Chapter 28 Climate Change

28.1 Introduction

This chapter describes the affected environment, methods of analysis, effects of climate change and sea level rise on the Project, and climate change effects that would potentially result from the operation of the Project, with a focus on water resources and related systems.

Climate change is defined as large-scale changes in the state of the climate that can be identified by changes in the mean and variability of its properties over an extended period of time. While climate change can occur naturally, change has accelerated due to human activity that alters the composition of the global atmosphere (Intergovernmental Panel on Climate Change 2018). The study area for the interaction of climate change with Project alternatives consists of the Sacramento Valley region.

There have been several recent changes in Council on Environmental Quality guidance with respect to GHG emissions (Section 28.3). This chapter and Chapter 21, *Greenhouse Gases*, use the Council on Environmental Quality *Final Guidance for Federal Departments and Agencies on Consideration of Greenhouse Gas Emissions and the Effects of Climate Change in National Environmental Policy Act Reviews* (Council on Environmental Quality 2016) to guide their respective analysis. The 2016 guidance indicates that NEPA analyses should consider (1) the potential effect of the proposed action on climate change by assessing GHG emissions and (2) the effects of climate change on the proposed action and its environmental impacts. This chapter, as described further below, evaluates the effects of climate change on the proposed action and its environmental impacts. Chapter 21 evaluates the project’s potential effect on climate change through evaluation of GHG emissions. The approach described in Chapter 21 is consistent with current scientific evidence that points to the need to achieve carbon neutrality by midcentury to avoid the most severe climate change impacts.

To analyze the effects of climate change on the proposed action and its environmental impacts, this chapter compares Project alternative effects through a “with climate change”—or with a future climate--scenario against a “without climate change” scenario, based on historical conditions. This serves to show the effects of climate change in isolation, to allow for analysis of future climate change effects on the proposed action. This chapter compares flow and volume indicators of Project performance under scenarios with and without climate change (Section 28.4*, Surface Water Resources, the Project, and Climate Change*), and the differences are used to analyze changes in project performance with a future changing climate. Project performance with climate change is then analyzed for all resource areas (Section 28.5, *Potential Project-Related Climate Change Effects*). In addition to adverse effects, this discussion also describes how the Project could mitigate anticipated climate change impacts based on evaluation of the same indicators and describes other benefits from the Project. Finally, this chapter describes key climate impacts on study area resources and discusses how the Project could help mitigate those impacts. Construction is not considered in the assessment of climate change impacts. The focus is instead on the relationship between climate change effects and their long-term interactions with Project operations and the resilience of the study area.

Table 28-1 summarizes the NEPA conclusions for Project operational impacts with climate change by alternative.

Table 28-1. Summary of Project Operation Effects with Climate Change by Alternative

Alternative	NEPA Conclusion	Rationale
Effect CC-1: Project-related climate change effects		
No Action Alternative	NE	Under a modeling scenario in which climate change occurs without the Project, existing reservoir storage, river flow, and system operations would be affected by climate change, but these conditions would occur regardless of construction and operation of the Project.
Alternatives 1A and 2	NE	Under a modeling scenario in which climate change occurs, operation of Alternative 1A or 2 would result in small changes in storage, flow, and operations indicators, compared to a modeling scenario in which climate change occurs and the Project is not constructed or operated. These effects would not be adverse.
Alternatives 1B and 3	NE, B	Under a modeling scenario in which climate change occurs, operation of Alternative 1B or 3 would result in small changes in flow and operations indicators, compared to a modeling scenario in which climate change occurs and the Project is not constructed or operated. These effects would not be adverse. Small year-round increases in storage during Critically Dry Water Years would occur with operation of Alternative 1B or 3, a beneficial effect.

Note: Storage, flow, and Sites Reservoir operations are variables analyzed in the climate change scenarios modeled using CALSIM and analyzed in this chapter.
NEPA = National Environmental Policy Act.
B = NEPA beneficial effects
NE = NEPA no effect or no adverse effect

28.2 Affected Environment

28.2.1. Climate

Climate in the Sacramento Valley is Mediterranean, with cool, wet winters and hot, dry summers. The rainy season primarily occurs between November and April, with less precipitation between May and October. The valley region receives less precipitation than coastal regions to the west and mountains to the east due to the topography of the mountains. The valley also experiences more temperature extremes than its surroundings; during winter, the valley is colder than the coast, while in summer it is much hotter (Huber-Lee et al. 2003).

Interannual climate fluctuations occur in the Sacramento Valley due to the El Niño—Southern Oscillation. During El Niño, the rainy season tends to be longer, and strong storms occur during winter. During La Niña, the dry season becomes longer, and fewer storms occur in winter. However, these trends may not hold every year (Huber-Lee et al. 2003). Table 28-2 shows baseline climate conditions for counties where the Project would be located.

Table 28-2. Baseline Climate Conditions in Glenn, Colusa, Tehama, and Yolo Counties (Historical Modeled Baseline from 1961–1990)

Climate Variable	Glenn County	Colusa County
Annual Average Minimum Temperature	43.2°F–43.7°F	44.3°F–44.8°F
Annual Average Maximum Temperature	71.3°F–71.8°F	72.6°F–73.1°F
Annual Precipitation	23.9 - 28.6 inches	20.8–24.6 inches
	Yolo County	**Tehama County**
Annual Average Minimum Temperature	46.2 - 46.9 °F	41.1 - 41.7 °F
Annual Average Maximum Temperature	73.8 - 74.3 °F	68.3 - 68.8 °F
Annual Precipitation	18.7 - 22.3 inches	34.9 - 41.0 inches

Source: Observed historical data derived from Gridded Observed Meteorological Data. Details are described in Livneh et al. 2015. Accessed via: Cal-Adapt

28.2.2. Global Climate Trends

Climate change has increased global temperatures in recent years and will continue to do so in the future. From 2006–2015, the observed global mean surface temperature was 0.87°C (1.6°F) higher than the historical (1850–1900) baseline. Warming is not equal everywhere—temperatures increase at two or three times the rate in the Arctic, and warming is usually higher over land than over the ocean. The global mean surface temperature continues to rise at about 0.2°C (0.4°F) per decade and may reach 1.5°C (2.7°F) above the historical baseline between 2030 and 2052 at the current rate of increase. If there are no global reductions of greenhouse gas (GHG) emissions, the global mean surface temperature could potentially reach a 2°C (3.6°F) increase by 2050, which would result in much greater impacts on natural and human systems (Intergovernmental Panel on Climate Change 2018).

As global mean surface temperature rises, the frequency of extreme heat events will increase. This may result in higher record-breaking temperatures, longer and more intense heat waves, and fewer cold days and nights that allow for recovery from extreme heat. Impacts from climate change may also include an increase in the intensity and frequency of precipitation extremes, such as heavier rainfall days, tropical cyclones and hurricanes, precipitation-induced flooding, and drought. Climate change may also result in changing seasonal patterns of temperature and precipitation, such as shortened rainy seasons and earlier snowmelt (Intergovernmental Panel on Climate Change 2018).

By 2100, global sea level rise may range from 0.26 to 0.77 meters under 1.5°C global warming (compared to 1985–2005 levels). Sea level rise can be especially impactful for small islands and low-lying coastal areas and deltas. Impacts include saltwater intrusion and flooding damage to leveed infrastructure (Intergovernmental Panel on Climate Change 2018).

Climate change could also result in indirect impacts. These include increases in risks from wildfires, vector-borne diseases, and ecosystem impacts from invasive species and alteration of native plant and animal species. These impacts are likely to have effects on human health, agriculture, energy and water systems, and urban and rural life (Intergovernmental Panel on Climate Change 2018).

28.2.3. Climate Change Effects on California

Climate change is already affecting California. Compared to the start of the twentieth century, peak runoff in the Sacramento River now occurs nearly a month earlier, and glaciers in the Sierra Nevada have lost about 70% of their area. The state has gone through major recent climate events, including a drought in 2012–2016 followed by an extremely wet winter in 2016–2017 (Bedsworth et al. 2018).

These impacts are likely to continue and worsen in the future under climate change. California expects to see temperature increases of up to 5.8°F (3.2°C) by 2050 and up to 8.8°F (4.9°C) by 2100 under Representative Concentration Pathway (RCP) 8.5, a GHG concentration trajectory adopted by the Intergovernmental Panel on Climate Change. The state's precipitation patterns consist of dry and wet periods, which are driven by winter storms and atmospheric river events. These atmospheric rivers are projected to increase in strength under climate change, with northern California experiencing more wet extremes while southern California becomes drier. Increases in frequency and intensity of drought are likely to occur across the state as warmer temperatures and decreases in precipitation exacerbate dryness. Warmer temperatures will also reduce the fraction of precipitation falling as snow; since the 1950s, April 1 snow water storage across the western United States has declined 10%, and continued snowpack decline poses significant issues for water supply as spring snowpack can hold as much as 70% of the water for the state's engineered reservoirs (Bedsworth et al. 2018).

The Sacramento Valley is likely to see these changes as well. Warmer temperatures and increases in extreme heat will occur, with July through September increases of 2.7°F (1.5 °C) to 10.8°F (6.0°C). Heat waves are expected to become longer and more spread out geographically, with higher daytime and nighttime temperatures and fewer cooling days, which allow for recovery (Houlton and Lund 2018).

While average precipitation may not change significantly, there will be a change in precipitation patterns and extremes. On the wet extreme, the Sacramento Valley will likely see rainier winter storms, more extreme floods, and greater floodplain vulnerability (Swain et al. 2018). On the dry extreme, the region will see increased dryness in Dry Water Years and more extreme droughts. Precipitation whiplash, which is an abrupt transition from one extreme to another, may also increase by 25% in northern California (Houlton and Lund 2018).

Precipitation timing and its effect on snowpack also have implications for water management in California, particularly the Sacramento Valley. The northern Sierra Nevada, which provides the primary source for water in the region, will see more years with low snowpack and may have almost no annual snowpack by 2100. Precipitation will also fall more often as rain rather than snow due to higher temperatures, which may shift timing of streamflow into the region from spring to winter, affecting inputs into rivers and reservoirs (Houlton and Lund 2018).

While the Sacramento Valley is not located on the coast, sea level rise is likely to affect the Delta by increasing flood potential and causing saltwater intrusion into the Delta's fresh waters (Houlton and Lund 2018).

The Project is based mostly in the Sacramento Valley, but climate change will also impact key hydrologic regions in the state where Storage Partners of the Sites Reservoir would be located. Table 28-3 shows projected trends for temperature, precipitation, wildfire, sea level rise, drought, and other variables under climate change for these hydrologic regions.

Table 28-3: Climate Change Trends for Hydrologic Regions Participating with Sites Reservoir

Hydrologic Region	Climate Change Trends
Sacramento River	• Increase in average daily maximum temperature by 10°F by 2100 • Increase in number of days above 104°F from 4 to 40 per year in midtown Sacramento • Increased Delta flood potential • Increased runoff and decreased groundwater recharge • Increased wildfire risk
Tulare Lake	• Increase in average annual maximum temperatures by 5°F–9°F by 2100 • Increase in extreme heat days and evapotranspiration and decrease in winter chill-hours • Increase in flooding frequency in low-lying areas • Increase in likelihood of extreme Wet and Dry Water Years • Decrease in snowpack, reducing reliability of surface water and increasing demand for groundwater
San Francisco Bay	• Increase in average annual maximum temperatures by 3.3°F by mid-century • Increase in dry and wet extremes • Increase in winter storm intensity (20-year storm will become 7-year storm or more frequent storm) • Frequent and sometimes large wildfires continue • Increase in sea level rise of 2.5–4.5 feet by 2100 • Beaches will narrow and many may be completely lost over next century
South Lahontan	• Increase in daily maximum temperatures by 5°F–6°F by mid-century • Decrease in southern Sierra snowpack water by 40% • Increase in winter streamflow and decrease in summer flows • Increase in extremes and drought • Decrease in soil moisture by 15%-40% below historic norms • Longer fire season, increase in wildfire frequency, expansion in fire-prone areas
South Coast	• Increase in heat wave frequency, intensity, and duration • Wetter winters, drier springs, and more frequent and severe droughts • Increase in wildfire risk due to drier autumns before Santa Ana wind season • Increase in sea level rise of 1 foot by mid-century and 3+ feet by 2100 • Increased flooding and erosion of beaches and property

Source: Climate projection data comes from California Fourth Climate Change Assessment (State of California 2019) as referenced in Water Resilience Portfolio (California Department of Water Resources 2020a).

