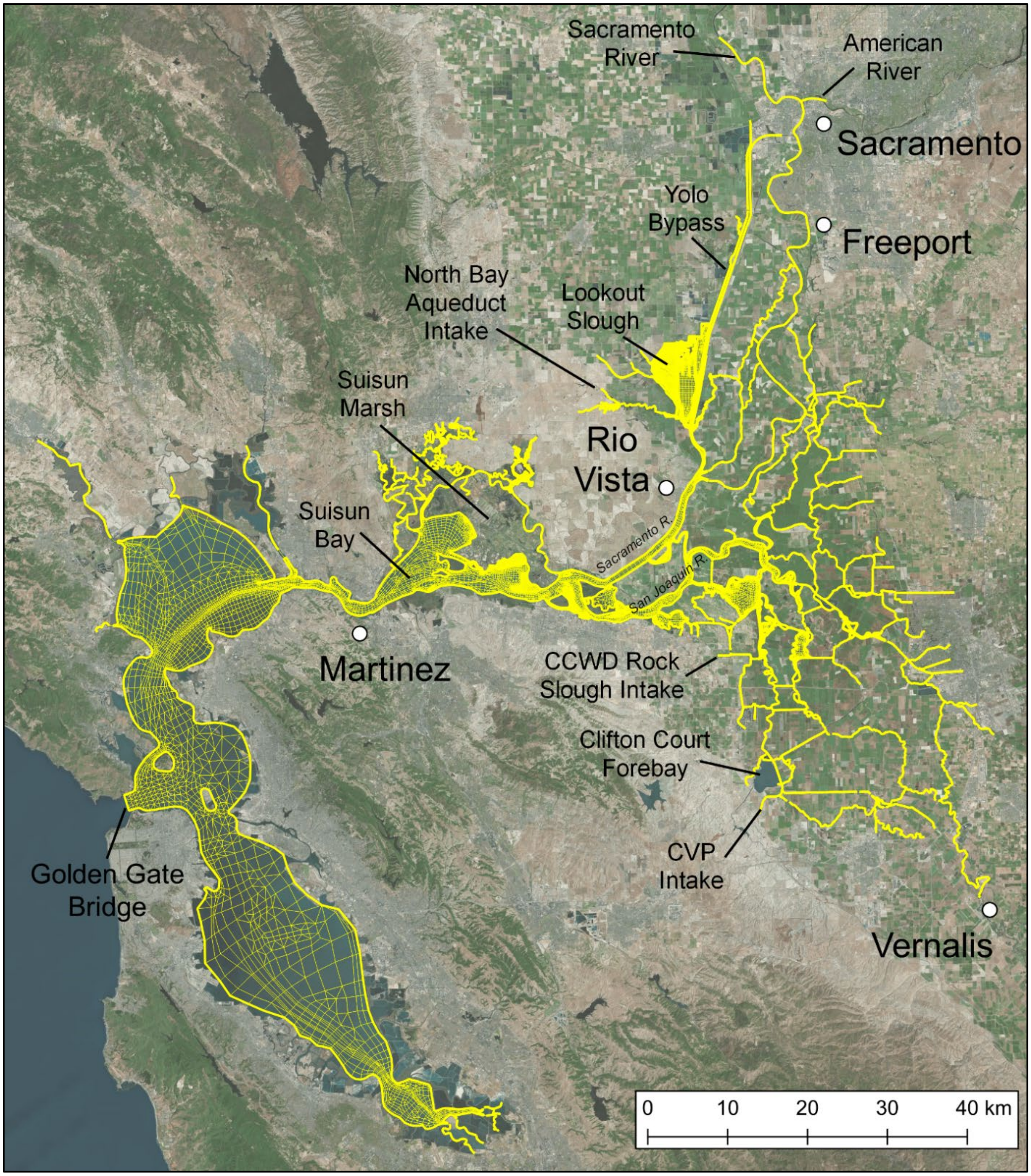

Figure 2 Extents of the RMA Bay-Delta model for the Lookout Slough restoration analysis.

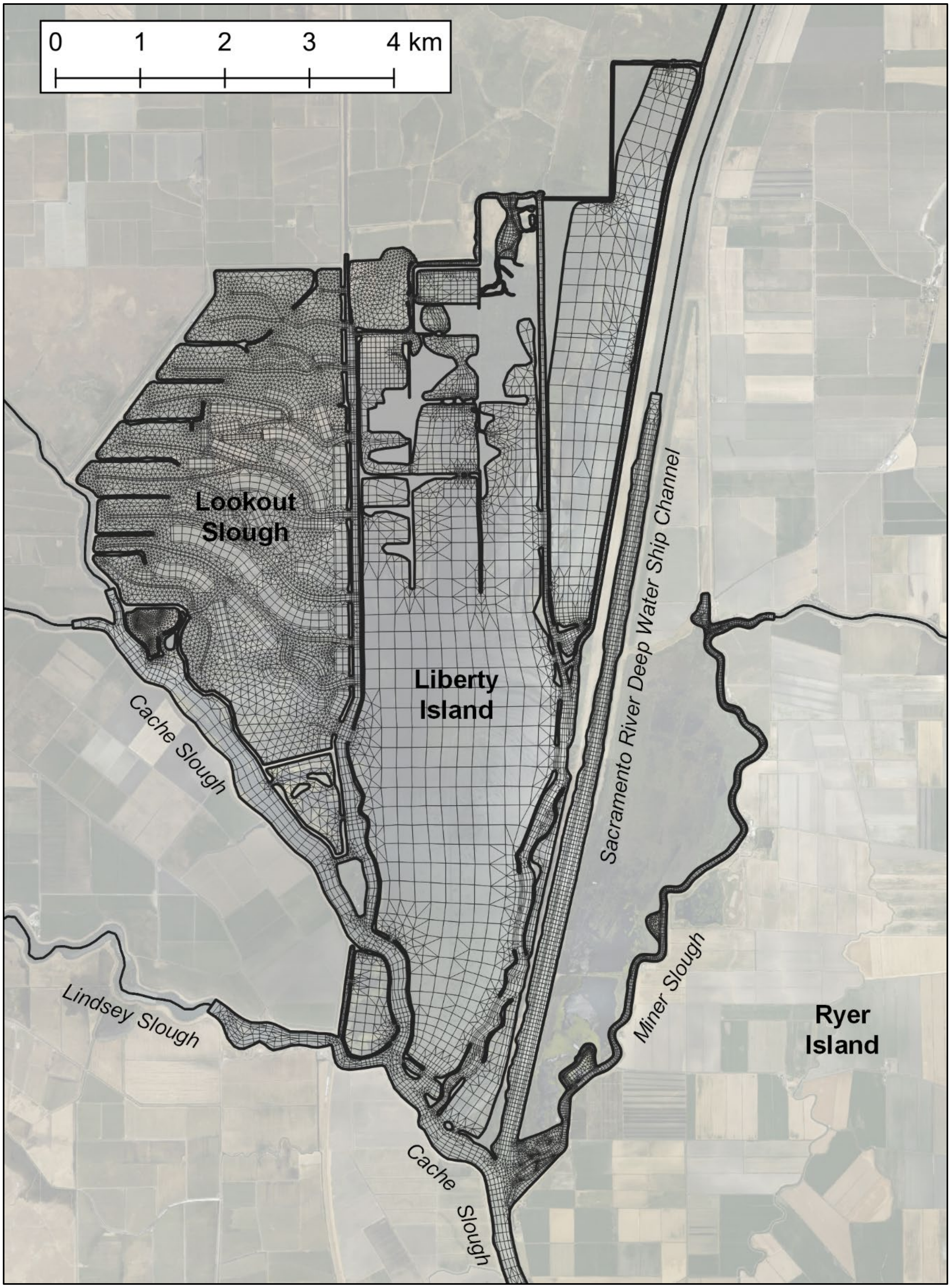

Figure 3 Detail view of the model configuration with Lookout Slough restoration.

Bathymetry

The RMA Bay-Delta model grid and bathymetry has been continually updated over the years as new and better bathymetry data becomes available. For all areas of the model grid, the most current, best quality bathymetric data were used to set grid elevations (Figure 4) as follows.

- Most recently, elevations were set using data collected in the CSC during 2015, 2017 and 2018 by the USGS[1].
- Deepwater Ship Channel and Upper Liberty Island elevations were set using data collected by DWR (DWR, 2012a and 2012b).
- Elevations in the portions of the Ship Channel upstream of the DWR survey were set using 2005 USACE data (USACE, 2005).
- In Cache Slough and Sutter Slough elevations were set using data collected by Environmental Data Solutions (EDS) 2012.
- Coarsely space single beam transects were available from the CVFED program for Upper Cache Slough, Hass Slough and Lindsey Slough. Additionally, the CVFED multibeam data were used to update the bathymetry of the Sacramento River above the Georgiana Slough confluence, above the American River confluence to the crossing of Interstate 5 (DWR, 2010 and 2011a).
- Data collected in 1997 for the USACE Comprehensive Study (USACE, 2002) were used to set elevations in Sacramento River above Cache Slough, Steamboat Sloughs.
- For the San Francisco Bay and Suisun Bay, DWR's 2012 10m San Francisco Bay and Sacramento – San Joaquin Delta DEM version 3[2] were used.
- The model grid includes elevations based on the multi-beam bathymetry surveys performed by DWR for selected Delta channels and posted on the DWR Delta Bathymetry website[3,4].
- For all areas not covered by more recent data sets listed above, bottom elevations and the extent of mudflats were based on bathymetry data collected by NOAA, DWR, USACE and USGS. These datasets have been compiled by DWR and can be downloaded from DWR's Cross Section Development Program (CSDP) websites[5] and;
- Topography data from DWR's Delta LiDAR survey (2007).

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[1] https://www.sciencebase.gov/catalog/item/5d781129e4b0c4f70d020cdd
[2] https://data.cnra.ca.gov/dataset/san-francisco-bay-and-sacramento-san-joaquin-delta-dem-v3
[3] https://gis.water.ca.gov/app/bathymetry/
[4] https://data.cnra.ca.gov/dataset/san-francisco-bay-and-sacramento-san-joaquin-delta-dem-for-modeling-version-4-1
[5] https://data.ca.gov/dataset/cross-section-development-program-navd88-update

Model bathymetry in Lookout Slough is shown in Figure 5. A DEM of the restoration design features was provided by Ecosystem Investment Partners (EIP).

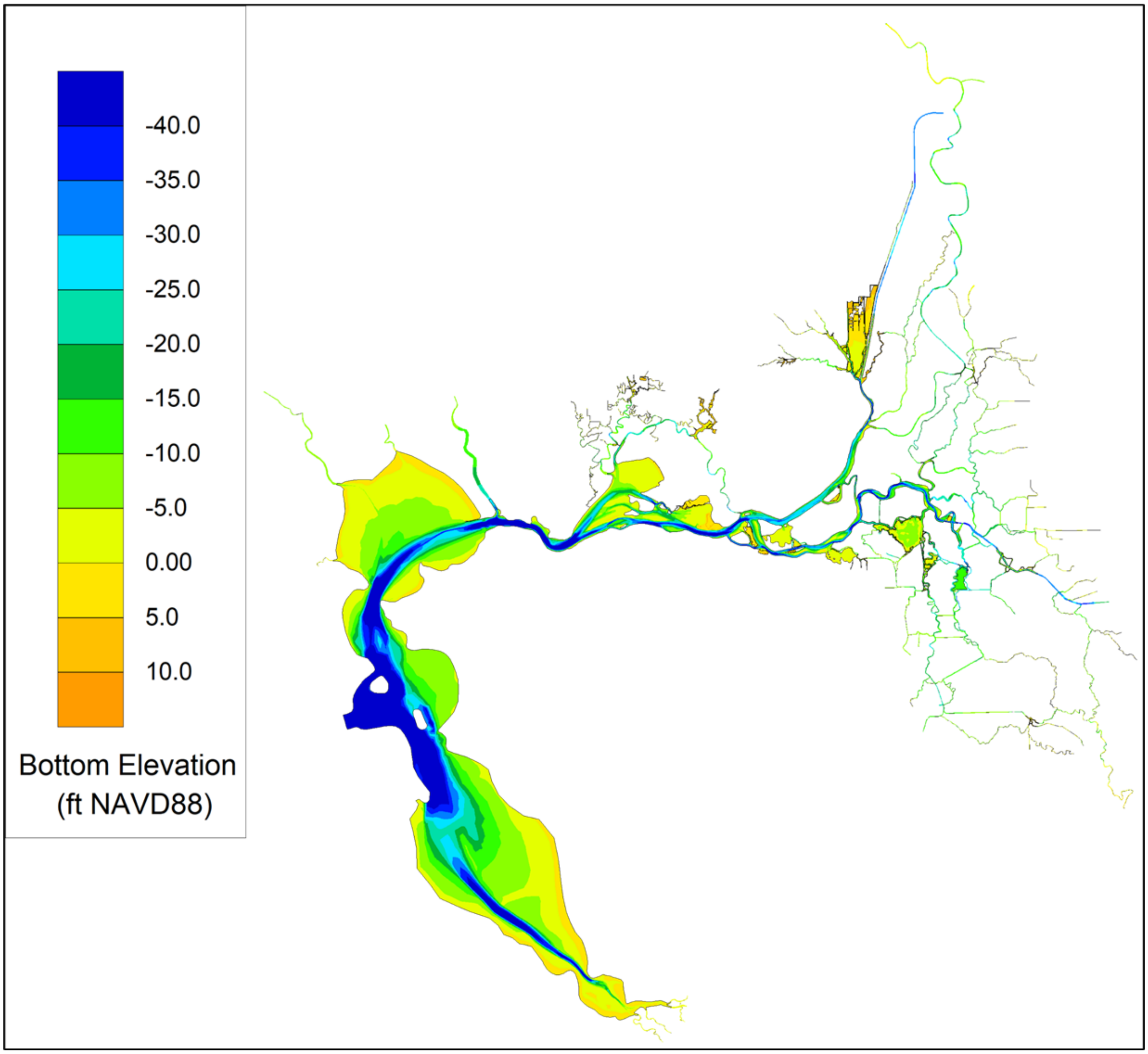

Figure 4 RMA Bay-Delta Base model bathymetry.

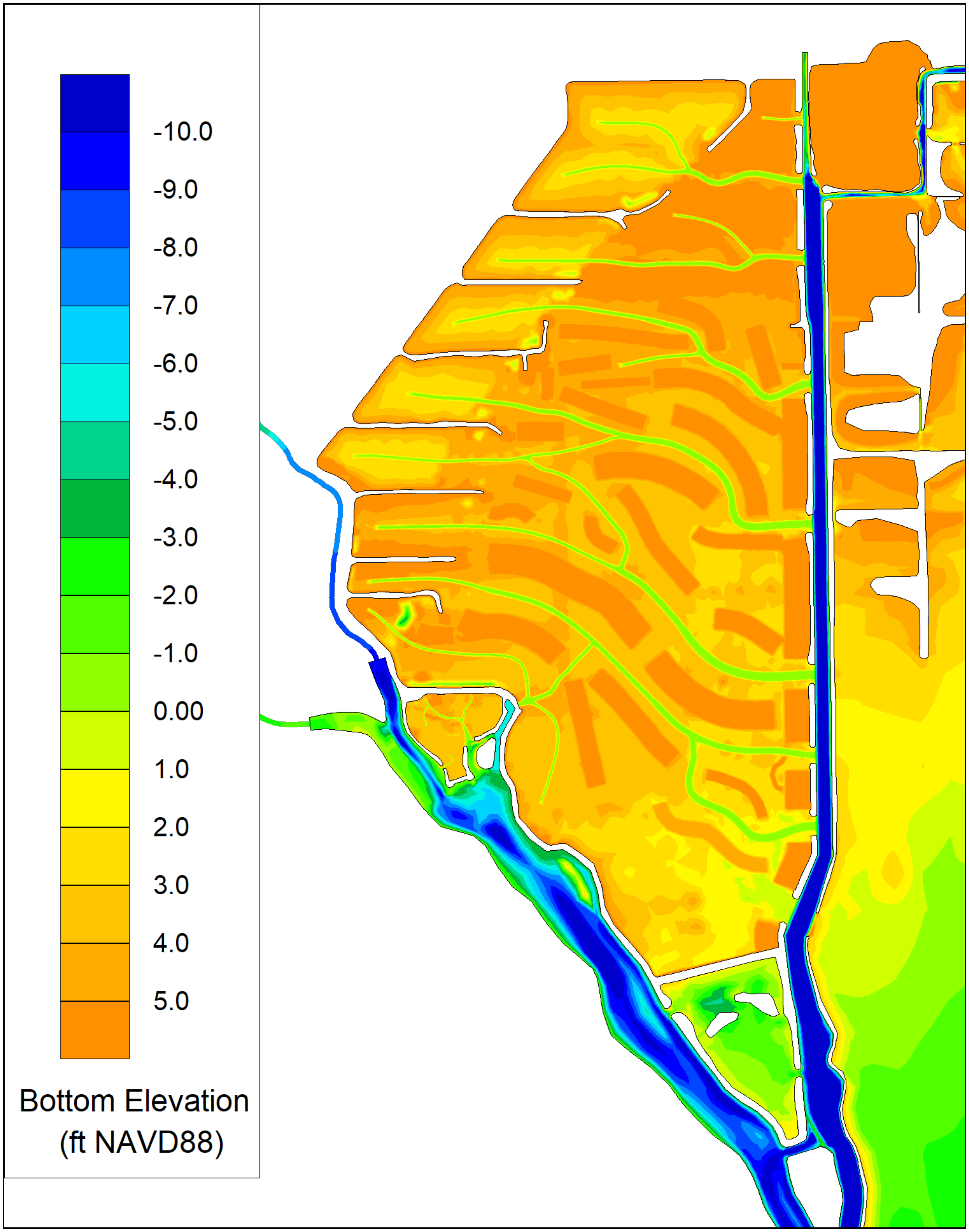

Figure 5 Lookout Slough model bathymetry for the Lookout Slough restoration configuration.

Model Boundary Conditions

Figure 6 through Figure 8 show the location of the model boundary conditions. Each model inflow and stage boundary condition requires a corresponding EC value be specified. The model boundary conditions are:

Tidal stage boundary at the Golden Gate

Inflows:
Sacramento River above American River
American River near Sacramento
San Joaquin River near Vernalis
Yolo Bypass at top of Liberty and Yolo Bypass Toe Drain
Mokelumne River near Thornton
Cosumnes River
Calaveras River near Stockton
Lindsey Slough, Barker Slough, Campbell Lake and Ulatis Creek inflows
Sacramento Regional, Vacaville Easterly, Stockton and Tracy WWTP inflows

Exports/Diversions:
State Water Project (SWP), Clifton Court Forebay gates
Central Valley Project (CVP) Tracy Pumping Plant
Contra Costa Water District (CCWD) intakes at Rock Slough, Old River and Victoria Canal
North Bay Aqueduct (NBA), Barker Slough Pumping Plant
Delta Island Consumptive Use (DICU), throughout Delta
Upper Cache, Hass Slough and Yolo Bypass duck club diversions
Evaporation in the Cache Slough Complex and Suisun Marsh

Major Control Structures:
Delta Cross Channel gates
Suisun Marsh Salinity Control Gate (SMSCG)
Lisbon Weir
South Delta Temporary Barriers

- Old River near Tracy (DMC) temporary barrier
- Old River at Head temporary barrier
- Middle River temporary barrier
- Grant Line Canal temporary barrier

Time series plots of model boundary conditions for the model calibration and analysis periods of January 2009 – December 2010 and January – December 2016 are provided in Appendix A: Model Boundary Conditions.

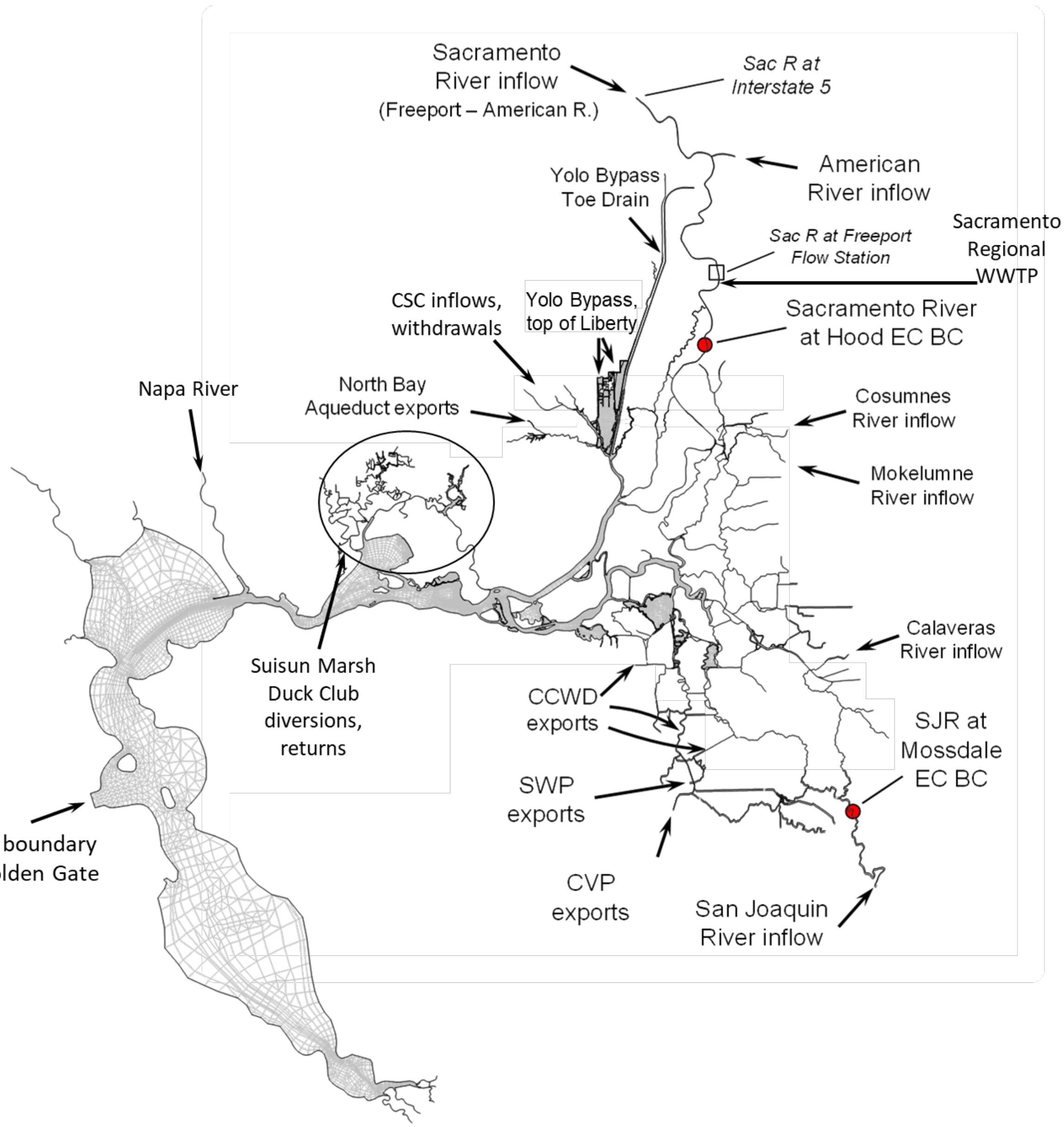

Figure 6 Model boundary condition locations. Internal EC boundary conditions are set for the San Joaquin River at Mossdale and for the Sacramento River at Hood.

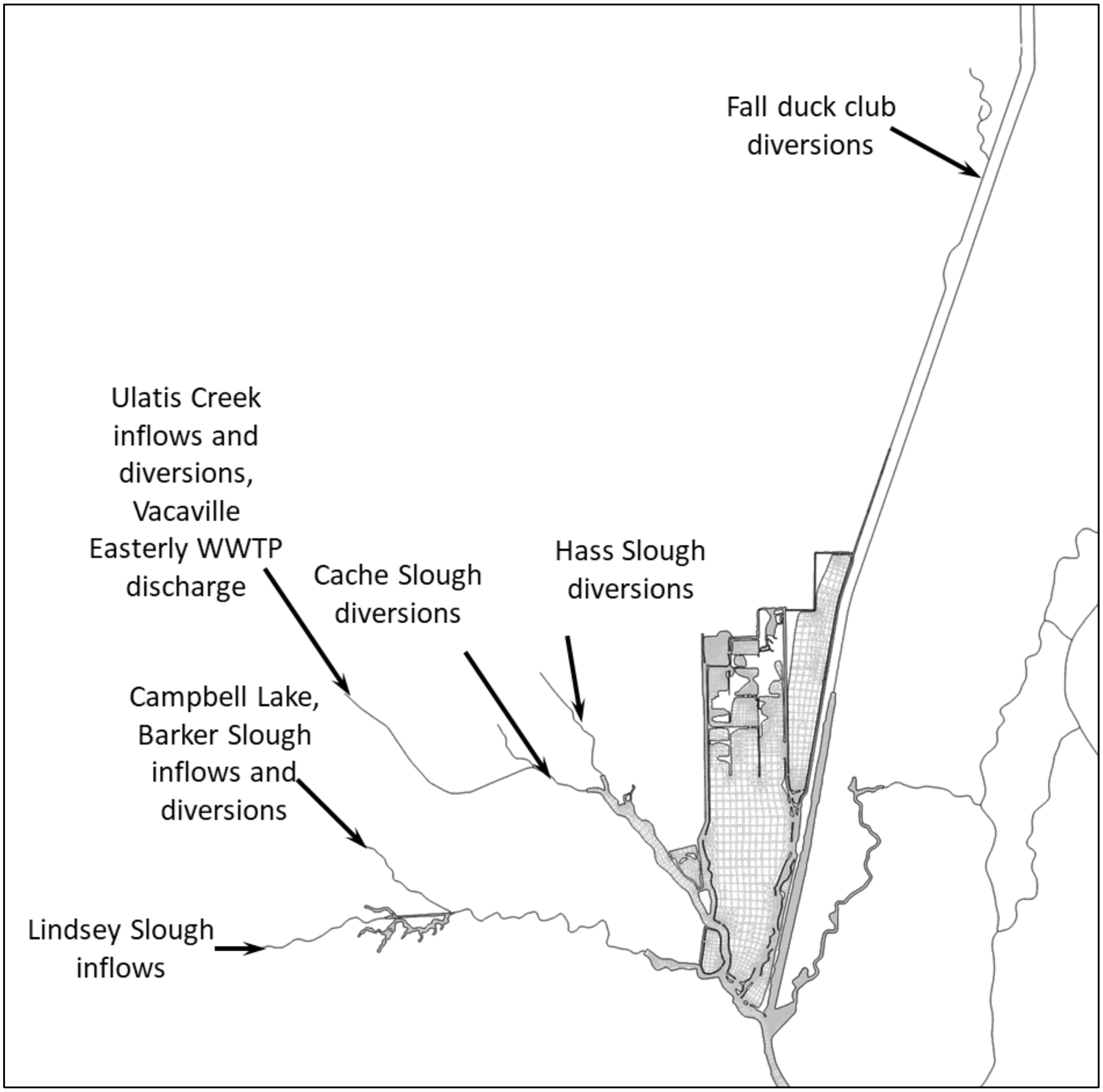

Figure 7 Additional CSC model boundary condition locations.

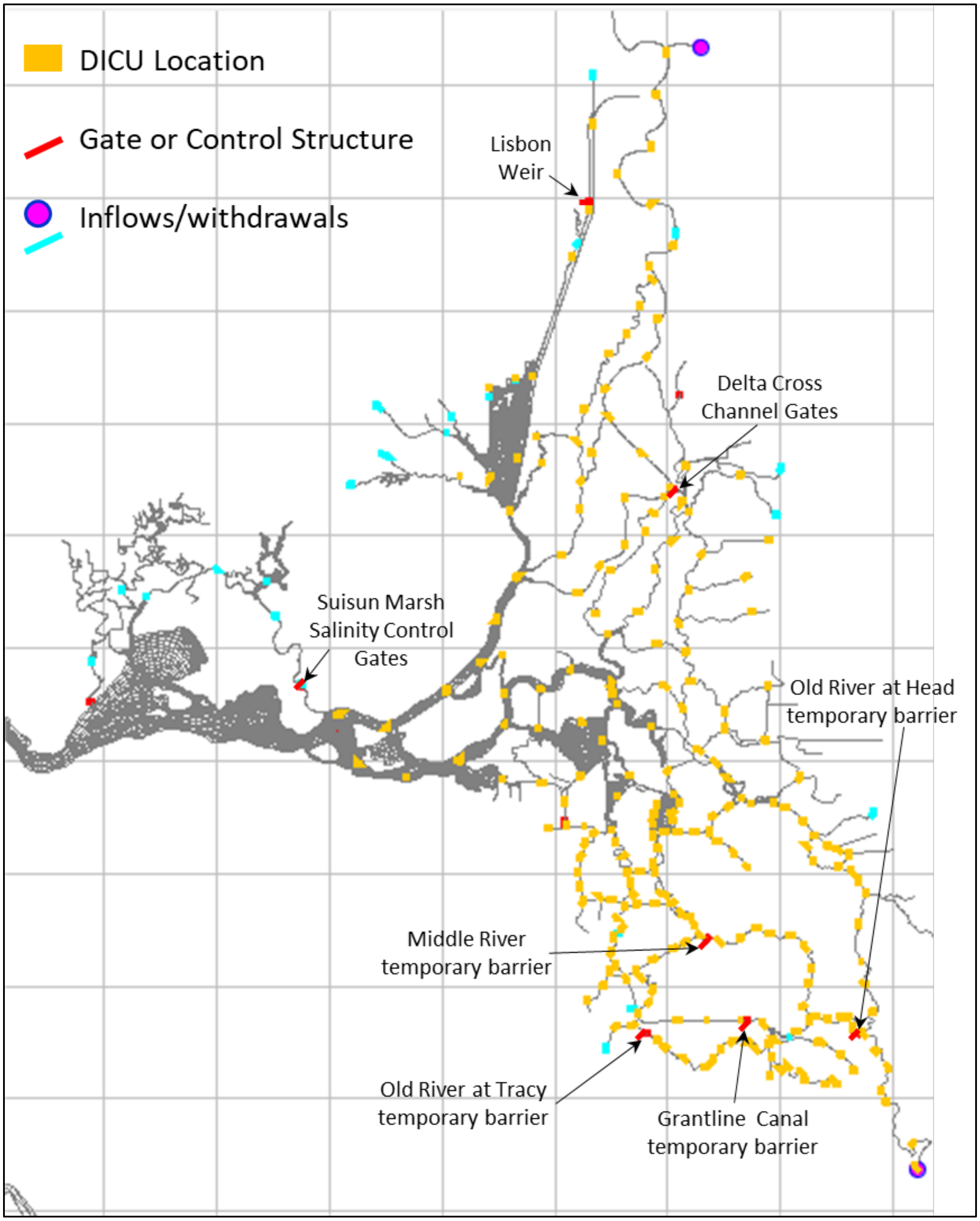

Figure 8 Location of DICU diversions and returns, and the major Delta control structures.

Bay-Delta Model Calibration

The Bay-Delta model was previously calibrated for the 2008 – 2013 period during the Regional Salinity modeling effort (RMA, 2017) and for the 2009 – 2010 period during the Prospect Island study (RMA, 2013). For the current effort, further calibration was performed in the CSC for the 2009-2010 and 2016 periods. Due to a lack of boundary condition data characterizing local watershed conditions in the CSC, some inflow, withdrawal and EC boundary conditions had to be estimated to bring modeled results into closer agreement with observed data. Minor adjustments to the water quality model calibration throughout the model domain were also made. Base simulation EC results were compared against observed data at locations shown in Figure 9 for the January 2009 – December 2010 and January – December 2016 periods and the analysis documented in Appendix B: Water Quality Model Calibration.

Overall, the model performed well for reproducing observed EC, replicating 90% of the observed EC variance in most of the Delta and 67-80% of the variance at some of the stations in the upper Cache Slough, CCS and UCS (see summary of model R^2 values in Table 1). The model underpredicts salinity for brief periods in the winter of 2009-2010 and fall of 2016 in the central Delta and confluence area (for example at Antioch by as much as 2,500 µmhos/cm [Figure 10] and Jersey Point by as much as 700 µmhos/cm [Figure 11]). These periods of underprediction do not occur when these stations have D-1641 compliance standards in effect.

Using updated boundary condition information discussed above, the focused calibration effort improved results in Upper Cache Slough (Figure 12, Figure 13). The model follows observed seasonal trends and more closely follows observed tidal dynamics than prior to calibration, but the variations between observed and modeled EC still reflect the lack of data to represent several local watershed sources of flow and salinity (including Ulatis Creek and local agricultural diversion and return flows) as boundary conditions. Locations nearest the boundaries where data is lacking and must be estimated (CCS, UCS) show the weakest calibration results. R^2 values at the CCS station are 0.67 for the 2009 – 2010 period and 0.80 at UCS for the 2016 period, indicating fair agreement between observed and modeled conditions. Although agreement between observed and modeled conditions in Upper Cache Slough is not as strong as in other areas of the Delta, the calibrated model still represents the processes which determine EC distribution in this area and is sufficient for assessing the magnitude of likely changes between existing and proposed conditions.

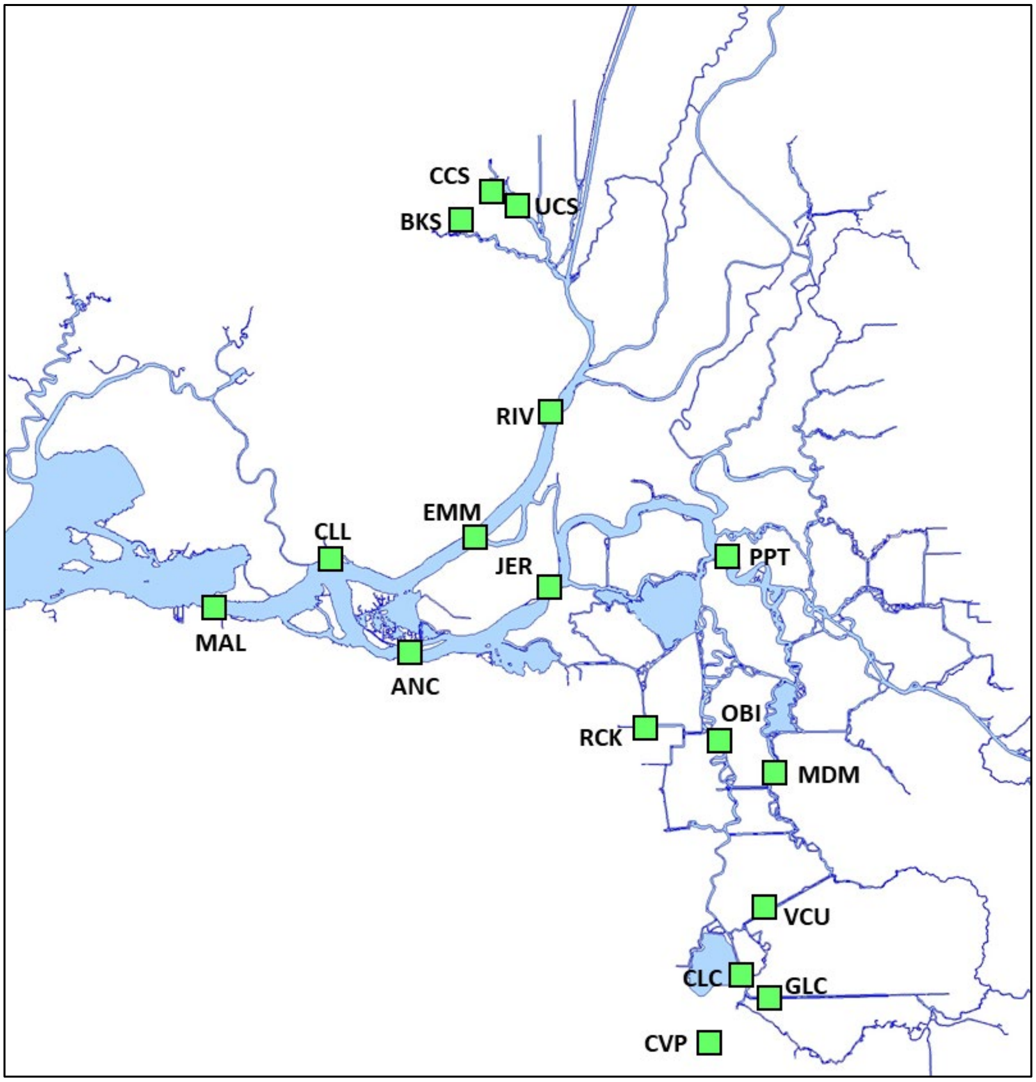

Figure 9 Salinity stations used for calibration.

Table 1 Model R^2 values (see detailed calibration results in Appendix B: Water Quality Model Calibration).

Site name	Years	R2
CCS – Cache Slough	2009-2010	0.671
CCS – Cache Slough	2016	n/a
UCS – Upper Cache Slough USGS	2009-2010	n/a
UCS – Upper Cache Slough USGS	2016	0.797
BKS – Barker Slough	2009-2010	0.919
BKS – Barker Slough	2016	0.961
RIV – Rio Vista	2009-2010	0.774
RIV – Rio Vista	2016	0.769
EMM – Emmaton	2009-2010	0.827
EMM – Emmaton	2016	0.913
EMB – Emmaton CDEC Bottom	2009-2010	0.815
EMB – Emmaton CDEC Bottom	2016	0.903
CLL – Collinsville USBR	2009-2010	0.929
CLL – Collinsville USBR	2016	0.952
CLL – Collinsville Bottom USBR	2009-2010	0.938
CLL – Collinsville Bottom USBR	2016	0.957
MAL – Sacramento River at Mallard	2009-2010	0.939
MAL – Sacramento River at Mallard	2016	0.961
MAL – Sacramento River at Mallard Bottom	2009-2010	n/a
MAL – Sacramento River at Mallard Bottom	2016	0.959
ANC – Antioch	2009-2010	0.877
ANC – Antioch	2016	0.925
JER- Jersey Point CDEC	2009-2010	0.864
JER- Jersey Point CDEC	2016	0.959
PPT – Prisoner Point	2009-2010	0.879
PPT – Prisoner Point	2016	0.899
RSC – Rock Slough at Delta Rd. Bridge	2009-2010	0.908
RSC – Rock Slough at Delta Rd. Bridge	2016	0.938
OBI – Old River at Bacon WQ	2009-2010	0.918
OBI – Old River at Bacon WQ	2016	0.947
CLC – Clifton Court Forebay	2009-2010	0.907
CLC – Clifton Court Forebay	2016	0.842
CVP – Central Valley Project	2009-2010	0.896
CVP – Central Valley Project	2016	0.595
GLC – Grantline Canal	2009-2010	0.911
GLC – Grantline Canal	2016	0.785
VCU – Victoria Canal	2009-2010	0.935
VCU – Victoria Canal	2016	0.913
MDM – Middle River at Middle River	2009-2010	0.919
MDM – Middle River at Middle River	2016	0.934

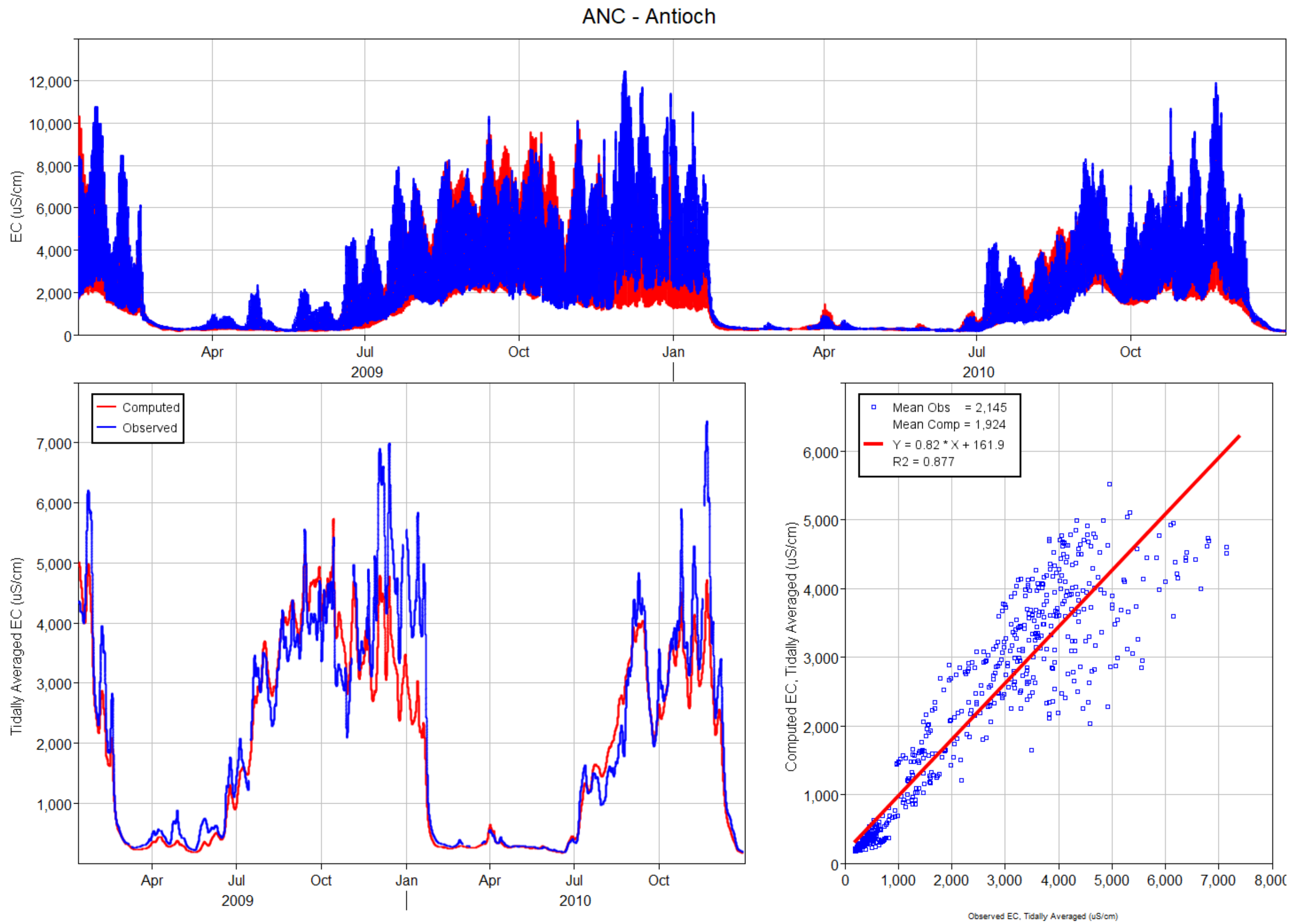

Figure 10 Comparison of modeled and observed EC at ANC, the SJR at Antioch for 2009 – 2010.

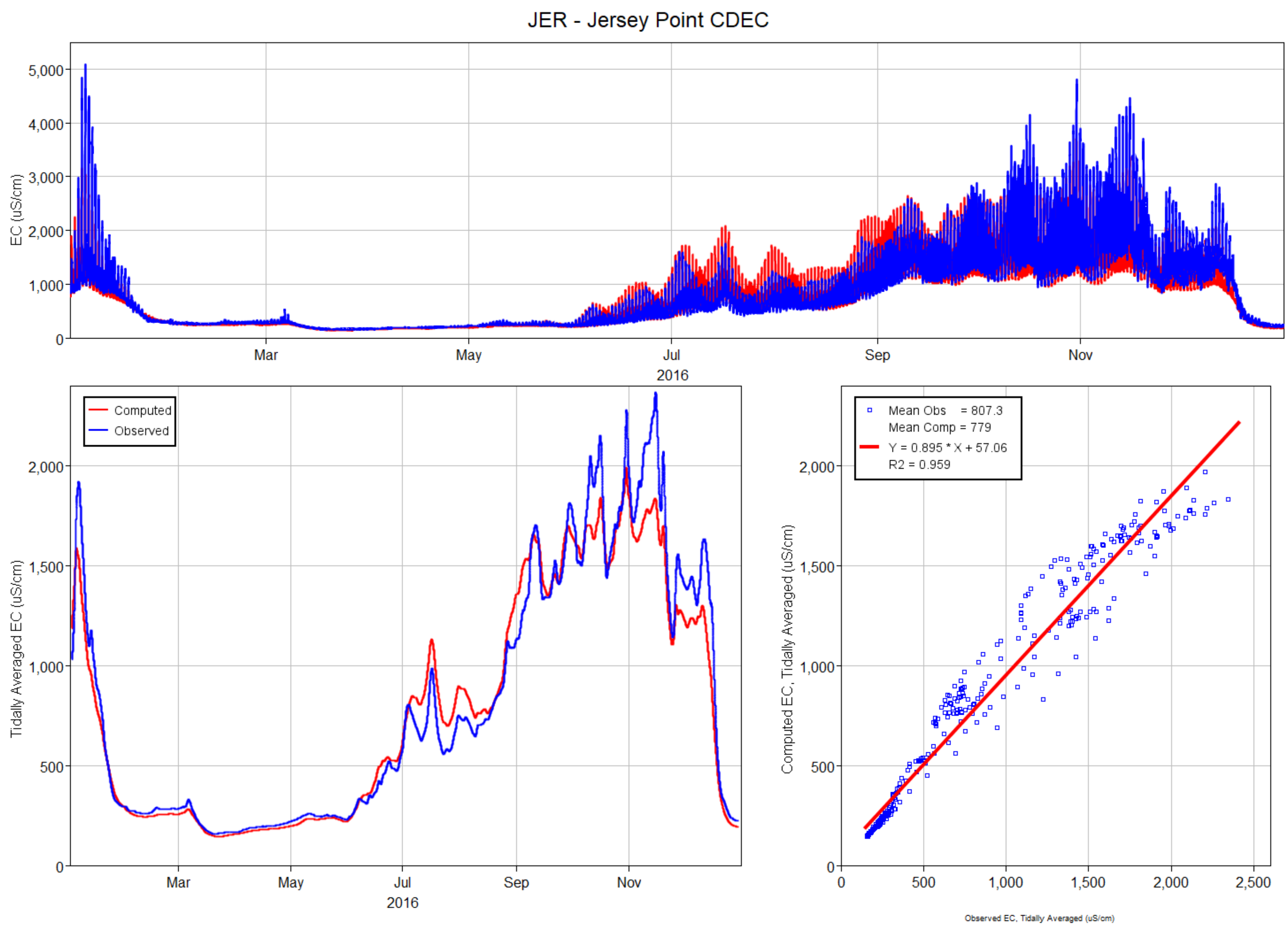

Figure 11 Comparison of modeled and observed EC at JER, the San Joaquin River at Jersey Point for 2016.

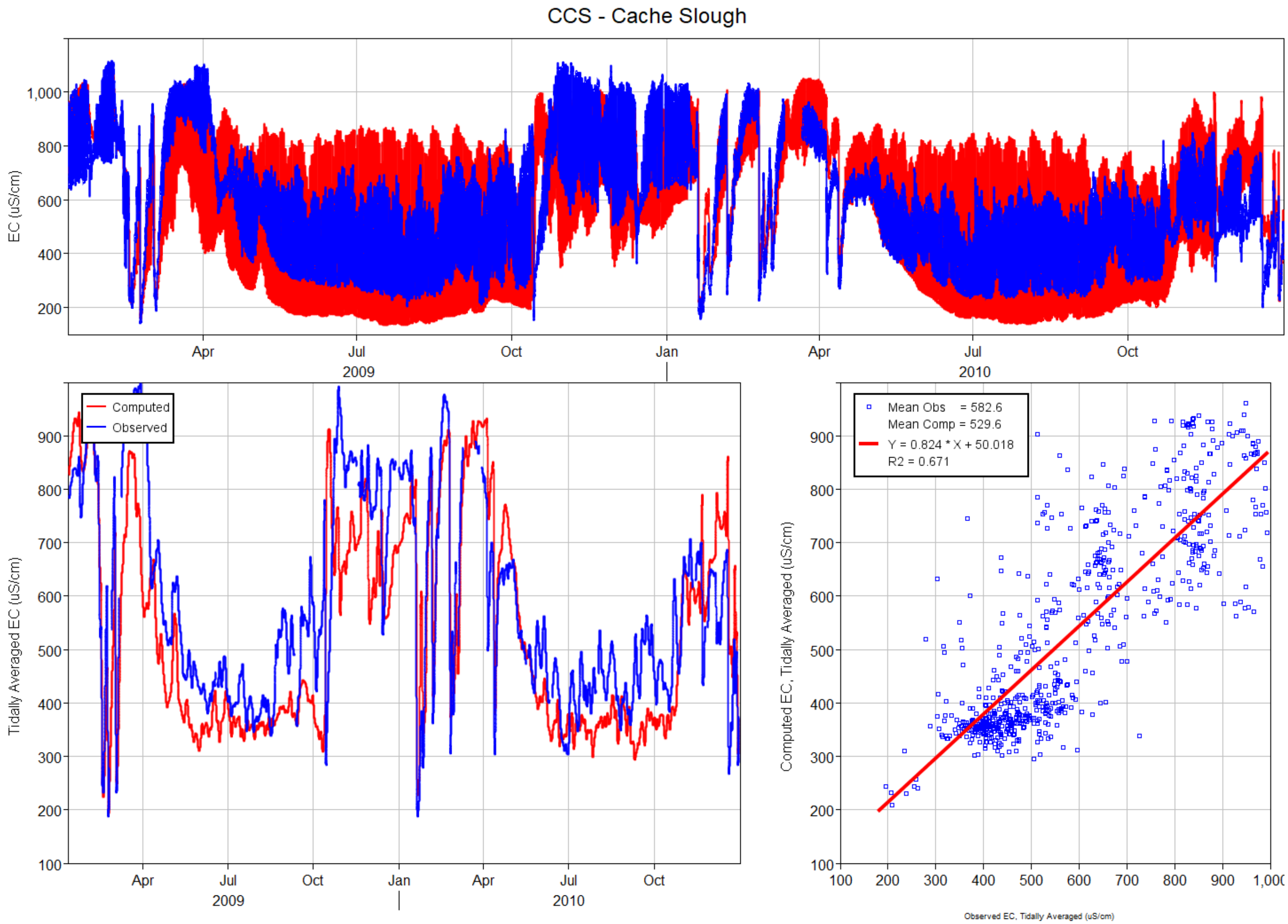

Figure 12 Comparison of modeled and observed EC at CCS, Cache Slough for 2009 - 2010.

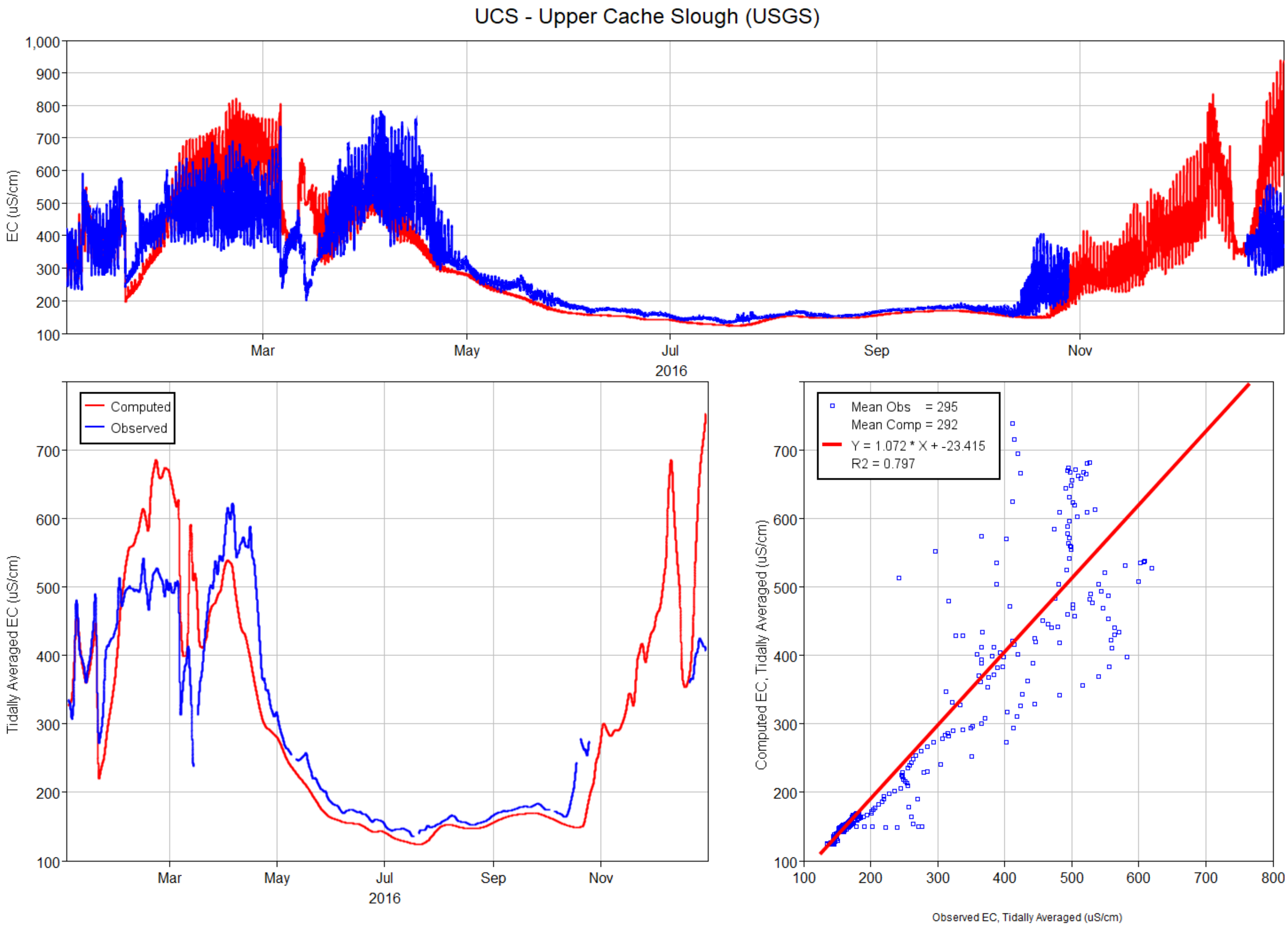

Figure 13 Comparison of modeled and observed EC at UCS, Cache Slough at Hastings for 2016.

Modeling Evaluation Process

Introduction

This section provides a description of the model configurations for the Base, Lookout Slough restoration and Regional Restoration cases and describes and discusses the model simulation periods for the analysis.

Base and Lookout Slough Restoration Model Configuration

The RMA Bay-Delta Base model bathymetry is shown in Figure 4. The Lookout Slough restoration model bathymetry and grid details are shown in Figure 5. For the Base configuration, there is no flow onto the Lookout Slough property. The Lookout Slough restoration design was simplified for modeling purposes. Channel meanders were smoothed and some smaller channels were eliminated. Additional bathymetric and topographic details did not alter the modeled tidal prism enough to significantly alter regional salinity modeling results. As such, restoration was represented in sufficient detail to achieve the modeling goal of assessing regional salinity impacts.

Regional Restoration Model Configuration

Regional Restoration model grids were developed with and without Lookout Slough restoration so that Lookout Slough impacts can be assessed relative not only to current conditions but to projected future conditions. Per DWR (personal communication), projected (and in the time since this list was made, under construction and recently completed) Regional Restoration conditions include restoration of the following sites (see map in Figure 14):

- Arnold Slough
- Bradmoor Island
- Chipps Island
- Decker Island (completed in 2018, included in Regional Restoration grid only)
- DOW Wetlands
- Dutch Slough
- Flyway Farms
- Hill Slough
- Lookout Slough
- Lower Yolo
- Mallard Farms
- McCormack Williamson
- Prospect Island
- Tule Red (completed in 2019, included in Regional Restoration grid only)
- West Island

- Wings Landing
- Winter Island

1. Chipps Island
2. Decker Island
3. DOW Wetlands
4. Dutch Slough
5. Winter Island
6. Tule Red
7. Lower Yolo
8. Prospect Island
9. Lookout Slough
10. Flyway Farms
11. McCormack Williamson
12. Arnold Slough
13. Wings Landing
14. Bradmoor
15. Hill Slough
16. West Island
17. Mallard Farms

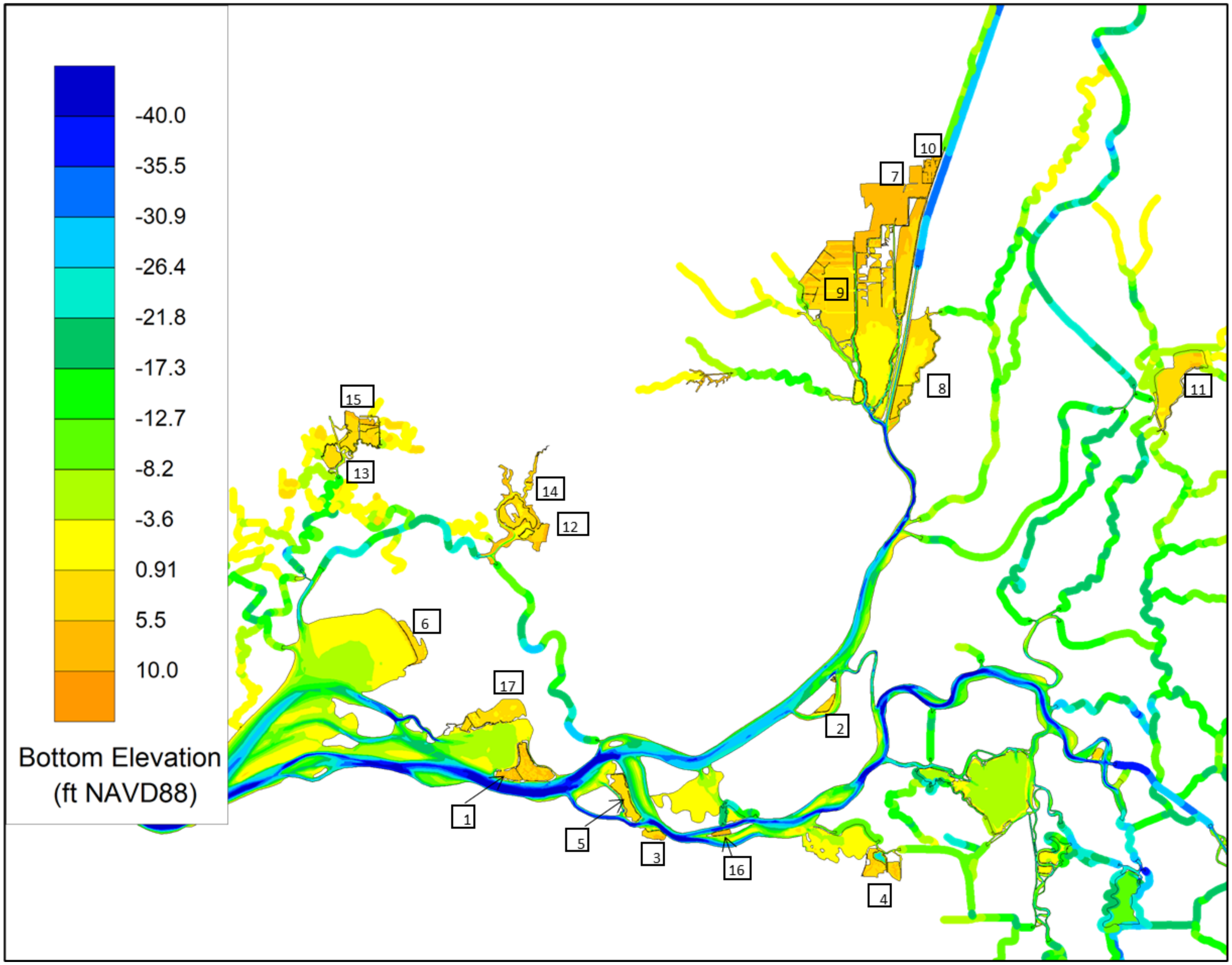

Figure 14 Map of Regional Restoration sites.

Analysis Periods

The Bay-Delta is a dynamic system in which EC fluctuates between seasons and years. Three year-long periods have been selected for analysis to cover some of the seasonal and yearly variation. The model analysis periods are January 2009 through December 2010 and January through December 2016, which include year three of drought conditions (2009), average conditions (2010) and year five of drought conditions (2016). By convention, the Sacramento Valley hydrology is used to characterize the overall water year hydrology (DWR, 2011b). The hydrologic conditions were classified as dry for 2009 and below normal for 2010 and 2016. The 2016 dry year followed four years of below normal, dry and critically dry conditions. For reference, Figure 15 and Figure 16 present the overall Delta hydrologic conditions for Water years 2008-2016. Figure 15 shows the major Delta inflows for Water years 2008-2016. The salinity intrusion in the western Delta over the WY2008-WY2016 period is illustrated with the plot of the observed EC for the San Joaquin River at Jersey Point location in Figure 16.

The water year begins on October 1st and is generally followed by freshening of the Delta with the rise of the wintertime inflows. This was mid-February for 2009 and mid-January for 2010 and 2016. Similarly, the build-up of salinity over 2010 and 2016 was flushed clear by rains in December of those years.

The 2009 -2010 model runs were initialized from observed Delta EC values for January 10, 2009. Similarly, the 2016 analysis simulations were initialized from observed data for January 1, 2016. The high Delta inflows of the winter months generally flush the Delta and reduce the effects of the initial EC condition.

The salinity impacts for the Lookout Slough restoration are examined on a relative basis in terms of the change and percentage change from Base condition values. For the Regional Restoration analysis, the salinity impacts with Lookout Slough and Regional Restoration are compared with Regional Restoration without Lookout Slough.

The model analysis examines the potential for non-compliance to the D-1641 water quality objectives. For this, model predicted values are compared to numerical thresholds. The model overestimates or underestimates EC at some locations at times during the simulation period, as seen in the calibration results. When comparing the computed Lookout Slough EC to the water quality compliance standards, these discrepancies can be taken into account by including observed data on the plots.

Time series plots of the major inflows, diversions and EC boundary conditions are provided for reference in Appendix A: Model Boundary Conditions.

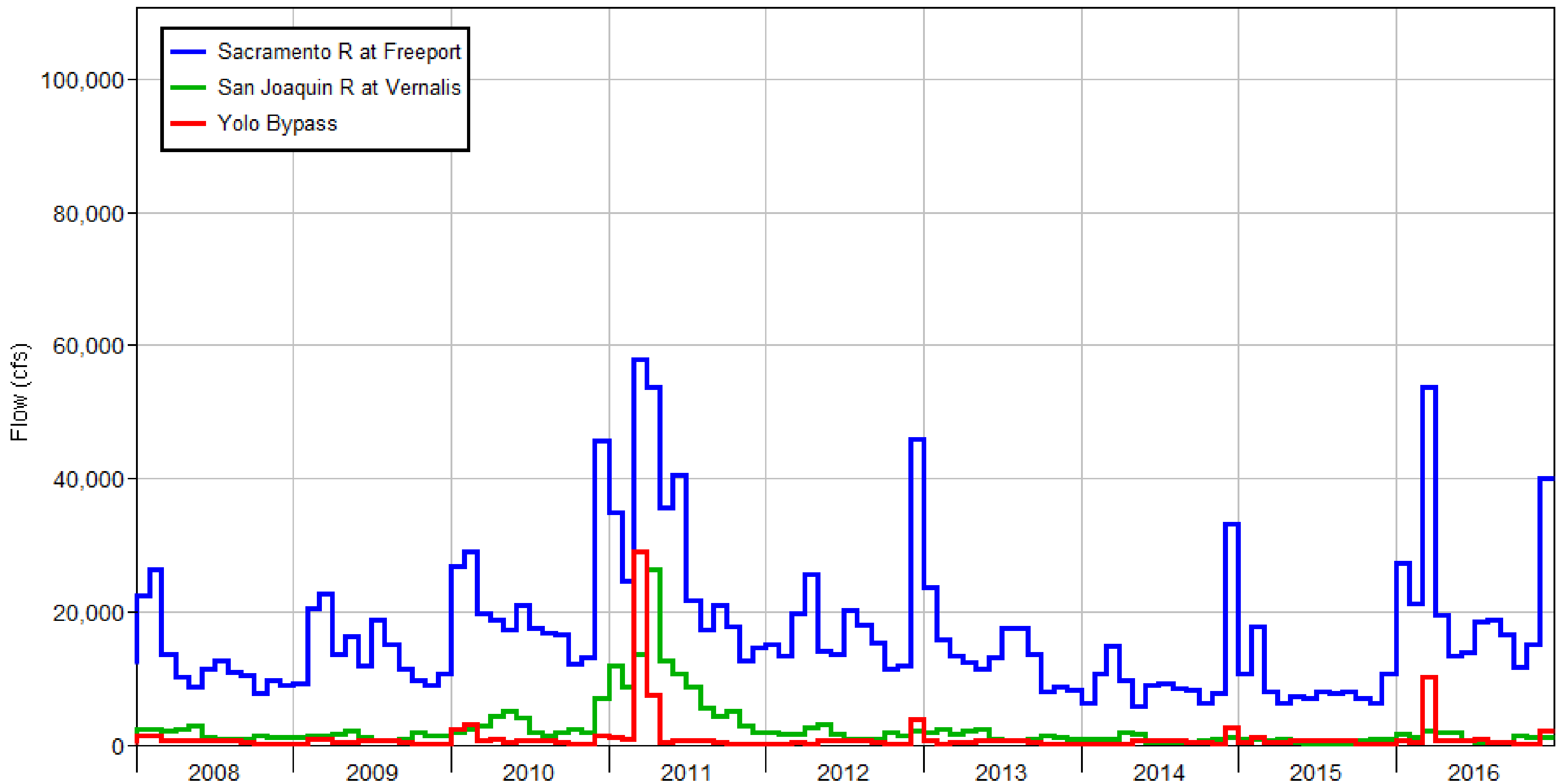

Figure 15 Monthly averaged Delta inflows for the Sacramento River, Yolo Bypass and San Joaquin River for WY2008-WY2016 (from DAYFLOW).

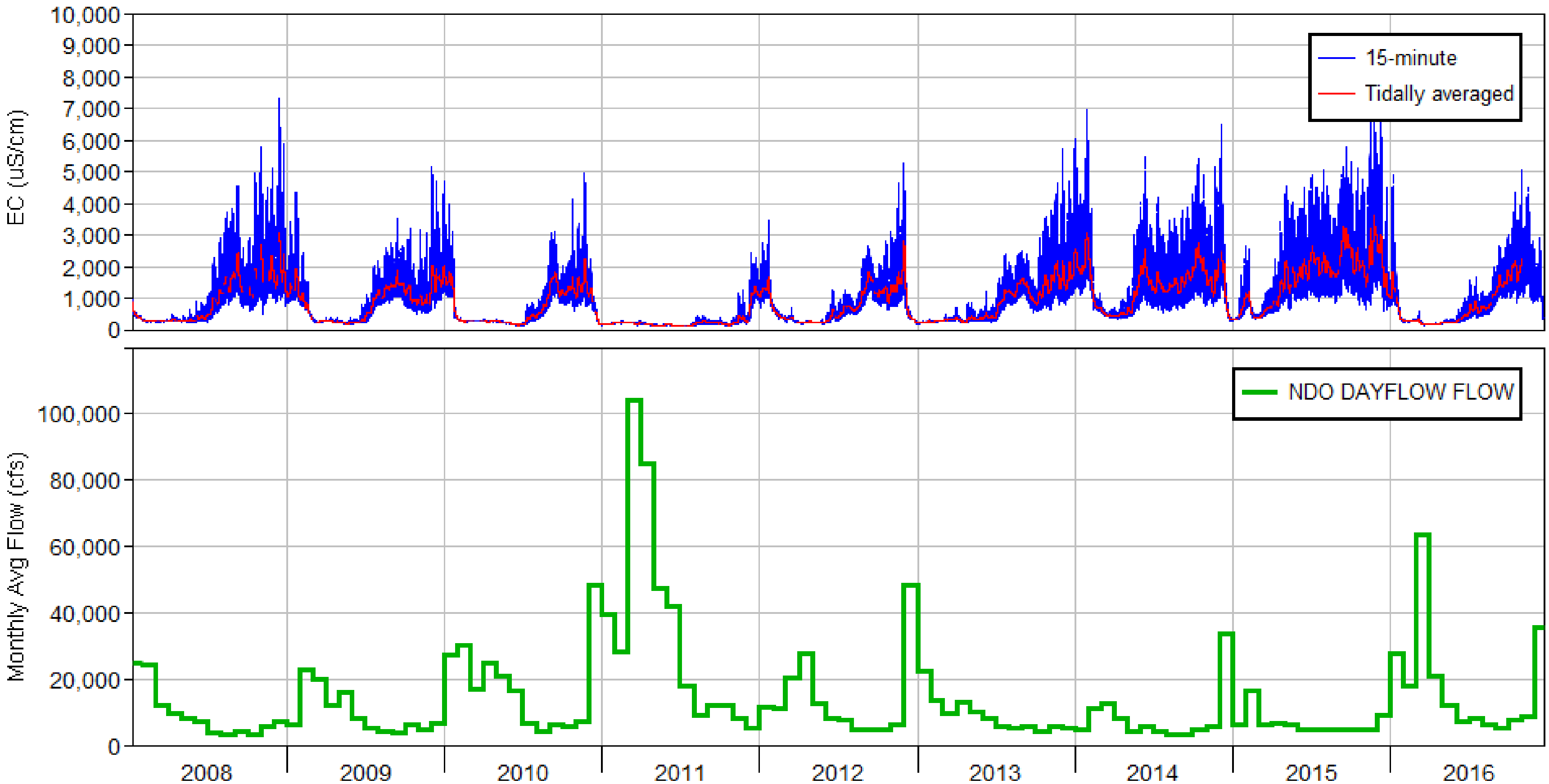

Figure 16 Observed San Joaquin River at Jersey Point EC and monthly averaged Net Delta Outflow (from DAYFLOW) for WY2008-WY2016. The plots illustrate the dry season salinity intrusion into the western Delta with low NDO and the response of the Jersey Point EC to variations in the NDO over the different water years.

Evaluation of Water Quality Impacts at Select D-1641 Compliance Stations and CCWD Intake Locations

Introduction

The salinity (EC) transport component of the RMA Bay-Delta model has been used to evaluate salinity impacts for numerous previous restoration studies (e.g. RMA, 2012, 2013, 2015a, 2015b, 2017). For the current study, the model was utilized to evaluate the potential salinity changes at D-1641 compliance locations and Contra Costa Water District intake locations listed in Table 2 (see Figure 17 for map). The locations were selected to cover key locations and provide broad spatial representation. The effects of the restoration project at these locations are considered representative of the effect of the project in various locations of the Delta as a whole. Chloride and bromide changes at the water intakes were evaluated as well as changes to X2.

Table 2 D-1641 Compliance Stations to be used for salinity evaluation.

D-1641 Station ID	Location
D22	Sacramento at Emmaton
D15	San Joaquin at Jersey Point
D29	San Joaquin at Prisoners Point
C5	Contra Costa Canal at Pumping Plant 1
C9	West Canal at mouth of Clifton Court Forebay
DMC1	Delta-Mendota Canal at Tracy Pumping Plant
SLBAR3	Barker Slough NBA Intake
C19	City of Vallejo Intake (Abandoned) Cache Slough
C2	Sacramento at Collinsville
D12	San Joaquin at Antioch
	CCWD Intake at Mallard Slough
	CCWD Intake at Old River
	CCWD Intake at Victoria Canal
D24*	Sacramento River at Rio Vista

*D24 evaluated for criteria 1) below. There are not D-1641 water quality criteria for this location.

The modeling evaluation criteria considered for the 2009 – 2010 and 2016 simulation periods were:

1) Evaluate the salinity impacts by quantifying the change and percentage change at the Table 2 locations for Lookout Slough versus the Base case and for Regional Restoration with Lookout Slough versus without Lookout Slough.
2) Examine if the restoration of Lookout Slough has the potential to change compliance status for D-1641 water quality objectives at the Table 2 locations.

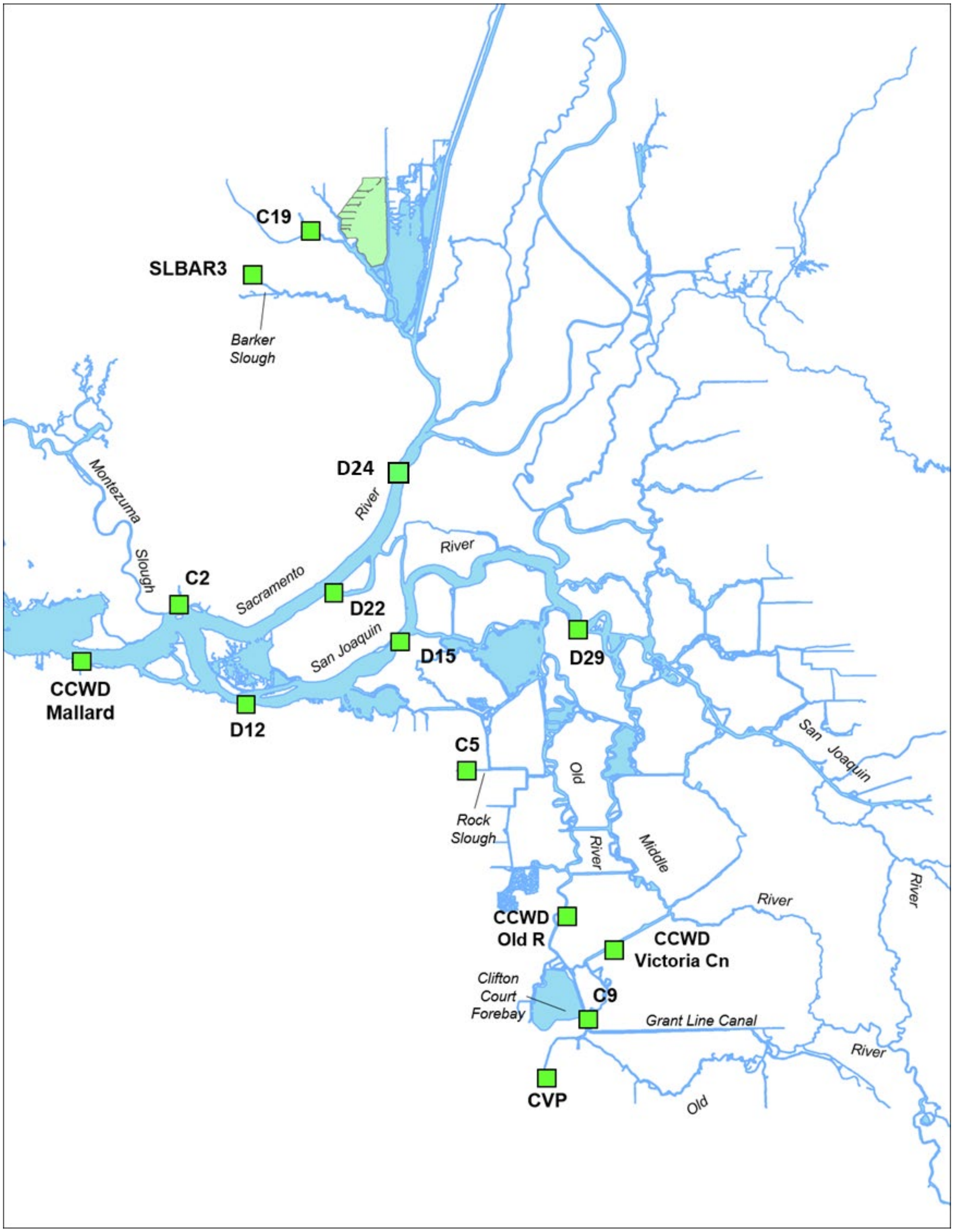

Figure 17 D-1641 compliance locations used for the evaluation for salinity impacts.

EC Changes at Compliance Locations

Four geometry conditions were modeled: Base (existing condition), Lookout Slough restoration, Regional Restoration (without Lookout Slough) and Regional Restoration with Lookout Slough. EC model results were computed for three calendar year periods to cover a range of flow conditions: January 10, 2009 to December 31, 2010 and January 1 through December 31, 2016. The year 2009 is characterized as a dry year following two years of dry and critical years and 2010 as a below normal year. The year 2016 is a below normal year following four years of below normal, dry and critically dry years. The model results were stored at 15-minute intervals for all model computational points allowing both temporal and spatial analysis.

Daily averaged results are provided at the Table 2 locations as time series of EC and absolute and relative (%) change from Base/Regional Restoration EC in Figure 18 through Figure 31 for the 2009 – 2010 period and in Figure 32 through Figure 45 for the 2016 period. These values are also monthly averaged and summarized in tabular format in Table 3 for 2009, in Table 4 for 2010 and in Table 5 for 2016. The tabular results are provided with tenths digit to provide reader with additional detail. While this level of precision is available from the model, the model's accuracy is likely only one to two significant digits. Although there is uncertainty in the results, as reflected by the effective significant digits, the model is considered sufficient for assessing potential impacts, particularly for the direction of change and relatively small % change.

Overall, the changes in EC predicted to occur as a result of Lookout Slough are considerably less than the natural variations between seasons and between the same time in different years.

The general observations for the 2009 Lookout Slough EC results are:

- Largest percent EC increases due to Lookout Slough restoration occur during the fall at Prisoners Point (3.3% relative to Base / 2.9% relative to Regional Restoration) and during the summer at C19 (5.5% / 5.4%).
- Other locations with EC increases between about 1 - 2% include West Canal at Clifton Court, DMC at Tracy Pumping Plant, Collinsville, Rio Vista and CCWD intakes at Rock Slough, Old River and Victoria Canal.
- Largest percent EC decreases due to Lookout Slough occur during the summer at Emmaton (-4.6% / -1.9%) and Jersey Point (-3.7% / -3.2%) and during the fall at Antioch (-3.6% / -3.0%) and Rio Vista (-4.3% / -1.8%).

The general observations for the 2010 Lookout Slough EC results are:

- Largest percent EC increases due to Lookout Slough restoration occur during the fall at Prisoners Point (2.1% relative to Base / 1.5% relative to Regional Restoration) and Victoria Canal (1.6% / 0.9%), and during the summer at C19 (5.1% / 4.9%).
- Largest percent EC decreases due to Lookout Slough occur during the spring in Barker Slough (-4.3% / -4.2%), during the summer at Antioch (-3.3% / -2.7%) and Jersey Point (-2.9% / -2.6%), and during the fall at Emmaton (-4.4% / -2.3%) and Rio Vista (-2.7% / -1.0%).

The general observations for the 2016 Lookout Slough EC results are:

- Largest percent EC increases due to Lookout Slough restoration occur during the fall at C19 (4.2% relative to Base / 4.0% relative to Regional Restoration), Prisoners Point (3.5% / 2.2%) and Victoria Canal (2.2% / 1.6%).
- Other locations with EC increases between about 1 - 2% include West Canal at Clifton Court, DMC at Tracy Pumping Plant, Collinsville, CCWD intakes at Rock Slough and Old River and Rio Vista.
- Largest percent EC decreases due to Lookout Slough occur during the summer at Antioch (-3.5% / -2.9%) and Jersey Point (-2.5% / -2.4%), and during the fall at Emmaton (-4.7% / -2.0%) and Rio Vista (-4.7% / -2.0%).

Additional details, including magnitude of the changes at the compliance locations, can be found in Table 3 through Table 5.

Under Base conditions, the average stage (and thus volume of water) in the Delta increases on the spring tide and decreases on the neap tide. The Delta salinity intrusion increases as the Delta “fills” on the spring tide and decreases as the Delta “drains” on the neap tide. The restoration of Lookout Slough enhances this effect. The oscillations in EC change / % change in locations like Collinsville and Rio Vista (e.g. Figure 26 and Figure 31) are the result of this spring – neap effect.

One of the primary mechanisms impacting modeled salinity is a decreased tidal range in the north Delta resulting from Lookout Slough restoration. This tidal range decrease results in slightly less flow through the Delta Cross Channel and Georgiana Slough and slightly more flow down Sutter and Steamboat Sloughs and the Sacramento River below Georgiana Slough. This shift of freshwater flow results in decreased salinity in the Sacramento River and western Delta as well as the corresponding increased salinity in the central Delta when the Delta Cross Channel is open, typically late June through October (see plots of Delta Cross Channel flows in Figure 46 through Figure 48).

The Regional Restoration shifts even more flow toward the Sacramento River. The Lookout Slough flow shift relative to the Regional Restoration flows is smaller and therefore the % EC changes are smaller than the changes from Base.

Restoring Lookout Slough increases tidal exchange between the CSC and the Sacramento River, thereby drawing lower salinity water from the Sacramento into most of the complex. As a result, the restoration is predicted to decrease EC at the Barker Slough Pumping Plant in 2009 and 2010 (Figure 24). In the winter of 2016, a 1% increase in EC is predicted at Barker Slough Pumping Plant, and later in the year, as in 2009-2010, Lookout Slough is predicted to decrease EC. EC decreases generally occur when the Barker Slough Pumping Plant diversion rate exceeds about 20 cfs, pulling slightly fresher water from downstream. At lower diversion rates, EC in Barker Slough is more sensitive to estimates of local inflow.

Lookout Slough reduces the tidal exchange in Upper Cache Slough, which reduces the mixing of fresher flows into the upper portion of the slough and thus reduces dilution of local-source EC near C19. Observed data confirm that salinity in Upper Cache Slough is of local source. Observed EC in Upper Cache Slough (Figure 112, Figure 130) is higher than observed EC in Barker Slough (Figure 113, Figure 131) and Sacramento River at Rio Vista (Figure 114, Figure 132), indicating that the Upper Cache Slough salinity is not seawater intruding upstream.

Spatial plots of monthly average computed Lookout Slough percent change from Base and Regional Restoration condition EC are provided in Figure 49 through Figure 60 for July and October of each simulation year. These plots provide a spatial illustration of the EC impacts occurring in the summertime when exports are high and, in the fall, when larger EC changes occur. The largest areas of change are decreased EC in the west Delta and occur in both July and October. Increased EC is more prevalent in October in portions of the central Delta. Figure 61 shows a closer view of EC in the CSC for July 2009. The left and middle panels of this figure show average July 2009 EC for the Base and Lookout simulations, illustrating the local salinity source impacting EC in upper Cache Slough. The right panel, showing % EC change, shows the limited area of increased EC resulting from a slight shift in the steep salinity gradient that occurs as the tidal energy is reduced upstream of the Lookout restoration.

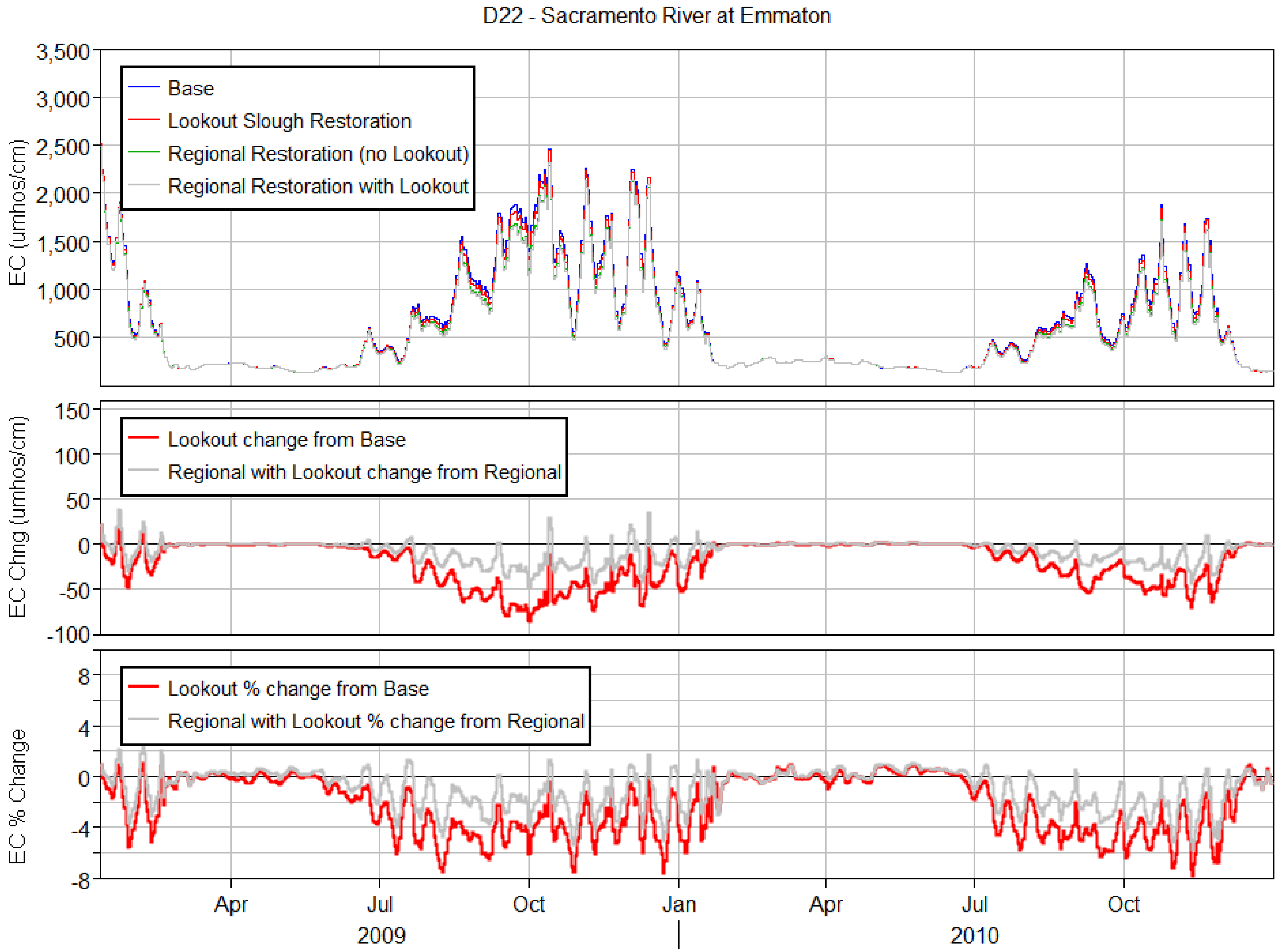

Figure 18 Daily average EC at Emmaton for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in EC for the 2009-2010 simulation period.

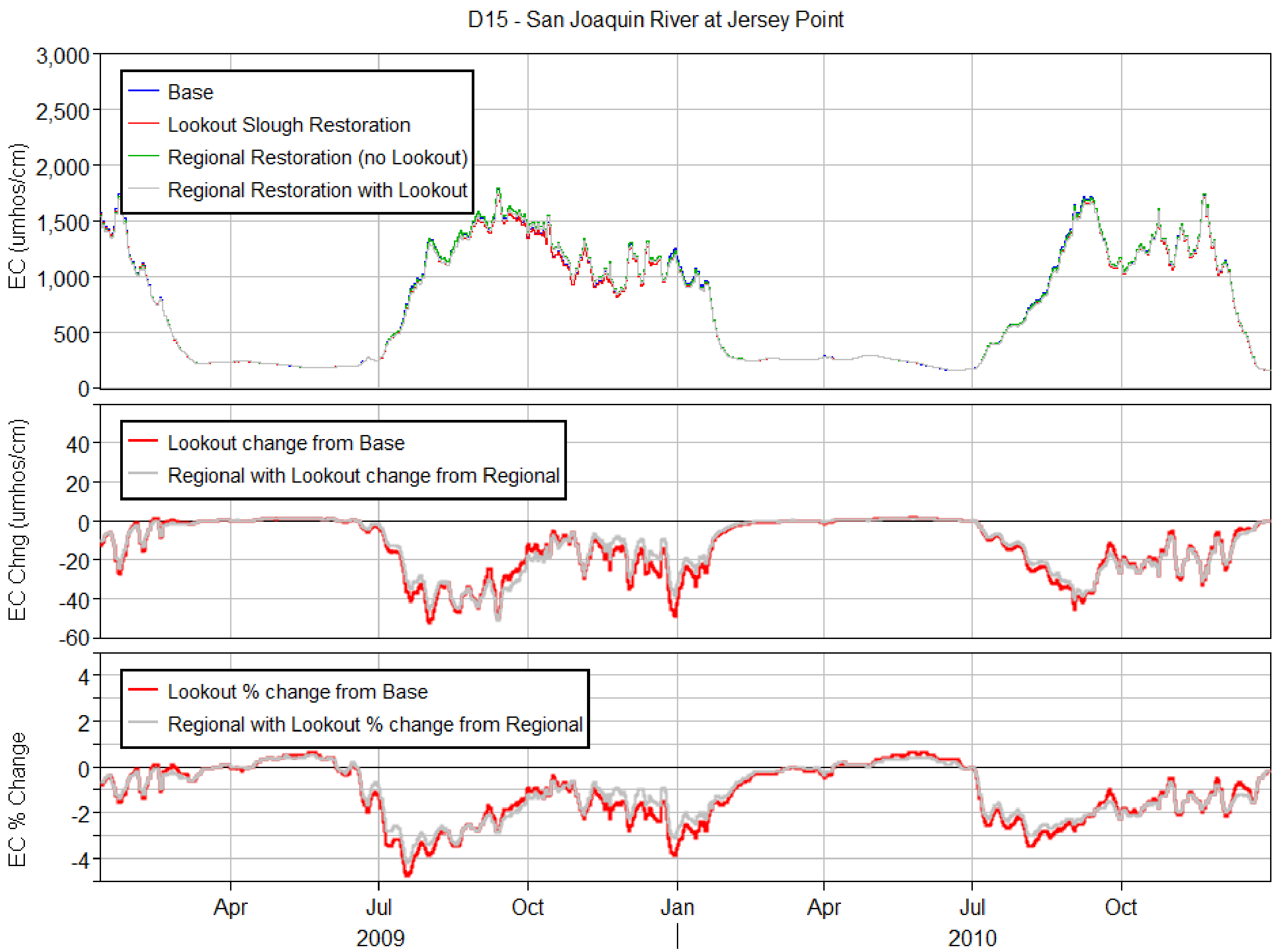

Figure 19 Daily average EC at Jersey Point for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in EC for the 2009-2010 simulation period.

