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U.S. BUREAU OF RECLAMATION
MONTHLY TEMPERATURE MODEL
SACRAMENTO RIVER BASIN

U.S. BUREAU OF RECLAMATION
MID-PACIFIC REGION
SACRAMENTO, CALIFORNIA

JUNE 1990

DRAFT REPORT

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J. H. ROWELL

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SUMMARY

This report documents a monthly time-step reservoir and stream temperature model and describes its application to the Sacramento River Basin in California. The model is intended as a tool for evaluating the effects of CVP-SWP project operations on mean monthly water temperatures in the basin.

The Sacramento River Basin model simulates temperatures in five major reservoirs (Clair Engle, Whiskeytown, Shasta, Oroville, and Folsom), four downstream regulating reservoirs (Lewiston, Keswick, Thermalito, and Natoma), and three main river systems (Sacramento, Feather, and American).

The report includes a detailed description of model input data requirements and assumptions. Also included are the results of model verification studies and model evaluations of Department of Water Resources' simulation model (DWRSIM) operation studies, which have been conducted for the Bay-Delta Hearings.

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I. INTRODUCTION

Water temperatures affect all life stages of chinook salmon and other fish inhabiting the inland waters of California. The specific effects of Sacramento River temperatures on survival of chinook salmon adults, eggs, fry, and fingerlings are discussed in the literature.[4] Studies by the Interagency Fisheries/Water Quality Committee have indicated that water temperature is an important factor in the survival of Chinook Salmon smolts passing through the Sacramento-San Joaquin Delta.[18]

This report describes a monthly reservoir and stream temperature model and its application to the Sacramento River Basin in California. The model is intended as a tool for evaluating the effects of CVP-SWP project operations on basin water temperatures.

Since the project operation simulation models used for planning and forecasting CVP-SWP operations use a monthly time-step,[11,24] it was necessary to develop a temperature model that could evaluate operations model output on a monthly frequency. Monthly temperature model results are useful for comparing temperature impacts of alternative operating scenarios and defining the extent to which various factors control river temperatures. For operation studies covering many years of hydrologic record, the temperature model can show exceedance frequencies of specified temperature criteria. While monthly model results can be used to assess qualitative fishery impacts, they do not define day-to-day temperature variations within a month and, thus, would not allow

quantification of specific fishery impacts. A daily temperature model would be required for such evaluations.

The U.S. Bureau of Reclamation (Reclamation) has used a daily temperature model on the Upper Sacramento River above Red Bluff.[35] Other daily model applications include the Trinity River,[30] the Sacramento River Basin,[29] and the American River.[17] Daily model studies use historical daily operations data, and are generally limited to a few years due to the extensive input data requirements. These limitations tend to make daily temperature models less suitable for evaluating long-term (i.e., 56 or more years) monthly operations studies.

II. GENERAL DESCRIPTION

The monthly temperature model consists of a Reclamation-modified version of a Corps of Engineers' monthly reservoir model[1] and a stream model developed by Reclamation. A network diagram of the model application to the Sacramento River Basin is shown in figure 1.

The reservoir model simulates monthly temperature vs. depth profiles in the major reservoirs (Clair Engle, Whiskeytown, Shasta, Oroville, and Folsom) and computes release temperatures from the dams. Changes in the downstream regulating reservoirs (Lewiston, Keswick, Thermalito, and Natoma) are computed using the upstream releases and temperatures as input. With the regulating reservoir releases and temperatures as upstream boundary conditions, the river model computes temperatures at 52 locations on the Sacramento River from Keswick Dam to Freeport, 10 locations on the Feather River from Thermalito Dam

to the mouth, and 8 locations on the American River from Nimbus Dam to the mouth.

The computed flows and temperatures at the mouths of the Feather and American Rivers are input to the Sacramento River model at their respective river locations. Minor tributaries and drainage inflows enter the Sacramento River at 39 specific control points.

III. RESERVOIR MODEL

A. Reservoir Model Description

The reservoir temperature model was developed by the Corps of Engineers' Hydrologic Engineering Center.[1] The users manual provides detailed information on the assumptions and input data required to run the model (appendix A).

The reservoir model simulates one-dimensional, vertical distribution of reservoir water temperature using monthly input data on initial storage and temperature conditions, inflow, outflow, evaporation, precipitation, radiation, and average air temperature.

The reservoir is divided into horizontal layers of uniform thickness. Each layer is assumed to be isothermal (i.e., the same temperature throughout its volume).

Inflow water descends into the reservoir to seek its temperature level. Since some mixing occurs between the inflowing and reservoir water, the model mixes a constant percentage of inflow with each layer as the inflow descends through the warmer reservoir layers. Therefore, the inflow ultimately reaches

a reservoir level at a temperature somewhat warmer than the original inflow temperature.

The energy exchange between the reservoir and the atmosphere is assumed to affect only the top layers of water except for energy transferred by diffusion. The depth of energy penetration was assumed to be 10 meters. The energy exchange is assumed to affect water temperature linearly from a maximum effect at the surface to a minimum at the depth of energy penetration. Solar radiation, evaporation, and a combination of conduction and long-wave radiation are expressed as functions of the difference between air and water temperatures. These energy exchanges are computed before the stability and diffusion computations are made.

Reservoir water is mixed from the surface downward until no lower levels contain warmer water than exists at higher levels. This stability function is constrained to temperatures above 4 °C, the maximum density of water.

The model assumes that incomplete mixing of adjacent layers occurs over a 10 meter range proceeding from the bottom to the top of the reservoir, one layer at a time. The degree of mixing is a function of the vertical diffusion calibration coefficient and the temperature difference between layers.

The model uses five calibration coefficients in calculating the various energy exchange functions:

C_1 =air temperature coefficient - index of energy transferred by conduction due to the difference between the air and water surface temperature.

C_2 =insolation coefficient - index of energy transferred to the reservoir due to net solar radiation - i.e., incoming minus absorbed and reflected radiation.

C_3 =evaporation coefficient - index of energy lost from the reservoir water surface due to evaporation.

C_4 =inflow mixing coefficient - index of energy transferred to the inflow due to the difference between modified inflow temperatures and the temperature of each layer.

C_5 =vertical diffusion coefficient - index of energy transferred between adjacent layers due to the difference in temperature between layers.

All of the coefficients have values ranging from zero to one - zero if no energy is transferred, and one if sufficient energy is transferred to reach equilibrium. In cases such as this study where observed reservoir temperature profiles are available, the program will derive the calibration coefficients automatically by minimizing the sum of squares of errors in temperature between computed and observed profiles. The program uses a gradient optimization technique developed by Beard[2] in which the coefficients are specified arbitrarily and then optimized by the computer so as to minimize the standard error of computed temperature.

Appendix A gives a detailed description of the calculation procedure and various energy exchange equations used in the model.

B. Reservoir Model Input Data

The reservoir operational data (inflows, releases, and evaporation) are obtained from project operation records if the model is simulating historical conditions or from operation model output if the model is being used to evaluate a theoretical operation. The application discussed in this report used output from DWRSIM, a planning operations model developed by DWR, which

simulated CVP-SWP project operations for the 1921-78 hydrologic period under present (1990) level of development.[11]

The reservoir geometry was obtained from area-capacity tables.[8 37] Storages at the top of each layer were input to the model. All reservoirs (Clair Engle, Whiskeytown, Shasta, and Folsom), except Oroville, used 5-foot layers. Oroville Reservoir required 10-foot layers because of its greater depth. The model limit of 100 layers would be exceeded with 5-foot layers at Oroville.

Outlet level elevations for each reservoir are shown in table 1. Except for spills or river outlet releases, all reservoir releases pass through hydroelectric power generation plants. Clair Engle, Whiskeytown, and Shasta Reservoirs all have single-level power outlets. Oroville and Folsom Reservoirs both have multilevel outlets attached to the power penstocks.

A multilevel temperature control device (TCD) is being designed for installation at Shasta Dam.[34] This device will allow selective level withdrawal of releases to the powerplant for the purpose of controlling downstream Sacramento River temperatures to benefit salmon. The normal operation of Shasta multilevel outlets for providing downstream salmon temperatures would be to release from upper levels in the winter and spring months (December-April), from mid levels in the late spring and summer (May-July), and from low levels in the late summer and fall (August-November). This outlet operation would conserve cold water in Shasta Reservoir during the winter and spring for release during the summer and fall when Sacramento River temperatures become critical for salmon spawning. Installation of temperature control devices are also being considered to cool the releases from Whiskeytown Lake to the Spring Creek Powerplant.[33] Cooler Spring Creek

Powerplant releases would reduce temperatures of Keswick Dam releases to the Sacramento River.

The operation of the Folsom temperature control device differs because the American River supports only a fall run of chinook salmon, whereas the Sacramento River has four salmon runs: fall, late-fall, winter, and spring. The typical Folsom operation involves mid to upper level releases from January to September and low level releases from October-December for fall salmon spawning in the Nimbus Hatchery and Lower American River. Releases from Oroville are managed to provide suitable temperatures for the Feather River Hatchery.

Mean monthly air temperatures for each study year (i.e., 1922-77) were obtained from NOAA weather records.[22] Redding air temperatures for the 56-year period (1922-77) were used to develop air temperatures at Clair Engle Whiskeytown and Shasta Reservoirs, which have only partial records. Regression equations were developed for each reservoir based on available reservoir air temperature data and the Redding air temperatures. Table 2 lists the regression equations. Air temperatures for Oroville and Folsom Reservoirs were obtained from complete Oroville and Folsom air temperature records, respectively.[22]

Reservoir inflow temperature data are limited in both duration and quality. Continuous thermograph records are preferred, but often only periodic measurements are available. Due to the scarcity of data, available inflow temperature records were averaged by month and used to represent mean monthly reservoir inflow temperatures for all 56 study years.[40] Table 2 summarizes the inflow temperature data for all five reservoirs. Inflow temperatures for Clair Engle and Shasta Reservoirs were obtained by flow-

weighting individual tributary temperatures. Whiskeytown natural inflow comes primarily from Clear Creek. Inflows and temperatures from the Clear Creek Tunnel to Whiskeytown Reservoir are model-generated inputs. While the operations model (DWRSIM) uses total inflows for Clair Engle, Shasta, and Oroville Reservoirs, the inflows to Folsom are divided into North Fork and South Fork inflows. Therefore, separate inflow temperature records were used to represent the two Folsom inflow sources.

The reservoir model inputs mean monthly values of total daily solar radiation at the top of the atmosphere. These values were obtained for each reservoir latitude from figure 2 of appendix A and are listed in table 2. The monthly solar radiation values were used for all 56 study years.

C. Reservoir Model Calibration

As discussed under DESCRIPTION, the reservoir model can be calibrated with measured temperature-depth profile data. The calibration procedure optimizes the five calibration coefficients defining the various energy exchange functions: air temperature, inflow mixing, vertical diffusion, evaporation, and insolation. Table 3 lists the calibration coefficients derived for each reservoir, the temperature data used, and the least-square errors between computed and observed temperatures.

D. Reservoir Model Verification

A previous application of the reservoir model to Clair Engle, Whiskeytown, and Shasta Reservoirs is discussed in a report by Rowell.[28] The model was calibrated and verified at the three reservoirs for selected years from 1951-66. Generally, the predicted release temperatures were within approximately

1 °F of the measured temperatures for all three reservoirs. The model was applied to Clair Engle Reservoir for the years 1964, 1974, 1975, and 1976 in a more recent study.[27] As in the previous study, the calibrated model release temperatures compared well (±1 °F) with observed temperatures measured below Trinity Dam. A verification of the model at Folsom Reservoir was done for 1966.[28] Application of the model to Folsom is also documented in a 1980 Bureau of Reclamation report.[26]

Recent comparisons of predicted and measured reservoir temperature profiles are shown in figure 2 (Clair Engle, Whiskeytown, and Shasta) and figure 3 (Oroville and Folsom). The predicted profile temperatures are usually within 1-2 °F of the measured temperatures.

A report by Christensen and Orlob[10] presents a detailed evaluation of the sensitivity and accuracy of the reservoir temperature model with respect to several input variables.

IV. RIVER MODEL

A. Description of River Model

The river temperature model calculates temperature changes in the four regulating reservoirs (Lewiston, Keswick, Thermalito, and Natoma) below the main reservoirs (Clair Engle, Shasta, Oroville, and Folsom). With regulating reservoir release temperatures as initial river temperatures, the river model computes temperatures at several locations in the Sacramento, Feather, and American Rivers. The nodel or calculation points for river temperatures generally coincide with tributary inflow locations. Figure 1 shows the temperature calculation points of the model.

Table 4 shows the main equations used in the river model, and the assumed surface areas for the regulating reservoirs. Equation 1 represents a steady-state, slug-flow algorithm based on the equilibrium temperature approach described in Edinger and Geyer.[15] The model is one-dimensional in the longitudinal direction and assumes fully mixed river cross sections. The effect of tributary inflow on river temperature is computed by mass balance calculation as shown in equation 2 (table 4).

Appendix C contains program listings of the Sacramento, Feather, and American River temperature models. Appendix D contains input file descriptions, input references to DWRSIM control points, and file organization data.

B. Climatic Input Data

Equilibrium temperatures (E) and heat exchange coefficients (K), the two climatic variables used in equation 1 (table 4), were computed for each month of the 56 year study period (1922-77) at 9 locations in the Sacramento River Basin. The nine weather stations are shown on table 6. A computer program was developed to calculate the monthly values of E and K using the procedures described in Edinger and Geyer.[15] Appendix B contains a listing of this program and a description of the variables.

The climatic data required to calculate values of E and K include air temperature, solar radiation, relative humidity, wind speed, cloud cover, solar altitude, solar reflectivity, and river shading. Monthly mean air temperatures for the 56 year study period were available at 9 locations in the Sacramento River Basin.[22] Since less extensive data were available for the other climatic variables, long-term average monthly values from two locations

(Red Bluff and Sacramento) were used.[20,21] Table 5 summarizes the long-term climatic data and the shade factors used in the E and K calculation. A summary by basin river reach of the air temperature, climatic, and shade data used to calculate the corresponding values of E and K are shown in table 6.

C. Hydrologic Input Data

1. Sacramento River

The river temperature model segments the Sacramento River into 52 reaches from Keswick Dam to Freeport.

The model computes Keswick Dam temperatures by mass-balance calculations of Shasta Dam flows, adjusted Shasta release temperatures, and Spring Creek powerplant flows and temperatures. The adjusted Shasta temperatures are computed from equation 1 using Shasta Dam flows and temperatures and the Keswick Lake surface area shown on table 4. The model then computes temperatures at the beginning and end of each river reach. The reach locations and corresponding river miles are listed in table 7. River mileages were obtained from DWR Bulletin 111.[9]

River geometry data are presented in table 8, which is one of the input files required to run the river model (appendix D). The geometry data, obtained from DWR Bulletin 111, include surface areas of each river reach in 10^6 ft^2 corresponding to riverflows ranging from 2,000 ft^3/s to 25,000 ft^3/s. The river model interpolates from table 8 to determine reach surface areas for specific riverflows. The surface area is used in equation 1 (table 4) - the river temperature algorithm.

The major and minor tributaries in the Sacramento River Basin and their corresponding drainage areas are shown in figure 4.[9] Tributary flows

which are specified in DWRSIM, the DWR planning simulation model,[11] are input directly to the river model. Figure 5 is a network diagram of DWRSIM. As shown on figure 5, the Sacramento River tributaries and diversions with flows specified by DWRSIM include Shasta Dam releases, Spring Creek, Clear Creek, Cottonwood Creek, Tehama Colusa Canal (diversion), Thomas Creek, Glen-Colusa Irrigation District (diversion), Stony Creek, Wilkens Slough (diversion), Colusa Basin Drain, Feather River, and American River. Shasta Dam, Spring Creek, and Clear Creek flows and temperatures are output from the reservoir temperature models. Feather and American River flows and temperatures are output from the Feather and American River temperatures models, respectively. All other major tributaries and diversions are output from DWRSIM. Appendix D lists the river temperature model input files.

The minor Sacramento River tributary flows, not defined by output from the other models, were obtained by applying flow factors to net accretions from the DWRSIM drainage areas shown in figure 6. The flow factors are the percentages of net DWR drainage area accretions that represent each tributary. They were calculated by dividing each tributary drainage area by the total drainage area for all tributaries within each DWR drainage area. Battle Creek flows were increased by 200 ft^3/s to account for Coleman hatchery discharges and other upstream regulation.[29] The tributary drainage areas (figure 4) and the computed tributary flow factors are shown in table 7.

Agricultural drainage flow factors were developed from drainage discharge data presented in table 9 (DWR Bulletin 111-Table 3.18). Drainage factors were calculated for nine agricultural drains (table 7) by computing percentages from the discharge data. The Colusa Basin Drain flows, as mentioned above, are defined by DWRSIM output.

Tributary temperature records are sparse or nonexistent for many of the tributaries to the Sacramento River. Available tributary temperature data used in the model are summarized in table 10. Monthly mean temperatures were computed from continuous thermograph records where available.[40] Otherwise, periodic measurements were used.[3 31] To compare the feasibility of using equilibrium temperature regressions versus average historical temperature records to represent the tributary temperatures, Cow Creek thermograph records for 1965-78 were tested using both approaches. The best fit (least error between predicted and measured temperatures) was found to be with use of average historical temperatures.

Temperature station periods of record and location (miles above the mouth) are noted on Table 10. While most tributary temperature stations are located near the mouth, the Thomes, Stony, and Butte Creek stations are significant distances above their confluences. For these creeks, therefore, equilibrium temperature equations similar to equation 1 were used to compute temperatures at the stream confluences with the Sacramento River. These equations use the thermograph records as initial temperatures, the tributary flows and E and K values, as defined previously, and estimated stream surface areas. The surface areas were developed by calibration using the equilibrium equations and available periodic temperatures at the mouths.[3] A similar approach is used for Clear Creek to compute temperature changes between Whiskeytown Dam and the mouth. The equations used for the Clear, Thomes, Stony, and Butte Creeks are summarized in table 11.

Agricultural drainage temperatures are virtually nonexistent. Since drainage waters are strongly influenced by climatic conditions, it was assumed that the calculated monthly mean equilibrium temperatures could be used to

represent agricultural drainage temperatures. Partial temperature records[3,31] were available for the Colusa Basin Drain (CBD) and are listed in table 10. A linear regression equation was developed for CBD using the average monthly temperature records and the 56-year average values of E developed for the Lower Sacramento River. This equation, presented in table 11, is used in the model to calculate CBD temperatures as a function of the mean monthly values of E.

Table 7 lists the assumed tributary temperature source for each stream and drain. For tributaries with no historical temperature data, temperatures from nearby streams are used.

2. Feather River

The river temperature model segments the Feather River into 10 reaches extending from Oroville Dam to the mouth. Table 12 identifies the reach locations.

Feather River geometry data were obtained from Corps of Engineers channel cross-section geometry used in the HEC-5 Model.[42] The HEC-5 cross-section data include stream channel energy grade line elevations, the cross-section river mileages, cross sectional areas, hydraulic radius to the 2/3 power, surface widths, and Manning's n (roughness coefficient). This information was available at each cross section for 21 elevations. A computer program was written to calculate riverflows corresponding to each river surface width using Manning's equation and the HEC-5 data. Aerial photos from a DWR spawning gravel study on the Feather River[14] were used to check the HEC-5 river widths. Some cross sectional width information was determined by these comparisons to be unrepresentative and was not used. Appendix E contains the computer program and cross-section data used in the Feather River

model. The model computes average surface widths for each river reach by interpolating the cross-section data.

Since DWRSIM output does not specify storages for Thermalito diversion pool, forebay, and afterbay, average storages were assumed based on historical operations.[6] Corresponding surface areas were obtained from area-capacity tables.[8] These surface areas, shown on table 4, are used in equation 1 to compute the temperature changes of Oroville Dam releases through the Thermalito reservoirs.

The three main tributaries entering the Feather River are Honcut Creek, Yuba River, and Bear River. DWRSIM output does not segregate river accretions by stream. Therefore, it was necessary to develop distribution factors for the three tributaries from USGS flow records.[40] These factors are indicated on table 12. Agricultural return flows specified by DWRSIM are assumed to enter the river near Nicolaus.

Yuba River near Marysville continuous temperature records were available for 1972-78.[40] Average monthly temperatures were developed from these records and used to represent Yuba River inflow temperatures to the Feather River (table 10). Due to lack of temperature data, the other tributaries and agricultural return flows were represented by mean monthly equilibrium temperatures computed from Marysville air temperatures.[22]

3. American River

The river temperature model segments the American River into eight reaches extending from Nimbus Dam to the mouth (table 13). Nimbus temperatures are computed from equation 1 using Folsom Dam flows and release temperatures and the Lake Natoma surface area shown on table 4.

American River geometry data were obtained from aerial photographs[36] and FWS instream flow studies.[38] Based on the available river width data, logarithmic relationships were developed between flow and width for each river reach. The coefficients for the relationships are shown on table 13.

Carmichael and City of Sacramento diversions, specified by DWRSIM output, are subtracted from American River flows at the Cordova Park and the City Filtration Plant river locations, respectively. The model neglects any effects that backwater influence from the Sacramento River may have on American River Temperatures between H Street and the mouth.

D. River Model Verification

The river temperature model was verified (predicted and measured temperatures compared) on the Sacramento, Feather, and American Rivers at several locations for the period 1971-77. The verifications are presented graphically in figures 7-11. Additional verifications for the Sacramento River (1987) and the American River (1981) are included in Appendix F. The predicted temperatures are generally within 1-2 °F of the measured temperatures. This is an acceptable difference since most measured temperatures are accurate to only about 0.5-1.0 °F. Christensen and Orlob[10] evaluated the sensitivity and accuracy of a previous version of the river temperature model[28] and recommended several potential improvements. The model reported herein has been substantially revised and includes several improvements, which are discussed in Chapter VI.

V. MODEL EVALUATIONS

A. River Temperature Control by Flow Augmentation

To provide input to the Bay-Delta Hearing process, the monthly model was used to evaluate Sacramento River flows that would be required to maintain river temperatures at Freeport suitable for salmon smolt out-migration.[25]

A DWRSIM operations model run (base study No. 75D) was used for temperature model input.[13] For each year of the 56-year study (1922-77), the model computed additional Shasta releases, above the base flows, required to meet Sacramento River temperatures at Freeport during May and June ranging from 65 to 69 °F. For this analysis, it was assumed that Shasta releases of about 50 °F would be available each year in unlimited amounts. Since each year was evaluated independently, the effects of increased Shasta releases on the storages and temperatures of Shasta Reservoir in subsequent years was not considered.

Table 14 and figures 12-13 summarize the flow study results. It is apparent that significant quantities of water would need to be released from Shasta Dam to achieve small temperature reductions at Freeport in May and June. For example, table 14 indicates that a 1 °F reduction in May could require additional Shasta releases of about 50-100 thousand acre-feet (TAF) (56-year average) with releases exceeding 250 TAF in some years. A 1 °F reduction in June could require additional releases of about 200-250 TAF (56-year average) with releases exceeding 300 TAF in some years. A 3 °F reduction could require releases of over 150 TAF in May and 600 TAF in June (56-year average) with high values exceeding 500 TAF in May and 1,000 TAF in June in certain years. As a check, these model results were compared with

output from a DWR regression model relating Freeport temperatures to flows and air temperatures.[16] A comparison of selected years shows reasonable agreement of the two models in the estimated flow increases required for Freeport temperature reductions of 1 °F and 3 °F.

To compare the effectiveness of different water supply sources on reducing Sacramento River temperatures at Freeport, the model was used to develop flow vs. temperature curves for Shasta, Oroville, and Folsom releases. Flow increases from each upstream reservoir were made separately, while the other two reservoirs were held constant at the base level. All reservoir releases were assumed to be 50 °F. May 1976 conditions from DWRSIM study No. 75D were used.[13]

The results of this analysis are shown in figure 14. As would be expected, Oroville and Folsom releases were more effective than Shasta releases in reducing Freeport temperatures because of the shorter distance and travel time from release point to Freeport. Folsom releases are most effective but would have the disadvantage of not reducing Sacramento River temperatures upstream of the American River confluence. Also, the ability to make additional releases from Folsom Reservoir is limited by its lower capacity.

In summary, the flow evaluations have demonstrated that substantial amounts of upstream reservoir releases would be required to achieve relatively small reductions of Sacramento River temperatures at Freeport. The effectiveness of flow augmentation is limited by the influence of air temperatures and other climatic factors on river temperatures. Also, large spring reservoir releases would reduce summer and fall storages, which would result in warmer summer and fall river temperatures in the salmon spawning

reaches. Warmer temperatures in the Sacramento and American Rivers, for example, would adversely impact the winter, spring, and fall salmon runs on the Sacramento River and the fall run on the American River.

B. River Temperature Control by Other Measures

Table 15 summarizes a temperature model evaluation of the ability of upstream management actions other than increased flows to reduce Freeport temperatures in May and June. These actions include a Shasta Dam TCD, bypassing Oroville Dam releases around Thermalito Forebay and Afterbay, increasing riparian shade along the entire length of the Sacramento River from Keswick Dam to Freeport by 10 percent, and eliminating the major agricultural drainage discharges to the Sacramento River from Butte Creek to Sacramento. The May and June temperature reductions at Freeport were computed to be 0.7 °F or less for each action, and 1.5 °F or less for all four actions combined, based on a 56-year average (1922-1977) of predicted temperatures using DWRSIM operations study No. 62B.[13]

The Shasta TCD has no significant effect on Freeport temperatures during any month of the year. The device would normally be operated to conserve cold water in the spring months so that river temperature reductions could be accomplished in the summer and fall months to benefit the winter and fall salmon spawning above Red Bluff. Table 15 shows the effects of an August-November Shasta TCD operation. While significant temperature decreases occur at Red Bluff (about 2-4 °F), Freeport temperature reductions are minor, ranging from 0.1 to 0.3 °F.

C. DWRSIM Operation Studies for Salmon

DWRSIM operation studies were run for a base condition (No. 75D) and a salmon flow condition (No. 144C).[13] Both studies assumed 1990 hydrology, 1990 level projected SWP-CVP demands, and existing facilities. The salmon study No. 144C imposed a salmon flow requirement from May 1-June 15 at Freeport on the Sacramento River, based on the DWR regression equation relating river temperature to flow and air temperature.[16] The target temperatures for Freeport were 63 °F in May and 67 °F in June.

The temperature model results for the two DWRSIM studies are presented in table 16 and figures 15 and 16. Monthly mean temperatures averaged over the 56-year study period are shown in table 16 for the Sacramento River at two locations: Red Bluff and Sacramento. Studies with and without a TCD at Shasta Dam were run. The TCD was operated to reduce salmon spawning temperatures between Keswick Dan and Red Bluff during the months of July-November.

The model results indicate a 56-year average reduction in Freeport temperatures of about 1.3 °F in May and 0.5 °F in June. Maximum reductions of over 6 °F in May and 3 °F in June occur in specific years (figure 15). The trade-off of providing cooler Freeport temperatures in May and June is an increase in river temperatures above Red Bluff during July-September,the spawning period of the winter and spring salmon runs. The 56-year average temperatures at Red Bluff are about 0.5-1.0 °F warmer in these months under the salmon flow scenario (No. 144C). Maximum increases of 4-6 °F occur in certain years (figure 16). The warmer river temperatures in July-September are due to lower Shasta storage levels resulting from the May-June salmon flow increases.

VI. POTENTIAL MODEL IMPROVEMENTS

The report by Christensen and Orlob[10] reviewed a previous version of Reclamation's monthly model[28] and recommended several potential improvements. The model reported herein has incorporated many of these improvements. They include a more definitive treatment of Sacramento River accretion flows and temperatures, updated climatic input data, improved geographic representation of climatic data, and a more detailed characterization of river geometry.

Despite these improvements there are additional modifications to the model that could potentially improve its accuracy. Some areas of potential improvement include:

1. Inflow temperatures - A better estimate of reservoir and tributary inflow temperatures may be obtainable by multiple regression of available measured temperatures with flows and air or equilibrium temperatures.

2. Regulating reservoirs - An improved estimate of temperature changes within the regulating reservoirs may be possible by using a two-dimensional model to simulate stratification, which may become significant under certain low flow conditions.

3. Whiskeytown Reservoir - Because of its relatively high inflow-storage ratio and unique geometry, Whiskeytown Reservoir temperature may be characterized more accurately by a two-dimensional reservoir model rather than the one-dimensional model.

4. Climatic data - While monthly mean air temperatures were specified for each year of the study period (1922-1977), the other climatic variables were represented by long-term average monthly means. There may be sufficient data

to extend some of these other variables by correlation throughout the study period, thereby improving the annual climatic variation.

5. River geometry - Feather and American River geometry input data can be improved by evaluating additional aerial photo sets to better define the flow vs. surface width relationships. Data from the recent Sacramento River instream flow study[23] could be useful in determining changes in river geometry that may have occurred since the 1962 study.[9] Data being collected on the American River in connection with the instream flow litigation[19] may be helpful in better defining the effects of backwater on the temperatures of the American River above the mouth.

VII. CONCLUSIONS

1. The monthly temperature model described in this report is useful for comparing temperature effects of alternative CVP-SWP operating scenarios, as defined by monthly operation models (i.e., DWRSIM or PROSIM).[11,24]

2. The model is best used for evaluating relative differences in river temperatures for different operating conditions. Any use of the predicted temperatures as absolute values must consider inherent model inaccuracies.

3. The model is limited to mean monthly, steady-state simulations of water temperature. Evaluation of the effects of unsteady flow conditions or short-term (i.e., daily or diurnal)fluctuations in air temperatures or other climatic variables would require a different modeling approach.

4. The studies evaluating different flow scenarios (i.e., DWRSIM No. 75D and No. 144C) have shown that increased reservoir releases can reduce Sacramento River temperatures at Freeport during May and June, but only at the cost of increasing upstream river temperatures during July-September.

VIII. RECOMMENDATIONS

1. The potential model improvements listed in section VI should be implemented to the extent that available resources and data allow.

2. Additional model studies should be conducted as necessary to further define the ability of CVP-SWP operations to meet existing or proposed temperature objectives for fisheries.

3. The model should be modified as necessary to operate with the new operations model PROSIM,[24] when it becomes fully operational.

4. Application of the model to the San Joaquin River Basin should be developed. The model should be designed to accept output from the operations model (SANJASM).[5]

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LIST OF FIGURES

FIGURE 1
SACRAMENTO RIVER BASIN TEMPERATURE MODEL NETWORK

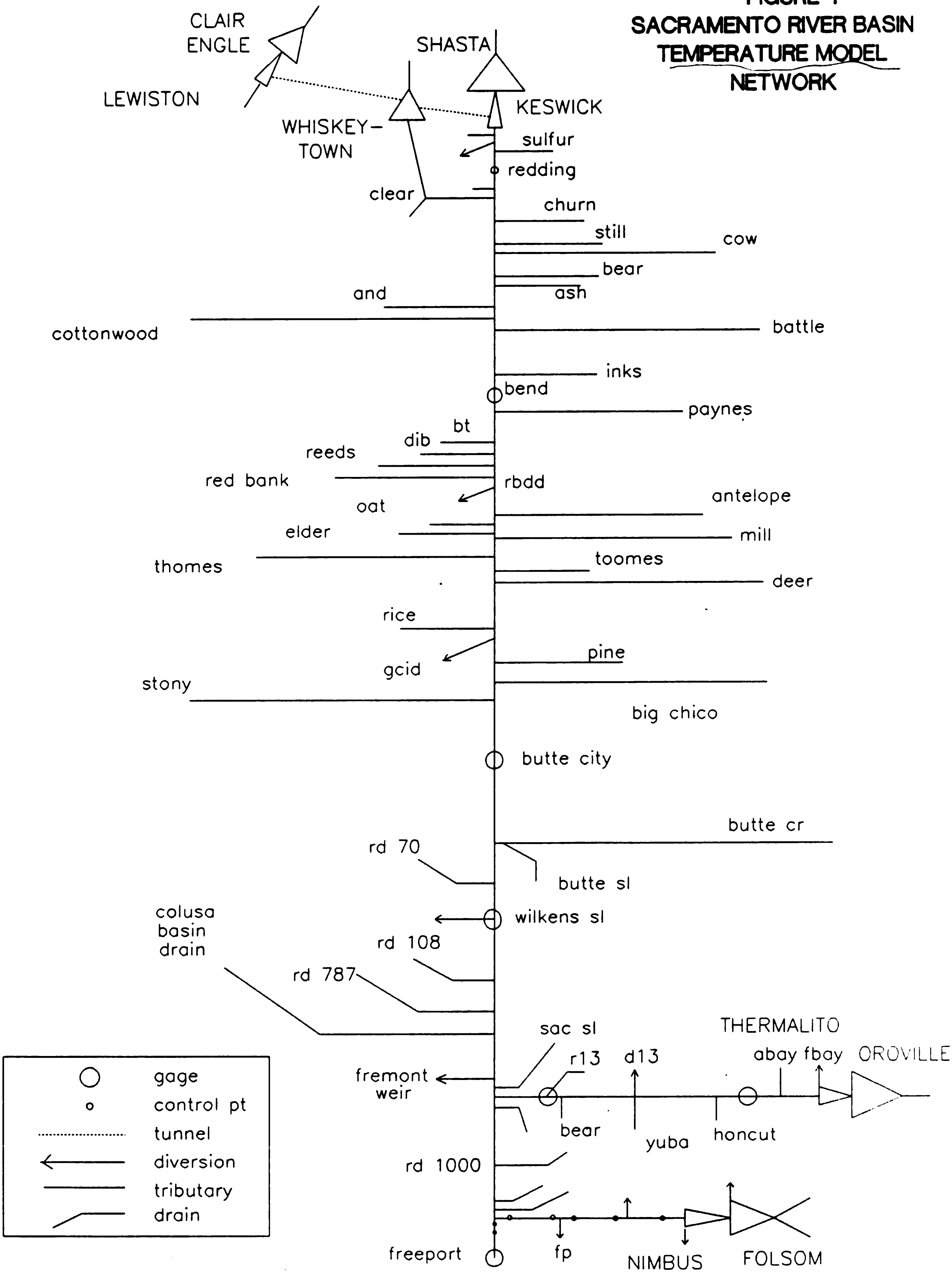


FIGURE 2
Lake Profiles – July 1987

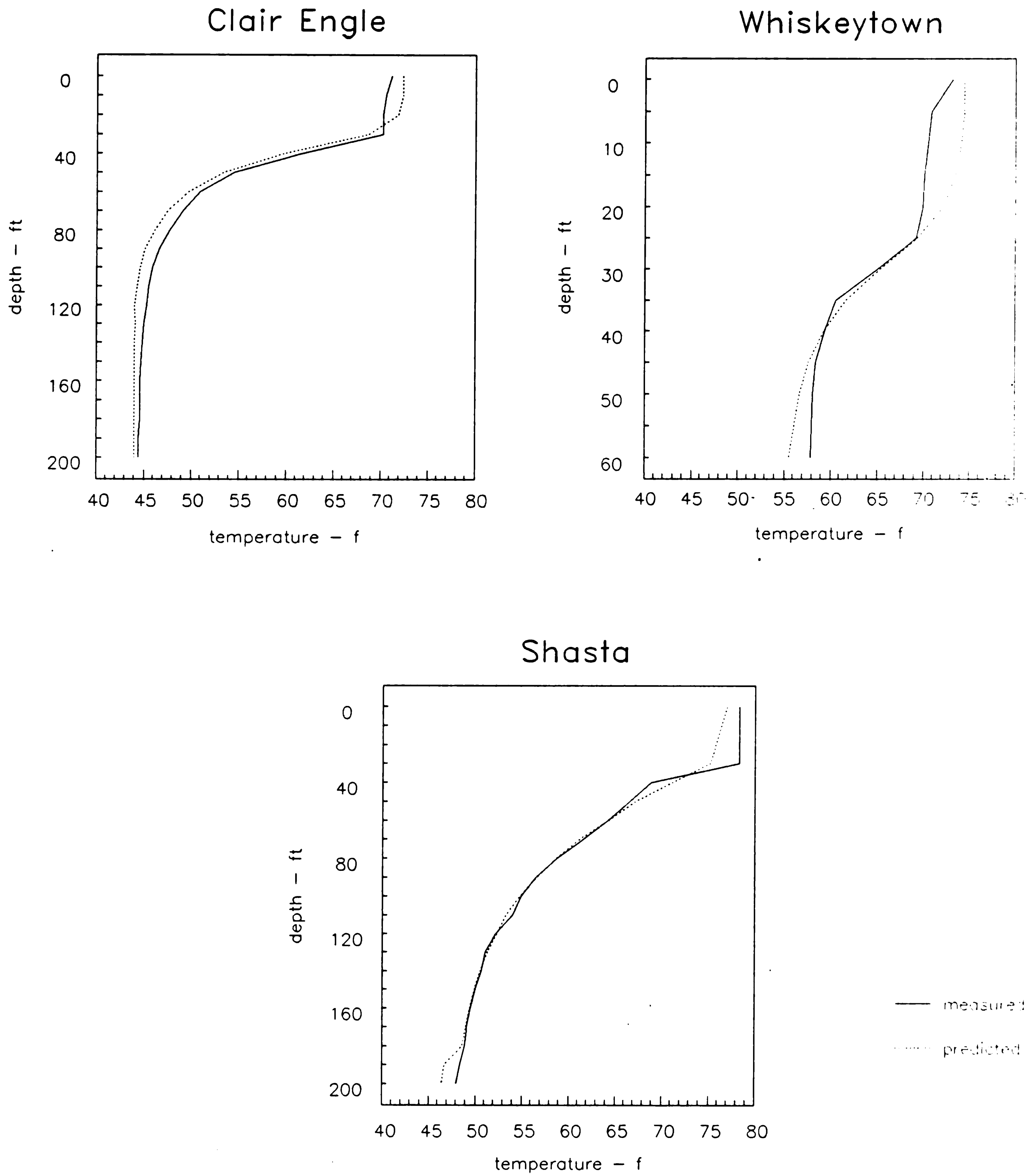
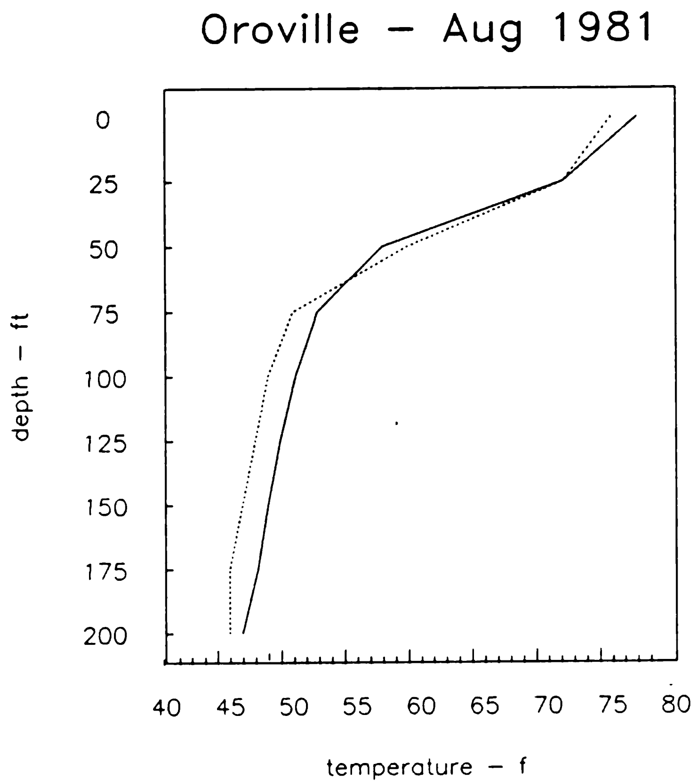


