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HEC-5Q SIMULATION OF WATER QUALITY IN THE RUSSIAN RIVER BASIN

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RUSSIAN RIVER BASIN

EXECUTIVE SUMMARY

HEC-5Q models were originally developed for the Russian River Basin to assess the impacts of future development and associated water demands on water quality. The objectives of this effort were to develop and calibrate a model capable of simulating the water quality responses in Lake Sonoma, Lake Mendocino and downstream reaches of the Russian River and Dry Creek. An interface with the Sonoma County Water Agency's (SCWA) Operations Model was created to expedite evaluation of the water quality impacts of alternative operation. The model is designed to provide a basin-wide comparison at 6-hour intervals of water quality impacts of alternative conditions such as changes in system operation and level of development within the basins.

The model development included modifications to the HEC-5Q program code to interface with the SCWA Operations Model and to consider the impacts of benthic algae on dissolved oxygen and nutrient concentrations. The principal water quality constituents simulated were temperature, ammonia, nitrate, phosphate, phytoplankton (reported as chlorophyll a), dissolved oxygen, dissolved and particulate organic material, and inorganic particulate matter. Benthic algae were included in the model but not explicitly simulated. The models were calibrated for data collected during the 1990-2000 historical period. Tributary stream inflow quality was developed from various temperature, dissolved oxygen, and nutrient data sets. All water quality simulations utilized 6-hour time steps.

To analyze the range in potential impacts of water allocation and system operation on water quality, two operation conditions were simulated for "Baseline" (2000 demand levels) and for "Cumulative Impact" (2020 projected demand levels). The water quality impacts of the 2020 cumulative impacts scenario relative to the baseline emphasized temperature and dissolved oxygen. Reservoir outflow temperatures were elevated during periods of increased reservoir drawdown due to withdrawal from warmer epilimnion waters. The remainder of the time, increased outflow from Lake Sonoma resulted in lower stream temperatures due to the higher flows, which translate to deeper water, shorter travel time, and thus less in-stream heating. The elevated temperatures of Lake Mendocino typically seen in the fall months were also predicted for the baseline and cumulative impacts scenarios. Due to the more rapid drawdown under the cumulative impacts scenario, the warming occurred earlier during the drought years. The impacts of the differences in outflow temperatures from Lake Mendocino are localized and little difference is seen in the Russian River above Dry Creek.

A CD accompanies this report that contains all simulation results and supporting data referenced in this report. The simulation results may be viewed using the graphical user interface directly from the CD.

LIST OF TABLES

1   INTRODUCTION

HEC-5Q models were originally developed for the Russian River Basin as part of the Water Resources Study to evaluate the impacts of project operation on water quality in Dry Creek and Russian River downstream of Warm Springs Dam and Coyote Dam, respectively. The model development included modifications to the HEC-5Q program code to meet the specific requirements of the Russian River system, including incorporation of benthic algae into the model, and the SCWA Operations Model interface. Model inputs were developed from 1990 – 1999 tributary and main stem quality data. Meteorological conditions developed from 1-hour CIMIS data from stations at Hopland and Windsor for 1990 – 2000 were input at 6-hour intervals. The model was calibrated using 1996 – 2000 Coyote Dam and Warm Springs Dam tailwater temperature data, 1999 – 2000 diel stream temperature and DO data, 1999 – 2000 reservoir temperature and DO profile data, and seasonal nutrient trends from 1990 – 2000 nutrient data. Calibration involved adjustment of rate coefficients, diffusion in the reservoirs, the benthic algae standing crop, and benthic source rates.

The principal water quality constituents simulated were temperature, ammonia, nitrate, phosphate, phytoplankton (reported as chlorophyll a), dissolved oxygen, dissolved and particulate organic matter, and inorganic particulate matter. Benthic algae were included in the model but were not explicitly simulated.

Daily average flows were based on reservoir operations data, main stem gage data and monthly consumptive use data. Flows were allocated to tributaries based on drainage area. All water quality simulations utilized 6-hour time steps with daily average flows.

To analyze the range in potential impacts of water allocation and system operation on water quality, two operation conditions were simulated for the "Baseline" condition and for "Cumulative Impact". Both scenarios used the 1929-1996 hydrologic period and the 1999 perspective on Potter Valley diversions. The only difference between the two simulations is the demand level. The Baseline and Cumulative Impact models are defined as:

Baseline: Model representing the current (2000) basin-wide operation procedures and demand levels.

Cumulative Impact: Model representing 2020 demand levels.

The specific details of the HEC-5 Baseline and Cumulative Impact Models for the Russian River basin for 2000 and 2020 levels of development are provided by SCWA upon request.

Analysis of the 2000 demand levels illustrates the immediate impacts of current system operation. The 2020 alternative flow conditions show the long-term impacts expected from projected future water demands.

Although each of these options was evaluated using the HEC-5Q water quality model for the 1929 - 1996 hydrologic period, for demonstration purposes, only the results for the 1986-1995 period are presented in the report.

1.1 PROJECT OBJECTIVES

The objectives of this modeling study were to develop and calibrate a model capable of simulating the water quality responses in reservoirs and river reaches of the Russian River basin and to evaluate potential water quality impacts of revised system operation under future demands. The model is designed to provide a basin-wide comparison of daily average, maximum, and minimum water quality impacts of alternative conditions such as changes in system operation and level of development within the basins.

1.2 REPORT ORGANIZATION

A description of the model is presented in Chapter 2 including a discussion of representation of the physical system with the model input provided, and water quality constituents simulated. Results of the HEC-5Q calibration effort are presented in Chapter 3. Results of the alternative operation evaluation for the period of 1986 through 1985 are presented in Chapter 4. References are provided in Chapter 5. The Operations Model Interface utility program is described in Appendix A. Appendix B provides a brief description of how to retrieve the ambient data (from STORET) that resides on the IBM compatible personal computer (PC) Compact Disc (CD) contained within this report. A listing of the contents of the CD is provided in Appendix C.

The benthic algae capability that was added to the HEC-5Q model as part of the Russian River application is described in the HEC-5Q users manual (HEC, 2001). Other model inputs contained in the various data sets are also described in this version of the Users Manual. Additionally, liberal comments are provided within the data sets to aid in the interpretation of the Russian River Model. Additional information regarding model operation and interpretation of results is provided by the training document (HEC, 1999b).

The HEC-5Q model provides time dependent results at numerous locations within the stream and reservoir components of each basin model. Due to the voluminous results, a graphical user interface (GUI) is provided for viewing and interpreting the model results. The GUI software is compatible with PC computers running under Windows 95, 98, 2000, and NT 4.0. The GUI is described in Appendix B.

The calibration and results of the alternative analysis reside on the CD and may be reviewed using the GUI. The CD also contains additional model output and other data and program files that support and augment the report text. Reference is made to the CD throughout this report.

2   MODEL DESCRIPTION

The water quality simulation module (HEC-5Q) was developed so that temperature, and conservative and non-conservative water quality constituents could be readily included as a consideration in system planning and management. Using daily average system flows generated by flow mass balance for the calibration, and by the SCWA Operations Model for the alternative simulations, HEC-5Q computed the distribution of temperature and other water quality constituents in the reservoirs and in the stream reaches.

HEC-5Q can be used to evaluate options for coordinating reservoir releases among projects to examine the effects on flow and water quality at specified locations in the system. Examples of applications of the flow simulation model include examination of reservoir capacities for flood control, hydropower and reservoir release requirements to meet water supply and irrigation diversions. The model can be used in applications including evaluation of in-stream temperatures and constituent concentrations at critical locations in the system or examination of the potential effects of changing reservoir operations or water use patterns on temperature or water quality constituent concentrations. Reservoirs equipped with selective withdrawal structures can be simulated using HEC-5Q to determine operations necessary to meet water quality objectives downstream. This option was utilized to operate the Lake Sonoma withdrawal structure.

For the Russian River project, reservoir release rates were specified as historical values for calibration, and by the SCWA Operations Model for alternative simulation.

HEC-5Q has been modified to meet the specific needs of the Russian River system. The revised model allows interface with the SCWA Operations Model. The interface, OPP25Q, converts Russian River Operations Model outputs to HEC-5Q model inputs. Daily average values extracted from the Operations Model include:

- Lake Sonoma inflow, elevation and outflow;
- Lake Mendocino inflow, elevation and outflow;
- West Fork Russian River inflow;
- Upper River (Cloverdale) inflow and demands;
- Lower River (Healdsburg) inflow and demands;
- Dry Creek inflow and demands; and
- Santa Rosa (Guerneville) inflow and demands.

The capability for simulation of the impacts of benthic algae in streams has been added during this project. Benthic algae were not explicitly simulated, however based on input benthic algae biomass, the impacts on related water quality parameters (i.e. nutrients and dissolved oxygen) were simulated.

HEC-5Q can be used to simulate concentrations of various combinations of the following water quality constituents, many of which may be coupled with other water quality constituents.

2.1

- Temperature
- TDS or conservative tracer
- Electrical Conductivity (EC)
- Ammonia (NH_3) – Nitrogen
- Nitrate (NO_3) - Nitrogen
- Phosphate (PO_4) - Phosphorus
- Phytoplankton
- Dissolved oxygen
- Dissolved organic material (DOM)
- Particulate organic material (TSS)
- Benthic algae
- Chloride
- Alkalinity
- Total inorganic carbon and pH
- Coliform bacteria
- 3 user-specified conservative constituents
- 3 user-specified non-conservative constituents
- Water column and sediment dissolved organic chemicals
- Water column and sediment heavy metals
- Water column and sediment dioxins and furans
- Water column and sediment iron, manganese and sulfur

The HEC-5Q model used in the Russian River analysis utilized the first eleven parameters listed. With the exception of benthic algae, all of these parameters are assumed passively transported by advection and diffusion. All rate coefficients regulating the parameter kinetics are first order and temperature dependent. A brief description of the processes affecting each of these parameters is provided below. Refer to the HEC-5Q users manual (HEC, 2001a) for a more complete description of the water quality relationships of the model.

Temperature

The external heat sources and sinks that were considered in HEC-5Q were assumed to occur at the air-water interface, and at the sediment-water interface. The method used to evaluate the net rate of heat transfer utilized the concepts of equilibrium temperature and coefficient of surface heat exchange. The equilibrium temperature was defined as the water temperature at which the net rate of heat exchange between the water surface and the overlying atmosphere was zero. The coefficient of surface heat exchange is the rate at which the heat transfer process progresses. All heat transfer mechanisms, except short-wave solar radiation, were applied at the water surface. Short-wave radiation penetrates the water surface and may affect water temperatures several meters below the surface. The depth of penetration is a function of adsorption and scattering properties of the water as affected by particulate material (i.e. phytoplankton and suspended solids). The heat exchange with the bottom is a function of conductance and the heat capacity of the bottom sediment.

Conservative parameter / tracer

The conservative parameter was unaffected by decay, settling, etc. Since TDS is not an issue in the Russian River basin, the primary use of this parameter was to check mass continuity. The mass continuity was checked by setting the quality of all inflows to a constant value and then checking to see that the simulation results did not deviate from that value. During calibration, the conservative parameter was treated as specific conductance (EC).

Ammonia (NH_3) – Nitrogen

Ammonia (as nitrogen) is a plant nutrient and is consumed with phytoplankton and benthic algae growth. The remaining ammonia sink is decay. Sources of ammonia include phytoplankton and benthic algae respiration, TSS and DOM decay, and aerobic and anaerobic release from bottom sediments.

Nitrate (NO_3) – Nitrogen

Nitrate (as nitrogen) is a plant nutrient and is consumed with phytoplankton and benthic algae growth. The remaining nitrate sink is denitrification associated with suboxic processes that occur at low dissolved oxygen levels. Decay of ammonia provides a source of nitrate (intermediate nitrite formation is considered rapid relative to the model time step and was included as a component of NO_3).

Phosphate (PO_4) – Phosphorus

Phosphate (as total inorganic phosphorus) was the third plant nutrient considered in the model and is consumed with phytoplankton and benthic algae growth. Phosphates tend to sorb to suspended solids and are subject to loss by settling. Sources of phosphate include phytoplankton and benthic algae respiration, TSS and DOM decay, and aerobic and anaerobic release from bottom sediments.

Phytoplankton

Photosynthesis acts as a phytoplankton source that is dependent on phosphate, ammonia, and nitrate. Photosynthesis is therefore a sink for these nutrients. Conversely, phytoplankton respiration releases phosphate and ammonia. Phytoplankton is an oxygen source during photosynthesis and an oxygen sink during respiration. Phytoplankton growth rates are a function of the limiting nutrient (or light) as determined by the Michaelis-Menten formulation. Respiration, settling and mortality are phytoplankton sinks.

Dissolved Oxygen (DO)

Exchange of dissolved oxygen at the water surface is a function of the surface exchange (reaeration) rate that is determined by wind speed in reservoirs and hydraulic characteristics in streams. Phytoplankton and benthic algae photosynthesis is a source of DO. Sinks for DO include ammonia, DOM and TSS decay, phytoplankton and benthic algae respiration, and benthic uptake.

<u>Dissolved and Particulate Organic Material (DOM and TSS)</u>

Sources of DOM and TSS include a component of phytoplankton and benthic algae respiration and mortality. DOM and TSS sinks include decomposition to phosphate and ammonia. TSS is also subject to settling.

<u>Inorganic Particulate Material</u>

Inorganic particulate material is conservative except for settling. It impacts light attenuation, affecting reservoir temperature, and phytoplankton and benthic algae growth.

<u>Benthic Algae</u>

Benthic algae biomass is not explicitly modeled, but is input as a spatially and temporally varying benthic algae standing crop. Growth of benthic algae produces DO, and consumes PO_4, NH_3, and NO_3. Respiration of benthic algae consumes DO, and releases PO_4, NH_3, DOM, and TSS. Growth and related nutrient uptake rates are a function of ambient temperature and nutrient concentration.

2.1 MODEL REPRESENTATION OF THE PHYSICAL SYSTEM

For application of HEC-5 and HEC-5Q, rivers and reservoirs comprising the Russian River system were represented as a network of reservoirs and streams and discretized into sections within which flow and water quality were simulated.   Control points (CP) represent reservoirs and selected stream locations.   Flows, elevations, volumes, etc. were computed at each control point.

Figure 2.1 provides a schematic representation of the HEC-5 model.   Arrows indicate points of defined inflow and withdrawals.   The river mile location of each control point is listed in Table 2.2

In HEC-5, flows and other hydraulic information are computed at each control point. Within HEC-5Q stream reaches and reservoirs were partitioned into computational elements to compute spatial variations in water quality between control points. Within each element, uniform quality was assumed, therefore the element size determines the spatial resolution. The model representation of streams and reservoirs is summarized in Section 2.2.
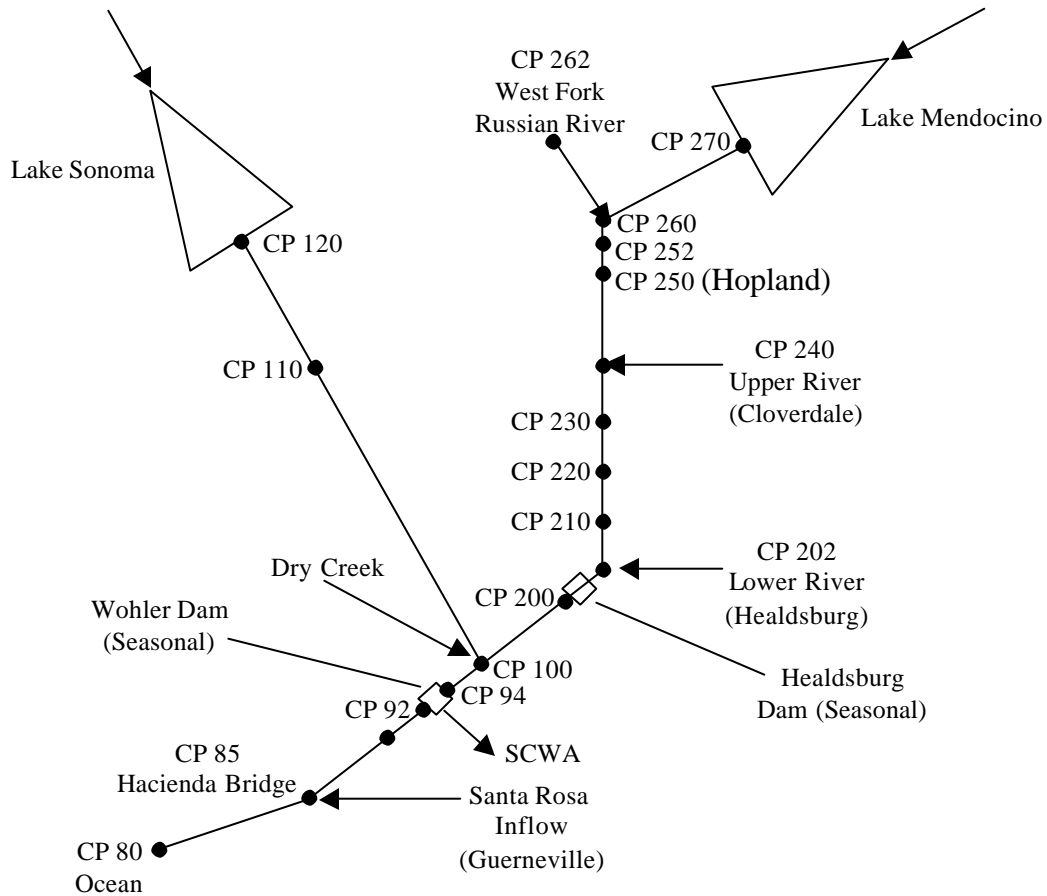
Figure 2.1 Schematic of HEC5 model of the Russian River and Dry Creek.

2.2 MODEL REPRESENTATION OF RESERVOIRS

For water quality simulations, Lake Sonoma and Lake Mendocino were geometrically discretized and represented as vertically segmented water bodies with 3' thick layers. The Wohler seasonal dam was represented as vertically layered and longitudinally segmented with three 1800' segments, each with five layers. The Healdsburg seasonal dam was represented as longitudinally segmented with two 1320' segments and no layers. A description of the different types of reservoir representation follows.

Vertically Segmented Reservoirs

Vertically stratified reservoirs are represented conceptually by a series of one-dimensional horizontal slices or layered volume elements, each characterized by an area, thickness, and volume. The aggregate assemblage of layered volume elements is a geometrically discretized representation of the prototype reservoir. The geometric characteristics of each horizontal slice are defined as a function of the reservoir's area-capacity curve. Within each horizontal layer (or 'element') of a vertically segmented reservoir, the water is assumed to be fully mixed with all isopleths parallel to the water surface both laterally and longitudinally. External inflows and withdrawals occur as sources or sinks within each element and are instantaneously dispersed and

2.5

homogeneously mixed throughout the layer from the headwaters of the impoundment to the dam. Consequently, simulation results are most representative of conditions in the main reservoir body and may not accurately describe flow or quality characteristics in shallow regions or near reservoir banks. It is not possible to model longitudinal variations in water quality constituents using the vertically segmented configuration.

The allocation of the inflow to individual elements is based on the relative densities of the inflow and the reservoir elements. Flow entrainment is considered as the inflowing water seeks the level of like density.

Vertical advection is one of two transport mechanisms used in HEC-5Q to simulate transport of water quality constituents between elements in a vertically segmented reservoir. Vertical transport is defined as the inter-element flow that results in flow continuity.

An additional transport mechanism used to distribute water quality constituents between elements is effective diffusion, representing the combined effects of molecular and turbulent diffusion, and convective mixing or the physical movement of water due to density instability. Wind and flow-induced turbulent diffusion and convective mixing are the dominant components of effective diffusion in the epilimnion of most reservoirs.

The outflow component of the model incorporates a selective withdrawal technique for withdrawal through a dam outlet or other submerged orifice, or for flow over a weir. The relationships developed for the 'WES Withdrawal Allocation Method' describe the vertical limits of the withdrawal zone and the vertical velocity distribution throughout the water column.

The Warm Springs Dam (Lake Sonoma) has selective withdrawal capability. Coyote Dam (Lake Mendocino) is equipped with a single low-level flood control outlet. Both reservoirs have uncontrolled emergency spillways. Flows were assigned to the selective withdrawal and low-level outlet first, with excess to the spillways.

Longitudinally Segmented Reservoirs

Longitudinally segmented reservoirs are represented conceptually as a linear network of a specified number of segments or volume elements. Length and the relationship between width and elevation characterize the geometry of each reservoir segment. The surface areas, volumes and cross-sectional areas are computed from the width relationship.

Longitudinally segmented reservoirs can be subdivided into vertical elements, with each element assumed fully mixed in the vertical and lateral directions. Branching of reservoirs is allowed. For reservoirs represented as layered and longitudinally segmented, all cross-sections contain the same number of layers and each layer is assigned the same fraction of the reservoir cross-sectional area. Therefore, the thickness of each element varies with the width versus elevation relationship for each element. The model performs a backwater computation to define the water surface profile as a function of the hydraulic gradient based on flow and Manning's equation.

External flows such as withdrawals and tributary inflows occur as sinks or sources. Inflows to the upstream ends of reservoir branches are allocated to individual elements in proportion to the fraction of the cross-section assigned to each layer. Other

inflows to the reservoir are distributed in proportion to the local reservoir flow distribution. External flows may be allocated along the length of the reservoir to represent dispersed non-point source inflows such as agricultural drainage and groundwater accretions.

The longitudinally segmented reservoirs of the Russian River and Dry Creek contained up to five layers. The layered representation was used for Wohler Dam to evaluate possible stratification. Very little stratification has been confirmed in the field.

Vertical variations in constituent concentrations can be computed for the layered and longitudinally segmented reservoir model. Mass transport between vertical layers is represented by net flow determined by mass balance and by diffusion.

Vertical flow distributions at dams are based on weir or orifice withdrawal. The velocity distribution within the water column is calculated as a function of the water density and depth using the WES weir withdrawal or orifice withdrawal allocation method.

A uniform vertical flow distribution is specified at the upstream end of each reservoir. Velocity profiles within the body of the reservoir may be calculated as flow over a submerged weir or as a function of a downstream density profile. Submerged weirs or orifices may be specified at the upstream face of the dams. Linear interpolation is performed for reservoir segments without specifically defined flow fields.

2.3 MODEL REPRESENTATION OF STREAMS

In HEC-5Q, a reach of a river or stream is represented conceptually as a linear network of segments or volume elements. The length, width, cross-sectional area and a flow versus depth relationship characterize each element. Cross-sections are defined at all control points and at intermediate locations when data are available. The flow versus depth relation is developed external to HEC-5Q using available cross-section data and appropriate hydraulic computation. Linear interpolation between input cross-section locations is used to define the hydraulic data for each element.

For the lower Russian River and Dry Creek, Corp of Engineers cross-sections were used to define the geometry of the stream reaches in the Russian River system. Above Healdsburg 1996 ARM cross-sections were used. Above Geyersville 1999 estimated cross-sections based on field reconnaissance were used. The locations, sources, and numbers of cross-sections input to the model are summarized in Table 2.1.

Table 2.1   Description of cross-sections used in HEC-5Q.

Location	Source	# of Cross-sections
Dry Creek	Corp of Engineers	33
Russian River below Wohler Dam	Corp of Engineers	43
Russian River Wohler Dam to RM 56.2 (above Geyersville)	ARM	34
Russian River above Mile 56.2	Estimated	64
	Total	174

Flow rates are calculated at stream control points by HEC-5 using one of several available hydrologic routing methods. For the Russian River project, all flows were routed using Muskingum routing. Within HEC-5, incremental local flows (i.e., inflow between adjacent control points) are assumed deposited at the control point. Within HEC-5Q, the incremental local flow may be divided into components and placed at different locations within the stream reach (i.e., that portion of the stream bounded by the two control points). The diversions (demands) are allocated to individual control points within the Upper River and Lower River reaches. A flow balance is used to determine the flow rate at element boundaries.

Inflows or withdrawals may include any point or non-point flow. Distributed flows such as groundwater accretions and non-specific agricultural return flows are defined on a rate per mile basis.   Withdrawals for drinking water supply may be represented by a distributed withdrawal. The approach was used in this application to represent infiltration into the SCWA collection facility.

For simulation of water quality, the tributary locations and associated water quality are specified. To allocate components of the diversion flow balance, HEC-5Q performs a calculation using any specified withdrawals, inflows, or return flows, and distributes the balance uniformly along the stream reach. Once inter-element flows are established, the water depth, surface width and cross sectional area are computed at each element boundary, assuming normal flow and downstream control (i.e., backwater). For this study, there were no return flows other than groundwater. Stream elements were 0.4 to 1.0 miles long.

2.4 HYDROLOGIC BOUNDARY CONDITIONS

The incremental local inflow is defined as the total inflow between adjacent control points. Since the majority of the tributaries within the Russian River basin are not gaged, the historical incremental inflow must be estimated as the difference between main stem gaged flows. USGS and CDEC daily flow data and CDEC and Corp of Engineers operations data were used to define the hydrologic inputs for calibration.

USGS and Corps of Engineers flow data were used when available. USGS flows were not available specifically for the entire 1996-2000 calibration period; therefore some CDEC flow data were used.

The 1996 – 2000 calibration period does not include "below normal" flow years. However, summertime flows are dominated by reservoir releases that tend to attenuate all but the most critical dry years. As an example, the 1986–1997 hydrologic period includes above normal years and an extended drought period. During this period, the annual runoff at Guerneville ranged between 120 to 909 thousand acre-feet (TAF), a range of 650%. However, the summertime runoff (July – September) ranged between 25.3 and 47.5 TAF or an 88% range. Lake Mendocino was operated to meet the flood control limitation of 737.5 feet every year during this period and filled all but three of the years. Lake Sonoma did not fill during 5 of the 12 years. However, the minimum Lake Sonoma July 1st volume during this period was 164 TAF, which is approximately four times the total average summertime release volume. Additionally, the minimum elevation was 394 feet, which is approximately 40 feet above the lowest outlet. Therefore, relatively cool water was available for release during the entire 12-year period.

CDEC data are raw data and are not corrected for measurement error or changes in the rating table. USGS data are carefully analyzed and are therefore assumed to be more reliable. The USGS and CDEC flows were compared for the overlapping data period of 1993 through 1997. The USGS and CDEC flows are plotted in Figures 2.2 – 2.4 for Hacienda Bridge (Guerneville), Healdsburg and Hopland. Many differences are seen between flows from the two sources, however the magnitudes of the differences were the smallest at the Hacienda Bridge gage (e.g., For the flows below 1,000 cfs, the average daily USGS and CDEC flows were 330 and 318 cfs respectively and the RMS difference in the daily flows was 60 cfs).

The ramification of any gage error is a computed incremental local inflow too large in one reach and too low (often negative) in another. The impact of the plus / minus inflows is that water is removed from the stream reach at the computed concentration and replaced by the defined quality of the tributary in another reach. To minimize the impact of gage error, a single mass balance computation was performed. The total incremental inflow was computed as the Russian River flow at Hacienda Bridge + diversions (monthly flows from the SCWA water balance model; the average of 1990 and 2010 demands), less the flows out of Lake Mendocino and Lake Sonoma with flow attenuation. This approach results in a total incremental local inflow that is subject only to the measurement error in Hacienda Bridge flows and the two dam release rates, all of which are believed to be reasonably accurate.

Flow fractions were computed to distribute the incremental flows throughout the basin. Flow fractions were based on 67 years (water years 1929 to 1995) of SCWA Operations Model period averages. Of the total 79.647 million AF over that period, 27.339 million AF (34%) were from the West Fork and Upper Russian River; 21.473 million AF (27%) were from the Lower River; and 30.835 million AF (39%) were from Dry Creek and Santa Rosa inflows. Therefore, above Cloverdale, 34% of the total incremental flow was input, 27% was input above Healdsburg, and 39% above Hacienda Bridge.

Flow fractions to the individual control points within each of the reaches described above were computed based on drainage area. Flow fractions are summarized in Table 2.2. The water quality model breaks the flows down further, assigning inflows from individual tributaries as fractions of the incremental inflows at each control point, as summarized in Table 2.3. This is for the purpose of water quality simulation only, and no additional routing is performed.

Table 2.2   Flow fractions at major stream inflow locations, and individual control point allocations.

Control Point / River Mile	Description	Sub-watershed (major inflow locations)	Flow Fraction to Sub-watershed	Flow Fraction to CP
270 / 95.0	Coyote Dam / Lake Mendocino	Net inflow	100%	100%
260 / 94.4	West Fork Russian River			27%
252 / 88.0	Ukiah (Willow Creek Dam)	Above Cloverdale	34%	22%
250 / 80.0	Russian River @ Hopland			17%
240 / 67.5	Russian River @ Cloverdale			34%
230 / 63.0	Russian River @ Big Sulfur Creek			35%
220 / 53.5	Russian River @ Geyersville	Above Healdsburg	27%	17%
210 / 41.3	Russian River @ Maacaca Creek			45%
202 / 34.0	Russian River @ Healdsburg			3%
200 / 33.5	Healdsburg Dam			-
120 / 13.3	Warm Springs Dam / Lake Sonoma	Mass balance net inflow	100%	100%
110 / 10.2	Dry Creek near Geyersville			8%
100 / 30.5	Russian River @ Dry Creek	Above Hacienda Bridge	39%	14%
94 / 25.0	Russian River u/s of SCWA withdrawal			8%
92 / 24.0	Wohler Dam – SCWA withdrawal			100%
90 / 22.5	Russian River @ Mark West Creek			60%
85 / 20.3	Russian River @ Hacienda Bridge			10%
80 / 0.0	Russian River @ mouth	Above river mouth	71%x39%*	100%

*The inflow was estimated as 71% of the total inflow between Healdsburg and Hacienda Bridge based on drainage area.
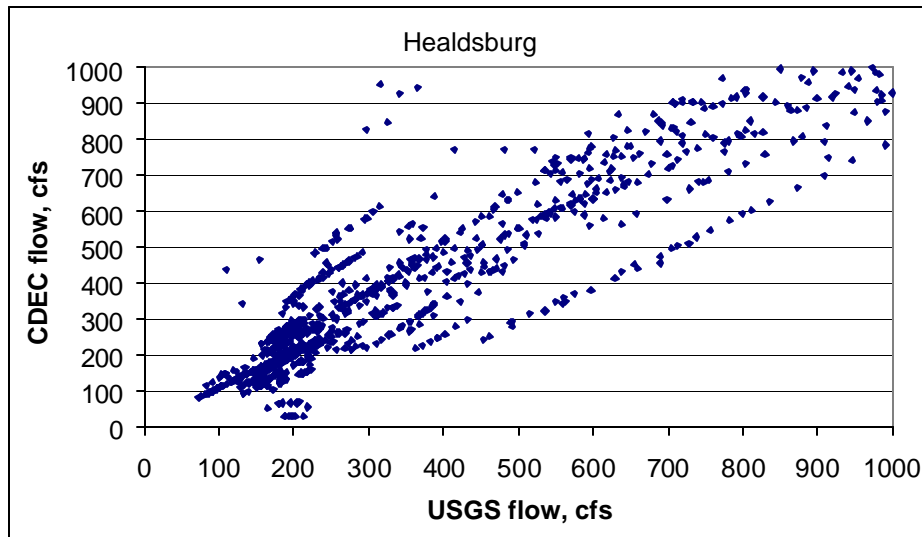
Figure 2.2   CDEC vs. USGS flow data for 1993 – 1997 at Healdsburg.
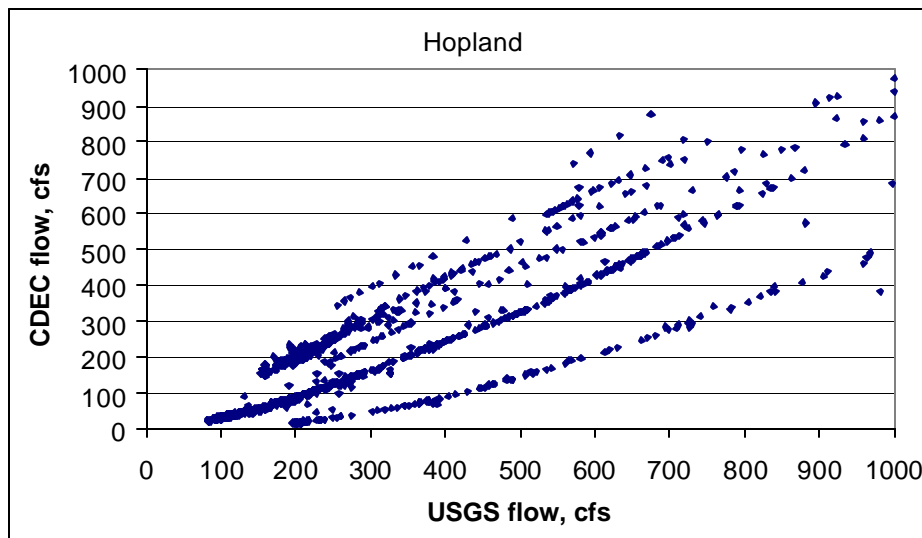
Figure 2.3   CDEC vs. USGS flow data for 1993 – 1997 at Hopland.
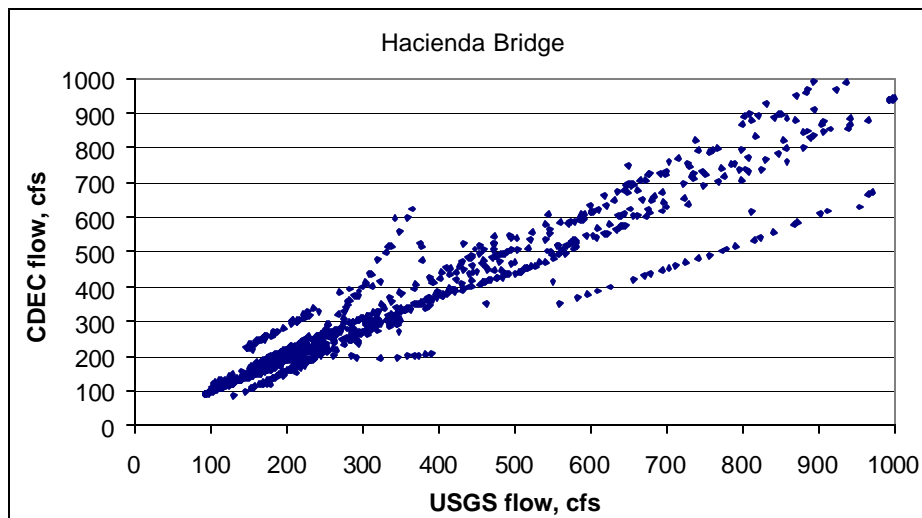
Figure 2.4   CDEC vs. USGS flow data for 1993 – 1997 at Hacienda Bridge.

