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Computer Program Documentation
USER'S MANUAL

One-Dimensional Reservoir-Lake Temperature and Dissolved Oxygen Model

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations 82-5

WATER RESOURCES DIVISION

Gulf Coast Hydroscience Center • NSTL Station, Mississippi

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The dissolved-oxygen and temperature profiles are computed for a conceptual vertical water column located at the deepest point in the lake or reservoir. The water column is divided into a series of uniform thickness horizontal layers for computation purposes. The model operates on a daily simulation interval, with summary output given for each day and detailed depth profiles printed on user-specified days. Model options allow the simulation of 5-day biochemical oxygen demand, sediment oxygen demand, and the density current effects of inflowing suspended sediment.

The model is a modification of the U.S. Army Corps of Engineer's "WESTEX" model number 722-F5-E1011. The user-specified withdrawal elevation, dissolved oxygen, biochemical oxygen demand, sediment oxygen demand, and suspended sediment simulation capabilities were not present in the earlier "WESTEX" model. The model is capable of simulating a stratified reservoir pool environment.

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DISCLAIMER:

Mention of a particular brand or model of equipment in this user manual does not imply a recommendation of its use by the U.S. Geological Survey.

CONVERSION FACTORS AND DEFINITIONS

Multiply	By	To obtain
foot (ft)	0.3048	meter (m)
foot (ft)	30.48	centimeter (cm)
mile per hour (mi/h)	0.447	meter per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
acre-foot (acre-ft)	43,560	cubic foot (ft^3)
acre-foot (acre-ft)	1233.6	cubic meter (m^3)
acre-foot (acre-ft)	0.504	cubic foot per second per day ($ft^3/s/d$)
British thermal unit (BTU)	1055.056	joule (J)

DEFINITIONS

BTU = British Thermal Unit--The amount of heat that will raise the temperature of 1 pound of water 1 degree Fahrenheit.

ACRE-FOOT = The volume of water that will cover 1 acre to a depth of 1 foot (43,560 ft^3).

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ABSTRACT

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The dissolved-oxygen and temperature profiles are computed for a conceptual vertical water column located at the deepest point in the lake or reservoir. The water column is divided into a series of uniform thickness horizontal layers for computation purposes. The model operates on a daily simulation interval, with summary output given for each day and detailed depth profiles printed on user-specified days. Model options allow the simulation of 5-day biochemical oxygen demand, sediment oxygen demand, and the density current effects of inflowing suspended sediment.

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This reservoir-lake model is most applicable to preliminary or reconnaissance studies of a proposed impoundment. Other more complex and accurate models exist to model existing lakes or reservoirs where onsite data can be collected.

INTRODUCTION

This report documents a computer model to predict DO (dissolved oxygen) and temperature-depth profiles in a lake or reservoir. The main emphasis of this report is to aid the user in applying the model to a real-life situation, rather than delve into the theory behind the model's computation schemes.

The first part of this report is devoted to an overview of the model and a discussion of the concepts and assumptions used in the model. The reader is then presented with the actual user's manual for the model, followed by a discussion of the required input data.

The final part of this report consists of a discussion of the model's output forms and techniques for model calibration.

Appendixes attached to the report include program flow charts, example input coding sheets, and output examples for the reservoir-lake model. An additional appendix also provides a brief user's manual for the auxiliary Heat Exchange Program needed to process data for use in the reservoir-lake model.

MODEL OVERVIEW

This model is a modification of the U.S. Army Corps of Engineers' "WESTEX" and "WESQAL" models developed by their Waterways Experiment Station (WES). The model has been modified for use by the U.S. Geological Survey (USGS). The selective-withdrawal optimization capability of these models has been deleted. The FORTRAN source deck has been modified to operate on IBM computer systems.

The model is meant to function with the type of input data that can be acquired for a proposed reservoir or lake. Other more complex and accurate models exist to study existing reservoirs and lakes, such as the U.S. Army Corps of Engineers' WQRRS model (U.S. Army Corps of Engineers, 1978).

The USGS model described in this report has greatly reduced input data requirements, even when compared to the earlier "WESTEX" and "WESQAL" models. However, the capabilities of the dissolved-oxygen simulation has been greatly improved in the USGS model. The USGS model functions with daily input values of average equilibrium air temperature, surface heat exchange coefficients, the quantity and quality of inflowing water, and the quantity of outflowing water.

The model is best suited to predict the probable DO and temperature conditions in a proposed lake or reservoir, or to compare the effects of altering the outflow withdrawal elevation of an existing or proposed lake or reservoir. Biochemical oxygen demand (BOD) and suspended sediment also can be simulated.

The model provides a daily simulation of the DO and temperature depth profiles within the lake or reservoir, as well as the daily average downstream release temperature values and DO concentrations. Summary information of each day's average inflow, outflow, pool elevation, and downstream release information is output in printed tables. Detailed information and depth profiles are printed for user-specified days.

The model can be used to predict temperature profiles and downstream release temperatures alone if DO simulation is not required, or if the needed DO input data are not available. If weekly BOD (biochemical oxygen demand) information is available on the inflowing water, then BOD can also be simulated and will enhance the accuracy of the DO simulation. Sediment oxygen demand (SOD) effects on DO can be simulated with a user-supplied SOD loading rate. Finally, the effects of suspended sediment on deep density current mixing can be simulated by the model. Both BOD and suspended sediment concentration versus depth profiles can be output along with DO and temperature.

In order to use this model, two other computer programs must first be employed; one to provide reservoir-routed flows, and another to compute the surface heat exchange input for the model. Because daily inflows and outflows are required as input data, the daily inflows must be routed through the proposed or actual reservoir outlet configuration. Numerous reservoir routing computer programs can be used for this or it can be done using graphic methods.

Daily values of equilibrium water temperature and the daily surface heat exchange coefficient must be computed using the Corps of Engineers' "HEAT EXCHANGE PROGRAM", number 722-F5-E1010. This program requires daily values of cloud cover, air temperature, dew point temperature, and windspeed in the study area as input data. A brief user's manual for this program is included as Appendix F of this report.

The DO simulation routine requires that a BOD decay rate be specified. This value can be assigned a typical value from literature or it can actually be computed using the results of laboratory analysis of BOD parameters. If such a procedure is used, water samples from nearby reservoirs or lakes similar to the one proposed must be collected. Several computer programs exist to compute the BOD decay rates from sample data.

Therefore, as many as three programs may be used in preparation for the use of the model. It will be seen that use of this model at a proposed reservoir site involves a carefully planned data-collection program involving stream gaging, a continuous DO and temperature-recording meter, and sampling of the stream and nearby impoundments for water-quality information.

MODEL CONCEPTS

This section of the report is intended to brief the model user with the basic concepts used in the reservoir-lake program. This section does not describe the mathematical computational schemes, but rather the underlying assumptions and procedures used to simulate physical processes with the model.

Those users wishing a further discussion of the computational schemes are referred to the original "WESTEX" documentation available from the Corps of Engineers, Waterways Experiment Station, P. O. Box 631, Vicksburg, Mississippi 39180.

A user familiar with the FORTRAN computer language should be able to follow the computational schemes by scanning the program listing provided in Appendix C.

Depth Profiles

The major purpose of this model is to compute depth versus temperature and dissolved-oxygen profiles for the lake or reservoir under study. Depth versus biochemical oxygen demand profiles can also be computed by the model. An example depth versus temperature curve is shown in figure 1. The temperature profile curve defines the three conceptual zones of the pool; they are the epilimnion, metalimnion, and hypolimnion.

The epilimnion typically is well mixed due to wind and wave action, and has high DO concentrations due to atmospheric aeration. The epilimnion water is warmer, and therefore lighter, than the other zones below. Most photosynthetic algae activity occurs within the epilimnion.

The thermocline zone exhibits a rapid temperature drop with depth. This sharp drop in temperature creates significant density differences between the water layers above and below the thermocline. This density difference creates a very stable water column which resists mixing and acts to block oxygen transfer to the bottom water from above. The inflection point of the temperature versus depth profile in the thermocline zone is called the "Thermocline Depth". This "depth" is influenced by sunlight penetration distance into the water column. In turbid lakes or reservoirs the thermocline depth will occur nearer to the surface than in clear lakes or reservoirs.

The water of the hypolimnion zone is colder, and therefore denser than the overlying water in the thermocline and epilimnion. There is little vertical mixing in this zone as it is far below the surface wind and wave action. Since oxygen does not move down through the thermocline, the effects of SOD can rapidly deplete the bottom water's DO content.

The Representative Water Column and Horizontal Layers

For the purposes of the model, the lake or reservoir is represented by a 1 ft^2 area water column located at the deepest part of the lake or reservoir. For a natural lake this is commonly located near the center of the lake, while in a reservoir it is near the dam. Since variations in DO, temperature, and other parameters are only computed with depth (and not laterally or longitudinally) the model is considered to be one dimensional. A schematic drawing of the conceptual representative water column and the horizontal layering is shown in figure 2.

The representative water column described above is divided into as many as 60 horizontal layers, all with an equal thickness specified by the user. The more layers used, the greater the model's accuracy. However, using a thickness less than one foot will cause the model to fail and generate an internal error code given in Appendix B.

Inflow to a given horizontal layer is assumed to become well mixed throughout the layer within 1 day (the simulation time step used). Reservoirs or lakes that have large isolated bays or would not be well mixed horizontally within 1 day do not fall within the assumptions of this model. A two-dimensional or three-dimensional model should be used in such cases.

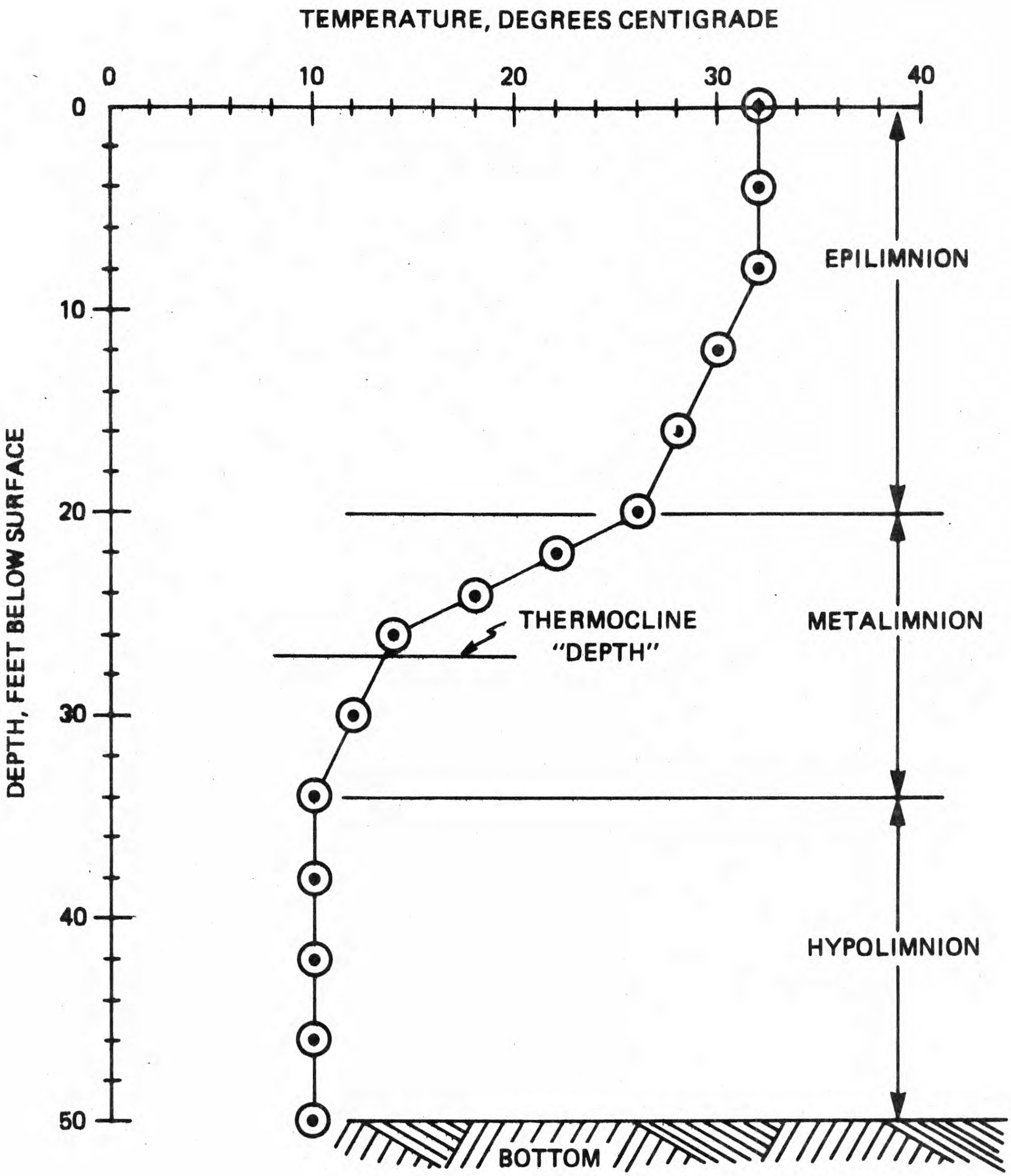

Figure 1.--Depth versus temperature profile for a stratified lake.

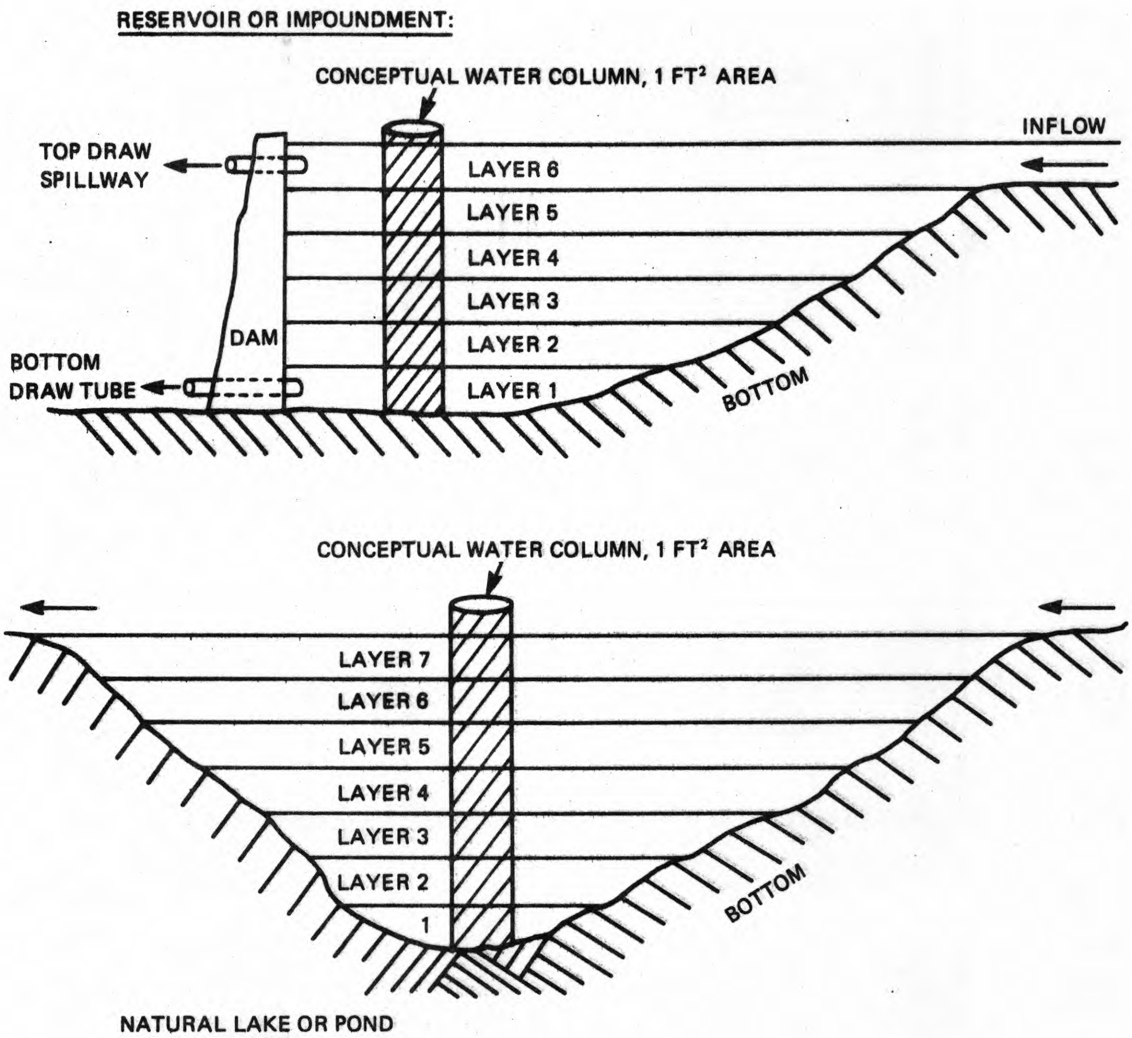

Figure 2.--Location of the conceptual water column and the horizontal layering scheme of the model.

Surface Heat Exchange

The surface heat exchange subroutine used in the model is based on procedures developed by Edinger, Duttweiler, and Geyer (1968). The basic equation used is given as:

$$H_{net} = EK\ (ET - \theta) \qquad (1)$$

where

H_{net} = net solar radiation entering water surface, in units of BTU/ft^2 per day,
EK = surface heat exchange coefficient, in units of BTU/ft^2 per degree Fahrenheit per day,
ET = equilibrium temperature, in degrees Fahrenheit,
and θ = water-surface temperature, in degrees Fahrenheit.

The surface heat exchange coefficient (EK) is solely a function of windspeed, while the equilibrium temperature (ET) is a complex function of air temperature, cloud cover, dew point, and windspeed.

The equilibrium temperature is defined as the water-surface temperature at which there is no net heat transfer across the air-water interface. A body of water with a surface temperature less than the equilibrium temperature will warm up through heat transfer from the atmosphere, while a water body with a surface temperature greater than the equilibrium value will cool off.

The daily values of the surface heat exchange coefficient and equilibrium temperature are computed using the auxiliary Heat Exchange Program developed by the Corps of Engineers. A brief, but functional, user's manual for this program is provided in Appendix F of this report. Full documentation of the program is available in "Thermal Simulation of Lakes" from the U.S. Army Engineer District, Baltimore, P. O. Box 1715, Baltimore, Maryland, 21203.

The H_{net} value computed in equation 1 is the total net heat entering the pool surface. Most of this heat is absorbed in the top 2 ft of the pool, but a portion of this heat is in the form of shortwave radiation and penetrates down deeper before being absorbed. The user specifies the fraction of shortwave (SW) radiation absorbed at the surface and also specifies a light extinction coefficient that determines the shortwave radiation penetration depth. Turbid or algae-filled waters will have a larger light extinction value than clear waters.

Internal Mixing

Vertical mixing within the conceptual water column is assumed to occur due to molecular diffusion, internal eddies set up by wind and wave action, and water density differences. The user specifies surface and bottom diffusion coefficients that account for internal eddy and molecular diffusion. The computer program computes intermediate depth diffusion coefficients by interpolating between the specified surface and bottom layer coefficients. The user specifies the diffusion coefficients in units of square centimeters per second (cm^2/s). This coefficient can be conceptually thought of as the rate at which a point drop of dye "spreads out" into the adjacent area in the water. The diffusion coefficient should be greater near the pool surface due to wave-action effects, and smaller near the pool bottom where wave-action effects are less.

Mixing due to density differences occurs when cooler, heavier layers sink down the water column, or as lighter, warmer water layers rise. Rising or falling water layers are mixed with the layers moved into, one at a time, until a stable density profile develops.

The model assumes that DO and BOD concentrations are mixed in a manner identical to the thermal characteristics.

Water Inflow and Surface Layer Entrainment

The process of surface-water inflow into the lake or reservoir is simulated in the model by placement of the inflow quantity into the pool layer where the density most closely corresponds to that of the inflowing water. Prototype observations and physical model studies at the Corps of Engineers' Waterways Experiment Station have shown that an amount of surface layer water is pulled down with descending inflow. The model allows the user to specify this amount as a percentage of the inflow quantity.

Water-quality characteristics of the inflow volume and the entrained surface layer volume are mixed, and volume-weighted average values of density, temperature, and other simulated qualities are placed in the density-corresponding pool layer as inflow.

Markofsky and Harleman (1971) discuss the times required for the inflow current to fall to the level of its own density and then for it to reach the pool outlet so it could be withdrawn. These traveltimes can be important when DO and BOD are being simulated. However, for the Survey model purposes, these processes are assumed to occur within 1 day. Reservoir-lake configurations that do not meet this assumption should perhaps be simulated using a two-dimensional model that accounts for the length of these flow paths.

Water Budget

Only surface-water inflow and outflow is accounted for in the model. Ground water and evaporation is not accounted for. This is consistent with the model's intended purpose as a reconnaissance tool or relatively inexpensive analysis model.

Daily inflow and outflow values must be specified by the user. The model does not include a reservoir-routing routine to determine outflow. Use of user-specified outflow data allows comparison of different flow regulation effects on outflow quality.

Conceptually, the reservoir pool is divided into numerous horizontal layers (fig. 1). Each layer is assigned a volume capacity by the user.

This volume capacity is determined from a volume versus elevation curve developed for the pool, based on the pool geometry. An internal accounting scheme keeps track of the percentage "filled" for each layer. The upper layers will be emptied of water as the pool elevation drops. The resulting new surface layer may be only partially filled. Those layers beneath the current surface layer will always be 100 percent filled.

Each horizontal layer has an accounting of the average temperature and water quality within that layer as well. The horizontal layering of the pool should be considered a fixed reference system, with the water mass moving up and down within this reference framework.

Inflowing water is added to and mixes with the water layer having the same density as the inflow. The water volume above the inflow layer is displaced upwards until a new water-surface elevation is established.

Outflowing water is withdrawn from a bottom draw outlet or user-specified surface layer, or combination of both. As the outflowing water volume is withdrawn, the water mass above the withdrawal layer moves down. Upper water layers will be drained as the water surface drops, and a new surface layer will be established.

If not enough water is available to meet the required outflow in the layers at or above the specified outflow layer, the excess is taken from the uppermost layer or layers beneath the specified withdrawal layer. This would simulate lowering the spillway crest (stoplogs) or opening lower outlet tubes in a real life situation.

The program will fail if more water is to be withdrawn than is available in the pool. The program will also fail if the specified pool volume is overfilled. Either case will generate an internal error code as given in Appendix B.

Dissolved Oxygen and Biochemical Oxygen Demand

The DO inflow is assumed to be provided by means of atmospheric oxygen transfer and by the inflowing water's DO content. Surface atmospheric aeration is accomplished by specifying a percent saturation value and the extent (depth) of the transfer zone beneath the surface. This oxygen diffuses downwards with time.

The oxygen demand to the reservoir-lake system is provided by the inflowing waters BOD, pool-bottom SOD, and in-pool biologic productivity induced BOD contributions.

The BOD values are input daily as 5-day BOD concentrations in units of milligrams per liter (mg/L) for the inflowing water. The SOD value is input as a constant loading rate in units of grams per square meter per day $\{(gm/m^2)/d\}$, and the total load released is computed as a function of bottom area and the bottom layer's water temperature. SOD is released from the bottom pool layers and diffuses upwards with time.

The biologically-induced BOD value is specified as a constant input of BOD in terms of milligrams per liter per day {(mg/L)/d}. This value is added to BOD concentration of each pool layer each day.

The biologically-induced BOD contribution is intended to simulate the effects of decaying organic matter falling through the water column from the algae-production zone above. Such a value is difficult to measure directly. In practice, this constant is used to calibrate the oxygen simulation routine when using BOD and SOD input, or is assigned a value from the literature available.

Five-day BOD (BOD_5) concentrations and the SOD loading rate are optional input to the DO simulation routine. If no BOD, SOD, or biologically induced BOD values are specified, then DO is treated as a conservative substance by the model.

A DO and BOD_5 inventory is kept for each pool layer by the model to account for the various reactions and mixings occurring. An average release DO and BOD_5 concentration is computed for the outflowing water each day by the program. These release concentrations depend on the pool layer they are withdrawn from. Typically, lower layers have less dissolved oxygen and greater BOD concentrations.

The basic equation used in the DO and BOD computations in each pool layer is given as:

$$BOD_R = BOD_I \times \exp\{-K_r\ (t)\} \qquad (2)$$

where

BOD_R = BOD concentration remaining at end of time interval 't', in milligrams per liter,
BOD_I = initial concentration in layer at start of time interval 't', in milligrams per liter,
exp = exponentiation of the natural logarithm 'e',
K_r = BOD decay rate, in units per day,
and t = time interval, equals 1 day in this model.

The DO loss is defined as:

$BOD_I - BOD_R$ = DO loss per day (milligrams per liter per day).

Suspended Sediment

A model option allows the user to simulate the density effects of suspended sediment in the lake or reservoir. An offshoot of this ability is a user-specified settling rate in units of feet per day. This is the average settling rate of the sediment size distribution. Once the sediment has settled out on the bottom it is not resuspended again and will not exit as part of the outflow. The settled-out sediment is not considered to occupy any of the volume capacity of the bottom pool layer. Once settled-out, the sediment cannot be resuspended by the model, and does not affect any other computations.

DESCRIPTION OF INPUT CARDS FOR THE RESERVOIR-LAKE MODEL

The following section of the report is to aid the program user in preparing the input card deck needed to run the computer program. Each card or card group has a specified FORTRAN input format given, along with a breakdown by card columns of where each variable's value is to be entered. The variable name used in the computer program is given, along with a description or listing of the allowable values.

IMPORTANT NOTE: The first 4 letters of all 'CHECK' variables are alphanumeric images (A4) and must appear in the first four columns of the input card. The four key code letters for each CHECK variable are underlined in the variable input item section.

Integer variable values must be right-justified. Integer variables begin with the letter I through N, or are specifically noted.

All input cards are required unless stated otherwise. Default values are noted where they occur.

Input item	Program variable	Format	Card columns
CARD 1			
Title card - any arbitrary information	TITLE	20A4	1-80
CARD 2			
This card indicates if the input deck is to be listed in the output (aids in debugging). Enter 'PRINT INPUT' to list input deck, anything else indicates NO LIST.	CHECK	PRIN	1-4

Input item	Program variable	Format	Card columns
CARD 3			
This card specifies what qualities the model will simulate, and sets the value of NQUAL.			
User must enter QUALITIES or program stops.	CHECK	QUAL	1-4
Ø = Temperature simulation only (default value) 1 = Temperature and Dissolved Oxygen simulation 2 = Temperature, Dissolved Oxygen, and Biochemical Oxygen Demand simulation 3 = Temperature, Dissolved Oxygen, BOD, and Suspended Sediment simulation	NQUAL	I5	11-15
CARD 4			
This card specifies how many horizontal layers to divide the lake or impoundment into, the outflow layer, and the extent of SOD loading effects.			
User must enter LAYERS or program stops.	CHECK	LAYE	1-4
Enter the maximum number of layers allowed, from 01 to 60. No default value.	MAXLAY	I5	14-15
Surface outflow withdrawal layer, must be $\leq$ MAXLAY value. Layer 01 is the bottom. See the discussion section about selecting a W value. No default value.	W*	I5	19-20

Input item	Program variable	Format	Card columns
Specifies the upmost layer that contributes a Sediment Oxygen Demand loading from its associated bottom area. See the discussion section about selecting a BOTLAY value. Default = 0 (No SOD loading). OMIT if NQUAL = 0 on Card 3, value must be ≤ MAXLAY if used.	BOTLAY* *Integer variable	I5	24-25
CARD 5			
This card specifies the thickness of each horizontal layer. All layers have the same thickness.			
User must enter THICKNESS or program stops.	CHECK	THIC	1-4
Layer thickness in feet. Must be ≥ 1.0 ft. Note that DELZ times MAXLAY must equal or exceed the maximum pool depth or the simulation will fail.	DELZ	F10.0	11-20
CARD 6			
This card specifies the pool bottom elevation and bottom draw outlet capacity.			
User must enter BOTTOM or program stops.	CHECK	BOTT	1-4
Pool bottom elevation in feet above mean sea level, or local datum.	BOTTOM	F10.0	11-20
Optional bottom withdrawal capacity, in cubic feet per second. Default = 0.0.	BOTOUT	F10.0	21-30

Input item	Program variable	Format	Card columns
CARD 7			
This card indicates that pool layer-volume information will follow in Card Group 8. User must enter VOLUME or program stops.	CHECK	VOLU	1-4
CARD GROUP 8			
These cards give the volume of each horizontal pool layer, eight values per card.			
Layer volume in thousands of acre-feet, from bottom layer (01) up to MAXLAY value. (Example: Enter 1.5 for 1,500 acre-feet.)	VOLUME (1) VOLUME (2) etc., up to VOLUME (MAXLAY)	8F10.0	1-10 11-20 etc.
CARD 9			
This card specifies vertical diffusion coefficients.			
User must enter DIFFUSION or program stops.	CHECK	DIFF	1-4
Surface diffusion coefficient in cm^2/s, typically $1.0 \leq AMAX \leq 100$.	AMAX	F10.0	11-20
Bottom diffusion coefficient in cm^2/s, typically $0.1 \leq AMIN \leq 1.0$, but may range up to 100.0 in shallow lakes or impoundments.	AMIN	F10.0	21-30
CARD 10			
This card specifies Solar Radiation coefficients.			
User must enter HEAT or program stops.	CHECK	HEAT	1-4

Input item	Program variable	Format	Card columns
Decimal fraction of shortwave radiation absorbed in the surface layer. Typical values range from 0.6 to 0.8, no default value.	BETA	F10.0	11-20
Light extinction coefficient (1/ft). Typical values range from 0.15 to 0.6, for clear to turbid waters, respectively. No default.	LAMBDA	F10.0	21-30
CARD 11			
This card specifies surface water entrainment and suspended sediment settling rates.			
User must enter ENTRAIN or program stops.	CHECK	ENTR	1-4
Decimal fraction of surface water that is entrained and mixed with the inflow. Default value = 0. (No entrainment.)	GAMMA	F10.4	11-20
Suspended sediment settling rate in feet per day. Must be an even multiple of the DELZ value given on Card 5. Use only if NQUAL = 3 on Card 3. Default value = 0. (No settling.)	SETTLE	F10.4	21-30
CARD 12			
This card specifies oxygen depletion parameters. Omit this card if NQUAL = 0 on Card 3.			
User must enter DEPLETION or program stops.	CHECK	DEPL	1-4
Sediment Oxygen Demand loading rate in grams/sq. meter/day at 20°C. See Table 3 for typical values. Default = 0.	SOD	F10.0	11-20

Input item	Program variable	Format	Card columns
The Surface Oxygen Transfer zone is defined by the DELTA value in terms of a depth in feet (enter a negative value) from the surface, or in terms of the depth to a specified change in temperature (enter a positive °C value) from the surface. Typical values are (-3.0) feet or (+2.0) degrees centigrade. No default.	DELTA (- for feet) (+ for Δ °C)	F10.0	21-30
Percent saturation of dissolved oxygen in the surface transfer zone. The value may range from 0.0 to 1.0, where 1.0 = 100%.	PERSAT	F10.0	31-40
Biochemical Oxygen Demand Decay Rate (1/day). Typical values range from 0.1 to 0.4 per day.	DKR	F10.0	41-50
Biologic Productivity-Induced BOD contribution in mg/L/day. Default = 0.	PBOD	F10.0	51-60
<u>CARD 13</u>			
This card specifies the first and last day of the year for the data input period.			
User must enter INTERVAL or program stops.	CHECK	INTE	1-4
Enter first day of data input, 001 to 366.	FIRST	I3	13-15
Enter last day of data input, must be ≥ FIRST, and ≤ 366.	LAST	I3	18-20
Enter simulation year.	YEAR	I4	22-25
<u>CARD 14</u>			
This card specifies the period to be simulated, from day number START to FINISH.			

