7.12 Hydrology and Water Quality

7.12.1 Surface Water

Protecting the Bay-Delta watershed and its many beneficial uses is one of the State Water Board's primary responsibilities and top priorities. The State Water Board's Bay-Delta Plan establishes water quality objectives for the protection of beneficial uses in the Bay-Delta and a program of implementation to achieve the objectives. The Bay-Delta Plan was adopted in 1978 and amended in 1991, 1995, 2006, and 2018. The State Water Board's current effort to update the Bay-Delta Plan is focused on fish and wildlife beneficial uses in the Sacramento River and its tributaries, Delta eastside tributaries (including the Calaveras, Cosumnes, and Mokelumne Rivers), Delta outflows, and interior Delta flows. These proposed Plan amendments are referred to as the Sacramento/Delta update to the Bay-Delta Plan and are the focus of this entire Staff Report.

The Sacramento/Delta update to the Bay-Delta Plan is critically important to the health and survival of the Bay-Delta ecosystem. Native species in the Bay-Delta ecosystem are experiencing an ecological crisis. For decades, valuable habitat has been converted to farmland and urban uses, the quality of water in the channels has been degraded, there has been a substantial overall reduction in flows and significant changes in the timing and distribution of those flows, and species have been cut off from natal waters. These issues have led to severe declines, and in some cases extinctions, of native fish and other aquatic species. The overall health of the estuary for native species is in trouble, and expeditious action is needed on the watershed level to address the crisis, including actions by the State Water Board, fisheries agencies, water users, and others to address the array of issues affecting the watershed. As such, water quality is a broad topic that is discussed throughout this Staff Report. Chapter 2, *Hydrology and Water Supply*, details existing hydrologic conditions of the Sacramento/Delta watershed compared to unimpaired flow and describes existing water use and supply in the study area. Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations*, provides detail on the ecosystem functions of flow and various species-specific flow needs. Chapter 4, *Other Aquatic Ecosystem Stressors*, details non-flow water quality stressors and how they interact with flow and other stressors, such as physical habitat loss or alteration, water quality constituents, nonnative species, fisheries management, and climate change. Chapter 5, *Proposed Changes to the Bay-Delta Plan for the Sacramento/Delta*, explains the proposed Plan amendments, including flow objectives that provide for a more natural hydrograph in the Sacramento/Delta.

Implementation of the proposed Plan amendments is expected to improve water quality conditions over a large geographic area, particularly for fish and wildlife beneficial uses in the Delta. Although the primary purpose of the proposed Plan amendments is to improve and protect water quality, changes in hydrology and changes in water supply (discussed in Chapter 6, *Changes in Hydrology and Water Supply*) could have negative effects on water quality at certain times and in specific locations that must be analyzed under CEQA.

This section describes the environmental setting, potential impacts, and mitigation measures for surface water impacts that may result from changes in hydrology and changes in water supply.

Surface water quality impacts include those related to violations of water quality standards, waste discharge requirements, or other degradation of water quality. The analysis focuses on constituents that can impair beneficial uses and that may be affected by implementing the proposed Plan amendments, including salinity, bromide, mercury, nutrients, turbidity, harmful algal blooms (HABs), and other contaminants. In addition, flooding and erosion impacts evaluated in this section include those that could result in adverse flooding or cause excessive erosion or sediment deposition.

Groundwater supplies and groundwater quality are analyzed in Section 7.12.2, *Groundwater*. Potential water quality and hydrologic environmental impacts on other resource areas are addressed further in the specific resource sections (e.g., potential temperature impacts on fisheries are discussed in Section 7.6.2, *Aquatic Biological Resources*). Potential modification of water or wastewater treatment facilities in response to changes in water quality are further evaluated in Section 7.20, *Utilities and Service Systems*.

Section 7.21, *Habitat Restoration and Other Ecosystem Projects*, and Section 7.22, *New or Modified Facilities,* describe and evaluate potential surface water hydrology and water quality impacts from various actions that involve construction.

7.12.1.1 Environmental Checklist

The checklist below contains questions relevant to the analysis of potential impacts on surface water quality and flooding. See Section 7.12.2, *Groundwater*, for a discussion of checklist Impact b and groundwater quality.

IX. Hydrology and Water Quality—Surface Water	Potentially Significant Impact	Less than Significant with Mitigation Incorporated	Less-than-Significant Impact	No Impact
Would the project:				
a. Violate any water quality standards or waste discharge requirements?	☒	☐	☐	☐
c. Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, in a manner which would result in substantial erosion or siltation on- or off-site?	☐	☒	☐	☐
d. Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, or substantially increase the rate or amount of surface runoff in a manner which would result in flooding on- or off-site?	☐	☒	☐	☐
e. Create or contribute runoff water which would exceed the capacity of existing or planned stormwater drainage systems or provide substantial additional sources of polluted runoff?	☐	☐	☐	☒
f. Otherwise substantially degrade water quality?	☒	☐	☐	☐

IX. Hydrology and Water Quality—Surface Water	Potentially Significant Impact	Less than Significant with Mitigation Incorporated	Less-than-Significant Impact	No Impact
g. Place housing within a 100-year flood hazard area as mapped on a federal Flood Hazard Boundary or Flood Insurance Rate Map or other flood hazard delineation map?	☐	☐	☐	☒
h. Place within a 100-year flood hazard area structures which would impede or redirect flood flows?	☐	☐	☐	☒
i. Expose people or structures to a significant risk of loss, injury, or death involving flooding, including flooding as a result of the failure of a levee or dam?	☐	☒	☐	☐
j. Inundation by seiche, tsunami, or mudflow?	☐	☐	☐	☒

7.12.1.2 Environmental Setting

This section describes the surface water setting to inform the impact discussion in this section and in Section 7.21, *Habitat Restoration and Other Ecosystem Projects*; Section 7.22, *New or Modified Facilities*; and Chapter 9, *Proposed Voluntary Agreements*.

The Clean Water Act is a comprehensive federal water quality law designed to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." (33 U.S.C. § 1251(a).) The regulatory framework follows a "cooperative federalism" approach whereby individual states adopt and implement major provisions of the law provided that certain minimum standards and criteria are met and approved by the U.S. Environmental Protection Agency (USEPA). The Clean Water Act requires states to establish water quality standards that specify both the beneficial uses of waterbodies and the levels of quality that must be met and maintained to protect the designated uses. In California, beneficial uses of waterbodies and the necessary objectives to protect those beneficial uses are prescribed in water quality control plans (WQCPs or basin plans). In addition, the basin plans reflect, incorporate, and implement applicable portions of national and statewide water quality plans and policies.

The State Water Board and the nine regional water quality control boards (regional water boards) administer the Porter-Cologne Water Quality Control Act (Wat. Code, § 13000 et seq.) to achieve an effective water quality control program for the state and are responsible for the regulation of activities and factors that may affect the quality of the waters of the state. Under the Porter-Cologne Water Quality Control Act, the State and regional water boards formulate and adopt basin plans that designate the beneficial uses of water to be protected within an area and establish water quality objectives to reasonably protect beneficial uses and a program of implementation to meet the objectives.

The State Water Board's Bay-Delta Plan identifies beneficial uses of water to be protected and establishes flow-dependent water quality objectives for the reasonable protection of the beneficial uses and a program of implementation to achieve the objectives. Table 7.12.1-1a lists the Bay-Delta Plan designated beneficial uses of water. The Bay-Delta Plan supplements the *Water Quality Control*

Plan for the Sacramento River and San Joaquin River Basins (Central Valley Basin Plan) and the *Water Quality Control Plan for the San Francisco Bay Basin* (San Francisco Bay Basin Plan), which were adopted and implemented by the Central Valley Regional Water Quality Control Board (Central Valley Water Board) and the San Francisco Bay Regional Water Quality Control Board (San Francisco Bay Water Board), respectively, and address point-source and nonpoint-source discharges and other water quality factors (^Central Valley Water Board 2018b; San Francisco Bay Water Board 2017).

Waterbodies are used for many purposes, as evidenced by the number of beneficial uses designated in each basin plan (Tables 7.12.1-1a, 7.12.1-1b, and 7.12.1-1c). The basin plans incorporate numerical drinking water maximum contaminant levels (MCL), which apply to treated drinking water systems, and are applicable to ambient receiving water. The basin plans also contain water quality objectives for other beneficial uses, such as agriculture and fish habitat. Specific numeric water quality objectives are established for constituents, such as bacteria, dissolved oxygen, pH, pesticides, electrical conductivity (EC), total dissolved solids, temperature, turbidity, and trace metals that are applicable to certain waterbodies or portions of waterbodies. The basin plans also contain narrative water quality objectives for certain parameters that must be attained through pollution control measures and watershed management. The State Water Board and regional water boards have regulatory programs that control discharges of waste from wastewater treatment facilities, industrial facilities, urban areas, irrigated agricultural lands, dredging operations, and other sources of pollution. Regional water boards implement the basin plans in part by issuing waste discharge requirements (WDRs) or National Pollutant Discharge Elimination System (NPDES) permits for discharges of waste.

Table 7.12.1-1a. Designated Beneficial Uses for Waterbodies Identified in the Bay-Delta Water Quality Control Plan

Beneficial Use	Abbreviation [a]	Description
Agricultural Supply	AGR	Uses of water for farming, horticulture, or ranching, including irrigation (including leaching of salts), stock watering, or support of vegetation for range grazing.
Cold Freshwater Habitat	COLD	Uses of water that support cold water ecosystems, including preservation or enhancement of aquatic habitats, vegetation, fish, and wildlife, including invertebrates.
Commercial and Sport Fishing	COMM	Uses of water for commercial or recreational collection of fish, shellfish, or other organisms, including uses involving organisms intended for human consumption or bait purposes.
Estuarine Habitat	EST	Uses of water that support estuarine ecosystems, including preservation or enhancement of estuarine habitats, vegetation, fish, shellfish, and wildlife (e.g., estuarine mammals, waterfowl, shorebirds).
Groundwater Recharge	GWR	Uses of water for natural or artificial recharge of groundwater for purposes of future extraction, maintenance of water quality, or halting of saltwater intrusion into freshwater aquifers.

Beneficial Use	Abbreviation [a]	Description
Industrial Service Supply	IND	Uses of water for industrial activities that do not depend primarily on water quality, including mining, cooling water supply, hydraulic conveyance, gravel washing, fire protection, and oil well pressurization.
Migration of Aquatic Organisms	MIGR	Uses of water that support habitats necessary for migration and other temporary activities by aquatic organisms, such as anadromous fishes.
Municipal and Domestic Supply	MUN	Uses of water for community, military, or individual water supply systems, including drinking water supply.
Navigation	NAV	Uses of water for shipping, travel, or other transportation by private, military, or commercial vessels.
Industrial Process Supply	PRO	Uses of water for industrial activities that depend primarily on water quality.
Rare, Threatened, or Endangered Species	RARE	Uses of water that support aquatic habitats necessary, at least in part, for the survival and successful maintenance of plant and animal species established under state or federal law as rare, threatened, or endangered.
Water Contact Recreation	REC-1	Uses of water for recreational activities involving body contact with water where ingestion of water is reasonably possible, including swimming, wading, water skiing, skin and scuba diving, surfing, whitewater activities, fishing, and use of natural hot springs.
Non-Contact Water Recreation	REC-2	Uses of water for recreational activities involving proximity to water but where there is generally no body contact with water or any likelihood of ingestion of water, including picnicking, sunbathing, hiking, beachcombing, camping, boating, tide pool and marine life study, hunting, sightseeing, and aesthetic enjoyment in conjunction with the above activities.
Shellfish Harvesting	SHELL	Uses of water that support habitats suitable for the collection of filter-feeding shellfish (e.g., clams, oysters, mussels) for human consumption, commercial, or sport purposes.
Spawning, Reproduction, and/or Early Development	SPWN	Uses of water that support high-quality aquatic habitats suitable for reproduction and early development of fish.
Warm Freshwater Habitat	WARM	Uses of water that support warm water ecosystems, including preservation or enhancement of aquatic habitats, vegetation, fish, and wildlife, including invertebrates.
Wildlife Habitat	WILD	Uses of water that support terrestrial or wetland ecosystems, including preservation and enhancement of terrestrial habitats or wetlands, vegetation, wildlife (e.g., mammals, birds, reptiles, amphibians, invertebrates), and wildlife water and food sources.

Source: ^2018 Bay Delta Plan.

[a] The beneficial use names, abbreviations, and descriptions are not identical in each water quality control plan.

Table 7.12.1-1b. Designated Beneficial Uses for Waterbodies Identified in the Water Quality Control Plan for the San Francisco Bay Basin

Beneficial Use	Abbreviation [a]	Description
Agricultural Supply	AGR	Uses of water for farming, horticulture, or ranching, including irrigation (including leaching of salts), stock watering, or support of vegetation for range grazing.
Areas of Special Biological Significance	ASBS	Areas designated by the State Water Board, including marine life refuges, ecological reserves, and designated areas, where the preservation and enhancement of natural resources requires special protection. In these areas, alteration of natural water quality is undesirable.
Cold Freshwater Habitat	COLD	Uses of water that support cold water ecosystems, including preservation or enhancement of aquatic habitats, vegetation, fish, and wildlife, including invertebrates.
Commercial and Sport Fishing	COMM	Uses of water for commercial or recreational collection of fish, shellfish, or other organisms, including uses involving organisms intended for human consumption or bait purposes.
Estuarine Habitat	EST	Uses of water that support estuarine ecosystems, including but not limited to, preservation or enhancement of estuarine habitats, vegetation, fish, shellfish, or wildlife (e.g., estuarine mammals, waterfowl, shorebirds), and the propagation, sustenance, and migration of estuarine organisms.
Freshwater Replenishment	FRSH	Uses of water for natural or artificial maintenance of surface water quantity or quality.
Groundwater Recharge	GWR	Uses of water for natural or artificial recharge of groundwater for purposes of future extraction, maintenance of water quality, or halting of saltwater intrusion into freshwater aquifers.
Industrial Service Supply	IND	Uses of water for industrial activities that do not depend primarily on water quality, including but not limited to, mining, cooling water supply, hydraulic conveyance, gravel washing, fire protection, and oil well repressurization.
Marine Habitat	MAR	Uses of water that support marine ecosystems, including but not limited to, preservation or enhancement of marine habitats and vegetation, such as kelp, fish, shellfish, or wildlife (e.g., marine mammals, shorebirds).
Fish Migration	MIGR	Uses of water that support habitats necessary for migration, acclimatization between fresh water and salt water, and protection of aquatic organisms that are temporary inhabitants of waters within the region.
Municipal and Domestic Supply	MUN	Uses of water for community, military, or individual water supply systems, including but not limited to, drinking water supply.

Beneficial Use	Abbreviation [a]	Description
Navigation	NAV	Uses of water for shipping, travel, or other transportation by private, military, or commercial vessels.
Industrial Process Supply	PRO	Uses of water for industrial activities that depend primarily on water quality.
Preservation of Rare and Endangered Species	RARE	Uses of water that support habitats necessary for the survival and successful maintenance of plant or animal species established under state or federal law as rare, threatened, or endangered.
Water-Contact Recreation	REC-1	Uses of water for recreational activities involving body contact with water where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water skiing, skin and scuba diving, surfing, whitewater activities, fishing, and use of natural hot springs.
Non-Contact Water Recreation	REC-2	Uses of water for recreational activities involving proximity to water, but not normally involving contact with water where water ingestion is reasonably possible. These uses include, but are not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, tide pool and marine life study, hunting, sightseeing, and aesthetic enjoyment in conjunction with the above activities.
Shellfish Harvesting	SHELL	Uses of water that support habitats suitable for the collection of crustaceans and filter-feeding shellfish (e.g., clams, oysters, mussels) for human consumption, commercial, or sport purposes.
Fish Spawning	SPWN	Uses of water that support high-quality aquatic habitats suitable for reproduction and early development of fish.
Warm Freshwater Habitat	WARM	Uses of water that support warm water ecosystems, including but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.
Wildlife Habitat	WILD	Uses of water that support wildlife habitats, including but not limited to, the preservation and enhancement of vegetation and prey species used by wildlife, such as waterfowl.

Source: San Francisco Bay Water Board 2017, Chapter 2.

[a] The beneficial use names, abbreviations, and descriptions are not identical in each water quality control plan.

Table 7.12.1-1c. Designated Beneficial Uses for Waterbodies Identified in the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins

Beneficial Use	Abbreviation [a]	Description
Agricultural Supply	AGR	Uses of water for farming, horticulture, or ranching including, but not limited to, irrigation (including leaching of salts), stock watering, or support of vegetation for range grazing.

Beneficial Use	Abbreviation [a]	Description
Aquaculture	AQUA	Uses of water for aquaculture or mariculture operations including, but not limited to, propagation, cultivation, maintenance, or harvesting of aquatic plants and animals for human consumption or bait purposes.
Preservation of Biological Habitats of Special Significance	BIOL	Uses of water that support designated areas or habitats, such as established refuges, parks, sanctuaries, ecological reserves, or Areas of Special Biological Significance, where the preservation or enhancement of natural resources requires special protection.
Cold Freshwater Habitat	COLD	Uses of water that support Coldwater ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.
Commercial and Sport Fishing	COMM	Uses of water for commercial or recreational collection of fish, shellfish, or other organisms including, but not limited to, uses involving organisms intended for human consumption or bait purposes.
Estuarine Habitat	EST	Uses of water that support estuarine ecosystems including, but not limited to, preservation or enhancement of estuarine habitats, vegetation, fish, shellfish, or wildlife (e.g., estuarine mammals, waterfowl, shorebirds).
Freshwater Replenishment	FRSH	Uses of water for natural or artificial maintenance of surface water quantity or quality.
Groundwater Recharge	GWR	Uses of water for natural or artificial recharge of groundwater for purposes of future extraction, maintenance of water quality, or halting of saltwater intrusion into freshwater aquifers.
Industrial Service Supply	IND	Uses of water for industrial activities that do not depend primarily on water quality including, but not limited to, mining, cooling water supply, hydraulic conveyance, gravel washing, fire protection, or oil well repressurization.
Migration of Aquatic Organisms	MIGR	Uses of water that support habitats necessary for migration or other temporary activities by aquatic organisms, such as anadromous fish.
Municipal and Domestic Supply	MUN	Uses of water for community, military, or individual water supply systems including, but not limited to, drinking water supply.
Navigation	NAV	Uses of water for shipping, travel, or other transportation by private, military, or commercial vessels.
Hydropower Generation	POW	Uses of water for hydropower generation.
Industrial Process Supply	PRO	Uses of water for industrial activities that depend primarily on water quality.
Rare, Threatened, or Endangered Species	RARE	Uses of water that support aquatic habitats necessary, at least in part, for the survival and successful maintenance of plant or animal species established under state or federal law as rare, threatened or endangered.

Beneficial Use	Abbreviation [a]	Description
Water Contact Recreation	REC-1	Uses of water for recreational activities involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water skiing, skin and scuba diving, surfing, whitewater activities, fishing, or use of natural hot springs.
Non-Contact Water Recreation	REC-2	Uses of water for recreational activities involving proximity to water, but where there is generally no body contact with water, nor any likelihood of ingestion of water. These uses include, but are not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, tide pool and marine life study, hunting, sightseeing, or aesthetic enjoyment in conjunction with the above activities.
Shellfish Harvesting	SHELL	Uses of water that support habitats suitable for the collection of filter-feeding shellfish (e.g., clams, oysters, and mussels) for human consumption, commercial, or sports purposes.
Spawning, Reproduction, and/or Early Development	SPWN	Uses of water that support high-quality aquatic habitats suitable for reproduction and early development of fish.
Warm Freshwater Habitat	WARM	Uses of water that support warm water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.
Wildlife Habitat	WILD	Uses of water that support terrestrial or wetland ecosystems including, but not limited to, preservation and enhancement of terrestrial habitats or wetlands, vegetation, wildlife (e.g., mammals, birds, reptiles, amphibians, invertebrates), or wildlife water and food sources.

Source: ^Central Valley Water Board 2018b, Chapter 2.

[a] The beneficial use names, abbreviations, and descriptions are not identical in each water quality control plan.

Clean Water Act section 303(d) requires all states to identify waters that are not attaining water quality standards and include a priority ranking of such waters (SWRCB 2022). The list of identified waterbodies and their impairments is referred to as the 303(d) list. Water quality impairments on the 303(d) list are addressed by developing total maximum daily loads (TMDLs), which set water quality objectives or targets and allocate allowable loads for sources of pollution. TMDLs have been adopted and are in the process of being implemented for various pollutants throughout California. TMDLs that have been adopted or are in the process of being developed for the most relevant portions of the study area are listed in Table 7.12.1-2.

Table 7.12.1-2. Summary of Completed and Ongoing Total Maximum Daily Loads

Region	Pollutant/Stressor	Waterbody	TMDL Status
R2	Pesticides	San Francisco Bay Area urban creeks	Adopted by regional water board in 2005. Approved by USEPA in 2007.
R2	Mercury	San Francisco Bay	Adopted by regional water board in 2006. Approved by USEPA in 2008.

Region	Pollutant/Stressor	Waterbody	TMDL Status
R2	Mercury	Guadalupe River watershed	Adopted by regional water board in 2008. Approved by USEPA in 2010.
R2	PCBs	San Francisco Bay	Adopted by regional water board in 2008. Approved by USEPA in 2010.
R2	Selenium	San Francisco Bay	Adopted by regional water board in 2015. Approved by USEPA in 2016.
R2	Mercury, dissolved oxygen/organic enrichment	Suisun Marsh	Adopted by regional water board in 2018. Approved by USEPA in 2019.
R3	Nitrogen compounds	Santa Ynez River basin	Adopted by regional water board in 2023. Approval by USEPA pending
R4	Chloride	Santa Clara River	Adopted by regional water board in 2004. Approved by USEPA in 2005.
R4	Nutrients	Santa Clara River	Adopted by regional water board in 2003. Approved by USEPA in 2004.
R5	Selenium	Salt Slough	Adopted by regional water board in 1999. Approved by USEPA in 1999.
R5	Selenium	Marshes in Grasslands Ecological Area	Adopted by regional water board in 2000. Approved by USEPA in 2000.
R5	Copper, cadmium, zinc	Upper Sacramento River	Adopted by regional water board in 2002. Approved by USEPA in 2002.
R5	Selenium	San Joaquin River	Adopted by regional water board in 2002. Approved by USEPA in 2002.
R5	Mercury	Clear Lake	Adopted by regional water board in 2002. Approved by USEPA in 2003.
R5	Diazinon/chlorpyrifos	Sacramento County urban creeks	Adopted by regional water board in 2004. Approved by USEPA in 2004.
R5	Salt/boron	Lower San Joaquin River	Adopted by regional water board in 2004. Approved by USEPA in 2007.
R5	Diazinon/chlorpyrifos	Lower San Joaquin River	Adopted by regional water board in 2005. Approved by USEPA in 2006.
R5	Mercury	Cache Creek	Adopted by regional water board in 2005. Approved by USEPA in 2007.
R5	Dissolved oxygen	Stockton Deep Water Ship Channel	Adopted by regional water board in 2005. Approved by USEPA in 2007.
R5	Diazinon/chlorpyrifos	Delta	Adopted by regional water board in 2006. Approved by USEPA in 2007.
R5	Nutrients	Clear Lake	Adopted by regional water board in 2006. Approved by USEPA in 2007.
R5	Diazinon/chlorpyrifos	Sacramento/Feather Rivers	Adopted by regional water board in 2007. Approved by USEPA in 2008.
R5	Mercury	Sulphur Creek	Adopted by regional water board in 2007. Approved by USEPA in 2009.
R5	Pathogens	Stockton urban waterways	Adopted by regional water board in 2008. Approved by USEPA in 2008.
R5	Mercury	Delta	Adopted by regional water board in 2010. Approved by USEPA in 2011.

Region	Pollutant/Stressor	Waterbody	TMDL Status
R5	Diazinon/chlorpyrifos	Central Valley	Adopted by regional water board in 2014. Approved by USEPA in 2017.
R5	Pyrethroids	Central Valley	Adopted by regional water board in 2017. Approved by USEPA in 2019.
R5	Mercury	American River (lower) watershed	Pending.

Sources: Central Valley Water Board 2018, 2020, 2022; San Francisco Bay Water Board 2019, 2020; Los Angeles Water Board 2018; Central Coast Water Board 2023; USEPA 2019a.

In some cases, the original TMDL was modified and re-adopted by the regional water board and USEPA. The dates shown are for the original version of the TMDL.

PCB = polychlorinated biphenyls; R2 = San Francisco Bay Regional Water Quality Control Board; R3 = Central Coast Water Board; R4 = Los Angeles Water Quality Control Board; R5 = Central Valley Regional Water Quality Control Board; TMDL = total maximum daily load; USEPA = U.S. Environmental Protection Agency.

The 303(d) list of impaired waterways in California is extensive, and many waterbodies on the list do not yet have an adopted TMDL (SWRCB 2022). Most of the impairments on the list are not expected to be negatively affected by the proposed Plan amendments. Those of greatest interest are shown in Table 7.12.1-3. They include contaminants that may respond negatively or in a unique way to changes in flow, reservoir storage, and water supply. However, the 303(d) list and Table 7.12.1-3 are not exhaustive. For example, there are additional locations where water temperature is a concern for fish and where HABs reduce water quality. In these instances, control mechanisms, such as flow requirements and water treatment, are occurring separately from the 303(d) listing process.

Table 7.12.1-3. Impaired Waterbodies in the Study Area

Location	Boron	Low Dissolved Oxygen	Mercury	Nutrients [a]	Salinity [b]	Sediment [c]	Selenium	Temperature
Sacramento River Watershed, Delta Eastside Tributaries, Delta, and San Francisco Bay Area								
Adobe Creek (Lake County)		X						
Almanor Lake			X					
Amador Lake			X					
American River			X					X
Antelope Creek	X	X						
Antelope Lake		X						
Bear Creek (Colusa County)	X		X		X			
Bear River			X					
Berryessa, Lake			X					
Big Chico Creek		X	X					
Black Butte Lake			X					
Britton Lake			X					
Burns Valley (Lake County)		X						
Butte Creek (Butte County)			X					
Butte Lake			X					
Butte Slough		X						
Cache Creek	X	X	X		X			
Calaveras River		X	X					
California, Lake			X					
Camanche Reservoir			X					
Camp Far West Reservoir			X					
Carquinez Strait			X				X	
Clear Creek			X					
Clear Lake	X	X	X	X				
Cole Creek (Lake County)		X			X			
Colusa Basin Drain		X	X					

Location	Boron	Low Dissolved Oxygen	Mercury	Nutrients [a]	Salinity [b]	Sediment [c]	Selenium	Temperature
Combie, Lake			X					
Coon Creek		X		X				
Cordellia Slough tributary		X	X					
Cosumnes River		X	X					
Coyote Creek (Tehama County)		X						
Davis Creek			X					
Davis Creek Reservoir			X					
Davis No 2, unnamed spillway (near North Podesta Lane)			X					
Deer Creek (Nevada County)			X					
Delta			X				X	
Delta—Bear Creek		X						
Delta—central			X					
Delta—Discovery Bay			X					
Delta—eastern			X					
Delta—Empire Tract		X			X			
Delta—export area			X		X			
Delta—Five Mile Slough		X						
Delta—Franks Tract								X
Delta—French Camp Slough		X						
Delta—Grant Line Canal		X			X			
Delta—Grant Line Canal subwatershed					X			
Delta—Middle River		X	X					
Delta—Mokelumne River			X					
Delta—Mormon Slough		X	X					
Delta—northern			X					
Delta—northwestern			X		X			
Delta—Old River		X			X			
Delta—Paradise Cut					X			
Delta—Pixley Slough		X						

Location	Boron	Low Dissolved Oxygen	Mercury	Nutrients [a]	Salinity [b]	Sediment [c]	Selenium	Temperature
Delta—San Joaquin River								X
Delta—Smith Canal		X						
Delta—southern			X		X			
Delta—Staten Island Drain				X				
Delta—Stockton Deep Water Ship Channel		X	X					X
Delta—Sugar Cut					X			
Delta—Tom Paine Slough		X			X			
Delta—Turner Cut		X						
Delta—Victoria Canal		X			X			
Delta—Walthall Slough		X			X			
Delta—western			X		X			
Duck Creek (San Joaquin County)		X	X					
Eagle Lake (Lassen County)				X				
East Park Reservoir			X					
Englebright Lake			X					
Fall River						X		
Feather River		X	X					X
Fingers Lake (Tehama County)			X					
Folsom Reservoir			X					
Forbes Creek (Lake County)		X						
Gilsizer Slough (Sutter County)		X						
Gold Run (Nevada County)			X					
Gordon Slough (Yolo County)		X						
Harley Gulch			X					
Hell Hole Reservoir			X					
Honcut Creek		X						
Humbug Creek			X			X		
Indian Creek (Plumas County)		X						
Indian Valley Reservoir		X	X					
Jack Slough		X						

Location	Boron	Low Dissolved Oxygen	Mercury	Nutrients [a]	Salinity [b]	Sediment [c]	Selenium	Temperature
Jahant Slough		X						
James Creek			X					
Kentucky Creek (Nevada County)		X						
Knights Landing Ridge Cut		X			X			
Laguna Creek (Sacramento County)		X						
Lake Clementine			X					
Linda Creek		X						
Little Deer Creek			X					
Littlejohns Creek		X						
Live Oak Slough		X						
Loon Lake			X					
Lower Blue Lake			X					
Main Drainage Canal		X						
McGaugh Slough (Lake County)		X						
Meadows Slough (Sacramento County)			X					
Merle Collins Reservoir			X					
Mile Long Pond (Butte County)			X					
Moon Lake			X					
Natoma, Lake			X					
Natomas Cross Canal			X					
Natomas East Main Drainage Canal (Steelhead Creek)			X					
New Bullards Bar Reservoir			X					
New Hogan Lake (Calaveras County)			X					
Oroville Reservoir			X					
Pardee Reservoir			X					
Pine Creek (Butte and Tehama Counties)		X						
Pit River	X	X		X	X			
Pleasant Grove Creek		X						
Powell Slough (Colusa County)		X						

Location	Boron	Low Dissolved Oxygen	Mercury	Nutrients [a]	Salinity [b]	Sediment [c]	Selenium	Temperature
Putah Creek			X					
Rice Creek					X		X	
Robinsons Riffle Pond			X					
Rock Creek (Nevada County)		X						
Rodman Slough (Lake County)		X						
Rollins Reservoir			X					
Sacramento River		X	X					X
Sacramento Slough		X	X					
San Francisco Bay			X				X	
San Francisco Bay-Richardson Bay			X					
San Pablo Bay			X				X	
Sand Creek (Colusa County)		X						
Scotchman Creek		X						
Scotts Flat Reservoir			X					
Shasta Reservoir			X					
Siskiyou, Lake			X					
Slab Creek Reservoir (El Dorado County)			X					
Sly Creek Reservoir (Butte County)			X					
Solano, Lake			X					
Spaulding, Lake			X					
Spring Creek (Colusa County)		X			X			
Stone Corral Creek		X						
Stony Gorge Reservoir			X					
Suisun Bay			X				X	
Suisun Marsh Wetlands		X	X	X	X			
Suisun Slough		X	X					
Sulphur Creek (Colusa County)			X					
Sutter Bypass		X	X					
Sycamore Slough (Yolo County)		X						
Thermalito Afterbay			X					

Location	Boron	Low Dissolved Oxygen	Mercury	Nutrients [a]	Salinity [b]	Sediment [c]	Selenium	Temperature
Tule Canal (Yolo County)	X				X			
Walker Creek (Glenn County)		X						
West Valley Reservoir			X					
Whiskeytown Lake			X					
Wildwood, Lake			X					
Willow Slough (Yolo County)	X							
Willow Slough Bypass (Yolo County)	X				X		X	
Yuba River		X	X					X
Zayak (Swan) Lake			X					
Waterbodies That Receive Sacramento/Delta Supply								
Anderson Reservoir			X					
Briones Reservoir			X					
Cachuma, Lake			X					
Castaic Lake			X					
Contra Loma Reservoir			X					
Del Valle Reservoir			X					
Diamond Valley Lake			X					
Kellogg Creek (downstream of Los Vaqueros Reservoir)					X			
Lafayette Reservoir			X					
Lake Chabot (Alameda County)			X					
Los Vaqueros Reservoir			X					
Mendota Pool			X				X	
Mojave River		X			X			
O'Neill Forebay			X					
Piru Creek	X				X			
Pyramid Lake			X					
San Luis Canal	X							
San Luis Reservoir			X					
San Pablo Reservoir			X					

Location	Boron	Low Dissolved Oxygen	Mercury	Nutrients [a]	Salinity [b]	Sediment [c]	Selenium	Temperature
Santa Clara River		X			X		X	X
Santa Clara River Estuary				X				
Santa Margarita River				X	X			
Santa Ynez River		X		X	X	X		X
Silverwood Lake			X					
Upper San Leandro Reservoir			X					
Warm Springs Creek (Riverside County)				X				

Source: SWRCB 2022.

[a] Nutrients include ammonia, nitrate, nitrite, nitrogen, nutrients, phosphate, phosphorus, and total Kjeldahl nitrogen.

[b] Salinity includes chloride, electrical conductivity, salinity, total dissolved solids, sodium, and specific conductance.

[c] Sediment includes total suspended solids, sediment, and sedimentation/siltation.

Regulation of Waste Discharges

Under section 402 of the Clean Water Act, point-source discharges of pollutants to waters of the United States are prohibited unless authorized under an NPDES permit issued by USEPA or by state government, if lawfully delegated. NPDES permits typically regulate the discharge of treated sewage, storm water, and other pollutants discharged through a discrete conveyance, such as a pipe, ditch, or channel. NPDES permits include technology-based and, where appropriate, water quality-based effluent limitations. Technology-based effluent limitations (TBEL) are performance standards based on secondary treatment or best practicable control technology. Water quality-based limits are additional or more stringent effluent limitations required to attain water quality objectives.

Establishing a numeric effluent limit takes into account the appropriate water quality standards/objectives, background concentrations in the receiving water, and allowable dilution credit. Effluent limitations may be adjusted to account for dilution in a manner consistent with procedures in the *Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California* (SWRCB 2005). An NPDES permit may designate mixing zones within which water quality objectives will not apply provided the discharger has demonstrated that the mixing zone will not adversely affect beneficial uses. If allowed, different mixing zones may be designated for different types of objectives, including but not limited to, acute aquatic life objectives, chronic aquatic life objectives, human health objectives, and acute and chronic whole effluent toxicity objectives, depending in part on the averaging period over which the objectives apply.

Nonpoint-source pollution includes all other pollution exempted from the NPDES permitting program. Nonpoint-source pollution can include controllable water quality factors not associated with discharges, such as saltwater intrusion and water diversions. In California, discharges of waste that are not NPDES "discharges of pollutants" require issuance of WDRs for the discharge or proposed discharge of waste that could affect the quality of waters of the state. Discharges of waste that are not subject to NPDES permits typically include runoff from nonpoint sources, such as agricultural and timber activities and waste discharges to land or to groundwater. WDRs prescribe requirements, such as limitations on temperature, toxicity, or pollutant levels, as to the nature of any discharge. (Wat. Code, § 13260, subd. (a).) WDRs may also specify conditions where no discharge will be permitted (*Id.,* § 13241) and may include monitoring and reporting requirements. (See *id.,* § 13267; Cal. Code Regs., tit. 23, § 2230.) Other existing regulatory tools available to the State or regional water boards include individual or general waivers of WDRs, basin plan prohibitions, and enforcement actions. Under Water Code section 13301, the State Water Board or a regional water board may issue a cease and desist order if it finds a discharge or threatened discharge of waste in violation of WDRs or prohibitions. Under Water Code section 13304, the State or regional water board may issue a cleanup and abatement order to any person who has discharged or discharges waste into waters of the state, or who has caused or permitted, or threatens to cause or permit, waste to be discharged or deposited where it will be discharged or threatens to create a condition of pollution or nuisance. Civil monetary remedies may be pursued for violations of WDRs, waivers, prohibitions, cease and desist orders, cleanup and abatement orders, and other orders. (See e.g., Wat. Code, § 13350.)

A variety of funding sources are available to assist dischargers in meeting Clean Water Act requirements. The State Water Board's Division of Financial Assistance administers the federal Clean Water Act's Clean Water State Revolving Fund (CWSRF) Program in California, which authorizes financial assistance through loans and other financing mechanisms for a wide variety of pollution control efforts, such as wastewater treatment plant (WWTP) capital improvements. Financing options include loans, refinancing debt, purchasing or guaranteeing local debt, and purchasing bond insurance. Interest rates must be below the market rate. Since 2009, federal CWSRF appropriations and California law have also authorized grants, negative interest rates, and principal forgiveness on a limited basis. The CWSRF is intended to provide financial assistance in perpetuity using state and federal funds.

The Small Community Grant Fund allows the State Water Board to help finance communities with the most need in California, helping those that cannot otherwise afford a loan or similar financing to move forward with wastewater projects. The Small Community Grant Fund includes funds available through the CWSRF Program's Small Community Grant Fund allocation, general obligation bond funds available as a result of Proposition 1, and any available residual general obligation bond funds. State law requires the State Water Board to give grant priority to projects that serve severely disadvantaged communities, defined as communities with a median household income of less than 60 percent of the statewide median household income.

Antidegradation

Section 131.12 of USEPA's water quality standards regulations includes the "federal antidegradation policy," which emphasizes protection of instream beneficial uses, especially protection of aquatic organisms. Each state's water quality standards must include a policy consistent with the federal antidegradation policy (40 C.F.R. § 131.6(d)). State Water Board Resolution No. 68-16 ("Statement of Policy with Respect to Maintenance of High Quality Waters in California") requires that, 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 must be maintained. Any change in the existing high quality is allowed by that policy only if it has been demonstrated 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 policy further requires that dischargers meet waste discharge requirements, which will result in the best practicable treatment or control of the discharge necessary to assure that pollution or nuisance will not occur and that the highest water quality consistent with maximum benefit to the people of the state will be maintained. The federal antidegradation policy is incorporated into the State of California's antidegradation policy where the federal antidegradation policy is applicable. (State Water Board Order WQ 86-17 [*R. C. Fay*].)

Drinking Water

A *public water system* is defined as a system for provision of water for human consumption, through pipes or other constructed conveyances, which has 15 or more service connections or regularly serves at least 25 individuals daily at least 60 days of the year. (Health & Saf. Code, § 116275, subd. (h).) In California, the State Water Board's Division of Drinking Water (DDW) regulates public drinking water systems. DDW implements the federal and California Safe Drinking Water Acts and has regulatory oversight of public water systems to ensure the delivery of safe drinking water to all Californians. DDW issues operating permits, reviews plans and specifications for new facilities, evaluates projects that utilize recycled treated wastewater, and assists public water systems in drought preparation and water conservation. DDW also completes sanitary surveys (i.e., inspections) of public water systems to evaluate the adequacy of the water system to provide safe drinking water and issues enforcement where appropriate.

All water supplies from surface water, such as rivers and lakes, must undergo a high level of treatment to remove sediment, pathogens, and other contaminants before being made available for consumption. Drinking water is placed in a distribution system, where it must maintain a level of safety to prevent regrowth of pathogens or formation of disinfection byproducts. Distribution systems are typically pumps, pipes, water tanks, and pressurization devices necessary to bring water to homes and businesses in the community. Some distribution systems are small and short, and others are long and complex and combine with other drinking water supplies.

All drinking water must meet MCLs for several health concern constituents that are tracked by the state and federal environmental protection agencies. DDW requires regular monitoring for these constituents based on regulatory requirements. DDW evaluates constituents of emerging concern in collaboration with others such as the California Office of Environmental Health Hazard Assessment (OEHHA). These constituents are typically referred to as contaminants of emerging concern (CEC) and include constituents in surface water, such as pharmaceuticals. Public water systems may monitor for select CECs at the request of DDW or USEPA.

Multiple funding sources are available to assist communities with obtaining clean, safe, and reliable water supplies. The Drinking Water State Revolving Fund and Proposition 1-eligible projects can assist publicly owned water systems (e.g., counties, cities, districts), privately owned community water systems (e.g., for-profit water utilities, nonprofit mutual water companies), and nonprofit or publicly owned noncommunity water systems (e.g., public school districts) with the planning, design, and construction of drinking water infrastructure projects that improve the community's water efficiency and ensure a drought-resilient water supply. The State Water Board's Low-Income Rate Assistance program provides rate relief for low-income ratepayers of water utilities. The aim of the program is to counteract the increasing unaffordability of drinking water as a result of drought, water leaks, and aging pipes and infrastructure. The program offers cost-effective methods of assistance to low-income water customers other than rate assistance, including billing alternatives, installation of water conservation devices, and leak repair. In addition, in 2019, Governor Newsom signed Senate Bill (SB) 200, which establishes the Safe and Affordable Drinking Water Fund to help local water systems provide safe drinking water over the near and long term. Among other statutory changes, the Safe and Affordable Drinking Water Fund will provide up to $130 million annually to enable the State Water Board to provide critical ongoing operations and maintenance support for small community water systems that are unable to meet safe drinking water standards (California Legislative Counsel 2019). See also the *Overview of Groundwater Hydrology* subsection of Section 7.12.2.2, *Environmental Setting,* for additional detail on drinking water regulation and assistance programs, including assistance to disadvantaged communities.

Water Quality Concerns

Water quality concerns include total suspended solids (TSS), turbidity, mercury, legacy contaminants, metals/metalloids (including boron and selenium), pathogens, current use pesticides, boron, nutrients, HABs, CECs, temperature, dissolved oxygen, and salinity. Many water constituents can be nearly ubiquitous and are detected in multiple areas because the chemicals occur as a result of the same land use practices or widespread geologic features and are transported downstream at sufficiently elevated concentrations to continue impairing beneficial uses. These constituents are discussed generally in the following subsections, followed by an overview of existing surface water quality conditions in the Sacramento River, Delta eastside tributaries, Delta, San Francisco Bay Area (Bay Area), San Joaquin Valley, Central Coast, and Southern California regions.