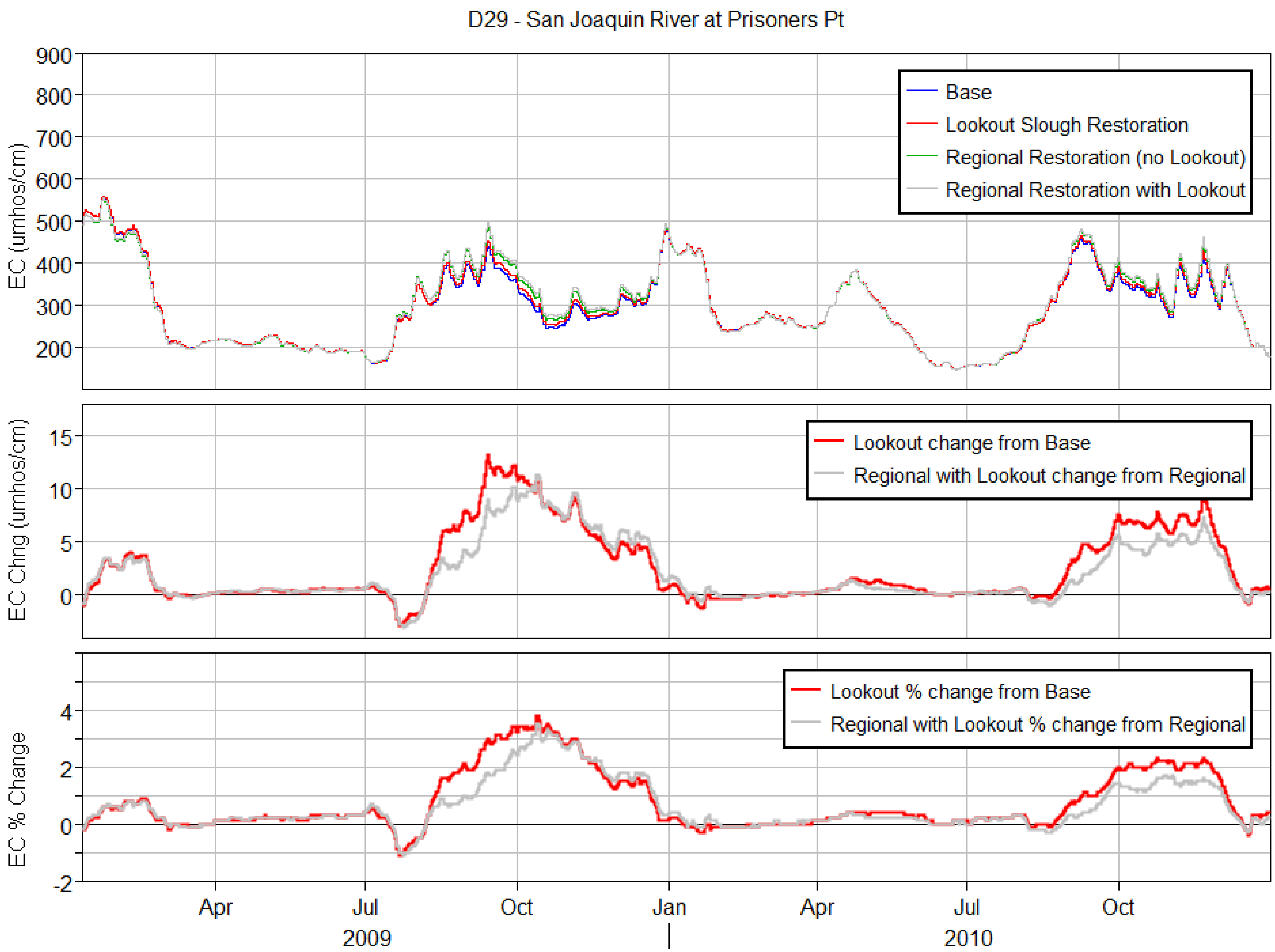

Figure 20 Daily average EC at Prisoners Point for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in EC for the 2009-2010 simulation period.

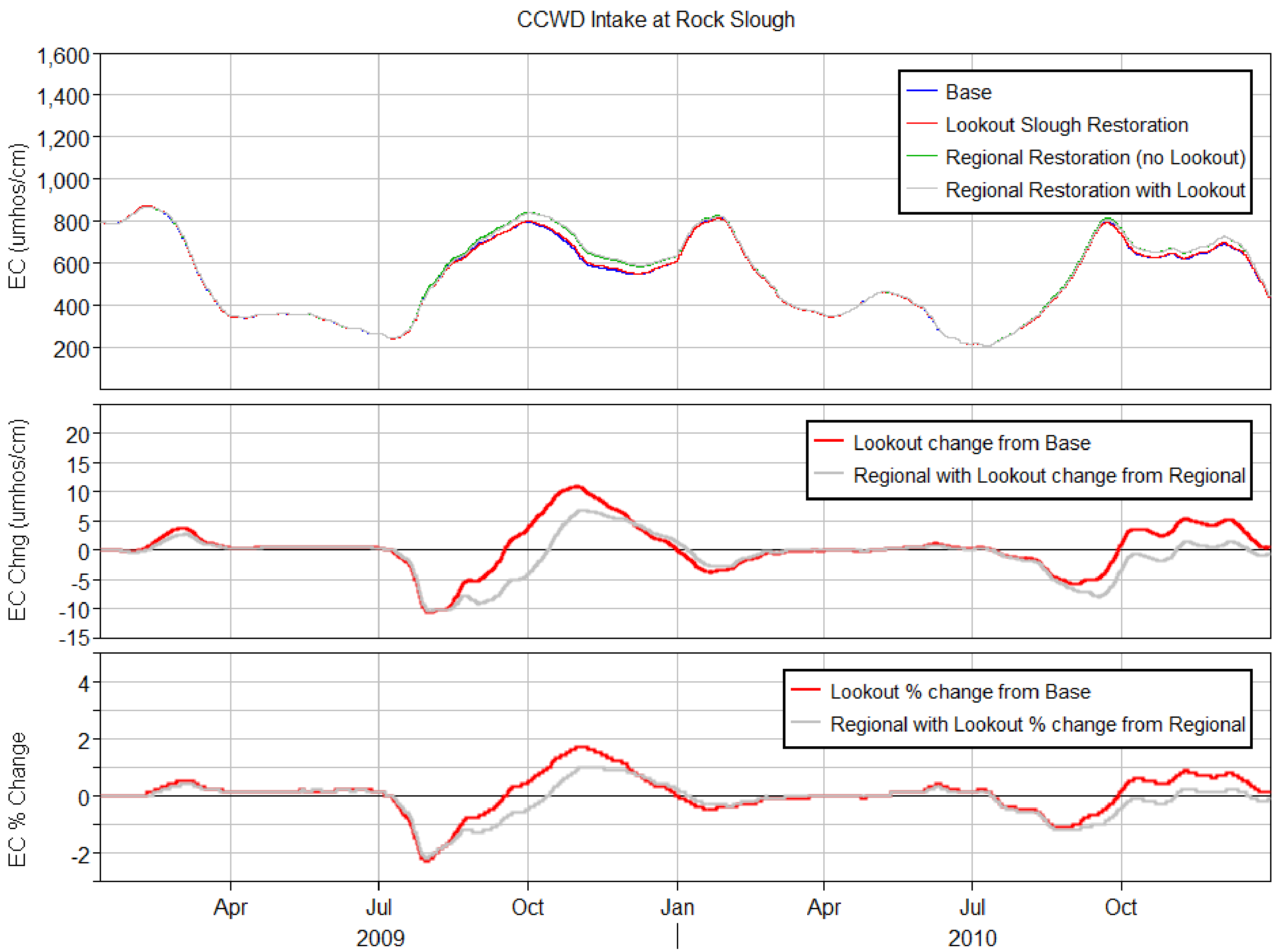

Figure 21 Daily average EC at CCWD intake at Rock Slough for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in EC for the 2009-2010 simulation period.

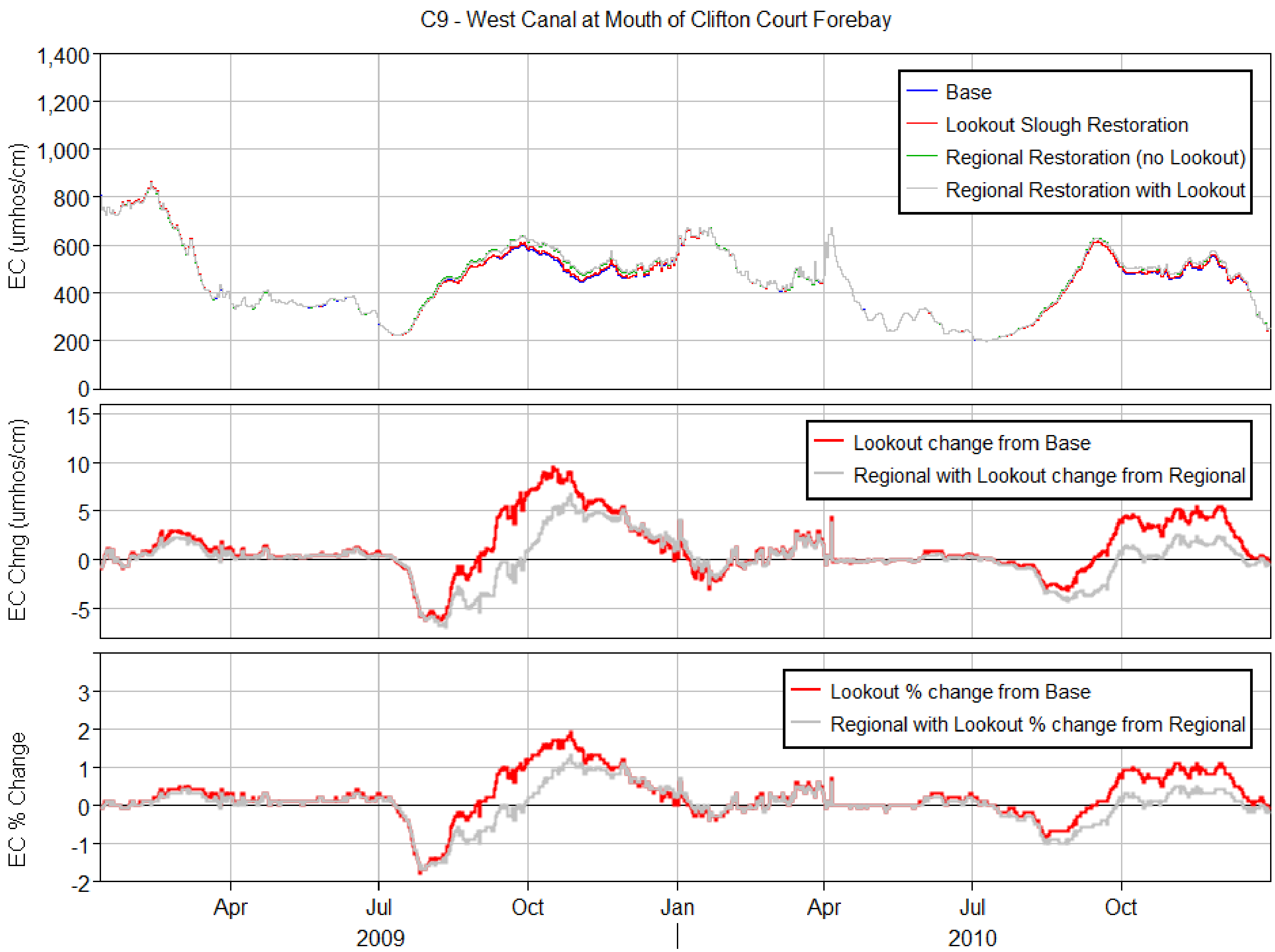

Figure 22 Daily average EC at West Canal at mouth of Clifton Court Forebay for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in EC for the 2009-2010 simulation period.

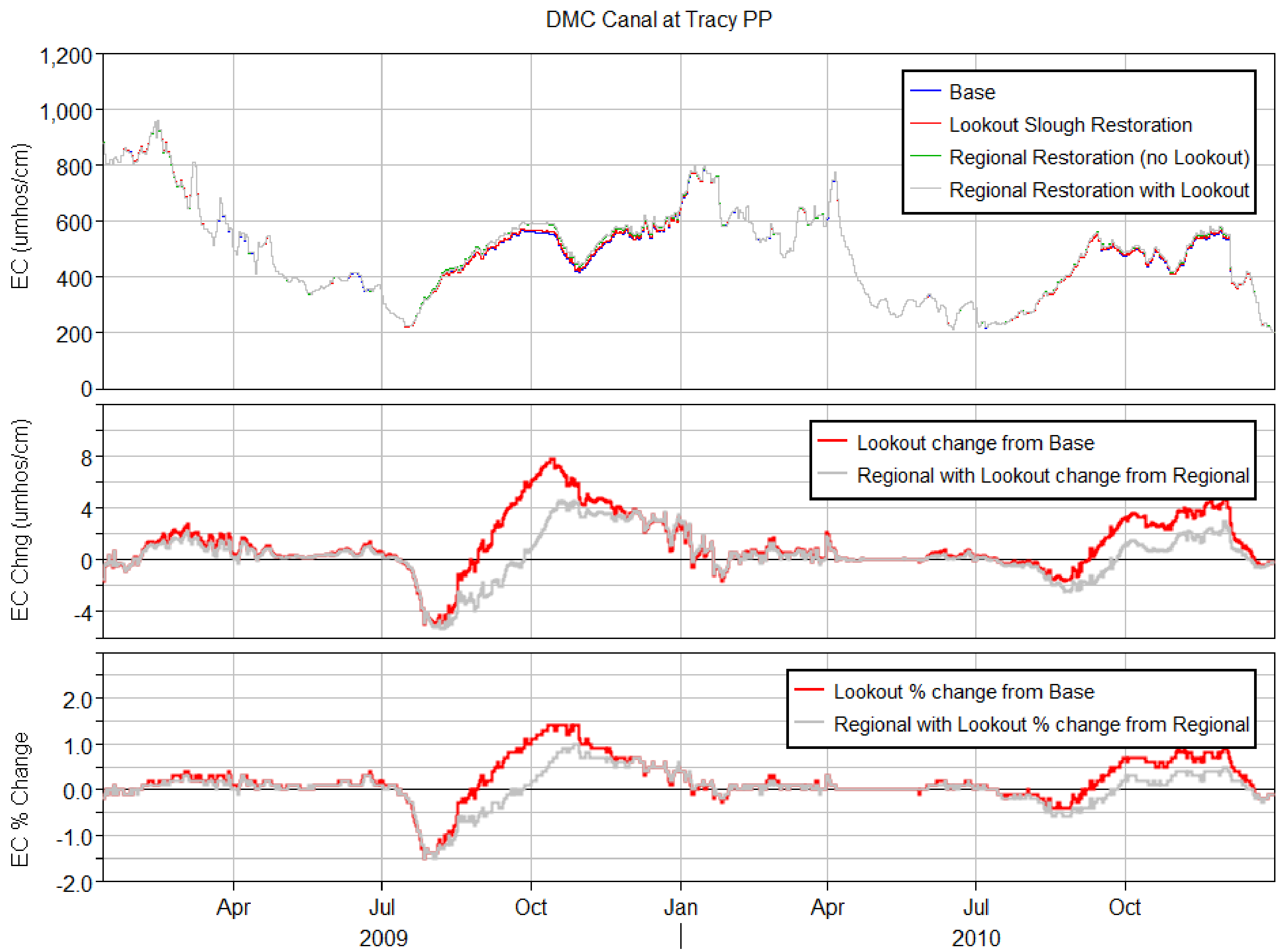

Figure 23 Daily average EC at DMC Canal at Tracy PP for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in EC for the 2009-2010 simulation period.

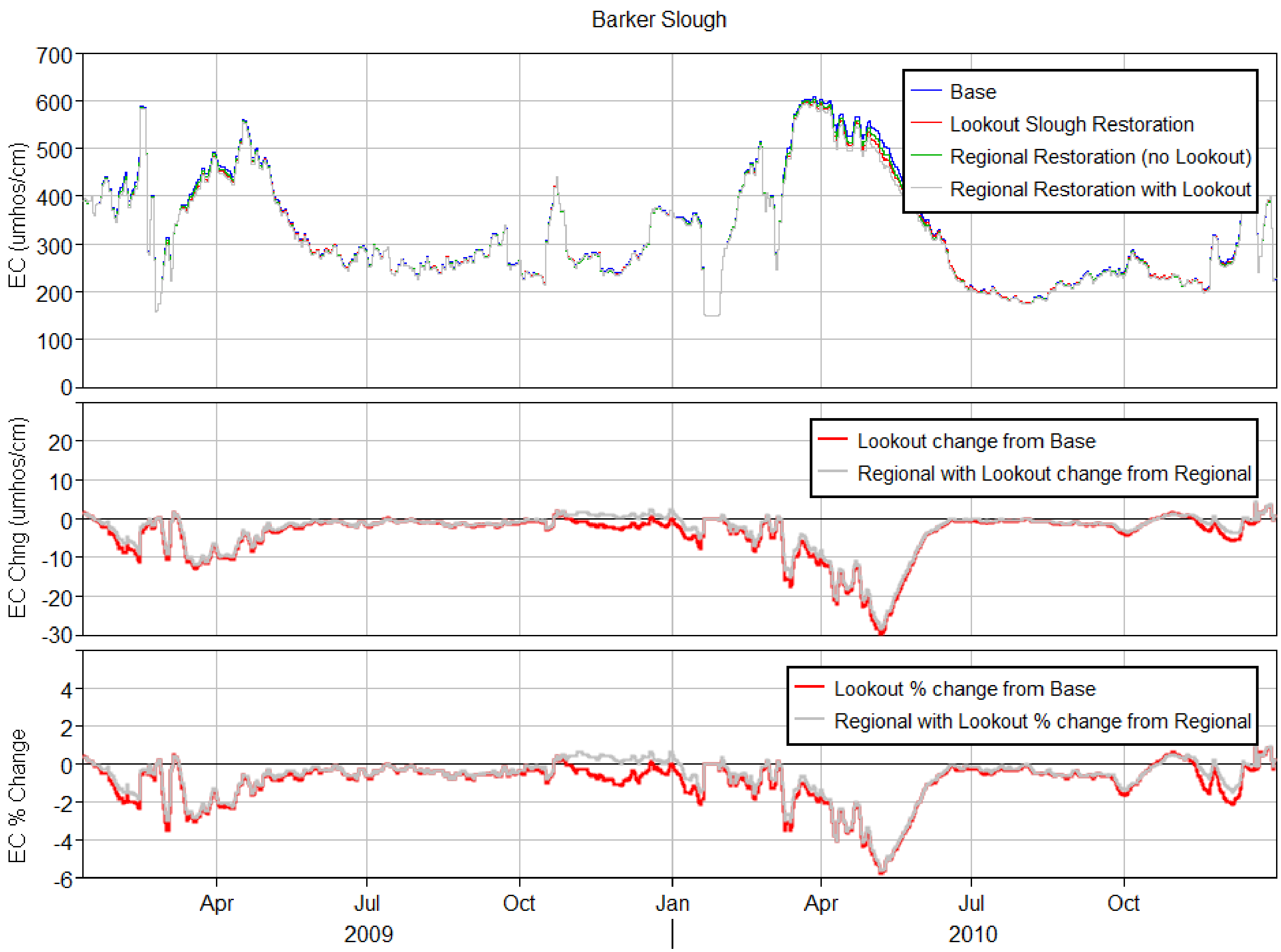

Figure 24 Daily average EC at Barker Slough for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in EC for the 2009-2010 simulation period.

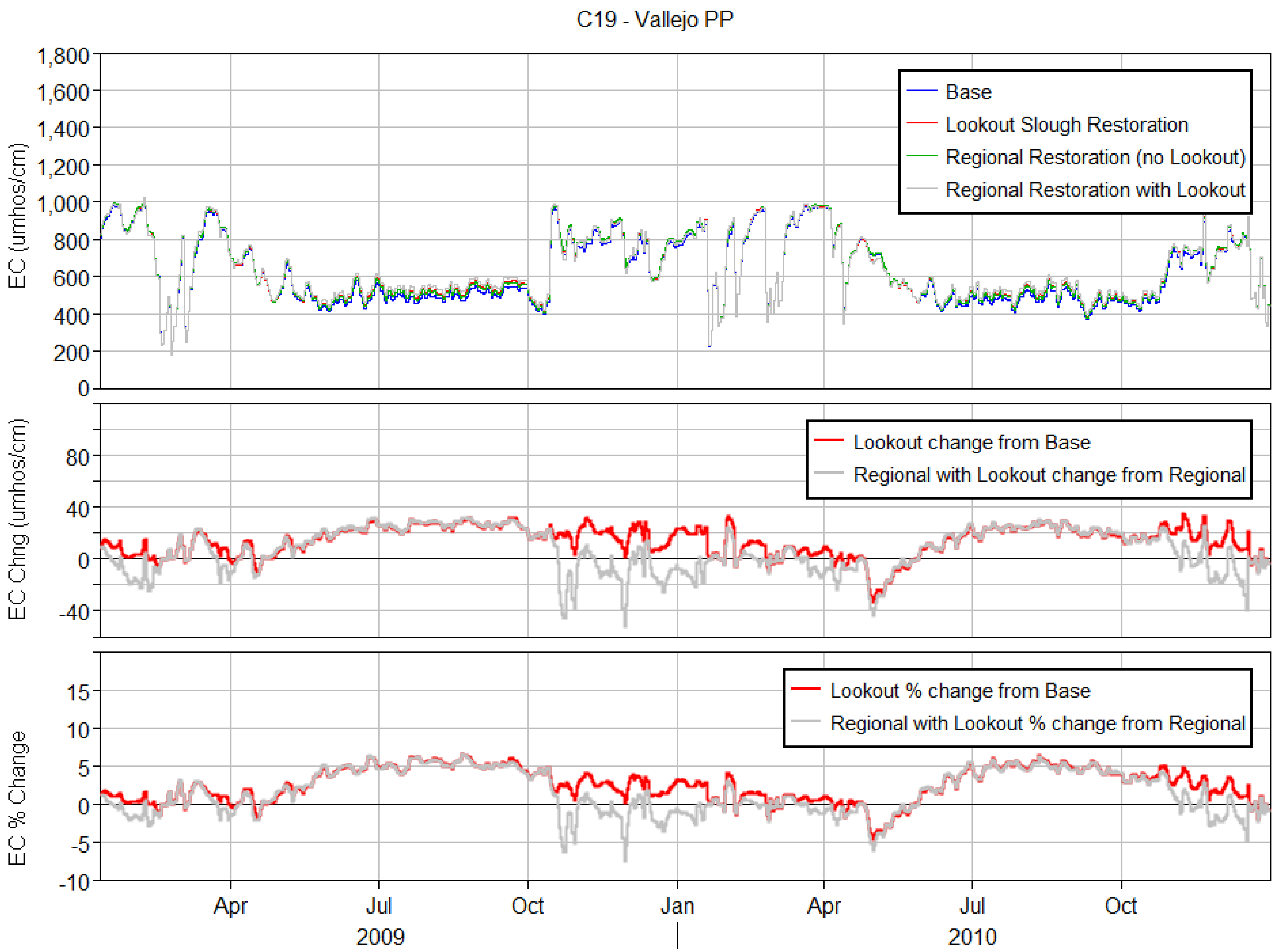

Figure 25 Daily average EC at C19 for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in EC for the 2009-2010 simulation period.

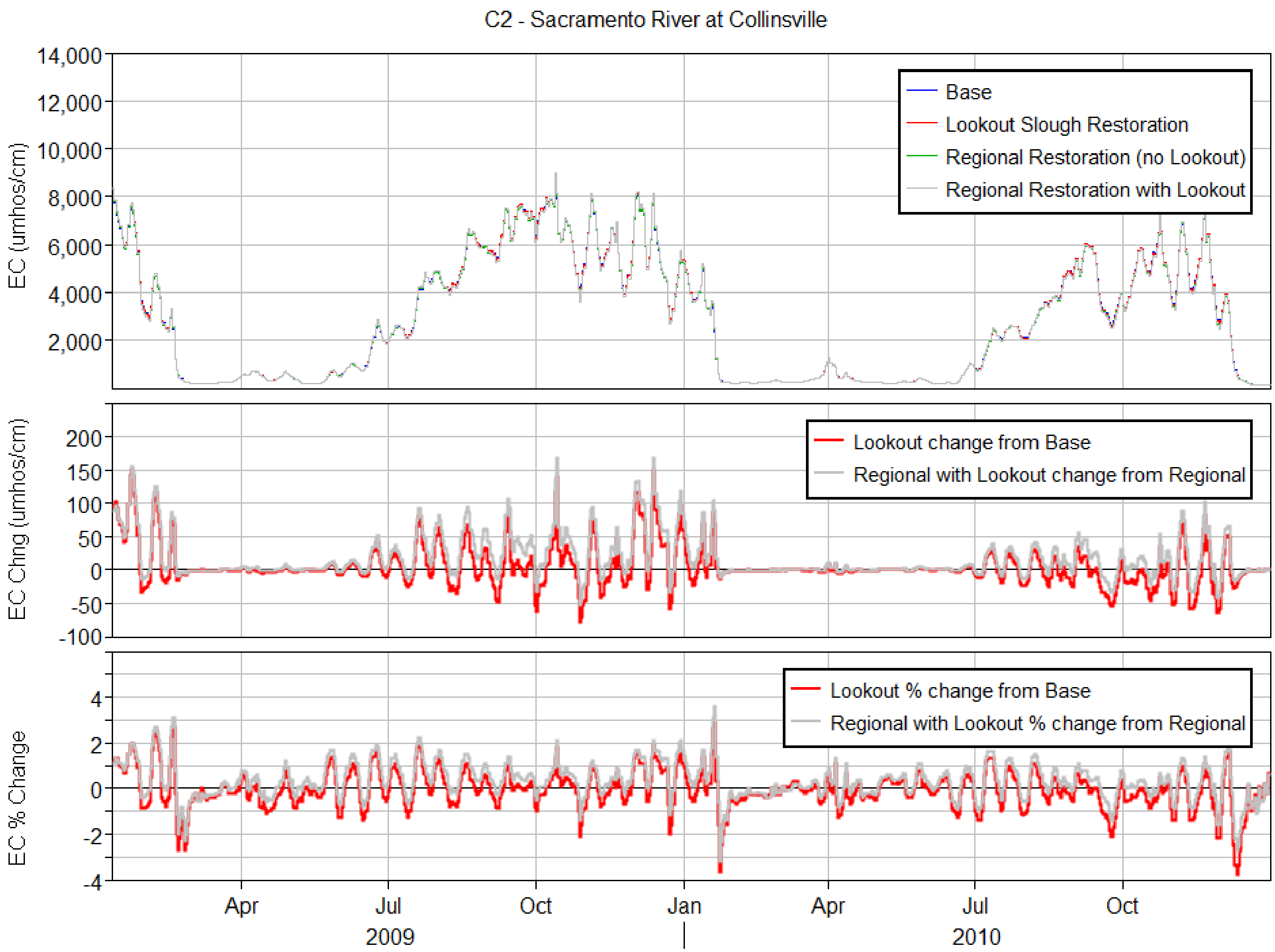

Figure 26 Daily average EC at Collinsville for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in EC for the 2009-2010 simulation period.

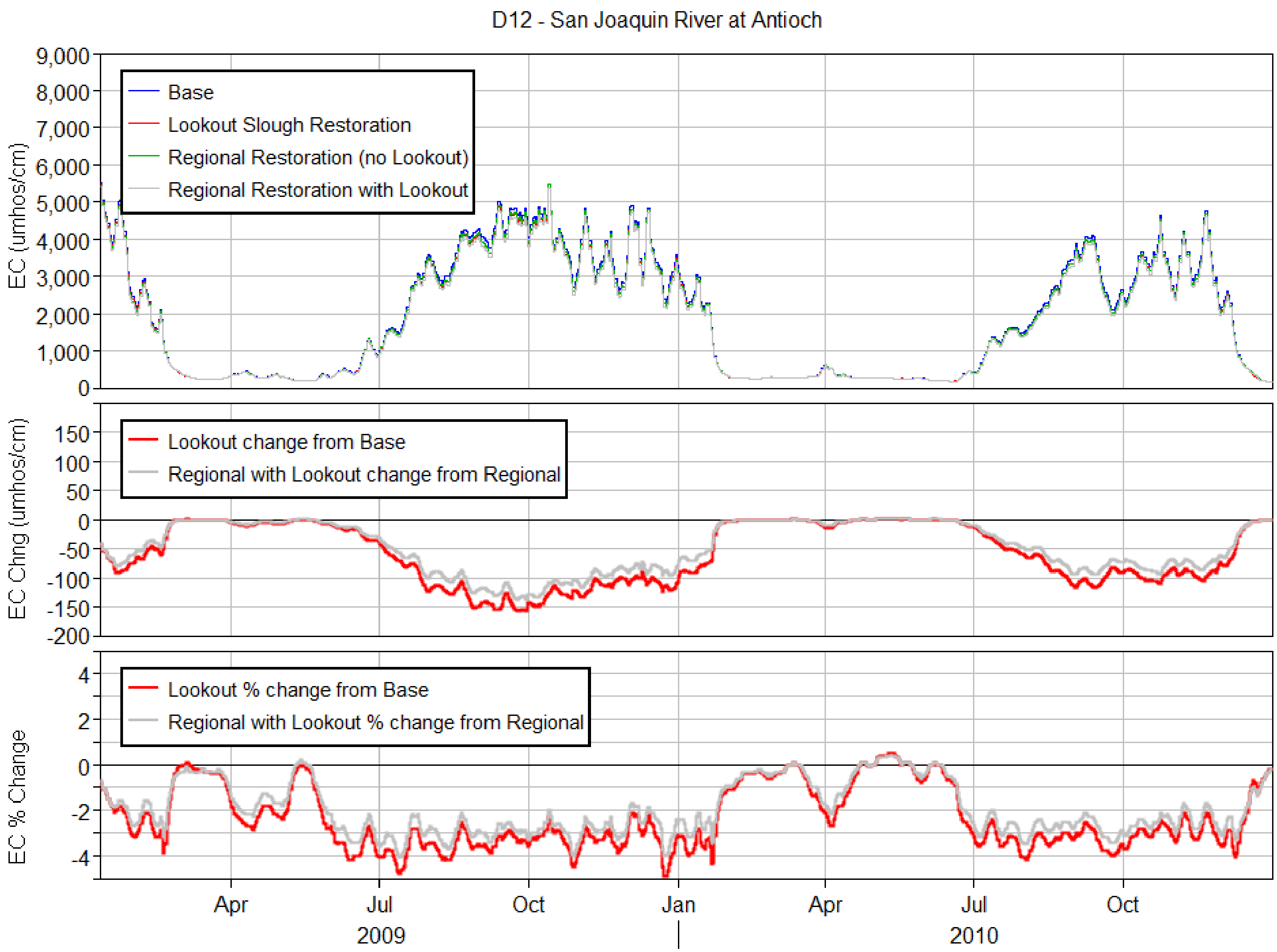

Figure 27 Daily average EC at Antioch for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in EC for the 2009-2010 simulation period.

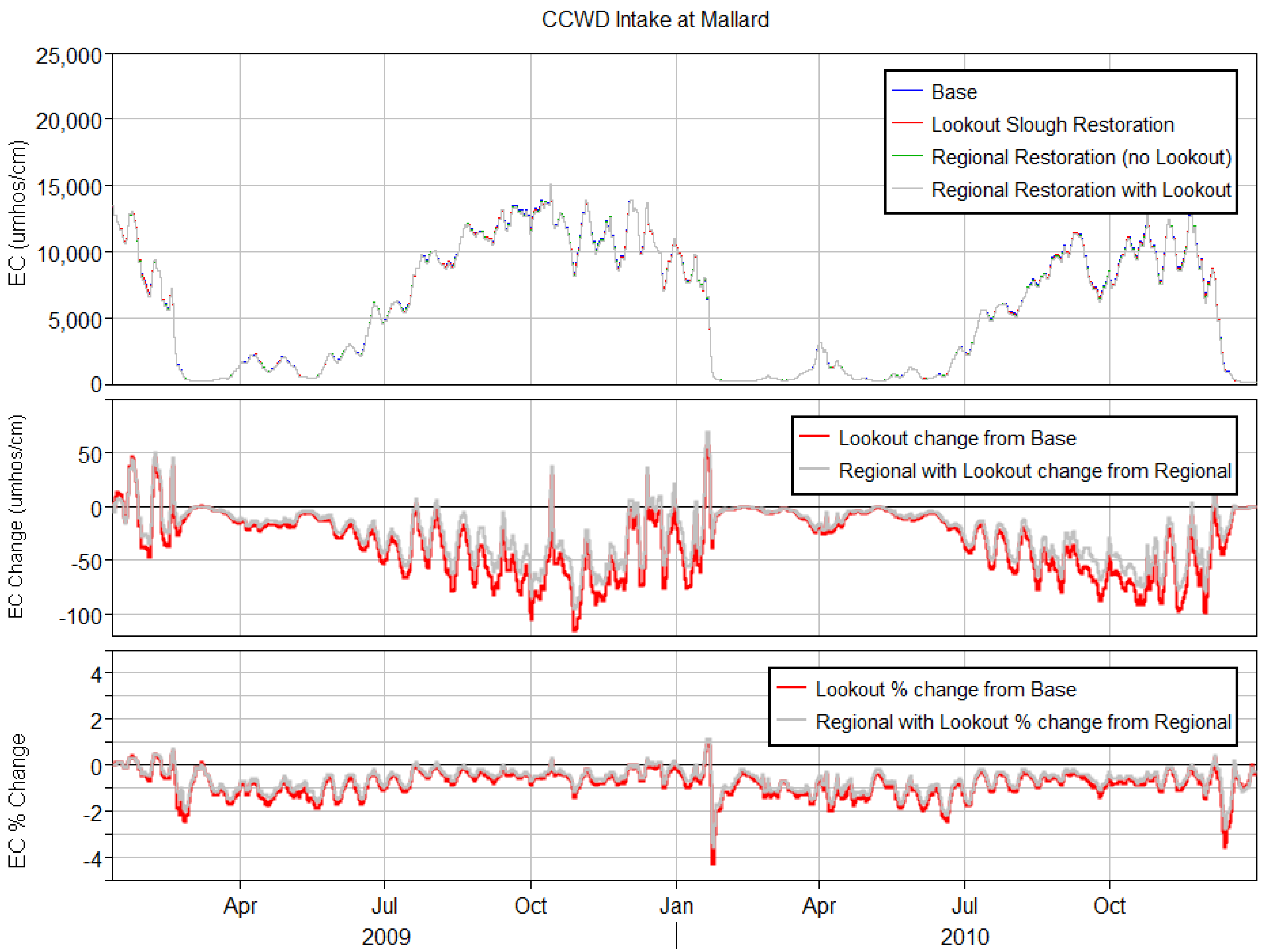

Figure 28 Daily average EC at CCWD intake at Mallard for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in EC for the 2009-2010 simulation per

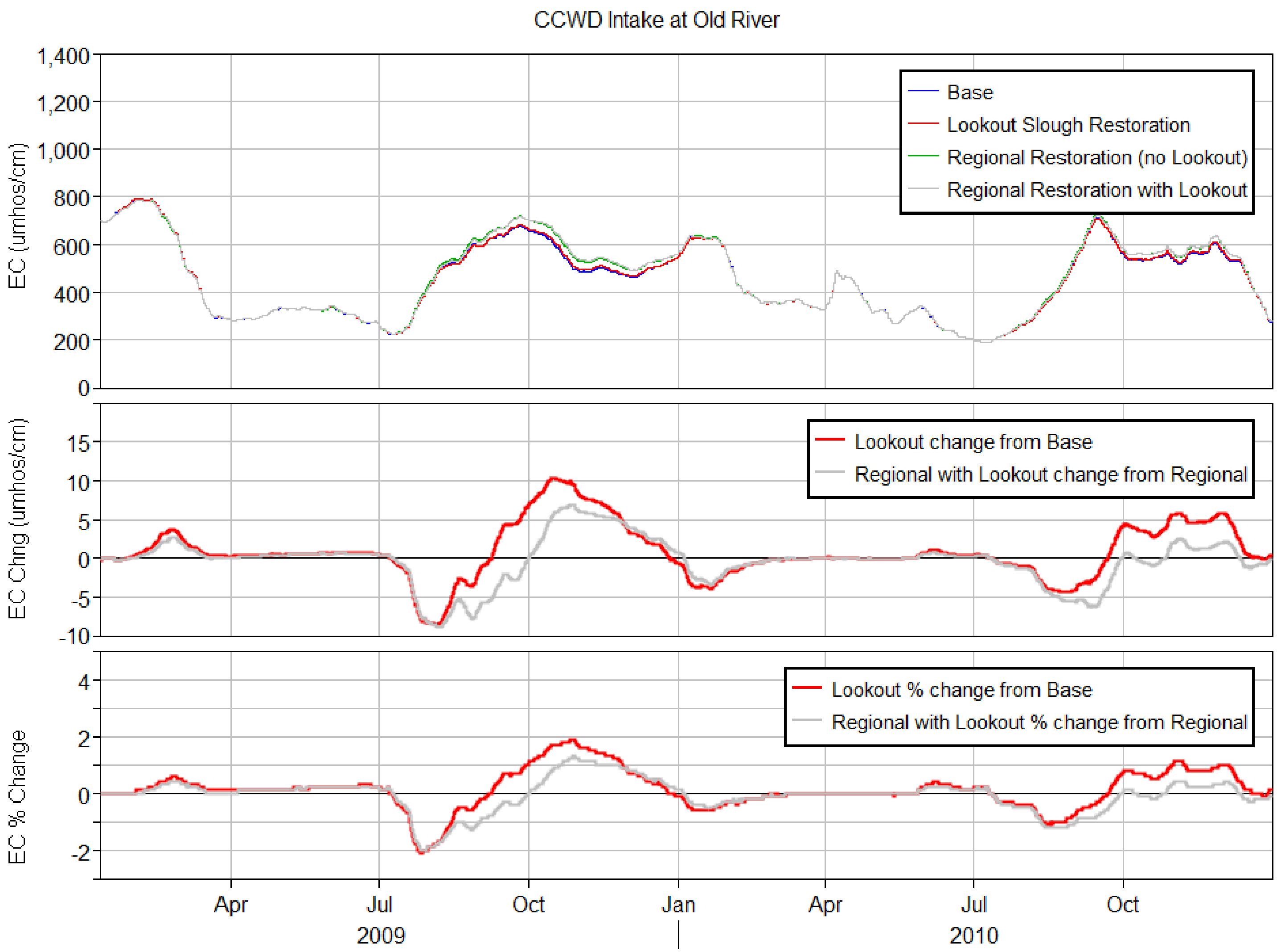

Figure 29 Daily average EC at CCWD intake at Old River for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in EC for the 2009-2010 simulation period.

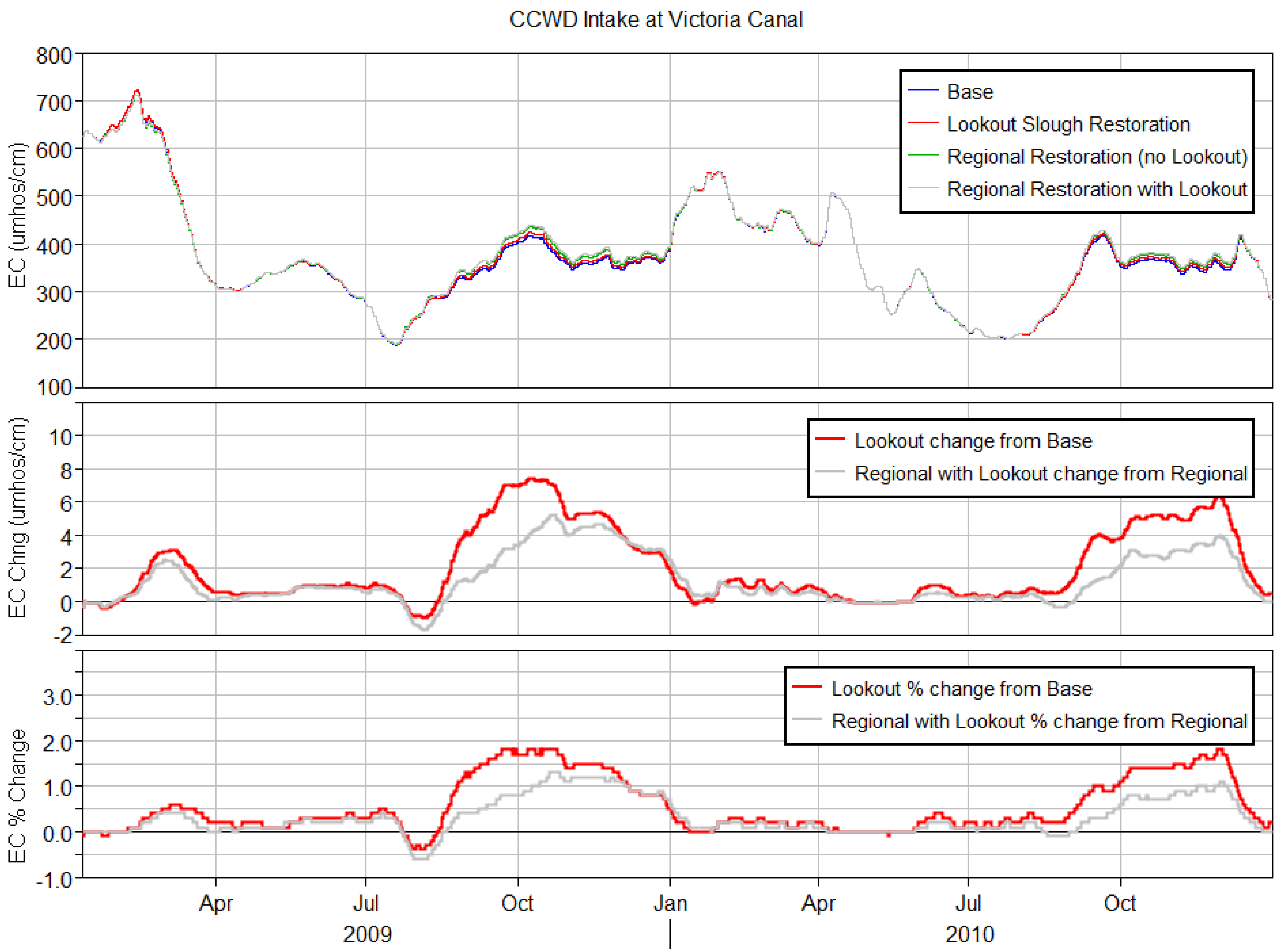

Figure 30 Daily average EC at CCWD intake at Victoria Canal for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in EC for the 2009-2010 simulation period.

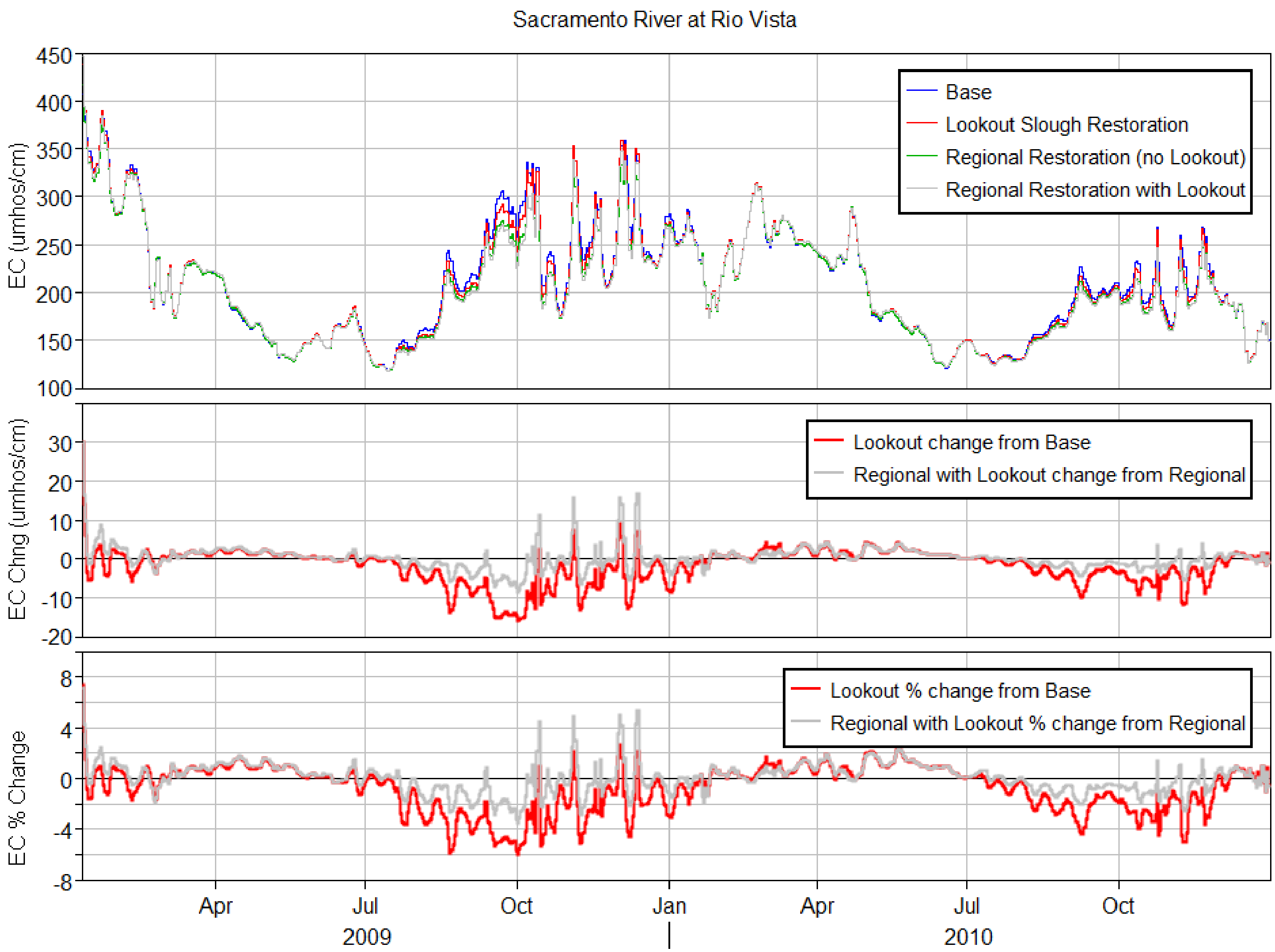

Figure 31 Daily average EC at Rio Vista for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in EC for the 2009-2010 simulation period.

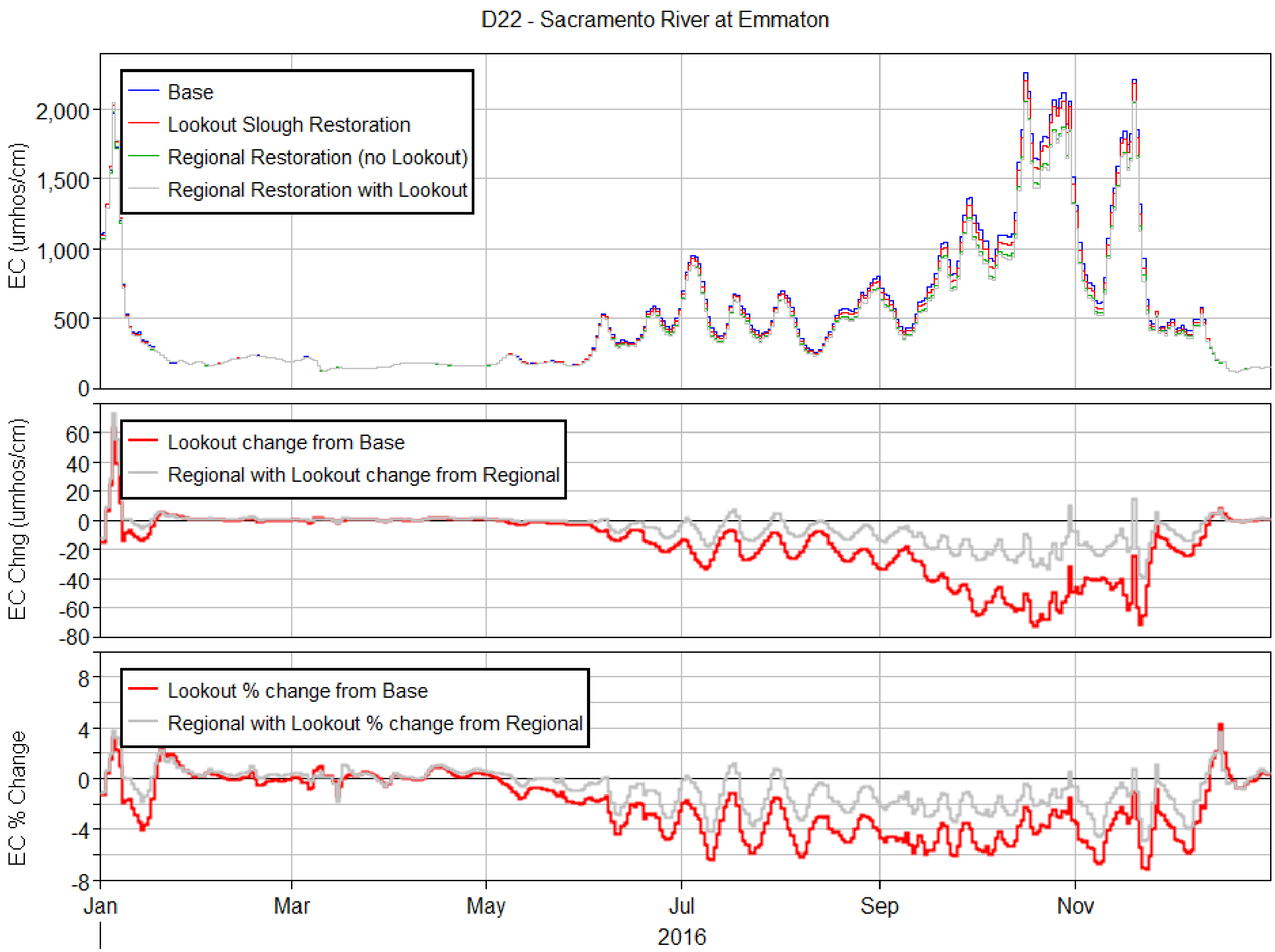

Figure 32 Daily average EC at Emmaton for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in EC for the 2016 simulation period.

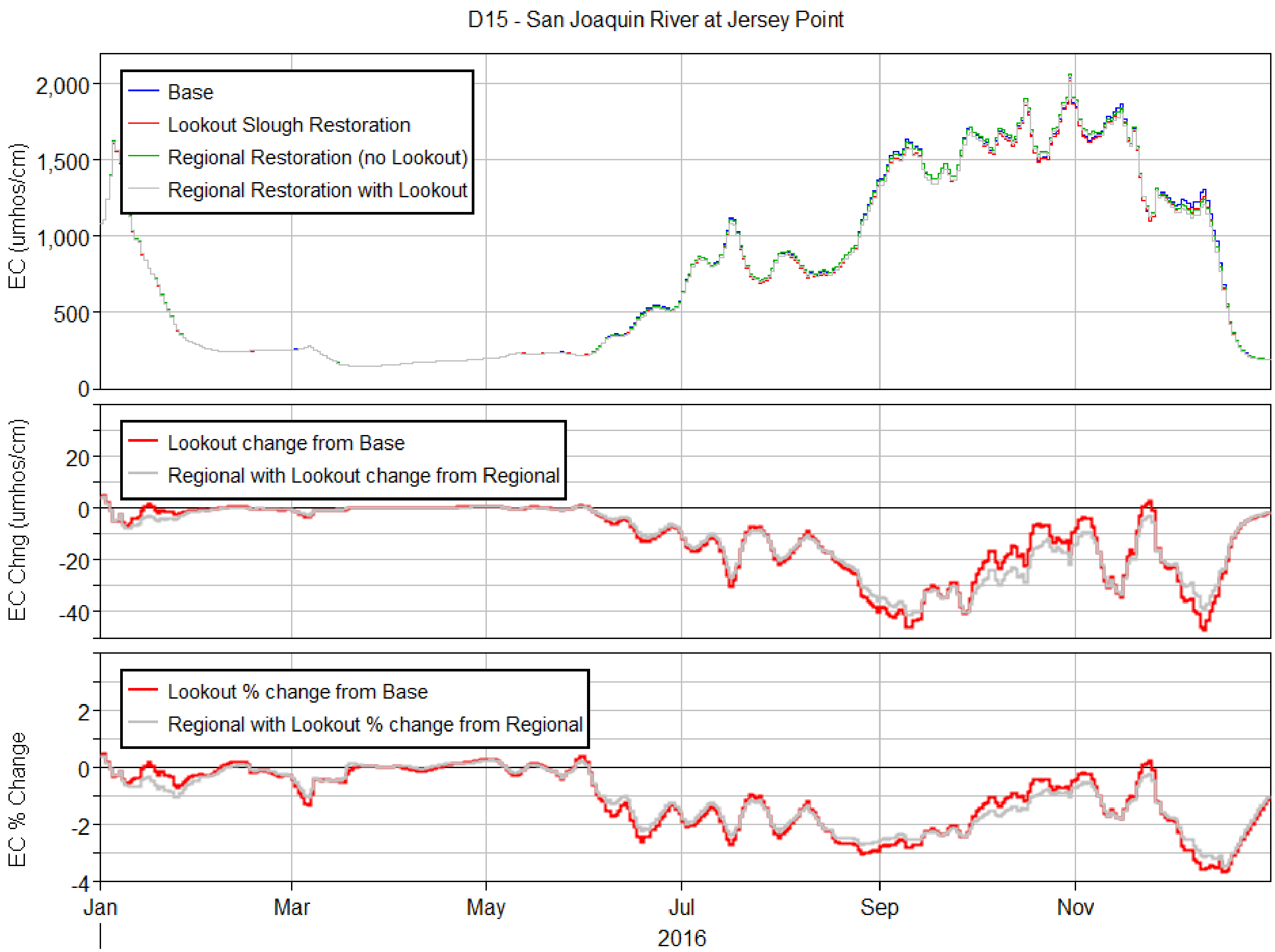

Figure 33 Daily average EC at Jersey Point for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in EC for the 2016 simulation period.

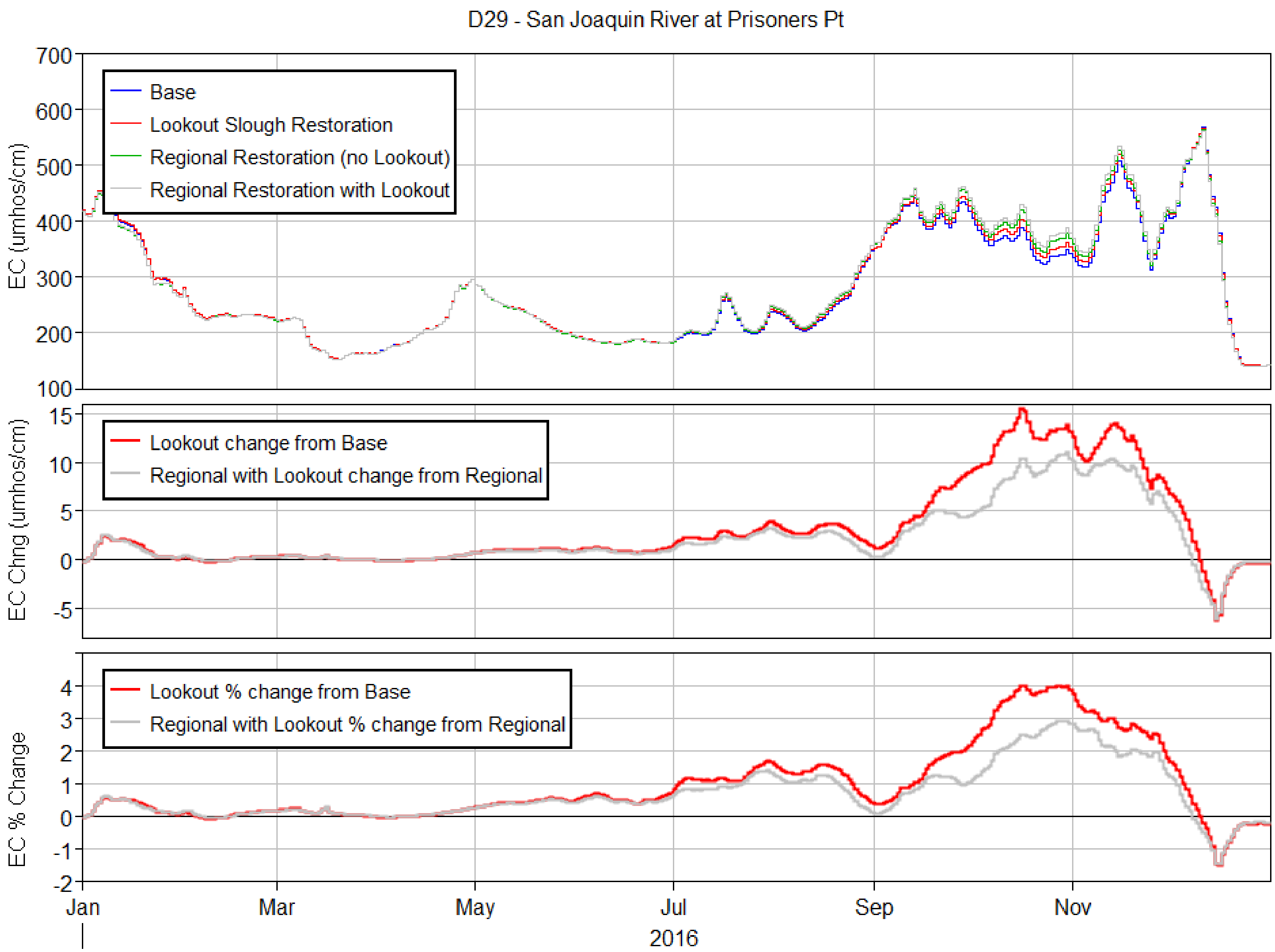

Figure 34 Daily average EC at Prisoners Point for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in EC for the 2016 simulation period.

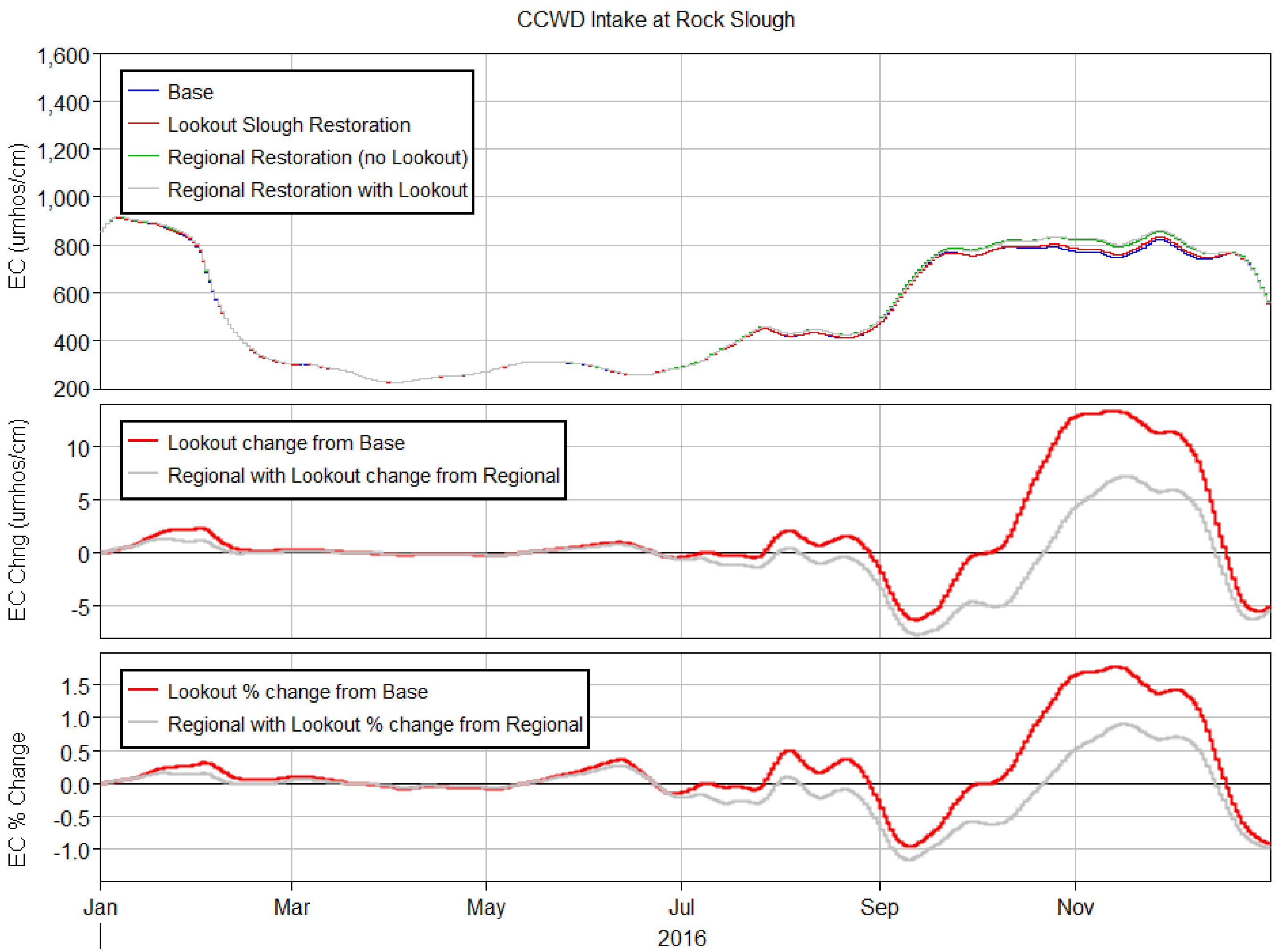

Figure 35 Daily average EC at CCWD intake at Rock Slough for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in EC for the 2016 simulation period.

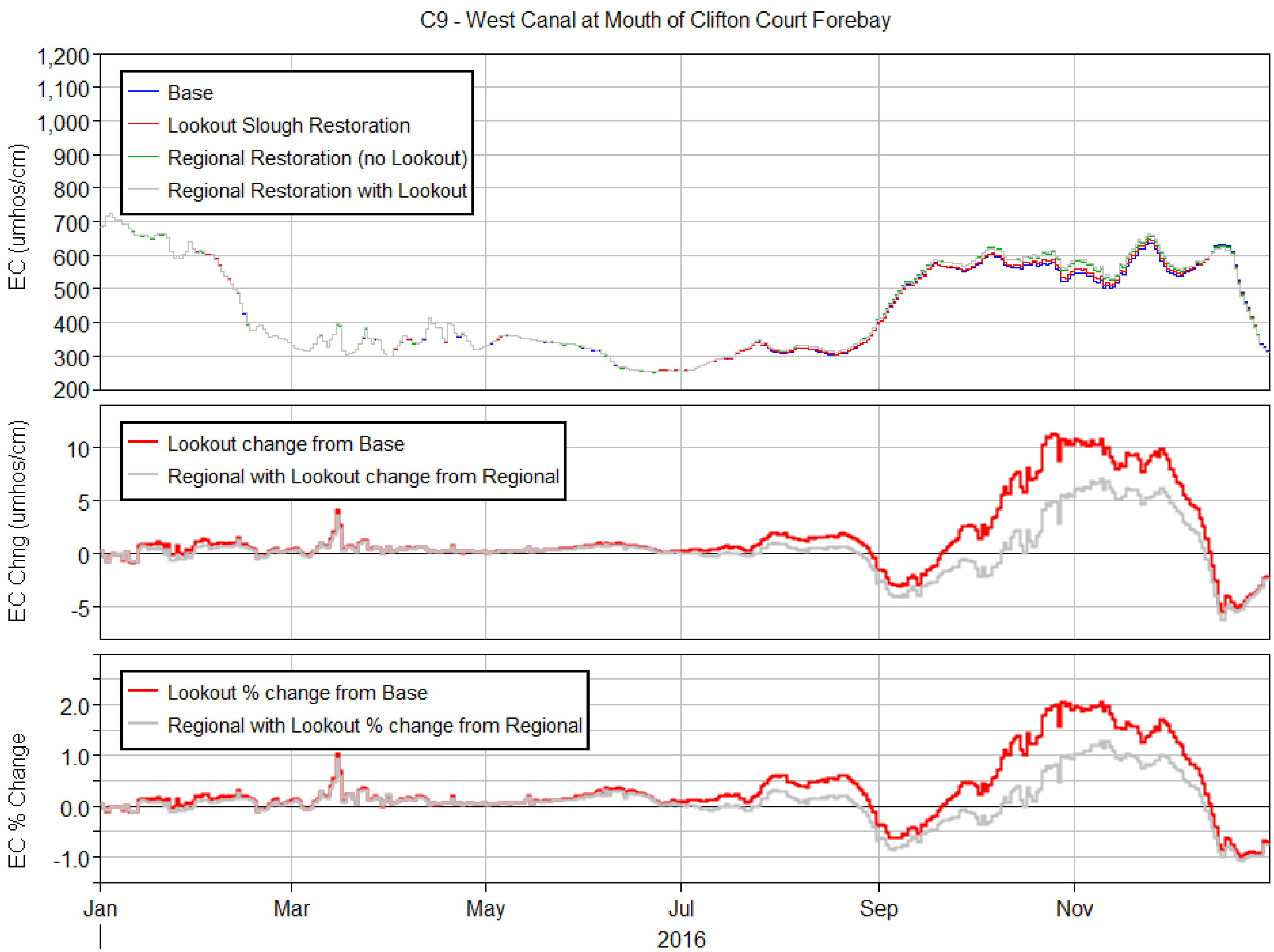

Figure 36 Daily average EC at West Canal at mouth of Clifton Court Forebay for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in EC for the 2016 simulation period.

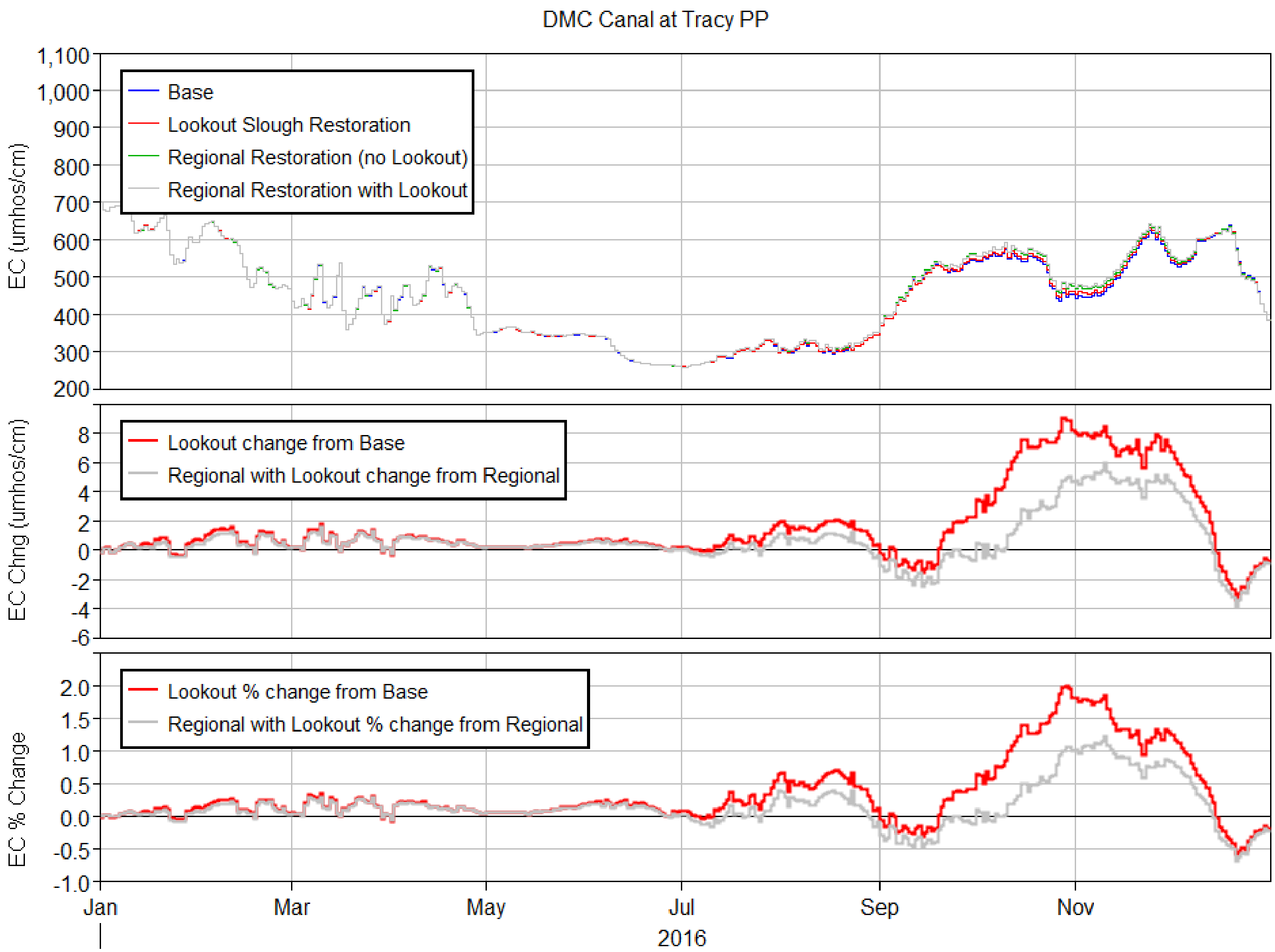

Figure 37 Daily average EC at DMC Canal at Tracy PP for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in EC for the 2016 simulation period.

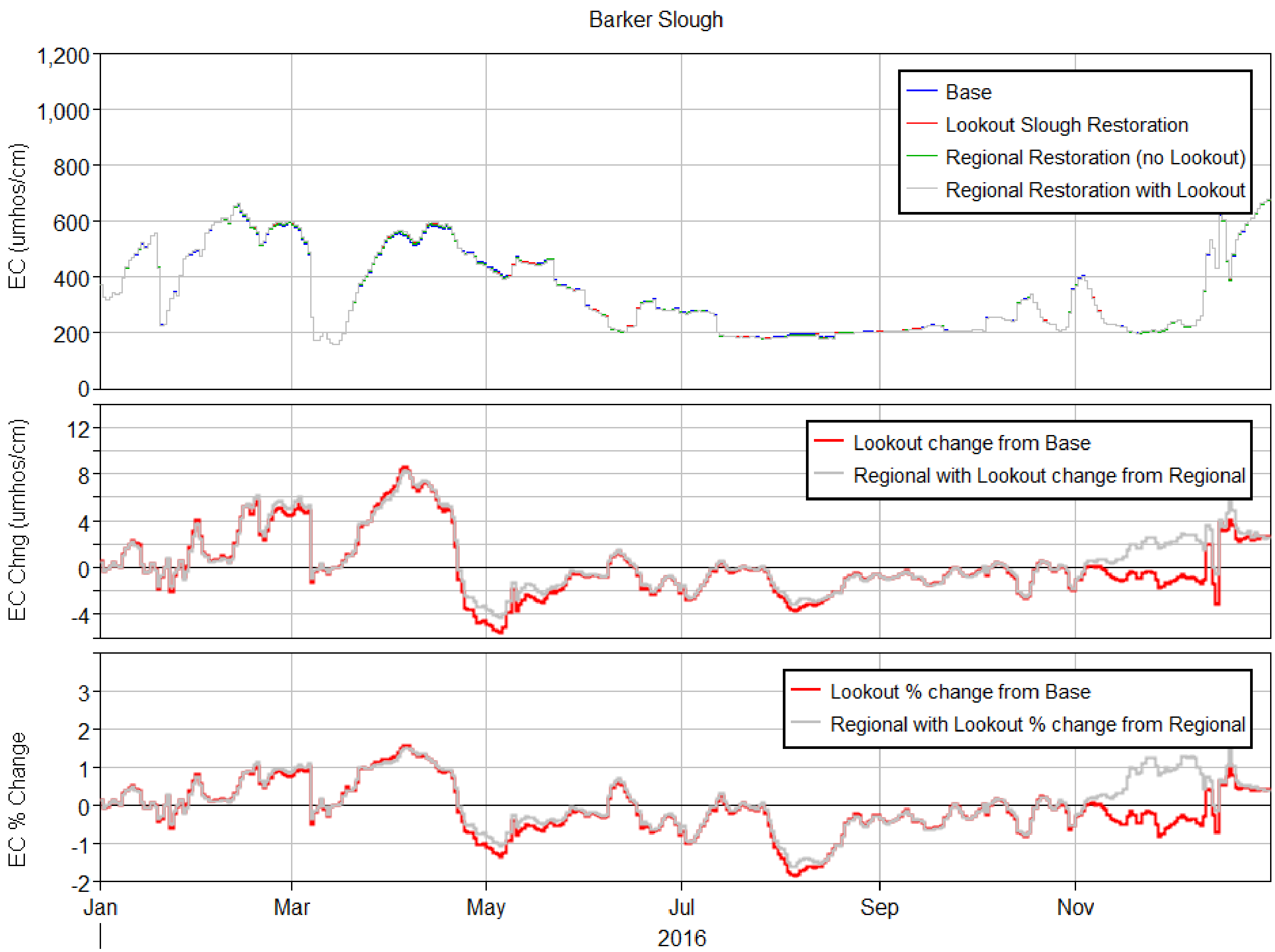

Figure 38 Daily average EC at Barker Slough for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in EC for the 2016 simulation period.

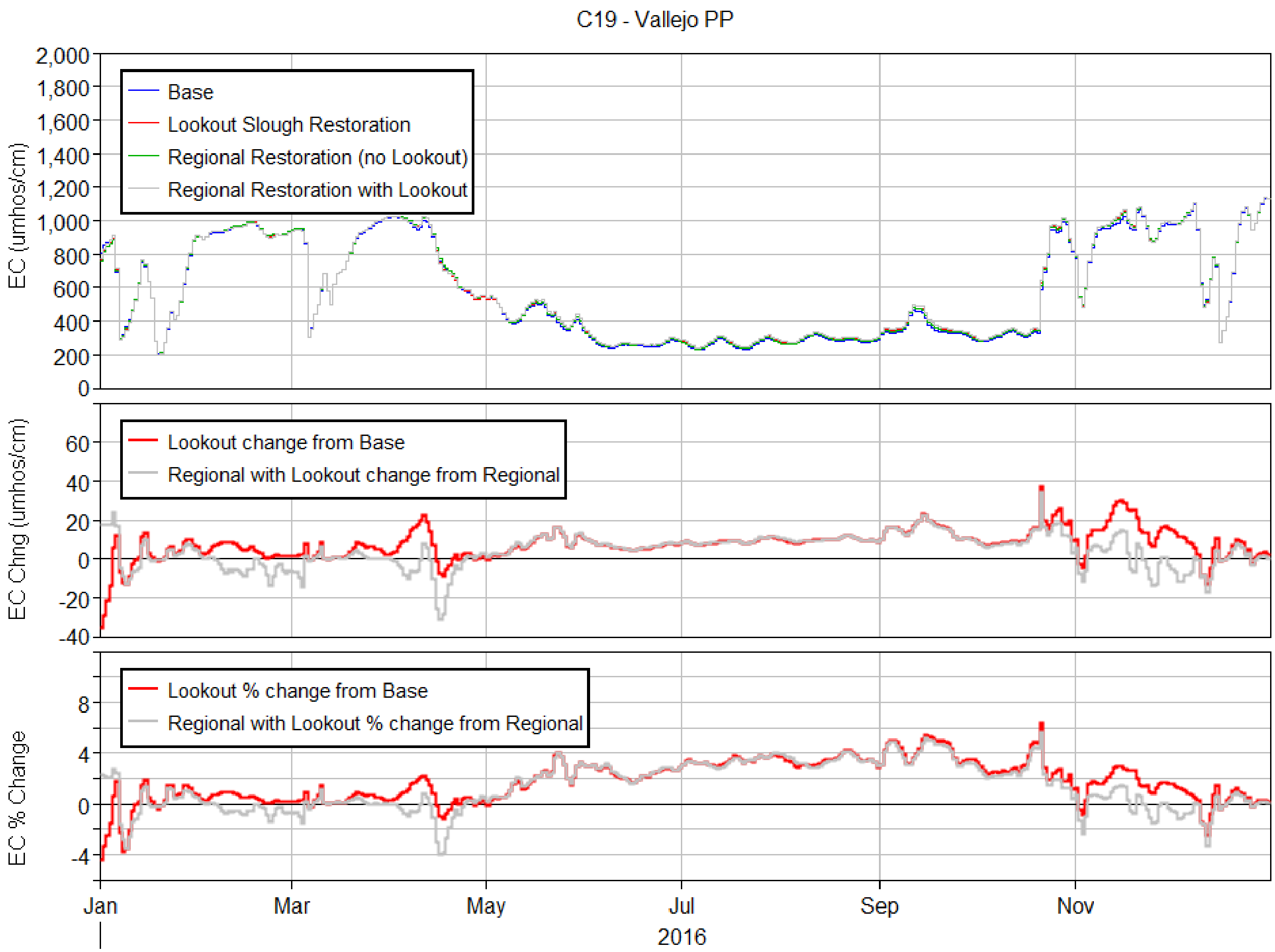

Figure 39 Daily average EC at C19 for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in EC for the 2016 simulation period.

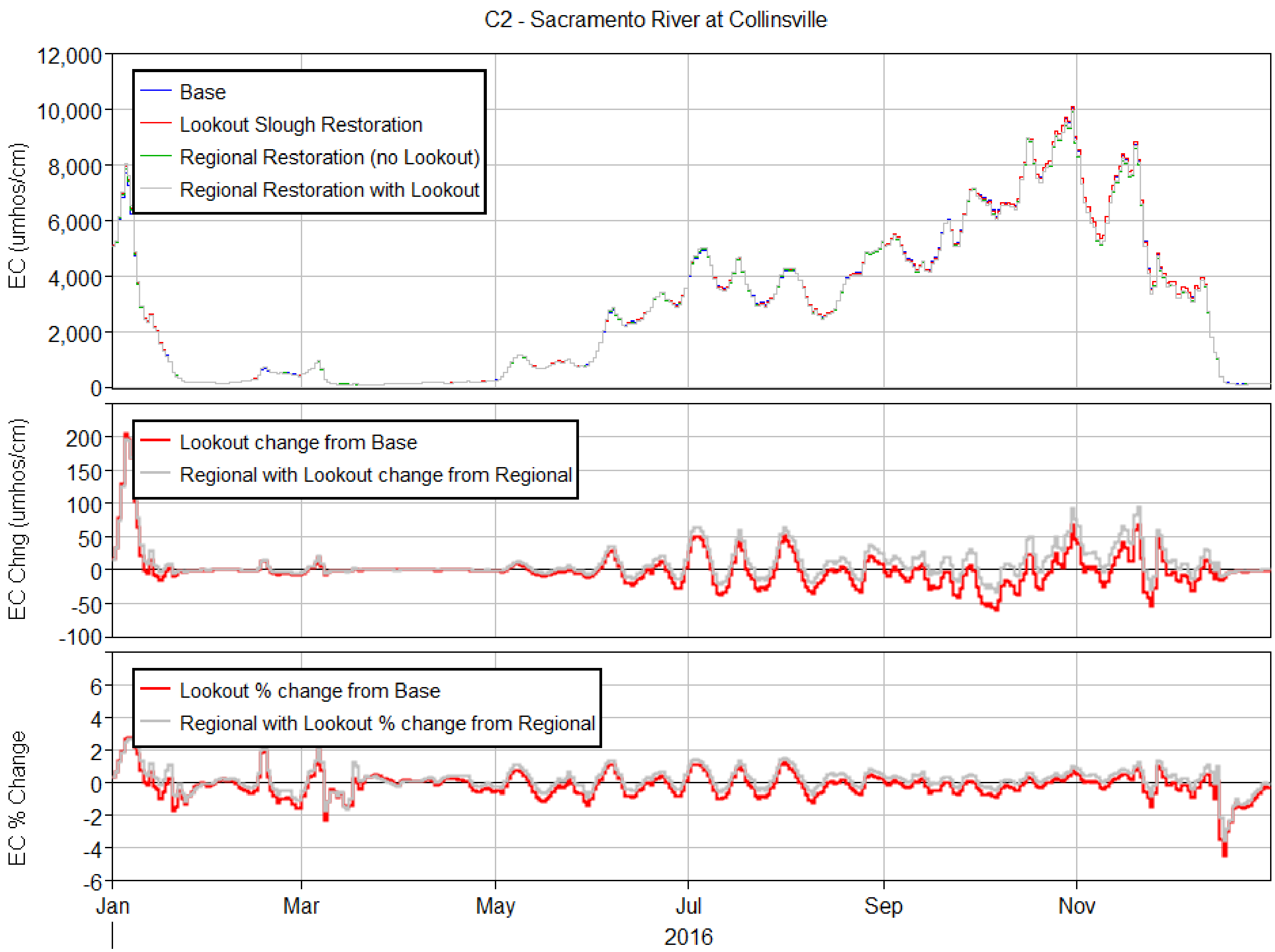

Figure 40 Daily average EC at Collinsville for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in EC for the 2016 simulation period.

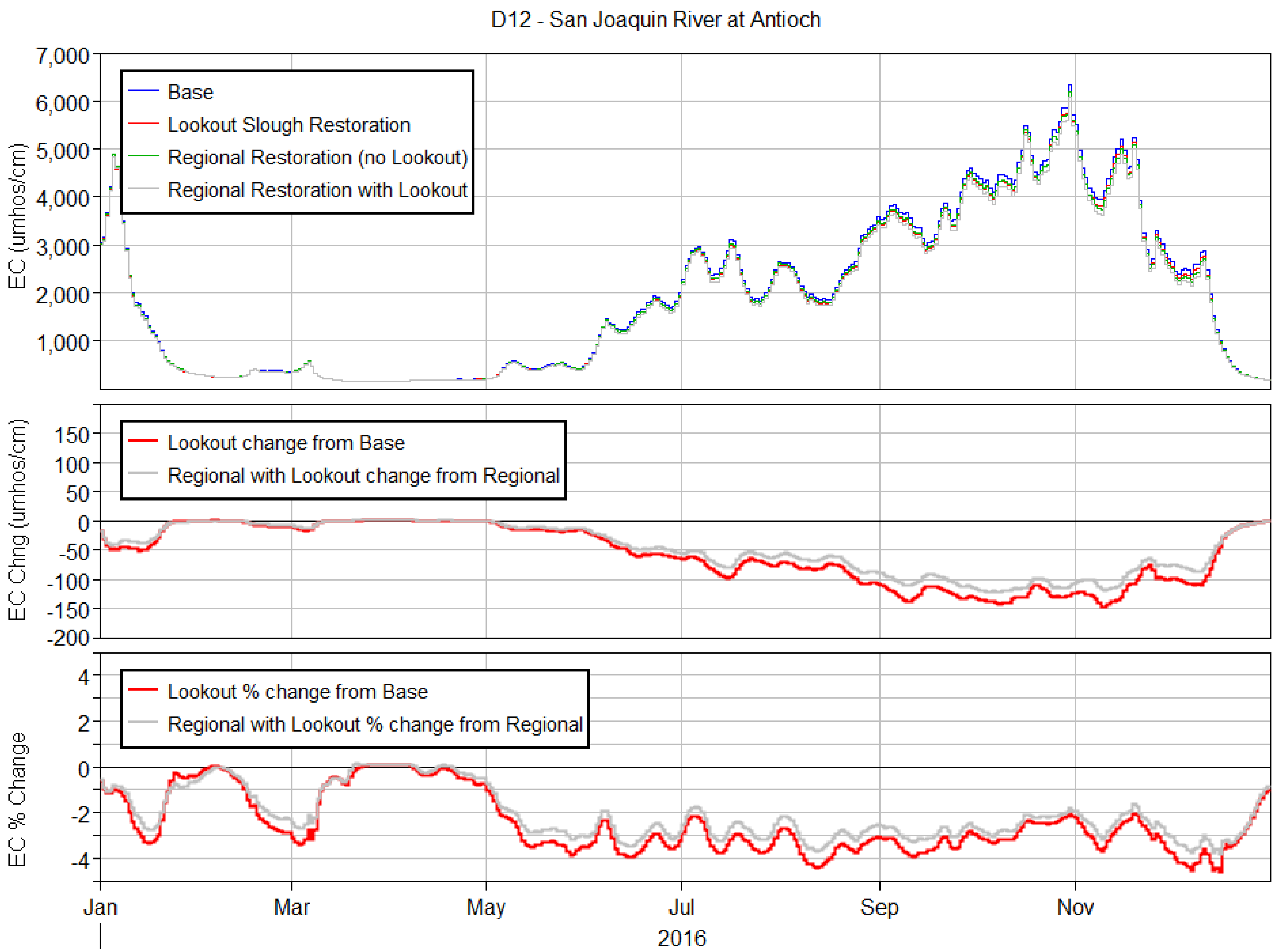

Figure 41 Daily average EC at Antioch for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in EC for the 2016 simulation period.