Input item	Program variable	Format	Card columns
User must enter SIMULATE or program stops.	CHECK	SIMU	1-4
Must be ≥ FIRST and ≤ LAST.	START	I3	13-15
Must be ≥ START and ≤ LAST. See the discussion section about the seasonal use of these parameters.	FINISH	I3	18-20
CARD 15			
This card specifies what days to print detailed simulation output, including depth profiles of all qualities simulated.			
User must enter PRINT DAYS or program stops.	CHECK	PRIN	1-4
Indicate days for detailed printouts. Up to 14 days can be specified. Enter in increasing order.	IPRINT (1) IPRINT (2) ..., up to IPRINT (14)	14I3	13-15 18-20 23-25 etc.
CARD 16			
This card specifies the range of the depth profile plotting axis for the simulated qualities. Range values must be given in multiples of ten.			
User must enter PLOT AXIS or program stops.	CHECK	PLOT	1-4
Maximum range of temperature axis, °C. Default value = 50°C.	MAXT	I5	11-15
Maximum range of dissolved oxygen axis in mg/L. Default = 20 mg/L. Needed only if NQUAL ≥ 1 on Card 3.	MAXQ(1)	I5	16-20
Maximum range of the BOD axis in mg/L. Default = 10 mg/L. Needed only if NQUAL ≥ 2 on Card 3.	MAXQ(2)	I5	21-25

Input item	Program variable	Format	Card columns
Maximum range of the suspended sediment axis in mg/L. Default = 500 mg/L. Needed only if NQUAL = 3 on Card 3.	MAXQ(3)	I5	26-30
CARD 17			
This card indicates that Daily Equilibrium Temperature data will follow in Card Group 18, and also provides the YEAR of simulation for ID purposes.			
User must enter EQUILIBRIUM TEMPERATURE DATA or program stops.	CHECK	EQUI	1-4
CARD GROUP 18			
These cards specify daily equilibrium temperature from day number FIRST to LAST.			
Equilibrium temperature in degrees Fahrenheit, eight values per card. There must be (LAST - FIRST + 1) values entered.	EQTEMP(N) where N is the day number, up to EQTEMP(LAST)	8F10.0	1-10 11-20 21-30 etc.
CARD 19			
This card indicates that Thermal Exchange Coefficient data will follow on Card Group 20. User must enter EXCHANGE COEFFICIENTS or program will stop.	CHECK	EXCH	1-4
CARD GROUP 20			
These cards specify daily thermal exchange coefficients from day number FIRST to LAST. Enter value in BTU/°F/ft^2/day, eight values per card. There must be (LAST - FIRST + 1) values entered.	EXCOEF(N), where N is the day number, up to EXCOEF(LAST)	8F10.0	1-10 11-20 21-30 etc.

Input item	Program variable	Format	Card columns
CARD 20A			
This card indicates that shortwave radiation input will follow on Card Group 20B.			
User must enter SHORTWAVE RADIATION or program will stop.	CHECK	SHOR	1-4
CARD GROUP 20B			
These cards specify the daily net shortwave radiation reaching the water surface in British Thermal Units/ft^2, from day number FIRST to LAST. Eight values per card.	SOLAR(N), where N is the day number	8F10.0	1-10 11-20 21-30 31-40 etc.
CARD 21			
This card indicates that the inflow hydrograph follows on Card Group 22, and specifies the flow units.			
User must enter INFLOW or program stops.	CHECK	INFL	1-4
User must left-justify the units code in col. 51, CFS indicates cubic feet per second (default).	UNITS	CFS	51-53
CARD GROUP 22			
These cards provide the daily average flow values of the inflow hydrograph in the UNITS specified on Card 21. There should be (LAST - FIRST + 1) daily values. Enter daily average inflow values, eight per card.	INFLOW(N), where N is the day number, up to INFLOW(LAST)	8F10.0	1-10 11-20 21-30 etc.

Input item	Program variable	Format	Card columns
CARD 23			
This card indicates if the inflow water temperature data to follow on Card Group 24 are in degrees Fahrenheit or Centigrade.			
User must enter TEMPERATURE or program stops.	CHECK	TEMP	1-4
Enter FAHRENHEIT or enter CENTIGRADE (default value). User must left-justify UNITS code in column 51.	UNITS	FAHR or CENT	51-54
CARD GROUP 24			
These cards give the average daily temperature of the inflow water in the UNITS specified on Card 23. Enter (LAST - FIRST + 1) daily values. Enter average daily temperature values, eight per card.	INTEMP(N), where N is the day number, up to INTEMP(LAST)	8F10.0	1-10 11-20 21-30 etc.

NOTE: OMIT CARDS 25 THROUGH 30 IF NQUAL = 0, WHEN THERMAL SIMULATION ONLY OPTION IS USED. CARDS 25-26 ARE USED TO ENTER DAILY DO INFLOW DATA.

Input item	Program variable	Format	Card columns
CARD 25			
This card indicates that daily average inflow values of dissolved oxygen will follow on Card Group 26. User must enter QUALITY DATA - DISSOLVED OXYGEN INFLOW or program will stop.	CHECK	QUAL	1-4

Input item	Program variable	Format	Card columns
CARD GROUP 26			
These cards give the daily average values of the inflow water's Dissolved Oxygen concentration from day number FIRST through LAST. Enter dissolved oxygen concentration values in units of milligrams per liter (mg/L), eight values per card. There should be (LAST - FIRST + 1) values entered.	INQUAL(N,1), where N is the day number, up to INQUAL (LAST, 1)	8F10.0	1-10 11-20 21-30 etc.

NOTE: OMIT CARDS 27 THROUGH 30 IF NQUAL = 0 or 1. CARD 27 and CARD GROUP 28 ARE REQUIRED IF NQUAL = 2 or 3. CARDS 27-28 ARE USED TO ENTER DAILY BOD INFLOW DATA.

Input item	Program variable	Format	Card columns
CARD 27			
This card indicates that daily 5-day Biochemical Oxygen Demand inflow data will follow on Card Group 28. User must enter QUALITY DATA - Suspended BOD Inflow or program will stop.	CHECK	QUAL	1-4
CARD GROUP 28			
These cards give the daily BOD_5 of the inflow water from day number FIRST through LAST. Enter BOD_5 daily values in milligrams/liter (mg/L), eight values per card. There should be (LAST - FIRST + 1) values entered.	INQUAL(N,2) where N is the day number, up to INQUAL (LAST, 2)	8F10.0	1-10 11-20 etc.

Input item	Program variable	Format	Card columns
NOTE: INCLUDE CARD 29 AND CARD GROUP 30 ONLY IF NQUAL = 3. THEY ARE USED TO ENTER SUSPENDED SEDIMENT DAILY INFLOW DATA.			
CARD 29			
This card indicates that daily values of the inflow water's Suspended Sediment concentration will follow. User must enter QUALITY DATA - SUSPENDED SEDIMENT or program stops.	CHECK	QUAL	1-4
CARD GROUP 30			
These cards give the daily Suspended Sediment concentration of the inflow water from day number FIRST through LAST. Enter daily Suspended Sediment concentration in milligrams per liter (mg/L), eight values per card. There should be (LAST - FIRST + 1) values entered.	INQUAL(N,3) where N is the day number, up to INQUAL (LAST, 3)	8F10.0	1-10 11-20 21-30 etc.
CARD 31			
This card indicates that the outflow hydrograph will follow and indicates flow units.			
User must enter OUTFLOW or program stops.	CHECK	OUTF	1-4
Enter CFS to indicate flow in cubic feet per second (default), no other units allowed. The UNITS code must be left-justified in column 51.	UNITS	CFS	51-53

Input item	Program variable	Format	Card columns
<u>CARD GROUP 32</u>			
These cards give the daily outflow hydrograph in the flow units specified on Card 31 from day number FIRST to LAST. Enter daily outflow values in specified units. There should be (LAST - FIRST + 1) values; enter eight per card.	SUMFLO(N), where N is the day number, from FIRST to LAST	8F10.0	1-10 11-20 21-30 31-40 41-50 51-60 etc.
<u>CARD 33</u>			
Initial Depth Card			
User must enter <u>DEPTH</u> or program stops.	CHECK	DEPT	1-4
Enter the initial height of the water surface in feet from the pool bottom.	DEPTH	F10.0	11-20

NOTE: CARD GROUPS 35, 37, 39, AND 41 CONTAIN INITIAL VALUES BY LAYER FROM BOTTOM TO TOP. IF THE INITIAL PROFILE IS UNIFORM, ENTER ONLY ONE VALUE, USING COLUMNS 1-10, OTHERWISE ENTER ONE VALUE FOR EACH LAYER UP TO AND INCLUDING THE MAXIMUM LAYER SPECIFIED (MAXLAY VALUE).

Input item	Program variable	Format	Card columns
<u>CARD 34</u>			
This card indicates that the initial temperature depth profile will follow on Card Group 35. User must enter <u>TEMPERATURE PROFILE</u> or program stops.	CHECK	TEMP	1-4
<u>CARD GROUP 35</u>			
These cards give the Initial Temperature Profile by layer, from bottom to the top. Enter the initial temperature of the layer in degrees centigrade, eight values per card. (Default = 0.0 degrees Centigrade.)	TEMP(I), where I is the layer number, from 01 to MAXLAY	8F10.0	1-10 11-20 21-30 31-40 41-50 51-60 61-70 71-80 etc.

Input item	Program variable	Format	Card columns

NOTE: OMIT CARDS 36 THROUGH 41 IF NQUAL = 0, (THERMAL SIMULATION ONLY). CARDS 36-37 ARE USED FOR THE INITIAL DO PROFILES.

CARD 36

This card indicates that the initial dissolved oxygen depth profile will follow on Card Group 37. User must enter QUALITY PROFILE - D.O., or program will stop.	CHECK	QUAL	1-4

CARD GROUP 37

These cards give the initial DO profile by layer from the bottom to the top. Enter the initial DO concentration of each layer in milligrams per liter (mg/L), eight values per card. (Default = 0.0 mg/L.)	QUAL(1,I) where I is the layer number, from 01 to MAXLAY	8F10.0	1-10 11-20 21-30 etc.

NOTE: OMIT CARDS 38 THROUGH 41 IF NQUAL EQUALS 0 OR 1, INCLUDE CARD 38 AND CARD 39 IF NQUAL = 2 or 3. CARDS 38-49 ARE USED FOR INITIAL BOD PROFILES.

CARD 38

This card indicates that the initial biochemical oxygen demand depth profile will follow on Card Group 39. User must enter QUALITY PROFILE - B.O.D., or program will stop.	CHECK	QUAL	1-4

CARD GROUP 39

These cards give the initial BOD_5 depth profile, from the bottom to the top. Enter the initial BOD_5 concentration for each layer in milligrams per liter (mg/L), eight values per card. (Default = 0.0 mg/L.)	QUAL(2,I) where I is the layer number, from 01 to MAXLAY	8F10.0	1-10 11-20 etc.

Input item	Program variable	Format	Card columns
NOTE: INCLUDE CARD 40 AND CARD GROUP 41 ONLY IF NQUAL = 3. CARDS 40-41 ARE USED FOR INITIAL SUSPENDED SEDIMENT PROFILES.			
CARD 40			
This card indicates that the initial Suspended Sediment concentration profile will follow on Card Group 41. User must enter QUALITY PROFILE - SUSPENDED SEDIMENT or program stops.	CHECK	QUAL	1-4
CARD GROUP 41			
These cards give the initial Suspended Sediment depth profile from the bottom to the top. Enter the initial Suspended Sediment concentration for each layer in milligrams per liter (mg/L), eight values per card. (Default = 0.0 mg/L.)	QUAL(3,I) where I is the layer number, from 01 to MAXLAY	8F10.0	1-10 11-20 21-30 31-40 41-50 51-60 etc.
CARD 42			
This card indicates the END of the input data. This must be the last card in the data deck. User must enter END of program.	CHECK	END	1-3

DISCUSSION OF INPUT DATA REQUIREMENTS

The following section of the report is intended to aid the user in planning data-collection programs to provide input to the model. This section also serves to aid the user in the selection of parameter values and rate coefficients needed by the model.

Simulation Scope

The extent of the model simulation is specified with the "NQUAL" variable on Input Card 3. The more qualities to be simulated, the greater the input data requirements. The model can be used as a thermal simulation only, thereby greatly reducing the required input. Dissolved oxygen also can be simulated, with or without BOD inflow data. In deep lakes or reservoirs where density currents may play an important role in mixing, the effects of suspended sediment on density can be simulated.

Pool Layer Configuration

Input Cards 4 through 8 are used to describe the horizontal layering of the reservoir or lake pool. The user specifies the number of layers (MAXLAY value) to divide the pool into, each layer having an equal thickness specified as the "DELZ" value. Enough layers must be specified to contain the maximum water-surface elevation that will occur in the simulation. In practice, the "DELZ" thickness value must not be less than 1.0 ft and multiples of 1 ft are desirable to facilitate plotting of the output depth profiles and tables. The more horizontal layers used, the greater the accuracy of the simulation. A maximum of 60 layers can be used. Shallow ponds or reservoirs may only allow 10 to 20 layers, however. Elevations are assigned to the bottom of each layer by specifying the elevation of the pool bottom in feet from mean sea level or other local datum.

The user also specifies the layer (and thereby elevation) that the outflow will be taken from. If the reservoir has a surface spillway outlet, the layer with the same elevation as the spillway should be specified as the outflow layer.

If the reservoir is equipped with a bottom draw outlet, the outlet capacity can be specified on Input Card 6 with the BOTOUT variable. Outflow for the day will be drawn from the bottom outlet first, with any outflow in excess of the specified capacity being withdrawn from the specified surface outflow layer on CARD 4.

CAUTION: The specified bottom draw capacity in ft^3/s must not exceed the total reservoir storage (in ft^3/s - days) below the specified surface outflow layer or erroneous outflow values may be output.

The volume of each horizontal layer must be specified by the user in terms of thousands of acre-feet. To acquire this information, the user must develop an area-elevation curve (fig. 3) for the reservoir pool or lake. This will involve field surveying and topographic map making if one does not already exist in sufficient detail. The area-elevation curve is developed by measuring the horizontal pool area at various elevations from the pool bottom. The area-elevation curve can then be used to generate the volume of each horizontal layer. The horizontal area at the midpoint elevation of the layer is multiplied by the layer thickness (DELZ) value to obtain the layer volume. Care should be taken to convert the volume to acre-feet units correctly.

If SOD is to be included in the oxygen simulation, then the bottom pool layers that contribute a SOD load must be specified on Input Card 4 as well as other layer parameters. The user specifies the uppermost pool layer that contributes a significant SOD load. All layers beneath the specified bottom layer are assumed to contribute SOD as well. The program computes the total SOD load released into a layer's water volume by multiplying the user-specified SOD loading rate by the incremental bottom area of that pool layer (fig. 4).

Care must be taken in specifying a bottom layer (BOTLAY) value on Card 4 to avoid too large or too small SOD total loads that dramatically affect the DO content of the lower pool layers. Physical inspection of the reservoir pool or lake is advised to determine the extent of SOD contributing bottom deposits. Where an actual pool does not already exist, the user should inspect nearby lakes or impoundments with similar inflow/outflow and depth characteristics. The BOTLAY layer value should be selected such that 90 percent of the bottom deposits are contained within the horizontal area of that layer's maximum elevation.

The bottom area of the near-shore littoral zone (fig. 4) is not to be considered when specifying a BOTLAY value. The oxygen depletion of this biologically productive zone is accounted for with the biologically-induced BOD parameter.

Vertical Diffusion Coefficients

The diffusion coefficient can be thought of as the rate at which a drop of dye spreads out in the vertical plane, in units of square centimeters per second. This value ranges from 0.01 to 1.0 cm^2/s in the hypolimnion zone, and from 1.0 to 100.0 cm^2/s in the epilimnion zone (fig. 1). The model user specified both bottom (AMIN) and surface (AMAX) diffusion coefficients on Input Card 9. The computer program linearly interpolates between these two values to determine coefficients at other depths. For shallow (under 20 ft deep) well-mixed lakes or reservoirs these two diffusion coefficients should be specified having the same order of magnitude, and AMW may be between 1.0 and 100.0 cm^2/s.

Baca and Arnet (1976) give the following empirical equation for estimating a diffusion coefficient for a given depth as follows:

$$D_v = a_1 + a_2 V_w (d)^{-4.6(Z/d)} \qquad (3)$$

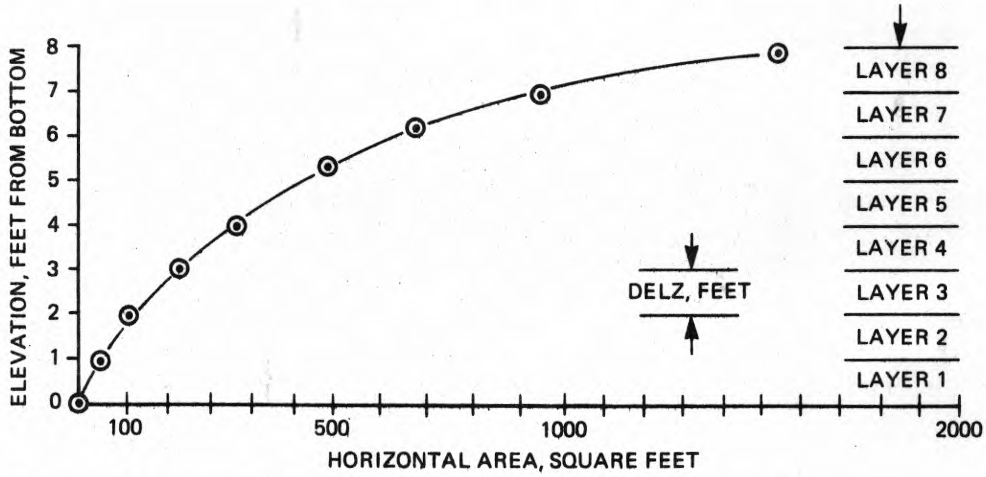

Figure 3.--Typical areas versus elevation curve.

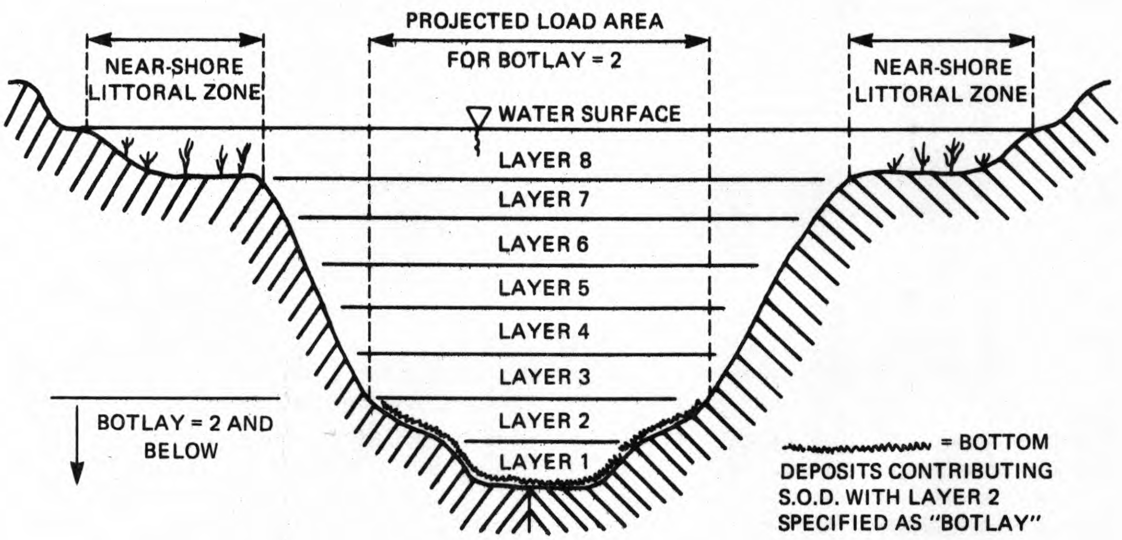

Figure 4.--Schematic of SOD loading bottom layers.

where

D_v = vertical diffusion coefficient, in square centimeters per second,
a_1, a_2 = empirical constants, in square centimeters per second and centimeters, respectively,
V_w = windspeed, in meters per second,
d = depth to thermocline, in meters,
and Z = depth at which diffusion coefficient is computed for, in meters.

Table 1 gives the values of a_1 and a_2 determined by Baca and Arnet (1976) through modeling studies.

An average depth to thermocline (d) in equation 3 ranges from 7 to 10 m. The actual thermocline depth depends on the sunlight penetration depth, the amount of incoming solar radiation, and the diffusion coefficient itself. The model user should check his output to verify that the thermocline is at the depth assumed to compute the diffusion coefficients.

In table 1 Lake Wingra is shown as having a maximum depth less than an average thermocline depth. In such a case, treat the maximum depth as the thermocline depth (d). With an assumed windspeed of 0.1 m/s, Lake Wingra has a bottom diffusion coefficient (AMIN) computed as:

$$D_v = (0.5) + (0.02)(0.1)(5)^{-4.6(5/5)} = 0.500 \text{ cm}^2/\text{s}$$

The surface diffusion coefficient (AMAX) is computed as:

$$D_v = (0.5) + (0.02)(0.1)(5)^{-4.6(0/5)} = 0.502 \text{ cm}^2/\text{s}$$

It can be seen that for shallow lakes, when windspeed is small, that the surface and bottom diffusion coefficients are identical for all intents and purposes. The user should select an average windspeed for the time period he wishes to simulate.

Solar Radiation Coefficients

All longwave radiation is considered to be absorbed in the top two ft of the water column. The percentage of shortwave radiation absorbed in the top two feet of water is specified by a user-supplied decimal fraction (BETA) given on Input Card 10. Typical values range from 0.6 to 0.8 with an average of 0.7 (Water Resources Research Labs, 1972). The remaining shortwave radiation penetrates further down as a function of the light extinction coefficient per foot (LAMBDA), also given on Input Card 10.

Table 1.--Values for empirical constants a_1 and a_2 for computing diffusion coefficients

Lake	Description	Maximum depth (m)	a_1 (cm^2/sec)	a_2 (cm)
American Falls	Well-mixed	18	0.1	0.01
Lake Washington	Stratified	65	0.01	0.001
Lake Mendota	Stratified	24	0.005	0.005
Lake Wingra	Well-mixed	5	0.5	0.02
Long Lake	Weak stratification	54	0.05	0.005

Specifying a large BETA value results in a warmer surface-water temperature and less heat being transmitted below. Specifying a small LAMBDA value results in shortwave radiation penetrating to greater depths, but does not increase the total amount of heat transmitted beneath the surface layer.

Typically, only 1 percent of the total incoming shortwave radiation penetrates to a depth of 10 m (32.8 ft). The amount of shortwave radiation penetrating to a given depth is given conceptually by the equation:

$$SW_{DEPTH} = SW_{IN} \times \exp\{-LAMBDA \times DEPTH\} \qquad (4)$$

where

SW_{DEPTH} = shortwave radiation penetrating to DEPTH, in BTU/ft^2 per day,
SW_{IN} = remaining shortwave radiation not absorbed at surface, in BTU/ft^2 per day,
exp = exponential to base 'e',
LAMBDA = light extinction coefficient, in units per foot,
and DEPTH = depth of concern, in feet.

The amount of shortwave radiation heat that enters a pool layer is computed as the shortwave radiation penetrating to the top of the layer, minus the shortwave radiation penetrating all the way to the bottom of the layer.

The light extinction coefficient (LAMBDA) depends primarily on water clarity. An empirical formula is given by Bierman (1976) as:

$$LAMBDA = 0.58/d_s + 0.052(TCROP) \qquad (5)$$

where

LAMBDA = light extinction coefficient per foot,
d_s = Secchi Disk depth, in meters,
and TCROP = total phytoplankton biomass, in units of milligrams dry weight per liter.

A liter grab sample of the lake or reservoir surface water should be taken at various locations to determine the average algae biomass concentration. Several Secchi Disk readings should also be made at various locations to determine an average Secchi depth value. Typical values of LAMBDA range from 0.15/ft to 0.60/ft. A "normal" value for a eutrophic impoundment ranges from 0.3 to 0.45/ft.

Surface-Water Entrainment

If surface-layer entrainment is specified as a nonzero decimal on Input Card 11, the flow entrained will be computed as a negative inflow to the surface layer and added to the density-determined inflow layer. This will be indicated on the detailed output tables as a negative inflow to the surface layer, with a like amount added to the inflow layer. If the surface layer is also the inflow layer, no change occurs.

Markofsky and Harleman (1971) suggest a value of 1.0 (100 percent) be specified for the entrainment percentage. In general, the contribution of heat to the reservoir depths by the entrainment process is small compared with the other heat transfer mechanisms, so the model is not sensitive to the heat value of the entrainment percentage. However, entrained surface water can be a major source of dissolved oxygen to deeper pool layers.

Suspended-Sediment Settling Rate

If suspended sediment is to be simulated (NQUAL = 3 on Input Card 3), then the user should specify a settling rate on Input Card 11 also. This is an average settling rate given in feet per day, and must be an even multiple of the DELZ value given on Input Card 5. Therefore, the sediment simulation is at best a crude approximation.

The settling rate can be determined using a sample water-sediment mixture and a fall tube, or estimated using a simplified Stokes Law equation:

$$V_s = 2.364 \times 10^{10} (d^2) \qquad (6)$$

where

V_s = settling rate, in feet per day,
and d = average particle size diameter, in feet.

Equation 6 assumes a sediment specific gravity of 2.65 and a water temperature of 20°C.

Oxygen-Depletion Parameters

If dissolved oxygen is to be simulated, then some or all of the parameters discussed below must be specified on Input Card 12.

Sediment Oxygen Demand

The loading rate for existing lakes or reservoirs can be determined using onsite respirometers that measure the drop in DO of a known volume of water sealed over a known bottom area. In this manner a loading rate in units of grams DO per square meter per day can be computed. Such field tests are expensive and time consuming, however.

Laboratory analysis for SOD loading rates is of questionable value. Rates will be too low if the bottom material sample is exposed to air or oxidizes before analysis begins. The loading rates will be too high if the sediment sample is disturbed and oxygen-demanding material is resuspended. Table 2 gives several onsite SOD loading rate comparisons and can be used to select on SOD loading rate in lieu of an actual onsite measurement.

The SOD loading rate input to the model must be corrected to 20°C using the equation:

$$SOD_{20} = SOD_T/(1.065)^{T-20} \qquad (7)$$

where

SOD_{20} = SOD loading rate corrected to 20°C,
SOD_T = SOD loading rate at temperature 'T',
and T = temperature, in degrees centigrade.

Surface Oxygen Transfer Zone

The DELTA value is used to specify the extent (depth) of the well-mixed surface oxygen zone. The percent oxygen saturation in this zone is specified by the PERSAT variable. The DELTA value should be specified large enough so that the DO concentration does not increase with depth due to higher cold water saturation values alone. Inspecting the model-computed DO versus depth profiles will reveal if this is occurring. Specifying too large a DELTA value results in an unrealistically large oxygen transfer. The PERSAT value typically ranges from 0.8 to 1.0 (80 to 100 percent saturation) and can be determined for existing lakes or reservoirs with a DO meter quite easily. If a field measurement of PERSAT indicates supersaturated oxygen conditions exist due to photosynthesis, set PERSAT equal to 100 percent. This is to reflect the average condition for the day, noting that oxygen-consuming plant respiration occurs at night. PERSAT values greater than 1.0 (100 percent) are not allowed by the program and will generate an internal error code given in Appendix B.

