Chapter 8
Water Quality

8.0 Summary Comparison of Alternatives

A summary comparison of important water quality impacts is provided in Figures 8-0a and 8-0b. These figures provides information on the magnitude of the most pertinent water quality-related impacts, both adverse and beneficial, that are expected to result from implementation of the alternatives. Important impacts to consider include the potential for increased electrical conductivity, increased mercury levels in fish, and increased production of *Microcystis* in the Delta.

As depicted in Figure 8-0a, the modeling shows that all action alternatives would exceed the water quality objective for electrical conductivity (EC) in the Sacramento River at Emmaton. Alternatives 1A and 6A would exceed the objective more than the other alternatives would. The percentage of days the Emmaton EC objective would be exceeded for the entire period modeled (1976–1991) would increase from 6% under Existing Conditions and 14% under the No Action Alternative late long-term (LLT) to 31% under Alternative 1A and 32% under Alternative 6A. Alternatives 4A, 2D, and 5A would result in the least exceedances of the threshold of 16%, 7%, and 10%, respectively. However, in reality, staff from DWR and Reclamation constantly monitor Delta water quality objectives. Their water system operational decisions take into account real-time conditions and are able to account for many factors that the best available models cannot simulate. It is likely that some of the objective exceedences simulated in the modeling would be avoided under the real-time monitoring and operational paradigm that would be in place to help prevent such exceedences.

Modeling results show that most of the action alternatives, as well as the No Action Alternative, would result in increased mercury levels in fish tissue concentrations at Delta locations. Alternatives 6A and 9 would result in the highest increases in mercury levels in fish tissue, increasing by up to 64% to 66% compared with Existing Conditions at certain Delta locations, and by up to 58% to 59%, compared to the No Action Alternative LLT. Alternative 4A would increase mercury levels in fish tissue by 8% or less compared with Existing Conditions and No Action Alternative early long-term (ELT), Alternative 2D would result in a 10% or less increase compared with Existing Conditions and No Action Alternative (ELT), and Alternative 5A would result in a 5% or less increase compared with Existing Conditions and No Action Alternative (ELT).

Modeling results show that the action alternatives would result in increased production of *Microcystis* in the Delta when compared with the No Action Alternative as a result of a number of factors. Blooms of *Microcystis* require high levels of nutrients and low turbidity, as well as high water temperature and, because the species is fairly slow growing, long residence time (Lehman et al. 2008; Lehman et al. 2013). In addition, low vertical mixing (due to low water flow) associated with high residence time allows *Microcystis* colonies to float to the surface of the water column, where they outcompete other species for light. Increases in ambient air temperature due to climate change relative to Existing Conditions are expected under all action alternatives. Increases in ambient air temperatures are expected to result in warmer ambient water temperatures, and thus conditions more suitable to *Microcystis* growth, in the water bodies of the State Water Project/Central Valley Project Export Service Areas. The incremental increase in long-term average air temperatures would be less at the ELT (2.0°F) than at the LLT (4.0°F). For Figure 8-0b, *Microcystis* predictions were ranked qualitatively, based on a combination of these factors. Lower numbers (e.g., 1 or 2) signify less suitable conditions for *Microcystis* blooms than higher numbers indicate (e.g., 4 or 5). The non-HCP alternatives (Alternatives 4A, 2D, and 5A), when compared to the No Action Alternative (ELT), would have a ranking of 2 because operations and the ELT timeframe under those alternatives would lead to less suitable conditions for *Microcystis* to bloom. The BDCP alternatives would have a ranking of 4, with the exception of Alternative 5, which would result in a ranking factor of 3; these alternatives would provide more suitable conditions for *Microcystis* to bloom.

Additional impacts discussed in the summary table include bromide concentrations, chloride levels, and increases in organic carbon and selenium. Executive Summary Table ES-8 provides a summary of all impacts disclosed in this chapter.

8.0.1 Readers Guide

Chapter 8, *Water Quality,* describes the environmental setting and potential impacts of the project alternatives on water quality in and upstream of the Sacramento-San Joaquin Delta. The chapter provides the results of the evaluation of the effects of implementing the project on water quality constituents under No Action Alternative conditions and 18 action alternatives. This guide is intended to help the reader understand the organization of the chapter and the impact analysis of the constituents of interest.

8.0.2 Overview

Chapter 8 is organized much like the other chapters in this document, but because of the chapter's greater scope, this guide is provided to help the reader navigate through the various components of the chapter.

The chapter is divided into three main sections.

- 8.1 *Environmental Setting/Affected Environment*
- 8.2 *Regulatory Setting*
- 8.3 *Environmental Consequences*

These sections parallel the same sections in other resource chapters.

8.0.3 Environmental Setting/Affected Environment

The first part of the chapter is the Environmental Setting and Affected Environment section. This section provides a general description of the existing environment, including the following:

- Overview of the Sacramento and San Joaquin River Watersheds
- Water Management and the State Water Project and Central Valley Project Systems
- Primary Factors Affecting Water Quality
- Beneficial Uses
- Water Quality Objectives and Criteria
- Water Quality Impairments

techniques to minimize turbidity in treated drinking water (U.S. Environmental Protection Agency 2006a).