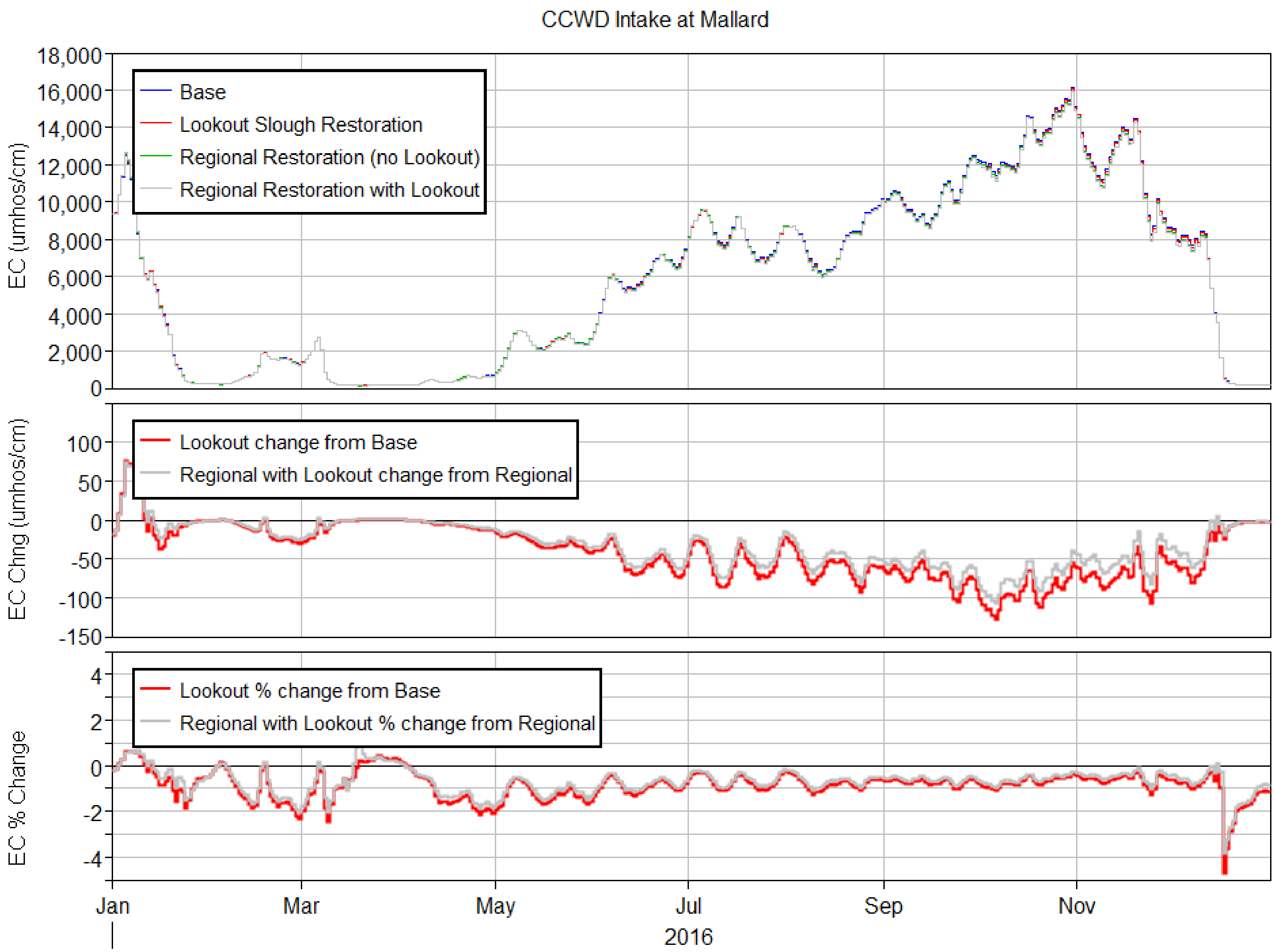

Figure 42 Daily average EC at CCWD intake at Mallard for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in EC for the 2016 simulation per

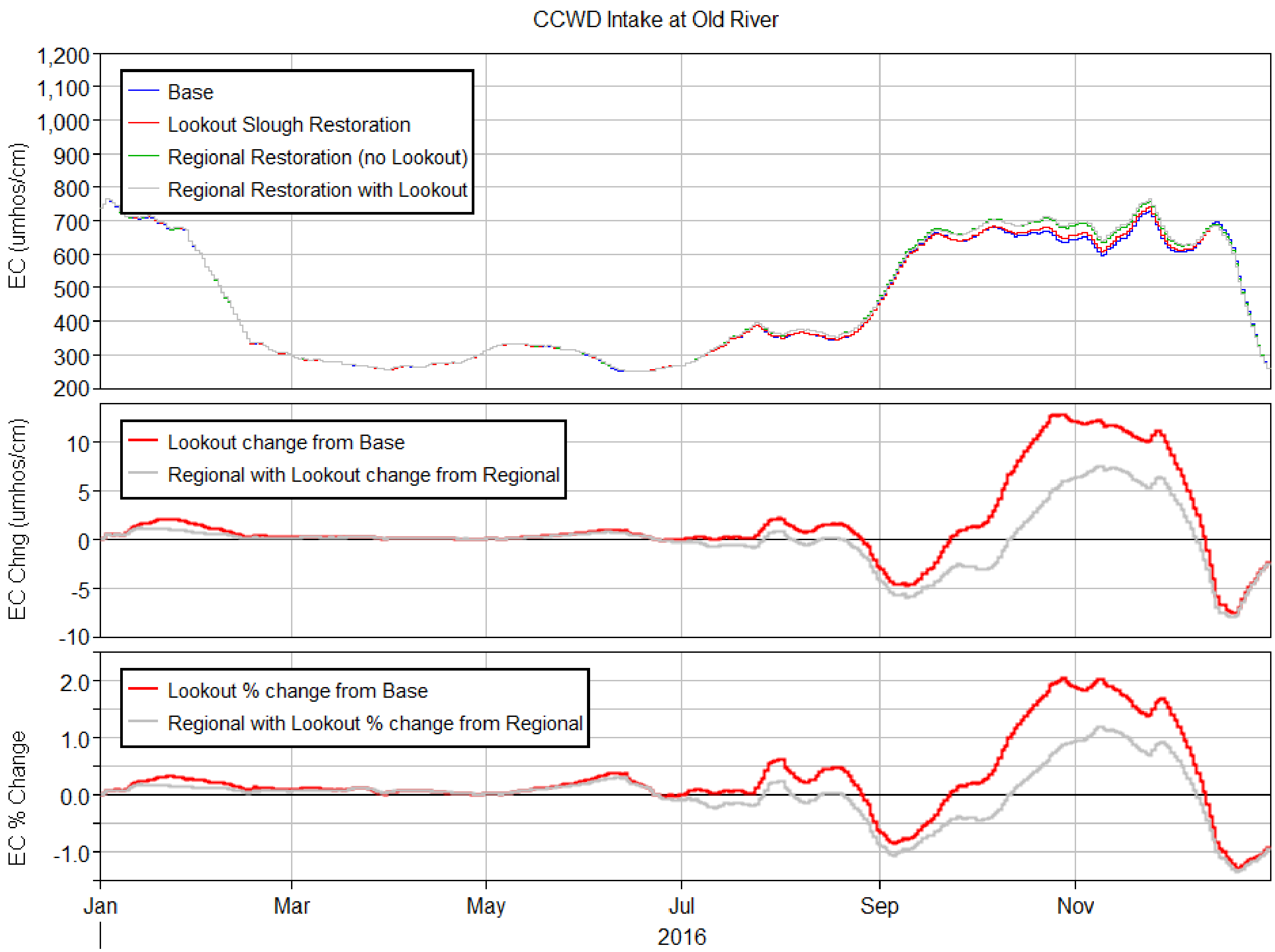

Figure 43 Daily average EC at CCWD intake at Old River for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in EC for the 2016 simulation period.

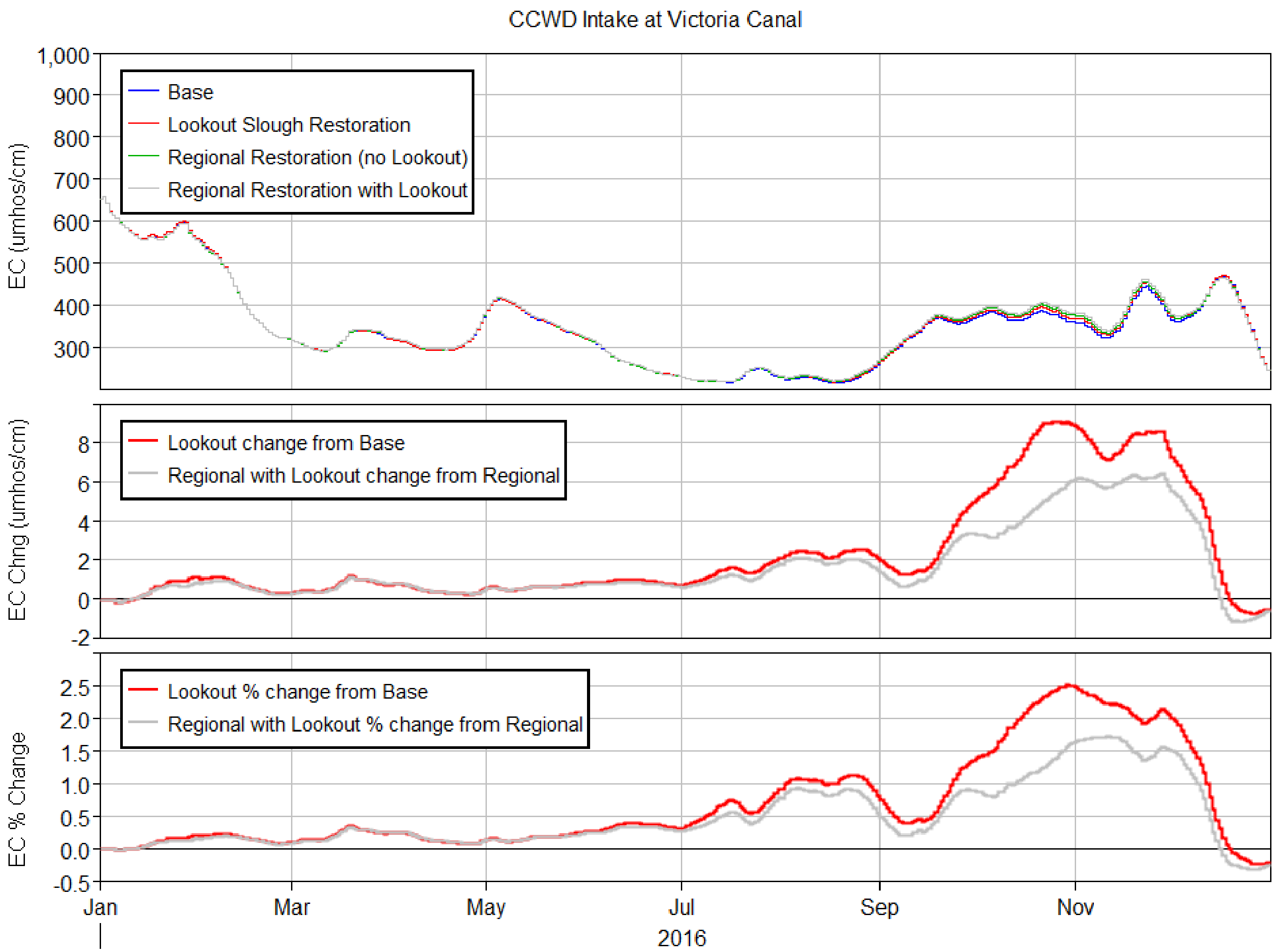

Figure 44 Daily average EC at CCWD intake at Victoria Canal for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in EC for the 2016 simulation period.

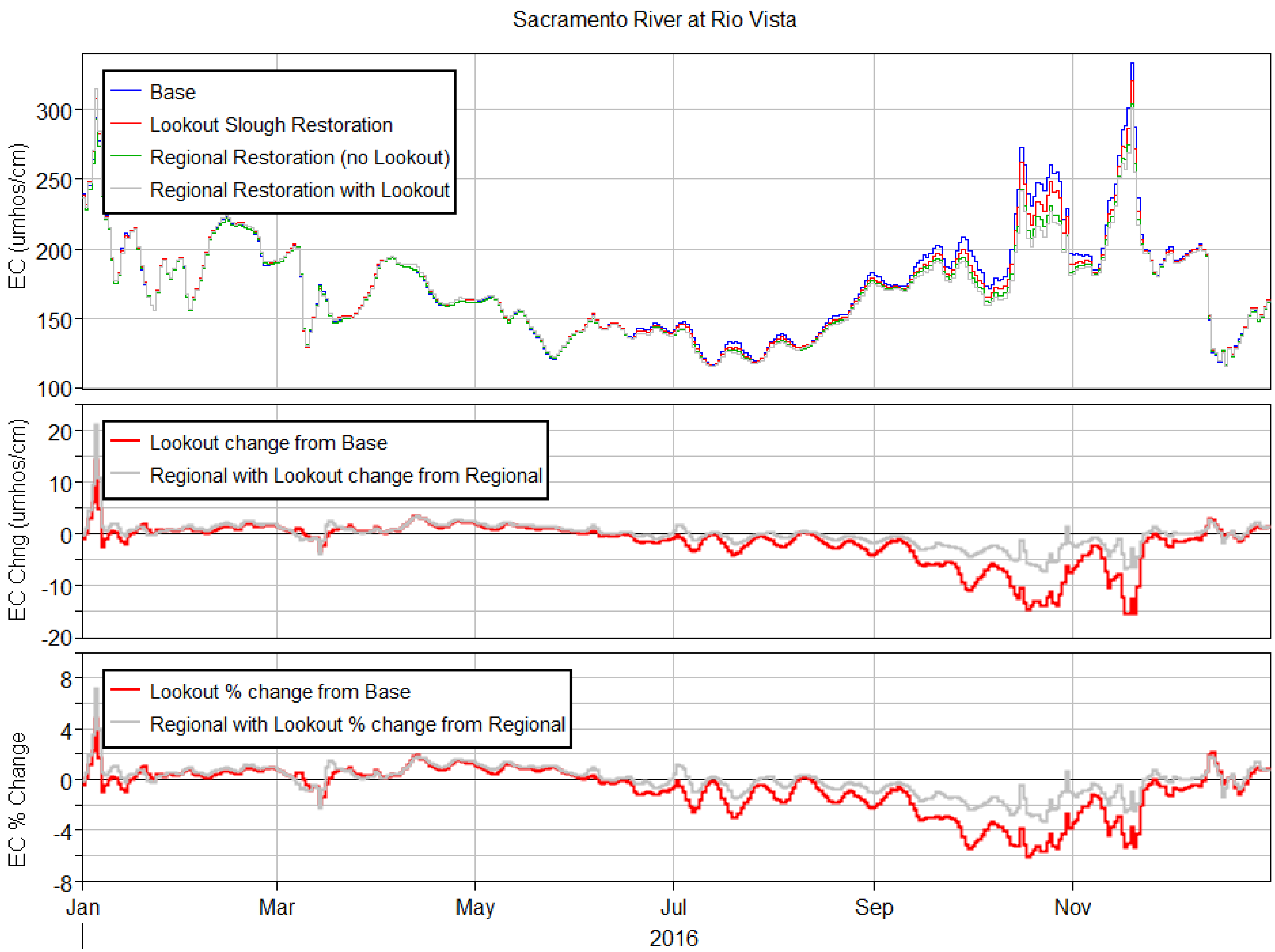

Figure 45 Daily average EC at Rio Vista for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in EC for the 2016 simulation period.

Table 3 Monthly average Base/Regional Restoration EC, and Lookout Slough change and percent change from Base/Regional Restoration EC at Table 2 locations for 2009.[6]

	D22 – Sacramento River at Emmaton						D15 – San Joaquin River at Jersey Point					
		With Lookout Slough			Regional Restoration with Lookout Slough			With Lookout Slough			Regional Restoration with Lookout Slough	
	Base EC µS/cm	EC change µS/cm	% EC change	Regional Restoration EC µS/cm	EC change µS/cm	% EC change	Base EC µS/cm	EC change µS/cm	% EC change	Regional Restoration EC µS/cm	EC change µS/cm	% EC change
Jan-2009	1748.2	-4.2	-0.2%	1696.5	6.0	0.4%	1477.0	-12.3	-0.8%	1453.6	-11.2	-0.8%
Feb-2009	526.1	-8.6	-1.6%	503.9	-1.3	-0.2%	760.5	-3.4	-0.4%	757.7	-3.9	-0.5%
Mar-2009	205.4	0.1	0.1%	205.0	0.3	0.2%	249.2	-0.5	-0.2%	251.1	-0.5	-0.2%
Apr-2009	202.3	-0.4	-0.2%	200.4	0.5	0.2%	233.6	0.2	0.1%	234.3	0.3	0.1%
May-2009	155.0	-0.3	-0.2%	153.5	0.3	0.2%	194.8	0.9	0.5%	195.8	0.8	0.4%
Jun-2009	297.6	-5.4	-1.8%	283.8	-1.3	-0.5%	221.6	-1.6	-0.7%	221.1	-1.1	-0.5%
Jul-2009	508.4	-17.6	-3.5%	464.3	-5.7	-1.2%	700.7	-26.1	-3.7%	692.5	-22.1	-3.2%
Aug-2009	972.7	-45.0	-4.6%	869.4	-16.7	-1.9%	1317.3	-40.0	-3.0%	1320.0	-38.4	-2.9%
Sep-2009	1476.5	-64.2	-4.3%	1315.0	-25.2	-1.9%	1536.8	-30.3	-2.0%	1564.2	-34.5	-2.2%
Oct-2009	1534.2	-56.9	-3.7%	1379.3	-22.9	-1.7%	1244.1	-12.0	-1.0%	1302.1	-13.9	-1.1%
Nov-2009	1349.9	-45.0	-3.3%	1239.7	-20.0	-1.6%	1005.7	-16.7	-1.7%	1035.4	-13.6	-1.3%
Dec-2009	1272.3	-34.2	-2.7%	1182.9	-8.1	-0.7%	1140.7	-27.5	-2.4%	1144.6	-20.5	-1.8%

[6] Results are provided with tenths digit to provide reader with additional detail. While this level of precision is available from the model, the model's accuracy is likely only one-two significant digits.

	D29 – San Joaquin River at Prisoners Point						C5 – Contra Costa Intake at Rock Slough					
		With Lookout Slough			Regional Restoration with Lookout Slough			With Lookout Slough			Regional Restoration with Lookout Slough	
	Base EC µS/cm	EC change µS/cm	% EC change	Regional Restoration EC µS/cm	EC change µS/cm	% EC change	Base EC µS/cm	EC change µS/cm	% EC change	Regional Restoration EC µS/cm	EC change µS/cm	% EC change
Jan-2009	511.1	0.9	0.2%	502.4	1.1	0.2%	798.7	-0.1	0.0%	798.0	-0.1	0.0%
Feb-2009	410.5	2.6	0.6%	399.6	2.4	0.6%	837.0	1.7	0.2%	836.5	1.0	0.1%
Mar-2009	209.0	-0.1	0.0%	206.3	-0.1	0.0%	505.6	1.7	0.3%	510.4	1.3	0.3%
Apr-2009	212.2	0.3	0.1%	210.7	0.3	0.2%	346.0	0.3	0.1%	348.7	0.3	0.1%
May-2009	207.7	0.4	0.2%	205.4	0.4	0.2%	347.2	0.5	0.1%	349.1	0.5	0.1%
Jun-2009	191.1	0.6	0.3%	190.1	0.5	0.3%	287.0	0.5	0.2%	288.2	0.4	0.1%
Jul-2009	216.2	-0.7	-0.3%	221.3	-0.7	-0.3%	303.1	-3.2	-1.1%	304.9	-2.9	-0.9%
Aug-2009	344.1	3.9	1.1%	366.4	1.9	0.5%	596.8	-8.1	-1.4%	608.6	-9.4	-1.5%
Sep-2009	381.0	10.5	2.8%	413.9	7.1	1.7%	745.5	-0.6	-0.1%	779.1	-6.7	-0.9%
Oct-2009	278.6	9.1	3.3%	302.9	8.9	2.9%	736.5	8.1	1.1%	793.9	1.5	0.2%
Nov-2009	277.7	5.9	2.1%	294.6	6.6	2.2%	577.5	8.2	1.4%	629.6	6.0	1.0%
Dec-2009	343.5	3.3	1.0%	354.4	4.4	1.2%	567.4	2.5	0.4%	600.6	3.1	0.5%

	C9 – Clifton Ct Forebay Intake						DMC1 – Delta Mendota Canal at Tracy PP					
		With Lookout Slough		Regional Restoration	Regional Restoration with Lookout Slough			With Lookout Slough		Regional Restoration	Regional Restoration with Lookout Slough	
	Base EC µS/cm	EC change µS/cm	% EC change	EC µS/cm	EC change µS/cm	% EC change	Base EC µS/cm	EC change µS/cm	% EC change	EC µS/cm	EC change µS/cm	% EC change
Jan-2009	769.7	-0.3	0.0%	767.8	-0.3	0.0%	844.5	-0.7	-0.1%	842.7	-0.7	-0.1%
Feb-2009	762.9	1.7	0.2%	758.4	1.3	0.2%	842.8	1.4	0.2%	840.2	1.1	0.1%
Mar-2009	465.3	1.6	0.3%	464.3	1.1	0.2%	620.6	1.6	0.3%	620.5	1.1	0.2%
Apr-2009	363.9	0.5	0.1%	364.2	0.4	0.1%	490.7	0.7	0.1%	491.5	0.5	0.1%
May-2009	351.7	0.4	0.1%	352.3	0.4	0.1%	371.3	0.2	0.1%	371.7	0.2	0.1%
Jun-2009	348.7	0.7	0.2%	349.6	0.6	0.2%	382.3	0.7	0.2%	383.2	0.6	0.1%
Jul-2009	267.6	-1.9	-0.7%	269.4	-1.8	-0.7%	273.5	-1.4	-0.5%	274.8	-1.3	-0.5%
Aug-2009	456.3	-3.1	-0.7%	469.6	-5.0	-1.1%	427.3	-2.4	-0.6%	438.1	-4.0	-0.9%
Sep-2009	560.9	3.7	0.7%	590.1	-1.7	-0.3%	530.3	3.5	0.7%	553.8	-1.0	-0.2%
Oct-2009	530.8	8.1	1.5%	569.0	4.1	0.7%	509.7	6.5	1.3%	538.2	3.3	0.6%
Nov-2009	479.1	5.5	1.1%	504.0	4.5	0.9%	511.9	4.2	0.8%	531.0	3.4	0.6%
Dec-2009	499.2	2.2	0.4%	515.9	2.6	0.5%	574.5	2.8	0.5%	587.1	2.9	0.5%

	SLBAR3 – Barker Slough NBA Intake						C19 – City of Vallejo Intake Cache Slough					
		With Lookout Slough			Regional Restoration with Lookout Slough			With Lookout Slough			Regional Restoration with Lookout Slough	
	Base EC µS/cm	EC change µS/cm	% EC change	Regional Restoration EC µS/cm	EC change µS/cm	% EC change	Base EC µS/cm	EC change µS/cm	% EC change	Regional Restoration EC µS/cm	EC change µS/cm	% EC change
Jan-2009	390.5	-0.8	-0.2%	390.5	-0.3	-0.1%	878.0	8.0	0.9%	886.5	-0.5	-0.1%
Feb-2009	372.4	-5.1	-1.3%	372.4	-3.8	-1.0%	625.9	2.9	0.5%	630.7	-5.7	-0.9%
Mar-2009	387.8	-8.0	-2.0%	387.8	-7.2	-1.9%	754.6	10.2	1.4%	766.0	4.7	0.6%
Apr-2009	479.1	-7.4	-1.5%	479.1	-6.7	-1.4%	613.0	2.0	0.3%	621.6	-0.1	0.0%
May-2009	345.8	-2.3	-0.6%	345.8	-1.7	-0.5%	501.9	12.9	2.6%	514.5	13.3	2.6%
Jun-2009	275.5	-1.3	-0.5%	275.5	-1.1	-0.4%	486.3	23.1	4.7%	504.0	23.9	4.7%
Jul-2009	260.5	-0.9	-0.3%	260.5	-0.8	-0.3%	488.0	25.1	5.1%	507.4	25.7	5.1%
Aug-2009	254.6	-1.4	-0.5%	254.6	-1.3	-0.5%	498.6	27.5	5.5%	518.6	28.2	5.4%
Sep-2009	285.4	-1.6	-0.6%	285.4	-1.4	-0.5%	522.9	26.4	5.1%	542.1	26.4	4.9%
Oct-2009	291.7	-0.7	-0.2%	291.7	-0.3	-0.1%	659.4	17.2	2.6%	674.9	-0.1	0.0%
Nov-2009	256.2	-1.7	-0.6%	256.2	0.9	0.4%	801.2	19.9	2.5%	823.7	-8.7	-1.1%
Dec-2009	312.5	-1.6	-0.5%	312.5	0.7	0.2%	703.9	15.7	2.2%	721.6	-7.5	-1.0%

	C2 – Sacramento River at Collinsville						D12 – San Joaquin River at Antioch					
		With Lookout Slough		Regional	Regional Restoration with Lookout Slough			With Lookout Slough		Regional	Regional Restoration with Lookout Slough	
	Base EC µS/cm	EC change µS/cm	% EC change	Restoration EC µS/cm	EC change µS/cm	% EC change	Base EC µS/cm	EC change µS/cm	% EC change	Restoration EC µS/cm	EC change µS/cm	% EC change
Jan-2009	6737.5	72.7	1.1%	6721.8	74.9	1.1%	4520.9	-64.8	-1.4%	4417.1	-58.0	-1.3%
Feb-2009	2193.0	17.9	0.8%	2163.1	27.8	1.3%	1569.2	-40.0	-2.5%	1514.5	-31.4	-2.1%
Mar-2009	251.8	-0.4	-0.2%	251.8	-0.1	-0.1%	264.8	-1.0	-0.4%	266.8	-1.0	-0.4%
Apr-2009	520.7	-0.8	-0.2%	512.9	1.3	0.3%	347.2	-8.0	-2.3%	336.8	-6.1	-1.8%
May-2009	356.1	0.3	0.1%	354.1	1.8	0.5%	247.2	-3.6	-1.5%	243.1	-2.5	-1.0%
Jun-2009	1331.7	5.4	0.4%	1333.3	11.4	0.9%	663.1	-22.9	-3.5%	645.0	-18.6	-2.9%
Jul-2009	3276.5	15.8	0.5%	3262.0	29.0	0.9%	2163.3	-77.8	-3.6%	2104.6	-63.0	-3.0%
Aug-2009	5246.2	12.9	0.2%	5191.3	39.2	0.8%	3596.6	-126.2	-3.5%	3500.1	-103.8	-3.0%
Sep-2009	6678.6	0.6	0.0%	6586.4	32.9	0.5%	4420.9	-147.7	-3.3%	4308.8	-126.2	-2.9%
Oct-2009	6560.5	3.9	0.1%	6488.8	29.5	0.5%	4087.6	-132.5	-3.2%	4008.3	-115.7	-2.9%
Nov-2009	5789.6	4.2	0.1%	5712.4	25.3	0.4%	3486.9	-112.8	-3.2%	3390.5	-94.8	-2.8%
Dec-2009	5642.0	49.4	0.9%	5616.8	71.1	1.3%	3597.7	-107.9	-3.0%	3502.9	-85.0	-2.4%

	CCWD Intake at Mallard Slough						CCWD Intake at Old River					
		With Lookout Slough		Regional	Regional Restoration with Lookout Slough			With Lookout Slough		Regional	Regional Restoration with Lookout Slough	
	Base EC µS/cm	EC change µS/cm	% EC change	Restoration EC µS/cm	EC change µS/cm	% EC change	Base EC µS/cm	EC change µS/cm	% EC change	Restoration EC µS/cm	EC change µS/cm	% EC change
Jan-2009	11808.3	2.8	0.0%	11748.0	2.6	0.0%	723.7	-0.1	0.0%	721.4	-0.1	0.0%
Feb-2009	4882.8	-7.5	-0.2%	4825.6	0.6	0.0%	731.2	2.2	0.3%	728.0	1.5	0.2%
Mar-2009	463.2	-5.1	-1.1%	457.5	-4.5	-1.0%	379.9	0.9	0.2%	379.3	0.5	0.1%
Apr-2009	1642.8	-17.8	-1.1%	1608.2	-14.5	-0.9%	299.0	0.4	0.1%	299.4	0.2	0.1%
May-2009	1124.9	-12.7	-1.1%	1110.9	-9.9	-0.9%	329.5	0.5	0.2%	330.3	0.5	0.2%
Jun-2009	3507.9	-30.9	-0.9%	3493.7	-24.6	-0.7%	298.6	0.7	0.2%	299.7	0.6	0.2%
Jul-2009	7358.1	-38.8	-0.5%	7318.2	-30.5	-0.4%	285.6	-3.0	-1.1%	287.5	-2.8	-1.0%
Aug-2009	10405.7	-43.5	-0.4%	10334.9	-29.1	-0.3%	530.2	-5.1	-1.0%	545.8	-7.3	-1.3%
Sep-2009	12276.8	-61.5	-0.5%	12170.4	-42.3	-0.3%	642.7	3.0	0.5%	677.4	-3.3	-0.5%
Oct-2009	12200.6	-66.9	-0.5%	12114.3	-51.0	-0.4%	588.0	9.1	1.6%	636.5	4.5	0.7%
Nov-2009	11145.6	-68.4	-0.6%	11022.9	-53.3	-0.5%	487.5	6.5	1.3%	524.4	5.3	1.0%
Dec-2009	10962.8	-23.7	-0.2%	10916.2	-9.8	-0.1%	500.4	1.7	0.3%	523.2	2.4	0.5%

	CCWD Intake at Victoria Canal						Sacramento River at Rio Vista					
		With Lookout Slough			Regional Restoration with Lookout Slough			With Lookout Slough			Regional Restoration with Lookout Slough	
	Base EC µS/cm	EC change µS/cm	% EC change	Regional Restoration EC µS/cm	EC change µS/cm	% EC change	Base EC µS/cm	EC change µS/cm	% EC change	Regional Restoration EC µS/cm	EC change µS/cm	% EC change
Jan-2009	630.4	-0.2	0.0%	627.8	-0.2	0.0%	361.8	10.1	2.8%	359.5	12.5	3.5%
Feb-2009	669.4	1.4	0.2%	660.0	1.1	0.2%	270.8	-0.9	-0.3%	269.2	0.1	0.0%
Mar-2009	434.3	2.0	0.5%	432.2	1.2	0.3%	214.7	1.2	0.5%	214.0	1.3	0.6%
Apr-2009	312.0	0.5	0.2%	312.0	0.3	0.1%	181.5	2.0	1.1%	182.0	2.3	1.3%
May-2009	349.5	0.7	0.2%	350.8	0.6	0.2%	140.6	1.0	0.7%	140.4	1.1	0.8%
Jun-2009	316.4	1.0	0.3%	318.1	0.8	0.2%	160.6	-0.2	-0.1%	158.9	0.3	0.2%
Jul-2009	222.2	0.4	0.2%	223.6	0.2	0.1%	133.7	-1.3	-1.0%	130.8	-0.1	-0.1%
Aug-2009	293.6	1.1	0.4%	301.0	-0.2	-0.1%	190.0	-6.2	-3.3%	179.6	-2.3	-1.3%
Sep-2009	361.7	5.8	1.6%	377.2	2.4	0.6%	262.6	-11.2	-4.3%	242.0	-4.3	-1.8%
Oct-2009	394.3	6.8	1.7%	411.4	4.4	1.1%	252.7	-8.2	-3.3%	230.2	-1.5	-0.6%
Nov-2009	357.7	5.1	1.4%	371.5	4.4	1.2%	257.8	-4.9	-1.9%	242.4	0.1	0.0%
Dec-2009	363.1	3.1	0.9%	371.9	3.3	0.9%	276.1	-3.2	-1.2%	264.2	1.7	0.7%

Table 4 Monthly average Base/Regional Restoration EC, and Lookout Slough change and percent change from Base/Regional Restoration EC at Table 1 locations for 2010.[7]

	D22 – Sacramento River at Emmaton						D15 – San Joaquin River at Jersey Point					
		With Lookout Slough			Regional Restoration with Lookout Slough			With Lookout Slough			Regional Restoration with Lookout Slough	
	Base EC µS/cm	EC change µS/cm	% EC change	Regional Restoration EC µS/cm	EC change µS/cm	% EC change	Base EC µS/cm	EC change µS/cm	% EC change	Regional Restoration EC µS/cm	EC change µS/cm	% EC change
Jan-2010	546.3	-17.7	-3.2%	517.5	-7.3	-1.4%	805.3	-20.3	-2.5%	793.9	-16.5	-2.1%
Feb-2010	238.0	-0.3	-0.1%	237.8	-0.1	0.0%	264.2	-1.5	-0.6%	265.1	-1.2	-0.5%
Mar-2010	248.5	0.4	0.1%	248.2	0.7	0.3%	263.4	-0.4	-0.2%	263.3	-0.2	-0.1%
Apr-2010	241.1	-0.4	-0.2%	240.1	0.3	0.1%	276.3	0.0	0.0%	276.2	0.1	0.0%
May-2010	186.0	1.0	0.5%	185.4	1.3	0.7%	257.6	1.1	0.4%	259.0	0.8	0.3%
Jun-2010	155.1	0.0	0.0%	153.4	0.6	0.4%	178.6	0.5	0.3%	179.4	0.3	0.2%
Jul-2010	334.4	-10.0	-3.0%	310.2	-3.8	-1.2%	409.4	-8.9	-2.2%	407.9	-7.8	-1.9%
Aug-2010	568.6	-23.6	-4.2%	509.8	-9.6	-1.9%	967.5	-27.7	-2.9%	956.8	-24.6	-2.6%
Sep-2010	771.7	-33.8	-4.4%	692.5	-13.6	-2.0%	1444.7	-29.3	-2.0%	1444.4	-29.6	-2.0%
Oct-2010	1030.0	-45.0	-4.4%	920.1	-21.6	-2.3%	1244.1	-20.3	-1.6%	1252.3	-21.4	-1.7%
Nov-2010	1029.2	-41.9	-4.1%	930.0	-19.4	-2.1%	1327.3	-18.9	-1.4%	1340.3	-19.5	-1.5%
Dec-2010	252.5	-3.1	-1.2%	244.8	-0.9	-0.4%	549.4	-7.3	-1.3%	554.5	-8.0	-1.4%

[7] Results are provided with tenths digit to provide reader with additional detail. While this level of precision is available from the model, the model's accuracy is likely only one-two significant digits.

	D29 – San Joaquin River at Prisoners Point						C5 – Contra Costa Intake at Rock Slough					
		With Lookout Slough		Regional	Regional Restoration with Lookout Slough			With Lookout Slough		Regional	Regional Restoration with Lookout Slough	
	Base EC µS/cm	EC change µS/cm	% EC change	Restoration EC µS/cm	EC change µS/cm	% EC change	Base EC µS/cm	EC change µS/cm	% EC change	Restoration EC µS/cm	EC change µS/cm	% EC change
Jan-2010	393.4	-0.1	0.0%	388.9	0.5	0.1%	762.9	-2.7	-0.4%	776.1	-1.6	-0.2%
Feb-2010	250.1	-0.2	-0.1%	247.8	-0.2	-0.1%	611.6	-1.7	-0.3%	619.5	-1.3	-0.2%
Mar-2010	260.1	0.0	0.0%	258.2	0.1	0.0%	392.0	-0.3	-0.1%	395.7	-0.2	0.0%
Apr-2010	325.1	0.9	0.3%	324.3	0.8	0.2%	376.3	-0.1	0.0%	376.9	-0.1	0.0%
May-2010	268.4	1.0	0.4%	266.5	0.5	0.2%	436.0	0.2	0.1%	437.9	0.2	0.1%
Jun-2010	161.6	0.1	0.1%	160.3	0.1	0.1%	269.8	0.6	0.2%	271.4	0.4	0.2%
Jul-2010	165.8	0.3	0.2%	167.0	0.3	0.2%	233.1	-0.4	-0.2%	234.2	-0.5	-0.2%
Aug-2010	280.9	0.3	0.1%	288.9	-0.2	-0.1%	400.2	-3.5	-0.9%	405.3	-3.9	-1.0%
Sep-2010	402.2	4.5	1.1%	419.0	2.7	0.6%	709.7	-4.0	-0.6%	723.2	-6.9	-1.0%
Oct-2010	330.3	6.8	2.1%	349.2	4.7	1.3%	647.5	2.9	0.5%	675.8	-1.5	-0.2%
Nov-2010	346.2	7.1	2.0%	366.2	5.3	1.5%	641.3	4.6	0.7%	671.6	0.7	0.1%
Dec-2010	264.2	1.3	0.5%	265.7	0.8	0.3%	603.0	2.9	0.5%	627.5	0.2	0.0%

	C9 – Clifton Ct Forebay Intake						DMC1 – Delta Mendota Canal at Tracy PP					
	Base EC µS/cm	With Lookout Slough		Regional Restoration EC µS/cm	Regional Restoration with Lookout Slough		Base EC µS/cm	With Lookout Slough		Regional Restoration EC µS/cm	Regional Restoration with Lookout Slough	
		EC change µS/cm	% EC change		EC change µS/cm	% EC change		EC change µS/cm	% EC change		EC change µS/cm	% EC change
Jan-2010	625.1	-0.8	-0.1%	627.9	-0.3	0.0%	711.9	0.4	0.1%	714.4	0.6	0.1%
Feb-2010	472.2	0.1	0.0%	472.4	0.1	0.0%	582.4	0.5	0.1%	583.3	0.4	0.1%
Mar-2010	449.1	1.6	0.3%	450.6	1.4	0.3%	572.3	0.4	0.1%	573.3	0.3	0.1%
Apr-2010	445.9	0.1	0.0%	445.9	0.0	0.0%	486.5	0.2	0.0%	486.9	0.2	0.0%
May-2010	288.6	-0.1	0.0%	288.6	-0.1	0.0%	296.2	0.0	0.0%	296.3	0.0	0.0%
Jun-2010	264.2	0.6	0.2%	264.6	0.3	0.1%	285.9	0.4	0.1%	286.3	0.2	0.1%
Jul-2010	215.8	-0.1	-0.1%	216.6	-0.3	-0.1%	243.9	-0.1	0.0%	244.3	-0.2	-0.1%
Aug-2010	334.3	-2.0	-0.6%	339.4	-2.6	-0.8%	346.3	-1.0	-0.3%	349.7	-1.5	-0.4%
Sep-2010	555.8	0.3	0.1%	570.5	-2.6	-0.5%	499.5	1.1	0.2%	509.1	-1.0	-0.2%
Oct-2010	483.0	3.8	0.8%	501.7	0.7	0.1%	466.1	2.9	0.6%	477.2	1.0	0.2%
Nov-2010	505.5	4.6	0.9%	525.5	1.9	0.4%	515.9	3.8	0.7%	529.1	1.9	0.4%
Dec-2010	398.9	1.7	0.4%	408.6	0.3	0.1%	347.5	1.0	0.3%	351.1	0.4	0.1%

	SLBAR3 – Barker Slough NBA Intake						C19 – City of Vallejo Intake Cache Slough					
		With Lookout Slough			Regional Restoration with Lookout Slough			With Lookout Slough			Regional Restoration with Lookout Slough	
	Base EC µS/cm	EC change µS/cm	% EC change	Regional Restoration EC µS/cm	EC change µS/cm	% EC change	Base EC µS/cm	EC change µS/cm	% EC change	Regional Restoration EC µS/cm	EC change µS/cm	% EC change
Jan-2010	274.1	-2.6	-0.9%	274.1	-1.1	-0.4%	667.6	14.3	2.1%	681.6	-5.6	-0.8%
Feb-2010	402.5	-3.5	-0.9%	402.5	-2.6	-0.6%	748.9	9.4	1.3%	755.9	2.3	0.3%
Mar-2010	502.0	-8.8	-1.7%	502.0	-7.0	-1.4%	845.1	5.0	0.6%	852.8	-1.6	-0.2%
Apr-2010	546.8	-16.6	-3.0%	546.8	-15.5	-2.8%	763.8	-2.0	-0.3%	768.9	-9.6	-1.2%
May-2010	446.2	-19.8	-4.3%	446.2	-18.6	-4.2%	584.4	-11.8	-2.0%	586.8	-12.2	-2.1%
Jun-2010	273.8	-1.9	-0.7%	273.8	-1.7	-0.6%	474.8	13.5	2.8%	486.6	14.5	3.0%
Jul-2010	192.5	-0.8	-0.4%	192.5	-0.5	-0.3%	473.2	22.4	4.7%	490.9	23.0	4.7%
Aug-2010	196.0	-1.1	-0.5%	196.0	-0.9	-0.5%	503.3	25.7	5.1%	523.0	25.8	4.9%
Sep-2010	232.9	-1.9	-0.8%	232.9	-1.6	-0.7%	453.9	20.2	4.5%	468.8	21.0	4.5%
Oct-2010	245.3	-1.1	-0.4%	245.3	-1.0	-0.4%	488.6	17.7	3.6%	503.5	16.1	3.2%
Nov-2010	236.0	-1.2	-0.5%	236.0	-0.3	-0.1%	698.8	18.7	2.7%	717.8	-1.0	-0.1%
Dec-2010	343.6	-1.5	-0.4%	343.6	-0.5	-0.2%	666.2	7.3	1.1%	674.8	-8.5	-1.3%

	C2 – Sacramento River at Collinsville						D12 – San Joaquin River at Antioch					
		With Lookout Slough			Regional Restoration with Lookout Slough			With Lookout Slough			Regional Restoration with Lookout Slough	
	Base EC µS/cm	EC change µS/cm	% EC change	Regional Restoration EC µS/cm	EC change µS/cm	% EC change	Base EC µS/cm	EC change µS/cm	% EC change	Regional Restoration EC µS/cm	EC change µS/cm	% EC change
Jan-2010	2684.4	11.3	0.4%	2674.5	25.8	1.0%	1829.7	-61.7	-3.4%	1775.8	-46.5	-2.6%
Feb-2010	249.8	-0.8	-0.3%	249.4	-0.5	-0.2%	266.3	-1.5	-0.6%	267.7	-1.2	-0.5%
Mar-2010	378.9	0.0	0.0%	378.1	0.5	0.1%	304.6	-2.4	-0.8%	302.6	-1.9	-0.6%
Apr-2010	474.0	-0.7	-0.1%	470.4	0.9	0.2%	345.5	-4.7	-1.3%	340.1	-3.5	-1.0%
May-2010	275.7	0.6	0.2%	275.1	1.2	0.4%	262.4	0.2	0.1%	262.3	0.2	0.1%
Jun-2010	394.2	0.3	0.1%	392.2	1.6	0.4%	252.3	-3.5	-1.4%	248.9	-2.7	-1.1%
Jul-2010	1962.6	3.0	0.2%	1946.6	11.0	0.6%	1191.2	-38.9	-3.3%	1160.7	-31.4	-2.7%
Aug-2010	3578.1	-2.2	-0.1%	3518.0	13.1	0.4%	2440.0	-80.8	-3.3%	2364.1	-65.0	-2.7%
Sep-2010	4351.9	-10.9	-0.3%	4266.7	11.0	0.3%	3183.0	-102.6	-3.2%	3088.0	-83.1	-2.7%
Oct-2010	5036.1	-13.3	-0.3%	4941.9	8.2	0.2%	3281.4	-97.1	-3.0%	3188.8	-81.1	-2.5%
Nov-2010	5003.8	-6.1	-0.1%	4907.2	15.7	0.3%	3360.1	-92.1	-2.7%	3270.0	-75.5	-2.3%
Dec-2010	992.1	-0.1	0.0%	965.5	5.1	0.5%	903.9	-26.3	-2.9%	880.1	-21.3	-2.4%

	CCWD Intake at Mallard Slough						CCWD Intake at Old River					
		With Lookout Slough			Regional Restoration with Lookout Slough			With Lookout Slough			Regional Restoration with Lookout Slough	
	Base EC µS/cm	EC change µS/cm	% EC change	Regional Restoration EC µS/cm	EC change µS/cm	% EC change	Base EC µS/cm	EC change µS/cm	% EC change	Regional Restoration EC µS/cm	EC change µS/cm	% EC change
Jan-2010	5720.0	-26.0	-0.5%	5695.8	-13.9	-0.2%	609.8	-2.9	-0.5%	614.0	-2.1	-0.3%
Feb-2010	327.7	-2.8	-0.8%	325.3	-2.2	-0.7%	399.1	-0.9	-0.2%	399.5	-0.8	-0.2%
Mar-2010	801.9	-9.5	-1.2%	790.4	-8.1	-1.0%	351.0	-0.1	0.0%	351.4	-0.1	0.0%
Apr-2010	1179.5	-13.6	-1.2%	1162.9	-10.8	-0.9%	411.6	0.0	0.0%	411.5	0.0	0.0%
May-2010	595.4	-6.4	-1.1%	589.7	-5.2	-0.9%	308.3	0.0	0.0%	308.4	0.0	0.0%
Jun-2010	1096.5	-14.1	-1.3%	1084.6	-11.6	-1.1%	247.3	0.6	0.3%	248.0	0.4	0.2%
Jul-2010	4804.6	-36.4	-0.8%	4764.8	-29.5	-0.6%	215.9	-0.3	-0.2%	217.0	-0.5	-0.2%
Aug-2010	7756.9	-51.0	-0.7%	7663.0	-40.2	-0.5%	373.1	-3.2	-0.9%	378.6	-3.9	-1.0%
Sep-2010	9082.7	-59.9	-0.7%	8966.1	-44.1	-0.5%	633.2	-1.1	-0.2%	649.6	-4.3	-0.7%
Oct-2010	10004.2	-70.2	-0.7%	9879.1	-54.3	-0.6%	542.8	3.8	0.7%	566.4	-0.1	0.0%
Nov-2010	10003.9	-63.7	-0.6%	9868.7	-47.3	-0.5%	560.7	5.1	0.9%	587.6	1.6	0.3%
Dec-2010	2393.4	-15.9	-0.7%	2340.1	-9.4	-0.4%	447.3	1.8	0.4%	460.0	0.0	0.0%

	CCWD Intake at Victoria Canal						**Sacramento River at Rio Vista**					
		With Lookout Slough			Regional Restoration with Lookout Slough			With Lookout Slough			Regional Restoration with Lookout Slough	
	Base EC µS/cm	EC change µS/cm	% EC change	Regional Restoration EC µS/cm	EC change µS/cm	% EC change	Base EC µS/cm	EC change µS/cm	% EC change	Regional Restoration EC µS/cm	EC change µS/cm	% EC change
Jan-2010	502.8	0.5	0.1%	501.8	0.9	0.2%	237.8	-2.0	-0.9%	234.8	-0.7	-0.3%
Feb-2010	460.7	1.1	0.2%	461.5	0.8	0.2%	258.5	0.8	0.3%	257.8	0.5	0.2%
Mar-2010	436.6	0.8	0.2%	438.6	0.6	0.1%	258.3	2.3	0.9%	258.6	2.0	0.8%
Apr-2010	432.2	0.2	0.0%	432.6	0.1	0.0%	239.5	1.8	0.7%	240.0	1.7	0.7%
May-2010	295.9	0.0	0.0%	295.8	0.0	0.0%	173.2	2.7	1.5%	173.5	2.7	1.6%
Jun-2010	270.2	0.7	0.3%	270.7	0.4	0.1%	138.6	1.0	0.7%	138.5	0.9	0.7%
Jul-2010	208.6	0.4	0.2%	208.9	0.2	0.1%	134.8	-0.5	-0.3%	133.2	0.1	0.1%
Aug-2010	247.7	0.6	0.3%	251.0	0.0	0.0%	157.1	-2.9	-1.8%	152.5	-1.2	-0.8%
Sep-2010	379.1	3.2	0.8%	387.9	1.1	0.3%	203.4	-4.6	-2.3%	195.7	-1.9	-1.0%
Oct-2010	361.2	4.9	1.4%	372.3	2.8	0.7%	203.9	-5.6	-2.7%	191.7	-1.8	-1.0%
Nov-2010	348.9	5.4	1.6%	360.6	3.3	0.9%	215.7	-4.6	-2.1%	204.6	-0.8	-0.4%
Dec-2010	357.4	2.6	0.7%	362.2	1.6	0.4%	167.9	0.3	0.2%	167.1	0.5	0.3%

Table 5 Monthly average Base/Regional Restoration EC, and Lookout Slough change and percent change from Base/Regional Restoration EC at Table 1 locations for 2016.[8]

	D22 – Sacramento River at Emmaton						D15 – San Joaquin River at Jersey Point					
		With Lookout Slough			Regional Restoration with Lookout Slough			With Lookout Slough			Regional Restoration with Lookout Slough	
	Base EC µS/cm	EC change µS/cm	% EC change	Regional Restoration EC µS/cm	EC change µS/cm	% EC change	Base EC µS/cm	EC change µS/cm	% EC change	Regional Restoration EC µS/cm	EC change µS/cm	% EC change
Jan-2016	549.2	1.2	0.2%	538.2	5.8	1.1%	828.0	-1.8	-0.2%	832.1	-3.6	-0.4%
Feb-2016	203.3	-0.1	0.0%	202.2	0.7	0.3%	253.1	-0.3	-0.1%	254.0	-0.4	-0.2%
Mar-2016	158.7	-0.1	0.0%	158.3	0.2	0.1%	192.4	-0.9	-0.5%	192.2	-0.7	-0.4%
Apr-2016	170.0	0.5	0.3%	169.8	0.8	0.5%	177.4	0.1	0.0%	177.5	0.1	0.1%
May-2016	189.3	-1.9	-1.0%	184.2	-0.3	-0.2%	225.3	-0.1	0.0%	224.2	-0.1	0.0%
Jun-2016	417.9	-12.5	-3.0%	387.2	-5.1	-1.3%	419.3	-7.2	-1.7%	412.9	-6.1	-1.5%
Jul-2016	572.8	-19.2	-3.3%	523.1	-6.0	-1.2%	836.3	-15.4	-1.8%	837.0	-14.6	-1.7%
Aug-2016	515.9	-20.6	-4.0%	466.6	-7.3	-1.6%	907.9	-21.8	-2.4%	909.9	-20.5	-2.3%
Sep-2016	780.2	-36.8	-4.7%	694.8	-14.2	-2.0%	1510.8	-37.0	-2.5%	1506.2	-36.0	-2.4%
Oct-2016	1547.3	-58.3	-3.8%	1372.2	-22.0	-1.6%	1674.9	-15.4	-0.9%	1701.4	-21.7	-1.3%
Nov-2016	1031.7	-39.8	-3.9%	928.0	-15.1	-1.6%	1556.4	-15.1	-1.0%	1565.1	-17.3	-1.1%
Dec-2016	273.7	-6.3	-2.3%	258.3	-2.7	-1.0%	751.1	-22.4	-3.0%	729.6	-19.6	-2.7%

[8] Results are provided with tenths digit to provide reader with additional detail. While this level of precision is available from the model, the model's accuracy is likely only one-two significant digits.

	D29 – San Joaquin River at Prisoners Point						C5 – Contra Costa Intake at Rock Slough					
		With Lookout Slough			Regional Restoration with Lookout Slough			With Lookout Slough			Regional Restoration with Lookout Slough	
	Base EC µS/cm	EC change µS/cm	% EC change	Regional Restoration EC µS/cm	EC change µS/cm	% EC change	Base EC µS/cm	EC change µS/cm	% EC change	Regional Restoration EC µS/cm	EC change µS/cm	% EC change
Jan-2016	367.4	1.1	0.3%	359.7	1.1	0.3%	875.0	1.3	0.1%	879.9	0.8	0.1%
Feb-2016	234.7	0.1	0.0%	232.3	0.1	0.0%	438.7	0.7	0.2%	442.2	0.2	0.0%
Mar-2016	181.5	0.2	0.1%	180.5	0.2	0.1%	271.0	0.1	0.0%	272.1	0.0	0.0%
Apr-2016	214.5	0.1	0.1%	214.0	0.1	0.1%	247.6	-0.2	-0.1%	248.0	-0.1	-0.1%
May-2016	235.5	1.0	0.4%	234.6	0.9	0.4%	301.5	0.1	0.0%	302.3	0.1	0.0%
Jun-2016	184.5	1.0	0.5%	183.8	0.8	0.5%	273.4	0.4	0.1%	273.8	0.3	0.1%
Jul-2016	212.2	2.5	1.2%	215.7	2.1	1.0%	377.9	0.0	0.0%	382.7	-0.9	-0.2%
Aug-2016	249.3	2.9	1.2%	256.9	2.2	0.8%	426.2	1.0	0.2%	440.2	-0.7	-0.2%
Sep-2016	403.0	5.1	1.3%	416.2	3.3	0.8%	680.0	-4.0	-0.6%	693.6	-6.2	-0.9%
Oct-2016	357.7	12.5	3.5%	381.3	8.4	2.2%	782.9	5.3	0.7%	815.5	-1.8	-0.2%
Nov-2016	395.3	11.0	2.8%	411.6	8.6	2.1%	776.8	12.5	1.6%	821.0	6.1	0.7%
Dec-2016	330.5	0.1	0.0%	327.8	-0.7	-0.2%	732.1	2.2	0.3%	749.0	-0.7	-0.1%

	C9 – Clifton Ct Forebay Intake						DMC1 – Delta Mendota Canal at Tracy PP					
		With Lookout Slough		Regional	Regional Restoration with Lookout Slough			With Lookout Slough		Regional	Regional Restoration with Lookout Slough	
	Base EC µS/cm	EC change µS/cm	% EC change	Restoration EC µS/cm	EC change µS/cm	% EC change	Base EC µS/cm	EC change µS/cm	% EC change	Restoration EC µS/cm	EC change µS/cm	% EC change
Jan-2016	657.2	0.2	0.0%	657.2	-0.1	0.0%	632.0	0.2	0.0%	631.8	0.1	0.0%
Feb-2016	459.3	0.6	0.1%	459.1	0.4	0.1%	549.3	0.9	0.2%	549.7	0.6	0.1%
Mar-2016	335.5	0.7	0.2%	335.7	0.6	0.2%	439.3	0.7	0.2%	440.1	0.6	0.1%
Apr-2016	351.5	0.3	0.1%	352.7	0.3	0.1%	446.0	0.6	0.1%	447.3	0.5	0.1%
May-2016	343.8	0.3	0.1%	345.2	0.3	0.1%	349.5	0.3	0.1%	350.8	0.3	0.1%
Jun-2016	273.7	0.6	0.2%	273.9	0.5	0.2%	290.7	0.4	0.1%	290.9	0.3	0.1%
Jul-2016	297.6	0.7	0.2%	300.8	0.1	0.0%	290.0	0.5	0.2%	292.4	0.0	0.0%
Aug-2016	323.0	1.2	0.4%	332.0	0.2	0.1%	312.4	1.5	0.5%	319.5	0.6	0.2%
Sep-2016	524.7	-0.8	-0.2%	536.6	-2.5	-0.5%	483.3	0.1	0.0%	492.5	-1.2	-0.2%
Oct-2016	569.3	7.0	1.2%	594.9	1.6	0.3%	524.5	6.2	1.2%	543.9	2.0	0.4%
Nov-2016	561.5	9.4	1.7%	586.8	5.9	1.0%	522.2	7.3	1.4%	539.7	4.8	0.9%
Dec-2016	525.3	-0.3	-0.1%	527.3	-1.6	-0.3%	547.4	0.9	0.2%	549.0	-0.1	0.0%

	SLBAR3 – Barker Slough NBA Intake						C19 – City of Vallejo Intake Cache Slough					
		With Lookout Slough			Regional Restoration with Lookout Slough			With Lookout Slough			Regional Restoration with Lookout Slough	
	Base EC µS/cm	EC change µS/cm	% EC change	Regional Restoration EC µS/cm	EC change µS/cm	% EC change	Base EC µS/cm	EC change µS/cm	% EC change	Regional Restoration EC µS/cm	EC change µS/cm	% EC change
Jan-2016	410.6	0.5	0.1%	410.9	0.4	0.1%	570.2	-1.1	-0.2%	567.0	3.8	0.7%
Feb-2016	579.4	3.0	0.5%	581.5	3.2	0.5%	935.2	4.2	0.5%	939.6	-4.4	-0.5%
Mar-2016	353.8	2.6	0.7%	355.5	2.7	0.8%	785.0	3.2	0.4%	787.5	-0.4	0.0%
Apr-2016	530.5	3.4	0.6%	532.9	3.8	0.7%	794.4	5.3	0.7%	805.6	-5.7	-0.7%
May-2016	416.2	-2.8	-0.7%	412.0	-2.0	-0.5%	436.8	7.8	1.8%	445.1	8.2	1.9%
Jun-2016	267.0	-0.7	-0.3%	264.7	-0.5	-0.2%	262.4	6.5	2.5%	267.5	6.7	2.5%
Jul-2016	217.6	-0.9	-0.4%	216.1	-0.7	-0.3%	261.4	8.9	3.4%	267.8	9.0	3.4%
Aug-2016	196.9	-2.2	-1.1%	193.4	-2.0	-1.0%	284.3	9.7	3.4%	290.0	9.8	3.4%
Sep-2016	213.0	-0.8	-0.4%	211.7	-0.8	-0.4%	355.7	15.1	4.2%	366.2	14.8	4.0%
Oct-2016	259.2	-0.5	-0.2%	258.4	-0.5	-0.2%	505.5	13.5	2.7%	515.9	11.1	2.1%
Nov-2016	252.7	-0.7	-0.3%	251.0	1.1	0.4%	904.2	15.8	1.8%	918.0	1.2	0.1%
Dec-2016	448.3	1.1	0.2%	448.2	2.8	0.6%	853.3	3.8	0.5%	857.2	-2.3	-0.3%

	C2 – Sacramento River at Collinsville						D12 – San Joaquin River at Antioch					
		With Lookout Slough		Regional	Regional Restoration with Lookout Slough			With Lookout Slough		Regional	Regional Restoration with Lookout Slough	
	Base EC µS/cm	EC change µS/cm	% EC change	Restoration EC µS/cm	EC change µS/cm	% EC change	Base EC µS/cm	EC change µS/cm	% EC change	Restoration EC µS/cm	EC change µS/cm	% EC change
Jan-2016	2461.8	30.6	1.2%	2462.2	35.2	1.4%	1785.6	-28.0	-1.6%	1770.2	-23.2	-1.3%
Feb-2016	386.1	-1.4	-0.4%	383.5	0.0	0.0%	310.6	-4.7	-1.5%	307.7	-3.7	-1.2%
Mar-2016	281.0	0.4	0.1%	281.0	1.1	0.4%	244.3	-4.1	-1.7%	241.4	-3.2	-1.3%
Apr-2016	208.8	-0.2	-0.1%	207.1	0.2	0.1%	183.3	-0.6	-0.3%	182.2	-0.3	-0.2%
May-2016	833.5	-2.6	-0.3%	823.4	0.8	0.1%	443.7	-13.6	-3.1%	427.1	-10.8	-2.5%
Jun-2016	2653.6	-3.0	-0.1%	2632.4	5.9	0.2%	1454.0	-48.5	-3.3%	1407.1	-40.3	-2.9%
Jul-2016	3902.9	5.7	0.1%	3877.7	19.7	0.5%	2461.9	-76.3	-3.1%	2403.0	-62.5	-2.6%
Aug-2016	3777.6	-2.9	-0.1%	3745.8	12.3	0.3%	2467.6	-86.7	-3.5%	2408.1	-70.5	-2.9%
Sep-2016	5316.7	-11.0	-0.2%	5251.6	9.6	0.2%	3667.7	-124.4	-3.4%	3572.4	-102.8	-2.9%
Oct-2016	7791.7	-11.5	-0.1%	7643.9	15.1	0.2%	4842.2	-130.5	-2.7%	4724.4	-113.8	-2.4%
Nov-2016	6230.5	6.9	0.1%	6040.5	30.7	0.5%	4078.5	-115.6	-2.8%	3923.3	-93.7	-2.4%
Dec-2016	1587.8	-5.6	-0.4%	1532.8	2.6	0.2%	1350.9	-53.6	-4.0%	1280.1	-42.6	-3.3%

	CCWD Intake at Mallard Slough						CCWD Intake at Old River					
	Base EC µS/cm	With Lookout Slough		Regional Restoration EC µS/cm	Regional Restoration with Lookout Slough		Base EC µS/cm	With Lookout Slough		Regional Restoration EC µS/cm	Regional Restoration with Lookout Slough	
		EC change µS/cm	% EC change		EC change µS/cm	% EC change		EC change µS/cm	% EC change		EC change µS/cm	% EC change
Jan-2016	4903.6	3.7	0.1%	4886.5	8.1	0.2%	699.4	1.4	0.2%	701.3	0.8	0.1%
Feb-2016	968.7	-12.7	-1.3%	955.0	-10.5	-1.1%	406.3	0.6	0.2%	407.2	0.3	0.1%
Mar-2016	616.5	-5.4	-0.9%	614.3	-4.1	-0.7%	273.7	0.2	0.1%	274.2	0.2	0.1%
Apr-2016	427.3	-6.0	-1.4%	417.9	-5.0	-1.2%	274.8	0.1	0.0%	275.7	0.1	0.0%
May-2016	2388.6	-28.8	-1.2%	2354.1	-24.3	-1.0%	322.2	0.3	0.1%	323.3	0.3	0.1%
Jun-2016	5900.4	-53.3	-0.9%	5844.9	-45.8	-0.8%	263.4	0.5	0.2%	263.5	0.3	0.1%
Jul-2016	8157.3	-54.7	-0.7%	8103.6	-44.7	-0.6%	333.3	0.5	0.1%	338.2	-0.3	-0.1%
Aug-2016	7974.0	-61.3	-0.8%	7918.6	-50.0	-0.6%	368.0	0.7	0.2%	379.3	-0.7	-0.2%
Sep-2016	10283.2	-74.0	-0.7%	10194.5	-60.7	-0.6%	608.7	-2.3	-0.4%	622.3	-4.4	-0.7%
Oct-2016	13393.4	-94.0	-0.7%	13223.0	-76.0	-0.6%	660.0	8.1	1.2%	692.1	1.6	0.2%
Nov-2016	11785.0	-69.7	-0.6%	11541.0	-50.2	-0.4%	654.7	11.2	1.7%	688.8	6.5	0.9%
Dec-2016	3679.8	-28.5	-0.8%	3588.9	-20.1	-0.6%	556.3	-1.6	-0.3%	559.0	-3.1	-0.5%

	CCWD Intake at Victoria Canal						Sacramento River at Rio Vista					
		With Lookout Slough		Regional	Regional Restoration with Lookout Slough			With Lookout Slough		Regional	Regional Restoration with Lookout Slough	
	Base EC µS/cm	EC change µS/cm	% EC change	Restoration EC µS/cm	EC change µS/cm	% EC change	Base EC µS/cm	EC change µS/cm	% EC change	Restoration EC µS/cm	EC change µS/cm	% EC change
Jan-2016	585.3	0.4	0.1%	582.5	0.3	0.1%	204.9	1.0	0.5%	203.5	2.1	1.0%
Feb-2016	419.3	0.7	0.2%	418.0	0.6	0.1%	200.1	1.1	0.6%	199.7	1.6	0.8%
Mar-2016	315.4	0.7	0.2%	316.3	0.6	0.2%	166.0	0.3	0.2%	165.5	0.2	0.1%
Apr-2016	307.9	0.4	0.1%	310.6	0.4	0.1%	175.0	1.7	1.0%	175.1	1.9	1.1%
May-2016	370.3	0.6	0.2%	372.8	0.6	0.2%	145.6	1.1	0.8%	145.4	1.4	1.0%
Jun-2016	263.4	0.9	0.3%	263.7	0.8	0.3%	143.8	-0.7	-0.5%	141.8	0.0	0.0%
Jul-2016	227.7	1.3	0.6%	228.4	1.0	0.5%	129.5	-1.7	-1.3%	126.0	-0.3	-0.3%
Aug-2016	225.9	2.3	1.0%	229.9	1.9	0.8%	147.9	-1.8	-1.2%	144.3	-0.6	-0.4%
Sep-2016	335.2	2.4	0.7%	341.6	1.7	0.5%	188.2	-4.9	-2.6%	181.1	-2.1	-1.1%
Oct-2016	372.7	7.5	2.0%	386.1	4.3	1.1%	217.1	-10.3	-4.7%	197.2	-4.0	-2.0%
Nov-2016	374.8	8.1	2.2%	387.2	6.1	1.6%	220.4	-6.0	-2.7%	210.5	-2.0	-1.0%
Dec-2016	384.2	2.4	0.6%	383.7	1.3	0.3%	161.8	-0.1	0.0%	160.7	0.5	0.3%

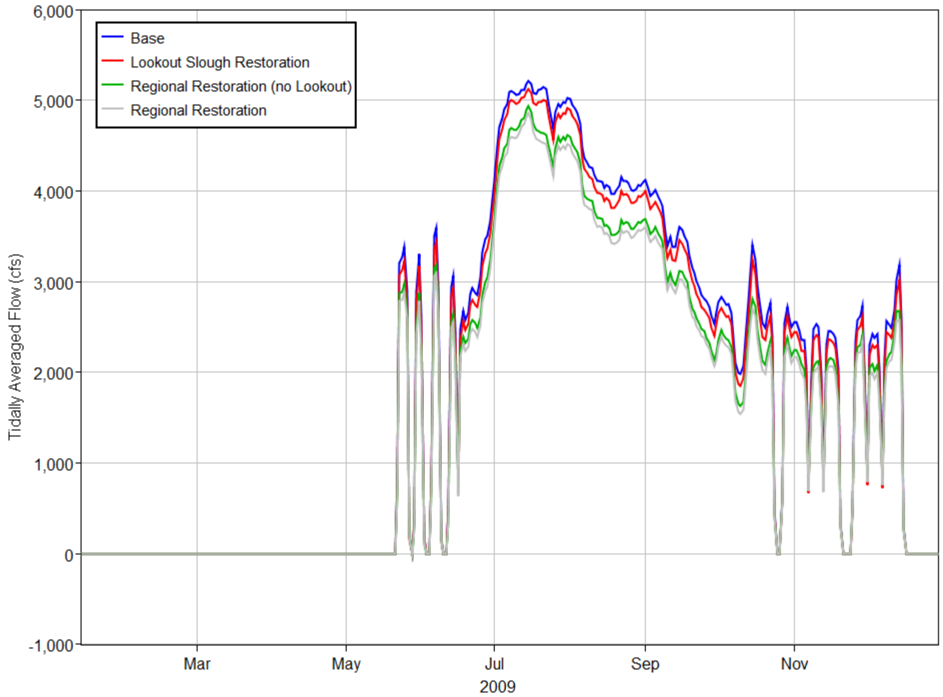

Figure 46 Tidally averaged flow in the Delta Cross Channel for the Base 2009 simulation.

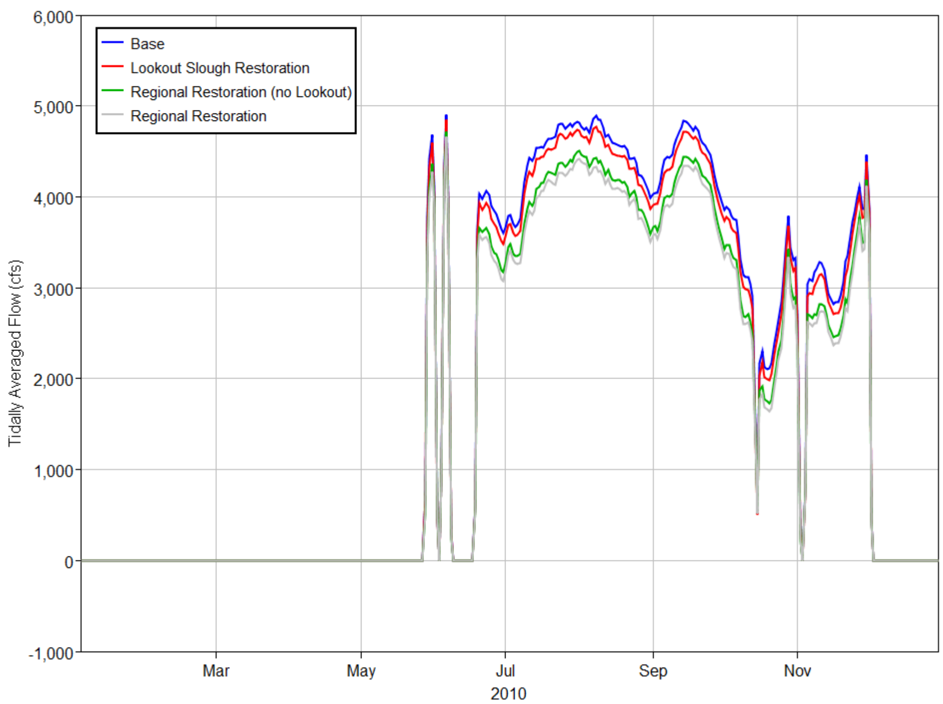

Figure 47 Tidally averaged flow in the Delta Cross Channel for the Base 2010 simulation.

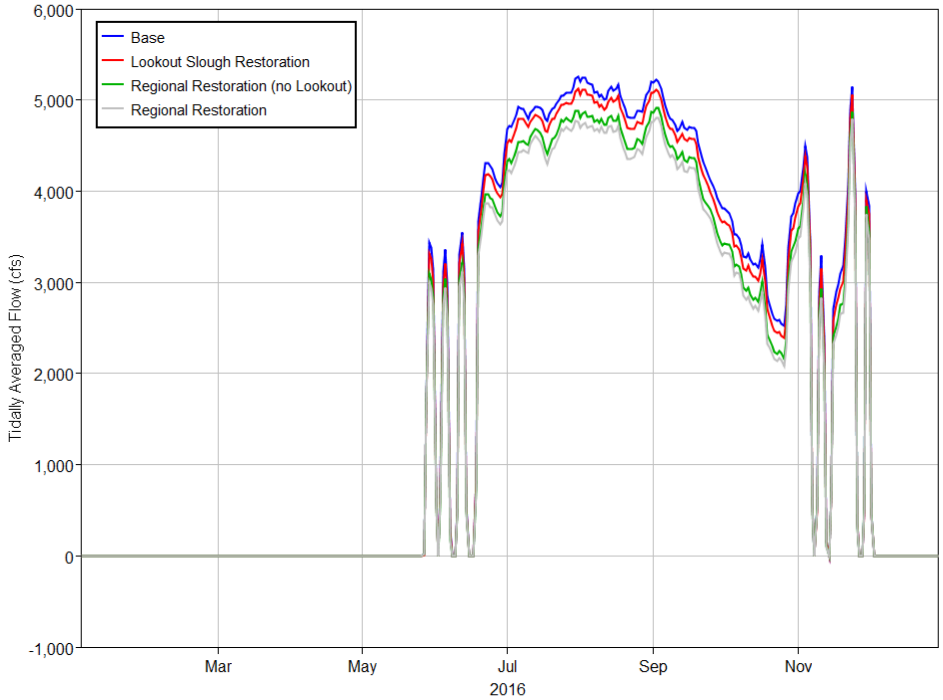

Figure 48 Tidally averaged flow in the Delta Cross Channel for the Base 2016 simulation.

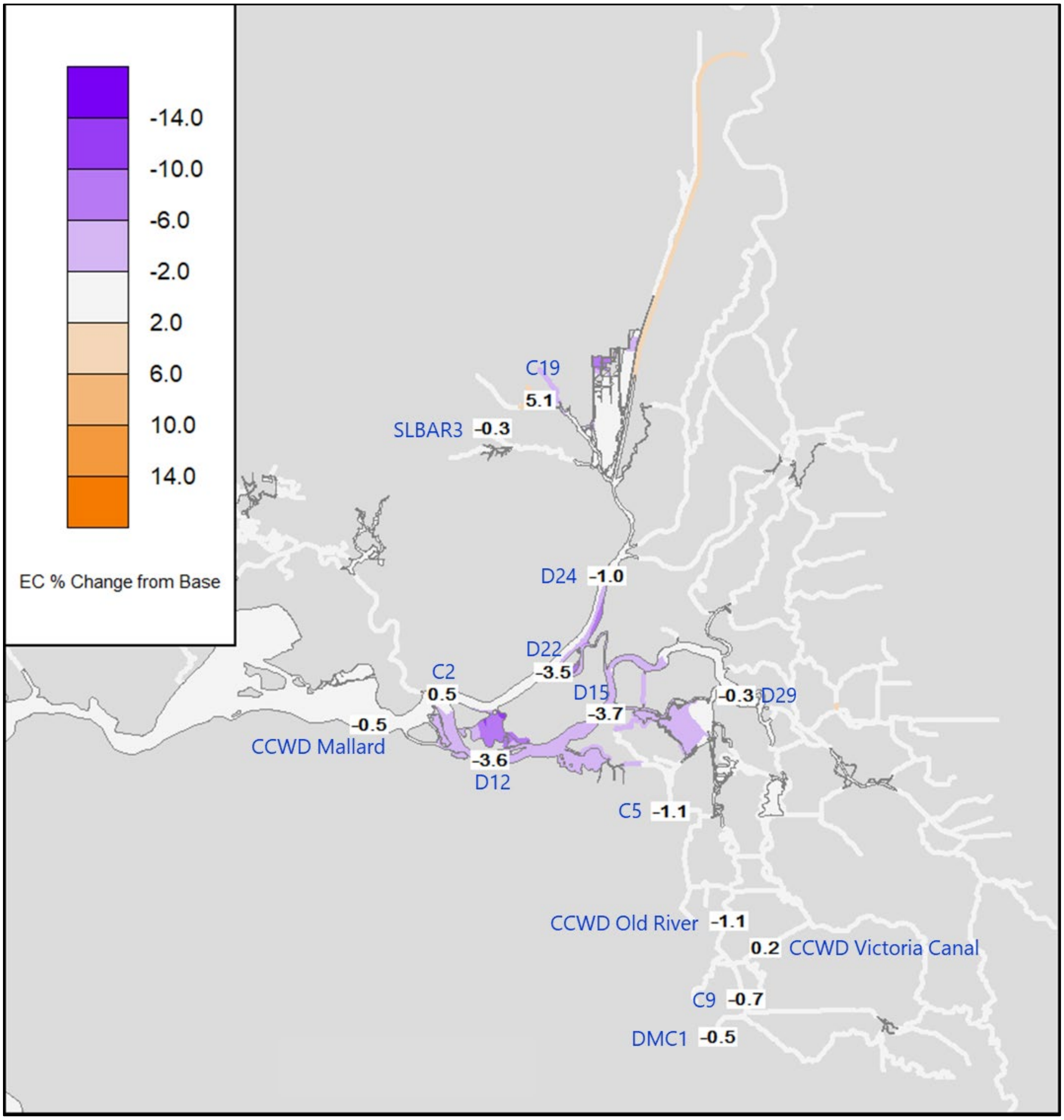

Figure 49 Lookout Slough average percent change from Base EC for July 2009.

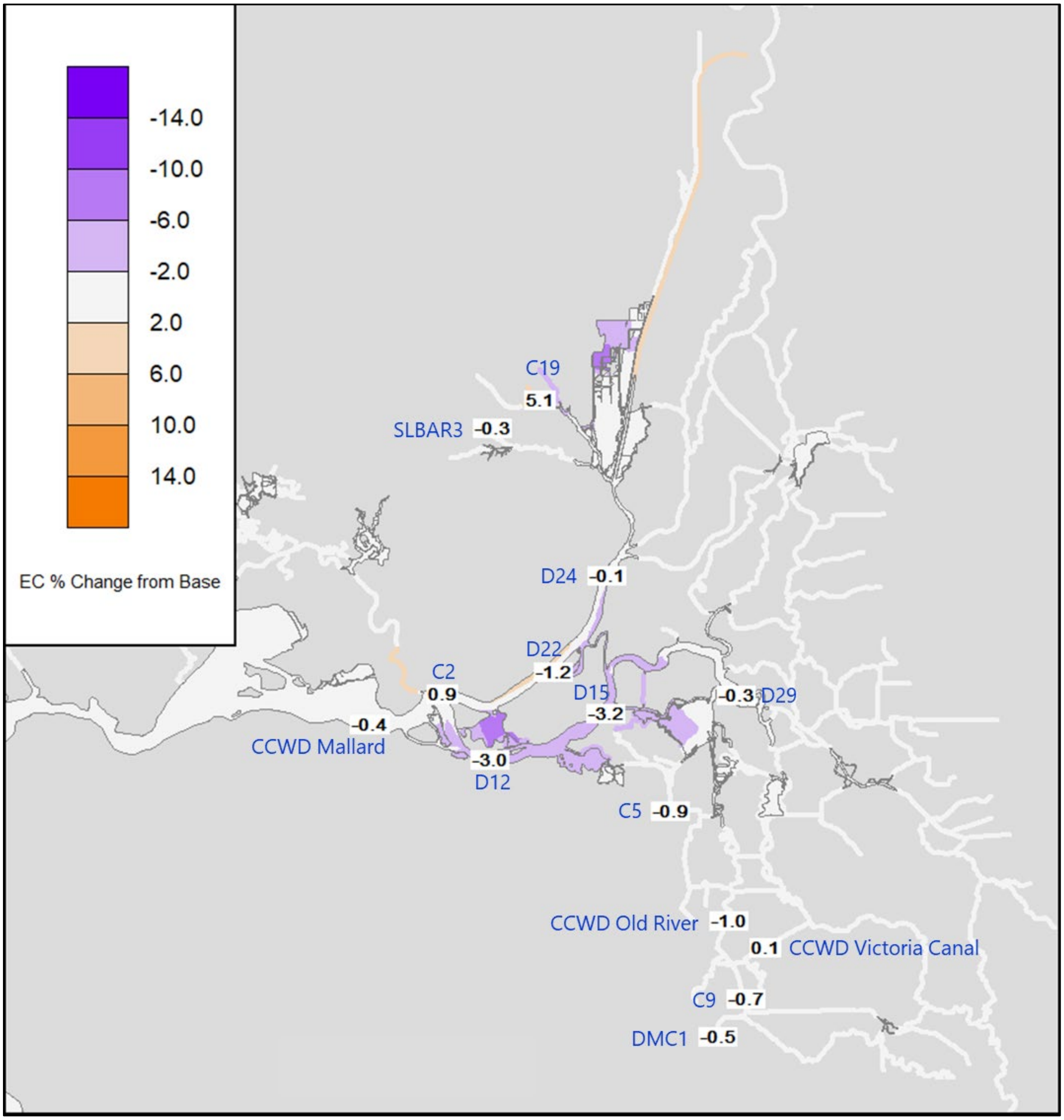

Figure 50 Lookout Slough average percent change from Regional Restoration EC for July 2009.

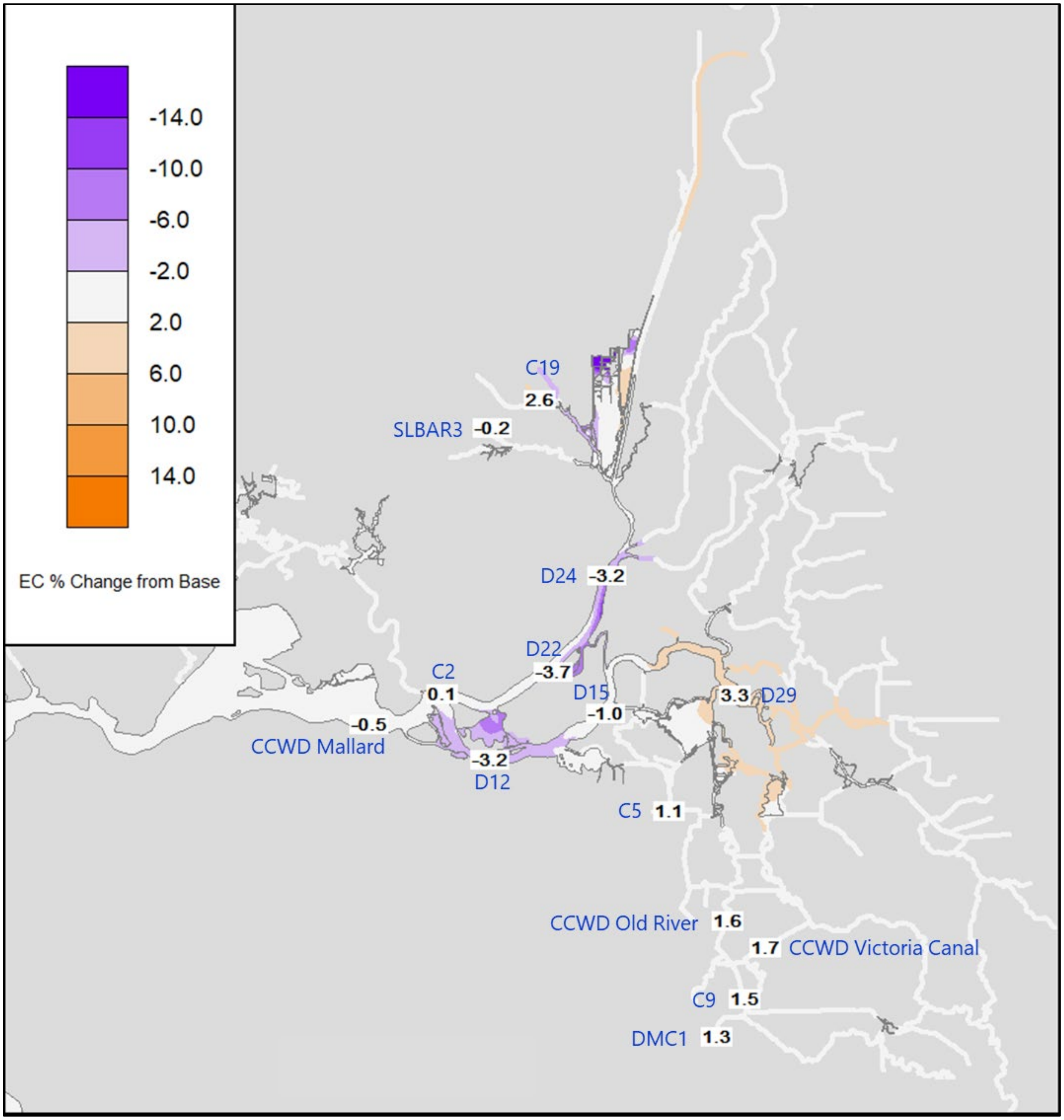

Figure 51 Lookout Slough average percent change from Base EC for October 2009.

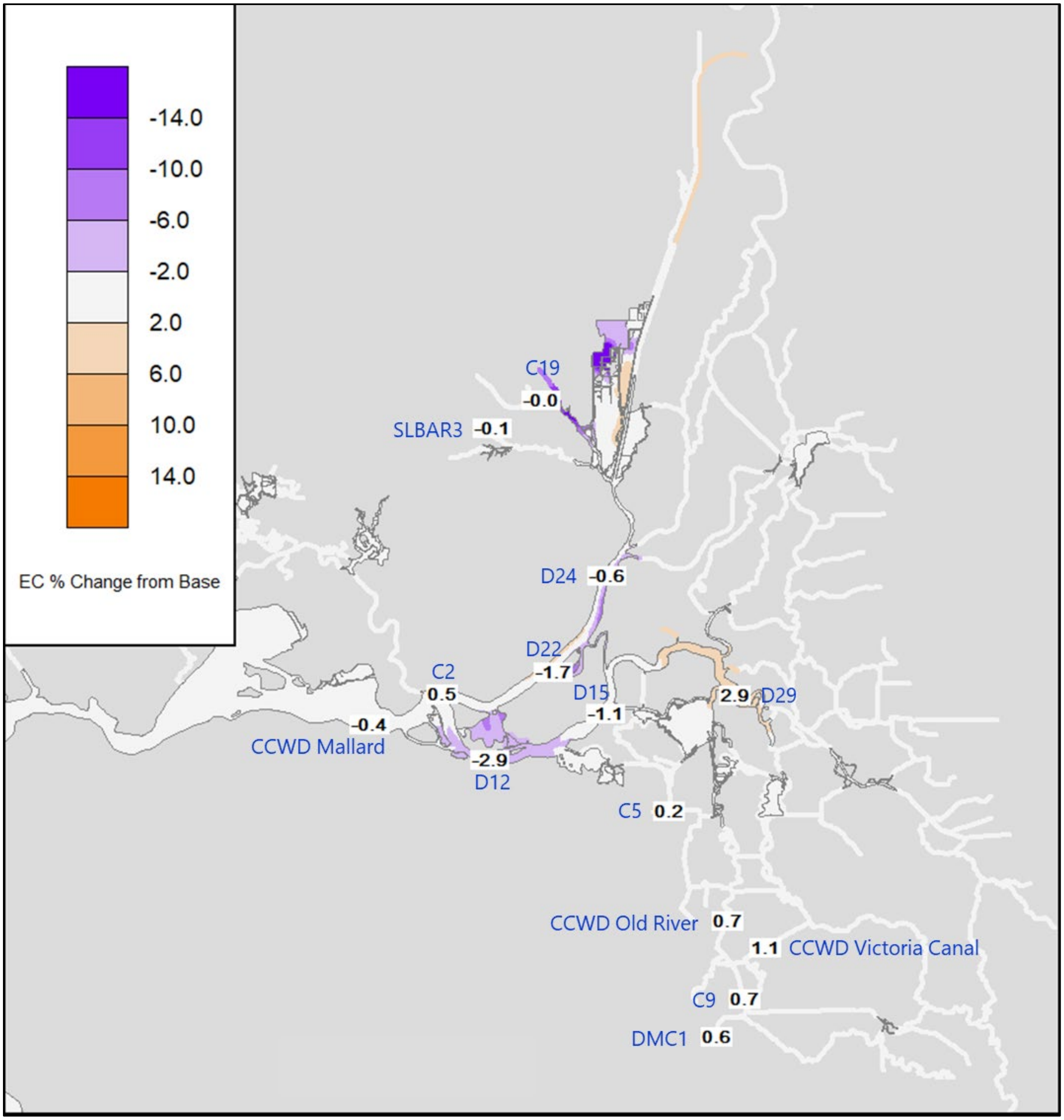

Figure 52 Lookout Slough average percent change from Regional Restoration EC for October 2009.

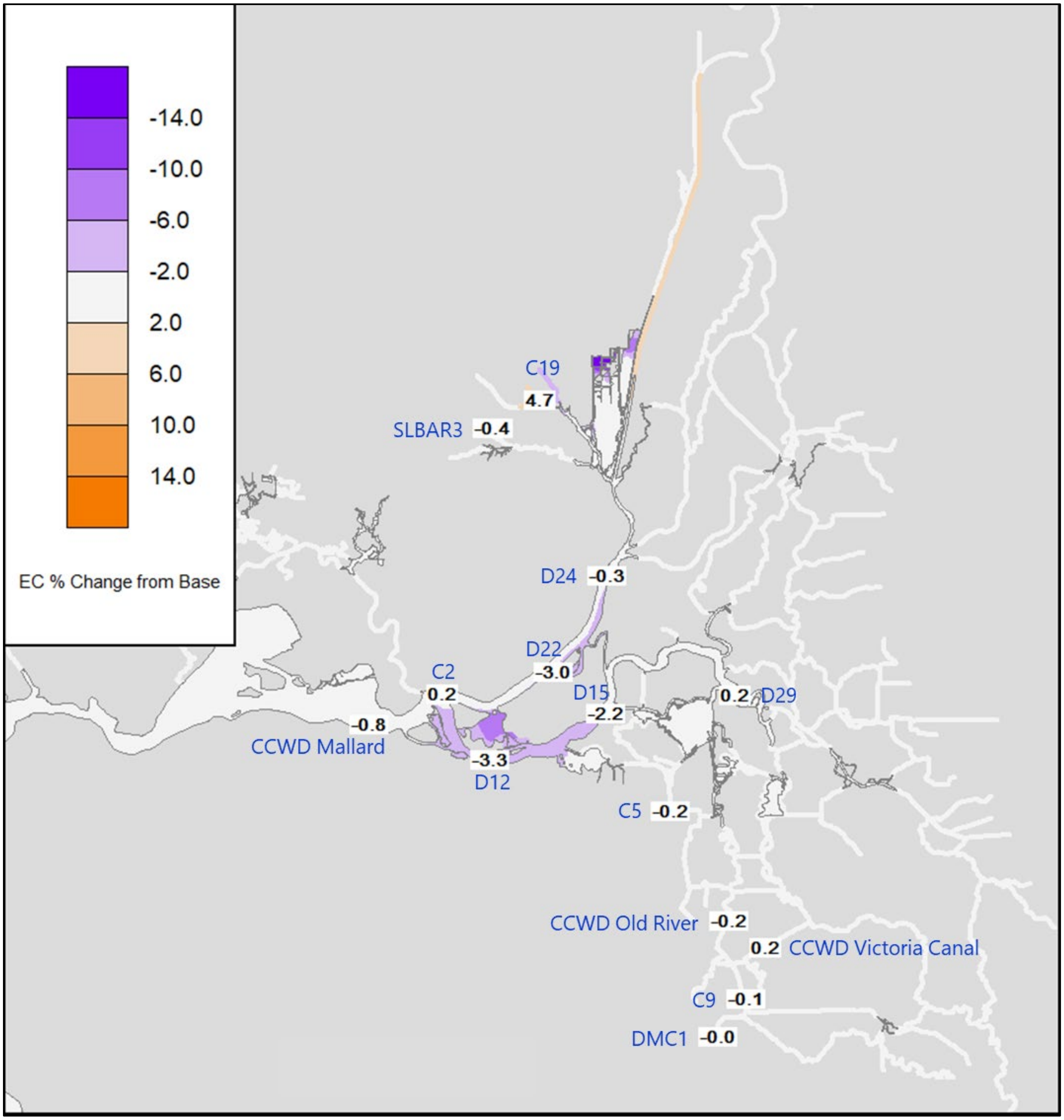

Figure 53 Lookout Slough average percent change from Base EC for July 2010.

