BUREAU OF RECLAMATION

Technical Memorandum

Water Temperature Modeling Platform: Project Workplan (INTERIM DRAFT)

Central Valley Project Water Temperature Modeling Platform

California-Great Basin Region

U.S. Department of the Interior

June 2022

Mission Statements

The U.S. Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated Island Communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Water Temperature Modeling Platform: Phase I Work Plan (INTERIM DRAFT)

Central Valley Project Water Temperature Modeling Platform

California-Great Basin Region

prepared by

United States Department of the Interior Bureau of Reclamation

California-Great Basin

With Technical Support by:

Watercourse Engineering, Inc.

Cover Photo: Keswick Dam on the Sacramento River by John Hannon

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Abbreviations and Acronyms

CPP	Community Participation Plan
CVP	Central Valley Project
GUI	Graphical User Interface
QA	Quality Assurance
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
TCD	Temperature Control Device
WTMP	Water Temperature Modeling Platform

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Chapter 1 Introduction

Flow and water temperature simulation models are useful and necessary tools to support resource managers in their understanding of temperature dynamics in U.S. Bureau of Reclamation (Reclamation) Central Valley Project (CVP) reservoirs and downstream river reaches. Such tools support evaluation of how operational decisions and various influencing factors can affect water temperature in reservoirs and rivers, and the resulting potential impacts to fishery species that are sensitive to water temperature.

The improvement of models, modeling approach, and associated tools to support operational decision-making is considered a necessary adaptation strategy that takes advantage of ongoing technological advancement, and additional information and data. These tools provide a means to assess strategies and define objectives for water temperature management, allowing reservoir operators with a finite cold-water supply to effectively plan, forecast, and operate storage and conveyance systems to meet a wide range of water supply demands and limit impacts to aquatic species sensitive to temperature. Water temperature modeling frameworks are used to forecast and assess future conditions for real-time, seasonal operations, and biological assessments to achieve goals. Reclamation's objective for the development of the Water Temperature Modeling Platform (WTMP) is the effective and efficient management of resources for downstream regulatory and environmental requirements within the context of an uncertain environment. A primary development goal of the WTMP is to provide realistic predictions of CVP reservoirs and downstream river water temperatures with sufficient confidence to carry out the necessary planning for seasonal and real-time applications while also describing situational risk and uncertainty.

The proposed approach aims to utilize existing models, update or refine existing model technology, and develop new models, as necessary, to be used to assist reservoir operation managers. The model development effort includes in order of priority:

- The northern system – Shasta Lake, Keswick Reservoir, and the Sacramento River from Keswick Dam to Bend Bridge; Trinity Lake, Lewiston Lake, and the Trinity River downstream to the North Fork Trinity River; and Whiskeytown Reservoir and Clear Creek from Whiskeytown Dam to the Sacramento River.
- The American River system – Folsom Reservoir, Lake Natoma, and the American River downstream to the Sacramento River.
- The Stanislaus River system – New Melones Lake, Tulloch Lake, and the Stanislaus River from Tulloch Dam to the San Joaquin River including Goodwin Reservoirs and Dam.

For each system, a two-phase process is planned, with the first phase focusing on the model development and the second phase addressing uncertainty and refining tools for application. In Phase I, models will be developed to include a stakeholder outreach strategy, data management plan and data development, suggested monitoring and data collection, evaluation and selection of

appropriate modeling framework, evaluation and selection of appropriate models, model development, model calibration and validation, and documentation. There is also an interim peer review scheduled as part of the Phase I activities that addresses model implementation, calibration and validation, and documentation for the Shasta Lake, Keswick Reservoir, and Sacramento River modeling.

In Phase II, the completed models shall be developed into applications usable by Reclamation, including the application of proposed model frameworks, pre- and post-data processing, and implementation of proposed downstream linkages for in-river temperature prediction and identifying and describing future uncertainty. The final Phase II report will document these activities. A final peer review will occur to address model development activities for the Trinity River and Clear Creek, American River, and Stanislaus River applications, as well as Phase II activities.

Activities that will occur throughout the project include stakeholder participation and technology transfer to build Reclamation expertise in the application and implementation of the temperature models. This document describes the work plan elements for Phase I activities as outlined in Reclamation (2020).

Chapter 2 Phase I Tasks

Certain Phase I tasks address broad, system-independent processes. For example, the approach to Task 3, Develop Reclamation's Institutional Knowledge, may not vary notably between the three systems. In these cases, there may be a single global approach document for the task without stand-alone, system specific documentation that covers activities and approaches to developing Reclamation's institutional knowledge.

Project workplan elements on a task-by-task basis are outlined below. Each task is introduced with the task objective and description. Subsequently, task activities, assignments, deliverables, and schedules for each system are detailed. Task activities refer to actions that will be undertaken by the Watercourse Engineering, Inc. (WCE) team, with collaboration from Reclamation as needed or appropriate. Assignments refers to the task or subtask leading the work as well as participants. Participants are defined as primary and secondary, with primary participants directly engaged in most task activities and secondary participants directly engaged on an as-needed basis.

Due to different priorities for different systems with unique attributes, the workplan will retain flexibility and adaptability: There is sufficient structure to track task progress and products, while also providing the opportunity for feedback, accommodation of new information (lessons learned), and adjustment in this large, complex project.

