USER'S MANUAL: HYDROTHERMAL AND WATER QUALITY MODELS FOR LAKES AND RESERVOIRS

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Battelle
Pacific Northwest Laboratories
Richland, Washington 99352

USER'S MANUAL: HYDROTHERMAL AND WATER QUALITY MODELS FOR LAKES AND RESERVOIRS

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SUMMARY

In a project recently completed for the Environmental Protection Agency, Battelle-Northwest developed a generalized water quality model[1] for lakes and reservoirs. The simulation models are designed to provide a complete portrayal of the dynamic processes which determine the eutrophic states in lakes and reservoirs. The models are formulated in terms of several key environmental variables: dissolved oxygen, biochemical oxygen demand, coliform bacteria, toxic material, algal populations and nutrient materials, and the major controlling factors: light, temperature, stream flows, and loading rates. The final simulation models were applied to American Falls Reservoir in Idaho with excellent results. The computer models consist of three programs: CLIMA, TERMA and AQUA-II. This document is provided to guide the general user in setting up and applying the models.

[1]Baca, R. G., M. W. Lorenzen, R. D. Mudd, and L. V. Kimmel. "A Generalized Water Quality Model for Eutrohpic Lakes and Reservoirs." Battelle, Pacific Northwest Laboratories, Richland, Washington, prepared for Office of Research and Monitoring, U.S. Environmental Protection Agency, August 1974.

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USER'S MANUAL

INTRODUCTION

This manual is a guide to the use of the Deep Reservoir Hydrothermal and Water Quality Models. The examples and illustrative data are given for American Falls Reservoir in Idaho. By following the instructions in this manual, the user should be able to set up and run water quality simulations for situations where sufficient data are available.

Theoretical considerations that are important in model development are discussed in the Documentation Report.[1]

MODEL DESCRIPTION

Program Operational Sequence

The overall numerical model for reservoirs and thermal impoundments consists of three component computer programs:

- a generalized input program, CLIMA
- a thermal-hydraulic simulation program, TERMA
- a water quality simulation program, AQUA-II

The separation of the overall numerical model into modular programs has an important advantage in that it allows calibration of individual models. In general application, the programs are used in sequence so that the determinations of one become input for the next.

The input program CLIMA reads a standard set of meteorologic, hydraulic, and hydrologic data for a particular simulation period and prepares a magnetic tape data file which may be used repeatedly as input to the thermal simulation program.

The thermal simulation program, TERMA, determines the vertical temperature profiles and interflow distributions for the entire simulation period. These predictions are required input data for the water quality program.

Reservoir water quality is modeled with the AQUA-II program which simulates advective-diffusive transport as well as chemical and biological reactions of the parameters being modeled. Figure 1 is a diagram of the basic information flow between the three programs.

Program Descriptions

CLIMA. Various kinds of input data must be prepared for modeling specific reservoir sites and their environments. CLIMA, the generalized input program, performs the important function of ordering, organizing, checking and outputting the standard set of data necessary to initiate a thermal-hydraulic or quality simulation.

In addition to the basic data preparation, this program estimates the net energy flux passing the air-water interface and the equilibrium water surface temperature. These quantities establish boundary conditions for the thermal simulation program.

The CLIMA program consists of five computational subroutines. Input data requirements are listed below.

Group I

Simulation specification and site characterization

1) Period of simulation, days
2) Latitude
3) Longitude
4) Average water surface elevation

Meteorologic-climatic data

1) Number of observations per day
2) Atmospheric pressure
3) Sky cover
4) Wind speed
5) Dry bulb temperature
6) Wet bulb temperature
7) Dew point temperature

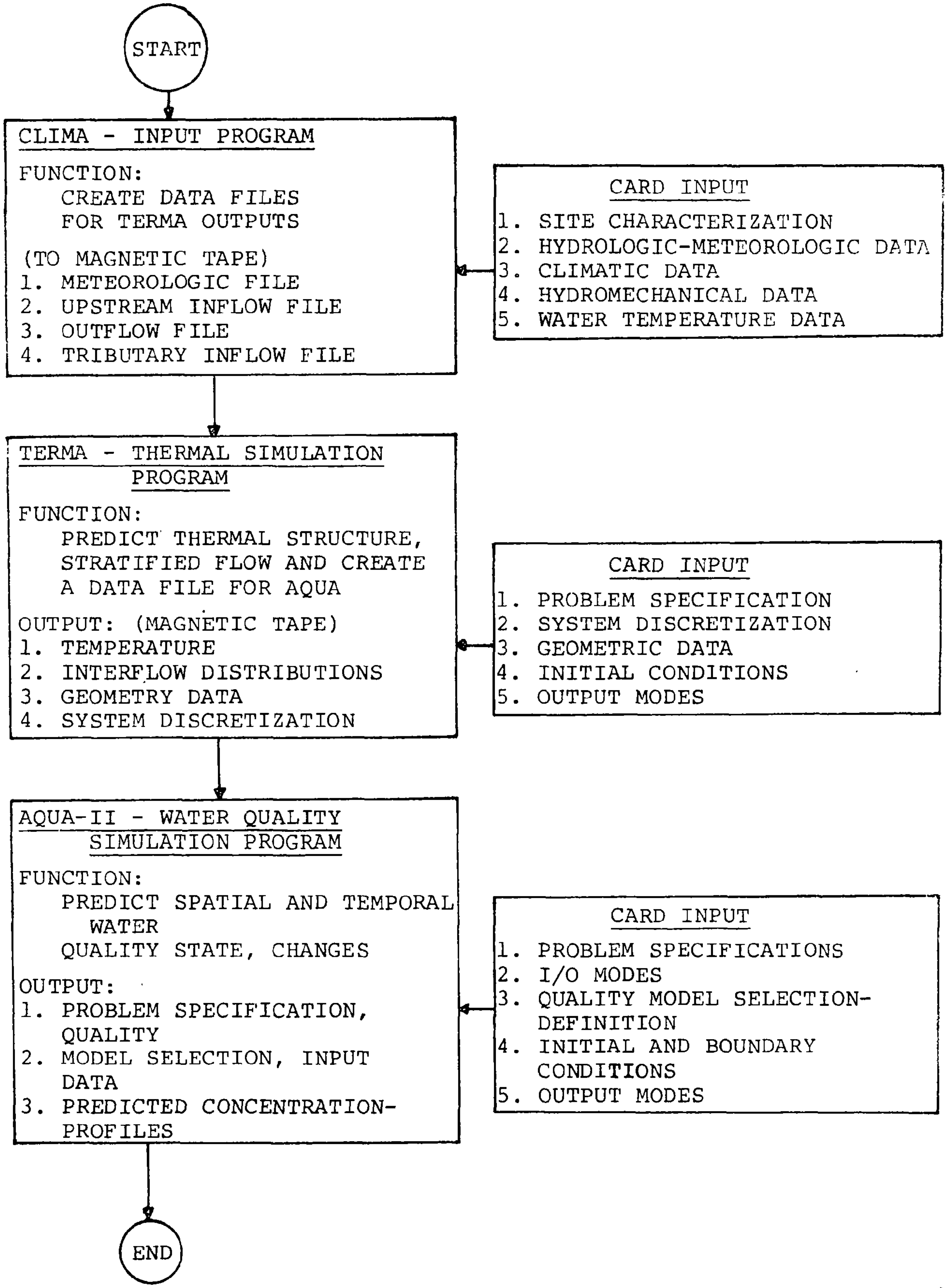

FIGURE 1. Information Flow Diagram

8) Short wave radiation
9) Relative humidity

Group II

Hydrologic data

1) Water surface elevations
2) Upstream inflow rates and temperatures
3) Outflow rates from reservoir
4) Tributary inflow rates and temperatures

General card input is structured to accommodate any units; conversion factors may be input by the user. A complete data echo initializes all printer output, listing all card images (numbered according to group) loaded for program execution. These listings aid in detecting random errors (such as keypunch errors or systematic inconsistencies in the original data). The CLIMA program organization is shown in Figure 2. Variables used are listed in Table 1.

TABLE 1. Variables Used in CLIMA

IYR	- Year of meteorological observations
lDAY	- First Julian day for the observations
LDAY	- Final Julian day for the observations
NOBS	- Number of meteorological observations per day
ITAPE	- Output tape number
A	- Evaporation coefficient 1
B	- Evaporation coefficient 2
LAT	- Latitude of site
LONG	- Longitude of site
RESEL	- Average water surface elevation
DATA (J,1)	- Atmospheric pressure (mb)
DATA (J,2)	- Sky cover (decimal fraction)
DATA (J,3)	- Wind speed (m/sec)
DATA (J,4)	- Dry bulb air temperature (°C)

DATA (J,5)	- Wet bulb air temperature (°C)
DATA (J,6)	- Dew point temperature (°C)
DATA (J,7)	- Short wave solar radiation (KcaL/m**2-sec)
DATA (J,8)	- Relative humidity (decimal fraction)
VPS(x)	- Vapor pressure (mb)
QNS(J)	- Net short wave radiation (KcaL/m**2-sec)
QAT(J)	- Long wave atmospheric radiation (KcaL/m**2-sec)
AP(J)	- Atmospheric pressure (mb)
DBT(J)	- Dry bulb temperature (°C)
EA(J)	- Atmospheric vapor pressure (mb)
WS(J)	- Wind speed (m/sec)
ET(J)	- Equilibrium temperature (°C)
CLD(J)	- Cloudiness
DPT(J)	- Dew point temperature
QS(J)	- Gross shortwave solar radiation (KcaL/m**2-sec)
WBT(J)	- Wet blub temperature (°C)
WC(J)	- Water content of atmosphere
TA(J)	- Average daily water surface elevation (m)
TB(J)	- Average daily upstream inflow (m**3/sec)
TC(J)	- Average daily upstream inflow temperature (°C)
NOUTS	- Number of discrete withdrawals
ELOUT	- Elevation of outlet
WOT	- Width of dam at outlet
QOUT(J)	- Average daily outflow (m**3/sec)
QIN(J)	- Average daily tributary inflow (m**3/sec)
TIN(J)	- Average daily tributary inflow temperature (°C)

