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[12]Abstract (Purpose, method, results, conclusions)

Wahiawa Reservoir is a small multi-use facility located on the central plain of Oahu, Hawaii. The goal of this study was to develop and apply a computer-simulation model of water quantity and quality in Wahiawa Reservoir. The model was used to evaluate alternate water quality management strategies. The model represents the reservoir as a dynamic, one-dimensional (vertical) system. Primary emphasis is placed on representing vertical and temporal changes in water level, water temperature and dissolved oxygen. A unique feature of the model is the inclusion of the effects of artificial aeration. Model calibration was accomplished by obtaining statistically acceptable comparisons between simulated and observed water quality values over a 1-yr interval. Model verification results demonstrated a low predictive accuracy for the model as calibrated. However, the general response behavior of the reservoir is well represented by the model. Examples of using the model to predict effects of alternate management strategies showed that anaerobic conditions depend on oxygen demanding sediments and high algal productivity of surface waters. Artificial aeration appeared to be the most effective water quality management strategy.

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WATER QUALITY SIMULATION
OF WAHIAWĀ RESERVOIR
O'AHU, HAWAI'I

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Technical Report No. 138

September 1981

Final Technical Completion Report
for
Water Quality and Quantity Simulation of Wahiawa Reservoir

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DISCLAIMER

ABSTRACT

Wahiawā Reservoir is a small multi-use facility located on the central plain of O'ahu, Hawai'i. The goal of this study was to develop and apply a computer-simulation model of water quantity and quality in Wahiawā Reservoir. The model was used to evaluate alternate water quality management strategies.

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Examples of using the model to predict effects of alternate management strategies showed that anaerobic conditions depend on oxygen demanding sediments and high algal productivity of surface waters. Artificial aeration appeared to be the most effective water quality management strategy.

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INTRODUCTION

Background

Wahiawā Reservoir is located at the confluence of the North and South Forks of Kaukonahua Stream in the central plain of O'ahu, Hawai'i. As shown in Figure 1, Wahiawā Reservoir consists of two long, narrow branches and a main basin. Storage capacity of the reservoir is 11.355×10^6 m^3 (3 bil gal) at a spillway height of 256.64 m (842 ft).

The reservoir was originally created to provide a source of irrigation water for sugarcane. However, since its construction, it is also used as a recreation site for sport fishing and as a receiving water for municipal waste water treatment plant (MWWTP) effluents.

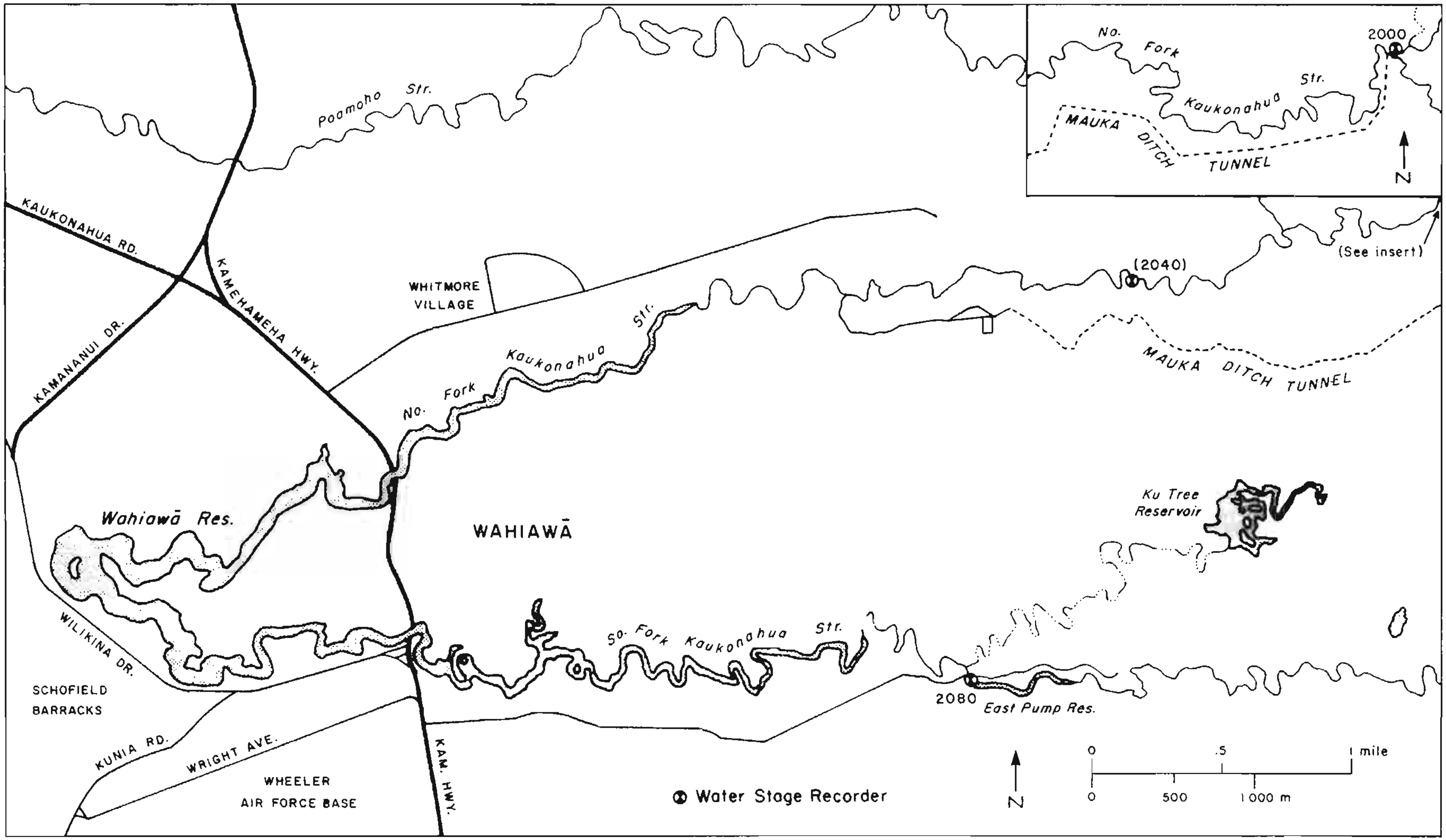
The goal of managing water quality in Wahiawā Reservoir to simultaneously accommodate these three uses has led to a variety of investigations and analyses, including the computer simulation study reported herein. The present study is a follow-up to an earlier investigation of reservoir water quality reported by Young et al. (1975).

The purpose of the previous project was to assess the eutrophic state of reservoir waters and to evaluate the effect of alternate management decisions on reservoir water quality. A particular concern of that study was the related effects of MWWTP effluents and reservoir drawdown for irrigation use on water quality, especially dissolved oxygen (DO). Fish kills in the reservoir have been historically attributed to low DO when the water surface elevation was lowered below certain critical levels. The low DO has been attributed to the highly eutrophic state of reservoir waters which is in part due to MWWTP effluents.

Study Objectives

The overall goal of the present study was to develop and apply a computer-simulation model of water quantity and quality in Wahiawā Reservoir. The purpose of this model was to facilitate further evaluation of the effects on reservoir water quality of alternate management practices. The model used in this study is the Water Quality for River-Reservoir Systems (WQRRS) model (Smith 1978).

To accomplish this research project, the following specific objectives



NOTE: (2040) Discontinued in September 1968.

Figure 1. Wahiawā Reservoir and its tributary stream gaging stations, O'ahu, Hawai'i

were identified:

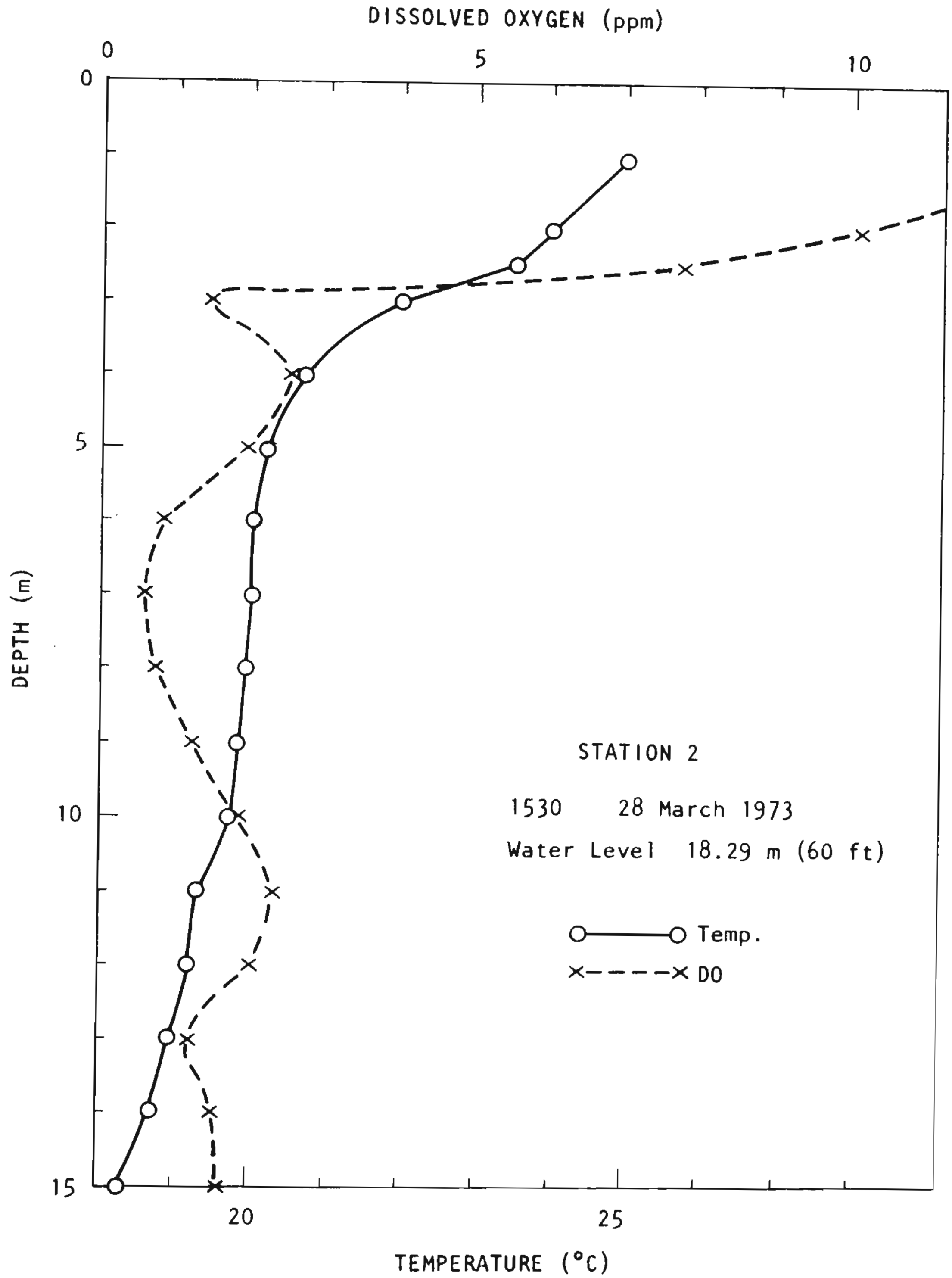
1. Set up and modify the WQRRS computer model as needed to be compatible with specific computer systems and needs of this study
2. Compile meteorologic, hydrologic, and water quality data for Wahiawā Reservoir and prepare model input data sets for calibration, verification, and prediction
3. Calibrate the model to obtain acceptable simulation of observed fluctuations in water level, temperature, and DO
4. Verify the calibrated model against a data set other than that used in calibration, and evaluate model accuracy
5. Simulate alternate management strategies and evaluate effects on reservoir temperature and DO, and estimate accuracy of results.

Project objectives included compiling and utilizing existing data from all available sources for modeling, and excluded the collection of new field data. Model calibration was used to estimate various coefficients in the absence of estimates based on field experiments.

Rationale for Choosing WQRRS Model

Numerous models of water quality exist and are potentially applicable to the Wahiawā Reservoir case. Pavoni (1979) reviewed and compared many of these models. Differences among these models include their representations of time (static or dynamic), space (0, 1, 2, or 3 dimensions), water quality variables, and input conditions. Previous studies of water quality in Wahiawā Reservoir (Young et al. 1975; Lum and Young 1976) have made effective use of simple, nutrient mass balance models to assess the effects of management practices on water quality in the reservoir.

Unfortunately, these nutrient models do not account for changes in DO, a critical water quality variable in Wahiawā Reservoir. Typical spatial fluctuations and vertical stratification in DO observed in Wahiawā Reservoir are shown in Figure 2. The dynamic WQRRS model is a well-known general water quality simulation program which can adequately represent and account for such changes in DO.



SOURCE: Schmitt (1973).

Figure 2. Typical vertical profile of temperature and dissolved oxygen, South Fork, Wahiawā Reservoir, O'ahu, Hawai'i

WQRRS MODEL DESCRIPTION

Background

The WQRRS model developed for the U.S. Army Corps of Engineers is the latest version in a sequence of models originating with the so-called "Chen-Orlob" reservoir model. A brief history of the development of the WQRRS model is presented by Smith (1978). In its present form, the model is capable of representing dynamic, one-dimensional flow and water quality in rivers and reservoirs.

The WQRRS model consists of three separate but integrable modules: the reservoir module, the stream hydraulic module, and the stream quality module. The reservoir and stream hydraulics modules are stand-alone programs and may be independently executed, analyzed, and interpreted. The stream quality module, however, has no hydraulic computation capability and requires a hydraulic data file which is generated by the stream hydraulics module. The three computer programs may also be integrated for a complete river basin water quality analysis through automatic storage of results for input to downstream simulations. The subsequent analysis may be a part of the same simulation or an entirely separate model execution. Input/output compatibility for downstream analysis is consistent among modules. Many subroutines are similar, if not identical, among the reservoir and stream modules.

In the present study, only the reservoir module was utilized. Therefore, all subsequent discussion is restricted to this one part of the model.

Reservoir Module

The methodology in the reservoir section of the program is applicable to aerobic impoundments that can be represented as one-dimensional systems in which the isotherms, or indeed the contours of any parameter, are horizontal. This approximation is generally satisfactory in small to moderately large lakes or reservoirs with long residence times. The approximation may be less satisfactory in shallow impoundments or those that have a rapid flow-through time. Although systems that have a rapid flow-through time are often fully mixed and can often be treated as slowly moving streams using the stream section of the model, results described below show that Wahiawā Reservoir is adequately represented by the reservoir module, in spite of being a long, narrow body of water with relatively short residence times.

Mass Transport

The reservoir or lake is represented conceptually by a series of one-dimensional horizontal slices (Fig. 3). Each horizontal slice or layered volume element is characterized by an area, thickness, and volume. In the aggregate, the assemblage of layered volume elements is a geometric representation in discretized form of the prototype lake or reservoir.

Within each element, the water is assumed to be fully mixed. This implies that only the vertical dimension was retained during the computation. Each horizontal layer is assumed to be completely homogeneous with all isotherms parallel, both laterally and longitudinally, to the water surface. External inflows and withdrawals occur as sources or sinks within each layer and are instantaneously dispersed and homogeneously mixed throughout each element from the headwaters of the impoundment to the dam. It is not possible, therefore, to look at longitudinal variations in water quality constituents.

Internal transport of heat and mass occurs only in the vertical direction, assumably by advection and through an effective diffusion mechanism that combines the effects of molecular and turbulent diffusion and convective mixing. Although the diffusion gradient among layers is based on the concentration differences of the individual constituents, the effective diffusion coefficient is always based on temperature. This is important to remember since mass diffusion may not be equivalent to dispersion of thermal energy.

Model results are most representative of conditions in the main reservoir body. It is inappropriate to draw conclusions about water quality in coves or the headwater area because of one-dimension, horizontal considerations.

The movement of water, and hence advective effects, are governed by the location of inflow to, and outflow from, the reservoir. Thus, the computation of the zones of distribution and withdrawal for inflows and outflows are of considerable significance in the operation of the model. In the simulation of Wahiawā Reservoir, the so-called Debler-Craya method is used for the allocation of outflows (Smith 1978).

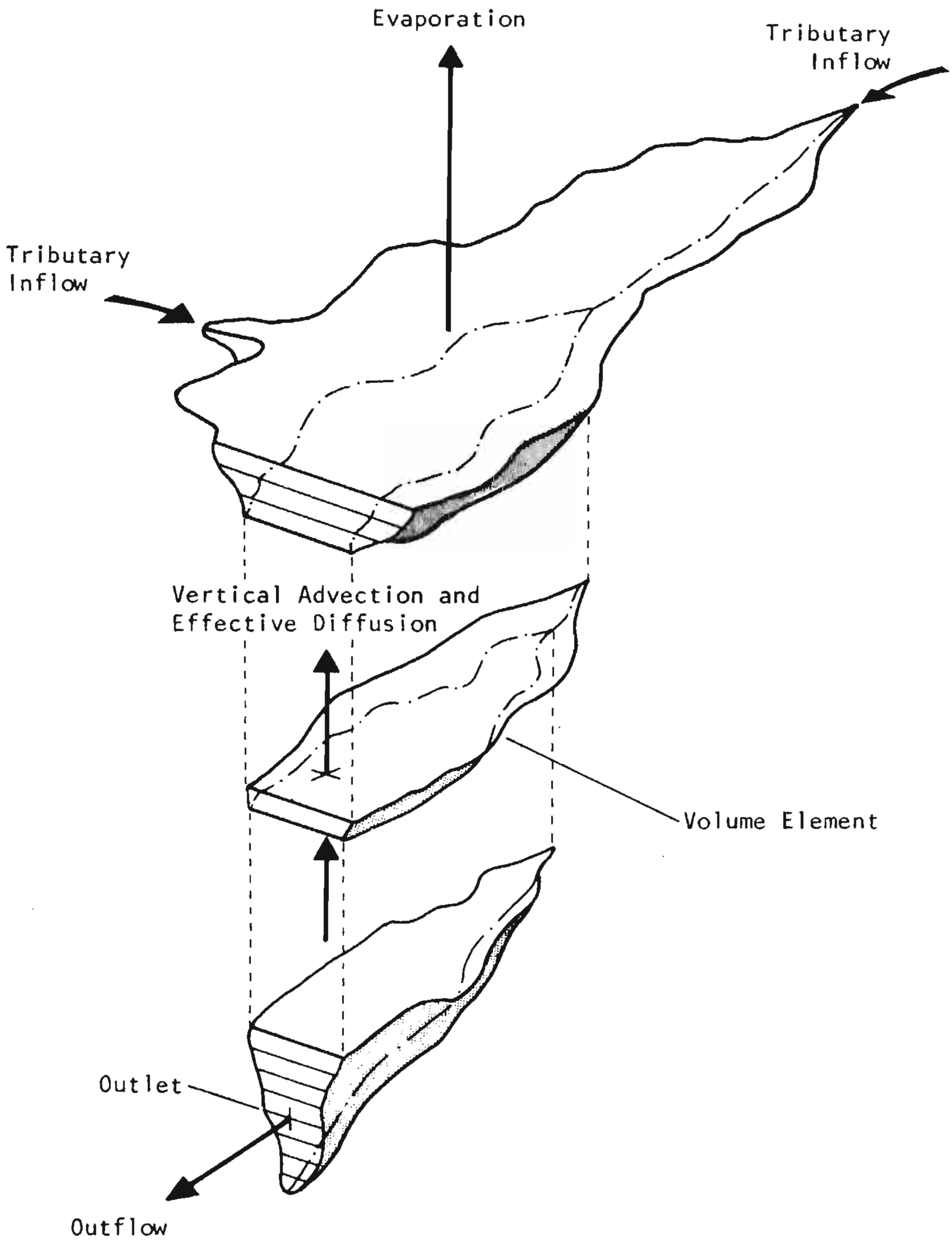


Figure 3. Geometric representation of a stratified reservoir and mass transport mechanisms

The allocation of inflows was based on the assumption that the inflow water would seek a level of like density within the lake. If the inflow water density were outside the range of densities found within the lake, the inflow would be deposited at either the surface or the bottom, depending on whether the inflow water density was less than the minimum or greater than the maximum water density found within the lake. Once the entry level was established, allocation of the inflow to the individual elements proceeded.

Vertical advection is the net interelement flow and was one of two transport mechanisms used in the model to transport heat and dissolved or suspended materials between elements. The vertical advection is defined as the interelement flows that result in a continuity of flow in all elements. Beginning with the lowermost element, the vertical advection was calculated by algebraically summing the inflows and outflows. Any flow imbalance was made up by vertical advection into or out of the element above. This process was repeated for all remaining elements, taking into account the vertical advection from or to the element below. Any resulting flow imbalance in the surface element was accounted for by an increase or decrease in the lake volume.

Effective diffusion, which is composed of molecular and turbulent diffusion and convective mixing, was the other transport mechanism used in the model to transport heat and mass between elements. Calculation of the effective diffusion coefficient was based on the assumption that mixing would be at a minimum when the water column density gradient was at a maximum.

Water Quality Relationships

The water quality model is designed to provide a detailed portrayal of the important processes that determine the thermal and water quality characteristics of the reservoir. The conceptual framework of the model was based on fundamental characterizations of the dynamics of constituent transport, and chemical and biological kinetics.

The modeling approach was based on the assumption that the dynamics of each chemical and biological component could be expressed by the law of conservation of mass and the kinetic principle, as well as on a very important assumption that all chemicals and biological rate processes occurred in an aerobic environment. The model was not capable of simulating processes that occurred under anaerobic or oxygen-devoid conditions. Several default algorithms were included to permit the simulation to continue until oxygen returned to the layer, but the results should be interpreted with extreme caution. The model can be appropriately used to determine whether anaerobic conditions develop in the reservoir but not to predict the duration of anoxic conditions.

The fundamental principle of conservation of heat and mass was used to derive the following differential equation model for the dynamics of heat and biotic and abiotic materials:

$$V \frac{\partial C}{\partial t} = \Delta z \cdot Qz \frac{\partial C}{\partial z} + \Delta z \cdot A_z \frac{\partial^2 C}{\partial z^2} + Q_i C_i - Q_o C \pm VS \qquad (1)$$

where

C = thermal energy or constituent concentration in the reservoir or stream, appropriate units (e.g., kcal/s, mg/ℓ, and MPN/100 mℓ)

V = volume of the fluid element, m^3

t = time coordinate, s

z = space coordinate (vertical for reservoir, horizontal for stream), m

Q_z = vertical advection, m^3/s

A_z = element surface area normal to the direction of flow, m^2

D_z = effective diffusion coefficient, m^2/s

Q_i = lateral inflow, m^3/s

C_i = inflow thermal energy or constituent concentration, in appropriate units

Q_o = lateral outflow, m^3/s

S = all sources and sinks, appropriate units (e.g., kcal/s, and mg/ℓ/s).

The source and sink term for temperature was limited to external heat fluxes. For the water quality constituents, sources and sinks may include settling, first order decay, reaeration, chemical transformations, biological uptake and releases, growth, respiration, and mortality including predation.

The water temperature was one of the most important parameters to be analyzed because nearly all rate coefficients are temperature dependent. In addition, the diffusive mass transport mechanism within the reservoir is directly dependent upon water density, which in turn is dependent on temperature.

The external source and sink for heat considered in the reservoir model was heat exchange at the air-water interface. Within the stream, model heat transfers at both the surface and stream bottom were considered.