Final products that are identified for public posting via Reclamation (e.g., made available on a website or public similar distribution method) will be 508-compliant[1] in their final form, publicly distributable form. Not all work products in this project will require such compliance measures, and products identified for 508-compliance will be identified in collaboration with Reclamation.

Phase I tasks include:

- Task 1. Project Workplan
- Task 2. Stakeholder Involvement and Outreach
- Task 3. Develop Reclamation's Institutional Knowledge
- Task 4. Data Management

[1] Section 508 of the Rehabilitation Act (29 U.S.C. § 794d), as amended by the Workforce Investment Act of 1998 (P.L. 105-220), requires federal agencies to develop, procure, maintain and use information and communications technology (ICT) that is accessible to people with disabilities – regardless of whether or not they work for the federal government. (see https://www.eeoc.gov/statutes/rehabilitation-act-1973).

- Task 5. Model Framework Design and Refinement
- Task 6. Model Selection/Design
- Task 7. Data Development
- Task 8. Model Development
- Task 9. Calibration, Validation, and Sensitivity
- Task 10. Documentation Phase I.

Peer Review (Task 17) is also discussed herein because there is a Phase I activity associated with this task. Each task is outlined below, with a summary of objective and description, as well as task deliverables. A Phase I preliminary schedule is presented at the end of the section.

TASK 1. Project Plan

The Phase I Project Workplan (PWP-I) will include a description of each task for Phase I, the general approach for the task, subtasks that outline where individual river basins deviate from the general approach, deliverables, assignments, and a timeline. The overall modeling project will follow identified model development protocols (outlined in the model development phase).

Task 1 objective and description are included in Table 2-1. Task 1 deliverables and schedule are listed in Table 2-2.

Table 2-1. Task 1 Objective and description.

Task	Objective	Description
Task 1. Project Workplan	Develop detailed workplan and schedule for the overall modeling project with emphasis on Phase I – Task 1 through Task 10.	Coordinate with Reclamation to develop a detailed Phase I schedule for the modeling project. This also includes prioritization of reservoirs and plans for completion of reservoir modeling whether in series or in parallel. Reclamation and Contractor shall discuss and clarify details such as data management and collection, holistic development of a cold-water management plan, seasonal and planning application, incorporation of uncertainty in model representation, calibration processes and validation result presentation, testing, and review strategies.

Table 2-2. Task 1 Deliverables and schedule.

Deliverable	Schedule
Technical Memorandum Task 1 – Water Temperature Modeling Platform: Phase I Workplan (DRAFT)	Ongoing
Technical Memorandum Task 1 – Water Temperature Modeling Platform: Phase I Workplan (FINAL)	June 2022

Because the Phase I workplan is subject to update and refinement, the draft is termed a "working document," and will be finalized at the end of Phase I activities.

TASK 2. Stakeholder Outreach

For individual systems, the stakeholder involvement and outreach are expected to follow the outline listed below, but with system-specific attributes crafted to address local conditions. Activities for stakeholder involvement and outreach include the development of a Community Participation Plan (CPP) and planning and convening stakeholder meetings.

Community Participation Plan Development

The CPP outlines the strategy to develop appropriate stakeholder groups to facilitate outreach through regular meetings. The goal of the CPP and associated activities is to facilitate broad support for the development and use of Reclamation's new modeling framework and model applications for water temperature management as part of CVP operations.

Stakeholder Meetings

Stakeholder meetings will occur at predetermined intervals to convey project information and solicit comments and feedback on progress made in the Phase I processes and to communicate and collaborate in an open and transparent fashion with the regional hydrologic modeling community, other agencies, and stakeholders.

Meetings are envisioned to include all modeling activities (i.e., Sacramento/Trinity, American, and Stanislaus Basins) to support a common modeling platform and approach and efficiently engage stakeholders.

Activities associated with stakeholder meetings include:

- Pre-meeting preparation (including internal meetings with Reclamation)
- Attendance and note taking at meetings and calls
- Preparation of meeting summaries and materials

- Coordination with meeting participants
- Follow-up on action items, and
- Other project administrator activities.

Members of the model development team will actively participate in stakeholder involvement and outreach meeting, presenting modeling technical information to these groups. In this manner, outcomes from the meetings that are pertinent to development of the WTMP and associated activities are communicated back to the model development teams, as necessary.

Task 2 objective and description are included in Table 2-3. Task 2 deliverables and schedule are listed in Table 2-4.

Table 2-3. Task 2 Objective and description.

Task	Objective	Description
Task 2. Stakeholder Involvement and Outreach	Maintain transparency and interaction with stakeholders through outreach activities.	Convene Technical Modeling Committee consisting of Reclamation and other identified agencies (i.e., National Marine Fisheries Service, California State Water Resources Control Board, CVP contractors, et al. provided by Reclamation) – through this group model development activities will be shared to maintain transparency. Conduct training as appropriate such as model application workshops to transfer capabilities to Reclamation and stakeholders. Contractor shall develop and implement a community participation plan, including but not limited to Modeling Technical Committee meetings.

Table 2-4. Task 2 Deliverables and schedule.

