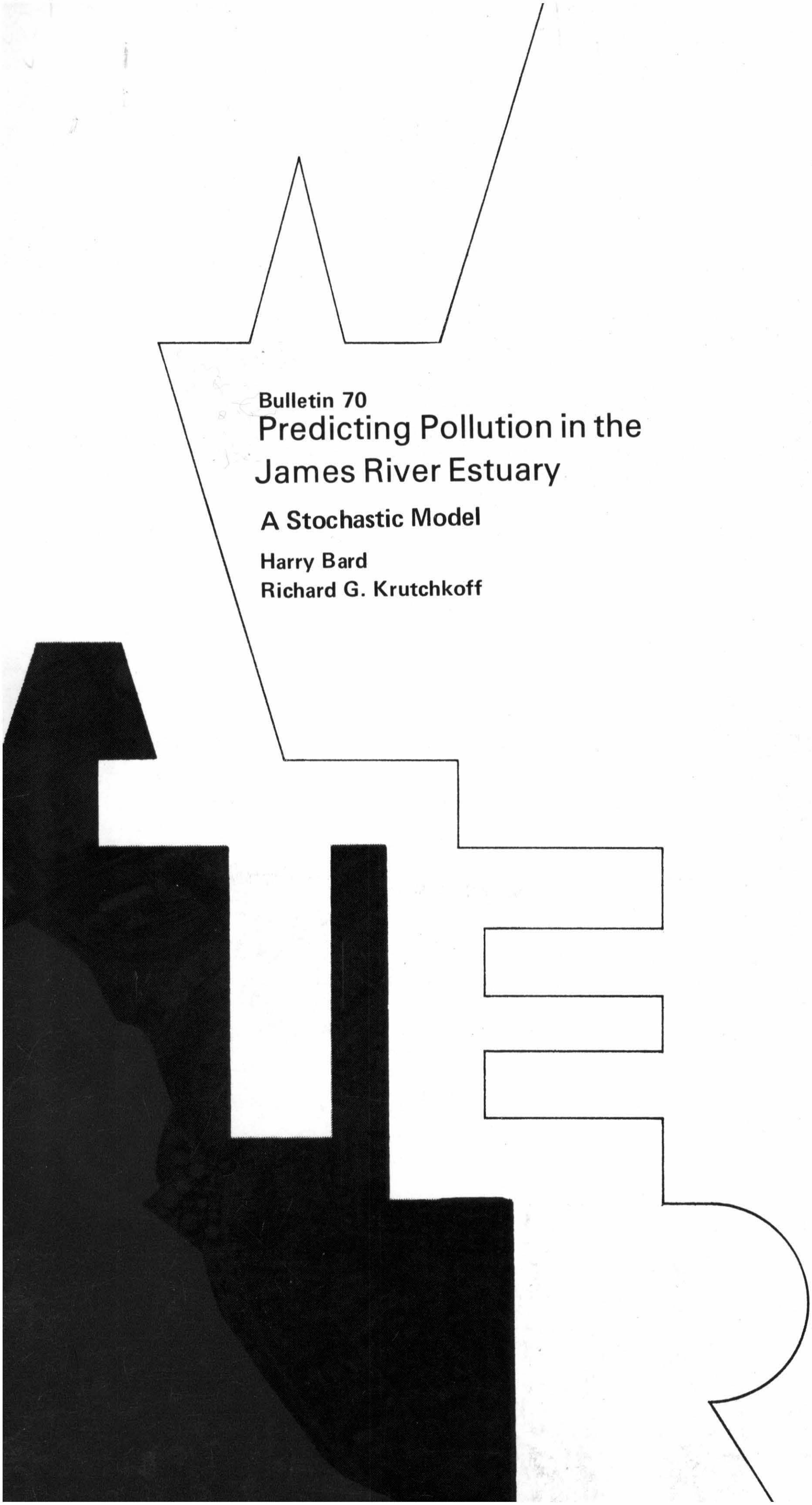

Bulletin 70

Predicting Pollution in the James River Estuary

A Stochastic Model

Harry Bard
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PREFACE

One function of water-quality management is insuring that no pollutants enter a given body of water in sufficient quantity to degrade water quality. To do this most effectively, a manager should be able to forecast what effects additional amounts of various pollutants would have on the body of water. And that is a complex and difficult task.

The purpose of this research project was to create a mathematical model of a 60-mile stretch of the James River Estuary beginning at Richmond, and then to predict how water quality would be affected under a variety of changed conditions, including higher contaminant levels. Using the Schofield Model, the investigators first provided basic inputs on the estuary's geometrical, hydrological, meterological, and water-quality characteristics, thus matching the model to the estuary. Then, by a complex computer program, they studied the effects on water quality of changes in rate constants, freshwater flow rates, sewage inputs, and temperature. In this way, they were able to specify which of the variables, if changed, would degrade water quality, and to what degree.

The research identified which input variables are most useful as indicators of water quality, and which must be watched most closely to insure that present water quality is maintained. The model also can predict the effect of increased industrial discharges of organic wastes, of greater sewage discharges, and of changes in sewage treatment methods, among other possibilities.

The model provides a valuable tool for water management personnel and agencies concerned with the James River Estuary.

Special acknowledgement is accorded the following who generously gave their time to a critical review of the manuscript: Mr. John Harrison, Engineer, Chief, Office of Dredged Material Research, Department of the Army, Vicksburg, Mississippi, and Dr. William Schofield, Senior Engineer, Air Products and Chemicals, Inc., Allentown, Pennsylvania.

TABLE OF CONTENTS

LIST OF TABLES

ABSTRACT

Modeling the James River Estuary with the Schofield model was the major goal of the project. The model was set up for a 60-mile stretch of the estuary beginning at Richmond.

Sensitivity studies involving rate constants, freshwater flow rate, sewage input, and water temperature were made and the results of these studies were analyzed. The average oxygen deficit concentration is insensitive to random water temperature, moderately sensitive to the sewage input rates investigated, and highly sensitive to changes in the organic carbon utilization rate constant. Organic carbon and carbon dioxide are insensitive to temperature and only moderately sensitive to change in the organic carbon rate constant. Ortho-phosphate concentration is insensitive to changes of the phosphate utilization rate constant and ortho-phosphate, organic carbon, and organic nitrogen are insensitive to a difference in the freshwater flow as great as 40 percent.

Finally, nitrate + nitrite concentration, bacteria growth, and algal growth are insensitive to a reduction of the nitrogen waste from the point sources.

PROJECT OBJECTIVES

Planning adequate protection for our rivers, streams, and estuaries is a difficult task requiring some predictive mechanism. This mechanism must simulate conjectured events and predict their outcomes so that any problem considered is completely evaluated. Three types of models capable of evaluating alternatives are: (1) scaled replicas, (2) analog models, and (3) mathematical models. Of the three types, mathematical models, which aid in assessing the state of an idealized world, are the most widely applied.

Mathematical models contain both analytical expressions derived from some physical phenomena and empirical expressions derived from data. In addition to analyzing planning problems related to population increases, industrial growth, and pollution control alternatives, models can determine by means of sensitivity studies, the parameters or variables which influence predictions the most. Holding all but one input parameter constant, a change in output for a change in input measures the sensitivity of the model to that input parameter. Highly sensitive results reveal which parameters require the most accurate measurement for reasonable predictions.

Modeling the James River Estuary and determining parameter sensitivity were major objectives of the project. The Schofield Model, a transient state model, simulated the James River using the available investigations for input data information. The sensitivity of the model predictions to changes in rate constants, freshwater flow rates, sewage input, and temperature was also investigated.

DESCRIPTION OF SCHOFIELD MODEL

The Schofield model is a one-dimensional dynamic model capable of predicting concentrations for 12 components, 7 chemical and 5 biological. A list of the components follows:

1. Organic carbon
2. Inorganic carbon
3. Organic nitrogen
4. Ammonia
5. Nitrite & Nitrate
6. Phosphorus
7. Oxygen deficit
8. Algae
9. Protozoa
10. Zooplankton
11. Higher Predator
12. Bacteria

The concentrations of the 12 components are predicted from general differential equations describing the diffusive and advective mechanisms of an estuary. Since the components are interactive, the 12 equations are solved simultaneously. The general equation for the ith component is shown on the next page.

$$\frac{\partial Ci(x,t)}{\partial t} = E(x,t)\frac{\partial^2 Ci(x,t)}{\partial x^2} + \frac{E(x,t)}{A(x,t)}\frac{\partial A(x,t)}{\partial x}\frac{\partial Ci(x,t)}{\partial x}$$

$$+ \frac{\partial E(x,t)}{\partial x}\frac{\partial Ci(x,t)}{\partial x} - V(x,t)\frac{\partial Ci(x,t)}{\partial x}$$

$$- \frac{V(x,t)Ci(x,t)}{A(x,t)}\frac{\partial A(x,t)}{\partial x} - Ci(x,t)\frac{\partial V(x,t)}{\partial x}$$

$$- \frac{Ci(x,t)}{A(x,t)}\frac{\partial A(x,t)}{\partial t} + Ri(x,t,\underset{\sim}{c})$$

where:

$Ci(x,t)$	is the concentration of component _i_ as a function of time and position
$A(x,t)$	is the cross-sectional area as a function of time and position
$E(x,t)$	is the diffusion coefficient as a function of time and position
$V(x,t)$	is the cross-sectional fluid velocity as a function of time and position
$Ri(x,t,\underset{\sim}{c})$	is the net rate of increase of the concentration of component _i_ as a function of time, position, and the other components.

The fact that the equations are very general, allowing all parameters to vary with time and position, necessitates a numerical solution. The equations are solved with the aid of a high speed computer. A more detailed discussion of the derivation and solution of the diffusion equations is found in Schofield's Ph.D. dissertation written in 1971 [10].

I. Explanation of Program

The computer program for the Schofield model is written in Fortran IV and is applicable on most IBM machines. The amount of storage required for a normal run is approximately 120K. Each day of simulated time takes usually from 15 to 30 seconds to execute.

The program consists of 11 subroutines beginning with MAIN. MAIN has three basic functions:

1. Reads data.
2. Calls upon the other subroutines for their part in the solution of the differential equations.
3. Checks the integrations for accuracy and adjusts the time step accordingly.

One of the subroutines called by MAIN is STORE which reads and stores initial values for the pollutants and other parameters. The subroutine will act according to the type of input data which may be in the form of discrete constants, point source discharge, or continuous values. More about the types of data will be discussed later.

OUTPUT provides specified output, either punched card or printed, at times requesting results. The subroutine also compares observed data with predicted mean concentrations for model verification purposes, and it keeps track of the time and day of the solutions.

UPDATE changes all parameters which are subject to change in time, temperature, flow rate, and sunlight intensity. Updates can be made daily, hourly, or minute to minute.

An easy method of storing data and assigning default values to parameters is with the use of a block data subroutine. BLOCK DATA initializes many of the parameters and values required for the operation of the program.

The subroutine RKMI integrates the partial derivative of concentration with respect to time ($\partial C / \partial t$) using the Kutta-Merson method of numerical integration. It also measures the accuracy of the integration in time by comparing the observed error to the allowable error.

FUNCT evaluates $\partial C/\partial t$ for the 12 components, that is the partial derivative of component concentration with respect to time. Predation rate, growth rate, respiration rate, and death rate are all calculated for the biological components, and the subroutines AREA, VELOC, VOLUM, and FIRST are called by FUNCT for their role in the evaluation.

FIRST numerically evaluates the first partial derivatives with respect to position by using sixth order difference equations. Points at either end of the grid system are evaluated by second and fourth order difference equations.

INTP determines the value of input data at grid points by interpolation. The subroutine also evaluates component concentrations at positions other than the grid points.

The three remaining subroutines perform simple but necessary tasks. AREA calculates the estuary cross-sectional areas as a function of tidal phase and position; VELOC calculates fluid velocity as a function of freshwater flow rate, tidal flow rate, tidal phase, position, and cross-sectional area; and VOLUM calculates the volumetric flow rates as a function of freshwater flow rate, position, and tidal phase.

II. Operation and Program Logic

An explanation of the purpose of each of the model's subroutines enhances one's knowledge of the model operation but a description of the main program loop is also helpful.

MAIN calls upon RKMI for initial evaluation of the constituent concentrations. The evaluation requires calling UPDATE three times and FUNCT five times in order to perform the Kutta-Merson method of integration. FUNCT in turn must call AREA, VELOC, VOLUM, and FIRST for their part in the evaluation of $\partial C/\partial t$.

Integration accuracy determines the next step taken. If the observed error is less than 10% of the allowable error, the time step (DT) is increased by 3%. However, a maximum has been set on DT to prevent temporal instability. If the observed error is 10% to 100% of the allowable error, the time step remains the same. Between 100% and 200% the integration is accepted but DT is decreased by 3%. When the observed error is more than 200% of the allowable error, the time step is reduced by an amount determined by the ratio of observed error to allowable error. The integration is also re-evaluated. A summary of these decisions follows.

Observed Over Allowable	Step Taken
$\frac{o.e.}{a.e.} < .1$	Increase DT by 3%
$.1 < \frac{o.e.}{a.e.} < 1$	DT unchanged
$1 < \frac{o.e.}{a.e.} < 2$	Decrease DT by 3% integration accepted
$\frac{o.e.}{a.e.} < 2$	Integration repeated with $DT_{NEW} = .97^{k} \times DT_{OLD}$ where K is the maximum integer less than or equal to o.e/a.e. The upper limit of K is 3.

When the error is greater than 200%, MAIN will call UPDATE and FUNCT and the main loop will be repeated. Otherwise, the subroutine OUTPUT is called. OUTPUT checks the simulated day and hour and then a decision is made to compare results with observed data, to print output, or to return to MAIN and continue the simulation. A return to MAIN essentially completes the loop.

III. Data Requirements

The Schofield model needs a variety of physical and chemical data to adequately simulate an estuary. All of the required data are categorized as geometrical data, hydrological data, meteorological data, or water quality data. A more specific discussion of the four categories follows.

a. Geometrical Data

The basic geometry of an estuary must be known. This includes water depth, average cross-sectional area, and the maximum fractional deviation of cross-sectional area at high or low tide.

Both cross-sectional area and water depth were recorded for each nautical mile of the James River Estuary in a study conducted by Johns Hopkins University [1]. Maximum fractional deviation of the cross-sectional area from its average was estimated for each 5 nautical mile stretch from available tidal range data taken from the same study.

b. Hydrological Data

An adequate description of flow in a one-space dimensional system includes information about the freshwater flow rate, the maximum tidal velocity, and the tidal phase lag.

Monthly averages of the freshwater flow rate were obtained from a 1969-1970 study on the Chesapeake Bay and its tributaries [6]. These volumetric flow rates were validated by data accumulated in 1964 by the Virginia Institute of Marine Science [11]. A regression analysis on the data collected in 1964 also yielded the following expression for maximum tidal velocity as a function of position in the estuary.

$$Vt = 0.158 + 0.055X - 0.00046X^2 - 0.0000073X^3 + 0.000000075X^4$$

where:

Vt — maximum tidal velocity (mi/hr)

X — position (mi)

Since a study on the tidal lag in the James was not complete prior to this investigation, an expression for tidal lag was developed from information found in the "Tide Tables," a U.S. Coast and Geodetic Survey publication [15]. Following is that formulation:

$$\ell(X) = 7.22 - 0.042X - 0.00042X^2$$

where:

X — position (mi)

$\ell(X)$ — phase lag (hr)

The collected geometrical and hydrological data are then used in two expressions that determine fluid velocity and cross-sectional area at any time and at any position in the estuary.

$$V(x,t)=Q(x,t)/A(x,t)+V_t(x)\cdot\sin\left[\frac{2\pi}{12.452}(t-\ell(x))\right]$$

$$A(x,t)=A(x)\cdot\left[1.0+d(x)\cdot\sin\left(\frac{2\pi}{12.425}\left(t-\ell(x)+\frac{\pi}{2}\right)\right)\right]$$

where:

$V(x,t)$ — fluid velocity (mi/hr)

$Q(x,t)$ — volumetric flow rate (mi^3/hr)

$A(x,t)$ — cross-sectional area (mi^2)

$Vt(x)$ — maximum tidal velocity (mi/hr)

t — time (hr)

$\ell(x)$ — tidal phase lag (hr)

$A(x)$ — average cross-sectional area (mi^2)

$d(x)$ — maximum fractional deviation of the cross-sectional area from the average.

c. Meteorological Data

Meteorological data requirements are minimal including only daily sunlight intensity totals. The sunlight totals, obtained from the U.S. Climatological bulletins, were used to calculate instantaneous surface intensity from the following expression.

$$I_0 = I_t \cdot 2.6225 \cdot \left(\sin\left(\frac{2\pi}{24}(t-6)\right)\right)^{\frac{1}{2}} \qquad 6 < t < 18$$

$$= 0 \qquad t < 6 \text{ and } t > 18$$

where:

I_0 — instantaneous sunlight intensity

I_t — sunlight intensity total

t — time of day (hr)

The instantaneous sunlight intensity partly determines the growth rate of algae and therefore it has a direct effect on the algal biomass.

d. Water Quality Data

Any studies made upon the river or estuary in question that give expressions or values for necessary modeling parameters, such as reaction rates, are invaluable sources. Little knowledge of the rate coefficients for organic carbon, carbon dioxide, organic nitrogen, ortho-phosphate, and oxygen deficit was gathered from studies on the James River Estuary, but established expressions for most of these parameters were utilized. For instance, the expression determining the oxygen reaeration rate coefficient was:

$$\boxed{K_2 = cu^a y^b}$$

where:

a,b,c — appropriate constants

u — fluid velocity (ft/sec)

y — water depth (ft)

K_2 — reaeration rate coefficient (1/day)

Many values for the constants have been determined but those chosen were suggested in an investigation by O'Connor and Dobbins, ($a = \frac{1}{2}$, $b = -1\frac{1}{2}$, $c = 12.9$ [8].

The one parameter that effects all reaction rates is temperature. Temperature is an important ecological factor to consider in any simulation of an estuary because of its effect upon the activity, distribution, and abundance of aquatic organisms. The Schofield model is written to allow for temperature corrections of rate constants. To be more specific, the biological rate coefficients are assumed linear functions of temperature while the chemical component rate coefficient expressions have the form:

$$K = K_{20} a^{(T-20)}$$

where:

K — rate coefficient (1/day)

K_{20} — rate coefficient at 20°C (1/day)

T — temperature °C

a — constant defined by the chemical component

The most vital influence temperature has upon a water environment is its effect upon the concentration of dissolved oxygen. Unfortunately, the oxygen saturation concentration decreases with increasing temperature. The following formulation accounts for the relationship between temperature and the saturation concentrative of oxygen.

$$C_S(T) = 14.652 - 0.4102T + 0.007991T^2 - 0.000077774T^3$$

where:

$C_S(T)$ — oxygen saturation concentration (ppm)

T — temperature (°C)

Estimating the extent and effect of diffusion in tidal waters requires an estimate of the turbulent diffusion coefficient. The expression applicable to this investigation is:

$$E = c \cdot |u| \cdot y$$

where:

2.5

c — an appropriate constant $(0 < c < 5)$

u — fluid velocity (ft/sec)

y — hydraulic radius (ft)

Finally the location and discharged quantity of point and line sources must be known along with the nutrient make-up of these sources.

The nutrient boundary conditions obtained from the 1970 study of the Chesapeake Bay tributaries are regression expressions in which nutrient loading is a function of the freshwater volumetric flow rate.

$$TPO4 = 0.101Q^{1.276}$$

$$TON = 2.797Q^{1.012}$$

$$NO_2 + NO_3 = 19.590\,Q^{.780}$$

$$NH_3 = 0.025\,Q^{1.37}$$

$$TOC = 33.960\,Q^{.965}$$

where:

TPO4 — Ortho-phosphate (lb/day)

TON — Total Organic Nitrogen (lb/day)

$NO_2 + NO_3$ — Nitrite + Nitrate (lb/day)

NH_3 — Ammonia (lb/day)

TOC — Total Organic Carbon (lb/day)

Q — Volumetric Flow Rate (cfs)

A listing of both municipal and industrial waste source locations along the James River Estuary was obtained, but projected or hypothetical waste discharges were input because of incomplete studies on waste effluent. For lack of better information, a sinusoidal discharge of effluent was used.

Listing of Pollution Sources

Source	Position (mi)	Input (lb/day)
1. City of Richmond	0.1	52000
2. Standard Paper Co.	0.5	1600
3. DuPont	6.9	4400
4. Chesterfield, Co., Falling Crk. Stp.	6.9	4000
5. U.S. Govt. Bellwood Depot	7.5	240
6. American Tobacco Co.	21.29	7000
7. Allied Chemical, Fibers	21.9	960
8. Appomattox River	23.02	10000
9. Allied Chemical, Plastics & Ag.	23.6	3000
10. Continental Can	23.88	39840
11. Hercules 1 & 2	24.171	39400
12. Hercules 3 & 4	24.171	1280
13. Fort Lee	24.71	1200
14. City of Hopewell	24.71	5000
15. Chickahominy River	52.95	16800

The preceding formulations are not the only ones available, but they are the most suitable to the model. However, these formulations should not be employed permanently because the use of mathematical models requires the continuous updating of parameter values and expressions. It follows that more accurate parameter values or more exact expressions can only result in better predictions.

e. Documentation

Modeling any stream or estuary requires internal program adjustments as well as basic input data. Mathematical expressions for maximum tidal velocity, tidal lag, rate constants, and boundary conditions are necessary internal adjustments for each stream modeled.