8.1.3.18 *Microcystis*

Background and Importance in the Study Area

This section provides a brief summary of the background and importance of *Microcystis* in the study area. A detailed discussion of the importance of *Microcystis* in the Delta, its biology, and potential adverse effects due to bloom formation is provided in Section 5.F.7 of BDCP Appendix 5.F, *Biological Stressors on Covered Fish*. The occurrence of *Microcystis aeruginosa* (*Microcystis*), a harmful species of cyanobacteria (also referred to as a blue-green algal species), in the Delta was first observed in 1999 (Lehman et al. 2005). In addition to producing surface scums that interfere with recreation and cause aesthetic problems, it also produces taste and odor compounds and toxic microcystins that are associated with liver cancer in humans and wildlife. Microcystin-LR is the most widely studied congener of the known microcystins, and it has been associated with most incidents of toxicity involving microcystins. *Microcystis* blooms can cause toxicity to phytoplankton, zooplankton, and fish, and also can affect feeding success or food quality for zooplankton and fish. Blooms of *Microcystis* require high levels of nutrients and low turbidity, but also require high water temperature (i.e., above 19°C) and long residence time, because the species is fairly slow growing (Lehman et al. 2008; Lehman et al. 2013). In addition, low vertical mixing associated with high residence time allows *Microcystis* colonies to float to the surface of the water column, where they out compete other species for light.

Existing Conditions in the Study Area

Since its first observance in the Delta in 1999, annual *Microcystis* blooms have occurred at varying levels throughout the Delta, with blooms typically beginning in the central Delta and spreading seaward into saline environments (Lehman et al. 2008; Lehman et al. 2013). Section 5.F.7 of BDCP Appendix 5.F, *Biological Stressors on Covered Fish*, cites numerous studies showing that *Microcystis* blooms produce adverse effects on phytoplankton, zooplankton and fish populations in the Delta. Water temperatures greater than 19°C, low water velocities, and high water clarity are necessary for *Microcystis* levels to reach bloom-forming scale (Paerl 1988; Lehman et al. 2008; Lehman et al. 2013). The water temperature requirement is considered the primary factor that restricts bloom development to the months of June through October (Lehman et al. 2013). Sufficiently high water temperature (i.e., 19°C), low flow and thus sufficiently long residence time, and increased clarity enable bloom formation, which occurs in the San Joaquin River, Old River, and Middle River earlier, and to a greater extent, than other areas of the Delta. Likewise, the Delta's shallow, submerged islands sustain high levels of *Microcystis* during the growing season because the physical drivers of bloom formation are amplified in these areas due to low flushing rates (Lehman et al. 2008). Although elevated pH is tolerated by *Microcystis*, pH is not currently thought to be a primary driver of seasonal and interannual variation in bloom formation (Lehman et al. 2013).

Nutrients have historically been sufficiently high to support *Microcystis* growth in the Delta, yet there is currently little evidence that levels of nitrogen, phosphorus, or their ratio control the seasonal or inter-annual variation in the bloom (Lehman et al. 2005; Lehman et al. 2008; Lehman et al. 2013; Lehman et al. 2015). This is likely because nutrient concentrations in the Delta are above the thresholds that limit *Microcystis* growth (Lehman et al. 2008; Lehman et al. 2013). However, blooms of *Microcystis* in the Delta have been shown to utilize ammonia from the Sacramento River over other forms of nitrogen (Lehman et al. 2015).

Impacts from *Microcystis* blooms outside of the Delta region have only occurred in highly eutrophic lakes, such as Clear Lake, because most reservoirs in the Central Valley region have relatively low nutrient levels. Hydrodynamic conditions of upstream rivers and watersheds are not conducive to *Microcystis* bloom formation. Microcystins have been detected throughout the Delta, but are generally below (Lehman et al. 2005) the World Health Organization (WHO) drinking water advisory level of 1 µg/L for microcystin-LR, the California water guidance level of 0.8 µg/L and the newly published USEPA 10-day Health Advisories (HA) for microcystins. The USEPA HA include a 0.3 µg/L HA for children under 6 and a 1.6 µg/L HA advisory for children over 6 and adults (U.S. Environmental Protection Agency 2015). However, in July and August 2012, microcystin concentrations in the southern area of the Delta exceeded the WHO advisory level, California guidance level and USEPA HA, with a maximum observed concentration of 2.14 µg/L (Spier et al. 2013). Problematic *Microcystis* blooms have not occurred in the Export Service Areas, but microcystins produced in waters of the Delta have been exported from Banks and Jones pumping plants to the SWP and CVP (Archibald Consulting et al. 2012). Levels of microcystin measured in water exported from the Delta were below the 1 µg/L reportable limit (Archibald et al. 2012). However, it is unknown if microcystin concentrations were below the California guidance levels or the USEPA 10-day HA.

8.2 Regulatory Setting

Numerous federal, state and local acts, rules, plans, policies, and programs define the framework for regulating water quality in California. The following discussion focuses on water quality requirements that are applicable to the project alternatives. The federal and state agencies responsible for regulating water quality in the study area are:

- USEPA.
- State Water Board.
- San Francisco Bay Water Board.
- Central Valley Water Board.