Deliverable	Schedule
Technical Memorandum Task 2 – Community Participation Plan (DRAFT - internal)	May 2021
Technical Memorandum Task 2 – Community Participation Plan (FINAL)	July 2021
Meeting Materials (e.g., presentations; meeting agenda, materials, and notes)	Aligned with each MTC meeting

Meeting materials will be developed prior to the meeting (agenda, presentations, materials), and post-meeting deliverables (notes and other meeting products) will be provided prior to the subsequent meeting.

TASK 3. Develop Reclamation's Institutional Knowledge

Institutional knowledge includes the experiences, processes, data, expertise, values, and information possessed by company or agency employees. This repository of knowledge can span years and include important trends, information about long-term projects, and historical perspectives and relationships. Briefly, activities for developing Reclamation's institutional knowledge will include active and passive components. Active components include model training sessions and relevant training material, and passive components include project team meetings, briefings, calls, and other activities related to all tasks that will provide ongoing opportunities for knowledge and technology transfer.

Training sessions will be developed to provide opportunities for Reclamation personnel to be exposed to model development, calibration/validation, and application processes; data management (input and output) procedures, and overall model framework function. To further organize the information developed throughout the modeling project, a project index that includes all technical memoranda and project materials will be developed to guide Reclamation, including new employees and personnel transferring into positions with modeling responsibilities, to relevant topic areas.

Because water temperature modeling requires a considerable investment by Reclamation, the project team will develop an institutional knowledge plan summary. To minimize the effects of the loss of institutional knowledge when staff leave or are transferred, a plan will increase opportunities to retain business processes, institutional policies and practices, and historical knowledge and expertise as they relate to temperature modeling.

Task 3 objective and description are included in Table 2-5. Task 3 deliverables and schedule are listed in Table 2-6.

Table 2-5. Task 3 Objective and description.

Task	Objective	Description
Task 3. Develop Reclamation's Institutional Knowledge	Build Reclamation's expertise in the application and implementation of temperature modeling.	Coordination with, and training of, Reclamation staff shall take place at Technical Modeling Committee, training workshops meetings, and meetings specifically designed to transfer modeling development or application use capabilities to Reclamation's modeling staff. Contractor shall also produce brief and relevant training materials.

Table 2-6. Task 3 Deliverables and schedule.

Deliverable	Schedule
Training and relevant training materials	TBD
Project index of technical memoranda and other project materials to guide	August 2023
Institutional knowledge plan summary	October 2021

The timing of training will be developed in cooperation with Reclamation.

TASK 4. Data Management

An important element in developing the temperature management platform is data management. Specifically, identifying necessary data and sources, measures for quality analysis and potentially quality control, methods for estimating missing data, how data is to be stored, metadata definitions and format, and how data shall be communicated. Reservoir and river model input data requirements fit into three general types of data in general: time series data, physical data, and operational data.

Time series data is a sequence of data points in time order. These data points usually are successive measurements made from the same source over a time interval and are used to track changes over time. Physical data refer to fixed information required for models, and can include geometry of reservoirs and rivers (location on the earth, morphology, location of tributaries/withdrawals), reservoir intake descriptions (elevation, diameter, capacity, stage-discharge relationships), conveyance capacities, and similar information. Operational data include reservoir operating rules, minimum instream flows, and a wide range of other operations related information.

One of the principal needs of the project is management of time series information. Input, in the form of boundary conditions for temperature models, includes time series of inflows, inflow temperatures, system outflows, and meteorological data. Model simulation will also produce extensive time series output. Certain operational data (e.g., TCD operations) may be represented as time series information, as well as calibration data (reservoir or river stage, reservoir temperature profiles). Some of these data types may not occur at fixed intervals, but may still be represented as unevenly spaced time series. The data management system will focus on time series data because of the importance of these data in modeling, the need to track data sources and QA actions, assigning metadata, and documentation.

The data management plan will address global time series data needs in all river basins with unique aspects addressed on a basin-by-basin approach. Due to the relative static nature of physical and operational data, these data types will be managed through direct documentation unique to each basin and addressed explicitly in Task 4 (Data Management). The data management plan will be updated as necessary as the project progresses, and refinements may occur in Phase II, and will be documented in the Phase II reporting.

Task 4 objective and description are included in Table 2-7. Task 4 deliverables and schedule are listed in Table 2-8.

Table 2-7. Task 4 Objective and description.

Task	Objective	Description
Task 4. Data Management	Develop data management plan for Phases I and II of project.	Coordinate with Reclamation to develop a data management plan, specifying how and where data is to be stored, define and format metadata, and determine how data shall be communicated.

Table 2-8. Task 4 Deliverables and schedule.

Deliverable	Schedule
Technical Memorandum Task 4 – Water Temperature Modeling Platform: Data Management Plan (DRAFT)	October 2021
Technical Memorandum Task 4 – Water Temperature Modeling Platform: Data Management Plan (FINAL)	January 2022

TASK 5. Model Framework Design and Refinement

Developing a system-wide model framework that addresses the spatial and temporal representation of reservoir, river, and associated facilities in the Sacramento/Trinity, American, and Stanislaus River basins requires a clear understanding of how temperature is managed in each of these basins. Critical to framework selection and design is defining how the different components (i.e., reservoirs and rivers) are represented using models and how they relate to one another, how information is shared among the models (e.g., how output from one model provides input to another model), and status of the models (e.g., latest calibration version, etc.). Additionally, there are unique attributes to each basin that may be important in developing a model framework.