TERMA. The TERMA program performs the component function of simulating the thermal-hydraulic behavior of a thermally stratified reservoir. Vertical temperature profiles and interflow distributions are computed for the specified simulation period in days. The thermal simulation program operates on a simple segment-element discretization. A complete reservoir system is represented by N segments, each composed of M horizontal elements (layers). The entire system is simulated segment by segment, working downstream. This successive simulation procedure

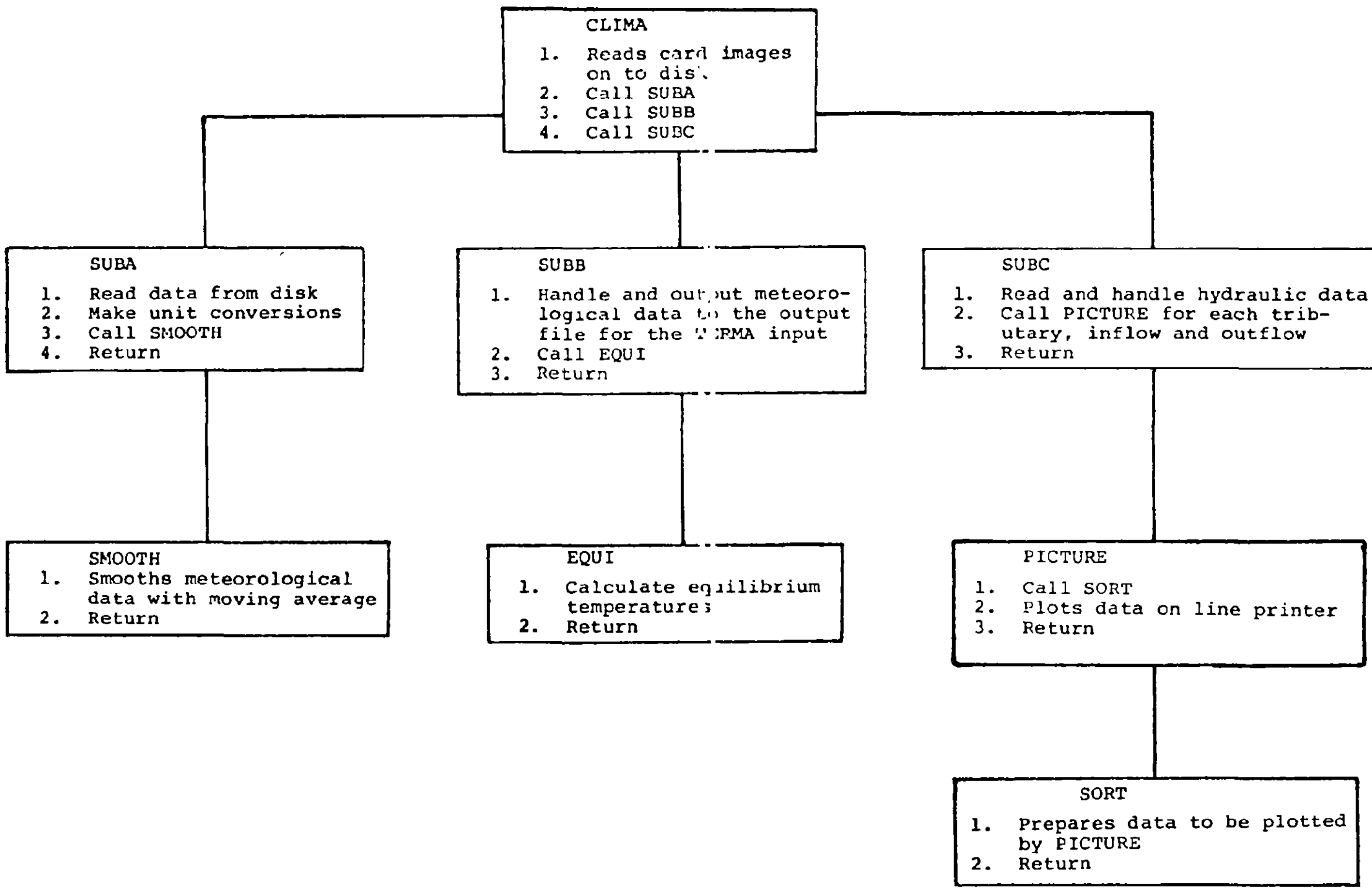

FIGURE 2 CLIMA. Program Organization

yields a quasi-two-dimensional representation of the reservoir in the form of a series of one-dimensional vertical profiles.

Time step selection for all simulations is a critical factor in program functionality and must be consistent with the input data time base (e.g., data - hourly → simulation step - hourly, data - daily average → simulation step - 1 day, etc.).

Basic card input to the thermal simulation program consists of two main groups and includes:

<u>Group I</u>

Simulation Specifications

1) Period of simulation, days
2) Initial and daily water surface elevations
3) Heat transfer coefficients
4) Thermal gradient range
5) System discretization
6) Location of tributary inflows

<u>Group II</u>

Segment parameters

1) Elevation - area profile
2) Segment lengths
3) Initial temperature profile
4) Element thickness
5) Diffusion coefficients
6) Output modes

All printer output is preceded by a complete listing of input card images and is numbered according to group. The TERMA program organization is shown in Figure 3. Table 2 lists the variables used.

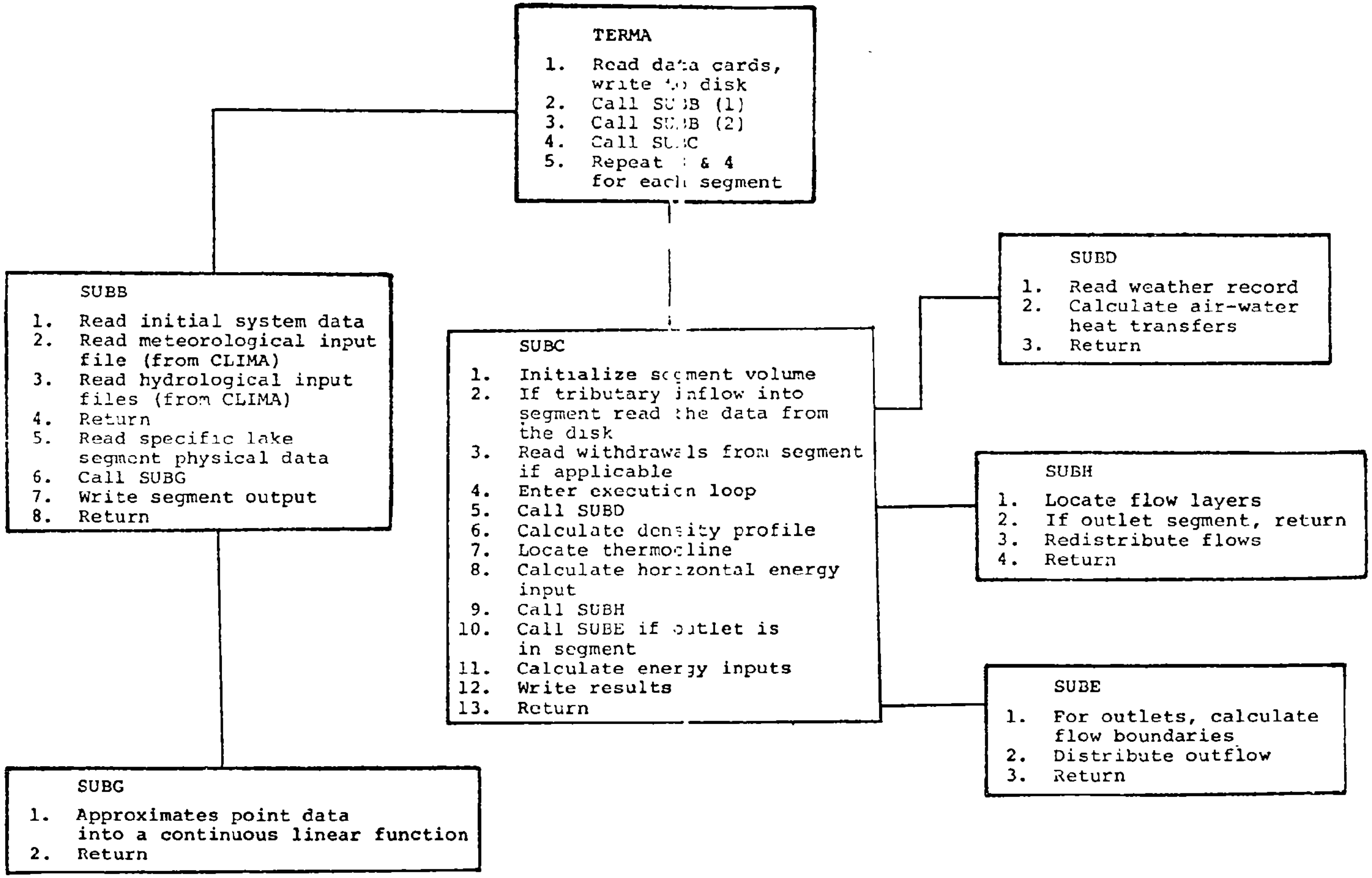

FIGURE 3. TERMA, Program Organization

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TABLE 2. Variables Used in TERMA