FIGURE 3 – Lake Profiles



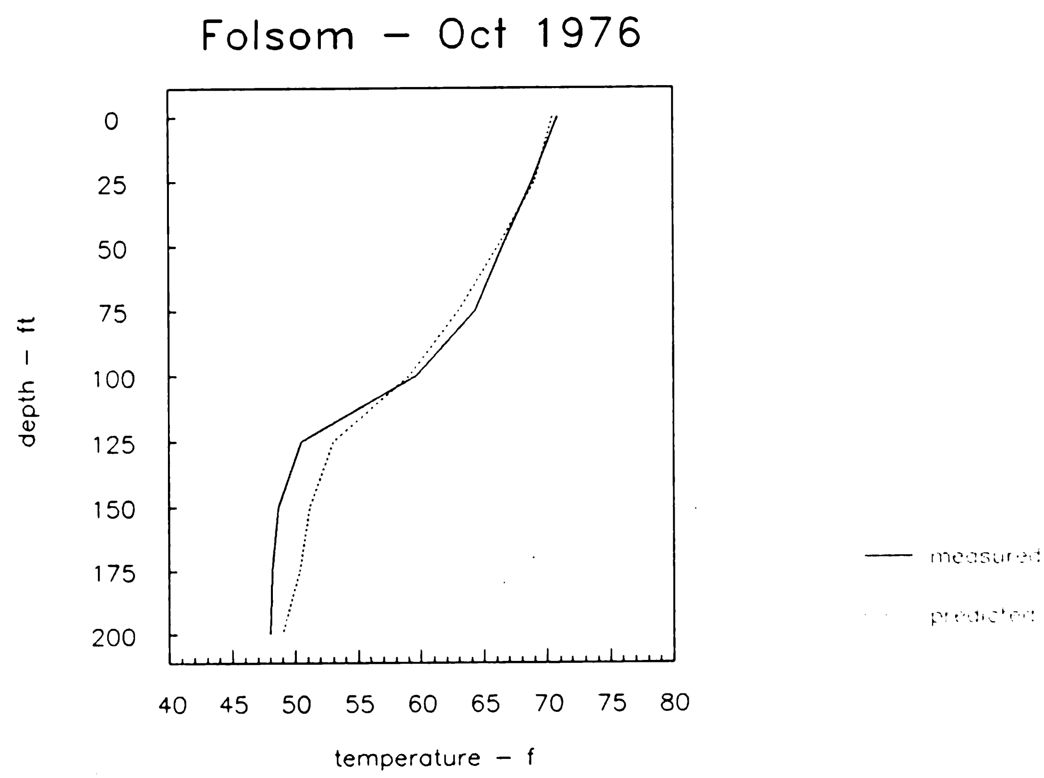


FIGURE 4

TRIBUTARY BASINS OF SACRAMENTO RIVER

(DWR Bul. 111)

FIGURE 4 (Continued)

LEGEND

DRAINAGE AREA OF SACRAMENTO RIVER SURVEY
TRIBUTARY BASIN BOUNDARIES
TRIBUTARY SUB-BASIN BOUNDARIES
(1) BASIN NUMBER

Basin No.	Basin
1	Shasta Lake Inflow
2	Local Keswick Inflow
3	Spring Creek
4	Middle Creek
5	Sulphur Creek
6	Olney Creek
7	Clear Creek
8	Churn Creek
9	Stillwater Creek
10	Cow Creek
11	Bear Creek
12	Ash Creek
13	Anderson Creek
14	Cottonwood Creek
15	Battle Creek
16	Inks Creek
17	Paynes Creek
18	Blue Tent Creek
19	Dibble Creek
20	Reeds Creek
21	Red Bank Creek
22	Antelope Creek
23	Oat Creek
24	Elder Creek
25	Mill Creek
26	Thomes Creek
27	Toomes Creek
28	Deer Creek
29	Rice Creek
30	Pine Creek
31	Big Chico Creek
32	Stony Creek
33	Butte Creek
34	Colusa Basin Drain
35	Sacramento Slough-Sutter Bypass
36	Feather River
37	Auburn Ravine
38	American River
39	Clear Lake
40	Putah-Cache Creeks

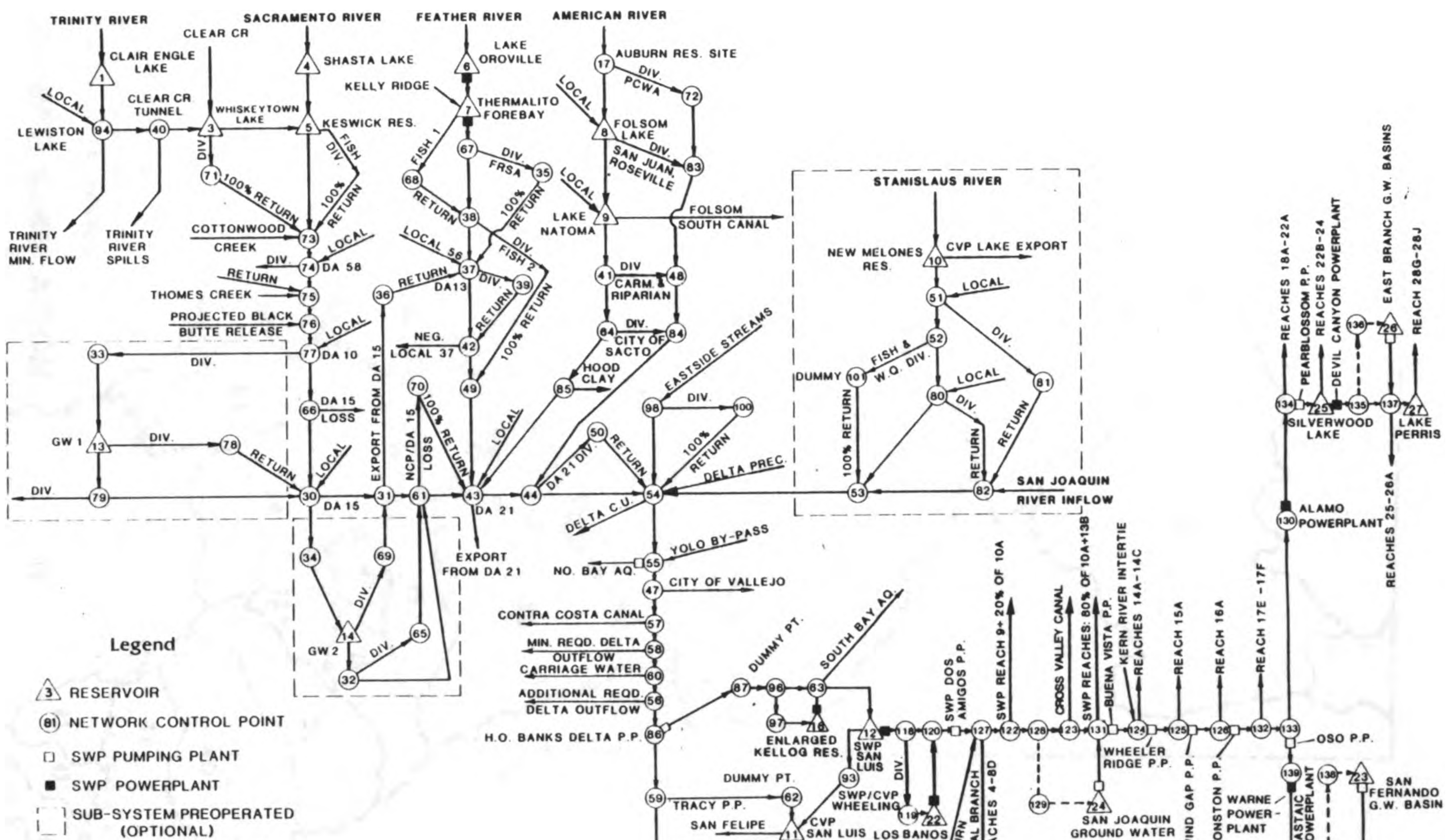
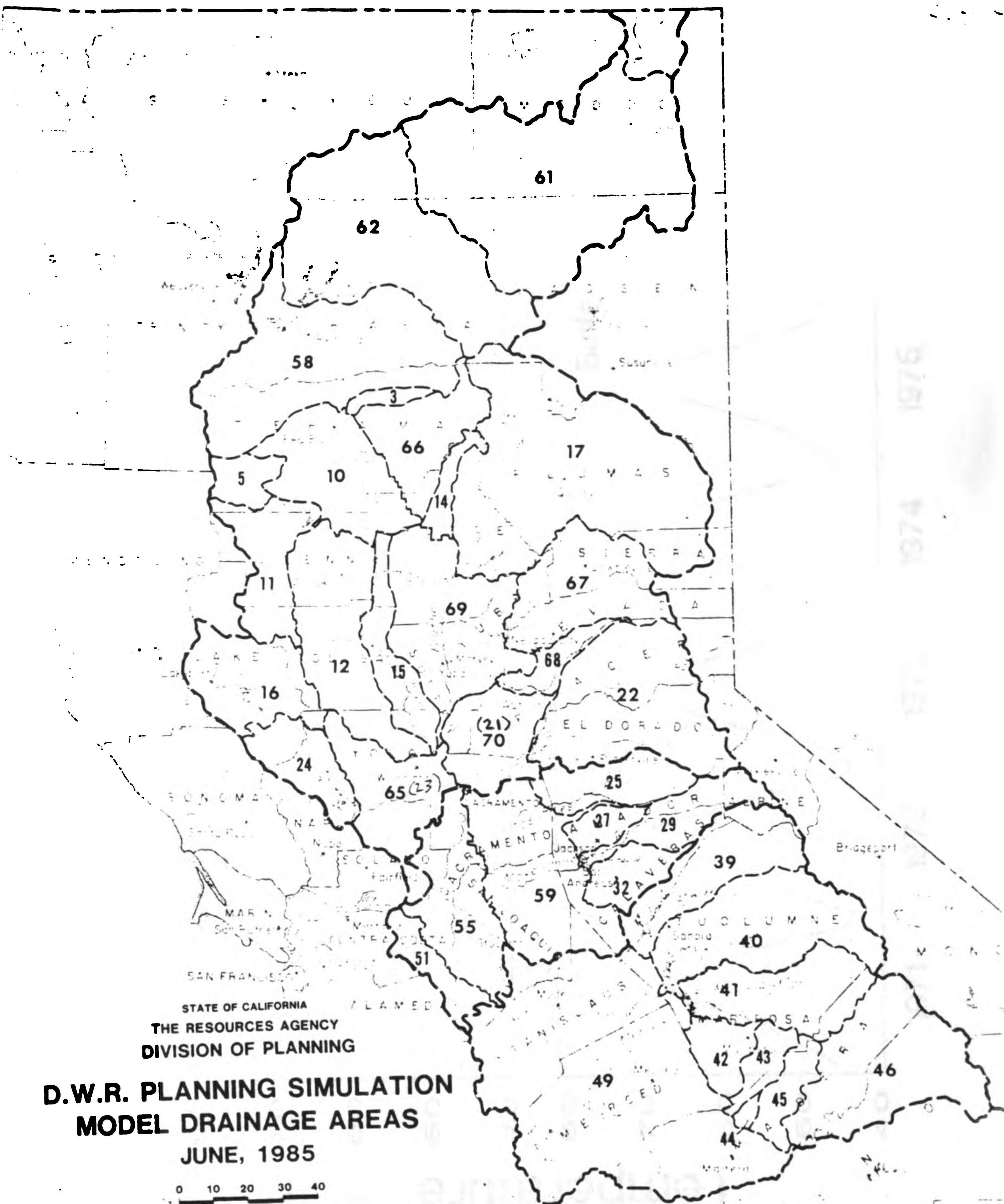


FIGURE 5

THE DWR PLANNING SIMULATION MODEL NETWORK REPRESENTATION

Revised January 1985

FIGURE 6



STATE OF CALIFORNIA
THE RESOURCES AGENCY
DIVISION OF PLANNING

D.W.R. PLANNING SIMULATION MODEL DRAINAGE AREAS
JUNE, 1985

Figure 9 Feather River Temperature

Model Verification 1971-77

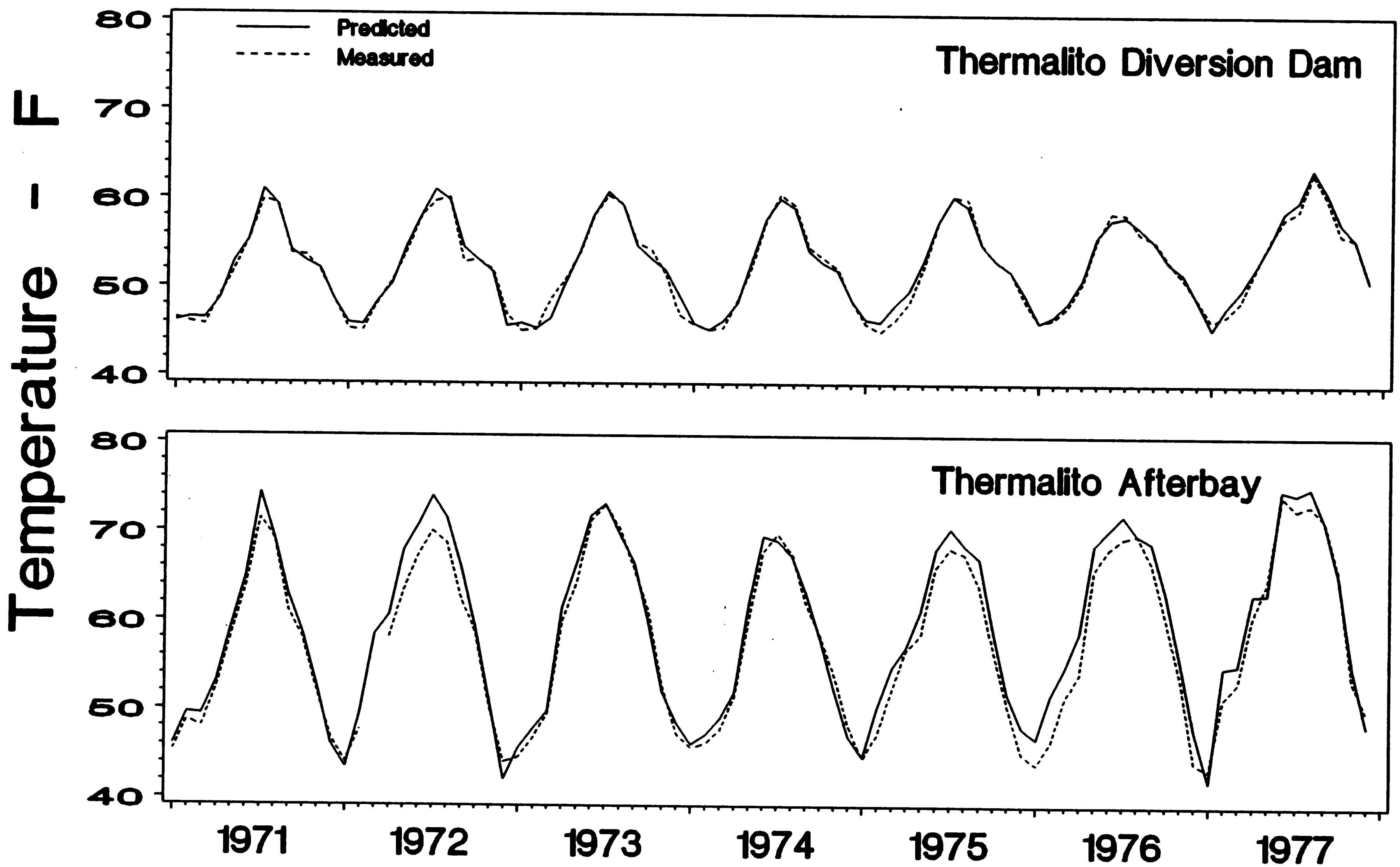


Figure 10 Feather River Temperature
Model Verification 1971-77

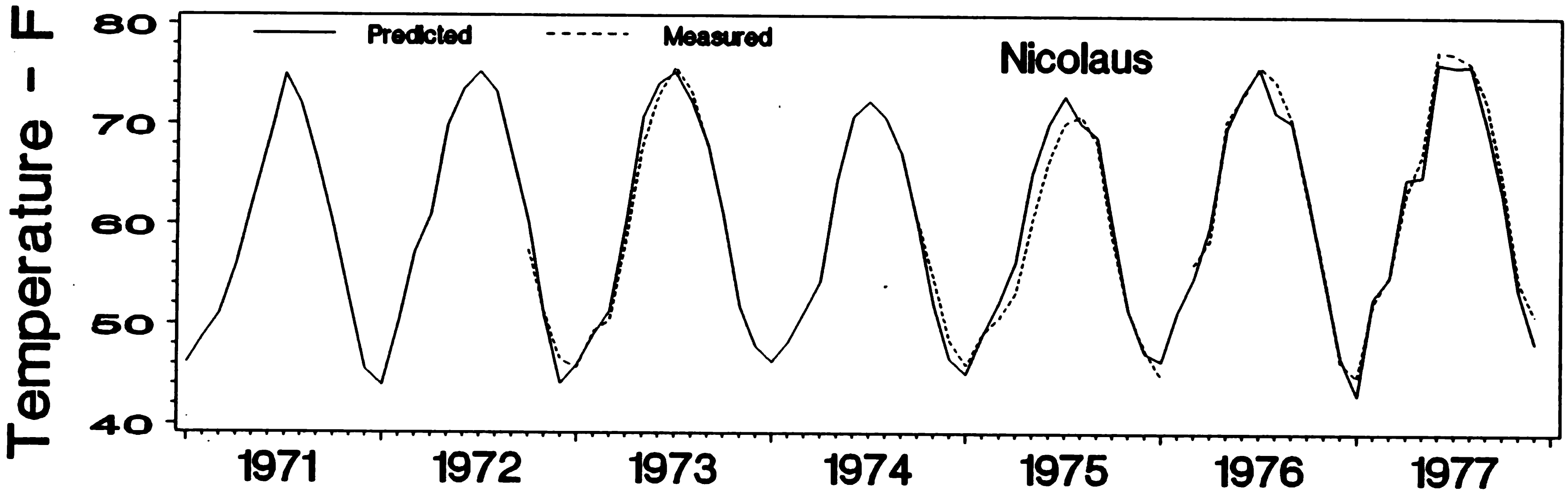
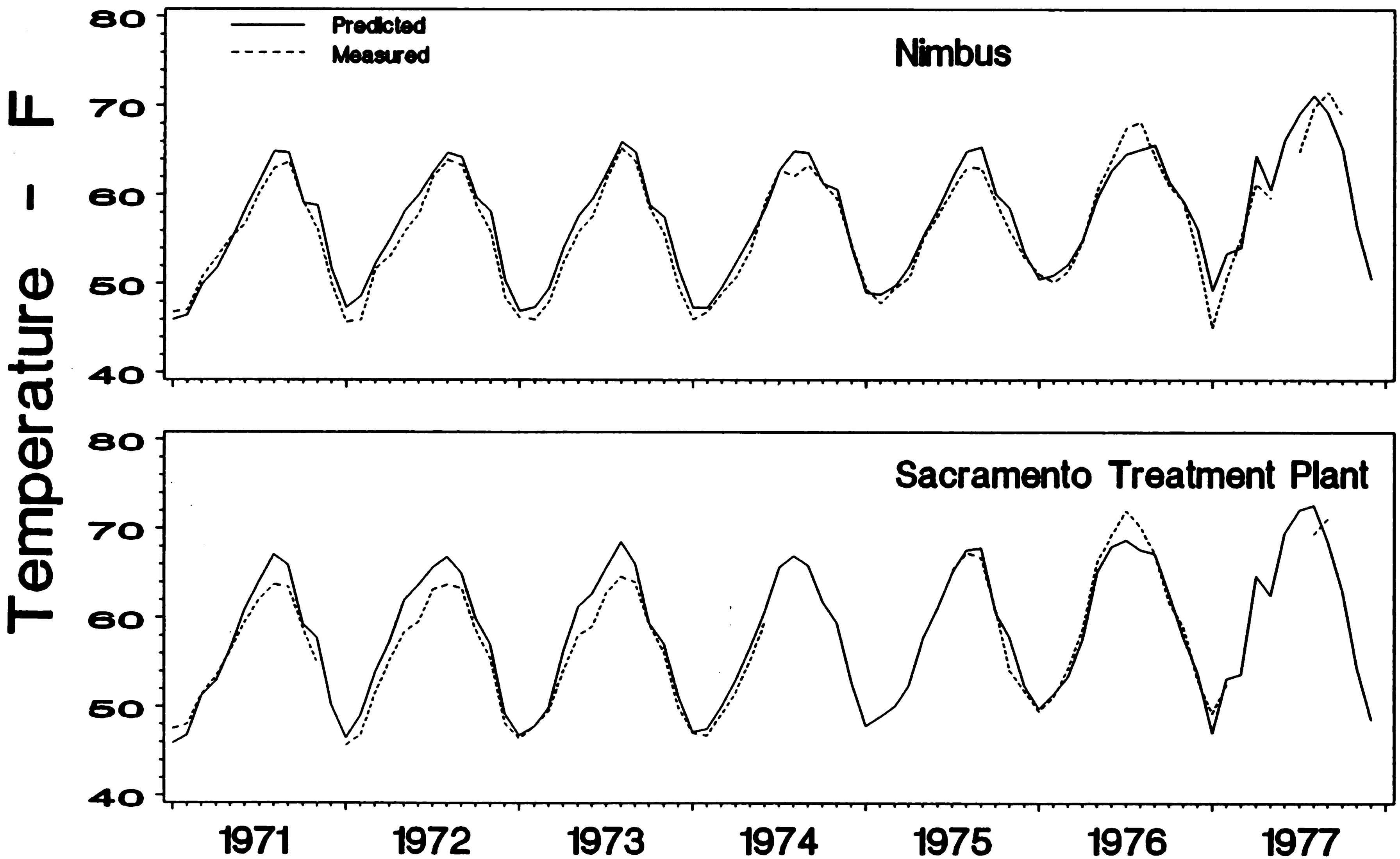


Figure 11 American River Temperature
Model Verification 1971-77



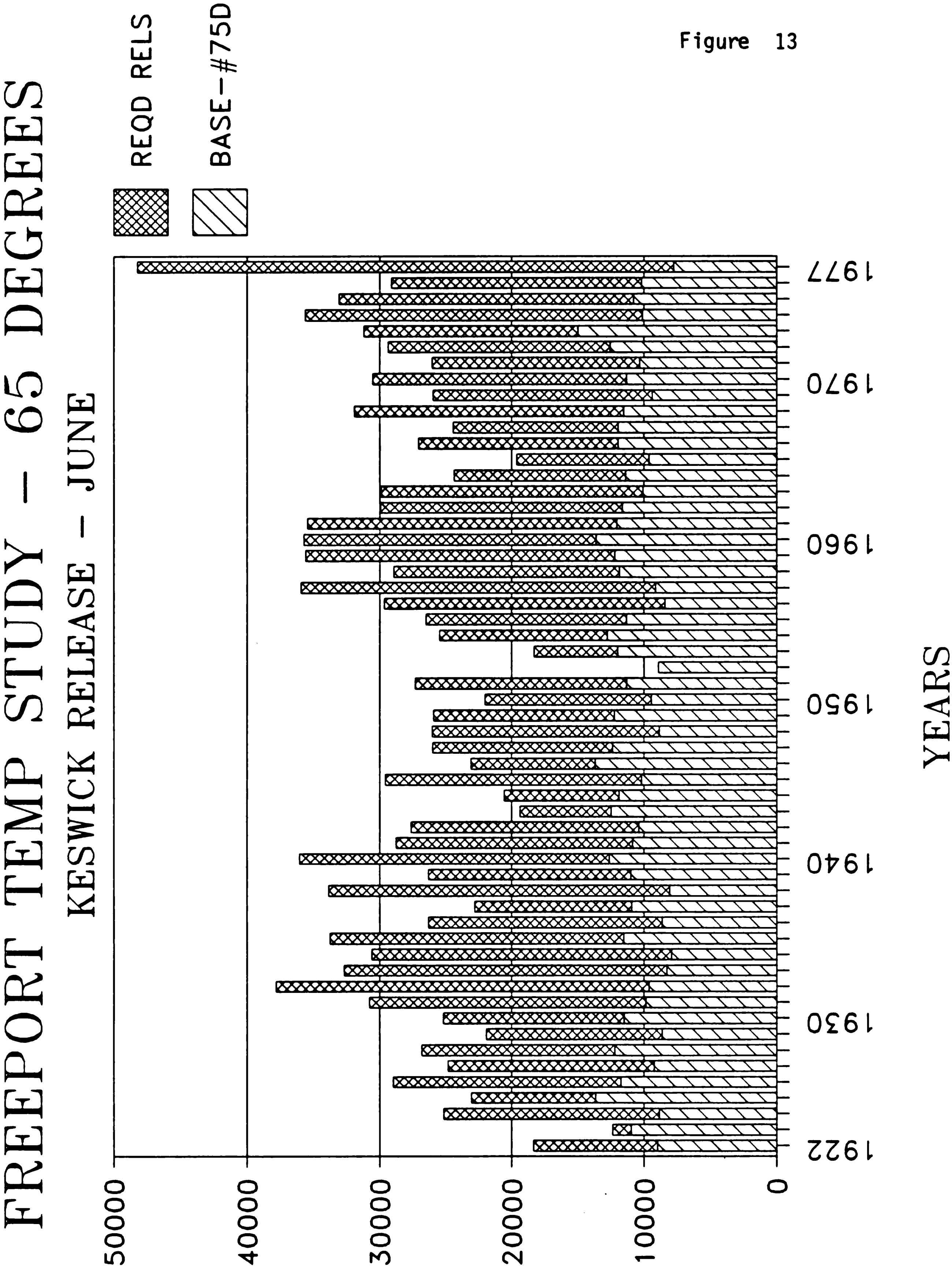
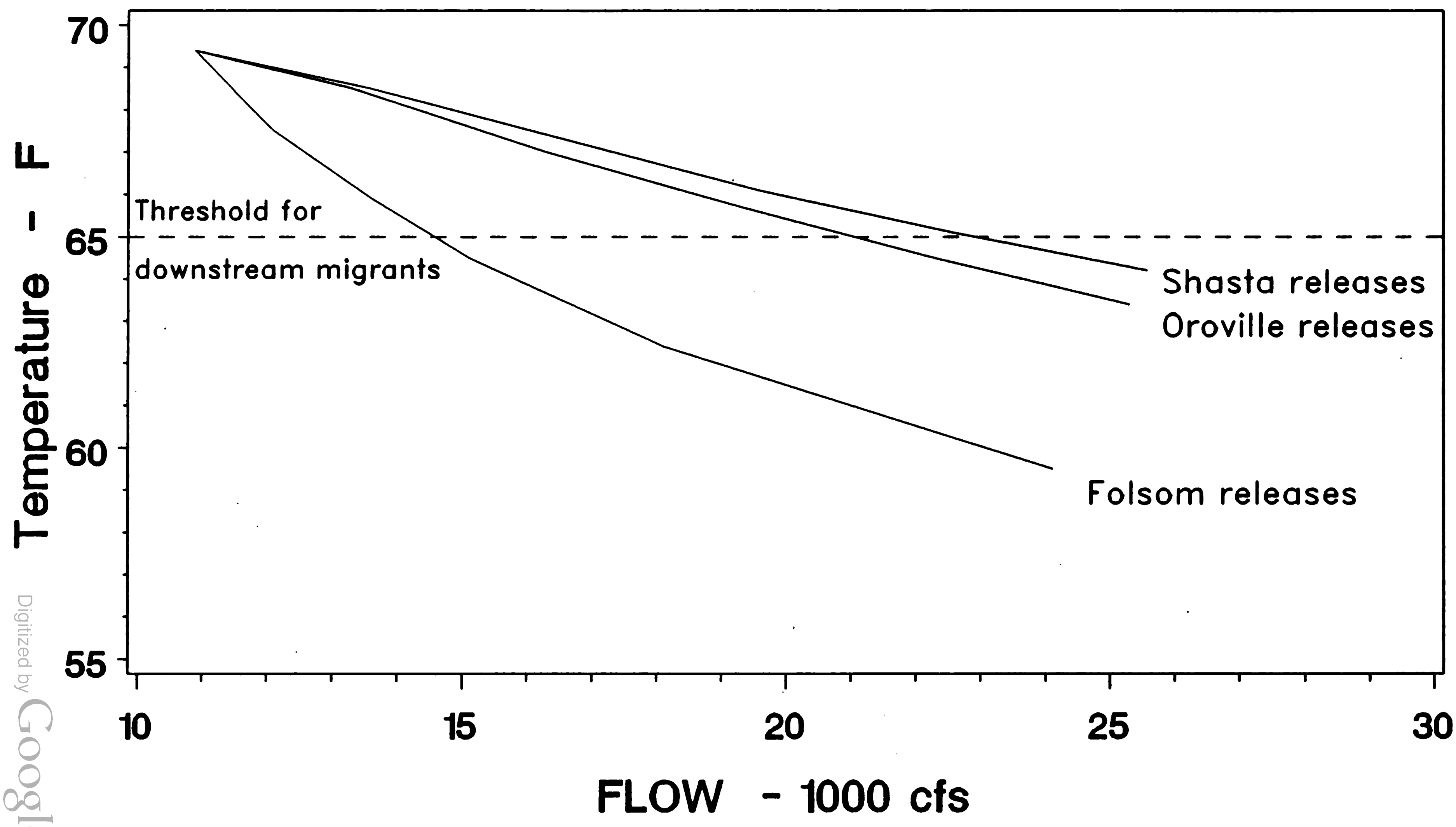

FREEPORT TEMP STUDY - 65 DEGREES
KESWICK RELEASE - JUNE
REQD RELS
BASE-#75D
RELEASE IN CFS
50000
40000
30000
20000
10000
0
YEARS
1922
1930
1940
1950
1960
1970
1977

Figure 13

Figure 14 Sacramento River at Freeport for May 1976



DWRSIM #75D – All releases at 50 F

Figure 15 Sacramento River at Freeport

May and June Temperatures: 1922-77

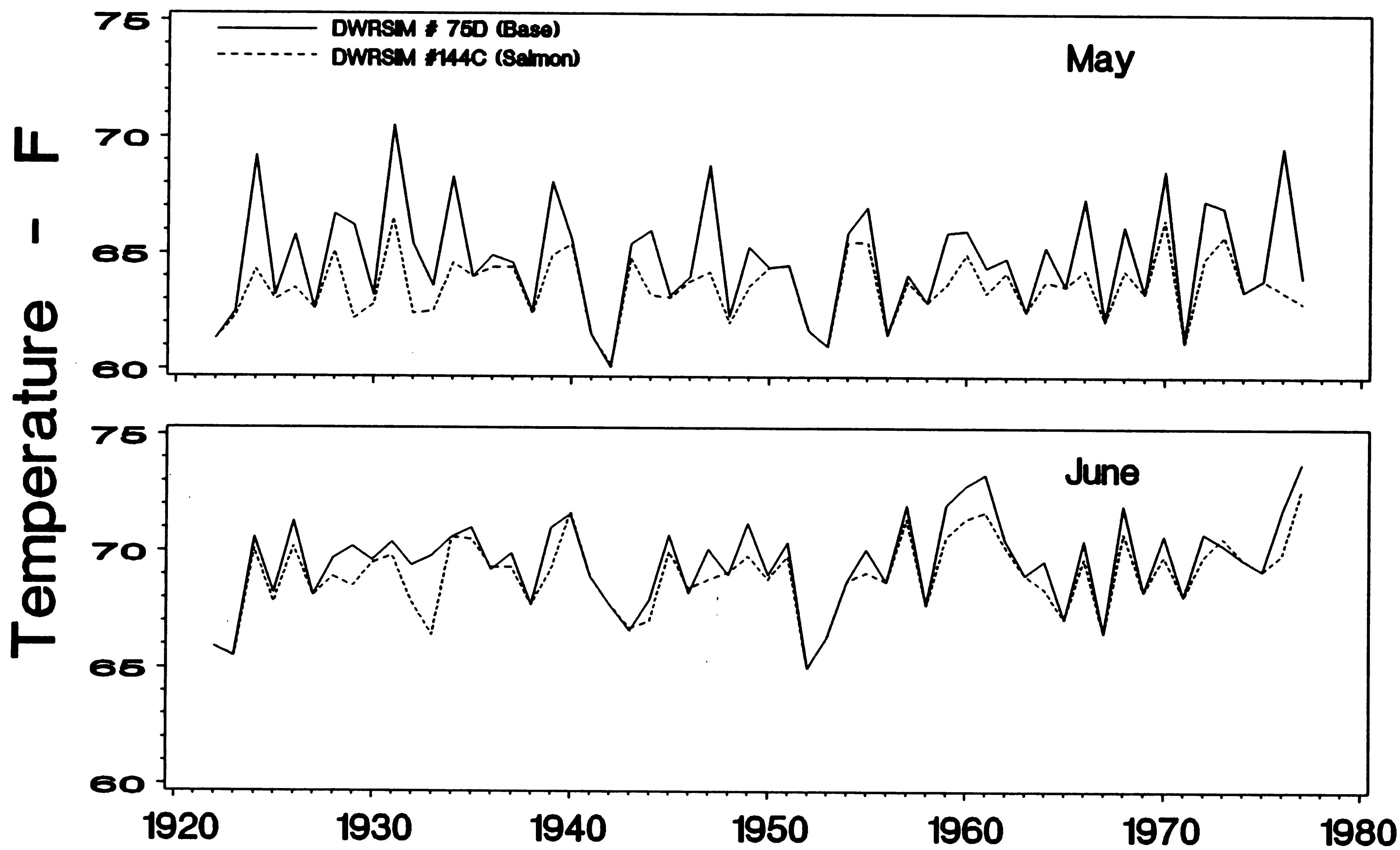
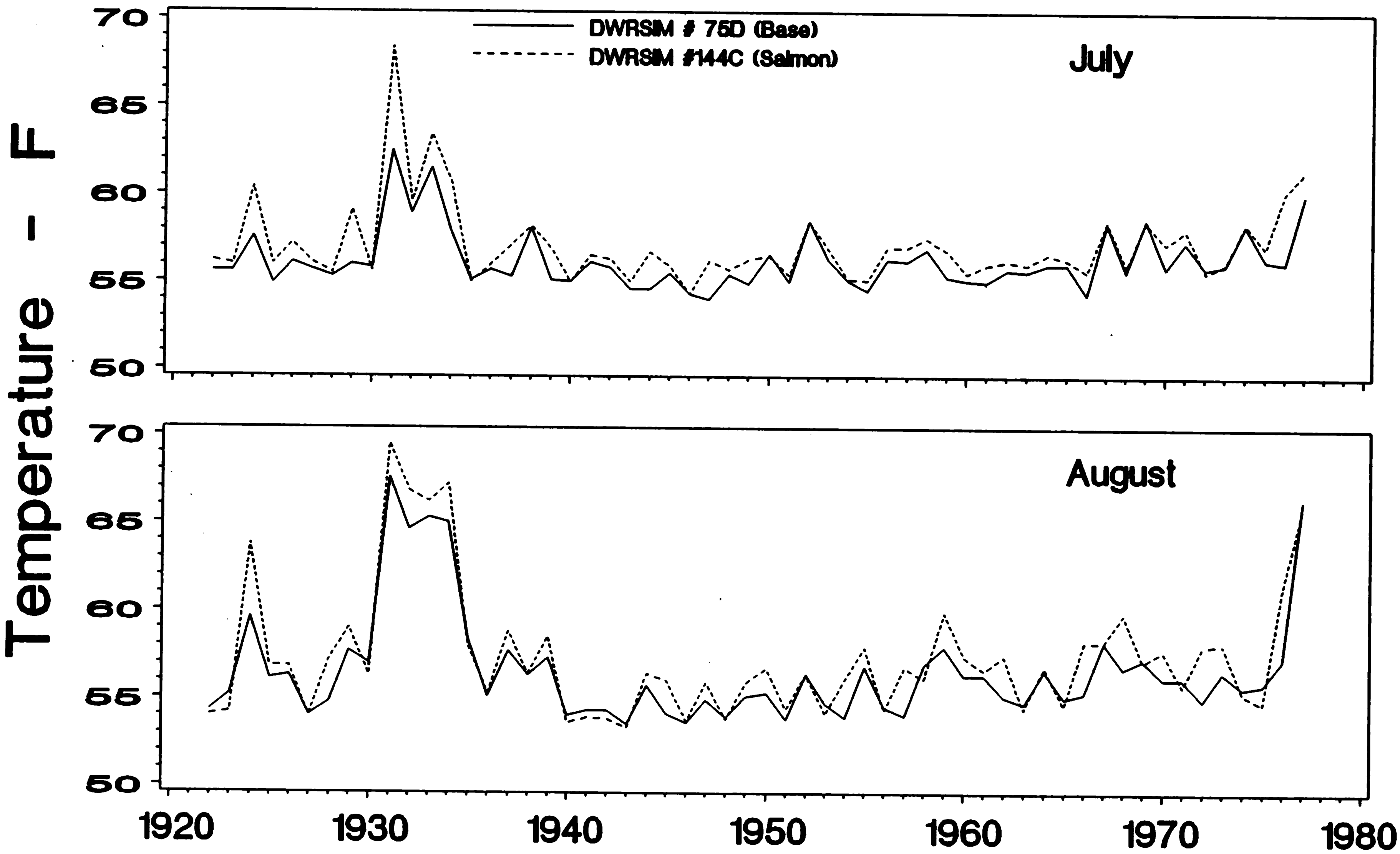


Figure 16 Sacramento River at Red Bluff

July and August Temperatures: 1922-77



LIST OF TABLES

TABLE 1

RESERVOIR OUTLET LEVEL ELEVATIONS

OUTLET LEVEL ELEVATION - FT

Reservoir	Power					River					Spill
Clair Engle			2110					2000			2350
Whiskeytown			1085				975		1110		1210
Shasta											
Existing			815			742		842		942	1037
Proposed TCD*	710	800		815	900	742		842		942	1037
	925	1000		1020	1045						
Oroville*	620	660		700	740			400			922
	770	800		830	860						
Folsom*	307	402		415	428	210		280		316**	468