Total Suspended Solids

TSS is a measure of particulate organic and inorganic material suspended in water. TSS concentrations in Suisun Bay and farther downstream are from Delta inflow and resuspension of bottom sediment within the Delta. Beneficial uses affected by elevated concentrations of TSS include municipal supply (MUN), industrial process supply (PRO), and aquatic life beneficial uses (e.g., WARM, COLD, MIGR, SPWN, EST). TSS affects drinking water supplies by clogging filters that remove pathogenic microorganisms and reducing the efficiency of disinfection processes (CALFED 2008). TSS is an important factor in the transport of sediment-bound contaminants from upstream tributaries to the Delta and Suisun and San Francisco Bays (^Schoellhamer et al. 2016; ^Central Valley Water Board 2010). Positive correlations exist between contaminant and TSS concentrations for mercury, trace metals, and legacy contaminants.

Turbidity

Turbidity and TSS are closely linked because the solids in TSS can also contribute to turbidity. Few turbidity and TSS impairments are included on the 303(d) list. However, California basin plans include regulations for limiting increases in turbidity from waste discharges, including from construction and other activities. For example, the 2018 Basin Plan for the Central Valley generally limits controllable increases in turbidity to 20 percent of baseline turbidity, although variations on the objectives are provided (^Central Valley Water Board 2018b).

Increased turbidity during high flows can originate from rainfall runoff, instream erosion resulting from elevated stream velocities, and sediment and organic material from floodplains inundated by higher river stages. Large rainfall and flood events are responsible for most sediment movement. Riverine loading studies indicate that typically more than 90 percent of the sediment load is transported less than 10 percent of the time (Owens 2005).

As turbidity increases, harmful pollutants can increase. For example, legacy pollutants such as organochlorine pesticides (e.g., dichlorodiphenyltrichloroethane [DDT]) and heavy metals (e.g., mercury, lead) may be bound to some suspended solids. Pathogen presence also is known to increase in turbid water (USGS 2018).

Surface water treatment plants remove suspended solids, including pollutants, and microscopic pathogens (e.g., giardia) from drinking water through flocculation and filtration processes. During periods of higher turbidity, treatment plants may have to increase the dose of flocculants and increase backwashing of filter beds. In addition, depending on a treatment plant's ability to reduce turbidity, elevated turbidity at the intake could require reducing flow through the facility or could reduce the effectiveness of treatment measures, such as disinfection and coagulation (CALFED 2005). However, increased turbidity within the treatment capability of the treatment plant does not affect the safety or quality of the resultant drinking water.

Mercury

Many waterbodies throughout California are on the 303(d) list as impaired by mercury levels that affect the beneficial use(s) associated with human and wildlife consumption of fish (Table 7.12.1-3).

Total mercury is converted to the more toxic and bioavailable methylmercury when anaerobic conditions are present in creeks, rivers, and wetlands (^Central Valley Water Board 2010). Human exposure to methylmercury occurs primarily through the consumption of fish and fish products (USEPA 2019b). Health effects of methylmercury include reproductive, nerve, and cardiovascular toxicity (Hong et al. 2012). OEHHA issues fish consumption advisories in California to limit consumption of fish with high concentrations of mercury.

Historically, mercuric sulfide was mined and processed to elemental mercury in the Coast Ranges and transported across the Central Valley to the Sierra Nevada for gold mining. Residual amounts of mercury are still present at mine sites and in downstream creek and river sediment in both the Coast Ranges and Sierra Nevada. Important sources elsewhere are inactive mines, natural-mercury-enriched soil, geothermal springs, and atmospheric deposition. Cleanup and abatement projects from selected abandoned or inactive mines known to be a significant source of total metals into receiving waters are underway through USEPA's abandoned mine lands program. Under the program, USEPA conducts and supervises investigation and cleanup actions at mine sites and explores reuse opportunities. In addition, regional water boards have issued cleanup and abatement orders to entities that own or operate abandoned or inactive mines. Mercury TMDLs for San Francisco Bay, Cache Creek, and the Delta have been approved by USEPA (Table 7.12.1-2).

Positive correlations exist between total mercury concentrations in sediment and methylmercury levels in sediment and water (^Central Valley Water Board 2010). Positive correlations also exist between methylmercury in water and fish tissue. Due to high levels of methylmercury found in fish tissue, consumption of fish contaminated with mercury is generally a greater concern for human health than mercury levels found in drinking water. As a result, waterbodies are placed on the 303(d) list as impaired for mercury when fish species have elevated tissue concentrations that pose a risk to human and wildlife consumers (^Central Valley Water Board 2010; San Francisco Bay Water Board 2006). Fish consumption advisories have been issued for these waterbodies. Studies also indicate that mercury poses a threat to wildlife, including rare and endangered species, like California least tern (USFWS 2003).

In 2017, the State Water Board adopted Resolution 2017-0027, which approved "Part 2 of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries of California—Tribal and Subsistence Fishing Beneficial Uses and Mercury Provisions." Resolution 2017-0027 provides a consistent regulatory approach throughout the state by setting mercury limits to protect the beneficial uses associated with the consumption of fish by both people and wildlife. Provisions are implemented through NPDES permits, water quality certifications, WDRs, and waivers of WDRs.

Over 100 reservoirs in California are on the 303(d) list as impaired by mercury as it pertains to the consumption of fish (SWRCB 2017a). These reservoirs are located throughout California, including in the Sacramento River watershed, Delta eastside tributaries, San Joaquin Valley, Central Coast, and Southern California regions; and include SWP, CVP, and drinking water supply reservoirs south of the Delta. The State Water Board is preparing a program for controlling mercury in reservoirs. A draft staff report for peer review of this program determined that three factors explained about 85 percent of the variance in fish mercury concentrations in reservoirs: the ratio of aqueous methylmercury to chlorophyll-a (a measure of algal primary productivity), aqueous total mercury, and annual average reservoir water level fluctuations (SWRCB 2017a). Aqueous total mercury concentrations are important because total mercury has been correlated with methylmercury in fish tissue. Chlorophyll is relevant because it indicates the amount of benthic and algal primary production occurring to support higher trophic-level organisms. In a process called *biodilution*, when primary production is high, the concentration of mercury in the food supply becomes low and bioaccumulation of mercury is reduced. In addition, when primary production is high, food availability allows fish to grow, thereby reducing the concentration of mercury in fish.

The 2017 draft staff report concluded that a combination of source control actions and reservoir and fish management practices will be needed to achieve both timely and measurable fish methylmercury reductions in most of California's mercury-impaired reservoirs. Reservoir-specific characteristics and operational requirements and mandates may not allow for all methylmercury management tools to be used in all reservoirs. During the first phase of the implementation program for the impaired reservoirs, the mercury reservoir provisions require pilot tests for reservoir water chemistry and fisheries management practices.

Metals and Metalloids

In addition to mercury, several other metal and metalloid elements appear on the 303(d) list, including copper, zinc, cadmium, boron, and selenium.

Water quality objectives for copper, zinc, and cadmium are expressed as hardness-adjusted dissolved concentrations because the dissolved form of the metal is the most bioavailable and toxic form. The largest source of heavy metals in the Central Valley is mine waste. Beneficial uses most negatively affected by trace metals are aquatic wildlife (e.g., COLD, WARM, EST, SPWN, RARE, MIGR, WILD), commercial and recreational harvesting activities (COMM), and municipal supplies (MUN).

Boron is naturally occurring in sedimentary rock in the Coast Ranges. The primary source of boron is natural weathering of parent rock; point sources are minor contributors of boron (Central Valley Water Board 2004a). Boron is an essential plant nutrient at low levels but a plant toxin at higher concentrations (Ayers and Westcot 1985, Section 4.1.3). Almonds and other tree crops are sensitive to elevated boron concentrations in irrigation water. Boron primarily exists in a dissolved state, with the irrigation season being the most sensitive period for agricultural exposure. Cache Creek is the only tributary in the Sacramento River watershed listed for boron. The primary beneficial use negatively affected by boron is agricultural supply (AGR).

Like boron, the primary source of selenium is the natural weathering of sedimentary rock in the Coast Ranges. Selenium released from this natural weathering moves with groundwater to the valley floor (USEPA 2015). Irrigation and subsurface drainage (e.g., tile drains) throughout the San Joaquin Valley accelerate selenium's movement from groundwater to surface water (USEPA 2015). Although it is a trace element that is an essential nutrient for animals, high bioaccumulated selenium levels are toxic to fish, birds, and humans. Waterways in the lower San Joaquin River basin and San Francisco Bay have TMDLs for selenium (Table 7.12.1-2) (Central Valley Water Board 2018; San Francisco Bay Water Board 2019). The primary beneficial uses negatively affected by selenium are agricultural supply (AGR), industrial service supply (IND), and municipal supply (MUN).

Dissolved Oxygen

Dissolved oxygen is important because it is essential for fish survival. In addition, anaerobic conditions are conducive to the formation of methylmercury. Dissolved oxygen is typically adequate in flowing streams but can be depleted at the bottom of the water column in areas of slow-moving water with high sediment oxygen demand or in eutrophic areas with large amounts of decaying organic material. In addition, dissolved oxygen may be depleted at the bottom of some reservoirs, where sediment oxygen demand may be high and little reaeration from the water surface occurs. This depletion of oxygen in the deeper, cooler portions of a reservoir may be problematic for fish if the aerated surface layer of the reservoir becomes unsuitably warm.

Dissolved oxygen concentration is controlled by the balance between dissolved oxygen removal and dissolved oxygen absorption in the water. Dissolved oxygen removal occurs when oxygen reacts with molecules in the water and becomes bound to form a new molecule that either stays in the water or leaves the water as a gas. For example, dissolved oxygen removal may occur when ammonia combines with oxygen to form nitrate, when organic material decays to form carbon dioxide, or when algae use oxygen at night and are not photosynthesizing. The rate of overall oxygen removal is determined by the level of biochemical oxygen demand. Dissolved oxygen concentrations increase in the water as a result of reaeration and algal photosynthesis.

Water is saturated with dissolved oxygen when the dissolved oxygen concentration in the water is in equilibrium with the oxygen in the atmosphere. The dissolved oxygen concentration in fully saturated water depends on water temperature and barometric pressure, with higher dissolved oxygen concentration occurring at cooler water temperatures and higher barometric pressures. Changes in temperature, therefore, can produce small fluctuations in dissolved oxygen concentration (approximately 1.1 milligrams per liter [mg/L] for a 55- to 65-degree Fahrenheit [°F] diurnal fluctuation in water temperature, which might be observed in summer but not in winter). Large diurnal fluctuations in dissolved oxygen, however, indicate algal growth. Algal photosynthesis is the only common process that can cause the dissolved oxygen concentration to become supersaturated (i.e., exceed saturation levels).

Temperature

Elevated water temperature is primarily a concern for cold water fish, although it can affect other water quality parameters, such as dissolved oxygen. Beneficial uses most affected by increases in water temperature are those related to cold water fish (e.g., COLD, EST, RARE, MIGR, SPWN, COMM).

Due to the dynamics of heat exchange, river temperatures generally increase if river flow is reduced and decrease if river flow is increased. Alterations in flow can cause a corresponding change in the water temperature downstream. If the existing flow is relatively high, a change in flow would likely cause a smaller change in temperature than would the same change in flow if the existing flows were lower. A change in flow during colder months causes a smaller change in water temperature than during warmer months because in colder months, temperatures are closer to the average ambient air temperatures.

River temperature also is affected by reservoir storage. Typically, during winter, little difference in water temperature exists between the top and bottom of a reservoir due to cool meteorological conditions. However, as the year progresses and solar radiation and air temperature increase, the surface of a reservoir will begin to become warmer. As the year progresses and as water is released from the reservoir, the cool water at the bottom of a reservoir may become depleted and the warm upper layer may drop toward the reservoir outlet(s). Reservoir operations that result in low storage in the late-summer and fall months (e.g., August through November) can cause release temperatures to become too warm for cold water fish. By November, water temperatures generally are declining in response to reductions in solar radiation and air temperatures and generally remain low through February.

A few waterbodies are included on the 303(d) list as impaired by elevated water temperature, and discharges of heat waste are regulated by NPDES permits. Regional water board basin plans contain general objectives for limiting increases in water temperature. The Central Valley Basin Plan states: “[a]t no time or place shall the temperature of COLD or WARM intrastate waters be increased more than 5 °F above natural receiving water temperature” (^Central Valley Water Board 2018b). The

State Water Board's *Water Quality Control Plan for Control of Temperature in the Coastal and Interstate Waters and Enclosed Bays and Estuaries of California* (California Thermal Plan) (SWRCB 1975) regulates warm discharges from industrial processes to coastal and interstate waters and enclosed bays and estuaries of California. These industrial processes include activities such as wastewater treatment and power plant cooling. For estuaries, existing waste discharges must not exceed the natural receiving water temperature by more than 20 °F, must not elevate the receiving water surface temperature by more than 4 °F, and must provide zones of passage around the elevated temperature discharge.

Elevated temperatures from water supply infrastructure and management are a concern in additional waterbodies; in some locations, reservoir storage and releases are regulated to maintain suitable habitat for fish through various mechanisms, including water right orders, implementation of the Endangered Species Act (e.g., through biological opinions [BiOps]), and the Federal Energy Regulatory Commission (FERC) licensing process.

Many streams and reservoirs are operated for hydropower under the Federal Power Act and licensed by the FERC. Recent water quality certifications have included terms and conditions, such as water temperature requirements, ramping criteria, development of plans for managing the coldwater pool in reservoirs to minimize exceedances of downstream temperature requirements, and development of plans for facility modifications if facilities cannot meet specified water temperature requirements. However, older FERC licenses may lack any measures for the protection of cold water species. In addition, Fish and Game Code section 5937 requires that "[t]he owner of any dam shall allow sufficient water at all times to pass through a fishway, or in the absence of a fishway, allow sufficient water to pass over, around, or through the dam to keep in good condition any fish that may be planted or exist below the dam." To date, this law has not been widely implemented.

More information on water temperature requirements for fish and water temperature impacts associated with the proposed Plan amendments is provided in Section 7.6.2, *Aquatic Biological Resources*.

Legacy Contaminants

Legacy contaminants are chemicals no longer in use but still present in sediment and fish tissue. Legacy pesticides include organochlorine pesticides like DDT and group A pesticides (aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, hexachlorocyclohexane, endosulfan, and toxaphene). These pesticides were extensively used in agriculture and urban areas and were banned by the late 1980s but degrade slowly and biomagnify in food chains, resulting in elevated levels in fish tissue. Legacy pesticides are neurotoxins and classified by USEPA as probable carcinogens (Connor et al. 2007). Polychlorinated biphenyls (PCB) and polycyclic aromatic hydrocarbons are legacy contaminants that were extensively used in industry. Both groups were banned in the late 1970s but are still detected periodically in fish tissue. Like organochlorine pesticides, they degrade slowly and biomagnify in food webs, with the highest concentration in top trophic-level fatty fish.

The presence of legacy contaminants in fish tissue has resulted in the issuance of fish advisories recommending limited consumption of some fish species (De Vlaming 2008) and placement of waterbodies on the 303(d) list due to impairment by these contaminants. Organochlorine, PCB, and polycyclic aromatic hydrocarbon chemicals strongly adsorb to sediment. They enter rivers through erosion of terrestrial soils during storm events and are carried downstream through resuspension of river bottom sediments. High flows that mobilize and transport sediment also increase the downstream movement of legacy contaminants. TMDL control programs for PCB and organochlorine pesticide contamination are due to be completed by 2021 and 2027, respectively, for the Central Valley. The beneficial uses affected by legacy contaminants include aquatic wildlife (e.g., COLD, WARM, EST, RARE, MIGR, SPWN, WILD), commercial and recreational fishing (COMM), and municipal supplies (MUN).

Pathogens

Pathogens are waterborne bacteria, protozoans, and viruses affecting human health through direct water contact or ingestion of contaminated material. Sources of pathogens are urban storm water runoff, confined animal facilities, municipal WWTPs, and domestic and wild animals. Most of the available data are for fecal coliform. Coliform counts do not show a correlation with river flow although concentrations increase in winter, suggesting contributions from storm runoff (Tetra Tech 2007). Municipal water treatment for pathogens includes filtration, disinfection with chlorine, or ozone and ultraviolet light (Tetra Tech 2007). The beneficial uses most at risk from pathogens are water contact recreation (REC-1), shellfish harvesting (COMM), and municipal water supplies (MUN).

Pesticides

Commonly used pesticides include pyrethroids, organophosphate, and carbamate insecticides, fungicides, and herbicides. Pesticide sources include agricultural and urban storm water runoff, irrigation tailwater return flows, and applications to surface water for mosquito and invasive aquatic weed control. Pesticide toxicity as an ecosystem stressor and the potential role of pesticides in species declines are further reviewed in Chapter 4, *Other Aquatic Ecosystem Stressors*. The timing and magnitude of pesticide occurrence in surface water is a function of the timing and magnitude of application rates, off-site transport, and instream flows. Depending on concentration and location, beneficial uses most likely affected by pesticides include municipal supply (MUN) and all of those related to aquatic wildlife (e.g., COLD, WARM, EST, RARE, MIGR, SPWN, WILD).

In 2017, USEPA approved the Central Valley pesticide TMDL for diazinon and chlorpyrifos (Central Valley Water Board 2014; USEPA 2017). The TMDL establishes diazinon and chlorpyrifos water quality objectives, as well as implementation and monitoring requirements to protect waterbodies throughout the Central Valley. The program is implemented through the California Department of Pesticide Regulation, the USEPA Office of Pesticide Programs, and county agricultural commissioners.

Pyrethroid insecticides have replaced diazinon and chlorpyrifos and are now widely used in urban and agricultural areas throughout the Central Valley (Central Valley Water Board 2017). The Central Valley Water Board adopted the *Basin Plan Amendment for the Control of Pyrethroid Pesticide Discharges*, which applies to waterbodies in the Central Valley with WARM and/or COLD aquatic life beneficial uses. The basin plan amendment includes TMDLs for nine urban waterbodies that are listed as impaired by pyrethroids on the 303(d) list. In 2019, USEPA approved the TMDLs for the nine urban creeks (Table 7.12.1-2) (USEPA 2019a). The TMDLs set goals for six pyrethroid insecticides that have been detected at toxic levels in surface water and have the highest use in the Central Valley. The TMDLs also propose agricultural and urban management practices to control off-site movement. Monitoring and assessment will be required to determine the effectiveness of the program.

The California Department of Parks and Recreation, Division of Boating and Waterways (CDBW), applies glyphosate, 2,4-D, and Imazamox herbicides directly to surface water to control invasive aquatic plants. Mosquito and vector control districts use integrated pest management to control mosquito populations around urban areas. Integrated pest management includes direct application of organophosphate and pyrethroid insecticides to surface water at concentrations that kill mosquito larvae. The State Water Board administers NPDES permits for pesticide applications for control of invasive species, aquatic weeds, and vectors such as mosquitos (SWRCB 2018a). The permit requires compliance with water quality standards, relevant state and federal laws, monitoring and reporting, and corrective action in the event of adverse effects on federally listed native species.

Constituents of Emerging Concern

CECs include endocrine-disrupting chemicals (EDCs) and personal care products and pharmaceuticals (PCPPs). EDCs interfere with the normal function of the hormonal system (Diamanti-Kandarakis et al. 2009). PCPPs include prescription and over-the-counter drugs and cosmetics for humans, and hormones and antibiotics for livestock. Sources of CECs are WWTPs, urban storm water runoff, and discharges from fish hatcheries and confined animal facilities. Information on concentrations, transport, and ultimate destination of EDC and PCPP chemicals is sparse because these chemicals are not traditionally part of ongoing monitoring programs. Limited information also exists on the biological effects of CECs. Available information on the impact of CECs on aquatic resources in Delta waterbodies is reviewed in Chapter 4, *Other Aquatic Ecosystem Stressors*.

The State Water Board is coordinating efforts to gather information and develop a monitoring program for CECs in tributaries and the Bay-Delta. The goal of the program is to identify sources, status, trends, and biological effects of CECs on aquatic resources (SWRCB 2016). CEC research is ongoing (e.g., SWRCB 2018b).

Nutrients and Harmful Algal Blooms

Nutrients can influence multiple ecological processes that impair water quality. Excess nutrients may promote algal blooms and invasive aquatic plant growth, potentially reducing oxygen levels to stressful or lethal levels for fish and other aquatic organisms. Elevated nutrient levels in export water also can result in excessive plant and algal growth in drinking water canals and reservoirs.

The Central Valley Water Board Basin Plan has no numeric standards for nutrients but relies instead on the narrative toxicity and biostimulatory objectives to regulate nutrients. The narrative objectives may be translated into a numeric limit for NPDES permits. The San Francisco Bay Water Board Basin Plan has numeric objectives for ammonium to protect aquatic resources and objectives for dissolved inorganic nitrogen and nitrate to protect irrigation and livestock watering.

Nitrogen and phosphorus are the two nutrients that most often affect aquatic plant and algal production (Wetzel 2001) because they are generally the most likely nutrients to drop to levels that limit growth. The main dissolved inorganic forms of nitrogen and phosphorus include nitrate, ammonium, and orthophosphate. The California drinking water MCL is 1 mg/L for nitrite (as nitrogen) and 10 mg/L for nitrate (as nitrogen). No MCL exists for phosphorus.

Moderate algal growth can be beneficial for aquatic ecosystems because it supplies the food web, ultimately supporting fish. An algal bloom can become problematic if it results in eutrophication and low dissolved oxygen; if it exists in certain locations, such as near a drinking water intake; or if it is composed of deleterious types of organisms, such as cyanobacteria (blue-green algae)—a type of photosynthetic bacteria. Most commonly, *HAB* refers to a bloom of cyanobacteria.

Increased inputs of nutrients like nitrogen and phosphorus (from fertilizers and human or animal wastes) can promote cyanobacterial growth and can lead to increased occurrences of HABs. Low flows, stagnant water, increased penetration of sunlight due to water clarity, and sustained high temperatures create ideal conditions for HABs. HABs can block sunlight, reduce dissolved oxygen when they decompose, produce surface scum that interferes with contact recreation, and cause drinking water taste and odor problems. Cyanobacteria in fresh water can be found in lakes, ponds, rivers, and reservoirs. Some species of cyanobacteria produce toxins (cyanotoxins) that can affect the nervous system, liver, skin, stomach, or intestines. Common cyanotoxins known to cause illness in humans and animals include microcystins, anatoxins, and saxitoxins. Exposure to cyanotoxins in fresh water can occur during recreational activities (e.g., swimming, boating) or by breathing in aerosolized toxins. Cyanotoxins are bioaccumulative; their toxicological effect on fish and wildlife is discussed in Chapter 4, *Other Aquatic Ecosystem Stressors*. (CDC 2017).

Generally, cyanobacteria such as *Microcystis*, which is the most common bloom-forming cyanobacteria HAB, are dependent on high nutrient levels, water temperatures higher than approximately 66 °F, low-flow conditions, a stable water column, and low turbidity (USEPA 2016a; ^Lehman et al. 2013). Whereas water temperatures exceeding 66 °F are generally considered the primary driver of bloom formation, low streamflow may be the most important factor for maintaining HABs, at least for *Microcystis* (^Lehman et al. 2013). Turbulence can disrupt HAB formation by disrupting cyanobacteria regulation of buoyancy, potentially reducing ability to regulate temperature, light, and nutrient access (American Water Works Association 2015). Most HAB-forming and toxin-producing cyanobacteria are freshwater species; however, studies have shown that freshwater cyanobacteria have a relatively wide range of salinity tolerance (^Berg and Sutula 2015).

The 303(d) list does not have any listing for HABs in the Central Valley (Region 5); however, some Central Valley waterbodies are listed for nutrients; and HABs have been reported in the Delta and multiple lakes and reservoirs throughout the Central Valley, including Oroville Reservoir, San Luis Reservoir, and O’Neill Forebay (USEPA 2016b; SWRCB 2022). Low water levels at reservoirs could result in higher water temperatures at shallow locations in reservoirs, particularly in summer months, which could help drive algal bloom formation (USEPA 2013). Low reservoir levels can result in large areas with shallow depth, reduced mixing between warm surface water and deeper cooler water, higher water temperatures, and a more stable water column—and could draw surface water closer to reservoir outlets, which may increase algal bloom formation and result in water quality degradation of reservoir withdrawals.

In drinking water, algae usually are removed as a suspended solid. When growth of certain varieties of algae results in concentrations high enough to affect the taste or odor of drinking water, it can elicit complaints from users. Large algal blooms and invasive aquatic plant beds restrict water pumping rates, clog filters, and cause taste and odor problems in drinking water (^Central Valley Water Board 2018a). Taste and odor problems may be treated with adsorption materials, ultraviolet light, or ozonation. However, taste and odor problems are not always prevented (CALFED 2005). Presence of cyanotoxins may cause additional need for monitoring and water treatment (USEPA 2014), with extracellular cyanotoxins being harder to treat than cyanotoxins retained in algal cells (American Water Works Association 2015).

The State Water Board and the regional water boards work with other water managers to conduct monitoring and tracking, take appropriate response actions to manage and control HABs, and communicate HAB concerns with other agencies and the public, including providing appropriate water quality warnings, conducting monitoring and tracking, and taking appropriate response actions to manage and control HABs. This work is aided by the passage of Assembly Bill 834, signed in September 2019, which formalizes a HABs program within the water boards with specific objectives, including event response, statewide assessment and monitoring, risk assessment, research, outreach and education, and reporting. The California Harmful Algal Blooms Portal (https://www.mywaterquality.ca.gov/habs/index.html) provides information, incident report maps, and response guidance for HABs.

Similar to HABs, invasive aquatic vegetation tends to grow in areas with stagnant water and high nutrient levels. Invasive aquatic vegetation is discussed further under *Regional Water Quality, Delta*.

Salinity

Management of salinity is important for protecting municipal and industrial, agricultural, and fish and wildlife beneficial uses. Salinity is a measure of the amount of dissolved salt in water and is usually measured as EC. Various terms are used to indicate salinity impairment on the 303(d) list. They include elevated chloride, EC, salinity, total dissolved solids, sodium, and specific conductance. The majority of salinity impairments occur in the Delta and western side of the San Joaquin Valley (Table 7.12.1-3). Sources of elevated salinity include seawater intrusion (in the Delta and Delta exports), saline groundwater, and concentration of salts resulting from evapotranspiration of irrigation water. Throughout this section, the terms “salinity” and “EC” are used interchangeably.

Regional Water Quality

Sacramento River Watershed and Delta Eastside Tributaries

The Sacramento River watershed drains about 27,000 square miles in the northern Central Valley to the Delta. Based on the Sacramento Water Allocation Model (SacWAM) unimpaired flow estimates, in a typical year, the Sacramento River contributes about 62 percent of the unimpaired flow to the Delta, the Yolo Bypass contributes about 12 percent, the San Joaquin River contributes about 21 percent, and the Delta eastside tributaries together contribute about 5 percent (see Section 2.4.1, *Delta Inflows* in Chapter 2, *Hydrology and Water Supply*). Land uses influence the type and amount of contaminants found in runoff and receiving waters. Land use in the mountainous Sierra Nevada portion of the Sacramento River watershed is mostly forest and rangeland, while it is agriculture on the valley floor. About 3,000 square miles of the Sacramento River watershed and Delta eastside tributaries regions are irrigated. The top-producing crops include rice, irrigated pasture, alfalfa, almonds, and wheat in the Sacramento River watershed and grapes (wine), silage, almonds, corn, and alfalfa in the Delta eastside tributaries (see Section 7.4, *Agriculture and Forest Resources*).

Water quality in the Sacramento River watershed is influenced by flows exiting Shasta Reservoir and flows from tributaries including the Feather, Yuba, and American Rivers and Putah and Cache Creeks. Large dams have been constructed on all the major tributaries to the Sacramento River and Delta eastside tributaries, except on the Cosumnes River. The upstream reservoirs capture and provide downstream water for urban and agricultural uses and for power generation. The reservoirs also intercept and sequester a large portion of sediment-bound constituents from upstream sources, delivering relatively clean water downstream. The reservoirs block fish access to cold upstream water but allow storage of cold water for later downstream release. Most of the contaminants in the lower Sacramento River and its tributaries originate downstream of reservoirs from mining, agriculture, and urban land uses.

The Sacramento River and Delta eastside tributaries provide a high volume of relatively clean water to the Delta, with the most downstream sections having the most elevated concentrations of pollutants compared to upstream tributaries. Runoff, erosion, remobilization of historical legacy pollutants (e.g., metals, organochlorines), and continued use of pesticides for urban and agricultural uses are of concern in the watershed. Discharges from agricultural operations include irrigation runoff, flows from tile drains, and storm water runoff. These discharges can affect water quality by transporting pollutants, including pesticides, sediment, nutrients, salts (including selenium and boron), pathogens, and heavy metals, from cultivated fields. The Irrigated Lands Regulatory Program regulates discharges of waste from irrigated agricultural lands through WDRs or conditional waivers of WDRs to growers. These conditional waivers require water quality monitoring of receiving waters and corrective actions when impairments are found, such as the Coalition Group Conditional Waiver of Waste Discharge Requirements for Discharges from Irrigated Lands (Central Valley Water Board 2011a).

The relatively good quality of the water in the Sacramento River and Delta eastside tributaries makes it a good water supply for many communities. For example, Sacramento River water supplies multiple communities, including Woodland, Davis, and West Sacramento. The American River is heavily used for municipal purposes throughout the Sacramento region, and much of the Mokelumne River water is used as the main water supply for the East Bay Municipal Utility District (EBMUD).

Temperature

The lower American River, portions of the Sacramento River downstream of Lake Shasta, the North Fork of the Feather River, and the South Fork of the Yuba River are listed as impaired for water temperature (Table 7.12.1-3). Multiple additional locations that provide habitat for cold water fish also have temperature concerns. Temperature control strategies for several of the largest rivers in the Sacramento/Delta include physical, regulatory, and operational actions.

- Sacramento River below Shasta Reservoir. Elevated temperature downstream of Keswick Dam has been implicated in the decline of winter-run Chinook salmon. Extensive efforts (e.g., modeling, operation of a temperature control device (TCD) in Shasta Reservoir, protection of carryover storage in Shasta Reservoir, and optimization of Shasta releases) have been made to provide adequate water temperature for winter-run Chinook.
- Feather River below Oroville Reservoir. Current FERC requirements for the Oroville facilities (including conditions established by the 2010 State Water Board water quality certification [SWRCB 2010] and National Marine Fisheries Service 2016 BiOp [NMFS 2016]) include interim water temperature targets and final temperature requirements following completion and testing of proposed facility modifications to improve cold water management capabilities in the Feather River.
- American River below Folsom Reservoir. The primary temperature target for the American River as described in the 2019 NMFS BiOp is attainment of a daily average temperature of 65 °F or lower at Watt Avenue from May 15 through October 31 for juvenile steelhead rearing (^NMFS 2019 BiOp; Reclamation 2019). Attainment of this target and prevention of severe deviation from the target is implemented through the “flow management standard” and

temperature management plan to preserve cold water, although there could still be frequent exceedances of 65 ˚F (^NMFS 2019 BiOp).

Total Suspended Solids and Sediment

The Sacramento River is the largest source of TSS to the Delta (^Wright and Schoellhamer 2004). Most of the sediment enters between December and April and is carried in first-flush events and high winter storm flows. The primary source of TSS to the Sacramento River watershed is from reservoir releases, erosion of river channel and levee material, and unregulated tributaries on the valley floor below rim dams. Positive correlations have been documented between TSS concentrations and river flow (^Central Valley Water Board 2010).

Analysis of sediment yields on the Sacramento River upstream and downstream of the Fremont and Sacramento Weirs, which allow sediments to enter the Yolo Bypass, has indicated a high likelihood of a decreasing trend in suspended sediment discharge for a given flow. The annual suspended sediment yield has decreased by 50 percent from 1957 to 2001. Over the same period, suspended sediment concentrations have decreased near the confluence of the Sacramento River and the Bay-Delta. During the largest flood events, peak sediment concentrations have decreased with time. From 1957 to 2001, three large reservoirs in the watershed (Oroville, Folsom, and Englebright) have accumulated a mass of sediment of the same order of magnitude as the decreases in suspended sediment yield (^Wright and Schoellhamer 2004). The total sediment load has decreased by 50 percent due to reduction of the sediment pulse created during hydraulic mining in the Sierra Nevada, trapping of sediment behind reservoirs, deposition of sediment in flood bypasses, and armoring of river channels (^Wright and Schoellhamer 2004).

Mercury

Multiple waterbodies are on the 303(d) list for mercury in fish tissue, including the lower American, Sacramento, and Bear Rivers; Big Chico, Clear, Cache, and Putah Creeks; the Colusa Basin Drain; and Sacramento Slough (Table 7.12.1-3). Multiple fish species sampling results indicate mercury bioaccumulation, with elevated mercury in fish found throughout the Sacramento River watershed. OEHHA has issued health advisories that recommend limiting consumption of fish taken from Clear Lake, Lake Berryessa, Black Butte Lake, and Marsh Creek Reservoir.

USEPA approved a methylmercury TMDL for Cache Creek and its tributaries in 2007 (USEPA 2007). Cache Creek drains about 2 percent of the Sacramento River watershed but contributes approximately 30 percent of all the mercury from the Sacramento River watershed (^Central Valley Water Board 2010). About half of the mercury from the Cache Creek watershed is trapped in the Cache Creek settling basin as a result of sediment deposition, although estimates of trapping efficiency are variable. The remainder of the mercury drains to the Yolo Bypass and the downstream Bay-Delta (Central Valley Water Board 2011b; DWR 2015). While the Cache Creek settling basin helps reduce total mercury, it has also been found to be a source of methylmercury. Alternative methods are being considered for maintaining or augmenting the mercury trapping ability of the settling basin while also reducing methylmercury formation. Deposition of sediment and attached particulate mercury depends on velocity and residence time within the settling basin, although in an evaluation of trapping efficiency between 2010 and 2013, trapping efficiency of particulate mercury during the relatively wet year of 2011 was not much different from the other years (DWR 2015).

Both the Cosumnes and Mokelumne Rivers are contributors of mercury and mercury-contaminated sediment to the Delta. Fish tissue monitoring throughout the Delta and its tributaries revealed that mercury in fish tissue was elevated at these two rivers. Largemouth bass was the most contaminated species and provided broad spatial comparisons throughout the Delta (Melwani et al. 2009).

Nutrients and Harmful Algal Blooms

HABs have been reported in multiple locations within the Sacramento River and Delta eastside tributary watersheds, including Clear Lake, Black Butte Lake, Sacramento River, Folsom Reservoir, Lake Berryessa, Oroville Reservoir, Shasta Reservoir, and the Natomas East Main Drainage Canal (California Water Quality Monitoring Council 2018). Generally, HABs form at lower elevations because many upstream waterbodies have water temperatures and nutrient concentrations that are too low to support HABs; nevertheless, HABs have been reported in some upper watershed reservoirs, including Mountain Meadows Reservoir and Lake Almanor, which are at elevations of approximately 5,000 and 4,500 feet, respectively.

Other Constituents

Several waterbodies in the Sacramento River watershed and Delta eastside tributaries are included on the 303(d) list because of elevated concentrations of copper, zinc, and/or cadmium (SWRCB 2022). The sources of these trace metals include erosion of natural deposits, discharges from abandoned mines, municipal wastewater discharges, and urban storm water runoff (Central Valley Water Board 2002). In the upper Sacramento River watershed, copper, zinc, and/or cadmium TMDLs have been successfully implemented at Iron Mountain Mine, West Squaw Creek, and Horse Creek. The TMDLs required mine owners to implement remediation actions to reduce off-site movement of acid mine drainage. The actions included site grading, waste rock containment and capping, and construction of concrete bulkhead seals in mine entrances. The remediation actions have significantly reduced off-site movement of mine waste at all sites.

Multiple waterbodies in the Sacramento River watershed and Delta eastside tributaries are on the 303(d) list for pathogens, including the American, Calaveras, and Cosumnes Rivers (SWRCB 2022). A pathogen TMDL control program was approved by USEPA in 2008 for Stockton urban waterbodies (Central Valley Water Board 2008). The TMDL is being implemented through the City of Stockton and County of San Joaquin municipal separate storm sewer system (MS4) permit. The permittees submitted a pathogen plan outlining an approach that included monitoring to identify sources, development and implementation of best management practices (BMPs), and effectiveness monitoring. The BMPs include public education and outreach for proper disposal of pet waste and reduction of contaminated discharges to storm drains.

A diazinon and chlorpyrifos TMDL was approved for the Sacramento and Feather Rivers by USEPA in 2008. The TMDL established concentration limits in discharges and development and implementation of management plans to reduce concentrations (Central Valley Water Board 2007). The Sacramento County Urban Creeks TMDL was approved by USEPA in 2004. The TMDL addresses impairments caused by diazinon and chlorpyrifos in creeks in Sacramento County dominated by urban runoff (Central Valley Water Board 2004b). The TMDL was implemented through the Sacramento MS4 permit. Ongoing monitoring in the Delta demonstrates that diazinon and chlorpyrifos concentrations are decreasing though periodic exceedances still occur (Central Valley Water Board 2015). More recently, the Central Valley Water Board developed a diazinon and chlorpyrifos TMDL to cover a much broader area—the Sacramento River and San Joaquin River basins below the major reservoirs—which was approved by USEPA in 2017 (Table 7.12.1-2) (Central Valley Water Board 2014).

Other water quality degradation and cleanup or control efforts are focused on other pesticides. For example, rice pesticides are of concern and are monitored in rice field runoff (Central Valley Water Board 2010a). A management program was enacted in the 1980s to reduce the levels of rice pesticides in surface water, which led to numerous improvements, such as significant declines in rice pesticides in both the Colusa Basin Drain and the Sacramento River.

Floodplains and Bypasses

High flows can increase river stage and cause inundation of floodplains within levees. As water passes over a floodplain, water quality may be affected. For example, organic material in the floodplain may be swept into the water column. In addition, processes on the floodplain, such as methylation of mercury or algal growth, affect water quality. Floodplain water may be more suitable for algal or aquatic plant growth due to shallow depth, slower movement of water, warmer temperatures, and greater light penetration. However, when flow is high, travel time over a floodplain may be too short for substantial changes in water quality other than a potential increase in sediment and organic material. In addition, floodplain acreage is often too small to have much effect on water quality.

In the Sacramento River watershed, the flood bypasses, particularly the Sutter and Yolo Bypasses, provide substantial floodplain inundation—approximately 59,000 acres in the Yolo Bypass and 18,000 acres in the Sutter Bypass (^Sommer et al. 2001b). The Yolo Bypass has been studied extensively for its potential benefits (e.g., floodplain spawning and rearing and input of organic material to estuarine fish habitat) and risks (e.g., methylmercury accumulation) to native fish species (e.g., ^Sommer et al. 2001b, Henery et al. 2010). Agricultural management of rice fields accelerates and amplifies methylmercury production in the Yolo Bypass (Windham-Myers et al. 2010). In 2010, the Central Valley Water Board adopted the Delta Mercury Control Program. The first phase of studies of the TMDL program emphasized development and evaluation of methods that control sediment-bound mercury in the Delta and Yolo Bypass that may become methylated in agriculture, wetland, and open water habitats.

Flood-control diversions into the Sutter Bypass and the Yolo Bypass can affect the transport of nutrients in the mainstem Sacramento River during winter and spring (Kratzer et al. 2011). Water quality of the Yolo Bypass is a dynamic process and depends greatly on how much Sacramento River water is flowing over Fremont Weir. During high flows, the water chemistry in the Yolo Bypass is dominated by inflow from the Sacramento River, except along the western margin of the floodplain where local stream inflow influences water quality (Schemel et al. 2002). During low flows, chemical concentrations in the perennial channel are influenced by inflows from Cache Creek and Knights Landing Ridge Cut, which are sources of nutrients and contaminants. However, runoff from spring storms increases flows and flushes accumulated nutrients and organic matter to the tidal area of the Sacramento River (Schemel et al. 2002). Most water quality issues originate from an increased prominence of tributary water, especially from Cache Creek, known for mercury contamination, and from Knights Landing Ridge Cut.

Schemel et al. (2002) provide a summary of potential Yolo Bypass effects on organic material in the Delta:

> Chlorophyll *a* measurements have confirmed that increased primary production by diatoms and other phytoplankton was a major feature of the [Yolo Bypass] draining period through mid-April (W. Sobczak and A. Mueller-Solger, personal communications). In addition, chlorophyll *a* monitors at Rio Vista have shown for many years that concentrations in the Sacramento River increase during

the draining of the Yolo Bypass and often following late-season storms that flush materials from the perennial channel (Sommer and others, 2001). These results suggest that the Yolo Bypass not only is a producer of highly nutritious organic matter for its inhabitants, but that it exports organic matter to the river-delta-estuary system, where supplies of phytoplankton organic carbon have become increasingly scarce in recent years (Jassby and others, 2002).

While this organic material may be beneficial for fish, it may be detrimental for drinking water supply and recreation (see the *Chloride and Bromide* and *Nutrients, Harmful Algal Blooms, and Invasive Aquatic Vegetation* sections for the Delta, particularly regarding dissolved organic material).

Delta

The Delta receives runoff from over 40 percent of California (DWR 1995). The major tributaries to the Delta are the Sacramento River, the three Delta eastside tributaries, and the San Joaquin River. The Delta is a maze of river channels and diked islands covering about 1,100 square miles, including 95 square miles of water surface. The Bay-Delta Plan specifies water quality objectives for many locations within the Delta for municipal, agricultural, and fish and wildlife beneficial uses. Many of these objectives are for salinity or other constituents related to salinity. Figure 7.12.1-1 provides a map of the Delta and water quality compliance locations. Delta hydrology is discussed in Chapter 2, *Hydrology and Water Supply.* Major Delta land uses are agriculture, recreation, and habitat for fish and wildlife. Several urban areas are located in the Delta.

The Delta is a major water supply for agricultural use within the Delta region, for municipalities in and near the Delta (e.g., Antioch, Brentwood, Stockton, Mountain House), and for people and agriculture dependent on water diverted from the Delta via the California Aqueduct, Delta-Mendota Canal, South Bay Aqueduct, North Bay Aqueduct, and the Contra Costa Water District (CCWD) diversion system. In addition, the Freeport Regional Water Authority diverts water for EBMUD and central Sacramento County from the Sacramento River at the northern edge of the Delta.

The Delta is on the 303(d) list for salinity, chloride, mercury, trace metals, legacy contaminants, pathogens, invasive species, and current use pesticides (SWRCB 2022). In addition, bromide and HABs are issues of concern.

