APPENDIX D3

Analysis of the Potential Effects of Water Temperature Changes on Special-Status Salmonids

D3 EFFECTS FROM CHANGES IN WATER TEMPERATURE ON SPECIAL-STATUS SALMONIDS IN THE LOWER AMERICAN RIVER

This appendix describes potential Project impacts from water temperature changes on special-status salmonids inhabiting the Lower American River between Nimbus Dam and the Watt Avenue bridge. This detailed discussion of methods, modeling and information sources supports the analysis and impact conclusions in Environmental Impact Report (EIR) Section 4.4, *Biological Resources*, regarding potential Project effects on special-status salmonids. The discussion below assesses potential impacts to Central Valley steelhead (*Oncorhynchus mykiss irideus* pop. 11), Central Valley fall-run and late-fall run chinook evolutionarily significant units (ESU) (*Oncorhynchus tshawytscha* pop. 11), Central Valley winter-run chinook (*Oncorhynchus tshawytscha* pop. 7), and Central Valley spring-run chinook ESU (*Oncorhynchus tshawytscha* pop. 11) from temperature changes due to Project operations.

D3.1 METHODOLOGY

The following methodology was used to evaluate potential Project effects from changes in water temperature on special-status salmonids in the Lower American River between Nimbus Dam and Watt Avenue bridge:

1. **Temperature modeling**. Water temperature in the Lower American River was modeled using a two-dimensional hydrodynamic and water quality model, CE-QUAL-W2 (Appendix C). This modeling provided information on potential water temperature changes due to Project operations for every month of each water year type (wet, above normal, below normal, dry and critically dry) for 40 years of modeled temperature data (1975 to 2014).

2. **Determining Potential Species Presence**. Steelhead juveniles could occur in the Lower American River throughout the year. None of the four runs of chinook salmon are present year-round in the Lower American River, but rather occur there at different times of the year depending on life stage (i.e., adult migrating, adult holding, spawner, egg/alevin, juveniles, and smolts). This species presence information provided the basis for analyzing the Project's potential water temperature effects on salmonid life stages for every month of each water year type.

3. **Assessing Temperature Tolerances**. Maximum temperature tolerances for each life stage were used to evaluate potential effects of the Project on the special-status salmonids present (or potentially present) in the Lower American River for every month of each water year type. The temperature tolerance information was compiled from laboratory and field studies that analyzed the effects of water temperatures on critical physiological processes and crucial behaviors for life stages of special-status salmonids.

4. **Ranking of Potential Effects**. Based on known temperature tolerances for special-status salmonids, the potential effects of water temperature changes on each life stage were assessed by month for each water year type. The potential effects were then ranked as negligible, low, moderate or high. These rankings helped to inform the conclusions regarding potential Project impacts from water temperature changes and whether they could affect a substantial number of individuals during sensitive life cycle stages of each species.

These four analytical steps, which are further described below, provide the supporting analysis for potential effects rankings and significance conclusions regarding potential Project impacts on special-status salmonids.

D3.1.1 WATER TEMPERATURE MODELING

Water temperature in the Lower American River was modeled using a two-dimensional hydrodynamic and water quality model, CE-QUAL-W2 (Appendix C). Baseline temperatures for the river and changes in water temperature were modeled for the following Project operations: (1) operations with existing infrastructure and existing water demands, (2) operations with existing infrastructure and future water demands, (3) post-construction operations with existing water demands and (4) post-construction operations with future water demands. Tables D3.1-1 to D3.1-8 show monthly water temperature in the Lower American River at Watt Avenue bridge modeled for Project and baseline conditions for these four operational conditions.

Table D3.1-1 shows the monthly water temperature in the Lower American River at Watt Avenue bridge modeled for Project and baseline conditions assuming current water demands and the use of existing infrastructure. Change in monthly temperature ranges from -0.5 degrees Celsius (°C) to 0.5°C, with a maximum increase in temperature of 0.5°C expected to occur in September of a critically dry water year. Modeled temperature changes of 0.3°C to 0.5°C were observed in three months during the 40-year period (i.e., the increased water temperatures found during June 1976, July 1977, and September 1977; see Appendix C).

Table D3.1-1. Monthly Water Temperature in the Lower American River at Watt Avenue, Existing Infrastructure (Baseline vs Project)

Water Year Type	Scenario	Monthly Water Temperature at Watt Avenue (°C)												
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	WY
Wet	Baseline (°C)	17.3	14.0	11.1	8.5	8.9	10.6	11.6	12.6	14.6	17.0	18.0	17.8	13.5
	Project (°C)	17.3	14.0	11.1	8.5	8.9	10.6	11.6	12.6	14.6	17.0	18.0	17.8	13.5
	Maximum Temperature Increase (°C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	
	Maximum Temperature Decrease (°C)	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Absolute Difference (°C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Above Normal	Baseline (°C)	16.8	14.0	11.3	9.0	9.0	11.9	12.8	13.6	15.8	17.8	18.3	18.2	14.1
	Project (°C)	16.8	14.0	11.3	9.0	9.0	11.9	12.8	13.6	15.8	17.8	18.3	18.2	14.1
	Maximum Temperature Increase (°C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	
	Maximum Temperature Decrease (°C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Absolute Difference (°C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Below Normal	Baseline (°C)	17.3	14.0	10.6	8.7	9.0	11.2	13.2	14.3	15.8	18.3	18.6	18.2	14.1
	Project (°C)	17.3	14.0	10.6	8.7	9.1	11.2	13.2	14.3	15.8	18.3	18.5	18.2	14.1
	Maximum Temperature Increase (°C)	0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	
	Maximum Temperature Decrease (°C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**-0.5**	0.0	
	Absolute Difference (°C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0
Dry	Baseline (°C)	16.8	14.0	10.7	8.5	9.5	12.2	14.4	15.5	17.1	18.8	19.7	19.4	14.7
	Project (°C)	16.8	14.0	10.7	8.5	9.6	12.2	14.4	15.5	17.1	18.8	19.7	19.4	14.7
	Maximum Temperature Increase (°C)	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	
	Maximum Temperature Decrease (°C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	-0.1	
	Absolute Difference (°C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Critically Dry	Baseline (°C)	17.4	14.1	10.9	9.1	10.0	12.6	15.2	17.5	18.9	20.0	20.8	20.3	15.6
	Project (°C)	17.4	14.2	10.9	9.1	10.0	12.6	15.2	17.5	19.0	20.1	20.7	20.3	15.6
	Maximum Temperature Increase (°C)	0.1	0.2	0.0	0.0	0.0	0.1	0.1	0.1	0.3	0.3	0.1	**0.5**	
	Maximum Temperature Decrease (°C)	-0.3	0.0	0.0	0.0	0.0	-0.1	-0.2	-0.1	-0.1	-0.2	-0.2	0.0	
	Absolute Difference (°C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0

Source: Appendix C (Kleinschmidt 2024, Table 3-12)
Note: Range in temperature changes shown in red (i.e., the maximum monthly increase and the maximum monthly decrease for the 40-year modeling period).
°C = degrees Celsius
WY = water year

Table D3.1-2 describes baseline conditions and changes in water temperature in the Lower American River at Watt Avenue bridge under three different temperature scenarios. Scenario 1 (Average Condition) indicates how

temperatures are expected to change on average with Project operations. Scenario 2 (Warmest Baseline) shows what types of Project-related changes are expected to occur when baseline temperatures are highest. Scenario 3 (Greatest Change) indicates conditions expected when maximum temperature changes occur due to Project operations. Water temperature changes due to Project operations are expected to range from 0.3°C in June and July to 0.5°C in September. The maximum water temperature change of 0.5°C in September is expected to occur in a critically dry year when baseline temperatures are greater than 20°C.

Table D3.1-2. Baseline Water Temperature and Change in Water Temperature at Watt Avenue, Existing Infrastructure (Baseline and Project)

Scenario	Monthly Water Temperature at Watt Avenue (°C)											
	October	November	December	January	February	March	April	May	June	July	August	September
Wet												
average condition	17.3 +0	14.0 +0	11.1 +0	8.5 +0	8.9 +0	10.6 +0	11.6 +0	12.6 +0	14.6 +0	17.0 +0	18.0 +0	17.8 +0
warmest baseline	19.4 +0	14.6 -0.1	12.5 +0	9.5 +0	9.8 +0	12.1 +0	13.4 +0	14.1 +0	16.3 +0	17.8 +0	18.3 +0	18.3 +0
greatest change	19.4 +0	13.2 +0	10.6 +0	8.1 +0	8.8 +0	11.3 +0	13.4 +0	13.7 +0	15.4 +0	17.4 +0	18.2 +0	17.1 +0.1
Above Normal												
average condition	16.8 +0	14.0+0	11.3 +0	9.0 +0	9.0 +0	11.9 +0	12.8 +0	13.6 +0	15.8 +0	17.8 +0	18.3 +0	18.2 +0
warmest baseline	17.3 +0	14.2 +0	12.0 +0	9.2 +0	9.7 +0	12.5 +0	12.8 +0	13.8 +0	16.3 +0	18.2 +0.1	18.4 +0	18.4 +0
greatest change	16.6 +0	14.2 +0	10.7 +0	9.2 +0	9.7 +0	12.5 +0	12.8 +0	13.7 +0	16.3 +0	18.2 +0.1	18.4 +0	18.2 +0
Below Normal												
average condition	17.3 +0	14.0 +0	10.6 +0	8.7 +0	9.0 +0	11.2 +0	13.2 +0	14.3 +0	15.8 +0	18.3 +0	18.6 -0.1	18.2 +0
warmest baseline	19.0 +0.2	14.5 +0	11.4 +0	9.2 +0	10 +0	11.9 +0	14.0 +0	15.1 +0	16.3 +0	18.7 +0	19.0 +0	18.9 +0
greatest change	19.0 +0.2	14.5 +0	10.7 +0	8.3 +0	8.2 +0	10.6 +0.1	14.0 +0	14.7 +0	16.2 +0	17.8 +0	18.2 +0.1	18.4 +0
Dry												
average condition	16.8 +0	14.0 +0	10.7 +0	8.5 +0	9.5 +0	12.2 +0	14.4 +0	15.5 +0	17.1 +0	18.8 +0	19.7 +0	19.4 +0
warmest baseline	18.7 +0.1	14.3 +0	11.4 +0	8.8 +0	10.5 +0	13.4 +0	15.6 +0	17.4 +0	18.7 +0	20.1 +0	21.1 +0	20.9 +0
greatest change	18.7 +0.1	14.3 +0	10.6 +0	8.4 +0	9.4 +0	13.4 +0	14.8 +0	15.4 +0	17.7 +0.2	18.3 +0	19.9 +0	18.3 +0
Critically Dry												
average condition	17.4 +0	14.1 +0	10.9 +0	9.1 +0	10.0 +0	12.6 +0	15.2 +0	17.5 +0	18.9 +0.1	20.0 +0	20.8 +0	20.3 +0
warmest baseline	19.3 +0.1	15.2 +0.1	11.9 +0	9.9 +0	10.9 +0	13.3 +0.1	16.4 +0	19.1 +0.1	20.9 **+0.3**	21.9 +0	23.4 +0	21.7 +0
greatest change	19.3 +0.1	14.0+0.2	11.0 +0	9.2 +0	10.5 +0	13.3 +0.1	15.1 +0.1	18.2 +0.1	20.9 **+0.3**	21.4 **+0.3**	20 +0.1	20.6 **+0.5**

Source: Derived from data in Appendix C (Kleinschmidt 2024, Tables 3-23 and 3-24)
Note: Modeled temperature increase >0.2°C indicated in red (increases evaluated before rounding to the one-tenths).
°C = degrees Celsius

Table D3.1-3 shows monthly water temperature in the Lower American River at Watt Avenue bridge modeled for Project and baseline conditions assuming future water demands and the use of existing infrastructure. Change in monthly water temperature would range from -0.3°C to 0.8°C with the maximum increase in temperature of 0.8°C expected to occur in October of a critically dry year. Modeled temperature changes of 0.3°C to 0.8°C were observed in four months during the 40-year period (i.e., the increased water temperatures found during June 1977, June 1981, August 1991, and October 1992; see Appendix C).

Table D3.1-3. Monthly Water Temperature in the Lower American River at Watt Avenue, Existing Infrastructure (Future Baseline vs Future Project)

Water Year Type	Scenario	Monthly Water Temperature at Watt Avenue (°C)												
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	WY
Wet	Baseline (°C)	17.3	14.0	11.1	8.5	8.9	10.6	11.6	12.6	14.6	17.0	18.0	17.8	13.5
	Project (°C)	17.2	14.0	11.1	8.5	8.9	10.6	11.7	12.6	14.6	17.0	18.0	17.8	13.5
	Maximum Temperature Increase (°C)	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Maximum Temperature Decrease (°C)	**-0.3**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	
	Absolute Difference (°C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Above Normal	Baseline (°C)	16.8	14.0	11.3	9.0	9.0	11.9	12.8	13.6	15.8	17.8	18.3	18.2	14.1
	Project (°C)	16.8	14.0	11.3	9.0	9.0	11.9	12.8	13.6	15.8	17.8	18.3	18.2	14.1
	Maximum Temperature Increase (°C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	
	Maximum Temperature Decrease (°C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Absolute Difference (°C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Below Normal	Baseline (°C)	17.3	14.0	10.6	8.7	9.0	11.2	13.2	14.3	15.8	18.3	18.6	18.2	14.1
	Project (°C)	17.3	14.0	10.6	8.7	9.1	11.2	13.2	14.3	15.8	18.3	18.6	18.2	14.1
	Maximum Temperature Increase (°C)	0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	
	Maximum Temperature Decrease (°C)	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	
	Absolute Difference (°C)	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dry	Baseline (°C)	16.8	14.0	10.7	8.5	9.5	12.2	14.4	15.5	17.1	18.8	19.7	19.4	14.8
	Project (°C)	16.8	14.0	10.7	8.5	9.6	12.2	14.4	15.6	17.1	18.9	19.8	19.4	14.8
	Maximum Temperature Increase (°C)	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.5	0.0	
	Maximum Temperature Decrease (°C)	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	-0.1	
	Absolute Difference (°C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Critically Dry	Baseline (°C)	17.4	14.1	10.9	9.1	10.0	12.6	15.1	17.5	18.9	20.1	20.7	20.3	15.6
	Project (°C)	17.5	14.1	10.9	9.1	10.0	12.6	15.2	17.5	19.0	20.1	20.7	20.4	15.6
	Maximum Temperature Increase (°C)	**0.8**	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.3	0.2	0.1	0.0	
	Maximum Temperature Decrease (°C)	-0.1	-0.1	-0.1	0.0	0.0	-0.1	-0.1	-0.1	0.0	-0.2	-0.1	0.0	
	Absolute Difference (°C)	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0

Source: Appendix C (Kleinschmidt 2024, Table 3-40)
Note: Range in temperature changes shown in red (i.e., the maximum monthly increase and the maximum monthly decrease for the 40-year modeling period).
°C = degrees Celsius
WY = water year

Table D3.1-4 describes baseline conditions and changes in water temperature in the Lower American River at Watt Avenue bridge during: (1) during Average Conditions, (2) Warmest Baseline, and (3) Greatest Change. Changes in monthly water temperature would range from -0.3°C to 0.8°C with the maximum increase of 0.8°C expected to occur in October of a critically dry year. when baseline temperatures are expected to be greater than 20°C.

Table D3.1-4. Baseline Water Temperature and Change in Water Temperature at Watt Avenue, Existing Infrastructure (Future Baseline and Future Project)

Scenario	Monthly Water Temperature at Watt Avenue (°C)											
	October	November	December	January	February	March	April	May	June	July	August	September
Wet												
average condition	17.3 +0	14.0 +0	11.1 +0	8.5 +0	8.9 +0	10.6 +0	11.6 +0	12.6 +0	14.6 +0	17 +0	18.0 +0	17.8 +0
warmest baseline	19.4 +0.1	14.6 +0.2	12.5 +0	9.5 +0	9.8 +0	12.1 +0	13.4 +0	14.1 +0	16.3 +0	17.8 +0	18.4 -0.1	18.3 +0
greatest change	19.4 +0.1	14.6 +0.2	10.1 +0	8.7 +0	9.7 +0	11.8 +0	13.4 +0	13.7 +0	15.9 +0	17.8 +0	18.2 +0	18.2 +0
Above Normal												
average condition	16.8 +0	14.0 +0	11.3 +0	9.0 +0	9.0 +0	11.9 +0	12.8 +0	13.6 +0	15.8 +0	17.8 +0	18.3 +0	18.2 +0
warmest baseline	17.3 +0	14.2 +0	12.0 +0	9.2 +0	9.7 +0	12.5 +0	12.8 +0	13.8 +0	16.3 +0	18.2 +0.1	18.4 +0	18.4 +0
greatest change	16.6 +0	14.2 +0	10.7 +0	9.2 +0	9.7 +0	12.5 +0	12.8 +0	13.8 +0	16.3 +0	18.2 +0.1	18.4 +0	18.2 +0
Below Normal												
average condition	17.3 +0.1	14.0 +0	10.6 +0	8.7 +0	9.0 +0	11.2 +0	13.2 +0	14.3 +0	15.8 +0	18.3 +0	18.6 +0	18.2 +0
warmest baseline	19.0 +0.2	14.5 +0	11.4 +0	9.2 +0	10.0 +0	11.9 +0	14.0 +0	15.1 +0	16.3 +0	18.7 +0	18.9 +0	18.9 +0
greatest change	19.0 +0.2	14.5 +0	10.3 +0	9.0 +0	8.2 +0	10.6 +0.1	14.0 +0	14.7 +0	16.3 +0	17.8 +0.1	18.9 +0	18.4 +0
Dry												
average condition	16.8 +0	14.0 +0	10.7 +0	8.5 +0	9.5 +0	12.2 +0	14.4 +0	15.5 +0	17.1 +0	18.8 +0	19.7 +0.1	19.4 +0
warmest baseline	18.7 +0.1	14.3 +0	11.4 +0	8.8 +0	10.5 +0	13.5 +0	15.6 +0	17.4 +0.1	18.7 +0.2	20.2 +0.1	21.1 +0	20.9 +0
greatest change	18.7 +0.1	14.3 +0	11.0 +0	8.8 +0	9.4 +0	12.1 +0	14.8 +0	17.4 +0.1	18.7 +0.2	18.5 +0.1	19.9 **+0.5**	19.3 +0
Critically Dry												
average condition	17.4 +0.1	14.1 +0	10.9 +0	9.1 +0	10.0 +0	12.6 +0	15.1 +0	17.5 +0.1	18.9 +0.1	20.1 +0	20.7 +0	20.3 +0
warmest baseline	19.3 +0	15.2 +0	11.9 +0	9.9 +0	10.9 +0	13.3 +0.1	16.4 +0	19.1 +0.1	21.1 +0.1	21.9 +0	23.4 +0	21.7 +0
greatest change	18.1 **+0.8**	13.5 +0	11.9 +0	8.5 +0	10.9 +0	13.3 +0.1	15.1 +0.2	16.7 +0.2	20.8 **+0.3**	18.7 +0.2	20 +0.1	19.8 +0

Source: Derived from data in Appendix C (Kleinschmidt 2024, Tables 3-51 and 3-52)
Note: Modeled temperature increase >0.2°C indicated in red (increases evaluated before rounding to the one-tenths).
°C = degrees Celsius

Table D3.1-5 shows the monthly water temperature in the Lower American River at Watt Avenue bridge for Project and baseline conditions that is expected to occur post-construction assuming current water demands. Change in monthly water temperature would range from -0.5°C to 0.5°C, with the maximum increase in temperature expected to occur in September of a critically dry year. Modeled temperature changes of 0.3°C to 0.5°C were observed in two months during the 40-year period (i.e., the increased water temperatures found during June 1976 and September 1977; see Appendix C).

Table D3.1-5. Monthly Water Temperature in the Lower American River at Watt Avenue, Post-Construction (Baseline vs Project)

Water Year Type	Scenario	Monthly Water Temperature at Watt Avenue (°C)												
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	WY
Wet	Baseline (°C)	17.3	14.0	11.1	8.5	8.9	10.6	11.6	12.6	14.6	17.0	18.0	17.8	13.5
	Project (°C)	17.2	13.9	11.1	8.5	8.9	10.6	11.6	12.6	14.6	17.0	18.0	17.8	13.5
	Maximum Temperature Increase (°C)	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	
	Maximum Temperature Decrease (°C)	-0.2	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Absolute Difference (°C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Above Normal	Baseline (°C)	16.8	14.0	11.3	9.0	9.0	11.9	12.8	13.6	15.8	17.8	18.3	18.2	14.1
	Project (°C)	16.8	14.0	11.3	9.0	9.0	11.9	12.8	13.6	15.8	17.8	18.3	18.2	14.1
	Maximum Temperature Increase (°C)	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Maximum Temperature Decrease (°C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	
	Absolute Difference (°C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Below Normal	Baseline (°C)	17.3	14.0	10.6	8.7	9.0	11.2	13.2	14.3	15.8	18.3	18.6	18.2	14.1
	Project (°C)	17.3	14.0	10.6	8.7	9.1	11.2	13.2	14.3	15.8	18.3	18.5	18.2	14.1
	Maximum Temperature Increase (°C)	0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
	Maximum Temperature Decrease (°C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	**-0.5**	0.0	
	Absolute Difference (°C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0
Dry	Baseline (°C)	16.8	14.0	10.7	8.5	9.5	12.2	14.4	15.5	17.1	18.8	19.7	19.4	14.7
	Project (°C)	16.8	14.0	10.7	8.5	9.6	12.2	14.4	15.5	17.1	18.8	19.7	19.4	14.7
	Maximum Temperature Increase (°C)	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	
	Maximum Temperature Decrease (°C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	-0.1	
	Absolute Difference (°C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Critically Dry	Baseline (°C)	17.4	14.1	10.9	9.1	10.0	12.6	15.2	17.5	18.9	20.0	20.8	20.3	15.6
	Project (°C)	17.4	14.2	10.9	9.1	10.0	12.6	15.1	17.5	19.0	20.1	20.7	20.3	15.6
	Maximum Temperature Increase (°C)	0.2	0.2	0.0	0.0	0.0	0.1	0.2	0.1	0.3	0.2	0.1	**0.5**	
	Maximum Temperature Decrease (°C)	-0.3	0.0	0.0	0.0	0.0	-0.1	-0.4	-0.1	-0.1	-0.2	-0.2	0.0	
	Absolute Difference (°C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0

Source: Appendix C (Kleinschmidt 2024, Table 3-13)
Note: Range in temperature changes shown in red (i.e., the maximum monthly increase and the maximum monthly decrease for the 40-year modeling period).
°C = degrees Celsius
WY = water year

Table D3.1-6 describes baseline conditions and changes in water temperature in the Lower American River at Watt Avenue bridge during (1) Average Condition, (2) Warmest Baseline, and (3) Greatest Change. Changes in monthly water temperature would range from 0.3°C in June to 0.5°C in September of critically dry years when baseline temperatures are greater than 20°C.