USEPA provides guidance and oversight to California in regulating water quality, as it does for other states and for tribes. As in other states across the country, USEPA delegates various authorities for establishing water standards and regulating controllable factors affecting water quality to the state. In California, this authority is delegated to the State Water Board. The State Water Board, in turn, delegates authority to its nine regional water boards to implement the state's water quality management responsibilities in the nine geographic regions. Although the state generally takes the lead on developing and adopting water quality standards for California, USEPA must approve new or modified standards. Thus, USEPA, the State Water Board, and the two Regional Water Boards cited above have worked together to establish existing water quality standards for the study area. Water quality standards have three components: (1) the beneficial uses of the water to be protected; (2) the water quality criteria (referred to as *objectives* in California) that must be met to protect the beneficial uses; and (3) an antidegradation policy to protect and maintain water quality when it is better than the criteria/objectives. Additionally, CDFW, USFWS, NMFS and the Federal Energy adjusted copper criteria presented in Table 8-59. Therefore, the calculated hardness-based CTR copper criteria are found to be adequately protective of fish olfaction.

Table 8-60. Biotic Ligand Model-Based Criteria for Dissolved Copper (µg/L)

	CMC	CCC
Sacramento		
Average of all BLM parameters	10.9299	6.7888
5th Percentile DOC; Average of remaining parameter	6.9774	4.3338
San Joaquin		
Average of all BLM parameters	15.9659	9.9167
5th Percentile DOC; Average of remaining parameter	10.0879	6.2658

Notes: BLM = biotic ligand model; DOC = dissolved organic carbon; µg/L = = micrograms per liter.

There is currently no single program or effort for the coordinated and comprehensive measurement of trace metals in the Delta and its primary source waters. Moreover, analytical techniques for trace metals measurement have improved considerably over time, often resulting in substantially lower detection limits and at time showing earlier techniques to be prone to analytical error. Nevertheless, local monitoring efforts such as the San Francisco Bay RMP and the Sacramento Coordinated Regional Monitoring Program have collected trace metals on the Sacramento River and the San Francisco Bay for more than a decade, resulting in an adequate long-term characterization of these waters. Unfortunately, there has been no equivalent effort on the San Joaquin River, eastside tributaries, or within the Delta itself. This imbalance in available data limits the effects assessment approach. Effects are qualitatively assessed.

Summaries of trace metals data compiled for this qualitative assessment are provided in Appendix 8N, *Trace Metals*. Data of sufficient quality were available for the Bay, Sacramento River and San Joaquin River source waters, although data for the San Joaquin are very few. These data used to inform the qualitative assessment on trace metal effects upstream of the Delta, within the Delta, and the SWP and CVP service areas. Due to the relatively short exposure durations related to aquatic life acute and chronic effects, long-term trace metals effects are evaluated on a 95th percentile concentration basis. Due to the relatively long exposure durations related to drinking water effects, long-term trace metals effects are evaluated on an average concentration basis.

Total Suspended Solids and Turbidity

TSS concentrations and turbidity levels in rivers upstream of the Delta are affected primarily by: 1) TSS concentrations and turbidity levels of the water released from the upstream reservoirs, 2) erosion occurring within the river channel beds, which is affected by river flow velocity and bank protection, 3) TSS concentrations and turbidity levels of tributary inflows, point-source inputs, and nonpoint runoff as influenced by surrounding land uses; and 4) phytoplankton, zooplankton and other biological material in the water.

TSS and turbidity in Delta waters is affected by TSS concentrations and turbidity levels of the Delta inflows (and associated sediment load). TSS and turbidity within Delta waters also is affected by 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 the near the maximum. TSS and turbidity variations can also be attributed to phytoplankton, zooplankton and other biological material in the water.

The TSS and turbidity assessments were conducted in a qualitative manner based on anticipated changes in these factors.

Microcystis

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, during summer and fall, *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 through a combination of active and passive processes (Verspagen et al. 2004; Mission and Latour 2012). In the Delta, there are five primary environmental factors that trigger the emergence and subsequent growth of *Microcystis*.

1. Warm water temperatures (>19°C) (Lehman et al. 2013).
2. Nutrient availability (e.g., nitrogen and phosphorus) (Smith 1986; Paerl 2008 as cited in Davis et al. 2009).
3. Water column irradiance and clarity (surface irradiance >100 Watts per square meter per second and total suspended solid concentration <50mg/L (Lehman et al. 2013).
4. Flows and long residence times (Lehman et al. 2013).

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. Once in the water column, and when environmental conditions are favorable, *Microcystis* rapidly multiplies. One study found the doubling time of *Microcystis aeruginosa* strains ranged from 1.5 to 5.2 days, with an average doubling time of 2.8 days (Wilson et al. 2006). This fast growth rate allows cells to form colonies which come together to form a "scum" layer at the water surface. In the Delta, scums are primarily composed of the colonial form of *Microcystis*, but single cells are also present (Baxa et al. 2010).

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). The collection of cells at the surface, primarily in calm waters, allows *Microcystis* to sustain a competitive advantage over other phytoplankton species by optimizing their photosynthetic needs while shading out other algal species, which they compete with for nutrients and light (Huisman et al. 2004).

Wind and tides can enhance the aggregation of *Microcystis* cells in slow moving waters (Baxa et al. 2010), but in faster moving, turbulent waters, the ability of *Microcystis* to maintain its positive buoyancy is reduced (Visser et al. 1996). Therefore, high flow rates make it difficult for *Microcystis* to collect and form dense colonies at the water surface. Turbulence effects 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 and articles cited within). 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). Although the amount of flow required to disrupt a *Microcystis* bloom varies by system, in the Zhongxin Lake system China, flow velocities of 0.5–1.0 feet/second shifted the dominant phytoplankton species from cyanobacteria to green algae and diatoms (Li et al. 2013).