Variations in Delta water quality can cause spikes in constituents that affect water treatment plants, resulting in plant shutdowns or the need to change or blend supply sources. Agencies use a mix of solutions to address these issues, including advanced treatment methods to remove total dissolved solids and other constituents, operation of reservoirs/conveyance systems in the region to provide a blended water supply, and source water protection.

Water Temperature

Several regions in the Delta are listed as impaired for water temperature (Table 7.12.1-3).

The effect of Delta inflow on water temperatures in the Delta is limited because water generally has warmed considerably by the time it reaches the Delta, approaching maximum values dictated by meteorological driven equilibrium values. As a result, substantial changes in flow may be needed to alter Delta inflow temperatures. In one study of Delta water temperatures, flow was not needed to produce accurate estimates of water temperature with statistical modeling, although the study noted that particularly high flows such as occurred during the winter of 1997–1998 could affect model accuracy (Wagner et al. 2011). Other studies indicate that water temperatures within the Delta may reach equilibrium values farther inland under low-flow conditions as a result of increased atmospheric forcing (i.e., longer residence time allows more time for meteorological conditions to affect water temperature) (Vroom et al. 2017; Gleichauf 2015) and that Delta water temperatures tend to be lower under average or high inflow conditions as compared to low inflow conditions (Jeffries et al. 2016; Gleichauf 2015). Effects of flow on Delta water temperature are complex; while lower flow may allow water temperatures to reach equilibrium farther inland, lower flow also may allow the cold ocean water to reach within the Delta (Gleichauf 2015).

Bashevkin and Mahardja (2022) found that Delta water temperature is positively or negatively correlated with Delta inflow depending on time of year and location within the Delta. These relationships are mediated by meteorology (Vroom et al. 2017; Bashevkin and Mahardja 2022) and snowmelt (Knowles and Cayan 2002). The summer period, when local precipitation is minimal, appears to be most influenced by upstream factors, whereas local precipitation and other meteorological conditions may influence much of the winter patterns (Bashevkin and Mahardja 2022).

Salinity and Electrical Conductivity

Multiple portions of the Delta are on the 303(d) list because of elevated salinity and/or EC levels (SWRCB 2022). In the Delta, the primary source of salt is seawater intrusion from San Francisco Bay. Higher freshwater outflow limits seawater intrusion to the Delta. Dry water year types with low runoff and smaller Delta outflow have greater seawater intrusion and higher Delta salinity. The Sacramento River and Delta eastside tributaries have low salt content and dilute the higher salinity found in the Delta. The San Joaquin River is an important influence on southern Delta salinity because of its higher salt content compared to the Sacramento River and its location in the far southern Delta near the CVP and SWP export pumps. Sacramento River EC is typically about 200 microSiemens per centimeter (μS/cm), whereas San Joaquin River EC at Vernalis usually ranges from 250 to 1,000 μS/cm, with the lower values occurring at higher flows (SWRCB 2018c).

In the Delta, flow modifications and physical diversion structures influence salinity patterns, with salinity affected by exports and floods. Salinity management in the Delta is a complex interplay between reservoir releases/tributary inflows and Delta exports, with the most important objective being maintenance of sufficient Delta outflow to repel tidal seawater intrusion. Reservoir releases/tributary inflows and SWP/CVP export pumping are managed jointly by the California Department of Water Resources (DWR) and U.S. Bureau of Reclamation (Reclamation) to control saltwater intrusion and meet salinity objectives in the Delta.

The Bay-Delta Plan has water quality objectives for protection of agricultural and fish and wildlife beneficial uses. Table 2 in the Bay-Delta Plan lists the water quality objectives for protection of agriculture. These objectives vary in duration and magnitude, depending on location and water year type, and include objectives for the western, interior, and southern Delta and Delta exports. Western Delta compliance stations are located on the Sacramento River at Emmaton and on the San Joaquin River at Jersey Point. Interior Delta compliance sites are on the Mokelumne River at Terminous and on the San Joaquin River at San Andreas Landing. Southern Delta compliance locations originally were point locations in the San Joaquin River at Vernalis and at Brandt Bridge, Old River near Middle River, and Old River at Tracy Boulevard. These compliance locations were modified in 2018 to include the San Joaquin River at Vernalis point location plus three river reaches (the San Joaquin River from Vernalis to Brandt Bridge, Middle River from Old River to Victoria Canal, and Old River/Grant Line Canal from head of Old River to West Canal) (Figure 7.12.1-1).

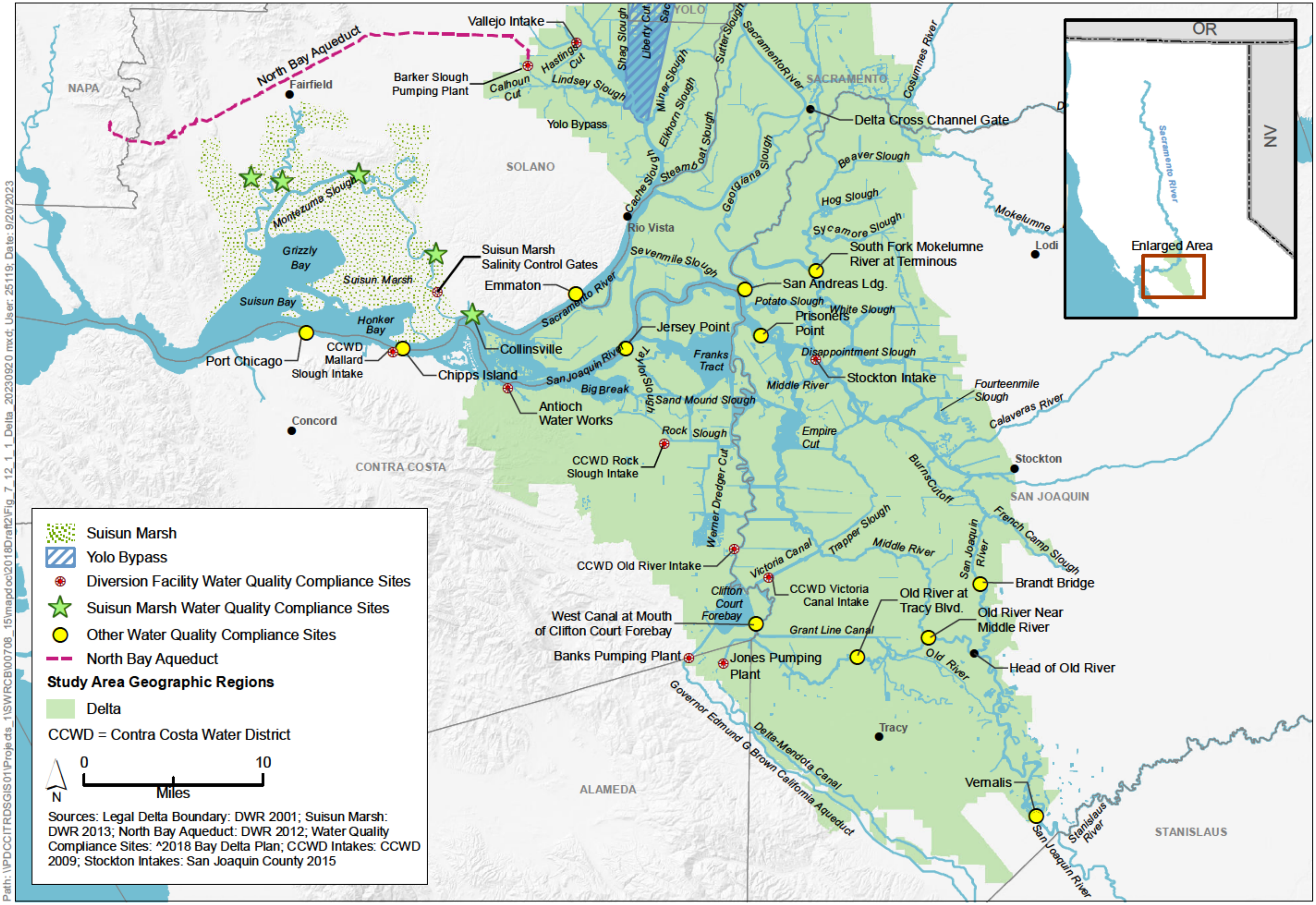

Figure 7.12.1-1
Water Quality Compliance Sites in the Delta Region

Table 3 of the Bay-Delta Plan contains the water quality objectives for protection of fish and wildlife beneficial uses, including an objective for the San Joaquin River between Jersey and Prisoner's Point to protect spawning and rearing habitat for striped bass and objectives to protect estuarine habitat in the eastern and western Suisun Marsh. The San Joaquin River objective applies between April and May in all water years. The Suisun Marsh objectives apply from October through May in all water years.

X2 often is used as an indicator of seawater intrusion. *X2* is defined as the horizontal distance in kilometers up the axis of the estuary from the Golden Gate Bridge to where the tidally averaged near-bottom salinity is 2 practical salinity units (^Jassby et al. 1995). Tables 3 and 4 of the Bay-Delta Plan also contain objectives for the position of X2 for the protection of fish and wildlife. In addition, X2 requirements are specified in the U.S. Fish and Wildlife Service (USFWS) 2008 and 2019 BiOps (^USFWS 2008 BiOp, ^USFWS 2019 BiOp) and the 2020 California Department of Fish and Wildlife Incidental Take Permit (^2020 ITP).

Chloride and Bromide

Chloride and bromide are constituents in the Delta that are related to salinity. Chloride salts give drinking water an unpalatable "salty" taste. Bromide is a component of salinity, although it makes up a much smaller percent of the salt (less than 0.2 percent for ocean salinity). Despite its relatively low concentration, bromide is a concern because, during treatment of drinking water, it is a precursor for the formation of carcinogenic disinfection byproducts, such as trihalomethanes, haloacetic acids, and bromate. Bromate forms when ozone is used to disinfect water. Trihalomethanes and haloacetic acids form when chlorine is used for disinfection in the presence of organic matter, which often is indicated by elevated dissolved organic carbon.

The Bay-Delta Plan has a chloride water quality objective to protect municipal drinking water beneficial uses. The drinking water (municipal) salinity objectives are given in units of chloride concentration (Table 1 of the Bay-Delta Plan). The chloride objective is generally 250 mg/L, with some periods (155–240 days during each calendar year) of 150 mg/L chloride at Antioch intake or at the CCWD Pumping Plant #1 on the Contra Costa Canal, which draws water from the western end of Rock Slough, which in turn connects with the Old River downstream of the Old River at Bacon EC station. No bromide water quality objectives exist for the Delta, but the CALFED Drinking Water Quality Program recommends a goal of 0.05 mg/L bromide at drinking water intakes (CALFED 2005).

The major source of chloride and bromide to the Delta is seawater intrusion (CALFED 2007). EC, chloride, and bromide concentrations have been extensively monitored in the Delta. Positive correlations exist between EC and chloride and EC and bromide (Suits 2001). The relationships are site specific and depend on the source water, but an EC concentration of 1,000 microSiemens per centimeter (μS/cm) corresponds to a chloride concentration of approximately 235 mg/L in the western delta (see Appendix A2, *Delta Simulation Model II* [*DSM2*] *Methods and Results*), and would, therefore represent a conservative value for achieving the chloride objective of 250 mg/L. An EC concentration of 1,000 μS/cm is correlated with a bromide concentration of about 0.8 mg/L, about an order of magnitude higher than the CALFED recommended goal of 0.05 mg/L.

Antioch is particularly susceptible to high salinity and chloride levels due to its proximity to the San Francisco Bay. The City of Antioch procures water for approximately 15 percent of its water use needs from the San Joaquin River when water quality in the river is adequate. The City can draw up to 16 million gallons per day from the river when the chloride concentration is below 250 mg/L

(Contra Costa County Local Agency Formation Commission 2007). The quality of the river water is usually dependent on net Delta outflow; in any given year, the City of Antioch stops drawing water in summer due to rising salinity levels. The city makes up the remainder of its water supply through a connection with CCWD. CCWD has an intake on Mallard Slough east of the Antioch intake that also is sensitive to net Delta outflow and is not used frequently for CCWD drinking water (CCWD 2010). Much of the remainder of the CCWD supply is secured from more interior portions of the Delta, where water often has lower salinity.

Nutrients, Harmful Algal Blooms, and Invasive Aquatic Vegetation

Microcystis was first observed in the Delta in 1999; since then, blooms have occurred annually at varying levels throughout the Delta. Abundance of *Microcystis* and the toxin, microcystin, have been greatest in August and September of dry years that were characterized by low streamflow and low turbidity and elevated water temperature and nutrient concentrations. (^Lehman et al. 2013) *Microcystis* is the most common HAB genus in the Delta and regularly occurs in multiple Delta channels (^Central Valley Water Board 2018a). Growth inhibition at higher salinity restricts HAB formation to the freshwater Delta.

Several studies indicate that low flows through the Delta are associated with increased HAB formation. HABs are more frequent and more severe in dry years (Hartman et al. 2022; Lehman et al. 2017). Retention time in the upper estuary (characterized by X2) and water temperature were key environmental correlates with the *Microcystis bloom* amplitude, and in regression models described 58 to 78 percent of the variation of the bloom surface biovolume or subsurface abundance (Lehman et al 2022). However, high-flow conditions such as occurred in 2017 do not prevent the formation of HABs (Lehman et al. 2022). In the southern Delta, blooms tend to be more severe when flows associated with Delta exports are low (Hartman et al. 2022).

Invasive aquatic plants are another category of problematic organisms in the Delta that thrive under conditions of low flow, low turbidity, and elevated water temperature and nutrient concentrations. High flows that increase velocity, depth, and turbidity can reduce occurrence of invasive aquatic vegetation, particularly non-rooted vegetation such as water hyacinth (Christman et al. 2023). A suite of nonnative plants has colonized the Delta (^Boyer and Sutula 2015). These plants include Brazilian waterweed (*Egeria densa*), water hyacinth (*Eichhornia crassipes*), water primrose (*Ludwigia* sp.), curly-leaf pondweed (*Potamogeton crispus*), and Eurasian watermilfoil (*Myriophyllum spicatum*) (^Ferrari et al. 2013; CDBW 2014; ^DSC 2013; ^Boyer and Sutula 2015). The most problematic nonnative aquatic plants are Brazilian waterweed and water hyacinth because of their ability to spread rapidly under the right environmental conditions, displacing native species, clogging waterways, altering turbidity, negatively affecting other aquatic species, and increasing diurnal fluctuations of pH and dissolved oxygen. The proliferation of Brazilian waterweed in the Delta in recent decades also has been implicated in the marked increase in abundance of largemouth bass and other nonnative fish species that prey on or compete with native species (^Brown and Michniuk 2007; Conrad et al. 2016). Herbicides are used to control large areas (hundreds of acres) of invasive aquatic plants, and physical removal is practical on a smaller scale (CDBW 2014).

A nutrient mass balance has been constructed for the Delta to determine how nutrients enter and leave the Delta (Tetra Tech 2006). The major sources of nutrients are the Sacramento and San Joaquin Rivers. The major sinks are Delta outflow to San Francisco Bay and exports south of the Delta. In addition, the Delta is a sink for both nitrogen and phosphorous as a result of algal and aquatic plant growth. The primary sources of nutrients in the Sacramento and San Joaquin Rivers are point-sources (e.g., WWTPs), runoff from forest and rangeland, and agricultural return flows. The highest nutrient concentrations occur in fall and winter when sediment flux and rainfall runoff are high (^Dahm et al. 2016).

The 2013 Delta Plan recommended that the State Water Board, San Francisco Bay Water Board, and Central Valley Water Board prepare a nutrient study plan to determine whether nutrient water quality objectives were needed for the Delta (^DSC 2013). The Central Valley Water Board assembled panels of HAB and invasive aquatic plant experts to prepare white papers describing the state of the science and identifying and prioritizing research recommendations. The white papers concluded that nutrient concentrations were not responsible for variability in HAB occurrence and growth of invasive aquatic vegetation in the Delta, although nutrient supply may affect duration and severity of HABs. For both HABs and invasive aquatic vegetation, the experts cautioned, based on their experience elsewhere, that nutrient management might not decrease the impairments and recommended follow-up studies to confirm their hypotheses (^Boyer and Sutula 2015; ^Berg and Sutula 2015). Recommendations for follow-up studies included routine monitoring of cyanobacteria and invasive aquatic vegetation and ecosystem modeling of biogeochemical processes focused on fate and transport of nutrients and organic carbon, including primary productivity of algae and cyanobacteria, and special studies that may be required for determining key information for ecosystem modeling. These and additional recommendations are included in the Central Valley Water Board's 2018 Delta Nutrient Research Plan (^Central Valley Water Board 2018a).

Nutrient concentrations are expected to decline in the Delta. The Sacramento Regional Wastewater Treatment Plant (SRWTP) and City of Stockton Regional Wastewater Control Facility (WCF) are the two largest WWTPs discharging to the Delta. In the past, the SRWTP contributed over 90 percent of the Delta's ammonium load (^Jassby 2008). The SRWTP has been upgraded to reduce ammonium loads by 95 percent and substantially reduce inorganic nutrients overall (^Dahm et al. 2016). The City of Stockton Regional WCF is also being upgraded and will reduce nitrogen loads by 2024 by about 25 percent (LWA 2017). Increased recycling of treated WWTP effluent also will reduce nutrient concentrations in waterbodies. Finally, restoration of wetlands has been identified as a high priority for California's EcoRestore program. Wetlands are efficient denitrifiers and phosphorus traps, and their restoration is expected to reduce nutrients in the Delta (^Dahm et al. 2016).

Total Suspended Solids and Turbidity

Overall, the Bay-Delta is depositional, trapping and sequestering most of the incoming material (^Schoellhamer et al. 2016). TSS and turbidity concentrations in the Delta are mostly determined by incoming material from tributaries and by submerged aquatic vegetation. TSS and turbidity affect multiple important biological processes in the Bay-Delta, including algal primary production, HABs, growth of submerged aquatic vegetation, spawning and rearing habitat for Delta smelt, and emigration success of juvenile salmonids. For Delta smelt, increased turbidity enhances feeding of young smelt (^Hasenbein et al. 2013) and provides refuge from predators (^Nobriga et al. 2008). Increased turbidity also reduces predation on young salmon (de Robertis et al. 2003).

Mercury

Mercury used in gold mining resulted in widespread mercury contamination in watercourses, including the Delta, and consequently in fish. Throughout the Delta, higher concentrations of mercury have been observed in the east, including the Cosumnes River, compared to interior locations such as Franks Tract (Marvin-DiPasquale et al. 2007; Melwani et al. 2009). Mercury concentrations in sport fish in the Delta frequently exceed the Central Valley Water Board TMDL target goal (the water quality goal expressed as fish tissue concentrations) of 0.24 milligrams of mercury per kilogram wet weight for large trophic-level 4 fish such as bass and catfish (Melwani et al. 2009).

Dissolved Oxygen in Stockton Deep Water Ship Channel

The Stockton Deepwater Ship Channel has experienced regular periods of low dissolved oxygen that resulted in fish kills and delayed upstream migration of fall-run Chinook salmon (^McConnell et al. 2015). The Central Valley Water Board adopted a low dissolved oxygen TMDL, which was approved by USEPA in 2007 (Central Valley Water Board 2005). The TMDL found that low dissolved oxygen resulted from loads of upstream oxygen-demanding substances, reduced flow through the Deepwater Ship Channel, and increased residence time because of channel geometry. The TMDL implementation plan included reductions in point- and nonpoint-source loads of oxygen-requiring substances and a requirement to assess the feasibility of operating an experimental aeration facility in the Stockton Deepwater Ship Channel. The City of Stockton Regional WCF was upgraded in 2007, reducing its ammonium load of oxygen-requiring material. An assessment of the experimental aeration demonstration project was completed in 2011 and demonstrated that aeration improved dissolved oxygen conditions without any redirected effects. Interim voluntary agreements have provided funds for operation and maintenance of the aeration facility.

The upgrade to the City of Stockton Regional WCF and operation of the aeration facility have significantly improved dissolved oxygen conditions in the Deepwater Ship Channel (^McConnell et al. 2015). The dissolved oxygen water quality objective has been violated less than 1 percent of the time since 2013, when both the WWTP and aeration facility became operational. The low dissolved oxygen TMDL was reviewed by the Central Valley Water Board in 2015 (^McConnell et al. 2015). The Central Valley Water Board determined that the present control program should continue, including use of the aeration facility to maintain channel oxygen levels above the water quality objective.

Dissolved Oxygen and Mercury in Suisun Marsh

Suisun Marsh is approximately 116,000 acres with about half of the marsh diked and operated as duck clubs. The diked wetlands are flooded in fall for vegetation control. Subsequent discharge of this water, laden with decaying organic material, causes oxygen sags in adjoining channels, which kills fish and impairs wildlife. Water depleted of oxygen and laden with organic matter also enhances methylmercury production and bioaccumulation. The northwest portion of Suisun Marsh is listed on the 303(d) list as impaired by low dissolved oxygen/organic enrichment and mercury (SWRCB 2022).

The San Francisco Bay Water Board has developed a TMDL to address low dissolved oxygen/organic enrichment and mercury impairments in Suisun Marsh; the TMDL was adopted in April 2018. The TMDL determined that the primary sources of oxygen-requiring substances to Suisun Marsh were discharges from the Fairfield-Suisun Sewer District and managed wetlands. The Central Valley was not a large source of oxygen-requiring material to the marsh. The TMDL also determined the major sources of mercury: the Central Valley and Delta were the largest source of inorganic and methylmercury to Suisun Marsh.

The TMDL is implemented through a Clean Water Act section 401 water quality certification for the U.S. Army Corps of Engineers (USACE) regional general permit, with actions coordinated by the

Suisun Resource Conservation District. The certification authorizes permittees to manage wetland operations and maintenance activities. Required BMPs on diked wetlands include control of sources of oxygen-requiring substances and methylmercury production, coordinating a staggered flooding and discharge schedule to avoid simultaneous releases of low dissolved oxygen from multiple clubs into the same slough, and monitoring to assess progress in meeting water quality objectives in Suisun Marsh and adjoining sloughs. Early implementation of the TMDL through incorporation of BMPs in the 2013–2017 USACE general permit has resulted in improved water quality conditions and significant reductions in the duration and frequency of episodes of low dissolved oxygen. Since early implementation began, there have been no fish kills. Mercury reductions and control in Suisun Marsh are implemented by extending objectives of the 2006 San Francisco Bay Mercury TMDL to Suisun Marsh. (San Francisco Bay Water Board 2018).

Other Constituents

A variety of bioaccumulative contaminants are found throughout the Delta, including PCBs. Water quality sampling surveys from 2011 and 2012 indicate widespread occurrence of several agricultural pesticides, including insecticides, herbicides, and fungicides, throughout the Delta. Over 100 types of pesticides are commonly used on the agricultural lands upstream of and in the Delta and in urban areas and are transported in runoff to Delta waters. Herbicides and insecticides are applied directly to Delta waterways for aquatic plant and mosquito control. Portions of the Delta are on the 303(d) list as impaired for pesticides, including dieldrin, chlordane, diazinon, and chlorpyrifos (SWRCB 2022). Pyrethroid insecticides also were found in the Delta due to urban runoff, municipal WWTPs, and agricultural discharges (^Weston and Lydy 2010). Pesticide transport is influenced by the timing of pesticide applications and by rainfall, runoff, and streamflow conditions.

San Francisco Bay Area

San Francisco Bay is a large saltwater embayment receiving fresh water from the Central Valley through the Delta. San Francisco Bay has many of the same water quality concerns as the Central Valley and Delta because the surrounding watersheds have many of the same land uses and runoff issues and because Delta outflow transports contaminants from the Central Valley and Delta downstream to San Francisco Bay. Water from San Francisco Bay is unsuitable for drinking water supply due to high salinity.

Some problematic constituents for San Francisco Bay include legacy contaminants and mercury. PCB contamination generally is associated with industrial areas and urban runoff throughout the Bay Area. Several other legacy contaminants still present in the Bay-Delta watershed include organochlorine pesticides such as DDT, chlordane, and dieldrin. Other problematic constituents include flame retardants, perfluorinated compounds, nonylphenol fipronil, pharmaceuticals, dioxins/furans, and selenium.

Selenium

Northern San Francisco Bay was placed on the 303(d) list because selenium exceeded thresholds of concern in fish and wildlife, and health advisories had been issued warning hunters to limit consumption of diving ducks (San Francisco Bay Water Board 2015). Bioaccumulation and toxicity of selenium are discussed in Chapter 4, *Other Aquatic Ecosystem Stressors*.

A TMDL addresses impairments in Suisun, San Pablo, and Central Bays. The TMDL determined that the two largest anthropogenic sources were petroleum refineries and subsurface agricultural drainage from the western San Joaquin Valley. USEPA approved the TMDL in 2016. Load reductions at petroleum refineries were achieved through enhanced selenium treatment mandated by NPDES permits (San Francisco Bay Water Board 2015).

Selenium impairment in the northern San Francisco Bay also is being addressed by implementation of the San Joaquin Valley selenium TMDL, which has substantially reduced the amount of selenium entering the Delta (Central Valley Water Board 2010b; USEPA 2015).

Imported Water Supply

Some of the Bay Area water supply comes from local sources. However, local water is insufficient to meet full demand, so several large importers also supply municipal water for the Bay Area. CCWD imports Delta water and stores water in Los Vaqueros Reservoir. Water quality in Los Vaqueros Reservoir is largely affected by water quality in the Delta and shares some of the same water quality impairments, including mercury. Napa County and southern Solano County receive SWP imports from the North Bay Aqueduct, which is subject to water quality conditions in the Delta at the canal intake at Barker Slough. Southern Solano County also receives water from Putah Creek through Putah South Canal. Anderson Reservoir on Coyote Creek and Lake Del Valle on Arroyo Valle are additional Bay Area water supply reservoirs that receive Delta water. The Santa Clara Valley Water District (Valley Water) receives CVP water from San Luis Reservoir, which is described under *Central Coast and Southern California*.

EBMUD imports water from the Mokelumne River and, during dry conditions, the Sacramento River at Freeport. EBMUD stores water in Briones, Lafayette, San Pablo, Upper San Leandro, and Chabot Reservoirs. Although the lower Mokelumne River is listed as being impaired by mercury, Mokelumne River water is generally high quality. During dry conditions, however, EBMUD has had some taste and odor problems associated with algal growth in reservoirs. This algal growth was partly attributed to a change in water supply that included use of Sacramento River water and a higher intake in Pardee Reservoir in order to preserve a cold water pool (EBMUD 2015). Although algae are filtered out during water treatment, taste and odor compounds, such as geosmin and 2-methylisoborneol, can remain.

San Joaquin Valley

The western and southern portions of the San Joaquin Valley floor receive Sacramento/Delta water from the CVP and SWP. This water is used primarily for agricultural purposes in these portions of the San Joaquin Valley and, as such, affects the quantity and quality of agricultural return flows. In addition, the Friant Division service area provides water from the upper San Joaquin River to more than 1 million acres of irrigable farmland and delivers municipal water to Fresno and several other disadvantaged communities (Friant Water Authority 2018; CARB 2018).

Generally, water quality problems in streams on the San Joaquin Valley floor result from salt loading from agricultural drainages and nutrients from municipal, industrial, and agricultural sources. Elevated selenium along the western side of the San Joaquin Valley generally co-occurs with elevated salinity. Major sources of selenium in the San Joaquin River stem from agricultural lands' runoff, which originates in the western San Joaquin Valley. The San Joaquin River basin is made up of seleniferous soils that are high in selenium and salts. The irrigation of these soils for agriculture leaches selenium and salt into shallow groundwater, which in turn is drained by farmers to protect crops (Central Valley Water Board 2001).

Downstream of Friant Dam, water quality in the San Joaquin River is degraded during summer and fall due to upstream diversion of the natural flow and from the large volumes of drainage, wastewater, and return flows. Diversion of the natural flow at Friant Dam lessens the ability of the lower San Joaquin River to assimilate the poor-quality discharges below Friant Dam. Delta water is also exported at the CVP pumping facilities in the southern Delta for agricultural use in the San Joaquin Valley on marine soils with high salt content. Agricultural return flows in the San Joaquin River contain higher salt levels than the water initially pumped south. Salt loads are a problem primarily under low-flow conditions when adequate dilution water is not available. Although the water in the lower San Joaquin River is still usable for agriculture, when salt concentrations exceed certain thresholds, severe crop damage can result.

During low-flow periods, discharges from north Mud Slough and Salt Slough can affect the quality and quantity of the San Joaquin River flows. Mud and Salt Sloughs are made up of agricultural return flows, wetland releases, and groundwater seepage, which typically can contain elevated levels of EC, boron, and selenium (Central Valley Water Board 1998). The Grassland Bypass Project, operated by Reclamation and the San Luis & Delta-Mendota Water Authority, utilizes a section of the San Luis Drain to divert agricultural tile drainage from the Grassland Drainage Area into Mud Slough and away from Salt Slough and nearby wildlife refuges and wetlands. Since its implementation in 1996, the Grassland Bypass Project has successfully reduced selenium and salt loads in the Grassland Drainage Area and Salt Slough (Reclamation 2017).

Westlands Water District is illustrative of the salinity issues along the western side of the San Joaquin Valley, which receives Sacramento/Delta supply. Inadequate drainage exists at many of Westlands Water District's irrigated farms because the farms lack natural drainage outlets (^Westlands Water District n.d.(a)). In some areas, a layer of impermeable clay traps irrigation water (^Westlands Water District n.d.(b)). Because the irrigated water does not have an outlet, salts originally present in the native soil, salts transported to farm sites in the irrigation water, and salts in fertilizer used at the site remain in the soil and are not flushed out through drainage as they would be at other sites with adequate drainage (University of California Agricultural Issues Center 2009). When salt levels become too high, crops become unable to take up water, and crop yields are negatively affected. The cumulative effect on soils and crop yields led to a political and economic decision to retire a minimum of 100,000 acres of land from agricultural production (^Reclamation 2015). As of 2017, Westlands Water District had retired approximately 40,000 acres of farmland because the soil had become too saline for growing food, and another 50,000 acres of land were to be farmed with dryland farming methods (^Benson 2017). Elevated salt and selenium remain a problem.

Grasslands Ecological Area

The Grasslands Ecological Area is a vast complex of wetland and upland habitat in the San Joaquin Valley composed of private, state, and federal conservation lands. It includes private duck club land, Great Valley Grasslands State Park, several state wildlife areas (Volta, Los Banos, and North Grasslands), and USFWS lands (San Luis and Merced National Wildlife Refuges and Grasslands Wildlife Management Area) (Audubon Society 2010). The water supply for the Grasslands Ecological Area includes CVP surface water supply, pumped groundwater, and agricultural drainage (Reclamation 2014; Grasslands Resource Conservation District 2011). Groundwater levels in much of this area are close to the ground surface (DWR 2018a), potentially helping to limit percolation losses.

Grasslands Ecological Area marshes are on the 303(d) list as impaired by elevated salinity and selenium, partly due to the natural condition of soils and groundwater in the area, but this condition has been exacerbated by agricultural drainage. The area includes the former site of Kesterson Reservoir, where accumulated agricultural drainage water had selenium levels that were high enough to cause birth defects in waterbirds. Cleanup and filling of Kesterson Reservoir and construction of the Grassland Bypass Project have helped improve conditions, but salinity and selenium problems remain.

San Luis Reservoir

San Luis Reservoir is the first major reservoir where CVP and SWP Delta export water is stored after it has left the Delta. The reservoir is in coastal mountains on the western flank of the San Joaquin Valley. The San Luis Reservoir complex is an off-channel facility used to store and distribute irrigation, refuge, and potable water supplies to the Bay Area, the San Joaquin Valley, the Central Coast, and Southern California regions. Conditions at San Luis Reservoir promote the growth of algae during summer months. Algae blooms vary in size among years but generally reach diversion facilities when the reservoir has 300 thousand acre-feet (TAF) of water remaining in storage. Reservoir water with algal blooms is not suitable for agricultural water users with drip irrigation systems in San Benito County or for municipal water users relying on existing water treatment facilities in Santa Clara County. (73 Fed. Reg. 50998 (August 29, 2008)) Valley Water receives water supplies from San Luis Reservoir through the San Felipe Division of the CVP. The intake for the San Felipe Division is on the western side of the reservoir, which is higher in elevation and more susceptible to algae production near the surface.

Central Coast and Southern California

The Central Coast and Southern California regions receive Sacramento/Delta water, primarily SWP water via the Coastal Branch Aqueduct and the California Aqueduct, in addition to CVP water provided to areas in the northern Central Coast via San Luis Reservoir. Water quality in the reservoirs receiving Sacramento/Delta supply (export reservoirs) is affected by Delta water quality as well as processes within the reservoirs that may be affected by reservoir water supply. Much of the water stored in these reservoirs is used for municipal purposes in portions of the regions.

Major export reservoirs receiving Sacramento/Delta supply from the Coastal Branch Aqueduct in the Central Coast and the California Aqueduct in Southern California are Lakes Cachuma, Piru, and Perris and Pyramid, Castaic, Silverwood, and Diamond Valley Lakes. All of these reservoirs can receive inflow from the SWP, and most of these reservoirs receive a large portion of water from the SWP and/or the Colorado River rather than water originating in reservoirs' watersheds (^DWR and LADWP 2016; ^DWR 2016a, Reclamation 1999).

Lake Cachuma and Castaic, Pyramid, and Silverwood Lakes are on the 303(d) list for elevated mercury. Factors contributing to increased fish tissue mercury concentrations in lakes and reservoirs are discussed under *Water Quality Concerns*. HABs also have been reported from several of these export reservoirs, including Lake Cachuma and Pyramid, Castaic, and Silverwood Lakes (California Water Quality Monitoring Council 2018).

Water in the streams downstream of these reservoirs can be affected by reservoir water quality. Most of these reservoirs are on small creeks with low or intermittent flow. Some of these streams are included on the 303(d) list of impaired waterbodies. For example, many streams have impairments with constituents covered in Table 7.12.1-3: Santa Margarita River, Mojave River, and Piru Creek have salinity impairments; the Santa Margarita River and Warm Springs Creek have nutrient impairments; the Santa Clara River has low dissolved oxygen, salinity, selenium, and temperature impairments; and the Santa Ynez River has low dissolved oxygen, nutrient, salinity, sediment, and temperature impairments.

Many small streams in the Southern California region do not directly receive Sacramento/Delta water. Flow in some of these streams often is minimal; and nonnatural sources of water, such as treated wastewater, urban runoff, and agricultural drainage, can sometimes contribute a relatively high percentage of the total water in the stream.

Flood Risk, Erosion, and Channel Processes

Major floods are common in the Sacramento/Delta watershed. Slow-rise flooding is the most common type of flooding, involving gradual inundation from heavy precipitation or snowmelt that causes waterways or lakes to overflow their banks. In addition, many miles of old and new levees have resulted in a high incidence of floods due to levee failure. Extreme rainfall events during winter result in rapid increases in flows and extremely high peak flows in river and stream channels. Both the Yuba and Feather Rivers are "flashy" systems that quickly rise and recede in the upper watersheds and canyons. Flooding within the North Sacramento Valley region is also largely attributed to heavy winter rains. Flows to the Delta arrive through the Sacramento, San Joaquin, and Mokelumne Rivers, historically forming a natural floodplain at lower elevation, which now contains numerous flood control facilities such as levees, weirs, and flood bypasses. The Delta levees are vulnerable due to poor construction, and levee failure could result from structural failure (e.g., caused by earthquakes, subsidence, and/or seepage) or overtopping of levees (e.g., due to high flow, high tides, high wind, and/or sea-level rise) (Suddeth et al. 2010). Since building of the levees, floods have become less frequent and more damaging (^2013 Water Plan V2, Sacramento River,). From 1985 to 1999, several record-breaking hydrological events occurred in the Yolo Bypass, including two record-breaking floods and a record number of consecutive years with and without inundation (^CDFG 2008).

The Federal Emergency Management Agency (FEMA) determines 100-year flood hazard areas, also known as Special Flood Hazard Areas. These areas are estimated to be at risk of inundation by a flood event that has a 1-percent chance of being equaled or exceeded in any given year. These areas are determined using levee quality information and hydrologic data. Figure 7.12.1-2a and Figure 7.12.1-2b show where sections of the study area are within the FEMA 100-year flood hazard areas. Sections of the study area most sensitive to flooding are low-lying areas adjacent to the Sacramento River, the Feather River, the Delta, and other tributaries and reservoirs. Some areas have flood hazards that have not been determined.

California's highly variable hydrologic pattern was demonstrated when the 2013–2015 drought was followed closely by the wettest water year on record. The storms of late 2016 through February 2017 caused local flooding and high water in major streams. More than 100 incidents in California were reported by the State-Federal Flood Operations Center by mid-March 2017. Most incidents, including boils, seepages, sloughing, bank erosion, overtopping, slippage, levee breaks, and local flooding, were addressed by local agencies. Several reservoirs encroached their flood reservation pool from the heavy precipitation and high reservoir inflows. In February 2017, erosion was discovered on the lower chute of the main flood control spillway at Oroville Reservoir. Following restricted use of the main spillway and continued substantial inflow to the reservoir, the reservoir overtopped the concrete weir at the emergency spillway for the first time ever, which resulted in erosion of the emergency spillway, a need to increase flow over the damaged main spillway, and cautionary evacuation of downstream communities (DWR n.d.).

Regional Flood Risk

The Sacramento River watershed has been subject to floods that result from winter and spring rainfall as well as combined rainfall and snowmelt. As the Sacramento River travels to the Delta, it picks up additional flows from its two largest tributaries, the Feather and American Rivers. Cottonwood Creek, entering the Sacramento River near the town of Cottonwood, is the largest tributary on the west side of the Sacramento River watershed that enters the river directly and is the only large tributary that is uncontrolled. Other significant westside tributaries include Cache, Putah, and Stony Creeks. Stony Creek enters the Sacramento River east of the city of Orland. Cache and Putah Creeks enter the Yolo Bypass, which discharges to the Sacramento River near Rio Vista. Tributaries on the east side of the Sacramento River are influenced greatly by snowmelt, whereas flood runoff in the westside tributaries has negligible influence from snowmelt. Tributary flows from numerous small creeks, primarily those draining the western slopes of the Cascade Range and the Sierra Nevada, feed the Sacramento River. Clear Creek is unique because flow on Clear Creek is affected by a trans-basin diversion that supplies water to Whiskeytown Lake within the Clear Creek watershed. Clear Creek natural flows are moved through the Spring Creek Tunnel that carries water from Whiskeytown Lake to Keswick Reservoir on the Sacramento River, with very little water being released to Clear Creek downstream of Whiskeytown Lake.

Along the stretch of river between Red Bluff and Chico Landing, flows accumulate as major tributaries enter from the east side—Antelope, Mill, Deer, Big Chico, Sycamore-Mud, Rock, and Pine Creeks—and from the west side—Thomes, Elder, Reeds, and Red Bank Creeks. These tributaries influence Sacramento River flows during storms. Through the valley floor reach, the Sacramento River is flanked by overflow basins, two of which (the Sutter and Yolo Bypasses) are leveed floodways.

A complex system of dams and associated reservoirs, levees, weirs, bypasses, and other features have been constructed over the last 150 years to help manage flooding along the Sacramento River. Table 7.12.1-4 shows major reservoirs in the Sacramento River watershed, most of which have flood control responsibilities. Reservoir operations are guided by flood control rule curves, which define the volume of flood space necessary during different months of the year. USACE is responsible for prescribing regulations for the use of storage allocated for flood control at certain reservoirs. (33 C.F.R. § 208.11.) Water control plans govern the use of reservoir storage space allocated for flood control. Reservoirs in the Sacramento/Delta watershed that are subject to this regulation include Camanche Dam and Reservoir (Mokelumne River), Folsom Dam and Reservoir (American River), Indian Valley Dam and Reservoir (Cache Creek watershed), New Bullards Bar Dam and Reservoir (Yuba River watershed), Oroville Dam and Reservoir (Feather River watershed), and Shasta Dam and Reservoir (mainstem Sacramento River).