Table D3.1-6. Baseline Water Temperature and Change in Water Temperature at Watt Avenue, Post-Construction (Baseline and Project)

Scenario	Monthly Water Temperature at Watt Avenue (°C)											
	October	November	December	January	February	March	April	May	June	July	August	September
Wet												
average condition	17.3 +0	14.0 +0	11.1 +0	8.5 +0	8.9 +0	10.6 +0	11.6 +0	12.6 +0	14.6 +0	17.0 +0	18.0 +0	17.8 +0
warmest baseline	19.4 +0	14.6 +0	12.5 +0	9.5 +0	9.8 +0	12.1 +0	13.4 +0	14.1 +0	16.3 +0	17.8 +0	18.3 +0.1	18.3 +0
greatest change	19.3 +0	13.2 +0	10.6 +0.1	8.1 +0	8.8 +0	12.1 +0	13.4 +0	13.7 +0	16.3 +0	17.8 +0	18.3 +0.1	18.3 +0
Above Normal												
average condition	16.8 +0	14.0 +0	11.3 +0	9.0 +0	9.0 +0	11.9 +0	12.8 +0	13.6 +0	15.8 +0	17.8 +0	18.3 +0	18.2 +0
warmest baseline	17.3 +0	14.2 +0	12.0 +0	9.2 +0	9.7 +0	12.5 +0	12.8 +0	13.8 +0	16.3 +0	18.2 +0	18.4 +0	18.4 -0.1
greatest change	16.6 +0.1	13.9 +0	12.0 +0	9.2 +0	9.7 +0	11.5 +0	12.8 +0	13.7 +0	16.3 +0	18.2 +0	18.3 +0	18.2 +0
Below Normal												
average condition	17.3 +0	14.0 +0	10.6 +0	8.7 +0	9.0 +0	11.2 +0	13.2 +0	14.3 +0	15.8 +0	18.3 +0	18.6 -0.1	18.2 +0
warmest baseline	19.0 +0.2	14.5 +0	11.4 +0	9.2 +0	10.0 +0	11.9 +0	14.0 +0	15.1 +0	16.3 +0	18.7 +0	19.0 +0	18.9 +0
greatest change	19.0 +0.2	14.0 +0	11.4 +0	8.3 +0	8.2 +0	10.6 +0.1	14.0 +0	14.7 +0	16.2 +0	17.9 +0	18.9 +0	18.4 +0
Dry												
average condition	16.8 +0	14.0 +0	10.7 +0	8.5 +0	9.5 +0	12.2 +0	14.4 +0	15.5 +0	17.1 +0	18.8 +0	19.7 +0	19.4 +0
warmest baseline	18.7 +0.1	14.3 +0	11.4 +0	8.8 +0	10.5 +0	13.4 +0	15.6 +0	17.4 +0	18.7 +0	20.1 +0	21.1 +0	20.9 +0
greatest change	18.7 +0.1	14.3 +0	10.6 +0	8.4 +0	9.4 +0	13.4 +0	14.8 +0	15.4 +0.1	17.7 +0.2	18.3 +0	19.4 +0	19.3 +0
Critically Dry												
average condition	17.4 +0	14.1 +0	10.9 +0	9.1 +0	10.0 +0	12.6 +0	15.2 +0	17.5 +0.1	18.9 +0.1	20.0 +0	20.8 +0	20.3 +0
warmest baseline	19.3 +0.2	15.2 +0.1	11.9 +0	9.9 +0	10.9 +0	13.3 +0.1	16.4 +0	19.1 +0.1	20.9 **+0.3**	21.9 +0	23.4 +0	21.7 +0
greatest change	19.3 +0.2	14.0 +0.2	11.0 +0	9.2 +0	10.5 +0	13.3 +0.1	15.1 +0.2	18.2 +0.1	20.9 **+0.3**	18.7 +0.2	20.0 +0.1	20.6 **+0.5**

Source: Derived from data in Appendix C (Kleinschmidt 2024, Tables 3-23 and 3-25)
Note: Modeled temperature increase >0.2°C indicated in red (increases evaluated before rounding to the one-tenths).
°C = degrees Celsius

Table D3.1-7 shows the monthly water temperature in the Lower American River at Watt Avenue bridge for Project and baseline conditions that is expected to occur post-construction assuming future water demands. Change in monthly water temperature would range from -0.3°C to 0.3°C, with the maximum increase in temperature of 0.3°C expected to occur in June of a critically dry water year. Modeled temperature changes of 0.3°C were observed in one month during the 40-year period (i.e., the increased water temperature found during June 1981; see Appendix C).

Table D3.1-7. Monthly Water Temperature in the Lower American River at Watt Avenue, Post-Construction (Future Baseline vs Future Project)

Water Year Type	Scenario	Monthly Water Temperature at Watt Avenue (°C)												
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	WY
Wet	Baseline (°C)	17.3	14.0	11.1	8.5	8.9	10.6	11.6	12.6	14.6	17.0	18.0	17.8	13.5
	Project (°C)	17.2	14.0	11.1	8.5	8.9	10.6	11.7	12.6	14.6	17.0	18.0	17.8	13.5
	Maximum Temperature Increase (°C)	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	
	Maximum Temperature Decrease (°C)	-0.3	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Absolute Difference (°C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Above Normal	Baseline (°C)	16.8	14.0	11.3	9.0	9.0	11.9	12.8	13.6	15.8	17.8	18.3	18.2	14.1
	Project (°C)	16.8	14.0	11.3	9.0	9.0	11.9	12.8	13.6	15.8	17.8	18.3	18.2	14.1
	Maximum Temperature Increase (°C)	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Maximum Temperature Decrease (°C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	
	Absolute Difference (°C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Below Normal	Baseline (°C)	17.3	14.0	10.6	8.7	9.0	11.2	13.2	14.3	15.8	18.3	18.6	18.2	14.1
	Project (°C)	17.3	14.0	10.6	8.7	9.1	11.2	13.2	14.3	15.8	18.3	18.6	18.2	14.1
	Maximum Temperature Increase (°C)	0.2	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.0	
	Maximum Temperature Decrease (°C)	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	-0.1	0.0	-0.1	0.0	
	Absolute Difference (°C)	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dry	Baseline (°C)	16.8	14.0	10.7	8.5	9.5	12.2	14.4	15.5	17.1	18.8	19.7	19.4	14.8
	Project (°C)	16.8	14.0	10.7	8.5	9.6	12.2	14.4	15.5	17.1	18.9	19.7	19.4	14.8
	Maximum Temperature Increase (°C)	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.1	0.0	0.0	
	Maximum Temperature Decrease (°C)	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0	0.0	0.0	
	Absolute Difference (°C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Critically Dry	Baseline (°C)	17.4	14.1	10.9	9.1	10.0	12.6	15.1	17.5	18.9	20.1	20.7	20.3	15.6
	Project (°C)	17.4	14.1	10.9	9.1	10.0	12.6	15.2	17.6	19.0	20.1	20.7	20.4	15.6
	Maximum Temperature Increase (°C)	0.1	0.0	0.0	0.0	0.0	0.1	0.2	0.2	**0.3**	0.2	0.1	0.1	
	Maximum Temperature Decrease (°C)	-0.1	0.0	0.0	0.0	0.0	-0.1	**-0.3**	-0.1	0.0	-0.2	-0.1	0.0	
	Absolute Difference (°C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0

Source: Appendix C (Kleinschmidt 2024, Table 3-41)
Note: Range in temperature changes shown in red (i.e., the maximum monthly increase and the maximum monthly decrease for the 40-year modeling period).
°C = degrees Celsius
WY = water year

Table D3.1-8 describes baseline conditions and changes in water temperature in the Lower American River at Watt Avenue bridge during (1) Average Condition, (2) Warmest Baseline, and (3) Greatest Change. Water temperatures are expected to increase by 0.3°C in June of critically dry years. This change is not expected to occur when baseline temperatures are greater than 20°C.

Table D3.1-8. Baseline Water Temperature and Change in Water Temperature at Watt Avenue, Post-Construction (Future Baseline and Future Project)

Scenario	Monthly Water Temperature at Watt Avenue (°C)											
	October	November	December	January	February	March	April	May	June	July	August	September
Wet												
average condition	17.3 +0	14.0 +0	11.1 +0	8.5 +0	8.9 +0	10.6 +0	11.6 +0	12.6 +0	14.6 +0	17.0 +0	18.0 +0	17.8 +0
warmest baseline	19.4 +0.1	14.6 +0.2	12.5 +0	9.5 +0	9.8 +0	12.1 +0	13.4 +0	14.1 +0	16.3 +0	17.8 +0	18.4 +0.1	18.3 +0
greatest change	19.4 +0.1	14.6 +0.2	10.6 +0.1	8.7 +0	9.7 +0	11.8 +0	13.4 +0	13.7 +0	16.3 +0	17.8 +0	18.4 +0.1	17.1 +0.1
Above Normal												
average condition	16.8 +0	14.0 +0	11.3 +0	9.0 +0	9.0 +0	11.9 +0	12.8 +0	13.6 +0	15.8 +0	17.8 +0	18.3 +0	18.2 +0
warmest baseline	17.3 +0	14.2 +0	12.0 +0	9.2 +0	9.7 +0	12.5 +0	12.8 +0	13.8 +0	16.3 +0	18.2 +0	18.4 +0	18.4 -0.1
greatest change	16.6 +0.1	13.9 +0	12.0 +0	9.2 +0	9.7 +0	11.7 +0	12.8 +0	13.8 +0	16.3 +0	18.2 +0	18.3 +0	18.2 +0
Below Normal												
average condition	17.3 +0.1	14.0 +0	10.6 +0	8.7 +0	9.0 +0	11.2 +0	13.2 +0	14.3 +0	15.8 +0	18.3 +0	18.6 +0	18.2 +0
warmest baseline	19.0 +0.2	14.5 +0	11.4 +0	9.2 +0	10.0 +0	11.9 +0	14.0 +0	15.1 +0	16.3 +0	18.7 +0	18.9 +0	18.9 +0
greatest change	19.0 +0.2	13.0 +0	10.3 +0	8.2 +0	8.2 +0.1	10.6 +0.1	14.0 +0	14.7 +0	16.3 +0	17.8 +0.1	18.9 +0	18.4 +0
Dry												
average condition	16.8 +0	14.0 +0	10.7 +0	8.5 +0	9.5 +0	12.2 +0	14.4 +0	15.5 +0	17.1 +0	18.8 +0.1	19.7 +0	19.4 +0
warmest baseline	18.7 +0.1	14.3 +0	11.4 +0	8.8 +0	10.5 +0	13.5 +0	15.6 +0	17.4 +0.1	18.7 +0.2	20.2 +0.1	21.1 +0	20.9 +0
greatest change	18.7 +0.1	13.8 +0	11.0 +0	8.8 +0	9.4 +0	12.1 +0	14.8 +0.1	17.4 +0.1	18.7 +0.2	18.5 +0.1	21.1 +0	19.8 +0
Critically Dry												
average condition	17.4 +0	14.1 +0	10.9 +0	9.1 +0	10 +0	12.6 +0	15.1 +0	17.5 +0.1	18.9 +0.1	20.1 +0	20.7 +0	20.3 +0
warmest baseline	19.3 +0.1	15.2 +0	11.9 +0	9.9 +0	10.9 +0	13.3 +0.1	16.4 +0	19.1 +0.1	21.1 +0.1	21.9 +0	23.4 +0	21.7 +0
greatest change	19.3 +0.1	13.5 +0	11.9 +0	8.5 +0	10.5 +0	13.3 +0.1	15.1 +0.2	18.2 +0.2	17.9 **+0.3**	18.7 +0.2	20.0 +0.1	19.8 +0.1

Source: Derived from data in Appendix C (Kleinschmidt 2024, Tables 3-51 and 3-53)
(increases evaluated before rounding to the one-tenths).
°C = degrees Celsius

D3.1.2 Potential Presence of Special-status Salmonids

A review of published data (Day and Morris 2023) was the starting point for determining when each life stage (adult migrating, adult holding, spawner, egg/alevin, juveniles, and smolts) of special-status salmonids were potentially present in the Lower American River. Lower American River Smolt Trap data, recorded between 2013 and 2023 in the Lower American River (Day and Morris 2023), the *Biological Opinion on the Long-Term Operation of the Central Valley Project and State Water Project* (NMFS 2019), the *Endangered Species Act Section 7(a)(2) Programmatic Biological Opinion for the Reinitiation of Consultation on the Long-Term Operation of the Central Valley Project and State Water Project* (NMFS 2024), and discussions with California Department of Fish and Wildlife (CDFW) staff (Burson pers. com. 2024) provided additional information. The Lower American River Smolt Trap is located in the Lower American River near the Watt Avenue bridge. It is typically in operation from January to June of a given year (depending on streamflow constraints) and uses length-by-date measuring criteria and genetic testing to determine which species of chinook are present (Day and Morris, 2023). Table D3.1-9 shows the potential presence of special-status salmonids in the Lower American River between Nimbus Dam and Watt Avenue bridge by month and life stage.

Table D3.1-9. Potential Presence of Special-Status Salmonids in the Lower American River between Nimbus Dam and Watt Avenue bridge

Species Potentially Present in the Lower American River	Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Central Valley fall-run chinook salmon	Adults (Upstream Migration)	N	N	N	N	N	Y	Y	Y	P	P	Y	Y
	Spawners	N	N	N	N	N	N	N	N	Y	P	P	Y
	Eggs/Alevin	Y	Y	N	N	N	N	N	N	N	Y	P	P
	Juveniles	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y
	Smolts	N	N	Y	Y	Y	Y	Y	N	N	N	N	N
Central Valley late fall-run chinook salmon	Adults (Upstream Migration)	Y	Y	Y	Y	N	N	N	N	N	Y	Y	P
	Spawners	Y	P	P	Y	N	N	N	N	N	N	N	N
	Eggs/Alevin	Y	Y	P	P	Y	Y	N	N	N	N	N	N
	Juveniles	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Smolts	Y	P	P	Y	Y	N	N	N	N	N	Y	Y
Central Valley winter-run chinook salmon	Adults (Upstream Migration)	Y	Y	P	Y	Y	Y	Y	N	N	N	N	Y
	Spawners	N	N	N	Y	P	P	Y	Y	N	N	N	N
	Eggs/Alevin	N	N	N	N	Y	P	P	Y	Y	N	N	N
	Juveniles	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Smolts	Y	P	P	Y	Y	N	N	N	N	N	Y	Y
Central Valley spring-run chinook salmon	Adults (Upstream Migration)	N	N	Y	Y	P	P	Y	Y	N	N	N	N
	Spawners	N	N	N	N	N	N	N	Y	P	Y	N	N
	Eggs/Alevin	N	N	N	N	N	N	N	N	Y	P	Y	N
	Juveniles	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Smolts	Y	Y	Y	Y	Y	Y	N	N	N	N	Y	Y
Central Valley steelhead	Adults (Upstream Migration)	N	N	N	N	N	N	N	Y	P	P	Y	N
	Spawners	Y	P	P	Y	N	N	N	N	N	N	N	Y
	Eggs/Alevin	Y	Y	P	P	Y	N	N	N	N	N	N	N
	Juveniles	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Smolts	N	N	Y	Y	Y	Y	N	N	N	N	N	N

Source: Yoshiyama et al. 1998, Zillig et al. 2022, Williams 2006; Hearn et al. 2014
Y = in the system; P = peak activity; N = not in system
Note: Life stages shown in grey have no confirmed presence in the Lower American River.

CENTRAL VALLEY FALL-RUN CHINOOK SALMON

Central Valley fall-run chinook are the most abundant of all special-status salmonids in the Lower American River, with over 125,000 individuals detected on average per year at the Lower American River Smolt Trap since 2013 (Day and Morris 2023). Central Valley fall-run chinook salmon adults are present June through December in the Lower American River. Adult upstream migration occurs between June and December and peaks in September through October, with spawning occurring between late-September to December and peaking in October through November (Yoshiyama et al. 1998). Fall-run chinook salmon are currently the only naturally extant run of chinook salmon on the Lower American River (Lasko et al. 2014). They are produced at the Nimbus Fish Hatchery and also occur as a natural population that spawns in the river. CDFW's Nimbus Fish Hatchery plays a crucial role in supporting the Lower American River's population of Central Valley fall-run chinook salmon (Sturrock et al. 2019). Eggs and alevin develop between October to February, and smolt tend to outmigrate quickly after hatching (i.e., within 1 to 7 months) (Zillig et al. 2022). Central Valley fall-run chinook individuals are present in the Lower American River at Watt Avenue every year and constitute a distinct, natal, and hatchery-supported population.

Central Valley fall-run chinook salmon juveniles are typically present December through July in the Lower American River. Juveniles emerge between December and March, reside in freshwater tributaries for 1 to 7 months, with smolt outmigration occurring between March and July (Yoshiyama et al. 1998). Juveniles rear in wider rivers or regions with a higher proportion of floodplain habitat, or outmigrate fully into the estuary a few months after emergence (Zillig et al. 2022).

CENTRAL VALLEY STEELHEAD

Central Valley steelhead are the second most abundant salmonid found within the Lower American River, with over 4,300 total individuals detected in the Lower American River Smolt Trap since 2013 (Day and Morris 2023). Multiple life stages are captured in the Lower American River Smolt Trap (from parr to adult), which is indicative of individuals reproducing within the Lower American River. Steelhead are a distinct, natal, and hatchery-supported population that is actively managed by CDFW at the Nimbus Fish Hatchery. Steelhead also have the highest thermal limits (i.e., the range of water temperatures that are tolerable for survival, growth, and reproduction) of any of the special-status salmonids (NMFS 2019).

Central Valley steelhead adults are present in the Lower American River August through April. Adult steelhead enter freshwater systems between August and November, but spawning occurs mainly from December through April (Williams 2006). Steelhead eggs typically hatch in 30 days, depending on water temperature, with fry emergence occurring between 4 to 6 weeks thereafter (McEwan 2001). Steelhead migrate into the upper Sacramento River system continuously through the year, with the first typically appearing as early as July, but very few have been detected moving between mid-March and mid-June (Hallock et al. 1961).

Central Valley steelhead juveniles are typically present in the Lower American River from December through March. Juveniles emerge from late winter to spring, and individuals from the Lower American River typically emigrate after one year (Day and Starr 2021). Juvenile steelhead in the Central Valley typically spend at least one full summer in freshwater (Myrick and Cech 2004).

CENTRAL VALLEY LATE FALL-RUN CHINOOK SALMON

Central Valley late fall-run chinook salmon most likely historically spawned in the upper Sacramento and McCloud rivers, which are now blocked by Shasta Dam, as well as in portions of major Sacramento and San Joaquin River tributaries with adequate cold water in summer. Today, most late fall- run chinook spawn in the mainstem Sacramento River between Red Bluff Diversion Dam and Keswick Dam, and in Battle Creek (Tehama County). Central Valley late fall-run chinook salmon were not recognized as a unique run until 1966, so little is known about their historical habitats or habits (Moyle et al. 2017).

Since 2013, a total of forty-one (41) late fall-run chinook juvenile smolts have been captured in the Lower American River rotary screw traps (Day and Morris 2023). It is unclear if these individuals are part of a self-sustaining and distinct Lower American River population, or if they are transitory individuals seeking overwintering habitat within the Lower American River. There is no published evidence that late fall-run chinook salmon reproduction occurs in the Lower American River or that adults occur there. Late fall-run chinook juveniles and smolts are not likely to be natal to the region (Lasko et al. 2014), and other life stages may not be present in the system. Additionally, no late fall-run chinook individuals have been identified in the Lower American River since 2016 based on length-by-date criteria or genetic analysis.

CENTRAL VALLEY WINTER-RUN CHINOOK SALMON

Central Valley winter-run chinook salmon breed in the upper reaches of the Sacramento River and its tributaries with primary spawning grounds between Keswick Dam and the Shasta Dam. Since 2013, a total of 330 winter-run chinook juveniles-smolts have been captured in the Lower American River rotary screw traps (Day and Morris 2023). It is unclear if these individuals are part of a self-sustaining and distinct Lower American River population, or if they are transitory individuals seeking overwintering habitat within the Lower American River. These juveniles and smolts are not natal to the region, and therefore the other life stages may not be present in the system (Burson pers. com. 2024).

CENTRAL VALLEY SPRING-RUN CHINOOK SALMON

Spring-run chinook salmon were historically abundant in the Central Valley, but now only remnant runs remain in Butte, Mill, Deer, Antelope, and Beegum Creeks, tributaries to the Sacramento River. Since 2013, a total of seventy-five (75) spring-run chinook juveniles-smolts have been captured in the Lower American River rotary screw traps (Day and Morris 2023). It is unclear if these individuals are part of a self-sustaining and distinct Lower American River population, or if they are transitory individuals seeking overwintering habitat within the Lower American River. There is a possibility that these juveniles and smolts are not natal to the region, and therefore the other life stages may not be present in the system (Burson pers. com. 2024).

D3.1.3 MAXIMUM TEMPERATURE TOLERANCES FOR SPECIAL-STATUS SALMONIDS

Table D3.1-10 shows optimal temperature ranges published by the National Marine Fisheries Service (NMFS 2019, NMFS 2024) for the different life stages of the special-status salmonids. However, Lower American River temperatures often do not meet optimal values under baseline conditions. Therefore, maximum temperatures tolerances were developed based on published values associated with both laboratory experimentation and in-situ measurements, which, in some cases, expanded upon the temperatures provided by NMFS. Table D3.1-11 shows the 7-day, daily average maximum temperature tolerances used in the analysis. These maximum temperature

tolerances were used to evaluate potential Project effects on different life stages of the special-status salmonids present (or potentially present) in the Lower American River between Nimbus Dam and Watt Avenue bridge.

Table D3.1-10. Optimal Temperature Ranges for Chinook and Steelhead

Salmonid	Egg/Alevin Incubation	Juvenile	Smolt Migration	Adult Migration	Spawning Initiation
Chinook	6.1 – 12.2°C	12.2 – 18.8°C	12.8 – 16.1°C	3.3 – 17.8°C	5.5 – 13.9°C
	43 – 45°F	54 – 66°F	55 – 61°F	38 – 64°F	42 – 57°F
Steelhead	7.2 – 11.1°C	7.2 – 20.5°C	12.2 – 12.7°C	3.9 – 18.9°C	3.9 – 11.1°C
	45 – 52°F	45 – 69°F	54 –55°F	39 – 66°F	39 – 52°F

Source: NMFS 2019
Note: Both the NMFS 2019 and 2024 Biological Opinions provide information on optimum temperatures and thresholds for chinook and steelhead. The NMFS 2019 document provided more specific temperature tolerances and therefore was the source of information for this table.
°C = degrees Celsius
°F = degrees Fahrenheit

Table D3.1-11. Maximum Temperature Tolerances for Special-Status Salmonids (the 7-day, daily average maximum temperature)

Salmonid	Adult Migrating	Adult Holding	Spawner	Egg/Alevin	Juveniles	Smolt
Fall-run chinook salmon	20°C	16°C	14°C	12°C	16°C	19°C
Late fall-run chinook salmon	20°C	16°C	14°C	12°C	16°C	19°C
Winter-run chinook salmon	20°C	16°C	16°C	12°C	15.5°C	19°C
Spring-run chinook salmon	21°C	16°C	16°C	13°C	16°C	19°C
Central Valley steelhead	20°C	20°C	16°C	10°C	19°C	21°C

Source: McCullough 1999, Moyle et al. 2017, Myrick and Cech 2004, NMFS 2019.
Note: Life stages shown in grey have no confirmed presence in the Lower American River.
°C = degrees Celsius

The data used in this analysis on temperature tolerances for salmonids and adverse effects to salmonid life stages under different temperature regimes are based largely on laboratory studies. These studies represent the best available science, but in evaluating the modeled data and potential effects on salmonids it should be noted that laboratory studies are typically simplified models that do not capture the full complexity of natural environments. Conditions in laboratory studies cannot replicate a natural riverine environment where adult and juvenile salmonids may exhibit adaptive physiological and/or behavioral responses to changing temperatures and diverse microenvironments (Myrick and Cech 2004).

CENTRAL VALLEY FALL-RUN CHINOOK SALMON

The maximum temperature tolerances for fall-run chinook salmon are based, in part, on the following information:

- Tagged hatchery individuals released from the Feather River Hatchery showed 50 percent mortality when migrating downstream at river temperatures of 23.01°C ± 1.08°C (Baker et al. 1995).
- Mortality rates for eggs reared in captivity at 13.9°C exceeded 82 percent with egg mortality increasing above 12°C (Myrick and Cech 2004).
- When reared in captivity and fed to 100 percent satiation, juvenile fall-run chinook salmon from the Lower American River were able to grow at temperatures between 17 and 24°C, but prolonged rearing at

temperatures above 20°C resulted in reduced growth rates and feeding, increased predation, and altered smoltification (Marine and Cech 2004).

- Juvenile chinook fed to 60 percent satiation thrive under temperatures of around 15°C. This is based on a growth model constructed for sockeye salmon and modified to chinook with field studies showing roughly 60 percent satiation in wild-fed chinook juveniles (Myrick and Cech 2004).

CENTRAL VALLEY LATE FALL-RUN CHINOOK SALMON

There is no explicit data on maximum temperature tolerances for late fall-run chinook because they have only recently been differentiated from fall-run; most studies consider their thermal requirements similar to fall-run chinook (Moyle et al. 2017).

CENTRAL VALLEY WINTER-RUN CHINOOK SALMON

The maximum temperature tolerances for winter-run chinook salmon are based, in part, on the following information:

- Optimal temperatures for holding are between 10 and 16°C and temperatures over 13.3°C result in reduced egg survival (Moyle et al. 2017).
- Likely no spawning occurred at temperatures between 16 and 23°C with the 100 individuals recorded (Slater 1963). Temperatures over 16°C were lethal to incubating eggs.
- In a laboratory experiment, winter-run chinook juveniles were reared at 11, 16, and 20°C, and showed reduced growth and metabolic rates at 20°C (Zillig et al. 2022). The thermal maximum for winter-run chinook is between 28 and 30°C.
- Winter-run chinook eggs can develop at temperatures between 5.6 and 14.0°C, but American River chinook incubated in water over 16.7°C resulted in 100 percent mortality prior to the eye-development stage (Myrick and Cech 2004).
- Winter-run smolts will delay migration if temperatures exceed 21°C (Mantua et al. 2009).

