# Sites Reservoir Discharge Temperature Modeling

## 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.

## 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.

### CE QUAL W2 Model Setup and Development

#### Model Construction

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#### Model Input Data

##### Reservoir Bathymetry

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##### Meteorological Data

CE QUAL W2 meteorological data consists of a monthly timeseries of evaporation rates at Sites Reservoir. The evaporation rate is consistent with the evaporation rate assumed in the CalSim II model.

##### 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.

#### Model Assumptions and Limitations

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#### 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.

### 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-1. 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.

#### 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 |
| 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-1. Sites Temperature Blending Tool Schematic**

Sacramento River

Sacramento River at Red Bluff

Sacramento River at Hamilton City

Sacramento River below Colusa Basin Drain

Tehama Colusa Canal

Tehama Colusa Canal

Colusa Basin Drain

Dunnigan Pipeline

Glenn Colusa Canal

Knights Landing Ridge Cut

Yolo Bypass

Funks Reservoir

Sites Reservoir

TRR

Sacramento River at Wilkins Slough

Dunnigan Pipeline to Sacramento River (Alternative 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**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **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.

## Results

### Reservoir Surface Water and Release Temperature

Reservoir surface water and release temperature results are provided in Appendix 6D, Sites Reservoir Dischange Temperature Modeling, Attachment 1.

### Water Temperature at Downstream Locations

Reservoir surface water and release temperature results are provided in Appendix 6D, Sites Reservoir Dischange Temperature Modeling, Attachment 2.

## 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.