TASK 1. DEVELOPMENT OF A SNTEMP MODEL FOR THE LOWER MOKELUMNE RIVER

1.1 OBJECTIVE

The objective of this task was to develop an instream water temperature model for the Mokelumne River between Camanche Dam and the Cosumnes River confluence using the Stream Network Temperature Model (SNTEMP). This model will be used to simulate the effects of altering the release temperature at Camanche Dam on the instream water temperature and fisheries of the Mokelumne River.

1.2 METHODS

1.2.1 Development of SNTEMP Model for the Mokelumne River

Although SNTEMP is the best instream water temperature simulation model available, its inability to calculate vertical water temperature variation presents a problem for an impounded section of the Mokelumne River. During the summer months (from April to mid-October), a segment of the Mokelumne River (Lake Lodi) is impounded for diversion and recreational purposes. This creates a seasonal reservoir in a segment of the Mokelumne River where vertical stratification occurs. Because of this situation, the temperature modeling of the Mokelumne River is separated temporally and spatially into four different modules. By separating the Mokelumne River into segments, Lake Lodi is isolated and a different temperature model is used. This model was developed at the Hydrologic Engineering Center at Davis, California, by the U.S. Army Corps of Engineers (COE) Water Quality for River-Reservoir System (WQRRS). WQRRS is capable of calculating and predicting the occurrence of stratification. The remaining river segments are further divided by season (summer and winter months).

The water temperature model for the Mokelumne River consists of three separate SNTEMP models and one WQRRS model. Module 1 (SNTEMP) is calibrated for the entire reach of the Mokelumne River during the winter months (from mid-October through March). Module 2 (SNTEMP) is calibrated for the Mokelumne River reach from Camanche Reservoir to the beginning of Lake Lodi during the summer months. Module 3 (SNTEMP) is calibrated for the reach of the Mokelumne River from Woodbridge Dam to the confluence of the Cosumnes River during the summer months. The Lake Lodi module (WQRRS) is calibrated for the summer months (discussed in further detail in Task 2). To run a simulation for the Mokelumne River for one entire year, all four of these modules must be executed in correct sequence, separately. If only the winter months are of interest, Module 1 is sufficient. If only the summer months are of interest, the simulation must make use of Module 2, the Lake Lodi module, and Module 3 in sequence. The output from each module requires a new format since three different models are used in sequence.

1.2.2 Data File Preparation for SNTEMP

SNTEMP requires a job control file, six additional data files, and an optional eighth file. The six input data sets are stream geometry data, time period information, meteorological information, study node information, hydrology node data, and hydrology data at the hydrology nodes. The optional eighth file is the shade data file. This is not used in this study because of the lack of precise shade data available for the Mokelumne River. The information necessary for the input data files includes stream geometry, hydrology, water temperature, and meteorology data.

Eight years of data were used to model the Mokelumne River. To best represent the Mokelumne River system for all hydrological year types (wet, normal, and dry), data for four dry years (1987 through 1990), two normal years (1964 and 1975) and two wet years (1965 and 1974) were used to create the calibrated model. Each year's data were broken down into bi-monthly time periods. Therefore, there are twenty-four time periods in a calendar year. For each time period, all non-geometry related data required by SNTEMP are averaged for that time period. The result is one datum point for each time period.

The stream geometry data were obtained from two sources. The main source of stream geometry information was *Determination of Channel Capacity of the Mokelumne River Downstream from Camanche Dam, San Joaquin and Sacramento Counties, California,* completed by the United States Geological Survey (USGS) in 1972. The USGS obtained 122 cross-sectional transects to determine the geometry of the stream between the Camanche Reservoir and the confluence of the Cosumnes River. The data from this report were used to determine the average widths of the segments of the river used as input to the temperature model. The elevation along the study reaches were determined from the USGS topographical maps (7.5 minute series).

The hydrology (flow) data were acquired through the USGS, which maintains three gaging stations: station numbers 11323500 below Camanche Dam, 11325000 at the Woodbridge Irrigation District (WID) Canal, and 11325500 below Woodbridge Dam in the Mokelumne River. Flow rates were averaged for each time period for each of the stations. The flow rates for the internal nodes of the river system downstream were calculated by using the discharge-distance relationship equation for known discharges and distances.