The transfer of heat to and from the water body occurs primarily at the air-water interface. The rate of heat transfer per unit of surface area can be expressed as the sum of the following five components:

$$H_n = q_{ns} + q_{na} - q_w - q_e - q_c \quad (2)$$

where

H_n = net rate of heat transfer, kcal/m^2/s

q_{ns} = net rate of shortwave solar radiation across the interface after losses by adsorption and scattering in the atmosphere and by reflection at the water surface

q_{na} = net rate of atmospheric longwave radiation across the interface after losses by reflection at the water surface

q_w = rate of longwave radiation from the water surface

q_e = rate of heat loss by evaporation

q_c = rate of convective heat exchange between the water surface and the overlying air mass.

As described by Smith (1978), the WQRRS model computes the various terms in equation (2) using methods reported by the Tennessee Valley Authority (TVA). However, in the case of Wahiawā Reservoir, direct measurements of net shortwave solar radiation and pan evaporation were available. Therefore, for Wahiawā Reservoir the heat budget equations in the computer program were modified to use these direct observations of net shortwave radiation and pan evaporation.

The modified program computed the various terms in equation (2) as

1. q_{ns} is directly read in as an input on the weather data card;
2. q_{na} is computed by the TVA method assuming a constant average cloud cover of 0.55, as,

$$q_{na} = [1.23E - 16^{*}(1.0 + 0.17^{*}C^2)]^{*} \; DBT^6 \; ,$$

where C^2 is the cloud cover and DBT^6 is the dry bulb temperature in Kelvin (K);

3. q_w is represented by the linear approximation,

$$q_w = 0.06693 + 0.001471 T_w$$

where T_w is the water temperature;

4. q_e is the fraction of observed pan evaporation, which is read as an input on the weather data card and which is adjusted during the calibration process (coefficients AA and BB on input card PHYS1 are used as pan evaporation coefficients, where AA applies to the period 1 May to 26 October, and BB applies to all other times);
5. q_c is accounted for as a fraction of pan evaporation and included in the coefficients AA and BB.

The WQRRS model was capable of simulating a large number of biotic and abiotic water quality constituents. In the case of Wahiawā Reservoir, only the subset of the variables listed below were simulated because of their importance in governing dissolved oxygen and eutrophication in the reservoir:

- Phytoplankton
- Zooplankton
- Detritus
- Organic sediment, i.e., settled detritus
- Dissolved phosphate as phosphorus
- Dissolved ammonia as nitrogen
- Dissolved nitrites as nitrogen
- Dissolved nitrates as nitrogen
- Dissolved biochemical oxygen.

A detailed description of these constituents and their interactions was presented by Smith (1978).

Numerical Solution Technique

The differential equations representing the behavior of various water quality constituents were solved by the finite difference method described by Smith (1978). General mass balance equations were rewritten in a finite difference form for each element (layer) in the reservoir, and the resulting set of equations was simultaneously solved using the Gaussian reduction scheme.

The differential equations were coupled between constituents, e.g., terms in the oxygen equation that depend on BOD and other constituents; however, the constituents were sequentially processed beginning with the least dynamic constituents and regressing to the most dynamic. Sources and sinks resulting from this coupling were assumed constant over the time step. The magnitude of the source and sink term is a function of the present concentration of the coupled constituents, e.g., end of time step concentration for constituents processed previously and beginning of time step concentration for constituents yet to be processed.

For reactions that demand oxygen, the model checked for oxygen availability before processing the parameter and adjusting the demand rate to reflect this availability.

Artificial Aeration

The WQRRS model contains no provision for artificial aeration. But because this is an important management consideration for Wahiawā Reservoir, the model was modified to include the effects of artificial aeration.

As described by Lorenzen and Fast (1977), the primary benefit of artificial aeration is to induce circulation, rather than to directly aerate the water.

Lorenzen and Fast (1977) explained that there has been little research on the relationships between air release and water flow rates. However, the best available theory indicates that the amount of water flow induced by a rising bubble plume is primarily a function of air-release depth and airflow rate. Kobus (1972) showed theoretically—and, to some extent, experimentally—that the water flow as a function of height above an orifice is given as

$$Q_w(x) = 35.6C(x + 0.8)\,\frac{-V_o \ln\left(1 - \frac{x}{h + 10.3}\right)}{\mu_b} \tag{3}$$

where

$Q_w(x)$ = water flow, m^3/s

x = height above orifice

$C = 2V_o + 0.05$

V_o = air flow, m^3/s at 1 atm

h = depth of orifice

$\mu_b = 25V_o + 0.7$ m/s.

Equation (3) was implemented in subroutine FLOWIN in the Wahiawā Reservoir model. The depth of aeration and the airflow rate at 1 atm of pressure are specified by the user as inputs (AIRDATA cards).

WQRRS MODEL APPLICATION

This section describes the specific details of applying the WQRRS model to Wahiawā Reservoir. Four parts of model application included are input data requirements, model calibration, model verification, and simulation results.

Input Data Sources and Preparation

Instructions for preparing an input deck for the Wahiawā Reservoir model (App. A) reflect several modifications in the instructions given by Smith (1978) for the WQRRS model. Appendix B is a listing of the input file actually used for final model calibration runs.

Physical Data

Inputs of primary concern were the physical data for the reservoir. Waialua Sugar Company (1972-1973) provided sufficient data to enable the model requirements to be met.

Wahiawā Reservoir has the following characteristics:

Minimum Elevation	231.65 m (760 ft)
Spillway Elevation	256.64 m (842 ft)
Maximum Pool Level	258.19 m (847 ft)
Capacity of Max. Level	11.355×10^6 m^3 (3 bil gal)
Area at Spillway Elev.	104.82 ha (259 acres).

In addition to the spillway, there are four gates in the outlet tower. The upper three gates were not used during the simulated time period. The fourth gate is 0.91 m (36 in.) in diameter and contains a 0.51 m (20 in.) diameter butterfly valve. The maximum flow through this gate is 2.234 m^3/s (51 mgd). The spillway is fitted with an inflatable rubber dam to allow an increase in maximum reservoir elevation from 256.64 to 258.17 m (842-847 ft).

Water levels were read from a staff gage near the outlet tower. A gage height of 24.38 m (80 ft) corresponds to an elevation of 256.64 m (842 ft).

Input requirements for the model included tabulated values describing the depth/area curve. A depth/area curve does not exist for Wahiawā Reservoir, but a depth/volume curve was provided by Waialua Sugar Co. Using this curve, the known surface area at 24.38 m and an assumption about the reservoir configuration, a depth/area curve was created.

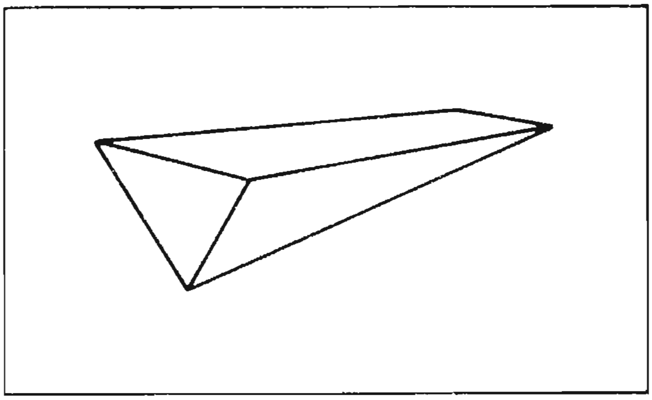


Figure 4. Assumed reservoir shape

If the reservoir is assumed to be a regular triangular solid with greatest depth near the dam wall (Fig. 4), then the volume of the reservoir can be approximated by $V = K \cdot A \cdot d$, where V = volume, A = surface area, d = depth at the gage, and K = shape-related constant.

Using the known values for volume and area at a depth of 24.38 m, K is estimated to be 0.375. With this value of K and values of volume at a specific depth from the volume/depth curve, a value for surface area at the chosen depth is calculated, thereby yielding the necessary depth/area values. Comparisons between simulated and measured water surface elevations given below confirm the accuracy of this method for determining a depth/area relationship.

The model also required values for "effective reservoir withdrawal widths" at those depths used for the depth/area curve. Widths were obtained from a contour map of the area around the dam wall that had been prepared for Waialua Sugar Company during the course of the National Dam Safety Program (Shannon and Wilson 1978).

Physical, Chemical, and Biological Rate Coefficients

With the exception of the conservative constituents (i.e., alkalinity, total dissolved solids [TDS], and unit toxicity), the differential equations representing water quality relationships incorporated one or more physical, chemical, or biological coefficients. Most of these coefficients were based upon an empirical understanding of a process, e.g., the BOD decay rate is a simplified description of a complex microbial activity. Many of these coefficients were highly variable and depended upon such factors as regional climatic variation; time of day; synoptic weather patterns; system geometry, e.g., shallow stream, deep lake; and type and general levels of pollution. Smith (1978, Table IV-1) listed the default values of coefficients used in the WQRRS model and gave selected ranges that had been previously used in various simulations. Appendix C (from Smith 1978, Table IV-1) lists the default values and selected ranges for coefficients used in the WQRRS model. These default values have been used in the Wahiawā Reservoir model except as listed below:

Coefficient	Code	Value
Phytoplankton Type 1 respiration rate	18	.07
Phytoplankton Type 1 settling velocity	28	.20
Organic sediment decay rate	109	.01
Detrital decay rate	108	.05

The foregoing values were obtained by model calibration, as described below.

Initial Conditions

To begin the simulation, an initial set of conditions for the reservoir was required. This information was consolidated from several data sources, including Konno and Tomita (1974), Schmitt (1973), Lum (1976), City and County of Honolulu (1973-1974), and the Hawaii Division of Fish and Game.* In general, specifications of initial values were not critical for simulations covering periods several times the reservoir residence time.

Temperature and DO were taken from Konno and Tomita's (1974) profiles or from Fish and Game profiles depending on when the simulation began. Data from Konno and Tomita covered December 1972 to May 1973 and September 1973 to November 1973, and from Fish and Game July to August 1972.

The BOD and organic detritus values were estimated from 1970 surface water data collected by the City and County for a mixing zone report. Organic detritus was estimated to be 1% of the reported solids concentration. BOD was given a constant value with depth while the detritus value increases.

Nutrient values were obtained from measurements reported by Konno and Tomita (1974) and Schmitt (1973).

Values for organic sediment were indirectly inferred, as no direct

*W. Devick, 12 April 1980 correspondence.

measurements of organic sediment were available. However, Young et al. (1975) reported a value of 30 mg carbon (C)/g sediment. Assuming a bulk density of 1.2 g/cm^2, this gives 36 mg C/cm^3 of sediment. Assuming further that the sediment is 40% C, the sediment load is (36 mg C/cm^3)/0.4 = 90 mg sediment/cm^3. With a 1 cm deep layer of active sediment, this value becomes 90 000 mg/m^2. Field inspection of the reservoir at low water indicated that the upper portion of the reservoir did not have any appreciable accumulation of organic sediments. Therefore, the initial conditions were so specified that bottom values of 10^6 mg/m^2 dropped off to 0 mg/m^2 above the 10-m depth.

Finally, the model required dry weight of fish biomass. Fish and Game data indicated a value of 464 000 kg (wet weight) of fish calculated as follows:

TABLE 1. FISH BIOMASS

Species	Number ($\times 10^6$)	Mean Weight (g)	Total Weight ($\times 10^4$ kg)
Tilapia	2.4	155	37.2
Shad	14	4	5.6
Others	0.072	500	3.6
TOTAL (kg)			464 000

SOURCE: Devick correspondence, 12 April 1980.

At 24.38 m (80 ft), the surface area is 100 ha (259 acres). Assuming dry weight is 10% of wet weight, the fish density is 464 kg/ha.

Meteorological Data

As described by Smith (1978), the WQRRS model requires inputs of latitude, longitude, atmospheric turbidity, cloud cover, dry- and wet-bulb temperatures, barometric pressure, and wind speed. These inputs were used to calculate solar radiation, evaporation, and other terms in the heat budget. For Wahiawā Reservoir, direct daily readings of shortwave solar radiation, pan evaporation, temperature, and wind speed were reported by Ekern (1977). These data were collected at Kunia Substation, about 8 000 m (5 miles) south of Wahiawā Reservoir. The computer program was modified to read in measured values of meteorologic variables as needed. In particular, WEATH1 cards in the input file consist of time of observation, shortwave solar radiation (cal/cm^2/day), dry bulb air temperature, pan evaporation (in./day), barometric pressure, and wind speed (miles/day).

Because pan evaporation is not the same as the evaporation from the reservoir, the computer program was modified to read in on card PHYS1 the fraction of pan evaporation to be used as reservoir evaporation. The fraction of pan evaporation is a seasonal variable and the program permits selection of one value for the summer season (BB) and another value for the winter (AA). Values of AA (.70) and BB (.85) were estimated as part of the model calibration process.

A model parameter related to these coefficients is the secchi disk depth. A value of 1.5 m was selected during model calibration because no direct measurements were available.

Inflows and Withdrawals

The Wahiawā Reservoir system is strongly affected by inflow/outflow hydraulics. Because residence time in the reservoir is relatively short, reliable information on the inflow and outflow data, and water quality of the inflow was necessary to model the system. Inflows consisted of the North and South Forks of Kaukonahua Stream, the Wahiawa and Whitmore WWTPs, and rainfall. Outflow consisted of discharge to the Waialua Sugar Co. irrigation system. Evaporation as an outflow was accounted for in the heat budget portion of the program, but seepage as an outflow was not directly accounted for.

Inflow data for the streams were based on U.S. Geological Survey (USGS) gaging stations, Nos. 2000 (North Fork) and 2080 (South Fork), on Kaukonahua Stream. For purposes of the program, the streamflows were combined and 10% was added to account for rain falling directly on the reservoir. The reported discharges from Station 2000 cannot be directly used because the station is located several miles upstream of the reservoir and is not an accurate record of reservoir inflows because of diversions along the stream. USGS Station No. 2040, discontinued in September 1968, was located 1 609 m (1.0 mile) downstream from Poamoho Tunnel on the North Fork of Kaukonahua Stream. By analyzing nine years of historical records from stations 2040 and 2000, the following relation was observed (correlation coefficient 0.93):

Flow Station 2040 = 2.0 * Flow Statio- 2000 + 1.85 (cfs).

Total stream, in m^3/s, is thus the sum of the two streams plus 10% for rainfall or

$$\text{Total Streamflow} = (\text{Flow Station 2080} + 2.0 * \text{Flow Station 2000} + 1.85) \cdot 1.10/35.5 .$$

Flows from the WWTPs were based on respective averages of 0.061 and 0.006 m^3/s (1.4 and 0.14 mgd) for Wahiawa and Whitmore. Thus, the input value was 0.067 m^3/s.

The source of outflow data was from a daily record sheet (with values in mgd reported twice a day) maintained by the Waialua Sugar Company. For an input value, the average value was computed as m^3/s by

$$Q, m^3/s = [(Q, AM + Q, PM)/2], \text{ mgd} \cdot 0.04381.$$

(These data sheets include a record of water levels which were calibrated to check the performance of the hydraulic portion of the model.)

Water quality data, which were assumed to be constant values through the simulation period, for the streamflow and WWTP flow were obtained from various sources. Most of the WWTP data were from weekly laboratory reports on Wahiawa WWTP prepared regularly by the City and County of Honolulu.

Quality data for the streams were scarce. Stream temperature values were available from the USGS for only a few days in 1973 through 1978. Nutrient data, where available, were obtained from averages of field data collected by Schmitt (1973).

Inflow stream temperature for the model was taken as the constant temperature difference below air temperature. To determine this difference, air temperatures were compared with water temperatures. However, air temperatures for Kunia did not exist for the same time period as for water temperatures. Thus, air temperature values from the Honolulu International Airport were used. A relation between Honolulu airport temperatures and Kunia temperatures was established using available 1972 data. Other relationships established between Honolulu temperature and stream temperature were

$$T_{KUNIA} = T_{AIRPORT} - 1.67°C$$

$$T_{AIRPORT} = T_{WATER} + 3.25°C .$$

From these two relationships, the desired relation was calculated as

$$T_{WATER} = T_{KUNIA} - 1.58°C .$$

Similarly, inflow WWTP temperature values showed a seasonal variation. To model this, a quarterly value for effluent temperature was calculated from the weekly data. This was in keeping with the fact that field data show the nutrient loading from the WWTP entering the reservoir at, or near, the surface. This would only be true if the effluent temperature were equal to or higher than surface temperatures.

Dissolved oxygen is input as a fraction of the saturated value for stream inflows and as a fixed value for WWTP flows. A value of 50% of saturation was selected for streamflow inputs. WWTP records show an average value of 3.2 mg/ℓ as suitable for this input. The model was relatively insensitive to these inputs over a wide range of values and, therefore, was not adjusted further during calibration.

Numerical Discretization

Although only daily values of meteorological data were available, 4-hr time steps were necessary to solve the model equations; longer time steps led to numerical instabilities in the model. Similarly, experience with the model demonstrated that a value of 0.5 m was necessary for the thickness of vertical layers. In the case of shortwave solar radiation and pan evaporation, the model computes (in subroutine RADIAT) actual periods of daylight and properly distributes the daily average values over periods of darkness and daylight. Although a 4-hr time step allowed the model to represent diurnal variations in DO, these variations should be recognized as being based on daily average meteorological values.

Model Calibration

Model calibration consisted of adjusting various model parameters until a satisfactory correspondence was obtained between simulated water quality and measured values. In the present case, calibration was focused on simulating temperature and DO. Coefficients adjusted during the calibration process for temperature were diffusion and pan evapotranspiration coefficients. Coefficients adjusted during calibration of DO were secchi disk depth, phytoplankton respiration, organic sediment decay rate, detritus decay rate, and phytoplankton settling velocity.

Measured values of water quality in Wahiawā Reservoir were available from several sources covering the July 1972 through November 1973 period. These data were divided into a calibration period (December 1972 through November 1973) and a verification period (July 1972 to December 1972).

The first step in calibration was to check the simulation of reservoir hydraulics. Figure 5 shows a comparison of simulated and observed water surface elevations. The maximum difference in measured and simulated values was approximately 1 m. The accuracy of these results was somewhat surprising because inflow and outflow data come from two different sources and the depth/area curve for the reservoir was indirectly derived from a depth/volume relationship.

Given a satisfactory representation of reservoir hydraulics, the next step was to calibrate temperature and DO simulations. To objectively compare simulated and observed temperature and DO values, a statistical method of analysis based on a regression model (Thomann 1979) was used.

The linear regression approach adopts the following statistical description of the model outputs relative to calibration data:

$$y_i = a_0 + a_1 x_i + \varepsilon_i \qquad i + 1, \ldots, N$$

where

y_i = the ith model output

x_i = the corresponding ith field measurement

a_0, a_1 = constant coefficients relating the field measurements and model outputs

ε_i = component of the ith model output for which the terms a_0 and $a_1 x_i$ (also called the model residual error) are not accounted.

If the model calibration is perfect, all model outputs coincide with their respective measurements $y_i = x_i$ and the following relationships hold:

$$\text{Perfect Calibration:} \quad a_0 = 0$$

$$a_1 = 1$$

$$\varepsilon_i = 0 \qquad i = 1, \ldots, N .$$

If the model calibration is not perfect, the variables a_0, a_1, and ε_i deviate from these ideal values.

Observed temperature and DO values in Wahiawa Reservoir consisted of vertical profiles, e.g., Fig. 2, plotted from measurements for the follow-

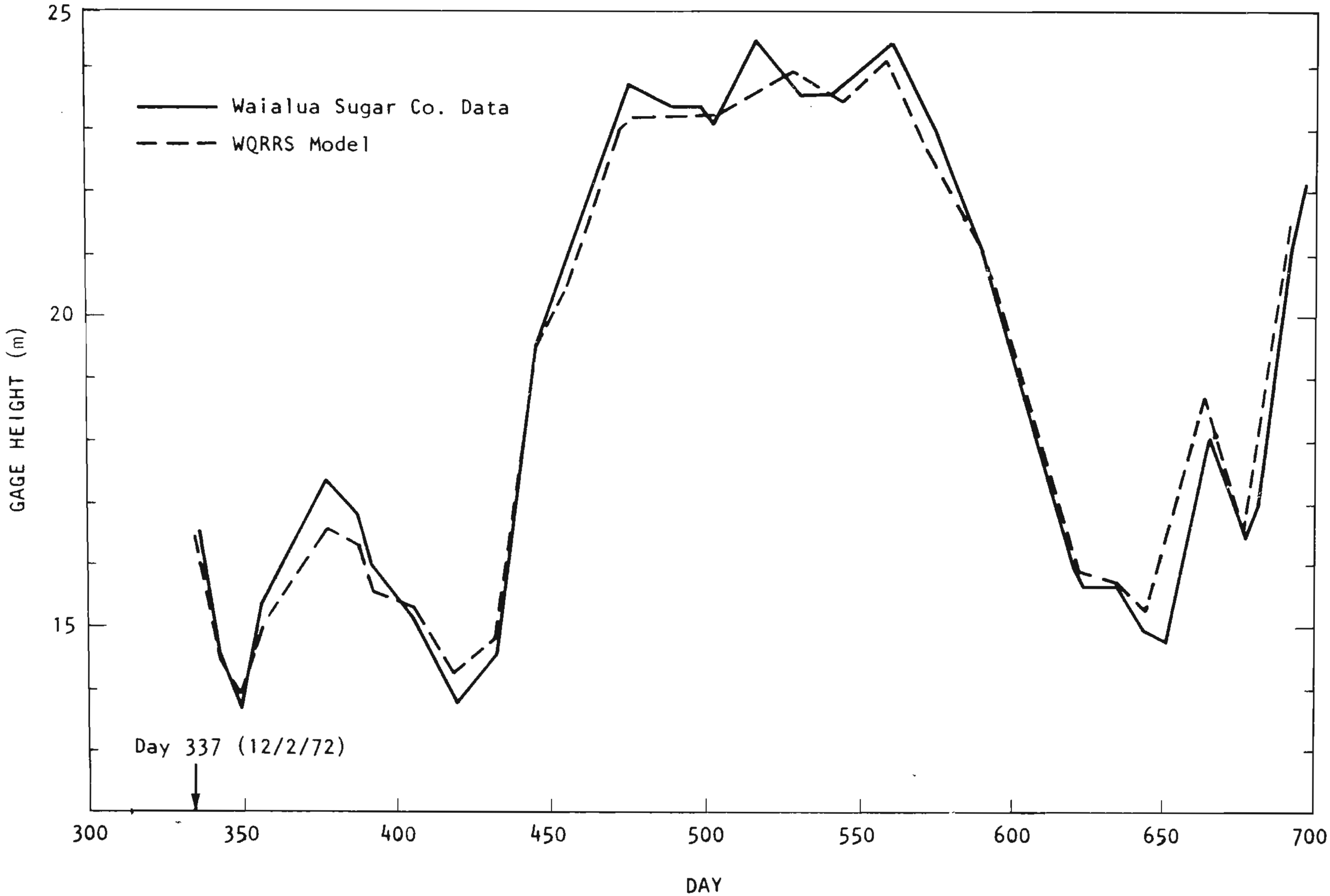


Figure 5. Simulated and observed water surface elevations in Wahiawā Reservoir during calibration period, O'ahu, Hawai'i

ing days:

20 Jan. 1973	Schmitt (1973)	15 Sept. 1973	Tomita (1974)
24 Feb. 1973		6 Oct. 1973	
28 Mar. 1973		21 Oct. 1973	
16 Apr. 1973		27 Oct. 1973	
16 May 1973		9 Nov. 1973	
		23 Nov. 1973	

The first five of these profiles were reported by Schmitt (1973); the remainder was unpublished data collected by Tomita (1974). Each plotted point on each profile represents a data point against which the model can be compared. Together, the collection of pairs of observed and simulated points provided a data set for applying the regression model described above.

