

**11.2 Iowa Hill Pumped Storage Development Water Temperature Study Plan**

This study is designed to assess the effects of water temperature changes from the upper storage reservoir and lower basin (Slab Creek Reservoir) of the Iowa Hill Pumped Storage Project. As identified in the Iowa Hill Pumped Storage Development (IHPSD) Project Description, SMUD is proposing to construct and operate a 6,400 acre ft reservoir for power production. Water would be pumped from Slab Reservoir through a multi-port intake at a depth of approximately 80 ft (well below the historic stratified thermocline) below the Slab Creek Reservoir maximum water level elevation of 1,850 feet. In the pumping mode, the estimated discharge capacity of the intake would range between 3,600 and 4,200 cfs. The water would then be held for later release back through a powerhouse and return to Slab Creek Reservoir.

This study is proposed to assist in determining the possible effects on water temperature in Slab Creek Reservoir resulting from this new pumped storage facility and describe an approach to analyze potential temperature effects.

**11.2.1 Pertinent Issue Questions**

1. What are the temperature regimes (daily min, mean, max) relative to duration of storage period in Iowa Hill Reservoir during the summer months? Would this maximum temperature result in a significant increase in temperature for the return flow to Slab Reservoir?
2. Will the Iowa Hill Reservoir stratify, and how long will stratification take? Will water quality impairments (e.g., decreased dissolved oxygen from higher temperatures) result for the return flow?
3. Does the water withdrawn and/or released from Iowa Hill Reservoir into Slab Creek Reservoir have the potential to significantly alter or otherwise destabilize the temperature stratification in Slab Creek Reservoir, assuming velocity currents for the intake and return flow are not a significant factor?
4. What are the effects to cold water volume and associated habitat available within SCR as a result of implementing the IHPSP?
5. Will the operation of the Iowa Hill pump storage facility result in altered summer temperature for all release flows from Slab Creek Reservoir to downstream waters?
6. What additional coldwater depletion rates might be seen at SCR with exercise of a proposed consumptive water use element at the Iowa Hill Reservoir? (To be addressed if and when SMUD proposes a consumptive water component to Iowa Hill.)

**11.2.2 Background**

The IHPSD is proposed as an addition to UARP facilities at Slab Creek Reservoir. The reservoir is known to support primarily Sacramento sucker, hardhead (a USFS species of special concern), brown trout and Sacramento pikeminnow (SMUD, 2003). Reservoir temperatures in 2003 ranged as follows in the vicinity of the proposed intake (SMUD, 2003 unpublished data).

Temperature (in C°)→	Near surface	Near bottom
Month ↓		
June	17.0 – 18.5	14.7 – 15.7
July	18.2 – 20.0	11.0 - 13.4
August	18.2 – 20.0	13.5 – 15.0
September	15.0 – 16.5	12.8 – 14.0
October	12.6 – 13.2	11.3 – 11.6

### 11.2.3 Study Assumptions and Analyses Objectives

1. Several assumptions are made to initially investigate temperature issues relevant to the proposed pumped storage project. These assumptions facilitate the assessment. Velocity patterns around the intake and outlet structures are assumed to only have a vertical and longitudinal component. Velocities at the intakes and outlets are provided as boundary conditions.
2. The model uses the hydrostatic assumption and therefore does not account explicitly for vertical momentum effects. Even though the model is able to track density inflows and surface cooling accurately, the vertical momentum equation is not used to compute vertical velocities. Vertical velocities are determined by a flow balance over each cell.
3. The analysis will initially assume temperature changes within the penstock and flow lines of the pump storage facility are negligible due to the short travel time. Tunnels can be expected to have cooling effects since the ambient environment is at a groundwater temperature equivalent; however, a short travel time does not allow penstock flow to reach equilibrium with the tunnel ambient temperature.
4. Velocity, water temperature and other water quality factors are assumed to not differ significantly in a lateral direction within either the Iowa Hill or the Slab Creek reservoirs.
5. The wind sheltering coefficient is a correction on the measured wind velocity but is not based on theory.
6. Calibration of the model is restricted to available temperature data, which consists of limited instantaneous temperature profiles. Slab Creek Reservoir is assumed to be homothermous throughout the reservoir at the initiation of the time period modeled.
7. A static turbidity level within Slab Creek Reservoir will be applied and evaluated for its potential to influence water temperature regimes. If predicted turbidity levels as affected by the Iowa Hill project can be provided from other assessment efforts, then these turbidity levels will be incorporated into the model. Algal growth and its influence on temperature is assumed to be minimal for both the current condition and all operating scenarios for the Iowa Hill Project. The CE-QUAL-W2 model can model algal dynamics for multiple algal species but calibration data are not available.