As described under Impact WQ-29 (Effects on TSS and Turbidity), changes in TSS and turbidity levels within the Delta under the project alternatives could not be quantified, but are expected to be similar under the project alternatives to Existing Conditions and the No Action Alternative. Minimal changes in water clarity would result in minimal changes in light availability for *Microcystis* under the project alternatives. As such, the project alternatives' influence on *Microcystis* production in the Delta, as influenced by the project alternatives' effects on Delta water clarity, is considered to be negligible.

Regarding nutrients the maintenance of *Microcystis* blooms in the Delta requires the availability of the nitrogen and phosphorus. However, the body of science produced by scientists studying *Microcystis* blooms in the Delta and elsewhere does not indicate that the specific levels of these nutrients, or their ratio, currently control the seasonal or inter-annual variation in the bloom. A large fraction of ammonia in the Sacramento River will be removed due to planned upgrades to the Sacramento Regional County Sanitation District's SRWTP, which will result in >95% removal of ammonia from the effluent discharge from this facility. Following the SRWTP upgrades, levels of ammonia in Sacramento River are expected to be similar to background ammonia concentrations in the San Joaquin River and San Francisco Bay (see Section 8.3.3.1, Impact WQ-1). The response of *Microcystis* production in the Delta to the substantial reduction in river ammonia levels (from removing ammonia from the SRWTP discharge) is unknown because nitrate and phosphorus levels in the Delta will remain well above thresholds that would limit *Microcystis* blooms.

Nutrient ratios in excess of the Redfield N:P ratio of 16 have also been hypothesized to favor *Microcystis* growth in the Delta (Glibert et al. 2011). However, considerable doubt has been cast on this hypothesis because median N:P molar ratios in the Delta during peak bloom periods are usually near or a little lower than the Redfield ratio of 16 needed for optimum phytoplankton growth, and when ammonia is considered the sole N source, the N:P ratio drops substantially to a median of 1.31:1 (Lehman et al. 2013). Based on this information, there is no evidence as to what type of effect small changes in nutrient concentrations and ratios would have on *Microcystis* blooms, given that such blooms are largely influenced by a host of other physical factors, including water temperature and water residence time within channels.

Based on the above, water clarity and nutrient effects on *Microcystis* were determined to not have substantial effects on *Microcystis* abundance under the project alternatives, relative to Existing Conditions and the No Action Alternative. A qualitative evaluation was performed to determine if the action alternatives would result in an increase in frequency, magnitude, and geographic extent of *Microcystis* blooms in the Delta based on the following two additional abiotic factors that may affect *Microcystis*: 1) changes to water operations and creation of tidal and floodplain restoration areas that change water residence times within Delta channels, and 2) increases in Delta water temperatures.

The methodology used to determine residence time for Alternatives 1A, 1B, 1C, 2A, 2B, 2C, 3, 4, 5, 6A, 6B, 6C, 7, 8, and 9 is described in BDCP Appendix 5.C, Section 5C.4.4.7, *Residence Time*. Briefly, residence time in different subregions of the Plan Area was assessed using the results of the DSM2 Particle Tracking Model for multiple neutrally buoyant particle release locations. Residence time was defined as the time at which 50% of particles from a given release location exited the Plan Area (either by movement downstream past Martinez or through entrainment at the south Delta export facilities, north Delta diversion, North Bay Aqueduct, or agricultural diversions in the Delta). The data were reduced into mean residence time by subregion and season. The data do not represent the length of time that water in the various subregions spends in the Delta in total, but do provide a useful parameter with which to compare generally how long algae would have to grow in the various subregions of the Delta. Table 8-60a shows the residence time results that are used in the *Microcystis* assessments. Results for summer and fall are most relevant for the *Microcystis* assessment, but all seasons are presented for completeness.

Table 8-60a. Average Residence Time for Subregions of the Plan Area by Season and Alternative

		Average Residence Time (days)										
Subregion	Season	Ex Cond.	No Act.	Alt 1	Alt 2	Alt 3	Alt 4 Scn H3	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
North Delta	Summer	33	38	43	38	41	39	41	43	40	46	40
	Fall	49	50	61	56	60	57	55	55	57	58	55
	Winter	36	37	40	40	40	39	41	37	37	37	40
	Spring	30	33	37	35	36	35	36	34	34	29	35
	Overall	35	38	43	41	43	41	41	40	40	40	41
Cache Slough	Summer	18	21	46	40	45	39	39	49	46	59	46
	Fall	46	46	44	39	43	40	39	39	45	56	39
	Winter	29	31	33	32	33	32	33	28	29	27	31
	Spring	22	24	33	33	33	33	33	31	30	33	31
	Overall	27	29	38	36	38	35	36	36	36	42	36
West Delta	Summer	22	24	32	28	30	28	29	40	27	33	28
	Fall	25	27	34	30	33	30	30	30	31	32	27
	Winter	18	20	21	21	21	21	21	19	19	19	19
	Spring	18	20	24	22	24	22	23	20	20	17	20
	Overall	20	22	27	25	26	25	25	27	23	24	23
East Delta	Summer	22	26	40	34	35	34	31	76	32	48	21
	Fall	15	35	33	47	32	48	48	58	55	55	21
	Winter	28	32	40	42	40	42	40	50	51	50	26
	Spring	42	47	57	54	59	54	56	61	57	54	35
	Overall	29	36	45	45	44	45	44	61	49	52	27
South Delta	Summer	8	10	16	17	14	16	11	70	23	33	35
	Fall	5	11	8	42	8	43	34	79	53	52	33
	Winter	10	11	19	19	14	16	15	59	57	56	28
	Spring	25	26	24	29	20	28	27	65	60	58	31
	Overall	13	16	18	26	15	25	21	67	49	50	32
Suisun Marsh	Summer	51	58	38	35	37	35	36	37	36	39	42
	Fall	17	19	39	34	38	34	33	32	34	34	38
	Winter	9	9	28	28	29	27	29	24	24	24	32
	Spring	45	51	32	31	31	30	30	29	28	25	33
	Overall	33	37	33	32	33	31	32	30	30	30	36