BOD Decay Rate (DKR)

This value can be determined for existing lakes or impoundments using BOD grab samples at various locations to determine an average value. The decay rate value can be computed using the USGS computer program G731 developed by Jennings and Bauer (1976). The decay rate can also be determined from BOD test observations by using the equation below:

$$DKR = -\ln \left[\frac{BOD_R}{BOD_5}\right] \frac{1}{DAYS} \qquad (8)$$

Table 2.--Comparison of various SOD loading rates determined onsite

Conditions	Average SOD load rate (grams/m^2/d) at 20°C
Shallow Oxbow lakes in Illinois[1] (average depth $\leq$ 2 feet)	
June	1.9
August	2.4
October	2.3
Eutrophic Swedish lakes with newly deposited dead algae cells[2] (three lakes - summer season)	4.6 5.4 2.9
Oligotrophic Swedish lakes[2] (two lakes - summer season)	1.2 0.73
Large river impoundment with cohesive muck bottom[3]	0.95
Green Bay, Wis. Estuary bottom sediments[3]	1.8
Oligotrophic Canadian lake during summer[4]	0.65

[1]From Butts and Evans (1979), Illinois lakes
[2]From Edeberg and Hofsten (1973), Swedish lakes
[3]From Wisconsin Department of Natural Resources (1978), Fox River study
[4]From Snodgrass and Holloran (1977), Gisborne Lake, Nova Scotia

where

DKR = BOD decay rate, per day,
ln = natural log, base 'e',
BOD_R = BOD remaining at time of observation, in milligrams per liter,
BOD_5 = total 5-day BOD determined by test, in milligrams per liter,
and $DAYS$ = number of days from start of test to observation time.

The DO of the BOD sample should be measured daily to determine the BOD remaining on that day. With a 5-day BOD test, four estimates of the decay rate can be computed using observations on the first four days. Use the average.

The greater the DKR values, the faster DO is depleted and BOD removed from the water. Typical DKR values range from 0.1 to 0.4 per day.

Biologic Productivity Induced BOD

The effects of decaying organic matter falling through the water column are accounted for using the PBOD parameter on Input Card 12. In practice, the PBOD parameter is used to calibrate the DO simulation. Typical PBOD values are on the order of from 0.1 to 2.0 {(mg/L)/d}. If SOD and BOD input are not used, the PBOD value is the only source of oxygen demand to the system.

Simulation Period

Up to 366 days (1 year) of input data can be stored in the program's memory at one time. However, it is unlikely that model parameters such as the light extinction coefficient, diffusion coefficients, and the oxygen depletion parameters would be valid during an entire year. Such parameters are seasonal in nature and should be adjusted for each season or month simulated.

The user can specify on Card 14 what period of the input data to use for the current set of parameters. This period can then be simulated and the end-of-period depth profiles recorded. New model parameters can then be specified for the next period of input data to be simulated, using the previous end-of-period depth profiles as the initial conditions for the next simulation period. In this manner the entire year can be simulated using seasonal periods with one simulation interval per season.

Shortwave Radiation, Equilibrium Temperature, and Thermal Exchange Coefficients

These values are a function of daily average atmospheric conditions. They can be calculated using the auxiliary HEAT EXCHANGE PROGRAM. The user manual is given in Appendix F. Necessary meteorologic input data can be obtained from most weather stations. CAUTION: Meteorologic data should be obtained from an appropriate weather station nearest to the study site. Transferring meteorologic data collected near an ocean or great lakes coast to an inland site has not proven satisfactory.

Water Inflow

Negative inflow values cannot be used to simulate the effects of evaporation. The program converts negative inflows to zero values. Flows must be specified in ft^3/s units.

Inflow Temperature

A continuous temperature recorder is needed to obtain daily average inflow temperature values. Numerous brands are available.

Dissolved Oxygen and BOD Inflow

The program calls for daily average inflow values of the DO and BOD concentrations. Daily average DO values can be obtained using a continuous DO recorder such as the Yellow Springs Instrument Company's model No. 56, which also includes a continuous temperature recorder. The recorder should be set up to monitor the inflow point to a proposed lake or reservoir. Daily BOD samples may be difficult, if not impossible, to collect. It is suggested that weekly BOD samples be made of the inflowing water, and a graphical curve interpolation be made between these points to fill in the intervening day's values. BOD should be sampled more frequently during periods of high runoff flows.

Suspended Sediment

The model's ability to account for suspended sediment was incorporated to simulate density-dependent turbidity currents that affect inflow mixing in the pool. Actual simulation of suspended-sediment dynamics is not intended and not recommended with this model. The model user should specify sediment concentrations so that the effects of density currents will be properly accounted for. The suspended sediment is assumed to have a specific gravity of 2.65 by the model.

Suspended-sediment concentrations will generally be higher during periods of high runoff. A detailed sediment data-collection program is not warranted for use in this model. Several typical seasonal sediment concentration values are all that is justified. Simply duplicate these values as daily inflows on Card Group 30 for appropriate time periods and discharge.

Outflow Hydrograph

The user must enter an outflow hydrograph on Card Group 32. The program does not route flows through the pool and outlet. For proposed impoundments with little storage and short retention times it is permissible to consider the outflow hydrograph to equal the inflow hydrograph. In such a case the user can simply duplicate Card Group 22 and use it as Card Group 32 as well.

This simplifying assumption is particularly attractive when considering proposed impoundments that do not have an outlet design or dimensions drawn up yet.

If the impoundment has a large storage potential and an outlet flow rating can be developed, then the inflow hydrograph should be routed through the pool to compute the outflow hydrograph. The USGS computer program A697, "Downstream-Upstream Reservoir Routing" developed by Jennings (1977) can be used to route the inflows through the pool.

Initial Profile Information

The user-specified initial conditions for temperature, DO, BOD, and suspended sediment on Cards 34 through 41 set depth profile values at the start of the simulation period. The initial conditions specified can have a significant effect on the simulation early period's results. Specification of large BOD concentrations in the pool may suppress dissolved oxygen beneath the surface zone for a considerable time. The initial profile conditions are very important when calibrating the model, and are discussed in the model calibration section of this manual.

If the user wishes to have a uniform value of temperature, DO, BOD, or suspended sediment within the water column at the simulation start, only one value should be entered on the appropriate data card.

However, if a depth-varying profile is desired the user must enter one value per layer on the appropriate data card. A value of zero can be entered for layers above the initial starting depth, but one value must be entered for each layer. The total number of layers is equal to the MAXLAY value specified on Card 4.

PROGRAM OUTPUT DISCUSSION

The output of the reservoir-lake model consists of the following items:

1. A listing of the input card data deck is printed if the user specifies PRINT INPUT on Card 2. It is advised to list the input deck to aid in debugging and calibrating the model.

2. A listing of the user-specified model control parameters is printed even if the input deck is not listed. Parameters listed include the NQUAL value, inflow entrainment fraction, number of pool layers, layer thickness, bottom elevation, withdrawal (outflow) layer, diffusion coefficients, surface heat absorption fraction, light extinction coefficient, data interval, and simulation interval. If DO is being simulated, the listing also includes the SOD affected layer limit, the SOD loading rate, the BOD decay rate, the biologic productivity induced BOD value, and the percent DO saturation of the surface transfer zone. The suspended-sediment settling rate is listed if the quality is being simulated.

3. Summary tables of daily pool elevation (feet), inflow temperature (°C), inflow quantity (cubic feet per second), release temperature (°C), and release quantity (cubic feet per second) are printed. If DO, BOD, or suspended sediment are simulated, then inflow and release concentration values are also listed for each day.

4. A detailed data table and a line printer plot is printed on user-specified days for the in-pool conditions. The data table gives elevation, depth, inflow, withdrawal, and temperature for each horizontal pool layer. If DO, SOD, BOD, or suspended sediment are simulated, then these concentrations are also listed in the data table. The line printer plot graphically displays these values for each layer in the form of a depth profile. The user may specify the range of the horizontal plot axis values on Card 16. The user may specify up to 14 detailed information days on Card 15. It is advised to have at least one detailed information day specified each month, as well as specifying the simulation period START and FINISH day numbers as detailed information days.

5. At the end of the simulation interval, a tabulation of all the daily water-quality release (outflow) values is printed. Therefore, there are final tabulations of the release water's temperature, DO concentration, BOD concentration, and suspended-sediment concentration if all those qualities are simulated. Such average daily release values are required input to stream water-quality models that could simulate downstream conditions.

An example of the program output is shown in Appendix E, for the input deck example shown in Appendix D.

MODEL CALIBRATION DISCUSSION

This section of the report is devoted to calibrating the model. To calibrate the model ideally, one would like to have an existing lake or reservoir to work with. If the model is to be used to study such an existing pool, the user could calibrate the model to existing conditions and then impose the hypothetical conditions to be studied on the model. This might be the case if the study were to compare changing a top-draw pool outlet to a bottom-draw outlet.

If the study was to investigate the probable effects of a proposed dam not yet built, the user should locate several nearby impoundments with similar conditions of size, depth, and inflow to that proposed. Sampling of these "similar" impoundments should be done to determine model parameters such as the light extinction coefficient, BOD decay rates, and others. Sample temperature and DO depth profiles should be made to aid in calibrating the model. Basically, one calibrates the model parameters using the "similar" impoundments and assumes that the calibrated parameters are applicable to the proposed impoundment.

The most important model parameters to calibrate are those that affect the temperature profile. This is because the model's mixing and heat transfer computations indirectly affect all other subroutines used in the model. If the heat transfer and mixing parameters are not calibrated correctly, the other simulated qualities in the model will not be valid.

The parameters that affect the temperature profile are the diffusion coefficients (AMAX, AMIN), the shortwave absorption fraction (BETA), and the light extinction coefficient (LAMBDA). Initial values for these parameters can be computed using the techniques outlined in the "Discussion of Input Data Requirements" section of this report. However, some adjustment of these parameters may be necessary to calibrate the model to observed conditions.

The model should be calibrated using a simulation interval where an initial and endpoint temperature profile is known. Using the initial profile and conditions, the model will hopefully be able to arrive at an end of simulation temperature profile similar to the one actually observed. If not, adjust the parameters until the simulated and observed profiles agree fairly well. No simulation is going to match the observed values perfectly, but the surface temperature and bottom temperatures should be fairly close to the observed values.

The effects of adjusting the heat transfer parameters are as follows.

Increasing the diffusion coefficients (AMAX, AMIN) results in a more uniform temperature profile, while decreasing them usually results in a greater difference between surface and bottom temperatures.

Increasing the shortwave absorption fraction (BETA) results in warming the top two ft of the pool water and cooling the underlying layers.

Decreasing the light extinction coefficient (LAMBDA) results in more heat being input directly into deeper pool layers than before. However, when doing so, the upper pool layers will be somewhat cooler than before.

Increasing the light extinction coefficient results in warming the surface pool layers and cooling those at greater depths.

Once the parameters affecting temperature are calibrated, the user can calibrate the oxygen depletion parameters if DO is to be simulated. These parameters are primarily the surface oxygen transfer zone (DELTA) value and the biologic productivity induced BOD contribution (PBOD) value.

Increasing the depth of the surface oxygen transfer zone puts more DO deeper into the pool. Increasing the biologic productivity (PBOD) value will decrease the DO concentration of all nonsurface zone layers and increase the BOD concentration of all nonsurface zone layers.

An increase in the BOD decay rate (DKR) will decrease the DO concentration of all nonsurface zone layers and also decrease the BOD concentration of all pool layers.

The surface oxygen transfer zone layers are essentially only affected by the user-specified percent of DO saturation (PERSAT) value. Any BOD concentration in this zone is quickly oxidized and removed. The PERSAT value should be based on actually measured surface DO values if possible.

As with temperature, the best way to calibrate the DO simulation is to use a simulation interval with known initial and endpoint DO depth profiles. Adjust the oxygen depletion parameters until the simulated profile at the endpoint agrees with that observed reasonably well.

BOD and suspended-sediment profiles should not be used to calibrate the model. Correct BOD and suspended-sediment profiles are a byproduct of correctly calibrated DO and temperature parameters. For the purposes of calibration and simulation, the initial profile conditions of BOD and suspended sediment can be set equal to zero or some other uniform value determined from samples within the pool.

In the case of deep lakes or impoundments the role of surface-water entrainment by plunging inflow may play an important role in transporting DO to deeper pool layers. In such a case the Inflow Entrainment Fraction (GAMMA) value may have to be considered along with the other DO parameters during calibration.

If this model cannot be calibrated reasonably well, it probably indicates the inadequacy of using a one-dimensional model to simulate the impoundment or lake under consideration. In such a case a two- or three-dimensional model will be required to simulate the water body under consideration.

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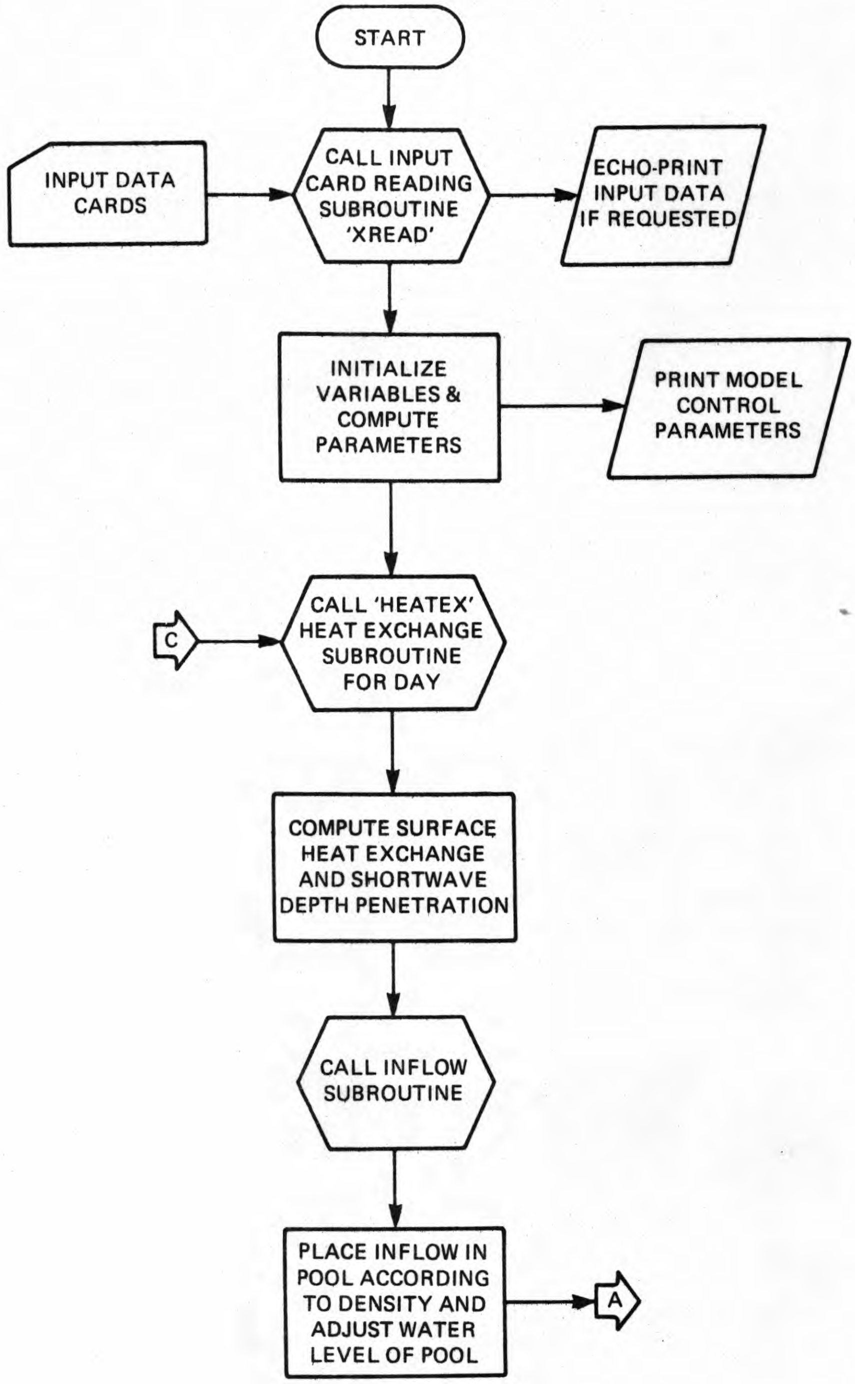
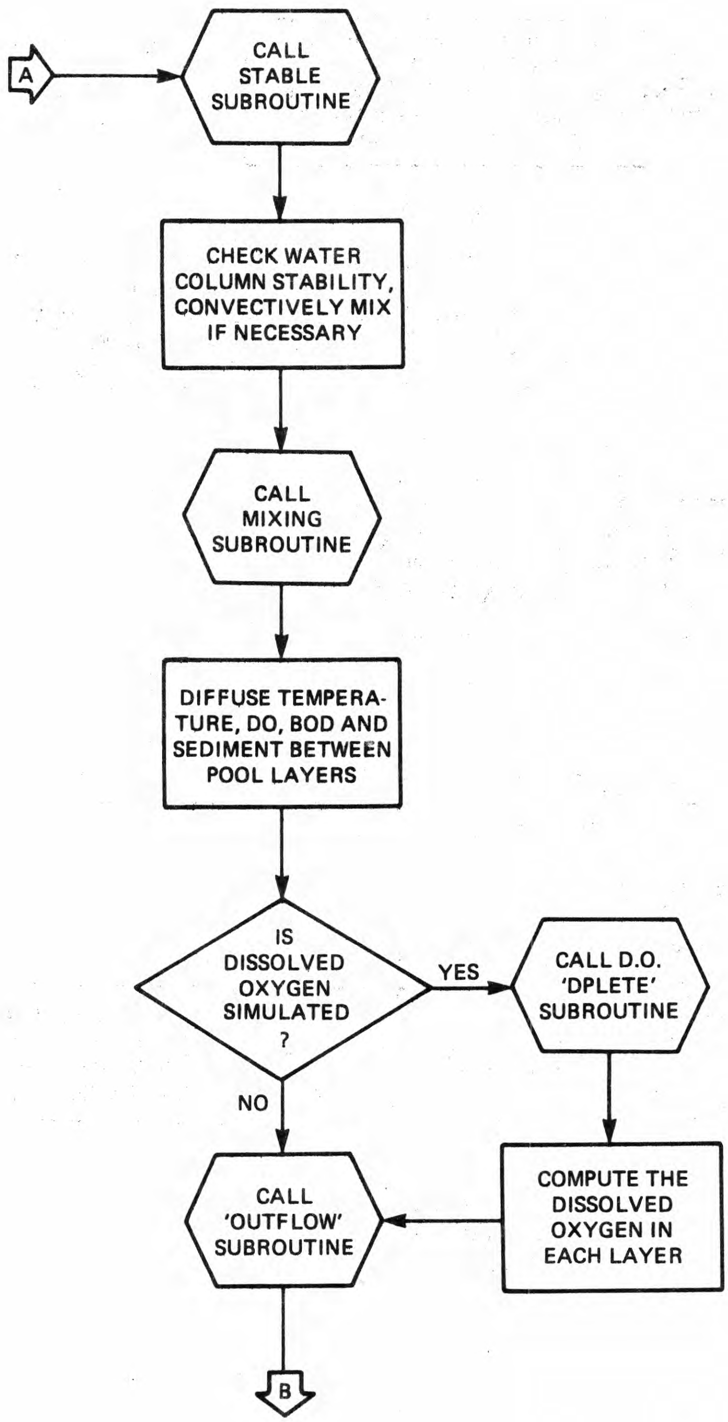
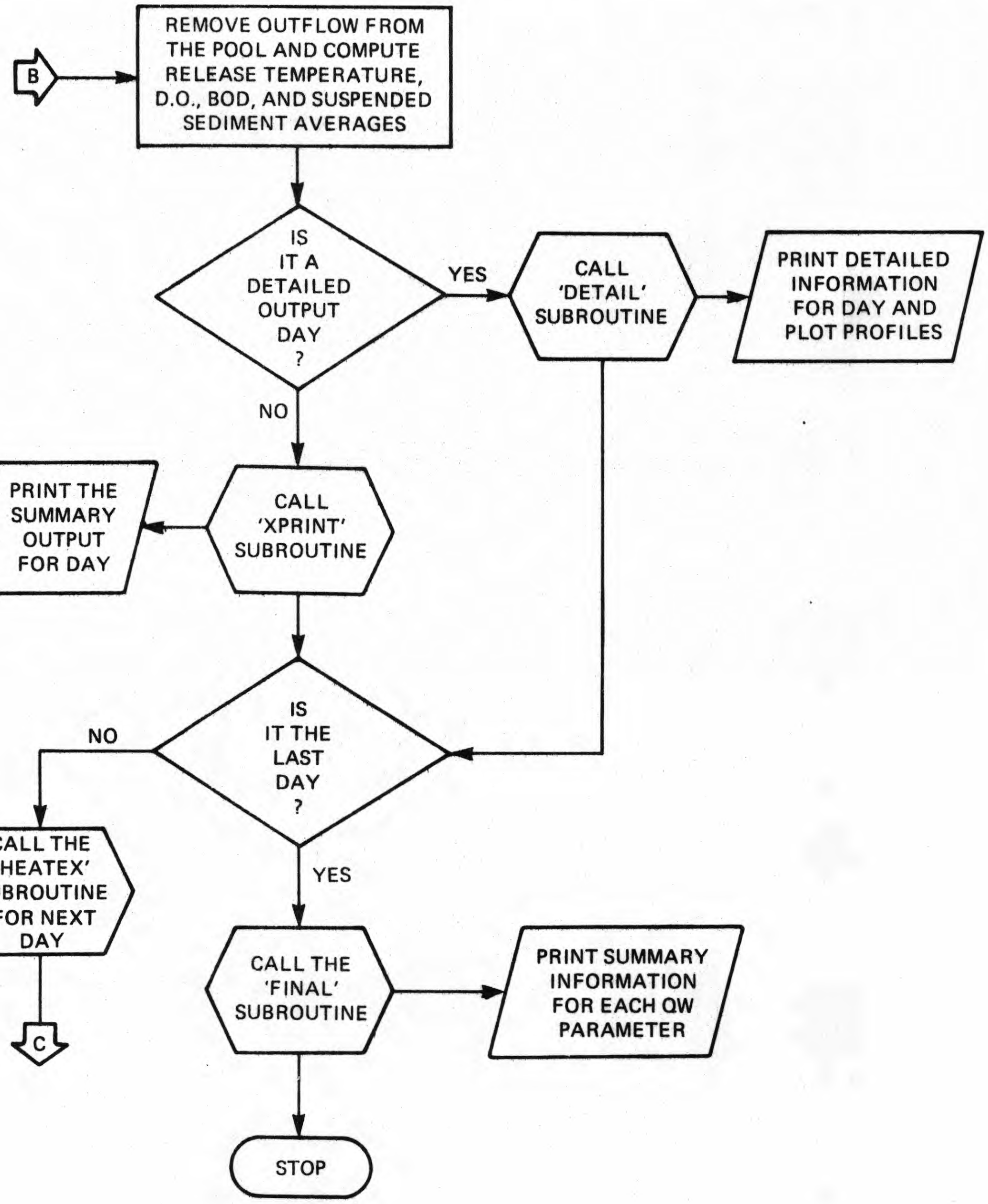
APPENDIX A.--RESERVOIR-LAKE MODEL FLOW CHART

Figure 5




A
CALL STABLE SUBROUTINE
CHECK WATER COLUMN STABILITY, CONVECTIVELY MIX IF NECESSARY
CALL MIXING SUBROUTINE
DIFFUSE TEMPERATURE, DO, BOD AND SEDIMENT BETWEEN POOL LAYERS
IS DISSOLVED OXYGEN SIMULATED ?
YES
CALL D.O. 'DPLETE' SUBROUTINE
COMPUTE THE DISSOLVED OXYGEN IN EACH LAYER
NO
CALL 'OUTFLOW' SUBROUTINE
B


B
REMOVE OUTFLOW FROM THE POOL AND COMPUTE RELEASE TEMPERATURE, D.O., BOD, AND SUSPENDED SEDIMENT AVERAGES
IS IT A DETAILED OUTPUT DAY ?
YES
CALL 'DETAIL' SUBROUTINE
PRINT DETAILED INFORMATION FOR DAY AND PLOT PROFILES
NO
CALL 'XPRINT' SUBROUTINE
PRINT THE SUMMARY OUTPUT FOR DAY
IS IT THE LAST DAY ?
NO
CALL THE 'HEATEX' SUBROUTINE FOR NEXT DAY
C
YES
CALL THE 'FINAL' SUBROUTINE
PRINT SUMMARY INFORMATION FOR EACH QW PARAMETER
STOP

APPENDIX B.--Reservoir-Lake Model Debugging Topics

If the SRM fails to execute, or executes incompletely, it may be due to missing data cards or cards coded improperly. In this case a 'STOP N' statement may be generated in the Job Control Language processing printout, or 'N' may be listed as a User Completion or Condition Code following the program's termination. The value of 'N' refers to which Input Card has its CHECK variable coded improperly, is missing, or is out of sequence. The reference list is given below:

N = 220 refers to Input Card 3; CHECK variable code must be QUAL.

N = 240 refers to Input Card 4; CHECK variable code must be LAYE.

N = 250 refers to Input Card 5; CHECK variable code must be THIC.

N = 260 refers to Input Card 6; CHECK variable code must be BOTT.

N = 265 refers to Input Card 7; CHECK variable code must be VOLU.

N = 370 refers to Input Card 9; CHECK variable code must be DIFF.

N = 375 refers to Input Card 10; CHECK variable code must be HEAT.

N = 400 refers to Input Card 11; CHECK variable code must be ENTR.

N = 405 refers to Input Card 12; CHECK variable code must be DEPL. Card 12 is only used when NQUAL $\geq$ 1.

N = 420 refers to Input Card 13; CHECK variable code must be INTE.

N = 430 refers to Input Card 14; CHECK variable code must be SIMU.

N = 450 refers to Input Card 15; CHECK variable code must be PRIN.

N = 460 refers to Input Card 16; CHECK variable code must be PLOT.

N = 470 refers to Input Card 17; CHECK variable code must be EQUI.

N = 475 refers to Input Card 19; CHECK variable code must be EXCH.

N = 520 refers to Input Card 21; CHECK variable code must be INFL.

N = 530 indicates that unrecognized inflow units were coded on Card 21.

N = 540 refers to Input Card 23; CHECK variable code must be TEMP.

N = 550 indicates that unrecognized temperature units were coded on Card 23.

N = 560 refers to Input Card 25, 27, or 29; CHECK variable code must be QUAL on these cards.

N = 565 refers to Input Card 31; CHECK variable code must be OUTF.

N = 570 indicates that unrecognized outflow units were coded on Card 31.

N = 630 refers to Input Card 33; CHECK variable code must be DEPT.

N = 640 refers to Input Card 34; CHECK variable code must be TEMP.

N = 650 refers to Input Card 36, 38, or 40; CHECK variable code must be QUAL on these cards.

INPUT PARAMETER PROBLEMS - Several 'STOP N' codes may be generated by a program failure due to problems with user-specified input parameters. These are:

STOP 1000 - This code indicates that the layer thickness (DELZ) specified is too small for the program to resolve. The solution is to specify a larger DELZ value on Input Card 5. This will also require entering new values for layer volumes on Card Group 8. Furthermore, the layer specifications made on Input Card 4 will have to be re-evaluated and possibly changed.

STOP 2000 - This code indicates that either the BETA value specified on Input Card 4 is greater than one, or that the LAMBDA value is equal or less than zero. Such values have no physical meaning and are not possible. See the discussion section on Solar Radiation Coefficients for further details.

STOP 5000 - This code indicates that more outflow was specified than actually exists in pool storage. The solution to this problem is to change the outflow on Card Group 32 to release less water. Make sure that you specified the correct units for the outflow on Input Card 31.

STOP 5010 - This code indicates that more inflow entered the pool layering configuration than there was volume available to store it. The solution to this problem is to raise the maximum number of layers specified on Card 4, and add their volumes to Card Group 8. You may need to specify a "dummy" layer for small impoundments that do not have enough storage to contain the day's entire inflow before releasing it.

STOP 6000 - This code indicates that the Percent Oxygen Saturation (PERSAT) variable on Input Card 12 is either less than zero or greater than 1.0 (100 percent). The user should specify a new value between 0.0 and 1.0.

Other Debugging Aids

Users are encouraged to use the PRINT INPUT option to get a list of their input deck. This can be very useful in locating input deck errors.

In addition, a list of the Input Parameters that drive the model is given in the output after the list of the input deck. These parameters should be verified to make sure they agree with the intended input values.

APPENDIX C.--Reservoir-Lake Model Fortran Listing

This appendix lists the fortran source deck for the Stratified Reservoir Model. The listing is broken down into program subroutines as follows:

BLOCK DATA - This subroutine sets the values of system control parameters such that they can be transferred to other subroutines via Common Blocks.

MAIN Program - The MAIN program sets daily values for computational parameters and calls the simulation subroutines.

XREAD - This subroutine reads all input data from the data card deck provided, and echo-prints it as output if requested.

CONVRT - This subroutine converts input data into the units needed for computation or output purposes.

INFLOW - This subroutine places inflow into the pool in a layer of similar density. Surface-water entrainment is accounted for, and the resulting mixed water-quality values are computed. The water surface is raised to account for the inflow volume entering.

HEATEX - This subroutine computes the surface heat exchange and shortwave radiation penetration in the pool. New water temperatures are computed for each layer.

MIXING - This subroutine mixes the pool water due to eddy diffusion and computes new temperature and water-quality values for each layer.

STABLE - This subroutine checks the pool's density profile for stability. If an instability exists, the water is mixed by convection currents until a stable profile evolves. New temperature and water-quality values are computed if a layer is mixed.

DEPLETE - This subroutine computes dissolved oxygen and biochemical oxygen demand values for each layer, if dissolved oxygen simulation is requested. Suspended sediment settling-out is also computed if requested.

OUTFLO - This subroutine withdraws outflow from the pool volume according to the specified withdrawal layer. The water surface of the pool is adjusted to reflect the removed volume. Average release flow temperature and water quality are computed for the day.

XFIRST - This subroutine prints the system control parameters specified by the user.

XPRINT - This subroutine prints daily summary information as output.

FINAL - This subroutine prints a summary table of daily release values of temperature and other simulated qualities for the entire simulation period.

