Appendix 6D Sites Reservoir Discharge Temperature Modeling

Appendices 6D1 and 6D2 were extensively revised after publication of the RDEIR/SDEIS. Because the revisions were extensive, individual changes from the RDEIR/SDEIS are not identified.

Appendix 6D Sites Reservoir Discharge Temperature Modeling

1 Introduction

This appendix describes methods and results of Sites Reservoir discharge temperature modeling. Sites Reservoir discharge temperature modeling was assessed with two tools: (1) CE QUAL W2 and (2) Sites Reservoir Release Temperature Blending Tool. A CE QUAL W2 model was developed and run to simulate water temperature of Sites Reservoir and its releases. The Sites Reservoir Release Temperature Blending Tool was developed to estimate temperature effects of Sites Reservoir releases to the Tehama Colusa Canal, GCID Main Canal, Colusa Basin Drain, and the Sacramento River. Sites Reservoir discharge temperature modeling methods and results are detailed in the sections below.

2 Methods

This section describes tools and methods for evaluating Sites Reservoir surface water temperature, release temperature, and blending of Sites discharge with the TC Canal, GCID Main Canal, CBD, and Sacramento River. Section 2.1 CE QUAL W2 Model Setup and Development describes the methodology for calculating Sites Reservoir surface water temperature and release temperature. Section 2.2 Reservoir Release Temperature Blending describes methods for calculating temperature blending of Sites Releases with the TC Canal, GCID Main Canal, CBD, and Sacramento River.

2.1 CE QUAL W2 Model Setup and Development

2.1.1 Model Construction

The hydrologic data and reservoir bathymetry developed for reservoir design are the most critical elements for model construction. Additionally, the model uses an adaptive time step subject to a user defined minimum, set at 100 seconds, and a user defined maximum, set at 400 seconds.

Given the long, open-source history of the model, there is a high degree of confidence in model physics with these inputs in conjunction with data. Because reservoir physics (e.g., vertical temperature distribution and hydrodynamics) largely determine all water quality parameters, modeling of a reservoir not yet constructed can be done also with a high level of confidence in the realism of model results. Final calibration of the model is advised once the reservoir fills.

2.1.2 Model Input Data

Reservoir Bathymetry

Elevation contours of the proposed site were developed for use as the bathymetric grid for the Sites Reservoir CE-QUAL model. The 2-foot contours were processed by DWR for elevations below 520 feet (relative to GCS North American 1983 datum), which exceeds the proposed maximum reservoir operating level. The contours were split into segments manually in ESRI ArcMap software, and elevation-area curves were generated for each segment. These elevation-area curves were then imported into Excel to calculate segment lengths and widths for input to the CE-QUAL-W2 model.

The model reservoir has four longitudinal branches, two along the main reservoir body and two along the two arms on the west side of the main branch. Final segmentation of the CE-QUAL-W2 grid starts with the upstream end of the main reservoir branch and the dam near the middle of the reservoir. Figure 6D-1 shows the model segments with branches color-coded in the image on the right. Branch 1 includes segments 2 through 8, branch 2 includes segments 11 through 24, branch 3 includes segments 27 through 31, and branch 4 includes segments 34 through 36. The outlet is located in segment 8. Figure 6D-2 shows the storage-elevation curve developed from the model segments.