28.2.4. Water Management and Climate

In normal water years, about 40% of California’s water supply comes from groundwater, while the rest comes mostly from surface water; groundwater usage increases to about half during Dry Water Years. Because northern California receives much more surface water flows than southern

California, water conveyance infrastructure delivers water from the Delta to central and southern California and relies heavily on snowpack and runoff for seasonal water storage (Bedsworth et al. 2018). Surface flows from Sacramento River runoff historically reach their peak in spring due to snowmelt. Releasing flows from reservoirs depends on seasonal needs and flooding considerations. Reservoirs historically release large flows in early winter to increase storage for spring, the main runoff season. During spring, reservoirs reduce flows as they capture spring runoff inflows for later release. In summer, reservoirs increase flows higher than they would be naturally to meet downstream irrigation needs (Huber-Lee et al. 2003).

Climate change is likely to alter hydrologic patterns and will require changes in water resources management. More extreme precipitation will result in increased runoff, which in turn is expected to lead to increased flooding (Swain et al. 2018). Furthermore, as precipitation falls more often as rain rather than snow, streamflow timing will shift from spring to winter in Sacramento Valley (Houlton and Lund 2018). Meanwhile, increased drought and potentially greater water demand may also put pressure on increasing water supply. These impacts may result in reduced Delta exports and reservoir carryover storage (i.e., the amount of water in reservoirs before the start of the wet season in October). Carryover in Shasta Lake and Lake Oroville is projected to decline by one-third over the century, reducing needed water supplies for Dry Water Years. The state will also face challenges related to drought resilience, such as flexibility and response time, particularly under longer, more frequent, and more intense droughts (Bedsworth et al. 2018).

The WSIP provides climate projections for four future scenarios for all of California: a 2030 central tendency scenario, a 2070 central tendency scenario, a 2070 drier and extreme warming scenario, and a 2070 wetter with moderate warming scenario (California Natural Resources Agency 2018). These climate scenarios were used by California Water Commission to project change to runoff into major reservoirs in the Sacramento River watershed for both 2030 and 2070 time horizons. Climate projections utilized by the California Water Commission showed that, by 2070, winter runoff may increase by an average of 2.1 MAF annually; spring runoff may decrease by an average of 1.6 MAF per year (California Water Commission 2017). This historical storage and general timing of releases of water from reservoirs may change to accommodate the runoff change demonstrated by these climate projections. In other words, altering flow releases from reservoirs and adjusting the timing are likely needed to cope with future climate change runoff changes.

Recent Reclamation assessments considering climate conditions reflect increases in temperature in major watersheds in the Sacramento and San Joaquin River Basins. These increases are at least 1.5°C (2.7°F) in all major watersheds in the Sacramento and San Joaquin River Basins under the 2035 Central Tendency (CT) scenario and at least 1°C (1.8°F) in each of the major watersheds under the Early Long-Term (ELT) Q5 scenario (U.S. Department of the Interior, Bureau of Reclamation 2019)[1]. The 2035 CT projections showed precipitation increases of at least 2% in all major watersheds in the Sacramento and San Joaquin River Basins. The ELT Q5 projections showed a 1.5% increase in precipitation in the Feather River watershed. Warmer and wetter climates in northern California would lead to increased storage volume and river flows

---

[1] 2035 Central Tendency scenario is centered around 2035 (2020–2049). The ELT Q5 projections centered around 2025 (2011–2040).

during the wet season, and decreased flow and storage volume in the dry season. While the upper Sacramento Valley may experience equal or greater precipitation, the San Joaquin Valley may experience equal or drier conditions and Tulare Lake region may experience drier conditions. Southern California shows drier projections than northern California (U.S. Department of the Interior, Bureau of Reclamation 2016).

Schwarz et al. (2018) modeled sea level rise impacts on the Delta and found that a future increase in temperature of 2.5°C (4.5°F) could result in sea level rise of 45 cm (18 in.) by the end of the century under RCP 8.5, increasing salinity in the Delta. By mid-century, climate change may increase precipitation and the rain-to-snow ratio in rainy months, slightly mitigating some of the salinity increases; however, the negative effect of sea level rise would still overpower the positive impact of increased rainfall (Wang et al. 2018). This overall increase in salinity would require greater summer outflow to repel sea level rise and maintain currently required Delta salinity standards. These water releases could come at the expense of other system functions, such as carryover storage and cold-water pools.

The state has recently produced regulations and plans related to planning for climate resilience in the water sector including: Sustainable Groundwater Management Act (2014), Executive Order B-30-15: Establishing 2030 CA Emissions Target, Adaptation Initiatives (2015), Adaptation Initiatives (2015), Senate Bill 246 (2015), Executive Order N-10-19 (2019), California Department of Water Resources California Water Plan Update (2018), and California Natural Resources Agency California Climate Change Adaptation Strategy and Safeguarding California Plan Update (2018). Together, these regulations and plans provide a policy framework for understanding and addressing climate-related risks to water resources. Related to the Project, Proposition 1 Water Bond, the Water Quality, Supply, and Infrastructure Improvement Act of 2014, was designed to appropriate bonds for water management projects to create more sustainable water supplies and water surface water storage, including through the Water Storage Investment Program. Reclamation conducted efforts towards the storage objectives of Proposition 1, including investigating and proposing a North of Delta Storage (NODOS) project to store water in wetter years and release water in drier years for use throughout areas dependent on supplies from the SWP and CVP (U.S. Department of the Interior, Bureau of Reclamation 2016). Additional information regarding statewide water policies for climate adaptation can be found in Appendix 4A, *Regulatory Requirements*.

28.3 Methods of Analysis

The Council on Environmental Quality released the *Final Guidance for Federal Departments and Agencies on Consideration of Greenhouse Gas Emissions and the Effects of Climate Change in National Environmental Policy Act Reviews* on August 5, 2016 (Council on Environmental Quality 2016). The 2016 guidance was withdrawn in April 2017 and then new draft guidance was issued in June 2019; however, the 2019 draft guidance was rescinded by Executive Order in January 2021, and the Council on Environmental Quality was directed to review, revise, and update the prior 2016 guidance. As discussed above, the 2016 guidance indicates that NEPA analyses should identify climate change effects on a proposed action and its environmental impacts.

This chapter evaluates interactions between Project alternatives and climate change by comparing model results "with" and "without" climate change. The "without climate change" modeled results are based on historical hydrologic conditions, whereas the "with climate change" modeled results are based on future climate-change driven hydrologic conditions. Incorporating modeling representing "without climate change" allows an understanding of changes to project performance that are climate driven. This analysis is based on comparison of flow and volume indicators of Project performance under no climate change using Chapter 5, *Surface Water Resources*, assessment of Project effects on surface water resources and the same indicators under climate change, using CT 2035 results.

In Section 28.4, *Surface Water Resources, the Project, and Climate Change*, the potential for climate change to impact key indicators of the Project is described, with insights on whether certain alternatives perform differently from others in the 2035 Central Tendency (CT 2035) near-term climate hydrology. The projection values presented (i.e., the 2035 mean values) were calculated based on averaging around the 30-year period of 2020–2049 projections from CALSIM model output to represent "with climate change". As described in Chapter 5, *Surface Water Resources*, "without climate change" is based on CALSIM results for an 82-year modified historical hydrology period (Water Years 1922–2003) developed jointly by DWR and Reclamation to consider hydrologic variability among water years.

The CT2035 model for hydrology and sea level rise, which forms the basis of the analysis for Section 28.4, *Surface Water Resources, the Project, and Climate Change,* was selected for use in coordination with the Reclamation Water Supply and Operations Branch. The CT2035 model boundary conditions were developed for the *Final EIR for State Water Project Long-Term Operations* (California Department of Water Resources 2020b). As indicated in Section 28.2.4, *Water Management and Climate*, this model was also utilized for sensitivity analysis in the *Reinitiation of Consultation on the Coordinated Long-Term Operation of the Central Valley Project and State Water Project Final Environmental Impact Statement* (U.S. Department of the Interior, Bureau of Reclamation 2019). Reclamation also plans to develop their updated baseline models with CT 2035 model hydrology. Use of the CT2035 model supports assessment of near-term hydrology relevant to the changes made with Project alternatives, in context of current water policy and management.

Section 28.5, *Potential Project-Related Climate Change Effects*, describes the key climate impacts on study area resources under the climate scenarios evaluated, including impacts on water supply, water quality, and aquatic biological resources. This assessment is based on literature review and evaluation of the alternatives under the climate scenario. Section 28.5 also identifies how and whether the Project would help to ameliorate the anticipated impacts of climate change. This is based on evaluation of the same indicators and assessment of whether there are any improvements to indicators associated with aquatic biological resources, water quality, and water supply under the modeled climate change scenario. This section also describes any other benefits from the Project (with climate change) compared to the No Project Alternative (also called No Action Alternative or NAA) under climate change, drawing from both CALSIM modeling and literature.

28.3.1. Indicators

Authority and Reclamation selected indicators to evaluate effects on aquatic biological resources, water quality, and water supply under climate change. The indicators for aquatic biological resources are preservation of cold-water pool; meeting fish flows, habitat, and food supply requirements; and meeting salmonid temperature requirements, especially temperature requirements for winter-run spawning. The indicators for water quality are maintaining storage in Sites Reservoir at a high enough level that releases do not need to come from the surface of the reservoir; meeting water temperature requirements; peak flow attenuation and the maintenance of minimum flows; and meeting Delta outflow, salinity, and water quality standards. The indicators for water supply are maintaining dry season yields; providing total water supply benefit; meeting supply demands of CVP and SWP south-of-Delta contractors; and meeting water provision requirements of the Storage Partners. These indicators are associated with broader water system considerations for habitat and water supply and are focal points for understanding how climate change may affect changes to the surface water system.

Modeling results were assessed for locations listed in Table 28-4 and variables were categorized into three subcategories: storage, flow, and Sites Reservoir Operations. Table 28-4 summarizes these analyzed variables. Table 28-5 indicates linkage between the variables and benefits.

Table 28-4. Variables Analyzed in Climate Change Model

Variable Type	Variable Analyzed
Storage	Shasta Lake storage
	Lake Oroville storage
	Folsom Lake storage
	Total San Luis Reservoir storage
	Total CVP and SWP storage (Shasta Lake, Lake Oroville, Folsom Lake, and total San Luis Reservoir)
Flow	Sacramento River flow at Bend Bridge
	Sacramento River flow below RBPP
	Sacramento River flow near Wilkins Slough
	Feather River flow at mouth
	American River flow at H Street
	Sacramento River at Freeport
	Yolo Bypass flow
	Delta outflow
	Total CVP and SWP Delta exports
Sites Reservoir Operations	Diversions at RBPP
	Diversions at Hamilton City
	Sites Reservoir storage
	Sites Reservoir release
	Sites Reservoir release to Yolo Bypass for habitat
	Sites Reservoir release to Dunnigan Pipeline

Variable Type	Variable Analyzed
	Sites Reservoir release to Sacramento River (Dunnigan Pipeline release minus Yolo Bypass release)

Note: CVP = Central Valley Project; RBPP = Red Bluff Pumping Plant; SWP = State Water Project.