2.5 WATER QUALITY BOUNDARY CONDITIONS INPUT DATA

HEC-5Q requires that flow rates and water quality be defined for all inflows. Inflow rates may be defined explicitly or as a fraction of the incremental local flow to the control point as defined by HEC-5. The flow fraction method was used for all stream inflows. Table 2.3 lists fractions of the total incremental inflow assigned to each of the individual tributaries to each reservoir and stream reach. This table also includes the location and water quality type code associated with each stream inflow. Water quality type codes are described in Table 2.4.

Water temperature, dissolved oxygen, nutrients, phytoplankton, benthic algae, dissolved and particulate organic matter, and inorganic particulate matter were simulated by HEC-5Q. A temporally and spatially varying benthic algae standing crop was defined. Nutrient concentrations were coupled with benthic algae, phytoplankton, DOM and organic suspended solids concentrations. DO concentrations were coupled with benthic algae, phytoplankton, DOM, TSS and NH_3.

Table 2.3   Flow fractions and water quality for individual tributaries.

CP	Upstream Description	Downstream Description	Inflow Description	Flow Fraction to CP	Water Quality Code*
270	Lake Mendocino	Reservoir	East Fork Russian River	100%	4
120	Lake Sonoma	Reservoir	Dry Creek	67%	5
			Warm Springs Creek	33%	8
270	Coyote Dam	Russian River confluence	Russian River	100%	3
260	Russian River confluence	Ukiah (Willow Creek Dam)	Ackerman Creek	40%	3
			Sulfur Creek	30%	3
			Talmage Creek	30%	3
252	Ukiah (Willow Creek Dam)	Gage near Hopland	Robinson Cr.	65%	3
			McNod Creek	35%	3
250	Russian River @ Hopland gage	Gage near Cloverdale	Feliz Creek	57%	3
			Pieta Creek	30%	3
			Cummiskey Creek	13%	3
240	Russian River @ Cloverdale gage	Big Sulfur Creek	Big Sulfur Creek	100%	2
230	Russian River @ Big Sulfur Cr.	Geyersville	Misc. creeks	100%	2
220	Russian River @ Geyersville	Maacaca Creek	Upstream creek	35%	2
			Maacaca Creek	65%	2
210	Russian River @ Maacaca Cr.	Healdsburg	Local runoff	100%	2
200	Russian River @ Healdsburg	Dry Creek	Local runoff	100%	1
120	Dry Creek near Geyersville	Russian River Confluence	Ducher Creek	19%	2
			Pene Creek	81%	2
110	Dry Creek near Geyersville		Grape Creek	8%	2
			Crane creek	10%	2
			Kelly Creek	10%	2
			Smith Creek	10%	2
			Mill Creek	57%	2
100	Dry Creek	Above SCWA withdrawal	Local runoff	100%	1
92	Russian River below SCWA withdrawal	Mark West Creek	Mark West Creek (Laguna de Santa Rosa)	100%	1
90	Russian River @ Mark West Cr.	Hacienda Bridge	Green Valley Creek	100%	1
85	Russian River @ Hacienda Br.	Ocean	Fife, Pocket & Hulbert Creeks	19%	1
			Dutch Bill Creek	9%	1
			Austin Creek	59%	1
			Sheephouse & Willow Creeks	13%	1

*Water Quality types are described in Table 2.4.

Table 2.4   Average, maximum, and minimum inflow quality for water quality codes associated with table 2.3.

	Avg/ Max/ Min	Temperature C	EC	NO3-N mg/L	PO4-P mg/L	NH3-N mg/L	Chlorophyll a mg/L	Dissolved Oxygen mg/L	Labile DOM mg/L	Refractory DOM mg/L	Organic solids mg/L	Inorganic solids mg/L
1	Avg	16.8	294	0.191	0.050	0.030	0.501	10.0	1.0	2.0	0.6	3.2
	Max	24.0	300	0.350	0.082	0.030	0.900	13.0	1.0	2.0	16.6	161.7
	Min	6.2	150	0.100	0.018	0.030	0.100	7.0	1.0	2.0	0.4	1.0
2	Avg	14.9	272	0.191	0.050	0.030	0.501	10.0	0.5	1.5	0.6	2.5
	Max	22.0	275	0.350	0.082	0.030	0.900	13.0	0.5	1.5	13.5	130.8
	Min	6.0	195	0.100	0.018	0.030	0.100	7.0	0.5	1.5	0.4	1.0
3	Avg	14.9	236	0.142	0.050	0.030	0.501	10.0	0.5	1.5	0.6	3.2
	Max	22.9	250	0.300	0.082	0.030	0.900	13.0	0.5	1.5	16.6	161.7
	Min	6.2	150	0.050	0.018	0.030	0.100	7.0	0.5	1.5	0.4	1.0
4	Avg	15.0	223	0.147	0.060	0.030	1.504	10.5	0.7	2.0	1.0	6.9
	Max	23.0	250	0.280	0.088	0.030	2.900	14.0	0.7	2.0	20.6	200.0
	Min	8.0	150	0.060	0.032	0.030	0.100	7.0	0.7	2.0	0.4	1.0
5	Avg	13.0	242	0.141	0.050	0.030	0.500	10.0	0.5	1.5	0.5	1.9
	Max	20.0	250	0.220	0.077	0.030	0.600	13.0	0.5	1.5	13.3	125.3
	Min	4.2	150	0.080	0.023	0.030	0.400	7.0	0.5	1.5	0.4	1.0
6	Avg	15.2	342	0.141	0.050	0.030	0.500	10.0	0.5	1.5	0.5	1.9
	Max	21.3	350	0.220	0.077	0.030	0.600	13.0	0.5	1.5	13.3	125.3
	Min	8.0	150	0.080	0.023	0.030	0.400	7.0	0.5	1.5	0.4	1.0
7	Avg	16.0	350	0.649	0.082	0.050	0.000	0.0	0.1	0.5	0.0	0.0
	Max	17.4	350	0.750	0.120	0.050	0.000	0.0	0.1	0.5	0.0	0.0
	Min	14.6	350	0.550	0.040	0.050	0.000	0.0	0.1	0.5	0.0	0.0
8	Avg	14.5	344	0.499	0.060	0.040	1.003	10.0	1.0	2.0	1.3	9.2
	Max	20.2	350	0.751	0.096	0.040	1.900	13.0	1.0	2.0	29.0	285.5
	Min	8.8	195	0.249	0.024	0.040	0.100	7.0	1.0	2.0	0.8	4.0

Tributary stream inflow water quality characteristics were developed from 1999 – 2000 diel temperature and dissolved oxygen data, 1999–2000 reservoir temperature and dissolved oxygen profile data, 1991–2000 nutrient monitoring data (seasonal trends), 1996 – 2000 Coyote and Warm Springs dam tailwater temperature data, and 1999 – 2000 USFS daily Russian River temperature data at Healdsburg. These data sets contain temperature and water quality data for the Russian River, Lake Sonoma, and Lake Mendocino. The seasonal trends seen in the various data were used for defining tributary water quality. The sparseness of the ambient water quality data makes it impossible to explicitly define the inflow water quality of all tributary streams. Therefore, the water quality of streams within a geographical region was combined to provide typical water quality characteristics for the streams of that region. Table 2.4 summarizes the average, maximum and minimum water quality concentrations for each of the different tributary types as referred to in Table 2.3. The variations in concentration are a result of the following definitions of the constituents as illustrated in the plots below:

- Temperature – function of equilibrium temperature, seasonal, or harmonic

- EC - seasonal

- Nitrate – seasonal, harmonic or constant

- Phosphate – harmonic

- Ammonia – constant

- Phytoplankton as Chlorophyll a – harmonic

- Dissolved Oxygen – harmonic

- Labile and refractory DOM – constant

- Dissolved organic matter – function of flow

- Inorganic Particulate Material – function of flow

Harmonic

Concentration

Date

Seasonal

Concentration

Date

Function of Flow

Constraints

Concentration/ Temperature

Log(Q)/ Equilibrium Temperature

2.16
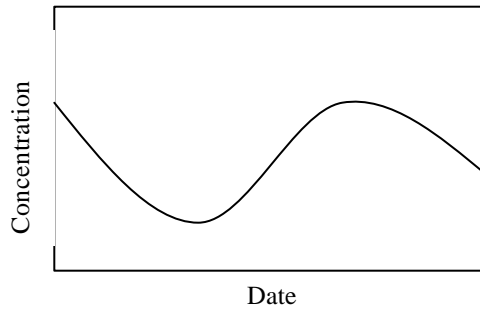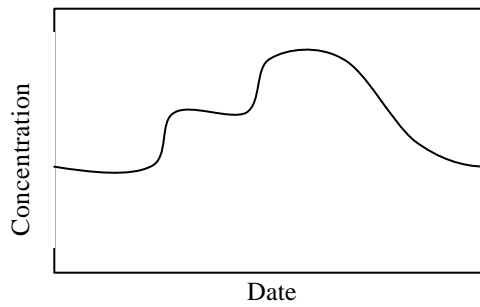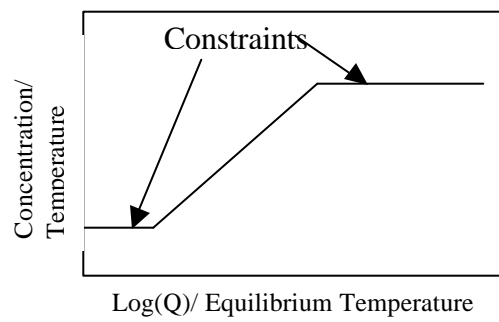
2.6 HYDROLOGIC AND METEOROLOGICAL DATA

Specification of water surface heat exchange data requires designation of meteorological zones within the study area. Meteorological zones may represent data from a single weather station or a combination of two or more stations. Each control point within the system or sub-system used in temperature or water quality simulation must be associated with one of the defined meteorological zones. Within a river basin, it may be appropriate to apply different atmospheric conditions over different regions. Reasons for defining more than one meteorological zone within a system include availability of data and variations in topography within a region.

Five meteorological zones were used in Russian River model: (1) Lake Mendocino, (2) Russian River, Coyote Dam to above Cloverdale, (3) Russian River, above Cloverdale to Maacaca Creek, (4) Lake Sonoma, and (5) Dry Creek and Russian River below Maacaca Creek.

For the calibration, 1990 – 2000 hourly CIMIS data at Hopland and Windsor were used. Within these data sets, missing hourly data (3 hours or less) were computed by interpolation between adjacent values. Larger data gaps were assigned the average hourly value for the day and hour. The average for each hour of each day was computed from the available good data – up to 11 values.

Meteorological data for the alternative simulation was developed from extrapolation of the 1990 – 2000 CIMIS data based on 1928 – 1997 USWS daily maximum and minimum air temperature, and daily precipitation data at Ukiah and Healdsburg. A relationship was developed between the maximum and minimum temperatures at the CIMIS and USWS sites as shown in Figures 2.5 - 2.8. In these figures, CIMIS vs. USWS minimum and maximum temperatures are plotted along with the best fit linear relationships between the two data sets. The CIMIS record with the temperature extreme closest to the adjusted USWS maximum and minimum was assigned for each day of the 1928 – 1997 period. Candidate CIMIS records were within 2 days before or after the USWS date, thus up to 5 days from each of the 11 years of CIMIS data (a total of 55 days) were available for assignment to each day of USWS data. Increased cloud cover was used for days with USWS precipitation.

For all simulations, hourly air temperature, wind speed, relative humidity, and cloud cover were used to compute equilibrium temperatures and exchange rates at 6-hour intervals for input to HEC5Q. Heat exchange was adjusted for individual stream sections to reflect environmental conditions such as wind speed, riparian shading, and open or sheltered water bodies.

Table 2.5 summarizes the application of meteorological data to the five meteorological zones.

Table 2.5   Meteorological zone descriptions.

Meteorological Zone	Adjustment Factors	CIMIS (Calibration)	USWS (Alternatives)
Lake Mendocino	wind speed	Hopland	Ukiah
Russian River: Coyote Dam to above Cloverdale	wind speed & riparian shading	Hopland	Ukiah
Russian River; above Cloverdale to Maacaca Cr.	wind speed & riparian shading	Avg. of Hopland & Windsor	Avg. of Ukiah & Healdsburg
Lake Sonoma	wind speed	Windsor	Healdsburg
Dry Creek and Russian River below Maacaca Cr.	wind speed & riparian shading	Windsor	Healdsburg

Within HEC-5Q, water temperatures are simulated based on an equilibrium temperature assumption. The equilibrium temperature is defined as the water temperature at which the net heat flux across the air-water interface is zero. The rate of heat flux is computed as a linear function of the departure from the equilibrium temperature.

During the processing of meteorological data to meet HEC-5Q model input requirements, the temperature of a hypothetical 10-foot deep pool of water was simulated. This calculation serves as a data check and provides a comparison between temperatures resulting from simulations using CIMIS and USWS data. Figures 2.9 and 2.10 show the computed temperature of the 10-foot deep hypothetical pool for the 1990 – 1997 period for the Lake Mendocino meteorological zone and the Lake Sonoma meteorological zone, respectively. Both the magnitude and phasing of the computed water temperatures are nearly identical, indicating that the synthesized data are representative of historical meteorological conditions. The root mean squared difference between the temperature results from the CIMIS data and the USWS data is 2.2 $^\circ$ F for the Lake Mendocino meteorological zone and 1.7° F for the Lake Sonoma meteorological zone.
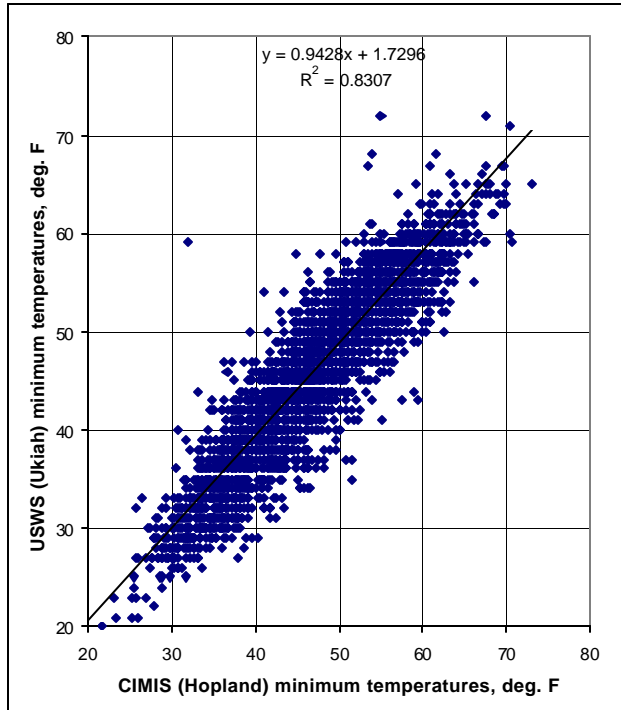
Figure 2.5 CIMIS vs. USWS minimum temperatures at Hopland - Ukiah.
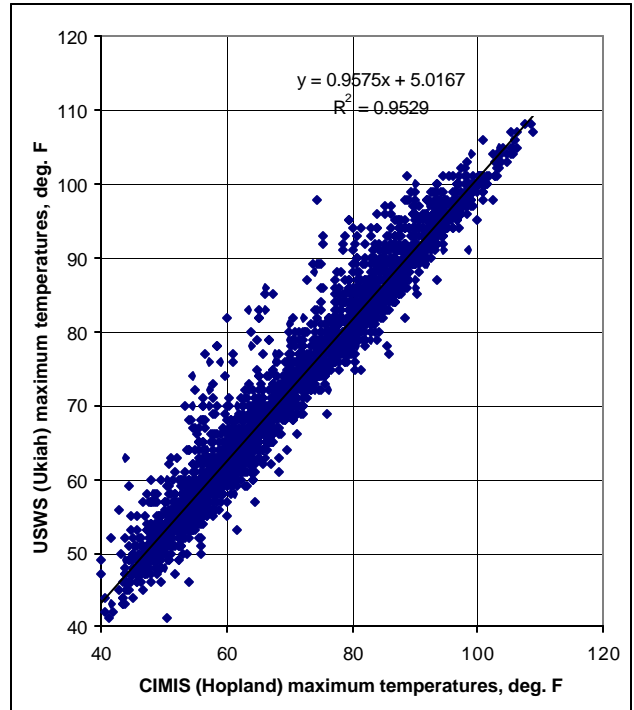
Figure 2.6 CIMIS vs. USWS maximum temperatures at Hopland - Ukiah.

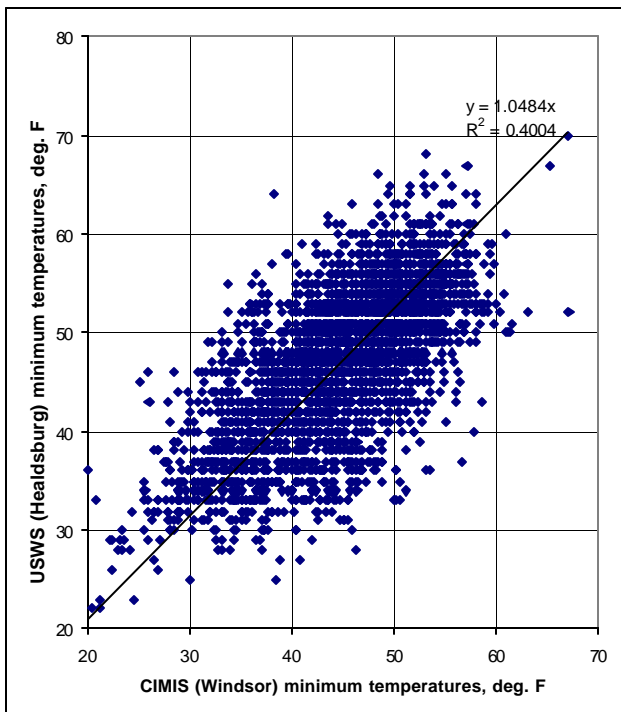Figure 2.7 CIMIS vs. USWS minimum temperatures at Windsor - Healdsburg.
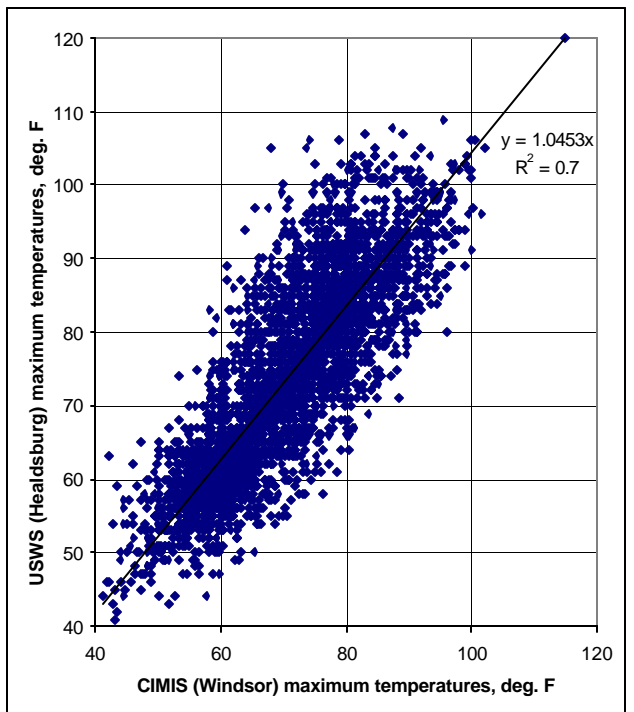

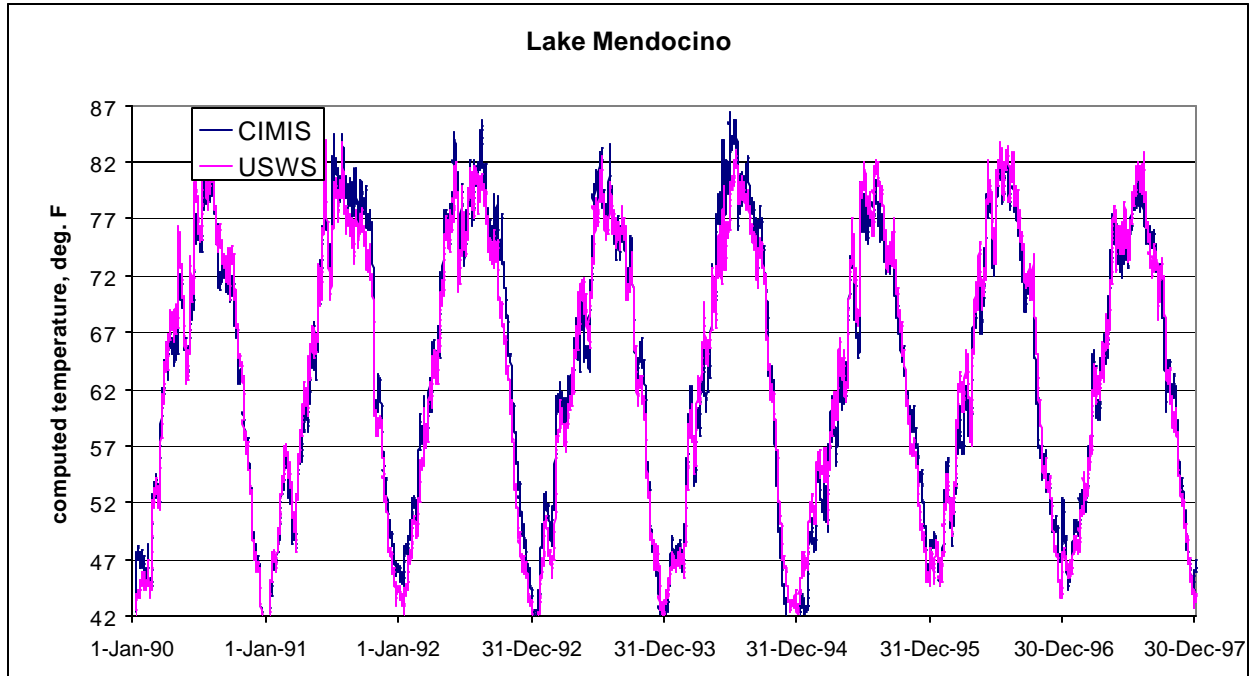Figure 2.8 CIMIS vs. USWS maximum temperatures at Windsor - Healdsburg.

2.19

Figure 2.9 Computed temperature of a hypothetical 10-foot deep pool for the Lake Mendocino meteorological zone, 1990 - 1997.
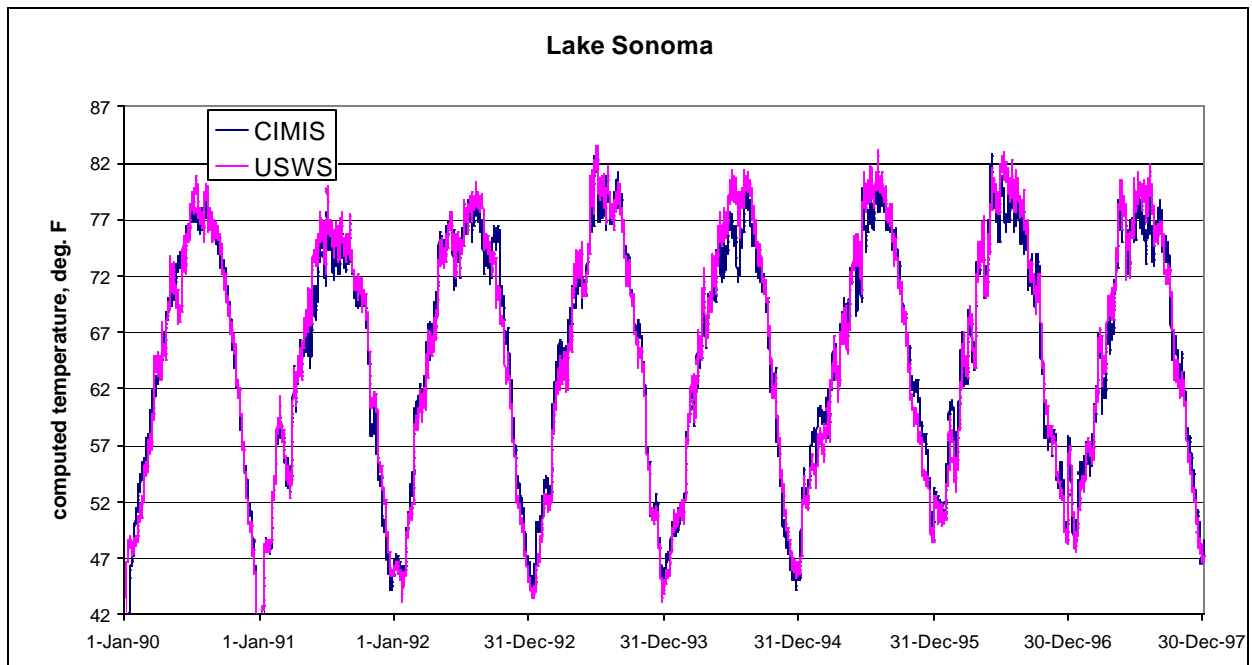

Figure 2.10 Computed temperature of a hypothetical 10-foot deep pool for the Lake Sonoma meteorological zone, 1990 - 1997.

2.20

3 MODEL CALIBRATION

HEC-5Q was calibrated using water quality field observations measured in 1990 – 2000. The following data sets were utilized.

- Lake Sonoma and Lake Mendocino temperature and dissolved oxygen profiles (Water Quality Control Board, 1999 – 2000)
- Continuous tailwater temperatures below Coyote and Warm Springs Dams (Corps of Engineers, 1996 – 2000)
- Spot measurements of temperature, dissolved oxygen and nutrients (STORET and Water Quality Control Board, 1990 – 2000) at stations shown on Figure 3.1
- Continuous river temperature above Healdsburg (USGS, 1998 – 2000)
- Diel temperature and dissolved oxygen (Water Quality Control Board, 1999 – 2000)

The hydrology, meteorology, and inflow water quality conditions described in Chapter 2 were assumed.

Tailwater temperatures below Warm Springs Dam are controlled by operation of the selective withdrawal structure. Detailed outlet operation data were not available; therefore, seasonal temperature objectives were defined based on the observed tailwater temperature. The selective withdrawal algorithm was then utilized to operate the selective withdrawal gates.

The intent of the model calibration exercise was to demonstrate that the model adequately represents the thermal and water quality responses of the prototype stream and reservoir system. This process involved a series of simulations during which model parameters were adjusted to minimize the differences between the computed and observed data.

The final water quality coefficients of the calibrated models are listed in the model output on the CD that accompanies this report. Water quality coefficients were defined globally and spatially. The global coefficients apply to the entire stream and reservoir system and control chemical and biological processes that are somewhat independent of environmental conditions. The spatial varying coefficients apply by reservoir and stream reach. Spatially varying coefficients apply until overridden by subsequent input. The spatially varying coefficients represent localized environmental conditions.

The results of the calibration effort are presented as plots of computed versus observed values using various formats. The plots are organized by plot type and therefore, the figure numbers may not coincide with the sequence referenced in the text. The final results of the calibration effort may be viewed using the graphical user interface (GUI). The GUI is described in Appendix B.

3.1 HEC-5Q CALIBRATION RESULTS

The following sections provide a brief discussion of the calibration results for reservoirs and streams by water quality parameter. The discussion proceeds by data set as listed above. Note that the tailwater temperature calibration is included with the

reservoir calibration since tailwater temperature is a direct indication of reservoir calibration.

1.1.1 RESERVOIR CALIBRATION RESULTS

Temperature

Computed and observed vertical temperature profiles for 13 sampling events during 1999 – 2000 are plotted for Lake Mendocino and Lake Sonoma in Figures 3.2 – 3.5. In most of the plots more than one distinct line is seen in the profile data because the data are for multiple locations within the lakes. These locations can be in different arms of the lakes, which were not represented in the model. The goal of the calibration was to achieve an average of the observed data profiles.

The location of the thermocline is in excellent agreement with observed data for both reservoirs in all of the profiles. The hypolimnion and epilimnion temperatures are an excellent match with observed data as well, with the exception of the 8/9/99 and 9/8/99 profiles in Lake Sonoma where the computed epilimnion temperatures are approximately 4 degrees warmer than the observed data indicate. Variation in epilimnion temperatures result from impacts of localized climatological differences. There is no impact on release temperature or water quality.