Water storage in reservoirs that are operated in part for flood management purposes is reduced gradually before the flood season begins in October and November. Reservoirs are operated throughout winter and spring to reduce flood potential and replenish storage toward the end of the

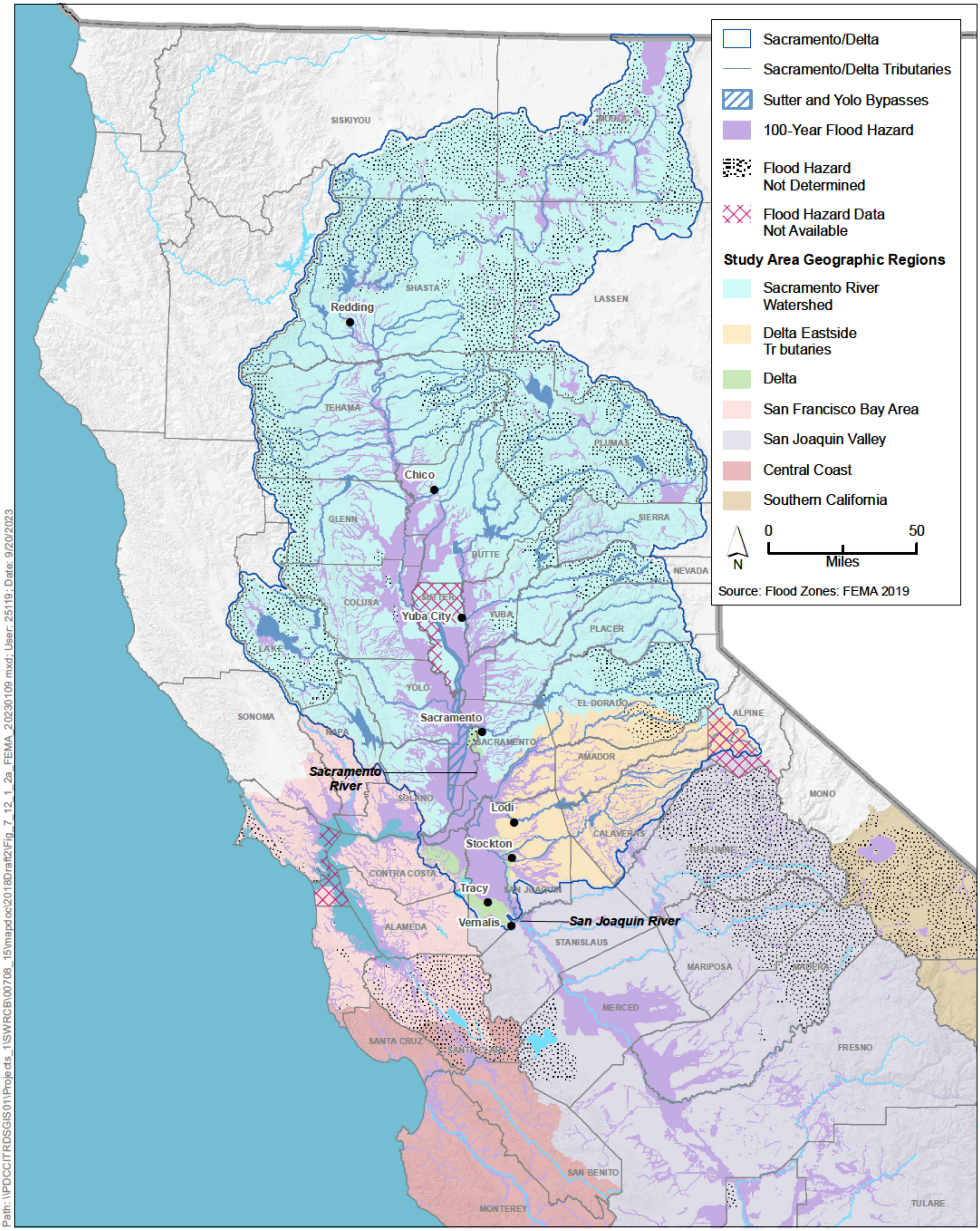

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Figure 7.12.1-2a
FEMA 100-Year Flood Hazard (northern)

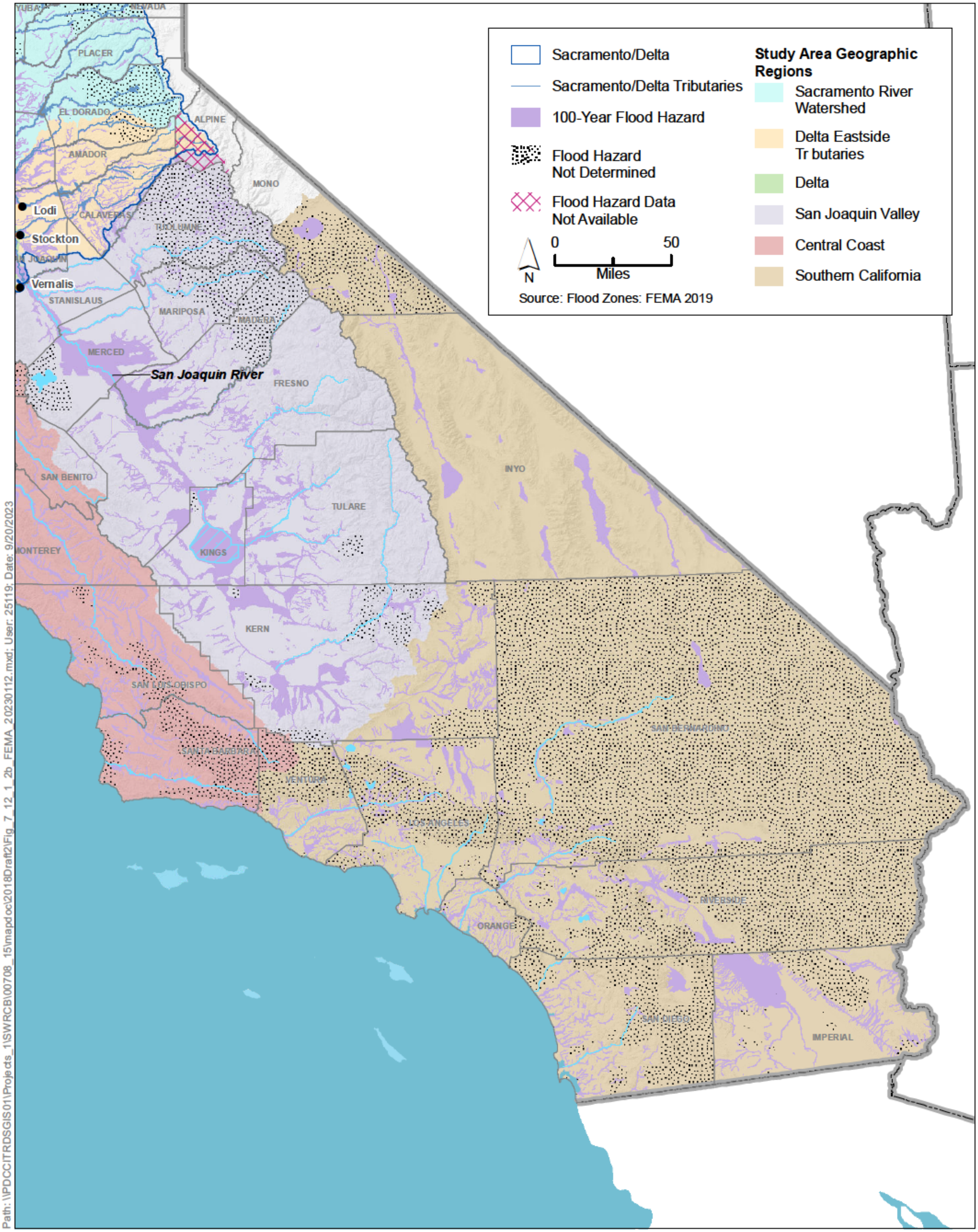

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Figure 7.12.1-2b
FEMA 100-Year Flood Hazard (southern)

flood season, in March and April. The reservoirs are operated in a coordinated manner to reduce the potential for peak flows from multiple tributaries to simultaneously reach the same location downstream, by timing releases based on water's travel time from the reservoirs to the Delta. Travel time to the Delta varies from 5 days from Shasta Dam, to 3 days from Oroville Dam and New Bullards Bar Dam, to 1 to 2 days from Folsom Reservoir.

Table 7.12.1-4. Sacramento River and Tributary Reservoirs

Reservoir Name	River/ Stream	Type of Dam	Storage (TAF)	Maximum Flood Control Storage (TAF)	Owner	Year Constructed
Shasta Reservoir	Sacramento River	Gravity	4,552	1,300	Reclamation	1945
Black Butte Lake	Stony Creek	Earth	144	137	USACE	1963
New Bullards Bar Reservoir	Yuba River	Double curvature arch	970	170	YCWA	1970
Oroville Reservoir	Feather River	Earth	3,538	750	DWR	1967
Clear Lake	Cache Creek	Gravity	1,155	0	YCFCWCD	1914
Indian Valley Reservoir	North Fork Cache Creek	Earth	301	40	YCFCWCD	1976
Folsom Reservoir	American River	Gravity	977	400-600	Reclamation	1956
Lake Berryessa	Putah Creek	Variable radius arch	1,602	0	Reclamation	1957

Sources: Northern California Water Association 2023a.; Northern California Water Association 2023b; YCWA 2014; DWR 2010; ^2022; ^SacWAM 2023; Stork et al. 2017.

DWR = California Department of Water Resources; EBMUD = East Bay Municipal Utility District; Reclamation = U.S. Bureau of Reclamation; TAF = thousand acre-feet; USACE = U.S. Army Corps of Engineers; YCFCWCD = Yolo County Flood Control and Water Conservation District; YCWA = Yuba County Water Agency.

On the Sacramento River, the primary flood control features are Shasta Reservoir and the federally authorized Sacramento River Flood Control Project (SRFCP). Shasta Reservoir provides flood control to the upper Sacramento River by providing 1,300 TAF of flood control storage. The reservoir is managed for flood control from October 1 through March 30 and sometimes maintains part of its flood reservation into May. The reservoir is operated to open the full flood reservation by December 1; flood space is reduced starting in late December to late March, depending on basin hydrologic conditions, to balance flood management with storing water supplies from snowmelt in spring. Downstream channel capacities and flood bypasses are important considerations in operation of the system. The SRFCP area that spans from Red Bluff to Verona (north of Sacramento on the Sacramento River) includes levees, cleared channels, bypasses, and overflow flood control facilities. The natural Sutter Bypass overflow area east of the river is used to convey high flows from the main channel, with flows entering the bypass through the Moulton, Colusa, and Tisdale Weirs. Flow from the Sutter Bypass reenters the main channel near the confluence with the Feather River; from that point, high flows are conveyed over the Fremont Weir into the Yolo Bypass to the west of the main channel. Yolo Bypass also receives flow over the Sacramento Weir near the confluence with the American River and ultimately drains back into the Sacramento River near Rio Vista in the Delta.

The mainstem of the Feather River is regulated by Oroville Dam. Oroville Reservoir's original flood control protocol developed by USACE calls for flood control storage volume between 375 and 750 TAF, depending on month and hydrologic conditions. Following the damage that occurred to the reservoir spillways in 2017, DWR adjusted flood control operations for enhanced flood protection during completion of repairs (DWR 2017). Pursuant to USACE's flood control regulations, the maximum controlled release capacity is 150,000 cubic feet per second (cfs). The right bank (looking downstream) of the Feather River is leveed downstream of the Thermalito Afterbay to Honcut Creek. Both banks of the river are leveed downstream of Honcut Creek. These levees and the river are part of the SRFCP. From Oroville Reservoir, the Feather River flows south through the Sacramento Valley where it is joined by two major tributaries. The Yuba River joins the Feather River at Marysville; the Bear River confluence is approximately 15 miles farther downstream. The lower Feather River joins the Sacramento River near where the Sutter Bypass and Yolo Bypass also connect with the Sacramento River, so high flows from the Feather River can enter the Yolo Bypass and move from there downstream to the Delta.

Folsom Reservoir on the American River has a maximum capacity of approximately 1 million acre-feet (USACE 2017) and is located approximately 15 miles northeast of Sacramento, near Folsom. Folsom Reservoir's full flood reservation varies from 400 to 600 TAF (USACE 2017), with more space required when three upstream reservoirs (Hell Hole, French Meadows, and Union Valley) are close to capacity. The maximum flood reservation was reduced from 670 to 600 TAF under USACE's water control manual update, prompted by completion of a new auxiliary spillway with increased capacity to convey floodwaters (USACE 2017). Because of its relative proximity to the Delta, and because the American River provides a large flow contribution to the Delta, Folsom Dam's operation also can influence Delta flood management. Floodwaters from the American River are diverted over the Sacramento Weir through the mile-long Sacramento Bypass into the Yolo Bypass. The American River downstream of Carmichael Bluffs is part of the SRFCP.

The Mokelumne and Calaveras Rivers flow into the lower San Joaquin River within the boundaries of the Delta. Table 7.12.1-5 shows the major reservoirs on the Delta eastside tributaries. The Cosumnes River originates in the lower elevations of the Sierra Nevada and enters the Mokelumne River within the Delta. Because no flood management projects exist in the basin, flood flows are uncontrolled on this river. Flooding on the Cosumnes River affects the towns of Thornton and Wilton, as well as adjacent agricultural communities. Because of the low elevation of its headwaters, the Cosumnes River receives most of its water from rainfall. The Mokelumne River originates at an elevation of approximately 10,000 feet in the Sierra Nevada. A total flood reservation of 200 TAF must be maintained in Pardee and Camanche Reservoirs combined, with most of that space normally held at Camanche Reservoir. The Calaveras River and its basin are entirely below the effective average snowline (5,000 feet), so it receives nearly all of its flow from rainfall. The major water management facility on the Calaveras River, New Hogan Dam and Lake, is operated for flood management and, when possible, for water supply.

Table 7.12.1-5. Delta Eastside Tributaries Reservoirs

Reservoir Name	River	Type of Dam	Storage (TAF)	Maximum Flood Control Storage (TAF)	Owner	Year Constructed
Pardee Reservoir	Mokelumne River	Gravity	210	NA [a]	EBMUD	1929
Camanche Reservoir	Mokelumne River	Rockfill	417	200 [a]	EBMUD	1963
New Hogan Lake	Calaveras River	Rockfill/Earth	317	165	USACE	1963

Sources: USACE 2021a, b, c; ^SacWAM 2023.

EBMUD = East Bay Municipal Utility District; NA = not applicable; TAF = thousand acre-feet; USACE = U.S. Army Corps of Engineers

[a] A total of 200 TAF of flood space is required at Pardee and Camanche Reservoirs combined, but most space is usually held at Camanche Reservoir (DWR 2022a).

Flood control in the Delta is a unique effort with unique problems. Many of the islands that make up the Delta are founded on peat soils, which are highly organic in composition and are susceptible to decomposition by microorganisms. Over time, the peat soils are consumed by the microorganisms and the surface of the island subsides. The subsidence has been considerable in some places, leading to an interior surface elevation of many islands that is lower than the water level in the Delta waterways surrounding it. In some places the land surface is 25 feet below sea level.

Peat soils are also highly compressible, so they are not ideal for foundational structural stability for the levees. As weight is placed on the levees to raise their height, cracks sometimes form because of differential settling. Levees also are targeted by burrowing animals, which can weaken the levee.

Floodwater levels in the Delta are influenced by both tides and river flow. Flow influences river stage close to the mainstem of the river, whereas tides are the major influence in the western Delta near Chipps Island. High tides and flows increase pressure on levees by increasing the height of the water the levee must hold back. High water, while adding pressure to a levee protecting an island, also contributes to wave wash—wind-generated waves hit a levee and wash water over the crest of the levee, eroding the backside of the levee as the water runs off. The eroded levees then cannot withstand as much pressure as the fully intact levee. High water also increases seepage through and under the levee. Levees, which are made of soil, become saturated when in constant contact with water. Higher water levels for extended periods of time increase the seepage, which also can damage levees.

Levees in the Delta were first constructed around 1848 to reclaim Delta islands from continual flooding caused by tides and seasonal river flooding. The islands were put into agricultural service to meet the needs of the Gold Rush. Wet weather in winter would often overtop the levees. Congressional and legislative acts added funding to incentivize the creation of reclaimed lands in the Delta. As channels were dredged by machine, the levees' size and height prevented flooding in most years, except when occasional levee failures occurred. The first flood management plan developed by the California Debris Commission in 1907 envisioned larger levees, flood bypasses, and dredging of the Sacramento River to Suisun Bay, all of which significantly reduced flooding in the Sacramento area. Levee failures in the Delta were more common in the first half of the twentieth century for several reasons and have become less common in recent years as a result of the following.

- Upstream reservoirs were constructed, including reservoir space to attenuate flood flows.
- Two federal flood control projects were constructed on the Sacramento and San Joaquin Rivers, which improved about one-third of the levees within the Delta.
- Some islands that flooded earlier in the century were not reclaimed, therefore reducing the total length of levee susceptible to failure. The added open water reduced tidal energy and provided some attenuation of some high river flows.
- The State of California began the Delta Levees Subventions and Special Projects Program in the late 1980s, which provided grant funds to reclamation districts for the purpose of maintaining and improving levees.
- Flood-fighting techniques, equipment, and practices were dramatically improved over the last century.

In 2006, California voters passed Proposition 1E, which included $500 million for nonfederal project levees, much of which went toward Delta levee improvements.

DWR's Delta levees program set a goal of raising the height and construction standard for all Delta levees to meet the Hazard Mitigation Plan standards, at a minimum. DWR may pay a portion of the cost to reach the Hazard Mitigation Plan standard. Levee construction standards associated with Public Law 84-99 provide an even higher level of flood protection than the Hazard Mitigation Plan standards. Once a reclamation district reaches the Public Law 84-99 standards and maintains them, the district may be eligible for rehabilitation funding from USACE if levees within the district are damaged by high water (DWR 2014).

State and Federal Levee System

All state-federal project flood control facilities in the Sacramento River and San Joaquin River watersheds (including the SRFCP and Oroville Reservoir) are part of the State Plan of Flood Control (SPFC) (DWR 2022a; 2022). The planning area for Central Valley flood protection includes the SPFC planning area and additional areas, particularly farther upstream, that provide and receive flood protection (DWR 2011).

As required by the Central Valley Flood Protection Act of 2008, DWR's *Central Valley Flood Protection Plan Update 2022* (CVFPP 2022 Update) was approved by the Central Valley Flood Protection Board in June 2012. The CVFPP 2022 Update provides a framework of flood management and flood risk reduction in both the Sacramento River and San Joaquin River basins. The CVFPP 2022 Update refines the programmatic vision for improving flood risk management in the Central Valley pursuant to the requirements of the Central Valley Flood Protection Act. (DWR 2022b). The CVFPP 2022 Update focuses on three key themes: climate resilience, performance tracking, and alignment with other state efforts (e.g., the Water Resilience Portfolio) (DWR 2022b).

In the Sacramento River watershed, flood management improvements have been developed along the lower 175 miles of the Sacramento River on the east bank, along the lower 185 miles of the west bank, and along the lower reaches of the river's major tributary rivers and streams. Facilities include levees, channels, and associated flood control structures. Table 7.12.1-6 shows channel capacities for the Sacramento River and its major tributaries, and the status of channel capacity as defined in DWR's *Flood System Status Report Update 2022,* which evaluated the conditions of SPFC facilities and contributed to development of the CVFPP 2022 Update (DWR 2022c).

Table 7.12.1-6. River Channel Capacities for the Sacramento River and Major Tributaries

River Reach	Design flow [a] (cfs)	Estimated Current Channel Conveyance Capacity at Design Freeboard (3 feet for most channels and 6 feet for most bypasses) (cfs)	Estimated Current Channel Conveyance Capacity at Design Freeboard (at top of levee) (cfs)	Channel Capacity Status [b]
Feather River				
Honcut Creek to upstream end of Project levees	210,000	250,500	326,200	Sufficient capacity
Jacks Slough to Honcut Creek	210,000	239,200	288,600	Sufficient capacity
Yuba River to Jack Slough	210,000	267,200	387,400	Sufficient capacity
Bear River to Yuba River	300,000	357,500	449,300	Sufficient capacity
Sutter Bypass to Bear River	320,000	347,100	404,500	Sufficient capacity
Parallel to Sutter Bypass	416,500	463,500	562,900	Sufficient capacity
Bear River				
Dry Creek to upstream end of Project levees	30,000	44,300	46,000	Sufficient capacity
Yankee Slough to Dry Creek	37,000	16,300	48,400	Potential encroachment
Feather River to Yankee Slough	40,000	21,800	46,800	Potential encroachment
Upper Sacramento River, above Fremont Weir				
Moulton Weir to upstream end of Project levees	160,000	201,800	245,700	Sufficient capacity
Colusa Weir to Moulton Weir	135,000	123,700	157,600	Potential encroachment
Tisdale Weir to Colusa Weir	66,000	53,800	76,000	Potential encroachment
Colusa Drain to Tisdale Weir	30,000	36,500	39,800	Sufficient capacity
Yolo Bypass (at Fremont Weir) to Colusa Drain	30,000	32,600	34,700	Sufficient capacity
Lower Sacramento River, below Fremont Weir				
Natomas Cross Canal to Sutter Bypass	107,000	111,700	146,400	Sufficient capacity
Sacramento Bypass to Natomas Cross Canal	107,000	104,500	112,900	Potential encroachment

River Reach	Design flow [a] (cfs)	Estimated Current Channel Conveyance Capacity at Design Freeboard (3 feet for most channels and 6 feet for most bypasses) (cfs)	Estimated Current Channel Conveyance Capacity at Design Freeboard (at top of levee) (cfs)	Channel Capacity Status [b]
American River to Sacramento Bypass	107,000	Controlled by Backwater Reverse Flow During Sacramento Bypass Opening	Controlled by Backwater Reverse Flow During Sacramento Bypass Opening	Sufficient capacity
Deep Water Ship Channel to American River	110,000	123,400	132,000	Sufficient capacity
Elk Slough to Deep Water Ship Channel	110,000	123,100	132,600	Sufficient capacity
Sutter Slough to Elk Slough	110,000	123,100	132,600	Sufficient capacity
Steamboat Slough to Sutter Slough	84,500	99,000	144,400	Sufficient capacity
Georgiana Slough to Steamboat Slough	56,500	68,700	106,000	Sufficient capacity
Cache Slough to Georgiana Slough	35,900	41,600	72,100	Sufficient capacity
Threemile Slough to Cache Slough	579,000	579,000+ tidal influenced	579,000+ tidal influenced	Sufficient capacity
Horseshoe Bend to Threemile Slough	514,000	514,000+ tidal influenced	514,000+ tidal influenced	Sufficient capacity
Sherman Lake to Horseshoe Bend	514,000	514,000+ tidal influenced	514,000+ tidal influenced	Potential encroachment
American River				
H Street Bridge to upstream end of Project levees	115,000	165,100	177,600	Sufficient capacity
Cal Expo to H Street Bridge	115,000	143,200	182,900	Sufficient capacity
NEMDC to Cal Expo	180,000	161,200	236,200	Potential encroachment
Sacramento River to NEMDC	180,000	144,900	191,600	Potential encroachment
Yolo Bypass Tributaries				
Knights Landing Ridge Cut: Yolo Bypass to Colusa Drain	20,000	Controlled by backwater stage in Yolo Bypass	Controlled by backwater stage in Yolo Bypass	Potential encroachment
Cache Slough: Yolo Bypass to upstream end of Project levees	N/A	Controlled by backwater stage in Yolo Bypass	Controlled by backwater stage in Yolo Bypass	Backwater zonec

River Reach	Design flow [a] (cfs)	Estimated Current Channel Conveyance Capacity at Design Freeboard (3 feet for most channels and 6 feet for most bypasses) (cfs)	Estimated Current Channel Conveyance Capacity at Design Freeboard (at top of levee) (cfs)	Channel Capacity Status [b]
Willow Slough Bypass: Yolo Bypass to upstream end of Project levees	6,000	Controlled by backwater stage in Yolo Bypass	Controlled by backwater stage in Yolo Bypass	Potential encroachment
Putah Creek: Yolo Bypass to upstream end of Project levees	62,000	24,600	52,200	Potential encroachment
Sacramento Bypass: Yolo Bypass to Sacramento Weir	112,000	Controlled by backwater stage in the Yolo Bypass	Controlled by backwater stage in the Yolo Bypass	Potential encroachment
Miner Slough: Yolo Bypass to Sutter Slough	10,000	12,900	11,000	Sufficient capacity
Lindsay Slough: Yolo Bypass to upstream end of Project levees	30,000	Controlled by backwater stage in Yolo Bypass	Controlled by backwater stage in Yolo Bypass	Potential encroachment

Source: DWR 2022c.

cfs = cubic feet per second; NEMDC = Natomas East Main Drainage Canal; Project = Central Valley Flood Protection Project

[a] Design flow is from the 1957 Revised Profile Drawings. The design flows from the 1957 Revised Profile Drawings are used for the basis of state operations, so it is important that channels can hold these flows.

[b] Determination of "sufficient capacity," "potential encroachment," and "potential overtopping" is based on a comparison of the estimated current channel capacities to capacities from the 1957 Revised Profile Drawings. If the estimated channel capacity at both freeboard and top of levee exceeds the 1957 capacity, the reach is considered to have "sufficient capacity." If the estimated channel capacity at top of levee exceeds the 1957 capacity, but at freeboard is below the 1957 capacity, the reach is "potentially encroached." If the estimated channel capacity at top of levee is below the 1957 capacity, the reach is "potentially overtopped."

[c] "Backwater zone" indicates that the estimate of current channel capacity may be affected by backwater flow, and additional evaluation is required.

Erosion and Channel Processes

Large flow events can serve to reset natural processes and redistribute large volumes of sediment through scour and fill, creating channel bed, bank, and floodplain variability. During the wet season, large-magnitude flows typically transport a substantial portion of the annual sediment load and restructure the channel and floodplain landforms. In contrast, flows that are too low can lead to sediment deficiencies downstream or surplus sediment deposition that could result in channel constriction in some areas. In regulated rivers with large dams such as the Sacramento River and Shasta Dam, the upstream sediment supply typically is trapped behind the dam, creating a sediment mass balance deficit downstream. If the flood duration, which correlates with total transport capacity, is not in balance with the limited sediment available below the dam, subsequent scour and bed degradation can occur (^Yarnell et al. 2015).

For rivers already susceptible to deficit sediment conditions, extended-duration floods can further erode sediment deposits and result in net erosion of the channel unless sediment supplies are augmented. Although more sediment could be mobilized and entrained by higher peak flows, variable flows (including receding flows) can also redistribute sediments. When sediments are conveyed and entrained at high flows, slowly receding flows allow for continued sediment movement in deeper channel locations and gradual deposition throughout shallow channel habitats (^Yarnell et al. 2015).

The very highest flows can cause flooding and excessive, large-scale erosion. The velocity associated with these flows is high enough to move large pieces of channel substrate, such as spawning gravel. These highest flows are associated with the highest concentration of sediment in the water column. More moderate rainy-season flows may be more beneficial, potentially allowing the ecological benefits of floodplain inundation without significant erosive damage. These more moderate flows generally move only fine sediment or sand, which may improve spawning gravel quality and cause modest increases in turbidity. Because these more moderate flows occur more frequently than the very highest flows, the total volume of sediment moved by these flows over time may be greater than the volume of sediment moved during the very highest flow events.

Other Hazards

The susceptibility of a project to a tsunami, seiche, or mudflow depends on location. *Tsunamis* are large waves that form in oceans and seas, typically as a result of an earthquake, landslide, or volcanic eruption. *Seiches* are large waves that form in enclosed waterbodies, typically from an earthquake or change in atmospheric pressure. *Mudflows* are landslides that typically occur in steep terrain and may or may not be the result of an earthquake.

Because of the study area's size and diverse topography, tsunamis, seiches, and mudslides could occur. Those portions within 1 mile of the coastline could be susceptible to tsunami hazard. To varying degrees, the entire coastline of California is susceptible to tsunamis, and the State of California has prepared Tsunami Inundation Maps for Emergency Planning for much of the coastline (California Office of Emergency Services 2021; DOC 2015). Those portions near enclosed waterbodies, such as lakes and reservoirs, may be susceptible to seiches, depending on the seismicity and topography of the area. Those portions located in or near steep terrain could be susceptible to mudflows. Many areas prone to landslides in California have been identified by the California Geological Survey through the Seismic Hazard Zonation Program and by the U.S. Geological Survey through its Landslide Hazards Program.

7.12.1.3 Impact Analysis

This analysis focuses on the water quality processes that are expected to occur as a result of changes in hydrology and changes in water supply. These changes were estimated with SacWAM and are described in Chapter 6, *Changes in Hydrology and Water Supply.* SacWAM results are based on potential instream flow requirements in increments of 10 percent, from 35 percent unimpaired flow to 75 percent unimpaired flow (referred to as numbered flow scenarios, such as the *35 scenario* and *45 scenario*). The proposed program of implementation for the Plan amendments provides for a range of flow scenarios from 45 to 65, with default implementation starting at the 55 scenario. The 35 and 75 flow scenarios are also presented to inform the analyses of low and high flow alternatives in Section 7.24, *Alternatives Analysis*.

Changes in hydrology, including changes in streamflows and reservoir levels, are generally analyzed qualitatively for potential water quality impacts under Impacts SW-a and SW-f. Increasing flows at certain places and times while decreasing flows at others, and changes in Delta outflow and the volume of water exported from the Delta, are evaluated for water quality impacts, including concentration of contaminants, mobilization and methylation of mercury, water temperature, and

HABs. Water quality in the Delta is assessed quantitatively with results from the Delta Simulation Model II (DSM2).

Changes in water supply, including reduced Sacramento/Delta deliveries to municipal and agricultural uses, are evaluated for impacts associated with replacing supply with lesser-quality sources and impacts associated with reduced runoff and waste discharge. Reduced Sacramento/Delta supply to refuges, and water quality compliance by utilities (drinking water treatment facilities and WWTPs), are also evaluated. Changes in supply include groundwater pumping and other water management actions that parties may take in response to reduced Sacramento/Delta water supply that could affect surface water. Groundwater storage and recovery, water transfers, and water recycling are evaluated for surface water quality impacts primarily associated with reduction in flow.

Changes in hydrology, including potential changes in runoff patterns, sediment movement, and flooding are evaluated under Impacts SW-c, SW-d, and SW-i. Some types of flooding and sediment movement are beneficial. For example, floodplain inundation can provide high-quality fish habitat, and high flows can remove fine sediment from gravel to improve spawning habitat for fish (see Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations;* Chapter 5, *Proposed Changes to the Bay-Delta Plan for the Sacramento/Delta;* and Section 7.6.2, *Aquatic Biological Resources*). This section's flood and erosion analysis focuses on the potential for adverse flooding or sediment movement, including overtopping of levees and erosion that threatens infrastructure such as roads, houses, and businesses.

Changes in water supply, including reductions in Sacramento/Delta water supplies and other water management actions in response to reduced supply would have no impact on flood control operations nor substantially increase drainage in a manner that would cause flooding or erosion. Reduced Sacramento/Delta supplies to agriculture or municipal uses could ultimately reduce agricultural and urban runoff, and as a result reduce erosion and siltation and flooding. It is expected that water management actions employed at the local or regional level, including groundwater storage and recovery, water transfers, water recycling, and water conservation, could result in beneficial impacts by incorporating multiple benefits into project design, including flood control. For example, DWR has acknowledged the synergistic benefits of managing for flood risk and increasing water supplies through its Flood-MAR program; this program proposes to facilitate projects that integrate flood control and groundwater management by actively managing flood events to recharge aquifers to provide multiple public benefits (DWR 2018b). The proposed Plan amendments promote and support these efforts. There would be no impacts, and these actions are not evaluated further under Impacts SW-c, SW-d, and SW-i.

Changes in hydrology, including flow requirements, would result in a change in the amount of surface water stored in the existing reservoirs or released to the rivers. These changes would not increase the amount of storm water generated, collected, or discharged to surface waters relative to baseline conditions. Changes in water supply, including reduced agricultural or landscape irrigation, could reduce runoff of polluted water, potentially improving the capacity of existing or planned storm water drainage systems. In addition, other water management actions (groundwater storage and recharge, water transfers, water recycling, and water conservation) could reduce runoff. The proposed Plan amendments would not cause exceedance of storm water drainage systems (e.g., storm sewers or detention basins) or increase the amount of polluted runoff. There would be no impact, and Impact SW-e is not evaluated further in this section.

Portions of the study area are within a 100-year flood hazard area. However, the proposed Plan amendments would not result in the development of housing and therefore would not place housing within a 100-year flood hazard area. Similarly, the proposed Plan amendments would not place structures within a 100-year flood hazard area. There would be no impact, and Impacts SW-g and SW-h are not evaluated further in this section.

Although some locations in the study area are prone to inundation by seiche, tsunami, or mudflow, changes in hydrology would not result in an increased risk or impacts related to flooding from inundation by tsunami, seiche, or mudflow because the changes in hydrology resulting from the proposed Plan amendments would not change the conditions that create these hazards: proximity to the source of the hazard (ocean, enclosed waterbody, or steep terrain) and seismic and topographic conditions. Changes in water supply, including reduced deliveries of Sacramento/Delta supplies and other water management actions, would not increase the risk of inundation by tsunami, seiche, or mudflow in these areas. There would be no impact, and Impact SW-j is not evaluated further in this section.

As discussed in Section 7.1, *Introduction, Project Description, and Approach to Environmental Analysis*, reasonably foreseeable methods of compliance and response actions also include actions that would require construction. These actions are described and analyzed for potential environmental effects in Section 7.21, *Habitat Restoration and Other Ecosystem Projects*, and Section 7.22, *New or Modified Facilities*.

Impact SW-a: Violate any water quality standards or waste discharge requirements

Impact SW-f: Otherwise substantially degrade water quality

The analyses of water quality standards and water quality degradation are closely related and are therefore combined and addressed together under Impact SW-a and Impact SW-f. Evaluation of impact questions SW-a and SW-f is divided into two main sections: *Changes in Hydrology* (impacts associated with changes in flow and reservoir levels) and *Changes in Water Supply* (impacts associated with reductions in Sacramento/Delta water supply). *Changes in Water Supply* includes a subsection on *Other Water Management Actions* (impacts associated with increased groundwater storage and recovery, water recycling, water transfers, and water conservation). Evaluation of changes in hydrology is the most detailed section and includes regional evaluations. An evaluation of the ability of drinking water treatment facilities and WWTPs to meet water quality standards and discharge requirements is considered in both the *Changes in Hydrology* section and the *Changes in Water Supply* section.

The goal of this water quality assessment is to determine whether the proposed Plan amendments could result in violation of water quality standards or waste discharge requirements or cause substantial degradation of water quality. A substantial degradation would cause increased exceedances of water quality objectives or otherwise adversely affect the beneficial uses of water. Conversely, small changes in the concentrations of water quality constituents would not constitute a significant impact because small changes would not result in exceedances of water quality objectives or adversely affect the beneficial uses of water.

The proposed Plan amendments could result in substantial improvements in water quality, including dilution and flushing of some contaminants and reduction in EC, bromide, and chloride in the Delta associated with reduced seawater intrusion. In addition, water quality for fish would be enhanced by increases in flow (e.g., increased low-salinity habitat in the Delta) and other beneficial effects associated with higher flows (e.g., reduced water temperature). Most potential adverse impacts would likely be less than significant, except for potential water quality effects associated with decreases in reservoir storage and streamflow, and reduced water supply for municipalities and managed wetlands.

Some water quality impacts would be considered negative for some resources and beneficial for others. For example, increases in nutrients could lead to HABs but also could increase primary production to support the ecosystem. Similarly, increases in turbidity may affect drinking water treatment plants but also could help Delta smelt.

Changes in Hydrology

The proposed Plan amendments would change flows in streams and rivers in the Sacramento River watershed and the Delta eastside tributaries regions, increasing flows at certain places and times while decreasing flows at others. The proposed Plan amendments could also change Delta outflow and the volume of water exported from the Delta. These changes in hydrology could affect surface water quality, including concentration of contaminants, mobilization and methylation of mercury, water temperature, and HABs. Impacts were evaluated by considering how the type and magnitude of the hydrologic change might affect environmental processes that affect water quality.

Sacramento River Watershed and Delta Eastside Tributaries Regions

A dynamic relationship between river flow and pollutant concentration, as well as other factors, influences river concentrations of pollutants such as those that originate from point sources and other discharges of waste. Many pollutants may be diluted by increases in flow. USEPA's NPDES Permit Manual considers dilution as a mitigating factor affecting the pollutant concentration instream (USEPA 2010). The magnitude of river flow can improve the total riverine assimilative capacity and can be used to decrease pollution concentration through dilution (Farhadian et al. 2015). To the extent that the changes in hydrology result in increased flows, these changes may result in a dilution effect for certain constituents in waterbodies, which would provide a benefit to water quality.

Total Suspended Solids and Turbidity

Increased streamflow tends to increase TSS and turbidity. Much sediment delivery is associated with rainfall runoff that occurs when water moving over the land surface causes erosion. This process would not be affected by changes in hydrology. However, increased flow in channels could by itself cause an increase in TSS and turbidity in the channel by increasing streambed erosion and resuspension of bottom sediments due to higher velocity and inundation of larger areas.

The relationship between TSS or turbidity and flow is nonlinear. The highest flows result in mobilization and transport of large amounts of sediment. Fluvial studies indicate that more than 90 percent of the sediment is transported in less than 10 percent of the time (Owens 2005). Large rainfall and flood events are responsible for most of the sediment movement.

As part of the flood-risk evaluation for Impact SW-i, occurrence of the highest flows was assessed by determining the average of the top 10 percent of the monthly SacWAM flows for the months of the year with the highest flows (see Table 7.12.1-21 under *Flood Risk Discussion* for Impact SW-i). Based on this analysis, changes in hydrology under the proposed Plan amendments would generally cause minimal change or a reduction in the highest 10 percent of flows. Putah Creek showed increases in high flows in January and the Yuba River showed increases in high flows in February, but these effects were counteracted by reductions during other months with high flows. As a result, the very highest turbidity and TSS levels are not expected to increase.

Clear Creek is the only stream expected to have substantial increases in high flows as a result of changes in hydrology (see Table 7.12.1-22 under *Flood Risk Discussion* for Impact SW-i). These increases in flows are expected because under baseline conditions, most of the Clear Creek flows are retained in Whiskeytown Lake and diverted through the Spring Creek Tunnel for hydropower generation. Revival of flow in Clear Creek is unlikely to cause adverse increases in TSS or turbidity because flows would not increase above levels that occurred under historical conditions prior to use of the Spring Creek Tunnel. Increases in turbidity might be greatest during the first time that higher flows are allowed in the channel, before the suspended sediment load reaches equilibrium.

While high-flow events and TSS and turbidity may increase above current baseline levels in Clear Creek, TSS and turbidity are not expected to increase to levels that would be detrimental to beneficial uses because the river corridor has not been extensively leveed or armored in other ways that could constrict high flows and cause high water velocities to degrade channel bed material, which consists mostly of coarse material and not the finer material that would affect TSS and turbidity. Further discussion on how high-flow impacts would be prevented on Clear Creek through real-time operations is presented under Impact SW-i, and similar operational rules would be used to prevent excessive erosion. Implementation of flow requirements on Clear Creek would be conducted in the context of ongoing stream restoration activities and would be managed to maintain a proper sediment balance. The impact on TSS and turbidity in Clear Creek would be less than significant. Potential erosion and siltation effects, which are related to but distinct from the water quality attributes of TSS and turbidity, are discussed under Impacts SW-c and SW-d.

Under the proposed Plan amendments, Delta inflow from the Sacramento River and Delta eastside tributaries would generally increase in comparison with baseline conditions between January and June and decrease from July to October. Most of the increase in flow, TSS, and turbidity would occur during storm runoff events. The increase is expected to fall within the range of flow, TSS, and turbidity concentrations that occur naturally under baseline conditions. The December-through-June increase in flow is expected to increase the number of days with moderate TSS and turbidity in the river during this time, but not the number of days with peak flows that would move the most sediment.

TSS and turbidity are important for multiple physical and biological processes in the Sacramento Valley and Bay-Delta. For example, turbidity may have beneficial effects on fish (e.g., enhanced predator refuge for Delta smelt and juvenile salmonids) (see Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations*), but very high levels of suspended sediment can cause injury (e.g., gill damage) or result in adverse effects on spawning and rearing habitat (e.g., sedimentation of spawning gravel). Increasing turbidity may decrease phytoplankton primary production rates in winter and spring due to reduced water clarity; but the higher turbidity levels would mostly occur during storm runoff events, when turbidity would already be high and algal growth low. Decreases in flow at some locations during summer and early fall would be unlikely to have much effect on TSS and turbidity because flow during this time is generally low enough that TSS and turbidity are already low. Changes in turbidity would have minimal effects on fish and aquatic habitat and primary production rates.

For drinking water, suspended solids are removed through settling, flocculation, and/or filtration processes. During periods of higher turbidity, drinking water treatment plants may have to increase the dose of flocculants and increase backwashing of filter beds. Increases in turbidity associated with increases in instream flows under the proposed Plan amendments are not anticipated to exceed drinking water treatment plant design parameters. Increased turbidity within design parameters does not harm a drinking water treatment plant and does not affect the safety or quality of the resultant drinking water.

Changes to hydrology are expected to increase the number of days with moderately elevated turbidity but also are expected to cause a general reduction in the occurrence of the highest turbidity levels. Any increase is expected to fall within the range of concentrations that occur naturally. Light effects on phytoplankton primary production would likely be small, and drinking water treatment facilities are equipped to handle the levels of turbidity expected to occur with the proposed Plan amendments.

Contaminants

Changes in hydrology under the proposed Plan amendments could affect the concentration of contaminants, such as pathogens, trace metals and metalloids; current-use pesticides; legacy contaminants; and CECs. This section covers processes that affect all these contaminants. Mercury is discussed separately and in more detail in the next section due to its widespread occurrence, toxicity, and tendency to be converted to methylmercury, the more toxic and bioavailable form of mercury, in anaerobic sediment.

When flows increase, movement of sediment and any adhered contaminants may increase. The long-term water quality impacts on movement and deposition of sediment and adhered contaminants would generally be minimal because contaminants are likely already present in areas where sediment deposition occurs. A temporary increase in sediment-bound contaminants in the water column is unlikely to affect beneficial uses because of its temporary nature and because contaminants generally remain bound to the sediment. Once the sediment settles, it would likely bury contaminants bound to sediment that was already present. In addition, while higher flows may cause more sediment to enter the water column, higher flows also can help move sediment and contaminants out of the system.

Increases in flow would help dilute local sources of dissolved contaminants, thus improving water quality. Conversely, reductions in flow could reduce dilution of local contaminants, either from WWTP discharges, other types of contaminated discharges, or uncontrolled and natural sources of contaminants. Dilutable contaminants originate from outside a waterbody and can be diluted by increased flow. Contaminants categorized as pesticides, other organics, other inorganics, or fecal indicator bacteria on the 303(d) list are generally dilutable (i.e., the concentration will decrease with increased flow).

Increased input of dissolved contaminants to the Sacramento River system may occur by increasing inundation of locations in flood bypasses subject to pesticide application. However, more frequent inundation of these agricultural areas is unlikely to substantially increase pesticide concentrations because the proposed Plan amendments would not cause increased pesticide application; repeated inundation would wash away pesticides; and inundation would occur during the rainy season, after many pesticides have had the chance to degrade after application.

As discussed in Chapter 6, *Changes in Hydrology and Water Supply,* regulated tributary streamflows could decrease during summer and early fall when streamflow is naturally low compared to baseline conditions. Under baseline conditions, substantial storage releases for diversions in the Delta create artificially high summer and early-fall flows, and these flows may be reduced to some extent under the proposed Plan amendments. Some of the tributaries that follow this pattern include the American River, Feather River, Mokelumne River, Stony Creek, Yuba River, and Sacramento River. In addition, because of reductions in imported Feather River water, lower streamflows could occur at the mouth of Butte Creek compared to baseline conditions. The Bear River also could experience flow reductions due to possible reductions in interbasin diversions.

Overall, the proposed Plan amendments would produce more dilution due to increases in flow than increased concentration of contaminants associated with decreases in flow. Most of the rivers expected to experience occasional reductions in flow are large and would still have relatively high flows that sufficiently dilute contaminants. Smaller streams that may experience reduction in flow are relatively free of dilutable contaminants due to their location higher in the Sacramento/Delta watershed; however, the reductions in flow occasionally could increase the concentration of contaminants and result in localized degradation in some areas. This impact would be potentially significant.

