ORNL-TM-4626

A TIME-DEPENDENT, TWO-DIMENSIONAL MATHEMATICAL MODEL FOR SIMULATING THE HYDRAULIC, THERMAL, AND WATER QUALITY CHARACTERISTICS IN SHALLOW WATER BODIES (thesis)

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OAK RIDGE NATIONAL LABORATORY
OPERATED BY UNION CARBIDE CORPORATION • FOR THE U.S. ATOMIC ENERGY COMMISSION

ORNL-TM-4626

Contract No. W-7405-eng-26

ORNL ENGINEERING

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Submitted as a dissertation to The University of Tennessee for the degree of Doctor of Philosophy.

AUGUST 1974

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UNION CARBIDE CORPORATION
for the
U.S. ATOMIC ENERGY COMMISSION

FOREWORD

The objective of this study was to develop a time-dependent, two-dimensional mathematical model for predicting the velocities, water levels, temperature, and mass concentrations of various constituents in shallow vertically mixed water bodies. The model developed and presented here meets the basic objective, but still much remains to be done. A general computer code of such a size and scope will necessarily have, in its initial phases, some limitations and drawbacks. It cannot become a truly reliable predictive tool unless evolutionalized through constant use and experience. It will, no doubt, require future modifications, capability improvements, verification with field data, and calibration before becoming a productive computer program. It is hoped that this computer model will indeed be used and adapted by careful thermal-hydraulic analysts who are fully aware of its capabilities and, most importantly, its limitations until it is proven to be completely reliable and productive.

Oak Ridge National Laboratory is providing technical assistance to the U.S. Atomic Energy Commission Directorate of Licensing in its analyses of the environmental impact of power reactors as required by the National Environmental Policy Act. The assessment of the environmental impact of a nuclear station has required the development of new analytical techniques and the expansion of many existing ones.

This document is one of the spin-off results of this effort by the Commission and its National Laboratories to protect the environment.

Other documents of this series in the thermal-hydraulic area published by Oak Ridge National Laboratory are listed below.

1. L. Dresner, "Steady Temperature Distributions in the Far-Field Region Obtained by Solution of the Equation of Convective Diffusion in Two Dimensions," USAEC Report ORNL-TM-4119, Oak Ridge National Laboratory, April 1973.

2. D. A. Pilati, "Transient Cooling of a One-Dimensional Thermal Plume and its Application for Determining Cold Shock," USAEC Report ORNL-TM-4160, Oak Ridge National Laboratory, May 1973.

3. L. Dresner, V. R. Cain, and W. Davis, Jr., "INTAKE: A Numerical Program to Calculate Fluid Velocity Profiles Near a Rectangular Inlet in a Stream with Cross Flow," USAEC Report ORNL-TM-4185, Oak Ridge National Laboratory, July 1973.

4. L. Dresner, "One-Dimensional Analysis of Heat Dissipation in a Sidearm of a Cooling Lake," USAEC Report ORNL-TM-4287, Oak Ridge National Laboratory, October 1973.

5. D. A. Pilati, "Cold Shock: Biological Implications and a Method for Approximating Transient Environmental Temperatures in the Near-Field Region of a Thermal Discharge," USAEC Report ORNL-TM-4267, Oak Ridge National Laboratory, November 1973.

6. M. E. Mitchell, "The Prediction of the Temperature Distribution in an Irregularly Shaped, Partially Mixed, Closed-Cycle Cooling Reservoir," USAEC Report ORNL-TM-4416, Oak Ridge National Laboratory (in press).

7. R. P. Wichner, "Program ESTU: A Method for Estimating Estuarine Temperature Distributions for Harleman's Closed-Form, One-Dimensional Model," USAEC Report ORNL-TM-4150, Oak Ridge National Laboratory, April 1974.

Internal Central Files memorandums which are not for external distribution are:

1. W. Davis, Jr., "Row of Buoyant Jets/Slot Jet Model for Koh and Fan on the IBM/360 Disk," USAEC Report ORNL-CF-72-11-36, Oak Ridge National Laboratory, November 22, 1972.

2. W. Davis, Jr., "Round Buoyant Jet Model of Hirst on the IBM/360 Disk," USAEC Report ORNL-CF-72-12-11, Oak Ridge National Laboratory, December 7, 1972.

3. W. Davis, Jr., "Three-Dimensional Heated Surface Discharge Model of Stolzenbach and Harleman on the IBM/360 Disk," USAEC Report ORNL-CF-73-2-39, Oak Ridge National Laboratory, February 27, 1973.

4. W. Davis, Jr., "Koh and Fan Model of Far-Field Heat Dissipation by Passive Turbulent Diffusion on the IBM/360 Disk," USAEC Report ORNL-CF-73-3-36, Oak Ridge National Laboratory, March 27, 1973.

5. V. R. Cain, "Interactive Access to the Thermal Modeling Computer Library," USAEC Report ORNL-CF-73-4-14, Oak Ridge National Laboratory, April 9, 1973.

6. W. Davis, Jr., "Heated Surface Jet Discharged into a Flowing Ambient Stream—Model of Motz and Benedict on the IBM/360 Disk," USAEC Report ORNL-CF-73-4-23, Oak Ridge National Laboratory, April 9, 1973.

7. W. Davis, Jr., "Energy Dispersion in Vertical Thermal Plumes Discharged into Shallow Water—Model of Trent and Welty on the IBM/360 Disk," USAEC Report ORNL-CF-73-7-15, Oak Ridge National Laboratory, July 11, 1973.

8. W. Davis, Jr., and M. Siman-Tov, "Heat Dispersion in an Estuary—One-Dimensional, Time-Dependent Model of Siman-Tov on the IBM/360 Disk," USAEC Report ORNL-CF-73-7-49, Oak Ridge National Laboratory, July 26, 1973.

9. J. W. Roddy, "Entrainment Probabilities at Oceanic Sites," USAEC Report ORNL-CF-73-9-17, Oak Ridge National Laboratory, September 14, 1973.

10. Ben L. Sill, "A Two-Dimensional Thermal Plume Model for Injection Parallel to a Free Stream in a Bounded Channel," USAEC Report ORNL-CF-73-9-20, Oak Ridge National Laboratory, September 14, 1973.

11. Fred Vaslow, "Fog Probabilities, Plume Visibility, and Drift Deposition from Mechanical and Natural Draft Wet Cooling Towers," USAEC Report ORNL-CF-73-10-7, Oak Ridge National Laboratory, October 4, 1973.

ABSTRACT

A time-dependent, two-dimensional model was developed to provide a practical analytical tool for simulating the transient behavior of the elevation, velocity, and temperature of water and the mass concentrations of various soluble constituents in vertically mixed shallow water bodies. The model is based on a time-dependent discrete element formulation of the basic conservation equations for total mass, momentum, energy, and mass concentration of soluble constituents. These equations are directly formulated in an integral form over each discrete element and then reduced to a set of initial-value ordinary differential equations with respect to time. The equations are numerically integrated by the multi-step explicit solution of the Runge-Kutta-Gill method. A stability analysis is presented for evaluation of the time step to be used to avoid computational instabilities.

The effects of bottom shear stresses, wind stresses, heat exchange with the atmosphere, Coriolis forces, seepage, evaporation, rain, tributaries, power plant intake and discharge, and other possible contributions are taken account of by the model. Internal normal and shear stresses are included fully in the momentum equations, and hydrostatic pressure is also considered. Turbulent diffusion as well as the longitudinal dispersion caused by vertical variations are taken account of by the use of general functions and nonconstant diffusion coefficients. Density and other physical properties can be expressed as functions of

temperature and constituent mass concentrations. Mesh size can be variable, and irregular physical boundaries can be simulated on a rectangular coordinate system.

The model is applicable to any natural water body wherein vertical stratification is not of major importance. This includes many rivers, estuaries, and coastal sites where the horizontal dimensions are usually at least two orders of magnitude larger than the vertical (depth) dimensions. The model is basically a far-field model, but because of the incorporation of stresses in the momentum equations, it can also be used for approximate simulation of the near field. The mutual effects of a number of power plants sharing the same water body as well as the recirculation of discharge water back into the intake structure can be simulated. In a more restricted way, the model can also be used to simulate the entrainment of organisms into the intake structure of a power plant as well as the cold shock effects on aquatic biota when sharp discontinuities in power plant operation occur. Because of the capability to include any number of constituents, the model has the potential for extension into a population distribution model for aquatic organisms.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FIGURE PAGE

LIST OF SYMBOLS

A	Surface area enclosing the discrete element, L^2
a	Radius of pipe in Eq. 3.17, L
b	Width of a jet's mixing zone in Prandtl's defect law (Eq. 3.12), L
C_k	Mass concentration of constituent k in the mixture, $Btu \cdot M^{-1}F^{-1}$
C_p	Specific heat at constant pressure, $Btu \cdot M^{-1}F^{-1}$
C_V	Specific heat at constant volume, $Btu \cdot M^{-1}F^{-1}$
C_Z	Chezy resistance factor for bottom friction, $L^{1/2}T^{-1}$
D	Overall diffusion coefficient combining the molecular, turbulent and shear effects, L^2T^{-1}
D_H	Overall thermal diffusion coefficient, L^2T^{-1}
D_m	Overall momentum diffusion coefficient, L^2T^{-1}
D_M	Overall binary mass diffusion coefficient, L^2T^{-1}
dA	Differential of surface area enclosing the discrete element, L^2
$d\forall$	Differential of volume within a discrete element, L^3
E	Longitudinal diffusion coefficient which is caused by shear effects, L^2T^{-1}
E'	See Table 3.1
E''	See Table 3.1
e	Specific internal energy, $Btu \cdot M^{-1}$
F	Right-hand side of the basic differential equations of the model
°F	Degrees Farenheit

$f(\omega)$	Dimensionless function for turbulent velocity distribution along vertical direction, Eq. 3.19
$\overline{f}$	Depth mean average of $f(\omega)$
f_b	Body force per unit volume, $ML^{-2}T^{2}$
f_c	Coriolis force per unit volume, $ML^{-2}T^{-2}$
g_r	Gravitational acceleration, LT^{-2}
$g(X,Y,Z,t)$	Instantaneous mass flow rate per unit area, $ML^{-2}T^{-1}$
$\vec{g}$	General instantaneous mass flux vector, $ML^{-2}T^{-1}$
h	Specific enthalpy, $Btu \cdot M^{-1}$
h_M	Film mass transfer coefficient across a boundary surface, $ML^{-2}T^{-1}$
h_H	Film heat transfer coefficient across a boundary surface, $Btu \cdot L^{-2}T^{-1}F^{-1}$
$H(X,Y,Z,t)$	Instantaneous local total Water depth, L
K	Heat exchange coefficient between the top water surface and the atmosphere, based on the equilibrium temperature concept, $Btu/ft^2 \cdot day \cdot °F$
k_o	Von Karman's constant (Eq. 3.21)
ℓ	Prandtl's mixing length (Eq. 3.0), L
ℓ_W	Taylor's mixing length (Eq. 3.10), L
$(Le)_\epsilon$	Turbulent Lewis number (Eq. 3.74)
n	Manning roughness coefficient, $TL^{-1/3}$
$\hat{n}$	Unit vector (outward positive) normal to surface area A
$P(X,Y,Z,t)$	Represents in general any one of the basic unknowns of the model (H, U, V, T, or C_k)
$\overline{P}(X,Y,t)$	Depth averaged and time averaged (over turbulent time scale) value of property P
P_r	Local instantaneous pressure, $ML^{-1}T^{-2}$

$(P_r)_a$	Local atmospheric pressure, $ML^{-1}T^{-2}$
$p'(X,Y,Z,t)$	Random turbulent fluctuations of property P compared to its time averaged value over turbulent time scale
$p(X,Y,Z,t)$	Difference between local turbulent time scale mean value of property P and its depth averaged value
$(PR)_\alpha$	Molecular Prandtl number (Eq. 3.55)
$(PR)_\varepsilon$	Turbulent Prandtl number (Eq. 3.56)
$(PR)_E$	Longitudinal diffusion Prandtl number (Eq. 3.57)
$(PR)_D$	Total Prandtl number (Eq. 3.58)
Q_s	Gross solar radiation heat flux, $Btu/ft^2 \cdot day$
$\vec{q}$	General instantaneous heat flux vector, $Btu \cdot L^{-2}T^{-1}$
$\dot{q}_V$	Heat generation (or decay) per unit volume, $Btu \cdot L^{-3} \cdot T^{-1}$
R_h	Hydraulic radius, L
S_B	Slope of channel bottom
$(Sc)_\alpha$	Molecular Schmidt number (Eq. 3.70)
$(Sc)_\varepsilon$	Turbulent Schmidt number (Eq. 3.71)
$(Sc)_E$	Longitudinal diffusion Schmidt number (Eq. 3.72)
$(Sc)_D$	Total Schmidt number (Eq. 3.73)
$T(X,Y,Z,t)$	Instantaneous local water temperature, °F
T_d	Dew point temperature, °F
T_E	Equilibrium temperature, °F
t	time, T
$U(X,Y,Z,t)$	Instantaneous local horizontal velocity in X direction, LT^{-1}
$\overline{U}(X,Y,t)$	Depth averaged and time averaged (over turbulent time scale) value of instantaneous velocity in X direction, LT^{-1}

$U_F(t)$	Freshwater velocity in oscillating water body (velocity averaged with respect to time over oscillating period time scale), LT^{-1}
$u'(X,Y,Z,t)$	Random turbulent fluctuations of velocity in X direction compared to its time averaged value over turbulent time scale, LT^{-1}
$u(X,Y,Z,t)$	Difference between local turbulent time scale mean value of velocity in X direction and its depth averaged value, LT^{-1}
u_τ	Friction velocity in X direction ($= \sqrt{\tau_X/\rho}$), LT^{-1}
$\hat{u}$	Internal energy, $Btu \cdot M^{-1}$
$V(X,Y,Z,t)$	Instantaneous local horizontal velocity in Y direction, LT^{-1}
$\overline{V}(X,Y,t)$	Depth averaged and time averaged (over turbulent time scale) value of instantaneous velocity in Y direction, LT^{-1}
$\vec{V}$	Velocity of mixture, LT^{-1}
$\vec{V}_k'$	Velocity of constituent k relative to the mixture velocity $\vec{V}$, LT^{-1}
V_n	Velocity (either U or V) normal to a boundary surface, LT^{-1}
V_t	Velocity (either U or V) tangent to a boundary surface, LT^{-1}
$\forall$	Volume of discrete element, L^3
v_τ	Friction velocity in Y direction ($= \sqrt{\tau_Y/\rho}$), LT^{-1}
W	Wind velocity, miles/hr
$W_S(X,Y,t)$	Local instantaneous rate of change of water elevation with time; that is, vertical velocity of the water top surface, LT^{-1}
X	Horizontal direction in the Cartesian coordinate system, L
Y	Horizontal direction in the Cartesian coordinate system, L
Z	Vertical direction in the Cartesian coordinate system, L
α_H	Molecular thermal diffusion coefficient, L^2T^{-1}

α_m	Molecular momentum diffusion coefficient, L^2T^{-1}
α_M	Molecular binary mass diffusion coefficient, L^2T^{-1}
Δt	Time step size used for numerical time integration, T
Δt_{CR}	Smallest time step size required for numerical stability, T
ΔX	Size of a discrete element in X direction, L
ΔY	Size of a discrete element in Y direction, L
$\delta(t)$	Discrete perturbation error of numerical solution at time t
$\delta F(t)$	Numerical error introduced in F(t) due to the discrete perturbation error (t)
ε_p	Turbulent diffusion coefficient either mass, momentum, or heat, L^2T^{-1}
ε_H	Turbulent thermal diffusion coefficient, L^2T^{-1}
ε_m	Turbulent momentum diffusion coefficient, L^2T^{-1}
ε_M	Turbulent binary mass diffusion coefficient, L^2T^{-1}
λ	Dimensionless friction coefficient on a solid surface
ρ	Density, ML^{-3}
$\dot{\rho}_k$	Mass addition (or subtraction) of constituent k per unit volume and per unit time, $ML^{-3}T^{-1}$
$\vec{\sigma}$	Surface force vector per unit area, $ML^{-1}T^{-2}$
σ_{XX}	Internal normal stresses in X direction, $ML^{-1}T^{-2}$
δ_{XY}	Internal shear stresses in X direction over a surface area directed in Y direction, $ML^{-1}T^{-2}$
δ_{YX}	Internal shear stresses in Y direction over a surface area directed in X direction, $ML^{-1}T^{-2}$
δ_{YY}	Internal normal stresses in Y direction, $ML^{-1}T^{-2}$
τ	Local shear stress on a solid surface, $ML^{-1}T^{-2}$
τ_W	Local shear stress on side walls, $ML^{-1}T^{-2}$

χ Empirical dimensionless coefficient in Von Karman's similarity theory (Eq. 3.11)

χ_1 Empirical dimensionless coefficient in Prandtl's defect law (Eq. 3.12).

ψ Coefficient of property P(H, U, V, T, or C_k) in the right-hand side functions of the system differential equations (Eq. 6.18)

ψ_G The term in the right-hand side functions of the system differential equations which is independent of P

ω Local dimensionless depth (Eq. 3.19)

Subscripts

A Identifies the value to be per unit cross sectional area

a Identifies the value to be for ambient conditions

B Identifies the value to be for the bottom surface of the water body

b Identifies the value to be on a boundary surface

bf Identifies the value to be a flux (flow rate for unit area) across a boundary surface

bo Identifies the value to be for the outside the boundary surface and outside the boundary layer thickness

i Identifies the location of the center of a discrete element along X direction

i±1/2 Identifies the location of the half-point boundaries of a discrete element in X direction

ib Identifies the location of the half-point boundary of a discrete element in X direction when this element is next to a boundary

j Same as i but in Y direction

j±1/2 Same as (i±1/2) but in Y direction

k Identifies the value to be for a certain constituent k in the mixture

T	Identifies the value to be for the top surface of the water body
W	Identifies the value to be of the wind
WS	Identifies the value to be for the water surface
X	Identifies the value of a component in X direction
Y	Identifies the value of a component in Y direction
Z	Identifies the value of a component in vertical direction
0	Identifies the value to be evaluated at initial time (initial condition value)

Superscripts

~	Indicates a numerically computed value which includes the discrete perturbation error δ (Eq. 6.19)
—	Indicates average value of either with respect to depth, or with respect to turbulent time scale or both

1. INTRODUCTION

During the past few years, considerable interest has arisen in developing the capabilities for predicting temperature distributions resulting from discharges of heated water from electric power plants into rivers, lakes, estuaries, and coastal waters. This interest arose because of a rapid growth in demand for electric power and an increased awareness of the possible environmental impact of electric power generating plants. Much of the additional electric power demanded is expected to be supplied by nuclear power plants, and these plants reject about 7,500 Btu/hr for every kilowatt of power generation rather than about 5,000 Btu/hr rejected by conventional steam plants. The rejected heat is transferred in one way or another to the natural environment. Among the presently available methods of heat disposal, the once-through cooling method, in which water is withdrawn from a water body and returned to it after being heated, is the least expensive[1] and, therefore, the most attractive to the utilities. The main disadvantage in this method is its possible destructive impact on aquatic biota resulting from entrainment of organisms through the plant cooling water intake and from elevation of the temperature of the water body to undesirable levels.

To put the problem in somewhat better perspective, it must be emphasized that the total cooling capacity of the earth still is far greater than the total heat generation rate from power plants anticipated for the next few decades. It has been estimated that for the total annual heat generation rate of 1.2 million MW(t) anticipated by the year 1990, the overall average water surface temperature will be increased by only about 0.25°F.[2] Unfortunately, the heat rejected from power plants is not released uniformly throughout the total body of water available. Instead, the heat is dumped locally to create large concentrations of thermal energy that must be diluted and dissipated to prevent local heat buildup.

Determination of the capability of a water body to dilute and dissipate concentrated thermal discharges is a major thermal pollution problem faced today. Estuaries and coastal waters are most effective thermal sinks, but their capabilities in this respect are not as limitless as some may wish to believe. The situation is usually more severe in rivers, lakes, and ponds. To evaluate properly the impact of thermal discharges, the biologist must know, among other things, what portion of the biota is affected by what levels of temperature increases and for how long. To answer such broad questions, one must have detailed information about the velocities, temperatures, and concentrations of dissolved substances as a function of three space dimensions and time. Unfortunately, attainment of such information is not an easy task.

Various modeling methods have been used in attempts to determine and predict the dilution and dissipation capabilities of specific water bodies. Although useful in many applications, physical models cannot simulate correctly many of the transport processes because of size limitations and the need to distort the models greatly. Field measurements are very expensive and are normally useful for "after-the-fact" information and for supplementing the supporting theoretical models. They cannot be used as predictive tools except for a very limited range of conditions that have already been monitored. As predictive tools, mathematical models are the most flexible and least expensive. Their main limitations are directly related to our level of understanding of the physical phenomena themselves. Many of these models suffer from lack of verification by field and experimental data. Nevertheless, their usefulness for predicting various possibilities and evaluating alternative options is unmatched by other methods.

1.1. Current Mathematical Models

The mathematical models currently available for predicting the effects of heat discharges into water bodies can be grouped in two major categories: (1) near-field models, which are used primarily for modeling the thermal plume in the immediate vicinity of the discharge point, and (2) far-field models, which are used to simulate the overall behavior of the plume at some distance from the point of discharge after it has lost its initial momentum. The distinction between the two regions is based on the type of dominating mechanism involved in the heat dissipation process. In the near-field region, the excess temperature of the jet is quite high and the jet has considerable momentum of its own. Therefore, the main cooling process is by entrainment and mixing with the ambient water. Buoyancy effects are of major importance because of the high excess temperatures involved. In the far-field region, the velocity of the jet is reduced in magnitude and is close to that of the ambient water. As a result, dilution by entrainment of cooler water into the plume is very small, and the cooling process is mainly by natural diffusion, convection, and heat transfer to the atmosphere. The zone where the near-field and far-field effects overlap is usually termed the intermediate zone.

1.1.1. Near-Field Models

General work related to near-field models (jets and plumes) has been reported by Abramovitch,[3] Pai,[4] Schlichting,[5] and Hinze.[6] More specific models for predicting the general behavior of submerged buoyant jets in the near field have been developed by Fan[7] (round buoyant jets), Fan and Brooks[8] (round and slot buoyant jets in uniform and stratified ambients), Koh and Fan[9] (multiport submerged discharges), Ditmars[10] (buoyant jets in arbitrary stratified ambient), and Hirst[11] (three-dimensional axisymmetric submerged jets in flowing and stratified ambients). Both two- and three-dimensional models have been developed for surface discharges in the near field. A two-dimensional surface discharge model that includes both heat dissipation to the atmosphere and wind shear stresses was developed by Zeller and his associates,[12] and two-dimensional models for surface discharges into cross-flow currents have been developed by Carter[13] and Motz and Benedict.[14] A three-dimensional surface discharge model that includes buoyancy and bottom-slope effects was developed by Stolzenbach and Harleman,[15,16] and Stefan and his associates[17] developed a three-dimensional surface discharge model that includes the effects of weak cross currents and weak wind velocities.

Most of the near-field jet models have common simplifications and limitations. These include the assumption of steady-state conditions, purely hydrostatic pressure variations, and axisymmetric flow within the jet (or plume symmetrical flow in the case of slot jets). The jet is assumed to be discharged into an ambient fluid of infinite extent, and it is assumed that the velocity and temperature profiles along the axis of the jet are similar. In most cases, these profiles are assumed to be Gaussian. Solution of these models is based on the radially integrated form of the continuity, momentum, and energy equations, leaving the distance along the axis of the jet as the only independent variable.

The similarity assumption and the integration and averaging processes employed in these near-field models eliminate some of the information related to local shear stresses and eddy dispersion that is included basically in the partial differential equations. An empirical entrainment coefficient, normally considered constant, is introduced in the solution (together with the profiles assumed) to account for the effects which cannot be derived from the solution because of the missing shear stress terms. The intuitive judgment of the model user is relied on considerably for application of the proper entrainment coefficient. The effects of confining boundaries and recirculation cannot be included in these models, and their validity with respect to ambient cross-flow conditions is questionable.

The effects of limited depth (shallow water) on jet behavior have been studied by Cederwall[18] and Maxwell and Pazwash.[19] Some improved entrainment functions, which relieve the model user to some extent from making purely arbitrary selections of entrainment coefficients, have been suggested by Hirst[11] and Campbell and Schetz.[20] However, these models are based on the integrated approach, and the built-in coefficients are largely empirical. The entrainment coefficient used by Hirst is a combination of a number of empirical coefficients derived for more restricted applications. Campbell and Schetz make use of the defect law based on Prandtl's hypothesis, while relying on a constant rate of jet spread for evaluation of the dimensionless constant.

It has become more and more evident that in order to overcome many of the limitations inherent in these models, the problem must be approached by employing the basic nonlinear partial differential equations of motion, energy, and mass with the proper stress model included. A model with such a finite difference approach has been developed by Trent[21-23] for the near-field behavior of a submerged axisymmetric vertical thermal plume. This model, which is for steady-state conditions, includes the effects of buoyancy, stratification, surface spreading, and interaction with physical boundaries. The Prandtl hypothesis (defect law) is used to simulate the eddy diffusivity, and no empirical entrainment coefficient or similarity assumptions are used. A similar but more general approach (exact numerical solution of the conservation equations) has been taken by Chien and Schetz[24] in their model for a three-dimensional buoyant jet in a cross flow with confined boundaries. These recent models are important contributions to the analysis of submerged jets.

Despite the recent advances in near-field models, it should be emphasized that a near-field model by itself is not adequate for complete assessment of the temperature distribution expected in the vicinity of a discharge. First, the zone analyzed by a near-field model is limited in extent to the zone of jet mixing wherein the hydrodynamics are dominated by the momentum of the jet. Second, jet cooling is dependent on the entrainment of ambient water. The water in the near field interacts directly with that in the so-called far field, and its temperature is also affected by that of the far-field water. Therefore, it should never be assumed that the temperature of the water entrained into the jet is the same as that of ambient water in an unaffected area. Third, a fact to be taken account of in the near-field model is that the condenser cooling water entering the intake structure is at some elevated temperature because of recirculation from the far-field region. This elevated temperature of the intake water is not necessarily the same as that of the water entrained into the jet. Thus, it must be concluded that a far-field analysis must precede any near-field analysis if these analyses must of necessity be handled separately.

1.1.2. Far-Field Models

Heat dissipation in the far-field region takes place primarily by natural turbulent diffusion and heat exchange with the atmosphere. In this region, the behavior of the plume depends primarily on the ambient conditions of the natural environment, and these conditions are often very complex and irregular with time. Among the many factors contributing to these conditions in a natural water body are tributary flows, rain, wind, solar heat loads, atmospheric radiation, evaporation, density variations, bottom and bank shear stresses, bottom seepage, Coriolis forces, tidal forces, and physical boundaries. Among the man-made factors contributing to these conditions are sewage, effluents from chemical plants and electric power plants, and the effects of pumped storage areas.

Simulation of these conditions by analytical models has been attempted, but such models, like those proposed by Edinger and Polk[25] and by Csanady,[26] are necessarily overly simplified and cannot simulate properly the actual conditions in most cases. A realization of the limitations of analytical models and an appreciation of the potential capabilities of modern computers for solving complex sets of partial differential equations have led many investigators to shift their efforts to numerical techniques. Such a solution for the behavior of a thermal plume in shallow water was presented recently by Barry and Hoffman,[27] but their model is a simplified stead-state two-dimensional one that does not take account of buoyancy, density variations, or physical boundaries.

Because of the dynamics existing in estuaries, coastal regions, and to a lesser extent in any other type of natural water body, a far-field model that simulates actual conditions properly must be time dependent. The major portion of available time-dependent far-field modesl are one dimensional, and a few are two dimensional. The state-of-the-art of mathematical modeling for thermal discharges in large lakes has been reported by Policastro and Tokar,[28] and that for estuaries has been reported by TRACOR, Inc.[29] Several one-dimensional time-dependent investigations applicable primarily to estuaries have been performed by Harleman and his colleagues at the Massachusetts Institute of Technology. A one-dimensional model for calculating tides and currents in estuaries was developed by Harleman and Lee.[30] That model was extended by Lee[31] for predicting the general water quality in estuaries, and Thatcher and Harleman[32,33] used it for predicting salt intrusion from the ocean into estuaries. In this latter use, a method for determining the longitudinal dispersion coefficient was developed and incorporated in the model. Dailey and Harleman[34] further developed the model into a complete one-dimensional time-dependent water quality model that includes water levels, water velocities, and multiple substance concentrations. The basic one-dimensional model is used for geometrically complex estuaries that can be simulated as a network of one-dimensional channels.

Other such one-dimensional models have been developed for channel network simulation. They include the model developed by R. V. Thomann, D. J. O'Connor, and associates in connection with a study of the Delaware River Estuary,[35] the Bay Delta models developed by G. T. Orlob, R. P. Shubinski, and associates in connection with studies of the Sacramento-San Joaquin Delta and San Francisco Bay,[36,37] and the QUAL-1 model[38] used by the Texas Water Development Board.

A general and flexible one-dimensional model developed recently by Eraslan[39] can also take account of the effects of in-and-out flows from storage areas, surface shear stresses (wind), seepage, evaporation, rain, density variations, and river inclinations. The computer program is kept flexible and general so that different expressions can be used for turbulent dispersion and heat exchange with the atmosphere. The mathematical solution is based on numerical integration with respect to time of a system of nonlinear ordinary differential equations in which the rate of change of each unknown is explicitly expressed in terms of all the rest of the variables. The Runge-Kutta-Gill method is used for that integration. No partial differential equations are derived. Instead, the physical conservation principles are used directly for numerical formulation.

Time-dependent models with two space dimensions expand greatly the applicability of numerical models for simulation of natural water bodies. A time-dependent two-dimensional model (TOPLYR-II) for thermal transport in the far field has been developed by Kolesar and Sonnichsen.[40] The model is based on the implicit finite difference form of the convection-diffusion equation for energy transport with specified velocity field. Buoyancy and stratification are not simulated, but bottom contour effects and heat exchange with the atmosphere are included. Eddy thermal diffusivities must be read in as constant values. The developers of this model intend to expand their program to include the motion equations within a three-dimensional model.

Eraslan has used his numerical method for a time-dependent two-dimensional model[41] for predicting temperature distribution only. The model is very flexible and general. It accepts the velocity field as input data and can handle, by using the improved FLIDE method,[41] variable mesh sizes in different regions as well as nonrectangular elements at the boundaries. A time-dependent two-dimensional hydrodynamic model for shallow vertically mixed water bodies has been developed by Masch and his colleagues.[42,43] The solution applies an explicit finite difference method in a completely rectangular coordinate system. A number of models for various aspects of thermal discharges, including the near-field area, have been developed by Wada.[44] These models are steady state in one, two, or three space dimensions, using constant empirical eddy diffusivities. A time-dependent two-dimensional water quality model was developed by Leendertse and his associates[45-50] for shallow, vertically mixed estuaries and coastal regions. The numerical solution is based on a time-centered implicit difference scheme for the continuity and momentum equations and an alternating implicit-explicit scheme for the quality equations. The model is quite general, but it does not explicitly include thermal diffusion considerations. The developers intend to extend the model for prediction of temperature distribution.[51,52]

None of the previously discussed models include local viscous stresses in their formulation of the momentum equations, and the two most applicable two-dimensional water quality models do not include temperature prediction as a part of their objectives.

1.1.3. Intermediate Region

Very few studies exist on the so-called intermediate region. As previously discussed, such a region has no independent identity other than as a zone wherein the effects of the near and far fields overlap.

Analysis of this zone without its two bounding regions, the near and far fields, appears unrealistic. The near-field analysis by itself is almost of no value for complete assessment unless combined somehow with the effects of the far field.

1.2. A Complete Model

It appears that unless one is interested only in long-term distant effects, a proper thermal assessment calls for a complete model in which the effects of both the near and far fields are combined. Such an approach must definitely rely on the basic physical laws that are applicable for both regions. The basic conservation principles of mass, momentum, and energy constitute the common starting point, and because of the complex mathematical and physical features of these principles, a numerical approach of some kind seems to be required for their solution.

The numerical approach used for solution of such a composite model should be flexible enough to handle the characteristic features of both the near- and far-field regions, which are quite different. A large number of small-size elements are needed for the near-field region to permit incorporation of the small-scale turbulence effects and the large spatial gradients that exist in this region. On the other hand, large-size elements are adequate for the far-field region because of the relatively large-scale characteristics of thermal plume behavior in this region. Use of the same resolution in both the near and far fields will result in either meaningless near-field analysis or an impossible load on computer memory and time. Some solution of this problem was proposed by Eraslan[41] and successfully used in a time-dependent two-dimensional thermal model for the far-field region, and his approach can probably be used in a general thermal-hydraulic model also.

A major obstacle to the development of such a complete model is related to the type of turbulent diffusion model to be used for the near-field and the far-field regions. At this point it should be emphasized that formulation of a proper turbulent diffusion model for either region is one of the most outstanding and difficult problems of fluid mechanics in general and of natural water bodies specifically. The various coefficients generally used in the diffusion terms of the conservation equations are no more than compensation factors for the inability to consider the convective phenomenon in its proper detail and the averaging technique used as a result of this inability. The gradient law for molecular diffusion (Fourier law for heat, Fick's law for mass) is generally an acceptable approximation of the microscale movements of molecular particles. Although successful in many specific applications, the gradient formulation of turbulent diffusion (Boussinesq approach) does not seem to be a universally correct representation of turbulent behavior. The gradient formulation of the so-called dispersion is even less substantiated.

The term "dispersion" created much confusion in the literature. Basically, dispersion is the term normally used to express the phenomenon of nonconvective transport of material in the direction of the main stream in addition to normal molecular and turbulent diffusion. The main reasons for such dispersion are the shear effects caused by variations of velocities in directions perpendicular to those of the main stream. The so-called dispersion phenomenon is a result of spatial averaging of those convective profiles that have an effect on the transport mechanism along the main stream because of the shearing effects between layers. A more detailed discussion of these terms is presented in Section 3. However, to put the problem in perspective, it must be remembered that molecular diffusion is in the order of about 10^{-6} to 10^{-7} smaller than turbulent diffusion, which is about one to two orders of magnitude smaller than longitudinal dispersion.

The contribution of velocity variations in the radial direction on the longitudinal transport mechanism in a pipe was studied by Taylor[53,54]. His approach was later expanded by Elder[55] for flow in an open channel. Both studies showed that the longitudinal dispersion coefficient is about two orders of magnitude greater than the turbulent diffusion coefficient in either the radial or the longitudinal direction. Elder[55] assumed that the vertical velocity variations have a dominant effect on longitudinal dispersion, and he therefore neglected the lateral effects. However, Fischer[56,57] showed that in natural streams the lateral effects may be far more important and that inclusion of these effects in the analysis can increase the longitudinal dispersion coefficient by an additional one or two orders of magnitude. Fischer's relationship is in better agreement with field observations of natural streams than the correlations presented by Elder or Taylor. In addition to velocity gradients, the longitudinal dispersion coefficient in natural streams is affected by density variations, wind, wave motions, and other factors.

In the near-field region (jet models), the turbulent diffusion coefficients are dominated primarily by jet dynamics. Here, the scale of turbulence is much smaller, and the applicable models rely mainly on an empirical entrainment coefficient, on the Boussinesq assumption of constant eddy viscosity,[58] or on one of the more sophisticated (but still gradient type by nature) turbulent models like those proposed by Prandtl,[59,60] von Karman,[61] and others. Application of these models to jets and plumes results in much better agreement with field data than their application in far-field regions. However, these correlations for free turbulence are based on axisymmetrical geometry in which the plume width is one of the major characteristic lengths, whereas most turbulent models for the far field rely on overall channel dimensions and average flow characteristics. This difference of approach in the applicable existing correlations for turbulent diffusion coefficients in the near- and far-field regions is another obstacle to the integration of the effects of the two regions into one composite model.

A third difficulty in combining the near- and far-field models into one is the fact that buoyancy effects are of major importance in the near-field region of thermal discharges. A two-dimensional model in which complete vertical mixing is assumed cannot be applied to a region wherein buoyancy is of major importance and therefore cannot be used to predict properly the effects of the near field. Expansion of the model to take account of three space dimensions would help solve this limitation.

A three-dimensional model is also very desirable for overcoming some of the difficulties encountered in finding an effective turbulent diffusion coefficient. Since the increase in the longitudinal dispersion coefficient in a two-dimensional model is a result of the spatial averaging procedure, a proper time-dependent three-dimensional model should not require a dispersion coefficient that is two to three orders of magnitude larger than the true turbulent diffusion coefficient. The only coefficients required would then be those for molecular and turbulent diffusion. Although the correct value of turbulent diffusivity to be used in such a model is not yet known, the importance of using an exact value will be reduced significantly since the relative importance of diffusion transport with respect to convective transport is much smaller in a time-dependent three-dimensional model. Of course, such a model must include the normal and shear stresses as part of the momentum equations, and an advanced locally evaluated function for turbulent behavior must also be included. There is much hope that some of the new and more sophisticated approaches to turbulent models taken recently by many investigators[62-66] can be successfully used for that purpose.

General time-dependent three-dimensional numerical solutions are presently being attempted. Of particular importance is the work being done at the Los Alamos Scientific Laboratory.[67-73]. The various computer methods resulting from this work include the PIC method,[67] the MAC method,[68] the FLIC method,[69] and the SMAC method.[70] The work done in simulating atmospheric behavior by Smagorinsky[74] and by Sklarew[75] should also be noted. However, these general numerical methods require very large computer storage capabilities. Their ratio of computer time to actual time is very large, and they are too general in format to be used directly for the thermal discharge problem at hand.

A time-dependent three-dimensional model designed primarily for thermal discharges is being developed by Brady and Geyer.[2] They have developed very interesting techniques to reduce computer storage requirements, and they have demonstrated the feasibility of using three-dimensional models for natural water bodies even with the presently available computers. Although the viscous normal stress effects are included in their model, the viscous shear stress effects are not included. Their work is still under development, and hopefully it will inspire other investigators to further contributions along those lines. The development and operation of such models will be very costly. However, this cost is exceeded greatly by that of the tremendous personal effort being expended to find larger and larger "diffusion" coefficients to compensate for the information destroyed in the basic conservation equations when they are averaged out over time and spatial dimensions.

1.3. Interim Model

This study was undertaken to develop a time-dependent two-dimensional model for predicting water elevations, horizontal velocities, temperatures, and dissolved substance concentrations. The model can be used to assess the effects of thermal or other discharges into vertically mixed shallow water bodies. The inclusion of the normal and shear stresses in the momentum equations advances the presently available models one step further toward a complete model that will include both the near- and far-field regions. This model cannot yet be used as a reliable near-field jet model because of its lack of buoyancy effects and the difficulty of incorporating a turbulent diffusivity model that can be used in all regions evaluated locally. However, the model does have the potential for such extension in the future.

2. FORMULATION OF THE MASS, MOMENTUM, AND ENERGY CONSERVATION PRINCIPLES

2.1. General Discussion of the Physical Assumptions

The model studied here is time-dependent and is based on two space dimensions. As such, it is primarily applicable to shallow, vertically mixed water bodies. Many estuaries and coastal regions and some natural streams fall in this category. A typical depth in many such water bodies will be in the order of 10 to 100 ft, while their width will fall in the order of 500 to 5000 ft. Such a ratio of about two orders of magnitude between horizontal and vertical dimensions can in many cases be reliably approximated by a two-dimensional analysis. Bottom roughness, wind stresses, and tidal motion considerably enhance the vertical mixing in such water bodies. Thermal discharges, however, tend to stratify vertically, especially in the near-field area, where the discharged water is normally about 10 to 30°F above the ambient water. For this and other reasons which will be discussed in subsequent sections, the model will not be applicable as a reliable near-field thermal jet analysis. However, a short distance from the discharge point the jet loses its initial momentum and much of its excess temperature. The behavior of the thermal plume from that point will depend primarily on the ambient hydraulic conditions, and the present model will be much more applicable for its analysis. In some cases that generally satisfy the two-dimensional assumptions but still possess some weak vertical variations, appropriate vertical distribution functions can be employed as proposed by Eraslan.[41] The model is not applicable to deep lakes and ponds, where stratification is of major importance. In many cases in such water bodies the time dependence is not of major concern, and some form of steady-state three-dimensional models might better be applied. In the present model the discrete elements are based on a rectangular coordinate system, and this creates some difficulties in describing complicated physical boundaries. The present model, however, does allow for variable element sizing along each direction, which gives some flexibility in this respect compared with other available models using constant mesh spacings. Other aspects of the applicability of the model are further discussed in subsequent sections.

2.2. General Discussion of the Numerical Method Employed

The numerical method used in this study is based on the physical conservation principles, which are expressed and applied directly in their integral form over a control volume. The modeled region is divided into variable-sized discrete elements. The integrated conservation principles are strictly enforced and satisfied over each discrete element, thus approximating the physical reality over each discrete element. The requirement that the dimensions of the elements approach zero is never employed, and no partial differential equations are ever formulated. Such an approach keeps a closer touch with the physical world and is very helpful in formulating complex boundary conditions, which are, after all, what distinguishes between various physical situations. This simulative approach was used in the Los Alamos work (FLIC[69] and PIC[67] methods), is very much emphasized by Cheng;[76,77] and has been used by others to various extents. Eraslan[41] has used the approach in his FLIDE method for treating vertical variation in a two-dimensional formulation and for greater flexibility in discrete element sizing. Excellent discussions of these and other methods can be found in the general text-type report by Harlow and Amsden[72] and in the more recent computational fluid mechanics text by Roach.[78]

2.3. The Integral Form of the Conservation Principles

As discussed in Section 2.2, the integral forms of the physical conservation principles will be employed. These principles will be formulated first in a general form, and then each integral will be evaluated on a typical discrete element. The general forms of these equations are as follows.

a. Conservation equation for total mass

$$\frac{\partial}{\partial t} \oint_{\forall} \rho \, d\forall = \oint_{A} \rho \vec{V} \cdot (-\hat{n}) \, dA \qquad (2.1)$$

b. Conservation equation for mass of constituent k

$$\frac{\partial}{\partial t} \oint_{\forall} \rho_k \, d\forall = \oint_{A} \rho_k \vec{V}_k \cdot (-\hat{n}) \, dA + \oint_{\forall} \dot{\rho}_k \, d\forall \qquad (2.2)$$

c. Momentum equation (second law of motion)

$$\frac{\partial}{\partial t} \oint_{\forall} (\rho\vec{V})\, d\forall + \oint_{A} (\rho\vec{V})\vec{V}\cdot(\hat{n})\, dA = \oint_{\forall} \vec{f}_b\, d\forall + \oint_{A} \vec{\sigma}_A\, dA \qquad (2.3)$$

This equation, which is in vectorial form, can be separated into X and Y directions as

$$\frac{\partial}{\partial t} \oint_{\forall} (\rho U)\, d\forall + \oint_{A} (\rho u)\vec{V}\cdot\hat{n}\, dA = \oint_{\forall} f_{bX}\, d\forall + \oint_{A} \sigma_X\, dA\ , \qquad (2.3a)$$

$$\frac{\partial}{\partial t} \oint_{\forall} (\rho V)\, d\forall + \oint_{A} (\rho V)\vec{V}\cdot\hat{n}\, dA = \oint_{\forall} f_{bY}\, d\forall + \oint_{A} \sigma_Y\, dA\ . \qquad (2.3b)$$

d. Energy conservation equation (first law of thermodynamics)

$$\frac{\partial}{\partial t} \oint_{\forall} (\rho e) d\forall = \oint_{A} \left[\sum_{k=1}^{K} (\rho_k e_k \vec{V}_k) + \vec{q} \right] \cdot (-\hat{n})\, dA + \oint_{\forall} \left[\sum_{k=1}^{K} (\dot{\rho}_k e_k) + \dot{q}_V \right] d\forall$$

$$+ \oint_{\forall} (\vec{f}_b \cdot \vec{V})\, d\forall + \oint_{A} \sum_{k=1}^{K} (\vec{\sigma}_k \cdot \vec{V}_k)\, dA\ . \qquad (2.4)$$

In all these equations the area unit vector $\hat{n}$ is outward positive.

In the mass conservation equation for constituent k, the velocity of the constituent, $\vec{V}_k$, can be expressed as

$$\vec{V}_k = \vec{V} + \vec{V}_k' \ , \qquad (2.5)$$

where V_k' is the relative velocity (or diffusion velocity) of substance k with respect to the overall mass-average flow velocity of the fluid, $\vec{V}$. Therefore, one can write

$$\rho_k\vec{V}_k = \rho_k(\vec{V} + \vec{V}_k') = \rho_k\vec{V} + \rho_k\vec{V}_k' , \quad (2.6)$$

where $\rho_k\vec{V}_k'$ is the relative flux of constituent k within the flow of the mixture. This flux can, in part, be assumed to obey Fick's law for binary diffusion between a constituent k and the rest of the mixture. However, Fick's law may not always be the proper representation of this flux, especially in turbulent flow. At this point the term $\rho_k\vec{V}_k'$ will be expressed as $\vec{g}_k$, and its evaluation will be left to later discussion (Section 3).

Substituting Eq. 2.6 into Eq. 2.2 and using $\vec{g}_k = \rho_k\vec{V}_k'$ gives

$$\frac{\partial}{\partial t} \oint_{V\!\!\!\!-} \rho_k \, dV\!\!\!\!- = \oint_A (\rho_k\vec{V} + \vec{g}_k)\cdot(-\hat{n}) \, dA + \oint \dot{\rho}_k \, dV , \quad (2.7)$$

where

$$\vec{g}_k = \rho_k\vec{V}_k' \quad (2.8)$$

and $\dot{\rho}_k$ is mass generation of constituent k per unit volume and unit time. It must be remembered that the summation of the mass conservation equation (Eq. 2.2 or 2.7) for constituent k over all the constituents should result in the conservation equation for total mass (Eq. 2.1). While doing this summation process, the definitions

$$C_k = \rho_k/\rho$$

and

$$\sum_{k=1}^{K} C_k = 1$$

must be extensively used.

In the momentum equations the only body forces explicitly considered are the Coriolis forces caused by the rotation of the earth. These forces are important in large shallow water bodies and should be taken into account. The gravitational forces, which are also body forces, do not appear explicitly in the two-dimensional formulation of the momentum conservation equations. However, they appear implicitly in the normal stress terms of these equations, as will be discussed in subsequent sections.

The last two integrals in the energy equation are the flow work done by the body forces and the surface stresses, respectively. In a two-dimensional formulation the gravitational body force will produce no flow work, since no vertical velocity is considered. The flow work produced by the Coriolis forces can be neglected. For the velocities of interest, the flow work produced by the viscous stresses can also be neglected. The only flow work that must still be considered is the work done by the fluid against the pressure. Therefore, the last two integrals in Eq. 2.5 can be replaced by

$$\oint_{\forall} \vec{f}_b \cdot \vec{V} \, d\forall = 0 \tag{2.9}$$

and

$$\oint_A \sum_{k=1}^{K} \vec{\sigma}_k \cdot \vec{V}_k \, dA = \oint_A \sum_{k=1}^{K} P_r(-\hat{n}) \cdot \vec{V}_k \, dA \ . \tag{2.10}$$

Substituting Eqs. 2.9 and 2.10 into Eq. 2.5 and rearranging gives

$$\frac{\partial}{\partial t} \oint_{\forall} (\rho e)\ d\forall = \oint \left(\sum_{k=1}^{K} \rho_k (e_k + \frac{P_r}{\rho_k}) \vec{V}_k + \vec{q} \right) \cdot (-\hat{n})\ dA$$

$$+ \oint_{\forall} \left(\sum_{k=1}^{K} \dot{\rho}_k e_k + \dot{q}_V \right) d\forall\ . \tag{2.11}$$

The specific energy e consists of internal energy $\hat{u}$, kinetic energy $V^2/2$, and potential energy gZ, where the last two can be neglected in comparison with the internal energy $\hat{u}$. The same is true for the specific energy e_k of constituent k. Combining the pressure flow work with the internal energy gives the enthalpy h. Therefore

$$e_k \cong \hat{u}_k\ , \tag{2.12}$$

$$h_k = e_k + \frac{P_r}{\rho_k} \approx \hat{u}_k + \frac{P_r}{\rho_k}\ , \tag{2.13}$$

$$e = \sum_{k=1}^{K} C_k e_k = \sum_{k=1}^{K} C_k \hat{u}_k = \hat{u}\ . \tag{2.14}$$

Substituting Eqs. 2.12 to 2.14 into Eq. 2.11 and using from Eqs. 2.6 and 2.8 that

$$\rho_k \vec{V}_k = \rho_k \vec{V} + \rho_k \vec{V}_k' = \rho_k \vec{V} + \vec{g}_k \tag{2.15}$$

gives

$$\frac{\partial}{\partial t} \oint_{\forall} (\rho e)\ d\forall = \oint_{A} \left(\sum_{k=1}^{K} h_k (\rho_k \vec{V} + \vec{g}_k) + \vec{q} \right) \cdot (-\hat{n})\ dA$$

$$+ \oint_{\forall} \left(\sum_{k=1}^{K} \dot{\rho}_k h_k + \dot{q}_V \right) d\forall\ . \tag{2.16}$$

Substituting

$$\vec{q}_k = \vec{g}_k h_k \ , \tag{2.17}$$

$$\sum_{k=1}^{K} \rho_k h_k \vec{V} = \rho h \vec{V} \ , \tag{2.18}$$

and

$$(\dot{q}_V)_k = \dot{\rho}_k h_k \tag{2.18a}$$

into Eq. 2.16 and rearranging gives

$$\frac{\partial}{\partial t} \oint_{V} (\rho e) \, dV = \oint_{A} \left[\rho h \vec{V} + \vec{q} + \sum_{k=1}^{K} \vec{q}_k \right] \cdot (-\hat{n}) \, dA$$

$$+ \oint_{V} \left[\dot{q}_V + \sum_{k=1}^{K} (\dot{q}_V)_k \right] dV \ , \tag{2.19}$$

where the symbol e for specific energy is used for internal energy $\hat{u}$, based on Eq. 2.14.

The term $\vec{q}$ appearing inside the brackets of the fluxes includes the nonconvective heat fluxes. These fluxes cannot always be represented as purely diffusion but can include other effects like turbulent fluctuations or contributions from shear effects. The detailed discussion on this term is given in Section 3.