The remainder of the input is read in on cards. The program setup enables cards to be read on three unit numbers, 5, 8, and 9. Since most input data are read through unit 5, its data will be considered first.

The first 12 cards identify the 12 components considered in the model. The complete titles of these components must be punched between CC1(card column) and CC40.

The next card contains basic information required for the solution as follows:

		CC	Format
1.	Number of segments in the estuary	1–5	I5
2.	Upstream boundary (mile)	6–10	F5.1
3.	Downstream boundary (mile)	11–15	F5.1
4.	Initial time (hr)	16–20	F5.1
5.	Initial day	21–25	I5
6.	Final time (hr)	26–30	F5.1

7.	Final day	31–35	I5
8.	Number of printouts/tidal cycle	36–40	F5.1
9.	Number of components modeled	41–45	I5
10.	Time of high tide the initial day	46–50	F5.2
11.	Moon phase on initial day	51–55	F5.2
12.	Number of minutes authorized for run	56–60	F5.2
13.	Logic variable to determine whether card output is required on the final day (KP = 0, No; KP $\neq$ 0, Yes)	61–65	I5

A header card which identifies the parameter and the form of the data to follow is necessary for the reading of input data. Data are categorized by the header card as continuous, constant within a segment, or a point source. The header card follows the form below with format (3I5, 5X, 10A4).

1. CC1-5 identifies the form of the data

    (a) IPT = 1 discharge at a point

    (b) = 2 constant within a segment

    (c) > 2 continuous data

2. CC6-10 identifies the parameter or pollutant in the utility matrix K. (See the list of definitions on page 18).

3. CC11-15 distinguishes between a pollutant or parameter

    (a) ITYPE = 1 parameter

    (b) = 2 pollutant

4. CC21-60 identifies the name of the parameter or pollutant.

If the first number read on the header card is 2, the following cards will contain a value and a position in the format (2E20.5). The grid points between the last position read and the new position are assigned the specified value. Reading terminates when a position less than or equal to zero is read. Examples of this type of input data are benthal demand, land runoff, and maximum deviation from the average cross-sectional area. The input units of benthal demand and land runoff are $lb/mi^3 \cdot hr$.

If IPT = 1, value-position cards will follow with a format (2E20.5). All municipal waste, industrial waste, and river point source discharges fall in this category with input units of lb/day. Reading terminates when a negative position appears.

A number greater than 2 indicates continuous data follow. The value of IPT determines the number of pairs of positions-values to be read. Each card contains 4 pairs with a format (8F10.6). All component initial conditions, estuary depth, and cross-sectional area are examples of continuous data used to model the James River Estuary.

A blank card at the end of the last data deck completes the reading of parameters and the next cards read include daily water temperatures, volumetric flow rates, daily sunlight totals, along with the options to read a card on unit 9 or request punched card output. Following is a description of the card with a format (3F10.4, 20X, 2I5).

Variable	CC
Temperature (°C)	1–10
Volumetric flow (cfs)	11–20
Sunlight total (langleys)	21–30
Skip 20 spaces	31–50
Punch option	51–55
Namelist option	56–60

Each day modeled required a card including the preceding information.

If no temperature data are read, temperature is determined by an expression internal to the program. This expression should be checked for its appropriateness to the particular estuary simulated. The number 1 in CC55 exercises the option to punch component concentrations for that day. For any integer value other than zero in CC56–60, specific parameter values are updated by reading a card on unit 9.

Cards read on unit 8 serve only model verification purposes. A card is read for each position and time data were collected. Each card has the format (I5, F5.0, F5.2, 5X, 6(I2, F8.3)) and includes:

	CC
Day of the year	1–5
Time (hr)	6–10
Position (mile)	11–15
Skip 5 spaces	16–20
Component number	21–22, 31–32, 41–42, 51–52, 61–62, 71–72
Observed value	23–30, 33–40, 43–50, 53–60, 63–70, 73–80

All variables included in the NAMELIST are subject to change by reading on unit 9. A new list can be read daily depending upon the namelist option value read that day.

The name of the list (&LIST1) must start in column two and each proceeding variable name is written followed by an equals sign and its value. Each variable is separated by a comma. After all variables have been defined, the last name written is &END.

Model users are not restricted to using the preceding procedure of input. Any modifications which simplify input are worthwhile.

Model description is completed with the following listing of variable names and definitions.

Variable Name	Definition
A(J)	Cross-section area (mi^2)
ABSE	Absolute allowable error of integration through time (ppm)
ABSX	Absolute value of the right hand side of the diffusion equation other than the source and sink terms
ACC	Defines the limit on interpolation error
ADJ	Adjustment of the sewage input with time
AREA	Subroutine which calculates X-area
AVE	Average yearly water temperature ($^{\circ}C$)
BA	Growth rate coefficient of bacteria at 20°C (day^{-1})
BCN	Boundary condition for organic nitrogen (not used in this study) (ppm)
BC(J)	
J = 1	Boundary condition for algae (ppm)
= 2	Boundary condition for protozoa (ppm)
= 3	Boundary condition for zooplankton (ppm)
= 4	Boundary condition for higher predator (ppm)
= 5	Boundary condition for bacteria (ppm)
C(I,IA,J)	
I = 1	Concentration of organic carbon
= 2	Concentration of carbon dioxide
= 3	Concentration of organic nitrogen
= 4	Concentration of ammonia
= 5	Concentration of nitrite + nitrate
= 6	Concentration of ortho-phosphate
= 7	Concentration of oxygen deficit
= 8	Concentration of algae
= 9	Concentration of protozoa
= 10	Concentration of zooplankton
= 11	Concentration of higher predator
= 12	Concentration of bacteria

Variable Name	Definition
CL	Factor adjusting pollution discharge
CK3	Fraction of the organic nutrients recycled
CSAT	CO_2 saturation concentration (ppm)
C28	Fraction of algae that is carbon
C29	Fraction of protozoa that is carbon
C210	Fraction of zooplankton that is carbon
C211	Fraction of higher predator that is carbon
C58	Fraction of algae that is nitrogen
C59	Fraction of protozoa that is nitrogen
C510	Fraction of zooplankton that is nitrogen
C511	Fraction of higher predator that is nitrogen
C68	Fraction of algae that is phosphorus
C69	Fraction of protozoa that is phosphorus
C610	Fraction of zooplankton that is phosphorus
C611	Fraction of higher predator that is phosphorus
C212	Fraction of bacteria that is carbon
C512	Fraction of bacteria that is nitrogen
C612	Fraction of bacteria that is phosphorus
CONC(I,J)	Name of components
I = 1	Organic carbon
= 2	Carbon dioxide
= 3	Organic nitrogen

Variable Name	Definition
= 4	Ammonia
= 5	Nitrite + nitrate
= 6	Phosphorus
= 7	Oxygen deficit
= 8	Algae
= 9	Protozoa
= 10	Zooplankton
= 11	Higher predator
= 12	Bacteria
DCDX(I,J)	Array of values equal to the right hand side of the diffusion equation other than the source of sink terms
DEV	Seasonal temperature deviation used in the expression for water temperature (°C)
DADT(J)	The partial derivative of cross-sectional area with respect to time
DT	Step in time used in integration (hr)
DX	The length of each segment or the distance between grid points (mile)
DZS	Step in time (hr)
DCDT(I,IA,J)	Partial derivative of concentration with respect to time
DIE(J)	
J = 1	Death rate coefficient for algae (1/hr)
= 2	Death rate coefficient for protozoa (1/hr)
= 3	Death rate coefficient for zooplankton (1/hr)
= 4	Death rate coefficient for higher predator (1/hr)
= 5	Death rate coefficient for bacteria (1/hr)
DIFF	Difference between an observed value and predicted concentration used for verification purposes (ppm)

Variable Name	Definition
DO2	Time step for integration DT/2
DO3	Time step for integration DT/3
DO15	Time step for integration DT/15
DX60	Variable required for the integration of the partial derivatives with respect to position; DX•60
DX12	Variable required for the integration of the partial derivatives with respect to position; DX•12
DY(J)	Vector of first derivatives of the dependent variable with respect to the independent variable. The array is used exclusively in the subroutine FIRST
D1	Light extinction coefficient due to causes other than self-shading 1/ft
D2	Coefficient of the correction for self-shading
E	Variable which adjusts oxygen reaeration rate constant as a function of temperature
EA(J)	Array which contains the product of the diffusion coefficient and the cross-sectional area
EADJ	Adjustment to the diffusion coefficient depending upon the grid spacing, 1/DX
ERRSET	Subroutine internal to the system which is part of the extended error message facility
FAZ	Moon phase on the initial time and day of computer simulation
FIRST	Subroutine integrating first partial derivative with respect to position

Variable Name	Definition
FRA(J)	
J = 1	Fraction of organic carbon in sewage discharge
= 2	Fraction of carbon dioxide in sewage discharge
= 3	Fraction of organic nitrogen in sewage discharge
= 4	Fraction of ammonia in sewage discharge
= 5	Fraction of nitrite + nitrate in sewage discharge
= 6	Fraction of phosphorus in sewage discharge
FUNCT	Subroutine to estimate $\partial C/\partial t$
FX	Array of values used in interpolation to determine values at grid points, printout points, and verification points
FXX	Resulting interpolated value
FY	Intermediate interpolated value
FYY	Intermediate interpolated value
F1	Proportion of organic carbon in land runoff
F3	Proportion of organic nitrogen in land runoff
F5	Proportion of nitrite + nitrate in land runoff
F6	Proportion of ortho-phosphate phosphorus in land runoff
GRO(J)	
J = 1	Constant in the temperature expression for the growth rate coefficient of algae $((^{\circ}C\text{—}hr)^{-1})$
= 2	Constant in the temperature expression for the growth rate coefficient of protozoa $((^{\circ}C\text{—}hr)^{-1})$
= 3	Constant in the temperature expression for the growth rate coefficient of zooplankton $((^{\circ}C\text{—}hr)^{-1})$
= 4	Constant in the temperature expression for the growth rate coefficient of higher predator $((^{\circ}C\text{—}hr)^{-1})$

Variable Name	Definition
GRO8	Growth rate coefficient for algae (hr^{-1})
GRO9	Growth rate coefficient for protozoa (hr^{-1})
GRO10	Growth rate coefficient for zooplankton (hr^{-1})
GRO11	Growth rate coefficient for higher predator (hr^{-1})
GRO12	Growth rate coefficient for bacteria (hr^{-1})
IA	An index to indicate which one of the steps in the integration the concentrations are for
IC	Number of components modeled
IDAY	Day of the year simulated
IER	Variable exponent in the expression to adjust the time step depending upon accuracy of the integration
III	Number of days from the present to the next day of computer printout
IK	The grid point at which STP discharges enter and at what grid point the discrete constants are assigned in the STORE subroutine. For verification purposes, it is the component number
ILIST	Logic variable to determine if the NAMELIST option is exercised
INTP	Subroutine which interpolates variable values
IPDAY	Day of printout
IPOS	Grid point closest to actual observed data
IPRI	Logic variable to determine whether punched card output is required
IPT	Variable which indicates the form of data

Variable Name	Definition
ITYPE	Defines input as a parameter or component
IZDAY	Initial day of the year modeled
JA	Index that indicates the step of integration between t and t + Dt
J1	Same as IER but used in the subroutine RKMI
JDAY	Day of the year that observed data are available for verification
K(I,J)	Utility array
I = 1	Diffusion coefficient ($mi^2 \cdot hr^{-1}$)
= 2	Benthal demand ($lb/mi^3 \cdot hr$)
= 3	Average cross-sectional area (mi^2)
= 4	Time variable pollution discharge rate ($lb/mi^3 \cdot hr$)
= 5	Oxygen reaeration rate constant (hr^{-1})
= 6	Land runoff ($lb/mi^3 \cdot hr$)
= 7	Predation rate on algae ($lb/mi^3 \cdot hr$)
= 8	Predation rate on protozoa ($lb/mi^3 \cdot hr$)
= 9	Predation rate on zooplankton ($lb/mi^3 \cdot hr$)
= 10	Predation rate on higher predator ($lb/mi^3 \cdot hr$)
= 11	Natural death rate for algae ($lb/mi^3 \cdot hr$)
= 12	Natural death rate of protozoa ($lb/mi^3 \cdot hr$)
= 13	Natural death rate for zooplankton ($lb/mi^3 \cdot hr$)
= 14	Natural death rate for higher predator ($lb/mi^3 \cdot hr$)

Variable Name	Definition
= 15	Recycle of organic carbon (lb/mi^3 • hr)
= 16	Recycle of inorganic carbon (lb/mi^3 • hr)
= 17	Recycle of organic nitrogen (lb/mi^3 • hr)
= 18	Recycle of organic phosphorus (lb/mi^3 • hr)
= 19	Growth rate for algae (lb/mi^3 • hr)
= 20	Growth rate for protozoa (lb/mi^3 • hr)
= 21	Growth rate for zooplankton lb/mi^3 • hr)
= 22	Growth rate for higher predator (lb/mi^3 • hr)
= 23	Respiration rate for algae (lb/mi^3 • hr)
= 24	Respiration rate for protozoa (lb/mi^3 • hr)
= 25	Respiration rate for zooplankton (lb/mi^3 • hr)
= 26	Respiration rate for higher predator (lb/mi^3 • hr)
= 27	Total ecosystem respiration rate (lb/mi^3 • hr)
= 28	Average pollution discharge rate (lb/day)
= 29	Inorganic carbon reaeration rate (hr^{-1})
= 30	Estuary depth, hydraulic radius (ft)
= 31	Tidal phase
= 32	Predation rate on bacteria (lb/mi^3 • hr)
= 33	Natural death rate of bacteria (lb/mi^3 • hr)
= 34	Respiration rate for bacteria (lb/mi^3 • hr)
= 35	Growth rate for bacteria (lb/mi^3 • hr)

Variable Name	Definition
= 36	Maximum fractional deviation in cross-sectional area from the average at high or low tide
= 37	Maximum tidal velocity (mi/hr)
= 38	Tidal lag (hr)
KM8	Michaelis-Menten or half saturation concentration of the substrate for algae (lb/mi^3)
KM9	Michaelis-Menton or half saturation concentration of the substrate for protozoa (lb/mi^3)
KM10	Michaelis-Menten or half saturation concentration of the substrate for zooplankton (lb/mi^3)
KM11	Michaelis-Menten or half saturation concentration of the substrate for higher predator (lb/mi^3)
KM12	Michaelis-Menten of half saturation concentration of the substrate for bacteria (lb/mi^3)
KP	Logic variable to indicate if punched output is required on the final day of simulation
K11	Organic carbon utilization rate coefficient (hr^{-1})
K12	Rate coefficient of the conversion of organic nitrogen to ammonia (hr^{-1})
K36	Rate coefficient for the utilization of orthophosphate (hr^{-1})
K2X	Constant in the expression for oxygen reaeration coefficient depending upon depth and velocity (day^{-1})
LIST1	Name of the NAMELIST

Variable Name	Definition
LOGUP	Logic variable which indicates the type of update to be executed = 1 before solution begins for initial definitions = 2 daily update = 3 minute to minute update
LOG	Logic variable determining whether there will be regular ouput or a comparison with actual data = 0 comparison with observed data = 1 regular output
MDAY	Final day of the year simulated
NC	The parameter or pollutant number in the array K(NC,J)
ND	Variable determining positions of printed concentration output
NDATA	The total number of data values used in the verification
NHSEC	The number of 1/100 seconds between printout
NM	Number of grid points
NN	Number of estuary sections
N02N03	Boundary condition of nitrite + nitrate (ppm)
NV(J)	Array of the component used in the verification
NVIK	Variable which specifies which component is being compared with the observed data
ODIFF	The difference in the saturation concentration of oxygen at two different temperatures
02SAT, OSAT	Saturation concentration of oxygen, as a function of temperature (ppm or lb/mi^3)

Variable Name	Definition
OUTPUT	Subroutine prints output and compares data
PHASE	Tidal phase
POS	Position at which observed data were taken (mile)
POSIT	The position at which parameter values or pollutant values are known (mile)
PRED(J)	
J = 1	Constant of the linear temperature expression for the predation rate coefficient on algae $((^{\circ}C \cdot ppm \cdot hr)^{-1})$
= 2	Constant of the linear temperature expression for the predation rate coefficient on protozoa $((^{\circ}C \cdot ppm \cdot hr)^{-1})$
= 3	Constant of the linear temperature expression for the predation rate coefficient on zooplankton $((^{\circ}C \cdot ppm \cdot hr)^{-1})$
= 4	Constant linear temperature expression for the predation rate coefficient on higher predator $((^{\circ}C \cdot hr)^{-1})$
= 5	Constant of the linear temperature expression for the predation rate coefficient on bacteria $((^{\circ}C \cdot ppm \cdot hr)^{-1})$
PRED8	Algae predation rate coefficient $((lb/mi^{3} \cdot hr)^{-1})$
PRED9	Protozoa predation rate coefficient $((lb/mi^{3} \cdot hr)^{-1})$
PRED10	Zooplankton predation rate coefficient $((lb/mi^{3} \cdot hr)^{-1})$
PRED11	Higher predator predation rate coefficient (hr^{-1})
PRED12	Bacteria predation rate coefficient $((lb/mi^{3} \cdot hr)^{-1})$

Variable Name	Definition
PRI	Number of printouts per tidal cycle
PRIE	Maximum allowable error between specified printout time and actual printout time
Q	Volumetric flow rate (cfs)
RELE	Allowable relative error of integration through time
RES(J)	
J = 1	Constant in the temperature expression for algae respiration rate coefficient $((^{\circ}\mathrm{C} \cdot \mathrm{hr})^{-1})$
= 2	Constant in the temperature expression for protozoa respiration rate coefficient $((^{\circ}\mathrm{C} \cdot \mathrm{hr})^{-1})$
= 3	Constant in the temperature expression for zooplankton respiration rate coefficient $((^{\circ}\mathrm{C} \cdot \mathrm{hr})^{-1})$
= 4	Constant in the temperature expression for higher predator respiration rate coefficient $((^{\circ}\mathrm{C} \cdot \mathrm{hr})^{-1})$
= 5	Constant in the temperature expression for bacteria respiration rate coefficient $((^{\circ}\mathrm{C} \cdot \mathrm{hr})^{-1})$
RESP8	Respiration rate coefficient for algae (hr^{-1})
RESP9	Respiration rate coefficient for protozoa (hr^{-1})
RESP10	Respiration rate coefficient for zooplankton (hr^{-1})
RESP11	Respiration rate coefficient for higher predator (hr^{-1})
RESP12	Respiration rate coefficient for bacteria (hr^{-1})

Variable Name	Definition
RKMI	Subroutine to evaluate $\partial C/\partial t$
R	Factor multiplied to maximum growth rate of algae due to non-optimum sunlight intensity
RR	Ratio of the sunlight intensity to the optimum sunlight intensity
S	Conversion of ppm to lb/mi^3 = 1ppm = 9.19×10^6 lb/mi^3
SS	Sum of squares of error in verification
STORE	Reads and stores data
SUM	Sum of the errors in the model verification
SUN	Daily sunlight totals (langleys)
SUNMAX	Maximum instantaneous sunlight intensity
SUNSAT	Optimum sunlight intensity
T	Real time of simulation (hr)
TDATA	Time at which actual data was taken
TEMP	Water temperature ($^\circ$C)
TI	Initial time of day
TIDE	Time of high tide on first day of simulation (hr)
TITLE(J)	Array of names of the parameter read as input data
TIMON, TIMECK	Internal subroutines designed to determine CPU for a certain amount of processing
TIC	Boundary condition for inorganic carbon (ppm)
TM	Final time of final day (hr)

Variable Name	Definition
TMAX	Maximum number of computer minutes allotted to run
TMIN	Machine minute used
TON	Boundary condition for organic nitrogen (ppm)
TOC	Boundary condition for organic carbon (ppm)
TP04	Boundary condition for ortho-phosphate (ppm)
TPR	The hour of the day requiring output
TQQ	Measure of the error in the integration through time
UA(J)	Array of the volumetric flow rates at the grid points (mi^3/hr)
UABS	Absolute value of fluid velocity (ft/sec)
UPDATE	Subroutine to update parameters
VAL(J)	Array of observed concentrations required in the verification (ppm)
VALUE	Input value of parameters for point source discharge or discrete constants
VELOC	Subroutine calculating fluid velocity
VOLUM	Subroutine calculating volumetric flow rate
WORK, WORK1	Utility matrices used in integration, interpolation, and
WORK2	and reading in initial values
WF	Period of the sine function used in the expressions for point source discharge and sunlight intensity (hr^{-1})
WT	$= 2\pi$, required for tidal and temperature expressions

Variable Name	Definition
XI	Upstream boundary (miles)
XO	Downstream boundary (miles)
XPOS(I)	Array of the grid point positions (mile)
XP2	The square of XPOS
XQ	Volumetric freshwater flow rate (mi^3/hr)
XSEC	Number of sec/real time day
XXX	Light extinction coefficient times water depth. Needed for calculating sunlight intensity
XY	Concentration of the growth limiting substrate in the Michaelis-Menten expression
X11	Organic carbon utilization rate coefficient at 20°C (day^{-1})
X36	Ortho-phosphate utilization rate coefficient at 20°C (day^{-1})
YYY	Constant in the time step determination expression

RESEARCH PROCEDURES

Modeling cannot begin without the collection of data required to completely describe a process. Data sources for the James River Estuary were consulted for relevant geometrical data, hydrological data, meteorological data, and water quality data. The data compiled led to model modifications and to a change in the original research plan.