DETAIL - This subroutine prints detailed output information tables for user-specified days.

PLOD - This subroutine plots depth profiles for the user-specified detailed output days.

```
                C  ONE-DIMENSIONAL RESERVOIR/LAKE MODEL                              00001000
                C  DEVELOPED FROM U.S. ARMY CORPS OF ENGINEERS 'WESTEX' MODEL        00002000
                C  BY LEO B. HOUSE, HYDROLOGIST, U.S. GEOLOGICAL SURVEY, WRD,        00003000
                C  WISCONSIN DISTRICT      (608) 262-2488, FTS = 262-2488            00004000
                C                                                                    00005000
                C                                                                    00006000
 0001                 BLOCK DATA                                                     00007000
 0002                 COMMON / A / ISURF,NQUAL,QUAL(3,60),SP(3)                      00008000
 0003                 COMMON / E / IFILE,LFILE,PFILE                                 00009000
 0004                 COMMON / H / DEPTH, MAXLAY, NIP, W, BOTLAY                     00010000
 0005                 DATA NIP / 1 /                                                 00011000
 0006                 DATA IFILE,LFILE / 05,06 /                                     00012000
 0007                 DATA SP / 1.0, 1.0, 2.65 /                                     00013000
 0008                 END                                                            00014000
```

```
0001            COMMON / A / ISURF, NQUAL, QUAL(3, 60), SP(3)
0002            COMMON / B / TEMP(60), HGT(60), VOL(60), TARGET
0003            COMMON / C / DEN(60), NUSURF, QDO, QBOD, QSED, DEMAND(60)
0004            COMMON / D / DELZ, BOTTOM, VEL(60), SETTLE, BOTOUT
0005            COMMON / E / IFILE,   LFILE, PFILE
0006            COMMON / F / NP, PAREA(15), PHGT(15)
0007            COMMON / G / FLOWIN(2), TEMPIN(2), QUALIN(2, 3), GAMMA
0008            COMMON / H / DEPTH, MAXLAY, NIP, W, BOTLAY
0009            COMMON / I / EK, ET, SHORT, BETA, LAMBDA
0010            COMMON / J / EVAP, AVTEMP, SUMOUT, WTHDRW(60), FLOW, VOLHGT
0011            COMMON / M / NDAY, PORT(3), PHLOW(3), OPEN
0012            COMMON / N / AMAX, AMIN
0013            COMMON / O / AVQUAL(3), AVGQ(366, 3), AVGT(366)
0014            COMMON / P / FIRST, LAST, TITLE(36), NJ, NM, INDEX(366)
0015            COMMON / Q / QVER, QOUTC, QINTC, QINCFS, QOCFS
0016            COMMON / R / INFLO(366, 2), INTEMP(366, 2), INQUAL(366, 2, 3)
0017            COMMON / T / EQTEMP(366), EXCOEF(366), SOLAR(366)
0018            COMMON / U / ENFLOW(60), SUMFLO(366), IPRINT (14),MAXT,MAXQ(3)
0019            COMMON / V / START, FINISH, QPUNCH, QPLOT, QGRAPH
0020            COMMON / W / QNKWAL, YEAR, SOD, DELTA, PERSAT, DKR, PBOD
0021            COMMON / X / QPRINT, ONE, TWO, QINMIX
0022            COMMON / Y / POOL(366)
0023            LOGICAL QVER, QOUTC, QINTC, QFIRST, QNP, QPLOT,
               *        QINCFS, QOCFS, QPUNCH, QPRINT, QNKWAL
0024            LOGICAL QDO, QGRAPH, QINMIX, QBOD, QSED
0025            INTEGER FIRST,YEAR, PFILE, W, BOTLAY
0026            INTEGER START, FINISH, ONE, TWO
0027            REAL   INTEMP, INQUAL, INFLO, LAMBDA
0028            EQUIVALENCE ( NDAY, N )
0029            DATA QFIRST / .TRUE. /
0030            DATA C1, C2 / - 3.9863, 508929.2 /
0031            DATA C3, C4 / 288.9414, 68.12963 /
0032            DENFUN ( T ) = 1. - ( T + C1 ) ** 2 / C2
               *                   * ( T + C3 ) / ( T + C4 )
0033      100   CONTINUE
0034            IF(.NOT.QFIRST) GO TO 110
0035            CALL XREAD
0036            QFIRST = .FALSE.
0037            IF(QBOD) GO TO 102
0038            DO 101 I = 1,MAXLAY
0039      101   QUAL(2,I) = 0.
0040      102   CONTINUE
0041            QNP = IPRINT(1) .LT. 0
0042            IF ( .NOT. QNP ) CALL XFIRST
0043            NF = NP + 1
0044      110   QFIRST = .FALSE.
0045            CALL CONVRT
          C
          C  DETERMINE THE NUMBER OF LAYERS
          C
0046            ISURF = 0.5 + DEPTH / DELZ
          C
          C  ESTABLISH PERCENTAGE EACH LAYER IS FILLED
          C
0047            DO 260 I = 1, ISURF
0048            HGT(I) = 1.
```

```
0049       260     CONTINUE                                                   00071000
0050               DO 270 I = ISURF, MAXLAY                                   00072000
0051               HGT(I) = 0.                                                00073000
0052       270     CONTINUE                                                   00074000
0053               HGT(ISURF) = ( DEPTH - DELZ * ( ISURF - 1 ) ) / DELZ       00075000
          C                                                                   00076000
          C  ESTABLISH INITIAL DENSITY PROFILE                                00077000
          C                                                                   00078000
0054               DO 290 I = 1, ISURF                                        00079000
0055               DENSQ = 0.                                                 00080000
0056               IF ( QNKWAL ) GO TO 285                                    00081000
0057               DO 280 J = 1, NQUAL                                        00082000
0058               DENSQ = DENSQ + QUAL(J, I) * ( 1. - 1. / SP(J) )           00083000
0059       280     CONTINUE                                                   00084000
0060               DENSQ = DENSQ * 1.E - 06                                   00085000
0061       285     CONTINUE                                                   00086000
0062               DENST = DENFUN ( TEMP(I) )                                 00087000
0063               DEN(I) = DENST + DENSQ                                     00088000
0064       290     CONTINUE                                                   00089000
          C                                                                   00090000
          C  INITIATE LOOP OF DAYS                                            00091000
          C                                                                   00092000
0065               DO 390 N = START, FINISH                                   00093000
0066               QPRINT = N .GE. ONE .AND. N .LE. TWO                       00094000
          C                                                                   00095000
          C  PREPARE HEAT EXCHANGE DATA FOR                                   00096000
          C  ONE DAY OF SIMULATION                                            00097000
          C                                                                   00098000
0067               ET = EQTEMP(N)                                             00099000
0068               EK = EXCOEF(N)                                             00100000
0069               SHORT = SOLAR(N)                                           00100500
          C                                                                   00101000
          C  PREPARE INFLOW DATA FOR                                           00102000
          C  ONE DAY OF SIMULATION                                            00103000
          C                                                                   00104000
0070               DO 340 L = 1, NIP                                          00105000
0071               FLOWIN(L) = INFLO(N, L)                                    00106000
0072               TEMPIN(L) = INTEMP(N, L)                                   00107000
0073               DO 330 J = 1, NQUAL                                        00108000
0074               QUALIN(L, J) = INQUAL(N, L, J)                             00109000
0075       330     CONTINUE                                                   00110000
0076       340     CONTINUE                                                   00111000
0077               SUMOUT = SUMFLO(N)                                         00112000
          C                                                                   00113000
          C  CALL THE SIMULATION SUBROUTINES                                  00114000
          C                                                                   00115000
0078               CALL HEATEX                                                00116000
0079               CALL INFLOW                                                00117000
0080               CALL STABLE                                                00118000
0081               CALL MIXING                                                00119000
0082               IF( QDO ) CALL DPLETE                                      00119600
0083               CALL OUTFLO                                                00120000
0084               CALL KONVRT                                                00122000
0085               IF ( .NOT. QNP ) CALL XPRINT                               00123000
          C                                                                   00124000
          C  SAVE RELEASE WATER QUALITY                                       00125000
```

```
             C  PARAMETER VALUES FOR POSTERITY                                        00126000
             C                                                                        00127000
 0086                  SUMFLO(N) = SUMOUT                                             00127500
 0087                  AVGT(N) = AVTEMP                                               00128000
 0088                  DO 380 J = 1, NQUAL                                            00129000
 0089                  AVGC(N, J) = AVQUAL(J)                                         00130000
 0090         380      CONTINUE                                                       00131000
 0091                  POOL(N) = DEPTH                                                00132000
 0092         390      CONTINUE                                                       00133000
 0093                  IF ( .NOT. GNP ) CALL FINAL                                    00134000
 0094                  END                                                            00135000
```

```
            C
0001                  SUBROUTINE XREAD
            C
            C  THIS SUBROUTINE READS ALL INPUT DATA
            C
0002                  COMMON / A / ISURF, NQUAL, QUAL(3, 60), SP(3)
0003                  COMMON / B / TEMP(60), HGT(60), VOLUME(60), TARGET
0004                  COMMON / C / DEN(60), NUSURF, QDO, QBOD, QSED
0005                  COMMON / D / DELZ, BOTTOM, V(60)   , SETTLE, BOTOUT
0006                  COMMON / E / IFILE,   LFILE, PFILE
0007                  COMMON / F / NP, PAREA(15), PHGT(15)
0008                  COMMON / G / FLOWIN(2), TEMPIN(2), QUALIN(2, 3), GAMMA
0009                  COMMON / H / DEPTH, MAXLAY, NIP, W, BOTLAY
0010                  COMMON / I / EK, ET, SHORT, BETA, LAMBDA
0011                  COMMON / J / EVAP, AVTEMP, SUMOUT, WTHDRW(60), FLOW, VOLHGT
0012                  COMMON / L / FGAREA, FGHGT, FGMAX, FGMIN, LPORT(15)
0013                  COMMON / M / NDAY, PORT(3), PHLOW(3), OPEN
0014                  COMMON / N / AMAX, AMIN
0015                  COMMON / O / AVCHEM(3), AVGQ(366, 3), AVGT(366)
0016                  COMMON / P / FIRST, LAST, TITLE(36), NJ, NM, INDEX(366)
0017                  COMMON / Q / QVER, QOUTC, QINTC, QINCFS, QOCFS
0018                  COMMON / R / INFLO(366, 2), INTEMP(366, 2), INQUAL(366, 2, 3)
0019                  COMMON / T / EQTEMP(366), EXCOEF(366), SOLAR(366)
0020                  COMMON / U / ENFLOW(60), SUMFLO(366), IPRINT (14),MAXT,MAXQ(3)
0021                  COMMON / V / START, FINISH, QPUNCH, QPLOT, QGRAPH
0022                  COMMON / W / QNKWAL, YEAR, SOD, DELTA, PERSAT, DKR, PBOD
0023                  COMMON / X / QPRINT, ONE, TWO, QINMIX
0024                  COMMON / Y / POOL(366)
0025                  REAL LAMBDA, INTEMP, INQUAL, INFLO
0026                  INTEGER FIRST,START,FINISH,PFILE,W,BOTLAY
0027                  LOGICAL QVAP, QVER, QFIRST, QOUTC, QPLOT, QINMIX,
                *            QPRINT, QPUNCH, QNKWAL, QINTC, QINCFS, QOCFS
0028                  LOGICAL QDO, QBOD, QSED
0029                  INTEGER CHECK, UNITS, DUMMY, TITLE, TYPE
0030                  DIMENSION DUMMY(20)
0031                  INTEGER XFILE, XSTOP, XPUNC, XPLOT, XBOTH, XGRAP,
                *            XPRED, XSINC, XVERI, XQUAL, XOXYG, XINFL,
                *            XLAYE, XTHIC, XBOTT, XVOLU, XWIDT, XPORT,
                *            XAREA, XHEIG, XMINI, XMAXI, XWETW, XSELM,
                *            XFLCO, XDIFF, XHEAT, XENTR, XWEIG, XINTE,
                *            XSIMU, XPRIN, XTARG, XFAHR, XCENT, BLANK,
                *            XEQUI, XEXCH, XSHOR, XFLOW, XKACF, XCFS,
                *            XTOTA, XOUTF, XDEPT, XTEMP, XDEPL, XEND,
                *            XMONT, XMIXI, BODCHK, XBIOL
0032                  DATA  XSTOP, XVOLU /  4HSTOP, 4HVOLU /
0033                  DATA XQUAL, XOXYG, XINFL / 4HQUAL, 4HOXYG, 4HINFL /
0034                  DATA XLAYE, XTHIC, XBOTT / 4HLAYE, 4HTHIC, 4HBOTT /
0035                  DATA XDIFF, XHEAT, XBIOL / 4HDIFF, 4HHEAT, 4HBIOL /
0036                  DATA XENTR,  XINTE / 4HENTR,  4HINTE /
0037                  DATA XSIMU, XPRIN, XPLOT / 4HSIMU, 4HPRIN, 4HPLOT /
0038                  DATA XFAHR, XCENT, BLANK / 4HFAHR, 4HCENT, 4H     /
0039                  DATA XEQUI, XEXCH, XSHOR / 4HEQUI, 4HEXCH, 4HSHOR /
0040                  DATA XFLOW, XKACF, XCFS  / 4HFLOW, 4HK-AC, 4HCFS  /
0041                  DATA XTOTA, XOUTF, XDEPT / 4HTOTA, 4HOUTF, 4HDEPT /
0042                  DATA XTEMP, XDEPL, XEND  / 4HTEMP, 4HDEPL, 4HEND  /
0043                  DATA QFIRST, QVAP / .TRUE., .FALSE. /
```

```
              C
              C  PROGRAM CONTROL PARAMETERS, READS CARDS 1 THRU 5
              C
 0044                   READ ( IFILE, 540 ) ( TITLE(M), M = 1, 18 )
 0045                   READ ( IFILE, 540 ) CHECK
 0046                   QPRINT = CHECK .EQ. XPRIN
 0047                   IF ( .NOT. QPRINT ) GO TO 130
 0048                   QPRINT = .FALSE.
 0049                   REWIND IFILE
 0050                   WRITE ( LFILE, 570 )
 0051                   LINE = 10
 0052           100     CONTINUE
 0053                   READ ( IFILE, 540 ) DUMMY
 0054                   WRITE ( LFILE, 580 ) LINE, DUMMY
 0055                   LINE = LINE + 10
 0056                   IF ( DUMMY(1) .NE. XEND  ) GO TO 100
 0057                   REWIND IFILE
 0058                   READ ( IFILE, 540 ) IJK
 0059                   READ ( IFILE, 540 ) IJK
 0060           130     CONTINUE
 0061                   READ ( IFILE, 590 ) CHECK, NQUAL
 0062                   IF ( CHECK .NE. XQUAL ) STOP 220
 0063                   QDO = NQUAL.GE.1
 0064                   QBOD = NQUAL.GE.2
 0065                   QSED = NQUAL.EQ.3
 0066                   QNKWAL = NQUAL .EQ. 0
 0067                   READ(IFILE,500) CHECK,MAXLAY,W,BOTLAY
 0068                   IF ( CHECK .NE. XLAYE ) STOP 240
 0069                   READ ( IFILE, 510 ) CHECK, DELZ
 0070                   IF ( CHECK .NE. XTHIC ) STOP 250
              C
              C  RESERVOIR GEOMETRY, READS CARDS 6 THRU CARD GROUP 8
              C
 0071                   READ ( IFILE, 510 ) CHECK, BOTTOM, BOTOUT
 0072                   IF ( CHECK .NE. XBOTT ) STOP 260
 0073                   READ ( IFILE, 510 ) CHECK
 0074                   IF ( CHECK .NE. XVOLU ) STOP 265
 0075                   READ ( IFILE, 530 ) (VOLUME(I), I = 1, MAXLAY )
              C
              C  INTERNAL PROCESSES, READS CARDS 9 THRU 12
              C
 0076                   READ ( IFILE, 510 ) CHECK, AMAX, AMIN
 0077                   IF ( CHECK .NE. XDIFF ) STOP 370
 0078                   READ(IFILE,510) CHECK,BETA,LAMBDA
 0079                   IF(CHECK.NE.XHEAT) STOP 375
 0080                   READ ( IFILE, 510 ) CHECK, GAMMA, SETTLE
 0081                   IF ( CHECK .NE. XENTR ) STOP 400
 0082                   IF ( QDO ) READ ( IFILE, 510 )
                    *            CHECK, SOD, DELTA,PERSAT,DKR,PBOD
 0083                   IF ( QDO .AND. CHECK .NE. XDEPL ) STOP 405
              C
              C  SIMULATION CONTROL DATA, READS CARDS 13 THRU 16
              C
 0084                   READ ( IFILE, 500 ) CHECK, FIRST, LAST, YEAR
 0085                   IF ( CHECK .NE. XINTE ) STOP 420
 0086                   READ ( IFILE, 500 ) CHECK, START, FINISH
```

```
0087            IF ( CHECK .NE. XSIMU ) STOP 430
0088            READ(IFILE,500) CHECK,(IPRINT(N),N=1,14)
0089            IF(CHECK.NE.XPRIN) STOP 450
0090            READ(IFILE,500) CHECK, MAXT, (MAXQ(I),I=1,3)
0091            IF(CHECK.NE.XPLOT) STOP 460
         C
         C  HEAT EXCHANGE DATA, READS CARDS 17 THRU 20B
         C
0092            READ ( IFILE, 600 ) CHECK
0093            IF ( CHECK .NE. XEQUI ) STOP 470
0094            READ ( IFILE, 530 ) ( EQTEMP(N), N = FIRST, LAST )
0095            READ ( IFILE, 600 ) CHECK
0096            IF ( CHECK .NE. XEXCH ) STOP 475
0097            READ ( IFILE, 530 ) ( EXCOEF(N), N = FIRST, LAST )
0098            READ( IFILE,510 ) CHECK
0099            IF( CHECK.NE.XSHOR ) STOP 500
0100            READ( IFILE,530 ) (SOLAR(N), N = FIRST, LAST )
         C
         C  INFLOW DATA, READS CARDS 21 THRU CARD GROUP 30
         C
0101            DO 210 L = 1, NIP
0102            READ ( IFILE, 560 ) CHECK, UNITS
0103            IF ( CHECK .NE. XFLOW .AND.
           *         CHECK .NE. XINFL ) STOP 520
0104            IF ( UNITS .NE. XKACF .AND.
           *         UNITS .NE. XCFS  .AND.
           *         UNITS .NE. BLANK ) STOP 530
0105            QINCFS = UNITS .NE. XFAHR
0106            READ ( IFILE, 530 ) ( INFLO(N, L), N = FIRST, LAST )
0107            READ ( IFILE, 560 ) CHECK, UNITS
0108            IF ( CHECK .NE. XTEMP ) STOP 540
0109            IF ( UNITS .NE. XFAHR .AND.
           *         UNITS .NE. XCENT .AND.
           *         UNITS .NE. BLANK ) STOP 550
0110            QINTC = UNITS .NE. XFAHR
0111            READ ( IFILE, 530 ) ( INTEMP(N, L), N = FIRST, LAST )
0112            IF ( QNKWAL ) GO TO 210
0113            DO 200 J = 1, NQUAL
0114            READ ( IFILE, 510 ) CHECK
0115            IF ( CHECK .NE. XQUAL ) STOP 560
0116            READ ( IFILE, 530 ) ( INQUAL(N, L, J), N = FIRST, LAST )
0117      200   CONTINUE
0118      210   CONTINUE
         C
         C  OUTFLOW DATA, READS CARDS 31 THRU 32
         C
0119      215   READ ( IFILE, 560 ) CHECK, UNITS
0120            IF ( CHECK .NE. XTOTA .AND.
           *         CHECK .NE. XOUTF ) STOP 565
0121            IF ( UNITS .NE. XKACF .AND.
           *         UNITS .NE. XCFS  .AND.
           *         UNITS .NE. BLANK ) STOP 570
0122            QOCFS = UNITS .NE. XKACF
0123            READ ( IFILE, 530 ) ( SUMFLO(N), N = FIRST, LAST )
         C
         C  INITIAL DEPTH AND TEMPERATURE, CARDS 33, 34, GROUP 35
```

```
C
            READ ( IFILE, 510 ) CHECK, DEPTH
            IF ( CHECK .NE. XDEPT ) STOP 630
            READ ( IFILE, 560 ) CHECK
            IF ( CHECK .NE. XTEMP ) STOP 640
            READ ( IFILE, 530 ) ( TEMP(I), I = 1, 8 )
            IF ( TEMP(2) .LE. 0. ) GO TO 260
            IF ( MAXLAY .LE. 8 ) GO TO 280
            READ ( IFILE, 530 ) ( TEMP(I), I = 9, MAXLAY )
            GO TO 280
  260       CONTINUE
            XYZ = TEMP(1)
            DO 270 I = 2, MAXLAY
            TEMP(I) = XYZ
  270       CONTINUE
  280       CONTINUE
C
C  INITIAL WATER QUALITY PROFILE CARDS 36 THRU 42
C
            IF ( QNKWAL ) GO TO 330
            DO 320 J = 1, NQUAL
            READ ( IFILE, 560 ) CHECK
            IF ( CHECK .NE. XQUAL ) STOP 650
            READ ( IFILE, 530 ) ( QUAL(J, I), I = 1, 8 )
            IF ( QUAL(J, 2) .LE. 0. ) GO TO 290
            IF ( MAXLAY .LE. 8 ) GO TO 310
            READ ( IFILE, 530 ) ( QUAL(J, I), I = 9, MAXLAY )
            GO TO 310
  290       CONTINUE
            XYZ = QUAL(J, 1)
            DO 300 I = 2, MAXLAY
            QUAL(J, I) = XYZ
  300       CONTINUE
  310       CONTINUE
  320       CONTINUE
  330       CONTINUE
            RETURN
  500       FORMAT ( A4, 6X, 14 I5 )
  510       FORMAT ( A4, 6X, ( 7F10.0 ) )
  520       FORMAT ( 16I5 )
  530       FORMAT ( 8F10.0 )
  540       FORMAT ( 20A4 )
  550       FORMAT ( 16F5.0 )
  560       FORMAT ( A4, 46X, A4, 6X, A4 )
  570       FORMAT ( 1H1 )
  580       FORMAT ( 10X, I6, 7X, 3H***, 20A4 )
  590       FORMAT ( A4, 6X, I5, 5X, 3 ( A4, 6X ) )
  600       FORMAT ( A4, 36X, I4 )
            END
```

```
                C
 0001                 SUBROUTINE CONVRT
                C
                C  CONVERT UNITS OF INPUT DATA TO (DEG-C)
                C  AND (K-ACRE FT/DAY).  CONVERT UNITS OF
                C  FLOW BACK TO (CFS) FOR PRINTOUT
                C
 0002                 COMMON / A / ISURF, NQUAL
 0003                 COMMON / D / DELZ, BOTTOM, VEL(60), SETTLE, ROTOUT
 0004                 COMMON / F / NP, PAREA(15), PHGT(15)
 0005                 COMMON / G / FLOWIN(2)
 0006                 COMMON / H / DEPTH, MAXLAY, NIP, W, BOTLAY
 0007                 COMMON / J / EVAP, AVTEMP, SUMOUT, WTHDRW(60), FLOW, VOLHGT
 0008                 COMMON / K / NWELL(15), FMAX(15), FMIN(15), SELMAX
 0009                 COMMON / L / FGAREA, FGHGT, FGMAX, FGMIN, LPORT(15)
 0010                 COMMON / M / NDAY, IPORT(3), PHLOW(3), OPEN
 0011                 COMMON / P / FIRST, LAST
 0012                 COMMON / Q / QVER, QOUTC, QINTC, QINCFS, QOCFS
 0013                 COMMON / R / INFLO(366, 2), INTEMP(366, 2), INQUAL(366, 2, 3)
 0014                 COMMON / S / OUTFLO(366, 15), TARG(366)
 0015                 COMMON / U / ENFLOW(60), SUMFLO(366)
 0016                 LOGICAL QVER, QOUTC, QINTC, QINCFS, QOCFS, QFIRST
 0017                 REAL INFLO, INTEMP, INQUAL
 0018                 INTEGER FIRST, OPEN
 0019                 DATA QFIRST / .TRUE. /
 0020                 DATA FACTOR / 1.98E - 03 /
 0021                 DATA SMALL / 1.E - 10 /
 0022                 IF ( .NOT. QFIRST ) GO TO 130
 0023                 QFIRST = .FALSE.
 0024                 NF = NP
                C
                C  IF INFLOW QUANTITIES ARE IN (CFS)
                C  THEN CONVERT TO (K-ACRE FT/DAY)
                C
 0025             130     IF ( .NOT. QINCFS ) GO TO 150
 0026                 DO 140 N = FIRST, LAST
 0027                 DO 140 L = 1, NIP
 0028                 INFLO(N, L) = INFLO(N, L) * FACTOR
 0029            140  CONTINUE
 0030            150  CONTINUE
                C
                C  IF INFLOW TEMPERATURES ARE IN
                C  (DEG-F) THEN CONVERT TO (DEG-C)
                C
 0031                 IF ( QINTC ) GO TO 170
 0032                 DO 160 N = FIRST, LAST
 0033                 DO 160 L = 1, NIP
 0034                 INTEMP(N, L) = 5. / 9. * ( INTEMP(N, L) - 32. )
 0035            160  CONTINUE
 0036            170  CONTINUE
                C
                C  ZERO ANY NEGATIVE INFLOW
                C  TEMPERATURES AND QUANTITIES
                C
 0037                 DO 180 N = FIRST, LAST
 0038                 DO 180 L = 1, NIP
```

```
0039            IF ( INFLO(N, L) .LT. SMALL ) INFLO(N, L) = 0.          00406000
0040            IF ( INTEMP(N, L) .LT. 0. ) INTEMP(N, L) = 0.           00407000
0041      180   CONTINUE                                                00408000
         C                                                              00409000
         C                                                              00409010
         C  CONVERT BOTTOM OUTFLOW TO K-ACRE FT/DAY                     00409020
         C                                                              00409030
0042            BOTOUT = BOTOUT * FACTOR                                00409040
         C                                                              00409050
         C  IF OUTFLOW QUANTITIES ARE IN (CFS)                          00410000
         C  THEN CONVERT TO (K-ACRE FT/DAY)                             00411000
         C                                                              00412000
0043            IF ( .NOT. GOCFS ) GO TO 220                            00413000
0044            DO 190 N = FIRST, LAST                                  00414000
0045            SUMFLO(N) = SUMFLO(N) * FACTOR                          00415000
0046      190   CONTINUE                                                00416000
0047      220   CONTINUE                                                00417000
0048            RETURN                                                  00418000
0049            ENTRY KONVRT                                            00419000
         C                                                              00420000
         C  CONVERT FLOWS FROM (K-ACRE FT/DAY)                          00421000
         C  TO (CFS) FOR PRINTOUT                                       00422000
         C                                                              00423000
0050            SUMOUT = SUMOUT / FACTOR                                00424000
0051            DO 240 L = 1, NIP                                       00425000
0052            FLOWIN(L) = FLOWIN(L) / FACTOR                          00426000
0053      240   CONTINUE                                                00427000
0054            DO 260 I = 1, MAXLAY                                    00428000
0055            WTHDRW(I) = WTHDRW(I) / FACTOR                          00429000
0056            ENFLOW(I) = ENFLOW(I) / FACTOR                          00430000
0057      260   CONTINUE                                                00431000
0058            RETURN                                                  00432000
0059            END                                                     00433000
```

```
              C
0001                    SUBROUTINE INFLOW
              C
              C  PLACE INFLOW QUANTITY AND QUALITY
              C  INTO LAKE AT LEVEL OF INFLOW DENSITY
              C  CALCULATE RE-DISTRIBUTION OF
              C  LAYERS DUE TO INFLOW PROCESS
              C
0002                    COMMON / A / ISURF, NQUAL, QUAL(3, 60), SP(3)
0003                    COMMON / B / TEMP(60), HGT(60), VOLUME(60)
0004                    COMMON / C / DEN(60), NUSURF, QDO, QBOD, QSED
0005                    COMMON / D / DELZ
0006                    COMMON / E / IFILE,   LFILE
0007                    COMMON / G / FLOWIN(2), TEMPIN(2), QUALIN(2, 3), GAMMA
0008                    COMMON / H / DEPTH, MAXLAY, NIP
0009                    COMMON / M / NDAY
0010                    COMMON / U / ENFLOW(60)
0011                    COMMON / W / QNKWAL
0012                    COMMON / X / QPRINT, ONE, TWO
0013                    LOGICAL QDO, QBOD, QSED
0014                    REAL INFLO, INLAY, INFLOE
0015                    LOGICAL QPRINT, QNKWAL, QXYZ
0016                    DIMENSION UPQUAL(3), QMIX(3), QVMIX(3), INLAY(60)
0017                    DATA C1, C2 / - 3.9863, 508929.2 /
0018                    DATA C3, C4 / 288.9414, 68.12963 /
0019                    DENFUN ( T ) = 1. - ( T + C1 ) ** 2 / C2
                   *                   * ( T + C3 ) / ( T + C4 )
              C
              C  INITIALIZE FLOW INTO EACH LAYER
              C
0020                    DO 100 I = 1, MAXLAY
0021                    ENFLOW(I) = 0.
0022           100      CONTINUE
0023                    DO 330 L = 1, NIP
0024                    INFLO = FLOWIN(L)
0025                    IF ( INFLO .LE. 0. ) GO TO 330
              C
              C  CALCULATE MIXED TEMPERATURES AND
              C  QUALITIES OF ENTRAINED VOLUME
              C
0026                    ENTFLO = GAMMA * INFLO
0027                    SUMFLO = INFLO + ENTFLO
0028                    FLOW = ENTFLO
              C
              C*  INITIALIZE MIXED QUALITIES
              C
0029                    TVMIX = 0.
0030                    IF ( QNKWAL ) GO TO 110
0031                    DO 105 J = 1, NQUAL
0032                    QVMIX(J) = 0.
0033           105      CONTINUE
0034           110      CONTINUE
              C
              C*  LOWER SURFACE TO ACCOUNT FOR ENTRAINMENT
              C
0035                    DO 170 I = 1, ISURF
```

```
              K = ISURF - I + 1
              VOLHGT = VOLUME(K) * HGT(K)
              IF ( FLOW .GE. VOLHGT ) GO TO 140
              TVMIX = TVMIX + TEMP(K) * FLOW
              ENFLOW(K) = ENFLOW(K) - FLOW
              IF ( QNKWAL ) GO TO 130
              DO 120 J = 1, NQUAL
              QVMIX(J) = QVMIX(J) + QUAL(J, K) * FLOW
    120       CONTINUE
    130       CONTINUE
              DEPTH = DELZ * ( K - 1 + HGT(K) - FLOW / VOLUME(K) )
              HGT(K) = DEPTH / DELZ - ( K - 1 )
              GO TO 180
    140       CONTINUE
              TVMIX = TVMIX + TEMP(K) * VOLHGT
              ENFLOW(K) = ENFLOW(K) - VOLHGT
              IF ( QNKWAL )  GO TO 160
              DO 150 J = 1, NQUAL
              QVMIX(J) = QVMIX(J) + QUAL(J, K) * VOLHGT
    150       CONTINUE
    160       CONTINUE
              HGT(K) = 0.
              FLOW = FLOW - VOLHGT
    170       CONTINUE
              IF(HGT(1).LE.0.0) ENTFLO = ENTFLO - FLOW
              SUMFLO = ENTFLO + INFLO
    180       CONTINUE
              ISURF = K
C
C  CALCULATE MIXED QUALITIES OF
C  ENTRAINED VOLUME AND INFLOW QUANTITY
C
              TVMIX = TVMIX + INFLO * TEMPIN(L)
              IF ( QNKWAL ) GO TO 200
              DO 190 J = 1, NQUAL
              QVMIX(J) = QVMIX(J) + INFLO * QUALIN(L, J)
    190       CONTINUE
    200       CONTINUE
              TMIX = TVMIX / SUMFLO
              IF ( QNKWAL ) GO TO 220
              DO 210 J = 1, NQUAL
              QMIX(J) = QVMIX(J) / SUMFLO
    210       CONTINUE
    220       CONTINUE
C
C  CALCULATE DENSITY OF INFLOW
C
              DENST = DENFUN ( TMIX )
              DENSQ = 0.
              IF ( QNKWAL ) GO TO 240
              DO 230 J = 1, NQUAL
              DENSQ = DENSQ + QMIX(J) * ( 1. - 1. / SP(J) )
    230       CONTINUE
              DENSQ = DENSQ * 1.E - 06
    240       CONTINUE
              DENMIX = DENST + DENSQ
```

```
             C                                                                    00546000
             C  DETERMINE LAYER OF INFLOW                                         00547000
             C                                                                    00548000
 0085                 DO 250 I = 1, ISURF                                         00549000
 0086                 INFLAY = I                                                  00550000
 0087                 IF ( DENMIX .GT. DEN(I) ) GO TO 260                         00551000
 0088          250    CONTINUE                                                    00552000
 0089                 INFLAY = ISURF                                              00553000
 0090          260    CONTINUE                                                    00554000
             C                                                                    00555000
             C  INITIALIZE INPUT INTO INFLOW LAYER                                00556000
             C                                                                    00557000
 0091                 UPFLOW = 0.                                                 00558000
 0092                 DO 270 I = 1, MAXLAY                                        00559000
 0093                 INLAY(I) = 0.                                               00560000
 0094          270    CONTINUE                                                    00561000
 0095                 INLAY(INFLAY) = SUMFLO                                      00562000
 0096                 ENFLOW(INFLAY) = ENFLOW(INFLAY) + SUMFLO                    00563000
             C                                                                    00564000
             C  COMPUTE NEW TEMPERATURES AND QUALITY                              00565000
             C  VALUES FOR LAYERS ABOVE INFLOW LAYER                              00566000
             C                                                                    00567000
 0097                 SUMIN = 0.                                                  00567500
 0098                 I = INFLAY - 1                                              00568000
 0099          290    CONTINUE                                                    00569000
 0100                 I = I + 1                                                   00570000
 0101                 IF ( I .GT. MAXLAY ) STOP 5010                              00571000
 0102                 INFLOE = INLAY(I)                                           00572000
 0103                 VOLHGT = VOLUME(I) * HGT(I)                                 00573000
 0104                 SUMVOL = UPFLOW + INFLOE + VOLHGT                           00574000
 0105                 TEMP(I) = ( UPFLOW * UPTEMP + VOLHGT * TEMP(I) +            00575000
                *                   INFLOE * TMIX ) / SUMVOL                      00576000
 0106                 UPTEMP = TEMP(I)                                            00577000
 0107                 IF ( QNKWAL ) GO TO 310                                     00578000
 0108                 DO 300 J = 1, NQUAL                                         00579000
 0109                 QUAL(J, I) = ( UPFLOW * UPQUAL(J) + VOLHGT * QUAL(J, I) +   00580000