In summary, the integral forms of the physical conservation equations that will be used in this study for an Eulerian control volume, incompressible fluid, and nonconstant physical properties are as follows.

a. Conservation equation for total mass

$$\frac{\partial}{\partial t} \oint_{\forall} \rho \, d\forall = \oint_{A} \vec{g} \cdot (-\hat{n}) \, dA \tag{2.20}$$

b. Conservation equation for mass of constituent k

$$\frac{\partial}{\partial t} \oint_{\forall} (\rho C_k) \, d\forall = \oint_{A} (C_k \vec{g} + \vec{g}_k) \cdot (-\hat{n}) \, dA + \oint_{\forall} \dot{\rho}_k \, d\forall \tag{2.21}$$

c. Energy conservation equation

$$\frac{\partial}{\partial t} \oint_{\forall} (\rho e) \, d\forall = \oint_{A} (\vec{g}h + \vec{q} + \sum_{k=1}^{K} \vec{q}_k) \cdot (-\hat{n}) \, dA$$

$$+ \oint_{\forall} \left[q_V + \sum_{k=1}^{K} (\dot{q}_V)_k \right] d\forall \tag{2.22}$$

d. Momentum equations

In the X direction,

$$\frac{\partial}{\partial t} \oint_{\forall} (\rho U) \, d\forall + \oint_{A} \left[(U)\vec{g} \right] \cdot (\hat{n}) \, dA = \oint_{\forall} (f_c)_X \, d\forall + \oint_{A} \sigma_X \, dA \tag{2.23}$$

In the Y direction,

$$\frac{\partial}{\partial t} \oint_{\forall} (\rho V) \, d\forall + \oint_{A} \left[(V)\vec{g} \right] \cdot (\hat{n}) \, dA = \oint_{\forall} (f_c)_Y \, d\forall + \oint_{A} \sigma_Y \, dA \, . \tag{2.24}$$

In these equations,

$$\vec{g} = \rho \vec{V} \, , \tag{2.25}$$

$$\vec{q}_k = \vec{g}_k h_k \ , \tag{2.26}$$

$$\dot{q}_V = \dot{\rho}_k h_k \ , \tag{2.27}$$

$$C_k = \rho_k/\rho \ . \tag{2.28}$$

The nonconvective fluxes $\vec{g}_k$ and $\vec{q}$ and the stresses σ_X and σ_Y will be discussed in detail in Section 3. Those fluxes and stresses, however, will be left in a general form for the discrete element formulation of the conservation equations developed in the rest of this section.

2.4. The Discrete Elements: Definitions and Notation

The discrete elements are defined by a net of grid lines in a rectangular coordinate system. The grid lines along the X and Y directions are marked successively by i and j indices, respectively, to indicate full points at the centers of the elements and by $i \pm 1/2$ and $j \pm 1/2$, respectively, to indicate half-value points on the boundaries between them. Figure 2.1 shows the way those indices are marked on an XY plane for a single discrete element.

The center of each discrete element is marked by (i, j), and its boundaries along the X and Y directions are marked by $i \pm 1/2$ and $j \pm 1/2$, respectively. The space increments along the X and Y directions are ΔX_i and ΔY_j, respectively. These increments may or may not be equal, and their sizes along each direction may vary. Each element will then have the horizontal dimensions ΔX_i and ΔY_j, which are constant, and the

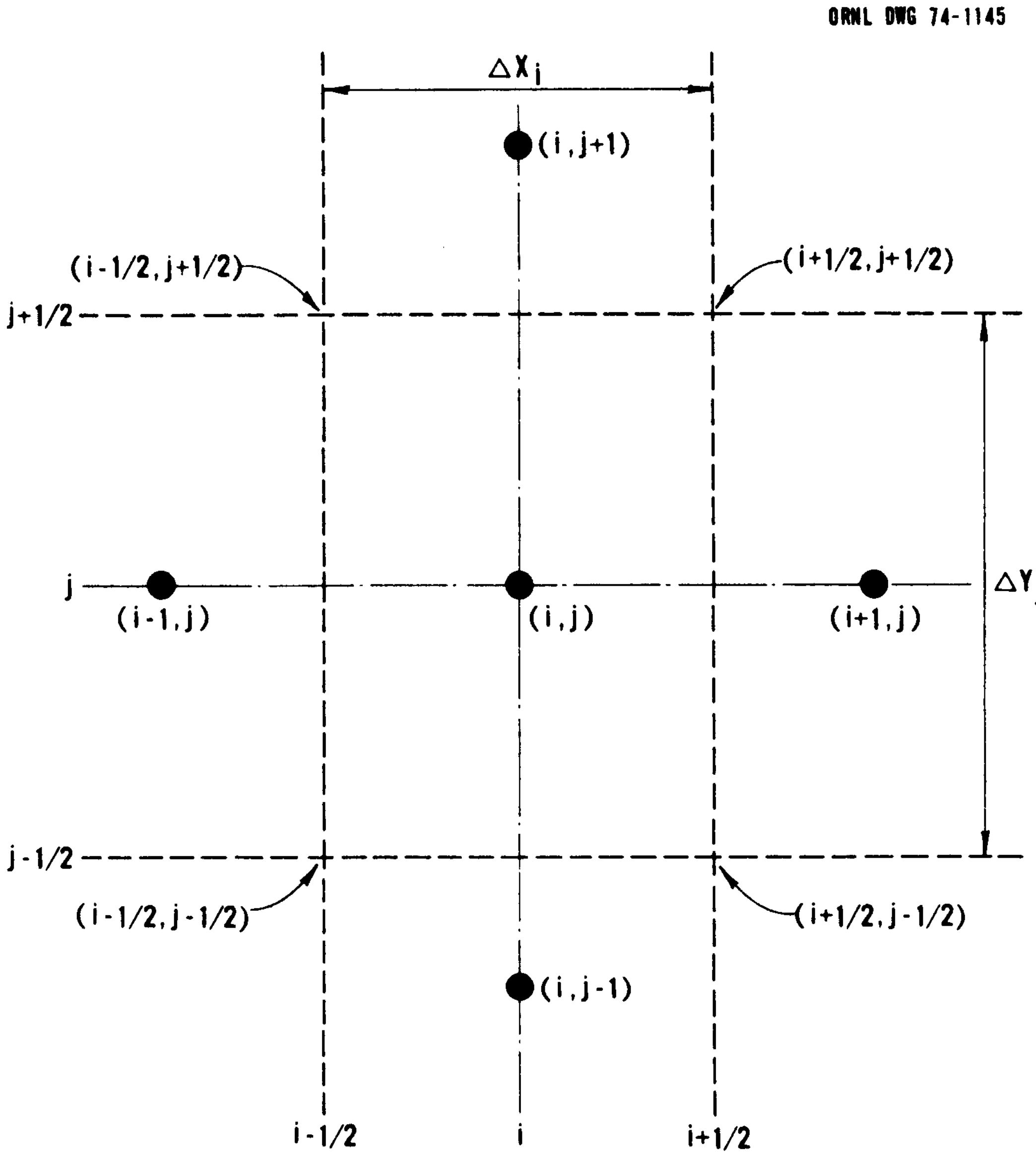


Figure 2.1. Arrangement of discrete elements.

depth $H_{i,j}$, which may vary with time. All the properties are considered uniform along the depth as well as along ΔX_i and ΔY_j. Based on these concepts, solid boundaries are defined by half points, so that all the elements, including those attached to boundaries, have full size. All the properties for both the center points and the half points are marked with the corresponding indices showing the exact location they refer to. Special effort is being made in the numerical formulation to evaluate all the properties and their fluxes in their appropriate locations. The properties in each discrete element are considered uniform throughout its volume and are represented by center-point values located at the centroid of the element volume. The fluxes into and out of each discrete element are evaluated at the common boundaries between the elements in terms of the average values in the neighboring elements. The program calculates and stores all the center-point values. The values on the common boundaries, termed half-point values, are recalculated at each time step but are not stored. All the quantities involved are shown schematically in three cross-sectional views (Figures 2.2 to 2.4). The volume of each element can be expressed as $\Delta X_i \ \Delta Y_j \ H_{i,j}$, the horizontal top and bottom boundary areas as $\Delta X_i \ \Delta Y_j$ and the four vertical boundary areas as $\Delta Y_j \ H_{i-1/2,j}$, $\Delta Y_j \ H_{i+1/2,j}$, $\Delta X_i \ H_{i,j-1/2}$, and $\Delta X_i \ H_{i,j+1/2}$ (see Figs. 2.2-2.4). Since average fluxes are being assumed for either the volume of each element or the area of each of its boundary surfaces, the integrals in Eqs. 2.18 to 2.22 can be directly evaluated for each element.

The area unit vector $\hat{n}$ is considered to be positive outward. The discrete element formulation of the conservation equations which were given by Eqs. 2.18 to 2.22 will be derived in the following sections.

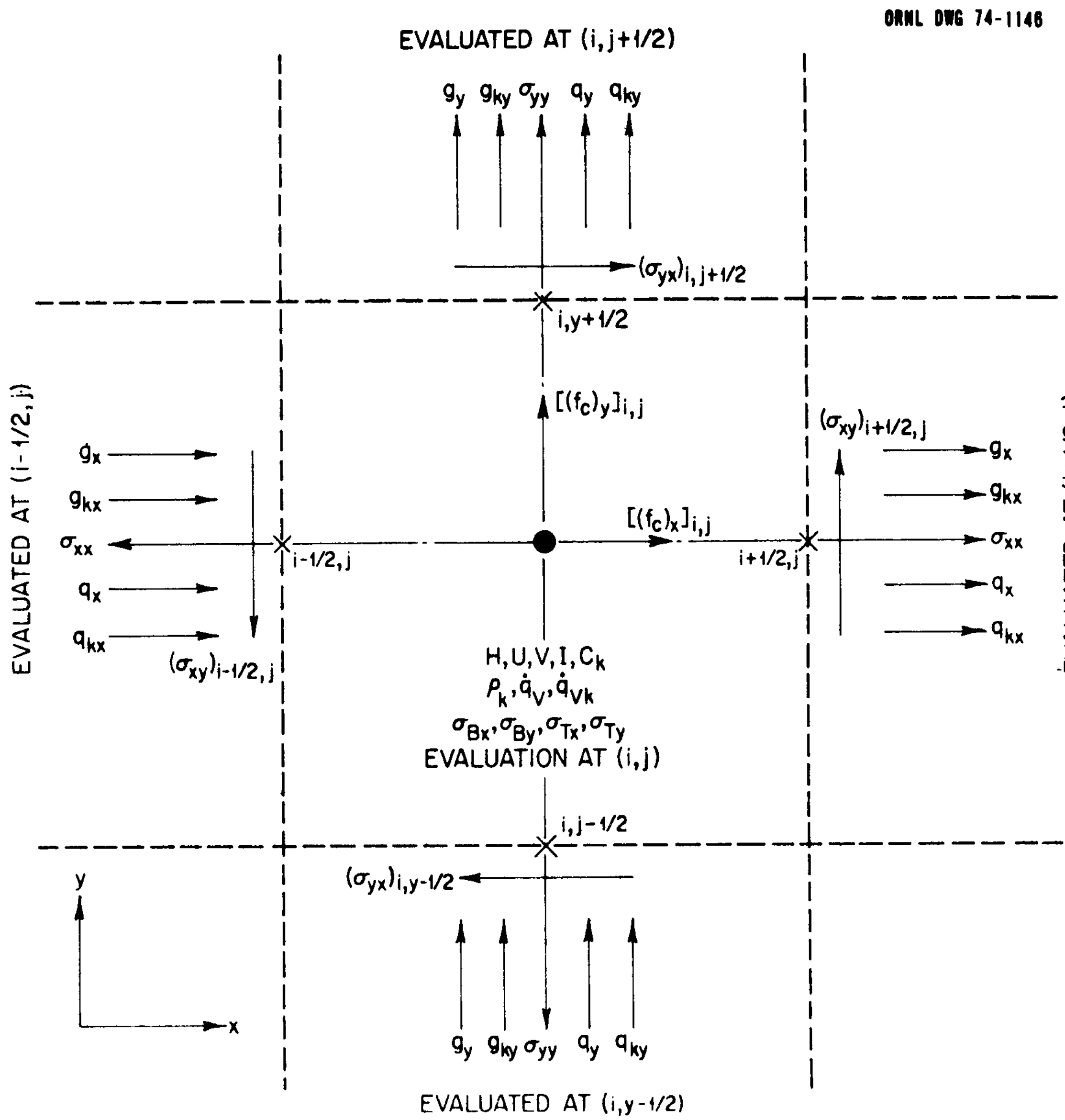


Figure 2.2. Top view presentation of properties and fluxes in a discrete element.

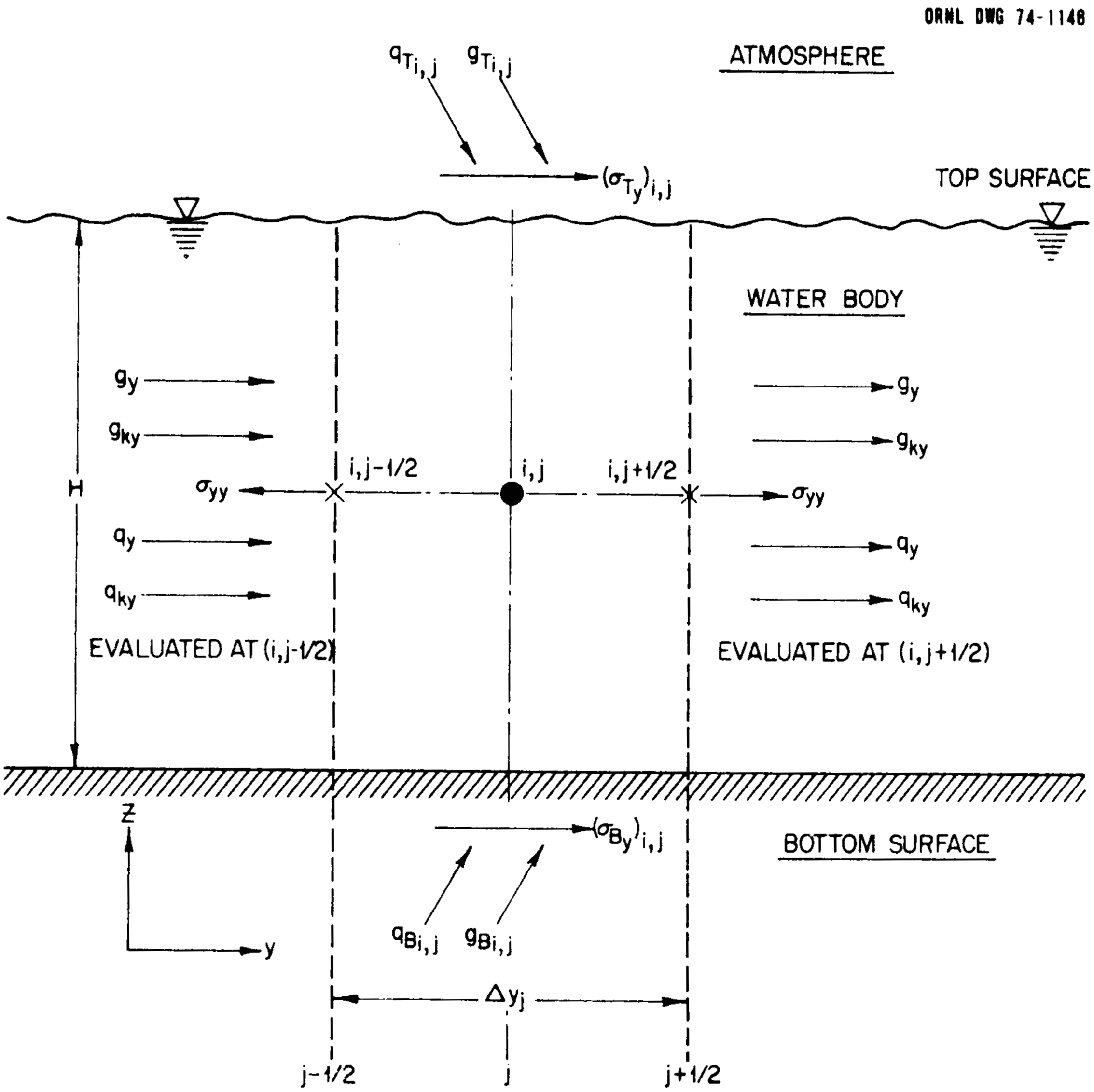


Figure 2.3. X-Z cross-sectional presentation of fluxes in a discrete element.

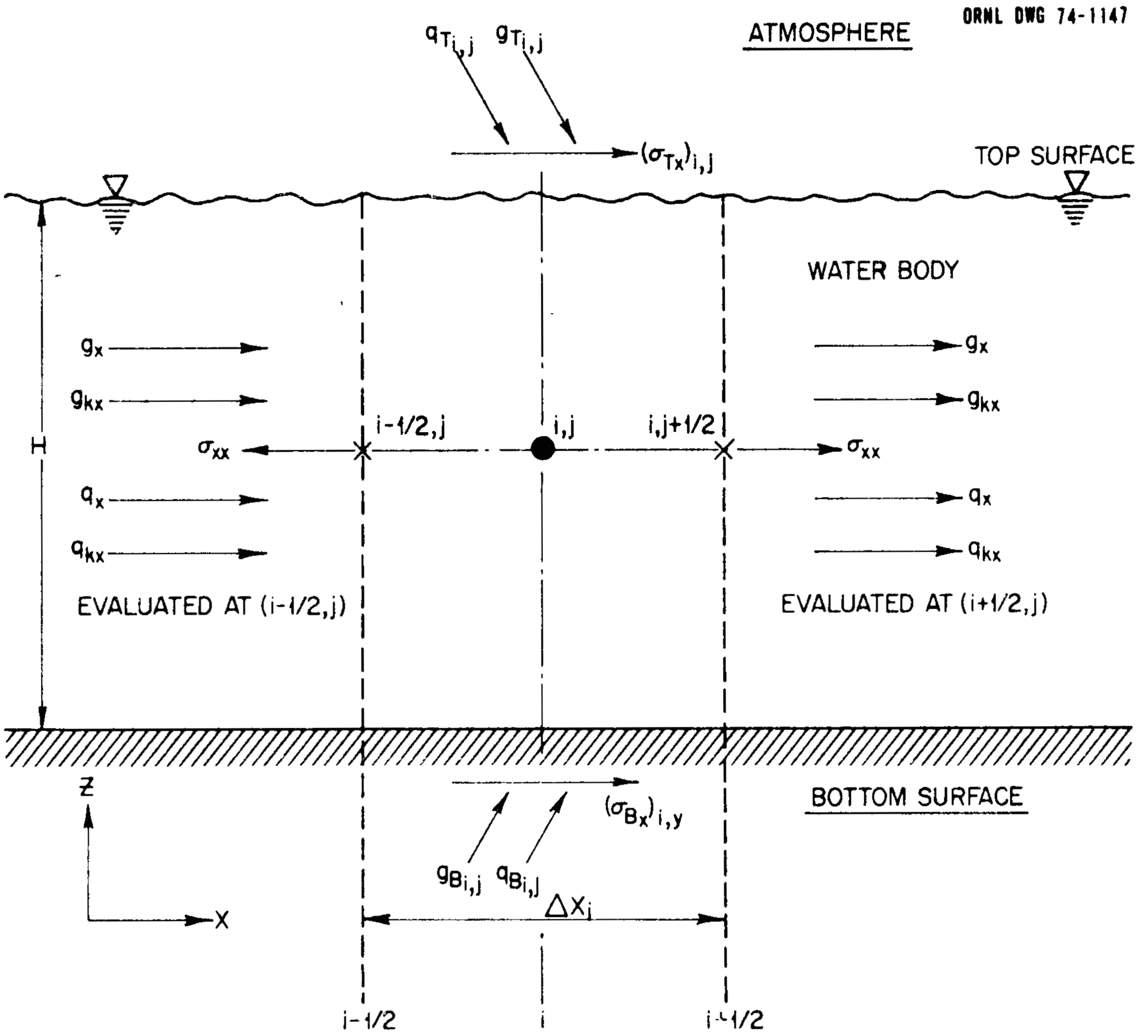


Figure 2.4. Y-Z cross-sectional presentation of fluxes in a discrete element.

2.5. The Discrete Element Formulation of the Conservation Equation for Total Mass

The integral form of the conservation equation for total mass was given in Eq. 2.20 as

$$\frac{\partial}{\partial t} \oint_{V} \rho \, dV = \oint_{A} \vec{g} \cdot (-\hat{n}) \, dA \ . \tag{2.29}$$

Considering the discrete element with constant horizontal dimensions ΔX_i and ΔY_j (see Figs. 2.2 to 2.4), time-dependent depth $H_{i,j}$, and uniform density throughout the volume, the term on the left of Eq. 2.29 becomes

$$\frac{\partial}{\partial t} \oint_{V} \rho \, dV = \Delta X_i \, \Delta Y_j \, \frac{\partial}{\partial t} (\rho_{i,j} H_{i,j}) \ . \tag{2.30}$$

The term on the right of Eq. 2.29 is a surface integral around the six faces of the discrete element over the instantaneous mass flux $\vec{g}$. The unit area vector $\hat{n}$ being positive outward, one gets for this surface integral (see Figs. 2.2-2.4)

$$\oint_{A} \vec{g} \cdot (-\hat{n}) \, dA = \Delta Y_j \int_0^{H_{i-1/2,j}} (g_X)_{i-1/2,j} \, dZ - \Delta Y_j \int_0^{H_{i+1/2,j}} (g_X)_{i+1/2,j} \, dZ$$

$$+ \Delta X_i \int_0^{H_{i,j-1/2}} (g_Y)_{i,j-1/2} \, dZ - \Delta X_i \int_0^{H_{i,j+1/2}} (g_Y)_{i,j+1/2} \, dZ$$

$$+ \Delta X_i \, \Delta Y_j \, (g_B)_{i,j} + \Delta X_i \, \Delta Y_j \, (g_T)_{i,j} \ , \tag{2.31}$$

where g_B is the mass flow rate coming from the bottom (seepage) per unit area ($ML^{-2}T^{-1}$) and g_T is the mass flow rate coming from the top (precipitation, evaporation) per unit area ($ML^{-2}T^{-1}$).

The instantaneous fluxes g_X and g_Y are defined as

$$g_X = \rho U \tag{2.32}$$

and

$$g_Y = \rho V \ , \tag{2.33}$$

where U and V are the two instantaneous horizontal velocities in the X and Y directions, respectively. These velocities are normally functions of the depth Z, and, in the case of turbulent flow, they also reflect the random turbulent fluctuations. Each velocity can then be expressed in three parts as

$$U_{i,j}(Z,\ t) = \overline{U}_{i,j}(t) + u_{i,j}(Z,\ t) + u'_{i,j}(Z,\ t) \tag{2.34}$$

and the same for V or any other property P.

The part due to turbulent fluctuations, $u'_{i,j}(Z, t)$, vanishes when time is averaged over a time scale larger than the turbulent fluctuations (but smaller than the time scale of interest, in order to keep $\overline{U}_{i,j}(t)$ time dependent). The vertical variation, $u_{i,j}(Z, t)$, vanishes by definition when integrated over the depth. Therefore, the integrated fluxes in Eq. 2.31 can be replaced by their depth-averaged counterparts to give

$$\oint_A \vec{g}\cdot(-\hat{n})\ dA = \Delta Y_j\ (\bar{g}_X)_{i-1/2,j}H_{i-1/2,j} - \Delta Y_j\ (\bar{g}_X)_{i+1/2,j}H_{i+1/2,j}$$

$$+ \Delta X_i\ (\bar{g}_Y)_{i,j-1/2}H_{i,j-1/2} - \Delta X_i\ (\bar{g}_Y)_{i,j+1/2}H_{i,j+1/2}$$

$$+ \Delta X_i\ \Delta Y_j\ (g_B)_{i,j} + \Delta X_i\ \Delta Y_j\ (g_T)_{i,j}\ , \qquad (2.35)$$

where the bar denotes average values over depth and turbulent time scale. Substituting Eqs. 2.30 and 2.35 into Eq. 2.29 and dividing by $\Delta X_i\ \Delta Y_j$ gives

$$\frac{\partial}{\partial t}(H_{i,j}\rho_{i,j}) = -\frac{1}{\Delta X_i}\left(H_{i+1/2,j}(\bar{g}_X)_{i+1/2,j} - H_{i-1/2,j}(\bar{g}_X)_{i-1/2,j}\right)$$

$$-\frac{1}{\Delta Y_i}\left(H_{i,j+1/2}(\bar{g}_Y)_{i,j+1/2} - H_{i,j-1/2}(\bar{g}_Y)_{i,j-1/2}\right)$$

$$+ (g_B)_{i,j} + (g_T)_{i,j} \qquad (2.36)$$

Differentiating $H_{i,j}\rho_{i,j}$ gives

$$\frac{\partial}{\partial t}(H_{i,j}\rho_{i,j}) = \rho_{i,j}(\partial H_{i,j}/\partial t) + H_{i,j}(\partial \rho_{i,j}/\partial t) \qquad (2.37)$$

Substituting Eq. 2.37 into Eq. 2.36 and dividing by $\rho_{i,j}$ gives

$$\frac{\partial H_{i,j}}{\partial t} = \frac{1}{\rho_{i,j}}\left(-H_{i,j}\ (\partial \rho_{i,j}/\partial t)\right.$$

$$-\frac{1}{\Delta X_i}\left(H_{i+1/2,j}(\bar{g}_X)_{i+1/2,j} - H_{i-1/2,j}(\bar{g}_X)_{i-1/2,j}\right)$$

$$- \frac{1}{\Delta Y_j} \left\{ H_{i,j+1/2} (\overline{g}_Y)_{i,j+1/2} - H_{i,j-1/2} (\overline{g}_Y)_{i,j-1/2} \right\}$$

$$+ (g_B)_{i,j} + (g_T)_{i,j} \Bigg] , \qquad (2.38)$$

which is the discrete element formulation of the total mass conservation equation for variable water elevation H. Since the density is a function of temperature and substance mass concentrations, one gets:

$$\frac{\partial \rho_{i,j}}{\partial t} = (\partial \rho/\partial T)_{i,j} (\partial T_{i,j}/\partial t) + \sum_{k=1}^{K} (\partial \rho/\partial C_k)_{i,j} (\partial C_{k\ i,j}/\partial t) . \qquad (2.39)$$

$\partial \rho/\partial T$ and $\partial \rho/\partial C_k$ are derivatives which can be evaluated once the equation of state is known (see Section 4.6). $\partial T_{i,j}/\partial t$ and $\partial C_{k\ i,j}/\partial t$ are evaluated from the energy conservation equation and constituent mass conservation equation, respectively, both of which are numerically evaluated before Eq. 2.38 is used. Equation 2.38 expresses explicitly the instantaneous rate of change of water surface elevation with respect to time and can be used with a proper integration routine to evaluate the instantaneous water surface elevation itself. The rate of change of H with respect to time actually gives the vertical velocity of the water surface at any point, and, therefore,

$$(W_S)_{i,j} = \partial H_{i,j}/\partial t . \qquad (2.40)$$

The convective fluxes $\overline{g}_X$ and $\overline{g}_Y$ are defined as $\rho\overline{U}$ and $\rho\overline{V}$ by Eqs. 2.32 and 2.33, and the bottom and top contributions g_B and g_T will be discussed in Section 4.

2.6. The Discrete Element Formulation of the Mass Conservation Equation for Constituent k

The integral form of the mass conservation equation for constituent k was given by Eq. 2.21 as

$$\frac{\partial}{\partial t} \oint_{V} (\rho C_k) \, dV = \oint_{A} (C_k \vec{g} + \vec{g}_k) \cdot (-\hat{n}) \, dA + \oint_{V} \dot{\rho}_k \, dV \, . \qquad (2.41)$$

Using the same approach as for the total mass conservation equation, the left-hand side of Eq. 2.41 for the discrete element formulation becomes

$$\frac{\partial}{\partial t} \oint_{V} (\rho C_k) \, dV = \Delta X_i \; \Delta Y_i \; \frac{\partial}{\partial t} [\rho_{i,j} (C_k)_{i,j} H_{i,j}] \; , \qquad (2.42)$$

and the last term on the right of Eq. 2.41 becomes

$$\oint_{V} \dot{\rho}_k \, dV = \dot{\rho}_k \; \Delta X_i \; \Delta Y_j \; H_{i,j} \; . \qquad (2.43)$$

The first term on the right of Eq. 2.41 is the surface integral around the six faces of the discrete element over the instantaneous mass fluxes of constituent k. Using again the discrete element notation and the schematic presentation of the fluxes in Figs. 2.2 to 2.4, pages 31 to 33, one gets:

$$\oint_{A} (\vec{g} C_k + \vec{g}_k) \cdot (-\hat{n}) \, dA = \Delta Y_j \int_0^{H_{i-1/2,j}} [(g_X)_{i-1/2,j} (C_k)_{i-1/2,j} + (g_{kX})_{i-1/2,j}] dZ$$

$$- \Delta Y_j \int_0^{H_{i+1/2,j}} [(g_X)_{i+1/2,j} (C_k)_{i+1/2,j} + (g_{kX})_{i+1/2,j}] dZ$$

$$+ \Delta X_i \int_0^{H_{i,j-1/2}} [(g_Y)_{i,j-1/2}(C_k)_{i,j-1/2} + (g_{kY})_{i,j-1/2}]dZ$$

$$- \Delta X_i \int_0^{H_{i,j+1/2}} [(g_Y)_{i,j+1/2}(C_k)_{i,j+1/2} + (g_{kY})_{i,j+1/2}]dZ$$

$$+ \Delta X_i \ \Delta Y_j [(g_B)_{i,j}(C_{kB})_{i,j} + (g_{kB})_{i,j}]$$

$$+ \Delta X_i \ \Delta Y_j [(g_T)_{i,j}(C_{kT})_{i,j} + (g_{kT})_{i,j}] \ , \qquad (2.44)$$

where g_{kB} is the nonconvective mass flow rate of constituent k coming from the bottom per unit area ($ML^{-2}T^{-1}$) and g_{kT} is the nonconvective mass flow rate of constituent k coming from the top per unit area ($ML^{-2}T^{-1}$).

As in the case of the total mass, each property may be a function of the depth Z and of turbulent fluctuations; i.e.,

$$P_{i,j}(Z,\ t) = \overline{P}_{i,j}(t) + p_{i,j}(Z,\ t) + p'_{i,j}(Z,\ t) \ , \qquad (2.45)$$

where P designates any property (U, V, C_k, T). Substituting Eq. 2.45 into Eq. 2.44 and then averaging with respect to the turbulent time scale does not result in complete vanishing of the turbulent fluctuations, $p'_{i,j}(Z, t)$. Nor does the vertical variation part, $p_{i,j}(Z, t)$, vanish when integrated over the depth. The reason for these nonvanishing terms is that the average of a product does not equal the product of the averages. This problem brings up the subject of the contributions of turbulent and longitudinal dispersion (shear effects) to the overall dispersion phenomenon. This subject will be discussed in detail in

Section 3. For the time being, the fluxes in each direction will be separated into two parts. One part, which is purely convective, includes only the averages over depth and time (over the turbulent time scale only). The second part, which will be termed the nonconvective flux, includes the contributions of both turbulence fluctuation and vertical variations. This last part will be combined with the relative flux of constituent k, designated in Eq. 2.8 as $\vec{g}_k$; that is, in general,

$$\int_0^H (\vec{g}_A C_k + \vec{g}_{kA})\ dZ = (\overline{g}_A \overline{C}_k = \overline{g}_{kA})H \ , \qquad (2.46)$$

where the subscript A means flux over area, the bar means average over depth and turbulent time scale, and $\overline{g}_{kA}$ represents the nonconvective mass flux, which will be discussed in Section 3.

Using Eq. 2.46 for all the half points in Eq. 2.44 gives

$$\begin{aligned}
\oint_A (\vec{g}C_k + \vec{g}_k)\cdot(-\hat{n})\ dA = {} & \Delta Y_j[(\overline{g}_X)_{i-1/2,j}(\overline{C}_k)_{i-1/2,j} + (\overline{g}_{kX})_{i-1/2,j}]H_{i-1/2,j} \\
& - \Delta Y_j[(\overline{g}_X)_{i+1/2,j}(\overline{C}_k)_{i+1/2,j} + (\overline{g}_{kX})_{i+1/2,j}]H_{i+1/2,j} \\
& + \Delta X_i[(\overline{g}_Y)_{i,j-1/2}(\overline{C}_k)_{i,j-1/2} + (\overline{g}_{kY})_{i,j-1/2}]H_{i,j-1/2} \\
& - \Delta X_i[(\overline{g}_Y)_{i,j+1/2}(\overline{C}_k)_{i,j+1/2} + (\overline{g}_{kY})_{i,j+1/2}]H_{i,j+1/2} \\
& + \Delta X_i\ \Delta Y_j[(g_B)_{i,j}(C_{kB})_{i,j} + (g_{kB})_{i,j}] \\
& + \Delta X_k\ \Delta Y_j[(g_T)_{i,j}(C_{kT})_{i,j} + (g_{kT})_{i,j}]\ . \qquad (2.47)
\end{aligned}$$

Substituting Eqs. 2.42, 2.43, and 2.47 into Eq. 2.41 and dividing by $\Delta X_i \ \Delta Y_j$ gives

$$\frac{\partial}{\partial t}[\rho_{i,j}(C_k)_{i,j}H_{i,j}] = -\frac{1}{\Delta X_i}\Big\{H_{i+1/2,j}\ [(\bar{g}_X)_{i+1/2,j}$$

$$(\bar{C}_k)_{i+1/2,j} + (\bar{g}_{kX})_{i+1/2,j}] - H_{i-1/2,j}\ [(\bar{g}_X)_{i-1/2,j}(\bar{C}_k)_{i-1/2,j}$$

$$+ (\bar{g}_{kX})_{i-1/2,j}]\Big\} - \frac{1}{\Delta Y_j}\Big\{H_{i,j+1/2}\ [(\bar{g}_Y)_{i,j+1/2}(\bar{C}_k)_{i,j+1/2}$$

$$+ (\bar{g}_{kY})_{i,j+1/2}] - H_{i,j-1/2}\ [(\bar{g}_Y)_{i,j-1/2}(\bar{C}_k)_{i,j-1/2} + (\bar{g}_{kY})_{i,j-1/2}]\Big\}$$

$$+ (g_B)_{i,j}(C_{kB})_{i,j} + (g_{kB})_{i,j} + (g_T)_{i,j}(C_{kT})_{i,j} + (g_{kT})_{i,j}$$

$$+ (\dot{\rho}_k)_{i,j}H_{i,j} \tag{2.48}$$

Differentiating $\rho_{i,j}H_{i,j}(C_k)_{i,j}$ gives

$$\frac{\partial}{\partial t}[\rho_{i,j}H_{i,j}\ (C_k)_{i,j}] = \rho_{i,j}H_{i,j}\frac{\partial(C_k)_{i,j}}{\partial t} + (C_k)_{i,j}\frac{\partial}{\partial t}(\rho_{i,j}H_{i,j}) \tag{2.49}$$

Substituting Eq. 2.36 for $(\partial/\partial t)(\rho_{i,j}H_{i,j})$ into Eq. 2.49 and then the result into Eq. 2.48 gives, after rearranging terms,

$$\frac{\partial C_k}{\partial t} = \frac{1}{\rho_{i,j}H_{i,j}}\Bigg\{-\frac{1}{\Delta X_i}\Big\{H_{i+1/2,j}\ [(\bar{g}_X)_{i+1/2,j}\Big((\bar{C}_k)_{i+1/2,j} - (\bar{C}_k)_{i,j}\Big)$$

$$+ (g_{kX})_{i+1/2,j}] - H_{i-1/2,j}\ [(\bar{g}_X)_{i-1/2,j}\Big((\bar{C}_i)_{i-1/2,j} - (\bar{C}_k)_{i,j}\Big)$$

$$+ (g_{kX})_{i-1/2,j}]\Big\} - \frac{1}{Y_j}\Big\{H_{i,j+1/2}\,[(\overline{g}_Y)_{i,j+1/2}\Big((\overline{C}_k)_{i,j+1/2}$$

$$- (\overline{C}_k)_{i,j}\Big) + (g_{kY})_{i,j+1/2}] - H_{i,j-1/2}\,[(\overline{g}_Y)_{i,j-1/2}\Big((\overline{C}_k)_{i,j-1/2}$$

$$- (\overline{C}_k)_{i,j}\Big) + (g_Y)_{i,j-1/2}]\Big\}$$

$$+ [(g_B)_{i,j}\Big((C_{kB})_{i,j} - (C_k)_{i,j}\Big) + (g_{kB})_{i,j}]$$

$$+ [(g_T)_{i,j}\Big((C_{kT})_{i,j} - (C_k)_{i,j}\Big) + (g_{kT})_{i,j}]$$

$$+ (\dot{\rho}_k)_{i,j}H_{i,j}\Big] , \qquad (2.50)$$

which is the discrete element formulation of the mass conservation equation for constituent k. The additional nonconvective mass fluxes of constituent k, $\vec{q}_{kX}$ and $\vec{q}_{kY}$, will be discussed in Section 3.5, and the bottom and top fluxes, g_{kB} and g_{kT}, in Section 4.6.

2.7. The Discrete Element Formulation of the Energy Conservation Equation

The integral form of the energy conservation equation was given by Eq. 2.22 as

$$\frac{\partial}{\partial t}\oint_{V} (\rho e)\, dV = \oint_{A} (\vec{g}h + \vec{q} + \sum_{k=1}^{K} \vec{q}_k)\cdot(-\hat{n})\, dA + \oint_{V} [\dot{q}_V + \sum_{k=1}^{K} (\dot{q}_V)_k]\, dV . \qquad (2.51)$$

As in the case of total mass and mass of constituent k, the volume integrals can be evaluated as

$$\frac{\partial}{\partial t} \oint_{\forall} (\rho e)\ d\forall = \Delta X_i\ \Delta Y_j\ \frac{\partial}{\partial t}(\rho_{i,j} e_{i,j} H_{i,j}) \ , \qquad (2.52)$$

and, assuming uniform heat and mass generation rates per unit volume throughout the discrete element i,j,

$$\oint_{\forall} [(\dot{q}_V) + \sum_{k=1}^{K} (\dot{q}_V)_k]\ d\forall = \Delta X_i\ \Delta Y_j\ [\dot{q}_V + \sum_{k=1}^{K} (\dot{q}_V)_k] H_{i,j} \ , \qquad (2.53)$$

where $(\dot{q}_V)_k$ was defined as $\dot{\rho}_k h_k$ by Eq. 2.27.

The first term on the right of Eq. 2.51 is the surface integral around the six faces of the discrete element over the instantaneous energy fluxes. Using again the discrete element notation and the schematic presentation of the fluxes in Figs. 2.2-2.4, pages 31-33, one gets:

$$\oint_A (\vec{g}h + \vec{q} + \sum_{k=1}^{K} \vec{q}_k)\cdot(-\hat{n})\ dA =$$

$$\Delta Y_j \int_0^{H_{i-1/2,j}} [(g_X)_{i-1/2,j} h_{i-1/2,j} + (q_X)_{i-1/2,j} + \sum_{k=1}^{K} (q_{kX})_{i-1/2,j}] dZ$$

$$- \Delta Y_j \int_0^{H_{i+1/2,j}} [(g_X)_{i+1/2,j} h_{i+1/2,j} + (q_X)_{i+1/2,j} + \sum_{k=1}^{K} (q_{kX})_{i+1/2,j}] dZ$$

$$+ \Delta X_i \int_0^{H_{i,j-1/2}} [(g_Y)_{i,j-1/2} h_{i,j-1/2} + (q_Y)_{i,j-1/2} + \sum_{k=1}^{K} (q_{kY})_{i,j-1/2}] dZ$$

$$- \Delta X_j \int_0^{H_{i,j+1/2}} [(g_Y)_{i,j+1/2} h_{i,j+1/2} + (q_Y)_{i,j+1/2} + \sum_{k=1}^{K} (q_{kY})_{i,j+1/2}] dZ$$

$$+ \Delta X_i \; \Delta Y_j \; [(g_B)_{i,j} (h_B)_{i,j} + (q_B)_{i,j} + \sum_{k=1}^{K} (q_{kB})_{i,j}]$$

$$+ \Delta X_i \; \Delta Y_j \; [(g_T)_{i,j} (h_T)_{i,j} + (q_T)_{i,j} + \sum_{k=1}^{K} (q_{kT})_{i,j}] \qquad (2.54)$$

As before, each property may be a function of depth Z and of turbulent fluctuations, as given by Eq. 2.45.

Substituting Eq. 2.45 into Eq. 2.54 and then averaging with respect to time does not result in complete vanishing of the turbulent fluctuations $p'_{i,j}(Z, t)$. Nor do the contributions of the vertical variations, $p_{i,j}(Z, t)$, vanish when integrated over the depth. The problem is the same as in the case of mass fluxes of constituent k except that here there are the additional terms

$$\sum_{k=1}^{K} (\vec{q}_k)$$

However, $\vec{q}_k$ was defined by Eq. 2.26 as

$$\vec{q}_k = \vec{g}_k h_k \; ,$$

and $\vec{g}_k$ was already discussed in Section 2.6. Then, using the same approach as before, the total integration heat flux will be expressed in three parts as

$$\int_0^H [g_A)h + q_A + \sum_{k=1}^{K} (q_{kA})]\ dZ = [\overline{g}_A\overline{h} + \overline{q}_A + \sum_{k=1}^{K} (\overline{q}_{kA})]H\ , \qquad (2.55)$$

where the subscript A means flux over area, the bar means average over depth and turbulent time scale, and q_A represents the nonconvective heat flux, which may result from the contribution of molecular diffusion, turbulent diffusion, and shear flow to the total dispersion phenomenon. The evaluation of $\overline{q}_A$ will be more fully discussed in Section 3.

Evaluating Eq. 2.55 for all the half points in Eq. 2.54 gives

$$\oint_A (\vec{g}h + \vec{q} + \sum_{k=1}^{K} \vec{q}_k)\cdot(-\hat{n})\ dA =$$

$$\Delta Y_j\ [(\overline{g}_X)_{i-1/2,j}\overline{h}_{i-1/2,j} + (\overline{q}_X)_{i-1/2,j} + \sum_{k=1}^{K} (\overline{q}_{kX})_{i-1/2,j}]H_{i-1/2,j}$$

$$-\ \Delta Y_j\ [(\overline{g}_X)_{i+1/2,j}\overline{h}_{i+1/2,j} + (\overline{q}_X)_{i+1/2,j} + \sum_{k=1}^{K} (\overline{q}_{kX})_{i+1/2,j}]H_{i+1/2,j}$$

$$+\ \Delta X_i\ [(\overline{g}_Y)_{i,j-1/2}\overline{h}_{i,j-1/2} + (\overline{q}_Y)_{i,j-1/2} + \sum_{k=1}^{K} (\overline{q}_{kY})_{i,j-1/2}]H_{i,j-1/2}$$

$$-\ \Delta X_i\ [(\overline{g}_Y)_{i,j+1/2}\overline{h}_{i,j+1/2} + (\overline{q}_Y)_{i,j+1/2} + \sum_{k=1}^{K} (\overline{q}_{kY})_{i,j+1/2}]H_{i,j+1/2}$$

$$+\ \Delta X_i\ \Delta Y_j\ [(g_B)_{i,j}(h_B)_{i,j} + (q_B)_{i,j} + \sum_{k=1}^{K} (q_{kB})_{i,j}]$$

$$+\ \Delta X_i\ \Delta Y_j\ [(g_T)_{i,j}(h_T)_{i,j} + (q_T)_{i,j} + \sum_{k=1}^{K} (q_{kT})_{i,j}] \qquad (2.56)$$

Substituting Eqs. 2.52, 2.53, and 2.56 into Eq. 2.51 and dividing by $\Delta X_i \ \Delta Y_i$ gives

$$\frac{\partial}{\partial t} (\rho_{i,j} e_{i,j} H_{i,j}) =$$

$$- \frac{1}{\Delta X_i} \Bigg(H_{i+1/2,j} \ [(\bar{g}_X)_{i+1/2,j} \bar{h}_{i+1/2,j} + (\bar{q}_X)_{i+1/2,j} + \sum_{k=1}^{K} (\bar{q}_{kX})_{i+1/2,j}]$$

$$- H_{i-1/2,j} \ [(\bar{g}_X)_{i-1/2,j} \bar{h}_{i-1/2,j} + (\bar{q}_X)_{i-1/2,j} + \sum_{k=1}^{K} (\bar{q}_{kX})_{i-1/2,j}] \Bigg)$$

$$- \frac{1}{\Delta Y_j} \Bigg(H_{i,j+1/2} \ [(\bar{g}_Y)_{i,j+1/2} h_{i,j+1/2} + (\bar{q}_Y)_{i,j+1/2} + \sum_{k=1}^{K} (\bar{q}_{kX})_{i,j+1/2}]$$

$$- H_{i,j-1/2} \ [(\bar{g}_Y)_{i,j-1/2} h_{i,j-1/2} + (\bar{q}_Y)_{i,j-1/2} + \sum_{k=1}^{K} (\bar{q}_{kX})_{i,j-1/2}]$$

$$+ (g_B)_{i,j} (h_B)_{i,j} + (q_B)_{i,j} + \sum_{k=1}^{K} (q_{kB})_{i,j} + (g_T)_{i,j} (h_T)_{i,j} + (q_T)_{i,j}$$

$$+ \sum_{k=1}^{K} (q_{kT})_{i,j} + (\dot{q}_V)_{i,j} + \sum_{k=1}^{NK} [(\dot{q}_V)_k]_{i,j} \ H_{i,j} \ . \qquad (2.57)$$

Differentiating $\rho_{i,j} e_{i,j} H_{i,j}$ gives

$$\frac{\partial}{\partial t}(\rho_{i,j} e_{i,j} H_{i,j}) = \rho_{i,j} H_{i,j} \frac{\partial}{\partial t}(e_{i,j}) + e_{i,j} \frac{\partial}{\partial t}(\rho_{i,j} H_{i,j}) \ . \qquad (2.58)$$

However, the internal energy e is a function of both the temperature and the concentrations of the constituents, and its time derivative can be evaluated by

$$\frac{\partial}{\partial t}(e_{i,j}) = \left(\frac{\partial e}{\partial T}\right)_{i,j} \left(\frac{\partial T_{i,j}}{\partial t}\right) + \sum_{k=1}^{K} \left(\frac{\partial e}{\partial C_k}\right)_{i,j} \frac{\partial (C_k)_{i,j}}{\partial t}$$

$$\cong \left(\frac{\partial e}{\partial T}\right)_{i,j} \frac{\partial T_{i,j}}{\partial t} + \sum_{k=1}^{K} (e_k)_{i,j} \frac{\partial (C_k)_{i,j}}{\partial t}$$

$$= (C_V)_{i,j} \frac{\partial T_{i,j}}{\partial t} + \sum_{k=1}^{K} (e_k)_{i,j} \frac{\partial (C_k)_{i,j}}{\partial t}, \qquad (2.59)$$

where use has been made of Eq. 2.14 ($e \approx \hat{u}$) and the thermodynamic definition of the specific heat at constant volume.

Substituting Eq. 2.59 into Eq. 2.58, one gets

$$\frac{\partial}{\partial t}(\rho_{i,j} e_{i,j} H_{i,j}) = \rho_{i,j} H_{i,j} (C_V)_{i,j} \frac{\partial T_{i,j}}{\partial t}$$

$$+ \rho_{i,j} H_{i,j} \sum_{k=1}^{K} (e_k)_{i,j} \left(\frac{\partial (C_k)_{i,j}}{\partial t}\right) + e_{i,j} \frac{\partial}{\partial t}(\rho_{i,j} H_{i,j}). \qquad (2.60)$$

Substituting Eq. 2.36 into Eq. 2.60 for eliminating $(\partial/\partial t)(\rho_{i,j} H_{i,j})$ and then substituting the result into Eq. 2.57 and rearranging terms gives

$$\frac{\partial T_{i,j}}{\partial t} = \frac{1}{\rho_{i,j} (C_V)_{i,j} H_{i,j}} \left\{ -\rho_{i,j} H_{i,j} \sum_{k=1}^{K} (e_k)_{i,j} \left(\frac{\partial (C_k)_{i,j}}{\partial t}\right) \right.$$

$$- \frac{1}{X_i} \left(H_{i+1/2,j} [(\overline{g}_X)_{i+1/2,j} (\overline{h}_{i+1/2,j} - \overline{e}_{i,j}) + (\overline{q}_X)_{i+1/2,j}\right.$$

$$+ \sum_{k=1}^{K} (\overline{q}_{kX})_{i+1/2,j}] - H_{i-1/2,j} \, [(\overline{g}_X)_{i-1/2,j} - \overline{e}_{i,j}) + (\overline{q}_X)_{i-1/2,j}$$

$$+ \sum_{k=1}^{K} (\overline{q}_{kX})_{i-1/2,j}]\Big) - \frac{1}{\Delta Y_j}\Big(H_{i,j+1/2}\ [(\overline{g}_Y)_{i,j+1/2}(\overline{h}_{i,j+1/2} - \overline{e}_{i,j})$$

$$+ (\overline{q}_Y)_{i,j+1/2} + \sum_{k=1}^{K} (\overline{q}_{kY})_{i,j+1/2}] - H_{i,j-1/2}\ [(\overline{g}_Y)_{i,j-1/2}(\overline{h}_{i,j-1/2} - \overline{e}_{i,j})$$

$$+ (\overline{q}_Y)_{i,j-1/2} + \sum_{k=1}^{K} (\overline{q}_{kY})_{i,j-1/2}]\Big)$$

$$+ [(g_B)_{i,j}\Big((h_B)_{i,j} - e_{i,j}\Big) + (q_B)_{i,j} + \sum_{k=1}^{K} (q_{kB})_{i,j}]$$

$$+ [(g_T)_{i,j}\Big((h_T)_{i,j} - e_{i,j}\Big) + (q_T)_{i,j} + \sum_{k=1}^{K} (q_{kT})_{i,j}]$$

$$+ [(\dot{q}_V)_{i,j} + \sum_{k=1}^{K}\Big((\dot{q}_V)_k\Big)_{i,j}]\ H_{i,j}\Bigg\} \ . \qquad (2.61)$$

The convective energy fluxes $\overline{q}_k$, q_{kB}, and q_{kT} are all evaluated on the basis of the corresponding mass fluxes; i.e.,

$$\overline{q}_k = \overline{g}_k h_k \ , \qquad (2.62)$$

$$(q_k)_B = (g_k)_B (h_k)_B \ , \qquad (2.63)$$

$$(q_k)_T = (g_k)_T (h_k)_T \ . \qquad (2.64)$$

The additional nonconvective heat fluxes $\overline{q}_X$ and $\overline{q}_Y$ will be discussed in Section 3.4, and the bottom and top fluxes q_B and q_T in Section 4.4. The use of $\dot{q}_V$ for the case of thermal discharge from a power plant will be discussed in Section 7.1.