* Power levels are approximate
** Local water supply diversion

TABLE 2
RESERVOIR TEMPERATURE MODEL INPUT DATA

INPUT DATA / RESERVOIR	DATA SOURCE	Mean monthly values J	F	M	A	M	J	J	A	S	O	N	D
INFLOW TEMPERATURE - °F													
Clair Engle	1	36.7	40.3	40.3	41.3	43.8	54.2	60.7	62.2	61.1	52.1	41.3	37.7
Whiskeytown	2	42.0	46.0	46.0	51.0	55.0	63.0	70.0	72.0	65.0	57.0	48.0	45.0
Shasta	3	42.5	44.8	46.9	49.6	54.4	61.1	67.2	65.9	61.5	54.6	48.8	43.1
Oroville	4	41.0	44.6	46.4	50.0	55.4	62.6	69.8	69.8	66.2	57.2	50.0	42.8
Folsom - North Fork	5	44.1	46.2	49.4	52.9	57.7	64.8	68.4	66.1	63.5	59.7	53.4	46.6
Folsom - South Fork	6	41.3	42.2	45.7	48.6	52.4	57.4	60.9	60.3	59.3	56.3	48.7	43.5
TOTAL SOLAR RADIATION - LY/D													
Clair Engle	7	350	500	650	820	920	950	935	870	710	550	400	310
Whiskeytown	7	350	500	650	820	920	970	960	870	710	550	400	310
Shasta	7	350	500	650	820	920	955	940	870	710	550	400	310
Oroville	7	360	505	660	830	940	980	965	860	710	550	400	320
Folsom	7	390	510	650	830	930	980	970	860	720	550	400	340
AIR TEMPERATURE REGRESSIONS													
Clair Engle	8	TA = .9381615 × RTA - 4.185949 , r = .998											
Whiskeytown	9	TA = .9791348 × RTA - 0.585167 , r = .997											
Shasta	10	TA = .9964047 × RTA - 1.288424 , r = .997											

Regression Terms:
- TA - Reservoir monthly mean air temperature
- RTA - Redding monthly mean air temperataure - NOAA - 1922-77
- r - Correlation coefficient

Data Sources:

1. USGS - Trinity, Coffee Creek; Flow - WTD Avg. - 1957-68
2. USGS - Clear Creek @ French Gulch - 1955-68
3. USGS/DWR - Sacramento (thermograph) McCloud, Pit; Flow - WTD Avg. - 1964-77
4. DWR - Feather River @ Oroville (thermograph) - 1954-67
5. USGS/USBR - North Fork American River (thermograph), M. Fork; FLOW-WTD AVG - 1961-78
6. USGS - South Fork American River (thermograph) - 1964-78
7. Figure 2 - Appendix A
8. NOAA - Trinity River Hatchery - 1976-85
9. NOAA - Whiskeytown Dam - 1976-85
10. NOAA - Shasta Dam - 1944-70

TABLE 3
RESERVOIR TEMPERATURE MODEL
Calibration Coefficients

Reservoir	Data Source	Coefficients					Calib. Error °F
		Air Temp	Inflow Mixing	Vertical Diffusion	Evapor-ation	Insol-ation	
Clair Engle	1	.500	.230	.003	.513	.325	0.7
Whiskeytown	1	.988	.072	.003	.866	.000	2.0
Shasta	1	1.000	.048	.013	.655	.155	1.1
Oroville	2	.924	.108	.097	1.000	.277	2.2
Folsom	1	.500	.230	.020	.440	.220	1.1

Data Source:

1. USBR - Temperature - Depth Profiles - selected years 1951-77
2. DWR - Temperature - Depth Profiles - 1981

TABLE 4
RIVER TEMPERATURE MODEL EQUATIONS

Equation 1: $T_2 = (T_1 - E)\, e^{-CK/Q} + E$

Equation 2: $T_2 = (T_1 Q + T_T Q_T)/(Q + Q_T)$

TERMS:

T_1 = River temperature at start of reach (EQ.1) or above tributary (EQ.2) - °F

T_2 = River temperature at end of reach (EQ.1) or below tributary (EQ.2) - °F

E = Equilibrium temperature - °F

Q = Riverflow over reach (EQ.1) or above tributary (EQ.2) - ft^3/s

e = Natural log = 2.7183

K = Heat exchange coefficient - $\frac{BTU}{ft^2\text{-day-}^\circ F}$

T_T = Tributary temperature - °F

Q_T = Tributary flow - ft^3/s

$$C = \frac{A}{C1 \times C2 \times 86{,}400}$$

Where: A = Surface area of river reach - ft^2
C1 = 62.4 lb/ft^3
C2 = 1 Btu/lb
43,560 ft^2/acre
86,400 sec/day

Assumed regulating reservoir surface areas:

Lewiston	736 acres
Keswick	620
Thermalito	
Diversion pool	319
Forebay	614
Afterbay	3,460
Natoma	450

TABLE 5
RIVER TEMPERATURE MODEL CLIMATIC INPUT DATA

VARIABLE/UNITS	DATA SOURCE	J	F	M	A	M	J	J	A	S	O	N	D
		Mean monthly values											
Red Bluff													
Solar radiation - LY/D	1	157	247	378	520	621	683	681	608	481	329	201	136
Relative humidity - %	2	72.5	67.3	60.0	51.8	46.3	38.5	33.5	35.0	36.5	47.5	64.3	73.8
Wind speed - mi/h	2	9.2	9.2	9.8	9.6	9.2	9.3	8.0	7.6	8.0	8.4	8.6	8.5
Cloud cover - 10ths	2	6.7	6.4	6.1	5.3	4.4	3.1	1.2	1.7	2.0	4.0	6.0	6.9
Solar altitude - Deg.	3	19.1	26.3	30.7	33.7	35.8	38.2	37.4	32.8	29.8	25.5	21.5	17.3
Solar reflectivity	4	.11	.09	.07	.07	.07	.06	.06	.07	.08	.10	.10	.11
Solar rad. factor	5	.896	.929	.962	.983	.990	1.000	.998	.993	.974	.953	.912	.908
Sacramento													
Solar radiation - LY/D	6	175	266	393	529	627	683	682	612	494	345	220	150
Relative humidity - %	7	82.5	77.0	69.8	63.3	58.8	54.8	53.0	54.8	55.3	61.3	75.3	82.8
Wind speed - mi/h	8	7.7	7.8	8.9	9.0	9.4	9.9	9.1	8.7	7.7	6.7	6.3	7.0
Cloud cover - 10ths	8	7.1	6.3	5.5	4.7	3.5	2.2	1.0	1.5	1.7	3.2	5.7	6.8
Solar altitude - Deg.	3	20.6	27.8	31.7	33.9	36.0	38.3	37.5	33.2	30.6	26.7	22.9	18.7
Solar reflectivity	4	.10	.08	.07	.07	.07	.06	.06	.07	.07	.09	.09	.10
Shade Factors													
Low	9	.09	.08	.07	.06	.06	.06	.06	.06	.07	.08	.09	.10
Moderate	9	.15	.13	.12	.10	.10	.10	.10	.10	.11	.13	.15	.16

Data Sources:

1. Sacramento Solar radiation (6) × Factor (5)
2. NOAA - Red Bluff - 1946-75 (REF. 21)
3. Red Bluff Lat. = 40.4°, Sacramento Lat. = 38.6° (REF 32)
4. Appendix B - Figure B-3 (REF 15)
5. Ratio solar radiation by latitude - (Red Bluff/Sacramento) (REF 41)
6. DWR - Davis - 1942-77 (REF 7)
7. NOAA - Sacramento - 1961-79 (REF 20)
8. NOAA - Sacramento - 1949-79 (REF 20)
9. FWS - (REF 12)

TABLE 6
RIVER TEMPERATURE MODEL
Data Sources for E and K Calculation

River/Reaches	Data Source			
	Air Temperature	Other Climatic	Shade Factor	File Name
<u>Trinity River</u>				
Lewiston Reservoir	Trinity *	Red Bluff	Low	LEWKE1
<u>Sacramento River</u>				
Keswick Reservoir	Redding	Red Bluff	Low	REDKE1
Sacramento Riv (RM 301-272)	Redding	Red Bluff	Low	REDKE1
Sacramento Riv (RM 272-191)	Red Bluff	Red Bluff	Low	RBKE1
Sacramento Riv (RM 191-100)	Colusa	Sacramento	Low	COLKE1
Sacramento Riv (RM 100-46)	Sacramento	Sacramento	Low	SACKE1
<u>Feather River</u>				
Thermalito Diversion Pool	Oroville	Sacramento	Low	OROKE1
Thermalito Forebay & Afterbay	Oroville	Sacramento	Low	OROKE1
Feather River (RM 68-51)	Oroville	Sacramento	Low	OROKE1
Feather River (RM 51-0)	Marysville	Sacramento	Mod	MARKE1
<u>American River</u>				
Natoma Reservoir	Folsom	Sacramento	Low	FOLKE1
American River (RM 23-0)	Sacramento	Sacramento	Mod	LARKE1

* Regression with Redding air temperature (table 2)

TABLE 7
SACRAMENTO RIVER MODEL
Reach Locations and Tributaries

Reach No. (1)	River mile (2)	Reach Location (3)	KE File (4)	DWR DA (5)	Drainage Area -Mi^2 (6)	Flow Factor (7)	Tributary Temperature (8)
1	300.68	Keswick Dam	RED	58		.000	
2	299.73	Middle Creek	RED	58	28.7	.017	TCOW
3	297.28	ACID - Diversion	RED	58		.000	
4	296.33	Sulfur Creek	RED	58	16.2	.010	TCOW
5	293.79	Redding STP	RED	58		.000	
6	288.33	Olney Creek	RED	58	20.6	.012	TCOW
7	288.12	Clear Creek	RED	58	24.0	QCL + .014	TCL, TCOTTON
8	283.46	Churn Creek	RED	58	64.2	.038	TCOW
9	279.75	Stillwater Creek	RED	58	53.1	.032	TCOW
10	278.93	Cow Creek	RED	58	540.0	.325	TCOW
11	276.45	Bear Creek	RED	58	47.4	.028	TCOW
12	275.15	Ash Creek	RED	58	36.2	.022	TCOW
13	272.60	Anderson Creek	RED	58	62.4	.037	TCOTTON
14	272.36	Cottonwood Creek	RED	58	(928.0)	IQCC	TCOTTON
15	270.10	Battle Creek	RED	58	346.0	.207 + 200	TBATTLE
16	263.32	Inks Creek	RB	58	48.7	.029	TPAYNES
17	256.33	Bend Bridge - Gauge	RB	58		.000	
18	251.67	Paynes Creek	RB	58	103.0	.062	TPAYNES
19	246.50	Blue Tent Creek	RB	58	48.7	.029	TANTLP1
20	245.38	Dibble Creek	RB	58	49.9	.030	TANTLP1
21	243.66	Reeds Creek	RB	58	64.3	.039	TANTLP1
22	242.82	Red Bluff STP	RB	58		.000	
23	241.92	Red Bank Creek	RB	58	115.0	.069	TREDBK
24	241.19	Red Bluff Diversion Dam - Div.	RB	58	(1668.4)	ITCC	
25	233.50	Antelope Creek	RB	10	246.0	.150	TANTLP2
26	231.98	Oat Creek	RB	10	75.5	.046	TANTLP2
27	229.44	Elder Creek	RB	10	175.0	.107	TELDER
28	229.05	Mill Creek	RB	10	259.0	.158	TMILL
29	224.44	Thomes Creek	RB	10	(370.0)	ITC	TTHOMES
30	221.03	Toomes Creek	RB	10	41.8	.025	TDEER

TABLE 7-CONTINUED
SACRAMENTO RIVER MODEL

Reach Locations and Tributaries

Reach No.	River mile	Reach Location	KE File	DWR DA	Drainage Area -Mi^2	Flow Factor	Tributary Temperature
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
31	219.07	Deer Creek	RB	10	236.0	.144	TDEER
32	207.22	Rice Creek	RB	10	132.0	.080	TTHOMES
33	205.06	GCID - Diversion	RB	10		IGCID	
34	197.11	Pine Creek	RB	10	150.0	.091	TCHICO
35	193.86	Big Chico Creek	RB	10	326.0	.199	TCHICO
36	190.84	Stony Creek	RB	10	(944.0)	ISC	TSTONY
37	168.28	Butte City - Gauge	COL	10	(1641.3)	.000	
38	138.86	Butte Sl.	COL	15	Table 9	.461	TBUTTE
39	124.15	R.D. 70 Drain	COL	15	Table 9	.079	EY3
40	118.11	Wilkins Sl. - Gauge - Div.	COL	15	Table 9	IWS	
41	100.06	R.D. 108 Drain	COL	15	Table 9	.411	EY3
42	93.60	R.D. 787 Drain	SAC	15	Table 9	.049	TCBD
43	90.23	Colusa Basin Drain	SAC	15	Table 9	ICBD	TCBD
44	80.75	Sacramento Sl.	SAC	21	Table 9	.673	TSACSL
45	80.00	Feather River	SAC	21	Table 9	QFR	TFR
46	79.13	Natomas Cross Canal	SAC	21	Table 9	.220	EY4
47	66.32	Pump. Pt. No. 3 (R.D. 1000)	SAC	21	Table 9	.036	EY4
48	61.51	Natomas Main Canal (R.D. 1000)	SAC	21	Table 9	.036	EY4
49	60.92	Natomas East Main Drain	SAC	21	Table 9	.035	EY4
50	60.36	American River	SAC	21	Table 9	QAR	TAR
51	60.13	Natomas STP	SAC	21	Table 9	.000	
52	58.00	West Sacramento STP	SAC	21	Table 9	.000	
53	46.36	Freeport Gauge	SAC	21	Table 9	.000	

TABLE 7-CONTINUED
SACRAMENTO RIVER MODEL

Reach Locations and Tributaries

Column Explanation

(1) Reach number.
(2) River mile - DWR Bul. 111 (REF 9).
(3) Reach location - usually at tributary or diversion points.
(4) KE File - Refers to climate file - (tables 6 and D-1).
(5) DWR drainage area number - see figure 6 and table D-1.
(6) Drainage areas of tributaries in square miles - figure 4 - DWR Bul. 111.
(7) Flow factors - Col. (6) divided by Col. (6) (total) corresponding to DWR DA - Col. (5). Variable names designate flows specified by input files - see table D-1. Agricultural drainage factors from table 9.
(8) Tributary temperatures - variable names of tributaries used to represent each tributary temperature (table 10). TCL, TTHOMES, TSTONY, TBUTTE, and TCBD are further explained on table 11. EY3 and EY4 are equilibrium temperatures - see table D-1. TCL, TFR, and TAR designate temperature input files (table D-1).

TABLE 8
SACRAMENTO RIVER GEOMETRY
Surface Areas in 10^6 Square Feet

River Mile	River Flow - 1,000 ft³/s 2	4	6	8	10	25
300.68	.78	.90	.92	.97	1.00	1.17
299.73	3.42	3.71	3.78	3.85	3.92	4.48
297.28	.26	.26	.27	.27	.27	.29
296.33	1.90	2.12	2.19	2.24	2.30	3.01
293.77	8.37	9.83	10.41	10.88	11.11	12.38
288.33	.33	.43	.45	.46	.46	.49
288.12	6.51	8.08	8.80	8.90	8.98	9.95
283.46	5.73	6.75	7.10	7.29	7.44	8.29
279.75	1.39	1.51	1.58	1.62	1.67	1.92
278.93	4.15	4.42	4.60	4.72	4.85	5.45
276.45	2.18	2.30	2.39	2.45	2.52	2.79
275.15	4.55	5.13	5.25	5.34	5.40	5.75
272.60	.36	.43	.44	.45	.45	.52
272.36	3.16	3.60	3.66	3.72	3.75	4.44
270.10	11.22	12.01	12.37	12.52	12.61	14.79
263.32	8.87	9.31	9.70	9.97	10.08	12.51
256.33	5.24	5.49	5.67	5.76	5.79	7.02
251.67	9.32	10.11	10.34	10.60	10.67	11.76
246.50	1.84	1.96	2.01	2.08	2.11	2.41
245.38	2.92	3.04	3.09	3.16	3.19	3.59
243.66	1.52	1.57	1.61	1.65	1.67	1.77
242.82	1.69	1.75	1.79	1.83	1.85	1.96
241.92	2.05	2.11	2.15	2.19	2.21	2.28
241.19	14.60	17.16	18.64	19.96	20.51	27.81
233.50	1.50	2.64	3.03	3.29	3.35	3.79
231.98	4.64	5.32	5.93	6.39	6.91	7.90
229.44	.83	.85	.87	.90	.92	1.00
229.05	8.22	9.12	9.92	10.29	10.63	12.07
224.44	6.05	6.53	6.95	7.27	7.52	8.46
221.03	3.41	4.06	4.45	4.77	5.01	7.45
219.07	21.67	25.60	28.07	29.61	31.35	37.86
207.22	5.52	5.95	6.39	6.76	7.07	7.96
205.06	17.72	18.34	18.78	19.16	19.49	20.57
197.11	5.91	6.65	7.05	7.35	7.67	9.19
193.86	7.28	8.10	8.72	9.07	9.33	10.49
190.84	43.58	49.35	52.72	54.81	55.63	63.90
168.28	50.73	53.39	55.16	56.89	58.10	69.15
138.86	21.91	22.74	23.63	24.24	24.76	29.16
124.15	7.03	7.39	7.64	7.83	8.04	9.23
118.11	18.79	19.70	20.74	21.36	22.04	26.46
100.06	6.28	6.71	7.09	7.30	7.59	9.47
93.60	3.16	3.36	3.51	3.59	3.70	4.49
90.23	11.11	11.30	11.47	11.81	12.16	14.49
80.75	1.17	1.21	1.23	1.26	1.28	1.43
80.00	2.29	2.36	2.41	2.45	2.50	2.74
79.13	27.62	28.45	29.01	29.33	29.55	31.44
66.32	10.71	11.46	11.81	12.10	12.19	12.93
61.51	1.48	1.58	1.64	1.66	1.67	1.74
60.92	1.40	1.50	1.56	1.57	1.58	1.65
60.36	.58	.61	.64	.65	.65	.68
60.13*	5.97	6.21	6.36	6.48	6.52	6.91
58.00*	33.28	34.59	35.46	36.12	36.34	38.53

* Estimated By Correlation - DWR Bulletin 111

TABLE 9
DISCHARGES FROM IRRIGATION DRAINS TO THE SACRAMENTO RIVER
1950-59

	Discharge (1000 acre-feet)										
	:1950	:1951	:1952	:1953	:1954	:1955	:1956	:1957	:1958	:1959	AVG
Butte Slough	228	168	104	181	205	180	141	122	83	128	154.0
Reclamation District 70	16	18	33	31	36	24	34	15	36	21	26.4
Reclamation District 108	121	159	172	141	167	126	132	93	151	111	137.3
Reclamation District 787	6	9	19	22	19	11	27	13	22	16	16.4
Colusa Basin Drain	261	310	225	305	271	355	326	353	236	356	299.8
Sacramento Slough	338	335	200	180	345	445	276	246	370	232	296.7
Natomas Cross Canal	172	N/R	214	81	83	107	152	48	12	4	97.0
Reclamation District 1000	43	38	77	45	46	51	65	17	82	9	47.3
TOTAL	1,184	1,037	1,043	987	1,172	1,298	1,152	907	992	877	

Source: DWR Bul. 111 (REF 9)

TABLE 10
SACRAMENTO RIVER TRIBUTARY TEMPERATURES

CREEK	MILES AB. MO.	RECORD	DATA	EQ.	AVERAGE TRIBUTARY TEMPERATURES - °F J	F	M	A	M	J	J	A	S	O	N	D
Cow	4.0	1965-78	T	No	44.3	48.3	52.4	57.7	65.5	74.0	81.0	79.6	73.5	62.3	52.3	44.9
Cotton	2.5	1977-85	T	No	46.0	48.8	53.1	59.0	67.4	73.3	76.8	75.0	69.4	62.4	52.6	46.6
Battle	5.7	1966-78	T	No	45.2	47.3	49.4	52.2	57.2	61.1	64.3	62.9	58.9	53.9	49.4	45.7
Paynes	0.4	1955-67	P	No	46.4	48.2	53.6	59.0	62.6	71.6	71.6	71.6	69.8	64.4	51.8	48.2
Red Bk	0.5	1963-67	P	No	48.2	48.2	53.6	53.6	66.2(1)	75.2(1)	75.2(2)	78.8(2)	71.6(2)	62.6(2)	51.8	51.8
Antlp1	9.7	1953-67	P	No	42.8	46.4	48.2	53.6	59.0	68.0	75.2	78.8	71.6	62.6	50.0	44.6
Antlp2	2.0	1950-66	P	No	44.6	48.2	51.8	57.2	62.6	71.6	73.4	75.2	69.8	62.6	55.4	46.4
Elder	3.5	1953-68	P	No	46.4	48.2	53.6	60.8	69.8	78.8	80.6	78.8	77.0	60.8	53.6	50.0
Mill	0.8	1950-67	P	No	44.6	44.6	48.2	53.6	57.2	64.4	73.4	78.8	71.6	62.6	51.8	46.4
Thomes	30.0	1961-78	T	Yes	41.5	44.7	47.1	50.4	58.5	69.6	78.4	77.8	71.7	61.6	49.0	43.3
Deer	2.0	1943-51	T	No	41.2	45.0	48.7	54.7	61.8	69.0	76.2	73.9	70.2	58.8	49.3	43.6
Chico	5.0	1956-68	P	No	42.8	48.2	50.0	57.2	60.8	69.8	75.2	75.2	69.8	59.0	51.8	44.6
Stony	24.0	1969-88	T	Yes	45.6	48.5	52.9	56.8	61.9	68.2	73.6	76.8	72.7	64.5	54.3	47.5
Butte Cr	40.0	1961-78	T	Yes	42.1	44.5	46.0	49.2	54.5	61.5	67.1	66.0	61.3	54.4	47.3	42.8
Butte Sl	0.0	1953-68	P	No	44.6	50.0	57.2	62.6	68.0	73.4	78.8	75.2	71.6	62.6	51.8	44.6
CBD	6.0	1953-88	P	Yes	44.6	49.1	60.2	60.3	69.6	75.2	79.1	76.8	70.3	63.5	52.9	47.8
SACSL	0.5	1954-68	P	No	44.6	50.0	55.4	66.2	69.8	75.2	75.2	75.2	69.8	60.8	51.8	46.4
NATCC	5.0	1953-58	P	No	44.6	51.8		59.0	69.8	69.8	78.8	71.6		57.2	51.8	48.2
Yuba	0.5	1972-78	T	No	46.5	47.6	50.3	53.3	59.7	65.4	69.1	66.3	64.6	60.1	50.8	47.6

(1) REDBK 20 mi ab mouth
(2) ANTLP1
T = Thermograph
P = Periodic
EQ = Equation (table 11)
REF. (3, 31, 40)

TABLE 11
SACRAMENTO RIVER
TRIBUTARY TEMPERATURE EQUATIONS

Clear Creek

$T_2 = E + (T_1 - E)\ e^{-KA1/CQ}$

$T_3 = (T_2Q + T_{AC}Q_{AC})/(Q + Q_{AC})$

$T_4 = E + (T_3 - E)\ e^{-KA2/C(Q + QAC)}$

Terms:

T_1 = Whiskeytown release temperature - TCL (table D-1)
E = Equilibrium temperature - EY1 (table D-1)
K = Heat exchange coefficient - XKY1 (table D-1)
e = Natural log = 2.7183
A_1 = Clear Creek surface area (Whiskeytown Dam-IGO) = .64 X 10^6 S.F.
C = Unit conversion factor = 5.39136
Q = Whiskeytown release flow - QCL (table D-1)
T_2 = Clear Creek temperature above IGO
T_{ac} = Accretion temperature = Tcotton (table 10)
Q_{ac} = Accretion flow = .014 (table 7) x IAC58 (table D-1)
T_3 = Clear Creek temperature Below IGO
A_2 = Clear Creek surface area (IGO-mouth) = 2.20 X 10^6 S.F.
T_4 = Clear Creek at mouth

Thomes Creek

$T_2 = E + (T_1 - E)\ e^{-KA/CQ}$

Terms:

T_1 = Thomes Creek temperature at RM 30 = TThomes (table 10)
E = Equilibrium temperature - EY2 (table D-1)
K = Heat exchange coefficient - XKY2 (table D-1)
A = Thomes Creek surface area (RM 30-mouth) = 4.75 X 10^6 S.F.
Q = Thomes Creek flow - ITC (table D-1)
T_2 = Thomes Creek temperature at mouth

Stony Creek

$T_2 = E + (T_1 - E)\ e^{-KA/CQ}$

Terms:

T_1 = Stony Creek temperature at RM 24 = TStony (table 10)
E = EY2 (table D-1)
K = XKY2 (table D-1)
A = Stony Creek surface area (RM 24-mouth) = 6.34 X 10^6 S.F.
Q = Stony Creek flow - ISC (table D-1)
T_2 = Stony Creek temperature at mouth

TABLE 11-CONTINUED
SACRAMENTO RIVER
TRIBUTARY TEMPERATURE EQUATIONS

Butte Creek/Slough

$$T_2 = E + (T_1 - E)\ e^{-KA/CQ}$$

Terms:

T_1 = Butte Creek temperature at RM 40 = TButte (table 10)
E = EY3 (table D-1)
K = XKY3 (table D-1)
A = Butte Creek surface area (RM 40-mouth) = 21.12 x 10^6 S.F.
Q = Butte Creek flow = .461 (table 7) x IACI5 (table D-1)
T_2 = Butte Creek temperature at mouth

Colusa Basin Drain

$$T = 1.1067\ (E) - 1.4082$$

Terms:

E = EY4 (table D-1)
Linear regression with TCBD (table 10)
and EY4 (1922-77 avg.)
N = No. data points = 12
r = Correlation coefficient = .984
T = Colusa Basin drain outfall temperature

TABLE 12
FEATHER RIVER MODEL
Reach Locations and Tributaries

Reach No.	River Mile	River Location	KE File	Tributary Data Flow	Tributary Data Temp.
(1)	(2)	(3)	(4)	(5)	(6)
1		Oroville Dam	ORO	IQKR	EY1
2	67.9	Thermalito Div. Dam	ORO	IQTD	
3	67.3	Fish Barrier Dam	ORO		
4	59.0	Thermalito Afterbay	ORO	IQTAB	TTAB
5	50.8	Gridley - Gauge	ORO		
6	44.0	Honcut Creek	MAR	IQD56 × F1	EY2
7	27.7	Yuba River	MAR	IQ56 × F2 -IQD13	TY
8	12.4	Bear River	MAR	IQ56 × F3	EY2
9	9.3	Nicolaus - Gauge	MAR	IQR13	EY2
10	7.4	Nelson Slough	MAR		
	0.0	Mouth			

<u>Column explanation</u>

(1) Reach number.
(2) River mile - USGS topographic map.
(3) River location - usually at tributary or diversion points.
(4) KE File - refers to climate file - (see tables 6 and D-2).
(5) Flow variable names (table D-2). Flow dist. factors: F1 = .022, F2 = .836, F3 = .142 (based on USGS flow records).
(6) Temperature variable names (table D-2). EY1, EY2 = equil. temperatures (table D-2), TTAB = computed therm. afterbay temperature, TY = TYUBA (table 10).

TABLE 13
LOWER AMERICAN RIVER TEMPERATURE MODEL
INPUT DATA RIVER CHARACTERISTICS

Reach No.	River Location	Mile Point[a] (Mi. U/S Month)	Reach Length (Miles)	Width Coefficients[b]		DWRSIM Diversion
				A	C	
1	Nimbus Dam	22.94				
2	Sunrise Bridge	20.08	2.86	102.516	67.242	
3	Cordova Park	15.35	4.73	-55.404	88.702	IQCAR
4	Arden Rapids	13.46	1.89	-55.404	88.702	
5	Watt Avenue Bridge	9.36	4.10	252.912	30.044	
6	American River Filtration Plant	7.34	2.02	190.912	30.044	IQFP
7	H Street Bridge	6.59	0.75	190.912	30.044	
8	16th Street Bridge	2.01	4.58	150.912	30.044	
	Mouth	0.00	2.01	150.912	30.044	

[a] Mile point from 1980 USGS quads 1:24000

[b] Widths from 1966 aerial photos: $Q = 1{,}000\ ft^3/s$, and from 1981 instream flow study

Notes: $W = C \log Q + A$

Where W = width - ft
Q = flow - ft^3/s

TABLE 14

KESWICK RELEASES TO MEET FREEPORT TEMPERATURES - DWRSIM # 75D

	base rels		incremental increase in releases									
			65 F	65 F	66 F	66 F	67 F	67 F	68 F	68 F	69 F	69 F
	May	June	May	June	May	June	May	June	May	June	May	June
YEAR	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1922	510	533	0	559	0	0	0	0	0	0	0	0
1923	538	652	0	83	0	0	0	0	0	0	0	0
1924	434	525	695	970	523	768	363	589	215	422	49	274
1925	289	812	0	559	0	369	0	184	0	0	0	0
1926	498	699	148	1,023	0	827	0	649	0	488	0	339
1927	567	549	0	928	0	666	0	405	0	71	0	0
1928	467	726	510	869	271	666	0	482	0	309	0	137
1929	479	513	191	791	31	625	0	470	0	327	0	190
1930	453	683	0	815	0	625	0	452	0	286	0	113
1931	408	586	1,070	1,244	849	940	652	690	474	482	308	298
1932	436	572	160	1,678	0	1,285	0	958	0	660	0	357
1933	448	493	0	1,452	0	1,119	0	839	0	589	0	345
1934	370	470	621	1,351	449	1,059	289	815	98	601	0	405
1935	285	686	0	1,321	0	1,065	0	839	0	631	0	434
1936	453	513	0	1,053	0	815	0	595	0	375	0	107
1937	413	649	0	708	0	553	0	411	0	268	0	119
1938	518	479	0	1,535	0	1,095	0	666	0	0	0	0
1939	503	655	443	910	308	732	172	571	12	422	0	286
1940	339	751	394	1,392	0	1,131	0	893	0	684	0	494
1941	909	646	0	1,065	0	779	0	524	0	280	0	0
1942	887	619	0	1,023	0	684	0	339	0	0	0	0
1943	494	742	141	411	0	173	0	0	0	0	0	0
1944	494	707	178	518	0	345	0	167	0	0	0	0
1945	413	605	0	1,154	0	928	0	726	0	541	0	363
1946	523	815	0	559	0	375	0	202	0	12	0	0
1947	614	737	603	809	443	631	289	464	135	309	0	161
1948	153	525	0	1,023	0	762	0	524	0	286	0	0
1949	463	727	49	815	0	666	0	524	0	393	0	262
1950	553	562	0	750	0	583	0	422	0	250	0	0
1951	409	673	0	952	0	762	0	583	0	422	0	256
1952	756	530	0	0	0	0	0	0	0	0	0	0
1953	759	714	0	375	0	83	0	0	0	0	0	0
1954	665	760	246	756	0	541	0	345	0	149	0	0
1955	463	672	387	904	203	714	0	541	0	375	0	214
1956	920	501	0	1,261	0	946	0	649	0	339	0	0
1957	527	543	0	1,595	0	1,321	0	1,083	0	863	0	666
1958	619	704	0	1,017	0	643	0	286	0	0	0	0
1959	573	725	203	1,392	0	1,131	0	898	0	696	0	518
1960	454	810	160	1,315	0	1,089	0	887	0	708	0	547
1961	591	717	0	1,392	0	1,154	0	946	0	762	0	601
1962	471	692	0	1,089	0	863	0	655	0	470	0	286
1963	518	599	0	1,178	0	875	0	601	0	339	0	6
1964	569	677	43	774	0	589	0	417	0	256	0	95
1965	445	572	0	595	0	345	0	42	0	0	0	0
1966	535	711	467	898	277	708	86	536	0	375	0	220
1967	1,060	711	0	744	0	292	0	0	0	0	0	0
1968	481	685	209	1,214	25	994	0	803	0	625	0	464
1969	898	557	0	988	0	708	0	434	0	125	0	0
1970	467	674	812	1,142	584	904	375	690	160	500	0	315
1971	870	614	0	934	0	649	0	369	0	36	0	0
1972	549	747	400	1,000	234	791	62	613	0	440	0	286
1973	659	891	449	964	228	750	0	553	0	369	0	196
1974	602	601	0	1,517	0	1,172	0	863	0	577	0	292
1975	970	641	0	1,327	0	1,000	0	702	0	417	0	77
1976	520	606	800	1,125	609	910	431	720	271	553	111	399
1977	325	460	0	2,410	0	1,886	0	1,488	0	1,178	0	922
Monthly Averages:			167	1,004	90	752	49	538	24	344	8	197

TABLE 15

EFFECTS OF MANAGEMENT ACTIONS ON SACRAMENTO RIVER TEMPERATURES
56 YR AVERAGE (1922-77) - DWRSIM #62B

Scenario	Mean monthly temperatures - °F											
	J	F	M	A	M	J	J	A	S	O	N	D
						Red Bluff						
Base	43.3	45.7	48.8	52.2	55.0	56.0	57.0	59.1	61.1	57.6	52.4	45.4
Shasta TCD	43.6	45.8	49.0	52.4	55.4	56.6	57.8	55.3	58.2	55.9	52.1	46.2
Thermalito Bypass	43.3	45.7	48.8	52.2	55.0	56.0	57.0	59.1	61.1	57.6	52.4	45.4
10% Shade	43.2	45.5	48.6	51.9	54.6	55.6	56.6	58.5	60.7	57.3	52.3	45.3
No Drains	43.3	45.7	48.8	52.2	55.0	56.0	57.0	59.1	61.1	57.6	52.4	45.4
All 4	43.5	45.7	48.7	52.1	55.0	56.2	57.4	54.7	57.8	55.6	52.0	46.1
						Freeport						
Base	44.6	48.6	53.2	59.3	65.0	70.8	73.7	73.4	71.1	61.4	53.0	45.7
Shasta TCD	44.7	48.6	53.2	59.3	65.0	70.9	73.8	73.1	70.9	61.2	52.9	45.9
Thermalito Bypass	44.7	48.4	52.8	58.9	64.6	70.2	73.1	73.1	71.0	61.2	52.9	45.9
10% Shade	44.4	48.3	52.8	58.8	64.3	70.2	72.9	72.7	70.5	60.9	52.7	45.5
No Drains	44.6	48.5	53.1	59.0	64.5	70.5	73.5	73.2	71.2	61.4	53.0	45.7
All 4	44.6	48.1	52.3	58.1	63.5	69.4	72.3	71.7	70.0	60.3	52.6	45.9

TABLE 16

DWRSIM OPERATION STUDIES FOR SALMON
56 YR AVERAGE (1922-77) - #75D, #144C

DWRSIM Study #	J	F	M	A	M	J	J	A	S	O	N	D
	Mean monthly temperatures - °F											
						Red Bluff						
W/O Shasta TCD												
#75D (base)	44.3	46.9	50.1	53.0	55.3	56.6	56.7	58.9	60.8	57.6	52.9	46.3
#144C (salmon)	44.3	46.9	50.4	53.3	53.8	56.4	57.9	59.7	61.1	57.5	52.8	46.3
Diff. (144C-75D)	0.0	0.0	0.3	0.3	-1.5	-0.2	1.2	0.8	0.3	-0.1	-0.1	0.0
W/Shasta TCD												
#75D	44.7	48.0	52.5	55.1	56.2	57.2	56.2	56.6	57.8	54.6	51.4	47.0
#144C	44.7	48.0	52.5	55.3	54.8	56.7	57.2	57.4	58.3	54.7	51.3	47.0
Diff.	0.0	0.0	0.0	0.2	-1.4	-0.5	1.0	0.8	0.5	0.1	-0.1	0.0
						Freeport						
W/O Shasta TCD												
#75D	44.7	48.9	53.3	59.1	64.7	69.5	71.7	71.8	69.3	60.8	52.9	46.0
#144C	44.7	48.9	53.5	59.3	63.4	68.9	72.5	72.2	69.4	60.8	52.9	46.0
Difference	0.0	0.0	0.2	0.2	-1.3	-0.6	0.8	0.4	0.1	0.0	0.0	0.0
W/Shasta TCD												
#75D	44.8	49.2	53.7	59.4	64.7	69.5	71.6	71.5	69.0	60.3	52.6	46.2
#144C	44.8	49.2	53.8	59.5	63.5	69.0	72.4	72.0	69.2	60.4	52.6	46.1
Difference	0.0	0.0	0.1	0.1	-1.2	-0.5	0.8	0.5	0.2	0.1	0.0	0.1

LIST OF APPENDICES

APPENDIX A

RESERVOIR TEMPERATURE STRATIFICATION

USERS MANUAL

THE HYDROLOGIC ENGINEERING CENTER
GENERALIZED COMPUTER PROGRAM
723-X6-L2410

JANUARY 1972

U. S. ARMY ENGINEER DISTRICT, SACRAMENTO
609 SECOND STREET
DAVIS, CALIFORNIA 95616

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RESERVOIR TEMPERATURE STRATIFICATION

TABLE OF CONTENTS

RESERVOIR TEMPERATURE STRATIFICATION

THE HYDROLOGIC ENGINEERING CENTER
GENERALIZED COMPUTER PROGRAM
723-X6-L2410

I. INTRODUCTION

1. ORIGIN OF PROGRAM

This program is a modification of program 723-X2-L2810 which was prepared for the Sacramento District, Corps of Engineers, by The Hydrologic Engineering Center. The input requirements have been modified to include several new options. Up-to-date information and copies of source statament cards can be obtained from the Center upon request by Government and cooperating agencies.

2. PROGRAM PURPOSE

This program is intended for application to design and planning problems involving consideration of multi-level intake structures. The program will simulate the vertical distribution of water temperature within a reservoir and estimate the mean monthly release temperature through each level of intake. The results of the program are useful in determining the required number of intake levels and their vertical location.[1] An alternative use of the program involves studying project and preproject conditions for evaluation of the thermal portion of the project's environmental impact.

3. PROGRAM CAPABILITY

The program simulates the vertical distribution of water temperature within a reservoir on a monthly basis from data on initial conditions and on inflow, outflow, evaporation, precipitation, radiation, and average air temperature. Outflow requirements can be specified as any combination of releases through specific outlets and in terms of maximum and minimum allowable outflow temperatures. Model coefficients can be determined automatically from observed temperature profiles, in which case a printout plot of the observed and computed profiles is shown. Input may be in either English or Metric units and the output will be in corresponding units. A provision is included to output release quantities and temperatures on tape and to accept inflow quantities and temperatures from tape so that studies for tandem reservoirs can be made in a single computer run.

[1] An Approach to Reservoir Temperature Analysis, The Hydrologic Engineering Center Technical Paper No. 21, L. R. Beard and R. G. Willey, April 1970.