At two of these stations (11323500 and 11325500), temperature data were available until 1976 when the temperature monitoring program ended. Temperature data used to calibrate the model beyond 1976 were obtained from various sources. These sources include BioSystems' temperature monitoring program (see Task 4), CDFG's (1991) temperature monitoring program in the Mokelumne River, EBMUD's Lake Lodi temperature profiles, and records from the Mokelumne River Fish Hatchery (MRFH).

The meteorological data used to develop the Mokelumne River SNTEMP model was obtained through the National Climatic Data Center, Asheville, North Carolina. The nearest complete weather station to the study site is at the Sacramento Airport. The meteorology data required by SNTEMP (air temperature, wind speed, relative humidity, and percent sunshine) came from the Sacramento Airport data. Given the location (latitude and elevation) of the meteorological station, SNTEMP assumes adiabatic conditions and corrects the changes in air temperature, relative humidity, and atmospheric pressure (calculated by the model using site elevation) for the study site.

1.2.3 Calibration Method for SNTEMP

Calibration is the process of tuning model behavior as close to the system's natural dynamics as possible. The model has two general locations at which calibration can take place. The first is a series of global constants and coefficients located in the "Job Control" file. These apply to each of the meteorological variables: air temperature, wind speed, relative humidity, and percent sunshine. Constants and coefficients are associated with each of these parameters. If the parameters are set to a value other than 0, the results of the model are in the form of a linear transformation of the original variable. This transformation applies directly to meteorological variables, but it is not an adjustment to the variable itself, which has been measured or determined from field data. The transformation is an adjustment of the heat transfer coefficients used in the model, and this entails some degree of uncertainty. This transformation also provides a means of correcting for local effects not detected by the meteorological stations. The second point at which calibration adjustments can be performed is in the "Time Period" file. This process is exactly the same as the first, but the process is localized to each time period chosen for a study.

The choice of which meteorological variable parameter shall be adjusted is arbitrary and varies from study to study. The rule of thumb is to choose parameters that provide the best model performance. Also, since the effects of many of the meteorological input functions are correlated, it is normally not worthwhile to vary more than one set of parameters at a time. In this study of the Mokelumne River, the air temperature parameter was used to calibrate the model.

Statistical output given by SNTEMP for each calibration node includes the error for each time step (time period), the average error for the entire study period, and the correlation coefficient between observed and predicted temperature.

1.3 CALIBRATION RESULTS

1.3.1 Calibration Results for Module 1

Module 1 covers the winter months that contain the time periods 1 through 6 (January through March) and 20 through 24 (mid-October through December). It contains 11 time periods per model year for eight years (1964, 1965, 1974, 1975, and 1987 through 1990). The calibration node is located near the middle of the study reach below Woodbridge Dam. Of the 88 possible calibration points for the eight years simulated, observed temperatures were available at only 42 points. The observed temperatures at these points were compared to predicted temperatures from model runs to assess model performance. The statistical

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output produced by SNTEMP for error terms for each time period reflects the observed data. The total mean difference between the observed and predicted data were 0.05° C and the maximum single error term was 1.5° C (see Figure 1-1).

1.3.2 Calibration Results for Module 2

Module 2 covers the summer months, which contain the time periods 7 through 19 (April through mid-October). It contains 13 time periods per model year for the eight years mentioned above. The calibration node is located near the end of the study reach at the beginning of Lake Lodi. Of the 104 possible calibration points for the eight years simulated, observed temperatures were available at only 18 points. The observed temperatures at these points were compared to predicted temperatures from model runs to assess model performance. The statistical output produced by SNTEMP for error terms for each time period reflect the observed data. The total mean difference between the observed and predicted data were 0.11° C and the maximum single error term was 0.91° C (see Figure 1-2).

1.3.3 Calibration Results for Module 3

Module 3 also covers the summer months that contain the time periods 7 through 19 (April through mid-October). It contains 13 time periods per model year for the eight years mentioned above. The calibration node is located near the end of the study reach at Ray Road. Of the 104 possible calibration points for the eight years simulated, observed temperatures were available at only 11 points. The observed temperatures at these points were compared to predicted temperatures from model runs to assess model performance. The statistical output produced by SNTEMP for error terms for each time period reflects the observed data. The total mean difference between the observed and predicted data were 0.03° C and the maximum single error term was 0.54° C (see Figure 1-3).