CENTRAL VALLEY SPRING-RUN CHINOOK SALMON

The maximum temperature tolerances for spring-run chinook salmon are based, in part, on the following information:

- In the Columbia River Basin (Washington), pre-spawn mortality of natural origin individuals rose to roughly 10 percent of the population when mean August stream temperatures increased above 16°C in spawning grounds (Bowerman et al. 2021). Acute lethality was found to occur at temperatures between 23 and 25°C, and mortality increased when individuals are exposed to prolonged elevated temperatures between 21 and 22°C.
- For Central Valley spring-run chinook, preferred holding temperatures occur below maximum weekly averages of 21°C, with an upper thermal limit between 21 and 24°C (Moyle et al. 2017). Eggs are less resilient at 13 to 15°C, meaning adults will delay spawning until water temperatures decrease.

- Optimal spawning temperatures for Central Valley spring-run chinook range from 4 to 11°C, with embryo mortality occurring at temperatures exceeding 13°C (Moyle et al. 2017).

CENTRAL VALLEY STEELHEAD

The maximum temperature tolerances for Central Valley steelhead are based, in part, on the following information:

- Optimal growth for juveniles occurs at temperatures between 15 and 19°C (NMFS 2019). Smoltification may be delayed at temperatures over 12°C.
- In the Columbia River Basin (Washington), temperatures ranging from 21.7 to 23.9°C may alter the behavior of adult steelhead, potentially resulting in delayed migration or reduced chances of successful spawning (Richter and Kolmes 2005).
- Egg development and survival is reduced below 5°C, is optimized between 7 and 10°C, and declines at temperatures above 10°C (Myrick and Cech 2004).
- Juvenile steelhead from the Lower American River show critical thermal maxima of 27.5°C, 28.4°C, and 29.6°C when acclimated to 11, 15, and 19°C (Myrick and Cech, 2004). Maximal growth for Central Valley steelhead occurs at 16.4°C and growth is possible at 22°C, but optimal growth temperature is reduced when satiation levels are reduced to 60 to 50 percent (Wurtsbaugh and Davis 1977).
- In Southern California, steelhead persist in streams where summer maximum temperatures stayed below 30°C but declined by 50 percent when temperatures reached 31.5°C (Sloat and Osterback 2013).

OVERVIEW OF POTENTIAL EFFECTS OF INCREASED WATER TEMPERATURE ON SALMONIDS

Potential effects on steelhead, fall run chinook and other salmonids from increased water temperatures include changes in the timing of life history processes such as spawning and migration, increased mortality, and for adults and spawners, reduction in the quality, number, or size of embryos. Warmer water temperatures may also reduce swimming efficiency and increase metabolic demands for metamorphosis, resulting in reduced energy stores that lead to lower gamete quality, and smaller gamete size and abundance, and potential increases in pre-spawn mortality (Martins et al., 2011). Increased stream temperatures can deleteriously affect salmonids across life stages in a variety of ways: warmer water exacerbates the spread of pathogens, disease, and contaminants, and increases predation rates of eggs, embryos, and fry (Windell et al., 2017). Quigley and Hinch (2006) found that when experimentally raising stream temperatures in the laboratory by as little as 0.4ºC, whole body cortisol levels of juvenile chinook increased between 116% to 253% compared to controls. Continued production of cortisol can cause reductions in growth and disease resistance in salmonids (Redding et al., 1984). When salmonids are exposed to temperatures above their thermal optimum, even minor increases in temperature can result in substantial increases in mortality (Brett 1958).

Water temperature may also affect behavior and timing of life history processes. Adults may delay upstream migration (Moyle et al., 2017), experience higher pre-spawn mortality (Bowerman et al., 2021), or produce fewer and smaller embryos resulting in reduced egg to juvenile survival (FitzGerald et al., 2021). Juveniles are also affected by warm water temperatures, which increase metabolic demands and reduce individual growth rates (Windell et al., 2017). Smolts may also delay outmigration if temperatures increase past their thermal optimums (Mantua et al., 2009). When water temperatures increase past the point of an individual's thermal optimum,

salmonids will search for cooler patches, provided by groundwater inflow (Railsback and Harvey, 2023), stream-side vegetation that creates shading (Linnansaari et al., 2023), or pockets of cold water released from dams (Sutton et al., 2007). These cold-water refuges can provide considerable relief to temperature-stressed individuals, and act as a behavioral thermoregulation whereby individuals move within the habitat to avoid warmer waters and the resulting reduced fitness (Snyder et al., 2022).

Stream temperatures peak during the summer months and may affect different salmonids at different life stages. For example, spring-run chinook will experience higher thermal stress than fall-run chinook during adult holding and egg incubation, but fall-run chinook are most affected during adult upstream migration (FitzGerald et al., 2021). Phenotypic plasticity may allow for various runs to shift their migration timings to avoid temperature stress, but the delaying of key life-cycle processes may result in the hybridization of overlapping runs (FitzGerald et al., 2021). Winter-run chinook can avoid high temperatures by migrating earlier in the year using winter precipitation and spring snowmelt, and their offspring may outmigrate more rapidly to avoid rearing in warmer streams (Zillig et al., 2022). Salmonid behaviors to avoid temperature stress in warming rivers may include finding cold water refuge, delaying critical life cycle processes, or, in the case of juveniles, outmigrating prior to peak water temperatures.

The potential adverse effects associated with increased water temperatures were considered in assessing and ranking the level of potential Project-related temperature impacts on all life stages of fall run chinook and steelhead and critical life stages of other salmonids in the Lower American River between Nimbus Dam and Watt Avenue.

D3.1.4 Potential Effect Rankings

Three water temperature scenarios were developed to evaluate and rank potential effects to special-status salmonids due to Project changes in water temperature for the Lower American River between Nimbus Dam and Watt Avenue. These rankings reflect a conservative "worst case" approach for assessing potential Project effects on special-status salmonids from water temperature increases. Rankings are based on the greatest change in water temperature, considering both month and year water type, taken from 40 years of modeled data. Model predictions for that month would therefore show the greatest potential water temperature increase and the greatest potential effect.

Baseline water temperature and Project changes in water temperature were evaluated by month and water year type for each of the three scenarios, as described below:

- **Scenario 1 (Average Condition).** In the first scenario, baseline water temperatures at Watt Avenue and expected Project changes in temperature were averaged by month and water year type to calculate average monthly temperature and change in monthly temperature. Scenario 1 provides an indication of how average water temperature conditions are expected to change with Project operations for each water year type.
- **Scenario 2 (Warmest Baseline).** The second scenario used to evaluate potential effects to special-status salmonids evaluates when baseline water temperatures were highest at Watt Avenue for each month and year type. It then considers the change in water temperature that is expected to occur during Project operations for that month. Scenario 2 provides an indication of what types of changes are expected to occur with Project operations when baseline temperatures are the highest.

- **Scenario 3 (Greatest Change).** The third scenario used to evaluate potential effects to special-status salmonids is focused on months and year types when Project operations are expected to result in the largest water temperature increases. Scenario 3 provides an indication of when maximum changes to water temperatures could occur due to Project operations.

These three scenarios were evaluated independently to assess the extent to which Project temperature changes might adversely affect each life stage of special-status salmonids. The rankings considered the effects of Project temperature changes on critical physiological processes such as reduced gamete production, developmental defects, increased metabolic demands or decreased metabolic efficiency, reduced growth rates, and susceptibility to disease. The rankings also assessed the potential for temperature changes to alter crucial behaviors, such as the timing of spawning or outmigration. The following effect rankings were applied in Tables D3.2-1 through D3.4-12 to characterize the effects of Project temperature changes on all life stages (adult migrating, adult holding, spawner, egg/alevin, juveniles, and smolts) of special-status salmonids:

None: Project operations result in no increase in water temperature from baseline conditions.

Negligible: Project operations that increase water temperature from baseline conditions by less than or equal to 0.2°C are negligible. Changes in temperatures that are less than or equal to 0.2°C are at or below the accuracy of calibrated temperature measurement equipment (EIR Section 4.10, *Hydrology and Water Quality*). Changes in temperatures that are less than or equal to 0.2°C would not be expected to result in adverse effects to any life stage because these minor changes would have little to no effect on critical physiological processes or crucial behaviors for sensitive life stages. There is little to no potential for these effects to result in reduced survival or reproduction for a substantial number of individuals.

Low: Project operations that increase water temperature greater than 0.2°C and occur when the baseline temperatures may already be causing thermal stress to sensitive life stages and further incremental temperature increases associated with the Project could result in changes to critical physiological processes or crucial behaviors for sensitive life stages. However, depending on the frequency, timing and magnitude of these temperature changes, there is a low potential for these effects to result in reduced survival or reproduction for a substantial number of individuals.

Moderate: Project operations that increase water temperature greater than 0.2°C and occur when baseline temperature conditions are already causing thermal stress for sensitive life stages and further incremental temperature increases associated with the Project could result in changes to critical physiological processes or crucial behaviors for sensitive life stages. Depending on the frequency, timing and magnitude of these temperature changes there is moderate potential for these effects to result in reduced survival or reproduction for a substantial number of individuals.

High: Project operations that increase water temperature more than 0.5°C and occur when baseline temperature conditions already cause thermal stress that result in changes to critical physiological processes or alter crucial behaviors. Depending on the frequency, timing and magnitude of these temperature changes there is high potential for reduced survival or reproduction for a substantial number of individuals.

D3.2 POTENTIAL TEMPERATURE EFFECTS ON FALL-RUN CHINOOK SALMON

Thermal stress from elevated water temperatures can adversely affect the health, survival, and reproduction of fall-run chinook salmon. Increased water temperatures can result in increased mortality, growth impairment, behavioral changes such as migration delays and altered spawning timing, and increased susceptibility to disease (NMFS 2019). As described below these effects from increased water temperatures can affect all stages of fall-run chinook salmon.

- **Adult migrating**. Upstream migrating adults face an array of challenges resulting from elevated stream temperature because they cease feeding once they return to freshwater, and they must undergo metamorphosis to reach spawning grounds (Sallinger and Anderson 2006). Warmer water temperatures may reduce swimming efficiency and increase metabolic demands for metamorphosis, resulting in reduced energy stores that lead to lower gamete quality, smaller gamete size and abundance, and potential increases in pre-spawn mortality (Martins et al. 2011).

- **Adult holding**. Without feeding, upstream migrants have a finite energy store that must be used to not only transition from ocean-type adults to freshwater tolerant spawners, but also to make it to spawning grounds while producing gametes. The 7-day, daily average maximum temperature for adult fall-run chinook salmon to successfully produce gametes is below 16°C (NMFS 2019).[1] Adults holding in temperatures above this limit may show a reduction in gamete size, quality, or abundance (Moyle et al. 2017). Warmer water temperatures can reduce reproductive success and can also decrease opportunities to find cold-water refuges.

- **Spawner**. Spawning typically begins in late September, and warm water temperatures are frequently linked to high pre-spawn mortality because of energy losses in transit, disease contractions, and in the case of females, exhaustion from redd formation (Bowerman et al. 2021). Spawning fall-run chinook salmon have a 7-day, daily average maximum temperature of 14°C (NMFS 2019). With warmer water temperatures, spawners can be under substantial temperature stress, but some individuals may be able to delay spawning to avoid negative effects on reproduction (Moyle et al. 2017).

- **Egg/Alevin**. Eggs and alevin are the most at-risk life stage of any salmonid species to adverse effects from warmer water temperatures because they have a finite energy supply that needs to last through development (Healey 2011) and they are unable to swim away to find a cold-water refuge (Whitney et al. 2014). Fall-run chinook salmon eggs and alevin have a 7-day, daily average maximum temperature of 12°C (Myrick and Cech 2004, NFMS 2019), which is the lowest of the life stages.

- **Juveniles**. Juvenile fall-run chinook salmon have a 7-day, daily average maximum temperature of 16°C (Myrick and Cech 2004). Warmer water temperatures could cause some individuals to leave the system earlier in search of a cold-water refuge, and there may be reduced metabolic efficiency and lower growth rates (Windell et al. 2017), but evidence shows that individuals who are reared in warmer starting waters have a higher thermal tolerance. Other conditions such as population densities and food availability determine thermal tolerances for this life stage (Myrick and Cech 2004).

[1] The seven-day average daily maximum temperature represents the arithmetic average of seven consecutive measures of daily maximum temperatures. It reflects an average of maximum temperatures that fish are exposed to over a week-long period but is not overly influenced by the maximum temperature of a single day (Environmental Protection Agency [EPA] 2003). The EPA recommends this guideline for determining suitable spawning and rearing temperatures for salmonids.

- **Smolts**. Smolts have a 7-day, daily average maximum temperature of 19°C (Myrick and Cech 2004, NMFS 2019). Similar to juvenile fall-run chinook salmon, smolts exhibit thermal plasticity when reared in warmer water and also have the ability to outmigrate earlier under stressful conditions.

D3.2.1 Project Operations with Existing Infrastructure and Current Water Demands

Table D3.2-1 provides an evaluation of potential Project effects on each life stage of fall-run chinook salmon in the Lower American River at Watt Avenue bridge from changes in water temperature modeled for Project operations assuming current water demands and the use of existing infrastructure.

Under Scenario 1 (Average Condition), change in water temperature is expected to be negligible for each life stage evaluated (adult migrating, adult holding, spawner, egg/alevin, juveniles, and smolts) for every month. Scenario 1 uses average temperatures for a given month and water year type across the 40-year dataset. For this scenario, there would be negligible effects on survival or reproduction for a substantial number of individuals; in all five water year types (wet, above normal, below normal, dry, and critically dry), the potential effect was negligible because either the average monthly temperature was within the thermal optimum of a given life stage, or the temperature increases due to the Project were at or below 0.2°C.

Under Scenario 2 (Warmest Baseline), where the baseline ambient stream temperature was the highest for a given month and water year type, effects are expected to occur in at least one critically dry year. In this scenario, water temperatures are already high, and several life stages would already be under temperature stress. In critically dry years under Scenario 2 (Warmest Baseline), the warmest June of the critically dry years had a 20.9°C baseline temperature, and a 0.3°C increase in water temperature with Project operations. Upstream migrants have a 7-day, daily average maximum temperature of 20°C, and while some individuals may be experiencing thermal stress, they are not substantially outside of their thermal optimums, and individuals may delay migration or seek out cold water habitat. Potential effects to upstream migrants were ranked as low because increased temperatures would occur at the beginning of the upstream migration season and are unlikely to affect a substantial proportion of the population because most individuals of the population would be entering the Lower American River after June. Holding adults (which have a 7-day, daily average maximum temperature of 16°C) would be substantially outside their thermal tolerance under baseline conditions. Effects are considered low because only the earliest migrants would be in the Lower American River at this time and therefore a comparatively small portion of the population would potentially be affected. The effects are also considered low because the magnitude of the temperature increase is relatively small (0.3ºC).

Effects to juveniles (which have a 7-day, daily average maximum temperature of 16°C) and smolts (which have a 7-day, daily average maximum temperature of 19°C) were both assigned a potential effect level of low because juveniles and smolts reared in warm water can tolerate higher temperatures (Myrick and Cech (2004) and because they can outmigrate early in response to temperature stress.

Table D3.2-1. Potential Effects from Change in Water Temperature to Fall-Run Chinook Salmon in the Lower American River at Watt Avenue, Existing Infrastructure [Baseline vs. Project]

	Fall Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	TºC Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 1 Average Condition	Adult Migrating	<20	Jun-Dec	None	None	None	None	None	Negligible	None	None	None	Negligible
	Adult Holding	<16	Jun-Dec	None	None	None	None	None	Negligible	None	None	None	Negligible
	Spawner	<14	Late Sep-Dec	None	None	None	None	None	None	None	None	None	None
	Egg/Alevin	<12	Oct-Feb	None	None	None	None	None	None	None	None	None	None
	Juveniles	<16	Dec-Oct	None	None	None	None	None	Negligible	None	None	None	Negligible
	Smolt	<19	Mar-Jul	None	None	None	None	None	None	None	None	None	Negligible
	Fall Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	TºC Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 2 Warmest Baseline	Adult Migrating	<20	Jun-Dec	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June	Low[1]
	Adult Holding	<16	Jun-Dec	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June	Low[2]
	Spawner	<14	Late Sep-Dec	None	Negligible	None	None	None	Negligible	None	Negligible	None	Negligible
	Egg/Alevin	<12	Oct-Feb	None	Negligible	None	None	None	Negligible	None	Negligible	None	Negligible
	Juveniles	<16	Dec-Oct	None	None	None	Negligible	None	Negligible	None	Negligible	June	Low[3]
	Smolt	<19	Mar-Jul	None	None	None	Negligible	None	None	None	None	June	Low[4]
	Fall Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	TºC Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 3 Greatest Change	Adult Migrating	<20	Jun-Dec	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June, July, Sep	Moderate[1]
	Adult Holding	<16	Jun-Dec	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June, July, Sep	Moderate[2]
	Spawner	<14	Late Sep-Dec	None	Negligible	None	None	None	Negligible	None	Negligible	Sep	Low[5]
	Egg/Alevin	<12	Oct-Feb	None	None	None	None	None	Negligible	None	Negligible	None	Negligible
	Juveniles	<16	Dec-Oct	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June, July, Sep	Low[6]
	Smolt	<19	Mar-Jul	None	None	None	Negligible	None	Negligible	None	Negligible	June, July	Low[7]

Sources: Temperature effects – Moyle et al. 2017, NMFS 2019, Myrick and Cech 2004. Temperature modeling – Appendix C – Folsom Temperature Modeling in Support of Modification of Water Right Permit 21112

Footnotes:

- Low[1]. Modeled baseline temperature in June is 20.9ºC and temperature increased by 0.3ºC due to the Project. Some adults may already be under temperature stress, and this may cause them to delay migrating and may cause reductions in gamete size, quality, or abundance. This potential effect is considered low because the magnitude of the temperature increase is relatively small (0.3ºC), and because the temperature increase occurs at the beginning of the migratory season when only a small proportion of the population may be present.
- Low[2]. Modeled baseline temperature in June is 20.9ºC and temperature increased by 0.3ºC due to the Project. Adults would already be under temperature stress, and this may cause reductions in gamete size, quality, or abundance. The effect is considered low because the magnitude of the temperature increase is relatively small (0.3ºC) and because the temperature increase occurs at the beginning of the holding season when only a comparatively small portion of the population may be present.
- Low[3]. Modeled baseline temperature in June is 20.9ºC and temperature increased by 0.3ºC due to the Project. Some individuals would be experiencing decreased metabolic efficiency and reduced growth rates, but individuals already acclimated to warmer temperatures develop thermal plasticity and may show no reduced fitness effects; research by Myrick and Cech (2004) shows that juveniles reared in warm water can tolerate higher temperatures. Effects are considered low because the magnitude of the temperature increase is relatively small (0.3ºC) and because of the thermal plasticity shown by juveniles reared in warm water.
- Low[4]. Modeled baseline temperature in June is 20.9ºC and Project increased temperature by 0.3ºC. Some individuals would be experiencing decreased metabolic efficiency and reduced growth rates, but individuals already acclimated to warmer temperatures develop thermal plasticity and may show no reduced fitness effects; research by Myrick and Cech (2004) shows that smolts reared in warm water can tolerate higher temperatures. Individuals may also outmigrate early in response to temperature stress. Effects are considered low because the magnitude of the temperature increase is relatively small (0.3ºC) and because of the thermal plasticity shown by juveniles reared in warm water. Individuals may also outmigrate early in response to temperature stress.
- Moderate[1]. Modeled baseline temperature in June is 20.9ºC, 21.4ºC in July, and 20.6ºC in September. Temperature increases due to the Project are 0.3ºC in June and July, and 0.5ºC in September. Some adults would already be under temperature stress, and this may cause them to delay migrating and may cause reductions in gamete size, quality, or abundance. Increased temperatures could occur during more than one month in the migratory season. June and July are relatively early for migrating adults to enter the system and therefore a comparatively small portion of the population would potentially be affected.
- Moderate[2]. Modeled baseline temperature in June is 20.9ºC, 21.4ºC in July, and 20.6ºC in September. Temperature increases due to the Project are 0.3ºC in June and July, and 0.5ºC in September. Some holding adults would already be under temperature stress, and this may cause them to delay migrating and may cause reductions in gamete size, quality, or abundance. Increased temperatures could occur during more than one month in the migratory season. June and July are relatively early for migrating adults to enter the system and therefore a comparatively small portion of the population would potentially be affected.
- Low[5]. Modeled baseline temperature in September is 20.6ºC and temperature increased by 0.5ºC due to the Project. Spawners would already be under temperature stress, and the increased temperature may cause pre-spawn mortality, spawning delays, or reductions in gamete size, quality, or abundance. The effect is considered low because the temperature increase occurs before the peak of spawning, and therefore a relatively small number of individuals would be affected.
- Low[6]. Modeled baseline temperature in June is 20.9ºC, 21.4ºC in July, and 20.6ºC in September. Temperature increases due to the Project are 0.3ºC in June and July, and 0.5ºC in September. Effects are considered low because the magnitude of the temperature increase is relatively small (0.3ºC). Some juveniles may experience decreased metabolic efficiency and reduced growth rates, but individuals already acclimated to warmer temperatures develop thermal plasticity and may show no reduced fitness effects; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperatures. Also, individuals may outmigrate early in response to temperature stress.
- Low[7]. Modeled baseline temperature in June is 20.9ºC and 21.4ºC in July. Temperature increases due to the Project are 0.3ºC in both months. Effects are considered low because the magnitude of the temperature increase is relatively small (0.3ºC). Some smolts may experience decreased metabolic efficiency, reduced growth rates, struggle to metamorphose, or delay outmigration entirely, but individuals already acclimated to warmer temperatures develop thermal plasticity and may show no reduced fitness effects; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperatures. Also, individuals may outmigrate early in response to temperature stress.

Under Scenario 3 (Greatest Change), effects on various life stages could occur in critically dry years. Scenario 3 depicts model outputs for month and water year type when the highest stream temperature changes occur during Project operations. The increased temperatures could occur during a single year, or the results shown could be from different years. In the specific case of water year 1977 hydrology, multiple months from the same year could affect various life stages. For fall-run chinook salmon upstream migrants (which have a 7-day, daily average maximum temperature of 20°C) and holding adults (which have a 7-day, daily average maximum temperature of 16°C), temperature increases occur in July 1977 (which has a 21.4°C baseline temperature, and 0.3°C Project increase) and September 1977 (which has a 20.6°C baseline temperature, and 0.5°C Project increase).[2] The highest value for June of a critically dry year occurred during water year 1976, which has a 20.9°C baseline temperature, and a 0.3°C Project increase.

Adult migrants (which have a 7-day, daily average maximum temperature of 20°C) and holding adults (which have a 7-day, daily average maximum temperature of 16°C) were assigned a potential effect level of moderate, because a substantial proportion of both life stages would be experiencing increased temperature stress in multiple months, with potential for adverse effects on migration timing and gamete production during that year. For fall-run chinook salmon spawners, the only month with a temperature increase greater than 0.2°C is September (20.6°C baseline temperature, 0.5°C Project increase). The 7-day, daily average maximum temperature for spawners is 14°C, and individuals could be adversely affected by the increased water temperatures (reduced gamete quality and a higher risk of pre-spawn mortality). However, effects are considered low for fall-run chinook salmon spawners because the temperature increase occurs before the peak of spawning, and therefore a relatively small number of individuals would be affected.

For the fall-run chinook salmon juveniles (which have a 7-day, daily average maximum temperature of 16°C), the potential effect level is low for June (20.9°C baseline temperature, 0.3°C Project increase), July (21.4°C baseline temperature, 0.3°C Project increase), and September (20.6°C baseline temperature, 0.5°C Project increase). Fall-run chinook salmon smolts (which have a 7-day, daily average maximum temperature of 19°C) were also given a potential effect level of low for June and July because smolts and juveniles reared in warmer temperatures develop thermal plasticity and can tolerate higher temperatures. Because smolt migration occurs between March and July (Yoshiyama et al. 1998) and individuals may outmigrate early in response to temperature stress it is expected that only a small portion of the population would be affected by the minor temperature increase (0.3°C) in June and July.

Conclusion: For fall-run chinook salmon, the Project's potential operational effects with existing infrastructure and current water demands are negligible or low for all three scenarios and in all water year types except for migrating and holding adults in the summer of critically dry years, when Project effects would be considered moderate. These moderate adverse effects are due to potential effects of increased temperature on migration timing and gamete production.

[2] Increased temperatures of more than 0.2°C during multiple months in the same year was found in only one in the 40 years modeled and therefore such an occurrence is rare and may not be representative.

