DRAFT Technical Memorandum

Temperature Model Selection

SAN JOAQUIN RIVER
RESTORATION PROGRAM

June 20, 2008

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Tables

List of Abbreviations and Acronyms

1-D	one-dimensional
2-D	two-dimensional
CalEPA	California Environmental Protection Agency
CIMIS	California Irrigation Management Information System
CVP	Central Valley Project
DFG	California Department of Fish and Game
DWR	California Department of Water Resources
FMWG	Fisheries Management Work Group
FWUA	Friant Water Users Authority
NMFS	National Marine Fisheries Service
NRDC	Natural Resources Defense Council
PEIS/R	Program Environmental Impact Statement/Report
Reclamation	U.S. Bureau of Reclamation
Settlement	Stipulation of Settlement
SJRRP	San Joaquin River Restoration Program
State	State of California
TCD	temperature control device
TM	Technical Memorandum
USFWS	U.S. Fish and Wildlife Service
USJRBSI	Upper San Joaquin River Basin Storage Investigation

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This Draft Technical Memorandum (TM) was prepared by the San Joaquin River Restoration Program (SJRRP) Team as a draft document in support of the preparing a Program Environmental Impact Statement/Report (PEIS/R). The purpose for circulating this document at this time is to facilitate early coordination regarding initial concepts and approaches currently under consideration by the SJRRP Team with the Settling Parties, Third Parties, other stakeholders, and interested members of the public. Therefore, the content of this document may not necessarily be included in the PEIS/R.

This Draft TM does not present findings, decisions, or policy statements of any of the Implementing Agencies. Additionally, all information presented in this document is intended to be consistent with the Settlement. To the extent inconsistencies exist, the Settlement should be the controlling document, and the information in this document will be revised prior to its inclusion in future documents. While the SJRRP Team is not requesting formal comments on this document, all comments received will be considered in refining the concepts and approaches described herein to the extent possible. Responses to comments will not be provided and this document will not be finalized; however, refinements will likely be reflected in subsequent SJRRP documents.

1.0 Introduction

This Temperature Model Selection Technical Memorandum (TM) was prepared in support of the San Joaquin River Restoration Program (SJRRP). This TM documents the analysis tool recommended for simulating water temperatures in the affected area of the SJRRP. This document is expected to undergo review, which may result in changes that expand on or clarify stated analysis needs and recommendations.

1.1 Background

In 1988, a coalition of environmental groups, led by the Natural Resources Defense Council (NRDC), filed a lawsuit challenging the renewal of long-term water service contracts between the United States and the Central Valley Project (CVP) Friant Division contractors. After more than 18 years of litigation of this lawsuit, known as *NRDC et al. v. Kirk Rodgers et al.*, a Stipulation of Settlement (Settlement) was reached. On September 13, 2006, the "Settling Parties" agreed on the terms and conditions of the Settlement, which was subsequently approved by the U.S. District Court on October 23, 2006. The Settling Parties include NRDC, Friant Water Users Authority (FWUA), and the U.S. Departments of the Interior and Commerce.

The SJRRP will implement the Settlement. The Implementing Agencies responsible for management of the SJRRP include the U.S. Department of the Interior, through the Bureau of Reclamation (Reclamation) and the Fish and Wildlife Service (USFWS); U.S. Department of Commerce through the National Marine Fisheries Service (NMFS); and the State of California through the Department of Water Resources (DWR), Department of Fish and Game (State), and California Environmental Protection Agency (CalEPA). Consistent with the Memorandum of Understanding between the Settling Parties and the

State, which was signed concurrently with the Settlement, the State, through DFG, DWR, the Resources Agency, and CalEPA, will play a major, collaborative role in planning, designing, funding, and implementing the actions called for in the Settlement.

The Settlement is based on two parallel goals:

- Restoration Goal – To restore and maintain fish populations in "good condition" in the main stem San Joaquin River below Friant Dam to the confluence of the Merced River, including naturally reproducing and self-sustaining populations of salmon and other fish.

- Water Management Goal – To reduce or avoid adverse water supply impacts to all of the Friant Division long-term contractors resulting from the Interim Flows and Restoration Flows provided for in the Settlement.