Salinity intrusion in the lower section of the James River Estuary caused alteration of the original research plan to model the entire estuary. A primary assumption of one-dimensional models is that the quality of water within any section is homogenous (no density stratification). Significant differences in the vertical chloride concentration profile occur 60 miles downstream from Richmond; therefore, vertical homogeneity is an invalid assumption beyond this point.

After completing data compilation, the model was set up for preliminary runs. These preliminary runs uncovered program errors and defined a system of grid points at which computations were made. Grid spacing depends upon required computation accuracy and allowable simulation time. Eighty grid points insured a convergent solution for the 60 miles of the estuary modeled without a significant increase in machine time.

Included among the preliminary runs was a 40-day simulation of the James to obtain concentration profiles for each of the components. The pollution concentrations predicted at the end of 40 days were then used as initial conditions for each sensitivity study.

The sensitivity studies made on the 60 miles of estuary included: (1) determining model sensitivity to change in the organic carbon utilization rate constant; (2) determining model sensitivity to change in the phosphorus utilization rate constant; (3) determining the effect of varying the freshwater flow rate upon organic carbon, organic nitrogen, and ortho-phosphate; (4) determining the effect of reducing the nitrogen waste load on the growth of algae and bacteria; (5) determining the effect of waste loading upon organic carbon and oxygen deficit; and (6) determining the effect of variable water temperature on organic carbon, organic nitrogen, carbon dioxide, and oxygen deficit.

In running the sensitivity studies, an error in the concentration profiles occurred due to the artificial nature of the boundary conditions. Some of the tables investigating the rate constants of organic carbon and ortho-phosphate, particularly Tables 1, 3, and 11, reveal a distortion of the concentrations near the upper boundary of the estuary. The reported results contradict a reasonable assumption that an increase in a component's rate constant will ultimately decrease its concentration.

One explanation for this distortion may be that an artificially depressed concentration profile caused the calculating of a large concentration gradient. As a result of the large gradient, the concentration increased greatly just inside the boundary. The downstream concentrations also increased with the normal advection of the pollutant.

Even with the distortion, the sensitivity studies on the rate coefficients still reveal the sensitivity of component concentration to these parameters.

The first study examined the sensitivity of the predicted concentrations of organic carbon, carbon dioxide, and oxygen deficit to changes of the organic utilization rate constant. The results are summarized in Tables 1 through 9. Ten situations, with rate constants between 0.25 day^{-1} and .50 day^{-1}, were simulated for 10 days each and the subsequent mean concentrations for the three components were calculated as functions of tidal phase and position. The average organic carbon concentration change between rate constant values of .025 and .25 was 1 ppm or about 35% decrease. Although most of the data sources investigated recommend rate constant values in this range, the values .30, .35, .40, and .50 were also investigated. The average concentration change over the entire range was just less than 2 ppm. Carbon dioxide concentration increased by 44% (1.3 ppm) on the average over the smaller range of rate constants; while over the entire range, the concentration differed by 3.4 ppm, the equivalent of 110% increase. The third component, oxygen deficit, differed the greatest. Oxygen deficit concentration increased 220% (1.94 ppm) between .025 and .25; while overall, the concentration increased 380% (3.35 ppm).

The concentration of organic carbon was expected to decrease to a degree, while the concentrations of carbon dioxide and oxygen deficit were expected to increase. However, the resulting extreme sensitivity of the oxygen deficit concentration to the value of the rate constant implies that the coefficient is important and should be measured accurately.

A similar study tested the ortho-phosphate utilization rate constant. Again the study considered 10 rate constants between .015 day^{-1} and .35 day^{-1}, but the results (Tables 10 to 12) differed from those of the first sensitivity study. The concentration changes were small revealing that phosphate concentration is insensitive to reasonable changes in the rate constant. Possibly the use of second order reaction kinetics makes the conversion of ortho-phosphate insignificant.

Tables 13 through 21 exhibit the effect of reducing nitrogen waste on the nitrate + nitrite concentration, bacteria growth and algal growth. The results from the reduction of nitrogen waste by 60%, 70%, 80%, and 90% were compared to the concentration profiles due to normal nitrogen waste loading. The land runoff contribution to the nitrate + nitrite concentration overshadows any change in concentration due to the relatively slow conversion of nitrogen waste into inorganic forms. It follows that insignificant changes in the concentration of algae are observed since algal growth is a function of the nitrate + nitrite concentration. The concentration of bacteria, whose limiting substrate is ammonia, also proved insensitive to the reduction in nitrogen waste from the point sources.

The results of changing the freshwater flow rate by ± 10%, ± 20%, ± 30%, and ±40% were investigated for organic carbon, organic nitrogen, and ortho-phosphate and these results are displayed in Tables 22 through 30. Component concentration changed only by 10 to 15% for a 40% increase or decrease in flow rate. The positions closest to the upstream boundary changed the greatest because the boundary condition concentrations are functions of the freshwater flow rate.

Six different waste discharge quantities simulated for 10 days resulted in an investigation of their effect upon the concentration of organic carbon and oxygen deficit. The effect of normal discharge compared to the effect of discharge rates 1.5, 2, 2.5, 3, and 4 times the normal showed a 10 to 20% increase in organic carbon concentration, near positions of input sources, for each 50% increase in waste input. Oxygen deficit concentration increased between 3 and 10% for the same 50% increase in waste input. Again, the most important factor is the rate of conversion of organic carbon resulting in the depletion of dissolved oxygen. The results of this sensitivity study are summarized in Tables 31 through 36.

The final study considered the effect of random water temperature on the mean concentrations of carbon dioxide, organic carbon, organic nitrogen, and oxygen deficit. Values of water temperature were generated with normal random errors for situations in which the standard deviation was 1, 2, and 3°C. The resulting mean concentration of the four components were compared to the mean concentrations calculated with no temperature variation. The effect of random temperature upon carbon dioxide, organic nitrogen, and organic carbon was negligible with the mean concentrations differing by one hundredths ppm. Oxygen deficit concentration, however, differed by an average maximum of 15% from the concentrations predicted without temperature variation. Since water temperature determines the saturation concentration for dissolved oxygen, varying the temperature should effect the rate at which oxygen is absorbed from the atmosphere. Temperature, more than likely, has a greater effect upon the variance of the oxygen deficit concentration than it has on the mean concentration. Tables 37 through 48 give the results of the study.

CONCLUSIONS

1. Organic carbon and carbon dioxide are moderately sensitive to changes of the organic carbon utilization rate. Oxygen deficit, however, is highly sensitive to change.

2. Ortho-phosphate concentration is insensitive to changes of the phosphate utilization rate constant.

3. Nitrate + nitrite concentration, algal concentration, and bacterial concentration are insensitive to a reduction of nitrogen waste from the point sources. Land runoff contributes the greatest quantity of nitrate and nitrite to the estuary.

4. The concentration of organic carbon, organic nitrogen, and ortho-phosphate are insensitive to change of measurement error of the freshwater flow rate at least as great as 40%.

5. The sensitivity of oxygen deficit concentration to sewage input is moderate in the range of loading rates investigated.

6. Randomizing water temperature has a negligible effect upon the concentrations of carbon dioxide, organic carbon, and organic nitrogen. Oxygen deficit concentration differs as much as 15% but still the effect is insignificant.

RECOMMENDATIONS

1. The variability of pollution concentration predicted by the model due to temperature variation should be compared to the observed variability of the components to indicate the significance of variable temperature.

2. The Schofield model, or any model, should be verified on the James River Estuary by comparing predicted results with actual observations before any practical use of the model is made.

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TABLES

Table 1

Effect of Varying the Organic Carbon Rate Constant on the Concentration of Organic Carbon

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
VALUE	TIDAL PHASE							
	0.097	0.123	0.154	0.188	0.225	0.267	0.312	0.361
1/DAY								
.025	6.241	4.401	6.137	3.612	4.443	4.605	1.448	1.208
.050	6.297	4.724	6.142	3.542	4.310	4.380	1.273	1.205
.100	6.423	5.048	6.000	3.454	3.900	3.884	1.150	1.098
.150	5.967	5.208	5.641	3.059	3.500	3.468	1.007	1.066
.200	6.051	5.522	5.532	3.002	3.241	3.123	0.951	0.936
.250	5.874	5.558	5.686	3.147	2.947	2.821	0.878	0.869
.300	5.784	5.612	5.445	2.964	2.955	2.281	0.591	0.619
.350	6.649	5.491	5.306	2.943	2.530	2.394	0.777	0.769
.400	7.088	6.462	6.124	3.169	2.287	1.646	0.467	0.496
.500	7.034	5.951	5.407	2.743	1.798	1.312	0.413	0.413

Table 2

Effect of Varying the Organic Carbon Rate Constant on the Concentration of Organic Carbon

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
VALUE	TIDAL PHASE							
	0.397	0.423	0.454	0.488	0.526	0.567	0.612	0.661
1/DAY								
.025	7.212	6.888	6.738	5.044	6.190	6.058	1.335	1.220
.050	5.854	5.735	5.597	4.274	5.421	5.707	1.268	1.211
.100	5.023	5.422	5.501	3.995	4.120	4.479	1.256	1.214
.150	5.620	5.587	5.669	3.924	3.861	4.001	1.109	1.119
.200	6.992	5.559	5.469	3.927	4.113	2.939	0.547	0.720
.250	6.253	5.821	5.517	3.867	4.028	3.261	0.900	0.976
.300	6.817	5.533	5.447	3.548	3.061	2.738	0.749	0.871
.350	6.938	5.641	5.445	3.427	2.878	2.525	0.694	0.830
.400	6.924	5.503	5.234	3.252	2.692	2.338	0.652	0.798
.500	6.965	5.305	4.894	2.992	2.404	2.044	0.572	0.741

Table 3

Effect of Varying the Organic Carbon Rate Constant on the Concentration of Organic Carbon

VALUE	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
1/DAY	0.696	0.723	0.753	0.787	0.825	0.866	0.911	0.960
.025	5.907	5.798	6.273	4.084	5.173	4.476	1.311	1.636
.050	5.260	5.131	5.367	3.326	4.219	4.121	1.243	1.621
.100	5.930	5.306	5.360	3.316	3.816	3.655	1.136	1.517
.150	6.462	5.436	5.304	3.319	3.483	3.277	1.040	1.425
.200	7.541	6.263	5.827	3.659	3.425	2.812	0.924	1.101
.250	8.175	6.489	5.986	4.127	3.261	2.396	0.757	0.997
.300	7.397	5.242	4.909	3.165	2.733	2.484	0.854	1.243
.350	7.469	5.182	4.725	3.097	2.523	2.284	0.803	1.189
.400	8.526	6.206	5.326	3.919	2.339	1.473	0.476	0.754
.500	8.122	5.632	4.709	3.446	1.715	1.133	0.417	0.642

Table 4

Effect of Varying the Organic Carbon Rate Constant on the Concentration of Carbon Dioxide

VALUE	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
1/DAY	0.097	0.123	0.154	0.188	0.225	0.267	0.312	0.361
.025	2.832	1.224	3.268	1.888	2.943	3.130	1.163	1.030
.050	2.844	1.297	3.493	2.085	3.190	3.394	1.116	1.133
.100	2.727	1.369	3.903	2.288	3.609	3.886	1.232	1.236
.150	2.496	1.754	4.553	2.401	4.184	4.459	1.229	1.235
.200	2.614	1.604	4.688	2.656	4.268	4.618	1.422	1.408
.250	2.589	1.691	4.983	2.783	4.505	4.852	1.476	1.483
.300	2.535	1.909	5.577	3.122	4.992	5.293	1.620	1.584
.350	2.141	2.283	6.605	3.511	6.481	6.905	1.829	1.805
.400	1.926	2.672	8.050	4.303	7.796	8.266	2.194	2.216
.500	1.833	2.896	9.379	4.973	8.601	9.203	2.470	2.501

Table 5

Effect of Varying the Organic Carbon Rate Constant on the Concentration of Carbon Dioxide

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
VALUE	TIDAL PHASE							
	0.397	0.423	0.454	0.488	0.526	0.567	0.612	0.661
1/DAY								
.025	0.319	2.931	2.067	2.332	3.071	4.185	1.129	0.879
.050	0.216	2.426	1.674	2.096	2.707	3.790	1.290	1.042
.100	0.168	2.616	1.860	2.336	3.012	4.252	1.420	1.131
.150	0.349	3.591	2.450	3.095	4.165	6.132	1.716	1.255
.200	0.205	3.846	2.839	3.223	4.508	6.465	1.679	1.248
.250	0.118	3.456	2.854	3.208	4.153	5.682	1.821	1.408
.300	0.121	3.597	3.038	3.369	4.301	5.849	1.874	1.447
.350	0.115	3.824	3.319	3.590	4.545	6.127	1.903	1.501
.400	0.038	5.038	3.619	4.191	5.824	8.549	2.389	1.772
.500	0.056	4.548	3.186	4.680	7.200	10.163	2.554	1.803

Table 6

Effect of Varying the Organic Carbon Rate Constant on the Concentration of Carbon Dioxide

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
VALUE	TIDAL PHASE							
1/DAY	0.696	0.722	0.753	0.787	0.824	0.866	0.911	0.959
.025	0.685	2.499	3.100	1.728	3.348	3.711	1.156	1.333
.050	1.149	3.194	3.198	1.759	3.639	3.894	1.131	1.218
.100	0.645	2.715	3.441	1.875	3.770	4.167	1.264	1.439
.150	0.604	2.947	3.772	2.023	4.148	4.554	1.354	1.528
.200	0.659	3.564	4.668	2.383	5.081	5.449	1.582	1.776
.250	0.657	3.741	4.913	2.483	5.306	5.647	1.638	1.832
.300	1.118	3.807	4.613	2.482	5.482	5.873	1.739	1.557
.350	0.859	4.102	5.151	2.733	6.232	6.596	1.908	1.803
.400	0.733	4.812	6.244	3.304	7.559	7.881	2.228	2.148
.500	1.484	5.742	7.084	4.324	8.599	8.928	2.929	2.378

Table 7

Effect of Varying the Organic Carbon Rate Constant on the Concentration of Oxygen Deficit

VALUE	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
1/DAY	0.097	0.123	0.154	0.188	0.225	0.267	0.312	0.361
.025	1.041	0.840	2.224	1.358	1.123	1.579	0.735	0.633
.050	1.008	0.987	2.582	1.606	1.436	1.979	0.779	0.771
.100	0.939	1.308	3.353	2.028	1.953	2.645	0.977	0.959
.150	0.922	1.730	4.067	2.044	2.211	2.741	0.914	0.914
.200	0.977	2.120	4.882	2.805	2.761	3.564	1.279	1.247
.250	1.024	2.625	5.592	3.117	3.042	3.849	1.367	1.361
.300	1.133	3.458	6.930	3.830	3.574	4.344	1.568	1.533
.350	1.317	3.950	7.628	4.024	4.378	4.647	1.331	1.306
.400	1.707	5.307	9.574	5.078	4.970	4.864	1.383	1.400
.500	2.289	6.538	12.019	5.975	5.384	5.186	1.437	1.436

Table 8

Effect of Varying the Organic Carbon Rate Constant on the Concentration of Oxygen Deficit

VALUE	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
1/DAY	0.397	0.423	0.454	0.488	0.526	0.567	0.612	0.661
.025	0.323	1.826	1.939	1.852	1.460	1.881	0.531	0.413
.050	0.033	1.490	1.603	1.637	1.073	1.970	0.862	0.685
.100	0.033	1.893	2.130	2.097	1.439	2.592	1.082	0.845
.150	0.412	3.143	3.035	3.311	2.912	4.561	1.480	1.034
.200	1.126	3.942	4.594	3.956	3.284	4.442	1.247	0.916
.250	0.094	3.458	4.869	4.253	2.857	4.366	1.688	1.302
.300	0.082	3.684	5.362	4.605	3.023	4.537	1.756	1.359
.350	0.337	4.133	6.272	5.268	3.333	4.819	1.799	1.442
.400	1.129	5.013	6.121	4.597	4.202	6.038	1.751	1.271
.500	3.488	6.658	8.145	7.929	7.158	8.311	2.058	1.413

Table 9

Effect of Varying the Organic Carbon Rate Constant on the Concentration of Oxygen Deficit

VALUE	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
1/DAY	0.696	0.723	0.753	0.787	0.825	0.866	0.911	0.960
.025	0.440	1.812	2.068	0.857	1.189	1.532	0.527	0.551
.050	0.115	1.737	2.431	1.047	1.538	2.341	0.806	0.848
.100	0.112	2.229	3.166	1.293	2.078	3.053	1.004	1.036
.150	0.122	2.735	3.881	1.553	2.567	3.644	1.167	1.194
.200	0.654	3.303	4.975	2.119	3.248	3.914	1.277	1.092
.250	0.769	3.829	5.978	2.726	3.997	4.480	1.425	1.284
.300	0.339	3.731	5.891	2.333	3.632	4.902	1.555	1.600
.350	0.366	4.051	6.468	2.554	3.877	5.155	1.647	1.699
.400	1.888	5.606	8.633	4.550	5.177	5.165	1.590	1.478
.500	3.131	6.316	9.466	5.403	5.153	5.060	1.796	1.432

Table 10

Effect of Varying the Phosphorus Rate Constant on the Concentration of Phosphate

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
VALUE	TIDAL PHASE							
	0.097	0.123	0.154	0.188	0.225	0.267	0.312	0.361
1/DAY								
.015	0.828	0.520	0.740	0.499	0.564	0.469	0.124	0.112
.020	0.829	0.521	0.738	0.498	0.560	0.465	0.123	0.111
.025	0.831	0.523	0.735	0.497	0.556	0.461	0.122	0.111
.050	0.836	0.534	0.722	0.492	0.539	0.443	0.119	0.108
.100	0.845	0.553	0.701	0.488	0.512	0.414	0.113	0.104
.150	0.848	0.566	0.683	0.475	0.483	0.387	0.108	0.101
.200	0.852	0.577	0.668	0.467	0.461	0.366	0.103	0.097
.250	0.858	0.593	0.654	0.465	0.444	0.348	0.099	0.094
.300	0.859	0.602	0.646	0.455	0.426	0.332	0.096	0.092
.350	0.861	0.609	0.633	0.449	0.411	0.319	0.093	0.089

Table 11

Effect of Varying the Phosphorus Rate Constant on the Concentration of Phosphate

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
VALUE	TIDAL PHASE							
	0.397	0.423	0.454	0.488	0.526	0.567	0.612	0.661
1/DAY								
.015	0.539	0.555	0.613	0.382	0.569	0.525	0.133	0.091
.020	0.546	0.557	0.615	0.380	0.565	0.520	0.132	0.091
.025	0.908	0.766	0.765	0.503	0.737	0.658	0.125	0.075
.050	0.579	0.624	0.601	0.476	0.773	0.780	0.166	0.110
.100	0.634	0.585	0.634	0.370	0.532	0.468	0.122	0.085
.150	0.686	0.604	0.643	0.369	0.517	0.444	0.114	0.082
.200	0.722	0.617	0.647	0.366	0.503	0.422	0.109	0.079
.250	0.745	0.620	0.643	0.357	0.487	0.402	0.106	0.077
.300	1.118	0.812	0.771	0.460	0.580	0.408	0.074	0.048
.350	1.160	0.833	0.768	0.517	0.655	0.452	0.080	0.052

Table 12

Effect of Varying the Phosphorus Rate Constant on the Concentration of Phosphate

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
VALUE	TIDAL PHASE							
	0.696	0.723	0.753	0.787	0.825	0.866	0.911	0.960
1/DAY								
.015	0.610	0.565	0.621	0.520	0.553	0.459	0.129	0.124
.020	0.681	0.605	0.692	0.579	0.611	0.457	0.109	0.085
.025	0.568	0.600	0.620	0.497	0.594	0.508	0.131	0.117
.050	0.565	0.531	0.566	0.466	0.539	0.499	0.147	0.120
.100	0.665	0.573	0.621	0.510	0.508	0.413	0.114	0.111
.150	0.699	0.559	0.586	0.487	0.507	0.441	0.125	0.108
.200	0.702	0.628	0.596	0.515	0.456	0.418	0.148	0.160
.250	0.779	0.597	0.600	0.503	0.442	0.355	0.103	0.102
.300	0.864	0.673	0.619	0.508	0.449	0.331	0.087	0.078
.350	0.931	0.668	0.613	0.525	0.415	0.301	0.084	0.066