This task includes several activities in the design and refinement of a modeling framework:

- Model Domain: Identify, by basin, the spatial and temporal representation of reservoir, river, and associated facilities. This spatial representation defines the spatial domain of the proposed modeling.
- Model Usage: Describe how models are used to represent these systems, the processes and flow of information, expected outcomes.
- Model Framework: Model framework description and purpose, strategies and benefits for employing frameworks, evaluation criteria and available frameworks for consideration.
- Framework Testing: A representative system will be tested for a defined period to illustrate the role that a modeling framework would play in the water temperature modeling platform.

This task and Task 6 (Model Selection) are to be completed in tandem because of the interrelated issues of the two tasks. For example, certain models can be more readily incorporated into modeling frameworks than others.

These activities will form the basis for the Task 5 technical memorandum. The flow and transfer of information through the framework for each system will be illustrated, as well as unique attributes of each river basin and system specific considerations. These representations and models will be refined in future tasks as the models are constructed and more information is developed.

Task 5 objective and description are included in Table 2-9. Task 5 deliverables and schedule are listed in Table 2-10.

Table 2-9. Task 5 Objective and description.

Task	Objective	Description
Task 5. Model Framework Design and Refinement	Develop a system-wide model framework that illustrates the spatial and temporal representation of each model used in the Trinity, Clear Creek, Sacramento, American, and Stanislaus River basins.	Determine how the different elements (reservoirs and rivers) relate to one another, how information is shared among the models (e.g., how output from one model provides input to another model), and status of the models (latest calibration version, etc.). This effort lays the foundational logistics of constructing and accomplishing the temperature management objectives in each river system, including gather information on existing tools, framework design, defining spatial and temporal scale, identifying the "path" of information through the models and data sharing from model inputs to model outputs, and identifying the status of the models and any potential development and data needs. This framework shall provide insight into model refinement/development and ensure that tasks and phases can be prioritized based on need and ability to efficiently implement each task upon completion (i.e., place into direct use in current or refined framework). The framework is expected to be similar to the current HEC-5Q operational framework, and is anticipated to ultimately include key elements such as: • Inflow volume, timing, and temperature forecasting/modeling, • Temperature and stratification forecasting/modeling based on forecasted inflow, meteorological conditions, and a forecasted release schedule, • Network representing physical linkages and physical characteristics (leakage, thermal curtain behavior, submerged structures, etc.) between the facilities, and • Simulation of selective withdrawal operation for automation provided downstream temperature target and specified forecasted release schedule

Table 2-10. Task 5 Deliverables and schedule.

Deliverable	Schedule
Technical Memorandum Task 5 – Water Temperature Modeling Platform: Model Framework Selection (DRAFT)	August 2021
Technical Memorandum Task 5 – Water Temperature Modeling Platform: Model Framework Selection (FINAL)	November 2021

TASK 6. Model Selection/Design

Model selection will be based on system attribute information developed in previous tasks (e.g., spatial domain, temporal aspects, relationships between model framework reservoir and river elements, unique basin considerations).

Selection of models for each framework element will be based on the overall project objectives and identified selection criteria. Selection criteria will be developed in collaboration with Reclamation. Criteria will include unique aspects of CVP facilities such as selective withdrawal facilities, temperature control curtains, or submerged dams. Qualitative attributes (e.g., ease of use) will also be identified. Subsequently, available models will be identified, and criteria tabulated.

As noted above, this task and Task 5 (Model Framework Design and Refinement) are to be completed in tandem because of the interrelated issues of the two tasks. Selected models will be tested for a defined period to illustrate how models would work within a modeling framework. Refinement of models will occur in Task 8 (Model Development).

These activities will form the basis for the Task 6 technical memorandum. Model selection criteria and available models, and the outcome of model performance in the modeling framework test application will be reported. At the termination of this task, all identified models and framework software will be acquired, including supporting documentation and technical support information. Documentation will include a recommendation for modeling framework and model(s).

Task 6 objective and description are included in Table 2-11. Task 6 deliverables and schedule are listed in Table 2-12.

Table 2-11. Task 6 Objective and description.

Task	Objective	Description
Task 6. Model Selection/Design	Select models for each of the elements of the framework based on objectives and selection criteria. Determine the appropriate spatial and temporal resolution of the selected models, and conduct any additional necessary design specification for the models.	For each model in the framework (and at appropriate timing in the overall project plan): • Identify specific selection criteria and requirements for model, • Identify existing models and potential modeling packages for new model development, • Evaluate identified models based on selection criteria, • Complete initial model design and/or identify necessary refinements (if selected modeling approach is to refine an existing one), • Model elements and capabilities for consideration will be based on selection criteria developed in cooperation with Reclamation, • Identify for each model unique aspects of operations such as Temperature Control Devices, temperature curtains, or submerged dams. The dimensional structure representation for each reservoir, including important side channels.

Table 2-12. Task 6 Deliverables and schedule.