The methodology used to characterize residence time changes under Alternatives 4A, 2D, and 5A relied on modeled residence times presented in the Biological Assessment for the California WaterFix (ICF International 2016) for July through November. In addition, changes in maximum daily channel velocities, as modeled by DSM2, for a number of locations in the Delta were evaluated.

8.3.1.8 San Francisco Bay

The western seaward boundary of the Plan Area has been delineated at Carquinez Strait. There are no actions proposed to occur in the bays seaward of the Plan Area. Nevertheless, because a substantial portion of Delta waters does flow seaward, an assessment of the effects of Delta water quality changes under the project alternatives on the San Francisco Bay water quality was conducted to identify potential effects in the Bay. The assessment addresses potential direct and indirect effects on water quality of areas seaward of the Delta, based on the best available scientific understanding. No hydrologic or hydrodynamic modeling was conducted seaward of Suisun Bay.

Because net Delta flows move seaward, water quality constituents present in the Delta water column could potentially be transported seaward. The Screening Analysis (see Sections 8.3.1.3, 8.3.2.1, and Appendix 8C, *Screening Analysis*) identified constituents present in Delta waters warranting detailed assessment in the Plan Area based on their historical concentrations in the water column or importance to beneficial uses of Delta waters. These same constituents were addressed in the assessment of effects on San Francisco Bay. The assessment of effects in San Francisco Bay was based on projected changes in constituent concentration/levels that would occur in the Delta and changes in Delta outflow under the project alternatives. The following sections describe constituent-specific considerations and methods for calculating changes in Delta loading that are common to the assessment of all project alternatives in the San Francisco Bay for nutrients (ammonia, nitrate, and phosphorus), mercury, and selenium.

Nutrients: Ammonia, Nitrate, Phosphorus

Constituent-specific Considerations

Nutrients in freshwater outflows from the Delta have the potential to impact the embayments that make up the San Francisco Bay, although oceanic flows in and out of the Golden Gate mute the influence of Delta-derived freshwater flows on the Central Bay, South Bay, and Lower South Bay (Senn and Novick 2013). Thus, nutrients effects to San Francisco Bay from changes in Delta outflow would be limited almost entirely to the northern part of San Francisco Bay, namely San Pablo Bay. The assessment specifically addresses effects on San Pablo Bay, but relies on research conducted in Suisun Bay, because very little research specific to San Pablo Bay has been conducted and because San Pablo Bay and Suisun Bay experience similar nutrient loading. Existing effects from nutrients on San Pablo Bay and Suisun Bay have been hypothesized, yet widespread impairment due to nutrients in these embayments is not thought to be occurring (Senn and Novick 2013).

Suisun Bay is currently characterized by levels of phytoplankton biomass and a community composition insufficient to support the pelagic food web. The highly altered phytoplankton community and low biomass levels are thought to be linked primarily to the invasive clam *Corbula amurensis*, which was established in Suisun Bay in 1987, and grazing by other aquatic macroinvertebrates, specifically zooplankton (Kimmerer and Thompson 2014). Notwithstanding, Dugdale et al. (2007; 2012) has argued that nitrate is preferred by and fuels blooms of diatoms, and that uptake of nitrate by diatoms is impaired until ammonia levels are depleted below 0.03–0.06

bioaccumulation of contaminants in organisms or humans or cause CWA Section 303(d) impairments to be discernibly worse. Based on these findings, this impact is determined to be less than significant. No mitigation is required.

Impact WQ-32: Effects on *Microcystis* Bloom Formation Resulting from Facilities Operations and Maintenance

Upstream of the Delta

Adverse effects from *Microcystis* upstream of the Delta have only been documented in lakes such as Clear Lake, where eutrophic levels of nutrients give cyanobacteria a competitive advantage over other phytoplankton during the bloom season. Large reservoirs upstream of the Delta are typically characterized by low nutrient concentrations, where other phytoplankton outcompete cyanobacteria, including *Microcystis*. In the rivers and streams of the Sacramento River watershed, watersheds of the eastern tributaries (Cosumnes, Mokelumne, and Calaveras Rivers), and the San Joaquin River upstream of the Delta under Existing Conditions, bloom development is limited by high water velocity and low residence times. These conditions are not expected to change under Alternative 4A or the No Action Alternative (ELT and LLT). Consequently, any modified reservoir operations under Alternative 4A are not expected to promote *Microcystis* production upstream of the Delta, relative to Existing Conditions and the No Action Alternative (ELT and LLT).

