GEM: GENERALIZED ESTUARY MODEL

A VARIATION ON THE SCHOFIELD-KRUTCHKOFF

STOCHASTIC MODEL FOR ESTUARIES

by

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I. INTRODUCTION

Environmental improvement is an important objective today in countries the world over. The term "pollution" has become very popular and is used to represent anything from a volcanic eruption to a political address. In this study, pollution will be considered as any impairment of the suitability of water for any of its intended beneficial uses, actual or potential, by man-made changes in the quality of the water.

1.1 General Problem

The degradation of rivers and estuaries has become a focal point of increasing concern not only of experts and governmental bodies, but of the general public as well. Too many estuaries, because of the enormous amount of waste materials they receive, have become unsightly, unproductive and are presenting a serious health hazard (3). Estuaries are important to man in providing him with accessibility to the sea. Many of the world's major seaports are situated on estuaries and are usually associated with centers of industry and a substantial population.

In the past it has been customary for sewage and other wastes to be disposed of directly into the estuary, but with the increasing volume of waste material and the introduction of new and persistent chemical compounds, restrictions have been made with respect to the condition of wastes which are discharged into estuaries.

There are a number of sound scientific and practical reasons for intensifying the study of estuaries. One tool for carrying out estuary investigation is the model. Developing reliable water pollution models and simplifying them so that they can be used by appropriate personnel regardless of their experience in computer programming is extremely important. Mathematical models have been applied as a panacea to some estuaries, no matter what the situation, because computer-wise they are easy to use. Concurrently, models of good quality are not used because the necessary internal computer program alterations are too complicated.

1.2 Objective

The objective of this work will be to simplify the twelve component Schofield model (14) so that it may be used by those requiring a tool for estuarine analysis, irrespective of their previous exposure to the science of computer programming. Changes will be made on a specific version of the Schofield model as employed by Harry Bard on the James River Estuary (2).

II. LITERATURE REVIEW

The response of an estuarine system is affected by unpredictable fluctuations in a variety of environmental factors. In studying a system from the modeling standpoint, many random components, just one or maybe none at all may be considered. A stochastic model will account for all three situations while the use of a deterministic model could justifiably be applied to the last case alone. The use of a deterministic model in the presence of random variables could lead to erroneous and misleading conclusions. Realistically speaking, there will always be a random variation around predicted values (whether qualitative or quantitative) affecting the estuarine environment and thus the stochastic nature of such components should be included.

2.1 The Model of Schofield and Krutchkoff

Schofield and Krutchkoff (14) developed a segmented estuary model in which parameters and conditions are allowed to vary through position and tidal phase and where constant coefficients within a segment are also free to vary. In an attempt to describe the behavior of an estuary, the model predicts concentrations of twelve interacting components, subdivided into five biological factors and seven chemical factors. A list of these components is as follows:

1. Organic carbon
2. Inorganic carbon
3. Organic nitrogen
4. Ammonia
5. Nitrite and nitrate

6. Phosphorus
7. Oxygen deficit
8. Algae
9. Protozoa
10. Zooplankton
11. Higher predators
12. Bacteria

The Schofield model is a one-dimensional dynamic model which predicts the concentrations of the above factors via twelve simultaneous differential equations. The general one-dimensional equation for the *i*th component is (14):

$$\frac{\partial C_i(x,t)}{\partial t} = \frac{1}{A(x,t)} \frac{\partial}{\partial x} [E(x,t)A(x,t) \frac{\partial C_i(x,t)}{\partial x} - V(x,t)A(x,t)C(x,t)]$$

$$- \frac{C_i(x,t)}{A(x,t)} \frac{\partial A(x,t)}{\partial t} + R_i(x,t,C')$$

where:

$A(x,t)$ is the estuary cross-sectional area as a function of position and time

$E(x,t)$ is the diffusion coefficient as a function of position and time

$C_i(x,t)$ is the concentration of component "i" as a function of position and time

$V(x,t)$ is the average cross section fluid velocity as a function of position and time

$R_i(x,t,C')$ is the net rate of increase of $C_i(x,t)$ based on all sources and sinks as a function of time, position and the other component concentrations.

Since these equations are quite general, it was found that a numerical solution was necessary. A more detailed discussion of the derivation and solution of the diffusion equations is found in Schofield's Ph.D. publication written in 1971 (14). Using a high speed computer, the method was to define a system of grid points at which computations were made. It was important to space these points far enough apart to curtail the amount of machine time used, while at the same time keeping them close enough together to insure a convergent solution with respect to integration.

2.2 The Bard Model

Schofield's program requires internal adjustments as well as basic input data when modeling any stream or estuary. This is due to the fact that watersheds have different applicable rate constants, boundary conditions, tidal lag and maximum tidal velocity rates. Harry Bard (2) made use of the Schofield program in modeling the James River Estuary and conducting sensitivity studies on a variety of specified parameters. Following is an explanation of program changes that were necessary in applying the model to the James.

The Schofield model is composed of a main program followed by eleven subroutines. In order to relate these separate entities into a smooth working unit, a 'common block' was used to allocate the same storage register to variables specified by their order of listing.

This common block appears in each subroutine, (including MAIN), stating the appropriate variables with respect to their use in a particular subroutine. Since the James River Estuary was studied over a distance of 58.6 miles (as opposed to the 30 mile long Potomac Estuary studied by Schofield) it was broken up into 79 segments or 80 grid points. Therefore the dimension of all arrays in 'common' which reflected the number of grid points utilized had to be increased accordingly.

The main program essentially reads data, calls upon a few of the subroutines for aid in solving the differential equations, adjusts the time step according to integration accuracy and defines some important variables. The variables of interest which had to be changed by Bard were those representing the maximum tidal velocity, [K(37,J)] and tidal lag, [K(38,J)]. (See section 3.15 for description of program variables). These mathematical expressions are functions of the grid point positions and as mentioned before, have to be adjusted for each estuary modeled. Another mathematical expression for a vector defined in MAIN, is that of average cross-sectional area, XAREA(J). Bard chooses to omit this equation altogether and simply read in sets of data for cross-sectional area at approximately 4.6 mile intervals. The actual reading of these values occurs in the subroutine STORE whose purpose is to read and store initial input data for parameters and concentrations. Many of these parameters are variable with respect to time, temperature, flow rate and sunlight intensity. This variability is accounted for in subroutine UPDATE, appropriately named since its function is to update parameters which are subject to change. As one might think, with each estuary modeled, slight modifications of the mathematical formulae must occur here. Particular to the James River Estuary, Bard had to replace the 'correction factor' in the expression for algae growth rate, GRO8, with a smaller value and modify the numerical definition of the rate coefficient for the conversion of organic nitrogen to ammonia. These alterations were minor but absolutely necessary with regard to reflecting the behavioral characteristics of this specific watershed.

Subroutine UPDATE also includes equations representing the boundary conditions for the twelve components considered in this model. Appropriate adjustments in these expressions for organic and inorganic carbon, nitrite and nitrate, organic nitrogen and ortho-phosphate which are all functions of the volumetric flow rate Q, were made. Again, modifications such as those mentioned above are vital in an attempt to represent the true nature of each stream or estuary modeled.

Subroutine FUNCT estimates partial derivatives of the twelve components with respect to time. For the Potomac, the organic carbon utilization rate coefficient, K11, and the rate coefficient for the conversion of organic nitrogen to ammonia, K12, assume three slightly different values according to grid point position along the estuary. In modeling the James, Bard chooses to maintain the same values of these coefficients throughout the stretch of the reach. Since the equations for the partial derivatives of organic carbon, carbon dioxide, organic nitrogen, ammonia nitrogen and oxygen deficit include the two coefficients, their respective values are affected by this change.

Subroutine AREA performs a simple but important task by calculating the estuary cross-sectional area as a function of tidal phase and position. In the expression for the above phenomenon, Bard found it necessary to reduce the 'correction factor' previously used on the Potomac due to the quantitative difference in the tidal phase lag vector of each estuary. Similarly, subroutines VELOC and VOLUM which calculate fluid velocity and volumetric flow rates respectively, as functions of freshwater flow rate, position and tidal phase, had to be altered for use on the James. This involved the manipulation of the volumetric flow rate Q, since its value depends on the grid point positions which naturally vary for every body of water modeled.

III. PROGRAM DESCRIPTIONS

This section describes the model GEM which is divided up into a main program and its thirteen subroutines. Each program description includes a brief written analysis of the program function. Section 3.15 contains an alphabetical listing of all variables used in GEM.

The computer program for the generalized Schofield model was written and developed in Fortran IV for application on an IBM 370 machine. The amount of storage necessary for the entire program is approximately 180K and each day of simulated time takes from 15-30 seconds to execute. The dimension of all applicable arrays was increased to enable the user to segment an estuary into a maximum of 199 sections or 200 grid points. If the user has reason to define a system of grid points which are more than 200 in number, he may do so by increasing the dimension of the first twelve arrays along with that of XAREA listed in the common statement to the appropriate size. The quantitative initialization values for arrays C, DCDX, K, XAREA and DCDT found in the BLOCK DATA subroutine must also be modified accordingly. Of course the user should realize that this type of action will require a larger number of storage locations and thus more computer time and expense.

3.1 The MAIN Program

MAIN has the basic function of receiving all pertinent information from the user that is particular to the estuary being modeled.

Once all of the variables are defined, subroutine SCHOFI is called to begin the solution.

The flowchart for MAIN is illustrated in Appendix III-1.

3.2 Subroutine SCHOFI

This is the first subroutine of the program whose function is to read data, define many important variables, call upon other subroutines for aid in the solution of the differential equations, check the integrations for accuracy and adjust the time step accordingly.

The subroutine flowchart is illustrated in Appendix III-2.

3.3 Subroutine STORE

Subroutine Store reads and stores initial input data for pollutant concentrations and other parameters. It responds to three different types of input data; discharge at a point, constant within a segment and continuous values.

The subroutine flowchart is shown in Appendix III-3.

3.4 Subroutine OUTPUT

As its name implies, subroutine Output provides specified output, either punched card, or printed, depending on the choice of the user. Output also keeps track of the time and day of the solutions along with comparing observed data to predicted data for model verfication purposes.

The subroutine flowchart is seen in Appendix III-4.

3.5 Subroutine UPDATE

The purpose of subroutine Update is to change all parameters which are variable with respect to time, temperature, flow rate and sunlight intensity. Updates concerning the component reaction rates and concentrations, which can be made on a daily, hourly or minute to minute basis, are executed in this program segment.

A flowchart of the subroutine can be seen in Appendix III-5.

3.6 BLOCK DATA

Block Data is a special subroutine which must be used when entering data into a labeled 'common' statement. It's used to initialize many parameters and values necessary to the program operation and is also helpful in storing data and assigning default values to the variables listed.

The subroutine flowchart is illustrated in Appendix III-6.

3.7 Subroutine RKMI

The subroutine RKMI is called by MAIN for initial evaluation of the component concentrations. Using the Runge-Kutta-Merson technique (14) of numerical integration, it integrates the partial derivative of concentration with respect to time, $\frac{\partial C}{\partial t}$, and also measures the accuracy of the integration in time by comparing the observed error to the allowable error.

The flowchart for subroutine RKMI is shown in Appendix III-7.

3.8 Subroutine FUNCT

Subroutine Funct evaluates the partial derivative for each component concentration with respect to time. Predation, growth and respiration rates are calculated for the five biological components and subroutines Area, Veloc, Volum and First are called for their aid in the evaluation.

The subroutine flowchart can be seen in Appendix III-8.

3.9 Subroutine FIRST

Subroutine First numerically evaluates the components first partial derivatives with respect to position through the use of sixth order difference equations. The endpoints of the grid system are evaluated by second and fourth order difference equations.

The subroutine flowchart is illustrated in Appendix III-9.

3.10 Subroutine AREA

The purpose of subroutine Area is simply to calculate the estuary cross-sectional area as a function of tidal phase and position.

The subroutine flowchart can be seen in Appendix III-10.

3.11 Subroutine VELOC

This short subroutine calculates fluid velocity as a function of the freshwater flow rate, position, cross-sectional area, tidal phase and tidal flow rate.

The flowchart for this subroutine is shown in Appendix III-11.

3.12 Subroutine VOLUM

Subroutine Volum is vital to the program operation in that it calculates the volumetric flow rates as a function of the freshwater flow rate, tidal phase and position.

The subroutine flowchart is displayed in Appendix III-12.

3.13 Subroutine INTP

The purpose of subroutine Intp is to evaluate input data at the grid points by interpolation. It's also used to determine the value of component concentrations at positions other than the grid points.

The subroutine flowchart is shown in Appendix III-13.

3.14 Subroutine BILDAX

The function of subroutine Bildax is to draw and label the X and Y axes, along with tic marks and the appropriate incrementing numbers. The component concentrations along with the actual drawing and partial calculation of the afore mentioned is executed by subroutines PLOT, NUMBER and SYMBOL which are internal to the system.

The subroutine flowchart is illustrated in Appendix III-14.

3.15 Description of Variables in GEM

Variable	Definition
A(J)	Cross-sectional area (mi^2)
AO	Coefficient in expression for maximum tidal velocity
A1	Coefficient of first order term in expression for maximum tidal velocity
A2	Coefficient of second order term in expression for maximum tidal velocity
A3	Coefficient of third order term in expression for maximum tidal velocity
A4	Coefficient of fourth order term in expression for maximum tidal velocity
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 sewage input with time
AREA	Subroutine to calculate X-area
AVE	Average yearly water temperature (°C)
BA	Bacteria growth rate coefficient at 20°C/day

Variable	Definition
BC(J)	Boundary conditions for:
J=1	Algae (ppm)
=2	Protozoa (ppm)
=3	Zooplankton (ppm)
=4	Higher Predator (ppm)
=5	Bacteria (ppm)
BCN	Boundary condition for organic nitrogen (ppm)
C(I,IA,J)	Concentration of:
I=1	Organic carbon
=2	Carbon dioxide
=3	Organic nitrogen
=4	Ammonia
=5	Nitrite and nitrate
=6	Ortho-phosphate
=7	Oxygen deficit
=8	Algae
=9	Protozoa
=10	Zooplankton
=11	Higher predator
=12	Bacteria
C28	Fraction of algae that is carbon
C29	Fraction of protozoa that is carbon
C58	Fraction of algae that is nitrogen

Variable	Definition
C59	Fraction of protozoa that is nitrogen
C68	Fraction of algae that is phosphorus
C69	Fraction of protozoa that is phosphorus
C210	Fraction of zooplankton that is carbon
C211	Fraction of higher predator that is carbon
C212	Fraction of bacteria that is carbon
C510	Fraction of zooplankton that is nitrogen
C511	Fraction of higher predator that is nitrogen
C610	Fraction of zooplankton that is phosphorus
C611	Fraction of bacteria that is phosphorus
CK3	Fraction of the organic nutrients recycled
CL	Factor adjusting pollution discharge
CONC(I,J)	Name of components:
I=1	Organic carbon
=2	Carbon dioxide
=3	Organic nitrogen
=4	Ammonia
=5	Nitrite and Nitrate
=6	Phosphorus
=7	Oxygen deficit
=8	Algae
=9	Protozoa
=10	Zooplankton

Variable	Definition
=11	Higher predator
=12	Bacteria
CSAT	CO_2 saturation concentration (ppm)
D1	Light extinction coefficient due to causes other than self-shading 1/ft
D2	Coefficient of the correction for self-shading
DADT(J)	Partial derivative of X-area with respect to time
DCDT(I,IA,J)	Partial derivative of concentration with respect to time
DCDX(I,J)	Array of values equal to the right hand side of the diffusion equation other than the source and sink terms
DEV	Seasonal temperature deviation (°C)
DIE(J)	Death rate coefficient for:
J=1	Algae (1/hr)
=2	Protozoa (1/hr)
=3	Zooplankton (1/hr)
=4	Higher predator (1/hr)
=5	Bacteria (1/hr)
DIFF	In verification, difference between an observed and predicted concentration (ppm)
DO2	Time step for integration DT/2

Variable	Definition
DO3	Time step for integration DT/3
DO15	Time step for integration DT/15
DT	Time step used in integration (hr)
DX	Length of each segment (mile)
DX12	DX • 12; variable used for integration of partial derivatives with respect to position
DX60	DX • 60; variable used for integration of partial derivatives with respect to position
DY(J)	Appears in subroutine First only - vector of first derivatives of the dependent variable with respect to the independent variable (DY/DX)
DZS	Step in time (hr)
E	Variable which adjusts oxygen reaeration rate constant as a function of temperature
EA(J)	Array containing the product of the diffusion coefficient and the X-area
EADJ	Adjustment to the diffusion coefficient dependent upon grid spacing, 1/DX
ERRSET	Subroutine built into the system which is part of the extended error message facility
F1	Proportion of organic carbon in land runoff

Variable	Definition
F3	Proportion of organic nitrogen in land runoff
F5	Proportion of nitrite and nitrate in land runoff
F6	Proportion of ortho-phosphate in land runoff
FAZ	Moon phase on initial time and day in computer operation
FIRST	Subroutine to integrate first partial derivative with respect to position
FRA(J)	Fraction of following components in sewage discharge:
J=1	Organic carbon
=2	Carbon dioxide
=3	Organic nitrogen
=4	Ammonia
=5	Nitrite and nitrate
=6	Phosphorus
FUNCT	Subroutine to estimate partial derivative of component concentrations with respect to time
FX(J)	Used in interpolation to determine values at grid points, printout points and verification points

Variable	Definition
FXX	Resulting interpolated value
FY	Intermediate interpolated value
GO	Coefficient in expression for tidal lag
G1	Coefficient of first order term in expression for tidal lag
G2	Coefficient of second order term in expression for tidal lag
GRO(J)	Constant in temperature expression for growth rate coefficient of:
J=1	Algae $(°C\text{-hr})^{-1}$
=2	Protozoa $(°C\text{-hr})^{-1}$
=3	Zooplankton $(°C\text{-hr})^{-1}$
=4	Higher predator $(°C\text{-hr})^{-1}$
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	Index to indicate which one of the steps in the integration the concentrations are for

Variable	Definition
IC	Number of components modeled
IDAY	Day of year simulated
IER	Variable exponent in expression to adjust time step depending upon integration accuracy
III	Number of days from the present to the next day of computer printout
IK	Grid point at which STP discharges enter. For verification purposes, it is the component number.
ILIST	Logic variable to determine if the Namelist option is exercised
INTP	Subroutine to interpolate variable values
IPDAY	Day of printout
IPOS	Grid point nearest actual observed data
IPRI	Logic variable to determine if punched output is required
IPT	Indicates the form of some input data
ITYPE	Defines input as a parameter or component
IWK2	Adjusts reaeration rate as a function of wind velocity
IZDAY	Initial day of year modeled
JA	Index to determine step of integration between t and t+Dt
JDAY	Day of year observed data available for verification

Variable	Definition
K(I,J)	Utility array
I=1	Diffusion coefficient (mi^2/hr)
=2	Benthal demand ($lb/mi^3 \cdot hr$)
=3	Average X-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 for protozoa ($lb/mi^3 \cdot hr$)
=13	Natural death rate for zooplankton ($lb/mi^3 \cdot hr$)
=14	Natural death rate for higher predator ($lb/mi^3 \cdot hr$)
=15	Recycle of organic carbon ($lb/mi^3 \cdot hr$)
=16	Recycle of inorganic carbon ($lb/mi^3 \cdot hr$)
=17	Recycle of organic nitrogen ($lb/mi^3 \cdot hr$)
=18	Recycle of organic phosphorus ($lb/mi^3 \cdot hr$)
=19	Growth rate for algae ($lb/mi^3 \cdot hr$)
=20	Growth rate for protozoa ($lb/mi^3 \cdot hr$)

Variable	Definition
=21	Growth rate for zooplankton ($lb/mi^3 \cdot hr$)
=22	Growth rate for higher predator ($lb/mi^3 \cdot hr$)
=23	Respiration rate for algae ($lb/mi^3 \cdot hr$)
=24	Respiration rate for protozoa ($lb/mi^3 \cdot hr$)
=25	Respiration rate for zooplankton ($lb/mi^3 \cdot hr$)
=26	Respiration rate for higher predator ($lb/mi^3 \cdot hr$)
=27	Total ecosystem respiration rate ($lb/mi^3 \cdot hr$)
=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 ($lb/mi^3 \cdot hr$)
=33	Natural death rate of bacteria ($lb/mi^3 \cdot hr$)
=34	Respiration rate for bacteria ($lb/mi^3 \cdot hr$)
=35	Growth rate for bacteria ($lb/mi^3 \cdot hr$)
=36	Maximum fractional deviation in X-area from the average at high or low tide
=37	Maximum tidal velocity (mi/hr)
=38	Tidal lag (hr)
K2	Indicates which reaeration equation to use

Variable	Definition
K2X	Constant in expression for oxygen reaeration coefficient (day^{-1})
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 ortho-phosphate (hr^{-1})
KM8	Michaelis-Menten or half saturation concentration of substrate for algae (lb/mi^3)
KM9	Michaelis-Menten or half saturation concentration of substrate for protozoa (lb/mi^3)
KM10	Michaelis-Menten or half saturation concentration of substrate for zooplankton (lb/mi^3)
KM11	Michaelis-Menten or half saturation concentration of substrate for higher predator (lb/mi^3)
KM12	Michaelis-Menten or half saturation concentration of substrate for bacteria (lb/mi^3)

Variable	Definition
KP	Logic variable to determine if punched output requested on final day of computer operation
LIST1	Name of the Namelist
LOG	Logic variable determining regular output (=1) or a comparison with observed data (=0)
LOGUP	Logic variable to indicate type of update:
=1	for initial definitions before solution begins
=2	for daily update
=3	for minute to minute update
MDAY	Final day of year of computer operation
NC	Parameter or pollutant number in array K(NC,J)
NCOEF	Number of estuary segments at which volumetric freshwater flow rate will change
ND	Determines positions of printed concentration output
NDATA	Total number of data values used in verification
NHSEC	Number of .01 seconds between printout
NM	Number of grid points

Variable	Definition
NN	Number of estuary sections
NO2NO3	Boundary condition of nitrite and nitrate (ppm)
NV(J)	Array of the component used in verification
NVIK	Specifies which component is being compared with the observed data
OSAT, O2SAT	Saturation concentration of oxygen, as a function of temperature (lb/mi^3 or ppm)
PHASE	Tidal phase
POS	Position at which observed data taken (mile)
POSIT	Position at which parameter or pollutant values are known (mile)
PRED(J)	Constant of linear temperature expression for the predation rate coefficient on:
J=1	Algae (1/°C·ppm·hr)
=2	Protozoa (1/°C·ppm·hr)
=3	Zooplankton (1/°C·ppm·hr)
=4	Higher predator (1/°C·ppm·hr)
=5	Bacteria (1/°C·ppm·hr)
PRED8	Algae predation rate coefficient $(lb/mi^3 \cdot hr)^{-1}$
PRED9	Protozoa predation rate coefficient $(lb/mi^3 \cdot hr)^{-1}$

Variable	Definition
PRED10	Zooplankton predation rate coefficient $(lb/mi^3 \cdot hr)^{-1}$
PRED11	Higher predator predation rate coefficient (hr^{-1})
PRED12	Bacteria predation rate coefficient $(lb/mi^3 \cdot hr)^{-1}$
PRI	Number of printouts per tidal cycle
PRIE	Maximum allowable error between specified and actual printout time
Q	Volumetric flow rate (cfs)
R	Factor multiplied to maximum growth rate of algae due to non-optimum sunlight intensity
RELE	Allowable relative error of integration through time
RES(J)	Constant in the temperature expression for:
J=1	Algae respiration rate coefficient $(°C \cdot hr)^{-1}$
=2	Protozoa respiration rate coefficient $(°C \cdot hr)^{-1}$
=3	Zooplankton respiration rate coefficient $(°C \cdot hr)^{-1}$
=4	Higher predator respiration rate coefficient $(°C \cdot hr)^{-1}$

Variable	Definition
=5	Bacteria respiration rate coefficient (°C hr)$^{-1}$
RESP8	Respiration rate coefficient for algae (hr^{-1})
RESP9	Respiration rate coefficient for protozoa (hr^{-1})
RESP10	Respiration rate coefficient for zoo-plankton (hr^{-1})
RESP11	Respiration rate coefficient for higher predator (hr^{-1})
RESP12	Respiration rate coefficient for bacteria (hr^{-1})
RKMI	Subroutine to evaluate partial derivative of component concentrations with respect to time
RR	Ratio of sunlight intensity to optimum sunlight intensity
S	Conversion factor for ppm to lb/mi^3; 1ppm=9.19×10^6 lb/mi^3
SS	Sum of squares of error in verification
STORE	Subroutine to read and store data
SUM	Sum or errors in verification
SUN	Daily sunlight totals (langleys)
SUNMAX	Maximum instantaneous sunlight intensity

Variable	Definition
SUNSAT	Optimum sunlight intensity
T	Real time of model operation (hr)
TDATA	Time at which actual data was taken
TEMP	Water temperature (°C)
TI	Initial time of day
TIDE	Time of high tide on first day of model operation (hr)
TITLE(J)	Array of names of the parameter read as input data
TIMON, TIMECK	Internal system subroutines to determine CPU time for a certain amount of processing
TIC	Boundary condition for inorganic carbon (ppm)
TM	Final time of final day (hr)
TMAX	Maximum number of computer minutes allotted to run
TMIN	Machine time used
TON	Boundary condition for organic nitrogen (ppm)
TOC	Boundary condition for organic carbon (ppm)
TPO4	Boundary condition for ortho-phosphate (ppm)
TPR	Hour of day requiring output

Variable	Definition
TQQ	Measure of error in integration through time
UA(J)	Array of 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 to calculate fluid velocity
VOLUM	Subroutine to calculate volumetric flow rate
WF	Period of the sine function used in expressions for point source discharge and sunlight intensity (hr^{-1})
WORK,WORK1,WORK2	Utility matrices used in integration, interpolation and reading in initial values
WT	$=2\Pi$, required for tidal and temperature expressions
XI	Upstream boundary (miles)
XK2	Variable to allocate user expression for oxygen reaeration (day^{-1})

Variable	Definition
X11	Organic carbon utilization rate coefficient at 20°C/day
X36	Ortho-phosphate utilization rate co-efficient at 20°C/day
XO	Downstream boundary (miles)
XPOS(I)	Array of grid point positions (mile)
XP2	The square of XPOS
XQ	Volumetric freshwater flow rate (mi^3/hr)
XQCOEF(I)	Array to increase value of XQ by a multiplicative constant as XPOS increases
XSEC	Number of sec/real time day
XXX	Product of light extinction coefficient and water depth--needed to calculate sunlight intensity
XY	Concentration of the growth limiting substrate in the Michaelis-Menten expression
YYY	Constant in the time step determination expression
Z(I)	Array to specify at which grid points the volumetric flow rate will increase

IV. PROGRAM LOGIC

Although a piece by piece breakdown of GEM is beneficial with respect to understanding the purpose of each subroutine, there is still need to explain the operation of the program as a combined unit.

MAIN depends on the user to define all listed variables which are subject to change for each estuary modeled. A description of these variables is supplied via comment cards in the main program and further elaboration is given in Section 6.1. Once this information is obtained, MAIN calls upon SCHOFI to begin the program loop by reading the data. SCHOFI, in turn, calls upon RKMI for initial evaluation of the component concentrations. In order to perform the Runge-Kutta-Merson technique of integration, UPDATE is called three times and FUNCT is called five times. With each call to FUNCT, subroutines AREA, VELOC, VOLUM and FIRST are called for aid in determining the value of the component concentrations with respect to time. This particular integration method has a variable step size in time whose magnitude is dependent upon the degree of accuracy of the solution. In fact, it is the integration accuracy which determines the next step taken. The integration technique provides an estimate of the maximum solution error (observed error) at each step. It is a function of the partial derivative of component concentrations with respect to time. A maximum allowable absolute error which is a function of the component concentrations is also defined, and the ratio (observed error/allowable error) is formed. If the observed error is less than 10% of the allowable error, the step size (DT) is increased by 3%. If the observed error is 10% to 100% of the allowable error, DT remains unchanged; between 100% and 200%, DT is decreased by 3% and the integration is accepted. When the observed error is more than 200% of the allowable error, the integration is rejected and the time step DT is reduced by the following formula:

$$DT_{NEW} = DT_{OLD} \times .97^{K}$$

where K is the maximum integer less than or equal to the ratio of the observed error to the allowable error. A maximum value of 3 was established for K to prevent DT from becoming much smaller than necessary for a convergent solution. It should also be noted that an upper bound has been placed on DT to prevent temporal instability. When the error exceeds 200%, SCHOFI will call UPDATE and FUNCT and the program loop will be repeated. Otherwise subroutine Output is called to decide whether verification is necessary, to print and/or punch output, or to continue the operation with a return to SCHOFI. Once all specified days are modeled and the results printed, SCHOFI returns to MAIN to cease execution.