                *                      INFLOE * QMIX(J) ) / SUMVOL                00581000
 0110                 UPQUAL(J) = QUAL(J, I)                                      00582000
 0111          300    CONTINUE                                                    00583000
 0112          310    CONTINUE                                                    00584000
 0113                 UPVOL = UPFLOW + INFLOE + VOLHGT - VOLUME(I)                00585000
 0114                 SUMIN = SUMIN + VOLUME(I)                                   00585100
 0115                 IF(SUMIN.LE.SUMFLO ) GO TO 314                              00585200
 0116                 IF(SUMIN.GT.SUMFLO) ENFLOW(I) = SUMFLO - ( SUMIN - VOLUME(I) ) 00585300
 0117                 IF(SUMIN.GE.SUMFLO + VOLUME(I)) ENFLOW(I) = 0.              00585400
 0118                 GO TO 315                                                   00585500
 0119          314    ENFLOW(I) = VOLUME(I)                                       00585600
 0120          315    CONTINUE                                                    00585700
 0121                 IF ( UPVOL .LE. 0. ) GO TO 320                              00586000
 0122                 UPFLOW = UPVOL                                              00587000
 0123                 HGT(I) = 1.                                                 00588000
 0124                 GO TO 290                                                   00589000
 0125          320    CONTINUE                                                    00590000
             C                                                                    00591000
             C  CALCULATE NEW WATER SURFACE AFTER INFLOW                           00592000
             C                                                                    00593000
```

```
 0126                ISURF = I                                                        00594000
 0127                HGT(ISURF) = HGT(I) + (UPFLOW + INFLOE) / VOLUME(ISURF)          00595000
 0128          330   CONTINUE                                                         00596000
 0129                DEPTH = DELZ * ( ISURF - 1 + HGT(ISURF) )                        00597000
 0130                IF ( QPRINT ) WRITE ( LFILE, 500 ) NDAY                          00599000
 0131                IF ( QPRINT ) WRITE ( LFILE, 510 )                               00600000
                *                      ( I, HGT(I), I = 1, MAXLAY )                   00601000
 0132                IF ( QPRINT ) WRITE ( LFILE, 520 ) ISURF, HGT(ISURF)             00602000
 0133                RETURN                                                           00603000
 0134          500   FORMAT ( /// 5X, 6HDAY - , I3, 5X, 12HAFTER INFLOW )             00604000
 0135          510   FORMAT ( /// ( 8 ( 5X, I2, 2X, F6.1 ) ) )                        00605000
 0136          520   FORMAT ( 5X, 'ISURF = ',I2,5X,'PERCENT FILLED = ', F5.3 )        00606000
 0137                END                                                              00607000
```

```
              C
0001                    SUBROUTINE HEATEX
              C
              C  THIS SUBROUTINE COMPUTES SURFACE HEAT TRANSFER AND
              C  SHORTWAVE RADIATION PENETRATION IN THE POOL
              C
0002                    COMMON / A / ISURF, NQUAL, QUAL(3, 60), SP(3)
0003                    COMMON / B / TEMP(60), HGT(60), VOLUME(60), TARGET
0004                    COMMON / D / DELZ
0005                    COMMON / E / IFILE,   LFILE
0006                    COMMON / I / EK, ET, SHORT, BETA, LAMBDA
0007                    COMMON / H / DEPTH
0008                    COMMON / M / NDAY
0009                    COMMON / X / QPRINT
0010                    DIMENSION HEAT(60)
0011                    REAL LAMBDA
0012                    LOGICAL QPRINT, QFIRST, QFEET, QMETR
0013                    DATA QFEET, QMETR / .TRUE., .FALSE. /
0014                    DATA RHO / 62.4 /
              C
              C  ESTABLISH DEPTH IN WHICH SURFACE
              C  HEAT EXCHANGE TAKES PLACE
              C
0015                    IF ( QFEET ) HDEPTH = 2.
0016                    IF ( QMETR ) HDEPTH = 0.6096
0017           100      CONTINUE
              C
              C  COMPARE SURFACE HEAT EXCHANGE
              C  DEPTH TO THICKNESS OF TOP LAYER
              C
0018                    THETA = 9. / 5. * TEMP(ISURF) + 32.
0019                    HTOTAL = EK * ( ET - THETA )
0020                    HDOWN = (1. - BETA) * SHORT
0021                    TOP = HGT(ISURF) * DELZ
0022                    IF ( TOP .GE. HDEPTH ) GO TO 110
0023                    IF ( TOP .LT. HDEPTH ) GO TO 120
0024           110      CONTINUE
              C
              C  COMPUTE HEAT TRANSFER INTO
              C  A LARGE SURFACE LAYER
              C
0025                    HSURF = HTOTAL - HDOWN
0026                    EXTRA = HDOWN * ( EXP ( - LAMBDA * HDEPTH ) -
                  *               EXP ( - LAMBDA * TOP ) )
0027                    HEAT(ISURF) = HSURF + EXTRA
0028                    BNEXT = TOP
0029                    HDOWN = HDOWN - EXTRA
0030                    ISM = ISURF - 1
0031                    GO TO 150
0032           120      CONTINUE
              C
              C  COMPUTE SURFACE HEAT TRANSFER
              C  WITH A SMALL SURFACE LAYER
              C
0033                    IF ( TOP + DELZ .GT. HDEPTH ) GO TO 130
0034                    IF ( TOP + 2. * DELZ .GE. HDEPTH ) GO TO 140
```

```
0035              STOP 1000
0036        130   CONTINUE
           C
           C  SURFACE HEAT DEPTH EXTENDS
           C  INTO SECOND LAYER
           C
0037              HEAT(ISURF) = ( HTOTAL - HDOWN ) * TOP / HDEPTH
0038              HSM1 = ( HTOTAL - HDOWN ) * ( 1. - TOP / HDEPTH )
0039              BNEXT = TOP + DELZ
0040              EXTRA = HDOWN * ( EXP ( - LAMBDA * HDEPTH ) -
                *         EXP ( - LAMBDA * BNEXT ) )
0041              HEAT(ISURF - 1) = HSM1 + EXTRA
0042              HDOWN = HDOWN - EXTRA
0043              ISM = ISURF - 2
0044              GO TO 150
0045        140   CONTINUE
           C
           C  SURFACE HEAT DEPTH EXTENDS
           C  INTO THIRD LAYER
           C
0046              HEAT(ISURF) = ( HTOTAL - HDOWN ) * TOP / HDEPTH
0047              HEAT(ISURF - 1) = ( HTOTAL - HDOWN ) * DELZ / HDEPTH
0048              HSM2 = ( HTOTAL - HDOWN ) * ( 1. - ( TOP + DELZ ) / HDEPTH )
0049              BNEXT = TOP + 2. * DELZ
0050              EXTRA = HDOWN * ( EXP ( - LAMBDA * HDEPTH ) -
                *         EXP ( - LAMBDA * BNEXT ) )
0051              HDOWN = HDOWN - EXTRA
0052              HEAT(ISURF - 2) = HSM2 + EXTRA
0053              ISM = ISURF - 3
0054        150   CONTINUE
           C
           C  COMPUTE HEAT TRANSFER
           C  INTO ALL OTHER LAYERS
           C
0055              HEAT(1) = HDOWN * EXP(-LAMBDA * (DEPTH-DELZ - BNEXT))
0056              DO 160 I = 2,ISM
0057              ZTOP = DEPTH - (I * DELZ) - BNEXT
0058              ZBOTT = DEPTH - (I * DELZ) + DELZ - BNEXT
0059              HEAT(I) = HDOWN * (EXP(-LAMBDA * ZTOP) - EXP(-LAMBDA * ZBOTT))
0060        160   CONTINUE
           C
           C  COMPUTE CHANGE OF TEMPERATURE IN EACH
           C  LAYER DUE TO SHORT WAVE PENETRATION
           C
0061              DO 180 I = 1, ISURF
0062              CHANGE = 5. / 9. * HEAT(I) / ( RHO * DELZ * HGT(I) )
0063              TEMP(I) = TEMP(I) + CHANGE
0064        180   CONTINUE
0065              IF ( QPRINT ) WRITE ( LFILE, 560 ) NDAY
0066              IF ( QPRINT ) WRITE ( LFILE, 540 )
                *                     ( I, TEMP(I), I = 1, ISURF )
0067              RETURN
0068        560   FORMAT ( /// 5X, 6HDAY - , I3, 5X, 10HAFTER HEAT )
0069        540   FORMAT ( /// ( 8 ( 5X, I2, 2X, F6.1 ) ) )
0070              END
```

```
      C
0001           SUBROUTINE MIXING
      C
      C  THIS SUBROUTINE DIFFUSES HEAT AND
      C  QUALITY CONSTITUENTS BETWEEN ALL
      C  ADJACENT LAYERS IN THE POOL
      C
0002           COMMON / A / ISURF, NQUAL, QUAL(3, 60), SP(3)
0003           COMMON / B / TEMP(60), HGT(60), VOLUME(60)
0004           COMMON / C / DEN(60)
0005           COMMON / D / DELZ
0006           COMMON / E / IFILE,   LFILE
0007           COMMON / H / DEPTH, MAXLAY
0008           COMMON / J / EVAP, AVTEMP, SUMOUT, WTHDRW(60), FLOW, VOLHGT
0009           COMMON / N / AMAX, AMIN
0010           COMMON / M / NDAY
0011           COMMON / W / QNKWAL
0012           COMMON / X / QPRINT
0013           INTEGER CYCLES
0014           LOGICAL QDOWN, QPRINT, QNKWAL
0015           DIMENSION ALPHA(60)
0016           DATA QDOWN / .TRUE. /
0017           DATA CYCLES / 3 /
0018           DATA C1, C2 / - 3.9863, 508929.2 /
0019           DATA C3, C4 / 288.9414, 68.12963 /
0020           DENFUN ( T ) = 1. - ( T + C1 ) ** 2 / C2
         *                    * ( T + C3 ) / ( T + C4 )
0021           ISM = ISURF - 1
      C
      C  CALCULATE EFFECTIVE DIFFUSION
      C  COEFFICIENT FOR EACH LAYER
      C
0022           ALMAX = AMAX
0023           ALMIN = AMIN
0024           RATIO = ( ALMAX - ALMIN ) / ( EXP ( 1. ) - 1. )
0025           DO 100 I = 1, MAXLAY
0026           Z = I * DELZ - DELZ / 2.
0027           EXTRA = RATIO * ( EXP ( Z / ( MAXLAY * DELZ ) ) - 1. )
0028           ALPHA(I) = ALMIN + EXTRA
0029     100   CONTINUE
0030     110   CONTINUE
0031           DO 160 IJKL = 1, CYCLES
0032           QDOWN = .NOT. QDOWN
      C
      C  IF ( QDOWN = .TRUE. ) THEN DIFFUSE
      C  FROM TOP TO BOTTOM.  OTHERWISE
      C  DIFFUSE FROM BOTTOM TO TOP
      C
0033           DO 130 I = 1, ISM
0034           K = ISM - I + 1
0035           IF ( .NOT. QDOWN ) K = I
0036           ALFA = ALPHA(K)
0037           V1 = VOLUME(K) * HGT(K)
0038           V2 = VOLUME(K + 1) * HGT(K + 1)
0039           VTOTAL = V1 + V2
0040           VRATIO = V1 / V2
```

```
              C
              C  COMPUTE NEW TEMPERATURES
              C  AFTER DIFFUSION PROCESS
              C
0041                T1 = TEMP(K)
0042                T2 = TEMP(K + 1)
0043                TMIX = ( T1 * V1 + T2 * V2 ) / VTOTAL
0044                EXTRA = ALFA * ( TMIX - T1 )
0045                TEMP(K) = T1 + EXTRA
0046                TEMP(K + 1) = T2 - EXTRA * VRATIO
              C
              C  COMPUTE NEW QUALITIES
              C  AFTER DIFFUSION PROCESS
              C
0047                IF ( QNKWAL ) GO TO 130
0048                DO 120 J = 1, NQUAL
0049                Q1 = QUAL(J, K)
0050                Q2 = QUAL(J, K + 1)
0051                QMIX = ( Q1 * V1 + Q2 * V2 ) / VTOTAL
0052                EXTRA = ALFA * ( QMIX - Q1 )
0053                QUAL(J, K) = Q1 + EXTRA
0054                QUAL(J, K + 1) = Q2 - EXTRA * VRATIO
0055           120  CONTINUE
0056           130  CONTINUE
              C
              C  MIX TEMPERATURES OF TOP TWO LAYERS
              C
0057                V1 = VOLUME(ISURF - 1)
0058                V2 = VOLUME(ISURF) * HGT(ISURF)
0059                T1 = TEMP(ISURF - 1)
0060                T2 = TEMP(ISURF)
0061                TMIX = ( T1 * V1 + T2 * V2 ) / ( V1 + V2 )
0062                TEMP(ISURF - 1) = TMIX
0063                TEMP(ISURF) = TMIX
              C
              C  IF SURFACE TEMPERATURE IS NEGATIVE
              C  THEN MIX FROM TOP TO BOTTOM
              C
0064                IF ( TMIX .GE. 0. ) GO TO 140
0065                VSUM = V1 + V2
0066                TSUM = TMIX * VSUM
0067                I = ISM
0068           135  CONTINUE
0069                I = I - 1
0070                VSUM = VSUM + VOLUME(I)
0071                TSUM = TSUM + VOLUME(I) * TEMP(I)
0072                TMIX = TSUM / VSUM
0073                IF ( I .GT. 1 .AND. TMIX .LT. 0. ) GO TO 135
0074                DO 136 K = I, ISURF
0075                TEMP(K) = TMIX
0076           136  CONTINUE
0077           140  CONTINUE
              C
              C  COMPUTE NEW DENSITIES
              C  AFTER DIFFUSION PROCESS
              C
```

```
      DO 150 I = 1, ISURF
      DENSQ = 0.
      IF ( QNKWAL ) GO TO 146
      DO 145 J = 1, NQUAL
      DENSQ = DENSQ + QUAL(J, I) * ( 1. - 1. / SP(J) )
  145 CONTINUE
      DENSQ = DENSQ * 1.E - 06
  146 CONTINUE
      DENST = DENFUN ( TEMP(I) )
      DEN(I) = DENST + DENSQ
  150 CONTINUE
  160 CONTINUE
      RETURN
      END
```

```
              C
 0001                 SUBROUTINE STABLE
              C
              C  THIS SUBROUTINE MIXES WHERE AN
              C  INSTABILITY EXISTS TO PRODUCE
              C  A STABLE DENSITY PROFILE
              C
 0002                 COMMON / A / ISURF, NQUAL, QUAL(3, 60), SP(3)
 0003                 COMMON / B / TEMP(60), HGT(60), VOLUME(60)
 0004                 COMMON / C / DEN(60)
 0005                 COMMON / E / IFILE,   LFILE
 0006                 COMMON / M / NDAY
 0007                 COMMON / W / QNKWAL
 0008                 COMMON / X / QPRINT
 0009                 DIMENSION QMIX(3), SUMQV(3)
 0010                 LOGICAL QPRINT, QNKWAL
 0011                 DATA C1, C2 / - 3.9863, 508929.2 /
 0012                 DATA C3, C4 / 288.9414, 68.12963 /
 0013                 DENFUN ( T ) = 1. - ( T + C1 ) ** 2 / C2
                *                    * ( T + C3 ) / ( T + C4 )
              C
              C  DETERMINE IF AN INSTABILITY EXISTS
              C
 0014                 K = 1
 0015          100    CONTINUE
 0016                 IF ( K .GE. ISURF ) GO TO 310
 0017                 IF ( DEN(K) .LT. DEN(K + 1) ) GO TO 110
 0018                 K = K + 1
 0019                 GO TO 100
 0020          110    CONTINUE
              C
              C  SUCCESSIVELY MIX LAYERS ABOVE THE
              C  LEVEL OF INSTABILITY UNTIL A STABLE
              C  DENSITY GRADIENT IS OBTAINED
              C
 0021                 MIXLOW = K
 0022                 MIXTOP = MIXLOW
 0023                 VOLHGT = VOLUME(MIXTOP) * HGT(MIXTOP)
 0024                 SUMTV = TEMP(MIXTOP) * VOLHGT
 0025                 IF ( QNKWAL ) GO TO 130
 0026                 DO 120 J = 1, NQUAL
 0027                 SUMQV(J) = QUAL(J, MIXTOP) * VOLHGT
 0028          120    CONTINUE
 0029          130    CONTINUE
 0030                 SUMVOL = VOLHGT
 0031          140    CONTINUE
 0032                 MIXTOP = MIXTOP + 1
 0033                 VLMXTP = VOLUME(MIXTOP) * HGT(MIXTOP)
 0034                 SUMVOL = SUMVOL + VLMXTP
 0035                 SUMTV = SUMTV + TEMP(MIXTOP) * VLMXTP
 0036                 IF ( QNKWAL ) GO TO 160
 0037                 DO 150 J = 1, NQUAL
 0038                 SUMQV(J) = SUMQV(J) + QUAL(J, MIXTOP) * VLMXTP
 0039          150    CONTINUE
 0040          160    CONTINUE
              C
```

```
              C  COMPUTE TEMPERATURE AND QUALITY
              C  VALUES FOR MIXED LAYERS
              C
0041                TMIX = SUMTV / SUMVOL
0042                IF ( QNKWAL ) GO TO 180
0043                DO 170 J = 1, NQUAL
0044                QMIX(J) = SUMQV(J) / SUMVOL
0045           170  CONTINUE
0046           180  CONTINUE
              C
              C  COMPUTE DENSITY OF MIXED LAYERS
              C
0047                DENST = DENFUN ( TMIX )
0048                DENSQ = 0.
0049                IF ( QNKWAL ) GO TO 200
0050                DO 190 J = 1, NQUAL
0051                DENSQ = DENSQ + QMIX(J) * ( 1. - 1. / SP(J) )
0052           190  CONTINUE
0053           200  CONTINUE
0054                DENSQ = DENSQ * 1.E - 06
0055                DENMIX = DENST + DENSQ
0056                IF ( MIXTOP .EQ. ISURF ) GO TO 210
0057                IF ( DENMIX .LT. DEN(MIXTOP + 1) ) GO TO 140
0058           210  CONTINUE
0059                IF ( MIXLOW .LE. 1 ) GO TO 280
              C
              C  DETERMINE IF AN INSTABILITY
              C  EXISTS BELOW THE MIXED LEVEL
              C
0060                IF ( DEN(MIXLOW - 1) .GE. DENMIX ) GO TO 280
              C
              C  SUCCESSIVELY MIX LAYERS BELOW THE
              C  MIXED LEVEL IN AN INSTABILITY EXISTS
              C
0061                MIXLOW = MIXLOW - 1
              C
              C  COMPUTE TEMPERATURE AND QUALITY
              C  VALUES FOR MIXED LAYERS
              C
0062                VLMXLW = VOLUME(MIXLOW)
0063                SUMVOL = SUMVOL + VLMXLW
0064                SUMTV = SUMTV + TEMP(MIXLOW) * VLMXLW
0065                IF ( QNKWAL ) GO TO 230
0066                DO 220 J = 1, NQUAL
0067                SUMQV(J) = SUMQV(J) + QUAL(J, MIXLOW) * VLMXLW
0068           220  CONTINUE
0069           230  CONTINUE
0070                TMIX = SUMTV / SUMVOL
0071                IF ( QNKWAL ) GO TO 250
0072                DO 240 J = 1, NQUAL
0073                QMIX(J) = SUMQV(J) / SUMVOL
0074           240  CONTINUE
0075           250  CONTINUE
              C
              C  COMPUTE DENSITY OF MIXED LAYERS
              C
```

```
 0076                DENST = DENFUN ( TMIX )                                00964000
 0077                DENSQ = 0.                                             00965000
 0078                IF ( QNKWAL ) GO TO 270                                00966000
 0079                DO 260 J = 1, NQUAL                                    00967000
 0080                DENSQ = DENSQ + QMIX(J) * ( 1. - 1. / SP(J) )          00968000
 0081          260   CONTINUE                                               00969000
 0082          270   CONTINUE                                               00970000
 0083                DENSQ = DENSQ * 1.E - 06                               00971000
 0084                DENMIX = DENST + DENSQ                                 00972000
 0085                GO TO 210                                              00973000
 0086          280   CONTINUE                                               00974000
             C                                                              00975000
             C  SET DENSITY TEMPERATURES AND                                00976000
             C  QUALITIES FOR MIXED LEVEL                                   00977000
             C                                                              00978000
 0087                DO 300 I = MIXLOW, MIXTOP                              00979000
 0088                TEMP(I) = TMIX                                         00980000
 0089                DEN(I) = DENMIX                                        00981000
 0090                IF ( QNKWAL ) GO TO 300                                00982000
 0091                DO 290 J = 1, NQUAL                                    00983000
 0092                QUAL(J, I) = QMIX(J)                                   00984000
 0093          290   CONTINUE                                               00985000
 0094          300   CONTINUE                                               00986000
 0095                K = MIXTOP                                             00987000
 0096                GO TO 100                                              00988000
 0097          310   CONTINUE                                               00989000
 0098                RETURN                                                 00990000
 0099                END                                                    00991000
```

```
      C
            SUBROUTINE DPLETE
      C
      C  DEPLETE DISSOLVED OXYGEN
      C
            COMMON / A / ISURF, NQUAL, QUAL(3, 60)
            COMMON / B / TEMP(60), HGT(60), VOL(60)
            COMMON / C / DEN(60), NUSURF, QDO, QBOD, QSED, DEMAND(60)
            COMMON / D / DELZ, BOTTOM, VEL(60), SETTLE
            COMMON / G / FLOWIN(2), TEMPIN(2), QUALIN(2, 3)
            COMMON / H / DEPTH, MAXLAY, NIP, W, BOTLAY
            COMMON / W / QNKWAL, YEAR, SOD, DELTA, PERSAT, DKR, PBOD
            INTEGER BOTLAY
            LOGICAL QFIRST, QTEMP, QDO, QBOD, QSED
            DATA QFIRST / .TRUE. /
            DATA AXY, BXY / .06719, .00209 /
            DATA CHANGE / 1.0 /
            DATA BASE1, BASE2 / 1.018, 1.047 /
            DATA SQMTR, CUBMTR / 4046822., 1233500. /
            IF ( .NOT. QFIRST ) GO TO 100
            QFIRST = .FALSE.
            QTEMP = DELTA .GT. 0.
            DELTA = ABS ( DELTA )
            IF ( PERSAT .GT. 1. .OR. PERSAT .LT. 0. ) STOP 6000
        100 CONTINUE
      C
      C  COMPUTE SEDIMENT OXYGEN DEMAND LOADING AND DISTRIBUTE
      C  SLOAD TO POOL LAYERS BASED ON EACH LAYER'S CONTIBUTING AREA.
            IF(BOTLAY.LE.0) GO TO 125
              AREA1 = 0.
              DO 125 I = 1,BOTLAY
              AREA2 = (VOL(I)/DELZ) * SQMTR
              AREAI = AREA2 - AREA1
              AREA1 = AREA2
              SLOAD = AREAI * SOD * BASE1**(TEMP(I)-20.)
              VOLCM = VCL(I) * CUBMTR
             OXY = QUAL(1,I)
             DEMAND(I) = SLOAD / (VOLCM * HGT(I) )
             IF(DEMAND(I).GT.OXY) DEMAND(I) = OXY
             QUAL(2,I) = QUAL(2,I) + DEMAND(I)
        125 CONTINUE
      C
      C  DEPLETE ALL LAYERS DUE TO DISSOLVED B.O.D.
      C
         DO 130 I = 1, ISURF
         ANEROB = 0.0
         DK1 = EXP(-DKR * BASE2 ** (TEMP(I)-20.))
         QUAL(2,I) = QUAL(2,I) + PBOD
         BODR = QUAL(2,I) * DK1
         OXLOSS = QUAL(2,I) - BODR
         OXYGEN = QUAL(1,I) - OXLOSS
         IF(OXYGEN.LT.0) ANEROB = OXYGEN
         IF(OXYGEN.LT.0) OXYGEN = 0.
         QUAL(1,I) = OXYGEN
         IF(OXYGEN.LE.0) BODR = BODR - ANEROB
         QUAL(2,I) = BODR
```

```
0047        130     CONTINUE
            C
            C  COMPUTE SUSPENDED SEDIMENT SETTLING IF NQUAL = 3
            C
0048              IF (.NOT.QSED) GO TO 131
0049              FALL = SETTLE/DELZ
0050              IFALL = INT(FALL)
0051              DO 131 I = 1,ISURF
0052              K = I + IFALL
0053              IF (K.GT.ISURF) QUAL(3,I) = 0.0
0054              QUAL(3,I) = QUAL(3,K)
0055         131  CONTINUE
            C
            C  IF WATER SURFACE IS FROZEN, NO REAERATION OCCURS
            C
0056                IF( TEMP(ISURF) .LT. 0.0 ) GO TO 140
0057                IF ( QTEMP ) GO TO 132
            C
            C  DETERMINE LAYER WHICH IS DELTA
            C  FEET FROM SURFACE.  IF LAKE IS
            C  ISOTHERMAL THEN SATURATE FROM TOP TO BOTTOM
            C
0058                K = 1. + ( DEPTH - DELTA ) / DELZ
0059                IF ( K .LE. 0 ) K = 1
0060                IF ( TEMP(ISURF) - TEMP(1) .LT. CHANGE ) K = 1
0061                GO TO 136
0062         132    CONTINUE
            C
            C  FIND THE LAYER AT WHICH THERE EXISTS
            C  AT LEAST A DELTA DEG-C TEMPERATURE
            C  DIFFERENCE FROM SURFACE TO LAYER
            C
0063                TSURF = TEMP(ISURF)
0064                DO 134 I = 1, ISURF
0065                K = ISURF - I + 1
0066                TDIFF = TSURF - TEMP(K)
0067                IF ( TDIFF .GE. DELTA ) GO TO 136
0068         134    CONTINUE
0069         136    CONTINUE
            C
            C  SATURATE ABOVE LAYERS OF DELTA
            C  DEG-C TEMPERATURE DIFFERENCE
            C
0070                DO 138 I = K, ISURF
0071                QUAL(1, I) = PERSAT / ( AXY + BXY * TEMP(ISURF) )
0072         138    CONTINUE
0073         140    CONTINUE
0074                RETURN
0075                END
```

```
             C
0001                    SUBROUTINE OUTFLO
             C
             C  CALCULATE WITHDRAWAL FROM EACH LAYER,
             C  DETERMINE RELEASE TEMPERATURE AND
             C  QUALITIES, AND REFILL EACH LAYER
             C
0002                    COMMON / A / ISURF, NQUAL, QUAL(3, 60), SP(3)
0003                    COMMON / B / TEMP(60), HGT(60), VOLUME(60)
0004                    COMMON / C / DEN(60), NUSURF
0005                    COMMON / D / DELZ, BOTTOM, VEL(60), SETTLE, BOTOUT
0006                    COMMON / E / IFILE,   LFILE
0007                    COMMON / H / DEPTH, MAXLAY, NIP, W, BOTLAY
0008                    COMMON / J / EVAP, AVTEMP, SUMOUT, WTHDRW(60), FLOW, VOLHGT
0009                    COMMON / M / NDAY
0010                    COMMON / O / AVQUAL(3)
0011                    COMMON / W / QNKWAL
0012                    COMMON / X / QPRINT
0013                    DIMENSION SUMQF(3)
0014                    LOGICAL QPRINT, QMOVE, QNKWAL
0015                    INTEGER W
0016                    DATA C1, C2 / - 3.9863, 508929.2 /
0017                    DATA C3, C4 / 288.9414, 68.12963 /
0018                    DENFUN ( T ) = 1. - ( T + C1 ) ** 2 / C2
                  *                    * ( T + C3 ) / ( T + C4 )
             C
             C COMPUTE NEW DEPTH AFTER WITHDRAWL
             C
0019                FLOW = SUMOUT
0020                DO 104 I = 1,ISURF
0021                K = ISURF - I + 1
0022                VOLHGT = VOLUME(K) * HGT(K)
0023                IF(FLOW.GT.VOLHGT) GO TO 102
0024                NUSURF = K
0025                DEPTH = DELZ * (NUSURF-1+HGT(K)- FLOW/VOLUME(K))
0026                GO TO 106
0027          102   CONTINUE
0028                FLOW = FLOW - VOLHGT
0029          104   CONTINUE
0030          106   CONTINUE
             C
             C      INITIALIZE WITHDRAWL FROM EACH LAYER
             C
0031                    DO 110 I = 1,MAXLAY
0032          110       WTHDRW(I) = 0.
             C
             C  WITHDRAWL BOTTOM DRAW OUTFLOW FIRST
             C
0033                    FLOW = BOTOUT
0034                    IF(BOTOUT.GE.SUMOUT) FLOW = SUMOUT
0035                    DO 130 K = 1, ISURF
0036                    VOLHGT = VOLUME(K) * HGT(K)
0037                    IF(FLOW.LT.VOLHGT) GO TO 120
0038                    WTHDRW(K) = VOLHGT
0039                    EXTRA = FLOW - VOLHGT
0040                    FLOW = EXTRA
```

```
0041              GO TO 130                                          01145120
0042        120   WTHDRW(K) = FLOW                                   01145130
0043              FLOW = 0.                                          01145140
0044              EXTRA = 0.                                         01145150
0045        130   CONTINUE                                           01145160
0046              EXTRA = 0.                                         01146000
           C                                                         01146900
           C  WITHDRAWL WATER FROM SURFACE LEVEL OUTLET              01146901
           C  MAXIMUM WITHDRAWAL FROM ANY LAYER                      01146902
           C  IS THE VOLUME OF THE LAYER.  ANY                       01146903
           C  EXTRA IS TAKEN FROM THE LAYER ABOVE                    01146904
           C                                                         01146905
0047              FLOW = SUMOUT - BOTOUT                             01147000
0048              IF(BOTOUT.GE.SUMOUT) FLOW = 0.0                    01147010
0049              DO 150 K = W, ISURF                                01148000
0050              VOLHGT = VOLUME(K) * HGT(K)                        01149000
0051              IF(FLOW.LT.VOLHGT) GO TO 140                       01150000
0052              WTHDRW(K) = VOLHGT                                 01151000
0053              EXTRA = FLOW - VOLHGT                              01152000
0054              FLOW = EXTRA                                       01153000
0055              GO TO 150                                          01154000
0056        140   WTHDRW(K) = FLOW                                   01155000
0057              FLOW = 0.                                          01156000
0058              EXTRA = 0.                                         01157000
0059        150   CONTINUE                                           01158000
           C                                                         01159000
           C  ANY EXTRA OUTFLOW REMAINING IS TAKEN FROM THE LAYERS BELOW  01160000
           C                                                         01161000
0060              IF(EXTRA.LE.0.0) GO TO 160                         01162000
0061              DO 160 I = 1,W                                     01163000
0062              K = W - I                                          01164000
0063              IF(K.EQ.0) GO TO 160                               01165000
0064              FLOW = EXTRA                                       01166000
0065              VOLHGT = VOLUME(K) * HGT(K)                        01167000
0066              IF(FLOW.LT.VOLHGT) GO TO 155                       01168000
0067              WTHDRW(K) = VOLHGT                                 01169000
0068              EXTRA = FLOW - VOLHGT                              01170000
0069              GO TO 160                                          01171000
0070        155   WTHDRW(K) = FLOW                                   01172000
0071              EXTRA = 0.0                                        01173000
0072        160   CONTINUE                                           01174000
0073              IF( EXTRA.GT.0.0 ) STOP 5000                       01175000
           C                                                         01176000
           C  INITIALIZE OUTLOW SUMMATIONS                           01177000
           C                                                         01178000
0074              SUMF = 0.                                          01179000
0075              SUMTF = 0.                                         01180000
0076              IF ( QNKWAL ) GO TO 180                            01181000
0077              DO 170 J = 1, NQUAL                                01182000
0078              SUMCF(J) = 0.                                      01183000
0079        170   CONTINUE                                           01184000
0080        180   CONTINUE                                           01185000
           C                                                         01186000
           C  WITHDRAWL FLOW FROM LAYERS                             01187000
           C                                                         01188000
0081              DO 240 I = 1, MAXLAY                               01189000
```

```
0082            FLOW = WTHDRW(I)
0083            IF ( FLOW .LE. 0. ) GO TO 240
      C
      C  SUM OUTFLOW CHARACTERISTICS
      C
0084            SUMF = SUMF + FLOW
0085            SUMTF = SUMTF + TEMP(I) * FLOW
0086            IF ( QNKWAL ) GO TO 200
0087            DO 190 J = 1, NQUAL
0088            SUMQF(J) = SUMQF(J) + QUAL(J, I) * FLOW
0089       190  CONTINUE
0090       200  CONTINUE
      C
      C  CONSECUTIVELY REFILL LAYERS FROM ABOVE
      C
0091            ISM = ISURF - 1
0092            DO 220 K = I, ISM
0093            VOL = VOLUME(K)
0094            REMVOL = VOL - FLOW
0095            VOLHGT = VOLUME(K + 1) * HGT(K + 1)
0096            DOWN = FLOW
0097            IF( FLOW.GE.VOLHGT ) DOWN = VOLHGT
0098            TREMV = TEMP(K) * REMVOL
0099            TDOWN = TEMP(K + 1) * DOWN
0100            VOL = REMVOL + DOWN
0101            IF( VOL.LE.0.0 ) GO TO 220
0102            TEMP(K) = ( TREMV + TDOWN ) / VOL
0103            IF ( QNKWAL ) GO TO 220
0104            DO 210 J = 1, NQUAL
0105            QREMV = QUAL(J, K) * REMVOL
0106            QDOWN = QUAL(J, K + 1) * DOWN
0107            QUAL(J, K) = ( QREMV + QDOWN ) / VOL
0108       210  CONTINUE
0109       220  CONTINUE
      C
      C  ADJUST WATER SURFACE TO ACCOUNT
      C  FOR WITHDRAWAL FROM ONE LAYER
      C
0110       225  IF( FLOW.GE.HGT(ISURF) * VOLUME(ISURF) ) GO TO 230
0111            HGT(ISURF) = ( VOLUME(ISURF) * HGT(ISURF) -
     *                  FLOW ) / VOLUME(ISURF)
0112            GO TO 240
0113       230  CONTINUE
0114            FLOW = FLOW - ( HGT(ISURF) * VOLUME(ISURF) )
0115            HGT(ISURF) = 0.
0116            ISURF = ISURF - 1
0117            GO TO 225
0118       240  CONTINUE
      C
      C  CALCULATE AVERAGE RELEASE CHARACTERISTICS
      C
0119            IF ( SUMF .LE. 0. ) GO TO 260
0120            AVTEMP = SUMTF / SUMF
0121            IF ( QNKWAL ) GO TO 260
0122            DO 250 J = 1, NQUAL
0123            AVQUAL(J) = SUMQF(J) / SUMF
```

```
0124      250     CONTINUE
0125      260     CONTINUE
         C
         C  COMPUTE RESULTANT DENSITY PROFILF
         C
0126              DO 290 I = 1, ISURF
0127              DENST = DENFUN ( TEMP(I) )
0128              DENSQ = 0.
0129              IF ( QNKWAL ) GO TO 280
0130              DO 270 J = 1, NQUAL
0131              DENSQ = DENSQ + QUAL(J, I) * ( 1. - 1. / SP(J) )
0132      270     CONTINUE
0133              DENSQ = DENSQ * 1.E - 06
0134      280     CONTINUE
0135              DEN(I) = DENST + DENSQ
0136      290     CONTINUE
0137      295     CONTINUE
0138              IF ( QPRINT ) WRITE ( LFILE, 500 ) NDAY
0139              IF ( QPRINT ) WRITE ( LFILE, 510 )
             *                        ( I, HGT(I), I = 1, MAXLAY )
0140              IF ( QPRINT ) WRITE ( LFILE, 520 ) ISURF, HGT(ISURF)
0141              RETURN
0142      500     FORMAT ( /// 5X, 6HDAY - , I3, 5X, 'AFTER OUTFLOW' )
0143      510     FORMAT ( /// ( 8 ( 5X, I2, 2X, F6.1 ) ) )
0144      520     FORMAT ( 5X, 'ISURF = ',I2,5X,'PERCENT FILLED = ', F5.3 )
0145              END
```

```
              C
0001                 SUBROUTINE XFIRST
              C
              C  PRINT SYSTEM CONTROL PARAMETERS
              C
0002                 COMMON / A / ISURF, NQUAL
0003                 COMMON / C / DEN(60), NUSURF, QDO, QBOD, QSED, DEMAND(60)
0004                 COMMON / D / DELZ, BOTTOM, VEL(60), SETTLE, BOTOUT
0005                 COMMON / E / IFILE,   LFILE