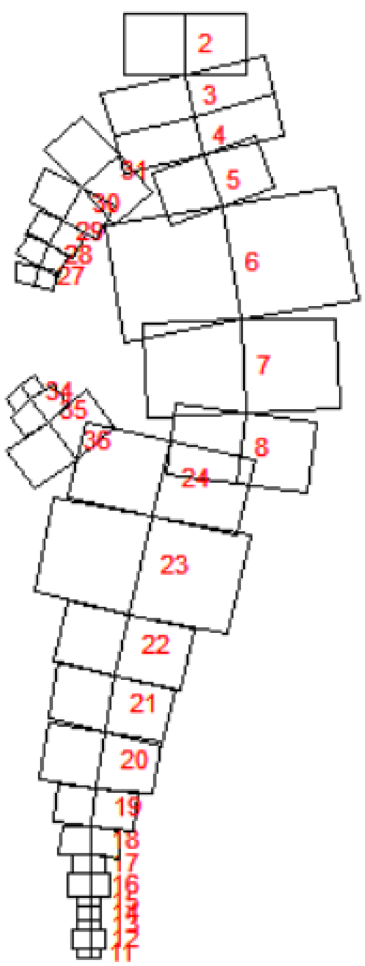


Figure 6D-1. CE-QUAL-W2 Model Segmentation

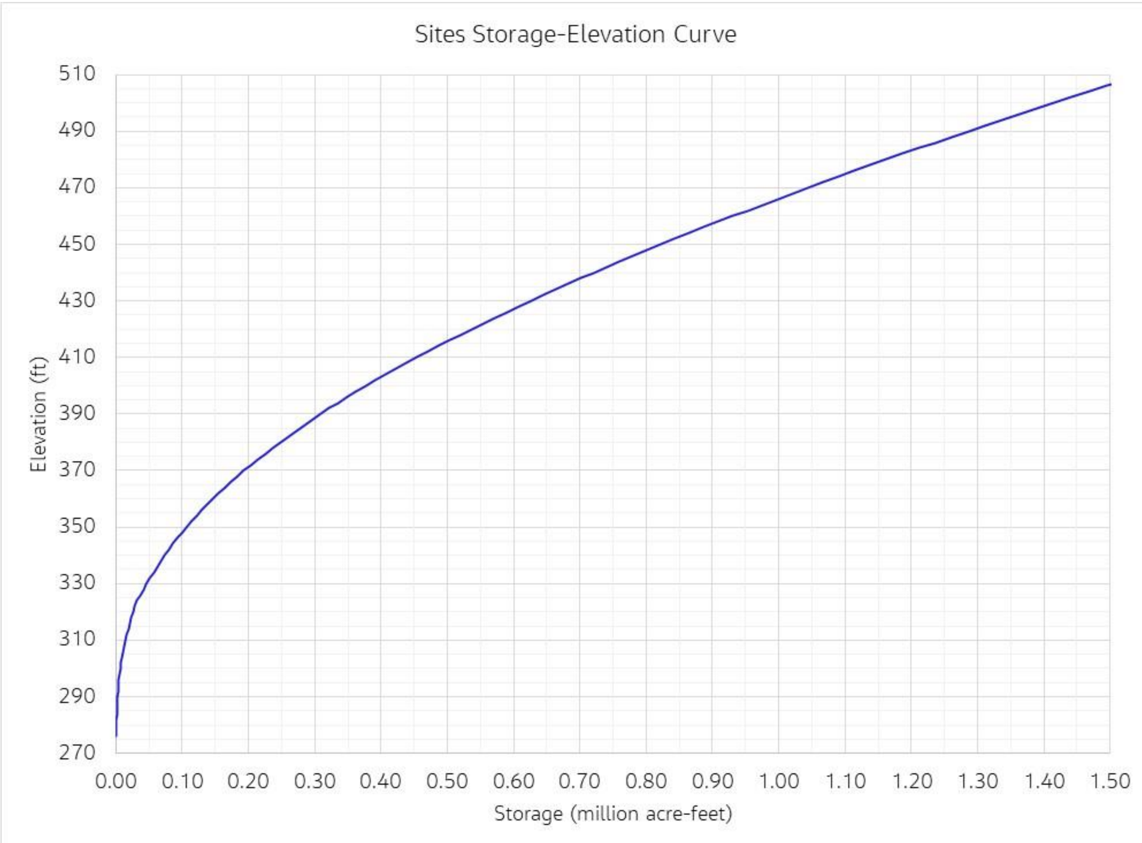


Figure 6D-2. Sites Storage-Elevation Curve

Meteorological Data

Meteorological data required for the Sites CE-QUAL model simulations includes hourly precipitation, dew point, average temperature, wind speed and direction, percent cloud coverage and solar radiation (optional if available) over the model geometry. Daily data from California Irrigation Management Information System (CIMIS) station located in Durham, south of Chico, California (approximately 35 miles east of the reservoir site) was obtained for the available period of 1983 - 2019. Daily average temperature, dew point, solar radiation and wind speed and direction were input into an Excel database for analysis.

Hourly data was available for a twelve year period 2007 to 2018 from the CIMIS Durham station. This hourly data record was reviewed for data quality, small data gaps were filled, and then the twelve year record was repeated to set meteorological conditions from 1921 to 2006 in the CE-QUAL-W2 model. Average annual air temparatures for the twelve year period ranged from 58 to 63 degrees F, with an average of 60 degrees F (14.4 to 17.0 degrees C with an average of 15.6 degrees C).