2.8. The Discrete Element Formulation of the Momentum Equation

The integral forms of the momentum equations in the X and Y directions are given by Eqs. 2.23 and 2.24, respectively, as:

$$\frac{\partial}{\partial t} \oint_{\forall} (\rho U)\ d\forall + \oint_{A} [(U)\vec{g}]\cdot(\hat{n})\ dA = \oint_{\forall} (f_c)_X\, d\forall + \oint_{A} \sigma_X\ dA\ , \qquad (2.65)$$

$$\frac{\partial}{\partial t} \oint_{\forall} (\rho V)\ d\forall + \oint_{A} [(V)\vec{g}]\cdot(\hat{n})\ dA = \oint_{\forall} (f_c)_Y\ d\forall + \oint_{A} \sigma_Y\ dA\ . \qquad (2.66)$$

Referring to Fig. 2.2, page 31, it can be seen that, unlike other vectorial surface fluxes, the stresses consist of normal stresses σ_{XX}, σ_{YY} acting normal to a surface and shear stresses σ_{XY}, σ_{YX} acting parallel to the surface. The normal stresses are considered positive when trying to stretch the element (tension), and the shear stresses are considered positive when creating a positive angle of deformation. Figures 2.2 to 2.4, pages 31 to 33, show all the stresses in their positive direction. When evaluating the various components of the integrals in Eqs. 2.65 and 2.66, one must suppose that the forces contribute to the acceleration of the discrete element as a rigid unit according to the second law of Newton and must keep in mind that force and acceleration are considered positive when directed toward the positive directions of the system coordinates.

As before, assuming uniform density (ρ) and Coriolis force per unit volume (f_c) within the volume of each discrete element, the volume integrals of Eq. 2.65 can be evaluated for the discrete element formulation as:

$$\frac{\partial}{\partial t} \oint_{\forall} (\rho U) \, d\forall = \Delta X_i \; \Delta Y_j \; \frac{\partial}{\partial t}(\rho_{i,j} U_{i,j} H_{i,j}) \tag{2.67}$$

and

$$\oint_{\forall} (f_c)_X \, d\forall = (f_{cX})_{i,j} \; \Delta X_i \; \Delta Y_j \; H_{i,j} \; . \tag{2.68}$$

The second term on the left of Eq. 2.65 is the surface integral around the six faces of each discrete element over the instantaneous momentum fluxes. Using the discrete element notation and the schematic presentation of the fluxes in Figs. 2.2 to 2.4, pages 31 to 33, gives:

$$\begin{aligned}
\oint_A (U)\vec{g}\cdot(\hat{n}) \, dA = {} & \Delta Y_j \int_0^{H_{i-1/2,j}} [(g_X)_{i-1/2,j} U_{i-1/2,j}] dZ \\
& - \Delta Y_j \int_0^{H_{i+1/2,j}} [(g_X)_{i+1/2,j} U_{i+1/2,j}] dZ \\
& + \Delta X_i \int_0^{H_{i,j-1/2}} [(g_Y)_{i,j-1/2} U_{i,j-1/2}] dZ \\
& - \Delta X_i \int_0^{H_{i,j+1/2}} [(g_Y)_{i,j+1/2} U_{i,j+1/2}] dZ \\
& + \Delta X_i \; \Delta Y_j (g_B)_{i,j} (U_B)_{i,j} + \Delta X_i \; \Delta Y_j (g_T)_{i,j} (U_T)_{i,j} \; .
\end{aligned} \tag{2.69}$$

The same is correct for the stress term on the right of Eq. 2.66; i.e.,

$$\oint_A \sigma_X \, dA = \Delta Y_j \int_0^{H_{i-1/2,j}} (-\sigma_{XX})_{i-1/2,j} \, dZ + \Delta Y_j \int_0^{H_{i+1/2,j}} (\sigma_{XX})_{i+1/2,j} \, dZ$$

$$+ \Delta X_i \int_0^{H_{i,j-1/2}} (-\sigma_{YX})_{i,j-1/2} \, dZ + \Delta X_i \int_0^{H_{i,j+1/2}} (\sigma_{YX})_{i,j+1/2} \, dZ$$

$$+ \Delta X_i \, \Delta Y_j \, (\sigma_{BX})_{i,j} + \Delta X_i \, \Delta Y_j \, (\sigma_{TX})_{i,j} \, . \qquad (2.70)$$

As explained before, the velocities may be a function of the depth Z and also may include the turbulent fluctuations, as expressed by Eq. 2.45. Substituting Eq. 2.45 into Eqs. 2.69 and 2.70 results in non-vanishing terms for those variations. As was done before, those additional terms will be combined with the stress terms. In general, then, a combined term will appear for these fluxes such that

$$- \int_0^H [(g_A)U] \, dZ + \int_0^H (\sigma_X)_A \, dZ = (\overline{g}_A \overline{U} + \overline{\sigma}_X)H \; , \qquad (2.71)$$

where the subscript A means fluxes or stress over area, the bar means value averaged over depth and turbulent time scale, and σ_X represents the combined effect of molecular stresses, turbulent stresses, and shear effects because of velocity variations with depth. The evaluation of σ_X, including the hydrostatic pressure effects involved, will be more fully discussed in Section 3. Evaluating Eq. 2.71 for all the half points in Eqs. 2.69 and 2.70 combined gives:

$$- \oint_A U\vec{g}\cdot(\hat{n})\, dA + \oint_A \sigma_X\, dA = \Delta Y_j\, [(g_X)_{i-1/2,j}\overline{U}_{i-1/2,j} - (\overline{\sigma}_{XX})_{i-1/2,j}]H_{i-1/2,j}$$

$$- \Delta Y_j\, [(\overline{g}_X)_{i+1/2,j}\overline{U}_{i+1/2,j} - (\overline{\sigma}_{XX})_{i+1/2,j}]H_{i+1/2,j}$$

$$+ \Delta X_i\, [(\overline{g}_Y)_{i,j-1/2}\overline{U}_{i,j-1/2} - (\overline{\sigma}_{YX})_{i,j-1/2}]H_{i,j-1/2}$$

$$- \Delta X_i\, [(\overline{g}_Y)_{i,j+1/2}\overline{U}_{i,j+1/2} - (\overline{\sigma}_{YX})_{i,j-1/2}]H_{i,j+1/2}$$

$$+ \Delta X_i\, \Delta Y_j\, [(g_B)_{i,j}(U_B)_{i,j} + (\sigma_{BX})_{i,j}]H_{i,j}$$

$$+ \Delta X_i\, \Delta Y_j\, [(g_T)_{i,j}(U_T)_{i,j} + (\sigma_{TX})_{i,j}]H_{i,j}\,. \tag{2.72}$$

Substituting Eqs. 2.67, 2.68, and 2.72 into Eq. 2.65 and dividing by $\Delta X_i\, \Delta Y_j$ gives:

$$\frac{\partial}{\partial t}(\rho_{i,j}U_{i,j}H_{i,j}) = -\frac{1}{\Delta X_i}\Big(H_{i+1/2,j}\,[(\overline{g}_X)_{i+1/2,j}\overline{U}_{i+1/2,j} - (\overline{\sigma}_{XX})_{i+1/2,j}]$$

$$- H_{i-1/2,j}\,[(\overline{g}_X)_{i-1/2,j}\overline{U}_{i-1/2,j} - (\overline{\sigma}_{XX})_{i-1/2,j}]\Big)$$

$$- \frac{1}{\Delta Y_j}\Big(H_{i,j+1/2}\,[(\overline{g}_Y)_{i,j+1/2}\overline{U}_{i,j+1/2} - (\overline{\sigma}_{YX})_{i,j+1/2}]$$

$$- H_{i,j-1/2}\,[(\overline{g}_Y)_{i,j-1/2}\overline{U}_{i,j-1/2} - (\overline{\sigma}_{YX})_{i,j-1/2}]\Big)$$

$$+ [(g_B)_{i,j}(U_B)_{i,j} + (\sigma_{BX})_{i,j}] + [(g_T)_{i,j}(U_T)_{i,j} + (\sigma_{TX})_{i,j}]$$

$$+ (f_{cX})_{i,j}\, H_{i,j}\,. \tag{2.73}$$

Differentiating $(\rho HU)_{i,j}$ gives:

$$\frac{\partial}{\partial t}(\rho_{i,j}H_{i,j}U_{i,j}) = \rho_{i,j}H_{i,j}(\partial U_{i,j}/\partial t) + U_{i,j}(\partial/\partial t)(\rho_{i,j}H_{i,j}) \quad . \qquad (2.74)$$

Substituting Eq. 2.36 for $(\partial/\partial t)(\rho_{i,j}H_{i,j})$ into Eq. 2.74, then substituting the result into Eq. 2.73 and rearranging terms gives:

$$\frac{\partial U_{i,j}}{\partial t} = \frac{1}{\rho_{i,j}H_{i,j}} \left\{ -\frac{1}{\Delta X_i} \left(H_{i+1/2,j} \, [(\bar{g}_X)_{i+1/2,j}(\bar{U}_{i+1/2,j} - \bar{U}_{i,j}) - (\bar{\sigma}_{XX})_{i+1/2,j}] \right.\right.$$

$$\left. - H_{i-1/2,j} \, [(\bar{g}_X)_{i-1/2,j}(\bar{U}_{i-1/2,j} - \bar{U}_{i,j}) - (\bar{\sigma}_{XX})_{i-1/2,j}] \right)$$

$$- \frac{1}{\Delta Y_j} \left(H_{i,j+1/2} \, [(\bar{g}_Y)_{i,j+1/2}(\bar{U}_{i,j+1/2} - \bar{U}_{i,j}) - (\bar{\sigma}_{YX})_{i,j+1/2}] \right.$$

$$\left. - H_{i,j-1/2} \, [(\bar{g}_Y)_{i,j-1/2}(\bar{U}_{i,j-1/2} - \bar{U}_{i,j}) - (\bar{\sigma}_{YX})_{i,j-1/2}] \right)$$

$$+ [(g_B)_{i,j}\left((U_B)_{i,j} - U_{i,j}\right) + (\sigma_{BX})_{i,j}] + [(g_T)_{i,j}\left((U_T)_{i,j} - \bar{U}_{i,j}\right) + (\sigma_{TX})_{i,j}]$$

$$\left. + (f_{cX})_{i,j} \, H_{i,j} \right\} \quad . \qquad (2.75)$$

In a similar way the momentum equation in the Y direction, given in its integral form by Eq. 2.66, can be formulated for a discrete element to give:

$$\frac{\partial V_{i,j}}{\partial t} = \frac{1}{\rho_{i,j}H_{i,j}} \left\{ -\frac{1}{\Delta X_i} \left(H_{i+1/2,j}[(\bar{g}_X)_{i+1/2,j}(\bar{V}_{i+1/2,j} - \bar{V}_{i,j}) - (\bar{\sigma}_{XY})_{i+1/2,j}] \right.\right.$$

$$- H_{i-1/2,j}[(\bar{g}_X)_{i-1/2,j}(\bar{V}_{i-1/2,j} - \bar{V}_{i,j}) - (\bar{\sigma}_{XY})_{i-1/2,j}]\Bigg)$$

$$- \frac{1}{\Delta Y_j}\Bigg(H_{i,j+1/2}[(\bar{g}_Y)_{i,j+1/2}(\bar{V}_{i,j+1/2} - \bar{V}_{i,j}) - (\bar{\sigma}_{YY})_{i,j+1/2}]$$

$$- H_{i,j-1/2}[(\bar{g}_Y)_{i,j-1/2}(\bar{V}_{i,j-1/2} - \bar{V}_{i,j}) - (\bar{\sigma}_{YY})_{i,j-1/2}]\Bigg)$$

$$+ \Bigg((g_B)_{i,j}[(V_B)_{i,j} - \bar{V}_{i,j}] + (\sigma_{BY})_{i,j}\Bigg)$$

$$+ \Bigg((g_T)_{i,j}[(V_T)_{i,j} - \bar{V}_{i,j}] + (\sigma_{TY})_{i,j}\Bigg)$$

$$+ (f_{cY})_{i,j}\, H_{i,j}\Bigg\} \, . \qquad (2.76)$$

The stresses $\bar{\sigma}_{XX}$, $\bar{\sigma}_{YY}$, $\bar{\sigma}_{YX}$, and $\bar{\sigma}_{XY}$, which include molecular stress, turbulent stresses, and shear stresses because of velocity variations with depth, will be discussed in Section 3. The Coriolis force per unit volume, f_c, will be discussed in Section 4.

2.9. The Half-Point Values on Discrete Element Surfaces and Corners

In Section 2.4 the discrete element notation and representation were discussed. However, as is seen from the discrete element formulation of the conservation equations, all the fluxes and many of the properties must be evaluated on the boundary faces between neighboring discrete elements. The properties for each discrete element are considered uniform along ΔX_i and along ΔY_j and are represented at a point (i, j) located at the center of each element. The properties on the faces, located at half-point values, must be calculated by using some extrapolation procedure. The first-order Taylor expansion approximation is used in this study for that purpose; i.e., for any point, one can write:

$$P(X + \Delta X, Y + \Delta Y) = P(X, Y) + \Delta X \frac{\partial P(X, Y)}{\partial X} + \Delta Y \frac{\partial P(X, Y)}{\partial Y} . \quad (2.77)$$

On the basis of Eq. 2.77, one gets the numerical approximation for half-point values as

$$P_{i+1/2,j} = P_{i,j} + \Delta X_i \frac{P_{i+1,j} - P_{i,j}}{\Delta X_{i+1} + \Delta X_i} . \quad (2.78)$$

After rearranging terms, Eq. 2.78, applied for the four faces of each discrete element at their centers, gives (see Fig. 2.1, page 29):

$$P_{i+1/2,j} = \frac{\Delta X_i}{\Delta X_i + \Delta X_{i+1}} P_{i+1,j} + \frac{\Delta X_{i+1}}{\Delta X_i + \Delta X_{i+1}} P_{i,j} , \quad (2.79)$$

$$P_{i-1/2,j} = \frac{\Delta X_i}{\Delta X_{i-1} + \Delta X_i} P_{i-1,j} + \frac{\Delta X_{i-1}}{\Delta X_{i-1} + \Delta X_i} P_{i,j} , \quad (2.80)$$

$$P_{i,j+1/2} = \frac{\Delta Y_j}{\Delta Y_j + \Delta Y_{j+1}} P_{i,j+1} + \frac{\Delta Y_{j+1}}{\Delta Y_j + \Delta Y_{j+1}} P_{i,j} , \quad (2.81)$$

$$P_{i,j-1/2} = \frac{\Delta Y_j}{\Delta Y_{j-1} + \Delta Y_j} P_{i,j-1} + \frac{\Delta Y_{j-1}}{\Delta Y_{j-1} + \Delta Y_J} P_{i,j} \ . \tag{2.82}$$

For the four corner points on each element, Eq. 2.77 gives:

$$P_{i+1/2,j+1/2} = P_{i,j} + \Delta X_i \frac{P_{i+1,j+1/2} - P_{i,j+1/2}}{\Delta X_{i+1} + \Delta X_i}$$

$$+ \Delta Y_j \frac{P_{i+1/2,j+1} - P_{i+1/2,j}}{\Delta Y_{j+1} + \Delta Y_j} \ , \tag{2.83}$$

$$P_{i-1/2,j+1/2} = P_{i,j} - \Delta X_i \frac{P_{i,j+1/2} - P_{i-1,j+1/2}}{\Delta X_i + \Delta X_{i-1}}$$

$$+ \Delta Y_j \frac{P_{i-1/2,j+1} - P_{i-1/2,j}}{\Delta Y_{j+1} + \Delta Y_j} \ , \tag{2.84}$$

$$P_{i+1/2,j-1/2} = P_{i,j} + \Delta X_i \frac{P_{i+1,j-1/2} - P_{i,j-1/2}}{\Delta X_{i+1} + \Delta X_i}$$

$$- \Delta Y_j \frac{P_{i+1/2,j} - P_{i+1/2}}{\Delta Y_j + \Delta Y_{j-1}} \tag{2.85}$$

$$P_{i-1/2,j-1/2} = P_{i,j} - \Delta X_i \frac{P_{i,j-1/2} - P_{i-1,j-1/2}}{\Delta X_i + \Delta Y_{i-1}}$$

$$- \Delta Y_j \frac{P_{i-1/2,j} - P_{i-1/2,j-1}}{\Delta Y_j + \Delta Y_{j-1}} \ . \tag{2.86}$$

As an alternative to the above Taylor expansion for the average values used in evaluating the fluxes on the discrete element faces, one can define those values on the basis of physical arguments. One such method, called the "donor cell" method, which is said to have good numerical stabilizing effects, will be discussed in Section 6.3.

3. FORMULATION OF DIFFUSIVE AND OTHER NONCONVECTIVE INTERNAL FLUXES

In Section 2 the discrete element formulation of the conservation equations has been developed. It was discussed there that since the model is two dimensional, the effects of vertical variations cannot be included directly in the model. However, in reality the vertical variations of the various properties may have considerable effects on the horizontal behavior of those properties. In addition, the random fluctuations existing in turbulent flows were not explicitly formulated. Instead, each flux was divided into two parts. The first part is purely convective in nature and reflects the depth- and time-average values of the corresponding fluxes (average over turbulent time scale only). The second part, which is termed the nonconvective flux, includes diffusive fluxes as well as the contributions of turbulent fluctuations and vertical variations. The purely convective part was already properly included in the discrete element equations developed in Section 2. The nonconvective fluxes were left as general expressions. These fluxes will be discussed in this section, first in a general form for all the properties and then specifically for mass, momentum, and energy fluxes.

3.1. The Gradient Law of Diffusion, Turbulent Diffusion, and Dispersion

The transport mechanism in turbulent flow and specifically in the flow of natural streams is a very complicated phenomenon. As a result, there is a tendency among investigators in this field to apply simplified and "easty-to-use" transport formulations in which all the transport phenomena are lumped into a single term in the conservation equation, using the gradient law of diffusion for that purpose. This law can be, in general, expressed as

$$\vec{P}_A = - D \vec{\nabla}(\rho P) \ , \tag{3.1}$$

where D is an overall effective coefficient that includes all nonconvective effects.

An extreme example of such a case can be seen in the practice of using a one-dimensional steady-state convection diffusion equation with a huge constant "dispersion coefficient" to predict the transport process in estuaries, i.e.,

$$\overline{U}_F \frac{dP}{dX} - D \frac{d^2P}{dX^2} + KP = 0 \ , \tag{3.2}$$

where $\overline{U}_F$ is the time-average nontidal fresh water flow velocity downstream toward the ocean. Such an equation is the result of averaging over two-space dimensions and time. The value of $\overline{U}_F$ is a time average of the instantaneous tidal velocity, which may be, at its peak, about 50 times as large as U_F itself. This means that the tidal movements, which are the most powerful ones in estuaries, are not properly expressed in Eq. 3.2. Instead, the diffusion-dispersion coefficient D is supposed to compensate for those effects. However, experience with such an attempt shows that there is no way to find a reliable value for such a coefficient except, maybe, by field measurement for a specific location in a specific water body and under a very specific set of conditions. Finding a correct value for D in Eq. 3.2 almost means solving the whole problem.

Trying to separate the various effects included in such an overall coefficient creates some difficulties because it is apparent that not all those effects can be reliably expressed by the gradient law (Eq. 3.1).

Such a gradient law was proved to be very successful for expressing molecular diffusion (Fourier law for heat and Fick's law for mass diffusion). In a one-dimensional case and for a general property P, such a law can be expressed as

$$(P_A)_X = -\alpha_P \frac{\partial(\rho P)}{\partial X}, \qquad (3.3)$$

where α_P expresses the molecular diffusivity (L^2T^{-1}) of a property P and $(P_A)_X$ is the flux in the X direction.

When convection and diffusion are combined, the flux of the property can be expressed as

$$(\vec{P}_A)_X = U(\delta P) \left(-\alpha_P \frac{\partial(\rho P)}{\partial X}\right), \qquad (3.4)$$

where U is the velocity of the fluid in the X direction.

However, U represents the velocity when the fluid is considered to be a continuum. The actual movements of the individual molecules are in no way described in Eqs. 3.3 and 3.4. Looking at the problem from this point of view, one realizes that the diffusion terms in Eqs. 3.3 and 3.4 are time-average expressions for the molecular random motions.

In turbulent flow a similar phenomenon of random motions exists except that in this case there are random motions of lumps of fluid rather than molecules. The time and space scales involved in turbulent fluctuations are much larger than those in molecular motions. Nevertheless, these motions are very complex for complete detection and description. If one expresses the instantaneous velocities and properties as a superposition of a mean time-averaged value (indicated by a bar) and an instantaneous random fluctuating value (indicated by a prime), one gets

$$U = \overline{U} + u' \ ,$$
$$P = \overline{P} + p' \ . \qquad (3.5)$$

Assuming that Eq. 3.4 is correct for turbulent flow as well as for laminar flow if instantaneous values are used, one can substitute Eq. 3.5 into Eq. 3.4. If the interest is not focused on the fluctuating terms themselves but rather on their overall effects on the mean flow, one can time-average the equations over the appropriate scale (smaller than the scale of interest but larger than the turbulent time scale) to get

$$(P_A)_X = \overline{U}(\overline{P}) + (- \alpha_P \frac{\partial P}{\partial X}) + \overline{u'p'} \ . \qquad (3.6)$$

The term $\overline{u'p'}$ is the only term left from the turbulent fluctuations, because based on the Reynolds averaging principles, all the other terms vanish on a time-average basis. Since in most cases the values of the fluctuating quantities u_i' and p_i' are not known, great effort has been made in the past 50 years to find a correlation that will relate the turbulent effects to the mean flow parameters. Boussinesq[58] has proposed that the effective transport associated with the turbulent fluctuation follows a gradient-type law and has represented the transport due to random turbulent fluctuations as

$$u'p' = - \varepsilon_p \frac{\partial(\rho\overline{P})}{\partial X} , \qquad (3.7)$$

where ε_p is a constant termed the eddy viscosity (other names like virtual, apparent, or turbulent viscosity are also used interchangeably in the literature).

Substituting Eq. 3.7 into Eq. 3.6 gives

$$(P_A)_X = \overline{U}(\overline{P}) + \left(- (\alpha_p + \varepsilon_p) \frac{\partial\overline{P}}{\partial X}\right) . \qquad (3.8)$$

Unfortunately, a relationship like the one given above, although successful in some cases, is not universally correct for all turbulent flow situations.

Other attempts to improve the relationship proposed by Boussinesq were made by developing nonconstant formulations for the eddy viscosity ε_p. Without going into the details of those correlations, a number of them will be mentioned here (see Refs. 79 and 80 for further discussions).

Prandtl mixing length theory (Ref. 59) defines the eddy viscosity as

$$\varepsilon = \ell^2 \left|\frac{d\overline{U}}{dY}\right| , \qquad (3.9)$$

where ℓ is a characteristic length, $\overline{U}$ is the velocity along the main flow, and Y is perpendicular to the flow. The mixing length is interpreted as that length which fluid particles travel in the turbulent mixing process before losing their identity. This is not an easy parameter to evaluate and is definitely not universally constant. However, Prandtl's mixing length theory was successfully used in many practical problems and is still considered one of the most helpful correlations.

Taylor's vorticity transfer theory (Ref. 81) states that

$$\varepsilon = \frac{1}{2}\,\ell_W^{\,2} \left|\frac{d\overline{U}}{dY}\right| \;, \tag{3.10}$$

where ℓ_W is also a characteristic mixing length but is larger than Prandtl's mixing length ℓ by a factor of $\sqrt{2}$. Taylor's vorticity transfer theory finds its application mainly to problems of free turbulence and does not agree well with experiments for turbulence along a solid surface.

Von Karman's similarity hypothesis (Ref. 61) results in

$$\varepsilon = \chi^2 \,\frac{(\partial\overline{U}/\partial Y)^3}{(\partial^2 U/\partial^2 Y)^2} \;, \tag{3.11}$$

where χ is an empirical dimensionless coefficient that must be determined from experiments. Equation 3.11 is more general than Prandtl's mixing length expression and has been especially useful in heat transfer calculations.

Prandtl's new hypothesis for free turbulence (Ref. 60) leads to the defect law

$$\varepsilon = \chi_1 b(\overline{U}_{max} - \overline{U}_{min}) , \qquad (3.12)$$

where b is the width of the mixing zone and χ_1 is again a dimensionless coefficient that must be determined experimentally. The defect law is actually a special application of Prandtl's mixing length theory. It is a simpler relationship but is also more limited. It is primarily used in free turbulence (jets and wakes) and has the advantage of not vanishing at the center where $d\overline{U}/dY$ is zero as the expression in the original Prandtl theory (Eq. 3.9) does. The relationship, however, is not locally evaluated but is rather considered to be constant across the area perpendicular to the flow.

It is apparent that there is no one locally dependent model for turbulent shear stress that is capable of satisfactorily predicting the entire range of turbulent flow. Serious doubts have recently been raised as to the validity of the initial assumptions that turbulent transport obeys the gradient-type relationship. The scope of this subject is far too wide and too complex to try to bring it to any kind of final conclusion at the present time. It is by far the most formidable problem in fluid mechanics, and in spite of major recent advances in recent years, the task is still unresolved at the present time.

The availability of high-speed and large-memory computers has given a new hope in this difficult field of fluid mechanics. Most of the new methods are based on applying the conservation principles to the turbulence parameters themselves. However, this approach created difficulties in achieving closure to the system of equations derived. First-order and second-order closures are presently being attempted.[62-66] These attempts are still in a state of flux, and their results are still uncertain, but they seem to be very promising.

The above discussion emphasized two levels of averaging processes--on a molecular scale and on a turbulent fluctuations scale. In both cases, however, the resultant equations could still be time-dependent and for three-dimensional space.

Let us now assume for the time being that our first two approximations for molecular and turbulent time scale averaging are indeed successful and that Eq. 3.8 is proper under those assumptions. Now using Eq. 3.8 in a three-dimensional conservation equation will give

$$\frac{\partial \overline{P}}{\partial t} = \frac{\partial}{\partial X}\left\{\overline{u}_X(\overline{P}) + \left[-(\alpha_{PX} + \varepsilon_{PX})\frac{\partial \overline{P}}{\partial X}\right]\right\} + \frac{\partial}{\partial Y}\left\{\overline{u}_Y(\overline{P}) + \left[-(\alpha_{PY} + \varepsilon_{PY})\frac{\partial \overline{P}}{\partial Y}\right]\right\} + \frac{\partial}{\partial Z}\left\{\overline{u}_Z(\overline{P}) + \left[-(\alpha_{PZ} + \varepsilon_{PZ})\frac{\partial \overline{P}}{\partial Z}\right]\right\} = \overline{P}_V \,, \tag{3.13}$$

where a bar indicates a time average over a time scale greater than turbulent fluctuations but smaller than the time scale of interest. Let us assume now that for the practical problem at hand the interest is focused only on the time-dependent two-dimensional behavior. However, we cannot simply drop all the terms connected with the third dimension (let us say Z), because their possible effects on the two dimensions of interest must be taken into account. Using the same technique used before for approximating turbulent characteristics, let

$$\bar{U}_X = \bar{\bar{U}}_X + u_X'' ,$$

$$\bar{U}_Y = \bar{\bar{U}}_Y + u_Y'' , \qquad (3.14)$$

$$\bar{P} = \bar{\bar{P}} + p'' ,$$

where one bar indicates a time average over the turbulent time scale, and two bars indicate an average of the one-bar value over the third dimension (Z). Two primes indicate the deviation of the actual value along the third dimension (Z) from the two-bar value. Substituting Eq. 3.14 into Eq. 3.13 and performing the averaging operations as before gives

$$\frac{\partial \bar{\bar{P}}}{t} + \frac{\partial}{\partial X}\left[\bar{\bar{U}}_X(\bar{\bar{P}}) + \left(-(\alpha_{PX} + \varepsilon_{PX})\frac{\partial \bar{\bar{P}}}{\partial X}\right) + \overline{\overline{u_X''P''}}\right]$$

$$+ \frac{\partial}{\partial Y}\left[\bar{\bar{U}}_Y(\bar{\bar{P}}) + \left(-(\alpha_{PY} + \varepsilon_{PY})\frac{\partial \bar{\bar{P}}}{\partial Y}\right) + \overline{\overline{u_Y''P''}}\right] = \bar{\bar{P}}_V . \qquad (3.15)$$

To evaluate $\overline{\overline{u_X''p''}}$ and $\overline{\overline{u_Y P''}}$, one needs a detailed knowledge of the variations along the third dimension, which are not known. If one takes the same approach as before and assumes that the contribution of vertical variation in the horizontal directions can be expressed by a gradient-type relationship, Eq. 3.15 can be rearranged to

$$\frac{\partial \overline{P}}{\partial t} + \frac{\partial}{\partial X}\left[\overline{\overline{u}}_X(\overline{\overline{P}}) + \left[-(\alpha_{PX} + \varepsilon_{PX} + E_X)\,\frac{\partial \overline{\overline{P}}}{\partial X}\right]\right]$$

$$+ \frac{\partial}{\partial Y}\left[\overline{\overline{u}}_Y(\overline{\overline{P}}) + \left[-(\alpha_{PY} + \varepsilon_{PY} + E_Y)\,\frac{\partial \overline{\overline{P}}}{\partial Y}\right]\right] = \overline{\overline{P}}_V \ , \qquad (3.16)$$

and the flux in, let us say, the X direction can be expressed as

$$P_X'' = \overline{\overline{u}}_X(\overline{\overline{P}}) + \left[-(\alpha_{PX} + \varepsilon_{PX} + E_X)\,\frac{\partial \overline{\overline{P}}}{\partial X}\right] \ .$$

This additional contribution of nonconvective transport in the X direction is a result of shear effects created between the layers because of the velocity variations along the dimensions that have been averaged out. In the literature, this transport phenomenon is often called "dispersion" or "longitudinal dispersion." "Virtual diffusion" or "longitudinal diffusion" may be a better term for that purpose.

This method of compensating for unknown convective transport by the use of ever-increasing "diffusion" coefficients is carried further by reducing the conservation equation from two-dimensional to one-dimensional (add another coefficient E_X') and from transient to steady state in the case of periodic or tidal flow (add another coefficient E_X''). When the problem of diffusion is viewed in this light, it seems that all those "diffusion" coefficients are nothing but good indicators of the level of our inability to express the actual transport phenomena in nature properly (see Table 3.1).

It must be emphasized at this point that molecular diffusion is normally very small compared with turbulent diffusion (ratio of about

Table 3-1. Averaging Levels of Transport Phenomena

Level of Averaging	Dimensionality of Model	Diffusion Coefficient Used to Compensate	Accumulated Diffusion Coefficient
Average over all microscale details	(X, Y, Z, t)	α - molecular diffusivity	$D = \alpha$
Average over all details of turbulent fluctuations	$(\bar{X}, \bar{Y}, \bar{Z}, \bar{t})$	ε - turbulent diffusivity	$D = \alpha + \varepsilon$
Average over all details of one direction	$(\bar{X}, \bar{Y}, \bar{t})$	E - dispersion coefficient	$D = \alpha + \varepsilon + E$
Average over all details of two directions	$(\bar{X}, \bar{t})$	E' - longitudinal dispersion coefficient	$D = \alpha + \varepsilon + E + E'$
Time average over cycle period in periodic flow	$(\bar{X}, t)$	E'' - dispersion coefficient	$D = \alpha + \varepsilon + E + E' + E''$

Note: One bar indicates average over turbulent scale fluctuations; two bars indicate average over time scale larger than cycle period but smaller than the time scale of interest.

10^{-6} to 10^{-3}). The contribution of molecular diffusivity is insignificant in turbulent flows except at the boundaries, where turbulent eddies are reduced to zero. The relative magnitude of dispersion in relation to the turbulent diffusion depends on the level of approximation made and the characteristics of the flow. The longitudinal dispersion in natural streams was found to be one or several orders of magnitude greater than turbulent diffusion. It is an unfortunate situation, then, that the level of confidence in the various "diffusion" coefficients used is inversely proportional to their relative magnitudes and importance.

It seems to the author that with the high-speed and large-memory computers available today, the time is right to eliminate at least part of those approximations. It seems unnecessary to get rid of the molecular diffusivity and hopeless at the present time to try to get rid of the turbulent diffusivity (which is indeed unfortunate). However, it seems certainly possible to get rid of the various dispersion coefficients, by investing most effort developing a workable time-dependent three-dimensional model in which convective movements are properly expressed. Such models are within our present technical capabilities. Of course, such models will be very costly both to develop and to use. However, when compared with the total cost being presently spent for not having such models, the balance will be in favor of developing them.

3.2. Applicable Turbulent Transport Properties

In the model developed in the present study, only one dimension is being averaged out (the vertical). The time-dependent momentum equations include both normal and shear stresses in both horizontal directions. Therefore, in addition to the need for molecular and turbulent diffusion coefficients, there is a need for a virtual diffusion coefficient which will compensate for the transport caused in both the X and the Y direction because of the variations in velocity profiles in the vertical direction. Taylor[54] has developed an expression for this virtual diffusion coefficient for an instantaneous discharge in an axisymmetric flow in a long straight circular pipe and found that

$$E_X = 10.06au_\tau \ , \tag{3.17}$$

where a is the pipe radius, u_τ is the shear velocity at the wall, $\sqrt{\tau_W/\rho}$, and E_X is the virtual diffusion coefficient in the flow direction X caused by shear effects from the velocity variations in the radial direction. This virtual diffusion coefficient in the flow direction is also called the longitudinal dispersion coefficient.

Elder[55] has developed a similar expression for a two-dimensional open channel. Elder assumed that for this case the variations with depth are the main contributors to the horizontal longitudinal dispersion and has found, based on Taylor's approach, that

$$E_X = 5.86Hu_\tau \ , \tag{3.18}$$

where H is the channel depth and u_τ is the shear velocity at the bottom, $\sqrt{\tau_B/\rho}$. Other investigators have derived similar expressions based upon various assumptions (Refs. 82-84).

Field data collected and compared by a number of investigators have shown longitudinal dispersion coefficients many times those predicted by Elder. Fischer[56,57] has shown that lateral variations in velocity profile, which were neglected by Elder, were most important. He has followed Aris's[85] and Taylor's[54] methods and developed an expression for the longitudinal dispersion coefficient based on the velocity profile in a lateral direction. His correlations agreed better with measured values in actual streams and, therefore, gave a theoretical basis for the large discrepancies found in many cases between measured values and previously predicting models. However, Fischer has also shown that the longitudinal dispersion coefficient is extremely sensitive to the vertical velocity profile assumed and has suggested that successful prediction may have to be based upon detailed experimental knowledge of these profiles.

The compensation for the effects of lateral variations as proposed by Fischer[56,57] is not needed in the present two-dimensional model, since those variations are incorporated and expressed in the model itself. It seems, then, that the approach taken by Elder[55] will be quite sufficient for the model proposed here in the far-field regions.

Elder's[55] basic expression for the longitudinal dispersion coefficient in an open channel where the effects of lateral variations are neglected can be expressed after some variations as:

$$E_X = - Hu \int_0^1 [\overline{f} - f(\omega)] \left[\int_0^\omega \omega^{-1}(df/d\omega) \left(\int_0^\omega [\overline{f} - f(\omega)]\, d\omega\right) d\omega\right] d\omega, \quad (3.19)$$

where H is the channel depth, $\omega = Z/H$, u_τ is the shear velocity at the bottom, $\sqrt{\tau_B/\rho}$, and $f(\omega)$ is any function of ω that specifies the vertical velocity profile, so that

$$U = U_{max} - u_\tau f(\omega) \tag{3.20}$$

and

$$\overline{U} = U_{max} - u_\tau \overline{f} .$$

If the vertical velocity profile is taken as logarithmic over the whole depth, one gets:

$$f(\omega) = -(1/k_0) \log (1 - \omega) , \tag{3.21}$$

where k_0 is the Von Karman constant and is equal to 0.41. Using this velocity distribution in Eq. 3.19, as was done by Elder, the longitudinal diffusion coefficient becomes

$$E_X = 5.86 H u_\tau . \tag{3.22}$$

Following Taylor's assumption of isotropic turbulence, Elder also derived an expression for turbulent diffusivity, which is assumed to be the same in any direction, and found

$$\varepsilon = H u_\tau \int_0^1 \omega (df/d\omega)^{-1} d\omega . \tag{3.23}$$

With the velocity function $f(\omega)$ given in Eq. 3.21, one gets

$$\varepsilon_X = \varepsilon_Y \cong 0.07 H u_\tau . \tag{3.24}$$

However, his experiments showed a value about 3 times as large, and he concluded that

$$\varepsilon_X = \varepsilon_Y \cong 0.23Hu_\tau \ . \qquad (3.25)$$

This increase may be the result of the lateral contribution, which was not included in Elder's analysis. However, the logarithmic vertical velocity profile is not always a good representation of the correct vertical velocity distribution. Other functions $f(\omega)$ can be assumed, and the proper coefficients can be evaluated based on Eqs. 3.19 and 3.23. The phenomenon of dispersion as investigated by Taylor and Elder is based on a Lagrangian frame of reference which is moving with the mean velocity of the fluid.

Bowden[86,87] has derived similar expressions for the longitudinal diffusion coefficient in an Eulerian frame of reference in alternating flow and for various assumptions of vertical velocity profiles. The results given in Table 1 of Ref. 87 may be useful for some corresponding situations. Since the assumption of isotropic turbulence was made, the turbulent diffusion coefficient is independent of direction. In a two-dimensional model, the shear velocity u_τ in Eqs. 3.23 to 3.25 must be replaced by the total velocity, i.e.,

$$u_\tau = \sqrt{(u_{\tau X})^2 + (u_{\tau Y})^2} \ , \qquad (3.26)$$

where $u_{\tau X}$ is the shear velocity at the bottom in the X direction $\sqrt{\sigma_{BX}/\rho}$, and $u_{\tau Y}$ is the shear velocity at the bottom in the Y direction $\sqrt{\sigma_{BY}/\rho}$.

The assumption of isotropy cannot, however, be extended to the longitudinal dispersion coefficient E as well. Extension of Elder's approach for E_X and E_Y may require replacing u_τ in Eq. 3.22 by $u_{\tau X}$ and $u_{\tau Y}$, respectively, so that if the logarithmic velocity profile is assumed in both directions, one gets from Eq. 3.22 that

$$E_X = 5.86Hu_{\tau X} \ , \qquad (3.27)$$

$$E_Y = 5.86Hu_{\tau Y} \ . \qquad (3.28)$$

However, this type of extension from the one-dimensional to the two-dimensional case has not been verified.

In addition, most previous studies (Taylor, Elder, Bowden, Fischer, and others) have been performed and tested for instantaneous discharges only. The applicability of these derived correlations for continuous discharges was not verified and may be incorrect.

Effects of vertical stratification and density currents produced in estuaries complicate things even further. A proper formulation of the dispersion coefficient for such cases is presently not available, and, therefore, it is hoped that the model will not be used in its present form for regions where stratification is of major importance.

Because of the state of the art in this area, it was judged preferable at present to keep in the computer model a general expression composed of two parts. One part is based on a gradient-diffusion-type model, and the other can be any type of function. The overall effective diffusion coefficient appearing in the first part is not considered a a constant. It is always a function of the local flow characteristic. The computer program is constructed so that any such desirable function, if available, can be used.

In the near-field area, where the momentum of the jet creates most of the flow distribution around it, the turbulent eddy diffusivity is probably the most important part of the overall effective diffusion coefficient. One of the turbulent theories should be applied here. Prandtl's mixing length theory (Eq. 3.9) or Prandtl's hypothesis (Eq. 3.12) seems to be most effective for free turbulence of jets and plumes. However, a difficulty arises here as to the application of such correlations in a fixed rectangular XY coordinate system. This is indeed a difficult problem, which must be solved before the model can be used for transient two-dimensional near-field analysis. However, since, as discussed in the introduction and in Section 7, there are other obstacles (stratification and element sizing) to achieving this goal, it will be assumed at the present time that the model will be used primarily as a far-field model with some approximation of the near field which is considered to be part of it.

The discussion above on turbulent diffusion and longitudinal dispersion referred primarily to transport of dissolved substances. However, similar coefficients will exist also for momentum and energy transport.

In the rest of this chapter the nonconvective transport terms and their discrete element formulation for mass, momentum, and energy will be discussed.

3.3. Viscous and Hydrostatic Stresses

In Section 2.8 the discrete element formulation of the momentum equations has been derived (Eqs. 2.75 and 2.76). In Section 2.9 it was shown how to eliminate the half-point values in terms of the values in the center of each discrete element. In this section the internal viscous stresses as well as the effects of hydrostatic pressure will be formulated so that the stress components σ_{XX}, σ_{YY}, σ_{YX}, and σ_{XY} from Eqs. 2.75 and 2.76 can be eliminated in terms of the appropriate basic values.

As indicated in Section 3.1, the gradient formulation will be basically assumed here to be valid for both laminar and turbulent viscous stresses. The momentum diffusivities used, however, are not constant but may themselves be complicated functions of the flow characteristics, as has already been discussed in Sections 3.1 and 3.2. With this approach, one gets for an incompressible flow that

$$\sigma_{XX} = -P_r + 2\rho D_{mX} \frac{\partial U}{\partial X} , \tag{3.29}$$

$$\sigma_{YY} = -P_r + 2\rho D_{mY} \frac{\partial V}{\partial Y} , \tag{3.30}$$

$$\sigma_{XY} = \sigma_{YX} = \rho \left(D_{mX} \frac{\partial V}{\partial X} + D_{mY} \frac{\partial U}{\partial Y} \right) . \tag{3.31}$$

The pressure P_r in Eqs. 3.29 and 3.30 can represent any pressure in the system and is considered always positive for compression. In the case of natural water bodies the most significant pressures involved are atmospheric and hydrostatic pressures, which are the only ones considered in this study. The hydrostatic pressure can be derived from the momentum equation in the vertical direction, in which the vertical velocities and all derivatives in the vertical direction, except for pressure, are set equal to zero. In this case we get that

$$0 = -(\partial P_r/\partial Z) - \rho g \ . \tag{3.32}$$

Integrating Eq. 3.32 with respect to depth and assigning the boundary condition that atmospheric pressure $(P_r)_a$ exists at the water surface elevation $Z = H_s$ gives

$$P_r = (P_r)_a + g \int_Z^{H_s} \rho \ dZ = (P_r)_a + g\rho (H_s - Z) \ , \tag{3.33}$$

where H_s is the total depth of water, Z is the vertical distance of the local point from the bottom, and $(P_r)_a$ is the atmospheric pressure.

Performing this integration along Z and assuming uniform water density along the depth, one gets

$$\overline{P}_r(X, Y) = \frac{1}{H_s} \int_0^{H_s} P_r \ dZ = (P_r)_a + g\rho (H_s - H_c) \ , \tag{3.34}$$

where

$$H_c = (1/H_s) \int_0^{H_s} Z \ dZ = H_s/2 \tag{3.35}$$

is the centroid of the height at each (X, Y) point. Therefore,

$$\overline{P}_r(X, Y) = (P_r)_a + (1/2) g\rho \ H_s \ . \tag{3.36}$$

Substituting Eq. 3.36 into Eqs. 3.29 and 3.30 gives for the stress components:

$$\sigma_{XX} = 2\rho D_{mX} \frac{\partial U}{\partial X} - (P_r)_a - (1/2) g\rho\, H_s \; , \qquad (3.37)$$

$$\sigma_{YY} = 2\rho D_{mY} \frac{\partial V}{\partial Y} - (P_r)_a - (1/2) g\rho\, H_s \; , \qquad (3.38)$$

$$\sigma_{XY} = \sigma_{YX} = \rho \left(D_{mX} \frac{\partial V}{\partial X} + D_{mY} \frac{\partial U}{\partial Y} \right) . \qquad (3.39)$$

D_{mX} and D_{mY} are the overall effective kinematic eddy viscosities and are used for that part of the viscous stresses which can be expressed with the gradient-type formulation. In this case, D_{mX} and D_{mY} can be expressed as

$$D_{mX} = \alpha_m + \varepsilon_m + E_{mX} \; , \qquad (3.40)$$

$$D_{mY} = \alpha_m + \varepsilon_m + E_{mY} \; , \qquad (3.41)$$

where α_m is the molecular momentum diffusivity (or molecular kinematic viscosity), which is independent of direction, and ε_m is the turbulent momentum diffusivity (or turbulent kinematic viscosity) which, for isotropic turbulence, is also independent of direction. E_{mX} and E_{mY} are momentum longitudinal dispersion coefficients (or longitudinal eddy kinematic viscosity) in the X and the Y direction which take into account the effects on the stresses resulting from velocity variations along the depth.

The discrete element formulation of the stress components can now be developed based on Eqs. 3.37 to 3.39. Figures 2.2 to 2.4, pages 31 to 33, show the locations and directions of those stresses. All of the stresses are evaluated at the half-point boundary values between the discrete elements; for example,

$$\left(\frac{\partial P}{\partial X}\right)_{i+1/2,j} = \frac{P_{i+1,j} - P_{i,j}}{0.5(\Delta X_{i+1} + \Delta X_k)} \quad (3.42)$$

Evaluating Eqs. 3.37 to 3.39 at the proper locations (see Figs. 2.2 to 2.4) and using the discrete element form of the derivatives (see Eq. 3.42) gives

$$(\sigma_{XX})_{i+1/2,j} = 2\rho_{i+1/2,j}(D_{mX})_{i+1/2,j}\frac{U_{i+1,j} - U_{i,j}}{0.5(\Delta X_{i+1} + \Delta X_i)}$$

$$- \frac{1}{2} g\rho_{i+1/2,j}H_{i+1/2,j} - (P_r)_a , \quad (3.43)$$

$$(\sigma_{XX})_{i-1/2,j} = 2\rho_{i+1/2,j}(D_{mX})_{i+1/2,j}\frac{U_{i,j} - U_{i-1,j}}{0.5(\Delta X_i + \Delta X_{i-1})}$$

$$- \frac{1}{2} g\rho_{i-1/2,j}H_{i-1/2,j} - (P_r)_a , \quad (3.44)$$

$$(\sigma_{YY})_{i,j+1/2} = 2\rho_{i,j+1/2}(D_{mY})_{i,j+1/2}\frac{V_{i,j+1} - V_{i,j}}{0.5(\Delta X_{i+1} + \Delta X_k)}$$

$$- \frac{1}{2} g\rho_{i,j+1/2}H_{i,j+1/2} - (P_r)_a , \quad (3.45)$$

$$(\sigma_{YY})_{i,j-1/2} = 2\rho_{i,j-1/2}(D_{mY})_{i,j-1/2} \frac{V_{i,j} - V_{i,j-1}}{0.5(\Delta X_i + \Delta X_{i-1})}$$

$$- \frac{1}{2} g\rho_{i,j-1/2}H_{i,j-1/2} - (P_r)_a , \qquad (3.46)$$

$$(\sigma_{XY})_{i,j+1/2} = \rho_{i,j+1/2} \left[(D_{mY})_{i,j+1/2} \left(\frac{U_{i,j+1} - U_{i,j}}{0.5(\Delta Y_{j+1} + \Delta Y_j)}\right)\right.$$

$$\left. + (D_{mX})_{i,j+1/2} \left(\frac{V_{i+1/2,j+1/2} - V_{i-1/2,j+1/2}}{X_i}\right)\right] , \qquad (3.47)$$

$$(\sigma_{XY})_{i,j-1/2} = \rho_{i,j-1/2} \left[(D_{mY})_{i,j-1/2} \left(\frac{U_{i,j} - U_{i,j-1}}{0.5(\Delta Y_j + \Delta Y_{j-1})}\right)\right.$$

$$\left. + (D_{mX})_{i,j-1/2} \left(\frac{V_{i+1/2,j-1/2} - V_{i-1/2,j-1/2}}{\Delta X_i}\right)\right] \qquad (3.48)$$

$$(\sigma_{XY})_{i+1/2,j} = \rho_{i+1/2,j} \left[(D_{mY})_{i+1/2,j} \left(\frac{U_{i+1/2,j+1/2} - U_{i+1/2,j-1/2}}{\Delta Y_j}\right)\right.$$

$$\left. + (D_{mX})_{i+1/2,j} \left(\frac{V_{i+1,j} - V_{i,j}}{0.5(\Delta X_{i+1} + \Delta X_i)}\right)\right] \qquad (3.49)$$

$$(\sigma_{XY})_{i-1/2,j} = \rho_{i-1/2,j} \left[(D_{mY})_{i-1/2,j} \left(\frac{U_{i-1/2,j+1/2} - U_{i-1/2,j-1/2}}{\Delta Y_i}\right)\right.$$

$$\left. + (D_{mX})_{i-1/2,j} \frac{V_{i,j} - V_{i-1,j}}{0.5(\Delta X_i + \Delta Y_{i-1})}\right)\Bigg] . \qquad (3.50)$$

The half-point values of the velocities both at the centers of the faces between the adjacent discrete elements and at the corners of those faces are all evaluated on the basis of the relations developed in Section 2.9.

3.4. Energy Fluxes

In Section 2.7 the discrete element formulation of the energy equation was derived (Eq. 2.61). The convective energy fluxes were formulated by Eqs. 2.62 to 2.64. In this section the internal energy fluxes q_X and q_Y appearing in Eq. 2.61 will be formulated. As in the case of viscous stress, it will be assumed that part of these fluxes can be expressed with the gradient formulation and that other formulations can be added when they are available. With this assumption, one gets

$$q_X = -\rho C_p D_{HX}(\partial T/\partial X) \ , \tag{3.51}$$

$$q_Y = -\rho C_p D_{HY}(\partial T/\partial Y) \ , \tag{3.52}$$

where D_{HX} and D_{HY} are the total effective thermal diffusivities in the X and the Y direction, respectively. As in the case of momentum fluxes, the total effective thermal diffusivities can be separated into three parts as

$$D_{HX} = \alpha_H + \varepsilon_H + E_{HX} \ , \tag{3.53}$$

$$D_{HY} = \alpha_H + \varepsilon_H + E_{HY} \ , \tag{3.54}$$

where α_H is the molecular thermal diffusivity, which is considered independent of direction, and ε_H is the turbulent thermal diffusivity, which, for isotropic turbulence, is also considered independent of direction. E_{HX} and E_{HY} are the thermal longitudinal dispersion coefficients in the X and the Y direction, respectively.

The ratio between the momentum diffusivity (kinematic viscosity) and the thermal diffusivity is called the Prandtl number,

$$PR_\alpha = \alpha_m/\alpha_H \ . \tag{3.55}$$

Similarly, the turbulent Prandtl number is defined as

$$PR_\varepsilon = \varepsilon_m/\varepsilon_H \ . \tag{3.56}$$

On the same basis, one can also define the "longitudinal dispersion Prandtl number" as

$$PR_E = E_m/E_H \tag{3.57}$$

and an effective Prandtl number as

$$PR_D = D_m/D_H \ . \tag{3.58}$$

The molecular Prandtl number, PR_α, like the molecular momentum and thermal diffusivities, is characteristic of the material itself, whereas the rest of the Prandtl numbers, like the corresponding diffusivities, are mainly dominated by the flow characteristics. The Reynolds analogy states that the turbulent Prandtl number equals 1, and therefore $\varepsilon_H = \varepsilon_m$. This assumption has been used very extensively in heat transfer analysis, often with good results. Many studies show, however, that this assumption is not always correct and that the turbulent Prandtl number will vary for different flow conditions.