A flowchart portraying the operational logic of GEM is illustrated in Appendix III-15.

V. PROGRAM DATA REQUIREMENTS

In order to adequately model an estuary, GEM requires a variety of both physical and chemical data. This information may be categorized into hydrological, geometrical, meteorological and water quality data.

5.1 Hydrological Data

A description of flow in a one-dimensional dynamic model includes information concerning the freshwater flow rate, the tidal phase lag and the maximum tidal velocity. A regression analysis was performed on collected data from different estuaries and the following expression for maximum tidal velocity was developed:

$$MTV = A_0 + A_1X + A_2X^2 + A_3X^3 + A_4X^4$$

where

MTV - maximum tidal velocity (mi/hr)

A_0, A_1, A_2, A_3, A_4 - appropriate constants

X - position (mi)

The values for the constants vary with each estuary modeled and are dependent upon some or all possible combinations of the following factors: the estuary width, depth, roughness, instantaneous water surface elevation with respect to a reference water level, lateral discharge per unit of longitudinal length, non-tidal freshwater flow and perhaps other features relative to a particular watershed. Similarly, a study on the tidal phase lag yielded the following general equation:

$$L = G_0 + G_1X + G_2X^2$$

where

L - phase (hr)

G_0, G_1, G_2 - appropriate constants

X - position (mi)

As in the first equation, the values of the constants change with each estuary studied and these values in both expressions can usually be estimated from information given in tide table surveys on a specific estuary.

5.2 Geometrical Data

The basic geometric parameters of an estuary must be known. These parameters are the average cross-sectional area, the maximum fractional deviation of cross-sectional area at high or low tide and the water depth. The collected hydrological and geometrical data are then used in two expressions to determine cross-sectional area and fluid velocity at any time and position in the estuary. These expressions are in subroutines AREA and VELOC, respectively.

5.3 Meteorological Data

Daily sunlight intensity totals (langleys) and moon phase on the initial day modeled are the only meteorological data requirements. The sunlight totals are used in the calculation of instantaneous surface intensity found in subroutine UPDATE. This solar intensity data relates to the growth rate and population of algae. The position of the moon affects not only the time of the tides but also the height and mass of water involved in the tidal current.

5.4 Water Quality Data

In order to determine sewage input, the location and discharged amount of point and line sources must be known as well as the nutrient composition of the effluent. Boundary conditions for the five biological components are given default values in the BLOCK DATA subprogram, but should be changed through the Namelist option (discussed in section 6.2) if more precise information is available. Also, if an estuary study is conducted which permits the generation of expressions for reaction rate coefficients or other necessary modeling parameters, they should be used in place of the existing expressions found in subroutine UPDATE. Modifications can only result in increasing the accuracy of the model's predictions. GEM is written to allow for temperature corrections of rate constants. To obtain an estimate of the turbulent diffusion coefficient, the user must know the estuary fluid velocity (ft/sec) and hydraulic radius or estuary depth (ft). The estimating equation for diffusivity is located in subroutine FUNCT. Replacement of the equations pertaining to the preceeding data requirements by more suitable expressions should be carried out wherever possible. The present formulations should not be permanently employed since the use of mathematical models requires continuous updating of parameter values and expressions to yield more precise predictions.

VI. INPUT DATA REQUIREMENTS

All input data required for the operation of GEM is supplied in card form either in program segment MAIN or at the end of the deck. The program is set up in such a way as to enable cards to be read on units 5, 8 and 9; however, the majority of the data is read on unit 5. Cards read on unit 8 serve only model verification purposes while those read on unit 9 pertain only to the Namelist option.

6.1 Data Supplied Through MAIN

The purpose of MAIN is to provide all information specific to each estuary modeled so that the user will not have to make any internal program adjustments. The user needs to be concerned only with basic input data which has no special format since it appears in the form of executable statements in the main program itself. Users are not restricted to this procedure and should take the liberty of changing any of the internal program formulations, providing such action yields a more representative description of the estuary being modeled.

The first thirteen cards in MAIN contain the essential data required for the solution as follows:

Card 1: NN = Number of sections in estuary ($1 \le NN \le 199$)

2: XI = Upstream boundary (mile)

3: XO = Downstream boundary (mile)

4: TI = Initial time of day (hour)

5: IDAY = Initial time of year

6: TM = Final time of day (hour)

7: MDAY = Final day of year

8: PRI = Number of printouts for each tidal cycle

9: IC = Number of pollution components modeled

10: TIDE = Time of high tide on initial day

11: FAZ = Moon phase at initial time and day

12: TMAX = Number of minutes authorized for computer run

13: KP = Logic variable used to choose punched output on final day: KP=∅, No; KP≠∅, Yes.

Cards fourteen and fifteen allow the user to choose one of several equations for determining the oxygen reaeration rate (K_2) accordingly:

Card 14: K2=1

Card 15: XK2=∅

The above specification uses the formula

$$K_2 = \frac{12.9\ u^{1/2}}{H^{3/2}} \qquad (14)$$

where

u - tidal velocity (fps)

H - depth (ft)

which applies to estuary depths of 1-30 feet and velocities of .5-1.6 feet per second. This formulation is used to describe the reaeration rate of both the Potomac and the James River Estuaries.

Card 14: K2=2

Card 15: XK2=∅

This particular choice opts the equation (4)

$$K_2 = \frac{11.6\ u}{H^{1.67}}$$

which should be applied to estuary depths of 2-11 feet and velocities of 1.8-5.0 feet per second.

Card 14: K2=3

Card 15: XK2=Ø

The above designation calls on the formula (15)

$$K_2 = \frac{21.6\ u^{0.67}}{H^{1.85}}$$

which pertains to estuary depths of 4-11 feet and velocities of .1-5.0 feet per second.

Card 14: K2=4

Card 15: XK2=Ø

This selection should be chosen for an estuary which does not fall into any of the three categories above. It uses the expression (13)

$$K_2 = \frac{(D \cdot u)^{.5}}{H^{1.5}}$$

where

D - diffusivity of oxygen in water (.000081 ft^2/hr)

Card 14: K2=Ø

Card 15: XK2=user expression or numerical value

The above specification allows the user to ignore all of the given formulas for reaeration and apply his own expression or numerical value. A reliable range of values for K_2 is 0-100/day. When employing a particular equation, the user must define all variables in 'common' throughout the program. The reaeration rate as a function of wind velocity is related by the variable IWK2 on card sixteen. Increasing

K_2 rates by 25% compensates for a 10-knot wind. Values should be assigned to the variable IWK2 as follows:

Card 16: IWK2=Ø for no wind

=1 for a 10 knot wind

=2 for a 20 knot wind

=3 for a 30 knot wind

=4 for a 40 knot wind

=5 for a 50 knot wind

=6 for a 60 knot wind

Cards seventeen to twenty-one pertain to the coefficients in the following expression for maximum tidal velocity:

$$MVT = A_0 + A_1X + A_2X^2 + A_3X^3 + A_4X^4$$

where

MVT - maximum tidal velocity (mi/hr)

A_0, A_1, A_2, A_3, A_4 - appropriate constants

X - position (mi)

The values of these constants must be derived from data collected. For example, in a study of the James River Estuary, the following coefficient values were evaluated:

Card 17: AØ = .58ØØ2

18: A1 = .Ø55Ø658

19: A2 = -.ØØØ457297

20: A3 = -.ØØØØØ731172

21: A4 = .ØØØØØØØ751213

Cards twenty-two to twenty-four deal with the coefficients in the formula for tidal lag:

$$L = G_0 + G_1X + G_2X^2$$

where

L - tidal phase lag (hr)

G_0, G_1, G_2 - appropriate constants

X - position (mi)

The value of these coefficients must be developed from the geometrical and hydrological data collected from each particular estuary. Modeling the James yielded these values:

Card 22: GØ = 7.2211

23: G1 = -.Ø415148

24: G2 = .ØØØ415578

Cards twenty-five to forty-five pertain to data input used in the determination of the volumetric freshwater flow rate (XQ) as a function of position. The flow rate tends to increase in the downstream direction due to various hydrological considerations. In reference to GEM, XQ is made to increase by a multiplicative constant (XQCOEF(I)) at specific grid point positions (Z(I)). These values are chosen by the user who shall also indicate the number of estuarine subdivisions (NCOEF) at which he expects a change in the flow rate. NCOEF must be assigned a minimum value of one, to indicate that no increase in XQ is expected throughout the estuary reach, and a maximum value of ten, to indicate that ten different increases in the volumetric flow rate are expected. It should be clear that NCOEF is free to assume any other integer value between one and ten. The arrays XQCOEF(I) and Z(I) each consist of ten parts, corresponding to the ten possible subdivisions determined by NCOEF. An example as applied to the James will help to clarify the function of the variables mentioned above.

Card 25: NCOEF = 2

26: Z(1) = 2Ø.Ø

27: XQCOEF(1) = 2.Ø

28: Z(2) = 45.Ø

29: XQCOEF(2) = 5.Ø

30: Z(3) = Ø.Ø

31: XQCOEF(3) = Ø.Ø

32: Z(4) = Ø.Ø

33: XQCOEF(4) = Ø.Ø

34: Z(5) = Ø.Ø

35: XQCOEF(5) = Ø.Ø

36: Z(6) = Ø.Ø

37: XQCOEF(6) = Ø.Ø

38: Z(7) = Ø.Ø

39: XQCOEF(7) = Ø.Ø

40: Z(8) = Ø.Ø

41: XQCOEF(8) = Ø.Ø

42: Z(9) = Ø.Ø

43: XQCOEF(9) = Ø.Ø

44: Z(10) = Ø.Ø

45: XQCOEF(10) = Ø.Ø

In this case, the value of 2 on card #25 indicates an expectation of two changes in the volumetric freshwater flow rate. Accordingly, Z(1) and XQCOEF(1) are indicative of an expectation of the flow rate doubling at the twentieth grid point. The variables Z(2) and XQCOEF(2) indicate that at the forty-fifth grid point, the flow rate will increase by a factor of five. Since NCOEF=2, Z(3), XQCOEF(3), Z(4), XQCOEF(4),..., Z(10), XQCOEF(10) are all equated to zero. In the event that five changes in the flow rate were expected at various grid point positions, NCOEF would equal five, Z(1), XQCOEF(1), Z(2), XQCOEF(2),..., Z(5), XQCOEF(5) would be specified as five different grid point positions coupled with an appropriate multiplicative constant and Z(6), XQCOEF(6), Z(7), XQCOEF(7),..., Z(10), XQCOEF(10) would all be designated as zero. In order to insure proper program operation, the grid point numbers assigned to Z(I) must appear in ascending order.

The program listing which appears in Appendix II is included as an aid to the user in visualizing the discussion given in this section. The numbers which appear in the main program segment have been chosen specifically for application to the James River Estuary and do not represent general values for modeling other estuaries.

6.2 Data Supplied Behind Program Deck

The remaining input data provided by the user is positioned after the program deck. The first twelve cards required in this section identify the twelve parameters considered in the model. The complete titles of these parameters (see section 2.1) must be punched between CC1 (card column one) and CC40. They are:

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

The next eighteen sets of input data must each be preceded by a "header card" which identifies the parameter and the form of the data to be read. The parameters considered in the following order are cross-sectional area (mi^2), sewage input (lb/day), benthal demand ($lb/mi^3 \cdot hr$), land runoff ($lb/mi^3 \cdot hr$), maximum fractional deviation of cross-sectional area, estuary depth (ft) and the concentrations of the twelve components (ppm). The header card categorizes this data and follows the form below with format (3I5, 5X, 10A4).

1. CC1-5 identifies the value of IPT which indicates the form of the data.

IPT	= 1	point source discharge
	= 2	constant within a segment
	> 2	continuous

2. CC6-10 identifies the variable NC which indicates the particular parameter or pollutant to be considered.

3. CC11-15 identifies ITYPE whose chosen value distinguishes between a parameter or a pollutant.

   ITYPE = 1 for a parameter

   = 2 for a pollutant

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

If IPT=1, the cards to follow will each contain a value in units of lb/day and a position in terms of miles with format (2E20.5). Reading will terminate when a negative position appears. Figure VI-1A illustrates a sample header card where IPT=1 indicating a point-source discharge, NC=28 indicating an average pollution discharge rate (see K(28,J) in section 3.15) and ITYPE=1 indicating a parameter description which is identified by the characters 'SEWAGE INPUT' in CC21-60. (Refer to program listing for illustration of data.) In this model, sewage input is the only point source discharge considered. In general, however, all industrial effluents, municipal wastes and river point source discharges would fall into this category.

If IPT=2, the proceeding data cards will each contain a value and a position in miles with format (2E20.5). The grid points which fall between the last position read and the new position are assigned the previously specified value. Reading terminates when a position less than or equal to zero is encountered. Figure VI-1B shows a sample header card with IPT=2 indicating a value which is constant within a segment, NC=6 indicating land runoff in lb/mi^3·hr (see K(6,J) in section 3.15) and ITYPE=1 indicating a parameter which is identified by the characters 'LAND RUNOFF' in CC21-60. (See program listing for illustration of data). Benthal demand, land runoff and maximum fractional deviation of cross-sectional area fall into this category.

If IPT>2, the cards to follow will contain continuous data. The numerical value of IPT determines the number of value-position (miles) pairs to be read. Each data card must include four pairs of data with format (8F10.6). Figure VI-1C illustrates a sample header card with IPT>2 indicating continuous data, NC=12 indicating bacteria concentration (see C(12, IA, J) in section 3.15) and ITYPE=2 indicating a pollutant which is described by the characters 'BACTERIA' in CC21-60. (See program listing for illustration of data). Examples of data sets appearing in this category are estuary depth, cross-sectional area and all component initial conditions. Immediately following the eighteenth data set in this section is a blank card which indicates completion of the reading of parameters.

The next set of cards read each contain data including the daily water temperature, volumetric flow rate, daily sunlight total, and the options to request punched card output, exercise the Namelist, and call for plotted data of the twelve components. Each day modeled requires a card with the preceding information in format (3F10.4, 20X, 3I5) as follows:

Variable	Card Columns
Water temperature (°C)	1-10
Volumetric flow rate (cfs)	11-20
Daily sunlight totals (langleys)	21-30
Skip 20 spaces	31-50
Punch option	51-55
Namelist option	56-60
Plot option	61-65

Since every day modeled calls for a card with the above information, the number of cards in this data segment corresponds to the number of days modeled. (See program listing for illustration of sample data). The user may choose to omit reading in values for water temperature, in which case they will be determined by an expression internal to the program. (See program listing--subroutine UPDATE). The number one in CC55 orders the computer to punch the component concentrations for that day. Any integer value other than zero in CC56-60 exercises the Namelist option to be explained later. Any integer value other than zero in CC61-65 calls for plotted output of the twelve component concentrations for that day. Figures 1-12 in Appendix I illustrate plots of the constituent concentrations for a typical day modeled.

The upcoming data set must be preceded by a job control language (JCL) card to designate commencement of reading on unit 8. The user should refer to the JCL manual for whatever system is available to him as to the contents of this card. Cards read on unit 8 serve only model verification purposes. A card is read for each position and

and time data was collected. Each card has the format (I5, F5.0, F5.2, 5X, 6 (I2, F8.3)), and includes:

Variable	Card Column
Day of the year	1-5
Time (hr)	6-10
Position (mi)	11-15
Blank	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

This set is immediately followed by a blank card specifying the end of the data set to be read. The user should realize that if model verification is not to take place, the afore mentioned data set is simply omitted.

The last segment corresponds to the Namelist option if selected by the user on one or more of the daily modeling data cards previously read. It means that the user has expressed a desire to update certain parameter values by reading a card on unit 9. Preceding this data set is a JCL card specifying that the upcoming values are to be read on unit 9. Again, to determine the contents of this card the user should refer to the JCL manual for the system applicable to him. All variables included in the Namelist (see program listing--subroutine SCHOFI) are subject to change. A new list can be read daily dependent upon the Namelist option value read that day. If the user exercises this option, he must punch the following card(s):

The first character must be blank. CC2 must be an ampersand (&) followed by the Namelist name (LIST1) in CC3. The next space must be blank. The end of the data associated with the Namelist is signaled by the characters "&END". Between the characters &LIST1 and &END, there should appear the combination

variable name = constant

for each value that is to be read. Each combination must be followed by a comma if there is more than one. If values are being read into an array, the array name should be written without subscripts, followed by an equal sign and values for all of the array elements written and separated by commas. Figure VI-1D illustrates a sample Namelist data card.

6.3 Obtaining Required Data

Before computer operation of GEM begins, the user must have all the data discussed in Section V. What he is not expected to know is the component concentrations. The header cards pertaining to this information must be present, however, followed by zero concentration value-position pairs on each card. Starting from the zero mile point and incrementing by the fraction $\left(\frac{\text{length of estuary}}{\text{\# of grid pts}}\right)$ up to the last mile point yields the correct position values corresponding to the grid points in miles. That is, all component concentrations are set equal to zero at the appropriate mile points. Next the model is run for approximately 15 minutes (computer time) or 30 days at which time pseudo-steady-state or equilibrium will be reached. The user is to request punched output on this last day of simulation, yielding predicted

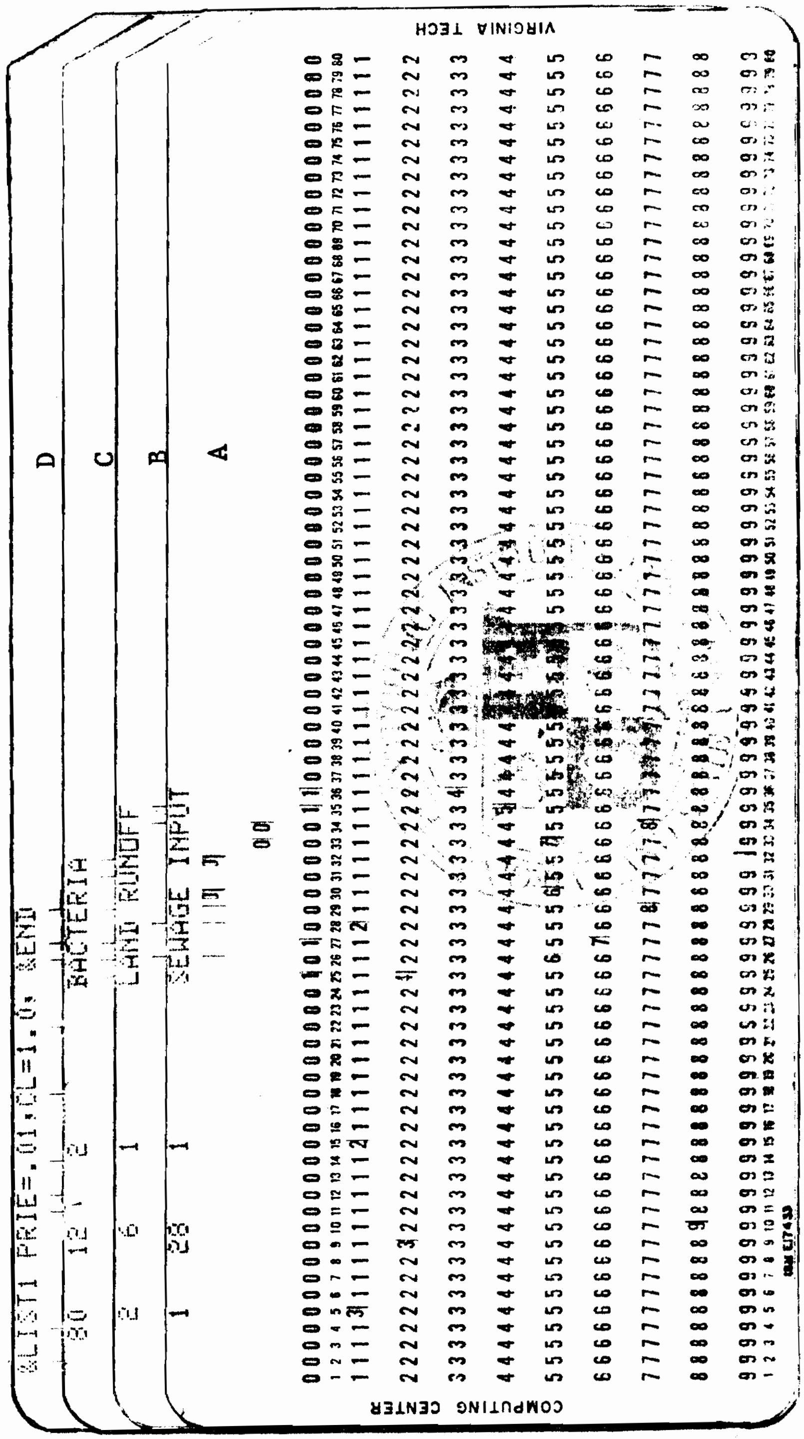

FIGURE VI-1. SAMPLE FORTRAN CARDS

data for the constituent concentrations at the beginning of pseudo-steady-state conditions. The pollution concentrations contained on the punched cards are already properly formatted and should be used as input for subsequent runs.

RECOMMENDATIONS

1. As the program stands, there is a strict ordering of the component concentration data; hence, all twelve components must be modeled. The expressions representing the pollutant concentrations, modeling parameters and reaction rates should be altered to enable the user to model as few or as many pollutants desired irrespective of their order.

2. It is recommended that the model be adjusted to enable continuous operation after the initial 30 day equilibrium has been reached. This would delete the chore of requesting punched output of the predicted pollution concentrations at the beginning of pseudo-steady-state conditions and making a second computer run.

3. It would also be helpful to modify the program in such a way that the predicted and observed concentrations of the same pollutant be plotted on one graph for visual inspection.