Daily precipitation from January 1st, 1983, through April 15, 2019, was analyzed to develop long-term precipitation data for input into the model to capture significant storm and drought events and to provide an accurate representation of actual inflows into the reservoir. This data was classified into hydrologic year types and mapped to the Sacramento basin’s hydrologic index to estimate precipitation input for the rest of the simulation period (1921 – 1982). Annual precipitation ranged from 10.0 to 44.4 inches for the 1983 to 2018 period.

Cloud cover data were not available from the CIMIS Durham station, so data for this period was obtained from National Weather Service Automated Surface Observing Systems (NWS ASOS) Marysville station, located approximately 40 miles southeast of the reservoir site. Data from 2014 were chosen to be representative of an average, recent meteorological year and was applied as an annual repeating pattern for model simulations. Cloud cover data was available for 1965 through 1972; 1967 was found to depict an average year and daily cloud cover for 1967 was input into the model as an annual repeating pattern.

Inflows, Outflows and Mass Balance

CE QUAL W2 flow boundary conditions are provided by the USRDOM model. Flow boundary conditions include: Sites diversions at Red Bluff (at existing TC Canal), Sites diversions at Hamilton City (at existing GCID Main Canal), and Sites releases. Please refer to Appendix 5C, *Upper Sacramento River Daily River Flow and Operations Model*, for more details regarding the USRDOM model.

Inflow Temperature

CE QUAL W2 input temperatures at Sites diversions locations in the Sacramento River are provided by the HEC5Q model. Please refer to Appendix 6C, *River Temperature Modeling*, for a description of the HEC5Q model.

2.1.3 Model Assumptions and Limitations

The governing equations that drive this model are lateral- and layer-averaged. Therefore, the model assumes that the lateral variations in velocities, temperatures, and constituents are negligible. These assumptions may not be suitable for larger water bodies that exhibit significant lateral variations in temperature. For the model used in this report, it is assumed that the temperature variations across individual model segments are negligible such that the width-averaged approach is acceptable. This model uses the scheme – TKE (Turbulent kinetic energy) – to model vertical turbulence. This model neglects vertical momentum and assumes that there is no significant vertical acceleration in the model domain. Transport scheme – ULTIMATE – is used with a vertical time-weighting factor (THETA) 0.5.

2.1.4 Testing and Validation

This sub-section describes the assumptions and methods for validating results from the CE QUAL W2 model.

Physical Parameter Validation

Results from the CE QUAL W2 model were compared against the input data sets (USRDOM) to confirm mass balance. As the Sites CE QUAL W2 model boundary conditions are USRDOM results, the reservoir volume from each model was compared at each timestep.

Temperature Release Targets

To maintain temperatures required for rice farming in the Sacramento Valley, the CE QUAL W2 model operates to a release temperature target of 65 degrees Fahrenheit for the months of April through November. In the remaining months of the year (December through March), little to no release is expected. Therefore, no target was determined and a 50 degrees Fahrenheit release temperature target was used as default.

2.2 Reservoir Release Temperature Blending

The Sites Release Temperature Blending tool calculates monthly average temperatures in the TC Canal, GCID Main Canal, CBD, and Sacramento River below Colusa Basin Drain for comparative analysis. Temperatures are estimated with: (1) blending calculations and (2) temperature exchange with the atmosphere at a monthly time step. All calculations are focused to assess temperature changes as a result of releases from Sites. A schematic of the model domain is presented in Figure 6D-3. All solid, blue lines represent pre-existing facilities and channels. All dot-dashed, red lines represent facilities associated with Sites Project.

Please note that this tool is not designed to predict, or specifically estimate, temperatures within its spatial domain. Although the tool uses physical assumptions for temperature calculations, this tool should only be used for comparative analysis of alternatives presented in the Sites 2021 DEIR/EIS.

2.2.1 Input Data

Inputs to the model are from CalSim II, HEC5Q, CE QUAL W2, and the California Water Data Library (CA WDL). Documentation for the CalSim II, HEC5Q and CE QUAL W2 models are provided separately. Flow and temperature boundary conditions are presented in Tables 6D-1 and 6D-2, respectively. All boundary conditions retrieved from CalSim II, HEC5Q and CE QUAL W2 models are input to the model as a monthly timeseries. As the CA WDL data does not include the entire planning simulation time series, these boundary conditions are input as long-term monthly averages. For example, all data in the month of October were averaged and used as input temperature for all Octobers in the model. The temperature boundary conditions at CA WDL boundary condition locations are presented in Table 6D-3.