Figure 6 shows plots of simulated vs. observed temperature and DO in Wahiawā Reservoir. The results shown were obtained by a series of simulation runs in which various model parameters were adjusted to obtain better fits between simulated and observed values of temperature and DO.

In each plot shown in Figure 6, two lines are shown. The 45° line represents an ideal case of exact correspondence between simulated and observed, i.e., a slope of 1.0 and an intercept of 0.0. The other line is the actual least-squares regression line for the plotted points. In the (ideal) case of perfect calibration, all plotted points would fall on a 45° line and the regression line would be coincident with the 45° line.

Comparisons between the actual and ideal regression lines may be based on comparisons of several quantitative regression parameters, including the intercept, slope, correlation coefficient, and percent-of-variance explained. All of these parameters may be computed without resorting to any assumptions about the statistical properties of the model outputs (y_i's) or the residual errors (ε_i's).

Table 2 shows the regression parameters for temperature and DO. For both temperature and DO, the regression parameters a_1 and a_0 are not statistically different—at a 0.05 significance level—from their respective ideal values of 1.0 and 0.0. Therefore, the calibrations were deemed satisfactory. However, it was evident that the temperature simulations contained a positive bias. Further refinement of model parameters governing simulated temperature could reduce this bias, in particular, better representation of inflow temperatures and water surface evaporation. Virtually no data cur-

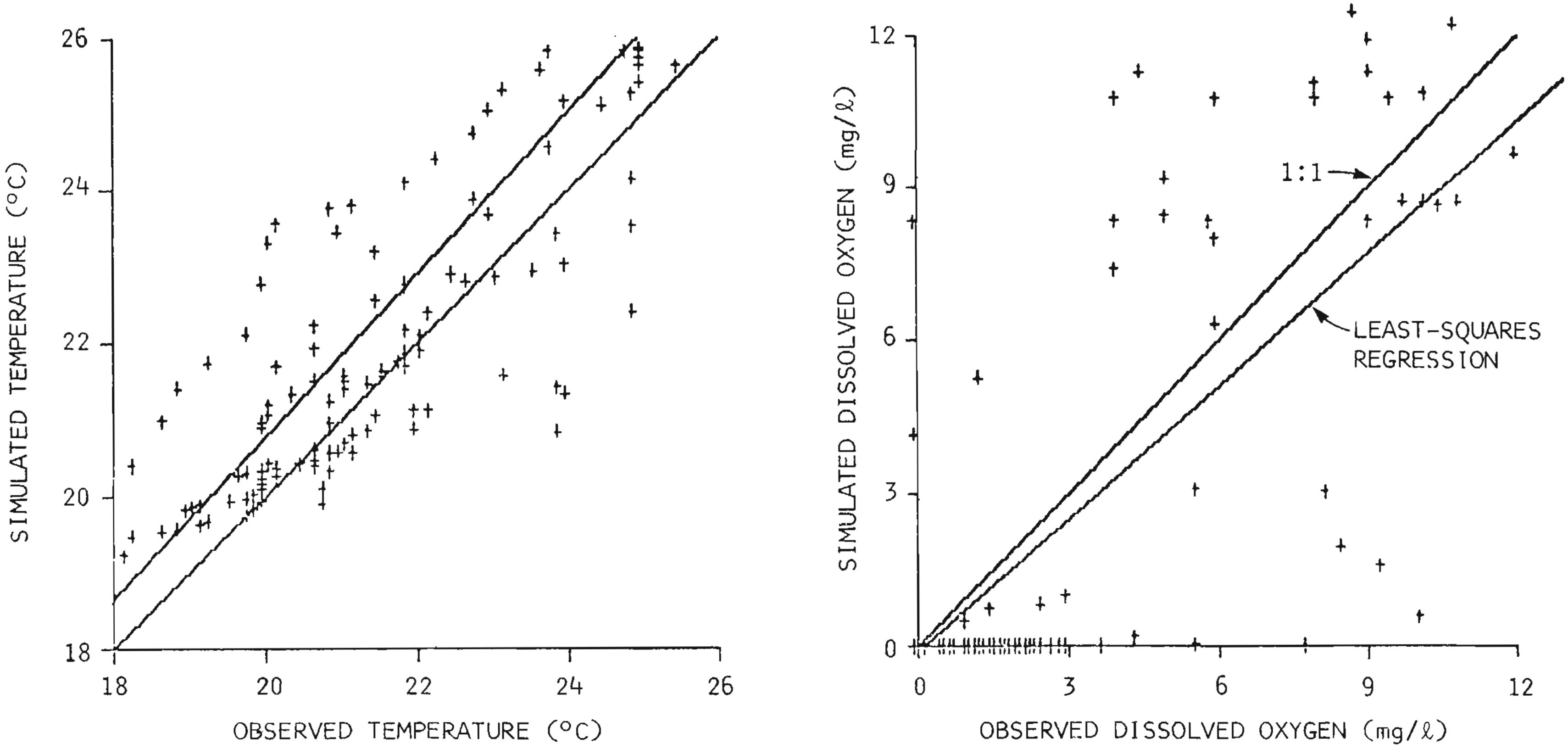


Figure 6. Final calibration results for simulated vs. observed temperature and dissolved oxygen in Wahiawā Reservoir, O'ahu, Hawai'i

TABLE 2. STATISTICAL ANALYSIS SUMMARY FOR CALIBRATION RESULTS

	Temp. (°C)	DO (mg/ℓ)
Slope (a_1)	1.06	0.87
Intercept (a_0)	-0.49	-0.19
Correl. Coef.	0.85	0.73

rently exist to determine these parameters other than by indirect model calibration.

Although the calibration results for DO were statistically acceptable, it was evident (Fig. 6) that relatively large discrepancies existed between simulated and observed values of DO at specific points in time and space (as shown more clearly in App. Figs. D.1-D.11). On the average, DO was simulated reasonable well by the model. However, for observed DO values greater than 3 mg/ℓ, there was a tendency to overpredict DO; and for DO values under 3 mg/ℓ, the model often predicted anaerobic conditions. These discrepancies are more clearly evident in Appendix Figures D.1 through D.11.

Results of simulations using final calibrations parameters are shown for each measured profile in Appendix Figures D.1 through D.11. Note that the model tends to underpredict DO in the bottom layers in the January to May period. However, during the critical low-flow period (days 264-666, App. Figs. D.6-D.9), the model simulated DO profiles which correspond fairly well with observed DO values and show a tendency to overpredict DO at mid-depths. Simulated surface water temperatures appeared to be fairly accurate throughout the year. However, simulated temperatures at lower depths in the September to November period tended to be too high. These high temperatures were most likely the result of inaccurate representation of inflow temperatures. However, the available data do not support the use of lower inflow values.

Because of the importance of nutrients and phytoplankton in Wahiawā Reservoir water quality, it would be desirable to also calibrate the model using this water quality variable. Although the scarcity of data for these parameters precludes any effective comparisons between simulated and observed values, the simulated results appear "reasonable" and do not exhibit unusual behavior.

In general, in the calibration runs, the model demonstrated a relatively high sensitivity to inflow streams, especially water temperature, and to secchi disk depth, and phytoplankton respiration and settling velocity. Further refinement of the model calibration would be greatly enhanced by obtaining field measurements of inflow quantities and qualities coordinated with on-going measurements of reservoir quality and water surface elevation, meteorology, and outflow rates. Given the lack of these important input data to which the model is sensitive, the authors found the calibration results very satisfactory.

Model Verification

Model verification was an important step in testing model validity for predictive purposes, and differed from calibration in that model parameters were not adjusted further to fit observed water quality. Rather, in verification, the calibrated model was used to simulate a data set not used in the calibration process. Comparison between simulated and observed values for this verification time period provided a basis for estimating predictive accuracy of the model.

Figure 7 shows the simulated and observed water surface elevations during the verification time period. A thorough review of the available data and the model structure has not led to an explanation for the apparent discrepancy shown in Figure 7. Three possible explanations were

1. The derived depth/area curve was inaccurate
2. Derived inflow relationship was not valid during this period
3. Unmeasured leakage from the reservoir occurred during the time period.

Given the accuracy of simulated water surface elevations during the calibration time period (obtained without adjustment of model parameters), the first two of these explanations seems unlikely. In our opinion, the most likely explanation is that unrecorded outflows from the reservoir occurred sometime during days 200-250. Unrecorded outflows over a short period of time would lead to a simulated water surface elevation discrepancy which would propagate throughout the remaining simulation period (Fig. 7).

In spite of this discrepancy in the simulated hydraulics, it was useful to analyze model predictions of temperature and DO during this period. The

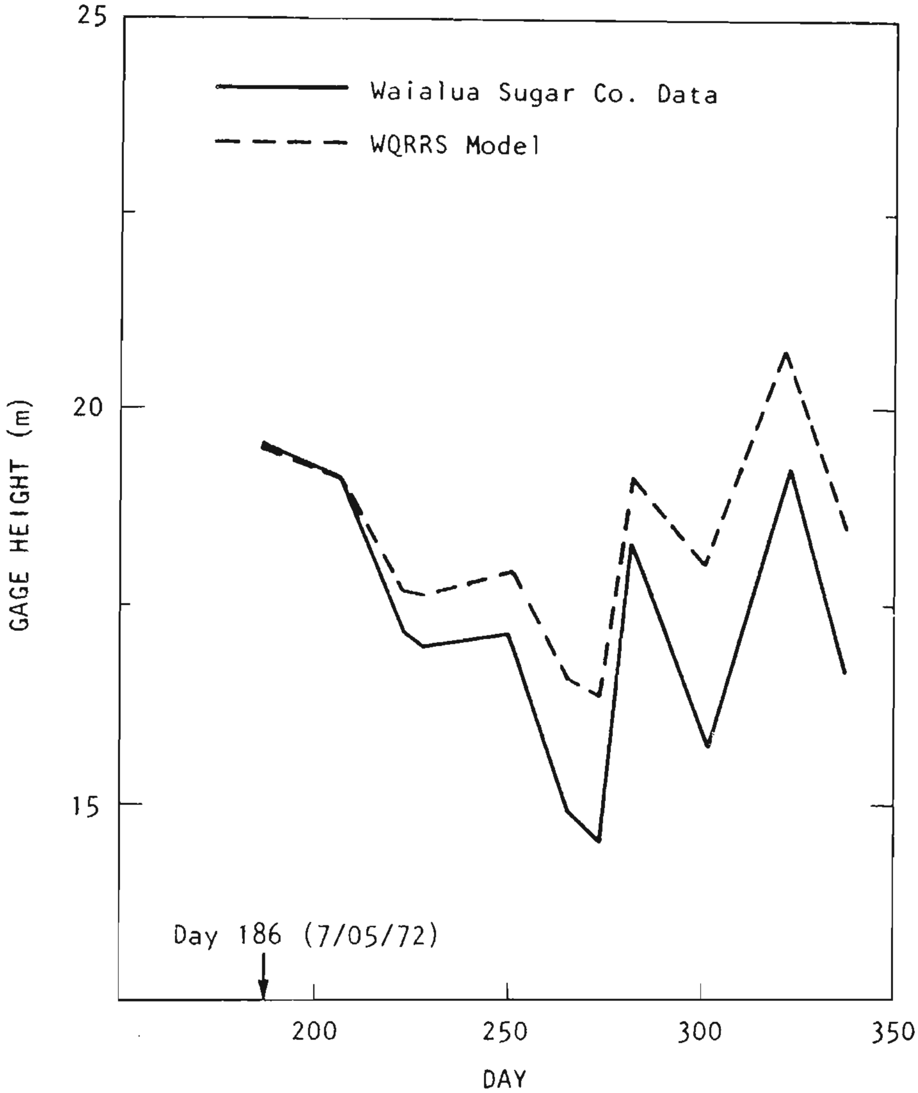


Figure 7. Simulated and observed water surface elevations during verification period, Wahiawā Reservoir, O'ahu, Hawai'i

available data consisted of profile measurements obtained from the Hawaii State Department of Fish and Game* for 5 and 25 July; 3, 9, and 14 August; 6 September; and 7 October 1972.

Plots of simulated and observed temperature and DO for these dates are shown in Figure 8, and the regression results for these comparisons in Table 3.

*W. Devick correspondence, 12 April 1980.

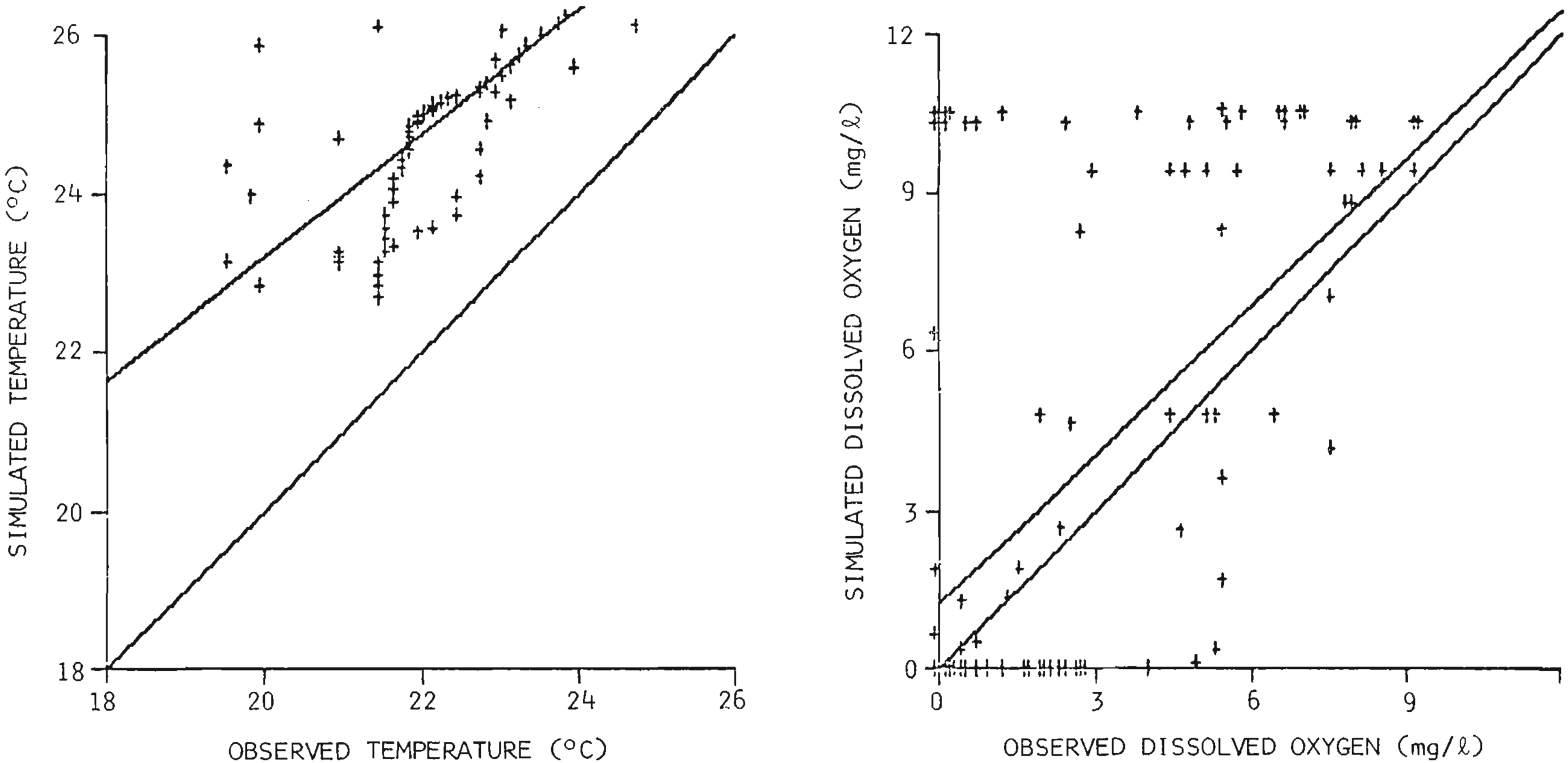


Figure 8. Verification comparison of simulated and observed values for temperature and dissolved oxygen in Wahiawā Reservoir, O'ahu, Hawai'i

TABLE 3. STATISTICAL ANALYSIS SUMMARY FOR VERIFICATION RESULTS

	Temp. (°C)	DO (mg/ℓ)
Slope	0.78	1.93
Intercept	7.60	1.25
Corr. Coef.	0.94	0.59

Except for the slope for DO, the regression parameters above (a_1, a_0) are significantly different, at a 0.05 significance curve, from their ideal values of 1.0 and 0.0. Clearly the temperature results are poor and indicate questionable predictive accuracy. However, the simulated values for DO are more acceptable. In the case of DO, the t-statistics for testing the slope and intercept are respectively 0.70 and 3.8. Critical test values at the 0.05 significance level are approximately 2.0 for this number of observations.

It should be pointed out that these results for verification use the same values for inflow temperature and DO as used for calibration, because no measurements of these variables were available. It is possible that better model results would be obtained if the input values better reflected the true conditions occurring during the verification period.

Appendix Figures E.1 to E.6 display the observed and simulated profiles of temperature and DO during the verification time period. Simulated temperature profiles show less stratification than displayed by observed data, suggesting a need to reduce the diffusion coefficient in the model. Simulated DO values were too high at the surface, but showed a good correspondence to measured values at mid and bottom depths.

Whether or not these results are accurate enough to justify simulating management alternatives must be determined in light of a particular user's requirements. However, it should be noted that the foregoing verification analysis essentially requires that the model accurately predict values of temperature and DO at particular points in time and space. This is a rigorous test of predictive ability. Although the model failed this detailed predictive test, it was evident that the general behavior of the system was well represented by the model. It is the authors' opinion that the model demonstrates adequate capability for the simulation of management alternatives. In cases requiring detailed predictive accuracy, accurate model inputs must be provided for the model. No such cases were undertaken in the present study.

Simulation of Management Alternatives

The ultimate purpose for developing a water quality model of Wahiawā Reservoir was to simulate alternative management strategies. Such similations would show the dynamic response of reservoir water quality, especially the effects on DO, under various management decisions. Management alternatives of interest included:

1. Phosphate removal from WWTP effluent
2. WWTP diversion
3. Sediment dredging to remove oxygen demanding organics
4. Subsurface discharge to enhance mixing of effluents with reservoir waters
5. Artificial aeration.

Alternative 4 required capabilities not currently available in the model, and therefore was not included in the present study. Simulation results of the other options are presented below.

Each management alternative was simulated over the calibration period of December 1972 through November 1973. In each case, the input data set was modified to reflect the strategy involved.

1. Phosphate removal. WWTP phosphate phosphorus inflow was set to a constant concentration of 0.0 mg/ℓ (Card 130, App. B)
2. WWTP diversion. WWTP inflow was set to 0.0 cfs (Card 113, App. B)
3. Sediment dredging. Sediment organic concentration was set to 0.0 mg/m^3 (Cards 33, 36, 39, 42; App. B)
4. Artificial aeration. Artificial aeration was activated during the low-flow, low DO period of 17 October to 1 November 1973. Aeration depth was 4 m with an 80 cfm air flow at 2 atm (160 cfm at 1 atm) (Card 1 plus necessary AIRDATA cards, App. B).

Figures 9 to 13 show simulated temporal distribution of DO at depths of 0.5 and 3.5 m for the calibration period (base condition) and each management alternative. The effect of each management strategy can be seen by comparing the results for that strategy with the base condition. Of particular interest is the low-flow period (days 625-675) typically associated with critical stress on the fish population. As suggested by Devick (1974)

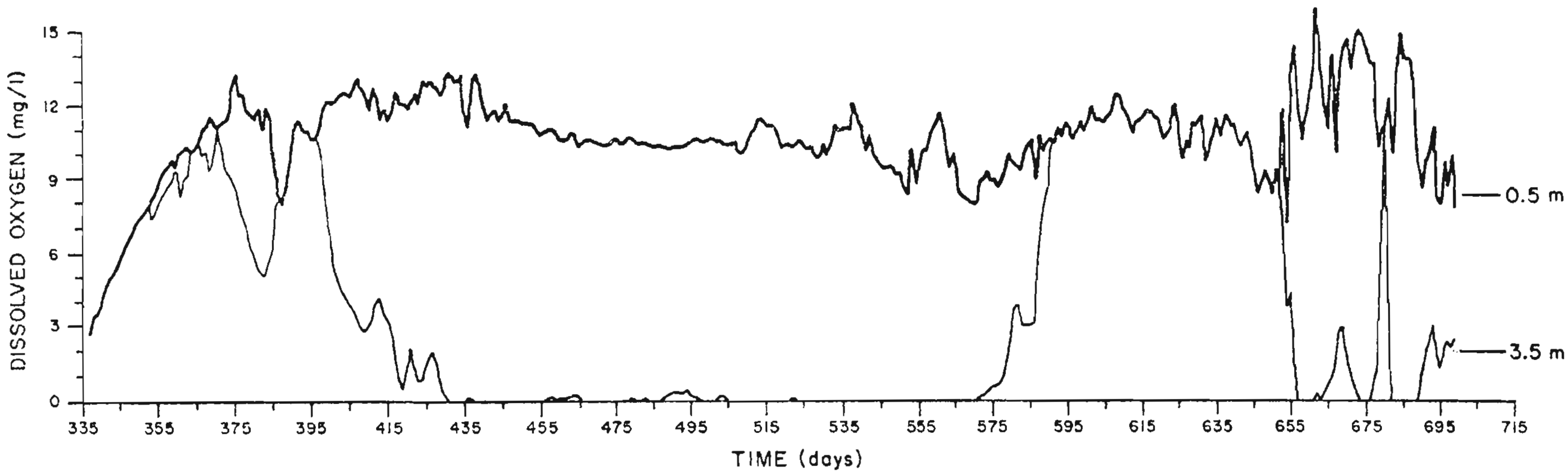


Figure 9. Simulated temporal distribution of dissolved oxygen at 0.5- and 3.5-m depths without management alternatives (base conditions)

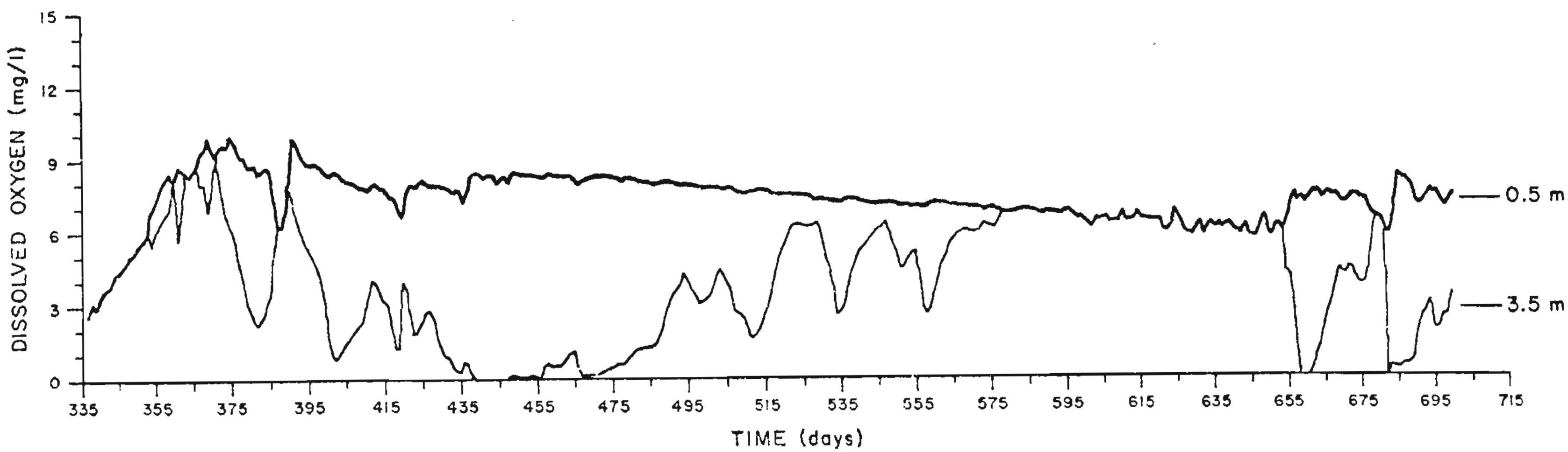


Figure 10. Simulated temporal distribution of dissolved oxygen at 0.5- and 3.5-m depth with phosphate removal