Vertical thermal stratification may be different from the vertical velocity variations, and each one of those vertical variations has its own effect on the corresponding dispersion coefficient. It is outside the scope of the present study to discuss this point properly. It will be assumed that the two-dimensional model proposed here will be used primarily in vertically mixed water bodies, and in this case the value of E_H will be conservatively neglected for environmental impact assessments. Any realistic analysis of a natural stream should, however, try to look for the proper way to take the effect of vertical variations into account, since they always exist to some extent.

The discrete element formulation of the energy fluxes (Eqs. 3.51 and 3.52) can now be developed. Using Figs. 2.2 to 2.4, pages 31 to 33, and the proper notation as used for the stress components gives:

$$(q_X)_{i+1/2,j} = -\rho_{i+1/2,j}(C_p)_{i+1/2,j}(D_{HX})_{i+1/2,j}\left(\frac{T_{i+1,j} - T_{i,j}}{0.5(\Delta X_{i+1} + \Delta X_k)}\right), \quad (3.59)$$

$$(q_X)_{i-1/2,j} = -\rho_{i-1/2,j}(C_p)_{i-1/2,j}(D_{HX})_{i-1/2,j}\left(\frac{T_{i,j} - T_{i-1,j}}{0.5(\Delta X_i + \Delta X_{i-1})}\right), \quad (3.60)$$

$$(q_Y)_{i,j+1/2} = -\rho_{i,j+1/2}(C_p)_{i,j+1/2}(D_{HX})_{i,j+1/2}\left(\frac{T_{i,j+1} - T_{i,j}}{0.5(\Delta Y_{j+1} + \Delta Y_j)}\right), \quad (3.61)$$

$$(q_Y)_{i,j-1/2} = -\rho_{i,j-1/2}(C_p)_{i,j-1/2}(D_{HX})_{i,j-1/2}\left(\frac{T_{i,j} - T_{i,j-1}}{0.5(\Delta Y_j + \Delta Y_{j-1})}\right). \quad (3.62)$$

Energy fluxes that cannot be expressed with the gradient formulation can be added to Eqs. 3.59 to 3.62 when they are needed and are available. The thermal fluxes from the bottom and top as well as the volumetric heat generation (or decay) will be discussed in Section 4.

3.5. Mass Diffusion Fluxes

In Section 2.6 the discrete element formulation of the conservation equation for the mass substance of k has been derived (Eq. 2.50). The internal convective fluxes were already formulated explicitly in this equation. In the present section the internal nonconvective mass fluxes of substance k appearing in Eq. 2.50 will be formulated. In Section 2.3 the velocity of substance k was expressed in terms of the mixture velocity $\vec{V}$ and the relative velocity $\vec{V}_k'$ of substance k with respect to the mixture velocity $\vec{V}$ (Eq. 2.6). The relative velocity (also called diffusive velocity) $\vec{V}_k'$ of substance k obeys the Fickian law for binary diffusion in most cases. This law expresses the diffusion of one substance into the rest of the fluid mixture. Neglecting the effects of pressure, temperature, and body forces, which are indeed negligible, Fick's law for binary diffusion can be expressed as:

$$\vec{V}_k' = -(D_M)_k \, \nabla(\vec{\ln}\, C_k) = -\frac{1}{C_k} (D_M)_k \, \vec{\nabla} C_k \; , \qquad (3.63)$$

or, for a two-dimensional case,

$$(V_k')_X = \frac{1}{C_k} (D_{Mk})_X \frac{\partial C_k}{\partial X} \; , \qquad (3.64)$$

$$(V'_k)_Y = \frac{1}{C_k} (D_{Mk})_Y \frac{\partial C_k}{\partial Y} . \quad (3.65)$$

$(D_{Mk})_X$ and $(D_{Mk})_Y$ are the total effective mass diffusivities of substance k into the rest of the mixture in the X and the Y direction, respectively. Since the mass flux of substance k was defined by Eq. 2.8 as $\vec{g}_k = \rho_k \vec{V}'_k$ and since $C_k = \rho_k/\rho$, Eqs. 3.64 and 3.65 can be written as:

$$g_{kX} = -\rho (D_{Mk})_X \frac{\partial C_k}{\partial X} , \quad (3.66)$$

$$g_{kY} = -\rho (D_{Mk})_Y \frac{\partial C_k}{\partial Y} . \quad (3.67)$$

As in the case of the momentum and energy fluxes, $(D_{Mk})_X$ and $(D_{Mk})_Y$ will be assumed to be composed of three parts, so that

$$(D_{Mk})_X = \alpha_{Mk} + \varepsilon_{Mk} + (E_{Mk})_X , \quad (3.68)$$

$$(D_{Mk})_Y = \alpha_{Mk} + \varepsilon_{Mk} + (E_{Mk})_Y , \quad (3.69)$$

where α_{Mk} is the molecular mass diffusivity of substance k, which is considered independent of direction, and ε_{Mk} is the turbulent mass diffusivity of substance k, which, for isotropic turbulence, is also considered independent of direction $(E_{Mk})_X$ and $(E_{Mk})_Y$ are the mass longitudinal dispersion coefficients of substance k in the X and the Y direction, respectively. The molecular binary diffusion coefficient α_{Mk} is a characteristic of the two materials involved. The turbulent counterparts ε_{Mk} and E_{Mk}, however, are mainly dominated by the flow characteristics. ε_{Mk} and E_{Mk} in Eqs. 3.68 and 3.69 can then be replaced by ε_M and E_M, respectively.

The ratio between the momentum diffusivity and the mass diffusivity is called the Schmidt number; i.e.,

$$(Sc_\alpha)_k = \alpha_m/\alpha_{Mk} \ . \qquad (3.70)$$

Similarly, the turbulent Schmidt number is defined as

$$Sc_\varepsilon = \varepsilon_m/\varepsilon_M \ . \qquad (3.71)$$

On the same basis, one can also define a "longitudinal dispersion Schmidt number" as

$$Sc_E = E_m/E_M \qquad (3.72)$$

and an effective Schmidt number as

$$(Sc_D)_k = D_m/D_{Mk} \ . \qquad (3.73)$$

The ratio between the turbulent Prandtl number and the turbulent Schmidt number is called the turbulent Lewis number; i.e.,

$$Le_\varepsilon = PR_\varepsilon/Sc_\varepsilon \ . \qquad (3.74)$$

The available experimental evidence shows that the turbulent Lewis number in the boundary layer has the value 1. This may be true also in free turbulence. However, in a large water body, thermal stratification has considerable effect on the thermal longitudinal dispersion coefficient E_H and probably also on the mass longitudinal dispersion coefficient. As in the case of the momentum and the thermal dispersion coefficient, it will be indicated here that it is outside the scope of the present study to settle those difficult issues of turbulent diffusion and dispersion for mass, momentum, and energy as well as the interaction between them. The discussion in Sections 3.1 and 3.2 has emphasized these problems and some possible partial solutions. It is hoped, again, that the model will be used primarily in vertically mixed shallow water bodies, in which case the dispersion coefficients can be conservatively neglected for environmental impact assessments.

The discrete element formulation of the mass fluxes (Eqs. 3.66 and 3.67) can now be developed. Using Figs. 2.2 to 2.4, pages 31 to 33, and the proper notation as used for the momentum and energy fluxes gives:

$$(g_{kX})_{i+1/2,j} = -\rho_{i+1/2,j}[(D_{Mk})_X]_{i+1/2,j}\left(\frac{(C_k)_{i+1,j} - (C_k)_{i,j}}{0.5(\Delta X_{i+1} + \Delta X_i)}\right), \quad (3.75)$$

$$(g_{kX})_{i-1/2,j} = -\rho_{i-1/2,j}[(D_{Mk})_X]_{i-1/2,j}\left(\frac{(C_k)_{i,j} - (C_k)_{i-1,j}}{0.5(\Delta X_i + \Delta X_{i-1})}\right), \quad (3.76)$$

$$(g_{kY})_{i,j+1/2} = -\rho_{i,j+1/2}[(D_{Mk})_Y]_{i,j+1/2}\left(\frac{(C_k)_{i,j+1} - (C_k)_{i,j}}{0.5(\Delta Y_{j+1} + \Delta Y_j)}\right), \quad (3.77)$$

$$(g_{kY})_{i,j-1/2} = -\rho_{i,j-1/2}[(D_{Mk})_Y]_{i,j-1/2}\left(\frac{(C_k)_{i,j} - (C_k)_{i,j-1}}{0.5(\Delta Y_j - \Delta Y_{j-1})}\right). \quad (3.78)$$

Additional mass fluxes that cannot be expressed by the gradient formulation can be added to Eqs. 3.75 to 3.78 when they are indeed needed and are available.

By now, all the internal fluxes of mass, momentum, and energy have been formulated for each discrete element. The interaction of the water body with its physical boundaries needs now to be discussed. This discussion will be divided into two parts. The first (Section 4) will discuss the interactions with the bottom and top surface as well as volumetric heat and mass generation or decay. The second part (Section 5) will discuss the interaction with the side boundary conditions as well as the initial conditions specified at a certain initial time. Since no formal differential equations have been derived, there is no need for "boundary conditions" in the classical sense. The purpose of the formulation of boundary conditions in Section 5 is to eliminate the half-point values on the boundaries from the basic numerical conservation equations in terms of either internal or otherwise specified values.

4. BOTTOM SURFACE, TOP SURFACE, AND VOLUMETRIC CONTRIBUTIONS

In this section the mass, momentum, and energy fluxes from the bottom and the surface of the water body will be discussed. This includes the quantities g_B, g_T, g_{kB}, g_{kT}, q_B, q_T, q_{kB}, q_{kT}, σ_{BX}, σ_{BY}, σ_{TX}, and σ_{TY} appearing in the discrete element formulation of the conservation equations (Section 2.6). In addition, the body forces, the mass and energy generation or decay per unit volume and unit time (i.e., f_c, $\dot{\rho}_k$, $\dot{q}_V$), and the thermophysical properties involved (ρ, C_p, e, h) will be discussed.

4.1. Shear Stresses at the Bottom

The shear stresses at the bottom appear as $(\sigma_{BX})_{i,j}$ and $(\sigma_{BY})_{i,j}$ in Eqs. 2.75 and 2.76, respectively. With the signs notation discussed in Section 2.5 and Figs. 2.2 to 2.4, pages 31 to 33, the bottom stresses were considered positive in the positive direction of the corresponding coordinates, and, therefore, the negative sign will be included in the stress expressions themselves, so that the direction of the bottom stresses is always opposite to that of the velocity.

The shear stresses over any solid surface are generally expresed in the form

$$\tau = \lambda \rho V^2 \ . \tag{4.1}$$

Similarly, the bottom shear stresses can be calculated in a modified form to suit a two-dimensional formulation (Ref. 88) and can be expressed as:

$$\sigma_{BX} = -\lambda_B \rho \sqrt{U^2 + V^2}\, U \,, \tag{4.2}$$

$$\sigma_{BY} = -\lambda_B \rho \sqrt{U^2 + V^2}\, V \,, \tag{4.3}$$

where σ_{BX} and σ_{BY} are the bottom friction stresses in the X and the Y direction, respectively, $(ML^{-1}T^{-2})$ and ρ is water density.

The dimensionless constant λ_B is mainly a function of Reynolds number and the roughness of the surface. It is basically similar to the commonly used nondimensional friction factor f for flow in closed conduits. Such a localized factor is very desirable for a two-dimensional model since the bottom shear stresses must be evaluated locally.

Bowden (Ref. 89) and others have evaluated, for the sea, a range of

$$2.4 \times 10^{-3} \leq \lambda_B \leq 2.8 \times 10^{-3} \,. \tag{4.4}$$

In rivers and estuaries the value of λ_B may be higher and its range wider, e.g.,

$$2.0 \times 10^{-3} \leq \lambda_B \leq 5 \times 10^{-3} \,. \tag{4.5}$$

A value for λ_B of about 3×10^{-3} to 4×10^{-3} seems to be reasonable for shallow water bodies. Most of the data available, however, are based on one-dimensional flow in open channels, in which cases it is common practice to use the Chezy formula in combination with the Manning coefficient. The Chezy formula can be expressed as:

$$U = C_Z \sqrt{R_h S_B} \ , \tag{4.6}$$

where U is the one-dimensional average velocity along the channel, R_h is the hydraulic radius, defined as the ratio between the cross-sectional area and its wetted perimeter, S_B is the slope of the channel bottom ($\tan\theta$), and C_Z is the Chezy resistance factor, which can be related to λ_B by

$$C_Z = \sqrt{g/\lambda_B} \ . \tag{4.7}$$

The dimensions of the Chezy resistance factor are $L^{1/2}T^{-1}$, and one should be careful in using the proper coefficient for the units in use. In practice the evaluation of the Chezy coefficient is based on empirical relationships which relate it to the effective roughness of the channel. The most widely accepted formula for determining the Chezy coefficient is the Manning formula,

$$C_Z = (1.486/n)R_h^{1/6} \ , \tag{4.8}$$

where n is the Manning roughness coefficient. Values of n are tabulated in various handbooks (Ref. 90). The dimensions of the Manning coefficient are $TL^{-1/3}$. Again one should keep in mind the units involved when using this coefficient. For a two-dimensional model where it is assumed that the water depth is small, one can approximate the hydraulic radius by the depth and get:

$$C_Z = (1.486/n)H^{1/6} \ . \tag{4.9}$$

Combining Eqs. 4.9 and 4.7, one gets:

$$\lambda_B = (gn^2)/(2.208H^{1/3}) \ , \tag{4.10}$$

which can be used in Eqs. 4.2 and 4.3. The discrete element formulation of Eqs. 4.2 and 4.3 will be

$$(\sigma_{BX})_{i,j} = -(\lambda_B)_{i,j}\ \rho_{i,j}\sqrt{U_{i,j}^{\ 2} + V_{i,j}^{\ 2}}\ U_{i,j} \ , \tag{4.11}$$

$$(\sigma_{BY})_{i,j} = -(\lambda_B)_{i,j}\ \rho_{i,j}\sqrt{U_{i,j}^{\ 2} + V_{i,j}^{\ 2}}\ V_{i,j} \ , \tag{4.12}$$

where λ_B can be evaluated by Eq. 4.10 as:

$$(\lambda_B)_{i,j} = \frac{g}{2.208}\ \frac{n_{i,j}^{\ 2}}{H_{i,j}^{\ 1/3}} \ . \tag{4.13}$$

4.2. Wind Shear Stresses

The wind shear stresses appear as $(\sigma_{TX})_{i,j}$ and $(\sigma_{TY})_{i,j}$ in Eqs. 2.75 and 2.76, respectively. The direction of the stress caused by the wind will be the same as the wind direction itself (see Figs. 2.2 to 2.4, pages 31 to 33).

The shear stresses exerted by the wind on the free surface of a water body can be expressed (Ref. 88) for a two-dimensional formulation in a form similar to the expression for the bottom friction as:

$$\sigma_{WX} = \lambda_W \rho \sqrt{W_X^{\ 2} + W_Y^{\ 2}}\ W_X \ , \tag{4.14}$$

$$\sigma_{WY} = \lambda_W \rho \sqrt{W_X^{\ 2} + W_Y^{\ 2}}\ W_Y \ , \tag{4.15}$$

where σ_{WX}, σ_{WY} are the wind shear stresses in the X and the Y direction, respectively, $(ML^{-1}T^{-2})$, ρ is the density of water, W_X, W_Y are the wind velocities in the X and the Y direction, and λ_W is a dimensionless constant, which must be empirically determined. Not all empirical studies result in correlations of the form expressed by Eqs. 4.14 and 4.15. In those correlations which do, λ_W is normally based on the density of air rather than water, and its evaluation is not consistent in the open literature. A summary of existing correlations is given by Hutchinson[91] and Dronkers.[88] Ekman[92] and Rosby[93] obtained (in c.g.s.)

$$\lambda_W\rho = (\lambda^2\rho_a) = 3.2 \times 10^{-6} \ . \qquad (4.16)$$

Von Dorn[94] has given those values as functions of anemometer height, and for the height range of 25 cm to 1000 cm, he gets the range for λ_W as:

$$1.2 \times 10^{-6} \leq \lambda_W\rho = \lambda^2\rho_a \leq 4.5 \times 10^{-6} \ . \qquad (4.17)$$

Since the density of water ρ in cgs units is about 1.0, one gets a reasonable range for λ_W as:

$$1.2 \times 10^{-6} < \lambda_W < 4.5 \times 10^{-6} \quad \text{(dimensionless)} \ . \qquad (4.18)$$

The discrete element formulation of Eqs. 4.14 and 4.15 will then be

$$(\sigma_{TX})_{i,j} = (\lambda_W)_{i,j}\rho_{i,j} \sqrt{(W_X)_{i,j}^2 + (W_Y)_{i,j}^2}\ (W_X)_{i,j} \ , \qquad (4.19)$$

$$(\sigma_{TY})_{i,j} = (\lambda_W)_{i,j}\rho_{i,j} \sqrt{(W_X)_{i,j}^2 + (W_Y)_{i,j}^2}\ (W_Y)_{i,j} \ , \qquad (4.20)$$

where W_X, W_Y, and λ_W are specified functions of time and must be given for each case as discussed before.

4.3. Rain, Evaporation, and Other Mass Fluxes at the Bottom and Top

The mass fluxes to the water body from either the bottom (seepage) or the top surface (rain, evaporation, etc.) are considered in the conservation equations as $(g_B)_{i,j}$, $(g_T)_{i,j}$, $(g_{kB})_{i,j}$, and $(g_{kT})_{i,j}$ $(ML^{-2}T^{-1})$.

The total mass fluxes g_B and g_T must either be measured or calculated. In most cases, information on such fluxes as seepage or rain can be found from published meteorological data. Evaporation can sometimes be calculated on the basis of equations discussed in Section 4.4.

The quantities g_{kB} and g_{kT} represent mass diffusion of substance k from the bottom and top, respectively. In a simplified form, such a mass diffusion can be expressed according to Fick's law for binary diffusion from one substance to the rest of the mixture as:

$$G_{kB} = -(D_M)_{kB} \left. \frac{\partial(\rho_B C_{kB})}{\partial n_B} \right|_B , \tag{4.21}$$

where D_{kB} is the mass diffusion coefficient (L^2T^{-1}) of substance k from the bottom (or top), n_B is the space direction perpendicular to the bottom (or top) surface, and C_{kB} is the mass concentration of substance k at bottom (or top).

However, practical evaluation of such diffusion from outside will depend on empirical correlation which will normally be based on a formulation of the Nusselt number type, such as

$$G_{kB} = -(h_M)_{kB}(C_k - C_{kB}) \;, \tag{4.22}$$

where C_k is the mass concentration of substance k inside the control volume, $(h_M)_{kB}$ is the mass film diffusion coefficient ($ML^{-2}T^{-1}$) of substance k from the bottom (or top) to the control volume, and h_M, like its equivalent for heat, is usually established empirically. The discrete element formulation of the mass flux from bottom will be

$$(g_B)_{i,j} = (\rho_B)_{i,j}|\vec{V}_B|_{i,j} \;, \tag{4.23}$$

and mass flux from the top

$$(g_T)_{i,j} = (\;_T)_{i,j}|\vec{V}_T|_{i,j} \tag{4.24}$$

where $|\vec{V}|$ indicates the magnitude of the vector $\vec{V}$. The mass fluxes of substance k by diffusion from the bottom and top using Eq. 4.22 are

$$(g_{kB})_{i,j} = -\,[(h_M)_{kB}]_{i,j}[(C_k)_{i,j} - (C_{kB})_{i,j}] \;, \tag{4.25}$$

$$(g_{kT})_{i,j} = -\,[(h_M)_{kT}]_{i,j}[(C_k)_{i,j} - (C_{kT})_{i,j}] \;, \tag{4.26}$$

where $(h_M)_{kB}$ and $(h_M)_{kT}$ are the mass film diffusion coefficients of substance k from the bottom and the top, respectively, to the discrete element (i,j).

4.4. Heat Exchange with the Atmosphere and Other Energy Fluxes at the Bottom and Top

4.4.1. General

Energy fluxes are considered in the conservation equation as $(q_B)_{i,j}$, $(q_T)_{i,j}$, $(q_{kB})_{i,j}$, and $(q_{kT})_{i,j}$ $(Btu \cdot L^{-2}T^{-1} {}^\circ F^{-1})$.

The quantities q_B and q_T are nonconvective energy fluxes from the bottom (considered to be negligible) and the top surface (primarily by heat exchange with the atmosphere). As in the case of mass diffusion, these quantities can be expressed according to the Fourier law as

$$q_B = -(D_H)_B \left. \frac{\partial(\rho_B e_B)}{\partial n_B} \right|_B , \qquad (4.27)$$

where n_B is the space direction perpendicular to the bottom (or top) surface, e_B is the energy per unit mass coming from the bottom (or top), ρ_B is the density of mass coming from the bottom (or top), and $(D_H)_B$ is the heat diffusion coefficient (L^2T^{-1}) from the bottom (or top).

Again, practical evaluation of such heat diffusion from outside the boundaries will depend on empirical correlation and will normally be based on the Nusselt number or the Newton law of cooling to give:

$$q_B = -(h_H)_B(T - T_B) , \qquad (4.28)$$

where T is the temperature inside the control volume, T_B is the temperature of the bottom (or top), and $(h_H)_B$ is the film heat transfer coefficient from the bottom (or top) to the control volume $(Btu \cdot L^{-2}T^{-1}F^{-1})$, which is usually established empirically.

The most important of this heat exchange takes place between the water surface and the atmosphere above it.

4.2.2. Heat Exchange with the Atmosphere

The heat exchange of a given water body with the atmosphere above it is a function of the particular meteorological conditions existing at a particular time and location. The proper way to consider this heat exchange is to sum up all the individual heat transfer rates due to the various heat exchange mechanisms. Such a summation, although a function of both surface water temperature and air temperature, cannot in general be linearized into a direct proportionality with respect to the "temperature drops" involved. Nevertheless, because of the simplicity achieved by such linearizations, two approaches have become extremely popular. One technique, recommended by Edinger et al.,[95-97] is based on the concept of surface heat exchange coefficient and the equilibrium temperature of the water body. Using these concepts the heat transfer across the water surface can be expressed as:

$$q_T = -K(T_{WS} - T_E) \ , \tag{4.29}$$

where q_T is the heat transfer rate, Btu/day, K is the heat exchange coefficient, Btu/day-ft^2-°F, T_{WS} is the water surface temperature, °F, and T_E is the equilibrium temperature, °F. The equilibrium temperature is the temperature to which a body of water would eventually come if it were exposed constantly to the same meteorological conditions which existed at the particular time and location. A body of water will continuously approach the equilibrium temperature but will always lag behind it because of continuous changes in the meteorological conditions. Both the equilibrium temperature and the heat exchange coefficient are functions of the meteorological conditions and normally should not be considered constant. However, it has been shown[98] that in many cases an approximate value for those parameters can be obtained by using the following relationships:

$$T_E = T_d + (Q_s/K) \ , \qquad (4.30)$$

$$K = 15.7 + (\beta + 0.26)(70 + 0.7\ W^2) \ , \qquad (4.31)$$

$$\beta = 0.255 - 0.0042(T_{WS} + T_d) + 5.1 \times 10^{-5}(T_{WS} + T_d)^2 \ , \qquad (4.32)$$

where T_d is the dew-point temperature, °F, T_{WS} is the surface water temperature, °F, Q_s is the gross heat rate of solar radiation, Btu/day-ft^2, K is the heat exchange coefficient, Btu/day-ft^2-°F, and W is the wind speed, miles/hr.

Another approach becoming extremely popular because of its simplicity is a technique based on what is called "excess temperature." This method also is based on the concepts of equilibrium temperature and heat exchange coefficient, but it eliminates the need for calculating the equilibrium temperature itself. This is achieved by using the applicable energy balance equation twice--once for the water temperature under no power plant thermal discharges and then for the water temperature under the specific thermal discharge analyzed, and subtracting the first equation from the second. If the terms are indeed linear, the equilibrium temperature drops out. The justification and advantage of this method is that in many cases the main interest of the analyst is to calculate the "excess temperature" created by the thermal discharge rather than the actual water temperature.

Both methods are useful and can be used under a specific set of conditions. However, neither will be correct as a general method. A more proper way should be based on individual computation of each heat exchange mechanism involved. Such an approach is used by Raphael[99] and was "computerized" by Tackston and Parker.[100] This approach is much more accurate than the previous two methods, has the advantage of being more closely related to the individual meteorological effects, and is adaptable to local and instantaneous time-dependent models. With the computing capabilities presently available, there is no justification for not applying such a method in a numerical model.

The equations used in the last approach and the parameters it requires are summarized here, but the reader should refer to Ref. 100 for further details. The net heat exchange between the water surface and its surrounding is

$$q_T = q_s + q_a + q_b + q_e + q_c , \tag{4.33}$$

where q_s is the absorbed solar radiation (positive), q_a is the absorbed long-wave atmospheric radiation (positive), q_b is the long-wave back radiation from the water body (negative), q_e is the heat lost by evaporation (negative), and q_c is the heat lost by conduction (negative)

Solar Radiation.

$$q_s = (1 - 0.0071\ c^2)q_0\ , \tag{4.34}$$

where

$q_0 = 2.044\alpha + 0.1296\alpha^2 - 0.0019\alpha^3 + 0.0000076\alpha^4$,

$\sin\alpha = \sin\phi\ \sin\delta + \cos\phi\ \cos\delta\ \cos h,$

$\delta = -23.28\ \cos\ [2\pi(d/365) + 0.164],$

c is the cloud cover in tenths of the sky, ϕ is the latitude of the site, h is the hour angle of the sun, and d is the day of the year.

Long-Wave Atmospheric Radiation.

$$q_a = 1.66 \times 10^{-9}\ \beta(T_a + 460)^4\ , \tag{4.35}$$

where

$\beta = A + Be_a,$

$e_a = \exp\ [17.62 - \frac{9501}{T_{WB} + 460}],$

$T_{WB} = (0.655 + 0.36\ R(T_a),$

T_a is the air temperature, °F, R is the relative humidity of the air, and A, B are constants that depend on cloud cover c (see Table 2 in Ref. 100).

Back Radiation.

$$q_b = -1.668 \times 10^{-9}(T_{WS} + 460)^4\ , \tag{4.36}$$

where T_{WS} is the surface water temperature, °F.

Evaporation Heat Loss.

$$q_e = -(e_{WS} - e_a)\ f(W)\ , \tag{4.37}$$

where

$$e_{WS} = \exp\ [17.62 - \frac{9501}{T_{WS} + 460}]$$

$$e_a = \exp\ [17.62 - \frac{9501}{T_a + 460}],$$

and f(W) is a function for wind speed effect. There are a number of empirical correlations for f(W) which can be expressed as:

$$f(W) = a + bW\ , \tag{4.38}$$

where W is wind speed in miles per hour. Table 4.1 summarizes three of those correlations.

Table 4.1. Coefficients for Various Wind Function Correlations to be Used in Equations 4.37 and 4.38

Correlation	Coefficient a	Coefficient b
Lake Hafner	0	11.4
Lake Colorado City	0	16.8
Meyer	73	7.3

Heat Gain by Conduction.

$$q_c = 0.00543\ WP(T_a - T_{WS})\ , \tag{4.39}$$

where

$$P = \frac{29.92}{\exp\left(\frac{32.15E}{1545(T_a + 460)}\right)},$$

E is the elevation of the site in feet, and W, T_a, and T_{WS} are as defined before.

In conclusion, the input data required to compute the various heat exchanges between surface water and the atmosphere are:

1. cloud cover, c
2. latitude of the site,
3. hour angle of the sun, h (this parameter is not needed if daily average calculations are desired)
4. elevation of the site, E
5. air temperature, T_a
6. surface water temperature, T_{WS}
7. relative humidity or wet bulb temperature
8. wind speed
9. cloud cover function, $\beta = A + Be$
10. wind speed function, $f(W) = a + bW$

The quantities q_{kB} and q_{kT} represent the energy convected to the water body with the mass diffusion of substance k through the bottom and top surfaces, respectively. The discrete element formulation of those energy fluxes will be

$$(q_{kB})_{i,j} = (g_{kB})_{i,j}(h_{kB})_{i,j}\ , \qquad (4.40)$$

$$(q_{kT})_{i,j} = (g_{kT})_{i,j}(h_{kT})_{i,j}\ , \qquad (4.41)$$

where h_{kB} and h_{kT} are the enthalpies of substance k coming from the bottom and top surface, respectively. The nonconvective heat fluxes from the bottom and top in a discrete element formulation will be

$$(q_B)_{i,j} = -[(h_H)_B]_{i,j}[T_{i,j} - (T_B)_{i,j}] , \tag{4.42}$$

$$(q_T)_{i,j} = -[(h_H)_T]_{i,j}[T_{i,j} - (T_T)_{i,j}] , \tag{4.43}$$

where $(h_H)_B$ and $(h_H)_T$ are the film heat transfer coefficients from the bottom and top, respectively, to the discrete element (i,j). (See discussion above on heat exchange with the atmosphere.)

4.5. Body Forces and Volumetric Heat and Mass Generation

The conservation equations developed in Section 2.6 for a discrete element include the effects of body forces (forces acting on the mass itself rather than on its surfaces) and heat and mass generation or decay per unit volume and time. In a two-dimensional model the gravitational body forces have no effect except implicitly through the hydrostatic pressure (see Section 3.3). Other body forces do act, to various degrees, in natural water bodies, but the most important is the Coriolis force resulting from the rotation of the earth. This force is important in large shallow water bodies and is the only body force considered in the present model.

The Coriolis force is a function of the angular velocity of the earth and the latitude of the site. For a two-dimensional model the Coriolis force per unit volume ($ML^{-2}T^{-2}$) can be expressed as[88,101]

$$(f_c)_X = \rho\Omega V \;, \tag{4.44}$$

$$(f_c)_Y = - \rho\Omega U \;, \tag{4.45}$$

where $\Omega = 2\omega \sin \phi$, ω is the angular velocity of the earth (0.73×10^{-4} radians/sec), and ϕ is the latitude of the site. It must be remembered that Eqs. 4.44 and 4.45 require that the coordinate system be rotating with the earth, that the XY plane be horizontal, and that the coordinate system be left-handed, with positve Z toward the center of the earth. The discrete element formulation of Eqs. 4.44 and 4.45 will be

$$(f_{cX})_{i,j} = \rho_{i,j}\Omega_{i,j} V_{i,j} \;, \tag{4.47}$$

$$(f_{cY})_{i,j} = - \rho_{i,j}\Omega_{i,j} U_{i,j} \;. \tag{4.48}$$

The generation or decay of mass and of heat per unit volume and time are optional and are used for expressing chemical and thermal reactions. They can also be used to simulate intake and discharge operations, including thermal discharges, as will be discussed in Section 7.

4.6. Thermophysical Properties

The conservation equations developed in Section 2.6 include thermophysical properties which can be functions of temperature as well as substance concentrations. Although the model is not necessarily restricted to water, this is the material of interest in the present study. The following thermophysical properties are needed: $\rho_k(T)$, the density of each substance k, as a function of temperature, and $C_{pk}(T)$, the specific heat of each substance k as a function of temperature. The total density and specific heat can then be calculated by

$$\rho = \sum_{k=1}^{K} C_k \rho_k \ , \tag{4.49}$$

$$C_p = \sum_{k=1}^{K} C_k C_{pk} \ , \tag{4.50}$$

where C_k is the concentration of substance k.

The formulation of the conservation equations also requires the time derivatives of density and specific heat, which in turn must be expressed in terms of other derivatives as follows:

$$\frac{\partial \rho}{\partial t} = \frac{\partial \rho}{\partial T}\frac{\partial T}{\partial t} + \sum_{k=1}^{K} (\partial \rho/\partial C_k)(\partial C_k/\partial t) \ , \tag{4.51}$$

$$\frac{\partial C_p}{\partial t} = \frac{\partial C_p}{\partial T}\frac{\partial T}{\partial t} + \sum_{k=1}^{K} (\partial C_p/\partial C_i)(\partial C_k/\partial t) \ . \tag{4.52}$$

The time derivatives of T and C_k are calculated in the corresponding conservation equations (see Section 2.6). The derivatives with respect to C_k, using Eqs. 4.49 and 4.50, are

$$(\partial \rho/\partial C_k) = \rho_k \ , \tag{4.53}$$

$$(\partial C_p/\partial C_k) = (C_p)_k \ . \tag{4.54}$$

The derivatives with respect to temperature must be derived from the corresponding functions $\rho_k = f(T)$ and $C_{pk} = f(T)$ and substituted in

$$\partial\rho/\partial T = \sum_{k=1}^{K} C_k(\partial\rho_k/\partial T) \ , \tag{4.55}$$

$$\partial C_p/\partial T = \sum_{k=1}^{K} C_k(\partial C_{pk}/\partial T) \ . \tag{4.56}$$

The density of saline water for the range of interest in this study can be expressed in practice as (Ref. 102)

$$\rho = 62.6651 + 46.013C - 0.00006238T^2 \ , \tag{4.58}$$

where ρ is the density lb/ft^3, C is the mass concentration of salt, and T is the temperature, °F.

Equation 4.58 has a standard error of 0.1022 for the range

$0.00 \leq C \leq 0.1034$

$60 \leq T \leq 260°F$.

In order to bring Eq. 4.58 to a form which can be used in Eq. 4.49, the equation was broken into two parts:

$$\rho_k(\text{salt}) = 46.013 \ , \tag{4.59}$$

$$\rho_k(\text{water}) = (62.6651 - 0.00006238T^2)/C_k \ , \tag{4.60}$$

so that if Eq. 4.49 is used in the case of water and salt only, one gets

$$\rho = \sum_{k=1}^{K} C_k \rho_k = C_1 \rho_1 + C_2 \rho_2 = 62.6651 + 46.013 C_{salt} - 0.00006238 T^2 ,$$

which is Eq. 4.58.

As discussed in Section 2, the contributions of kinetic energy $V^2/2$ and potential energy gZ to the specific internal energy are negligible. Therefore, for each constituent we have

$$e_k = (e_0)_k + \int_{T_0}^{T} (C_V)_k \, dT , \quad (4.61)$$

$$h_k = (h_0)_k + \int_{T_0}^{T} (C_p)_k \, dT , \quad (4.62)$$

where e_0 and h_0 are internal energy of formation and the enthalpy of formation for constituent k.

The internal energy and the enthalpy of the mixture must be calculated from

$$e = \sum_{k=1}^{K} C_k e_k , \quad (4.63)$$

$$h = \sum_{k=1}^{K} C_k h_k . \quad (4.64)$$

Expressions for e_k and h_k must be found in the literature for each constituent and combined by using Eqs. 4.63 and 4.64.

5. FORMULATION OF INITIAL AND BOUNDARY CONDITIONS

5.1. Initial Conditions

The mathematical formulation of a time-dependent model requires that all unknown values at certain time (t_0) should be specified as a function of position. Such information must be either available or assumed. If the actual "history" of the case is not necessarily of interest, any set of initial conditions can be specified, and the problem must then be investigated for a sufficient length of time to let the existing external conditions dominate. In a case of an estuary, one may be interested in quasi-steady-state conditions. In this case, any set of initial conditions can be used, although a solution will be achieved sooner if those conditions are as close to the expected solution as possible. A quasi-steady state is assumed to be achieved, in an estuary case, when the results are practically repeating themselves every tidal cycle.

The discrete element formulation of the initial conditions can in general be expressed as

$$P_{i,j}(t = t_0) = (P_0)_{i,j} , \qquad (5.1)$$

where P is any property and P_0 is the value of P at time t_0, which can be a function of position.

5.2. General Discussion of Analytical and Numerical (Half Points) Boundary Conditions

In a classical analytical formulation the boundary conditions can be expressed by specifying the values of the unknowns themselves (Dirichlet condition), the values of their derivatives (Neuman condition), or the appropriate fluxes involved. For the numerical approach used in this study, no partial differential equations have been derived, but rather the conservation principles have been directly applied on each discrete element. The method, therefore, does not call for boundary conditions in the classical sense, which are applied in the process of integrating the partial differential equations to retrieve back the original integrated ones. Nevertheless, the discrete element formulation of the conservation equations developed in Sections 2.5 to 2.8 does call for half-point values, which are normally evaluated on an average basis, as discussed in Section 2.9 for internal discrete elements. On the boundaries, however, the elements do not have neighboring elements from all sides, but rather some of their faces coincide with the physical boundaries. The purpose of the "boundary conditions" from the discrete element point of view is to allow the elimination of those half-point values on the boundaries either in terms of specified values or in terms of values of internal discrete elements. This section will discuss the way this can be done for each type of physical boundary case on hand. For the purpose of discussion, the classical analytical formulation of the boundary conditions will be used, although the actual application of those conditions will be only for deriving half-point value expressions. The discussion here will be related to a discrete element with a single side boundary, and the formulation for other situations can be similarly derived. A corner element will be discussed later separately. Figure 5.1 shows such a discrete element with a physical boundary on its right-hand side. The center of the element is located at (ib, j). The boundary plane itself coincides with the half grid line, ib + 1/2. An imaginary node is created outside of the boundary with an imaginary grid line ib + 1 and with $\Delta X_{ib+1} = \Delta X_{ib}$. The letter P will indicate any one of the unknowns, that is, H, V, U, T, or C_k. This imaginary element is considered to have properties which are based on linear extrapolation from the properties of its internal element counterpart, i.e.,

$$P_{ib+1,j} = P_{ib,j} + \frac{P_{ib+1/2,j} - P_{ib,j}}{0.5\ \Delta X_{ib}}\ \Delta X_{ib}\ ; \qquad (5.2)$$

therefore,

$$P_{ib+1,j} = 2P_{ib+1/2,j} - P_{ib,j}\ . \qquad (5.3)$$

The half-point values in the center of each face of a discrete element ($P_{ib+1/2,j}$ in Fig. 5.1), when this point falls on a boundary, will be developed in Sections 5.4 to 5.7. For the boundary points in a corner of a discrete element ($P_{ib+1/2,j+1/2}$ or $P_{ib+1/2,j-1/2}$ in Fig. 5.1) a linear averaging procedure is used based on its two neighboring face-centered boundary points. In the sample shown in Fig. 5.1, this averaging procedure can be expressed as:

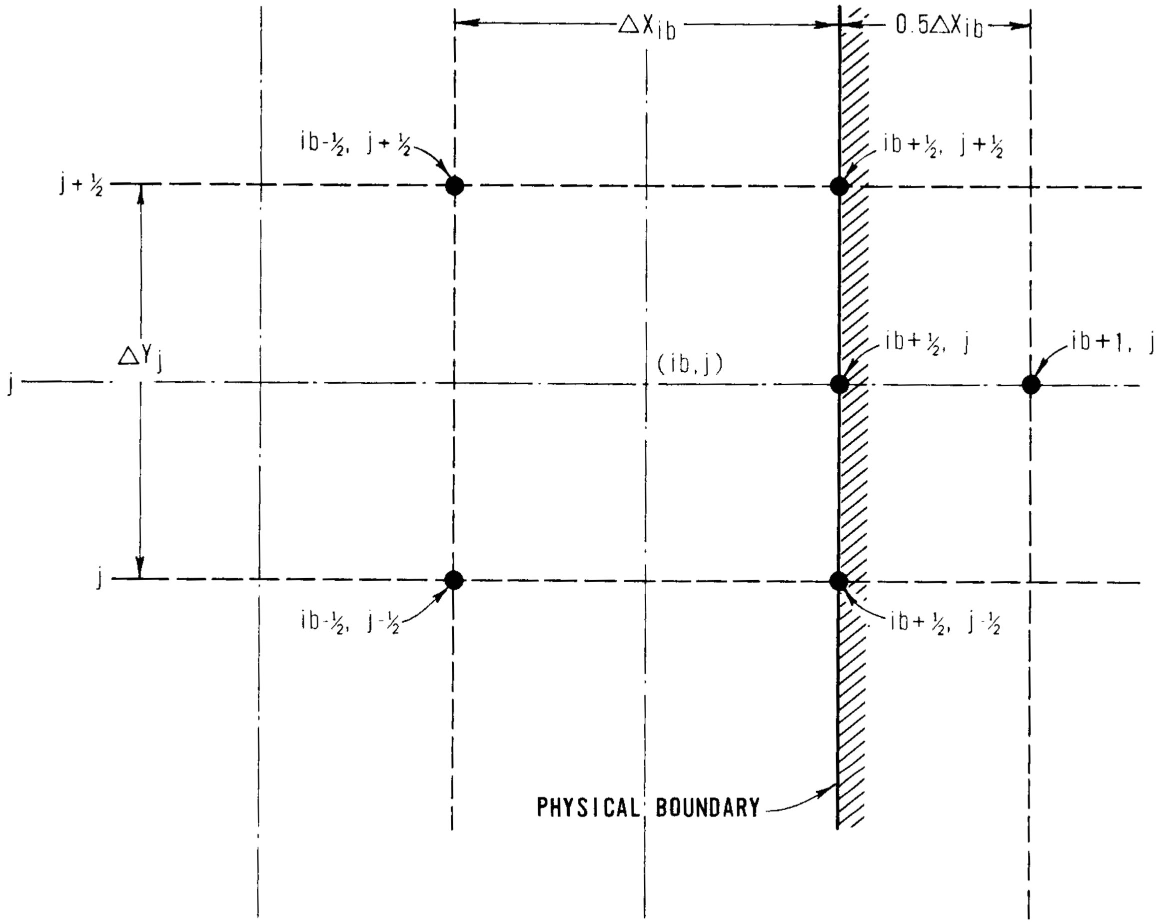


Figure 5.1. A discrete element with a physical boundary on its right hand side.

$$P_{ib+1/2,j+1/2} = \frac{\Delta Y_j}{\Delta Y_j + \Delta Y_{j+1}} P_{ib+1/2,j+1} + \frac{\Delta Y_{j+1}}{\Delta Y_j + \Delta Y_{j+1}} P_{ib+1/2,j} , \quad (5.4)$$

$$P_{ib+1/2,j-1/2} = \frac{\Delta Y_j}{\Delta Y_{j-1} + \Delta Y_j} P_{ib+1/2,j-1} + \frac{\Delta Y_{j-1}}{\Delta Y_{j-1} + \Delta Y_j} P_{ib+1/2,j} . \quad (5.5)$$

The applicable boundary conditions, which will be considered in Sections 5.4 to 5.7, can be grouped into four types, which are discussed below.

5.3. Types of Boundary Conditions

Boundary condition type No. 1 represents the case where the value of the unknown itself is specified, i.e.,

$$P_{boundary} = P_b(t) . \quad (5.6)$$

This boundary condition is a Dirichlet condition type which specifies the value of the unknown itself. The value can be a function of time or constant, including zero. It is a most restricting specification, and in order to be used, one must be sure that it does indeed reflect the reality intended to be modeled. For discrete element formulation of half-point values on the boundaries, this type of boundary condition is simply defined by

$$P_{ib+1/2,j} = P_b(t) \ , \tag{5.7}$$

where $P_b(t)$ is a specified function of time for the property on the boundary surface.

Boundary condition type No. 2 represents the case where the first derivative of the unknown with respect to the direction perpendicular to the boundary surface is known, i.e.,

$$\left.\frac{\partial P}{\partial n}\right|_{\text{boundary}} = P_{bf}(t) \ . \tag{5.8}$$

This boundary condition is a Neuman condition type, and it specifies that the flux across the boundary is known. This is a definite specification of the boundary condition, although it is less restrictive than defining the value of the unknown itself. The specified flux can be a function of time or a constant (including zero). In order to use this type of condition, one must definitely know that it does reflect the reality intended to be modeled.

For discrete element formulation of half-point values on the boundaries, this type of boundary condition is defined as

$$\frac{P_{ib+1,j} - P_{ib,j}}{\Delta X_{ib}} = P_{bf}(t) \ . \tag{5.9}$$

Using Eq. 5.3 for $P_{ib+1,j}$ and rearranging, one gets

$$P_{ib+1/2,j} = P_{ib,j} + \frac{(\Delta X)_{ib}}{2} P_{bf} \ . \tag{5.10}$$

The flux P_{bf} of the property at the boundary may, of course, also be zero.

Boundary condition No. 3, which is equivalent to Newton's law of cooling, represents a case where the conditions outside the modeled boundaries rather than on the boundaries are known. The flux between a boundary and its external surroundings is normally empirically correlated as

$$P_{bf} = -h_b(P_b - P_{bo}) \; , \tag{5.11}$$

where P_{bf} is the flux of the property across the boundary surface to the surroundings, P_b is the value of the property at the boundary surface, P_{bo} is the value of the property outside of the boundary, and h_b is the film transfer coefficient, which defines the reciprocal of the resistance to the flux of the property. On the basis of Eq. 5.11, if the flux P_{bf} and the outside value, P_{bo}, of the property are known, the value at the boundary surface, P_b, can be evaluated. Here again, when using this type of boundary condition, one must be sure that the value of the property outside the boundaries is indeed independently known and that the flux itself is indeed a forcing reality which must be satisfied by the mathematical model.

Expressing this condition for discrete element half-point values and rearranging gives

$$P_{ib+1/2,j} = P_{ib,j} + (1/h_b)P_{bf} \; , \tag{5.12}$$

where P_{bf} is the flux through the boundary surface into the element and $1/h_b$ is the "resistance" to this flux.

Boundary condition type No. 4 represents the case where the second derivative of the unknown in the direction perpendicular to the boundary surface equals zero, i.e.,

$$\frac{\partial}{\partial n}\left(\frac{\partial P}{\partial n}\right)\bigg|_{boundary} = 0 \; , \tag{5.13}$$

or

$$\frac{\partial P}{\partial n}\bigg|_{boundary} = \text{constant (unknown)} \; . \tag{5.14}$$

This type of boundary can be interpreted as specifying only that the flux across the boundary is not a function of the directions perpendicular to the boundary surface. It is a most unrestrictive condition and practically leaves the condition unspecified in a second-order differential equation. From an analytical formulation point of view, there is no justification for this type of condition. The closest type of analytical boundary condition that may have such unrestrictive characteristics is the condition of specified ambient value at infinity. However, such a condition is not available for finite difference formulation, since an infinite space dimension is not realistically possible. Nevertheless, the half-point value on the boundary must always be specified, if not in terms of known values, at least in terms of values of adjacent internal elements. This is the only purpose of boundary condition type No. 4. Equation 5.14 can be expressed for discrete element formulation as:

$$\frac{P_{ib+1/2,j} - P_{ib-1/2,j}}{\Delta X_{ib}} = \frac{P_{ib+1,j} - P_{ib,j}}{\Delta X_{ib}} \; . \tag{5.15}$$

Using Eq. 5.3 for $P_{ib+1,j}$ and the half-point relationship for $P_{ib-1/2,j}$ given by Eq. 2.81, one gets, after reordering terms and some algebraic manipulation, that the property on the boundary itself, $P_{ib+1/2}$, can be expressed in terms of known internal values as:

$$P_{ib+1/2,j} = P_{ib,j} + \left(\frac{\Delta X_{ib}}{\Delta X_{ib} + \Delta X_{ib-1}} \right) (P_{ib,j} - P_{ib-1,j}) \ . \qquad (5.16)$$

A summary of the four types of boundary conditions and their physical meaning as discussed above is given in Table 5.1. The classical analytical formulation is used only for clarity, but, as said before, the conditions are directly used for formulating half-point values of the discrete elements.

In the next sections, various situations in reality that are of interest in the present study will be discussed. The types of boundary conditions to be used in each case for each unknown will also be discussed.

5.4. Solid Wall, No-Slip, and Free-Slip Conditions

Any fluid that has a finite viscosity will have at the point of contact with a solid boundary the same velocity as the boundary itself. This means that both the relative normal and tangential velocities of the fluid with respect to the solid boundaries must vanish at the points of contact. Those are known as the "no slip" conditions, which are in principle always correct and can be expressed as

Table 5.1. Types of Boundary Conditions

Boundary Condition Type	Mathematical Evaluation at the Boundary Surface	Physical Meaning
1	$P = P_b(t)$	Property itself on the boundary surface is a known function of time which can also be constant or zero.
2	$\partial P/\partial n = P_{bf}(t)$	Flux of property through boundary surface is a known function of time, which may also be constant or zero.
3	$P = P_{bo} + (P_{bf}/h_b)$	Flux of property on boundary surface and value of property itself outside of boundaries are known.
4	$(\partial/\partial n)/(\partial P/\partial n) = 0$	Flux of property through open boundary is undisturbed. A very unrestrictive boundary condition.

$$v_n = 0 \text{ (boundary condition type No. 1)} , \qquad (5.17)$$

$v_t = 0$ (boundary condition type No. 1), at the boundary.

However, there are many situations under which the "free slip" conditions are assumed to exist. In this case the relative normal velocity vanishes at the solid surface (assuming no permeability), but the tangential velocity is unaffected by it. This condition can be expressed as follows. At the boundary,

$$v_n = 0 \text{ (boundary condition type No. 1)} , \qquad (5.18)$$

$(\partial v_t)/\partial n = 0$ (boundary condition type No. 2).

Some examples of situations under which the "free slip" conditions can be assumed are

1. ideal "nonviscous" fluid,
2. boundary represents an ideally smooth surface,
3. boundary represents a symmetry line,
4. zone of interest far from the physical boundaries,
5. in numerical solutions where the grid intervals are very large compared with the thickness of the boundary layer.

A third possibility is that the tangential velocity will be left undefined by using boundary condition type No. 4. In this way the velocity is left to take its value under the constraints of the conservation equations themselves.

The boundary conditions to be imposed on water elevation, temperature, and substance mass concentrations will depend again on the best boundary condition type which can be chosen to reflect an existing reality. For the case involving natural water bodies, it will be most common to use boundary condition type No. 2 (flux assumed to be zero) for temperature and mass concentration and boundary condition type No. 4 for water elevation (since it is desired to allow the water elevation at the boundary to find its position on the basis of the continuity equation).

5.5. Open Channel, Flow In

In the case of flow coming into the controlled volume through the open channel, commonly all the unknowns are specified as boundary condition type No. 1 (values specified based on the inlet conditions) except water elevation, which is specified as boundary condition type No. 4. Other situations are, of course, possible, and the appropriate boundary conditions should then be used (see Table 5.2).