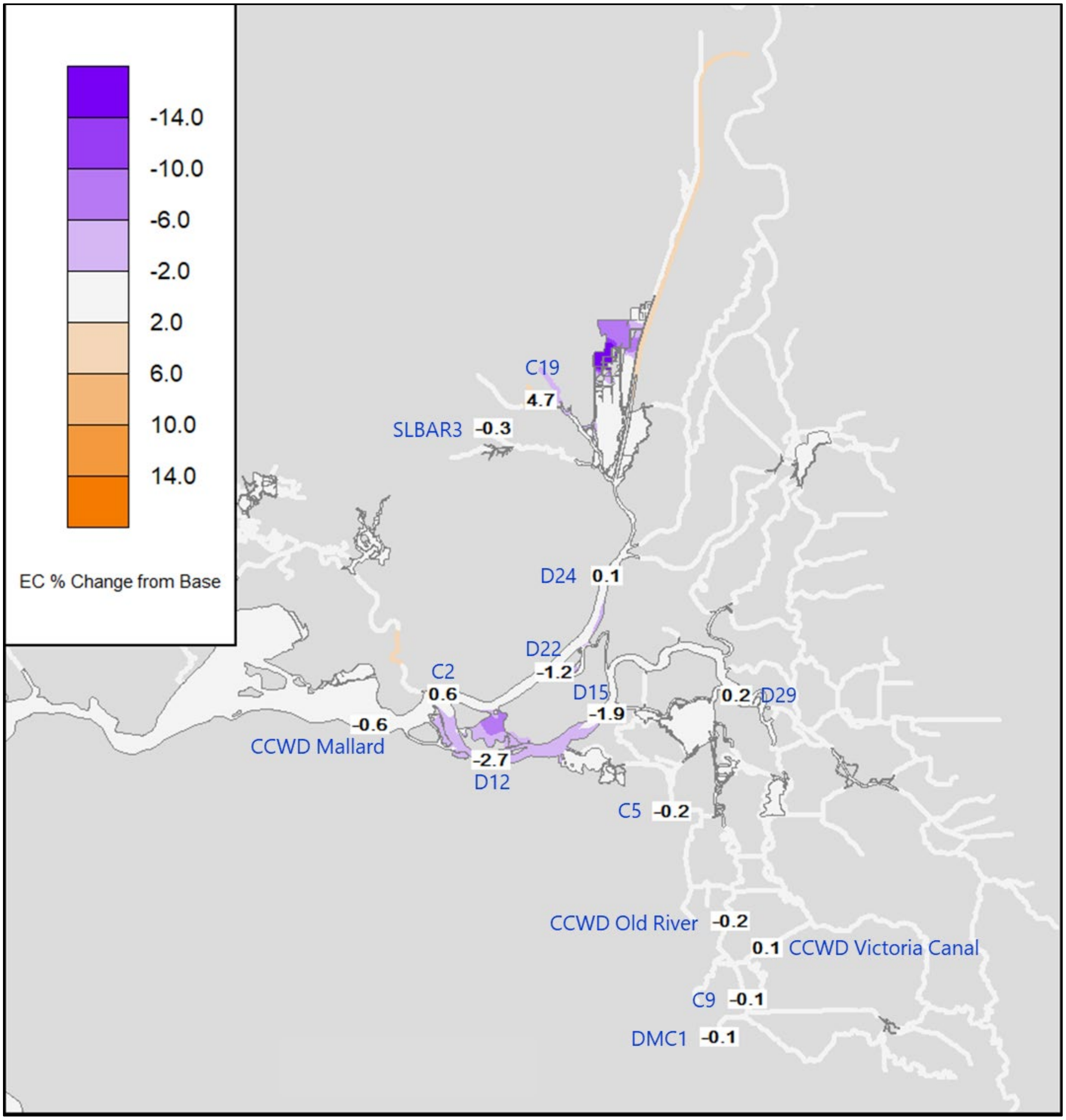

Figure 54 Lookout Slough average percent change from Regional Restoration EC for July 2010.

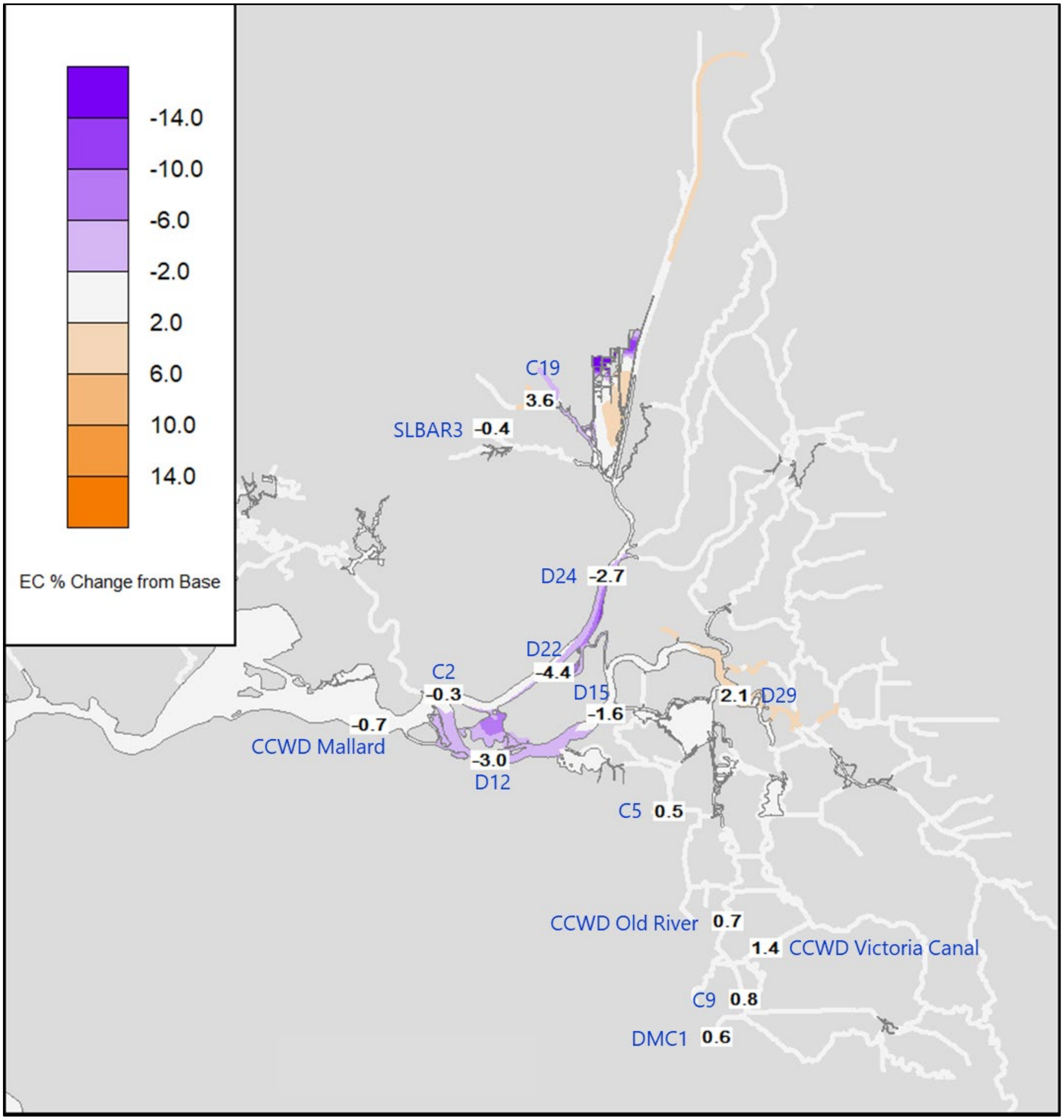

Figure 55 Lookout Slough average percent change from Base EC for October 2010.

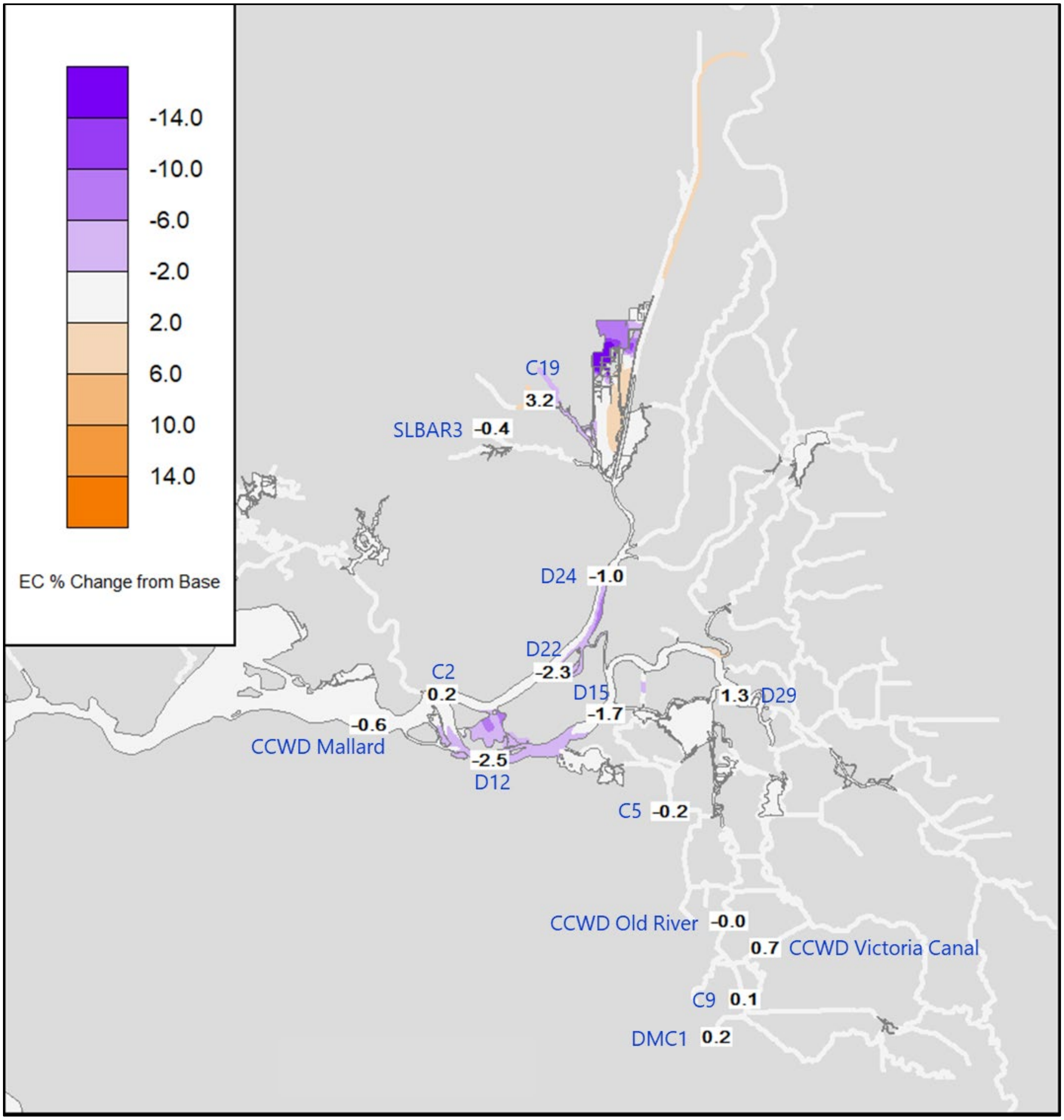

Figure 56 Lookout Slough average percent change from Regional Restoration EC for October 2010.

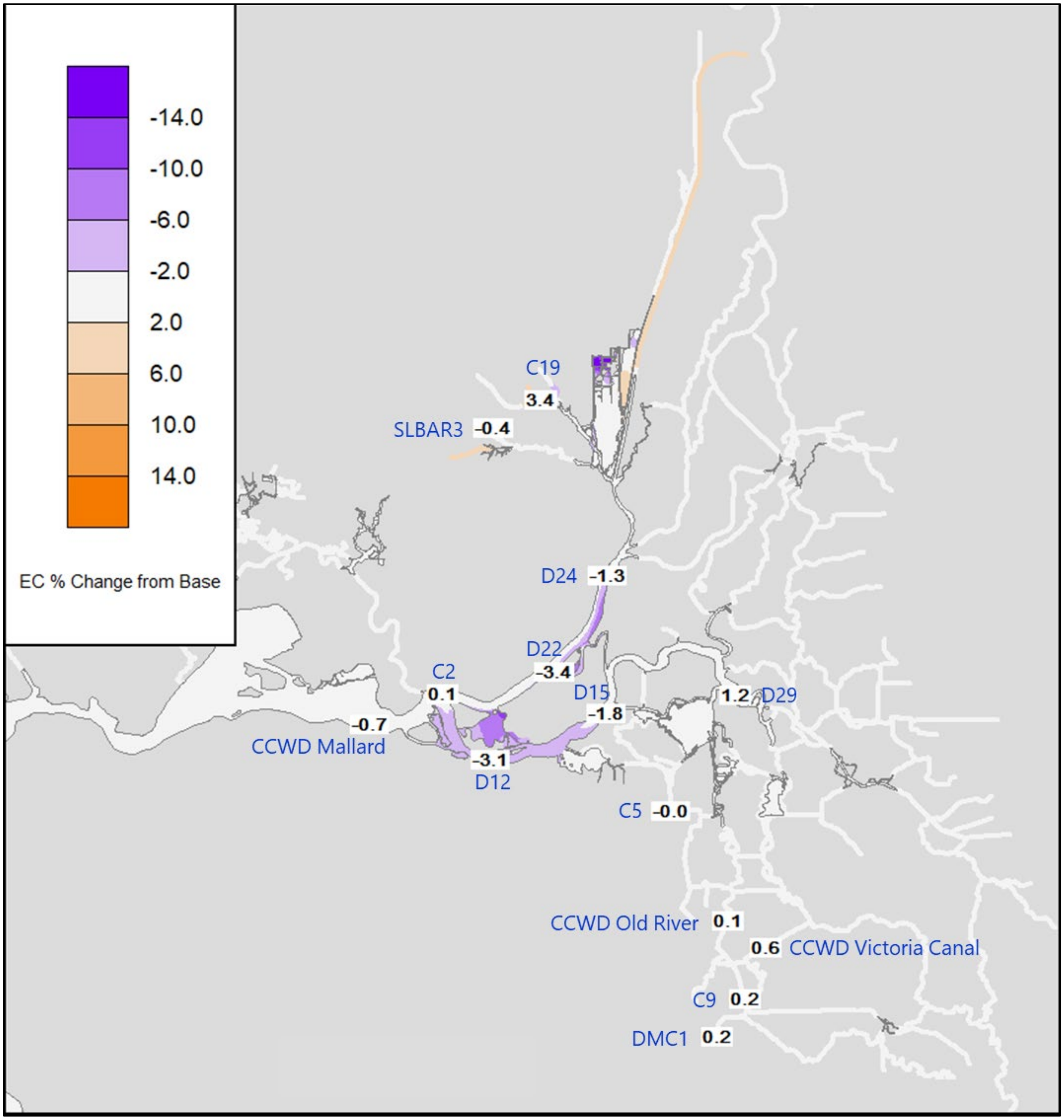

Figure 57 Lookout Slough average percent change from Base EC for July 2016.

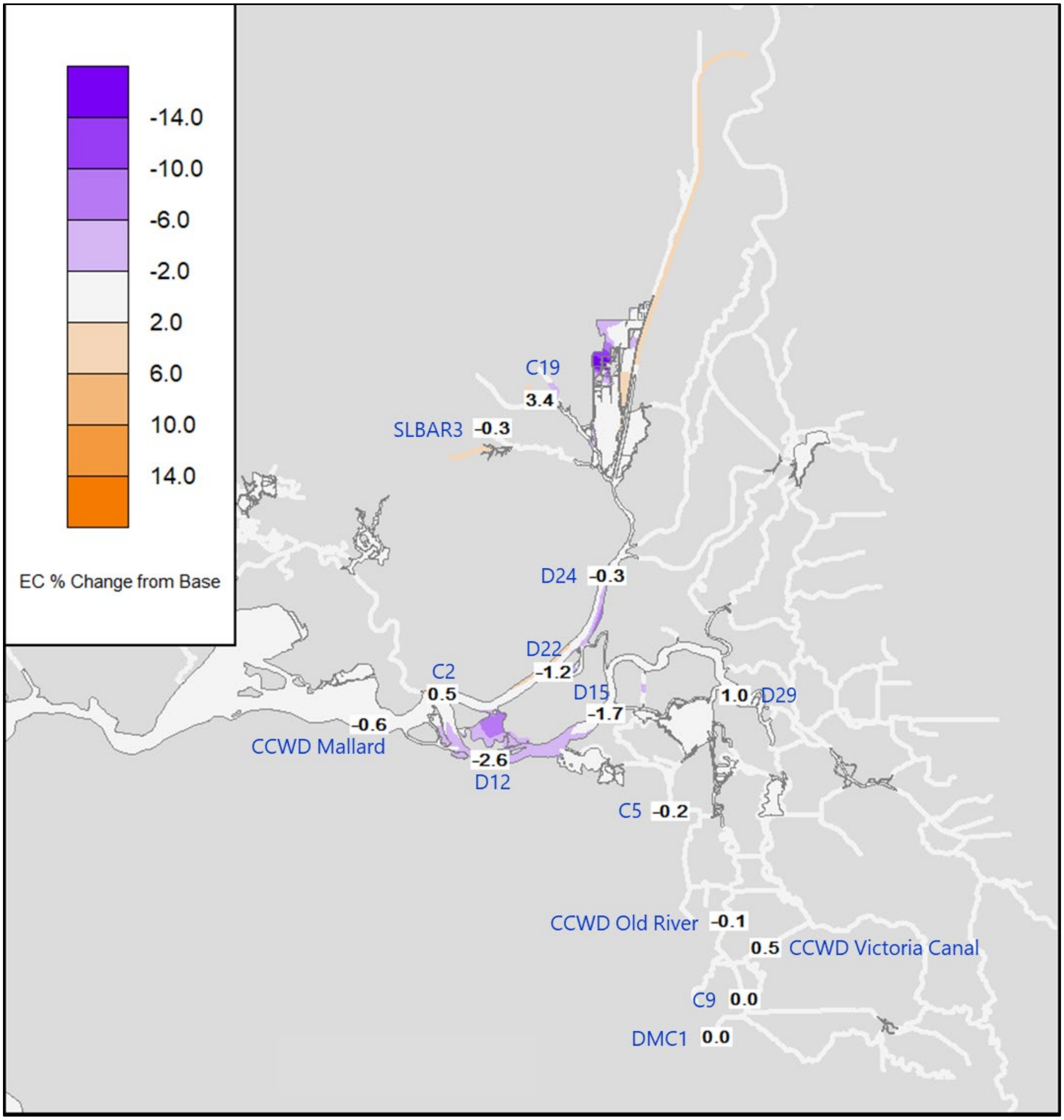

Figure 58 Lookout Slough average percent change from Regional Restoration EC for July 2016.

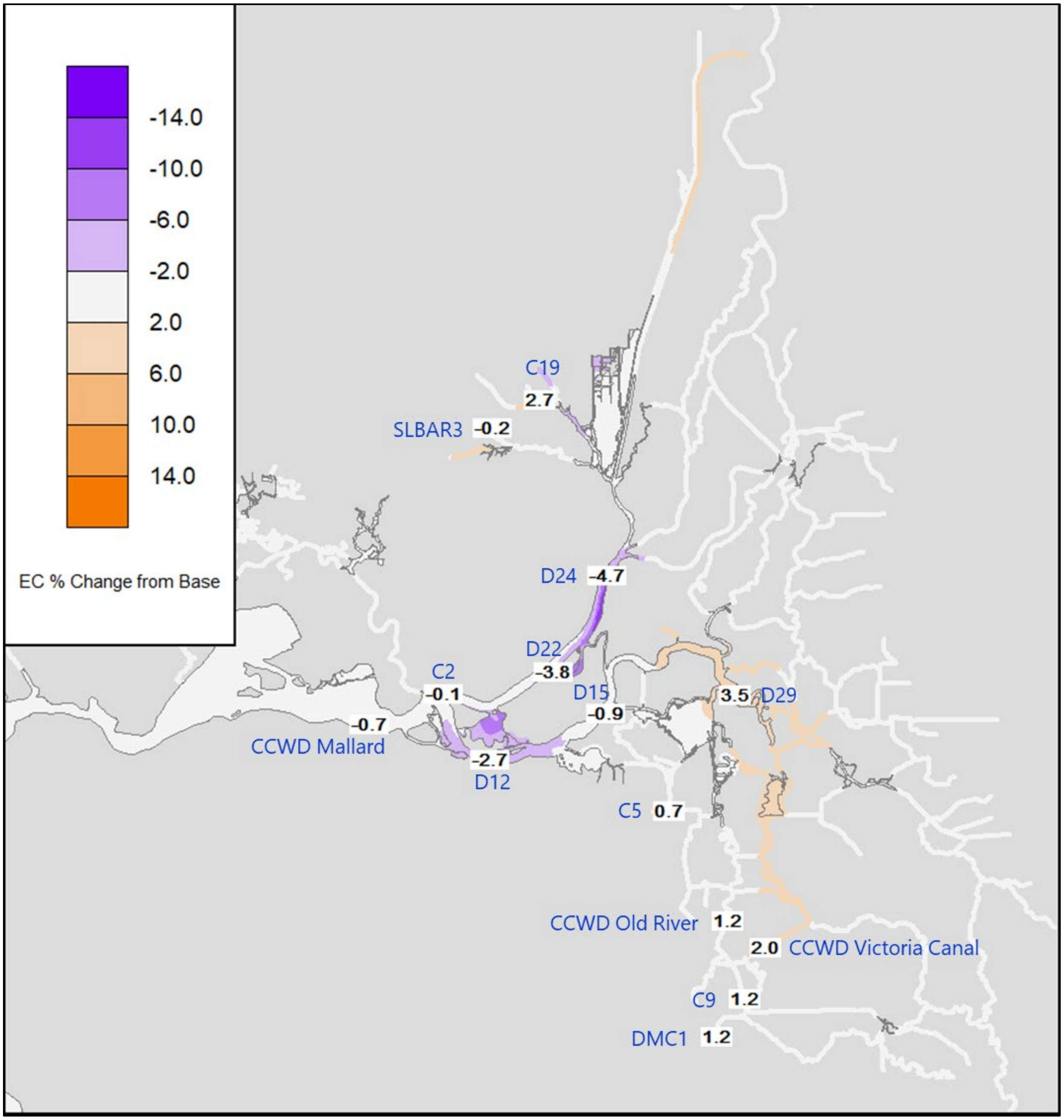

Figure 59 Lookout Slough average percent change from Base EC for October 2016.

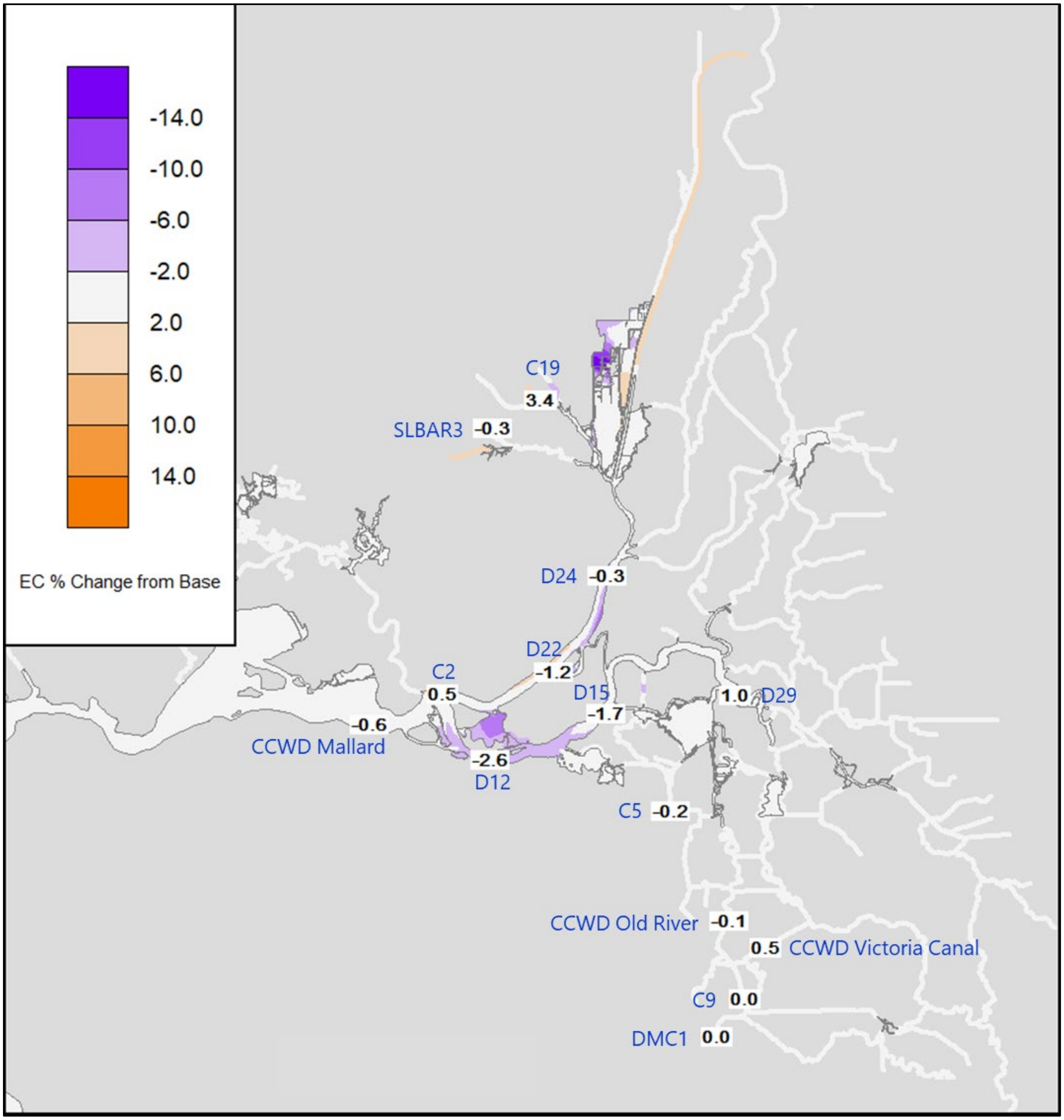

Figure 60 Lookout Slough average percent change from Regional Restoration EC for October 2016.

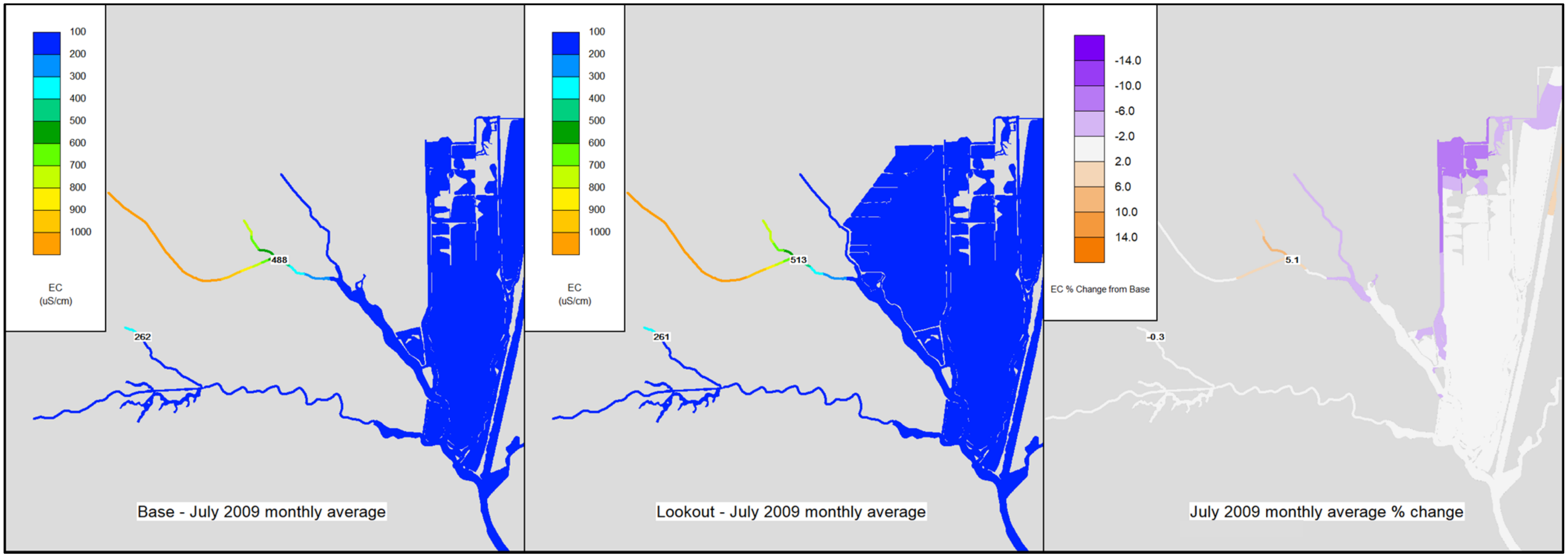

Figure 61 Average July 2009 EC in CSC for Base (left) and Lookout (middle), with average percent change (right).

Evaluation of Potential Non-Compliance at Select D-1641 Stations

The second goal of the salinity modeling analysis was to evaluate the potential for Lookout Slough restoration to result in changes to compliance status with the D-1641 water quality objectives. The compliance locations can be grouped into stations with salinity (EC) water quality objectives for agriculture, and fish and wildlife (Table 6) and chloride objectives for municipal and industrial or water intakes (Table 7).

The water quality objectives applied for 2009 are for the dry Sacramento Valley hydrologic year type. The water quality objectives used for the 2010 and 2016 evaluation are for a below normal hydrologic year type.

Table 6 D-1641 Station Salinity Water Quality Objects – Fish and Wildlife and Agriculture.

Station	Water Year Type [1]	Fish and wildlife		Agriculture			
		Value[2]	Time Period	Value[2]	Time Period	Value[2]	Time Period
Sacramento at Emmaton	Wet	not applicable		0.45	Apr 1 - Aug 15	not applicable	
	Above Normal			0.45	Apr 1 - Jun 30	0.63	Jul 1 - Aug 15
	Below Normal			0.45	Apr 1 - Jun 19	1.14	Jun 20 - Aug 15
	Dry			0.45	Apr 1 - Aug 15	1.67	Jun 15 - Aug 15
	Critical			2.78	Apr 1 - Aug 15	not applicable	
San Joaquin at Jersey Point	Wet	0.44	Apr 1 - May 31	0.45	Apr 1 - Aug 15	not applicable	
	Above Normal	0.44	Apr 1 - May 31	0.45	Apr 1 - Aug 15	not applicable	
	Below Normal	0.44	Apr 1 - May 31	0.45	Apr 1 - Jun 19	0.74	Jun 20 - Aug 15
	Dry	0.44	Apr 1 - May 31	0.45	Apr 1 - Jun 14	1.35	Jun 15 - Aug 15
	Critical	not applicable		2.2	Apr 1 - Aug 15	not applicable	
San Joaquin at Prisoners Point	Wet, Above Normal, Below Normal, Dry	0.44	Apr 1 - May 31	not applicable			
Collinsville[3]	not applicable	19.0	Oct	not applicable			
		15.5	Nov-Dec				
		12.5	Jan				
		8.0	Feb-Mar				
		11.0	Apr-May				

[1] Sacramento Valley Water Year Hydrologic Classification
[2] Maximum 14-day running average of mean daily EC (mmhos/cm)
[3] Maximum monthly average of both daily high tide EC values (mmhos/cm)

Table 7 D-1641 water quality objectives for water intakes.

Compliance Location	Station Number	Criteria Description	Water Year type	Value
Contra Costa at Rock Slough or Antioch Intake	C5 or D12	Maximum mean daily Chloride of 150 mg/L for required number of days	Wet Abv Norm. Blw Norm. Dry Critical	# of days* each calendar year ≤ 150 mg/L Cl 240 190 175 165 155
CCWD at Rock Slough -and- West Canal at Clifton Court -and- DMC Canal at Tracy PP -and- Barker Sl -and- Vallejo PP	C5 C9 DMC1 SLBAR3 C19	Maximum mean daily Chloride	All	250 mg/L

* # of days must be met in intervals not less than two weeks

Agriculture, Fish and Wildlife Compliance Stations

Compliance for each station was determined from the 14-day running average of mean daily EC. The compliance period begins on April 1 and ends August 15 for the Emmaton (D22) and Jersey Point (D15) stations, and end May 31 for the Prisoners Point (D29) station.

Sacramento River at Emmaton (D22)

No potential compliance issues for the Sacramento River at Emmaton (D22) were predicted during the periods analyzed (2009-2010 and 2016), nor did the Lookout Slough project make non-compliance more likely. The 14-Day average observed, Base and Lookout Slough ECs are compared in Figure 62 for 2009 – 2010 and Figure 66 for 2016. Lookout Slough restoration slightly decreases EC at this location.

San Joaquin River at Jersey Point (D15)

The D-1641 compliance period for the Jersey Point location extends from April 1 to August 15. During the summer of 2010, computed EC at Jersey Point recovers slightly sooner than observed so that at the end of the compliance period in 2010 computed Base values are about 200 µmhos/cm higher than observed. As shown in Figure 63, this causes the model to predict non-compliance for both Base and Regional Restoration without Lookout Slough over the last one to two days of the 2010 compliance period. Observed data do not show non-compliance and Lookout Slough restoration decreases EC during this time. Therefore, there is no concern for potential compliance issues, nor did the Lookout Slough project make non-compliance substantially more likely. In 2016 (Figure 67), observed data indicate non-compliance for four days during July. The Base case modeled results indicate a longer period of non-compliance, however, similar to the earlier period, the model overpredicts EC during this time and Lookout Slough restoration decreases EC during this time relative to the Base case, therefore Lookout Slough restoration is not expected to exacerbate non-compliance and could potentially assist with bringing this station into compliance.

<u>San Joaquin River at Prisoners Point (D29)</u>

Figure 64 and Figure 68 show computed 14-Day average EC for all scenarios is well below the compliance standard at Prisoners Point during 2009, 2010 and 2016. Lookout Slough restoration slightly increases EC at this location but does not make non-compliance substantially more likely.

<u>Sacramento River at Collinsville (C2)</u>

At Collinsville, EC compliance is based on the maximum monthly EC value of the daily average of the two high tides. These values are plotted for observed CDEC EC and all modeled scenarios along with the EC standard in Figure 65 for 2009 – 2010 and in Figure 69 for 2016.

Observed data indicate a historical non-compliance with the Fish and Wildlife standard in January and February 2009. The observed EC value (maximum monthly of daily average of two high tides) for January is 13.1 mmhos/cm and the standard is 12.5 mmhos/cm. The observed EC value for February is 9.9 mmhos/cm and the standard is 8.0 mmhos/cm. Lookout Slough results in virtually no change to EC in January and in February increases EC by 0.1 mmhos/cm, slightly worsening the magnitude that compliance is exceeded but does not change the duration of non-compliance.

There are no other compliance issues nor times of increased likelihood of non-compliance during the 2009, 2010 or 2016 periods.

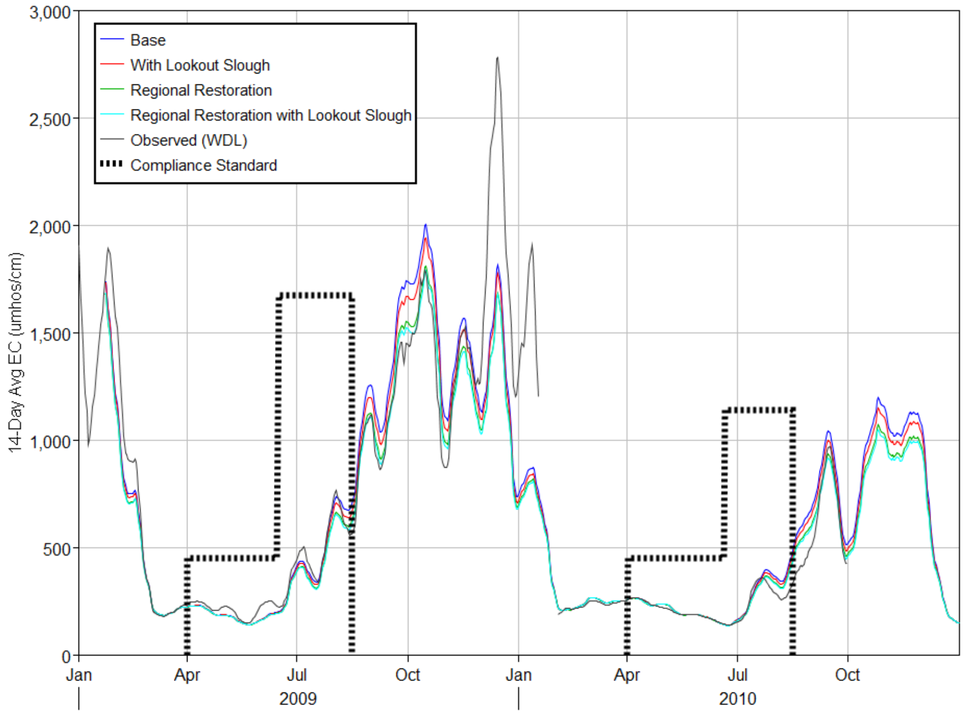

Figure 62 2009 – 2010 14-Day running average EC for the Sacramento River at Emmaton (D22). Results for all modeled scenarios are plotted with the D-1641 standard and observed Emmaton EC.

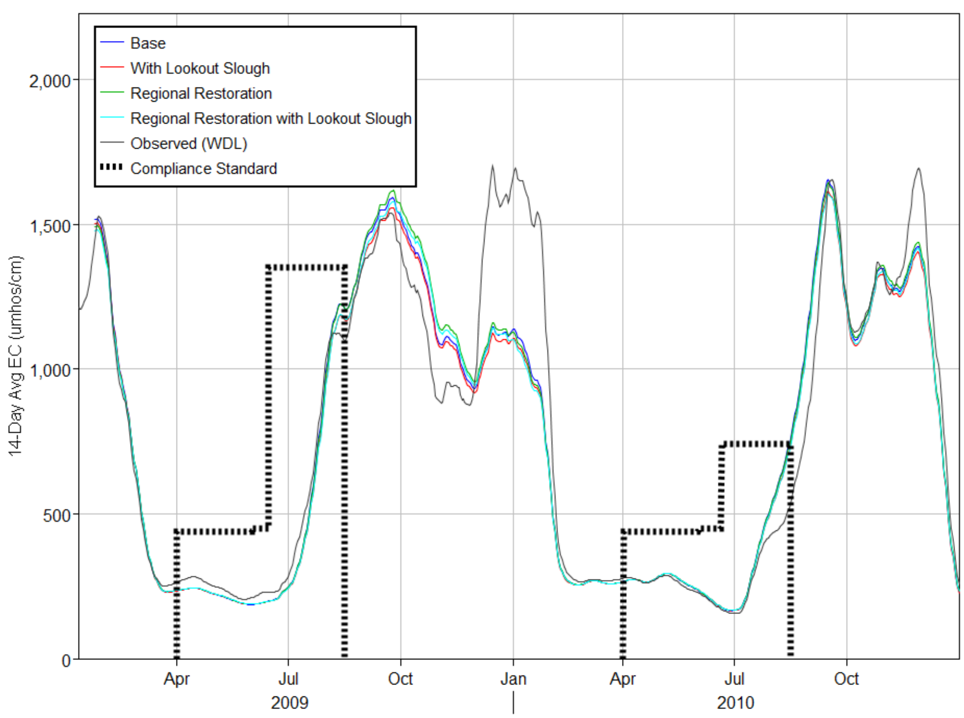

Figure 63 14-Day running average EC for the San Joaquin River at Jersey Point (D15). Results for all modeled scenarios are plotted with the D-1641 standard and observed Jersey Point EC.

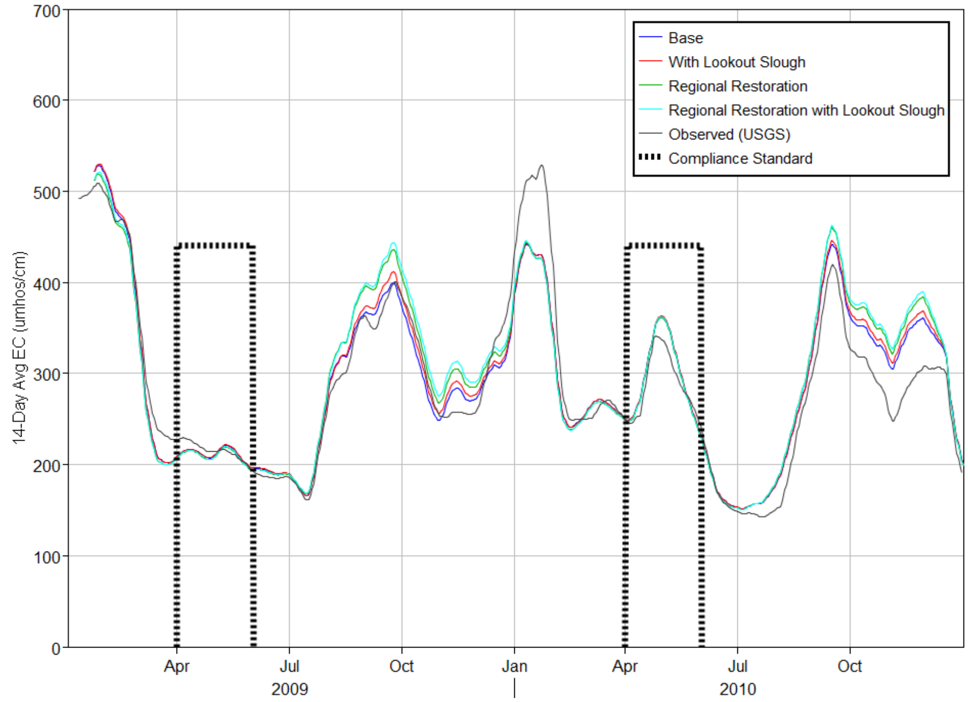

Figure 64 2009 -2010 14-Day running average EC for the San Joaquin River at Prisoners Point (D29). Results for all modeled scenarios are plotted with the D-1641 standard and observed Prisoners Point EC.

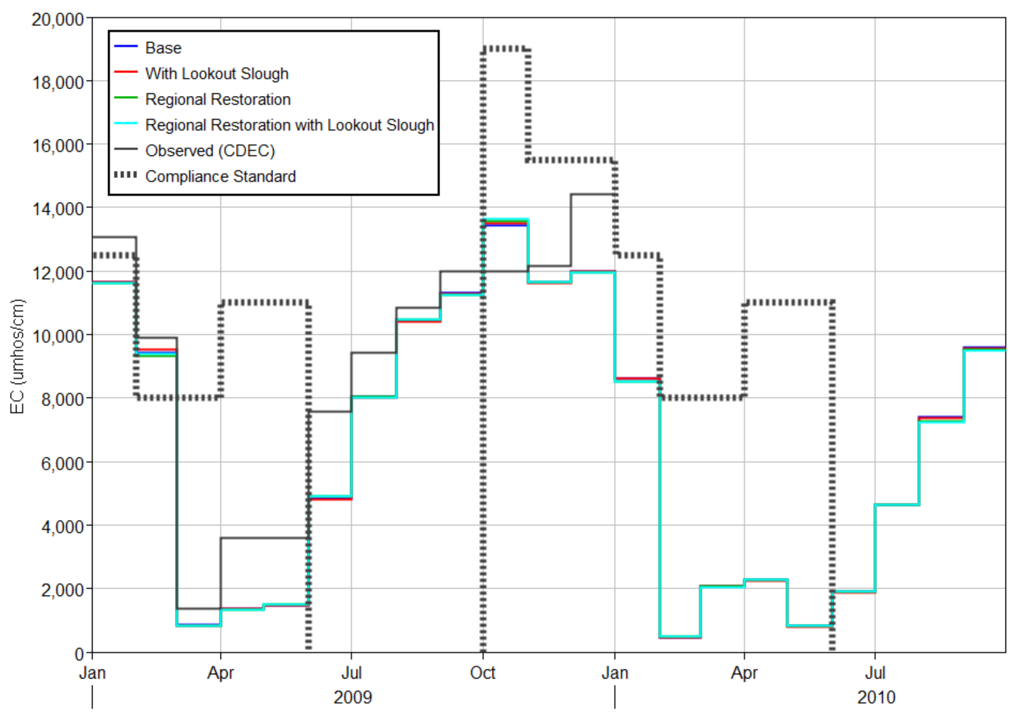

Figure 65 2009 – 2010 max monthly of daily average of high tide EC for the Sacramento River at Collinsville (C2). Results for all modeled scenarios are plotted with the D-1641 standard and observed Collinsville EC.

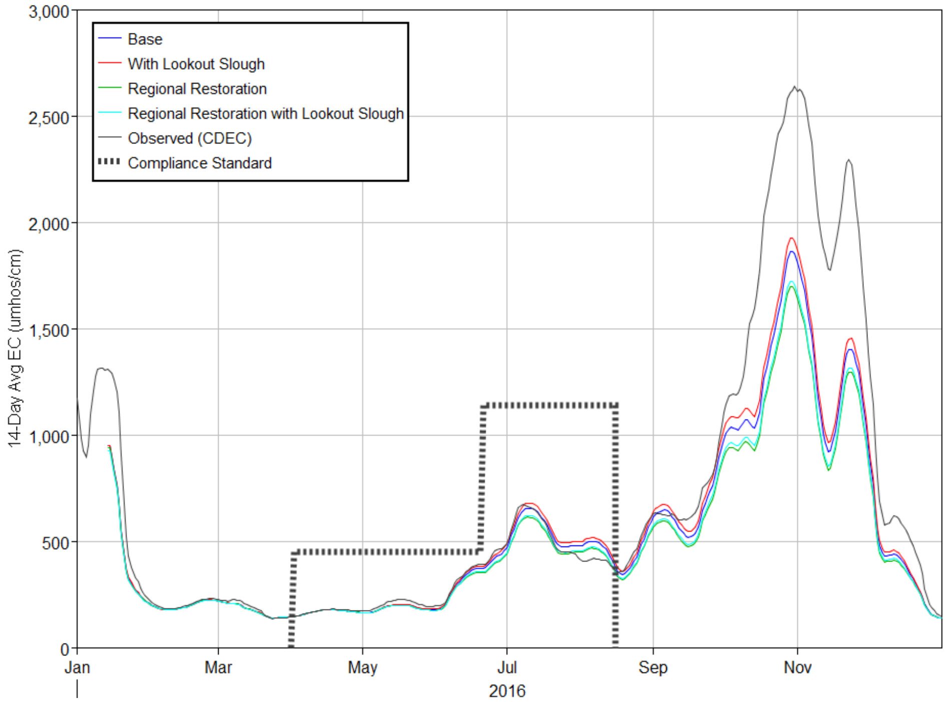

Figure 66 2016 14-Day running average EC for the Sacramento River at Emmaton (D22). Results for all modeled scenarios are plotted with the D-1641 standard and observed Emmaton EC.

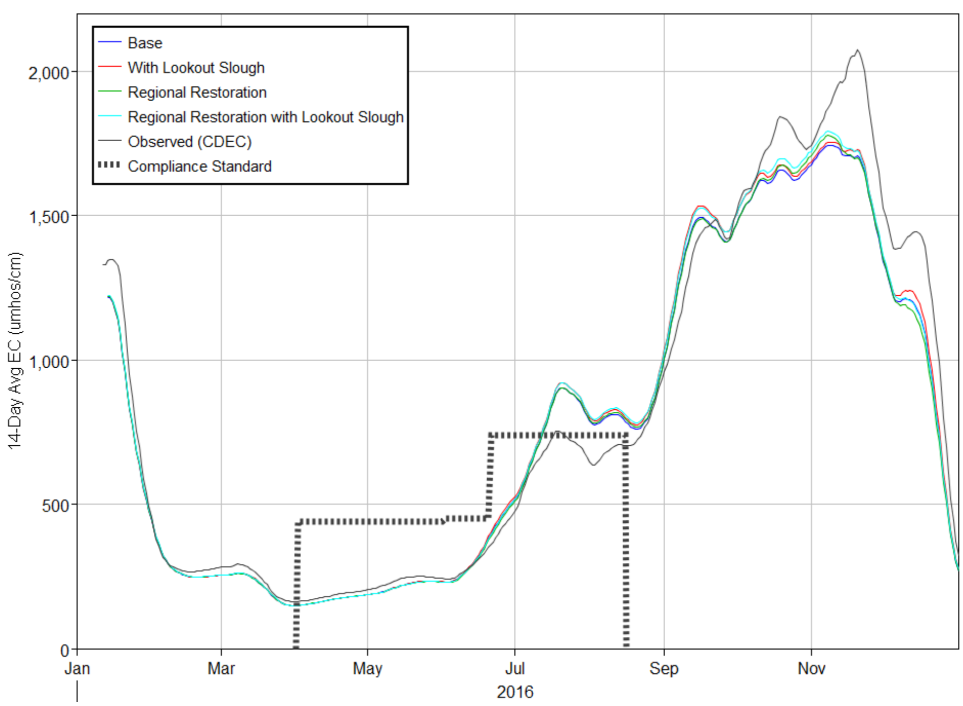

Figure 67 2016 14-Day running average EC for the San Joaquin River at Jersey Point (D15). Results for all modeled scenarios are plotted with the D-1641 standard and observed Jersey Point EC.

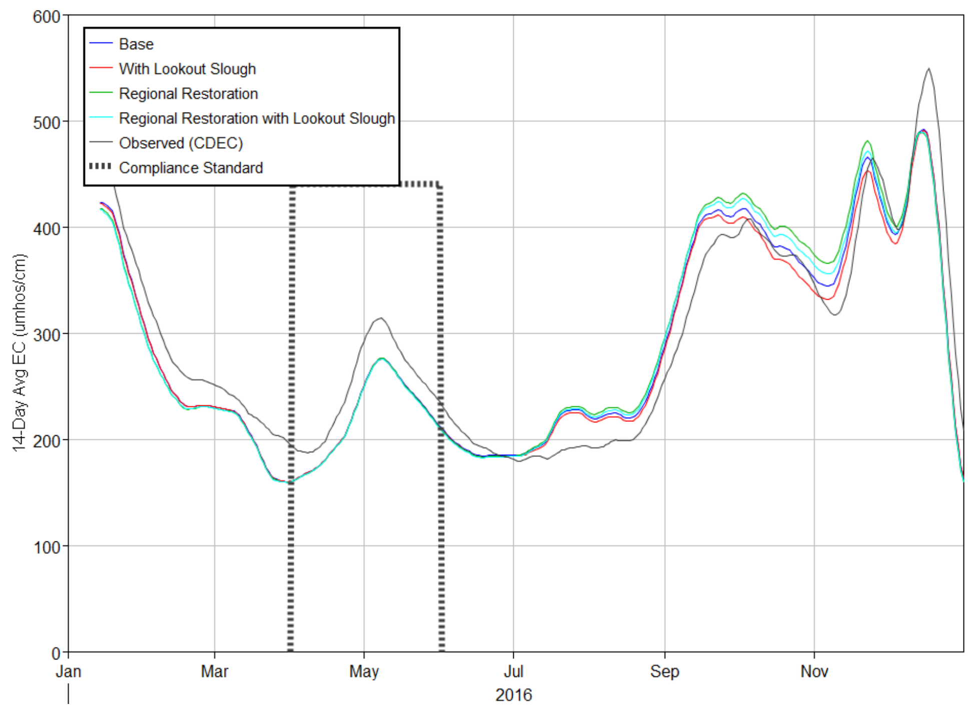

Figure 68 2016 14-Day running average EC for the San Joaquin River at Prisoners Point (D29). Results for all modeled scenarios are plotted with the D-1641 standard and observed Prisoners Point EC.

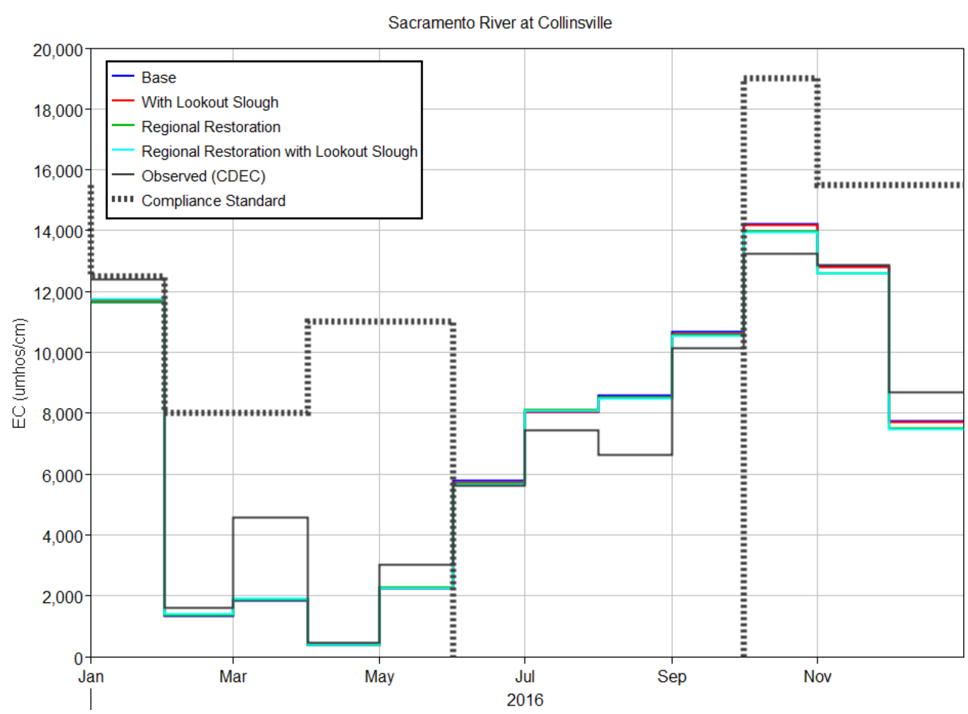

Figure 69 2016 max monthly of daily average of high tide EC for the Sacramento River at Collinsville (C2). Results for all modeled scenarios are plotted with the D-1641 standard and observed Collinsville EC.

Water Intakes

D-1641 water quality objectives at the water intakes are based on chloride, which can be estimated from the modeled EC results along with volumetric source fraction from Martinez. To determine the volumetric source fraction, Martinez fingerprinting simulations were performed for all scenarios and time periods. Martinez volumetric source fraction simulation results can be found in Appendix C: Martinez Volumetric Source Fraction.

Chloride was estimated from modeled EC in conjunction with volumetric Martinez fraction based on the following equations (USBR, 2010).

When volumetric Martinez source fraction is greater than or equal to 0.4%:

$Cl = 0.285(EC) - 50$

When volumetric Martinez source fraction is less than 0.4%:

$Cl = 0.15(EC) - 12$

Other versions of these equations were considered (Denton, 2015; RMA, 2010). All resulted in the same conclusion that there were no violations of the water quality objectives at any of the intakes under any of the modeled configurations or time periods. Chloride criteria, based on the maximum mean daily chloride value, are summarized in Table 7. Results for each simulation year are summarized in Table 8 through Table 10. Relative to Base and Regional Restoration, Lookout Slough restoration had almost no impact on the maximum mean daily chloride values used to determine compliance.

Table 8 Chloride results at D-1641 water intakes for 2009.

	Base	With Lookout	Regional Restoration	Regional Rest with Lookout
Intake Location	**# days < 150 mg/L (165 days req'd at Rock Slough or Antioch)**			
CC Rock Slough*	293	293	279	280
Antioch	119	119	119	119
	Max mean daily chloride, mg/L (req'd < 250 mg/L)			
CC at Rock Slough	198	198	197	197
CC at Old River	176	176	174	174
CC at Victoria Canal	153	153	153	153
West Canal at Clifton Court	196	196	195	195
DMC Canal	224	224	223	223
Barker Slough	76	76	76	75
C19	139	141	141	141

* # of days are consecutive, meeting the requirement that criteria must be met in intervals of not less than two weeks

Table 9 Chloride results at D-1641 water intakes for 2010.

Intake Location	Base	With Lookout	Regional Restoration	Regional Rest with Lookout
	# days < 150 mg/L (165 days req'd at Rock Slough or Antioch)			
CC Rock Slough*	312	313	295	295
Antioch	183	183	183	183
	Max mean daily chloride, mg/L (req'd < 250 mg/L)			
CC at Rock Slough	182	181	185	184
CC at Old River	152	152	157	155
CC at Victoria Canal	107	108	107	107
West Canal at Clifton Court	142	142	142	142
DMC Canal	177	177	178	178
Barker Slough	79	78	78	77
C19	134	136	136	136

* # of days are in intervals not less than two weeks

Table 10 Chloride results at D-1641 water intakes for 2016.

	Base	With Lookout	Regional Restoration	Regional Rest with Lookout
Intake Location	**# days < 150 mg/L (165 days req'd at Rock Slough or Antioch)**			
Rock Slough*	245	246	245	245
Antioch	148	148	148	148
	Max mean daily chloride, mg/L (req'd < 250 mg/L)			
CC at Rock Slough	210	210	211	211
CC at Old River	168	168	167	168
CC at Victoria Canal	138	138	138	138
West Canal at Clifton Court	157	157	157	157
DMC Canal	147	148	147	148
Barker Slough	89	89	89	89
C19	158	158	158	158

* # of days are consecutive, meeting the requirement that criteria must be met in intervals not less than two weeks

X2

X2 distances for all modeled scenarios are plotted in Figure 70 and Figure 72, with monthly averaged differences plotted in Figure 71 and Figure 73. Lookout Slough Restoration results in small (< 0.2 km on a monthly averaged basis) reductions in X2, and therefore is not predicted to cause or exacerbate non-compliance with X2 objectives.

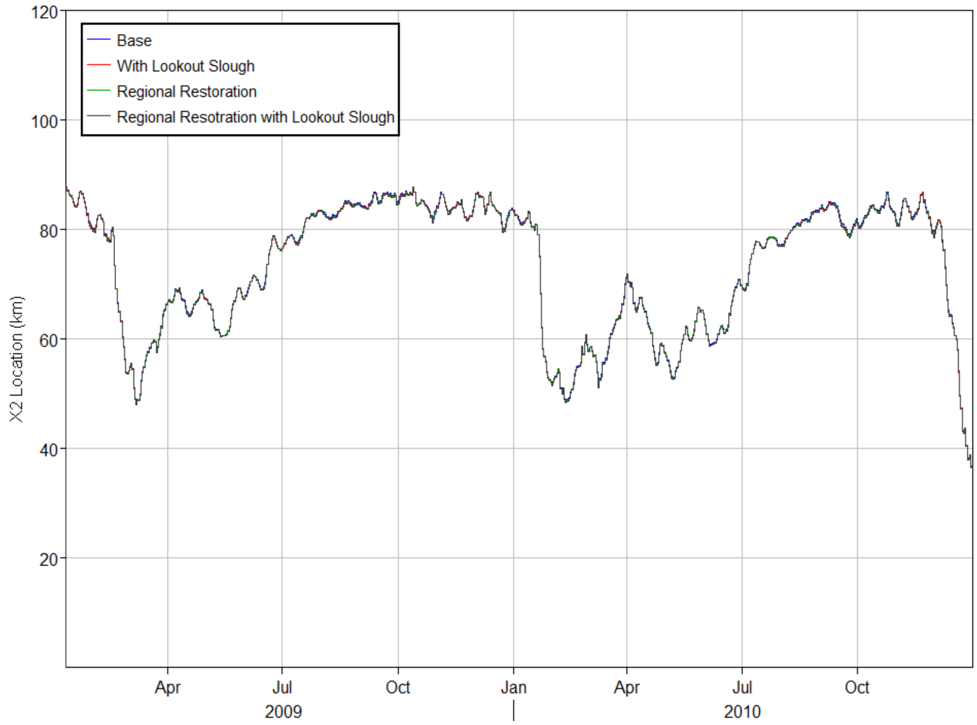

Figure 70 X2 locations for the 2009 - 2010 simulation period.

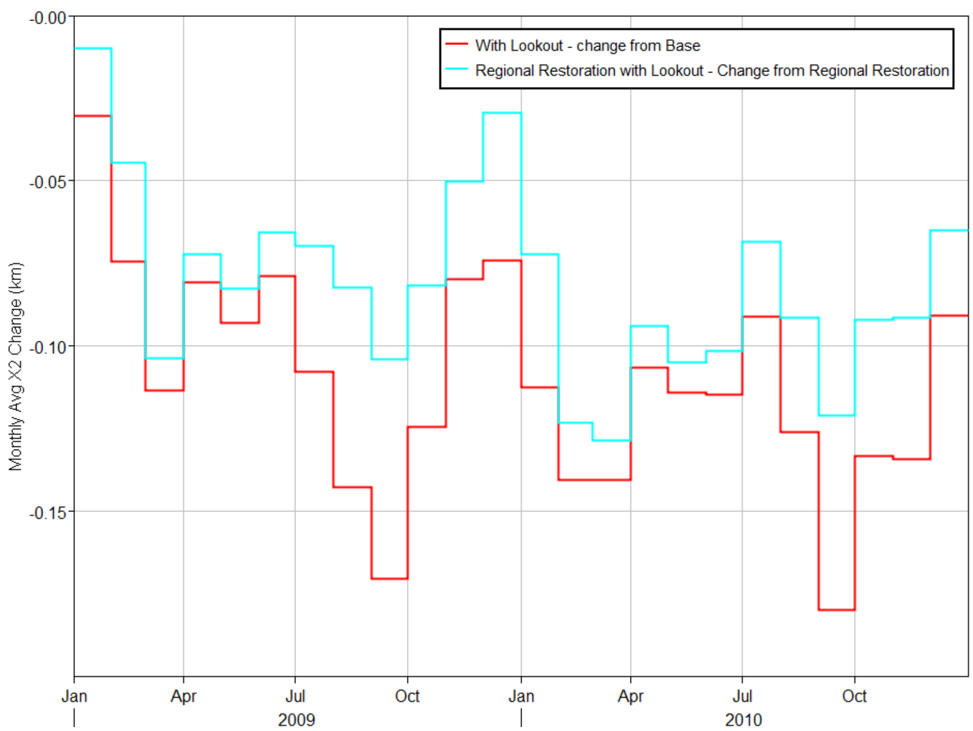

Figure 71 Monthly average change in X2 location for the 2009 - 2010 simulation period.

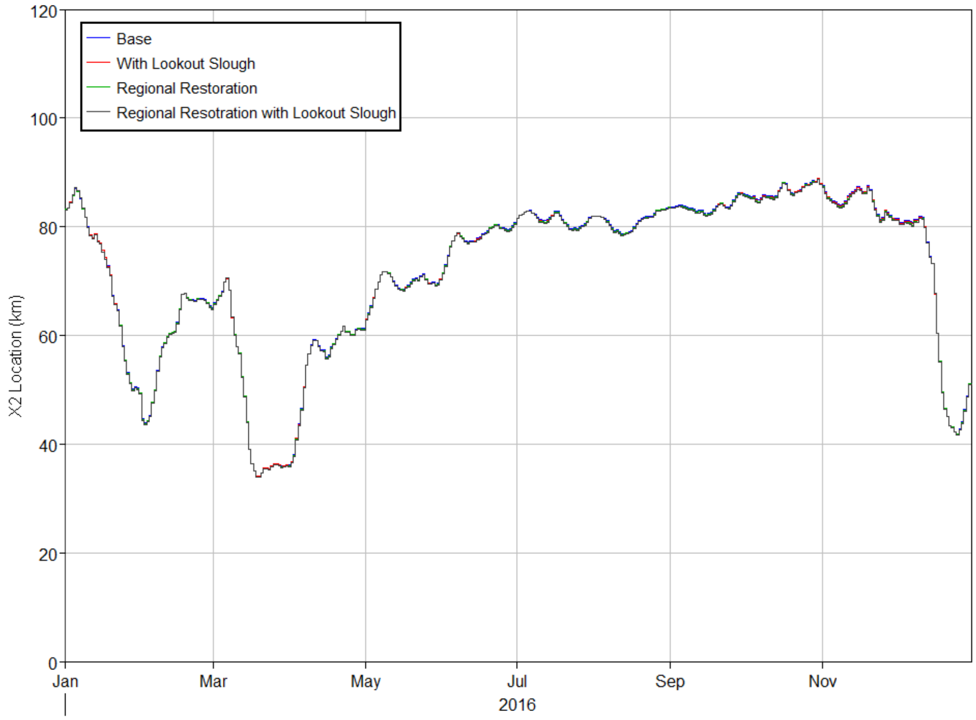

Figure 72 X2 locations for the 2016 simulation period.

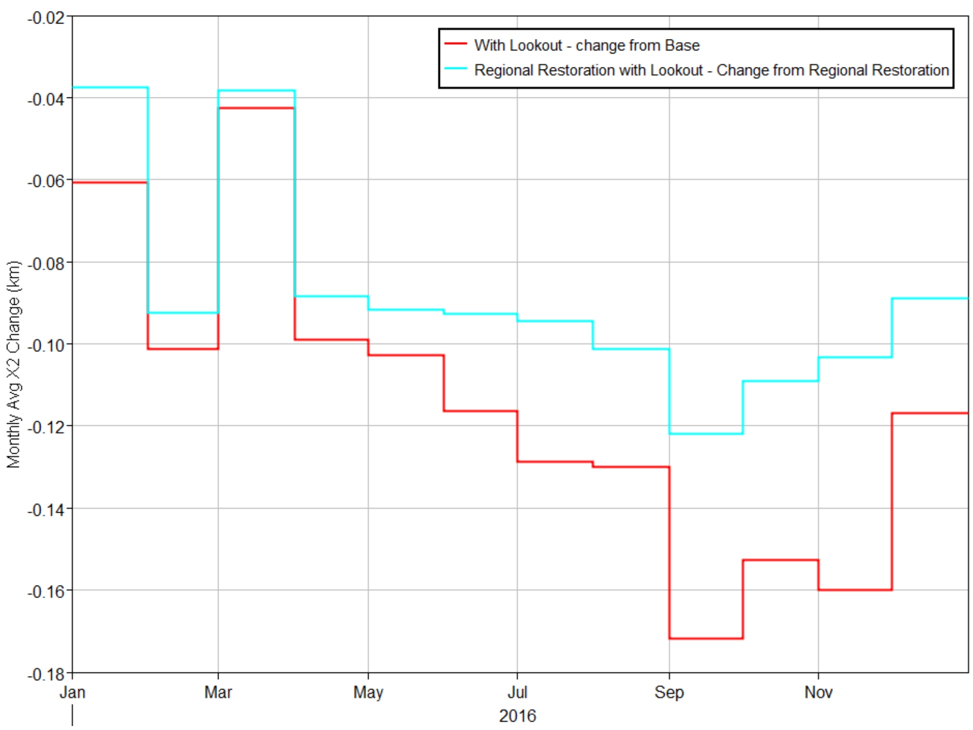

Figure 73 Monthly average change in X2 location for the 2016 simulation period.

Evaluation of Bromide Impacts at Drinking Water Intakes

Bromide can be estimated from the modeled EC results along with volumetric source fraction from Martinez. To determine the volumetric source fraction, Martinez fingerprinting simulations were performed for all scenarios and time periods. For these simulations, a tracer was applied at Martinez and the fraction of tracer was output at each water intake location. Martinez volumetric source fraction simulation results can be found in Appendix C: Martinez Volumetric Source Fraction. Martinez volumetric source fraction is an indication of fraction of seawater.

Bromide was estimated from modeled EC in conjunction with volumetric Martinez fraction based on the following equations (USBR, 2015).

When volumetric Martinez source fraction is greater than or equal to 0.4%:

$$Br = 0.000827(EC) - 0.112 \qquad (1)$$

When volumetric Martinez source fraction is less than 0.4%:

$$Br = 0.000552(EC) - 0.073 \qquad (2)$$

These equations were developed based on whether water at any location is seawater or riverine dominant. Seawater is typically the primary source of bromide in the Delta, so equation (1) is appropriate for estimating bromide from EC in the central and south Delta where EC variations from the Lookout Slough restoration are predominantly due to changes in the seawater fraction. In the north Delta where seawater fractions are very small and salinity is from local sources (neither seawater nor riverine), the USBR (2015) equations may not be appropriate. While the USBR equations have been applied to the Barker Slough and Vallejo water intakes with results reported below, they should be interpreted with caution. The direction of bromide change likely follows the direction of EC change in the north Delta, however, there is uncertainty in the predicted magnitude of change based on the USBR equations.

Daily averaged bromide results are provided at the water intake locations as time series of bromide and absolute and relative (%) change from Base/Regional Restoration bromide in Figure 78 through Figure 82 for the 2009 – 2010 period and in Figure 87 through Figure 91 for the 2016 period. These values are also monthly averaged and summarized in tabular format in Table 11 for 2009, in Table 12 for 2010 and in Table 13 for 2016. Tabular results are provided with sufficient detail to provide reader with information about small changes. While this level of precision is available from the water quality (EC) model, the model's accuracy is likely only one to two significant digits with further uncertainty in the EC to bromide conversions. Although there is uncertainty in the results, as reflected by the effective significant digits, the model is considered sufficient for assessing potential impacts, particularly for the direction of change and relatively small % change. Additionally, the USBR (2015) equations are considered sufficient for converting EC to bromide for assessing potential impacts when EC change is primarily due to changes in seawater fraction.

Since bromide is calculated as a function of EC as shown in the equations above, the causes for the changes in bromide are the same as the causes for the changes in EC discussed in section above (see EC Changes at Compliance Locations). The general observations for the 2009 Lookout Slough bromide results (Table 11) are:

- Largest percent bromide increases (outside north Delta) due to Lookout Slough restoration occur during the fall at the CCWD intake at Victoria Canal (2.6% relative to Base / 1.9% relative to Regional Restoration).
- Bromide increases greater of 1 to 3% occur in the fall at all south Delta water intakes.
- Largest percent bromide decreases due to Lookout Slough occur at Antioch where decreases are 3% - 4% from April through December. Peak percent decreases occur in June.
- Bromide decreases of 1 to 3% also occur at Barker Slough (various times throughout the year), decreases of up to 1% at C19 (winter and late fall, relative to Regional Restoration only), decreases of 1 to 2% during the spring at Contra Costa at Mallard, and during the summer at the CCWD intakes at Rock Slough and Old River, Clifton Court Forebay intake and decreases of up to 1% at DMC Canal.

The general observations for the 2010 Lookout Slough bromide results (Table 12) are:

- Largest percent bromide increases (outside north Delta) due to Lookout Slough restoration occur during the fall at the CCWD intake at Victoria Canal (2.6% relative to Base / 1.5% relative to Regional Restoration).
- Bromide increases of around 1% occur in the fall at Clifton Court Forebay Intake, DMC Canal and CCWD intakes at Rock Slough and Old River (the latter two, relative to Base only).
- Largest percent bromide decreases (outside north Delta) due to Lookout Slough occur at Antioch where decreases are generally 3% - 4% during January and June through December. Peak percent decreases occur in July.
- Bromide decreases of around 1% also occur during the spring at Contra Costa at Mallard, and during the summer at the CCWD intakes at Rock Slough and Old River, Clifton Court Forebay intake and DMC Canal.

The general observations for the 2016 Lookout Slough bromide results (Table 13) are:

- Largest percent bromide increases (outside north Delta) due to Lookout Slough restoration occur during the summer at Victoria Canal (3.4% relative to Base / 2.4% relative to Regional Restoration).
- Bromide increases of 1 to 2% occur in the fall at the CCWD intakes at Rock Slough and Old River, Clifton Court Forebay intake and DMC Canal, and increases of 1 to 3% occur during the summer and fall at the CCWD intake at Victoria Canal.
- Largest percent bromide decreases due to Lookout Slough occur at Antioch where decreases are 1% - 4% throughout the year. Peak percent decreases occur in May and December.
- Bromide decreases of 1 to 2% also occur throughout the year at Contra Costa at Mallard, and decreases around 1% occur during fall at the CCWD intakes at Rock Slough and Old River.

Although results based on published relationships between EC and bromide predict increases in bromide at C19 and at times in Barker Slough, there is uncertainty in the magnitude of these changes because the EC to bromide conversion equations were not developed specifically for the conditions occurring in this area, where local inflows are the primary source of salinity.

Additional details, including magnitude of the changes at the compliance locations, can be found in Table 11 through Table 13.

Table 11 Monthly average Base/Regional Restoration Bromide, and Lookout Slough change and percent change from Base/Regional Restoration Bromide at water intakes for 2009.[9,10]

	SLBAR3 – Barker Slough NBA Intake						C19 – City of Vallejo Intake Cache Slough					
		With Lookout Slough			Regional Restoration with Lookout Slough			With Lookout Slough			Regional Restoration with Lookout Slough	
	Base Br mg/L	Brchange mg/L	% Br change	Regional Restoration Br mg/L	Brchange mg/L	% Br change	Base Br mg/L	Brchange mg/L	% Br change	Regional Restoration Br mg/L	Brchange mg/L	% Br change
Jan-2009	0.14	0.000	-0.3%	0.14	0.000	-0.1%	0.41	0.004	1.1%	0.42	0.000	-0.1%
Feb-2009	0.13	-0.003	-2.1%	0.13	-0.002	-1.6%	0.27	0.002	0.6%	0.28	-0.003	-1.1%
Mar-2009	0.14	-0.004	-3.1%	0.14	-0.004	-2.8%	0.34	0.006	1.6%	0.35	0.003	0.7%
Apr-2009	0.19	-0.004	-2.1%	0.19	-0.004	-1.9%	0.27	0.001	0.4%	0.27	0.000	0.0%
May-2009	0.12	-0.001	-1.0%	0.12	-0.001	-0.8%	0.20	0.007	3.5%	0.21	0.007	3.5%
Jun-2009	0.08	-0.001	-0.9%	0.08	-0.001	-0.8%	0.20	0.013	6.5%	0.21	0.013	6.4%
Jul-2009	0.07	0.000	-0.7%	0.07	0.000	-0.7%	0.20	0.014	7.0%	0.21	0.014	6.9%
Aug-2009	0.07	-0.001	-1.1%	0.07	-0.001	-1.1%	0.20	0.015	7.5%	0.21	0.016	7.3%
Sep-2009	0.09	-0.001	-1.0%	0.08	-0.001	-0.9%	0.22	0.015	6.8%	0.23	0.015	6.4%
Oct-2009	0.09	0.000	-0.4%	0.09	0.000	-0.2%	0.29	0.009	3.3%	0.30	0.000	0.0%
Nov-2009	0.07	-0.001	-1.3%	0.07	0.001	0.8%	0.37	0.011	3.0%	0.38	-0.005	-1.3%
Dec-2009	0.10	-0.001	-0.9%	0.10	0.000	0.4%	0.32	0.009	2.8%	0.33	-0.004	-1.3%

[9] Results are provided with sufficient detail to provide reader with information about small changes. While this level of precision is available from the model, the model's accuracy is likely only one-two significant digits.

[10] Equations converting EC to bromide may be less accurate at the SLBAR3 and C19 locations than for other areas in the Delta, given that these equations were not developed for conditions where local inflows are the primary salinity source, as is the case at these locations.

	D12 – San Joaquin River at Antioch						CCWD Intake at Mallard Slough					
	Base Br mg/L	With Lookout Slough		Regional Restoration Br mg/L	Regional Restoration with Lookout Slough		Base Br mg/L	With Lookout Slough		Regional Restoration Br mg/L	Regional Restoration with Lookout Slough	
		Brchange mg/L	% Br change		Brchange mg/L	% Br change		Brchange mg/L	% Br change		Brchange mg/L	% Br change
Jan-2009	3.29	-0.051	-1.5%	3.20	-0.045	-1.4%	9.65	0.002	0.0%	9.60	0.002	0.0%
Feb-2009	1.17	-0.033	-2.8%	1.13	-0.026	-2.3%	3.92	-0.006	-0.2%	3.87	0.001	0.0%
Mar-2009	0.08	-0.001	-0.9%	0.08	-0.001	-0.8%	0.27	-0.004	-1.6%	0.26	-0.004	-1.4%
Apr-2009	0.17	-0.007	-3.9%	0.16	-0.005	-3.1%	1.25	-0.015	-1.2%	1.22	-0.012	-1.0%
May-2009	0.08	-0.003	-3.5%	0.08	-0.002	-2.6%	0.82	-0.011	-1.3%	0.81	-0.008	-1.0%
Jun-2009	0.44	-0.019	-4.3%	0.42	-0.015	-3.6%	2.79	-0.026	-0.9%	2.78	-0.020	-0.7%
Jul-2009	1.68	-0.064	-3.8%	1.63	-0.052	-3.2%	5.97	-0.032	-0.5%	5.94	-0.025	-0.4%
Aug-2009	2.86	-0.104	-3.6%	2.78	-0.086	-3.1%	8.49	-0.036	-0.4%	8.43	-0.024	-0.3%
Sep-2009	3.54	-0.122	-3.4%	3.45	-0.104	-3.0%	10.04	-0.051	-0.5%	9.95	-0.035	-0.4%
Oct-2009	3.27	-0.110	-3.4%	3.20	-0.096	-3.0%	9.98	-0.055	-0.6%	9.91	-0.042	-0.4%
Nov-2009	2.77	-0.093	-3.4%	2.69	-0.078	-2.9%	9.11	-0.057	-0.6%	9.00	-0.044	-0.5%
Dec-2009	2.86	-0.089	-3.1%	2.78	-0.070	-2.5%	8.95	-0.020	-0.2%	8.92	-0.008	-0.1%

	C5 – Contra Costa Intake at Rock Slough						CCWD Intake at Old River					
	Base Br mg/L	With Lookout Slough		Regional Restoration Br mg/L	Regional Restoration with Lookout Slough		Base Br mg/L	With Lookout Slough		Regional Restoration Br mg/L	Regional Restoration with Lookout Slough	
		Brchange mg/L	% Br change		Brchange mg/L	% Br change		Brchange mg/L	% Br change		Brchange mg/L	% Br change
Jan-2009	0.50	0.000	0.0%	0.50	0.000	0.0%	0.33	0.000	0.0%	0.33	0.000	0.0%
Feb-2009	0.39	0.001	0.2%	0.39	0.001	0.1%	0.33	0.001	0.4%	0.33	0.001	0.2%
Mar-2009	0.21	0.001	0.5%	0.21	0.001	0.3%	0.14	0.000	0.3%	0.14	0.000	0.2%
Apr-2009	0.12	0.000	0.2%	0.12	0.000	0.1%	0.09	0.000	0.2%	0.09	0.000	0.1%
May-2009	0.12	0.000	0.2%	0.12	0.000	0.2%	0.11	0.000	0.3%	0.11	0.000	0.3%
Jun-2009	0.09	0.000	0.3%	0.09	0.000	0.3%	0.09	0.000	0.4%	0.09	0.000	0.4%
Jul-2009	0.13	-0.003	-2.1%	0.13	-0.002	-1.9%	0.11	-0.002	-2.2%	0.11	-0.002	-2.0%
Aug-2009	0.38	-0.007	-1.7%	0.39	-0.008	-2.0%	0.33	-0.004	-1.3%	0.34	-0.006	-1.8%
Sep-2009	0.50	-0.001	-0.1%	0.53	-0.006	-1.0%	0.42	0.002	0.6%	0.45	-0.003	-0.6%
Oct-2009	0.50	0.007	1.4%	0.54	0.001	0.2%	0.37	0.008	2.0%	0.41	0.004	0.9%
Nov-2009	0.37	0.007	1.9%	0.41	0.005	1.2%	0.29	0.005	1.8%	0.32	0.004	1.4%
Dec-2009	0.36	0.002	0.6%	0.38	0.003	0.7%	0.30	0.001	0.5%	0.32	0.002	0.6%

	C9 – Clifton Ct Forebay Intake						DMC1 – Delta Mendota Canal at Tracy PP					
	Base Br mg/L	With Lookout Slough		Regional Restoration Br mg/L	Regional Restoration with Lookout Slough		Base Br mg/L	With Lookout Slough		Regional Restoration Br mg/L	Regional Restoration with Lookout Slough	
		Brchange mg/L	% Br change		Brchange mg/L	% Br change		Brchange mg/L	% Br change		Brchange mg/L	% Br change
Jan-2009	0.35	0.000	0.0%	0.35	0.000	0.0%	0.39	0.000	-0.1%	0.39	0.000	-0.1%
Feb-2009	0.35	0.001	0.3%	0.35	0.001	0.2%	0.39	0.001	0.2%	0.39	0.001	0.2%
Mar-2009	0.18	0.001	0.5%	0.18	0.001	0.3%	0.27	0.001	0.3%	0.27	0.001	0.2%
Apr-2009	0.13	0.000	0.2%	0.13	0.000	0.2%	0.20	0.000	0.2%	0.20	0.000	0.1%
May-2009	0.12	0.000	0.2%	0.12	0.000	0.2%	0.13	0.000	0.1%	0.13	0.000	0.1%
Jun-2009	0.12	0.000	0.3%	0.12	0.000	0.3%	0.14	0.000	0.3%	0.14	0.000	0.2%
Jul-2009	0.09	-0.002	-1.6%	0.10	-0.001	-1.6%	0.09	-0.001	-1.2%	0.10	-0.001	-1.2%
Aug-2009	0.27	-0.003	-1.0%	0.28	-0.004	-1.5%	0.24	-0.002	-0.8%	0.25	-0.003	-1.3%
Sep-2009	0.35	0.003	0.9%	0.38	-0.001	-0.4%	0.33	0.003	0.9%	0.35	-0.001	-0.2%
Oct-2009	0.33	0.007	2.1%	0.36	0.003	1.0%	0.30	0.005	1.8%	0.33	0.003	0.8%
Nov-2009	0.28	0.005	1.6%	0.30	0.004	1.2%	0.28	0.003	1.2%	0.30	0.003	0.9%
Dec-2009	0.30	0.002	0.6%	0.31	0.002	0.7%	0.32	0.002	0.7%	0.34	0.002	0.7%

	CCWD Intake at Victoria Canal					
		With Lookout Slough			Regional Restoration with Lookout Slough	
	Base Br mg/L	Brchange mg/L	% Br change	Regional Restoration Br mg/L	Brchange mg/L	% Br change
Jan-2009	0.28	0.000	0.0%	0.27	0.000	0.0%
Feb-2009	0.30	0.001	0.3%	0.29	0.001	0.2%
Mar-2009	0.17	0.001	0.7%	0.17	0.001	0.4%
Apr-2009	0.10	0.000	0.3%	0.10	0.000	0.1%
May-2009	0.12	0.000	0.3%	0.12	0.000	0.3%
Jun-2009	0.10	0.001	0.5%	0.10	0.000	0.4%
Jul-2009	0.05	0.000	0.3%	0.06	0.000	0.1%
Aug-2009	0.13	0.001	0.7%	0.14	0.000	-0.1%
Sep-2009	0.19	0.005	2.5%	0.20	0.002	1.0%
Oct-2009	0.20	0.005	2.6%	0.22	0.003	1.6%
Nov-2009	0.16	0.004	2.3%	0.18	0.003	1.9%
Dec-2009	0.17	0.002	1.3%	0.19	0.003	1.4%

Table 12 Monthly average Base/Regional Restoration Bromide, and Lookout Slough change and percent change from Base/Regional Restoration Bromide at water intakes for 2010.[11,12]

	SLBAR3 – Barker Slough NBA Intake						C19 – City of Vallejo Intake Cache Slough					
		With Lookout Slough			Regional Restoration with Lookout Slough			With Lookout Slough			Regional Restoration with Lookout Slough	
	Base Br mg/L	Brchange mg/L	% Br change	Regional Restoration Br mg/L	Brchange mg/L	% Br change	Base Br mg/L	Brchange mg/L	% Br change	Regional Restoration Br mg/L	Brchange mg/L	% Br change
Jan-2010	0.08	-0.001	-1.8%	0.08	-0.001	-0.8%	0.30	0.008	2.7%	0.30	-0.003	-1.0%
Feb-2010	0.15	-0.002	-1.3%	0.15	-0.001	-1.0%	0.34	0.005	1.5%	0.34	0.001	0.4%
Mar-2010	0.21	-0.005	-2.4%	0.20	-0.004	-1.9%	0.39	0.003	0.7%	0.40	-0.001	-0.2%
Apr-2010	0.23	-0.009	-3.9%	0.23	-0.009	-3.7%	0.35	-0.001	-0.3%	0.35	-0.005	-1.5%
May-2010	0.18	-0.011	-6.0%	0.17	-0.010	-5.9%	0.25	-0.006	-2.6%	0.25	-0.007	-2.7%
Jun-2010	0.08	-0.001	-1.3%	0.08	-0.001	-1.2%	0.19	0.007	3.9%	0.20	0.008	4.1%
Jul-2010	0.03	0.000	-1.2%	0.03	0.000	-0.9%	0.19	0.012	6.6%	0.20	0.013	6.4%
Aug-2010	0.04	-0.001	-1.6%	0.04	-0.001	-1.5%	0.20	0.014	6.9%	0.22	0.014	6.6%
Sep-2010	0.06	-0.001	-1.8%	0.06	-0.001	-1.6%	0.18	0.011	6.3%	0.19	0.012	6.2%
Oct-2010	0.06	-0.001	-0.9%	0.06	-0.001	-0.9%	0.20	0.010	5.0%	0.20	0.009	4.3%
Nov-2010	0.06	-0.001	-1.1%	0.06	0.000	-0.3%	0.31	0.010	3.3%	0.32	-0.001	-0.2%
Dec-2010	0.12	-0.001	-0.7%	0.12	0.000	-0.3%	0.29	0.004	1.4%	0.30	-0.005	-1.6%

[11] Results are provided with sufficient detail to provide reader with information about small changes. While this level of precision is available from the model, the model's accuracy is likely only one-two significant digits.
[12] Equations converting EC to bromide may be less accurate at the SLBAR3 and C19 locations than for other areas in the Delta, given that these equations were not developed for conditions where local inflows are the primary salinity source, as is the case at these locations.