0006                 COMMON / F / NP, PAREA(15), PHGT(15)
0007                 COMMON / G / FLOWIN(2), TEMPIN(2), QUALIN(2, 3), GAMMA
0008                 COMMON / H / DEPTH, MAXLAY, NIP, W, BOTLAY
0009                 COMMON / I / EK, ET, SHORT, BETA, LAMBDA
0010                 COMMON / N / AMAX, AMIN
0011                 COMMON / P / FIRST, LAST, TITLE(36)
0012                 COMMON / V / START, FINISH
0013                 COMMON / W / QNKWAL, YEAR, SOD, DELTA, PERSAT, DKR, PBOD
0014                 LOGICAL OVER, QNKWAL, QDO, QBOD, QSED
0015                 INTEGER START, FINISH, FIRST, YEAR, BOTLAY, W
0016                 REAL LAMBDA
0017                 WRITE ( LFILE, 500 )
0018                 WRITE ( LFILE, 510 ) ( TITLE(I), I = 1, 18 )
0019                 IF ( YEAR .GT. 0 ) WRITE ( LFILE, 515 ) YEAR
0020                 IF ( QNKWAL ) GO TO 120
0021                 WRITE ( LFILE, 540 ) NQUAL
0022           120   CONTINUE
0023                 WRITE ( LFILE, 550 ) GAMMA
0024                 WRITE ( LFILE, 560 ) MAXLAY
0025                 WRITE ( LFILE, 570 ) DELZ
0026                 WRITE ( LFILE, 580 ) BOTTOM
0027                 WRITE ( LFILE, 585 ) BOTOUT
0028                 WRITE (LFILE,590) W
0029                 IF (QDO) WRITE(LFILE,591) BOTLAY
0030                 IF (QDO) WRITE(LFILE,592) SOD
0031                 IF (QDO) WRITE(LFILE,596) PBOD
0032                 IF (QDO) WRITE(LFILE,593) PERSAT
0033                 IF (QDO) WRITE(LFILE,594) DKR
0034                 IF(QSED) WRITE(LFILE,595) SETTLE
0035                 WRITE ( LFILE, 600 ) AMAX, AMIN
0036                 WRITE ( LFILE, 610 ) BETA
0037                 WRITE ( LFILE, 620 ) LAMBDA
0038                 WRITE ( LFILE, 630 ) FIRST, LAST
0039                 WRITE ( LFILE, 640 ) START, FINISH
0040           130   CONTINUE
0041                 RETURN
0042           500   FORMAT ( 1H1 )
0043           510   FORMAT ( /// 15X, 18A4 )
0044           515   FORMAT ( 15X, 18HSIMULATION YEAR - , I4 )
0045           540   FORMAT ( / 15X,'NQUAL VALUE EQUALS',2X,I1)
0046           550   FORMAT ( / 15X,'INFLOW ENTRAINMENT FRACTION = ',F6.2)
0047           560   FORMAT ( / 15X,'MAXIMUM NUMBER OF LAYERS = ',3X,I3)
0048           570   FORMAT ( / 15X, 15HLAYER THICKNESS, 12X,
                  *           F3.0, 5X, 4HFEET )
0049           580   FORMAT ( / 15X, 16HBOTTOM ELEVATION, 9X,
                  *           F6.1, 5X, 4HFEET )
0050           585   FORMAT( / 15X,'BOTTOM WITHDRAWL CAPACITY = ', F7.2, ' CFS')
```

```
0051     590    FORMAT ( / 15X, 25HSURFACE WITHDRAWL LAYER = , I4)              01326000
0052     591    FORMAT( / 15X,'S.O.D. AFFECTS LAYERS UP TO',I3)                 01327000
0053     592    FORMAT( / 15X,'S.O.D. LOADING RATE = ',F6.2,2X,'GM/M-SQ/DAY')   01328000
0054     593    FORMAT( / 15X,'SURFACE OXYGEN SATURATION = ',F4.2)              01329000
0055     594    FORMAT( / 15X,'B.O.D. DECAY RATE = ',F4.2,2X,'PER DAY')         01330000
0056     595    FORMAT( / 15X,'SUSPENDED SEDIMENT SETTLING RATE = ',F6.2,2X,    01331000
             *  'FEET PER DAY')                                                 01332000
0057     596    FORMAT( / 15X,'BIOLOGICALLY INDUCED B.O.D. = ',F6.2,            01333000
             *    2X,'MG/L/DAY')                                                01334000
0058     600    FORMAT ( / 15X,'DIFFUSION COEFFICIENTS = ',F4.2,2X,F4.2)        01335000
0059     610    FORMAT ( / 15X,'SURFACE HEAT ABSORBTION FRACTION = ',F4.2)      01336000
0060     620    FORMAT ( / 15X,'LIGHT EXTINCTION COEFFICIENT = ',F4.2, 2X,      01337000
             *    'PER FOOT' )                                                  01338000
0061     630    FORMAT ( / 15X, 13HDATA INTERVAL, 14X, I3, 5H  -  , I3 )        01339000
0062     640    FORMAT ( / 15X, 19HSIMULATION INTERVAL,                         01340000
             *            8X, I3, 5H  -  , I3 )                                 01341000
0063            END                                                             01342000
```

```
           C
0001             SUBROUTINE XPRINT
           C
           C  PRINT SUMMARY INFORMATION
           C  FOR EVERY DAY OF SIMULATION
           C
0002             COMMON / A / ISURF, NQUAL
0003             COMMON / B / TEMP(60), HGT(60), VOLUME(60), TARGET
0004             COMMON / C / DEN(60), NUSURF, QDO, QBOD, QSED
0005             COMMON / E / IFILE,   LFILE
0006             COMMON / G / FLOWIN(2), TEMPIN(2), QUALIN(2, 3)
0007             COMMON / H / DEPTH, MAXLAY, NIP, W, BOTLAY
0008             COMMON / J / EVAP, AVTEMP, SUMOUT
0009             COMMON / M / NDAY, PORT(3), PHLOW(3), OPEN
0010             COMMON / O / AVQUAL(3)
0011             COMMON / P / FIRST, LAST, TITLE(36)
0012             COMMON / U / ENFLOW(60), SUMFLO(366), IPRINT(14)
0013             COMMON / V / START, FINISH, QPUNCH, QPLOT, QGRAPH
0014             COMMON / W / QNKWAL, YEAR
0015             LOGICAL QDO, QBOD, QSED, QNKWAL, QHEAD, QPDAY, QGRAPH
0016             INTEGER START, FINISH, PORT, OPEN, YEAR, FIRST
0017             DATA MAXLIN / 40 /
           C
           C  DETERMINE IF HEADING IS NEEDED
           C
0018             IF ( NDAY .GT. START ) GO TO 130
0019             KOUNT = 1
0020             QHEAD = .TRUE.
0021             GO TO 140
0022        130  CONTINUE
0023             QHEAD = LINES .GT. MAXLIN .OR. QPDAY
0024        140  CONTINUE
0025             QPDAY = NDAY .EQ. IPRINT(KOUNT)
0026             IF ( .NOT. QHEAD ) GO TO 150
           C
           C  PRINT HEADING
           C
0027             LINES = 0
0028             WRITE ( LFILE, 510 ) ( TITLE(I), I = 1, 18 )
0029             IF ( YEAR .GT. 0 ) WRITE ( LFILE, 515 ) YEAR
0030             WRITE ( LFILE, 520 )
0031             IF ( QDO ) WRITE ( LFILE, 530 )
0032             IF( QBOD ) WRITE(LFILE,540)
0033             IF(QSED) WRITE(LFILE,545)
0034             WRITE ( LFILE, 550 )
0035             IF ( QDO ) WRITE ( LFILE, 560 )
0036             IF( QBOD ) WRITE(LFILE,570)
0037             IF(QSED) WRITE(LFILE,575)
0038             WRITE ( LFILE, 580 )
0039             IF ( QDO ) WRITE ( LFILE, 590 )
0040             IF( QBOD ) WRITE(LFILE,600)
0041             IF(QSED) WRITE(LFILE,605)
0042             WRITE ( LFILE, 500 )
0043        150  CONTINUE
           C
           C  PRINT SUMMARY INFORMATION
```

```
      C
                  LINES = LINES + 1
                  WRITE ( LFILE, 610 ) NDAY, DEPTH, TEMPIN(1),
           *                        FLOWIN(1), AVTEMP, SUMOUT
                  IF ( QDO ) WRITE ( LFILE, 620 )
           *                        QUALIN(1, 1), AVQUAL(1)
                  IF( QBOD ) WRITE(LFILF,625) QUALIN(1,2), AVQUAL(2)
                  IF( QSED ) WRITE(LFILF,627) QUALIN(1,3), AVQUAL(3)
      C
      C  ADDITIONAL INFLOW POINTS
      C
                  IF ( NIP .LE. 1 ) GO TO 170
                  LINES = LINES + NIP
                  DO 160 L = 2, NIP
                  WRITE ( LFILE, 640 ) TEMPIN(L), FLOWIN(L)
                  IF ( QDO ) WRITE ( LFILE, 650 ) QUALIN(L, 1)
       160        CONTINUE
                  WRITE ( LFILE, 500 )
       170        CONTINUE
      C
      C  PRINT PROFILES FOR SPECIAL PRINT DAYS
      C
                  IF ( .NOT. GPDAY ) GO TO 180
                  KOUNT = KOUNT + 1
                  CALL DETAIL
                  CALL PLOD
       180        CONTINUE
                  RETURN
       500        FORMAT ( / )
       510        FORMAT ( 1H1 // 20X, 18A4 )
       515        FORMAT ( 20X, 18HSIMULATION YEAR - , I4 )
       520        FORMAT ( // 2X, 3HDAY, 3X, 4HPOOL, 4X, 6HINFLOW,
           *          13X, 6HINFLOW, 14X, 7HOUTFLOW, 14X, 7HOUTFLOW )
       530        FORMAT ( 1H+, 25X, 6HINFLOW, 34X, 7HOUTFLOW )
       540        FORMAT (1H+, 45X, 6HINFLOW, 35X, 7HOUTFLOW)
       545        FORMAT (1H+, 100X, 6HINFLOW, 5X, 7HOUTFLOW)
       550        FORMAT ( 8X,5HDEPTH, 5X, 4HTEMP, 13X, 8HQUANTITY,
           *          15X,4HTEMP, 14X, 8HQUANTITY)
       560        FORMAT ( 1H+, 25X, 6H D.O. , 35X, 6H D.O.  )
       570        FORMAT (1H+, 45X, 6HB.O.D., 35X, 7H B.O.D.)
       575      FORMAT (1H+, 99X, 8HSUSP-SED, 4X, 8HSUSP-SED)
       580        FORMAT ( 8X, 4H(FT), 3X, 7H(DEG-C), 14X, 5H(CFS),
           *          14X, 7H(DEG-C), 15X, 5H(CFS), 1X)
       590        FORMAT ( 1H+, 25X, 6H(MG/L), 35X, 6H(MG/L) )
       600        FORMAT ( 1H+, 45X, 6H(MG/L),35X,7H (MG/L))
       605        FORMAT (1H+, 100X, 6H(MG/L), 6X, 6H(MG/L) )
       610        FORMAT ( 2X, I3, 2X, F5.1, 3X, F6.2, 12X, F8.2, 14X, F6.2,
           *          13X, F8.2, 1X, 3 ( 4X, I2, 3X, F6.0 ) )
       620        FORMAT ( 1H+, 25X, F5.1, 36X, F5.1 )
       625        FORMAT (1H+, 45X, F5.1, 35X, F6.2)
       627        FORMAT (1H+,100X,F6.1, 6X, F6.1 )
       630        FORMAT ( 1H+, 45X, F6.2 )
       640        FORMAT ( 15X, F6.2, 14X, F6.0 )
       650        FORMAT ( 1H+, 25X, F5.1 )
                  END
```

```
       C                                                              01454000
                SUBROUTINE FINAL                                      01455000
       C                                                              01456000
                COMMON / A / ISURF, NQUAL, QUAL(3, 60), SP(3)         01457000
                COMMON / E / IFILE,   LFILE                           01458000
                COMMON / O / AVCHEM(3), AVGQ(366, 3), AVGT(366)       01459000
                COMMON / P / FIRST, LAST, TITLE(36), NJ, NM, INDEX(366)  01460000
                COMMON / U / ENFLOW(60), SUMFLO(366)                  01460900
                COMMON / V / START, FINISH                            01461000
                COMMON / W / ONKWAL, YEAR                             01462000
                DIMENSION  X(10), L(10), B(10)                        01463000
                INTEGER FIRST,A,B,START,FINISH,YEAR,W                 01464000
                LOGICAL ONKWAL, QVER                                  01465000
                WRITE(LFILE, 550) (TITLE(I), I=1,18)                  01466000
                WRITE(LFILE, 560) YEAR                                01467000
       C                                                              01468000
       C  WRITE CORRECT HEADING                                       01469000
       C                                                              01470000
                WRITE(LFILE,500)                                      01472000
                IF(NQUAL.GE.1) WRITE(LFILE,501)                       01473000
                IF(NQUAL.GE.2) WRITE(LFILE,502)                       01474000
                IF(NQUAL.GE.3) WRITE(LFILE,503)                       01475000
                WRITE(LFILE,510)                                      01476000
                IF(NQUAL.GE.1) WRITE(LFILE,511)                       01477000
                IF(NQUAL.GE.2) WRITE(LFILE,512)                       01478000
                IF(NQUAL.GE.3) WRITE(LFILE,513)                       01479000
       C                                                              01480000
       C  PRINT OUTPUT SUMMARY                                        01481000
       C                                                              01482000
                WRITE(LFILE,570)                                      01482500
                DO 100 N = START, FINISH                              01483000
                IF(NQUAL.EQ.0) WRITE(LFILE,520) N,SUMFLO(N),AVGT(N)   01484000
                IF(NQUAL.GT.0) WRITE(LFILE,530) N,SUMFLO(N),AVGT(N),  01485000
          *                        (AVGQ(N,M), M=1,NQUAL)             01486000
         100    CONTINUE                                              01487000
         500    FORMAT( // 5X,'DAY',10X,'OUTFLOW', 5X,'TEMPERATURE')  01489000
         501    FORMAT( 1H+, 45X,'DISSOLVED OXYGEN')                  01490000
         502    FORMAT( 1H+, 68X,'FIVE DAY BOD')                      01491000
         503    FORMAT( 1H+, 80X,'SUSPENDED SEDIMENT')                01492000
         510    FORMAT( 20X,'CFS',10X,'DEGREES C')                    01493000
         511    FORMAT( 1H+,50X,'MG / L')                             01494000
         512    FORMAT( 1H+,70X,'MG / L')                             01495000
         513    FORMAT( 1H+,85X,'MG / L')                             01496000
         520    FORMAT(    5X,I3,5X,F10.1,11X,F6.1)                   01497000
         530    FORMAT(    5X,I3,5X,F10.1,11X,F6.1,11X,F6.1,14X,F6.1,19X,F6.1)  01498000
         550    FORMAT( 1H1 // 10X, 18A4 )                            01499000
         560    FORMAT( 10X,'OUTFLOW SUMMARY FOR YEAR - ',I4)         01500000
         570    FORMAT( // )                                          01501000
                END                                                   01517000
```

```
            C
0001                SUBROUTINE DETAIL
            C
            C  PRINT INTERESTING DATA
            C  FOR SPECIAL PRINT DAYS
            C
0002                COMMON / A / ISURF, NQUAL, QUAL(3, 60), SH(3)
0003                COMMON / B / TEMP(60), HGT(60), VOL(60), TARGET
0004                COMMON / C / DEN(60), NUSURF, QDO, QBOD, QSED, DEMAND(60)
0005                COMMON / D / DELZ, BOTTOM, VEL(60)
0006                COMMON / E / IFILE,   LFILE
0007                COMMON / F / NP, PAREA(15), PHGT(15)
0008                COMMON / G / FLOWIN(2), TEMPIN(2), QUALIN(2, 3)
0009                COMMON / H / DEPTH, MAXLAY, NIP, W, BOTLAY
0010                COMMON / I / EK, ET, SHORT, BETA, LAMBDA
0011                COMMON / J / EVAP, AVTEMP, SUMOUT, WTHDRW(60)
0012                COMMON / M / NDAY, PORT(3), PHLOW(3), OPEN
0013                COMMON / P / FIRST, LAST, TITLE(36), NJ, NM
0014                COMMON / O / AVQUAL(3)
0015                COMMON / U / ENFLOW(60)
0016                COMMON / W / QNKWAL, YEAR, SOD, DELTA, PERSAT, DKR, PBOD
0017                LOGICAL QNKWAL, QDO, QBOD, QSED
0018                DIMENSION NUMBER(12), MONTH(12)
0019                INTEGER PORT, OPEN, START, FINISH, BOTLAY,
                 *           FIRST, TITLE, YEAR, BLANK, XXXX
0020                DATA MONTH / 3HJAN, 3HFEB, 3HMAR, 3HAPR,
                 *                  3HMAY, 3HJUN, 3HJUL, 3HAUG,
                 *                  3HSEP, 3HOCT, 3HNOV, 3HDEC /
0021                DATA NUMBER / 31, 28, 31, 30, 31, 30,
                 *                   31, 31, 30, 31, 30, 31 /
0022                LEAP = MOD(YEAR,4)
0023                IF(LEAP.EQ.0) NUMBER(2) = 29
            C
            C  DETERMINE AND PRINT DATE INFORMATION
            C
0024                M = 0
0025         120    CONTINUE
0026                DO 130 K = 1, 12
0027                M = M + NUMBER(K)
0028                IF ( NDAY .GT. M ) GO TO 130
0029                NJ = NUMBER(K) + NDAY - M
0030                NM = MONTH(K)
0031                GO TO 140
0032         130    CONTINUE
0033                GO TO 120
0034         140    CONTINUE
0035                WRITE ( LFILE, 500 ) ( TITLE(I), I = 1, 18 )
0036                IF ( YEAR .GT. 0 ) WRITE ( LFILE, 510 ) YEAR
0037                WRITE ( LFILE, 520 ) NDAY, NJ, NM
            C
            C  PRINT INPUT DATA AND
            C  COMPUTED VALUES
            C
0038                DO 160 L = 1, NIP
0039                WRITE ( LFILE, 530 ) FLOWIN(L)
0040                WRITE ( LFILE, 540 ) TEMPIN(L)
```

```
              IF( QNKWAL) GO TO 160
              GO TO (153, 152, 151), NQUAL
        151   WRITE (LFILE,551) QUALIN(L,3)
        152   WRITE (LFILE,552) QUALIN(L,2)
        153   WRITE (LFILE,553) QUALIN(L,1)
        160   CONTINUE
              WRITE ( LFILE, 560 ) ET
              WRITE ( LFILE, 570 ) EK
              WRITE( LFILE, 580 ) SHORT
              WRITE ( LFILE, 600 ) DEPTH
              WRITE ( LFILE, 620 ) AVTEMP
              IF ( QNKWAL ) GO TO 180
              IF( QDO ) WRITE(LFILE,631) AVQUAL(1)
              IF( QBOD ) WRITE(LFILE,632) AVQUAL(2)
              IF( QSED ) WRITE(LFILE,633) AVQUAL(3)
        180   CONTINUE
              WRITE ( LFILE, 640 ) SUMOUT
      C
      C  PRINT HEADING
      C
              WRITE ( LFILE, 500 ) ( TITLE(I), I = 1, 18 )
              IF ( YEAR .GT. 0 ) WRITE ( LFILE, 510 ) YEAR
              WRITE ( LFILE, 520 ) NDAY, NJ, NM
              WRITE ( LFILE, 660 )
              IF ( QNKWAL ) GO TO 260
              DO 250 J = 1, NQUAL
              GO TO ( 220, 230, 240 ), J
        220   CONTINUE
              WRITE ( LFILE, 670 )
              GO TO 250
        230   CONTINUE
              WRITE ( LFILE, 680 )
              GO TO 250
        240   CONTINUE
              WRITE ( LFILE, 690 )
        250   CONTINUE
        260   WRITE(LFILE,695)
      C
      C  COMBINE OUTFLOW ABOVE SURFACE LAYER FOR PRINTOUT PURPOSES
      C
              TOPOUT = 0.0
              DO 265 I = ISURF, MAXLAY
              TOPOUT = TOPOUT + WTHDRW(I)
        265   CONTINUE
              WTHDRW(ISURF) = TOPOUT
      C
      C  PRINT INFORMATION TABLES
      C
              DEEP = - DELZ
              ELEV = 0.0
              DO 270 M = 1, ISURF
              I = ISURF - M + 1
              DEEP = DEEP + DELZ
              ELEV = ELEV - DELZ
              IF ( I .EQ. 1 ) ELEV = BOTTOM
              IF ( I .EQ. ISURF ) ELEV = BOTTOM + DEPTH
```

```
0088               IF ( I .EQ. ISURF - 1 ) ELEV = BOTTOM + DEPTH -                01618000
            *              DELZ * ( HGT(ISURF) + 0.5 )                            01619000
0089               WRITE ( LFILE, 700 )  I,ELEV,DFEP,ENFLOW(I),WTHDRW(I),TEMP(I)  01620000
0090               IF ( QNKWAL ) GO TO 270                                        01621000
0091               WRITE ( LFILE, 710 ) ( QUAL(J, I), J = 1, NQUAL )              01622000
0092        270    CONTINUE                                                       01623000
0093               RETURN                                                         01624000
0094        500    FORMAT ( 1H1 // 20X, 18A4 )                                    01625000
0095        510    FORMAT ( 20X, 18HSIMULATION YEAR - , I4 )                      01626000
0096        520    FORMAT ( /// 20X, 6HDAY - , I3,                                01627000
            *              5X, I2, 1X, A3 // )                                    01628000
0097        530    FORMAT ( // 20X, 15HINFLOW QUANTITY,                           01629000
            *              15X, F10.2, 5X, 3HCFS )                                01630000
0098        540    FORMAT (  / 20X, 18HINFLOW TEMPERATURE,                        01631000
            *              12X, F10.2, 5X, 5HDEG-C )                              01632000
0099        551   FORMAT (  / 20X,25HSUSPENDED-SEDIMENT INFLOW, 5X,F10.2,5X,4HMG/L)01633000
0100        552   FORMAT (  / 20X,25HSUSPENDED B.O.D. INFLOW   , 5X,F10.2,5X,4HMG/L)01634000
0101        553   FORMAT (  / 20X,25HDISSOLVED OXYGEN INFLOW   , 5X,F10.2,5X,4HMG/L)01635000
0102        560    FORMAT ( // 20X, 23HEQUILIBRIUM TEMPERATURE,                   01636000
            *               7X, F10.2, 5X, 5HDEG-F )                              01637000
0103        570    FORMAT (  / 20X, 25HHEAT EXCHANGE COEFFICIENT,                 01638000
            *               5X, F10.2, 5X, 'BTU/DEG-F/DAY' )                      01639000
0104        580    FORMAT (  / 20X, 20HSHORT WAVE RADIATION,                      01639500
            *              10X, F10.2, 5X, 3HHTU )                                01639510
0105        600    FORMAT (  / 20X, 14HPOOL DEPTH    ,                            01640000
            *              16X, F10.2, 5X, 4HFEET )                               01641000
0106        620    FORMAT (  / 20X, 19HOUTFLOW TEMPERATURE,                       01642000
            *              11X, F10.2, 5X, 5HDEG-C )                              01643000
0107        631    FORMAT(  / 20X,16HOUTFLOW OXYGEN  ,14X,F10.2,5X,4HMG/L)        01644000
0108        632    FORMAT(  / 20X,16HOUTFLOW B.O.D.  ,14X,F10.2,5X,4HMG/L)        01645000
0109        633    FORMAT(  / 20X,16HOUTFLOW SUSP-SED,14X,F10.2,5X,4HMG/L)        01646000
0110        640    FORMAT (  / 20X, 16HOUTFLOW QUANTITY,                          01647000
            *              14X, F10.2, 5X, 3HCFS )                                01648000
0111        660    FORMAT( // 15X,'LAYER',3X,'ELEVATION',3X,'DEPTH',3X,'INFLOW',  01649000
            *        5X,'OUTFLOW',4X,'TEMPERATURE',/,15X,' NO. ',3X,'(IN FEET)',  01650000
            *        3X,' (FT)',3X,' (CFS)',5X,' (CFS) ',4X,'(DEGREES-C)' )       01651000
0112        670    FORMAT ( 1H+,  91X, 8H  D.O.  , I1 )                           01652000
0113        680    FORMAT ( 1H+, 103X, 8H B.O.D. , I1 )                           01653000
0114        690    FORMAT ( 1H+, 115X, 8HSUSP-SED, I1 )                           01654000
0115        695    FORMAT(  // )                                                  01655000
0116        700    FORMAT (         10X, 7X, I2, 1X, F10.1,                       01656000
            *              1X, F9.1, 1X, F8.2, 1X, F10.2, 3X, F10.2 )             01657000
0117        705    FORMAT ( 1H+, 76X, F8.2 )                                      01658000
0118        710    FORMAT ( 1H+, 84X, 3 ( 3X, F10.1 ) )                           01659000
0119               END                                                            01660000
```

```
               C
0001                 SUBROUTINE PLOD
               C
               C  THIS SUBRCUTINE PLOTS PROFILES OF TEMPERATURE
               C  AND AN ARBITRARY NUMBER OF QUALITY PARAMETERS
               C
0002                 COMMON / A / ISURF, NQUAL, QUAL(3, 60), SP(3)
0003                 COMMON / C / DEN(60), NUSURF, QDO, QBOD, QSED
0004                 COMMON / B / TEMP(60)
0005                 COMMON / D / DELZ, BOTTOM
0006                 COMMON / E / IFILE,   LFILE
0007                 COMMON / H / DEPTH, MAXLAY, NIP, W, BOTLAY
0008                 COMMON / M / NDAY, IPORT(3), PHLOW(3), NOPEN
0009                 COMMON / P / ABCDE, FGHI, TITLE(36), NJ, NM
0010                 COMMON / U / ENFLOW(60), SUMFLO(366), IPRINT (14),MAXT,MAXQ(3)
0011                 COMMON / W / QNKWAL, YEAR
0012                 DIMENSION P(3),  COLUMN(100),
                *              NUMBER(12), MONTH(12), CON(3), RCON(3),
                *              TSPACE(11), CSPACE(3, 11)
0013                 INTEGER T, P, X, BLANK, PEGGED, YEAR,
                *           PLUS, FIRST, COLUMN, TMP,
                *           TSPACE, CSPACE, CHANGE
0014                 LOGICAL QTFST, QRANGE, QNKWAL
0015                 LOGICAL QDO, QBOD, QSED
0016                 EQUIVALENCE ( NCHEM, NQUAL )
0017                 DATA PEGGED, T, P / 1H*, 1HT, 1H1, 1H2, 1H3 /
0018                 DATA X, BLANK, PLUS / 1HX, 1H , 2H + /
               C
               C  PRINT DATE INFORMATION
               C
0019                 WRITE ( LFILE, 500 ) ( TITLE(I), I = 1, 18 )
0020                 IF ( YEAR .GT. 0 ) WRITE ( LFILE, 505 ) YEAR
0021                 WRITE ( LFILE, 510 ) NDAY, NM, NJ
               C
               C  SET PLOTTING RANGE LIMITS
               C
0022                 IF(MAXT.LE.0) MAXT = 50
0023                 IF(MAXQ(1).LE.0) MAXQ(1) = 20
0024                 IF(MAXQ(2).LE.0) MAXQ(2) = 10
0025                 IF(MAXQ(3).LE.0) MAXQ(3) = 500
0026                 CHANGE = MAXT / 10
0027                 TSPACE(1) = 0
0028                 DO 140 K = 1, 10
0029                 TSPACE(K + 1) = TSPACE(K) + CHANGE
0030            140  CONTINUE
0031                 IF(QNKWAL) GO TO 165
               C
               C  DETERMINE CONCENTRATION AXES SPACING
               C
0032                 DO 160 J = 1, NQUAL
0033                 CHANGE = MAXQ(J) / 10
0034                 CSPACE(J, 1) = 0
0035                 DO 150 K = 1, 10
0036                 CSPACE(J, K + 1) = CSPACE(J, K) + CHANGE
0037            150  CONTINUE
0038            160  CONTINUE
```

```
0039      165     CONTINUE                                                   01716500
              C                                                              01717000
              C  PRINT TEMPERATURE BANNER AND AXIS                           01718000
              C                                                              01719000
0040              WRITE ( LFILE, 520 )                                       01720000
0041              WRITE ( LFILE, 530 ) ( TSPACE(K), K = 1, 11 )              01721000
0042              WRITE ( LFILE, 540 )                                       01722000
              C                                                              01723000
0043              WRITE(LFILE, 570)                                          01723500
              C  BEGIN TO FILL IN COLUMN ARRAY                               01724000
              C                                                              01725000
0044              ELEV = BOTTOM + DEPTH + DELZ                               01726000
0045              DEEP = - DELZ                                              01727000
0046              DO 230 I = 1, ISURF                                        01728000
0047              K = ISURF - I + 1                                          01729000
0048              DEEP = DEEP + DELZ                                         01730000
0049              ELEV = ELEV - DELZ                                         01731000
              C                                                              01732000
              C  BLANK OUT COLUMN ARRAY                                      01733000
              C                                                              01734000
0050              FIRST = BLANK                                              01735000
0051              LAST = BLANK                                               01736000
0052              DO 170 L = 1, 100                                          01737000
0053              COLUMN(L) = BLANK                                          01738000
0054      170     CONTINUE                                                   01739000
              C                                                              01740000
              C  DETERMINE IF TEMPERATURE AND QUALITY                        01741000
              C  VALUES ARE WITHIN RANGE OF PLOT                             01742000
              C                                                              01743000
0055              TMP = TEMP(K) + 0.5 * MAXT / 100.                          01744000
0056              IF(GNKWAL) GO TO 185                                       01745000
0057              DO 180 J = 1, NQUAL                                        01746000
0058              RCON(J) = QUAL(J, K) + 0.5 * MAXQ(J) / 100.                01747000
0059              CON(J) = RCON(J)                                           01748000
0060      180     CONTINUE                                                   01749000
0061      185     CONTINUE                                                   01749500
0062              IF ( TMP .LE. 0 ) FIRST = PEGGED                           01750000
0063              IF ( TMP .GT. MAXT ) LAST = PEGGED                         01751000
0064              IF(GNKWAL) GO TO 195                                       01752000
0065              DO 190 J = 1, NQUAL                                        01753000
0066              IF ( CON(J) .GT. MAXQ(J) ) LAST = PEGGED                   01754000
0067              IF ( CON(J) .LT. 0 ) FIRST = PEGGED                        01755000
0068      190     CONTINUE                                                   01756000
0069      195     CONTINUE                                                   01756500
              C                                                              01757000
              C  DETERMINE COLUMN FOR                                        01758000
              C  PLOTTING EACH COMPONENT                                     01759000
              C                                                              01760000
0070              GRANGE = TMP .GT. 0 .AND. TMP .LE. MAXT                    01761000
0071              IF ( .NOT. GRANGE ) GO TO 200                              01762000
0072              IJK = TMP * 100 / MAXT                                     01763000
0073              IJK = IJK + 1                                              01764000
0074              COLUMN(IJK) = T                                            01765000
0075      200     CONTINUE                                                   01766000
0076              IF(GNKWAL) GO TO 225                                       01767000
0077              DO 220 J = 1, NQUAL                                        01768000
```

```
0078                QRANGE = CON(J) .GE. 0 .AND. CON(J) .LE. MAXQ(J)            01769000
0079                IF ( .NOT. QRANGE ) GO TO 220                               01770000
0080                IJK = RCON(J) * 100 / MAXQ(J)                               01771000
0081                IJK = IJK + 1                                               01772000
0082                QTEST = COLUMN(IJK) .EQ. BLANK                              01773000
0083                IF ( QTEST ) GO TO 210                                      01774000
0084                COLUMN(IJK) = X                                             01775000
0085                GO TO 220                                                   01776000
0086         210    CONTINUE                                                    01777000
0087                COLUMN(IJK) = P(J)                                          01778000
0088         220    CONTINUE                                                    01779000
0089         225    CONTINUE                                                    01779500
           C                                                                    01780000
           C  PRINT ONE LINE OF PLOT                                            01781000
           C                                                                    01782000
0090                WRITE ( LFILE, 550 ) ELEV, DEEP, PLUS,                      01783000
              *           FIRST, COLUMN, LAST                                   01784000
0091         230    CONTINUE                                                    01785000
           C                                                                    01786000
           C  PRINT BOTTOM AXES                                                 01787000
           C                                                                    01788000
0092                IF(GNKWAL) GO TO 250                                        01789000
0093                DO 240 J = 1, NQUAL                                         01790000
0094                WRITE ( LFILE, 540 )                                        01791000
0095                WRITE ( LFILE, 530 ) ( CSPACE(J, L), L = 1, 11 )            01792000
0096                IF(J.EQ.1) WRITE(LFILE, 580)                                01792100
0097                IF(J.EQ.2) WRITE(LFILE, 590)                                01792200
0098                IF(J.EQ.3) WRITE(LFILE, 600)                                01792300
0099         240    CONTINUE                                                    01793000
0100                WRITE(LFILE, 560)                                           01793500
0101                IF( QDO )  WRITE(LFILE,563)                                 01794000
0102                IF( QBOD ) WRITE(LFILE,562)                                 01795000
0103                IF( QSED ) WRITE(LFILE,561)                                 01796000
0104         250    CONTINUE                                                    01797000
0105                RETURN                                                      01798000
0106         500    FORMAT ( 1H1 // 20X, 18A4 )                                 01799000
0107         505    FORMAT ( 20X, 18HSIMULATION YEAR - , I4 )                   01800000
0108         510    FORMAT ( // 30X, 6HDAY - , I3,                              01801000
              *           5X, A3, 1X, I2 /// )                                  01802000
0109         520    FORMAT ( 2X,'ELEV',4X,'DEPTH',18X,'DEPTH PROFILES BELOW', / )  01803000
0110         530    FORMAT ( 11X, 11 I10 )                                      01804000
0111         540    FORMAT ( 20X, 10 ( 10HI--------- ), 1HI )                   01805000
0112         550    FORMAT (  1X, F5.0, 2X, F5.0, 4X, A2, 102A1)                01806000
0113         560    FORMAT ( // 30X,'T - TEMPERATURE, DEGREES CENTIGRADE')      01806500
0114         561    FORMAT ( 30X,'3 - SUSPENDED SEDIMENT      MG/L')            01807000
0115         562    FORMAT ( 30X,'2 - FIVE DAY B.O.D.         MG/L')            01808000
0116         563    FORMAT ( 30X,'1 - DISSOLVED OXYGEN        MG/L')            01809000
0117         570    FORMAT ( 1H+, 125X,'TEMP')                                  01809100
0118         580    FORMAT ( 1H+, 125X, 'D.O.' )                                01809200
0119         590    FORMAT ( 1H+, 125X, 'BOD5' )                                01809300
0120         600    FORMAT ( 1H+, 125X, 'SED.' )                                01809400
0121                END                                                         01810000
```