5.6. Open Channel, Flow Out

In the case of flow leaving the control volume through an open channel, all the fluxes are assumed to stay constant along the flow by using boundary condition type No. 4. The values at the boundaries are then functions of their corresponding internal values. The water level, however, is specified by using boundary condition type No. 1. The flow out can also be specified, but then the water level should be left unspecified by using boundary condition type No. 4. Other situations are possible, and the appropriate boundary conditions should be used on a case-by-case basis.

Table 5.2. Some Examples of Possible Boundary Conditions and Boundary Condition Types to be Used for Each Unknown (See Table 5.1)

Unknown Property	Water Surface Elevation, H	Normal Velocity, V_n	Tangential Velocity, V_t	Transported Properties, T, C_k
Solid wall, "no slip" condition	4	1, $V_n = 0$	1, $V_t = 0$	2, $\partial P/\partial n = 0$
Solid wall, "free slip" conditions	4	1, $V_n = 0$	2 4 $\frac{\partial V_t}{\partial n} = 0$;	2, $\partial P/\partial n = 0$
Open channel, flow in (controlled by flow volume)	4	1, $V_n = (V_n)_b(t)$	1, $V_t = (V_t)_b(t)$	1, $P = P_b(t)$
Open channel, flow in (controlled by water level differential)	4	3, $V_n = h(H_b - H)$	1, $V_t = (V_t)_b = 0$	1, $P = P_b(t)$
Open channel, flow out	1 or 4	4 or 1	4	4
Flow out over a dam	1, $H = H_b$	4	4	4
Oceanic opening of an estuary (tidal)	1, $H = H_b(t)$	4	4	Flood 4; Ebb 1, $P = P_b(t)$
Open channel, flow in (controlled by water level)	1,	4	4	1, $P = P_b(t)$

Note: Type 1: $P = P_b(t)$.

Type 2: $\partial P/\partial n = P_{bf}(t)$.

Type 3: $P = P_{bo} + (P_{bf}/h_b)$.

Type 4: $\partial P/\partial n = \text{const}$ (or $\partial^2 P/\partial n^2 = 0$).

5.7. Ocean Opening in an Estuary

An estuary opening to the ocean is a special case and a very complicated one. The dynamics in the estuary are mostly controlled by the tidal movements in the ocean. In principle the zone being simulated should include a large portion of the ocean itself, so that the conditions at the model boundaries will be those of the unaffected ocean. Such an attempt will, however, create major practical difficulties because of the complicated conditions existing at the ocean itself. It seems that a reasonable solution would be to limit the extent of an estuary model to some location close to the ocean where conditions are routinely monitored. Such a location is not always available, and the issue must be settled on a case-by-case basis.

In many cases there are published data on the water elevation at the estuary mouth as a function of time which can be used for specifying water elevation at the boundary as boundary condition type No. 1. The velocities, in this case, should be specified as boundary condition type No. 4, so that their values will be established from internal values which are calculated from the conservation equations. The transported values (temperature and substance mass concentrations) must also be specified as boundary condition type No. 4 when the flow is leaving the estuary. However, when the flow is reversed and is penetrating back from the ocean into the estuary, the conditions are not well defined. A large zone of the ocean itself was affected by dilution and mixing with the discharge from the estuary at the previous ebb period; and, therefore, one cannot specify the inlet conditions during the tide period as being the same as for the unaffected ocean itself. This problem cannot be solved correctly without analyzing at least part of the ocean close to the estuary discharge point. A reasonable estimate may be to use specified conditions (boundary condition type No. 1) for temperature and mass concentration when flow is coming in (ebb period) and to express their values as functions of either time or velocities. One possibility of such a function, but speculative in nature, may be to assume an exponential decay of the property with time immediately after the stage of low slack water. The simplest possibility, although not accurate, is to assume that the property transported into the estuary during the flood period is constant and identical to the value in the ocean far from the boundary point. Other possibilities exist, and much is left here to the analyst's judgment of the specific case on hand.

5.8. Summary of Boundary Conditions

Table 5.2 gives a summary of various examples of interest in this study. The boundary condition type suggested for each unknown in each case is indicated. It must be remembered that this is not a complete list of possible cases, nor are the boundary condition types recommended the only ones that can be used for these cases. The boundary conditions are the best chance for the analyst to integrate "reality" into his mathematical model, and much professional judgment is required for taking full advantage of this opportunity.

6. THE NUMERICAL SOLUTION OF EQUATIONS AND STABILITY ANALYSIS

The discrete element forms of the conservation equations have been developed in Sections 2.5 to 2.8. The compatibility of this formulation with the classical differential equations will be discussed in this section, as well as the numerical solution of those equations and their stability.

6.1. The Reduction of the Discrete Element Forms of the Conservation Equations to Their Classical Differential Form

As discussed in Section 2.2, the discrete element forms of the conservation equations were derived directly from the corresponding conservation principles without taking the limiting procedure for deriving the classical form of partial differential equations. This raises the question of whether these equations will reduce to the classical differential equations if the limits $\Delta X_{i,j} \to 0$, $\Delta Y_{i,j} \to 0$ are indeed applied. This can be easily shown to be the case.

6.1.1. The Total Mass Conservation Equation

The discrete element form of this equation is given by Eq. 2.38. Substituting backward Eq. 2.37 into Eq. 2.38, taking the limits $\Delta X_{i,j} \to 0$, $\Delta Y_{i,j} \to 0$, dropping the i, j notation of the properties to represent local values, and rearranging gives

$$\frac{\partial}{\partial t} (\rho H) + \frac{\partial}{\partial X} (Hg_X) + \frac{\partial}{\partial Y} Hg_Y) = g_B + g_T + \dot{\rho}_G H \; ; \tag{6.1}$$

replacing g_X and g_Y by ρU and ρV, respectively,

$$\frac{\partial}{\partial t} (\rho H) + \frac{\partial}{\partial X} (\rho HU) + \frac{\partial}{\partial Y} (\rho HV) = g_B + g_Y + \dot{\rho}_G H \; , \tag{6.2}$$

which is the classical partial differential equation for the conservative form of the total mass conservation in two space dimensions and variable water depth. The right-hand side of Eq. 6.2 will, of course, be zero if no external contributions are considered.

6.1.2. The Mass Conservation Equation for Constituent k

The discrete element form of the mass conservation equation for a constituent k is given by Eq. 2.50. Substituting backward Eq. 2.49 into Eq. 2.50, taking the limits $\Delta X_{i,j} \to 0$, $\Delta Y_{i,j} \to 0$, dropping the i, j notation of the properties to represent local values, and rearranging gives

$$\frac{\partial}{\partial t} (\rho HC_k) + \frac{\partial}{\partial X} H(g_X C_k + g_{kX}) + \frac{\partial}{\partial Y} H(g_Y C_k + g_{kY})$$

$$= g_B C_{kB} + g_{kB} + g_T C_{kT} + g_{kT} + \dot{\rho}_k HC_k \; . \tag{6.3}$$

Substituting ρU and ρV for g_X and g_Y and also ρ_k for ρC_k gives

$$\frac{\partial}{\partial t} (\rho_k H) + \frac{\partial}{\partial X} H(\rho_k U + g_{kX}) + \frac{\partial}{\partial Y} H(\rho_k V + g_{kY})$$

$$= g_B C_{kB} + g_{kB} + g_T C_{kT} + g_{kT} + \dot{\rho}_k HC_k \; , \tag{6.4}$$

which is the classical partial differential equation for the conservative form of the mass conservation of constituent k in two space dimensions and variable water depth. Equation 6.4 can be rearranged to a more familiar form by moving the fluxes g_{kX} and g_{kY} to the right side. If those fluxes are considered to obey Fick's law, Eq. 6.4 can be rearranged to

$$\frac{\partial}{\partial t}(\rho HC_k) + \frac{\partial}{\partial X}(\rho HUC_k) + \frac{\partial}{\partial Y}(\rho HVC_k)$$

$$= \frac{\partial}{\partial X}(\rho D_{Mk} \frac{\partial C_k}{\partial X}) + \frac{\partial}{\partial Y}(\rho D_{Mk} \frac{\partial C_k}{\partial Y})$$

$$+ g_B C_{kB} + g_{kB} + g_T C_{kT} + g_{kT} + \dot{\rho}_k HC_k , \qquad (6.5)$$

which may be a more familiar version.

6.1.3. Energy Conservation Equation

The discrete element form of the energy conservation equation is given by Eq. 2.61. Substituting backward Eq. 2.60 into Eq. 2.61, taking the limits $\Delta X_{i,j} \rightarrow 0$, $\Delta Y_{i,j} \rightarrow 0$, dropping the i, j notation of the properties to represent local values and rearranging gives:

$$\frac{\partial}{\partial t}(\rho He) + \frac{\partial}{\partial X}\left(H\left(g_X h + q_X + \sum_{k=1}^{K} q_{kX}\right)\right) + \frac{\partial}{\partial Y}\left(H\left(g_Y h + q_Y + \sum_{k=1}^{K} q_{kY}\right)\right)$$

$$= g_B h_B + q_B + \sum_{k=1}^{K} q_{kB} + g_T h_T + q_T + \sum_{k=1}^{NK} q_{kT}$$

$$+ \left(\dot{q}_V + \sum_{k=1}^{K} (\dot{q}_V)_k\right)H . \qquad (6.6)$$

Substituting $g_X = \rho U$, $g_Y = \rho V$ gives:

$$\frac{\partial}{\partial t}(\rho He) + \frac{\partial}{\partial X}\left[H\left(\rho Uh + q_X + \sum_{k=1}^{K} q_{kX}\right)\right] + \frac{\partial}{\partial Y}\left[H\left(\rho Vh + q_Y + \sum_{k=1}^{K} q_{kY}\right)\right]$$

$$= g_B h_B + q_B + \sum_{k=1}^{K} q_{kB} + g_T h_T + q_T + \sum_{k=1}^{K} q_{kT}$$

$$+ \left[\dot{q}_V + \sum_{k=1}^{K} (\dot{q}_V)_k\right] H \;, \tag{6.7}$$

which is the classical partial differential equation for the conservative form of the energy conservation in two space dimensions, variable water depth, and multisubstance mixture. Equation 6.7 can be reduced to a more familiar form if applied to a single constituent and by moving the fluxes q_X and q_Y to the right-hand side of the equation. If those fluxes are also considered to be by diffusion only, Eq. 6.7 can be rearranged by using the effective thermal conductivity k_H to give

$$\frac{\partial}{\partial t}(\rho HC_pT) + \frac{\partial}{\partial X}(H\rho C_pUT) + \frac{\partial}{\partial Y}(H\rho C_pVT) = \frac{\partial}{\partial X}(k_H \frac{\partial T}{\partial X}) + \frac{\partial}{\partial Y} (k_H \frac{\partial T}{\partial Y})$$

$$+ g_B h_B + q_B + g_T h_T + q_T + \dot{q}_V H \;, \tag{6.8}$$

which may be a more familiar form.

6.1.4. The Momentum Conservation Equations

The discrete element form of the momentum equations in the X and Y directions are given by Eqs. 2.75 and 2.76, respectively. Substituting backward Eq. 2.74 into Eq. 2.75, taking the limits $\Delta X_{i,j} \rightarrow 0$, $\Delta Y_{i,j} \rightarrow 0$, dropping the i, j notation of the properties to represent local values, replacing g_X and g_Y by ρU and ρV, respectively, and rearranging gives:

$$\frac{\partial}{\partial t}(\rho HU) + \frac{\partial}{\partial X}(\rho HUU) + \frac{\partial}{\partial Y}(\rho HVU) = \frac{\partial}{\partial X}(H\sigma_{XX}) + \frac{\partial}{\partial Y}(H\sigma_{YX})$$

$$+ g_B U_B + \sigma_{BX} + g_T U_T + \sigma_{TX} + f_{bX} H \ , \qquad (6.9)$$

which is the classical partial differential equation for the conservative form of the momentum equation in the X direction in two space dimensions and variable water depth. A similar reduction can be accomplished for the momentum equation in the Y direction.

The discrete element formulation is then competent with the classical partial differential form but is not equivalent to it. The Taylor expansion series normally used to get the finite difference equations from the corresponding partial differential equations are not needed for deriving the discrete element form of the conservation principles.

6.2. The Numerical Solution of the Governing Equations

The system of equations presented by Eqs. 2.38, 2.50, 2.61, 2.75, and 2.76 for the conservation of mass, momentum, and energy constitute a set of nonlinear first-order simultaneous ordinary differential equations with respect to time of the form

$$\frac{dP^{(\ell)}}{dt} = F^{(\ell)}[t,\ P^{1}(t),\ P^{2}(t),\ \ldots\ P^{(N)}(t)] \qquad (6.10)$$

with the initial conditions

$$P^{(\ell)}(t_0) = P_0^{(\ell)} , \qquad (6.11)$$

where $\ell = 1, 2, \ldots, N$.

In order for this initial value problem to have a solution which is both unique and continuous and also satisfies the initial conditions, the functions $F^{(\ell)}$ must have no singular points and may have only a finite number of finite discontinuities in the neighborhood of the initial point F_0, t_0. The system of equations on hand will satisfy these conditions if the forcing functions involved (bottom, top, and volumetric conditions) satisfy these conditions.

The conservation equations that were developed in Section 2.6 using the discrete element approach do not involve a solution of nonlinear second-order simultaneous partial differential equations with respect to space and time but rather a set of ordinary differential equations with respect to time which can be solved by numerical integration methods. Because of the complexity of the problem, the number of unknowns and equations involved, the complex and nonlinear boundary conditions which must be handled, an explicit method of a marching computational technique starting from a known set of initial conditions seems to be preferable. Such a scheme will, of course, have stability limitations on the size of time step used. Implicit schemes, which are known to be in most cases unconditionally stable, may have some advantage over explicit schemes from the stability point of view. However, for such a complex system as the one discussed here, the computational time which will be required to achieve convergence of the matrix solution within each time step may be very large, and, therefore, it is definitely not certain that the choice of a larger time step will result in a net gain of computing time. In addition, the stability of implicit methods is not actually guaranteed for nonlinear simultaneous partial differential equations with nonlinear boundary conditions, since there exists no rigorous mathematical proof for such systems.

The discrete element system of Eqs. 2.38, 2.50, 2.61, 2.75, and 2.76 with the proper fluxes and volumetric generation have been integrated by a forward marching technique. Both the simple Euler method for one-time step integration and the more accurate modified fourth-order Runge-Kutta method with Gill coefficients have been used. The Runge-Kutta method is considerably more accurate than the Euler method but requires about four times as much computing time for each complete time step. One can also expect that the Runge-Kutta method will have better stability characteristics compared with the Euler method. The optimal trade-off between size of time step and computing time required for each will depend on the case at hand. It may be desirable in many cases to use the Eulerian method for one part of the problem and then when closer to steady state or quasi steady state, to switch to the Runge-Kutta method. This capability was included in the computer program described in Section 7.

6.3. The Donor Cell Differencing Method

The donor cell differencing method has been used in this study because of its improved stability effects on the convective terms of the conservation equations.[78] The method is known under various names (upwind differencing, skew differencing, upstream differencing, and others). In the Los Alamos FLIC method[69] it is called the donor cell method and by Roache[78] the second upwind differencing method. It was also used by Kurzrock[103] for two-dimensional viscous compressible flow and by many others with good success. The method is based on the physical consideration that the property transported into a cell through its edge should be always that of the cell "upstream" of it which supplies the transported property, that is, of the "donor cell."

Therefore, the half-point values used in Section 2.9 and expressed by Eqs. 2.79 and 2.86 will be altered for the density and the transport properties as follows (see Fig. 2.2, page 31):

$$P_{i+1/2,j} = P_{i,j} \quad \text{for } U_{i+1/2,j} > 0$$

$$= P_{i+1,j} \quad \text{for } U_{i+1/2,j} < 0 \qquad (6.12)$$

$$P_{i-1/2,j} = P_{i,j} \quad \text{for } U_{i-1/2,j} < 0$$

$$= P_{i-1,j} \quad \text{for } U_{i-1/2,j} > 0 \qquad (6.13)$$

$$P_{i,j+1/2} = P_{i,j} \quad \text{for } V_{i,j+1/2} > 0$$

$$= P_{i,j+1} \quad \text{for } V_{i,j+1/2} < 0 \qquad (6.14)$$

$$P_{i,j-1/2} = P_{i,j} \quad \text{for } V_{i,j-1/2} < 0$$

$$= P_{i,j-1} \quad \text{for } V_{i,j-1/2} > 0 \qquad (6.15)$$

where P denotes either density or any one of the transport properties. For the case of zero velocity, no alteration of the usual equations (Eqs. 2.79 to 2.86) is needed. It must be remembered that the donor cell values are used only for the density and the transport properties U, V, T, C_k, and only in the convective terms of the conservation equations. This means that in the case of velocities appearing in the convective terms of the momentum equations, the velocities used for g_X and g_Y will not be donor cell values, since here the velocities are not the transported properties but the transporting ones. The second velocity appearing in those convective terms is a transported property and will therefore be of the donor cell type.

6.4. Stability Analysis of the Numerical Solution

The numerical solution employed for solving the governing equations was discussed in Section 6.2. Any numerical solution will differ from its exact counterpart because of both transaction errors (approximate presentation of the exact equations) and round-off errors (computational round-off errors). The difference between the computed value and its exact counterpart can be defined as

$$\delta_{i,j} = \tilde{P}_{i,j} - \overline{P}_{i,j} , \qquad (6.16)$$

where $\tilde{P}_{i,j}$ is the actual computed value of any unknown (H, U, V, T, C_k) at a discrete element i, j and $\overline{P}_{i,j}$ is its exact counterpart.

In order to prevent computational instability, the error $\delta_{i,j}$ must die out or at least not grow unbounded. Therefore, one must require that for any two successive steps

$$\left|\frac{\delta_{i,j}(t + \Delta t)}{\delta_{i,j}(t)}\right| \leq 1 \ . \tag{6.17}$$

Each one of the discrete element conservation equations developed in Sections 2.5 to 2.8 can be expressed in general in the form

$$\begin{aligned} \frac{\partial \overline{P}_{i,j}}{\partial t} = \overline{F}_{i,j} = \ & \psi_{i-1/2,j} P_{i-1/2,j} + \psi_{i+1/2,j} P_{i+1/2,j} \\ & + \psi_{i,j-1/2} P_{i,j-1/2} + \psi_{i,j+1/2} P_{i,j+1/2} \\ & + \psi_{i,j} P_{i,j} + \psi_G \ , \end{aligned} \tag{6.18}$$

where $\overline{P}$ indicates the value of any one of the unknowns (H, U, V, T, C_k) and the subscript indicates the location at which P is evaluated. ψ indicates the corresponding coefficient of $\overline{P}$ in the proper location, and ψ_G is the term in Eq. 6.18 that is independent of $\overline{P}$.

The stability analysis in this section will be developed for an explicit single time step integration method like the classical Euler-Cauchy explicit method. The stability criteria developed for this method of solution should be sufficient for the stable solution of the more accurate multistep integration method by Runge-Kutta with Gill coefficients. It will also be assumed, for the purpose of the present stability analysis, that the various equations are linear and noncoupled. This is not an entirely correct assumption for the set of equations developed in the present study. However, stability analysis for a set of several coupled nonlinear equations does not exist and does not seem to be possible at the present time. The stability conditions developed here will be based on the discrete perturbation stability analysis,[104,105] which, although not as rigorous as the Von Neuman[106] and Hirt[107] analyses, was successful in predicting the same criteria.[78]

In the discrete perturbation stability analysis, it is assumed that up to a certain time t the computed value $\tilde{P}_{i,j}$ is exact everywhere and no error $\delta_{i,j}$ exists. Then a certain arbitrary error $\delta_{i,j}$ is induced at only one arbitrary discrete element (i, j), so that

$$\tilde{P}_{i,j}(t) = \overline{P}_{i,j}(t) + \delta_{i,j}(t) \qquad (6.19)$$

but

$$\tilde{P}_{i\pm,j\pm}(t) = \overline{P}_{i\pm,j\pm} ,$$

where the subscript i±, j± indicates any location other than i, j itself. From Eq. 6.18 one gets

$$\frac{\partial \overline{P}_{i,j}}{\partial t} = \overline{F}_{i,j} , \qquad (6.20)$$

$$\frac{\partial \tilde{P}_{i,j}}{\partial t} = \tilde{F}_{i,j} . \qquad (6.21)$$

Substituting Eq. 6.19 into Eq. 6.21,

$$\frac{\partial \overline{P}_{i,j}}{\partial t} + \frac{\partial \delta_{i,j}}{\partial t} = \overline{F}_{i,j} + (\delta F)_{i,j} \ , \qquad (6.22)$$

or

$$\frac{\partial \delta_{i,j}}{\partial t} = (\delta F)_{i,j} \ . \qquad (6.23)$$

The stability condition expressed in Eq. 6.17 gives then

$$\left| \frac{\delta_{i,j}(t + \Delta t)}{\delta_{i,j}(t)} \right| = \left| \frac{\delta_{i,j}(t) + \frac{\partial \delta_{i,j}}{\partial t} \quad t}{\delta_{i,j}(t)} \right| = \left| 1 + \frac{(\delta F)_{i,j}}{\delta_{i,j}} \Delta t \right| \leq 1 \ , \qquad (6.24)$$

or

$$\Delta t \leq \left| \frac{\delta_{i,j}}{(\delta F)_{i,j}} \right| \ . \qquad (6.25)$$

From Eq. 6.18 one gets

$$\begin{aligned} \delta F_{i,j} = \tilde{F}_{i,j} - F_{i,j} = {} & \psi_{i-1/2,j}(\tilde{P}_{i-1/2,j} - \overline{P}_{i-1/2,j}) \\ & + \psi_{i+1/2,j}(\tilde{P}_{i+1/2,j} - \overline{P}_{i+1/2,j}) \\ & + \psi_{i,j-1/2}(\tilde{P}_{i,j-1/2} - \overline{P}_{i,j-1/2}) \\ & + \psi_{i,j+1/2}(\tilde{P}_{i,j+1/2} - \overline{P}_{i,j+1/2}) \\ \psi + {} & {}_{i,j}(\tilde{P}_{i,j} - \overline{P}_{i,j}) \ . \end{aligned} \qquad (6.26)$$

However, based on the discrete perturbation error analysis, the difference between computed and exact values is zero everywhere except at i, j, where it equals $\delta_{i,j}$. Therefore, Eq. 6.26 reduces to

$$(\delta F)_{i,j} = \psi_{i,j}\delta_{i,j} ,$$

or

$$\frac{\delta_{i,j}}{(\delta F)_{i,j}} = \frac{1}{\psi_{i,j}} . \qquad (6.27)$$

Substituting Eq. 6.27 into the stability condition in Eq. 6.25 gives the desired stability condition

$$\Delta t \leq \left|\frac{1}{\psi_{i,j}}\right| , \qquad (6.28)$$

where $\psi_{i,j}$ is the coefficient of $\overline{P}_{i,j}$ in the right-hand side of Eq. 6.18.

The separate stability criteria for each one of the discrete element conservation equations will be based on Eq. 6.28, where the proper $\psi_{i,j}$ is the sum of all the coefficients of the terms in which $P_{i,j}$ is involved.

6.4.1. Stability Criteria for Calculating Temperature

The basic discrete element equation to be solved is given by Eq. 2.61, in which Eqs. 3.59 to 3.62 must be substituted for the non-convective heat fluxes q_X and q_Y and Eqs. 4.42 and 4.43 for the bottom and top heat fluxes q_B and q_T, respectively. Performing this substitution and then collecting all the coefficients of $T_{i,j}$, one gets

$$(\psi_{i,j})_{temp} = -\left\{\frac{1}{\rho_{i,j}H_{i,j}} \quad \frac{H_{i-1/2,j}\rho_{i-1/2,j}U_{i-1/2,j}}{\Delta X_i} - \frac{H_{i+1/2,j}\rho_{i+1/2,j}U_{i+1/2,j}}{\Delta X_i}\right.$$

$$+ \frac{H_{i,j-1/2}\rho_{i,j-1/2}V_{i,j-1/2}}{\Delta Y_j} - \frac{H_{i,j+1/2}\rho_{i,j+1/2}V_{i,j+1/2}}{\Delta Y_j}$$

$$- \frac{H_{i-1/2,j}}{\Delta X_i} \left(- \frac{\rho_{i-1/2,j} (D_{HX})_{i-1/2,j}}{0.5(\Delta X_i + \Delta X_{i-1})} \right)$$

$$+ \frac{H_{i+1/2,j}}{\Delta X_i} \left(+ \frac{\rho_{i+1/2,j} (D_{HX})_{i+1/2,j}}{0.5(\Delta X_i + \Delta X_{i+1})} \right)$$

$$- \frac{H_{i,j-1/2}}{\Delta Y_j} \left(- \frac{\rho_{i,j-1/2} (D_{HY})_{i,j-1/2}}{0.5(\Delta Y_j + \Delta Y_{j-1})} \right)$$

$$+ \frac{H_{i,j+1/2}}{\Delta Y_j} \left(+ \frac{\rho_{i,j+1/2} (D_{HY})_{i,j+1/2}}{0.5(\Delta Y_j + \Delta Y_{j+1})} \right)$$

$$+ (g_B)_{i,j} + \frac{(h_{HB})_{i,j}}{(C_p)_{i,j}} + (g_T)_{i,j} + \frac{(q_T)_{i,j}}{(C_p)_{i,j} T_{i,j}}$$

$$+ H_{i,j} \delta G \Bigg) , \qquad (6.29)$$

where q_T is the total heat flux to the atmosphere and can be calculated from Eqs. 4.33 to 4.39. As an alternative, one can replace

$$\frac{(q_T)_{i,j}}{T_{i,j}} \text{ by } K ,$$

where K is the heat exchange coefficient based on the equilibrium temperature concept (Eq. 4.31). Substituting Eq. 6.29 into Eq. 6.28 and rearranging terms gives the stability condition for calculating temperature as:

$$
\begin{aligned}
(\Delta t_{CR})_{T_{ij}} \le 1 \Bigg/ \Bigg\{ & \left(\frac{\rho_{i-1/2,j}}{\rho_{i,j}}\right)\left(\frac{H_{i-1/2,j}}{H_{i,j}}\right)\left(\frac{U_{i-1/2,j}}{\Delta X_i} + \frac{2(D_{HX})_{i-1/2,j}}{\Delta X_i(\Delta X_i + \Delta X_{i-1})}\right) \\
& + \left(\frac{\rho_{i+1/2,j}}{\rho_{i,j}}\right)\left(\frac{H_{i+1/2,j}}{H_{i,j}}\right)\left(-\frac{U_{i+1/2,j}}{\Delta X_i} + \frac{2(D_{HX})_{i+1/2,j}}{\Delta X_i(\Delta X_i + \Delta X_{i+1})}\right) \\
& + \left(\frac{\rho_{i,j-1/2}}{\rho_{i,j}}\right)\left(\frac{H_{i,j-1/2}}{H_{i,j}}\right)\left(\frac{V_{i,j-1/2}}{\Delta Y_j} + \frac{2(D_{HY})_{i,j-1/2}}{\Delta Y_j(\Delta Y_j + \Delta Y_{j-1})}\right) \\
& + \left(\frac{\rho_{i,j+1/2}}{\rho_{i,j}}\right)\left(\frac{H_{i,j+1/2}}{H_{i,j}}\right)\left(-\frac{V_{i,j+1/2}}{\Delta Y_j} + \frac{2(D_{HY})_{i,j+1/2}}{\Delta Y_j(\Delta Y_j + \Delta Y_{j+1})}\right) \\
& + \frac{1}{\rho_{i,j}H_{i,j}}\left[(g_B)_{i,j} + \frac{(h_{HB})_{i,j}}{(C_p)_{i,j}} + (g_T)_{i,j} + \frac{(q_T)_{i,j}}{(C_p)_{i,j}T_{i,j}}\right]\Bigg\} .
\end{aligned}
\tag{6.30}
$$

The donor cell method discussed in Section 6.3 changes the stability criteria of Eq. 6.30. Based on this method, the half values $P_{i\pm1/2,j\pm1/2}$ in the convective terms are replaced by center values of the "donor cells" (see Section 6.3). When the values $P_{i\pm1/2,j\pm1/2}$ are replaced by $P_{i,j}$, the corresponding terms in Eq. 6.30 drop out. When the values $P_{i\pm1/2,j\pm1/2}$ are replaced by $P_{i\pm1,j\pm1}$, there is no effect on the stability criteria. Therefore, for the donor cell method, the convective parts of the criteria will be effected as follows:

$U_{i-1/2,j} > 0$, $P_{i-1/2,j} = P_{i-1,j} \rightarrow$ no effect ($U_{i-1/2,j} > 0$);

$U_{i-1/2,j} < 0$, $P_{i-1/2,j} = P_{i,j} \rightarrow$ corresponding term drops;

$U_{i+1/2,j} < 0$, $P_{i+1/2,j} = P_{i,j} \rightarrow$ corresponding term drops;

$U_{i+1/2,j} < 0$, $P_{i+1/2,j} = P_{i+1,j} \rightarrow$ no effect $(U_{i+1/2,j} < 0)$;

$V_{i,j-1/2} > 0$, $P_{i,j-1/2} = P_{i,j-1} \rightarrow$ no effect $(V_{i,j-1/2} > 0)$;

$V_{i,j-1/2} < 0$, $P_{i,j-1/2} = P_{i,j} \rightarrow$ corresponding term drops;

$V_{i,j+1/2} > 0$, $P_{i,j+1/2} = P_{i,j} \rightarrow$ corresponding term drops;

$V_{i,j+1/2} < 0$, $P_{i,j+1/2} = P_{i,j+1} \rightarrow$ no effec- $(V_{i,j+1/2} < 0)$.

To be on the conservative side, one can leave all the convective terms and always use the absolute value of the velocities to get:

$$(\Delta t_{CR})_{T_{i,j}} \leq 1/\left[\left(\frac{\rho_{i-1/2,j}}{\rho_{i,j}}\right)\left(\frac{H_{i-1/2,j}}{H_{i,j}}\right)\left(\frac{|U_{i-1/2,j}}{\Delta X_i} + \frac{2(D_{HX})_{i-1/2,j}}{\Delta X_i(\Delta X_i + \Delta X_{i-1})}\right)\right.$$

$$+ \left(\frac{\rho_{i+1/2,j}}{\rho_{i,j}}\right)\left(\frac{H_{i+1/2,j}}{H_{i,j}}\right)\left(\frac{|U_{i+1/2,j}|}{\Delta X_i} + \frac{2(D_{HX})_{i+1/2,j}}{\Delta X_i(\Delta X_i + \Delta X_{i+1})}\right)$$

$$+ \left(\frac{\rho_{i,j-1/2}}{\rho_{i,j}}\right)\left(\frac{H_{i,j-1/2}}{H_{i,j}}\right)\left(\frac{|V_{i,j-1/2}|}{\Delta Y_j} + \frac{2(D_{HY})_{i,j-1/2}}{\Delta Y_j(\Delta Y_j + \Delta Y_{j-1})}\right)$$

$$+ \left(\frac{\rho_{i,j+1/2}}{i,j}\right)\left(\frac{H_{i,j+1/2}}{H_{i,j}}\right)\left(\frac{|V_{i,j+1/2}|}{Y_j} + \frac{2(D_{HY})_{i,j+1/2}}{Y_j(Y_j + Y_{j+1})}\right)$$

$$\left.+ \frac{1}{\rho_{i,j}H_{i,j}}\left((g_B)_{i,j} + \frac{(h_{HB})_{i,j}}{(C_p)_{i,j}} + (q_T)_{i,j} + \frac{(q_T)_{i,j}}{(C_p)_{i,j}T_{i,j}}\right)\right] \quad (6.31)$$

Equation 6.31 establishes, then, a time step limit to avoid numerical instability at discrete element i, j when calculating temperature. However, the actual time step to be used in the model will depend on the time step criteria for the rest of the unknowns, which will be developed next.

6.4.2. Stability Criteria for Calculating Constituent Concentration C_k

The basic discrete element equation to be solved is given by Eq. 2.50, in which Eqs. 3.75 to 3.78 must be substituted for the nonconvective mass fluxes g_X and g_Y and Eqs. 4.25 and 4.26 for the bottom and top mass fluxes g_{kB} and g_{kT}, respectively. Performing this substitution as in the case of temperature gives an expression for stability criteria similar to Eq. 6.31 except that some heat quantities are replaced by the corresponding mass quantities. The result is:

$$[\Delta t_{CR}]_{(C_k)_{i,j}} \leq 1 \Bigg/ \left\{ \left(\frac{\rho_{i-1/2,j}}{\rho_{i,j}}\right)\left(\frac{H_{i-1/2,j}}{H_{i,j}}\right)\left(\frac{|U_{i-1/2,j}|}{\Delta X_i} + \frac{2(D_{MX})_{i-1/2,j}}{\Delta X_i(\Delta X_i + \Delta X_{i-1})}\right) \right.$$

$$+ \left(\frac{\rho_{i+1/2,j}}{\rho_{i,j}}\right)\left(\frac{H_{i+1/2,j}}{H_{i,j}}\right)\left(\frac{|U_{i+1/2,j}|}{\Delta X_i} + \frac{2(D_{MX})_{i+1/2,j}}{\Delta X_i(\Delta X_i + \Delta X_{i+1})}\right)$$

$$+ \left(\frac{\rho_{i,j-1/2}}{\rho_{i,j}}\right)\left(\frac{H_{i,j-1/2}}{H_{i,j}}\right)\left(\frac{|V_{i,j-1/2}|}{\Delta Y_j} + \frac{2(D_{MY})_{i,j-1/2}}{\Delta Y_j(\Delta Y_j + \Delta Y_{j-1})}\right)$$

$$+ \frac{\rho_{i,j+1/2}}{\rho_{i,j}}\ \frac{H_{i,j+1/2}}{H_{i,j}}\left(\frac{|V_{i,j+1/2}|}{\Delta Y_j} + \frac{2(D_{MY})_{i,j+1/2}}{\Delta Y_j(\Delta Y_j + \Delta Y_{j+1})}\right)$$

$$+ \frac{1}{\rho_{i,j}H_{i,j}} \{(g_B)_{i,j} + [(h_k)_B]_{i,j} + (g_T)_{i,j} + [(h_k)_T]_{i,j}\} \Bigg] .$$

(6.32)

6.4.3. Stability Criteria for Calculating Velocities

The basic discrete element equations to be solved are given by Eqs. 2.75 and 2.76, in which Eqs. 3.42 to 3.50 must be substituted for the stresses σ_{XX}, σ_{YY}, and σ_{XY}, Eqs. 4.11 and 4.12 for the bottom shear stresses σ_{BX} and σ_{BY}, and Eqs. 4.19 and 4.20 for the wind shear stresses σ_{TX} and σ_{TY}, respectively. Performing this substitution and then evaluating $\alpha_{i,j}$ as for temperature and mass concentration C_k gives an expression for stability criteria similar to Eqs. 6.31 and 6.32 except that momentum quantities are used. The result for the U velocity is

$$(\Delta t_{CR})_{U_{i,j}} \leq 1 \Bigg/ \Bigg(\left(\frac{\rho_{i-1/2,j}}{\rho_{i,j}}\right)\left(\frac{H_{i-1/2,j}}{H_{i,j}}\right)\left(\frac{|U_{i-1/2,j}|}{\Delta X_i} + \frac{4(D_{mX})_{i-1/2,j}}{\Delta X_i(\Delta X_i + \Delta X_{i-1})}\right)$$

$$+ \left(\frac{\rho_{i+1/2,j}}{\rho_{i,j}}\right)\left(\frac{H_{i+1/2,j}}{H_{i,j}}\right)\left(\frac{|U_{i+1/2,j}|}{\Delta X_i} + \frac{4(D_{mX})_{i+1/2,j}}{\Delta X(\Delta X_i + \Delta X_{i+1})}\right)$$

$$+ \left(\frac{\rho_{i,j-1/2}}{\rho_{i,j}}\right)\left(\frac{H_{i,j-1/2}}{H_{i,j}}\right)\left(\frac{|V_{i,j-1/2}|}{\Delta Y_j} + \frac{2(D_{mY})_{i,j-1/2}}{\Delta Y_j(\Delta Y_j + \Delta Y_{j-1})}\right)$$

$$+ \left(\frac{\rho_{i,j+1/2}}{\rho_{i,j}}\right)\left(\frac{H_{i,j+1/2}}{H_{i,j}}\right)\left(\frac{|V_{i,j+1/2}|}{\Delta Y_j} + \frac{2(D_{mY})_{i,j+1/2}}{\Delta Y_j(\Delta Y_j + \Delta Y_{j+1})}\right)$$

$$+ \frac{1}{\rho_{i,j}H_{i,j}} \left[(g_B)_{i,j} - \frac{(\sigma_B)_{i,j}}{U_{i,j}} + (g_T)_{i,j} \right] \Bigg\} , \qquad (6.33)$$

and the result for the V velocity is:

$$(\Delta t_{CR})_{V_{i,j}} \leq 1/\left\{ \left(\frac{\rho_{i-1/2,j}}{\rho_{i,j}}\right)\left(\frac{H_{i-1/2,j}}{H_{i,j}}\right)\left(\frac{|U_{i-1/2,j}|}{\Delta X_i} + \frac{2(D_{mX})_{i-1/2,j}}{\Delta X_i(\Delta X_i + \Delta X_{i-1})}\right)\right.$$

$$+ \left(\frac{\rho_{i+1/2,j}}{\rho_{i,j}}\right)\left(\frac{H_{i+1/2,j}}{H_{i,j}}\right)\left(\frac{|U_{i+1/2,j}|}{\Delta X_i} + \frac{2(D_{mX})_{i+1/2,j}}{\Delta X_i(\Delta X_i + \Delta X_{i+1})}\right)$$

$$+ \left(\frac{\rho_{i,j-1/2}}{\rho_{i,j}}\right)\left(\frac{H_{i,j-1/2}}{H_{i,j}}\right)\left(\frac{|V_{i,j-1/2}|}{\Delta Y_j} + \frac{4(D_{mY})_{i,j-1/2}}{\Delta Y_j(\Delta Y_j + \Delta Y_{j-1/2})}\right)$$

$$+ \left(\frac{\rho_{i,j+1/2}}{\rho_{i,j}}\right)\left(\frac{H_{i,j+1/2}}{H_{i,j}}\right)\left(\frac{|V_{i,j+1/2}|}{\Delta Y_j} + \frac{4(D_{mY})_{i,j+1/2}}{\Delta Y_j(\Delta Y_j + \Delta Y_{j+1/2})}\right)$$

$$\left. + \frac{1}{\rho_{i,j}H_{i,j}} \left[(g_B)_{i,j} - \frac{(\sigma_{BY})_{i,j}}{V_{i,j}} + (g_T)_{i,j} \right] \right\} , \qquad (6.34)$$

where $(\sigma_{BX})_{i,j}$ and $(\sigma_{BY})_{i,j}$ can be calculated from Eqs. 4.11 to 4.13 to get:

$$\frac{(\sigma_{BX})_{i,j}}{U_{i,j}} = \frac{(\sigma_{BY})_{i,j}}{V_{i,j}} = - \frac{g\rho_{i,j}n_{i,j}{}^{2}\sqrt{U_{i,j}{}^{2} + V_{i,j}{}^{2}}}{2.208H_{i,j}{}^{1/3}} . \qquad (6.35)$$

6.4.4. Stability Criteria for Calculating Water Elevation H

The basic discrete element equation to be solved is given by Eq. 2.38. Collecting the coefficients of $H_{i,j}$, one gets:

$$\sigma_{i,j} = -\left(\frac{1}{\rho_{i,j}}\left(\frac{\partial\rho_{i,j}}{\partial t}\right)\right) . \qquad (6.36)$$

Substituting Eq. 6.29 into Eq. 6.28 and rearranging terms gives the stability criterion for calculating H as

$$(\Delta t_{CR})_{H_{i,j}} \leq 1/\left(\frac{1}{\rho_{i,j}}\left(\frac{\partial\rho_{i,j}}{\partial t}\right)\right) . \qquad (6.37)$$

The term $\partial\rho/\partial t$ is usually small or nonexisting. This will mean that the time step stability limit for calculating H is very large. However, combining Eqs. 6.23 and 6.27 gives

$$\frac{\partial\delta_{i,j}}{\partial t} = \psi_{i,j}\delta_{i,j} . \qquad (6.38)$$

If $\psi_{i,j}$ is zero, this will mean that any induced error $\delta_{i,j}$ will not grow but will also not die out. Using the donor cell method for H and replacing the half-point values by the corresponding center-point values (see Section 6.4.1) in Eq. 2.38 changes $\psi_{i,j}$ by bringing in new terms involving $P_{i,j}$. Assuming, on the conservative side, that the velocity is always in the direction which requires $P_{i,j}$ to be used, one gets:

$$(\psi_{i,j})_{elev} = -\frac{1}{\rho_{i,j}}\left(\frac{\partial\rho_{i,j}}{\partial t} + \frac{\rho_{i-1/2,j}|V_{i-1/2,j}|}{\Delta X_i} + \frac{\rho_{i+1/2,j}|V_{i+1/2,j}|}{\Delta X_i}\right.$$

$$\left. + \frac{\rho_{i,j-1/2}|V_{i,j-1/2}|}{\Delta Y_j} + \frac{\rho_{i,j+1/2}|V_{i,j+1/2}|}{\Delta Y_j}\right) . \qquad (6.39)$$

Substituting Eq. 6.39 into Eq. 6.38 and rearranging terms gives the stability criterion for calculating water elevation with the donor cell method as:

$$(\Delta t_{CR})_{H_{i,j}} \leq 1 \Bigg/ \left(\left(\frac{\rho_{i-1/2,j}}{\rho_{i,j}}\right) \frac{|U_{i-1/2,j}|}{X_i} + \left(\frac{\rho_{i+1/2,j}}{\rho_{i,j}}\right) \frac{|U_{i+1/2,j}|}{X_i} + \left(\frac{\rho_{i,j-1/2}}{\rho_{i,j}}\right) \frac{|V_{i,j-1/2}|}{\Delta Y_j} + \left(\frac{\rho_{i,j+1/2}}{\rho_{i,j}}\right) \frac{|V_{i,j+1/2}|}{\Delta Y_j} + \frac{1}{\rho_{i,j}}\left(\frac{\partial \rho_{i,j}}{\partial t}\right) \right) . \quad (6.40)$$

6.4.5. Total Time Step Limit Approximation

The final time step limit to avoid numerical instabilities will be the smallest of $(\Delta t_{CR})_T$, $(\Delta t_{CR})_{C_k}$, $(\Delta t_{CR})_U$, $(\Delta t_{CR})_V$, and $(\Delta t_{CR})_H$ (given by Eqs. 6.31, 6.32, 6.33, 6.34, and 6.40, respectively) when calculated for each one of the discrete elements of i, j.

For a more simplified, but somewhat more conservative, expression which combines all four conditions for all the elements, one can assume the maximum or minimum values of the parameters which will give the smallest time step. Such an expression will have the form

$$(\Delta t_{CR})_{total} \leq 1 \Bigg/ \left(\left(\frac{H_{max}}{H_{min}}\right)\left(\frac{\rho_{max}}{\rho_{min}}\right)\left(2\left(\frac{U_{max}}{\Delta X_{min}} + \frac{V_{max}}{\Delta Y_{min}}\right) + 8\left(\frac{(D_X)_{max}}{(\Delta X)^2_{min}} + \frac{(D_Y)_{max}}{(\Delta Y)^2_{min}}\right)\right) + \frac{(g_B)_{max} + (g_T)_{max} + L_{max}}{\rho_{min} H_{min}} \right) . \quad (6.41)$$

L_{max} is the largest of the quantities

$$\left(\frac{h_{HB}}{C_p}\right)_{max} + \left(\frac{q_T}{C_p T}\right)_{max}, \quad (h_{kB})_{max} + (h_{kT})_{max}, \text{ and } (-\sigma_B/V)_{max},$$

where

$$\left(-\frac{\sigma_B}{V}\right)_{max} = \left(-\frac{\sigma_{BX}}{U}\right)_{max} = \left(-\frac{\sigma_{BY}}{V}\right)_{max} = \frac{g\rho_{max} n^2_{max}\sqrt{U^2_{max} + V^2_{max}}}{2.208 H_{min}^{1/3}} \tag{6.42}$$

and q_T/T can be calculated from Eqs. 4.33 to 4.39 or replaced by the heat exchange coefficient K.

7. APPLICATION OF THE MODEL AND ITS COMPUTER PROGRAM

The main purpose of this study is to solve for the water elevation, temperature, and mass concentrations of all constituents k dissolved in the water as functions of time and two horizontal space dimensions, X and Y. As explained in Section 6.2, the Euler method and the modified fourth-order Runge-Kutta formula with Gill coefficients have been chosen for simultaneously integrating the equations expressing the time derivatives of all the unknowns explicitly as function of known values from the previous time step. A computer program was developed to handle those solutions and to facilitate simulation of various complex situations occurring in natural water bodies. However, when a computer program of the type produced in this study is available, there always exists the risk that it will be used to model situations for which it is not properly designed. It is important to recognize the capabilities of the program as well as its limitations. These capabilities and limitations will be described in this chapter to help the user to decide if the program is applicable to a specific situation at hand. The structure of the program is such that many modifications and additional capabilities can be incorporated with no major effort. In some situations, however, it may be uneconomical to try to modify the program to respond to specific requirements. Some other available programs may be more readily used for the case.

The computer program itself will be briefly described in Section 7.2. No attempt is being made to give a complete documentation of the computer program. The complete listing of the program and its flow diagram and nomenclature are attached in the appendices.

Two sample problems are described in Section 7.3, including their full input and output information.

7.1. Applicability of the Model

A discussion of the applicability of the model to some situations occurring in reality is given in this section. Additional capabilities of the computer program itself are given in Section 7.2.3.

7.1.1. Simulation of Power Plant Intake and Discharge

There are a number of ways in which the intake and discharge conditions can be modeled with the various terms available in the conservation equations developed in Sections 2.5 to 2.8. Thermal discharges or intakes which are located offshore can be simulated by the bottom or top heat fluxes q_B, q_{kB}, q_T, q_{kT} $(Btu \cdot L^{-2}T^{-1})$ or by the volumetric heat generation $\dot{q}_V$ $(Btu \cdot L^{-3} \cdot L^{-1})$. Since the model is two dimensional, it makes no difference which method is used. If the effect of mass contribution is of interest, the heat fluxes may be replaced by the mass fluxes g_B, g_{kB}, g_T, g_{kT} $(ML^{-2}T^{-1})$ or volumetric mass generation $\dot{\rho}_k$ $(ML^{-3}T^{-1})$ with the corresponding enthalpies specified for each. If the intake or the discharge structures extend over a number of discrete elements, they can be simulated correctly with corresponding portions on each discrete element. All of the information can be supplied as time dependent or if needed as a function of X, Y, or any other independent variable (see Section 7.2.3).

If either the intake or the discharge is located along a shoreline and it is desired to take into account the correct contribution of momentum (velocity), it must be simulated as a boundary condition. The proper mass flow, heat, velocities, enthalpies, and other properties, as the case may require, must be specified. It must be remembered, however, that in most cases the actual size of the structure is smaller than the economically desirable size of the discrete elements. Using a discrete element that is too small may require an undesirable time step for stable solution. The user has here the choice of either accepting this situation of smaller discrete elements and, therefore, smaller time steps and specifying the boundary velocities in their correct magnitudes and directions or choosing element sizes larger than the actual size of the structure and then specifying a reduced velocity so that the correct flow rate will be simulated. In the second case, however, the momentum effects will not be correctly simulated.

In the special case of power generating plant simulation, the intake and discharge structures are coupled by the condenser installation, where a certain heat load is transferred to the flow. A special handling of the boundary conditions was incorporated in the program to account for this situation. If a boundary simulates a power plant, the user specifies, in addition to other regular information, the location (X, Y) at which the power plant intake is located and the total condenser temperature increase instead of the discharge temperature itself. The program will then use the existing temperature at the specified intake location as the current intake temperature, will add to it the temperature increase across the condenser, and will use the increased temperature as the discharge temperature at the boundary condition. This procedure is a means of accounting for recirculation of heated water between the intake and discharge either of the same power plant or of neighboring power plants mutually affected (see Sections 7.1.4 and 7.1.5 for discussion).

7.1.2. Vertical Variations

Since the model is based on two space dimensions only, it cannot be used in deep water bodies or in other cases where vertical stratification (thermal or otherwise) is significant. The program can be used in shallow water bodies and cases where vertical mixing is significant. Many estuaries, coastal regions, and some natural streams in the U.S.A. will satisfy these conditions, but, on the other hand, many lakes and ponds will not. Bottom roughness, wind stresses, and tidal motions may considerably enhance the vertical mixing, whereas thermal discharges will tend to stratify such water bodies. In some cases where vertical variations do exist but are not considerable, some specified functions which simulate those variations can be employed, as proposed by Eraslan.[41]

In some other situations where stratification is so strong that two distinct layers can be detected, the model can be used by assuming the depth of the layer of interest (usually the upper) as the effective depth of the model. A corresponding adjustment must be made in this case to other parameters such as velocities and others.

7.1.3. Geometrical Considerations

The geometry can be described in rectangular coordinates in the X and Y directions only. Space increments can be varied along X and Y, which gives some flexibility in describing irregular geometry. At the present time, no partial elements are possible, nor is it possible to use other than rectangular elements. This limitation is indeed important when attempting to model a complex geometry. In addition, grid lines cannot be stopped in the middle of the modeled zone. This limits the flexibility in controlling the size of the elements in different regions. Once a grid line is established, it must be extended all along the model. This creates difficulty in using the program as a combined near- and far-field model, as discussed in the next section. The method used by Eraslan[41] or another applicable method can be incorporated in future versions of this model.

7.1.4. Near- and Far-Field Modeling

As discussed in the introduction, most of the thermal hydraulic models are either near-field or far-field oriented. By including the viscous shear stresses in the present model, its potential capability to analyze both the near field and the far field at the same time has been greatly increased. However, there are three major drawbacks which do not allow a full use of that potential.

1. The turbulent eddy diffusivity, as has been discussed in Sections 3.1 and 3.2, is a very difficult parameter to be correctly evaluated. As discussed before, it depends primarily not only on the existing velocity profiles in the directions modeled but also on the velocity profile in the plane perpendicular to the main flow. In almost all cases, some empirical constants are needed for its full evaluation. It is clear that while in the far field the vertical velocity profile is the controlling factor, in the near-field area the axisymmetric approach (defect law or others) is the only one presently possible. To express this asisymmetrical dependence for a jet, whose direction may be three dimensional and probably in some curvilinear path, in a general far-field rectangular coordinate system is a major difficulty.

2. Even if one could find a common way to express the eddy diffusivities in both the far and near field, it is clear that the near-field area will require a much finer grid line mesh than the far-field area for proper description of the fluid dynamics. Since, as was mentioned before, the program in its present form will not allow complete flexibility in mesh sizing, a very large number of unnecessary elements will be created in the far field, requiring an extensive amount of machine calculation time as well as machine storage. This problem, as was explained in Section 7.1.3, is technical and can be corrected in future versions of the program.