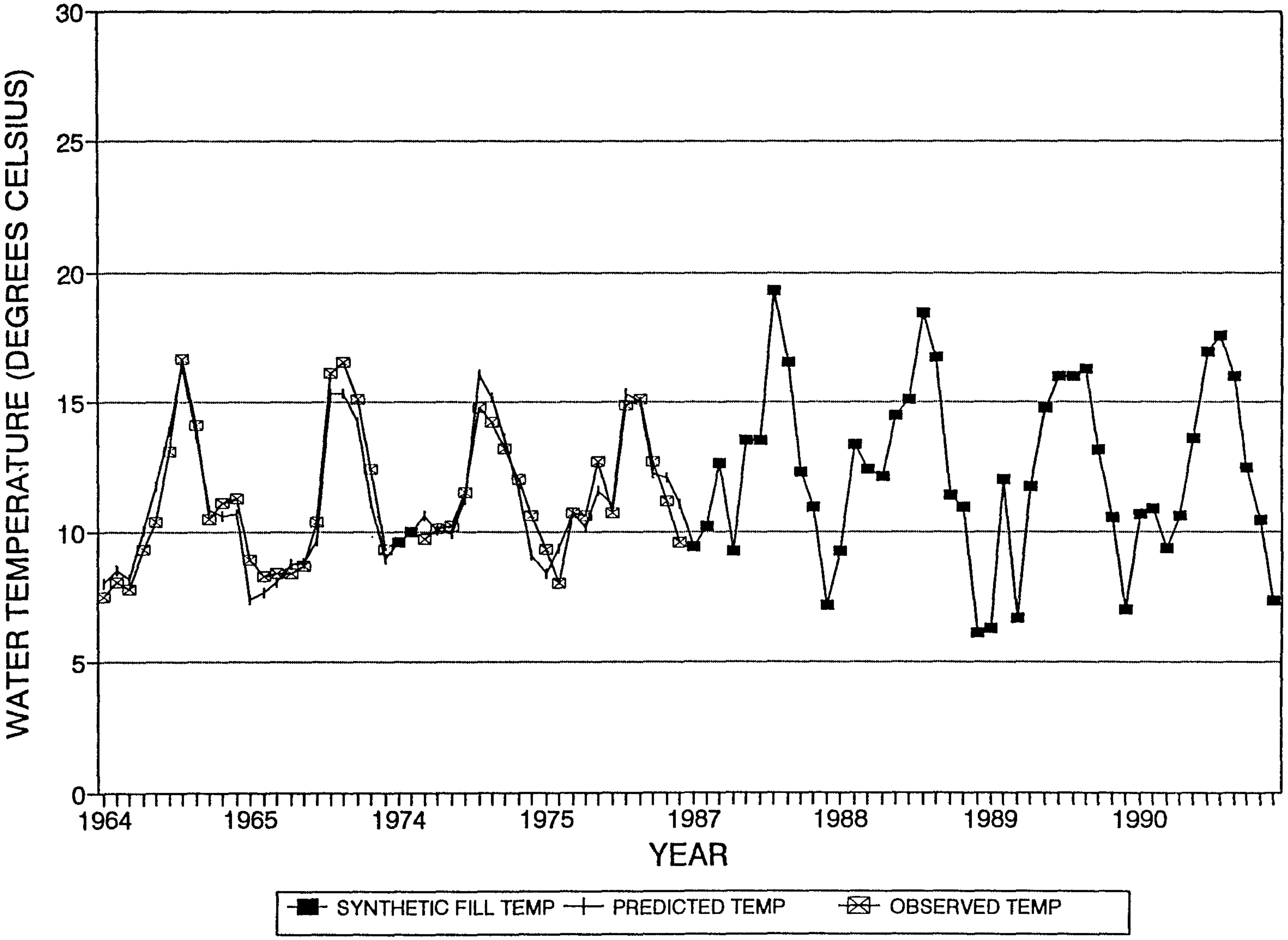

Figure 1-1. Comparison between model output (predicted), observed, and synthetic fill temperatures for Module 1 of SNTEMP.