IDAY	- Initial day of simulation period
LDAY	- Last day of simulation period
UDZ	- Segment element thickness (m)
ELRES	- Initial system water surface elevation (m)
ELMAX	- Maximum system water surface elevation (m)
EDMAX	- Depth of short wave extinction (m)
A	- Evaporation rate coefficient 1 (m/sec-mb)
BB	- Evaporation rate coefficient 2 (mb)
NTRIBS	- Total number of tributary inflows
ITRIB	- Numbers of segments with tributary inflows
NLETS	- Number of the segment with outflows
NOUTS	- Number of reservoir system outlets
NOBS	- Number of meteorological observations per simulation day
POOL(J)	- Average daily surface elevation (m)
QUP(J)	- Average daily upstream inflow (m^3/sec)
TUP(J)	- Average daily inflow temperature (°C)
ELOUT(I)	- Elevation of Ith outflow (m)
WOT(I)	- Width of Ith outflow (m)
QOT(I)	- Daily value of withdrawal of Ith outflow (m^3/sec)
IAT	- First day of tributary data from CLIMA
IBT	- Last day of tributary data from CLIMA
NSEG	- Segment number
NAP	- Number of points in segment area profile
NTP	- Number of points in segment temperature profile
NSD	- Number of days for which output is specifically requested
IPRT	- Printing Interval (days)
INTP	- Printing interval for vertical elements (every INTPth element)
NXEQ	- Number of executions per simulation day
IVAL	- Simulation interval in a day with output
GSWH	- Critical stability parameter
A1	- Diffusion Coefficient 1
A2	- Diffusion Coefficient 2

A3	- Epilimnion diffusion coefficient (not used)
SDZ	- Vertical thickness of standard element (m)
RLEN	- Horizontal segment length (m)
Z(I)	- Elevation of Ith element (m)
AREA(I)	- Area of Ith element (m)
DZ(I)	- Thickness of Ith element (m)
MAXP	- Maximum possible number of elements
MAXE	- MAXP-1
T(K)	- Initial temperature (°C) at Kth element
TDOT(K)	- Initial rate of temperature change (C°/sec)
IDOUT	- Julian day number for specific printed output
NOU(J)	- Element number of outfall "J" location
VOL(J)	- Volume of Jth element
DVOL(J)	- Difference in volume between Jth and (J+1) the element
RESEL	- Reservoir elevation (m)
AT	- Air Temperature
DZT	- Vertical thickness of uppermost element (NUME)
ABAR(J)	- Average of J & J+1 element areas
DRLT	- Number of seconds in each execution per simulation day
DTBY2	- DELT/2
NHOB	- Number of hours between meteorological observations
NHXQ	- Number of hours in each execution per simulation day
QIN(K)	- Daily tributary inflow rate (m^3/sec)
TIN(K)	- Temperature of tributary inflow (°C)
NUMP	- Total number of element faces
NUME	- Total number of element (NUMP-1)
NUM	- NUME-1
NULL	- NUM-1
DZTOP	- Thickness of surface element
EXCO	- Extinction coefficient
TFX(J)	- Temperature of Jth element
DRNS(J)	- Density of Jth element
ELTC	- Elevation of thermocline
TOUT(J)	- Temperature of outflow at outfall J
QOUT	- Total outflow
QI	- Total inflow to segment

NUSI	- Number of upstream inflows
IMIX	- Layer above which reservoir is mixed
DC(J)	- Diffusion coefficient for Jth element
QN	- Net radiation heat transfer (KcaL/(m**2)-sec)
QNS	- Net shortwave solar radiation (KcaL/m**2)-sec)
QNA	- Atmospheric longwave radiation (KcaL/m**2)-sec)
QW	- Longwave back radiation (KcaL/m**2)-sec)
QE	- Evaporative heat (KcaL/m**2)-sec)
QC	- Sensible heat
RESTM(I)	- Residence time for Ith day
WS	- Wind speed (m/sec)
DST(I)	- Downstream temperature on Ith day
SHEAT	- Net rate of surface heating
EVA	- Rate of evaporation
EVAP	- Cumulative evaporation
EA	- Atmospheric vapor pressure
EV	- Evaporation rate per unit area
VSUM	- Total volume of segment
ATWO	- Surface area of layer
VTOP	- Volume of surface element
ATOP	- Average surface area of top element
DZI(I)	- 1/standard element thickness
NTC	- Element in which thermocline is located
AV(J)	- Vertical energy input to Jth element
QHI(I)	- Inflow to element I
QHO(I)	- Outflow from element I

AQUA-II. The AQUA-II program solves the water quality reaction and mass transport equations for concentrations of each parameter at the end of each time step.

Card input to the AQUA-II program is necessarily complex due to the variety of input modes (e.g., constant, variable, uniform, etc.). One standard data group is required for each simulation consisting of:

Group I

Site Characterization - specifications

1) Simulation period
2) Reservoir discretization
3) Simulation mode (i.e., with or without water quality reactions)
4) Quality model selection
5) Rate constants
6) Initial and boundary conditions
7) Output modes

The AQUA-II program organization is shown in Figure 4 and variables used are listed in Table 3. A detailed description of card input structure for each program is presented in the following sections.

TABLE 3. Variables Used in AQUA-II

	Variable	Units
RLC	Carbonaceous BOD	mg/l
BODCAL(1)	Decay rate constant	day^{-1}
REACAL(1)	Reaeration coefficient	
DOXCAL(1)	Saturation oxygen concentration	
RLD	Benthic BOD	$g/m^2/day$
TININ(1)	Rate constant $NH_4 \rightarrow NO_2$	day^{-1}
TININ(2)	Rate constant $NO_2 \rightarrow NO_3$	day^{-1}
TININ(3)	Rate constant organic - $N \rightarrow NH_4$	day^{-1}
C1	NH_4 concentration	mg/l
C2	NO_2 concentration	mg/l
C3	NO_3 concentration	mg/l
C4	Organic N concentration	mg/l
PHO (1)	Rate constant, dissolved P $\rightarrow$ Sed. P	day^{-1}
PHOIN (2)	Rate constant, SedP$\rightarrow HPO_4$	day^{-1}
PHOIN (3)	Rate constant, Org.P$\rightarrow HPO_4$	day^{-1}

D1	HPO_4 concentration	mg/l
D2	Sediment-P concentration	mg/l
D3	Organic-P concentration	mg/l
COLI	Coliform concentration	NO/100ml
COLCAL (1)	Rate constant, decay	day^{-1}
TC	Toxic compound concentration	mg/l
TOXCAL(1)	Rate constant, decay	day^{-1}
TOXIN (2)	Algal toxicity constant	mg/l
Z	Zooplankton concentration	mg-C/l
P	Phytoplankton concentration	mg-C/l
ALGIN(1)	Maximum specific growth rate	day^{-1}/°C
(2)	Adaption to light	lux^{-1}
(3)	Extinction coefficient	m^{-1}
(4)	Self shading factor	m^{-1}/mg/l
(5)	Detrital settling velocity	m/day
(6)	Michaelis constant for nitrogen	mg/l
(7)	Michaelis constant for phosphoros	mg/l
(8)	Algal repiration rate	day^{-1}/°C
(9)	Zooplankton grazing rate	
(10)	Phyto/Zoo conversion efficiency	
(11)	Michaelis constant for Zoo or phyto	mg/l
(12)	N/carbon ratio, phytoplankton	
(13)	P/carbon ratio, phytoplankton	
(14)	N/carbon ratio, zooplankton	
(15)	P/carbon ratio, zooplankton	
(16)	Zooplankton respiration rate	day^{-1}/°C
(17)	Zooplankton decay rate	day^{-1}
(18)	Algal setting velocity	m/day
ALGCAL (1)	Gross phytoplankton growth rate	day^{-1}
(2)	Phytoplankton decay rate	day^{-1}
(3)	Zooplankton growth rate	day^{-1}
(4)	Zooplankton death rate	day^{-1}
(5)	Effective nitrogen concentration	mg/l
(6)	Effective phosphorus concentration	mg/l