	D12 – San Joaquin River at Antioch						CCWD Intake at Mallard Slough					
	Base Br mg/L	With Lookout Slough		Regional Restoration Br mg/L	Regional Restoration with Lookout Slough		Base Br mg/L	With Lookout Slough		Regional Restoration Br mg/L	Regional Restoration with Lookout Slough	
		Brchange mg/L	% Br change		Brchange mg/L	% Br change		Brchange mg/L	% Br change		Brchange mg/L	% Br change
Jan-2010	1.40	-0.051	-3.6%	1.36	-0.038	-2.8%	4.62	-0.021	-0.5%	4.60	-0.011	-0.2%
Feb-2010	0.08	-0.001	-1.1%	0.08	-0.001	-0.9%	0.15	-0.002	-1.5%	0.15	-0.002	-1.2%
Mar-2010	0.12	-0.002	-1.6%	0.12	-0.002	-1.3%	0.55	-0.008	-1.4%	0.54	-0.007	-1.2%
Apr-2010	0.16	-0.004	-2.4%	0.15	-0.003	-1.9%	0.86	-0.011	-1.3%	0.85	-0.009	-1.1%
May-2010	0.08	0.000	-0.1%	0.08	0.000	0.0%	0.38	-0.005	-1.4%	0.37	-0.004	-1.2%
Jun-2010	0.09	-0.003	-3.2%	0.09	-0.002	-2.6%	0.79	-0.012	-1.5%	0.79	-0.010	-1.2%
Jul-2010	0.87	-0.032	-3.7%	0.85	-0.026	-3.1%	3.86	-0.030	-0.8%	3.83	-0.024	-0.6%
Aug-2010	1.91	-0.067	-3.5%	1.84	-0.054	-2.9%	6.30	-0.042	-0.7%	6.23	-0.033	-0.5%
Sep-2010	2.52	-0.085	-3.4%	2.44	-0.069	-2.8%	7.40	-0.050	-0.7%	7.30	-0.036	-0.5%
Oct-2010	2.60	-0.080	-3.1%	2.53	-0.067	-2.7%	8.16	-0.058	-0.7%	8.06	-0.045	-0.6%
Nov-2010	2.67	-0.076	-2.9%	2.59	-0.062	-2.4%	8.16	-0.053	-0.6%	8.05	-0.039	-0.5%
Dec-2010	0.63	-0.022	-3.4%	0.61	-0.018	-2.9%	1.86	-0.013	-0.7%	1.82	-0.008	-0.4%

	C5 – Contra Costa Intake at Rock Slough						CCWD Intake at Old River					
		With Lookout Slough			Regional Restoration with Lookout Slough			With Lookout Slough			Regional Restoration with Lookout Slough	
	Base Br mg/L	Brchange mg/L	% Br change	Regional Restoration Br mg/L	Brchange mg/L	% Br change	Base Br mg/L	Brchange mg/L	% Br change	Regional Restoration Br mg/L	Brchange mg/L	% Br change
Jan-2010	0.52	-0.002	-0.4%	0.53	-0.001	-0.2%	0.39	-0.002	-0.6%	0.40	-0.002	-0.4%
Feb-2010	0.36	-0.001	-0.4%	0.36	-0.001	-0.3%	0.16	-0.001	-0.3%	0.16	0.000	-0.3%
Mar-2010	0.14	0.000	-0.1%	0.15	0.000	-0.1%	0.12	0.000	0.0%	0.12	0.000	0.0%
Apr-2010	0.13	0.000	-0.1%	0.14	0.000	0.0%	0.15	0.000	0.0%	0.15	0.000	0.0%
May-2010	0.17	0.000	0.1%	0.17	0.000	0.1%	0.10	0.000	0.0%	0.10	0.000	0.0%
Jun-2010	0.08	0.000	0.4%	0.08	0.000	0.3%	0.06	0.000	0.5%	0.06	0.000	0.3%
Jul-2010	0.07	0.000	-0.5%	0.07	0.000	-0.6%	0.06	0.000	-0.5%	0.06	0.000	-0.7%
Aug-2010	0.22	-0.003	-1.3%	0.22	-0.003	-1.4%	0.20	-0.003	-1.4%	0.20	-0.003	-1.6%
Sep-2010	0.48	-0.003	-0.7%	0.49	-0.006	-1.2%	0.41	-0.001	-0.2%	0.43	-0.004	-0.8%
Oct-2010	0.42	0.002	0.6%	0.45	-0.001	-0.3%	0.34	0.003	0.9%	0.36	0.000	0.0%
Nov-2010	0.42	0.004	0.9%	0.44	0.001	0.1%	0.35	0.004	1.2%	0.37	0.001	0.4%
Dec-2010	0.39	0.002	0.6%	0.41	0.000	0.0%	0.25	0.001	0.6%	0.26	0.000	0.0%

	C9 – Clifton Ct Forebay Intake						DMC1 – Delta Mendota Canal at Tracy PP					
	Base Br mg/L	With Lookout Slough		Regional Restoration Br mg/L	Regional Restoration with Lookout Slough		Base Br mg/L	With Lookout Slough		Regional Restoration Br mg/L	Regional Restoration with Lookout Slough	
		Brchange mg/L	% Br change		Brchange mg/L	% Br change		Brchange mg/L	% Br change		Brchange mg/L	% Br change
Jan-2010	0.40	-0.001	-0.2%	0.40	0.000	-0.1%	0.43	0.000	0.1%	0.43	0.001	0.1%
Feb-2010	0.20	0.000	0.0%	0.20	0.000	0.0%	0.25	0.000	0.1%	0.25	0.000	0.1%
Mar-2010	0.17	0.001	0.5%	0.18	0.001	0.4%	0.24	0.000	0.1%	0.24	0.000	0.1%
Apr-2010	0.17	0.000	0.0%	0.17	0.000	0.0%	0.20	0.000	0.1%	0.20	0.000	0.0%
May-2010	0.09	0.000	0.0%	0.09	0.000	0.0%	0.09	0.000	0.0%	0.09	0.000	0.0%
Jun-2010	0.07	0.000	0.4%	0.07	0.000	0.3%	0.08	0.000	0.2%	0.09	0.000	0.1%
Jul-2010	0.05	0.000	-0.2%	0.05	0.000	-0.4%	0.06	0.000	-0.1%	0.07	0.000	-0.2%
Aug-2010	0.16	-0.002	-1.0%	0.17	-0.002	-1.3%	0.17	-0.001	-0.5%	0.18	-0.001	-0.7%
Sep-2010	0.35	0.000	0.1%	0.36	-0.002	-0.6%	0.30	0.001	0.3%	0.31	-0.001	-0.3%
Oct-2010	0.29	0.003	1.1%	0.30	0.001	0.2%	0.26	0.002	0.9%	0.27	0.001	0.3%
Nov-2010	0.31	0.004	1.3%	0.32	0.002	0.5%	0.29	0.003	1.1%	0.30	0.002	0.5%
Dec-2010	0.20	0.001	0.7%	0.21	0.000	0.1%	0.14	0.001	0.6%	0.15	0.000	0.2%

	CCWD Intake at Victoria Canal					
		With Lookout Slough			Regional Restoration with Lookout Slough	
	Base Br mg/L	Brchange mg/L	% Br change	Regional Restoration Br mg/L	Brchange mg/L	% Br change
Jan-2010	0.30	0.000	0.1%	0.30	0.001	0.2%
Feb-2010	0.18	0.001	0.3%	0.18	0.000	0.2%
Mar-2010	0.17	0.000	0.3%	0.17	0.000	0.2%
Apr-2010	0.17	0.000	0.1%	0.17	0.000	0.0%
May-2010	0.09	0.000	0.0%	0.09	0.000	0.0%
Jun-2010	0.08	0.000	0.5%	0.08	0.000	0.3%
Jul-2010	0.04	0.000	0.5%	0.04	0.000	0.3%
Aug-2010	0.09	0.000	0.6%	0.09	0.000	0.0%
Sep-2010	0.20	0.003	1.3%	0.21	0.001	0.4%
Oct-2010	0.19	0.004	2.2%	0.20	0.002	1.2%
Nov-2010	0.18	0.005	2.6%	0.19	0.003	1.5%
Dec-2010	0.15	0.002	1.3%	0.15	0.001	0.8%

Table 13 Monthly average Base/Regional Restoration Bromide, and Lookout Slough change and percent change from Base/Regional Restoration Bromide at water intakes for 2016.[13,14]

	SLBAR3 – Barker Slough NBA Intake						C19 – City of Vallejo Intake Cache Slough					
		With Lookout Slough			Regional Restoration with Lookout Slough			With Lookout Slough			Regional Restoration with Lookout Slough	
	Base Br mg/L	Brchange mg/L	% Br change	Regional Restoration Br mg/L	Brchange mg/L	% Br change	Base Br mg/L	Brchange mg/L	% Br change	Regional Restoration Br mg/L	Brchange mg/L	% Br change
Feb-2016	0.25	0.002	0.7%	0.25	0.002	0.7%	0.44	0.002	0.5%	0.45	-0.002	-0.5%
Mar-2016	0.12	0.001	1.2%	0.12	0.001	1.2%	0.36	0.002	0.5%	0.36	0.000	-0.1%
Apr-2016	0.22	0.002	0.8%	0.22	0.002	0.9%	0.37	0.003	0.8%	0.37	-0.003	-0.8%
May-2016	0.16	-0.002	-1.0%	0.15	-0.001	-0.7%	0.17	0.004	2.6%	0.17	0.005	2.6%
Jun-2016	0.07	0.000	-0.5%	0.07	0.000	-0.4%	0.07	0.004	5.0%	0.07	0.004	5.0%
Jul-2016	0.05	0.000	-1.0%	0.05	0.000	-0.9%	0.07	0.005	6.9%	0.07	0.005	6.6%
Aug-2016	0.04	-0.001	-3.3%	0.03	-0.001	-3.2%	0.08	0.005	6.4%	0.09	0.005	6.2%
Sep-2016	0.04	0.000	-1.0%	0.04	0.000	-1.0%	0.12	0.008	6.8%	0.13	0.008	6.3%
Oct-2016	0.07	0.000	-0.4%	0.07	0.000	-0.4%	0.21	0.007	3.6%	0.21	0.006	2.9%
Nov-2016	0.07	0.000	-0.6%	0.07	0.001	0.9%	0.43	0.009	2.1%	0.43	0.001	0.2%
Dec-2016	0.17	0.001	0.3%	0.17	0.002	0.9%	0.40	0.002	0.5%	0.40	-0.001	-0.3%

[13] Results are provided with sufficient detail to provide reader with information about small changes. While this level of precision is available from the model, the model's accuracy is likely only one-two significant digits.

[14] Equations converting EC to bromide may be less accurate at the SLBAR3 and C19 locations than for other areas in the Delta, given that these equations were not developed for conditions where local inflows are the primary salinity source, as is the case at these locations.

	D12 – San Joaquin River at Antioch						CCWD Intake at Mallard Slough					
	Base Br mg/L	With Lookout Slough		Regional Restoration Br mg/L	Regional Restoration with Lookout Slough		Base Br mg/L	With Lookout Slough		Regional Restoration Br mg/L	Regional Restoration with Lookout Slough	
		Brchange mg/L	% Br change		Brchange mg/L	% Br change		Brchange mg/L	% Br change		Brchange mg/L	% Br change
Feb-2016	0.13	-0.004	-2.9%	0.13	-0.003	-2.3%	0.69	-0.010	-1.5%	0.67	-0.009	-1.3%
Mar-2016	0.09	-0.003	-3.9%	0.08	-0.003	-3.1%	0.40	-0.004	-1.1%	0.39	-0.003	-0.9%
Apr-2016	0.03	0.000	-1.3%	0.03	0.000	-0.7%	0.24	-0.005	-2.1%	0.23	-0.004	-1.8%
May-2016	0.25	-0.011	-4.4%	0.24	-0.009	-3.7%	1.86	-0.024	-1.3%	1.83	-0.020	-1.1%
Jun-2016	1.09	-0.040	-3.7%	1.05	-0.033	-3.2%	4.77	-0.044	-0.9%	4.72	-0.038	-0.8%
Jul-2016	1.92	-0.063	-3.3%	1.88	-0.052	-2.8%	6.63	-0.045	-0.7%	6.59	-0.037	-0.6%
Aug-2016	1.93	-0.072	-3.7%	1.88	-0.058	-3.1%	6.48	-0.051	-0.8%	6.44	-0.041	-0.6%
Sep-2016	2.92	-0.103	-3.5%	2.84	-0.085	-3.0%	8.39	-0.061	-0.7%	8.32	-0.050	-0.6%
Oct-2016	3.89	-0.108	-2.8%	3.80	-0.094	-2.5%	10.96	-0.078	-0.7%	10.82	-0.063	-0.6%
Nov-2016	3.26	-0.096	-2.9%	3.13	-0.077	-2.5%	9.63	-0.058	-0.6%	9.43	-0.042	-0.4%
Dec-2016	1.00	-0.044	-4.4%	0.94	-0.035	-3.7%	2.93	-0.023	-0.8%	2.85	-0.016	-0.6%

	C5 – Contra Costa Intake at Rock Slough						CCWD Intake at Old River					
	Base Br mg/L	With Lookout Slough		Regional Restoration Br mg/L	Regional Restoration with Lookout Slough		Base Br mg/L	With Lookout Slough		Regional Restoration Br mg/L	Regional Restoration with Lookout Slough	
		Brchange mg/L	% Br change		Brchange mg/L	% Br change		Brchange mg/L	% Br change		Brchange mg/L	% Br change
Feb-2016	0.17	0.000	0.2%	0.17	0.000	0.1%	0.15	0.000	0.2%	0.15	0.000	0.1%
Mar-2016	0.08	0.000	0.1%	0.04	0.000	0.0%	0.08	0.000	0.2%	0.08	0.000	0.1%
Apr-2016	0.06	0.000	-0.2%	-0.15	0.000	-0.1%	0.08	0.000	0.1%	0.08	0.000	0.1%
May-2016	0.09	0.000	0.1%	0.06	0.000	0.0%	0.11	0.000	0.2%	0.11	0.000	0.1%
Jun-2016	0.09	0.000	0.2%	0.28	0.000	0.1%	0.08	0.000	0.3%	0.08	0.000	0.2%
Jul-2016	0.20	0.000	0.0%	-0.03	-0.001	-0.4%	0.16	0.000	0.2%	0.17	0.000	-0.2%
Aug-2016	0.24	0.001	0.4%	0.36	-0.001	-0.2%	0.19	0.001	0.3%	0.20	-0.001	-0.3%
Sep-2016	0.45	-0.003	-0.7%	-0.77	-0.005	-1.1%	0.39	-0.002	-0.5%	0.40	-0.004	-0.9%
Oct-2016	0.54	0.004	0.8%	0.82	-0.001	-0.3%	0.43	0.007	1.5%	0.46	0.001	0.3%
Nov-2016	0.53	0.010	2.0%	1.96	0.005	0.9%	0.43	0.009	2.2%	0.46	0.005	1.2%
Dec-2016	0.49	0.002	0.4%	0.30	-0.001	-0.1%	0.35	-0.001	-0.4%	0.35	-0.003	-0.7%

	C9 – Clifton Ct Forebay Intake						DMC1 – Delta Mendota Canal at Tracy PP					
		With Lookout Slough		Regional Restoration Br mg/L	Regional Restoration with Lookout Slough			With Lookout Slough		Regional Restoration Br mg/L	Regional Restoration with Lookout Slough	
	Base Br mg/L	Brchange mg/L	% Br change		Brchange mg/L	% Br change	Base Br mg/L	Brchange mg/L	% Br change		Brchange mg/L	% Br change
Feb-2016	0.18	0.000	0.2%	0.18	0.000	0.1%	0.23	0.000	0.2%	0.23	0.000	0.2%
Mar-2016	0.11	0.000	0.4%	0.11	0.000	0.3%	0.17	0.000	0.2%	0.17	0.000	0.2%
Apr-2016	0.12	0.000	0.1%	0.12	0.000	0.1%	0.17	0.000	0.2%	0.17	0.000	0.2%
May-2016	0.12	0.000	0.2%	0.12	0.000	0.1%	0.12	0.000	0.1%	0.12	0.000	0.1%
Jun-2016	0.08	0.000	0.4%	0.08	0.000	0.3%	0.09	0.000	0.3%	0.09	0.000	0.2%
Jul-2016	0.13	0.001	0.4%	0.13	0.000	0.0%	0.12	0.000	0.4%	0.12	0.000	0.0%
Aug-2016	0.16	0.001	0.7%	0.16	0.000	0.1%	0.15	0.001	0.8%	0.15	0.001	0.3%
Sep-2016	0.32	-0.001	-0.2%	0.33	-0.002	-0.6%	0.29	0.000	0.0%	0.30	-0.001	-0.3%
Oct-2016	0.36	0.006	1.6%	0.38	0.001	0.4%	0.32	0.005	1.6%	0.34	0.002	0.5%
Nov-2016	0.35	0.008	2.2%	0.37	0.005	1.3%	0.32	0.006	1.9%	0.33	0.004	1.2%
Dec-2016	0.32	0.000	-0.1%	0.32	-0.001	-0.4%	0.32	0.001	0.2%	0.32	0.000	0.0%

	CCWD Intake at Victoria Canal					
		With Lookout Slough			Regional Restoration with Lookout Slough	
	Base Br mg/L	Brchange mg/L	% Br change	Regional Restoration Br mg/L	Brchange mg/L	% Br change
Feb-2016	0.16	0.000	0.2%	0.16	0.000	0.2%
Mar-2016	0.10	0.000	0.4%	0.10	0.000	0.4%
Apr-2016	0.10	0.000	0.2%	0.10	0.000	0.2%
May-2016	0.13	0.000	0.3%	0.13	0.000	0.2%
Jun-2016	0.07	0.000	0.7%	0.07	0.000	0.6%
Jul-2016	0.06	0.001	1.4%	0.06	0.001	1.1%
Aug-2016	0.06	0.001	2.4%	0.06	0.001	1.9%
Sep-2016	0.17	0.002	1.2%	0.17	0.001	0.8%
Oct-2016	0.20	0.006	3.2%	0.21	0.004	1.7%
Nov-2016	0.20	0.007	3.4%	0.21	0.005	2.4%
Dec-2016	0.20	0.002	1.0%	0.20	0.001	0.5%

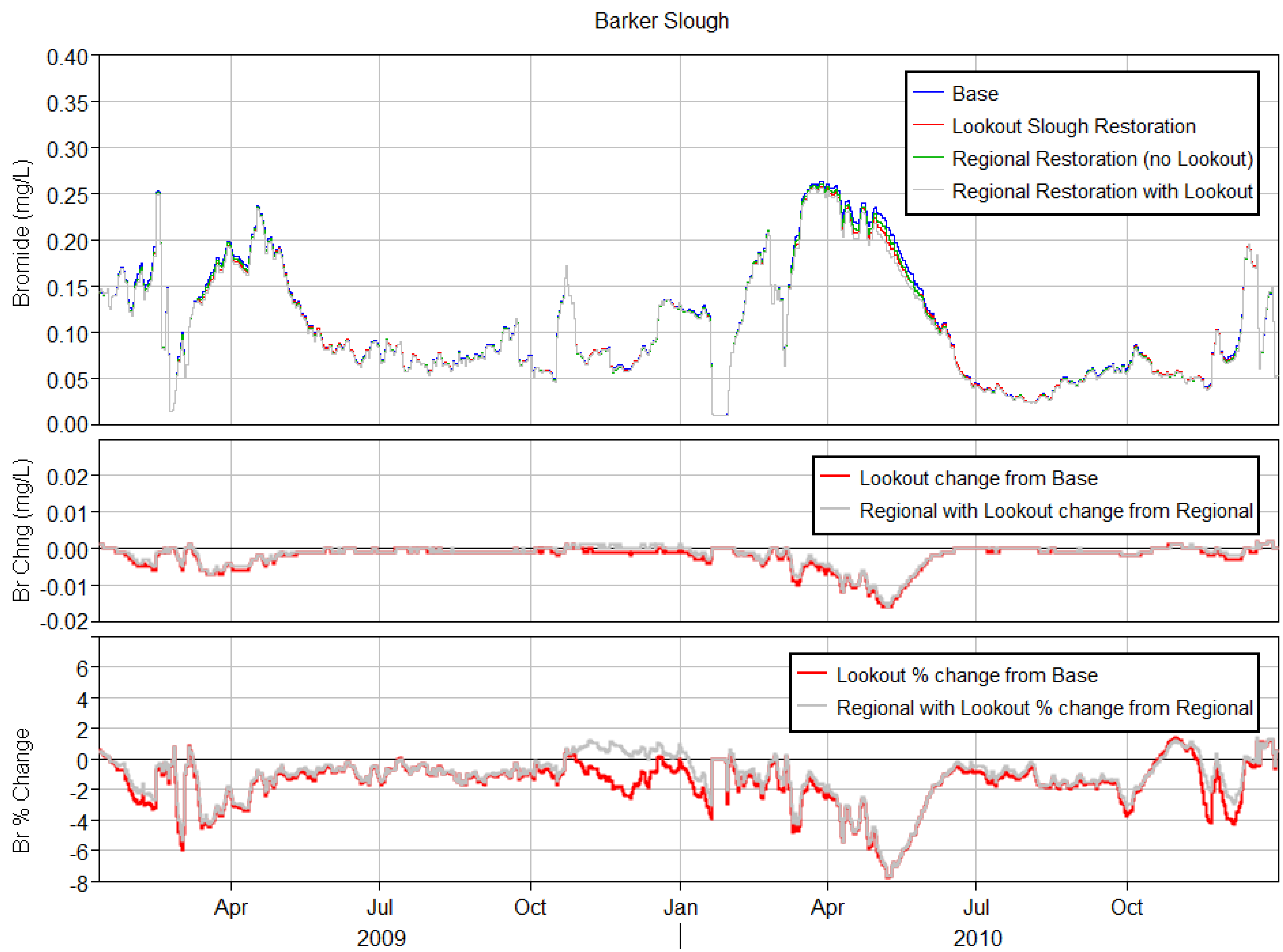

Figure 74 Daily average bromide at Barker Slough for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in bromide for the 2009-2010 simulation period.

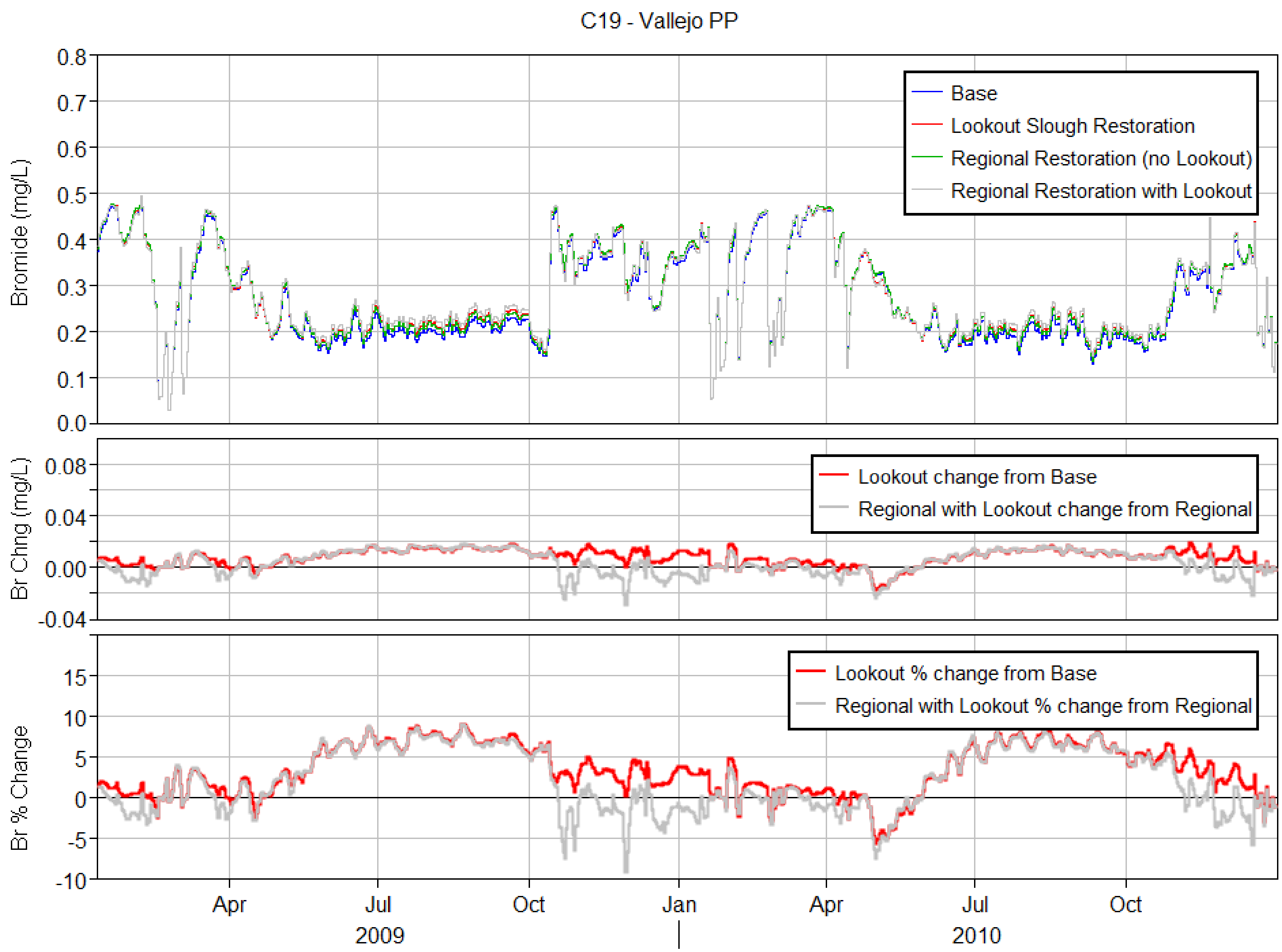

Figure 75 Daily average bromide at C19 for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in bromide for the 2009-2010 simulation period.

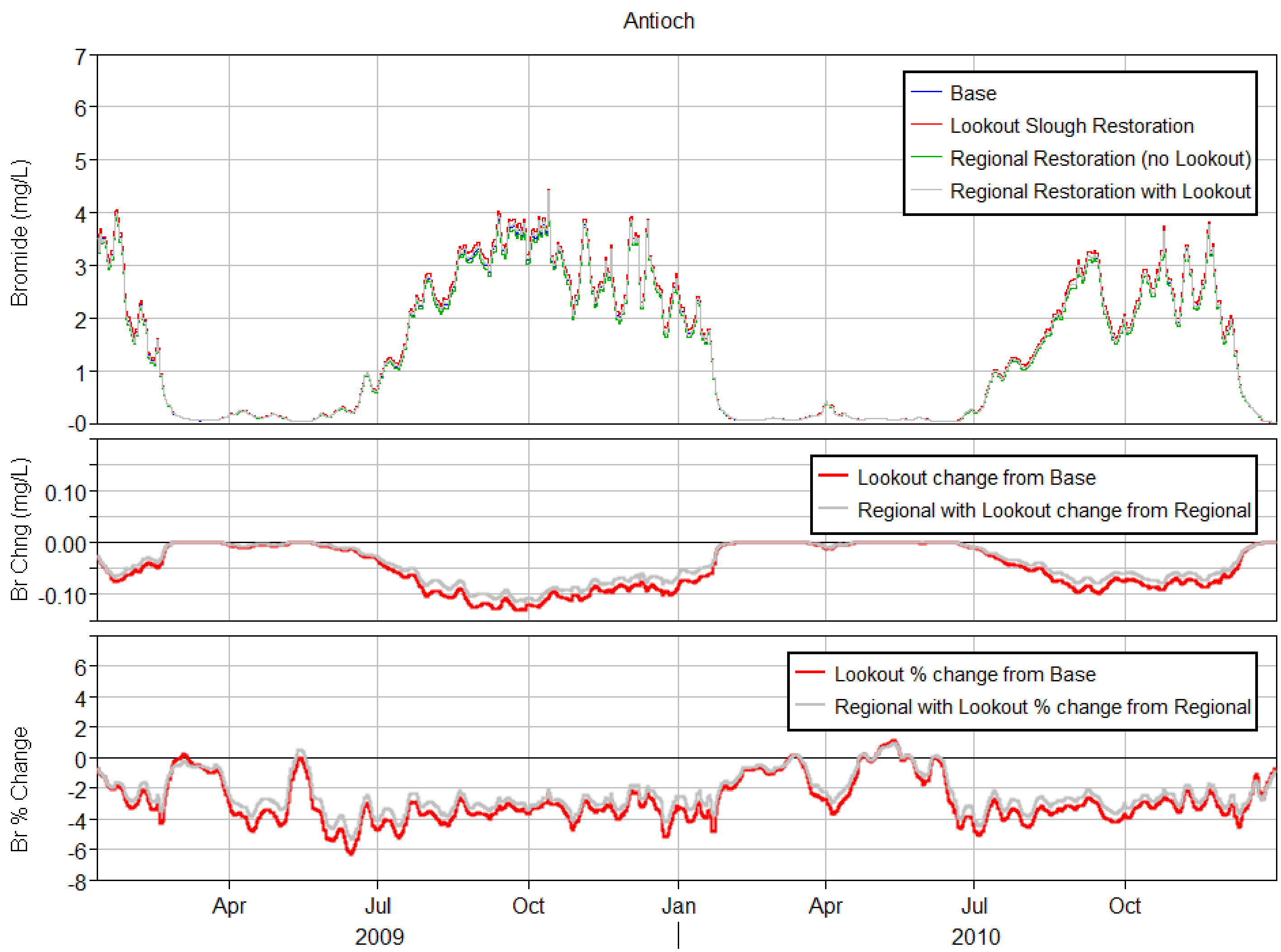

Figure 76 Daily average bromide at Antioch for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in bromide for the 2009-2010 simulation period.

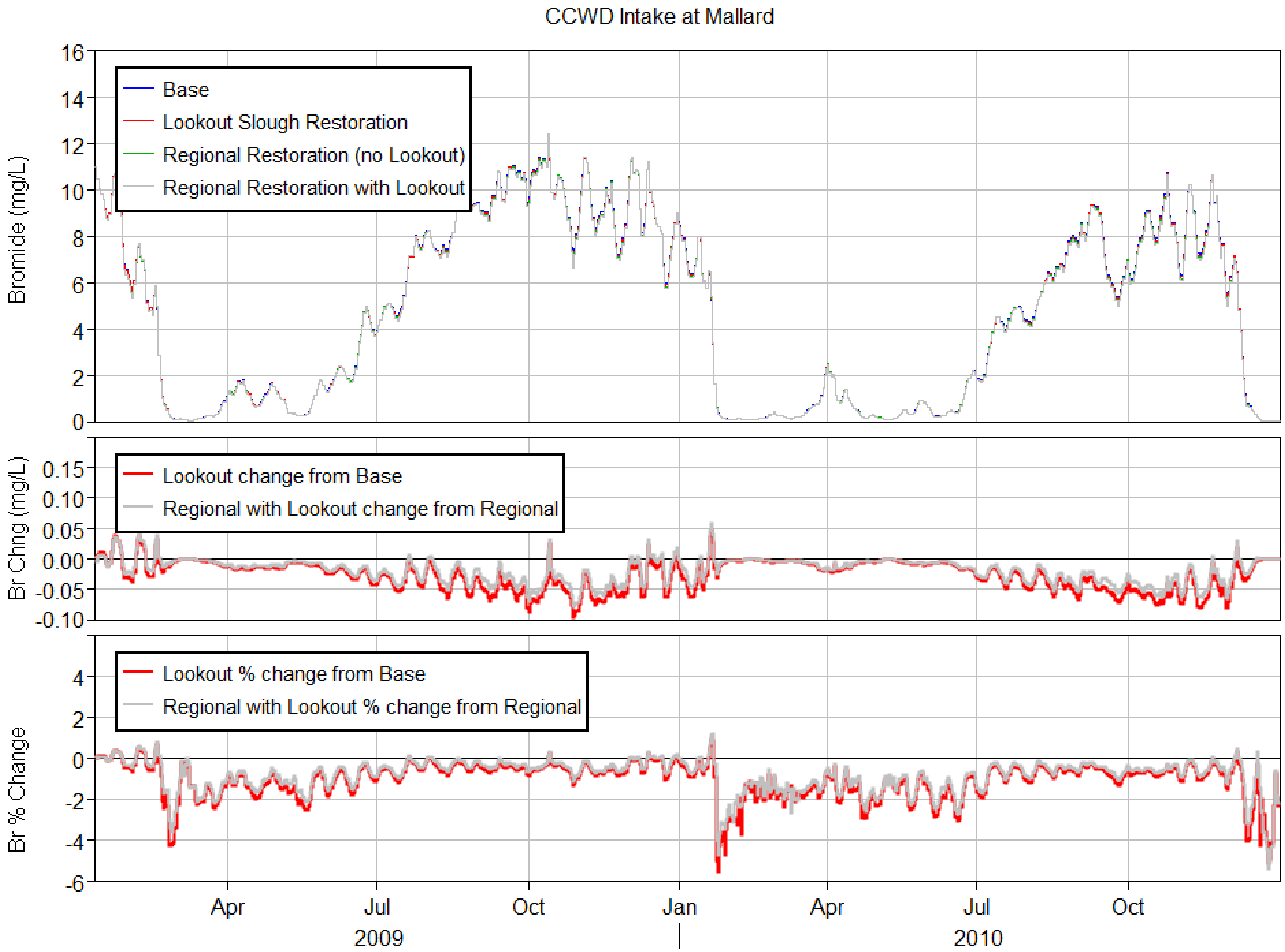

Figure 77 Daily average bromide at CCWD intake at Mallard for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in bromide for the 2009-2010 simulation per

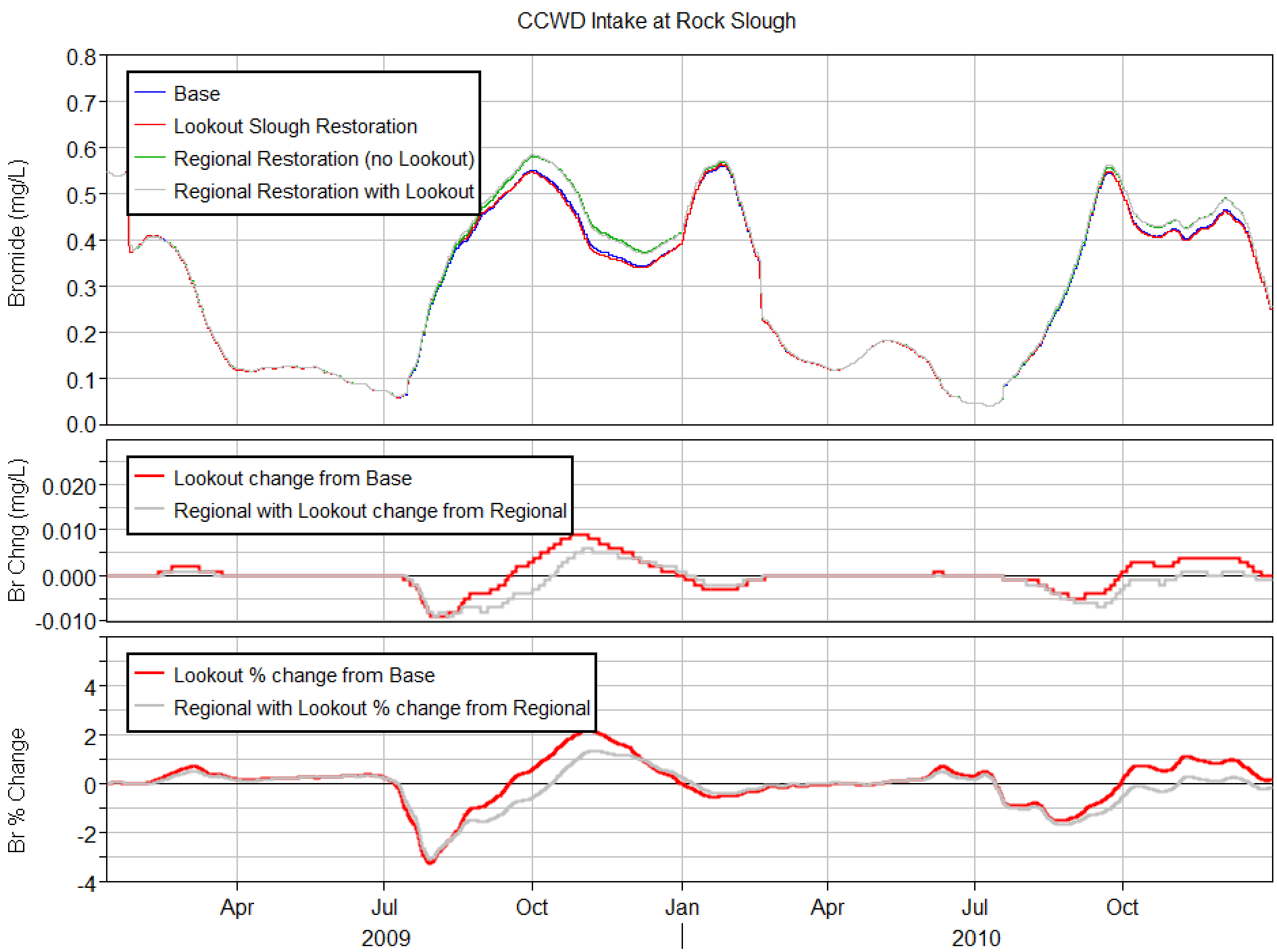

Figure 78 Daily average bromide at CCWD intake at Rock Slough for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in bromide for the 2009-2010 simulation period.

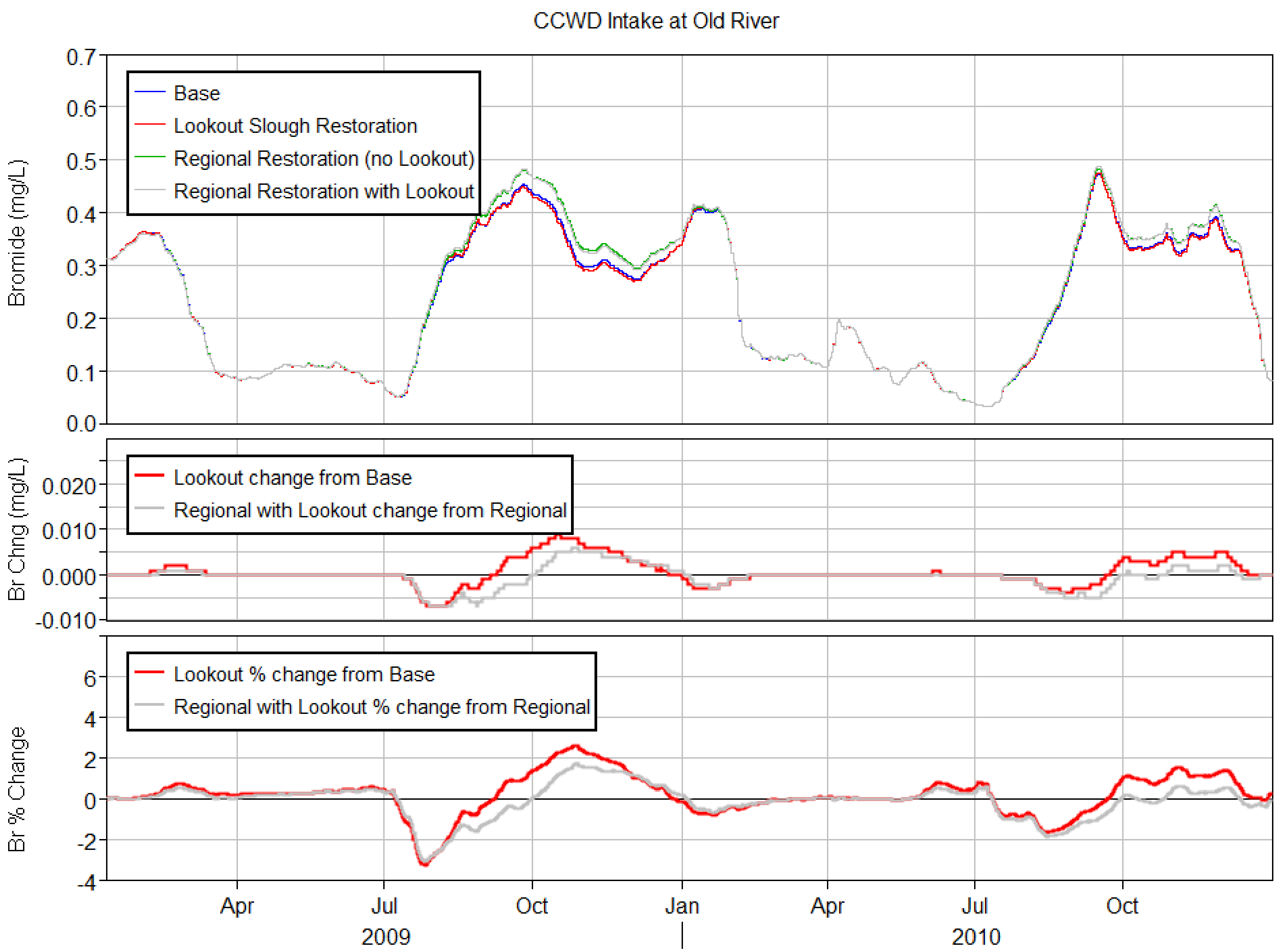

Figure 79 Daily average bromide at CCWD intake at Old River for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in bromide for the 2009-2010 simulation period.

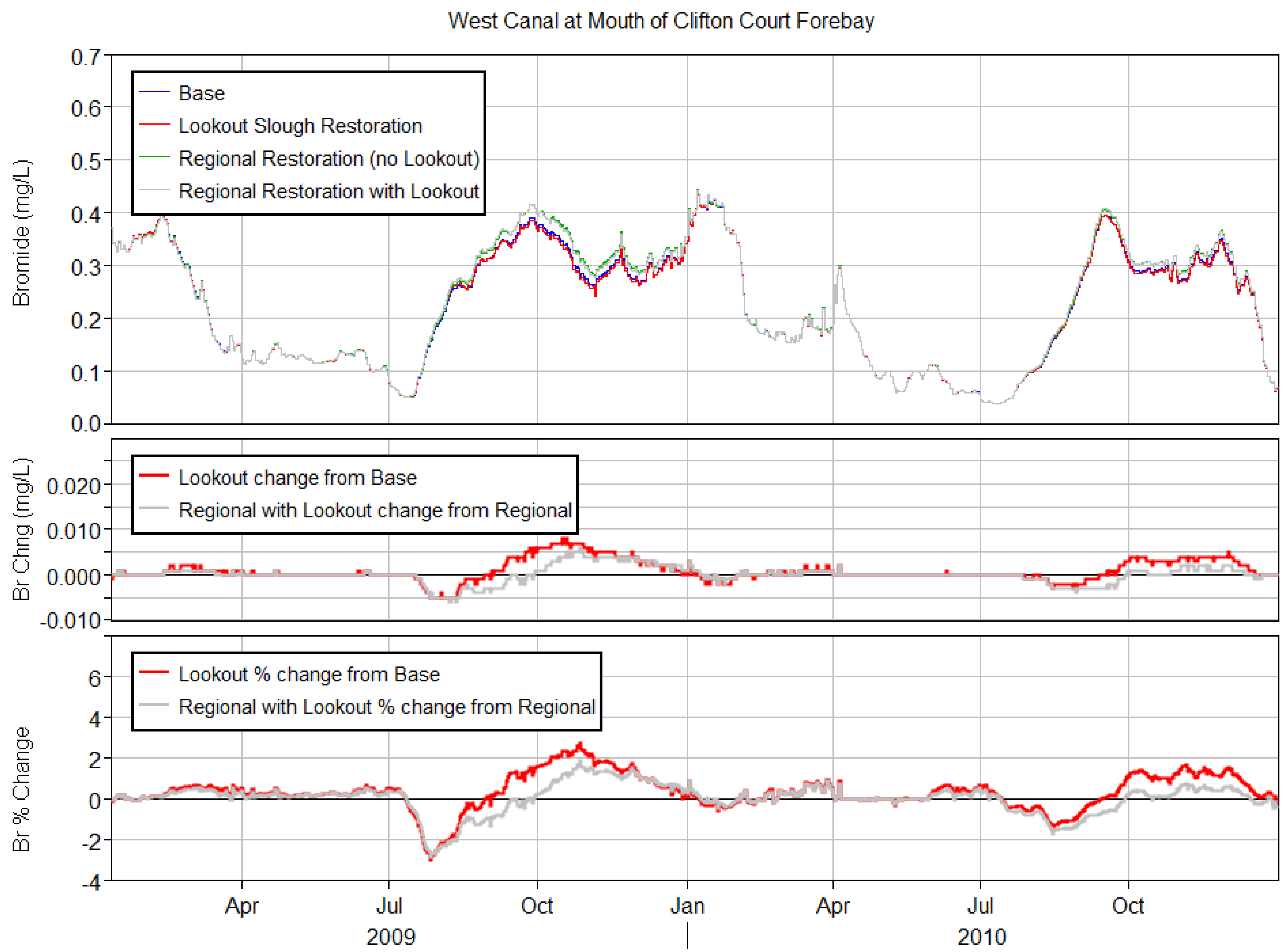

Figure 80 Daily average bromide at West Canal at mouth of Clifton Court Forebay for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in bromide for the 2009-2010 simulation period.

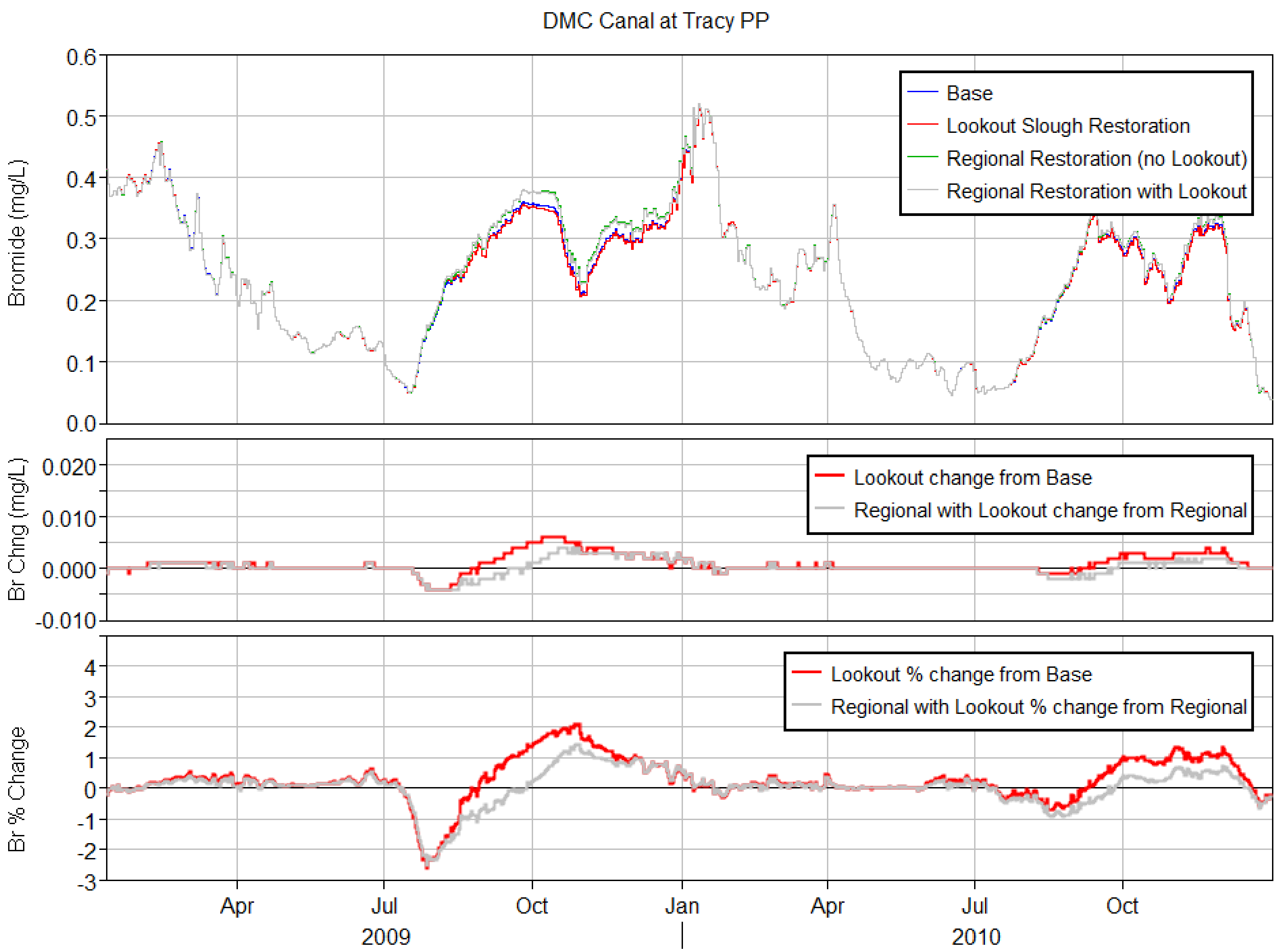

Figure 81 Daily average bromide at DMC Canal at Tracy PP for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in bromide for the 2009-2010 simulation period.

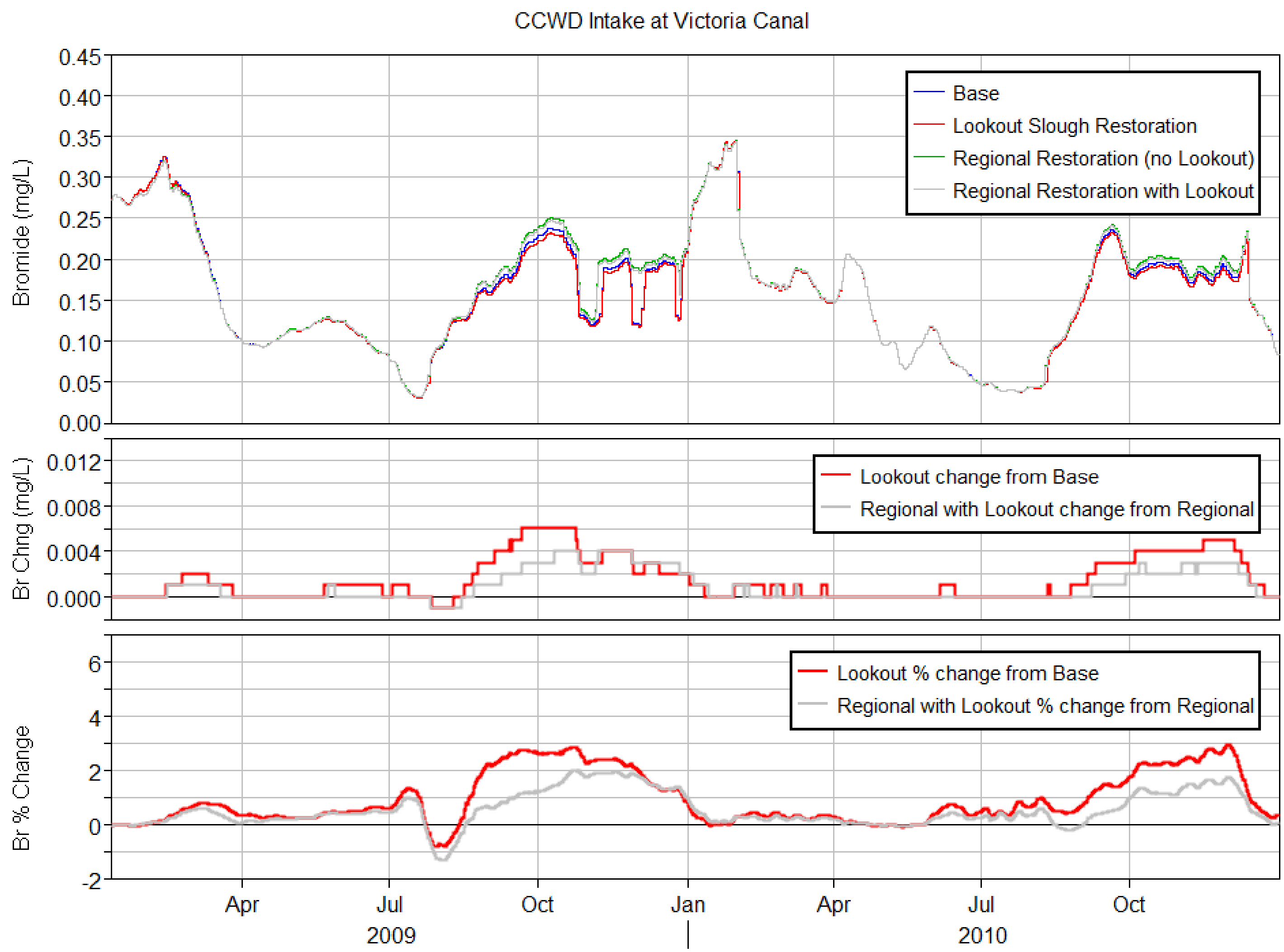

Figure 82 Daily average bromide at CCWD intake at Victoria Canal for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in bromide for the 2009-2010 simulation period.

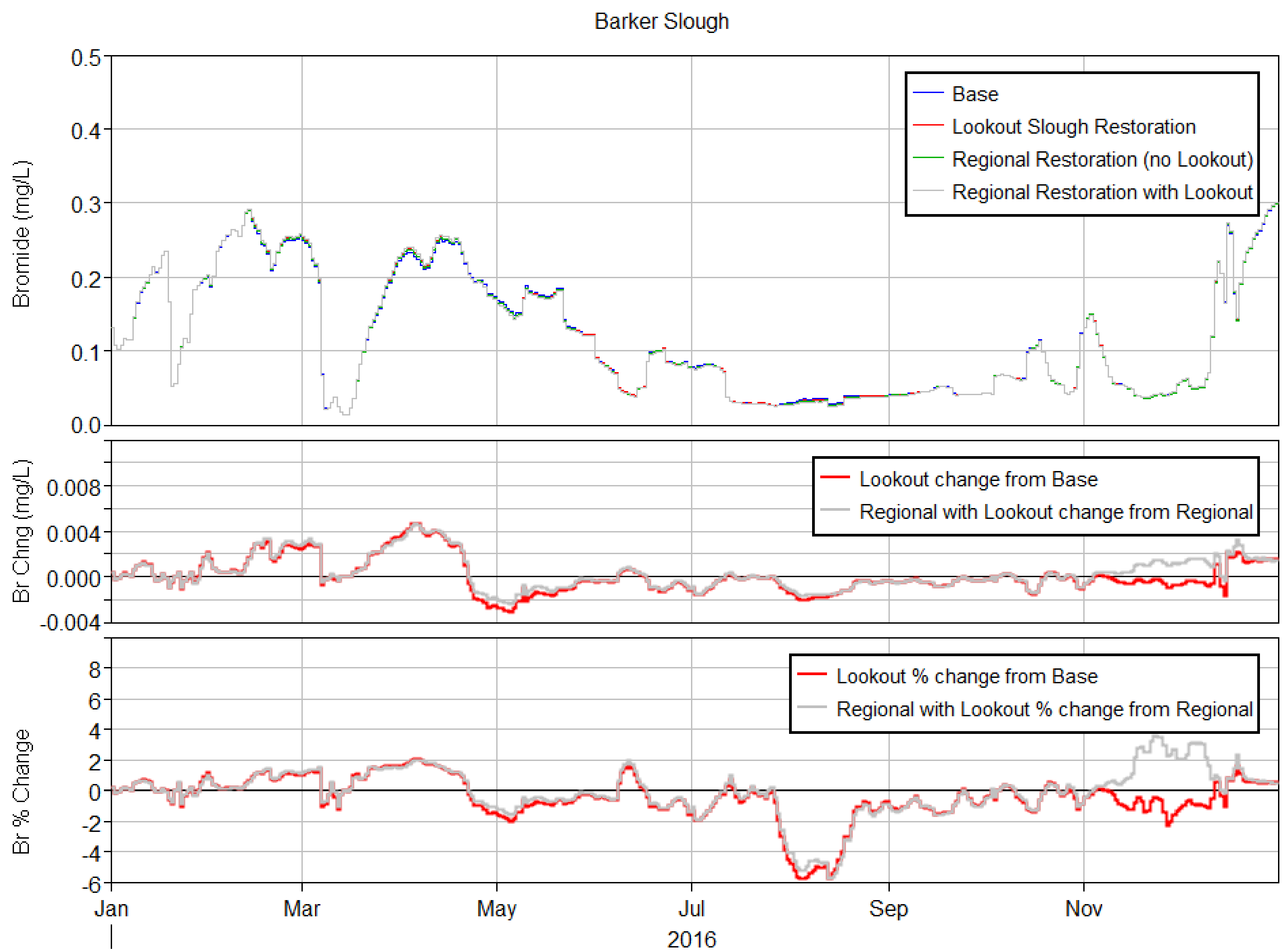

Figure 83 Daily average bromide at Barker Slough for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in bromide for the 2016 simulation period.

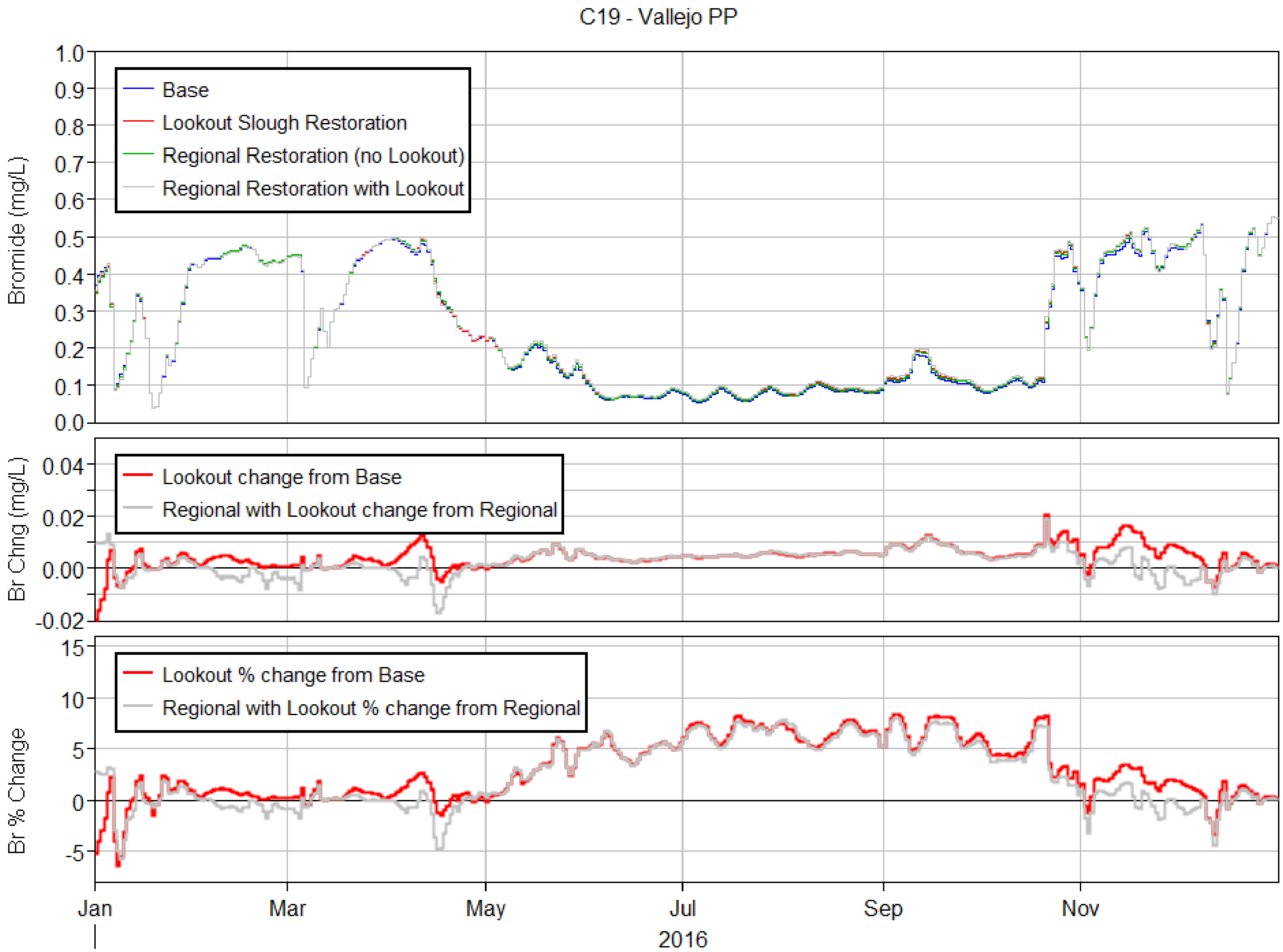

Figure 84 Daily average bromide at C19 for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in bromide for the 2016 simulation period.

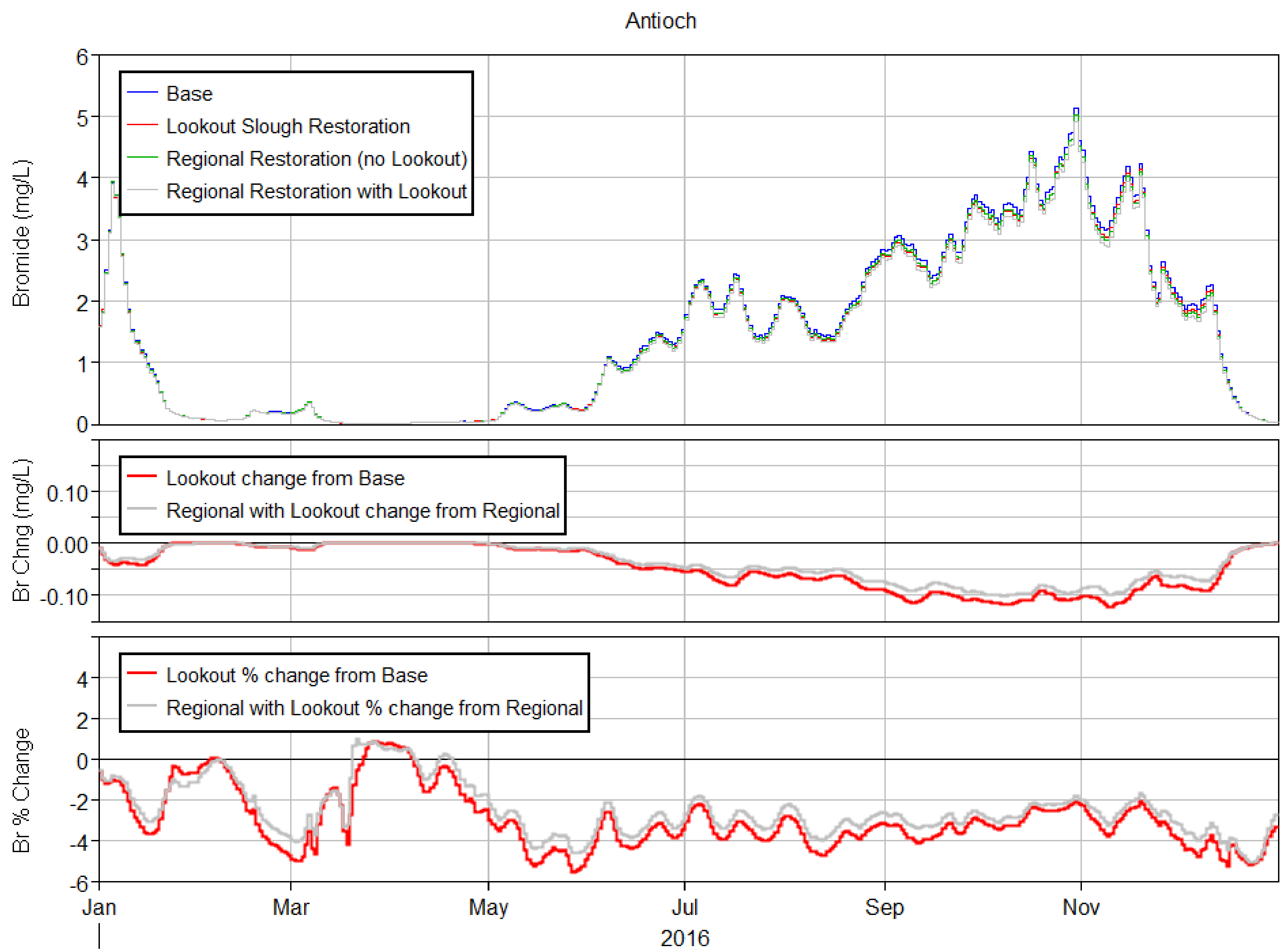

Figure 85 Daily average bromide at Antioch for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in bromide for the 2016 simulation period.

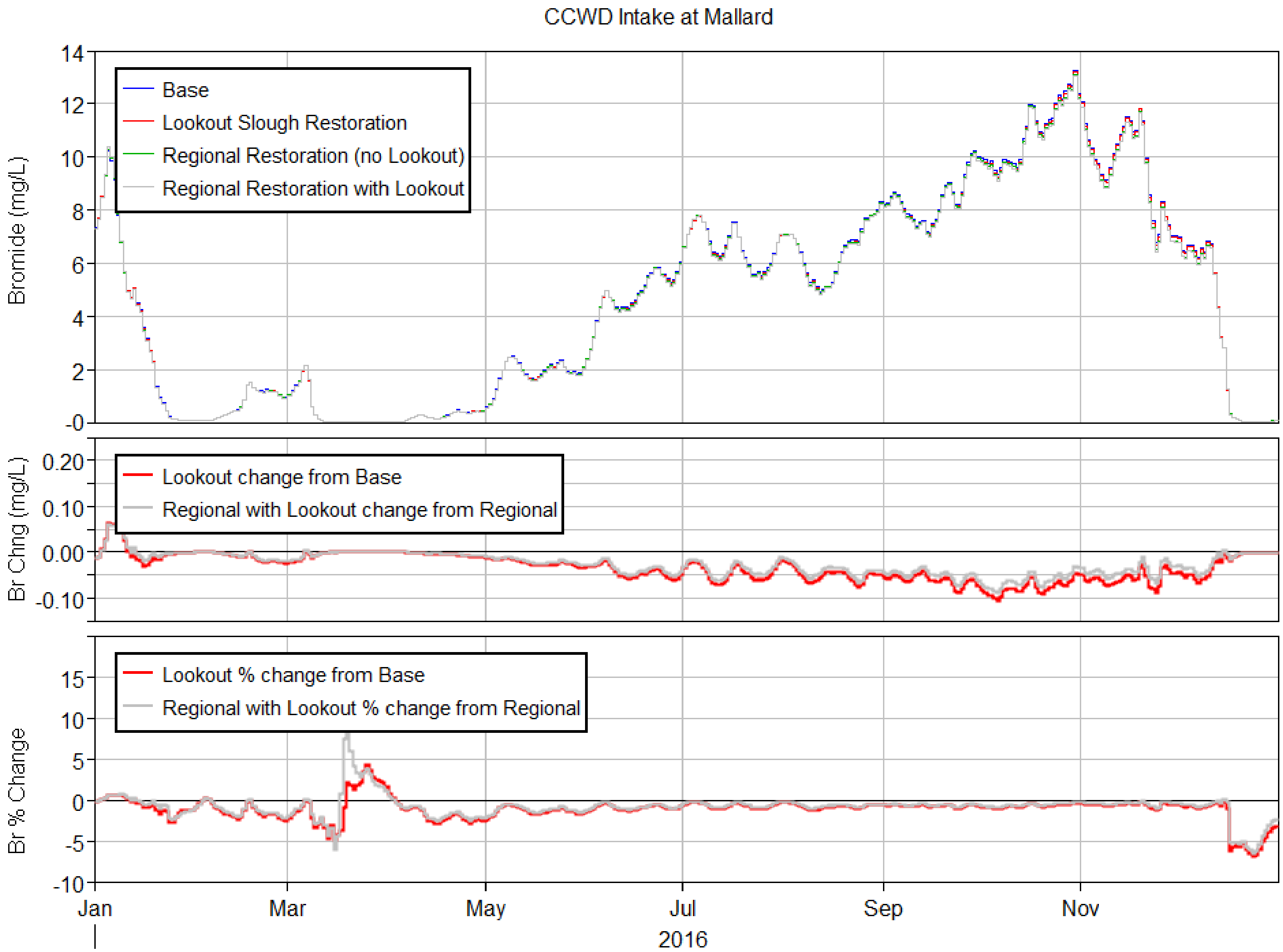

Figure 86 Daily average bromide at CCWD intake at Mallard for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in bromide for the 2016 simulation period.

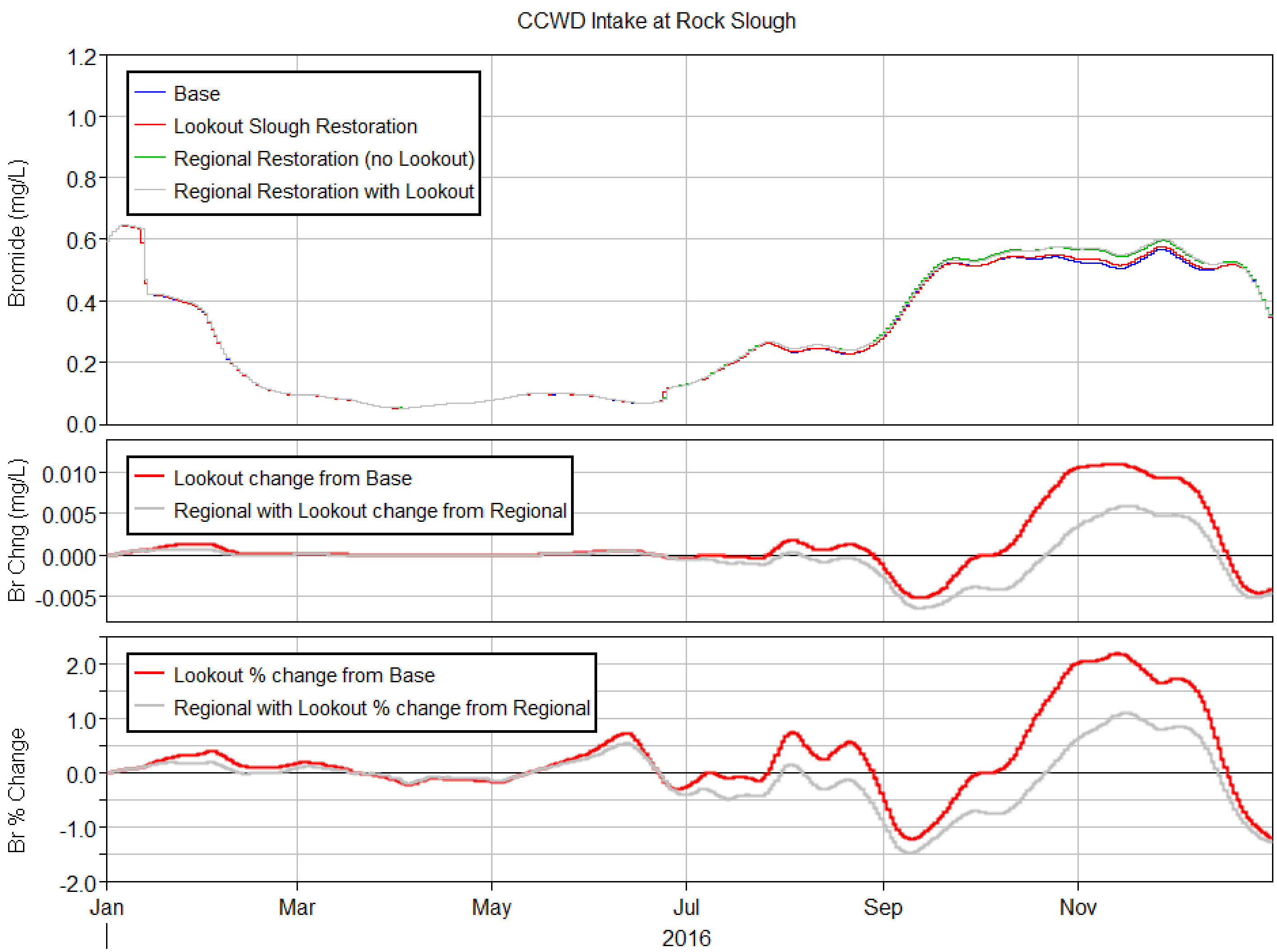

Figure 87 Daily average bromide at CCWD intake at Rock Slough for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in bromide for the 2016 simulation period.

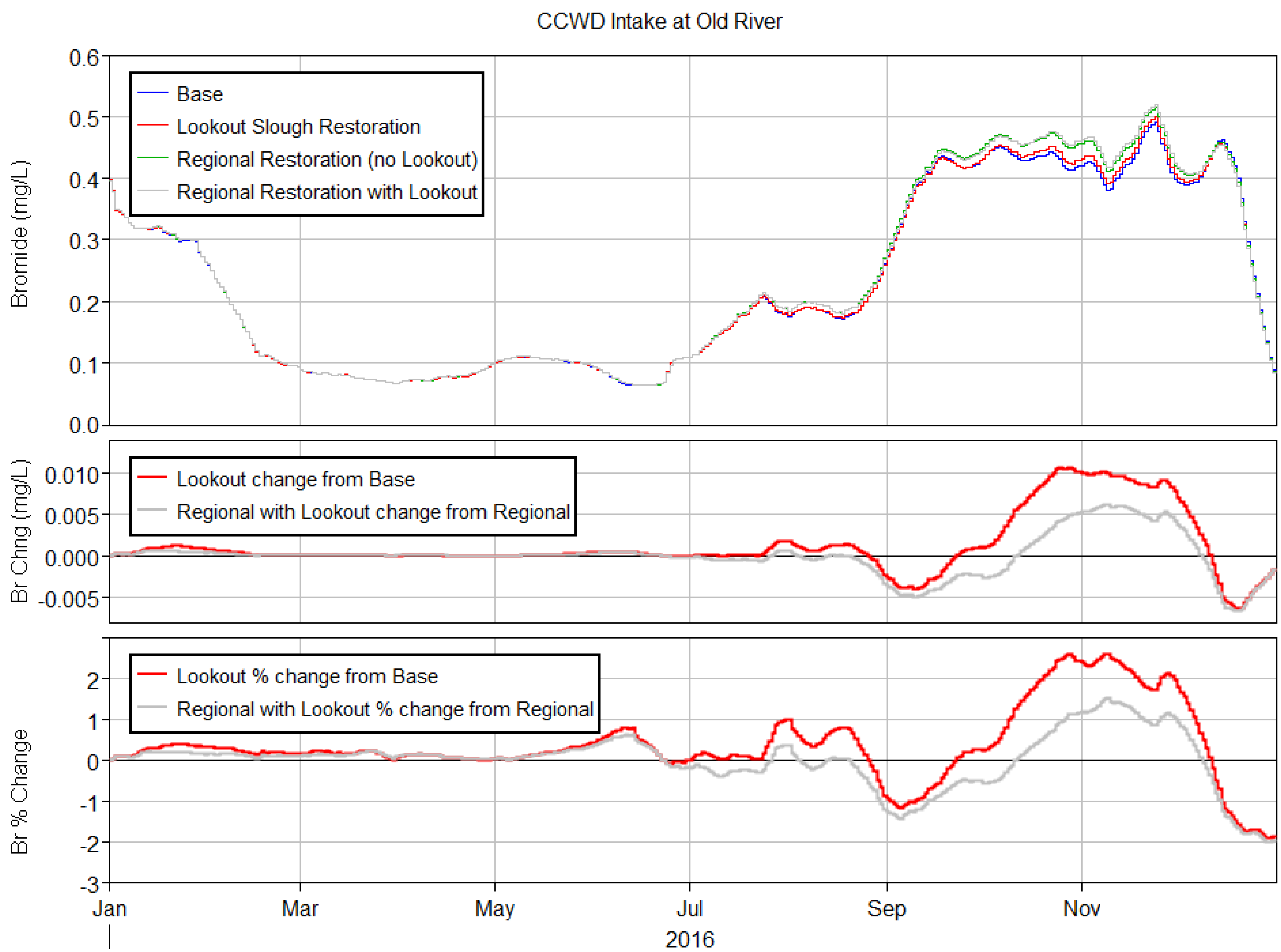

Figure 88 Daily average bromide at CCWD intake at Old River for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in bromide for the 2016 simulation period.

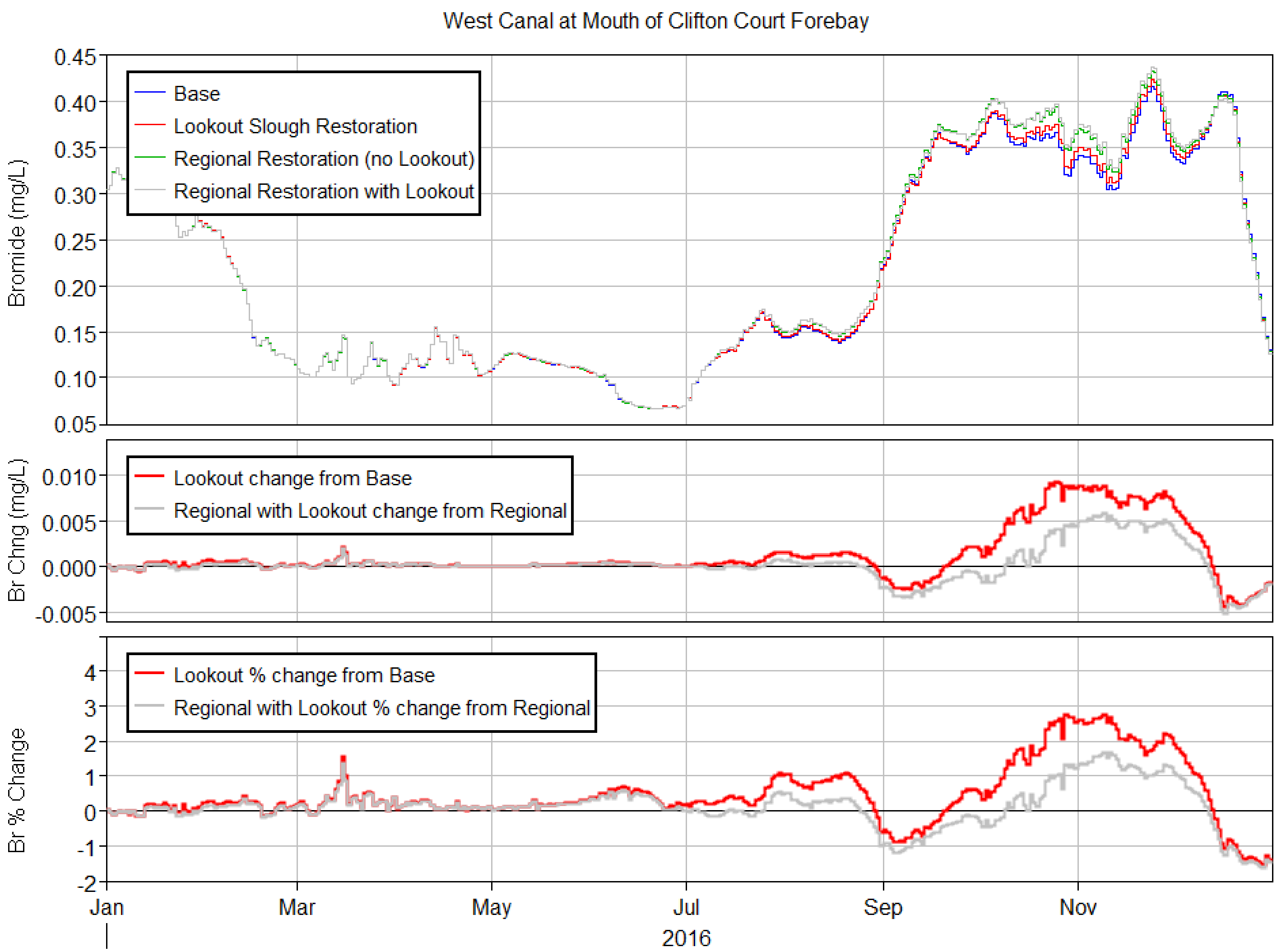

Figure 89 Daily average bromide at West Canal at mouth of Clifton Court Forebay for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in bromide for the 2016 simulation period.

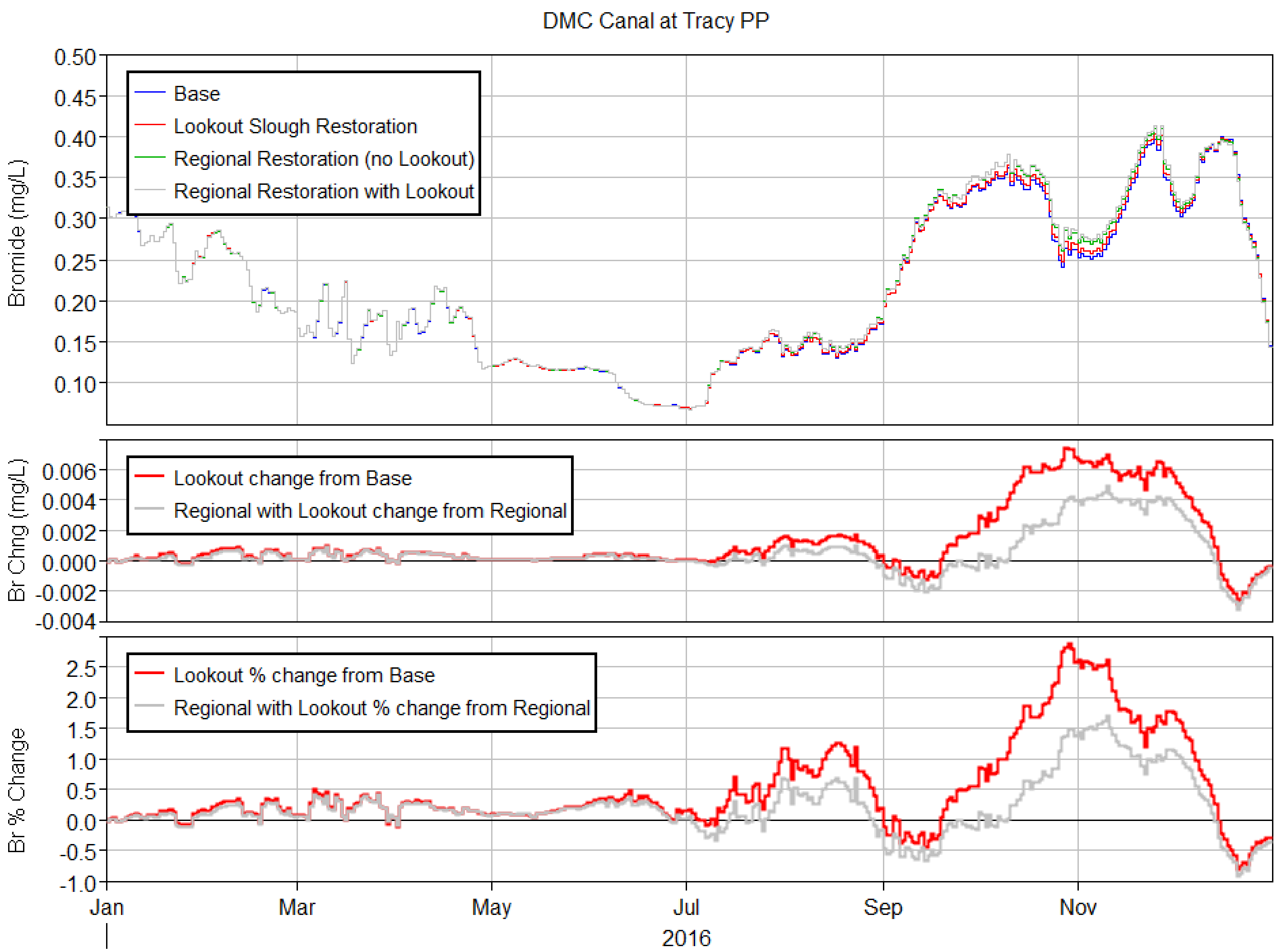

Figure 90 Daily average bromide at DMC Canal at Tracy PP for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in bromide for the 2016 simulation period.

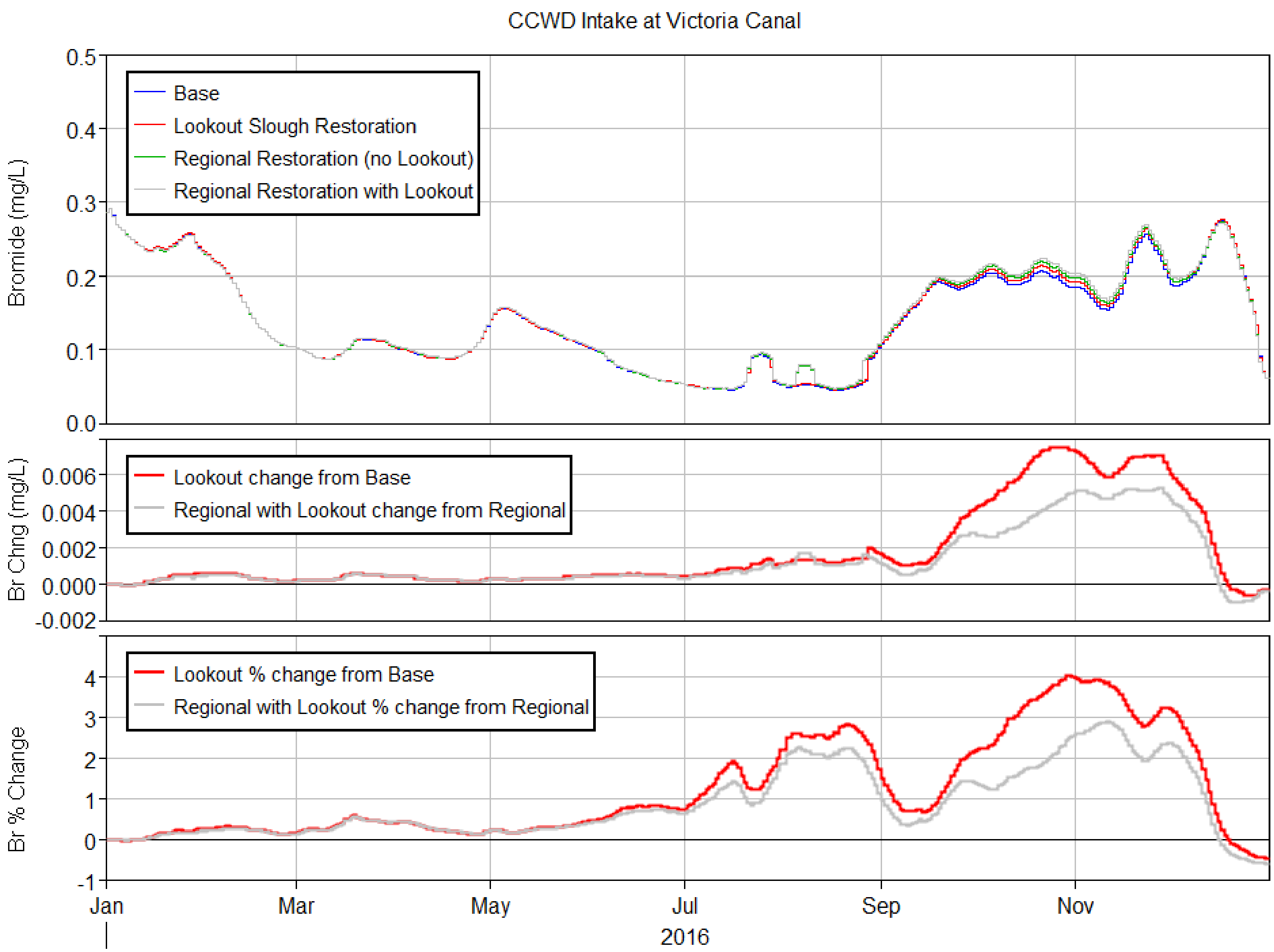

Figure 91 Daily average bromide at CCWD intake at Victoria Canal for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough plotted with daily average absolute and relative (%) change in bromide for the 2016 simulation period.

Summary and Conclusions

The RMA Bay-Delta model was applied to evaluate the potential for salinity impacts due to Lookout Slough Tidal Marsh Restoration and Flood Improvement Project relative to Base (existing) condition and to proposed Regional Restoration. Restoration was represented in sufficient detail to achieve the modeling goal of assessing regional salinity impacts. The evaluation periods were January 10, 2009 to December 31, 2010 and January 1 to December 31, 2016. These periods cover a dry year hydrology (2009) and a below normal year hydrology (2010) as well as a below normal year hydrology following four years of dry to critically dry conditions (2016).

The model was previously calibrated for the 2008 – 2013 period during the Regional Salinity modeling effort (RMA, 2017). For the current effort, further calibration was performed in the Cache Slough Complex (CSC) for the 2009-2010 and 2016 periods. Due to a lack of boundary condition data in this region, some inflow, withdrawal and EC boundary conditions had to be estimated to bring modeled results into closer agreement with observed data. Minor adjustments to the water quality model calibration throughout the model domain were also made. Overall, the model performed well for reproducing observed EC. The model underpredicts salinity in the winter of 2009-2010 in the central Delta and confluence area. Results in Upper Cache Slough are improved but the quality of the results still reflects the lack of data to characterize local sources of salinity from Ulatis Creek and local agricultural returns.

The first objective of the salinity evaluation was to quantify EC changes from the Base and Regional Restoration conditions arising with Lookout Slough. Daily and monthly averaged EC for all modeled scenarios were compared for select D-1641 compliance locations and water intakes. Lookout Slough generally decreases EC in the lower Sacramento River and in the San Joaquin River below Threemile Slough. Lookout Slough causes slight increases in EC in the central and south Delta, particularly from July through October. In the CSC, Lookout Slough restoration tends to reduce EC in Barker Slough and increase EC in upper Cache Slough. The increase in upper Cache Slough is the result of reduced mixing of local-source salinity.

The general observations are:

- Largest percent EC increases due to Lookout Slough restoration occur during the fall at Prisoners Point (as much as 3.5% relative to Base / 2.9% relative to Regional Restoration) and during the fall and summer at C19 (as much as 5.5% / 5.4%).

- Other locations with EC increases between about 1 and 2% include West Canal at Clifton Court, DMC at Tracy Pumping Plant, Collinsville, Rio Vista and CCWD intakes at Rock Slough, Old River and Victoria Canal.
- Largest percent EC decreases due to Lookout Slough occur during the spring in Barker Slough (as much as -4.3% / -4.2%), during the summer at Emmaton (as much as -4.7% / -2.3%) and Jersey Point (as much as -3.7% / -3.2%), during the summer and fall at Antioch (as much as -3.6% / -3.0%) and during the fall at Rio Vista (as much as -4.7% / -2.0%).