4. SUPPORTING PROGRAMS AND PLANNED EXPANSION

It is anticipated that this program will be expanded to include quality parameters other than temperature, and that a separate program will be developed to analyze the variation of temperature and other quality parameters with distance downstream of a reservoir. It is requested that any user who finds an inadequacy or desirable addition or modification notify The Hydrologic Engineering Center.

II. PROGRAM DESCRIPTION

5. THEORETICAL ASSUMPTIONS

a. One dimensional model - The present state of the art of reservoir hydrodynamics and the current availability of meteorological data suggests the use of a relatively straightforward method to analyze reservoir temperature profiles. It is assumed in the temperature model that the reservoir can be divided into conceptual horizontal layers that are isothermal throughout the volume of the layer. This assumption is necessary for development of a one dimensional model. It is probably sufficiently accurate in most situtations; but cases do exist where sloping isothermal lines are observed. The latter situation generally occurs at reservoirs having a high ratio of mean monthly inflow to storage capacity.

b. Other assumptions - Assumptions which are an inherent part of the calculations are discussed in appendix 1.

6. AREAS OF APPLICATION

a. Existing reservoirs - Because of recently established stream temperature standards, there is a need for methods to analyze the capability of existing reservoir systems to meet operational temperature limits. If recent thermal data have been collected in the reservoir for one or more years, the model can be calibrated with the observed data and then used to simulate historic thermal conditions that existed prior to the collection of the thermal data.

b. Proposed reservoirs - When a thermal analysis is required at a proposed reservoir, thermal data from nearby existing reservoirs are used for model calibration. The thermal conditions in the proposed reservoir can then be evaluated using the regional calibration coefficients.

7. METHODOLOGY

The reservoir is divided into horizontal layers of uniform thickness equal to any integral number of feet or meters. The choice of layer thickness involves a trade-off between the degree of profile definition desired, and the cost of both data preparation and computer time.

Usually a layer of thickness between 1 and 5 feet is satisfactory. It is necessary to specify the reservoir storage capacity at the top of each layer and at the bottom of each level of outlets. Although water released from a particular outlet actually comes from both above and below the outlet invert, releases as computed in this model are made from the water immediately above the intake invert elevation of each outlet. It is considered that this approximation will have minor effect on computation accuracy, because water ordinarily blended from higher and lower levels would have approximately the same temperature as the water at the invert level.

a. Atmospheric energy exchange - The exchange of energy between the reservoir and the atmosphere is assumed to affect only the top several meters of water, except for diffusion within the reservoir, which is computed separately. The exchange is considered to affect water temperatures linearly, with maximum effect at the surface and zero effect at the selected depth of energy penetration. Three atmospheric factors are considered in the energy exchange computation. These are solar radiation, evaporation, and a combination of conduction and long-wave radiation expressed as a function of the difference between air temperature and water temperature. All three exchanges are computed before stability and diffusion computations are made. In doing this, the exchange that is a function of air temperature is based on the water surface temperature at the start of the computation interval. Equations for these exchanges are described in appendix 1.

b. Thermal stability and ice formation - Water is mixed from the surface downward until no lower levels contain warmer water than exists at higher levels. This computation is constrained to temperatures above 4°C, corresponding to the maximum density of water. If water is cooled below this temperature, the temperature of each layer from the surface downward is allowed to go negative until an amount of energy equal to that required to form ice has been extracted from that layer.

c. Vertical diffusion - A rather simple diffusion computation has been found to work reasonably well where observed temperature profiles have been reconstituted. It is assumed that incomplete mixing of adjacent layers occurs over a 10-meter range, starting from the bottom and proceeding upward through the reservoir one layer at a time. The degree of mixing is controlled by a calibration coefficient. Paragraph 7i and appendix 1 describe model calibration and vertical diffusion respectively.

d. Inflow energy - It is recognized that there is some mixing as the inflow water descends into the reservoir to seek its temperature level. The model contains a provision for mixing a constant percentage of inflow with each layer as the inflow water descends through the warmer reservoir layers. The inflow temperature is consequently modified upward, and the inflow ultimately reaches a reservoir level at a temperature somewhat warmer than the original inflow temperature.

e. Computational interval - In some cases, inflow during a period as long as a month can exceed the total reservoir content. When this happens, computation on a monthly interval becomes very unstable. In order to preserve computational stability, it is possible to specify that the computation be divided into any number of parts and that only a fraction of the water and energy transfers be computed in each part. Thus the partial computations would be repeated the specified number of times before the quantities for the entire computational interval are printed out.

f. Selection of intake levels - Where there is latitude in selection of outlets for releasing water of a required temperature, two methods of operation are available. Method 1 selects the two intakes closest together that can blend water of the required temperature. With this method, a maximum choice of temperatures is available for subsequent months. Method 2 blends water from the highest and lowest available intakes. This operation generally provides a mixture of water having high and low dissolved oxygen content.

g. Target release temperature - When selecting the best release temperature from a target temperature range, the model has the capability of examining future target temperature criteria for any number of desired months. The model calculates the release temperature that would change the average reservoir temperature from its existing value to the average value of the temperature criteria for the specified number of future months.

h. Reservoir system input-output - A provision is included to output release quantities and temperatures on tape and to accept inflow quantities and temperatures from tape so that studies for tandem reservoirs can be made in a single computer run. If the temperature of the release water changes before it enters the downstream reservoir, the program must be modified as explained in the Programmers Manual.

i. Model calibration - Model calibration coefficients can be derived automatically on the basis of minimizing the sum of squares of errors in temperature between computed and observed profiles. Observed profiles must extend from the surface downward to any depth for which data are obtained. Any number of observed profiles can be used for a single model calibration. Errors are measured between computed and observed temperatures for each level and each profile. Computed temperatures are interpolated for the date of the observed profile by linear interpolation between end-of-month temperatures at the depth corresponding to the depth of the observed temperature. The program uses a gradient optimization technique[2] in which the coefficients are specified arbitrarily and are changed by the computer in accordance with the resulting effect of minimizing the standard error of computed temperatures. It is not necessary to calibrate the model for all coefficients. Fixed values for any of the coefficients can be prespecified, and the computer will optimize only the remaining coefficients. In order to facilitate evaluation of the calibration, a plot of the computed and observed

[2] Optimization Techniques for Hydrologic Engineering, The Hydrologic Engineering Center Technical Paper No. 2, Leo R. Beard, April 1966.

profiles is printed out. The proper selection of model calibration coefficients is an important element in any temperature study using this program. The HEC has developed calibration at numerous reservoirs in various regions of the United States. The information is available to the user on request. It is asked that program users notify the Center of their results on model calibration so that this information can be shared with other users.

j. Calculation procedure - A detailed description of the calculation procedure, including the required equations, is given in appendix 1. A functional flow chart for the program is shown in figure 1.

III. PROGRAM USAGE

8. EQUIPMENT REQUIREMENTS

a. Computer storage and speed - The program requires a FORTRAN IV compiler and a computer of at least the GE-400 series (32K) capacity. The use of higher speed computers (UNIVAC 1108, CDC 6600, etc.) is much more efficient for calibrating the model when 2 or more years of thermal profile data are used. However the program runs sufficiently fast for long term records (30 or more years) once the calibration coefficients have been determined. A list of approximate execution times and storage requirements for various types of computers is shown in table 1.

TABLE 1

Computer	Program Storage (in words)	Program Execution Time (per year of record)
	Model Calibration	
CDC-7600	14K	30 sec
CDC-6600	14K	3 min
UNIVAC-1108	12K	6 min
IBM 360/50	---	30 min
GE-425	11K	60 min
	Calibrated Model	
CDC-6600	14K	5 sec
UNIVAC-1108	12K	9 sec
CDC-3300	---	1 min
GE-425	11K	3 min

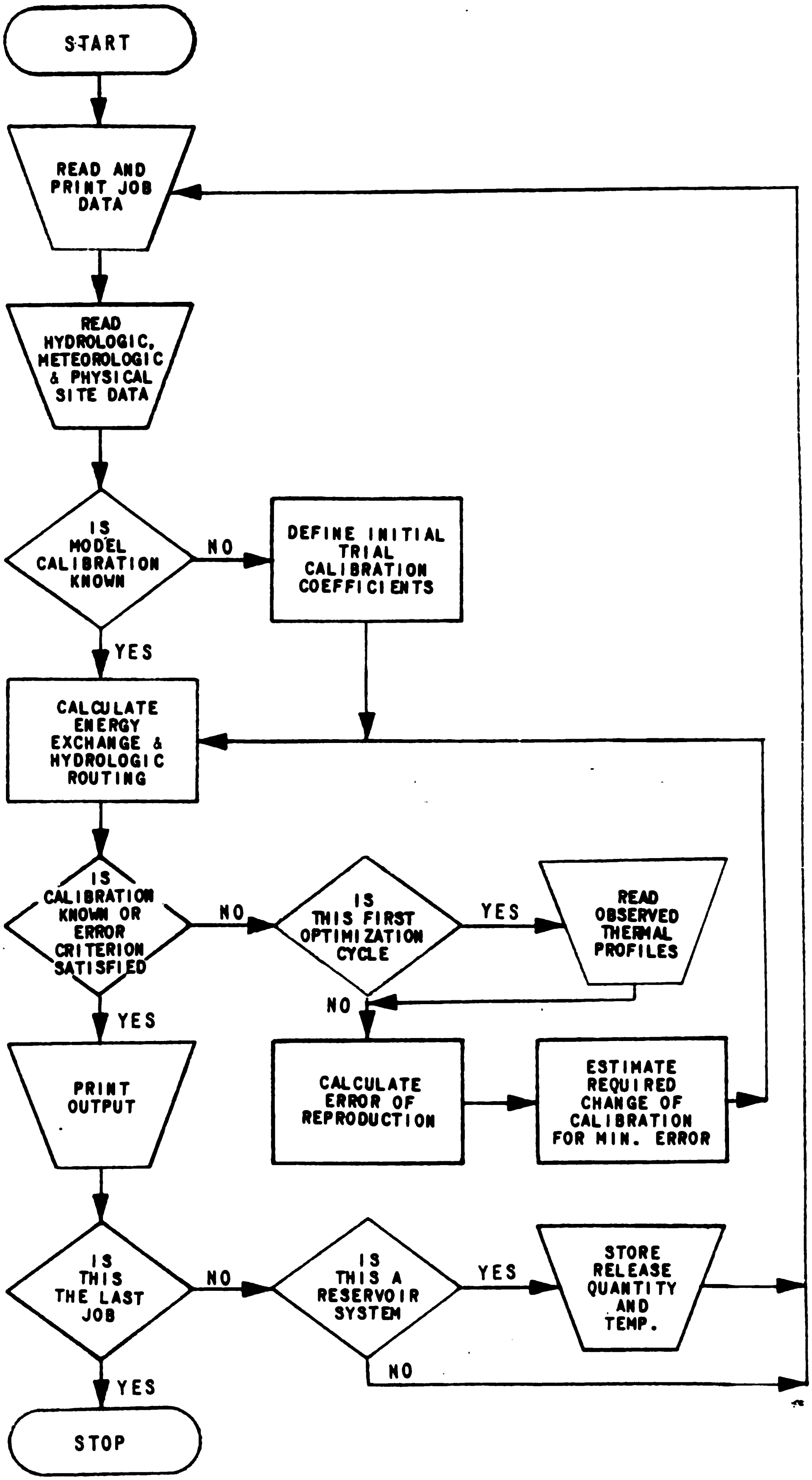


FIGURE 1. FUNCTIONAL FLOW CHART

b. I-0 equipment - Cards are used for input, printer for output and units 92, 93, and 94 for temporary binary storage.

9. INPUT PREPARATION

Input data requirements are described in appendix 3 and examples are shown on pages 10-25. Consistent unit systems are "Metric and °C" or "English and °F". Required input is summarized as follows:

1. Inflow quantity and temperature for each month
2. Lake evaporation and precipitation for each month
3. Total monthly outflow quantity
4. Monthly discharge through each intake level or downstream temperature criteria
5. Average air temperature for each month
6. Solar radiation (obtained from figure 2 or table 2 for known latitude)
7. Reservoir physical data (i.e., storage-elevation data, intake configuration, etc.)
8. Thermal depth profiles or estimated calibration coefficients

10. PROGRAM OUTPUT

The output includes a printout of most input data; the calibration coefficients (given or derived), results of the optimization subroutine (if model is being calibrated), plots of observed and calculated temperature profiles (if model is being calibrated), end-of-month calculated temperature profiles, end-of-month storage, monthly average outflow temperature and quantity through each level of outlets and flow-weighted average temperature for all outlets.

11. EXAMPLE PROBLEMS

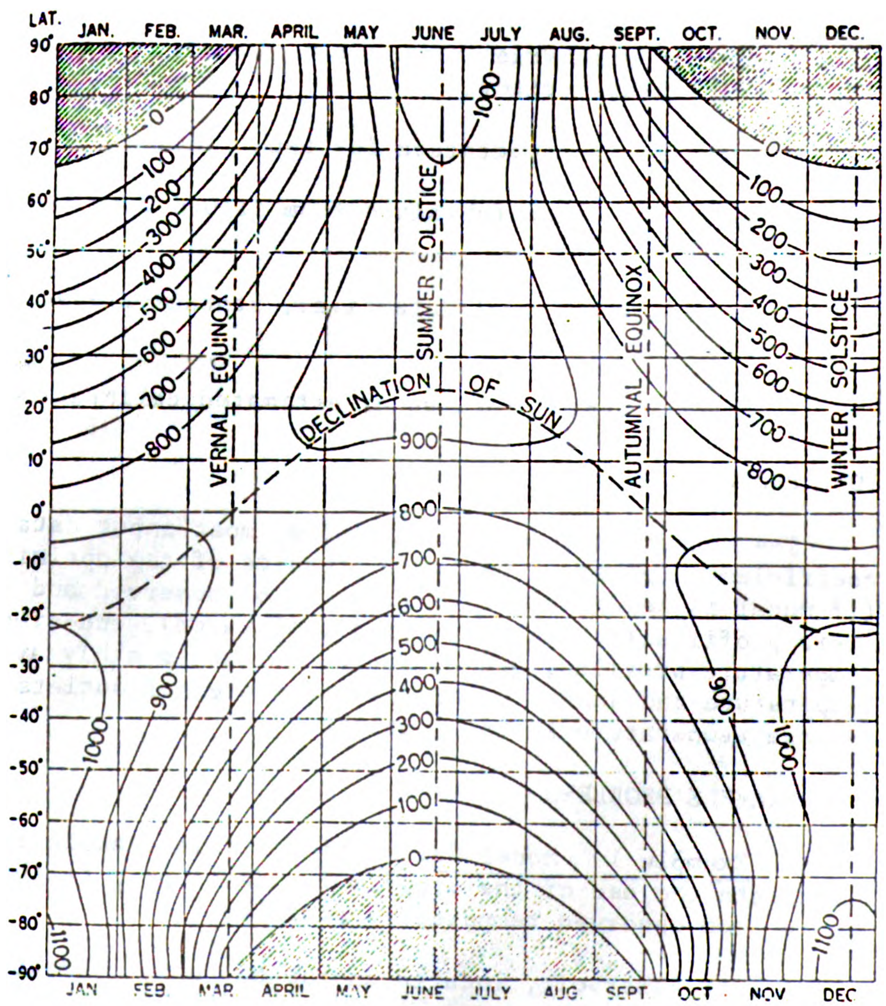
a. Example 1. Model Calibration - This example is intended to illustrate the use of the program for developing calibration coefficients from observed temperature profiles.

Detroit Reservoir, located on the North Santiam River in Oregon, has the physical characteristics shown in table 3.

FIGURE 2

CHART OF THE TOTAL DAILY SOLAR RADIATION AT THE TOP OF THE ATMOSPHERE

The solid curves represent total daily solar radiation on a horizontal surface at the top of the atmosphere, measured in cal. $cm.^{-2}$ Shaded areas represent regions of continuous darkness.



The above data was obtained from the Smithsonian Meteorological Tables, by Robert J. List, 6th revised edition, 1949.

TABLE 2

TOTAL DAILY SOLAR RADIATION AT THE TOP OF THE ATMOSPHERE

Values are in cal. cm.$^{-2}$ and apply to a horizontal surface

Latitude	0°	22½°	45°	67½°	90°	112½°	135°	157½°	180°	202½°	225°	247½°	270°	292½°	315°	337½°
	Mar. 21	Apr. 13	May 6	May 29	June 22	July 15	Aug. 8	Aug. 31	Sept. 23	Oct. 16	Nov. 8	Nov. 30	Dec. 22	Jan. 13	Feb. 4	Feb. 26
	cal. cm.$^{-2}$															
90°		423	772	999	1077	994	765	418								
80	155	423	760	984	1060	980	754	418	153	7						7
70	307	525	749	939	1012	934	742	519	303	129	24				24	131
60	447	635	809	934	979	929	801	629	442	273	146	72	49	73	146	276
50	575	732	867	958	989	954	859	725	568	414	286	204	176	205	289	419
40	686	807	910	972	991	967	901	798	677	545	429	348	317	350	434	553
30	775	865	929	967	975	960	921	856	765	663	564	492	466	494	568	670
20	841	894	923	935	935	930	916	884	831	760	685	627	605	630	691	769
10	882	897	893	881	873	877	886	887	871	835	789	748	733	752	795	845
0	895	873	837	804	790	800	830	863	885	886	870	851	843	855	878	896
−10	882	824	760	707	687	704	753	814	871	910	927	931	933	936	936	921
−20	841	750	660	593	567	590	654	741	831	907	959	988	999	993	968	918
−30	775	654	543	465	436	463	538	646	765	877	964	1020	1041	1025	973	883
−40	686	538	413	329	297	328	409	533	677	819	944	1027	1059	1032	953	828
−50	575	408	276	193	165	192	274	404	568	743	901	1014	1056	1018	909	752
−60	447	269	140	68	47	68	139	266	442	644	840	987	1046	992	847	652
−70	307	127	23				23	126	303	532	778	993	1081	998	785	539
−80	155	7						7	153	429	790	1041	1132	1046	796	434
−90										429	801	1056	1149	1062	809	434

The above data was obtained from the Smithsonian Meteorological Tables, prepared by Robert J. List, 6th revised edition, 1949.

TABLE 3

Parameter	Magnitude
length at full pool	10 miles
maximum width at full pool	1.5 miles
surface area at full pool	3,500 acres
capacity at full pool	455,000 acre-feet

Detroit Dam is a gravity structure 386 feet high. The dam has four levels for possible withdrawal (spillway, power plant penstock, and two lower sluices).

The project weather station collects the required meteorological input data of air temperature, rain, and evaporation. Inflow temperature measurements are available for 75% of the inflow volume and reservoir temperature profiles are measured daily near the dam. The remaining 25% of the inflow was assumed to have a temperature equal to the average (flow-weighted) measured inflow temperature. Often inflow temperature data is available for only a small portion of the hydrologic record, but can be extended in time by graphically correlating it with air temperature.

Example input is shown on page 12 and is explained in appendix 3. A part of the example output is shown on page 15 and the output variables are defined in appendix 2. In examining the output, the top half of page 15 should be checked to insure that the correct input data has been used. The bottom half of page 15 and the top half of page 16 is output from the optimization subroutine. The changes made to each variable in the attempt to minimize the least-square error in the reproduction of observed temperature profiles are indicated. The last two lines in this set of output read as follows:

```
CRITERION FOR VARIABLE 1     1.6679     1.6677     1.6676
VAR 1 ADJ FROM     .83 TO .81
```

These lines indicate that variable 1 (the air temperture coefficient) has been changed from .83 to .81 and that the least-square error on this trial (the final trial) was 1.6679 temperature units. The other two least-square error values pertain to the magnitude of the error function at points used to measure the slope and change in slope of the error function. This printout option is controlled by the variable IDGST on the "B" card. The next set of output defines the "optimized" set of calibration coefficients. If the last change in each variable was a small percentage of the variable's magnitude, then these values can be used as optimum values. If the percentage change is large, the job should be rerun using the final values from this first run as the initial estimate of the calibration coefficients for the second run.

Each end-of-month calculated temperature profile is printed out by layers followed by a plot of any observed profiles for the next month. The plot includes a calculated profile which has been interpolated to the date of the observed profile. Before any confidence is place in the model calibration, the plots should show a comparison between calculated and observed values that is satisfactory to the user. The numerical value that describes the degree of reproducibility is the least-square error discussed above. The summary printout which follows the temperature profile output for all 12 months includes some input data which should be checked against the recorded data as well as a printout of calculated end-of-month storage, calculated discharge temperature through each outlet and the flow-weighted average temperature through all outlets.

GENERAL PURPOSE DATA FORM

(8 COLUMN FIELDS)

PROGRAM 723-X6-L2410 | DATE

REQUESTED BY RGH | PREPARED BY | CHECKED BY | PAGE 1 OF 3

Card	1	2	3	4	5	6	7	8	9	10
A	DETRØIT RESERVØIR									
A	TEMPERATURE STRATIFICATIØN STUDY									
A	PERIØD ØF RECØRD, JAN 1965 - 1967									
B	3	1965	12	1	1	48	8	4	4	1
B	0	1	1	0	0	4	0	3		
D	367000	1.983472	1.983472	494973	114700	-2	-2	-2	-2	-2
D	65	40	.504167	-1	0					
E	-.7	-.1	-.04	-.6	-.2					
F	-2	-2	-2	-2						
G	31	28	31	30	31	30	31	31	30	31
G	30	31								
H	45	125	197	402	607	967	1482	1997	2600	4200
H	6100	8200	10341	14000	17500	21000	25100	29238	35200	40800
H	47000	53700	61546	68500	77200	86200	96500	108027	119000	131000
H	144500	158300	172224	188000	204000	220000	237000	254593	272000	292000
H	314000	336500	360245	386000	410000	438000	466000	494973		
I	40	40	40	40	40	40	41	42	42	42
I	41	41	41	41	41	41	40	40	41	41
I	41	41	41	41	41	41	41	41	41	40
I	40	40	40	40	40	40	40	40	40	40
I	40	40	40	40	-1	-1	-1	-1		
J	2000	27000	76000	364000						
M	38	41	46	49	51	59	68	66	60	56
M	47	37								
N	.30	1.10	2.78	2.54	3.15	4.04	5.51	4.35	4.53	2.77
N	1.02	.48								
Ø	21.22	5.64	1.76	5.70	3.97	.64	.28	2.32	.36	4.81
Ø	10.[illegible]	11.25								
P	5553	4682	935	906	1875	[illegible]	957	1033	1758	2147
P	3243	1425								

Input for Example 1

GENERAL PURPOSE DATA FORM

(8 COLUMN FIELDS)

PROGRAM 723-X6-L2410　　DATE

REQUESTED BY [illegible]　PREPARED BY　CHECKED BY　PAGE 2 OF 3

	1	2	3	4	5	6	7	8	9	10
S	300	420	600	800	920	980	960	850	680	490
S	340	260								
T	2	0	0	0	0	0	0	0	0	0
T	0	0								
T	2746	2312	0	0	0	19	0	0	0	0
T	0	0								
T	3135	2370	935	906	1827	1213	957	1022	1758	2147
T	3243	1428								
T	0	0	0	0	48	0	0	0	0	0
T	0	0								
U	5563	3118	1827	2722	2087	1361	879	683	615	669
U	1411	1134								
V	39	38	39	41	46	50	52	55	50	47
V	4[illegible]	39								
W	11	201	301	405	501	601	701	801	902	1002
W	1101	1201								
X	10	348035	0	39	68.63	39	93.63	38	118.63	39
	168.63	39	193.63	38	218.63	39	243.63	40	268.63	41
	293.63	40								
X	8	266535	0	38	12.80	39	112.80	39	137.80	40
	[illegible]	39	212.80	39	237.80	41	262.80	40		
X	5	327163	0	40	136.16	40	161.16	41	186.16	39
	211.16	40	236.16	40	261.16	41	286.16	40		
X	12	427231	0	44	43.92	44	68.92	43	118.92	4[illegible]
	143.92	42	168.92	41	193.92	41	218.92	40	243.92	40
	268.92	41	293.92	41	318.92	40				
X	11	4401[illegible]	0	[illegible]	[illegible]	[illegible]	47.66	50	7[illegible].66	46
	97.66	45	1[illegible]	43	[illegible]	42	172.66	41	197.66	41
	2[illegible]	40	[illegible]	40						

SPK Form [illegible]　(Previous editions are obsolete)

Input for Example 1

GENERAL PURPOSE DATA FORM

(8 COLUMN FIELDS)

PROGRAM 723-X[illegible] DATE

REQUESTED BY FG[illegible] PREPARED BY CHECKED BY PAGE 3 OF 3

1	2	3	4	5	6	7	8	9	10
X 11	447643	0	62	24.50	56	49.50	52	74.50	50
97.50	47	124.50	44	149.50	44	174.50	42	199.50	43
224.50	41	324.50	41						
X 13	440652	0	70	22.70	62	47.70	58	72.70	54
97.70	51	122.70	48	147.70	45	172.70	44	197.70	44
222.70	42	272.70	42	297.70	41	322.70	41		
X 14	41[illegible]	0	64	15.90	65	40.90	61	65.90	57
90.90	55	115.90	51	140.90	47	165.90	45	190.90	44
215.90	42	240.90	43	265.90	43	290.90	42	315.90	42
X 10	347085	0	63	18.29	59	43.29	59	68.29	59
93.29	56	118.29	55	143.29	46	168.29	46	193.29	43
293.29	43								
X 12	257828	0	59	9.30	56	34.30	56	59.30	55
84.30	55	109.30	53	134.30	48	159.30	43	184.30	43
209.30	44	234.30	43	259.30	43				
X 8	154606	0	49	7.80	48	57.80	48	82.80	47
107.80	44	157.80	44	182.80	43	207.80	43		

The M, N, Ø, P, T, U, V, W and X cards for years 1966 and 1967 are not shown.

A
A
A
A
A

SPK Form 1 [illegible] 6 32 (Previous editions are obsolete)

Input for Example 1

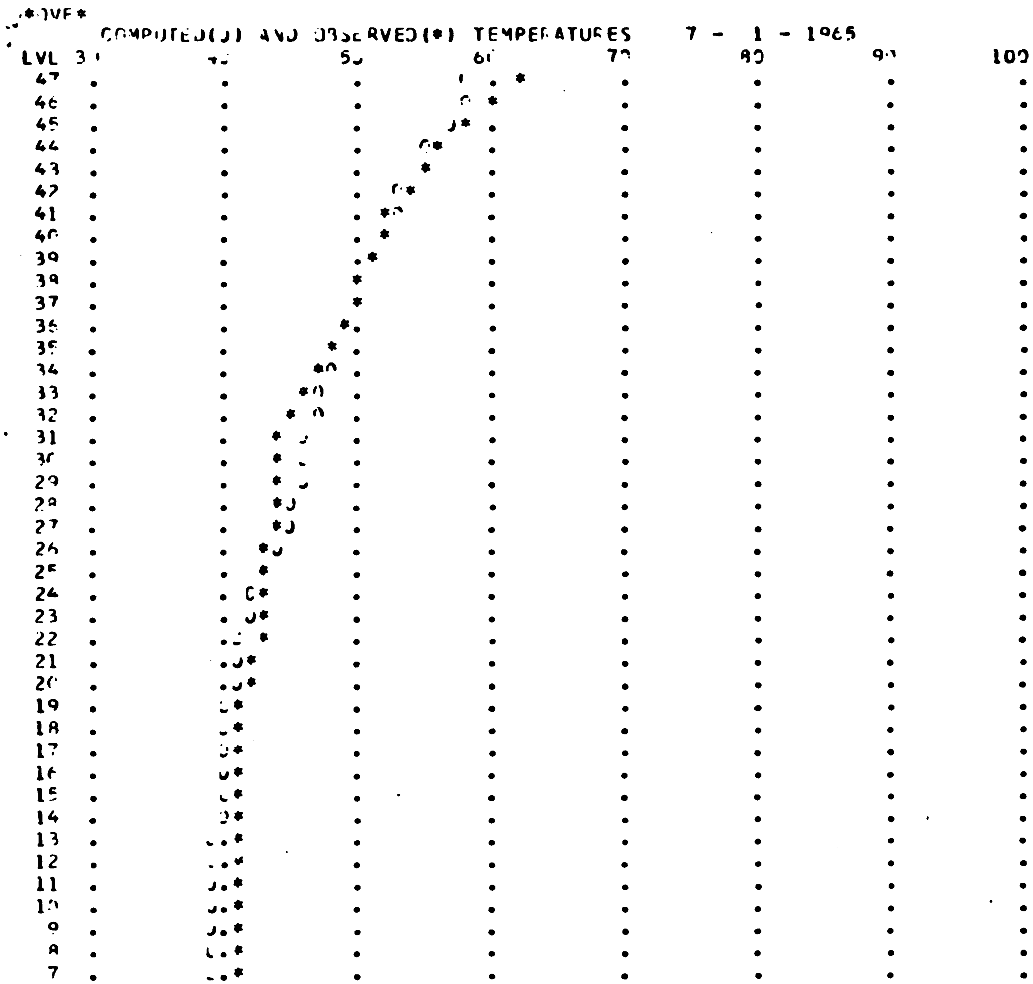
```
          DETROIT RESERVOIR
     TEMPERATURE STRATIFICATION STUDY
   PERIOD OF RECORD,   JAN 1965 - 1967

THE OUTPUT UNITS ON INFLOW AND OUTFLOW ARE IN CFS, EVAP AND PRECIP IN INCHES, STORAGE IN AF, AND TEMPERATURE IN DEGREES F

     NYR      IYR     NPER    IPEP    MSTRT    NLAYR    LAYER    NOUTL    NMINQ    IDERV    METRC    IDGST      NIC      NIT     NOTL    INTER
       3     1965       12       1        1       48        8        4        4        1        0        1        1        0        0        4
    NRFL      NMO
       0        3

   STORA     CISA     COSA    STRMX    STRMN      TIN     TAIR     EVAP     PRCP     QMIN     TMAX     TMIN    CSOUT     SOLR      DEP
  367000    1.983    1.983   494973   114700       -2       -2    -2.00    -2.00       -2       65       40     .504       -1    32.81

      AIR-TEMP COEF     INFLO MIXING COEF     DIFFUSION COEF     EVAP HEAT COEF     INSOLATION COEF
        -.700               -.100                -.040               -.600              -.200
         .700                .100                 .040                .600               .200

QOMIN=      -2.0      -2.0      -2.0      -2.0

STCAP=        45       125       197       402       607       967      1482      1997      2600      4200
            6100      9260     13341     14000     17500     21000     25100     29238     35200     40800
           47300     53700     61546     68500     77200     86200     96500    108027    119000    131000
          144500    158300    172224    188000    204000    220000    237000    254593    272000    292000
          314000    336510    360245    386000    410000    438000    466000    494973

TSTPT=      40.0      40.0      40.0      40.0      40.0      40.0      41.0      42.0      42.0      42.0
            41.0      41.0      41.0      41.0      41.0      41.0      40.0      40.0      41.0      41.0
            41.0      41.0      41.0      41.0      41.0      41.0      41.0      41.0      41.0      40.0
            40.0      40.0      40.0      40.0      40.0      40.0      40.0      40.0      40.0      40.0
            40.0      40.0      40.0      40.0      -1.0      -1.0      -1.0      -1.0

STOUT=     26000     27000     70000    364000

CRITERION FOR VARIABLE 1       1.6855       1.6881       1.6892
VAR  1 ADJ FROM    .70 TO    1.00

CRITERION FOR VARIABLE 2       1.6949       1.6951       1.6951

CRITERION FOR VARIABLE 3       1.6949       1.6956       1.6965
VAR  3 ADJ FROM    .04 TO   .04

CRITERION FOR VARIABLE 4       1.6929       1.6947       1.6962
VAR  4 ADJ FROM    .50 TO   .69

CRITERION FOR VARIABLE 5       1.6818       1.6816       1.6815
VAR  5 ADJ FROM    .20 TO   .20

CRITERION FOR VARIABLE 1       1.6915       1.6906       1.6798
VAR  1 ADJ FROM   1.00 TO   .93

CRITERION FOR VARIABLE 2       1.6758       1.6760       1.6762
VAR  2 ADJ FROM    .10 TO   .10

CRITERION FOR VARIABLE 3       1.6757       1.6767       1.6779
VAR  3 ADJ FROM    .04 TO   .04

CRITERION FOR VARIABLE 4       1.6747       1.6743       1.6739
VAR  4 ADJ FROM    .69 TO   .57
```

Printout for Example 1

```
CRITERION FOR VARIABLE 5          1.6737      1.6739      1.6728

CRITERION FOR VARIABLE 1          1.6737      1.6730      1.6735
VAR  1 ADJ FROM     .93 TO       .92

CRITERION FOR VARIABLE 2          1.6730      1.6730      1.6734

CRITERION FOR VARIABLE 3          1.6730      1.6734      1.6741
VAR  3 ADJ FROM     .34 TO       .04

CRITERION FOR VARIABLE 4          1.6725      1.6726      1.6738
VAR  4 ADJ FROM     .67 TO       .57

CRITERION FOR VARIABLE 5          1.6726      1.6724      1.6716
VAR  5 ADJ FROM     .20 TO       .19

CRITERION FOR VARIABLE 1          1.6717      1.6713      1.6709
VAR  1 ADJ FROM     .92 TO       .83

CRITERION FOR VARIABLE 2          1.6717      1.6720      1.6722
VAR  2 ADJ FROM     .10 TO       .12

CRITERION FOR VARIABLE 3          1.6719      1.6713      1.6717
VAR  3 ADJ FROM     .34 TO       .04

CRITERION FOR VARIABLE 4          1.6709      1.6701      1.6693
VAR  4 ADJ FROM     .67 TO       .63

CRITERION FOR VARIABLE 5          1.6689      1.6679      1.6683
VAR  5 ADJ FROM     .19 TO       .19

CRITERION FOR VARIABLE 1          1.6679      1.6677      1.6676
VAR  1 ADJ FROM     .83 TO       .81

DERIVED VARIABLES

      AIR TEMP COEF    INFLO MIXING COEF     DIFFUSION COEF      EVAP HEAT COEF      INSOLATION COEF
          .811               .116                 .045                .634                .188

                                                   RESERVOIR TEMPERATURES
YEAR  PER     1     2     3     4     5     6     7     8     9    10    11    12    13    14    15    16    17    18    19    20
1965    1  39.3  39.3  39.3  39.3  39.3  39.3  39.3  39.3  39.3  39.3  39.3  39.3  39.3  39.3  39.3  39.3  39.3  39.3  39.4  39.6
           39.5  39.5  39.7  39.7  39.7  39.7  39.7  39.8  39.8  39.8  39.8  39.8  39.8  39.8  39.8  39.8  39.8  39.8  39.8  39.8
           39.8  39.8  39.8
```

Plotted profiles for Feb. 1965 through Jun. 1965 are not shown.

End-of-month calculated temperature profiles for Feb. 1965 through Jun. 1965 are not shown.



Plotted profiles for Aug. 1965 through Dec. 1965 are not shown.

End-of-month calculated temperature profiles for Jul. 1965 through Nov. 1965 are not shown.

Printout for Example 1

DVN

RESERVOIR TEMPERATURES

YEAR	PER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1965	12	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.7	39.8	39.8	40.1	40.2	40.4	40.5	40.8 ---
		40.9	41.1	41.2	41.2	41.3	41.3	41.3	41.3	41.3	41.3	41.3									

FLOWS AND TEMPERATURES FOR 1965

	YEAR	1	2	3	4	5	6	7	8	9	10	11	12
INFLO	1342.1	5563.0	3118.0	1827.0	2722.0	2087.0	1361.0	879.0	683.0	615.0	669.0	1442.0	1139.0
EVAP	2.7	.3	1.1	2.8	2.5	3.2	4.0	5.5	4.3	4.5	2.8	1.0	.5
PRCP	5.8	21.2	5.6	1.8	5.7	4.0	.6	.3	2.3	.4	4.8	11.0	11.9
OUTFL	2172.3	5383.0	4682.0	935.0	906.0	1875.0	1232.0	957.0	1022.0	1758.0	2147.0	3243.0	1428.0
REQDQ	2172.3	5383.0	4682.0	935.0	906.0	1875.0	1231.0	957.0	1022.0	1758.0	2147.0	3243.0	1428.0
STMX		494973	494973	494973	494973	494973	494973	494973	494973	494973	494973	494973	494973
STOP		352498	266679	321292	430199	443474	450158	443837	422400	353344	262933	157428	141292
STMN		114700	114700	114700	114700	114700	114700	114700	114700	114700	114700	114700	114700
TA	51.5	38.0	41.0	46.0	49.0	51.0	59.0	68.0	66.0	60.0	56.0	47.0	37.0
TMPIN	42.2	39.0	38.0	39.0	41.0	46.0	50.0	52.0	55.0	50.0	47.0	43.0	38.0
TMPMX	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0
TPOUT	43.9	39.5	39.2	39.6	40.0	41.3	42.9	44.9	47.4	51.7	54.3	50.4	43.4
TMPMN	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
RELEASES THRU OUTLET 1													
QDMN		2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
QOUTL		2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOUTL		39.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RELEASES THRU OUTLET 2													
QDMN		2745.0	2312.0	0.0	0.0	0.0	19.0	0.0	0.0	0.0	0.0	0.0	0.0
QOUTL		2745.0	2312.0	0.0	0.0	0.0	19.0	0.0	0.0	0.0	0.0	0.0	0.0
TOUTL		39.4	39.3	0.0	0.0	0.0	39.8	0.0	0.0	0.0	0.0	0.0	0.0
RELEASES THRU OUTLET 3													
QDMN		3135.0	2370.0	935.0	906.0	1827.0	1213.0	957.0	1022.0	1758.0	2147.0	3243.0	1428.0
QOUTL		3135.0	2370.0	935.0	906.0	1827.0	1213.0	957.0	1022.0	1758.0	2147.0	3243.0	1428.0
TOUTL		39.6	39.3	39.6	40.0	41.2	43.0	44.9	47.4	51.7	54.3	50.4	43.4
RELEASES THRU OUTLET 4													
QDMN		0.0	0.0	0.0	0.0	48.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
QOUTL		0.0	0.0	0.0	0.0	48.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOUTL		0.0	0.0	0.0	0.0	48.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Results for calender years 1966 and 1967 are not shown.

b. Example 2. Analysis of a Proposed Reservoir - This example illustrates application of the program for situations where estimates of the calibration coefficients have been obtained by regional analysis. Detroit Reservoir is analyzed assuming thermal profiles do not exist but that the model calibration coefficients are known. Refer to example 1 for physical characteristics of the dam and reservoir.

Example input is shown on page 20 and is explained in appendix 3. Example output is shown on page 22 and the variables are defined in appendix 2. Examination of the output should include checking the top half of page 22 and the summary of "flows and temperatures" at the end of each year to insure that the program obtained correct input data. The remainder of the output includes the end-of-month calculated temperature profiles and reservoir storage, discharge temperature and quantity through each outlet and flow-weighted average temperature through all outlets.