Table 28-5. Benefit Criteria for Climate Change Model Variables

Variable Type	Location of Benefit Criteria Variable	Benefit Criteria Variable
Storage	Shasta Lake storage	Increased storage (TAF) May - October
Flow	Sacramento River at Bend Bridge	Increased flow for months important to fish
Sites Reservoir Operations	Diversions at Hamilton City Pump Station and RBPP	Total diversion for all months
Flow	Sacramento River at Wilkins Slough	Increased flow for months important to fish, Decreased flow during winter flooding
Sites Reservoir Operations	Sites Reservoir total storage	Increased storage for all months
Sites Reservoir Operations	Sites Reservoir releases (total and to Sacramento River)	Increased deliveries (cfs) in all months
Storage	Folsom Lake storage	Increased storage (TAF) May – October
Storage	Lake Oroville storage	Increased storage (TAF) during summer months (May–October) for preservation of cold-water pool.
Flow	Feather River flow at mouth	Increased flow management flexibility
Flow	American River at H Street	Increased flow (cfs) in select months
Flow	Total SWP and CVP exports	Increased deliveries (cfs) in all months
Flow	Yolo Bypass winter–early spring flows	Number of months with bypass inundation during winter and early spring as indicated by flow over Freemont Weir (the Project would cause a small decrease in winter inundation)
Flow	Delta outflow (total)	Increased outflow (cfs) during all months

Note: CBD = Colusa Basin Drain; cfs = cubic feet per second; RBPP = Red Bluff Pumping Plant; TAF = thousand acre-feet.

Reservoir storages must follow U.S. Army Corps of Engineer flood control rules and releases.

28.4 Surface Water Resources, the Project, and Climate Change

A multitude of scientific literature and datasets exist to showcase the potential effects of climate change at local and national scales (Intergovernmental Panel on Climate Change 2018, Bedsworth et al. 2018, Houlton and Lund 2018, California Department of Water Resources 2020a). This section qualitatively and quantitatively addresses key effects of climate change observed through CT 2035 model results categorized by alternative: No Project Alternative (no structural changes), Alternative 1A, Alternative 1B, Alternative 2, and Alternative 3. Variables are broken into three separate categories: storage/volume, flow, and Sites Reservoir operations. Variables were analyzed to better understand cascading effects that may exist under climate change and the Project. Average results for Wet and Critically Dry Water Years were analyzed to represent likely hydrologic conditions that would be observed under the modeled climate change.

28.4.1. Modeling Results

The results presented in the following section show the variables from Table 28-5 with and without climate change, compared across alternatives. The variables from Table 28-5 were identified as the most salient to site operations based on knowledge of water resources and aquatic biological resources. They are also presented below in hydrologic order (upstream to downstream flow).

Even without the Project, changes are expected with climate change. This section is meant to provide an understanding of overall changes under climate change simulations from the CALSIM model and the differences that arise between the No Action Alternative and operations of Alternatives 1, 2, and 3. The quantitative analyses include raw value changes (for Sites Reservoir Operations variables and percent changes for Storage and Flow variables).

To understand the full extent of future climate scenarios, the two extremes of Critically Dry and Wet Water Years were analyzed. Many of the results presented are for the Critically Dry Water Years with only a few variables for Wet Water Years. This was intentional because the greatest ramifications occur in the Project area when drier conditions prevail. Analyses of individual seasons and months are presented below. Seasons are referred to by the conventional meteorological seasons; winter is December through February, spring is March through May, summer is June through August, and fall/autumn is September through November.

The hydrologic modeling results show that there would be small changes in Sites Reservoir operations due to climate change. Water would still be available for diversion to storage during high flow conditions and water could still be released from storage for water supply and habitat purposes during dry conditions. Climate change is generally expected to reshape the hydrograph by increasing winter runoff and reducing runoff during other times of the year, as is exemplified by simulated flows downstream of Shasta Lake at Bend Bridge that are presented below. Sites Reservoir could help counteract this effect by diverting high flows when water is plentiful and releasing it when it is most needed.

28.4.1.1. Storage (overall)

The scientific literature shows that extended periods of drought and/or dry spells in California are expected to increase over the next century (Bedsworth et al. 2018). Under climate change in Critically Dry Water Years, the climate analysis showed decreases for Folsom Lake and Lake Shasta storage while Lake Oroville storage shows slight increases.

28.4.1.2. Flow (overall)

Across most rivers, flow is highest in rainy months from January to May, and particularly from January to March. In Wet Water Years, flow during rainy months increases substantially, up to

50 times higher than flow in Critically Dry Water Years. Climate change also tends to increase flow during rainy months for Wet Water Years due to a higher proportion of precipitation falling as rain rather than snow. Exchanges between reservoirs and diversions to and releases from Sites Reservoir will have relatively small effects on flow during this period of time.

28.4.1.3. Sites Reservoir Operations (overall)

Sites Reservoir operations showed relatively consistent results for all alternatives. Unlike the results for storage and flow variables, comparisons between alternatives for Sites Reservoir Operations were analyzed by absolute change in the appropriate unit –cubic feet per second (cfs) or thousand-acre feet (TAF)– *not percent change*. This is because many Sites Reservoir Operations variables would not exist without Project construction, and thus percent change was not a feasible option to assess. Also, unlike the other two variables, the Sites Reservoir operations were most sensitive to Wet Water Year changes under climate change. While many results from storage and flow showed small changes for Wet Water Years, variation in Sites Reservoir Operations were relatively larger.

The tables below show changes to the variables listed in Table 28-5 for the NAA and each alternative due to climate change.

Table 28-6: Shasta Lake Storage: Alternatives Compared with NAA (No Project) without Climate Change (a) and with Climate Change (b) — Critically Dry Water Years

a) Without climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (TAF)	1,714	1,667	1,806	2,548	2,718	2,914	2,987	2,813	2,486	2,143	1,882	1,831
Alt 1A % change	1	1	2	1	1	1	1	2	2	3	3	3
Alt 1B % change	2	2	2	1	1	1	1	3	3	4	4	3
Alt 2 % change	0	1	1	1	1	0	0	2	2	2	3	2
Alt 3 % change	4	4	4	2	2	2	2	4	5	5	6	5

b) With climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (TAF)	1,504	1,485	1,673	2,361	2,520	2,706	2,774	2,568	2,215	1,868	1,677	1,635
Alt 1A % change	1	1	1	1	1	1	2	3	3	4	3	3
Alt 1B % change	0	0	0	0	0	0	0	2	2	3	2	1
Alt 2 % change	1	0	0	0	0	1	1	2	2	3	2	2
Alt 3 % change	4	4	4	2	3	3	3	4	5	7	7	6

Shasta Lake typically stores the most amount of water from January to June, with peak volume in April and minimum volume in November (Table 28-6a). The Project would increase storage at Shasta Lake due to exchanges with Sites Reservoir, particularly from June to October. Climate change in Critically Dry Water Years would cause storage to decrease in Shasta Lake by about 200 TAF across all months (Table 28-6b compared to Table 28-6a). Even so, with climate change, the Project would continue to increase storage at Shasta Lake, especially during summer months (Table 28-6b). The alternatives that show the highest increases (Alternative 1B and Alternative 3, and especially Alternative 3) include the most CVP participation.

Table 28-7: Sacramento River Flow at Bend Bridge: Alternatives Compared with NAA (No Project) without Climate Change (a) and with climate change (b) — Critically Dry Water Years.

a) Without climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (cfs)	6,058	6,376	6,565	6,390	6,515	6,599	5,463	8,754	10,013	10,030	8,545	4,844
Alt 1A % change	8	0	-1	2	-1	1	0	-8	0	1	-1	4
Alt 1B % change	7	0	0	0	-1	0	0	-9	-1	0	1	5
Alt 2 % change	7	0	0	0	-1	1	0	-8	0	0	0	4
Alt 3 % change	6	0	0	-1	-1	0	-3	-9	0	0	0	4

b) With climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (cfs)	5,979	6,115	6,957	6,253	7,134	7,248	5,438	8,914	10,043	9,880	7,316	4,835
Alt 1A % change	6	1	0	0	-1	-1	-2	-4	0	0	3	3
Alt 1B % change	5	2	-1	0	-2	-1	-2	-5	-1	-1	2	5
Alt 2 % change	6	2	0	0	-2	-2	-2	-4	0	0	3	3
Alt 3 % change	9	4	-3	0	-3	-2	-3	-5	-1	-1	2	6

Sacramento River Flow at Bend Bridge typically has slight fluctuations from October through March, dips slightly in April, increases in May to peak in June and July, and then decreases throughout August and September (Table 28-7a). The Project would result in decreases in flow in May and increases in September and October during Critically Dry Water Years to retain water in storage and preserve cold water at the bottom of the reservoir. Under climate change without the Project (Table 28-7b), Sacramento River Flow at Bend Bridge would fluctuate slightly, with notable increases in December, February, and March, and notable decreases in August. Under climate change during Critically Dry Water Years, the Project would still reduce flow in May and increase flow in the fall.

Table 28-8: Sacramento River Flow at Bend Bridge: Alternatives Compared with NAA (No Project) without Climate Change (a) and with climate change (b) — Wet Water Years.

a) Without climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (cfs)	8,722	9,466	13,051	28,508	31,283	24,660	14,483	12,724	10,822	13,475	11,605	10,811

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Alt 1A % change	0	0	0	0	0	0	0	0	0	0	0	0
Alt 1B % change	0	-1	0	0	0	0	0	0	0	0	0	0
Alt 2 % change	0	0	0	0	0	0	0	0	0	0	0	0
Alt 3 % change	0	-1	0	0	1	0	0	0	0	0	0	0

b) With climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (cfs)	7,441	9,255	14,503	31,595	33,266	25,867	14,296	10,761	10,506	14,423	10,779	8,866
Alt 1A % change	0	0	0	0	0	0	0	-1	0	0	0	1
Alt 1B % change	0	-1	0	0	0	0	0	-1	0	0	0	1
Alt 2 % change	0	0	0	0	0	0	0	-1	0	0	0	1
Alt 3 % change	0	-1	0	0	1	0	0	-1	0	0	0	1

In Wet Water Years without climate change, flow from January through March is almost three times the amount as it is during Critically Dry Water Years and flow during the remaining months is up to twice the amount without the Project (Table 28-8a). With climate change, flow increases during the rainy months (December to March) but is generally lower from April to November (Table 28-8b). The Project would result in little effect on flow with or without climate change.

Table 28-9: RBPP Diversions: Alternatives Compared with NAA (No Project) without Climate Change (a) and with climate change (b) — Wet Water Years.

a) Without climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (cfs)	154	15	0	0	0	20	184	668	1,121	1,289	1,020	261
Alt 1A change	1	341	37	1,065	1,052	804	382	134	45	21	44	0
Alt 1B change	1	325	37	1,188	1,179	829	414	194	45	21	45	0
Alt 2 change	1	338	37	1,026	971	675	318	134	45	21	9	0
Alt 3 change	2	325	37	1,205	1,179	1,047	531	244	85	21	44	0

b) With climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (cfs)	143	16	0	0	0	19	204	609	1,066	1,212	961	230
Alt 1A change	10	218	42	1,309	1,177	860	366	75	-2	-14	-2	14
Alt 1B change	10	218	43	1,365	1,218	1,026	382	129	-2	-14	-2	14
Alt 2 change	8	236	39	1,301	1,121	671	326	72	-2	-14	-2	14
Alt 3 change	9	217	28	1,398	1,242	1,141	567	130	0	-6	0	14

Historically, RBPP diversions during the Wet Water Years show large contrasts between winter and summer months, with the largest values in June, July, and August, and no flow in December, January, and February (Table 28-9a). The construction of the Project would change the diversion for January through March and result in slight decreases across most other months (diversions from May to September are primarily agricultural use). Under climate change for NAA conditions during Wet Water Years (when diversions to storage would be highest), RBPP diversions would see consistent small decreases throughout all months without the Project (Table 28-9b). With the Project under climate change, RBPP diversions would increase in January through February compared to the Project alternatives without climate change, likely due to more precipitation falling as rain rather than as snow. Thus, the Project would help compensate for climate change by allowing capture of heavier runoff.