1.2 Purpose of this Technical Memorandum

Development of the SJRRP Program Environmental Impact Statement/Environmental Impact Report (PEIS/R) requires tools to evaluate San Joaquin River temperatures downstream from Millerton Reservoir resulting from implementation of the Settlement. These temperatures will become input into various other tools and analyses in order to evaluate the potential impact of the SJRRP on affected resource areas. This TM documents the selection of a water temperature model(s) to be used in this process.

2.0 Need for Water Temperature Model

The Settlement's Restoration Goal aims to restore the San Joaquin River's salmon fishery. Having water temperatures that meet fishery life cycle needs is an important factor for meeting the Restoration Goal. Therefore, knowing the water temperatures resulting from proposed physical and operational features of the SJRRP is critical to development of an effective program. Water temperature simulation modeling can help provide this information.

Temperature modeling in the SJRRP must do the following:

1. Produce quantitative temperature results of sufficient accuracy and at locations required for further analysis of the SJRRP
2. Facilitate comparisons with other Reclamation temperature studies, particularly with the Upper San Joaquin River Basin Storage Investigation (USJRBSI)
3. Simulate the operation of a temperature control device (TCD) on river and canal diversion outlets
4. Meet SJRRP schedule

2.1 Produce Quantitative Temperature Results

The Restoration Goal is concerned with temperatures in the San Joaquin River, from Millerton Reservoir downstream to its confluence with the Merced River. Implementation of the Settlement will provide larger releases of water to the San Joaquin River, subsequently affecting storages in Millerton Reservoir and canal diversions at the reservoir. These operational changes could impact the temperature of Millerton Reservoir, as well as the San Joaquin River above and below its confluence with the Merced River.

Reservoirs require different temperature models than rivers. Thus, the SJRRP requires two models to fully evaluate the impact of operations on Millerton Reservoir and the San Joaquin River. This review provides a separate evaluation of the reservoir and river components of combined models for use in the SJRRP. Reservoir temperature models are required to simulate the temperature of Millerton Reservoir, as well as its releases. River temperature models are required to simulate temperatures along the San Joaquin River, to its confluence with the Merced River, on a time step interval that is consistent with the needs of the Fisheries Management Work Group (FMWG).

2.2 Facilitate Compatibility with USJRBSI

The USJRBSI is investigating opportunities for additional water storage in or near Millerton Reservoir. The USJRBSI treats the SJRRP as an existing condition, and will need to test the SJRRP alternatives for temperature impacts and/or enhancements at some

point in the future. Compatibility between the technical analyses of the two projects would facilitate evaluation of SJRRP alternatives, thereby reducing development time and financial costs for the USJRBSI.

The USJRBSI has completed a substantial amount of technical analysis, including water temperature modeling, of Millerton Reservoir. The temperature analyses conducted under the USJRBSI are presently being reviewed by SJRRP Work Groups as part of alternatives development.

2.3 Simulate TCD on Millerton Reservoir River and Canal Diversion Outlets

The reservoir model will be required to simulate the impacts of TCDs on both the San Joaquin River outlets and the diversions to the Madera and Friant-Kern canals.

2.4 Meet SJRRP Schedule

More than one existing water temperature model has the potential to meet the temperature modeling needs of the SJRRP.

The schedule for implementation of the Settlement is very compressed. While a number of modeling tools could be used to develop a water temperature model, the development, calibration, and verification process would be very time-consuming. The system to be modeled includes both a reservoir and a river segment, which may require different modeling tools. This time constraint implies that the selection process will be limited to existing temperature models of Millerton Reservoir and the San Joaquin River in order to meet the project schedule.

3.0 Temperature Model Selection Process

The Water Management Work Group conducted a review of all temperature models that are ready, or easily adaptable, for use by the SJRRP. These models were compared to the temperature model needs described in Section 2.

3.1 Evaluated Temperature Models

This section provides an overview of each water temperature model evaluated for use by the SJRRP.

3.1.1 SJR5Q

The SJR5Q model was developed under the San Joaquin River Riparian Habitat Restoration Program. This HEC-5Q-based model is the result of combining and extending a number of smaller model development efforts throughout the San Joaquin Basin. The final SJR5Q model includes a reservoir operation and temperature model of Millerton Reservoir, and a river temperature model of the San Joaquin River from Millerton Reservoir downstream to the Old River bifurcation north of Mossdale, and the major tributaries, which includes the Merced, Tuolumne, and Stanislaus rivers.