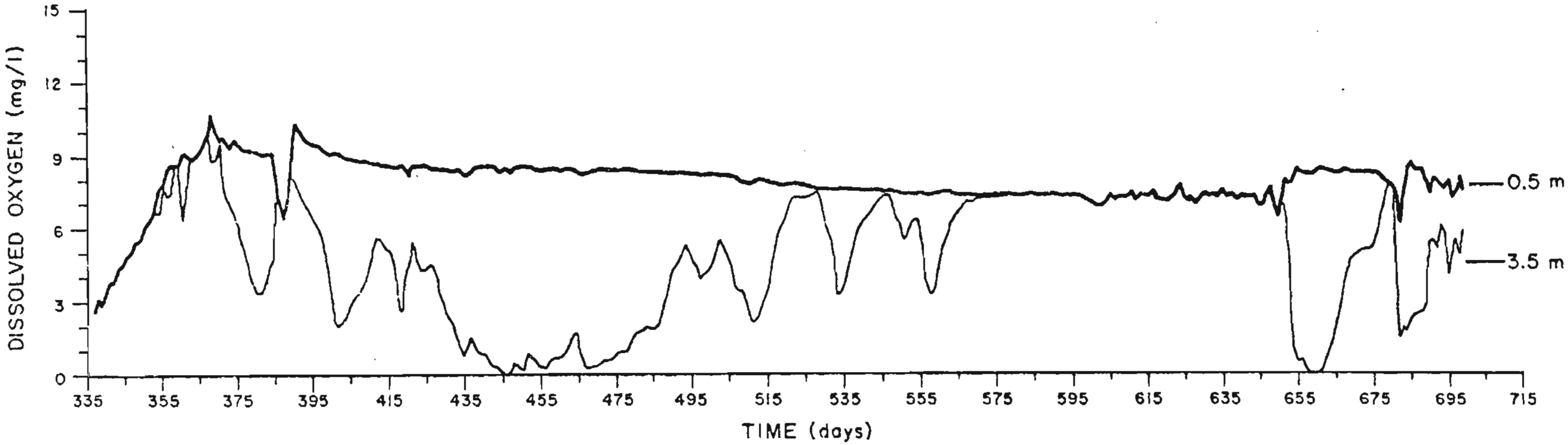


Figure 11. Simulated temporal distribution of dissolved oxygen at 0.5- and 3.5-m depth with STP diversion

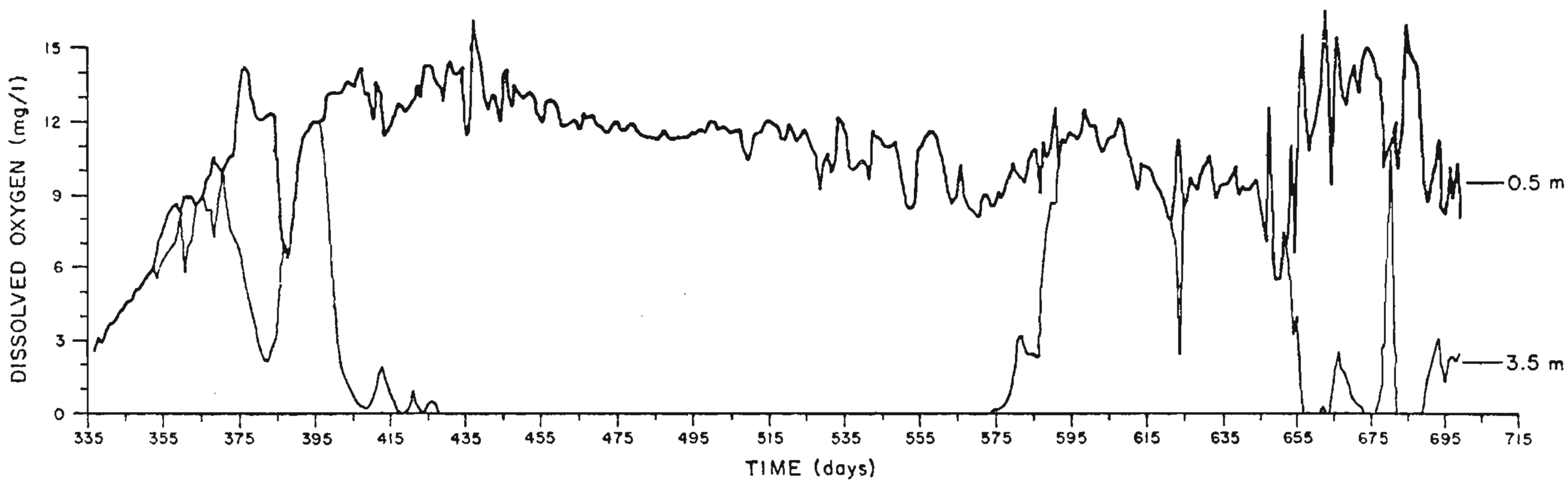


Figure 12. Simulated temporal distribution of dissolved oxygen at 0.5- and 3.5-m depth with sediment dredging

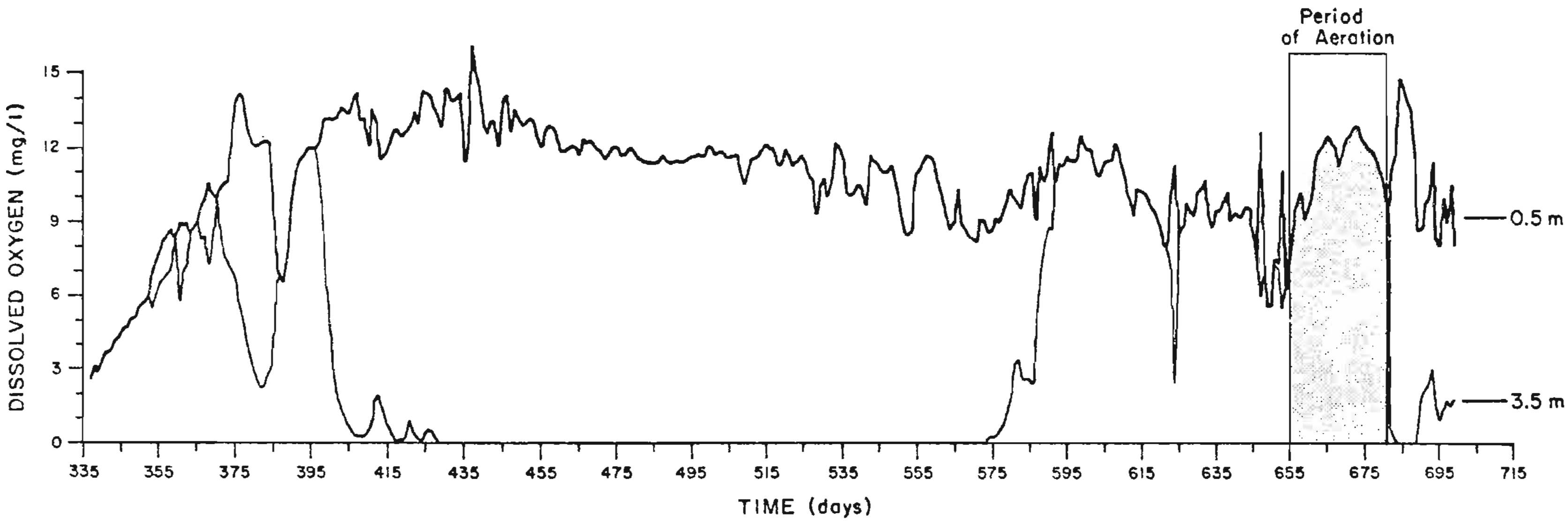


Figure 13. Simulated temporal distribution of dissolved oxygen at 0.5- and 3.5-m depth with artificial aeration

in his studies of artificial aeration, a goal of management practices during such critical periods is to maintain well-aerated water to a depth of 3 to 4 m.

In general, these simulations suggested that, except for artificial aeration, none of these strategies by themselves eliminated low DO in the deeper waters. Phosphorus removal and complete diversion of the WWTP effluent reduced surface DO values because of reduced phytoplankton growth. However, the large reservoir of oxygen-demanding sediments maintains low DO in deeper waters. It is likely that over a period of years these sediments may stabilize, if algal productivity is reduced so that the effect of organic sediments eventually decreases.

Removal (dredging) of organic sediments allowed DO in deeper water to increase significantly. However, anaerobic conditions were not eliminated. Apparently, there is sufficient surface productivity to still cause anaerobic conditions in deeper waters; thus, a combination of these management strategies may be required to eliminate the occurrence of anaerobic conditions.

Figure 13 shows the results for artificial aeration during the period from day 655 (17 Oct. 1973) to day 680 (1 Nov. 1973). During this period, water—to a depth of at least 3.5 m—was completely mixed and contained high levels of DO. This response to artificial aeration was consistent with field studies reported by Devick (1974), wherein the aerated layer "turns over" and becomes well oxygenated.

This result suggests that artificial aeration may be an effective management practice for Wahiawā Reservoir. Further field studies of artificial aeration are warranted and serious doubt is raised as to the efficacy of other water quality management practices. In particular, these results suggest that costly alternatives, such as WWTP diversion, may not alleviate low DO conditions in Wahiawā Reservoir.

CONCLUSIONS AND RECOMMENDATIONS

Based on the work described in this report, the following conclusions were drawn:

1. For purposes of simulating water quality responses to influent characteristics, Wahiawā Reservoir can be adequately represented

as a vertical, one-dimensional body of water by using the WQRRS model as modified for this study.

2. Although no coordinated data collection program was undertaken for Wahiawā Reservoir, sufficient data were assembled from various sources to calibrate and evaluate model accuracy during the July 1972 through November 1973 period.
3. Overall model calibration results were statistically acceptable; however, the accuracy of model results for particular days was quite variable. In general, simulated DO values during critical low-flow periods were satisfactory.
4. Model verification results demonstrated a low predictive accuracy for the model as calibrated for this study, especially temperature. However, results demonstrated that the model represents adequately the general behavior of the reservoir.
5. Examples of using the model to predict effects of alternate management strategies showed that the occurrence of anaerobic conditions depends on the existing oxygen demanding sediments and on the high algal productivity in surface waters. Simulation results indicated that diversion of WWTP effluents alone was not sufficient to eliminate anaerobic conditions in deeper water.
6. Artificial aeration appeared to be the most effective management strategy. Simulated aeration during critical low-flow conditions caused full mixing of the aerated layer and maintenance of well-oxygenated water. Further field studies of aeration are warranted based on these results.

The following recommendations for further investigation are made from this study.

1. Compare model predictions of nutrient and phytoplankton with available data on these water quality variables
2. Undertake a coordinated field study program to collect daily water quality and meteorological data needed to further test and refine the Wahiawā Reservoir model
3. Undertake additional field studies of artificial aeration to test its efficacy as a water quality management strategy in Wahiawā Reservoir.

ACKNOWLEDGMENTS

This study could not have been possible without information and data provided by the following persons: Frederick Gross (Director, Civil Engineering and Environmental Standards, Civil Engineering Dept.) of Waialua Sugar Company, Inc.; William Devick of the Division of Fish and Game, Department of Land and Natural Resources, State of Hawaii; and Eugene Akazawa, Department of Health, State of Hawaii.

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APPENDIX CONTENTS

APPENDIX TABLE

APPENDIX FIGURES

APPENDIX A. INPUT DATA INSTRUCTIONS

The input data requirements for the Wahiawā Reservoir model can be separated into the following categories.

1. Artificial aeration (AIRDATA cards)
2. Job titles (TITLE cards)
3. Job controls (JOB cards) which include water quality constituent interaction modification specifications, input and print controls, tape and file assignments, and other general data that control operation of the module
4. Physical data (PHYS cards), such as invariant meteorological data, general reservoir geometry data, dispersion characteristics, inflow and withdrawal location data, and the table of reservoir elevation vs. surface area and width at dam
5. Chemical, physical, and biological coefficients (COEFF and SSOL cards)
6. Initial quality conditions (INIT cards)
7. Time variant inflow data (INFL cards) which include the quality parameters to be read, length and description of inflow record, and inflow rates and water quality constituent concentrations
8. Time variant meteorological data (WEATH cards)
9. Time variant withdrawal rates and temperature objectives (OUTL cards).

All data categories are input via the card reader. Categories 7 and 8 are processed and written on files for later use during the simulation. At the user's option, the files may be made permanent and used during subsequent simulation, thus eliminating the need to reread and reprocess the data.

Description of Data Card Requirements

ARTIFICIAL AERATION CONTROL CARD (one card required)

Field	Variable	Value	Description
1	----	AIRDATA	Card identification
2	IAIR	0 1	Artificial aeration not used Switches on artificial aeration
3	AELEVI	-	Depth of artificial aeration

SOURCE: Smith (1978).

ARTIFICIAL AERATION CARDS (omit if IAIR = 0)

Field	Variable	Value	Description
1	-----	AIRDATA	Card identification
2	IVDATE	-------	Date in Julian days (negative value indicates end of data)
3	VZER	-------	Air flow for given date
4	IVDATE	-------	Date in Julian days (negative value indicates end of data)
5	VZER	-------	Air flow for given date
6	IVDATE	-------	Date in Julian days (negative value indicates end of data)
7	VZER	-------	Air flow for given date
8	IVDATE	-------	Date in Julian days (negative value indicates end of data)
9	VZER	-------	Air flow for given date

JOB TITLE CARDS* (three cards required)

Field	Variable	Value	Description
1	----	TITLE†	Card identification
2-10	TITLE	alpha	Job title (to be printed) on first page of printout

JOB CONTROL CARD 1

Field	Variable	Value	Description
1	----	JOB1	Card identification
2	IDAY	+	Date of first day of simulation; year, month, day (e.g., 560701)
3	LDAY	+	Date of last day of simulation; year, month, day
4	NHOI	4	Simulation time interval in hr (usually between 6 and 24 hr)
5	NHMI	24	Meteorological data interval in hr (usually between 1 and 6 hr).

*These and all remaining cards in this description are required cards unless the specific card description defines it as being optional.

†Field 1 is always reserved for card identification, which must be left justified.

JOB CONTROL CARD 2* (Water Quality Constituent Interaction Modification Option)

Field	Variable	Value	Description
1	--------	JOB2	Card identification
2	ITEST(1)	*	Temperature option
3	ITEST(2)	*	Dissolved oxygen option
4	ITEST(3)	*	5-day carbonaceous BOD option
5	ITEST(4)	*	Coliform bacteria option
6	ITEST(5)	*	Organic detritus option
7	ITEST(6)	*	Ammonia option
8	ITEST(7)	*	Nitrate option
9	ITEST(8)	*	Nitrite option
10	ITEST(9)	*	Phosphate option

JOB CONTROL CARD 2A* (Water Quality Constituent Interaction Modification Option)

Field	Variable	Value	Description
1	--------	JOB2A	Card identification
2	ITEST(10)	*	Total dissolved solids option
3	ITEST(11)	*	Type 1 phytoplankton option
4	ITEST(12)	*	Type 2 phytoplankton option
5	ITEST(13)	*	Zooplankton option
6	ITEST(14)	*	Total inorganic carbon and pH option
7	ITEST(15)	*	Alkalinity option
8	ITEST(16)	*	Organic sediment option
9	ITEST(17)	*	Benthic animals option
10	ITEST(18)	*	Type 1 fish option

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* -1 specified constituent to be held constant at its initial value in quality analysis.
0 specified constituent set to zero and ignored in quality analysis.
1 specified normal constituent treatment in quality analysis.

JOB CONTROL CARD 2B* (Water Quality Constituent Interaction Modification Option)

Field	Variable	Value	Description
1	---------	JOB2B	Card identification
2	ITEST(19)	*	Type 2 fish option
3	ITEST(20)	*	Type 3 fish option
4	ITEST(21)	*	Inorganic suspended solids groups 1 through 5 option
5	ITEST(22)		
6	ITEST(23)		
7	ITEST(24)		
8	ITEST(25)		
9	ITEST(26)	*	Inorganic sediment option

JOB CONTROL CARD 3

Field	Variable	Value	Description
1	-----	JOB3	Card identification
2	NOUTS	5	Number of outlets; maximul of 10
3	IWES	1	Index to select Debler/Craya withdrawal option
4	NTRIBS	2	Number of tributaries entering the reservoir; maximum of 10
5	NPOINT	5	Number of points defining the initial concentration profiles; maximum of 100

*-1 specified constituent to be held constant at its initial value in quality analysis;
0 Specified constituent set to zero and ignored in quality analysis;
1 specified normal constituent treatment in quality analysis.

JOB CONTROL CARD 4

Field	Variable	Value	Description
1	----	JOB4	Card identification
2	IPRT	+	Normal printout interval; output printed every IPRT days
3	IVAL	+	Output printed every IVAL hr within each day specified by IPRT (JOB4 card, field 2); IVAL should be a multiple of NHOI (JOB1 card, field 4)
4	INTP	+	Vertical layer printout frequency (e.g., a 1 prints every layer, a 2 prints every other layer, etc.)
5	ICT	0	Index that specifies input water temperature data, in °C
		1	Index that specifies input water temperature data, in °F
6	ICM	0	Index that specifies input data other than meteorological (WEATH1 cards), in metric units
		1	Index that specifies input data other than meteorlogical data (WEATH1 cards), in English units
7	NSD	+	Number of "additional" print days shown on JOB5 card other than those specified by "normal" printout interval, IPRT (JOB4 card, field 2); maximum of 45

JOB CONTROL CARD 5*

Field	Variable	Value	Description
1	--------	JOB5	Card identification
2-10	NDAYP(I)	+	Print days other than those specified by normal printout interval, IPRT (JOB4 card, field 2); use year, month, day

*Include only if NSD (JOB4 card, field 7) is positive. Use up to 9 numbers per card, and as many cards as needed for all NSD (JOB4 card, field 7) values.

JOB CONTROL CARD 6* (Tape or file related data)

Field	Variable	Value	Description
1	-----	JOB6	Card identification
2	ITAPE	+	Output unit identification; this unit contains the reservoir discharge rate and quality data for input to subsequent simulations of downstream river reaches or reservoirs
		0	Data will not be saved for further analysis
3	IFILE	+	Output unit identification; this unit contains reservoir discharge hydrograph for input to hydraulics module
		0	Data will not be saved for further analysis
4 5 6	JTAPE(1) JTAPE(2) JTAPE(3)	+	Input unit identification; these units contain flow and quality data from previous simulation of upstream river reaches and reservoirs, and 0 to 3 units may be assigned any numbers acceptable to the users' computer system
7 8 9	NHP(1) NHP(2) NHP(3)	+	Inflow rate and quality data interval on input units JTAPE (JOB6 card, field 4-6); set to zero if the corresponding JTAPE is equal to zero
10	LPLOT	+	Output unit identification; this unit contains simulation results for use in reservoir plot routines
		0	Not interested in using plot routines

*Any unit numbers acceptable to the users' computer system may be used. The numbers used may need to be assigned a magnetic tape or disk name using the specific job control language for the users computer system.

JOB CONTROL CARD 7* (Tape or file related data)

Field	Variable	Value	Description
1	----	JOB7	Card identification
2	IEQF	+	Input unit identification; this unit contains meteorological data to calculate surface heat exchange rates by using the equilibrium temperature approach.
		0	The heat budget approach to surface heat exchange will be used.
3	IMETF	+	Output unit identification; this unit contains processed meteorological data generated from card input data (WEATH1 cards).
		0	Used if IEQF (JOB7 card, field 2) is positive.
		-	Input unit identification; this unit must contain a permanent record of processed meteorological data generated by a previous quality simulation.
4	IINFL	+	Output unit identification; this unit contains processed tributary inflow and quality data generated from card input data (INFL cards) for use during the quality simulation
		-	Input unit identification; this unit must contain a permanent record of processed tributary inflow and quality data generated by a previous quality simulation.
5	LMF	+	Input unit identification; this unit contains raw meteorological data (WEATH1 cards). Use a 5 for card input. May be left blank if IMETF (JOB7 card, field 3) is negative or IEQF (JOB7 card, field 2) is positive.
6	LQF	+	Input unit identification; this unit contains raw tributary inflow and quality data (INFL cards). Use a 5 for card input. May be left blank if IINFL (JOB7 card, field 3) is negative.
7	LOF	+	Input unit identification; this unit contains reservoir release data.

*Any unit numbers acceptable to the users computer system may be used. The numbers used may need to be assigned a magnetic tape or disk name using the specific job control language for the users' computer system.

PHYSICAL DESCRIPTION CARD 1

Field	Variable	Value	Description
1	----	PHYS1	Card identification
2	IDEW	1	Wet bulb temperature is required (WEATH1 card, field 5)
		0	Dew point temperature is required (WEATH1 card, field 5)
3	AA	+	Pan evaporation coefficient (winter season)
4	BB	+	Pan evaporation coefficient (summer season)
5	XLAT	+	North latitude of reservoir site in degrees
6	XLON	+	West longitude of reservoir site in degrees
		-	East longitude of reservoir site in degrees
7	TURB	+	Atmospheric turbidity factor (range from 2 for clear unpolluted atmosphere to 5 for highly polluted atmosphere)

PHYSICAL DESCRIPTION CARD 2

Field	Variable	Value	Description
1	---	PHYS2	Card identification
2	SDZ	+	Thickness of vertical layer, in ft or in m (usually about 1 m)
3	ELMAX	+	Maximum water surface elevation, in ft or m
4	ELMIN	+	Elevation of bottom of reservoir, in ft or m
5	RESEL	+	Initial water surface elevation, in ft or m
6	EDMAX	+	Secchi disk reading, in ft or m; exclude the effects of all particular materials being modeled or held constant)
7	XQPCT	+	Fraction of the solar radiation absorbed in the top XQDEP (PHYS2 card, field 8) depth (usually 0.4)
8	XQDEP	+	Depth in which XQPCT (PHYS2 card, field 7) of the solar radiation is absorbed, in ft or m (usually 1 ft)

PHYSICAL DESCRIPTION CARD 2—*(Continued)*

Field	Variable	Value	Description
9	BPCT	+	Maximum fraction of total outflow allowed through the lowest outlet under selective withdrawal option

PHYSICAL DESCRIPTION CARD 3

Field	Variable	Value	Description
1	----	PHYS3A	Card identification
2	GMIN	+	Water column minimum stability, in $kg/m^3/m$
3	GSWH	+	Water column critical stability, in $kg/m^3/m$
4	A1	+	Diffusion coefficient when the water column stability is less than GWSH (PHYS3A card, field 2) in m^2/s
5			Not used
6	A3	-	Empirical constant for computing diffusion coefficients based on density gradients

PHYSICAL DESCRIPTION CARD 4

Field	Variable	Value	Description
1	--------	PHYS4	Card identification
2-10	RLEN(K)	+	Effective length of reservoir at each tributary inflow point, in ft or m. This value is divided into the surface area of the layer into which the inflow penetrates to calculate the effective width for use in the allocation of inflow to the individual elements. NTRIBS (JOB3 card, field 4) values are required. If NTRIBS = 10, an additional PHYS3 card is required with the effective length for tributary 10 in field 2. The inflow will be allocated to all elements down to the level of like density within the lake.