Examination of the output shows that the release temperature was below the temperature criteria in January through March for the first two years. The January profiles for the first two years show that the warmest water in the reservoir can not satisfy the criteria, but the February and March temperature criteria might be met by using two penstock intake levels at elevations above the existing level.

In many cases, for analysis of a proposed reservoir, the releases are not specified for particular outlet levels and the program makes the decision as to which levels are used to meet the downstream temperature criteria. In such cases, the program uses the NMINQ(B-9) value equal to zero and therefore no F card or T cards would be required.

GENERAL PURPOSE DATA FORM

(8 COLUMN FIELDS)

PROGRAM 723-X6-L2410

REQUESTED BY RGW PREPARED BY CHECKED BY DATE PAGE 1 OF 2

	1	2	3	4	5	6	7	8	9	10
A	DETRØIT RESERVØIR									
A	TEMPERATURE STRATIFICATIØN STUDY									
A	PERIØD ØF RECØRD, JAN 1965 - DEC 1967									
B	3	1965	12	1	1	48	8	4	4	0
B	0	0	1	0	0	4	0	3		
D	367000	1.983472	1.983472	494973	114700	-2	-2	-2	-2	-2
D	65	40	.504167	-1	0					
E	.816	.114	.043	.637	.193					
F	-2	-2	-2	-2						
G	31	28	31	30	31	30	31	31	30	31
G	30	31								
H	45	125	197	402	607	967	1482	1997	2600	4200
H	6100	8200	10341	14000	17500	21000	25100	29238	35200	40800
H	47000	53700	61546	68500	77200	86200	96500	108027	119000	131000
H	144500	158300	172224	188000	204000	220000	237000	254593	272000	292000
H	314000	336500	360245	386000	410000	438000	466000	494973		
I	40	40	40	40	40	40	41	42	42	42
I	41	41	41	41	41	41	40	40	41	41
I	41	41	41	41	41	41	41	41	41	40
I	40	40	40	40	40	40	40	40	40	40
I	40	40	40	40	-1	-1	-1	-1		
J	2000	27000	76000	364000						
M	38	41	46	49	51	59	68	66	60	56
M	47	37								
N	.30	1.10	2.78	2.54	3.15	4.04	5.51	4.35	4.53	2.77
N	1.02	.48								
Ø	21.22	5.64	1.76	5.70	3.97	.64	.28	2.32	.36	4.81
Q	10.99	11.85								
P	5883	4682	935	906	1875	1231	957	1022	1758	2147
F	3243	1426								

SPK Form

Input for Example 2

GENERAL PURPOSE DATA FORM

(8 COLUMN FIELDS)

PROGRAM 723-X6-L2410 DATE

REQUESTED BY RGW PREPARED BY CHECKED BY PAGE 2 OF 2

	1	2	3	4	5	6	7	8	9	10
S	300	420	600	800	920	980	960	850	680	490
S	340	260								
T	2	0	0	0	0	0	0	0	0	0
T	0	0								
T	2746	2372	0	0	0	19	0	0	0	0
T	0	0								
T	3135	2370	935	906	1827	1213	957	1022	1758	2147
T	3243	1428								
T	0	0	0	0	48	0	0	0	0	0
T	0	0								
U	5563	3118	1827	2722	2087	1361	879	683	615	669
U	1442	1139								
V	39	38	39	41	46	50	52	55	50	47
V	43	38								

The M, N, Ø, P, T, U, and V cards for years 1966 and 1967 are not shown

A
A
A
A
A

SPK Form 321

(Previous editions are obsolete)

Input for Example 2

DETROIT RESERVOIR
TEMPERATURE STRATIFICATION STUDY
PERIOD OF RECORD, JAN 1965 - DEC 1967

THE OUTPUT UNITS ON INFLOW AND OUTFLOW ARE IN CFS, EVAP AND PRECIP IN INCHES, STORAGE IN AF, AND TEMPERATURE IN DEGREES F

NYR	IYR	NPER	IPER	MSTRT	NLAYR	LAYER	NOUTL	NMINQ	IDERV	METRC	IDGST	NIC	NIT	NOTL	INTER
3	1965	12	1	1	48	8	4	4	0	0	1	1	0	0	4

MREL	NMO
0	3

STORA	CISA	COSA	STRMX	STRMN	TIN	TAIR	EVAP	PRCP	QMIN	TMAX	TMIN	CSOUT	SOLR	DEP
367000.	1.983	1.983	494973.	114700.	-2.	-2.	-2.00	-2.00	-2.	65.	40.	.504	-1.	32.81

AIR TEMP COEF	INFLO MIXING COEF	DIFFUSION COEF	EVAP HEAT COEF	INSOLATION COEF
.811	.116	.045	.634	.188

QQMIN= -2.0 -2.0 -2.0 -2.0

STCAP=	45.	125.	197.	402.	607.	967.	1482.	1997.	2600.	4200.
	6100.	8200.	10341.	14000.	17500.	21000.	25100.	29238.	35200.	40800.
	47000.	53700.	61546.	68500.	77200.	86200.	96500.	108027.	119000.	131000.
	144500.	158300.	172224.	188000.	204000.	220000.	237000.	254593.	272000.	292000.
	314000.	336500.	360245.	386000.	410000.	438000.	466000.	494973.		

TSTRT=	40.0	40.0	40.0	40.0	40.0	40.0	41.0	42.0	42.0	42.0
	41.0	41.0	41.0	41.0	41.0	41.0	40.0	40.0	41.0	41.0
	41.0	41.0	41.0	41.0	41.0	41.0	41.0	41.0	41.0	40.0
	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
	40.0	40.0	40.0	40.0	-1.0	-1.0	-1.0	-1.0		

STOUT= 2000. 27000. 76000. 364000.

RESERVOIR TEMPERATURES

YEAR	PER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1965	1	39.3	39.3	39.3	39.3	39.3	39.3	39.3	39.3	39.3	39.3	39.3	39.3	39.3	39.3	39.3	39.3	39.3	39.3	39.4	39.6
		39.6	39.6	39.7	39.7	39.7	39.7	39.7	39.8	39.8	39.8	39.8	39.8	39.8	39.8	39.8	39.8	39.8	39.8	39.8	39.8
		39.8	39.8	39.8																	
1965	2	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0
		39.2	39.3	39.4	39.4	39.4	39.5	39.5	39.6	39.7	39.7	39.8	39.9	40.1	40.3	40.4	40.6	40.8	41.1	41.4	
1965	3	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.1	39.1	39.1	39.1	39.2	39.2	39.2
		39.3	39.4	39.4	39.5	39.6	39.8	39.9	40.0	40.0	40.1	40.2	40.3	40.4	40.6	40.9	41.3	41.8	42.2	42.8	43.7
		44.5	44.9																		
1965	4	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.1	39.1	39.1	39.1	39.1	39.1	39.1	39.2	39.2	39.2	39.3	39.3	39.4
		39.5	39.6	39.7	39.8	40.0	40.4	40.5	40.7	40.9	41.1	41.3	41.5	41.7	41.9	42.1	42.3	42.5	42.7	43.1	43.5
		44.2	44.9	45.7	46.6	47.7	48.4														
1965	5	39.0	39.0	39.1	39.1	39.1	39.1	39.1	39.1	39.1	39.1	39.2	39.2	39.2	39.3	39.3	39.4	39.4	39.5	39.6	39.8
		39.9	40.2	40.4	40.7	41.2	42.4	42.6	42.9	43.1	43.4	43.7	44.1	44.5	44.9	45.4	45.8	46.2	46.7	47.0	47.4
		47.8	48.4	49.1	49.7	50.4	51.3	51.8													
1965	6	39.1	39.1	39.1	39.1	39.1	39.2	39.2	39.2	39.2	39.3	39.3	39.4	39.4	39.5	39.6	39.7	39.9	40.1	40.3	40.6
		40.9	41.3	41.8	42.3	43.1	44.4	44.8	45.1	45.5	45.8	46.2	46.7	47.1	47.6	48.2	48.8	49.5	50.3	51.0	51.8
		52.4	53.3	54.3	55.2	56.4	57.4	58.0													
1965	7	39.1	39.2	39.2	39.3	39.3	39.3	39.4	39.4	39.5	39.5	39.6	39.7	39.8	40.0	40.1	40.3	40.6	40.9	41.2	41.6
		42.1	42.6	43.3	44.0	44.9	46.5	47.0	47.5	48.0	48.5	49.1	49.7	50.3	51.0	51.8	52.6	53.5	54.4	55.4	56.3
		57.4	58.6	59.8	61.1	63.0	64.5	65.2													
1965	8	39.3	39.4	39.4	39.5	39.5	39.6	39.7	39.8	39.9	40.0	40.1	40.2	40.4	40.6	40.9	41.2	41.5	41.9	42.4	43.0
		43.6	44.3	45.2	46.1	47.4	49.7	50.2	50.9	51.6	52.2	52.9	53.6	54.2	55.0	55.8	56.7	57.5	58.3	59.0	59.8

Printout for Example 2

YEAR	PER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
		60.7	61.6	62.4	63.2	64.1	64.4														
1965	9	39.5	39.7	39.8	39.9	39.9	40.1	40.2	40.3	40.5	40.6	40.8	41.0	41.3	41.5	41.9	42.3	42.8	43.4	44.1	44.9
		45.8	46.9	48.1	49.4	51.4	54.7	55.2	55.6	55.9	56.3	56.7	57.1	57.4	57.7	58.1	58.3	58.6	58.7	58.9	58.9
		59.0	59.0	59.0																	
1965	10	39.9	40.2	40.3	40.4	40.6	40.7	40.9	41.1	41.3	41.5	41.8	42.1	42.4	42.8	43.3	43.9	44.6	45.3	46.1	47.0
		48.0	49.1	50.2	51.4	53.1	55.5	55.8	55.9	55.9	56.0	56.0	56.0	56.0	56.0	56.0	56.0	56.0	56.0	56.0	
1965	11	40.5	40.9	41.1	41.3	41.4	41.6	41.9	42.1	42.4	42.7	43.0	43.3	43.6	44.0	44.4	44.7	45.1	45.4	45.5	45.7
		45.8	46.1	46.4	46.7	47.4	49.6	49.7	49.7	49.8	49.8	49.8	49.8								
1965	12	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.7	39.7	39.8	39.8	40.1	40.2	40.4	40.5	40.8
		40.9	41.1	41.2	41.3	41.3	41.3	41.3	41.3	41.3	41.3	41.3									

FLOWS AND TEMPERATURES FOR 1965

	YEAR	1	2	3	4	5	6	7	8	9	10	11	12
INFLO	1842.1	5563.0	3118.0	1827.0	2722.0	2087.0	1361.0	879.0	683.0	615.0	669.0	1442.0	1139.0
EVAP	2.7	.3	1.1	2.8	2.5	3.1	4.0	5.5	4.4	4.5	2.8	1.0	.5
PRCP	5.8	21.2	5.6	1.8	5.7	4.0	.6	.3	2.3	.4	4.8	11.0	11.8
OUTFL	2172.3	5883.0	4682.0	935.0	906.0	1875.0	1232.0	957.0	1022.0	1758.0	2147.0	3243.0	1428.0
REQDU	2172.3	5883.0	4682.0	935.0	906.0	1875.0	1231.0	957.0	1022.0	1758.0	2147.0	3243.0	1428.0
STMX		494973.	494973.	494973.	494973.	494973.	494973.	494973.	494973.	494973.	494973.	494973.	494973.
STOR		352498.	266679.	321292.	430199.	443474.	450158.	443837.	422400.	353344.	262933.	157428.	141292.
STMN		114700.	114700.	114700.	114700.	114700.	114700.	114700.	114700.	114700.	114700.	114700.	114700.
TA	51.5	38.0	41.0	46.0	49.0	51.0	59.0	68.0	66.0	60.0	56.0	47.0	37.0
TMPIN	42.2	39.0	38.0	39.0	41.0	46.0	50.0	52.0	55.0	50.0	47.0	43.0	38.0
TMPMX	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0
TMPOUT	43.9	39.5	39.2	39.6	40.0	41.3	42.9	45.0	47.5	51.7	54.3	50.5	43.4
TMPMN	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
RELEASES THRU OUTLET 1													
QOMN		2.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
QOUTL		2.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
TOUTL		39.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
RELEASES THRU OUTLET 2													
QOMN		2746.0	2312.0	.0	.0	.0	19.0	.0	.0	.0	.0	.0	.0
QOUTL		2746.0	2312.0	.0	.0	.0	19.0	.0	.0	.0	.0	.0	.0
TOUTL		39.4	39.0	.0	.0	.0	39.8	.0	.0	.0	.0	.0	.0
RELEASES THRU OUTLET 3													
QOMN		3135.0	2370.0	935.0	906.0	1827.0	1213.0	957.0	1022.0	1758.0	2147.0	3243.0	1428.0
QOUTL		3135.0	2370.0	935.0	906.0	1827.0	1213.0	957.0	1022.0	1758.0	2147.0	3243.0	1428.0
TOUTL		39.6	39.3	39.6	40.0	41.2	43.0	45.0	47.5	51.7	54.3	50.5	43.4
RELEASES THRU OUTLET 4													
QOMN		.0	.0	.0	.0	48.0	.0	.0	.0	.0	.0	.0	.0
QOUTL		.0	.0	.0	.0	48.0	.0	.0	.0	.0	.0	.0	.0
TOUTL		.0	.0	.0	.0	48.0	.0	.0	.0	.0	.0	.0	.0

RESERVOIR TEMPERATURES

YEAR	PER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1966	1	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0
		39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	36.0									
1966	2	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0
		39.0	39.0	39.0	39.0	39.1	39.2	39.2	39.4	39.6	39.9	40.2	40.7	41.0							
1966	3	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.1	39.1
		39.1	39.1	39.2	39.2	39.3	39.4	39.4	39.5	39.5	39.5	39.6	39.6	39.7	39.9	40.1	40.5	40.9	41.2	41.9	42.6
		43.2																			
1966	4	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.1	39.1	39.1	39.1	39.2	39.2	39.3
		39.4	39.5	39.7	39.9	40.4	41.3	41.5	41.6	41.7	41.8	41.9	42.0	42.1	42.2	42.3	42.5	42.9	43.3	43.9	44.6
		45.3	46.3	47.5	48.6																
1966	5	39.0	39.0	39.0	39.0	39.0	39.0	39.1	39.1	39.1	39.1	39.1	39.1	39.1	39.2	39.2	39.3	39.4	39.5	39.7	39.9
		40.1	40.5	40.9	41.4	42.2	44.2	44.4	44.7	44.9	45.1	45.3	45.6	45.7	45.9	46.2	46.5	47.0	47.6	48.2	49.2
		49.9	51.2	52.7	54.4	54.9															
1966	6	39.0	39.1	39.1	39.1	39.1	39.1	39.1	39.2	39.2	39.2	39.3	39.4	39.4	39.5	39.7	39.8	40.0	40.3	40.6	41.0

Printout for Example 2

		41.4	41.9	42.5	43.1	43.9	45.2	45.6	46.0	46.4	46.7	47.1	47.6	48.0	48.5	49.1	49.7	50.4	50.9	51.6	52.4
		53.4	54.3	55.5	56.9	58.5	59.1														
1966	7	39.1	39.2	39.2	39.2	39.3	39.3	39.4	39.4	39.5	39.6	39.7	39.8	40.0	40.1	40.4	40.6	40.9	41.4	41.8	42.2
		42.3	43.4	44.0	44.8	45.8	47.2	47.7	48.3	48.7	49.2	49.8	50.4	51.0	51.6	52.4	53.2	53.9	54.8	55.6	56.5
		57.5	58.5	59.5	60.8	62.2	62.7														
1966	8	39.3	39.4	39.5	39.5	39.6	39.7	39.8	39.9	40.0	40.1	40.3	40.5	40.7	40.9	41.2	41.6	42.0	42.5	43.1	43.6
		44.3	45.1	45.9	46.8	48.1	50.0	50.6	51.3	51.9	52.4	53.0	53.7	54.3	55.0	55.7	56.4	57.1	57.9	58.9	59.8
		60.6	61.5	62.7	63.7	64.1															
1966	9	39.6	39.8	39.9	40.0	40.1	40.2	40.4	40.5	40.7	40.9	41.1	41.4	41.7	42.0	42.4	42.9	43.4	44.1	44.8	45.6
		46.5	47.5	48.6	49.8	51.7	54.2	54.8	55.3	55.7	56.1	56.4	56.9	57.3	57.8	58.3	58.8	59.4	59.9	60.4	60.7
		61.2	61.5	61.7																	
1966	10	40.1	40.4	40.6	40.7	40.8	41.0	41.2	41.4	41.7	41.9	42.2	42.5	42.9	43.3	43.8	44.4	45.0	45.7	46.5	47.3
		48.1	49.0	49.9	50.8	51.8	54.0	54.2	54.3	54.3	54.3	54.4	54.4	54.4	54.4	54.4	54.4	54.4	54.4	54.4	
1966	11	40.8	41.2	41.4	41.6	41.7	42.0	42.2	42.4	42.7	42.9	43.1	43.4	43.5	43.7	43.7	43.8	43.8	43.9	44.1	44.3
		44.5	44.9	45.7	48.2	48.2	48.3	48.3	48.4	48.4	48.4	48.4									
1966	12	40.4	40.4	40.4	40.4	40.4	40.4	40.4	40.4	40.4	40.4	40.4	40.4	40.4	40.4	40.4	40.4	40.4	40.4	40.4	40.4
		40.4	40.5	40.5	40.6	41.4	42.0	42.1	42.2	42.3	42.4	42.4									

FLOWS AND TEMPERATURES FOR 1966

	YEAR	1	2	3	4	5	6	7	8	9	10	11	12
INFLO	2063.8	2959.0	1368.0	3375.0	3973.0	2931.0	1457.0	877.0	615.0	551.0	769.0	2517.0	3374.0
EVAP	2.6	.6	.5	2.0	3.0	3.9	3.5	4.4	5.1	3.8	3.0	.8	.5
PRCP	6.7	17.1	6.3	11.9	3.0	2.1	2.4	1.9	.2	1.7	6.5	14.4	13.5
OUTFL	2074.9	2948.0	966.0	1144.0	2705.0	2777.0	1007.0	902.0	947.0	1426.0	2085.0	4523.0	3469.0
REQQQ	2074.9	2948.0	966.0	1144.0	2705.0	2777.0	1007.0	902.0	947.0	1426.0	2085.0	4523.0	3469.0
STMX		494973.	494973.	494973.	494973.	494973.	494973.	494973.	494973.	494973.	494973.	494973.	494973.
STOR		144298.	167449.	306377.	381809.	390825.	417337.	415056.	393417.	340793.	260668.	143565.	139565.
STMN		114700.	114700.	114700.	114700.	114700.	114700.	114700.	114700.	114700.	114700.	114700.	114700.
TA	51.6	38.0	40.0	43.0	50.0	56.0	59.0	64.0	66.0	63.0	53.0	46.0	41.0
TMPIN	41.9	38.0	38.0	39.0	41.0	44.0	48.0	52.0	52.0	51.0	45.0	42.0	40.0
TMPMX	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0
TPOUT	44.3	39.3	39.1	39.3	40.1	42.2	44.1	45.6	47.9	51.3	53.5	47.7	42.3
TMPMN	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
RELEASES THRU OUTLET 1													
QOMN		.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
QOUTL		.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
TOUTL		.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
RELEASES THRU OUTLET 2													
QOMN		408.0	.0	.0	49.0	.0	.0	28.0	18.0	32.0	.0	1051.0	327.0
QOUTL		408.0	.0	.0	49.0	.0	.0	28.0	18.0	32.0	.0	1051.0	327.0
TOUTL		39.0	.0	.0	39.1	.0	.0	40.9	42.0	43.4	.0	44.9	40.8
RELEASES THRU OUTLET 3													
QOMN		2540.0	966.0	1144.0	2642.0	2777.0	1007.0	874.0	929.0	1394.0	2085.0	3472.0	3142.0
QOUTL		2540.0	966.0	1144.0	2642.0	2777.0	1007.0	874.0	929.0	1394.0	2085.0	3472.0	3142.0
TOUTL		39.4	39.1	39.3	40.0	42.2	44.1	45.7	48.0	51.5	53.5	48.6	42.5
RELEASES THRU OUTLET 4													
QOMN		.0	.0	.0	14.0	.0	.0	.0	.0	.0	.0	.0	.0
QOUTL		.0	.0	.0	14.0	.0	.0	.0	.0	.0	.0	.0	.0
TOUTL		.0	.0	.0	47.3	.0	.0	.0	.0	.0	.0	.0	.0

RESERVOIR TEMPERATURES

YEAR	PER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1967	1	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2
		40.2	40.2	40.2	40.2	40.3	40.4	40.4	40.5	40.6	40.8	41.0	41.1	41.3	41.5	41.8	42.0	42.1			
1967	2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.3	40.3	40.3	40.3
		40.3	40.3	40.4	40.4	40.5	40.7	40.7	40.8	40.9	41.1	41.2	41.5	41.7	41.9	42.2	42.6	42.9	43.0		
1967	3	40.1	40.1	40.1	40.1	40.1	40.1	40.1	40.1	40.1	40.1	40.1	40.1	40.1	40.1	40.1	40.1	40.1	40.1	40.1	40.1
		40.1	40.1	40.2	40.2	40.2	40.3	40.3	40.4	40.5	40.6	40.8	41.0	41.2	41.4	41.8	42.1	42.4	42.8	43.4	43.8
1967	4	40.1	40.1	40.1	40.1	40.1	40.1	40.1	40.1	40.1	40.1	40.1	40.1	40.1	40.1	40.1	40.1	40.2	40.2	40.2	40.2

Printout for Example 2

		40.3	40.3	40.4	40.5	40.7	41.0	41.2	41.3	41.5	41.6	41.8	42.0	42.2	42.3	42.6	42.9	43.4	43.9	44.3	44.9
		45.5	45.8																		
1967	5	40.1	40.1	40.1	40.1	40.1	40.1	40.1	40.1	40.1	40.1	40.1	40.2	40.2	40.2	40.2	40.2	40.3	40.3	40.4	40.5
		40.7	40.8	41.0	41.3	41.8	42.6	42.9	43.2	43.6	43.9	44.2	44.6	45.0	45.4	45.8	46.2	46.5	46.9	47.4	48.1
		48.9	49.7	50.9	52.3	53.6															
1967	6	40.1	40.1	40.1	40.1	40.1	40.1	40.2	40.2	40.2	40.2	40.2	40.3	40.3	40.4	40.4	40.5	40.6	40.8	41.0	41.2
		41.5	41.9	42.4	42.9	43.8	45.3	45.7	46.1	46.5	46.9	47.4	47.9	48.5	49.1	49.8	50.5	51.3	52.1	52.7	53.4
		54.4	55.6	56.7	58.1	59.9	61.0														
1967	7	40.1	40.2	40.2	40.2	40.2	40.3	40.3	40.3	40.4	40.4	40.5	40.5	40.6	40.8	40.9	41.1	41.3	41.6	42.0	42.4
		42.9	43.5	44.2	45.0	46.2	48.2	48.7	49.4	49.9	50.5	51.1	51.9	52.5	53.4	54.3	55.3	56.3	57.4	58.5	59.4
		60.5	61.5	62.7	64.1	65.4															
1967	8	40.2	40.3	40.4	40.4	40.4	40.5	40.6	40.6	40.7	40.8	40.9	41.1	41.3	41.5	41.8	42.1	42.6	43.2	43.8	44.4
		45.2	46.1	47.1	48.3	49.9	52.4	53.1	53.8	54.5	55.2	55.9	56.7	57.5	58.3	59.2	60.1	61.0	62.2	63.4	64.6
		65.6	66.8	68.1	68.7																
1967	9	40.5	40.6	40.7	40.8	40.8	40.9	41.1	41.2	41.4	41.6	41.8	42.0	42.3	42.7	43.1	43.6	44.3	45.0	45.8	46.8
		47.8	49.0	50.4	51.8	54.0	57.0	57.7	58.2	58.7	59.1	59.6	60.1	60.6	61.1	61.6	62.0	62.4	62.8	63.1	63.4
		63.6	63.7																		
1967	10	40.9	41.1	41.3	41.4	41.5	41.7	41.9	42.1	42.4	42.7	43.0	43.3	43.7	44.1	44.7	45.2	45.9	46.6	47.3	48.0
		48.7	49.3	49.9	50.4	51.2	53.8	54.3	54.7	54.9	55.0	55.1	55.1	55.2	55.2	55.2	55.2	55.2	55.2	55.2	55.2
		55.2																			
1967	11	41.5	41.9	42.2	42.3	42.5	42.7	43.0	43.3	43.6	43.9	44.2	44.5	44.8	45.2	45.5	45.8	46.0	46.3	46.6	46.8
		47.1	47.4	47.8	48.7	49.9	49.9	49.9	49.9	49.9	49.9	50.0									
1967	12	39.5	39.5	39.5	39.5	39.5	39.5	39.5	39.5	39.5	39.5	39.5	39.5	39.5	39.5	39.5	39.5	39.5	39.5	39.6	39.7
		39.8	39.8	39.9	40.0	40.2	40.6	40.7	40.7	40.7	40.7	40.7	40.7	40.7							

FLOWS AND TEMPERATURES FOR 1967

	YEAR	1	2	3	4	5	6	7	8	9	10	11	12
INFLO	1845.8	4024.0	2267.0	1872.0	1470.0	2646.0	1825.0	841.0	615.0	560.0	1815.0	1728.0	2486.0
EVAP	2.8	.2	.6	.7	1.5	4.0	4.0	6.0	6.8	5.8	2.1	.8	.5
PRCP	6.1	18.0	4.5	7.3	5.3	2.3	1.1	.0	.1	2.1	14.9	6.5	11.7
OUTFL	1829.3	2717.0	2018.0	1009.0	910.0	1336.0	1429.0	1136.0	1172.0	1458.0	2173.0	4364.0	2230.0
REQUQ	1829.3	2717.0	2018.0	1009.0	910.0	1336.0	1429.0	1136.0	1171.0	1459.0	2173.0	4364.0	2230.0
STMX		494973.	494973.	494973.	494973.	494973.	494973.	494973.	494973.	494973.	494973.	494973.	494973.
STOR		222855.	237362.	291619.	325807.	405892.	428601.	408698.	372769.	318432.	299364.	143518.	160868.
STMN		114700.	114700.	114700.	114700.	114700.	114700.	114700.	114700.	114700.	114700.	114700.	114700.
TA	52.7	41.0	42.0	42.0	44.0	55.0	63.0	69.0	73.0	67.0	53.0	47.0	37.0
TMPIN	43.4	40.0	40.0	39.0	41.0	45.0	50.0	56.0	55.0	52.0	46.0	44.0	39.0
TMPMX	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0
TPOUT	45.8	40.4	40.5	40.3	40.6	41.6	43.6	46.5	49.3	53.9	53.0	50.1	42.8
TMPMN	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
RELEASES THRU OUTLET 1													
QOMN		.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
QOUTL		.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
TOUTL		.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
RELEASES THRU OUTLET 2													
QOMN		.0	.0	.0	.0	.0	.0	.0	61.0	19.0	.0	664.0	.0
QOUTL		.0	.0	.0	.0	.0	.0	.0	61.0	19.0	.0	664.0	.0
TOUTL		.0	.0	.0	.0	.0	.0	.0	42.5	44.2	.0	47.0	.0
RELEASES THRU OUTLET 3													
QOMN		2717.0	2018.0	1009.0	910.0	1336.0	1429.0	1111.0	1098.0	1430.0	2173.0	3700.0	2230.0
QOUTL		2717.0	2018.0	1009.0	910.0	1336.0	1429.0	1111.0	1098.0	1434.5	2173.0	3700.0	2230.0
TOUTL		40.4	40.5	40.3	40.6	41.6	43.6	46.1	49.5	54.0	53.0	50.7	42.8
RELEASES THRU OUTLET 4													
QOMN		.0	.0	.0	.0	.0	.0	25.0	13.0	9.0	.0	.0	.0
QOUTL		.0	.0	.0	.0	.0	.0	25.0	13.0	4.5	.0	.0	.0
TOUTL		.0	.0	.0	.0	.0	.0	61.5	67.0	65.0	.0	.0	.0

Printout for Example 2

APPENDIX 1

Calculation Procedure

A thermal analysis of a reservoir is made by calculating an energy balance. The energy balance accounts for all significant energy exchanges into and out of the reservoir. Figure A1-1 illustrates the driving forces which are considered in the energy balance. The arrowhead indicates whether a particular force can transfer energy into or out of the reservoir. Conduction can transfer energy in either direction dependent on the sign of the temperature gradient between air temperature and surface water temperature. Figure A1-1 also illustrates that vertical diffusion transfers energy between the horizontal isothermal layers of the reservoir. Assuming the initial state of a reservoir is adequately defined, the following procedure is used to conduct a thermal analysis of an existing or proposed reservoir:

a. Calculate the transfer of energy by conduction between the water and the atmosphere by the following equation:

$$E_1 = \Sigma FC_1 (T_A - TW_L) S_L \qquad (1)$$

where the summation is over all layers within the selected depth of energy penetration, and:

E_1 = Energy transferred to the water within the selected depth of energy penetration in acre-feet-degrees F (or thousand cubic meters-degrees C)

F = A factor which decreases linearly with depth from 1 at the surface to 0 at the bottom to properly account for the change in energy transfer with depth

C_1 = A calibration coefficient between 0 and 1

T_A = Monthly average air temperature in degrees F (or degrees C)

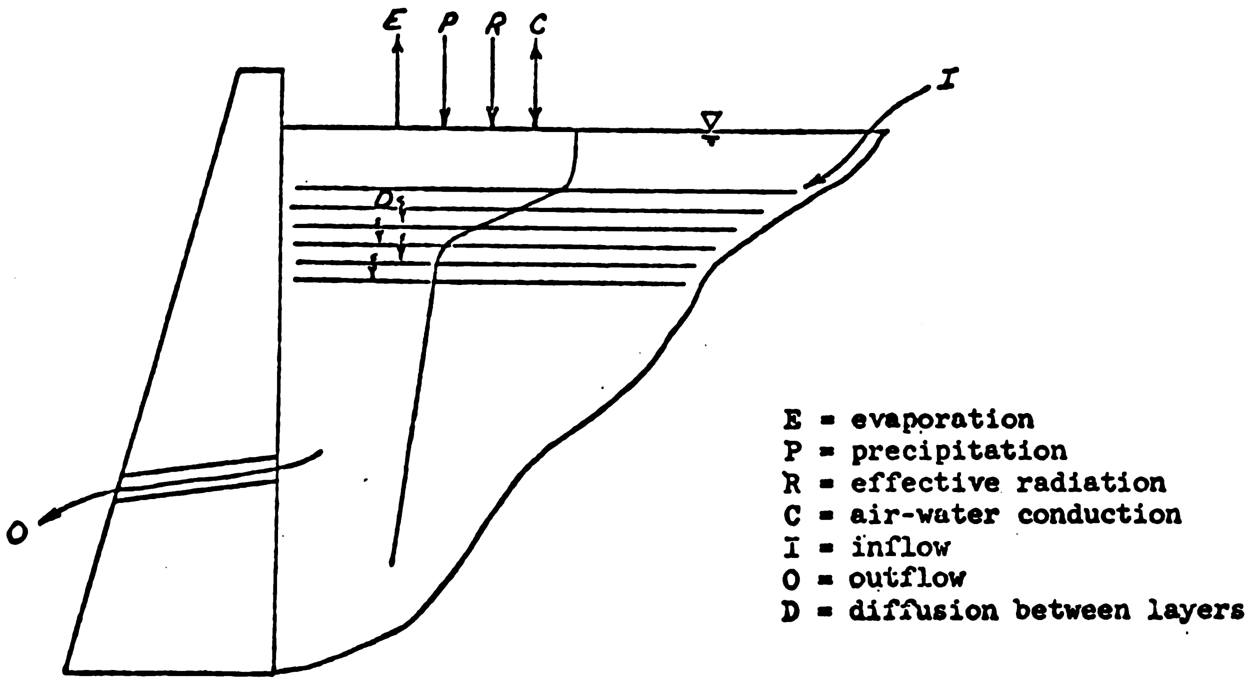
TW_L = Water temperature of layer L in degrees F (or degrees C)

S_L = Storage in layer L in acre-feet (or thousand cubic meters)

b. Calculate the energy transferred to water from solar radiation by the following equation:

$$E_2 = KC_2 (R)(A)(ND) \qquad (2)$$

where the energy transfer is assumed to decrease linearly from a maximum at the surface to zero at the bottom of the selected depth and:



evaporation - cools the water to some limited depth (approx. 30 feet).

effective radiation - warms the water to some limited depth. (approx. 30 feet)

air-water conduction - can cool or warm the water to some limited depth (approx. 30 feet)

inflow - cools the water in each layer above the layer where it concludes its descent.

outflow - removal of energy and quantity from specific layers, causing redistribution of energy and quantity.

diffusion - heat transfer to the next lower layer. Tends to make the reservoir isothermal.

Figure A1-1. Energy Budget

E_2 = Energy transferred to the water within the selected depth of energy penetration in acre-feet-degrees F (or thousand cubic meters-degrees C)

K = A conversion constant = .0036 for English units (or .002 for metric units)

C_2 = A calibration coefficient between 0 and 1

R = Solar radiation in calories per sq. cm. per day (figure 2 of main document)

A = Reservoir surface area in acres (or thousand square meters)

ND = Number of days in the month

c. Calculate the energy removed from the water by gross lake evaporation by the following equation:

$$E_3 = C_3 (H_E)(V_E) \qquad (3)$$

where the energy transfer is assumed to decrease linearly from a maximum at the surface to zero at the bottom of the selected depth and:

E_3 = Energy removed from the water within the selected depth of energy penetration in acre-feet-degrees F (or thousand cubic meters-degrees C)

C_3 = A calibration coefficient between 0 and 1

H_E = Latent heat of vaporization plus approximate heat to warm water = 1062 BTU per pound (or 590 calories per gram)

V_E = Volume of water evaporated in acre-feet (or thousand cubic meters)

d. The coefficients in equations 1, 2, and 3 (along with the three coefficients in equations 4, 5, and 7) can be determined from recorded data. The energy calculated with equations 1, 2, and 3 is transferred in the order discussed, to (or from) the top several layers of reservoir water as a function of depth, decreasing linearly from a maximum at the top layer to a value of zero at the selected depth of energy penetration.

e. Rainfall on the water surface is added to the reservoir volume at the average temperature of the top layer, and evaporation volume is subtracted from the top layer.

f. Any thermally unstable layers are thoroughly mixed from the surface downward until no lower levels contain warmer water than exists at higher levels. This computation is constrained to temperatures above 4°C, corresponding to the maximum density of water. If water is cooled below this temperature, the temperature of each layer from the surface downward is allowed to go negative until an amount of energy equal to that required to form ice has been extracted from that layer.

g. If the reservoir inflow is cooler than the surface temperature, it will descend and partially mix with the upper layers. The temperature of each layer and the temperature of the inflow that results from the exchange of energy between the inflow and the reservoir volume at each level is calculated by use of the following equations:

$$T'_L = T_L + C_4 (T_{avg} - T_L) \qquad (4)$$

$$T'_I = T_I + C_4 (T_{avg} - T_I) \qquad (5)$$

where: T'_L = Temperature at layer L in degrees F (or degrees C) after inflow energy transfer

T_L = Temperature at layer L in degrees F (or degrees C) prior to inflow energy transfer

C_4 = A calibration coefficient between 0 and 1

T_{avg} = Average (weighted by volume) of inflow temperature and temperature of layer L in degrees F (degrees C)

T'_I = Temperature of inflow in degrees F (or degrees C) after inflow energy transfer

T_I = Temperature of inflow in degrees F (or degrees C) prior to inflow energy transfer

T_{avg} = Average (weighted by volume) of inflow temperature and temperature of layer L in degrees F (degrees C)

The calculations involving equations 4 and 5 must be repeated for each layer. The inflow is thus warmed slightly as it descends to a level where the temperature equals the modified inflow temperature, but never descends below water which has a temperature of maximum water density (4°C). It is then added to the reservoir, and all water in higher layers is raised. A thermal stability check is made and any unstable layers are thoroughly mixed.

h. The temperature changes resulting from the vertical diffusion of energy can be calculated by the following equations:

$$T_{av} = \frac{\Sigma T_L V_L}{\Sigma V_L} \qquad (6)$$

$$T'_L = T_L + C_5 (T_{av} - T_L) \qquad (7)$$

where the summation is for all layers L over a 10-meter range and:

T_{av} = Average temperature of all layers within a 10-meter range

T_L = Temperature at layer L in degrees F (or degrees C) prior to diffusion of energy

V_L = Volume in layer L in acre-feet (or thousand cubic meters)

T'_L = Temperature at layer L in degrees F (or degrees C) after diffusion of energy

C_5 = A calibration coefficient between 0 and 1

This calculation involving equations 6 and 7 must be repeated for each set of layers 10 meters thick, starting at the bottom of the reservoir and proceeding upward a layer at a time. This process is repeated once per computation interval. If the computation interval is less than 6 times per month, the process is repeated 6 times per computational interval to insure adequate opportunity for diffusion of energy. It should be recognized that energy transfers computed for long intervals leave the reservoir in an unreal condition and that his diffusion computation is a practical means of overcoming this and accounting for diffusion.

i. The releases assigned to specific outlets are made by withdrawing the required quantity from the storage available immediately above the outlet invert level, accounting for the total released quantity and energy.

j. The temperature limits which apply to the remaining required release are calculated as follows:

$$T'_{max} = (T_{max}Q_T - Q_1T_1)/(Q_T - Q_1) \quad (8)$$

$$T'_{min} = (T_{min}Q_T - Q_1T_1)/(Q_T - Q_1) \quad (9)$$

where: T'_{max} = Maximum desirable release temperature for remaining (after specific outlet releases) required release in degrees F (or degrees C)

T_{max} = Maximum desirable release temperature for total release in degrees F (or degrees C)

Q_T = Total required release in acre-feet (or thousand cubic meters)

Q_1 = Release required through specific outlets in acre-feet (or thousand cubic meters)

T_1 = Temperature of water released through specific outlets in degrees F (or degrees C)

T'_{min} = Minimum desirable release temperature for remaining (after specific outlet releases) required release in degrees F (or degrees C)

T_{min} = Minimum desirable release temperature for total release in degrees F (or degrees C)

k. The target temperature of the remaining required release is calculated by the following equation:

$$T = [E - T_N(V-Q)]/Q \qquad (10)$$

where: T = Target temperature of the remaining release in degrees F (or degrees C)

E = Reservoir energy above the lowest usable outlet in acre-feet-degrees F (or thousand cubic meters-degrees C)

T_N = The average of the "N" succeeding months' maximum and minimum temperature requirements in degrees F (or degrees C)

N = The number of future months of target temperature criteria used to determine a best release temperature

V = Reservoir volume remaining above the lowest usable outlet in acre-feet (or thousand cubic meters)

Q = Remaining release required during the current month in acre-feet (or thousand cubic meters)

Equation 10 is used to determine the discharge temperature of the remaining release (Q) such that the average temperature of the water remaining above the lowest usable outlet is changed to equal the average temperature of the selected number of succeeding months' maximum and minimum temperature requirements. If the target temperature calculated with equation 10 is outside the desirable range calculated with equations 8 and 9, the closest temperature limit is adopted as the target temperature.

l. Water is released to meet the target temperature calculated in step k by one of 2 operational release methods. Method 1 calculates the energy that could be released through the two nearest usable outlets that are above and below where the target temperature exists. With this method, maximum choice of temperatures is available for subsequent months. Method 2 selects the highest and lowest usable outlets, which leaves the temperature of the lake more uniform. Using either method, the quantity of water released through the two outlets is mixed so as to match the target temperature.