Computed and observed tailwater temperatures below Warm Springs Dam (Lake Sonoma) and Coyote Dam (Lake Mendocino) are shown in Figures 3.6 and 3.7, respectively. Both plots illustrate that the model accurately represented the magnitude and seasonal variation in tailwater temperatures. Warm Springs Dam tailwater temperatures reflected operation of the selective withdrawal structure that operated to match the tailwater temperature targets. Withdrawals originated within the hypolimnion throughout the year due to the low temperature targets. Coyote Dam tailwater temperatures represented depletion of the cold water pool at the single withdrawal point. The good match between the computed and observed temperatures of the profiles and tailwater indicate that the model accurately represents the thermal regime under 1999-2000 hydrologic conditions.

A summary of storage and outflow for Lake Sonoma and Lake Mendocino is provided in Table 3.1. These data illustrate the larger volume, lower outflow and greater residence time in Lake Sonoma, which result in maintenance of an ample cold water pool under typical operation, while the cold water pool in Lake Mendocino is depleted each year.

Dissolved Oxygen (DO)

Computed and observed vertical DO concentration profiles for 13 sampling events during 1990 – 2000 are plotted for Lake Mendocino and Lake Sonoma in Figures 3.8 – 3.11. As with the temperature plots, more than one distinct line in the profile data represents multiple locations within the lakes. These locations can be in different arms of the lake, which were not represented in the model. The goal of the calibration was to achieve an average of the observed data profiles.

Simulated vertical dissolved oxygen profiles in Lake Mendocino are generally within 2 mg/L of observed data for all sampling times, as shown in Figures 3.8 and 3.9. The model results tend to be slightly more stratified than observed data indicate. In Lake Sonoma during August through October of both simulation years, computed DO profiles are in excellent agreement with observed data, as shown in Figures 3.10 and 3.11. During May through July, computed DO profiles show surface concentrations 1 to 2 mg/L higher than observed surface concentrations while the observed concentrations lower in the water column are well represented by the model. Note that most of the observed DO profiles within Lake Sonoma terminate at about 20 meters. Therefore no evaluation of the DO below that level can be made. It is recommended that future profile measurements be extended to the bottom so that future evaluation will not be subject to this limitation.

Limited tailwater DO data indicate that discharge turbulence results in rapid reaeration and that DO concentrations near saturation are achieved immediately downstream of each dam. The rapid reaeration minimizes the importance of the differences between the computed and observed DO concentration of the reservoir profiles.

1.1.1 STREAM CALIBRATION RESULTS

Maximum, average and minimum simulated temperature, dissolved oxygen, ammonia, nitrate, phosphate, and specific conductance are plotted at 6-hour intervals with observed data for the Russian River at Hopland, Cloverdale, Healdsburg, Wohler Bridge, and Johnson Beach in Figures 3.12 – 3.17. Calibration results and observed data from 1990-2000 are plotted by Julian day so that multiple years are plotted on the same 365-day scale. The intent of these plots is to compare seasonal trends in the simulated and observed concentrations.

Continuous temperature data for October 1998 – 2000 were available at Healdsburg and are plotted in Figure 3.18 along with the computed daily maximum and minimum. Horizontal temperature and DO profiles along the Russian River are provided to illustrate that the model reproduced observed temperature and DO gradients throughout the Russian River system. Temperature profiles are plotted in Figures 3.19 – 3.23, and DO profiles are plotted in Figures 3.24 – 3.28.

Ammonia, nitrate and phosphate data were collected during 1999-2000, however the vast majority of the measurements were reported as non-detects. Therefore profile plots for these parameters are not included. The GUI and simulation results on the CD accompanying this report are available to view these parameters in profile.

Temperature

Maximum, average and minimum stream temperature calibration results for 1990 – 2000 are plotted with observed data in Figure 3.12. These results show that the magnitude and seasonal variations seen in the data are well represented by the model at all five locations.

Computed maximum, average and minimum horizontal temperature profiles along the Russian River are plotted with observed data for 5 sampling events in Figures

3.19 – 3.23. Computed maximum, average and minimum temperatures are generally within 2 degrees of the respective observed data points and most often within less than 1 degree of observed data for each of the sampling events.

Computed temperature time series in the Russian River at Healdsburg closely match observed data for the 1999 – 2000 period, as shown in Figure 3.18.

Dissolved Oxygen (DO)

Figure 3.13 shows the 1990 – 2000 maximum, average and minimum computed DO concentrations plotted with observed DO concentrations for the same period. Seasonal fluctuations in DO levels are apparent in these plots. The simulated dissolved oxygen concentrations are of the same magnitude as the observed data and exhibit the seasonal trends seen in the observed data. Maximum and average simulated concentrations generally coincide best with observed data. This is likely because the lowest DO concentrations occur during the nighttime hours, and DO samples were taken only during the daytime.

Computed maximum, average, and minimum horizontal DO profiles along the Russian River are plotted with observed data for 5 sampling events in Figures 3.24 – 3.28. Computed DO profiles are generally within 0 to 2 mg/L of observed data points for each of the sampling events. Computed DO on June 12 deviates from observed values by as much as 3 mg/L near river miles 19 and 80. No attempt was made to replicate the June 12 oxygen level, as it would require atypical rates that are inconsistent with the other sampling data.

The dissolved oxygen concentration below Coyote Dam is near saturation even though the DO within the lake at the withdrawal level is well below saturation. The tailwater reaeration coefficient within the model is predicated on the current discharge configuration that does not include hydroelectric generation. Less turbulence is generally associated with hydroelectric facilities and therefore lower DO may result. A revised tailwater reaeration coefficient would need to be determined by calibration should the hydroelectric facilities be brought back on line.

Ammonia (NH_3 as nitrogen)

Figure 3.14 shows the computed and observed ammonia nitrogen concentrations. Random spikes occur in the data throughout the year with most values at the detection limit of 0.03 mg/L. The average and minimum computed values are at or below the detection limit for the observed data. Those values below the detection limit cannot be confirmed by the data. Simulated ammonia results at each location are fairly constant and near the detection limit throughout the year. The model did not reproduce the random spikes. The most numerous observed data points at the highest concentrations occur at Johnson Beach as a result of Santa Rosa winter and spring discharge via Laguna de Santa Rosa. The Santa Rosa wastewater disposal system provides a large storage capacity and therefore, the discharge rate is quite variable. Intermittent nitrification also results in variable ammonia discharge concentrations. No attempt was made to model the effects of the discharge due to its variability. Additionally, the bulk of Santa Rosa discharge will be diverted to the geysers within a few years.

Nitrate (NO$_3$ + NO$_2$ as nitrogen)

The maximum, average and minimum computed nitrate nitrogen concentrations and the observations are shown in Figure 3.15. These results show that the magnitude and seasonal trends seen in the observed data were generally well represented by the model except the simulated concentrations drop off approximately 50 days earlier than indicated by the observed data. These inconsistencies are likely because the nitrate inputs in the model did not have the variation of the natural environment, and therefore could not represent wintertime nitrate concentrations.

Diurnal variations in nitrate concentrations occur due to benthic algae and phytoplankton growth (primarily during the day) and respiration (primarily at night). The lowest nitrate concentrations occur during the day. All monitoring samples were taken during the daytime thus the lower (daytime) computed values on any day best correspond with observed data.

The most recent nitrate monitoring data (for 1999-2000) are typically non-detect values. The calibration was biased toward these lower values.

Phosphate (PO$_4$) – Phosphorus

Maximum, average and minimum computed phosphate concentrations and the observations are shown in Figure 3.16. At Johnson Beach, observed data indicate that concentrations are higher during the winter than for the rest of the year. The model did not reproduce the higher wintertime concentrations at that station. As with ammonia, the higher observed phosphate concentrations are believed to be associated with the Santa Rosa discharge entering the river. Data at the other four locations do not indicate any strong seasonal trends. The model adequately represented observed phosphate concentrations at those locations.

Specific Conductance

Maximum, average and minimum specific conductance calibration results are shown with observed data in Figure 3.17. These results show that the model adequately represented the magnitude and small seasonal variations seen in the data. Specific conductance is not considered an important water quality parameter since the total dissolved solids is within the limits of the recognized beneficial uses of the Russian River system.

Table 3.1   Summary of storage and outflow for Lake Sonoma and Lake Mendocino.

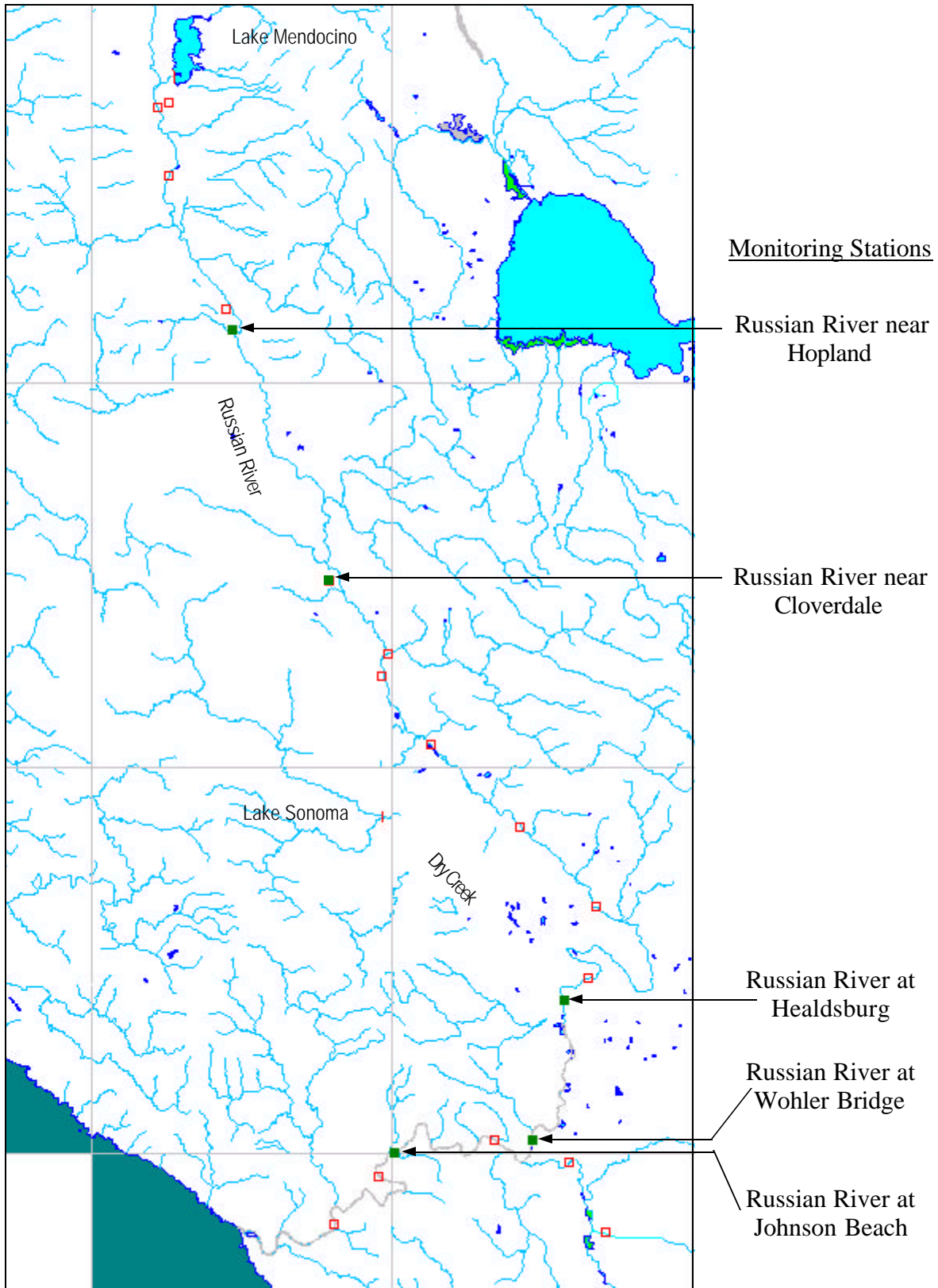|	Volume	Average outflow		Volume replacement time
	AF	cfs	AF/yr	Days
Lake Sonoma	217,200	390.0	282,300	280
Lake Mendocino	68,340	608.5	440,500	57

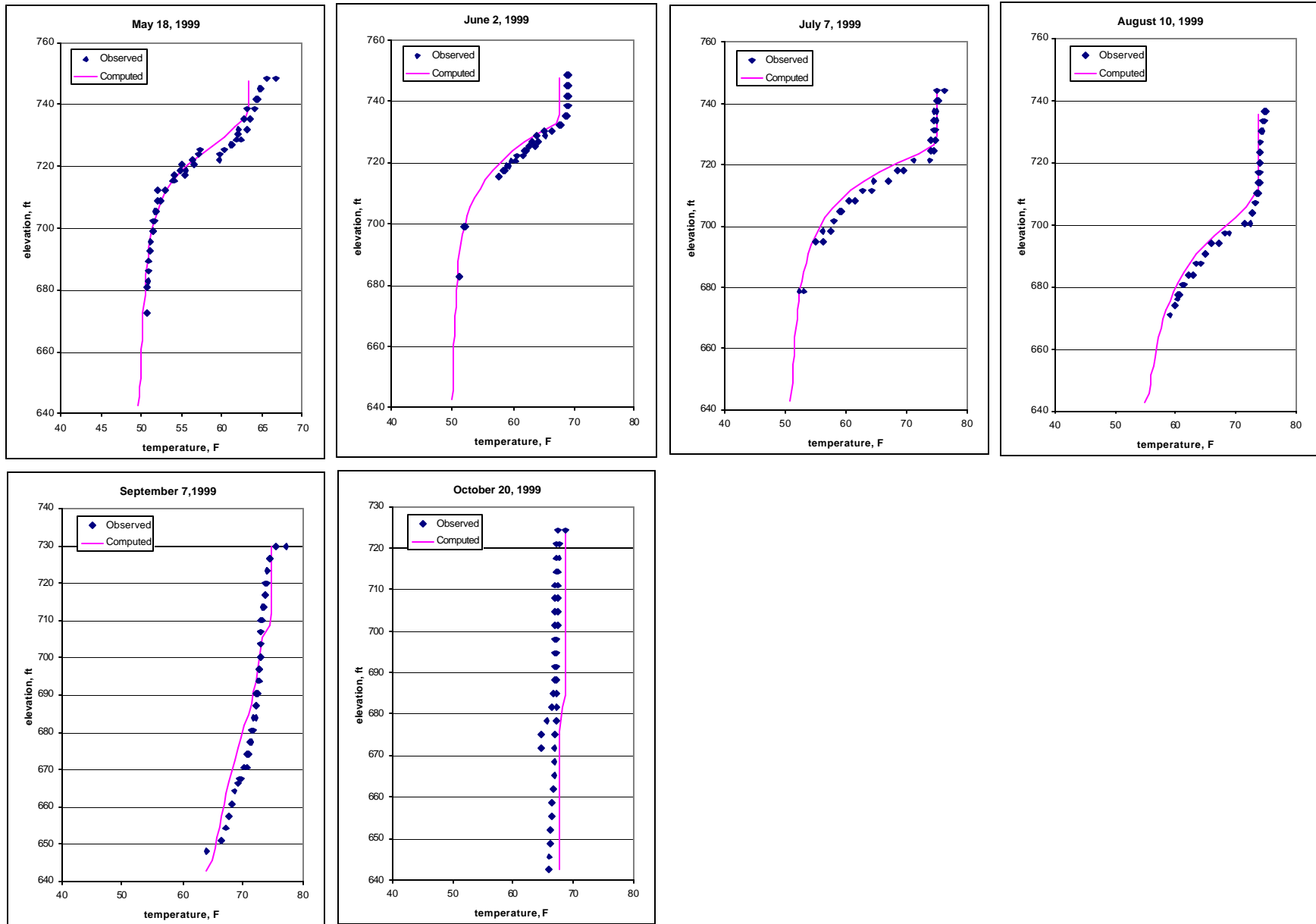Figure 3.1 Map showing water quality monitoring stations used in calibration.

3.6

Figure 3.2 Computed and observed temperature profiles in Lake Mendocino for 1999.
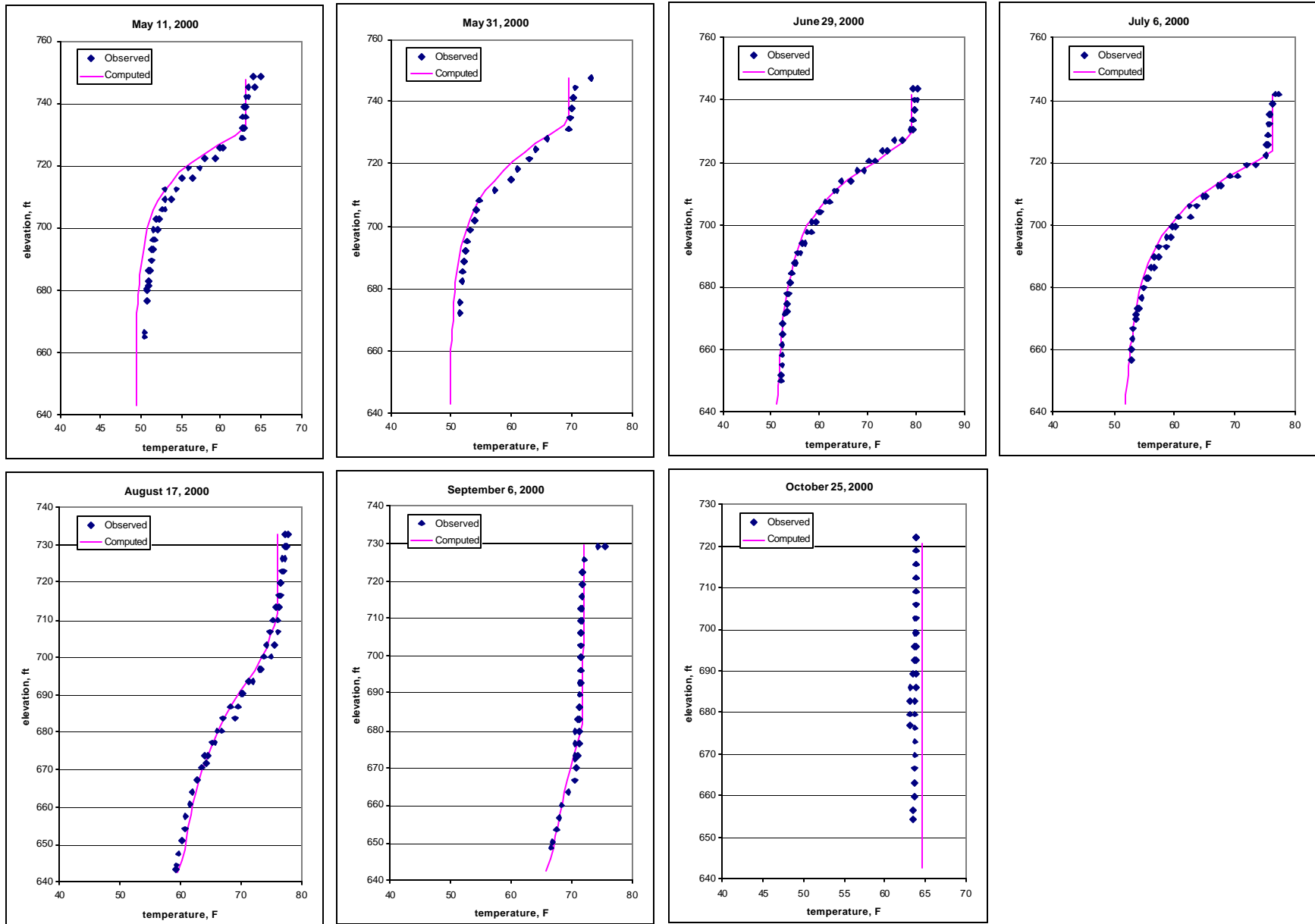
Figure 3.3 Computed and observed temperature profiles in Lake Mendocino for 2000.

Figure 3.4 Computed and observed temperature profiles in Lake Sonoma for 1999.

Figure 3.5 Computed and observed temperature profiles in Lake Sonoma for 2000.
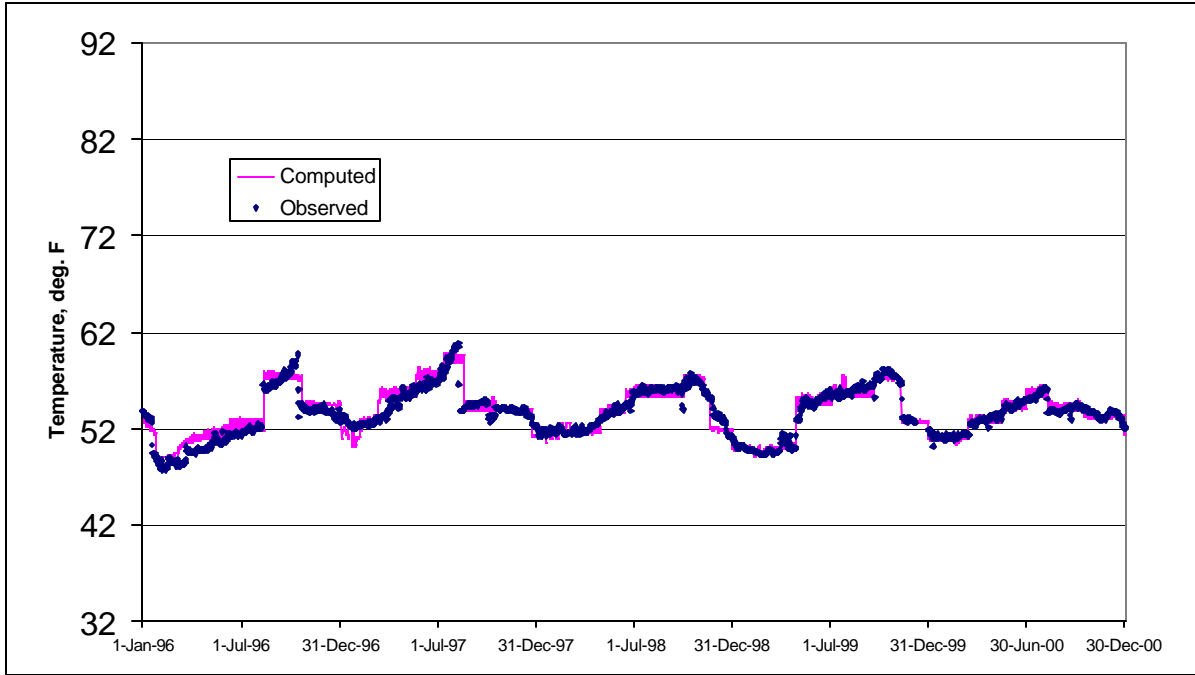
Figure 3.6 Lake Sonoma computed and observed tailwater temperatures.
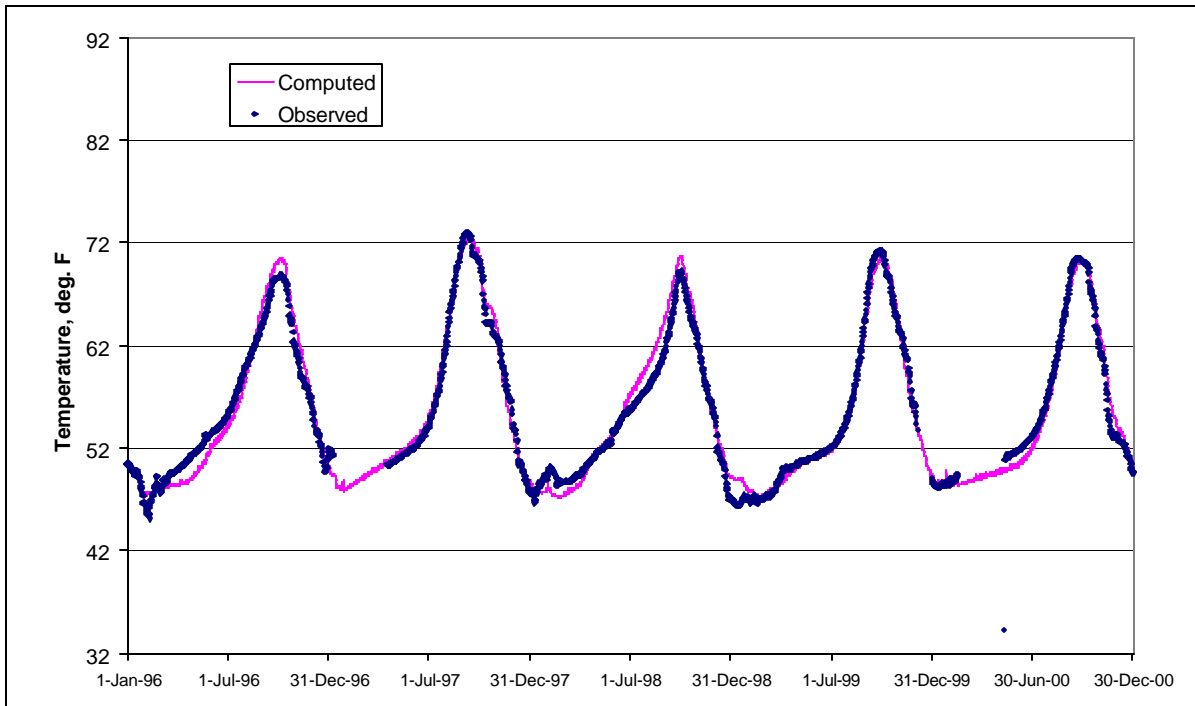
Figure 3.7 Lake Mendocino computed and observed tailwater temperatures.
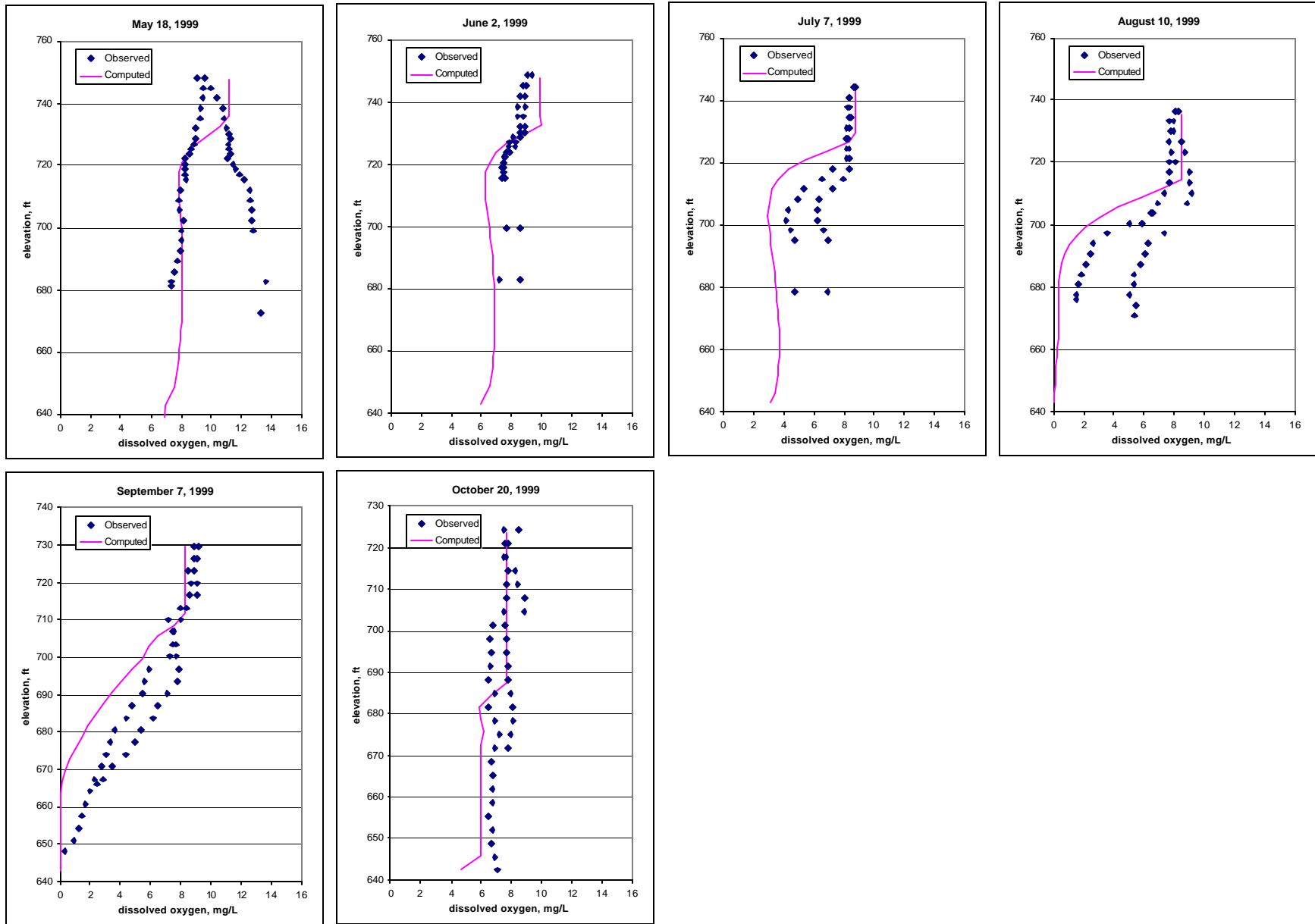
Figure 3.8 Computed and observed DO profiles in Lake Mendocino for 1999.
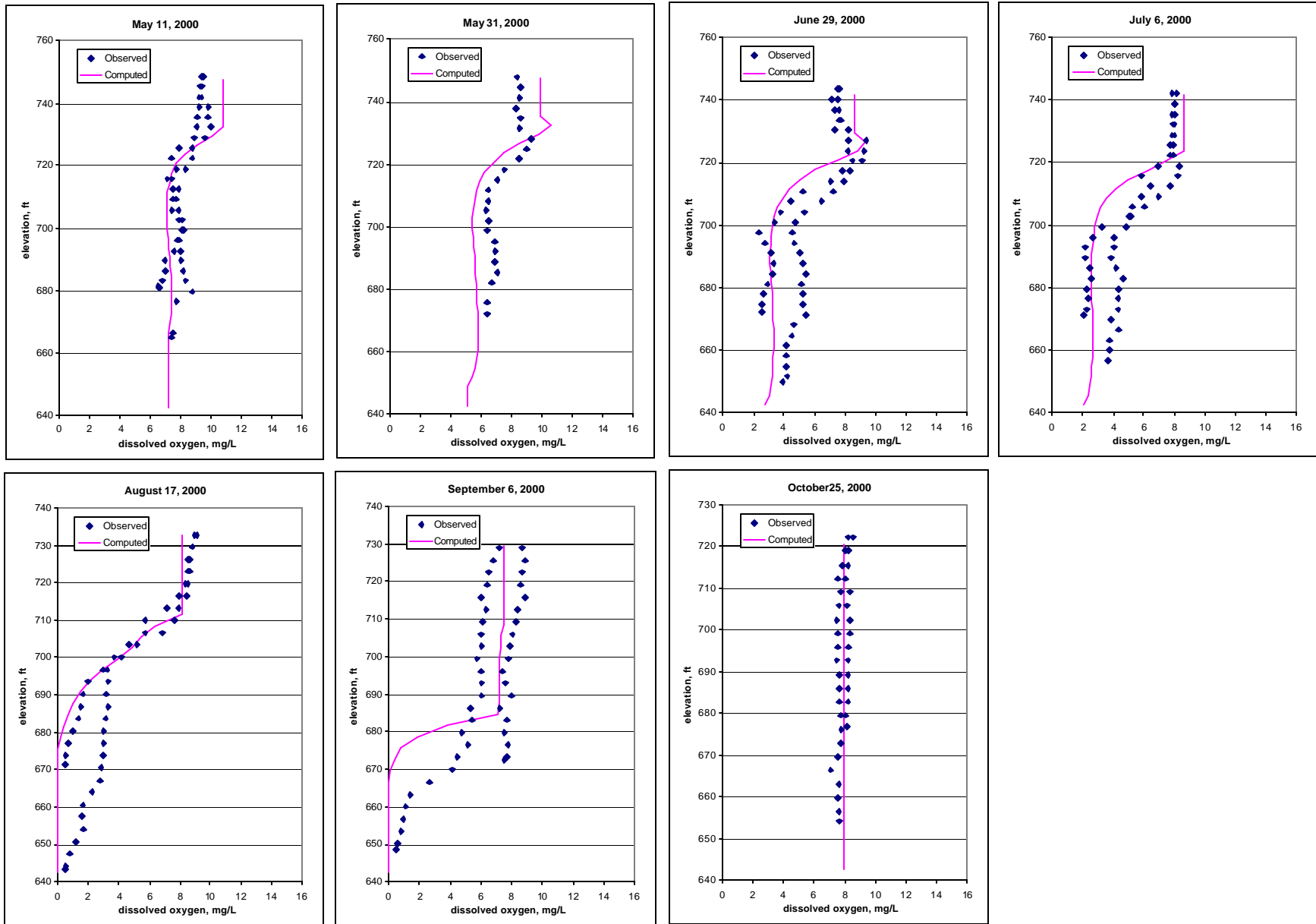
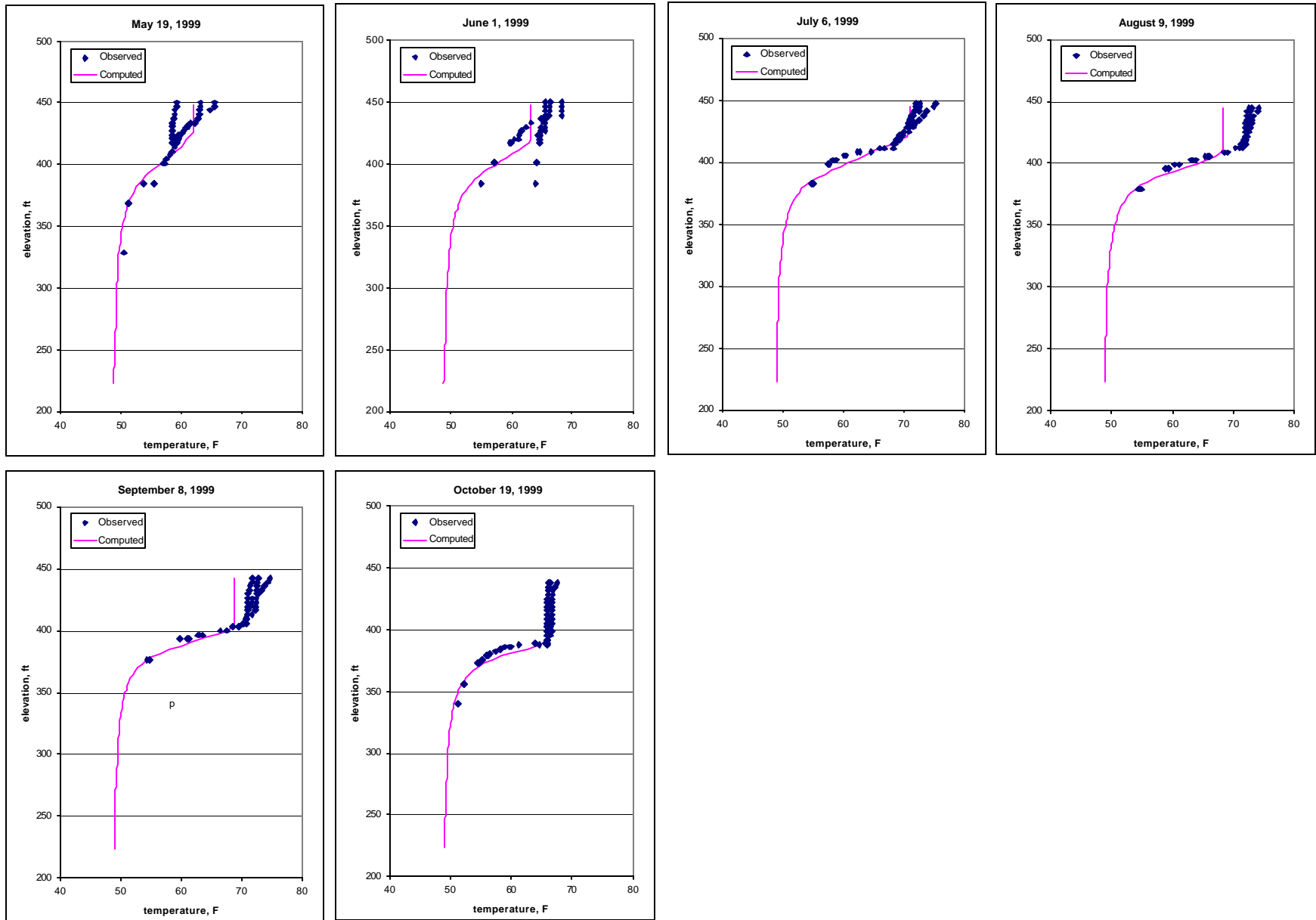Figure 3.9 Computed and observed DO profiles in Lake Mendocino for 2000.
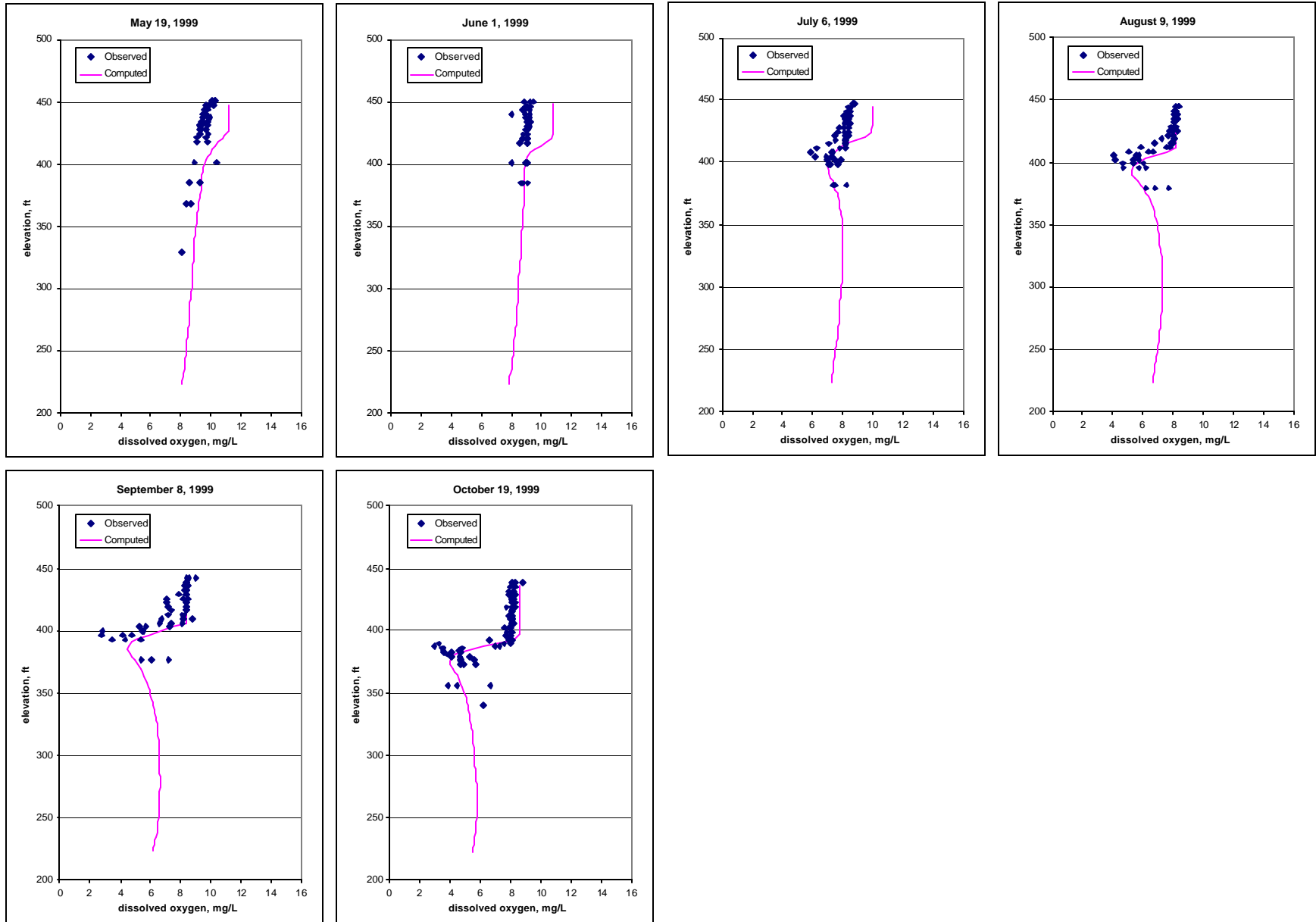
Figure 3.10 Computed and observed DO profiles in Lake Sonoma for 1999.