### 11.2.4 Study Area

The study area will include Slab Creek Reservoir and the as-planned design for the Iowa Hill Reservoir. Flowlines, penstocks and power generation facilities for the Iowa Hill pump storage project are included in the model setup but only as conduits for water transfer; i.e. modeling of water quality within the flowlines is not considered necessary due to short residence times.

### 11.2.5 Information Needed From Other Studies

Data from the Water Temperature Study will be used in identifying temperature versus time curves from between below Camino Powerhouse (located upstream of Slab Creek Reservoir) and below Slab Creek Reservoir Dam. Data from monthly temperature profiles will also be used in the analysis. SMUD has increased the frequency of thermal profiles taken in Slab Creek Reservoir to monthly measurements throughout the summer of 2003 in anticipation of this study plan. Data from nearby climate stations will be used. Bathymetric data for the Slab Creek Reservoir and the design bathymetry for Iowa Hill Reservoir will be used. Water surface elevation data for the Slab Creek Reservoir for the current condition is available from operations records. Volume elevation rating curves are also available as well as generated from the model. Volume – elevation rating curves for the Iowa Hill reservoir are required and can be provided from the engineering design. Pump rates are provided as a user specified boundary condition. [Note – After consultation with in-house experts, the agencies request the possible SCR profile data from May through October 2004. Aquatic TWG 12/4/03]

### 11.2.6 Study Methods Analysis, and Schedule

A dynamic 1-D reservoir temperature model is suitable for analyzing temperature regimes within the Iowa Hill reservoir but a dynamic 2-D model is most suitable for modeling both the Slab Creek Reservoir and the Iowa Hill reservoir. The model should be capable of analyzing vertical stratification in the pump storage reservoir and both longitudinal and vertical temperature gradients within the Slab Creek Reservoir. An hourly or smaller model time step is needed.

It is recommended that CE-QUAL-W2 model be applied for modeling the pump storage reservoir and its effect on temperature dynamics within Slab Creek Reservoir. The CE-QUAL-W2 River Basin Model Version 3 (as schematized in Figure 4.3) was selected as most appropriate for modeling the Slab Creek Reservoir/ Iowa Hill Pump Storage Project temperature assessment. This is a two-dimensional (vertical and longitudinal) water quality and hydrodynamic model that was originally developed for deep, long and narrow waterbodies. This model has been under development for many years and is a public-domain code maintained by the Corps of Engineers, Waterways Experiments Station (WES), located in Vicksburg, Mississippi. The current version, Version 2 (Cole and Buchak 1995), has been superseded by Version 3 developed by WES and Wells (1997). Version 2 of the model has been successfully used in more than 200 river and reservoir applications. Version 3 has undergone rigorous testing and has been successfully applied to many river basin systems; applications include a 244 km section of the Lower Snake River, a multi-reservoir-river system on the Bull Run watershed, a series of 33 lakes and estuary segments in the Columbia Slough, and several other/lake/reservoir systems. Version 3 can be applied to both the density stratified environment of the reservoirs and sloping river channel sections. The W2 model uses a state-of-the-art numerical scheme, called Ultimate Quickest, which minimizes numerical dispersion problems. The use of an implicit numerical solution scheme for the water surface and vertical momentum equation minimizes the time step limitations for numerical stability.

Primary physical processes modeled by CE-QUAL-W2 include surface heat transfer, short-wave and long-wave radiation and penetration, convective mixing, wind and flow induced mixing, entrainment of ambient water by pumped-storage inflows, inflow density stratification as impacted by temperature and dissolved and suspended solids. Major chemical and biological processes in CE-QUAL-W2 include: the effects of DO of atmospheric exchange, photosynthesis, respiration, organic matter decomposition, nitrification, and chemical oxidation of reduced substances; uptake, excretion, and regeneration of phosphorus and nitrogen and nitrification-denitrification under aerobic and anaerobic conditions; carbon cycling and alkalinity-pH-CO<sub>2</sub> interactions; trophic relationships for six algal types; accumulation and decomposition of detritus and organic sediment; and coliform bacteria mortality. This application of the CE-QUAL-W2 model focuses on water temperature.

Modeling development and application will follow the following work elements:

- Data Collection and Analysis (use existing information),
- Develop boundary conditions,
- Discretization of the system into river and reservoir model segments,
- Develop model bathymetry,
- Develop Boundary condition,
- Model Calibration/Verification, and
- Model Application

Discretization of the basin involves partitioning the river and reservoir into model segments for the computational domain. The drainage basin is digitized and entered into a Geographic Information System (GIS). Reservoir bathymetry is used to identify fairly homogeneous segments. Typical reservoir segments are approximately ¼ mile in length or less, dependent upon bathymetry. Channel geometry and reservoir bathymetry can initially be developed from existing USGS maps and Project drawings showing pre-project conditions. Once the system is discretized, these geometry files are prepared that are compatible with CE-QUAL-W2 Version 3.