Table 13

Effect of Reducing Nitrogen Waste on the Concentration of $NO_2 + NO_3$

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
RED'N	0.097	0.123	0.154	0.188	0.225	0.267	0.312	0.361
0%	0.464	0.326	0.607	0.356	0.450	0.586	0.196	0.192
60%	0.426	0.306	0.583	0.336	0.428	0.573	0.196	0.193
70%	0.419	0.302	0.577	0.332	0.423	0.571	0.195	0.192
80%	0.411	0.297	0.572	0.328	0.417	0.568	0.195	0.192
90%	0.403	0.293	0.568	0.324	0.413	0.565	0.195	0.192

Table 14

Effect of Reducing Nitrogen Waste on the Concentration of NO_2 + NO_3

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
	0.397	0.423	0.454	0.488	0.526	0.567	0.612	0.661
RED'N								
0%	0.082	0.388	0.412	0.364	0.340	0.559	0.206	0.203
60%	0.303	0.576	0.549	0.432	0.445	0.637	0.182	0.186
70%	0.140	0.534	0.513	0.399	0.398	0.631	0.193	0.195
80%	0.074	0.369	0.374	0.347	0.307	0.539	0.202	0.200
90%	0.074	0.366	0.370	0.345	0.302	0.536	0.202	0.200

Table 15

Effect of Reducing Nitrogen Waste on the Concentration of $NO_2 + NO_3$

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
RED'N	0.696	0.723	0.753	0.787	0.825	0.866	0.911	0.960
0%	0.187	0.434	0.542	0.284	0.446	0.592	0.194	0.261
60%	0.283	0.512	0.653	0.324	0.554	0.601	0.196	0.253
70%	0.253	0.517	0.639	0.293	0.516	0.623	0.215	0.246
80%	0.357	0.505	0.627	0.311	0.513	0.562	0.189	0.238
90%	0.152	0.417	0.508	0.251	0.415	0.581	0.192	0.260

Table 16

Effect of Reducing Nitrogen Waste on the Concentration of Algae

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
RED'N	0.097	0.123	0.154	0.188	0.225	0.267	0.312	0.361
0%	0.134	0.444	0.972	1.693	0.496	0.202	0.097	0.061
60%	0.130	0.392	0.838	1.488	0.476	0.202	0.093	0.059
70%	0.130	0.392	0.836	1.487	0.475	0.201	0.093	0.059
80%	0.129	0.391	0.835	1.485	0.475	0.201	0.093	0.059
90%	0.129	0.391	0.833	1.483	0.474	0.201	0.093	0.059

Table 17

Effect of Reducing Nitrogen Waste on the Concentration of Algae

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
RED'N	0.397	0.423	0.454	0.488	0.526	0.567	0.612	0.661
0%	0.234	0.924	1.504	1.698	0.803	0.204	0.070	0.048
60%	0.427	0.918	1.496	1.676	0.800	0.321	0.053	0.037
70%	0.577	0.910	1.477	1.666	0.789	0.620	0.085	0.051
80%	0.249	0.909	1.458	1.658	0.785	0.201	0.070	0.048
90%	0.252	0.925	1.488	1.693	0.793	0.202	0.070	0.048

Table 18

Effect of Reducing Nitrogen Waste on the Concentration of Algae

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
RED'N	0.696	0.723	0.753	0.787	0.825	0.866	0.911	0.960
0%	0.171	0.425	0.726	0.725	0.560	0.201	0.070	0.061
60%	0.183	0.424	0.722	0.725	0.555	0.200	0.070	0.061
70%	0.163	0.287	0.409	0.305	0.605	0.227	0.074	0.063
80%	0.116	0.310	0.513	0.474	0.328	0.126	0.072	0.081
90%	0.156	0.266	0.387	0.274	0.599	0.224	0.068	0.058

Table 19

Effect of Reducing Nitrogen Waste on the Concentration of Bacteria

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
RED'N	0.097	0.123	0.154	0.188	0.225	0.267	0.312	0.361
0%	0.086	0.048	0.074	0.037	0.041	0.039	0.010	0.010
60%	0.088	0.050	0.076	0.037	0.041	0.039	0.011	0.009
70%	0.088	0.050	0.076	0.037	0.040	0.039	0.011	0.009
80%	0.088	0.049	0.076	0.037	0.040	0.039	0.011	0.009
90%	0.088	0.049	0.075	0.037	0.040	0.039	0.011	0.009

Table 20

Effect of Reducing Nitrogen Waste on the Concentration of Bacteria

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
RED'N	0.397	0.423	0.454	0.488	0.526	0.567	0.612	0.661
0%	0.035	0.061	0.053	0.042	0.034	0.040	0.011	0.009
60%	0.054	0.073	0.063	0.042	0.032	0.030	0.006	0.004
70%	0.051	0.071	0.061	0.041	0.032	0.030	0.006	0.004
80%	0.038	0.065	0.055	0.044	0.035	0.041	0.011	0.007
90%	0.038	0.065	0.055	0.044	0.035	0.041	0.011	0.007

Table 21

Effect of Reducing Nitrogen Waste on the Concentration of Bacteria

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
RED'N	0.696	0.723	0.753	0.787	0.825	0.866	0.911	0.960
0%	0.052	0.064	0.067	0.029	0.040	0.039	0.010	0.010
60%	0.060	0.066	0.063	0.026	0.032	0.025	0.007	0.006
70%	0.061	0.069	0.064	0.026	0.032	0.024	0.007	0.005
80%	0.066	0.071	0.066	0.027	0.032	0.023	0.006	0.005
90%	0.053	0.068	0.067	0.029	0.041	0.039	0.010	0.009

Table 22

Effect of Freshwater Flow on the Concentration of Organic Carbon

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
FLOW	0.097	0.123	0.154	0.188	0.225	0.267	0.312	0.361
STAND	6.423	5.048	6.000	3.454	3.900	3.884	1.150	1.098
.6 STD	8.515	6.261	6.092	3.487	3.704	3.751	1.115	1.010
.7 STD	9.647	9.834	8.750	5.586	5.009	4.042	0.980	0.886
.8 STD	8.023	8.061	7.709	4.644	4.256	3.500	0.923	0.868
.9 STD	6.489	5.129	6.078	3.263	3.767	3.808	1.126	1.039
1.1STD	6.327	4.743	5.652	3.269	3.818	3.826	1.153	1.155
1.2STD	6.358	4.470	5.710	3.329	3.825	3.798	1.198	1.222
1.3STD	6.412	5.361	6.660	3.574	4.090	3.719	1.093	1.152
1.4STD	5.875	5.201	6.237	3.290	4.023	4.003	1.351	1.346

Table 23

Effect of Freshwater Flow on the Concentration of Organic Carbon

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
FLOW	0.397	0.423	0.454	0.488	0.526	0.567	0.612	0.661
STAND	5.620	5.587	5.669	3.924	3.861	4.001	1.109	1.119
.6 STD	7.213	6.743	6.931	3.371	3.623	3.790	1.097	1.168
.7 STD	6.635	6.090	6.692	3.529	3.612	3.802	1.108	1.128
.8 STD	6.453	5.674	6.448	3.666	3.586	3.829	1.111	1.113
.9 STD	5.972	5.619	6.007	3.792	3.684	3.905	1.106	1.111
1.1STD	8.105	7.120	6.801	4.522	5.158	4.673	0.979	1.003
1.2STD	5.604	5.273	5.384	3.849	3.941	4.171	1.063	1.119
1.3STD	5.012	5.093	5.152	3.669	3.781	4.141	1.023	1.105
1.4STD	5.524	5.155	5.038	3.750	3.786	4.116	0.959	1.097

Table 24

Effect of Freshwater Flow on the Concentration of Organic Carbon

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
FLOW	0.696	0.723	0.753	0.787	0.825	0.866	0.911	0.960
STAND	5.930	5.306	5.360	3.316	3.816	3.655	1.136	1.517
.6 STD	7.445	6.044	5.963	3.315	3.627	3.255	1.008	1.714
.7 STD	6.838	5.434	5.630	3.136	3.644	3.358	1.004	1.564
.8 STD	6.264	5.217	5.537	3.023	3.670	3.449	1.031	1.504
.9 STD	5.756	5.388	5.565	3.060	3.756	3.553	1.073	1.507
1.1STD	6.135	5.186	5.304	3.506	3.882	3.730	1.203	1.516
1.2STD	6.331	6.047	5.823	4.369	4.551	3.883	1.202	1.322
1.3STD	6.319	5.385	5.066	3.686	4.154	4.153	1.383	1.435
1.4STD	5.951	5.186	5.191	3.819	4.183	4.129	1.412	1.430

Table 25

Effect of Freshwater Flow on the Concentration of Organic Nitrogen

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
FLOW	0.097	0.123	0.154	0.188	0.225	0.267	0.312	0.361
STAND	1.190	1.074	0.928	0.642	0.432	0.334	0.111	0.106
.6 STD	1.802	1.123	0.721	0.678	0.333	0.288	0.136	0.116
.7 STD	1.954	1.594	1.140	1.177	0.503	0.282	0.131	0.113
.8 STD	1.566	1.269	0.953	0.849	0.408	0.274	0.120	0.108
.9 STD	1.260	1.066	0.878	0.656	0.411	0.322	0.116	0.105
1.1STD	1.159	1.031	0.917	0.601	0.439	0.343	0.109	0.108
1.2STD	1.086	0.941	0.885	0.559	0.436	0.352	0.108	0.111
1.3STD	1.139	0.935	0.971	0.623	0.422	0.334	0.103	0.111
1.4STD	0.999	0.894	0.951	0.561	0.448	0.368	0.116	0.118

Table 26

Effect of Freshwater Flow on the Concentration of Organic Nitrogen

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
FLOW	0.397	0.423	0.454	0.488	0.526	0.567	0.612	0.661
STAND	1.591	1.088	1.033	0.664	0.599	0.337	0.079	0.146
.6 STD	1.509	1.043	1.021	0.558	0.442	0.261	0.110	0.173
.7 STD	1.536	1.036	1.067	0.632	0.496	0.275	0.098	0.163
.8 STD	1.590	1.045	1.065	0.676	0.543	0.294	0.089	0.155
.9 STD	1.605	1.066	1.050	0.680	0.576	0.315	0.083	0.150
1.1STD	1.672	1.128	1.016	0.661	0.642	0.373	0.075	0.139
1.2STD	1.411	1.067	0.916	0.621	0.602	0.374	0.075	0.138
1.3STD	1.325	1.018	0.837	0.577	0.576	0.379	0.074	0.135
1.4STD	1.334	0.983	0.798	0.554	0.535	0.370	0.071	0.134

Table 27

Effect of Freshwater Flow on the Concentration of Organic Nitrogen

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
FLOW	0.696	0.723	0.753	0.787	0.825	0.866	0.911	0.960
STAND	1.553	0.937	0.775	0.787	0.382	0.264	0.099	0.197
.6 STD	1.901	0.977	0.765	0.671	0.305	0.227	0.101	0.234
.7 STD	1.833	0.969	0.772	0.719	0.324	0.235	0.099	0.219
.8 STD	1.762	0.949	0.776	0.775	0.346	0.244	0.098	0.208
.9 STD	1.658	0.937	0.786	0.801	0.369	0.254	0.098	0.202
1.1STD	1.505	0.934	0.754	0.772	0.390	0.271	0.100	0.195
1.2STD	1.384	0.961	0.783	0.761	0.406	0.291	0.104	0.182
1.3STD	1.282	0.933	0.745	0.755	0.415	0.308	0.108	0.183
1.4STD	1.249	0.886	0.654	0.712	0.391	0.313	0.108	0.187

Table 28

Effect of Freshwater Flow on the Concentration of Phosphate

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
FLOW	0.097	0.123	0.154	0.188	0.225	0.267	0.312	0.361
STAND	0.845	0.553	0.701	0.488	0.512	0.414	0.113	0.104
.6 STD	1.392	0.867	0.769	0.570	0.499	0.381	0.095	0.076
.7 STD	1.330	1.032	0.924	0.748	0.701	0.490	0.090	0.064
.8 STD	1.058	0.782	0.803	0.611	0.600	0.446	0.091	0.069
.9 STD	0.869	0.566	0.703	0.476	0.509	0.403	0.107	0.095
1.1STD	0.825	0.517	0.672	0.474	0.509	0.415	0.117	0.113
1.2STD	0.787	0.481	0.647	0.439	0.500	0.412	0.126	0.124
1.3STD	0.742	0.522	0.623	0.461	0.524	0.431	0.125	0.127
1.4STD	0.715	0.554	0.633	0.420	0.501	0.417	0.143	0.140

Table 29

Effect of Freshwater Flow on the Concentration of Phosphate

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
FLOW	0.397	0.423	0.454	0.488	0.526	0.567	0.612	0.661
STAND	0.634	0.585	0.634	0.370	0.532	0.468	0.122	0.085
.6 STD	0.922	0.909	0.871	0.384	0.585	0.431	0.106	0.067
.7 STD	0.762	0.782	0.785	0.384	0.583	0.445	0.113	0.071
.8 STD	0.706	0.666	0.722	0.373	0.568	0.456	0.118	0.075
.9 STD	0.674	0.603	0.672	0.367	0.546	0.463	0.120	0.080
1.1STD	0.837	0.725	0.690	0.438	0.622	0.557	0.115	0.077
1.2STD	0.600	0.608	0.607	0.396	0.525	0.490	0.119	0.093
1.3STD	0.500	0.613	0.579	0.379	0.500	0.486	0.116	0.096
1.4STD	0.507	0.630	0.559	0.373	0.481	0.476	0.109	0.096

Table 30

Effect of Freshwater Flow on the Concentration of Phosphate

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
FLOW	0.696	0.723	0.753	0.787	0.825	0.866	0.911	0.960
STAND	0.665	0.573	0.621	0.510	0.508	0.413	0.114	0.111
.6 STD	1.053	0.823	0.723	0.577	0.488	0.358	0.089	0.094
.7 STD	0.906	0.693	0.682	0.542	0.498	0.373	0.092	0.090
.8 STD	0.788	0.600	0.654	0.517	0.504	0.387	0.098	0.095
.9 STD	0.694	0.580	0.640	0.508	0.510	0.401	0.105	0.104
1.1STD	0.688	0.570	0.612	0.522	0.507	0.423	0.124	0.114
1.2STD	0.681	0.589	0.587	0.543	0.567	0.489	0.147	0.116
1.3STD	0.690	0.577	0.540	0.495	0.518	0.473	0.157	0.121
1.4STD	0.726	0.633	0.575	0.538	0.505	0.450	0.150	0.110

Table 31

Effect of Varying the STP Discharge on the Concentration of Organic Carbon

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
DISCHG	0.097	0.123	0.154	0.188	0.225	0.267	0.312	0.361
STAND	6.423	5.048	6.000	3.454	3.900	3.884	1.150	1.098
1.5STD	7.258	6.024	6.877	3.959	4.266	4.005	1.161	1.102
2 STD	8.096	7.043	7.778	4.491	4.642	4.130	1.168	1.108
2.5STD	8.922	8.065	8.715	5.037	5.040	4.257	1.183	1.112
3 STD	9.797	8.664	9.038	5.453	5.321	4.443	1.315	1.068
4 STD	11.508	11.060	11.463	6.794	6.247	4.643	1.219	1.121

Table 32

Effect of Varying the STP Discharge on the Concentration of Organic Carbon

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
DISCHG	0.397	0.423	0.454	0.488	0.526	0.567	0.612	0.661
STAND	5.347	5.490	5.496	3.855	3.830	4.032	1.118	1.149
1.5STD	8.856	7.700	7.368	4.889	5.553	4.944	1.098	1.126
2 STD	9.092	8.107	7.798	4.999	6.067	5.584	1.251	1.182
2.5STD	9.805	8.392	8.756	5.362	5.550	4.552	1.133	1.121
3 STD	10.822	9.736	9.331	5.870	7.351	6.600	1.457	1.341
4 STD	11.911	10.872	10.476	6.402	8.655	7.901	1.787	1.493

Table 33

Effect of Varying the STP Discharge on the Concentration of Organic Carbon

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
DISCHG	0.696	0.723	0.753	0.787	0.825	0.866	0.911	0.960
STAND	5.930	5.306	5.360	3.316	3.816	3.655	1.136	1.517
1.5STD	7.197	6.095	6.116	3.984	4.130	3.719	1.143	1.516
2 STD	8.488	6.889	6.907	4.707	4.483	3.786	1.144	1.518
2.5STD	9.726	7.706	7.672	5.420	4.838	3.857	1.149	1.520
3 STD	10.946	8.450	8.421	6.080	5.155	3.917	1.159	1.523
4 STD	13.437	10.174	9.989	7.614	5.902	4.045	1.162	1.510

Table 34

Effect of Varying the STP Discharge on the Concentration of Oxygen Deficit

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
DISCHG	0.097	0.123	0.154	0.188	0.225	0.267	0.312	0.361
STAND	0.939	1.308	3.353	2.028	1.953	2.645	0.977	0.959
1.5STD	0.977	1.431	3.561	2.141	2.106	2.728	0.995	0.968
2 STD	1.004	1.569	3.798	2.265	2.252	2.816	1.003	0.970
2.5STD	1.052	1.701	4.005	2.383	2.409	2.907	1.023	0.978
3 STD	1.039	1.688	4.144	2.497	2.516	3.005	1.125	0.938
4 STD	1.158	2.122	4.712	2.771	2.875	3.169	1.050	0.984

Table 35

Effect of Varying the STP Discharge on the Concentration of Oxygen Deficit

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
DISCHG	0.397	0.423	0.454	0.488	0.526	0.567	0.612	0.661
STAND	0.071	1.871	2.122	2.147	1.447	2.621	1.082	0.863
1.5STD	0.276	2.944	2.971	2.500	2.253	3.512	1.107	0.848
2 STD	0.323	3.158	3.166	2.632	2.404	3.946	1.252	0.910
2.5STD	0.042	2.148	2.687	2.518	1.879	2.943	1.110	0.838
3 STD	0.233	3.538	3.421	2.929	2.750	4.549	1.467	1.096
4 STD	0.281	3.980	3.823	3.266	3.103	5.320	1.767	1.254

Table 36

Effect of Varying the STP Discharge on the Concentration of Oxygen Deficit

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
DISCHG	0.696	0.723	0.753	0.787	0.825	0.866	0.911	0.960
STAND	0.112	2.229	3.166	1.293	2.078	3.053	1.004	1.036
1.5STD	0.103	2.319	3.388	1.369	2.231	3.112	1.011	1.037
2 STD	0.112	2.424	3.607	1.464	2.383	3.171	1.015	1.040
2.5STD	0.123	2.525	3.801	1.549	2.534	3.227	1.017	1.041
3 STD	0.147	2.597	4.010	1.629	2.665	3.279	1.031	1.045
4 STD	0.150	2.815	4.434	1.834	2.983	3.388	1.037	1.033

Table 37

Effect of Varying the Water Temperature on the Concentration of Carbon Dioxide

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
STAND DEV C	0.097	0.123	0.154	0.188	0.225	0.267	0.312	0.361
0	2.363	1.824	4.805	2.595	4.518	4.966	1.323	1.398
1	2.337	1.837	4.842	2.623	4.599	5.046	1.336	1.413
2	2.339	1.831	4.844	2.621	4.598	5.045	1.336	1.412
3	2.339	1.831	4.843	2.620	4.597	5.044	1.335	1.412

Table 38

Effect of Varying the Water Temperature on the Concentration of Carbon Dioxide

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
STAND DEV C	0.397	0.423	0.454	0.488	0.526	0.567	0.612	0.661
0	0.168	2.616	1.860	2.336	3.012	4.252	1.420	1.131
1	0.165	2.621	1.856	2.347	3.043	4.292	1.429	1.135
2	0.165	2.621	1.854	2.347	3.042	4.292	1.429	1.135
3	0.165	2.622	1.853	2.346	3.041	4.291	1.429	1.135

Table 39

Effect of Varying the Water Temperature on the Concentration of Carbon Dioxide

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
STAND DEV C	0.696	0.723	0.753	0.787	0.825	0.866	0.911	0.960
0	0.645	2.715	3.441	1.875	3.770	4.167	1.264	1.439
1	0.642	2.722	3.453	1.880	3.811	4.198	1.270	1.443
2	0.636	2.730	3.458	1.879	3.813	4.197	1.267	1.441
3	0.637	2.730	3.458	1.879	3.812	4.197	1.267	1.441

Table 40

Effect of Varying the Water Temperature on the Concentration of Organic Carbon

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
STAND DEV C	0.097	0.123	0.154	0.188	0.225	0.267	0.312	0.361
0	6.707	6.290	7.668	3.935	4.741	4.113	0.987	0.966
1	6.742	6.410	7.789	3.977	4.753	4.092	0.978	0.956
2	6.741	6.410	7.789	3.976	4.753	4.093	0.978	0.956
3	6.741	6.410	7.790	3.976	4.753	4.093	0.978	0.956

Table 41

Effect of Varying the Water Temperature on the Concentration of Organic Carbon

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
STAND DEV C	0.397	0.423	0.454	0.488	0.526	0.567	0.612	0.661
0	5.620	5.587	5.669	3.924	3.861	4.001	1.109	1.119
1	5.652	5.600	5.685	3.930	3.852	3.985	1.104	1.118
2	5.652	5.599	5.685	3.929	3.852	3.985	1.104	1.118
3	5.652	5.598	5.685	3.928	3.851	3.985	1.104	1.118