The reservoir model portion of SJR5Q is a one-dimensional (1-D) vertically segmented model of Millerton Reservoir. The river portion of the model is a 1-D longitudinally segmented model of the San Joaquin River from Millerton Reservoir to the Old River bifurcation. The model functions on a daily flow time step with a 6-hour temperature interval to capture diurnal temperature fluctuations. As currently implemented, the model simulates the time interval of 1980 to 2006. This model has been used in the SJRRP to generate temperature simulation estimates assuming existing channel geometry and implementation of Settlement flows, with results summarized in Draft TMs Temperature Model Sensitivity Analysis Sets 1 and 2 (Reclamation, 2008b), and Temperature Model Sensitivity Analysis Set 3 (Reclamation, 2008c).

The SJR5Q model uses the embedded HEC-5 model to simulate the daily water operations of Millerton Reservoir.

3.1.2 Upper San Joaquin River Basin Storage Investigation Millerton Reservoir Temperature Model

This model was developed for Reclamation during the *NRDC et al. v. Kirk Rodgers et al.* litigation period and has since been updated and modified for continued use in the USJRBSI. This CE-QUAL-W2-based model is a two-dimensional (2-D) (vertical and longitudinal) laterally averaged, hydrodynamic and water quality model. The model has been modified to include the use of a TCD on the Madera and Friant-Kern canals as well as at the San Joaquin River outlet. The model functions on a daily flow time step with a 1-hour temperature interval to capture diurnal temperature fluctuations. As currently

implemented, the model simulates the time interval of 1984 to 2003. This model application to the USJRBSI is extensively documented (Reclamation, 2008a).

3.1.3 JSATEMP

Jones and Stokes Associates developed and applied a temperature model of the San Joaquin River from Millerton Reservoir downstream to the Merced River. The JSATEMP model is a spreadsheet-based (Deas and Lowney, 2000) semiempirical 1-D steady state representation of heat transfer processes formulated as a heat balance approach with an hourly time step using meteorological data from the California Irrigation Management Information System (CIMIS) to calculate minimum and maximum daily temperatures

3.2 Preliminary Screening

The models listed above were screened against the specific needs of the SJRRP, as listed in Section 2.

The SJR5Q includes a temperature model of both Millerton Reservoir and the San Joaquin River. This model has been used by Reclamation in previous efforts, and has the potential to meet the needs for temperature simulations at Millerton Reservoir and along the San Joaquin River.

The USJRBSI model only considers temperature simulations for Millerton Reservoir. This model's results were used during Settlement litigation in both the ongoing USJRBSI and in alternatives development under the SJRRP. This model has the potential to meet the needs for SJRRP temperature simulations at Millerton Reservoir.

Little information is available on the JSATEMP model, and it does not appear that this model has capabilities beyond those in the other models. Both of the other existing models described in Section 3.1 have been recently accepted by Reclamation and used in Reclamation activities. Because of lack of information on specific features that would meet the needs of the SJRRP, and lack of the same level of use by Reclamation as the other temperature models, the JSATEMP model was removed from consideration for the SJRRP.

3.3 River Water Temperature Model

The SJR5Q was developed and used for preliminary analysis of temperatures in the San Joaquin River. This model was built within the HEC-5Q water temperature modeling environment with 1-day flow and 6-hour temperature time steps to allow analysis of diurnal temperature fluctuations.

SJR5Q was calibrated using data from 2004 and 2005. Calibration statistics for several locations along the river are summarized in Table 3-1.

Table 3-1.
SJR5Q River Temperature Model Calibration Statistics

	Above Mendota	Below Mendota
Mean Error	-0.46	+0.55
Mean Absolute Error	0.96	1.18
Root Mean Square Error	1.22	1.45

Note:
Statistical measurements indicate the difference between recorded and simulated river temperatures in degrees Celsius.

The negative bias above Mendota may be at least partially attributed to ignoring the heating effects of offline storage during spring and summer 2005. There is a possibility that heating of water trapped in offstream gravel pits may contribute to warmer temperatures in the San Joaquin River in this reach. The capability to simulate this warming was added to the SJR5Q model by adding a "virtual" offstream reservoir to the system. This addition improved the calibration but was not included in any of the preliminary temperature analysis work performed using this model.