One of the primary mechanisms impacting modeled salinity is a decreased tidal range in the north Delta resulting from Lookout Slough restoration. This tidal range decrease results in slightly less flow through the Delta Cross Channel and Georgiana Slough and slightly more flow down Sutter and Steamboat Sloughs and the Sacramento River below Georgiana Slough. This shift of freshwater flow results in decreased salinity in the Sacramento River and western Delta as well as the corresponding increased salinity in the central Delta when the Delta Cross Channel is open, typically late June through October.

The Regional Restoration shifts even more flow toward the Sacramento River. The Lookout Slough flow shift relative to the Regional Restoration flows is smaller and therefore the % salinity changes are smaller than the changes from Base.

The second goal of the salinity model evaluation was to determine the potential for Lookout Slough restoration to result in changes to compliance status with the D-1641 water quality objectives. The compliance analysis considered seasonal agriculture, fish and wildlife EC standards for the Sacramento River at Emmaton and Collinsville, and the San Joaquin River at Jersey Point and Prisoners Point and chloride standards at the water intakes. At Emmaton, Jersey Point and Prisoner Point there were no new compliance issues resulting from Lookout Slough. Where historical standards violations occurred, Lookout Slough slightly decreased EC. At Collinsville the same was true except for February 2009, where Lookout Slough resulted in slight EC increases when a historical violation occurred.

Modeled EC results were converted to chloride to assess compliance at the water intakes. No violations of the water quality objectives occurred at any of the intakes under any of the modeled configurations or time periods and, relative to Base and Regional Restoration, Lookout Slough restoration had almost no impact on the maximum mean daily chloride values used to determine compliance.

Evaluation of changes to X2, a Bay-Delta Plan compliance standard, indicates that Lookout Slough restoration would generally decrease monthly averaged X2 by 0.2 km or less and not cause any changes in compliance.

Bromide concentrations were estimated from modeled EC and Martinez volumetric source fraction. Lookout Slough was found to increase bromide at south Delta water intakes by as much as 1 to 3% and decrease bromide at Antioch and the CCWD intake at Mallard by 1 to 4%.

Although results based on published relationships between EC and bromide predict increases in bromide at C19 and at times in Barker Slough, there is uncertainty in the magnitude of these changes because the EC to bromide conversion equations were not developed specifically for the conditions occurring in this area, where local inflows are the primary source of salinity.

References

cbec (2011). Prospect Island Tidal Restoration Project, Summary of Bathymetric and Topographic Data Sources, Technical Memorandum. DWR Task Order SS-02, Task 3.

Denton, R. (2015). Delta Salinity Constituent Analysis, February 2015.

Department of Water Resources (DWR) (2007). Sacramento-San Joaquin Delta LiDAR Acquisition. California Department of Water Resources, Delta-Suisun Marsh Office.

DWR (2010). State of California, Department of Water Resources, Delta Habitat conservation and Conveyance Program (DHCCP), Bathymetric Survey (Multibeam and Dynamic LiDAR Method).

DWR (2011a). State of California, Department of Water Resources, FloodSAFE California Initiative, Central Valley Floodplain Evaluation and Delineation Program, Bathymetric Survey (Single Beam Method).

DWR (2011b). Water Quality Conditions in the Sacramento-San Joaquin Delta and Suisun and San Pablo Bays during 2010, December 2011.

DWR (2012a). *(DRAFT)* Multibeam Bathymetry Project Report, Miner Slough & Sacramento Deep Water Ship Channel near Prospect Island.

DWR (2012b). Liberty Island bathymetry, March 2012, Metadata.

Environmental Data Solutions (2012). Prospect Island Tidal Wetland Restoration Project Condition Bathymetric Survey: Cache Slough, Sutter Slough and the Sacramento River at Rio Vista. DWR Task Order SS-02, Task 2.

RMA (2003). RMASIM Users Guide, April 2003.

RMA (2009). Numerical Modeling in Support of Suisun Marsh PEIR/EIS, Technical Appendix, September 2009.

RMA (2010). Franks Tract Project Model Evaluation of Hydrodynamics and Water Quality, October 2010.

RMA (2012). Appendix D: Prospect Island Tidal Restoration Project Calibration and Verification of Hydrodynamic Model Used for Phase 1 Preliminary Alternatives Screening. Technical Memorandum, June 2012. From, Stillwater Sciences and Wetlands and Water Resources, Inc. (2012). Prospect Island Tidal Restoration: Synthesis of Phase 1 Screening-

Level Modeling Evaluation of Conceptual Restoration Alternatives, Final Report, September 2012.

RMA (2013). Prospect Island Tidal Restoration Project Calibration and Verification of Water Quality Model Used for Phase 2 Alternatives Evaluation. Technical Memorandum. Prepared for Wetlands and Water Resources, July 2013.

RMA (2015a). *Initial Modeling of Local and Regional Impacts of the Proposed Winter Island Tidal Marsh Restoration*. Technical Memorandum, July 2015. https://coveredactions.deltacouncil.ca.gov/services/download.ashx?u=447f1b4a-3332-4af4-8b5b-6806ef11c7d6

RMA (2015b). Salinity Modeling Analysis of the Proposed Tule Red Tidal Marsh Restoration, Grizzly Island, California. Technical Memorandum, November 2015. https://coveredactions.deltacouncil.ca.gov/services/download.ashx?u=228cf586-0206-44ba-bbf0-104f8a4f8fc9

RMA (2017). RMA Delta Model Calibration Report, April 13, 2107.

USACE (2002). Sacramento and San Joaquin River Basins Comprehensive Study. US Army Corps of Engineers Sacramento District, December 2002.

USACE (2005). Sacramento River Deep Water Ship Channel, California, Maintenance Dredging Site – Task Order #6.

USBR 2010. Delta-Mendota Canal Recirculation Feasibility Study, Appendix G: Drinking Water Evaluation. Plan Formulation Report. U.S Dept. of the Interior, Bureau of Reclamation, Mid-Pacific Region. Sacramento, California, January 2010.

USBR 2015. Central Valley Project Municipal and Industrial Water Shortage Policy Environmental Impact Statement, Final. Appendix C: Delta Water Quality Model Documentation. U.S Dept. of the Interior, Bureau of Reclamation, Mid-Pacific Region. Sacramento, California, August 2015.

Appendix A: Model Boundary Conditions

2009-2010 Boundary Conditions

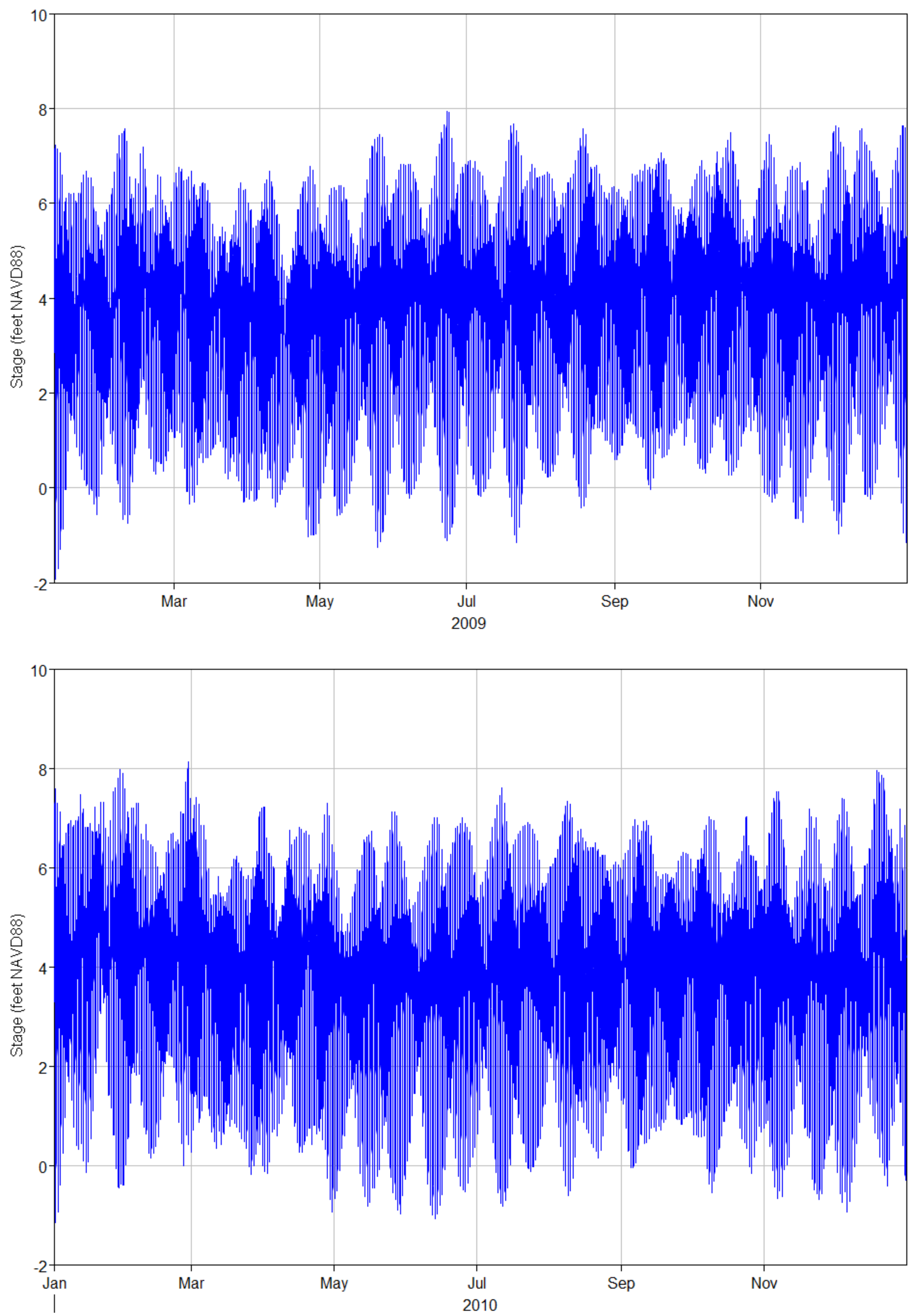

Figure 92 Golden Gate stage boundary for 2009 – 2010 (data source: NOAA, shifted +0.46 ft).

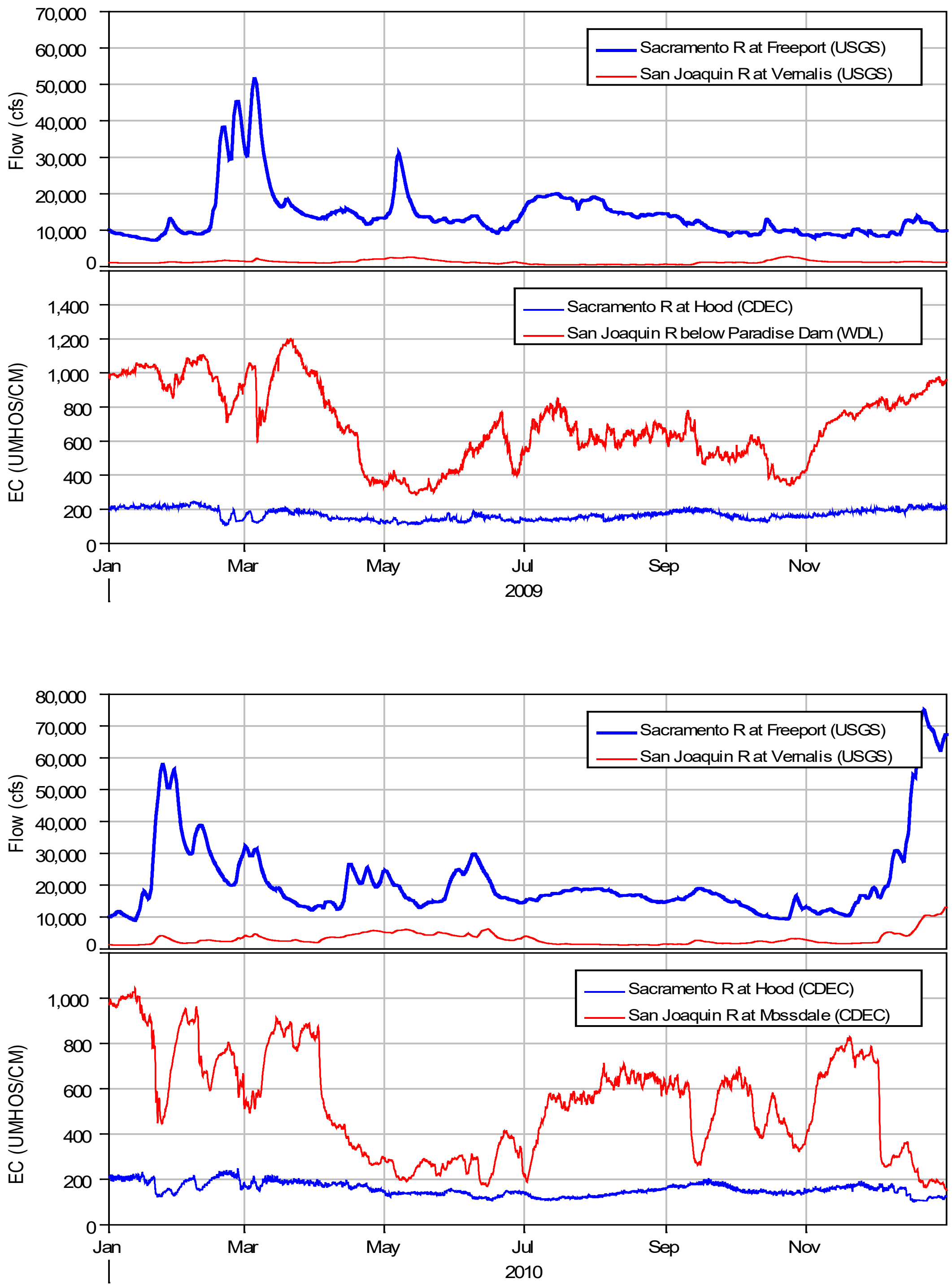

Figure 93 Flow and EC boundary conditions for the Sacramento River and San Joaquin River for 2009-2010.

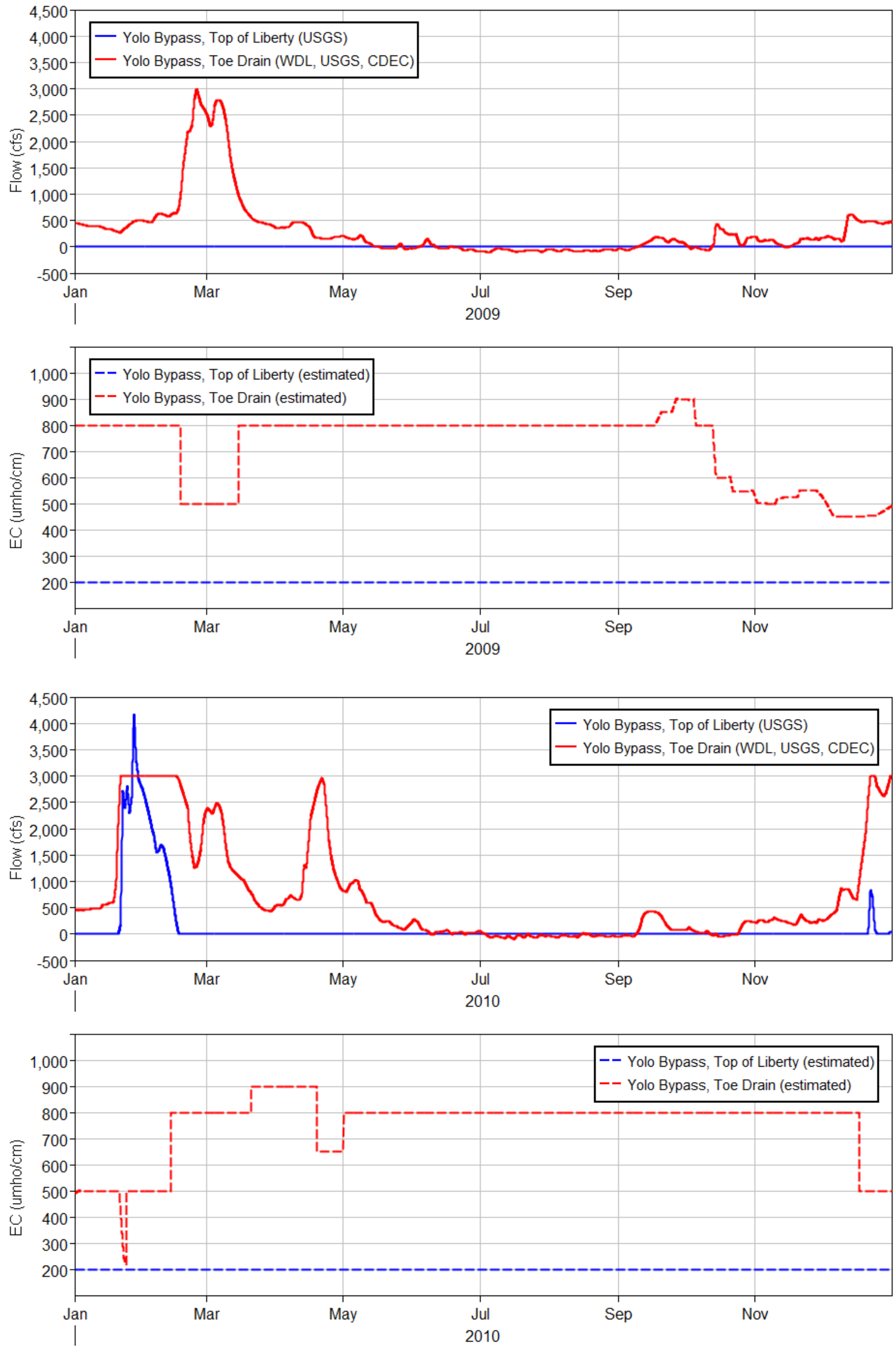

Figure 94 Flow and EC boundary conditions for Yolo Bypass for 2009-2010.

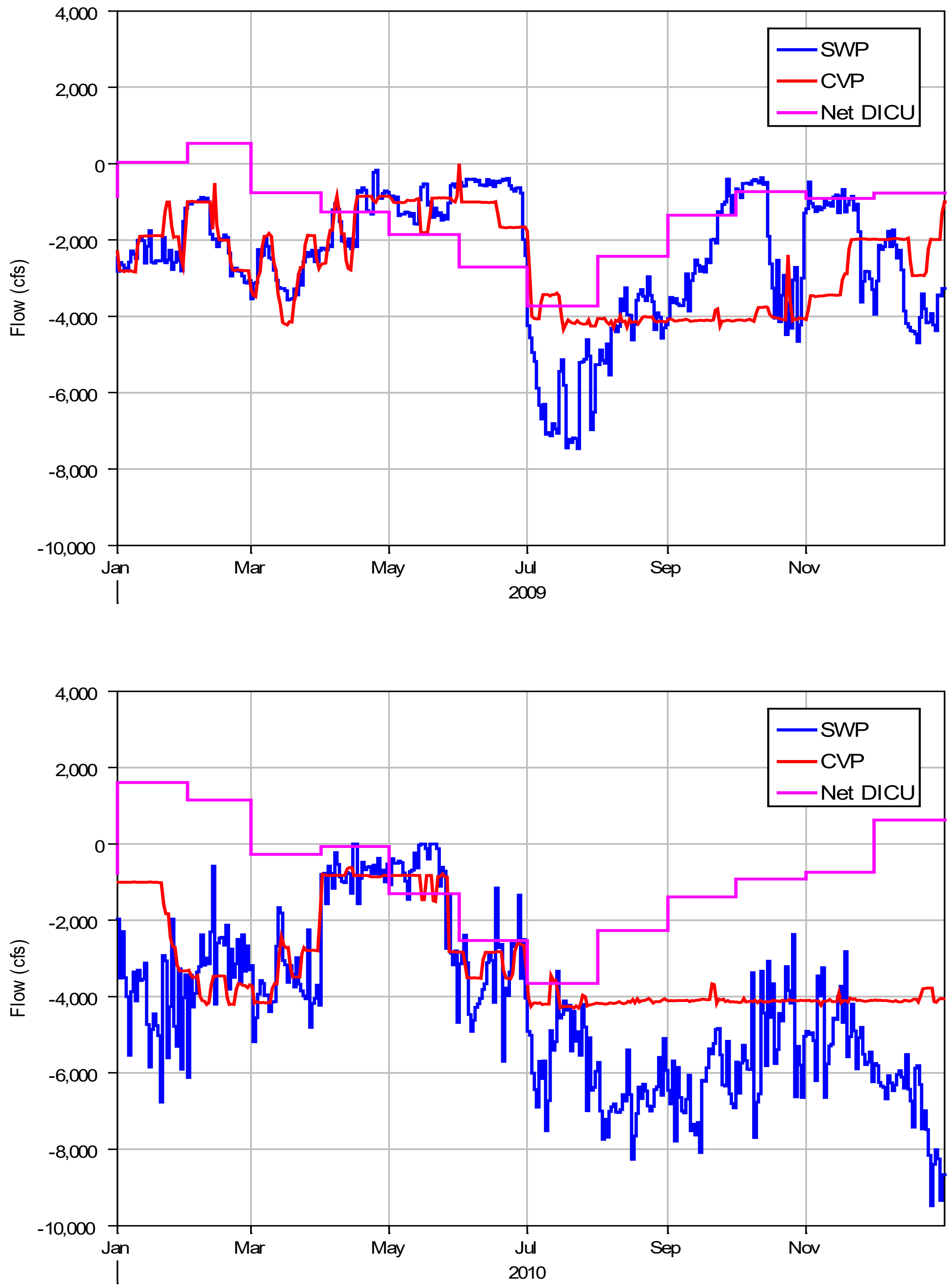

Figure 95 Delta exports and diversions for 2009-2010. Positive Net DICU occurs when overall Delta Island return flow exceeds diversion flow.

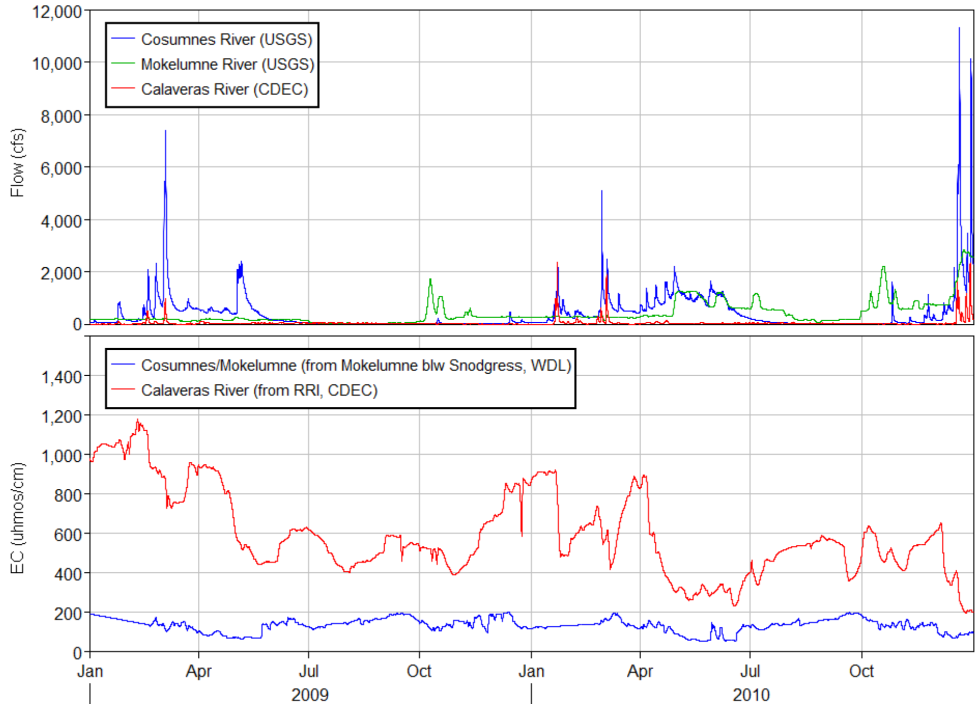

Figure 96 Flow and EC boundary conditions for the Cosumnes, Mokelumne and Calaveras Rivers for the 2009-2010 model analysis period.

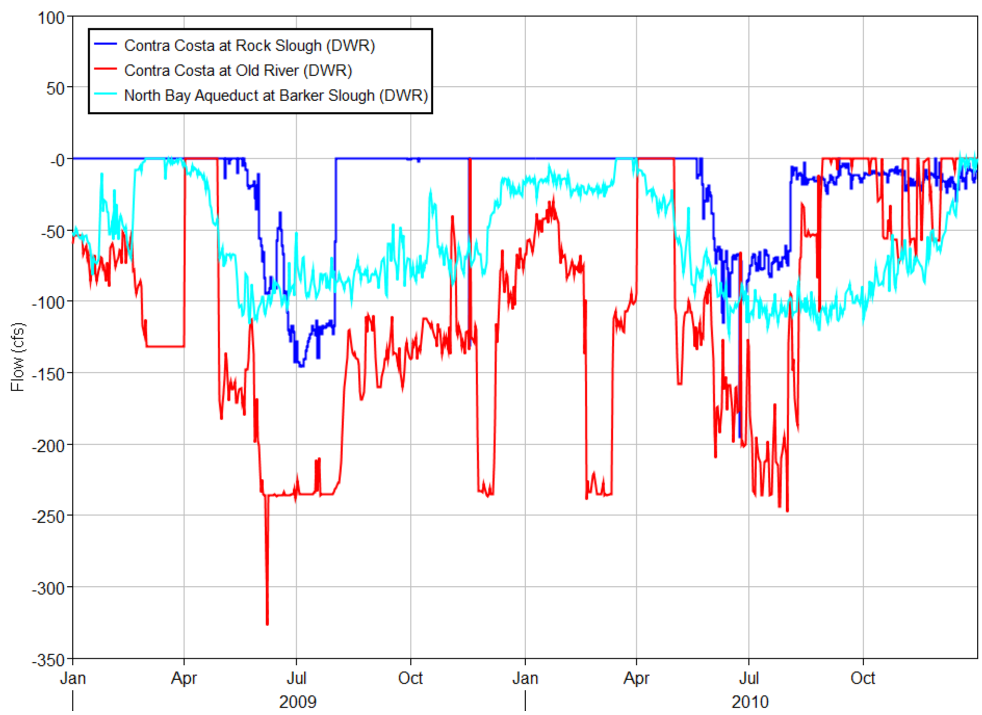

Figure 97 Flow diversion boundary conditions for the Contra Costa and North Bay Aqueduct water intakes for 2009 – 2010.

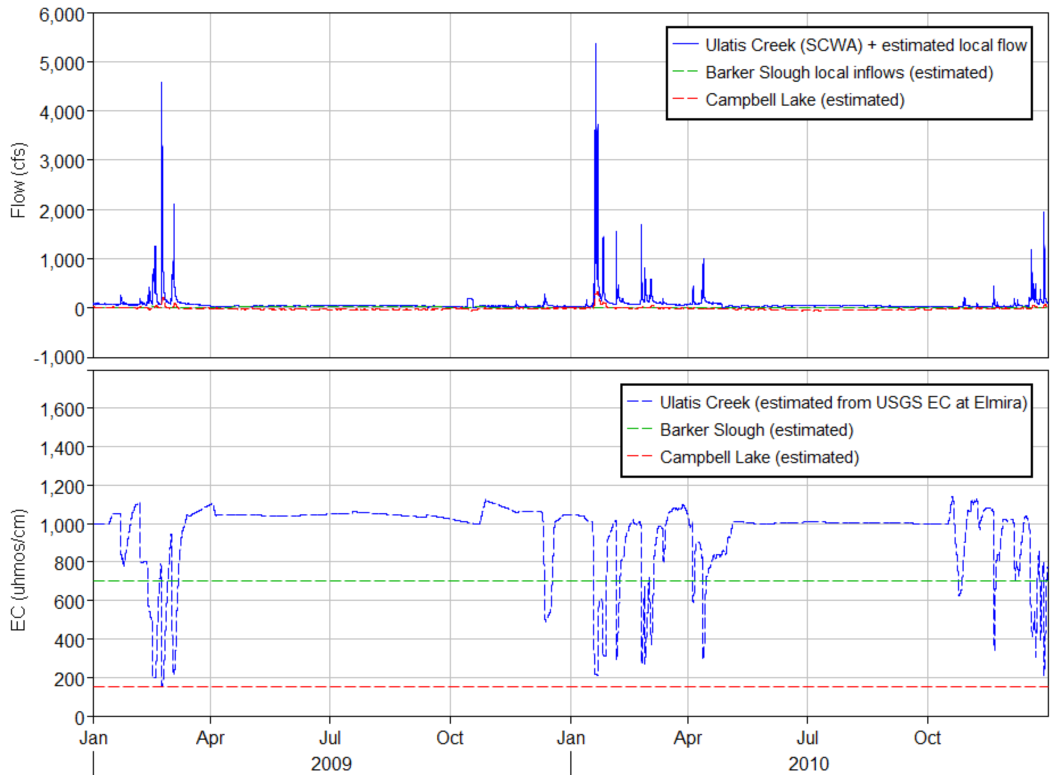

Figure 98 Flow and EC boundary conditions for Ulatis Creek, Barker Slough (estimated) and Campbell Lake (estimated) for 2009-2010.

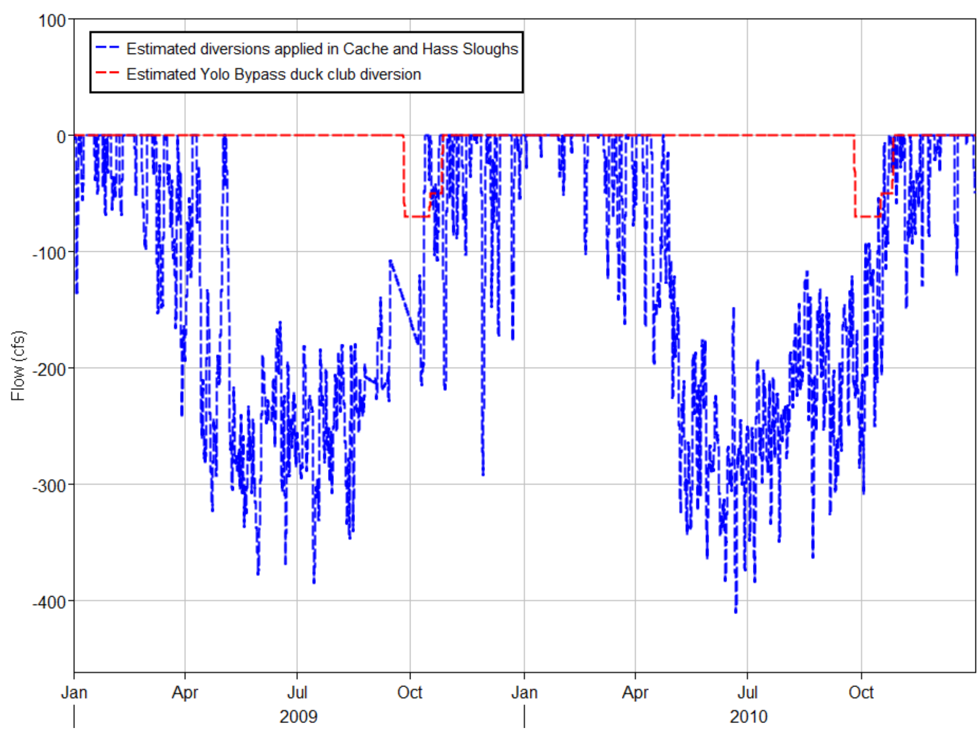

Figure 99 Estimated flow diversion boundary conditions for Cache and Hass Sloughs and Yolo Bypass duck club for 2009-2010.

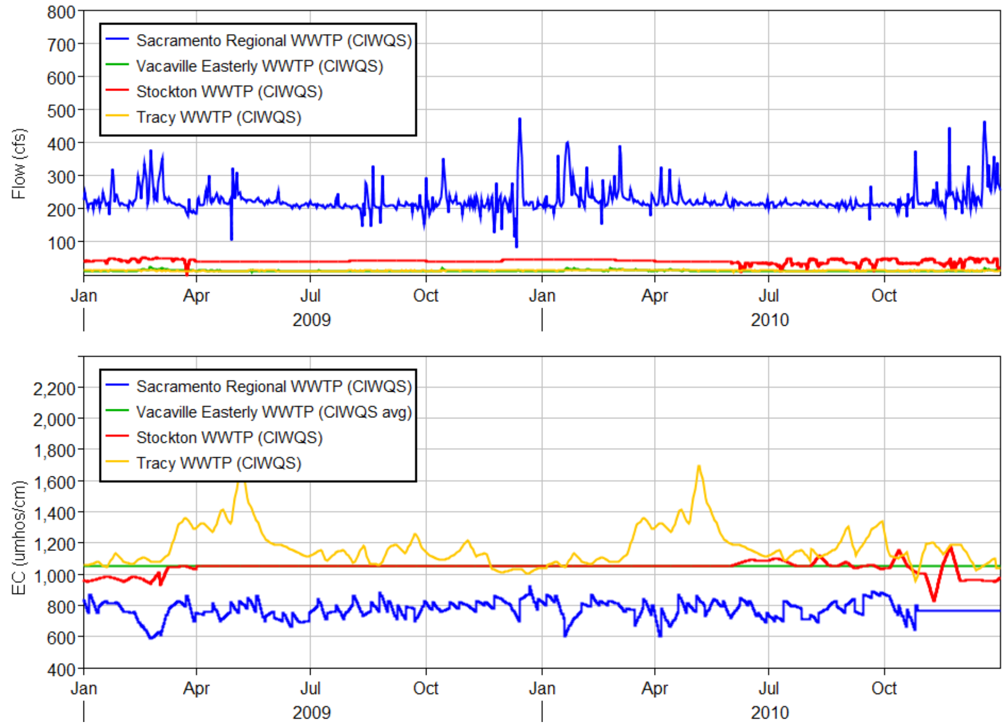

Figure 100 Flow and EC boundary conditions for wastewater treatment plants for 2009-2010.

2016 Boundary Conditions

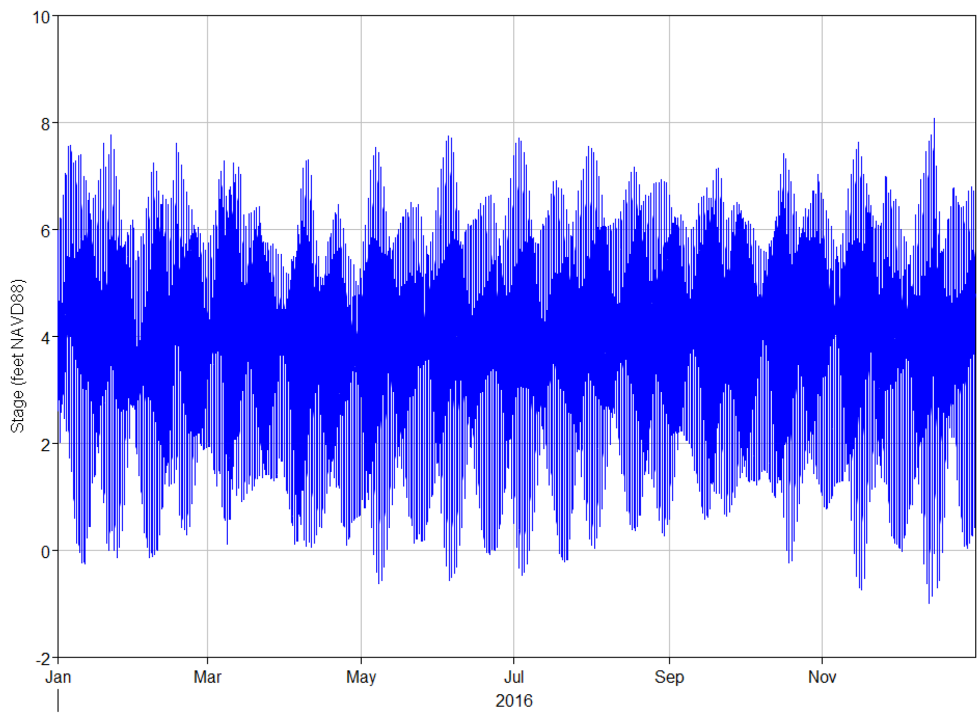

Figure 101 Golden Gate stage boundary for 2016 (data source: NOAA, shifted +0.46 ft).

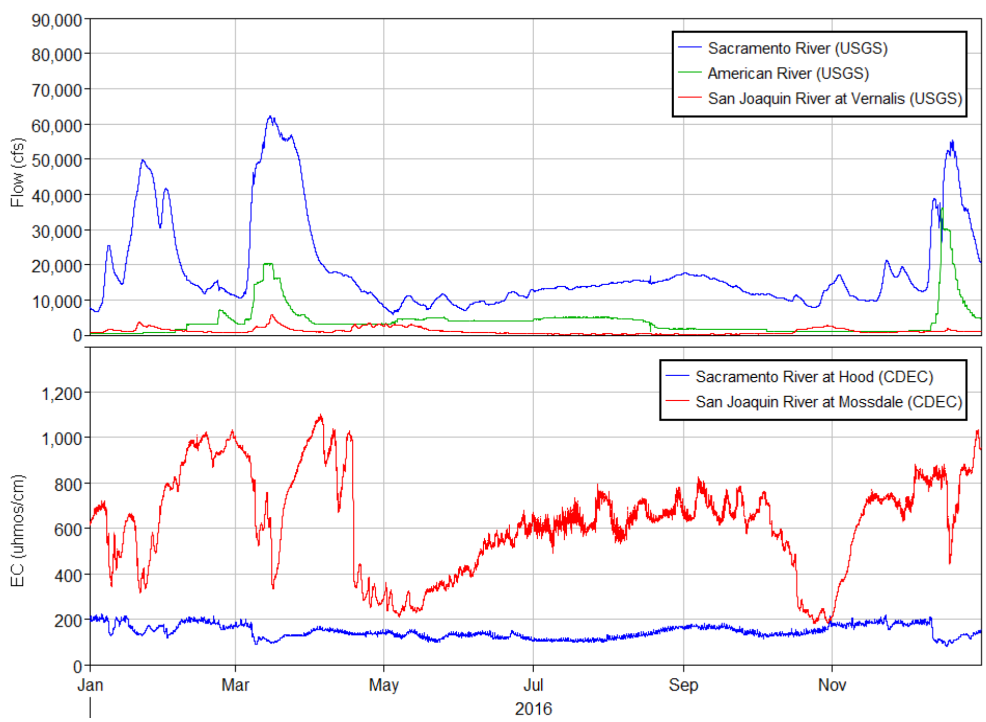

Figure 102 Flow and EC boundary conditions for the Sacramento River and San Joaquin River for 2016.

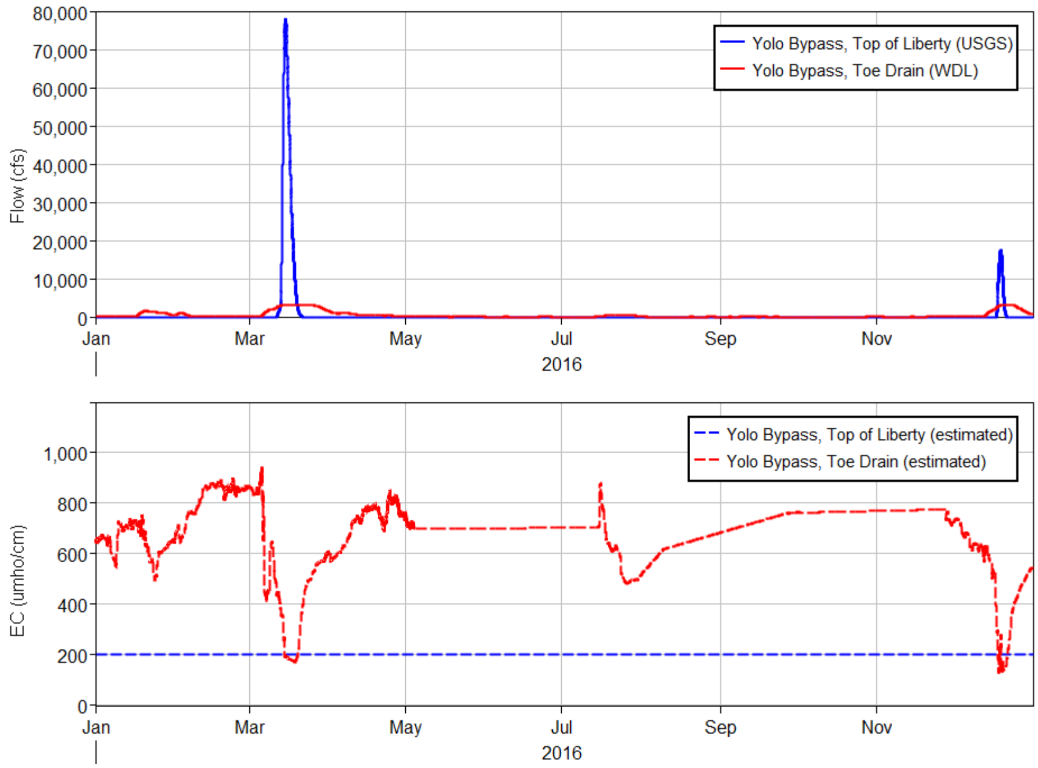

Figure 103 Flow and EC boundary conditions for Yolo Bypass for 2016.

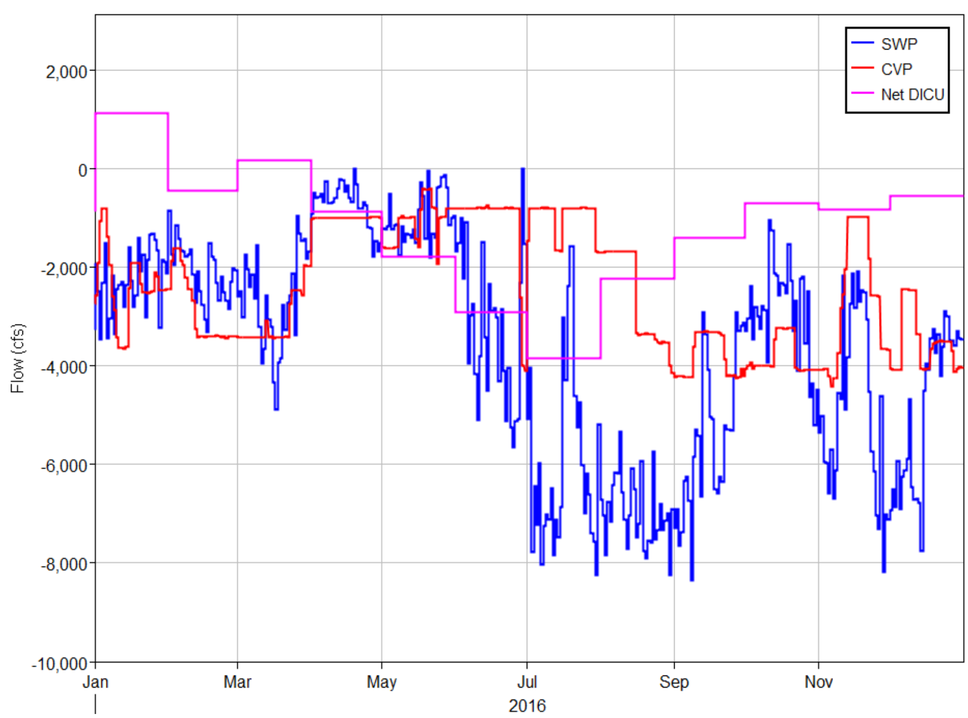

Figure 104 Delta exports and diversions for 2016. Positive Net DICU occurs when overall Delta Island return flow exceeds diversion flow.

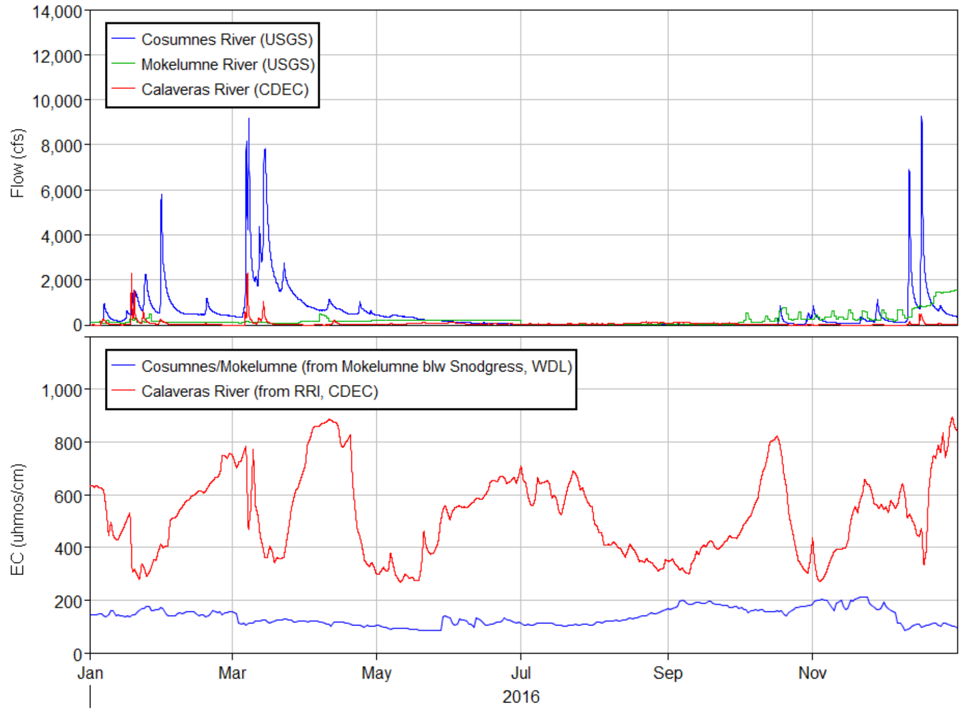

Figure 105 Flow and EC boundary conditions for the Cosumnes, Mokelumne and Calaveras Rivers for 2016.

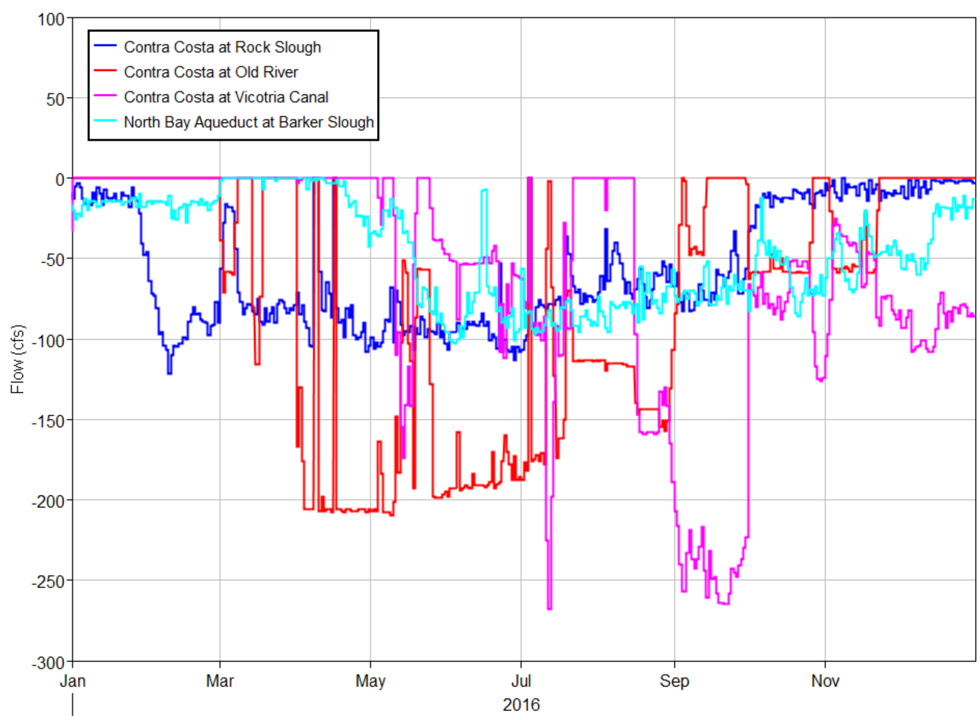

Figure 106 Flow diversion boundary conditions for the Contra Costa and North Bay Aqueduct water intakes for 2016.

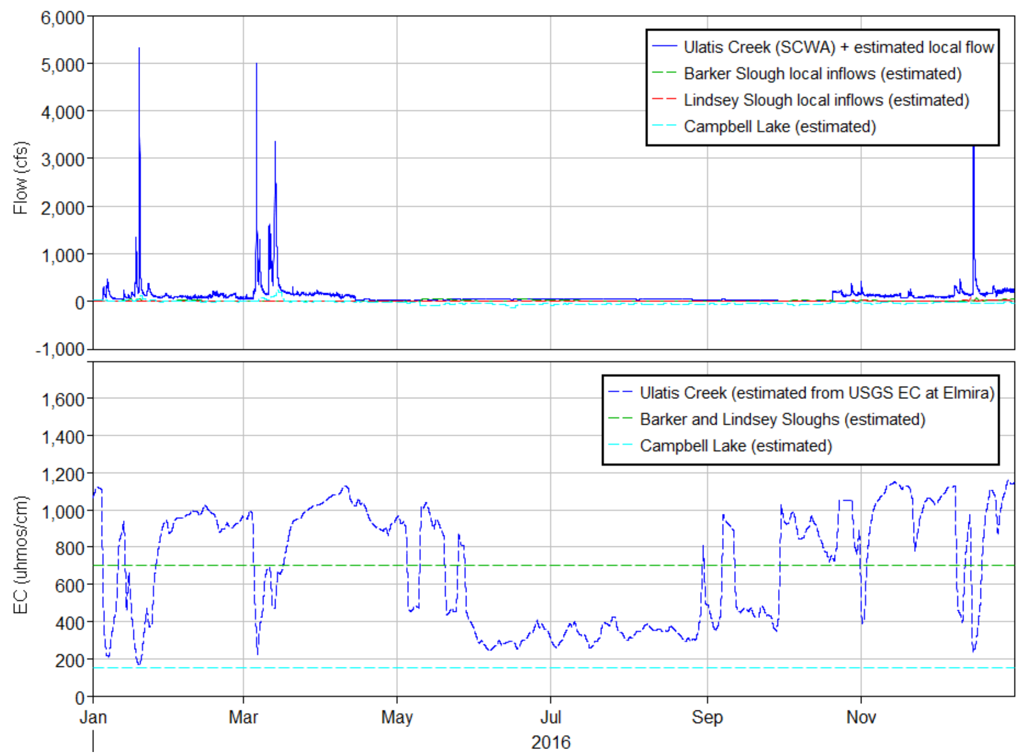

Figure 107 Flow and EC boundary conditions for Ulatis Creek, Barker Slough (estimated) Lindsey Slough (estimated) and Campbell Lake (estimated) for 2016.

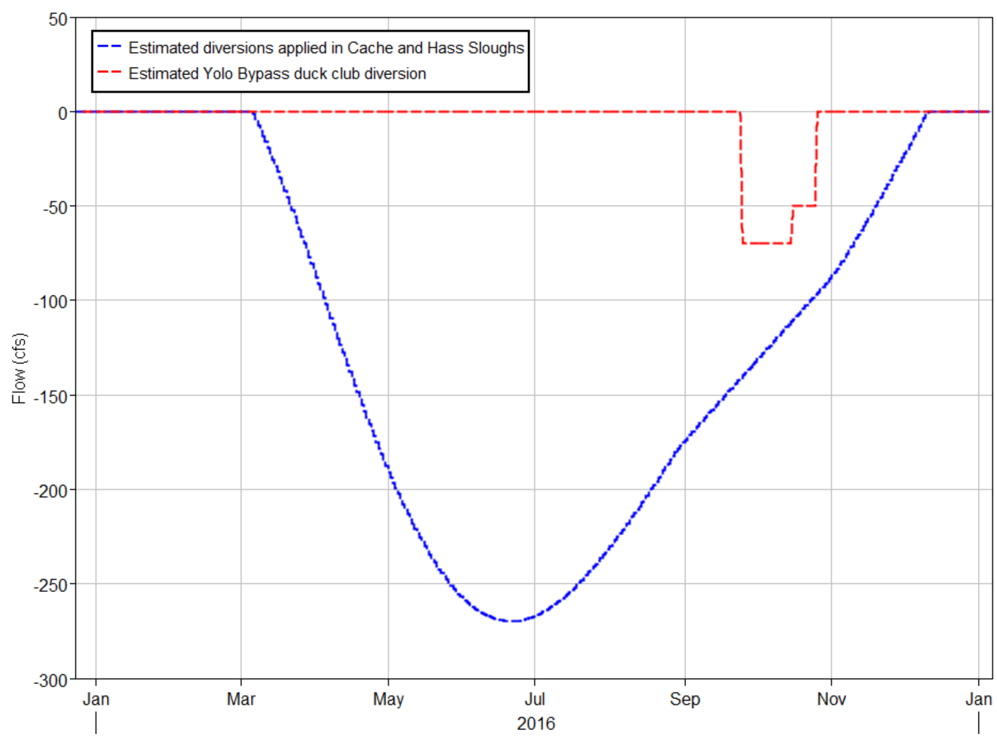

Figure 108 Estimated flow diversion boundary conditions for Cache and Hass Sloughs and Yolo Bypass duck club for 2016.

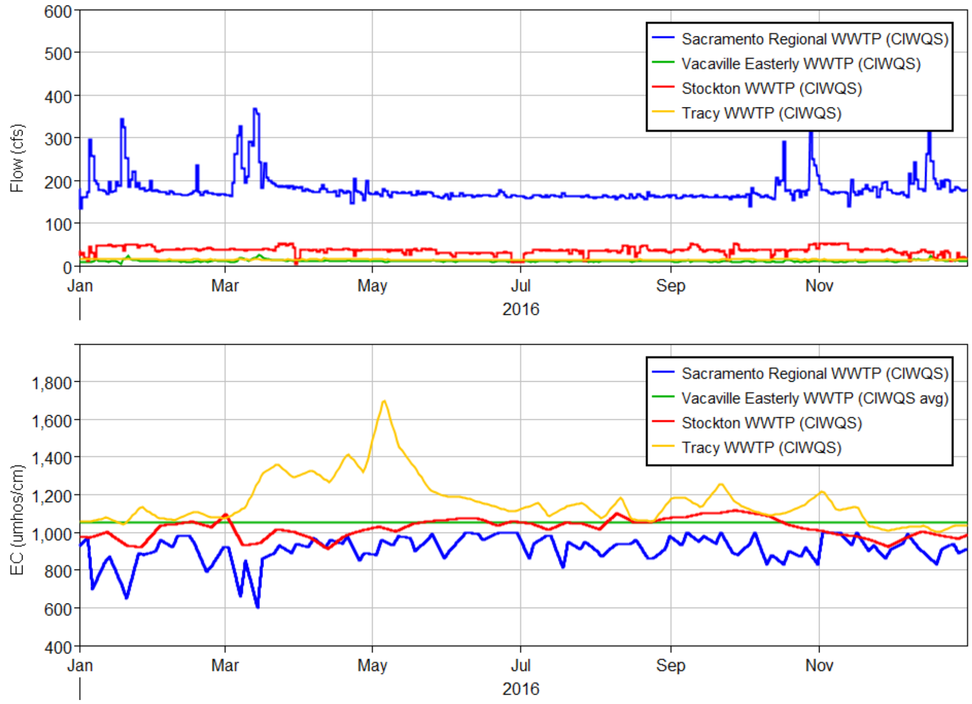

Figure 109 Flow and EC boundary conditions for wastewater treatment plants for 2016.

Appendix B: Water Quality Model Calibration

Introduction

The RMA Bay-Delta model was calibrated for hydrodynamics and water quality transport for the 2008 – 2013 period during the Regional Salinity modeling effort (RMA, 2017). For the current study the water quality calibration was refined in the north Delta. This involved estimation of boundary conditions where no data are available. Calibration in other areas of the Delta was also refined as needed. The calibration refinement was performed for the January 2009 – December 2010 and January – December 2016 periods.

The objective of the calibration section is to show that the model can reasonably reproduce historical salinity (EC) in the Delta system and to provide the information about where the model values differ from observed data.

Calibration Metrics

The observed and model EC at selected Delta monitoring stations are compared in 3-panel plots as shown in Figure 110.

- The top panel provides a visual comparison of the 15-minute interval observed and computed EC to illustrate how well the model reproduces the inter-tidal dynamics of the system.
- The lower-left panel provides a visual comparison of the tidally-averaged observed and computed EC time series to illustrate how well the model reproduces the net transport of EC over the simulation period.
- The lower-right panel presents a linear regression analysis of tidally averaged values of observed and computed EC to provide statistical values of the model performance.

Tidal Filtering

For the EC impacts analysis presented in this report, EC was evaluated on mean daily or mean monthly basis. As such, the calibration plots and statistics are focused on the tidally averaged observed and computed time series data. Daily averaged values can produce some artifacts in the output time series due to the mismatch between the 24-hour solar day and the 24.83-hour tidal day so evaluating tidally filtered time series was preferred.

The 15-minute computed and observed EC time series were tidally averaged or tidally filtered with two passes of a 24.75 hour moving average window. With only a single pass of the averaging window, a significant tidal signal can still be present especially for a flow record where the net flow may be a small fraction of the peak tidal flow. A Godin tidal filter was considered but not used because it produces somewhat more smoothing than the two-pass filter, which may not always be desirable. Digital filters such as the Godin tidal filter can provide better control of the frequency content of the filtered record but can have undesirable effects at the ends of the time series, and at data gaps, which are common in the observed records.

Calibration Statistics

Mean value and linear regression statistics were computed from mean daily values of the tidally filtered time series described above. The mean value and linear regression statistics are presented in the lower right panel of the calibration plot (Figure 110).

Mean values were computed to provide an overall measure of the model bias. The mean values were computed using all points within the specific simulation period, for example January 2009 – December 2010. Model values were excluded from the computation for the times when observed values were missing.

The tidally averaged observed and computed time series EC were compared on a point by point basis through a linear regression analysis. The better the model is at reproducing detailed variations and trends of the observed values, the smaller the scatter will be. One measure of the scatter is the goodness of fit parameter, R^2. Additionally, the slope of the regression line should be close to 1 to indicate a good fit.

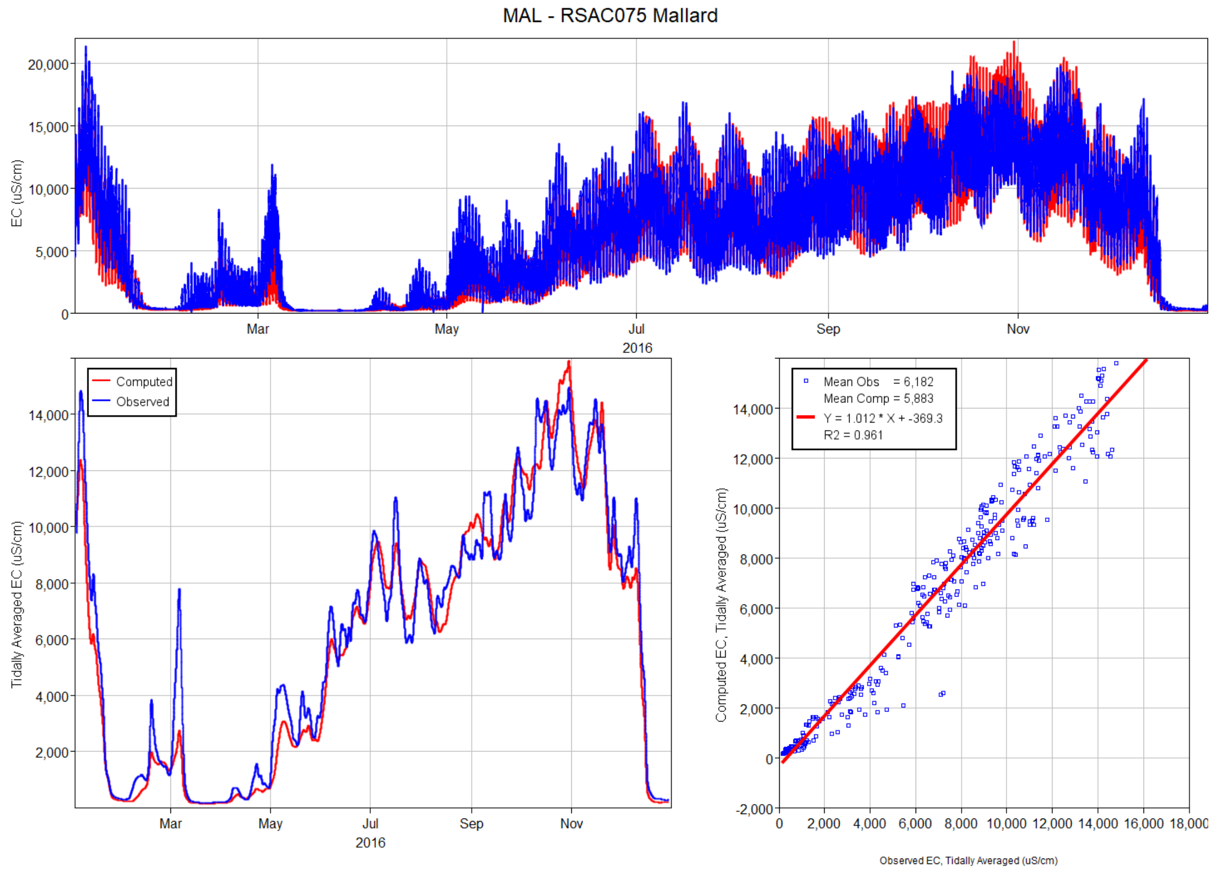

Figure 110. Example calibration plots and calibration metrics.

Salinity (EC) Calibration Results

Model EC calibration was performed for the January 10, 2009 – December 31, 2010 and January – December 2016 time periods using the observed EC data from the monitoring stations shown in Figure 111. Observed data sources include USGS[15], Water Data Library[16], and CDEC[17]. USGS and WDL data were used preferentially over CDEC when available due to known quality issues in CDEC data. Data were cleaned and filled where appropriate. Time shifts were removed from CDEC data.

Figure 112 through Figure 129 present the calibration plots of EC for the 2009 – 2010 simulation period and Figure 130 through Figure 148 present the calibration plots of EC for the 2016 calibration period.

For brief periods, the model underpredicts EC in the central Delta. For example, in December 2009-January 2010, EC is underpredicted at Antioch, Emmaton, Jersey Point, Prisoners Point,

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[15] https://waterdata.usgs.gov/ca/nwis/
[16] http://wdl.water.ca.gov/waterdatalibrary/
[17] http://cdec.water.ca.gov/

and Old River at Bacon. Another period of underprediction occurs in October-November at Emmaton. Local and cross channel gradients at these locations make calibration more challenging. However, none of these stations have D-1641 compliance standards during these periods.

Data in upper Cache Slough at station CCS are only available for the 2009-2010 period. During this time the model follows the seasonal trends seen in the observed data but shows greater tidal variation than observed, with a tendency to be too low on a tidally averaged basis. The R^2 value for the correlation between computed and observed EC is 0.67 (see Figure 112), indicating fair agreement between observed and predicted EC. This level of calibration is lower than the calibration to observations in the rest of the domain, however a lack of boundary condition data to represent the local inflow of freshwater and salinity in this region makes further improvement of the calibration difficult. Observed EC values at CCS are higher than both Barker Slough (BKS, Figure 113) and Rio Vista (Figure 114), indicating salinity is probably sourced from the local Cache Slough watershed. This local sourcing is represented by Ulatis Creek and Vacaville WWTP (Figure 5) boundary condition EC concentrations which are often 1,000 mS/cm (Figure 98, Figure 100, Figure 107 and Figure 109). This local-source EC remains in upper Cache Slough until it is tidally mixed with lower EC water downstream. Additional data collection and/or development of a hydrologic model to describe the local watershed sources would be needed to improve the calibration.

For 2016, data are available slightly further downstream at the UCS station (Figure 130). At this location the computed values also follow the seasonal trends with some deviations on a tidally averaged basis. The R^2 value is 0.80. This station exhibits similar characteristics of locally-sourced salinity as noted for CCS.

At Rio Vista, modeled EC tends to be higher than observed in the fall and can also be somewhat lower than observed in the spring, resulting in R^2 value for the correlation of 0.78 and 0.77 for the 2009 – 2010 and 2016 periods, respectively.

Model results are otherwise in good to excellent agreement with observed data, with R^2 values generally at 0.9 or higher.

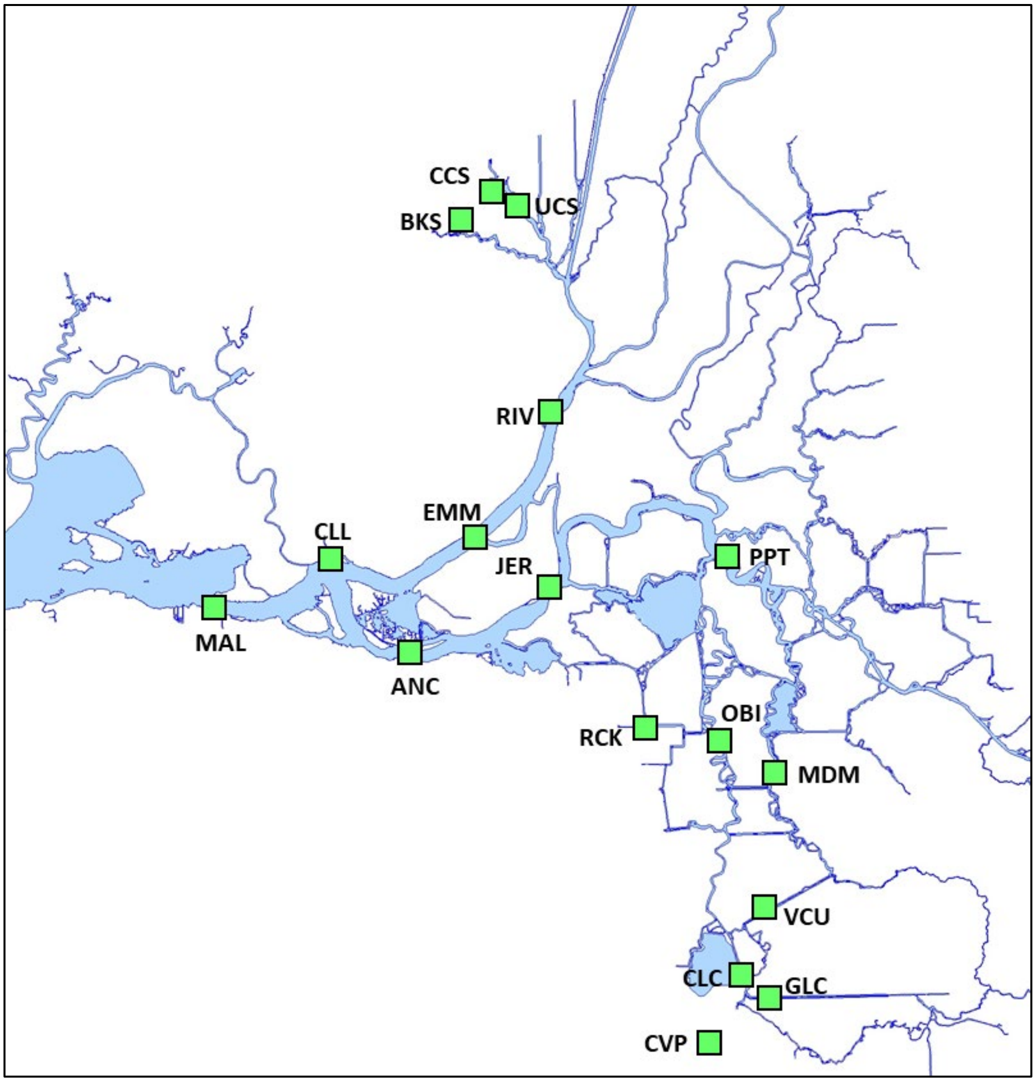

Figure 111 Salinity stations used for calibration.

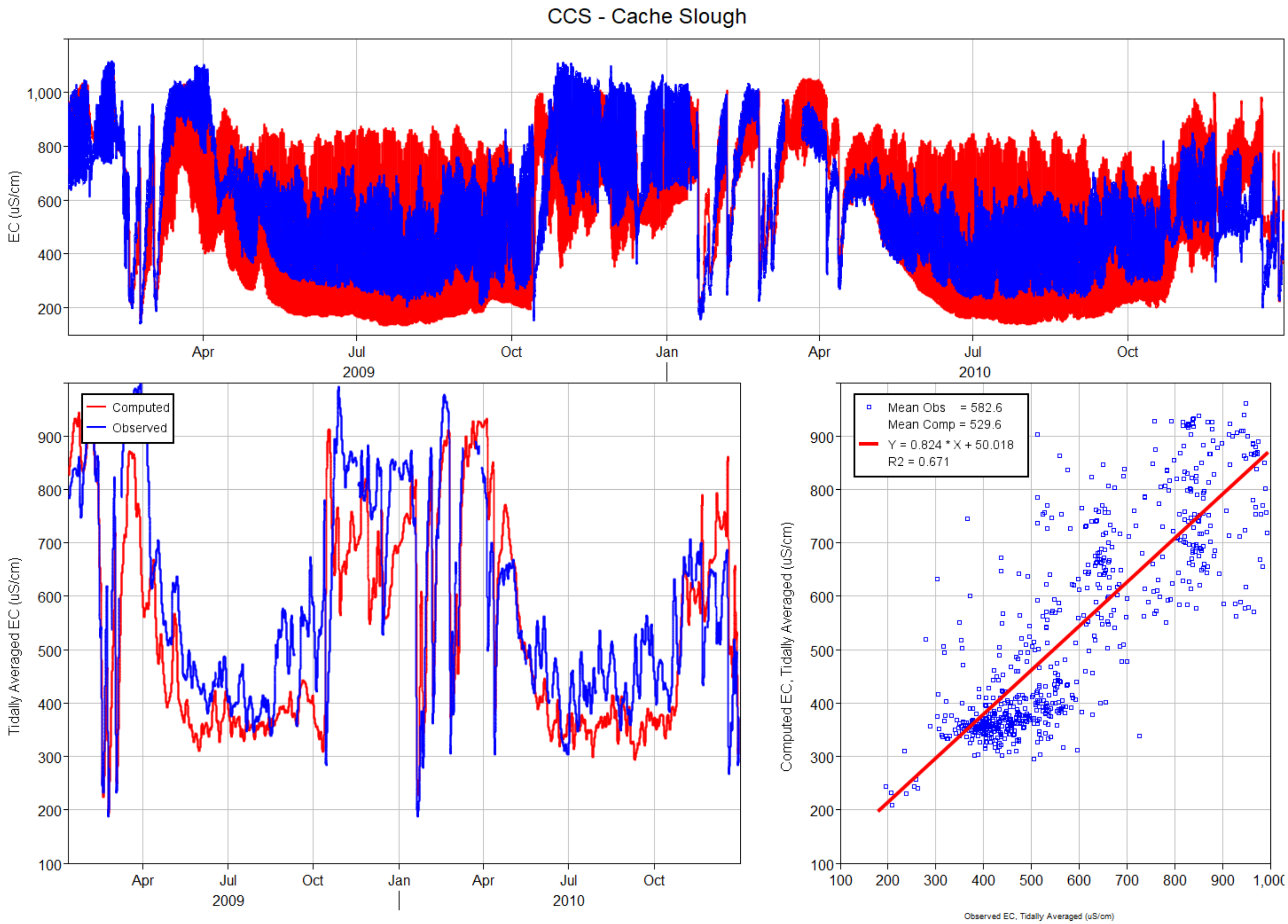

Figure 112 Comparison of modeled and observed EC at CCS, Cache Slough for 2009 - 2010.

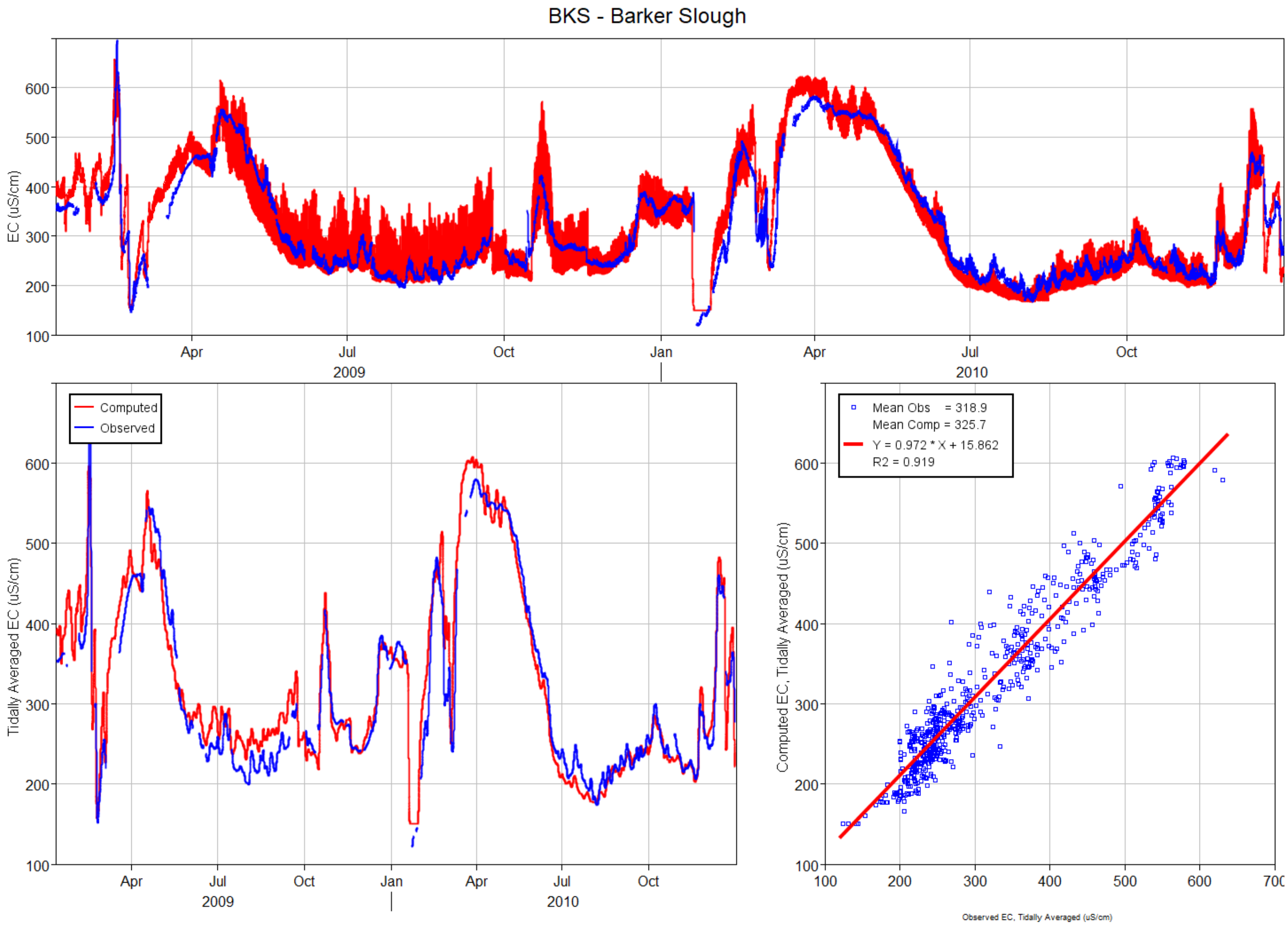

Figure 113 Comparison of modeled and observed EC at BKS, Barker Slough at the NBAQ for 2009 – 2010.

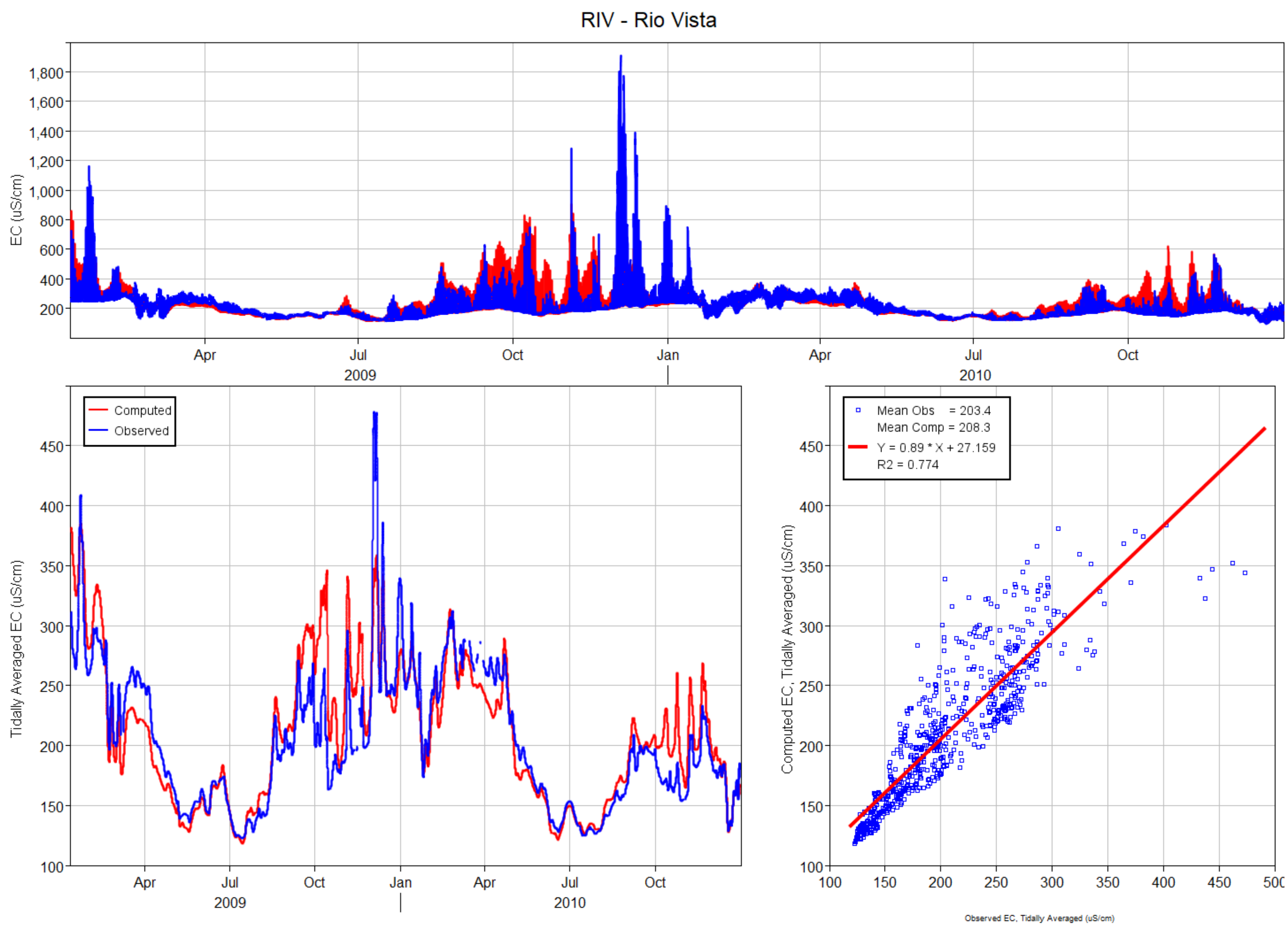

Figure 114 Comparison of modeled and observed EC at RIV, the Sacramento River at Rio Vista for 2009 – 2010.

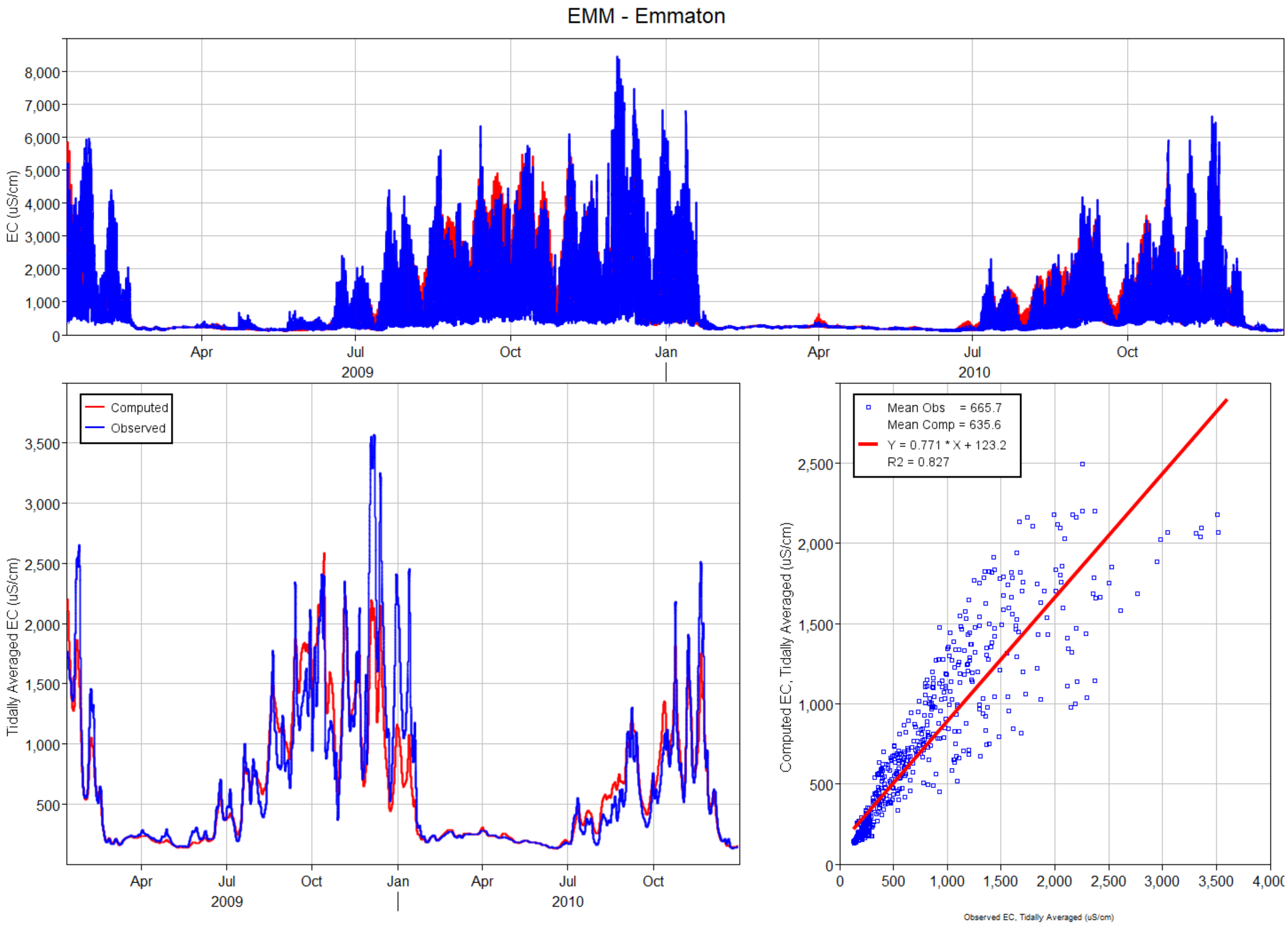

Figure 115 Comparison of modeled and observed EC at EMM, the Sacramento R at Emmaton 2009 - 2010.

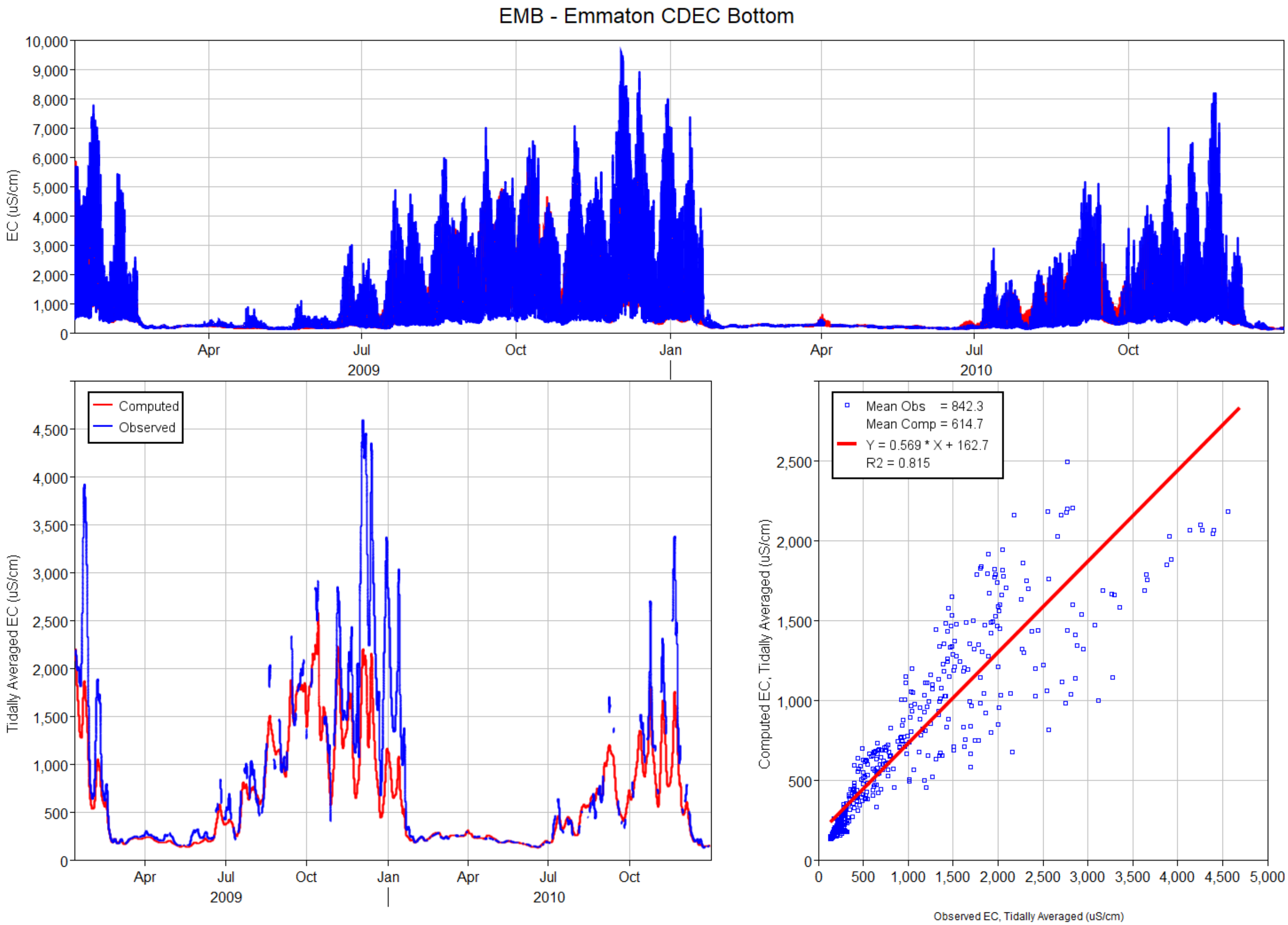

Figure 116 Comparison of modeled and observed EC at EMM (bottom sensor), the Sacramento R at Emmaton 2009 - 2010.