Implementation of Mitigation Measure MM-SW-a,f: 1 will reduce or avoid water quality impacts from increased concentration of contaminants that may occur if streamflow is reduced in the summer and early fall. Contaminants in waterbodies are a statewide water quality issue that exists independently of potential incremental effects from the proposed Plan amendments; various ongoing state efforts are addressing this problem. The regulation of water quality pollution is accomplished primarily through waste discharge permits, including NPDES permits for point-source discharges, and WDRs for nonpoint-source discharges. As explained in Section 7.12.1.2, *Environmental Setting,* the State and regional water boards administer a variety of permit programs that regulate discharges of waste. TMDLs are adopted and implemented to bring waterbodies into compliance over time when water quality impairments persist. The State and regional water boards, pursuant to their pre-existing duties and Mitigation Measure MM-SW-a,f: 1, will continue to regulate waste discharges and support TMDL development and implementation. Efforts to control some contaminants may take time. The State Water Board cannot be certain that these efforts will mitigate every incremental water quality impact associated with reduced flows to a less-than-significant level. Unless and until the mitigation is fully implemented and proven effective, the impacts remain potentially significant.

The ability for waste dischargers and drinking water treatment providers to meet water quality standards and waste discharge requirements in tributaries with reduced flows is addressed further under *Water Quality Compliance by Utilities*.

Mercury

Mercury is a statewide problem, and the amount of mercury moved from one area to another is of concern under existing conditions. Due to high levels of methylmercury found in fish tissue, consumption of contaminated fish is a greater concern for human health than is mercury in drinking water (^Central Valley Water Board 2010). High levels of methylmercury in the environment also pose a threat to fish and wildlife because of methylmercury's toxicity and ability to accumulate in the aquatic food web (Davis et al. 2003).

Given mercury's high affinity for particles, increased suspended sediments in greater streamflow from changes in hydrology could increase the transport of mercury, potentially affecting the achievement of water quality standards in tributaries with mercury TMDLs or known impairments. However, the largest mercury mobilization occurs during the largest rainfall runoff events, which would not be increased. Generally, however, increases in the total volume of water from tributaries could increase the amount of mercury entering downstream waterways. The extent of this effect would depend on the magnitude of the increase in a particular tributary's flow; the mercury concentration in the tributary; and the flow, mercury concentration, and velocity of the receiving water. The potential negative consequences of this effect could be exacerbated if the receiving water forms intermittent wetlands that are conducive to converting mercury to methylmercury.

The Yolo Bypass exemplifies a location where the combination of increased mercury input and transformation to methylmercury could occur due to the existing concentration of mercury in the tributaries and large wetland acreage. The main tributaries to the Yolo Bypass (the Sacramento River, Cache Creek, and Putah Creek) intermittently deliver mercury to the Yolo Bypass under existing conditions. The Sacramento River often contributes the most flow to the bypass during high-flow conditions, but Putah Creek and, particularly, Cache Creek have higher concentrations of mercury (^Central Valley Water Board 2010).

Cache Creek drains about 2 percent of the Sacramento River watershed but contributes approximately 30 percent of all the mercury from the watershed (^Central Valley Water Board 2010). The settling basin at the downstream end of Cache Creek has been estimated to capture about half the mercury moving through Cache Creek, and improvements in the settling basin to retain more water are one method proposed by the Delta TMDL for mercury to reduce the amount of mercury entering the Delta (^Central Valley Water Board 2010). The use of the settling basin would continue under the proposed Plan amendments. More rapid flow through the basin from changes in hydrology could reduce the sediment and mercury trapping efficiency of the settling basin; however, an evaluation of trapping efficiency between 2010 and 2013 showed that trapping efficiency of particulate mercury during the relatively wet year of 2011 was not much different from the other years (DWR 2015).

As described in Chapter 6, *Changes in Hydrology and Water Supply*, and shown in Appendix A1, *Sacramento Water Allocation Model Methods and Results,* increases in outflows from Cache and Putah Creeks associated with the proposed Plan amendments are expected to produce increases in the flow in the lower half of the Yolo Bypass, which could result in increased deposition of mercury-laden sediment in the bypass. Although mobilization and deposition of mercury-laden sediments is dependent on many factors, particularly velocity, increases in flow can be used as a rough indicator of the magnitude of increases in the movement of mercury from Putah and Cache Creeks to the Yolo Bypass. Because sediment (and mercury attached to sediment) moves more under high-flow conditions, average increases in flow during the high-flow months of January through March are illustrative of potential increases in mercury transport (Table 7.12.1-7).

Table 7.12.1-7. Average Flow at Downstream Ends of Cache Creek, Putah Creek, and Yolo Bypass during January through March for Baseline and Flow Scenarios (cubic feet per second)

Location	Month	Baseline	35	45	55	65	75
Cache Creek	January	936	961	979	1,055	1,169	1,278
Cache Creek	February	1,413	1,399	1,400	1,431	1,501	1,613

Location	Month	Baseline	35	45	55	65	75
Cache Creek	March	961	984	991	996	1,036	1,099
Putah Creek	January	206	475	602	734	862	993
Putah Creek	February	345	623	718	876	1,029	1,186
Putah Creek	March	350	400	459	556	628	726
Yolo Bypass	January	9,172	9,454	9,755	9,820	10,123	10,738
Yolo Bypass	February	12,741	12,668	12,564	12,865	13,146	13,665
Yolo Bypass	March	7,687	7,737	7,536	7,658	7,905	8,227

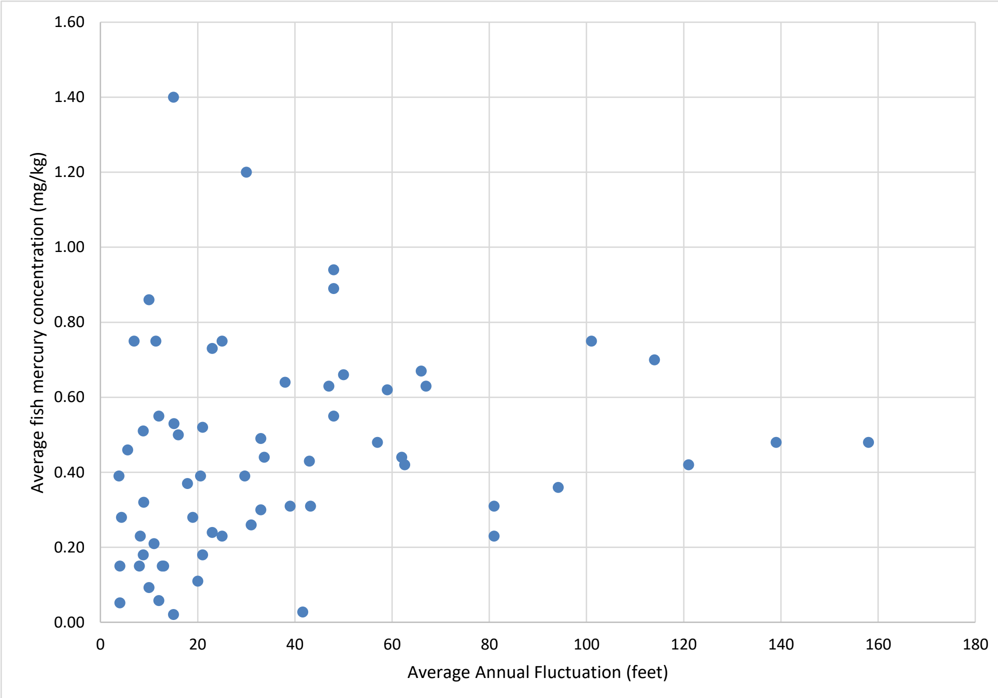
Increased flows into Yolo Bypass from all sources, including those with lower mercury concentrations (e.g., the Sacramento River) could affect the transformation of mercury into methylmercury due to floodplain inundation. In situ transformation in the Yolo Bypass is a major source of methylmercury (^Central Valley Water Board 2010). The wetting and drying cycle of the agricultural and natural lands of the Yolo Bypass is conducive to the formation of methylmercury (Marvin-DiPasquale et al. 2009; Windham-Myers et al. 2014). As a result, increased frequency of flooding in the Yolo Bypass could increase the formation and transport of methylmercury. Although little change in flow into the Yolo Bypass is expected to occur at either the Fremont or Sacramento Weirs, increased flow into the Yolo Bypass from Cache and Putah Creeks would increase inundated acreage in the bypass, particularly downstream of Putah Creek. Putah Creek is expected to have the largest increase in flow entering the bypass and is the farthest downstream of the inflows. Average Yolo Bypass flows downstream of Putah Creek during high-flows months of January through March (Table 7.12.1-7) indicate the degree to which the proposed Plan amendments (45 to 65 scenarios) may increase inundation and methylation of mercury in the Yolo Bypass. The largest effect on Yolo Bypass inundation is likely to occur in January, when average flow downstream of Putah Creek is estimated to increase from approximately 9,172 cfs under baseline conditions to approximately 9,820 cfs with the 55 scenarios (an increase of 7 percent).

Changes in hydrology could incrementally increase the existing movement of mercury from upstream watersheds with naturally occurring and legacy mining sources and increase floodplain inundation, leading to increased deposition of mercury and transformation of mercury to methylmercury in the Yolo Bypass. This potential impact (i.e., increased downstream mercury transport associated with increased flow and transformation to methylmercury) associated with increased floodplain inundation could occur in other locations, although the effects would likely be smaller than the Yolo Bypass effects. This impact would be potentially significant, and mitigation is discussed at the end of this mercury section. The State Water Board recognizes that wetlands and floodplain inundation provide valuable water quality, wildlife habitat, and flood control functions and should not be disincentivized due to mercury concerns (SWRCB 2017b). Floodplain benefits are described in Section 3.14.2, *Salmonid Tributary Habitat Analyses*, and Appendix A8, *Salmonid Tributary Habitat Analysis*. Methylmercury production from physical habitat restoration projects, such as notching the Fremont Weir, is evaluated in Section 7.21, *Habitat Restoration and Other Ecosystem Projects*.

The effect of increases in mercury and methylmercury may carry downstream to the Delta, San Francisco Bay, exports, export reservoirs, and streams downstream of export reservoirs. The effect would be dissipated by mixing with other water sources, settling of mercury attached to sediment, dredging, accumulation in organisms, and photodegradation of methylmercury back to mercury (^Central Valley Water Board 2010).

In addition to the potential impact associated with downstream mercury transport and inundation of floodplains, mercury impacts could occur due to increases in water level fluctuation in reservoirs. Increases in annual average water level fluctuation (maximum yearly elevation minus minimum yearly elevation) is one of several factors that have been linked to increased bioaccumulation of mercury (SWRCB 2017a). Two theories explain how reservoir fluctuation may increase bioaccumulation of methylmercury in fish. One is that drying and rewetting an area may result in conditions that promote bacterial methylation (similar to the mechanism for floodplain inundation for the Yolo Bypass). The other is that fluctuation may result in movement of fine sediments and other material (including attached nutrients) from the reservoir banks, where light is present for algal and plant growth, into the deeper, darker part of the reservoir, causing a reduction in both benthic primary productivity and food supply. A reduction in primary productivity is associated with a higher concentration of mercury in algae and, therefore, fish. A reduction in primary productivity also is associated with less food for fish growth; because fish must still eat to survive, the ratio of mercury intake to fish tissue mass increases.

The State Water Board's 2017 draft staff report on mercury in California reservoirs included a comparison of average annual reservoir fluctuation to mercury data for 65 California reservoirs. It indicated that annual fluctuation had little effect on formation of methylmercury in these reservoirs, but fluctuation did increase methylmercury concentrations in fish (SWRCB 2017a). Spreadsheet data included with Appendix B of the 2017 staff report suggest that many factors other than water level fluctuation affect bioaccumulation and that water level fluctuation must be fairly large to induce a modest effect. Figure 7.12.1-3, based on data from that draft staff report, shows average annual water level fluctuations of 20 feet correlating to an increase in mercury accumulation of approximately 0.2 milligram per kilogram, until fluctuation reaches approximately 60 feet, when accumulation seems to level off.



Source: SWRCB 2017a.

Each point in the graph represents a reservoir. Data for Guadalupe and Almaden Reservoirs are not shown due to high values: an average of 4.7 and 4.3 mg/kg, respectively. Average fish mercury concentrations are from legal-sized trophic-level 4 fish (150–500 millimeters) with more than one sample collected.

mg/kg = milligrams per kilogram

Figure 7.12.1-3. Average Fish Mercury Concentrations Relative to Average Annual Reservoir Fluctuation in 65 California Reservoirs

Although large water level fluctuations in reservoirs have been associated with increased levels of methylmercury in fish, water level fluctuation is necessary for reservoirs to function as designed. Reservoir water levels must decrease during California's long dry season, as recognized in the State Water Board's draft staff report (SWRCB 2017a). During the first phase of the implementation program for mercury-impaired reservoirs, draft provisions include pilot tests for reservoir water chemistry and fisheries management practices, such as oxidant additions to reduce anoxia or adjust redox potential when reservoirs are stratified, in-reservoir sediment removal or encapsulation, and changes to fish stocking practices to increase the abundance of fish with lower methylmercury levels.

Increased water level fluctuation in some reservoirs could incrementally increase ongoing bioaccumulation of methylmercury in those reservoirs. As described in Chapter 6, *Changes in Hydrology and Water Supply*, SacWAM results were used to calculate average annual fluctuation in reservoir elevation as the average of annual maximum minus average minimum water surface elevations. While there is uncertainty in how reservoir operators eventually will manage storage for water supply and cold water pool, the results suggest that a few reservoirs may experience increased fluctuation but generally fluctuation is expected to decrease. For the few reservoirs that experience increased fluctuation, the impact would be potentially significant.

Mercury impacts can be reduced through implementation of Mitigation Measure MM-SW-a,f: 2. Mercury is a statewide water quality issue that exists independently of the potential incremental effects from the proposed Plan amendments and is being addressed through various state and federal water quality efforts. The State Water Board will continue its efforts to develop and implement mercury control measures for reservoirs, including efforts to understand and control sources of methylmercury and to address fish consumption concerns. Reservoir owners and operators will describe participation in any adopted mercury control program for reservoirs, and if applicable, incorporate mercury measures into long-term strategy and annual operations plans. In addition, the State Water Board will work with the appropriate regional water boards to implement the San Francisco Bay Mercury and the Sacramento-San Joaquin Delta Methylmercury TMDLs. In addition, the State Water Board will coordinate with USACE, DWR, and other appropriate agencies to ensure that implementation of flow requirements does not interfere with the functioning of the Cache Creek settling basin in reducing mercury inputs to the Sacramento/Delta. Health-related effects associated with mercury will be limited by issuance of fish consumption advisories from OEHHA. Resolving mercury issues is expected to take time and will occur on multiple fronts; however, the State Water Board cannot be certain that these efforts will mitigate all potential mercury impacts associated with the proposed Plan amendments to a less-than-significant level. Unless and until the mitigation is fully implemented and proven effective, the impacts remain potentially significant.

Water Temperature

Elevated water temperatures are an existing concern in California, particularly in rivers where rim reservoirs prevent access to upper watershed habitat for native cold water anadromous fish. In general, consistent with the narrative cold water habitat objective and the flexibility provided in the flow objectives, the proposed Plan amendments are expected to improve water temperature conditions for native cold water fish. Streamflows are expected to resemble a more natural pattern, with higher peak flows in winter and spring on most tributaries in response to precipitation and runoff events. Tributaries without major reservoirs but with significant summer and fall diversions, such as Mill, Deer, Antelope, and Cow Creeks, are expected to have higher flows and cooler temperatures in summer. Streamflows and associated river temperatures in tributaries without major reservoirs or significant summer and fall diversions are not expected to change substantially.

In the upper watersheds, substantial effects on storage are not expected in most reservoirs. However, some upper watershed reservoirs might experience substantial temperature effects, especially those involved with interbasin diversions and those that need to release additional water to meet inflow requirements for the rim reservoirs downstream (see Chapter 6, *Changes in Hydrology and Water Supply*). The largest changes to interbasin diversions, and associated reservoir operations, occur in the Upper Yuba and Bear Rivers, with less water being diverted to the Bear River watershed and more remaining in the Yuba River watershed. Cold water habitat measures could be required for these upper watershed reaches if water temperature concerns exist or become problematic as a result of implementation of the proposed Plan amendments.

For tributaries with major storage reservoirs, changes in reservoir operations associated with the proposed Plan amendments are summarized by changes in spring (end-of-April) storage, carryover (end-of-September) storage, and reservoir releases as presented in figures in Chapter 6, *Changes in Hydrology and Water Supply*, and Appendix A1, *Sacramento Water Allocation Model Methods and Results*. The hydrologic effects shown in these figures represent reservoir operations that strive to maintain adequate cold water supply while simultaneously meeting the flow requirements of the proposed Plan amendments. Future operations could be optimized through further evaluation. Carryover storage is important for maintaining a supply of cool water deep in a reservoir, although spring storage also may be important because early release of water may reduce the initial volume of cold water captured in a reservoir. An additional way storage can affect reservoir release temperature is by influencing how TCDs can be used; higher reservoir storage may allow more points of withdrawal that can allow release of warmer water when cold water is not needed and colder water when it is needed. Lower reservoir storage typically is associated with a smaller cold water pool, but during late fall and winter, low reservoir volume could result in faster meteorological cooling of the reservoir. River flow controls the longitudinal rate at which water temperature approaches equilibrium values as water moves downstream. Generally, the flow scenarios result in higher spring flows and occasionally in lower summer flows. Cool reservoir release temperatures are maintained for greater distances at higher flows. Changes in carryover storage and flow downstream of a reservoir are most likely to affect water temperature if storage and flow are already relatively low (e.g., within the lowest 25 percent of values).

The proposed Plan amendments could result in some reductions in flows on tributaries with major storage reservoirs, particularly during summer and fall. Streamflows in summer and fall are expected to return to a more natural pattern. Currently, streams with reservoirs can have flows substantially elevated above required flow levels and above unimpaired conditions in summer and fall to support downstream water diversions from the streams and the Delta or during some flood control releases to preserve space in reservoirs. To meet the instream flow and cold water habitat (storage) requirements, diversions would need to be reduced from both storage and streams, allowing retention of more water in storage for cold water habitat protection, which could reduce flows on some tributaries at times. In particular, summer and early-fall flows would be reduced to some extent for CVP/SWP tributaries such as the Sacramento, Feather, and American Rivers, where, under baseline conditions, substantial storage releases to downstream diversions create artificially high summer and early fall flows. In some cases, reservoir releases would be reduced, but flows would not be reduced to the same level at the confluence of the tributary because diversions would be reduced on the stream above the confluence (to meet instream flow requirements).

In general, storage in rim reservoirs would be lower and downstream flow would be higher in spring than under baseline conditions, but subsequent reductions in reservoir releases in summer would protect carryover storage. It is difficult to model full protection of carryover storage for all reservoirs. The modeling indicates that carryover storage at rim reservoirs could be lower, similar, or greater than baseline conditions depending on reservoir and water year type. Carryover storage during average or critical water year types could be substantially reduced in a few reservoirs. For example, during critical water years, carryover storage may be reduced more than 20 percent in Black Butte Reservoir, Folsom Lake, and New Bullards Bar Reservoir, with the largest reductions occurring in the 65 scenario (see Chapter 6, *Changes in Hydrology and Water Supply*).

Temperature Modeling

Water temperature was simulated for water years 1923–2015 in the three largest tributaries in the Sacramento/Delta: the Sacramento, Feather, and American Rivers. For these simulations, SacWAM results for baseline conditions and the flow scenarios were used as hydrologic input to two HEC-5Q models, one for the Sacramento River and another for the Feather and American Rivers. More details on the methodology and results are provided in Appendix A6, *Water Temperature Modeling and Fish Assessment for the Sacramento, Feather, and American Rivers*. The effect of changes in hydrology on water temperatures simulated for the Sacramento, Feather, and American Rivers is indicative of changes in stream temperature that may occur downstream of other rim reservoirs.

Simulated temperature effects are summarized here by indicating temperature increases and decreases of 1° F or more for the 50th and 90th percentiles for locations that represent effects of reservoir storage and river flow on temperature (Table 7.12.1-8 through Table 7.12.1-11). Reservoir release temperatures represent the effect of reservoir storage on temperature, and downstream temperatures represent the increasing effect of flow on temperatures. One degree Fahrenheit was chosen only as an indicator of notable change and is not an impact threshold.

The 50th and 90th percentile temperatures represent the temperatures of greatest concern for cold water fish because they represent typical and warmer temperatures, respectively. Maximum values are not shown because they represent only a single month out of the entire simulation period. Full sets of changes in 10th, 50th, and 90th percentile temperatures for multiple key locations are presented in Appendix A6, *Water Temperature Modeling and Fish Assessment for the Sacramento, Feather, and American Rivers*. Section 7.6.2, *Aquatic Biological Resources*, contains additional detail on how native anadromous fish may be affected by changes in temperature.

Sacramento River. Simulated effects of changes in hydrology are summarized here with simulated Shasta Dam release temperatures and simulated temperatures in the Sacramento River at Butte City (Table 7.12.1-8). The Shasta Dam release temperatures represent the effect of reservoir storage on temperature, and the Butte City temperatures represent the effect of flow on temperatures. Butte City is the approximate location where changes in flow produce the maximum effect on water temperature. Downstream of this location, differences in temperature between the scenarios are muted as temperatures for all scenarios approach the same equilibrium values.

Some of the biggest effects of Shasta storage on 90th percentile water temperatures occur in October, with lower release temperatures, and in June and July, with higher release temperatures (Table 7.12.1-8). These temperature effects result from changes in end-of-month storage (both in the current and prior months) and interaction between changes in storage and TCD operations. By the time the Sacramento River water reaches Butte City, the effect of flow on water temperature is substantial, with the biggest effects being generally cooler spring temperatures under the 45 to 65 scenarios (particularly during April) and warmer summer temperatures (particularly during July) (Table 7.12.1-8). Generally, the magnitude of temperature effect associated with the flow scenarios increases with the level of unimpaired flow required.

Table 7.12.1-8. Patterns of Change in Sacramento River Temperatures Associated with the Flow Scenarios (50th and 90th percentiles) as Simulated with HEC-5Q

Percentile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Sacramento River below Shasta Dam												
Baseline (°F)												
50	51.0	52.8	53.7	50.0	48.1	48.4	51.1	49.8	48.3	48.3	48.6	49.5
90	56.2	56.0	55.2	51.7	49.7	50.1	53.0	53.4	51.5	51.1	50.4	52.1
35 Scenario minus Baseline (°F)												
50												
90	–								+			
45 Scenario minus Baseline (°F)												

Percentile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
50												
90	–								+			
55 Scenario minus Baseline (°F)												
50												
90	–								+	+		
65 Scenario minus Baseline (°F)												
50									+			
90	–								+	+		
75 Scenario minus Baseline (°F)												
50	–	–						+	+			
90	–								+	+		
Sacramento River at Butte City												
Baseline (°F)												
50	57.6	52.1	48.7	47.0	48.5	52.8	59.1	63.1	64.7	65.7	65.5	63.4
90	59.9	55.1	50.3	48.6	50.6	55.5	62.4	65.4	67.2	68.6	67.5	66.6
35 Scenario minus Baseline (°F)												
50												
90									+	+		–
45 Scenario minus Baseline (°F)												
50												
90									+	+		
55 Scenario minus Baseline (°F)												
50												
90							–			+		
65 Scenario minus Baseline (°F)												
50							–			+		
90							–	–		+	+	
75 Scenario minus Baseline (°F)												
50						–	–	–		+	+	
90							–			+	+	

+ indicates increase in temperature of more than 1 °F; – indicates decrease in temperature of more than 1 °F
One degree Fahrenheit (1 °F) was chosen only as an indicator of change and is not an impact threshold.

Feather River. Temperatures in the Feather River are complicated by the Thermalito Afterbay. Most Feather River water, including the simulated increases in flow associated with changes in hydrology, is diverted around the Feather River low flow channel (LFC) and into the Thermalito Afterbay. The LFC flows in SacWAM adhere to the minimum flow requirements specified in the NMFS 2016 BiOp for relicensing of Oroville hydropower facilities (NMFS 2016). Baseline and the flow scenarios have almost identical flows through the LFC. Flow that is not diverted from Thermalito Afterbay eventually is returned to the Feather River at the downstream end of the LFC. The 2016 NMFS BiOp suggests that flow through the LFC could be increased to up to 1,500 cfs if necessary to meet temperature goals of the BiOp (NMFS 2016), but this was not incorporated into SacWAM or the water temperature modeling.

Simulated temperature effects are summarized here with simulated temperatures at the Oroville Reservoir release, in the Feather River LFC at Robinson Riffle, and in the Feather River at Gridley (Table 7.12.1-9). The Oroville release temperatures represent the effect of reservoir storage on temperature. The Robinson Riffle temperatures represent temperatures at a location important for fish. It is upstream of the return flow from the Thermalito Afterbay. The Gridley temperatures represent a combination of the effects of reservoir storage, flow, and discharge from Thermalito Afterbay on water temperature.

Simulated changes in reservoir hydrology result in notable decreases in release temperature (>1 °F change) in March and increases in release temperature in September and October (Table 7.12.1-9). These temperature effects result from generally lower storage values through the year (which affects the size of the cold water pool and relative importance of meteorological conditions) and interaction between changes in storage and shutter operations for the power intake.

By the time the Feather River water reaches Robinson Riffle, the effect of storage on water temperature dissipates somewhat and some cooling effects of increased spring flow are apparent, especially in April (Table 7.12.1-9). The effect of increases in reservoir releases is limited at this location, however, because of the relatively short section of river channel that experiences the increased flow before diversion to the Thermalito Afterbay.

Increases and decreases in flow through the Thermalito Afterbay could cause substantial changes in water temperature due to the large, shallow dimensions of the Afterbay. These changes carry downstream to the Feather River at Gridley, causing notable decreases in water temperature during April and May, and contribute to some of the increases during July through October (Table 7.12.1-9). Generally, the magnitude of temperature effect associated with the flow scenarios increases with the level of unimpaired flow required.

Table 7.12.1-9. Patterns of Change in Feather River Temperatures Associated with the Flow Scenarios (50th and 90th percentiles) as Simulated with HEC-5Q

Percentile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Feather River below Oroville Dam												
Baseline (°F)												
50	51.0	52.1	54.2	48.5	47.9	50.4	50.2	51.5	55.7	57.8	56.9	50.8
90	55.2	55.0	56.4	53.4	50.5	53.1	50.6	52.0	56.2	58.5	57.9	51.7
35 Scenario minus Baseline (°F)												
50												
90	+	+										+
45 Scenario minus Baseline (°F)												
50						–						
90	+					–						+
55 Scenario minus Baseline (°F)												
50						–						
90	+			–		–						+
65 Scenario minus Baseline (°F)												
50				+		–						
90	+										+	+

Percentile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
75 Scenario minus Baseline (°F)												
50						–						
90	+	+				–				+	+	+
Feather River in the Low-Flow Channel at Robinson Riffle												
Baseline (°F)												
50	52.6	51.2	50.8	47.3	47.9	51.2	54.3	55.9	60.0	62.1	61.5	55.4
90	56.0	53.3	52.8	50.6	50.0	53.8	55.2	56.5	60.6	62.7	62.2	57.2
35 Scenario minus Baseline (°F)												
50												
90	+											+
45 Scenario minus Baseline (°F)												
50							–					
90	+					–						+
55 Scenario minus Baseline (°F)												
50							–					
90	+					–	–					+
65 Scenario minus Baseline (°F)												
50							–					+
90	+					–	–					+
75 Scenario minus Baseline (°F)												
50						–	–					+
90	+	+				–	–			+	+	+
Feather River at Gridley												
Baseline (°F)												
50	56.5	53.1	50.9	47.9	49.7	53.8	59.4	61.6	65.6	64.9	65.7	60.4
90	59.8	54.4	53.8	51.3	52.3	57.7	62.3	62.9	66.7	68.2	69.0	64.0
35 Scenario minus Baseline (°F)												
50						+						+
90	+											+
45 Scenario minus Baseline (°F)												
50							–	–		+	+	+
90	+	+								+		+
55 Scenario minus Baseline (°F)												
50	+						–	–		+	+	+
90	+									+		+
65 Scenario minus Baseline (°F)												
50	+		+				–	–		+	+	+
90	+	+					–		+	+		+
75 Scenario minus Baseline (°F)												
50	+		+				–	–		+	+	+
90	+	+				–	–		+	+	+	+

+ indicates increase in temperature of more than 1 °F; – indicates decrease in temperature of more than 1 °F

One degree Fahrenheit (1 °F) was chosen only as an indicator of change and is not an impact threshold.

For Feather River water temperature modeling, Oroville Reservoir was operated for both baseline and the flow scenarios with power bypass starting at 1,190 TAF if necessary to meet temperature criteria by accessing deeper, cooler water (Appendix A6). The 1,190-TAF storage threshold was developed to mimic existing operations. To check if the simulated temperature effects in September and October could be reduced, a sensitivity run was performed in which power bypass for the flow scenarios was increased by allowing power bypass to begin at storage of 1,500 TAF. The results of this sensitivity analysis (Table 7.12.1-10), show that increased power bypass could generally lead to reductions in water temperatures during September and October with effects carrying downstream, particularly at Robinson Riffle, but some effect even at Gridley. The purpose of this exercise was to demonstrate that the simulated temperatures do not necessarily represent final temperature effects and that further actions and optimization could further improve temperatures for fish.

Table 7.12.1-10. Sensitivity Analysis of Feather River Temperatures with Increased Power Bypass (50th and 90th percentiles) as Simulated with HEC-5Q

Percentile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Feather River below Oroville Dam												
Baseline (°F)												
50	51.0	52.1	54.2	48.5	47.9	50.4	50.2	51.5	55.7	57.8	56.9	50.8
90	55.2	55.0	56.4	53.4	50.5	53.1	50.6	52.0	56.2	58.5	57.9	51.7
35 Scenario minus Baseline (°F)												
50												
90	–	–										
45 Scenario minus Baseline (°F)												
50						–						
90	–	–				–						
55 Scenario minus Baseline (°F)												
50						–						
90	+											+
65 Scenario minus Baseline (°F)												
50				+		–						
90												
75 Scenario minus Baseline (°F)												
50				+		–						
90	+					–					+	+
Feather River in the Low-Flow Channel at Robinson Riffle												
Baseline (°F)												
50	52.6	51.2	50.8	47.3	47.9	51.2	54.3	55.9	60.0	62.1	61.5	55.4
90	56.0	53.3	52.8	50.6	50.0	53.8	55.2	56.5	60.6	62.7	62.2	57.2
35 Scenario minus Baseline (°F)												
50							–					
90	–	–										
45 Scenario minus Baseline (°F)												

Percentile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
50							–					
90	–	–					–					
55 Scenario minus Baseline (°F)												
50							–					
90	+					–	–					
65 Scenario minus Baseline (°F)												
50							–					+
90						–	–					
75 Scenario minus Baseline (°F)												
50						–	–					+
90	+	+				–	–				+	+
Feather River at Gridley												
Baseline (°F)												
50	56.5	53.1	50.9	47.9	49.7	53.8	59.4	61.6	65.6	64.9	65.7	60.4
90	59.8	54.4	53.8	51.3	52.3	57.7	62.3	62.9	66.7	68.2	69.0	64.0
35 Scenario minus Baseline (°F)												
50						+						+
90	–											
45 Scenario minus Baseline (°F)												
50							–	–		+	+	+
90	–									+		
55 Scenario minus Baseline (°F)												
50							–	–		+	+	+
90	+											+
65 Scenario minus Baseline (°F)												
50	+		+				–	–		+	+	+
90							–		+	+		+
75 Scenario minus Baseline (°F)												
50	+		+				–	–		+	+	+
90	+	+				–	–		+	+	+	+

+ indicates increase in temperature of more than 1 °F; – indicates decrease in temperature of more than 1 °F
One degree Fahrenheit was chosen only as an indicator of change and is not an impact threshold.
Power bypass was allowed to begin at 1,500 TAF (thousand acre-feet) at Oroville Reservoir.

American River. Simulated temperature effects from changes in hydrology under the proposed Plan amendments are summarized here with simulated temperatures at the Folsom Reservoir release and the American River at Watt Avenue (Table 7.12.1-11). The Folsom release temperatures represent the effect of reservoir storage on temperature and the Watt Avenue temperatures represent temperatures at a location that is important for fish and far enough downstream of Folsom Dam to experience substantial changes in temperature associated with changes in flow.

Simulated changes in Folsom Reservoir storage result in increases in 50th and 90th percentile release temperatures during April through August, particularly for the 65 scenario (Table 7.12.1-11). By the time the American River water reaches Watt Avenue, the effect of storage on water temperature dissipates somewhat and some cooling and warming effects associated with increased spring flow and decreased summer flows are apparent, with notable cooling in March–May and warming in June–August (Table 7.12.1-11).

Table 7.12.1-11. Patterns of Change in American River Temperatures Associated with the Flow Scenarios (50th and 90th percentiles) as Simulated with HEC-5Q

Percentile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
American River below Folsom Dam												
Baseline (°F)												
50	63.2	58.1	55.2	49.4	48.1	49.2	50.2	51.6	54.2	56.5	60.0	63.2
90	66.9	59.2	59.2	52.1	49.7	50.3	52.8	54.9	57.4	61.3	63.6	67.0
35 Scenario minus Baseline (°F)												
50												
90									+			
45 Scenario minus Baseline (°F)												
50								+		+		
90									+	+		
55 Scenario minus Baseline (°F)												
50								+	+			
90	–							+	+			–
65 Scenario minus Baseline (°F)												
50							+	+	+	+	+	
90								+	+	+		
75 Scenario minus Baseline (°F)												
50			–	–	–		+	+	+	+	+	+
90								+	+	+	+	
American River at Watt Avenue												
Baseline (°F)												
50	64.2	58.1	53.8	49.3	49.5	51.9	55.0	57.4	59.3	63.2	66.5	66.8
90	67.4	59.3	56.8	51.7	51.9	56.0	60.2	65.7	68.4	70.0	71.3	70.9
35 Scenario minus Baseline (°F)												
50												
90							–	–	+	+	+	
45 Scenario minus Baseline (°F)												
50									+	+	+	
90						–	–	–	+	+	+	
55 Scenario minus Baseline (°F)												
50									+	+	+	
90						–	–	–	+	+	+	
65 Scenario minus Baseline (°F)												
50									+	+	+	
90						–	–	–	+	+	+	

Percentile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
75 Scenario minus Baseline (°F)												
50			–	–	–				+	+	+	+
90					–	–	–	–	+	+	+	+

+ indicates increase in temperature of more than 1 °F'; – indicates decrease in temperature of more than 1 °F
One degree Fahrenheit was chosen only as an indicator of change and is not an impact threshold.

Temperature Effects on Water Quality Objectives

The Central Valley Basin Plan states: "[a]t no time or place shall the temperature of COLD or WARM intrastate waters be increased more than 5 °F above natural receiving water temperature" (^Central Valley Water Board 2018b). This objective is primarily for protection of cold water fish. Because the objective applies to "receiving water," it is most applicable to situations where water receives a discharge, although it could be more broadly interpreted as being applicable to instream actions such as dam construction and changes in storage and flow. Existing infrastructure already has a profound effect on water temperatures. For example, reservoirs often release water that is cooler than inflow temperatures in summer and warmer than inflow temperatures in winter, although their main water temperature impact is to prevent fish access to upper watersheds where water temperature is naturally cooler. Based on temperature model results presented in Appendix A6, *Water Temperature Modeling and Fish Assessment for the Sacramento, Feather, and American Rivers*, temperature increases of more than 5 °F would generally be unlikely to occur, but might occur under some circumstances (e.g., September and October in the Feather River). If cold water fish are present, the 5 °F-objective is generally less stringent than the Central Valley Basin Plan objective that states: "The natural receiving water temperature of intrastate waters shall not be altered unless it can be demonstrated to the satisfaction of the Regional Water Board that such alteration in temperature does not adversely affect beneficial uses" (^Central Valley Water Board 2018b).

Depending on fish species and life stage present and temperatures under existing conditions, detrimental temperature effects on cold water fish could occur when temperature increases are substantially less than 5 °F. Section 7.6.2, *Aquatic Biological Resources*, evaluates possible effects of changes in water temperature on native cold water anadromous fish. If the month-water year type average exceedance of a criteria is greater than 0.5 °F, temperature effects are considered potentially significant if other criteria co-occur.

Water temperature can affect other water quality parameters, such as dissolved oxygen and HABs. The effect of changes in water temperature are likely to be limited. In reservoirs, HABs usually form near the surface where water temperature is warm. Water temperature at the surface of reservoirs will be warm regardless of changes in hydrology, although some variation associated with low storage and increased shallow areas is considered in the discussion of HABs and could affect HAB occurrence in some reservoirs. The effects of the proposed Plan amendments on stream temperatures are unlikely to cause increases in HABs in the streams below rim reservoirs. In general, HABs are unlikely to form in the relatively fast-moving, cold streams below Sacramento/Delta reservoirs. Possible Delta temperature effects on HABs are discussed below in the *Delta* discussion.

Water temperature has a direct physical effect on dissolved oxygen. Cold water with full saturation of dissolved oxygen will have higher dissolved oxygen concentrations than warm water. However, low dissolved oxygen is primarily a problem when dissolved oxygen concentration is far below full saturation. This tends to occur in water that is deep (with little surface reaeration) and/or stagnant (with less reaeration and more organic matter). If water is released from deep in a reservoir, it might have low dissolved oxygen either with or without changes in hydrology under the proposed Plan amendments. However, as it moves downstream, it would become reaerated regardless of water temperature. Water temperature can affect dissolved oxygen concentrations in fully saturated water, but concentrations in fully saturated water are almost always adequate for aquatic life. For fresh water at sea level, a relatively warm temperature of 77 °F corresponds to saturated dissolved oxygen concentration of approximately 8.3 mg/L (Chapra et al. 2021), which is above the 7.0 mg/L objective for cold water ecosystems and spawning specified in the Central Valley Basin Plan. The most stringent objective in the Central Valley Basin Plan is 9.0 mg/L for June 1 – August 31 in the Sacramento River between Keswick and Hamilton City (^Central Valley Water Board 2018b). A saturated dissolved oxygen concentration of 9.0 mg/L corresponds to a water temperature of 68.9 °F for fresh water at sea level (Chapra et al. 2021). With changes in hydrology, temperatures at the warmest part of this reach (Hamilton City) were estimated to reach 67.5 °F in July (90th percentile values for the 55 scenario) (see Appendix A6, *Water Temperature Modeling and Fish Assessment for the Sacramento, Feather, and American Rivers*, Table A6-29) and therefore would not preclude attainment of the dissolved oxygen objective. Any effect of changes in temperature on attainment of dissolved oxygen objectives would likely be small and is considered part of the water temperature impact.

Conclusion—Water Temperature

Water temperature was assessed using SacWAM output linked to temperature models for some rivers and SacWAM changes in hydrology for others. Specifically, model results were evaluated to determine instances where an increase in water temperatures could occur due to reduced reservoir storage levels and reduced streamflows. Because the cold water habitat objective is narrative and is intended to be implemented based on the specific circumstances of each watershed, the modeling does not include specific prescriptive requirements. Instead, it includes assumptions that are generally reflective of management actions that could be taken to provide cold water habitat protection that focuses on the rim reservoirs. Increases in stream temperature could affect fish, depending on several specific factors, including the fish species, their distribution and temperature tolerance, and other factors evaluated in more detail in Section 7.6.2, *Aquatic Biological Resources*.

As described in Section 7.12.1.2, *Environmental Setting,* and Chapter 5, *Proposed Changes to the Bay-Delta Plan for the Sacramento/Delta*, existing temperature protections are in place for some stream reaches and reservoirs, but legal requirements are applied unevenly and, in some cases, not at all. The proposed cold water habitat objective is intended to address this issue and to ensure that salmonids have access to cold water habitat at critical times and that adequate water is available for minimum instream flow purposes downstream of reservoirs. Cold water habitat conditions, species needs, and the measures for best implementing the narrative objective will vary among the tributaries due in part to tributary-specific complexities. The proposed Plan amendments would require reservoir operators to develop and implement long-term strategies and annual operations plans for approval by the State Water Board to implement the cold water habitat objective. Those strategies and plans would be based on the unique structural, operational, and hydrological characteristics and species requirements for each tributary. Specific implementation may include a combination of cold water storage provisions, TCDs, flow provisions, passage to cold water habitat, and other measures.

The intent of the cold water habitat objective is to bolster existing legal protections to ensure comprehensive temperature protection over time. Although approaches may differ among tributaries, the effectiveness of cold water management will require ongoing coordination, collaboration, and technical review among water managers, stakeholders, and technical experts to facilitate both short-term and long-term planning and decision-making efforts. The cold water habitat objective is narrative in order to provide sufficient flexibility for implementation options, including coordination with existing regulatory efforts on tributaries with hydropower projects undergoing FERC relicensing or other regulatory processes. Managing these factors to protect cold water habitat for fish is complex and challenging. While implementation of the cold water habitat requirement and other mitigation measures are intended to avoid potential impacts, it may take time to implement protective measures, and water temperature increases associated with changes in hydrology could occur in some streams under some circumstances. Increases in temperature would primarily be a concern for native cold water fish. For this reason, the cold water habitat objective and the water temperature mitigation measures are tailored to fish.

Impacts on water temperature could be potentially significant. Implementation of Mitigation Measure MM-SW-a,f: 3 will avoid or reduce temperature impacts in the Sacramento/Delta. This mitigation measure incorporates MM-AQUA-a,d: 1 for temperature control and reservoir management. Implementation of the proposed cold water habitat objective is expected to reduce or avoid any temperature impacts. In addition, temperature effects can be minimized due to the flexibility provided in the flow objectives (range of flow levels, shaping and shifting of flows, groups of tributaries working together) and other proposed provisions of the program of implementation. However, because some uncertainty exists regarding the precise implementation measures for the cold water habitat objective and application of the flexibilities provided for implementation of the inflow objective (including decisions regarding tradeoffs between instream flows and cold water supplies), it is possible that limited instances of temperature impacts would occur, even with mitigation or where mitigation activities require time to be implemented effectively. Therefore, temperature impacts from changes in reservoir levels and lower flows below reservoirs remain potentially significant.