Table 28-10: Hamilton City Diversions: Alternatives Compared with NAA (No Project) without Climate Change (a) and with climate change (b) — Wet Water Years.

a) Without climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (cfs)	575	695	229	78	67	22	378	2,117	2,238	2,538	2,190	621
Alt 1A change	165	-2	-4	239	392	324	501	117	129	41	46	34
Alt 1B change	166	-2	-4	286	457	340	592	138	160	40	46	-1
Alt 2 change	163	-2	-4	238	378	231	446	114	125	40	45	-1
Alt 3 change	167	-2	-4	286	494	490	723	197	158	39	46	35

b) With climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (cfs)	572	691	225	80	66	22	405	2,110	2,229	2,553	2,160	621
Alt 1A change	118	1	1	358	580	369	429	111	32	9	14	-2
Alt 1B change	118	1	1	376	656	382	507	111	28	8	14	-2
Alt 2 change	116	1	1	358	557	265	429	88	31	8	14	-2
Alt 3 change	118	1	1	414	657	528	688	109	27	8	15	-1

Hamilton City diversions are typically highest during summer months and lowest in winter during Wet Water Years (Table 28-10a). The Project would result in increased diversions from January through June and in the month of October with less change for the rest of the year. Climate change during Wet Water Years will result in little change to Hamilton City diversions without the Project construction. However, with the introduction of Project alternatives, large increases are seen from January to March. These increased diversions were previously identified as a beneficial change to overall Project operations. With the Project under climate change, diversions would also increase slightly from the NAA across the rest of the year, but these increases are less than what would occur if the Project were to happen without climate change (Table 28-10b). The diversions for Alternative 3 increase the most from January to April.

Table 28-11: Sacramento River Flow near Wilkins Slough: Alternatives Compared with NAA (No Project) without Climate Change (a) and with climate change (b) — Critically Dry Water Years.

a) Without climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (cfs)	5,102	5,450	8,000	8,126	8,394	8,727	5,560	4,378	4,755	4,761	4,847	4,000
Alt 1A % change	11	0	-6	-2	-2	-3	0	-11	2	11	4	8
Alt 1B % change	10	1	-5	-3	-2	-4	0	-11	1	11	8	8
Alt 2 % change	10	0	-5	-3	-2	-3	0	-11	1	10	6	7
Alt 3 % change	8	0	-5	-4	-2	-3	-3	-10	0	9	4	6

b) With climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (cfs)	4,936	5,204	8,637	8,208	9,222	9,384	5,370	4,432	4,758	4,670	3,660	4,046
Alt 1A % change	9	2	-7	-3	-3	-3	-2	-6	0	9	15	6
Alt 1B % change	7	2	-7	-3	-3	-5	-2	-7	-1	8	13	7
Alt 2 % change	9	2	-7	-3	-3	-6	-2	-6	0	9	11	5
Alt 3 % change	11	4	-9	-3	-4	-4	-2	-8	0	5	12	8

Sacramento River Flow near Wilkins Slough is typically highest during Critically Dry Water Years from December to March with lower flows for the rest of the year (Table 28-11a). The Project aims to reduce flows from December to March and in May and increase flows from July to October. This is likely due to exchanges between Sites Reservoir and Shasta Lake. Under climate change with the NAA, flow would increase from December to March and not change significantly for the rest of the year, except in August where there would be a notable decrease (Table 28-11b). The Project would result in larger reductions to flow under climate change in Critically Dry Water Years from December to March and larger increases in August to make up for the significantly decreased flow.

Table 28-12: Sacramento River Flow near Wilkins Slough: Alternatives Compared with NAA (No Project) without Climate Change (a) and with climate change (b) — Wet Water Years.

a) Without climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (cfs)	7,961	9,018	12,477	20,933	21,863	19,607	16,301	10,572	6,786	7,085	6,077	10,096
Alt 1A % change	-2	-4	0	-1	-1	-2	-3	-2	-3	0	-1	0
Alt 1B % change	-2	-4	0	-2	-1	-3	-3	-3	-4	0	-1	0
Alt 2 % change	-2	-4	0	-1	-1	-2	-3	-2	-3	0	-1	0

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Alt 3 % change	-2	-4	0	-2	-1	-3	-3	-4	-4	0	-2	0

b) With climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (cfs)	6,625	8,860	13,478	21,499	22,282	19,684	15,564	8,002	6,095	7,893	5,227	8,199
Alt 1A % change	-2	-3	0	-2	-1	-3	-3	-3	-1	0	0	1
Alt 1B % change	-2	-3	0	-2	-1	-3	-3	-4	0	0	0	1
Alt 2 % change	-2	-2	0	-2	-1	-2	-2	-3	-1	0	0	1
Alt 3 % change	-2	-3	0	-2	-1	-4	-3	-4	-1	0	0	1

During Wet Water Years, Sacramento River Flow near Wilkins Slough is highest from January to April; throughout all months, the Project results in slight reductions in flow, with the largest reductions in November (Table 28-12a). With climate change during Wet Water Years, flow in the NAA increases slightly from December to March and decreases across the other months. Under climate change, the Project still reduces flow across most months except September, where there is a slight increase in flow (Table 28-12b).

Table 28-13: Sites Reservoir (Total) Storage: Alternatives Compared with NAA (No Project) without Climate Change (a) and with climate change (b) — Critically Dry Water Years.

a) Without climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (TAF)	0	0	0	0	0	0	0	0	0	0	0	0
Alt 1A change	225	216	244	551	559	577	551	490	436	353	289	248
Alt 1B change	193	185	213	512	521	538	512	451	395	312	250	212
Alt 2 change	189	180	209	485	493	512	486	427	378	300	242	209
Alt 3 change	169	162	190	446	453	464	438	375	326	249	202	180

b) With climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (TAF)	0	0	0	0	0	0	0	0	0	0	0	0
Alt 1A change	219	209	247	541	552	561	536	488	432	350	282	240
Alt 1B change	201	194	232	497	511	530	506	452	397	311	250	217
Alt 2 change	186	177	215	474	485	507	482	434	381	296	241	207
Alt 3 change	166	160	197	437	447	450	427	379	326	258	207	178

Without climate change, the Project is designed to store between about 160 and 580 TAF water (Table 28-13a). Sites Reservoir storage values differ by month and alternative, with the highest volume of storage expected to occur from January to May and in Alternatives 1A and 1B. With climate change, Sites Reservoir storage may expect slight fluctuations compared to without climate change (Table 28-13b). These are mostly decreases but they are not significant in value. Amongst alternatives, storage would be highest for Alternative 1A and lowest for Alternative 3.

Table 28-14: Sites Reservoir Releases (Total): Alternatives Compared with NAA (No Project) without Climate Change (a) and with climate change (b) — Critically Dry Water Years.

a) No climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (cfs)	0	0	0	0	0	0	0	0	0	0	0	0
Alt 1A change	350	155	17	0	1	53	397	932	837	1,253	980	649
Alt 1B change	297	132	24	20	1	68	407	936	866	1,255	961	597
Alt 2 change	303	148	17	0	0	38	397	899	750	1,188	889	517
Alt 3 change	182	116	24	24	27	126	408	962	760	1,171	710	332

b) With climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (cfs)	0	0	0	0	0	0	0	0	0	0	0	0
Alt 1A change	354	170	17	0	41	76	376	723	856	1,255	1,039	657
Alt 1B change	273	130	24	0	8	81	376	807	848	1,318	932	521
Alt 2 change	369	165	17	0	40	51	383	718	822	1,290	839	519
Alt 3 change	215	124	24	24	53	185	353	730	820	1,033	770	458

The Project would result in exchanges of water between Sites Reservoir and other nearby storage reservoirs (Shasta Lake, Lake Oroville, Folsom Lake), as well as diversions to and releases from Sites Reservoir (Table 28-14a). Releases would be highest from May to August and would be the smallest from December to February. Under climate change during Critically Dry Water Years, these releases would still follow that same pattern but fluctuate slightly, with notable decreases in May (Table 28-14b). Under Alternative 3, releases tend to be lower than for other alternatives (likely due to decisions that CVP will make surrounding their water) and Sites water tends to deplete more quickly, resulting in less water available for Critically Dry Water Years.

Table 28-15: Sites Reservoir Release to Sacramento River: Alternatives Compared with NAA (No Project) without Climate Change (a) and with climate change (b) — Critically Dry Water Years.

a) Without climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (cfs)	0	0	0	0	0	0	0	0	0	0	0	0
Alt 1A change	204	99	3	0	0	0	108	432	529	615	416	428
Alt 1B change	127	96	10	15	0	13	123	417	520	621	435	373
Alt 2 change	131	100	3	0	0	0	109	425	497	605	346	319
Alt 3 change	80	83	10	19	21	78	148	396	464	593	379	179

b) With climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (cfs)	0	0	0	0	0	0	0	0	0	0	0	0
Alt 1A change	259	126	3	0	36	17	101	346	564	646	469	449
Alt 1B change	176	83	10	0	2	32	101	378	560	684	445	370
Alt 2 change	259	116	3	0	36	6	109	343	554	686	340	342
Alt 3 change	160	97	10	19	43	126	137	376	509	583	379	371

Without climate change in Critically Dry Water Years, the Project's releases to Sacramento River will be highest from about May to September and be close to or at zero from December to March (Table 28-15a). Under climate change, these releases would fluctuate slightly, with notable increases in May compared to without climate change (Table 28-15b). Amongst the alternatives, Alternative 3 would generally result in the smallest releases in both climate change scenarios.

Table 28-16: Folsom Storage: Alternatives Compared with NAA (No Project) without Climate Change (a) and with climate change (b) — Critically Dry Water Years.

a) Without climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (TAF)	314	338	415	427	426	482	509	524	496	426	362	334
Alt 1A % change	-4	-3	-4	-3	-1	-2	-1	-1	0	0	-2	-2
Alt 1B % change	0	1	-1	-1	-1	-1	0	0	0	1	2	2
Alt 2 % change	-1	0	-1	-1	-1	-1	0	0	0	0	1	1
Alt 3 % change	0	-2	-2	-1	1	1	0	1	1	1	-1	-2

b) With climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (TAF)	260	283	385	392	407	499	495	474	420	361	316	286
Alt 1A % change	0	1	0	0	0	0	0	0	0	-1	-1	-1
Alt 1B % change	-2	-1	-1	1	0	0	0	0	0	-1	-1	-2
Alt 2 % change	-1	1	0	0	0	0	0	0	-1	-1	-1	-1
Alt 3 % change	7	7	5	4	2	2	2	2	2	2	1	2

Folsom Storage volume during Critically Dry Water Years typically peaks in March to June and is at its lowest in October; the Project would generally result in small reductions in storage for all months (Table 28-16a). With climate change, storage in the NAA would decrease slightly across all months likely due to a combination of reduced snowpack and changes in reservoir operations (Table 28-16b). Alternative 3 under climate change, however, shows some increases, potentially related to decisions the CVP may make in exchanges that increase Folsom Storage.