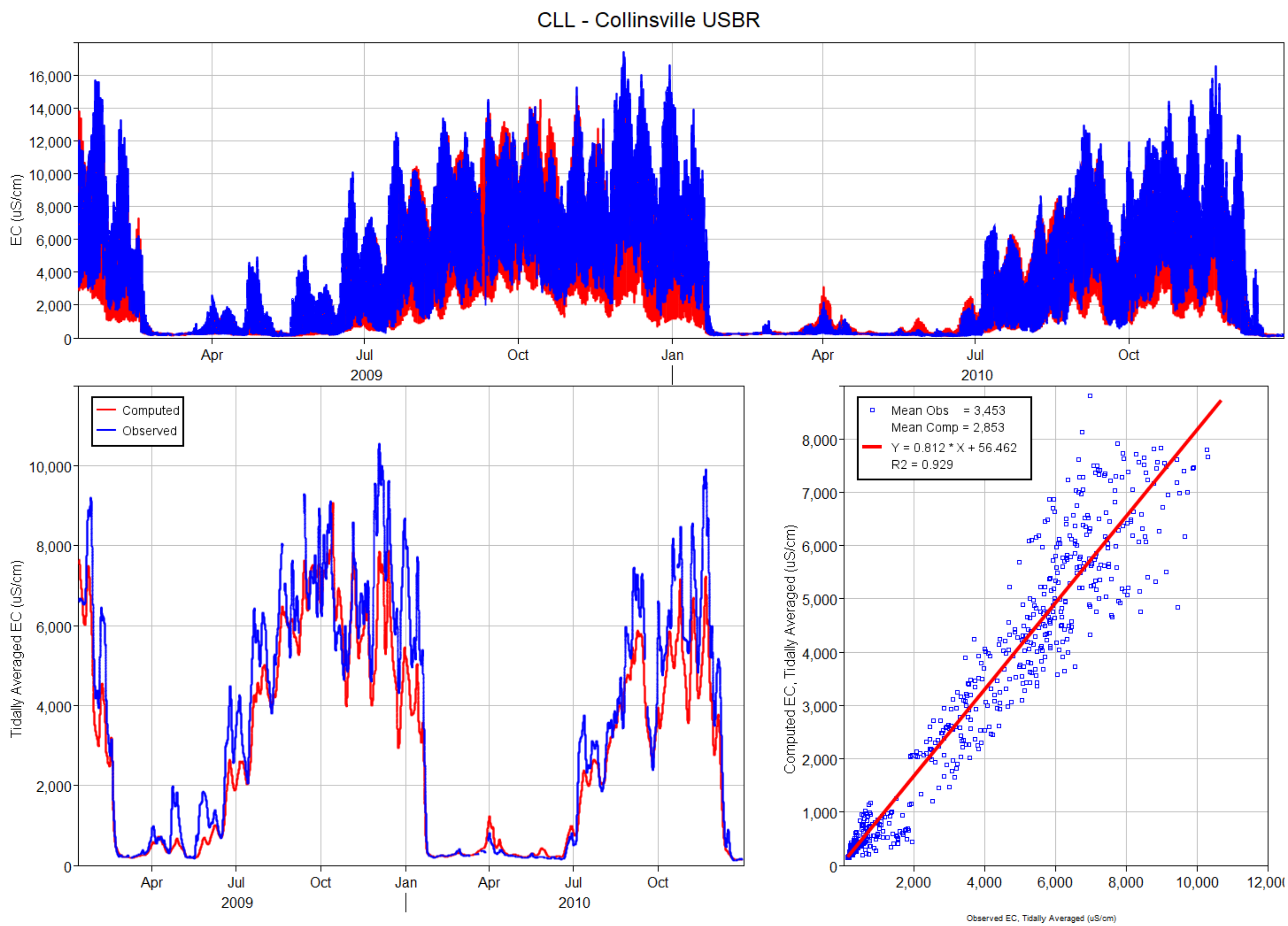

Figure 117 Comparison of modeled and observed EC at the CLL, Collinsville for 2009 - 2010.

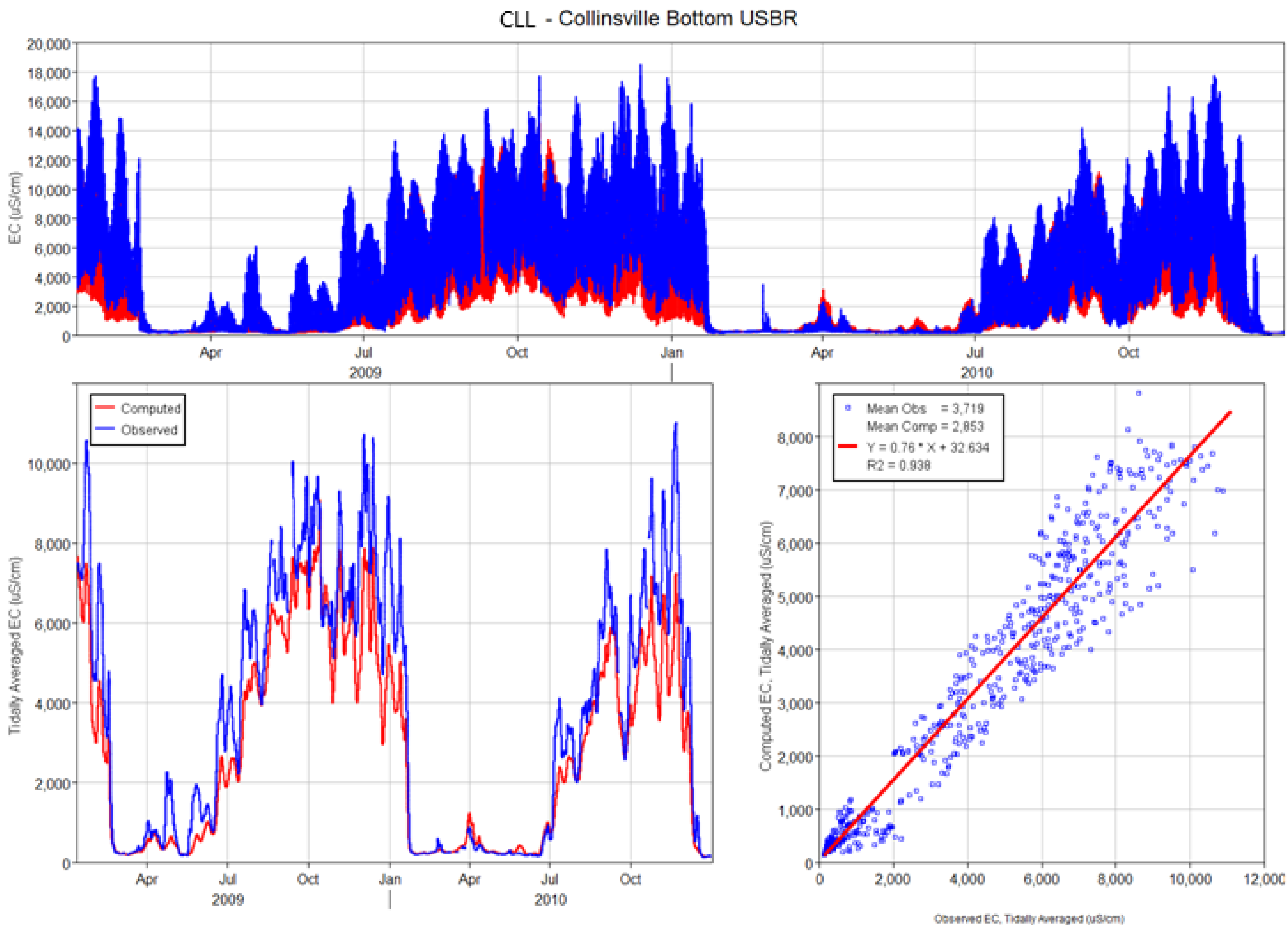

Figure 118 Comparison of modeled and observed EC at the CLL (bottom sensor), Collinsville for 2009 - 2010.

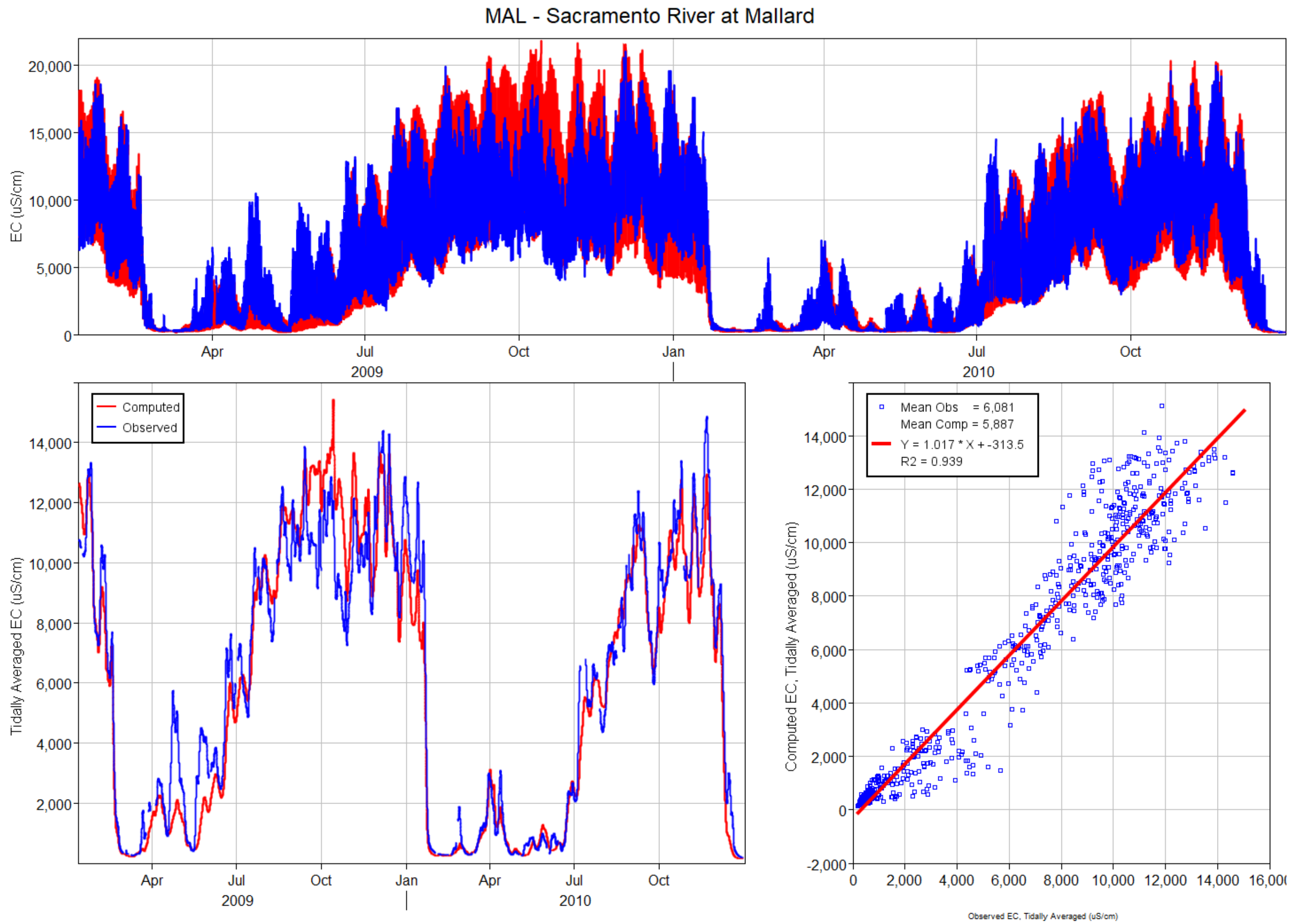

Figure 119. Comparison of modeled and observed EC at MAL, Mallard Island for 2009 – 2010.

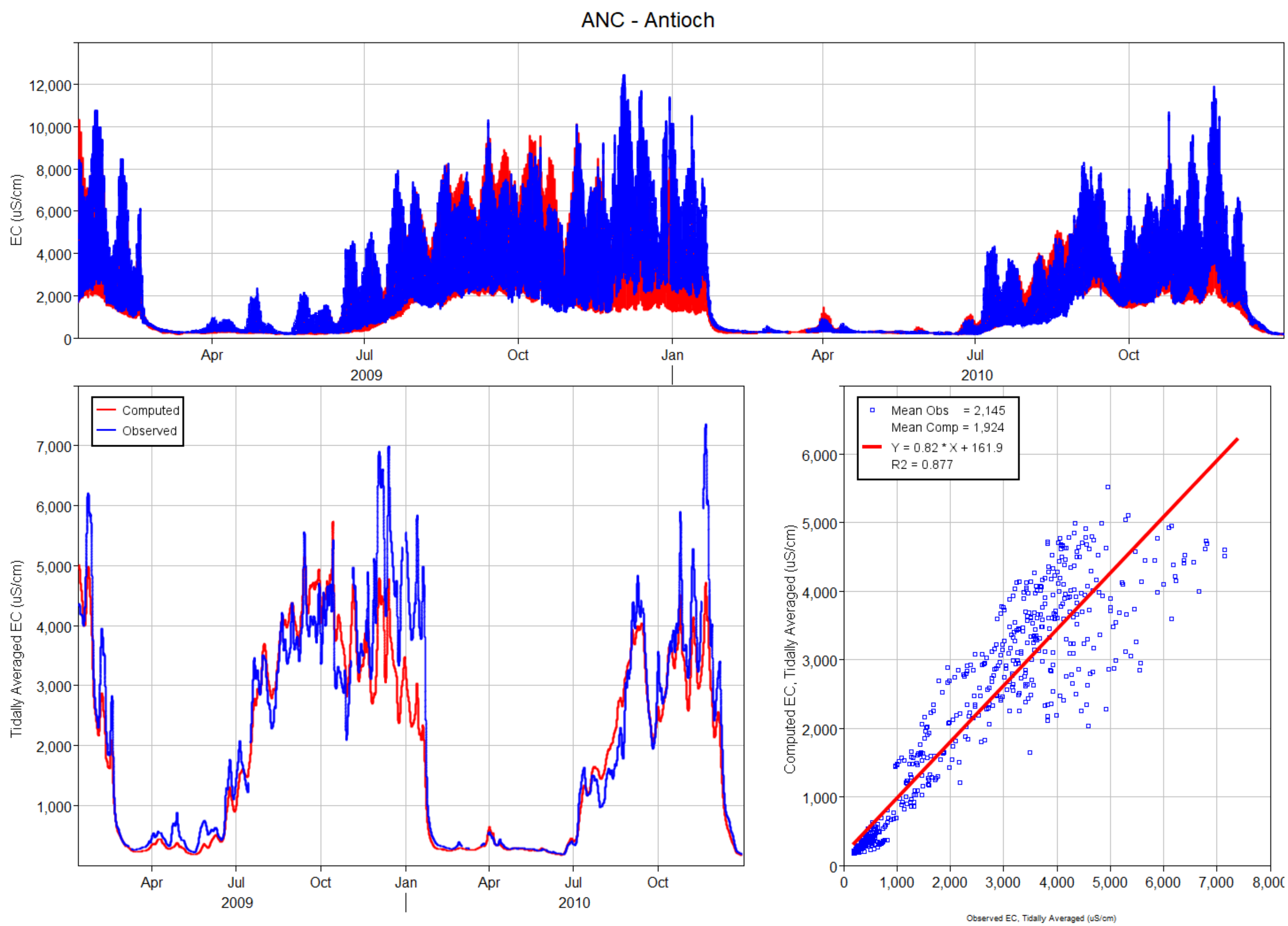

Figure 120 Comparison of modeled and observed EC at ANC, the SJR at Antioch for 2009 – 2010.

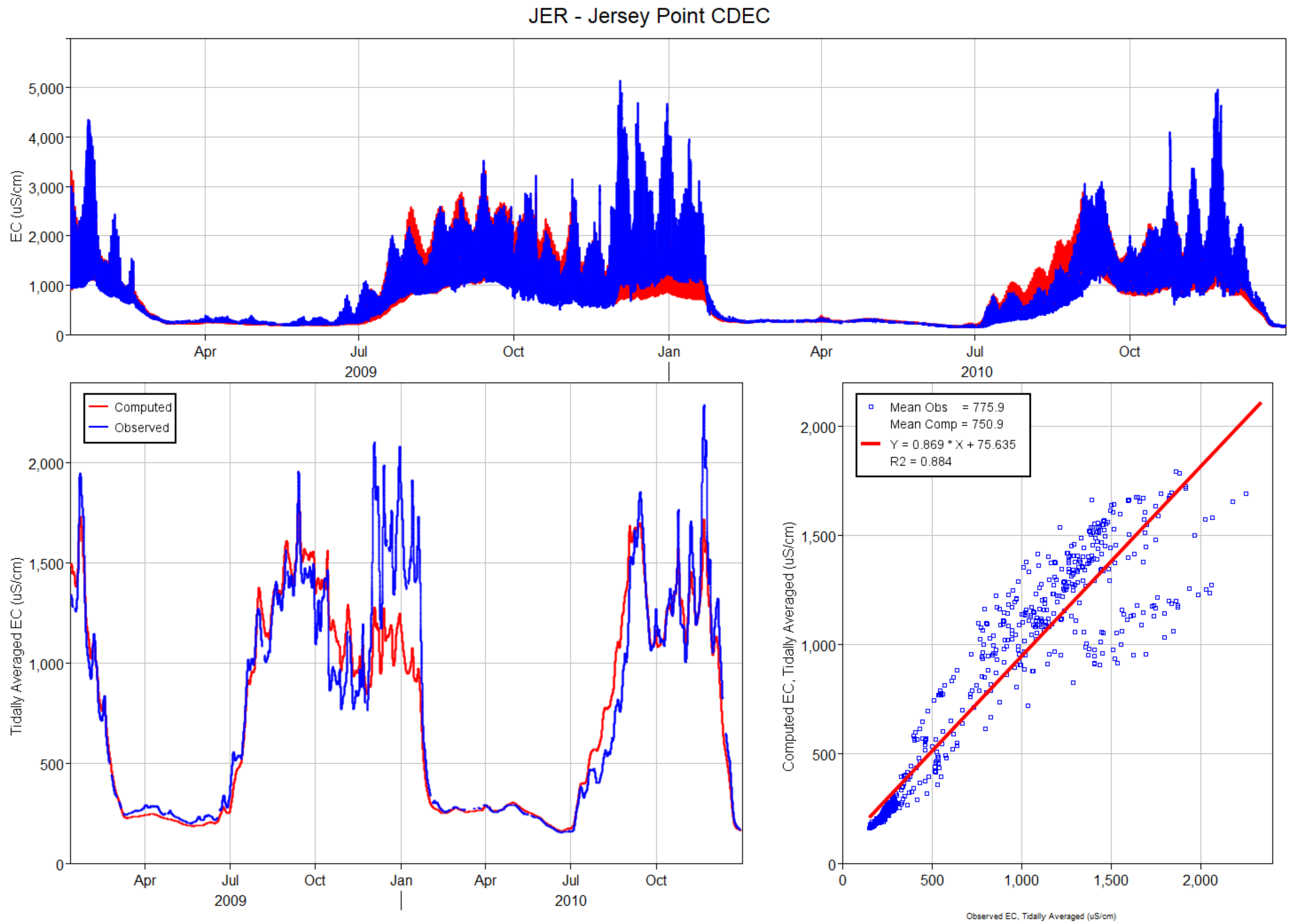

Figure 121 Comparison of modeled and observed EC at JER, the San Joaquin River at Jersey Point for 2009 – 2010.

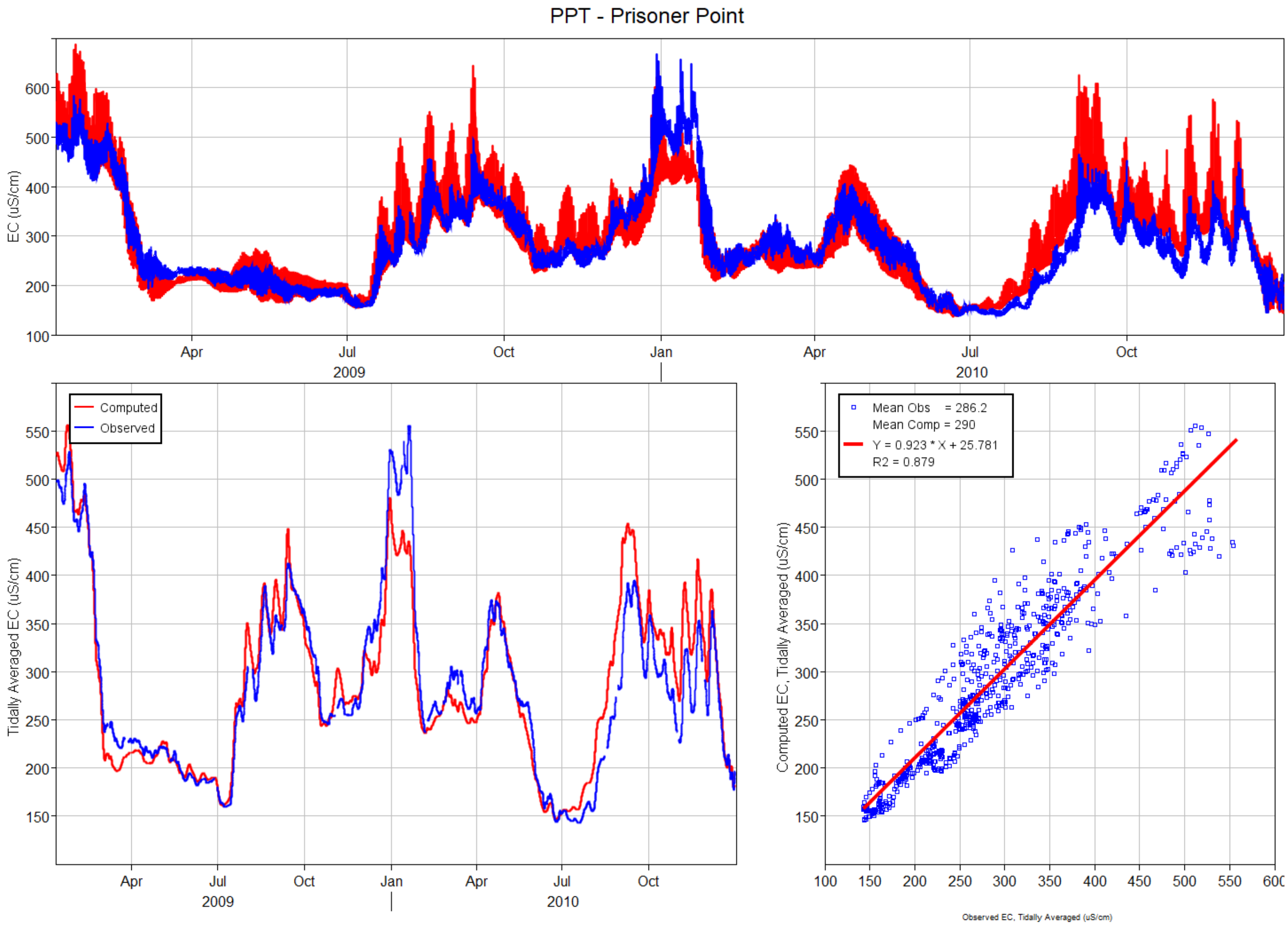

Figure 122 Comparison of modeled and observed EC at PPT, the San Joaquin River at Prisoner Point for 2009 – 2010.

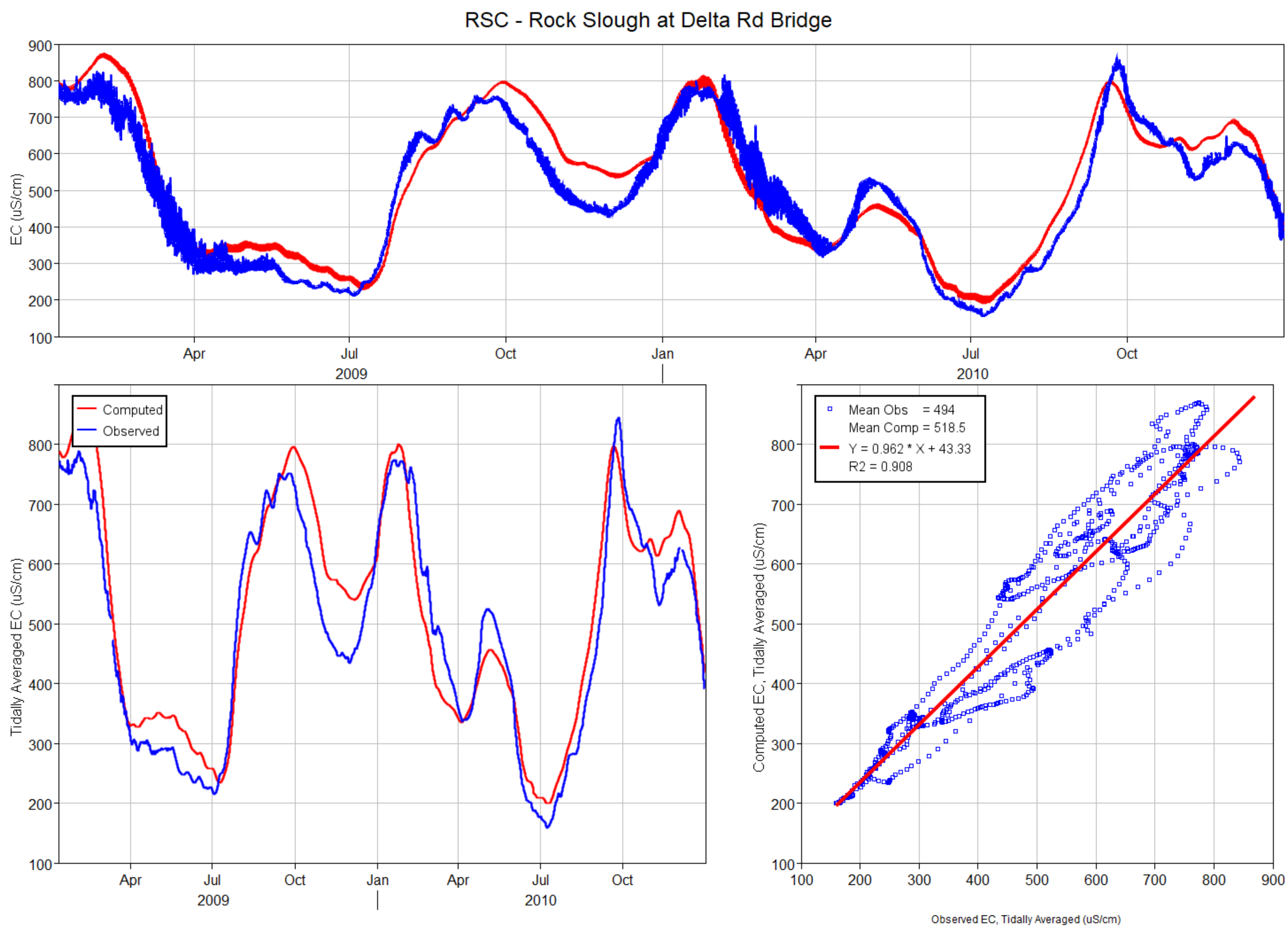

Figure 123 Comparison of modeled and observed EC at RCK, Rock Slough at Delta Rd Bridge for 2009 – 2010.

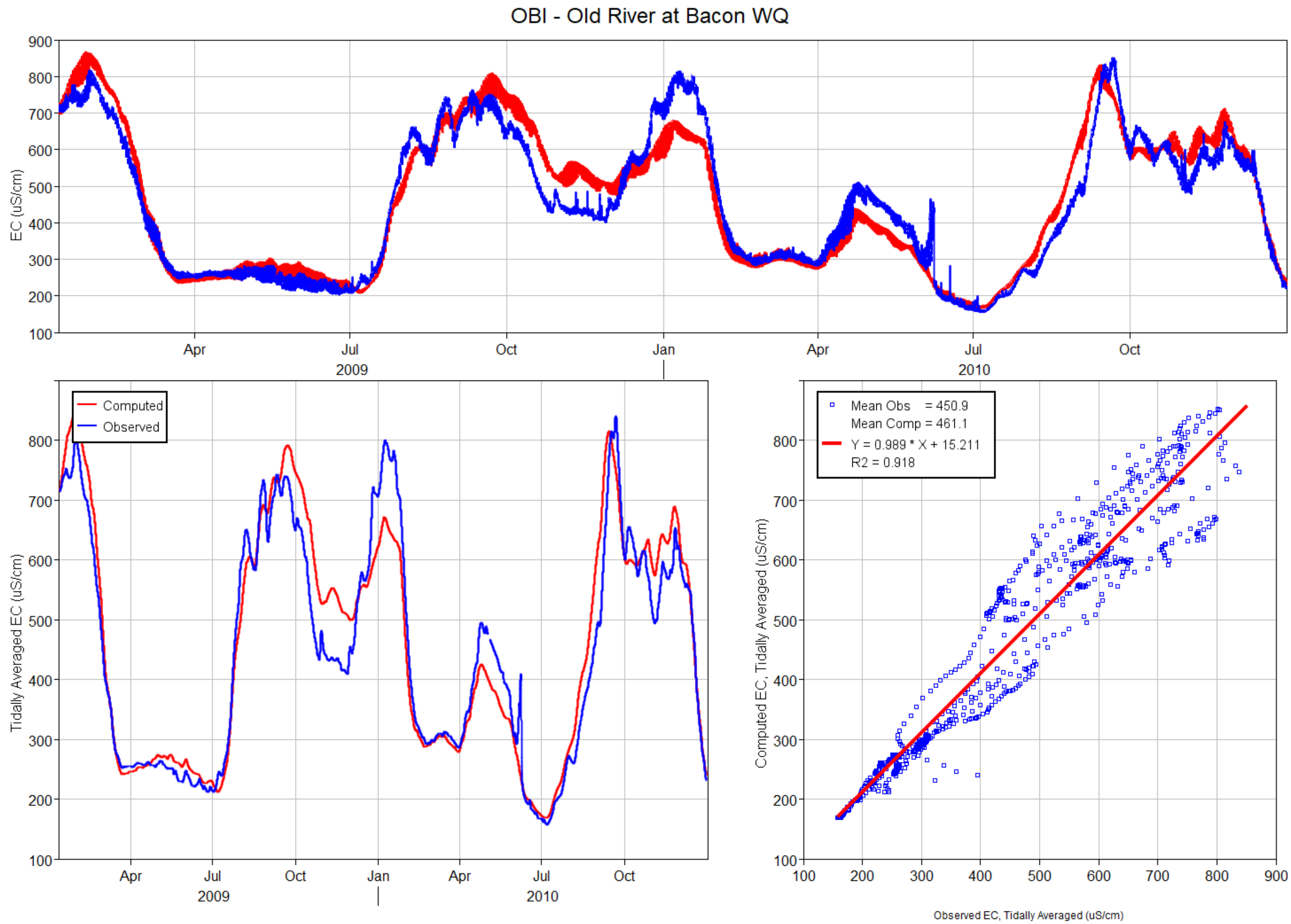

Figure 124 Comparison of modeled and observed EC at OBI, Old River at Bacon Island for 2009 – 2010.

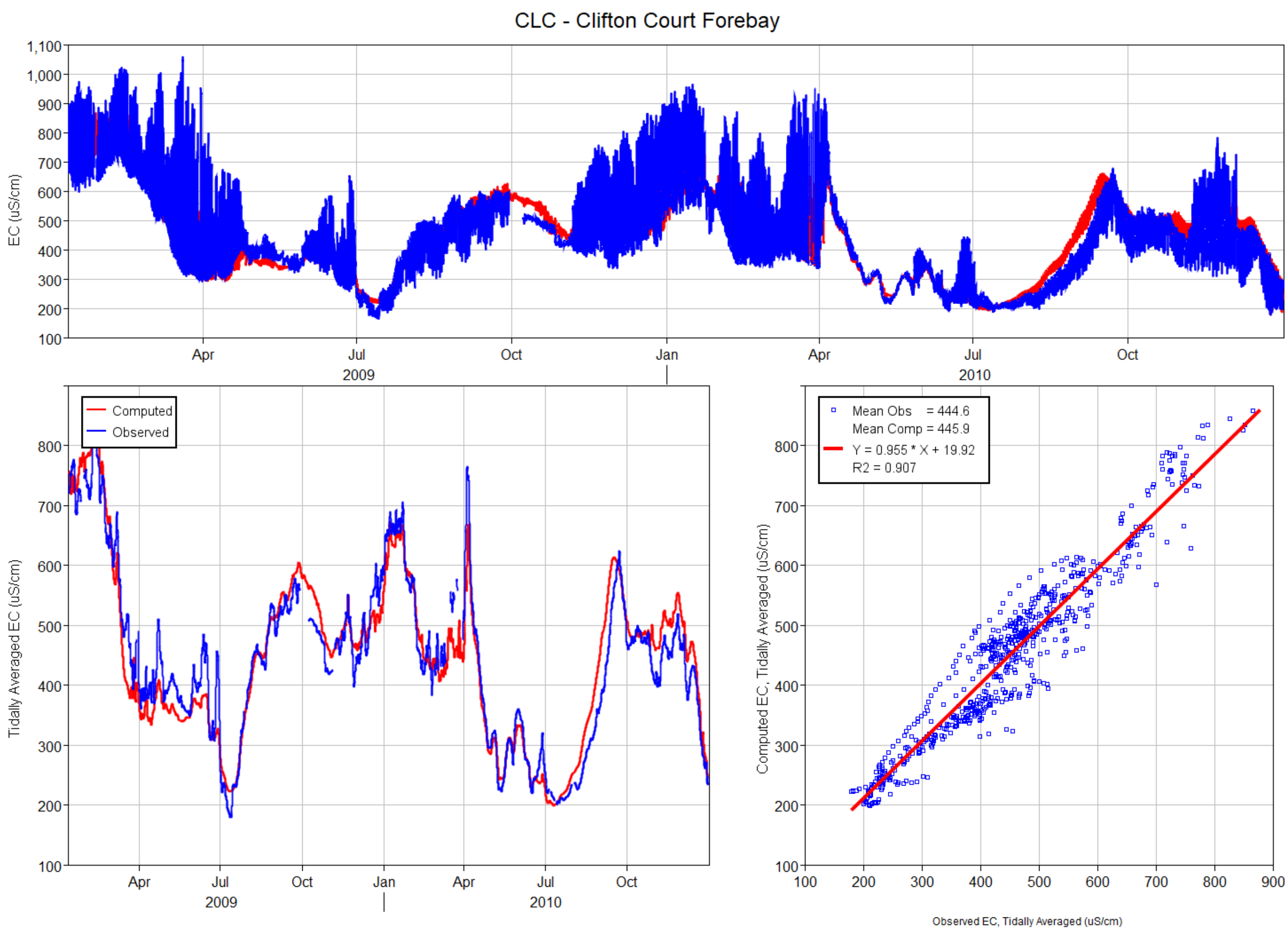

Figure 125 Comparison of modeled and observed EC at the CLC, Clifton Court Forebay for 2009 – 2010.

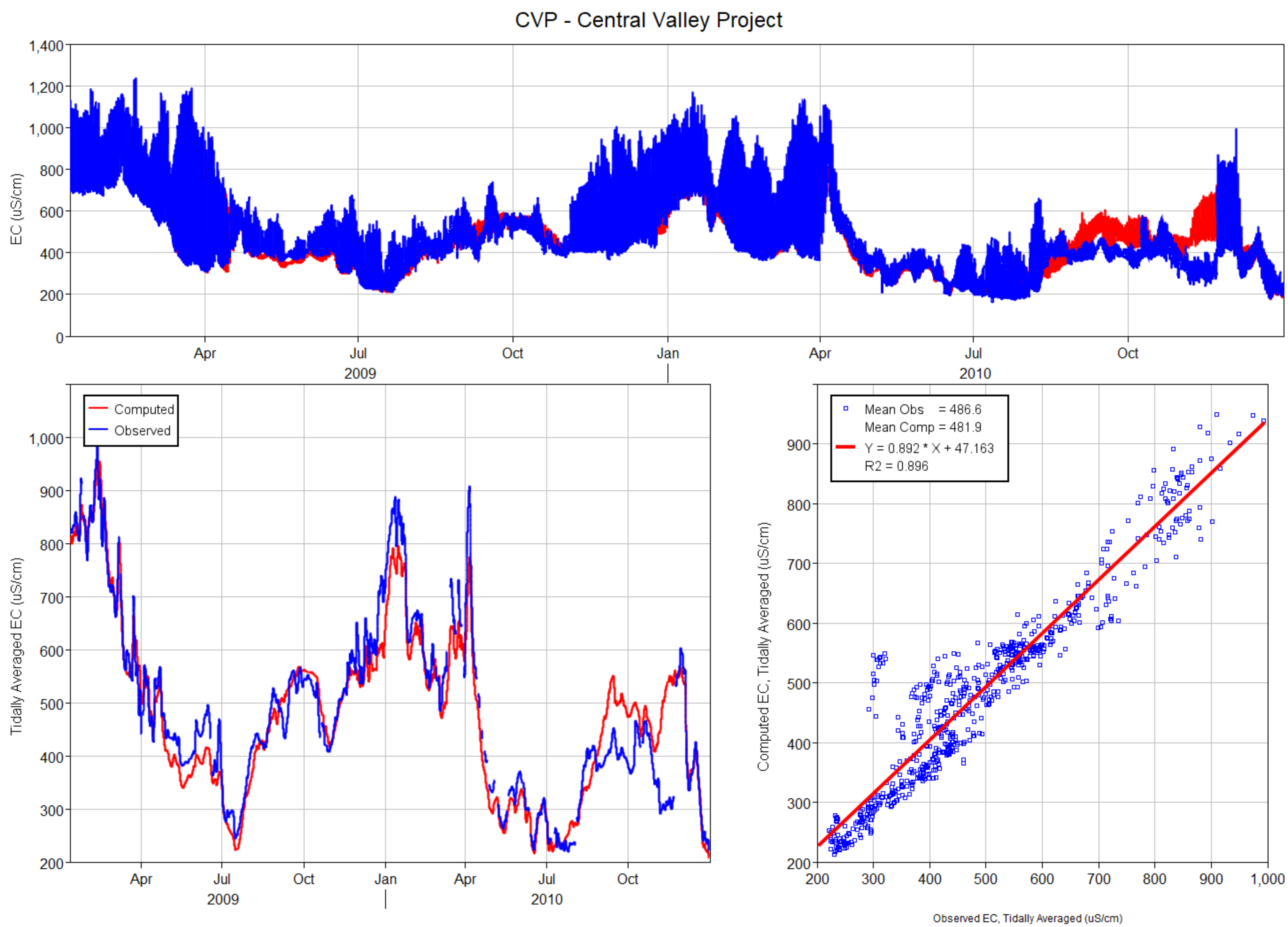

Figure 126 Comparison of modeled and observed EC at CVP, DMC headworks for 2009 – 2010.

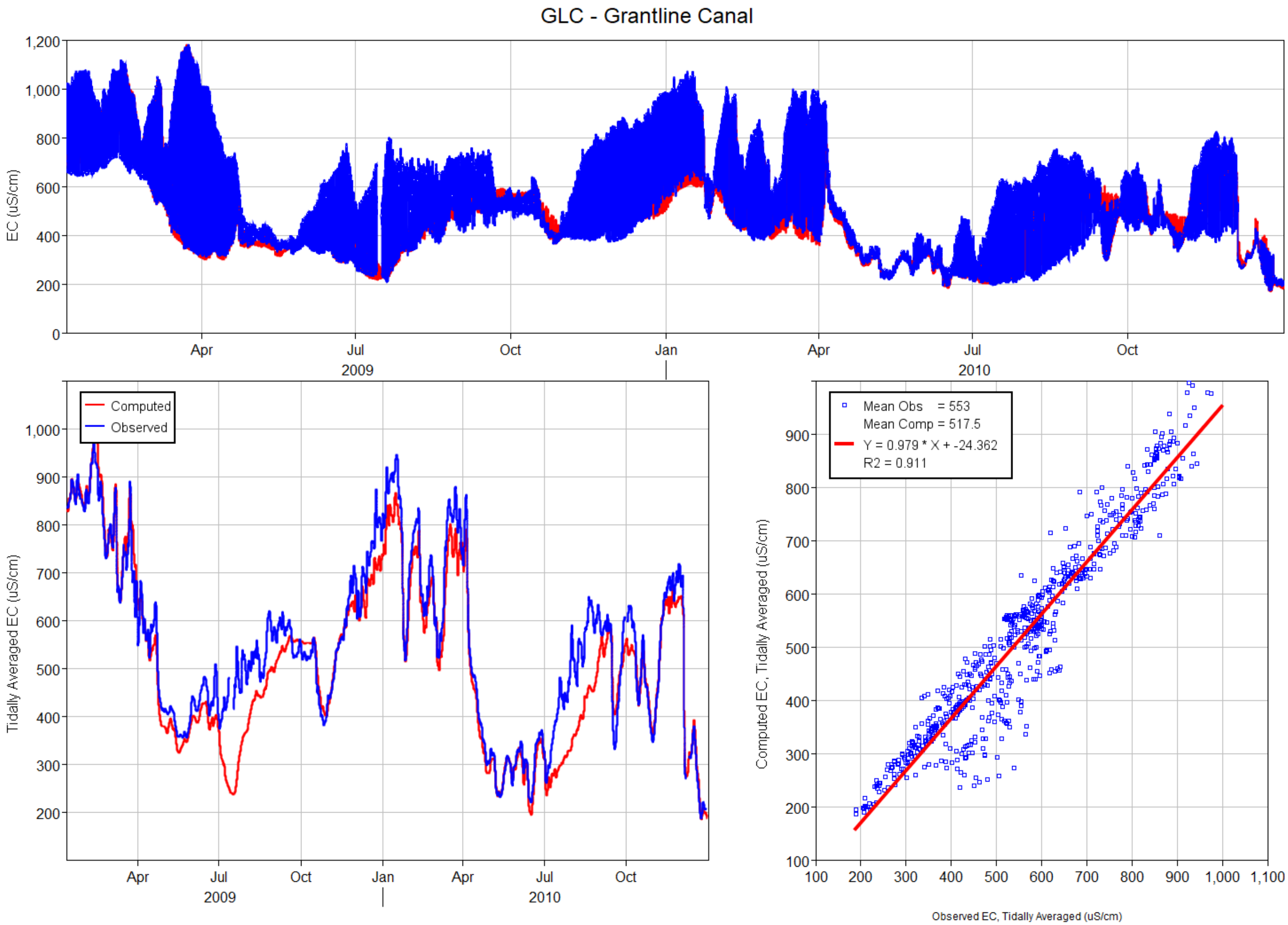

Figure 127 Comparison of modeled and observed EC at GLC, Grantline Canal for 2009 – 2010.

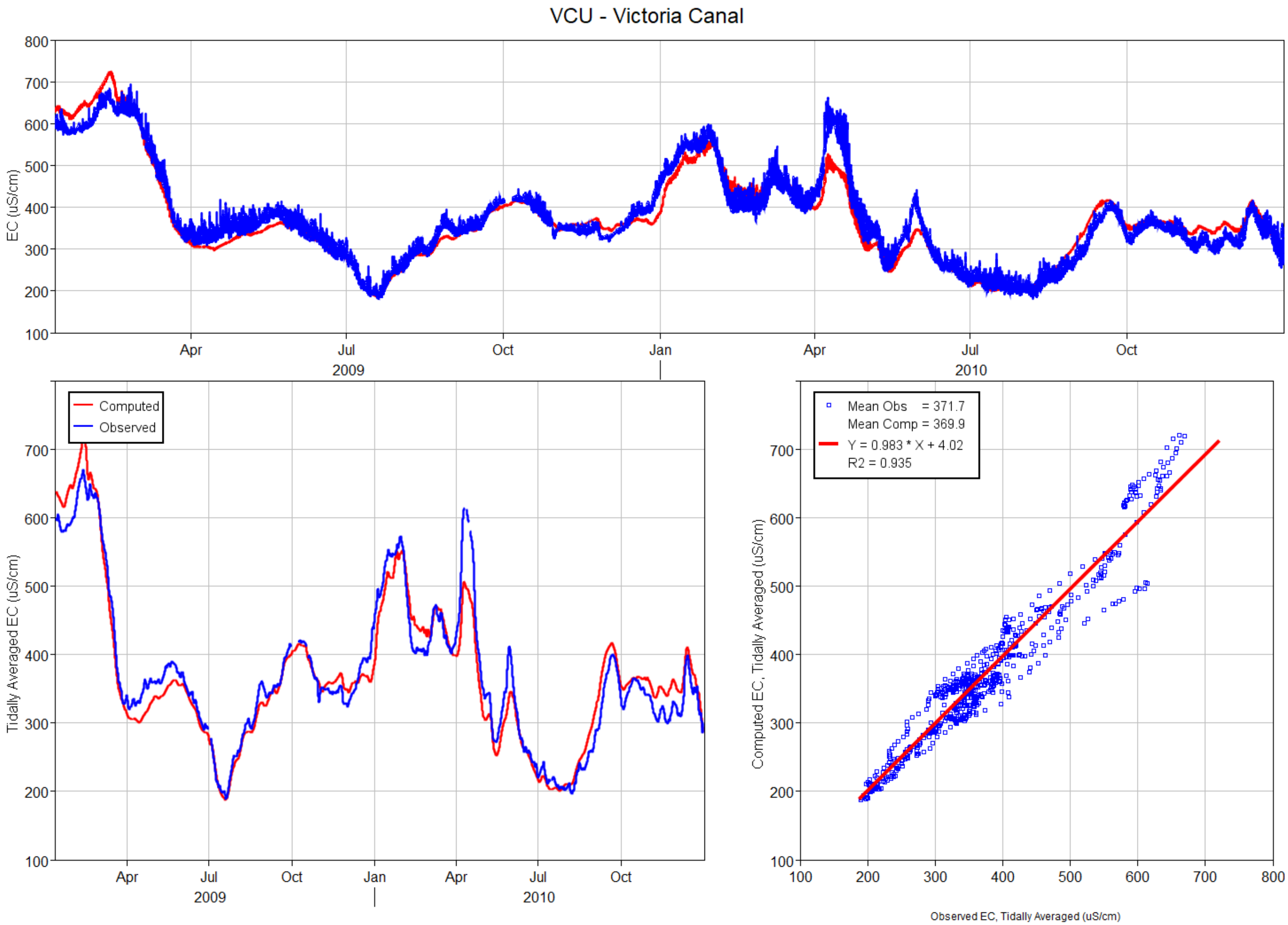

Figure 128 Comparison of modeled and observed EC at VCU, Victoria Canal for 2009 – 2010.

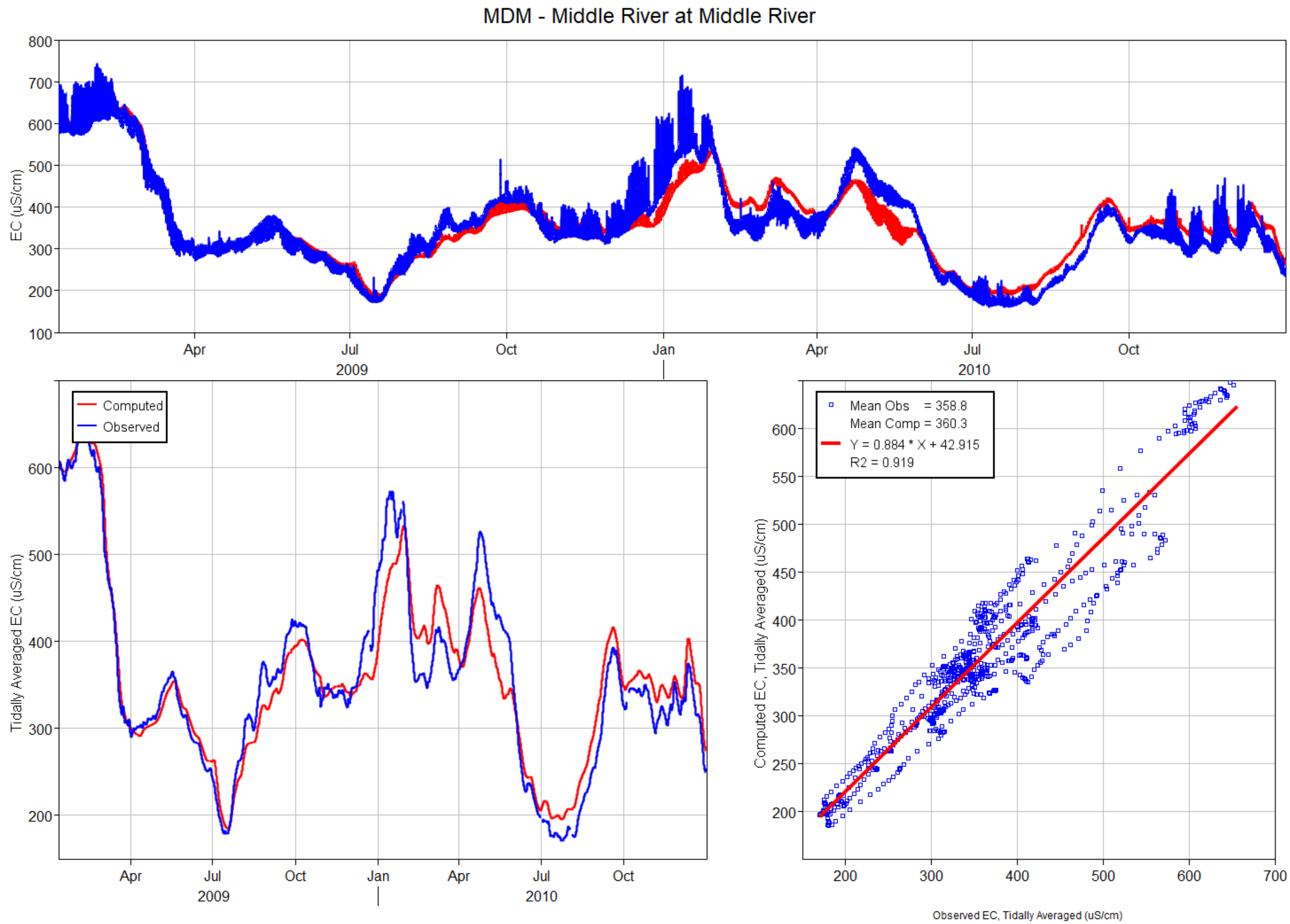

Figure 129 Comparison of modeled and observed EC at MDM, Middle River at Middle River for 2009 – 2010.

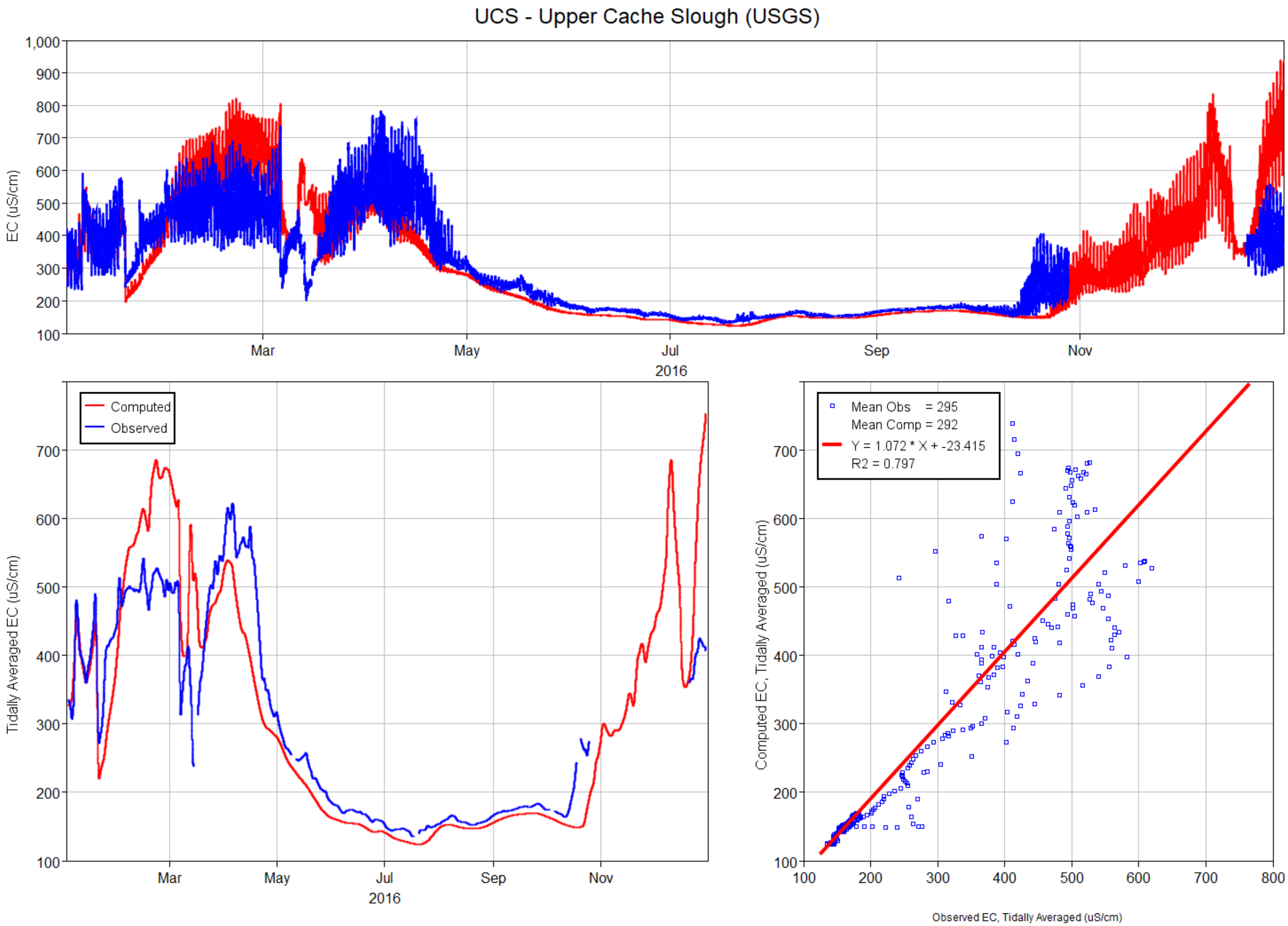

Figure 130 Comparison of modeled and observed EC at UCS, Cache Slough at Hastings for 2016.

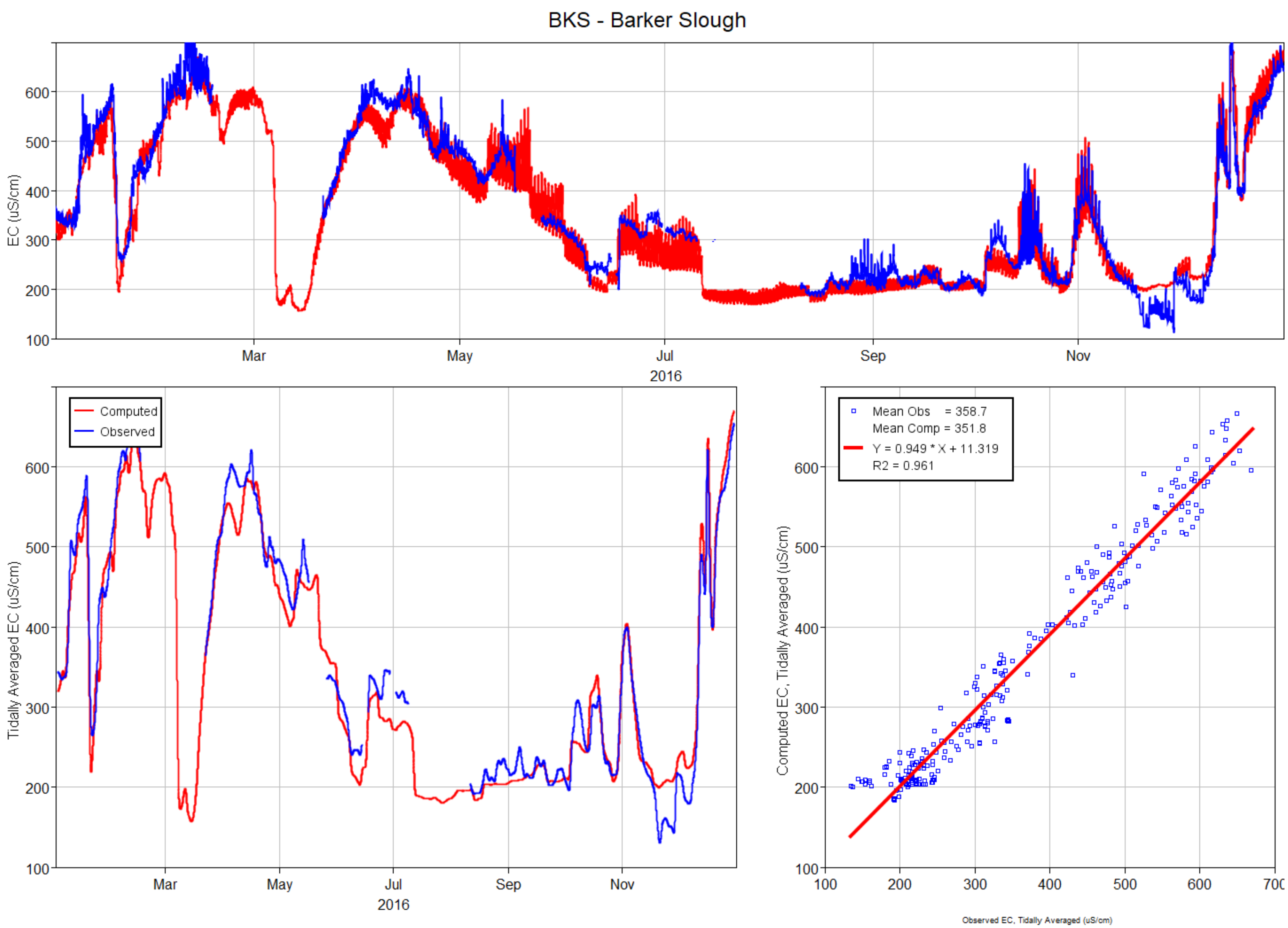

Figure 131 Comparison of modeled and observed EC at BKS, Barker Sl at the NBAQ for 2016.

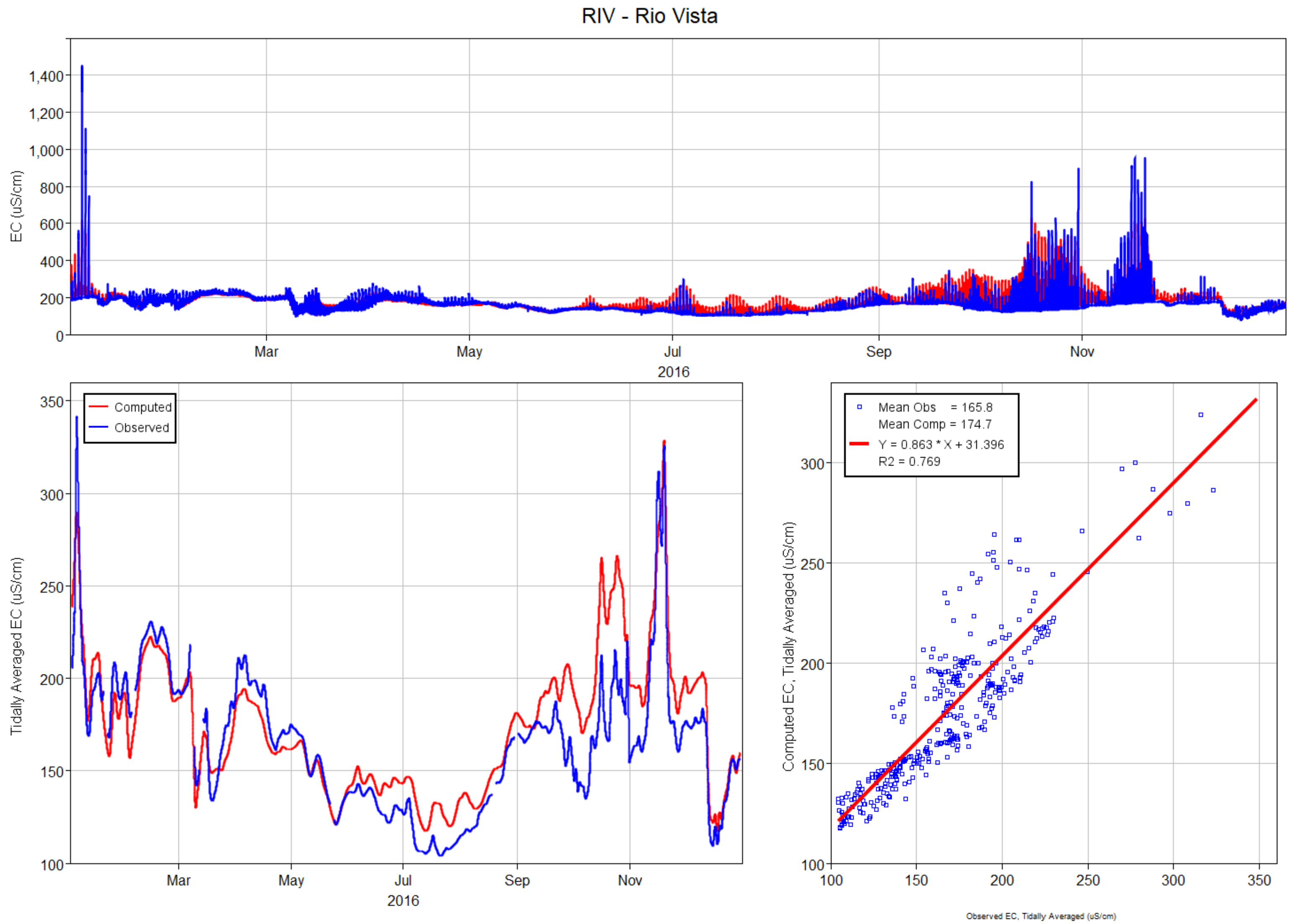

Figure 132 Comparison of modeled and observed EC at RIV, the Sacramento River at Rio Vista for 2016.

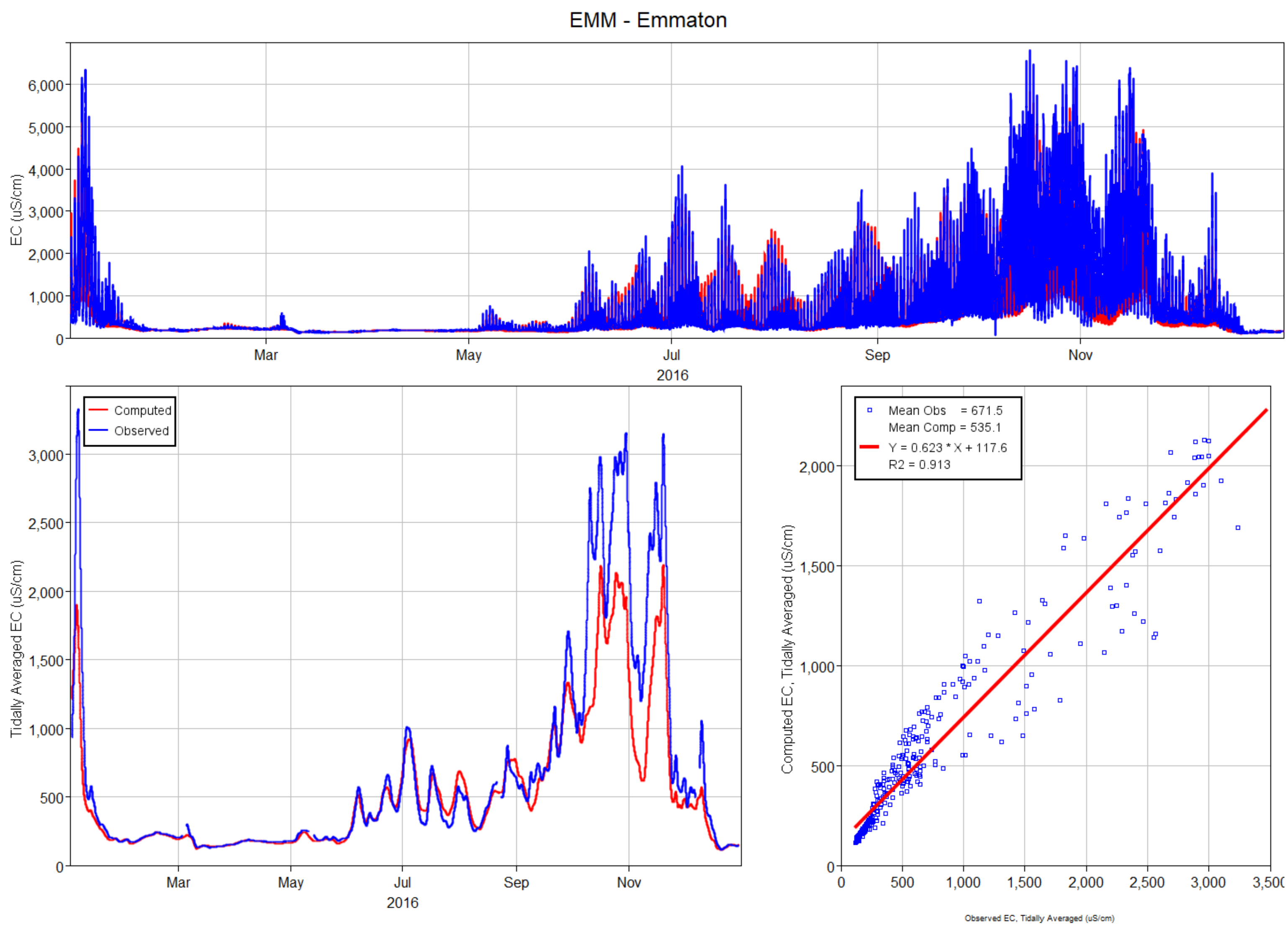

Figure 133 Comparison of modeled and observed EC at EMM, the Sacramento R at Emmaton 2016.

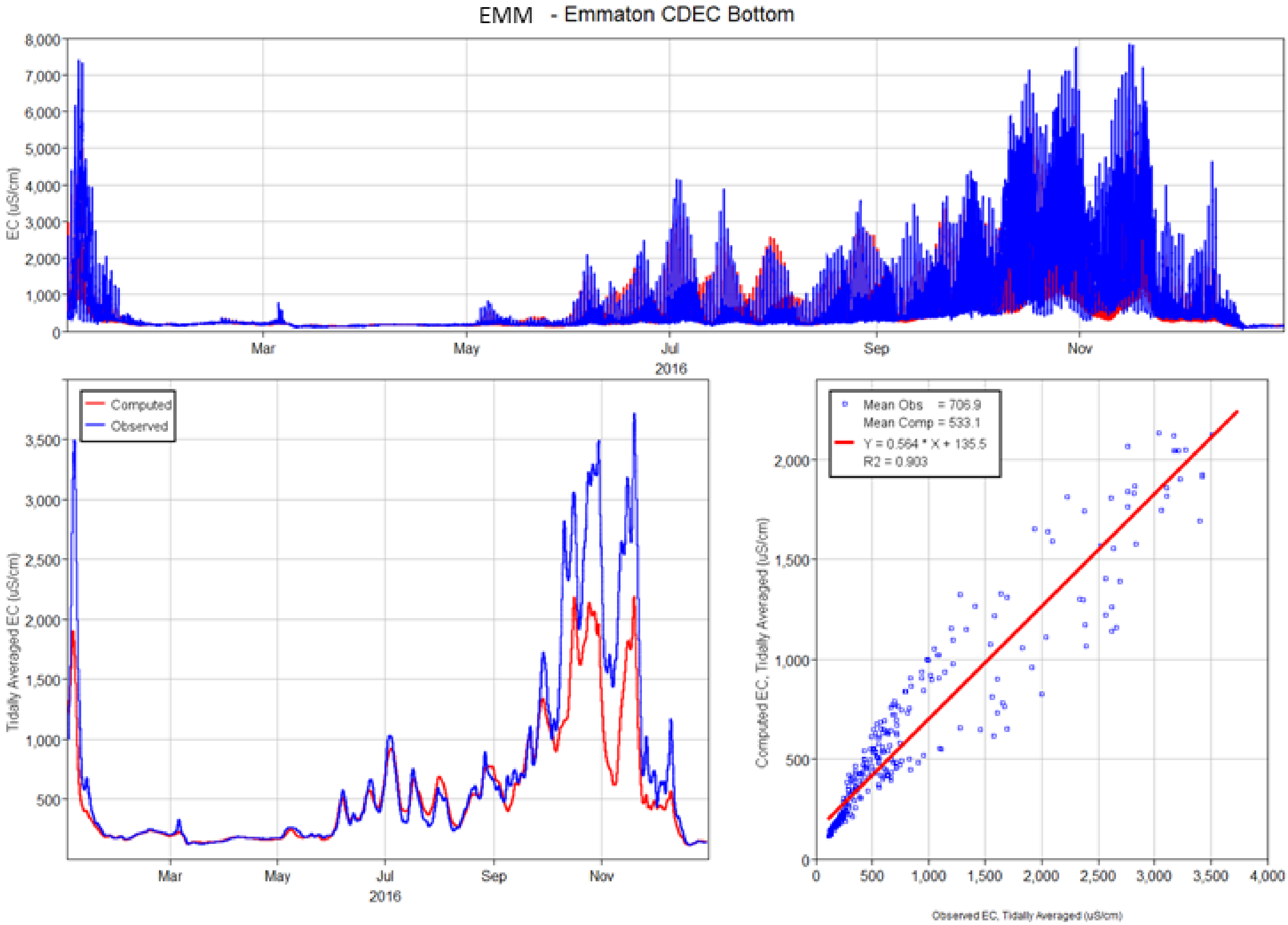

Figure 134 Comparison of modeled and observed EC at EMM (bottom sensor), the Sacramento R at Emmaton 2016.

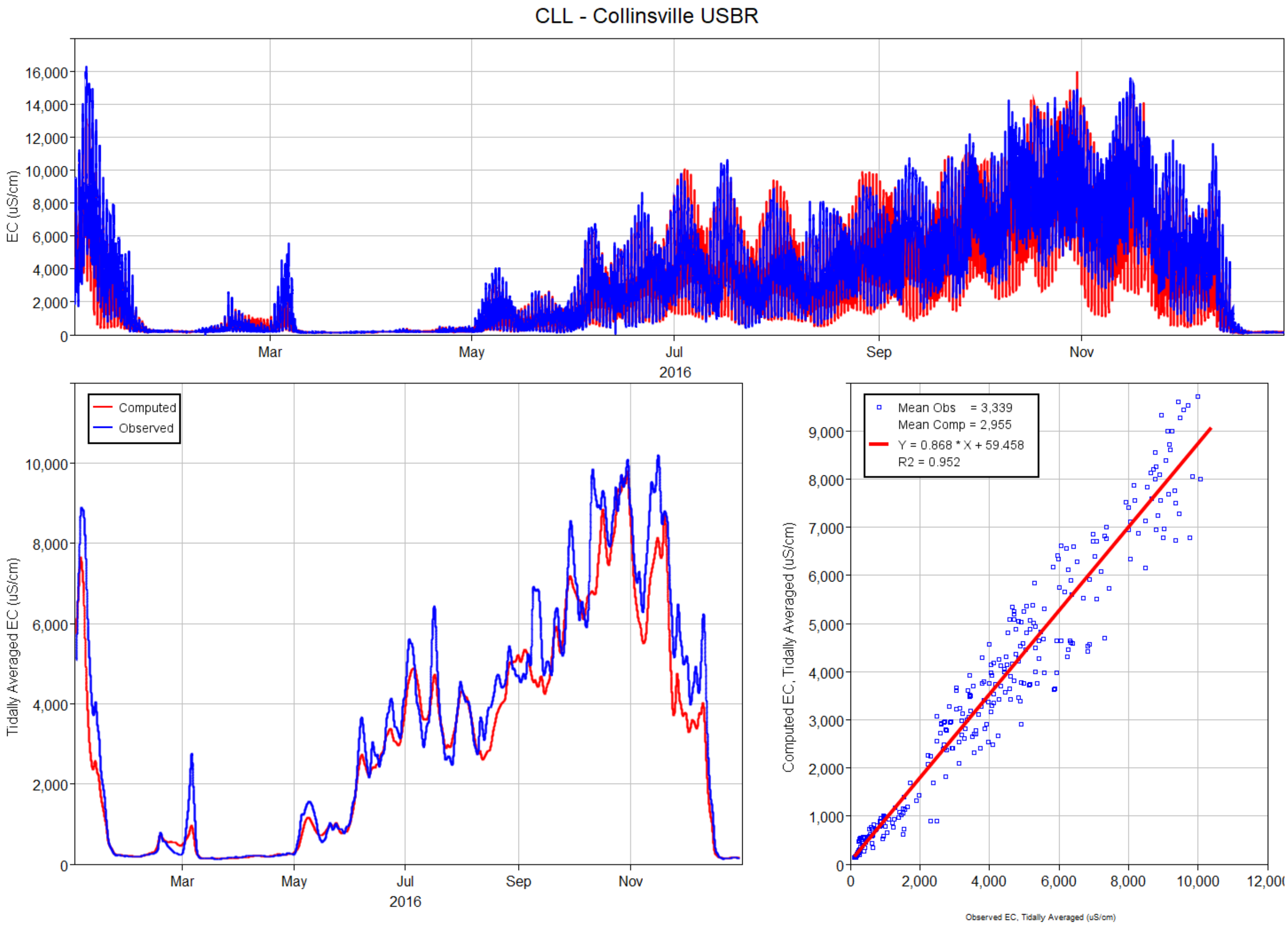

Figure 135 Comparison of modeled and observed EC at the CLL, Collinsville for 2016.

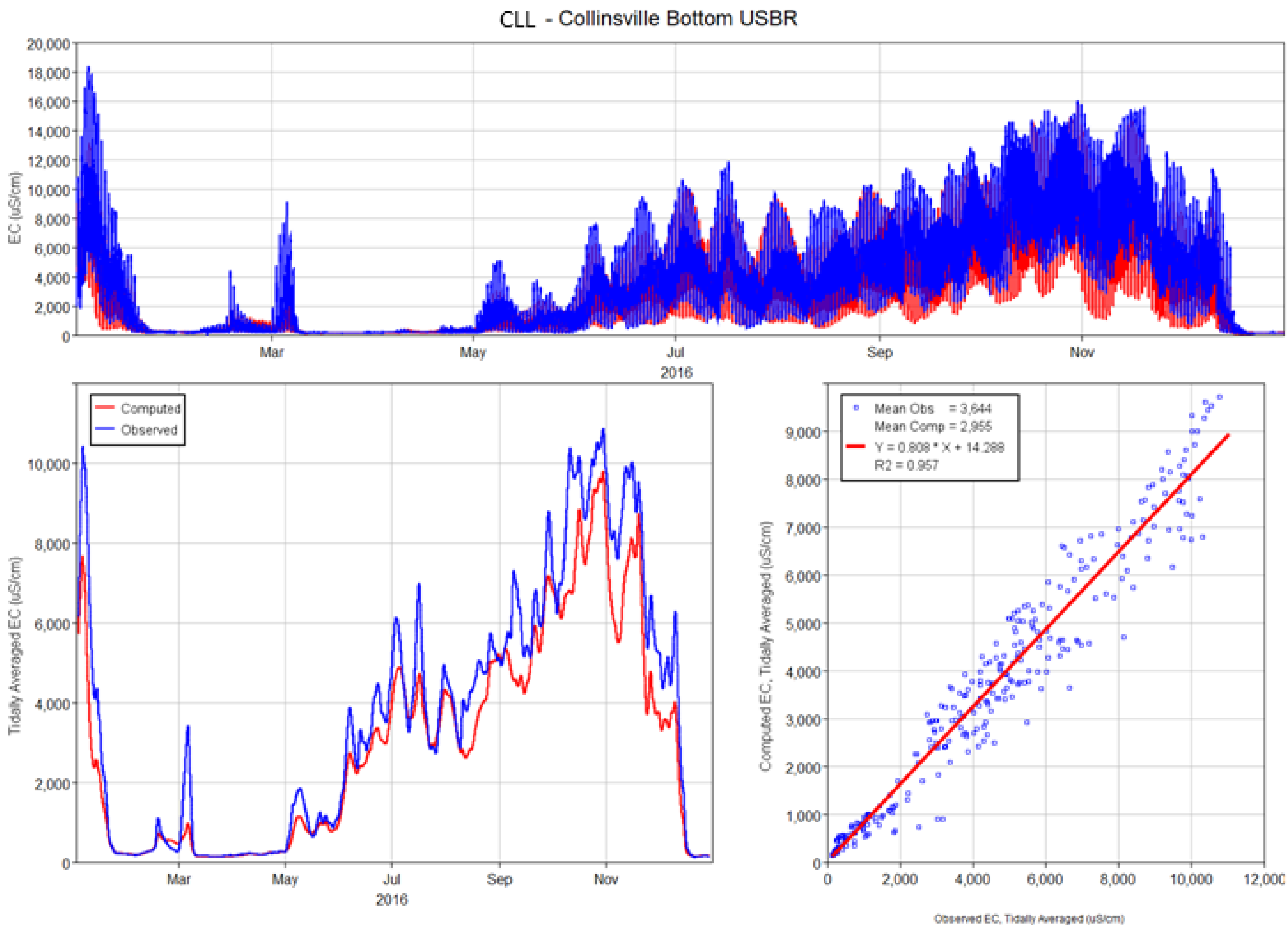

Figure 136 Comparison of modeled and observed EC at the CLL (bottom sensor), Collinsville for 2016.

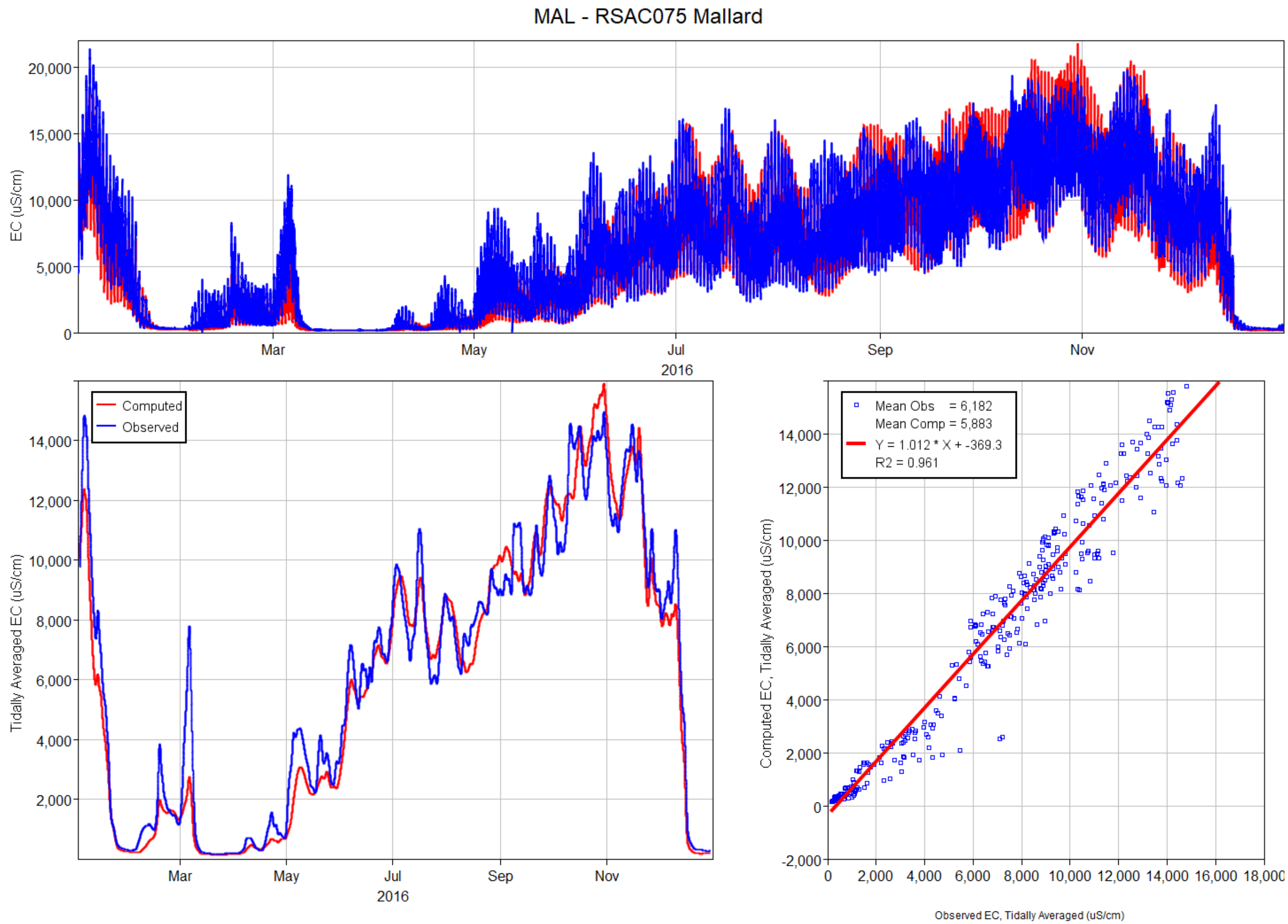

Figure 137. Comparison of modeled and observed EC at MAL, Mallard Island for 2016.

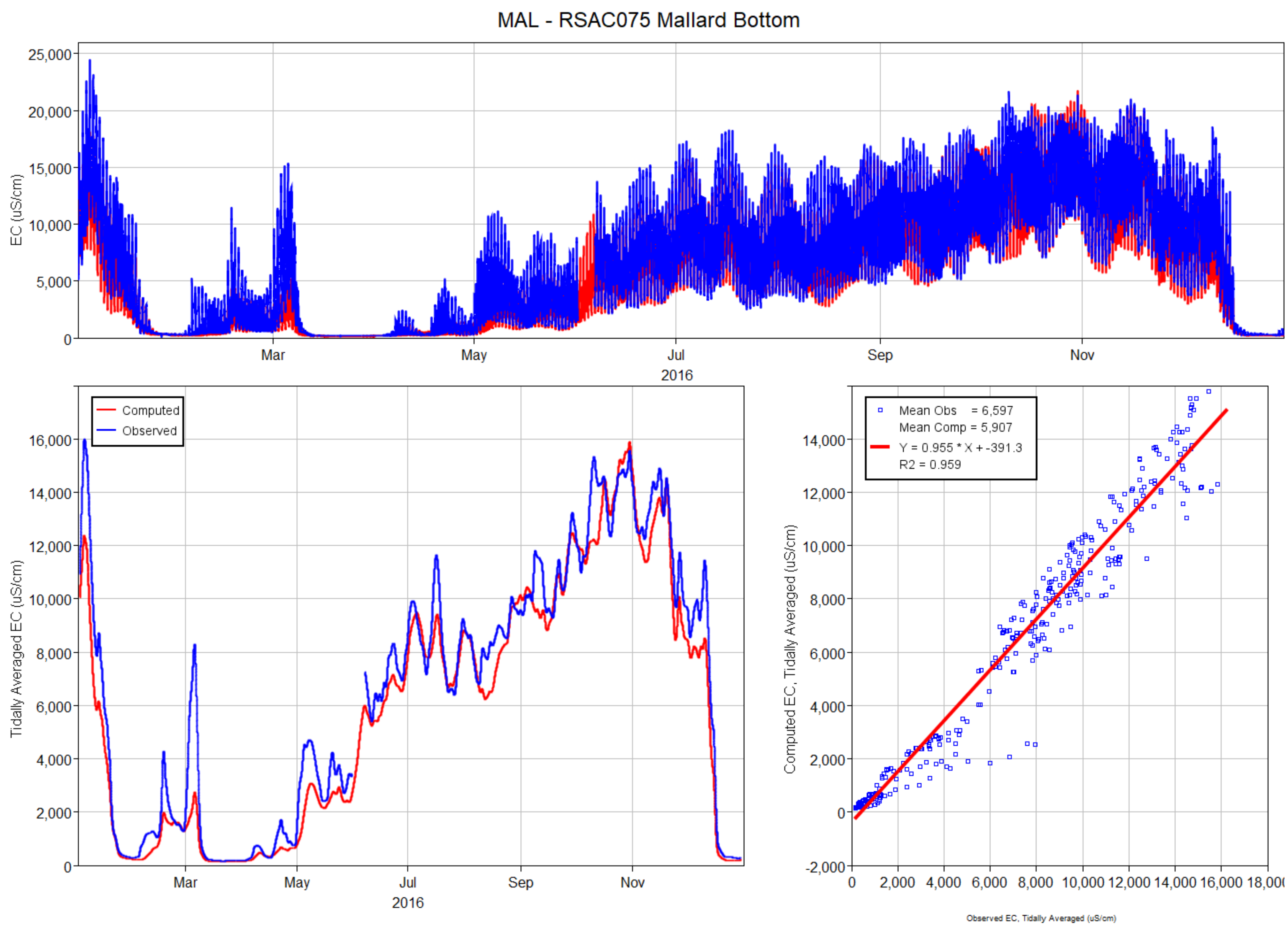

Figure 138. Comparison of modeled and observed EC at MAL (bottom sensor), Mallard Island for 2016.

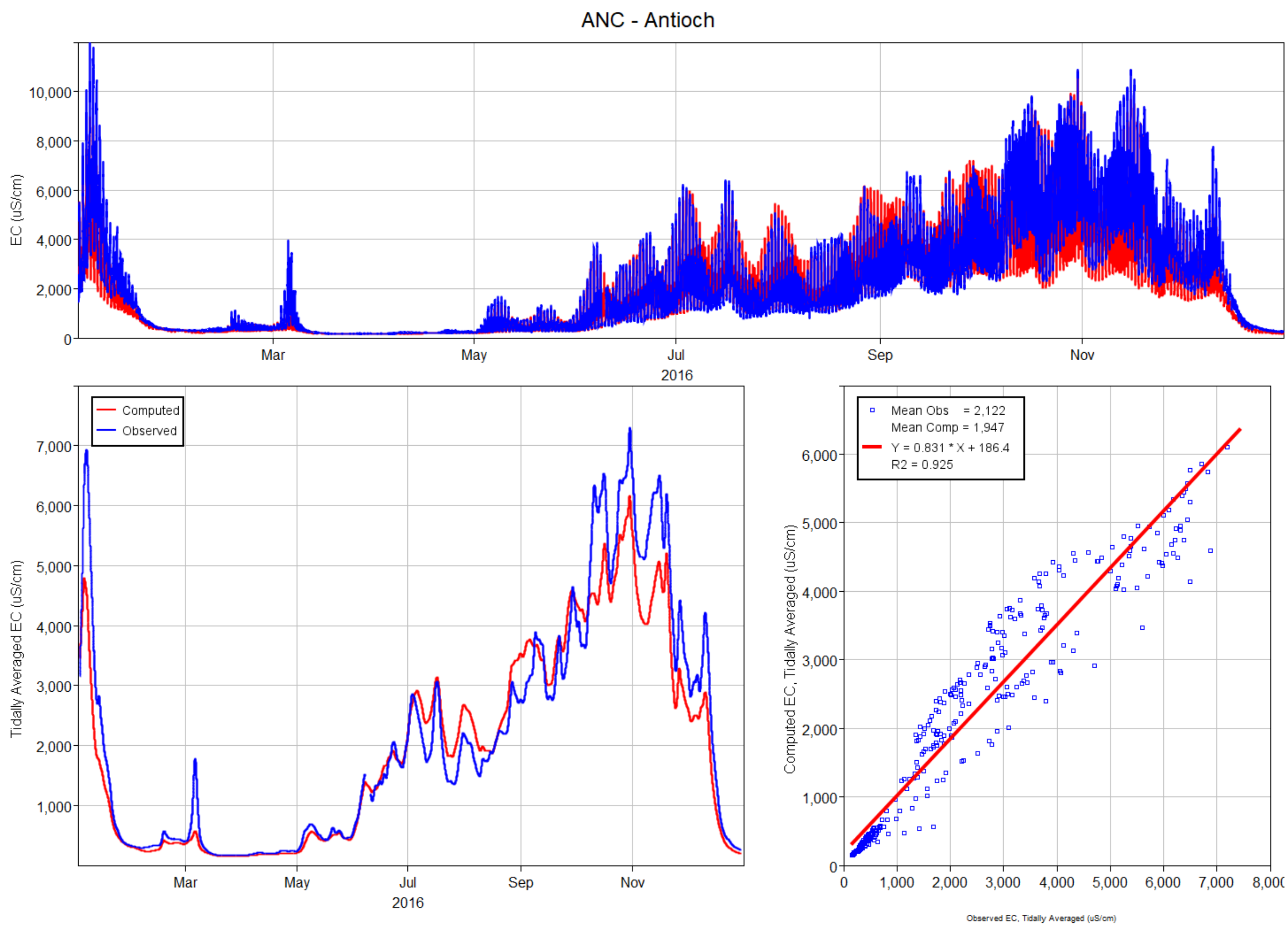

Figure 139 Comparison of modeled and observed EC at ANC, the SJR at Antioch for 2016.