Harmful Algal Blooms

Changes in hydrology may result in reduced reservoir storage levels in some reservoirs at some times and in associated shallower, warmer, more stable water column conditions in those reservoirs. These conditions could lead to increased reservoir algal bloom formations; with lower storage levels, blooms could be more likely to be exposed to reservoir outlets, affecting supplies from the reservoir for downstream releases and water supply purposes.

HABs occur in both lower- and higher-elevation reservoirs under existing conditions, although they are less common at higher elevations due to lower temperatures and lower concentrations of nutrients. The cold water habitat requirement is intended to be implemented in a manner that avoids significant reservoir drawdowns and associated temperature effects that could lead to the production of HABs, but HAB production would possibly increase in some reservoirs, at some times.

Under the proposed Plan amendments, reservoir storages would likely fall within historical ranges, but the distribution of those storages could change based on changes in operations. Although reservoirs eventually may be operated using protocols that differ from the scenarios as modeled, the model results are indicative of potential effects on reservoir levels. In general, the proposed Plan amendments may result in lower storage in rim reservoirs at the beginning of the irrigation season and less total water being released in summer months, eventually resulting in carryover storage that is closer to baseline conditions. The modeling indicates that carryover storage at rim reservoirs with the proposed Plan amendments could be lower, similar, or greater than baseline conditions depending on reservoir and water year type. Carryover storage could be reduced in a few rim reservoirs, with the largest reductions occurring under the 65 scenario. In the upper watersheds, substantial effects on storage are not expected in most reservoirs. However, some upper watershed reservoirs might experience substantial effects, especially those involved with interbasin diversions and those that need to release additional water to meet inflow requirements for the rim reservoirs downstream (see Chapter 6, *Changes in Hydrology and Water Supply*). Lower reservoir levels could increase the production of HABs. This impact would be potentially significant.

Potential HAB impacts in Sacramento/Delta reservoirs can be reduced through implementation of Mitigation Measures MM-SW-a,f: 1 and 3 through 5. HABs are a statewide water quality issue that exists independently of potential incremental effects from changes in hydrology. Several ongoing activities to address HABs, such as those coordinated by the Freshwater and Estuarine Harmful Algal Bloom (FHAB) Program, also could be employed to mitigate impacts. The State and regional water boards regulate discharges of nitrogen and phosphorus, which contribute to HAB formation. The most immediate HAB response efforts include public education and notification efforts to minimize exposure of pets and people to waterbodies containing HABs. The California Water Quality Monitoring Council maintains a website for the California Cyanobacteria and Harmful Algal Bloom (CCHAB) Network that tracks HABs and provides information about how to respond to HABs, including information from the USEPA on measures that should be implemented to prevent and respond to HABs in surface waters and drinking water supplies. In addition, the cold water habitat requirement is intended to be implemented in a manner that does not affect cold water supplies for fish, which may also serve to mitigate HAB impacts. While the State Water Board and others are engaged in efforts to address HABs, those efforts will take time and may not fully resolve HAB issues, including the incremental impacts associated with changes in hydrology under the proposed Plan amendments. Unless and until the mitigation is fully implemented and proven effective, the impacts remain potentially significant.

Delta

Changes in hydrology would increase annual Delta outflow in all months except August. The DSM2 model of Delta hydrodynamics and water quality was used to simulate the effect of changes in hydrology on salinity (EC) in the Delta, as described in Appendix A2, *Delta Simulation Model II* (*DSM2*) *Methods and Results*. All tables and figures in this Delta-region section contain DSM2 results that also are presented in Appendix A2.

The SacWAM results for Delta inflows provide input to the DSM2 model and produce the differences between the DSM2 results for each flow scenario. The DSM2 results for EC and flow were used to infer water quality effects for other Delta water quality constituents, including chloride, bromide, and HABs. Because the DSM2 analysis includes Suisun Marsh, the marsh is discussed in this analysis of the Delta and not in the Bay Area analysis.

DSM2 is a one-dimensional mathematical model typically used for simulations of hydrodynamics, water quality, and particle tracking in a network of riverine or estuarine channels (DWR 2002). The DSM2 model is used to calculate tidal elevations, flows, velocities, and EC in the Delta. DSM2 calculates the tidal flows in each Delta channel and calculates the seawater intrusion effects, which are controlled by the tidal flows and the net Delta outflow.

The DSM2 model was run using a 15-minute time increment. However, the SacWAM inputs to the model were monthly, with the Sacramento River and San Joaquin River inflows disaggregated to daily values to smooth the transition in flows between months. The analysis of impacts is based on monthly values. The time increment of the surface water quality objectives described in the Bay-Delta Plan varies with the particular objective. For example, Bay-Delta Plan Table 1 objectives for municipal water quality use maximum mean daily values of the chloride concentration, whereas Bay-Delta Plan Table 2 objectives for agricultural water quality use maximum 14-day or 30-day running averages of the mean daily EC. Even though the time increment for the water quality objectives does not always match the time increment of the monthly evaluation, the monthly evaluation can still be used to determine whether changes in hydrology would hinder the ability to meet the water quality objectives.

Electrical Conductivity

As described in Section 7.12.1.2, *Environmental Setting,* many water quality compliance locations in the Delta have EC objectives. Excessive salinity may harm drinking water, agriculture, and aquatic species. The goal of the EC objectives is to maintain adequately low salinity at locations that support these uses. Average monthly DSM2 results for the scenarios were compared to baseline conditions to evaluate EC effects and the attainment of water quality objectives for habitat, agriculture, and municipal water supply at the following locations in the Bay-Delta.

- Western Delta: Sacramento River at Mallard Slough and Emmaton, and San Joaquin River at Antioch and Jersey Point.
- Suisun Marsh: Four compliance locations within Suisun Marsh and the Sacramento River at Collinsville, near where water enters the marsh at Montezuma Slough.
- Interior Delta and exports (for convenience of discussion, this region extends from the SWP and CVP exports to the northern Delta): Barker Slough in the northern Delta; San Joaquin River at San Andreas Landing, Prisoners Point, and Stockton Intake; Mokelumne River at Terminous; Old River at Bacon Island (near Rock Slough) and Highway 4; Victoria Canal; Clifton Court Forebay; and Delta-Mendota Canal Intake.
- Southern Delta: San Joaquin River at Brandt Bridge, Old River near Middle River, and Old River at Tracy Boulevard.

For the southern Delta, the 2018 Bay-Delta Plan specifies salinity objectives for one point location and three river segments. The three point locations used to evaluate DSM2 results for the southern Delta were compliance locations specified in older versions of the Bay-Delta Plan and fall within the compliance reaches specified in the 2018 Bay-Delta Plan. EC in the San Joaquin River at Vernalis is a DSM2 model input and does not change between the scenarios, so is not one of the compliance locations evaluated.

DSM2 results are presented here as a series of graphs and tables for key locations to evaluate compliance with water quality objectives for habitat, agriculture, and municipal supply. The graphs provide a time-series comparison of simulated baseline monthly average EC values to each of the scenarios and to compliance objectives. The tables provide quantitative information about the higher of the EC values (90th percentile) presented in the figures (i.e., those most likely to exceed water quality objectives). Ninetieth percentile values are shown in the tables instead of the maximum values because they provide a better general representation of the higher salinity values; maximum values are defined by the single highest model result for each month. Information about the relevant objectives is provided in table notes.

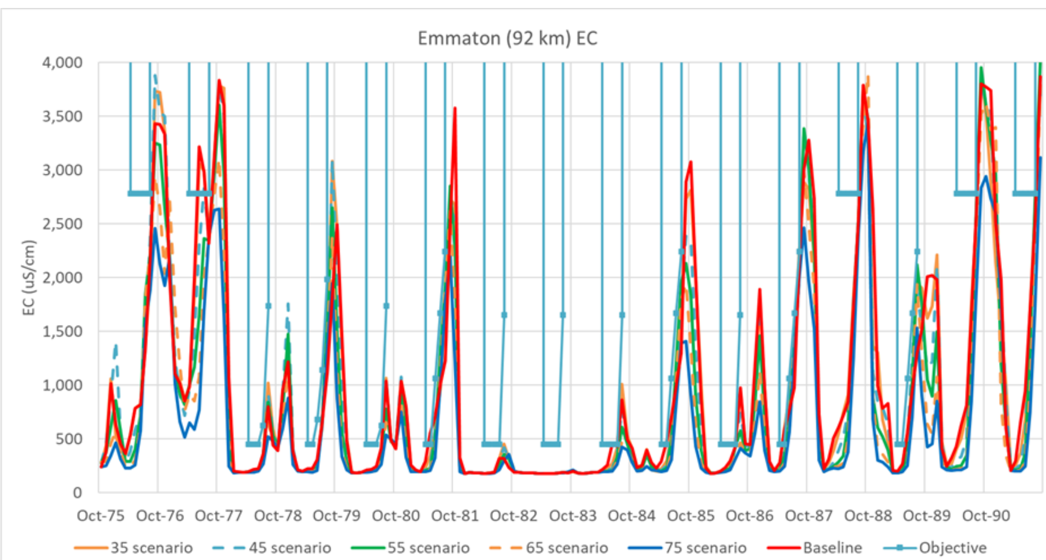
The DSM2 results show that salinity within the Delta channels is largely influenced by seawater intrusion, which is controlled by the balance between tidal exchange (constant at each location) and Delta outflow. As a result of the increased Delta inflows and reduced Delta exports, the proposed Plan amendments (45 to 65 scenarios) generally would increase Delta outflows relative to baseline conditions in most months, thereby reducing seawater intrusion and salinity.

Western Delta

The proposed Plan amendments (45 to 65 scenarios) generally would result in little change or reductions in EC associated with reductions in seawater intrusion, although occasional small increases in EC may occur in the western Delta. The Sacramento River at Emmaton is shown here because it is a location where EC values tend to be closer to the objectives (Figure 7.12.1-4 and Table 7.12.1-12). Reservoir releases and exports generally are managed to ensure that EC objectives are attained in the western Delta; therefore, while EC may occasionally increase, it would not result in exceedances. The DSM2 results show that the changes in hydrology under the proposed Plan amendments would not cause an increase in exceedances of the western Delta agricultural objectives, and reductions in EC are expected to be far more common than increases in EC.

Water quality in the western Delta is suitable for municipal water supply only during parts of the year when EC is less than about 1,000 microSiemens per centimeter (µS/cm). Changes in hydrology could slightly increase the duration of water quality suitability for drinking water intakes in the western Delta at Antioch and Mallard Slough (Figure 7.12.1-5 and Table 7.12.1-13).

Seawater intrusion into the western Delta also is indicated by the X2 value. Attainment of X2 regulatory objectives is part of SacWAM. Potential changes in X2 associated with the proposed Plan amendments are discussed in Section 7.6.2, *Aquatic Biological Resources*.



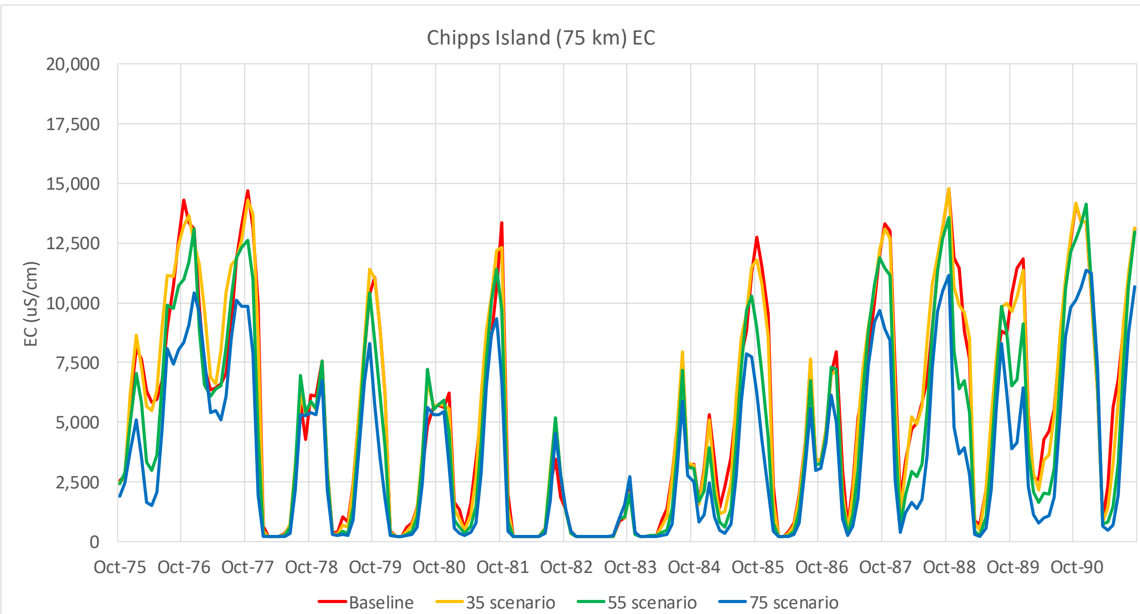
Electrical conductivity objectives are included for reference.
EC = electrical conductivity
km = kilometer
µS/cm = microSiemens per centimeter

Figure 7.12.1-4. Average Monthly DSM2 Electrical Conductivity Values for Emmaton under Baseline and Flow Scenarios (Water Years 1976–1991)

Table 7.12.1-12. Electrical Conductivity Values (µS/cm) for Emmaton under Baseline and Flow Scenarios (90th Percentile Values for Water Years 1976–1991)

Scenario	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Baseline	3,678	3,467	1,995	1,039	715	436	570	750	895	1,729	2,519	3,798
35 minus Baseline	-55	-339	113	9	21	-69	-26	13	3	77	-5	-57
45 minus Baseline	-88	30	137	282	32	-156	-183	-206	-113	-36	53	-26
55 minus Baseline	-146	-666	-144	-54	-119	-169	-283	-376	-188	58	80	58
65 minus Baseline	-313	-1,343	-58	-345	-350	-196	-327	-462	-272	-51	-128	-309
75 minus Baseline	-889	-1,683	-464	-299	-241	-211	-345	-501	-325	-314	-332	-823

Shading indicates when objectives are applicable. The Bay-Delta Plan has April 1 through August 15 electrical conductivity objectives for agriculture at Emmaton. The objective is 450–2,780 microSiemens per centimeter (µS/cm), depending on date and water year type.



Electrical conductivity objectives are included for reference.

EC = electrical conductivity

km = kilometer

µS/cm = microSiemens per centimeter

Figure 7.12.1-5. Average Monthly DSM2 Electrical Conductivity Values for Chipps Island near Mallard Slough under Baseline and Flow Scenarios (Water Years 1976–1991)

Table 7.12.1-13. DSM2 Electrical Conductivity Values (µS/cm) for Chipps Island near Mallard Slough under Baseline and Flow Scenarios (90th Percentile Values for Water Years 1976–1991)

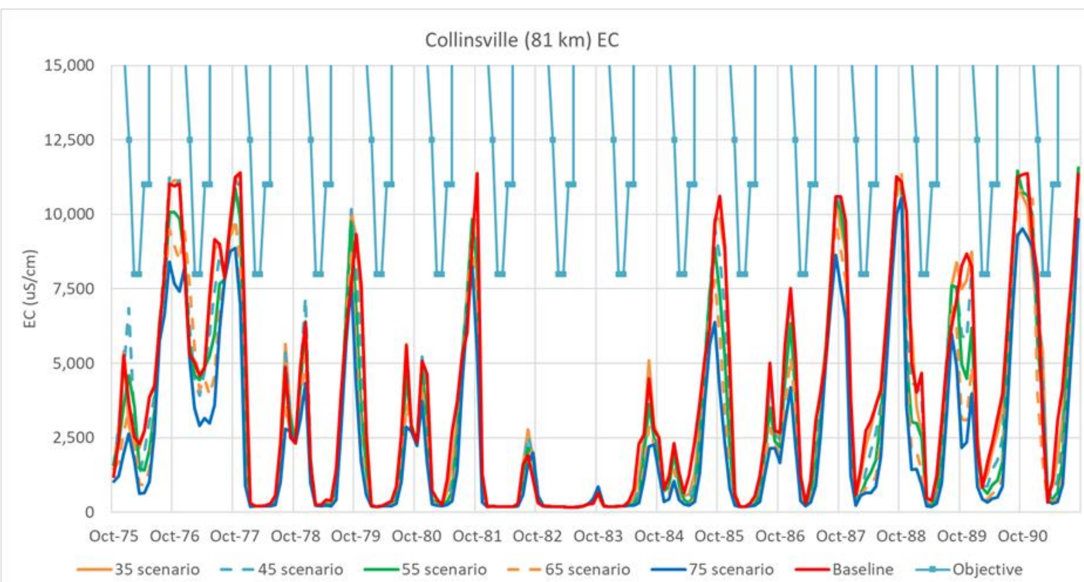
Scenario	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Baseline	15,442	15,301	12,355	8,927	6,946	5,091	5,554	6,652	7,292	9,851	12,458	15,387
35 minus Baseline	-256	-467	70	17	2	-475	-195	25	49	85	164	-75

Scenario	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
45 minus Baseline	-318	-241	46	1,454	512	-2,037	-1,296	-1,214	-516	-45	192	-63
55 minus Baseline	-475	-1,286	-929	-314	-205	-2,121	-2,406	-2,642	-1,277	-148	-97	50
65 minus Baseline	-969	-2,840	-1,237	-2,193	-2,567	-2,913	-3,299	-3,657	-1,856	-510	-838	-730
75 minus Baseline	-2,174	-4,251	-2,528	-1,976	-1,846	-3,452	-3,898	-4,377	-2,287	-1,233	-1,372	-1,832
Objective [a]	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000

[a] Contra Costa Water District can operate the Mallard Slough pumping plant for municipal water supply when chloride at Chipps Island is less than 250 milligrams per liter (electrical conductivity less than approximately 1,000 microSiemens per centimeter (µS/cm) as described in Appendix A2, *Delta Simulation Model II* [*DSM2*] *Methods and Results*).

Suisun Marsh

EC in Suisun Marsh is dominated by tidal flux from Suisun Bay. As such, the EC effects at Collinsville, near the Montezuma Slough entry to Suisun Marsh, indicate the likely impact of the proposed Plan amendments on EC in Suisun Marsh. The proposed Plan amendments (45 to 65 scenarios) would result in little change in EC at Collinsville during some months, some relatively small increases in EC during others (primarily outside of the October through May fish and wildlife objective period), and some substantial reductions in EC associated with reductions in seawater intrusion during the fish and wildlife objective period (Figure 7.12.1-6 and Table 7.12.1-14). Only the 35 and 45 scenarios show any increases in EC during the October through May fish and wildlife objective period, but these would not be expected to cause violations in Suisun Marsh objectives because the general effect under these scenarios would be a reduction in EC, and real-time operations would be managed to meet objectives.



Electrical conductivity objectives are included for reference.
EC = electrical conductivity
km = kilometer
µS/cm = microSiemens per centimeter

Figure 7.12.1-6. Average Monthly DSM2 Electrical Conductivity Values for Collinsville under Baseline and Flow Scenarios (Water Years 1976–1991)

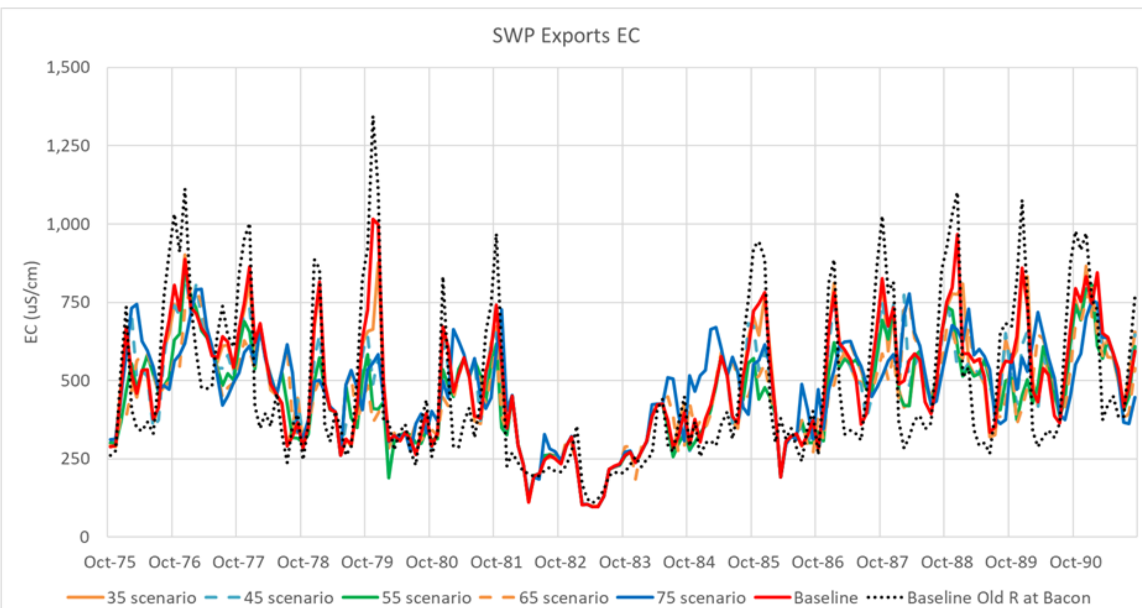
Table 7.12.1-14. DSM2 Electrical Conductivity Values (µS/cm) for Collinsville under Baseline and Flow Scenarios (90th Percentile Values for Water Years 1976–1991)

Scenario	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Baseline	11,286	11,193	8,267	5,278	3,877	2,516	2,908	3,711	4,208	6,357	8,491	11,257
35 minus Baseline	-308	-500	60	14	-3	-322	-127	20	3	47	152	-79
45 minus Baseline	-373	-240	120	1,252	311	-1,201	-872	-866	-389	-65	198	-65
55 minus Baseline	-475	-1,329	-786	-189	-211	-1,261	-1,534	-1,798	-891	-64	-1	68
65 minus Baseline	-935	-2,795	-915	-1,566	-1,781	-1,648	-1,992	-2,390	-1,275	-361	-696	-665
75 minus Baseline	-2,092	-3,997	-1,993	-1,373	-1,265	-1,882	-2,261	-2,754	-1,546	-986	-1,141	-1,694

Shading indicates when objectives are applicable. The Bay-Delta Plan has October through May electrical conductivity objectives for fish and wildlife at Collinsville and in Suisun Marsh. The objectives are 8,000–19,000 microSiemens per centimeter (µS/cm), depending on month and, for some locations, on hydrologic conditions.

Interior Delta and Exports

Changes in EC in the interior Delta and the exports would be driven primarily by reductions in seawater intrusion. Intermittent increases in EC as a result of the proposed Plan amendments (45 to 65 scenarios) would be small, tend to occur when EC is low, and often be associated with an increase in San Joaquin River water relative to Sacramento River water (Figure 7.12.1-7 and Figure 7.12.1-8 and Table 7.12.1-15 and Table 7.12.1-16).



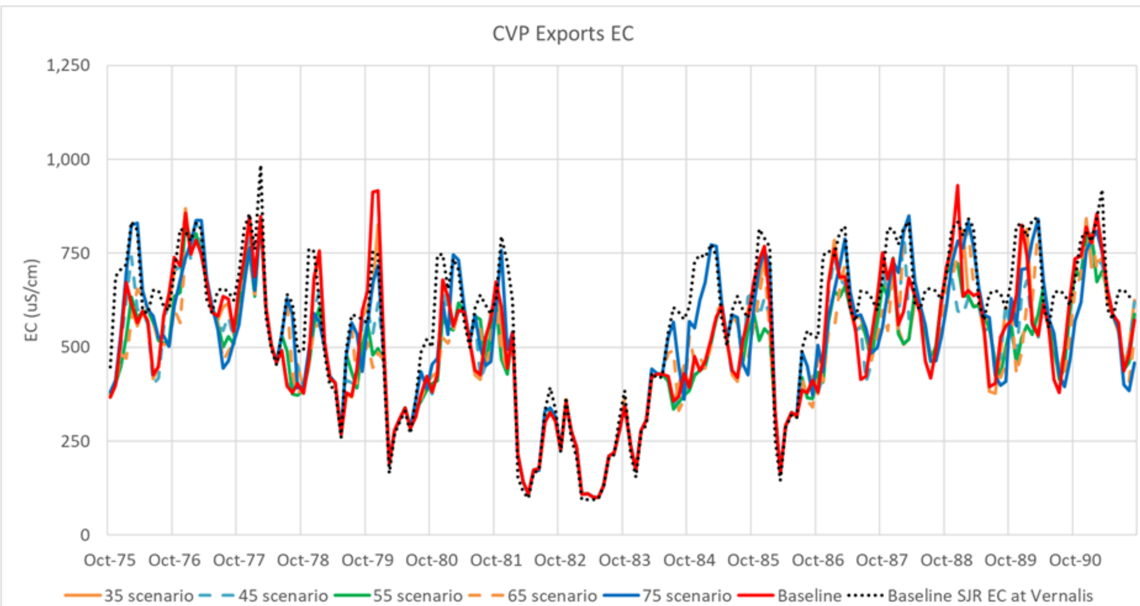
Baseline Old River (Old R) at Bacon Island electrical conductivity is included for reference.
EC = electrical conductivity
µS/cm = microSiemens per centimeter

Figure 7.12.1-7. Average Monthly DSM2 Electrical Conductivity Values for SWP Exports under Baseline and Flow Scenarios (Water Years 1976–1991)

Table 7.12.1-15. DSM2 Electrical Conductivity Values (µS/cm) for Clifton Court Forebay under Baseline and Flow Scenarios (90th Percentile Values for Water Years 1976–1991)

Scenario	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Baseline	800	775	928	763	698	625	612	573	484	415	574	664
35 minus Baseline	-49	-48	-57	47	-9	-24	-30	6	15	47	-16	-12
45 minus Baseline	-55	-64	-152	-31	45	-37	-13	12	40	14	-38	3
55 minus Baseline	-85	-84	-166	-68	-55	-53	8	16	70	87	-88	-52
65 minus Baseline	-160	-129	-263	-80	2	74	25	24	65	99	-105	-127
75 minus Baseline	-211	-142	-288	-95	41	137	38	30	75	116	-92	-177
Objective [a]	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000

[a] As described in Appendix A2, *Delta Simulation Model II* (*DSM2*) *Methods and Results,* based on maximum contaminant levels for electrical conductivity and chloride and Bay-Delta Plan objectives for agriculture, target electrical conductivity at the SWP intake (West Canal at the mouth of Clifton Court Forebay) is less than 1,000 microSiemens per centimeter (µS/cm).



Baseline San Joaquin River electrical conductivity is included for reference.
EC = electrical conductivity
µS/cm = microSiemens per centimeter
SJR = San Joaquin River

Figure 7.12.1-8. Average Monthly DSM2 Electrical Conductivity Values for CVP Exports under Baseline and Flow Scenarios (Water Years 1976–1991)

Table 7.12.1-16. DSM2 Electrical Conductivity Values (µS/cm) for Delta-Mendota Canal Intake under Baseline and Flow Scenarios (90th Percentile Values for Water Years 1976–1991)

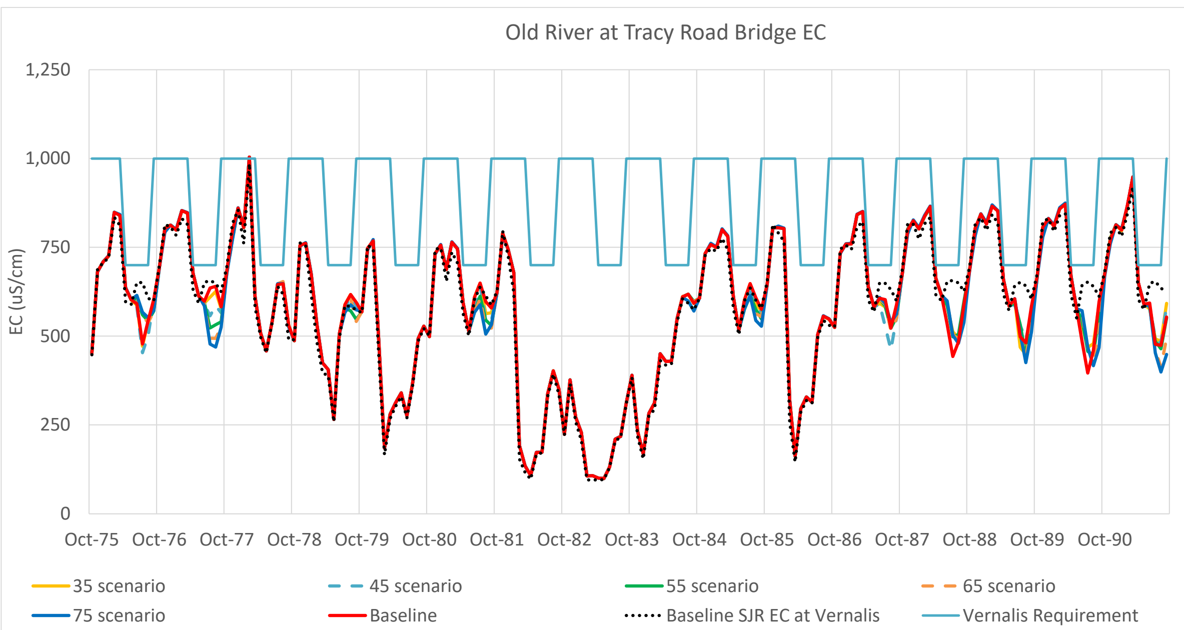
Scenario	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Baseline	737	756	887	759	817	718	649	591	528	443	556	629
35 minus Baseline	-27	-33	-51	39	-56	-16	-15	1	20	65	-14	-9

Scenario	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
45 minus Baseline	-32	-50	-92	-24	9	-24	-4	7	29	22	-35	-2
55 minus Baseline	-55	-56	-109	-42	-78	-36	8	13	54	107	-50	-39
65 minus Baseline	-98	-71	-136	4	3	97	24	15	52	116	-70	-100
75 minus Baseline	-124	-40	-126	11	19	122	27	15	58	130	-23	-122
Objective [a]	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000

[a] As described in Appendix A2, *Delta Simulation Model II* (*DSM2*) *Methods and Results,* based on maximum contaminant levels for electrical conductivity and chloride and Bay-Delta Plan objectives for agriculture, target electrical conductivity at the CVP intake (Delta-Mendota Canal at the Jones Pumping Plant) is less than 1,000 microSiemens per centimeter (μS/cm).

Southern Delta

The EC at southern agricultural compliance stations is controlled primarily by the EC of the San Joaquin River and local drainage, which would not be affected by the proposed Plan amendments (45 to 65 scenarios). The proposed Plan amendments thus would cause little change in EC. The EC in Old River at Tracy Boulevard is shown as an example (Figure 7.12.1-9 and Table 7.12.1-17). The proposed Plan amendments are not expected to cause or contribute to any exceedances of the southern Delta water quality objectives, and in some cases may result in a decrease in EC.



Electrical conductivity objectives are included for reference.
EC = electrical conductivity
μS/cm = microSiemens per centimeter
SJR = San Joaquin River

Figure 7.12.1-9. Average Monthly DSM2 Electrical Conductivity Values for Old River at Tracy Boulevard under Baseline and Flow Scenarios (Water Years 1976–1991)

Table 7.12.1-17. DSM2 Electrical Conductivity Values (µS/cm) for Old River at Tracy Boulevard under Baseline and Flow Scenarios (90th Percentile Values for Water Years 1976–1991)

Scenario	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Baseline	684	805	837	807	866	868	666	607	606	646	629	596
35 minus Baseline	0	0	-2	0	-3	-1	0	0	-3	0	-7	-4
45 minus Baseline	-1	-1	-1	0	-2	-1	0	0	-16	-12	-15	-3
55 minus Baseline	-1	-2	0	0	-1	-1	0	1	-6	-33	-33	-12
65 minus Baseline	-4	-3	1	1	0	2	1	1	-3	-36	-17	-31
75 minus Baseline	-5	-14	1	2	1	2	1	1	1	-35	-36	-25
Objective[a]	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000

[a] The Bay-Delta Plan has a year-round electrical conductivity objective of 1,000 microSiemens per centimeter (µS/cm) for agriculture in southern Delta channels, although the program of implementation in the 2018 Bay Delta Plan update continues the requirement for Vernalis salinity to be maintained at the older objective of 700 µS/cm for April through August to provide assimilative capacity downstream during irrigation season.

Because San Joaquin River water enters the southern Delta near the CVP and SWP export pumping plants, and because San Joaquin River flows are usually less than the CVP and SWP exports, most of the San Joaquin River water usually is exported. When exports and in-Delta diversions in the southern Delta are larger than San Joaquin River inflow, water from the Sacramento River flows to the southern Delta. The Sacramento River water is generally of better quality than the San Joaquin River water and can sometimes reduce salinity in the southern Delta. However, the difference between San Joaquin River EC and Sacramento River EC is small compared to the difference between the EC in the two rivers and the EC of seawater (approximately 54,000 µS/cm), so the ratio of Sacramento River water to San Joaquin River water has a limited effect on EC in the southern Delta.

Reduced exports could result in less Sacramento River water entering the southern part of the interior Delta. However, the DSM2 results indicate that this effect of altering the ratio of Sacramento River water to San Joaquin River water is relatively small and intermittent, as indicated by effects on export EC in the 45, 55, and 65 scenarios (e.g., Figure 7.12.1-7 and Figure 7.12.1-8). The reductions in EC associated with reduced seawater intrusion generally have a greater effect on EC in the southern part of the interior Delta. Furthermore, the increases in EC associated with reduction in exports and reduced Sacramento River water in the southern Delta tend to occur when EC is relatively low. In contrast, the reductions in EC associated with reduced seawater intrusion tend to occur when the EC is higher.

Under the baseline conditions, the Delta is operated to meet water quality objectives. Operations to meet water quality objectives would continue under the proposed Plan amendments. The DSM2 results indicate that ability to meet the objectives would not be affected by changes in hydrology under the proposed Plan amendments, and in many cases there would be reductions in EC. In general, the proposed Plan amendments would have little effect on EC or would reduce EC in the Delta and Suisun Marsh. The impacts would range from less than significant to beneficial.

Chloride and Bromide

Because concentrations of chloride and bromide are correlated with salinity, the effects of the proposed Plan amendments on chloride and bromide are similar to the effects on salinity. Chloride and bromide are most relevant to drinking water quality because specific objectives for chloride at drinking water intakes are listed in Table 1 of the Bay-Delta Plan and because the presence of bromide in water can result in harmful disinfection byproducts during water treatment. An evaluation of EC for all drinking water intakes in the Delta, based on DSM2 results, is described in Appendix A2, *Delta Simulation Model II* (*DSM2*) *Methods and Results,* and summarized under *Changes in Delta Channel Salinity (EC)* in that appendix. Delta drinking water intakes include those identified in Table 2 of the Bay-Delta Plan: Mallard Slough (CCWD), Antioch (City of Antioch), Contra Costa Canal at Pumping Plant #1 (CCWD Rock Slough), Clifton Court Forebay (SWP), Delta-Mendota Canal at Jones Pumping Plant (CVP), and Barker Slough at North Bay Aqueduct intake. Salinity was also evaluated for three new municipal drinking water intakes that have been constructed since adoption of D-1641: CCWD Old River intake, CCWD Middle River (Victoria Canal) intake, and City of Stockton San Joaquin River intake.

The general discussion of salinity effects throughout the Delta is applicable to chloride and bromide at drinking water intakes. The proposed Plan amendments generally would increase Delta outflow and reduce exports, which would reduce seawater intrusion events and decrease concentrations of chloride and bromide in the Delta. The proposed Plan amendments are expected to produce either little change or reductions in chloride and bromide at municipal intakes and would not result in exceedances of water quality objectives. The impact would range from less than significant to beneficial.

Nutrients, Organic Material, Harmful Algal Blooms, Invasive Aquatic Plants, and Dissolved Oxygen

Spring runoff and increased flows could result in overbank flows, which may lead to more nutrients and organic material transported into the Delta (Schemel et al. 2002). Increases in nutrients and organic material could result in increased algal growth, which may be beneficial for fish but at high levels could cause eutrophication or degradation of drinking water quality (USEPA 2021). Excessive growth of algae and cyanobacterial HABs can harm beneficial uses of water. HABs can block sunlight, reduce dissolved oxygen when they decompose, produce surface scum that interferes with contact recreation, and cause drinking water taste and odor problems. Some species of cyanobacteria produce toxins (cyanotoxins) that can affect the nervous system, liver, skin, stomach, or intestines. Cyanotoxins are bioaccumulative; their toxicological effect on fish and wildlife is discussed in Chapter 4, *Other Aquatic Ecosystem Stressors*.

Nitrate is a primary nutrient of concern because it can promote algal growth and at high levels can exceed the MCL for drinking water. However, it is unlikely that the effect of increased floodplain inundation would cause nutrient levels to exceed drinking water thresholds, especially because algal growth would deplete nutrients and likely would limit the extent of any elevated nutrient concentrations.

Increases in particulate organic material, including algae, also are unlikely to cause impacts on drinking water quality because particulate matter may be removed from drinking water prior to water treatment through settling, flocculation, and/or filtration. Increases in dissolved organic carbon could increase the production of disinfection byproducts during chlorine treatment, but this effect would likely be small. Because additional major sources of organic material would not be affected by changes in hydrology, such as runoff from forests, rangelands, agricultural lands, and point sources (Tetra Tech 2006), increases in floodplain inundation associated with the proposed Plan amendments are unlikely to cause substantial increases in the concentration of organic material at drinking water intakes. However, small increases in organic material at drinking water treatment plants may require small adjustments to treatment processes.

Increased floodplain inundation also is unlikely to increase blooms of harmful algal species (e.g., blue-green algae) or invasive aquatic plants, and, therefore, is unlikely to result in increased eutrophication and low dissolved oxygen. Increases in nutrients could result in increased biomass of HAB species and invasive aquatic plants. However, a panel of HAB and invasive aquatic plant experts that was assembled to write white papers and inform the Central Valley Water Board in the development of a Delta Nutrient Research Plan cautioned, based on their experience elsewhere, that nutrient management might not reduce HAB and invasive aquatic plant impairments, and they recommended studies to confirm their hypotheses (^Boyer and Sutula 2015; ^Berg and Sutula 2015). Consequently, the limited increase in nutrients that might be associated with increased floodplain inundation is unlikely to cause substantial increases in HABs or invasive aquatic vegetation. In addition, HABs, growth of invasive aquatic vegetation, and eutrophication tend to occur when flows are low and not during periods of floodplain inundation. Increased floodplain inundation associated with the proposed Plan amendments would have a less-than-significant impact on nutrients, organic material, invasive aquatic plants, and HABs.

Changes in Delta channel flows is an additional mechanism by which the proposed Plan amendments might affect HABs and invasive aquatic plants in the Delta. HABs and invasive aquatic plants occur in backwaters, dead-end sloughs, and other waterways with poor water circulation in the central and southern Delta. HABs also occur in larger rivers and channels with more circulation, which may be affected by changes in hydrology. These rivers and channels include the San Joaquin and Old Rivers and channels that convey Delta exports (California Water Quality Monitoring Council 2018).

HABs and invasive aquatic plants are affected by both tidal (back-and-forth) flows and net flows under existing conditions. Tidal flows produce turbulence that can disrupt HAB formation and growth of invasive aquatic plants under all flow scenarios. Turbulent mixing can disrupt HAB formation by increasing turbidity, reducing buoyancy control, and breaking apart colonies (American Water Works Association 2015; ^Lehman et al. 2013). Tidal flows would not be affected by the proposed Plan amendments.

Net flow in some Delta channels could be affected by changes in hydrology. Net flow is important because it controls residence time and can move harmful algae and floating invasive aquatic plants out of an area. Water residence times must be long relative to cell doubling rates for HAB species to form and increase in size within a region. The reported *Microcystis* doubling time average is about 2.8 days at 25°C (Wilson et al. 2006). Increase in *Microcystis* abundance in the Delta is correlated with low flow in the San Joaquin River, Sacramento River, and central Delta (^Lehman et al. 2013) as well as low flows in general through the Delta as indicated by X2 values (Lehman et al. 2022). In the southern Delta, blooms tend to be more severe when flows associated with Delta exports are low (Hartman et al. 2022).

DSM2 results were used to predict net flows in southern Delta channels and assess the increased probability of HABs and invasive aquatic plants. Harmful algal blooms have been particularly problematic near Stockton, especially near the Stockton Waterfront. As presented in Appendix A2, *Delta Simulation Model II (DSM2) Methods and Results*, the proposed Plan amendments are expected to cause either little change in flow or increases in flow in the San Joaquin River near Stockton during the June through October HAB season, with a trend towards larger increases in the higher flow scenarios. This change in hydrology would have minimal effect on HABs in the San Joaquin River or could cause the San Joaquin River to be slightly less suitable for HAB formation. The bigger HAB problem, however, for the city of Stockton occurs near the Stockton Waterfront, which is located upstream of the Port of Stockton turning basin for cargo vessels in a dead-end slough that connects to the San Joaquin River at its west end. Dead-end sloughs have limited tidal exchange and minimal net flow, resulting in stagnant water and long residence times, which are conducive to HAB formation. The proposed Plan amendments would not affect HABs in the Stockton Waterfront slough because, as shown in Appendix A2, the proposed Plan amendments would not affect flow in and out of this slough.

Flow effects on HAB formation are more likely in channels that convey water to the export pumps. Travel times through Victoria Canal were estimated using DSM2 results for baseline conditions and proposed Plan amendments (Appendix A2, *Delta Simulation Model II* [*DSM2] Methods and Results*). Victoria Canal was selected as a representative large channel that could be affected by changes in Delta exports and that already has experienced some limited formation of HABs (California Water Quality Monitoring Council 2018). Victoria Canal is almost 4 miles long and carries Middle River reverse flows to Clifton Court Forebay for SWP export. Net flow in Victoria Canal and other southern Delta channels is the result of an interplay between San Joaquin River flow, operation of the southern Delta temporary barriers, Delta agricultural diversions, and CVP and SWP exports. All these factors were the same or similar for baseline conditions and the flow scenarios except export pumping.