The next step in modeling is to prepare the boundary condition data in a format compatible with CE-QUAL-W2 Version 3. These files include flow and temperature for each point source, non-point source, and upstream flow boundary condition. Boundary conditions for this study include the inflow and outflow for Slab Creek Reservoir and the inflow and outflow for the Iowa Hill Project. Temperature response within the penstock and flowlines is assumed to be minimal and therefore will not be modeled. Even though the pumpback storage uses the same flowlines for withdrawal and return flow, separate boundary ports for each will be defined in the model. A system model check will be performed ensuring that input files are correct. Model preprocessor will be run for error-trapping.

Model predictions for water quality parameters are compared to field data in order to calibrate the model. The calibration will first evaluate the water levels (and/or flow rate and velocities) predicted by the model and then temperatures. Other water quality constituents including organic matter (soluble and particulate labile and refractory), nutrients (ammonia, nitrate, PO<sub>4</sub>-P), algae, dissolved oxygen, bacteria, pH, carbonate cycle, and sediment are not being modeled in this assessment. If substantial alteration of temperature regimes within the Slab Creek Reservoir due to operation of the pumpback storage facility are predicted, then the same model could be expanded to evaluate effects on other water quality constituents. The calibration will be performed by iterating on the choice of model coefficients as well as re-examining assumptions of boundary conditions. Calibration will be based on the available data, which consists of instantaneous vertical profiles within the reservoir and continuous thermograph data for the Slab Creek Reservoir tailrace. A statistical evaluation of the calibrated model's performance is based on the absolute mean error (AME) which gives an indication of how close, on average, computed values are to observed values for a given water quality parameter at a given sampling station.

Once the model is calibrated for the existing current condition within Slab Creek Reservoir, then the temperature response for various operating scenarios for the Iowa Hill Project can be modeled. The results of these comparative modeling scenarios will be analyzed and reported including statistics and graphical comparisons of model alternatives with base conditions.

Modeling will focus on summer conditions for 1) current conditions, 2) warm/dry and 3) cool/wet based on air temperatures at Camino and DWR May 1 Forecast into Folsom. SMUD will email a description of the boundary conditions when available. The reservoir geometry file will use 0.5 m layers so that stratification can be assessed. Bathymetry data for both the Iowa Hill Reservoir (design drawings) and the Slab Creek Reservoir will be utilized. Water surface elevation data for the Slab Creek Reservoir for the current condition is available from operations records. Volume elevation rating curves are also available as well as generated from the model. Volume – elevation rating curves for the Iowa Hill reservoir are required and can be provided from the engineering design. Pump rates are provided as a user specified boundary condition. Climate data are available as on-site air temperature data plus locally available meteorological stations including the nearby Camino station. The same climate data used in SNTMP modeling is also applicable to this modeling effort.

It is expected that the analyses will be completed in early 2004.

#### 11.2.7 Study Output

A presentation of study results will be made to the Aquatics TWG in early 2004. Summary statistics on water temperature stratification and volume relative to temperature in SCR will be provided (e.g., change in cold water pool in SCR with and without the Iowa Hill Development). A written report including the issues addressed, objectives, description of study area, methods, results, discussion and conclusions will be prepared for inclusion in the license application, to evaluate the effects of the IHPSD on water temperature in Slab Creek Reservoir.

#### 11.2.8 TWG and Plenary Group Endorsement

This study plan was approved on December 4, 2003 by the following entities of the Aquatic TWG: CDFG, SWRCB, BLM, Camp Lotus, PG&E and SMUD, given the provisional note in 11.2.5.

The Plenary Group approved this plan on January 7, 2004. The participants at the meeting who said they could “live with” this study plan were the U.S. Forest Service, American River Recreation Association & Camp Lotus, El Dorado County Water Agency, El Dorado County, El Dorado Irrigation District, El Dorado County Citizen's for Water, National Park Service, U.S. Bureau of Land Management, Placer County Water Agency, City of Sacramento, California Outdoors, California Department of Fish and Game, Friends of the River, State Water Resources Control Board, and SMUD. None of the participants at the meeting said they could not “live with” this study plan.

11.2.9 Literature Cited

Cole, T. and Buchak, E. (1995) "CE-QUAL-W2: A Two-Dimensional, Laterally Averaged, Hydrodynamic and Water Quality Model, Version 2.0," Tech. Rpt. EL-95-May 1995, Waterways Experiments Station, Vicksburg, MS

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Sacramento Municipal Utility District. 2003. Temperature Profile Data for Slab Creek Reservoir (unpublished data) for months May – October.