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APPENDIX I

PLOTS

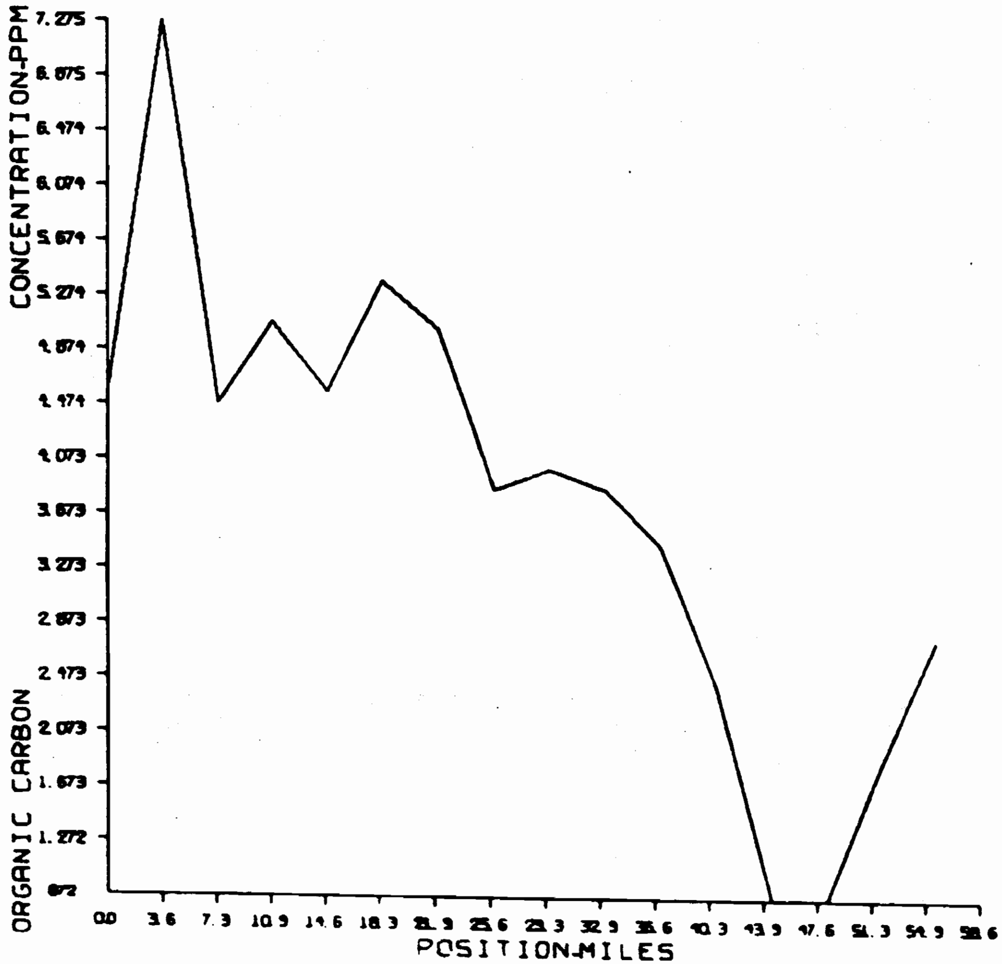

FIGURE 1. ORGANIC CARBON CONCENTRATION (ppm) FOR FIRST DAY MODELED

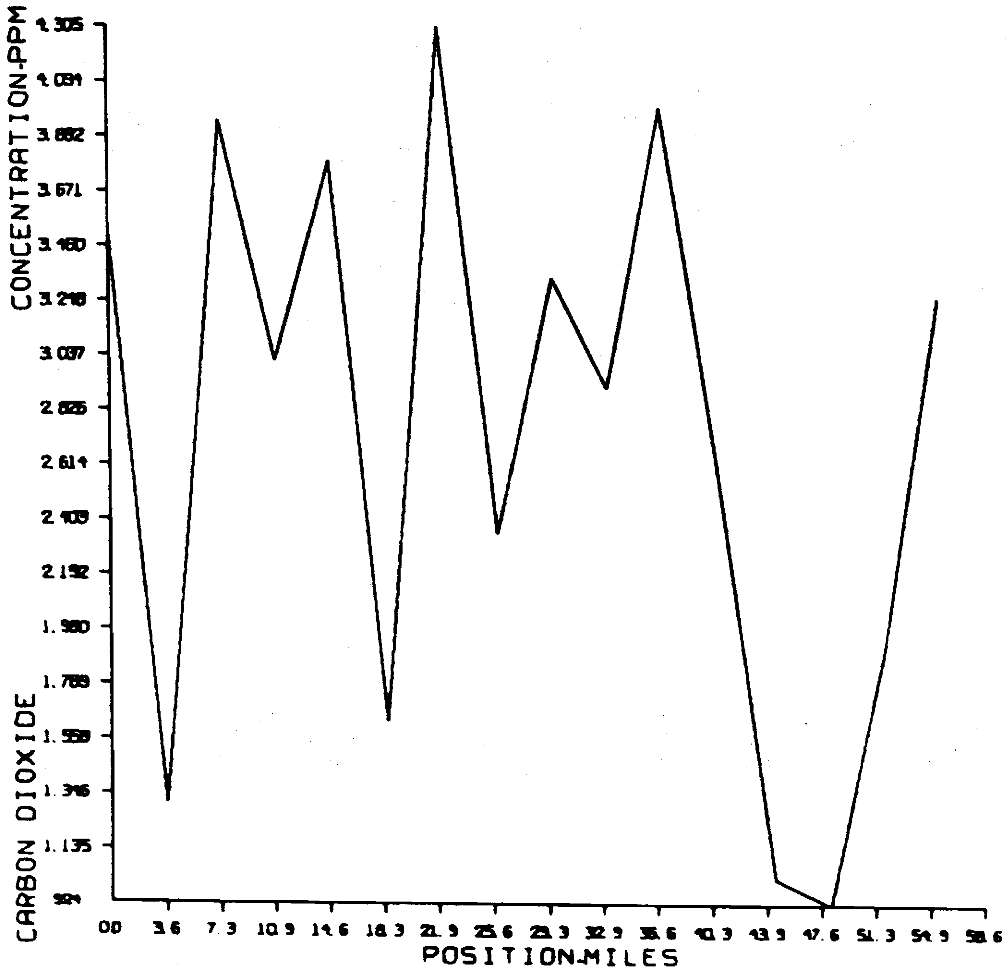

FIGURE 2. CARBON DIOXIDE CONCENTRATION (ppm) FOR FIRST DAY MODELED

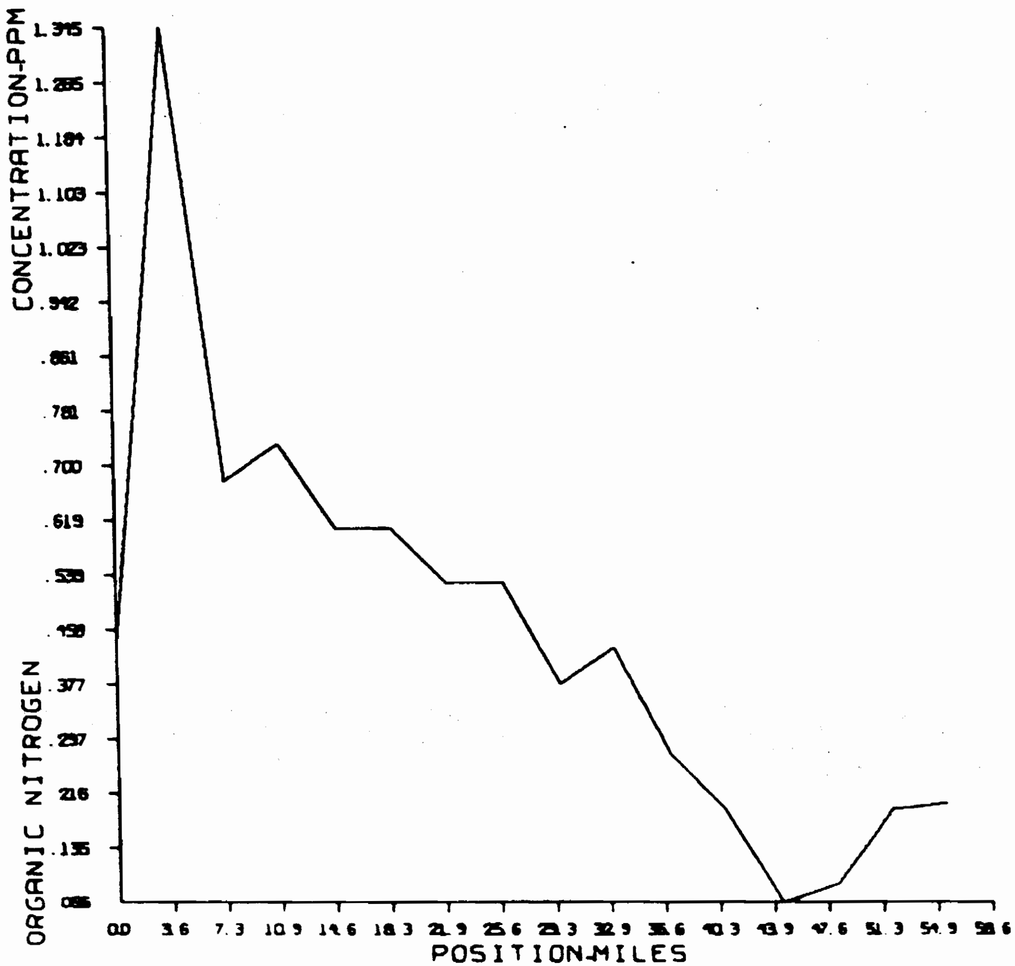

FIGURE 3. ORGANIC NITROGEN CONCENTRATION (ppm) FOR FIRST DAY MODELED

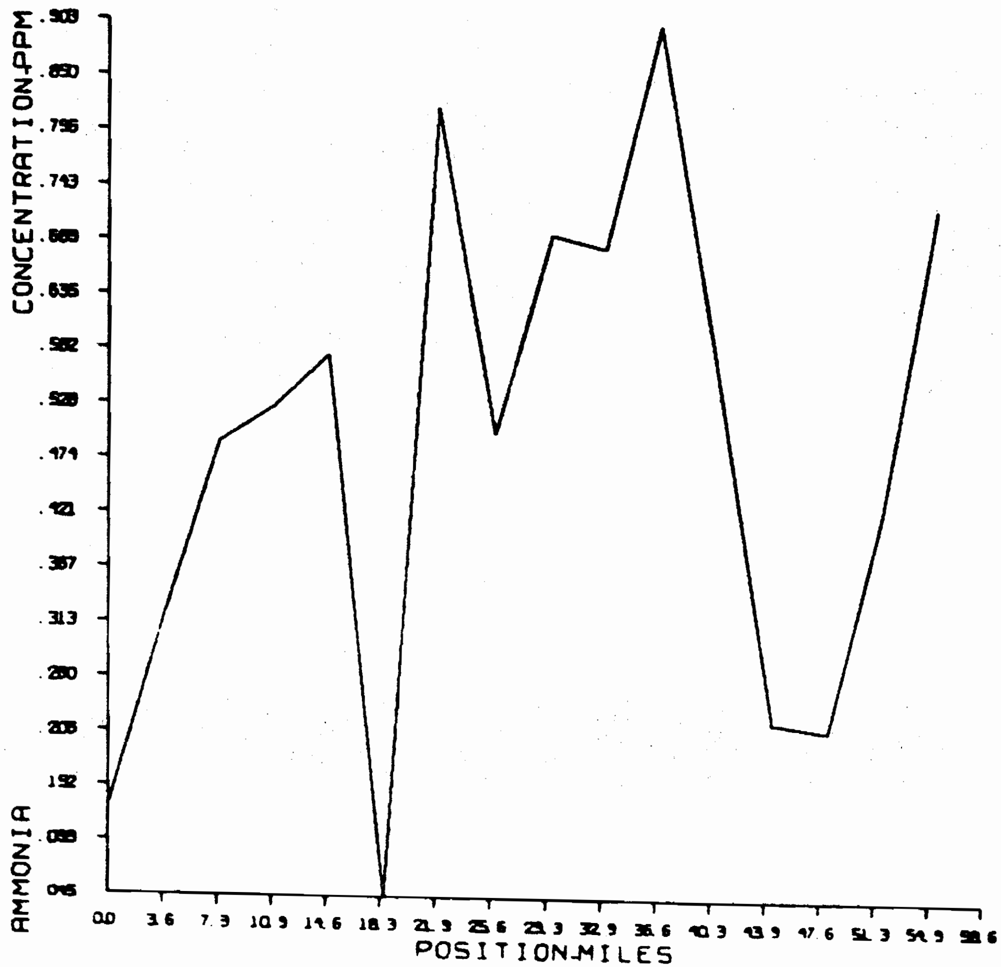

FIGURE 4. AMMONIA CONCENTRATION (ppm) FOR FIRST DAY MODELED

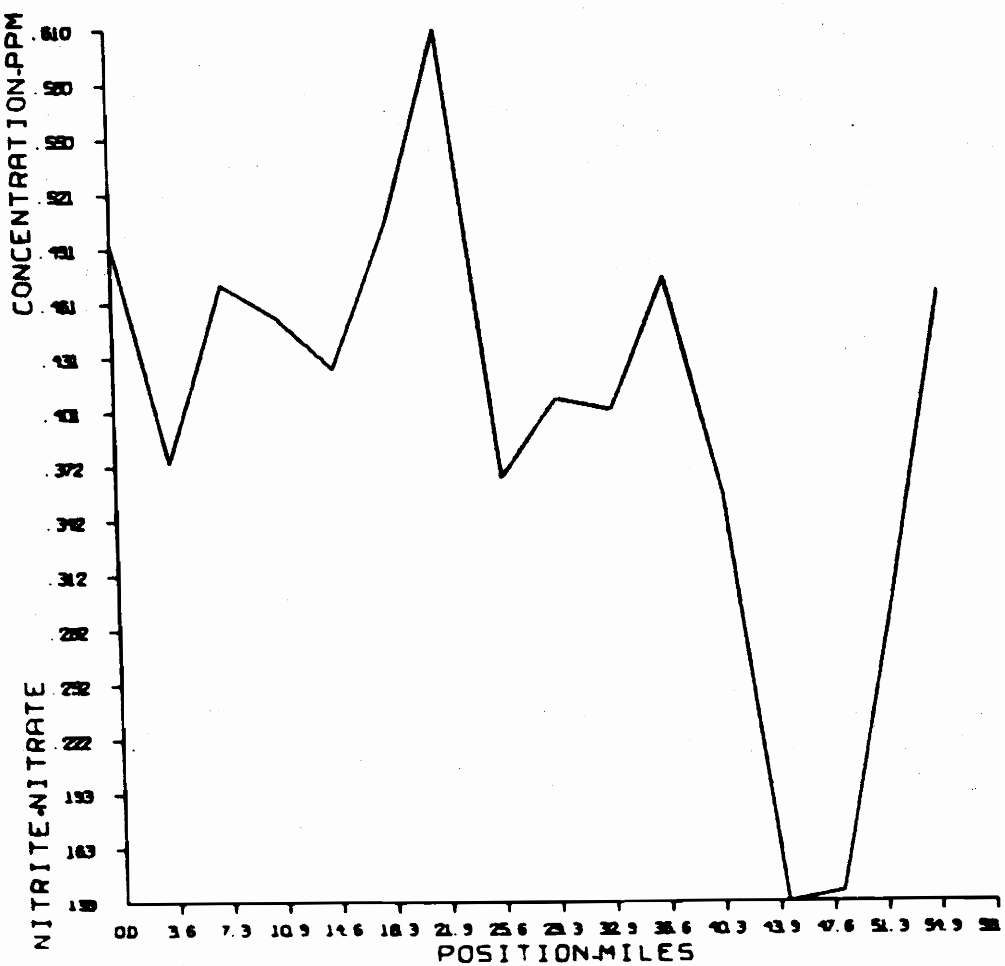

FIGURE 5. NITRITE AND NITRATE CONCENTRATION (ppm) FOR FIRST DAY MODELED

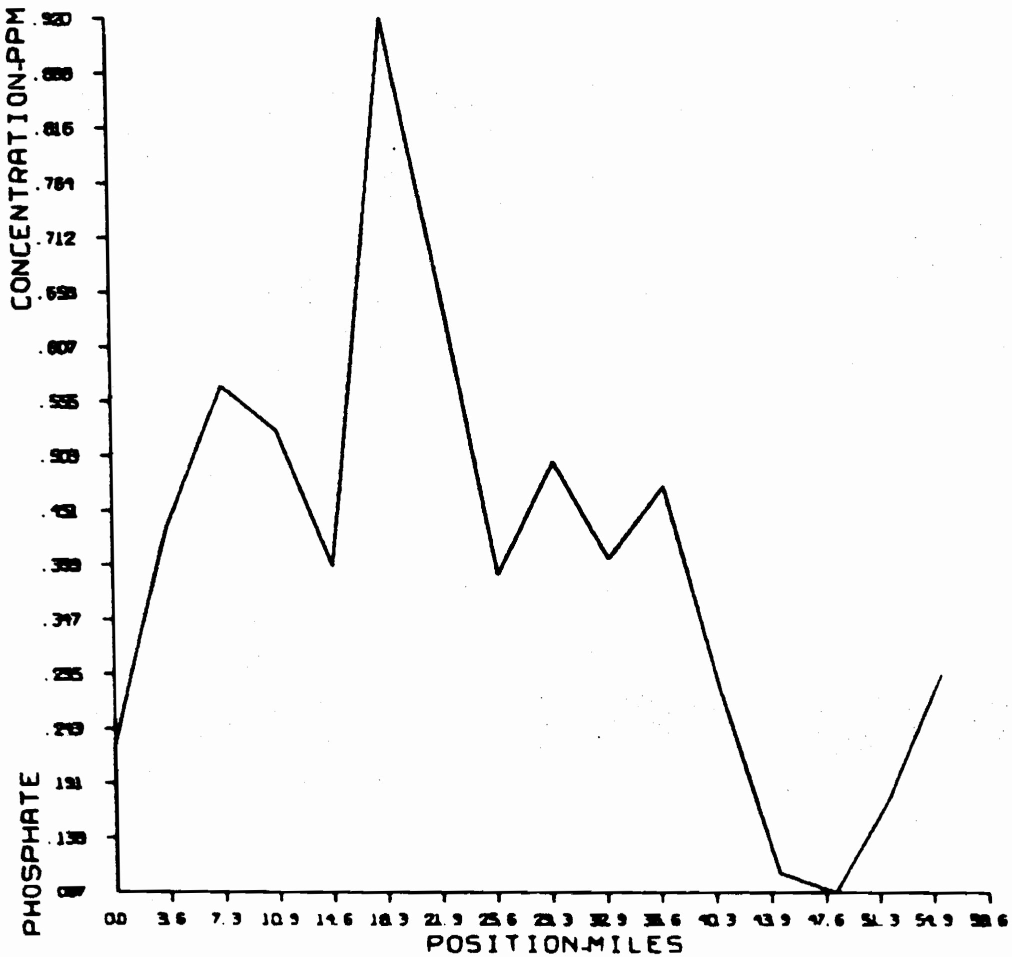

FIGURE 6. PHOSPHATE CONCENTRATION (ppm) FOR FIRST DAY MODELED

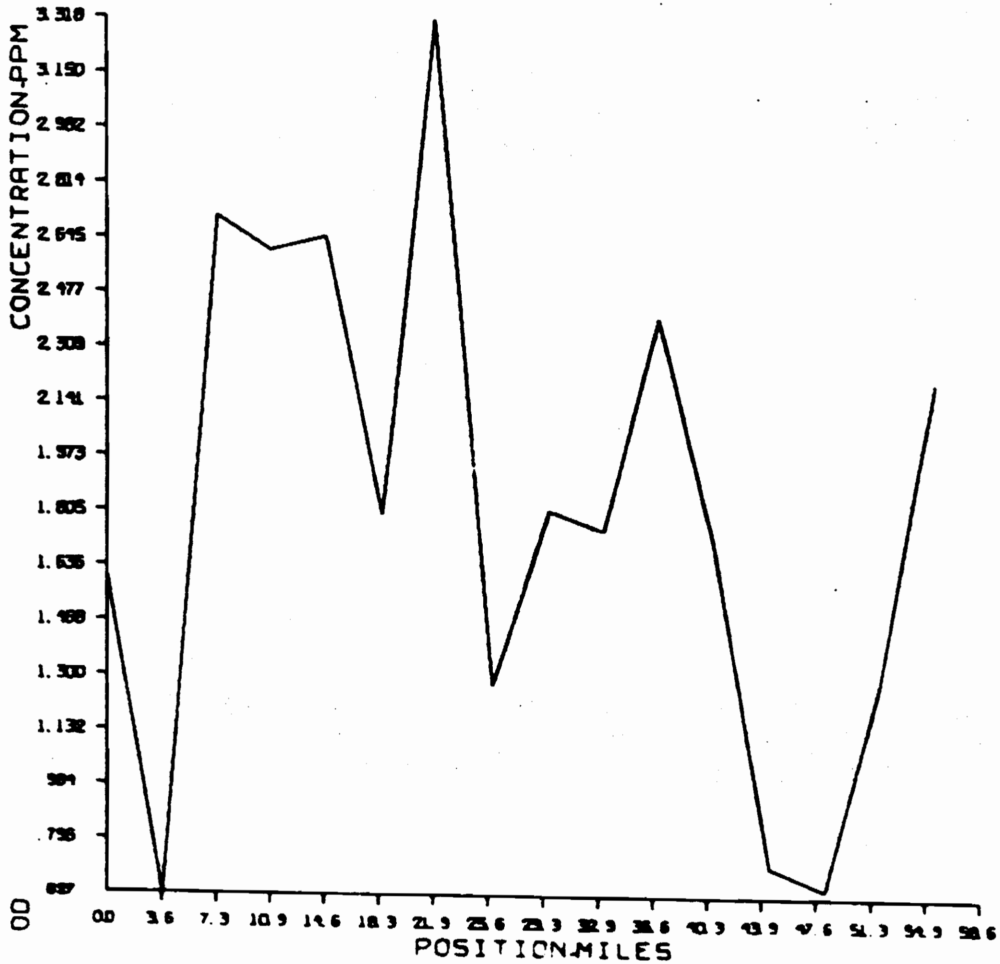

FIGURE 7. OXYGEN DEFICIT CONCENTRATION (ppm) FOR FIRST DAY MODELED

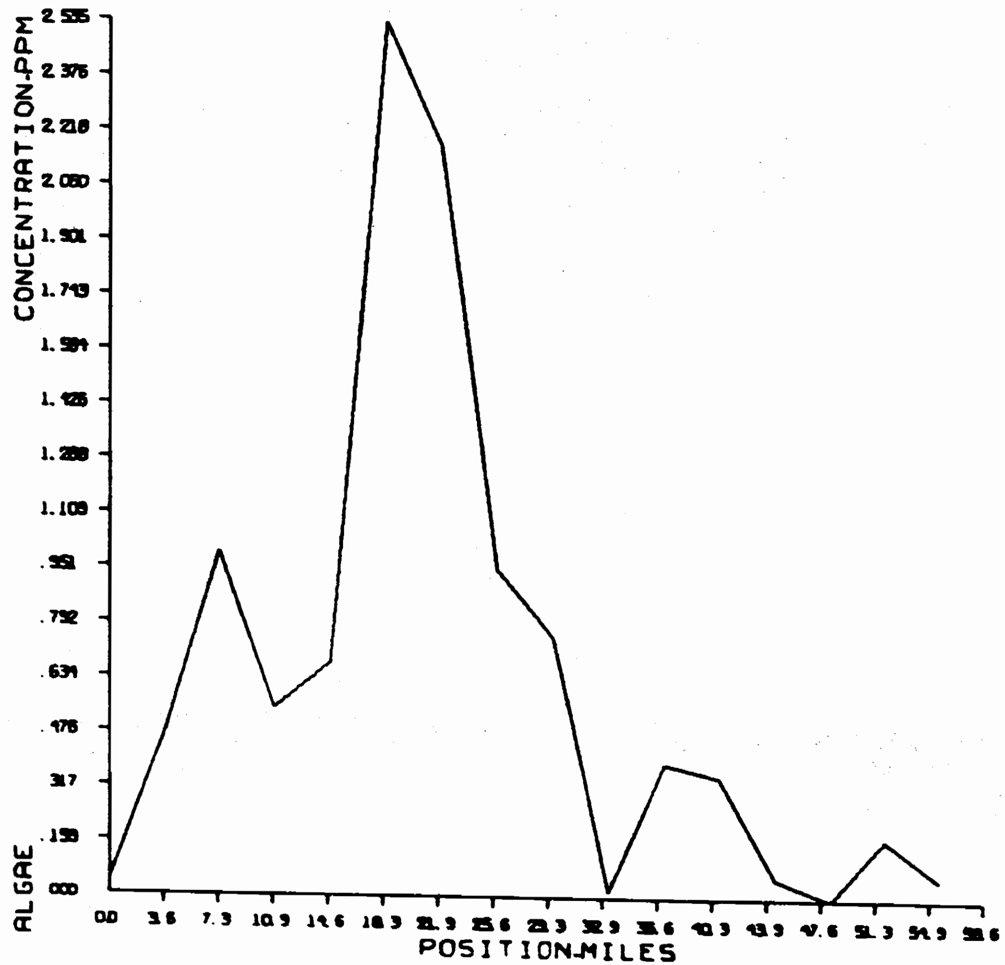

FIGURE 8. ALGAE CONCENTRATION (ppm) FOR FIRST DAY MODELED

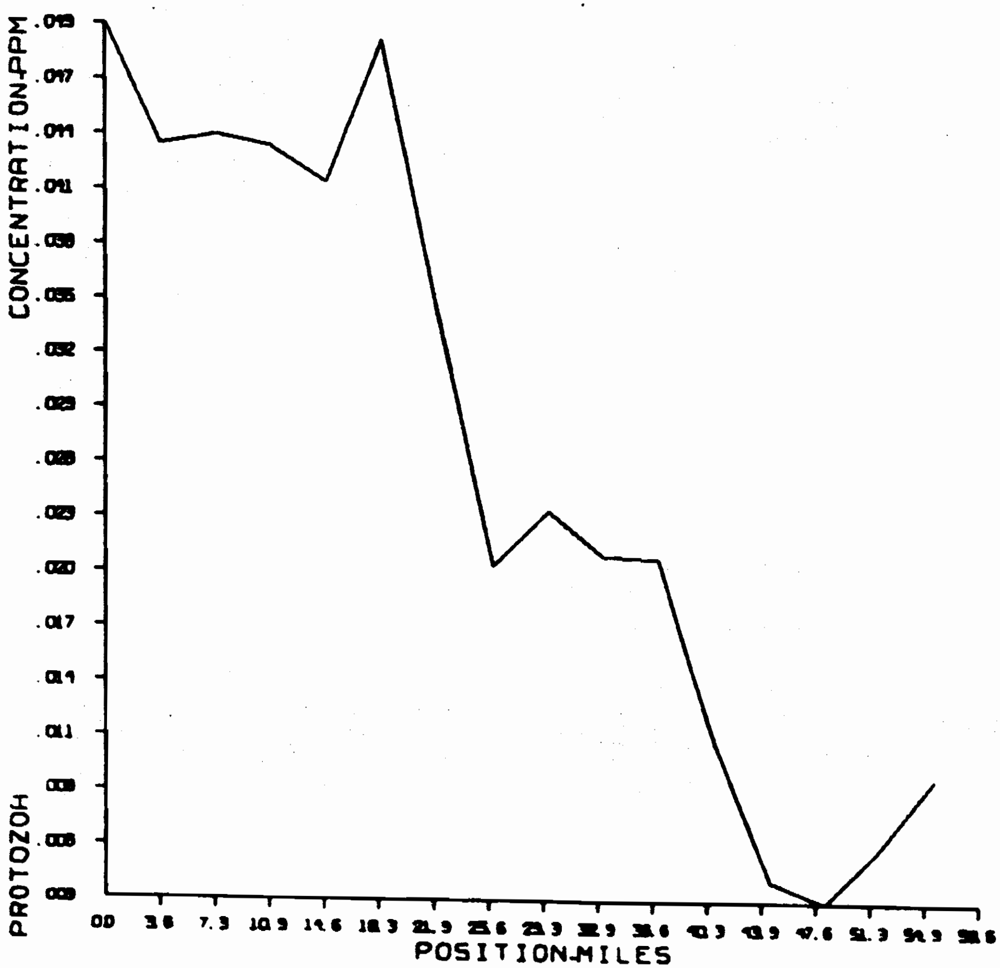

FIGURE 9. PROTOZOA CONCENTRATION (ppm) FOR FIRST DAY MODELED

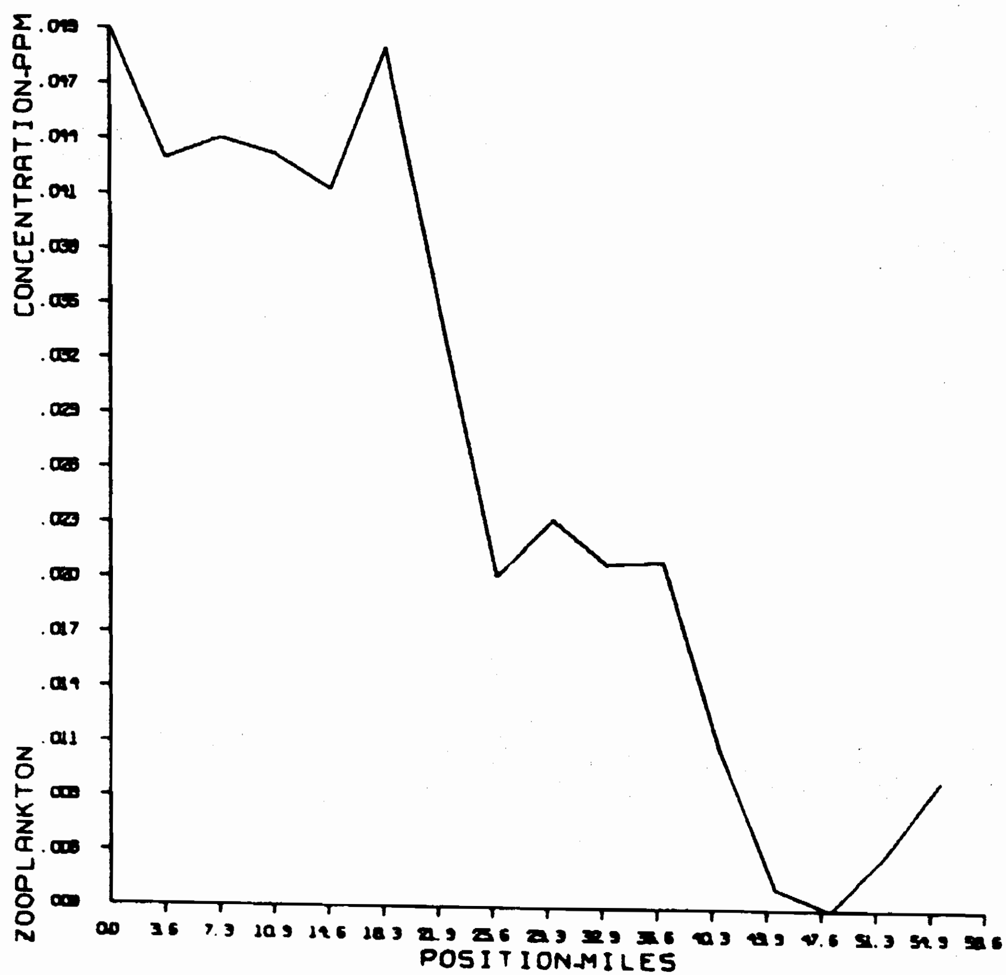

FIGURE 10. ZOOPLANKTON CONCENTRATION (ppm) FOR FIRST DAY MODELED

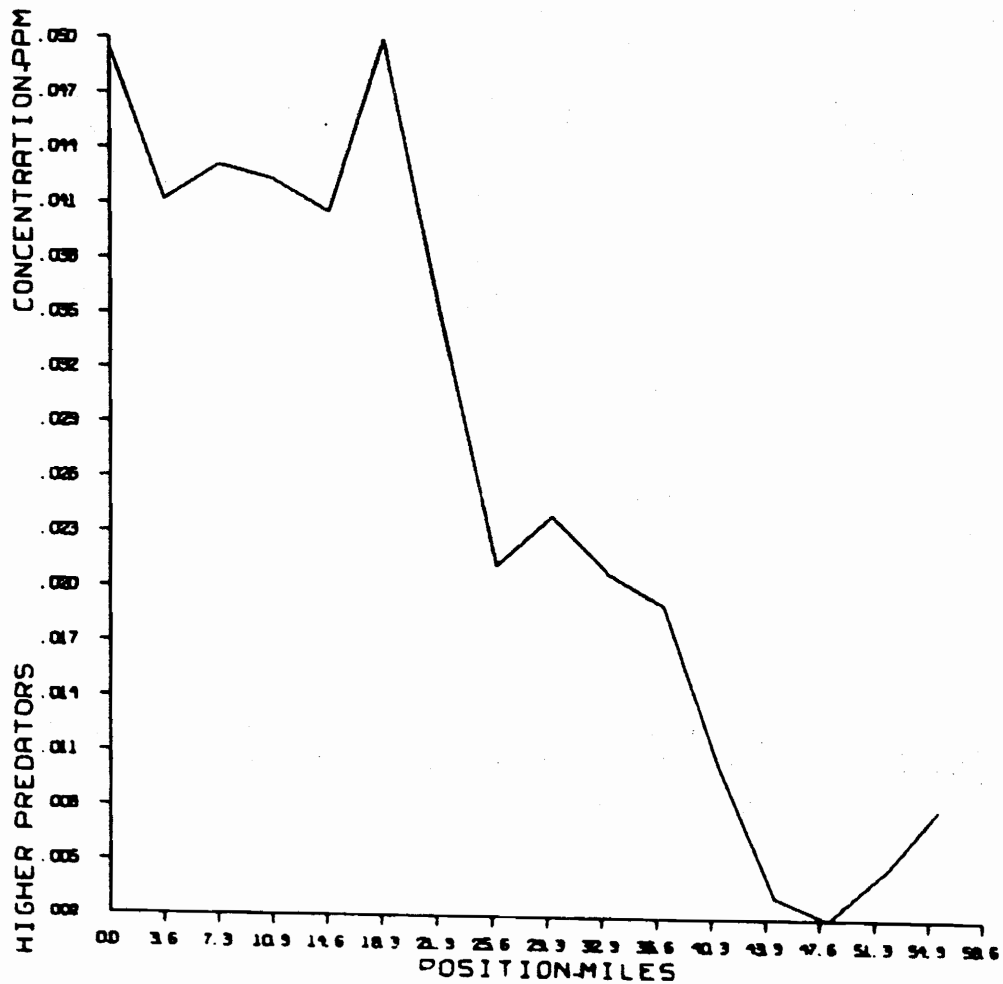

FIGURE 11. HIGHER PREDATOR CONCENTRATION (ppm) FOR FIRST DAY MODELED

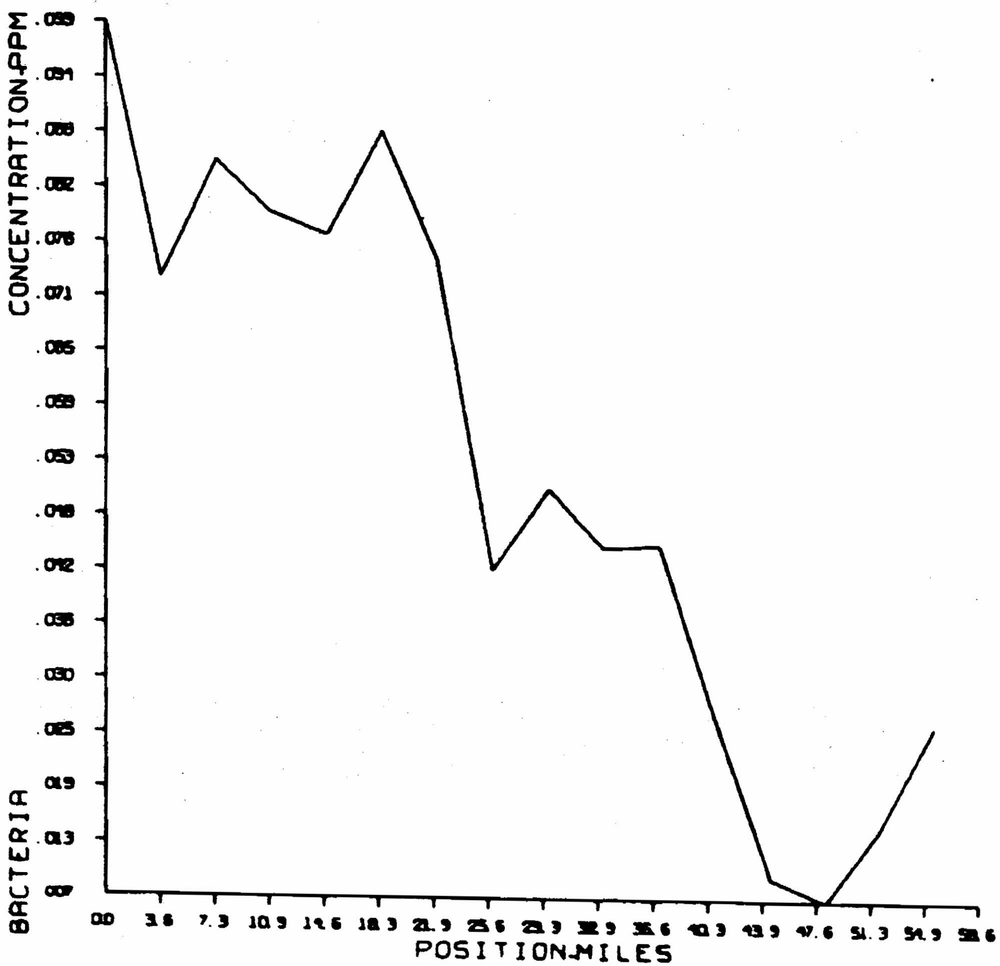

FIGURE 12. BACTERIA CONCENTRATION (ppm) FOR FIRST DAY MODELED

APPENDIX II

LISTING OF COMPUTER PROGRAM

```
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(12,2,200),DCDT(12,5,200 ),K(38,200),WORK(200),
      *WORK1(200),WORK2(200),DCDX(12,200),EA(200 ),UA(200),XPOS(200),
      *DEV,ND,DADT(200),A(200),WT,NM,NN,DT,DX,DZS,IA,TPR,LOGUP,INLOG
      *,ABSE,RELF,TEMP,TIDE,T,SUN,Q,O2SAT,CSAT,IDAY,JDAY,TDATA,K11,
      *K14,K27,K36,GRO8,GRO9,GRO10,IC,E,GRO11,XC,K2X,FRA(6),DIE(5),
      *RESP12,GRO12,IPRI,CL,PRED8,PRED9,PRED10,PRED11,WF,RR/B1/CK3/
      *B2/KM8,KM9,KM10,KM11/B3/C28,C29,C210,C211/B4/C58,C59,C510,
      *C511/B5/C68,C69,C610,C611/B6/C8,C9,C10,C11,C12,KM12,S/B7/C212,
      *C512,C612/B8/RESP8,RESP9,RESP10,RESP11/B9/F1,F3,F5,F6,FAZ,
      *IZDAY,POS,CONC(12,10),NV(6),VAL(6),TITLE(10),IPDAY,LOG,OSAT,D1,
      *PRI,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(12,200),K12,AVE,D2,TI,TM,MDAY,TMAX/B11/KP,K2,A0,A1,A2,
      *A3,A4,G0,G1,G2,XK2/B12/XQCOEF(10),Z(10),NCOFF,IWK2/B13/IPLOT,NPL
C**********************************************************************
C                                                                   *
C          THE INFORMATION IN THIS MAIN PROGRAM SEGMENT IS TO BE    *
C               SUPPLIED BY THE USER                                *
C                                                                   *
C**********************************************************************
C**********************************************************************
C
C          NN = NO OF SECTIONS TO BE USED                           *
       NN=79
C
C          XI  = UPSTREAM BOUNDARY LOCATION IN MILES                *
       XI=0.0
C
```

```
C          XO = DOWNSTREAM LOCATION IN MILES                                *
      XO=58.65
C
C          TI = INITIAL TIME OF DAY                                         *
      TI=0.022
C
C          IDAY = INITIAL DAY OF YEAR                                       *
      IDAY=120
C
C          TM = FINAL TIME OF DAY                                           *
      TM=0.0
C
C          MDAY = FINAL DAY OF YEAR                                         *
      MDAY=127
C
C          PRI = NO OF TIME/TIDAL CYCLE PRINTED OUTPUT REQUIRED             *
      PRI=0.5
C
C          IC = NO OF POLLUTION COMPONENTS                                  *
      IC=12
C
C          TIDE = TIME OF HIGH TIDE ON IDAY                                 *
      TIDE=9.0
C
C          FAZ = MOON PHASE AT TI & IDAY                                    *
      FAZ=0.0
C
C          TMAX = MAX NO OF COMPUTER MINUTES AUTHORIZED FOR THIS RUN *
      TMAX=999.
C
C          KP = LOGIC VARIABLE TO INDICATE IF PUNCHED OUTPUT AT TM          *
C                 & MDAY IS REQUIRED                                        *
```

```
      KP=0.
C
C          DETERMINING APPROPRIATE EQUATION FOR REAERATION              *
C                                                                       *
C                 K2 = OXYGEN REAERATION RATE                           *
C                 U = TIDAL VELOCITY (FPS)                              *
C                 H = DEPTH (FT)                                        *
C                 D = DIFFUSIVITY OF OXYGEN IN WATER                    *
C                                                                       *
C          FOR DEPTHS OF 1 FT-30 FT AND VEL OF .5-1.6 FPS               *
C                 PUT K2 = 1  TO USE THE FOLLOWING EQUATION:            *
C                 K2 = 12.9*SQRT U/H**1.5                               *
C                                                                       *
C          FOR DEPTHS OF 2 FT-11 FT AND VEL OF 1.8-5.0 FPS              *
C                 PUT K2 = 2  TO USE CHURCHILL'S EQUATION:              *
C                 K2 = 11.6*U/H**1.67                                   *
C                                                                       *
C          FOR DEPTHS OF 4 FT-11 FT AND VEL OF .1-5.0 FPS               *
C                 PUT K2 = 3  TO USE OWENS EQUATION:                    *
C                 K2 = 21.6*U**0.67/H**1.85                             *
C                                                                       *
C          FOR AN ESTUARY WHICH DOES NOT FALL INTO ANY OF               *
C                 THE 3 CATEGORIES ABOVE,                               *
C                 PUT K2 = 4  TO USE O'CONNOR'S EQUATION INVOLVING      *
C                 THE DIFFUSIVITY CONSTANT D: ( D=.000081 FT**2/HR )    *
C                 K2 = (D*U)**.5/H**1.5                                 *
C                                                                       *
C          TO USE OWN EXPRESSION FOR REAERATION,                        *
C                 PUT K2 = 0                                            *
C                 PUT XK2 = EXPRESSION OR NUMERICAL VALUE               *
C                                                                       *
      K2 = 1
```

```
      XK2 = 0
C
C         REAERATION WILL INCREASE 25% WITH EVERY 10 KNOT WIND OR     *
C              APPROXIMATELY 11.5 MPH WIND
C
C              PUT IWK2 = 0,1,2,3,4,5,6 TO COMPENSATE FOR NO WIND,    *
C              10 KNOT, 20 KNOT...60 KNOT WINDS RESPECTIVELY          *
C
      IWK2=1
C
C         THE COEFFICIENTS IN THE FOLLOWING EQUATIONS FOR             *
C              MAX TIDAL VEL & TIDAL LAG MUST BE DERIVED              *
C              FOR EACH ESTUARY MODELED                               *
C                                                                     *
C              X = POSITION (MILE)                                    *
C         MAX TIDAL VEL:                                              *
C              K(37,J) = A0+A1*X+A2*X**2+A3*X**3+A4*X**4
C
      A0 = .158002
      A1 = .0550658
      A2 = -.000457297
      A3 = -.00000731172
      A4 = .0000000751213
C                                                                     *
C         TIDAL LAG:                                                  *
C              K(38,J) = G0+G1*X+G2*X**2                              *
C                                                                     *
      G0 = 7.2211
      G1 = -.0415148
      G2 = -.000415578
C                                                                     *
C         TO DETERMINE VOLUMETRIC FRESHWATER FLOW RATE                *
```

```
C               AS A FUNCTION OF POSITION:                               *
C                                                                        *
C               XPOS = GRID POINT POSITION (MILE)                        *
C                                                                        *
C               XQ = VOL FRESHWATER FLOW RATE (CUBIC MI/HR)              *
C
C               NCOEF = NO OF ESTUARY SUBDIVISIONS WITH RESPECT          *
C               TO VOL FRESHWATER FLOW RATE                              *
C                                                                        *
C          AS GRID POINT POSITION INCREASES, XQ INCREASES BY A           *
C               MULTIPLE OF XQCOEF                                       *
C                                                                        *
C               Z(I) = GRID POINT POSITION (MILE) IN ASCENDING           *
C               ORDER                                                    *
C                                                                        *
C          IF (XPOS .GT. Z(I)) XQ = XQ*XQCOEF(I)    I=1,10               *
C
      NCOEF = 2
C                                                                        *
      Z(1) = 20.0
      XQCOEF(1) = 2.0
C                                                                        *
      Z(2) = 45.0
      XQCOEF(2) = 5.0
C                                                                        *
      Z(3) = 0.0
      XQCOEF(3) = 0.0
C                                                                        *
      Z(4) = 0.0
      XQCOEF(4) = 0.0
C                                                                        *
      Z(5) = 0.0
```

```
      XQCOEF(5) = 0.0
C                                                                       *
      Z(6) = 0.0
      XQCOEF(6) = 0.0
C                                                                       *
      Z(7) = 0.0
      XQCOEF(7) = 0.0
C                                                                       *
      Z(8) = 0.0
      XQCOEF(8) = 0.0
C                                                                       *
      Z(9) = 0.0
      XQCOEF(9) = 0.0
C                                                                       *
      Z(10) = 0.0
      XQCOEF(10) = 0.0
C                                                                       *
C                                                                       *
C***********************************************************************
      NPL=0
      CALL SCHOFI
      IF (NPL .GT. 0) CALL PLOT(0.,0.,-4)