Table 28-17: Lake Oroville Storage: Alternatives Compared with NAA (No Project) without Climate Change (a) and with Climate Change (b) — Critically Dry Water Years.

a) Without climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (TAF)	867	855	910	1,440	1,546	1,686	1,702	1,649	1,410	1,124	965	914
Alt 1A % change	-3	-3	-3	-1	-1	-1	-1	-1	1	2	1	0
Alt 1B % change	-3	-3	-3	-1	-1	-1	-1	-1	1	2	1	0
Alt 2 % change	-3	-3	-3	-1	-1	-1	-1	-1	1	2	1	-1
Alt 3 % change	-1	-1	-1	-1	-1	-1	-1	-1	1	2	1	-1

b) With climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (TAF)	906	892	997	1,473	1,604	1,773	1,775	1,700	1,426	1,160	1,017	969
Alt 1A % change	0	-1	0	0	0	0	0	0	2	4	2	2
Alt 1B % change	0	0	0	1	1	0	0	0	2	4	2	2
Alt 2 % change	0	-1	-1	0	0	0	0	0	2	4	2	1
Alt 3 % change	0	0	0	0	0	0	0	0	2	4	2	2

Lake Oroville storage during Critically Dry Water Years typically peaks from January through June and is at its lowest in October and November (Table 28-17a). The Project would result in slight decreases across most months, with larger decreases from October to December, and slight increases from June to August. With climate change, Lake Oroville storage in the NAA is slightly higher across all months (Table 28-17b). The Project would not result in as many decreases to storage under climate change but would still have slight increases from June to September.

Table 28-18: Feather River Flow at Mouth: Alternatives Compared with NAA (No Project) without Climate Change (a) and with climate change (b) — Critically Dry Water Years.

a) Without climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (cfs)	1,327	1,290	1,785	3,212	2,954	2,814	3,129	2,534	3,780	3,388	2,148	1,826
Alt 1A % change	25	5	0	1	0	0	0	0	-14	-5	12	11
Alt 1B % change	23	5	0	0	0	0	0	0	-14	-4	10	13
Alt 2 % change	20	5	0	0	0	0	0	0	-13	-5	11	12
Alt 3 % change	6	5	0	0	0	0	0	0	-12	-3	12	12

b) With climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (cfs)	1,281	1,188	1,717	3,355	3,208	3,060	3,217	2,671	4,192	3,330	2,142	1,857
Alt 1A % change	27	5	0	0	0	0	0	1	-13	-7	21	3
Alt 1B % change	24	4	0	0	0	0	0	1	-12	-8	21	4
Alt 2 % change	21	5	0	0	0	0	0	2	-12	-7	20	6
Alt 3 % change	22	1	0	0	0	0	0	0	-11	-7	19	4

Feather River flow at mouth during Critically Dry Water Years is normally highest from January to July and at its lowest in October and November (Table 28-18a). The Project would decrease flow from June to July and increase flow from August to November. This is due to exchanges with Sites Reservoir, likely to improve cold water supply in the reservoir to reduce river temperatures for fish. Under climate change in the NAA, flow from January to June increases (Table 28-18b). The Project would still decrease flow from June to July and increase flow from August to November, but the August and October increases would be slightly higher while the September increases would be slightly lower than compared to without climate change.

Table 28-19: American River Flow at H Street: Alternatives Compared with NAA (No Project) without Climate Change (a) and with climate change (b) — Critically Dry Water Years.

a) Without climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (cfs)	662	517	538	974	1,187	803	1,054	888	827	986	1,014	682
Alt 1A % change	13	-9	18	0	-9	9	-8	-3	-4	-1	8	0
Alt 1B % change	13	-2	15	-3	1	5	-9	-1	-2	-3	-5	0

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Alt 2 % change	13	-2	11	0	1	4	-8	0	-2	-1	-6	0
Alt 3 % change	-15	20	-2	0	-15	3	2	-7	-1	0	12	0

b) With climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (cfs)	787	544	599	1,188	1,363	745	1,293	1,032	900	809	771	720
Alt 1A % change	-2	-9	4	2	0	-1	1	1	0	0	0	0
Alt 1B % change	2	-11	5	-2	2	0	1	1	1	3	1	0
Alt 2 % change	0	-14	6	1	0	-1	0	1	0	0	0	0
Alt 3 % change	-24	-10	6	0	10	-1	-2	1	-2	5	2	0

American River Flow at H Street during Critically Dry Water Years is typically high from January to August and low from September to December (Table 28-19a). The Project would have small to moderate effects on this, though there are no noteworthy trends. Under climate change, flow would increase for most months except March, July, and August; once again, the Project would have varying effects on this, with some moderate decreases in flow during November (Table 28-19b). Alternative 3 differs from the other alternatives the most in terms of its effects on flow both with and without climate change.

Table 28-20: Total SWP and CVP Exports: Alternatives Compared with NAA (No Project) without Climate Change (a) and with climate change (b) — Critically Dry Water Years.

a) Without climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (cfs)	3,890	4,735	5,917	5,856	6,080	4,146	1,551	2,237	1,921	2,240	3,707	3,577
Alt 1A % change	7	9	0	2	0	1	1	0	3	42	23	28
Alt 1B % change	5	10	1	0	0	2	1	-1	2	43	22	26
Alt 2 % change	5	10	1	0	0	2	1	0	3	40	18	24
Alt 3 % change	-5	9	0	-1	0	1	2	0	1	39	24	19

b) With climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (cfs)	4,333	4,237	4,943	5,539	6,153	4,525	1,565	2,285	1,912	1,866	2,243	3,770
Alt 1A % change	9	7	5	0	1	-2	6	0	0	47	58	19
Alt 1B % change	6	8	2	0	0	-2	6	0	0	48	55	19
Alt 2 % change	8	6	5	0	0	-3	6	0	0	50	47	17
Alt 3 % change	4	10	1	1	-2	-1	6	0	0	39	48	20

Total SWP and CVP exports in Critically Dry Water Years are normally high from December to February and are at their lowest in April (Table 28-20a). The Project would substantially increase (by 20-40%) exports from July to September, with less significant increases throughout the rest of the year. This is due to combined effects of diversions to and releases from Sites Reservoir and operational changes for the three reservoirs that would overall increase water supply to downstream users. There is no consistent trend for what climate change would do to exports in the NAA, although overall there would be a small reduction (Table 28-20b). Percent increases in July and August exports from the Project would be slightly higher under climate change, but this is mostly due to changes in the NAA flow.

Table 28-21: Yolo Bypass Flow: Alternatives Compared with NAA (No Project) without Climate Change (a) and with climate change (b) — Critically Dry Water Years

a) Without climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (cfs)	41	22	385	406	599	351	107	68	64	48	54	78
Alt 1A % change	75	0	0	-2	-4	-4	0	0	0	0	189	70
Alt 1B % change	101	0	-3	-2	-4	-4	0	0	0	0	148	87
Alt 2 % change	75	0	0	-2	-4	-4	0	0	0	0	231	43
Alt 3 % change	75	0	-4	-2	-4	-4	0	0	0	0	60	43

b) With climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (cfs)	41	22	542	445	655	358	107	68	64	48	54	67
Alt 1A % change	0	14	-5	-3	-3	-3	0	0	0	0	120	54
Alt 1B % change	0	15	-5	-2	-4	-5	0	0	0	0	111	9
Alt 2 % change	0	14	-5	-3	-4	-5	0	0	0	0	171	12
Alt 3 % change	0	14	-5	-1	-5	-4	0	0	0	0	60	9

Yolo Bypass Flow in Critically Dry Water Years is high from December to March and reaches a low in October and November (Table 28-21a). The Project would slightly decrease flows from December to March and substantially increase flows from August to October, with up to a 200% increase in August. Climate change does not result in significant changes to flow in the NAA. With the Project under climate change, the increases to flow in August to October would be slightly lower than without climate change, with October increases going to zero (Table 28-21a). Alternative 3 shows overall smaller increases in flow for both climate change scenarios.

Table 28-22: Yolo Bypass Flow: Alternatives Compared with NAA (No Project) without Climate Change (a) and with climate change (b) — Wet Water Years

a) Without climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (cfs)	86	596	5,365	29,169	35,753	21,857	7,148	688	172	48	139	79
Alt 1A % change	269	-2	0	-3	-2	-3	-3	-11	0	0	218	399
Alt 1B % change	267	-2	1	-3	-3	-3	-4	-11	0	0	218	388
Alt 2 % change	255	-2	0	-3	-2	-2	-3	-11	0	0	218	434
Alt 3 % change	227	-2	1	-3	-3	-3	-7	-13	0	0	218	378

b) With climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (cfs)	83	564	6,752	37,193	42,394	26,222	7,500	214	111	48	142	80
Alt 1A % change	266	-1	0	-3	-3	-2	-3	-10	0	0	195	379
Alt 1B % change	257	-1	1	-3	-3	-3	-4	-11	0	0	195	375
Alt 2 % change	269	-1	0	-3	-3	-2	-3	-10	0	0	195	389
Alt 3 % change	226	-1	1	-3	-3	-3	-7	-11	0	0	195	378

In Wet Water Years, Yolo Bypass Flow is about 50 times the amount as it is during Critically Dry Water Years from January to March, and about twice the amount in other months (Table 28-22a). The Project would result in slight decreases in flow from November to May and large increases (up to 400%) from August to October. Climate change would increase flow in the NAA from December to March, likely due to more precipitation falling as rain rather than snow, and not change flow substantially for other months. Under climate change, the Project would also slightly decrease flow from November to May and result in large increases to flow from August to October; these changes are not significantly different from the Project effects without climate change (Table 28-22b).

Table 28-23: Delta Outflow: Alternatives Compared with NAA (No Project) without Climate Change (a) and with climate change (b) — Critically Dry Water Years.

a) Without climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (cfs)	4,083	3,905	8,495	10,608	13,663	11,103	9,539	5,682	5,371	4,019	3,375	3,110
Alt 1A % change	24	-8	-5	-2	-2	-2	0	-1	0	1	5	0
Alt 1B % change	22	-6	-5	-2	-1	-3	0	-1	0	1	5	1
Alt 2 % change	22	-7	-4	-2	-1	-3	0	-1	0	1	5	0
Alt 3 % change	17	-4	-5	-2	-3	-2	0	-2	0	1	2	-1

b) With climate change

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NAA (cfs)	3,702	4,110	10,307	11,499	15,115	11,680	9,644	5,876	5,888	4,126	3,433	3,057
Alt 1A % change	18	-1	-8	-2	-2	-2	-1	2	0	-2	9	2
Alt 1B % change	17	-3	-7	-3	-2	-3	-1	2	0	-2	8	1
Alt 2 % change	17	-1	-8	-2	-2	-3	-1	2	0	-2	8	1
Alt 3 % change	16	-4	-7	-3	-1	-2	-1	1	0	-2	7	1

In Critically Dry Water Years, Delta outflow is normally highest from January through March and lowest in August and September (Table 28-23a). The Project would result in slight decreases to outflow from November to May and larger increases to outflow in October; this October increase is due to Sites releases for habitat flows for Yolo Bypass. With climate change in the NAA, outflow may increase slightly from December to March, likely due to precipitation falling as rain more than snow (Table 28-23b). The Project would also result in moderate increases to outflow in October and slight decreases from November to April.

28.5 Potential Project-Related Climate Change Effects

This section qualitatively describes the following Project-related climate change effects based on a literature review and other chapters in the RDEIR/SDEIS as well as the modeled effects described above:

- How will operations of the Project have an impact on these resource areas?
- How will climate change exacerbate the impacts that the Project would have on these resource areas?
- How could the Project potentially mitigate anticipated impacts due to climate change?