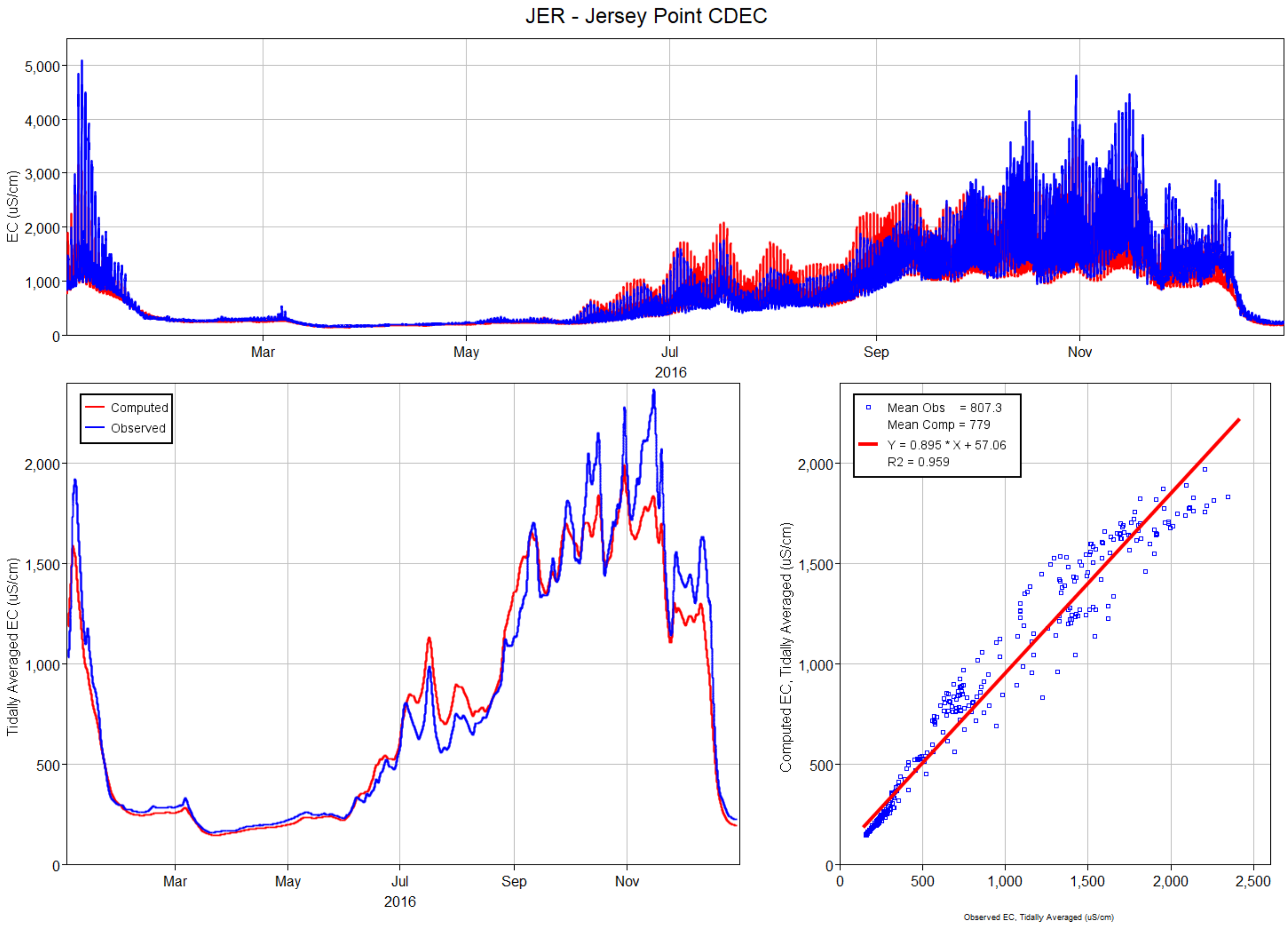

Figure 140 Comparison of modeled and observed EC at JER, the San Joaquin River at Jersey Point for 2016.

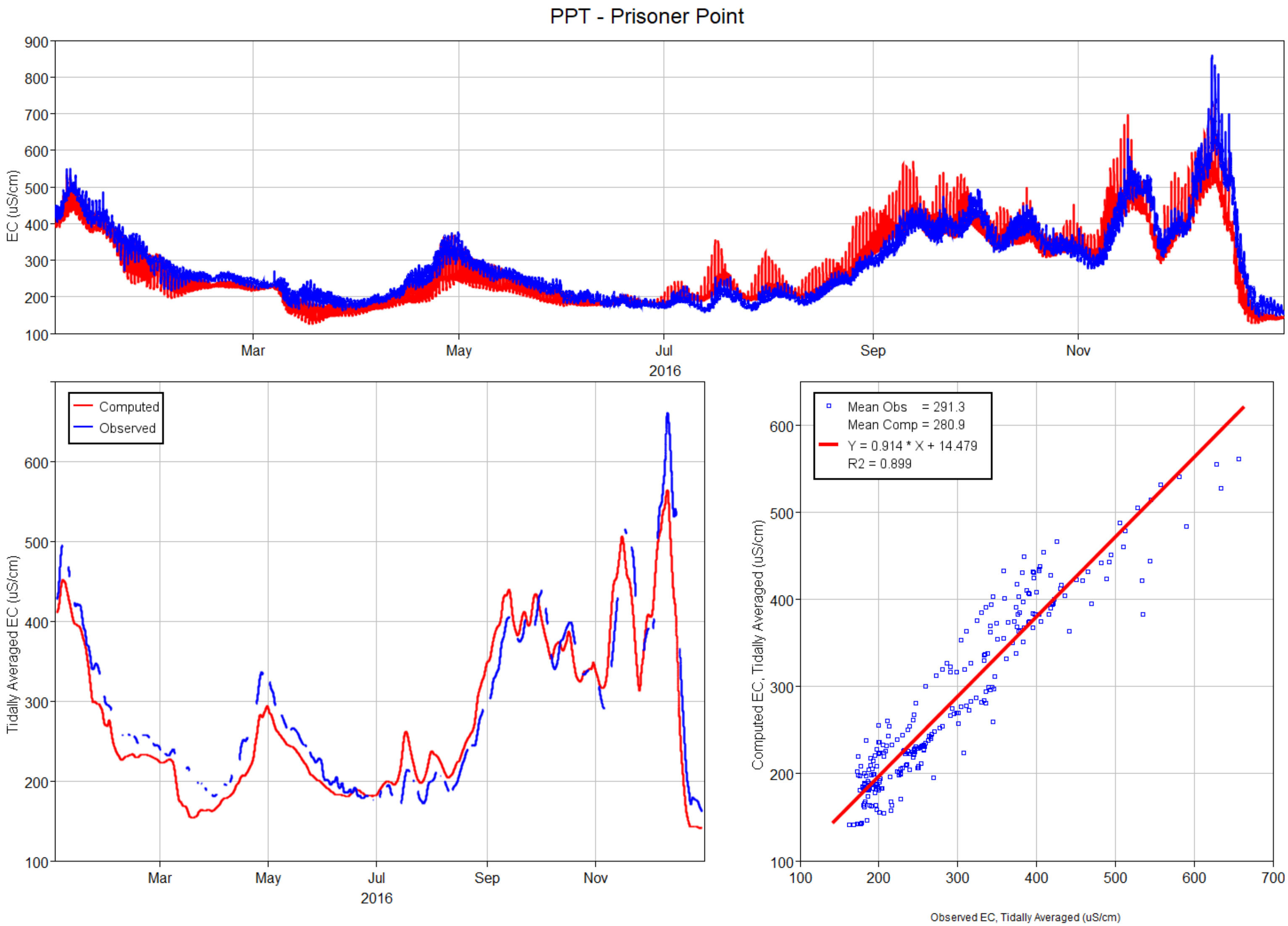

Figure 141 Comparison of modeled and observed EC at PPT, the San Joaquin River at Prisoner Point for 2016.

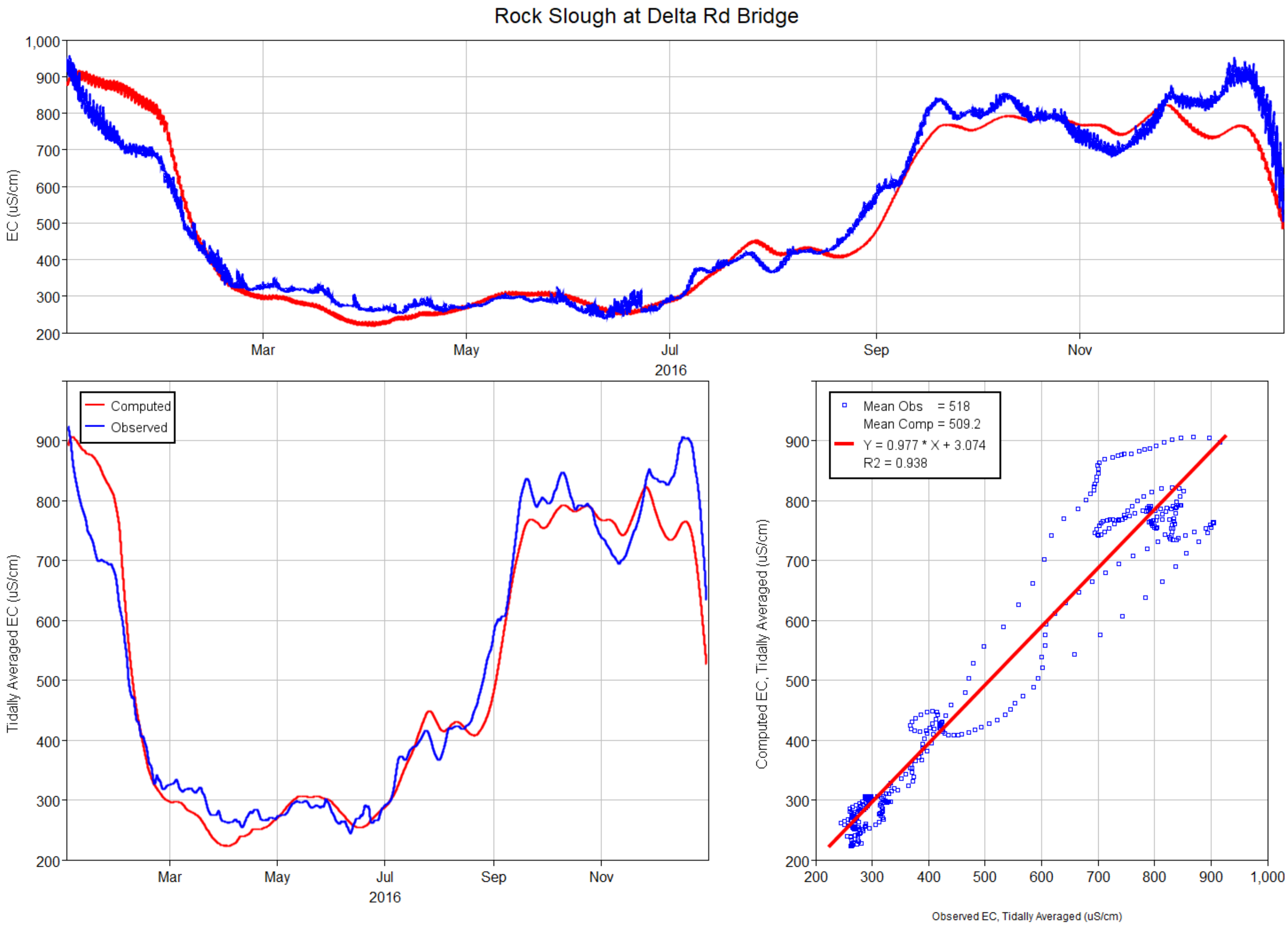

Figure 142 Comparison of modeled and observed EC at RSC, Rock Slough at Delta Rd Bridge for 2016.

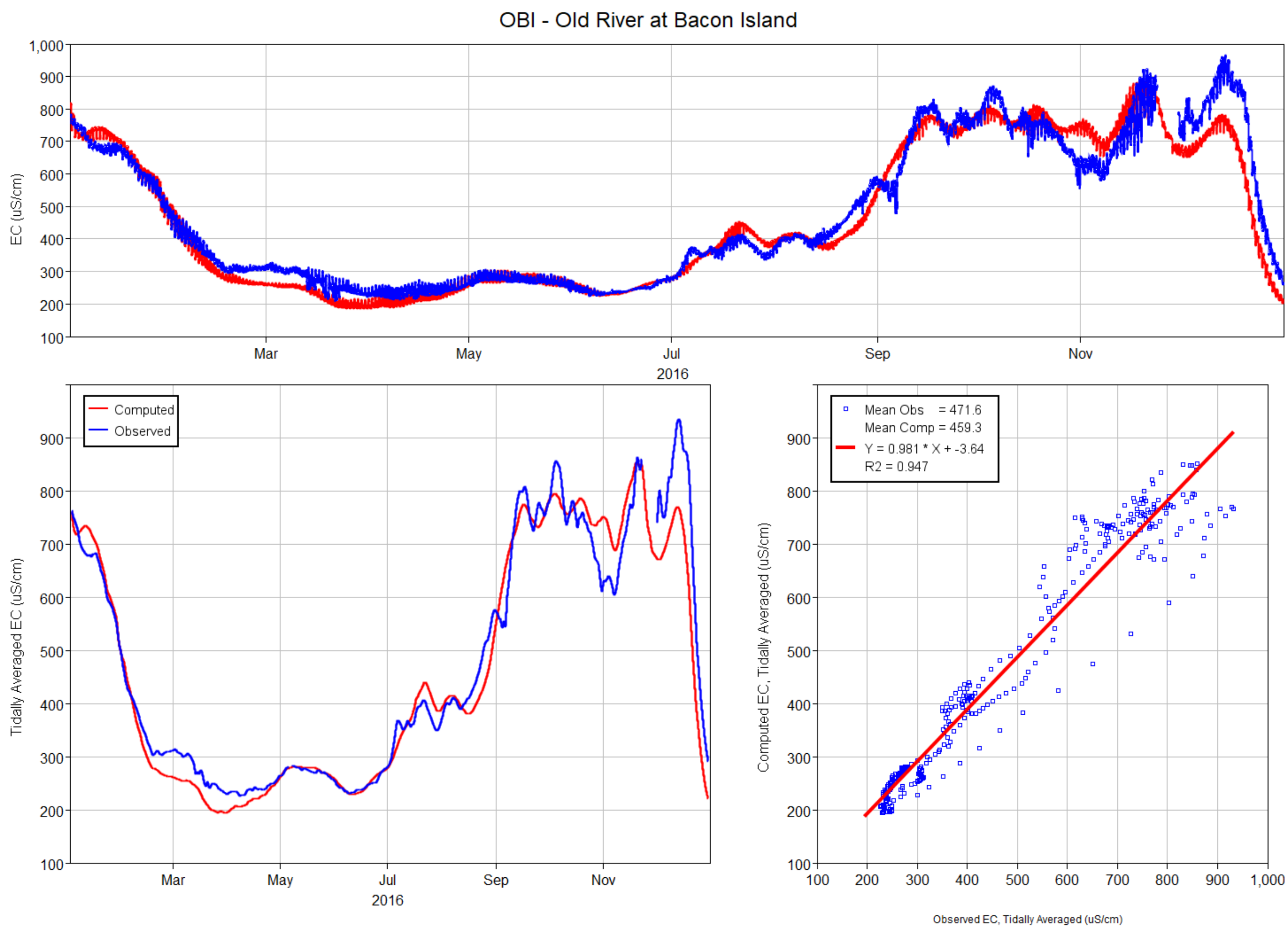

Figure 143 Comparison of modeled and observed EC at OBI, Old River at Bacon Island for 2016.

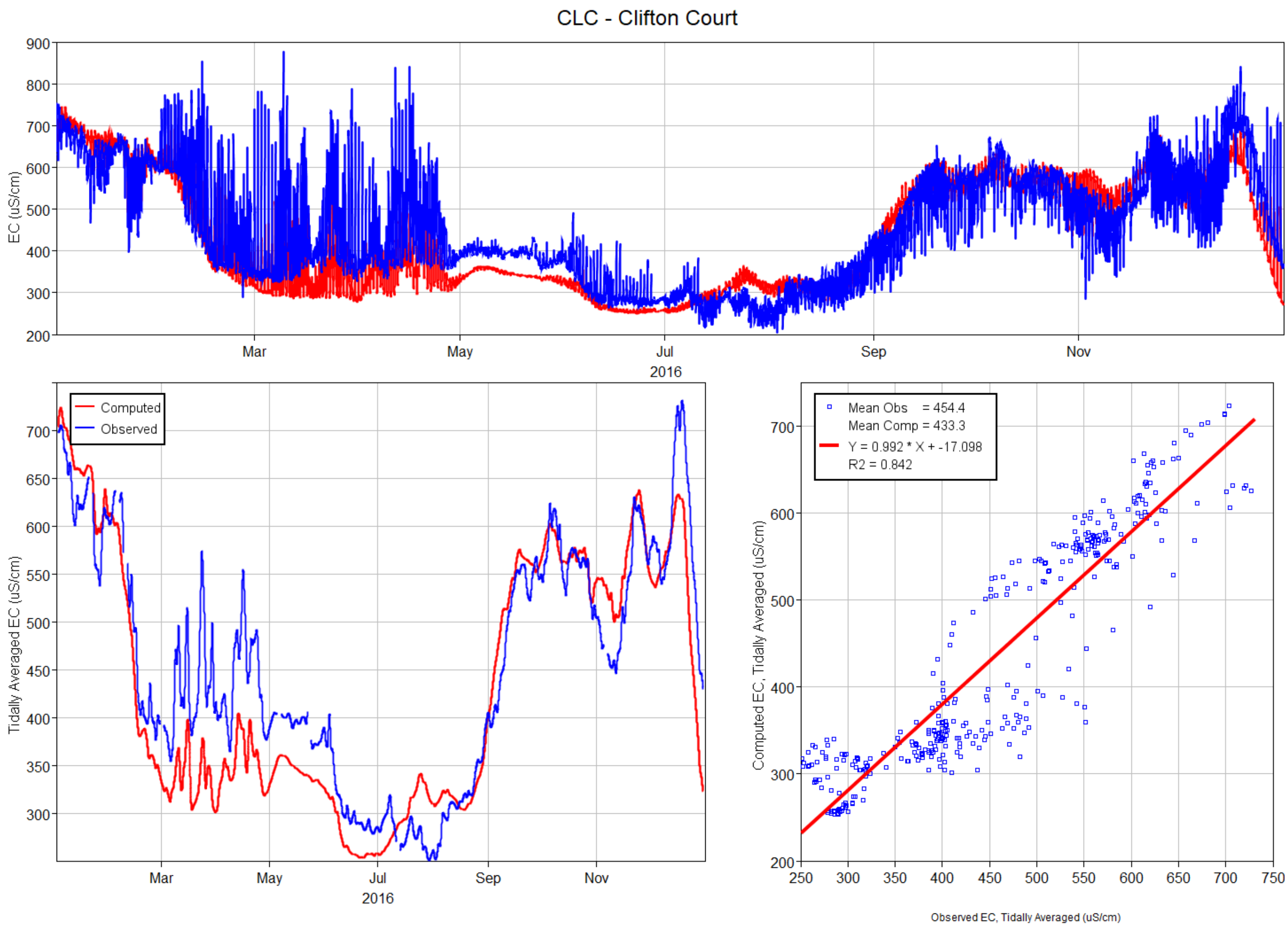

Figure 144 Comparison of modeled and observed EC at the CLC, the entrance to Clifton Court Forebay for 2016.

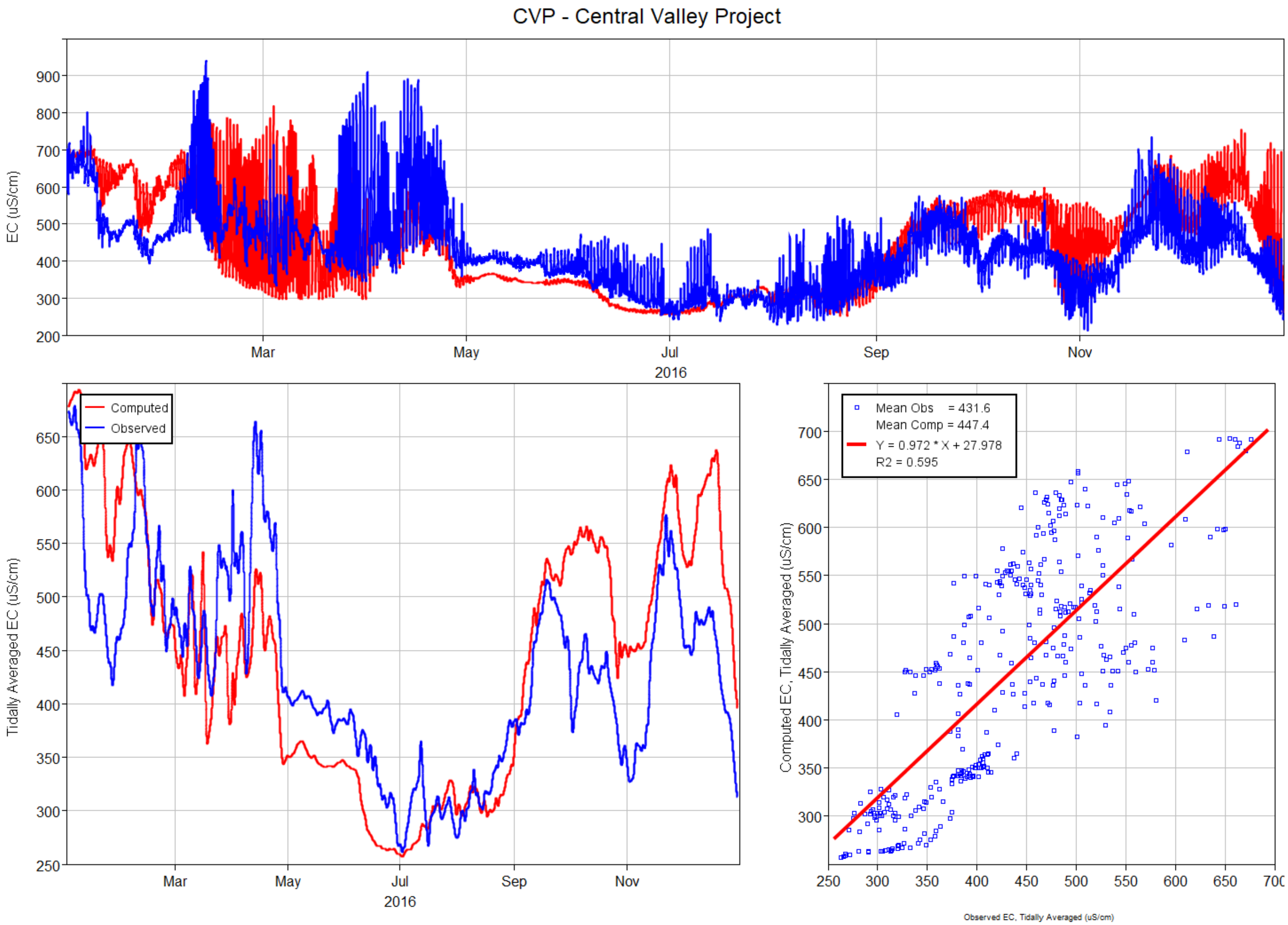

Figure 145 Comparison of modeled and observed EC at CVP, DMC headworks for 2016.

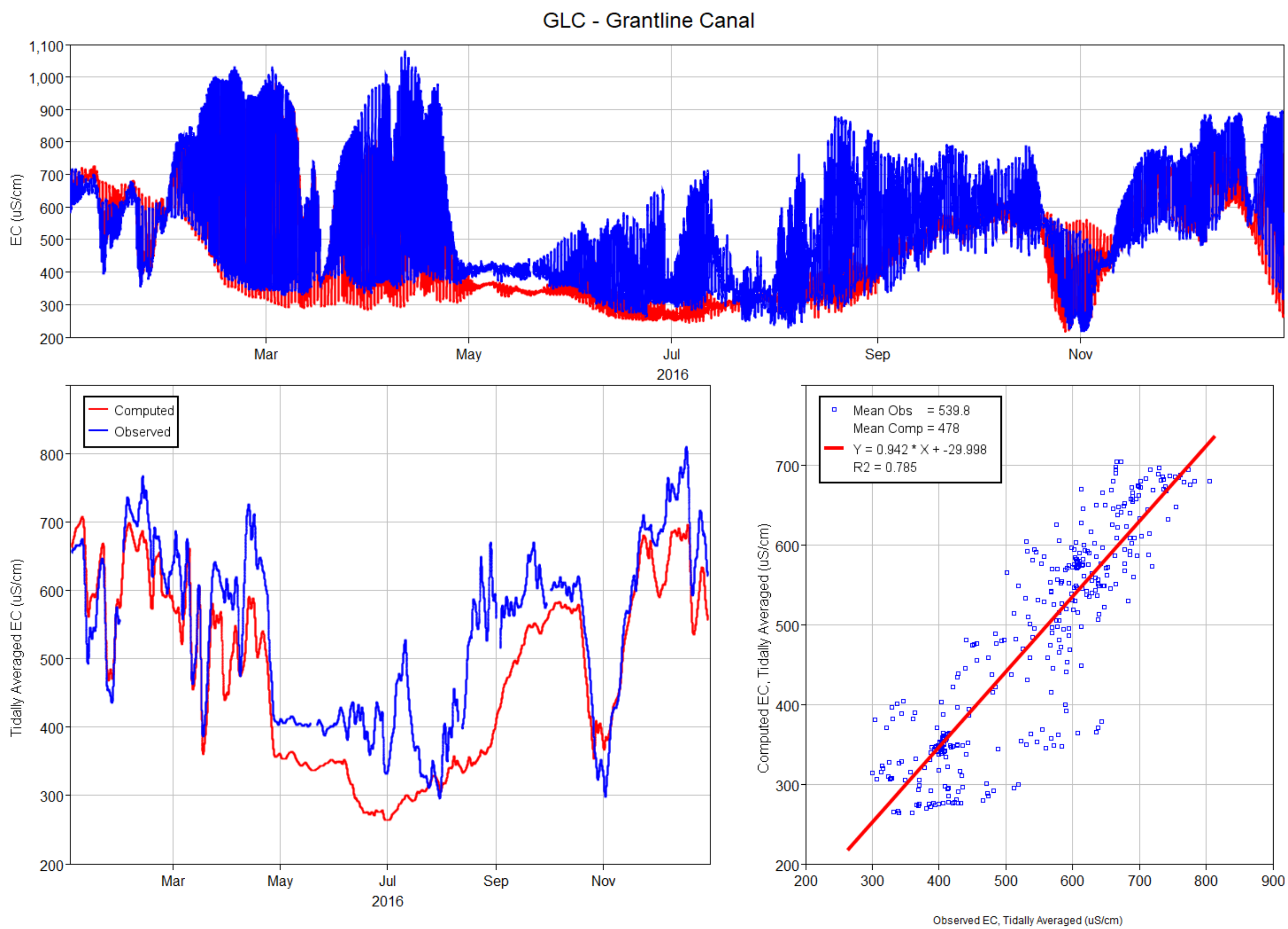

Figure 146 Comparison of modeled and observed EC at GLC, Grantline Canal for 2016.

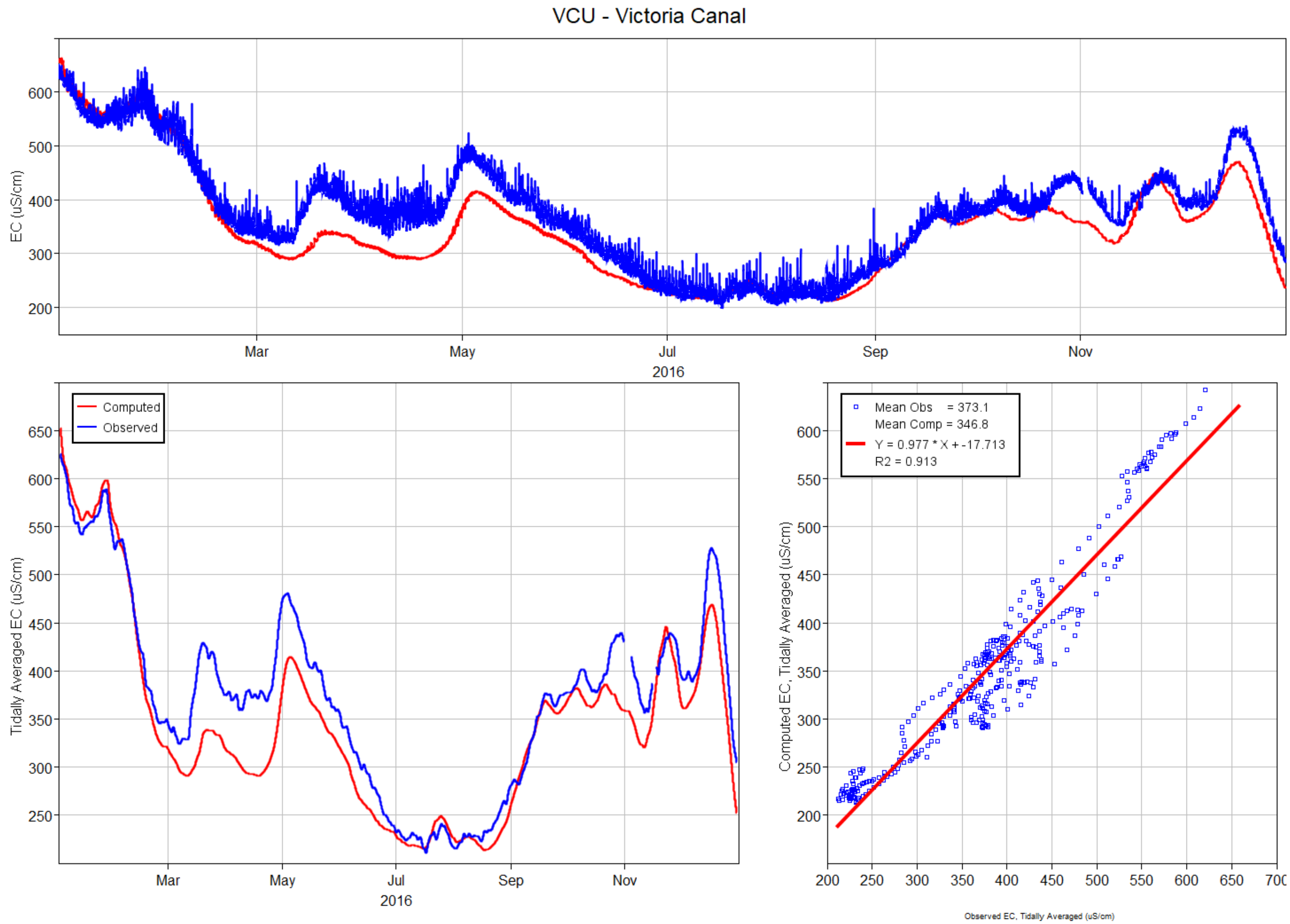

Figure 147 Comparison of modeled and observed EC at VCU, Victoria Canal at Byron for 2016.

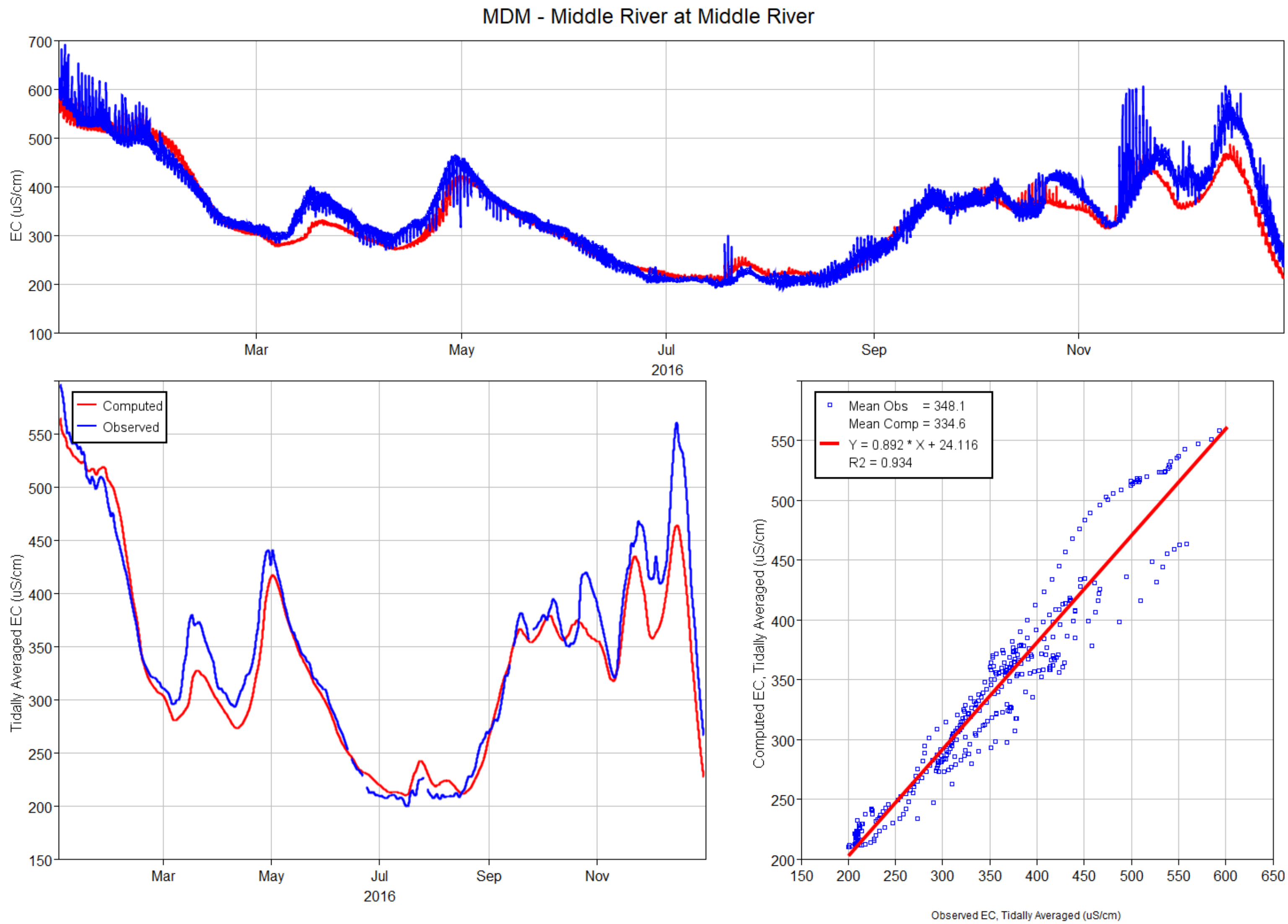

Figure 148 Comparison of modeled and observed EC at MDM, Middle River at Middle River for 2016.

Appendix C: Martinez Volumetric Source Fraction

Chloride and bromide can be estimated from the modeled EC results along with volumetric source fraction from Martinez. To determine the volumetric source fraction, Martinez fingerprinting simulations were performed for all scenarios and time periods. For these simulations, a tracer was applied at Martinez and the fraction of tracer was output at each water intake location. Tracer simulations were run for an entire year and then restarted again using the end of year conditions as initial conditions to develop reasonable starting conditions. For example, the simulation was run for January – December 2009 and the result at the end of 2009 was used to restart January 2009. Because this starting condition is not based on the actual previous year (e.g. 2008), the first months of the results (January 2009 and January 2016) are considered spin-up.

Time series of volumetric source fraction from Martinez are plotted for water intake locations in Figure 149 through Figure 157 for 2009 – 2010 and Figure 158 through Figure 166 for 2016.

For all years, Lookout Slough slightly increases volumetric source fraction from Martinez at the south Delta water intakes, while there is a slight decrease at Antioch. In the Cache Slough Complex, volumetric source fraction is very low (less than 0.01%) and Lookout Slough further decreases that fraction. With or without restoration, this fraction can be considered essentially zero, given the accuracy of the model.

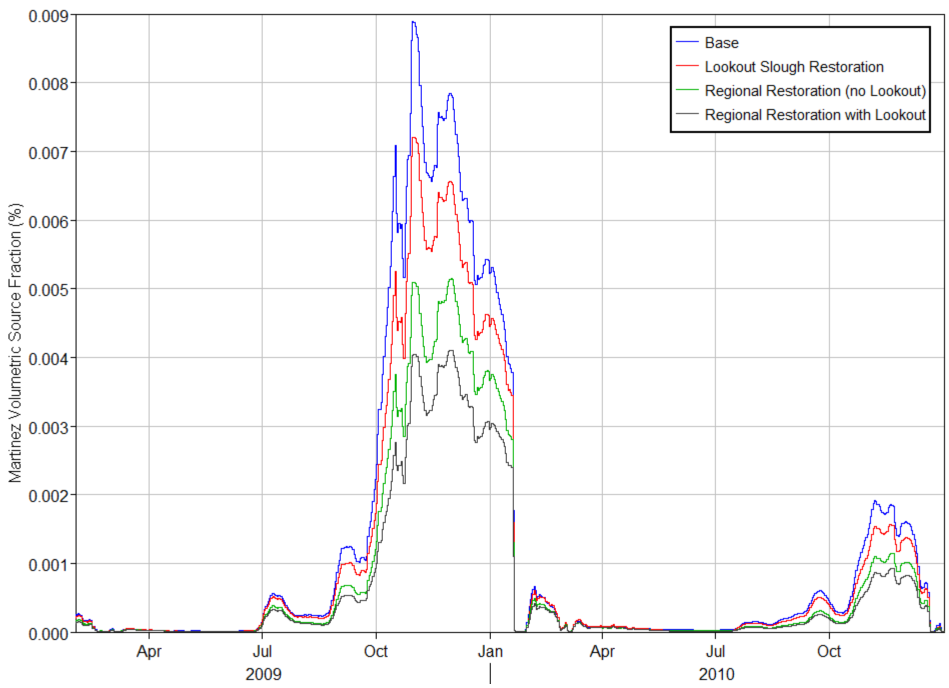

Figure 149 Daily average Martinez volumetric source fraction at Barker Slough for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough for the 2009 – 2010 simulation period.

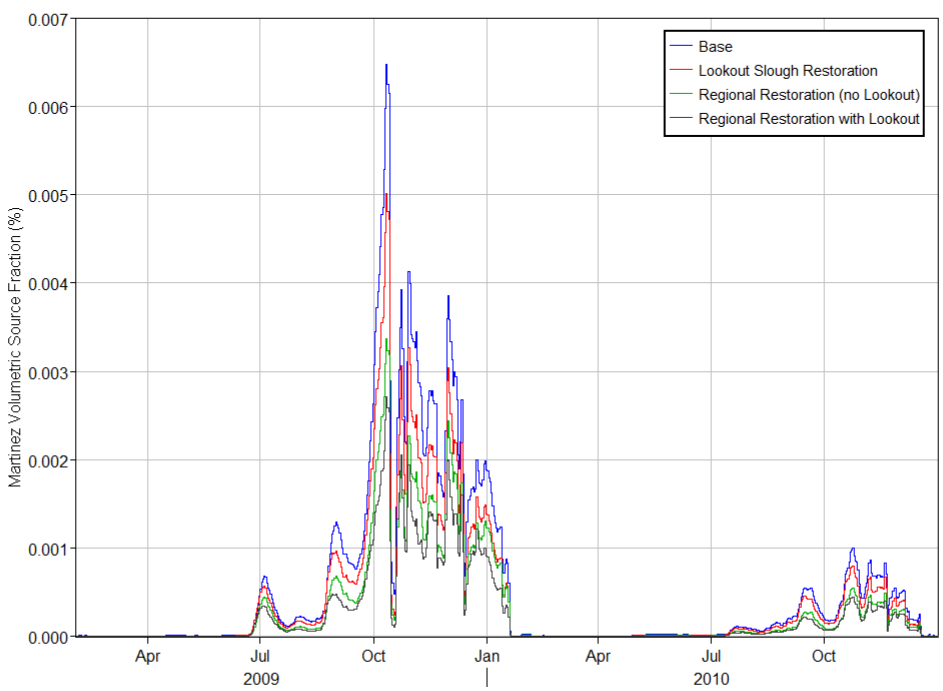

Figure 150 Daily average Martinez volumetric source fraction at C19 for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough for the 2009 – 2010 simulation period.

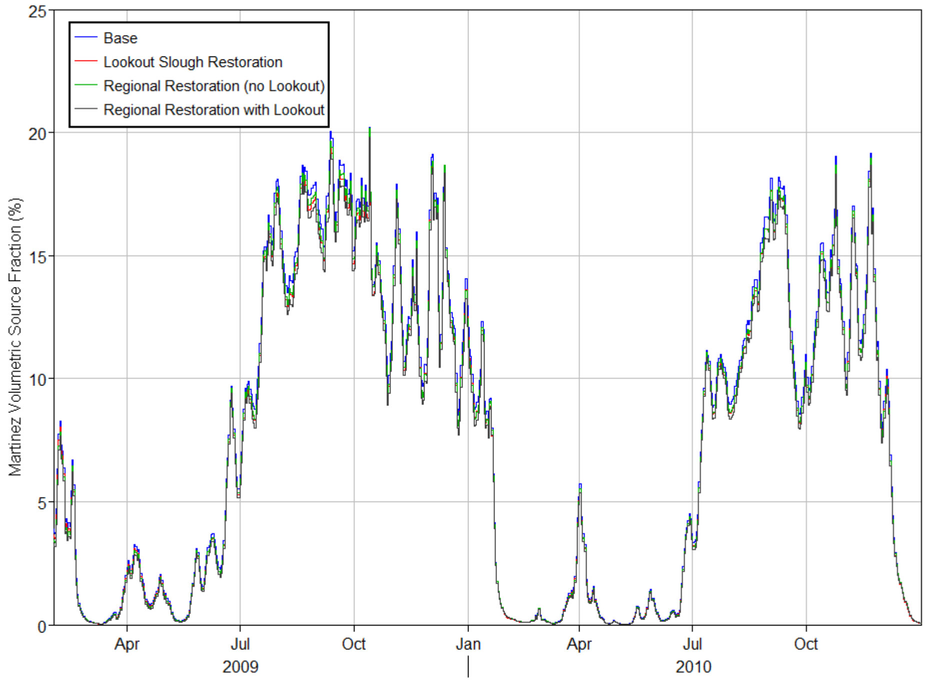

Figure 151 Daily average Martinez volumetric source fraction at Antioch for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough for the 2009 – 2010 simulation period.

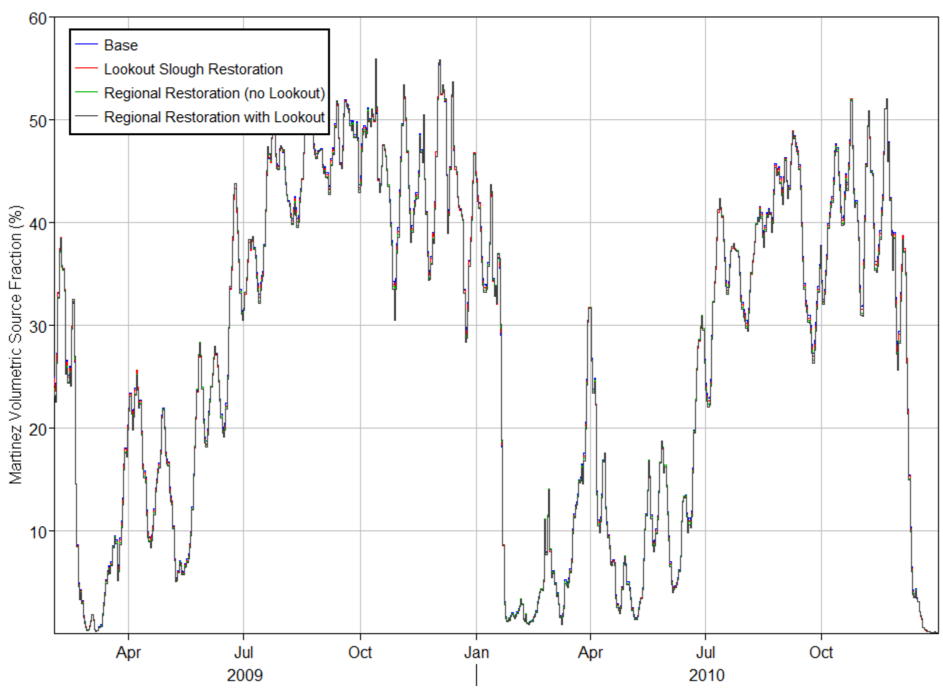

Figure 152 Daily average Martinez volumetric source fraction at CCWD intake at Mallard for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough for the 2009 – 2010 simulation period.

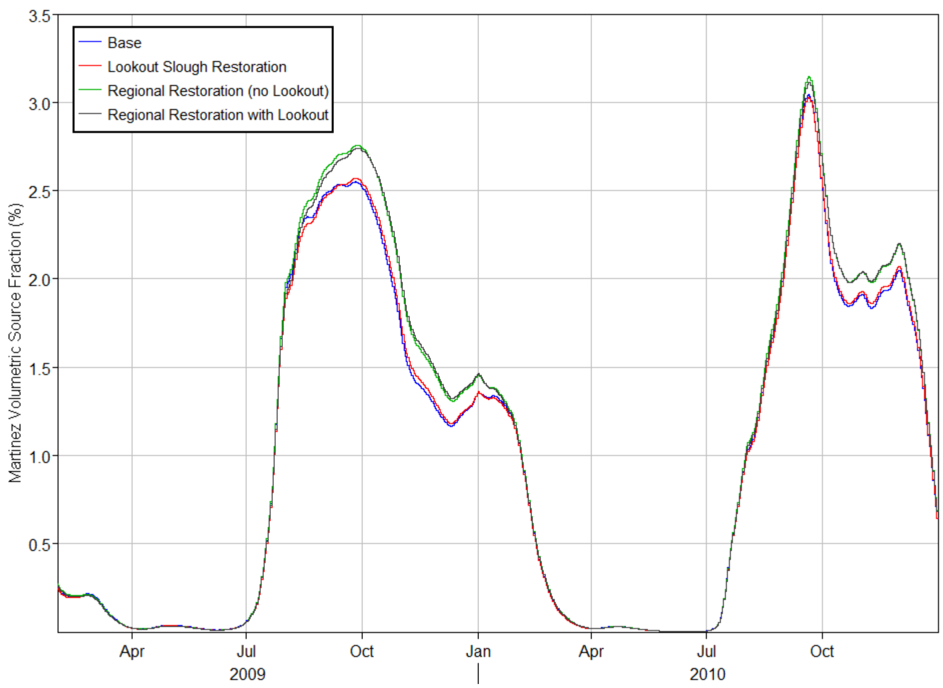

Figure 153 Daily average Martinez volumetric source fraction at CCWD intake at Rock Slough for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough for the 2009 – 2010 simulation period.

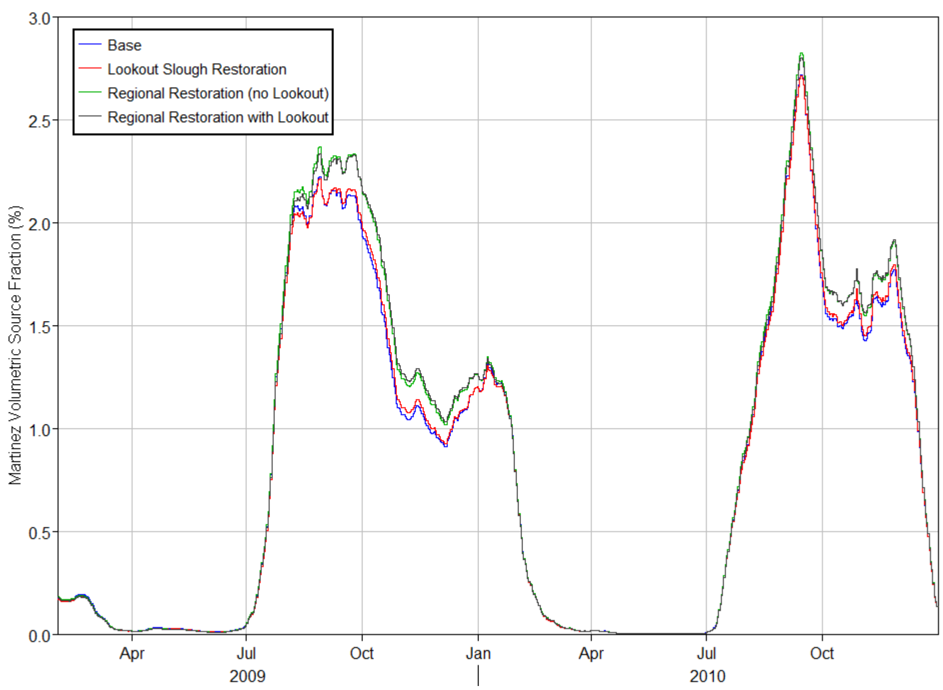

Figure 154 Daily average Martinez volumetric source fraction at CCWD intake at Old River for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough for the 2009 – 2010 simulation period.

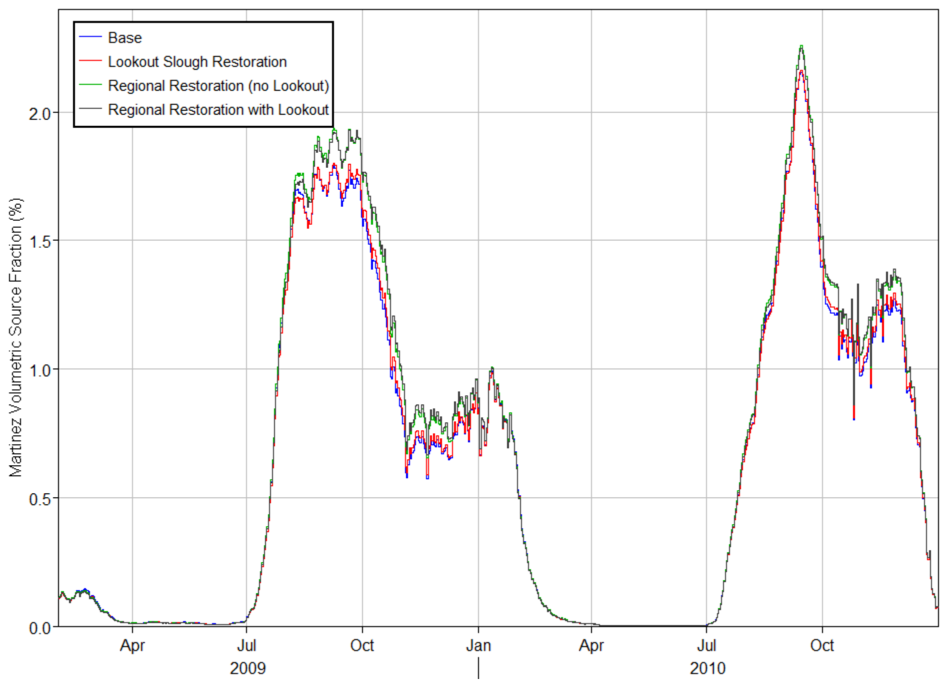

Figure 155 Daily average Martinez volumetric source fraction at West Canal at mouth of Clifton Court for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough for the 2009 – 2010 simulation period.

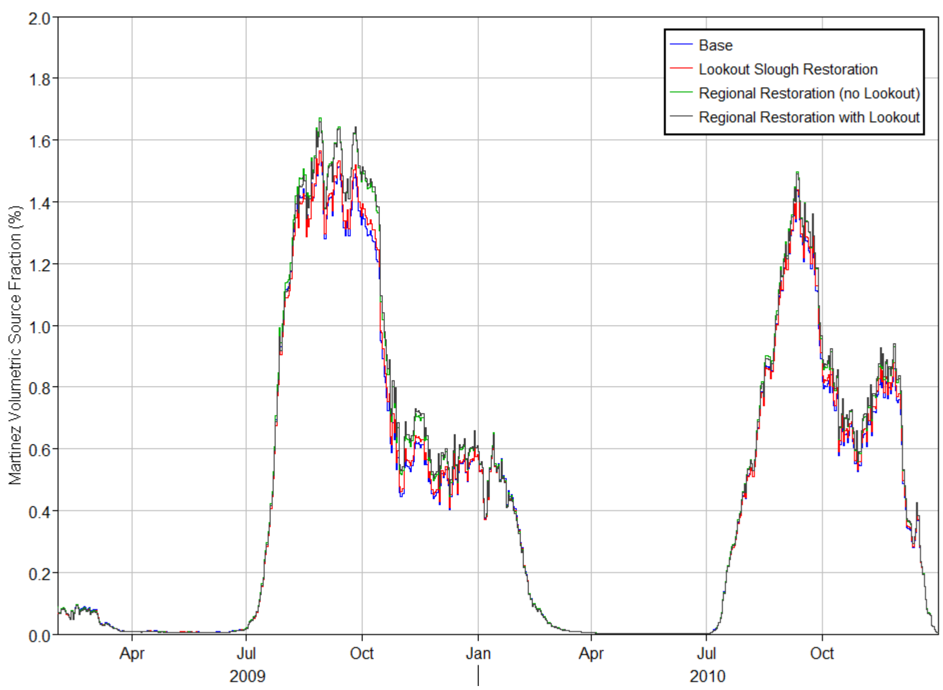

Figure 156 Daily average Martinez volumetric source fraction at DMC Canal at Tracy PP for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough for the 2009 – 2010 simulation period.

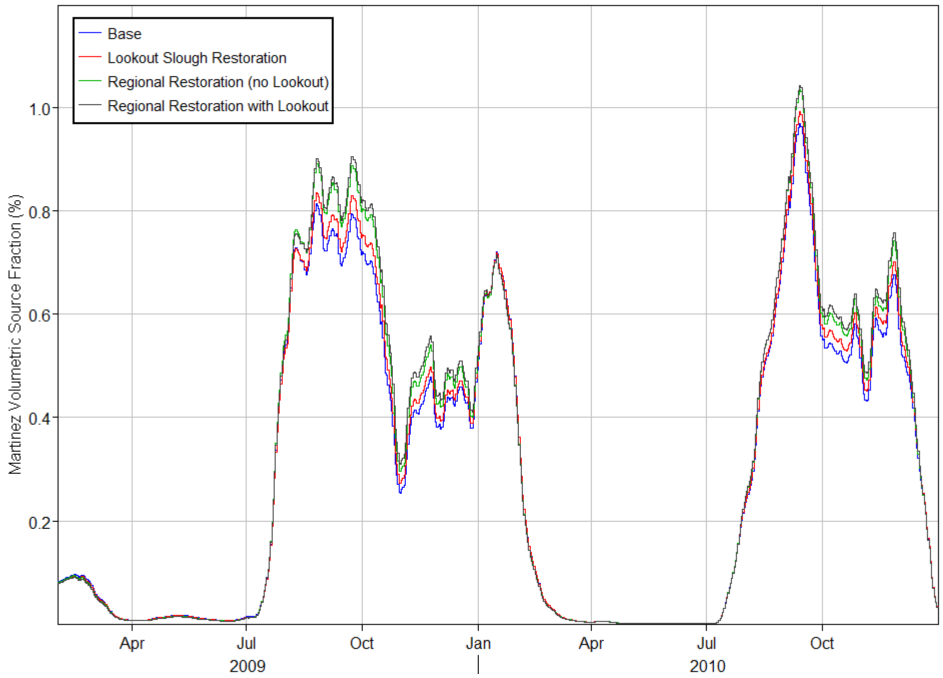

Figure 157 Daily average Martinez volumetric source fraction at CCWD intake at Victoria Canal for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough for the 2009 – 2010 simulation period.

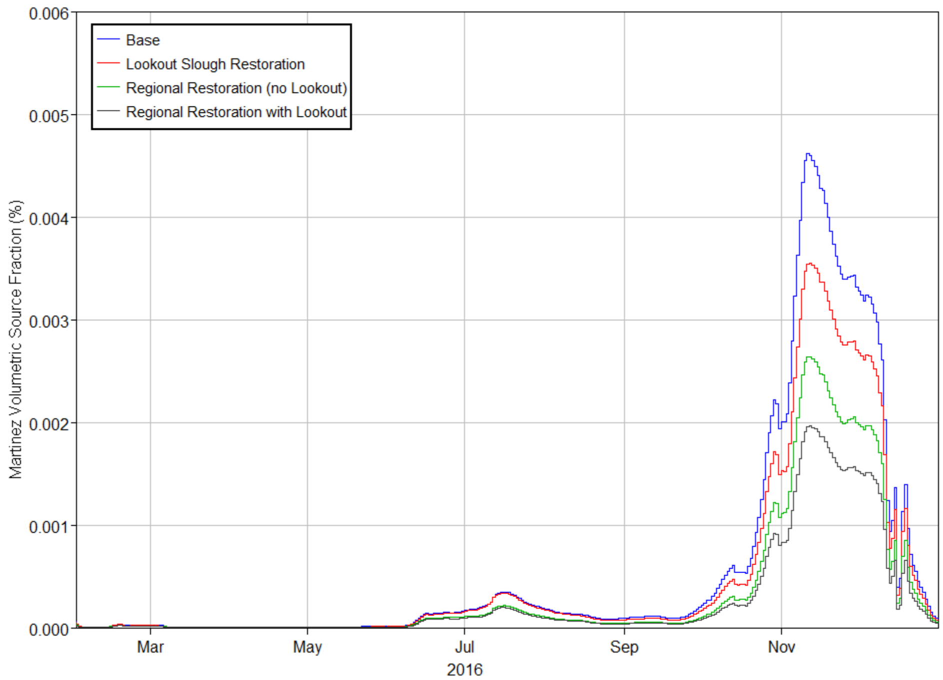

Figure 158 Daily average Martinez volumetric source fraction at Barker Slough for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough for the 2016 simulation period.

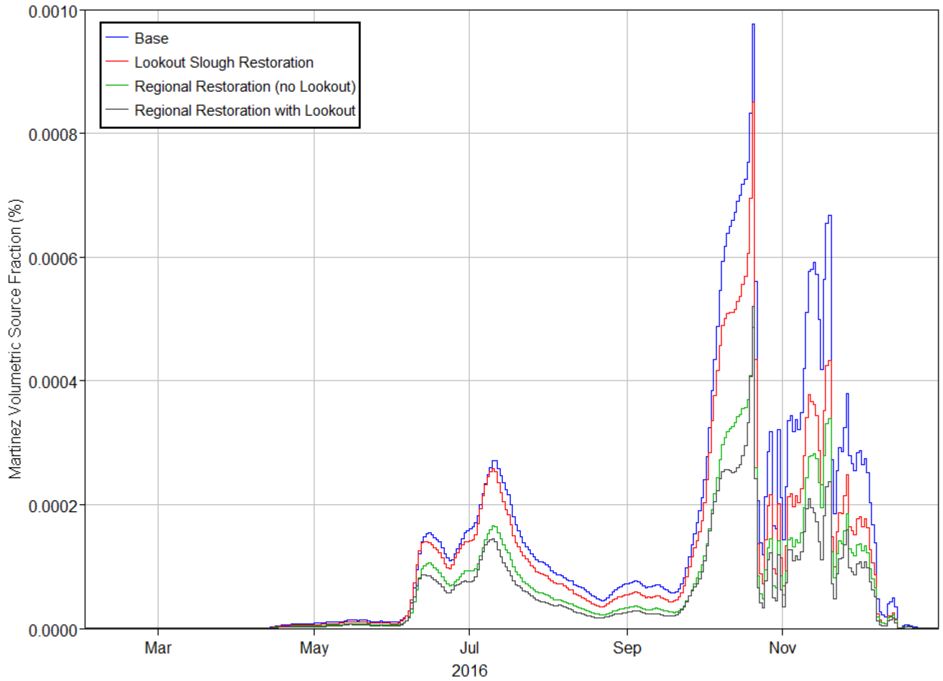

Figure 159 Daily average Martinez volumetric source fraction at C19 for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough for the 2016 simulation period.

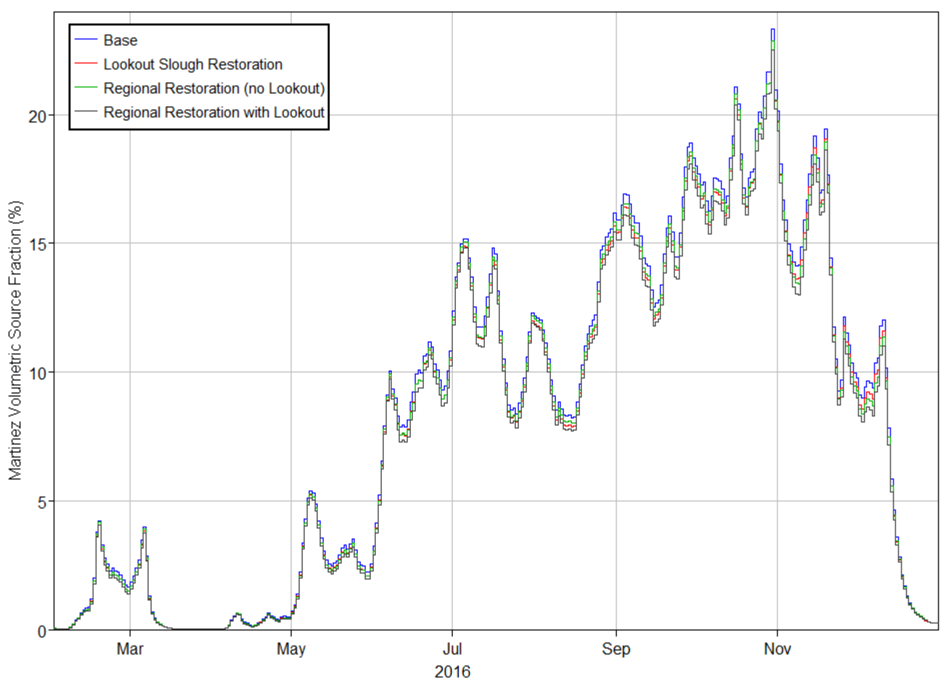

Figure 160 Daily average Martinez volumetric source fraction at Antioch for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough for the 2016 simulation period.

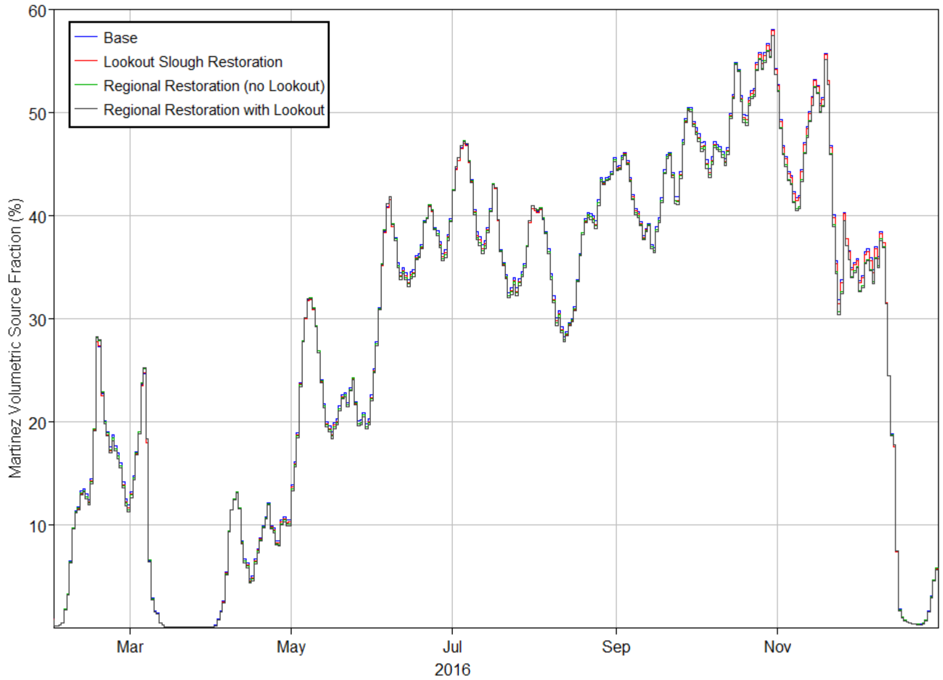

Figure 161 Daily average Martinez volumetric source fraction at CCWD intake at Mallard for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough for the 2016 simulation period.

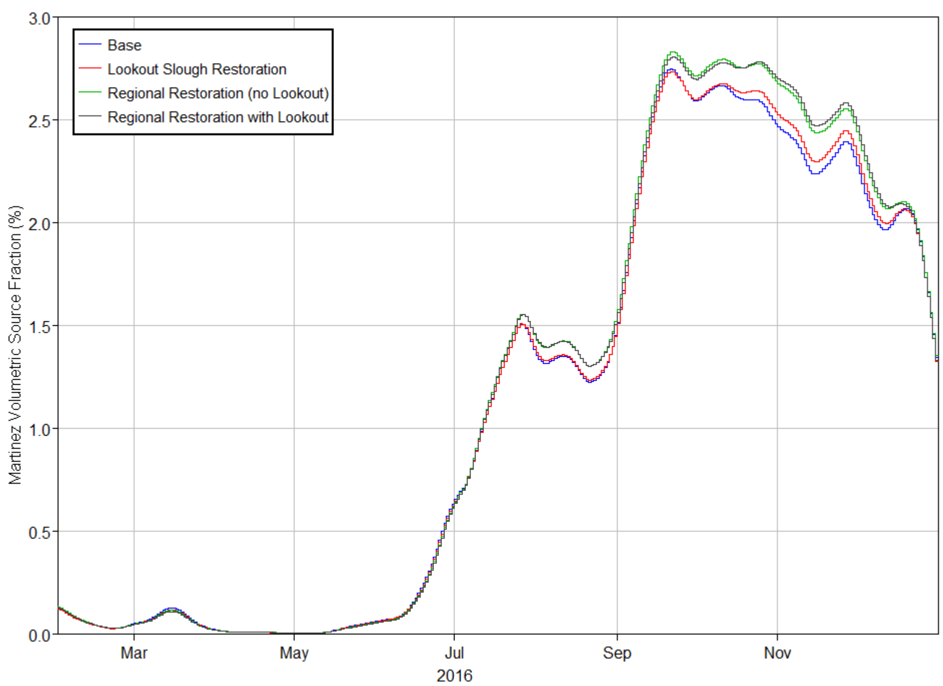

Figure 162 Daily average Martinez volumetric source fraction at CCWD intake at Rock Slough for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough for the 2016 simulation period.

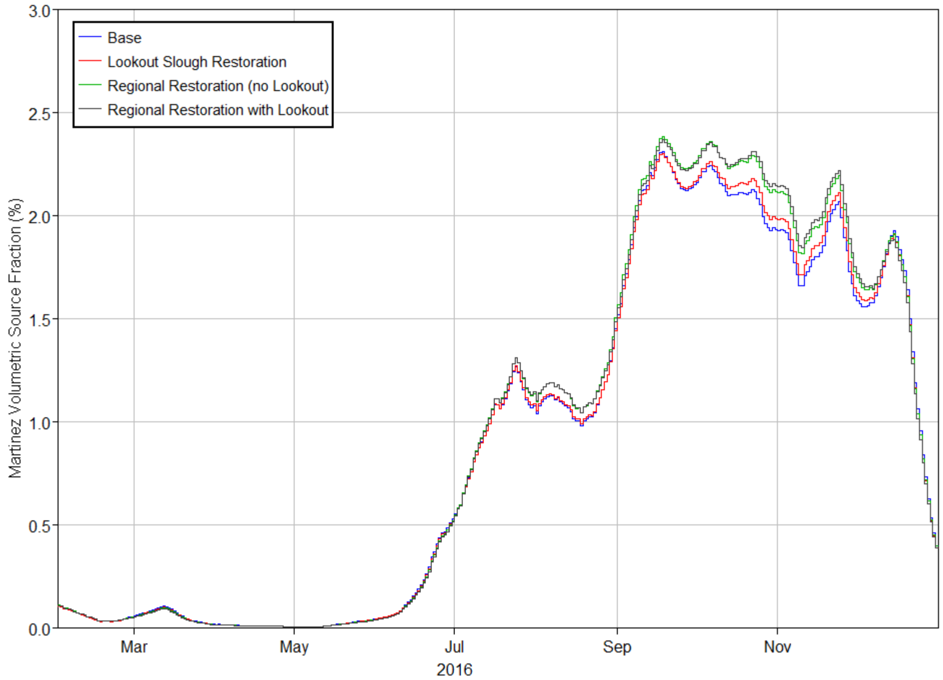

Figure 163 Daily average Martinez volumetric source fraction at CCWD intake at Old River for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough for the 2016 simulation period.

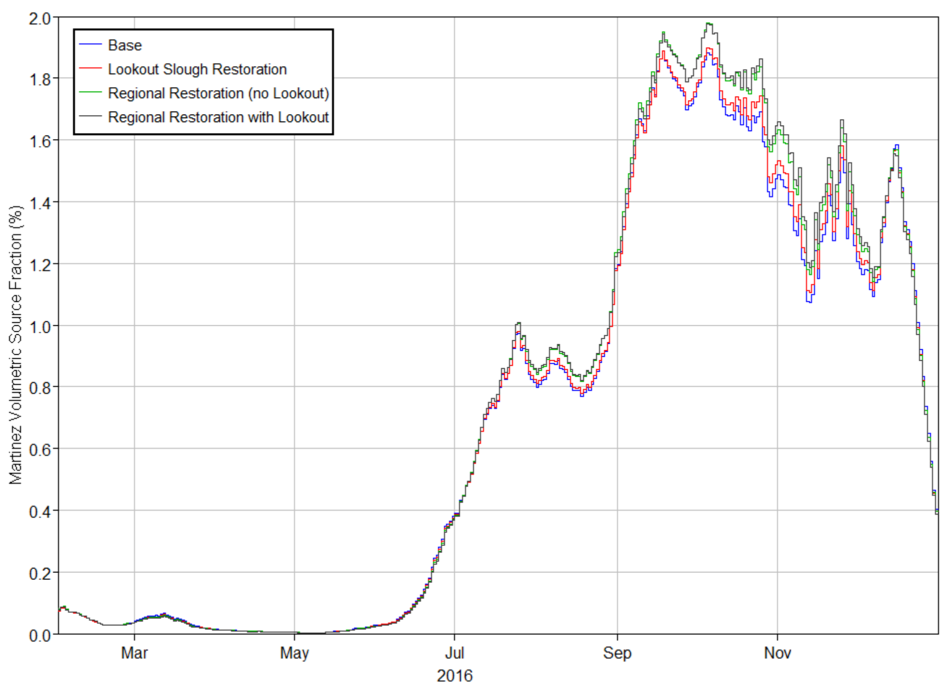

Figure 164 Daily average Martinez volumetric source fraction at West Canal at mouth of Clifton Court for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough for the 2016 simulation period.

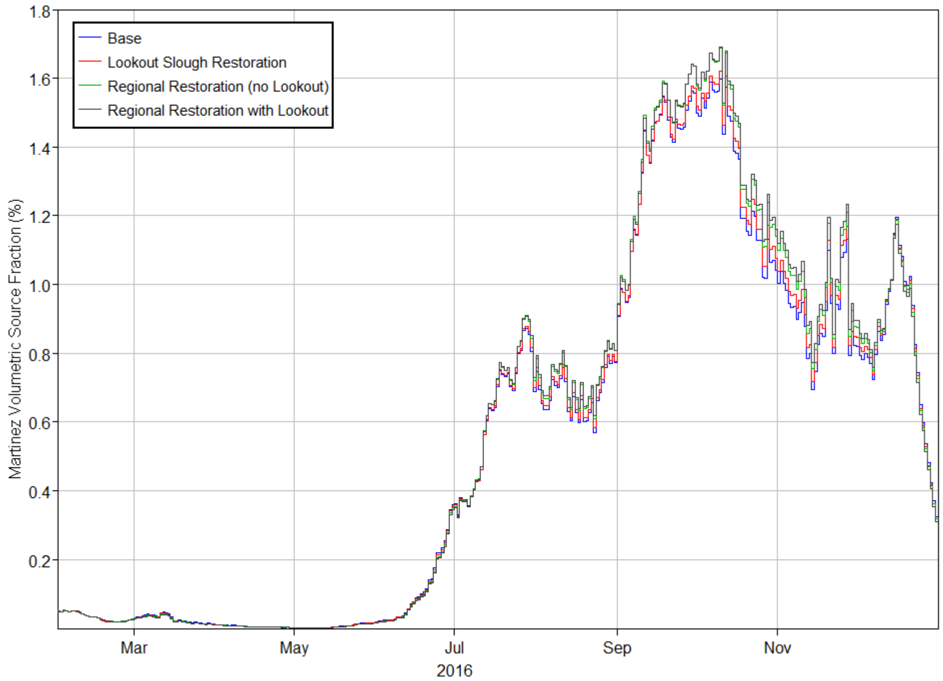

Figure 165 Daily average Martinez volumetric source fraction at DMC Canal at Tracy PP for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough for the 2016 simulation period.

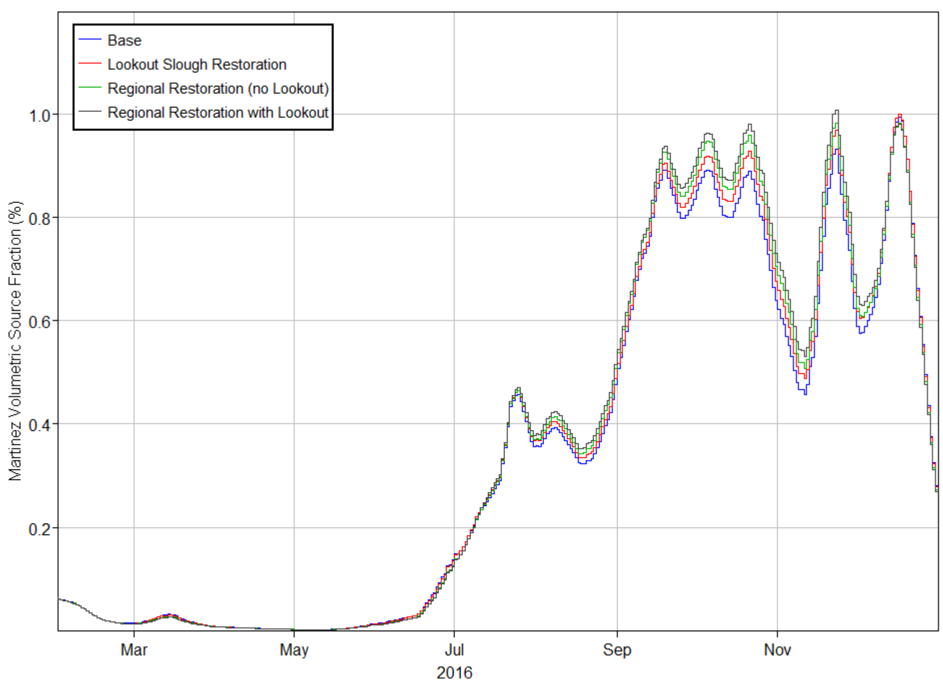

Figure 166 Daily average Martinez volumetric source fraction at CCWD intake at Victoria Canal for Base, Lookout Slough Restoration, Regional Restoration and Regional Restoration with Lookout Slough for the 2016 simulation period.

Appendix Y

Lookout Slough Tidal Habitat Restoration and Flood Improvement Project Wind Wave Summary

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memorandum

date September 3, 2020

to David Urban, PE (Ecosystem Investment Partners)

from Matt Brennan, PE, and Bob Battalio, PE

subject Wave Modeling and Erosion Hazard for Lookout Slough Tidal Marsh Restoration and Flood Improvement Project – Executive Progress Summary

PURPOSE

Lookout Slough Tidal Habitat Restoration and Flood Improvement Project (Project) is seeking to restore tidal wetland habitat and improve flood management in the northwestern portion of the Sacramento-San Joaquin Delta. To re-connected tidal exchange, the Project will breach the levee between the eastern side of the Project site and Shag Slough (Figure 1). Because of this breaching, tides and riverine runoff will regularly inundate approximately 3,000 acres of the Project site that currently is used for agriculture and duck hunting. To maintain flood protection for neighboring properties, the Project will construct the new Duck Slough Setback Levee along its north and northwestern boundaries, re-grade the existing Cache Hass Training Levee along its southwestern boundary and maintain the Cross Levee along its southern boundary. All of these levees will be designed to meet specific flood management criteria and to resist erosion from currents and wind waves. In addition, the Project intends to maintain the existing level of erosion hazard for offsite levees that could be affected by the re-configuration of hydrology and levees on the Project site.

The Project is being designed and constructed by Ecosystem Investment Partners on land owned by California's Department of Water Resources (DWR). After construction, long-term operations, monitoring, and maintenance of the levees will be managed by DWR, with the intent of preserving the as-built geometry of the Duck Slough Setback Levee, the Cache Hass Training Levee, and the Cross Levee. The breached levee along Shag Slough will not be maintained and will be allowed to degrade at its own pace.

The purpose of this study is to quantify wind wave conditions and erosion hazard to inform levee design and to assess potential for offsite impacts.

An initial wind wave analysis was conducted as part of the Project's 65% design[1]. This prior analysis made several simplifying assumptions and did not address the design questions and potential for offsite impacts in enough detail. This current study conducts the wind wave analysis with more sophisticated methods (e.g. a two-dimensional wind wave model instead of one-dimensional empirical equations) and carries the analysis further to estimate overtopping rates and erosion hazard. In general, the current study confirms the findings of the prior analysis in terms of levee wave exposure and provides greater detail that was used to modify the Project's design and clarify analysis of potential offsite impacts.

Erosion potential was assessed as follows:

1. For offsite levees, based on potential wave height increase with Project; and,
2. For select Project levees, adequacy of reinforced turf armor for levee crest and lee side[2], based on computed wave runup and overtopping.

This executive progress summary describes the methods used for the wind wave modeling and erosion hazard assessment, and then summarizes the findings from these analyses completed to date.

METHODS

This study uses standard methods from coastal engineering planning and design. These methods are consistent with approaches recommended by the Central Valley Flood Protection Board and US Army Corps of Engineers. Steps in this process include:

- Use available data to describe the site and the hydrology and wind meteorology which are responsible for wind waves and their interaction with levees.
- Develop a two-dimensional wave model to characterize wave conditions across the Project site and adjacent areas potentially affected by the Project. This model, Simulating WAves Nearshore (SWAN) is a third-generation model that accounts for wave generation, propagation, and dissipation.
- Select scenarios that describe a range of possible conditions that the site may be exposed to, including extreme flood and wind events, and quantify these scenarios with data from the first step.
- Predict wave conditions across the Project site and neighboring property with the model for the specified scenarios.
- Analyze wave model output to predict wave runup, wave overtopping, and wave erosion hazard to the crest and lee side.

These methods were applied with engineering judgment according to current standards of practice, using the available data and within the capabilities of the coastal engineering analytic methods. Because of the limitations of these data and methods, as well as the variability inherent in natural hydrologic and biologic systems, this study has not considered all possible conditions that may result from the Project. However, this study is intended

[1] Wood Rodgers. 2019. Lookout Slough Tidal Habitat Restoration and Flood Improvement Project: Wave Runup and Wind Setup Analysis Technical Memorandum. Prepared for Ecosystem Investment Partners.

[2] The lee side of a levee refers to the opposite side from the exposed side, which refers to the side exposed to direct wave action. Because of the fetch created by restoring the Project site to inundation, for the Project levees, the side of the levees facing the site's interior are considered wave exposed and the side of the levees facing outward are considered the lee side.

to be sufficient to inform the refinements of the Project design and analysis of potential impacts that will be undertaken by the Project's engineering, construction, and management team.

STUDY FINDINGS

The study findings for five levee segments within and near the Project are summarized below. Unless otherwise stated, these findings about wave conditions and wave erosion hazard assume that the levees retain their existing or as-built conditions. Over the long term, levees may face intermittent erosion of its top and side slope. Within the Project site, this erosion is assumed to be addressed with intermittent maintenance by DWR.

Cache Slough South Levee (Hastings Island)

Across Cache Slough from the Project site, the south levee of Cache Slough protects Hastings Island from flooding. Model results show the Project has no significant impacts on the wave erosion hazard faced by the Cache Slough South Levee along Hastings Island.

Wave modeling predicts negligible (0.1 ft or less) change in wave heights in Cache Slough adjacent to the Cache Slough South Levee, even for the 1% annual exceedance probability (AEP or 100-year) water surface elevation and 1.38% AEP (72.6-year) wind speed blowing across the Project site. This lack of change on the Cache Slough South Levee occurs because the Project maintains the crest of the Cache Hass Training Levee one foot above the 1% AEP (100-year) water surface elevation. This levee blocks waves generated in the Project site from propagating into Cache Slough. When the water surface is at the 4% AEP (25-year) elevations or higher, waves that break on the levee's inboard side could generate runup that overtops the levee and discharges water to Cache Slough, but the breaking will completely dissipate all the wave energy. Only the waves which are generated wholly within Cache Slough impinge upon Cache Slough South Levee.

Deep Water Ship Channel West Levee

The Deep Water Ship Channel West Levee is designated an urban levee because of its role mitigating flood risk for areas to its east, including the City of West Sacramento. The Urban Levees Evaluations Project[3] found that portions of this levee nearest the Project are generally at low risk of wave erosion and this levee's primary performance deficiency is not meeting freeboard requirements.

Using the same 0.5% AEP (200-yr) water surface elevations and 48 mph wind speed as the Urban Levee evaluation, two-dimensional wave modeling was used to predict the potential changes in wave conditions resulting from the Project. When comparing existing conditions to as-built Project conditions, the wave modeling indicates negligible (0.1 ft or less) change in wave heights along all of the Deep Water Ship Channel West Levee.

[3] URS. 2014. Geotechnical Evaluation Report Volume 1, Existing Conditions. Urban Levee Evaluations Project. Prepared for California Department of Water Resources.

Since the Project does not propose to maintain the unbreached portions of the levee between the project site and Shag Slough, this levee will eventually degrade. To represent possible conditions at least several decades into the future when the levee is degraded, the model was configured to assume this levee degrades in height by 12 to 18 feet along its entire length, so its crest elevation matches mean higher high tide level. Even with levee degradation this extensive and for an extreme and infrequent wave scenario, wave modeling indicates only a slight increase in wave heights of up to 0.3 ft, constrained to just a southern segment of the Deep Water Ship Channel West Levee.

Duck Slough Setback Levee Design Elevation with Wave Runup

The purpose of the Duck Slough Setback Levee is to maintain the current level of flood protection for neighboring property to the north and west of the Project.

The design criteria for this levee's crest elevation based off of the 1957 water surface elevation, which is higher than the 1% AEP (100-year) water surface elevation in the northern portion of the site. The levee's crest was set at eight feet above the 1957 water surface elevation, the sum of six feet to be consistent with other regional projects' allowance for wave runup, one foot of long-term settlement, and one foot to adapt to future sea-level rise.

Wave modeling was conducted for the 1957 water surface elevation and the 1.38% AEP (72.6-year) wind speed. The resulting waves were then calculated to have runup heights less than seven feet.

Cache Hass Slough Training Levee Erosion Control

The levee between Cache Slough and the project site will be transformed from having water on one side (Cache Slough) to have water on both sides. Its revised purpose is to limit the transfer of peak water levels and waves from the Project site to the adjacent Cache Slough. As part of the Project, this levee will be re-graded with its new crest elevation set to one foot above the 1% AEP (100-year) water surface elevation and with a shallower inboard slope that improves the levee's geotechnical stability.

Wave modeling and wave runup analysis were conducted for a range of water surface elevations. Although this is not an Urban Levee, the Urban levee criteria were the only published criteria which could be used for analysis. Results indicate that substantial overtopping (i.e. greater than the Urban Levee design criteria of 0.1 cfs/lf) is not predicted to occur for water surface elevations at or below the 5% AEP (20-year) conditions with 1.38% AEP (72.6-year) wind speeds. Wave overtopping greater than the Urban Levee design criteria is predicted to occur for the 1% AEP (100-year) water surface elevation and the 10% AEP (10-year) wind speed or the 4% AEP (25-year) water surface elevation and the 1.38% AEP (72.6-year) wind speed. Analysis of wave erosion hazard at the crest and lee side for these overtopping conditions indicate that that high performance turf re-enforcement matting would resist erosion for more than 6 hours, the Urban levee event duration criteria for these scenarios.

Cross Levee Erosion Control

The Cross Levee will retain its current crest elevations, as a continuation of the Project's perimeter levees limiting the propagation of peak water levels and wind waves into Cache Slough.

Because of its crest elevation is several feet higher than that of the Cache Hass Training Levee, the only scenario predicted to result in overtopping is the 1% AEP (100-year) water surface elevation and the 1.38% (72.6-year) wind speed. The overtopping predicted for this scenario is substantially less than the Urban Levee design criteria. And the wave erosion hazard for these overtopping conditions indicate that native grass cover would resist erosion for considerably longer than the Urban levee event duration criteria, so would not require the addition of turf re-enforcement matting.

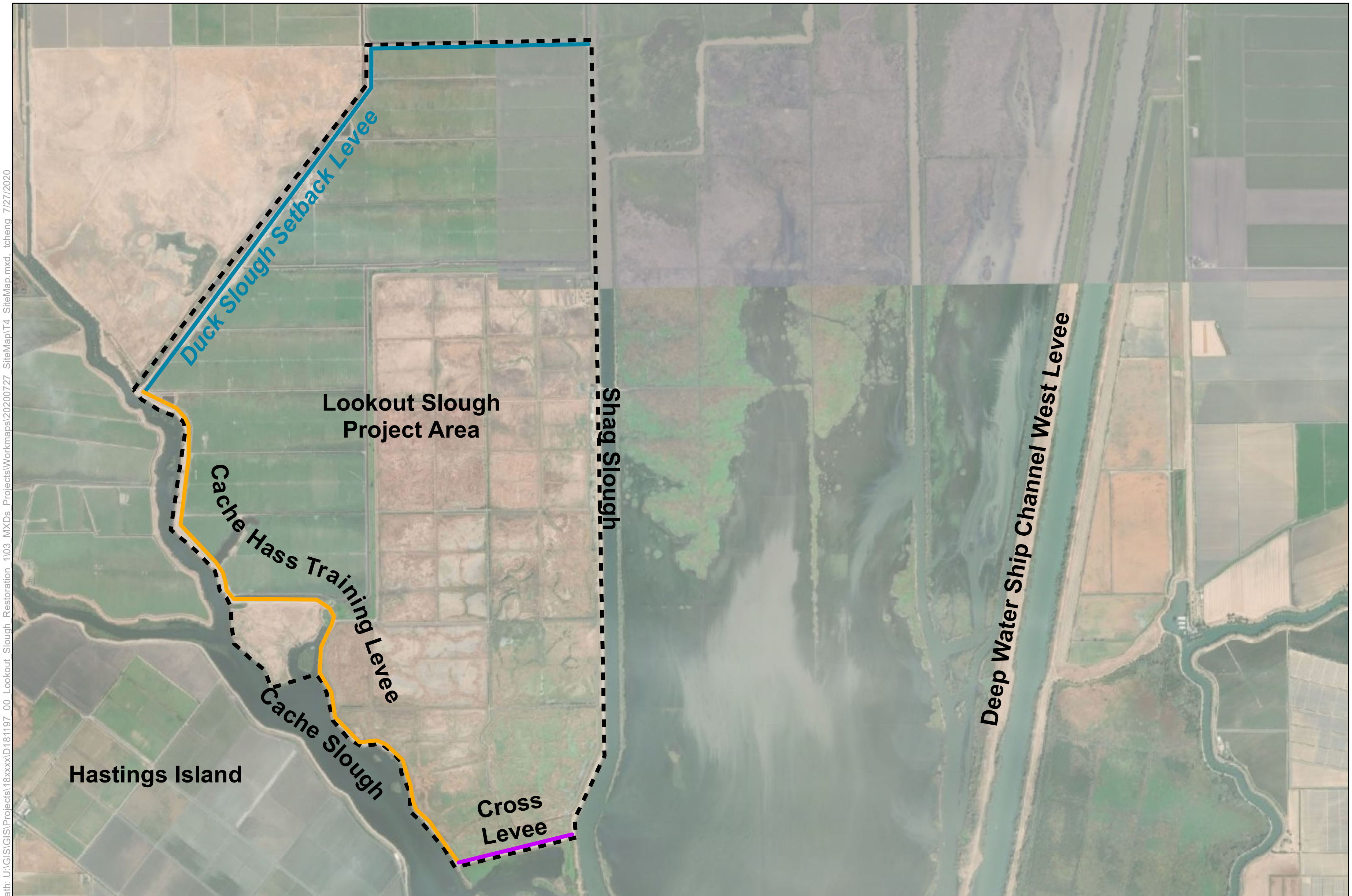

Figure 1
Proposed Project Levees

Lookout Slough Tidal Habitat Restoration
and Flood Improvement Project

Ecosystem Investment Partners
ESA