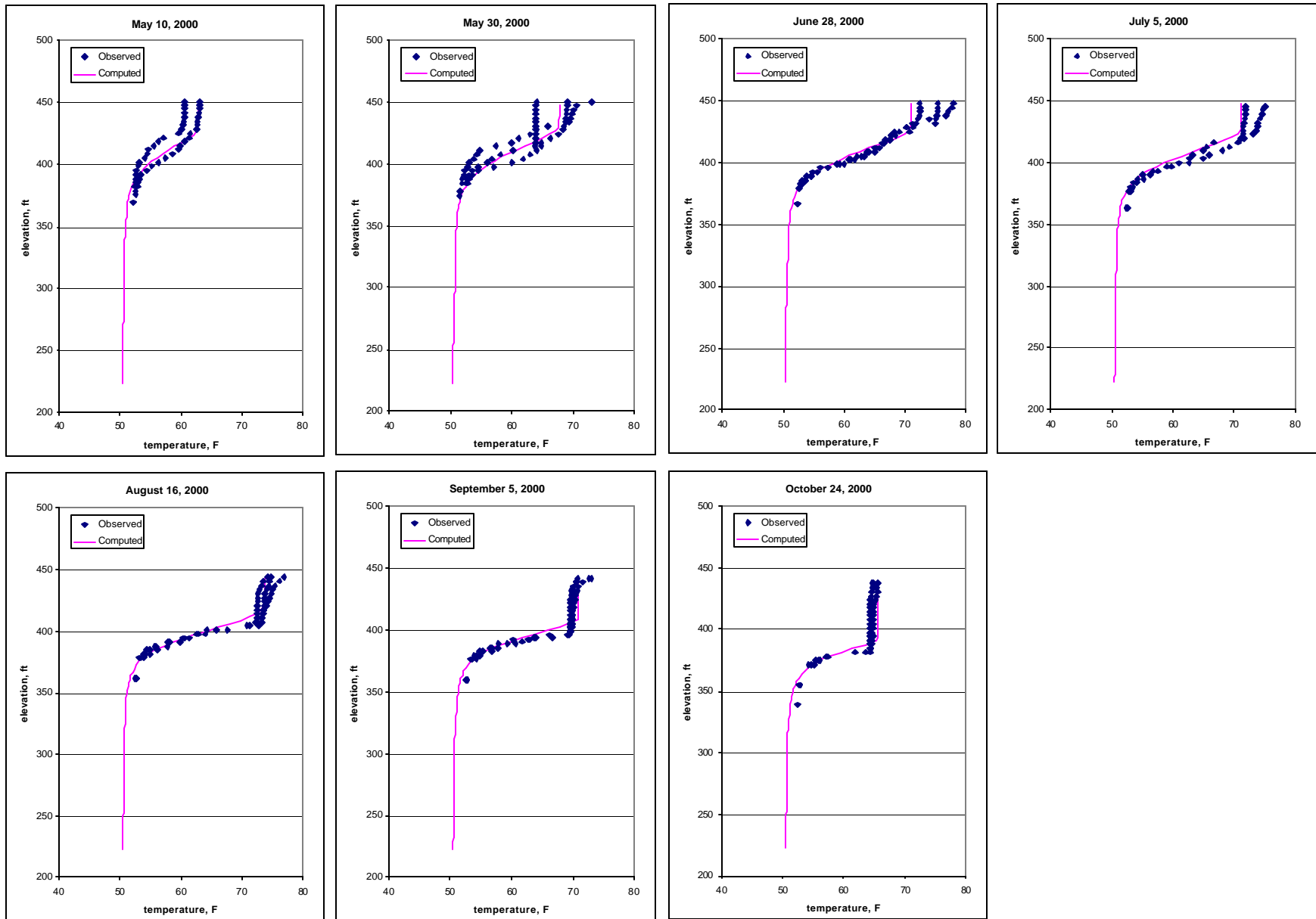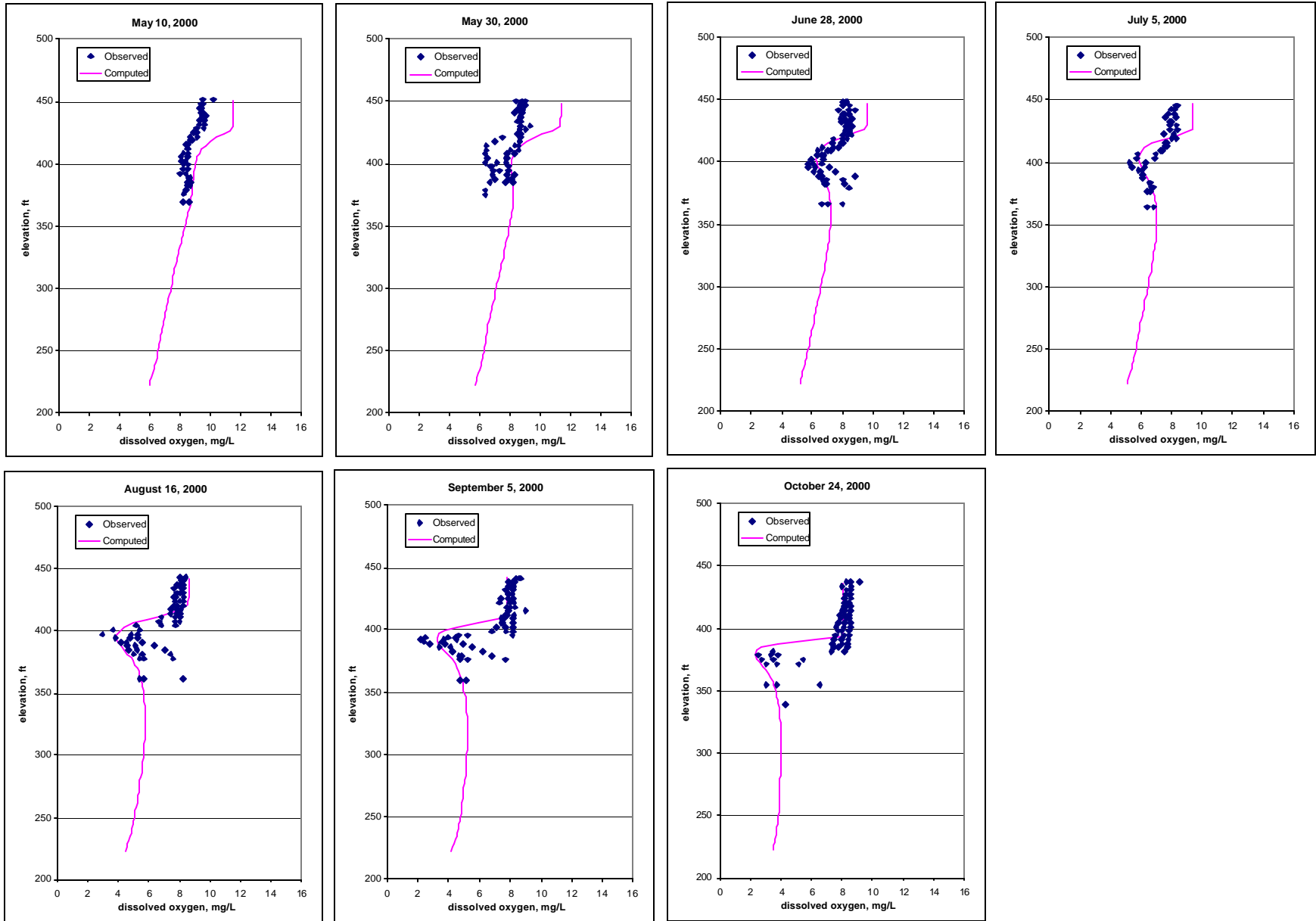Figure 3.11 Computed and observed DO profiles in Lake Sonoma for 2000.
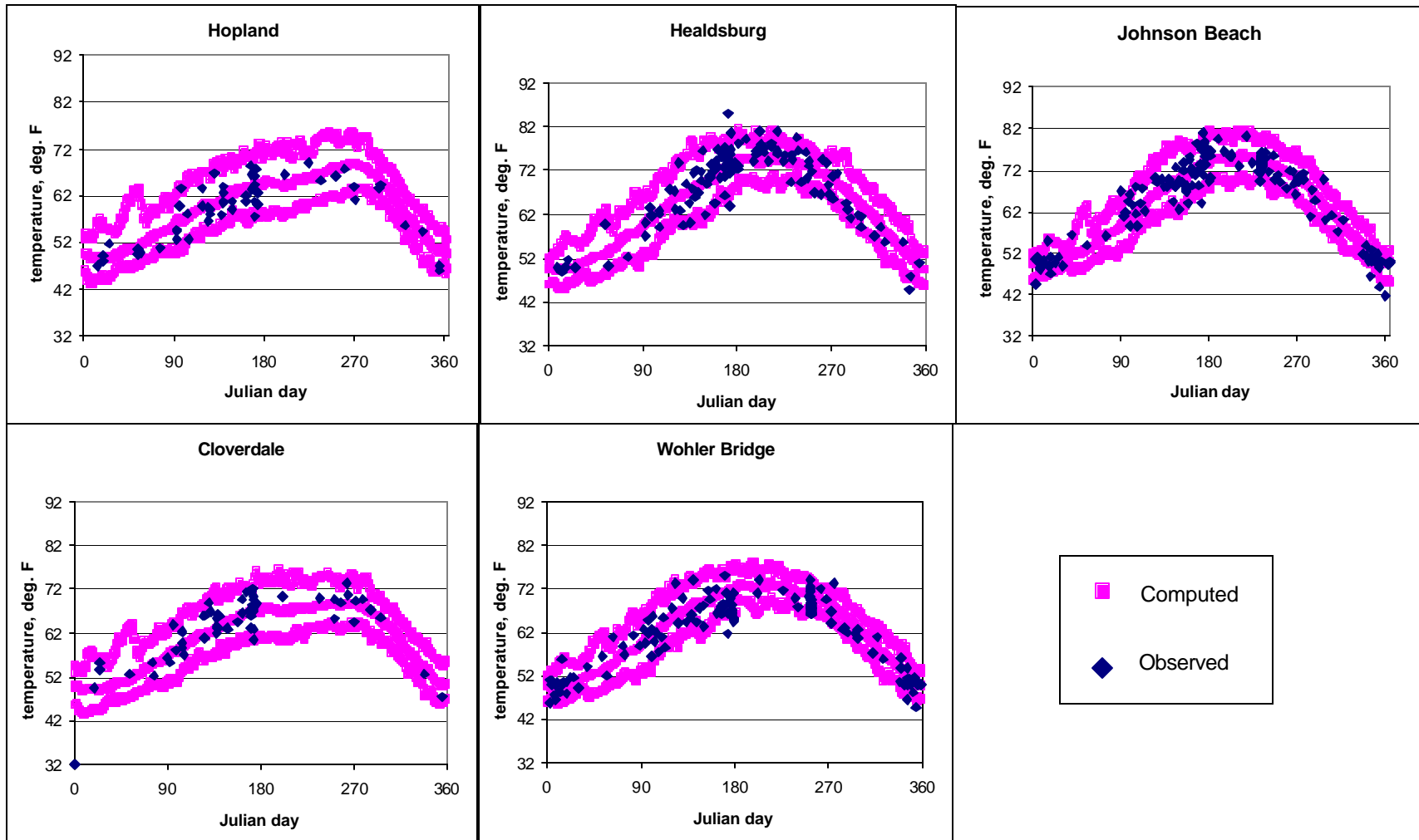
Figure 3.12 Computed and observed temperatures by Julian day.
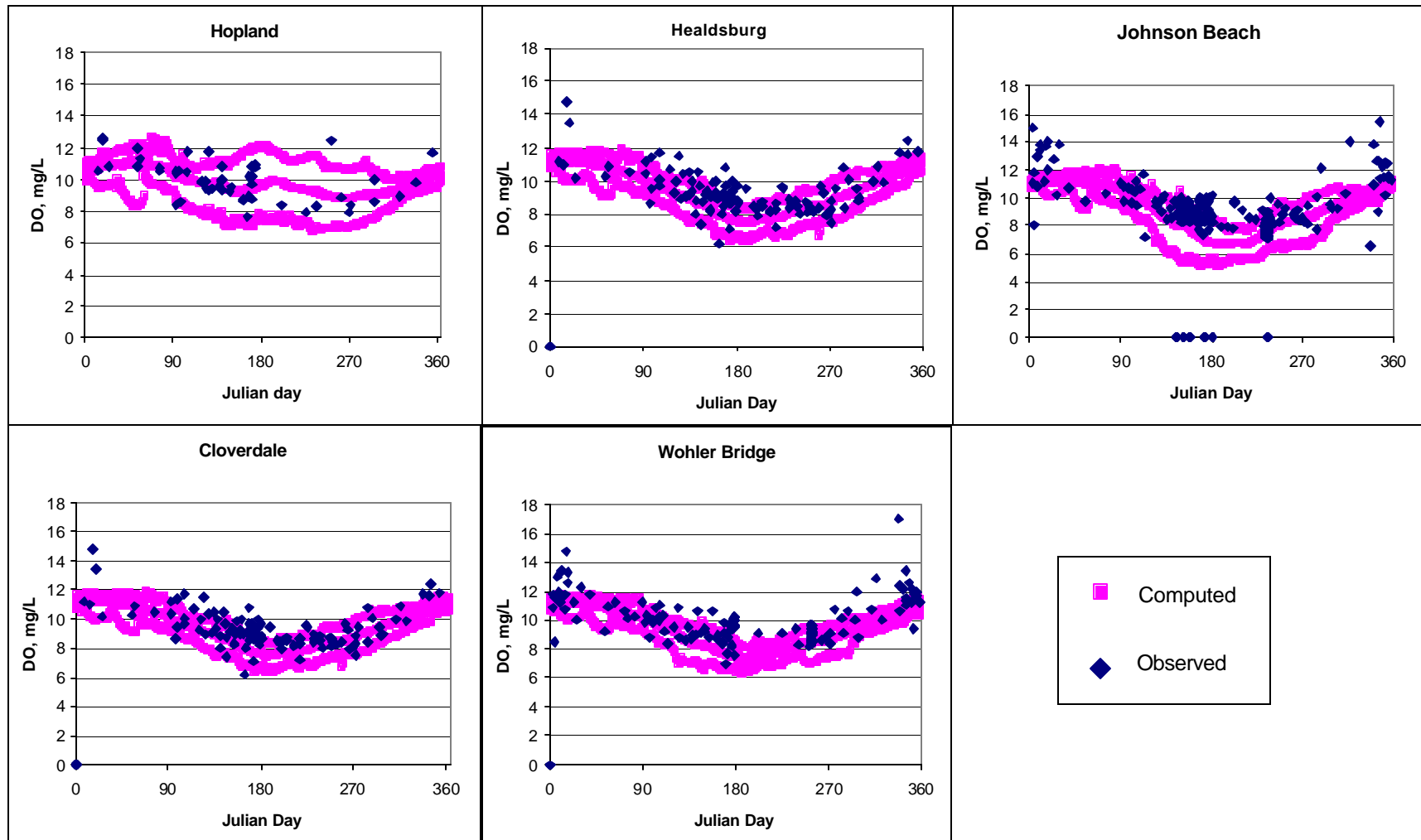
Figure 3.13 Computed and observed dissolved oxygen by Julian day.
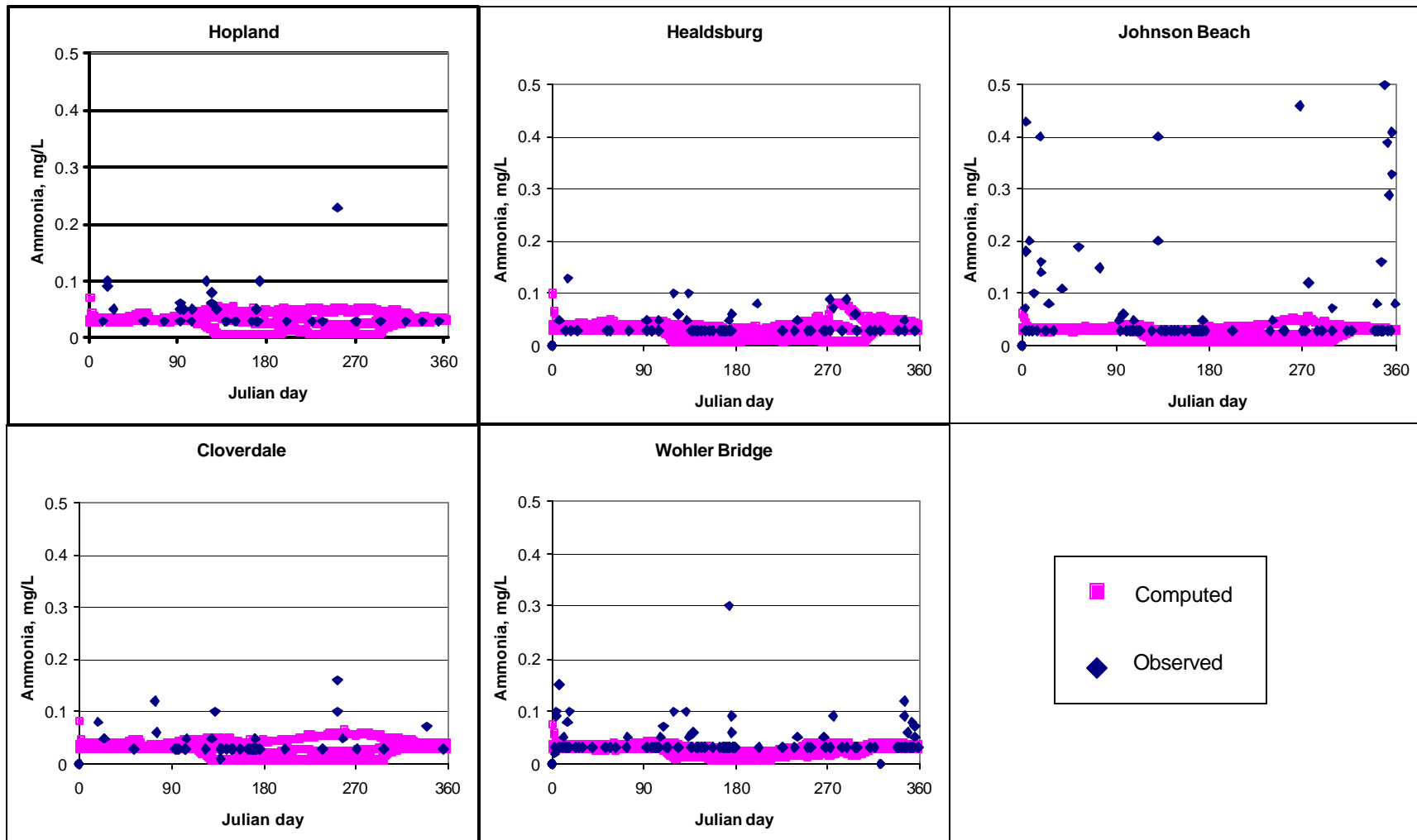
Figure 3.14 Computed and observed ammonia by Julian day.
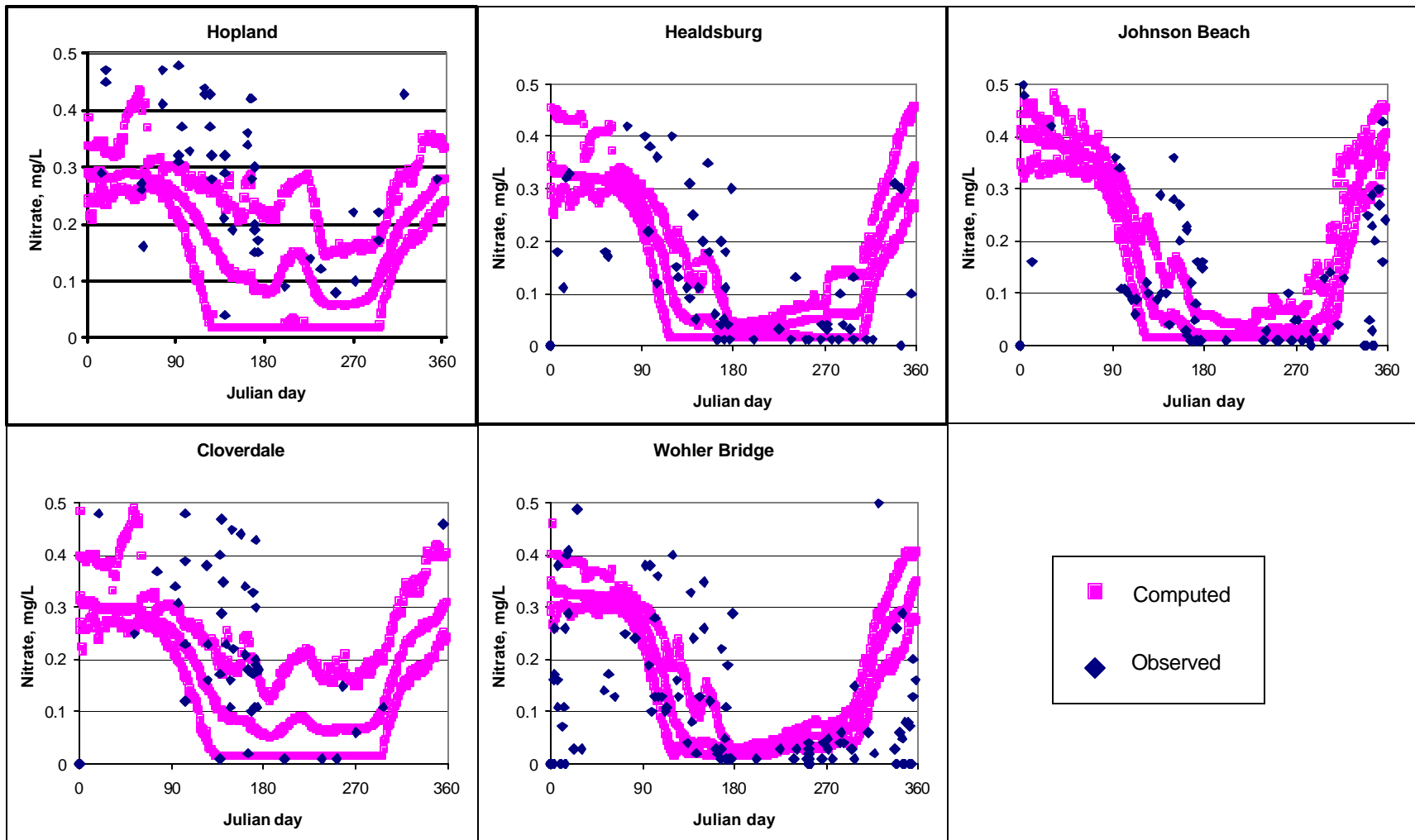
Figure 3.15 Computed and observed nitrate by Julian day.
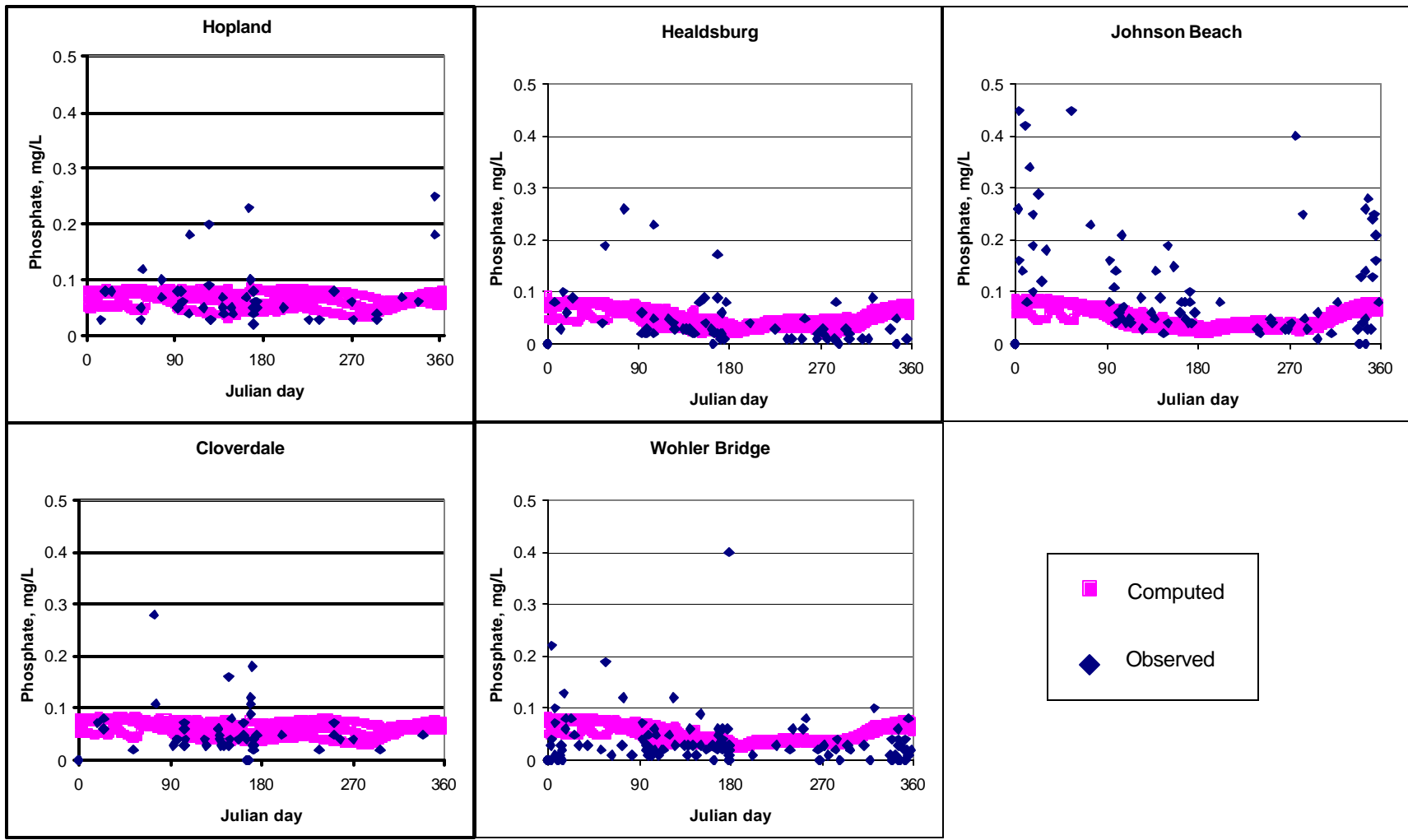
Figure 3.16 Computed and observed phosphate by Julian day.
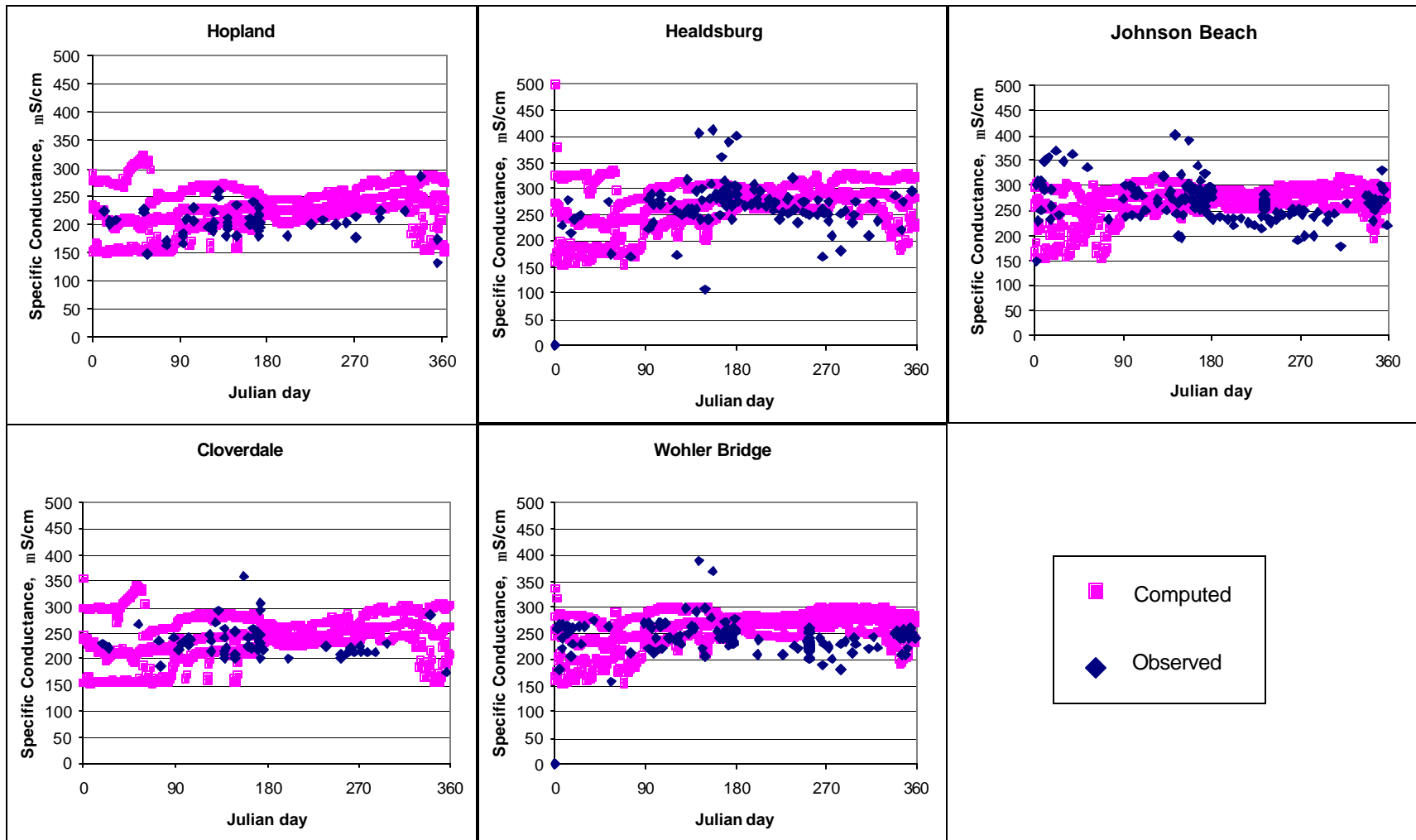
Figure 3.17 Computed and observed specific conductance by Julian day.
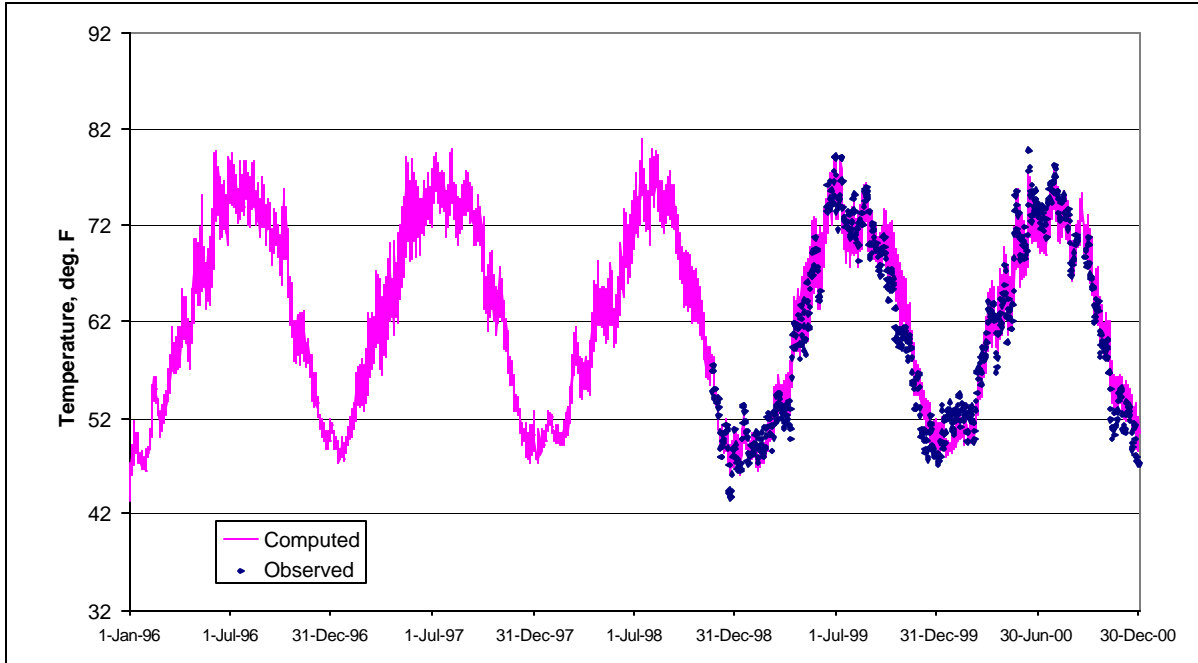
Figure 3.18 Computed and observed temperatures at Healdsburg.
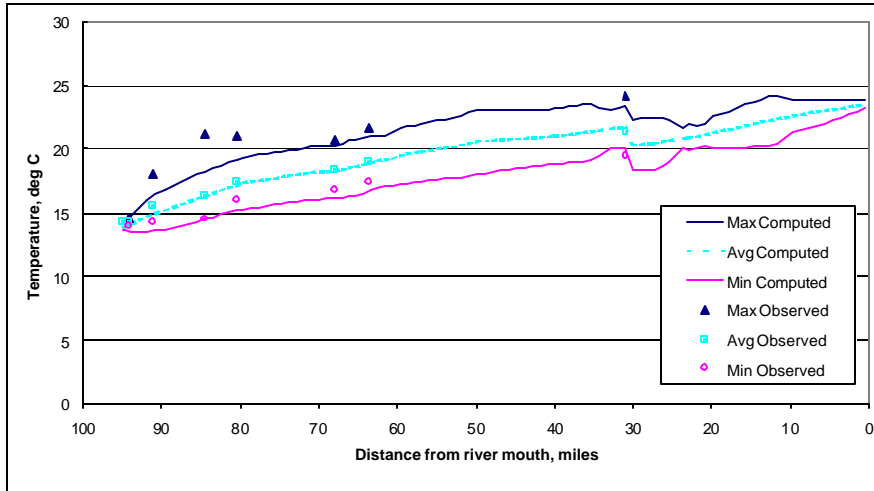
Figure 3.19 Computed maximum, minimum, and average temperature profiles with maximum, minimum and average observed data observations for August 11, 1999.
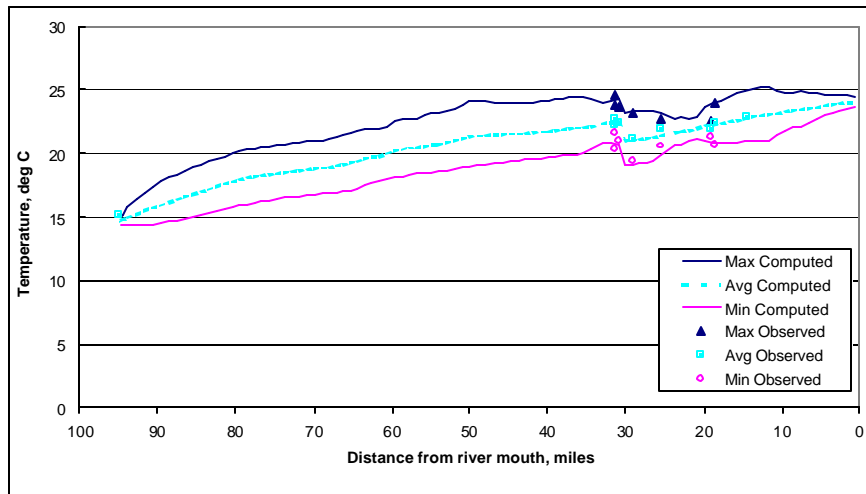
Figure 3.20 Computed maximum, minimum, and average temperature profiles with maximum, minimum and average observed data observations for August 17, 1999.
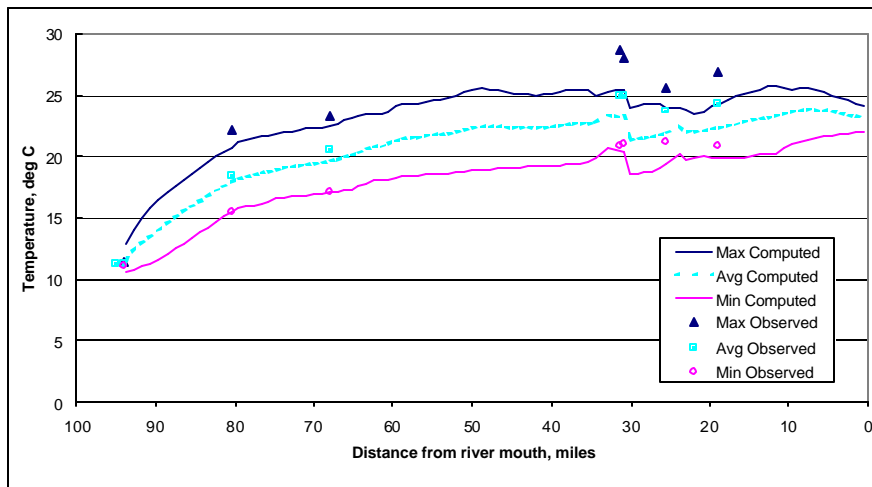
Figure 3.21 Computed maximum, minimum, and average temperature profiles with maximum, minimum and average observed data observations for June 12, 2000.
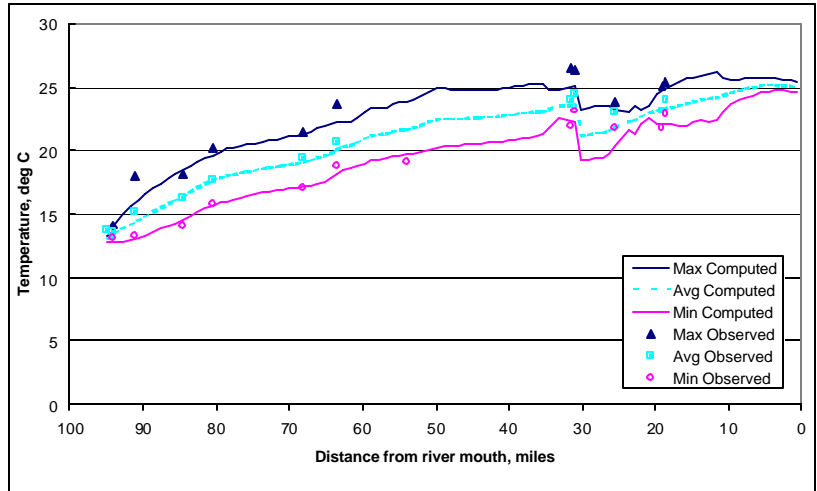
Figure 3.22 Computed maximum, minimum, and average temperature profiles with maximum, minimum and average observed data observations for July 25, 2000.
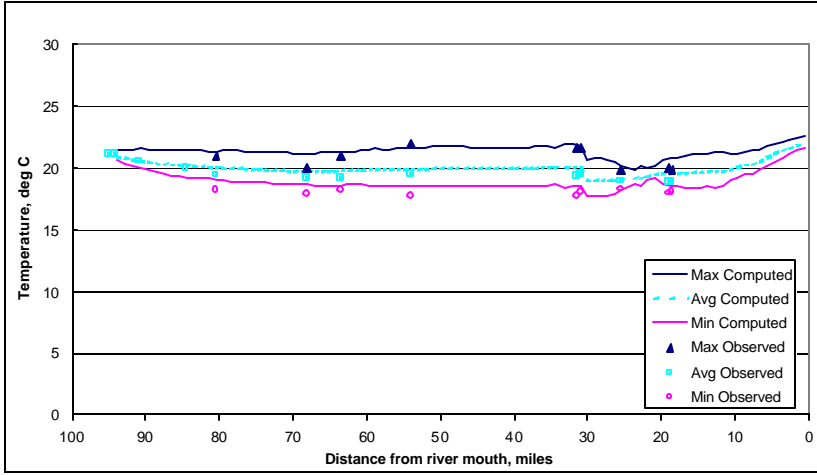
Figure 3.23 Computed maximum, minimum, and average temperature profiles with maximum, minimum and average observed data observations for October 3, 1999.