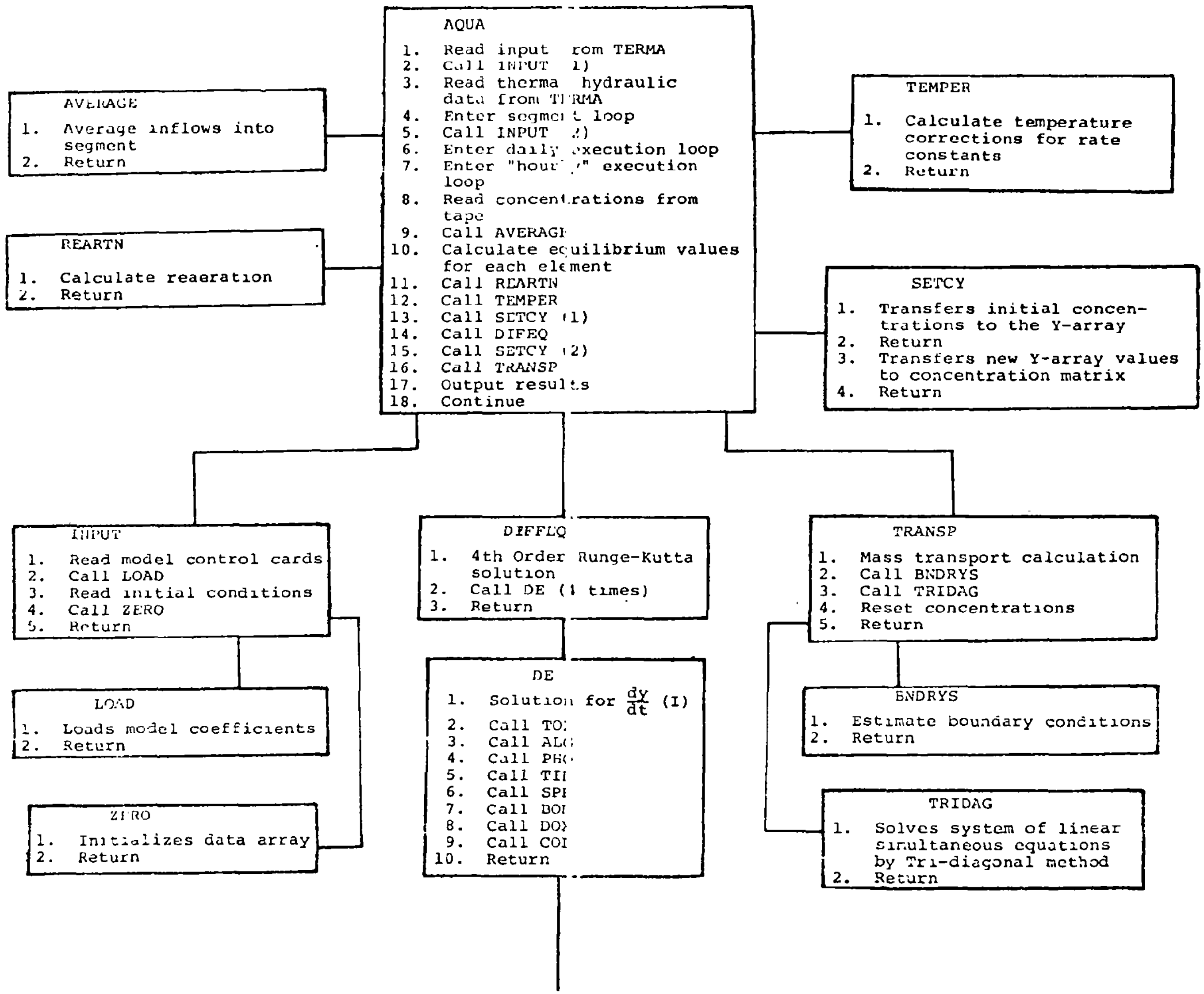

FIGURE 4. AQUA-II Program Organization

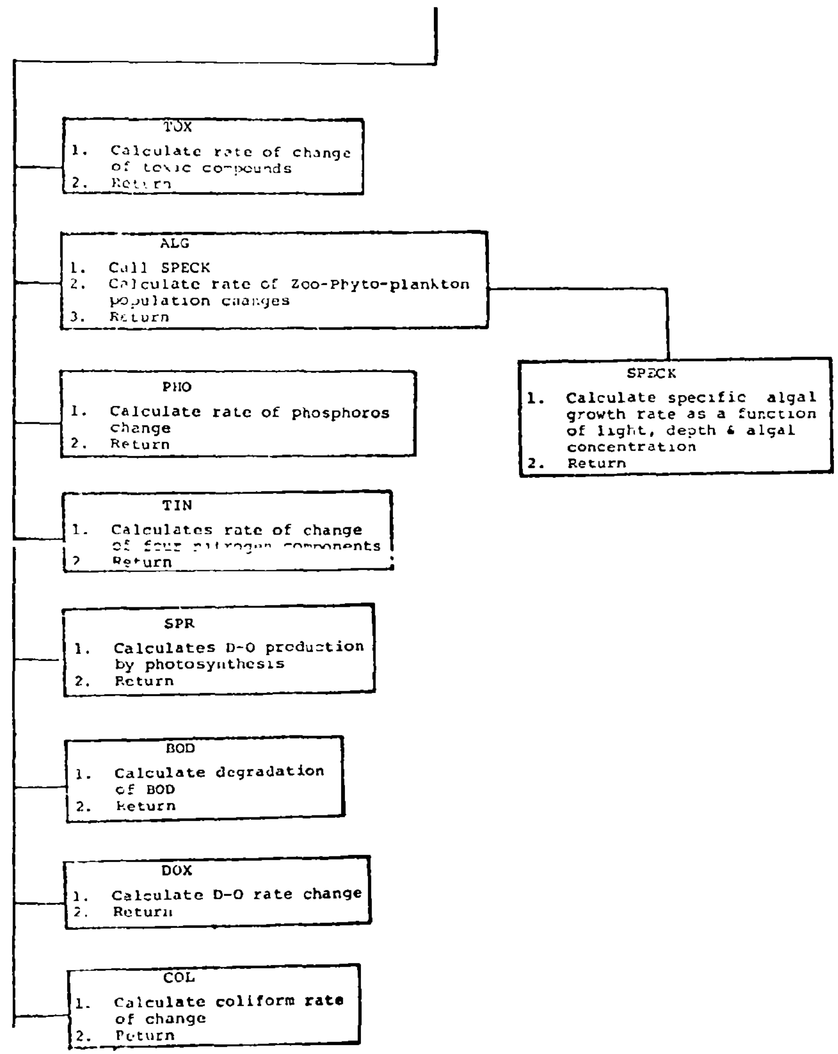

FIGURE 4. (Continued)

DATA SOURCES

Input data for the three component programs are available from a variety of sources according to the data category (meteorology, hydraulics, hydrology or quality).

Some reservoirs routinely collect onsite daily meteorologic data such as air temperature, water surface temperature, evaporation, wind speed, and relative humidity; however, in most cases, meteorologic data recorded at the nearest weather station must be used. Most of the meteorologic data can be obtained from the National Weather Records Center, Ashville, North Carolina, in either tabular or punched card form.

The required hydraulic data consist of the reservoir outflow regulation policy tributary flows and the observed pool elevations. These data are routinely collected and recorded by the Corps of Engineers for Corps dams and are usually summarized by the U.S. Geological Survey.

PREPARATION OF INPUT DATA

Card input modes for CLIMA, TERMA, and AQUA have been designed for ease of use. All program listings identify and define the necessary card input and include descriptions of the variables, appropriate units, and suggested and/or default coefficient values.

Inherent in the overall reservoir model is the use of certain empirical coefficients which attempt to lump complex phenomena into simple mathematical characterizations. The specific values assigned to these coefficients are very important to the correct operation and accuracy of the model components. The computer programs are presently designed to default to a "workable set" of coefficients. However, calibration of the model to specific reservoir sites requires "workable ranges" for these coefficients in order to obtain good spatial and temporal correlation between predicted and observed data.

The formal card input structures for the component programs of the reservoir model are presented in Tables 4, 6 and 8.

CLIMA. Card input requirements for the program CLIMA are described in Table 4. Table 5 is a sample listing of input data used at American Falls Reservoir for the period April through December, 1968.

TERMA. Card input requirements for the program TERMA are described in Table 6. Table 7 is a listing of input data cards used at American Falls Reservoir.

AQUA-II. Card input requirements for the program AQUA-II are listed in Table 8. Table 9 is a listing of input data cards used at American Falls.

Sample listings of output from TERMA and AQUA-II are shown in Tables 10 and 11 respectively.

Table 12 is a complete listing of all three programs.

TABLE 4. Card Input for CLIMA

Card No.	Format	Card Columns	Description	Variable Name	Default Value
GROUP I - SITE CHARACTERIZATION AND METEOROLOGY					
1	16A5	1-80	Title	TITLE	NONE
2	5I10	1-10	Year of the meteorologic observations	IYR	NONE
		11-20	First Julian day for simulation	IDAY	NONE
		21-30	Final Julian day for simúlation	LDAY	NONE
		31-40	Number of meteorologic observations per day	NOBS	NONE
		41-50	Tape No. for data file output	ITAPE	0
3	5E10.0	1-10	Evaporation coefficient No. 1	A	0.0
		11-20	Evaporation coefficient No. 2	B	1.E-10
		21-30	Latitude of reservoir site	LAT	NONE
		31-40	Longitude of reservoir site	LONG	NONE
		41-50	Average water surface elevation (m)	RESEL	NONE
4	I10	1-10	Code identifying meteorologic parameter to be entered next (0 terminates Group 4 input)	ID	NONE

	ID Code	Parameter	Units
(Optional)	1	Atmospheric pressure	Millibars
	2	Sky cover	Decimal fraction
	3	Wind speed	Meters/sec
	4	Dry bulb air temperature	Centigrade
	5	Wet bulb air temperature	Centigrade
	6	Dew point temperature	Centigrade
(Optional)	7	Short wave solar rad.	Kcal/M**2*sec
(Optional)	8	Relative humidity	Decimal fraction

Card No.	Format	Card Columns	Description	Variable Name	Default Value
	3E10.0	11-20	Conversion factor 1	CV	1.0
		21-30	Conversion factor 2 — $X_{ID}=CV*(X_{ID}^{raw} + CVA)+CVB$	CVA	0.0
		31-40	Conversion factor 3 — X_{ID}-meteorologic parameter	CVB	0.0
	I5	41-45	Switch for inputting constant or variable meteorologic data values (positive #→constant, 0→variable)	LOGIC	0

TABLE 4 (continued)

Card No.	Format	Card Columns	Description	Variable Name	Default Value
5	8E10.0	1-80	Data set for the meteorologic parameter designated in ID code in card 4:	DATA	NONE
			Note: A. ID 2, 3, 4, and 5 or 6 are necessary to run. If data for ID 5 are not available, it is recommended that data for ID 8 be included in addition to data for ID 6 if at all possible.		
			B. There should be as many card group 4 and 5 sets as the number of ID parameters used (with a minimum of 4 sets). An equal number of card group 5 cards will also be needed to provide input data for the simulation period if variable input is used. If constant input is used, each card group 4 will be followed by one card group 5 with the constant value to be used for that parameter.		
6	I10	10	Insert a 0 (zero) in column 10 to terminate Group I input data		
7	A5	1-5	The Sentry designating end of Group I card input is <u>END</u> (right justified)	END	NONE

TABLE 4 (continued)

Card No.	Format	Card Columns	Description	Variable Name	Default Value
GROUP II - HYDRAULIC AND HYDROLOGIC INPUT					
1	3I5	1-5	First Julian day with hydraulic and hydrologic data	IDAY	NONE
		6-10	Last Julian day with hydraulic and hydorlogic data	LDAY	NONE
		11-15	Blank		NONE
	4E10.0	16-25	Units conversion factor 1 — units → m	A1	1.0
		26-35	Units conversion factor 2 — units → cms	B1	1.0
		36-45	Units conversion factor 3 — units → °C	C1	1.0
		46-55	Units conversion factor 4 — units → °C	C2	0.0
			Conversion factors transform raw data to metric units indicated		
2	3E10.0	1-10	Average daily water surface elevations	TA	NONE
		11-20	Average daily upstream inflow rates	TB	NONE
		21-30	Average daily upstream inflow temperatures	TC	NONE
			Repeat card group 2 for each day in simulation period		
3	3I5	1-5	First Julian day with outflow (discrete withdrawals)	IDAY	NONE
		6-10	Last Julian day with outflow (discrete withdrawals)	LDAY	NONE
		11-15	Number of outlets with withdrawals	NOUTS	NONE
	3E10.0	16-25	Units conversion factor 1 — units → m	A1	1.0
		26-35	Units conversion factor 2 — units → m	B1	1.0
		36-45	Units conversion factor 3 — units → cms	C1	1.0
4	2E10.0	1-10	Elevation of the outflow	ELOUT	NONE
		11-20	Width of dam at elevation of outlet	WOT	NONE
			Repeat card group 4 for each outlet in system		