If it becomes necessary to use other outlets also, lower and higher outlets are used as required. If it is found that this process does not satisfy the target temperature, the release will be withdrawn only from the one outlet which will produce water with a temperature closest to the target temperature.

m. The end-of-month storage and the temperature of the water in each layer is determined by redistributing the reservoir water to fill all the "empty spaces" resulting from the release. A thermal stability check is made and any unstable layers are thoroughly mixed.

n. The above computation procedure is repeated for each month.

APPENDIX 2

DEFINITION OF OUTPUT VARIABLES

CISA	- Coefficient to convert inflow for 1 day to storage units per day, preceded by minus sign if inflow is in volume units
COSA	- Coefficient to convert outflow for 1 day to storage units per day, preceded by minus sign if outflow is in volume units
CSOUT	- Coefficient to convert storage units to cfs-days (or cms-days)
DEP	- Depth of energy penetration in feet (or meters)
EVAP	- Evaporation during period in inches (or millimeters)
IDERV	- Calls for derivation of coefficients, when positive
IDGST	- Calls for diagnostic printout, when positive
INFLOW	- Inflow during period in cfs (or cms)
INTER	- Number of computational intervals per month
IPER	- Number of first period in year
IYR	- Calendar year during which operation study starts
LAYER	- Depth of layer in feet (or meters)
METRC	- Positive value indicates use of metric system
MREL	- Index to specify the operational method of release
MSTRT	- Month number at which computation is to start during first year
NIC	- Number of local inflow locations to be read from cards
NIT	- Number of inflow locations to be read from tape
NLAYR	- Total number of layers in reservoir
NMINQ	- Number of outlet levels through which minimum flows are required
NMO	- Number of future months of target temperature criteria used to calculate best release temperature
NOTL	- Number of separate outflow distribution channels
NOUTL	- Total number of outlet levels
NPER	- Number of periods in year
NYR	- Number of years of study
OUTFL	- Actual outflow during period in cfs (or cms)
PER	- Calender month number
PRCP	- Precipitation during period in inches (or millimeters)
QMIN	- Required outflow, average for year
QOMIN	- Average required release through each outlet for period
QOMN	- Required release through each outlet for period
QOUTL	- Actual outflow through each outlet for period in cfs (or cms)
REQDQ	- Input value of required outflow during period

SOLR	- Average solar radiation in calories per day for year
STCAP	- Storage capacity in acre-feet (or thousand cubic meters) at top of each layer
STMN	- Minimum permissible storage at end of period in storage units
STMX	- Maximum permissible storage at end of period in storage units
STOR	- Storage at end of period in storage units
STORA	- Initial storage in acre-feet (or thousand cubic meters)
STOUT	- Storage capacity at invert of each outlet in storage units
STRMN	- Minimum permissible storage constant for year in storage units
STRMX	- Maximum permissible storage constant for year in storage units
TA	- Average air temperature for period in degrees F (or °C)
TAIR	- Average air temperature if same for all periods in °F (or °C)
TIN	- Average inflow temperature if same for all periods in °F (or °C)
TMAX	- Maximum permissible release temperature if same for all periods in degrees F (or °C)
TMIN	- Minimum permissible release temperature if same for all periods in degrees F (or °C)
TMPIN	- Average inflow temperature for period in degrees F (or °C)
TMPMN	- Minimum permissible release temperature for period in degrees F (or °C)
TMPMX	- Maximum permissible release temperature for period in degrees F (or °C)
TPOUT	- Release temperature for period in degrees F (or °C)
TOUTL	- Temperature of QOUTL
TSTRT	- Starting temperature profile in degrees F (or °C)

A,B

APPENDIX 3
INPUT REQUIREMENTS

1. Card Format

Input is entered in ten 8-column fields per card, except that the first column of each card is retained for card identification. Thus, the first item of data on each card occupies columns 2-8. If they are right justified in their field, whole numbers can be punched without decimal points. All integer numbers (identified by variable names starting with letters I through N) must be punched without decimal points. Where the value of a variable is zero, the field may be left blank. The first title card of each job must have an A in column 1 in order to identify the start of the job. In certain cases where a job is aborted, the computer can waste cards until it finds the start of the next job.

2. Multiple Jobs

When several jobs are to be computed during the same run (stacked jc[illegible] the data cards for the last job only are to be followed by five blank ca[illegible] If only a single job is to be run, five blank cards must follow the data cards for that run. An A in column 1 of the first of the five blank cards is required.

3. Card Contents

A Three title cards are required at the beginning of each job. Alphabetical characters and numbers may be used in any of the fields of all three cards. The contents of the cards will be printed at the beginning of the program output. An A in column 1 of the first card is required.

B Job specification

Field	Variable	Value	Description
1	NYR	+	Number of years of data
2	IYR	+	Calendar year during which operation study starts
3	NPER	+	Number of periods per year (not to exceed 12)
4	IPER	+	Number of first period in year; e.g., 1 if using calendar year or 10 if using water year
5	MSTRT	+	Month number of first period of computation for first year (ordinarily same as IPER, B-4) (-2 if IPER=10)

B Job specification (continued)

Field	Variable	Value	Description
6	NLAYR	+	Number of layers in reservoir (not to exceed 100)
7	LAYER	+	Depth of layers in feet (or meters)
8	NOUTL	+	Number of levels of outlets (not to exceed 9)
9	NMINQ	0	All outlet releases are varied to meet target temperature criteria
		+	Number of outlets through which required releases will be specified
10	IDERV	0	All five model calibration coefficients are known
		1	Positive integer indicates 1 or more coefficients are to be derived from observed temperature profiles
11	METRC	0	English system of units are used (temperature values must be in °F)
		1	Metric system of units are used (temperature values must be in °C)
12	IDGST	0	Suppresses diagnostic printout from optimization routine
		1	Calls for diagnostic printout from optimization routine
13	NIC	0	No local inflow in a tandem reservoir system
		+	Number of tributaries having inflow data to be read from cards
14	NIT	0	Run is for a single reservoir calculation or the upstream reservoir in a tandem system
		+	Number of tributaries having inflow and temperature data to be read from tape output calculated at an upstream reservoir for input to a downstream reservoir in a tandem reservoir system
** 20	KE	0	RUN USES AVERAGE K AND E VALUES IN D/S RIVER TEMP. CALCULATION
		1	RUN USES YEARLY K AND E VALUES IN D/S RIVER TEMP. CALCULATION

B Job specification (continued)

Field	Variable	Value	Description
15	NOTL	0	Used for a single reservoir calculation
		+	Number of separate outflow distribution channels which deliver discharge to a downstream reservoir in a tandem reservoir system
16	INTER	0	Program uses four computational intervals per month
		+	Number of computational intervals per month
17	MREL	0	Uses the method of release which searches for the first usable outlet above and the first usable outlet below the layer which contains the desired release temperature
		1	Uses the method of release which draws water from the highest and lowest usable outlet
18	NMO	0	Program uses 3 future months of target temperature criteria to calculate a best release temperature for any given month
		+	Number of future months of target temperature criteria used to calculate a best release temperature for any given month
* 19			
** 20			

C Outlet distribution channels (NOTL, B-15, cards); omit if NOTL (B-15) is zero

Field	Variable	Value	Description
1	NOUL	+	Number of outlets releasing to distribution channel I
2	KOUTL(I,K)	+	Outlet number K (numbered from bottom upward) which releases to distribution channel I (NOUL, C-1, items)

D Job data

Field	Variable	Value	Description
1	STORA	+	Initial reservoir storage in acre-feet (or thousand cubic meters)

* 19	NRIV	0	Run does not include d/s river Temp. calc.
		1	Run includes d/s river calculation

D Job data (continued)

Field	Variable	Value	Description
2	CISA	+	Coefficient to convert inflow rate to storage units per day
		-	Coefficient to convert inflow volume to storage units

Some examples are as follows:

Storage units	Inflow units	CISA
acre-feet	cfs	1.983472
acre-feet	acre-feet	-1.00
acre-feet	day-second-feet	-1.983472
thousand m^3	cms	86.4
thousand m^3	m^3	-10^{-3}

Field	Variable	Value	Description
3	COSA	+	Coefficient to convert outflow rate to storage units per day
		-	Coefficient to convert outflow volume to storage units

Some examples are as follows:

Storage units	Outflow units	COSA
acre-feet	cfs	1.983472
acre-feet	acre-feet	-1.00
acre-feet	day-second-feet	-1.983472
thousand m^3	cms	86.4
thousand m^3	m^3	-10^{-3}

Field	Variable	Value	Description
4	STRMX	+	Maximum permissible storage in acre-feet (or thousand cubic meters)
		-1	Monthly maximum permissible storage will be read on K card in first year only
		-2	Monthly maximum permissible storage will be read on K card for each year

D Job data (continued)

Field	Variable	Value	Description
5	STRMN	+	Minimum permissible storage in acre-feet (or thousand cubic meters)
		-1	Monthly minimum permissible storage will be read on L card in first year only
		-2	Monthly minimum permissible storage will be read on L card for each year
6	TIN	+	Inflow temperature in degrees F (or C)
		-1	Monthly inflow temperature will be read on V card in first year only
		-2	Monthly inflow temperature will be read on V card for each year
7	TAIR	+	Average air temperature in degrees F (or C)
		-1	Monthly average air temperature will be read on M card in first year only
		-2	Monthly average air temperature will be read on M card for each year
8	EVAP	+	Lake evaporation for year in inches (or millimeters)
		-1	Monthly lake evaporation will be read on N card in first year only
		-2	Monthly lake evaporation will be read on N card for each year
9	PRCP	+	Precipitation for year in inches (or millimeters)
		-1	Monthly precipitation will be read on O card in first year only
		-2	Monthly precipitation will be read on O card for each year

D Job data (continued)

Field	Variable	Value	Description
10	QMIN	+	Outflow in units corresponding to COSA (D-3)
		-1	Monthly outflow will be read on P card in first year only
		-2	Monthly outflow will be read on P card for each year
11	TMAX	+	Maximum permissible outflow temperature in degrees F (or C)
		-1	Monthly maximum permissible outflow temperature will be read on Q card in first year only
		-2	Monthly maximum permissible outflow temperature will be read on Q card for each year
12	TMIN	+	Minimum permissible outflow temperature in degrees F (or C)
		-1	Monthly minimum permissible outflow temperature will be read on R card in first year only
		-2	Monthly minimum permissible outflow temperature will be read on R card for each year
13	CSOUT	+	Coefficient to convert storage units to cfs-days (or cms-days) for output

Some examples are as follows:

Storage units	CSOUT
acre-feet	.504167
thousand m^3	.011574

D Job data (continued)

Field	Variable	Value	Description
14	SOLR	+	Solar radiation in calories per sq. cm. per day
		-1	Monthly solar radiation will be read on S card in first year only
		-2	Monthly solar radiation will be read on S card for each year
15	DEP	+	Depth of penetration of solar radiation, conduction, and evaporation energy in feet (or meters). The depth used for application should be the same as that used for calibration
		0	Uses programmed value of 32.81 feet (or 10 meters) for depth of energy penetration

E Coefficients

Field	Variable	Value	Description
1	VAR(1)	+	Air Temperature Coefficient--Index† of energy transferred by conduction due to the difference between the air and water surface temperature
		negative value between 0 and -1	Initial estimate of index† to be used for calibrating the air temperature coefficient
		-1	Uses programmed initial index† for calibrating the air temperature coefficient
2	VAR(2)	+	Inflow Mixing Coefficient--Index† of energy transferred to the inflow due to the difference between the modified inflow temperature and the temperature of each reservoir layer. The transfer affects each layer as the inflow descends through the reservoir.

† Index equals zero if no energy is transferred and equals one if sufficient energy is transferred to reach equilibrium.

E Coefficients (continued)

Field	Variable	Value	Description
		negative value between 0 and -1	Initial estimate of index† to be used for calibrating the inflow mixing coefficient
		-1	Uses programmed initial index† for calibrating the inflow mixing coefficient
3	VAR(3)	+	Vertical Diffusion Coefficient--Index† of energy transferred between adjacent layers (downward) due to the difference in temperature between layers
		negative value between 0 and -1	Initial estimate of index† to be used for calibrating the vertical diffusion coefficient
		-1	Uses programmed initial index† for calibrating the vertical diffusion coefficient
4	VAR(4)	+	Evaporation Coefficient--Index† of energy lost from the reservoir water surface due to evaporation. The remaining energy required for the heat of vaporization is obtained by cooling the air.
		negative value between 0 and -1	Initial estimate of index† to be used for calibrating the evaporation coefficient
		-1	Uses programmed initial index† for calibrating the evaporation coefficient
5	VAR(5)	+	Insolation Coefficient--Index† of energy transferred to the reservoir due to solar radiation. The solar radiation energy that is not effective in warming the reservoir has been "lost" due to absorption and reflection within the atmosphere and reflection at the water surface

† Index equals zero if no energy is transferred and equals one if sufficient energy is transferred to reach equilibrium.

E Coefficients (continued)

Field	Variable	Value	Description
		negative value between 0 and -1	Initial estimate of index† to be used for calibrating the insolation coefficient
		-1	Uses programmed initial index† for calibrating the insolation coefficient

F Required outlet releases (NOUTL, B-8, items); omit if NMINQ (B-9) is zero

Variable	Value	Description
QOMIN(K)	+	Required release from each successive outlet K in order of elevation (from bottom upward) with units corresponding to COSA
	-1	Monthly required release for each outlet K will be read on T cards in first year only
	-2	Monthly required release for each outlet K will be read on T cards for each year
	-3	Monthly release will be varied to meet target temperature criteria and does not require T cards for outlet K

G Period lengths (NPER, B-3, items)

Variable	Value	Description
NDAYS(I)	+	Number of days in each successive period I

H Storage capacity (NLAYR, B-6, items)

Variable	Value	Description
STCAP(L)	+	Storage capacity in acre-feet (or thousand cubic meters) at top of each successive layer L (from bottom to top)

† Index equals zero if no energy is transferred and equals one if sufficient energy is transferred to reach equilibrium.

I Initial reservoir temperature (NLAYR, B-6, items)

Variable	Value	Description
TSTRT(L)	+	Average temperature in degrees F (or C) for each successive layer L at start of computation (from bottom to top).
	-1	Designates layers without any water.

J Location of outlets (NOUTL, B-8, items)

Variable	Value	Description
STOUT(K)	+	Storage capacity in acre-feet (or thousand cubic meters) at lowest point that can discharge through outlet K (from bottom to top)

K Maximum storage (NPER, B-3, items); Omit if STRMX (D-4) is positive. Supply for first year only if STRMX (D-4) is -1 and for every year if index is -2.

Variable	Value	Description
STMX(I)	+	Maximum permissible storage in acre-feet (or thousand cubic meters) at end of each successive period I

L Minimum storage (NPER, B-3, items); omit if STRMN (D-5) is positive. Supply for first year only if STRMN (D-5) is -1 and for every year if index is -2.

Variable	Value	Description
STMN(I)	+	Minimum permissible storage in acre-feet (or thousand cubic meters) at end of each successive period I

M Average air temperature (NPER, B-3, items); Omit if TAIR (D-7) is positive. Supply for first year only if TAIR (D-7) is -1 and for every year if index is -2.

Variable	Value	Description
TA(I)	+	Average air temperature for each successive period I in degrees F (or C)

N Evaporation (NPER, B-3, items); Omit if EVAP(D-8) is positive. Supply for first year only if EVAP(D-8) is -1 and for every year if index is -2.

Variable	Value	Description
EVP(I)	+	Lake evaporation in inches (or millimeters) for each successive period I

O Precipitation (NPER, B-3, items); Omit if PRCP(D-9) is positive. Supply for first year only if PRCP(D-9) is -1 and for every year if index is -2.

Variable	Value	Description
PCP(I)	+	Precipitation in inches (or millimeters) for each successive period I

P Required outflow (NPER, B-3, items); Omit if QMIN(D-10) is positive. Supply for first year only if QMIN(D-10) is -1 and for every year if index is -2.

Variable	Value	Description
QMN(I)	+	Required total release for each successive period I in units corresponding to COSA(D-3)

Q Maximum outflow temperatures (NPER, B-3, items); Omit if TMAX(D-11) is positive. Supply for first year only if TMAX(D-11) is -1 and for every year if index is -2.

Variable	Value	Description
TMX(I)	+	Maximum permissible temperature of outflow for each successive period I in degrees F (or C)

R Minimum outflow temperatures (NPER, B-3, items); Omit if TMIN(D-12) is positive. Supply for first year only if TMIN(D-12) is -1 and for every year if index is -2.

Variable	Value	Description
TMN(I)	+	Minimum permissible temperatue of outflow for each successive period I in degrees F (or C)

S Solar radiation (NPER, B-3, items); Omit if SOLR(D-~~13~~ 14) is positive. Supply for first year only if SOLR(D-13) is -1 and for every year if index is -2.

S (Continued)

Variable	Value	Description
SOL(I)	+	Average solar radiation for period I in calories per sq. cm. per day (from figure 2 or table 2 in main document)

T Required outlet releases (NPER, B-3, items) (NMINQ, B-9, pairs of cards); Omit for outlets having a QOMN value (F card) that is positive or -3. Supply first year only for outlets having a QOMN value (F card) of -1 and for every year if index is -2.

Variable	Value	Description
QOMN(I,K)	+	Required release in period I through specific outlet K, numbered by elevation (from bottom upward), with units corresponding to COSA(D-3). Only supplied for outlets where QOMIN (F card) is -1 or -2 (bottom to top)

U Inflow (NPER, B-3, values) (NIC, B-13, pairs of cards); Use local inflow for a downstream reservoir in a tandem reservoir system.

Variable	Value	Description
QI(I)	+	Average inflow for each successive period I in units corresponding to CISA(D-2)

V Inflow temperatures (NPER, B-3, items) (NIC, B-13, pairs of cards); Use local inflow temperature for a downstream reservoir in a tandem reservoir system. Omit if TIN(D-6) is positive. Supply for first year only if TIN(D-6) is -1 and for every year if index is -2.

Variable	Value	Description
TI(I)	+	Average temperature of inflow for each successive period I in degrees F (or C)

W Observed temperature profile dates (card required every year); omit if IDERV(B-10) is zero.

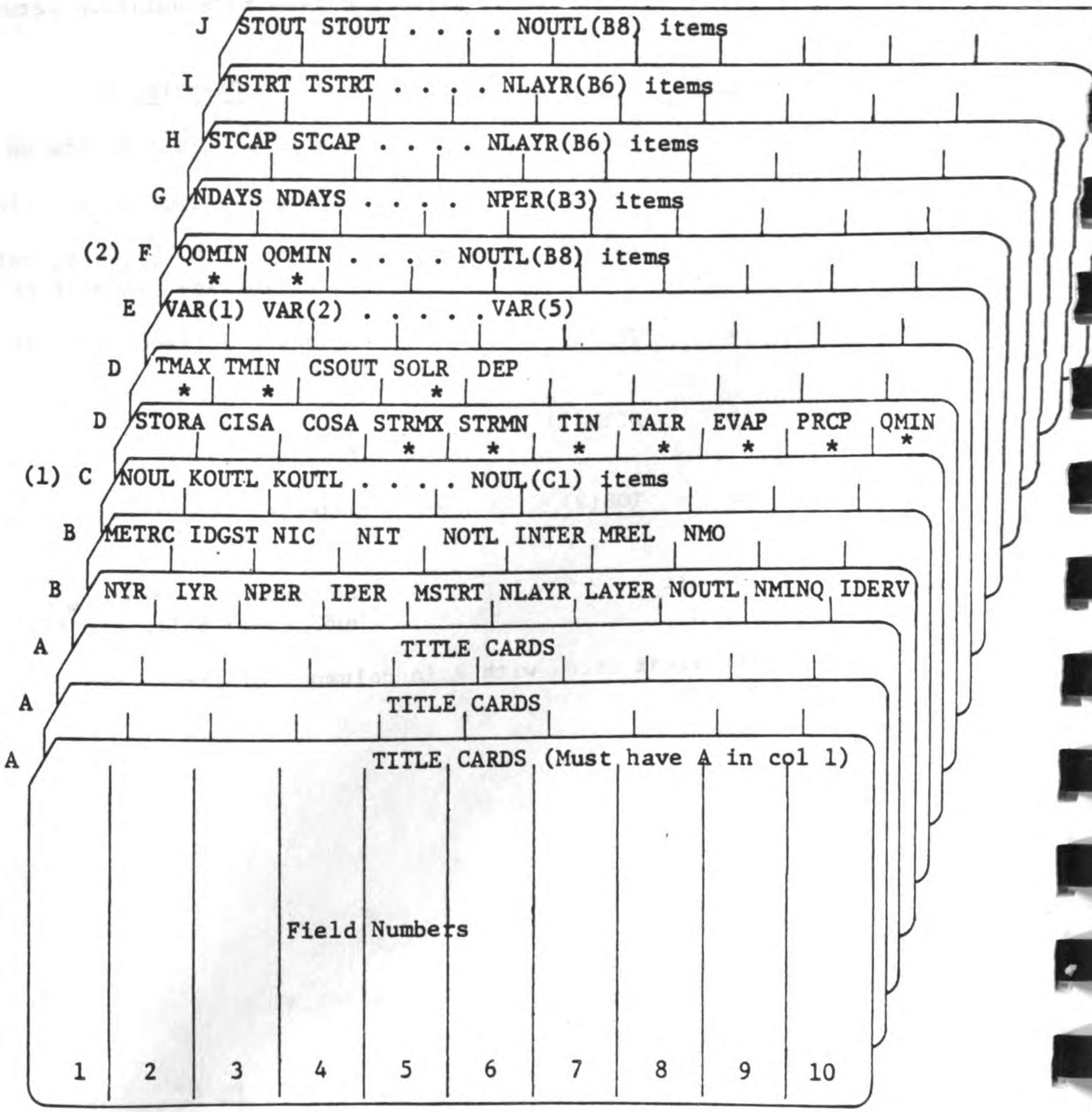
Field	Variable	Value	Description
1	NPFL	+	Number of observed profiles during year
2	IDAY(K)	+	Date of each successive profile (NPFL, W-1, items); calendar month number followed by two digits for day of month, no decimal points

X Observed temperature profile, repeat for each value of IDAY (W card); omit if IDERV(B-10) is zero. Data should contain sufficient depth-temperature pairs to allow accurate interpolation between points for profile definition.

Field	Variable	Value	Description
1	NOBS	+	Number of given points on profile
2	STORX	+	Storage at time of profile
3	DPTH(1)	0	Indicates TOB(1), X-4, value is the water surface temperature
4	TOB(1)	+	Observed surface temperature in degrees F (or C)
5	DPTH(2)	+	Depth below surface to TOB(2), X-6, in feet (or meters)
6	TOB(2)	+	Observed temperature at DPTH(2), X-5, in degrees F (or C)
7, etc			Repeat for increasing depths until NOBS (X-1) pairs are read

A Five blank cards with A in column 1 of first card will cause computer to stop

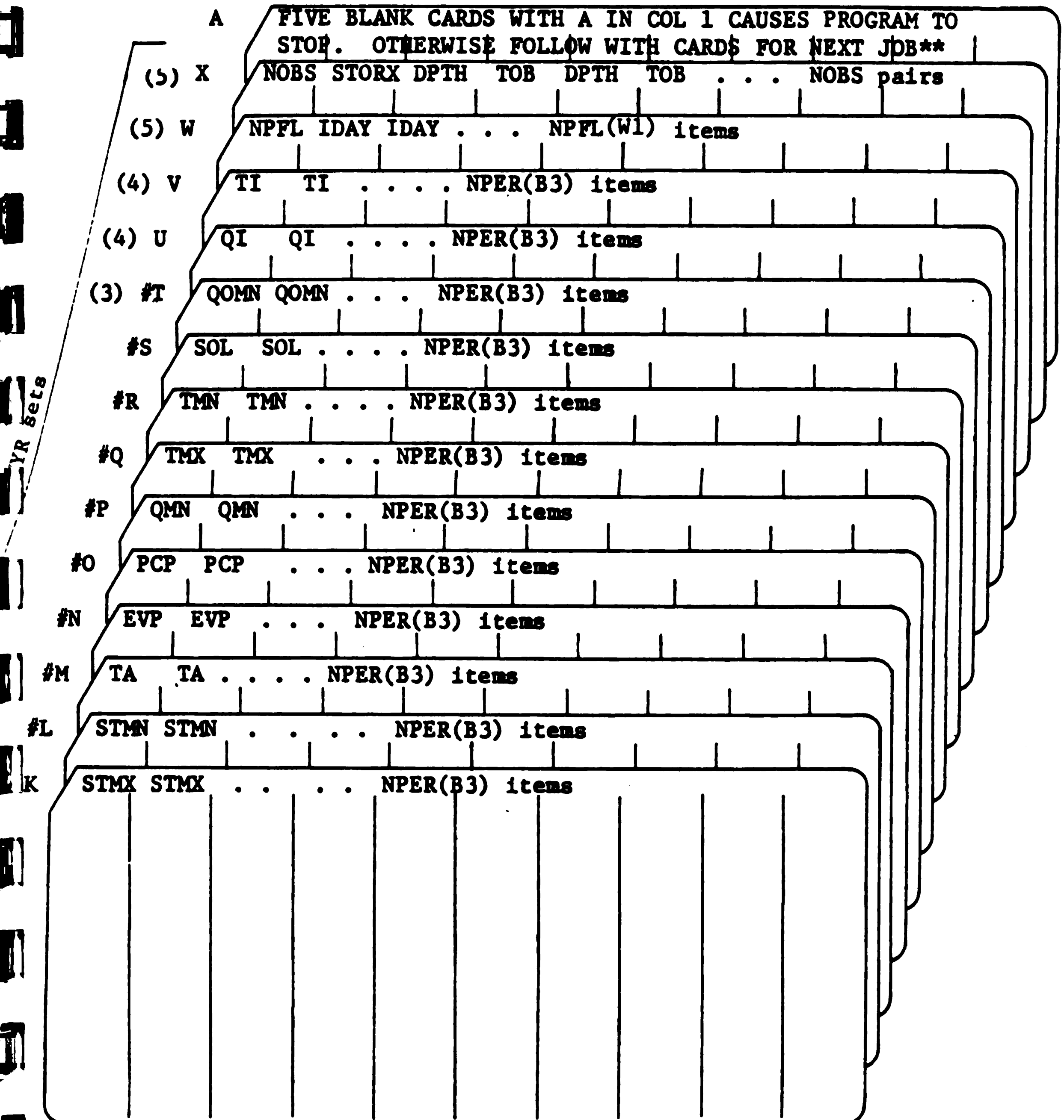
4. SUMMARY OF INPUT CARDS



Notes: (1) Repeat NOTL (B15) times

(2) Omit if NMINQ (B9) is zero

* -1 for any of these items will call for monthly data that is the same for all years. -2 will call for different monthly data every year.



Notes: (3) Omit if NMINQ(B9) is equal to zero, otherwise repeat a number of times equal to the number of QOMIN values (F card) that are equal to -1 or -2.

(4) Use local inflows and local inflow temperatures for a downstream reservoir in a tandem reservoir system. Repeat NIC(B13) times.

(5) Omit if IDFRV(B10) is less than or equal to zero. Repeat the X card for each value of IDAY (W card).

\# Supplied in first year if corresponding index marked with * is -1 and supplied every year in same order if index is -2.

**NEXT JOB CAN BE NEXT RESERVOIR OF TANDEM RESERVOIR SYSTEM

107.

DEPARTMENT OF THE ARMY
SACRAMENTO DISTRICT, CORPS OF ENGINEERS
THE HYDROLOGIC ENGINEERING CENTER
609 2D STREET, DAVIS, CALIFORNIA 95616

SPKHE

8 February 1972

SUBJECT: HEC Computer Program 723-X6-L2410

780

US Bureau of Reclamation
ATTN: Jack Rowell
2800 Cottage Way
Sacramento, California 95825

ACTION
DATE:

1. The Reservoir Temperature Stratification computer program has been revised and a new source deck will be forwarded upon request. The old deck, identified by the date of November 1970 on the first card, should be discarded or marked superseded.

2. The new program contains some minor changes of the input requirements, a more refined routine for determination of the reservoir surface area, and the addition of an alternative method for making releases through multilevel intakes to meet downstream temperature criteria. Both methods for selection of intake level are discussed in paragraph 7f of the inclosed program description.

3. The new model has been verified at 13 lakes which have a wide variety of physical characteristics as shown in table 1. The calibration coefficients derived for the 13 lakes and the "least-square error" obtained in reproducing observed profiles are shown in table 2.

4. The use of the model for studying proposed lakes requires an estimate of the model calibration coefficients. A regional study of the model coefficients, using existing lakes with observed temperature profile data, is the best method for determining appropriate coefficients to use for proposed lakes or for existing lakes where temperature data do not exist. The difficulty of estimating the required coefficients accurately depends on the number of coefficients to be estimated and the amount of variability of the coefficients in a given region. Recent tests on the 13 lakes referenced in paragraph 3 have shown that the results of the basic model are not significantly affected by prespecifying .00 for the evaporation

coefficient and that the remaining calibration coefficients have less variation, as shown in table 3, when using this simplified version. However, regional studies should be conducted in the area where the model will be applied before conclusions are reached as to which version of the model will perform best. When the evaporation energy transfer function is eliminated (prespecifying .00 for its value), the radiation coefficient is used as an index of the net energy transfer effect of evaporation and radiation.

5. In many cases, there are little or no data available on temperature profiles in existing local reservoirs, therefore, generalized regional calibration coefficients have been developed. The regional values are given in table 4. The regional values should be used only as a last resort and may give results significantly less accurate than values derived at existing reservoirs in the region of interest.

FOR THE DISTRICT ENGINEER:

Leo R. Beard

LEO R. BEARD, Director
The Hydrologic Engineering Center

5 Incl
1. Prog Desc
2. Table 1
3. Table 2
4. Table 3
5. Table 4

TABLE 1

Lake Physical Characteristics
(at Full Pool)

Lake	State	Surface Area (Acres)	Depth (Feet)	Capacity (Thousand Ac-Ft)
Detroit	Oregon	3,700	370	470
Lookout Point	Oregon	4,340	235	480
Dorena	Oregon	2,340	125	130
Shasta	Calif.	29,800	490	4,550
Bullards Bar	Calif.	520	220	34
Englebright	Calif.	815	260	70
Folsom	Calif.	11,450	260	1,010
Pine Flat	Calif.	5,970	390	1,020
Lake Mead	Nevada	157,700	590	29,800
Milford	Kansas	32,300	105	1,160
Perry	Kansas	16,200	75	415
Pomme deTerre	Missouri	7,890	90	242
J. Percy Priest	Tenn.	14,200	85	390

TABLE 2

Calibration Coefficients*

Basic Model

Reservoir	Standard Error (°F)	Air Temperature	Inflow Mixing	Vertical Diffusion	Evaporation	Solar Radiation
Detroit	1.67	.81	.12	.04	.63	.19
Lookout Point	1.86	1.00	.07	.01	.00	.13
Dorena	2.25	.47	.52	.00	.34	.20
Shasta	1.09	1.00	.04	.01	.75	.17
Bullards Bar	3.84	1.00	.00	.03	.15	.18
Englebright	3.52	1.00	.02	.02	.07	.01
Folsom	1.14	1.00	.23	.02	.44	.22
Pine Flat	2.03	.96	.21	.01	.61	.36
Lake Mead	1.76	.86	.09	.04	.40	.23
Milford	2.38	1.00	.00	.27	.02	.16
Perry	2.96	1.00	.02	.00	.16	.17
Pomme deTerre	3.81	1.00	.00	.00	.29	.17
J. Percy Priest	3.83	.60	.01	.00	.32	.16

*Valid when using 10 meter depth of energy penetration for conduction, evaporation, and radiation and 4 computation intervals per month.

Incl 3

TABLE 3

Calibration Coefficients*

Simplified Model (4 Variables)

Reservoir	Standard Error (°F)	Air Temperature	Inflow Mixing	Vertical Diffusion	Evaporation **	Solar Radiation
Detroit	1.67	.79	.10	.04	.00	.04
Lookout Point	1.86	1.00	.07	.01	.00	.13
Dorena	2.41	.64	.39	.00	.00	.07
Shasta	1.24	1.00	.04	.01	.00	.01
Bullards Bar	3.91	1.00	.06	.03	.00	.17
Englebright	3.52	1.00	.07	.02	.00	.00
Folsom	1.22	1.00	.46	.01	.00	.04
Pine Flat	2.13	.85	.21	.01	.00	.18
Lake Mead	1.90	.80	.08	.04	.00	.07
Milford	2.37	1.00	.00	.09	.00	.15
Perry	2.87	1.00	.00	.00	.00	.10
Pomme deTerre	3.98	1.00	.00	.00	.00	.00
J. Percy Priest	4.05	.58	.00	.00	.00	.08

*Valid when using 10 meter depth of energy penetration for conduction, evaporation, and radiation and 4 computation intervals per month.

**Prespecified

Incl 4

TABLE 4

Regional Temperature Model Coefficients*

Air Temperature	=	1.00
Inflow mixing	=	.10
Vert. Diffusion	=	.02
Evaporation	=	.00

The radiation coefficient seems to be a linear function of latitude. A generalized relationship could be developed using .08 at 45° and .20 at 35° N. latitude.

*Valid when using 10 meter depth of energy penetration for conduction, evaporation, and radiation and 4 computation intervals per month.