D3.2.2 PROJECT OPERATIONS WITH EXISTING INFRASTRUCTURE AND FUTURE WATER DEMANDS

Table D3.2-2 provides an evaluation of potential effects on each life stage of fall-run chinook salmon in the Lower American River at Watt Avenue bridge from changes in water temperature with Project operations assuming future water demands and the use of existing infrastructure.

Under Scenario 1 (Average Condition) and Scenario 2 (Warmest Baseline), changes in water temperature are expected to be negligible for each life stage evaluated and for all five water year types.

Under Scenario 3 (Greatest Change), Project changes in water temperature could have potential negative effects to fall-run chinook salmon in dry and critically dry years. Holding adults (which have a 7-day, daily average maximum temperature of 16°C) were ranked as experiencing moderate effects due to modeled water temperatures resulting in one dry year in August of 1991 when baseline temperatures were estimated at 19.9°C and Project operations were estimated to increase temperatures by 0.5°C. While this temperature increase of 0.5°C would be infrequent (i.e., observed only once in the 40-year record) this potential Project effect was considered moderate rather than low because the holding adults were already under thermal stress, and this increase would occur during the middle of the holding adult life stage and therefore has a higher likelihood to affect a substantial number of individuals when they may be unable to arrive late or leave early to avoid high temperatures. Juvenile effects were ranked as low because juveniles can leave the system to avoid Project-related temperature increases. Juveniles typically begin their smoltification and outmigration between January and June (Starr and Day 2020) and therefore most individuals would avoid the effects of Project-related temperature increases.

In critically dry years, all life stages could be adversely affected by warmer temperatures from Project operations. Fall-run chinook adult upstream migrants (which have a 7-day, daily average maximum temperature of 20°C) could experience reduced gamete production or delayed migration in June (20.8°C baseline, Project 0.3°C increase). However, the potential effect level is considered low because migration does not begin until June when only a comparatively small portion of the population may be present. In addition, the baseline temperature is only minimally outside thermal optimums, and the magnitude of the temperature increase is relatively small (0.3ºC), further supporting a low effect conclusion.

Holding adults (which have a 7-day, daily average maximum temperature of 16°C) could be thermally stressed in June or October (18.1°C baseline temperature, 0.8°C Project increase). The assigned potential effect level was considered moderate because more than one month would be affected by warmer water during the holding season that included the 0.8°C increase. Spawners would also be affected by the October temperature (they have a 7-day, daily average maximum temperature of 14°C). The effect on spawners was ranked as moderate because this warming occurs in the middle of spawning season, and could therefore increase pre-spawn mortality, reduce gamete production, or delay spawning.

In critically dry years, all eggs/alevin would already be under extreme temperature stress and are unlikely to survive the baseline temperatures, therefore a 0.8ºC increase in October is unlikely to result in additional mortality. Laboratory experiments showed 82 percent mortality in eggs reared at 13.9°C (Myrick and Cech 2004).

Table D3.2-2. Potential Effects from Change in Water Temperature to Fall-Run Chinook Salmon in the Lower American River at Watt Avenue, Existing Infrastructure [Future Baseline vs. Future Project]

	Fall Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 1 Average Condition	Adult Migrating	<20	Jun-Dec	None	None	None	None	None	Negligible	None	Negligible	None	Negligible
	Adult Holding	<16	Jun-Dec	None	None	None	None	None	Negligible	None	Negligible	None	Negligible
	Spawner	<14	Late Sep-Dec	None	None	None	None	None	Negligible	None	None	None	Negligible
	Egg/Alevin	<12	Oct-Feb	None	None	None	None	None	Negligible	None	None	None	Negligible
	Juveniles	<16	Dec-Oct	None	None	None	None	None	Negligible	None	Negligible	None	Negligible
	Smolt	<19	Mar-Jul	None	None	None	None	None	None	None	None	None	Negligible
	Fall Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 2 Warmest Baseline	Adult Migrating	<20	Jun-Dec	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Adult Holding	<16	Jun-Dec	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Spawner	<14	Late Sep-Dec	None	Negligible	None	None	None	Negligible	None	Negligible	None	None
	Egg/Alevin	<12	Oct-Feb	None	Negligible	None	None	None	Negligible	None	Negligible	None	None
	Juveniles	<16	Dec-Oct	None	None	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Smolt	<19	Mar-Jul	None	None	None	Negligible	None	None	None	Negligible	None	Negligible
	Fall Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 3 Greatest Change	Adult Migrating	<20	Jun-Dec	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June	Low[2]
	Adult Holding	<16	Jun-Dec	None	Negligible	None	Negligible	None	Negligible	August	Moderate[1]	June, Oct	Moderate[2]
	Spawner	<14	Late Sep-Dec	None	Negligible	None	None	None	Negligible	None	Negligible	Oct	Moderate[3]
	Egg/Alevin	<12	Oct-Feb	None	Negligible	None	None	None	Negligible	None	Negligible	Oct	Not Applicable [1]
	Juveniles	<16	Dec-Oct	None	Negligible	None	Negligible	None	Negligible	August	Low[1]	June, Oct	Low[3]
	Smolt	<19	Mar-Jul	None	None	None	Negligible	None	Negligible	None	Negligible	June	Low[4]

Sources: Temperature effects – Moyle et al. 2017, NMFS 2019, Myrick and Cech 2004. Temperature modeling – Appendix C – Folsom Temperature Modeling in Support of Modification of Water Right Permit 21112

Footnotes:

- Moderate[1]. Modeled baseline temperature in August is 19.9ºC and Project increased temperature by 0.5ºC. Many adults would already be under temperature stress, and this may cause reductions in gamete size, quality, or abundance. Warming is expected to occur during the middle of this life stage.
- Low[1]. Modeled baseline temperature in August is 19.9ºC and Project increased temperature by 0.5ºC. Some individuals could experience decreased metabolic efficiency and reduced growth rates, but individuals already acclimated to warmer temperatures develop thermal plasticity and may show no reduced fitness effects. Individuals may also outmigrate early in response to temperature stress. Effects are considered low rather than moderate because of the thermal plasticity shown by juveniles; research by Myrick and Cech (2004) shows that juveniles and smolts reared in warm water develop thermal plasticity and can tolerate warmer temperatures.
- Low[2]. Modeled baseline temperature in June is 20.8ºC and Project increased temperature by 0.3ºC. Effects are considered low because the 0.3ºC temperature increase is relatively small (0.3ºC). Some adults may already be under temperature stress, and this may cause them to delay migrating and may cause reductions in gamete size, quality, or abundance.
- Moderate[2]. Modeled baseline temperature in June is 20.8ºC and 18.1ºC in October, and the increased temperature due to the Project is 0.3ºC and 0.8ºC, respectively. Many adults would already be under temperature stress, and may cause reductions in gamete size, quality, or abundance. More than one month is expected to be affected by warmer water during the holding season which included the 0.8°C increase.
- Moderate[3]. Modeled baseline temperature in October is 18.1ºC and increased temperature is 0.8ºC. Many spawners would already be under temperature stress, and this may cause pre-spawn mortality, cause individuals to delay spawning, or cause reductions in gamete size, quality, or abundance. Warming is expected to occur in the middle of spawning season.
- Not applicable[1]. Modeled baseline temperature in October is 18.1ºC and Project increased temperature by 0.8ºC. All eggs/alevin would already be under extreme temperature stress and are unlikely to survive the baseline temperatures, therefore a 0.8ºC increase is unlikely to result in additional mortality.
- Low[3]. Modeled baseline temperature in June is 20.8ºC and 18.1ºC in October, and the increased temperature due to the Project is 0.3ºC and 0.8ºC, respectively. Effects to juveniles in June are considered low because the temperature increase in June is relatively small (0.3ºC). Some individuals could experience decreased metabolic efficiency and reduced growth rates, but individuals already acclimated to warmer temperatures develop thermal plasticity and may show no reduced fitness; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperatures. Individuals may also outmigrate early in response to temperature stress.
- Low[4]. Modeled baseline temperature in June is 20.8ºC and Project increased temperature by 0.3ºC.Effects are considered low because the 0.3ºC temperature increase is relatively small (0.3ºC). Some individuals may experience decreased metabolic efficiency, reduced growth rates, struggle to metamorphose, or delay outmigration entirely. Some individuals already acclimated to warmer temperatures may show no reduced fitness; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperatures.

In critically dry years, juveniles (which have a 7-day, daily average maximum temperature of 16°C) would experience thermal stress in June when baseline temperatures (20.8°C baseline temperature, 0.3°C Project increase) are already considerably higher than their 7-day, daily average maximum, and in October, when baseline temperatures are 18.1ºC with a 0.8°C Project increase. Smolts would also be affected in June, but effects to both juveniles and smolts are considered low because both smolts and juveniles can leave the system in response to temperature increases during Project operations.

Conclusion. For fall-run chinook salmon the Project's potential operational effects with existing infrastructure and future water demands are negligible for Scenarios 1 (Average Condition) and 2 (Warmest Baseline) in all five water year types. For Scenario 3 (Greatest Change), holding adults would experience moderate effects in dry and critically dry years, and spawners would also be moderately affected in critically dry years. Smolts and juveniles would experience low effects during dry and critically dry years. The effect was considered low rather than moderate because when smolts and juveniles are reared in warm water they can tolerate higher temperatures, and because they are able to outmigrate earlier in response to thermal stress.

D3.2.3 POST-CONSTRUCTION OPERATIONS WITH CURRENT WATER DEMANDS

Table D3.2-3 provides an evaluation of potential effects on each life stage of fall-run chinook salmon in the Lower American River at Watt Avenue bridge due to changes in water temperature modeled for Project operations which are expected to occur post-construction assuming current water demands.

Under Scenario 1 (Average Condition), change in water temperature is expected to be negligible for each life stage evaluated and for all five water year types.

Under Scenario 2 (Warmest Baseline) adult upstream migrants (which have a 7-day, daily average maximum temperature of 20°C) show a potential effect level of low in June (20.9°C baseline temperature, 0.3°C Project increase) in critically dry years. This effect was considered low because the increased temperature is not substantially outside their thermal optimums and occurs at the start of the migration season. Some adults may experience temperature stress but others may migrate later in the season. Holding adults (which have a 7-day, daily average maximum temperature of 16°C) could experience adverse effects in June of critically dry years; however, the potential effect level is low for the same reasons as described above for migrants. Fall-run chinook salmon juveniles and smolts could experience temperature-related effects due to the Project in June of critically dry years and were assigned a potential effect level of low due to their thermal plasticity and because the magnitude of the temperature increase was relatively low.

Under Scenario 3 (Greatest Change), effects could occur in critically dry years with nearly every life stage showing some negligible or low effects in a variety of months. Holding adults are the only life stage to experience moderate effects in summers of critically dry years. Holding adults, which have a 7-day, daily average maximum temperature of 16°C, could be affected in June (20.9°C baseline temperature, 0.3°C Project increase),

Table D3.2-3. Potential Effects from Change in Water Temperature to Fall-Run Chinook Salmon in the Lower American River at Watt Avenue, Post-Construction [Baseline vs. Project]

	Fall Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	TºC Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 1 Average Condition	Adult Migrating	<20	Jun-Dec	None	None	None	None	None	Negligible	None	None	None	Negligible
	Adult Holding	<16	Jun-Dec	None	None	None	None	None	Negligible	None	None	None	Negligible
	Spawner	<14	Late Sep-Dec	None	None	None	None	None	None	None	None	None	None
	Egg/Alevin	<12	Oct-Feb	None	None	None	None	None	None	None	None	None	None
	Juveniles	<16	Dec-Oct	None	None	None	None	None	Negligible	None	None	None	Negligible
	Smolt	<19	Mar-Jul	None	None	None	None	None	None	None	None	None	Negligible
	Fall Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	TºC Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 2 Warmest Baseline	Adult Migrating	<20	Jun-Dec	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June	Low[1]
	Adult Holding	<16	Jun-Dec	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June	Low[2]
	Spawner	<14	Late Sep-Dec	None	None	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Egg/Alevin	<12	Oct-Feb	None	None	None	None	None	Negligible	None	Negligible	None	Negligible
	Juveniles	<16	Dec-Oct	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June	Low[3]
	Smolt	<19	Mar-Jul	None	None	None	None	None	None	None	Negligible	June	Low[4]
	Fall Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	TºC Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 3 Greatest Change	Adult Migrating	<20	Jun-Dec	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June, Sep	Low[5]
	Adult Holding	<16	Jun-Dec	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June, Sep	Moderate[1]
	Spawner	<14	Late Sep-Dec	None	Negligible	None	Negligible	None	Negligible	None	Negligible	Sep	Low[6]
	Egg/Alevin	<12	Oct-Feb	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Juveniles	<16	Dec-Oct	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June, Sep	Low[7]
	Smolt	<19	Mar-Jul	None	None	None	None	None	Negligible	None	Negligible	June	Low[8]

Sources: Temperature effects – Moyle et al. 2017, NMFS 2019, Myrick and Cech 2004. Temperature modeling – Appendix C – Folsom Temperature Modeling in Support of Modification of Water Right Permit 21112

Footnotes:

- Low[1]. Modeled baseline temperature in June is 20.9ºC and Project increased temperature by 0.3ºC. Some adults may already be under temperature stress, and this may cause them to delay migrating and may cause reductions in gamete size, quality, or abundance. Effects are considered low because the magnitude of the temperature increase is relatively small (0.3ºC).
- Low[2]. Modeled baseline temperature in June is 20.9ºC and Project increased temperature by 0.3ºC. Many adults would already be under temperature stress, and this may cause reductions in gamete size, quality, or abundance. Effects are considered low because the magnitude of the temperature increase is relatively small (0.3ºC).
- Low[3]. Modeled baseline temperature in June is 20.9ºC and Project increased temperature by 0.3ºC. Some individuals could experience decreased metabolic efficiency and reduced growth rates, but individuals already acclimated to warmer temperatures develop thermal plasticity and may show no reduced fitness effects; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperatures. Also, individuals may outmigrate early to in response to temperature stress. Effects are considered low because potential effects would occur to a relatively small percentage of the population due to of the thermal plasticity shown by juveniles reared in warm water (Myrick and Cech 2004) and because early outmigration allows some individuals to in response to temperature stress altogether. In addition, effects are considered low because the magnitude of the temperature increase is relatively small (0.3ºC).
- Low[4]. Modeled baseline temperature in June is 20.9ºC and Project increased temperature by 0.3ºC. Individuals could experience decreased metabolic efficiency, reduced growth rates, struggle to metamorphose, or delay outmigration entirely. Some individuals already acclimated to warmer temperatures may show no reduced fitness effects due to thermal plasticity and tolerance for higher temperatures, as described above (Myrick and Cech 2004). In addition, effects are considered low because the magnitude of the temperature increase is relatively small (0.3ºC).
- Low[5]. Modeled baseline temperature in June is 20.9ºC and 20.6ºC in September, and increased temperature due to Project is 0.3ºC and 0.5ºC, respectively. Some adults may already be under temperature stress, and this may cause them to delay migrating and may cause reductions in gamete size, quality, or abundance.
- Moderate[1]. Modeled baseline temperature in June is 20.9ºC, , and 20.6ºC in September and temperature increases due to the Project are 0.3ºC, and 0.5ºC, respectively. Many adults would already be under temperature stress (particularly in June and Sep.) and this may cause reductions in gamete size, quality, or abundance. Effects are considered moderate because of the potential for multiple months being affected within the holding season.
- Low[6]. Modeled baseline temperature in September is 20.6ºC and Project increased temperature by 0.5ºC. Many spawners would already be under temperature stress, and this may cause pre-spawn mortality, delays in spawning, or reductions in gamete size, quality, or abundance.
- Low[7]. Modeled baseline temperature in June is 20.9ºC, , and 20.6ºC in September and temperature increases due to the Project are 0.3ºC, and 0.5ºC, respectively. Some individuals could experience decreased metabolic efficiency and reduced growth rates, but individuals already acclimated to warmer temperatures develop thermal plasticity may show no reduced fitness effects; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperatures. Also, individuals may outmigrate early in response to temperature stress.
- Low[8]. Modeled baseline temperature in June is 20.9ºC and Project increased temperature by 0.3ºC. Effects are considered low because the magnitude of the temperature increase is relatively small (0.3ºC). Individuals could experience decreased metabolic efficiency, reduced growth rates, struggle to metamorphose, or delay outmigration entirely. Some individuals already acclimated to warmer temperatures may show no reduced fitness; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperature.

and September (20.6°C baseline temperature, 0.5°C Project increase). The potential effect level was considered moderate because the baseline temperature is substantially outside their thermal optimums and an increase of 0.5°C in September occurs during the middle of the adult holding season, when a comparatively larger portion of the population may be present.

In critically dry years migrating adults (which have a 7-day, daily average maximum temperature of 20°C) could experience thermal stress in June (20.9°C baseline temperature, 0.3°C Project increase) and September (20.6°C baseline temperature, 0.5°C Project increase); however, the potential effect level assigned was low because the increased temperature was not substantially outside their thermal optimums. Spawners (which have a 7-day, daily average maximum temperature of 14°C) would be affected in September, but because spawning begins near the end of the month, the potential effect level was designated low. Juveniles (which have a 7-day, daily average maximum temperature of 16°C) could be affected in June, July, and September, and smolts (with a 7-day, daily average maximum temperature of 19°C) could be affected in June. The effect was considered low rather than moderate because when smolts and juveniles are reared in warm water they can tolerate higher temperatures (Myrick and Cech 2004), and because they are able to outmigrate earlier in response to thermal stress.

In critically dry years holding adults (which have a 7-day, daily average maximum temperature of 16°C) could be affected in June (20.9°C baseline temperature, 0.3°C Project increase) and September (20.6°C baseline temperature, 0.5°C Project increase. The potential effect level was considered moderate because the baseline temperature is substantially outside their thermal optimums and more individuals could be affected temporally.

Conclusion. For fall-run chinook salmon the Project's potential operational effects post-construction with current water demands would be negligible for Scenario 1 (Average Condition) in all five water year types, and would have low or negligible effects in Scenario 2 (Warmest Baseline) in critically dry years. For Scenario 3 (Greatest Change), holding adults are the only life stage to experience potential moderate effects in summers of critically dry years.

D3.2.4 POST-CONSTRUCTION OPERATIONS WITH FUTURE WATER DEMANDS

Table D3.2-4 provides an evaluation of potential effects on each life stage of fall-run chinook salmon in the Lower American River at Watt Avenue bridge due to changes in water temperature modeled for Project operations which are expected to occur post-construction assuming future water demands.

Under Scenario 1 (Average Condition) and Scenario 2 (Warmest Baseline), changes in water temperature due to the Project are expected to be negligible for each life stage evaluated in all five water year types.

Table D3.2-4. Potential Effects from Change in Water Temperature to Fall-Run Chinook Salmon in the Lower American River at Watt Avenue, Post-Construction [Future Baseline vs. Future Project]

	Fall Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	TºC Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 1 Average Condition	Adult Migrating	<20	Jun-Dec	None	None	None	None	None	Negligible	None	Negligible	None	Negligible
	Adult Holding	<16	Jun-Dec	None	None	None	None	None	Negligible	None	Negligible	None	Negligible
	Spawner	<14	Late Sep-Dec	None	None	None	None	None	Negligible	None	None	None	None
	Egg/Alevin	<12	Oct-Feb	None	None	None	None	None	Negligible	None	None	None	None
	Juveniles	<16	Dec-Oct	None	None	None	None	None	Negligible	None	Negligible	None	Negligible
	Smolt	<19	Mar-Jul	None	None	None	None	None	None	None	Negligible	None	Negligible
	Fall Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	TºC Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 2 Warmest Baseline	Adult Migrating	<20	Jun-Dec	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Adult Holding	<16	Jun-Dec	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Spawner	<14	Late Sep-Dec	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Egg/Alevin	<12	Oct-Feb	None	Negligible	None	None	None	Negligible	None	Negligible	None	Negligible
	Juveniles	<16	Dec-Oct	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Smolt	<19	Mar-Jul	None	None	None	None	None	None	None	Negligible	None	Negligible
	Fall Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	TºC Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 3 Greatest Change	Adult Migrating	<20	Jun-Dec	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Adult Holding	<16	Jun-Dec	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June	Low[1]
	Spawner	<14	Late Sep-Dec	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Egg/Alevin	<12	Oct-Feb	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Juveniles	<16	Dec-Oct	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June	Low[2]
	Smolt	<19	Mar-Jul	None	None	None	None	None	Negligible	None	Negligible	None	Negligible

Sources: Temperature effects – Moyle et al. 2017, NMFS 2019, Myrick and Cech 2004. Temperature modeling – Appendix C – Folsom Temperature Modeling in Support of Modification of Water Right Permit 21112

Footnotes:

- Low[1]. Modeled baseline temperature in June is 17.9ºC and Project increased temperature by 0.3ºC. Many adults would already be under temperature stress, and this may cause reductions in gamete size, quality, or abundance. However, the effect is considered low because the temperature increase occurs in the start of the holding season and is unlikely to affect a substantial proportion of the population and because the magnitude of the temperature increase is relatively small (0.3ºC).
- Low[2]. Modeled baseline temperature in June is 17.9ºC and the increased temperature due to the Project is 0.3ºC. Modeled baseline temperature in June is 20.9ºC and Project increased temperature by 0.3ºC. Effects are considered low because the magnitude of the temperature increase is relatively small (0.3ºC). Individuals could experience decreased metabolic efficiency, reduced growth rates, struggle to metamorphose, or delay outmigration entirely. Some individuals already acclimated to warmer temperatures may show no reduced fitness; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperature.

Under Scenario 3 (Greatest Change), holding adults could be affected in June (17.9°C baseline temperature, 0.3°C Project increase) in critically dry years. The potential effect is considered low because warmer water occurs in the start of the holding season when relatively few holding adults would be present and therefore the temperature increase is unlikely to affect a substantial proportion of the population. In addition, the magnitude of the temperature increase is relatively small (0.3ºC).

Conclusion. For fall-run chinook salmon the Project's potential operational effects post-construction with future water demands would be negligible for all life stages for Scenario 1 (Average Condition) and Scenario 2 (Warmest Baseline) and in all five water year types. For Scenario 3 (Greatest Change), holding adults are the only life stage to experience moderate effects in summers of critically dry years.

D3.3 POTENTIAL TEMPERATURE EFFECTS ON STEELHEAD TROUT

D3.3.1 PROJECT OPERATIONS WITH EXISTING INFRASTRUCTURE AND CURRENT WATER DEMANDS

Thermal stress from elevated water temperatures can adversely affect Central Valley steelhead trout throughout their life stages. These adverse effects range from migration challenges, physiological stress, increased susceptibility to disease and predation, and impaired growth and survival. All life stages can be affected, as described below.

- **Adult migrating**. Elevated water temperatures during the migration period can cause increased metabolic stress for adult steelhead, leading to reduced stamina, slower migration rates, and higher vulnerability to predators. Adults are also more likely to experience thermal stress-induced mortality. Crozier et al. (2011) found that increased water temperatures can reduce the migration success of adult salmonids, with migration delays and increased physiological stress. Similarly, temperatures above 18°C may reduce the swimming endurance of adult steelhead.
- **Adult holding**. During the holding phase, adult steelhead can become increasingly stressed by higher water temperatures. Prolonged exposure to elevated temperatures can result in weakened immune function, reduced feeding, and increased susceptibility to disease and predation. Jeffries et al. (2008) demonstrated that elevated temperatures during adult holding in the Sacramento River contributed to poor health, reduced fat stores, and greater vulnerability to disease and mortality.
- **Spawner** Higher water temperatures may result in delayed spawning, poor egg fertilization, and increased mortality of adult spawners due to metabolic stress. Busch et al. (2008) showed that elevated temperatures during spawning can reduce fertilization success and cause poor egg development, reducing overall reproductive success.
- **Egg/Alevin**. Elevated temperatures can lead to abnormal egg development and reduced hatching success in steelhead. Higher temperatures during incubation speed up embryonic development but can also cause malformation or early hatching, increasing mortality rates in eggs and alevins.
- **Juveniles**. Warmer water temperatures can impair the growth and survival of juvenile steelhead, making them more vulnerable to predators and diseases. Juveniles exposed to thermal stress are often less efficient at foraging, leading to poorer growth rates and higher mortality. McCullough et al. (2001) showed that elevated temperatures (above 20°C) significantly hindered juvenile steelhead growth and survival, and that juveniles in warmer waters had reduced feeding efficiency.

- **Smolts**. Smolts, which are preparing to migrate to the ocean, are particularly sensitive to thermal stress. Elevated temperatures can delay the timing of smoltification, impair osmoregulatory capacity, and decrease survival during downstream migration. Jeffries et al. (2008) found that elevated temperatures delayed smoltification in steelhead and reduced their overall survival rates during migration due to thermal stress.