Delta

During the June through October period when *Microcystis* blooms occur in the Delta, it is a combination of flows, associated residence time, and water temperatures that are believed to most influence *Microcystis* bloom formation.

Since Delta water temperatures are largely driven by air temperature, climate change that increases air temperatures relative to Existing Conditions would be expected to increase ambient water temperatures in the Delta by 1.3–2.5°F. These climate changes in the ELT are expected to occur in the Delta under the No Action Alternative, relative to Existing Conditions. Alternative 4A operations and maintenance is not expected to cause increased Delta water temperatures, relative to Existing Conditions or the No Action Alternative.

Under Alternative 4A, a portion of the Sacramento River water which is conveyed through the Delta to the south Delta intakes under Existing Conditions would be replaced at various locations throughout the Delta by other source water due to diversion of Sacramento River water at the north Delta intakes. To determine how hydrologic effects of Alternative 4A, relative to Delta hydrology under the No Action Alternative (ELT), may affect *Microcystis* occurrence and bloom formation, flows, residence time, and peak daily channel velocity were analyzed for various Delta locations.

Frequency of given flows were assessed in the Biological Assessment for the California WaterFix (ICF International 2016) using flow in the San Joaquin River past Jersey Point and flow in the Sacramento River at Rio Vista. The San Joaquin River analysis found that flow conditions conducive to *Microcystis* blooms in the San Joaquin River would occur less frequently under the Proposed Action, which is Alternative 4A, compared to the No Action Alternative. Based on flow analysis in the Sacramento River, there could be a decrease in flows at Rio Vista compared to the No Action Alternative. Because turbid conditions and sufficient flow to create channel turbulence are the norm here, and are expected to remain consistent with Existing Conditions in the future, it is expected that current conditions will continue and that *Microcystis* blooms will not increase here (ICF International 2016).

Based on *Microcystis* life history strategy to outcompete other algal species and the inhibitory effect of flow and turbulence on its ability to do so, maximum daily channel velocities (which creates channel turbidity and turbulence) also were assessed using DSM2 velocity output for a number of locations throughout the Delta (Appendix 8P). The evaluation of flow velocities shows little to no effects on peak daily velocities under Alternative 4A compared to the No Action Alternative at each location assessed. This indicates that areas of the Delta that are currently turbid will remain turbid and vertical mixing of the water column will be similar under Alternative 4A and the No Action Alternative. As stated in Section 8.3.1.7, *Microcystis* cannot effectively retain its buoyancy or outcompete other faster growing phytoplankton in turbid, turbulent waters. Therefore, based on Alternative 4A maintaining similar to equivalent peak daily flow velocities in Delta channels (and turbidity and turbulence conditions), Alternative 4A would not be expected to substantially increase the frequency or geographic extent of Microcystis blooms in the Delta, relative to what would occur under the No Action Alternative.

Changes in flow paths of water through the Delta and change in operation of the south Delta pumps that would occur due to facilities operations and maintenance of Alternative 4A could result in localized increases in residence time in various Delta sub-regions and decreases in residence time in other areas. In addition to the effects of operations and maintenance of Alternative 4A, increases in water residence times are expected occur due to separate factors and actions concurrent with the alternative, including habitat restoration (8,000 acres of tidal habitat and enhancements in the Yolo Bypass) and sea level rise due to climate change.

Residence times in 19 Delta sub-regions during the *Microcystis* bloom season of July through October was modeled for the Biological Assessment for the California WaterFix (ICF International 2016). The Proposed Action modeled in the Biological Assessment is Alternative 4A. Modeling results show varying levels of change in residence time, depending on sub-region, month and water year type (Tables 6.6-5 through 6.6-25, ICF International 2016). DSM2 PTM output indicates residence times may increase in parts of the southern and central Delta. Because there is no published analysis of the relationship between *Microcystis* occurrence and residence time, there is uncertainty on how increased residence times may affect *Microcystis* occurrences (ICF International 2016). In some areas of the Delta currently affected by *Microcystis* blooms, decreasing median residence times in some months (decreases from 0.1 – 3.8 days) has potential to lower the magnitude and duration of *Microcystis* blooms. However, in other areas of the Delta that experience *Microcystis* blooms, longer median residence times in some months (0.1 - 16.5 days) has potential to increase the magnitude and duration of *Microcystis* blooms.

The changes in residence time are driven by a number of factors accounted for in the modeling, including diversion of Sacramento River water at the proposed north Delta intake facilities, which does not account for the flexibility of operations of the north and south Delta intakes or real-time management of reservoir releases. To ensure project operations do not create increased *Microcystis* blooms in the Delta, water flow through Delta channels would be managed through real-time operations, particularly the balancing of the north and south Delta diversions. By operating the south Delta pumps more frequently during periods conducive to increased *Microcystis* blooms, residence times would be substantially reduced from those modeled for Alternative 4A. Reducing residence times would decrease the potential for blooms to develop, and thus decrease potential microcystin increases due to project operations. As such, effects of Alternative 4A on *Microcystis* levels, and thus microcystin concentrations in the Delta, would not be made more adverse relative to Existing Conditions and the No Action Alternative (ELT and LLT).