It should be noted that CA WDL temperature for Knight Landing Ridge Cut at Highway 113 is downstream from the Colusa Basin Drain. However, it is the closest available observed water temperature data. Given the close proximity of Knights Landing Ridge Cut and Colusa Basin Drain at Sacramento River, differences in temperature are negligible. Additionally, it should be noted that there are no observed data for the months of January through May. Although the analysis focuses on the Sites release (mostly in June through September) and months outside the release period (January through May) are of less concern, temperature boundary condition data were estimated by mimicking the monthly pattern of temperature changes observed in the Sacramento River. Estimated values temperature boundary condition values are highlighted and italicized in Table 6D-3.

Table 6D-1. Flow Boundary Conditions

Location	Source Data	Description	Notes
Inflow to TCC	CalSim II	D112	Monthly flow timeseries
Inflow to GCC	CalSim II	D114	Monthly flow timeseries
Sites release to Funks	CalSim II	C17602 + C17603A – C17502	Monthly flow timeseries
Sites release to TRR	CalSim II	C17502	Monthly flow timeseries
TCC downstream of Funks	CalSim II	C17501 + (C17602 + C17603A – C17502)	Monthly flow timeseries
GCC downstream of TRR	CalSim II	C17502A + C17502B + D114 + C17502	Monthly flow timeseries

Location	Source Data	Description	Notes
Colusa Basin Drain above Dunnigan Pipeline	CalSim II	C184A	Monthly flow timeseries
Sites release to Yolo Bypass	CalSim II	C34D_DUN	Monthly flow timeseries
Sites release to Sacramento River	CalSim II	C178	Monthly flow timeseries
Colusa Basin Drain Losses	CalSim II	L184	Monthly flow timeseries
Sacramento River above Sites Discharge	CalSim II	C129	Monthly flow timeseries

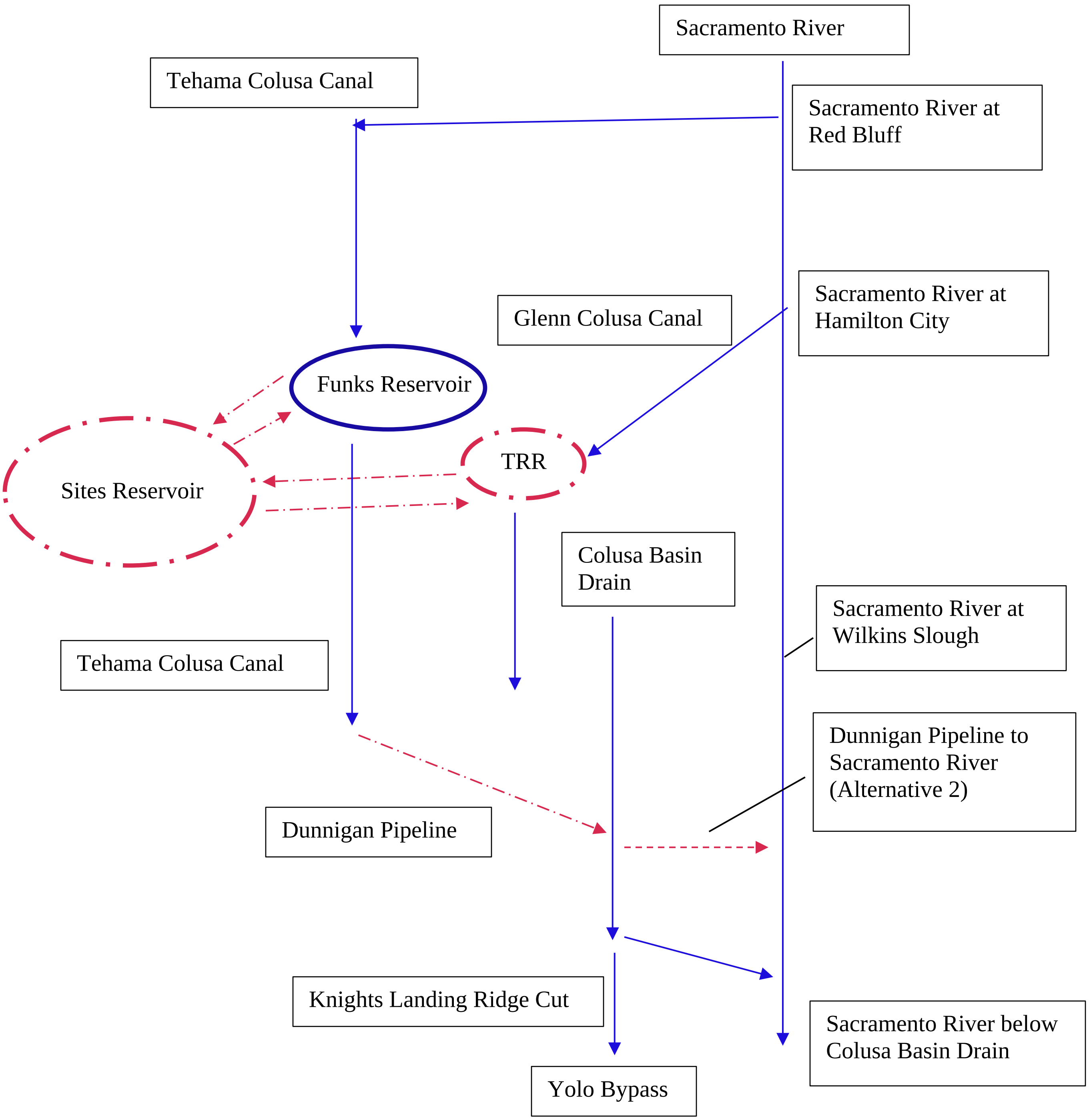
Table 6D-2. Temperature Boundary Conditions