      STOP
      END
```

```
C
C THE ORIGINAL MAIN PROGRAM
C
      SUBROUTINE SCHOFI
      REAL K,K11,K14,K22,K27,K36,KM8,KM9,KM10,KM11,KM12,K12,K2X
      COMMON /B0/C(12,2,200),DCDT(12,5,200 ),K(38,200),WORK(200),
     *WORK1(200),WORK2(200),DCDX(12,200),EA(200 ),UA(200),XPOS(200),
     *DEV,ND,DADT(200),A(200),WT,NM,NN,DT,DX,DZS,IA,TPR,LOGUP,INLOG
     *,ABSE,RELE,TEMP,TIDE,T,SUN,Q,O2SAT,CSAT,IDAY,JDAY,TDATA,K11,
     *K14,K27,K36,GRO8,GRO9,GRO10,IC,E,GRO11,XO,K2X,FRA(6),DIE(5),
     *RESP12,GRO12,IPRI,CL,PRED8,PRED9,PRED10,PRED11,WF,RR/B1/CK3/
     *B2/KM8,KM9,KM10,KM11/B3/C28,C29,C210,C211/B4/C58,C59,C510,
     *C511/B5/C68,C69,C610,C611/B6/C8,C9,C10,C11,C12,KM12,S/B7/C212,
     *C512,C612/B8/RESP8,RESP9,RESP10,RESP11/B9/F1,F3,F5,F6,FAZ,
     *IZDAY,POS,CONC(12,10),NV(6),VAL(6),TITLE(10),IPDAY,LOG,OSAT,D1,
     *PRI,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(12,200),K12,AVE,D2,TI,TM,MDAY,TMAX/B11/KP,K2,A0,A1,A2,
     *A3,A4,G0,G1,G2,XK2/B12/XQCOEF(10),Z(10),NCOEF,IWK2/B13/IPLOT,NPL
C*****************************************************************************
C
C          NAMELIST OPTION TO MODIFY DEFAULT VALUES OR TO UPDATE ACC *
C                PARAMETERS INCLUDED IN LIST.                       *
C          ANY VARIABLE MENTIONED IN THE ABOVE COMMON STATEMENT     *
C                MAY BE INCLUDED IN THIS LIST                       *
C
C*****************************************************************************
      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 (207,260,-1,1,0,208)
      READ(9,LIST1,END=1005)
```

```
      WRITE(6,LIST1)
C          SUBROUTINES TIMON AND TIMECK ARE SUPPLIED ON THE SYSTEM USED *
C                 FOR THIS WORK.THEY MOST BE DUMMIED OUT IF NOT AVAILABLE.*
      CALL TIMON
C          READING NAMES FOR THE TWELVE POLLUTICN COMPONENTS           *
 1005 DO 10 I=1,12
   10 READ(5,17,END=999) (CONC(I,J),J=1,10)
   17 FORMAT(10A4)
      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,'UPSTRFAM
     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 TIMF 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***********************************************************************
C     FORMING POSITICN 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)
C
      K(37,J) = A0+A1*XPOS(J )+A2*XP2+A3*XP2*XPOS(J)+A4*XP2*XP2
C
```

```
      K(38,J) = G0+G1*XPOS(J)+G2*XP2
C
C*******************************************************************************
    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         CONTAINS 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                                                                          *
C                CARDS READ ON UNIT 8 SERVE ONLY MODEL VERIFICATION        *
C                PURPOSES                                                  *
```

```
C                                                                     *
C     READING FIRST OBSERVED DATA CARD.                               *
C                                                                     *
    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 IS REQUESTED.IF(ILIST.NE.0) PARAMETER UPDATE IS REQUESTED*
C         THROUGH NAMELIST OPTION.                                    *
      READ(5,14,END=999) TEMP,Q,SUN,IPRI,ILIST,IPLOT
   14 FORMAT(3F10.4,20X,3I5)
      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 DD2=DT/2.0
      DD3=DT/3.0
      DD15=DT/15.0
C     CHECKING FOR FINISHING TIME.                                    *
      IF(T.GE.TM.AND.IDAY.GE.MDAY) GO TO 1000
C     CHECKING FOR MACHINE TIME ALLOCATION.                           *
      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)
      GC 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 CCNDITIONS                     *
 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)
 999  RETURN
      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(2E20.5).*
C    72 DATA IS IN THE FORM 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
      DIMENSION 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 OF 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
      DIMENSION HOLD(16),RLIT(15)
      COMMON /B0/C(12,2,200),DCDT(12,5,200 ),K(38,200),WORK(200),
     *WORK1(200),WORK2(200),DCDX(12,200),EA(200 ),UA(200),XPOS(200),
     *DEV,ND,DADT(200),A(200),WT,NM,NN,DT,DX,DZS,IA,TPR,LOGUP,INLOG
     *,ABSE,RELE,TEMP,TIDE,T,SUN,Q,O2SAT,CSAT,IDAY,JDAY,TDATA,K11,
     *K14,K27,K36,GRO8,GRO9,GRO10,IC,E,GRO11,XO,K2X,FRA(6),DIE(5),
     *RESP12,GRO12,IPRI,CL,PRED8,PRED9,PRED10,PRED11,WF,RR/B1/CK3/
     *B2/KM8,KM9,KM10,KM11/B3/C28,C29,C210,C211/B4/C58,C59,C510,
     *C511/B5/C68,C69,C610,C611/B6/C8,C9,C10,C11,C12,KM12,S/B7/C212,
     *C512,C612/B8/RESP8,RESP9,RESP10,RESP11/B9/F1,F3,F5,F6,FAZ,
     *IZDAY,POS,CONC(12,10),NV(6),VAL(6),TITLE(10),IPDAY,LOG,OSAT,D1,
     *PRI,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(12,200),K12,AVE,D2,TI,TM,MDAY,TMAX/B11/KP,K2,A0,A1,A2,
     *A3,A4,G0,G1,G2,XK2/B12/XQCOEF(10),Z(10),NCOEF,IWK2/B13/IPLOT,NPL
      DATA RLIT(11)/' CON'/, RLIT(12)/'CENT'/, RLIT(13)/'RATI'/,
     *RLIT(14)/'ON-P'/, RLIT(15)/'PM  '/
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 OUTPUT OPTION (IPRI=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
C                                                                      *
C            CHECKING FOR PLOTTED OUTPUT                               *
C
      IF (IPLOT .EQ. 0) GO TO 38
      NPL=NPL+1
      SCALX=XO/16.
      DO 33 I=1,IC
      L=0
      DO 34 J=1,NM,ND
      L=L+1
   34 HOLD(L)=C(I,IA,J)/S
      IF(NPL .EQ. 1 .AND. I .EQ. 1) GO TO 36
      CALL PLOT(12.,O.,-3)
      GO TO 35
```

```
 36   CALL PLOT(3.,2.,-3)
35    DO 37 J=1,10
37    RLIT(J)=CONC(I,J)
      CALL SCALE(HOLD,16,8.,XMIN,SCALF,1)
      CALL BILDAX(0.,0.,0.,0.,1,SCALX,8.,' POSITION-MILES ',4,.5,1,0)
      CALL BILDAX(0.,0.,0.,XMIN,3,SCALF/2.,8.,RLIT,15,.5,1,1)
      L=0
      DO 33 J=1,NM,ND
      RMILE=XPOS(J)*(8./XO)
      L=L+1
      CALL PLOT(RMILE,HOLD(L),2)
  33  CONTINUE
C                                                                              *
  38  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
C*******************************************************************************
C
C          THE FOLLOWING CARDS MAY BE OMITTED IF MODEL VERIFICATION           *
C               IS NOT INTENDED.                                               *
C
      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
C
C*****************************************************************************
  999 IF(T.LT.24.0) GO TO 1000
C     UPDATING TIME,DAY,AND CONDITICNS.                                      *
      READ(5,12,END=51) TEMP,Q,SUN,IPRI,ILIST,IPLOT
   12 FORMAT(3F10.4,20X,3I5)
   51 IDAY=IDAY+1
      T=T-24.0
      LOGUP=2
      CALL UPDATE
 1000 RETURN
      END
```

```
      SUBROUTINE UPDATE
C     SUBROUTINE TO UPDATE ANY TIME,DAY,OR TEMPERATURE VARIABLE PARA-   *
C         METERS,FORMING FUNCTIONS,CONDITIONS,ETC.                      *
      REAL K,K11,K14,K22,K27,K36,KM8,KM9,KM10,KM11,KM12,K12,K2X
      COMMON /B0/C(12,2,200),DCDT(12,5,200 ),K(38,200),WORK(200),
     *WORK1(200),WORK2(200),DCDX(12,200),EA(200 ),UA(200),XPOS(200),
     *DEV,ND,DADT(200),A(200),WT,NM,NN,DT,DX,DZS,IA,TPR,LOGUP,INLOG
     *,ABSE,RELE,TEMP,TIDE,T,SUN,Q,O2SAT,CSAT,IDAY,JDAY,TDATA,K11,
     *K14,K27,K36,GRO8,GRO9,GRO10,IC,E,GRO11,XC,K2X,FRA(6),DIE(5),
     *RESP12,GRO12,IPRI,CL,PRED8,PRED9,PRED10,PRED11,WF,RR/B1/CK3/
     *B2/KM8,KM9,KM10,KM11/B3/C28,C29,C210,C211/B4/C58,C59,C510,
     *C511/B5/C68,C69,C610,C611/B6/C8,C9,C10,C11,C12,KM12,S/B7/C212,
     *C512,C612/B8/RESP8,RESP9,RESP10,RESP11/B9/F1,F3,F5,F6,FAZ,
     *IZDAY,POS,CONC(12,10),NV(6),VAL(6),TITLE(10),IPDAY,LOG,OSAT,D1,
     *PRI,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(12,200),K12,AVE,D2,TI,TM,MDAY,TMAX/B11/KP,K2,A0,A1,A2,
     *A3,A4,G0,G1,G2,XK2/B12/XQCOEF(10),Z(10),NCOEF,IWK2
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 DEFINITIONS.          *
C           =2 FOR DAILY UPDATE.                                        *
C           =3 FOR 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
      NC=1+(NM-1)/16
    2 SUNMAX=SUN*2.6224
C*****************************************************************************
C         IF TEMP IS NOT INCLUDED IN THE DATA THE FOLLOWING
```

```
C                 EXPRESSION WILL CALCULATE ITS VALUE:                   *
C
      IF(TEMP.EQ.0.0) TEMP=AVE+DEV*SIN(WT/365.0*FLOAT(IDAY-120))
C
C             DEFAULT VALUES FOR AVE AND DEV FOUND IN BLK DATA SHOULD    *
C                 BE CHECKED FOR APPROPRIATENESS FOR EACH ESTUARY        *
C                 MODELED.                                               *
C
C*********************************************************************************
      PRED8=PRED(1)*TEMP/S
      PRED9=PRED(2)*TEMP/S
      PRED10=PRED(3)*TEMP/S
      PRED11=PRED(4)*TEMP
      GRO8=GRO(1)*TEMP+0.02
      GRO9=GRO(2)*TEMP
      GRO10=GRO(3)*TEMP
      GRO11=GRO(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*1.010**(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     BOUNDARY 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.O.C) 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(12,2,200),DCDT(12,5,200 ),K(38,200),WORK(200),
     *WORK1(200),WORK2(200),DCDX(12,200),EA(200 ),UA(200),XPOS(200),
     *DEV,ND,DADT(200),A(200),WT,NM,NN,DT,DX,DZS,IA,TPR,LOGUP,INLOG
     *,ABSE,RELE,TEMP,TIDE,T,SUN,Q,C2SAT,CSAT,ICAY,JCAY,TCATA,K11,
     *K14,K27,K36,GRO8,GRO9,GRO10,IC,E,GRO11,XC,K2X,FRA(6),DIE(5),
     *RESP12,GRO12,IPRI,CL,PRED8,PRED9,PRED10,PRED11,WF,RR/B1/CK3/
     *B2/KM8,KM9,KM10,KM11/B3/C28,C29,C210,C211/B4/C58,C59,C510,
     *C511/B5/C68,C69,C610,C611/B6/C8,C9,C10,C11,C12,KM12,S/B7/C212,
     *C512,C612/B8/RESP8,RESP9,RESP10,RESP11/B9/F1,F3,F5,F6,FAZ,
     *IZDAY,POS,CCNC(12,10),NV(6),VAL(6),TITLE(10),IPDAY,LOG,OSAT,D1,
     *PRI,D02,D03,D015,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(12,200),K12,AVE,D2,TI,TM,MDAY,TMAX/B11/KP,K2,A0,A1,A2,
     *A3,A4,G0,G1,G2,XK2/B12/XQCOEF(10),Z(10),NCOEF,IWK2
      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/0.40,0.05,0.40,0.05,0.0
     .,0.10/,DIE/0.010,2*0.0050,0.0020,0.005/,KM12,PRIE,CL/9.19E+06,0.05