Table D3.3-1 provides an evaluation of potential effects on each life stage of steelhead in the Lower American River at Watt Avenue bridge due to changes in water temperature modeled for Project operations assuming current water demands and the use of existing infrastructure.

Under Scenario 1 (Average Condition), change in water temperatures are expected to be negligible for each life stage in all five water year types.

Under Scenario 2 (Warmest Baseline), only the juveniles (which have a 7-day, daily average maximum temperature of 19°C; NMFS 2019) would be affected during the warmest June (20.9°C baseline temperature, 0.3°C Project increase) of dry years. Steelhead juveniles show remarkable growth potential when incubated at higher temperatures, and growth is possible at up to 22°C (Wurtsbaugh and Davis 1977). Additionally, individuals reared at higher baseline water temperatures show substantially increased thermal maxima (Myrick and Cech 2004), so it is possible that effects would be negligible. To be conservative and knowing that individuals may leave the system early, the potential effect level was instead categorized as low.

Under Scenario 3 (Greatest Change), multiple life stages could experience adverse effects during different months in critically dry years. Both upstream migrants and holding adults (which share a 7-day, daily average maximum temperature of 20°C) could be affected in September (20.6°C baseline temperature, 0.5°C Project increase). There could be effects to migration timing and gamete production, but the increased temperature is not substantially outside their thermal optimums, and individuals could delay migration while holding in cooler water to reduce these effects.[3] Juveniles (which have a 7-day, daily average maximum temperature of 19°C) could be affected in June (20.9°C baseline temperature, 0.3°C Project increase), July (21.4°C baseline temperature, 0.3°C Project increase), and September (20.6°C baseline temperature, 0.5°C Project increase). Because juveniles can withstand slightly warmer temperatures and can emigrate to avoid warmer water, potential effects remain low. In addition, for June and July the magnitude of the temperature increases are relatively low. Lastly, smolts (which have a 7-day, daily average maximum temperature of 21°C) could be affected in June, but the Lower American River Smolt Trap data has not recorded a steelhead smolt captured in June in any year between 2013 to 2023 (Day and Morris 2023). Because of the low likelihood of smolt presence in June potential effects are considered low.

Conclusion. For steelhead trout the Project's operational effects with existing infrastructure and current water demands would be negligible for all life stages for Scenario 1 (Average Condition) for all five water year types. For Scenario 2 (Warmest Baseline) juveniles could experience low effects in dry years, and for Scenario 3 (Greatest Change) migrating adults, holding adults, juveniles and smolt could experience low effects in critically dry years.

[3] Note that warmer temperatures ranging between 21.7°C to 23.9°C may alter the behavior of adult steelhead, potentially resulting in delayed migration or reduced chances of successful spawning (Richter and Kolmes, 2005).

Table D3.3-1. Potential Effects from Change in Water Temperature to Steelhead in the Lower American River at Watt Avenue, Existing Infrastructure [Baseline vs. Project]

	Steelhead			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	TºC Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 1 Average Condition	Adult Migrating	<20	Aug-Nov	None	None	None	None	None	Negligible	None	None	None	None
	Adult Holding	<20	Aug-Nov	None	None	None	None	None	Negligible	None	None	None	None
	Spawner	<16	Dec-Apr	None	None	None	None	None	None	None	None	None	None
	Egg/Alevin	<10	Jan-May	None	None	None	None	None	None	None	None	None	None
	Juveniles	<19	Year-round	None	None	None	None	None	Negligible	None	None	None	Negligible
	Smolt	<21	Mar-Jun	None	None	None	None	None	None	None	None	None	Negligible
	Steelhead			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	TºC Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 2 Warmest Baseline	Adult Migrating	<20	Aug-Nov	None	Negligible	None	None	None	Negligible	None	Negligible	None	Negligible
	Adult Holding	<20	Aug-Nov	None	Negligible	None	None	None	Negligible	None	Negligible	None	Negligible
	Spawner	<16	Dec-Apr	None	None	None	None	None	None	None	None	None	Negligible
	Egg/Alevin	<10	Jan-May	None	None	None	None	None	None	None	None	None	Negligible
	Juveniles	<19	Year-round	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June	Low[1]
	Smolt	<21	Mar-Jun	None	None	None	None	None	None	None	None	None	Negligible
	Steelhead			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	TºC Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 3 Greatest Change	Adult Migrating	<20	Aug-Nov	None	Negligible	None	None	None	Negligible	None	Negligible	Sep	Low[2]
	Adult Holding	<20	Aug-Nov	None	Negligible	None	None	None	Negligible	None	Negligible	Sep	Low[3]
	Spawner	<16	Dec-Apr	None	None	None	None	None	Negligible	None	None	None	Negligible
	Egg/Alevin	<10	Jan-May	None	None	None	None	None	Negligible	None	None	None	Negligible
	Juveniles	<19	Year-round	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June, July, Sep	Low[4]
	Smolt	<21	Mar-Jun	None	None	None	None	None	Negligible	None	Negligible	June	Low[5]

Source: Temperature effects – NMFS 2019, Myrick and Cech 2005. Temperature modeling – Appendix C – Folsom Temperature Modeling in Support of Modification of Water Right Permit 21112

Footnotes:

- Low[1]. Modeled baseline temperature in June is 20.9ºC and Project increased temperature by 0.3ºC. Some individuals would be experiencing decreased metabolic efficiency and reduced growth rates, but individuals already acclimated to warmer temperatures show a thermal acclimation effect may show no reduced fitness effects; research on thermal acclimation (Myrick and Cech 2005) shows that rearing steelhead at elevated temperatures confers greater tolerance for higher temperatures. Effects are considered low because the magnitude of the temperature increase is relatively small (0.3ºC), because of the thermal tolerance shown by juveniles, and because early outmigration allows some individuals to avoid temperature stress altogether.
- Low[2]. Modeled baseline temperature in September is 20.6ºC and Project increased temperature by 0.5ºC. Some adults may already be under temperature stress, and this may cause them to delay migrating and may cause reductions in gamete size, quality, or abundance. The 0.5ºC temperature increase is considered a low effect because the individuals experiencing the increase would only be slightly outside their thermal optimums.
- Low[3]. Modeled baseline temperature in September is 20.6ºC and Project increased temperature by 0.5ºC. Some adults may already be under temperature stress, and this may cause reductions in gamete size, quality, or abundance. The 0.5ºC temperature increase is considered a low effect because the individuals experiencing the increase would only be slightly outside their thermal optimums.
- Low[4]. Modeled baseline temperature in June is 20.9ºC, 21.4ºC in July, and 20.6ºC in September and temperature increases due to the Project are 0.3ºC in June and July, and 0.5ºC in September. Some individuals would be experiencing decreased metabolic efficiency and reduced growth rates, but individuals already acclimated to warmer temperatures may show no reduced fitness effects; research on thermal acclimation (Myrick and Cech 2005) shows that steelhead reared at elevated temperatures can tolerate a higher critical thermal maximum. Individuals may also outmigrate early to avoid temperature stress. Effects are considered low because the magnitude of the temperature increase is relatively small (0.3ºC), because of the thermal tolerance of steelhead reared in higher temperatures, and because early outmigration allows some individuals to avoid temperature stress altogether.
- Low[5]. Modeled baseline temperature in June is 20.9ºC and Project increased temperature by 0.3ºC. Individuals would be experiencing decreased metabolic efficiency, reduced growth rates, struggle to metamorphose, or delay outmigration entirely. Effects are considered low because the magnitude of the temperature increase is relatively small (0.3ºC) and because of the thermal tolerance of steelhead reared in higher temperatures.

D3.3.2 PROJECT OPERATIONS WITH EXISTING INFRASTRUCTURE AND FUTURE WATER DEMANDS

Table D3.3-2 provides an evaluation of potential effects on each life stage of steelhead in the Lower American River at Watt Avenue bridge due to changes in water temperature modeled for Project operations assuming future water demands and the use of existing infrastructure.

Potential effects to steelhead life stages from changes in water temperatures during Project operations would be negligible for both Scenario 1 (Average Condition) and Scenario 2 (Warmest Baseline).

For Scenario 3 (Greatest Change), potential effects could occur for juveniles (which have a 7-day, daily average maximum temperature of 19°C) in August (19.9°C baseline temperature, 0.5°C Project increase) of dry years and June (20.8°C baseline temperature, 0.3°C Project increase) of critically dry years. These potential effects are considered low for both water year types because juvenile steelhead can withstand slightly warmer temperatures or emigrate in response to increased temperatures.

Conclusion. For steelhead trout the Project's potential operational effects with existing infrastructure and future water demands would be negligible for all life stages and all scenarios and all five water years types except for Scenario 3 (Greatest Change). Juveniles could experience low effects in dry and critically dry years. The effects are considered low because of the thermal plasticity shown by juveniles (Myrick and Cech 2005) and because individuals may outmigrate early in response to temperature stress.

Table D3.3-2. Potential Effects from Change in Water Temperature to Steelhead in the Lower American River at Watt Avenue, Existing Infrastructure [Future Baseline vs. Future Project]

	Steelhead			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
Scenario 1 Average Condition	Life Stage	TºC Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
	Adult Migrating	<20	Aug-Nov	None	None	None	None	None	Negligible	None	Negligible	None	Negligible
	Adult Holding	<20	Aug-Nov	None	None	None	None	None	Negligible	None	Negligible	None	Negligible
	Spawner	<16	Dec-Apr	None	None	None	None	None	None	None	None	None	None
	Egg/Alevin	<10	Jan-May	None	None	None	None	None	None	None	None	None	Negligible
	Juveniles	<19	Year-round	None	None	None	None	None	Negligible	None	Negligible	None	Negligible
	Smolt	<21	Mar-Jun	None	None	None	None	None	None	None	None	None	Negligible
	Steelhead			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
Scenario 2 Warmest Baseline	Life Stage	TºC Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
	Adult Migrating	<20	Aug-Nov	None	Negligible	None	None	None	Negligible	None	Negligible	None	None
	Adult Holding	<20	Aug-Nov	None	Negligible	None	None	None	Negligible	None	Negligible	None	None
	Spawner	<16	Dec-Apr	None	None	None	None	None	None	None	None	None	Negligible
	Egg/Alevin	<10	Jan-May	None	None	None	None	None	None	None	Negligible	None	Negligible
	Juveniles	<19	Year-round	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Smolt	<21	Mar-Jun	None	None	None	None	None	None	None	Negligible	None	Negligible
	Steelhead			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
Scenario 3 Greatest Change	Life Stage	TºC Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
	Adult Migrating	<20	Aug-Nov	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Adult Holding	<20	Aug-Nov	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Spawner	<16	Dec-Apr	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Egg/Alevin	<10	Jan-May	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Juveniles	<19	Year-round	None	Negligible	None	Negligible	None	Negligible	Aug	Low[1]	June	Low[2]
	Smolt	<21	Mar-Jun	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible

Source: Temperature effects – NMFS 2019, Myrick and Cech 2005; Temperature modeling – Appendix C – Folsom Temperature Modeling in Support of Modification of Water Right Permit 21112

Footnotes:

- Low[1]. Modeled baseline temperature in August is 19.9ºC and Project increased temperature by 0.5ºC. Some individuals could experience decreased metabolic efficiency and reduced growth rates, but individuals already acclimated to warmer temperatures may show no reduced fitness effects because when steelhead are reared at higher temperatures they show greater thermal tolerances (Myrick and Cech 2005). Effects are considered low because of the thermal plasticity shown by juveniles and because individuals may outmigrate early to in response to temperature stress.
- Low[2]. Modeled baseline temperature in June is 20.8ºC and Project increased temperature by 0.3ºC. Some individuals could experience decreased metabolic efficiency and reduced growth rates, but individuals already acclimated to warmer temperatures may show no reduced fitness effects. Individuals may also outmigrate early in response to temperature stress. Effects are considered low because the magnitude of the temperature increase is relatively small (0.3ºC) and because of the thermal plasticity shown by juveniles (Myrick and Cech 2005).

D3.3.3 POST-CONSTRUCTION OPERATIONS WITH CURRENT WATER DEMANDS

Table D3.3-3 provides an evaluation of potential effects on each life stage of steelhead in the Lower American River at Watt Avenue bridge due to changes in water temperature modeled for Project operations which are expected to occur post-construction assuming current water demands.

Under Scenario 1 (Average Condition) potential effects to steelhead from changes in water temperatures during Project operations would be negligible for all five water years.

Under Scenario 2 (Warmest Baseline) Juveniles (which have a 7-day, daily average maximum temperature of 19°C) could be affected in June of a critically dry year (20.9°C baseline temperature, 0.3°C Project increase). Potential effects to juveniles are low because the magnitude of the temperature increase is relatively small (0.3ºC), the thermal plasticity shown by juveniles and because they could emigrate to avoid the warmer water if needed.

Under Scenario 3 (Greatest Change), potential effects to steelhead from changes in water temperatures during Project operations are considered low. Adult migrants and holding adults (which share a 7-day, daily average maximum temperature of 20°C) could be adversely affected in September (20.6°C baseline temperature, 0.5°C Project increase). Although there could be effects to migration timing and gamete production, the increased temperature is not substantially outside their thermal optimums and individuals could delay migration while holding in cooler water to reduce these effects; as such, potential effects remain low. Juveniles (which have a 7-day, daily average maximum temperature of 19°C) could be affected in both June (20.9°C baseline temperature, 0.3°C Project increase) and September (20.6°C baseline temperature, 0.5°C Project increase). Potential effects to juveniles are considered low because of the magnitude of the temperature increase is relatively small, the thermal plasticity shown by juveniles and because they could emigrate to avoid the warmer water if needed.

Conclusion. For steelhead trout the Project's potential operational effects post-construction with current water demands would be negligible for all life stages and all scenarios except for Scenarios 2 (Warmest Baseline) and 3 (Greatest Change) in critically dry years. Juveniles could experience low effects in June of dry years in Scenario 2 and in critically dry years of June and September in Scenario 3. In Scenario 3 (Greatest Change) in critically dry years migrating adults, holding adults and juveniles could experience low effects.

Table D3.3-3. Potential Effects from Change in Water Temperature to Steelhead in the Lower American River at Watt Avenue, Post-Construction [Baseline vs. Project]

	Steelhead			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	TºC Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 1 Average Condition	Adult Migrating	<20	Aug-Nov	None	None	None	None	None	Negligible	None	None	None	None
	Adult Holding	<20	Aug-Nov	None	None	None	None	None	Negligible	None	None	None	None
	Spawner	<16	Dec-Apr	None	None	None	None	None	None	None	None	None	None
	Egg/Alevin	<10	Jan-May	None	None	None	None	None	None	None	None	None	Negligible
	Juveniles	<19	Year-round	None	None	None	None	None	Negligible	None	None	None	Negligible
	Smolt	<21	Mar-Jun	None	None	None	None	None	None	None	None	None	Negligible
	Steelhead			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	TºC Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 2 Warmest Baseline	Adult Migrating	<20	Aug-Nov	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Adult Holding	<20	Aug-Nov	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Spawner	<16	Dec-Apr	None	None	None	None	None	None	None	None	None	Negligible
	Egg/Alevin	<10	Jan-May	None	None	None	None	None	None	None	None	None	Negligible
	Juveniles	<19	Year-round	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June	Low[1]
	Smolt	<21	Mar-Jun	None	None	None	None	None	None	None	None	None	Negligible
	Steelhead			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	TºC Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 3 Greatest Change	Adult Migrating	<20	Aug-Nov	None	Negligible	None	Negligible	None	Negligible	None	Negligible	Sep	Low[2]
	Adult Holding	<20	Aug-Nov	None	Negligible	None	Negligible	None	Negligible	None	Negligible	Sep	Low[3]
	Spawner	<16	Dec-Apr	None	Negligible	None	None	None	Negligible	None	None	None	Negligible
	Egg/Alevin	<10	Jan-May	None	None	None	None	None	Negligible	None	Negligible	None	Negligible
	Juveniles	<19	Year-round	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June, Sep	Low[4]
	Smolt	<21	Mar-Jun	None	None	None	None	None	Negligible	None	Negligible	None	Negligible

Source: Temperature effects – NMFS 2019, Myrick and Cech 2005; Temperature modeling – Appendix C – Folsom Temperature Modeling in Support of Modification of Water Right Permit 21112

Footnotes:

- Low[1]. Modeled baseline temperature in June is 20.9ºC and Project increased temperature by 0.3ºC. Some individuals could experience decreased metabolic efficiency and reduced growth rates. Effects are considered low because the magnitude of the change is small (0.3ºC) and because these conditions would occur infrequently. Furthermore, research on thermal acclimation (Myrick and Cech 2005) shows that steelhead reared at elevated temperatures can tolerate a higher critical thermal maximum. Individuals may also outmigrate early to avoid temperature stress allowing some individuals to avoid temperature stress altogether.
- Low[2]. Modeled baseline temperature in September is 20.6ºC and Project increased temperature by 0.5ºC. Some adults would already be under temperature stress, and this may cause them to delay migrating and may cause reductions in gamete size, quality, or abundance. Effects are considered low because increased temperature is not substantially outside thermal optimums and individuals could delay migration while holding in cooler water.
- Low[3]. Modeled baseline temperature in September is 20.6ºC and Project increased temperature by 0.5ºC. Some adults would already be under temperature stress, and this may cause reductions in gamete size, quality, or abundance. Effects are considered low because the increased temperature is not substantially outside thermal optimums and individuals could delay migration while holding in cooler water.
- Low[4]. Modeled baseline temperature in June is 20.9ºC and 20.6ºC in September, and the increased temperature due to the Project is 0.3ºC and 0.5ºC, respectively. Some individuals may experience decreased metabolic efficiency and reduced growth rates, but research on thermal acclimation (Myrick and Cech 2005) shows that steelhead reared at elevated temperatures can tolerate a higher critical thermal maximum. Individuals may also outmigrate early to avoid temperature stress. Effects are considered low because the magnitude of the temperature increase is relatively small (0.3ºC), because of the thermal tolerance for steelhead reared in higher temperatures and because early outmigration allows some individuals to avoid temperature stress altogether.

D3.3.4 POST-CONSTRUCTION OPERATIONS WITH FUTURE WATER DEMANDS

Table D3.3-4 provides an evaluation of potential effects on each life stage of steelhead in the Lower American River at Watt Avenue bridge due to changes in water temperature modeled for Project operations which are expected to occur post-construction assuming future water demands.

Effects to steelhead life stages from changes in water temperatures during Project operations would be negligible for Scenario 1 (Average Condition), Scenario 2 (Warmest Baseline) and Scenario 3 (Greatest Change) in all five water year types.

Conclusion. For steelhead trout the Project's operational effects post-construction and with future water demands would be negligible for all life stages, all three Scenarios and all five water years.

Table D3.3-4. Potential Effects from Change in Water Temperature to Steelhead in the Lower American River at Watt Avenue, Post-Construction [Future Baseline vs. Future Project]

	Steelhead			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
Scenario 1 Average Condition	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
	Adult Migrating	<20	Aug-Nov	None	None	None	None	None	Negligible	None	None	None	None
	Adult Holding	<20	Aug-Nov	None	None	None	None	None	Negligible	None	None	None	None
	Spawner	<16	Dec-Apr	None	None	None	None	None	None	None	None	None	None
	Egg/Alevin	<10	Jan-May	None	None	None	None	None	None	None	None	None	Negligible
	Juveniles	<19	Year-round	None	None	None	None	None	Negligible	None	Negligible	None	Negligible
	Smolt	<21	Mar-Jun	None	None	None	None	None	None	None	None	None	Negligible
	Steelhead			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
Scenario 2 Warmest Baseline	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
	Adult Migrating	<20	Aug-Nov	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Adult Holding	<20	Aug-Nov	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Spawner	<16	Dec-Apr	None	None	None	None	None	None	None	None	None	Negligible
	Egg/Alevin	<10	Jan-May	None	None	None	None	None	None	None	Negligible	None	Negligible
	Juveniles	<19	Year-round	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Smolt	<21	Mar-Jun	None	None	None	None	None	None	None	Negligible	None	Negligible
	Steelhead			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
Scenario 3 Greatest Change	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
	Adult Migrating	<20	Aug-Nov	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Adult Holding	<20	Aug-Nov	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Spawner	<16	Dec-Apr	None	Negligible	None	None	None	Negligible	None	Negligible	None	Negligible
	Egg/Alevin	<10	Jan-May	None	None	None	None	None	Negligible	None	Negligible	None	Negligible
	Juveniles	<19	Year-round	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Smolt	<21	Mar-Jun	None	None	None	None	None	Negligible	None	Negligible	None	Negligible

Source: Temperature effects – NMFS 2019. Temperature modeling – Appendix C – Folsom Temperature Modeling in Support of Modification of Water Right Permit 21112

D3.4 POTENTIAL TEMPERATURE EFFECTS ON OTHER SALMONIDS

The Lower American River Smolt Trap data provides evidence that winter-run, spring-run, and late fall-run chinook salmon may be present in the Lower American River at certain times of the year, however, their abundances are substantially lower than fall-run chinook salmon and steelhead (Day and Morris 2023). Since 2013, there have been a combined total of 330 winter-run chinook salmon, 75 spring-run chinook salmon, and 41 late fall-run chinook salmon captured in the Lower American River Smolt Trap. No late fall-run chinook individuals have been recorded since 2016. The CDFW crew that operates the Lower American River Smolt Trap use rigorous criteria including both length-at-date information combined with genetic analysis to determine which species of chinook is caught each day (Day and Morris 2023).

Because the recorded abundances of these salmonids are so low and because there is no published spawner data to confirm that these runs are naturally occurring and natal in the Lower American River, potential effects for these three species focus solely on the juveniles and smolts that may be entering the Lower American River to find rearing habitat, refugia, or feeding opportunities. Migratory or holding adults, spawners, or eggs and are not expected to be present in the Lower American River, but effect rankings and an analysis of potential Project effects for all life stages of winter-run, spring-run, and late fall-run chinook salmon are provided in Tables D3.4-1 through Table D3.4-12. The rationales for the effects ranking for all life stages are detailed in the table footnotes but the discussion in the section below focuses on juveniles and smolts.

D3.4.1 PROJECT OPERATIONS WITH CURRENT INFRASTRUCTURE AND EXISTING WATER DEMANDS

Tables D3.4-1 to D3.4-3 provide an evaluation of potential effects on each life stage of late fall-run, spring-run, and winter-run chinook salmon in the Lower American River at Watt Avenue bridge due to changes in water temperature modeled for Project operations when assuming current water demands and the use of existing infrastructure.

Under Scenario 1 (Average Condition) potential effects to late fall-run, spring-run, and winter-run chinook juveniles due to changes in water temperatures during Project operations would be negligible in all five water year types.

Under Scenario 2 (Warmest Baseline), juveniles of all three species would experience low level effects in June (20.9°C baseline temperature, 0.3°C Project increase) of critically dry years. Both late fall-run and spring-run chinook salmon juveniles have a 7-day, daily average maximum temperature of 16°C, and winter-run chinook salmon juveniles have a 7-day, daily average maximum temperature of 15.5°C. While higher water temperatures would affect juvenile rearing and behavior, the potential effect level is considered low, because the magnitude of the temperature increase is relatively small (0.3ºC), because of the thermal plasticity shown by juvenile chinook (Myrich and Cech 2004) as well as their ability to emigrate into cooler habitats.