28.5.1. Surface Water Resources and Fluvial Geomorphology

The summary of changes in hydrology described here and in Chapter 5, *Surface Water Resources*, focuses on Wet and Critically Dry Water Years to concisely capture the type of hydrologic responses that could occur with the Project. The Project would result in exchanges of water between Sites Reservoir and other nearby storage r;./eservoirs (Shasta Lake, Lake Oroville, Folsom Lake) due to diversions to and releases from Sites Reservoir. The Project is expected to result in reduced flows in Sacramento River below RBPP for some alternatives due to increases in winter diversions to Sites Reservoir and potential increases in flow during September and October of Critically Dry Water Years due to increased releases from Shasta Lake. Sites Reservoir releases to the Sacramento River would happen most often during dry conditions, while releases to the Yolo Bypass would occur more during Wet Water Years. The alternatives could also increase flow at the downstream end of Sacramento River at Freeport during July through October of Critically Dry Water Years. Shasta Lake storage is expected to increase slightly, with more increases in Critically Dry Water Years than Wet Water Years. There could be smaller effects on Lake Oroville and Folsom Lake. In the Delta, the combined effects of diversions to Sites Reservoir, releases from Sites Reservoir to the Sacramento River and Yolo Bypass, and operational changes for the three reservoirs would result in small reductions in Delta outflow during wetter months and increases in Delta outflow during drier months, particularly during Critically Dry Water Years. Overall, the Project would increase water supply to downstream users, and Delta exports are expected to increase, especially during summers of Critically Dry Water Years (Table 28-20a).

Climate change could also affect surface water resources. Expected climate change impacts include slight decreases in storage during Critically Dry Water Years and increases in flow during rainy months during Wet Water Years. Section 28.4.1, *Modeling Results*, describes climate change impacts on surface water resources in more detail.

The presence of Sites Reservoir is expected to help mitigate or reduce impacts of climate change. Increases in precipitation extremes, such as flooding during the wet season and drought during the dry season, are expected to occur more frequently in the future. Timed diversions from the Sacramento River and releases from Sites Reservoir can help reduce these flooding risks and provide increased water deliveries during drought. The Project is expected to result in slight reductions in Sacramento River Flow at Wilkins Slough in Wet Water Years, reducing potential for winter flooding (Table 28-12a). Sites Reservoir is expected to release the most water during summer months (June to September) under Critically Dry Water Year conditions (Table 28-15a and Table 28-15b). The Project would provide water to downstream users when most needed. The Project under climate change conditions would cause substantial increase in exports July through November (Table 28-20b). Habitat flows in Yolo Bypass would result in increased Delta outflows in fall (August to October).

The risks and potential mitigation described above also apply to climate change impacts on fluvial geomorphology. The Project is not expected to have significant impacts on factors related to fluvial geomorphology (Chapter 7, *Fluvial Geomorphology*). These include potential changes to drainage patterns that would result in increased erosion and sedimentation; altering of river geomorphic processes and characteristics; and altering of instream woody material, boulders, aquatic habitat, and spawning gravel. Climate change could result in increased sediment load due to increased flow and runoff in rainy months during Wet Water Years (e.g., Table 28-8a and Table 28-8b). This could positively affect fluvial geomorphology and provide benefits for some fish species.

28.5.2. Surface Water Quality

The Project could have substantial and unavoidable effects associated with methylmercury. Mitigation measure WQ 1.1 would reduce those effects; however, there is uncertainty associated with the feasibility of this mitigation measure and therefore effects would remain substantial. The Project is not expected to have substantial adverse effects on water quality for other metals and pesticides with the incorporation of mitigation (WQ-2.1 and WQ-2.2). The Project would not have adverse effects on other water quality constituents (e.g., salinity and harmful algal blooms [HABs]).

Climate change could exacerbate existing water quality effects. With climate change, water storage and flow could be reduced by increased severity of drought and increased evaporation, thus increasing concentrations of pollutants in reservoirs and rivers. Decreases in storage and flow during summer and fall months of Critically Dry Water Years is expected to occur for Shasta Lake storage (Table 28-6a and Table 28-6b), Folsom Storage (Table 28-16a and Table 28-16b), and Sacramento River (Table 28-12a and Table 28-12b).

Water temperature could increase under climate change due to higher air temperatures and lower flow and storage. Higher water temperature could also result in increased occurrence of HABs. Sites Reservoir storage levels would not be substantially lower under climate change conditions (Table 28-13a and Table 28-13b). Therefore, changes in storage would not exacerbate HAB production when compared to conditions without climate change. Furthermore, the operation of Sites Reservoir would be managed and monitored on a regulator basis as required by multiple existing regulations and the provisions of the RMP, as well as the mitigation measures, thus accounting for changes over time and for appropriately planning reservoir operations and diversions.

In the Delta, sea level rise could result in increased salinity (Bedsworth et al. 2018). Climate change may increase inflow to the Delta during the winter but cause decreases in other parts of the year (Table 28-22 and Table 28-23). The effect on Delta outflow under climate change would depend on changes in exports (Table 28-20a and Table 28-20b).

At the other extreme, increases in severe storms associated with climate change could result in more flooding and runoff that wash pollutants into surface waters and results in sedimentation. Under climate change, peak flows in Sacramento River at Bend Bridge may increase compared to peak flows absent climate change, resulting in higher metal concentrations entering Sites Reservoir (Table 28-8a and Table 28-8b). However, settling of suspended sediments may reduce these concentrations, as expected under the Project without climate change. Increases in wildfires could have similar effects by burning vegetation that stabilizes soil, creating conditions conducive to flash flooding and debris flows, both of which could worsen water quality. As identified below, the Project is not expected to substantially exacerbate wildfire risk, and the Project could act as a barrier to flash flooding or debris flow if a wildfire were to occur upstream of the reservoir.

The Project could mitigate or reduce the climate change effects on water quality. Through storage exchanges and use of CVP Op Flex water, the Project could help maintain storage in Shasta Lake (Tables 28-6a and Table 28-6b) or Lake Oroville (Table 28-17a and Table 28-17b) as modeled by CALSIM over the summer to help preserve cold-water pools. The Project would result in increases to Shasta Lake storage from June to October, particularly for Alternative 3. In addition, the Project could augment flow through the Delta in October and contribute to Delta outflow during dry conditions, which would limit increases in Delta salinity. With climate change the Project would increase Delta outflow during August through October and cause smaller changes with some decreases November through July (Table 28-23a and Table 28-23b). These changes in outflow would affect Delta salinity. Increases in Delta outflow would reduce seawater intrusion under climate change. The Project-related decreases in Delta outflow occur at a time of year when Delta outflow is higher and are therefore less concerning with respect to water quality.

28.5.3. Groundwater Resources

The Project is expected to have no adverse effects on groundwater resources. During operations some seepage would occur resulting in a potential increase in groundwater levels, but this is not anticipated to adversely affect recharge or groundwater quality.

Climate change could have effects on groundwater resources. Drought and high temperatures could increase water demand, causing water users to draw more on groundwater. During the wet season, intensifying heavy precipitation may increase surface runoff. If annual precipitation does not also increase, this could result in a reduction of overall annual volumes available for infiltration and recharge. Sea level rise could also result in saltwater intrusion of groundwater resources (Houlton and Lund 2018).

The Project would help mitigate these effects by regulating flow, allowing more surface water to be available when needed and reducing reliance on groundwater. Flows would generally be released during Dry and Critically Dry Water Years and flows on Funks and Stone Corral Creeks would be captured by Sites Reservoir in Wet Water Years. This could provide more surface water resources for water users during drought, reduce groundwater withdrawal, and support infiltration for groundwater recharge.

28.5.4. Wildlife and Vegetation Resources

The Project would result in effects on wildlife, vegetation, and wetland resources. Impacts on vegetation and wetland resources are described in Chapter 9, *Vegetation and Wetland Resources*, and impacts on wildlife and their habitats are described in Chapter 10, *Wildlife Resources*. Affected wildlife species and habitats include aquatic and terrestrial invertebrates, reptiles and amphibians, birds, mammals, and various natural communities. The Project would result in permanent and temporary losses of wildlife habitat, injury or mortality of wildlife from construction and operations, impediments to wildlife movement, and disruption of activities, such as foraging, nesting, breeding, and dispersal. Once completed, Sites Reservoir would be a permanent barrier to terrestrial wildlife movement. For vegetation and wetland resources, construction of the Project would result in removal of special-status plant species, sensitive natural communities, wetlands, and non-wetland waters, as well as hydrological alteration and increased erosion and sedimentation.

The Project includes mitigation measures that would minimize or avoid some impacts on wildlife, vegetation, and wetland resources, as well as specific BMPs, the LMP, and the Recreation Management Plan. Implementing the variety of mitigation measures will reduce the severity of effects. These include conducting special-status wildlife and plant surveys, implementing various measures to protect special-status species and sensitive communities during construction, conducting a wildlife connectivity and crossing assessment, restoring temporarily disturbed areas, adjusting the temporal and spatial boundaries of construction as necessary, preserving and restoring wildlife habitat and sensitive communities offsite to compensate for permanent losses, and purchasing mitigation credits from conservation banks. With the implementation of BMPs, the LMP, the Recreation Management Plan, and mitigation measures, the Project would comply with federal, state, and local regulations. With implementation of mitigation measures, the Project would not conflict with local policies and ordinances protecting wildlife. The Project would have substantial adverse effects on riparian, foothill pine, oak savanna, and blue oak woodland after implementation of mitigation due to the time required for replacement of mature trees in these communities. The Project would also have substantial adverse effects on golden eagle and wildlife movement.

Climate change impacts in the Sacramento Valley region could exacerbate effects on wildlife, vegetation, and wetland resources. Changes in temperature and precipitation patterns and extremes could modify habitats and plant community and wildlife species compositions as some vegetation and wildlife species become unable to survive in the new conditions. Increased wildfire risk may also result in additional acres of vegetation being burned. Increases in extreme precipitation may result in more flooding, exacerbating existing erosion and water quality problems due to pollutants in runoff or increased concentration of contaminants in water. Increases in drought may result in effects on wildlife including lack of drinking water, reduced food supply, increased stress, and increased disease (Cook 2012). These climate impacts may increase the number of wildlife species that need to migrate to other suitable habitats, thus increasing the need to find solutions for wildlife connectivity (Houlton and Lund 2018).

The Project may mitigate some of the effects exacerbated by climate change, given anticipated regulation of flows that can help to maintain habitat required by some species, such as western pond turtle.

28.5.5. Aquatic Biological Resources

The Sacramento River and its tributaries support state and/or federally listed salmon, steelhead, and sturgeon, among other native species. The Sacramento Valley region contains the highest number of California endemic fish (Houlton and Lund 2018). A wide variety of aquatic species that the Project must consider include Chinook salmon, steelhead, green sturgeon, white sturgeon, delta smelt, longfin smelt, lamprey, native minnows, starry flounder, northern anchovy, striped bass, American shad, threadfin shad, black bass, and California bay shrimp (Chapter 11, *Aquatic Biological Resources*). Overall, the Project would not have adverse effects on flow-survival effects to winter-run Chinook salmon, spring-run Chinook salmon, fall-run/late fall–run Chinook salmon, Central Valley steelhead during their dispersal to rearing habitat and/or migration downstream; habitat impacts on longfin smelt; and water quality impacts on delta smelt, as mitigation measures are required to reduce adverse effects. In addition, overall, the Project is not expected to have adverse effects on green sturgeon, white sturgeon, lampreys, native minnows, starry flounder, northern anchovy, striped bass, American shad, threadfin shad, black bass, California bay shrimp, reservoir species, and southern resident killer whale. Finally, with the implementation of BMPs and technical studies and adaptive management the Project will comply with federal, state, and local regulations and will validate modeling results and analyses.

The indicators for benefits to aquatic biological resources assessed are preservation of cold-water pool to meet salmonid temperature requirements and temperature requirements for winter-run spawning (Shasta Lake: Tables 28-6a and Table 28-6b and Lake Oroville: Tables 28-17a and 28-17b); meeting flow needs for fishes (Feather River: Table 28-18a and Table 28-18b), fish habitat, and fish food supply (Yolo Bypass: Tables 28-21a and 28-21b and Tables 28-22a and 28-22b). These factors and the climate change impacts on them are listed below.