     .,1.0/,C/1440*9.19E06,3360*0.0/,DCDX/2400*0.0/,K/7600*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/2400*0.0/,DCDT/12000*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(12,2,200),DCDT(12,5,200 ),K(38,200),WORK(200),
     *WORK1(200),WORK2(200),DCDX(12,200),EA(200 ),UA(200),XPOS(200),
     *DEV,ND,DADT(200),A(200),WT,NM,NN,DT,DX,DZS,IA,TPR,LOGUP,INLOG
     *,ABSE,RELE,TEMP,TIDE,T,SUN,Q,O2SAT,CSAT,IDAY,JDAY,TDATA,K11,
     *K14,K27,K36,GRO8,GRO9,GRO10,IC,E,GRO11,XC,K2X,FRA(6),DIE(5),
     *RESP12,GRO12,IPRI,CL,PRED8,PRED9,PRED10,PRED11,WF,RR/B1/CK3/
     *B2/KM8,KM9,KM10,KM11/B3/C28,C29,C210,C211/B4/C58,C59,C510,
     *C511/B5/C68,C69,C610,C611/B6/C8,C9,C10,C11,C12,KM12,S/B7/C212,
     *C512,C612/B8/RESP8,RESP9,RESP10,RESP11/B9/F1,F3,F5,F6,FAZ,
     *IZDAY,POS,CONC(12,10),NV(6),VAL(6),TITLE(10),IPDAY,LOG,OSAT,D1,
     *PRI,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(12,200),K12,AVE,D2,TI,TM,MDAY,TMAX/B11/KP,K2,A0,A1,A2,
     *A3,A4,G0,G1,G2,XK2/B12/XQCOEF(10),Z(10),NCOEF,IWK2
      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 AT 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)+DD3*(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)+DD3*(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-DD3+DD2
      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)+DD3*(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+DD2
      CALL UPDATE
      CALL FUNCT(5)
C     ESTIMATING C AT  T&DT USING C AND DCDT AT T&DT/2                  *
C     CHECKING 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)-DD3*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=DD15*TQ/(RELE*ABS(C(I,JA,J))+ABSF)
```

```
      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(12,2,200),DCDT(12,5,200 ),K(38,200),WORK(200),
     *WORK1(200),WORK2(200),DCDX(12,200),EA(200 ),UA(200),XPOS(200),
     *DEV,ND,DADT(200),A(200),WT,NM,NN,DT,DX,CZS,IA,TPR,LOGUP,INLOG
     *,ABSE,RELE,TEMP,TIDE,T,SUN,Q,O2SAT,CSAT,IDAY,JDAY,TDATA,K11,
     *K14,K27,K36,GRO8,GRO9,GRO10,IC,E,GRO11,XO,K2X,FRA(6),DIE(5),
     *RESP12,GRO12,IPRI,CL,PRED8,PRED9,PRED10,PRED11,WF,RR/B1/CK3/
     *B2/KM8,KM9,KM10,KM11/B3/C28,C29,C210,C211/B4/C58,C59,C510,
     *C511/B5/C68,C69,C610,C611/B6/C8,C9,C10,C11,C12,KM12,S/B7/C212,
     *C512,C612/B8/RESP8,RESP9,RESP10,RESP11/B9/F1,F3,F5,F6,FAZ,
     *IZDAY,POS,CONC(12,10),NV(6),VAL(6),TITLE(10),IPDAY,LOG,OSAT,D1,
     *PRI,DO2,DO3,DO15,BC(5),PRED(5),GRO(5),RES(5),BA,X11,X14,X36,
     *SUNSAT/B10/TMIN,ILIST,PRIF,XI,BCN,SUM,SS,NDATA,YYY,EADJ,
     *XAREA(12,200),K12,AVE,D2,TI,TM,MDAY,TMAX/B11/KP,K2,A0,A1,A2,
     *A3,A4,G0,G1,G2,XK2/B12/XQCOEF(10),Z(10),NCOEF,IWK2
      IA=3-IA
C   CALCULATE PREDATION
    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,J))+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)))
C     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
C*****************************************************************************
C                                                                     *
C          FORMULATIONS FOR K2 OPTION                                 *
      GO TO ( 10,20,30,35 ), K2
      IF (K2 .EQ. 0) K(5,J)=XK2
      GO TO 36
 10   K(5,J) = K2X*SQRT(UABS/K(30,J))/K(30,J)
      GO TO 36
 20   K(5,J) = 11.6*UABS/K(30,J)**1.67
      GO TO 36
 30   K(5,J) = 21.6*UABS**0.67/K(30,J)**1.85
      GO TO 36
 35   K(5,J) = 12.96*UABS**.5/K(30,J)**1.5
 36   K(5,J) = K(5,J)/24.0
C
C          TO COMPENSATE FOR NO WIND, 10 KNOT, 20 KNOT...60 KNOT      *
C                 WINDS                                               *
      IF (IWK2 .EQ. 0) GO TO 37
      GO TO (7,8,3,4,5,6),IWK2
  7   K(5,J)=K(5,J)*1.25
      GO TO 37
  8   K(5,J)=K(5,J)*1.5
      GO TO 37
```

```
  3    K(5,J)=K(5,J)*1.75
       GO TO 37
  4    K(5,J) = K(5,J)*2.0
       GO TO 37
  5    K(5,J)=K(5,J)*2.25
       GO TO 37
  6    K(5,J)= K(5,J)*2.5
C                                                                       *
C*****************************************************************************
  37   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,
     .           J)
C 2 CARBON DIOXIDE
      DCDT(2, L,J)=DCDX(2,J)+FRA(2)*K(4,J)+K11*C(1,IA,J)+K(29,J)*E*(CSAT
     .          -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 NITROGEN
      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
      DCDT(12,L,J)=DCDX(12,J)+K(35,J)-K(33,J)-K(32,J)
   94 CONTINUE
```

```
      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,IZCAY,T,TIDE,FAZ,NM,XAREA,R,WT,A)
C     SUBROUTINE TC CALCULATE ESTUARY CROSS SECTIONAL AREA AS A FUNCT- *
C         ION OF TIDAL PHASE AND POSITION                               *
      DIMENSION XAREA(12,NM),R(38,NM),A(NM)
      DO 10 J=1,NM
      PHASE=(T+(ICAY-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,POSITION,CROSS SECTIONAL AREA,AND TIDAL PHASE*
      COMMON /B12/XQCOEF(10),Z(10),NCOEF,IWK2
      DIMENSION XPOS(NM),A(NM),R(38,NM),UA(NM)
      DO 10 J=1,NM
      XQ=Q*2.445E-08
      DO 20 L=1,NCOEF
      IF(XPOS(J) .GT. Z(L)) XQ=XQ*XQCOEF(L)
 20   CONTINUE
   10 UA(J)=(XQ/A(J)+R(37,J)*SIN(WT*R(31,J)))
      RETURN
      END
```

```
      SUBROUTINE VCLUM(A,NM,UA,Q,WORK,XPOS)
C     SUBROUTINE TO CALCULATE VOLUMETRIC FLOW RATE AS A FUNCTION OF     *
C         FRESH WATER FLOW RATE,POSITICN,AND TIDAL PHASE.               *
      CCMMON /B12/XQCOEF(10),Z(10),NCOEF,IWK2
      DIMENSION A(NM),UA(NM),WORK(NM),XPOS(NM)
      DC 10 J=1,NM
      XQ=Q*2.445E-C8
      DO 20 L=1,NCCEF
      IF(XPOS(J) .GT. Z(L)) XC=XQ*XQCOEF(L)
   20 CCNTINUE
   10 WORK(J)=A(J)*UA(J)-XQ+2.445E-08*Q
      RETURN
      END
```

```fortran
      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
```

```
C*********************************************************************
C                                                                   *
C          THE REST OF THE USER INPUT INFORMATICN IS TO FOLLOW      *
C               IMMEDIATELY AFTER THIS SUBROUTINE                   *
C                                                                   *
C*********************************************************************
C $ $ $ $ $ $  $ $ $ $ $ $ $ $ $ $ $ $  $ $ $ $ $ $ $ $$ $ $ $ $ $ $ $ $PLD
C  SUBROUTINE BILDAX  ***** DRAW VERTICAL AND HORIZONTAL AXIS  ***
C $ $ $ $ $ $  $ $ $ $ $ $ $ $ $ $ $ $  $ $ $ $ $ $ $ $$ $ $ $ $ $ $ $ $PLD
C     THIS ROUTINE PLOTS AN AXIS(VERTICAL OR HORIZONAL) WITH TIC MARKS
C     AT EACH GIVEN INTERVAL OR AT 1 INCH INTERVALS, PUTS NUMBERS AT
C     TIC MARK, AND LABELS THE AXIS.
C     A SINGLE CALL DRAWS ONE (X OR Y) AXIS DEPENDING ON 'NT' BELOW.
C
C     CONTROL PARAMETERS
C     X,Y = LOCATION OF GRAPH ORGIN(0.0,0.0) IN INCHES  (REAL)
C     HT = HEIGHT IN INCHES OF THE NUMBERS TO BE PLOTTED ON AXIS (REAL)
C          IF HEIGHT =0.0 PROGRAM WILL SET HEIGHT =0.10
C     FP = BEGINNING NUMBER TO BE PLOTTED AT ORGIN OF AXIS (REAL)
C     ND = NUMBER OF DECIMAL DIGITS TO THE RIGHT OF THE DECIMAL POINT
C          OF NUMBERS TO BE PLOTTED, IF ND=-1 NUMBERS WILL BE PLOTTED
C          WITHOUT A DECIMAL POINT(ONLY DIGITS TO LEFT OF DECIMAL)
C          IF ND=0 PROGRAM WILL SET ND=2 FOR 2 DECIMAL POINTS(INTEGER)
C     VI = VALUE TO INCREMENT NUMBERS BY FOR EACH TIC MARK (REAL)
C     AL = LENGTH OF AXIS IN INCHES    (REAL)
C     ALAB = LABEL TO BE WRITTEN ON AXIS(MAX OF 80 CHARACTERS)
C           THE LABEL FOR AXIS MAY BE PASSED TO THE ROUTINE
C              BY ONE OF THE FOLLOWING METHODS IN THE CALL STATEMENT;;;
C           1. CALL BILDAX(X,Y,HT,FP,ND,VI,AL,ALAB,N4,TC,LD,NT) WHERE
C             ALAB IS A VARIABLE READ INTO STORAGE AS A4 WORDS
C           2. CALL BILDAX(X,Y,HT,FP,ND,VI,AL,'Y-AXIS--',2,TC,LD,NT)
C                WHERE LABEL IS A LITERAL STRING
```

```
C           3. CALL BILDAX(X,Y,HT,FP,ND,VI,AL,8HY-AXIS--,2,TC,LD,NT)
C                WHERE LABEL IS HOLLERITH STRING
C           THE NINTH ARGUMENT IN THE CALL IS THE TOTAL NUMBER OF
C                LETTERS IN STRING DIVIDE BY 4 PADDED BLANKS MAKE THE
C              LABEL EVENLY DIVISIABLE BY 4). SEE N4 BELOW::
C     N4 = NUMBER OF A4'S ALAB WILL DIVIDE INTO(THE ALAB IS READ
C          IN A4 FORMAT N4 WILL BE THE NUMBER OF A4'S READ MAX 20A4'S
C     TC = LENGTH IN INCHES BETWEEN TIC MARKS: TC IS SET TO 1.0 BY
C          ROUTINE IF TC WAS CODED =0.0            (REAL)
C     LD = SIDE OF AXIS TIC MARKS WILL APPEAR ON:
C          IF Y-AXIS 0=RIGHT SIDE, 1= LEFT SIDE OF AXIS
C          IF X-AXIS 0=UP, 1= DOWN FROM AXIS
C     NT = TYPE OF AXIS TO BE DRAWN ON THIS CALL::
C          0= HORIZONAL(X), 1=VERTICAL(Y) AXIS TYPE
C
C
      SUBROUTINE BILDAX(X,Y,HT,FP,ND,VI,AL,ALAB,N4,TC,LD,NT)
      DIMENSION ALAB(N4)
      NSTART=0
      A=X
      B=Y
      AT=HT
      IF(AT.LE.0.0)AT=0.10
      BT=AT*1.5
      AC=TC
      IF(AC.LE.0.0)AC=1.0
      AP=FP
      KD=ND
      IF(KD.EQ.0)KD=2
      CN=6./7.
      CL=7.5/7.
      NX=N4*4
```

```
      C=AT
      D=-1.0
      WN=AT*CN
      WL=BT*CL
      G=AT/2.
      W=BT/2.
      NMAX=0
      R=0.0
C
C     DRAW AXIS
C
      IF(NT.EQ.0) GO TO 4
      AY=AL+B
      CALL PLOT(A,AY,2)
      GO TO 6
 4    AX=AL+A
C     AX=AL+A
C     COUNT DIGITS AND DRAWN NUMBERS AND TIC MARKS
C
      CALL PLOT(AX,B,2)
 6    IMAX=IFIX(AP)
      N=1
      L=9
      DO 1 J=1,7
      IF(IMAX.LE.L) GO TO 2
      N=N+1
      L=((L+1)*10)-1
 1    CONTINUE
 2    IF(KD.GT.0) N=N+KD+1
      IF(N.GT.NMAX) NMAX=N
      TN=FLOAT(N)*WN
      AD=0.0
```

```
      IF(LD.EQ.1)AC=C
      IF(NT.EQ.0)GO TO 7
      E=D*(TN+AD+AT+X)
      F=B-G
      GO TO 9
    7 E=A-(TN/2.0)
      F=Y+(D*(AD+(2.0*AT)))
 9    IF(NSTART.EQ.1) GO TO 3
      CALL NUMBER(E,F,AT,AP,0.0,KD)
      NSTART=1
      GO TO 5
 3    CALL PLOT(A,B,3)
      S=C
      IF(LD.EQ.1)S=C*D
      IF(NT.EQ.0) S=S+Y
      IF(NT.EQ.1) S=S+X
      IF(NT.EQ.0) CALL PLOT(A,S,2)
      IF(NT.EQ.1) CALL PLOT(S,B,2)
      CALL NUMBER(E,F,AT,AP,0.0,KD)
 5    IF(NT.EQ.0) A=A+AC
      IF(NT.EQ.1) B=B+AC
      R=R+AC
      AP=AP+VI
      IF(R.LE.AL) GO TO 6
C
C     PUT ON LABELS
C
      AD=0.0
      IF(LD.EQ.1)AD=C
      IF(NT.EQ.0) GO TO 10
      TN=FLOAT(NMAX)*WN
      E=D*(X+TN+AD+(2.0*AT))
```

```
      F=Y+((AL-(NX*WL))/2.0)
      CALL SYMBOL(E,F,BT,ALAB,90.0,NX)
      GO TO 11
   10 E=X+((AL-(NX*WL))/2.0)
      F=Y+(D*(AD+(3.0*AT)+BT))
      CALL SYMBOL(E,F,BT,ALAB,0.0,NX)
   11 CALL PLOT(X,Y,3)
      RETURN
      END
```