Table D3.4-1. Potential Effects from Change in Water Temperature to Late Fall-Run Chinook Salmon in the Lower American River at Watt Avenue, Existing Infrastructure [Baseline vs. Project]

	Late Fall Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 1 Average Condition	Adult Migrating	<20	Oct-Apr	None	None	None	None	None	None	None	None	None	None
	Adult Holding	<16	Oct-Apr	None	None	None	None	None	None	None	None	None	None
	Spawner	<14	Early Jan-Apr	None	None	None	None	None	None	None	None	None	None
	Egg/Alevin	<12	Jan-June	None	None	None	None	None	None	None	None	None	Negligible
	Juveniles	<16	Year-round	None	None	None	None	None	Negligible	None	None	None	Negligible
	Smolt	<19	Nov-May	None	None	None	None	None	None	None	None	None	None
	Late Fall Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 2 Warmest Baseline	Adult Migrating	<20	Oct-Apr	None	Negligible	None	None	None	Negligible	None	Negligible	None	Negligible
	Adult Holding	<16	Oct-Apr	None	Negligible	None	None	None	Negligible	None	Negligible	None	Negligible
	Spawner	<14	Early Jan-Apr	None	None	None	None	None	None	None	None	None	Negligible
	Egg/Alevin	<12	Jan-June	None	None	None	None	None	None	None	None	June	Not Applicable[1]
	Juveniles	<16	Year-round	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June	Low[1]
	Smolt	<19	Nov-May	None	Negligible	None	None	None	None	None	None	None	Negligible
	Late Fall Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 3 Greatest Change	Adult Migrating	<20	Oct-Apr	None	None	None	None	None	Negligible	None	Negligible	None	Negligible
	Adult Holding	<16	Oct-Apr	None	None	None	None	None	Negligible	None	Negligible	None	Negligible
	Spawner	<14	Early Jan-Apr	None	None	None	None	None	Negligible	None	None	None	Negligible
	Egg/Alevin	<12	Jan-June	None	None	None	None	None	Negligible	None	Negligible	June	Not Applicable[2]
	Juveniles	<16	Year-round	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June, July, Sep	Low[2]
	Smolt	<19	Nov-May	None	None	None	None	None	Negligible	None	None	None	Negligible

Sources: Temperature effects – Moyle et al. 2017, NMFS 2019, Myrick and Cech 2004. Temperature modeling – Appendix C – Folsom Temperature Modeling in Support of Modification of Water Right Permit 21112

Note: Life stages shown in grey have no confirmed presence in the Lower American River. Since 2013, a total of 41 late fall-run chinook juveniles-smolts have been captured in the Lower American River rotary screw traps. It is unclear if these individuals are part of a self-sustaining and distinct Lower American River population, or if they are transitory individuals seeking overwintering habitat within the project area. The rankings assume that these individuals constitute their own, distinct subpopulation of late fall-run chinook within the Lower American River. There is no published evidence that late fall-run chinook salmon reproduction occurs in the Lower American River or that these life stages are naturally occurring in the Lower American River. These juveniles and smolts may not be natal to the region, and therefore the other life stages would not be present in the system. Additionally, no late fall-run individuals have been identified using length-by-date criteria or genetic analysis since 2016.

Footnotes:

- Not applicable[1]. Modeled baseline temperature in June is 20.9ºC and Project increased temperature by 0.3ºC. All eggs/alevin would already be under extreme temperature stress and are unlikely to survive the baseline temperature of 20.9ºC and therefore a 0.3ºC increase is unlikely to result in additional mortality.
- Low[1]. Modeled baseline temperature in June is 20.9ºC and Project increased temperature by 0.3ºC. Some individuals would be experiencing decreased metabolic efficiency and reduced growth rates, but individuals already acclimated to warmer temperatures may show no reduced fitness; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperatures. Individuals may also outmigrate early to avoid temperature stress.
- Not applicable[2]. Modeled baseline temperature in June is 20.9ºC and Project increased temperature by 0.3ºC. All eggs/alevin would already be under extreme temperature stress and are unlikely to survive the baseline temperature of 20.9ºC and therefore a 0.3ºC increase is unlikely to result in additional mortality.
- Low[2]. Modeled baseline temperature in June is 20.9ºC, 21.4ºC in July, and 20.6ºC in September. Temperature increases caused by Project operations are 0.3ºC in June and July, and 0.5ºC in September. Effects to juveniles are considered low because the temperature increase is relatively small (0.3ºC). Some individuals could experience decreased metabolic efficiency and reduced growth rates, but individuals already acclimated to warmer temperatures develop thermal plasticity and may show no reduced fitness; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperatures. Individuals may also outmigrate early in response to temperature stress.

Table D3.4-2. Potential Effects from Change in Water Temperature to Winter-Run Chinook Salmon in the Lower American River at Watt Avenue, Existing Infrastructure [Baseline vs. Project]

	Winter-Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 1 Average Condition	Adult Migrating	<20	Dec-Jul	None	None	None	None	None	None	None	None	None	Negligible
	Adult Holding	<16	Dec-Jul	None	None	None	None	None	None	None	None	None	Negligible
	Spawner	<16	Late Apr - Early Aug	None	None	None	None	None	Negligible	None	None	None	Negligible
	Egg/Alevin	<12	May-Sep	None	None	None	None	None	Negligible	None	None	None	Negligible
	Juveniles	<15.5	Year-round*	None	None	None	None	None	Negligible	None	None	None	Negligible
	Smolt	<19	Nov-May	None	None	None	None	None	None	None	None	None	None
	Winter-Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 2 Warmest Baseline	Adult Migrating	<20	Dec-Jul	None	None	None	Negligible	None	None	None	None	June	Low[1]
	Adult Holding	<16	Dec-Jul	None	None	None	Negligible	None	None	None	None	June	Moderate[1]
	Spawner	<16	Late Apr - Early Aug	None	None	None	Negligible	None	None	None	None	June	Moderate[2]
	Egg/Alevin	<12	May-Sep	None	None	None	Negligible	None	None	None	None	June	Not Applicable[1]
	Juveniles	<15.5	Year-round*	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June	Low[2]
	Smolt	<19	Nov-May	None	Negligible	None	None	None	None	None	None	None	Negligible
	Winter-Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 3 Greatest Change	Adult Migrating	<20	Dec-Jul	None	None	None	Negligible	None	Negligible	None	Negligible	June, July	Low[3]
	Adult Holding	<16	Dec-Jul	None	None	None	Negligible	None	Negligible	None	Negligible	June, July	Moderate[3]
	Spawner	<16	Late Apr - Early Aug	None	None	None	Negligible	None	Negligible	None	Negligible	June, July	Moderate[4]
	Egg/Alevin	<12	May-Sep	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June, July, Sep	Not Applicable[2]
	Juveniles	<15.5	Year-round*	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June, July, Sep	Low[4]
	Smolt	<19	Nov-May	None	None	None	None	None	Negligible	None	None	None	Negligible

Sources: Temperature effects – NMFS 2019, McCullough 1999. Temperature modeling – Appendix C – Folsom Temperature Modeling in Support of Modification of Water Right Permit 21112

Note: Life stages shown in grey have no confirmed presence in the Lower American River. Since 2013, a total of 330 winter-run chinook juveniles-smolts have been captured in the Lower American River rotary screw traps. It is unclear if these individuals are part of a self-sustaining and distinct Lower American River population, or if they are transitory individuals seeking overwintering habitat within the Lower American River. The rankings assume that these individuals constitute their own, distinct subpopulation of winter-run chinook within the Lower American River. These juveniles and smolts may not be natal to the region, and therefore the other life stages would not be present in the system.

Footnotes:

- Low[1]. Modeled baseline temperature in June is 20.9ºC and Project increased temperature by 0.3ºC. Some adults would be under temperature stress, and this may cause them to delay migrating and may cause reductions in gamete size, quality, or abundance.
- Moderate[1]. Modeled baseline temperature in June is 20.9ºC and Project increased temperature by 0.3ºC. Many adults would already be under temperature stress, and this may cause reductions in gamete size, quality, or abundance.
- Moderate[2]. Modeled baseline temperature in June is 20.9ºC and Project increased temperature by 0.3ºC. Many spawners would already be under temperature stress, and this may cause pre-spawn mortality, cause individuals to delay spawning, or cause reductions in gamete size, quality, or abundance.
- Not applicable[1]. Modeled baseline temperature in June is 20.9ºC and Project increased temperature by 0.3ºC. All eggs/alevin would already be under extreme temperature stress and are unlikely to survive the baseline temperature of 20.9ºC and therefore a 0.3ºC increase is unlikely to result in additional mortality.
- Low[2]. Modeled baseline temperature in June is 20.9ºC and Project increased temperature by 0.3ºC. Some individuals would be experiencing decreased metabolic efficiency, reduced growth rates, struggle to metamorphose, or delay outmigration entirely, but those already acclimated to warmer temperatures may show no reduced fitness effects due to increased tolerance for higher temperatures; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperatures. Also, individuals may outmigrate early to avoid temperature stress.
- Low[3]. Modeled baseline temperature in June is 20.9ºC and 21.4ºC in July and Project increased temperature by 0.3ºC in both months. Some adults would already be under temperature stress, and this may cause them to delay migrating and may cause reductions in gamete size, quality, or abundance.
- Moderate[3]. Modeled baseline temperature in June is 20.9ºC and 21.4ºC in July and Project increased temperature by 0.3ºC in both months. Many adults would already be under temperature stress, and this may cause reductions in gamete size, quality, or abundance.
- Moderate[4]. Modeled baseline temperature in June is 20.9ºC and 21.4ºC in July and Project increased temperature by 0.3ºC in both months. Many spawners would already be under temperature stress, and this may cause pre-spawn mortality, cause individuals to delay spawning, or cause reductions in gamete size, quality, or abundance.
- Not applicable[2]. Modeled baseline temperature in June is 20.9ºC, 21.4ºC in July, and 20.6ºC in September. Temperature increases caused by Project operations are 0.3ºC in June and July, and 0.5ºC in September. All eggs/alevin would already be under extreme temperature stress and are unlikely to survive the baseline temperature of 20.9ºC and therefore temperature increases of 0.3ºC in June and July, and 0.5ºC in September are unlikely to result in additional mortality.
- Low[4]. Modeled baseline temperature in June is 20.9ºC, 21.4ºC in July, and 20.6ºC in September. Temperature increases caused by Project operations are 0.3ºC in June and July, and 0.5ºC in September. Effects are considered low because the magnitude of the temperature increases are relatively small. Some individuals would be experiencing decreased metabolic efficiency, reduced growth rates, struggle to metamorphose, or delay outmigration entirely, but those already acclimated to warmer temperatures may show no reduced fitness; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperatures. Also, individuals may outmigrate early to avoid temperature stress.

Table D3.4-3. Potential Effects from Change in Water Temperature to Spring-Run Chinook Salmon in the Lower American River at Watt Avenue, Existing Infrastructure [Baseline vs. Project]

	Spring-Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 1 Average Condition	Adult Migrating	<21	Mar-Late Aug	None	None	None	None	None	Negligible	None	None	None	Negligible
	Adult Holding	<16	Mar-Late Aug	None	None	None	None	None	Negligible	None	None	None	Negligible
	Spawner	<16	Late Aug-Oct	None	None	None	None	None	Negligible	None	None	None	None
	Egg/Alevin	<13	Sep-Nov	None	None	None	None	None	None	None	None	None	None
	Juveniles	<16	Year-round	None	None	None	None	None	Negligible	None	None	None	Negligible
	Smolt	<19	Mar-Jun & Nov-Apr	None	None	None	None	None	None	None	None	None	Negligible
	Spring-Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 2 Warmest Baseline	Adult Migrating	<21	Mar-Late Aug	None	None	None	Negligible	None	None	None	None	None	Negligible
	Adult Holding	<16	Mar-Late Aug	None	None	None	Negligible	None	None	None	None	June	Moderate[1]
	Spawner	<16	Late Aug-Oct	None	None	None	None	None	Negligible	None	Negligible	None	Negligible
	Egg/Alevin	<13	Sep-Nov	None	Negligible	None	None	None	Negligible	None	Negligible	None	Negligible
	Juveniles	<16	Year-round	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June	Low[1]
	Smolt	<19	Mar-Jun & Nov-Apr	None	Negligible	None	None	None	None	None	None	June	Low[2]
	Spring-Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 3 Greatest Change	Adult Migrating	<21	Mar-Late Aug	None	None	None	Negligible	None	Negligible	None	Negligible	July	Low[3]
	Adult Holding	<16	Mar-Late Aug	None	None	None	Negligible	None	Negligible	None	Negligible	June, July	Moderate[2]
	Spawner	<16	Late Aug-Oct	None	Negligible	None	None	None	Negligible	None	Negligible	Sep	Moderate[3]
	Egg/Alevin	<13	Sep-Nov	None	Negligible	None	None	None	Negligible	None	Negligible	Sep	Not Applicable[1]
	Juveniles	<16	Year-round	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June, July, Sep	Low[4]
	Smolt	<19	Mar-Jun & Nov-Apr	None	None	None	None	None	Negligible	None	Negligible	June	Low[5]

Sources: Temperature effects – Moyle et al. 2017, NMFS 2019, Myrick and Cech 2004. Temperature modeling – Appendix C – Folsom Temperature Modeling in Support of Modification of Water Right Permit 21112

Note: Life stages shown in grey have no confirmed presence in the Lower American River. Since 2013, a total of 75 spring-run chinook juveniles-smolts have been captured in the Lower American River rotary screw traps. It is unclear if these individuals are part of a self-sustaining and distinct Lower American River population, or if they are transitory individuals seeking overwintering habitat within the Lower American River. The rankings assume that these individuals constitute their own, distinct subpopulation of spring-run chinook within the Lower American River. These juveniles and smolts may not be natal to the region, and therefore the other life stages would not be present in the system.

Footnotes:

- Moderate[1]. Modeled baseline temperature in June is 20.9ºC and Project increased temperature by 0.3ºC. Many adults would already be under temperature stress resulting in reductions in gamete size, quality, or abundance.
- Low[1]. Modeled baseline temperature in June is 20.9ºC and Project increased temperature by 0.3ºC. Some individuals would be experiencing decreased metabolic efficiency and reduced growth rates, but individuals already acclimated to warmer temperatures may show no reduced fitness; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperature. Individuals may also outmigrate early to avoid temperature stress.
- Low[2]. Modeled baseline temperature in June is 20.9ºC and Project increased temperature by 0.3ºC. Individuals would be experiencing decreased metabolic efficiency, reduced growth rates, struggle to metamorphose, or delay outmigration entirely. Some individuals already acclimated to warmer temperatures may show no reduced fitness; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperature.
- Low[3]. Modeled baseline temperature in July is 21.4ºC and Project increased temperature by 0.3ºC. Some adults may be under temperature stress, and this may cause them to delay migrating and may cause reductions in gamete size, quality, or abundance.
- Moderate[2]. Modeled baseline temperature in June is 20.9ºC and 21.4ºC in July and Project increased temperature by 0.3ºC in both months. Many adults would already be under temperature stress, and this may cause reductions in gamete size, quality, or abundance.
- Moderate[3]. Modeled baseline temperature in September is 20.6ºC and Project increased temperature by 0.5ºC. Many spawners would already be under temperature stress, and this may cause pre-spawn mortality, cause individuals to delay spawning, or cause reductions in gamete size, quality, or abundance.
- Not applicable[1]. Modeled baseline temperature in September is 20.6ºC and Project increased temperature by 0.5ºC. All eggs/alevin would already be under extreme temperature stress and are unlikely to survive the baseline temperature of 20.9ºC, therefore a 0.3ºC increase is unlikely to result in additional mortality.
- Low[4]. Modeled baseline temperature in June is 20.9ºC, 21.2ºC in July, and 20.6ºC in September. Temperature increases caused by Project operations are 0.3ºC in June and July, and 0.5ºC in September. Some individuals would be experiencing decreased metabolic efficiency and reduced growth rates, but individuals already acclimated to warmer temperatures may show no reduced fitness; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperatures. Individuals may also outmigrate early to avoid temperature stress.
- Low[5]. Modeled baseline temperature in June is 20.9ºC and Project increased temperature by 0.3ºC. Individuals would be experiencing decreased metabolic efficiency, reduced growth rates, struggle to metamorphose, or delay outmigration entirely. Some individuals already acclimated to warmer temperatures may show no reduced fitness; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperatures.

Under Scenario 3 (Greatest Change), low level effects are expected in June (20.9°C baseline temperature, 0.3°C Project increase), July (21.4°C baseline temperature, 0.3°C Project increase), and September (20.6°C baseline temperature, 0.5°C Project increase) of critically dry years for the juveniles of all three species. Late fall-run chinook juveniles have a 7-day, daily average maximum temperature of 16°C, winter-run chinook juveniles have a 7-day, daily average maximum temperature of 15.5°C, and spring-run chinook juveniles have a 7-day, daily average maximum temperature of 16°C. The potential effect level is considered low across runs because the magnitude of the temperature increase is relatively small (0.3ºC), because of the thermal plasticity shown by juvenile chinook as well as their ability to emigrate into cooler habitats.

D3.4.2 Project Operations with Existing Infrastructure and Future Water Demands

Tables D3.4-4 to D3.4-6 provide an evaluation of potential effects on each life stage of late fall-run, spring-run, and winter-run chinook salmon in the Lower American River at Watt Avenue bridge due to changes in water temperature modeled for Project operations when assuming future water demands and the use of existing infrastructure.

Under Scenario 1 (Average Condition) and Scenario 2 (Warmest Baseline) potential effects to late fall-run, spring-run, and winter-run chinook juveniles due to changes in water temperatures during Project operations would be negligible in all five water year types..

Under Scenario 3 (Greatest Change) there would be low effects in dry and critically dry years to all species. In a single dry year in the 40-year modeled period, all three species would potentially experience low effects in August (19.9°C baseline temperature, 0.5°C Project increase). In critically dry years, all three species would potentially experience low effects in June (20.8°C baseline temperature, 0.3°C Project increase) and October (18.1°C baseline temperature, 0.8°C Project increase). The potential effect level is considered low across runs due to the thermal plasticity shown by juvenile chinook as well as their ability to emigrate into cooler habitats.

Table D3.4-4. Potential Effects from Change in Water Temperature to Late Fall-Run Chinook Salmon in the Lower American River at Watt Avenue, Existing Infrastructure [Future Baseline vs. Future Project]

	Late Fall Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 1 Average Condition	Adult Migrating	<20	Oct-Apr	None	None	None	None	None	Negligible	None	None	None	Negligible
	Adult Holding	<16	Oct-Apr	None	None	None	None	None	Negligible	None	None	None	Negligible
	Spawner	<14	Early Jan-Apr	None	None	None	None	None	None	None	None	None	None
	Egg/Alevin	<12	Jan-June	None	None	None	None	None	None	None	None	None	Negligible
	Juveniles	<16	Year-round	None	None	None	None	None	Negligible	None	Negligible	None	Negligible
	Smolt	<19	Nov-May	None	None	None	None	None	None	None	None	None	Negligible
	Late Fall Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 2 Warmest Baseline	Adult Migrating	<20	Oct-Apr	None	Negligible	None	None	None	Negligible	None	Negligible	None	Negligible
	Adult Holding	<16	Oct-Apr	None	Negligible	None	None	None	Negligible	None	Negligible	None	Negligible
	Spawner	<14	Early Jan-Apr	None	None	None	None	None	None	None	None	None	Negligible
	Egg/Alevin	<12	Jan-June	None	None	None	None	None	None	None	Negligible	None	Negligible
	Juveniles	<16	Year-round	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Smolt	<19	Nov-May	None	Negligible	None	None	None	None	None	Negligible	None	Negligible
	Late Fall Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 3 Greatest Change	Adult Migrating	<20	Oct-Apr	None	Negligible	None	None	None	Negligible	None	Negligible	None	Negligible
	Adult Holding	<16	Oct-Apr	None	Negligible	None	None	None	Negligible	None	Negligible	Oct	Moderate[1]
	Spawner	<14	Early Jan-Apr	None	None	None	None	None	Negligible	None	None	None	Negligible
	Egg/Alevin	<12	Jan-June	None	None	None	None	None	Negligible	None	Negligible	June	Not Applicable[1]
	Juveniles	<16	Year-round	None	Negligible	None	Negligible	None	Negligible	Aug	Low[1]	June, Oct	Low[2]
	Smolt	<19	Nov-May	None	Negligible	None	None	None	Negligible	None	Negligible	None	Negligible

Sources: Temperature effects – Moyle et al. 2017, NMFS 2019, Myrick and Cech 2004. Temperature modeling – Appendix C – Folsom Temperature Modeling in Support of Modification of Water Right Permit 21112

Note: Life stages shown in grey have no confirmed presence in the Lower American River. Since 2013, a total of 41 late fall-run chinook juveniles-smolts have been captured in the Lower American River rotary screw traps. It is unclear if these individuals are part of a self-sustaining and distinct LAR population, or if they are transitory individuals seeking overwintering habitat within the Lower American River. The rankings assume that these individuals constitute their own, distinct subpopulation of late fall-run chinook within the Lower American River. These juveniles and smolts may not be natal to the region, and therefore the other life stages would not be present in the system. Additionally, no late fall-run individuals have been identified using length-by-date criteria or genetic analysis since 2016.

Footnotes:

- Low[1]. Modeled baseline temperature in August is 19.9ºC and Project increased temperature by 0.5ºC. Some individuals could experience decreased metabolic efficiency and reduced growth rates, but individuals already acclimated to warmer temperatures may show no reduced fitness; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperature. Individuals may also outmigrate early to avoid temperature stress.
- Moderate[1]. Modeled baseline temperature in October is 18.1ºC and Project increased temperature by 0.8ºC. Many adults would already be under temperature stress, and this may cause reductions in gamete size, quality, or abundance.
- Not applicable[1]. Modeled baseline temperature in June is 20.8ºC and Project increased temperature by 0.3ºC. All eggs/alevin would already be under extreme temperature stress and unlikely to survive the baseline temperature, therefore a 0.3ºC increase is unlikely to result in additional mortality.
- Low[2]. Modeled baseline temperature in June is 20.8ºC and 18.1ºC in October, and the Project increased temperature by 0.3ºC and 0.8ºC, respectively. Some individuals could experience decreased metabolic efficiency and reduced growth rates, but individuals already acclimated to warmer temperatures may show no reduced fitness; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperature.

Table D3.4-5. Potential Effects from Change in Water Temperature to Winter-Run Chinook Salmon in the Lower American River at Watt Avenue, Existing Infrastructure [Future Baseline vs. Future Project]

	Winter-Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 1 Average Condition	Adult Migrating	<20	Dec-Jul	None	None	None	None	None	None	None	None	None	Negligible
	Adult Holding	<16	Dec-Jul	None	None	None	None	None	None	None	None	None	Negligible
	Spawner	<16	Late Apr - Early Aug	None	None	None	None	None	None	None	Negligible	None	Negligible
	Egg/Alevin	<12	May-Sep	None	None	None	None	None	None	None	Negligible	None	Negligible
	Juveniles	<15.5	Year-round*	None	None	None	None	None	Negligible	None	Negligible	None	Negligible
	Smolt	<19	Nov-May	None	None	None	None	None	None	None	None	None	Negligible
	Winter-Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 2 Warmest Baseline	Adult Migrating	<20	Dec-Jul	None	None	None	Negligible	None	None	None	Negligible	None	Negligible
	Adult Holding	<16	Dec-Jul	None	None	None	Negligible	None	None	None	Negligible	None	Negligible
	Spawner	<16	Late Apr - Early Aug	None	Negligible	None	Negligible	None	None	None	Negligible	None	Negligible
	Egg/Alevin	<12	May-Sep	None	Negligible	None	Negligible	None	None	None	Negligible	None	Negligible
	Juveniles	<15.5	Year-round*	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Smolt	<19	Nov-May	None	Negligible	None	None	None	None	None	Negligible	None	Negligible
	Winter-Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 3 Greatest Change	Adult Migrating	<20	Dec-Jul	None	None	None	Negligible	None	Negligible	None	Negligible	June	Low[3]
	Adult Holding	<16	Dec-Jul	None	None	None	Negligible	None	Negligible	None	Negligible	June	Moderate[2]
	Spawner	<16	Late Apr - Early Aug	None	None	None	Negligible	None	Negligible	Aug	Moderate[1]	June	Moderate[3]
	Egg/Alevin	<12	May-Sep	None	None	None	Negligible	None	Negligible	Aug	Not Applicable[1]	June, Oct	Not Applicable[2]
	Juveniles	<15.5	Year-round*	None	Negligible	None	Negligible	None	Negligible	Aug	Low[1]	June, Oct	Low[4]
	Smolt	<19	Nov-May	None	Negligible	None	None	None	Negligible	Aug	Low[2]	June	Low[5]

Sources: Temperature effects – NMFS 2019, McCullough 1999. Temperature modeling – Appendix C – Folsom Temperature Modeling in Support of Modification of Water Right Permit 21112

Note: Life stages shown in grey have no confirmed presence in the Lower American River. Since 2013, a total of 330 winter-run chinook juveniles-smolts have been captured in the Lower American River rotary screw traps. It is unclear if these individuals are part of a self-sustaining and distinct LAR population, or if they are transitory individuals seeking overwintering habitat within the Lower American River. The rankings assume that these individuals constitute their own, distinct subpopulation of winter-run chinook within the Lower American River. These juveniles and smolts may not be natal to the region, and therefore the other life stages would not be present in the system.