3.24
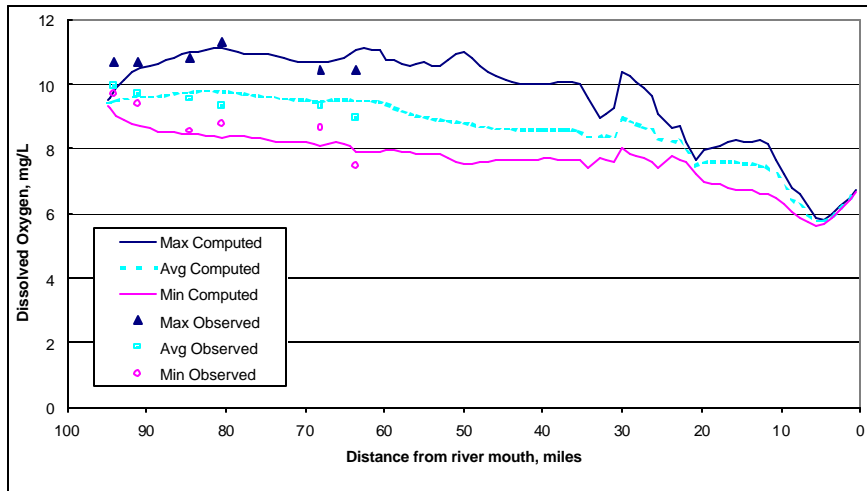
Figure 3.24 Computed maximum, minimum, and average dissolved oxygen profiles with maximum, minimum and average observed data observations for August 11, 1999.
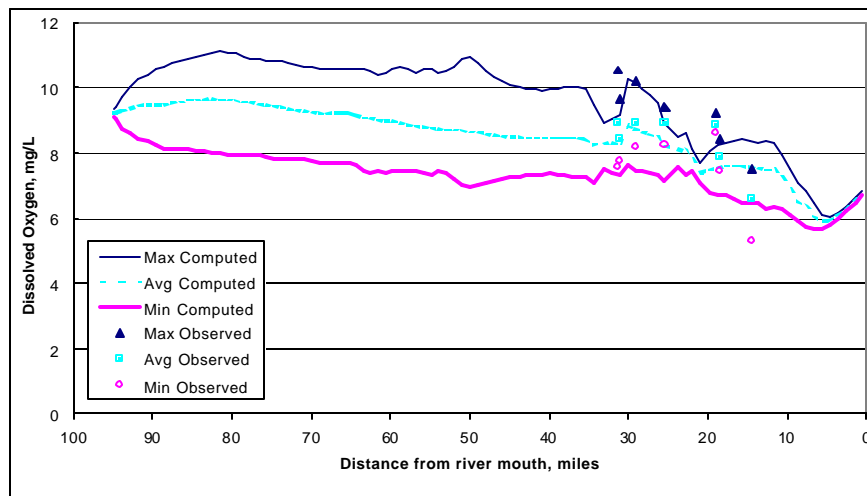
Figure 3.25 Computed maximum, minimum, and average dissolved oxygen profiles with maximum, minimum and average observed data observations for August 17, 1999.
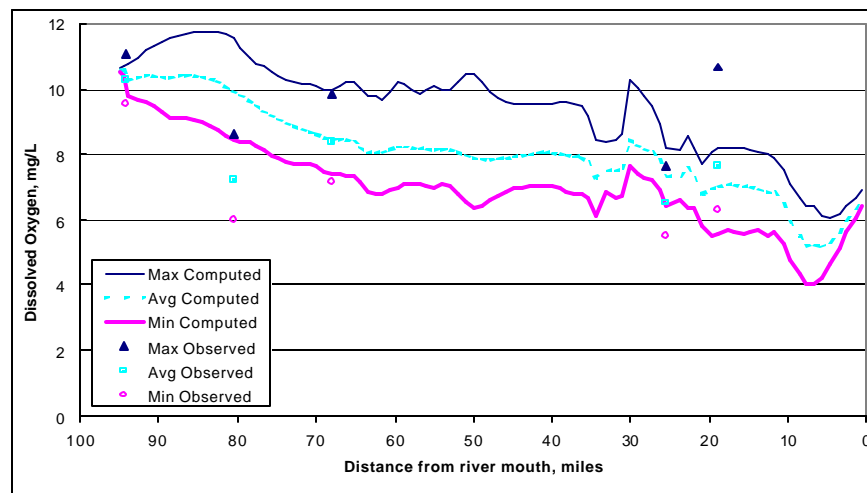
Figure 3.26 Computed maximum, minimum, and average dissolved oxygen profiles with maximum, minimum and average observed data observations for June 12, 2000.

3.25
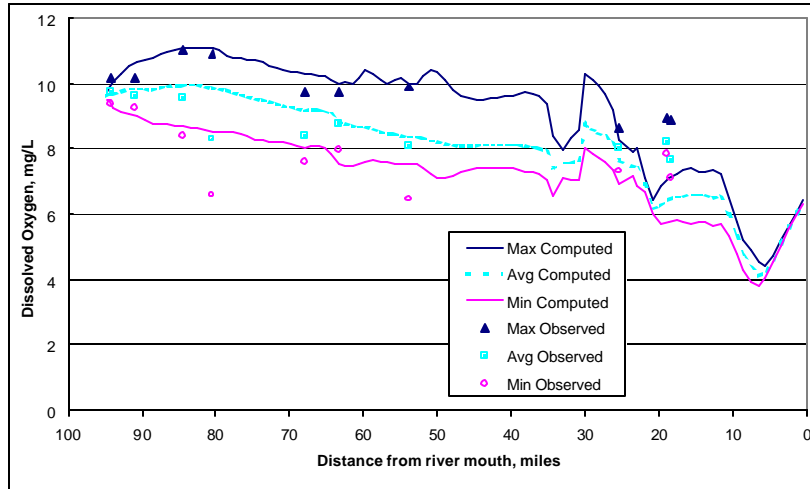
Figure 3.27 Computed maximum, minimum, and average dissolved oxygen profiles with maximum, minimum and average observed data observations for July 25, 2000.
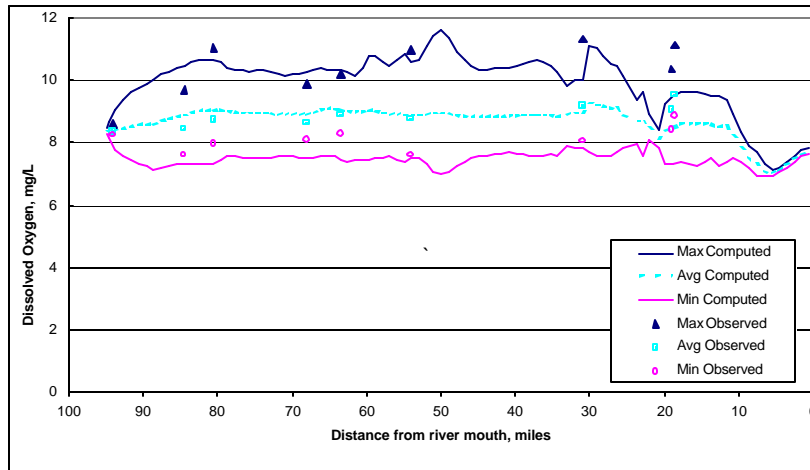
Figure 3.28 Computed maximum, minimum, and average dissolved oxygen profiles with maximum, minimum and average observed data observations for October 3, 1999.

4   MODEL RESULTS

4.1 WATER QUALITY BOUNDARY CONDITIONS AND INPUT DATA

For demonstration purposes in this report, alternative simulations were run for the period of 1986 – 1995 using the baseline conditions and cumulative impact demands and operations procedures. This 10-year period was selected since it encompassed a wide range of hydrology. Simulations were performed for the full January 1929 – September 1995 period and were used in the fisheries analysis, but will not be discussed in this report.

The specific details of the baseline conditions and cumulative impact models for the Russian River basin for 2000 and 2020 levels of development are provided within the SCWA Operations Model output files (SCWA, October 1999).

The inflow water quality constituent concentrations used during calibration (see Tables 2.3 and 2.4) were used for both the baseline and cumulative impact scenarios, although flow allocations were varied for each demand level. Hydrologic inputs as defined by the operations study, and meteorological conditions for 1986 – 1995 were used for both alternative simulations.

4.2 RESULTS OF THE ALTERNATIVE ANALYSIS

HEC-5Q was used to simulate water quality in the Russian River basin under the baseline condition and cumulative impact operations and demand levels. Hydrologic conditions from the 1986-1995 period were used to simulate water quality under current (2000) and projected long-term (2020) system operations and demand levels. Baseline conditions and cumulative impact models for 2000 and 2020 provided an evaluation of the impacts of system operations on water quality. Effects of changing flow allocations were determined by comparison of results from baseline levels versus cumulative impact levels. Selected results are presented in the Figures 4.1 through 4.17. All plots are for the 1990 – 1994 period. This period was chosen because it illustrates the maximum impact on temperature and dissolved oxygen. Fourteen-day center moving averages are used in all flow plots for clarity. Since impacts of operation assumptions on water quality vary with depth and time, simulation results for both alternatives may be viewed using the graphical user interface (GUI). Operation of the GUI is described in Appendix B.

Reservoir Elevations and Stream Flow

Baseline and cumulative impact simulation water surface elevations in Lake Sonoma and Lake Mendocino are plotted in Figures 4.1 and 4.2, respectively. The increased demand in the cumulative impact scenario results in more drawdown in both reservoirs.

Coyote Dam (Lake Mendocino) outflow is plotted in Figure 4.3. Only flows from 0 to 500 cfs are shown in the flow plots to emphasize low flow differences. Although Lake Mendocino elevations are lower for the cumulative impact scenario as seen in Figure 4.2, outflows for the cumulative impact scenario are similar to and at times lower than the baseline outflows. This is due to a 9% decrease in inflow to Lake Mendocino

resulting from smaller Potter Valley diversions from the Eel River and additional consumptive use above the reservoir.

Warm Springs Dam (Lake Sonoma) outflow is plotted in Figure 4.4. For the cumulative impact scenario there are large increases in summer withdrawal due primarily to Santa Rosa demand. The winter/spring flow spikes in 2000 do not occur in 2020 because with 2020 drawdown the reservoir does not fill and thus the large winter/spring releases are unnecessary.

Russian River flow above Dry Creek is plotted in Figure 4.5. There is very little difference between the baseline and cumulative impact flows at this location, aside from one spike in the baseline flows in October 1990 (also seen in Figure 4.3), which is unexplained.

Russian River flow below Dry Creek is plotted in Figure 4.6. The Warm Springs Dam release to meet the cumulative impact Santa Rosa demands results in an increase over baseline flows at this locations.

In Figure 4.7 cumulative impact flows are plotted for the Russian River at Healdsburg (above Dry Creek) and for Dry Creek to illustrate the relative contribution of Dry Creek to the Russian River. Dry Creek flows are up to 2.5 times the Russian River flows during the summers of 1990, 1991 and 1994. In 1992 and 1993 however, Russian River flows are greater than Dry Creek flows.

Temperature

Different thermal structures are present in Lake Sonoma and Lake Mendocino. Lake Sonoma has larger volume, longer residence time, and low summer inflow, resulting in an ample cold water pool under typical operation. Lake Mendocino has smaller volume, shorter residence time, and continuous summer inflow at higher temperatures flowing through the reservoir. The result of the more rapid flow-through rate is that the cold water pool is depleted each year. A summary description of the residence times of both reservoirs is provided in Table 3.1.

Daily average baseline and cumulative impact temperatures are plotted in Figures 4.8 – 4.12 for several locations on Dry Creek and Russian River. Coyote Dam outflow temperatures are plotted in Figure 4.8, and Russian River above Dry Creek temperatures are plotted in Figure 4.9. Coyote Dam outflow temperatures are very similar for the baseline and cumulative impact scenarios except during periods of reservoir drawdown. Lake Mendocino remains stratified through mid-summer. The earlier and more rapid drawdown that occurs with the cumulative impact scenario results in quicker depletion of the cold water pool and subsequent withdrawal of warmer epilimnion waters. This is reflected in increased outflow temperatures earlier in the summer for the cumulative impacts scenario. The impact of the increased drawdown is diminished in early fall because Lake Mendocino temperatures become uniform over depth and outflow temperature is not dependent on depth of withdrawal.

There appear to be no important differences between the baseline and cumulative impact temperatures at the Russian River above Dry Creek. These temperatures are insensitive to Coyote Dam outflow temperatures due to the long travel time and resulting heating to near equilibrium temperature.

Warm Springs Dam outflow temperatures are plotted in Figure 4.10. The outlet is operated to meet a tailwater temperature of 50° F through the year for both flow conditions. The spikes in the cumulative impact temperatures occur when Lake Sonoma is drawn down to the lower elevations. At these low elevations, the withdrawal occurs in the warmer waters of the epilimnion, whereas withdrawal is usually from the cooler hypolimnion waters. The model has not been calibrated for the low water surface elevations that occur in the cumulative impact scenario, therefore there is some uncertainty in these results.

Temperatures for Dry Creek above the Russian River and Russian River below Dry Creek are plotted in Figures 4.11 and 4.12. At both locations, cumulative impact temperatures are generally lower than baseline temperatures because of the increased flow from Lake Sonoma. The greater depths and higher velocities (less travel time) allow less in-stream heating. The spikes in Warm Springs Dam outflow temperatures produce cumulative impact temperatures that are higher than baseline temperatures for brief periods at the latter two stations. This effect is more apparent at Dry Creek above Russian River than at the Russian River below Dry Creek station due to mixing of Dry Creek flows with Russian River flows. The relative difference is a function of the relative flow seen in Figure 4.7.