Location	Source Data	Description	Notes
Inflow to TCC	HEC5Q	RED BLUFF DAM	Monthly temperature timeseries
Inflow to GCC	HEC5Q	GCID	Monthly temperature timeseries
Sites release to Funks	CE QUAL W2		Daily temperature timeseries
Sites release to TRR	CE QUAL W2		Daily temperature timeseries
Colusa Basin Drain	CA WDL	A0D84761435	Monthly averages of observed daily data; Ridge Cut Slough at Hwy 113; June through October of 2014 through 2019
Sacramento River above Colusa Basin Drain	CA WDL	A0223002	Monthly averages of observed daily data; 2010 - 2017

Table 6D-3. Average Month Temperature at CA Water Data Library Boundary Conditions

Month	Average Monthly Temperature (deg F)			
	Observed		Estimated	
	Sacramento River Above CBD	Knights Landing Ridge Cut at Hwy 113	Sacramento River Above CBD	Knights Landing Ridge Cut at Hwy 113
Oct	62.12	64.47	62.12	64.47
Nov	54.85	55.67	54.85	55.67
Dec	48.77	47.41	48.77	47.41
Jan	48.58		48.58	*47.41*
Feb	51.96		51.96	*52.66*
Mar	55.30		55.30	*57.85*
Apr	60.39		60.39	*65.78*
May	66.11		66.11	*74.66*
Jun	69.78	80.37	69.78	80.37
Jul	71.11	80.01	71.11	80.01
Aug	70.77	76.65	70.77	76.65
Sep	67.80	71.70	67.80	71.70

Figure 6D-3. Sites Temperature Blending Tool Schematic



2.2.2 Model Assumptions and Limitations

This section describes assumptions and limitations associated with the Sites Release Temperature Blending tool. As noted above, the tool estimates flows and temperatures at a monthly timestep, with data provided by CalSim II, USRDOM, HEC5Q and CE QUAL W2. Please refer to Appendix 5B, *Water Resources System Modeling*, for a description of the CalSim II model, Appendix 6C, *River Temperature Modeling*, for a description of the HEC5Q model, and Appendix 5C, *Upper Sacramento River Daily River Flow and Operations Model*, for a description of the USRDOM model. A description of the CE QUAL W2 model is provided in this Appendix.

Diversions from TC Canal and GCID Main Canal are only considered at boundary condition locations (locations specified in Table 6D-1) not considered in this tool.

Assumptions related to temperature exchange with the atmosphere and temperature blending are detailed below.

Atmospheric Temperature Exchange Assumptions

Temperature exchange with the atmosphere is calculated in the three longest canal segments, as temperature data at the upstream and downstream ends are not available. These three segments are: (1) TC Canal: Red Bluff Pumping Plant to Funks Reservoir, (2) GCID Main Canal: Hamilton City to Terminal Regulating Reservoir (TRR), and (3) TC Canal: Funks Reservoir to Terminus of TC Canal (Dunnigan Pipeline). The assumed canal distance in each of these segments is presented in Table 6D-4.