Table 42

Effect of Varying the Water Temperature on the Concentration of Organic Carbon

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
STAND DEV C	0.696	0.723	0.753	0.787	0.825	0.866	0.911	0.960
0	5.930	5.306	5.360	3.316	3.816	3.655	1.136	1.517
1	5.960	5.317	5.366	3.319	3.800	3.643	1.133	1.515
2	5.967	5.322	5.363	3.316	3.801	3.644	1.131	1.515
3	5.967	5.322	5.363	3.316	3.801	3.644	1.131	1.515

Table 43

Effect of Varying the Water Temperature on the Concentration of Organic Nitrogen

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
STAND DEV C	0.097	0.123	0.154	0.188	0.225	0.267	0.312	0.361
0	1.284	1.145	1.043	0.707	0.493	0.350	0.105	0.097
1	1.286	1.151	1.049	0.712	0.485	0.341	0.104	0.095
2	1.286	1.151	1.048	0.711	0.484	0.341	0.104	0.095
3	1.286	1.151	1.048	0.711	0.484	0.341	0.104	0.095

Table 44

Effect of Varying the Water Temperature on the Concentration of Organic Nitrogen

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
STAND DEV C	0.397	0.423	0.454	0.488	0.526	0.567	0.612	0.661
0	1.591	1.088	1.033	0.664	0.599	0.337	0.079	0.146
1	1.594	1.088	1.034	0.664	0.594	0.332	0.079	0.145
2	1.593	1.087	1.034	0.664	0.593	0.332	0.079	0.145
3	1.593	1.087	1.034	0.663	0.593	0.332	0.079	0.145

Table 45

Effect of Varying the Water Temperature on the Concentration of Organic Nitrogen

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
STAND DEV C	0.696	0.723	0.753	0.787	0.825	0.866	0.911	0.960
0	1.553	0.937	0.775	0.787	0.382	0.264	0.099	0.197
1	1.555	0.938	0.775	0.787	0.378	0.261	0.099	0.197
2	1.554	0.937	0.774	0.786	0.378	0.261	0.099	0.197
3	1.553	0.937	0.774	0.786	0.378	0.261	0.099	0.197

Table 46

Effect of Varying the Water Temperature on the Concentration of Oxygen Deficit

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
STAND DEV C	0.097	0.123	0.154	0.188	0.225	0.267	0.312	0.361
0	0.983	1.834	4.079	2.099	2.474	2.946	0.851	0.896
1	1.149	2.200	4.131	2.633	2.707	3.029	0.931	0.900
2	1.500	3.587	4.528	3.679	2.906	2.928	0.954	0.906
3	1.680	4.150	5.134	4.579	3.160	3.090	0.942	0.996

Table 47

Effect of Varying the Water Temperature on the Concentration of Oxygen Deficit

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
STAND DEV C	0.397	0.423	0.454	0.488	0.526	0.567	0.612	0.661
0	0.033	1.893	2.130	2.097	1.439	2.592	1.082	0.845
1	0.004	2.146	2.274	2.255	1.568	2.502	0.917	0.825
2	0.090	2.388	2.438	2.472	1.699	2.408	0.744	0.841
3	0.358	2.638	2.607	2.689	1.874	2.422	0.630	0.844

Table 48

Effect of Varying the Water Temperature on the Concentration of Oxygen Deficit

	POSITION (MILES)							
	0.742	8.166	15.590	23.014	30.439	37.863	45.287	52.711
	TIDAL PHASE							
STAND DEV C	0.696	0.723	0.753	0.787	0.825	0.866	0.911	0.960
0	0.112	2.229	3.166	1.293	2.078	3.053	1.004	1.036
1	0.063	2.133	3.376	1.441	2.128	3.243	1.073	0.957
2	0.628	2.297	3.671	1.689	2.211	3.420	1.140	1.007
3	0.991	2.432	3.902	2.058	2.324	3.587	1.247	1.162

LISTING OF COMPUTER PROGRAM

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C                                                                      *
C     SOLUTION PROGRAM FOR GENERAL DETERMINISTIC MODEL.                *
C                                                                      *
      REAL K,K11,K14,K22,K27,K36,KM8,KM9,KM10,KM11,KM12,K12,K2X
      COMMON /B0/C(12,2,80),DCDT(12,5,80),K(38,80),WORK(80),WORK1(80),WO
     1RK2(80),DCDX(12,80),EA(80),UA(80),XPOS(80),DEV,ND   ,DADT(80),A(80)
     2,WT  ,NM,NN,DT,DX,DZS,IA,TPR,LOGUP,INLOG,ABSE,RELE,TEMP,TIDE,T,SUN,
     3Q,O2SAT,CSAT,IDAY,JDAY,TDATA,K11,K14,K27,K36,GRO8,GRO9,GRO10,IC,E,
     4GRO11,XO,K2X,FRA(6),DIE(5),RESP12,GRO12,IPRI,CL,PRED8,PRED9,PRED10
     5,PRED11,WF,RR/B1/CK3/B2/KM8,KM9,KM10,KM11/B3/C28,C29,C210,C211/B4/
     6C58,C59,C510,C511/B5/C68,C69,C610,C611/B6/C8,C9,C10,C11,C12,KM12,S
     7/B7/C212,C512,C612/B8/RESP8,RESP9,RESP10,RESP11/B9/F1,F3,F5,F6,FAZ
     8,IZDAY,PCS,CONC(12,10),NV(6),VAL(6),TITLE(10),IPDAY,LOG,OSAT,D1,
     9PRI,DO2,DO3,DO15,BC(5),PRED(5),GRO(5),RES(5),BA,X11,X14,X36,SUNSAT
     */B10/TMIN,ILIST,PRIE,XI,BCN,SUM,SS,NDATA,YYY,EADJ,XAREA(12,80),K12
     1,AVE,D2
C         NAMELIST OPTION TO MODIFIED DEFAULT VALUES OR TO UPDATE ACC  *
C              PARAMETERS INCLUDED IN LIST.                            *
      NAMELIST /LIST1/ABSE,RELE,BC,PRED,GRO,RES,BA,X11,X14,X36,FRA,DIE,
     1DT,F1,F3,F5,F6,PRIE,KM8,KM9,KM10,KM11,KM12,CL,BCN,IPRI,YYY,AVE,DEV
     2,K2X,D1,D2,CK3
      CALL ERRSET(   208,260,-1,1,0)
      READ(9,LIST1,END=1005)
      WRITE(6,LIST1)
C         SUBROUTINES TIMON AND TIMECK ARE SUPPLIED ON THE SYSTEM USED *
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C              FOR THIS WORK.THEY MOST BE DUMMIED OUT IF NOT AVAILABLE.*
      CALL TIMON
   17 FORMAT(10A4)
C         READING NAMES FOR THE TWELVE POLLUTION COMPONENTS            *
 1005 DO 10 I=1,12
   10 READ(5,17,END=999) (CONC(I,J),J=1,10)
C         READING HEADER CARD FOR WHOLD PROGRAM:NN=NO.OF SECTIONS TO BE*
C              USED,X1=UPSTREAM BOUNDARY LOCATION IN MILES,XO=DOWN-    *
C              STREAM LOCATION(XI.XO),T1=INITIAL TIME OF DAY,IDAY=INIT-*
C              IAL DAY OF YEAR,TM=FINAL TIME OF DAY,MDAY=FINAL DAY OF  *
C              YEAR,PRI=NO.OT TIME/TIDAL CYCLE PRINTED OUTPUT IS REQU- *
C              IRED,IC=NO.OF POLLUTION COMPONENTS,TIDE=TIME OF HIGH    *
C              TIDE ON IDAY,FAZ=MOON PHASE AT TI&IDAY,TMAX=MAX. NUMBER *
C              OF COMPUTER MINUTES AUTHORIZED FOR THIS RUN,KP=LOGIC    *
C              VARIABLE TO INDICATE IF PUNCHED OUTPUT AT TM&MDAY IS    *
C              REQUIRED.                                               *
   19 READ(5,2,END=999) NN,XI,XO,TI,IDAY,TM,MDAY,PRI,IC,TIDE,FAZ,TMAX,KP
    2 FORMAT(I5,3F5.1,I5,F5.1,I5,F5.2,I5,3F5.2,I5)
      PRI=12.425/PRI
      IZDAY=IDAY
      T=TI
      TPR=TI
      IPDAY=IDAY
      DX=(XO-XI)/NN
      NM=NN+1
```

```
      WRITE(6,18) NM,XI,XO,TI,IDAY,TM,MDAY,PRI,IC,TIDE,FAZ
   18 FORMAT('1',19X,'NO OF GRID POINTS',14X,I5/          20X,'UPSTREAM
     1BOUNDARY,MILES',10X,F5.1/          20X,'DOWNSTREAM BOUNDARY',14X,
     2F5.1/          20X,'INITIAL TIME OF DAY',14X,F5.1/
     320X,'INITIAL DAY OF YEAR',12X,I5/20X,'FINAL TIME OF DAY',16X,F5.1/
     420X,'FINAL DAY',22X,I5/20X,'PRINT INTERVAL,HOURS',14X,F5.2/
     520X,'NO OF SIMU DIFF EQUATIONS',6X,I5/           20X,'TIME OF HIGH
     6TIDE ON FIRST DAY',4X,F5.2/20X,'MOON PHASE AT BEGINNING',11X,F5.2)
C     FORMING POSITION VECTOR (XPOS), MAXIMUM TIDAL VELOCITY VECTOR   *
C        (K(37,*)), AND TIDAL PHASE LAG VECTOR (K(38,*))               *
      DO 4 J=1,NM
      XPOS(J)=XI+FLOAT(J-1)*DX
      XP2=XPOS(J)*XPOS(J)
      K(37,J)=0.158002+0.550658E-01*XPOS(J)-0.457297E-03*XP2-0.731172E-0
     15*XP2*XPOS(J)+0.751213E-07*XP2*XP2
      K(38,J)= 0.72211E01-0.415148E-01*XPOS(J)-0.415578E-03*XP2
    4 CONTINUE
C     READING CONDITIONS AND SOME PARAMETER VALUES A HEADER            *
C         CARD MUST BE READ BEFORE EACH NEW SET OF DATA.THE HEAD CARD  *
C         CONTAIN VALUES FOR IPT,NC,ITYPE,AND TITLE.IPT INDICATES THE  *
C         FORM OF THE DATA,NC WHICH PARAMETER OR POLLUTANT WILL BE DES *
C         CRIBED AND ITYPE INDICATES IF IT IS A PARAMETER OR A POLLUT. *
C     IPT=; 1 MEANS STP DISCHARGE, 2 MEANS DISCRETE CONSTANTS, >2 CONT.*
C         INUOUS DATA.                                                 *
C     NC= ;I MEANS THE ITH PARAMETER OR POLLUTANT IS BEING DEFINED     *
```

```
C     ITYPE= ; 1 MEANS PARAMETER, 2 MEANS POLLUTANT ,AND 0 MEANS INPUT *
C         COMPLETED.                                                   *
    1 READ(5,6,END=999) IPT,NC,ITYPE,TITLE
    6 FORMAT(3I5,5X,10A4)
      IF(ITYPE.LT.1) GO TO 7
      CALL STORE(IPT,XI,DX,NM,WORK,WORK1,WORK2,XPOS,CL,K)
      GO TO(8,9),ITYPE
    8 DO 12 J=1,NM
   12 K(NC,J)=WORK(J)
    9 IF(IPT.LE.2) WRITE(6,3) TITLE,(WORK(J),J=1,NM)
    3 FORMAT(///  20X,10A4 //(' ',10F12.2))
 1002 FORMAT(///20X,10A4//(' ',10F12.4))
      IF(IPT.GT.2) WRITE(6,1002) TITLE,(WORK(J),J=1,NM)
      IF(ITYPE.EQ.1) GO TO 1
      DO 13 J=1,NM
   13 C(NC,1,J)=WORK(J)*S
      GO TO 1
C     READING FIRST OBSERVED DATA CARD.                                *
    7 READ(8,11,END=999) JDAY,TDATA,POS,(NV(J),VAL(J),J=1,6)
   11 FORMAT(I5,F5.0,F5.2,5X,6(I2,F8.3))
C     READING CONDITIONS FOR FIRST DAY IF(IPR1.EQ.1) PUNCHED CARD OUT  *
C         PUT IF REQUESTED.IF(ILIST.NE.0) PARAMETER UPDATE IS REQUESTED*
C         THROUGH NAMELIST OPTION.                                     *
      READ(5,14,END=999) TEMP,Q,SUN,IPRI,ILIST
   14 FORMAT(3F10.4,20X,2I5)
```

```
      CALL AREA(IDAY,IZDAY,T,TIDE,FAZ,NM,XAREA,K,WT,A)
      OSAT=(14.652-0.4102*TEMP+0.00799*TEMP*TEMP-0.77774*TEMP*TEMP/10000
     ..0*TEMP)*S
      CALL UPDATE
      CALL FUNCT(1)
      GO TO 39
C     MAIN PROGRAM LOOP.                                               *
   36 DO2=DT/2.0
      DO3=DT/3.0
C     CHECKING FOR FINISHING TIME.                                     *
      IF(T.GE.TM.AND.IDAY.GE.MDAY) GO TO 1000
C     CHECKING FOR MACHINE TIME ALLOCATION.                            *
      DO15=DT/15.0
      IF(TMIN.GT.TMAX) GO TO 1000
C     CALLING INTEGRATION SUBROUTINE.                                  *
      CALL RKMI(IER)
C     ADJUSTING TIME STEP(DT).                                         *
      DT=DT*YYY**IER
C     CHECKING FOR ACCURACY.                                           *
   40 IF(IER.LT.3) GO TO 41
   42 T=T-DZS
      CALL UPDATE
      CALL FUNCT(1)
      GO TO 36
C     CHECKING FOR UPPER LIMITS ON DT.                                 *
```

```
   41 IF(DT.GT.PRI) DT=PRI
      IF(DT.GT.1.4) DT=1.4
      IA=3-IA
   39 DZS=DT
      CALL OUTPUT
      DT=DZS
C     CHECKING FOR NAMELIST OPTION FOR PARAMETER UPDATE                 *
      IF(ILIST.EQ.0) GO TO 36
      READ(9,LIST1)
      WRITE(6,LIST1)
      ILIST=0
      GO TO 36
C     CHECKING FOR PUNCHED OUTPUT OF FINAL CONDITIONS                   *
 1000 IF(KP.EQ.0) GO TO 994
      DO 998 I=1,IC
      DO 996 J=1,NM
  996 C(I,IA,J)=C(I,IA,J)/S
  998 WRITE(7,997) NM,I,(CONC(I,J),J=1,10),(C(I,IA,J),XPOS(J),J=1,NM)
  997 FORMAT(2I5,'    2',5X,10A4/(8F10.4))
  994 WRITE(6,995) SUM,SS,NDATA,IDAY,T
  995 FORMAT('1'///' SUM OF ERRORS=',F10.2,'    SUMSQ ERRORS=',F10.2,'
     . NO OF DATA VALUES=',I5//////'    DAY=',I5,'     TIME=',F7.3)
      GO TO 19
  999 STOP
      END
```

```
      SUBROUTINE STORE(IPT,XI,DX,NM,WORK,WORK1,WORK2,XPOS,CL,R)
C     SUBROUTINE TO READ AND STORE INITIAL INPUT DATA FOR CONCENTR-     *
C         ATIONS AND PARAMETERS.                                         *
C     INPUT FORMAT IF IPT=                                              *
C     1 DATA IS IN THE FORM DISCHARGE RATE(IN LBS/DAY)AND LOCATION OF   *
C         DISCHARGE(IN MILES) WITH A (2E20.5) FORMAT.MORE THAN ONE STP *
C         CAN BE CONSIDERED.THE STP DATA INPUT TERMINATES WHEN A NEGAT.*
C         POSITION IS READ.                                             *
C     2 DATA IS IN FORM OF VALUE-POSITION.THE PARAMETER OR POLLUTANT IS*
C         GIVEN THE READ VALUE FOR ALL LOCATIONS BETWEEN THE PREVIOUS  *
C         POSITION(IF ANY OR XI) AND THE PRESENT POSITION.THIS TERMIN- *
C         ATES WHEN A ZERO OR NEGATIVE POSITION IS READ.FORMAT(ZEZO.S).*
C     72 DATA IS IN THE FOR OF VALUE AND POSITION PAIRS WITH THE NO.OF *
C         PAIRS EQUAL TO IPT.THE DATA IS TREATED AS VALUES FROM A CONT-*
C         INUOUS FUNCTION AND VALUES ARE INTERPOLATED FOR LOCATIONS    *
C         BETWEEN THE POSITIONS GIVEN.                                  *
C     WORK1 AND WORK2 ARE DIMENSIONED THE GREATER OF IPT OR NM
      DIMENSICN WORK(NM),WORK1(80) ,WORK2(80) ,XPOS(NM),R(38,NM)
C     IPT=1 FOR FF,IPT=2 FOR DISCRETE CONSTANTS,AND IPT>2 FOR INTERPOLING.
      IF(IPT.GT.2) GO TO 3
      IF(IPT.EQ.2) GO TO 2
      DO 9 J=1,NM
    9 WORK(J)=0.0
    4 READ(5,1,END=999) VALUE,POSIT
    1 FORMAT(2E20.5)
```

```
      IF(POSIT.LT.XI) GO TO 999
      IK=IFIX((POSIT-XI)/DX+1.5)
      IF(IK.EQ.1) IK=2
      IF(IK.GE.NM) IK=NM-1
      WORK(IK)=WORK(IK)+VALUE*CL/(DX*24.0*R(3,IK))
      GO TO 4
    2 IK=0
    6 READ(5,1,END=999) VALUE,POSIT
      IF(POSIT.LE.XI) GO TO 999
      II=IK+1
      IK=IFIX((POSIT -XI)/DX+1.5)
      IF(IK.GT.NM) IK=NM
      DO 5 I=II,IK
    5 WORK(I)=VALUE
      GO TO 6
    3 READ(5,7,END=999) (WORK1(J),WORK2(J),J=1,IPT)
    7 FORMAT(8F10.6)
      DO 8 I=1,NM
      X=XPOS(I)
      CALL INTP(3,IPT,WORK2,WORK1,X,Y,0.001,NM)
    8 WORK(I)=Y
  999 RETURN
      END
```

```
      SUBROUTINE OUTPUT
C     SUBROUTINE TO PROVIDE SPECIFIED OUTPUT,MAKE COMPAIRISON WITH ACT-*
C         UAL DATA,KEEP TRACK TO TIME AND DAY OF SOLUTION,ETC.LOG IS A *
C         LOGIC VARIABLE WHICH INDICATES WHETHER STANDARD PRINTED OUT- *
C         PUT OR A COMPARISON TO ACTUAL DATA WILL BE REQUIRED AT THE   *
C         NEXT OUTPUT TIME.                                             *
      REAL K,K11,K14,K22,K27,K36,KM8,KM9,KM10,KM11,KM12,K12,K2X
      COMMON /B0/C(12,2,80),DCDT(12,5,80),K(38,80),WORK(80),WORK1(80),WO
     1RK2(80),DCDX(12,80),EA(80),UA(80),XPOS(80),DEV,ND  ,DADT(80),A(80)
     2,WT ,NM,NN,DT,DX,DZS,IA,TPR,LOGUP,INLOG,ABSE,RELE,TEMP,TIDE,T,SUN,
     3Q,O2SAT,CSAT,IDAY,JDAY,TDATA,K11,K14,K27,K36,GRO8,GRO9,GRO10,IC,E,
     4GRO11,XO,K2X,FRA(6),DIE(5),RESP12,GRO12,IPRI,CL,PRED8,PRED9,PRED10
     5,PRED11,WF,RR/B1/CK3/B2/KM8,KM9,KM10,KM11/B3/C28,C29,C210,C211/B4/
     6C58,C59,C510,C511/B5/C68,C69,C610,C611/B6/C8,C9,C10,C11,C12,KM12,S
     7/B7/C212,C512,C612/B8/RESP8,RESP9,RESP10,RESP11/B9/F1,F3,F5,F6,FAZ
     8,IZDAY,POS,CONC(12,10),NV(6),VAL(6),TITLE(10),IPDAY,LOG,OSAT,D1,
     9PRI,DO2,DO3,DO15,BC(5),PRED(5),GRO(5),RES(5),BA,X11,X14,X36,SUNSAT
     */B10/TMIN,ILIST,PRIE,XI,BCN,SUM,SS,NDATA,YYY,EADJ,XAREA(12,80),K12
     1,AVE,D2
C     LOG=1 MEANS REG.OUTPUT ;LOG=0 MEANS A COMPARISON WITH ACTUAL DATA.
   14 IF(ABS(TPR-T).LT.PRIE.AND.IPDAY.EQ.IDAY) GO TO 21
   22 IF(T+DZS.LT.TPR.OR.IDAY.LT.IPDAY) GO TO 999
   23 DT=TPR-T
      DO3=DT/3.
      DO2=DT/2.
```