Table 4.1 summarizes degree-days over 60° F for several locations on the Russian River and Dry Creek. Degree-days over 60° F are computed as the number of days and degrees the average temperature at a location is greater than 60° F for the period of January 1, 1986 – September 30, 1995 (3560 days). For example if the temperature was 65° degrees for 5 days, that would be $(65^{\circ} - 60^{\circ})*5$ days $= 25$ degree-days over 60°. The annual averages of these values are reported in Table 4.1. The temperature of 60° F was chosen arbitrarily but provides a measure of an environment consistent with salmonids and other cold water fishes (higher values indicate less desirable conditions). This computation is used as an indication of the aggregate effect of 2020 operating conditions and demand levels on temperature.

Table 4.1   Degree-days above 60° F for baseline and cumulative impact scenarios.

Location	Baseline Conditions	Cumulative Impact	% Change
	Average degree-days above 60° F per year		
Dry Creek @ Russian River	6,379	4,301	-32.6%
Russian Rive above Dry Creek	21,188	21,300	0.5%
Russian River below Dry Creek	14,948	12,045	-19.4%
Below Coyote Dam	6,433	8,479	31.6%
Below Warm Springs Dam	0	154	–

Dissolved Oxygen

Daily average baseline and cumulative impact DO results are plotted in Figures 4.13 – 4.17. In general, all changes in DO are related to temperature differences because saturation concentration is temperature dependent.

DO concentrations for the two alternatives are plotted in Figure 4.13 at the Russian River below Coyote Dam. At this location, there appear to be no important differences between the baseline and cumulative impact DO concentrations. Tailwater reaeration at both dams minimizes impact of low DO in the hypolimnion. The Coyote Dam tailwater reaeration coefficient reflects current operation, which bypasses the power plant. Less turbulence is generally associated with power production, therefore the model may not be representative of hydroelectric facility operation. Less turbulence may act to lower the tailwater DO concentration.

DO concentrations for the Russian River above Dry Creek are plotted in Figure 4.14. Again, there appear to be no important differences in DO at this location.

DO concentrations below Warm Springs Dam are plotted in Figure 4.15. Cumulative impact concentrations are generally slightly higher than baseline concentrations due to the lower temperatures, except during the periods of lowest reservoir elevations when cumulative impact temperatures spike and DO drops. The higher cumulative impact DO concentrations are reflected downstream at the Dry Creek above Russian River and Russian River below Dry Creek stations as shown in Figures 4.16 and 4.17. Lower DO in Dry Creek for the cumulative impact scenario during January – February 1991 is due to low flow (20 cfs). Low flow results in lower reaeration, and higher sensitivity to sediment demand due to the larger sediment area to water volume ratio. The results under these conditions may not be representative because the model has not been calibrated for very low flows.

Nutrients

There were virtually no differences in nutrient concentrations between the baseline and cumulative impact scenarios.

The model assumed the same tributary water quality and benthic algae density for both alternatives. Since there were no major differences in Russian River flow rates, it is not surprising that there are only minor differences in nutrient concentrations. The model analysis does not address water quality impacts of possible changes in inflow quality due to changes in land use and watershed management.
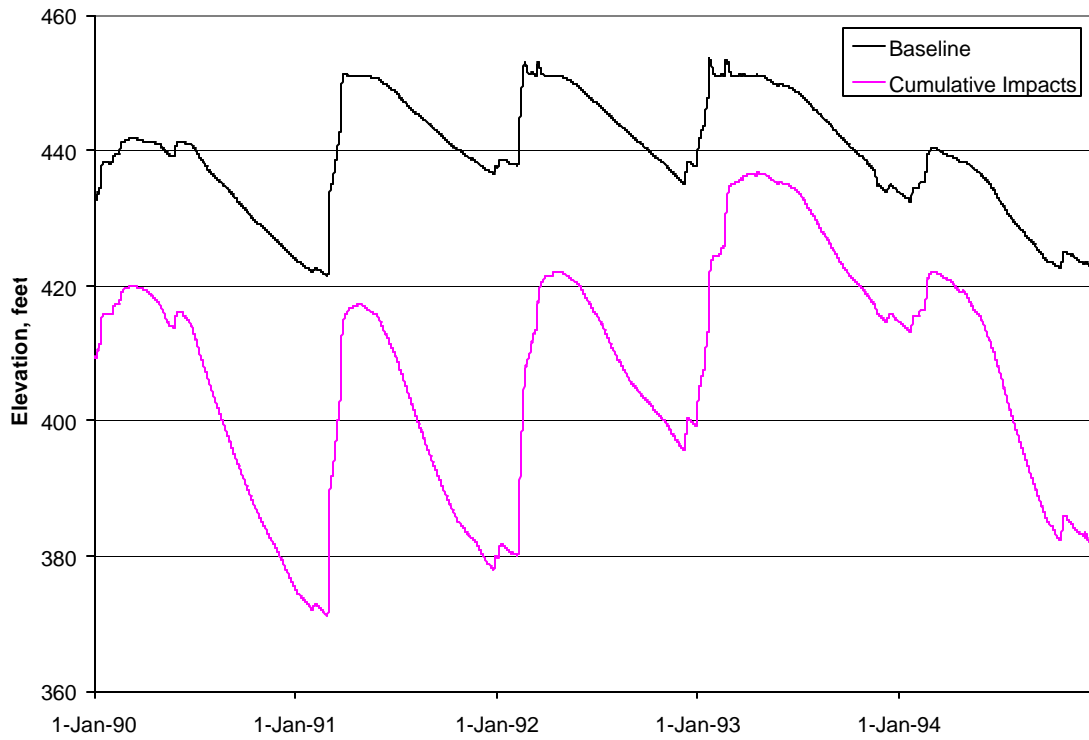
Figure 4.1 Baseline and cumulative impact simulation water surface elevations in Lake Sonoma.
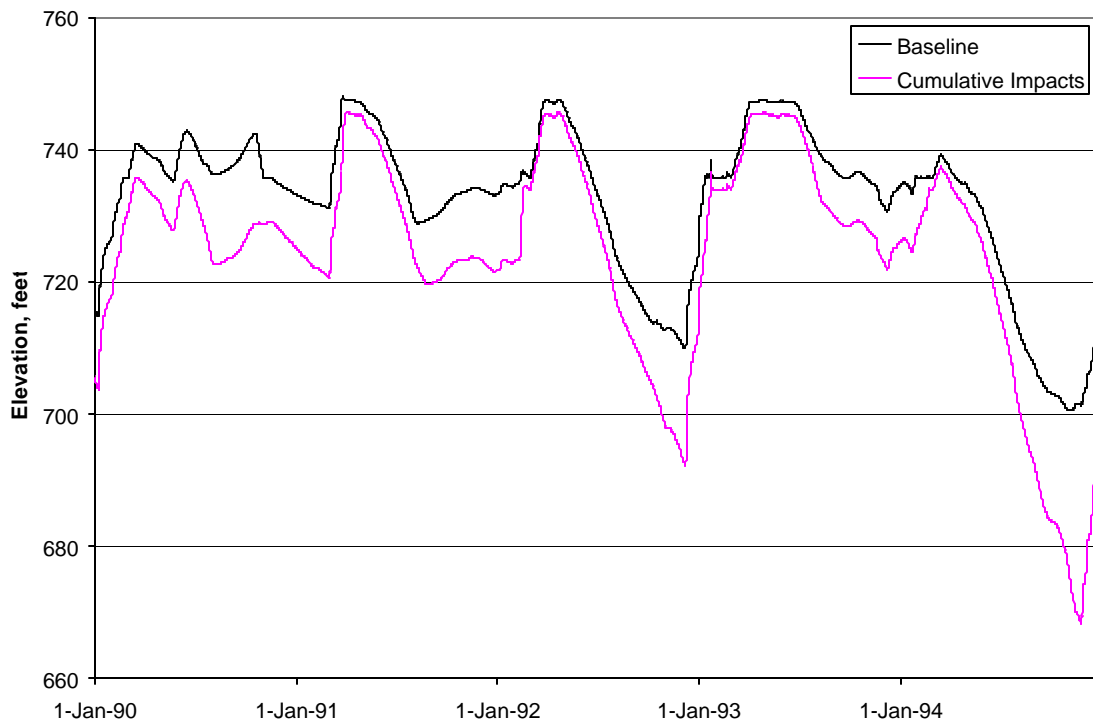
Figure 4.2 Baseline and cumulative impact simulation water surface elevations in Lake Mendocino.
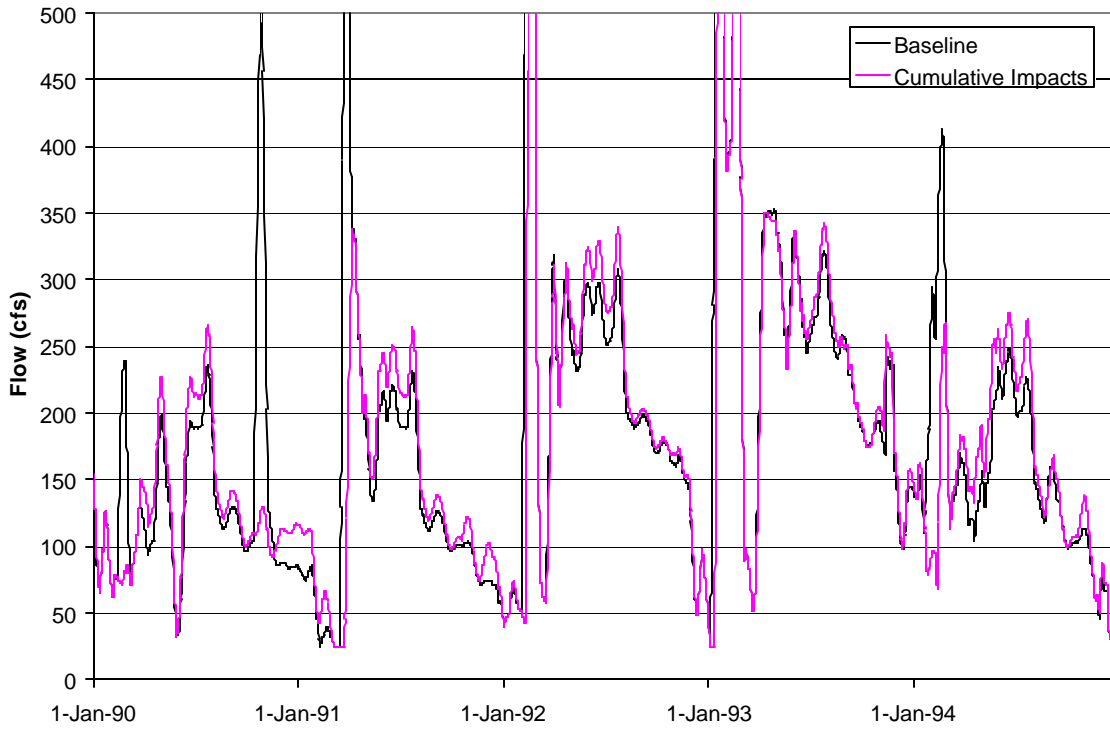
Figure 4.3 Simulated Coyote Dam outflow for baseline and cumulative impact scenarios.
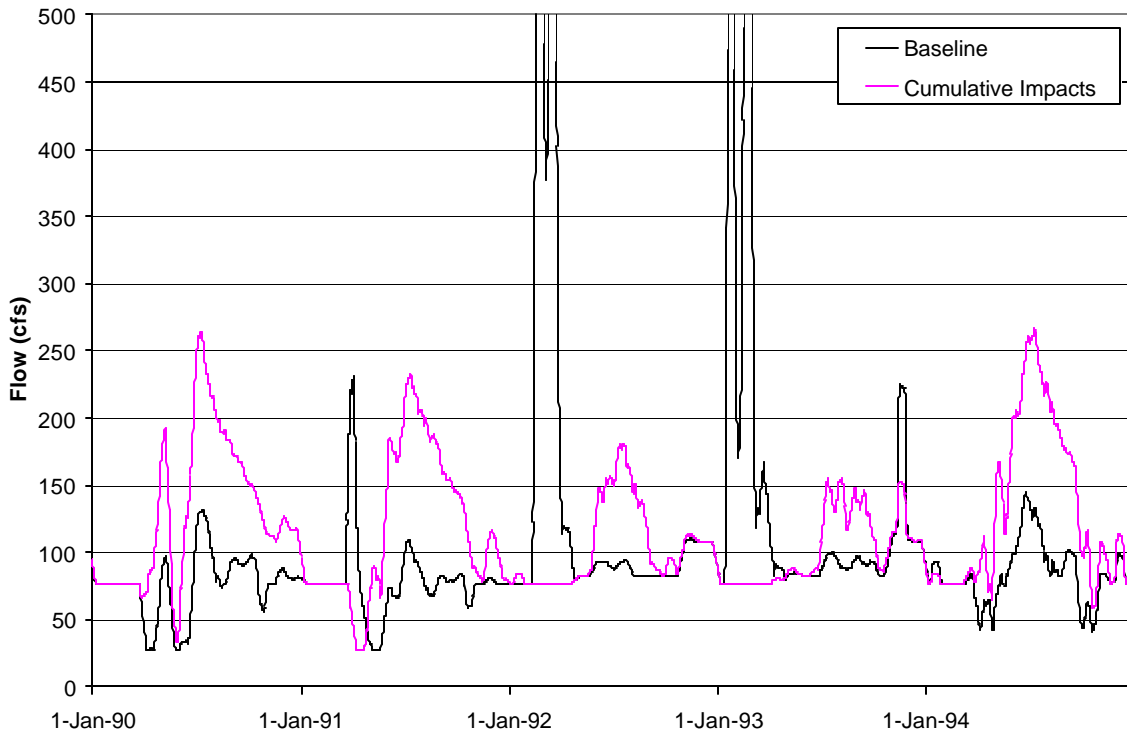
Figure 4.4 Simulated Warm Springs Dam outflow for baseline and cumulative impact scenarios.
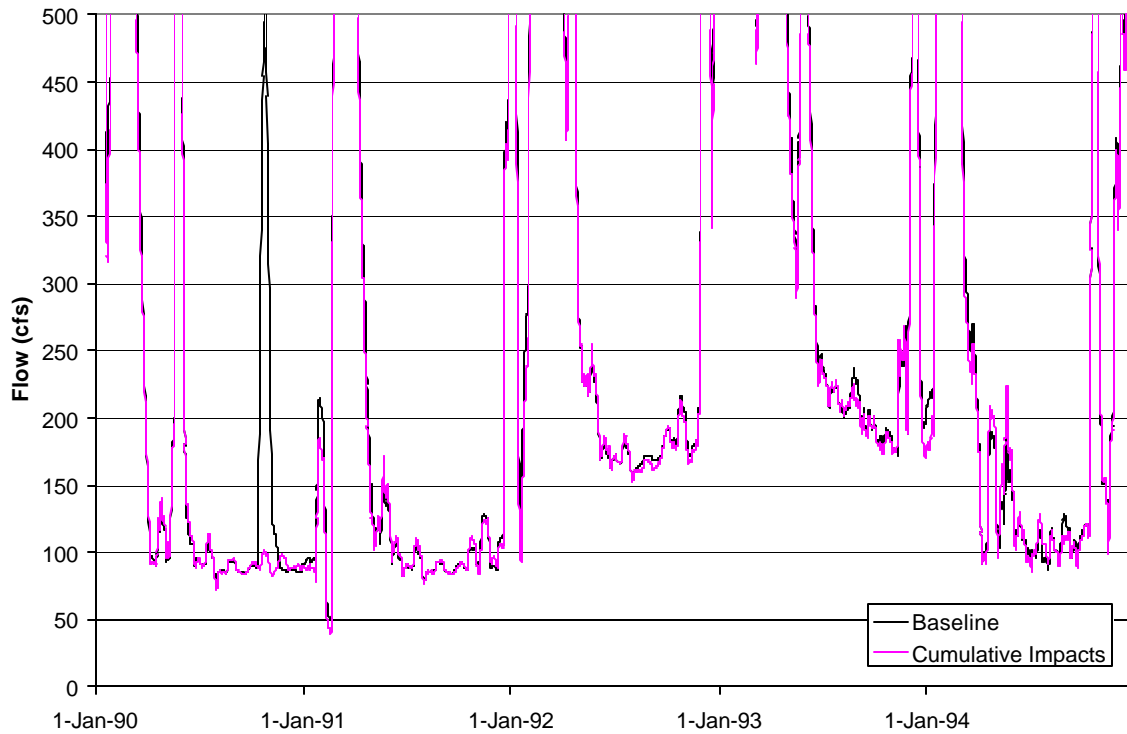
Figure 4.5 Simulated flow in Russian River at Healdsburg (above Dry Creek) for baseline and cumulative impact scenarios.
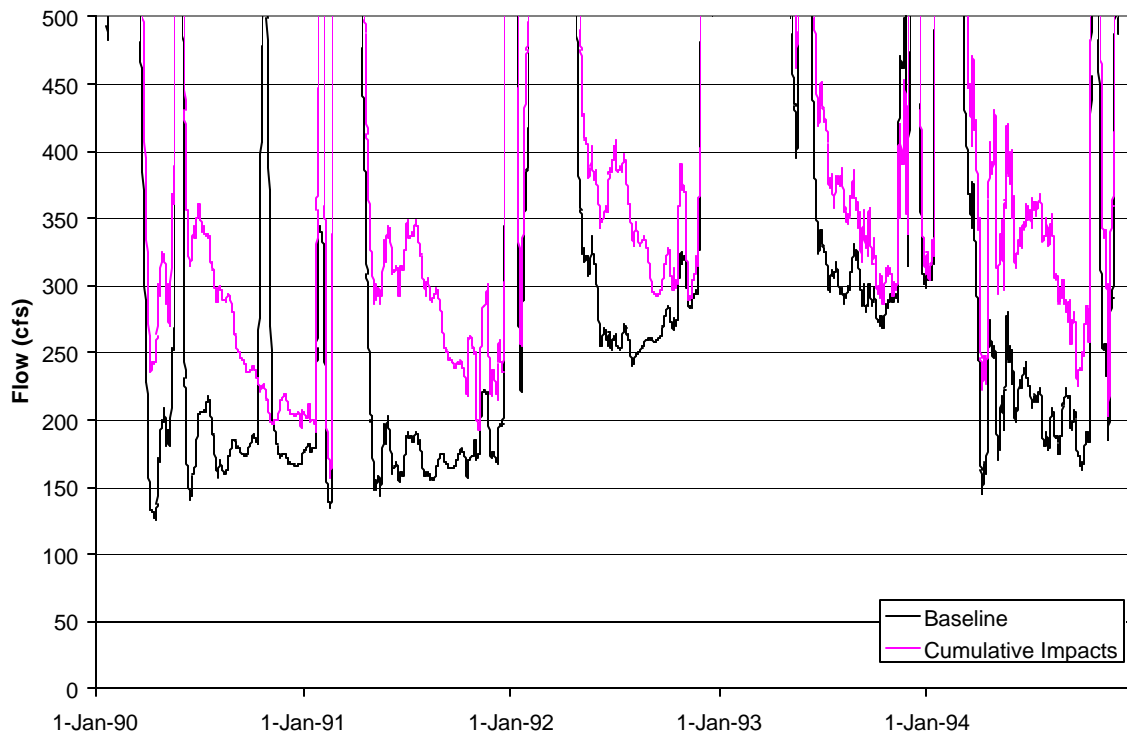
Figure 4.6 Simulated flow in Russian River below Dry Creek for baseline and cumulative impact scenarios.

4.7
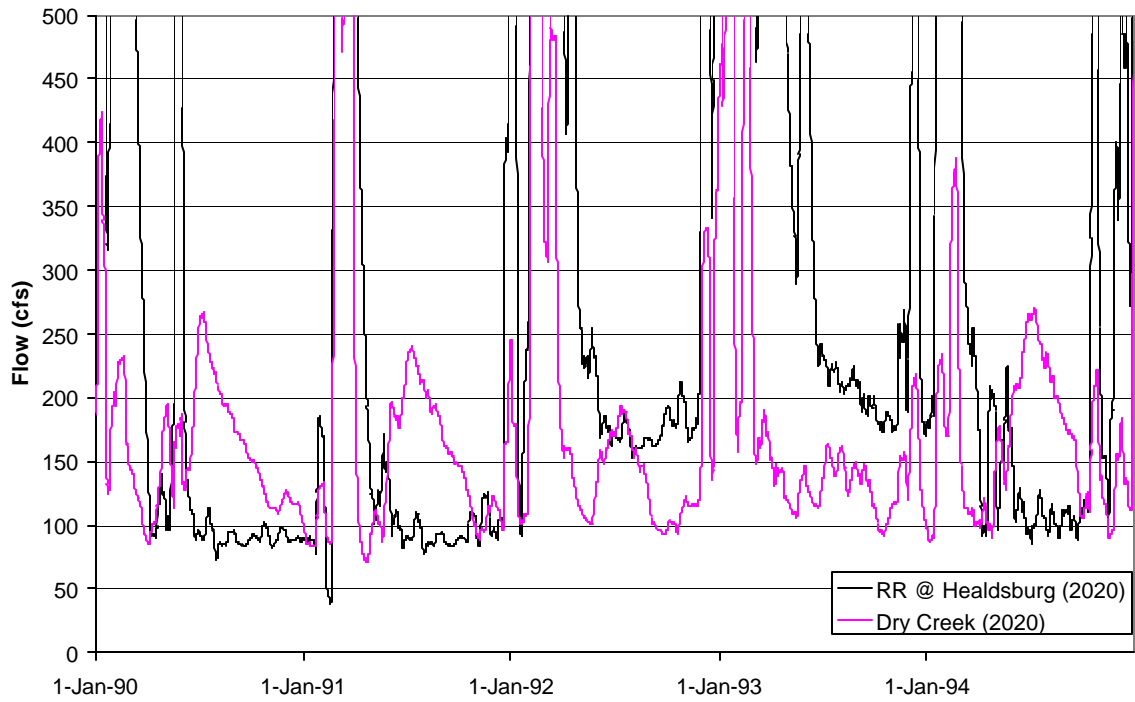
Figure 4.7 Simulated cumulative impact scenario flows in Russian River at Healdsburg (above Dry Creek), and in Dry Creek.
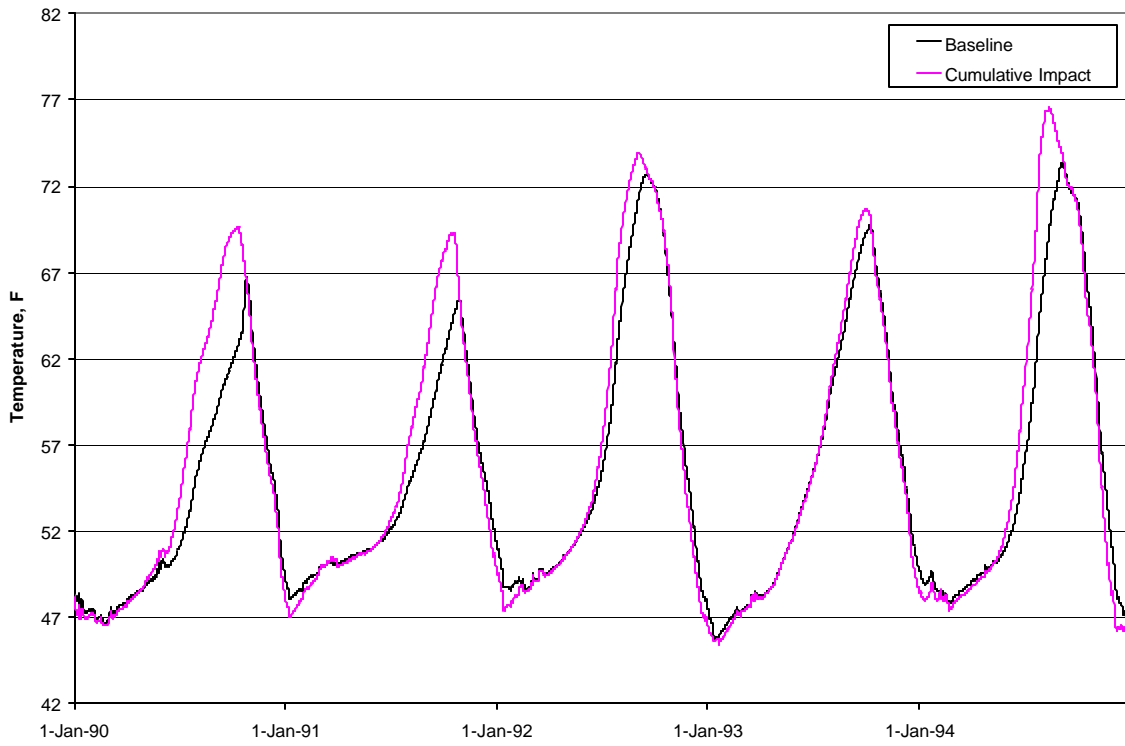
Figure 4.8 Simulated baseline and cumulative impact outflow temperatures below Coyote Dam .
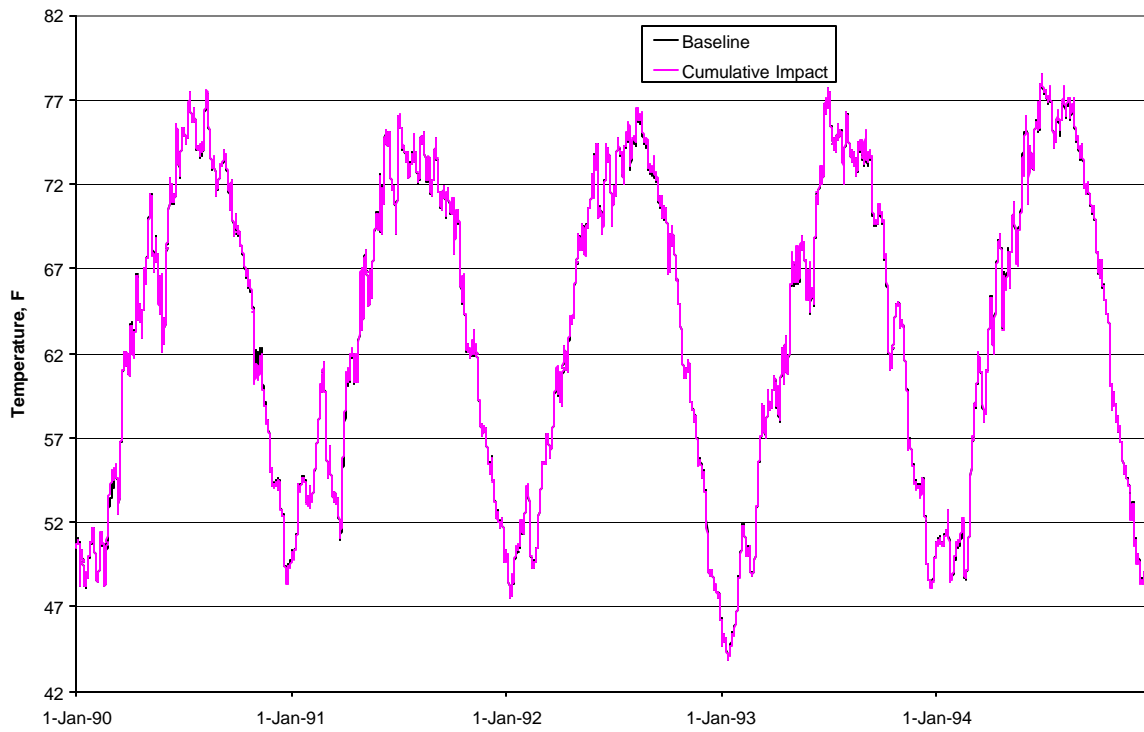
Figure 4.9 Simulated baseline and cumulative impact temperatures at Russian River above Dry Creek .

4.9
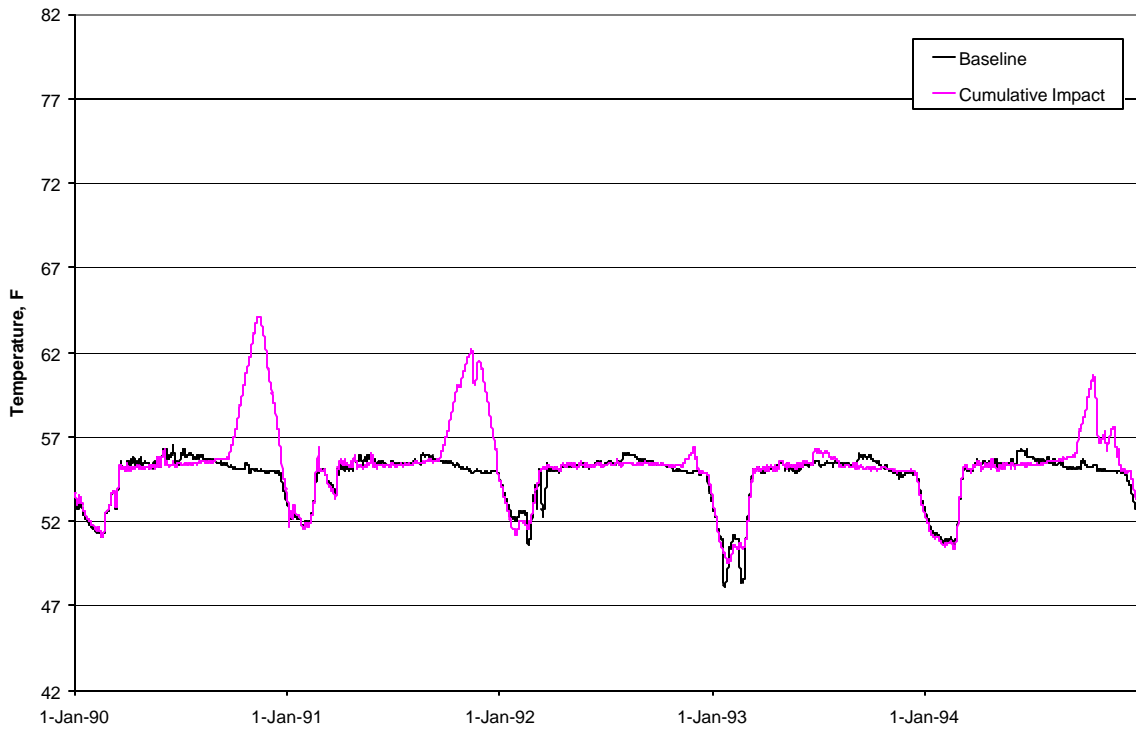
Figure 4.10 Simulated baseline and cumulative impact outflow temperatures below Warm Springs Dam .
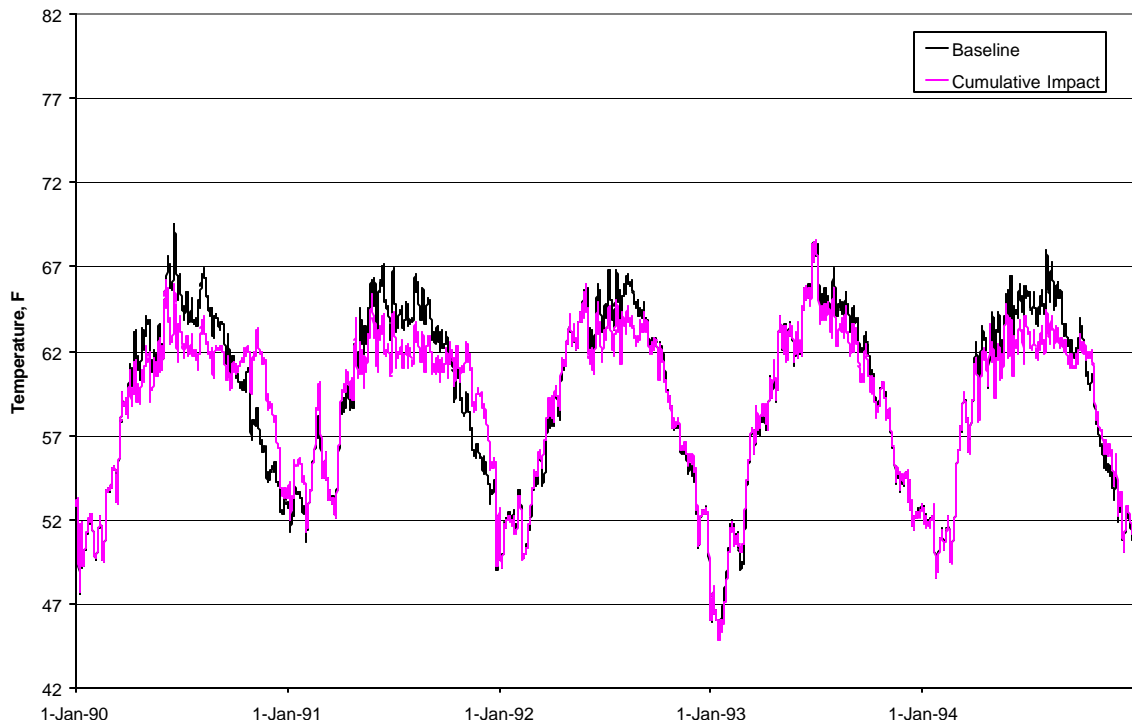
Figure 4.11 Simulated baseline and cumulative impact temperatures at Dry Creek above Russian River .