3. Since one of the main purposes of this study is to analyze thermal discharges, it is clear that a near field will involve a buoyant plume, which, because of its buoyancy, will require the vertical

dimension for proper analysis. The same is true for the so-called intermediate field, in which a stratified layer of heated water may be stably created.

Because of the above drawbacks, it is recommended that the model in its present form should be used primarily as a far-field model. The near-field area can still be included in the model zone but should not be looked upon for quantitative evaluations. After completing the analysis based on the present model, an additional jet analysis should be made for the near field using the results of this model as ambient or background temperature distribution. In any case a near-field model analysis should not stand alone. As has been already discussed in the introduction, any near-field model calls for the ambient temperature to be specified and uses this temperature for the fresh water entrained into the jet. It must be remembered that the entrained water is not at ambient temperature but rather is affected by its interaction with the far-field zones. This effect of the far field on the near field must be analyzed by using a far-field model, or, if this is not possible, the effect must be conservatively estimated.

7.1.5. Recirculation, Interacting Power Plants, and Intake Entrainment

The importance of these three subjects for proper assessment of power plant environmental impact cannot be overemphasized. It is the tendency in many present thermal analyses to isolate the near-field effect from the far-field effects. This is a dangerous approach, since intuition, which many times is being relied upon for that purpose, can be very misleading. The feedback of thermal discharges through the intake to the condenser system creates a closed loop which keeps heating the same water until some thermal equilibrium is achieved. This partially closed loop circulation results in localized temperatures which are much higher than if recirculation does not exist. This is specifically true if the intake structure is close to the discharge or, in estuaries, when the distance between intake and discharge is less than a tidal excursion length. When analytical studies are not possible, hydraulic physical models and field dye studies should be performed. The method indicated in Section 7.1.1 to simulate power plant intake and discharge considers this recirculation effect to a certain degree. It must be remembered, however, that this method of accounting for recirculation suffers from the same three deficiencies mentioned before for the near-field area.

Entrainment of passive aquatic species into the intake structure is similar in nature to the problem of intake recirculation. It can be simulated in the same fashion but will also have the same type of limitations.

All these three cases--discharge jet, intake entrainment, and intake recirculation--can be simulated in the model on an overall basis but should be looked upon only for rough approximation of the near-field area.

Mutual effects between power plants basically constitute a far-field problem, since the distance between such power plants is normally greater than the zone of the near field. The present model can then be effectively used for proper assessment of interacting power plants by specifying each power plant in its proper location in the model.

It must be remembered, however, that the model expresses only the average properties in the vertical direction, and this must be taken into account when the intake structure is built in such a way that it withdraws water at conditions much different from the depth-averaged conditions.

7.1.6. Multicomponent Analysis

The program is set to handle any number of dissolved substances, although the interaction between them is handled in a simplified form only, by using Fick's law of binary diffusion between one substance and the rest of the mixture. The dimension statements in the program are presently set to four dissolved substances, but this can be easily increased if computer storage allows it.

7.2. The Computer Program

In this section the various features of the computer program itself will be discussed. This includes the program's overall structure, its various capabilities and limitations, the individual subroutines, and some machine time and storage requirements.

7.2.1. Program Structure and Condensed Flow Diagram

The purpose of the computer program is to solve for the unknowns, water elevation, velocities, temperature, and substance concentrations as functions of time and the two horizontal space dimensions X and Y. As discussed in Section 6.2, the initial value problem defined by Eqs. 2.38, 2.50, 2.61, 2.75, and 2.76 were integrated by using either Euler's method or the Runge-Kutta method. A computer program was written to facilitate the solution of these methods as well as the overall computational requirements for the system. The actual integration solutions by either the Euler or the Runge-Kutta method were programmed under two alternative subroutines: SOLEUL for the Euler method and SOLRKG for the Runge-Kutta method with Gill coefficients. The user, by means of a flag, can choose the desired technique for the case at hand. Both subroutines will be termed SOLVET in this section. The most important input data required by SOLVET are time derivative functions of all the unknowns (Eqs. 2.38, 2.50, 2.61, 2.75, and 2.76). These derivatives are evaluated in a subroutine called SOLFNC. All the fluxes involved are calculated in a subroutine FLXCON. The rest of the program is constructed around these major subroutines. Figure 7.1 gives an overall flow diagram for the various subroutines being used. In general the logic of the program is as follows (see Fig. 7.1). The main program reads input information from subroutines INPUT and GEOM. Based on this information, the number of elements is calculated, the size of the vector array Z is defined, and the storage requirements are established. It then calls subroutine DRIVE, which does the monitoring of the rest of the subroutines and keeps track of the time. DRIVE first calls practically all the subroutines from which any input information must be read in. It then sets the counter for time, time steps, and number of time steps (iterations) performed

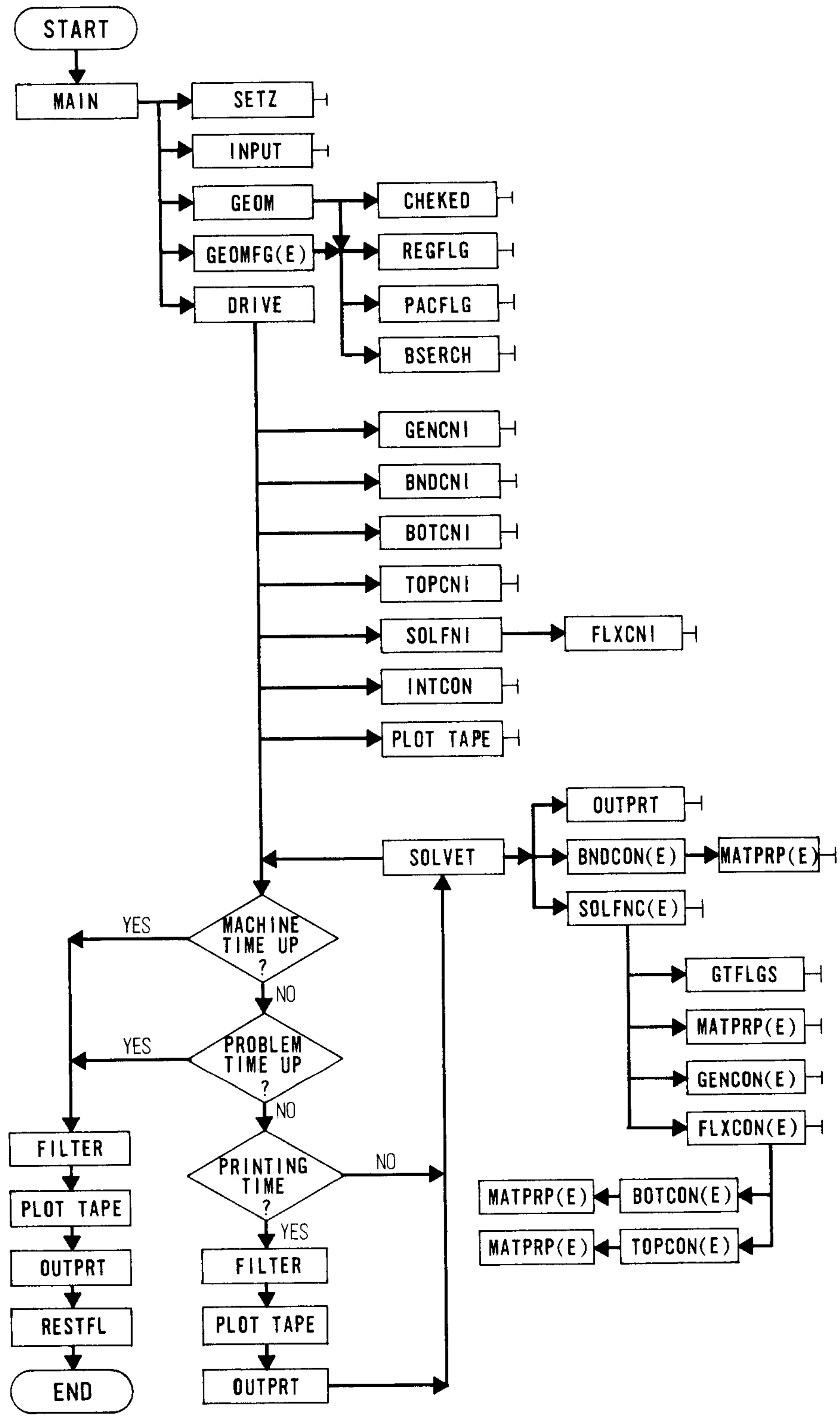


Figure 7.1. Simplified flow diagram for computer code.

and calls subroutine SOLVET in each time step. SOLVET is the program that integrates the equations with respect to time, using the information coming from subroutines BNDCON and SOLFNC. BNDCON is an entry into BNDCNI which updates the conditions on all the boundaries based on functions specified by the user in GNRLFC and ANLFNC routines. SOLFNC calculates the time derivatives of all the unknowns. For that purpose it calls GTFLGS, which retrieves the boundary condition indices of each element and its region number. MATPRP is called next to get the updated information about the physical properties. GENCON brings in the updated information about heat and mass generation (or decay) per unit volume. FLXCON calculates the transport coefficients as well as all the fluxes involved. For calculating the fluxes from bottom and top, FLXCON calls subroutines BOTCON and TOPCON, which supply the updated conditions at the bottom and top, respectively. Updating the conditions in all of the above subroutines is done by using the functions specified by the user in GNRLFC and ANLFNC routines. Those user functions can be either analytical or tabulated and can be dependent on time, position (X, Y), temperature, substance concentration, and other independent variables.

7.2.2. The Region Subdivision and the Flagging Technique

The zone modeled by the computer program is subdivided into "regions." Each region is geometrically defined by two bounding planes in the X direction and two in the Y direction. On each face bounding the region, there is assigned a certain boundary condition identified by a "boundary condition function number." If a face of a region has no boundary (internal plane), it needs no such identification. The actual data of the boundary conditions are given in each boundary condition function number. In addition to the boundary conditions around it, each region is also assigned the following.

1. Depth, which is the uniform depth of the region.
2. "Initial condition function number," which identifies a set of initial conditions to be used for the region.
3. "Volumetric heat and mass generation (or decay) function number," which specifies the heat and/or mass generation (or decay) per unit volume in the region.
4. "Top conditions function number," which specifies a set of conditions to which the top of the region is exposed.
5. "Bottom condition function number," which specifies a set of conditions to which the bottom of the region is exposed.

Each one of these types of functions is separately documented with identification numbers so that each function number readily identifies the full set of conditions involved (see individual description). The decision of the analyst on how to subdivide the modeled zone into regions will depend largely on his judgment on what conditions can be considered as uniform for a specific region. Once a function number is assigned to a region, the conditions of this function are considered characteristic for the whole region. In the present form of the program, each region can be geometrically described by rectangular grid lines only.

A special flagging technique has been developed in this program for identifying all the characteristics of a specific discrete element.

Before starting any time-dependent calculations, the program processes the input information and files this information in an easy-to-access compartment. An important tool in this procedure is the assignment of a flag to each one of the discrete elements. The flag is an integer variable dimensioned for the total number of elements in use. This integer contains 32 hexadecimal bits which are subdivided into six blocks. The first four blocks from the right have five bits each and are used to identify the boundary function numbers on the four sides of the element, one block for each side. If a block is empty (zero), the face has no boundary and is assumed to be on an internal grid line. If all four blocks are empty, the element is a completely internal node (surrounded by water on all sides). The next four bits are presently unused. The last block on the left, which has eight bits, identifies the region number to which the element belongs. Once element region number is identified, all the conditions of this element are clearly specified, since each region number carries with it function numbers for the initial conditions, heat and mass volumetric generation conditions, top conditions, bottom conditions, and depth. A zero region number indicates an element which is outside the modeled zone, that is, a land element, which is for all purposes inactive. A special routine installs those five identifying numbers in the flag, and another two routines retrieve them any time they are needed. This procedure is designed to save storage, since six integers (or more) can be stored into one variable. This is, of course, at the expense of machine time required for retrieving those numbers each time they are needed. If storage is not a restricting problem and saving in machine calculation time is more important, it is better to replace the flag by five integer variables. Each one of those variables will have to be dimensioned for the total number of elements in use.

7.2.3. Program Capabilities and Limitations

In Section 7.1 some application capabilities and limitations of the model have been described. In this section some additional technical features of the program as it presently exists will be described. Many additional ones can be incorporated in the program if so desired. The full listing which is given in the appendix can be of much help for that purpose. Those features are as follows.

a. Bottom, top, and volumetric conditions. Natural phenomena like wind, rain, evaporation, heat exchange with the atmosphere, seepage, bottom shear stresses, and volumetric heat and mass generation or decay can all be specified as functions of time, position, temperature, and other parameters. Heat exchange with the atmosphere can be based on either the equilibrium temperature concept or the actual balance of heat fluxes across the water surface (see Section 4.4.2).

b. Transport properties. As discussed in Section 3.1 and 3.2, the turbulent transport properties are difficult parameters to be evaluated. Nevertheless, the program is set in such a form that each transport property is a sum of molecular and turbulent parts. The molecular part is specified by the user in INPUT as a constant, while the turbulent part is calculated internally on the basis of the discussion in

Sections 3.1 and 3.2. Any one of the expressions for transport properties can be easily modified with the program.

c. Boundary conditions. The program has extensive capabilities for accepting almost any type of physical boundary condition. These conditions can be technically imposed at any location along the "shoreline" of the modeled zone and can simulate power plants, tributaries, or any other intake or discharge points. All or part of the unknowns and their fluxes can be specified as functions of time and other independent parameters. The boundary conditions are discussed in detail in Section 5.

d. Initial conditions. The initial conditions can be specified for each region as functions of position (see Section 5.1 for discussion).

e. Analytical and tabulated functions. As was mentioned before, most of the conditions can be set to be functions of time, position, temperature, substance mass concentrations, and other parameters. This is done by the use of subroutine GNRLFC, which multiplies the original constant value, set by the user, by a proper function. This function can be either in tabulated form, and therefore restricted to one parameter at a time, or in a general analytical expression which is almost unrestricted by either form or number and type of independent parameters which can be used.

f. Control of time step. The program is set to evaluate the minimum time step required for stability using for the time being a simplified but conservative criterion. The program will evaluate the required time step and use either this value or the value specified by the user if indeed it is smaller. If the user's value is greater than the time increment required for stability, it will be overridden and the user will be notified. However, if the user's value is negative, its positive value will be used in any case.

g. Restart file. The program can create, if so instructed, a file that stores on disk all the values of the unknowns and other needed values at the end of a computer run. This file can be used for restarting the problem again from the exact point at which it has been stopped.

h. Monitoring points of temperatures in estuary. In cases of periodic behavior as found in estuaries, the user can specify a number of points in which he has special interest. The program will then keep track of the temperature at these points and will print, at the end of each cycle, the maximum, the minimum, and the average temperature at each one of those points over a full cycle period. These values are very helpful for testing if a quasi steady state has been indeed achieved.

k. Program termination. The program will terminate the case when the maximum value of either computer time or the problem (real) time specified by the user has been exceeded. In both cases a restart file will be created if requested by the user.

l. Plotting. Contour plotting for water elevations and temperature and streak plotting for velocities can be generated by using the program developed for that purpose.

7.2.4. Brief Description of Input and Output

The purpose of this section is to give a brief description of the input and output of the computer program and give some instructions as to how to prepare the input data required. It is not intended here to give a full user manual.

Table 7.1 is a concentrated summary of the input variables, their format, and some other information needed to prepare the input data. The table is not self-explanatory but can be very helpful to the user who is already familiar with the program. Columns 71-80 of each card are reserved for card identification, but are not required by the program. The first word in each box is the name of the variable. Then its meaning is briefly indicated, and some limitations on its size if any. The format is always either E10.3 for a real variable or I5 for an integer one.

The input information is a good reflection of the various capabilities of the program. Many additional capabilities can be easily incorporated. Table 7.1 represents the input required and possible at the present time. The meaning of the input variables and some explanation of their use will now be given in the order in which they are being called for in the program.

Table 7.1. Summary of Input Variables and Their Format

Columns	1–5	6–10	11–15	16–20	21–25	26–30	31–35	36–40	41–45	46–50	51–55	56–60	61–65	66–70	71–80
Title	Title (Format 18A4)														
No. of	NK (max 4)	NREG (max 25)	NINTLF (max 25)	NGENF (max 25)	NBNDF (max 25)	NTOPF (max 25)	NBOTF (max 25)	NANLFC	NTBLFC (max 10)	NXGRL (max 50)	NYGRL (max 50)	NTMAX (max 10)			CARD 1
Control Flags	ISTART	IFINIS	IPLOT	INTRT											CARD 2
Time Control	STM		PRBTM		CPUSEC		DPRTTM		TIDAL						CARD 3
Time Increment Control	SDTM		FDTM		DTMLT		INDTM	NDTMC	LOTMCR						CARD 4
Tabulated Functions	ITBLFC No. I	NTBLP(I) (max 25)	TABARG(1,I)		TABFNC(1,I)		TABARG(2,I)		TABFNC(2,I)		Can continue up to 25 pairs				TABL1
X Gross Lattice Lines	XGRL(1)		XGRL(2)		XGRL(3)		Can continue up to 50 points								LTX
X Subdivision	IXFD(1)	IXFD(2)	IXFD(3)				Can continue up to 49 points								LTDX
Y Gross Lattice Lines	YGRL(1)		YGRL(2)		YGRL(3)		Can continue up to 50 points								LTY
Y Subdivision	IYFD(1)	IYFD(2)	IYFD(3)				Can continue up to 49 points								LTDY
Region Cards (Coupled Together)	IREG No. I	INTF(I)	IGENF(I)		DEPTH(I)		UPX(I)		DNX(I)		UPY(I)		DNY(I)		RG1
	ITOPF(I)	IBOTF(I)						IUPXB(I)		IDNXB(I)		IUPYB(I)		IDNYB(I)	RG2
Monitoring Temperature	XTMAX(1)		YTMAX(1)		XTMAX(2)		YTMAX(2)		Can continue up to 10 pairs						TMAX
Volumetric Generation	IGENFC No. 1		QDV(I)		IQDVF(I)		GKDV(1,I)		IGKDVF(1,I)		GKDV(2,I)		IGKDVF(2,I)		GN
Boundary Conditions (coupled together)	IBNDFC No. 1	NHBDTP(I)	NUBDTP(I)	NVBDTP(I)	NTBDTP(I)										BND1
	FHBD(I)		FUBD(I)		FVBD(I)		FTBD(I)		XINT(I)		YINT(I)				BND2
	FGBD(I)		FQBD(I)		FSBDN(I)		FSBDSH(I)								BND3
	FCKBD(1,I)		FGKBD(1,I)		FCKBD(2,I)		FGKBD(2,I)								BND4
	IHBDF(I)	IUBDF(I)	IVBDF(I)	ITBDF(I)	IGBDF(I)	IQBDF(I)	ISNBDF(I)	ISHBDF(I)	ICKBDF(1,I)	IGKBDF(1,I)	ICKBDF(2,I)	IGKBDF(2,I)			BND5
Bottom Conditions (coupled together)	IBOTFC No. 1		UB(I)		VB(I)		WB(I)		TB(I)		QB(I)		HCB(I)		BT1
	BMANGC(I)														BT2
	CKB(1,I)		DCKB(1,I)		CKB(2,I)		DCKB(2,I)								BT3
	IUBF(I)	IVBF(I)	IWBF(I)	ITBF(I)	IQBF(I)	IHCBF(I)	ICKBF(1,I)	IDCKBF(1,I)	ICKBF(2,I)	IDCKBF(2,I)					BT4
Top Conditions (coupled together)	ITOPFC No. 1		UT(I)		VT(I)		WT(I)		TT(I)		QT(I)		HCT(I)		TP1
	TD(I)		QSOL(I)		WNDX(I)		WNDY(I)								TP2
	CKT(1,I)		DCKT(1,I)		CKT(2,I)		DCKT(2,I)								TP3
	IUTF(I)	IVTF(I)	IWTF(I)	ITTF(I)	IQTF(I)	IHCTF(I)	ITDF(I)	IQSOLF(I)	ICKTF(1,I)	IDCKTF(1,I)	ICKTF(2,I)	IDCKTF(2,I)			TP4
Transport Coefficient (coupled together)	XKPC		YKPC		XTVSC		YTVSC								TRSP1
	DKXC(1)		DKYC(1)		DKXC(2)		DKYC(2)								TRSP2
Initial Conditions (coupled together)	INTFC No. I		STH(I)		STU(I)		STV(I)		STWS(I)		STT(I)				IN1
	STCK(1,I)		STCK(2,I)		STCK(3,I)										IN2
	ISTHF(I)	ISTUF(I)	ISTVF(I)	ISTWSF(I)	ISTTF(I)	ISTCKF(1,I)	ISTCKF(2,I)								IN3
Restart File	Presently read from restart file stored on disk in binary characters.														RESTART

NOTE: The format is always E10.3 for real variables and I5 for an integer except the format of the title which is 18A4.

Title — Title of the case in 72 alphanumerical characters.

Card No. 1

NK — Total number of constituents in the mixture. A maximum number of 4 can be presently specified.

NREG — Number of regions used (present limit, 25).

NINTLF — Number of initial condition functions used to specify the conditions existing at starting time of the case (STM) (present limit, 25).

NGENF — Number of volumetric heat or mass generation functions used to specify heat or mass generation (or decay) per unit volume and time (present limit, 25).

NBNDF — Number of boundary condition functions used to specify the conditions on the physical boundaries of the model (present limit, 25).

NTOPF — Number of top condition functions used to specify the conditions on the top surface (present limit, 25).

NBOTF — Number of bottom condition functions used to specify the conditions at the bottom of the water body modeled (present limit, 25).

NANLFC — Number of analytical functions used as factors by which a corresponding variable is multiplied every time step. The functions can be any analytical expression and can involve almost any parameter like time, position (X, Y), temperature, constituent mass concentration, velocities, and others. The function is specified by the user in a FUNCTION routine named ANLFNC, which must be supplied by the user. There is no limit on the number of functions that can be specified since this is controlled completely by the user.

NTBLFC — Number of tabulated functions used as factors by which a corresponding variable is multiplied every time step (present limit, 10). The tabulated functions are used in the same way as the analytical functions except that each function is specified in a tabulated form and therefore is limited to one parameter only. The index numbers for both analytical and tabulated functions are in one sequence, and the program distinguishes between the two by the sign. Positive sign designates a tabulated function, and negative sign designates an analytical function.

NXGRL	Total number of gross lattice lines in the X direction normally used for defining the various regions (present limit, 50).
NYGRL	Total number of gross lattice lines in the Y direction (present limit, 50).
NTMAX	Number of points at which temperature will be monitored. The temperature monitoring is performed by detecting the minimum temperature and the maximum temperature occurring at the specified points during each tidal cycle. The average temperature during each tidal cycle is also calculated, and all three values are printed after each tidal cycle is completed.

Card No. 2

ISTART	A restart flag for restarting and continuing a problem from a previous run. If nonzero (one), a restart information file is called for and must be available.
IFINIS	A flag for creating a restart file which can be used to continue the case if desired. If zero, no such file will be created.
IPLOT	A plotting flag for storing information required for contour plotting of water elevations, temperatures, and mass concentration of streak plotting of velocity vectors.
INTRT	A numerical integration routine flag. Presently set to choose between Runge-Kutta method (INTRT = 1), Euler-Cauchy method (INTRT = 2).

Card No. 3

STM	Starting time for the case. If a restart file is used, the final time in the restart file will be used as STM.
PRBTM	Span of actual time for which the case should be analyzed. Final time of the case will be STM plus PRBTM.

CPUSEC	Computer time cutoff limit in seconds. The output will be printed and a restart file created if so specified.
DPRTTM	Time increment for printing output information in addition to the output printed at both the beginning and the end of the case.
TIDAL	Tidal period in the case of oscillating flow. Used for calculating tidal maximum, minimum, and average temperature during each tidal cycle.

Card No. 4

SDTM	Initial time step used for the integration routines. If a restart file is used, the last time increment in the restart file will be used as SDTM unless SDTM is negative. If SDTM is negative, its positive value will be used, overriding the time step given in the restart file.
FDTM	The largest time step permitted in the integration routines. The program will start the integration with a time step equal to SDTM. After INDTM time steps, using SDTM, the program will start multiplying the current time step by a factor DTMLT every NDTMC time steps until the largest time step allowed, FDTM, is achieved or the calculated time step is larger than the minimum time step required for maintaining numerical stability.
DTMLT	See FDTM above.
INDTM	See FDTM above.
NDTMC	See FDTM above.
LDTMCR	Stability criterion flag. If nonzero, the program will calculate a minimum time step required to maintain numerical stability and will use this value whenever it is smaller than the value calculated by the basic procedure described under FDTM. The time step stability criterion used is presently simplified and temporary. If LDTMCR is zero, the option will not be activated at all.

Cards: TABL1 and TABL2

These cards are used to describe the tabulated functions by specifying the points of each such table.

ITBLFC	Tabulated function number (I).
NTBLP(I)	Number of pairs used to describe the tabulated function I (present limit, 25).
TABARG(K,I)	Argument (independent value) K of tabulated function I.
TABFNC(K,I)	Dependent value K of tabulated function I.

Cards: LTX, LTDX, LTY, LTDY

These cards are used to describe the geometrical grid lines creating the mesh of the model.

XGRL(I)	Gross lattice line I in the X direction. Those lines are used to describe the various regions.
LTDX(I)	Number of subdivisions between gross lattice line XGRL(I) and XGRL(I+1).
YGRL(I)	Gross lattice line I in the Y direction.
LTDY(I)	Number of subdivisions between gross lattice line YGRL(I) and YGRL(I+1).

Cards: RG1 and RG2

These cards are used to first subdivide the zone modeled into regions. Then the various characteristics of each region, including boundary conditions, are defined by specifying a function number for each such characteristic. The actual specification of those functions is done in different cards (those which describe the functions themselves). There are two cards for each region.

IREG	Region number (I).
INTF(I)	Initial conditions function number for region I. This function specifies the initial conditions existing in region I at the time STM (see cards IN).

IGENF(I)	Volumetric generation function number for region I. This function specifies the generation (or decay) of heat and/or mass per unit volume and unit time for region I (see card GN).
DEPTH(I)	The depth of region I. Considered uniform throughout the region. The depth is measured from a constant arbitrary reference level.
UPX(I)	Smallest X dimension (gross lattice line) bounding region I.
DNX(I)	Largest X dimension (gross lattice line) bounding region I.
UPY(I)	Smallest Y dimension (gross lattice line) bounding region I.
DNY(I)	Largest Y dimension (gross lattice line) bounding region I.
ITOPF(I)	Top conditions function number for region I. Specifies all the conditions on the top surface of the water in region I (see cards TP).
IBOTF(I)	Bottom conditions function number for region I. Specifies all the conditions at the bottom of the water body in region I (see cards BT).
IUPXB(I)	Boundary conditions function number existing on the smallest X lattice line, UPX(I), of region I. Describes all the conditions existing on this line if it constitutes a physical boundary. If it does not, the entry is left blank. A region with all its boundary entries blank is completely surrounded by water (see cards BND).
IDNXB(I)	Same as IUPXB(I) but for DNX(I) line.
IUPYB(I)	Same as IUPXB(I) but for UPY(I) line.
IDNYB(I)	Same as IUPXB(I) but for DNY(I) line.

Card: TMAX

This card describes the points at which temperature monitoring is desired (see NTMAX).

XTMAX(I)	X dimension of point I.

YTMAX(I) Y dimension of point I.

Card: GN

This card describes any heat and/or mass generation (or decay) per unit volume and time. There is one card for each set of such conditions (that is, for each volumetric function number).

IGENFC Volumetric generation function number (I).

QDV(I) Value of heat generation (or decay if negative) per unit time for function I.

IQDVF(I) Multiplier function number by which QDV(I) will be multiplied every time step. The function can be analytical (negative) or tabulated (positive). The function can include almost any number of parameters (see NANLFC and NTBLFC).

GKDV(K,I) Value of mass generation (or decay if negative) of constituent K per unit volume and unit time for function I.

IGKDV(K,I) Multiplier function number by which GKDV(K,I) will be multiplied every time step (see IQDVF(I)).

Cards: BN1 to BN5

These cards are used to specify the boundary conditions for each boundary conditions function. There are five cards for each such function. Card BN1 specifies the types of boundaries for H, U, V, and T, as discussed in Section 5.3, which are, in short:

B.C. type 1: $P = P_b$ (value of property itself is specified).

B.C. type 2: $\frac{\partial P}{\partial n} = P_{bf}(t)$ (the property's normal derivative is specified).

B.C. type 3: $P = P_b + (P_{bf}/h_b)$ (forced flux from outside is specified).

B.C. type 4: $\partial^2 P/\partial n^2 = 0$ (the property's second normal derivative equals zero).

The boundary condition type specified for T is also used for C_k.

IBNDFC Boundary conditions function number (I).

NHBDTP(I) Type of boundary condition specified for water elevation H.

NUBDTP(I)	Type of boundary condition specified for velocity in the X direction (U).
NVBDTP(I)	Type of boundary condition specified for velocity in the Y direction (V).
NTBDTP(I)	Type of boundary condition specified for temperature T or constituent mass concentration C_k.
FHBD(I)	The value specified (if required) for the water elevation at the boundary I. This value is multiplied each time step by the factor specified in IHBDF(I).
FUBD(I)	The value specified (if required) for the U velocity (X direction) at the boundary I. This value is multiplied each time step by the factor specified in IUBDF(I).
FVBD(I)	The value specified (if required) for the V velocity (Y direction) at the boundary I. This value is multiplied each time step by the factor specified in IVBDF(I).
FTBD(I)	The value specified (if required) for the temperature at the boundary I. If this value is negative, then the boundary is assumed to simulate the heat discharge from a power plant. In this case the positive value of FTBD(I) is taken as the temperature increase across the condensers, and the discharge temperature is calculated as the sum of this temperature increase and the intake temperature. The intake temperature is the temperature existing at any time at the element simulating the intake structure, whose location is specified by the next two entries of this card. FTBD(I) is multiplied every time step by the factor specified in ITBDF(I).
XINT(I)	X dimension of the intake structure location. Not required if FTBD(I) is positive.
YINT(I)	Y dimension of the intake structure location. Not required if FTBD(I) is positive.

Based on the above, the discharge temperature at boundary I at any time will be

$$T_{discharge} = T[XINT(I), YINT(I)] + |TBD(I)| , \qquad (7.1)$$

where TBD(I) is the updated value of the temperature increase across the condenser FTBD(I). This arrangement allows recirculation to be taken into account.

FGBD(I)	The value specified (if required) for the mass flow ($ML^{-2}T^{-1}$) at boundary I. This value is multiplied every time step by the factor specified in IGBDF(I). Note that the total mass flux through the boundary will be the sum of GBD(I) and the density times velocity UBD(I) or VBD(I). FGBD(I) allows mass flux from the boundary without affecting momentum.
FQBD(I)	The value specified (if required) for the heat flux ($Btu \cdot L^{-2}T^{-1}$) at the boundary I. This value is multiplied every time step by the factor specified in IQBD(I). Note that the total heat flux through the boundary will be the sum of QBD(I) and the convective heat flux specified by VBD(I) and TBD(I). FQBD(I) allows heat flux from the boundary without specifying mass flow or velocity.
FSBDN(I)	The value specified (if required) for the normal shear stresses (pressure) at the boundary I. This value is multiplied every time step by the factor specified in ISNBD(I).
FSBDSH(I)	The value specified (if required) for the shear stresses (friction forces per unit area) at boundary I. This value is multiplied every time step by the factor specified in ISHBDF(I).
FCKBD(K,I)	The value specified (if required) for mass concentration of constituent k at boundary I. This value is multiplied each time step by the factor specified in ICKBDF(K,I).
FGKBD(K,I)	The value specified (if required) for mass flow of constituent k at boundary I. This value is multiplied each time step by the factor specified in IGKBDF(K,I). This mass flow of constituent k is in addition to the mass flow of constituent k convected with the total mass flow (GBD(I)).
IGBDF(I)	Multiplier function number for boundary water elevation (see FHBD).
IUBDF(I)	Multiplier function number for boundary U velocity (see FUBD).
IVBDF(I)	Multiplier function number for boundary V velocity (see FVBD).

ITBDF(I) — Multiplier function number for boundary temperature (see FTBD).

IGBDF(I) — Multiplier function number for boundary mass flux (see FGBD).

IQBDF(I) — Multiplier function number for boundary heat flux (see FQBD).

ISNBDF(I) — Multiplier function number for boundary normal stresses (see FSBDN).

ISHBDF(I) — Multiplier function number for boundary shear stresses (see FSBDSH).

ICKBDF(K,I) — Multiplier function number for boundary mass concentration of constituent k (see FCKBD).

IGKBDF(K,I) — Multiplier function number for boundary mass flux of constituent k (see FGKBD).

<u>Cards: BT1 to BT4</u>

These cards are used to specify the conditions at the bottom of the water body modeled. There are four cards for each such function.

IBOTFC — Bottom conditions function number (I).

UB(I) — The value specified (if required) for the velocity in the X direction of the flow coming from the bottom. This value is multiplied each time step by the factor specified in IUBF(I).

VB(I) — The value specified (if required) for the velocity in the Y direction of the flow coming from the bottom. This value is multiplied each time step by the factor specified in IVBF(I).

WB(I) — The value specified (if required) for the velocity in the vertical upward direction of the flow coming from the bottom. This value is multiplied each time step by the factor specified in IWBF(I). WB(I) contributes to the total mass flow coming from the bottom but has no effect on the momentum. The total flow is calculated based on vectorial summation of UB, VB, and WB.

TB(I)	The value specified (if required) for the temperature of the bottom for bottom conditions function I. This value is multiplied every time step by the factor specified in ITBF(I).
QB(I)	The value specified (if required) for the heat flux coming from the bottom. This value is multiplied each time step by the factor specified in IQB(I). This heat flux is in addition to the convective heat flux coming with the flow or the diffusive flux caused by temperature drop.
HCB(I)	The value specified (if required) for the film heat transfer coefficient between the bottom and the water for bottom conditions function I. This value is multiplied each time step by the factor specified in IHCBF(I). The heat flux will be calculated based on Eq. 4.42.
BMANGC(I)	The value specified for the Manning roughness coefficient used to calculate the bottom shear stresses at bottom conditions function I. This value is not updated each time step. The units of the Manning coefficient are $hr/ft^{-1/3}$.
CKB(K,I)	The value specified for the mass concentration of constituent k at the bottom for bottom conditions function I. This value is multiplied each time step by the factor specified in ICKBF(K,I).
DCKB(K,I)	The value specified for the film mass transfer coefficient between the bottom and the water for bottom conditions function I. This value is multiplied every time step by the factor specified in IDCKBF(K,I). The mass flux will be calculated based on Eq. 4.25.
IUBF(I)	Multiplier function for the bottom velocity in the X direction (see UB).
IVBF(I)	Multiplier function for the bottom velocity in the Y direction (see VB).
IWBF(I)	Multiplier function for the bottom vertical velocity (see WB).
ITBF(I)	Multiplier function for the bottom temperature (see TB).

IQBF(I)	Multiplier function for the bottom heat flux (see QB).
IHCBF(I)	Multiplier function for the bottom film heat transfer coefficient (see HCB).
ICKBF(K,I)	Multiplier function for the bottom mass concentration of constituent k (see CKB).
IDCKBF(K,I)	Multiplier function for the bottom film mass transfer coefficient (see DCKB).

Cards: T1 to T4

These cards are used to specify the conditions on the top surface of the water body modeled. There are four cards for each such function. Most of the variables have meaning analogous to the corresponding bottom conditions variables with two differences. First, instead of the Manning coefficient, there is a need for a wind stress coefficient. However, since no reliable values are given in the literature, a constant value (3.2×10^{-6}) is used inside the program based on Section 4.2. Second, the film heat transfer coefficient between the top surface and the atmosphere above it is HCT(I). If HCT(I) $\geq$ 0, it is used as the heat exchange coefficient, and the equilibrium temperature is specified by TD(I) in card TP2 (see Section 4.4). If HCT < 0, the heat exchange coefficient is calculated based on Eqs. 4.31 and 4.32 in Section 4.4, and the equilibrium temperature is calculated based on Eq. 4.30 in this section. The additional information required is specified in card TP2 as follows.

TD(I)	Dew point temperature
QSOL(I)	Solar radiation heat flux
WINDX(I)	Wind velocity in the X direction
WINDY(I)	Wind velocity in the Y direction

Cards: TRSP1 and TRSP2

These cards are used to specify the transport properties of the fluid. For the present, only constant values are used from the input format. However, in the program itself, each transport property is the sum of the constant value specified in these cards and a built-in corresponding function for that property based on the discussion in Sections 3.1 and 3.2.

XKPC	The constant part of the thermal conductivity of the fluid in the X direction ($Btu \cdot L^{-1}T^{-1}F^{-1}$).

YKPC — The constant part of the thermal conductivity of the fluid in the Y direction ($Btu \cdot L^{-1}T^{-1}F^{-1}$).

XTVSC — The constant part of the dynamic viscosity of the fluid in the X direction ($ML^{-1}T^{-1}$).

YTVSC — The constant part of the dynamic viscosity of the fluid in the Y direction ($ML^{-1}T^{-1}$).

DKXC(K) — The constant part of the mass diffusivity of constituent k into the rest of the mixture in the X direction (L^2T^{-1}).

DKYC(K) — The constant part of the mass diffusivity of constituent k into the rest of the mixture in the Y direction (L^2T^{-1}).

Cards: IN1, IN2, and IN3

These cards are used to specify the initial conditions that exist at the starting time of the problem. There are three cards for each such function.

INTFC — Initial function number (I).

STH(I) — Initial water elevation for initial function I.

STU(I) — Initial velocity in the X direction for initial function I.

STV(I) — Initial velocity in the Y direction for initial function I.

STWS(I) — Initial rate of change of water elevation for initial function I.

STT(I) — Initial temperature for initial function I.

STCK(K,I) — Initial mass concentration of constituent k for initial function I.

Any one of the above values is multiplied by a factor specified in a corresponding multiplier function. These factors allow the initial conditions to be specified as functions of position (X, Y) within the same region. The functions are specified by the following.

ISTHF(I) — Multiplier function for the initial water elevation (see STH).

ISTUF(I)	Multiplier function for the initial velocity in the X direction (see STU).
ISTVF(I)	Multiplier function for the initial velocity in the Y direction (see STV).
ISTWSF(I)	Multiplier function for the initial rate of change of water elevation (see STWS).
ISTTF(I)	Multiplier function for the initial temperature (see STT).
ISTCKF(K,I)	Multiplier function for the initial mass concentration of constituent k.

Card: RESTART

These cards are used for restarting and continuing a problem from the point at which the previous case has been stopped (see ISTART and IFINIS). The cards (or file) are generated if IFINIS > 0 and are required only if ISTART > 0. The data in this card include the final time from the previous case, the last time step used, and all the values of the unknowns. The program will continue calculations using those values and overriding any information specified by the initial conditions or by card 3 and card 4. If, however, the starting time step SDTM is negative, its positive value will be used, overriding the value given in the restart file.

7.3. Application of the Model to Sample Problems

Two sample problems have been shosen to demonstrate the workability of the model and its capabilities. The first problem is a very simplified case of flow of warm seawater (27 ppt salt concentration) into and out of a rectangular water body. The case demonstrates the symmetry of the flow and temperature distributions as well as the mass and heat balance achieved. The second problem represents two power plants located on two banks of the same water body. The flow in the water body is oscillating and can represent an estuary. There is an interaction between the flow and temperature distributions of the two power plants. The intake of each is located about 1,500 ft upstream of its discharge.

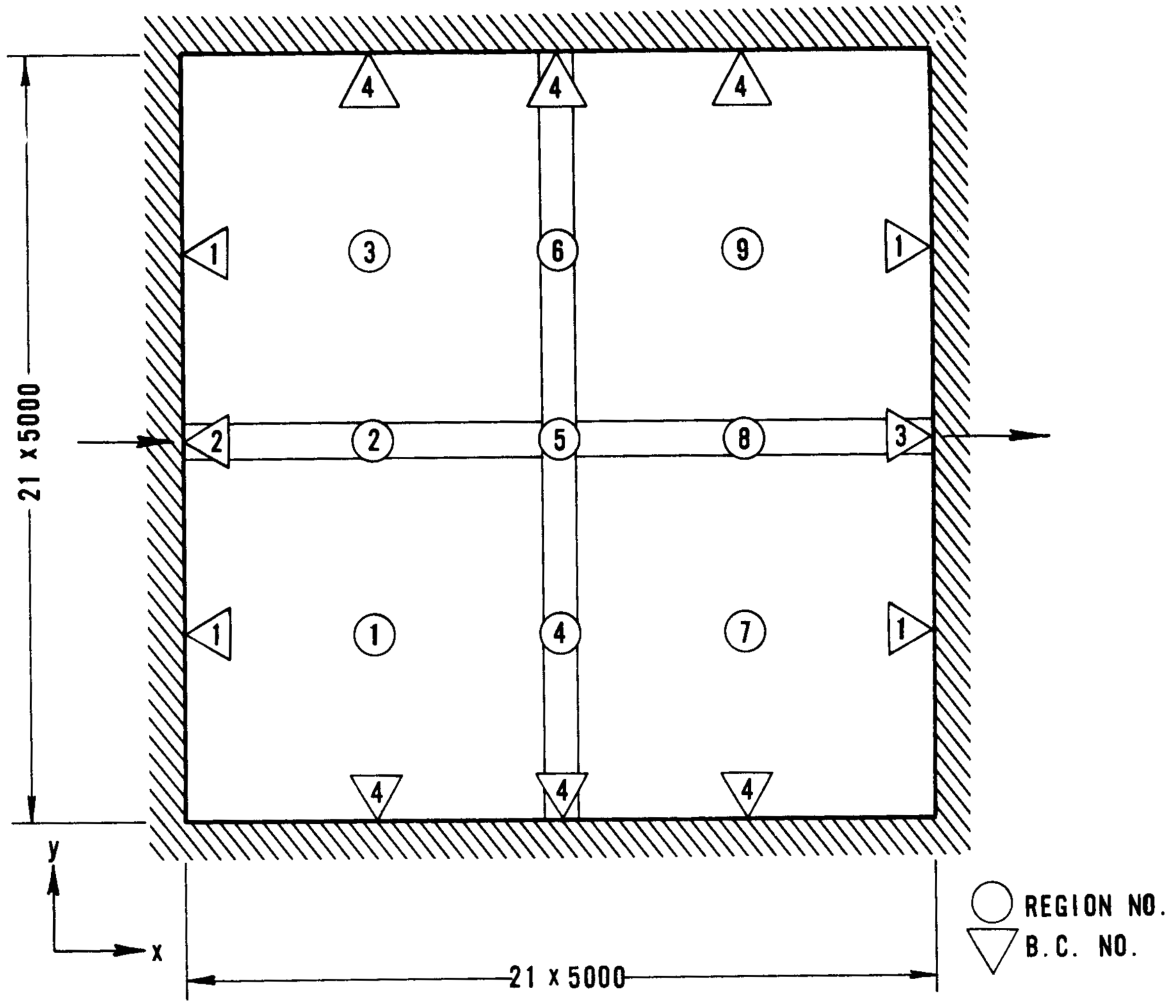
In order to save computer time, both sample problems have been run on a reduced version of the program which does not include constituent concentrations. However, a short-time run was made with the full version to demonstrate the capability of the program to calculate mass concentrations of a number of constituents in a water body.

7.3.1. Sample Problem No. 1

This case represents warm seawater (27 ppt salt concentration) flowing into and out of a rectangular water body. The overall dimensions of the water body are 105,000 by 105,000 ft. Initially, the water body is filled with a 40-ft depth of pure water at 80°F and completely at rest. Then a 30,000-cfs flow of water enters at the center of one bank with a velocity of 0.15 ft/sec at a temperature of 95°F and salt concentration of 27 ppt. At the center of the opposite bank there is an opening 5,000 ft wide which is kept at a constant level at 40.0 ft. As a result, symmetrical flow is initiated within the water body. The water elevation adjusts itself correspondingly. Figure 7.2 shows a schematic presentation of the case, including the specification of both initial and boundary conditions.

The modeled water body is subdivided into nine regions (although three regions could be sufficient for this specific case). Each region is defined by its own dimensions, initial conditions, volumetric generation conditions, bottom conditions, top surface conditions, and boundary conditions on its four edges. Boundary conditions 1 and 4 represent solid walls. These are assumed to be impermeable to both heat and mass. The normal velocity, V_n, at the wall is set to zero, while free-slip conditions are assumed for the tangential velocity, V_t. Water elevation is a free boundary and is specified as boundary condition type 4 (see Section 5). For the inlet (boundary condition 2) the values of velocities, temperature, and constituent mass concentrations are specified, while the water elevation is again left as boundary condition type 4. At the outlet (boundary condition 3) the water elevation is specified to be constantly 40.0 ft, and the exit velocity is specified as having zero gradient along the flow. The rest of the unknowns are left as boundary condition type 4.

The bottom is considered impermeable to both mass and heat. A Manning roughness coefficient of 0.03 sec/ft$^{1/3}$ is assumed for calculating the bottom shear stresses. On the top surface, rain and wind stresses are considered to be negligible. A constant value of



INITIAL CONDITIONS	B.C. 2	B.C. 3	B.C.'s 1 & 4
$H_0 = 40.0$ ft	$\partial^2 H/\partial x^2 = 0$	$H = 40.0$ ft	$\partial^2 H/\partial x^2 = 0$
$U_0 = 0.0$	$U = 540$ ft/hr	$\partial^2 U/\partial x^2 = 0$	$V_n = 0$
$V_0 = 0.0$	$V = 0.0$	$\partial^2 V/\partial x^2 = 0$	$\partial V_t/\partial n = 0$
$T_0 = 80.0°F$	$T = 95.0°F$	$\partial^2 T/\partial x^2 = 0$	$\partial T/\partial n = 0$
$C_k(1) = 1.0$	$C_k(1) = 0.973$	$\partial^2 C_k/\partial x^2 = 0$	$\partial C_k/\partial n = 0$
$C_k(2) = 0.0$	$C_k(2) = 0.027$		

Figure 7.2. Regions and boundary conditions arrangement in sample problem No. 1.

5 Btu/ft^2·hr·°F is considered for the heat exchange coefficient between the water surface and the atmosphere with 80.0°F equilibrium temperature.

The diffusion coefficients for mass, momentum, and heat were considered as the sum of molecular and turbulent coefficients. The turbulent diffusion coefficient was based on Elder's results[55] for isotropic turbulence. Evaluating the bottom shear stresses with a Manning coefficient of 0.03 sec/ft$^{1/3}$ gives (see Eq. 3.24)

$$\varepsilon = 0.07Hu_\tau = 0.0043H\sqrt{U^2 + V^2} \ . \qquad (7.2)$$

The shear effects caused by velocity variations in the lateral direction, which, as claimed by Fischer,[56,57] are very important in one-dimensional models, do not have to be considered here, since the model is two dimensional and the velocity variations in the lateral direction and the proper normal and shear stresses are properly included in the model itself.

Some shear effects caused by velocity variations with depth must be added to the above diffusion coefficient. However, since the correct formulation for continuous discharges is not available, it was decided to conservatively use Eq. 7.2 as it is.

An actual printout of the computer runs made for this sample problem, with the full version and the reduced version, is given in Appendix A. The input information is printed out in full, while the output results are printed here only for two times--one for the full version and one for the reduced version.

The results of the run were plotted for a number of successive times and are shown in Figures 7.3 to 7.27. A discussion of these results is given in Section 7.3.3.

7.3.2. Sample Problem No. 2

This case represents two power plants located on the same water body where the flow is oscillating in nature. The overall dimensions of the water body are 4,500 ft by 178,500 ft. Initially the water body is filled with a 40-ft depth of water at 80°F and completely at rest. Then a 4,000-cfs flow of water comes in at the center of one narrow bank with a velocity of 0.2 ft/sec and at a temperature of 80°F. At the opposite bank the water elevation is oscillating sinusoidally as

$$H = 40 + 2.25 \sin 2\pi(t/T) \ , \tag{7.3}$$

where t is the instantaneous time and T is the cycle period. This behavior simulates the mouth of an estuary, with a tidal period of 12.4 hours. Figure 7.28 shows a schematic presentation of the case and its initial and boundary conditions. Two power plants are simulated on the two opposing longer banks of the water body. Each power plant discharges about 2,480 cfs of water (7 ppt salt concentration) at a velocity of about 0.125 ft/sec perpendicular to the shoreline and about 8.33×10^9 Btu/hr of heat. The intake of each power plant is about 1,500 ft upstream of its discharge point. Recirculation is properly taken into account since the intake temperature is the actual temperature existing at any time at the intake element. The discharge temperature

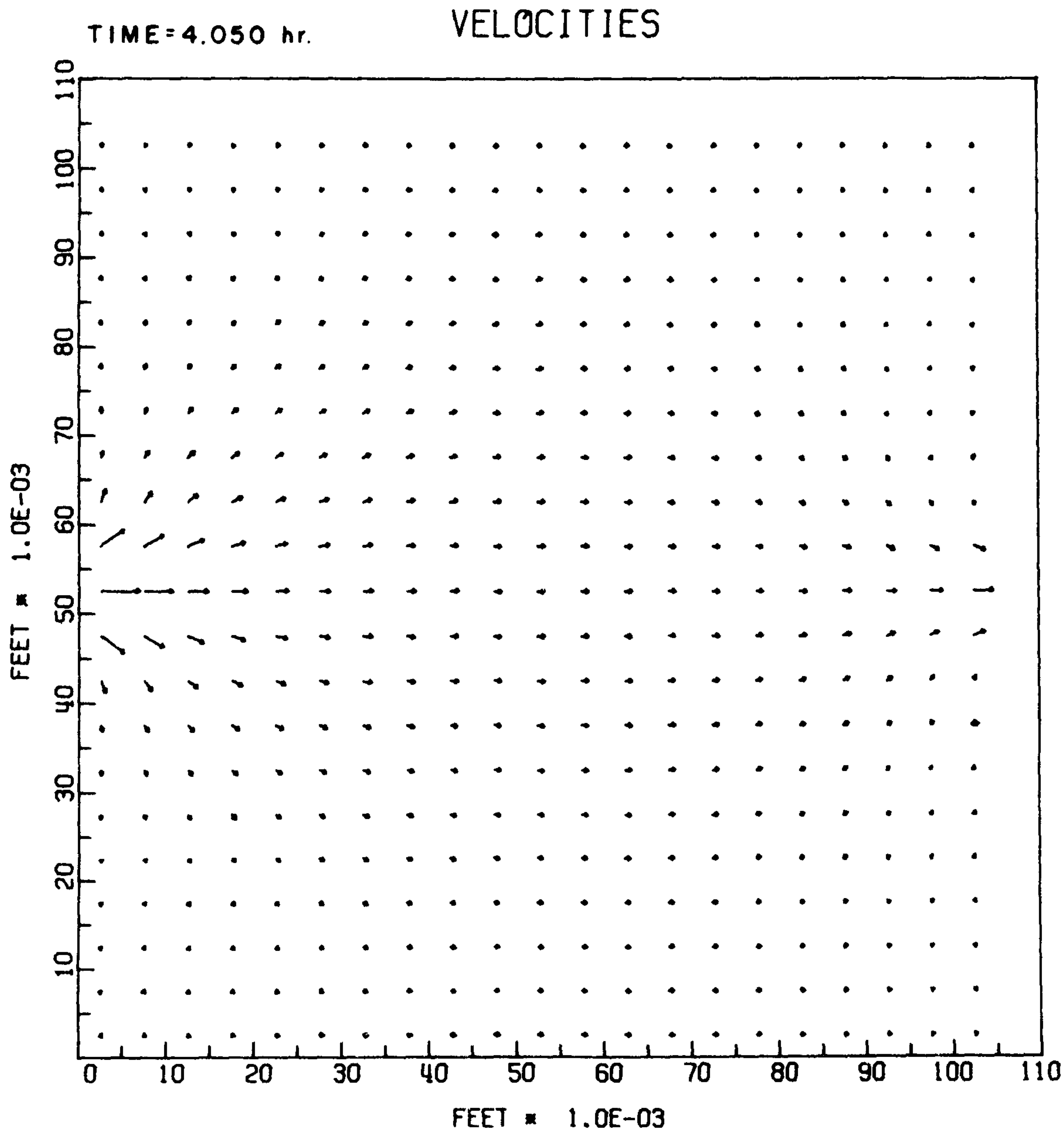


Figure 7.3. Velocity distribution (ft/hr) for sample problem No. 1 at time = 2.050 hr.