```
      DO15=DT/15.
      CALL RKMI(IER)
      IA=3-IA
   21 IF(LOG.EQ.1) GO TO 1
C     COMPARISON TO ACTUAL DATA WILL BE MADE AND THE DIFFERENCE PUNCHED*
C         FOR DETAILED ANALYSIS                                         *
      IK=1
    2 IF(NV(IK).EQ. 0.OR.IK.GT.6) GO TO 3
      NVIK=NV(IK)
      DO 4 J=1,NM
      WORK(J)=C(NVIK,IA,J)
    4 WORK2(J)=K(31,J)
      CALL INTP(5,NM,XPOS,WORK,POS,FXX,0.001,NM)
      DIFF=VAL(IK)-FXX/S
      SUM=SUM+DIFF
      SS=SS+DIFF*DIFF
      NDATA=NDATA+1
      CALL INTP(5,NM,XPOS,WORK2,POS,PHASE,0.001,NM)
      IPOS=IFIX((POS-XI)/DX+1.499)
      VELO=UA(IPOS)/A(IPOS)
      WRITE(7,5) NV(IK),DIFF,T,IDAY,PHASE,SUN,VAL(IK),VELO,POS
    5 FORMAT(I5,2F10.4,I5,5F10.4)
      IK=IK+1
      GO TO 2
    3 READ(8,9,END=50) JDAY,TDATA,POS,(NV(J),VAL(J),J=1,6)
```

```
    9 FORMAT(I5,F5.0,F5.2,5X,6(I2,F8.2))
      IF(POS.GT.XO.OR.POS.LT.XI) GO TO 3
      GO TO 10
   50 JDAY=10000
      GO TO 10
C     STANDARD PRINTED OUTPUT .SEE OUTPUT LISTING FOLLOWING THIS PRO-   *
C         GRAM LISTING FOR DETAILS.                                     *
    1 CALL TIMECK(NHSEC)
      XSEC=FLOAT(NHSEC)/100.0/PRI*24.0
      TMIN=TMIN+FLOAT(NHSEC)/6000.0
      WRITE(6,7) IDAY,T,DZS,XSEC,TMIN,(XPOS(J),J=1,NM,ND)
    7 FORMAT('1'///10X,'DAY=',I5,'  TIME=',F5.2,'   DELTA T=',F5.2,'
     .MACHINE TIME=',F10.3,' SEC/REAL TIME DAY    MACHINE MIN USED=',
     *F9.2//23X,'POSITION,MILES'/(' ',16F8.3))
      WRITE(6,11) (K(31,J),J=1,NM,ND)
   11 FORMAT(/23X,'TIDAL PHASE'/(' ',16F8.3))
C     PUNCHED OLTPUT OPTION (IPR1=1).                                   *
      IF(IPRI.EQ.1) WRITE(7,16) IDAY,T
   16 FORMAT('$$$$$$**********$$$$$',I5,F10.4)
      DO 6 I=1,IC
      DO 13 J=1,NM
   13 C(I,IA,J)=C(I,IA,J)/S
      WRITE(6,8) (CONC(I,J),J=1,10),(C(I,IA,J),J=1,NM,ND)
      IF(IPRI.EQ.1) WRITE(7,15) NM,I,(CONC(I,J),J=1,10),(C(I,IA,J),
     *XPOS(J),J=1,NM)
```

```
      DO 6 J=1,NM
    6 C(I,IA,J)=C(I,IA,J)*S
      IPRI=0
    8 FORMAT(// 20X,10A4/ (' ',16F8.3))
   15 FORMAT(2I5,'     2',5X,10A4/(8F10.4))
      WRITE(6,17) Q,TEMP,SUN
   17 FORMAT('0Q=',F10.2,'    TEMP=',F10.2,'    SUN LIGHT  INTENS=',F10.2)
      CALL TIMON
   10 III=IFIX((T+PRI)/24.0)
      TPR=T+PRI-24.0*FLOAT(III)
      IPDAY=IDAY+III
      LOG=1
      IF(JDAY.GE.IPDAY.AND.TDATA.GE.TPR) GO TO 999
      IF( JDAY.GT.IPDAY.AND.TDATA.LT.TPR) GO TO 999
      TPR=TDATA
      IPDAY=JDAY
      LOG=0
      GO TO 14
  999 IF(T.LT.24.0) GO TO 1000
C     UPDATING TIME,DAY,AND CONDITIONS.                                    *
      READ(5,12,END=51) TEMP,Q,SUN,IPRI,ILIST
   12 FORMAT(3F10.4,20X,2I5)
   51 IDAY=IDAY+1
      T=T-24.0
      LOGUP=2
```

```
      CALL UPDATE
 1000 RETURN
      END
```

```
      SUBROUTINE UPDATE
C     SUBROUTINE TO UPDATE AND TIME,DAY,OR TEMPERATURE VARIABLE PARA-  *
C         METERS,FORSING FUNCTIONS,CONDITIONS,ETC.                      *
      REAL K,K11,K14,K22,K27,K36,KM8,KM9,KM10,KM11,KM12,K12,NO2NO3,K2X
      COMMON /B0/C(12,2,80),DCDT(12,5,80),K(38,80),WORK(80),WORK1(80),WO
     1RK2(80),DCDX(12,80),EA(80),UA(80),XPOS(80),DEV,ND  ,DADT(80),A(80)
     2,WT ,NM,NN,DT,DX,DZS,IA,TPR,LOGUP,INLOG,ABSE,RELE,TEMP,TIDE,T,SUN,
     3Q,O2SAT,CSAT,IDAY,JDAY,TDATA,K11,K14,K27,K36,GRO8,GRO9,GRO10,IC,E,
     4GRO11,XO,K2X,FRA(6),DIE(5),RESP12,GRO12,IPRI,CL,PRED8,PRED9,PRED10
     5,PRED11,WF,RR/B1/CK3/B2/KM8,KM9,KM10,KM11/B3/C28,C29,C210,C211/B4/
     6C58,C59,C510,C511/B5/C68,C69,C610,C611/B6/C8,C9,C10,C11,C12,KM12,S
     7/B7/C212,C512,C612/B8/RESP8,RESP9,RESP10,RESP11/B9/F1,F3,F5,F6,FAZ
     8,IZDAY,POS,CONC(12,10),NV(6),VAL(6),TITLE(10),IPDAY,LOG,OSAT,D1,
     9PRI,DO2,DO3,DO15,BC(5),PRED(5),GRO(5),RES(5),BA,X11,X14,X36,SUNSAT
     */B10/TMIN,ILIST,PRIE,XI,BCN,SUM,SS,NDATA,YYY,EADJ,XAREA(12,80),K12
     1,AVE,D2
C     LOGUP IS A LOGIC VARIABLE WHICH INDICATES WHAT TYPE OF UPDATE IS *
C         TO BE EXECUTED.                                              *
C     LOGUP=1 BEFORE SOLUTION BEGINS FOR INITIAL DEFINATIONS.          *
C          =2 FOR DAILY UPDATE.                                        *
C          =3 FCR MINUTE TO MINUTE UPDATE.                             *
      GO TO(1,2,3),LOGUP
    1 DO 4 I=8,12
      DO 4 J=1,2
    4 C(I,J,1)=BC(I-7)*S
```

```
      EADJ=1.0/DX
      ND=1+(NM-1)/16
    2 SUNMAX=SUN*2.6224
      IF(TEMP.EQ.0.0) TEMP=AVE+DEV*SIN(WT/365.0*FLOAT(IDAY-120))
      PRED8=PRED(1)*TEMP/S
      PRED9=PRED(2)*TEMP/S
      PRED10=PRED(3)*TEMP/S
      PRED11=PRED(4)*TEMP
      GRO8=GRC(1)*TEMP+0.02
      GRO9=GRC(2)*TEMP
      GRO10=GRO(3)*TEMP
      GRO11=GRC(4)*TEMP
      GRO12= BA*1.050**(TEMP-20.0)/24.0
      RESP8=RES(1)*TEMP
      RESP9=RES(2)*TEMP
      RESP10=RES(3)*TEMP
      RESP11=RES(4)*TEMP
      RESP12=RES(5)*TEMP
      E=1.021**(TEMP-20.0)
      CSAT=(2550.0-43.0*TEMP)*S
C     K11= X11*1.047**(TEMP-20.0)/24.0
      K11= X11*1.010**(TEMP-20.0)/24.0
      K12=X14*1.01C**(TEMP-20.0)/24.0
      K14= X14*1.188**(TEMP-20.0)/24.0
C     K36=  X36*1.084**(TEMP-20.0)/24.0/S
```

```
      K36=  X36*1.010**(TEMP-20.0)/24.0/S
      O2SAT=(14.652-0.4102*TEMP+0.00799*TEMP*TEMP-0.77774*TEMP*TEMP/1000
     .0.0*TEMP)*S
      ODIFF=O2SAT-OSAT
      DO 6 J=1,NM
    6 C(7,IA,J)=C(7,IA,J)+ODIFF
      OSAT=O2SAT
C     BOUNDARD CONDITIONS                                                *
      BOD=67.3*Q**(0.8172-1.0)/5.4*S
      PI=0.110*Q**(1.209-1.0)/5.38*S
      TPO4=0.101*Q**(1.276-1.0)/5.38*S
      TKN=2.797*Q**(1.012-1.0)/5.38*S
      TOC=33.960*Q**(.965-1.0)/5.38*S
      NO2NO3=19.590*Q**(.780-1.0)/5.38*S
      TIC=2468.0*Q**(0.5395-1.0)/5.4*S*0.5
      C(1,1,1)=TOC
      C(1,2,1)=TOC
      C(2,1,1)=TIC
      C(2,2,1)=TIC
      C(5,1,1)=NO2NO3
      C(5,2,1)=NO2NO3
      C(6,1,1)=TPO4
      C(6,2,1)=TPO4
      C(4,1,1)=0.025*Q**(1.37-1.0)/5.38*S
      C(4,2,1)=0.025*Q**(1.37-1.0)/5.38*S
```

```
      TON=TKN-C(4,1,1)
      C(3,1,1)=TON
      C(3,2,1)=TON
      C(7,1,1)=3.0*(1.0-Q/(10000.0+Q))*S
      C(7,2,1)=C(7,1,1)
    3 SUN=0.0
      IF(T.LT.6.0.OR.T.GT.18.0) GO TO 8
C     SUNLIGHT INTENSITY
      SX=SIN(WF*(T-6.0))
      IF(SX.LT.0.0) SX=0.0
      SUN=SUNMAX*SQRT(SX)
C     STP DISCHARGE RATE
    8 ADJ=1.0+0.4*SIN(WF*(T-16.0))
      DO 5 J=1,NM
    5 K(4,J)=ADJ*K(28,J)*K(3,J)/A(J)
      RR=SUN/SUNSAT
      RETURN
      END
```

```
      BLOCK DATA
C     SUBPROGRAM TO DEFINE DEFAULT VALUES FOR VARIABLES LISTED          *
      REAL K,K11,K14,K22,K27,K36,KM8,KM9,KM10,KM11,KM12,K12,K2X
      COMMON /B0/C(12,2,80),DCDT(12,5,80),K(38,80),WORK(80),WORK1(80),WO
     1RK2(80),DCDX(12,80),EA(80),UA(80),XPOS(80),DEV,ND  ,DADT(80),A(80)
     2,WT ,NM,NN,DT,DX,DZS,IA,TPR,LOGUP,INLOG,ABSE,RELE,TEMP,TIDE,T,SUN,
     3Q,O2SAT,CSAT,IDAY,JDAY,TDATA,K11,K14,K27,K36,GRO8,GRO9,GRO10,IC,E,
     4GRO11,XO,K2X,FRA(6),DIE(5),RESP12,GRO12,IPRI,CL,PRED8,PRED9,PRED10
     5,PRED11,WF,RR/B1/CK3/B2/KM8,KM9,KM10,KM11/B3/C28,C29,C210,C211/B4/
     6C58,C59,C510,C511/B5/C68,C69,C610,C611/B6/C8,C9,C10,C11,C12,KM12,S
     7/B7/C212,C512,C612/B8/RESP8,RESP9,RESP10,RESP11/B9/F1,F3,F5,F6,FAZ
     8,IZDAY,POS,CONC(12,10),NV(6),VAL(6),TITLE(10),IPDAY,LOG,OSAT,D1,
     9PRI,DO2,DO3,DO15,BC(5),PRED(5),GRO(5),RES(5),BA,X11,X14,X36,SUNSAT
     */B10/TMIN,ILIST,PRIE,XI,BCN,SUM,SS,NDATA,YYY,EADJ,XAREA(12,80),K12
     1,AVE,D2
      DATA CK3/0.9/,KM8,KM9,KM10,KM11/0.23E07,0.66E07,9.19E06,9.19E06/,
     .C28,C29,C210,C211/.70,.83,.77,.83/,C58,C59,C510,C511/.28,.14,.18,
     ..14/,C68,C69,C610,C611/.07,.04,.05,.04/,C8,C9,C10,C11,C12/.66,.662
     .,.66,.662,.667/,C212,C512,C612/.77,.18,.05/,F1,F3,F5,F6/.7,.2,.1,.
     .0/,ABSE,RELE,LOG,S,DT,IA,LOGUP/ 500000.,0.000,1,9.19E+06,1.0,1,1/,
     .SUNSAT,WF/300.0,0.2618/,BC/5*.05/,PRED/3*0.0002,0.0001,.0/,GRO/.00
     .40, 0.004, 0.004, 0.002,0.0/,RES/2*0.0002,0.0002,0.0001,.0001/,BA,
     .X11,X14,X36/0.33,0.230,0.068,0.0225/,FRA/0.45,0.05,0.40,0.05,0.0
     .,0.10/,DIE/0.010,2*0.0050,0.0020,0.005/,KM12,PRIE,CL/9.19E+06,0.05
     .,1.0/,C/1440*9.19E06,480*0.0/,DCDX/960*0.0/,K/3040*0.0/,SS,SUM,BCN
```

```
.,NDATA/0.0,0.0,0.1,0/,TMIN/0.0/,IPRI/0/,YYY/.970/,AVE,DEV/16.,14./
.,ND/2/,WT/6.283185/,K2X/12.9/,D1,D2/1.0,0.05/,XAREA/960*0.0/
 END
```

```
      SUBROUTINE RKMI( J1)
C     SUBROUTINE TO INTEGRATE THROUGH TIME.                                  *
      REAL K,K11,K14,K22,K27,K36,KM8,KM9,KM10,KM11,KM12,K12,K2X
      COMMON /B0/C(12,2,80),DCDT(12,5,80),K(38,80),WORK(80),WORK1(80),WO
     1RK2(80),DCDX(12,80),EA(80),UA(80),XPOS(80),DEV,ND   ,DADT(80),A(80)
     2,WT  ,NM,NN,DT,DX,DZS,IA,TPR,LOGUP,INLOG,ABSE,RELE,TEMP,TIDE,T,SUN,
     3Q,O2SAT,CSAT,IDAY,JDAY,TDATA,K11,K14,K27,K36,GRO8,GRO9,GRO10,IC,E,
     4GRO11,XO,K2X,FRA(6),DIE(5),RESP12,GRO12,IPRI,CL,PRED8,PRED9,PRED10
     5,PRED11,WF,RR/B1/CK3/B2/KM8,KM9,KM10,KM11/B3/C28,C29,C210,C211/B4/
     6C58,C59,C510,C511/B5/C68,C69,C610,C611/B6/C8,C9,C10,C11,C12,KM12,S
     7/B7/C212,C512,C612/B8/RESP8,RESP9,RESP10,RESP11/B9/F1,F3,F5,F6,FAZ
     8,IZDAY,POS,CCNC(12,10),NV(6),VAL(6),TITLE(10),IPDAY,LOG,OSAT,D1,
     9PRI,DO2,DO3,DO15,BC(5),PRED(5),GRO(5),RES(5),BA,X11,X14,X36,SUNSAT
     */B10/TMIN,ILIST,PRIE,XI,BCN,SUM,SS,NDATA,YYY,EADJ,XAREA(12,80),K12
     1,AVE,D2
      TQQ=0.0
      JA=3-IA
      LOGUP=3
C     ESTIMATING C AT  T&DT/3 USING C AND DCDT AT T                          *
      DO 1 I=1,IC
      DO 1 J=2,NM
      C(I,JA,J)=C(I,IA,J)+DO3*DCDT(I, 1,J)
      IF(C(I,JA,J).LE.0.0) C(I,JA,J)=0.0
    1 CONTINUE
      T=T+DO3
```

```
      CALL UPDATE
      CALL FUNCT(2)
C     UPDATING ESTIMATE OF C A T&DT/3 USING C AND DCDT AT T&DT/3        *
      DO 2 I=1,IC
      DO 2 J=2,NM
      C(I,JA,J)=C(I,JA,J)+DO3*(DCDT(I, 2,J)-DCDT(I, 1,J))/2.0
      IF(C(I,JA,J).LE.0.0) C(I,JA,J)=0.0
    2 CONTINUE
      CALL FUNCT(3)
      DO 3 I=1,IC
      DO 3 J=2,NM
      C(I,JA,J)=C(I,JA,J)+DO3*(1.125*DCDT(I,3,J)-0.5*DCDT(I,2,J)-0.125*
     .         DCDT(I,1,J))
      IF(C(I,JA,J).LE.0.0) C(I,JA,J)=0.0
    3 CONTINUE
      T=T-DO3+DO2
      CALL UPDATE
      CALL FUNCT(4)
C     ESTIMATING C AT  T+DT/2 USING C AND DCDT AT T&DT/3                *
      DO 4 I=1,IC
      DO 4 J=2,NM
      C(I,JA,J)=C(I,JA,J)+DO3*(1.125*DCDT(I,1,J)-5.625*DCDT(I,3,J)+6.0*
     .          DCDT(I, 4,J))
      IF(C(I,JA,J).LE.0.0) C(I,JA,J)=0.0
    4 CONTINUE
```

```
      T=T+DO2
      CALL UPDATE
      CALL FUNCT(5)
C     ESTIMATING C AT  T&DT USING C AND DCDT AT T&DT/2                 *
C     CHECHING ACCURACY                                                *
      DO 5 I=1,IC
      DO 5  J=2,NM
      TQ=DCDT(I,1,J)-4.5*DCDT(I,3,J)+4.0*DCDT(I,4,J)-0.5*DCDT(I,5,J)
      C(I,JA,J)=C(I,JA,J)-DO3*TQ
      IF(C(I,JA,J).LE.0.0) C(I,JA,J)=0.0
      IF(I.NE.1.AND.I.NE.3) GO TO 5
      TQ=DO15*TQ/(RELE*ABS(C(I,JA,J))+ABSE)
      TQ=ABS(TQ)
      IF(TQ.GT.TQQ) TQQ=TQ
    5 CONTINUE
      J1=IFIX(TQQ)
      IF(TQQ.LT.0.10) J1=-1
      IF(J1.GT.3) J1=3
      CALL FUNCT(1)
      RETURN
      END
```

```
      SUBROUTINE FUNCT(L)
C     SUBROUTINE TO ESTIMATE DCDT                                      *
      REAL K,K11,K14,K22,K27,K36,KM8,KM9,KM10,KM11,KM12,K12,K2X
      COMMON /B0/C(12,2,80),DCDT(12,5,80),K(38,80),WORK(80),WORK1(80),WO
     1RK2(80),DCDX(12,80),EA(80),UA(80),XPOS(80),DEV,ND  ,DADT(80),A(80)
     2,WT  ,NM,NN,DT,DX,DZS,IA,TPR,LOGUP,INLOG,ABSE,RELE,TEMP,TIDE,T,SUN,
     3Q,O2SAT,CSAT,IDAY,JDAY,TDATA,K11,K14,K27,K36,GRO8,GRO9,GRO10,IC,E,
     4GRO11,XC,K2X,FRA(6),DIE(5),RESP12,GRO12,IPRI,CL,PRED8,PRED9,PRED10
     5,PRED11,WF,RR/B1/CK3/B2/KM8,KM9,KM10,KM11/B3/C28,C29,C210,C211/B4/
     6C58,C59,C510,C511/B5/C68,C69,C610,C611/B6/C8,C9,C10,C11,C12,KM12,S
     7/B7/C212,C512,C612/B8/RESP8,RESP9,RESP10,RESP11/B9/F1,F3,F5,F6,FAZ
     8,IZDAY,POS,CONC(12,10),NV(6),VAL(6),TITLE(10),IPDAY,LOG,OSAT,D1,
     9PRI,DC2,DC3,DO15,BC(5),PRED(5),GRO(5),RES(5),BA,X11,X14,X36,SUNSAT
     */B10/TMIN,ILIST,PRIE,XI,BCN,SUM,SS,NDATA,YYY,EADJ,XAREA(12,80),K12
     1,AVE,C2
      IA=3-IA
C   CALCULATE PREDITION
    1 DO 86 J=2,NM
      K(7,J)=PRED8*C(8,IA,J)*(C(9,IA,J)+C(10,IA,J)+C(11,IA,J))
      K(8,J)=PRED9*C(9,IA,J)*C(10,IA,J)
      K(9,J)=PRED10*C(10,IA,J)*C(11,IA,J)
      K(10,J)=PRED11*C(11,IA,J)
   86 K(32,J)=PRED8*C(9,IA,J)*C(12,IA,J)
C   CALCULATE GROWTH
      DO 84 J=2,NM
```