The DSM2 results indicate that average monthly baseline condition travel times through Victoria Canal were between 0.6 and 1.3 days during primary months for HAB activity, June through October. Model results indicate that average travel time increased in the 45, 55, and 65 scenarios during the bloom period as compared to baseline conditions, with the higher (55 and 65) flow scenarios having a larger effect on exports and travel time through Victoria Canal. For the 65 scenario, monthly average travel times increased by 0.3 to 3.8 days, varying by month (Table 7.12.1-18). For the 55 scenario, monthly average travel times increased by 0.1 to 3.6 days. These increases could incrementally increase the chances of HAB formation and bloom size; similar increases could occur in other Delta channels that convey Sacramento River water to Delta export pumps.

Table 7.12.1-18. Average Travel Time (in days) through Victoria Canal Estimated with DSM2 Flows—Baseline and Increase under Flow Scenarios Relative to Baseline

Scenario	June	July	August	September	October
Baseline	1.3	0.7	0.6	0.6	0.6
35 minus Baseline	0.4	0.4	0.0	0.0	0.1
45 minus Baseline	1.2	0.4	0.0	0.1	0.1
55 minus Baseline	3.6	1.2	0.2	0.1	0.4
65 minus Baseline	3.8	1.7	0.5	0.3	1.1
75 minus Baseline	5.1	2.7	1.1	0.4	1.8

HAB formation and presence of aquatic invasive plants in dead-end sloughs and other channels with poor circulation is unlikely to be affected because tidal and net flow in these channels would not be affected by the proposed Plan amendments. However, increases in water travel time through channels that convey water to the CVP and SWP export pumps could increase HAB formation or increase the presence of invasive aquatic plants.

Both HABs and invasive aquatic plant concerns exist independently of the potential incremental effects from changes in hydrology under the proposed Plan amendments. The proposed Plan amendments generally would result in Delta outflows that are similar to or greater than baseline outflow and X2 values that are similar to or less than baseline values, which could lead to reduced HAB formation and invasive aquatic vegetation in large portions of the Delta. It is also possible, however, that the reduced Delta inflows in summer and fall and reduced exports could lead to an incremental increase in the production of HABs and invasive aquatic plants in some Delta channels at some times, particularly in the southern Delta. Although this impact is not expected to be frequent or widespread, because HABs and invasive aquatic vegetation are already a significant concern in the Delta, the impact would be potentially significant.

Potential HAB impacts in the Delta can be reduced through implementation of Mitigation Measures MM-SW-a,f: 1, 4, and 5. Several ongoing activities to address HABs and invasive aquatic plants, such as those coordinated by the FHAB Program, also would mitigate impacts from the proposed Plan amendments. For example, the State and regional water boards regulate discharges of nitrogen and phosphorus that may contribute to HAB and invasive aquatic plant concerns in the Delta. The most immediate response efforts include public education and notification efforts to minimize exposure of pets and people to waterbodies containing HABs. The California Water Quality Monitoring Council maintains a website for the CCHAB Network that tracks HABs and provides information about how to respond to HABs, including information from USEPA on measures that should be implemented to prevent and respond to HABs in surface waters and drinking water supplies. CDBW also is engaged in efforts to monitor and control invasive aquatic weeds in the Delta through chemical, mechanical, and biological control measures, as well as hand picking when needed. While the State Water Board and others are engaged in efforts to address HABs and invasive aquatic plants, those efforts will take time and may not fully address potential impacts to a less-than-significant level. Unless and until the mitigation is fully implemented and proven effective, the impacts remain potentially significant.

Water Temperature

As described in the *Environmental Setting*, by the time water reaches the Delta, it generally has warmed considerably, approaching equilibrium values. As water approaches equilibrium, effects of changes in hydrology would be diminished because temperatures would approach the same equilibrium values for all scenarios. Nonetheless, changes in flow could cause limited temperature effects on Delta water temperature due to changes in temperature entering the Delta from the Sacramento River, with some potentially cooler temperatures in spring and warmer temperatures in summer/early fall (see Appendix A6, *Water Temperature Modeling and Fish Assessment for the Sacramento, Feather, and American Rivers*). Flow may also affect the location where equilibrium temperatures might eventually be reached within the Delta if equilibrium temperatures have not already been reached before entering the Delta and may also affect the inland extent of ocean influence on water temperature. While potential decreases in Delta temperatures in the spring would be beneficial, potential limited increases in Delta temperatures later in the year at some locations could contribute to the Delta HABs impact described above. Potential increases in Delta temperatures would be mitigated by Mitigation Measure MM-SW-a,f: 3, which is described above for water temperature in the *Sacramento River Watershed and Delta Eastside Tributaries*.

San Francisco Bay Area—San Francisco Bay

The Bay Area has many of the same contaminant issues as the Sacramento River watershed, Delta eastside tributaries, and Delta because Delta outflow transports contaminants from the Central Valley and Delta downstream to San Francisco Bay. As described in the San Francisco Bay Basin Plan, increased flow through the San Francisco Bay will generally be beneficial for water quality (San Francisco Bay Water Board 2017).

> In addition to pollution control measures, achieving water quality objectives and protecting the beneficial uses of the San Francisco Bay Estuary system (particularly fish migration and estuarine habitat) are [sic] depends on freshwater outflow from the Delta. Adequate freshwater inflow to the Bay system is necessary to control salinity, to provide mixing (particularly in the entrapment zone), to maintain proper temperature, and to flush out residual pollutants that cannot be eliminated by treatment or nonpoint source management. Except for local drainage and wastewater discharges, Delta outflow provides virtually all the freshwater inflow to San Francisco Bay.

Increased flows under the proposed Plan amendments are generally expected to improve water quality conditions in the Bay Area. The highest flows, which transport the highest concentrations of sediment, are generally not expected to increase as a result of the proposed Plan amendments. Moderately high flows may transport the most sediment over extended periods of time due to their more frequent occurrence. Although the proposed Plan amendments may increase the frequency of moderately high flows, deposition of contaminated sediments in San Francisco Bay is not expected to increase adversely. The long-term water quality effects of the proposed Plan amendments on the movement and deposition of sediment and adhered contaminants would generally be minimal because, while higher flows may cause more sediment to enter the water column, higher flows also can help move sediment and adhered contaminants out of the system. Therefore, the deposition of sediment-bound contaminants would not increase significantly as a result of changes in hydrology under the proposed Plan amendments.

Mercury has a high affinity for particles, and most mercury is transported in the particulate phase. Increased erosion of contaminated sediment as a result of increased flows associated with high-intensity storms result in increased mercury to San Francisco Bay. At flows above approximately 150,000 cfs, proportionally greater levels of mercury-contaminated particles from historical mining sources in the watershed are transported through the system, mixing with the less-contaminated urban- and agricultural-derived particles. Particles mobilized during larger discharge events (i.e., above 150,000 cfs) have had 1.9 times higher total mercury concentrations normalized to suspended sediment concentrations than those transported at lower flows (i.e., below 150,000 cfs) (David et al. 2009). During storms that induce moderate flows, the total mercury load is dominated by urban and agricultural sources. Recent analysis indicates that total mercury from the Sacramento and San Joaquin Rivers is substantially lower (20 percent of the load to the San Francisco Bay) than previously estimated, suggesting that the Sacramento and San Joaquin Rivers are not the dominant sources of total mercury to the San Francisco Bay, as was once believed (David et al. 2009). Changes in hydrology are not expected to alter mobilization of mercury within the San Francisco Bay, and mercury effects upstream of the Bay would be dissipated by mixing with other water sources, settling of mercury attached to sediment, dredging, accumulation in organisms, and photodegradation of methylmercury back to mercury (^Central Valley Water Board 2010).

PCB contamination in the Bay Area is generally associated with industrial areas and urban runoff throughout the Bay Area. The major sources of selenium in San Francisco Bay are discharges from petroleum refineries. TMDLs have been approved for both impairments, and water quality conditions are expected to improve. The proposed Plan amendments would not result in increases in PCB and selenium concentrations because the sources and tidal dilution of these contaminants would be unaffected.

Export Reservoirs (San Francisco Bay Area, San Joaquin Valley, Central Coast, and Southern California)

Reduced exports from the Sacramento/Delta watershed may reduce the volume of water delivered to export reservoirs in the Bay Area, San Joaquin Valley, Central Coast, and Southern California regions. In response, operators may reduce water supply deliveries from the reservoirs, reduce storage in the reservoirs, and/or reduce streamflows below the reservoirs. While many of the streams below export reservoirs have streamflow requirements that would not allow for reductions below the historical minimum flows, reduced export reservoir levels and reduced streamflows below export reservoirs are assumed for the environmental analysis.

Some export reservoirs historically have been held at relatively constant storage levels, but others have fluctuated with water supply availability. The export reservoirs that show historical interannual and intra-annual fluctuations in response to variable water supply are most likely to be affected by reduction in Sacramento/Delta water supply associated with the proposed Plan amendments. The exact effect on storage at the reservoirs would depend on the local response. If operators responded with long-term planning that considered the reduced Sacramento/Delta supply, they may be able to operate the reservoirs as they have historically by maintaining storage for severe droughts.

As discussed under the following subheadings, reductions in export reservoir storage or streamflow downstream of the reservoirs could affect water quality in the reservoirs or downstream. The magnitude of these effects would depend on the reduction in Sacramento/Delta water supply for these reservoirs as well as the ways in which the reservoirs are operated.

Mercury

Many export reservoirs are impaired by elevated mercury under existing conditions (Table 7.12.1-3). In the Bay Area, impaired reservoirs include all EBMUD reservoirs (which receive water from the Mokelumne River) and Los Vaqueros, Anderson, and Del Valle Reservoirs (which receive water from the Delta). Southern reservoirs that are supplied by Sacramento/Delta water and have mercury impairments include O'Neill Forebay and San Luis Reservoir along the western edge of the San Joaquin Valley region; Lake Cachuma in the Central Coast region; and Castaic Lake, Pyramid Lake, and Silverwood Reservoir in the Southern California region.

The proposed Plan amendments could increase annual average reservoir water level fluctuation in some export reservoirs as a result of reduced Sacramento/Delta exports (see Section 6.3.2.5, *Reservoirs in Other Regions*). As discussed in detail under *Changes in Hydrology: Sacramento River Watershed and Delta Eastside Tributaries Regions: Mercury*, increases in annual average water level fluctuation is one of several factors linked to increased bioaccumulation of methylmercury in fish. Impacts related to increases in bioaccumulation would be potentially significant. Mercury impacts can be reduced through implementation of Mitigation Measure MM-SW-a,f: 2. As explained previously in this section, mercury is a statewide water quality issue that exists independently of the potential incremental effects from the proposed Plan amendments and is being addressed through various state and federal water quality efforts. Unless and until the mitigation is fully implemented and proven effective, the impacts remain potentially significant.

Harmful Algal Blooms

Similar to the potential impacts in the Sacramento/Delta reservoirs (see *Changes in Hydrology: Sacramento River Watershed and Delta Eastside Tributaries Regions: Harmful Algal Blooms*), lower reservoir storage could result in increased algal growth in export reservoirs, which could also affect drinking water quality. The presence of HABs could necessitate additional drinking water treatment protocols to remove the algae, cyanotoxins, and associated taste and odor compounds. Optimal treatment could be complicated and depends on factors such as knowing the type of cyanotoxins present, the location of the cyanotoxins (in the algal cells and/or in the water), the algal growth pattern and species, and water pH and temperature (USEPA 2014).

Lake Cachuma, Castaic Lake, and San Luis Reservoir are examples of reservoirs that may experience an increase in HABs. HABs have been observed in all these reservoirs under existing conditions. Because these reservoirs historically have been drawn down during periods of low water supply, they could experience a reduction in water levels and increases in HABs due to reduced exports of Sacramento/Delta supply under the proposed Plan amendments.

San Luis Reservoir provides an example of a different type of algal problem associated with low reservoir levels that could affect water quality. Potentially lower reservoir elevations mean that the water entering points of diversion could come from nearer the surface of the reservoir, where more algae are present, which could pose a problem for both drinking water and agriculture. In San Luis Reservoir, algae blooms generally reach diversion facilities when the reservoir has 300 TAF of water remaining in storage. Reservoir water with algal blooms is not suitable for agricultural water users with drip irrigation systems in San Benito County or for municipal water users relying on existing water treatment facilities in Santa Clara County (73 Fed. Reg. 50998 (August 29, 2008)). Increased HABs could occur in any reservoir with a substantial reduction in storage supplied primarily by surface water from the Sacramento/Delta. This impact would be potentially significant.

Potential HAB impacts can be reduced through implementation of Mitigation Measures MM-SW-a,f: 1 and 3 through 5. HABs are a statewide water quality issue that exists independently of potential incremental impacts from the proposed Plan amendments. Several ongoing activities to address HABs, such as those coordinated by the FHAB Program, also could be employed to mitigate the impacts of the proposed Plan amendments. As explained in Section 7.12.1.2, *Environmental Setting,* HABs can pose a potential health risk to humans and animals. The most immediate response efforts include public education and notification efforts to minimize exposure of pets and people to waterbodies containing HABs. The California Water Quality Monitoring Council maintains a website for the CCHAB Network that tracks HABs and provides information about how to respond to HABs, including information from USEPA on measures that should be implemented to prevent and respond to HABs in surface waters and drinking water supplies. The State and regional water boards also regulate discharges of nitrogen and phosphorus, which help control these discharges that contribute to HAB formation. While the State Water Board and others are engaged in efforts to address HABs, those efforts will take time and may not fully resolve HAB issues, including the incremental impacts associated with the proposed Plan amendments, to a less-than-significant level. Unless and until the mitigation is fully implemented and proven effective, the impacts remain potentially significant.

Water Temperature

The proposed Plan amendments could lead to reduced storage levels in export reservoirs and associated reductions in cold water reserves. Several export reservoirs release water to streams that provide habitat to special-status fish species. For example, Coyote Creek, Piru Creek, the Santa Clara

River, and the Santa Ynez River (receiving streams of Lake Anderson, Pyramid Lake, Lake Piru, and Lake Cachuma) contain steelhead and other special-status species (see Section 7.6.2, *Aquatic Biological Resources*). Special-status fish in these streams benefit from cold water releases. It is possible that reduced storage levels could result in increased temperatures in streams below some export reservoirs, either from less flow in general or release of warmer water. The impact would be potentially significant.

Implementation of Mitigation Measure MM-SW-a,f: 3 will reduce or avoid temperature impacts at export reservoirs. This mitigation incorporates MM-AQUA-a,d: 1.ii for temperature control and reservoir management. Export reservoirs receiving Sacramento/Delta supplies are not subject to the narrative cold water habitat objective and would not be required to develop and implement a long-term strategy and annual plan for reservoir operations. MM-AQUA-a,d: 1.ii protects stream temperature below export reservoirs with existing regulations. For example, upon receipt of information indicating that temperature management issues are associated with export reservoir operations (e.g., monitoring data indicate that water temperatures are too high for aquatic resources in streams below dams), the State Water Board will investigate and take measures, as appropriate, under its authorities to address water temperature concerns to protect fish and wildlife. Specifically, the State Water Board may hold a public trust hearing in response to notification by the California Department of Fish and Wildlife, a valid public trust complaint, or other relevant evidence indicating problematic reservoir operations. In exercising its regulatory authorities, the State Water Board would consider water temperature needs of aquatic species and ensure that any water temperature impacts on fish and wildlife are avoided or minimized. In addition, export reservoirs and streams below export reservoirs are subject to other existing regulatory requirements, such as California Fish and Game Code section 5937, FERC license requirements, NMFS BiOp requirements, regional water board basin plan requirements for the protection of beneficial uses, and species recovery plans—independent of the Bay-Delta Plan. However, until and unless the mitigation is implemented, impacts of changes in reservoir storage levels on temperature in export reservoirs in other regions (Bay Area, San Joaquin Valley, Central Coast, and Southern California) that receive Sacramento/Delta supply remain potentially significant.

Streams below Export Reservoirs

Reduction in water supply for export reservoirs could reduce flows and affect water quality downstream of some of these reservoirs at times. Lower flows could reduce the longitudinal extent of cool temperatures downstream of reservoirs and result in less dilution of contaminants that might enter the waterway downstream of the reservoir release. Many of the same constituents that negatively affect water quality in the Sacramento River watershed and Delta eastside tributaries are present in creeks below export reservoirs. These constituents include current-use pesticides, nutrients, pathogens, sodium, and chloride (SWRCB 2022). The sources vary by watershed but may include agriculture, urban runoff, municipal wastewater, and runoff from natural areas. This impact would be potentially significant.

Implementation of Mitigation Measure MM-SW-a,f: 1 will reduce or avoid water quality impacts from increased concentration of contaminants that may occur if streamflow is reduced below export reservoirs. Maintaining streamflows below export reservoirs through imports of water from another watershed, particularly an ecologically important watershed like the Sacramento/Delta, should not be the primary mechanism for addressing water quality contaminant issues in another watershed. Contaminants in waterbodies are a statewide water quality issue that exists independent of potential incremental impacts that could occur from the proposed Plan amendments and is being addressed through various ongoing state efforts. The regulation of water quality pollution is accomplished primarily through the State and regional water board waste discharge permits, including NPDES permits for point-source discharges and WDRs for nonpoint-source discharge. As explained in Section 7.12.1.2, *Environmental Setting,* the State and regional water boards have a variety of permit programs that regulate discharges of waste. The State and regional water boards will continue to regulate waste discharges and support TMDL development and implementation. Efforts to control some contaminants may take time. The State Water Board cannot be certain that these efforts will mitigate any incremental water quality impacts associated with reduced flows below export reservoirs to a less-than-significant level. Unless and until the mitigation is fully implemented and proven effective, the impacts remain potentially significant.

Water Quality Compliance by Utilities

Changes in streamflow could affect instream chemical constituent concentrations due to changes in instream dilution, potentially affecting the ability of a waste discharger or drinking water provider to comply with waste discharge requirements and/or water quality standards. Generally, these utilities are highly regulated and are unlikely to violate waste discharge requirements and drinking water quality standards; however, as discussed below, streamflow reductions could affect a utility's ability to comply with waste discharge requirements or water quality standards, potentially causing the need to modify treatment operations.

Municipal point-source discharges of waste to surface waters are regulated through NPDES permits. NPDES permits include technology-based and, where appropriate, water quality-based effluent limitations. TBELs are performance standards based on secondary treatment or best practicable control technology. Water quality-based effluent limits (WQBEL) are additional and sometimes more stringent effluent limitations needed to meet applicable water quality criteria (e.g., priority toxic pollutants). WQBELs take into account the appropriate water quality objectives and background concentrations in the receiving water. If a dilution credit or mixing zone is not allowed, the relevant water quality criterion must be attained at the point of discharge or "end of pipe," and a water quality model is not needed to characterize the interaction between the effluent and receiving water.

Pursuant to the State Water Board's *Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California (*referred to as the *State Implementation Policy* or *SIP*) (SWRCB 2005), a *mixing zone* is a limited volume of receiving water that is allocated for mixing with a wastewater discharge where water quality criteria can be exceeded without causing adverse effects to the overall waterbody. The SIP notes that a mixing zone shall be as small as practicable and require compliance with a number of conditions.

In developing WQBELs, the interaction between the effluent and receiving water is generally studied via a water quality model, using conservative values for flow and pollutant concentration in both the effluent and receiving water. These values are selected based on measured data and represent critical conditions, conditions most likely to be associated with poor quality of receiving water, such as low streamflow, high effluent flow, and high pollutant concentrations. Permit writers generally use a steady-state model for a "reasonable potential analysis" to characterize water quality of the effluent and receiving water under critical conditions; according to 40 C.F.R. section 122.44(d)(1)(i), limitations must control all pollutants that are or may be discharged at a level which will cause, have reasonable potential to cause, or contribute to an excursion above any state water quality standard.

Critical environmental conditions might apply instead of or in addition to flow (e.g., tidal flux, temperature), depending on the type of pollutant and the WWTP's discharge location.

If streamflows decrease, it may be more difficult for WWTPs to achieve permit requirements. For example, the SRWTP is permitted to discharge treated wastewater effluent up to 181 million gallons per day to the Sacramento River just downstream of the Freeport Bridge. The SRWTP is not allowed to discharge to the Sacramento River when the dilution ratio (river:effluent) is less than 14:1 during a rolling 1-hour period, or if instantaneous river flows are less than 1,300 cfs. The SRWTP diverts all effluent discharge to emergency storage basins when those conditions exist and returns the discharge to the river when conditions improve. These requirements help to limit double-dosing of the river with effluent during tidal flow reversals (Central Valley Water Board 2016). A significant reduction in Sacramento River flows could affect the frequency that dilution ratios fall below 14:1. Violations of water quality standards due to double-dosing during tidal flow reversals could occur if the SRWTP does not adjust plant operations to maintain compliance with this discharge requirement.

NPDES permits also may include mixing zones that establish WQBELs for compliance with chronic aquatic life criteria and human health criteria. These mixing zones typically are developed using a low flow that is derived from historical measured flows to represent poor mixing conditions. A significant reduction in flows could decrease the river to effluent dilution ratio at the edge of designated mixing zones, which may affect the adequacy of existing WQBELs that were calculated to protect aquatic life or human health. If this decrease were to occur, mixing zones or dilution credits specified in NPDES permits may no longer offer adequate protection of water quality; a facility operating to its permitted standards thus could degrade water quality outside the boundaries of the mixing zone prescribed in its NPDES permit.

NPDES permits contain requirements based on applicable plans, policies, and regulations. Basin plans include temperature objectives that prohibit discharges that would raise the natural stream temperature by more than 5 °F or harm beneficial uses. The State Water Board's *Water Quality Control Plan for Control of Temperature in the Coastal and Interstate Waters and Enclosed Bays and Estuaries of California* (Thermal Plan) is applicable to discharges of elevated temperature wastes, including WWTPs that discharge to the Delta, other enclosed bays and estuaries, and coastal waters. The Thermal Plan contains water quality objectives applicable to discharges of elevated temperature wastes for the protection of beneficial uses. (SWRCB 1975). The Thermal Plan provides exceptions in the form of alternative effluent limits, provided the exceptions will result in maintenance of balanced indigenous communities of shellfish, fish, and wildlife in the vicinity of the waste discharge, pursuant to federal Clean Water Act section 316(a). Compliance with receiving water temperature requirements in NPDES permits is measured by monitoring temperature in upstream and downstream receiving waters. WWTPs subject to Thermal Plan requirements include the SRWTP and WWTPs operated by the City of Stockton, City of Tracy, City of Manteca, and Mountain House Community Services District. Decreases in streamflow could exacerbate the effects of WWTP discharge on instream water temperature and affect the discharger's ability to meet receiving water temperature requirements.

Lowered river flows, such as reduced Sacramento River flows during summer and fall, could reduce assimilative capacity, creating the potential for violation of waste discharge requirements and potential degradation of water quality near WWTPs' discharge locations. NPDES permits include provisions for reopening waste discharge requirements if new information is received. If changes in river flows and constituent concentrations were to contribute to an exceedance or exceedances of surface water quality objectives, waste discharge requirements would be modified to account for the change in the available dilution.

Drinking water providers also may experience effects due to lowered river flows. Changes in water quality associated with reduced dilution in a surface supply source could cause changes in water quality near drinking water intakes. Drinking water providers must regularly monitor water quality to ensure that drinking water standards are achieved, but increased concentrations of some constituents may cause temporary violation of drinking water standards if the treatment plant operator is initially unaware of the problem or is unable to address it immediately by modifying facility operations.

Due to the flexibility under the proposed program of implementation, it is uncertain whether, and to what extent, flows would be reduced and if any such reduction would actually interfere with compliance with water quality standards and waste discharge requirements. However, potential impacts could occur, and the impacts would be potentially significant. These impacts could require providers to modify operations or provide additional treatment at WWTPs and drinking water treatment plants to continue to comply with existing or modified waste discharge requirements and drinking water quality standards. Physical modifications to treatment plants are further discussed in Section 7.20, *Utilities and Service Systems,* and impacts from the construction of new or modified treatment plants is evaluated in Section 7.22, *New or Modified Facilities*.

Implementation of Mitigation Measures MM-SW-a,f: 1 and 5 will reduce or avoid violations of waste discharge requirements by wastewater dischargers and water quality standards by drinking water providers. The regulation of water quality constituents is accomplished primarily through waste discharge permits issued by the State and regional water boards, including NPDES permits for point-source discharges, and WDRs for nonpoint-source discharge. DDW implements the Safe Drinking Water Act through measures such as (1) issuance of permits for public water systems and their sources and treatment to ensure compliance with drinking water standards; (2) inspection of water systems; (3) tracking of monitoring requirements of water systems to determine compliance; and (4) enforcement actions. Continued regulation by DDW will protect municipal drinking water quality. A variety of funding programs provide loans and grants for capital improvements to WWTPs and projects that help provide safe drinking water, including the Safe and Affordable Drinking Water Fund established by SB 200. The State and regional water boards will continue to regulate waste discharges and drinking water standards and will continue to promote and support future funding sources as appropriate. However, unless and until the mitigation is fully implemented and proven effective, the impacts remain potentially significant.

Changes in Water Supply

This section describes water quality impacts that could occur as a result of reduced Sacramento/Delta surface water supply to municipal and agricultural uses, including impacts associated with replacing Sacramento/Delta municipal water supply with lesser-quality sources, which could affect drinking water treatment facility operations due to changes in influent chemical constituent concentrations, and impacts associated with reduction in WWTP influent flows from reduced municipal supply and indoor water conservation. This section also evaluates impacts associated with reduced water supply for agriculture and impacts associated with replacing reduced Sacramento/Delta agricultural supply with lesser-quality sources, such as groundwater, which could affect the quality of agricultural runoff. Potential impacts associated with changes in groundwater-surface water interaction are discussed. Water quality impacts from reduced Sacramento/Delta supply to managed wetlands, including wildlife refuges, also are evaluated.

Reductions in surface water supplies for municipalities could result in the use of alternative sources of water for municipal use. Some sources, such as fresh water generated through desalination, could be of very high quality. Other supplies could represent a transition to lower-quality water. For example, Southern California municipalities might replace Sacramento/Delta water with more saline Colorado River water. In the Bay Area, the degradation in water quality that EBMUD experienced during the drought of 2014–2015 provides an example of a reduction in water quality that may be associated with transitioning from one surface water source to another. During this time, EBMUD had taste and odor problems associated with algal growth in its Bay Area export reservoirs. This algal growth was partly attributed to a change in water supply that included use of Sacramento River water and use of a higher intake in Pardee Reservoir to preserve the cold water pool (EBMUD 2015). Municipal surface water supplies could be replaced with groundwater. In many cases, groundwater is of lower quality than surface water and may contain higher concentrations of contaminants such as nitrates and salts.

Drinking water providers must regularly monitor water quality to ensure that drinking water standards are met. However, a change in source water composition could result in some reduction of water quality. Although algae are filtered out during water treatment, taste and odor compounds can be left behind. New or additional sources of water may cause drinking water treatment facilities to temporarily fall short of drinking water standards if the facility operators are either initially unaware of the problem or unable to address it. This impact would be potentially significant, and mitigation is discussed below. A drinking water treatment facility operator may need to take additional actions (such as increased monitoring or chemical treatment) to ensure that a new or additional source of water does not result in water quality concerns, including corrosion of pipes and other water quality concerns, once the new source has been introduced into the distribution system. Physical modifications to drinking water treatment plants are further discussed in Section 7.20, *Utilities and Service Systems*, and impacts from the construction of new or modified treatment plants are evaluated in Section 7.22, *New or Modified Facilities*.

Reductions in surface water supplies for municipalities and indoor water conservation could cause a reduction in overall wastewater flow rates, which could result in lower pipe velocities and longer detention times in municipal sewer collection systems, causing less scour and more odor. Odors may be considered nuisance conditions pursuant to Water Code section 13050, subdivision (m). Waste discharge permits for municipal sewer collection systems typically include provisions limiting objectionable odors such that they are not perceivable beyond a certain geographic area. Sewer collection system operators could incur additional operational and preventive maintenance expenses for increased collection system cleaning and odor control. This issue is further analyzed in Section 7.5, *Air Quality*.

Reduced discharge rates into sewers with the same amount of produced waste could lead to increased chemical constituent concentrations in WWTP influents, such as biochemical oxygen demand and ammonia, which could require wastewater treatment process modifications to provide more treatment time or additional treatment processes to meet discharge requirements. The total amount of contaminants entering WWTPs may stay about the same, but the concentration of some contaminants in the treatment plant effluent, such as organic material, ammonia, and salinity, may increase (^DeZellar and Maier 1980; Tran et al. 2017). These effects could require modified operation or enhancements of existing WWTP processes to modify treatment to continue to comply with waste discharge requirements.

Factors that could influence whether violations of NPDES discharge requirements might occur include the changed chemical composition of the municipal water supply (either due to use of alternative sources of water supply or increased concentration associated with indoor water conservation), the types and capacities of the treatment processes at the WWTP, the assimilative capacity of the receiving waters, the locations where compliance with effluent limitations are measured, and whether a portion of the plant effluent is recycled. Changes in WWTP influent chemical constituent composition may require adjusting WWTP operations to ensure continued compliance with NPDES discharge requirements. Managers may need to modify operations or facilities to avoid exceedances. If operators do not make such changes quickly enough, effluent may violate discharge requirements.

In some areas, such as the San Joaquin Valley and inland portions of Southern California, waste discharge permits for WWTPs allow discharge only to land. Land disposal of treated wastewater effluent can include evaporation-percolation basins, irrigation of land, disposal to constructed or natural wetlands, drying ponds or beds for municipal effluent sludge, and disposal to lined evaporation ponds. Waste discharge permits do not allow degradation of local groundwater. Pollutants of concern are total salt content, nitrate, boron, pathogenic organisms, and toxic chemicals. If increases in constituent concentration were to violate waste discharge requirements or be detrimental as a water supply for irrigation or refuges, WWTPs may need to modify operations or perform facility upgrades to improve discharge quality.

Ocean discharge is regulated by the State Water Board's Water Quality Control Plan for Ocean Waters of California (the Ocean Plan) (SWRCB 2019). Ocean discharge is generally allowed for WWTPs along the coast in the Bay Area, Central Coast, and Southern California regions. Changes in water supply are unlikely to affect the ability of these WWTPs to meet ocean discharge requirements because the ocean's large assimilative capacity allows for standards that provide for the discharge of more concentrated effluent. Ocean discharge plant operators are less likely to need to change operations or modify facilities in response to changes in water supply, although such changes are possible.

Generally, if constituents in WWTP influent are more concentrated, plant operations can be modified to ensure compliance with NPDES regulations. Past droughts have already provided WWTP operators with experience in handling reductions in inflow. However, in some instances, operators may not be able to respond quickly enough to prevent exceedances of NPDES criteria, as has occurred in some locations when reduced supply and indoor water conservation have increased during a drought (Tran et al. 2017). If operational changes are insufficient, modified or additional facilities may be needed. Physical modifications to WWTPs are further discussed in Section 7.20, *Utilities and Service Systems*, and impacts from construction of new or modified treatment plants are evaluated in Section 7.22, *New or Modified Facilities*.

If dischargers do not implement proper adjustments, they could risk violating waste discharge requirements in the event that reduced municipal supply increases the concentration of constituents entering WWTPs. This impact would be potentially significant.

Implementation of Mitigation Measures MM-SW-a,f: 1 and 5 will reduce or avoid violations of water quality standards or waste discharge requirements for drinking water providers and wastewater dischargers. The State Water Board oversees water quality standards and waste discharge requirements. Regulation of water quality constituents is accomplished primarily through the State and regional water board waste discharge permits, including NPDES permits for point-source discharges and WDRs for nonpoint-source discharge. DDW implements the Safe Drinking Water Act through measures such as (1) issuing permits for public water systems and their sources and treatment to ensure compliance with drinking water standards; (2) inspecting water systems; (3) tracking monitoring requirements of water systems to determine compliance; and (4) enforcement actions. Continued regulation by DDW will protect municipal drinking water quality. A variety of funding programs provide loans and grants for capital improvements to WWTPs and projects that help provide safe drinking water, including the Safe and Affordable Drinking Water Fund established by SB 200. The State and regional water boards will continue to regulate waste discharges and drinking water standards and will continue to promote and support future funding sources as appropriate. However, unless and until the mitigation is fully implemented and proven effective, the impacts remain potentially significant.

For agriculture, reduced surface water deliveries could lead to a reduction in irrigated acreage, use of other water sources, deficit irrigation, crop substitution, or an increase in dryland farming. For land that is no longer irrigated, there may be an initial period of increased erosion; however, ultimately, it is expected that the reduced tillage and other activities would result in less erosion. As such, reducing existing levels of soil disturbance associated with active agricultural practices and irrigation could reduce erosion and the loss of topsoil. Thus, the potential for soil erosion and sediment delivery to streams would be reduced overall under the proposed Plan amendments.

Reductions in surface water supply for agriculture could result in the use of other sources of water, particularly groundwater. Irrigation water does not need to meet the same water quality standards as municipal water. However, elevated levels of some constituents, particularly salinity, can reduce crop yield. Ultimately, if groundwater salinity is too high for even the most salt-tolerant plants to be grown profitably, it will not be used. A transition from surface water supply to groundwater supply for agriculture could affect agriculture and groundwater quality, particularly related to salinity in the western side of the San Joaquin Valley; potential impacts are discussed in Section 7.4, *Agriculture and Forest Resources*, and Section 7.12.2, *Groundwater*.

Increased use of groundwater for agriculture could result in agricultural drainage that is of lower quality, particularly on the western side of the San Joaquin Valley. Regardless of the water source, agricultural drainage is generally of low quality, with constituents including pesticides, nitrates, selenium, and high salinity. A reduction in surface water supply could also reduce the total volume of runoff from fallowing and conservation measures. Agricultural water conservation measures, such as reuse of agricultural drainage water and on-field application measures for improved irrigation efficiency (e.g., drip irrigation), would reduce the volume of agricultural drainage. The net effect of reduced drainage quality and quantity would generally be a negligible change in the amount of contaminants entering waterways in flowing streams where drainage water constitutes a small percent of the total flow.

Reductions in Sacramento/Delta supplies could affect water quality in managed wetlands if those lands receive some or all of their water supply from the Sacramento/Delta. Managed wetlands can include many of the wetlands maintained by national wildlife refuges and state wildlife areas; privately owned wetlands such as those managed by duck clubs; and some agricultural croplands that are managed for multiple uses, including waterfowl habitat. The effect is likely to be more substantial in the San Joaquin Valley, where water quality is already poor. For example, the extensive and ecologically important areas within the Grasslands Ecological Area are fed by a combination of surface water imports, groundwater pumping, and agricultural drainage. As indicated in Chapter 6, *Changes in Hydrology and Water Supply,* there could be some reductions of Sacramento/Delta surface water supplies to refuges, as well as a reduction in Sacramento/Delta supplies to agriculture in this region, especially under the higher (55 and 65) scenarios. The reductions in agricultural supply could cause reductions in agricultural drainage and lowering of groundwater levels. Agricultural drainage in this area is already high in salts and selenium. With less Sacramento/Delta supply, the remaining inflow from agricultural drainage and groundwater could become more degraded, while dilution of this low-quality water with fresh surface water supplies could be reduced. Water quality impacts from reduced supply to managed wetlands would be potentially significant.

Implementation of Mitigation Measures MM-SW-a,f: 6 and MM-SW-a,f: 7 can reduce or avoid water quality impacts on managed wetlands. The proposed program of implementation includes measures to prioritize refuge water supplies. Mitigation also includes mitigation measures to reduce lowering of groundwater levels. Many efforts are underway to develop and implement actions to address poor-quality agricultural discharges in the southern San Joaquin Valley, including those described in the Central Valley Salinity Alternatives for Long-Term Sustainability Program. The program is a joint effort of the State Water Board and the Central Valley Water Board to address salinity and nitrate problems in the Central Valley and to adopt long-term solutions that will lead to enhanced water quality and economic sustainability, including source control, BMPs to reduce the introduction of new salts, farmland retirement, and desalination. These efforts have produced some improvements and will likely continue to do so, but considerable challenges will likely persist. Unless and until the mitigation is fully implemented and proven effective, the impacts remain potentially significant.

Increased groundwater pumping to replace reductions in Sacramento/Delta supplies and reduced incidental recharge from applied irrigation water could reduce groundwater levels. Reductions in groundwater levels could reduce streamflow either by increasing surface water percolation to groundwater or by reducing groundwater accretions to surface water. In addition, increased groundwater pumping adjacent to streams could accelerate stream depletions more directly. Groundwater accretions are generally beneficial to streams because they increase flow and may provide cold water inflow in summer. Groundwater accretions are most important in streams where the accretions contribute a large portion of the summer base flow or create cold water refugia for fish and other aquatic species (Yarnell et al. 2022). Potential reductions in groundwater accretions could cause increases in water temperature. They also could cause decreases in water quality due to lower streamflows or improvements in water quality due to less input from low-quality groundwater. The adverse impacts would be potentially significant. Sections 7.6.1, *Terrestrial Biological Resources*, and 7.6.2, *Aquatic Biological Resources,* provide more detailed discussion about surface water–groundwater interaction from the perspective of habitat availability.

These surface water quality effects from lowered groundwater levels can be reduced through implementation of Mitigation Measures MM-SW-a,f: 6 and 8, which incorporate groundwater mitigation measures to reduce lowering of groundwater levels. In addition, groundwater impacts and associated impacts on surface water quality can be reduced through diversification of water portfolios that include sustainable groundwater management, groundwater storage and recovery, increased use of recycled water from existing facilities, and agricultural and municipal water conservation measures. However, unless and until the mitigation is fully implemented, impacts of reduced groundwater levels on water quality remain potentially significant.

Other Water Management Actions

Several strategies could be implemented at the local or regional level by utilizing existing infrastructure to reduce the potential impacts from reduced Sacramento/Delta surface water supplies, including groundwater storage and recovery, water transfers, water recycling, and water conservation measures (see Mitigation Measure MM-SW-a,f: 8). Local conditions would determine which actions are most effective. These responses to reduced Sacramento/Delta supply may have additional impacts on surface water quality and may affect water quality in multiple or all regions. Desalination, and other possible response actions involving construction, are discussed in Section 7.22, *New or Modified Facilities*.

Groundwater Storage and Recovery

Groundwater storage and recovery involves intentional recharging of groundwater basins with excess surface water or other available water sources. Water sources for groundwater storage and recovery primarily include surface water supply during above-average years or treated wastewater. Decentralized groundwater recharge actions may also occur with Low Impact Development projects designed to allow storm water runoff to infiltrate into the ground. Groundwater storage and recovery can not only augment supply but also help prevent environmental impacts that can result from groundwater overdraft and flooding.

Potential surface water impacts from recharging groundwater with treated wastewater are addressed under *Water Recycling*. Groundwater recharge based on the capture of storm water runoff could reduce streamflow during storm events to some extent but would be likely to improve surface water quality by reducing contaminants and trash associated with storm water runoff.

Recharge using surface water diversions would likely occur during wet years when extra water is present, and removal of water from a river would be unlikely to negatively affect river water quality. Removal of peak flows from rivers could reduce water velocity and turbidity, which could be beneficial to water quality. However, substantial reductions in flow could degrade water quality by limiting the dilution effect of existing flows and exacerbating existing water quality impairments. Diversion of peak flows for groundwater recharge usually occurs when flows are already high, reducing the potential for water quality impacts; nevertheless, reduction of water quality due to substantial reductions in flow would be a potentially significant impact. Implementation of Mitigation Measure MM-SW-a,f: 9 will reduce potential water quality impacts associated with using surface water for groundwater storage and recovery to a less-than-significant level. Diversion of flood flows would be subject to State Water Board regulation to ensure that enough water remains instream to protect water quality.

Water Transfers

More surface water transfers could result in a reduction of water in the source region and an increase of water in the destination region, potentially shifting the location of water quality impacts from one area to another. In areas that receive transfer water, impacts from reduced supplies could decrease; and in areas providing transfer water, impacts could be exacerbated. Transfers can benefit water quality in the stream where the transfer is released, especially in dry and critical years when flows may already be low. Increased summer flows may have small water quality benefits because they could dilute water quality constituents, including pesticides and fertilizers present in agricultural runoff. If transfers are conveyed to irrigate lands with existing water quality problems, a transfer could exacerbate poor conditions by increasing poor-quality agricultural runoff. Because transfers are used in times of scarcity, excessive runoff in an area receiving a water transfer is unlikely. If less agricultural land is irrigated because of crop-idling transfers in areas where transfers originate, water quality concerns associated with agriculture could be reduced, including nutrients, pesticides, and other agricultural-related water quality constituents; temperature-related concerns from return flows with elevated temperatures also could be reduced. If more groundwater-substitution transfers take place, water quality impacts could result from increased pumping in the source area. If more stored-water transfers take place, greater water quality impacts could result within reservoirs when storage levels are reduced and until reservoirs refill. Impacts on water quality from water transfers would be potentially significant.

Implementation of Mitigation Measure MM-SW-a,f: 10 will avoid or reduce potential water quality impacts associated with water transfers. As discussed in Section 7.1, *Introduction, Project Description, and Approach to Environmental Analysis,* water transfers generally require environmental review and approval by the same agencies that would be expected to address any water quality impacts (DWR 2016). Transfers approved by the State Water Board and/or facilitated by the CVP/SWP are required to avoid unreasonable impacts on fish and wildlife and prevent injury to other legal users of water. Water quality is a consideration in determining whether a water transfer would result in injury to a legal user or unreasonable impacts on fish and wildlife. To avoid or minimize impacts, when processing petitions for water transfers, the State Water Board will ensure that the transfer would not result in water quality impacts. The State Water Board cannot guarantee that mitigation will be implemented for transfers not subject to State Water Board approval. Unless and until the mitigation is fully implemented, the impacts remain potentially significant.

Water Recycling

Increased use of recycled water would not violate standards or waste discharge requirements because operations at treatment plants and water recycling facilities are subject to regulatory oversight. The regional water boards require practices at these facilities to protect water quality. Water recycling facilities are required to comply with all regulations pertaining to water quality standards and regulations to prevent degradation of water quality. Recycled water could contain CECs, which include certain pharmaceuticals, pesticides, industrial chemicals, EDCs, and PCPPs (SWRCB 2018d). However, recycled water generally is of good quality.

In addition, rather than being discharged into receiving waters, recycled water is typically distributed to users in the service area for irrigation purposes. Recycled water could run off or percolate into groundwater; however, under the General Order for Recycled Water Use adopted by the State Water Board, an administrator of a recycled water program would prepare management plans to limit and control runoff and percolation into receiving waters, and users of recycled water (e.g., golf courses) would have to undergo inspections by the administrator. Because water recycling generally occurs in areas with limited water supply, runoff or excessive percolation is unlikely to occur.