Deliverable	Schedule
Technical Memorandum Task 6 – Water Temperature Modeling Platform: Model Selection (DRAFT)	August 2021
Technical Memorandum Task 6 – Water Temperature Modeling Platform: Model Selection (FINAL)	November 2021

TASK 7. Data Development

Upon completion of Tasks 5 and 6, the input data necessary to support the identified models will be developed. Data gathering and management will follow the data management plan (Task 4). This task will be completed for each river basin, with the initial work occurring in the Sacramento/Trinity system, followed by the American River and Stanislaus River systems.

Data specification information will be developed for each system to address necessary physical, operations, and time series data. This data specification information will also accommodate unique attributes for each basin and will offer a mechanism to identify the information used in each model. Coupled with the Task 4 Data Management Plan, each data type will be managed according to type

and role in modeling, with attention focused on time series boundary conditions to the modeling framework.

Key elements of data development include:

- Defining modeling period and necessary data frequency
- Data acquisition
- Data quality analysis and quality control (QAQC)
- Information metadata
- Documentation

Each of these elements will be applied to time series data, as well as physical and operational data. While physical data are largely independent of modeling period, modifications to infrastructure during the modeling period that would change system representation should be addressed.

Data acquisition will vary due to data types and may differ among individual river systems. Time series, physical, and operations data will be requested from Reclamation and other sources for each system. QAQC associated with these data largely rely on sources of data and available information. Each data set will be documented (including metadata). Representative physical and operations data types are presented in Table 2-13 and Table 2-14.

Table 2-13. Basic physical data types (not all attributes may be applicable to all models).

Model Element	Data Representation	Examples
Reservoir	Bathymetry	Reservoir geometry, location of thalweg; location of tributaries, diversions, discharges to reservoir; location of intake works. Support 1-D and 2-D modeling.
Reservoir	State-area-volume curve	Relate state to area and volume for 1-D models. Can be used to confirm 2-D model representations (bathymetry).
Reservoir	Reservoir control infrastructure	Define intake/outlet works size, capacity, elevation, location in the reservoir (e.g., at dam, at an upstream location), spillway configuration.
Reservoir	Other infrastructure	Diversion works, tunnels (egress and ingress), location of discharge to reservoir, inundated structures (e.g., submerged dams).
Reservoir	Other information	Topographic shade, wind sheltering.
River	Bathymetry and/or planform of river (e.g., lat/long)	River geometry, location of thalweg, location of tributaries, diversions, discharges, location of intake works. River mileage determination, diversion dams or channel controls, key landmarks (e.g., compliance locations).
River	Longitudinal profile	Stream gradient for stream modeling.

Model Element	Data Representation	Examples
River	Cross-section measurements	River geometry; stage-flow-surface area relationships; development of stage-discharge relationships for downstream boundary conditions.
River	Other information	Side channels, topographic shade, riparian vegetation shade.

Table 2-14. Basic operational data types (not all attributes may be applicable to all models).

Model Component	Data Type	Description
Reservoirs	Storage rule curve	Flood control, water supply, navigation, and other rule-curve supported uses
Reservoirs	Selective withdrawal operations	Temperature control device (or shutter system) operational requirements/limitations, strategies, leakage
Reservoirs	Hydropower operations/requirements	Hydropower agreements
Reservoirs	Minimum storage	Dead pool, navigation
Reservoirs	Biological regulatory requirements	In-reservoir and/or downstream water quality requirements for ESA-listed species
Reservoirs	Other	Fish hatchery requirements, other
Rivers	Minimum downstream flows	Intake (diversion) requirements, water quality, navigation, environmental requirements
Rivers	Diversion and return flows	Water diversion schedules, return flow timing and quantity schedules
Rivers	Biological regulatory requirements	Water quality requirements for ESA-listed species
Rivers	Other	Tribal flows, sediment transport flows, environmental flows, Delta requirements, other

Time series data will rely on automated data acquisition (e.g., USGS gages), collection of electronic records (e.g., thermal profiles), and other sources. QAQC will rely on automated procedures, followed by additional checks to confirm automated procedures and screen for additional levels of QAQC. As part of the QAQC process, data gap filling procedures will be employed. The data management process tracks all data activities from raw data and as data are processed through QAQC and gap filling or smoothing, providing a self-documenting process for all model inputs (e.g., captures metadata information). Basic time series data types are included in Table 2-15.

Table 2-15. Basic time series data types, including initial conditions, boundary conditions, and calibration/validation data for reservoir and river model elements (Initial conditions are not necessarily time series but are included here for completeness). An "X" indicates the model applications (initial condition, boundary condition,

calibration/validation) for which a data type is utilized; "--" indicates data type is not utilized for the specified model application.

Model Component	Data Representation	Initial Conditions	Boundary Condition	Calibration/ Validation
Reservoir	Reservoir Inflow (tributary)	--	X	--
Reservoir	Reservoir Inflow (discharge)	--	X	--
Reservoir	Reservoir Outflow (dam)	--	X	--
Reservoir	Reservoir Outflow (diversion)	--	X	--
Reservoir	Reservoir Stage	X	--	X
Reservoir	Reservoir Inflow Temperature (tributary)	--	X	--
Reservoir	Reservoir Inflow Temperature (discharge)	--	X	--
Reservoir	Reservoir Outflow Temperature	--	--	X
Reservoir	Reservoir Temperature Profiles	X	--	X
River	River Inflow (headwater)	--	X	--
River	River Inflow (tributary)	--	X	--
River	River Inflow (discharge)	--	X	--
River	River Outflow (diversion)	--	X	--
River	River Downstream Boundary Flow	--	--	X
River	River Stage	X	--	X
River	River Downstream Boundary Temperature	--	--	X
River	River Temperature (within Domain)	--	--	X
Meteorology	Meteorology	--	X	--

As part of data development, additional sources of data will be explored (i.e., data that are maintained in agency data bases and unavailable online or through Reclamation) and the need for new data collections efforts identified. The project team will work cooperatively with Reclamation to determine the ability to collect identified additional data needs.