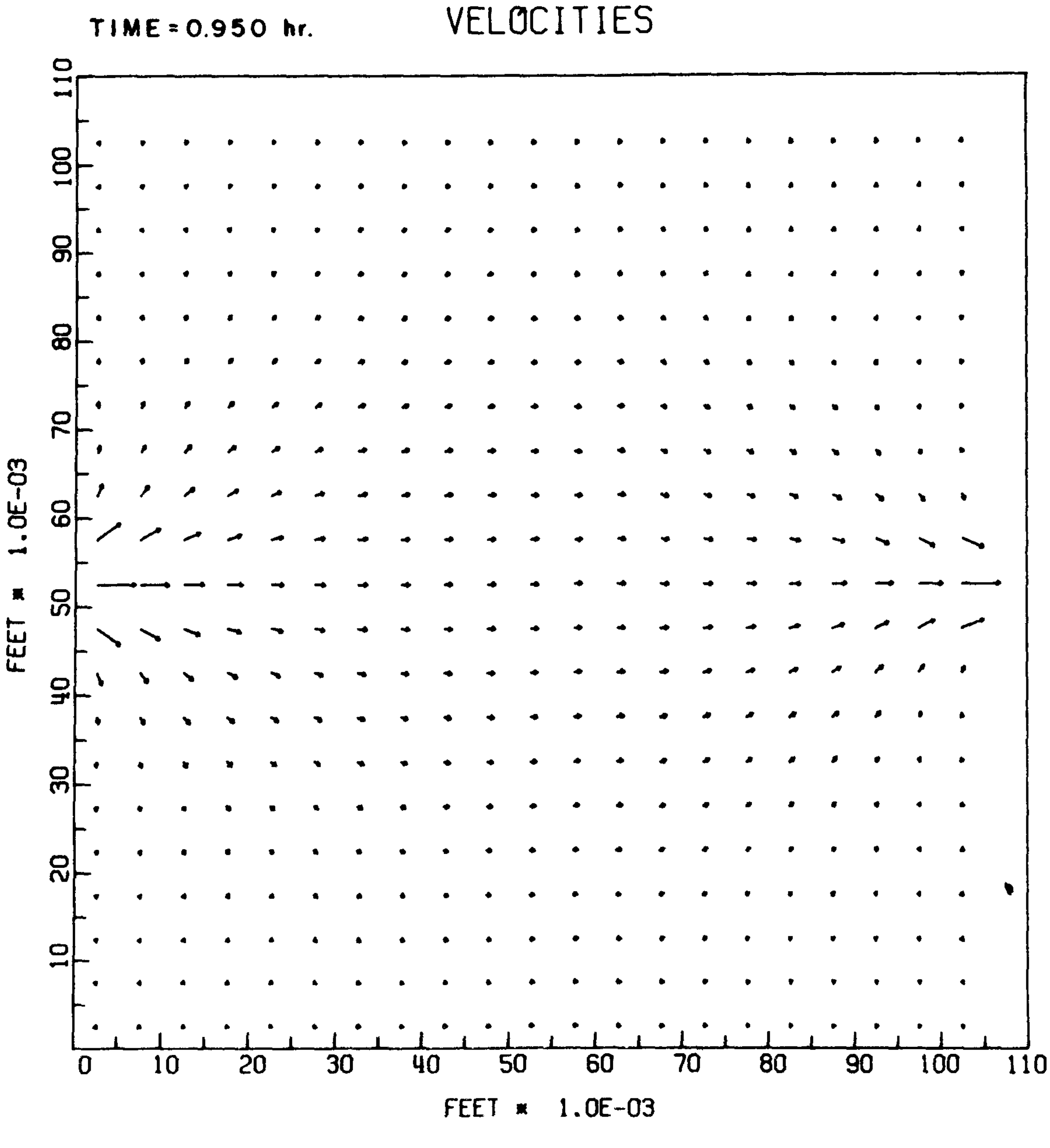


Figure 7.4. Velocity distribution (ft/hr) for sample problem No. 1 at time = 10.950 hr.

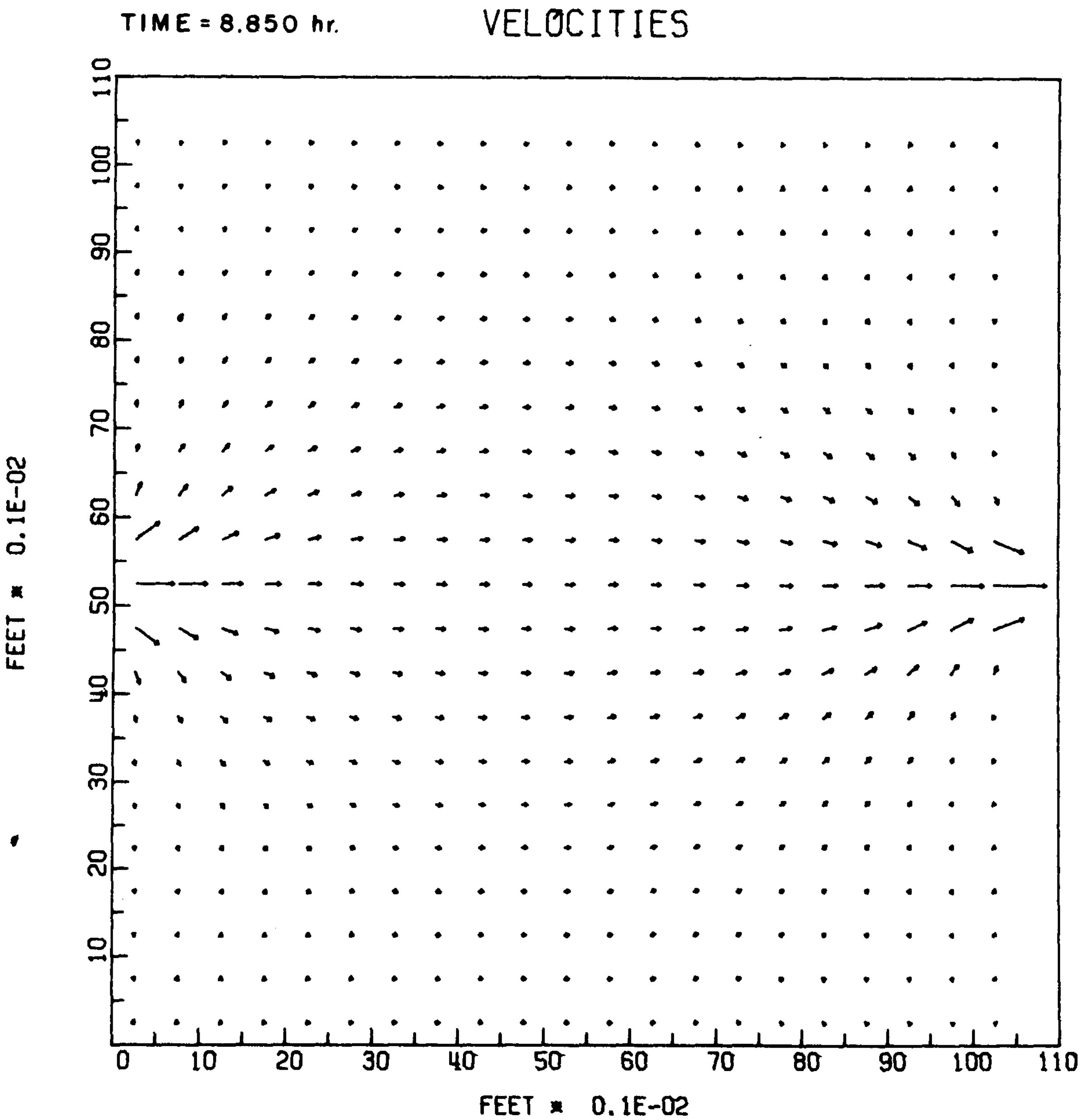


Figure 7.5. Velocity distribution (ft/hr) for sample problem No. 1 at time = 118.850 hr.

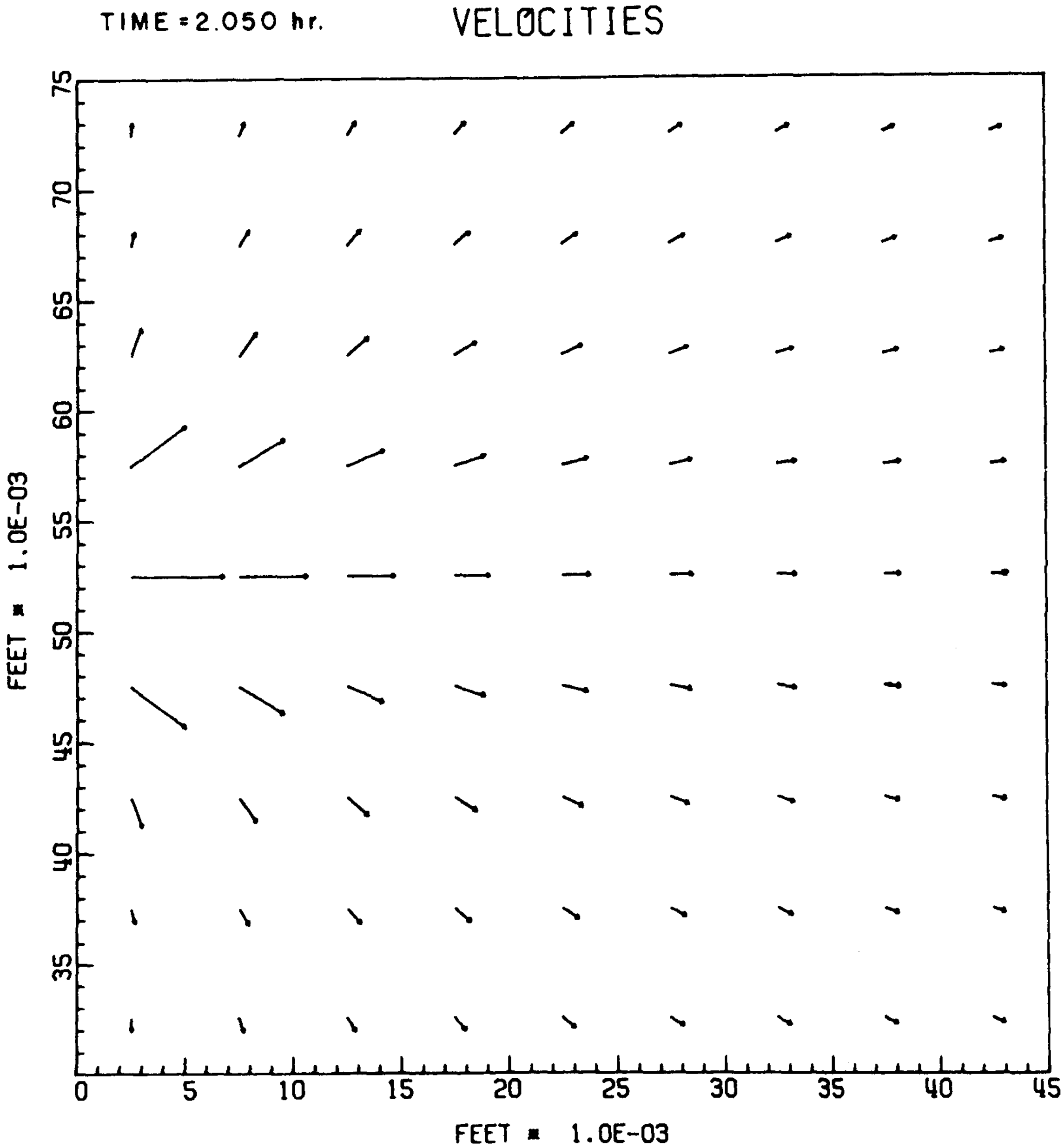


Figure 7.6. Velocity distribution (ft/hr) at the zone of discharge for sample problem No. 1 at time = 2.050 hr.

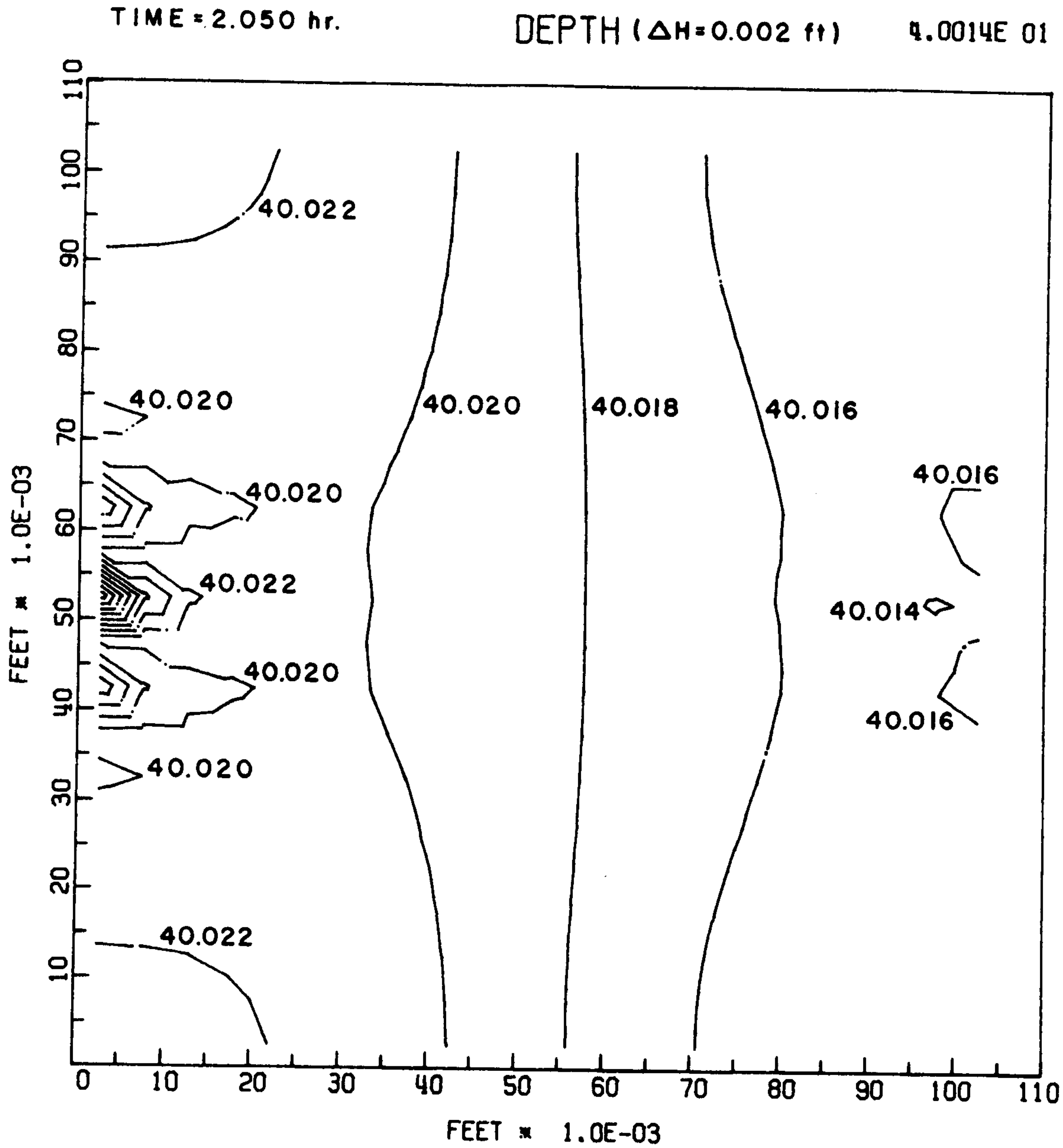


Figure 7.7. Water depth distribution (ft) for sample problem No. 1 at time = 2.050 hr.

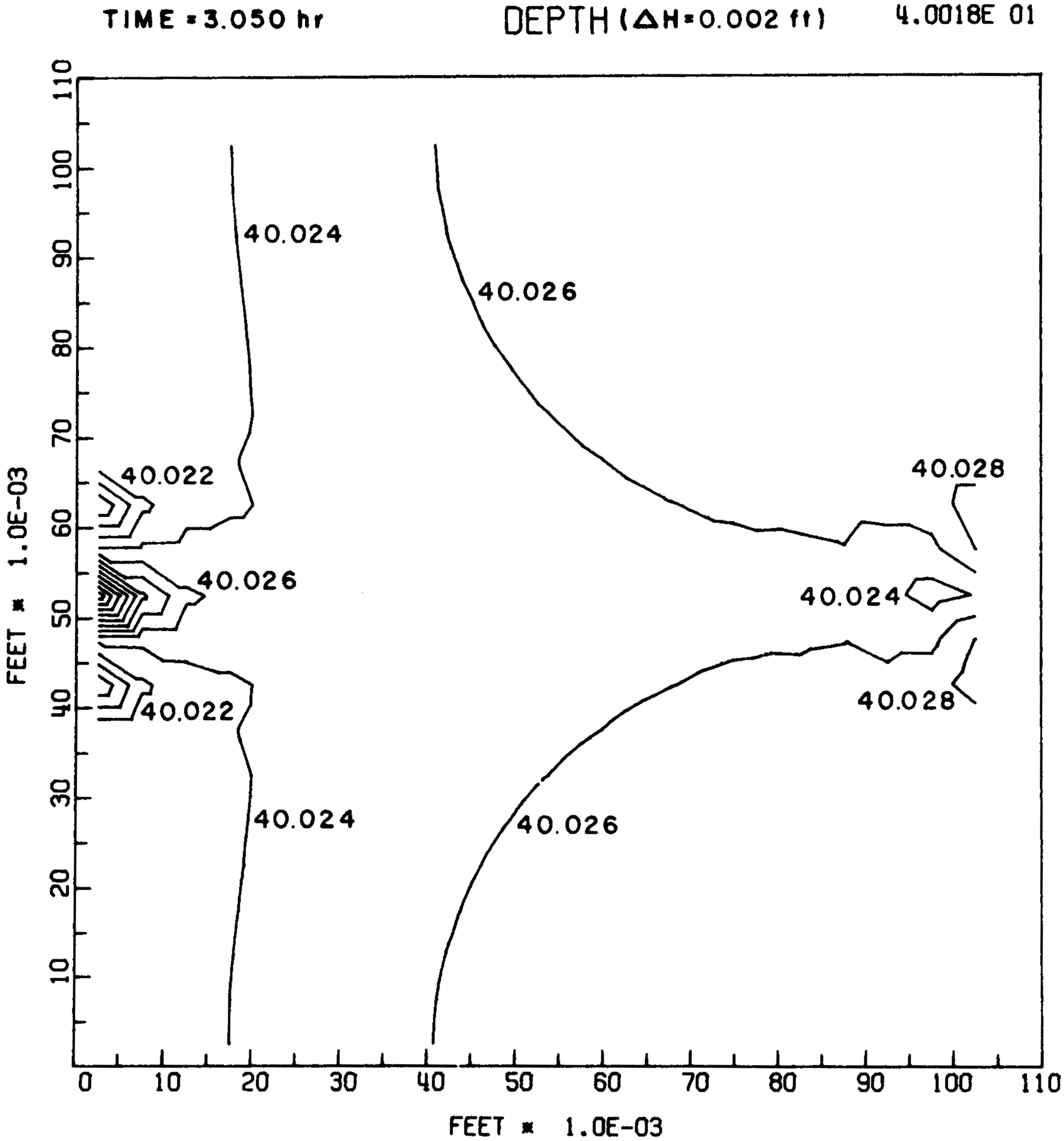


Figure 7.8. Water depth distribution (ft) for sample problem No. 1 at time = 3.050 hr.

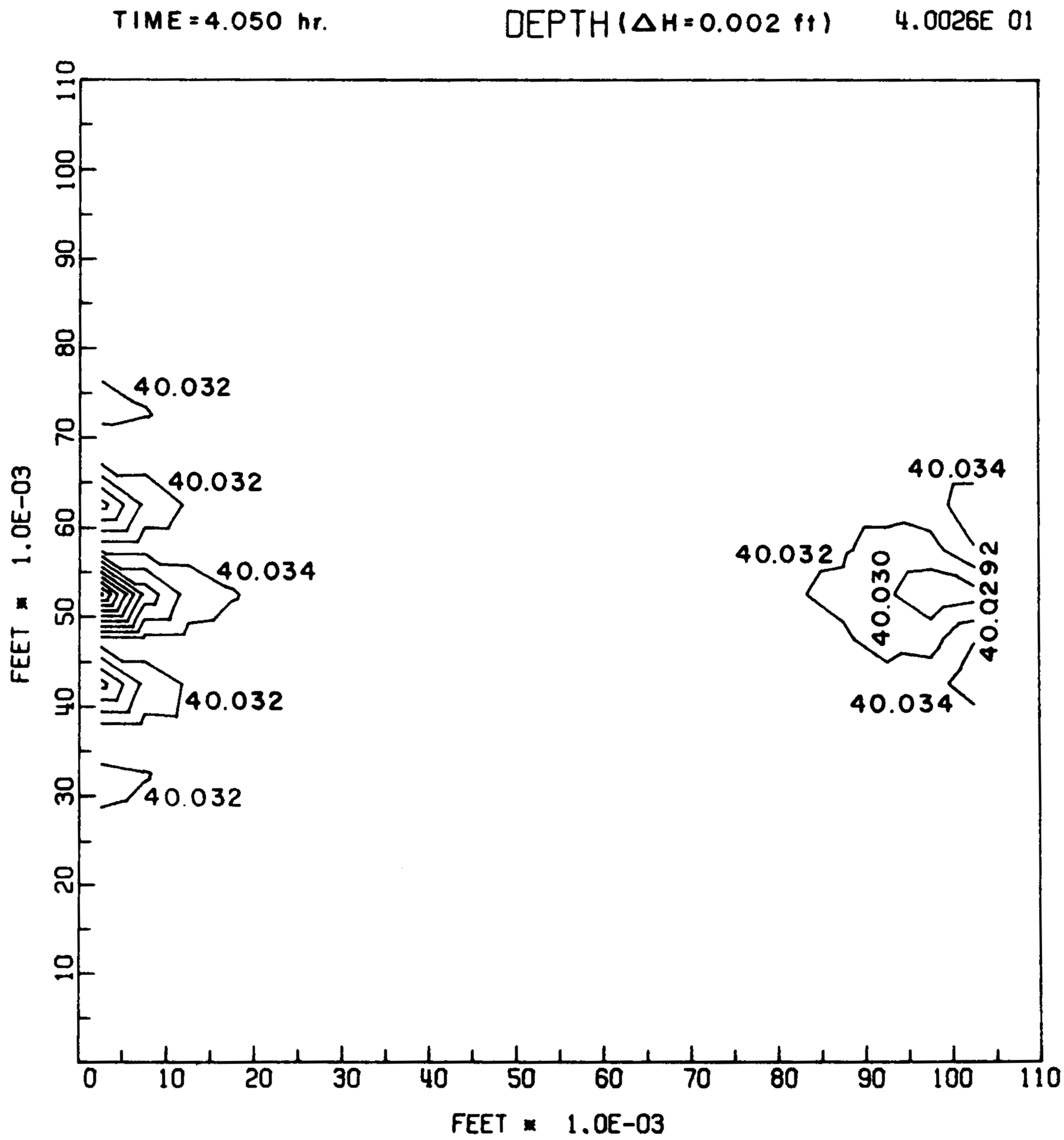


Figure 7.9. Water depth distribution (ft) for sample problem No. 1 at time = 4.050 hr.

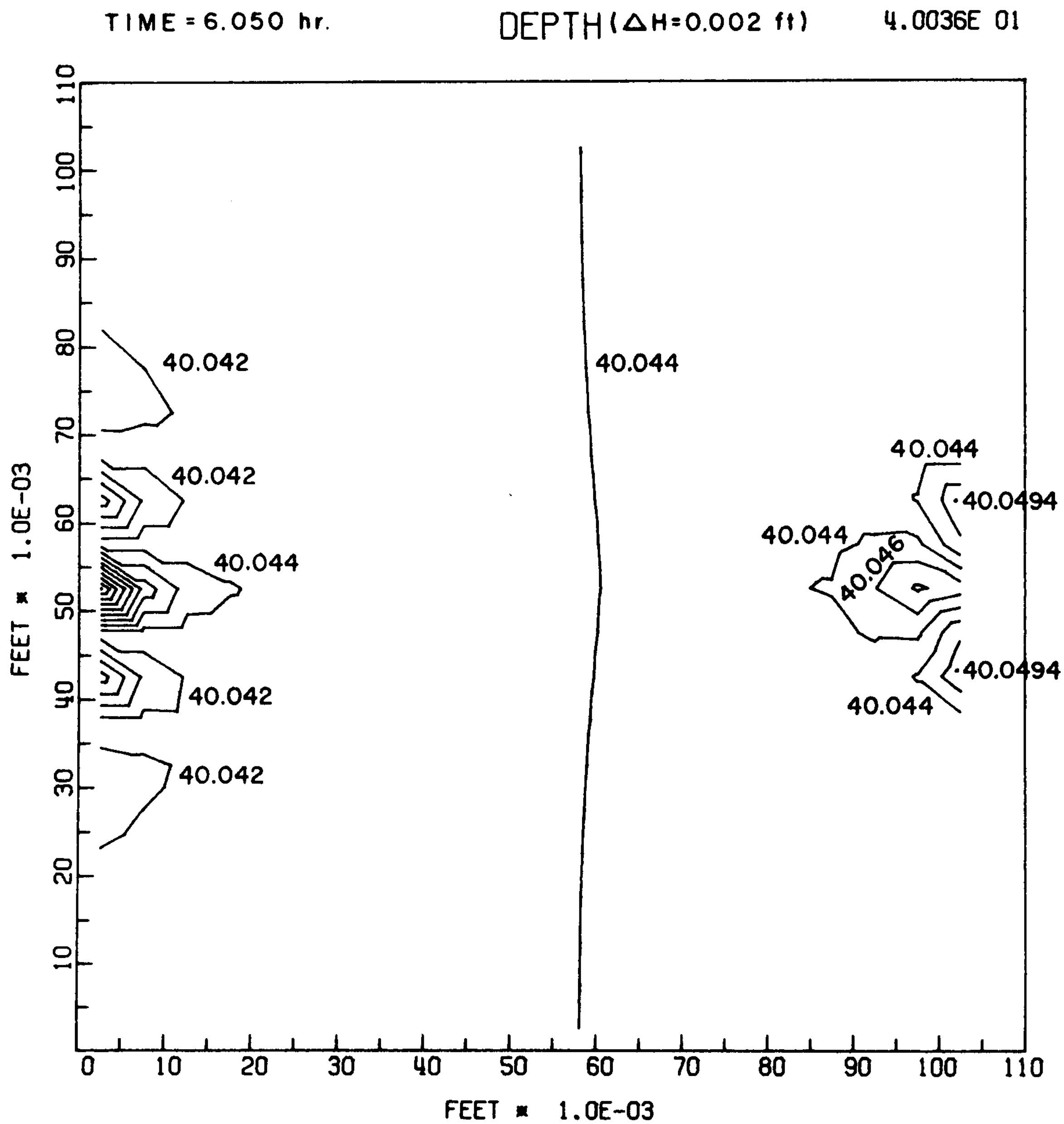


Figure 7.10. Water depth distribution (ft) for sample problem No. 1 at time = 5.050 hr.

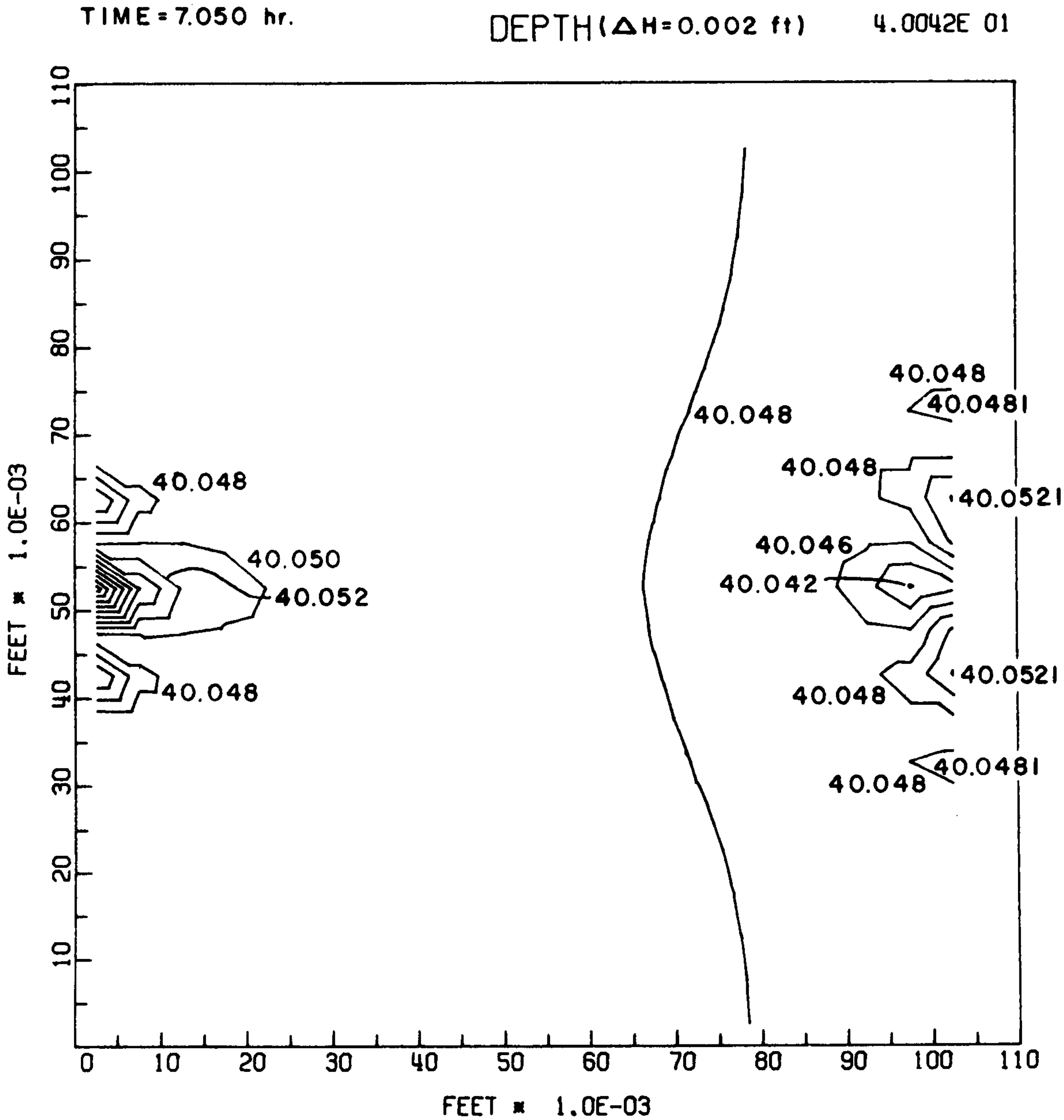


Figure 7.11. Water depth distribution (ft) for sample problem No. 1 at time = 7.050 hr.

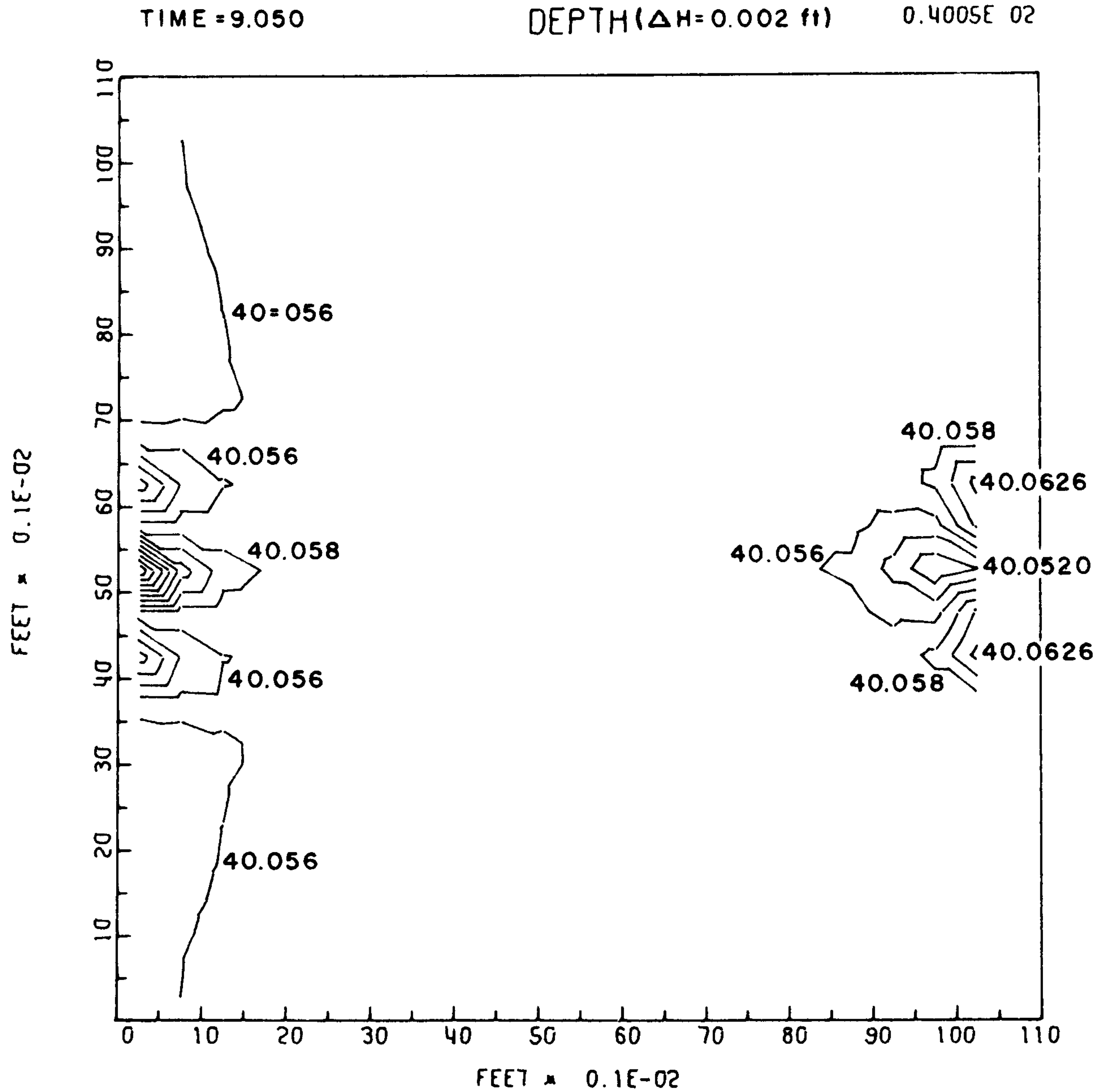


Figure 7.12. Water depth distribution (ft) for sample problem No. 1 at time = 9.050 hr.

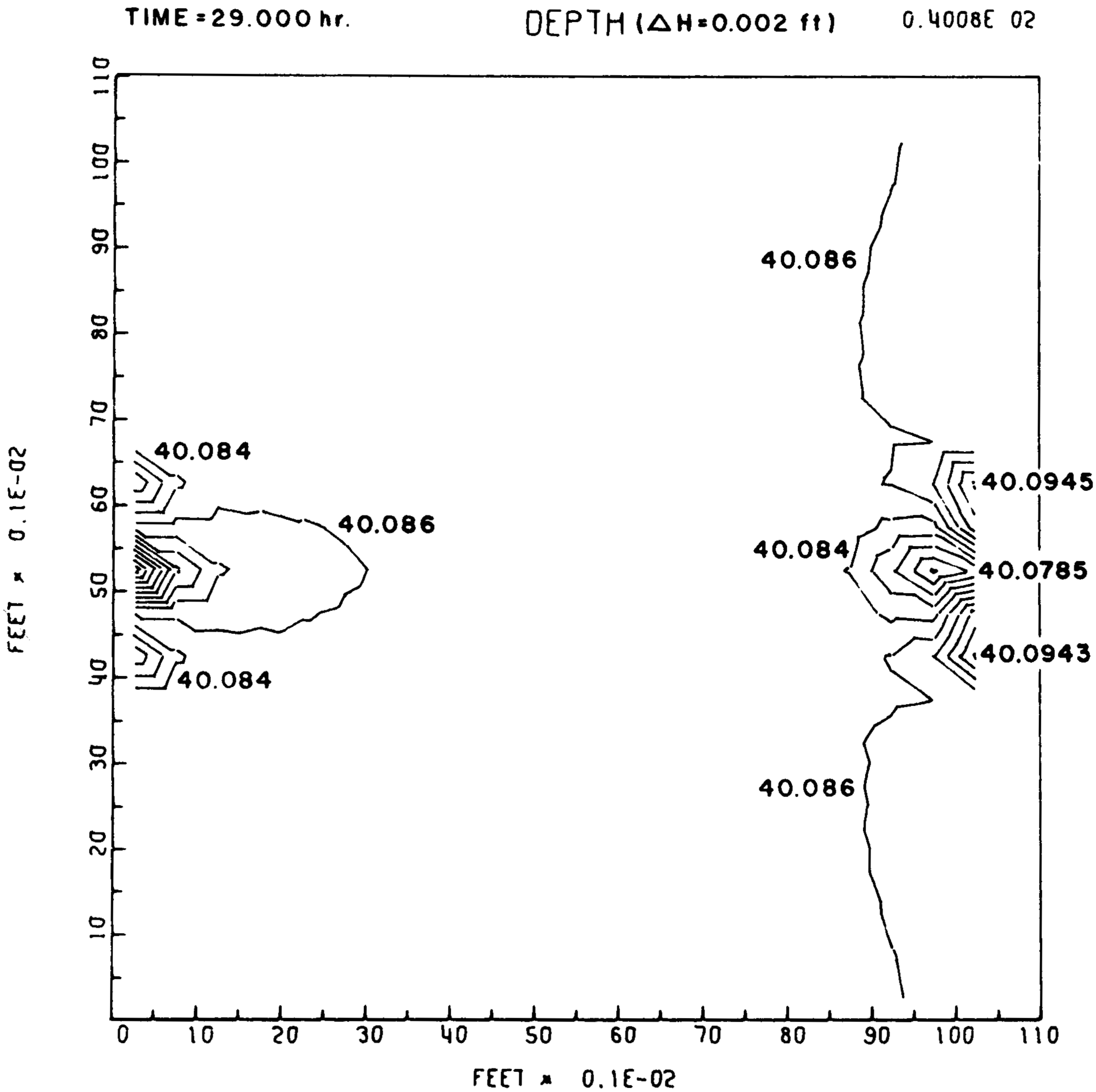


Figure 7.13. Water depth distribution (ft) for sample problem No. 1 at time = 29.000 hr.

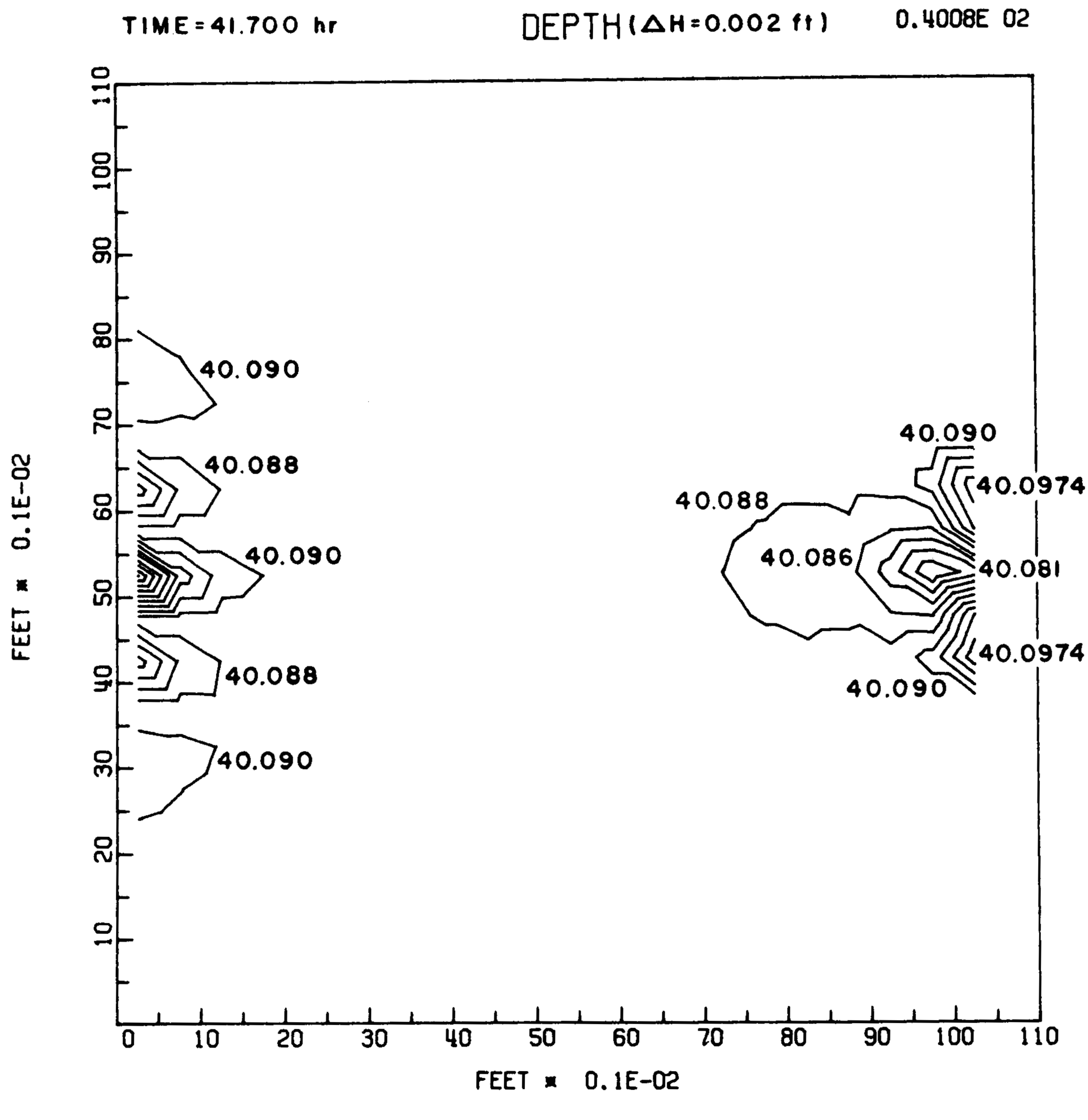


Figure 7.14. Water depth distribution (ft) for sample problem No. 1 at time = 41.7 hr.

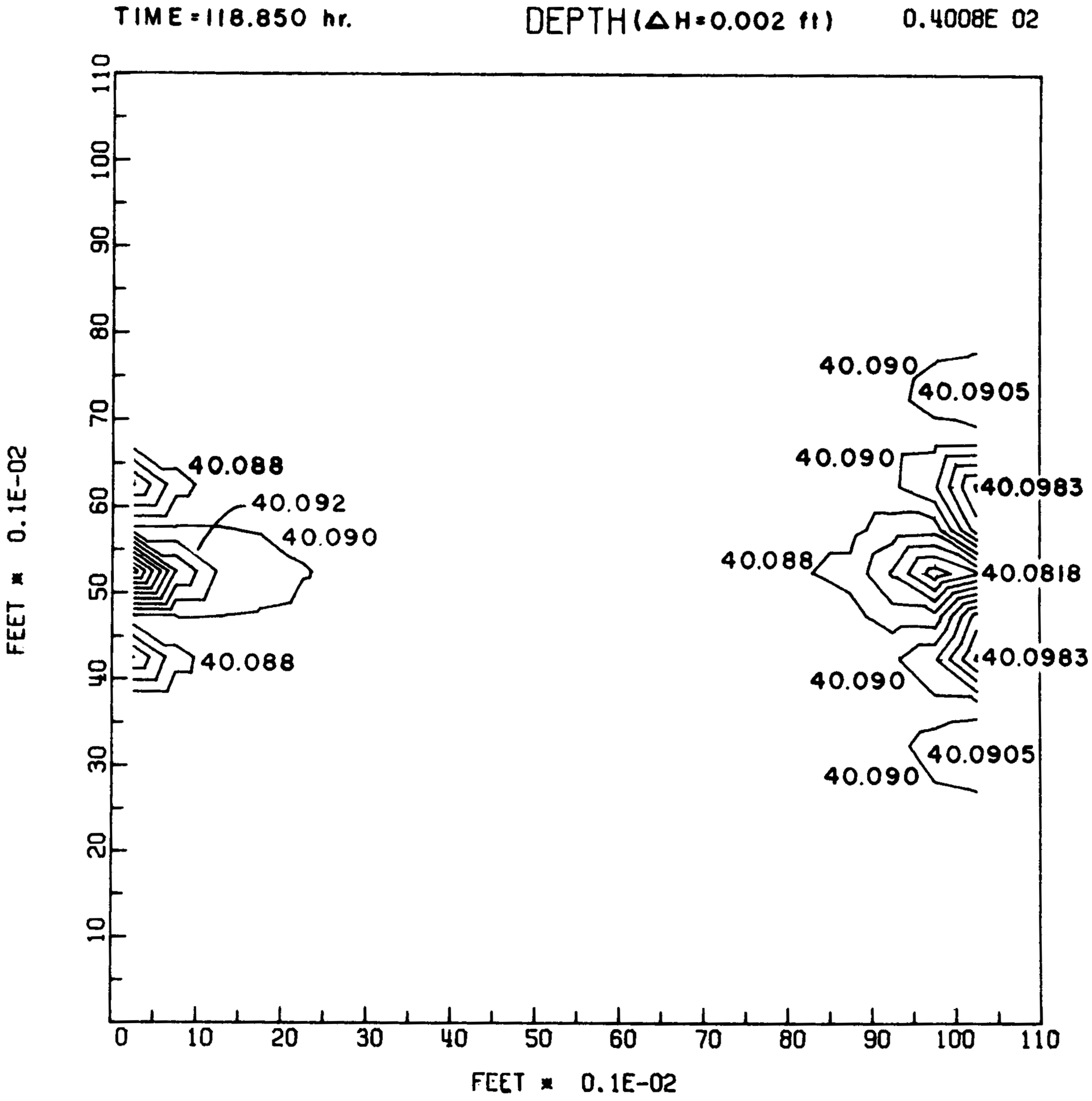


Figure 7.15. Water depth distribution (ft) for sample problem No. 1 at time = 118.85 hr.

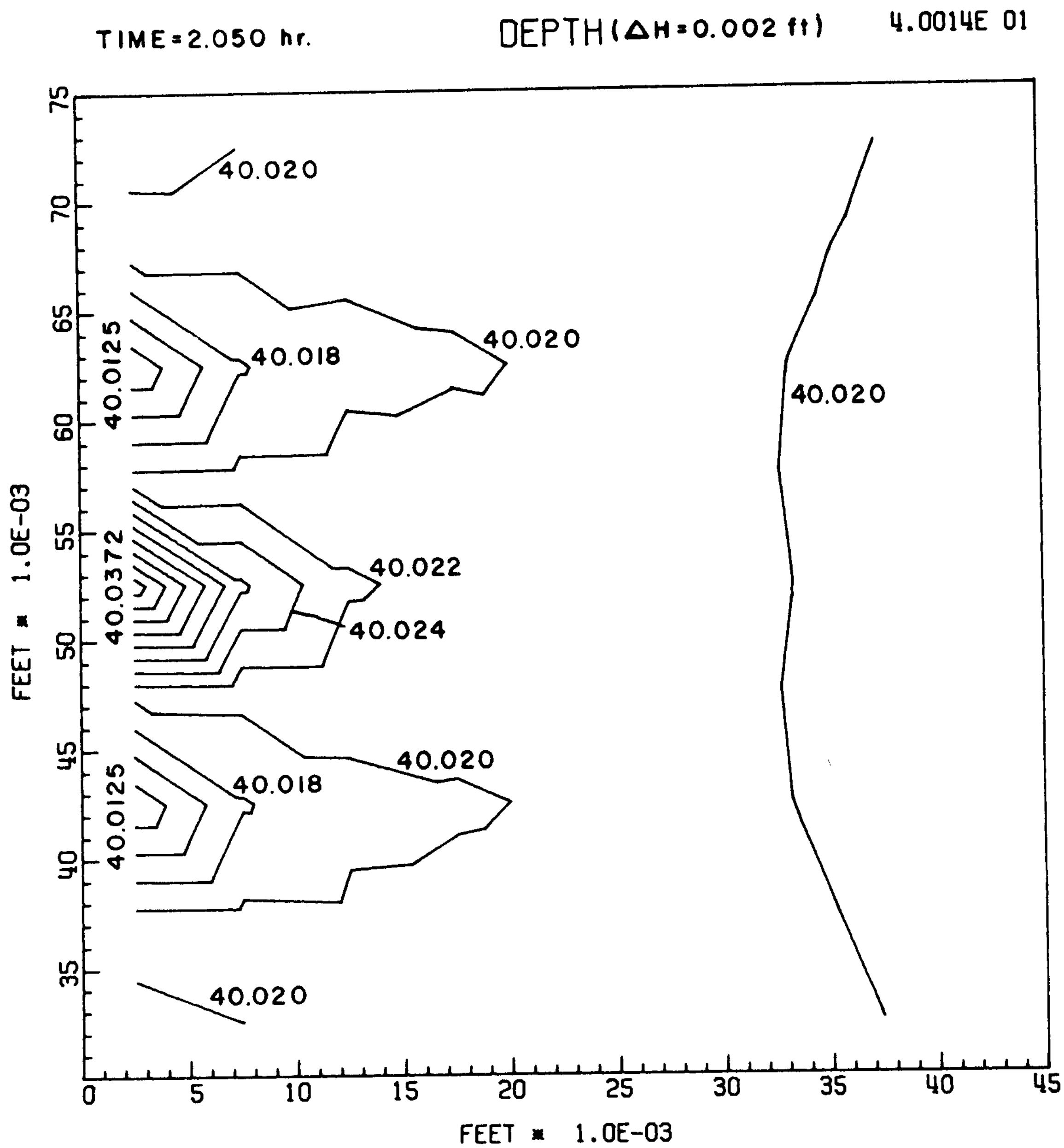


Figure 7.16. Water depth distribution (ft) at the zone of discharge for sample problem No. 1 at time = 2.050 hr.