```
      XXX=K(30,J)*(D1+D2/C8*C(8,IA,J)/S)
      R=(EXP(-RR*EXP(-XXX))-EXP(-RR))/XXX*2.718
      K(19,J)=GRO8*R*(C(5,IA,J)/(KM8+C(5,IA,J)))*C(8,IA,J)
      XY=PRED8*C(9,IA,J)*(C(8,IA,J)+C(12,IA,J))
      K(20,J)=GRO9*(XY/(KM9+XY))*C(9,IA,J)
      XY=(PRED8*C(8,IA,J)+PRED9*C(9,IA,J))*C(10,IA,J)
      K(21,J)=GRO10*(XY/(KM10+XY))*C(10,IA,J)
      XY=(PRED8*C(8,IA,J)+PRED10*C(10,IA,J))*C(11,IA,J)
      K(22,J)=GRO11*(XY/(KM11+XY))*C(11,IA,J)
   84 K(35,J)=GRO12*C(4,IA,J)/(KM12+C(4,IA,J))*C(12,IA,J)
C   CALCULATE RESPIRATION
      DO 85 J=2,NM
      K(23,J)=RESP8*C(8,IA,J)
      K(24,J)=RESP9*C(9,IA,J)
      K(25,J)=RESP10*C(10,IA,J)
      K(26,J)=RESP11*C(11,IA,J)
      K(34,J)=RESP12*C(12,IA,J)
   85 K(27,J)=K(23,J)+K(24,J)+K(25,J)+K(26,J)+K(34,J)
C   CALCULATE DEATH
      DO 87 J=2,NM
      K(11,J)=DIE(1)*C(8,IA,J)
      K(12,J)=DIE(2)*C(9,IA,J)
      K(13,J)=DIE(3)*C(10,IA,J)
      K(14,J)=DIE(4)*C(11,IA,J)
   87 K(33,J)=DIE(5)*C(12,IA,J)
```

```
C   CALCULATE RECYCLING
      DO 89 J=2,NM
      K(15,J)=CK3*(C28*(K(7,J)+K(11,J))+C29*(K(8,J)+K(12,J)-K(20,J)-K(24
     .       ,J))+C210*(K(9,J)+K(13,J)-K(21,J)-K(25,J))+C211*(K(10,J)+K(
     .       14,J)-K(22,J)-K(26,J))+C212*(K(32,J)+K(33,J)))
      K(16,J)=C28*K(23,J)+C29*K(24,J)+C210*K(25,J)+C211*K(26,J)+C212*
     .         K(34,J)
      K(17,J)=CK3*(C58*(K(7,J)+K(11,J)+K(23,4))+C59*(K(8,J)+K(12,J)-K(20
     .,J))+C510*(K(9,J)+K(13,J)-K(21,J))+C211*(K(10,J)+K(14,J)-K(22,J))+
     .C512*(K(32,J)+K(33,J)+K(34,J)))
   89 K(18,J)=CK3*(C68*(K(7,J)+K(11,J)+K(23,J))+C69*(K(8,J)+K(12,J)-K(20
     .,J))+C610*(K(9,J)+K(13,J)-K(21,J))+C611*(K(10,J)+K(14,J)-K(22,J))+
     .C612*(K(32,J)+K(33,J)+K(34,J)))
G     UPDATING VALUES FOR AREA,VELOCITY,VOLUMETRIC FLOW RATE AND THEN  *
C         REAERATION RATES,AND DIFFUSION COEFFICIENTS.                 *
      CALL AREA(IDAY,IZDAY,T,TIDE,FAZ,NM,XAREA,K,WT,A)
      CALL VELOC(XPOS,Q,A,WT,NM,K,UA)
      CALL VOLUM(A,NM,UA,Q,WORK,XPOS)
   40 DO 88 J=1,NM
      UABS=ABS(UA(J))*1.466
      K(1,J)=0.0036*UABS*K(30,J)*EADJ
      K(5,J)= K2X*SQRT(UABS/K(30,J))/K(30,J)/24.0
      K(29,J)=0.0003*K(5,J)
      EA(J)=K(1,J)*A(J)
   88 UA(J)=UA(J)*A(J)
```

```
      CALL FIRST(WORK,WORK2,DX,NM)
      DO 93 J=1,NM
   93 DADT(J)=-WORK2(J)
      DO 90 I=1,IC
      DO 91 J=1,NM
   91 WORK(J)=C(I,IA,J)
      CALL FIRST(WORK,WORK2,DX,NM)
      MM=NM-2
      DO 41 J=MM,NM
   41 IF(WORK2(J).GT.0.0) WORK2(J)=0.0
      DO 92 J=1,NM
      WORK(J)=WORK2(J)*EA(J)-UA(J)*C(I,IA,J)
   92 IF(I.EQ.8) WORK(J)=0.60*WORK(J)
      CALL FIRST(WORK,WORK2,DX,NM)
      DO 90 J=2,NM
      DCDX(I,J)=(WORK2(J)-C(I,IA,J)*DADT(J))/A(J)
      ABSX=ABS(DCDX(I,J))
   90 IF(ABSX.GT.1.0E+08) DCDX(I,J)=DCDX(I,J)/ABSX*1.0E+08
      DO 94 J=2,NM
C 1 ORGANIC CARBON
      DCDT(1, L,J)=DCDX(1,J)+FRA(1)*K(4,J)-K11*C(1,IA,J)+K(15,J)+F1*K(6,
     1            J)
C 2 CARBON DICXIDE
      DCDT(2, L,J)=DCDX(2,J)+FRA(2)*K(4,J)+K11*C(1,IA,J)+K(29,J)*E*(CSAT
     1           -C(2,IA,J))+K(16,J)-(C28*K(19,J)+C29*K(20,J)+C210*K(21,
```

```
     .          J) +C211*K(22,J)+C212*K(35,J))
C 3 ORGANIC NITROGEN
      DCDT(3, L,J)=DCDX(3,J)+FRA(3)*K(4,J)-K12*C(3,IA,J)+K(17,J)+F3*K(6,
     .          J)
C 4 AMMONIA NITRCGEN
      DCDT(4, L,J)=DCDX(4,J)+FRA(4)*K(4,J)+K12*C(3,IA,J)-20.0*K(35,J)
C 5 NITRITE AND NITRATE NITROGEN
      DCDT(5, L,J)=DCDX(5,J)+FRA(5)*K(4,J)+19.0*K(35,J) -(C58*K(19,J)+
     . C59*K(20,J)+C510*K(21,J)+C511*K(22,J)+C512*K(35,J))+F5*K(6,J)
C 6 ORTHO-PHOSPHATE PHOSPHORUS
      DCDT(6, L,J)=DCDX(6,J)+FRA(6)*K(4,J)-K36*C(6,IA,J)*C(6,IA,J)+
     .          K(18,J)-(C68*K(19,J)+C69*K(20,J)+C610*K(21,J)+C611*
     .          K(22,J)+C612*K(35,J))+F6*K(6,J)
C 7 OXYGEN DEFICIT
      DCDT(7, L,J)=DCDX(7,J)-K(5,J)*E*C(7,IA,J)  +  K(2,J)+2.667*(K(27,
     .          J)-C28*K(19,J)+K11*C(1,IA,J))+4.571*19.0*K(35,J)
C 8 ALGAE
      DCDT(8, L,J)=DCDX(8,J)+K(19,J)-K(23,J)-K(7,J)-K(11,J)
C 9 PROTOZOA
      DCDT(9, L,J)=DCDX(9,J)+K(20,J)-K(8,J)-K(12,J)
C 10 ZOOPLANKTON
      DCDT(10 ,L,J)=DCDX(10,J)+K(21,J)-K(9,J)-K(13,J)
C 11 HIGHER PREDITORS
      DCDT(11, L,J)=DCDX(11,J)+K(22,J)-K(10,J)-K(14,J)
C 12 BACTERIA
```

```
94 DCDT(12, L,J)=DCDX(12,J)+K(35,J)-K(33,J)-K(32,J)
   IA=3-IA
 2 RETURN
   END
```

```
      SUBROUTINE FIRST(Y,DY,DX,NM)
C     SUBROUTINE TO NUMERICALLY EVALUATE FIRST DERIVATIVES.            *
C         Y IS A VECTOR OF VALUES FOR THE INDEPENDENT VARIABLE CORRES-  *
C              PONDING TO EQUALLY SPACED VALUES OF THE INDEPENDENT      *
C              VARIABLE(X).                                             *
C         DY IS THE VECTOR OF FIRST DERIVATIVES OF THE DEPENDENT VARI-  *
C              ABLE WITH RESPECT TO THE INDEPENDENT VARIABLE/DYDX).     *
C         DX IS THE SPACING BETWEEN SUCCESSIVE VALUES OF THE INDEP.VAR.*
C         NM IS THE LENGTH OF THE VECTORS Y AND DY.                     *
      DIMENSION Y(NM),DY(NM)
      DX60=DX*60.0
      DX12=DX*12.0
      DY(NM)=(Y(NM)-Y(NM-1))/DX
      DY( 2)=(Y( 3)-Y( 1))/(2.0*DX)
      DY(NM-1)=(Y(NM)-Y(NM-2))/(2.0*DX)
      DY( 3)=(-Y( 5)+8.*Y( 4)-8.*Y( 2)+Y( 1))/DX12
      DY(NM-2)=(-Y(NM)+8.0*Y(NM-1)-8.0*Y(NM-3)+Y(NM-4))/DX12
      MM=NM-3
      DO 1 I=4,MM
    1 DY(I)=(Y(I+3)-Y(I-3)-9.*(Y(I+2)-Y(I-2))+45.*(Y(I+1)-Y(I-1)))/DX60
      RETURN
      END
```

```
      SUBROUTINE AREA(IDAY,IZDAY,T,TIDE,FAZ,NM,XAREA,R,WT,A)
C     SUBROUTINE TO CALCULATE ESTUARY CROSS SECTIONAL AREA AS A FUNCT- *
C         ICN OF TIDAL PHASE AND POSITICN                              *
      DIMENSICN XAREA(12,NM),R(38,NM),A(NM)
      DO 10 J=1,NM
      PHASE=(T+(IDAY-IZDAY)*24.0-TIDE-R(38,J))/12.425
      R(31,J)=PHASE-FLOAT(IFIX(PHASE))
      IF(R(31,J).LT.0.0) R(31,J)=1.0+R(31,J)
   10 A(J)=R(3,J)*(1.0+R(36,J)*SIN(WT*(R(31,J)+0.126)))
      RETURN
      END
```

```
      SUBROUTINE VELOC(XPOS,Q,A,WT,NM,R,UA)
C     SUBROUTINE TO CALCULATE FLUID VELOCITY AS A FUNCTION OF FRESH    *
C        WATER FLOW RATE,POSITICN,CROSS SECTIONAL AREA,AND TIDAL PHASE*
      DIMENSICN XPOS(NM),A(NM),R(38,NM),UA(NM)
      DO 10 J=1,NM
      XQ=Q*2.445E-08
      IF(XPOS(J).GT.20.0) XQ=2.*XQ
      IF(XPOS(J).GT.45.0)  XQ=5.*XQ
   10 UA(J)=(XQ/A(J)+R(37,J)*SIN(WT*R(31,J)))
      RETURN
      END
```

```
      SUBROUTINE VOLUM(A,NM,UA,Q,WORK,XPOS)
C     SUBROUTINE TO CALCULATE NOLUMETRIC FLOW RATE AS A FUNCTION OF    *
C         FRESH WATER FLOW RATE,POSITION,AND TIDAL PHASE.               *
      DIMENSION A(NM),UA(NM),WORK(NM),XPOS(NM)
      DO 10 J=1,NM
      XQ=Q*2.445E-08
      IF(XPOS(J).GT.20.0) XQ=2.*XQ
      IF(XPOS(J).GT.45.0)  XQ=5.*XQ
   10 WORK(J)=A(J)*UA(J)-XQ+2.445E-08*Q
      RETURN
      END
```

```
      SUBROUTINE  INTP(LN,NP,X,FX,XX,FXX,ACC,NM)
      DIMENSION FY(7), Y(7), X( NM), FX( NM)
      L=0
      K=-1
      MM=1
      DO 90 I=1,NP
      IF(X(I)-XX) 90,91,91
   91 IF(ABS(X(I)-XX)-(ACC+ABS(XX))*ACC)92,92,93
   92 FY(1)=FX(I)
      GO TO 94
   93 J=I
      GO TO 95
   90 CONTINUE
      J=NP
      L=-1
   95 Y(1)=X(J)-XX
      FY(1)=FX(J)
      FYY=FY(1)
   96 IF(L)  97,98,97
   97 J=J+L
      GO TO 99
   98 J=J+K
      IF(K) 1,2,3
    1 XK=-1.
      GO TO 4
```

```
  2 XK=0.0
    GO TO 4
  3 XK=1.
  4 K=K-(2*K+XK)
    IF(J-NP)101,101,100
100 J=J+K
    L=-1
    GO TO 99
101 IF(J-1) 102,99,99
102 J=J+K
    L=1
 99 MM=MM+1
    Y(MM)=X(J)-XX
    FY(MM)=FX(J)
    LL=MM-1
    DO 104 NN=1,LL
104 FY(MM)=(FY(NN)*Y(MM)-FY(MM)*Y(NN))/(Y(MM)-Y(NN))
    IF(LN-LL) 105,94,105
105 IF(ABS(FYY-FY(MM))-ACC*(ACC+ABS(FY(MM)))) 94 ,106,106
106 IF(MM-6) 107,107,94
107 FYY=FY(MM)
    GO TO 96
 94 FXX=FY(MM)
    RETURN
    END
```

```
    ORGANIC CARBCN
    CARBON DIOXIDE
    ORGANIC NITROGEN
    AMMCNIA
    NITRITE+NITRATE
    PHOSPHATE
    OD
    ALGAE
    PROTOZOA
    ZOOPLANKTCN
    PREDITORS
    BACTERIA
    79  0.058.65C.022  120  0.0  127  0.5   12  9.0  0.0 999.
    52    3    1     CROSS-SECTIONAL AREA
0.000232  0.0       0.000232  1.150779  0.000232  2.301558  0.000232  3.452336
0.000270  4.603116  0.000579  5.753895  0.000309  6.904674  0.000425  8.055452
0.000347  9.206232  0.000347  10.357010  0.000270 11.507780 0.000386  12.658550
0.000386  13.8C9330 0.000347  14.960120 0.000386  16.1109   0.000772  17.261670
0.000463  18.412460 0.000386  19.563230 0.000965  20.714    0.001120  21.86479
0.000888  23.01556  0.001197  24.16635  0.00112   25.31712  0.001583  26.46789
0.002162  27.61868  0.002317  28.76947  0.002664  29.92024  0.001815  31.07101
0.002471  32.2218   0.001313  33.37257  0.001699  34.52336  0.001815  35.67413
0.002317  36.82492  0.001815  37.97569  0.002896  39.12646  0.001815  40.27725
0.002780  41.42803  0.001506  42.57881  0.001853  43.72958  0.003668  44.88037
0.004286  46.C3114  0.004286  47.18193  0.003127  48.3327   0.003707  49.48347
```

```
0.004015  50.63426  0.00444   51.78504  0.005483  52.93582  0.005367  54.0866
0.004556  55.23738  0.003784  56.38815  0.004402  57.53894  0.004826  58.68971
    1   28    1     SEWAGE INPUT
            52000.                   0.1
             1600.                   0.5
             4400.                 6.906
             4000.                 6.906
              240.                 7.482
             7000.               21.2935
            10000.                 23.02
             3000.                23.596
            39840.                 23.88
            39400.                24.171
             1280.                24.171
             1200.                 24.71
             5000.                 24.71
                                     -1.
    2    2    1     BENTHAL DEMAND
            40000.                  58.65

    2    6    1     LAND RUNOFF
           100000.                  52.00
          1000000.                  54.00
           100000.                  58.65

    2   36    1     MAXIMUM DEVIATION OF X-AREA
```

```
      0.24881E 00         0.69047E 01
      0.21358E 00         0.12659E 02
      0.16069E 00         0.18412E 02
      0.19727E 00         0.24166E 02
      0.39267E 00         0.29920E 02
      0.22857E 00         0.35674E 02
      0.12906E 00         0.41428E 02
      0.92593E-01         0.47182E 02
      0.13583E 00         0.52936E 02
      0.16416E 00         0.58690E 02

52   30     1     HYDRAULIC RADIUS, ESTUARY DEPTH
  2.8871     0.0     13.2874    1.7262   12.0735    2.8769   14.1404     4.0277
 21.5879    5.1785   19.0945    6.3293   18.2415    7.4801   19.5866     8.6308
 12.9593    9.7816   12.1719   10.9324   10.0066   12.0832    8.0381    13.2339
 13.6811   14.3847   11.3517   15.5355   35.2362   16.6863   19.4882    17.8371
 11.2205   18.9878   31.3648   20.1386   10.8596   21.2894    8.1693    22.4402
  5.7415   23.5910    3.7402   24.7417    5.1509   25.8925    6.1680    27.0433
  5.5118   28.1941   10.7612   29.3448   12.0407   30.4956   11.6798    31.6464
  9.2192   32.7972    6.0367   33.9480   12.6969   35.0987   28.5105    36.2495
 13.9764   37.4003   13.0906   38.5511   14.6325   39.7019   13.6811    40.8526
 27.9199   42.0034   14.5013   43.1542   19.0617   44.3050   23.1955    45.4557
 23.3924   46.6065   20.1772   47.7573   19.4554   48.9081   10.6299    50.0589
 10.7612   51.2097    9.0223   52.3604   11.7126   53.5112   10.8268    54.6620
  8.4318   55.8128   14.0748   56.9635   13.9108   58.1143   16.1745    59.2651
```

```
80     1      2          ORGANIC CARBON
 4.5673    0.0        8.1113     0.7424      4.8366     1.4848      7.2304     2.2272
 4.8460    2.9696     6.8224     3.7120      5.1097     4.4544      6.3696     5.1968
 5.1424    5.9392     5.5697     6.6816      5.7401     7.4240      5.1129     8.1665
 5.3345    8.9089     4.7722     9.6513      4.4805    10.3937      4.6910    11.1361
 4.3078   11.8785     4.7165    12.6209      4.6585    13.3633      5.2391    14.1057
 5.0527   14.8481     5.3862    15.5905      5.3640    16.3329      5.7524    17.0753
 5.8620   17.8177     6.1146    18.5601      4.9405    19.3025      2.1862    20.0449
 3.8244   20.7873     3.7597    21.5297      4.5968    22.2721      3.8790    23.0145
 5.0151   23.7570     5.3906    24.4994      5.4485    25.2418      4.3750    25.9842
 3.4299   26.7266     3.7039    27.4690      4.1305    28.2114      3.1436    28.9538
 3.0560   29.6962     3.2766    30.4386      4.1643    31.1810      4.1104    31.9234
 4.4384   32.6658     3.9341    33.4082      4.2454    34.1506      4.1219    34.8930
 4.0307   35.6354     3.9925    36.3778      3.8943    37.1202      4.0216    37.8626
 3.8989   38.6051     4.0201    39.3475      3.8286    40.0899      4.1257    40.8323
 3.7253   41.5747     3.4536    42.3171      1.1412    43.0595      0.8118    43.8019
 0.5894   44.5443     1.5042    45.2867      1.8072    46.0291      1.2488    46.7715
 1.5462   47.5139     1.0091    48.2563      0.9055    48.9987      0.6757    49.7411
 0.6505   50.4835     0.8740    51.2259      1.2913    51.9683      1.5393    52.7107
 1.4809   53.4532     1.3124    54.1956      1.0842    54.9380      1.0770    55.6804
 1.0328   56.4228     1.1925    57.1652      1.5567    57.9076      1.7961    58.6500
80     2      2          CARBON DIOXIDE
 3.2362    0.0        0.7602     0.7424      3.0742     1.4848      0.4329     2.2272
 3.0475    2.9696     0.9118     3.7120      3.7997     4.4544      1.9489     5.1968
 4.8408    5.9392     1.5701     6.6816      4.7213     7.4240      1.5398     8.1665
```