TABLE 4 (continued)

Card No.	Format	Card Columns	Description	Variable Bane	Default Value
5	8E10.0	1-80 . . 1-80	Average daily outflow rates	QOT	NONE
			Repeat card group 5 for each outlet, maintaining the same outlet order established in card group 4		
6	3I5	1-5	First Julian day of tributary inflow	IDAY	NONE
		6-10	Last Julian day of tributary inflow	LDAY	NONE
		11-15	Number of tributaries with significant inflows	NTRIB	NONE
	3E10.0	16-25	Conversion factor 1 | units → cms	A1	1.0
		26-35	Conversion factor 2 | units → °C	B1	1.0
		36-45	Conversion factor 3 | units → °C	B2	010
7	2E10.0	1-10	Average daily tributary inflow rate	QIN	NONE
		11-20	Average daily tributary inflow temperature	TIN	NONE
			List all data for first tributary, then proceed to other tributaries in succession		
8	A5	1-5	The Sentry designating the end of Group II card input is END (right justified)	END	NONE

TABLE 5. Input Data - CLIMA

```
AMERICAN FALLS RESERVOIR CALIBRATION 1968 DATA
      68          1          365          1          1
   0.0E0     1.0E-10        43.         113.      1320.0
       1     3.39E1         0.0         0.0      0
 2.526E01  2.544E01  2.565E01  2.572E01  2.549E01  2.581E01  2.563E01  2.546E01
 2.540E01  2.519E01  2.573E01  2.596E01  2.586E01  2.570E01  2.545E01  2.540E01
```

.

. Continue atmospheric pressure data cards

.

```
 2.503E01  2.527E01  2.519E01  2.534E01  2.555E01  2.574E01
        2    1.0E-1       0.0       0.0   0
   1.0E01    1.0E01    0.6E01    0.4E01    0.9E01    0.2E01    0.6E01    1.0E01
   1.0E01    1.0E01    0.4E01    0.2E01    0.6E01    0.8E01    0.8E01    0.8E01
```

.

. Continue sky cover data cards

.

```
0.9E01    1.0E01    0.9E01    0.2E01    0.4E01    0.9E01
3   4.47E-1     0.0       0.0     0
1.57E01   0.50E01   1.44E01   1.14E01   1.88E01   0.63E01   0.40E01   1.71E01
1.60E01   2.67E01   0.71E01   0.53E01   0.52E01   0.60E01   0.37E01   0.99E01
```

.

. Continue wind speed data cards

.

```
      4   5.56E-1   -3.2E1      0.0      0
2.7E01    1.5E01    2.1E01    2.0E01    2.4E01    1.4E01    0.9E01    2.4E01
3.4E01    3.1E01    1.4E01    0.8E01    1.2E01    2.1E01    2.6E01    2.9E01
```

TABLE 5. continued

.
. Continue dry bulb temperature data cards
.

2.4E01	2.6E01	3.0E01	1.8E01	0.4E01	0.0E01		
5	5.56E-1	-3.2E1	0.0	0			
2.71E01	1.49E01	1.88E01	1.78E01	2.35E01	1.25E01	0.50E01	2.48E01
2.95E01	2.98E01	1.50E01	0.48E01	1.04E01	1.79E01	2.16E01	2.56E01

.
. Continue wet bulb temperature data cards
.

2.50E01	2.28E01	2.66E01	1.48E01	0.56E01	0.09E01		
6	5.56E-1	-3.2E1	0.0	0			
2.3E01	1.1E01	1.2E01	1.0E01	1.6E01	0.7E01	0.0E00	1.5E01
2.1E01	2.3E01	1.0E01	0.1E01	0.5E01	1.2E01	1.5E01	2.0E01

.
. Continue dew point data cards
.

2.0E01	1.7E01	2.2E01	0.9E01	-0.2E01	-0.7E01		
7	1.157E-4	0.0	0.0	0			
6.71E01	8.88E01	19.66E01	16.56E01	14.36E01	20.01E01	17.99E01	6.19E01
3.71E01	3.74E01	20.83E01	20.29E01	10.69E01	11.67E01	12.21E01	13.69E01

.
. Continue shortwave solar radiation data cards
.

9.06E01	1.55E01	12.12E01	7.37E01	10.36E01	9.23E01		
8	1.0E-2	0.0	0.0	0			
7.48E01	8.16E01	6.88E01	6.54E01	6.53E01	7.53E01	7.64E01	5.43E01
5.73E01	6.55E01	7.63E01	8.16E01	7.33E01	7.10E01	6.80E01	7.08E01

TABLE 5. continued

```
        .
        .  Continue relative humidity data cards
        .

   7.51E01   6.93E01   7.45E01   7.09E01   6.78E01   6.61E01

 END    GROUP 1
     1  365            .3048    .02832       1.0       0.0
  434.15E01  352.0E01   0.42E01
  434.17E01  342.0E01   0.42E01

        .
        .  Continue flow, temperature, elevation data cards
        .

 434.60E01  343.0E01   0.47E01
    1  365    2      .3048    .30480    1.0
      4300.        285.
  4343.8           240.
  4.2449E1  4.2023E1 10.5765E1 17.2601E1 11.8906E1 12.4254E1 11.6305E1 17.7600E1
 10.8248E1 18.8753E1 12.0457E1 18.2358E1 17.4820E1  5.0000E1 11.1717E1 11.3803E1

        .
        .  Continue outflow data cards
        .

 0.0000E0  0.0000E0  0.0000E0  0.0000E0  0.0000E0  0.0000E0  0.0000E0  0.0000E0
   1  365     3       1.0       1.0       0.0
 6.734E01   0.42E01
 6.997E01   0.42E01

        .
        .  Continue inflow and temperature data cards
        .

    0.72E00   0.47E01
 END       CLIMA INPUT
```

TABLE 6. Card Input for TERMA

Card No.	Format	Card Colums	Description	Variable Name	Default Value
GROUP I					
1-2	16A5	1-80	Title or comment identifying the simulation	CMENT	NONE
3	2I10	1-10	First Julian day in the simulation period	IDAY	NONE
		11-20	Last Julian day in the simulation period	LDAY	NONE
4	3E10.0	1-10	Segment element thickness (m)	UDZ	NONE
		11-20	Initial reservoir water surface elevation (m)	ELRES	NONE
		21-30	Maximum reservoir water surface elevation (m)	ELMAX	NONE
5	5E10.0	1-10	Depth of shortwave extinction (m)	EDMAX	NONE
		11-20	Evaporation rate coefficient 1	A	0.0
		21-30	Evaporation rate coefficient 2	BB	1.E-9
		31-40	Maximum thermal gradient allowed (not used)	GMAX	NONE
		41-50	Minimum thermal gradient allowed (not used)	GMIN	NONE
6	8I10	1-10	Total number of tributary inflows	NTRIBS	NONE
		11-60	Segment numbers with tributary inflows	ITRIBS	NONE
		61-70	Number of the segment with outflows	NLETS	NONE
		71-80	Number of reservoir system outlets	NOUTS	NONE
7	A5	1-5	The Sentry designating end of Group I card input is END	END	NONE
GROUP II (NOTE: This data group is repeated for each reservoir segment)					
1	8I10	1-10	Segment number	NSEG	NONE
		11-20	Number of points in segment area profile	NAP	NONE
		21-30	Number of points in segment temperature profile	NTP	NONE
		31-40	Number of days for which printed output is requested	NSD	NONE
		41-50	Time interval for printing (days)	IPRT	NONE
		51-60	Print interval for vertical elements (1→every element, 2→every other element, etc.)	INTP	NONE
		61-70	Flag for output of temperature to tape (>0)	ITAPE	NONE
		71-80	Flag for output temperature and flow predictions for quality program (the number assigned to output tape)	NTAPE	NONE

Table 6 (Continued)

Card No.	Format	Card Columns	Description	Variable Name	Default Value
2	2I10	1-10	Number of executions per simulation day	NXEQ	1.0
		11-20	Simulation interval in a day with output	IVAL	1.0
3	6E10.0	1-10	Critical stability parameter	GSWH	1.E-6
		11-20	Diffusion coefficient 1	A1	1.E-3
		21-30	Diffusion coefficient 2	A2	1.0E-9
		31-40	Diffusion coefficient 3	A3	0.0
		41-50	Vertical thickness of standard element (m)	SDZ	
		51-60	Horizontal segment length (m)	RLEN	NONE
4	2E10.0	1-10	Elevation at which area is specified (m)	TA	NONE
		11-20	Horizontal surface area (m^2)	TB	NONE
		.			
		.			
		1-10	Note: Start with bottom elevation		
		11-20			
5	3E10.0	1-10	Elevation at which initial temperature is specified (m)	TA	NONE
		11-20	Initial temperature at this elevation (°C)	TB	NONE
		21-30	Initial time rate of change of temperature (°C/sec)	TC	NONE
6	16I5	1-5	Julian day numbers with printed output (up to 50 days) (NSD > 0)	IDOUT	NONE
		6-10			
		.			
		.			
		76-80			
7	A5	1-5	The sentry designating end of Group II card input is END	END	NONE