4.10
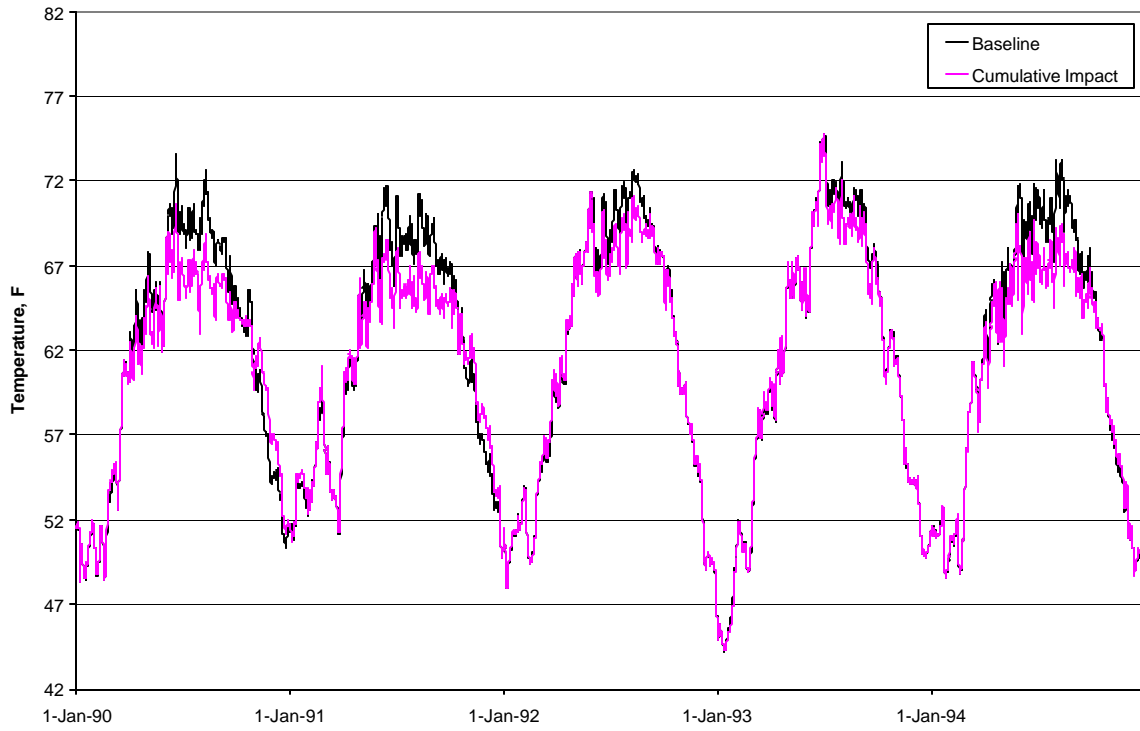
Figure 4.12 Simulated baseline and cumulative impact temperatures at Russian River below Dry Creek .
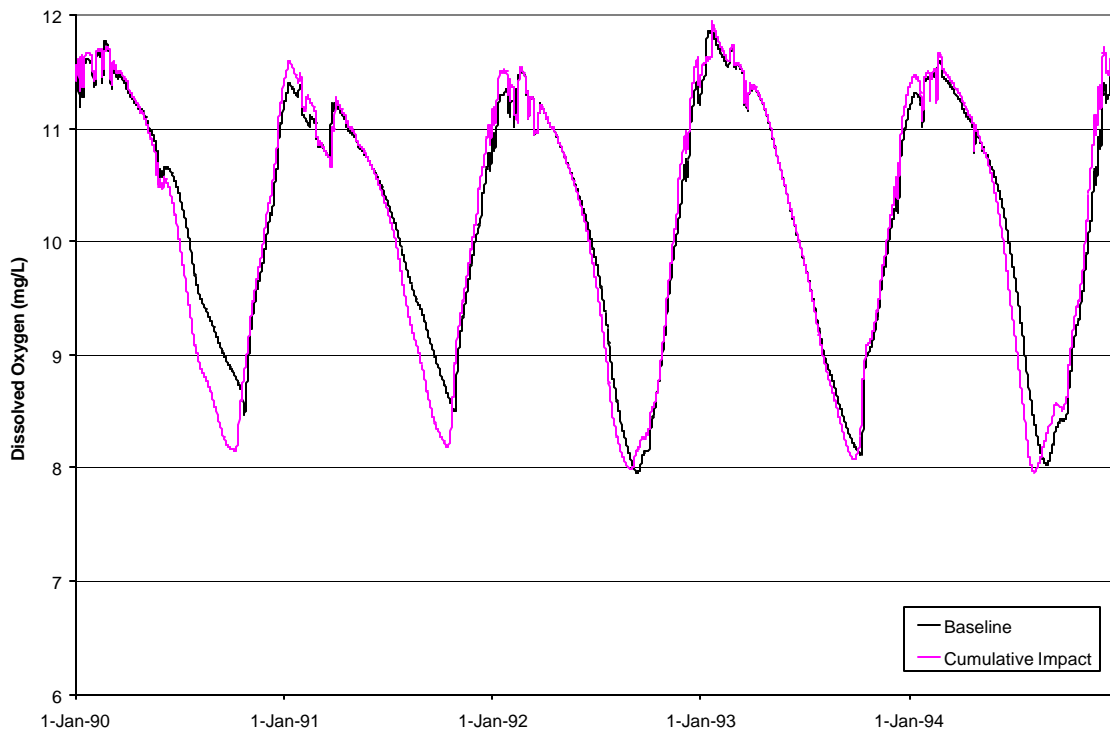
Figure 4.13 Simulated baseline and cumulative impact outflow dissolved oxygen concentration below Coyote Dam.
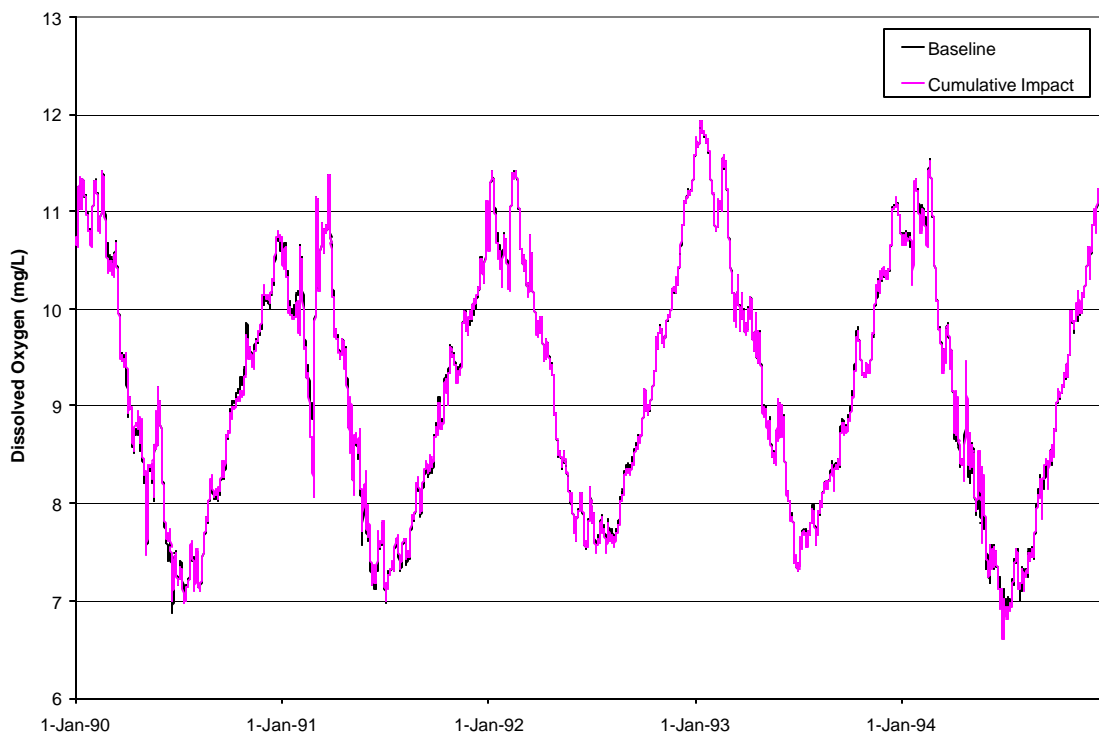
Figure 4.14 Simulated baseline and cumulative impact dissolved oxygen concentration at Russian River above Dry Creek.

4.12
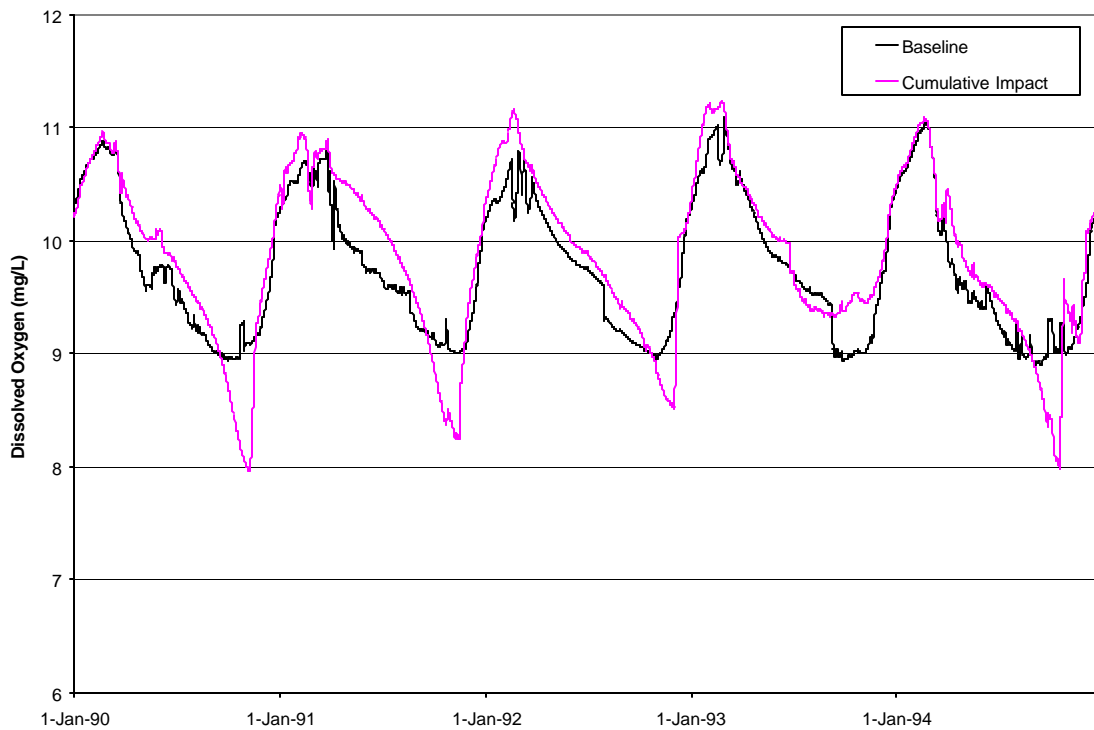
Figure 4.15 Simulated baseline and cumulative impact outflow dissolved oxygen concentration below Warm Springs Dam.
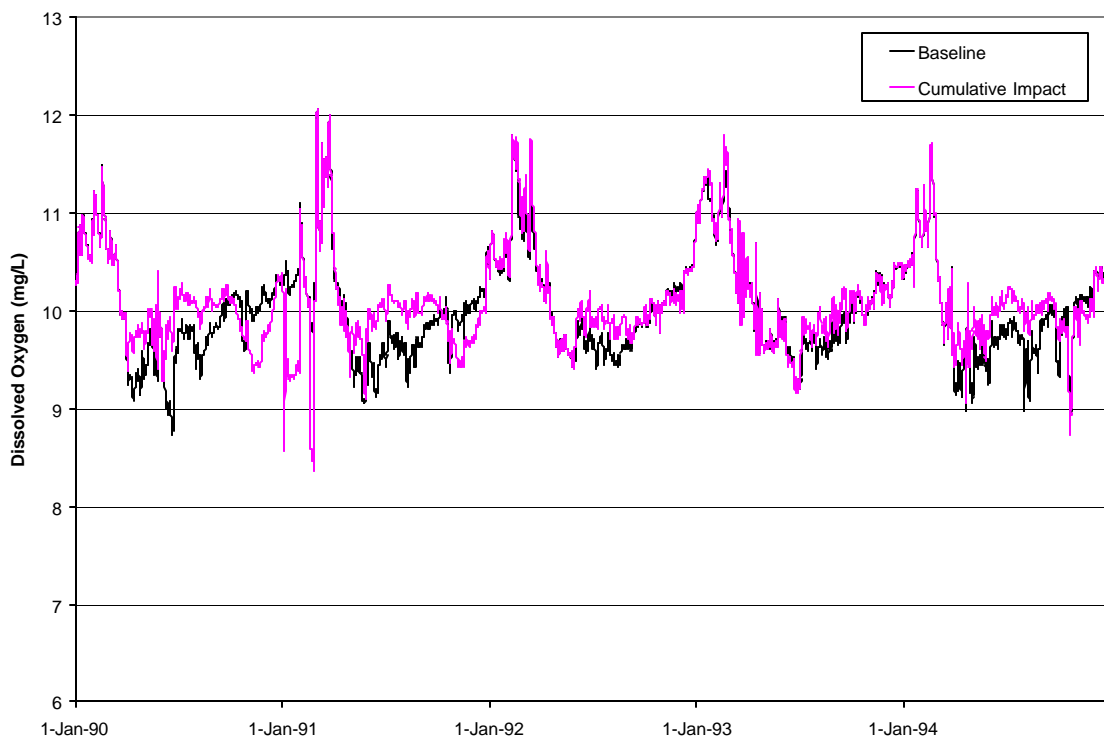
Figure 4.16 Simulated baseline and cumulative impact dissolved oxygen concentration at Dry Creek above Russian River.

4.13
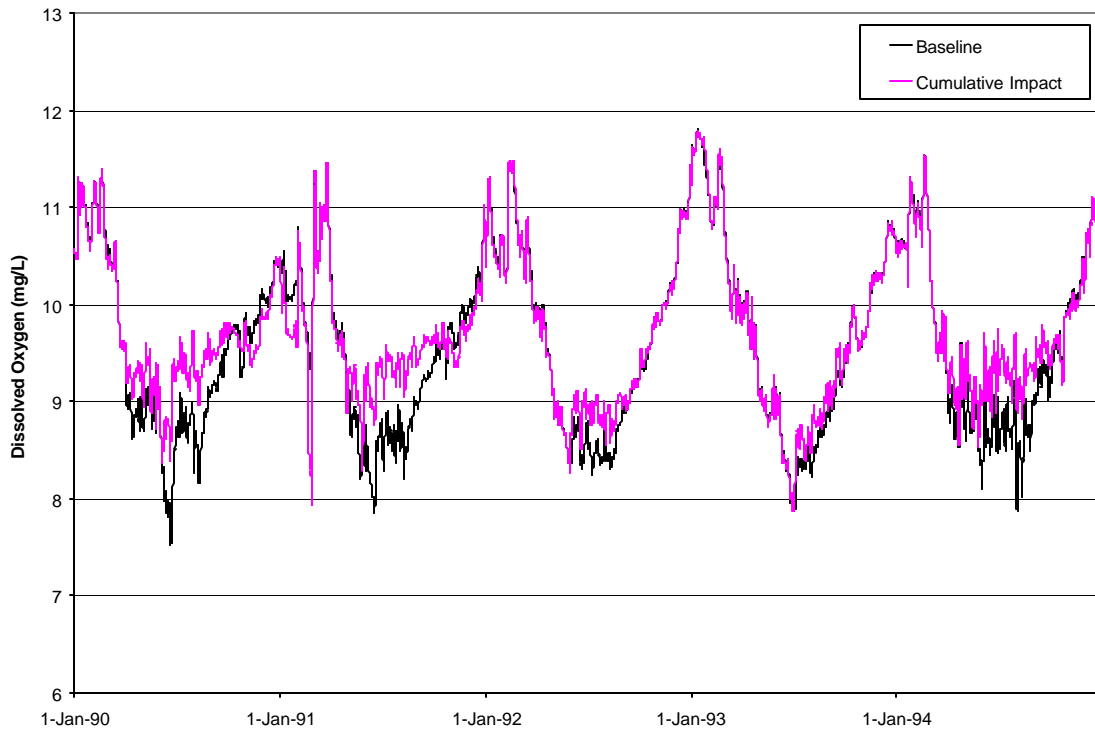
Figure 4.17 Simulated baseline and cumulative impact dissolved oxygen concentrations at Russian River below Dry Creek.

5 REFERENCES

Hydrologic Engineering Center (HEC). 1999b. "Water Quality Modeling of Reservoir System Operations Using HEC-5, Training Document", Davis, CA.

Hydrologic Engineering Center (HEC). 2000. "HEC-5, Simulation of Flood Control and Conservation Systems, Appendix on Water Quality Analysis", Davis, CA.

SCWA October 29, 1999 (Bryan Smith email, 7/14/2000). SCWA Operations Model output:

Russian River Existing Conditions, 2000 Demands .."rr2020day_doi_d1610.dat"

Russian River Existing Conditions, 2020 Demands .."rr2020day_doi_d1610.dat"

Dry Creek Existing Conditions, 2000 Demands ...."dc2000day_doi_d1610.dat"

Dry Creek Existing Conditions, 2020 Demands ...."dc2020day_doi_d1610.dat"

6   APPENDIXES

Appendix A

Sonoma County Operations Model Interface

APPENDIX B

Graphical Users Interface (GUI)

Appendix C

Users Instruction for RMA_View

Appendix D

Description of Contents of the Accompanying Compact Disc

APPENDIX A

SONOMA COUNTY OPERATIONS MODEL INTERFACE

Introduction

OPP25Q (Opp. to 5Q) is used to convert the output from the Sonoma County Water Agencies operation model to HEC-5Q compatible input. OPP25Q resides on the accompanying CD in the "SR_5Q\OPP_OUTPUT" directory. The following steps will produce a file that replaces the historical flow rates used in the calibration effort.

Pre-processing of Operation Model output

The OPP25Q utility program expects output from the two components (Upper-Russian River Model and Lower-Russian River Model) in a specific format. The Operation Model output is comma delineated and must be converted to fields of eight. Excel is recommended for this purpose using the following steps.

- Import the output files (*.dat files of the OPP_OUTPUT directory) to Excel and separate into columns using "data\text to columns"

- Set column widths to 8

- Set significant figures for each column such that the first 3 fields (date) are in I8 format and the remaining columns in F8.1 format except larger numbers (volume & power) where I8 is required to avoid '########'

- Save file as *.prn (space delineated)

An example of a *.prn file is included below. Due to the width of these files, the reader may wish to view the *.prn files of the OPP_OUTPUT directory using "NOTEPAD" or other software.

Running OPP25Q

The OPP25Q is a Fortran utility program that runs under a command prompt window (DOS shell) and provides prompts that direct interactive input of file name and time controls. As an alternative, the response to these prompts may be pre-specified by creating a batch file that names a file containing the expected inputs. The *.bat and *.run files of the OPP_OUTPUT directory are examples of such files. Regardless of the mode of input, the following inputs are required.

- Name of the output file that will contain the hydrologic inputs to HEC-5Q (Note that 8/3 character FTN77 file name limits apply to all files!)

- Year limits of the data to be processed. An entry of "1975 1995" would extract January 1, 1975 through December 31, 1995.

- SCWA Upper-Russian River Model output file. (Note that 8-character field width is also required for both operation model outputs!)

- SCWA Lower-Russian River Model output file

<u>OPP25Q output</u>

The output provides all hydrologic inputs required by HEC-5Q. The file is named in response to the first prompt of HEC-5Q (see *.in files that reside in "SR_5Q\RR model\opp86"). The response to the first HEC-5Q prompt must take the form "SCWA_RR=___.__". The "SCWA_RR=" character sequence triggers the SCWA operation model option making this input option transparent to other users of HEC-5Q.

An example of the output is provided below. Note that the header information of both SCWA Operations Model outputs is included along with the controls that were provided when the OPP25Q utility program was run.

Example Upper-Russian River Model output formats assumed by Opp25Q

```
        Upper-Russian River Model
Demand/Sedimentation file:  H:\rrdcmodvb\lmsc.ci4
Run Date/Time:  02-05-2000 @ 14:04:18
Potter Valley Imports flow file:  H:\pvp\pvdiv_doi2022.out

        Demand distribution file:  \urdist.1999

        0% demand curtailment in critically dry months

        0% demand curtailment in dry months

        Healdsburg flow file:  H:\pvp\hb60b.out

        Minimum flow margin at:

        Forks      =2 cfs

        Hopland    =15 cfs

        Cloverdale =15 cfs

        Healdsburg =10 cfs
```

Water Year	Potter Water Month	Lake Day of Month	West Supply Condition	Upper Valley Release (AF)	Middle Mendo. Inflow (AF)	Lake Fork Inflow (AF)	Lake River Inflow (AF)	Redwood River Inflow (AF)	Mendo. Storage (AF)	Upper Mendo. Evap. (AF)	Middle Valley Demand (AF)	Lake Coyote Demand (AF)	River Demand (AF)	River Demand (AF)	Russian Mendo. Release (AF)	Combined Flow (AF)	River Min Flow (AF)	Forks Flow (AF)	Hopland Flow (AF)	Cloverdale Flow (AF)	Healdsburg Flow (AF)
1929	1	1N	440.0	-4.0	-5.0	-14.0	-15.0	30070.0	5.0	1.4	2.7	6.5	4.7	356.8	-59.3	297.5	351.8	341.7	331.4	311.7
1929	1	2N	458.0	-4.0	-5.0	-14.0	-15.0	30150.7	8.2	2.8	5.5	13.0	9.4	356.8	-59.3	297.5	351.8	339.0	324.9	300.5
1929	1	3N	451.0	-4.0	-5.0	-14.0	-15.0	30224.3	8.2	2.8	5.5	13.0	9.4	356.8	-59.3	297.5	351.8	339.0	324.9	300.5
1929	1	4N	440.0	-4.0	-5.0	-14.0	-15.0	30258.9	8.2	0.7	1.4	3.2	2.4	391.1	-93.6	297.5	386.1	376.2	334.6	307.5
1929	1	5N	436.0	-4.0	-5.0	-14.0	-15.0	30289.4	8.2	0.7	1.4	3.2	2.4	391.1	-93.6	297.5	386.1	376.2	368.9	307.5
1929	1	6N	427.0	-4.0	-5.0	-14.0	-15.0	30310.4	8.2	0.9	1.7	4.1	3.0	391.1	-93.6	297.5	386.1	375.5	368.1	316.6
1929	1	7N	432.0	-4.0	-5.0	-14.0	-15.0	30331.1	8.3	1.1	2.0	4.8	3.5	396.0	-98.5	297.5	391.0	379.7	367.3	350.4
1929	1	8N	423.0	-4.0	-5.0	-14.0	-15.0	30332.3	8.3	4.6	8.9	21.0	15.3	396.0	-98.5	297.5	391.0	366.8	355.9	337.8
1929	1	9N	432.0	-4.0	-5.0	-14.0	-15.0	30339.5	8.3	5.7	11.0	25.9	18.8	396.0	-98.5	297.5	391.0	362.9	351.1	333.6
1929	1	10N	496.0	-4.0	-5.0	-14.0	-15.0	30393.0	8.3	5.7	11.0	25.9	18.8	413.7	-116.1	297.5	408.7	380.6	351.1	322.2

<u>Example Lower-Russian River Model output formats assumed by Opp25Q</u>

```
Lower-Russian River Model

Run Date:  10-29-1999 @ 09:37:49

Demand File:  H:\rrdcmodvb\completed program\lssc.ci3

Dry Month Deficiency:  0%

Healdsburg Flow File:  H:\section7\entrix\hb2020_doi_d1610.dat

Demand Distribution File:  \scwa.dist


Warm Springs Dam minimum flow margin = 2 cfs

Dry Creek Minimum flow margin = 5 cfs

Russian River Minimum flow margin = 0 cfs

Initial storage = 150000
```

Water Year	Water Month	Day of Month	Water Supply Conditio	Lake Sonoma Inflow (AF)	Dry Creek Inflow (AF)	Dry Creek Demand (AF)	Healds-burg Inflow (AF)	Santa Rosa Inflow (AF)	Santa Rosa Demand (AF)	Lake Sonoma Storage (AF)	Lake Sonoma Evap. (AF)	Combined Flow (AF)	Lake Sonoma Release (AF)	Hydro-power Gen. (kW-h)	Dry Creek Min Flow (AF)	Dry Creek Flow (AF)	Russian River Min Flow (AF)	Healds-burg Flow (AF)	Guerne-ville Flow (AF)
1929	1	1N	-7.0	-4.0	5.7	312.0	-16.0	216.6	149694	12.5	-293.0	286.8	0	158.7	277.1	247.9	589.1	298.9
1929	1	2N	-7.0	-4.0	5.9	300.0	-16.0	223.8	149387	12.5	-293.0	286.8	0	158.7	276.9	247.9	576.9	298.9
1929	1	3N	-7.0	-4.0	6.6	300.0	-16.0	251.1	149081	12.5	-293.0	286.8	0	158.7	276.2	247.9	576.2	298.9
1929	1	4N	-7.0	-4.0	6.9	308.0	-16.0	264.0	148812	12.5	-249.4	249.4	0	158.7	275.9	247.9	583.9	297.0
1929	1	5N	-7.0	-4.0	8.3	308.0	-16.0	318.5	148536	20.0	-249.4	249.4	0	158.7	237.1	247.9	545.1	241.7
1929	1	6N	-7.0	-4.0	7.3	317.0	-16.0	277.6	148259	20.0	-249.4	249.4	0	158.7	238.2	247.9	555.2	290.3
1929	1	7N	-7.0	-4.0	7.1	350.0	-16.0	271.2	147966	20.0	-266.0	266.0	41191	158.7	238.3	247.9	588.3	257.9
1929	1	8N	-7.0	-4.0	7.6	338.0	-16.0	291.2	147673	20.0	-266.0	266.0	41191	158.7	254.4	247.9	592.4	247.9
1929	1	9N	-7.0	-4.0	5.7	334.0	-16.0	216.6	147380	19.9	-266.0	266.0	41191	158.7	256.3	247.9	590.3	355.7
1929	1	10N	-7.0	-4.0	8.0	322.0	-16.0	304.9	147089	19.9	-264.0	264.0	40702	158.7	254.0	247.9	576.0	271.5

Example Opp25q.for HEC-5Q interface file

First and last year of simulation: **1989 1995**

Upper Russian River Model output File name: **rr60b_dy.prn**

Lower Russian River Model output File name: **dc60b_dy.prn**

Healdsburg and Guerneville flows (DSS format) file : **60b_day.2ds**

Upper-Russian River Model	Lower-Russian River Model
Demand/Sedimentation file: H:\rrdcmodvb\lmsc.ci4	Run Date: 02-05-2000 @ 14:04:38
Run Date/Time: 02-05-2000 @ 14:04:18	Demand File: H:\rrdcmodvb\lssc.ci3
Potter Valley Imports flow file: H:\pvp\pvdiv_doi2022.out	Dry Month Deficiency: 0%
Demand distribution file: \urdist.1999	Healdsburg Flow File: H:\pvp\hb60b.out
0% demand curtailment in critically dry months	Demand Distribution File: \scwa.dist
0% demand curtailment in dry months	
Healdsburg flow file: H:\pvp\hb60b.out	Warm Springs Dam minimum flow margin = 2 cfs
Minimum flow margin at:	Dry Creek Minimum flow margin = 5 cfs
Forks =2 cfs	Russian River Minimum flow margin = 0 cfs
Hopland =15 cfs	Initial storage = 150000
Cloverdale =15 cfs	
Healdsburg =10 cfs	

date	LM elev	LM inf	LM out	WF inf	UR inf	LR inf	QD 252	QD 250	QD 240	QD 230	QD 220	QD 210	QD 200	LS elev	LS inf	LS out	DC inf	SR inf	QD 100	QD 92
31DEC1988	718.6	745.3	25.0	301.5	1519.1	244.0	2.5	1.2	2.5	2.7	9.6	9.6	5.5	416.5	246.1	107.0	153.8	624.2	1.6	106.9
1JAN1989	719.6	457.5	25.0	142.2	715.9	155.3	2.5	1.2	2.5	4.2	14.8	14.8	8.5	416.6	156.4	107.0	97.8	396.8	1.7	110.4
2JAN1989	720.3	400.0	57.7	94.3	474.9	112.9	2.5	1.2	2.5	4.2	14.8	14.8	8.5	416.7	113.3	77.0	71.1	288.4	1.8	117.7
3JAN1989	720.7	381.3	78.9	73.1	368.0	98.8	2.5	1.2	2.5	4.2	14.8	14.8	8.5	416.7	98.2	77.0	62.5	252.6	1.6	106.3
4JAN1989	721.2	370.2	92.5	59.5	299.0	73.1	2.5	1.2	2.5	4.2	14.8	14.8	8.5	416.7	73.0	77.0	46.4	187.6	1.8	117.7
5JAN1989	721.5	602.1	25.0	212.8	1071.9	245.0	2.5	1.2	2.5	4.2	14.8	14.8	8.5	416.7	248.4	77.0	154.8	627.7	1.8	121.8
6JAN1989	722.3	487.2	26.0	126.0	635.8	135.1	2.5	1.2	2.5	4.2	14.8	14.8	8.5	416.9	136.5	77.0	85.2	346.4	1.9	125.5
7JAN1989	722.9	452.3	52.2	99.8	502.7	129.6	2.5	1.2	2.5	4.2	14.8	14.8	8.5	416.9	129.9	77.0	81.7	331.7	1.8	121.8
8JAN1989	723.5	464.9	42.6	109.4	551.1	138.1	2.5	1.2	2.5	4.2	14.8	14.8	8.5	417.0	139.0	77.0	87.2	353.4	1.8	117.7
9JAN1989	724.1	676.7	25.0	268.7	1354.2	174.9	2.5	1.2	2.5	4.2	14.8	14.8	8.5	417.0	176.3	77.0	110.4	447.2	1.8	117.7
10JAN1989	724.9	867.7	25.0	412.9	2079.7	197.1	2.5	1.2	2.5	4.2	14.8	14.8	8.5	417.1	199.5	77.0	124.5	504.7	1.7	114.1

APPENDIX B. GRAPHICAL USER INTERFACE

6.1 PROGRAM CAPABILITIES

The HEC-5Q Graphical User Interface (GUI) is designed to facilitate the analysis of HEC-5Q model results. The interface displays a schematic representation of an HEC-5Q model on a map display. Background maps may be used to associate components of the model with geographic features in the prototype system. The map display is used to select locations in the model for which results are to be plotted. Longitudinal and depth profiles and time series plots can be created. Longitudinal and depth profile plots may be animated over the simulation period. Data stored in the DSS files may be plotted with stream time series or reservoir profile data from the model for calibration.