Incl 5

TABLE B-1

PROGRAM KEAVG

```
      PROGRAM KEAVG(INPUT,OUTPUT,TAPE4)
      DIMENSION RH(12),EAPSI(10,9),WMPH(12),HS(12),CC(12),RS(12),
     +RFO(11),RF8(11),TA(12,94),XK(12,94),E(12,94),SHADE(12)
      DATA RH/76.,68.,63.,56.,51.,41.,34.,36.,40.,50.,64.,76./
      DATA(EAPSI(1,I),I=1,9)/.006,.010,.013,.018,.023,.029,.035,
     +.040,.044/,(EAPSI(2,I),I=1,9)/.008,.014,.023,.030,.037,.046,
     +.055,.064,.071/,(EAPSI(3,I),I=1,9)/.013,.024,.035,.048,.060,
     +.071,.084,.094,.107/,(EAPSI(4,I),I=1,9)/.017,.034,.054,.070,
     +.088,.106,.123,.141,.158/,(EAPSI(5,I),I=1,9)/.025,.050,.076,
     +.101,.127,.151,.177,.203,.229/,(EAPSI(6,I),I=1,9)/.036,.072,
     +.108,.144,.180,.215,.254,.290,.329/,(EAPSI(7,I),I=1,9)/.051,
     +.101,.153,.202,.254,.303,.354,.410,.460/,
     +(EAPSI(8,I),I=1,9)/.071,.140,.210,.280,.350,.422,.494,.562,
     +.650/,(EAPSI(9,I),I=1,9)/.097,.193,.290,.374,.485,.573,.640,
     +.720,.850/,(EAPSI(10,I),I=1,9)/.130,.258,.389,.520,.640,.750,
     +.950,1.20,1.35/
      DATA WMPH/6.8,7.1,7.4,7.3,7.1,7.0,5.7,5.1,5.9,6.2,6.1,6.1/
      DATA HS/157.,247.,378.,520.,621.,683.,681.,608.,481.,
     +329.,201.,136./
      DATA CC/6.6,6.4,6.2,5.3,4.4,3.1,1.2,1.7,2.0,4.0,6.0,6.9/
      DATA RS/.11,.09,.07,.07,.07,.06,.06,.07,.08,.10,.10,.11/
      DATA SHADE/.09,.08,.07,.06,.06,.06,.06,.06,.07,.08,.09,.10/
      DATA RFO/.74,.75,.76,.77,.78,.79,.80,.81,.825,.845,.865/
      DATA RF8/.864,.87,.877,.885,.893,.9,.908,.916,.923,.93,.938/
      NYR=56
  201 FORMAT(12F6.1)
      DO 200 II=1,NYR
      READ 201,(TA(I,II),I=1,12)
  200 CONTINUE
      DO 300 II=1,NYR
      DO 310 I=1,12
      IF(TA(I,II)-20.)2,2,3
    2 L=1
      GO TO 11
    3 IF(TA(I,II)-110.)4,5,5
    5 L=10
      GO TO 11
    4 DO 8 N=30,110,10
      IF(TA(I,II)-N)6,7,8
    8 CONTINUE
    7 L=N/10-1
      GO TO 11
    6 L=N/10-2
      GO TO 17
   11 IF(RH(I)-10.)9,9,10
    9 M=1
      GO TO 15
   10 DO 14 K=20,90,10
      IF(RH(I)-K)12,13,14
```

PROGRAM KEAVG

```
   14  CONTINUE
   13  M=K/10
   15  EA=EAPSI(L,M)
       GO TO 24
   12  M=K/10-1
       F=(RH(I)-(K-10))/10
       EA=EAPSI(L,M)+F*(EAPSI(L,M+1)-EAPSI(L,M))
       GO TO 24
   17  IF(RH(I)-10.)18,18,19
   18  M=1
       GO TO 20
   19  DO 23 K=20,90,10
       IF(RH(I)-K)21,22,23
   23  CONTINUE
   22  M=K/10
   20  F=(TA(I,II)-(N-10))/10
       EA=EAPSI(L,M)+F*(EAPSI(L+1,M)-EAPSI(L,M))
       GO TO 24
   21  M=K/10-1
       F=(RH(I)-(K-10))/10
       EA1=EAPSI(L,M)+F*(EAPSI(L,M+1)-EAPSI(L,M))
       EA2=EAPSI(L+1,M)+F*(EAPSI(L+1,M+1)-EAPSI(L+1,M))
       EA=EA1+((TA(I,II)-(N-10))/10)*(EA2-EA1)
   24  EA=EA*2.0357896
       DO 27 K=1,10
       IF(CC(I)-K)25,26,27
   25  RF1=RF0(K)+(CC(I)-(K-1))*(RF0(K+1)-RF0(K))
       RF2=RF8(K)+(CC(I)-(K-1))*(RF8(K+1)-RF8(K))
       RF=RF1+(EA/.8)*(RF2-RF1)
       GO TO 28
   26  RF=RF0(K+1)+(EA/.8)*(RF8(K+1)-RF0(K+1))
       GO TO 28
   27  CONTINUE
   28  ET=TA(I,II)
       DO 30 K=1,3
       IF(ET-20.)31,31,32
   31  B=.102
       CB=.533
       GO TO 50
   32  IF(ET-30.)33,33,34
   33  B=.157
       CB=-.610
       GO TO 50
   34  IF(ET-40.)35,35,36
   35  B=.211
       CB=-2.223
       GO TO 50
   36  IF(ET-50.)37,37,38
   37  B=.292
```

PROGRAM KEAVG

```
      CB=-5.525
      GO TO 50
  38  IF(ET-60.)39,39,40
  39  B=.404
      CB=-11.14
      GO TO 50
  40  IF(ET-70.)41,41,42
  41  B=.554
      CB=-20.17
      GO TO 50
  42  IF(ET-80.)43,43,44
  43  B=.744
      CB=-33.57
      GO TO 50
  44  IF(ET-90.)45,45,46
  45  B=.991
      CB=-53.34
      GO TO 50
  46  IF(ET-100.)47,47,48
  47  B=1.303
      CB=-81.57
      GO TO 50
  48  IF(ET-109.)49,49,49
  49  B=1.662
      CB=-117.49
  50  HNA=.97*RF*.0000000415*((TA(I,II)+460.)**4.)
      HNS=3.69*(1.-RS(I))*HS(I)*(1.-SHADE(I))
      HT=HNA+HNS
      XKT=15.7+(.26+B)*16.8*WMPH(I)
      FXKT=(XKT-15.7)/XKT
      ET1=(HT-1801.)/XKT
      ET2=.26*TA(I,II)/(.26+B)
      ET3=(EA*25.4-CB)/(.26+B)
      XM=ET1+FXKT*(ET2+ET3)
      XKT2=XKT/.051
      ET=((XKT2**2.+4.*XM*XKT2)**.5-XKT2)/2.
  30  CONTINUE
      XK(I,II)=XKT
      E(I,II)=ET
 310  CONTINUE
 300  CONTINUE
      DO 400 II=1,NYR
      WRITE (4,201)(XK(I,II),I=1,12)
      WRITE (4,201)(E(I,II),I=1,12)
 400  CONTINUE
      END
#EOR
#EOI
```

TABLE B-2

KEAVG: VARIABLE DESCRIPTION

RH - RELATIVE HUMIDITY - %

EAPSI - VAPOR PRESSURE - PSIA

WMPH - WIND SPEED - MPH

HS - SOLAR RADIATION - LY/DAY

CC - CLOUD COVER - TENTHS

RS - SOLAR REFLECTIVITY

RF - RADIATION FACTOR

TA - AIR TEMPERATURE - °F

XK - HEAT EXCHANGE COEFFICIENT - BTU/FT^2-DAY-°F

E - EQUILIBRIUM TEMPERATURE - °F

SHADE - SHADE FACTOR - % REDUCTION IN SOLAR RADIATION

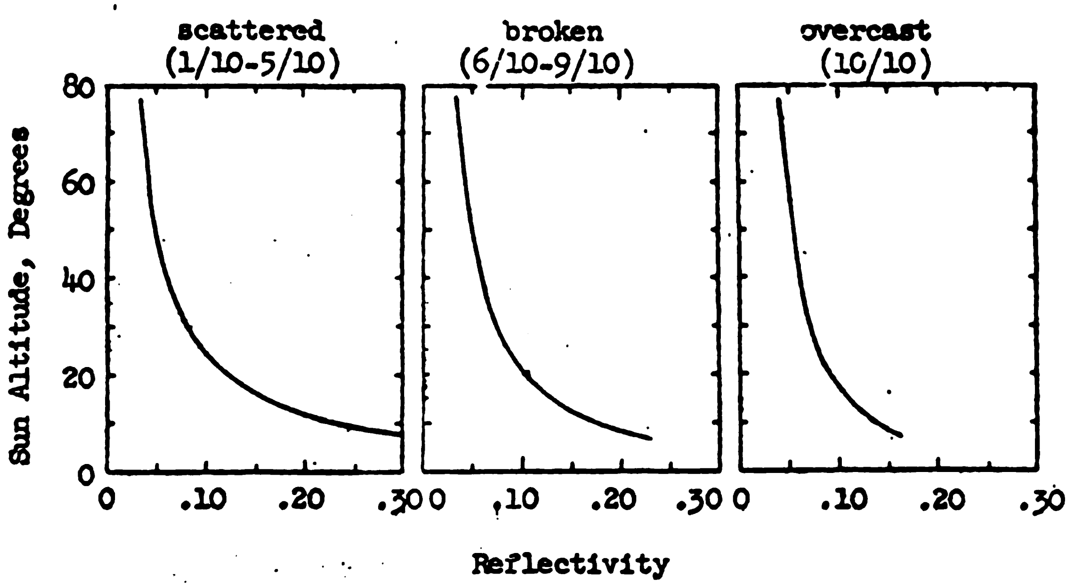
HNA - NET ATMOSPHERIC RADIATION

HNS - NET SOLAR RADIATION

FIGURE B-3
[FROM EDINGER AND GEYER (15)]

SHORTWAVE SOLAR REFLECTIVITY, R_s, FOR A WATER SURFACE

High Clouds



Low Clouds

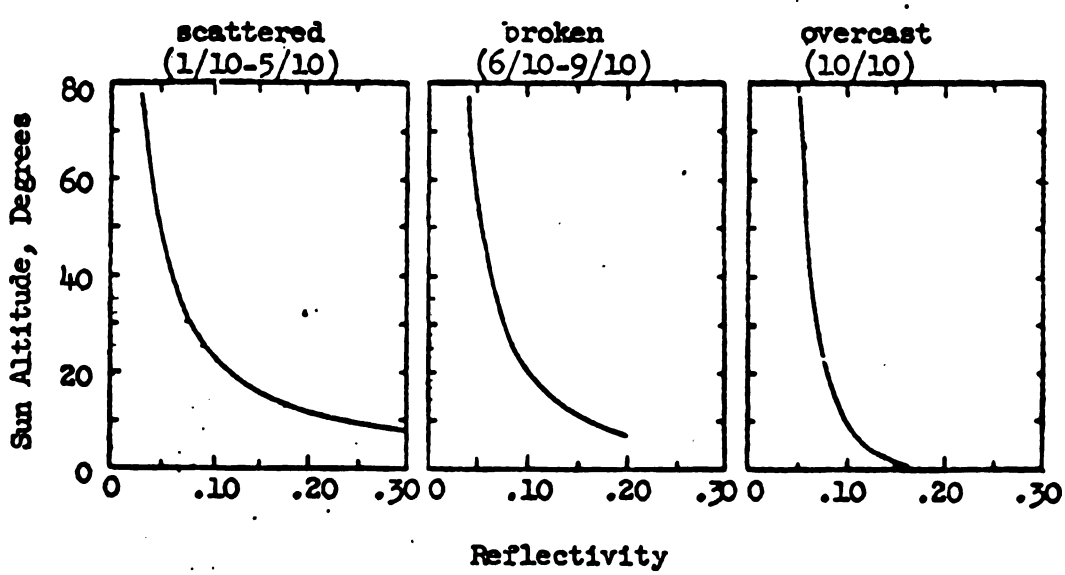


TABLE C-1

PROGRAM SACTEMP

```
      PROGRAM SACTEMP(INPUT,OUTPUT,TAPE11,TAPE21,TAPE22,TAPE23,TAPE24,
     +TAPE25,TAPE19,TAPE27,TAPE28,TAPE29,TAPE30,TAPE31,TAPE18,
     +TAPE33,TAPE20,TAPE34,TAPE35,TAPE36,TAPE37,TAPE38,TAPE39,
     +TAPE40,TAPE47,TAPE42,TAPE43,TAPE44,TAPE45,TAPE46,TAPE48)
      DIMENSION QSC(12,56),TSC(12,56),XKY1(12,56),EY1(12,56),QS(12,56),
     +TASC(12,56),FCONV(12),TCRIT(36),NTEMP(12,11,36),ATEMP(12,11),
     +IYR(56),NAME(11),TEMP(12,53,56),XMTEMP(12,11),XKY2(12,56),
     +EY2(12,56),CV(12,11),IAC58(12,56),IAC10(12,56),QCL(12,56),
     +TCL(12,56),ACL(2),DF(53),SA(6,52),IQCC(12,56),ITCC(12,56),
     +IGCID(12,56),ICBD(12,56),IAC15(12,56),IAC21(12,56),ITC(12,56),
     +IWS(12,56),IFS(12,56),TFR(12,56),QFR(12,56),TAR(12,56),
     +QAR(12,56),ISC(12,56),SCT(12),XKY3(12,56),EY3(12,56),XKY4(12,56),
     +EY4(12,56),TCOW(12),TCOTTON(12),TBATTLE(12),TPAYNES(12),
     +TANTLP1(12),TREDBK(12),TANTLP2(12),TELDER(12),TTHOMES(12),
     +TCHICO(12),TMILL(12),TDEER(12),TSTONY(12),TBUTTE(12),TSACSL(12)
      DATA FCONV/16.262,18.005,16.262,16.806,16.262,16.806,16.262,
     +16.262,16.806,16.262,16.806,16.262/
      DATA TCRIT/40.,41.,42.,43.,44.,45.,46.,47.,48.,49.,50.,
     +51.,52.,53.,54.,55.,56.,57.,58.,59.,60.,61.,62.,63.,64.,
     +65.,66.,67.,68.,69.,70.,71.,72.,73.,74.,75./
      DATA ACL/.64416,2.19648/
      DATA DF/.000,.017,.000,.010,.000,.012,.014,.038,.032,.325,
     +.028,.022,.037,.000,.207,.029,.000,.062,.029,.030,.039,.000,
     +.069,.000,.150,.046,.107,.158,.000,.025,.144,.080,.000,.091,
     +.199,.000,.000,.461,.079,.000,.411,.049,.000,.673,.000,
     +.220,.036,.036,.035,.000,.000,.000,.000/
      DATA TCOW/44.3,48.3,52.4,57.7,65.5,74.0,81.0,79.6,73.5,
     +62.3,52.3,44.9/
      DATA TCOTTON/46.0,48.8,53.1,59.0,67.4,73.3,76.8,75.0,69.4,
     +62.4,52.6,46.6/
      DATA TBATTLE/45.2,47.3,49.4,52.2,57.2,61.1,64.3,62.9,58.9,
     +53.9,49.4,45.7/
      DATA TPAYNES/46.4,48.2,53.6,59.0,62.6,71.6,71.6,71.6,69.8,
     +64.4,51.8,48.2/
      DATA TREDBK/48.2,48.2,53.6,53.6,66.2,75.2,75.2,78.8,71.6,
     +62.6,51.8,51.8/
      DATA TANTLP1/42.8,46.4,48.2,53.6,59.0,68.0,75.2,78.8,71.6,
     +62.6,50.0,44.6/
      DATA TANTLP2/44.6,48.2,51.8,57.2,62.6,71.6,73.4,75.2,69.8,
     +62.6,55.4,46.4/
      DATA TELDER/46.4,48.2,53.6,60.8,69.8,78.8,80.6,78.8,77.0,
     +60.8,53.6,50.0/
      DATA TMILL/44.6,44.6,48.2,53.6,57.2,64.4,73.4,78.8,71.6,
     +62.6,51.8,46.4/
      DATA TTHOMES/41.5,44.7,47.1,50.4,58.5,69.6,78.4,77.8,71.7,
     +61.6,49.0,43.3/
      DATA TDEER/41.2,45.0,48.7,54.7,61.8,69.0,76.2,73.9,70.2,
     +58.8,49.3,43.6/
      DATA TCHICO/42.8,48.2,50.0,57.2,60.8,69.8,75.2,75.2,69.8,
```

PROGRAM SACTEMP

```
     +59.0,51.8,44.6/
      DATA TSTONY/45.6,48.5,52.9,56.8,61.9,68.2,73.6,76.8,72.7,
     +64.5,54.3,47.5/
      DATA TBUTTE/42.1,44.5,46.0,49.2,54.5,61.5,67.1,66.0,61.3,
     +54.4,47.3,42.8/
      DATA TSACSL/44.6,50.0,55.4,66.2,69.8,75.2,75.2,75.2,69.8,
     +60.8,51.8,46.4/
      NYR=56

C           READ TEMPERATURE AND FLOW DATA

   11 FORMAT(1X,11A10/)
    5 FORMAT(12F7.0)
 101  FORMAT(8X,6F8.2)
  105 FORMAT(14X,12I6)
  106 FORMAT(32X,9I6)
  107 FORMAT(14X,3I6)
  373 FORMAT(1X,I5,2X,12F9.1)
      DO 10 N=1,NYR
      READ(22,373)(IYR(N),(TASC(I,N),I=1,12))
      READ(24,373)(IYR(N),(TSC(I,N),I=1,12))
      READ(28,373)(IYR(N),(TCL(I,N),I=1,12))
      READ(42,373)(IYR(N),(TFR(I,N),I=1,12))
      READ(45,373)(IYR(N),(TAR(I,N),I=1,12))
   10 CONTINUE
      READ(27,11)(NAME(I),I=1,11)
      DO 20 N=1,NYR
      READ(23,5)(QS(I,N),I=1,12)
      READ(25,5)(QSC(I,N),I=1,12)
      READ(29,5)(QCL(I,N),I=1,12)
      READ(43,5)(QFR(I,N),I=1,12)
      READ(46,5)(QAR(I,N),I=1,12)
   20 CONTINUE
      READ(31,106)(IAC58(I,1),I=1,9)
      READ(33,106)(IAC10(I,1),I=1,9)
      READ(30,106)(IQCC(I,1),I=1,9)
      READ(35,106)(ITCC(I,1),I=1,9)
      READ(36,106)(IGCID(I,1),I=1,9)
      READ(37,106)(IFS(I,1),I=1,9)
      READ(38,106)(IAC15(I,1),I=1,9)
      READ(39,106)(IWS(I,1),I=1,9)
      READ(40,106)(ICBD(I,1),I=1,9)
      READ(44,106)(IAC21(I,1),I=1,9)
      READ(47,106)(ITC(I,1),I=1,9)
      READ(48,106)(ISC(I,1),I=1,9)
      DO 120 N=2,56
      READ(31,105)((IAC58(I,N-1),I=10,12),(IAC58(I,N),I=1,9))
      READ(33,105)((IAC10(I,N-1),I=10,12),(IAC10(I,N),I=1,9))
      READ(30,105)((IQCC(I,N-1),I=10,12),(IQCC(I,N),I=1,9))
```

PROGRAM SACTEMP

```
      READ(35,105)((ITCC(I,N-1),I=10,12),(ITCC(I,N),I=1,9))
      READ(36,105)((IGCID(I,N-1),I=10,12),(IGCID(I,N),I=1,9))
      READ(37,105)((IFS(I,N-1),I=10,12),(IFS(I,N),I=1,9))
      READ(38,105)((IAC15(I,N-1),I=10,12),(IAC15(I,N),I=1,9))
      READ(39,105)((IWS(I,N-1),I=10,12),(IWS(I,N),I=1,9))
      READ(40,105)((ICBD(I,N-1),I=10,12),(ICBD(I,N),I=1,9))
      READ(44,105)((IAC21(I,N-1),I=10,12),(IAC21(I,N),I=1,9))
      READ(47,105)((ITC(I,N-1),I=10,12),(ITC(I,N),I=1,9))
      READ(48,105)((ISC(I,N-1),I=10,12),(ISC(I,N),I=1,9))
  120 CONTINUE
      READ(31,107)(IAC58(I,56),I=10,12)
      READ(33,107)(IAC10(I,56),I=10,12)
      READ(30,107)(IQCC(I,56),I=10,12)
      READ(35,107)(ITCC(I,56),I=10,12)
      READ(36,107)(IGCID(I,56),I=10,12)
      READ(37,107)(IFS(I,56),I=10,12)
      READ(38,107)(IAC15(I,56),I=10,12)
      READ(39,107)(IWS(I,56),I=10,12)
      READ(40,107)(ICBD(I,56),I=10,12)
      READ(44,107)(IAC21(I,56),I=10,12)
      READ(47,107)(ITC(I,56),I=10,12)
      READ(48,107)(ISC(I,56),I=10,12)
      DO 121 J=1,52
      READ(34,101)(SA(K,J),K=1,6)
 121  CONTINUE

C                 READ YEARLY K AND E VALUES

 602  FORMAT(12F6.1)
      DO 610 N=1,NYR
      READ(21,602)(XKY1(I,N),I=1,12)
      READ(21,602)(EY1(I,N),I=1,12)
      READ(18,602)(XKY2(I,N),I=1,12)
      READ(18,602)(EY2(I,N),I=1,12)
      READ(19,602)(XKY3(I,N),I=1,12)
      READ(19,602)(EY3(I,N),I=1,12)
      READ(20,602)(XKY4(I,N),I=1,12)
      READ(20,602)(EY4(I,N),I=1,12)
 610  CONTINUE

C          COMPUTE RIVER TEMPERATURES

      DO 200 N=1,NYR
      DO 100 I=1,12
      QBAT=12.
      IAC58(I,N)=IAC58(I,N)-12
      IF(IAC58(I,N).GE.0)GO TO 22
      QBAT=12.+IAC58(I,N)
      IAC58(I,N)=0
```

PROGRAM SACTEMP

```
 22  TEMP(I,1,N)=(TASC(I,N)*QS(I,N)+TSC(I,N)*QSC(I,N))/(QS(I,N)+
    +QSC(I,N))
     Q=QS(I,N)+QSC(I,N)
     TI=TEMP(I,1,N)
     DO 300 J=2,53
  1  IF(Q-2000.)32,32,3
 32  A=SA(1,J-1)*(Q/2000.)
     GO TO 15
  3  IF(Q-4000.)4,4,35
  4  A=SA(1,J-1)+(SA(2,J-1)-SA(1,J-1))*((Q-2000.)/2000.)
     GO TO 15
 35  IF(Q-6000.)6,6,7
  6  A=SA(2,J-1)+(SA(3,J-1)-SA(2,J-1))*((Q-4000.)/2000.)
     GO TO 15
  7  IF(Q-8000.)8,8,9
  8  A=SA(3,J-1)+(SA(4,J-1)-SA(3,J-1))*((Q-6000.)/2000.)
     GO TO 15
  9  IF(Q-10000.)31,31,14
 31  A=SA(4,J-1)+(SA(5,J-1)-SA(4,J-1))*((Q-8000.)/2000.)
     GO TO 15
 14  IF(Q-25000.)12,12,12
 12  A=SA(5,J-1)+(SA(6,J-1)-SA(5,J-1))*((Q-10000.)/15000.)
 15  IF(J.GT.15)GO TO 17
     E=EY1(I,N)
     XK=XKY1(I,N)
     GO TO 18
 17  IF(J.GT.36)GO TO 19
     E=EY2(I,N)
     XK=XKY2(I,N)
     GO TO 18
 19  IF(J.GT.41)GO TO 16
     E=EY3(I,N)
     XK=XKY3(I,N)
     GO TO 18
 16  E=EY4(I,N)
     XK=XKY4(I,N)
 18  TF=(TI-E)*2.7183**(-XK*A/(5.39136*Q))+E
     IF(J.EQ.7)GO TO 51
     IF(J.EQ.14)GO TO 52
     IF(J.EQ.15)GO TO 53
     IF(J-16)49,54,48
 48  IF(J-24)54,55,47
 47  IF(J-26)56,56,46
 46  IF(J-33)156,57,45
156  IF(J.EQ.29)GO TO 69
     GO TO 56
 45  IF(J-37)158,58,44
158  IF(J.EQ.36)GO TO 72
     GO TO 58
```

PROGRAM SACTEMP

```
 44   IF(J.EQ.38)GO TO 62
      IF(J.EQ.39)GO TO 62
      IF(J.EQ.40)GO TO 61
      IF(J.EQ.41)GO TO 62
      IF(J.EQ.42)GO TO 62
      IF(J.EQ.43)GO TO 64
      IF(J.EQ.44)GO TO 65
      IF(J.EQ.45)GO TO 66
      IF(J-49)67,67,43
 43   IF(J.EQ.50)GO TO 68
      IF(J.GT.50)GO TO 67
 49   QAC=IAC58(I,N)*FCONV(I)*DF(J)
      TAC=TCOW(I)
      IF(J.EQ.13)TAC=TCOTTON(I)
      TI=(TF*Q+TAC*QAC)/(Q+QAC)
      Q=Q+QAC
      GO TO 30
 51   K=1
      TCLEAR=TCL(I,N)
      QCLEAR=QCL(I,N)
      IF(QCLEAR.EQ.0.)QCLEAR=1.
151   TCLEAR=(TCLEAR-EY1(I,N))*2.7183**(-XKY1(I,N)*ACL(K)/(5.39136*
     +QCLEAR))+EY1(I,N)
      IF(K.EQ.2)GO TO 152
      TAC=TCOTTON(I)
      QAC=IAC58(I,N)*FCONV(I)*DF(J)
      QCLEAR=QCL(I,N)+QAC
      IF(QCLEAR.EQ.0.)QCLEAR=1.
      TCLEAR=(TCLEAR*QCL(I,N)+TAC*QAC)/QCLEAR
      K=2
      GO TO 151
152   QAC=QCL(I,N)+QAC
      TI=(TF*Q+TCLEAR*QAC)/(Q+QAC)
      Q=Q+QAC
      GO TO 30
 52   QAC=IQCC(I,N)*FCONV(I)
      TI=(TF*Q+TCOTTON(I)*QAC)/(Q+QAC)
      Q=Q+QAC
      GO TO 30
 53   QAC=IAC58(I,N)*FCONV(I)*DF(J)+QBAT*FCONV(I)
      TI=(TF*Q+TBATTLE(I)*QAC)/(Q+QAC)
      Q=Q+QAC
      GO TO 30
 54   QAC=IAC58(I,N)*FCONV(I)*DF(J)
      TAC=TPAYNES(I)
      IF(J.GT.18)TAC=TANTLP1(I)
      IF(J.EQ.23)TAC=TREDBK(I)
 71   TI=(TF*Q+TAC*QAC)/(Q+QAC)
      Q=Q+QAC
```

PROGRAM SACTEMP

```
      GO TO 30
  55  TI=TF
      Q=Q-(ITCC(I,N)*FCONV(I))
      GO TO 30
  56  QAC=IAC10(I,N)*FCONV(I)*DF(J)
      IF(QAC.EQ.0.)QAC=1.
      TAC=TANTLP2(I)
      IF(J.EQ.27)TAC=TELDER(I)
      IF(J.EQ.28)TAC=TMILL(I)
      IF(J.EQ.30)TAC=TDEER(I)
      IF(J.EQ.31)TAC=TDEER(I)
      IF(J.EQ.32)GO TO 169
      GO TO 71
  69  QAC=ITC(I,N)*FCONV(I)
      IF(QAC.EQ.0.)GO TO 71
 169  TAC=(TTHOMES(I)-EY2(I,N))*2.7183**(-XKY2(I,N)*4.752/
     +(5.39136*QAC))+EY2(I,N)
      GO TO 71
  57  TI=TF
      Q=Q-(IGCID(I,N)*FCONV(I))
      GO TO 30
  58  QAC=IAC10(I,N)*FCONV(I)*DF(J)
      TI=(TF*Q+TCHICO(I)*QAC)/(Q+QAC)
      Q=Q+QAC
      GO TO 30
  72  QAC=ISC(I,N)*FCONV(I)
      IF(QAC.EQ.0.)GO TO 71
      TAC=(TSTONY(I)-EY2(I,N))*2.7183**(-XKY2(I,N)*6.336/
     +(5.39136*QAC))+EY2(I,N)
      TI=(TF*Q+TAC*QAC)/(Q+QAC)
      Q=Q+QAC
      GO TO 30
  29  TI=(TF*Q+EY3(I,N)*QAC)/(Q+QAC)
      Q=Q+QAC
      GO TO 30
  62  QAC=IAC15(I,N)*FCONV(I)*DF(J)
      IF(J.EQ.38)GO TO 138
      IF(J.EQ.42)GO TO 130
      GO TO 29
 138  IF(QAC.EQ.0.)GO TO 71
      TAC=(TBUTTE(I)-EY3(I,N))*2.7183**(-XKY3(I,N)*21.12/
     +(5.39136*QAC))+EY3(I,N)
      GO TO 71
  61  TI=TF
      Q=Q-(IWS(I,N)*FCONV(I))
      GO TO 30
  64  QAC=ICBD(I,N)*FCONV(I)
      GO TO 130
  65  Q=Q-(IFS(I,N)*FCONV(I))
```

PROGRAM SACTEMP

```
      TAC=TSACSL(I)
      GO TO 67
   66 QAC=QFR(I,N)
      TI=(TF*Q+TFR(I,N)*QFR(I,N))/(Q+QAC)
      Q=Q+QAC
      GO TO 30
   67 QAC=IAC21(I,N)*FCONV(I)*DF(J)
      IF(J.EQ.44)GO TO 71
  129 TI=(TF*Q+EY4(I,N)*QAC)/(Q+QAC)
      Q=Q+QAC
      GO TO 30
  130 TAC=1.01671534*EY4(I,N)-1.408196057
      GO TO 71
   68 QAC=QAR(I,N)
      TI=(TF*Q+TAR(I,N)*QAR(I,N))/(Q+QAC)
      Q=Q+QAC
   30 TEMP(I,J,N)=TI
  300 CONTINUE
  100 CONTINUE
  200 CONTINUE
C             PRINT RIVER TEMPERATURE TABLES

  475 FORMAT(35X,*MONTHLY MEAN TEMPERATURES AT*,1X,A10)
  485 FORMAT(20X,*MONTHLY MEAN TEMPERATURES AT*,1X,A10)
  376 FORMAT(/2X,*YEAR*,9X,*J*,8X,*F*,8X,*M*,8X,*A*,8X,*M*,8X,
     1*J*,8X,*J*,8X,*A*,8X,*S*,8X,*O*,8X,*N*,8X,*D*/)
    2 FORMAT(///)
  479 FORMAT(/2X,*AVG*,3X,12F9.1)
      K=0
      DO 800 L=1,53
      IF(L.EQ.1)GO TO 410
      IF(L.EQ.14)GO TO 410
      IF(L.EQ.17)GO TO 410
      IF(L.EQ.24)GO TO 410
      IF(L.EQ.33)GO TO 410
      IF(L.EQ.37)GO TO 410
      IF(L.EQ.40)GO TO 410
      IF(L.EQ.43)GO TO 410
      IF(L.EQ.45)GO TO 410
      IF(L.EQ.50)GO TO 410
      IF(L.EQ.53)GO TO 410
      GO TO 800
  410 K=K+1
      DO 450 N=1,NYR
      IF(N.GT.1)GO TO 474
      PRINT 508
      WRITE(11,508)
      PRINT 475, NAME(K)
      WRITE(11,475)(NAME(K))
```

PROGRAM SACTEMP

```
      PRINT 376
      WRITE(11,376)
  474 PRINT 373,(IYR(N),(TEMP(I,L,N),I=1,12))
      WRITE(11,373)(IYR(N),(TEMP(I,L,N),I=1,12))
  450 CONTINUE
      DO 477 I=1,12
      ATEM=0.
      DO 478 N=1,NYR
      ATEM=TEMP(I,L,N)+ATEM
  478 CONTINUE
      ATEMP(I,K)=ATEM/NYR
  477 CONTINUE
      PRINT 479,(ATEMP(I,K),I=1,12)
      WRITE(11,479)(ATEMP(I,K),I=1,12)

C                   COMPUTE MEDIAN TEMPERATURES

  579 FORMAT(2X,*MED*,3X,12F9.1)
      DO 577 I=1,12
      DO 578 N=1,NYR
      NG=0
      NS=0
      NL=0
      DO 601 M=1,NYR
      IF(TEMP(I,L,N)-TEMP(I,L,M))702,603,604
  702 NG=NG+1
      GO TO 601
  603 NS=NS+1
      GO TO 601
  604 NL=NL+1
  601 CONTINUE
      IF(NS.GT.NYR/2)GO TO 710
      IF(NL.EQ.NG)GO TO 710
      IF(NL.EQ.NG+1)GO TO 710
      IF(NS.GE.IABS(NG-NL))GO TO 710
  578 CONTINUE
      XMTEMP(I,K)=0.
      GO TO 577
  710 XMTEMP(I,K)=TEMP(I,L,N)
  577 CONTINUE
      PRINT 579,(XMTEMP(I,K),I=1,12)
      WRITE(11,579)(XMTEMP(I,K),I=1,12)

C                          COMPUTE COEFFICIENT OF VARIATION

  679 FORMAT(2X,*C.VAR*,1X,12F9.3)
      DO 670 I=1,12
      SD=0.
      DO 680 N=1,NYR
```

PROGRAM SACTEMP

```
      SD=SD+(ABS(TEMP(I,L,N)-ATEMP(I,K)))**2.
 680  CONTINUE
      CV(I,K)=((SD/NYR)**.5)/ATEMP(I,K)
 670  CONTINUE
      PRINT 679,(CV(I,K),I=1,12)
      WRITE(11,679)(CV(I,K),I=1,12)
 800  CONTINUE
C            PRINT TEMPERATURE EXCEEDANCE TABLES
 508  FORMAT(////35X,*5-AGENCY STUDIES: DWR #144C (SALMON) *
     +*-1990 LEVEL   *)
 518  FORMAT(////20X,*5-AGENCY STUDIES: DWR #144C (SALMON) *
     +*-1990 LEVEL   *)
 507  FORMAT(6X,*TEMPERATURE EXCEEDANCE - NO. OF YEARS IN 56 YR STUDY*
     +*(1922-77)*)
 513  FORMAT(21X,*EXCEEDING INDICATED TEMPERATURE*)
 509  FORMAT(/2X,*TEMP-F*,8X,*J*,4X,*F*,4X,*M*,4X,*A*,4X,*M*,4X,
     +*J*,4X,*J*,4X,*A*,4X,*S*,4X,*O*,4X,*N*,4X,*D*/)
 511  FORMAT(3X,F4.1,5X,12I5)
      KK=0
      DO 900 L=1,53
      IF(L.EQ.1)GO TO 510
      IF(L.EQ.14)GO TO 510
      IF(L.EQ.17)GO TO 510
      IF(L.EQ.24)GO TO 510
      IF(L.EQ.33)GO TO 510
      IF(L.EQ.37)GO TO 510
      IF(L.EQ.40)GO TO 510
      IF(L.EQ.43)GO TO 510
      IF(L.EQ.45)GO TO 510
      IF(L.EQ.50)GO TO 510
      IF(L.EQ.53)GO TO 510
      GO TO 900
 510  KK=KK+1
      DO 70 I=1,12
      DO 80 K=1,36
      NTEMP(I,KK,K)=0
      DO 90 N=1,NYR
      IF(TEMP(I,L,N).LE.TCRIT(K))GO TO 90
      NTEMP(I,KK,K)=NTEMP(I,KK,K)+1
  90  CONTINUE
  80  CONTINUE
  70  CONTINUE
      PRINT 518
      PRINT 485,NAME(KK)
      PRINT 507
      PRINT 513
      PRINT 509
```

PROGRAM SACTEMP

```
      DO 550 K=1,36
      PRINT 511,(TCRIT(K),(NTEMP(I,KK,K),I=1,12))
  550 CONTINUE
      PRINT 2
  900 CONTINUE
      END
#EOR
#EOI
```

TABLE C-2

PROGRAM FEATEMP

```
      PROGRAM FEATEMP(INPUT,OUTPUT,TAPE51,TAPE20,TAPE53,TAPE54,
     +TAPE50,TAPE52,TAPE55,TAPE56,TAPE57,TAPE58,TAPE27,TAPE21,TAPE11,
     +TAPE42,TAPE43)
      DIMENSION IQTD(12,56),TOD(12,56),XKY2(12,56),EY2(12,56),
     +TTAB(12,56),FCONV(12),TCRIT(36),NTEMP(12,12,36),ATEMP(12,12),
     +IYR(56),NAME(12),TEMP(12,12,56),XMTEMP(12,12),RM(12),IQTAB(12,56),
     +CV(12,12),QOD(12,56),IQD13(12,56),IQR13(12,56),IQKR(12,56),
     +QCC(24,21),WCC(24,21),CC(24),TY(12),IQ56(12,56),XKY1(12,56),
     +EY1(12,56),QFR(12,56)
      DATA FCONV/16.262,18.005,16.262,16.806,16.262,16.806,16.262,
     +16.262,16.806,16.262,16.806,16.262/
      DATA TCRIT/40.,41.,42.,43.,44.,45.,46.,47.,48.,49.,50.,
     +51.,52.,53.,54.,55.,56.,57.,58.,59.,60.,61.,62.,63.,64.,
     +65.,66.,67.,68.,69.,70.,71.,72.,73.,74.,75./
      DATA RM/0.0,0.0,67.9,67.3,59.0,50.8,44.0,27.7,12.4,9.3,7.4,0.0/
      DATA TY/46.5,47.6,50.3,53.3,59.7,65.4,69.1,66.3,64.6,
     +60.1,50.8,47.6/
      NYR=56
      F1=.022
      F2=.836
      F3=.142

C           READ TEMPERATURE AND FLOW DATA

   11 FORMAT(1X,12A10/)
  108 FORMAT(F8.2,2F8.0)
    5 FORMAT(12F7.0)
  105 FORMAT(14X,12I6)
  106 FORMAT(32X,9I6)
  107 FORMAT(14X,3I6)
  373 FORMAT(1X,I5,2X,12F9.1)
      DO 4 K=1,18
      DO 3 L=1,21
      READ(58,108)(CC(K),QCC(K,L),WCC(K,L))
    3 CONTINUE
    4 CONTINUE
      DO 10 N=1,NYR
      READ(50,373)(IYR(N),(TOD(I,N),I=1,12))
      READ(51,5)(QOD(I,N),I=1,12)
   10 CONTINUE
      READ(27,11)(NAME(I),I=1,12)
      READ(52,106)(IQKR(I,1),I=1,9)
      READ(53,106)(IQTD(I,1),I=1,9)
      READ(54,106)(IQTAB(I,1),I=1,9)
      READ(55,106)(IQ56(I,1),I=1,9)
      READ(56,106)(IQD13(I,1),I=1,9)
      READ(57,106)(IQR13(I,1),I=1,9)
      DO 120 N=2,56
      READ(52,105)((IQKR(I,N-1),I=10,12),(IQKR(I,N),I=1,9))
```

PROGRAM FEATEMP

```
      READ(53,105)((IQTD(I,N-1),I=10,12),(IQTD(I,N),I=1,9))
      READ(54,105)((IQTAB(I,N-1),I=10,12),(IQTAB(I,N),I=1,9))
      READ(55,105)((IQ56(I,N-1),I=10,12),(IQ56(I,N),I=1,9))
      READ(56,105)((IQD13(I,N-1),I=10,12),(IQD13(I,N),I=1,9))
      READ(57,105)((IQR13(I,N-1),I=10,12),(IQR13(I,N),I=1,9))
  120 CONTINUE
      READ(52,107)(IQKR(I,56),I=10,12)
      READ(53,107)(IQTD(I,56),I=10,12)
      READ(54,107)(IQTAB(I,56),I=10,12)
      READ(55,107)(IQ56(I,56),I=10,12)
      READ(56,107)(IQD13(I,56),I=10,12)
      READ(57,107)(IQR13(I,56),I=10,12)

C                 READ YEARLY K AND E VALUES

  602 FORMAT(12F6.1)
      DO 610 N=1,NYR
      READ(20,602)(XKY1(I,N),I=1,12)
      READ(20,602)(EY1(I,N),I=1,12)
      READ(21,602)(XKY2(I,N),I=1,12)
      READ(21,602)(EY2(I,N),I=1,12)
  610 CONTINUE

C           COMPUTE RIVER TEMPERATURES

      DO 200 N=1,NYR
      DO 100 I=1,12
      TEMP(I,1,N)=TOD(I,N)
      Q=QOD(I,N)+FCONV(I)*IQKR(I,N)
      TI=(QOD(I,N)*TOD(I,N)+FCONV(I)*IQKR(I,N)*EY1(I,N))/Q
      TEMP(I,3,N)=(TI-EY1(I,N))*2.7183**(-2.5774*XKY1(I,N)/Q)+EY1(I,N)
      TI=TEMP(I,3,N)
      Q=IQTD(I,N)*FCONV(I)
      DO 30 J=4,12
      DO 40 K=1,18
      IF(RM(J-1).GT.CC(K))GO TO 41
   40 CONTINUE
   41 DO 85 M=1,2
      DO 50 L=1,21
      IF(Q-QCC(K-1,L))42,43,50
   50 CONTINUE
   43 W=WCC(K-1,L)
      GO TO 44
   42 W=WCC(K-1,L-1)+((Q-QCC(K-1,L-1))/(QCC(K-1,L)-QCC(K-1,L-1)))*
     +(WCC(K-1,L)-WCC(K-1,L-1))
   44 IF(M.EQ.1)W1=W
      IF(M.EQ.1)K=K+1
   85 CONTINUE
      K=K-1
```

PROGRAM FEATEMP

```
      W2=W
      W=W1+(W2-W1)*((CC(K-1)-RM(J-1))/(CC(K-1)-CC(K)))
      A=.5*(RM(J-1)-CC(K))*(W+W2)
      IF(RM(J)-CC(K))45,51,47
   47 W3=W1+(W2-W1)*((CC(K-1)-RM(J))/(CC(K-1)-CC(K)))
      A=.5*(RM(J-1)-RM(J))*(W+W3)
      GO TO 51
   45 DO 95 L=1,21
      IF(Q-QCC(K+1,L))61,62,95
   95 CONTINUE
   62 WK=WCC(K+1,L)
      GO TO 63
   61 WK=WCC(K+1,L-1)+((Q-QCC(K+1,L-1))/(QCC(K+1,L)-QCC(K+1,L-1)))*
     +(WCC(K+1,L)-WCC(K+1,L-1))
   63 IF(RM(J)-CC(K+1))64,65,66
   64 A=A+.5*(CC(K)-CC(K+1))*(W2+WK)
      K=K+1
      W2=WK
      GO TO 45
   65 A=A+.5*(CC(K)-CC(K+1))*(W2+WK)
      GO TO 51
   66 W3=W2+(WK-W2)*((CC(K)-RM(J))/(CC(K)-CC(K+1)))
      A=A+.5*(CC(K)-RM(J))*(W2+W3)
   51 IF(J.GT.6)GO TO 52
      TEMP(I,J,N)=(TI-EY1(I,N))*2.7183**(-XKY1(I,N)*A/
     +(1021.091*Q))+EY1(I,N)
      GO TO 53
   52 TEMP(I,J,N)=(TI-EY2(I,N))*2.7183**(-XKY2(I,N)*A/
     +(1021.091*Q))+EY2(I,N)
   53 IF(J.EQ.4)GO TO 71
      IF(J.EQ.5)GO TO 72
      IF(J.EQ.6)GO TO 71
      IF(J.EQ.7)GO TO 73
      IF(J.EQ.8)GO TO 74
      IF(J.EQ.9)GO TO 75
      IF(J.EQ.10)GO TO 77
   71 TI=TEMP(I,J,N)
      GO TO 30
   72 QFB=QOD(I,N)+FCONV(I)*(IQKR(I,N)-IQTD(I,N))
      TTAB(I,N)=(TEMP(I,3,N)-EY1(I,N))*2.7183**(-32.9163*XKY1(I,N)/
     +QFB)+EY1(I,N)
      TEMP(I,2,N)=TTAB(I,N)
      QTAB=IQTAB(I,N)*FCONV(I)
      TI=(TEMP(I,J,N)*Q+TTAB(I,N)*QTAB)/(Q+QTAB)
      Q=Q+QTAB
      GO TO 30
   73 QAC=IQ56(I,N)*FCONV(I)*F1
   78 TI=(TEMP(I,J,N)*Q+EY2(I,N)*QAC)/(Q+QAC)
      Q=Q+QAC
```