In summary, operations and maintenance of Alt 4A is not expected to result in flow or velocity changes in the Delta that would cause substantial increases in the frequency, magnitude, and geographic extent of *Microcystis* blooms, relative to Existing Conditions or the No Action Alternative. In some areas of the Delta that experience *Microcystis* blooms, longer median residence times in some months has potential to increase the magnitude and duration of *Microcystis* blooms. However, factors that control *Microcystis* blooms in the Delta are still under study, so there is some uncertainty regarding this impact finding. *Microcystis* blooms may also occur more frequently in the Delta in the future, relative to Existing Conditions, due to factors unrelated to the project alternative, including: 1) increased residence times resulting from restoration activities and climate change-related sea level rise and 2) climate change-related increased Delta water temperatures. To ensure project operations under Alternative 4A do not create significant increases in *Microcystis* blooms in the Delta, that may be associated with increased residence times, water flow through Delta channels would be managed through real-time operations.

SWP/CVP Export Service Area

As described above for the Delta, source waters to the south Delta intakes could be adversely affected, relative to Existing Conditions, by *Microcystis* both from an increase in Delta water temperatures associated with climate change and from an increase in water residence times. The impacts from increased Delta water residence times would be primarily related to habitat restoration (8,000 acres of tidal habitat restoration and enhancements in the Yolo Bypass) that is assumed to occur separate from Alternative 4A. The combined effect of these factors on the potential for *Microcystis* blooms in source waters to the south Delta intakes is expected to be much greater than the influence of operations and maintenance of Alternative 4A, the effects of which will be mitigated through real time operations. Increases in ambient air temperatures due to climate change relative to Existing Conditions are expected under this alternative. Increases in ambient air temperatures are expected to result in warmer ambient water temperatures, and thus conditions more suitable to *Microcystis* growth, in the water bodies of the SWP/CVP Export Service Areas. The incremental increase in long-term average air temperatures would be less at the ELT (2.0°F), compared to the LLT (4.0°F).

As discussed in the Delta section above, Alternative 4A facilities operations and maintenance is not expected to substantially adversely affect *Microcystis* blooms, relative to Existing Conditions and the No Action Alternative (ELT and LLT). Additionally, residence time and water temperature conditions in the SWP/CVP Export Service Areas are not expected to become more conducive to *Microcystis* bloom formation due to the operations and maintenance of Alternative 4A, relative to Existing Conditions and the No Action Alternative (ELT and LLT), because water residence times are not projected to increase in the SWP/CVP Export Service Areas and any temperature increases there would be due to climate change and not due to Alternative 4A.

NEPA Effects: Modified reservoir operations under Alternative 4A are not expected to promote *Microcystis* production upstream of the Delta, relative to the No Action Alternative (ELT and LLT). Similarly, operations and maintenance of Alternative 4A are not expected to substantially increase water residence times or ambient water temperatures in the Delta, including at the Banks and Jones pumping plants, and thus is not expected to result in adverse effects on *Microcystis* in the Delta, relative to No Action Alternative (ELT and LLT). Lack of adverse effects on *Microcystis* in the Delta would mean that Delta waters diverted into the SWP/CVP Export Service Areas would not be adversely affected. Finally, the potential for *Microcystis* bloom formation within the SWP/CVP Export Service Area water bodies and canals would not be expected to change substantially, if at all, because water residence times are not projected to increase in the SWP/CVP Export Service Areas and any temperature increases there would be due to climate change and not due to Alternative 4A. Thus, the effects on *Microcystis* in surface waters upstream of the Delta, in the Delta, and in the SWP/CVP Export Service Areas from implementing Alternative 4A are determined to be not adverse.

CEQA Conclusion: Modified reservoir operations under Alternative 4A are not expected to promote *Microcystis* production upstream of the Delta, relative to the Existing Conditions. Increased frequency and magnitude of *Microcystis* blooms may occur in the Delta in the future, relative to Existing Conditions, due to increased residence times resulting from restoration activities unrelated to the project alternative, as well as climate change and sea level rise that are expected to increase Delta water temperatures. Such increases in residence time and water temperatures would not be caused by implementation of Alternative 4A. Operations and maintenance of Alternative 4A, including the use of real-time operations, are not expected to result in flow and temperature conditions in the Delta, including at the Banks and Jones pumping plants, that would cause substantial increases in the frequency, magnitude, and geographic extent of *Microcystis* blooms. As such, this alternative would not be expected to cause additional exceedance of applicable water quality objectives/criteria by frequency, magnitude, and geographic extent that would cause significant impacts on any beneficial uses of waters in the affected environment. *Microcystis* and microcystins are not CWA Section 303(d) listed within the affected environment and thus any increases that could occur in some areas of the Delta would not make any existing *Microcystis* impairment measurably worse because no such impairments currently exist. Microcystin, the toxin produced by *Microcystis,* is bioaccumulative in the Delta foodweb (Lehman 2010). Thus, potential increases in *Microcystis* occurrences due to climate change and sea level rise may lead to increased microcystin presence in the Delta, relative to Existing Conditions. This has potential to cause microcystins to bioaccumulate to greater levels in aquatic organisms that would, in turn, pose health risks to fish, wildlife or humans. While long-term water quality degradation related to microcystin levels may occur and, thus, impacts on beneficial uses could occur, these impacts are not related to implementation of Alternative 4A. Although there is uncertainty regarding this impact, the effects on *Microcystis* from implementing water conveyance facilities are determined to be less than significant. No mitigation is required.