Increased use of recycled water could further reduce instream flows if wastewater is recycled instead of being discharged to streams. In some circumstances, reductions in flows could reduce dilution of local sources of contaminants, particularly in streams with low flows that are dominated by relatively high-quality WWTP effluent and that have local input of poor-quality water. Implementation of Mitigation Measure MM-SW-a,f: 11 will reduce potential water quality impacts associated with increased use of recycled water previously discharged to surface water to a less-than-significant level. When processing wastewater change petitions, pursuant to Water Code section 1211, the State Water Board will ensure that the change in wastewater discharge does not affect water quality, especially in dry seasons and in low-flow conditions where the stream is dependent on wastewater discharges.

Water Conservation

Increased implementation of water conservation measures, such as reduced water use and tailwater reuse, could result in less runoff from lawns, impervious surfaces, agricultural fields, and other areas. Reduction in this type of drainage or discharge may result in a reduction in contaminants (e.g., pesticides, metals, CECs, oil and grease) entering surface waters, resulting in water quality improvements.

Indoor water conservation measures could contribute to changes in water quality associated with decreased influent flows to WWTPs. The majority of reductions in municipal water use would be likely to occur through reductions in outdoor irrigation, which generally does not contribute to WWTP influent flow. In addition, baseline per capita indoor water use has been decreasing for decades (^PPIC 2016) independently from the proposed Plan amendments, and further decreases in wastewater production are expected over time as a result of recent statutory changes. Changes in WWTP influent chemical constituent composition may require adjustment of WWTP operation to ensure continued compliance with NPDES discharge requirements. Reoperation and modification of WWTPs are discussed and mitigation is identified under *Changes in Water Supply* in connection with reduced municipal supply and reduced quality of other supplies.

Impact SW-c: Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, in a manner which would result in substantial erosion or siltation on- or off-site

Impact SW-d: Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, or substantially increase the rate or amount of surface runoff in a manner which would result in flooding on- or off-site

The analyses of Impact SW-c and Impact SW-d are closely related and therefore are combined and addressed together.

Potential erosion impacts evaluated are those that could result in excessive erosion or deposition, as opposed to sediment movement that is ecologically beneficial. Similarly, potential flooding impacts evaluated focus on flooding outside the floodplain bounded by levees. These types of impacts could negatively affect infrastructure and would also indicate unstable stream conditions.

Extremely high flows are considered the primary means of negative sediment transport and channel change. Excessive sedimentation (i.e., deposition and siltation) can reduce channel conveyance capacities. Substantial erosion or siltation can also result in a major rearrangement of channel gravels that would disrupt salmonid spawning beds or cause substantial instream siltation that would adversely affect in-sediment fauna, including salmon eggs and alevin. Scouring that can undermine streambanks or levees is most likely to occur when flows are near or exceeding channel capacities.

The new flow requirements under the proposed Plan amendments are intended to mimic a more natural hydrograph, which would help restore beneficial geomorphic processes to some extent rather than cause negative effects. Beneficial geomorphic processes include those that clean fine sediment from spawning gravels, maintain a diversity of bed forms (e.g., bars, riffles, pools, runs), and help maintain functional floodplain and riparian habitats through floodplain inundation (see Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations*).

On unregulated Sacramento/Delta tributaries, the SacWAM results show no changes in streamflows during winter, with increases in streamflows during late-spring through early-fall on tributaries with high water demand. Because the proposed Plan amendments would not result in changes in winter peak flows on unregulated tributaries, there would likely be no change to sediment transport processes and flooding on these tributaries.

On regulated Sacramento/Delta tributaries, the SacWAM results show that monthly streamflows downstream of rim reservoirs would generally increase during winter and spring, sometimes as late as June, under the proposed Plan amendments compared with existing conditions. Flows in spring show the largest increases. This increase could result in an increased frequency of small-magnitude spikes in flow that maintain channel size, shape, and bed texture and could provide ancillary ecosystem benefits. The intent of the proposed Plan amendments is to provide flexibility to allow flows to be managed, including geomorphic flows. The proposed program of implementation provides opportunities for variable winter and spring flows while minimizing potential detrimental impacts related to erosion and flooding and includes controlled peak flow pulses.

Changes in high flows under the proposed Plan amendments were evaluated and are presented in detail in the flood risk evaluation under Impact SW-i. The flood risk evaluation analyzed high flows during the wettest months on 11 reservoir-controlled rivers that would be subject to flow requirements under the proposed Plan amendments. Except for the Sacramento River at Knights Landing (discussed in more detail under impact SW-i), maximum monthly flows in these months never exceeded channel capacities, and, most importantly, the new flow requirements do not increase flows at high levels, when adverse erosion and alteration of drainage patterns could occur. No significant increases in high flows would occur under the proposed Plan amendments compared with baseline conditions. A limitation of this analysis is that it analyzed only monthly average flows because SacWAM uses this time step. Higher flows would occur on an hourly or daily basis. A monthly analysis is sufficient because, if the monthly average flows during the wettest months and years do not increase, peak flows also should not increase at shorter time scales. During storm events, a lower monthly flow indicates that more storage space is available in reservoirs, so peak flood-control releases also would be lower. See Impact SW-i for further discussion.

Accordingly, excessive sedimentation that reduces channel conveyance capacities would be unlikely to occur under the proposed Plan amendments. While local channel aggradation could occur for short periods, total sedimentation would not be expected to increase. To the extent that flow volumes do shift seasonally, the flow requirements would ensure that there would always be sufficient flow to move the sediment through the system and prevent reductions in channel capacity. Impacts from siltation would be generally similar to gravel and sand erosion because peak flows that transport large volumes of fine sediment would not change.

Similarly, although occasional flooding does occur, flows under the proposed Plan amendments would usually be substantially below channel capacities. The model results show that the new flow requirements would not increase flows at peak levels when flood risk is highest. Because the flow requirements would generally maintain or decrease baseline condition storage levels and would maintain the USACE flood control space in reservoirs, flood control releases generally would not increase during major flood events. Based on the evaluation of high-flow conditions, the proposed Plan amendments would not substantially alter the existing drainage pattern in a manner that would cause increases in excessive erosion or deposition (siltation) and flooding. Similarly, these flows would not be expected to cause changes in levee erosion compared with baseline conditions. Consequently, changes in hydrology represent a less-than-significant impact, with the possible exception of Clear Creek.

Clear Creek is the only stream analyzed under Impact SW-i for which an increase in high flows would occur. However, these flow increases may be more in the beneficial range that would improve habitat rather than cause excessive erosion. According to a 2015 annual work plan from Reclamation and other agencies involved with the Clear Creek Restoration Program (Kisanuki et al. 2015):

> Studies have been undertaken by CVPIA and CALFED since 1999 to develop channel maintenance flows, which may be vital for maintaining ecosystem processes that provide salmonid habitat in Clear Creek. These efforts resulted in a FWS proposal to Reclamation to re-operate Whiskeytown Dam, between March 1 and May 15, such that a glory hole spill produces a minimum target release of 3,250 cfs for one day occurring three times in a ten year period. Flows of this magnitude and duration could reactivate fluvial geomorphic processes to re-create and maintain diverse instream and floodplain habitat required to support and recover aquatic and riparian species. This flow prescription is also required in the NMFS OCAP BO.

The work plan later provides an estimated upper limit of 6,000 cfs for channel maintenance flows (Kisanuki et al. 2015).

Average monthly flows in Clear Creek above the confluence with the Sacramento River exceed 3,250 cfs in only 3 months during the entire 94-year SacWAM run for the 65 scenario and not at all for the 45 and 55 scenarios (Table 7.12.1-19). A monthly flow of 6,000 cfs is not exceeded in any month under any of the flow scenarios. Peak daily flows during a month can be substantially greater than the monthly average flows, but Clear Creek flows can generally be controlled to maintain levels in the beneficial range, with the ability to control flow under the proposed Plan amendments being at least as effective as under baseline conditions.

Table 7.12.1-19. Number of Months with SacWAM-Modeled Flow in Clear Creek Greater than 3,250 and 6,000 Cubic Feet per Second (94-Year Simulation Period)

Scenario	Number of Months with Flow Greater than 3,250 Cubic Feet per Second	Number of Months with Flow Greater than 6,000 Cubic Feet per Second
Baseline	0	0
35	0	0
45	0	0
55	0	0
65	3	0
75	3	0

Discussion on how flood impacts would be prevented on Clear Creek through real-time operations is presented under Impact SW-i, and similar operational rules would be used to prevent excessive erosion. Implementation of increased flows on Clear Creek would likely be conducted in the context of ongoing stream restoration activities and would be managed to maintain a proper sediment balance. Stream restoration activities on Clear Creek include gravel additions to improve fish habitat (Earley et al. 2013); any gravel transport from the highest flows would be managed to be consistent with those activities.

Changes in hydrology would not increase surface runoff and, for all streams except Clear Creek, would not increase flows when flood risk is highest. In addition, increases in short-term peak flows would be prevented through real-time operations, and sediment and channel management practices would continue to maintain channel capacities. As a result, implementing the flow requirements would not substantially alter the existing drainage pattern of the area or alter the course of a stream or river in a manner that would result in adverse sediment transport, streambank erosion, or flooding on-site or off-site. Impacts SW-c and SW-d would be less than significant with the possible exception of Clear Creek. Although unlikely, increases in Clear Creek flow downstream of Whiskeytown Lake could increase the risk of adverse erosion and flooding in this area. As described for Impact SW-i, implementation of Mitigation Measure MM-SW-i, will mitigate this impact to a less-than-significant level by establishing safe flow levels that would avoid significant erosion or flooding effects.

Impact SW-i: Expose people or structures to a significant risk of loss, injury, or death involving flooding, including flooding as a result of the failure of a levee or dam

Reservoir operations are guided by flood control rule curves, which define the volume of flood space necessary during different months of the year. The same flood control curves and daily operations would be used for operations of reservoirs under the proposed Plan amendments, and the same end-of-month flood control storage space would be maintained. Some reservoirs would release more water than the baseline to meet flow requirements, and the storage would be reduced so that flood control releases would be delayed and/or reduced.

SacWAM modeling mimics flood control operations by not allowing encroachment into the flood control space that is determined for each reservoir by USACE or other operational requirements. Although the most damaging floods occur during peak-flow events that last hours or days, the monthly output from SacWAM can be used to generate the following indicators of potentially increased flood risk.

- Peak flows: Increased flows during months when flows are highest on each river could be associated with increased daily or hourly peak flows that exceed channel capacity and increase flood risk. Rivers where this increased monthly flow occurs can be further analyzed to assess the true impact on flood risk.
- Reservoir storage: Increased upstream reservoir storage during the flood control season could be interpreted as a reduction in the flexibility of real-time operations to capture flood flows and avoid downstream flood risk.

These flood risk indicators were computed using SacWAM results. The months with highest maximum monthly flows under baseline conditions were identified, although these months are often not the months with the highest average monthly flows. For example, for the Mokelumne River, the highest average monthly flows under baseline conditions are in April, May, and June, but the highest maximum monthly flows occur in January and February. While the occurrences of monthly maximum flows are infrequent, flood risk is highest during these periods. For the months with the highest maximum monthly flows, the change between baseline conditions and the proposed Plan amendments was computed for (1) the maximum flow in each month and (2) the average flow in the top 10 percent of flows for each month. Increases in these maximum and top 10th percentile flows for each month could indicate that, at some point during these months, a peak flow would lead to increased flood risk. The change in average reservoir storage levels during these same months was then computed for wet and above-normal water year types, when flood risk would be highest; if reservoir storage levels were higher during these months, it could indicate a decrease in the ability to capture flood flows.

Although changes to reservoir operations under the proposed Plan amendments could increase the risk of downstream flooding if the flow requirements were higher than existing standards, in practice, this increase is unlikely to occur. For regulated rivers, the flow requirements can often result in increased flow releases during rainfall runoff events. When this situation happens, it can lead to lower reservoir storage levels during the flood control season, especially in wetter years where flood risk is highest, which increases the ability for operators to capture potentially damaging flood flows.

In real time, operators would manage reservoir storage and releases to eliminate an increase in flood risk. To reduce risk of flooding and provide minimal effects on low-lying lands, the proposed Plan amendments include provisions to ensure that flow requirements would not cause flows to exceed levels that could cause or contribute to flooding or other related public safety concerns. The flow requirements of the proposed Plan amendments would temporarily be reduced if they would cause flooding. As described in Chapter 5, *Proposed Changes to the Bay-Delta Plan for the Sacramento/Delta*, available flood space in reservoirs would be used to temporarily hold back flows that would cause flooding. The water held back in the reservoir to temporarily reduce downstream flood risk could be released later, when flood risk subsides, so that on a monthly basis the flow requirement could still be met.

Flood Risk Analysis

Table 7.12.1-20 lists the rivers and reservoirs analyzed, using SacWAM modeling, for flood risk impacts. The flows in all listed rivers are affected by existing upstream storage regulation and diversions. For these rivers, the furthest downstream location was used for analysis, under the assumption that potential flood impacts would be greatest at these locations. The only exception to this is that flows on the Sacramento River were analyzed at Knights Landing, which is above the confluence with the Feather River. Other locations that do not have substantial upstream regulation were not analyzed because in those locations, peak flows under the proposed Plan amendments would not be different from the flows under baseline conditions. The only location with upstream reservoir storage that was not included in the analysis is Clear Creek. Clear Creek is unique because some flows that pass from Whiskeytown Lake through Spring Creek Tunnel to Keswick Reservoir under baseline conditions would instead flow out of Whiskeytown Lake into Clear Creek under the proposed Plan amendments. Because the flow pattern is different from other plan area tributaries, Clear Creek is evaluated separately.

Table 7.12.1-20. Rivers and Locations Analyzed for Flood Impacts

River	State Water Board Compliance Location	Reservoir	SacWAM Maximum Reservoir Storage (thousand acre-feet)
American River	Upstream of Sacramento River confluence	Folsom Reservoir	977
Bear River	Upstream of Feather River confluence	Camp Far West Reservoir	104.5
Cache Creek	Upstream of Yolo Bypass confluence	Clear Lake	1,155
Calaveras River	Upstream of San Joaquin River confluence	New Hogan Lake	317
Clear Creek	Upstream of Sacramento River confluence	None	NA
Feather River	Upstream of Sacramento River confluence	Oroville Reservoir	3,538
Mokelumne River	Upstream of Cosumnes River confluence	Camanche Reservoir	417
Putah Creek	Upstream of Yolo Bypass confluence	Lake Berryessa	1,602
Sacramento River	Knights Landing (just upstream of Feather River confluence)	Shasta Reservoir	4,552
Stony Creek	Upstream of Sacramento River confluence	Black Butte Lake	144
Yuba River	Upstream of Feather River confluence	New Bullards Bar Reservoir	970

Source: ^SacWAM 2023.

Table 7.12.1-21 presents a summary of the flood risk indicators (flow and upstream reservoir storage) for the 55 scenario in all locations except Clear Creek. Flood risk indicators are presented for each river only for months when maximum monthly flows are highest under baseline conditions because flood risk is greatest during these months. Tables that show flood indicators for the 55 scenario for October through May are provided in Appendix A1, *Sacramento Water Allocation Model Methods and Results*. Appendix A1 also shows results for the full range of scenarios evaluated. While Table 7.12.1-21 shows model output under the 55 scenario, the conclusions would be identical for the entire flow range provided under the proposed Plan amendments (45 to 65 scenarios).

Flood risk would increase only if flows or storage levels increased in the highest flow months, or if flows in other months increased above the levels in the highest flow months. For the majority of rivers, flow and storage levels presented in Table 7.12.1-21 either stay the same or decrease compared with baseline conditions for the high-flow months. Most of the exceptions to this are increases that are very minor (1 percent or less). Even when there are very minor increases in flow indicators, the flows causing these increases are almost always less than the maximum monthly flow in any month in the baseline. Only Putah Creek and the Yuba River show increases of greater than 1 percent in certain indicators, but these do not indicate an increased flood risk for reasons discussed below.

On Putah Creek, the results indicate that, in January, the average of the top 10 percent of monthly flows would increase by 53 percent. However, the highest flows that result in this degree of increase would remain below the maximum monthly flow under baseline conditions (6,187 cfs), indicating that no increase in overall flood risk would occur. In addition, in the 3 months with highest January flows in the 55 scenario, Lake Berryessa storage is either below the storage in the same month in the baseline or more than 500 TAF below the reservoir's maximum capacity. Lake Berryessa would always maintain sufficient storage space to prevent any flood damage from these higher flows and could be managed to keep the river stage at safe levels.

On the Yuba River, the results show that, in February, the average of the top 10 percent of monthly flows would increase by 3 percent. This is a very minor increase, and while flows are typically slightly higher in the months contributing to this increase compared with the baseline, in no case are those flows greater than the maximum monthly flow under baseline conditions (22,279 cfs). Three storage indicators (at New Bullards Bar) are also larger by 3 percent: above-normal year storages in December, wet year storages in January, and wet year storages in February. Storages are slightly higher due to operational adjustments used to approximate what might be needed for the cold water habitat objective. But again, these increases are relatively minor; in all months of the simulation, storage in New Bullards Bar meets flood control requirements, indicating that sufficient flood storage capacity exists to manage floods that occur on a sub-monthly basis. Hence no increase in flood risk is expected in the Yuba River.

SacWAM results for the 45 scenario and the 65 scenario support the same conclusions reached for the 55 scenario for all flood indicators (see results in Appendix A1, *Sacramento Water Allocation Model Methods and Results*). In the 45 scenario, there are increases in flood indicators that are greater than 1 percent on three rivers, but in none of these cases do they indicate an increase in flood risk. The Mokelumne River has an increase of 2 percent in the average of the top 10 percent of monthly flows in January, but the flows causing this increase are well below the maximum flow in any month on the Mokelumne River in the baseline, and there is always substantial storage in Camanche Reservoir in these months. The average of the top 10 percent of monthly flows in January on Putah Creek shows an increase of 26 percent. This indicator shows a smaller increase than in the 55 scenario, so for the 45 scenario there is no increase in flood risk for the same reasons as discussed for the 55 scenario.

The Yuba River shows multiple increases in flood indicators in the 45 scenario. The maximum flow in December increases by 3 percent; the average of the top 10 percent of monthly flows in January increases by 2 percent; in February, the maximum flow increases by 8 percent, and the average of the top 10 percent of monthly flows increases by 10 percent. The pattern of increases is similar to the 55 scenario, though with larger percent changes, but all of the flows that contribute to these flow increases are still less than the maximum monthly flow under baseline conditions (22,279 cfs). All storage indicators on the Yuba River show an increase of 3 to 6 percent in the 45 scenario, again to approximate what might be needed for the cold water habitat objective. Though consistent, these are not large changes in storage; in all months of the simulation, storage in New Bullards Bar meets flood control requirements, indicating that sufficient flood storage capacity exists to manage floods that occur on a sub-monthly basis. So no increase in flood risk is expected on the Yuba River.

The 65 scenario again has increases on Putah Creek in the average of the top 10 percent of monthly flows in January. This increase is 80 percent, which is greater than in the 55 scenario. But, as with the 55 scenario, the flows contributing to this increase are all below the maximum monthly flow under baseline conditions (6,187 cfs). The discussion of Lake Berryessa storage levels for the

55 scenario above also applies here, indicating that in none of these scenarios is there an increased flood risk in January on Putah Creek. Under the 65 scenario, there are also flow increases on the Yuba River. The average of the top 10 percent of monthly flows in January increases by 2 percent; in February, the maximum flow increases by 4 percent, and the average of the top 10 percent of monthly flows increases by 7 percent. Similar to the 45 scenario, all of the flows that contribute to these flow increases are less than the maximum monthly flow under baseline conditions (22,279 cfs). For this reason, no increase in flood risk is expected.

Finally, the 65 scenario has one other flood indicator that increases. On the Feather River, the results indicate that, in February, the maximum monthly flow would increase by approximately 7 percent. However, that flow would not exceed the maximum monthly flow under baseline conditions (66,475 cfs) during any month, and storage in Lake Oroville in that month is below the storage in the baseline, indicating that no increase in overall flood risk would occur. DWR, which operates the Oroville Dam, could also adjust its operations to ensure safe release levels by using available flood space in Oroville Reservoir. The modeling indicates that this flood space would be available in all high-flow months.

The Central Valley Flood Protection Plan's *2022 Flood System Status Report* shows channel capacities (current channel conveyance capacity and design flow) on rivers throughout the Central Valley (DWR 2022c). These channel capacities were reviewed and compared to maximum monthly flows from SacWAM. In almost all cases, the channel capacities are greater than the SacWAM output flows. However, at Knights Landing on the Sacramento River, the highest monthly flows under baseline conditions and under the proposed Plan amendments are above the current channel conveyance capacity but not above the design flow.

The DWR report identifies channel capacities at Knights Landing as 19,500 cfs for current channel conveyance capacity and 30,000 cfs for design flow. Although maximum monthly flows under baseline conditions and the 55 scenario would not exceed 30,000 cfs, they could be above 19,500 cfs during the high-flow months of November through April (Table 7.12.1-21). Conditions with flows above the current channel conveyance capacity should not be interpreted as an increase in flood risk because the modeling indicates that minimal changes in flow levels would occur in most months when compared with baseline conditions. Additionally, the results indicate that some substantial reductions in flow may occur during February in some years. Therefore, even if flows are above 19,500 cfs, the proposed Plan amendment would not increase the frequency of flows above this level, and flood risk would not be increased relative to baseline conditions. Results for the 45 scenario and the 65 scenario are the same.

Table 7.12.1-21. Flow and Storage Changes on Central Valley Rivers during High-Flow Months under the 55 Scenario as Simulated by SacWAM

High-Flow Month	High Flow Indicator	Baseline Condition	55 Scenario	Difference	Percent Change	Water Year Type	Baseline Condition	55 Scenario	Difference	Percent Change
	American River Flow (cfs)					**Folsom Reservoir Storage (TAF)**				
January	Maximum flow	28,322	28,394	72	0	Wet	543	543	0	0
	Top 10 average	15,824	15,918	94	1	Above normal	548	540	-8	-1
February	Maximum flow	30,920	30,924	4	0	Wet	523	524	0	0
	Top 10 average	15,051	15,037	-14	0	Above normal	548	548	0	0
	Bear River Flow (cfs)					**Camp Far West Reservoir Storage (TAF)**				
January	Maximum flow	6,016	6,021	5	0	Wet	94	93	-1	-1
	Top 10 average	4,538	4,422	-116	-3	Above normal	94	87	-7	-7
February	Maximum flow	7,649	7,632	-17	0	Wet	94	94	0	0
	Top 10 average	4,796	4,720	-76	-2	Above normal	94	92	-1	-2
March	Maximum flow	5,445	5,431	-14	0	Wet	94	94	0	0
	Top 10 average	3,966	3,904	-62	-2	Above normal	94	94	0	0
	Cache Creek Flow (cfs)					**Clear Lake Storage (TAF)**				
February	Maximum flow	11,608	10,453	-1,155	-10	Wet	1152	1142	-10	-1
	Top 10 average	6,315	5,552	-763	-12	Above normal	1121	1088	-33	-3
March	Maximum flow	8,516	8,516	0	0	Wet	1155	1152	-3	0
	Top 10 average	4,515	4,040	-474	-11	Above normal	1146	1113	-34	-3
	Calaveras River Flow (cfs)					**New Hogan Lake Storage (TAF)**				
January	Maximum flow	2,967	2,962	-5	0	Wet	156	150	-6	-4
	Top 10 average	1,559	1,561	1	0	Above normal	139	134	-6	-4
February	Maximum flow	3,313	3,227	-87	-3	Wet	172	164	-8	-5
	Top 10 average	2,137	2,094	-43	-2	Above normal	160	147	-13	-8
March	Maximum flow	2,608	2,608	0	0	Wet	187	178	-9	-5
	Top 10 average	1,766	1,642	-124	-7	Above normal	187	166	-21	-11

High-Flow Month	High Flow Indicator	Baseline Condition	55 Scenario	Difference	Percent Change	Water Year Type	Baseline Condition	55 Scenario	Difference	Percent Change
	Feather River Flow (cfs)					**Oroville Reservoir Storage (TAF)**				
January	Maximum flow	66,475	62,210	-4,265	-6	Wet	2769	2449	-320	-12
	Top 10 average	37,501	35,528	-1,973	-5	Above normal	2340	1870	-470	-20
February	Maximum flow	54,456	53,840	-617	-1	Wet	2885	2657	-227	-8
	Top 10 average	35,270	33,405	-1,865	-5	Above normal	2586	2122	-464	-18
March	Maximum flow	54,566	49,980	-4,585	-8	Wet	2947	2831	-116	-4
	Top 10 average	37,927	34,116	-3,812	-10	Above normal	2891	2416	-475	-16
	Mokelumne River Flow (cfs)					**Camanche Reservoir Storage (TAF)**				
January	Maximum flow	6,335	6,336	0	0	Wet	303	294	-9	-3
	Top 10 average	2,992	2,945	-47	-2	Above normal	260	257	-3	-1
February	Maximum flow	5,565	4,841	-724	-13	Wet	304	299	-6	-2
	Top 10 average	2,748	2,511	-237	-9	Above normal	282	273	-9	-3
	Putah Creek Flow (cfs)					**Lake Berryessa Storage (TAF)**				
January	Maximum flow	4,813	3,891	-922	-19	Wet	1305	1159	-146	-11
	Top 10 average	1,713	2,622	909	53	Above normal	1082	1035	-47	-4
February	Maximum flow	6,187	4,471	-1,716	-28	Wet	1397	1224	-173	-12
	Top 10 average	2,981	286	-2,695	-90	Above normal	1203	1093	-110	-9
March	Maximum flow	5,725	4,780	-945	-17	Wet	1442	1266	-176	-12
	Top 10 average	2,278	2,114	-163	-7	Above normal	1252	1120	-132	-11
	Sacramento River Flow (cfs)					**Shasta Reservoir Storage (TAF)**				
November	Maximum flow	21,263	21,245	-18	0	Wet	3125	2959	-166	-5
	Top 10 average	17,163	16,849	-313	-2	Above normal	2745	2756	11	0
December	Maximum flow	22,301	22,349	47	0	Wet	3252	3199	-53	-2
	Top 10 average	21,495	21,480	-15	0	Above normal	2897	2885	-13	0
January	Maximum flow	23,406	23,357	-49	0	Wet	3470	3445	-25	-1
	Top 10 average	22,617	22,616	-1	0	Above normal	3357	3346	-11	0
February	Maximum flow	24,394	22,301	-2,093	-9	Wet	3623	3613	-10	0
	Top 10 average	23,061	21,495	-1,566	-7	Above normal	3589	3580	-9	0

High-Flow Month	High Flow Indicator	Baseline Condition	55 Scenario	Difference	Percent Change	Water Year Type	Baseline Condition	55 Scenario	Difference	Percent Change
March	Maximum flow	23,579	23,579	0	0	Wet	3897	3869	-28	-1
	Top 10 average	22,263	22,283	20	0	Above normal	4050	4031	-19	0
April	Maximum flow	22,033	22,033	0	0	Wet	4358	4295	-62	-1
	Top 10 average	20,770	20,771	1	0	Above normal	4506	4449	-57	-1
	Stony Creek Flow (cfs)					**Black Butte Lake Storage (TAF)**				
January	Maximum flow	8,078	7,419	-659	-8	Wet	31	31	0	-1
	Top 10 average	4,740	4,603	-137	-3	Above normal	31	30	-1	-3
February	Maximum flow	8,585	8,555	-30	0	Wet	80	70	-9	-12
	Top 10 average	4,879	4,760	-119	-2	Above normal	81	75	-5	-6
March	Maximum flow	6,390	6,388	-1	0	Wet	124	108	-16	-13
	Top 10 average	3,212	3,173	-39	-1	Above normal	126	114	-12	-9
	Yuba River Flow (cfs)					**New Bullards Bar Reservoir Storage (TAF)**				
December	Maximum flow	15,368	14,946	-422	-3%	Wet	686	688	2	0%
	Top 10% average	9,906	9,657	-249	-3%	Above normal	578	594	15	3%
January	Maximum flow	22,279	21,864	-415	-2%	Wet	716	735	19	3%
	Top 10% average	11,715	11,640	-75	-1%	Above normal	645	642	-3	0%
February	Maximum flow	19,091	19,119	27	0%	Wet	759	778	19	3%
	Top 10% average	9,885	10,215	330	3%	Above normal	705	694	-11	-2%

cfs= cubic feet per second
TAF = thousand acre-feet

The typical effect of the new flow requirements would be to lower reservoir storage levels during the wet season, and flood risk impacts would be less than significant. The proposed program of implementation for the inflow objective is intended to provide for floodplain inundation to benefit native species. It is not intended to be implemented in a way that contributes to flooding related to public safety concerns and major property damage. The proposed program of implementation includes provisions for developing accounting methods for floodplain inundation flows and for ensuring that implementation of the objective does not contribute to adverse flooding, including provisions for maximum required flow levels. Where a monitor stage exists on the California Nevada River Forecast Center (https://www.cnrfc.noaa.gov/), a flow equivalent to that monitor stage would represent the maximum flow release.[1] Where a channel or stream has no set monitor stage under the River Forecast Center, or an existing monitor stage is inadequate for some reason, the State Water Board (in coordination with the DWR Division of Flood Management and local flood management agencies) would determine maximum allowable flow levels, based on existing information on local flood control districts and other relevant published information related to flow levels that would create public safety concern or major property damage. Criteria that would be considered include levee freeboard, risk to structures, public safety within the floodplain (i.e., presence of public parks, bridges, roadways, bike trails, or other public use facilities), activation of floodplain habitat, the speed at which the water stage rises, and the ability of people to evacuate affected areas. The proposed program of implementation and SacWAM results show that the flow requirements would not increase flood risk in any of the rivers modeled and that this impact would be less than significant, with the possible exception of Clear Creek.

Table 7.12.1-22 shows SacWAM results for Clear Creek, comparing baseline conditions with the 55 scenario. The 55 scenario was chosen because it is the starting point for the proposed Plan amendments. Increases in peak Clear Creek flows for the 45 and 65 scenarios are expected to be smaller or larger, respectively (see Appendix A1, *Sacramento Water Allocation Model Methods and Results*). The months with highest flows, and thus the greatest flood risk, are February and March. Significant increases in flows would occur in February and March, as well as in other months when flows could be greater than the highest flows under baseline conditions in February and March. These higher flows would result from operating the system to release additional flow from Whiskeytown Lake into Clear Creek rather than diverting the water into the Spring Creek Tunnel. To date, no creek flow level has been established to alert local residents of any potential flooding issues on Clear Creek.

[1] A monitor stage on a non-leveed stream is the stage at which initial action must be taken by concerned interests (livestock warning, removal of equipment from lowest overflow areas, or simply general surveillance of the situation). This level may produce overbank flows sufficient to cause minor flooding of low-lying lands and local roads. A monitor stage on a leveed stream is the stage at which patrol of flood control project levees by the responsible levee-maintaining agency becomes mandatory, or the stage at which flow occurs into bypass areas from project overflow weirs (DWR 2000, p. 1).

Table 7.12.1-22. Flow Changes on Clear Creek (cubic feet per second) above the Confluence with the Sacramento River under the 55 Scenario (October through May)

High-Flow Month	Clear Creek Flow	Baseline Condition	55 Scenario	Difference	Percent Change
October	Maximum flow	209	2,151	1,941	927
	Top 10% average	204	421	217	106
November	Maximum flow	293	1,137	843	288
	Top 10% average	216	557	341	158
December	Maximum flow	354	1,310	955	269
	Top 10% average	292	1,072	780	267
January	Maximum flow	651	2,375	1,724	265
	Top 10% average	418	1,560	1,141	273
February	Maximum flow	1,572	3,179	1,607	102
	Top 10% average	658	1,870	1,213	184
March	Maximum flow	1,342	3,080	1,738	130
	Top 10% average	471	1,565	1,094	232
April	Maximum flow	406	1,571	1,165	287
	Top 10% average	291	1,132	841	289
May	Maximum flow	284	787	504	177
	Top 10% average	280	559	279	100

Gray-shading shows months with highest flood risk.

Flow in Clear Creek below Whiskeytown Lake is not monitored by the River Forecast Center. Whiskeytown Lake receives water from the Trinity River system and passes much of that water, along with some of the runoff from the upper Clear Creek watershed, through Spring Creek Tunnel to Keswick Reservoir. For the past several decades, Clear Creek has not experienced flows that would be considered flood levels, so no creek flow level has been established to alert local residents of any potential flooding issues. Clear Creek below Clear Creek Road possesses floodplain habitat that could be activated by flows released from Whiskeytown Dam. Release of new flow requirements in this reach could increase the risk of downstream flooding in this area. Implementation of MM-SW-i will mitigate this impact to a less-than-significant level. To establish safe flow levels, State Water Board staff would coordinate with the DWR Division of Flood Management, Reclamation (owner of Whiskeytown Lake), and local flood management authorities to develop a flow cap that would activate floodplain habitat while maintaining public safety (e.g., on Clear Creek Road) and protecting property (e.g., Win-River Resort and Casino on the Redding Rancheria near the Sacramento River).

7.12.1.4 Mitigation Measures

MM-SW-a,f: Avoid or reduce violations of water quality standards or waste discharge requirements, and/or degradations of water quality

1. **Water Quality Contaminants and Regulation of Waste Discharges:**

    i. The State Water Board and regional water boards will continue regulation of waste discharges through a variety of programs, including but not limited to, the following.

- Storm water regulatory programs and the Strategy to Optimize Resource Management of Storm Water.
- Irrigated Lands Regulatory Program.
- Individual NPDES and WDR permitting.

ii. The State Water Board and regional water boards will implement existing TMDLs for contaminants and continue to update the 303(d) list of water quality-impaired waterbodies.

iii. The State Water Board will continue to implement funding programs that provide loans and grants for capital improvements to WWTPs.

2. **Minimize Mercury Impacts:**

i. Mercury Control Program for Reservoirs: The State Water Board will continue to develop and implement mercury control measures for reservoirs. Reservoir owners and operators will describe participation in any adopted mercury control program for reservoirs, and if applicable, incorporate mercury measures into long-term strategy and annual operations plans under Mitigation Measure MM-AQUA-a,d: 1 (Section 7.6.2, *Aquatic Biological Resources*). Proposed actions include efforts to understand and control sources of methylmercury and to address fish consumption concerns.

ii. The State Water Board will work with regional water boards to ensure that the Central Valley Water Board and San Francisco Bay Regional Water Board mercury TMDLs are implemented.

iii. The State Water Board will coordinate with USACE, DWR, and other appropriate agencies to ensure that implementation of flow requirements does not interfere with the functioning of the Cache Creek settling basin in reducing mercury inputs to the Sacramento/Delta.

iv. OEHHA issues fish consumption advisories in California. These fish consumption advisories are guidelines that recommend how often an individual can safely eat fish caught from waterbodies in California. Most of these fish consumption advisories are issued due to mercury. OEHHA has issued over 100 site-specific advisories throughout the state, as well as statewide advisories for lakes and reservoirs, rivers, streams, and creeks without site-specific advisories. OEHHA provides separate guidelines in their fish advisories for the following two groups: (1) women 18–49 years old and children 1–17 years old (sensitive populations); and (2) women 50 years and older and men 18 years and older. These recommendations apply to all fish consumers, including tribal and subsistence fisherpersons who typically consume fish at higher rates (e.g., grams of fish per day) than recreational fisherpersons (SWRCB 2017c). Water quality standards and OEHHA fish consumption advisories would continue to be implemented for the consumption of study area fish, which would serve to protect people against overconsumption of fish with increased body burdens of mercury.

3. **Temperature Control and Reservoir Management:** Implement Mitigation Measure MM-AQUA-a,d: 1 (Section 7.6.2, *Aquatic Biological Resources*) to reduce potential temperature and other water quality impacts from changes in reservoir levels and streamflows.

4. **Avoid or Reduce Harmful Algal Blooms and Invasive Aquatic Weeds:**

    i. The State Water Board will continue to monitor HABs under the Surface Water Ambient Monitoring Program (SWAMP). The State Water Board and the regional water boards will work with other water managers to monitor HABs, communicate HAB concerns with other agencies and the public, and take appropriate response actions to manage and control HABs. With the passage of AB 834 in 2019, the FHAB Program was provided with funding and given six responsibilities: event response, statewide assessment and monitoring, risk assessment, research, outreach and education, and reporting. SWAMP has developed a framework and a strategy to develop and implement a FHAB Monitoring Program for California (Smith et al. 2021).

    ii. The regional water boards will continue to require monitoring through permitting for some nutrients, such as nitrate and ammonia, which contribute to conditions favorable to HAB and invasive aquatic weed formation. The regional water boards will continue to identify waterbodies that are impaired by elevated levels of nutrients and develop and implement TMDLs and associated NPDES permit and WDR conditions to implement narrative and numeric water quality objectives. Specifically, the Central Valley Regional Water Board will continue to implement the Irrigated Lands Regulatory Program, which regulates waste discharge, including fertilizers, from irrigated lands to prevent discharges from causing or contributing to exceedances of water quality objectives. In addition, implementation of the Delta Nutrient Research Plan is leading to new information for determining whether numeric water quality objectives for nutrients are needed to address specific water quality issues in the Delta, including HABs and associated toxins and nuisance compounds, excess aquatic plant growth, low abundance of phytoplankton species that support the food web, and low dissolved oxygen in some waterways (^Central Valley Water Board 2018a).

    iii. State Water Board staff from the Division of Water Rights are coordinating with other staff within the regional water boards and other divisions within the State Water Board (including the Central Valley and San Francisco Bay Water Boards, the Division of Water Quality, and Office of Information Management and Analysis) and other agencies working on HABs, including the Delta Stewardship Council and DWR to inform how HABs should be addressed in the Bay-Delta Plan update and implementation processes. The intent of this coordination is to develop new special studies for HAB monitoring, identify gaps in long-term monitoring, and communicate the latest science on HABs and prevention and mitigation measures. Technologies for preventing and mitigating HABs are being developed by other agencies (e.g., USACE) that could be promising for managing HABs in the Delta. Prevention measures such as gene-silencing agents could reduce biomass or toxicity of HABs. Chemical management measures like algaecides and physical or biological management could reduce HABs biomass and toxins. Rapid detection technologies may also improve HAB monitoring. These technologies are still under development and testing (Pokrzywinski et al. 2021). Coordination and communication among the State Water Board and other agencies will be essential to understanding the latest science behind testing these HAB prevention and management strategies to inform whether the State Water Board could require implementation of these technologies as mitigation measures. CDBW has an Aquatic Invasive Species Program that is responsible for monitoring, managing, and controlling invasive aquatic plants in the Delta. Under this program, CDBW uses chemical, mechanical, and biological control measures, as well as hand picking when needed, to control problematic aquatic weeds in the Delta.

5. **Protect Municipal Water Quality:**

    i. The State Water Board and DDW will continue to require public water systems to comply with regulations to implement the Safe Drinking Water Act, including applicable permit conditions. DDW will continue to inspect water systems, track and monitor for compliance, and take appropriate enforcement action if needed.

    ii. The State Water Board will continue to implement funding programs for various types of assistance projects that (1) provide interim access to safe water sources; (2) contract with or provide a grant to an administrator to address or prevent failure to provide safe and affordable drinking water; (3) improve water delivery infrastructure; (4) provide technical assistance to disadvantaged communities; (5) consolidate systems; and (6) fund operation and maintenance for disadvantaged and low-income communities.

    iii. Service providers should modify water treatment procedures or mix water sources to retain adequate drinking water quality and to comply with their drinking water permits.

6. **Reduce Impacts on Groundwater:** Implementation of groundwater Mitigation Measure MM-GW-b will reduce potential impacts of lowered groundwater levels on surface water quality.

7. **Agricultural Drainage Control:** The Central Valley Water Board will continue to implement the Irrigated Lands Regulatory Program. In addition, the State Water Board and Central Valley Water Board will continue efforts of the Central Valley Salinity Alternatives for Long-Term Sustainability Program to develop and implement long-term solutions to salinity and nitrate water quality concerns in the Central Valley, including source control, BMPs to reduce the introduction of new salts, farmland retirement, and desalination, among others.

8. **Diversify Water Portfolios:** Water users can and should diversify their water supply portfolios to the extent possible in an environmentally responsible manner and in accordance with the law to mitigate potential impacts on water quality from reduced water supplies to agricultural and municipal uses. Water supply diversification includes sustainable conjunctive use of groundwater and surface water, groundwater storage and recovery, water transfers, water recycling, and water conservation and efficiency upgrades.

9. **Support and Approval of Groundwater Storage and Recovery:** The State Water Board will continue efforts to encourage and promote environmentally sound recharge projects that use surplus surface water, including prioritizing the processing of temporary and long-term water right permits for projects that enhance the ability of a local or state agency to capture high-runoff events for local storage or recharge. In processing water right applications that involve groundwater storage, the State Water Board will ensure that enough flow remains instream to protect water quality.

10. **Oversight and Approval of Water Transfers:**

    i. When processing petitions for transfers, the State Water Board will ensure that the transfer would not result in water quality impacts.

    ii. When processing transfers, DWR, Reclamation, and other agencies involved in approving transfers should require the transferor to show that the transfer would not result in water quality impacts in the source area or the area receiving the transfer.

11. **Support and Approval of Water Recycling:** The State Water Board will continue efforts to encourage and promote water recycling projects, including projects that involve use of recycled water for groundwater recharge. The State Water Board will continue to support the goals of the

Recycled Water Policy, the statewide streamlined process for permitting of non-potable water recycling projects, and the Water Recycling Funding Program (currently funded by Proposition 1 and the CWSRF Program). When processing wastewater change petitions pursuant to Water Code section 1211, the State Water Board will ensure that the change in wastewater discharge does not affect water quality, especially in dry seasons and in low-flow conditions where the stream is dependent on wastewater discharges.

MM-SW-i: Avoid or Reduce Exposure of People or Structures to Flood Risk on Clear Creek:

State Water Board staff, in coordination with DWR's Division of Flood Management, Reclamation (owner of Whiskeytown Lake), and local flood management authorities, would develop a flow cap that would activate floodplain habitat while maintaining public safety and protecting property.

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