ORGANIC CARBON
CARBON DIOXIDE
ORGANIC NITROGEN
AMMONIA
NITRITE+NITRATE
PHOSPHATE
OD
ALGAE
PROTOZOA
ZOOPLANKTON
HIGHER PREDATORS
BACTERIA

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	3.055452
0.000347	9.206232	0.000347	10.357010	0.000270	11.507780	0.000386	12.658550
0.000386	13.809330	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	46.03114	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
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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
1.9462	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
1.4309	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
2.0512	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
0.5590	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
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	0.3046	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	0.1093	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	0.1438	51.9683	0.1762	52.7107
0.1500	53.4532	0.1273	54.1956	0.0850	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	8.9089	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	0.6907	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	0.6142	22.2721	0.4422	23.0145
0.6021	23.7570	0.5124	24.4994	0.4573	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	0.8649	31.1810	0.7777	31.9234
0.9118	32.6658	0.6336	33.4082	0.9154	34.1506	0.8581	34.8930
0.9295	35.6354	0.9050	36.3778	0.9417	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	0.5095	46.0291	0.3446	46.7715
0.4488	47.5139	0.2672	48.2563	0.2638	48.9987	0.1910	49.7411
0.1336	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	0.6051	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	0.5102	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	0.3316	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
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
0.1036	56.4228	0.1019	57.1652	0.1285	57.9076	0.1464	58.6500
80 7	2	OD					
1.4742	0.0	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	17.0753
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	0.9948	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	0.9717	4.4544	0.4323	5.1968
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	PROTOZCA					
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
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
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	HIGHER PREDATORS					
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	0.0038	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	0.1086	7.4240	0.0773	8.1665
0.1074	8.9089	0.0756	9.6513	0.0987	10.3937	0.0775	11.1361
0.0946	11.6785	0.0795	12.6209	0.0944	13.3633	0.0779	14.1057