TABLE 7. Sample Input Data Listing - TERMA

```
AMERICAN FALLS RESERVOIR  CALIBRATION   MAY1-DEC.31 1968

        128         365
    5.0E-1 1326.0249     1327.6
     1.0E1        0.0     1.0E-9
         3          1          2          3          0          0          3          2
END  - GROUP I  INPUT DATA
         1          3          3         15         24          4          0          7
         1          1
    1.0E-6     1.0E-5     1.0E-4        7.0     5.0E-1      1.0E4
    1317.6      5.0E6
    1316.6      5.0E6
    1327.6      1.0E3
    1316.6     1.20E1    1.65E-6
    1325.5     1.32E1    5.79E-6
    1326.8     1.55E1   -1.24E-6
  128  142  163  177  191  205  219  235  247  266  273  290  309  328  347  365
         2          3          5         16         24          4          0          7
         1          1
    1.0E-6     1.0E-5     1.0E-4        4.0     5.0E-1      1.0E4
    1316.0      3.6E7
    1316.6      7.2E7
    1327.6      7.2E7
    1316.0     1.15E1    6.61E-7
    1320.4     1.24E1    1.24E-7
    1324.0     1.29E1    6.27E-7
    1325.5     1.34E1    4.96E-7
    1326.8     1.55E1    1.  E-9
  128  142  163  177  191  203  219  235  247  266  273  290  309  328  347  365
         3          3          5         16         24          4          0          7
         1          1
    1.0E-6     1.0E-5     1.0E-4        4.0     5.0E-1      1.0E4
    1316.0      4.4E7
    1316.0      5.6E7
    1327.6      5.6E7
    1310.0      5.7E0    2.73E-6
    1314.6      9.5E0    2.97E-6
    1324.0     1.00E1    2.07E-6
    1325.5     1.06E1    1.57E-6
    1326.5     1.06E1    1.82E-6
  128  142  163  177  191  205  219  235  247  266  273  290  309  328  347  365
END
```

TABLE 8. Card Input for AQUA-II

Card No.	Format	Card Column	Description	Variable Name	Default Value
			PROBLEM SPECIFICATION		
1-2	16A5	1-80	Comment cards or label	TITLE	NONE
		1-80	identifying the simulation		
3	10I5	1-5	First Julian day of simulation (NOTE: Must be the same days as run for TERMA)	IDAY	NONE
		6-10	Final Julian day of simulation (NOTE: Must be the same days as run for TERMA)	LDAY	NONE
		11-15	Switch for selecting transport only (>0)	LOGIC	NONE
		16-20	Time print frequency (hours)	IPRINT	NONE
		21-25	Space print frequency (elements)	NPRINT	NONE
		26-30	Tape No. W/ thermal and hydraulic input	NTAPE1	4
		31-35	Tape No. W/ upstream inflow concentrations	NTAPE2	4
		36-40	Tape No. for quality output	NTAPE3	NONE
		41-45	Number of reservoir segments	NSEG	NONE
		46-50	Number of days for which special printed output will be requested		
3a	16I5	1-80	Julian day numbers for special printed output		
4	2I5	1-5	Number of elements in the segment	NELEM1	NONE
		6-10	Dummy variable (blank)	NADA	
	2E10.0	11-20	Simulation time step (hours)	DELTH	
		21-30	Standard element thickness (m)	DELZ	
5	5I5	1-5	Algae models (2) 1 = Algae calculations performed 2 = Algae calculation not performed	MODALG	2
		6-10	BOD models (1) 1 = Only total BOD is modeled	MODBOD	1
		11-15	Dissolved oxygen models (1) 1 = Calculates rate of change for D.O.	MODDOX	1
		16-20	Nitrogen models (2) 1 = Algal nitrogen model 2 = Ammonia-nitrate only model	MODTIN	2
		21-25	Phosphorous models (2) 1 = Algal phosphorus model 2 = First order decay model	MODPHO	2

Table 8 (continued)

Card No.	Format	Card Column	Description	Variable Name	Default Value
			PROBLEM SPECIFICATION		
6	I5	1-5	Parameter Identification	ID	NONE
			ID Code Quality Submodel		
			1 Algae		
			2 Coliform		
			3 BOD		
			4 Toxic compounds		
			5 Nitrogen		
			6 Phosphorous		
7	7E10.0		Coefficients for submodel indicated in Card 6		
		ID	Coefficient		
		1	Saturation growth rate (1/day-C)	ALGIN(1)	0.53
			Adaptation to low light (1/LUX)	ALGIN(2)	0.00054
			Extinction coefficient (1/m)	ALGIN(3)	0.5
			Algal attentuation coefficient (1/m-mg/l)	ALGIN(4)	0.20
			Organic nitrogen setting velocity (m/day)	ALGIN(5)	0.30
			Nitrogen limiting constant (mg/l)	ALGIN(6)	0.025
			Phosphorus limiting constant (mg/l)	ALGIN(7)	0.006
			Phytoplankton respiration((1/day-C°)	ALGIN(8)	0.005
			Zooplankton grazing rate (1/mg-C.-day)	ALGIN(9)	0.13
			Phyto to zoo utilization efficiency	ALGIN(10)	0.6
			Michaelis constant for phytoplankton (mg-C./L)	ALGIN(11)	1.5
			Nitrogen to phytoplankton ratio	ALGIN(12)	0.08
			Phosphorous to phytoplankton ratio	ALGIN(13)	0.02
			Phosphorous to zooplankton ratio	ALGIN(14)	0.02
			Nitrogen to zooplankton ratio	ALGIN(15)	0.08
			Zooplankton respiration (1/day-C)	ALGIN(16)	0.01
			Zooplankton death rate (1/day)	ALGIN(17)	0.1
			Algal settling velocity (m/day)	ALGIN(18)	0.1
		ID	Coefficient		
		2	Coliform decay rate (1/day)	COLIN(1)	0.5
			Order of decay law	COLIN(2)	1.0
			Temperature coefficient	COLIN(3)	1.1

Table 8 (continued

Card No.	Format	Card Column	Description	Variable Name	Default Value
			PROBLEM SPECIFICATION		
		ID			
		3	Total BOD decay rate (1/day)	BODIN(1)	0.1
			Benthic BOD uptake rate (g/m^2/day)	BODIN(2)	0.0
			Temperature coefficient	BODIN(3)	1.02
		4	Toxic degradation rate (1/day)	TOXIN(1)	0.0
			Algal toxicity constant (mg/l)	TOXIN(2)	1.0
			Temperature coefficient	TOXIN(3)	1.05
		5	Ammonia to nitrite rate (1/day)	TININ(1)	0.10
			Nitrite to nitrate rate (1/day)	TININ(2)	5.00
			Organic-N to ammonia rate (1/day)	TININ(3)	0.10
		6	Phosphorus to sedimentary-P rate (1/day)	PHOIN(1)	0.10
			Sedimentary-P to soluble phosphorus rate (1/day)	PHOIN(2)	0.10
			Organic-P to soluble phosphorus rate (1/day)	PHOIN(3)	0.10

NOTE: Card groups 6 and 7 must be repeated for each of the six submodels given in the ID code list in the card group 6 list above.

Card No.	Format	Card Column	Description	Variable Name	Default Value
8A	I5	1-5	A sentry for selecting the mode of input- Switch<0 -- constant (no vertical variation for the K-TH parameter) Switch=0 -- variable	SWITCH	NONE
		6-15	Parameter value (switch<0)	CONC	NONE
8B	8E10.0		Parameter values (switch=0)	C(J,K)	NONE
			C(J,1) ....soluble phosphorus (mg/l)		
			C(J,2).....organic phosphorus (mg/l)		
			C(J,3).....total B.O.D. (mg/l)		
			C(J,4).....coliform (No./100ml)	J=element number/W bottom → J=1	
			C(J,5).....ammonia nitrogen (mg/l)		
			C(J,6).....nitrite nitrogen (mg/l)		
			C(J,7).....nitrate nitrogen (mg/l)		
			C(J,8).....organic nitrogen (mg/l)		

Table 8 (continued)

Card No.	Format	Card Column	Description	Variable Name	Default Value
			C(J,9).....toxic compound (mg/l) C(J,10)....phytoplankton (mg-C/L) C(J,11)....zooplankton (mg-C/L) C(J,12)....dissolved oxygen (mg/l)		
	Card Group 8B is a set of initial conditions for the segment beginning with the bottom element. Elements in each segment are indexed from the reservoir bottom to the water surface, and the initial conditions must be loaded in a similar order.				
	Twelve Card 8B groups are loaded for each segment, starting with the first parameter (soluble phosphorus) and ending with the twelfth (DO).				
9	I5	1-5	Interval for upstream inflow quality variation (days) 0 = constant input 1 = daily variation 7 = weekly variation etc.	INT	NONE
10	7E10.0	1-70	Upstream inflow quality (12 parameters)	CCIN(1,K)	
	Must be in same order as indicated for Card Group 8B.				
11	L5	1-5	Logical sentry to determine tributary inflow True = one tributary inflow to segment False = no tributary inflow to segment	NTRIBS	NONE
	I5	6-10	Interval for tributary inflow Quality variation (days) 0 = constant input 1 = daily 7 = weekly etc.	INT	NONE

Table 8 (continued)

Card No.	Format	Card Column	Description	Variable Name	Default Value
12	7E10.0	1-70	Tributary inflow quality (12 parameters) must be in same order as Card Group 10	CTRIB(K)	NONE
13.	A5	1-5	Sentry designating end of input deck The last card of input deck has END starting in Column 1	END	NONE

TABLE 9. Sample Input Listing - AQUA-II

```
AMERICAN FALLS RESERVOIR CALIBRATION     MAY 8 - DEC 31,1966

 128  365    0   24    2    1         13    3   16
 126  142  155  177  191  205  218  235  247  266  273  290  309  328  347  365
  19          2.451     5.0E-1
   1    1    1    1    1
   1
0.05        0.001     4.5        0.4        2.5                  0.05
0.007      0.15                  1.5        0.28       0.02      0.02
0.08       0.01                  5.0
   2
.25
   3

   4
            0.02
   5
1.0                  0.03
   6
2.0                  0.02

  -1      1.5E-1
  -1      2.2E-1
  -1       1.5E0
  -1       2.0E0
  -1      1.0E-1
  -1      1.0E-2
  -1      7.0E-2
  -1      2.50E0
  -1      1.0E-3
  -1      2.0E-2
  -1      2.0E-3
  -1       7.0E0
   7
   1.5E-2     1.5E-1     2.53E02     4.90E2     3.0E-2     1.0E-2     2.1E-1
   4.4E-1     1.0E-3     2.0E-2      2.0E-3     8.00E0                       MAY8-14
```

. Continue upstream quality data

.