PHYSICAL DESCRIPTION CARD 5*

Field	Variable	Value	Description
1	-----	PHYS5	Card identification
2	ELOUT	+	Center-line elevation of the outlet, in ft or m
3	WOUT	+	Virtual width† of outlet, in ft or m
4	OUTMAX	+	Maximum allowable flow rate through outlet, in cfs or cm

*One card required for each outlet (NOUTS cards, JOB3, field 2) beginning with the lowest outlet and progressing to the highest outlet.

†Actual outlet area divided by the depth of a vertical layer, SDZ (PHYS2 card, field 2).

PHYSICAL DESCRIPTION CARD 6* (Reservoir depth, area, and width table)

Field	Variable	Value	Description
1	--	PHYS6	Card identification
2	D1	+	Elevation, in ft or m
3	AREA	+	Reservoir area at elevation D1, in acres or m^2
4	WIDTH	+	Effective reservoir withdrawal width at elevation D1, in ft or m (normally, dam width at elevation D1)
5	VOL	+	Reservoir volume below elevation 1 ELMIN (PHYS2 card, field 4); input on first card to account only for any "dead storage" below elevation ELMIN

DEFAULT COEFFICIENT OVERRIDE CARD†

Field	Variable	Value	Description
1	--------	COEFF	Card identification
2	ICODE(1)	+	Coefficient code number (see App. C)
		-1	Denotes final default coefficient override value
3	RATE(1)	+	New value for coefficient corresponding to ICODE(1)
4	ICODE(2)	+ / -1	Coefficient code numbers and corresponding new values of coefficients
5	RATE(2)		
6	ICODE(3)		
7	RATE(3)		
8	ICODE(4)		
9	RATE(4)		

*Repeat PHYS7 card as necessary to define reservoir depth, area and width between elevations ELMIN and ELMAX (PHYS2 card, fields 3 and 2) beginning at the bottom and progressing to the top. The depth D1 on the first card must equal ELMIN and the depth D1 on the last card must equal ELMAX.

†Repeat as necessary to redefine any or all of the chemical, physical and biological coefficients listed in App. C. The final card must have a -1 in one of the ICODE fields.

INITIAL CONDITIONS CARD 1 (Fish densities)

Field	Variable	Value	Description
1	-------	INIT1	Card identification
2	FISH(1)	+	Type 1 fish density, in kg/ha
3	FISH(2)	+	Type 2 fish density, in kg/ha
4	FISH(3)	+	Type 3 fish density, in kg/ha

INITIAL CONDITIONS CARD 2* (Water quality at specified elevation)

Field	Variable	Value	Description
1	--	INIT2	Card identification
2	TA	+	Elevation at which quality parameters are specified
3	TEMP	+	Temperature, in °C or °F
4	OXY	+	Dissolved oxygen, in mg/ℓ
5	BOD	+	5-day carbonaceous BOD, in mg/ℓ
6	COLIF	+	Coliform bacteria, in MPN/100 mℓ
7	SEDMT	+	Organic sediment (settled detritus) in mg/m^2
8	DETUS	+	Organic detritus, in mg/ℓ
9	CNH3	+	Ammonia as nitrogen, in mg/ℓ
10	CNO3	+	Nitrate as nitrogen, in mg/ℓ

*The cards, INIT2, INIT3, and INIT4, in that order, are repeated for NPOINT (JOB3 card, field 5) elevations. The order of repetition is from lowest to highest elevation. Input data should at least include the quality data at the reservoir bottom and at the elevation of the initial water surface, RESEL (PHYS2 card, field 5). Any parameter on this card can be left blank if the corresponding ITEST (JOB2, JOB2A, or JOB2B card) value equals zero.

INITIAL CONDITIONS CARD 3* (Water quality at specified elevation)

Field	Variable	Value	Description
1	----	INIT3	Card identification
2	CNO2	+	Nitrite as nitrogen, in mg/ℓ
3	PO4	+	Phosphate as phosphorus, in mg/ℓ
4	TDS	+	Total dissolved solids, in mg/ℓ
5	BEN	+	Benthic animals, in mg/m^2
6	ALGAE(1)	+	Type 1 phytoplankton, in mg/ℓ
7	ALGAE(2)	+	Type 2 phytoplankton, in mg/ℓ
8	ZOO	+	Zooplankton, in mg/ℓ
9	PH	+	pH, in units
10	ALKA	+	Alkalinity as calcium carbonate, in mg/ℓ

INFLOW RATE AND QUALITY CARD 1† (Input via unit LQF [JOB7 card, field 6])

Field	Variable	Value	Description
1	-------	INFL1	Card identification
2	ICON(2)	‡	Temperature, in °C or °F
3	ICON(3)	‡	Dissolved oxygen, in mg/ℓ
4	ICON(4)	‡	5-day carbonaceous BOD, in mg/ℓ
5	ICON(5)	‡	Coliform bacteria, in MPN/100 mℓ
6	ICON(6)	‡	Organic detritus, in mg/ℓ
7	ICON(7)	‡	Ammonia as nitrogen, as mg/ℓ
8	ICON(8)	‡	Nitrate as nitrogen, in mg/ℓ
9	ICON(9)	‡	Nitrite as nitrogen, in mg/ℓ
10	ICON(10)	‡	Phosphate as phosphorus, in mg/ℓ

*The cards, INIT2, INIT3 and INIT4, in that order, are repeated for NPOINT (JOB3 card, field 5) elevations. The order of repetition is from lowest elevation to highest elevation. Input data should at least include the quality data at the reservoir bottom and at the elevation of the initial water surface, RESEL (PHYS2 card, field 5). Any parameter on this card can be left blank if the corresponding ITEST (JOB2, JOB2A or JOB2B card) value equals zero.

†INFL1 cards determine which inflow quality parameters will be input via sets of INFL3 and INFL4 cards or sets of INFL3 and INFL5 cards. One set is required for each non-zero value of ICON(I) for each tributary inflow. ICON(1) controls the reading of tributary flow rate and is set internally to 1 (e.g., tributary flow rates are always read). Omit all INFL cards if IINFL (JOB7 card, field 4) is negative.

‡-1 inflow quality data will be read but not printed.
0 inflow quality data will not be read.
+1 inflow quality data will be read and printed.

INFLOW RATE AND QUALITY CARD 1A* (Input via unit LQF [JOB7 card, field 6])

Field	Variable	Value	Description
1	--------	INFL1A	Card identification
2	ICON(11)	†	Total dissolved solids, in mg/ℓ
3	ICON(12)	†	Type 1 phytoplankton, in mg/ℓ
4	ICON(13)	†	Type 2 phytoplankton, in mg/ℓ
5	ICON(14)	†	Zooplankton, in mg/ℓ
6	ICON(15)	†	pH, in units
7	ICON(16)	†	Alkalinity as $CaCO_3$, in mg/ℓ

INFLOW RATE AND QUALITY CARD 1B* (Input via unit LQF [JOB7 card, field 6])

Field	Variable	Value	Description
1		INFL1B	Card identification
2	ICON(17)	†	Suspended solids groups 1 through 5, in mg/ℓ
3	ICON(18)		
4	ICON(19)		
5	ICON(20)		
6	ICON(21)		

INFLOW RATE AND QUALITY CARD 2‡ (Input via unit LQF [JOB7 card, field 6])

Field	Variable	Value	Description
1	-----	INFL2	Card identification
2	IIDAY	+	First day of inflow rate and quality record for all tributaries; year, month, and day
3	LLDAY	+	Last day of inflow rate and quality record for all tributaries; year, month, and day

*INFL1 cards determine which inflow quality parameters will be input via sets of INFL3 and INFL4 cards or sets of INFL3 and INFL5 cards. One set is required for each non-zero value of ICON(I) for each tributary inflow. ICON(1) controls the readings of tributary flow rate and is set internally to 1 (e.g., tributary flow rates are always read). Omit a-1 INFL cards if IINFL (JOB7 card, field 4) is negative.

†-1 inflow quality data will be read but not printed.
 0 inflow quality data will not be read.
+1 inflow quality data will be read and printed.

‡Omit all INFL cards if IINFL (JOB7 card, field 4) is negative.

INFLOW RATE AND QUALITY CARD 3* (Input via unit LQF [JOB7 card, field 6])

Field	Variable	Value	Description
1	-----	INFL3	Card identification
2	IDINT	+	Inflow rate and quality data update interval in hours; inflow data is input using a series of INFL4 cards under this option
		0	Inflow data is input at variable time intervals using a series of INFL5 cards under this option
3-7	CON(I)	alpha	Description of inflow data

INFLOW RATE AND QUALITY CARD 4*† (Input via unit LQF [JOB7 card, field 6])

Field	Variable	Value	Description
1	-------	INFL4	Card identification
2-10	CONC(I)‡	+	Inflow rate (cms or cfs) or inflow quality in appropriate units

*Repeat sets of INFL3 and INFL4 or sets of INFL3 or INFL5 cards for each parameter and each tributary (excluding those input via JTAPE, JOB6 card, field 4-6). Controlled by INFL1, INFL1A and INFL1B cards. Omit all INFL cards if IINFL (JOB7 card, field 4) is negative.

†The number of INFL4 cards is determined by the length of inflow data record (INFL2 cards, fields 2 and 3) and the inflow data update interval (INFL3 card, field 3), (e.g., 60 day of record with 4 hr update interval would require $60 \times 24/4 = 360$ values and a total of 40 cards).

‡A negative value for temperature will result in an inflow temperature equal to the daily average dry bulb air temperature less the input temperature value.

A negative value for oxygen signifies a fraction of saturation.

A negative value of BOD denotes BOD values which include the oxygen demands of ammonia, nitrite and detritus. These BOD values will be reduced commensurated with the concentration of the other constituents.

INFLOW RATE AND QUALITY CARD 5[*]† (Input via unit LQF [JOB7 card, field 6])

Field	Variable	Value	Description
1	-----	INFL5	Card identification
2	ITIME‡	+	Time of observation; in year, month, day, and hour (e.g., 56070100)
		-1	Denotes the end of the data set
3	CONC§	+	Inflow rate (cms or cfs) or inflow quality, in appropriate units
4	ITIME		
5	CONC		
6	ITIME	+	Sets of time and corresponding inflow rate of quality
7	CONC	-1	
8	ITIME		
9	CONC		

[*]Repeat sets of INFL3 and INFL4 or sets of INFL3 of INFL5 cards for each parameter and each tributary (excluding those input via JTAPE, JOB6 card, field 4-6). Controlled by INFL1, INFL1A and INFL1B cards. Omit all INFL CARDS if IINFL (JOB7 card, field 4) is negative.

†Use one or more INFL5 cards to input the inflow rate or quality over the length of the inflow data record.

‡The first time of observation must be on or before hour zero of IIDAY (INFL2 card, field 2).

§A negative value for temperature will result in an inflow temperature equal to the daily average dry bulb air temperature less the input temperature value.

A negative value for oxygen signifies a fraction of saturation.

A negative value of BOD denotes BOD values which include the oxygen demands of ammonia, nitrite and detritus. These BOD values will be reduced commensurated with the concentration of the other constituents.

WEATHER DATA CARD 1* (Input via unit LMF [JOB7 card, field 5])

Field	Variable	Value	Description
1	-----	WEATH1	Card identification
2	ITIME†	+	Time of observation; in year, month, day, and hour
3	CLOUD	+	Daily average shortwave solar radiation, $cal/cm^2/day$
4	DBT	+	Dry bulb air temperature, in °F
5	DPT	+	Daily pan evaporation, in inches/day
6	APRESS	+	Barometric pressure, in inches of mercury
7	WIND	+	Wind run, in miles/day
8	----	0	Not used
9	----	0	Not used
10	IEND	0	Denotes other than last weather data card
		-1	Denotes last weather data card

*The WEATH1 card is repeated at NHMI (JOB1 card, field 5) intervals during a day. (24/NHMI) WEATH1 cards are required per day (i.e., if NHMI = 3, 8 WEATH1 cards would be required per day). This data would define the meteorological conditions at hours 0, 3, 6,..., 18 and 21. The meteorological conditions at hour 24 would be set equal to hour 0 of the next day if data were input at daily interval. If other than daily data, hour 24 would be set equal to hour 0 of the same day. Sets of WEATH1 cards can be input at any interval. Omit if IEQF (JOB7 card, field 2) is positive or if IMETF (JOB7 card, field 3) is negative.

†The time of the first observation must be on or before the first day of simulation (JOB1 card, field 2).

OUTLET GATE OPERATION CARD 1* (Input via unit LQF [JOB7 card, field 7])

Field	Variable	Value	Description
1	-----	OUTL1	Card identification
2	ITIME†	+	Time of observation; in year, month, and day
		-	Time of observation; in year, month, and day; however, negative time denotes final OUTL1 card
3	FLOW(1)	+	Release rate through gate number one (lowest gate), in m^3/s or cfs
4	FLOW(2)	+	Release rate through gates 2 through 8, in m^3/s or cfs
5	FLOW(3)		
6	FLOW(4)		
7	FLOW(5)		
8	FLOW(6)		
9	FLOW(7)		
10	FLOW(8)		

*Either OUTL1 or OUTL2 cards may be input at any interval.

†The time of the first observation must be on or before the first day of simulation (JOB1 card, field 2).

APPENDIX B. FINAL CALIBRATION INPUT FILE: WAHIAWĀ RESERVOIR WATER QUALITY, O'AHU, HAWAI'I

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 1) AIRDATA          0
 2) TITLE     WAHIAWA RESERVOIR WATER QUALITY     U OF H
 3) TITLE     WATER RESOURCES RESEARCH       TEMPERATURE AND DO
 4) TITLE      FINAL CALIBRATION INPUTS
 5) JOB1        721202    731130        04        24
 6) JOB2             1         1         1         0         1         1         1         1         1
 7) JOB2A            0         1         0         1         0         0        -1         0        -1
 8) JOB2B            0         0         0         0         0         0         0         0         0
 9) JOB3             5         1         2         5
10) JOB4           200        12         2         0         0        17
11) JOB5        730120    730224    730328    730416    730514    730530    730614    730629    730714
12) JOB5        730729    730915    730929    731006    731021    731027    731109    731123
13) JOB6             0         0         0         0         0         0         0         0        13
14) JOB7             0         9        11         5         5         5
15) PHYS1            0        70       .85        21       157         3
16) PHYS2            5      258.       232     248.6       1.5        .4       .33         1
17) PHYS3A          0.  10.E-06 2.0E-05                  -.7
18) PHYS4         5000     1850.
19) PHYS5          236       .33         4
20) PHYS5          240       .56        4.
21) PHYS5         248.       .56        4.
22) PHYS5         252.       .56        4.
23) PHYS5        255.5       50.      500.
24) PHYS6         232.     1000.       50.        0.
25) PHYS6        236.6 8.10E04         152
26) PHYS6        239.6 2.18E05         168
27) PHYS6        242 7 3.12E05        183.
28) PHYS6        247.2 4.83E05        213.
29) PHYS6        258.0 1.15E06        259.
30) COEF            28        .2        18       .07       108       .05       109        01
31) COEF            16       2.0        -1
32) INIT1          900         0        0.
33) INIT2         232.       22.       1.0       5.0        0. 1000000         1        .6        08
34) INIT3          .02       .06        0.        0.        0.        0.        0.
35) INIT4
36) INIT2         242.       22.       1.0       5.0        0.  470000.       .1        .2         3
37) INIT3          .01       .06        0.        0.       .01         0        0.
38) INIT4
39) INIT2         245.       22.       2.0       5.0        0.  320000.      .05       .18       .35
40) INIT3          .02       .15        0.        0.       .02        0.       .01
41) INIT4
42) INIT2         249.       23.       5.0       5.0        0.  100000.      .05       .16        .4
43) INIT3          .06       .22        0.        0.       .85        0.       .05
44) INIT4
45) INIT2         259.       23.       5.0       5.0        0.        0.       .05       .16        .4
46) INIT3          .06       .22        0.        0.       .85        0.        05
47) INIT4
48) INFL1            1         1         1         0         1         1         1         1         1
49) INFL1A           0         0         0         1         0         0
50) INFL1B           0         0         0         0         0
51) INFL2       721201    731130
52) INFL3           24     FLOWS
53) INFL4         .209      .200      .200      .187       184      .184      .178      .206       234
54) INFL4         .181      .166      .161      .155      .148       145      .145      .810      3.68
55) INFL4         2.13      .355      .228      .184      .178      .171      1.78      1.09       287
56) INFL4         .944      1.20      .311      .348      .296      .212      .175      .163      .152
57) INFL4         .209      .321      .243      .172      .148      .136      .128      .124      .120
58) INFL4         .115      .112      .110      .108      .105      .107      .123      .116      .106
59) INFL4         .102      .099       098      .104      .105      .108      .330      .330      .392
60) INFL4         1.19      3 65      0.57      .231      .169       148      .178      .174      .130
61) INFL4         .120      .261      .253      .187      .142      .129      .130      .115       103
62) INFL4         2.78      1.16      .228      .161      1.82      2.32      .361      .215      .181
63) INFL4         .161      .191      1.20      .386      1.58      .559       999      2.10      .671
64) INFL4         1.85      9.17      3.28      1.67      1.25      .956      1.92      1.85       925
65) INFL4         .906      6 69      1.64      2.29      6.32      2.27      1.98      2.32      1 55
66) INFL4         1.58      2.13      3.68      3.93      1.57      1.07      0.94      0.88       745
67) INFL4         .655      .593       562      2.63     10.43      2.26      2.57      1.92       993
68) INFL4         1.64      1.14      2 63      .857      .689      .962      2.56      1.30      1 23
69) INFL4         1.17      .727      1.45      .981      1.45      .944      1.23      .906       773
70) INFL4         .751       575      .581      .758      .621      1.07      3.83      1.33      3 06
71) INFL4         1 23       789      .612      .553      .516      .525      3.37      1.02      3 96
72) INFL4         3.12      3.34      1.63      6.19      2.66      1.31      1.31      1.14      1 95
73) INFL4         .881      .807       720      .615      .599      .689     1.075     1.607     2.288
74) INFL4         .807      .627      .547      .621      .705     6.100      5.39      1.07      7.40
75) INFL4         2.60      1.09      1.20      .888      .761      .671      .643      .590      .541
76) INFL4         .510      .479       488      .447      1.70      4.40      3.19      4.92      2 01
77) INFL4         1.95      1 46       925      2.32      7.96      5.11      3.09      1.30      1 33
78) INFL4          887      1.98      .999      .975      .720       625      .587      .550      .510
79) INFL4         .552      .544       913      .665      .454      .407      .528      .392      .364
80) INFL4         .339       417       621      2 94      1.05      1 88      1.61      .602      .646
81) INFL4          950       407       581       395       460      .386       432      .875       386
82) INFL4          324       392      .302      .290       733       662      .296      .249       426
83) INFL4         .284       293      .259      .271      .225      .243      .215       308       358
84) INFL4         .277       274      .192      .167      .150      .142      .142       134      1 21
85) INFL4         .271       178      .228       209      .164      1 70       510      .435      2 29
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APPENDIX B.—*Continued*

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 86)  INFL4         1 33     392      234      550      .832     2.19     578     .720     .373
 87)  INFL4          271     218      191      178       411     1 64    .268     .191      981
 88)  INFL4          383    4 15     11 1     1 88      3 65      882    8 14     3 84     2 07
 89)  INFL4         1 00    1 99      795      705      .711      507     504     .482      510
 90)  INFL4         1 48     414     1 18      584       376     .330     308     .293     .277
 91)  INFL4          268    1 03      733    19 30     17 44     1 98    1 82     2.01     .962
 92)  INFL4          696     581     .525     1 58      .944     .640    1.61     5.17     4 58
 93)  INFL4         1 76    3 43     3 37     1 14       993       -1
 94)  INFL3            0    TEMPERATURE
 95)  INFL5     72120100  -1 50       -1
 96)  INFL3            0     DISSOLVED OXYGEN
 97)  INFL5     72120100   -.50       -1
 98)  INFL3            0      BOD
 99)  INFL5     72120100    2         -1
100)  INFL3            0      ORGANIC DETRITUS
101)  INFL5     72120100     1        -1
102)  INFL3            0     NH4
103)  INFL5     72120100    05        -1
104)  INFL3            0     NO3
105)  INFL5     72120100   .04        -1
106)  INFL3            0     NO2
107)  INFL5     72120100   .01        -1
108)  INFL3            0     PO4
109)  INFL5     72120100    02        -1
110)  INFL3            0      ZOOP
111)  INFL5     72120100  1.0E-9      -1
112)  INFL3            0      FLOWS
113)  INFL5     72120100   0674       -1
114)  INFL3            0   TEMPERATURE
115)  INFL5     72120100   25.073030100     31 073060100     33.073100100     27.0
116)  INFL5           -1
117)  INFL3            0    DISSOLVED OXYGEN
118)  INFL5     72120100   3 2        -1
119)  INFL3            0   BOD
120)  INFL5     72120100   16.        -1
121)  INFL3            0   ORGANIC DETRITUS
122)  INFL5     72120100    .8        -1
123)  INFL3            0   NH4
124)  INFL5     72120100   15         -1
125)  INFL3            0   NO3
126)  INFL5     72120100    2.        -1
127)  INFL3            0   NO2
128)  INFL5     72120100     2        -1
129)  INFL3            0   PO4
130)  INFL5     72120100     7        -1
131)  INFL3            0    ZOOP
132)  INFL5     72120100  1.0E-9      -1
133)  WEATH1    72120100   401.4     68.     .169     29.9     112.
134)  WEATH1    72120200   282.5     69.     .096     29.9     145.
135)  WEATH1    72120300   282 5     67.     .096     29.9     145.
136)  WEATH1    72120400   303.6     66.     .096     29.9     145.
137)  WEATH1    72120500   273.4     67.     .130     29.9     183.
138)  WEATH1    72120600   244.4     68.     .094     29.9     100.
139)  WEATH1    72120700   293.9     69.     .066     29.9     109.
140)  WEATH1    72120800   362 0     69.     .091     29.9     133.
141)  WEATH1    72120900   296 2     66      .115     29.9      97.
142)  WEATH1    72121000   296 2     65.     .115     29.9      97.
143)  WEATH1    72121100   429 1     64      .115     29.9      97.
144)  WEATH1    72121200   372 7     65       126     29.9     100.
145)  WEATH1    72121300   414.2     67.     .130     29 9     100.
146)  WEATH1    72121400   295.9     67.     .149     29.9     138.
147)  WEATH1    72121500   418 3     67.     .091     29.9      96.
148)  WEATH1    72121600   212.5     69.     .057     29 9     159
149)  WEATH1    72121700   212 5     74.      057     29 9     159
150)  WEATH1    72121800   132.1     72.      057     29 9     159
151)  WEATH1    72121900   418.8    66 3      058     29.9      81.
152)  WEATH1    72122000   430 1    62 5      194     29.9     100.
153)  WEATH1    72122100   433.7    67 5      144     29.9     169.
154)  WEATH1    72122200   435 2    69 0      182     29.9     189.
155)  WEATH1    72122300   320 8    71 5     .130     29.9     178.
156)  WEATH1    72122400   320.8    70.5     .130     29.9     178.
157)  WEATH1    72122500   320.8    70.0     .130     29.9     178.
158)  WEATH1    72122600   427.5    68.5     .130     29.9     178.
159)  WEATH1    72122700   352 3    68.3     .164     29 9     210.
160)  WEATH1    72122800   294 4    69 0     .112     29.9     156.
161)  WEATH1    72122900   212 5    69 0     .077     29.9     111.
162)  WEATH1    72123000   294.9    66.3      086     29.9     120
163)  WEATH1    72123100   294 9    71.3     .086     29.9     120.
164)  WEATH1    73010100   319 0    62.3      085     29.9     119.
165)  WEATH1    73010200   381 4    64 5      110     29.9     118.
166)  WEATH1    73010300   306.7    73 0     .110     29 9     118.
167)  WEATH1    73010400    255     71 8      145     29.9     171.
168)  WEATH1    73010500   252 4    70 8     .080     29 9     106.
169)  WEATH1    73010600   254 0    73 0     .061     29.9     154
170)  WEATH1    73010700   254 0    68 3      061     29 9     154.
171)  WEATH1    73010800   227 8    69 5      061     29 9     154
172)  WEATH1    73010900   393.2    70 8      100     29 9    . 99
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APPENDIX B.--*Continued*