Impact WQ-33: Effects on *Microcystis* Bloom Formation Resulting from Environmental Commitments

Under Alternative 4A, fisheries enhancements to the Yolo Bypass would not be implemented, but under a plan separate and distinct from Alternative 4A, enhancements to the Yolo Bypass and 8,000 acres of tidal habitat restoration would be implemented in the ELT. The Yolo Bypass enhancements are assumed to occur under the No Action Alternative, as well as 8,000 acres of tidal habitat restoration. These activities would create shallow backwater areas that could result in local warmer water and increased water residence time of magnitude and extent that could result in measurable changes on *Microcystis* levels in the Delta, relative to Existing Conditions. However, the area of tidal habitat restoration to be implemented as a component of Alternative 4A, relative to the No Action Alternative, is so small that it would have negligible effects compared to the development of 8,000 acres of tidal habitat that would be developed independent of Alternative 4A. Thus, compared to the No Action Alternative, which isolates the effects of Alternative 4A habitat actions, Alternative 4A

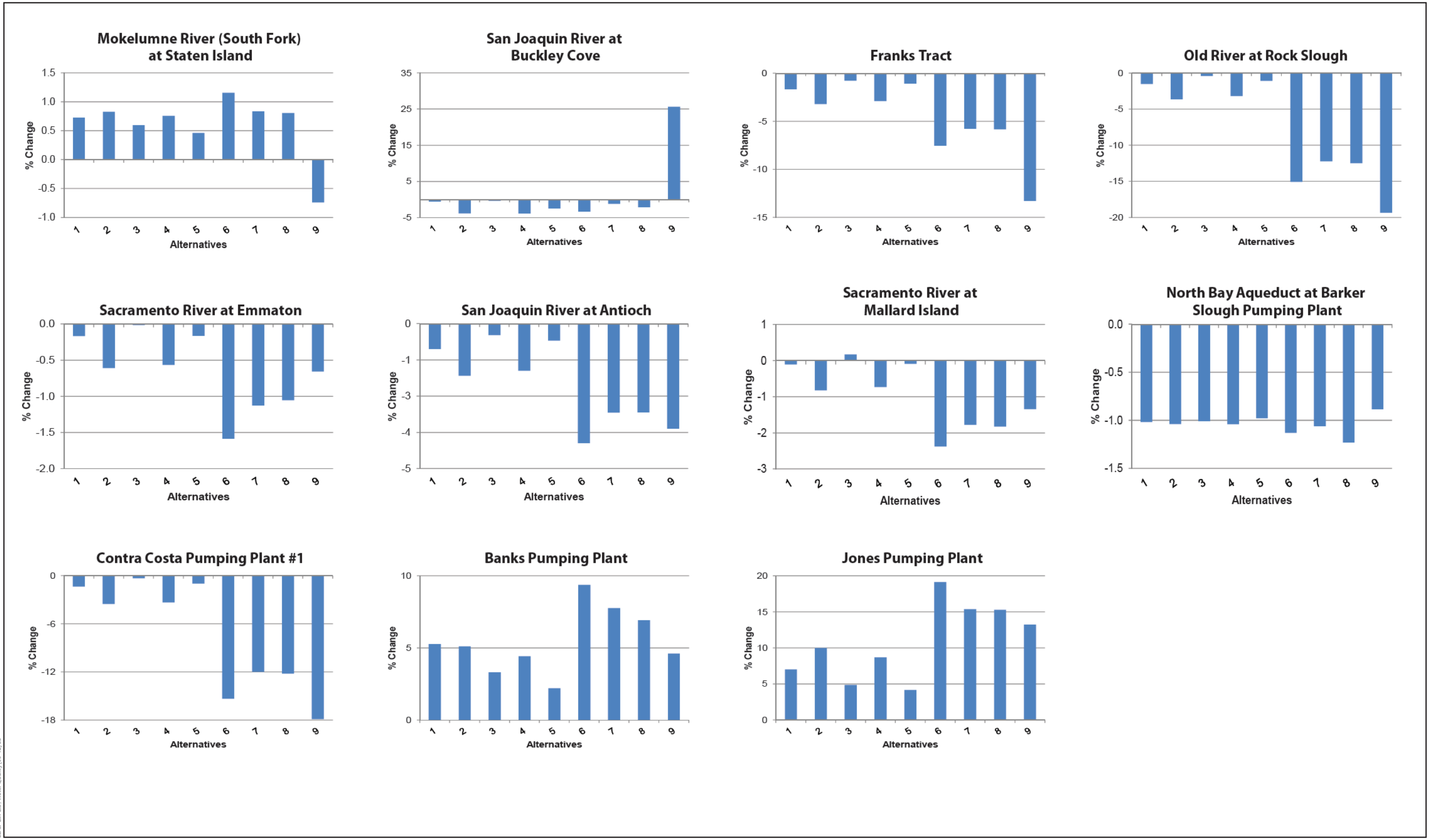

Figure 8-60a
Percent Change in Available Assimilative Capacity for Selenium (Based on 2 μg/L Ecological Risk Benchmark) with Respect to No Action Alternative for All Years