APPENDIX D.--Example Input Card Deck Listing

This appendix provides an example input deck for simulating a small proposed impoundment during an actual summer low-flow period. Temperature, dissolved oxygen, and BOD_5 are to be simulated so the number of qualities is indicated as '2' on Input Card 3.

In this example the pool is divided into 13 horizontal layers, with the surface spillway outlet located at layer number 9, with Sediment Oxygen Demand affecting layers up to number 2. The layer thickness is 1 ft. Pool bottom elevation is 84 feet in relation to a local datum, and a bottom draw outlet in the dam has a 7.5 ft^3/s outflow capacity. The impoundment has a relatively small volume capacity, the volume of each layer is expressed in units of 1000 acre-feet ranging from 0.00020 in the bottom layer to 0.5000 in the uppermost layer.

The diffusion coefficients were estimated using equation 3 in this manual. The shortwave radiation surface absorption fraction was set to 0.8, and the light extinction coefficient was specified as 0.3 per foot, both values based on turbid eutrophic conditions.

The oxygen depletion data card indicates that the Sediment Oxygen Demand released from the pool bottom is 1.0 $gram/m^2/day$. The surface oxygen transfer zone extends 2.0 ft below the surface, and is 100 percent saturated. The BOD decay rate is 0.5 units per day and the biologic productivity-induced BOD contribution is 1.0 mg/L/day.

Input data is provided for Julian day 189 (July 8) through 212 (July 31). Detailed depth profile output is requested for the three days indicated.

Daily values of Equilibrium Temperature, Thermal Exchange Coefficients, and Shortwave Radiation are computed using the Heat Exchange Program described in Appendix F of this manual.

The inflow hydrograph was obtained from USGS streamgage records at the site. The inflow temperature and dissolved oxygen values were obtained using a Yellow Springs Instrument Co. Model 56 continuous strip chart recorder. BOD_5 data was derived by interpolating values between weekly samples taken. Outflow was assumed equal to inflow since the reservoir has little storage effect.

The initial pool depth at the deepest point is set to 8.5 ft. Initial temperature, dissolved oxygen, and BOD_5 conditions were all specified as uniform values rather than as depth-dependent values.

The job control language needed to execute the program is subject to change with time. Contact the USGS office indicated on the front cover of this user manual for updates.

PROGRAM IDENTIFICATION: ONE DIMENSIONAL RESERVOIR / LAKE MODEL
TEMPERATURE AND DISSOLVED OXYGEN SIMULATION

```
PROPOSED IMPOUNDMENT OF BRIDGE CREEK - JULY 8 THRU 31, 1980
PRINT INPUT
QUALITIES      2
LAYERS        13    09    02
THICKNESS      1.0
BOTTOM        84.0        7.5
VOLUME OF EACH LAYER FROM BOTTOM TO TOP IN THOUSANDS OF ACRE-FEET
0.00020   0.00040   0.00275   0.00275   0.00631   0.00631   0.01079   0.01079
0.01469   0.01469   0.01687   0.01687   0.5000
DIFFUSION    0.586      0.502
HEAT           0.80      0.3
ENTRAIN      0.00
DEPLETION      1.0       -2.0        1.0        0.50       1.0
INTERVAL     190   213 1980
SIMULATE     190   213
PRINT DAYS   190   195   213
PLOT AXIS     40
EQUILIBRIUM TEMPERATURE DATA IN DEG-F
  75.1      80.2      81.2      82.5      78.1      80.6      81.9      75.8
  74.1      81.0      75.4      77.0      75.3      72.7      70.8      79.2
  74.8      73.4      71.3      78.9      74.6      77.9      74.0      79.2
EXCHANGE COEFFICIENTS IN BTU/DEG-F/DAY PER SQUARE FOOT
  116.5     114.7     157.8     179.0     192.1     136.4     221.0     195.9
  211.3     114.4     205.6     125.7     149.1     172.6     125.2      86.1
  173.5     124.1     106.9      85.3     139.6     102.3     161.6     138.4
SHORTWAVE RADIATION IN BTU/SQ-FT/DAY
  2141.     2236.     2468.     1400.     2203.     2205.     1990.     1902.
  2200.     2304.     1851.     2042.     1536.     2020.     2050.     2434.
  2258.     1384.     2289.     2392.     1810.     2369.     1579.     1895.
INFLOW HYDROGRAPH - MEAN DAILY FLOW IN UNITS OF   CFS
  7.5       7.5       7.4       7.3       7.3       7.2       7.3       7.4
  8.2       7.7       7.5       7.5       7.4       7.3       7.2       7.3
  7.0       7.2       7.9       7.4       7.2       7.3       7.2       7.2
TEMPERATURE OF INFLOW HYDROGRAPH IN DEGREES       CENTIGRADE
 21.5      22.5      24.0      23.0      23.5      21.5      22.0      23.0
 22.0      22.0      21.5      21.5      21.5      21.0      20.0      19.0
 20.0      20.5      19.5      19.0      19.5      20.0      20.0      21.0
QUALITY DATA - DISSOLVED OXYGEN INFLOW (MG/L)
  6.4       7.5       7.4       7.0       6.8       7.2       7.0       6.8
  6.7       6.9       7.0       7.0       7.0       7.0       7.2       6.9
  7.1       7.1       7.2       7.3       7.2       7.4       7.5       7.4
QUALITY DATA - SUSPENDED B.O.D. INFLOW (MG/L)
  1.6       1.6       1.6       1.7       1.8       1.8       1.8       1.9
  2.0       1.9       1.8       1.8       1.7       1.6       1.5       1.4
  1.4       1.5       1.5       1.6       1.5       1.7       1.7       1.6
OUTFLOW HYDROGRAPH - MEAN DAILY OUTFLOW, UNITS OF CFS
  7.5       7.5       7.4       7.3       7.3       7.2       7.3       7.4
  8.2       7.7       7.5       7.5       7.4       7.3       7.2       7.3
  7.0       7.2       7.9       7.4       7.2       7.3       7.2       7.2
DEPTH        8.5
TEMPERATURE PROFILE - INITIAL ISOTHERMAL CONDITIONS
 22.0
QUALITY PROFILE - INITIAL WELL-MIXED DISSOLVED OXYGEN CONDITIONS
 6.4
QUALITY CONDITION - INITIAL B.O.D. CONCENTRATION BASED ON 7/9/80 SAMPLE
 1.6
END
- CONTACT GULF COAST HYDROSCIENCE CENTER AT 494-3071 FTS FOR CURRENT JCL SET-UP
```

APPENDIX E.--Example Output

This appendix contains the output for the coded input in Appendix D.

The first page of the output example contains the echo-print of the input deck as requested on Input Card 2.

The second page of output lists the simulation control parameters that are user-specified.

Detailed output has been specified for days 189, 195, and 212 on Input Card 15. This entails output of tables and plots of depth profiles for temperature, DO, and BOD values.

A daily summary information table is provided for the time interval between the specially requested output days. This summary table contains pool depth, inflow temperature, inflow DO, inflow quantity, and inflow BOD information. The table also contains the outflow values of water temperature, DO, quantity, and BOD. Suspended sediment information is provided if that option is used.

The end of the output consists of a daily summary of the outflowing value for each water quality simulated - temperature, DO, and BOD in this example. This value is listed adjacent to its corresponding Julian day number.

```
***PROPOSED IMPOUNDMENT OF BRIDGE CREEK - JULY 8 THRU 31, 1980
***PRINT INPUT
***QUALITIES      2
***LAYERS        13   09   02
***THICKNESS      1.0
***BOTTOM        84.0       7.5
***VOLUME OF EACH LAYER FROM BOTTOM TO TOP IN THOUSANDS OF ACRE-FEET
***0.00020   0.00040   0.00275   0.00275   0.00631   0.00631   0.01079   0.01079
***0.01469   0.01469   0.01687   0.01687   0.5000
***DIFFUSION    0.586      0.502
***HEAT          0.80       0.3
***ENTRAIN      0.00
***DEPLETION     1.0       -2.0        1.0        0.50       1.0
***INTERVAL     190  213 1980
***SIMULATE     190  213
***PRINT DAYS   190  195  213
***PLOT AXIS     40
***EQUILIBRIUM TEMPERATURE DATA IN DEG-F
***   75.1      80.2      81.2      82.5      78.1      80.6      81.9      75.8
***   74.1      81.0      75.4      77.0      75.3      72.7      70.8      79.2
***   74.8      73.4      71.3      78.9      74.6      77.9      74.0      79.2
***EXCHANGE COEFFICIENTS IN BTU/DEG-F/DAY PER SQUARE FOOT
***  116.5     114.7     157.8     179.0     192.1     136.4     221.0     195.9
***  211.3     114.4     206.6     125.7     149.1     172.6     126.2      86.1
***  173.5     124.1     106.9      85.3     139.6     102.3     161.6     138.4
***SHORTWAVE RADIATION IN BTU/SQ-FT/DAY
***  2141.     2236.     2468.     1400.     2203.     2205.     1990.     1902.
***  2200.     2304.     1851.     2042.     1636.     2020.     2050.     2434.
***  2258.     1384.     2289.     2392.     1810.     2369.     1579.     1895.
***INFLOW HYDROGRAPH - MEAN DAILY FLOW IN UNITS OF   CFS
***   7.5       7.5       7.4       7.3       7.3       7.2       7.3       7.4
***   8.2       7.7       7.5       7.5       7.4       7.3       7.2       7.3
***   7.0       7.2       7.9       7.4       7.2       7.3       7.2       7.2
***TEMPERATURE OF INFLOW HYDROGRAPH IN DEGREES        CENTIGRADE
*** 21.5      22.5      24.0      23.0      23.5      21.5      22.0      23.0
*** 22.0      22.0      21.5      21.5      21.5      21.0      20.0      19.0
*** 20.0      20.5      19.5      19.0      19.5      20.0      20.0      21.0
***QUALITY DATA - DISSOLVED OXYGEN INFLOW (MG/L)
***   6.4       7.5       7.4       7.0       6.8       7.2       7.0       6.8
***   6.7       6.9       7.0       7.0       7.0       7.0       7.2       6.9
***   7.1       7.1       7.2       7.3       7.2       7.4       7.5       7.4
***QUALITY DATA - SUSPENDED B.O.D. INFLOW (MG/L)
***   1.6       1.6       1.6       1.7       1.8       1.8       1.8       1.9
***   2.0       1.9       1.8       1.8       1.7       1.6       1.5       1.4
***   1.4       1.5       1.5       1.6       1.6       1.7       1.7       1.6
***OUTFLOW HYDROGRAPH - MEAN DAILY OUTFLOW, UNITS OF CFS
***   7.5       7.5       7.4       7.3       7.3       7.2       7.3       7.4
***   8.2       7.7       7.5       7.5       7.4       7.3       7.2       7.3
***   7.0       7.2       7.9       7.4       7.2       7.3       7.2       7.2
***DEPTH        8.5
***TEMPERATURE PROFILE - INITIAL ISOTHERMAL CONDITIONS
*** 22.0
***QUALITY PROFILE - INITIAL WELL-MIXED DISSOLVED OXYGEN CONDITIONS
*** 6.4
***QUALITY CONDITION - INITIAL B.O.D. CONCENTRATION BASED ON 7/9/80 SAMPLE
*** 1.6
***END
```

```
PROPOSED IMPOUNDMENT OF BRIDGE CREEK - JULY 8 THRU 31, 1980
SIMULATION YEAR - 1980

NQUAL VALUE EQUALS  2

INFLOW ENTRAINMENT FRACTION =    0.0

MAXIMUM NUMBER OF LAYERS =      13

LAYER THICKNESS               1.      FEET

BOTTOM ELEVATION            84.0      FEET

BOTTOM WITHDRAWL CAPACITY =     7.50 CFS

SURFACE WITHDRAWL LAYER =    9

S.O.D. AFFECTS LAYERS UP TO  2

S.O.D. LOADING RATE =    1.00  GM/M-SQ/DAY

BIOLOGICALLY INDUCED B.O.D. =    1.00  MG/L/DAY

SURFACE OXYGEN SATURATION = 1.00

B.O.D. DECAY RATE = 0.50  PER DAY

DIFFUSION COEFFICIENTS = 0.59  0.50

SURFACE HEAT ABSORPTION FRACTION = 0.80

LIGHT EXTINCTION COEFFICIENT = 0.30  PER FOOT

DATA INTERVAL               190  -  213

SIMULATION INTERVAL         190  -  213
```

PROPOSED IMPOUNDMENT OF BRIDGE CREEK - JULY 8 THRU 31, 1980
SIMULATION YEAR - 1980

DAY	POOL DEPTH (FT)	INFLOW TEMP (DEG-C)	INFLOW D.O. (MG/L)	INFLOW QUANTITY (CFS)	INFLOW B.O.D. (MG/L)	OUTFLOW TEMP (DEG-C)	OUTFLOW D.O. (MG/L)	OUTFLOW QUANTITY (CFS)	OUTFLOW B.O.D. (MG/L)
190	8.5	21.50	6.4	7.50	1.6	22.06	8.8	7.50	1.54