173)	WEATH1	73011000	440 8	69 8	122	29.9	108
174)	WEATH1	73011200	451.1	68.5	.122	29.9	108
175)	WEATH1	73011300	373 2	69 80	.134	29.9	179
176)	WEATH1	73011400	373.2	68 5	.134	29.9	179
177)	WEATH1	73011500	346.6	68.3	.134	29.9	179.
178)	WEATH1	73011600	441.9	68 0	.190	29.9	100
179)	WEATH1	73011700	441.9	68.0	.190	29.9	100.
180)	WEATH1	73011800	412.2	69.5	.147	29.9	99
181)	WEATH1	73011900	383.0	71.0	.133	29.9	127.
182)	WEATH1	73012000	108.2	71.0	.144	29.9	144
183)	WEATH1	73012100	108.2	69.0	.144	29.9	144.
184)	WEATH1	73012200	108.2	72.0	.144	29.9	144.
185)	WEATH1	73012300	329.7	70.0	.113	29.9	100.
186)	WEATH1	73012400	422.9	71.0	.132	29.9	184.
187)	WEATH1	73012500	471.0	72.0	.177	29.9	192.
188)	WEATH1	73012600	402.4	72.0	.237	29.9	216.
189)	WEATH1	73012700	361.4	67.5	.141	29.9	230.
190)	WEATH1	73012800	361.4	67.3	.141	29.9	230.
191)	WEATH1	73012900	389.6	67.0	.141	29.9	230.
192)	WEATH1	73013000	357.4	67.8	.171	29.9	227.
193)	WEATH1	73013100	416.8	67.3	.119	29.9	191.
194)	WEATH1	73020100	410.6	68.5	.154	29.9	183.
195)	WEATH1	73020200	448.5	69.3	.135	29.9	177.
196)	WEATH1	73020300	398.6	67.5	.130	29.9	167.
197)	WEATH1	73020400	398.6	65.8	.130	29.9	167.
198)	WEATH1	73020500	397.3	67.5	.130	29.9	167.
199)	WEATH1	73020600	391.2	68.0	.128	29.9	147.
200)	WEATH1	73020700	470.0	67.8	.115	29.9	145.
201)	WEATH1	73020800	332.2	68.5	.179	29.9	100.
202)	WEATH1	73020900	449.5	67.	.124	29.9	199.
203)	WEATH1	73021000	496.7	66.3	.237	29.9	56.3
204)	WEATH1	73021100	496.7	68.3	.237	29.9	56.3
205)	WEATH1	73021200	348.7	68.0	.237	29.9	56.3
206)	WEATH1	73021300	335.4	66.5	.109	29.9	104.
207)	WEATH1	73021400	294.4	66.8	.148	29.9	170.
208)	WEATH1	73021500	457.4	66.5	.060	29.9	131.
209)	WEATH1	73021600	392.7	71.5	.082	29.9	134.
210)	WEATH1	73021700	437.0	71.3	.201	29.9	137.
211)	WEATH1	73021800	437.0	70.5	.201	29.9	137.
212)	WEATH1	73021900	406.0	70.5	.201	29.9	137.
213)	WEATH1	73022000	341.0	69.0	.174	29.9	100.
214)	WEATH1	73022100	409.6	67.0	.090	29.9	100.
215)	WEATH1	73022200	281.6	65.3	.239	29.9	100.
216)	WEATH1	73022300	337.4	64.5	.106	29.9	100.
217)	WEATH1	73022400	385.0	64.8	.128	29.9	190.
218)	WEATH1	73022500	385.0	66.3	.128	29.9	190.
219)	WEATH1	73022600	403.5	65.8	.128	2 .	1 0.
220)	WEATH1	73022700	298.5	66.8	.155	29.9	100.
221)	WEATH1	73022800	448.5	67.8	.091	29.9	126.
222)	WEATH1	73030100	563.2	67.8	.178	29.9	179.
223)	WEATH1	73030200	519.2	69.5	.214	29.9	202.
224)	WEATH1	73030300	449.8	70.8	.203	29.9	263.
225)	WEATH1	73030400	449.8	69.5	.203	29.9	263.
226)	WEATH1	73030500	340.0	70.5	.203	29.9	263.
227)	WEATH1	73030600	561.2	69.3	.116	29.9	203.
228)	WEATH1	73030700	534.5	69.8	.217	29.9	236.
229)	WEATH1	73030800	407.6	71.5	.251	29.9	232.
230)	WEATH1	73030900	433.7	71.8	.218	29.9	271.
231)	WEATH1	73031000	486.7	68.0	.194	29.9	202.
232)	WEATH1	73031100	486.7	69.3	.194	29.9	202.
233)	WEATH1	73031200	395.3	70.0	.194	29.9	202.
234)	WEATH1	73031300	425.0	73.5	.158	29.9	123.
235)	WEATH1	73031400	455.2	71.8	.192	29.9	100.
236)	WEATH1	73031500	464.4	73 3	.226	29.9	179.
237)	WEATH1	73031600	276.5	72.5	.249	29.9	187
238)	WEATH1	73031700	425.0	69.0	.135	29.9	284.
239)	WEATH1	73031800	425.0	70.5	.135	29.9	284.
240)	WEATH1	73031900	370.2	69 3	.135	29.9	284
241)	WEATH1	73032000	440.3	70.3	.172	29.9	219.
242)	WEATH1	73032100	547.3	69.0	.200	29.9	200.
243)	WEATH1	73032200	496.6	70.0	.236	29.9	156
244)	WEATH1	73032300	523.8	70.3	.158	29.9	146.
245)	WEATH1	73032400	539 7	69.3	.241	29.9	235
246)	WEATH1	73032500	539.7	69.5	.241	29.9	235.
247)	WEATH1	73032600	520.2	69.5	.241	29.9	235.
248)	WEATH1	73032700	554.0	69.5	.211	29.9	218.
249)	WEATH1	73032800	519.2	69 5	.224	29.9	211.
250)	WEATH1	73032900	554.5	70.5	.220	29.9	201.
251)	WEATH1	73033000	338.9	72.3	.252	29.9	207.
252)	WEATH1	73033100	417.3	70.0	.179	29.9	176.
253)	WEATH1	73040100	417.3	71 8	.178	29.9	177.
254)	WEATH1	73040200	484.4	73.5	.178	29.9	177
255)	WEATH1	73040300	399.9	69 8	.213	29.9	141.
256)	WEATH1	73040400	503.3	67.5	.157	29.9	182
257)	WEATH1	73040500	276.5	63.8	.242	29.9	212.
258)	WEATH1	73040600	346.6	63.0	.108	29.9	136.
259)	WEATH1	73040700	510.0	65.3	.140	29.9	189.

APPENDIX B.—*Continued*

260)	WEATH1	73040800	510.	71.0	.140	29.9	189.
261)	WEATH1	73040900	568.8	69.3	.140	29.9	189.
262)	WEATH1	73041000	392.7	71.5	.220	29.9	200.
263)	WEATH1	73041100	631.3	68.5	.167	29.9	178
264)	WEATH1	73041200	352.8	70.3	.269	29.9	179
265)	WEATH1	73041300	593.8	70.3	.127	29.9	183
266)	WEATH1	73041400	427.0	71.5	.244	29.9	221.
267)	WEATH1	73041500	427.0	70.3	.244	29.9	221.
268)	WEATH1	73041600	515.6	70.5	.244	29.9	221.
269)	WEATH1	73041700	566.3	70.5	.223	29.9	286.
270)	WEATH1	73041800	559.6	69.5	.273	29.9	228.
271)	WEATH1	73041900	337.9	71.0	.214	29.9	121.
272)	WEATH1	73042000	316.2	70.5	.132	29.9	146.
273)	WEATH1	73042100	316.2	68.5	.132	29.9	146.
274)	WEATH1	73042200	316.2	70.5	.132	29.9	146.
275)	WEATH1	73042300	604.2	73.0	.132	29.9	146.
276)	WEATH1	73042400	635.4	71.3	.280	29.9	100.
277)	WEATH1	73042500	515.6	71.3	.304	29.9	193.
278)	WEATH1	73042600	416.3	70.3	.210	29.9	200.
279)	WEATH1	73042700	486.9	68.8	.094	29.9	202.
280)	WEATH1	73042800	545.0	70.5	.241	29.9	205.
281)	WEATH1	73042900	545.0	69.8	.241	29.9	205.
282)	WEATH1	73043000	559.6	71.0	.241	29.9	205.
283)	WEATH1	73050100	481.3	69.8	.233	29.9	190.
284)	WEATH1	73050200	513.5	70.8	.250	29.9	197.
285)	WEATH1	73050300	643.1	70.8	.226	29.9	223.
286)	WEATH1	73050400	594.4	69.8	.308	29.9	233.
287)	WEATH1	73050500	588.1	72.0	.267	29.9	208.
288)	WEATH1	73050600	588.1	71.5	.267	29.9	208.
289)	WEATH1	73050700	628.2	71.5	.267	29.9	208.
290)	WEATH1	73050800	591.9	70.5	.287	29.9	228.
291)	WEATH1	73050900	503.8	71.3	.215	29.9	175.
292)	WEATH1	73051000	605.2	71.0	.213	29.9	189.
293)	WEATH1	73051100	591.9	71.8	.251	29.9	172.
294)	WEATH1	73051200	542.0	70.5	.224	29.9	182.
295)	WEATH1	73051300	542.0	68.8	.224	29.9	182.
296)	WEATH1	73051400	386.0	70.5	.224	29.9	182
297)	WEATH1	73051500	431.1	68.5	.186	29.9	150
298)	WEATH1	73051600	642.0	71.0	.164	29.9	183.
299)	WEATH1	73051700	269.8	71.5	.268	29.9	194.
300)	WEATH1	73051800	445.4	69.8	.092	29.9	152.
301)	WEATH1	73051900	557.5	69.5	.162	29.9	207.
302)	WEATH1	73052000	557.5	71.5	.162	29.9	207
303)	WEATH1	73052100	430.6	70.5	.162	29.9	207.
304)	WEATH1	73052200	630.3	70.8	.131	29.9	176.
305)	WEATH1	73052300	645.1	70.0	.253	29.9	189.
306)	WEATH1	73052400	502.8	71.0	.272	29.9	209.
307)	WEATH1	73052500	651.3	71.0	.201	29.9	309
308)	WEATH1	73052600	462.1	71.5	.274	29.9	148.
309)	WEATH1	73052700	462.1	70.0	.274	29.9	148.
310)	WEATH1	73052800	506.4	70.0	.274	29.9	148.
311)	WEATH1	73052900	656.4	72.8	.178	29.9	117.
312)	WEATH1	73053000	648.2	71.0	.278	29.9	100.
313)	WEATH1	73053100	503.3	71.3	.254	29.9	100.
314)	WEATH1	73060100	525.3	75.0	.232	29.9	100.
315)	WEATH1	73060200	527.9	74.5	.236	29.9	227.
316)	WEATH1	73060300	527.9	72.0	.236	29.9	227.
317)	WEATH1	73060400	447.0	71.5	.236	29.9	227.
318)	WEATH1	73060500	540.7	72.3	.162	29.9	200.
319)	WEATH1	73060600	471.6	73.0	.270	29.9	221.
320)	WEATH1	73060700	492.5	72.8	.202	29.9	214.
321)	WEATH1	73060800	407.6	73.0	.211	29.9	120.
322)	WEATH1	73060900	635.2	73.0	.253	29.9	219.
323)	WEATH1	73061000	635.2	72.3	.253	29.9	219.
324)	WEATH1	73061100	582.7	74.5	.253	29.9	219.
325)	WEATH1	73061200	575.5	74.8	.256	29.9	251.
326)	WEATH1	73061300	353.3	74.5	.306	29.9	256.
327)	WEATH1	73061400	575.5	72.3	.071	29.9	195.
328)	WEATH1	73061500	575.5	74.3	.262	29.9	254.
329)	WEATH1	73061600	453.7	75.3	.192	29.9	178.
330)	WEATH1	73061700	453.7	71.0	.192	29.9	178.
331)	WEATH1	73061800	538.1	72.5	.192	29.9	178.
332)	WEATH1	73061900	463.9	73.3	.219	29.9	165.
333)	WEATH1	73062000	594.9	72.0	.174	29.9	157.
334)	WEATH1	73062100	520.7	72.3	.254	29.9	164.
335)	WEATH1	73062200	432.1	72.0	.208	29.9	136.
336)	WEATH1	73062300	522.0	72.8	.206	29.9	143.
337)	WEATH1	73062400	522.0	74.8	.206	29.9	143.
338)	WEATH1	73062500	616.4	76.3	.206	29.9	143.
339)	WEATH1	73062600	380.9	74.3	.273	29.9	124.
340)	WEATH1	73062700	517.6	72.0	.162	29.9	110.
341)	WEATH1	73062800	444.9	73.5	.206	29.9	122.
342)	WEATH1	73062900	520.7	76.0	.248	29.9	179.
343)	WEATH1	73063000	473.6	74.0	.254	29.9	171.
344)	WEATH1	73070100	301.6	73.5	.089	29.9	187.
345)	WEATH1	73070200	539.6	71.5	.089	29.9	187.
346)	WEATH1	73070300	496.1	73.5	.190	29.9	110.

APPENDIX B.—*Continued*

347)	WEATH1	73070400	603.1	73.0	.210	29.9	213.
348)	WEATH1	73070500	536.6	74.8	.210	29.9	213.
349)	WEATH1	73070600	585.7	76.0	.267	29.9	211.
350)	WEATH1	73070700	468.0	75.8	.221	29.9	221.
351)	WEATH1	73070800	468.0	76.0	.221	29.9	221.
352)	WEATH1	73070900	489.5	74.0	.221	29.9	221.
353)	WEATH1	73071000	648.7	75.8	.221	29.9	200.
354)	WEATH1	73071100	524.3	75 8	285	29.9	183.
355)	WEATH1	73071200	571.4	75.0	250	29.9	171.
356)	WEATH1	73071300	471.6	74 8	.252	29.9	156.
357)	WEATH1	73071400	530.4	74.3	.227	29.9	196.
358)	WEATH1	73071500	530.4	72.5	.227	29.9	196.
359)	WEATH1	73071600	658.9	74 3	.227	29.9	196.
360)	WEATH1	73071700	628 7	73.0	.281	29.9	191.
361)	WEATH1	73071800	634.9	73 3	.299	29.9	199.
362)	WEATH1	73071900	603.6	72.8	.283	29.9	175.
363)	WEATH1	73072000	573.4	73.0	.263	29.9	182.
364)	WEATH1	73072100	630.8	73.3	.267	29.9	169.
365)	WEATH1	73072200	630.8	75.5	.267	29.9	169.
366)	WEATH1	73072300	413.7	76.8	.267	29.9	169.
367)	WEATH1	73072400	577.5	74.3	.183	29.9	215.
368)	WEATH1	73072500	427.0	74.0	.260	29.9	167.
369)	WEATH1	73072600	478.7	75.0	.199	29.9	129.
370)	WEATH1	73072700	609.8	74.5	.203	29.9	132.
371)	WEATH1	73072800	604.4	81.0	.296	29.9	200.
372)	WEATH1	73072900	604.4	81.5	.296	29.9	200.
373)	WEATH1	73073000	636.4	74.0	.296	29.9	200.
374)	WEATH1	73073100	472.6	78.8	.353	29.9	227
375)	WEATH1	73080100	604.7	73.5	.270	29.9	211.
376)	WEATH1	73080200	472.1	76.0	.261	29.9	177.
377)	WEATH1	73080300	514.6	73.0	.157	29.9	134.
378)	WEATH1	73080400	552.0	75.0	.223	29.9	309.
379)	WEATH1	73080500	552.0	74.3	.223	29.9	309.
380)	WEATH1	73080600	458.8	79.5	.223	29.9	309.
381)	WEATH1	73080700	614.9	75.8	.227	29.9	204.
382)	WEATH1	73080800	633.9	76.0	.293	29.9	207.
383)	WEATH1	73080900	442.9	74.8	.281	29.9	167.
384)	WEATH1	73081000	511.5	74.5	.186	29.9	159.
385)	WEATH1	73081100	510.5	75.5	.233	29.9	137.
386)	WEATH1	73081200	510.5	78.8	.233	29.9	137.
387)	WEATH1	73081300	566.8	76.0	.233	29.9	137.
388)	WEATH1	73081400	480.3	75.8	.285	29.9	200.
389)	WEATH1	73081500	622.6	75.3	.221	29.9	138.
390)	WEATH1	73081600	492.5	75.8	.284	29.9	200.
391)	WEATH1	73081700	615.9	75.5	.182	29.9	180.
392)	WEATH1	73081800	460.6	76.3	.246	29.9	199.
393)	WEATH1	73081900	460.6	75.8	.246	29.9	199.
394)	WEATH1	73082000	422.4	75.5	.246	29.9	199.
395)	WEATH1	73082100	522.8	75.5	.206	29.9	165.
396)	WEATH1	73082200	295.9	75.5	.249	29.9	183.
397)	WEATH1	73082300	310.3	76.0	.134	29.9	121.
398)	WEATH1	73082400	264.2	77.3	.130	29.9	100.
399)	WEATH1	73082500	474.4	78.0	.207	29.9	308.
400)	WEATH1	73082600	474.4	77.3	.207	29.9	308.
401)	WEATH1	73082700	567.8	72.8	.207	29.9	308.
402)	WEATH1	73082800	563.7	71.5	.301	29.9	228.
403)	WEATH1	73082900	584.2	75.3	.300	29.9	206.
404)	WEATH1	73083000	593.9	75.0	.269	29.9	121.
405)	WEATH1	73083100	523.3	74.8	.278	29.9	206.
406)	WEATH1	73090100	495.1	74.8	.241	29.9	184.
407)	WEATH1	73090200	513.3	75.5	.227	29.9	266.
408)	WEATH1	73090300	513.3	75.0	.227	29.9	266.
409)	WEATH1	73090400	387.6	75.0	227	29.9	266.
410)	WEATH1	73090500	516.6	74.5	.162	29.9	198.
411)	WEATH1	73090600	454.7	76.3	.213	29.9	160.
412)	WEATH1	73090700	550.4	75.5	.173	29.9	179.
413)	WEATH1	73090800	514 3	75.3	.265	29.9	188.
414)	WEATH1	73090900	514.3	74.5	.265	29.9	188.
415)	WEATH1	73091000	489.6	75.8	.265	29.9	188.
416)	WEATH1	73091100	408.6	75.0	.248	29.9	162
417)	WEATH1	73091200	302.6	74.0	.224	29.9	156.
418)	WEATH1	73091300	446.0	74 3	.128	29.9	113.
419)	WEATH1	73091400	508.4	75.5	.195	29.9	153
420)	WEATH1	73091500	471.6	75.3	.169	29.9	201
421)	WEATH1	73091600	471.6	76.3	.269	29.9	201.
422)	WEATH1	73091700	508.9	76.0	.269	29.9	201
423)	WEATH1	73091800	526.8	74.0	.249	29.9	118.
424)	WEATH1	73091900	492.5	74.8	.276	29.9	216.
425)	WEATH1	73092000	463.4	75.0	.244	29.9	155.
426)	WEATH1	73092100	547.3	76.3	.232	29.9	146.
427)	WEATH1	73092200	471.3	75.5	.253	29.9	190.
428)	WEATH1	73092300	471.3	76.0	.253	29.9	190.
429)	WEATH1	73092400	501.2	77.3	.253	29.9	190.
430)	WEATH1	73092500	400.9	76.3	.289	29.9	101.
431)	WEATH1	73092600	515.6	76.0	.202	29.9	134.
432)	WEATH1	73092700	368.6	76.3	.250	29.9	161.
433)	WEATH1	73092800	508 9	75.5	.087	29.9	127.