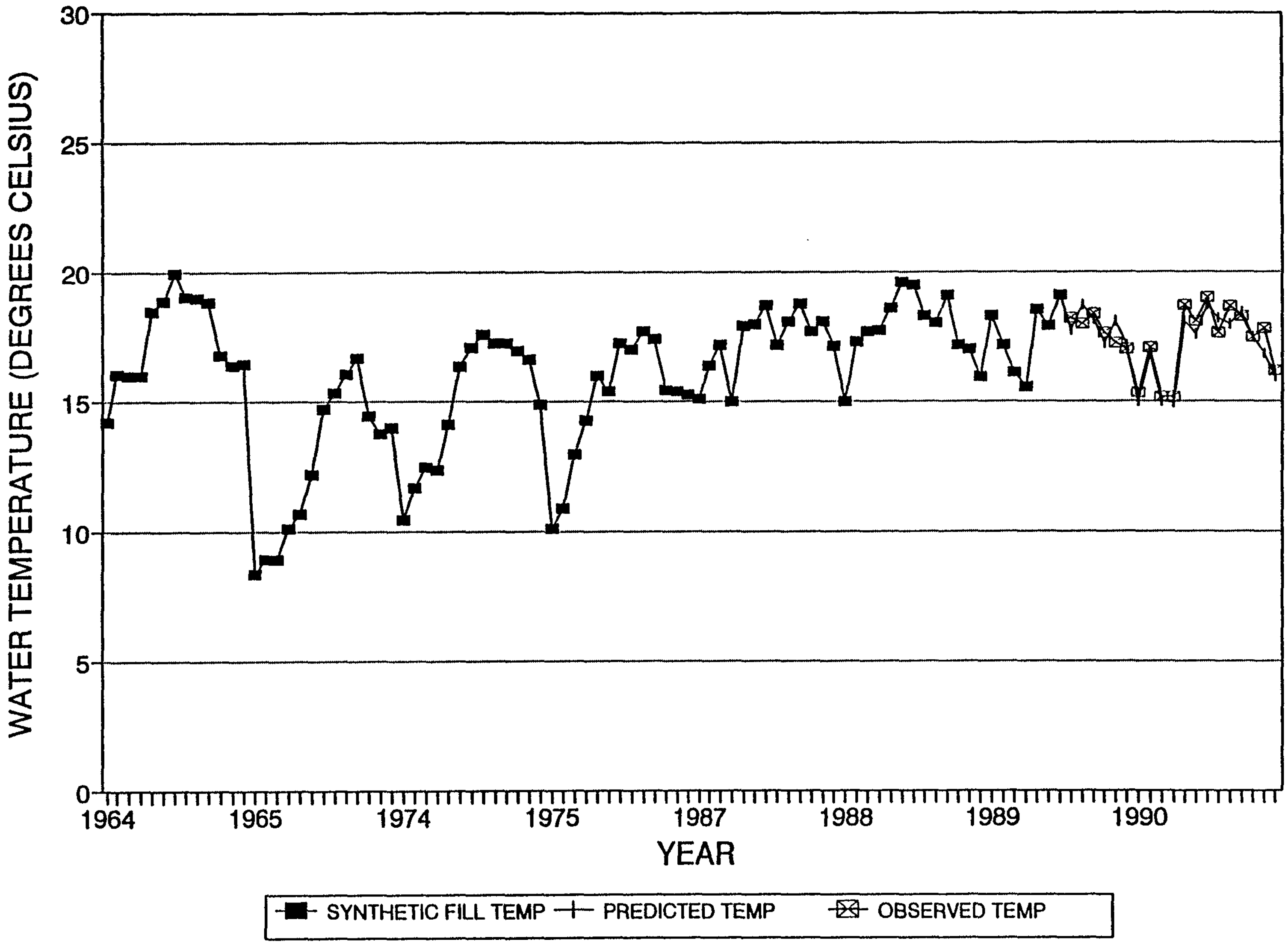

Figure 1-2. Comparison of predicted, observed, and synthetic fill temperatures for Module 2 of SNTEMP.