Footnotes:

- Moderate[1]. Modeled baseline temperature in August is 19.9ºC and Project increased temperature by 0.5ºC. Many spawners would already be under temperature stress, and increased temperature may cause pre-spawn mortality or cause reductions in gamete size, quality, or abundance.
- Not applicable[1]. Modeled baseline temperature in August is 19.9ºC and Project increased temperature by 0.5ºC. All eggs/alevin would already be under extreme temperature stress and are unlikely to survive the baseline temperature, therefore a 0.5ºC increase is unlikely to result in additional mortality.
- Low[1]. Modeled baseline temperature in August is 19.9ºC and Project increased temperature by 0.5ºC. Some individuals would be experiencing decreased metabolic efficiency and reduced growth rates. However, individuals already acclimated to warmer temperatures may show no reduced fitness; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperatures. Individuals may also outmigrate early to avoid temperature stress.
- Low[2]. Modeled baseline temperature in August is 19.9ºC and Project increased temperature by 0.5ºC. However, individuals already acclimated to warmer temperatures may show no reduced fitness; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperatures.
- Low[3]. Modeled baseline temperature in June is 20.8ºC and Project increased temperature by 0.3ºC. Some adults would be under temperature stress, and this may cause them to delay migrating and may cause reductions in gamete size, quality, or abundance.
- Moderate[2]. Modeled baseline temperature in June is 20.8ºC and Project increased temperature by 0.3ºC. Many adults would already be under temperature stress, and this may cause reductions in gamete size, quality, or abundance.
- Moderate[3]. Modeled baseline temperature in June is 20.8ºC and Project increased temperature by 0.3ºC. Many spawners would already be under temperature stress, and this may cause pre-spawn mortality, cause individuals to delay spawning, or cause reductions in gamete size, quality, or abundance.
- Not applicable[2]. Modeled baseline temperature in June is 20.8ºC and 18.1ºC in October, and the Project increased temperature by 0.3ºC and 0.8ºC, respectively. All eggs/alevin would already be under extreme temperature stress and are unlikely to survive the baseline temperatures, therefore a 0.3 ºC or 0.8ºC increase is unlikely to result in additional mortality.
- Low[4]. Modeled baseline temperature in June is 20.8ºC and 18.1ºC in October, and the Project increased temperature by 0.3ºC and 0.8ºC, respectively. Some individuals may experience decreased metabolic efficiency and reduced growth rates However, individuals already acclimated to warmer temperatures may show no reduced fitness; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperatures. Individuals may also outmigrate early to avoid temperature stress.
- Low[5]. Modeled baseline temperature in June is 20.8ºC and Project increased temperature by 0.3ºC. Some individuals may experience decreased metabolic efficiency, reduced growth rates, struggle to metamorphose, or delay outmigration entirely. However, individuals already acclimated to warmer temperatures may show no reduced fitness; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperatures.

Table D3.4-6. Potential Effects from Change in Water Temperature to Spring-Run Chinook Salmon in the Lower American River at Watt Avenue, Existing Infrastructure [Future Baseline vs. Future Project]

	Spring-Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 1 Average Condition	Adult Migrating	<21	Mar-Late Aug	None	None	None	None	None	None	None	Negligible	None	Negligible
	Adult Holding	<16	Mar-Late Aug	None	None	None	None	None	None	None	Negligible	None	Negligible
	Spawner	<16	Late Aug-Oct	None	None	None	None	None	Negligible	None	Negligible	None	Negligible
	Egg/Alevin	<13	Sep-Nov	None	None	None	None	None	Negligible	None	None	None	Negligible
	Juveniles	<16	Year-round	None	None	None	None	None	Negligible	None	Negligible	None	Negligible
	Smolt	<19	Mar-Jun & Nov-Apr	None	None	None	None	None	None	None	None	None	Negligible
	Spring-Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 2 Warmest Baseline	Adult Migrating	<21	Mar-Late Aug	None	Negligible	None	Negligible	None	None	None	Negligible	None	Negligible
	Adult Holding	<16	Mar-Late Aug	None	Negligible	None	Negligible	None	None	None	Negligible	None	Negligible
	Spawner	<16	Late Aug-Oct	None	None	None	None	None	Negligible	None	Negligible	None	None
	Egg/Alevin	<13	Sep-Nov	None	Negligible	None	None	None	Negligible	None	Negligible	None	None
	Juveniles	<16	Year-round	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Smolt	<19	Mar-Jun & Nov-Apr	None	Negligible	None	None	None	None	None	Negligible	None	Negligible
	Spring-Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 3 Greatest Change	Adult Migrating	<21	Mar-Late Aug	None	None	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Adult Holding	<16	Mar-Late Aug	None	None	None	Negligible	None	Negligible	Aug	Moderate[1]	June	Moderate[3]
	Spawner	<16	Late Aug-Oct	None	Negligible	None	None	None	Negligible	Aug	Moderate[2]	Oct	Moderate[4]
	Egg/Alevin	<13	Sep-Nov	None	Negligible	None	None	None	Negligible	None	Negligible	Oct	Not Applicable[1]
	Juveniles	<16	Year-round	None	Negligible	None	Negligible	None	Negligible	Aug	Low[1]	June, Oct	Low[2]
	Smolt	<19	Mar-Jun & Nov-Apr	None	Negligible	None	None	None	Negligible	None	Negligible	June	Low[3]

Sources: Temperature effects – Moyle et al. 2017, NMFS 2019, Myrick and Cech 2004. Temperature modeling – Appendix C – Folsom Temperature Modeling in Support of Modification of Water Right Permit 21112

Note: Life stages shown in grey have no confirmed presence in the Lower American River. Since 2013, a total of 75 spring-run chinook juveniles-smolts have been captured in the Lower American River rotary screw traps. It is unclear if these individuals are part of a self-sustaining and distinct LAR population, or if they are transitory individuals seeking overwintering habitat within the project area. The rankings assume that these individuals constitute their own, distinct subpopulation of spring-run chinook within the Lower American River. These juveniles and smolts may not be natal to the region, and therefore the other life stages would not be present in the system.

Footnotes:

- Moderate[1]. Modeled baseline temperature in August is 19.9ºC and Project increased temperature by 0.5ºC. Some adults may be under temperature stress, and this may cause reductions in gamete size, quality, or abundance.
- Moderate[2]. Modeled baseline temperature in August is 19.9ºC and Project increased temperature by 0.5ºC. Some spawners may be under temperature stress, and this may cause reductions in gamete size, quality, or abundance.
- Low[1]. Modeled baseline temperature in August is 19.9ºC and Project increased temperature by 0.5ºC. Some individuals could experience decreased metabolic efficiency and reduced growth rates, but individuals already acclimated to warmer temperatures may show no reduced fitness; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperatures. Individuals may also outmigrate early to avoid temperature stress.
- Moderate[3]. Modeled baseline temperature in June is 20.8ºC and Project increased temperature by 0.3ºC. The magnitude of the temperature increase is relatively small (0.3ºC), but many adults would already be under temperature stress, and this may cause reductions in gamete size, quality, or abundance.
- Moderate[4]. Modeled baseline temperature in October is 18.1ºC and Project increased temperature by 0.8ºC. Many spawners would already be under temperature stress, and this may cause pre-spawn mortality, cause individuals to delay spawning, or cause reductions in gamete size, quality, or abundance.
- Not applicable[1]. Modeled baseline temperature in October is 18.1ºC and Project increased temperature by 0.8ºC. All eggs/alevin would already be under extreme temperature stress and are unlikely to survive the baseline temperature of 18.1ºC, therefore a 0.8ºC increase is unlikely to result in additional mortality.
- Low[2]. Modeled baseline temperature in June is 20.8ºC and 18.1ºC in October. Temperature increases due to Project operations are 0.3ºC and 0.8ºC, respectively. Some individuals could experience decreased metabolic efficiency and reduced growth rates, but individuals already acclimated to warmer temperatures may show no reduced fitness; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperatures. Individuals may also outmigrate early to avoid temperature stress.
- Low[3]. Modeled baseline temperature in June is 20.8ºC and Project increased temperature is 0.3ºC. The magnitude of the temperature increase is relatively small (0.3ºC), but some individuals could experience decreased metabolic efficiency and reduced growth rates, but individuals already acclimated to warmer temperatures may show no reduced fitness; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperatures. Individuals may also outmigrate early to avoid temperature stress.

D3.4.3 POST-CONSTRUCTION OPERATIONS WITH CURRENT WATER DEMANDS

Tables D3.4-7 to D3.4-9 provide an evaluation of potential effects on each life stage of late fall-run, spring-run, and winter-run chinook salmon in the Lower American River at Watt Avenue bridge due to changes in water temperature modeled for Project operations which are expected to occur post-construction assuming current water demands.

Under Scenario 1 (Average Conditions) potential effects to late fall-run, spring-run, and winter-run chinook juveniles due to changes in water temperatures during Project operations would be negligible in all five water year types.

Under Scenario 2 (Warmest Baseline), there would be potential low effects for late fall-run chinook and spring-run chinook juveniles (7-day, daily average maximum temperature 16°C) and winter-run chinook juveniles (7-day, daily average maximum temperature of 15.5°C) in June (20.9°C baseline temperature, 0.3°C Project increase) of critically dry years. The potential effect level is low across runs because the magnitude of the temperature increase is relatively small (0.3ºC), the thermal plasticity shown by juvenile chinook as well as their ability to emigrate into cooler habitats.

Under Scenario 3 (Greatest Change), there would be potential low effects for juvenile late fall-run chinook, winter-run chinook, and spring-run chinook salmon in June (20.9°C baseline temperature, 0.3°C Project increase) and September (20.6°C baseline temperature, 0.5°C Project increase) in critically dry years. The potential effect level is low across runs because the magnitude of the temperature increase is relatively small, the thermal plasticity shown by juvenile chinook as well as their ability to emigrate into cooler habitats.

Table D3.4-7. Potential Effects from Change in Water Temperature to Late Fall-Run Chinook Salmon in the Lower American River at Watt Avenue, Post-Construction [Baseline vs. Project]

	Late Fall Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 1 Average Condition	Adult Migrating	<20	Oct-Apr	None	None	None	None	None	None	None	None	None	None
	Adult Holding	<16	Oct-Apr	None	None	None	None	None	None	None	None	None	None
	Spawner	<14	Early Jan-Apr	None	None	None	None	None	None	None	None	None	None
	Egg/Alevin	<12	Jan-June	None	None	None	None	None	None	None	None	None	Negligible
	Juveniles	<16	Year-round	None	None	None	None	None	Negligible	None	None	None	Negligible
	Smolt	<19	Nov-May	None	None	None	None	None	None	None	None	None	Negligible
	Late Fall Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 2 Warmest Baseline	Adult Migrating	<20	Oct-Apr	None	None	None	None	None	Negligible	None	Negligible	None	Negligible
	Adult Holding	<16	Oct-Apr	None	None	None	None	None	Negligible	None	Negligible	None	Negligible
	Spawner	<14	Early Jan-Apr	None	None	None	None	None	None	None	None	None	Negligible
	Egg/Alevin	<12	Jan-June	None	None	None	None	None	None	None	None	June	Not Applicable[1]
	Juveniles	<16	Year-round	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June	Low[1]
	Smolt	<19	Nov-May	None	None	None	None	None	None	None	None	None	Negligible
	Late Fall Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 3 Greatest Change	Adult Migrating	<20	Oct-Apr	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Adult Holding	<16	Oct-Apr	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Spawner	<14	Early Jan-Apr	None	None	None	None	None	Negligible	None	None	None	Negligible
	Egg/Alevin	<12	Jan-June	None	None	None	None	None	Negligible	None	Negligible	June	Not Applicable[1]
	Juveniles	<16	Year-round	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June, Sep	Low[2]
	Smolt	<19	Nov-May	None	Negligible	None	None	None	Negligible	None	Negligible	None	Negligible

Sources: Temperature effects – Moyle et al. 2017, NMFS 2019, Myrick and Cech 2004. Temperature modeling – Appendix C – Folsom Temperature Modeling in Support of Modification of Water Right Permit 21112

Note: Life stages shown in grey have no confirmed presence in the Lower American River. Since 2013, a total of 41 late fall-run chinook juveniles-smolts have been captured in the Lower American River rotary screw traps. It is unclear if these individuals are part of a self-sustaining and distinct LAR population, or if they are transitory individuals seeking overwintering habitat within the project area. The rankings assume that these individuals constitute their own, distinct subpopulation of late fall-run chinook within the Lower American River. These juveniles and smolts may not be natal to the region, and therefore the other life stages would not be present in the system. Additionally, no late fall-run individuals have been identified using length-by-date criteria or genetic analysis since 2016.

Footnotes:

- Not applicable[1]. Modeled baseline temperature in June is 20.9ºC and Project increased temperature by 0.3ºC. All eggs/alevin would already be under extreme temperature stress and are unlikely to survive the baseline temperature of 20.9ºC, therefore a 0.3ºC increase is unlikely to result in additional mortality
- Low[1]. Modeled baseline temperature in June is 20.9ºC and Project increased temperature by 0.3ºC Some individuals may experience decreased metabolic efficiency and reduced growth rates, but individuals already acclimated to warmer temperatures may show no reduced fitness; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperatures. Individuals may also outmigrate early to avoid temperature stress.
- Low[2]. Modeled baseline temperature in June is 20.9ºCand 20.6ºC in September. Temperature increases due to Project operations are 0.3ºC and 0.5ºC, respectively. Some individuals may experience decreased metabolic efficiency and reduced growth rates but individuals already acclimated to warmer temperatures may show no reduced fitness; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperatures. Individuals may also outmigrate early to avoid temperature stress

Table D3.4-8. Potential Effects from Change in Water Temperature to Winter-Run Chinook Salmon in the Lower American River at Watt Avenue, Post-Construction [Baseline vs. Project]

	Winter-Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 1 Average Condition	Adult Migrating	<20	Dec-Jul	None	None	None	None	None	None	None	None	None	Negligible
	Adult Holding	<16	Dec-Jul	None	None	None	None	None	None	None	None	None	Negligible
	Spawner	<16	Late Apr - Early Aug	None	None	None	None	None	Negligible	None	None	None	Negligible
	Egg/Alevin	<12	May-Sep	None	None	None	None	None	Negligible	None	None	None	Negligible
	Juveniles	<15.5	Year-round*	None	None	None	None	None	Negligible	None	None	None	Negligible
	Smolt	<19	Nov-May	None	None	None	None	None	None	None	None	None	Negligible
	Winter-Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 2 Warmest Baseline	Adult Migrating	<20	Dec-Jul	None	None	None	None	None	None	None	None	June	Low[1]
	Adult Holding	<16	Dec-Jul	None	None	None	None	None	None	None	None	June	Moderate[1]
	Spawner	<16	Late Apr - Early Aug	None	Negligible	None	None	None	None	None	None	June	Moderate[2]
	Egg/Alevin	<12	May-Sep	None	Negligible	None	Negligible	None	None	None	None	June	Not Applicable[1]
	Juveniles	<15.5	Year-round*	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June	Low[2]
	Smolt	<19	Nov-May	None	None	None	None	None	None	None	None	None	Negligible
	Winter-Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 3 Greatest Change	Adult Migrating	<20	Dec-Jul	None	Negligible	None	None	None	Negligible	None	Negligible	June	Low[1]
	Adult Holding	<16	Dec-Jul	None	Negligible	None	None	None	Negligible	None	Negligible	June	Moderate[3]
	Spawner	<16	Late Apr - Early Aug	None	Negligible	None	None	None	None	None	Negligible	June	Moderate[4]
	Egg/Alevin	<12	May-Sep	None	Negligible	None	None	None	None	None	Negligible	June, Sep	Not Applicable[2]
	Juveniles	<15.5	Year-round*	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June, Sep	Low[3]
	Smolt	<19	Nov-May	None	Negligible	None	None	None	Negligible	None	Negligible	None	Negligible

Sources: Temperature effects – NMFS 2019, McCullough 1999. Temperature modeling – Appendix C – Folsom Temperature Modeling in Support of Modification of Water Right Permit 21112

Note: Life stages shown in grey have no confirmed presence in the Lower American River. Since 2013, a total of 330 winter-run chinook juveniles-smolts have been captured in the Lower American River rotary screw traps. It is unclear if these individuals are part of a self-sustaining and distinct LAR population, or if they are transitory individuals seeking overwintering habitat within the Lower American River. The rankings assume that these individuals constitute their own, distinct subpopulation of winter-run chinook within the Lower American River. These juveniles and smolts may not be natal to the region, and therefore the other life stages would not be present in the system.

Footnotes:

- Low[1]. Modeled baseline temperature in June is 20.9ºC and Project increased temperature by 0.3ºC. Some adults would be under temperature stress, and this may cause them to delay migrating and may cause reductions in gamete size, quality, or abundance.
- Moderate[1]. Modeled baseline temperature in June is 20.9ºC and Project increased temperature by 0.3ºC. Many adults would already be under temperature stress, and this may cause reductions in gamete size, quality, or abundance.
- Moderate[2]. Modeled baseline temperature in June is 20.9ºC and Project increased temperature by 0.3ºC. Many spawners would already be under temperature stress, and this is may cause pre-spawn mortality, cause individuals to delay spawning, or cause reductions in gamete size, quality, or abundance.
- Not applicable[1]. Modeled baseline temperature in June is 20.9ºC and Project increased temperature by 0.3ºC. All eggs/alevin would already be under extreme temperature stress and are unlikely to survive the baseline temperature of 20.9ºC, therefore a 0.3ºC increase is unlikely to result in additional mortality.
- Low[2]. Modeled baseline temperature in June is 20.9ºC and Project increased temperature by 0.3ºC. Some individuals may experience decreased metabolic efficiency and reduced growth rates, but individuals already acclimated to warmer temperatures may show no reduced fitness; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperatures. Individuals may also outmigrate early to avoid temperature stress.
- Moderate[3]. Modeled baseline temperature in June is 20.9ºC. Temperature increase due to Project operations is 0.3ºC. The magnitude of the temperature increase is relatively small (0.3ºC), but many adults would already be under temperature stress, and this may cause reductions in gamete size, quality, or abundance.
- Moderate[4]. Modeled baseline temperature in June is 20.9ºC. Temperature increase due to Project operations is 0.3ºC. Many spawners would already be under temperature stress, and this may cause pre-spawn mortality, cause individuals to delay spawning, or cause reductions in gamete size, quality, or abundance.
- Not applicable[2]. Modeled baseline temperature in June is 20.9ºC and 20.6ºC in September. Temperature increases due to Project operations are 0.3ºC and 0.5ºC, respectively. All eggs/alevin would already be under extreme temperature stress and are unlikely to survive the baseline temperatures, therefore increases of 0.3ºC 0.2ºC, or 0.5ºC are unlikely to result in additional mortality.
- Low[3]. Modeled baseline temperature in June is 20.9ºCand 20.6ºC in September. Temperature increases due to Project operations are 0.3ºC and 0.5ºC, respectively. Some individuals may experience decreased metabolic efficiency and reduced growth rates but individuals already acclimated to warmer temperatures may show no reduced fitness; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperatures. Individuals may also outmigrate early to avoid temperature stress effects.

Table D3.4-9. Potential Effects from Change in Water Temperature to Spring-Run Chinook Salmon in the Lower American River at Watt Avenue, Post-Construction [Baseline vs. Project]

	Spring-Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 1 Average Condition	Adult Migrating	<21	Mar-Late Aug	None	None	None	None	None	Negligible	None	None	None	Negligible
	Adult Holding	<16	Mar-Late Aug	None	None	None	None	None	Negligible	None	None	None	Negligible
	Spawner	<16	Late Aug-Oct	None	None	None	None	None	None	None	None	None	None
	Egg/Alevin	<13	Sep-Nov	None	None	None	None	None	Negligible	None	None	None	None
	Juveniles	<16	Year-round	None	None	None	None	None	Negligible	None	None	None	Negligible
	Smolt	<19	Mar-Jun & Nov-Apr	None	None	None	None	None	None	None	None	None	Negligible
	Spring-Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 2 Warmest Baseline	Adult Migrating	<21	Mar-Late Aug	None	Negligible	None	None	None	None	None	None	None	Negligible
	Adult Holding	<16	Mar-Late Aug	None	Negligible	None	None	None	None	None	None	June	Moderate[1]
	Spawner	<16	Late Aug-Oct	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Egg/Alevin	<13	Sep-Nov	None	None	None	Negligible	None	Negligible	None	Negligible	Oct	Negligible
	Juveniles	<16	Year-round	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June	Low[1]
	Smolt	<19	Mar-Jun & Nov-Apr	None	None	None	None	None	None	None	None	June	Low[2]
	Spring-Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 3 Greatest Change	Adult Migrating	<21	Mar-Late Aug	None	Negligible	None	None	None	Negligible	None	Negligible	None	Negligible
	Adult Holding	<16	Mar-Late Aug	None	Negligible	None	None	None	Negligible	None	Negligible	June	Moderate[2]
	Spawner	<16	Late Aug-Oct	None	Negligible	None	Negligible	None	Negligible	None	Negligible	Sep	Moderate[3]
	Egg/Alevin	<13	Sep-Nov	None	None	None	Negligible	None	Negligible	None	Negligible	Sep	Not Applicable [1]
	Juveniles	<16	Year-round	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June, Sep	Low[3]
	Smolt	<19	Mar-Jun & Nov-Apr	None	Negligible	None	None	None	Negligible	None	Negligible	None	Negligible

Sources: Temperature effects – Moyle et al. 2017, NMFS 2019, Myrick and Cech 2004. Temperature modeling – Appendix C – Folsom Temperature Modeling in Support of Modification of Water Right Permit 21112

Note: Life stages shown in grey have no confirmed presence in the Lower American River. Since 2013, a total of 75 spring-run chinook juveniles-smolts have been captured in the Lower American River rotary screw traps. It is unclear if these individuals are part of a self-sustaining and distinct LAR population, or if they are transitory individuals seeking overwintering habitat within the Lower American River. The rankings assume that these individuals constitute their own, distinct subpopulation of spring-run chinook within the Lower American River. These juveniles and smolts may not be natal to the region, and therefore the other life stages would not be present in the system.

Footnotes:

- Moderate[1]. Modeled baseline temperature in June is 20.9ºC and Project increased temperature by 0.3ºC. Many spawners would already be under temperature stress, and this may cause pre-spawn mortality, cause individuals to delay spawning, or cause reductions in gamete size, quality, or abundance.
- Low[1]. Modeled baseline temperature in June is 20.9ºC and Project increased temperature by 0.3ºC. Some individuals could experience decreased metabolic efficiency and reduced growth rates, but individuals already acclimated to warmer temperatures may show no reduced fitness effects; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperatures. Individuals may also outmigrate early to avoid temperature stress
- Low[2]. Modeled baseline temperature in June is 20.9ºC and Project increased temperature by 0.3ºC. Individuals could experience decreased metabolic efficiency, reduced growth rates, struggle to metamorphose, or delay outmigration entirely. Some individuals already acclimated to warmer temperatures may show no reduced fitness; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperatures. Individuals may also outmigrate early to avoid temperature stress.
- Moderate[2]. Modeled baseline temperature in June is 20.9ºC. Temperature increase due to Project operations is 0.3ºC. Many adults would already be under temperature stress, and this may cause reductions in gamete size, quality, or abundance.
- Moderate[3]. Modeled baseline temperature in September is 20.6ºC and Project increased temperature by 0.5ºC. Many spawners would already be under temperature stress, and this may cause pre-spawn mortality, but is may cause individuals to delay spawning, or cause reductions in gamete size, quality, or abundance.
- Not applicable[1]. Modeled baseline temperature in September is 20.6ºC and Project increased temperature by 0.5ºC. All eggs/alevin would already be under extreme temperature stress and are unlikely to survive the baseline temperature of 20.6ºC, therefore a 0.5ºC increase is unlikely to result in additional mortality.
- Low[3]. Modeled baseline temperature in June is 20.9ºCand 20.6ºC in September. Temperature increases due to Project operations are 0.3ºCand 0.5ºC, respectively. Some individuals may experience decreased metabolic efficiency and reduced growth rates, but individuals already acclimated to warmer temperatures may show no reduced fitness; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperatures. Individuals may also outmigrate early to avoid temperature stress.

D3.4.4 POST-CONSTRUCTION OPERATIONS WITH FUTURE WATER DEMANDS

Tables D3.4-10 to D3.4-12 provide an evaluation of potential effects on each life stage of late fall-run, spring-run, and winter-run chinook salmon in the Lower American River at Watt Avenue bridge due to changes in water temperature modeled for Project operations which are expected to occur post-construction assuming future water demands.

Under Scenario 1 (Average Condition) and Scenario 2 (Warmest Baseline) potential effects to late fall-run, spring-run, and winter-run chinook juveniles due to changes in water temperatures during Project operations would be negligible in all five water year types.

Under Scenario 3 (Greatest Change), in critically dry years, the juveniles of all three species would be under temperature stress in June (17.9°C baseline temperature, 0.3°C Project increase). The potential effect is considered low across runs because the magnitude of the temperature increase is relatively small (0.3ºC), the thermal plasticity shown by juvenile chinook as well as their ability to emigrate into cooler habitats.