PROGRAM FEATEMP

```
      GO TO 30
   74 QAC=IQ56(I,N)*FCONV(I)*F2
      TI=(TEMP(I,J,N)*Q+TY(I)*QAC)/(Q+QAC)
      Q=Q+QAC-IQD13(I,N)*FCONV(I)
      GO TO 30
   75 QAC=IQ56(I,N)*FCONV(I)*F3
      GO TO 78
   77 QAC=IQR13(I,N)*FCONV(I)
      IF(QAC.LE.0.)GO TO 76
      GO TO 78
   76 Q=Q+QAC
      TI=TEMP(I,J,N)
   30 CONTINUE
      QFR(I,N)=Q
  100 CONTINUE
  200 CONTINUE

C           COMPUTE TEMPERATURE EXCEEDANCE

      DO 60 L=1,12
      DO 70 I=1,12
      DO 80 K=1,36
      NTEMP(I,L,K)=0
      DO 90 N=1,NYR
      IF(TEMP(I,L,N).LE.TCRIT(K))GO TO 90
      NTEMP(I,L,K)=NTEMP(I,L,K)+1
   90 CONTINUE
   80 CONTINUE
   70 CONTINUE
   60 CONTINUE

C             PRINT RIVER TEMPERATURE TABLES

  475 FORMAT(35X,*MONTHLY MEAN TEMPERATURES AT*,1X,A10)
  485 FORMAT(20X,*MONTHLY MEAN TEMPERATURES AT*,1X,A10)
  376 FORMAT(/2X,*YEAR*,9X,*J*,8X,*F*,8X,*M*,8X,*A*,8X,*M*,8X,
     1*J*,8X,*J*,8X,*A*,8X,*S*,8X,*O*,8X,*N*,8X,*D*/)
    2 FORMAT(///)
  479 FORMAT(/2X,*AVG*,3X,12F9.1)
      DO 400 L=1,12
      DO 450 N=1,NYR
      IF(N.GT.1)GO TO 474
      PRINT 508
      WRITE(11,508)
      PRINT 475, NAME(L)
      WRITE(11,475)(NAME(L))
      PRINT 376
      WRITE(11,376)
```

PROGRAM FEATEMP

```
 474  PRINT 373,(IYR(N),(TEMP(I,L,N),I=1,12))
      WRITE(11,373)(IYR(N),(TEMP(I,L,N),I=1,12))
 450  CONTINUE
      DO 477 I=1,12
      ATEM=0.
      DO 478 N=1,NYR
      ATEM=TEMP(I,L,N)+ATEM
 478  CONTINUE
      ATEMP(I,L)=ATEM/NYR
 477  CONTINUE
      PRINT 479,(ATEMP(I,L),I=1,12)

C                    COMPUTE MEDIAN TEMPERATURES

 579  FORMAT(2X,*MED*,3X,12F9.1)
      DO 577 I=1,12
      DO 578 N=1,NYR
      NG=0
      NS=0
      NL=0
      DO 601 M=1,NYR
      IF(TEMP(I,L,N)-TEMP(I,L,M))702,603,604
 702  NG=NG+1
      GO TO 601
 603  NS=NS+1
      GO TO 601
 604  NL=NL+1
 601  CONTINUE
      IF(NS.GT.NYR/2)GO TO 710
      IF(NL.EQ.NG)GO TO 710
      IF(NL.EQ.NG+1)GO TO 710
      IF(NS.GE.IABS(NG-NL))GO TO 710
 578  CONTINUE
      XMTEMP(I,L)=0.
      GO TO 577
 710  XMTEMP(I,L)=TEMP(I,L,N)
 577  CONTINUE
      PRINT 579,(XMTEMP(I,L),I=1,12)

C                    COMPUTE COEFFICIENT OF VARIATION

 679  FORMAT(2X,*C.VAR*,1X,12F9.3)
      DO 670 I=1,12
      SD=0.
      DO 680 N=1,NYR
      SD=SD+(ABS(TEMP(I,L,N)-ATEMP(I,L)))**2.
 680  CONTINUE
      CV(I,L)=((SD/NYR)**.5)/ATEMP(I,L)
 670  CONTINUE
```

PROGRAM FEATEMP

```
      PRINT 679,(CV(I,L),I=1,12)
 400  CONTINUE
      DO 410 N=1,NYR
      WRITE(42,373)(IYR(N),(TEMP(I,12,N),I=1,12))
      WRITE(43,5)(QFR(I,N),I=1,12)
 410  CONTINUE

C             PRINT TEMPERATURE EXCEEDANCE TABLES

 508  FORMAT(////35X,*5-AGENCY STUDIES: DWR # 75D (BASE)*
     +*-1990 LEVEL *)
 518  FORMAT(////20X,*5-AGENCY STUDIES: DWR # 75D (BASE)*
     +*-1990 LEVEL *)
 507  FORMAT(6X,*TEMPERATURE EXCEEDANCE - NO. OF YEARS IN 56 YR STUDY*
     +*(1922-77)*)
 513  FORMAT(21X,*EXCEEDING INDICATED TEMPERATURE*)
 509  FORMAT(/2X,*TEMP-F*,8X,*J*,4X,*F*,4X,*M*,4X,*A*,4X,*M*,4X,
     +*J*,4X,*J*,4X,*A*,4X,*S*,4X,*O*,4X,*N*,4X,*D*/)
 511  FORMAT(3X,F4.1,5X,12I5)
      DO 500 L=1,12
      PRINT 518
      PRINT 485,NAME(L)
      PRINT 507
      PRINT 513
      PRINT 509
      DO 550 K=1,36
      PRINT 511,(TCRIT(K),(NTEMP(I,L,K),I=1,12))
 550  CONTINUE
      PRINT 2
 500  CONTINUE
      END
#EOR
#EOI
```

TABLE C-3

PROGRAM NARTEM1

```
      PROGRAM NARTEMP(INPUT,OUTPUT,TAPE1,TAPE3,TAPE4,TAPE12,
     +TAPE2,TAPE6,TAPE45,TAPE46)
      DIMENSION RL(8),TNIM(12,84),XKY(12,84),EY(12,84),A(8),C(8),
     +FPDIV(12),QNIM(12,84),TCRIT(36),NTEMP(12,9,36),ATEMP(12,9),
     +IYR(84),NAME(9),TEMP(12,9,84),XMTEMP(12,9),FPDIV7(12),FPDIV8(12),
     +CV(12,9),FCONV(12),IQNIM(12,56),IQCAR(12,56),IQFP(12,56),
     +QAR(12,56)
      DATA RL/2.86,4.73,1.89,4.10,2.02,.75,4.58,2.01/
      DATA XK/77.8,94.9,110.5,136.,137.4,174.3,162.4,154.,133.8,
     +97.8,78.2,75.1/
      DATA E/45.9,52.5,57.2,62.1,69.4,74.5,78.4,77.1,73.5,64.9,53.9,
     +45.1/
      DATA A/102.516,-55.404,-55.404,252.912,190.912,190.912,
     +150.912,150.912/
      DATA C/67.242,88.702,88.702,30.044,30.044,
     +30.044,30.044,30.044/
      DATA FPDIV/244.,252.,276.,336.,423.,571.,
     +602.,602.,571.,325.,286.,244./
      DATA FPDIV/244.,252.,49.,67.,81.,118.,
     +114.,114.,118.,65.,67.,33./
      DATA FPDIV8/81.,90.,211.,269.,325.,454.,472.,472.,454.,
     +260.,218.,195./
      DATA TCRIT/40.,41.,42.,43.,44.,45.,46.,47.,48.,49.,50.,
     +51.,52.,53.,54.,55.,56.,57.,58.,59.,60.,61.,62.,63.,64.,65.,
     +66.,67.,68.,69.,70.,71.,72.,73.,74.,75./
      DATA FCONV/16.262,18.005,16.262,16.806,16.262,16.806,16.262,
     +16.262,16.806,16.262,16.806,16.262/
      C1=62.4
      C2=86400.
      NYR=56

C           READ NIMBUS TEMPERATURE AND FLOW DATA

   11 FORMAT(1X,9A10)
    5 FORMAT(12F7.0)
  373 FORMAT(1X,I5,2X,12F9.1)
 105  FORMAT(14X,12I6)
 106  FORMAT(32X,9I6)
 107  FORMAT(14X,3I6)
      READ 2
      DO 10 N=1,NYR
      READ 373,(IYR(N),(TNIM(I,N),I=1,12))
   10 CONTINUE
      READ(3,11)(NAME(I),I=1,9)
      READ(4,106)(IQNIM(I,1),I=1,9)
      READ(2,106)(IQCAR(I,1),I=1,9)
      READ(6,106)(IQFP(I,1),I=1,9)
      DO 20 N=2,NYR
      READ(4,105)((IQNIM(I,N-1),I=10,12),(IQNIM(I,N),I=1,9))
```

PROGRAM NARTEM1

```
      READ(2,105)((IQCAR(I,N-1),I=10,12),(IQCAR(I,N),I=1,9))
      READ(6,105)((IQFP(I,N-1),I=10,12),(IQFP(I,N),I=1,9))
   20 CONTINUE
      READ(4,107)(IQNIM(I,NYR),I=10,12)
      READ(2,107)(IQCAR(I,NYR),I=10,12)
      READ(6,107)(IQFP(I,NYR),I=10,12)

C                 READ YEARLY K AND E VALUES

  602 FORMAT(12F6.1)
      DO 610 N=1,NYR
      READ(1,602)(XKY(I,N),I=1,12)
      READ(1,602)(EY(I,N),I=1,12)
  610 CONTINUE

C          COMPUTE RIVER TEMPERATURES

      DO 200 N=1,NYR
      DO 100 I=1,12
      TEMP(I,1,N)=TNIM(I,N)
      TI=TNIM(I,N)
      DO 50 L=1,8
      IF(L.GT.2)GO TO 19
      FLOW=IQNIM(I,N)*FCONV(I)
      GO TO 18
   19 IF(L.GT.5)GO TO 21
      FLOW=(IQNIM(I,N)-IQCAR(I,N))*FCONV(I)
      GO TO 18
   21 FLOW=(IQNIM(I,N)-IQCAR(I,N)-IQFP(I,N))*FCONV(I)
   18 W=C(L)*ALOG10(FLOW)+A(L)
   22 ALPHA=-XKY(I,N)*W*RL(L)*5280/(C1*C2*FLOW)
      TF=(TI-EY(I,N))*2.7183**ALPHA+EY(I,N)
      TEMP(I,L+1,N)=TF
      TI=TF
   50 CONTINUE
      QAR(I,N)=FLOW
  100 CONTINUE
  200 CONTINUE
      DO 30 N=1,NYR
      WRITE(45,373)(IYR(N),(TEMP(I,9,N),I=1,12))
      WRITE(46,5)(QAR(I,N),I=1,12)
   30 CONTINUE

C          COMPUTE TEMPERATURE EXCEEDANCE

      DO 60 L=1,9
      DO 70 I=1,12
      DO 80 K=1,36
      NTEMP(I,L,K)=0
```

PROGRAM NARTEM1

```
      DO 90 N=1,NYR
      IF(TEMP(I,L,N).LE.TCRIT(K))GO TO 90
      NTEMP(I,L,K)=NTEMP(I,L,K)+1
   90 CONTINUE
   80 CONTINUE
   70 CONTINUE
   60 CONTINUE

C             PRINT RIVER TEMPERATURE TABLES

  475 FORMAT(35X,*MONTHLY MEAN TEMPERATURES AT*,1X,A10)
  485 FORMAT(20X,*MONTHLY MEAN TEMPERATURES AT*,1X,A10)
  376 FORMAT(/2X,*YEAR*,9X,*J*,8X,*F*,8X,*M*,8X,*A*,8X,*M*,8X,
     1*J*,8X,*J*,8X,*A*,8X,*S*,8X,*O*,8X,*N*,8X,*D*/)
    2 FORMAT(///)
  479 FORMAT(/2X,*AVG*,3X,12F9.1)
      DO 400 L=1,9
      DO 450 N=1,NYR
      IF(N.GT.1)GO TO 474
      PRINT 508
      WRITE(12,508)
      PRINT 475, NAME(L)
      WRITE(12,475)(NAME(L))
      PRINT 376
      WRITE(12,376)
  474 PRINT 373,(IYR(N),(TEMP(I,L,N),I=1,12))
      WRITE(12,373)(IYR(N),(TEMP(I,L,N),I=1,12))
  450 CONTINUE
      DO 477 I=1,12
      ATEM=0.
      DO 478 N=1,NYR
      ATEM=TEMP(I,L,N)+ATEM
  478 CONTINUE
      ATEMP(I,L)=ATEM/NYR
  477 CONTINUE
      PRINT 479,(ATEMP(I,L),I=1,12)

C                  COMPUTE MEDIAN TEMPERATURES

  579 FORMAT(2X,*MED*,3X,12F9.1)
      DO 577 I=1,12
      DO 578 N=1,NYR
      NG=0
      NS=0
      NL=0
      DO 601 M=1,NYR
      IF(TEMP(I,L,N)-TEMP(I,L,M))702,603,604
  702 NG=NG+1
      GO TO 601
```

PROGRAM NARTEM1

```
 603   NS=NS+1
       GO TO 601
 604   NL=NL+1
 601   CONTINUE
       IF(NS.GT.NYR/2)GO TO 710
       IF(NL.EQ.NG)GO TO 710
       IF(NL.EQ.NG+1)GO TO 710
       IF(NS.GE.IABS(NG-NL))GO TO 710
 578   CONTINUE
       XMTEMP(I,L)=0.
       GO TO 577
 710   XMTEMP(I,L)=TEMP(I,L,N)
 577   CONTINUE
       PRINT 579,(XMTEMP(I,L),I=1,12)

C                      COMPUTE COEFFICIENT OF VARIATION

 679   FORMAT(2X,*C.VAR*,1X,12F9.3)
       DO 670 I=1,12
       SD=0.
       DO 680 N=1,NYR
       SD=SD+(ABS(TEMP(I,L,N)-ATEMP(I,L)))**2.
 680   CONTINUE
       CV(I,L)=((SD/NYR)**.5)/ATEMP(I,L)
 670   CONTINUE
       PRINT 679,(CV(I,L),I=1,12)
 400   CONTINUE

C            PRINT TEMPERATURE EXCEEDANCE TABLES

 508   FORMAT(////35X,*5-AGENCY STUDIES: DWR #144C (SALMON)*
      +*-1990 LEVEL*)
 518   FORMAT(////20X,*5-AGENCY STUDIES: DWR #144C (SALMON)*
      +*-1990 LEVEL*)
 507   FORMAT(6X,*TEMPERATURE EXCEEDANCE - NO. OF YEARS IN 56 YR STUDY*
      +*(1922-77)*)
 513   FORMAT(21X,*EXCEEDING INDICATED TEMPERATURE*)
 509   FORMAT(/2X,*TEMP-F*,8X,*J*,4X,*F*,4X,*M*,4X,*A*,4X,*M*,4X,
      +*J*,4X,*J*,4X,*A*,4X,*S*,4X,*O*,4X,*N*,4X,*D*/)
 511   FORMAT(3X,F4.1,5X,12I5)
       DO 500 L=1,9
       PRINT 518
       PRINT 485,NAME(L)
       PRINT 507
       PRINT 513
       PRINT 509
       DO 550 K=1,36
       PRINT 511,(TCRIT(K),(NTEMP(I,L,K),I=1,12))
 550   CONTINUE
```

PROGRAM NARTEM1

```
      PRINT 2
 500  CONTINUE
      END
#EOR
#EOI
```

TABLE D-1
SACRAMENTO RIVER (SACTEMP)
Input Files

Tape No.	File name	Variable name	Description	DWRSIM control points (Jan 1985 NETWK)
18	RBKE1	XKY2, EY2	K&E: Red Bluff	
19	COLKE1	XKY3, EY3	K&E: Colusa	
20	SACKE1	XKY4, EY4	K&E: Sacramento	
21	REDKE1	XKY1, EY1	K&E: Redding	
22	TASCXXX	TASC	Temp Ab, Spring Creek	Shasta Reservoir output
23	QSXXX	QS	Flow Bl Shasta	Shasta Reservoir output
24	TSCXXX	TSC	Temp from Spring Creek	Whiskeytown Res. output
25	QSCXXX	QSC	Flow from Spring Creek	Whiskeytown Res. output
27	SACNAME	NAME	Sac. River Station Labels	
28	TCLXXX	TCL	Temp Bl Whiskeytown	Whiskeytown Res. output
29	QCLXXX	QCL	Flow Bl Whiskeytown	Whiskeytown Res. output
30	QCCXXX	IQCC	Flow from Cottonwood Creek	IN73
31	AC58XXX	IAC58	Accretions from DA58	IN74
33	AC10XXX	IAC10	Accretions from DA10	IN75 + IN77 + RF78
34	SACRA	SA	Sacto River Reach Areas	
35	TCCXXX	ITCC	Tehama CC Diversion	DV74
36	GCIDXXX	IGCID	GCID Diversion	DV77
37	FSXXX	IFS	Fremont Weir Spills	DV43
38	AC15XXX	IAC15	Accretions from DA15	IN30
39	WSXXX	IWS	Wilkins Sl. Diversion	DV30 + DV66
40	CBDXXX	ICBD	Colusa Basin Drain	RF65 + RF32
42	TFRXXX	TFR	Temp from Feather River	Feather River output
43	2FRXXX	QFR	Flow from Feather River	Feather River output
44	AC21XXX	IAC21	Accretions from DA21	IN43 + RF84 - DV44 + RF50
45	TARXXX	TAR	Temp from American River	American River output
46	QARXXX	QAR	Flow from American River	American River output
47	TCXXX	ITC	Thomes Creek Inflow	LIN75
48	SCXXX	ISC	Stony Creek Inflow	IN76

XXX denotes DWRSIM RUN #

TABLE D-2
FEATHER RIVER (FEATEMP) AND AMERICAN RIVER (NARTEM1)

INPUT FILES

Tape No.	File name	Variable name	Description	DWRSIM control points (Jan 1985 NETWK)
			FEATHER RIVER MODEL (FEATEMP)	
20	OROKE1	XKY1, EY1	K&E: Oroville	
21	MARKE1	XKY2, EY2	K&E: Marysville	
27	FEANAME	NAME	Feather River, Station Labels	
50	TODXXX	TOD	Temp. Bl Oroville Dam	Oroville Res. output
51	QODXXX	QOD	Flow Bl Oroville Dam	Oroville Res. output
52	KRXXX	IQKR	Kelly Ridge Inflow	IN7
53	TDXXX	IQTD	Therm. Div Dam Rel.	DV7
54	TABXXX	IQTAB	Therm. Afbay Rel	RF67
55	Q56XXX	IQ56	Accretions from DA56	IN37
56	D13XXX	IQD13	Net Divert. from DA13	DV37 - RF35 - RF36
57	R13XXX	IQR13	Net Accr. from DA13	RF39 - DV42
58	FEAQW1	CC, QCC, WCC	Feather River Geometry	
			AMERICAN RIVER MODEL (NARTEM1)	
File	NIMXXX	TNIM	Temp. Bl Nimbus Dam	Folsom Res. output
1	LARKE1	XKY, EY	K&E: Sacramento	
2	QCARXXX	IQCAR	Carmichael Diversion	DV41
3	NIMNAME	NAME	American River Station Labels	
4	QNIMXXX	IQNIM	Flow Bl Nimbus Dam	RF9
6	QFPXXX	IQFP	Sacramento City Diversion	DV64

XXX denotes DWRSIM RUN #

TABLE D-3
SACRAMENTO RIVER BASIN
RESERVOIR AND STREAM MODEL
FILE ORGANIZATION

CLAIR ENGLE - WHISKEYTOWN		OUTPUT
SUBTRIN, TRIN1 (RES. MODEL)	→	TP32 - LEWxxx (LEW. DAM TEMP.)
TRINxxx (RES. INPUT)		TP24 - TSCxxx, TP28 - TCLxxx
TP1 - LEWKE1		TP25 - QSCxxx, TP29 - QCLxxx
SHASTA		
SUBSHAS, SHAS1 (RES. MODEL)	→	TP22 - TAXCxxx
SHASxxx (RES. INPUT)		TP23 - QSxxx
OROVILLE		
SUBOROV, OROV1 (RES. MODEL)	→	TP50 - TODxxx
OROVxxx (RES. INPUT)		TP51 - QODxxx
FOLSOM		
SUBAUB, AUBURN (RES. MODEL)	→	TP2 - NIMxxx
FOLxxx (RES. INPUT)		
TP1 - FOLKE1		
FEATHER RIVER		
SUBFEA, FEATEMP (RIV. MODEL)	→	TP42 - TFRxxx
TAPES (SEE TABLE D-2)		TP43 - QFRxxx
AMERICAN RIVER		
SUBAR, NARTEM1 (RIV. MODEL)	→	TP45 - TARxxx
NIMxxx		TP46 - QARxxx
TAPES (SEE TABLE D-2)		
SACRAMENTO RIVER		
SUBSAC, SACTEMP (RIV. MODEL)	→	TP11 - SACxxx (OUTPUT FILE)
TAPES (SEE TABLE D-1)		

NOTES: xxx - RUN CODE

SUBxxxx - SUBMIT OR PROCEDURE FILE

TPxx - TAPE NO.

→ - PROGRAM EXECUTION

TABLE E-1

PROGRAM QMANN

```
      PROGRAM QMANN(INPUT,OUTPUT,TAPE1)
      DIMENSION CS(24),EGLE(24),S(24),A(24,21),R23(24,21),WD(24,21),
     +XN(24,21),Q(24,21)
      DATA EGLE/225.,207.,207.,150.,126.4,105.,94.,80.,72.,61.,60.,57.,
     +54.,48.,45.,44.,37.,36.,35.,34.,33.,27.,19.,11./
    1 FORMAT(8X,F8.2,8X,3F8.2,F8.4)
      DO 10 I=1,24
      DO 20 J=1,21
      READ 1,CS(I),A(I,J),R23(I,J),WD(I,J),XN(I,J)
   20 CONTINUE
   10 CONTINUE
      DO 30 I=1,23
      S(I)=(EGLE(I)-EGLE(I+1))/((CS(I)-CS(I+1))*5280.)
      IF(S(I).EQ.0.)S(I)=.0001
   30 CONTINUE
      S(24)=S(23)
      DO 40 I=1,24
      DO 50 J=1,21
      Q(I,J)=(1.49/XN(I,J))*A(I,J)*R23(I,J)*(S(I)**.5)
   50 CONTINUE
   40 CONTINUE
    2 FORMAT(F8.2,F8.0,F8.0)
      DO 60 I=1,24
      DO 70 J=1,21
      WRITE(1,2)(CS(I),Q(I,J),WD(I,J))
   70 CONTINUE
   60 CONTINUE
      END
#EOR
#EOI
```

TABLE E-2

QMANN: VARIABLE DESCRIPTION

CS - CROSS SECTION RIVER MILE - MILES ABOVE MOUTH

A - CROSS SECTIONAL AREA BELOW EACH ELEVATION - FT^2

R23 - HYDRAULIC RADIUS

WD - SURFACE WIDTH OF EACH ELEVATION - FT

XN - MANNING'S N (ROUGHNESS COEFFICIENT)

EGLE - STREAM CHANNEL ENERGY GRADE LINE ELEVATION AT EACH CROSS SECTION - FT

S - SLOPE OF REACH

Q - FLOW AT EACH CROSS SECTION WIDTH FT^3/S

TABLE E-3

RM	Q	W
75.38	0.	0.
75.38	0.	6.
75.38	3.	91.
75.38	16.	171.
75.38	61.	203.
75.38	123.	265.
75.38	741.	296.
75.38	1727.	299.
75.38	3011.	301.
75.38	4576.	303.
75.38	6380.	306.
75.38	8437.	308.
75.38	10719.	311.
75.38	13209.	313.
75.38	15888.	316.
75.38	18777.	318.
75.38	21866.	320.
75.38	25148.	323.
75.38	28665.	325.
75.38	32306.	328.
75.38	36173.	330.
56.16	0.	0.
56.16	0.	1.
56.16	1.	22.
56.16	27.	58.
56.16	133.	86.
56.16	324.	114.
56.16	604.	147.
56.16	1105.	187.
56.16	1657.	249.
56.16	2415.	308.
56.16	3955.	342.
56.16	5905.	374.
56.16	8186.	419.
56.16	10857.	467.
56.16	13850.	585.
56.16	16653.	729.
56.16	20191.	797.
56.16	24082.	835.
56.16	28468.	867.
56.16	33895.	895.
56.16	39453.	922.
52.56	0.	1.
52.56	0.	4.
52.56	0.	19.
52.56	14.	54.
52.56	98.	98.
52.56	293.	141.
52.56	637.	187.

RM	Q	W
52.56	1152.	245.
52.56	1893.	308.
52.56	2900.	366.
52.56	4197.	422.
52.56	5912.	475.
52.56	7963.	524.
52.56	10385.	571.
52.56	13159.	614.
52.56	16474.	645.
52.56	20164.	676.
52.56	24232.	707.
52.56	28671.	731.
52.56	33558.	753.
52.56	38891.	772.
49.26	0.	0.
49.26	2.	37.
49.26	60.	102.
49.26	342.	156.
49.26	850.	187.
49.26	1578.	217.
49.26	2511.	244.
49.26	3620.	272.
49.26	4970.	310.
49.26	6509.	344.
49.26	8687.	364.
49.26	11147.	390.
49.26	13793.	421.
49.26	16679.	448.
49.26	19760.	475.
49.26	22832.	505.
49.26	25753.	542.
49.26	29171.	582.
49.26	33454.	626.
49.26	37998.	726.
49.26	42302.	878.
45.56	0.	0.
45.56	0.	11.
45.56	4.	34.
45.56	33.	62.
45.56	85.	97.
45.56	175.	143.
45.56	331.	185.
45.56	600.	218.
45.56	964.	245.
45.56	1443.	269.
45.56	2012.	295.
45.56	2640.	324.
45.56	3372.	351.
45.56	4221.	382.

RM	Q	W
45.56	5137.	416.
45.56	6258.	437.
45.56	7809.	448.
45.56	9516.	455.
45.56	11351.	465.
45.56	12952.	486.
45.56	14688.	515.
43.61	0.	0.
43.61	57.	134.
43.61	220.	178.
43.61	497.	216.
43.61	912.	249.
43.61	1473.	279.
43.61	2104.	326.
43.61	2962.	361.
43.61	3979.	397.
43.61	5171.	431.
43.61	8053.	503.
43.61	11759.	575.
43.61	15902.	692.
43.61	21926.	833.
43.61	29260.	1294.
43.61	39765.	2134.
43.61	52094.	3176.
43.61	68428.	4415.
43.61	104111.	5400.
43.61	152624.	5672.
43.61	211706.	5920.
40.88	0.	0.
40.88	238.	339.
40.88	765.	355.
40.88	1515.	370.
40.88	2470.	386.
40.88	3620.	401.
40.88	4941.	417.
40.88	6464.	432.
40.88	8148.	448.
40.88	10026.	463.
40.88	14281.	494.
40.88	19292.	525.
40.88	25001.	556.
40.88	31564.	1035.
40.88	40081.	2407.
40.88	51399.	3333.
40.88	67136.	4085.
40.88	85885.	5633.
40.88	132758.	5850.
40.88	192618.	5916.
40.88	262484.	5983.

TABLE E-3

RM	Q	W
38.26	0.	0.
38.26	194.	180.
38.26	621.	189.
38.26	1235.	199.
38.26	2015.	209.
38.26	2958.	219.
38.26	4056.	228.
38.26	5303.	238.
38.26	6715.	248.
38.26	8250.	258.
38.26	11824.	277.
38.26	16025.	297.
38.26	20825.	316.
38.26	26358.	426.
38.26	32677.	803.
38.26	41292.	2813.
38.26	57314.	4995.
38.26	84903.	5485.
38.26	144589.	5625.
38.26	223044.	5654.
38.26	316615.	5684.
36.07	0.	0.
36.07	40.	91.
36.07	146.	115.
36.07	325.	140.
36.07	608.	269.
36.07	1155.	462.
36.07	2080.	496.
36.07	3229.	531.
36.07	4598.	565.
36.07	6210.	600.
36.07	10211.	636.
36.07	14723.	706.
36.07	20131.	797.
36.07	26166.	922.
36.07	32648.	1170.
36.07	38349.	2410.
36.07	50523.	4094.
36.07	65517.	5031.
36.07	105777.	6436.
36.07	164933.	6460.
36.07	236340.	6483.
33.23	0.	0.
33.23	72.	213.
33.23	236.	229.
33.23	478.	246.
33.23	783.	333.
33.23	1251.	462.
33.23	1961.	486.

RM	Q	W
33.23	2808.	509.
33.23	3793.	532.
33.23	4893.	556.
33.23	7594.	581.
33.23	10592.	629.
33.23	14121.	690.
33.23	18260.	752.
33.23	23024.	825.
33.23	26348.	1506.
33.23	31346.	2658.
33.23	38063.	3486.
33.23	57542.	4694.
33.23	86098.	4715.
33.23	120041.	4736.
30.68	0.	0.
30.68	183.	159.
30.68	587.	168.
30.68	1164.	176.
30.68	1898.	185.
30.68	2789.	194.
30.68	3827.	202.
30.68	4998.	211.
30.68	6330.	220.
30.68	7781.	228.
30.68	11155.	246.
30.68	15123.	263.
30.68	19698.	280.
30.68	26414.	945.
30.68	35817.	2446.
30.68	51229.	4598.
30.68	78558.	4627.
30.68	113859.	4654.
30.68	179382.	4696.
30.68	258283.	4736.
30.68	349832.	4777.
28.43	0.	0.
28.43	20.	88.
28.43	91.	127.
28.43	222.	156.
28.43	415.	180.
28.43	672.	204.
28.43	1002.	224.
28.43	1398.	244.
28.43	1875.	263.
28.43	2449.	277.
28.43	3811.	303.
28.43	5483.	325.
28.43	7449.	348.
28.43	10270.	699.

TABLE E-3

RM	Q	W
28.43	14011.	811.
28.43	18548.	963.
28.43	23880.	1058.
28.43	30531.	1416.
28.43	42351.	1522.
28.43	53978.	2120.
28.43	69846.	2199.
26.25	0.	0.
26.25	11.	99.
26.25	67.	145.
26.25	172.	173.
26.25	323.	204.
26.25	526.	237.
26.25	791.	264.
26.25	1116.	291.
26.25	1506.	318.
26.25	1959.	345.
26.25	3168.	410.
26.25	4821.	432.
26.25	6784.	488.
26.25	9095.	563.
26.25	11744.	638.
26.25	14759.	716.
26.25	18233.	798.
26.25	22017.	1042.
26.25	29340.	2069.
26.25	40404.	4034.
26.25	56910.	4834.
21.86	0.	0.
21.86	25.	138.
21.86	101.	195.
21.86	200.	243.
21.86	324.	391.
21.86	659.	498.
21.86	1162.	557.
21.86	1830.	594.
21.86	2637.	631.
21.86	3625.	640.
21.86	5990.	658.
21.86	8804.	677.
21.86	12085.	695.
21.86	15757.	719.
21.86	19970.	1044.
21.86	24595.	1252.
21.86	29982.	1323.
21.86	37022.	1651.
21.86	48332.	1855.
21.86	61422.	2506.
21.86	77650.	2535.

TABLE E-3

RM	Q	W
13.14	0.	0.
13.14	11.	42.
13.14	67.	84.
13.14	199.	127.
13.14	426.	169.
13.14	776.	211.
13.14	1257.	253.
13.14	1903.	295.
13.14	2711.	337.
13.14	3717.	380.
13.14	6002.	515.
13.14	9563.	702.
13.14	15073.	854.
13.14	22535.	974.
13.14	32047.	1114.
13.14	41494.	1415.
13.14	54305.	1689.
13.14	75655.	2592.
13.14	119316.	2639.
13.14	173636.	2918.
13.14	235968.	2968.
8.76	0.	0.
8.76	9.	31.
8.76	55.	61.
8.76	162.	91.
8.76	342.	127.
8.76	635.	156.
8.76	1039.	185.
8.76	1530.	227.
8.76	2212.	259.
8.76	3037.	300.
8.76	4616.	490.
8.76	7806.	819.
8.76	14240.	1055.
8.76	23116.	1252.
8.76	34348.	1554.
8.76	48081.	2081.
8.76	68631.	2538.
8.76	98304.	2771.
8.76	157572.	2784.
8.76	234559.	3409.
8.76	321498.	3431.
4.38	0.	0.
4.38	8.	30.
4.38	50.	58.
4.38	147.	84.
4.38	297.	127.
4.38	577.	151.
4.38	953.	175.

TABLE E-3

RM	Q	W
4.38	1336.	236.
4.38	1985.	269.
4.38	2731.	329.
4.38	4798.	438.
4.38	8043.	628.
4.38	13478.	765.
4.38	20619.	878.
4.38	29658.	1043.
4.38	41144.	1319.
4.38	56751.	1559.
4.38	77114.	1683.
4.38	114506.	1695.
4.38	163227.	2024.
4.38	216250.	2040.
0.00	0.	0.
0.00	7.	29.
0.00	47.	54.
0.00	132.	77.
0.00	259.	127.
0.00	520.	145.
0.00	872.	164.
0.00	1166.	246.
0.00	1786.	279.
0.00	2467.	358.
0.00	4951.	385.
0.00	8099.	439.
0.00	12205.	476.
0.00	17213.	505.
0.00	23193.	534.
0.00	30317.	561.
0.00	38421.	585.
0.00	47484.	601.
0.00	62629.	612.
0.00	79885.	645.
0.00	98773.	656.

#EOR
#EOI

Table F-1
BUREAU TEMPERATURE MODEL VERIFICATION
SACRAMENTO RIVER - 1987
AVERAGE MONTHLY TEMPERATURES - °F

Location	J	F	M	A	M	J	J	A	S	O	N	D	Avg.
						PREDICTED TEMPERATURES							
Keswick	46.7	46.4	47.5	47.1	47.6	48.0	50.7	54.1	54.6	53.1	52.0	46.9	
Clear Creek	46.5	47.1	48.7	48.2	49.1	49.5	52.1	55.4	56.0	53.9	51.8	46.6	
Cottonwood Cr.	46.4	47.8	49.9	49.4	50.7	51.2	53.7	56.8	57.5	54.8	51.7	46.3	
Red Bluff	45.8	48.2	51.8	52.1	53.8	54.2	56.4	59.7	60.5	56.5	51.9	46.0	
						MEASURED TEMPERATURES							
Keswick	48.7	47.8	47.5	47.8	48.5	49.0	51.6	54.7	55.9	54.6	53.7	50.6	
Clear Creek	-	-	47.9	49.9	51.2	51.2	53.2	55.4	56.0	54.9	52.7	-	
Cottonwood Cr.	47.8	-	50.2	50.7	50.4	52.6	54.0	57.3	58.6	56.9	-	-	
Red Bluff	-	49.0	50.5	52.8	53.5	54.5	56.2	58.8	59.6	57.8	53.3	47.0	
						PREDICTED - MEASURED							
Keswick	-2.0	-1.4	0.0	-0.7	-0.9	-0.1	-0.9	-0.6	-1.3	-1.5	-1.7	-3.7	1.3
Clear Creek			0.8	-1.7	-2.1	-1.7	-1.1	0.0	0.0	-1.0	-0.9		1.0
Cottonwood Cr.	-1.4		-0.3	-1.3	0.3	-1.4	-0.3	-0.5	-1.1	-2.1			1.0
Red Bluff		-0.8	1.3	-0.7	0.3	-0.3	0.2	1.1	0.9	-1.3	-1.4	-1.3	0.8
AVG.	1.7	1.1	0.6	1.1	0.9	1.1	0.6	0.6	0.8	1.5	1.3	2.5	1.0

Notes: Measured temperature from DWR continuous recorders
AVG. = Absolute value averages

Table F-2
BUREAU TEMPERATURE MODEL VERIFICATION
AMERICAN RIVER - 1981
AVERAGE TIME PERIOD TEMPERATURES - °F

Location	Aug 14-19	Aug 27-31	Sept 2-10	Sept 12-18	Sept 20-25	Sept 27-Oct 1	Oct 3-23	Oct 24-Nov 5	AVG
PREDICTED TEMPERATURES									
Cordova Park	66.4	69.8	68.1	70.4	65.6	64.4	61.0	57.3	
Watt Avenue Bridge	68.2	72.8	70.2	72.9	66.8	65.1	61.3	57.9	
H Street Bridge	68.9	73.9	71.0	73.6	67.3	65.4	61.5	58.2	
16th Street Bridge	69.8								
MEASURED TEMPERATURES									
Cordova Park			68.1	68.2	66.4	65.2	62.8		
Watt Avenue Bridge	67.9	69.9	69.4	70.9	66.7	64.9	62.2	58.3	
H Street Bridge	70.1	71.8	71.7	72.3	69.0	67.2			
16th Street Bridge	70.0								
PREDICTED - MEASURED									
Cordova Park			0.0	2.2	-0.8	-0.8	-1.8		1.1
Watt Avenue Bridge	0.3	2.9	0.8	2.0	0.1	0.2	-0.9	-0.4	1.0
H Street Bridge	-1.2	2.1	-0.7	1.3	-1.7	-1.8			1.5
16th Street Bridge	-0.2								0.2
AVG	0.6	2.5	0.8	1.8	0.9	0.9	1.4	0.4	1.2

Notes: Measured temperatures from Bureau and City of Sacramento records
AVG = Absolute value averages