TABLE 9. Continued

```
      .
     4.2E-1     1.0E-3     2.0E-2     2.0E-3     8.00E0
  TRUE      7
     1.8E-1     3.9E-1     2.16E00    15.80E1    2.1E-1     1.7E-2     5.6E-1
     5.1E-1     1.0E-3     2.0E-2     2.0E-3     9.1E00                                MAY8-14
      .
      .   Continue tributary one quality data
      .
     1.7E-1     1.0E-3     2.0E-2     2.0E-3     7.7E00
    23           2.4E1     5.0E-1
     1    1    1    1    1
     1
   0.05       0.001     0.5        0.4        2.5                  0.05
   0.007      0.03                 0.3        0.08      0.02       0.02
   0.08       0.01                 5.0
     2
   .25
     3

     4
              0.02
     5
   1.0                  0.03
     6
   2.0                  0.02

    -1     0.7E-1
    -1     0.2E-1
    -1      2.0E0
    -1      2.0E0
    -1     1.6E-1
    -1     1.0E-2
    -1     7.0E-2
    -1     0.57E0
    -1     1.0E-3
    -1     2.0E-2
    -1     2.0E-3
    -1      9.0E0
  TRUE      7
```

TABLE 9. Continued

```
 0.20E0    0.37E0    6.20E00    10.15E2    0.10E0    6.0E-2    3.0E-1
 1.37E2    1.0E-3    2.0E-2     2.0E-3     7.4E00                      MAY8-14
```

.
. Continue tributary two quality data
.

Continue same format for all tributaries.

```
    9.9E-2    2.0E-1    2.35E00    15.20E2    5.0E-4    4.0E-3    8.0E-1
    4.2E-1    1.0E-3    2.0E-2     2.0E-3     7.59E0
END
```

TABLE 10. Sample Output - TERMA

```
     RESERVOIR SIMULATION PROGRAM
          BATTELLE-NORTHWEST
   WATER RESOURCES SYSTEMS SECTION
 P.O. BOX 999, RICHLAND WASHINGTON

          PAGE NO.      1
          SEGMENT       1


              SUMMARY OF OUTPUT FOR SIMULATION DAY  168      EXECUTION INT     1

    GENERAL SYSTEM INFORMATION

          RESERVOIR ELEVATION    1327.19 M            SURFACE AIR TEMP        16.68 DEG C
              SURFACE ELEMENT       1.19 M          SURFACE WATER TEMP        19.01 DEG C
           TOTAL SYSTEM INFLOW     665.5 CMS       EVAPORIZATION RATE      4.77E 00 CMS
          TOTAL SYSTEM OUTFLOW     624.5 CMS       CULM EVAPORIZATION         0.193 M
              ELEV THERMOCLINE    1325.0 M        NET SURFACE HEATING   -1.62E-02 KC/M2/S
               DOWNSTREAM TEMP      0.00 DEG C      LOWEST MIXED ELEV        1326.0 M
                RETENTION TIME      14.0 DAYS        TRIBUTARY INFLOW         104.8 CMS


  SURFACE HEAT EXCHANGES

                            QN    5.400E-02 KC/M2/S
                           QNS    7.653E-02 KC/M2/S
                           QNA    7.286E-02 KC/M2/S
                            QW    9.539E-02 KC/M2/S
                            QE    2.430E-02 KC/M2/S
                            QC    1.483E-06 KC/M2/S
```

TABLE 10. continued

RESERVOIR SIMULATION PROGRAM
BATTELLE-NORTHWEST
WATER RESOURCES SYSTEMS SECTION
P.O. BOX 999, RICHLAND WASHINGTON

PAGE NO. 2
SEGMENT 1

SUMMARY OF OUTPUT FOR SIMULATION DAY 168 EXECUTION INT 1

NO	ELEVATION	TEMP DEG C	TEMP DEG F	HORZ OUT	HORZ IN	DIFF COEF
1	1318.0	14.6994	58.4589	58.5507	62.3940	0.000E-01
2	1319.0	14.9383	58.8889	64.1270	68.3363	1.000E-09
3	1320.0	15.2167	59.3901	69.7032	74.2786	1.000E-09
4	1321.0	15.5899	60.0618	75.2795	80.2208	1.000E-09
5	1322.0	16.1168	61.0103	80.8558	86.1631	1.000E-09
6	1323.0	16.8741	62.3735	86.4320	92.1054	1.000E-09
7	1324.0	17.8793	64.1827	92.0083	98.0477	1.000E-09
8	1325.0	18.6272	65.5290	97.5845	103.9900	1.000E-09
9	1326.0	19.0135	66.2242	0.0000	0.0000	1.000E-09

TABLE 11. Sample Output - AQUA-II

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* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
*                                                                     *
*           WATER QUALITY RESERVOIR SIMULATION PROGRAM                *
*                     BATTELLE-NORTHWEST                              *
*               WATER RESOURCES SYSTEMS SECTION                       *
*             P.O. BOX 999,RICHLAND WASHINGTON                        *
*                                                                     *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

                      PROGRAM SPECIFICATIONS

AMERICAN FALLS RESERVOIR CALIBRATION      MAY 8 - DEC 31,1966


     FIRST DAY..................................................     128
     FINAL DAY..................................................     365
     LOGIC (>0 TRANSPORT ONLY - NO QUALITY SIMULATION)..........       0
     PRINT FREQUENCY (DAYS).....................................      24
     PRINT FREQUENCY (ELEMENTS).................................       2
     INPUT TAPE 1 (HYDROTHERMAL)................................       7
     INPUT TAPE 2 (UPSTREAM QUALITY)............................      -0
     OUTPUT TAPE (QUALITY RESULTS)..............................      13
     NUMBER OF SEGMENTS.........................................       3
     TIME STEP (HOURS)..........................................    24.0
     ELEMENT THICKNESS (METERS).................................      .5
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TABLE 11 (continued)

QUALITY SIMULATION FOR SEGMENT 1
NUMBER OF ELEMENTS IN SEGMENT IS 19

MODEL SELECTION

1 ALGAE WILL BE MODELED
1 TOTAL BOD IS MODELED
1 P-R IS PROPORTIONAL TO PHYTOPLANKTON CONCENTRATION
1 THE ALGAL NITROGEN MODEL WILL BE USED
1 THE ALGAL PHOSPHOROUS MODEL WILL BE USED

MODEL CONSTANTS

ALGAE MODEL CONSTANTS

SATURATION GROWTH RATE (1/DAY-C)	ADAPTION TO LOW LIGHT (1/LUX)	EXTINCTION COEFFICIENT (1/M)	ALGAL ATTENUATION COEFFICIENT (1/M-MG/L)	DETRITUS DECAY RATE (1/DAY)	NITROGEN LIMITING CONSTANT (MG/L)
.059	.001	.500	.400	2.500	.025
PHOSPHOROUS LIMITING CONSTANT (MG/L)	**PHYTOPLANKTON RESPIRATION RATE (1/DAY)**	**ZOOPLANKTON GRAZING RATE (L/MG-C,-DAY)**	**PHYTO TO ZOO UTILIZATION EFFICIENCY**	**MICHAELIS CONSTANT FOR PHYTOPLANKTON (MG-C,/L)**	**NITROGEN TO PHYTOPLANKTON RATIO**
.050	.007	.030	.600	.300	.080
PHOSPHOROUS TO PHYTOPLANKTON RATIO	**PHOSPHOROUS TO ZOOPLANKTON RATIO**	**NITROGEN TO ZOOPLANKTON RATIO**	**ZOOPLANKTON RESPIRATION (1/DAY-C)**	**ZOOPLANKTON DEATH RATE (1/DAY)**	**SETTLING VELOCITY (M/DAY)**
.020	.020	.080	.010	.000	2.000

COLIFORM MODEL CONSTANTS			BOD MODEL CONSTANTS		
DECAY RATE (1/DAY)	ORDER OF DECAY LAW	TEMPERATURE COEFFICIENT	TOTAL BOD DECAY RATE (1/DAY)	BENTHIC BOD UPTAKE RATE	TEMPERATURE COEFFICIENT
.250	1.000	1.100	.100	.000	1.020

TOXIC MODEL CONSTANTS			NITROGEN RATE CONSTANTS		
TOXIC DEGRADATION RATE (1/DAY)	ALGAL TOXICITY CONSTANT (MG/L)	TEMPERATURE COEFFICIENT	AMMONIA TO NITRITE RATE (1/DAY)	NITRITE TO NITRATE RATE (1/DAY)	ORGANIC-N TO AMMONIA RATE (1/DAY)
.000	.020	1.050	1.000	5.000	.015

PHOSPHOROUS RATE CONSTANTS			
ORGANIC PHOSPHOROUS TO SEDIMENTARY-P RATE	SEDIMENTARY PHOSPHOROUS PHOSPHOROUS	ORGANIC-P TO SOLUBLE PHOSPHOROUS RATE	SEDIMENTARY PHOSPHOROUS
2.000	.100	.020	-.000

TABLE 11 (continued)