APPENDIX B.—*Continued*

434)	WEATH1	73092900	448.5	75.8	.218	29.9	200.
435)	WEATH1	73093000	448 5	75.5	.218	29.9	200.
436)	WEATH1	73100100	496.1	75.0	.218	29.9	200.
437)	WEATH1	73100200	430.6	75.0	.250	29.9	189.
438)	WEATH1	73100300	500.7	75.0	.225	29.9	159.
439)	WEATH1	73100400	508 4	74.2	.230	29.9	129.
440)	WEATH1	73100500	457.7	77.7	.233	29.9	105.
441)	WEATH1	73100600	340.0	78.3	.201	29.9	205.
442)	WEATH1	73100700	340.0	78.5	.201	29.9	205.
443)	WEATH1	73100800	405.5	75.8	.201	29 9	205
444)	WEATH1	73100900	527.9	75.8	.238	29.9	210
445)	WEATH1	73101000	403.5	75.5	.330	29 9	141.
446)	WEATH1	73101100	327.7	75.0	.224	29.9	192.
447)	WEATH1	73101200	502.8	74.8	.170	29.9	100.
448)	WEATH1	73101300	327.2	75.5	.172	29.9	179.
449)	WEATH1	73101400	327.2	72.5	.172	29.9	179.
450)	WEATH1	73101500	340.0	72.0	.172	29.9	179.
451)	WEATH1	73101600	272.4	73.8	.157	29.9	163.
452)	WEATH1	73101700	441.9	73.0	.096	29.9	111.
453)	WEATH1	73101800	381.4	75.0	.215	29.9	121.
454)	WEATH1	73101900	345.6	71.8	.158	29.9	177.
455)	WEATH1	73102000	304.2	71.3	.121	29.9	161.
456)	WEATH1	73102100	304.2	70.5	.121	29.9	161.
457)	WEATH1	73102200	302.6	70.5	.121	29.9	161.
458)	WEATH1	73102300	497.7	70.0	.102	29.9	158.
459)	WEATH1	73102400	373.8	72.8	.260	29.9	149.
460)	WEATH1	73102500	422.4	72.8	.192	29.9	219.
461)	WEATH1	73102600	478.7	74.3	.226	29.9	167.
462)	WEATH1	73102700	375.0	74.5	.220	29.9	224.
463)	WEATH1	73102800	375.0	75.5	.220	29.9	224.
464)	WEATH1	73102900	390.1	75.8	.220	29.9	224.
465)	WEATH1	73103000	399.4	74.5	.201	29.9	102.
466)	WEATH1	73103100	379.4	73.3	.163	29.9	100.
467)	WEATH1	73110100	325.6	74.0	.152	29.9	101.
468)	WEATH1	73110200	342.5	74.3	.089	29.9	108.
469)	WEATH1	73110300	396.3	73.5	.168	29.9	115.
470)	WEATH1	73110400	396.3	73.0	.168	29.9	115.
471)	WEATH1	73110500	335.4	75.2	.168	29.9	115.
472)	WEATH1	73110600	362.0	72.5	.145	29.9	116.
473)	WEATH1	73110700	319.0	73.5	.145	29.9	110.
474)	WEATH1	73110800	308.7	74.0	.146	29.9	100.
475)	WEATH1	73110900	337.9	74.8	.125	29.9	101.
476)	WEATH1	73111000	229.9	73.3	.090	29 9	116.
477)	WEATH1	73111200	356.9	73.0	.090	29.9	116.
478)	WEATH1	73111300	441.9	70.0	.129	29.9	199.
479)	WEATH1	73111400	440.8	71.0	.198	29.9	170.
480)	WEATH1	73111500	413.7	74.3	.186	29.9	131.
481)	WEATH1	73111600	373.2	75.3	.206	29.9	185
482)	WEATH1	73111700	408 8	73 5	.176	29.9	136.
483)	WEATH1	73111800	408.8	73.5	.176	29.9	136.
484)	WEATH1	73111900	218.6	73.5	.176	29.9	136
485)	WEATH1	73112000	113.7	75.3	.100	29.9	100.
486)	WEATH1	73112100	315.9	75.3	.059	29.9	100.
487)	WEATH1	73112200	338.4	72.5	.154	29.9	210.
488)	WEATH1	73112300	338.4	70.8	.154	29.9	210.
489)	WEATH1	73112400	338.4	71.8	154	29.9	211.
490)	WEATH1	73112500	338.4	72.5	.154	29.9	211.
491)	WEATH1	73112600	295.4	72.0	.154	29.9	211.
492)	WEATH1	73112700	300.5	72.0	.088	29.9	122.
493)	WEATH1	73112800	296.5	73.0	.113	29.9	140.
494)	WEATH1	73112900	134.7	74.0	.062	29.9	100.
495)	WEATH1	73113000	247.8	68.8	.043	29.9	97.
496)	OUTL1	721201	1.83				
497)	OUTL1	721202	1.44				
498)	OUTL1	721203	1.44				
499)	OUTL1	721204	2.20				
500)	OUTL1	721205	2.20				
501)	OUTL1	721206	2.20				
502)	OUTL1	721207	1.98				
503)	OUTL1	721208	1.65				
504)	OUTL1	721209	1.52				
505)	OUTL1	721210	1.52				
506)	OUTL1	721211	0.87				
507)	OUTL1	721212	0.22				
508)	OUTL1	721213	0.33				
509)	OUTL1	721214	0.76				
510)	OUTL1	721215	0.87				
511)	OUTL1	721216	0.87				
512)	OUTL1	721217	0.22				
513)	OUTL1	721218	0.22				
514)	OUTL1	721219	0 22				
515)	OUTL1	721220	0.22				
516)	OUTL1	721221	0.00				
517)	OUTL1	721222	0 00				
518)	OUTL1	721223	0.00				
519)	OUTL1	721224	0.00				
520)	OUTL1	721225	0.00				

APPENDIX B.—*Continued*

521)	OUTL1	721226	0.00
522)	OUTL1	721227	0.00
523)	OUTL1	721228	0.00
524)	OUTL1	721229	0.00
525)	OUTL1	721230	0.00
526)	OUTL1	721231	0.00
527)	OUTL1	730101	0.00
528)	OUTL1	730102	0.00
529)	OUTL1	730103	0.00
530)	OUTL1	730104	0.00
531)	OUTL1	730105	0.00
532)	OUTL1	730106	0.00
533)	OUTL1	730107	0.00
534)	OUTL1	730108	0.00
535)	OUTL1	730109	0.00
536)	OUTL1	730110	0.00
537)	OUTL1	730111	0.00
538)	OUTL1	730112	0.00
539)	OUTL1	730113	0.00
540)	OUTL1	730114	0.00
541)	OUTL1	730115	0.65
542)	OUTL1	730116	.130
543)	OUTL1	730117	0.52
544)	OUTL1	730118	0.91
545)	OUTL1	730119	0.76
546)	OUTL1	730120	0.61
547)	OUTL1	730121	0.61
548)	OUTL1	730122	0.76
549)	OUTL1	730123	0.74
550)	OUTL1	730124	0.76
551)	OUTL1	730125	0.67
552)	OUTL1	730126	0.61
553)	OUTL1	730127	0.61
554)	OUTL1	730128	0.61
555)	OUTL1	730129	0.61
556)	OUTL1	730130	0.80
557)	OUTL1	730131	0.87
558)	OUTL1	730201	.870
559)	OUTL1	730202	.696
560)	OUTL1	730203	.522
561)	OUTL1	730204	.522
562)	OUTL1	730205	1.00
563)	OUTL1	730206	1.10
564)	OUTL1	730207	1.10
565)	OUTL1	730208	1.10
566)	OUTL1	730209	.957
567)	OUTL1	730210	.783
568)	OUTL1	730211	.783
569)	OUTL1	730212	1.09
570)	OUTL1	730213	1.04
571)	OUTL1	730214	.979
572)	OUTL1	730215	.979
573)	OUTL1	730216	.827
574)	OUTL1	730217	.653
575)	OUTL1	730218	.653
576)	OUTL1	730219	.827
577)	OUTL1	730220	.892
578)	OUTL1	730221	.892
579)	OUTL1	730222	.892
580)	OUTL1	730223	.805
581)	OUTL1	730224	.697
582)	OUTL1	730225	.697
583)	OUTL1	730226	.631
584)	OUTL1	730227	.631
585)	OUTL1	730228	.783
586)	OUTL1	730301	.892
587)	OUTL1	730302	.740
588)	OUTL1	730303	.566
589)	OUTL1	730304	566
590)	OUTL1	730305	.892
591)	OUTL1	730306	892
592)	OUTL1	730307	.892
593)	OUTL1	730308	.892
594)	OUTL1	730309	.761
595)	OUTL1	730310	.609
596)	OUTL1	730311	.609
597)	OUTL1	730312	.587
598)	OUTL1	730313	.609
599)	OUTL1	730314	.631
600)	OUTL1	730315	.718
601)	OUTL1	730316	.522
602)	OUTL1	730317	.305
603)	OUTL1	730318	.305
604)	OUTL1	730319	.675
605)	OUTL1	730320	609
606)	OUTL1	730321	.674
607)	OUTL1	730322	.761
608)	OUTL1	730323	.522
609)	OUTL1	730324	.392
610)	OUTL1	730325	.392
611)	OUTL1	730326	.500
612)	OUTL1	730327	.609
613)	OUTL1	730328	.587
614)	OUTL1	730329	.587
615)	OUTL1	730330	.609
616)	OUTL1	730331	305
617)	OUTL1	730401	.609
618)	OUTL1	730402	.631
619)	OUTL1	730403	.631
620)	OUTL1	730404	.631
621)	OUTL1	730405	1.11
622)	OUTL1	730406	1.00
623)	OUTL1	730407	.870
624)	OUTL1	730408	.870
625)	OUTL1	730409	.891
626)	OUTL1	730410	.783
627)	OUTL1	730411	.674
628)	OUTL1	730412	.740
629)	OUTL1	730413	.718
630)	OUTL1	730414	.609
631)	OUTL1	730415	609
632)	OUTL1	730416	.761
633)	OUTL1	730417	.783
634)	OUTL1	730418	.761
635)	OUTL1	730419	.827
636)	OUTL1	730420	.827
637)	OUTL1	730421	.827
638)	OUTL1	730422	.827
639)	OUTL1	730423	.848
640)	OUTL1	730424	.848
641)	OUTL1	730425	.870
642)	OUTL1	730426	1.31
643)	OUTL1	730427	848
644)	OUTL1	730428	0.00
645)	OUTL1	730429	.827
646)	OUTL1	730430	1.22
647)	OUTL1	730501	1.54
648)	OUTL1	730502	1.74
649)	OUTL1	730503	1.76
650)	OUTL1	730504	1.39
651)	OUTL1	730505	1.00
652)	OUTL1	730506	1.00
653)	OUTL1	730507	1.39
654)	OUTL1	730508	1.76
655)	OUTL1	730509	1.65
656)	OUTL1	730510	1.54
657)	OUTL1	730511	.892
658)	OUTL1	730512	.914
659)	OUTL1	730513	.914
660)	OUTL1	730514	.870
661)	OUTL1	730515	1.09
662)	OUTL1	730516	1.54
663)	OUTL1	730517	1.83
664)	OUTL1	730518	1.37
665)	OUTL1	730519	.827
666)	OUTL1	730520	.827
667)	OUTL1	730521	1.65
668)	OUTL1	730522	1.59
669)	OUTL1	730523	1.57
670)	OUTL1	730524	1.37
671)	OUTL1	730525	1.07
672)	OUTL1	730526	.870
673)	OUTL1	730527	.870
674)	OUTL1	730528	1.76
675)	OUTL1	730529	1.76
676)	OUTL1	730530	1.98
677)	OUTL1	730531	2.20
678)	OUTL1	730601	1.80
679)	OUTL1	730602	1.39
680)	OUTL1	730603	1.39
681)	OUTL1	730604	2.20
682)	OUTL1	730605	2.20
683)	OUTL1	730606	2.20
684)	OUTL1	730607	2.20
685)	OUTL1	730608	1.52
686)	OUTL1	730609	.827
687)	OUTL1	730610	.827
688)	OUTL1	730611	2.20
689)	OUTL1	730612	2.20
690)	OUTL1	730613	2.20
691)	OUTL1	730614	2.18
692)	OUTL1	730615	1.52
693)	OUTL1	730616	.827
694)	OUTL1	730617	.827

APPENDIX B.—*Continued*

695)	OUTL1	730618	1.52
696)	OUTL1	730619	1.37
697)	OUTL1	730620	1.76
698)	OUTL1	730621	1.76
699)	OUTL1	730622	1.35
700)	OUTL1	730623	.914
701)	OUTL1	730624	.914
702)	OUTL1	730625	2.09
703)	OUTL1	730626	2.20
704)	OUTL1	730627	2.20
705)	OUTL1	730628	2.20
706)	OUTL1	730629	2.20
707)	OUTL1	730630	1.91
708)	OUTL1	730701	1.61
709)	OUTL1	730702	2.20
710)	OUTL1	730703	1.48
711)	OUTL1	730704	.740
712)	OUTL1	730705	2.20
713)	OUTL1	730706	2.20
714)	OUTL1	730707	1.72
715)	OUTL1	730708	1.52
716)	OUTL1	730709	1.96
717)	OUTL1	730710	1.41
718)	OUTL1	730711	1.24
719)	OUTL1	730712	2.04
720)	OUTL1	730713	2.07
721)	OUTL1	730714	1.91
722)	OUTL1	730715	1.91
723)	OUTL1	730716	2.20
724)	OUTL1	730717	2.13
725)	OUTL1	730718	1.96
726)	OUTL1	730719	2.01
727)	OUTL1	730720	2.20
728)	OUTL1	730721	1.81
729)	OUTL1	730722	1.44
730)	OUTL1	730723	2.20
731)	OUTL1	730724	2.20
732)	OUTL1	730725	2.20
733)	OUTL1	730726	2.20
734)	OUTL1	730727	2.02
735)	OUTL1	730728	1.52
736)	OUTL1	730729	1.44
737)	OUTL1	730730	2.20
738)	OUTL1	730731	2.20
739)	OUTL1	730801	2.20
740)	OUTL1	730802	2.20
741)	OUTL1	730803	2.11
742)	OUTL1	730804	1.46
743)	OUTL1	730805	1.24
744)	OUTL1	730806	2.11
745)	OUTL1	730807	1.96
746)	OUTL1	730808	1.87
747)	OUTL1	730809	1.89
748)	OUTL1	730810	2.09
749)	OUTL1	730811	1.83
750)	OUTL1	730812	1.48
751)	OUTL1	730813	1.94
752)	OUTL1	730814	2.11
753)	OUTL1	730815	2.20
754)	OUTL1	730816	2.20
755)	OUTL1	730817	2.20
756)	OUTL1	730818	1.78
757)	OUTL1	730819	1.39
758)	OUTL1	730820	2.20
759)	OUTL1	730821	2.20
760)	OUTL1	730822	2.13
761)	OUTL1	730823	2.13
762)	OUTL1	730824	1.63
763)	OUTL1	730825	1.04
764)	OUTL1	730826	1.04
765)	OUTL1	730827	2.20
766)	OUTL1	730828	2.07
767)	OUTL1	730829	2.20
768)	OUTL1	730830	2.20
769)	OUTL1	730831	1.61
770)	OUTL1	730901	1.00
771)	OUTL1	730902	1.00
772)	OUTL1	730903	1.00
773)	OUTL1	730904	2.20
774)	OUTL1	730905	2.20
775)	OUTL1	730906	2.20
776)	OUTL1	730907	1.78
777)	OUTL1	730908	1.35
778)	OUTL1	730909	1.35
779)	OUTL1	730910	1.78
780)	OUTL1	730911	1.00
781)	OUTL1	730912	0.67
782)	OUTL1	730913	0.67
783)	OUTL1	730914	0.54
784)	OUTL1	730915	0.52
785)	OUTL1	730916	0.39
786)	OUTL1	730917	0.39
787)	OUTL1	730918	0.39
788)	OUTL1	730919	0.39
789)	OUTL1	730920	0.39
790)	OUTL1	730921	0.50
791)	OUTL1	730922	0.61
792)	OUTL1	730923	0.61
793)	OUTL1	730924	1.63
794)	OUTL1	730925	1.65
795)	OUTL1	730926	1.76
796)	OUTL1	730927	1.76
797)	OUTL1	730928	1.22
798)	OUTL1	730929	.653
799)	OUTL1	730930	0.65
800)	OUTL1	731001	1.33
801)	OUTL1	731002	1.33
802)	OUTL1	731003	1.33
803)	OUTL1	731004	0.74
804)	OUTL1	731005	0.44
805)	OUTL1	731006	0.43
806)	OUTL1	731007	0.44
807)	OUTL1	731008	0.44
808)	OUTL1	731009	0.50
809)	OUTL1	731010	0.54
810)	OUTL1	731011	0.54
811)	OUTL1	731012	0.35
812)	OUTL1	731013	0.13
813)	OUTL1	731014	0.33
814)	OUTL1	731015	1.52
815)	OUTL1	731016	1.87
816)	OUTL1	731017	1.91
817)	OUTL1	731018	1.70
818)	OUTL1	731019	1.67
819)	OUTL1	731020	1.13
820)	OUTL1	731021	1.13
821)	OUTL1	731022	2.20
822)	OUTL1	731023	1.76
823)	OUTL1	731024	1.33
824)	OUTL1	731025	1.22
825)	OUTL1	731026	1.31
826)	OUTL1	731027	1.48
827)	OUTL1	731028	1.48
828)	OUTL1	731029	1.85
829)	OUTL1	731030	1.87
830)	OUTL1	731031	1.67
831)	OUTL1	731101	2.00
832)	OUTL1	731102	1.72
833)	OUTL1	731103	1.22
834)	OUTL1	731104	1.22
835)	OUTL1	731105	1.98
836)	OUTL1	731106	2.20
837)	OUTL1	731107	2.20
838)	OUTL1	731108	2.18
839)	OUTL1	731109	1.67
840)	OUTL1	731110	1.42
841)	OUTL1	731111	1.17
842)	OUTL1	731112	1.57
843)	OUTL1	731113	0.91
844)	OUTL1	731114	1.31
845)	OUTL1	731115	0.89
846)	OUTL1	731116	0.65
847)	OUTL1	731117	0.39
848)	OUTL1	731118	0.39
849)	OUTL1	731119	1.65
850)	OUTL1	731120	1.17
851)	OUTL1	731121	.131
852)	OUTL1	731122	.131
853)	OUTL1	731123	.131
854)	OUTL1	731124	.131
855)	OUTL1	731125	0.13
856)	OUTL1	731126	1.11
857)	OUTL1	731127	1.37
858)	OUTL1	731128	1.48
859)	OUTL1	731129	0.44
860)	OUTL1	-731130	0.44
861)			
862)			
863)			
864)			

APPENDIX TABLE C. PHYSICAL, CHEMICAL, AND BIOLOGICAL COEFFICIENTS

		COEFFICIENT CODE Res.	COEFFICIENT CODE Str.	DEFAULT VALUE	NORMAL RANGE
Carbon Fraction (by wt.) of:					
Phytoplankton & Benthic Algae		1	1	0.4	.4-.5
Zooplankton		4	4	0.4	.4-.5
Aquatic Insects		-	7	0.4	.4-.5
Benthic Animals		7	10	0.4	.4-.5
Fish		0	13	0.4	.4-.5
Detritus & Organic Sediment		13	16	0.4	.2-.5
Nitrogen Fraction (by wt.) of:					
Phytoplankton & Benthic Algae		2	2	0.08	.07-.09
Zooplankton		5	5	0.08	.07-.09
Aquatic Insects		-	8	0.08	.07-.09
Benthic Animals		8	11	0.08	.07-.09
Fish		11	14	0.08	.07-.09
Detritus & Organic Sediment		14	17	0.08	.05-.09
Phosphorus Fraction (by wt.) of:					
Phytoplankton & Benthic Algae		3	3	0.012	.01-.012
Zooplankton		6	6	0.012	.01-.012
Aquatic Insects		-	9	0.012	.01-.012
Benthic Animals		9	12	0.012	.01-.012
Fish		12	15	0.012	.01-.012
Detritus & Organic Sediment		15	18	0.012	.005-.012
RATE COEFFICIENT TEMP. ADJUSTMENT FACTORS					
Temp. Limits (°C)					
Type 1 Phytoplankton & Benthic Algae	T_1	135	186	5	0-10
	T_2	137	188	22	15-25
	T_3	139	190	25	20-30
	T_4	141	192	34	25-40
Type 2 Phytoplankton	T_1	136	187	10	5-15
	T_2	138	189	28	20-30
	T_3	140	191	30	25-35
	T_4	142	193	40	30-45

SOURCE: Smith (1978, Table IV-1).

APPENDIX TABLE C.—*Continued*

		COEFFICIENT CODE Res.	Str.	DEFAULT VALUE	NORMAL RANGE
Zooplankton	T_1	147	198	5	0-10
	T_2	148	199	28	15-30
	T_3	149	200	30	20-35
	T_4	150	201	38	30-40
Aquatic Insects	T_1	---	206	5	0-10
	T_2	---	207	28	15-30
	T_3	---	208	30	20-35
	T_4	---	209	38	30-40
Benthic Animals	T_1	155	214	5	0-10
	T_2	156	215	22	15-30
	T_3	157	216	25	20-35
	T_4	158	217	38	30-40
Type 1 Fish	T_1	171	230	5	0-5
	T_2	174	233	20	15-20
	T_3	177	236	20	15-25
	T_4	180	239	25	20-30
Type 2 Fish	T_1	172	231	10	5-15
	T_2	175	234	27	20-30
	T_3	178	237	30	25-35
	T_4	181	240	38	30-40
Type 3 Fish	T_1	173	232	5	0-10
	T_2	176	235	55	20-30
	T_3	179	238	30	25-35
	T_4	182	241	36	30-40
Carbonaceous	T_1	185	244	4	0-5
BOD Decay	T_2	186	245	30	25-35
Ammonia Decay	T_1	189	248	4	0-5
	T_2	190	249	30	25-35
Nitrite Decay	T_1	193	252	4	0-5
	T_2	194	253	30	25-35
Detritus &	T_1	197	256	4	0-5
Sediment Decay	T_2	198	257	30	25-35
Q_{10} Temp. Coefficients					
Coliform bacteria die-off		199	258	1.04	1.03-1.06
Reaeration		*	263	1.022	1.02-1.3
BOD Decay		200	264	0	1.03-1.06
Ammonia Decay		201	265	0	1.02-1.03
Nitrite Decay		202	266	0	1.02-1.03

*No override capability provided for the Q_{10} temperature coefficient for reaeration in the lake model.

APPENDIX TABLE C.—*Continued*

	COEFFICIENT CODE Res.	Str.	DEFAULT VALUE	NORMAL RANGE
Detritus & Sediment Decay	203	267	0	1.02-1.4
Nongrowth Related Biological Activity	204	268	0	1.02-1.04
Type 1 Fish Related Coefficients				
Maximum growth Rate (1/day)	45	78	.02	.02-.03
Respiration Rate (1/day)	48	81	.003	.001-.005
Natural Mortality rate (1/day)	51	84	.002	.001-.005
Toxic mortality rate (1/day/mg/ℓ)	--	87	0	0-1
Growth Half Saturation Constant for Grazing Zooplankton (mg/ℓ)	54	90	.2	.05-.2
Feeding Preference Number 1 Relating Benthic Animals to Zooplankton (m^2/ℓ)	60	96	.005	.001-.01
Assimilative Efficiency	63	102	.5	.3-.6
Particulate Fraction of Excreta	66	105	.6	.5-.8
Type 2 Fish Related Coefficients				
Maximum growth rate (1/day)	46	79	.025	.02-.03
Respiration Rate (1/day)	49	82	.003	.001-.005
Natural Mortality Rate (1/day)	52	85	.002	.001-.005
Toxic Mortality Rate (1/day/mg/ℓ)	--	88	0	0-1
Growth Half Saturation Constant for Grazing Zooplankton (mg/ℓ)	55	91	.2	.05-.2
Feeding Preference Number 1 Relating Benthic Animals to Zooplankton (m^2/ℓ)	61	97	.005	.001-.01
Feeding Preference Number 2 Relating Aquatic Insects to Zooplankton (m^2/ℓ)	--	100	.005	.001-.01
Assimilative Efficiency	64	103	.5	.3-.6
Particulate Fraction of Excreta	67	106	.6	.5-.8
Type 3 Fish Related Coefficients				
Maximum Growth Rate (1/day)	47	80	.02	.02-.03
Respiration Rate (1/day)	50	83	.003	.001-.005

APPENDIX TABLE C.—*Continued*

	COEFFICIENT CODES Res.	Str.	DEFAULT VALUE	NORMAL RANGE
Natural Mortality Rate (1/day)	53	86	.002	.001-.005
Toxic Mortality Rate (1/day/mg/ℓ)	--	89	0	0-1
Growth Half Saturation Constant for Grazing Benthic Animals and/or Aquatic Insects (mg/m^2)	56	92	500	100-2000
Feeding Preference Number 1 Relating Organic Sediment to Benthic Animals and Aquatic Insects	62	101	.001	.001-.01
Feeding Preference Number 2 Relating Benthic Algae Type 1 to Benthic Animals and Aquatic Insects	--	95	.2	.1-.5
Feeding Preference Number 3 Relating Benthic Algae Type 2 to Bentic Animals and Aquatic Insects	--	98	.5	.5-1
Assimilative Efficiency	65	104	.5	.3-.6
Particulate Fraction of Excreta	68	107	.6	.5-.8
Benthic Animals Related				
Maximum Growth Rate (1/day)	39	71	.04	.02-.05
Respiration Rate (1/day)	40	72	.008	.001-.01
Natural Mortality Rate (1/day)	41	73	.004	.001-.005
Growth Half Saturation Constant for Grazing Organic Sediment (mg/m^2)	42	75	2000	100-2000
Assimilative Efficiency	43	76	.6	.4-.8
Particulate Fraction of Excreta	44	77	.6	.5-.8
Aquatic Insects Related				
Maximum Growth Rate (1/day)	--	61	.1	.05-.2
Respiration rate (1/day)	--	62	.01	.01-.03
Natural Mortality RAte (1/day)	--	63	.005	.002-.005
Toxic Mortality Rate (1/day/mg/ℓ)	--	64	0	0-1