Table D3.4-10. Potential Effects from Change in Water Temperature to Chinook late Fall-Run Salmon in the Lower American River at Watt Avenue, Post-Construction [Future Baseline vs. Future Project]

	Late Fall Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 1 Average Condition	Adult Migrating	<20	Oct-Apr	None	None	None	None	None	Negligible	None	None	None	None
	Adult Holding	<16	Oct-Apr	None	None	None	None	None	Negligible	None	None	None	None
	Spawner	<14	Early Jan-Apr	None	None	None	None	None	None	None	None	None	None
	Egg/Alevin	<12	Jan-June	None	None	None	None	None	None	None	None	None	Negligible
	Juveniles	<16	Year-round	None	None	None	None	None	Negligible	None	Negligible	None	Negligible
	Smolt	<19	Nov-May	None	None	None	None	None	None	None	None	None	Negligible
	Late Fall Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 2 Warmest Baseline	Adult Migrating	<20	Oct-Apr	None	Negligible	None	None	None	Negligible	None	Negligible	None	Negligible
	Adult Holding	<16	Oct-Apr	None	Negligible	None	None	None	Negligible	None	Negligible	None	Negligible
	Spawner	<14	Early Jan-Apr	None	None	None	None	None	None	None	None	None	Negligible
	Egg/Alevin	<12	Jan-June	None	None	None	None	None	None	None	Negligible	None	Negligible
	Juveniles	<16	Year-round	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Smolt	<19	Nov-May	None	Negligible	None	None	None	None	None	Negligible	None	Negligible
	Late Fall Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 3 Greatest Change	Adult Migrating	<20	Oct-Apr	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Adult Holding	<16	Oct-Apr	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Spawner	<14	Early Jan-Apr	None	None	None	None	None	Negligible	None	Negligible	None	Negligible
	Egg/Alevin	<12	Jan-June	None	None	None	None	None	Negligible	None	Negligible	June	Not Applicable[1]
	Juveniles	<16	Year-round	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June	Low[1]
	Smolt	<19	Nov-May	None	Negligible	None	None	None	Negligible	None	Negligible	None	Negligible

Sources: Temperature effects – Moyle et al. 2017, NMFS 2019, Myrick and Cech 2004. Temperature modeling – Appendix C – Folsom Temperature Modeling in Support of Modification of Water Right Permit 21112

Note: Life stages shown in grey have no confirmed presence in the Lower American River. Since 2013, a total of 41 late fall-run chinook juveniles-smolts have been captured in the Lower American River rotary screw traps. It is unclear if these individuals are part of a self-sustaining and distinct LAR population, or if they are transitory individuals seeking overwintering habitat within the project area. The rankings assume that these individuals constitute their own, distinct subpopulation of late fall-run chinook within the Lower American River. These juveniles and smolts may not be natal to the region, and therefore the other life stages would not be present in the system. Additionally, no late fall-run individuals have been identified using length-by-date criteria or genetic analysis since 2016.

Footnotes:

- Not applicable[1]. Modeled baseline temperature in in June is 17.9ºC. Temperature increase due to Project operations is 0.3ºC. All eggs/alevin would already be under extreme temperature stress and are unlikely to survive baseline temperature of 17.9ºC, therefore an increase of 0.3ºC is unlikely to result in additional mortality.
- Low[1]. Modeled baseline temperature in June is 17.9ºC. Temperature increase due to Project operations is 0.3ºC. The magnitude of the temperature increase is relatively small (0.3ºC),, but some individuals could experience decreased metabolic efficiency and reduced growth rates. Individuals already acclimated to warmer temperatures may show no reduced fitness; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperatures. Individuals may also outmigrate early to avoid temperature stress.

Table D3.4-11. Potential Effects from Change in Water Temperature to Winter-Run Chinook Salmon in the Lower American River at Watt Avenue, Post-Construction [Future Baseline vs. Future Project]

	Winter-Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 1 Average Condition	Adult Migrating	<20	Dec-Jul	None	None	None	None	None	None	None	Negligible	None	Negligible
	Adult Holding	<16	Dec-Jul	None	None	None	None	None	None	None	Negligible	None	Negligible
	Spawner	<16	Late Apr - Early Aug	None	None	None	None	None	None	None	Negligible	None	Negligible
	Egg/Alevin	<12	May-Sep	None	None	None	None	None	None	None	Negligible	None	Negligible
	Juveniles	<15.5	Year-round*	None	None	None	None	None	Negligible	None	Negligible	None	Negligible
	Smolt	<19	Nov-May	None	None	None	None	None	None	None	None	None	Negligible
	Winter-Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 2 Warmest Baseline	Adult Migrating	<20	Dec-Jul	None	None	None	None	None	None	None	Negligible	None	Negligible
	Adult Holding	<16	Dec-Jul	None	None	None	None	None	None	None	Negligible	None	Negligible
	Spawner	<16	Late Apr - Early Aug	None	Negligible	None	None	None	None	None	Negligible	None	Negligible
	Egg/Alevin	<12	May-Sep	None	Negligible	None	Negligible	None	None	None	Negligible	None	Negligible
	Juveniles	<15.5	Year-round*	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Smolt	<19	Nov-May	None	Negligible	None	None	None	None	None	Negligible	None	Negligible
	Winter-Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 3 Greatest Change	Adult Migrating	<20	Dec-Jul	None	Negligible	None	None	None	Negligible	None	Negligible	None	Negligible
	Adult Holding	<16	Dec-Jul	None	Negligible	None	None	None	Negligible	None	Negligible	June	Moderate[1]
	Spawner	<16	Late Apr - Early Aug	None	Negligible	None	None	None	Negligible	None	Negligible	June	Moderate[2]
	Egg/Alevin	<12	May-Sep	None	Negligible	None	None	None	Negligible	None	Negligible	June	Not Applicable[1]
	Juveniles	<15.5	Year-round*	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June	Low[1]
	Smolt	<19	Nov-May	None	Negligible	None	None	None	Negligible	None	Negligible	None	Negligible

Sources: Temperature effects – NMFS 2019, McCullough 1999. Temperature modeling – Appendix C – Folsom Temperature Modeling in Support of Modification of Water Right Permit 21112

Note: Life stages shown in grey have no confirmed presence in the Lower American River. Since 2013, a total of 330 winter-run chinook juveniles-smolts have been captured in the Lower American River rotary screw traps. It is unclear if these individuals are part of a self-sustaining and distinct LAR population, or if they are transitory individuals seeking overwintering habitat within the Lower American River. The rankings assume that these individuals constitute their own, distinct subpopulation of winter-run chinook within the Lower American River. These juveniles and smolts may not be natal to the region, and therefore the other life stages would not be present in the system.

Footnotes:

- Moderate[1]. Modeled baseline temperature in June is 17.9ºC. Temperature increase due to Project operations is 0.3ºC. The magnitude of the temperature increase is relatively small (0.3ºC) but some adults may be under temperature stress, potentially resulting in reductions in gamete size, quality, or abundance.
- Moderate[2]. Modeled baseline temperature in in June is 17.9ºC. Temperature increase due to Project operations is 0.3ºC. The magnitude of the temperature increase is relatively small (0.3ºC) but there may be an increase in pre-spawn mortality, and some spawners may delay migration or be under temperature stress that may cause reductions in gamete size, quality, or abundance.
- Not applicable[1]. Modeled baseline temperature in June is 17.9ºC. Temperature increase due to Project operations is 0.3ºC. All eggs/alevin would already be under extreme temperature stress and are unlikely to survive baseline temperature of 17.9ºC, therefore a temperature increase of 0.3ºC is unlikely to result in additional mortality.
- Low[1]. Modeled baseline temperature in in June is 17.9ºC. Temperature increase due to Project operations is 0.3ºC. The magnitude of the temperature increase is relatively small (0.3ºC) but some individuals could experience decreased metabolic efficiency and reduced growth rates. Individuals already acclimated to warmer temperatures may show no reduced fitness; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperatures. Furthermore, individuals may outmigrate early to avoid temperature stress.

Table D3.4-12. Potential Effects from Change in Water Temperature to Spring-Run Chinook Salmon in the Lower American River at Watt Avenue, Post-Construction [Future Baseline vs. Future Project]

	Spring-Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 1 Average Condition	Adult Migrating	<21	Mar-Late Aug	None	None	None	None	None	None	None	Negligible	None	Negligible
	Adult Holding	<16	Mar-Late Aug	None	None	None	None	None	None	None	Negligible	None	Negligible
	Spawner	<16	Late Aug-Oct	None	None	None	None	None	Negligible	None	None	None	None
	Egg/Alevin	<13	Sep-Nov	None	None	None	None	None	Negligible	None	None	None	None
	Juveniles	<16	Year-round	None	None	None	None	None	Negligible	None	Negligible	None	Negligible
	Smolt	<19	Mar-Jun & Nov-Apr	None	None	None	None	None	None	None	None	None	Negligible
	Spring-Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 2 Warmest Baseline	Adult Migrating	<21	Mar-Late Aug	None	Negligible	None	None	None	None	None	Negligible	None	Negligible
	Adult Holding	<16	Mar-Late Aug	None	Negligible	None	None	None	None	None	Negligible	None	Negligible
	Spawner	<16	Late Aug-Oct	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Egg/Alevin	<13	Sep-Nov	Nov	**Low**[1]	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Juveniles	<16	Year-round	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Smolt	<19	Mar-Jun & Nov-Apr	None	Negligible	None	None	None	None	None	Negligible	None	Negligible
	Spring-Run Chinook			Water Year Type									
				Wet		Above Normal		Below Normal		Dry		Critically Dry	
	Life Stage	T°C Max	Months In Stream	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect	Months Affected	Potential Effect
Scenario 3 Greatest Change	Adult Migrating	<21	Mar-Late Aug	None	Negligible	None	None	None	Negligible	None	Negligible	None	Negligible
	Adult Holding	<16	Mar-Late Aug	None	Negligible	None	None	None	Negligible	None	Negligible	June	Moderate[1]
	Spawner	<16	Late Aug-Oct	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Egg/Alevin	<13	Sep-Nov	None	Negligible	None	Negligible	None	Negligible	None	Negligible	None	Negligible
	Juveniles	<16	Year-round	None	Negligible	None	Negligible	None	Negligible	None	Negligible	June	Low[1]
	Smolt	<19	Mar-Jun & Nov-Apr	None	Negligible	None	None	None	Negligible	None	Negligible	None	Negligible

Sources: Temperature effects – Moyle et al. 2017, NMFS 2019, Myrick and Cech 2004. Temperature modeling – Appendix C – Folsom Temperature Modeling in Support of Modification of Water Right Permit 21112

Note: Life stages shown in grey have no confirmed presence in the Lower American River. Since 2013, a total of 75 spring-run chinook juveniles-smolts have been captured in the Lower American River rotary screw traps. It is unclear if these individuals are part of a self-sustaining and distinct LAR population, or if they are transitory individuals seeking overwintering habitat within the Lower American River. The rankings assume that these individuals constitute their own, distinct subpopulation of spring-run chinook within the Lower American River. These juveniles and smolts may not be natal to the region, and therefore the other life stages would not be present in the system.

Footnotes:

- Moderate[1]. Modeled baseline temperature in June is 17.9ºC. Temperature increase due to Project operations is 0.3ºC. The magnitude of the temperature increase is relatively small (0.3ºC), but there may be an increase in pre-spawn mortality, and some spawners may delay migration or be under temperature stress potentially resulting in reductions in gamete size, quality, or abundance.
- Low[1]. Modeled baseline temperature in June is 17.9ºC. Temperature increase due to Project operations is 0.3ºC. Some individuals could experience decreased metabolic efficiency and reduced growth rates, but effects are considered low because the magnitude of the temperature increase is relatively small (0.3ºC). Furthermore, individuals already acclimated to warmer temperatures may show no reduced fitness; research by Myrick and Cech (2004) shows that smolts and juveniles reared in warm water can tolerate higher temperatures, and individuals may also outmigrate early to avoid temperature stress.

D3.5 REFERENCES

Baker, Peter Fritz, Franklin K. Ligon, and Terence P. Speed. 1995. "Estimating the influence of temperature on the survival of chinook salmon smolts (*Oncorhynchus tshawytscha*) migrating through the Sacramento–San Joaquin River Delta of California." *Canadian Journal of Fisheries and Aquatic Sciences* 52.4 (1995): 855-863.

Bowerman, Tracy E., Matthew L. Keefer, and Christopher C. Caudill. 2021. "Elevated Stream Temperature, Origin, and Individual Size Influence Chinook Salmon Prespawn Mortality across the Columbia River Basin." *Fisheries Research* 237 (2021): 105874.

Brett, J.R., M. Hollands and D.F. Alderice. 1958. The effect of temperature on the cruising speed of young sockeye and coho salmon. J. Fish. Res. Board Can. 15:587-605.

Brett, J. R., W. C. Clarke and J. E. Shelbourn. 1982. Experiments on thermal requirements for growth and food conversion efficiency of juvenile chinook salmon. Nanaimo, B.C.: Department of Fisheries and Oceans, Fisheries Research Branch, 1982.

Burson, Skyler. 2024. Environmental Scientist – District Biologist, North Central Region, Anadromous Fisheries, CDFW. Email correspondence with Alex Johanson, AECOM Fish Biologist II, regarding screw trap data for salmonids on the Lower American River. September 4, 2024.

Busch, D. S., M. B. Sheer, K. M. Burnett, Pl McElhany, and T. D. Cooney. (2008). "Impacts of temperature and habitat conditions on the reproductive success of chinook salmon and steelhead in California." Environmental Biology of Fishes, 83(4), 405-419.

Carter, Katharine. 2005. "The Effects of Temperature on Steelhead Trout, Coho Salmon, and Chinook Salmon Biology and Function by Life Stage." California Regional Water Quality Control Board (2005): 1-26.

Crozier, L. G., Zabel, R. W., & Scheuerell, M. D. (2011). "Effects of hydroclimatic and physiological stressors on the migration and survival of salmonids in the Pacific Northwest." Ecology, 92(10), 2013–2024.

Day, Logan, and Hunter Morris. 2023. "Juvenile Salmonid Emigration Monitoring in the Lower American River, California." (2023).

Dusek Jennings, Eva, and A. Noble Hendrix. 2020. "Spawn timing of winter-run chinook salmon in the upper Sacramento River." *San Francisco Estuary and Watershed Science* 18.2 (2020).

Environmental Protection Agency (EPA). 2003. EPA Region 10 Guidance for Pacific Northwest State and Tribal Water Quality Standards. EPA 910-B-03-002. April 2003

FitzGerald, A.M., S.N. John, T.M. Apgar, N.J. Mantua, T. Martin. 2021. Quantifying thermal exposure for migratory riverine species: Phenology of chinook salmon populations predicts thermal stress. Global Change Biology, 27 (3) February.

Hallock, Richard J., William F. Van Woert, and Leo Shapovalov. 1961. "Fish Bulletin No. 114. An Evaluation of Stocking Hatchery-Reared Steelhead Rainbow Trout (*Salmo gairdnerii gairdnerii*) in the Sacramento River System." (1961).

Hassrick, Jason L., Arnold J. Ammann, Russell W. Perry, Sara N. John, and Miles E. Daniels. 2022. "Factors affecting spatiotemporal variation in survival of endangered winter-run chinook salmon out-migrating from the Sacramento River." *North American Journal of Fisheries Management* 42.2 (2022): 375-395.4

Healey, Michael. 2011. "The Cumulative Impacts of Climate Change on Fraser River Sockeye Salmon (*Oncorhynchus nerka*) and Implications for Management." *Canadian Journal of Fisheries and Aquatic Sciences* 68.4 (2011): 718-737.

Hearn, Alex R., Eric D. Chapman, Gabriel P. Singer, William N. Brostoff, Peter E. LaCivita, and A. Peter Klimley. 2014. "Movements of out-migrating late-fall run chinook salmon (Oncorhynchus tshawytscha) smolts through the San Francisco Bay Estuary." *Environmental Biology of Fishes* 97 (2014): 851-863.

Jeffries, K. M., S. G. Hinch, E. G. Martins, T. D. Clark, A. G. Lotto, D.A. Patterson, S. J. Cooke, K. M. Miller and A. P. Farrell. (2008). "Effects of water temperature and river flow on adult salmonid health and migration success." *Transactions of the American Fisheries Society*, 137(5), 1114-1127.

Kleinschmidt Associates (Kleinschmidt). 2024. Folsom Temperature Modeling, in Support of Modification of Water Right Permit 21112. July 22, 2024.

Linnansaari, T. 2023 A. O'Sullivan C. Breau E. Corey, E.N. Collet, R. A. Curry., R. A. Cunjak. 2023. The Role of Cold-Water Thermal Refuges for Stream Salmonids in a Changing Climate-Experiences from Atlantic Canada. Fishes 8 (471):471.

Mantua, Nathan, Ingrid Tohver, and Alan Hamlet. 2009. "Impacts of climate change on key aspects of freshwater salmon habitat in Washington State." (2009).

Marine, Keith R., and Joseph J. Cech Jr. 2004. "Effects of high water temperature on growth, Smoltification, and predator avoidance in juvenile Sacramento River chinook salmon." *North American Journal of Fisheries Management* 24.1 (2004): 198-210.

Martins, Eduardo G., Scott G. Hinch, David A. Patterson, Merran J. Hague, Steven J. Cooke, Kristina M. Miller, Michael F. Lapointe, Karl K. English, and Anthony P. Farrell. 2011. "Effects of River Temperature and Climate Warming on Stock-Specific Survival of Adult Migrating Fraser River Sockeye Salmon (*Oncorhynchus nerka*)." *Global Change Biology* 17.1 (2011): 99-114.

McCullough, Dale A. 1999. *A Review and Synthesis of Effects of Alterations to the Water Temperature Regime on Freshwater Life Stages of Salmonids, with Special Reference to Chinook Salmon*. U.S. Environmental Protection Agency, Region 10, 1999.

McCullough, D. A., J.M. Bartholow, H.I. Jager, R. L Beschta, E. F Cheslak, M. L Deas, J. L. Ebersole, J.S. Foott, S. L Johnson, K. R Marine, M. G Mesa, J. H., Petersen, Y. Souchon, K.F. Tiffan, and W. A. Wurtsbaugh. (2001). "The effect of temperature on the survival and growth of juvenile salmonids in the Columbia River Basin." North American Journal of Fisheries Management, 21(1), 191-205.

McEwan, Dennis R. 2001. “Central Valley Steelhead.” *Fish Bulletin* 179.1 (2001): 1-43.

Moyle, Peter B., Robert A. Lusardi, Patrick J. Samuel, and Jacob VE Katz. 2017. “State of the Salmonids.” (2017).

Myrick, Christopher A., and Joseph J. Cech. 2004. “Temperature Effects on Juvenile Anadromous Salmonids in California’s Central Valley: What Don’t We Know?.” *Reviews in Fish Biology and Fisheries* 14 (2004): 113-123.

National Marine Fisheries Service (NMFS). 2014. “Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon and the Distinct Population Segment of California Central Valley Steelhead.” (2014).

National Marine Fisheries Service (NMFS). 2019. “Biological Opinion on Long-term Operation of the Central Valley Project and the State Water Project.” (2019).

National Marine Fisheries Service (NMFS). 2024. Endangered Species Act Section 7(a)(2) Programmatic Biological Opinion for the Reinitiation of Consultation on the Long-Term Operation of the Central Valley Project and State Water Project. December 6. Available: https://www.fisheries.noaa.gov/resource/document/endangered-species-act-section-7a2-programmatic-biological-opinion-reinitiation. Accessed: January 2025.

Quigley J.T., Hinch S.G. (2006) *Effects of rapid experimental temperature increases on acute physiological stress and behaviour of stream dwelling juvenile Chinook salmon*. J Therm Biol 31: 429–441.

Railsback, S.F., B.C. Harvey 2023 *Can thermal refuges save salmonids? Simulation of cold-pool benefits to salmonid populations.* Transactions of the American Fisheries Society. Volume 152, Issue 4, 383-396.

Redding, J.M., C.B. Schreck, E.K. Birks, R.D. Ewing. 1984 †Cortisol and its effects on plasma thyroid hormone and electrolyte concentrations in fresh water and during seawater acclimation in yearling coho salmon, (*Oncorhynchus kisutch*). General and Comparative Endocrinology. Volume 56, Issue 1, October 1984, Pages 146-155.

Richter, Ann, and Steven A. Kolmes. 2005. “Maximum temperature Limits for Chinook, Coho, and Chum Salmon, and Steelhead Trout in the Pacific Northwest.” *Reviews in Fisheries science* 13.1 (2005): 23-49.

Salinger, David H., and James J. Anderson. 2006. “Effects of Water Temperature and Flow on Adult Salmon Migration Swim Speed and Delay.” *Transactions of the American Fisheries Society* 135.1 (2006): 188-199.

Slater, Daniel W. 1963. Winter-run chinook salmon in the Sacramento River, California with notes on water temperature requirements at spawning. Vol. 461. US Department of the Interior, Bureau of Commercial Fisheries, 1963.

Sloat, Matthew R., and Ann-Marie K. Osterback. 2013. “Maximum stream temperature and the occurrence, abundance, and behavior of steelhead trout (Oncorhynchus mykiss) in a southern California stream.” *Canadian Journal of Fisheries and Aquatic Sciences* 70.1 (2013): 64-73.

Snyder, M.N., N.H. Schumaker, J.B. Dunham, J.L. Ebersole, M.L. Keefer, J. Halama, R.L. Comeleo, P. Leinenbach, A. Brookes, B. Cope, J. Wu, J. Palmer. 2022. Tough places and safe spaces: Can refuges save salmon from a warming climate? Ecosphere. Vol 13, Issue 11 November.

Sutton, R.J., M.L. Dead, S.K. Tanaka, T. Soto, R.A. Corum. 2007. Erratum: Salmonid observations at a Klamath River thermal refuge under various hydrological and meteorological conditions. River Research and Applications 23(7):775 – 785.

Starr, C. and L. Day. 2020. Juvenile Salmonid Emigration Monitoring in the Lower American River, California January – June 2020. Unpublished report prepared for the U.S. Fish and Wildlife Service and California Department of Fish and Wildlife, Sacramento, California. 54 pp.

Sturrock, A. M., W. H. Satterthwaite, K. M. Cervantes-Yoshida, E. R. Huber, H. J.W. Sturrock, S. Nussie, S. M. Carlson. 2019. "Eight decades of Hatchery Salmon Releases in the Central Valley: Factors Influencing Straying and Resilience." Published by Wiley Periodicals, Inc, on behalf of the American Fisheries Society.

Thorn, Michael W., and Yolanda E. Morbey. 2018. "Egg Size and the Adaptive Capacity of Early Life History Traits in Chinook Salmon (*Oncorhynchus tshawytscha*)." *Evolutionary Applications* 11.2 (2018): 205-219.

Whitney, C. K., S. G. Hinch, and D. A. Patterson. 2014. "Population Origin and Water Temperature Affect Development Timing in Embryonic Sockeye Salmon." *Transactions of the American Fisheries Society* 143.5 (2014): 1316-1329.

Williams, John G. 2006. "Central Valley salmon: a perspective on Chinook and steelhead in the Central Valley of California." *San Francisco Estuary and Watershed Science* 4.3 (2006).

Windell, Sean, Patricia L. Brandes, J. Louise Conrad, John W. Ferguson, Pascale A.L. Goertler, Brett N. Harvey, Joseph Heublein, Joshua A. Israel, Daniel W. Kratville, Joseph E. Kirsch, Russell W. Perry, Joseph Pisciotto, William R. Poytress, Kevin Reece, Brycen G. Swart, and Rachel C. Johnson. 2017. "Scientific Framework for Assessing Factors Influencing Endangered Sacramento River Winter-run Chinook Salmon (*Oncorhynchus tshawytscha*) across the life cycle." (2017).

Wurtsbaugh, W.A. and G.E. Davis. 1977. Effects of Temperature and Ration Level on the Growth and Food Conversion Efficiency of *Salmo gairdneri*, Richardson. J. Fish. Biol. 11 (1977), 87–98.

Yoshiyama, Ronald M., Frank W. Fisher, and Peter B. Moyle. 1998. "Historical Abundance and Decline of Chinook Salmon in the Central Valley Region of California." *North American Journal of Fisheries Management* 18.3 (1998): 487-521.

Zillig, Kenneth W., Robert A. Lusardi, Dennis E. Cocherell, and Nann A. Fangue. 2022. "Interpopulation variation in thermal physiology among seasonal runs of Chinook salmon." *Canadian Journal of Fisheries and Aquatic Sciences* 80.1 (2022): 1-13.