INITIAL CONDITIONS

SEGMENT 1 TIME12[illegible]. DAYS 24.00 HOURS

SEGMENT ELEV	PO4 MG/L	ORG P MG/L	BOD MG/L	COLIF NO/100ML	NH3 MG/L	NO2 MG/L	NO3 MG/L	ORG N MG/L	TOXIC MG/L	PHYTO MG-C/L	ZOO MG-C/L	D.O. MG/L	TEMP CENT
1327.825	1.50-01	2.00-02	1.50+00	2.00+00	1.80-01	1.00-02	7.00-02	5.00-01	1.00-03	2.00-02	2.00-03	7.00+00	1.23+01
1326.600	1.50-01	2.00-02	1.50+00	2.00+00	1.80-01	1.00-02	7.00-02	5.00-01	1.00-03	2.00-02	2.00-03	7.00+00	1.23+01
1325.600	1.50-01	2.00-02	1.50+00	2.00+00	1.80-01	1.00-02	7.00-02	5.00-01	1.00-03	2.00-02	2.00-03	7.00+00	1.23+01
1324.600	1.50-01	2.00-02	1.50+00	2.00+00	1.80-01	1.00-02	7.00-02	5.00-01	1.00-03	2.00-02	2.00-03	7.00+00	1.23+01
1323.600	1.50-01	2.00-02	1.50+00	2.00+00	1.80-01	1.00-02	7.00-02	5.00-01	1.00-03	2.00-02	2.00-03	7.00+00	1.23+01
1322.600	1.50-01	2.00-02	1.50+00	2.00+00	1.80-01	1.00-02	7.00-02	5.00-01	1.00-03	2.00-02	2.00-03	7.00+00	1.23+01
1321.600	1.50-01	2.00-02	1.50+00	2.00+00	1.80-01	1.00-02	7.00-02	5.00-01	1.00-03	2.00-02	2.00-03	7.00+00	1.23+01
1320.600	1.50-01	2.00-02	1.50+00	2.00+00	1.80-01	1.00-02	7.00-02	5.00-01	1.00-03	2.00-02	2.00-03	7.00+00	1.17+01
1319.600	1.50-01	2.00-02	1.50+00	2.00+00	1.80-01	1.00-02	7.00-02	5.00-01	1.00-03	2.00-02	2.00-03	7.00+00	7.69+00
1319.100	1.50-01	2.00-02	1.50+00	2.00+00	1.80-01	1.00-02	7.00-02	5.00-01	1.00-03	2.00-02	2.00-03	7.00+00	5.20+00

UPSTREAM INFLOW CONCENTRATIONS

SEGMENT 1 TIME12[illegible]. DAYS 24.00 HOURS

SEGMENT ELEV	PO4 MG/L	ORG P MG/L	BOD MG/L	COLIF N/100ML	NH3 MG/L	NO2 MG/L	NO3 MG/L	ORG N MG/L	TOXIC MG/L	PHYTO MG-C/L	ZOO MG-C/L	D.O. MG/L	TEMP CENT
1327.825	1.50-02	1.50-01	2.63+00	4.90+02	3.00-02	1.00-02	2.10-01	4.40-01	1.00-03	2.00-02	2.00-03	8.00+00	1.23+01
1326.600	1.50-02	1.50-01	2.63+00	4.90+02	3.00-02	1.00-02	2.10-01	4.40-01	1.00-03	2.00-02	2.00-03	8.00+00	1.23+01
1325.600	1.50-02	1.50-01	2.63+00	4.90+02	3.00-02	1.00-02	2.10-01	4.40-01	1.00-03	2.00-02	2.00-03	8.00+00	1.23+01
1324.600	1.50-02	1.50-01	2.63+00	4.90+02	3.00-02	1.00-02	2.10-01	4.40-01	1.00-03	2.00-02	2.00-03	8.00+00	1.23+01
1323.600	1.50-02	1.50-01	2.63+00	4.90+02	3.00-02	1.00-02	2.10-01	4.40-01	1.00-03	2.00-02	2.00-03	8.00+00	1.23+01
1322.600	1.50-02	1.50-01	2.63+00	4.90+02	3.00-02	1.00-02	2.10-01	4.40-01	1.00-03	2.00-02	2.00-03	8.00+00	1.23+01
1321.600	1.50-02	1.50-01	2.63+00	4.90+02	3.00-02	1.00-02	2.10-01	4.40-01	1.00-03	2.00-02	2.00-03	8.00+00	1.23+01
1320.600	1.50-02	1.50-01	2.63+00	4.90+02	3.00-02	1.00-02	2.10-01	4.40-01	1.00-03	2.00-02	2.00-03	8.00+00	1.17+01
1319.600	1.50-02	1.50-01	2.63+00	4.90+02	3.00-02	1.00-02	2.10-01	4.40-01	1.00-03	2.00-02	2.00-03	8.00+00	7.69+00
1319.100	1.50-02	1.50-01	2.63+00	4.90+02	3.00-02	1.00-02	2.10-01	4.40-01	1.00-03	2.00-02	2.00-03	8.00+00	5.20+00

SIMULATION RESULTS

SEGMENT 1 TIME12[illegible]. DAYS 24.00 HOURS

SEGMENT ELEV	PO4 MG/L	ORG P MG/L	BOD MG/L	COLIF N/100ML	NH3 MG/L	NO2 MG/L	NO3 MG/L	ORG N MG/L	TOXIC MG/L	PHYTO MG-C/L	ZOO MG-C/L	D.O. MG/L	TEMP CENT
1327.825	1.48-01	3.74-02	1.44+00	2.03+01	7.65-02	1.70-02	1.[illegible]9-01	4.92-01	1.00-03	2.25-02	1.81-03	7.37+00	1.23+01
1326.600	1.49-01	3.72-02	1.44+00	1.87+01	7.67-02	1.70-02	1.[illegible]7-01	4.92-01	1.00-03	2.25-02	1.81-03	7.17+00	1.23+01
1325.600	1.49-01	3.95-02	1.44+00	1.76+01	7.68-02	1.70-02	1.[illegible]5-01	4.93-01	1.00-03	2.25-02	1.81-03	6.85+00	1.23+01
1324.600	1.50-01	4.01-02	1.43+00	1.69+01	7.72-02	1.70-02	1.[illegible]5-01	4.93-01	1.00-03	2.24-02	1.81-03	6.67+00	1.23+01
1323.600	1.50-01	4.09-02	1.43+00	1.63+01	7.76-02	1.70-02	1.[illegible]-01	4.93-01	1.00-03	2.24-02	1.81-03	6.65+00	1.23+01
1322.600	1.51-01	4.19-02	1.43+00	1.57+01	7.83-02	1.70-02	1.[illegible]7-01	4.93-01	1.00-03	2.23-02	1.81-03	6.66+00	1.23+01
1321.600	1.51-01	4.36-02	1.44+00	1.53+01	7.91-02	1.70-02	1.[illegible]9-01	4.93-01	1.00-03	2.22-02	1.81-03	6.67+00	1.23+01
1320.600	1.51-01	4.73-02	1.44+00	1.57+01	8.08-02	1.70-02	1.[illegible]4-01	4.94-01	1.00-03	2.18-02	1.82-03	6.69+00	1.17+01
1319.600	1.24-01	3.79-02	1.43+00	1.28+01	7.97-02	1.71-02	1.[illegible]0-01	4.94-01	1.00-03	2.09-02	1.87-03	6.67+00	7.69+00
1319.100	6.24-02	3.06-02	1.43+00	1.22+01	7.93-02	1.71-02	1.[illegible]-01	4.94-01	1.00-03	2.04-02	1.90-03	6.66+00	5.20+00

TABLE 11 (continued)

SIMULATION RESULTS

SEGMENT 1 TIME142. DAYS 24.00 HOURS

ELEV	PO4 MG/L	ORG P MG/L	CBOD MG/L	COLIFM N//100 ML	NH3 MG/L	NO2 MG/L	NO3 MG/L	ORG N MG/L	TOXIC MG/L	PHYTO MG-C/L	ZOO MG-C/L	D.O. MG/L	TEMP CENT
1327.398	2.62-01	3.55-01	1.32+00	1.00+02	5.84-02	6.45-03	2.4[illegible]-01	3.41-01	1.00-03	9.80-02	1.08-03	7.89+00	1.67+01
1326.600	2.61-01	3.58-01	1.31+00	9.87+01	5.96-02	6.46-03	2.45-01	3.42-01	1.00-03	9.81-02	1.07-03	7.80+00	1.67+01
1325.600	2.69-01	3.75-01	1.3[illegible]+00	9.49+01	5.98-02	6.53-03	2.36-01	3.43-01	1.00-03	9.76-02	1.07-03	7.43+00	1.66+01
1324.600	2.75-01	3.96-01	1.3[illegible]+00	9.10+01	6.21-02	6.70-03	2.[illegible]4-01	3.45-01	1.00-03	9.56-02	1.07-03	6.95+00	1.64+01
1323.600	2.84-01	4.02-01	1.3[illegible]+00	8.76+01	6.54-02	6.97-03	2.[illegible]7-01	3.46-01	1.00-03	9.12-02	1.07-03	6.57+00	1.60+01
1322.600	2.95-01	4.22-01	1.3[illegible]+00	8.44+01	6.97-02	7.35-03	2.[illegible]9-01	3.47-01	1.00-03	8.34-02	1.07-03	6.34+00	1.55+01
1321.600	3.04-01	4.47-01	1.32+00	8.15+01	7.60-02	7.93-03	2.[illegible]-01	3.47-01	1.00-03	7.11-02	1.07-03	6.21+00	1.50+01
1320.600	2.94-01	4.36-01	1.35+00	7.89+01	8.79-02	8.86-03	2.[illegible]3-01	3.47-01	1.00-03	5.42-02	1.09-03	6.15+00	1.46+01
1319.600	1.69-01	3.10-01	1.30+00	7.91+01	8.04-02	8.46-03	2.[illegible]1-01	3.51-01	1.00-03	3.76-02	1.07-03	6.02+00	1.42+01
1319.100	9.42-02	1.54-01	1.2[illegible]+00	6.73+01	7.66-02	8.08-03	2.[illegible]2-01	3.53-01	1.00-03	3.14-02	1.06-03	5.97+00	1.41+01

FINAL REMARKS

It is anticipated that these computer models will provide an important decision-making tool for assessing future eutrophic states of reservoirs and lakes as functions of nutrient inputs, waste loadings, and hydraulic and morphometric site characteristics. Other potential applications of these models are:

- Waste allocation studies
- Evaluation of waste discharge impacts
- Management of reservoir operations
- Preimpoundment analyses
- Nutrient diversion and lake recovery studies

These models, when applied by experienced analysts, can be used to find sound and economical solutions to the complex problems of lake and reservoir management.

Up-to-date program listings and source decks can be obtained by contacting the Environmental Protection Agency, Region X in Seattle, Washington. Battelle-Northwest will also accept requests for program listings and source decks.