- **Flows**: Regulators work with water managers to maintain flows to support aquatic and riparian wildlife and habitat. Climate change may increase precipitation extremes, such as increased frequency and intensity of drought and extreme precipitation events, which affect these flows (California Natural Resources Agency et al. 2020). Reduced flows also increase the likelihood of over-drafting ground water supplies, which causes land and canals to subside.
- **Temperature**: Fish species in the Delta are adapted to certain ranges of temperatures. Higher temperatures may result in waters becoming too warm to support life stages of many of these species. Warmer water temperatures tend to favor nonnative and invasive species of fish that can outcompete native species under these conditions (Houlton and Lund 2018). Therefore, management of cold-water pool in reservoirs is important for maintaining temperatures downstream for native cold water–adapted fish species. If storage in these reservoirs is too low at the end of April, there may not be enough cold water to adjust water temperatures in the Sacramento River during warm months. Thus, increased drought and temperatures can result in decreased storage and increased evaporation, further affecting temperatures important to incubating eggs and rearing salmon alevin (U.S. Department of the Interior, Bureau of Reclamation 2014).
- **Water quality and nutrients**: Excessive nutrients and high concentration of pollutants can be harmful to aquatic life. Increased drought and increased extreme precipitation events can worsen water quality, as drought can reduce water levels (thus increasing concentrations of pollutants), and heavy rainfall can cause more surface runoff to wash nutrients and pollutants into surface waters (Houlton and Lund 2018).
- **Salinity**: Fish species in the Delta are adapted to certain ranges of salinity. Sea level rise and increased drought cause salt water to intrude into the Delta (Houlton and Lund 2018). This could limit available habitat for some species of fish that rely on low salinity or freshwater for some or all of their life cycles.
- **Turbidity**: Increased drought and low flows can lead to lower sediments in the water column, increasing light attenuation which facilitates photosynthesis of floating and submerged aquatic vegetation, the majority of which in the Delta is invasive Brazilian waterweed (*Egeria densa*) and water hyacinth (*Eichhornia crassipes*). Invasive, warm water fish species (e.g., largemouth bass [*Micropterus salmoides*]) use aquatic cover to ambush migrating native fishes (Zeug et al. 2021). On the other extreme, an overload of sediments can increase the turbidity of water, decreasing the amount of light that can aid in primary productivity to feed fish. High turbidity may also decrease visibility that allows predators to catch prey and allow prey to escape. Increasing extreme precipitation may cause more sedimentation in rivers, increasing turbidity levels (Houlton and Lund 2018). The IEP MAST (2015) conceptual model identifies predation risk as a habitat attribute affecting delta smelt. Flows interact with erodible sediment supply to affect turbidity. In general, greater turbidity is thought to lower the risk of predation on delta smelt. Large amounts of sediment enter the Delta from winter and spring storm runoff, with resuspension by tidal and wind action. A conceptual model of sedimentation in the Delta includes a submodel for river supply, which notes that dams and reservoirs have contributed to decreased sediment supply to the Delta (Schoellhamer et al. 2012: their Figure 4). However, a recent analysis examining future climate scenarios predicted

significant increases in large flow events and sediment transport over the next century, which may increase turbidity (Stern et al. 2020).

The Project may help mitigate or reduce some of the climate effects on aquatic resources. For example, the Project would help reduce the climate-change induced effect of increases in water temperature on fish. Through temperature exchanges, the Project would help preserve cold water pool for fish and meet salmonid temperature requirements in rivers. Increases flows to Feather River at the mouth August through November for the Project (all alternatives) under climate change would help keep flows stable and support salmonid temperature requirements. The ambient temperatures under climate change and reduced snowpack could counteract some of these potential temperature benefits. Through exchanges and Op Flex water the Project could increase storage in Shasta Lake relative to baseline with and without climate change during Critically Dry Water Years. This would allow additional operational flexibility related to temperature control downstream of Keswick Dam during the summer months to assist in survival of spawning winter-run Chinook salmon. Increased storage at Lake Oroville and Folsom Lake during key months can have also benefits for listed salmonids by making it easier to meet downstream temperature targets, particularly if these increases are in Dry or Critically Dry Water Years. As an example, the NMFS 2019 BiOp requires key steelhead egg-to-fry temperature targets for December through May (temperatures below 54°F) and steelhead juveniles for May 15 through October (temperatures below 68°F).

There are additional ways the Project may help mitigate or reduce some of the climate effects on fish. The Project would result in moderate increases to Delta outflow in October for fish, counteracting increases in salinity and improving fish habitat by keeping the low-salinity zone closer to Suisun Marsh (Table 28-23a and Table 28-23b). The Yolo Bypass habitat flows would support North Delta fish by providing food resources. The Project would enhance reliability of the refuge water source, providing habitat, under climate change conditions. Finally, to the extent that increased reservoir storage reduces dependence on groundwater pumping, this will help protect trees that provide riparian shading that fishes use for cover and temperature refuge, in addition to ensuring levee stability.

28.5.6. Public Health, Environmental Hazards, Environmental Justice, and Socioeconomics

The Project is not expected to have substantial adverse effects on public health and environmental hazards (Chapter 27, *Public Health and Environmental Hazards*). This includes exposure to hazardous materials, impairment of emergency response plans, or substantially exacerbated wildfire risk, and vector-borne diseases. While the Project is not likely to substantially increase the risk of these hazards, climate change may increase the frequency, severity, and geographic extent of wildfires in the future, and extreme precipitation occurring after wildfires may also trigger more landslides. Increased heat may also expand the range of mosquitos, potentially increasing the risk of vector-borne diseases (Bedsworth et al. 2018).

The Project would have some substantial adverse effects on environmental justice, since the Project could have a disproportionate impact on air quality and visual resources for minority and low-income populations for Alternatives 1 and 3 (Chapter 30, *Environmental Justice and Socioeconomics*). For Alternative 2, these effects would also occur, in addition to disproportionate effects on land use and transportation and traffic for minority and low-income populations. Mitigation Measures AQ-1.1, 1.2, 2.1, and 2.2 would reduce air quality emissions; however, it is anticipated these measures would not reduce emissions below existing thresholds. Climate change is also expected to have disproportionate impacts on minority and low-income populations in general and may thus exacerbate any impacts on these populations from the Project. Minority and low-income populations already experience disproportionate environmental pollution, which may have affected their health in the long term as a result, potentially making them more sensitive to climate hazards such as decreased air quality. These populations may also have less adaptive capacity to respond to natural hazards due to socioeconomic and political constraints (Bedsworth et al. 2018). Thus, they may lack access to adaptation strategies such as using more air conditioning during heat waves, migrating to other locations in extreme events, or paying healthcare bills resulting from climate-related injuries (Bedsworth et al. 2018).

28.5.7. Energy, Air Quality, and Greenhouse Gas Emissions

The GHG analysis is based upon a net-zero threshold and consistency with EO B-55-18 (Chapter 21, *Greenhouse Gases*). The net-zero threshold approach is conservative and is in line with current scientific evidence that points to the need to achieve carbon neutrality by midcentury to avoid the most severe climate change impacts. GHG-related impacts would be significant for the Project, because construction and operations emissions would generate substantial emissions of GHGs that constitute a net increase in emissions and thus do not meet the carbon-neutral threshold. The net increase in emissions could also conflict with the state's plans to reduce GHG emissions, resulting in a potentially significant impact with respect to the Project conflicting with plans or policies adopted for the purpose of reducing GHG emissions. Implementation of Mitigation Measure GHG-1.1 would reduce or offset these emissions to net zero through a GHG Reduction Plan. This measure ensures GHG emissions would not result in a significant GHG impact, because there would be no net increase in emissions. Further, with implementation of Mitigation Measure GHG-1.1, conflicts with any plans adopted for the purpose of reducing GHG emissions would not occur because there would be no net increase in emissions.

The Project is not expected to substantially adversely affect energy consumption, nor conflict with renewable energy and energy efficiency plans or require increased regional capacity (Chapter 17, *Energy*). The Project would consume energy to pump water into the reservoir and transfer water out. However, it could provide benefits to the electricity system by generating power through releases of water when demand for electricity is high; the Project is expected to have high releases and thus high power generation during summer months (Tables 28-14a and 28-14b). The Project would also result in increased storage during the summer for Shasta Lake and Lake Oroville under climate change (Tables 28-6a and 28-6b and 28-17a and 28-17b), benefitting hydropower generation. This provides a general resilience benefit by supporting the grid when energy demand is highest; Sites Reservoir is projected to generate 39 to 46 GWh of energy per year long-term and 75 to 65 GWh of energy per year in Dry and Critically Dry Water Years. The GHG reduction plan and purchase of carbon offsets, described above, would be implemented to offset GHG emissions associated with energy use.

Climate change could increase impacts related to energy and greenhouse gas emissions. Extreme heat could result in a need for increased air conditioning use and cooling in facilities associated with the reservoir, which could then result in increased energy and GHG emissions. Heat and drought associated with climate change could also increase water demand from downstream users, thus increasing the need to increase water releases; however, this could result in incidental benefits due to power generation associated with releases. Climate change is also expected to have impacts on the energy system. For example, extreme heat could lower power generation efficiency for power plants and transmission lines, flooding could damage energy infrastructure, and increased wildfire risk could result in decreased power reliability as utilities institute Public Safety Power Shutoff (PSPS) events (Bedsworth et al. 2018). Sites operations that depend on energy are thus vulnerable to climate change threats that affect the electricity system broadly.

Climate change may cause air quality impacts. Potential increase in wildfires could increase the concentration of PM_{10} and $PM_{2.5}$ in the air during wildfire events. An increase in drought could potentially increase the spread of valley fever spores. Climate change could also increase the concentration of other air pollutants, such as ozone, particulates, and respiratory allergens, which may have impacts on sensitive populations (Houlton and Lund 2018). The Project would not directly contribute to these climate-induced air quality impacts. However, under climate change some local or state air quality targets may be more difficult for local and state governments to achieve, as climate change will worsen existing air pollution levels (Nolte et al. 2018). The Project would conflict with air quality plans or expose sensitive receptors to criteria pollutants during construction and operations (Chapter 20, *Air Quality*). Mitigation measures AQ-1.1, 1.2, 2.1, and 2.2 are proposed for the Project that would reduce emissions; however, it is anticipated these measures would not reduce emissions below existing thresholds.

28.5.8. Other

28.5.8.1. Geology, Soils, and Minerals

The Project was not found to have substantial adverse effects or adverse effects on geology, soils, and minerals (Chapter 12, *Geology and Soils*; Chapter 13, *Minerals*). Climate change is not expected to affect seismicity or minerals. Climate change may indirectly affect soil as a result of drought or flooding induced by climate change (e.g., loss of topsoil through erosion or wind). The Project may mitigate some of these climate effects. The Project would provide flooding benefit by capturing runoff and reducing flows during heavy precipitation events, which could reduce erosion and landslide risk. The Project would be built according to strict design and engineering standards, and substantial adverse effects from landslides are unlikely to occur (Chapter 7, *Fluvial Geomorphology*; Chapter 12, *Geology and Soils*).

28.5.8.2. Land Use, Population, and Housing

The Project is expected to have some impacts on land use, population, and housing (Chapter 14, *Land Use*; Chapter 25, *Population and Housing*). Alternative 2 would result in physical division of an established community, resulting in a substantial adverse effect with no feasible mitigation (Chapter 14, *Land Use*). The Project would not result in unplanned population growth but would displace members of an existing community; this is not expected to be a significant effect, as there is sufficient housing in the larger region for relocation (Chapter 14, *Land Use*; Chapter 25, *Population and Housing*).