Task 7 objective and description are included in Table 2-16. Task 7 deliverables and schedule are listed in Table 2-17.

Table 2-16. Task 7 Objective and description.

Task	Objective	Description
Task 7. Data Development	Identify necessary input data to models and obtain or develop datasets for use with models.	Identify necessary data and sources for use with models Reservoir and river model input data requirements will fit into three types of data in general: time series data, physical data, and operational data. Input requirements shall use current or very recent historic data sources obtained from appropriate sources. Perform quality analysis and potentially quality control on data. Develop automated mechanisms for data retrieval and/or quality analysis/quality control as necessary. This plan shall describe surrogates or alternative modeling paths to deal with data that is not available. For input requirements which shall use forecast data, identify and/or develop data sources (see Phase II). . To the extent that information is not readily available for components of the river/reservoir system, new data may need to be collected as part of this process (i.e., bathymetric data, etc.). Make and document recommendations for supplemental data collection to support or enhance model performance. Where necessary, work shall be conducted through Reclamation staff based on their availability; Contractor shall also work closely with Reclamation modelers, ensuring they understand the choices made in data collection.

Table 2-17. Task 7 Deliverables and schedule.

Deliverable	Schedule
Technical Memorandum Task 7 – Water Temperature Modeling Platform: Data Development (DRAFT)	August 2022
Technical Memorandum Task 7 – Water Temperature Modeling Platform: Data Development (FINAL)	November 2022

Because this task necessarily includes all river basins, the draft and final technical memoranda are close to the end of Phase I.

TASK 8. Model Development

The model development process is a resource intensive task and follows a multi-step process. Once models are selected, gathering the necessary information and data and model implementation includes:

- Model software acquisition

- Reviewing existing modeling efforts
- Updating or developing model representations
- Developing model data and associated information
- Model Testing

Model Software Acquisition

Selected model and modeling framework software will be acquired and tested to ensure they are installed properly and functioning as designed.

Review Existing Modeling Efforts

Review of previous modeling provides useful direction on available model representations, data, and any challenges encountered that can assist in developing the selected models. In addition to these basic data types, there are also model assumptions, parameters, and coefficients that can lend insight into new or updated modeling efforts.

Updating and/or Developing Models

After acquiring model software and previous modeling efforts, identify model representations or model attributes that may be desired in the new modeling approach. If new models are being developed, simply transferring information from a previous model may not be sufficient, feasible, or appropriate. In certain cases, models may need to be modified to accommodate specific reservoir or river elements or infrastructure.

Developing Model Data

Implementing the full model includes developing system geometry, boundary conditions, initial conditions, model parameters to represent flow and temperature, and model control parameters (time step, start and end dates, input and output controls, and other factors). Due to their system and model specific nature, physical and operations model data will be incorporated into the models and documented. The extent of model (domain) and spatial and temporal resolution are addressed in this activity. Time series data will be managed in a database and the modeling framework providing the information (data) flow and model simulation control. The data base will provide a means to track data sources, modification, and metadata, and in concert with the modeling framework will provide model input information in the proper format for the simulation.

Model Testing

The final stage in model development is testing the model. At this stage of the process, the model is reading all input information, and is simulating flow and temperature, but is uncalibrated. Simulations are assessed to ensure results though uncalibrated, are reasonable and model is simulating results as designed (e.g., steady-state conditions are confirmed, transients are represented, simulation times are not longer than expected). Modifications to the input data, model parameters, or even models source code may occur during model testing. For example, revisiting data gaps that were filled, modifying model parameters to assess model performance and sensitivity, or modifying and testing new model representations or logic to manage input and output.

Task 8 objective and description are included in Table 2-18. Task 8 deliverables and schedule are listed in Table 2-19.

Table 2-18. Task 8 Objective and description.

Task	Objective	Description
Task 8. Model Development	For each of the model components in the framework, the model selected for use may need to be revised, refined, or a new model developed.	Obtain existing models (if modeling effort is a revision or refinement of existing model), refine existing model, or develop new model depending on approach determined through selection process. Repeat model refinement and testing until the model represents general system conditions (e.g., simulating reasonable temperatures but not calibrated). Set up and use a version control process to track model modifications/refinements. Produce documentation on iterative improvements. Task 8 activities may overlap with Task 9 (Calibration, Validation, and Sensitivity) activities due to the closely related elements, and technical memoranda may be combined for these two tasks (to be determined in discussions with Reclamation and Contractor).

Table 2-19. Task 8 Deliverables and schedule.