```
  4.5481    8.9089    1.3669    9.6513    4.1426   10.3937    1.4634   11.1361
  4.1075   11.8785    2.0525   12.6209    4.5089   13.3633    1.9955   14.1057
  4.2957   14.8481    2.3950   15.5905    4.0915   16.3329    2.6954   17.0753
  4.9500   17.8177    1.5962   18.5601    3.5798   19.3025    0.9100   20.0449
  2.5301   20.7873    1.7552   21.5297    3.2957   22.2721    2.0919   23.0145
  3.0854   23.7570    2.1072   24.4994    2.3971   25.2418    1.3715   25.9842
  2.0572   26.7266    3.0256   27.4690    3.6163   28.2114    2.5620   28.9538
  2.9554   29.6962    2.8443   30.4386    3.9990   31.1810    3.5215   31.9234
  4.3122   32.6658    2.7488   33.4082    4.3602   34.1506    3.8836   34.8930
  4.1905   35.6354    3.9718   36.3778    4.1082   37.1202    3.9607   37.8626
  4.1626   38.6051    4.1796   39.3475    4.3564   40.0899    4.4210   40.8323
  4.2317   41.5747    3.8115   42.3171    1.5064   43.0595    0.9245   43.8019
  0.7292   44.5443    1.7958   45.2867    2.2150   46.0291    1.5045   46.7715
  1.9815   47.5139    1.2058   48.2563    1.2142   48.9987    0.9218   49.7411
  0.8960   50.4835    1.0235   51.2259    1.3934   51.9683    1.6164   52.7107
  1.6996   53.4532    1.5832   54.1956    1.4873   54.9380    1.2427   55.6804
  1.3642   56.4228    1.3797   57.1652    1.7381   57.9076    1.9758   58.6500
 80     3    2         ORGANIC NITROGEN
  0.4387    0.0       1.3736    0.7424    0.7809    1.4848    1.3797    2.2272
  0.8105    2.9696    1.2772    3.7120    0.7034    4.4544    1.0494    5.1968
  0.5390    5.9392    1.0036    6.6816    0.6386    7.4240    0.9441    8.1665
  0.5999    8.9089    0.9288    9.6513    0.5456   10.3937    0.8874   11.1361
  0.5198   11.8785    0.7762   12.6209    0.4627   13.3633    0.7700   14.1057
  0.4979   14.8481    0.7178   15.5905    0.5429   16.3329    0.7050   17.0753
  0.4953   17.8177    0.8265   18.5601    0.4332   19.3025    0.2640   20.0449
```

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  0.3568    20.7873     0.4524    21.5297     0.3867    22.2721     0.4653    23.0145
  0.5410    23.7570     0.7929    24.4994     0.6033    25.2418     0.6067    25.9842
  0.4113    26.7266     0.3968    27.4690     0.5463    28.2114     0.6146    28.9538
  0.5073    29.6962     0.4851    30.4386     0.3867    31.1810     0.4168    31.9234
  0.3321    32.6658     0.4873    33.4082     0.3004    34.1506     0.3663    34.8930
  0.3115    35.6354     0.3424    36.3778     C.3046    37.1202     0.3432    37.8626
  0.2791    38.6051     0.2911    39.3475     0.2232    40.0899     0.2835    40.8323
  0.2299    41.5747     0.2412    42.3171     0.0464    43.0595     0.0592    43.8019
  0.0341    44.5443     0.0976    45.2867     C.1093    46.0291     0.0874    46.7715
  0.0927    47.5139     0.0864    48.2563     0.0628    48.9987     0.0556    49.7411
  0.0506    50.4835     0.0895    51.2259     C.1438    51.9683     0.1762    52.7107
  0.1500    53.4532     0.1273    54.1956     C.0850    54.9380     0.1246    55.6804
  0.0923    56.4228     0.1330    57.1652     0.1677    57.9076     0.1918    58.6500
 80     4     2        AMMONIA
  0.1421     0.0        0.1995     0.7424     0.4627     1.4848     0.2976     2.2272
  0.5449     2.9696     0.3592     3.7120     0.5625     4.4544     0.3590     5.1968
  0.5611     5.9392     0.3500     6.6816     0.5671     7.4240     0.3828     8.1665
  0.5522     8.9C89     0.3782     9.6513     0.5023    10.3937     0.3197    11.1361
  0.4803    11.8785     0.3221    12.6209     0.5773    13.3633     0.4018    14.1057
  0.6812    14.8481     0.4829    15.5905     C.6907    16.3329     0.5386    17.0753
  0.8822    17.8177     0.4078    18.5601     0.6826    19.3025     0.2090    20.0449
  0.5064    20.7873     0.4031    21.5297     C.6142    22.2721     0.4422    23.0145
  0.6021    23.7570     0.5124    24.4994     C.4573    25.2418     0.3126    25.9842
  0.3922    26.7266     0.5444    27.4690     0.7811    28.2114     0.6580    28.9538
  0.6992    29.6962     0.6622    30.4386     C.8649    31.1810     0.7777    31.9234
```

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 0.9118    32.6658    0.6336   33.4082    0.9154   34.1506    0.8581   34.8930
 0.9295    35.6354    0.9050   36.3778    C.9417   37.1202    0.9462   37.8626
 0.9777    38.6051    0.9988   39.3475    1.0255   40.0899    1.0589   40.8323
 1.0044    41.5747    0.9094   42.3171    0.3475   43.0595    0.2172   43.8019
 0.1679    44.5443    0.4164   45.2867    C.5095   46.0291    0.3446   46.7715
 0.4488    47.5139    0.2672   48.2563    0.2638   48.9987    0.1910   49.7411
 0.1836    50.4835    0.2139   51.2259    0.2955   51.9683    0.3454   52.7107
 0.3604    53.4532    0.3312   54.1956    0.3059   54.9380    0.2528   55.6804
 0.2795    56.4228    0.2841   57.1652    0.3689   57.9076    0.4239   58.6500
80     5     2       NITRITE+NITRATE
 0.4764     0.0       0.3498    0.7424    0.5234    1.4848    0.3060    2.2272
 0.5009     2.9696    0.3130    3.7120    0.5549    4.4544    0.3986    5.1968
 0.6602     5.9392    0.3704    6.6816    0.6600    7.4240    0.3666    8.1665
 0.6376     8.9089    0.3338    9.6513    0.5753   10.3937    0.3142   11.1361
 0.5463    11.8785    0.3518   12.6209    C.6051   13.3633    0.3894   14.1057
 0.6320    14.8481    0.4561   15.5905    0.6196   16.3329    0.4825   17.0753
 0.6962    17.8177    0.3834   18.5601    C.5102   19.3025    0.1665   20.0449
 0.3759    20.7873    0.3118   21.5297    0.4768   22.2721    0.3545   23.0145
 0.4636    23.7570    0.3611   24.4994    C.3316   25.2418    0.2097   25.9842
 0.2562    26.7266    0.3890   27.4690    0.4498   28.2114    0.3093   28.9538
 0.3466    29.6962    0.3485   30.4386    0.4787   31.1810    0.4344   31.9234
 0.5151    32.6658    0.3998   33.4082    0.5396   34.1506    0.5250   34.8930
 0.5339    35.6354    0.5211   36.3778    0.5170   37.1202    0.5258   37.8626
 0.5247    38.6051    0.5479   39.3475    0.5556   40.0899    0.6023   40.8323
 0.5635    41.5747    0.5347   42.3171    0.1860   43.0595    0.1337   43.8019
```

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 0.1004   44.5443    0.2563   45.2867    0.3093   46.0291    0.2170   46.7715
 0.2673   47.5139    0.1796   48.2563    0.1606   48.9987    0.1244   49.7411
 0.1207   50.4835    0.1604   51.2259    0.2351   51.9683    0.2810   52.7107
 0.2771   53.4532    0.2490   54.1956    0.2127   54.9380    0.2020   55.6804
 0.2070   56.4228    0.2321   57.1652    0.3071   57.9076    0.3558   58.6500
80    6     2       PHOSPHATE
 0.2408    0.0       0.7261    0.7424    0.8625    1.4848    0.8341    2.2272
 0.9403    2.9696    0.8195    3.7120    0.8562    4.4544    0.6784    5.1968
 0.7287    5.9392    0.6334    6.6816    0.7048    7.4240    0.6134    8.1665
 0.6009    8.9089    0.5524    9.6513    0.4769   10.3937    0.4537   11.1361
 0.4238   11.8785    0.4415   12.6209    0.5468   13.3633    0.5961   14.1057
 0.6829   14.8481    0.6284   15.5905    0.6580   16.3329    0.5949   17.0753
 0.7183   17.8177    0.5415   18.5601    0.5663   19.3025    0.2176   20.0449
 0.4343   20.7873    0.4028   21.5297    0.5202   22.2721    0.4181   23.0145
 0.5701   23.7570    0.5515   24.4994    0.3704   25.2418    0.2798   25.9842
 0.3002   26.7266    0.4339   27.4690    0.5772   28.2114    0.4533   28.9538
 0.4547   29.6962    0.4397   30.4386    0.5452   31.1810    0.4881   31.9234
 0.5418   32.6658    0.3895   33.4082    0.5270   34.1506    0.4846   34.8930
 0.5067   35.6354    0.4814   36.3778    0.4825   37.1202    0.4566   37.8626
 0.4672   38.6051    0.4605   39.3475    0.4630   40.0899    0.4670   40.8323
 0.4388   41.5747    0.3882   42.3171    0.1504   43.0595    0.0898   43.8019
 0.0699   44.5443    0.1715   45.2867    0.2110   46.0291    0.1401   46.7715
 0.1872   47.5139    0.1077   48.2563    0.1098   48.9987    0.0788   49.7411
 0.0759   50.4835    0.0852   51.2259    0.1163   51.9683    0.1346   52.7107
 0.1405   53.4532    0.1286   54.1956    0.1187   54.9380    0.0957   55.6804
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 0.1036   56.4228    0.1019   57.1652    0.1285   57.9076    0.1464   58.6500
80     7   2        OD
 1.4742    0.C       0.1679    0.7424    1.3577    1.4848    0.1544    2.2272
 1.6196    2.9696    0.5403    3.7120    2.0407    4.4544    0.9539    5.1968
 2.5260    5.9392    0.7573    6.6816    2.5155    7.4240    0.8500    8.1665
 2.5171    8.9089    0.9396    9.6513    2.4223   10.3937    1.2201   11.1361
 2.5865   11.8785    1.6949   12.6209    2.9332   13.3633    1.7270   14.1057
 2.8573   14.8481    1.9210   15.5905    2.8474   16.3329    2.3037   17.C753
 3.5886   17.8177    1.9569   18.5601    2.8064   19.3025    0.8794   20.0449
 2.1467   20.7873    1.7526   21.5297    2.7653   22.2721    1.9110   23.0145
 2.4624   23.7570    1.6521   24.4994    1.7885   25.2418    1.0349   25.9842
 1.4105   26.7266    1.9261   27.4690    2.1630   28.2114    1.3541   28.9538
 1.5300   29.6962    1.4087   30.4386    2.2748   31.1810    1.9337   31.9234
 2.5669   32.6658    1.3511   33.4082    2.6427   34.1506    2.3869   34.8930
 2.6412   35.6354    2.4570   36.3778    2.5547   37.1202    2.5116   37.8626
 2.7510   38.6051    2.8739   39.3475    3.1557   40.0899    3.2268   40.8323
 3.1446   41.5747    2.7996   42.3171    1.1207   43.0595    0.6593   43.8019
 0.5281   44.5443    1.3491   45.2867    1.6870   46.0291    1.1354   46.7715
 1.5050   47.5139    0.9177   48.2563    0.9083   48.9987    0.6712   49.7411
 0.6380   50.4835    0.7268   51.2259    C.9948   51.9683    1.1669   52.7107
 1.2218   53.4532    1.1138   54.1956    1.0247   54.9380    0.8391   55.6804
 0.9352   56.4228    0.9219   57.1652    1.1846   57.9076    1.3570   58.6500
80     8   2        ALGAE
 0.0500    0.0       0.0       0.7424    0.7074    1.4848    0.0007    2.2272
 1.0978    2.9696    0.1257    3.7120    C.9717    4.4544    0.4323    5.1968
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 1.0574    5.9392    0.0380    6.6816    0.9097    7.4240    0.0731    8.1665
 1.1849    8.9089    0.0111    9.6513    1.1760   10.3937    0.0      11.1361
 1.3589   11.8785    0.2972   12.6209    1.5886   13.3633    0.2912   14.1057
 1.3047   14.8481    0.2992   15.5905    1.1246   16.3329    1.0227   17.0753
 2.3380   17.8177    0.2697   18.5601    1.6818   19.3025    0.2524   20.0449
 1.0448   20.7873    1.4000   21.5297    1.5008   22.2721    1.0102   23.0145
 0.5918   23.7570    0.1341   24.4994    1.3561   25.2418    1.0727   25.9842
 0.6802   26.7266    0.8781   27.4690    0.9628   28.2114    0.6828   28.9538
 0.5216   29.6962    0.4680   30.4386    0.3482   31.1810    0.3947   31.9234
 0.5566   32.6658    0.2609   33.4082    0.3928   34.1506    0.4364   34.8930
 0.4445   35.6354    0.4108   36.3778    0.4455   37.1202    0.2014   37.8626
 0.3229   38.6051    0.3308   39.3475    0.2446   40.0899    0.1974   40.8323
 0.2512   41.5747    0.1977   42.3171    0.1117   43.0595    0.0535   43.8019
 0.0328   44.5443    0.0661   45.2867    0.1066   46.0291    0.0707   46.7715
 0.0911   47.5139    0.0381   48.2563    0.0355   48.9987    0.0396   49.7411
 0.0552   50.4835    0.0633   51.2259    0.0575   51.9683    0.0543   52.7107
 0.0575   53.4532    0.0690   54.1956    0.0667   54.9380    0.0593   55.6804
 0.0420   56.4228    0.0386   57.1652    0.0524   57.9076    0.0586   58.6500
80     9  2         PROTOZOA
 0.0500    0.0       0.0544    0.7424    0.0439    1.4848    0.0487    2.2272
 0.0417    2.9696    0.0461    3.7120    0.0439    4.4544    0.0475    5.1968
 0.0483    5.9392    0.0443    6.6816    0.0516    7.4240    0.0438    8.1665
 0.0524    8.9089    0.0447    9.6513    0.0505   10.3937    0.0464   11.1361
 0.0493   11.8785    0.0455   12.6209    0.0459   13.3633    0.0418   14.1057
 0.0430   14.8481    0.0421   15.5905    0.0443   16.3329    0.0446   17.0753
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  0.0458   17.8177    0.0462   18.5601    0.0365   19.3025    0.0162   20.0449
  0.0283   20.7873    0.0279   21.5297    0.0333   22.2721    0.0287   23.0145
  0.0331   23.7570    0.0326   24.4994    0.0311   25.2418    0.0240   25.9842
  0.0214   26.7266    0.0262   27.4690    0.0306   28.2114    0.0262   28.9538
  0.0245   29.6962    0.0231   30.4386    0.0250   31.1810    0.0236   31.9234
  0.0248   32.6658    0.0208   33.4082    0.0239   34.1506    0.0223   34.8930
  0.0223   35.6354    0.0213   36.3778    0.0206   37.1202    0.0188   37.8626
  0.0183   38.6051    0.0173   39.3475    0.0162   40.0899    0.0162   40.8323
  0.0148   41.5747    0.0130   42.3171    0.0048   43.0595    0.0029   43.8019
  0.0022   44.5443    0.0053   45.2867    0.0065   46.0291    0.0042   46.7715
  0.0057   47.5139    0.0031   48.2563    0.0032   48.9987    0.0022   49.7411
  0.0021   50.4835    0.0023   51.2259    0.0032   51.9683    0.0037   52.7107
  0.0038   53.4532    0.0035   54.1956    0.0032   54.9380    0.0025   55.6804
  0.0027   56.4228    0.0026   57.1652    0.0032   57.9076    0.0037   58.6500
 80   10    2         ZOOPLANKTON
  0.0500    0.0       0.0534    0.7424    0.0442    1.4848    0.0481    2.2272
  0.0421    2.9696    0.0457    3.7120    0.0442    4.4544    0.0472    5.1968
  0.0485    5.9392    0.0442    6.6816    0.0517    7.4240    0.0438    8.1665
  0.0527    8.9089    0.0449    9.6513    0.0510   10.3937    0.0466   11.1361
  0.0499   11.8785    0.0456   12.6209    0.0463   13.3633    0.0417   14.1057
  0.0433   14.8481    0.0419   15.5905    0.0445   16.3329    0.0444   17.0753
  0.0460   17.8177    0.0459   18.5601    0.0365   19.3025    0.0162   20.0449
  0.0283   20.7873    0.0279   21.5297    0.0333   22.2721    0.0287   23.0145
  0.0330   23.7570    0.0323   24.4994    0.0305   25.2418    0.0235   25.9842
  0.0213   26.7266    0.0263   27.4690    0.0309   28.2114    0.0268   28.9538
```

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 0.0250   29.6962   0.0234   30.4386    0.0253   31.1810    0.0237   31.9234
 0.0249   32.6658   0.0209   33.4082    0.0242   34.1506    0.0227   34.8930
 0.0228   35.6354   0.0218   36.3778    0.0211   37.1202    0.0194   37.8626
 0.0189   38.6051   0.0179   39.3475    0.0168   40.0899    0.0169   40.8323
 0.0154   41.5747   0.0135   42.3171    0.0050   43.0595    0.0030   43.8019
 0.0023   44.5443   0.0056   45.2867    0.0068   46.0291    0.0044   46.7715
 0.0060   47.5139   0.0032   48.2563    0.0034   48.9987    0.0023   49.7411
 0.0022   50.4835   0.0024   51.2259    0.0033   51.9683    0.0038   52.7107
 0.0040   53.4532   0.0036   54.1956    0.0033   54.9380    0.0026   55.6804
 0.0027   56.4228   0.0027   57.1652    0.0033   57.9076    0.0038   58.6500
80    11     2         PREDITORS
 0.0500   0.0       0.0549    0.7424    0.0440    1.4848    0.0472    2.2272
 0.0414    2.9696   0.0444    3.7120    0.0446    4.4544    0.0464    5.1968
 0.0499    5.9392   0.0418    6.6816    0.0528    7.4240    0.0403    8.1665
 0.0519    8.9089   0.0399    9.6513    0.0475   10.3937    0.0415   11.1361
 0.0461   11.8785   0.0424   12.6209    0.0450   13.3633    0.0413   14.1057
 0.0431   14.8481   0.0419   15.5905    0.0440   16.3329    0.0438   17.0753
 0.0453   17.8177   0.0445   18.5601    0.0364   19.3025    0.0156   20.0449
 0.0279   20.7873   0.0266   21.5297    0.0338   22.2721    0.0276   23.0145
 0.0335   23.7570   0.0317   24.4994    0.0321   25.2418    0.0239   25.9842
 0.0209   26.7266   0.0257   27.4690    0.0279   28.2114    0.0209   28.9538
 0.0201   29.6962   0.0198   30.4386    0.0236   31.1810    0.0220   31.9234
 0.0238   32.6658   0.0185   33.4082    0.0223   34.1506    0.0197   34.8930
 0.0194   35.6354   0.0180   36.3778    0.0172   37.1202    0.0153   37.8626
 0.0154   38.6051   0.0146   39.3475    0.0143   40.0899    0.0143   40.8323
```

```
  0.0133    41.5747     0.0117    42.3171     0.0045    43.0595     0.0027    43.8019
  0.0021    44.5443     0.0052    45.2867     0.0063    46.0291     0.0042    46.7715
  0.0056    47.5139     0.0033    48.2563     0.0034    48.9987     0.0025    49.7411
  0.0024    50.4835     0.0027    51.2259     0.0037    51.9683     0.0043    52.7107
  0.0045    53.4532     0.0041    54.1956     C.0038    54.9380     0.0031    55.6804
  0.0035    56.4228     0.0035    57.1652     0.0044    57.9076     0.0051    58.6500
 80   12     2         BACTERIA
  0.1000     0.0        0.1033     0.7424     0.0901     1.4848     0.0894     2.2272
  0.0855     2.9696     0.0846     3.7120     0.0921     4.4544     0.0896     5.1968
  0.1035     5.9392     0.0798     6.6816     C.1086     7.4240     0.0773     8.1665
  0.1074     8.9C89     0.0756     9.6513     0.0987    10.3937     0.0775    11.1361
  0.0948    11.8785     0.0795    12.6209     C.0944    13.3633     0.0779    14.1057
  0.0914    14.8481     0.0809    15.5905     C.0913    16.3329     0.0846    17.0753
  0.0971    17.8177     0.0812    18.5601     0.0761    19.3025     0.0302    20.0449
  0.0577    20.7873     0.0532    21.5297     C.0703    22.2721     0.0564    23.0145
  0.0691    23.7570     0.0636    24.4994     0.0636    25.2418     0.0463    25.9842
  0.0430    26.7266     0.0547    27.4690     0.0598    28.2114     0.0442    28.9538
  0.0436    29.6962     0.0423    30.4386     C.0519    31.1810     0.0476    31.9234
  0.0535    32.6658     0.0410    33.4082     0.0534    34.1506     0.0493    34.8930
  0.0499    35.6354     0.0471    36.3778     C.0459    37.1202     0.0423    37.8626
  0.0428    38.6051     0.0417    39.3475     0.0417    40.0899     0.0421    40.8323
  0.0395    41.5747     0.0351    42.3171     0.0134    43.0595     0.0081    43.8019
  0.0062    44.5443     0.0153    45.2867     C.0188    46.0291     0.0124    46.7715
  0.0166    47.5139     0.0095    48.2563     0.0096    48.9987     0.0068    49.7411
  0.0066    50.4835     0.0074    51.2259     C.0101    51.9683     0.0117    52.7107
```

```
 0.0122   53.4532    0.0111   54.1956    0.0102   54.9380    0.0082   55.6804
 0.0088   56.4228    0.0087   57.1652    0.0110   57.9076    0.0125   58.6500

16.     10350.           450.   120                1
         8750.           597.   121                1
         8000.           600.   122                1
         7250.           590.   123                1
         5000.           522.   124                1
         5125.           612.   125                1
         4825.           612.   126                1
         4015.           536.   127                1

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