Temperature exchange with the atmosphere is based upon the average of HEC5Q-estimated temperature change per unit length in the Sacramento River. These temperature change rates are presented in Table 6D-5. For each reach of the Sacramento River, temperature change, as estimated by HEC5Q, was calculated and divided by the distance of the reach. The temperature change rates referenced by the Sites Release Temperature Blending Tool (Table 6D-5) are representative of the range of temperature changes observed along each reach of the Sacramento River. The average temperature changes by month and Sacramento River reach are presented in Table 6D-6.

Effects of temperature and flow of tributaries were not considered in this calculation. This analysis is specific to effects of Sites release temperature to the TC Canal, GCID Main Canal, CBD and Sacramento River. Sites releases occur in summer months, when tributary flows are low. Therefore, the temperature effect of tributaries is negligible for the purpose of calculating temperature change per river mile in this analysis.

Table 6D-4. Estimated Canal Lengths

Facility	Start Location	End Location	Distance (miles)
TC Canal	Red Bluff Pumping Plant	Funks Reservoir	60
TC Canal	Funks Reservoir	Dunnigan Pipeline	40
GCID Main Canal	Hamilton City	Terminal Regulating Reservoir	40

Table 6D-5. Estimated Temperature Change per River Mile

Temperature Change per River Mile by Location and Month (deg F/mile)												
Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Temperature Change per River Mile	0.05	-0.01	-0.03	-0.01	0.02	0.04	0.06	0.09	0.12	0.12	0.12	0.10

Table 6D-6. Average Temperature Changes by Month and Sacramento River Reach (°F)

Reach	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Sacramento River below Keswick to Sacramento River below Clear Creek	0.05	-0.02	-0.03	-0.01	0.03	0.07	0.10	0.11	0.12	0.12	0.12	0.12
Sacramento River below Clear Creek to Sacramento River at Balls Ferry	0.04	-0.03	-0.07	-0.04	0.01	0.05	0.09	0.12	0.12	0.10	0.09	0.09
Sacramento River at Balls Ferry to Sacramento River at Jellys Ferry	0.06	-0.04	-0.08	-0.04	0.01	0.06	0.10	0.17	0.19	0.16	0.15	0.14
Sacramento River at Jellys Ferry to Sacramento River at Bend Bridge	0.04	-0.03	-0.05	-0.02	0.02	0.05	0.07	0.09	0.11	0.13	0.13	0.12
Sacramento River at Bend Bridge to Sacramento River at Red Bluff Div Dam	0.04	0.00	-0.01	0.00	0.02	0.03	0.05	0.07	0.11	0.12	0.12	0.11
Sacramento River at Red Bluff Div Dam to Sacramento River at Woodson Bridge	0.04	0.00	-0.02	-0.01	0.01	0.02	0.03	0.07	0.09	0.09	0.09	0.08
Sacramento River at Woodson Bridge to Sacramento River at Hamilton City	0.05	0.01	0.00	0.01	0.02	0.04	0.06	0.09	0.11	0.13	0.13	0.11
Sacramento River at Hamilton City to Sacramento River at Butte City	0.05	0.01	-0.01	0.00	0.02	0.03	0.05	0.08	0.11	0.13	0.12	0.09

Temperature Blending Assumptions

TC Canal storage (including Funk's reservoir) and average flow are 10,000 acre-feet and 1,000 cfs, respectively. Therefore, under average flow conditions, residence time in the TC Canal is 5 days. Considering variations from average flow conditions, residence time could range from 3 to 8 days. As the tool estimates temperature blending at a monthly time step and a TC Canal residence time of 3 to 8 days, complete mixing of water (conservation of mass) is assumed for temperature calculations (Blankinship and Associates, 2004). It is assumed that the residence time of the GCID Main Canal is similar to the residence time of the TC Canal.

3 Results

3.1 Reservoir Surface Water and Release Temperature

Reservoir surface water and release temperature results are provided in Appendix 6D1, *Reservoir Surface Water and Release Temperature*.

3.2 Water Temperature at Downstream Locations

Reservoir surface water and release temperature results are provided in Appendix 6D2, *Water Temperature at Downstream Locations*.

4 References Cited

Blankinship and Associates, Inc. 2004. *Use of Copper and Acrolein to Control Aquatic Weeds in Irrigation Canals: California Environmental Quality Act Initial Study and Mitigated Negative Declaration*. Davis, CA. Prepared for Tehama-Colusa Canal Authority, Willows, CA.