Deliverable	Schedule
Technical Memorandum Task 8 – Water Temperature Modeling Platform: Model Development (DRAFT)	August 2022
Technical Memorandum Task 8 – Water Temperature Modeling Platform: Model Development (FINAL)	November 2022

Because this task necessarily includes all river basins and overlaps with calibration and validation (Task 9), the draft and final technical memoranda are close to the end of Phase I.

TASK 9. Calibration, Validation, and Sensitivity

Model calibration, validation, and sensitivity testing is the final stage of modeling prior to application. Model calibration is the process of adjusting selected model parameters and minimizing the difference between simulated results to field observations (CWEMF 2021). Model validation simulations are completed without modifying any calibration parameters, and summary statistics computed. Sensitivity analysis is systematically modifying selected model inputs or parameters to assess model response. The outcome of these activities provides a measure of model performance

and responsiveness to key inputs and assumptions, and coupled with model performance metrics, yields insight into model uncertainty.

Specific activities in Task 9 include:

- Develop system-wide model performance statistics and metrics
- Calibration and validation of both system models and discrete element models
- Sensitivity analysis
- Documentation

Each of these topics is discussed below.

Model Performance Statistics and Metrics

To assess model performance and guide calibration and validation, appropriate performance statistics (e.g., bias, mean absolute error, root mean squared error or other metrics (Ji 2017, Chin 2013) will be developed. Theses metrics are calculated based on observed values and simulated model output of time series (flow, stage, and temperature) and reservoir profiles (temperature). For identified model outputs (flow, stage, temperature), appropriate target metrics will be defined prior to calibration to assess model performance, guide calibration, and assist in quantifying model uncertainty. A global set of metrics will be developed for all CVP project systems.

Calibration and Validation

Calibration assessment will be completed for a pre-determined simulation period for:

- Hourly time series comparison of flow and water temperature data downstream of dams and river reaches, as well as time series reservoir elevations and river stages.
- Temperature profiles, with measured data available at approximately monthly intervals (or available frequency), for reservoirs.

A portion of the simulation period will be reserved for model validation. This period will be determined by the modeling team in cooperation with Reclamation. Data availability may impact calibration and validation periods. Model results will be presented graphically and statistically for assessment.

Sensitivity Analysis

Sensitivity analysis can be used to:

- Confirm that model response to give in hydrology, temperature, and meteorology is consistent with theory,
- Quantify the effect of error on state (model) variables,
- Identify sensitive parameters or variables that must be reliably estimated,

- Indicate the relationship between control variables and decision (or state) variables to help ensure that a change in control variable can have a desirable effect on the decision variables, and
- Identify regions of "design invariance" where target levels of decision variables are insensitive to errors of estimation in control variables and parameters (Ji 2017, Chin 2013, Chapra 1997).

Sensitivity testing of important state variables will be carried out for specific parameters, providing insight on model performance. Parameter values will be modified over representative ranges, and overall approach developed in collaboration with Reclamation.

Task 9 objective and description are included in Table 2-20. Task 9 deliverables and schedule are listed in 21.

Table 2-20. Task 9 Objective and description.

Task	Objective	Description
Task 9. Calibration, Validation, and Sensitivity	Calibrate and validate model components as they are refined/developed and perform a sensitivity analysis on selected/estimated parameters.	Complete calibration and validation of modeling components. Calibrate model representation of reservoir temperatures to historical thermocline data to provide a stable modeling platform for future use by Reclamation. Include simulations of the fullest extent of historical data in the model package, allowing for analysis of dry and wet periods within this time frame. Contractor shall produce updates on calibration for Modeling Technical Committee and Reclamation modelers. Contractor shall also perform parameter sensitivity analysis and provide a summary of results. Contractor shall provide functional model and, as applicable/available, source code of application models.

Table 2-21. Task 9 Deliverables and schedule.

Deliverable	Schedule
Technical Memorandum Task 9 – Water Temperature Modeling Platform: Calibration, Validation, and Sensitivity (DRAFT)	August 2022
Technical Memorandum Task 9 – Water Temperature Modeling Platform: Calibration, Validation, and Sensitivity (FINAL)	November 2022

Because this task necessarily includes all river basins and overlaps with previous tasks (Task 7, 8), the draft and final technical memoranda are close to the end of Phase I.

TASK 10. Documentation - Phase I

The Phase I report is the culmination of the model development activities covered in Task 4 through 9. Individual task technical memos (TM's) will be used to develop the Phase I draft and final modeling report will present data development, model assumptions, calibration/validation and model performance, procedures for operation of the framework and model, and recommendations for next steps. This comprehensive report will cover all aspects of modeling platform development for all basins. Feedback from the Modeling Technical Committee (Task 2) as well as interim peer review (Task 17) will be incorporated into the report. The draft report will use the Sacramento River system application to identify all pertinent information, formats, layout, appendices, supporting documents, and associated information. This draft will be provided to the Peer Review Panel for the interim peer review. This approach will provide efficiency in the subsequent development of the American and Stanislaus River sections of the final report. A basic outline is provided below (subject to change):

- Background
- Purpose
- Modeling Approach
    - Framework and Model Selection and Testing
- Data Development – General
    - General
        - Geometry Data
        - Hydrologic Data
        - Water Temperature Data
        - Meteorological Data
    - Data and System Description
        - Sacramento/Trinity
        - American
        - Stanislaus
- Modeling Framework and Model Development
    - General
    - Unique modeling attributes and assumptions of each system
        - Sacramento/Trinity

    - American
    - Stanislaus
- Model Calibration and Validation, Sensitivity
    - Model Performance Metrics
    - Sacramento/Trinity - Results
    - American - Results
    - Stanislaus - Results
- Water Temperature Modeling Platform
- Recommendations
- Appendices

Task 10 objective and description are included in Table 2-22. Task 10 deliverables and schedule are listed in Table 2-23.