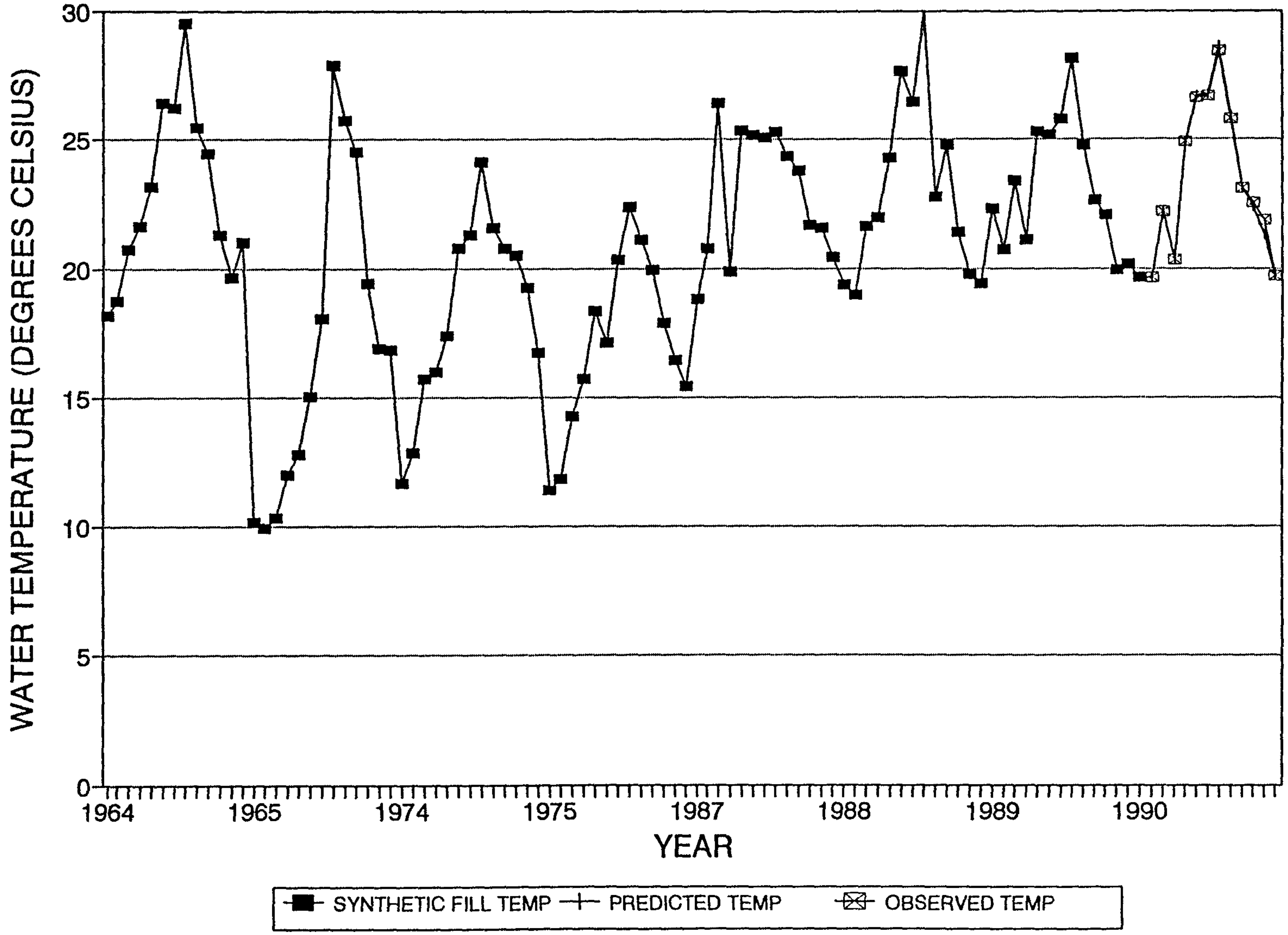

Figure 1-3. Comparison of predicted, observed, and synthetic fill temperatures for Module 3 of SNTEMP.

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