0.0914	14.8481	0.0809	15.5905	0.0913	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	0.0703	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
[illegible]	29.6962	0.0423	30.4386	0.0519	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	0.0459	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	0.0188	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	0.0101	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	0	2
	8750.	597.	121	0	3
	8000.	600.	122	0	3
	8700.	650.	123	0	3
	8700.	655.	124	0	3
	8722.	543.	125	0	3
	8705.	643.	126	0	3
	7622.	563.	127	0	3
	7660.	569.	128	0	3

```
&LIST1 PRIE=.01,CL=1.0 ,FRA=.44,.10,.164,.0915,.0175,.181,X11=.10,X36=0.10,
 BA=0.16,D1=.20,GRO(1)=.0015,X14=.6    ,KM12=.50E07,PRFD(1)=.0010,D2=.40,
CK3=1.0,BC(1)=0.05,BC(5)=0.10,DEV=11.0,  &END
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APPENDIX III

FLOWCHARTS

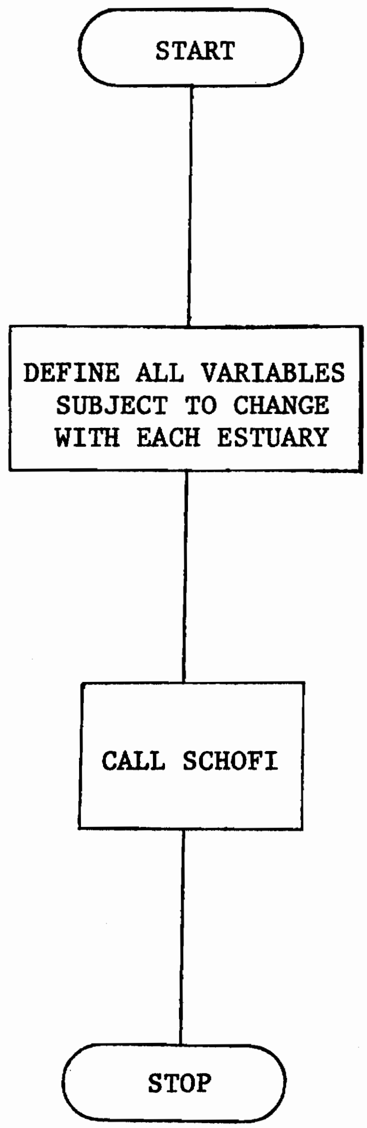

FIGURE 1. FLOWCHART FOR MAIN PROGRAM

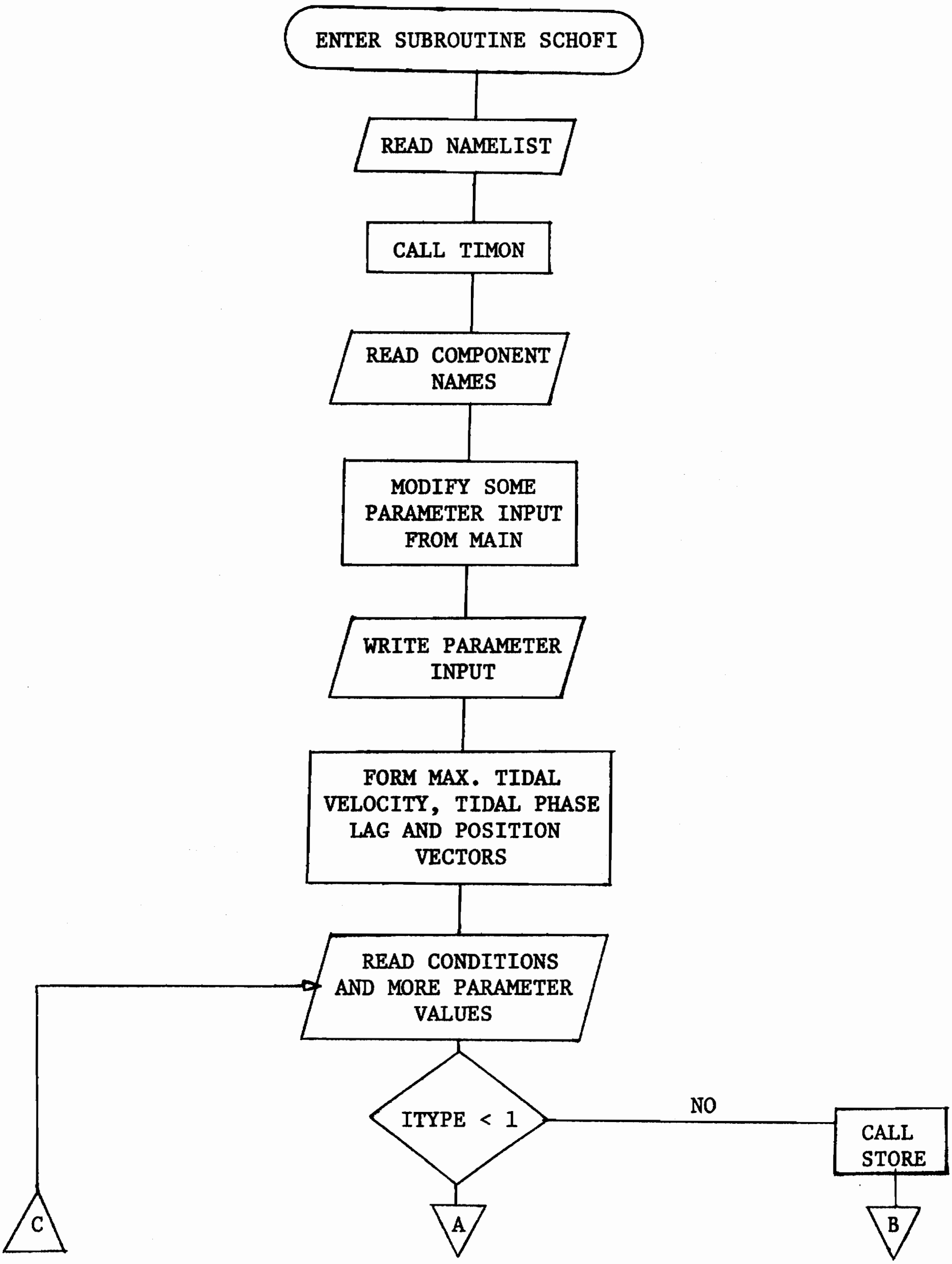

FIGURE 2. FLOWCHART FOR SUBROUTINE SCHOFI

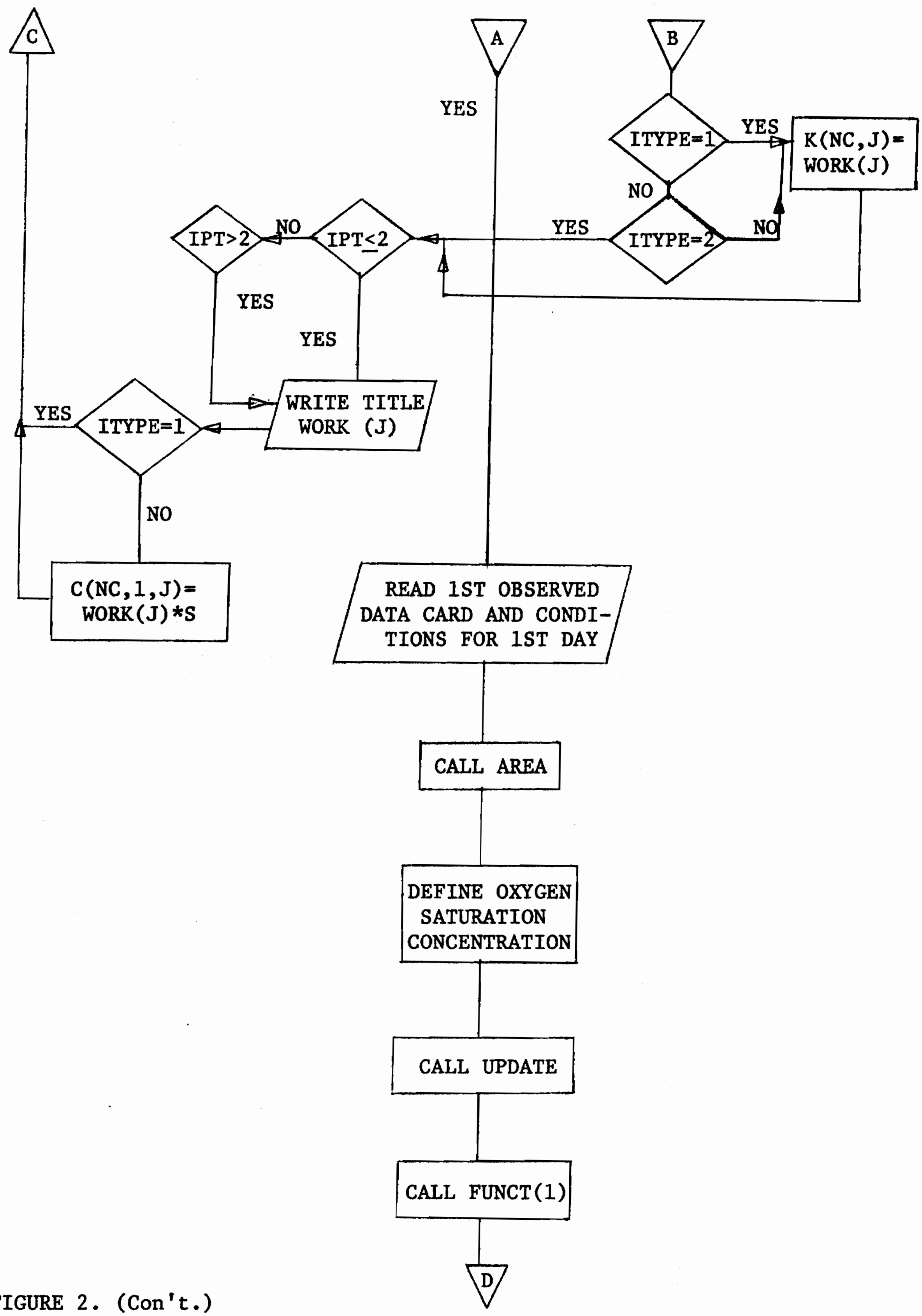

FIGURE 2. (Con't.)

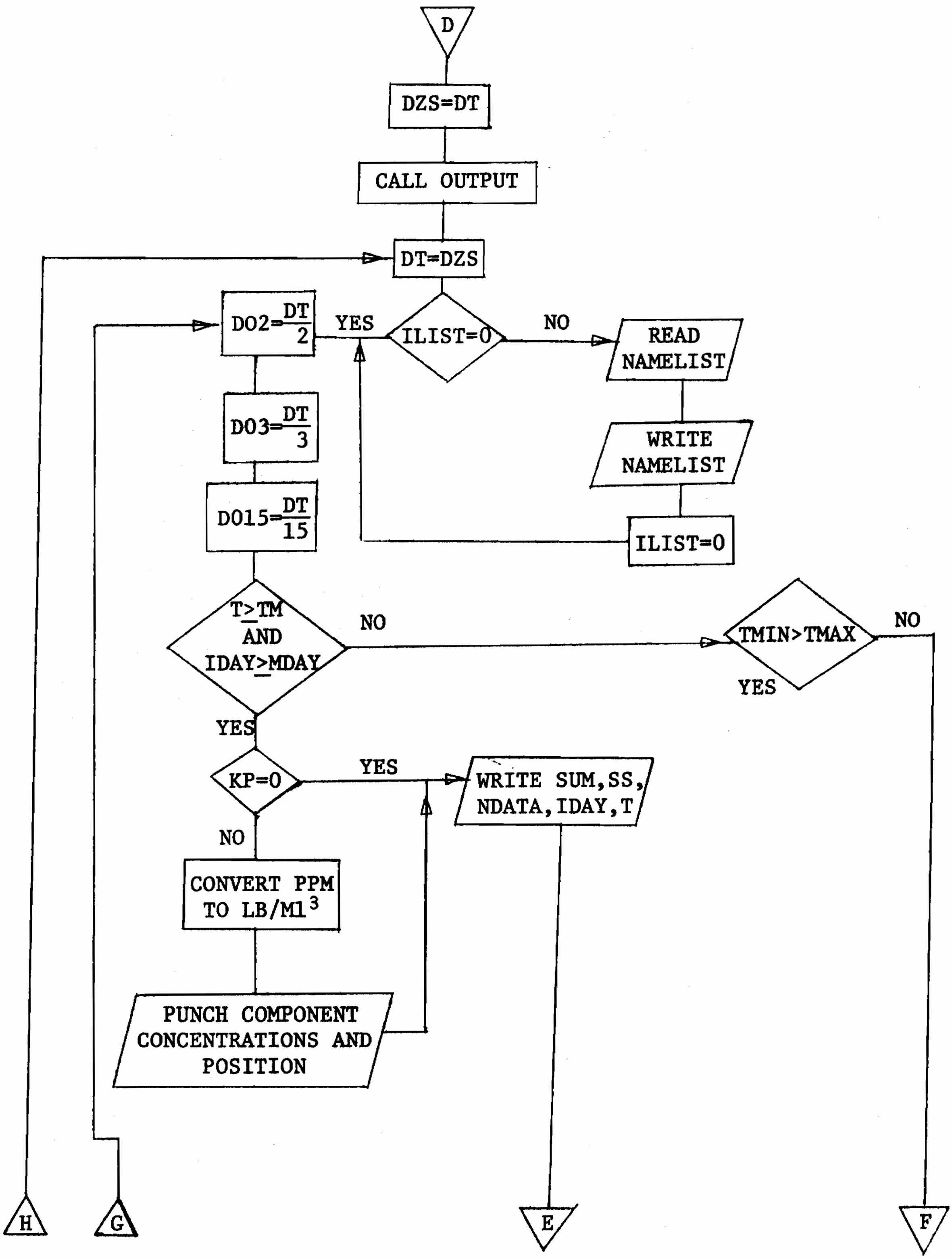

FIGURE 2. (Con't.)

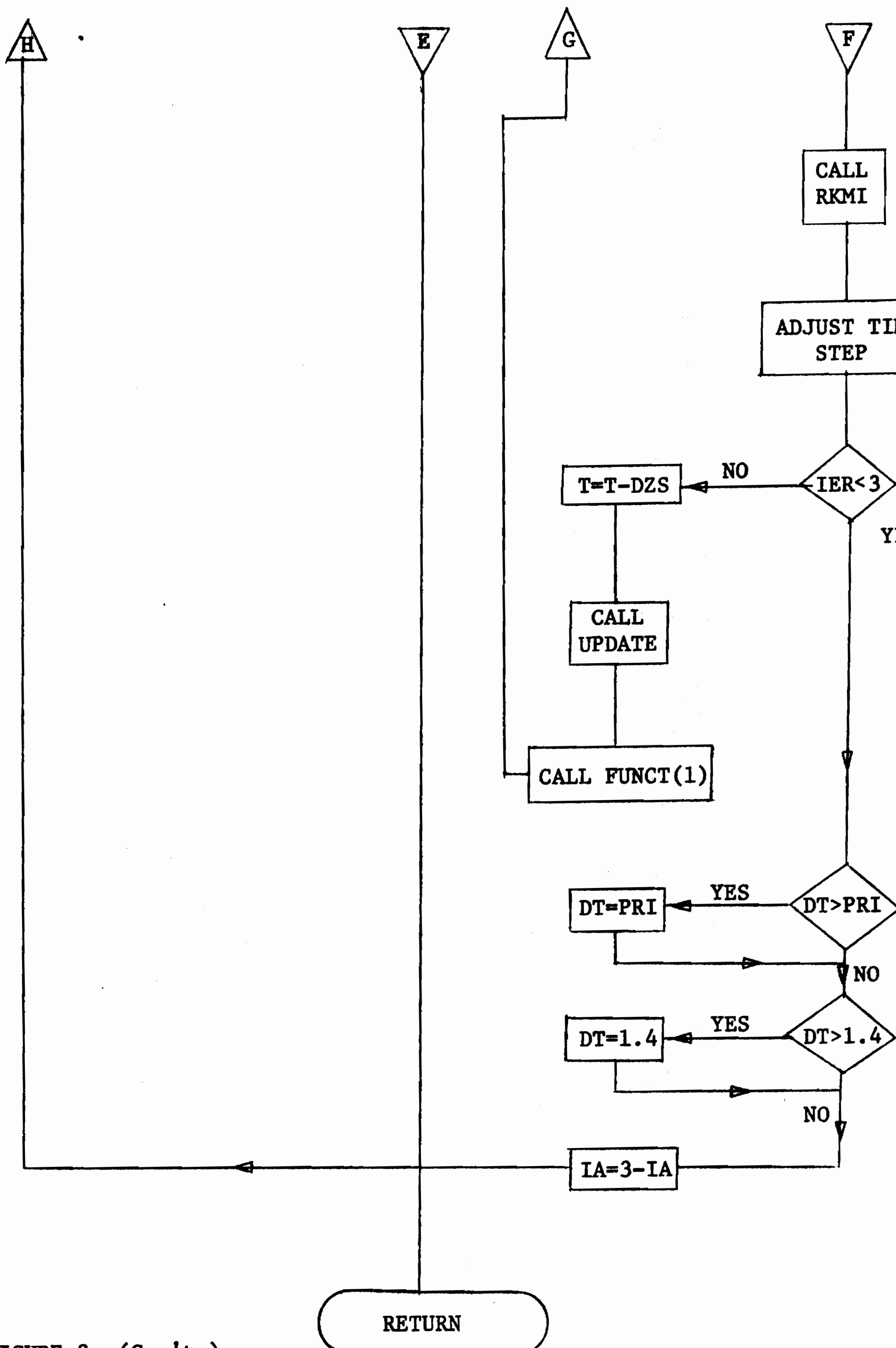

FIGURE 2. (Con't.)

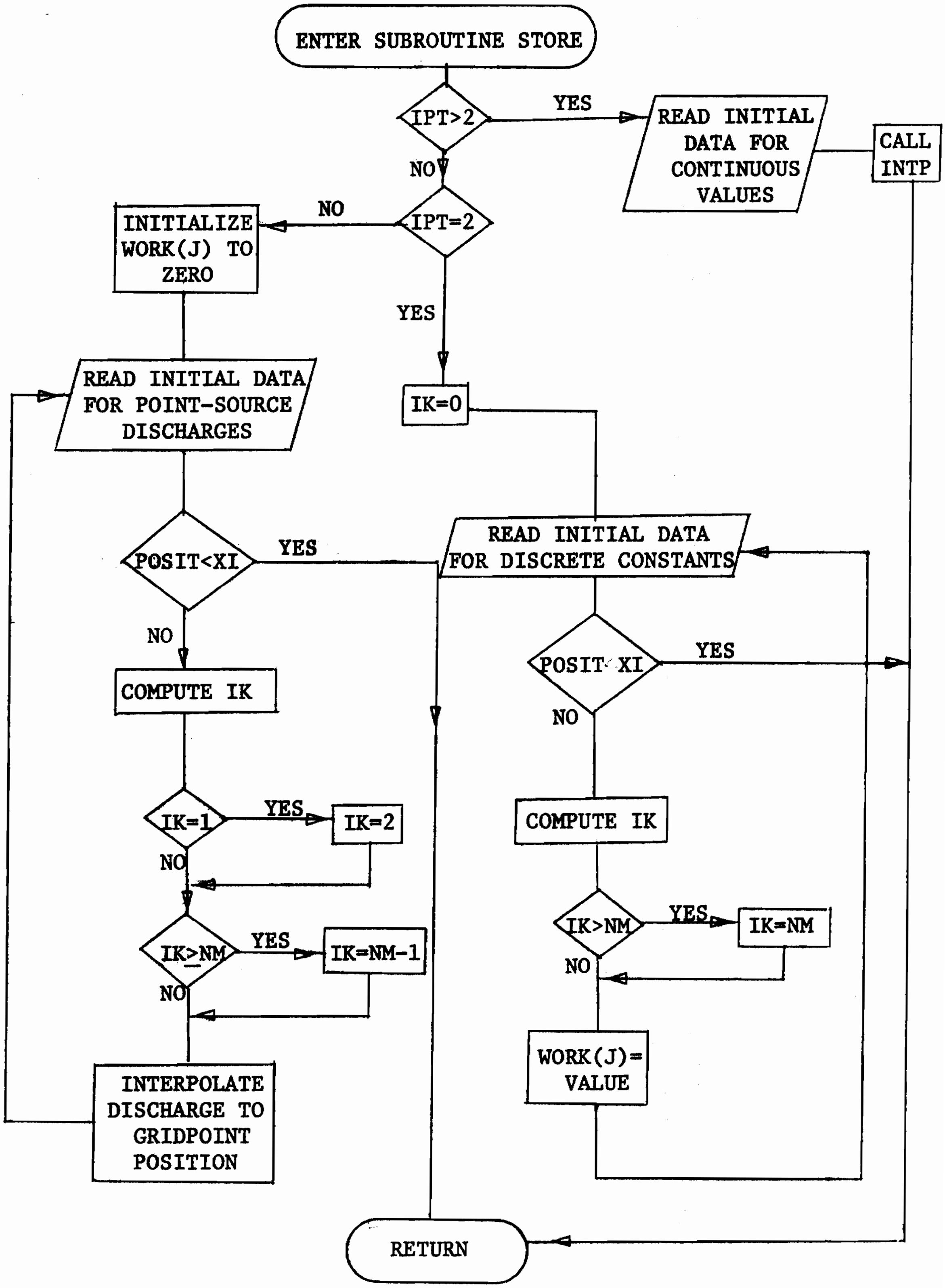

FIGURE 3. FLOWCHART FOR SUBROUTINE STORE

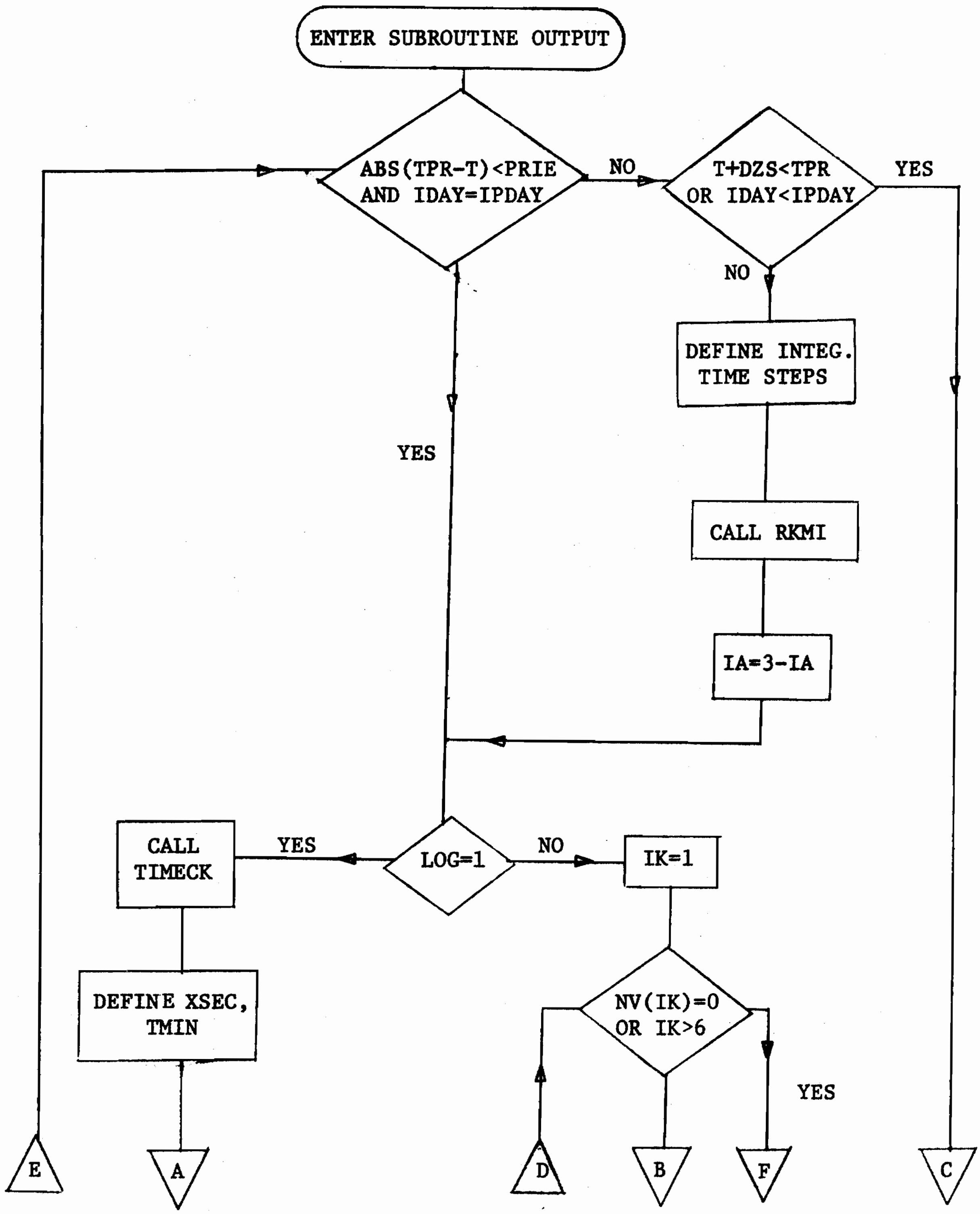

FIGURE 4. FLOWCHART FOR SUBROUTINE OUTPUT

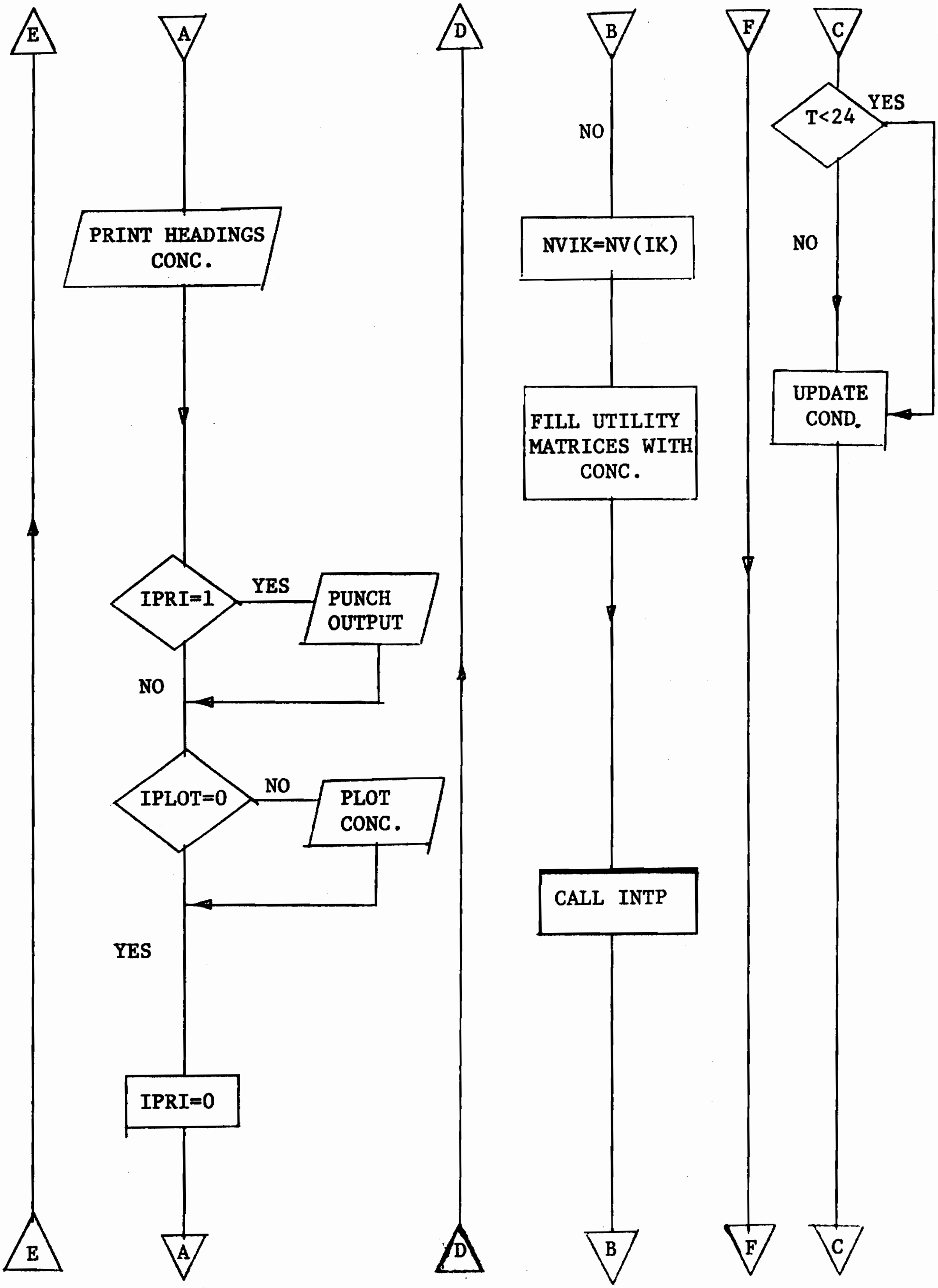

FIGURE 4. (Con't.)

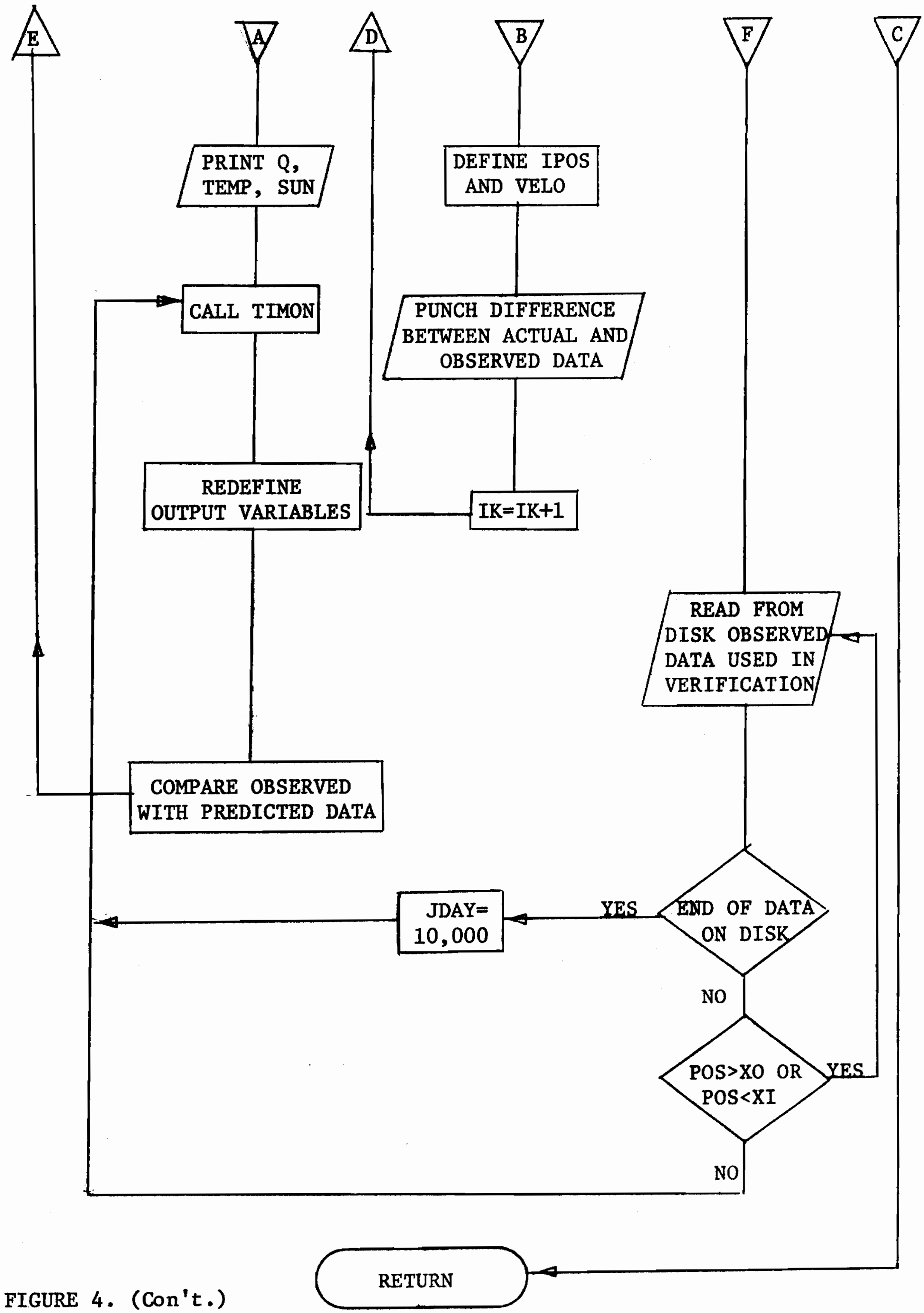

FIGURE 4. (Con't.)

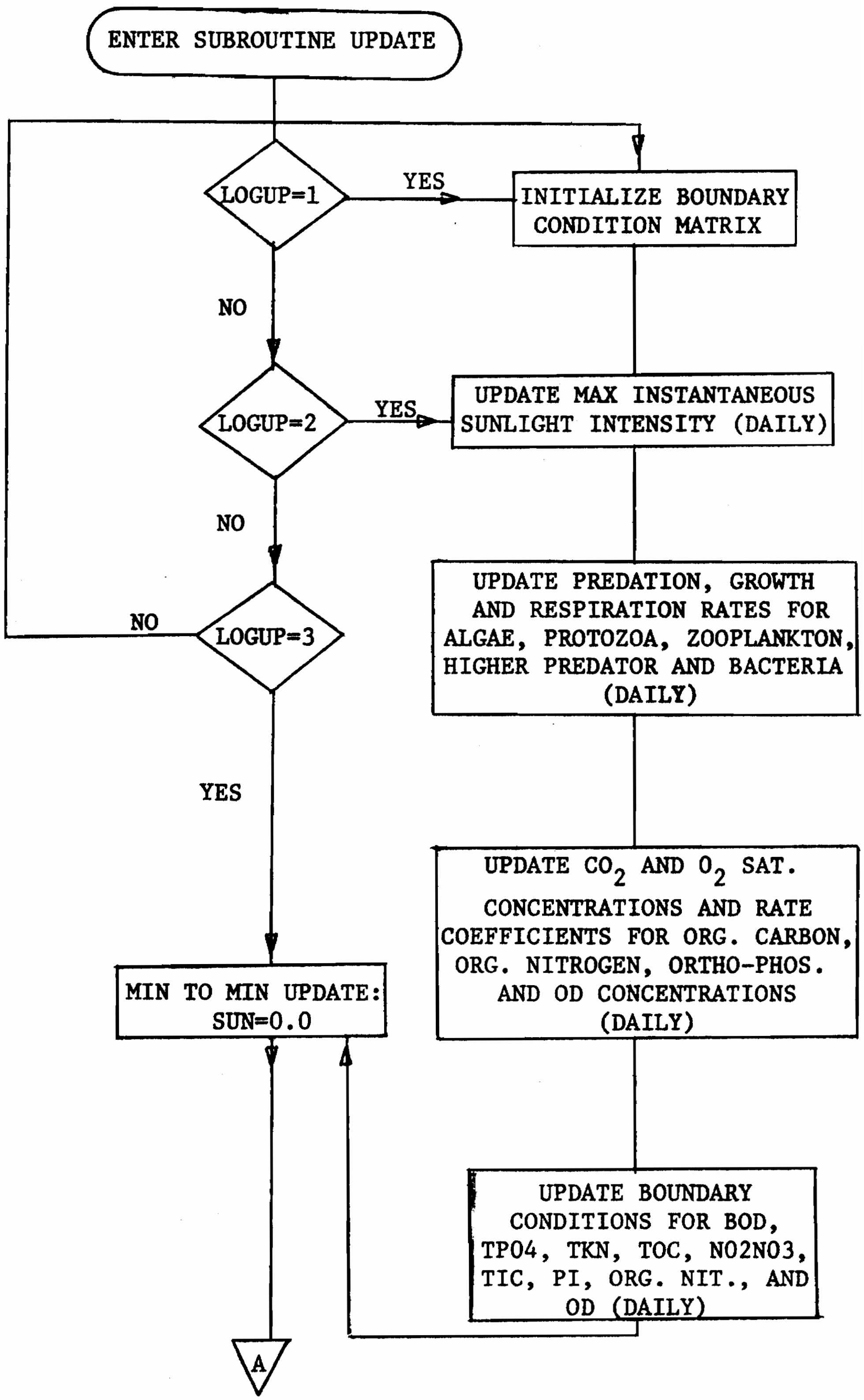

FIGURE 5. FLOWCHART FOR SUBROUTINE UPDATE

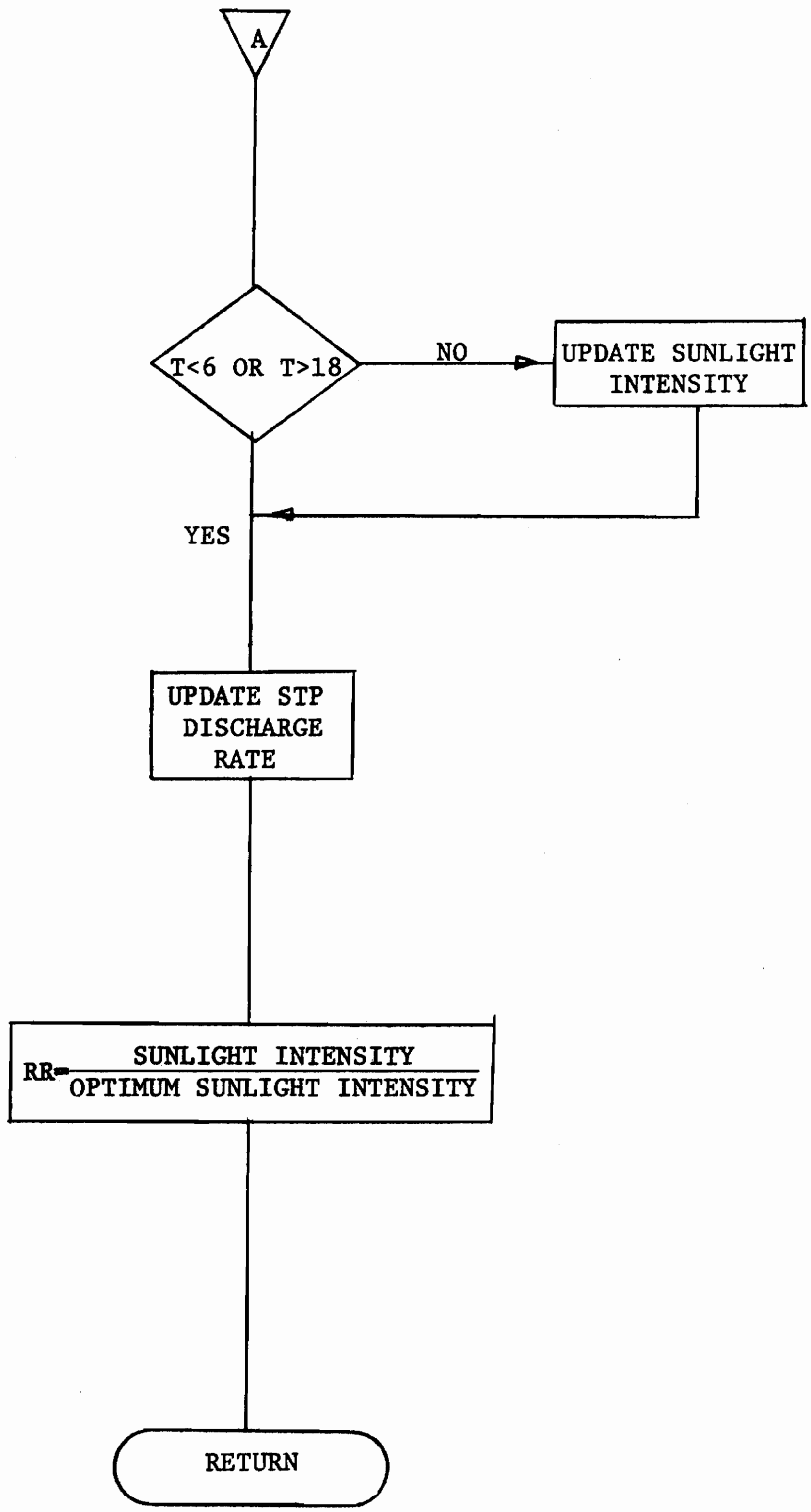

FIGURE 5. (Con't.)

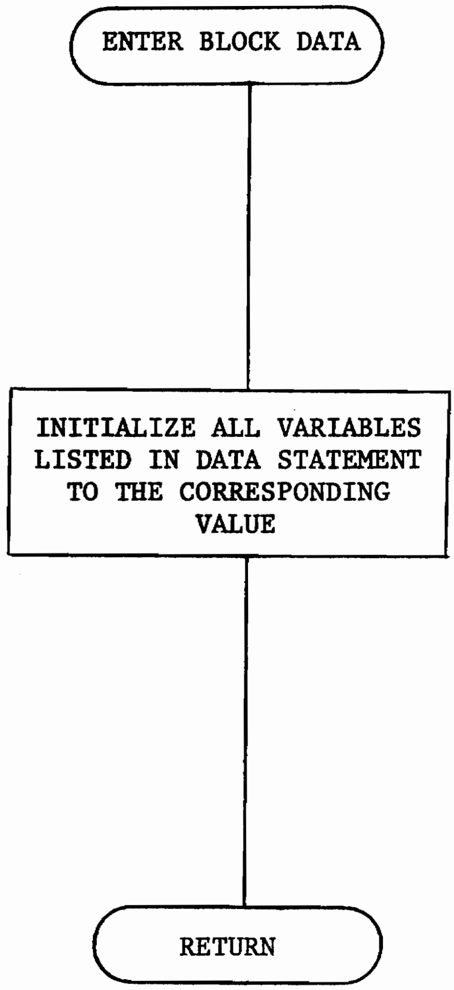

FIGURE 6. FLOWCHART FOR BLOCK DATA

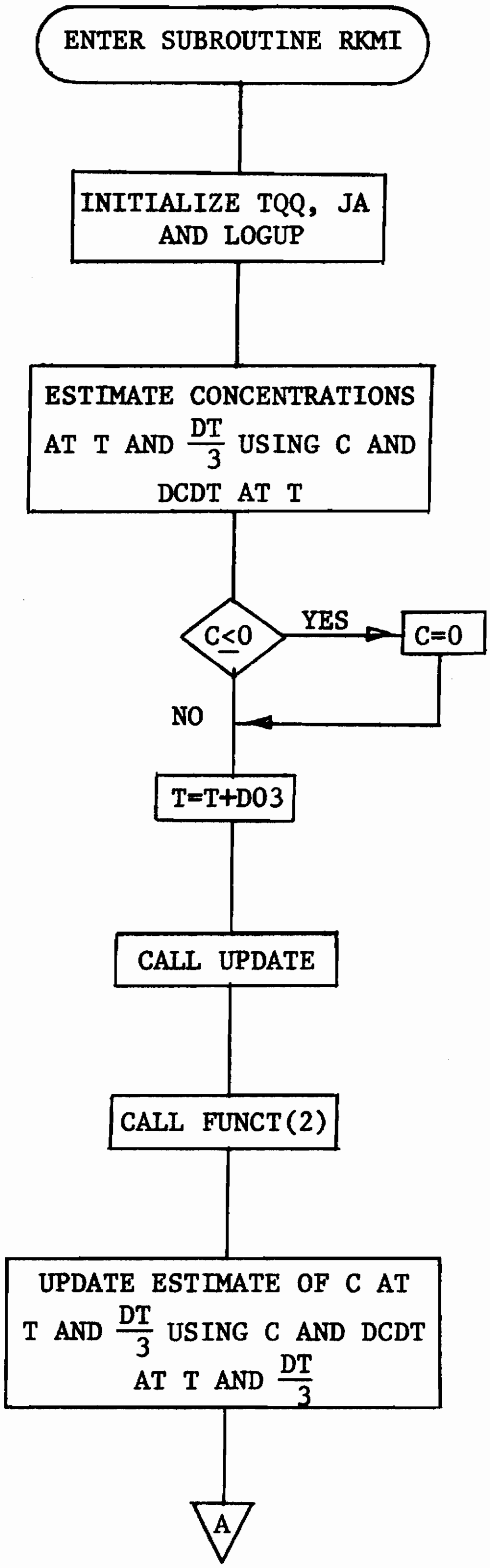

FIGURE 7. FLOWCHART FOR SUBROUTINE RKMI

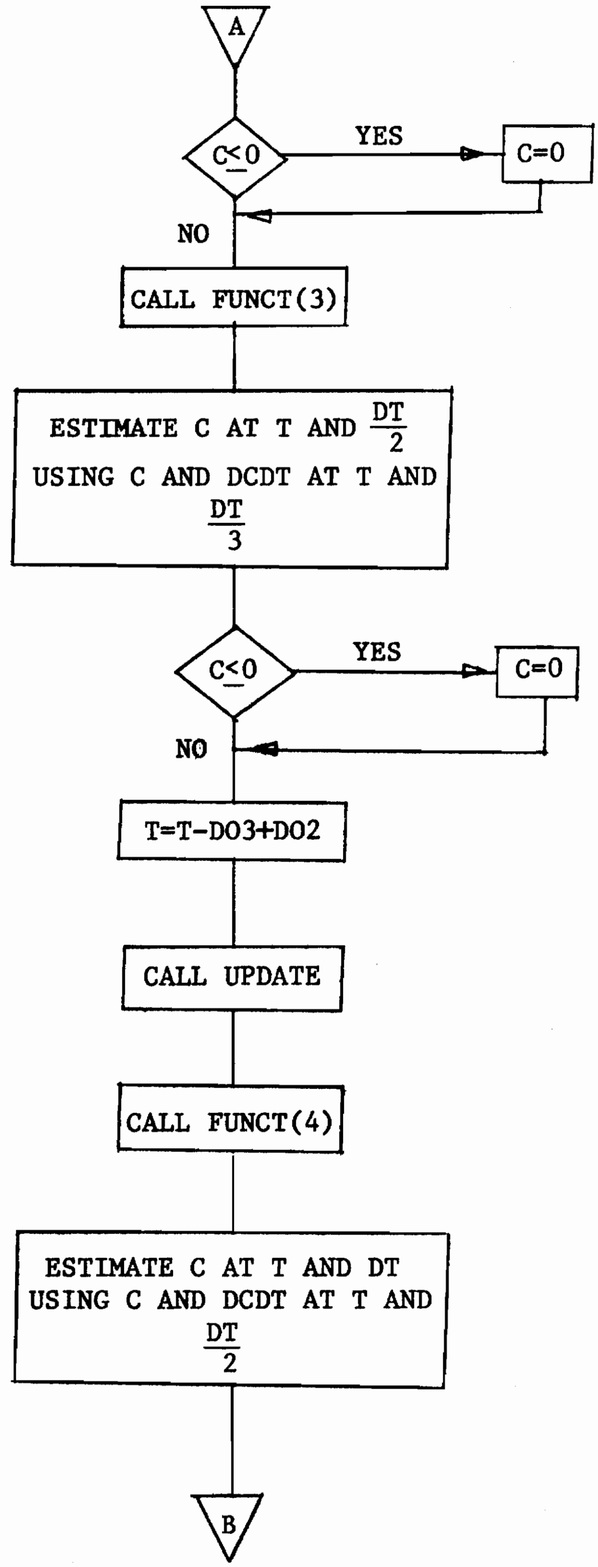

FIGURE 7. (Con't.)

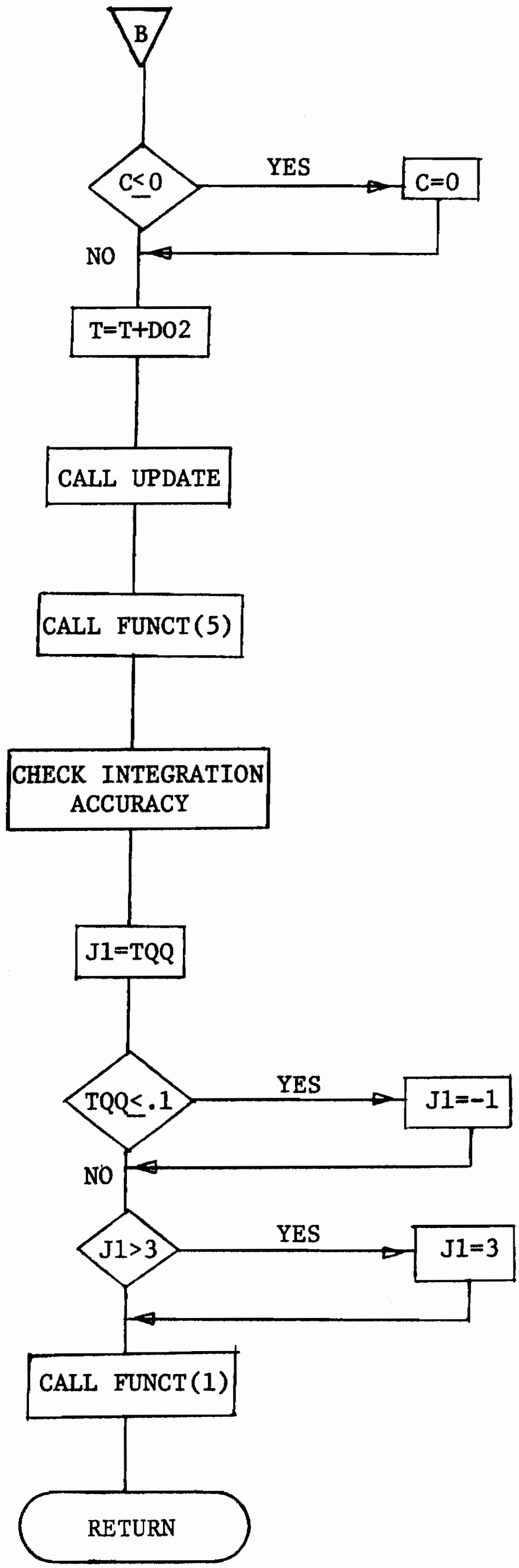

FIGURE 7. (Con't.)

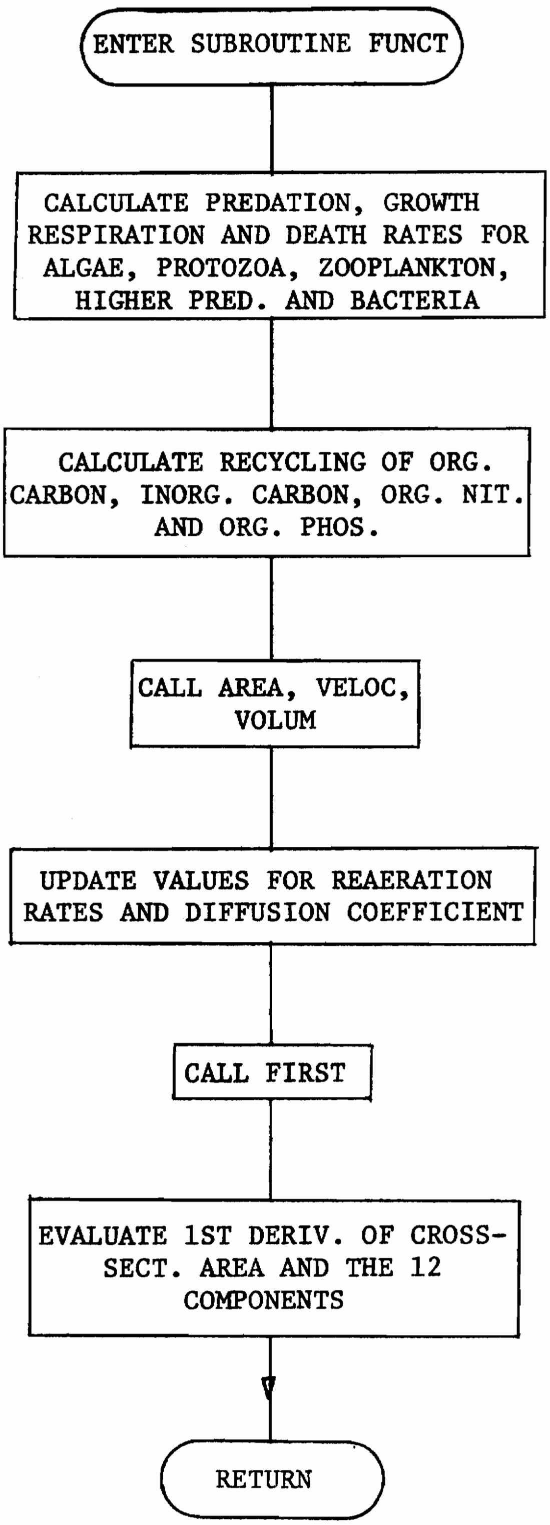

FIGURE 8. FLOWCHART FOR SUBROUTINE FUNCT

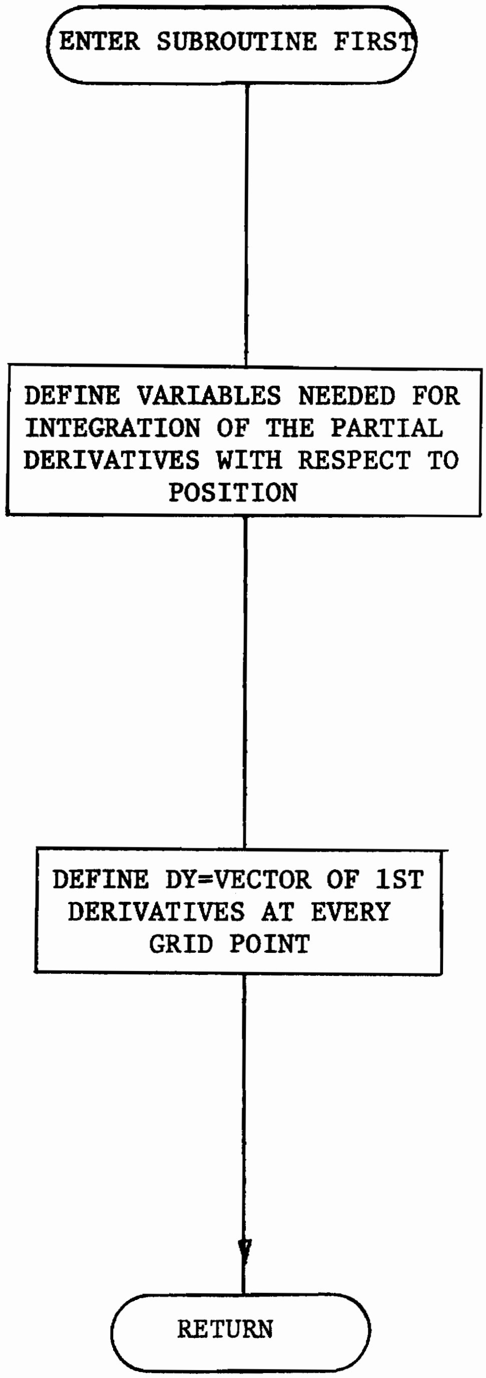

FIGURE 9. FLOWCHART FOR SUBROUTINE FIRST

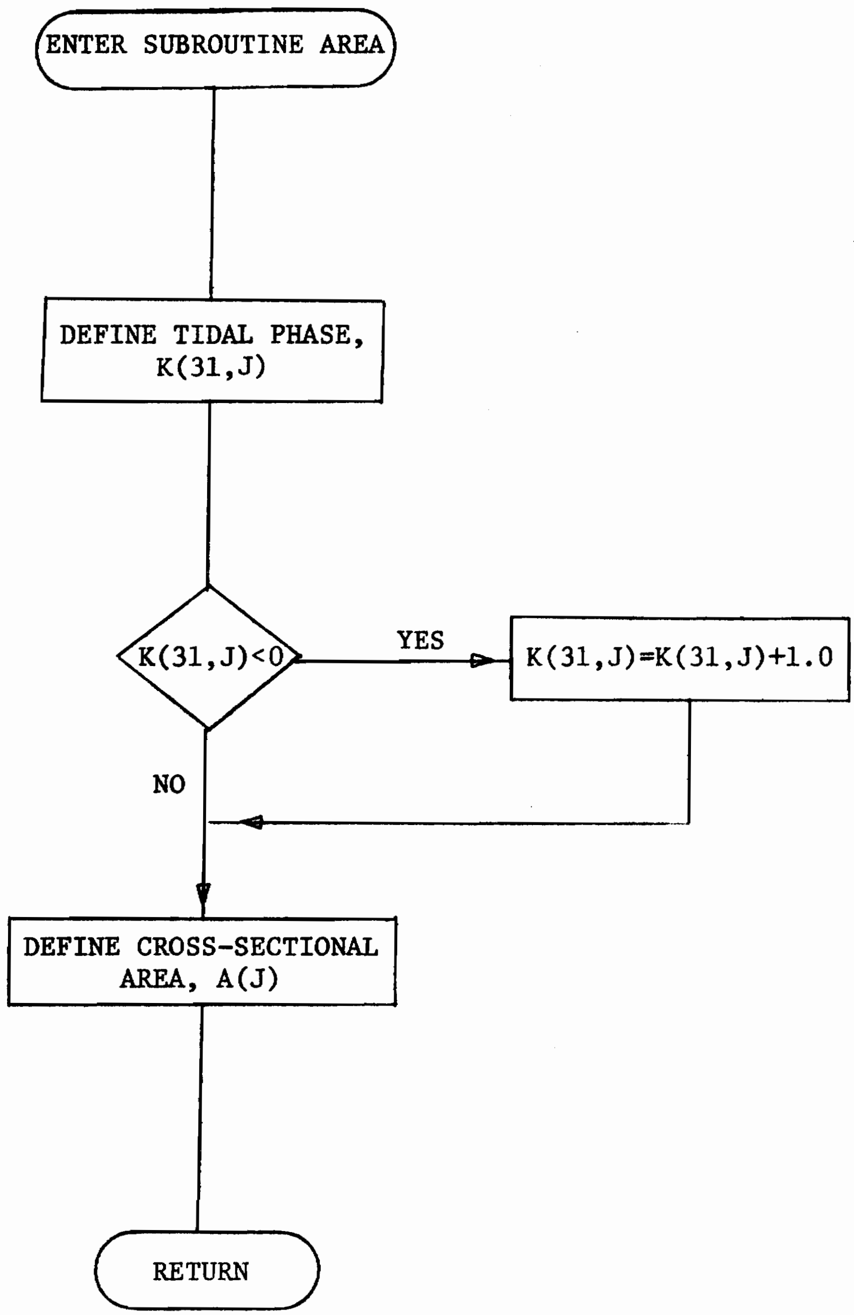

FIGURE 10. FLOWCHART FOR SUBROUTINE AREA

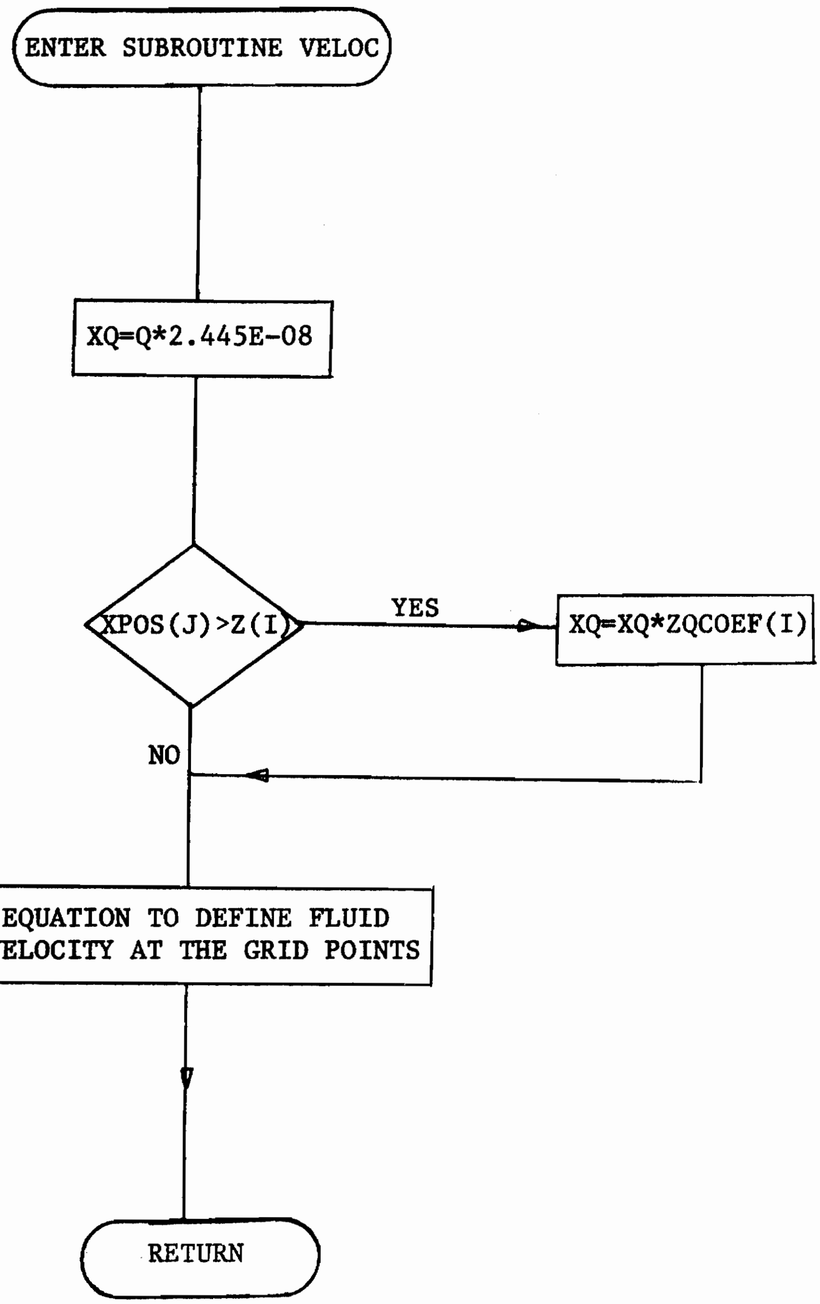

FIGURE 11. FLOWCHART FOR SUBROUTINE VELOC

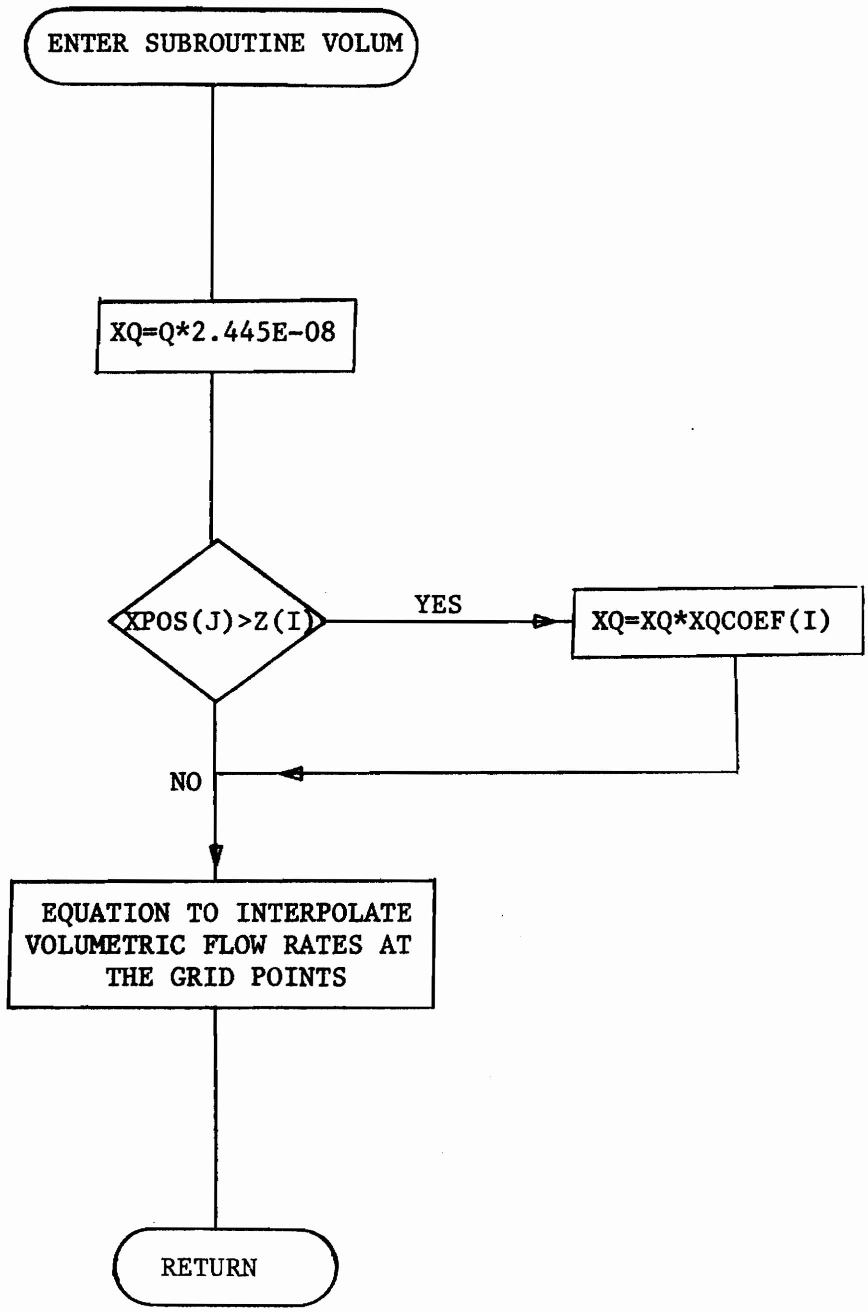

FIGURE 12. FLOWCHART FOR SUBROUTINE VOLUM

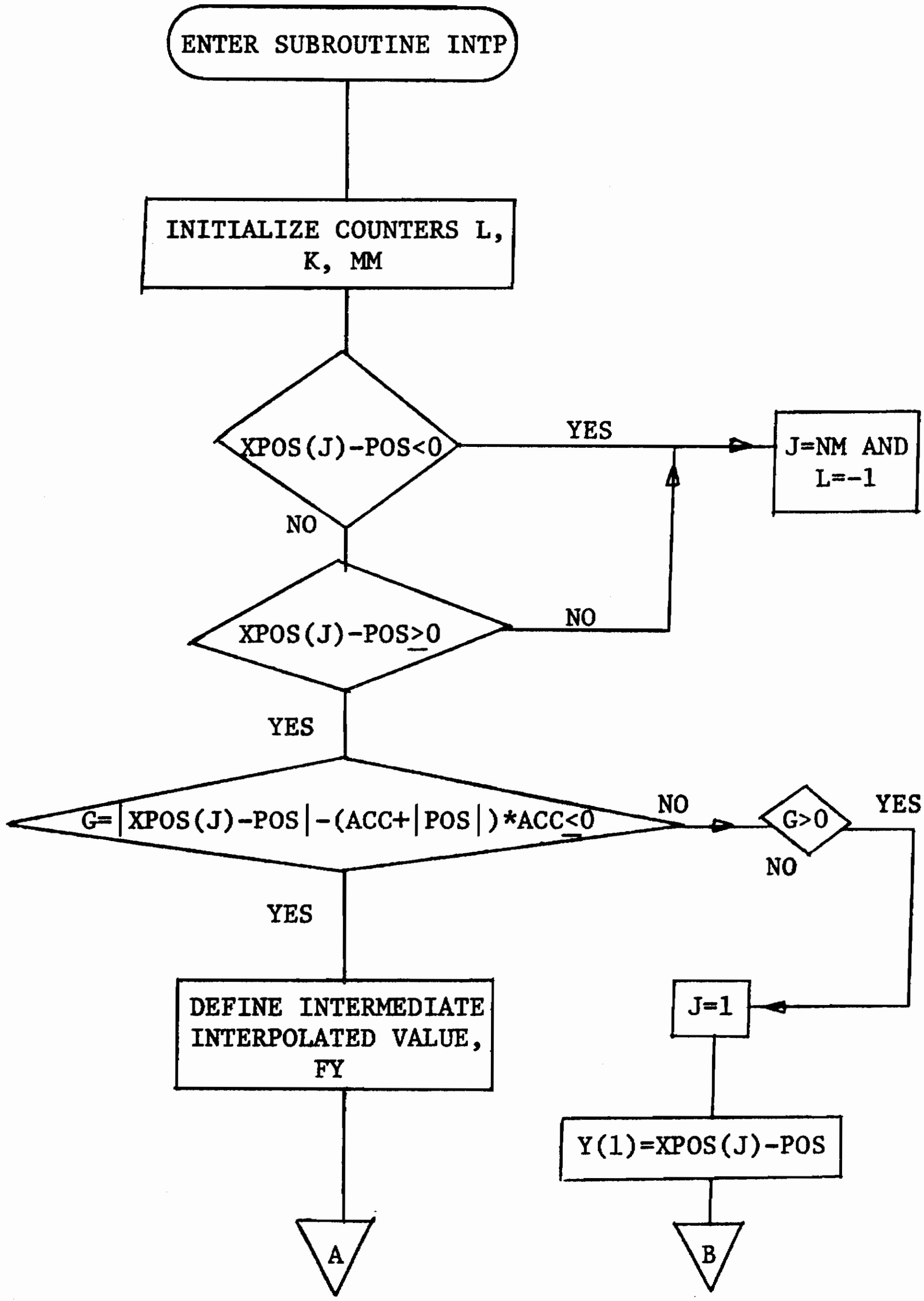

FIGURE 13. FLOWCHART FOR SUBROUTINE INTP

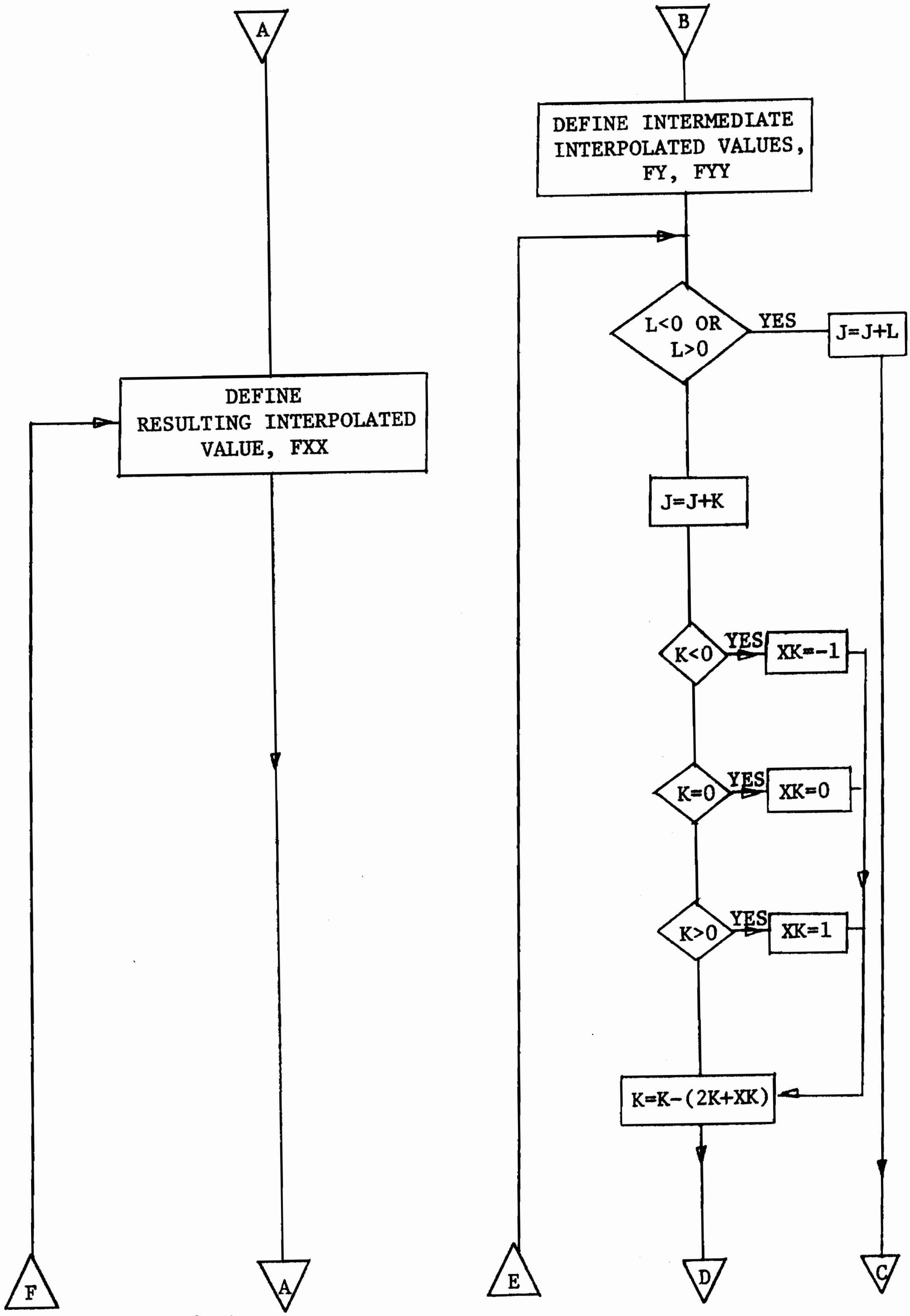

FIGURE 13. (Con't.)

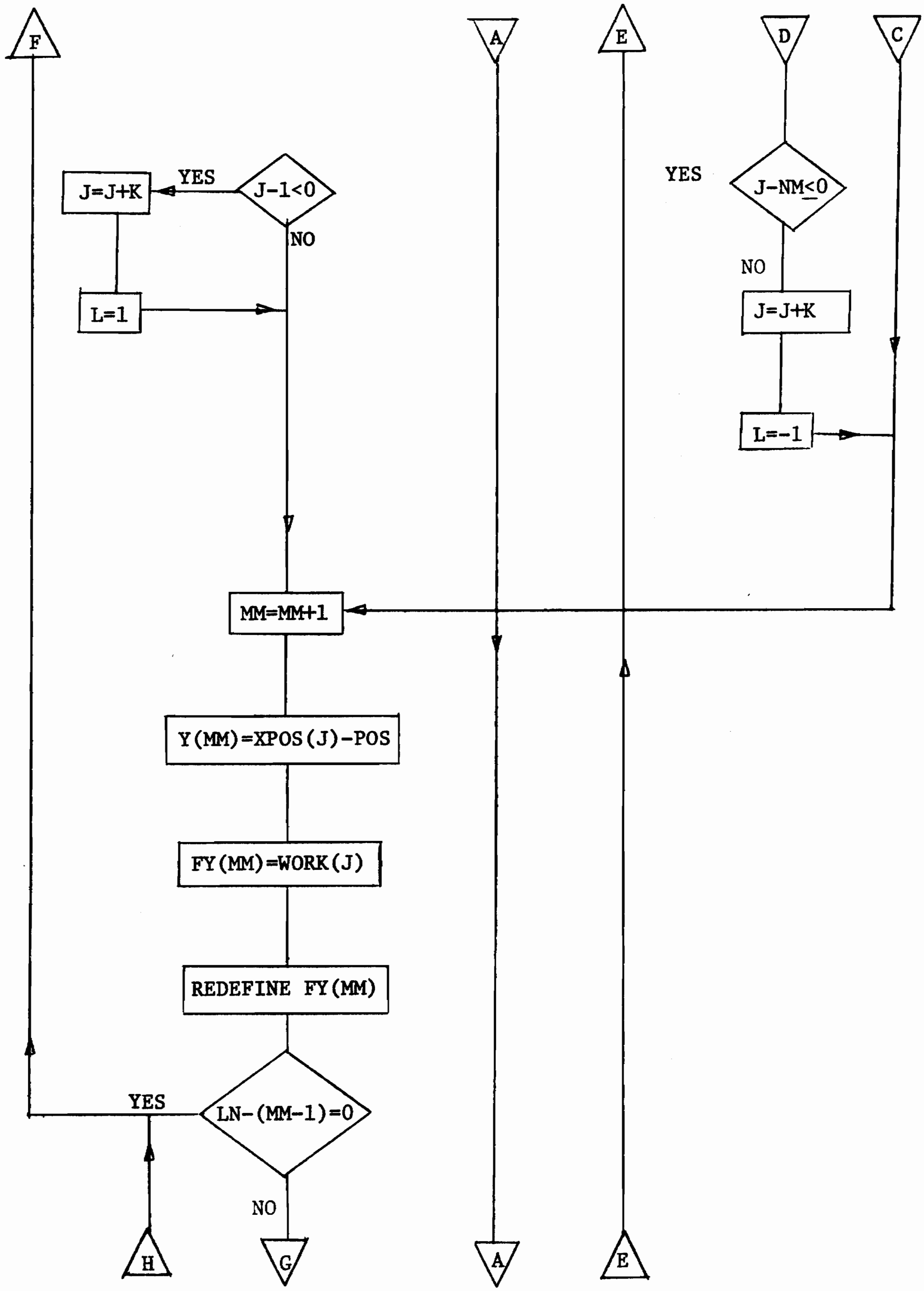

FIGURE 13. (Con't.)

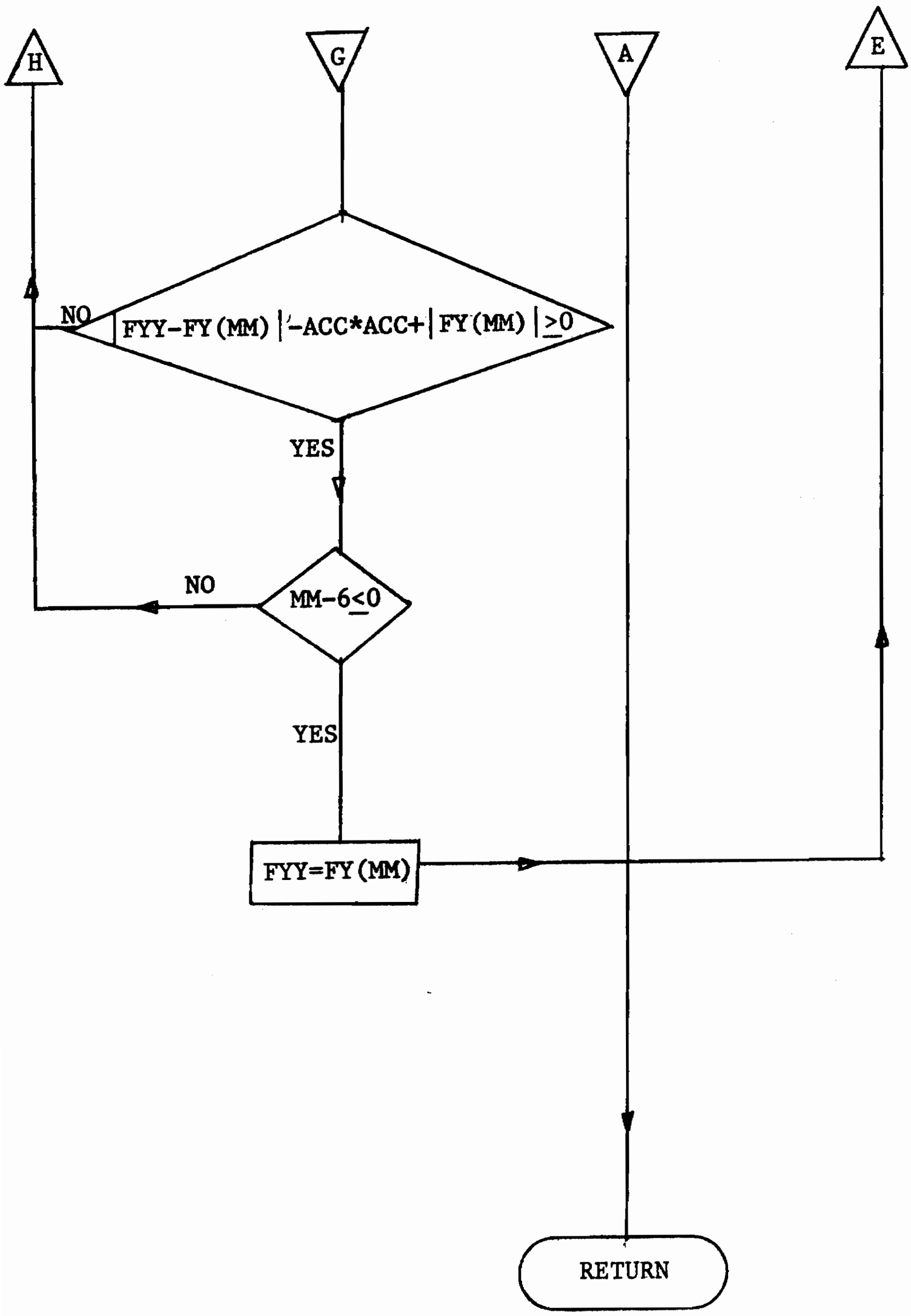

FIGURE 13. (Con't.)

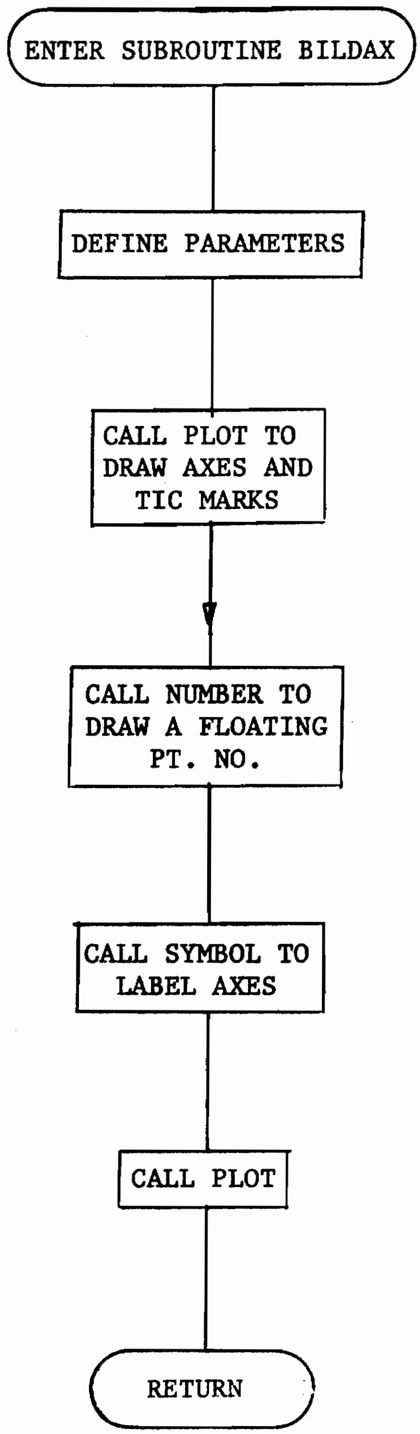

FIGURE 14. FLOWCHART FOR SUBROUTINE BILDAX