APPENDIX TABLE C.—*Continued*

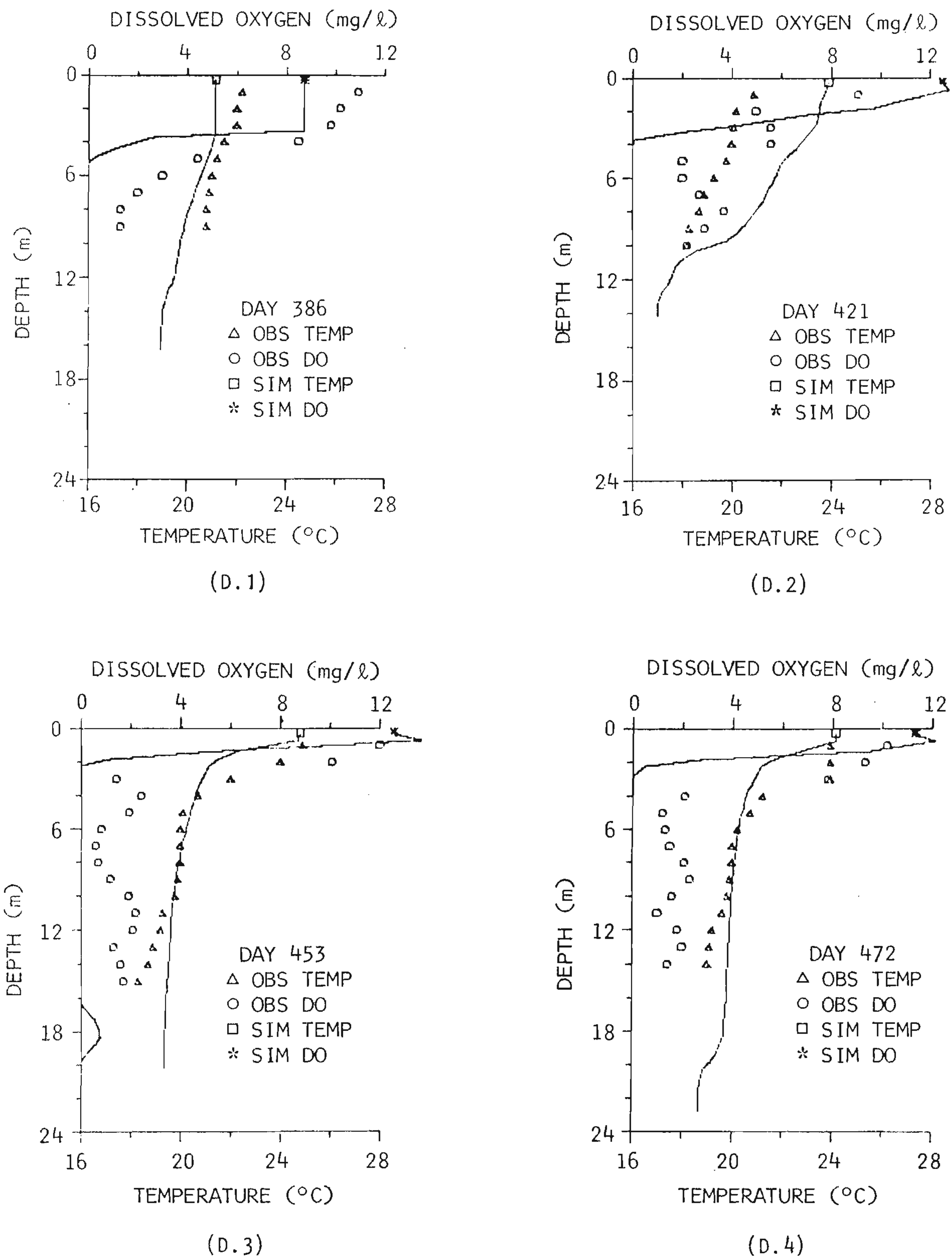
	COEFFICIENT CODE Res.	Str.	DEFAULT VALUE	NORMAL RANGE
Growth Half Saturation Constant for Grazing Benthic Algae Type 1 (mg/m^2)	--	65	1000	100-1000
Feeding Preference Number 1 Relating Benthic Algae Type 2 to Benthic Algae Type 1	--	67	2	1-2
Feeding Preference Number 2 Relating Organic Sediment to Benthic Algae Type 1	--	68	.05	.01-.1
Assimilative Efficiency	--	69	.6	.4-.7
Particulate Fraction of Excreta	--	70	.6	.5-.8
<u>Zooplankton Related</u>				
Maximum Growth Rate (1/day)	30	51	.15	.1-.3
Respiration Rate (1/day)	31	52	.015	.01-.03
Natural Mortality (1/day)	32	53	.01	.005-.02
Toxic Mortality Rate (1/day/mg/ℓ)	--	54	0	0-1
Growth Half Saturation Constant for Grazing Type 1 Phytoplankton (mg/ℓ)	33	55	.3	.2-.6
Feeding Preference Number 1 Relating Type 2 Phytoplankton to Type 1 Phytoplankton	35	57	.5	.5-1
Feeding Preference Number 2 Relating Detritus to Type 1 Phytoplankton	36	58	.2	.1-1
Assimilative Efficiency	37	59	.6	.5-.8
Particulate Fraction of Excreta	38	60	.6	.5-.8
<u>Type 1 Phytoplankton Related</u>				
Maximum Growth Rate (1/day)	16	19	2	1-2
Respiration Rate (1/day)	18	23	.15	.05-.20
Toxic Mortality Rate (1/day/mg/ℓ)	--	27	0	0-1
Growth Half Saturation Constants	--			
Light Energy ($kcal/m^2/s$)	20	31	.003	.002-.004

APPENDIX TABLE C.—*Continued*

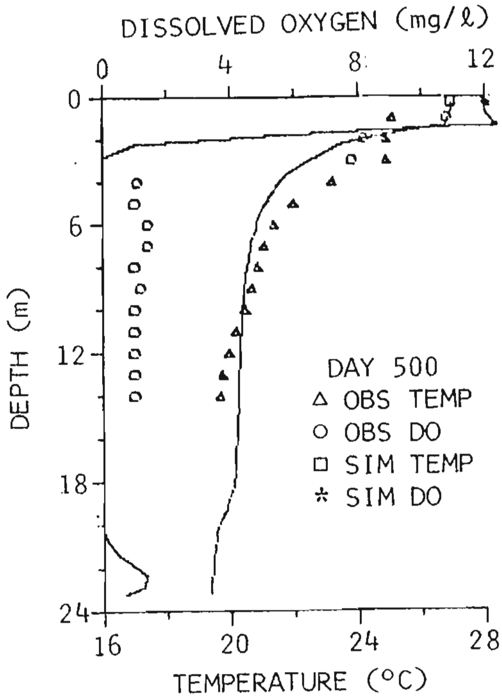
	COEFFICIENT CODE Res.	Str.	DEFAULT VALUE	NORMAL RANGE
Phosphate as P (mg/ℓ)	23	36	.03	.02-.05
Ammonia + Nitrate as N (mg/ℓ)	25	40	.06	.04-.10
Carbon Dioxide as C (mg/ℓ)	27	44	.025	.02-.04
Sinking Velocity (m/day)	29	--	.1	0-1
Sinking Velocity (m/day)	--	48	0	0-1
Type 1 Benthic Algae Related				
Maximum Growth Rate (1/day)	--	21	1	.5-1.5
Respiration Rate (1/day)	--	25	.07	.05-.2
Toxic Mortality Rate (1/day/mg/ℓ)	--	29	0	0-1
Growth Half Saturation Constants				
Light Energy (kcal/m^2/s)	--	33	.003	.002-.004
Phosphate as P (mg/ℓ)	--	37	.03	.02-.05
Ammonia + Nitrate as N (mg/ℓ)	--	41	.06	.04-.10
Carbon Dioxide as C (mg/ℓ)	--	45	.025	.02-.04
Scour Rate (1/day/m^2/s)	--	49	.02	0-1
Type 2 Benthic Algae Related				
Maximum Growth Rate (1/day)	--	22	1.2	.5-1.5
Respiration Rate (1/day)	--	26	.1	.05-.2
Toxic Mortality Rate (1/day/mg/ℓ)	--	30	0	0-1
Growth Half Saturation Constants				
Light Energy (kcal/m^2/s)	--	34	.004	.003-.006
Phosphate as P (mg/ℓ)	--	38	.03	.02-.05
Ammonia + Nitrate as N (mg/ℓ)	--	42	.06	.04-.10
Carbon Dioxide as C (mg/ℓ)	--	46	.025	.02-.04
Scour Rate (1/day/m^2/s)				
Decay Rates in 1/day				
Carbonaceous BOD Decay Rate	105	156	.3	.1-.3
Ammonia Decay Rate	106	157	.2	.05-.2

APPENDIX TABLE C.—*Continued*

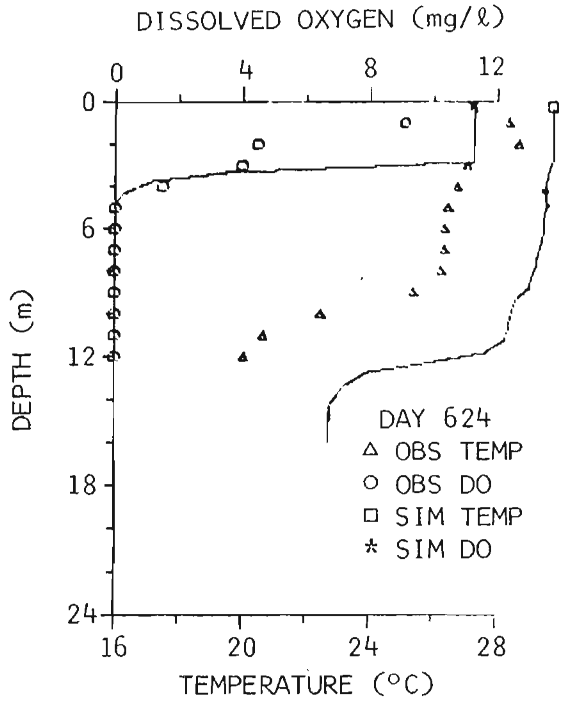
	COEFFICIENT CODE Res.	Str.	DEFAULT VALUE	NORMAL RANGE
Nitrate Decay Rate	107	158	.5	.2-.5
Coliform Die-off Rate	110	161	1.0	.5-2
Detritus Decay Rate	108	159	.02	.005-.05
Organic Sediment Decay Rate	109	160	.005	.001-.01
Stoichiometric Equivalences				
Carbon Released with Carbonaceous BOD Decay	111	162	.2	.2
Oxygen Consumed with Ammonia (N) Decay	112	163	3.5	3.5
Oxygen Consumed with Nitrite (N) Decay	113	164	1.2	1.2
xygen Consumed with Detritus and Organic Sediment Decay	114	165	1.6	1.6-2
Oxygen Consumed with Biomass Respiration	115	166	1.6	1.6-2
Oxygen Produced with Algae Growth	116	167	1.6	1.6
Settling Velocity (m/s)				
Detritus	117	---	.5	0-2
Detritus	---	168	0	0-2
Phytoplankton Type 1	28	---	.5	0-2
Phytoplankton Type 1	--	47	0	0.2
Phytoplankton Type 2	29	--	.1	0-1
Phytoplankton Type 1	--	48	0	0-1
Shading/Light Attenuation Constant (1/m/mg/ℓ) for:				
Phytoplankton Type 1	118	169	.2	.15-.2
Phytoplnakton Type 2	119	170	.2	.15-.2
Zooplnakton	120	171	.02	.01-.05
Detritus	121	172	.1	.01-.25



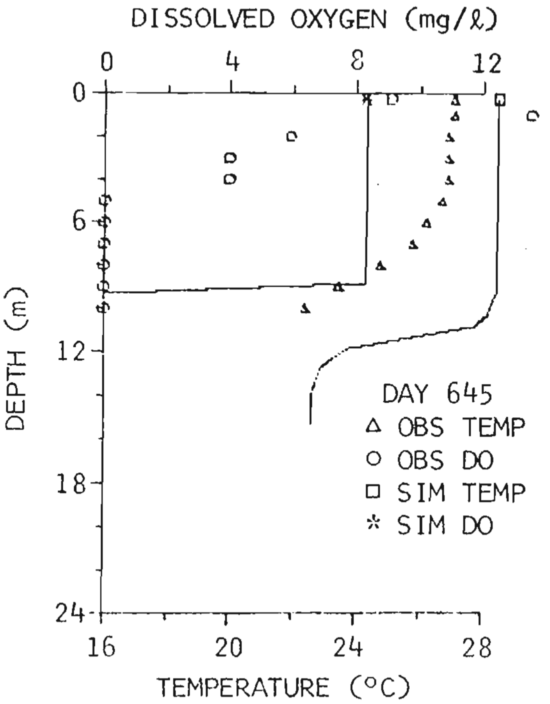
Appendix Figure D. Observed and simulated profiles of temperature and dissolved oxygen during calibration period, Wahiawā Reservoir, O'ahu, Hawai'i



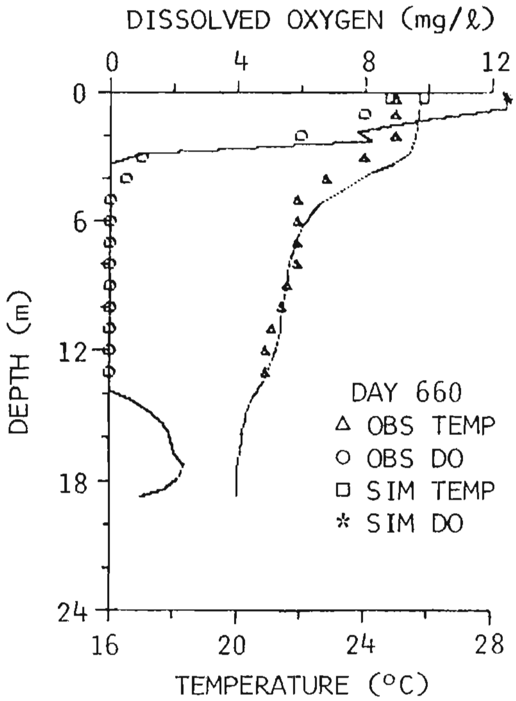
(D.5)



(D.6)

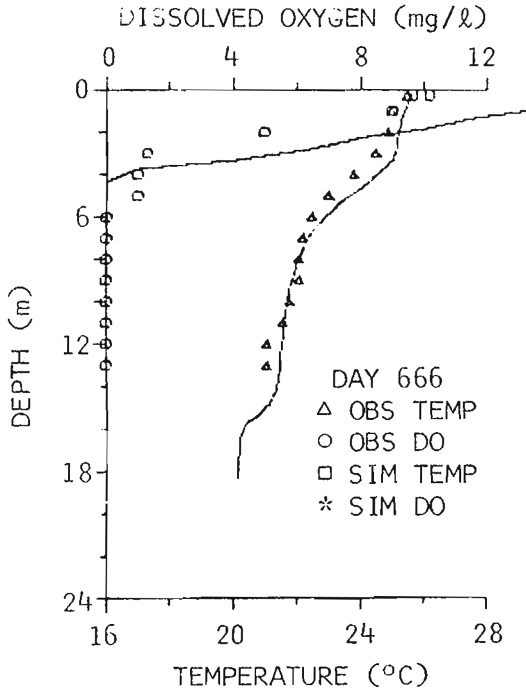


(D.7)

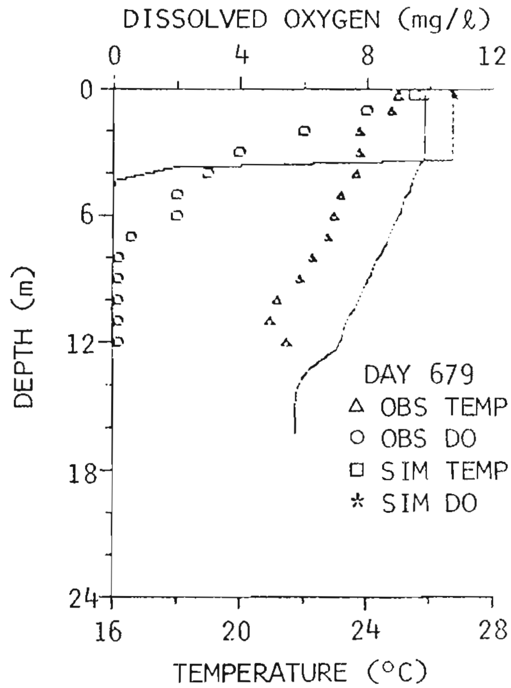


(D.8)

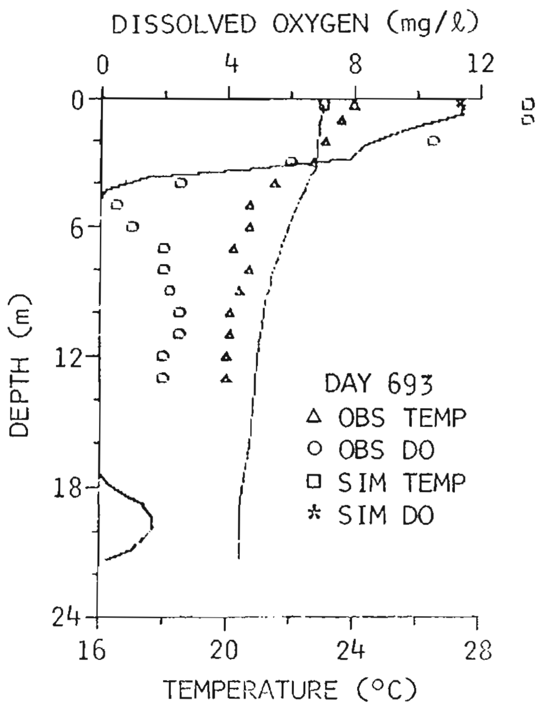
Appendix Figure D.—*Continued*



(D.9)

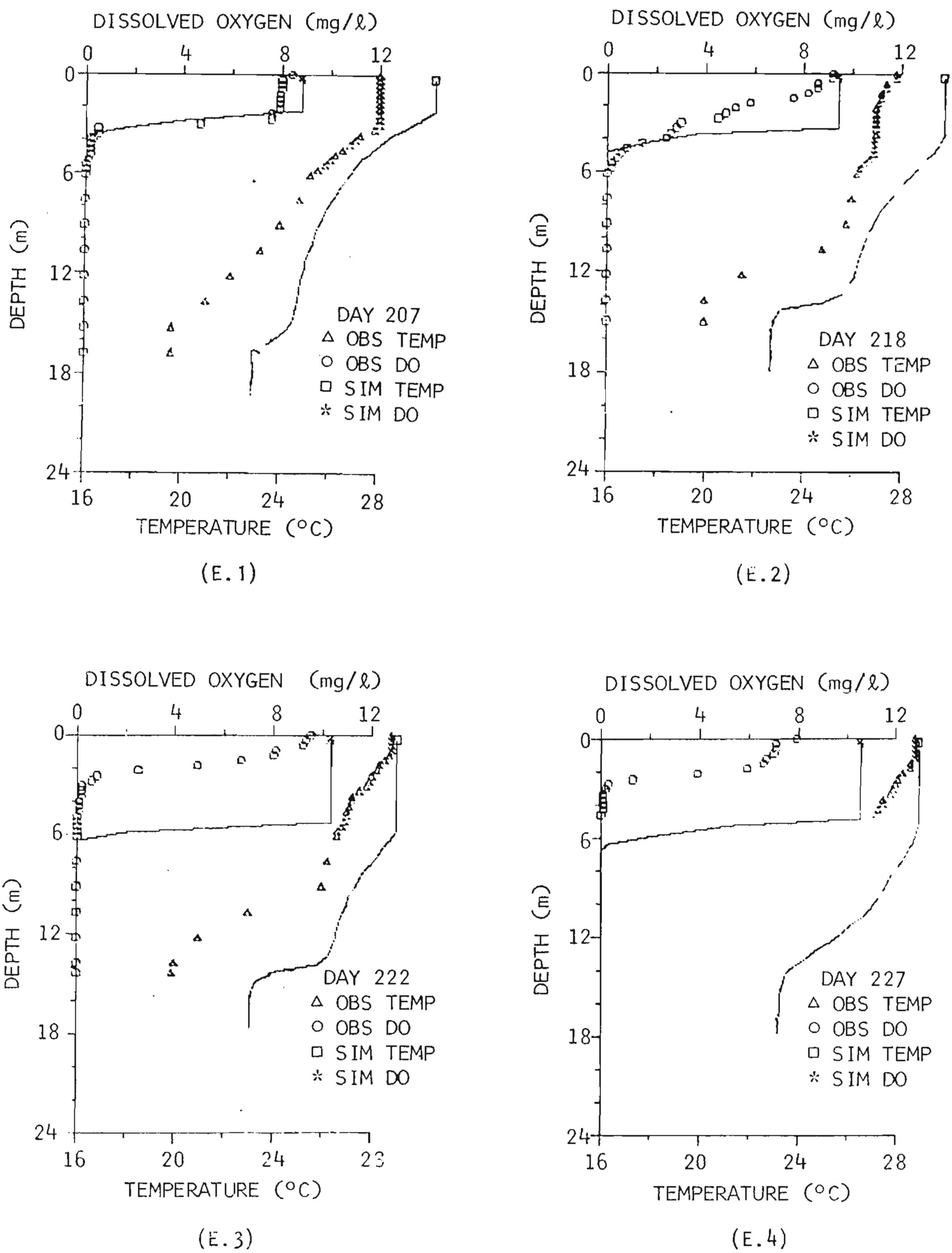


(D.10)

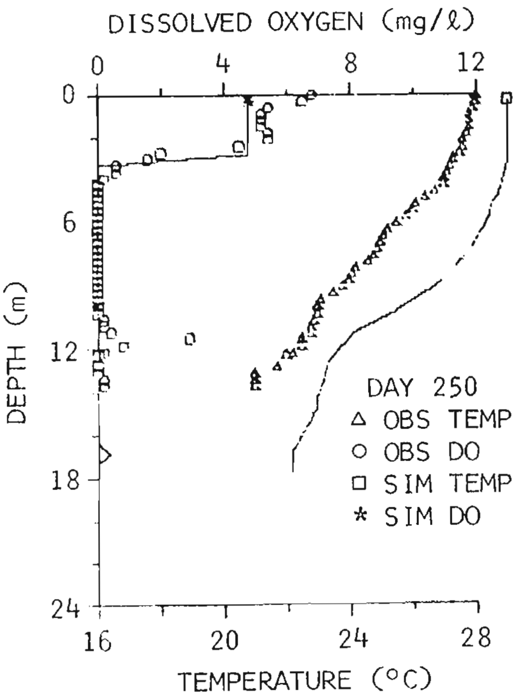


(D.11)

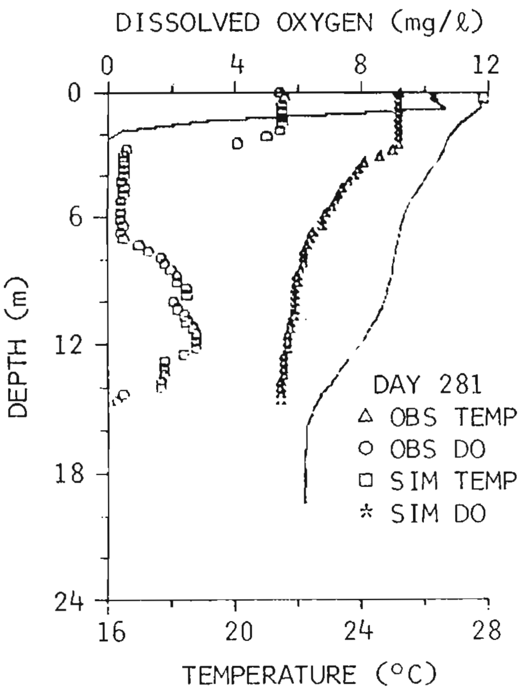
Appendix Figure D.—*Continued*



Appendix Figure E. Observed and simulated temperatures and dissolved oxygen profiles during the verification time period, Wahiawā Reservoir, O'ahu, Hawai'i



(E.5)



(E.6)

Appendix Figure E.—*Continued*