The following components are contained within this chapter:

Section 1.2 provides an overview of the design of the GUI.

Section 1.3 presents a step-by-step example of using the interface to analyze model results.

Section 1.4 describes how projects are used to manage the geographic and other system data used by the GUI.

Section 1.5 discusses the contents of run files and the use of model input data and results.

Section 1.6 discusses the procedures used in viewing results using the Map Editor window and Plot Windows.

Section 1.7 provides a reference for the commands, options and procedures available in the GUI.

6.2 USING THE HEC-5Q GUI

6.2.1. PROJECTS

The first step in using the HEC-5Q GUI is to open a project file. A project defines the geographic extents of the project region and manages background map layers and observed HEC-DSS files used in evaluating model results.

6.2.2. RUNS

Next, a run file must be opened. A run file identifies the HEC-5 and HEC-5Q input data sets used for simulation and the HEC-5Q binary results file. It may also identify an additional HEC-DSS file.

6.2.3. DISPLAYING RESULTS

When a project and run have been selected the GUI may be used to display results from the HEC-5Q simulation. The Map Editor window is used to select locations in the model schematic for which longitudinal profile, depth profile and time series plots will be created. Longitudinal and depth profile plots can be animated over the simulation period. Data from the DSS files can be overlaid onto time series plots of model results.

6.3 EXAMPLE APPLICATION

The Russian River Application serves as the sample. The remainder of this section will be used to demonstrate the capabilities of the HEC-5Q GUI using this data set. The menu options available in the GUI are presented here in boldface.

1.   Opening the Project

Launch the HEC-5Q GUI from the CD using the Windows Program Manager or File manager. Click on the Maximize button in the upper right hand corner of the window so that the application uses the full screen. Choose **Open Project** from the **File** menu. Select the project file Russian.PRJ and click on the OK button.

Open a map editor window using the **Open Map Editor** command from the **Window** menu. The Map Editor window will show DLG maps and a Latitude-Longitude coordinate grid covering the project region. When the mouse is moved over the grid, the coordinates are displayed in the status bar at the bottom of the window. Click on the maximize button in the upper right hand corner of the Map Editor window to enlarge the window.

2.   Zooming and Panning

Click on the Zoom In tool in the Map Editor tool palette. Zoom in on desired features by pressing the left mouse button down and dragging over the region. Release the left mouse button and click with the right mouse button to accept the region. The map display will zoom in on the selected region. Clicking the right button, when no zoom selection has been made, will pan the map such that the location at which the mouse button was clicked will be moved to the center of the view. Clicking on the Zoom Out tool in the tool palette will zoom out by a factor of two. Choosing **Show All** from the **Map** menu will restore the view to show the entire project.

3.   Opening an HEC-5Q Run

Choose **Open Run** from the **Run** and select the run file 00_1.RUN. Choose **Show All** from the **Map** menu to redraw the map display. The schematic representation of the HEC-5Q data set will be shown on the map. This schematic is reproduced in Figure B.1 with important locations labeled. Vertically segmented reservoirs are shown as light blue triangles. Longitudinally segmented reservoirs are shown as light blue reaches with rectangles representing computational elements. Stream reaches are shown as white outlined in dark blue with rectangles representing computational elements. HEC-5 control points are shown as red circles with control point ID numbers.

The layout shown schematically was created by interpretation of the HEC-5 and HEC-5Q input data sets identified in the run file. The layout does not reflect the real system geometry since those data are not explicitly defined in the input data sets.

5.   Editing the Model Schematic Geometry

If desired, control points can be moved using the digitizer tool on the Map Editor tool palette to make the model schematic better represent the prototype system (however, no adjustment to this schematic is necessary). Select the digitizer tool, then drag a control point using the left mouse button. After releasing the left mouse button, click the right mouse button to accept the new position. Clicking the right mouse button when no control point is selected will pan the map display.

When the model schematic is laid out properly, the configuration can be saved by choosing **Save Run** from the **Run** menu.

6.   Viewing Model Results

When the HEC-5Q model is run, results are saved in a binary file for use by the HEC-5Q GUI. Model results can be viewed as longitudinal profile, depth profile or time series plots. Longitudinal and depth profile plots can be animated over time. Time series data stored in DSS files can be plotted with model results for comparison.

Plots are constructed by selecting desired locations on the map editor and using the **New Profile Plot**, **New Depth Profile Plot**, or **New Time Series Plot** command from the **Window** menu. Data from the selected locations will be retrieved from the results file and displayed. The default constituent to be displayed is temperature. Once a plot is created, other constituents may be chosen from the **Constituent** sub-menu in the **Graph** menu.

7.   Profile Plots

Select the Profile Plot tool from the tool palette. Using the left mouse button, click on several longitudinally segmented reservoir reaches and / or stream reaches (it may be helpful to zoom in on the map). Selected reaches will be colored yellow. After selecting the reaches, choose **New Profile Plot** from the **Window** menu. A plot window will be displayed showing the selected data at the first time step in the results file. The X-Y plot scales may be set using the **Graph Options** from the **Graph** menu. Choose **Animate** from the **Graph** menu to open the Animation Control dialog box. Click on the **Play** button to animate the plot. Click on the **Stop** button to pause the animation. The scroll bar can be moved by clicking on the arrows or dragging the 'thumb' icon to select any required time step. To clear selected segments click on them to unselect or choose **Clear Profile Plot Selection** from the **Edit** menu.

8.   Depth Profile Plots

Select the Depth Profile Plot tool from the tool palette. Using the left mouse button, click on a reservoir segment. The selected reservoir will be colored green (a vertically segmented reservoir will be colored orange). After selecting the reservoir segment, choose **New Depth Profile Plot** from the **Window** menu. A plot window will

be displayed showing the selected data at the first time step in the results file. The X-Y plot scales may be set using the **Graph Options** from the **Graph** menu. You can animate this plot as described above to match the dates of observed data. Data may be extracted from a DSS file associated with either the project or the run by using the **Plot from DSS** sub-menu in the **Graph** menu. A list of available DSS path names will be presented. Select a name from the list and enter the number of records to be retrieved, then click OK. The DSS data will be plotted onto the current graph. To clear selected segments click on them to unselect or choose **Clear Depth Profile Plot Selection** from the **Edit** menu.

        9.   Time Series Plots

Select the Time Series Plot tool from the tool palette. Using the left mouse button, click on one or more computational elements in streams or reservoirs. Selected elements will be highlighted in green. After selecting the elements, choose **New Time Series Plot** from the **Window** menu. The X-Y plot scales may be set using the **Graph Options** from the **Graph** menu.   A plot window will be displayed showing the time series for the selected simulation period. (The time scale defaults to the entire simulation period but may be set by the **Time-Series Options** from the **Window** menu. A plot time of 5 years or less is recommended. Note that the slide bar on the time series plots allows viewing of the entire period.) DSS data can be plotted onto a time series graph as well by following the steps described in section 8 above. To clear selected elements click on them to unselect or choose **Clear Time Series Plot Selection** from the **Edit** menu.

This completes the description of the example application. The software will be described in more detail in the following sections.

6.4 PROJECTS

The 'geometric extents', map layers and observed data used by the HEC-5Q GUI are organized into projects. 'Geometric extents' represent the geographic region where the modeling project is located. Vector, raster and site maps can be used to provide the geographic background for the project. Observed data sets stored in DSS files may be made available for comparison with model results.

6.4.1. REGION EXTENTS

The project region extents provide the default viewing area for the Map Editor Window. The extents may be described in either Latitude-Longitude or simple rectangular coordinates. When using a Latitude-Longitude coordinate system, the vertical scale is adjusted relative to the horizontal scale based on the latitude to provide correct ground distances in the center of the Map view. For a simple rectangular coordinate system, the vertical and horizontal scaling are equal. A rectangular coordinate system may be used to represent UTM (Universal Transverse Mercator) coordinates.

6.4.2. MAP LAYERS

Map layers may include vector maps, raster maps and site locations that provide a visual background for interpreting the geographic layout of the HEC-5Q model. The

capability to display raster and site maps has not yet been included in the alpha version of the HEC-5Q GUI.

1. Vector Map Layers

A vector map is a collection of points, lines and polygons that may be drawn at any scale desired by the user. One of the most commonly available types of vector maps is the USGS digital line graph series (DLGs). DLG map coverages include transportation, hydrography and boundaries. The HEC-5Q GUI can use DLG files with a 1:100,000 scale. DLGs are added to the project by selecting **Add DLG to Project** from the **Map** menu. After adding DLGs to the project, the project file may be saved to preserve the selection.

2. Raster Map Layers

A raster map is a bitmap image whose pixel value (color) represents some aspect of the geographic data. Typical raster map layers include satellite images and digital terrain models.

3. Site Map

A site map consists of points with labels depicting features such as monitoring stations or city locations.

6.4.3. OBSERVED DATA

Time series or profile data stored in a DSS file may be associated with the project. Data from the DSS file may be retrieved by the GUI and plotted together with model results. To use the data from a DSS file, a catalog file must be created using the DSSUTL program. The catalog file must have a *.DSC extension.

A DSS file is associated with a project by including it in the project file. Only one DSS file may be associated with the project, but a separate DSS file may be associated with each run. When a time series or reservoir profile plot is displayed, data from the DSS file may be plotted. For the Russian River project, all observed stream time series data are stored in the project DSS file while reservoir profile data reside on the run DSS file.

6.5 RUN DATA

The information required to extract and view results from HEC-5Q is manipulated by the GUI as a run. A model run is comprised of the HEC-5 and HEC-5Q input data files, the binary results files generated by HEC-5Q. The GUI uses the HEC-5 and HEC-5Q input data sets to display a schematic representation of the model configuration and to interpret the binary files containing simulation results from HEC-5Q. To relate the schematic of the HEC-5Q model to the actual geographic configuration of the prototype system, additional geometric data are required beyond the data stored in the model input files. This information may be generated via the GUI or input as spatial coordinates of the control points in the model. A run file contains the names of the files mentioned above together with any extra geometric information added to facilitate display of the model schematic.

6.5.1. HEC-5 INPUT FILE

The HEC-5 input file contains the initial definition of all control points used by the HEC-5Q model. The GUI uses the HEC-5 input data to develop the correct connectivity among control points.

6.5.2. HEC-5Q INPUT FILE

The HEC-5Q input file contains the program controls determining the period of simulation for the run and extra geometric information defining the discretization of the reservoirs and rivers, as used in the water quality simulation module. The GUI uses the HEC-5Q input data to further define the geometric configuration of the system and to determine the format of the data stored in the binary results file.

6.5.3. HEC-5Q RESULTS FILE

The HEC-5Q GUI accesses results generated by the HEC-5Q model directly from a binary results file. When the model is run the option to generate a binary results file must be selected.

6.5.4. DSS FILE

Time series or profile data stored in a DSS file may also be associated with the run. Data from the DSS file may be retrieved by the GUI and plotted together with model results. For the Russian River project, all observed reservoir profile data are stored on run DSS file.

6.5.5. GEOMETRIC DATA

Because the HEC-5Q model does not require the user to explicitly describe the spatial arrangement of the control points, additional geometric data are required to display the model schematic on the map windows. The GUI will automatically generate a schematic layout for the model. The control point locations may be changed to better represent the prototype system. One method is to use the Digitizer tool on the map display to drag control points to new positions (see Section 1.3). After moving control points, the run file may be saved to preserve the new locations. Alternatively, control point coordinates may be added manually to the run file.

6.6 VIEWING RESULTS

Model results can be displayed as longitudinal profile, depth profile or time series plots. Data stored in DSS files can be displayed on time series plots for calibration or verification purposes. The Map Editor window is used to select locations in the system for which data will be plotted. Profile and depth profile plots can be animated over the simulation period.

6.6.1. MAP DISPLAY

The Map Editor window is used to select locations in the model schematic for which data are to be plotted. In the model schematic, vertically segmented reservoirs are

represented by light blue triangles and longitudinally segmented reservoirs are represented by light blue reaches with rectangles representing computational elements. Stream reaches are shown as white outlined in dark blue with rectangles representing computational elements. HEC-5 control points are shown as red circles with control point ID numbers.

Reaches are selected for generating profile plots by selecting the Profile Plot tool ⌁ in the tool palette and clicking on desired reaches with the left mouse button. Similarly, depth profile plots may be generated for vertically segmented reservoirs using the Depth Profile Plot tool ⌁. Computational elements are selected for time series plots using the Time Series tool ⌁. Selected reaches are shown in yellow, selected reservoirs are shown in orange and selected elements are shown in green.

6.6.2. GRAPHS

Once a selection has been made on the Map Editor window, a plot is created by selecting the **New Profile Plot**, **New Depth Profile Plot** or **New Time Series Plot** from the **Window** menu.

Temperature is used as the default constituent for plotting purposes. Other constituents may be selected using the **Constituent** sub-menu of the **Graph** menu.

Profile and depth profile plots may be animated over the simulation period by selecting the **Animate** command from the **Graph** menu to display the Animation dialog box. The Play button on the Animation dialog box begins the animation. The animation may be paused using the Stop button. A delay may be added if the animation progresses too rapidly, by specifying the number of seconds between frames. If the animation is progressing too slowly, a value can be added in the Skip field, causing the animation to skip over the specified number of time steps in the results file between frames displayed.

DSS data may be selected from either the project or run DSS files to be overlaid onto time series plots. Choosing a **Plot DSS** option from the **Graph** menu brings up a dialog box showing all path names for the selected DSS file. When the OK button is clicked, the data are retrieved and displayed on the plot.

6.7 PROGRAM REFERENCE

This section contains detailed descriptions of the commands, options and procedures available in the HEC-5Q GUI. Information is organized according to the window or dialog box from which it is accessed.

6.7.1. APPLICATION WINDOW

File Menu

Open Project - Brings up the standard file window listing files within a directory to allow the user to select a project file to open. When a project is selected, the current project is deleted and the new project is loaded.

Save Project - Saves the current project to the project file.

Save Project As - Brings up the standard file window listing files in the directory to allow the user to enter a new name for the current project. When a file name is selected, the current project is saved to a project file with the new name.

Print - Prints the active window (map or graph window) to the default printer.

Exit - Exits the program.

Run Menu

Open Run - Brings up the standard file window listing files in the directory to allow the user to select a run file to open. When a run is selected, the run is loaded and becomes the current run.

Close Run - Closes the current run.

Save run - Saves the run to the run file.

Save Run As - Brings up the standard file window listing files in the directory to allow the user to enter a new name for the current run. When a file name is selected, the current run is saved to a run file with the new name.

Window Menu

Open Map Editor - Opens the map editor window if it is not already open.

New Profile Plot - Opens a new Graph window and creates a profile plot using the selected reaches of the current run.

New Depth Profile Plot - Opens a new Graph window and creates a depth profile plot using the selected vertically segmented reservoirs of the current run.

New Time Series Plot - Opens a new Graph window and creates a time series plot using the selected elements of the current run.

Time-Series Options – Specifies the time scale for the time series plots. All subsequent time series plots will use these limits. (Note that the slide bar on the time series plots allows viewing of the entire record.)

Close - Closes the active window.

6.7.2. MAP WINDOW

Map Menu

Zoom In x2 - Zooms in on the map display by a factor of two, keeping the current center view.

Zoom Out x2 - Zooms Out on the map display by a factor of two, keeping the current center view.

Show All - Resets the map display so that the entire project region is visible.

Select DLG to Display - Displays the locations of the DLG files currently used by the project as a series of rectangles on the map display. Clicking with the left mouse

button selects and deselects DLGs for display. Selected DLGs are indicated by green rectangles. Clicking with the right mouse button redraws the map.

> **Close All DLGs** - Closes all DLGs currently selected for display.

> **Add DLG to Project** - Opens a binary DLG file and adds it to the project.

> **Import ASCII DLG** - Imports an ASCII DLG, saves it as a binary DLG file and adds it to the Project.

> ### Tool Palette

> **Zoom Tool** - Pressing and dragging the left mouse button will select a region on the map. Releasing the Left mouse button and clicking with the right mouse button will zoom in to the selected region. Clicking the right mouse button when no zoom selection is made will redraw the map with the selected location at the center of the display.

> **Zoom Out Tool** - Zooms out on the map display by a factor of two, keeping the current center of view.

> **Profile Reach Selector** - Clicking with the left mouse button will select longitudinally segmented reservoirs and stream reaches to be used in plotting profiles. Clicking with the right mouse button will pan the display as for the zoom tool.

> **Depth Profile Reach Selector** - Clicking with the left mouse button will select vertically segmented reservoirs to be used in plotting profiles. Clicking with the right mouse button will pan the display as for the zoom tool.

> **Time Series Element Selector** - Clicking with the left mouse button will select computational elements to be used for plotting time series. Clicking with the right mouse button will pan the display as for the zoom tool.

> **Digitizer** - Pressing the left mouse button over a control point will allow the selection indicator to be dragged to a new location. The new location is accepted by releasing the left mouse button and clicking the right mouse button. Clicking the right mouse button when no selection is made will redraw the map with the selected location at the center of the display.

> #### 6.7.3. GRAPH WINDOW

> ### Graph Menu

> **Constituent** - Brings up a sub-menu listing the constituents available for plotting. Selecting one of the constituents for plotting retrieves the data for that constituent from the HEC-5Q results file and redraws the current plot.

Plot from DSS - Brings up a dialog box listing the DSS path names available in either the project or run DSS file. When the user selects a path name and the number of records to retrieve, the data are collected from the DSS file and plotted over the current time series plot. If the current plot is not a time series plot, the plot is cleared and then the DSS data are displayed.

Animate - Brings up the Animation dialog box. This command is only available for profile and depth profile plots.

Animation Dialog

Play Button - Begins animation of the current plot over the period of simulation.

Stop Button - Pauses the animation.

Scrollbar - Clicking on the right or left arrows will step one tine step forward or backward. Dragging the 'thumb' icon interactively scrolls the animation forward or backward.

Delay Field - Adds a delay of the given number of seconds between frames of the animation.

Skip Field - Specifies the number of time steps to be skipped in the results files between animation frames.

6.7.4. FILES USED BY THE HEC-5Q GUI

HEC-5/5Q Input File: Refer to the HEC publication:
Hydrologic Engineering Center (HEC), 1997. "HEC-5 Simulation of Flood Control and Conservation Systems," Computer Program User's Manual.

HEC-DSS Files: Refer to the HEC publication:
Hydrologic Engineering Center (HEC), 1995. "HEC-DSS User's Guide and Utility Manuals," User's Manual.

USGS Digital Line Graph Files: The HEC-5Q GUI uses a binary representation of the USGS DLG file. The binary file is created by the GUI when an ASCII DLG file is imported. For information on the format of ASCII DLG files, refer to USGS publication:
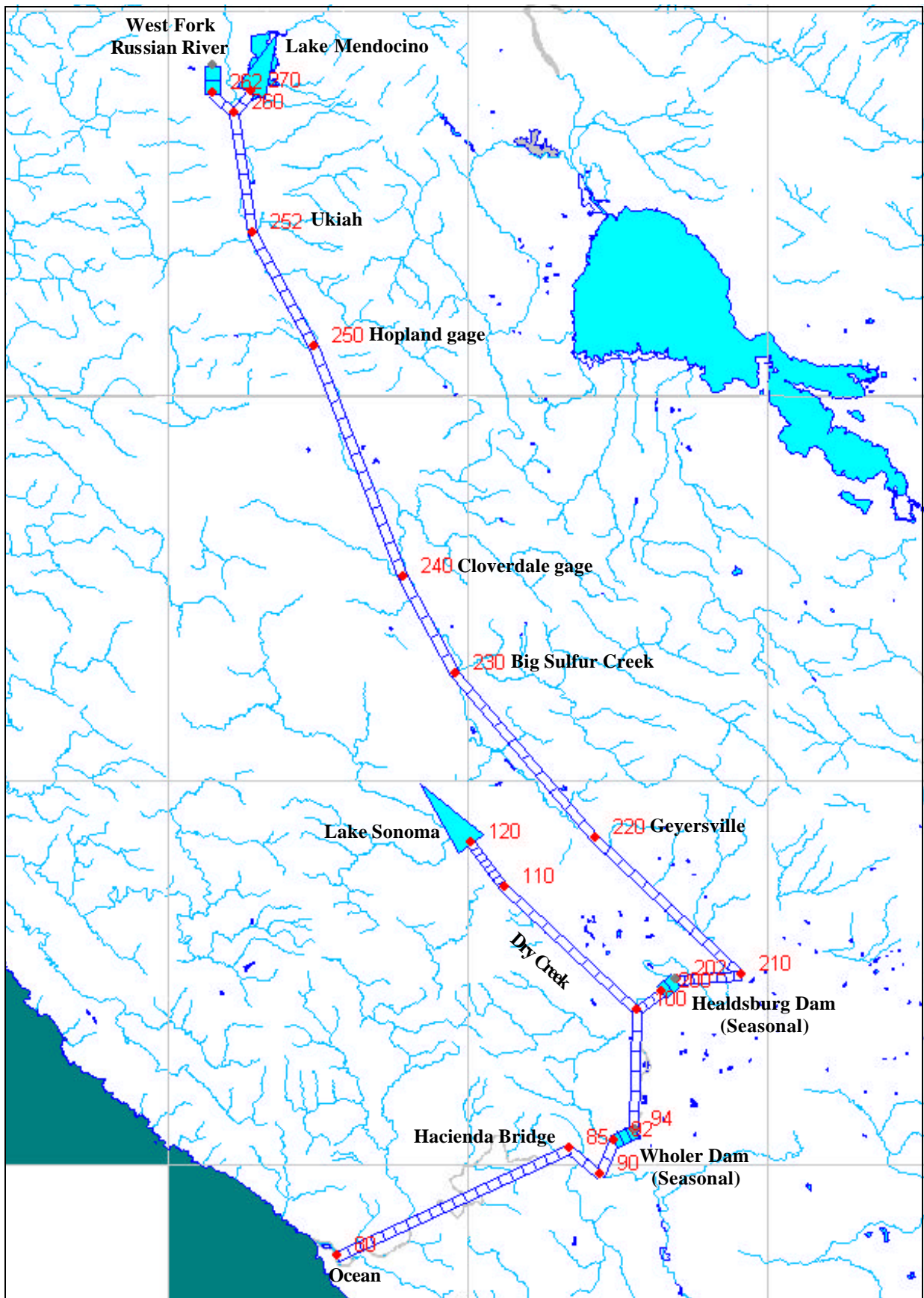Digital Line Graphs from 1:2,000,000 - Scale Maps, Data Users Guide 2.

Figure B.1 HEC-5Q GUI schematic of Russian River system with important locations labeled.

APPENDIX C

USERS INSTRUCTION FOR RMA_VIEW

Introduction

RMA_View is used to view ambient water quality monitoring data extracted from STORET stations. Data from these stations can be plotted and statistically analyzed for various water quality constituents. Individual or multiple stations may be plotted and analyzed together.

Viewing and Selecting Stations

Execute RMA_View by double clicking on RMA_View.exe from Windows Explorer. Select "rr.p5q" form the File\open menu to view the system map. Use the zoom tools to zoom in 🔍 or out 🔍 on the map. The zoom in operation is accomplished by left clicking at the upper left location of interest and dragging to the lower right before releasing. Then right click to implement the zoom in option.

To select stations from the map, choose the Select Stations tool 🎯. With this tool selected, hold down the left mouse button and circle desired stations. Ambient water quality monitoring stations are shown as red squares. When the mouse button is released, selected stations will turn green. Right click to view a list of the selected stations.

Plotting Data

From the selected station list, choose the stations for which data is to be plotted. Clicking OK without making any selections will bring up a plot of all stations on the list. To plot fewer stations, click on the desired station(s) to be plotted. Hold down the shift key to select a block of stations, or the control key to select several stations from anywhere in the list. Selected stations will be highlighted. Once a station or stations have been selected, click OK to view the plot.

The default parameter will be temperature. To view other plots, select the desired constituent from the Stream WQ menu. Data points are plotted as green squares. Green X's indicate duplicate data. An exact match of time and magnitude identifies duplicates. The mean of all plotted data is shown as a red line and the data statistics are shown below the plot. Duplicate data points are not included in the statistical computations. The number of points (and duplicates), the mean and the root mean square (rms) of the data are shown at the lower left of the plot.

From the Graph menu, data points, may be moved, deleted or added. Any changes to data points will be reflected in the statistical values. Select Graph Options from the Graph menu to change axes scales or to add a harmonic curve fit. To fit a harmonic curve, input the number of harmonics (1 to 3; default of 1) for the curve fit and click OK. The red line will now be plotted as the harmonic curve fit. The coefficients of the harmonic curve fit are shown at the lower left. The ability to move data points allows the user to affect the harmonic curve fit to represent the preponderance of the data.

APPENDIX D

COMPACT DISC TABLE OF CONTENTS

SR_5Q: Main directory contain HEC-5Q executable

CODE: HEC-5Q FORTRAN code included as reference material

documentation: program documentation and training manual

OPP_output : SCWA Operations Model interface

RR model: HEC-5Q data sets and output for the calibration period
    GUI: Graphical User Interface (GUI)
  opp86 : HEC-5Q data sets and output for alternative analysis

STORET data: data viewer for evaluating STORET data

HEC_utl: DSS utility programs

Directory / File	Description
SR_5Q	main directory
HEC5Q.EXE	HEC-5Q executable
HEC_utl	HEC DSS utility programs
Documentation	
ACF ACT training.doc	Training Document referencing the ACF/ACT project
Users Guide.doc	Users guide and supporting exhibits and figures
exhibit1.doc	
exhibit2.doc	
exhibit3.doc	
Exhibit4.doc	
Exhibit5.doc	
other Figures.ppt	

Opp_output	Files pertaining to the utility program that converts SCWA Operations Model output to HEC-5Q input
OPP25Q.EXE	program executable
Opp25Q.for	FORTRAN code
Crv.for	
opp25Q.doc	documentation
opp25Q.bat	batch file
opp2000.run	year 2000 run file referenced by "opp25Q.bat",
dc2000day_doi_d1610.dat	CDF output from the SCWA operations Model, Excel version and
dc2000day_doi_d1610.xls	space delineated version of the upper and lower Russian River for
d00_d161.prn	the year 2000
rr2000day_doi_d1610.dat	
rr2000day_doi_d1610.xls	
r00_d161.prn	
opp2020.run	year 2020 run file referenced by "opp25Q.bat",
dc2020day_doi_d1610.dat	CDF output from the SCWA operations Model, Excel version and
dc2020day_doi_d1610.xls	space delineated version of the upper and lower Russian River for
d20_d161.prn	the year 2020
rr2020day_doi_d1610.dat	
rr2020day_doi_d1610.xls	
r20_d161.prn	
RR model	Files pertaining to Russian River HEC-5Q calibration
F77L3.EER	system file required to interprets program error
90R.bat	batch and run file to run the various calibration periods from windows. Note
96R.bat	that the two groups of files for 1996 - 2000 are for 12-hour and 2-day GUI
96Ra.in	output
99R.bat	
allR.bat	
90.r	
96.r	
96a.r	
99a.r	
90Ra.in	
96Ra.in	
96R.in	
99R.in	
rrgscd.dsc	historical flow and meteorological data. HEC-5Q reads flow and
rrgscd.dsd	meteorological data from DSS however, the *.Y2K files are included if one
rrgscd.dss	wishes to review these data
M1_6HR.Y2K	
M2_6HR.Y2K	
M3_6HR.Y2K	
M4_6HR.Y2K	
M5_6HR.Y2K	
HEC5.dat	ASCII input files. The two version of the OPP5Q*.dat differ only in the GUI
HEC5Q.dat	output file time interval
HEC5Qa.dat	
Trib.dat	
X-sec.dat	
balgae.dat	
HEC5.OUT	ASCII output files (flow and quality) for the 1996-2000 simulation period
HEC5Q.OUT	
5ggui_90.01	GUI output files
5ggui_96.01	
5ggui_96.02	
5ggui_99.01	
SCWAPRT.TXT	CDF files of stream time series and reservoir profiles at user specified
	location. The profile data are output at internally specified dates
WSMENDO.TXT	corresponding to the 1999-2000 sampling dates
running 5Q.doc	Description of file assignment procedures

R model\gui	Graphical User Interface (GUI) file
H5QGUI.exe	
H5QGUI.VR	
vgalaxy5.vr	executable and supporting programs
Russian.prj	project file defining map limits
RR_00_1.run	run files for viewing 2000 and 2020 alternative results and calibration results for 1990-2000, 1996-2000 and 1999-2000. Note that there are two run files for the 1996-2000 period that view at either 12-hour or 2-day averages.
RR_20_1.run	
RR_90_1.run	
RR_96_1.run	
RR_96_2.run	
RR_99_1.run	
ob2k.dsc	DSS files containing reservoir profile and stream time series data
OB2K.DSS	
ts96.dsc	
TS96.DSS	
*.dlg	base map digital line graphs
RR model\opp86	alternative analysis input data and output
F77L3.EER	system file required to interpret program error
2000.bat	batch and run file to run the two alternatives from windows
2020.bat	
both.bat	
OPP00.r	
OPP00.in	
OPP20.r	
OPP20.in	
BL2000.25Q	interface file created by "opp_output\opp25Q" for 1986 - 1996 under 2000 and 2020 SCWA operations model conditions
CI2020.25Q	
noflow.dsd	meteorological data. HEC-5Q reads the data from DSS however, the *.Y2K files are included if one wishes to review these data
NOFLOW.DSS	
M1_WS.Y2K	
M2_WS.Y2K	
M3_WS.Y2K	
M4_WS.Y2K	
M5_WS.Y2K	
OPP5.dat	ASCII input files. The two version of the OPP5Q*.dat differ only in the naming of the output files
OPP5Q_00.dat	
OPP5Q_20.dat	
Trib.dat	
X-sec.dat	
balgae.dat	
OPP5_00.OUT	ASCII output files (flow and quality) for 2000 and 2020.
OPP5_20.OUT	
HEC5Q_00.OUT	
HEC5Q_20.OUT	
Gui00_86.01	GUI output files for 2000 and 2020.
Gui20_86.01	
SCWA2020.xls	Selected time series files in CDF (model output, "EXCEL OUT" option) and Excel for 2000 and 2020
SCWA_00.TXT	
SCWA_20.xls	
SCWA_20.TXT	
STORET data	data viewer and data
rma_view.exe	executable
rr.p5q	viewer support files
Dlglist.txt	
Russian.txt	
Russian.prj	
RR_Qual.bin	Binary ambient data files and index. Note that the "_WP" files are required by the program and would normally contain reservoir profile data. No profile data were retrieved from STORET
stan_wp.bin	
Index_wP.dat	
Index_wq.dat	