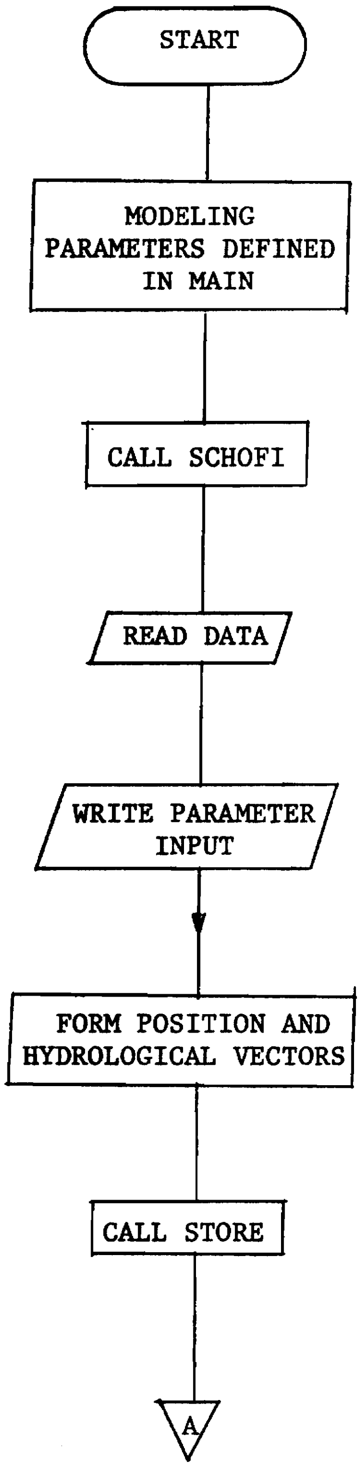

FIGURE 15. FLOWCHART FOR OPERATION OF GEM

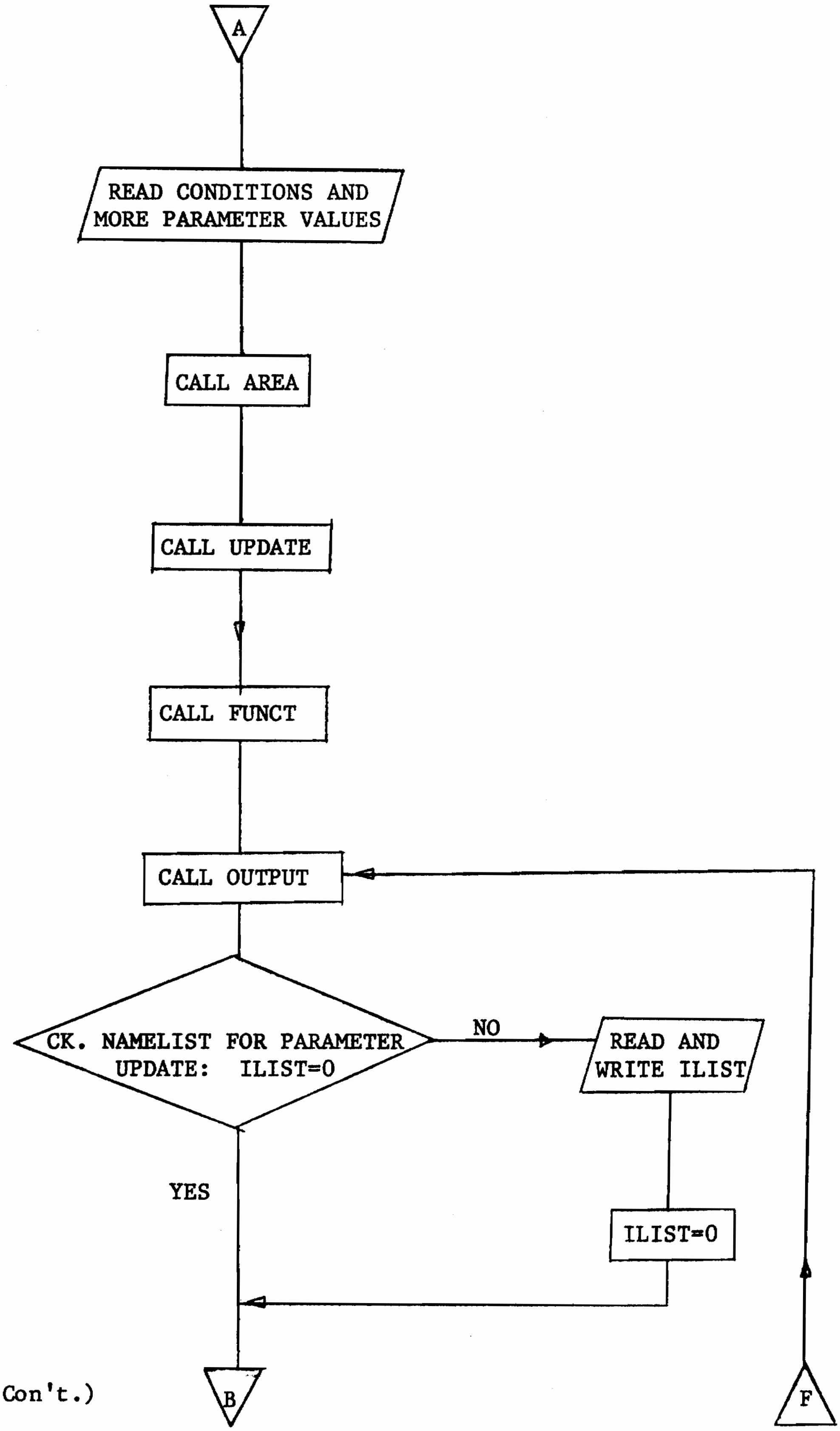

FIGURE 15. (Con't.)

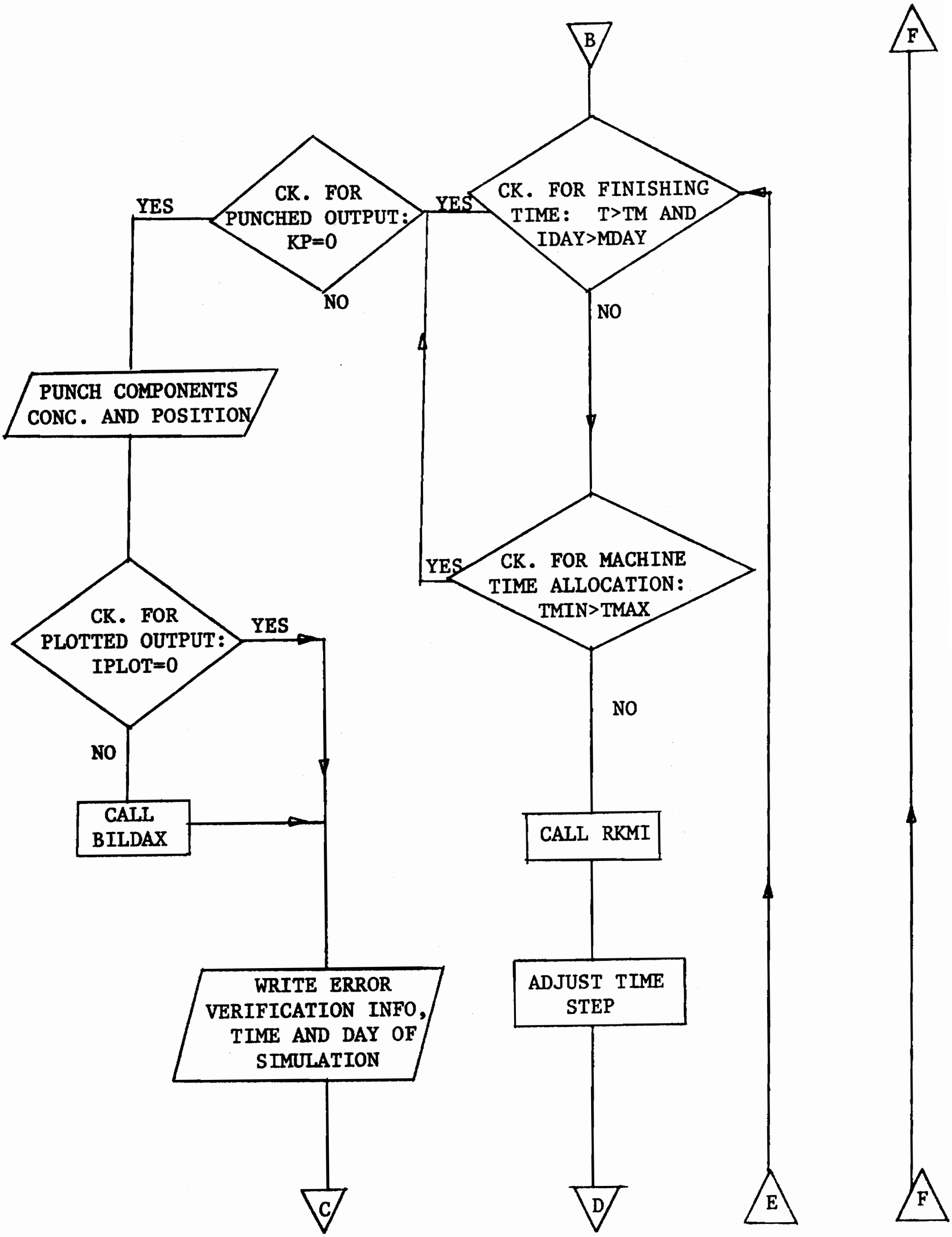

FIGURE 15. (Con't.)

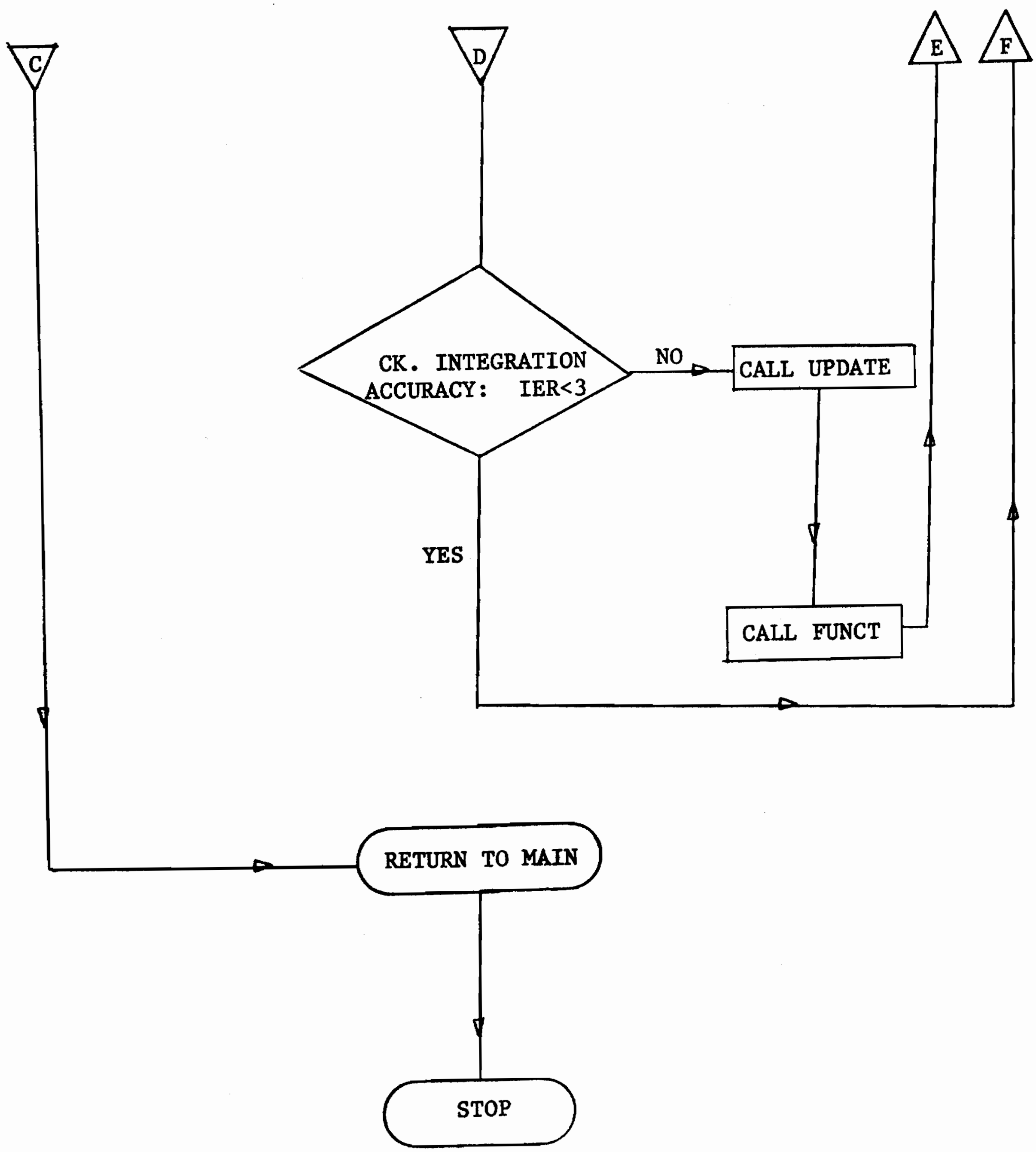

FIGURE 15. (Con't.)

VITA

The author was born September 30, 1952, in upstate New York. Attending the Schenectady county public school system, she graduated from Linton High School in June, 1970. She decided to continue her education in the fall of that same year, enrolling at Keene State College, a small liberal arts institute located in New Hampshire. After four years of part-time jobs sandwiched between essential study hours, she was awarded a Bachelor of Arts degree in Mathematics. In an attempt to combine her educational background with her personal interest in ecological development, she began studies at Virginia Polytechnic Institute and State University on an Environmental Protection Agency grant in September, 1974. Since that time she has been diligently working as a candidate for the Master of Science degree in Statistics.

Sandra Ann DePietro

GEM: GENERALIZED ESTUARY MODEL
A VARIATION ON THE SCHOFIELD-KRUTCHKOFF
STOCHASTIC MODEL FOR ESTUARIES

by

Sandra Ann DePietro

(ABSTRACT)

In recent years, many mathematical models have been developed to be used as mechanisms for carrying out stream and estuary investigations. In 1971, W.R. Schofield and R.G. Krutchkoff completed work on a stochastic model in an attempt to accurately describe the behavior of an estuary. Through the use of a high-speed computer this one-dimensional model predicts the concentrations of twelve interacting components, subdivided into five biological and seven chemical factors. This is a valuable tool, but from a practical viewpoint the model is difficult to apply without a fairly strong background in computer science. It is the aim of the present study to simplify the use of the Schofield-Krutchkoff estuary model so that it can be readily accessible to the appropriate personnel, irrespective of their previous exposure to computer programming.

Dependent upon the particular estuary studied, it was necessary to make internal program adjustments with respect to boundary conditions, applicable rate constants, tidal lag and maximum tidal velocity rates. These constants have been replaced by variables for the user to define as input data to the main program segment. The options to choose one of several expressions for the oxygen reaeration rate K_2, whether

to weight this equation with wind velocity, vary the volumetric fresh-water flow rate with position and request plotted output for each day modeled have also been added.