PROPOSED IMPOUNDMENT OF BRIDGE CREEK - JULY 8 THRU 31, 1980
SIMULATION YEAR - 1980

DAY - 190   8 JUL

INFLOW QUANTITY	7.50	CFS
INFLOW TEMPERATURE	21.50	DEG-C
SUSPENDED B.O.D. INFLOW	1.60	MG/L
DISSOLVED OXYGEN INFLOW	6.40	MG/L
EQUILIBRIUM TEMPERATURE	75.10	DEG-F
HEAT EXCHANGE COEFFICIENT	116.50	BTU/DEG-F/DAY
SHORT WAVE RADIATION	2141.00	BTU
POOL DEPTH	8.50	FEET
OUTFLOW TEMPERATURE	22.06	DEG-C
OUTFLOW OXYGEN	8.82	MG/L
OUTFLOW B.O.D.	1.54	MG/L
OUTFLOW QUANTITY	7.50	CFS

PROPOSED IMPOUNDMENT OF BRIDGE CREEK - JULY 8 THRU 31, 1980
SIMULATION YEAR - 1980

DAY - 190 8 JUL

LAYER NO.	ELEVATION (IN FEET)	DEPTH (FT)	INFLOW (CFS)	OUTFLOW (CFS)	TEMPERATURE (DEGREES-C)	D.O.	B.O.D.
9	92.5	0.0	0.0	0.0	22.09	8.8	1.5
8	91.5	1.0	0.0	0.0	22.10	8.8	1.5
7	90.5	2.0	0.0	0.0	22.13	8.8	1.5
6	89.5	3.0	1.23	1.23	22.15	8.8	1.5
5	88.5	4.0	3.19	3.19	22.18	8.8	1.5
4	87.5	5.0	1.39	1.39	22.13	8.8	1.5
3	86.5	6.0	1.39	1.39	21.97	8.8	1.5
2	85.5	7.0	0.20	0.20	21.79	8.8	1.5
1	84.0	8.0	0.10	0.10	21.69	8.8	2.5

```
                  PROPOSED IMPOUNDMENT OF BRIDGE CREEK - JULY 8 THRU 31, 1980
                  SIMULATION YEAR - 1980

                            DAY - 190     JUL  8

ELEV    DEPTH                  DEPTH PROFILES BELOW

                   0         4         8        12        16        20        24        28        32        36        40
                   I---------I---------I---------I---------I---------I---------I---------I---------I---------I---------I     TEMP
 92.     0.      +                2                            1          T
 91.     1.      +                2                            1          T
 90.     2.      +                2                            1          T
 89.     3.      +                2                            1          T
 88.     4.      +                2                            1          T
 87.     5.      +                2                            1          T
 86.     6.      +                2                            1          T
 85.     7.      +                2                            1       T
 84.     8.      +                          2                  1       T
                   I---------I---------I---------I---------I---------I---------I---------I---------I---------I---------I
                   0         2         4         6         8        10        12        14        16        18        20     D.O.
                   I---------I---------I---------I---------I---------I---------I---------I---------I---------I---------I
                   0         1         2         3         4         5         6         7         8         9        10     BOD5

                            T - TEMPERATURE, DEGREES CENTIGRADE
                            1 - DISSOLVED OXYGEN      MG/L
                            2 - FIVE DAY B.O.D.       MG/L
```

PROPOSED IMPOUNDMENT OF BRIDGE CREEK - JULY 8 THRU 31, 1980
SIMULATION YEAR - 1980

DAY	POOL DEPTH (FT)	INFLOW TEMP (DEG-C)	INFLOW D.O. (MG/L)	INFLOW QUANTITY (CFS)	INFLOW B.O.D. (MG/L)	OUTFLOW TEMP (DEG-C)	OUTFLOW D.O. (MG/L)	OUTFLOW QUANTITY (CFS)	OUTFLOW B.O.D. (MG/L)
191	8.5	22.50	7.5	7.50	1.6	23.20	7.5	7.50	1.46
192	8.5	24.00	7.4	7.40	1.6	24.50	6.9	7.40	1.35
193	8.5	23.00	7.0	7.30	1.7	25.10	6.3	7.30	1.35
194	8.5	23.50	6.8	7.30	1.8	24.70	8.5	7.30	1.38
195	8.5	21.50	7.2	7.20	1.8	23.94	6.9	7.20	1.40

PROPOSED IMPOUNDMENT OF BRIDGE CREEK - JULY 8 THRU 31, 1980
SIMULATION YEAR - 1980

DAY - 195   13 JUL

INFLOW QUANTITY	7.20	CFS
INFLOW TEMPERATURE	21.50	DEG-C
SUSPENDED B.O.D. INFLOW	1.80	MG/L
DISSOLVED OXYGEN INFLOW	7.20	MG/L
EQUILIBRIUM TEMPERATURE	80.60	DEG-F
HEAT EXCHANGE COEFFICIENT	136.40	BTU/DEG-F/DAY
SHORT WAVE RADIATION	2205.00	BTU
POOL DEPTH	8.50	FEET
OUTFLOW TEMPERATURE	23.94	DEG-C
OUTFLOW OXYGEN	6.95	MG/L
OUTFLOW B.O.D.	1.40	MG/L
OUTFLOW QUANTITY	7.20	CFS

PROPOSED IMPOUNDMENT OF BRIDGE CREEK - JULY 8 THRU 31, 1980
SIMULATION YEAR - 1980

DAY - 195   13 JUL

LAYER NO.	ELEVATION (IN FEET)	DEPTH (FT)	INFLOW (CFS)	OUTFLOW (CFS)	TEMPERATURE (DEGREES-C)	D.O.	B.O.D.
9	92.5	0.0	0.0	0.0	24.84	8.4	1.2
8	91.5	1.0	0.0	0.0	24.83	8.4	1.2
7	90.5	2.0	0.0	0.0	24.79	8.2	1.3
6	89.5	3.0	0.93	0.93	24.75	7.9	1.3
5	88.5	4.0	3.19	3.19	24.57	7.3	1.3
4	87.5	5.0	1.39	1.39	24.00	6.9	1.4
3	86.5	6.0	1.39	1.39	23.41	6.7	1.4
2	85.5	7.0	0.20	0.20	23.14	6.6	1.5
1	84.0	8.0	0.10	0.10	23.04	5.8	2.4

```
                   PROPOSED IMPOUNDMENT OF BRIDGE CREEK - JULY 8 THRU 31, 1980
                   SIMULATION YEAR - 1980

                             DAY - 195     JUL 13

ELEV    DEPTH                   DEPTH PROFILES BELOW

                   0         4         8         12        16        20        24        28        32        36        40
                   I---------I---------I---------I---------I---------I---------I---------I---------I---------I---------I     TEMP
 92.     0.      +             2                             1                   T
 91.     1.      +             2                             1                   T
 90.     2.      +              2                           1                  T
 89.     3.      +              2                         1                    T
 88.     4.      +              2                      1                       T
 87.     5.      +               2                    1                        T
 86.     6.      +               2                   1                      T
 85.     7.      +                2                 1                       T
 84.     8.      +                         2    1                           T
                   I---------I---------I---------I---------I---------I---------I---------I---------I---------I---------I
                   0         2         4         6         8         10        12        14        16        18        20    D.O.
                   I---------I---------I---------I---------I---------I---------I---------I---------I---------I---------I
                   0         1         2         3         4         5         6         7         8         9         10    BOD5

                             T - TEMPERATURE, DEGREES CENTIGRADE
                             1 - DISSOLVED OXYGEN         MG/L
                             2 - FIVE DAY B.O.D.          MG/L
```

PROPOSED IMPOUNDMENT OF BRIDGE CREEK - JULY 8 THRU 31, 1980
SIMULATION YEAR - 1980

DAY	POOL DEPTH (FT)	INFLOW TEMP (DEG-C)	INFLOW D.O. (MG/L)	INFLOW QUANTITY (CFS)	INFLOW B.O.D. (MG/L)	OUTFLOW TEMP (DEG-C)	OUTFLOW D.O. (MG/L)	OUTFLOW QUANTITY (CFS)	OUTFLOW B.O.D. (MG/L)
196	8.5	22.00	7.0	7.30	1.8	24.21	6.3	7.30	1.41
197	8.5	23.00	6.8	7.40	1.9	23.84	8.7	7.40	1.43
198	8.5	22.00	6.7	8.20	2.0	22.85	8.7	8.20	1.44
199	8.5	22.00	6.9	7.70	1.9	23.12	6.9	7.70	1.51
200	8.5	21.50	7.0	7.50	1.8	22.72	6.4	7.50	1.50
201	8.5	21.50	7.0	7.50	1.8	22.65	6.3	7.50	1.50
202	8.5	21.50	7.0	7.40	1.7	22.50	6.2	7.40	1.49
203	8.5	21.00	7.0	7.30	1.6	21.84	8.9	7.30	1.46
204	8.5	20.00	7.2	7.20	1.5	20.98	9.1	7.20	1.49
205	8.5	19.00	6.9	7.30	1.4	20.87	7.3	7.30	1.49
206	8.5	20.00	7.1	7.00	1.4	21.20	6.7	7.00	1.47
207	8.5	20.50	7.1	7.20	1.5	21.34	6.5	7.20	1.49
208	8.5	19.50	7.2	7.90	1.5	20.70	9.1	7.90	1.50
209	8.5	19.00	7.3	7.40	1.6	20.69	7.5	7.40	1.54
210	8.5	19.50	7.2	7.20	1.6	20.81	6.8	7.20	1.55
211	8.5	20.00	7.4	7.30	1.7	21.25	6.6	7.30	1.56
212	8.5	20.00	7.5	7.20	1.7	21.24	6.6	7.20	1.55
213	8.5	21.00	7.4	7.20	1.6	22.08	6.4	7.20	1.50

PROPOSED IMPOUNDMENT OF BRIDGE CREEK - JULY 8 THRU 31, 1980
SIMULATION YEAR - 1980

DAY - 213   31 JUL

INFLOW QUANTITY	7.20	CFS
INFLOW TEMPERATURE	21.00	DEG-C
SUSPENDED B.O.D. INFLOW	1.60	MG/L
DISSOLVED OXYGEN INFLOW	7.40	MG/L
EQUILIBRIUM TEMPERATURE	79.20	DEG-F
HEAT EXCHANGE COEFFICIENT	138.40	BTU/DEG-F/DAY
SHORT WAVE RADIATION	1895.00	BTU
POOL DEPTH	8.50	FEET
OUTFLOW TEMPERATURE	22.08	DEG-C
OUTFLOW OXYGEN	6.40	MG/L
OUTFLOW B.O.D.	1.50	MG/L
OUTFLOW QUANTITY	7.20	CFS

PROPOSED IMPOUNDMENT OF BRIDGE CREEK - JULY 8 THRU 31, 1980
SIMULATION YEAR - 1980

DAY - 213   31 JUL

LAYER NO.	ELEVATION (IN FEET)	DEPTH (FT)	INFLOW (CFS)	OUTFLOW (CFS)	TEMPERATURE (DEGREES-C)	D.O.	B.O.D.
9	92.5	0.0	0.0	0.0	23.85	8.5	1.3
8	91.5	1.0	0.0	0.0	23.77	8.5	1.4
7	90.5	2.0	0.0	0.0	23.49	8.2	1.4
6	89.5	3.0	2.62	0.93	23.25	7.8	1.4
5	88.5	4.0	3.19	3.19	22.78	7.0	1.4
4	87.5	5.0	1.39	1.39	22.06	6.4	1.5
3	86.5	6.0	0.0	1.39	21.55	6.0	1.5
2	85.5	7.0	0.0	0.20	21.30	5.7	1.5
1	84.0	8.0	0.0	0.10	21.13	4.6	2.6

```
PROPOSED IMPOUNDMENT OF BRIDGE CREEK - JULY 8 THRU 31, 1980
SIMULATION YEAR - 1980

          DAY - 213     JUL 31

ELEV     DEPTH                   DEPTH PROFILES BELOW

                        0         4         8         12        16        20        24        28        32        36        40
                        I---------I---------I---------I---------I---------I---------I---------I---------I---------I---------I   TEMP
92.      0.      +                   2                             1                T
91.      1.      +                    2                            1             T
90.      2.      +                    2                          1               T
89.      3.      +                    2                        1                 T
88.      4.      +                    2                    1                   T
87.      5.      +                     2                1                      T
86.      6.      +                     2              1                     T
85.      7.      +                     2            1                       T
84.      8.      +                             1  2                         T
                        I---------I---------I---------I---------I---------I---------I---------I---------I---------I---------I
                        0         2         4         6         8         10        12        14        16        18        20   D.O.
                        I---------I---------I---------I---------I---------I---------I---------I---------I---------I---------I
                        0         1         2         3         4         5         6         7         8         9         10   BOD5

          T - TEMPERATURE, DEGREES CENTIGRADE
          1 - DISSOLVED OXYGEN        MG/L
          2 - FIVE DAY B.O.D.         MG/L
```

PROPOSED IMPOUNDMENT OF BRIDGE CREEK - JULY 8 THRU 31, 1980
OUTFLOW SUMMARY FOR YEAR - 1980

DAY	OUTFLOW CFS	TEMPERATURE DEGREES C	DISSOLVED OXYGEN MG / L	FIVE DAY BOD MG / L
190	7.5	22.1	8.8	1.5
191	7.5	23.2	7.5	1.5
192	7.4	24.5	6.9	1.4
193	7.3	25.1	6.3	1.4
194	7.3	24.7	8.5	1.4
195	7.2	23.9	6.9	1.4
196	7.3	24.2	6.3	1.4
197	7.4	23.8	8.7	1.4
198	8.2	22.9	8.7	1.4
199	7.7	23.1	6.9	1.5
200	7.5	22.7	6.4	1.5
201	7.5	22.7	6.3	1.5
202	7.4	22.5	6.2	1.5
203	7.3	21.8	8.9	1.5
204	7.2	21.0	9.1	1.5
205	7.3	20.9	7.3	1.5
206	7.0	21.2	6.7	1.5
207	7.2	21.3	6.5	1.5
208	7.9	20.7	9.1	1.5
209	7.4	20.7	7.5	1.5
210	7.2	20.8	6.8	1.5
211	7.3	21.2	6.6	1.6
212	7.2	21.2	6.6	1.6
213	7.2	22.1	6.4	1.5

APPENDIX F.--Heat Exchange Program User's Manual

Program No. 722-F5-E1010

This appendix provides a brief user's manual for use of the auxiliary Heat Exchange Program. This program computes daily surface-water Equilibrium Temperatures and Thermal Exchange Coefficients. The program requires daily average values of cloud cover, windspeed, air temperature, dew point, and daily totals of incoming shortwave solar radiation. If measured shortwave radiation values are not available, the program computes them using the previously mentioned meteorologic information and the user-specified elevation, latitude, and longitude data.

The program output consists of a daily tabulation of computed Equilibrium Temperatures and Exchange Coefficients. Input meteorologic data and computed radiation values are also listed in the output.

For complete documentation of this program, contact the U.S. Army Engineer District-Baltimore, P.O. Box 1715, Baltimore, Maryland 21203, and request the "Thermal Simulation of Lakes" documentation.

The contents of this appendix are as follows:

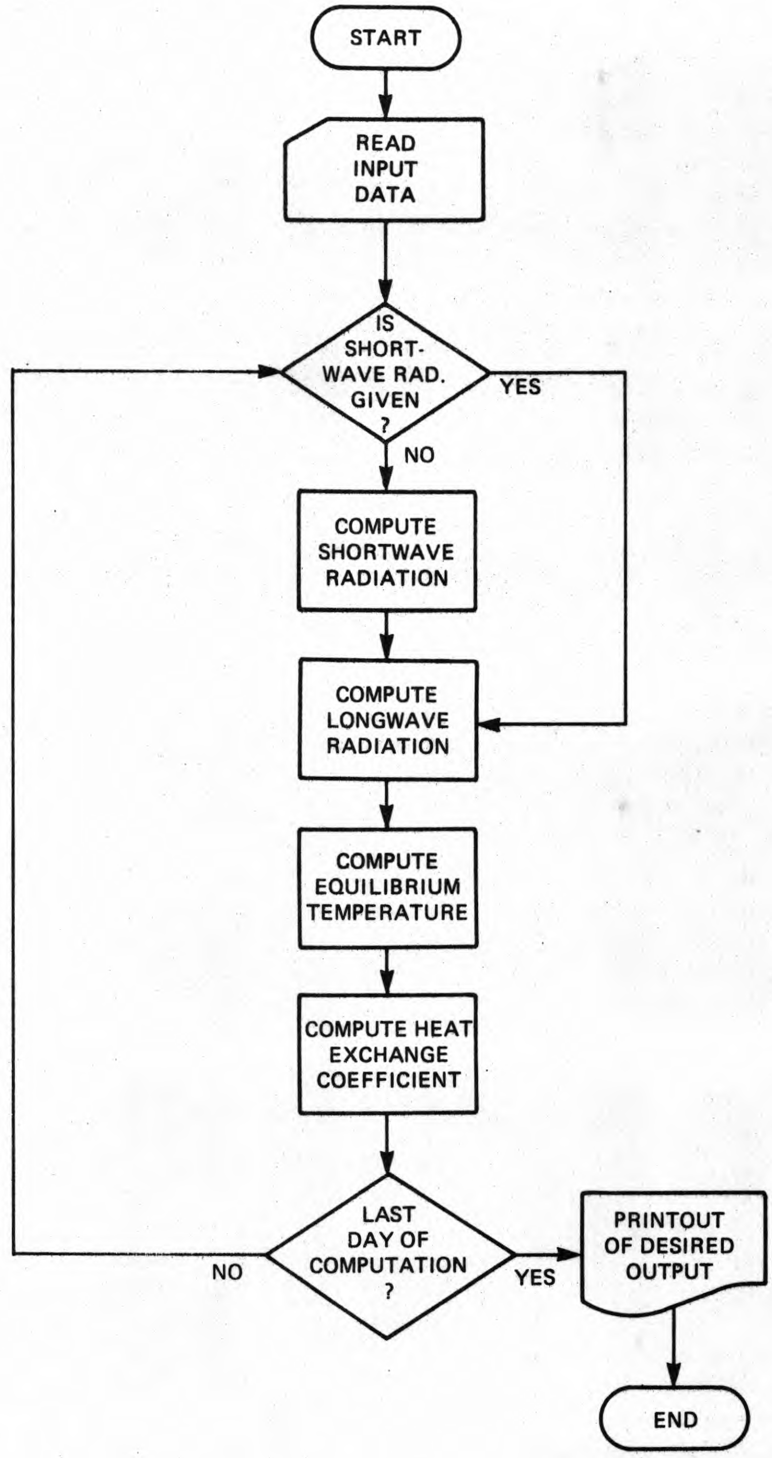


Figure 6.--Auxiliary heat exchange program flow chart.

INPUT CARD DESCRIPTION

(Must right-justify all Integer Values)

Input item	Program variable	Format	Card columns
<u>CARD 1</u>			
Specifies the number of jobs to be run, set N = 1	N	I10	10
<u>CARD 2</u>			
Title Card, any information may be given here	TITLE	18A4	2-72
<u>CARD 3</u> - Program Control Card			
Number of days that data are provided for	NLAST	I10	1-10
Set = 1 if shortwave radiation is provided as input, Set = 2 if it is to be computed. No default.	ISW	I1	20
Number of day's worth of shortwave radiation input data furnished, should equal NLAST value if ISW = 1, leave blank otherwise	NSW	I10	21-30
First day of computation Last day of computation, given in Julian Day numbers	IDAY LDAY	I10 I10	31-40 41-50
Set output to line printer, enter 1 in column 60	IPNCH	I1	60
<u>CARD 4</u>			
Enter estimate of the initial Equilibrium Temperature in °F, do not set equal or within 1°F of the first day's dewpoint temperature.	ETEMP1	F10.2	1-10
Set computation period equal to 24.0 hours for daily data output, 1.0 for hourly output	XPER	F10.2	11-20

Input item	Program variable	Format	Card columns
CARD 5 - Heat Budget Information			
Evaporation formula constant, set = 0. for daily data.	AEV	F10.2	1-10
Evaporation formula constant, set = 426. for daily data.	BEV	F10.2	11-20
Reflected fraction of short-wave radiation, set = 0. when shortwave radiation is to be computed (ISW = 2 on Card 3).	RFS	F10.2	21-30
Reflected fraction of long-wave radiation, ranges from 0.07 to 0.10 for a water surface,	RFA	F10.2	31-40
NOTE: OMIT CARD 6 if shortwave radiation is provided as input data (ISW = 1 on CARD 3) and not to be computed.			
CARD 6 - Shortwave Computation Data			
Elevation of project area in feet above Mean Sea level.	BOTEL	F10.2	1-10
Latitude of Project area in decimal degrees.	XLAT	F10.2	11-20
Longitude of Project area in decimal degrees.	XLONG	F10.2	21-30
Enter Reflectivity of Groundcover (see Table 3).	RFG	F10.2	31-40
CARD GROUP 7 - Cloud Cover		12x,34I2	
Enter mean daytime cloudcover as integer tenths values up to 34 days per card. 0 = Clear Skies, 10 = Completely overcast	CLOUD(N) up to CLOUD(NLAST), where 'N' is the day number		13-14, 15-16, 17-18, etc.
CARD GROUP 8 - Windspeed		12x,34I2	
Enter mean daily windspeed in knots as integer values, up to 34 days per card.	WIND(N) up to WIND(NLAST), where 'N' is the day number		13-14, 15-16, 17-18, etc.

Input item	Program variable	Format	Card columns
<u>CARD GROUP 9</u> - Air Temperature		12x,22I3	
Enter mean daily air temperature in °F as integer values. Values must be $\geq$ 0, up to 22 values per card.	AIRT(N) up to AIRT(NLAST), where 'N' is the day number.		13-15, 16-18, 19-21, etc.
<u>CARD GROUP 10</u> - Dew Point		12x,22I3	
Enter mean daily dew point in °F as integer values. Values must be $\geq$ 0, up to 22 values per card.	DEWT(N) up to DEWT(NLAST), where 'N' is the day number.		13-15, 16-18, 19-21, etc.

NOTE: INCLUDE CARD GROUP 11 only if Shortwave Radiation Input is to be included (ISW = 1 on CARD 3).

Input item	Program variable	Format	Card columns
<u>CARD GROUP 11</u> - Shortwave Radiation		12x,11F6.1	
Enter the total daily incoming shortwave radiation in units of BTU/FT^2/DAY, up to 11 values per card.	SW(N) up to SW(LAST), where 'N' is the day number.		13-18, 19-24, 25-30, etc.

<u>CARD 12</u> - Insert one blank card at end of data deck (Required).

Table 3.--Typical Values for Ground Reflectivity (RFG Value)

Calm water surface	0.07 - 0.10
Meadows and fields	0.14*
Leaf and needle forest	0.07 - 0.09*
Dark, extended mixed forest	0.045*
Flat ground, grass covered	0.25 - 0.33
Flat ground, rock	0.12 - 0.15
Sand	0.18
Vegetation early summer, leaves with high water content	0.19
Vegetation late summer, leaves with low water content	0.29
Fresh Snow	0.83
Old Snow	0.42 - 0.70

*May be too low

Reference:

Tennessee Valley Authority, Division of Water Control Planning, Engineering Laboratory, "Heat and Mass Transfer Between a Water Surface and The Atmosphere," Water Resources Research, Lab. Rept. No. 14, Norris, Tennessee, July 1967, Rev. May 1970.

```
PROGRAM IDENTIFICATION:   HEAT EXCHANGE PROGRAM
PROGRAM INFORMATION:      COMPUTES EQUILIBRIUM WATER TEMPERATURE
                          AND EXCHANGE COEFFICIENT
```

NOTE: CONTACT THE USGS DETERMINISTIC MODELS PROJECT, GULF COAST HYDROSCIENCE CENTER AT 601-688-3071 FOR A LIST OF THE JOB CONTROL CARDS NEEDED TO RUN THIS PROGRAM.

EXAMPLE INPUT CODE:

```
        1
 BRIDGE CREEK AT AUGUSTA, WISCONSIN - JULY 1980
       31          2                          184        214          1
  100.       24.0
            426.                     0.07
  960.     45.6817       91.1194     0.1
CLOUD COVER    5 2 5 6 7 7 4 5 4 0 8 4 4 5 6 4 3 6 5 7 5 5 1 3 8 3 1 6 0 7 5
WIND SPEED     9 4 4 7 9 9 7 6 5 7 7 9 6 91011 510 6 7 9 7 4 9 6 6 4 7 5 8 6
AIR TEMP 1     70 66 71 73 68 71 80 71 73 81 84 79 78 83 82 75 75 75 73 71 69 65
AIR TEMP 2     69 75 69 63 68 73 72 73 75
DEW POINT 1    57 50 55 63 60 61 70 56 63 64 73 65 64 72 61 62 62 66 61 66 62 56
DEW POINT 2    54 60 64 52 54 61 55 64 67
  -INSERT BLANK CARD AT END OF DATA-
```

WATER QUALITY SECTION-BALTIMORE DISTRICT

BRIDGE CREEK AT AUGUSTA, WISCONSIN - JULY, 1980

OUTPUT ONLY IF MEASURED SW INPUT USED

DAY	PER	EQ TEMP	EQ TPER	EX COEFF	SW DAY TOT (COMPUTED VALUES)	SW DAY (COMPUTED VALUES)	SW	SW NET	LW	LW NET	SKY	WIND	AIRT	DEWT
184	0	71.7		161.3	3604.9	2163.8			2771.3	2577.3	5	10.	70.	57.
185	0	78.7		82.0	3599.9	2557.8			2557.4	2378.4	1	5.	66.	50.
186	0	79.4		86.5	3594.5	2168.7			2802.8	2606.6	5	5.	71.	55.
187	0	76.2		145.7	3588.7	1941.0			2918.1	2713.9	5	8.	73.	63.
188	0	70.5		164.2	3582.6	1740.6			2815.1	2618.1	6	10.	68.	60.
189	0	72.0		169.3	3576.1	1731.6			2912.5	2708.6	6	10.	71.	61.
190	0	82.4		172.2	3569.2	2188.0			3054.7	2840.8	3	8.	80.	70.
191	0	75.1		116.5	3562.0	2141.1			2802.8	2606.6	5	7.	71.	56.
192	0	80.4		114.7	3554.4	2236.5			2824.6	2626.9	3	6.	73.	63.
193	0	81.2		157.8	3546.5	2467.6			3007.0	2796.5	0	8.	81.	64.
194	0	82.5		179.0	3538.1	1400.0			3446.6	3205.3	7	8.	84.	73.
195	0	78.1		192.1	3529.4	2203.4			3020.9	2809.4	3	10.	79.	65.
196	0	80.6		136.4	3520.3	2204.9			2987.4	2778.3	3	7.	78.	64.
197	0	81.9		221.0	3510.9	1990.5			3204.9	2980.6	5	10.	83.	72.
198	0	75.8		195.9	3501.3	1901.7			3226.5	3000.7	5	11.	82.	61.
199	0	74.1		211.3	3492.1	2199.7			2888.8	2686.6	3	13.	75.	62.
200	0	81.0		114.4	3482.5	2303.9			2855.4	2655.5	2	6.	75.	62.
201	0	75.4		206.6	3472.6	1851.3			2984.5	2775.5	5	11.	75.	66.
202	0	77.0		125.7	3462.4	2042.0			2866.7	2666.0	5	7.	73.	61.
203	0	75.3		149.1	3451.8	1635.6			2912.5	2708.6	6	8.	71.	66.
204	0	72.7		172.6	3440.9	2020.3			2740.0	2548.2	5	10.	69.	62.
205	0	70.8		126.2	3429.6	2049.5			2618.0	2434.8	5	8.	65.	56.
206	0	79.7		86.1	3418.0	2434.5			2632.8	2448.5	0	5.	69.	54.
207	0	74.8		173.5	3406.0	2258.3			2855.4	2655.5	2	10.	75.	60.
208	0	73.4		124.1	3393.7	1384.5			2914.3	2710.3	7	7.	69.	64.
209	0	71.3		106.9	3381.0	2288.8			2492.0	2317.6	2	7.	63.	52.
210	0	78.9		85.3	3368.0	2391.9			2603.1	2420.9	0	5.	68.	54.
211	0	74.6		139.6	3354.6	1810.3			2918.1	2713.9	5	8.	73.	61.
212	0	77.9		102.3	3340.9	2368.7			2719.0	2528.7	0	6.	72.	55.
213	0	74.0		161.6	3326.8	1579.1			2978.9	2770.4	6	9.	73.	64.
214	0	79.2		138.4	3312.4	1895.3			2931.9	2726.6	5	7.	75.	67.

EQ TPER: EQUILIBRIUM TEMP FOR COMPUTING PERIOD IF LESS THAN ONE DAY, NO OUTPUT IN THIS COLUMN IF A DAILY INTERVAL IS USED

SW: LIST OF MEASURED SHORTWAVE RADIATION INPUT IN BTU/FT^2/DAY

SW NET: LIST OF NET SW RADIATION ENTERING WATER BODY IN BTU/FT^2/DAY

DAY: JULIAN DAY NUMBER

PER: COMPUTATION PERIOD, HRS ZERO INDICATES DAILY DATA

EQ TEMP: EQUILIBRIUM SURFACE WATER TEMPERATURE IN DEGREES F

EX COEFF: THERMAL EXCHANGE COEFFICIENT, BTU/^{o}F/FT^2

SW DAY TOT: SHORTWAVE RADIATION AT TOP OF ATMOSPHERE, BTU/FT^2/DAY

SW DAY: NET SW RADIATION ENTERING WATER BODY, BTU/FT^2/DAY

LW: COMPUTED LONGWAVE RADIATION, BTU/FT^2/DAY

LW NET: NET LW RADIATION ABSORBED, BTU/FT^2/DAY

SKY, WIND, AIRT, DEWT: LIST OF INPUT DATA WITH VALUES TRUNCATED TO INTEGERS