Table 2-22. Task 10 Objective and description.

Task	Objective	Description
Task 10. Documentation Phase I	Documentation of Phase I is the development of the physical and facility components of reservoir/after-bay models, data development, model assumptions, calibration, performance, procedures for operation, and recommendations for next steps.	Develop documentation for each modeling component. Deliver a Phase I report to Reclamation describing framework, model structure and calibration, and validation to historical data. The report shall be professionally written, including a title page, table of contents, acronyms, references, and illustrative figures throughout.

Table 2-23. Task 10 Deliverables and schedule.

Deliverable	Schedule
Technical Memorandum Task 10 – Water Temperature Modeling Platform: Calibration, Validation, and Sensitivity (DRAFT)	April 2022

Deliverable	Schedule
Technical Memorandum Task 10 – Water Temperature Modeling Platform: Calibration, Validation, and Sensitivity (FINAL)	December 2022

Because this task encompasses all of Phase I activities, the final technical memorandum occurs at the end of Phase I. Interim peer review findings based on the draft report of the Sacramento River model application will be incorporated, as applicable, in the Phase I final report.

TASK 17. Peer Review

Peer review guidance from CWEMF (2021) identifies "Peer review is the process of soliciting input from experts who are not involved in a particular study but are familiar with the general topic. Peer review should provide timely, open, fair and helpful input and should ideally occur at various stages of the modeling life cycle, including conceptual framework development, model implementation in code, and model application to specific geographic area or problem. Engagement of the peer reviewers early rather than solely near the end of the project can allow for adaptive corrections of the modeling study." (page 52)

Two reviews are planned with the specific purposes of assessing model development and model application. A midterm review will focus on model development and the final review on model application. The Independent Review Panel's findings and recommendations will provide important guidance for the ongoing temperature model development effort to improve tools for managing water temperature.

The midterm review is intended to highlight the process and the development of the Shasta-Keswick temperature models. The final review is intended to highlight the representation of system features within the temperature models (temperature curtains, selective withdrawal facilities), as well as constructively evaluate the application of the models for the intended uses, including abilities to utilize real-time/seasonal tools in a forecast mode and to incorporate and address uncertainty.

Reclamation is also exploring other pathways and mechanisms for model technical review including stakeholder outreach and involvement, targeted external technical review, and publication. While these activities do not replace a formal peer review process, they provide an opportunity for experts familiar with the general topic to provide transparent, fair, and helpful input on model development activities. Further, the proposed approach captures an adaptive approach to technical review that provides ongoing "course corrections" throughout the project. The project team will continue to work with Reclamation to further define the need for and form of peer review. Any materials required for a peer review will be provided by the project team.

Task 17 objective and description are included in Table 2-14.

Table 2-24. Task 17 Objective and description.

Task	Objective	Description
Task 17. Peer Review	Provide support for peer review of model components and overall framework.	Upon completion of new/refined model components and/or data development, conduct peer review. As part of the 2019 Biological Opinions, a peer review is anticipated at end of fiscal year 2024 (separate from this project). Reclamation expects an interim and final peer review of project work to assess the quality of the modeling conducted in the course of this project as well as application of the WTMP. Contractor shall be available to provide information on the process, respond to questions during the review, and assist Reclamation in providing responses to completed reviews.

Deliverables and Schedule

There are no identified deliverables, but the project team will provide requested materials to the peer review panels.

Chapter 3 Schedule

The WTMP schedule for Phase I activities extends from September 2020 to December 2022. Certain tasks carry on beyond Phase I. Stakeholder outreach (Task 2), development of Reclamation's institutional knowledge (Task 3), and peer review (Task 17) are three tasks that will extend throughout the project lifespan. Estimated beginning and ending dates of each task is included in Table 3-1 and as a Gantt chart in Figure 3-1.

Table 3-1. Phase I Tasks (Tasks 1 through 10).

Project Task	Begin Date	End Date
TASK 1. Phase I Project Plan	10/26/2020	10/1/2021
TASK 2. Stakeholder Outreach	1/3/2021	9/23/2023
TASK 3. Develop Reclamations Institutional Knowledge	9/30/2020	9/23/2023
TASK 4. Data Management Plan	1/21/2021	12/31/2021
TASK 5. Model Framework Design and Refinement	1/31/2021	11/14/2021
TASK 6. Model Selection/Design	3/2/2021	1/2/2022
TASK 7. Data Development	2/2/2021	12/1/2022
TASK 8. Model Development	4/1/2021	11/30/2022
TASK 9. Calibration, Validation, and Sensitivity	7/25/2021	10/4/2022
TASK 10. Documentation - Phase I	11/11/2021	12/29/2022

Figure 3-1. Phase I Tasks – Gantt chart.

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Chapter 4 References

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