The river water temperature model portion of the SJR5Q model is selected for use as the river water temperature model in the SJRRP. This is the only existing, calibrated, and accepted model of the reaches of the San Joaquin River included in the SJRRP.

3.4 Reservoir Water Temperature Model Evaluation

Two models were screened for evaluating Millerton Reservoir temperatures for the SJRRP:

- SJR5Q
- USJRBSI

These two models are evaluated against the water temperature modeling needs discussed in section 2.0.

3.4.1 Produce Quantitative Temperature Results

The reservoir temperature model simulates outflow temperatures, which will be used as input into the river model. The outflow temperatures are a function of the water temperature profile and the operation/elevation of the outlets. This information can be supplied by a 1-D model or a 2-D model.

The accuracy of the water temperature profile at the outlets is more a function of calibration than the dimensionality of the model. Table 3-2 summarizes calibration statistics of outlet temperatures from both reservoir temperature models.

Table 3-2.
Reservoir Temperature Model Calibration Statistics

	SJR5Q	USJRBSI
Mean Error	-0.25	-0.20
Mean Absolute Error	0.52	0.52
Root Mean Square Error	0.68	0.71

Note:
Statistical measurements indicate the difference between recorded and simulated reservoir release temperatures in degrees Celsius.
Key:
SJR5Q = temperature model
USJRBI = Upper San Joaquin River Basin Storage Investigation temperature model

3.4.2 Facilitate Compatibility with USJRBSI

The calibration statistics of the two models are very similar. This implies that overall the simulated temperature results between the two models are similar, but there can be differences in temperatures between the model results for specific hours and days. These differences would create some level of incompatibility between the results of the two models, requiring additional testing, documentation, and explanation of the magnitude and the significance of the differences.

The USJRBSI model has been used to simulate water temperatures for 32 alternatives in the USJRBSI process. Using the same model provides absolute compatibility with the USJRBSI.

3.4.3 Integration with Water Operation Simulation

The SJRRP has selected the CALSIM II simulation model to simulate monthly time step water operations for Millerton Reservoir and the San Joaquin River (2008). These monthly time step operations will need to be split, or disaggregated into daily water operations, while maintaining the overall monthly guidelines from CalSim II, for use in the selected temperature model(s). The disaggregation will also need to correctly incorporate specialized Millerton Reservoir operation rules, such as prerelease for future snow-melt inflow operations.

SJR5Q has the capability to perform a daily water operation simulation of Millerton Reservoir and the San Joaquin River using the logic built into the underlying HEC-5

water operations model. The current SJR5Q water operations simulation does not include the need to maintain the monthly operational guidelines from CALSIM II or the specialized Millerton Reservoir operation logic. The model would require updating or modification to implement these rules.

The USJRBSI reservoir water temperature model is a pure water temperature simulation; it must be furnished the daily water operations as input. A monthly to daily water operations disaggregation tool was developed for the USJRBSI that uses CALSIM II simulation results and generates a set of daily Millerton Lake maintaining the monthly guidelines and implementing the specialized operation logic. The combination of the disaggregation tool and the USJRBSI reservoir water temperature model is ready for use in the SJRRP with no further development required.

3.4.4 Simulate TCD on Millerton Reservoir river and diversion outlets

As mentioned, the SJR5Q model has the capability of modeling a TCD on the river outlet; however, this has not been implemented. Adding a TCD to the diversions could require modification to the underlying HEC-5Q environment that the SJR5Q model is built within. Shortcuts could also be developed to manually raise/lower outlet elevations based on temperature profiles. These modeling fixes would require additional development before implementation.

The USJRBSI model includes a TCD on the river and on the Madera and Friant-Kern canal diversions.

3.4.5 Meet SJRRP Schedule

While both models have been calibrated and verified, other factors must be considered when evaluating the ability to meet the SJRRP schedule.

As discussed in Section 3.4.3, the SJR5Q reservoir water temperature model would require additional development be fully integrated in the anticipated water operation simulations done for the SJRRP.

As discussed in section 3.4.4, the SJR5Q reservoir water temperature model would require additional development to implement the ability to simulate a TCD on the river and diversion outlets.