Climate change could affect land use, population, and housing. Increased frequency and severity of extreme heat, wildfire, and flooding events could damage homes and drive migration to other communities less at risk. Expanding designated floodplains and potential increases in insurance related to climate change–induced flooding could result in financial stress, resulting in decisions to relocate (Houlton and Lund 2018). The Project could reduce potential land use–induced effects of climate change. The Project is expected to reduce flooding downstream in the area surrounding the community of Maxwell; this would result in a positive effect under climate change and may lead to a contraction of designated floodplain.

28.5.8.3. Agriculture and Forestry Resources

The Project would result in conversion of some farmland designations to permanent nonagricultural use, resulting in a substantial adverse effect despite proposed mitigation measures (Chapter 15, *Agriculture and Forestry Resources*).

Climate change will have effects on agriculture. Changing heat and precipitation patterns and extremes will likely alter the types of crops that can be grown and change crop productivity (Houlton and Lund 2018). For example, field crops, orchards, grains, grapes, corn, and truck crops are likely to decline 1.9% to 11% in productivity, while cotton, alfalfa, citrus, rice, tomato, and pasture may increase in productivity up to 5%.

The Project would result in some loss of agricultural land, while climate change may drive the loss of agricultural land described above. However, the Project could reduce some of the climate change effects on agricultural productivity. The reservoir would provide a reliable agricultural water supply could use during dry periods, increasing resilience to climate change. This could reduce the impact of climate change reducing acres available for agriculture. The Project would provide releases downstream from Sites Reservoir, with larger releases expected during summer.

28.5.8.4. Recreation Resources

The Project is expected to have no substantial adverse effects on recreation resources. Recreational facilities and water-based recreational resources (such as rivers and reservoirs) are not expected to see significant changes under the Project (Chapter 16, *Recreation Resources*).

Climate change could potentially result in impacts on recreation resources if increases in extreme heat, wildfire, and heavy precipitation and flooding events degrade water-based recreation resources or dissuade activities. Changes to precipitation extremes, such as increased heavy precipitation or increased drought, may also alter water levels or water quality in rivers and reservoirs, potentially changing long-term recreational potential in these waters. The Project could increase water levels in rivers and reservoirs to increase recreational opportunities due to increases to Shasta Lake and Lake Oroville storage in summer (Tables 28-6a, 28-6b, 28-17a, and 28-17b).

28.5.8.5. Navigation, Transportation, and Traffic

Alternatives 1 and 3 would not have substantial adverse effects on navigation, transportation, and traffic. Alternatives 1 and 3 are not expected to result in increased roadway hazards or affect emergency, school bus, and recreational and commercial navigation. Alternative 2 would result in a substantial adverse effect that cannot be reduced on school bus routes (Chapter 18, *Navigation, Transportation, and Traffic*).

Climate change effects could result in roadway degradation and traffic disruptions. Increased average and extreme temperatures increase the incidence of rail buckling and pavement warping. Roads, railways, and sidewalks are all vulnerable to flooding and wildfire, which can cause direct damage to infrastructure, block access to areas, and result in increased traffic (Bedsworth et al. 2018). The Project is not anticipated to increase or decrease climate effects on navigation, transportation, and traffic.

28.5.8.6. Noise and Visual Resources

Implementation of the Project would significantly degrade visual character of the existing Antelope Valley and there is no feasible mitigation measure (Chapter 24, *Visual Resources*). Climate change is not expected to degrade visual resources. The Project would not have an adverse effect on noise (Chapter 19, *Noise*); climate change is also not expected to worsen impacts related to noise.

28.5.8.7. Cultural Resources and Indian Trust Assets

Operations of the Project could disturb cultural resources due to fluctuating water levels within reservoirs, which can cause erosion and uncover remains in the area (Chapter 22, *Cultural Resources*). The Project would not have an adverse effect on Indian Trust Assets. Various climate change hazards, including extreme heat, wildfire, and flooding could result in damage or increased degradation to cultural and archaeological resources. Climate change is also altering historic temperature, precipitation, flooding, and wildfire patterns, threatening traditional ecological knowledge that developed from knowing the land for centuries (Goode et al. 2018).

28.5.8.8. Public Services and Utilities

The Project would not have a substantial adverse effect on public services and utilities (Chapter 26, *Public Services and Utilities*). Climate change could exacerbate the need for reliable water. Increased heat and drought could put more strain on groundwater and surface water resources, preventing this water source from fully replenishing in the future (Bedsworth et al. 2018). Climate change hazards may also result in a variety of effects on water and wastewater treatment, stormwater drainage, energy, and telecommunications, including direct damage to infrastructure, increase in demand of services, and disrupted operations (Bedsworth et al. 2018). The Project is anticipated to help decrease flooding and decrease drought risks by controlling and releasing water during times of increased wetness or dryness, thereby mitigating climate stressors on water supply and wastewater treatment.

28.6 References

28.6.1. Printed References

Bedsworth, L., D. Cayan, G. Franco, L. Fisher, and S. Ziaja (Bedsworth et al.). 2018. *Statewide Summary Report*. California's Fourth Climate Change Assessment. SUMCCCA4-2018-013. California Governor's Office of Planning and Research, Scripps Institution of

Oceanography, California Energy Commission, and California Public Utilities Commission.

California Department of Water Resources. 2018. *California Water Plan Update*.

California Department of Water Resources. 2020a. *Water Resilience Portfolio*.

California Department of Water Resources. 2020b. *Final EIR for State Water Project Long-Term Operations.*

California Natural Resources Agency. 2018. *California Climate Change Adaptation Strategy and Safeguarding California Plan Update*.

California Natural Resources Agency, California Environmental Protection Agency, and California Department of Food and Agriculture (California Natural Resources Agency et al.). 2020. *Water Resilience Portfolio*. California Department of Water Resources.

California Water Commission. 2017. Climate Change Projections for Water Storage Investment Program in *Los Vaqueros Reservoir Expansion Project EIR*. Projection data available: https://data.ca.gov/dataset/climate-change-projections-for-water-storage-investment-program-wsip.

Cook, B. 2012. *Drought and Wildlife: Explore the Connection*. Michigan State University Extension. October 17. Available: https://www.canr.msu.edu/news/drought_and_wildlife_explore_the_connection. Accessed: July 20, 2021.

Council on Environmental Quality. 2016. *Final Guidance for Federal Departments and Agencies on Consideration of Greenhouse Gas Emissions and the Effects of Climate Change in National Environmental Policy Act Reviews*. (Withdrawn in April 2017 and then new draft guidance was issued in June 2019.)

Goode, R., S. Gaughen, M. Fierro, D. Hankins, K. Johnson-Reyes, B. R. Middleton, T. R. Owl, and R. Yonemura (Goode et al.). 2018. *Tribal and Indigenous Communities*. Available: https://www.energy.ca.gov/sites/default/files/2019-11/Statewide_Reports-SUM-CCCA4-2018-010_TribalCommunitySummary_ADA.pdf. Accessed: May 25, 2021.

Houlton, B., and J. Lund. 2018. *Sacramento Summary Report*. California's Fourth Climate Change Assessment. SUM-CCCA4-2018-002. University of California, Davis.

Huber-Lee, A., D. Yates, D. Purkey, W. Yu, and B. Runkle (Huber-Lee et al.). 2003. *Water, Climate, Food, and Environment in the Sacramento Basin.* Contribution to the project ADAPT-Adaptation strategies to changing environments, Stockholm Environment Institute. Boston, MA.

IEP MAST. 2015. *Interagency Ecological Program for the San Francisco Bay/Delta Estuary*. Technical Report 90. Available: https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/california_ waterfix/exhibits/docs/petitioners_exhibit/dwr/part2/DWR-1089%20IEP_MAST_Team_2015_Delta_Smelt_MAST_Synthesis_Report_January%202015.pdf.

Intergovernmental Panel on Climate Change. 2018. Summary for Policymakers. In V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.), *Global Warming of 1.5°C: An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*. In Press. Available: https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf. Accessed: May 20, 2021.

Livneh, B., T. Bohn, D. W. Pierce, F. Munoz-Arriola, B. Nijssen, R. Vose, D. R. Cayan, and L. Brekke. 2015. A Spatially Comprehensive, Hydrometeorological Data Set for Mexico, the U.S., and Southern Canada 1950–2013. *Sci Data* 2, 150042. Available: https://doi.org/10.1038/sdata.2015.42. Accessed: July 20, 2021.

Nolte, C. G., P. D. Dolwick, N. Fann, L. W. Horowitz, V. Naik, R. W. Pinder, T. L. Spero, D. A. Winner, and L. H. Ziska. 2018. Air Quality. In D. R. Reidmiller, C. W. Avery, D. R. Easterling, K. E. Kunkel, K. L. M. Lewis, T. K. Maycock, and B. C. Stewart (eds.), *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II*. Washington, DC: U.S. Global Change Research Program. Available: doi:10.7930/NCA4.2018.CH13.

Schoellhamer, D. H., S. A. Wright, and J. Drexler. 2012. A Conceptual Model of Sedimentation in the Sacramento–San Joaquin Delta. *San Francisco Estuary and Watershed Science* 10(3). Available: doi:https://doi.org/10.15447/sfews.2012v10iss3art3.

Schwarz, A., P. Ray, S. Wi, C. Brown, M. He, and M. Correa. 2018. *Climate Change Risk Faced by the California Central Valley Water Resource System*. California's Fourth Climate Change Assessment. Publication number: CCCA4-EXT-2018-001. Available: https://www.energy.ca.gov/sites/default/files/2019-12/Water_CCCA4-EXT-2018-001_ada.pdf. Accessed: July 20, 2021.

State of California. 2019. "California's Fourth Climate Change Assessment." Sacramento, CA: State of California Governor's Office of Planning and Research, California Natural Resources Agency, and California Energy Commission.

Stern, M. A., L. E. Flint, A. L. Flint, N. Knowles, and S. A. Wright. 2020. The Future of Sediment Transport and Streamflow Under a Changing Climate and the Implications for Long-Term Resilience of the San Francisco Bay-Delta. *Water Resources Research* 56:e2019WR026245. Available: https://doi.org/10.1029/2019WR026245.

Swain, D. L., B. Langenbrunner, J. D. Neelin, and A. Hall. 2018. Increasing precipitation volatility in twenty-first-century California. Nature Climate Change 8:427–433.

U.S. Department of the Interior, Bureau of Reclamation. 2014. *West-Wide Climate Risk Assessment: Sacramento and San Joaquin Basins Climate Impact Assessment*. September 2014. Prepared for Reclamation by CH2M HILL.

U.S. Department of the Interior, Bureau of Reclamation. 2016. *Sacramento and San Joaquin Rivers Basin Study*: *Basin Study Technical Report*. Prepared for Reclamation by CH2M Hill.U.S. Department of the Interior, Bureau of Reclamation. 2019. *Reinitiation of Consultation on the Coordinated Long-Term Operation of the Central Valley Project and State Water Project Final Environmental Impact Statement*.

Wang, J., H. Yin, J. Anderson, E. Reyes, T. Smith, and F. Chung. 2018. *Mean and Extreme Climate Change Impacts on the State Water Project*. California's Fourth Climate Change Assessment. Publication number: CCCA4-EXT-2018-004. Available: https://www.energy.ca.gov/sites/default/files/2019-12/Water_CCCA4-EXT-2018-004_ada.pdf. Accessed: July 20, 2021.

Zeug, S. C., M. Beakes, J. Wiesenfeld, M. Greenwood, L. Grimaldo, J. Hassrick, A. Collins, S. Acuña, and M. Johnston. 2021. Experimental Quantification of Piscivore Density and Habitat Effects on Survival of Juvenile Chinook Salmon in a Tidal Freshwater Estuary. *Estuaries and Coasts* 44:1157–1172. Available: https://doi.org/10.1007/s12237-020-00836-8. Accessed: July 20, 2021.