The USJRBSI model and supporting tools include these capabilities.

3.4.6 Other Factors

A number of other potential evaluation criteria for reservoir model selection were also considered. These criteria were determined to have much less impact on the selection process than the four main criteria discussed above. This section presents an evaluation of these other criteria; a combined rating of the criteria will be included in the selection table.

Simulation Run Times

The USJRBSI reservoir temperature model, which is a 2-D model, requires substantially longer run times than the SJR5Q reservoir temperature model, which has a 1-D formulation. The USJRBSI model's run time is several hours, versus several minutes for the SJRQ5 model. Since the models will be used as long-term planning models on a limited number of alternatives, and not for real-time "gaming," the difference in computer run times is not a significant difference between the two models.

Linkage Between Reservoir and River Temperature Models

The reservoir water temperature model will simulate the temperature of the San Joaquin River release from Millerton Reservoir. These data will become input to the river water temperature model to link the two models into a single model of the area of concern.

The river water temperature model portion of the SJR5Q model was selected for use to model the water temperature of the San Joaquin River. If the reservoir water temperature model portion of the SJR5Q model is chosen as the reservoir water temperature model, the linkage is fully implemented in the combined SJR5Q model.

The USJRBSI reservoir temperature model outputs time series data in ASCII format. A simple conversion utility would need to be created to convert the time series data to HEC-DSS to be read by the river temperature model.

Dynamic Adjustment of Reservoir Operations for Temperature Control Purposes Downstream Along the San Joaquin River

The SJR5Q model includes the capability to dynamically adjust Millerton Reservoir water operations for temperature management purposes downstream in the San Joaquin River. Since this is not a need of the SJRRP, this is not a valid evaluation criterion for model selection.

3.4.7 Reservoir Model Comparison Summary

Both reservoir temperature models were rated for each of the factors discussed in Chapter 2. The possible ratings are as follows:

- High – Models with this ranking address the modeling need at an adequate level. The model will require minimal modification, enhancement, or updates. Simple supplemental tools may be required to completely meet the need.

- Medium – Models with this ranking somewhat address the modeling need. The model may need moderate modification, enhancement, or updates. Moderately complicated supplemental tools may be required to completely meet the need.

- Low – Models with this ranking are unable to address the modeling need. Extensive modification, enhancement, or updates would be required. Complicated supplemental tools would be required to completely meet the need.

Analysis of the two models is summarized in Table 3-3.

Table 3-3.
Summary of the Evaluation Factors Considered

	SJR-5Q	USJRBSI
Produce Quantitative Temperature Results	**High**	**High**
Facilitate Compatibility with USRBI	Med	**High**
Integration with water operations	Med	**High**
Simulation of TCD on outlet and diversions	Med	**High**
Meet SJRRP schedule	Med	**High**
Other Factors	Med	**High**

Key:
SJR5Q = temperature model
SJRRP = San Joaquin River Restoration Project
TCD = temperature control device
USJRBSI = Upper San Joaquin River Basin Storage Investigation temperature model

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4.0 Recommendations

This section presents the recommended water temperature models for use in the SJRRP.

4.1 Selected River Water Temperature Model

The SJR5Q river water temperature model was selected for use in the SJRRP. This model has good calibration, and has been used in preliminary temperature analysis for the SJRRP.

4.2 Selected Reservoir Water Temperature Model

The USJRBSI reservoir water temperature model was selected for use in the SJRRP. The model is currently used by the USJRBSI, is currently integrated with the selected CALSIM operations model, has good calibration, and has a TCD on the river outlets and the diversions.

4.3 Recommended Model Development

Additional model development may be required to fully integrate these temperature models into the overall modeling system, including the following:

- Removing Millerton Reservoir from the SJR5Q model to create a stand-alone temperature model of the San Joaquin River model.
- Developing an interface between the river and reservoir water temperature models.
- Developing new input data for the river temperature model to incorporate new settlement channel geometry, and Mendota Bypass to River model for with settlement modeling.
- Comparing meteorological conditions, reservoir inflow volume, and temperature assumptions with between the river and reservoir water temperature models.
- Developing interface between these temperature models and the CALSIM II water operations models.

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5.0 References

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