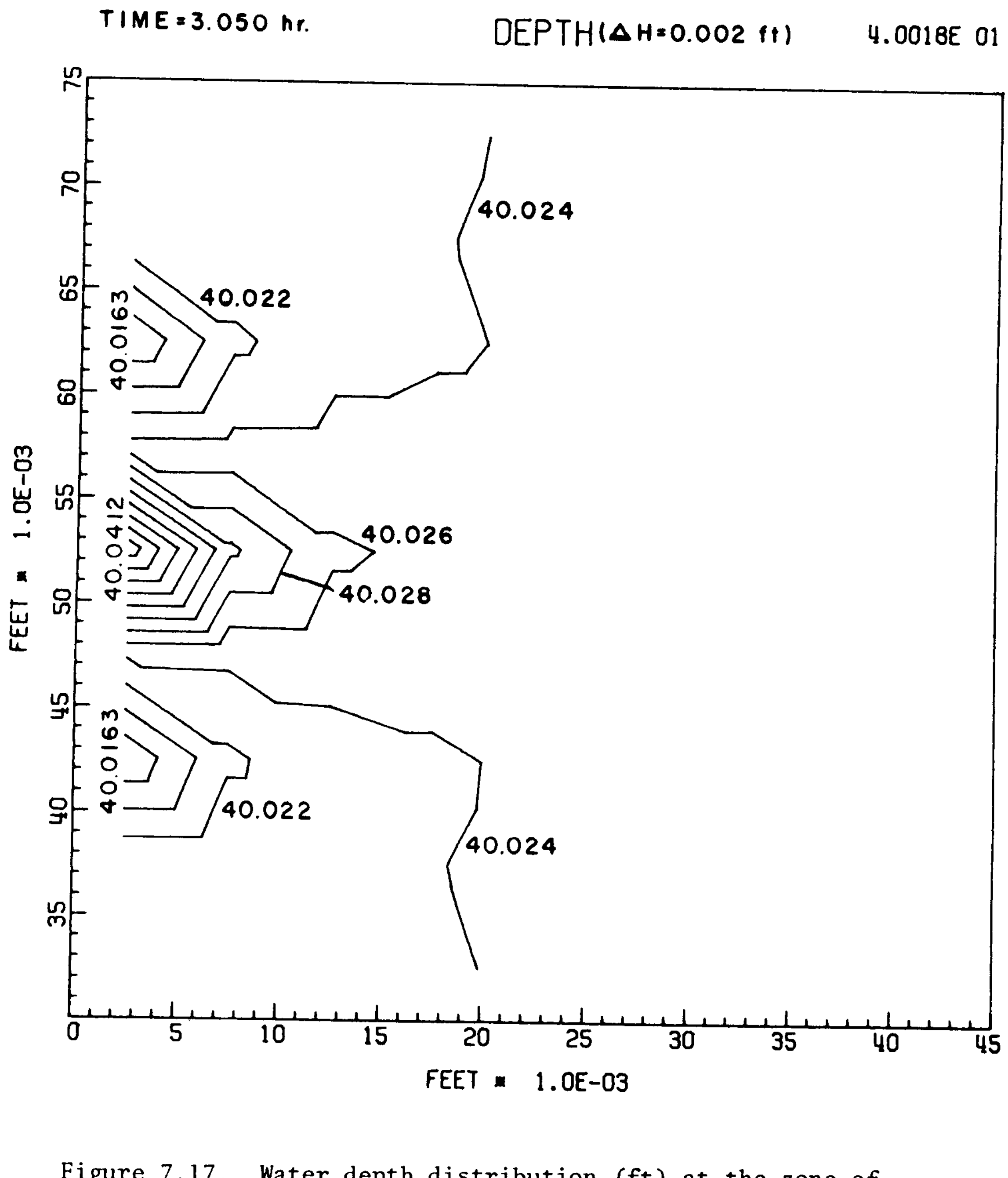


Figure 7.17. Water depth distribution (ft) at the zone of discharge for sample problem No. 1 at time = 3.050 hr.

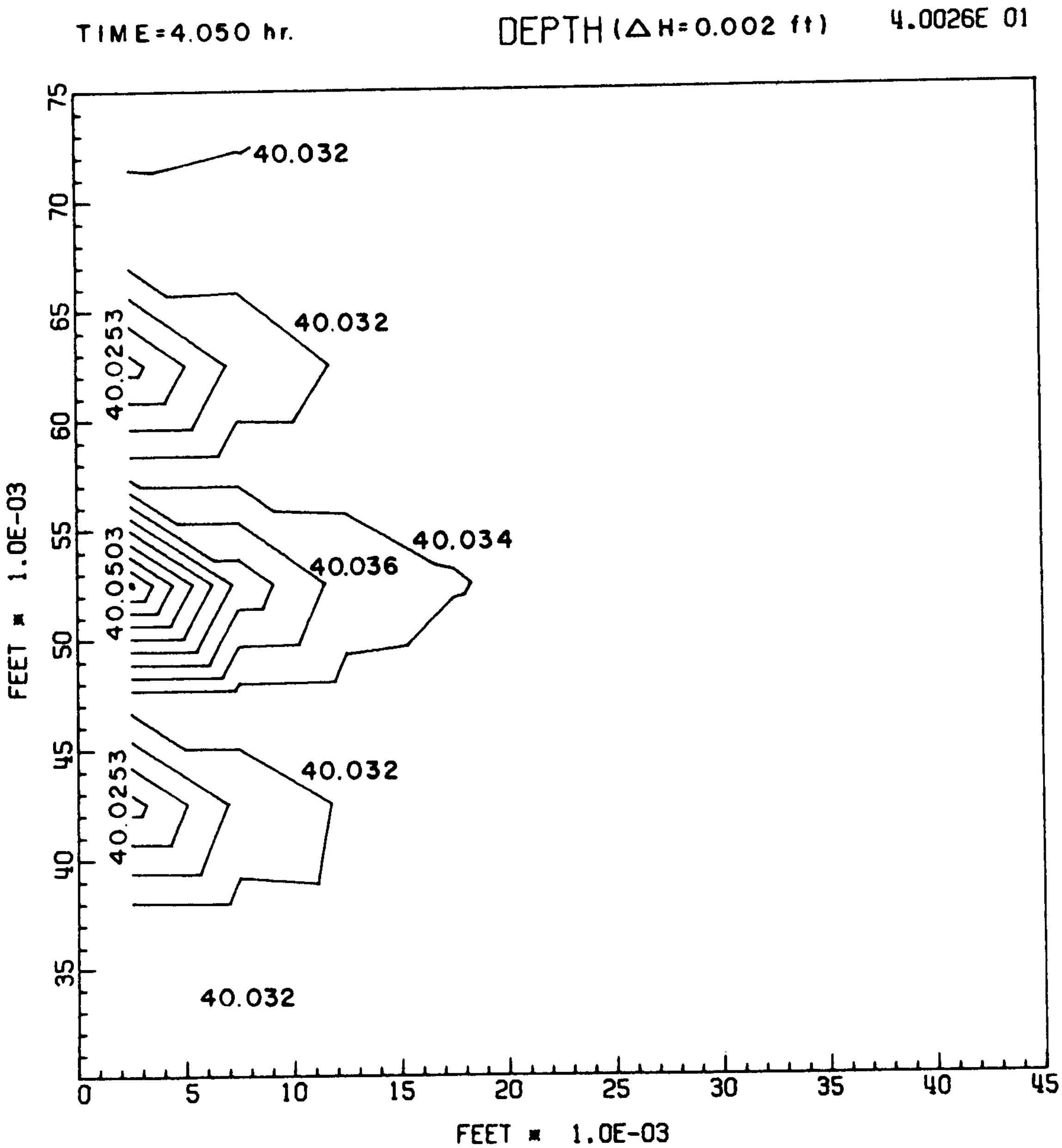


Figure 7.18. Water depth distribution (ft) at the zone of discharge for sample problem No. 1 at time = 4.050 hr.

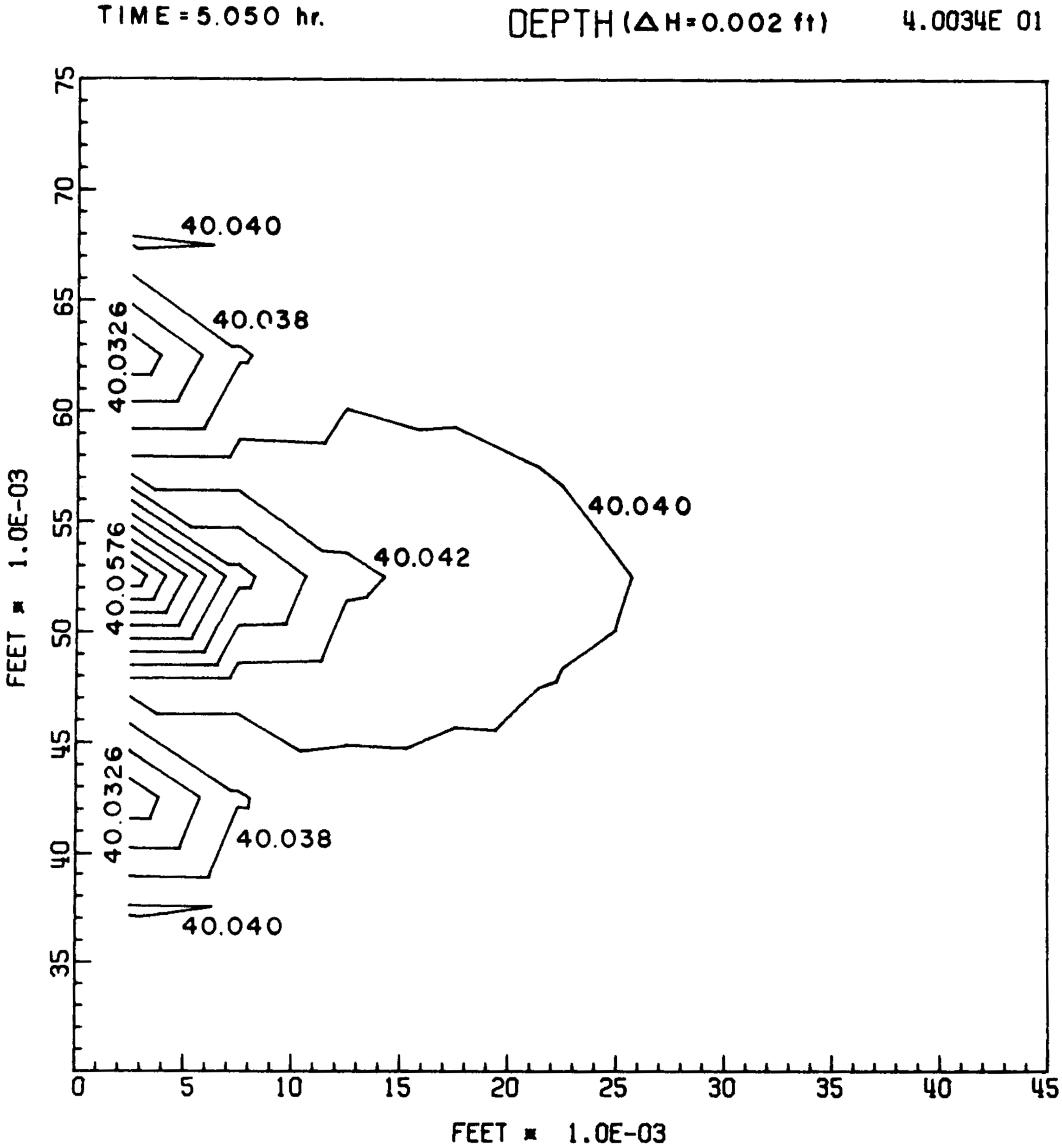


Figure 7.19. Water depth distribution (ft) at the zone of discharge for sample problem No. 1 at time = 5.050 hr.

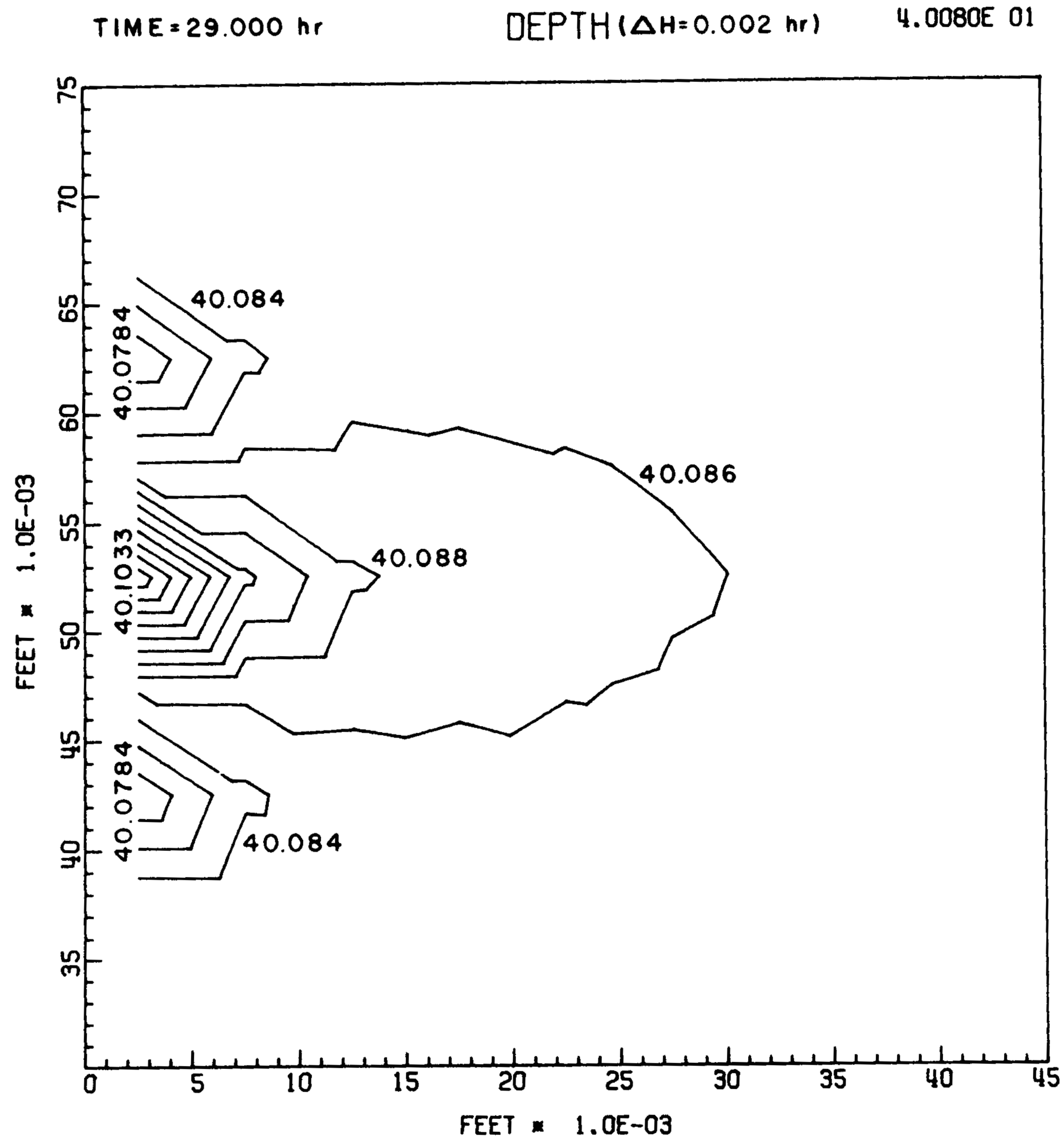


Figure 7.20. Water depth distribution (ft) at the zone of discharge for sample problem No. 1 at time = 29.00 hr.

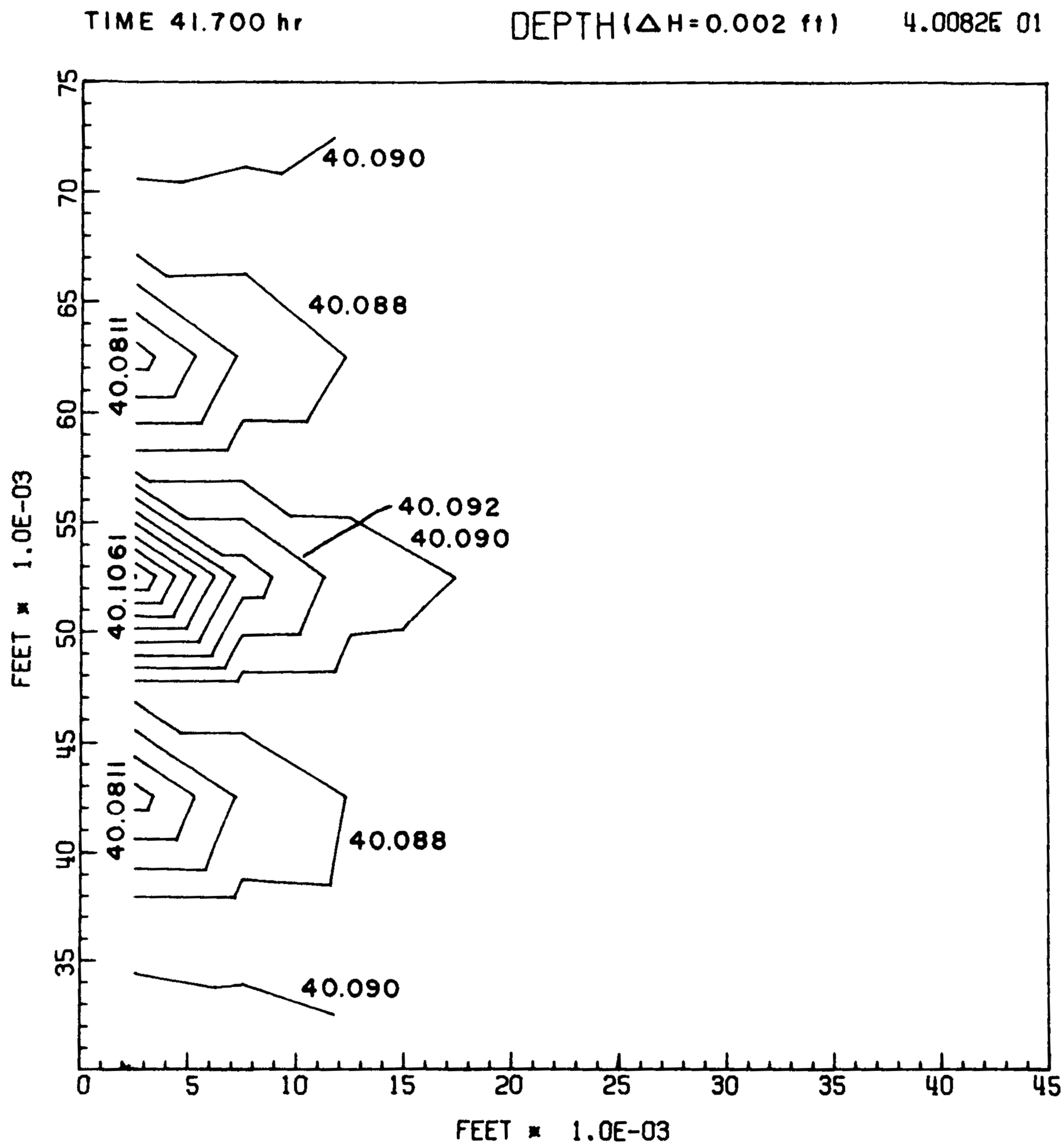


Figure 7.21. Water depth distribution (ft) at the zone of discharge for sample problem No. 1 at time = 41.700 hr.

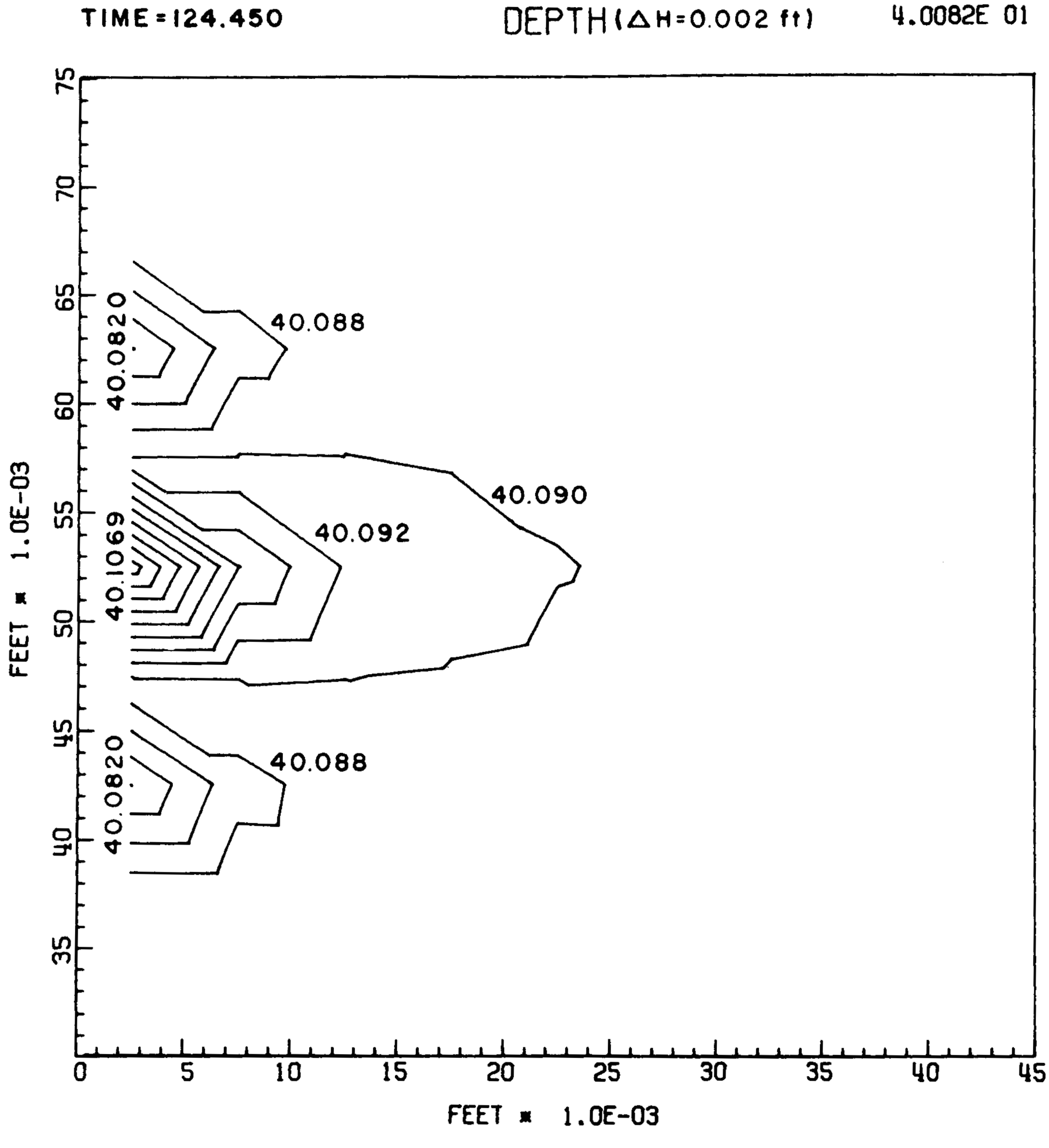


Figure 7.22. Water depth distribution (ft) at the zone of discharge for sample problem No. 1 at time = 124.450 hr.

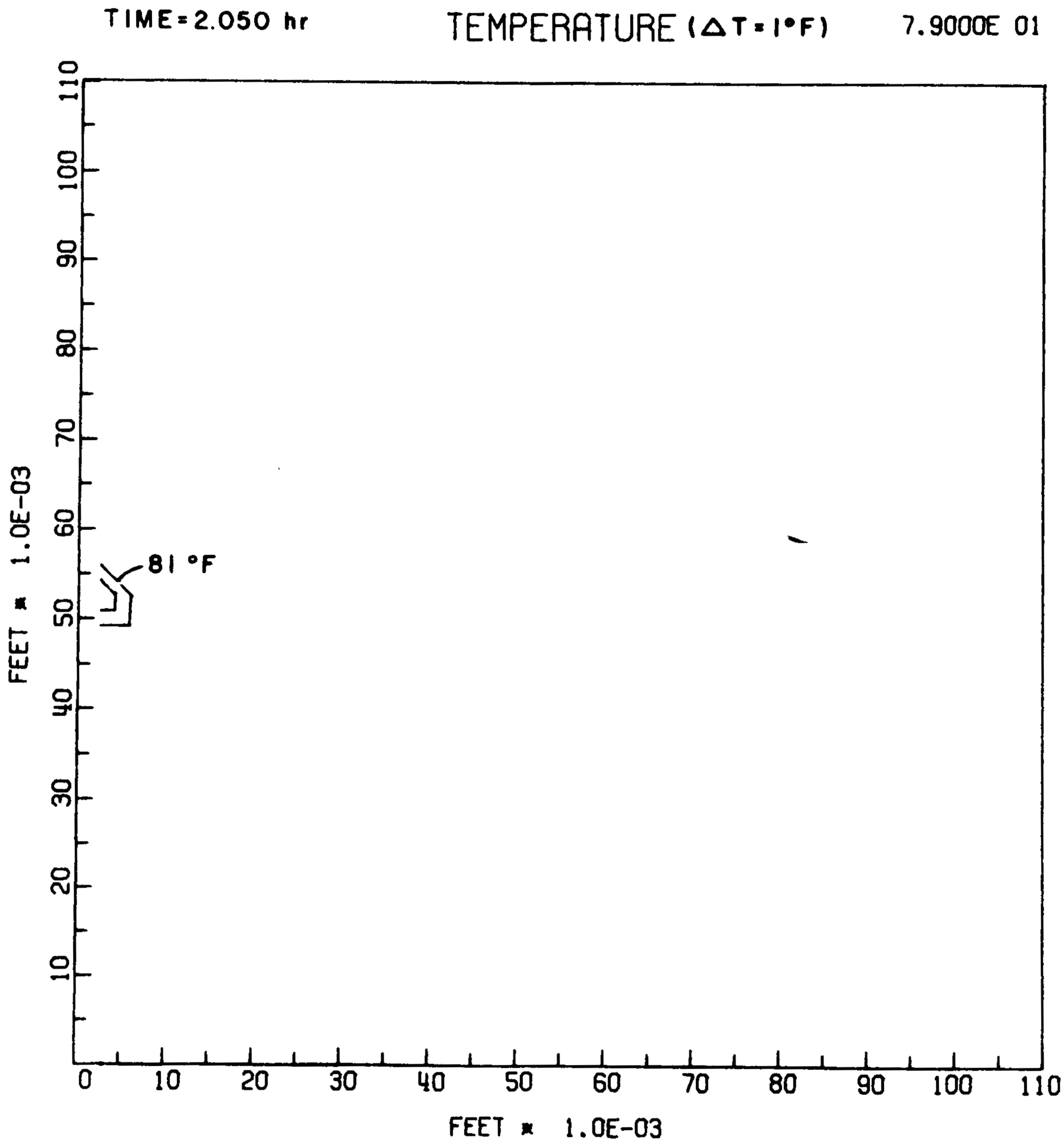


Figure 7.23. Temperature distribution (°F) for sample problem No. 1 at time = 2.05 hr.

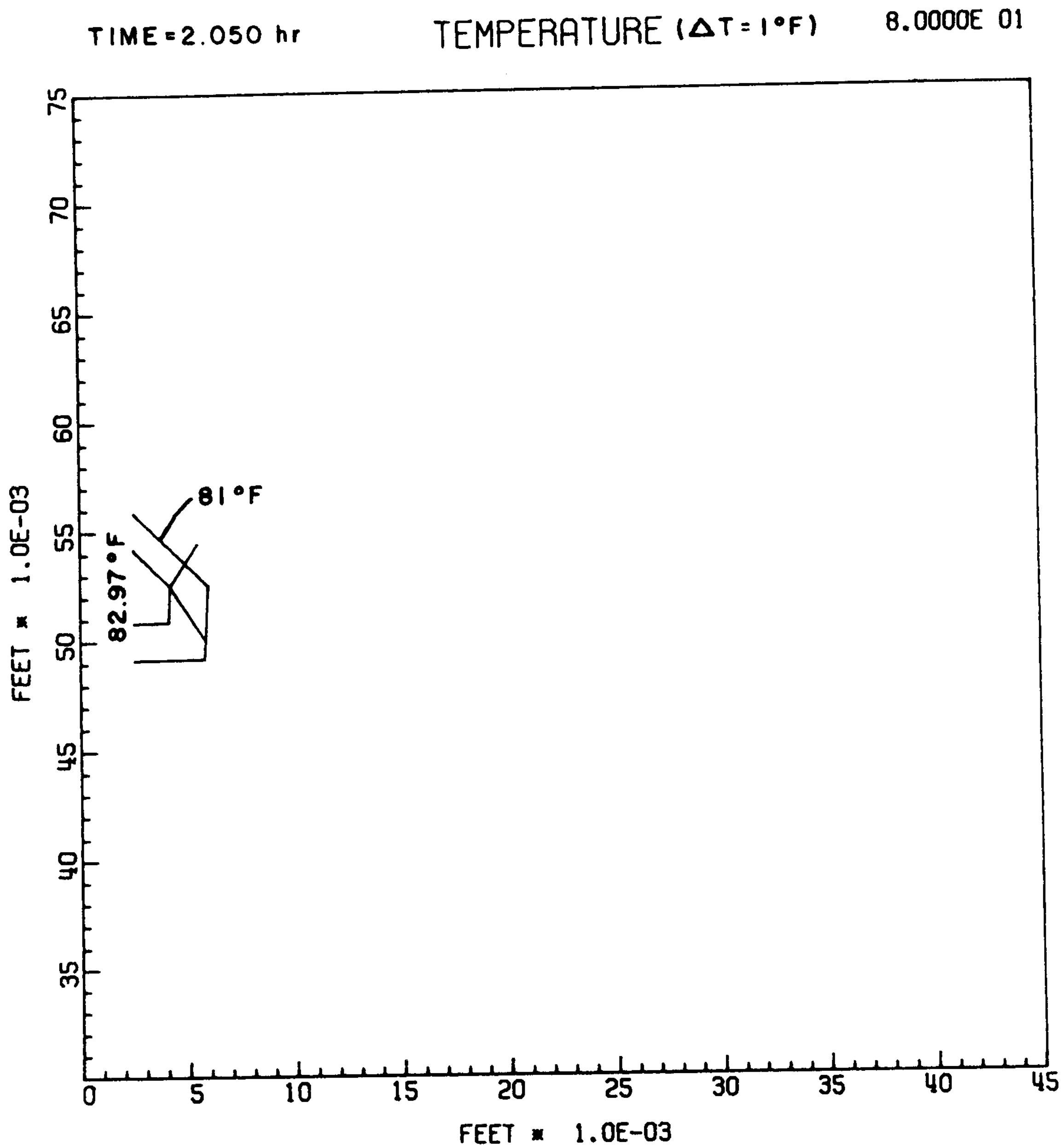


Figure 7.24. Temperature distribution (°F) at the zone of discharge for sample problem No. 1 at time = 2.050 hr.

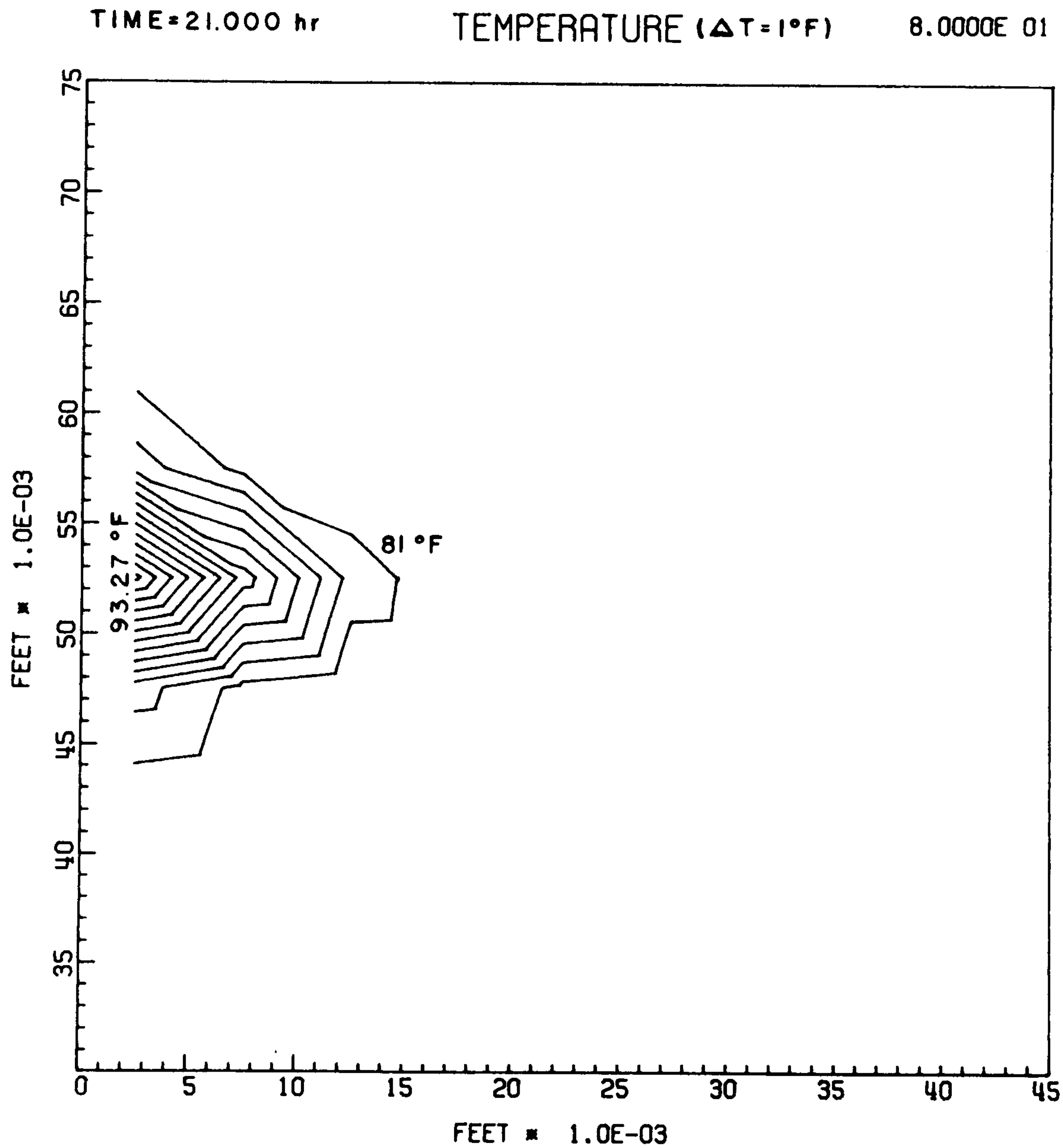


Figure 7.25. Temperature distribution (°F) at the zone of discharge for sample problem No. 1 at time = 21.0 hr.

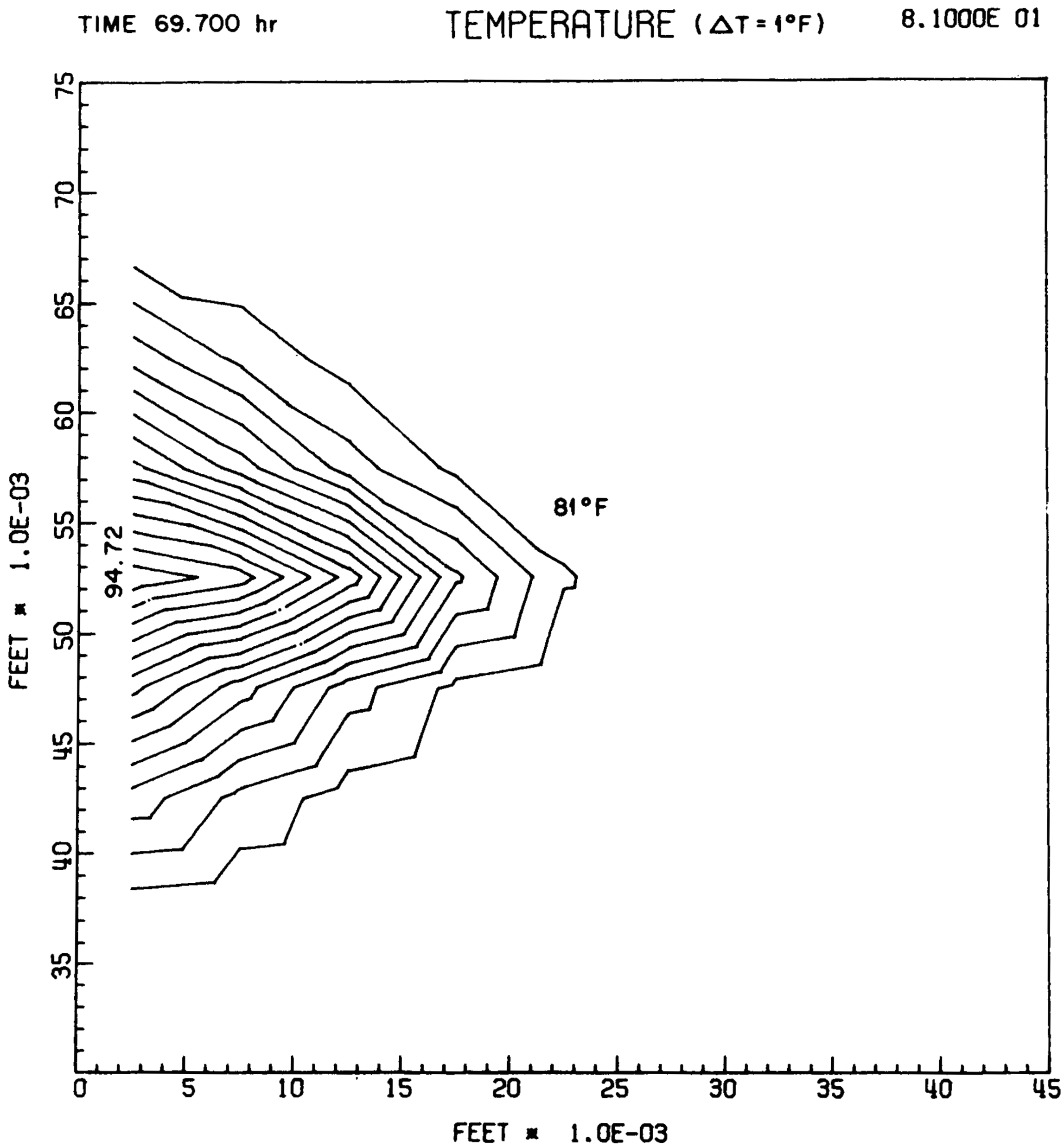


Figure 7.26. Temperature distribution (°F) at the zone of discharge for sample problem No. 1 at time = 69.7 hr.

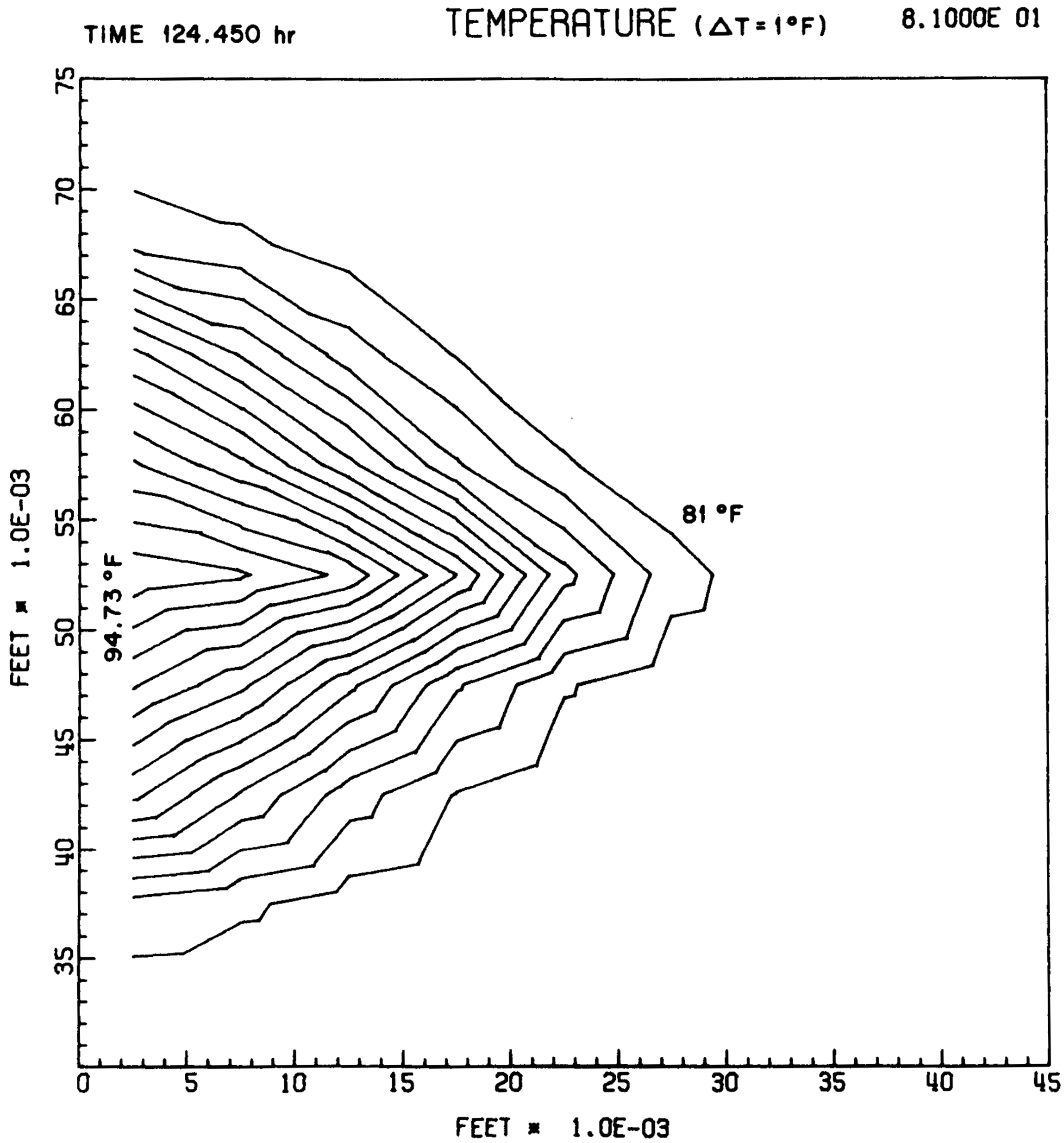
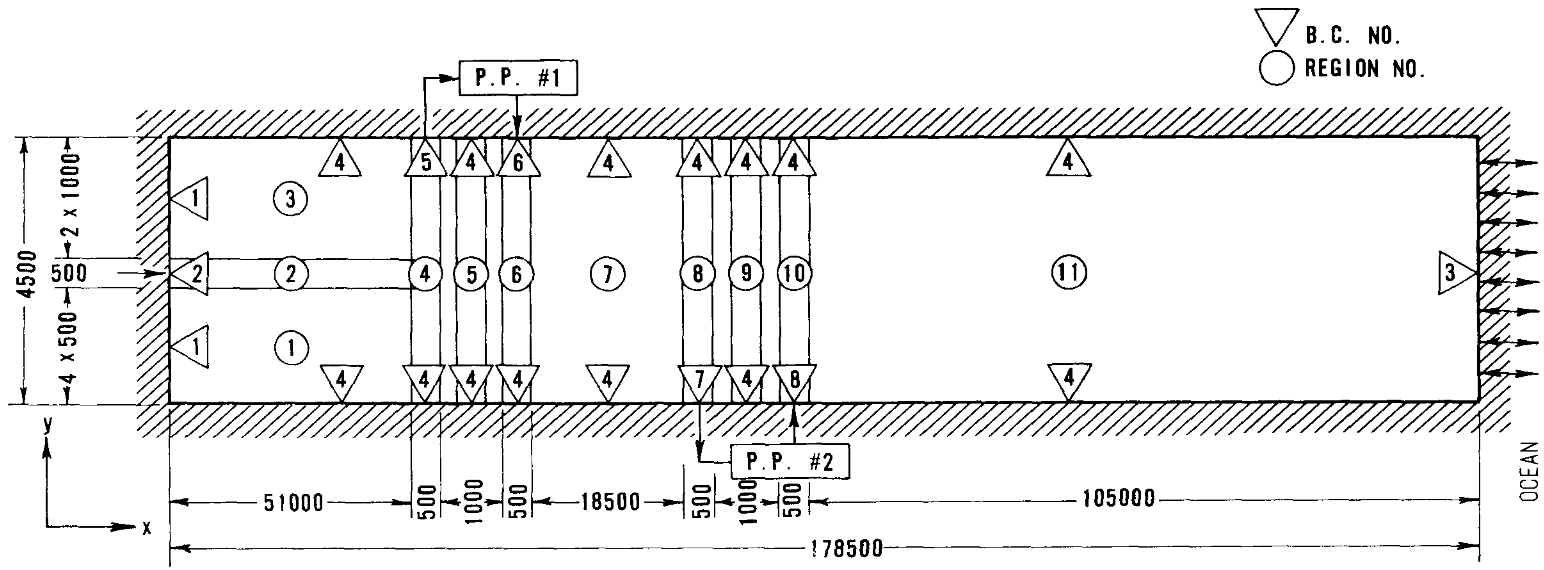


Figure 7.27. Temperature distribution (°F) at the zone of discharge for sample problem No. 1 at time = 124.450 hr.



INITIAL CONDITIONS	B.C. 2	B.C. 3	B.C.'s 1 & 4	B.C.'s 5 & 7	B.C.'s 6 & 8
$H_0 = 40.0$ ft	$\partial^2 H/\partial x^2 = 0$	$H = 40 + 2.25\ \mathrm{SIN}(2\pi \frac{t}{T})$	$\partial^2 H/\partial n^2 = 0$	$\partial^2 H/\partial y^2 = 0$	$\partial^2 H/\partial y^2 = 0$
$U_0 = 0.0$	$U = 720$ ft/hr	$\partial^2 U/\partial x^2 = 0$	$V_n = 0$	$\partial^2 U/\partial y^2 = 0$	$V = 0.0$
$V_0 = 0.0$	$V = 0.0$	$\partial^2 V/\partial x^2 = 0.0$	$\partial V_t/\partial n = 0$	$V = \pm 446.58$ ft/hr	$V = \pm 446.58$ ft/hr
$T_0 = 80.0^0$F	$T = 80.0^0$F	$\partial^2 T/\partial x^2 = 0.0$ [70^0]	$\partial T/\partial n = 0$	$\partial^2 T/\partial y^2 = 0$	$T = T_{INT} + 15^oF$
$C_k(1) = 1.0$	$C_k(1) = 1.0$	$\partial^2 C_k/\partial x^2 = 0$	$\partial C_k/\partial n = 0$	$\partial^2 C_k/\partial y^2 = 0$	$C_k(1) = 0.993$
$C_k(2) = 0.0$	$C_k(2) = 0.0$	[0.973.0.027]			$C_k(2) = 0.007$

Figure 7.28. Regions and boundary conditions arrangement in sample problem No. 2.

is calculated to be at any time 15°F above the intake temperature. The two power plants are 20,500 ft apart along the main stream and are located on two opposing banks of the water body. Interaction and recirculation between the two power plants are properly considered.

The modeled water body is subdivided into 11 regions. Each region is defined by its own dimensions, initial conditions, volumetric generation conditions, bottom conditions, top surface conditions, and boundary conditions on its four edges. Boundary conditions 1 and 4 represent solid walls with conditions the same as for sample problem No. 1. The inlet conditions (boundary condition 2) and outlet conditions (boundary condition 3) are also similar to those in sample problem No. 1 except that the water elevation is specified sinusoidally by Eq. 7.3 rather than being constant. This difference completely changes the nature of the flow field in the water body. The temperature in boundary condition 3 is specified as type 4. This imposes a constant temperature gradient when the flow is positive (outward) and requires that the temperature be equal to the outside temperature (70°F) when the flow is negative (inlet). The same types of boundary conditions are used for the mass concentration (ocean salt concentration of 27 ppt) as for the temperature. Boundary conditions 5 and 6 simulate, respectively, the intake and discharge structures of one power plant, while boundary conditions 7 and 8 simulate the same for the second power plant. The intake boundary conditions (5 and 7) have specified intake velocities, and the rest of the properties are left as boundary condition type 4. The discharge boundary conditions (6 and 8) have specified values for all the properties except water elevation, which is left as boundary condition type 4. In addition, each power plant discharge is coupled to its own intake by way of temperature; that is, the discharge temperature is always based on the current intake temperature plus the condenser ΔT (15°F).

The conditions at the bottom surface and top surface as well as the transport properties are the same as in sample problem No. 1.

An actual printout of the computer runs made for this sample problem, both with the full version and the reduced version, is given in Appendix A. The input information is printed out in full, while the output results are printed here only for two times--one for the full version and one for the reduced version.

The results of the run were plotted for a number of successive times and cycle fractions and are shown in Figures 7.29 to 7.70. A discussion of these results is given in Section 7.3.3.

7.3.3. Results and Discussion of Sample Problems

Before discussing the actual results of the two sample problems presented in Sections 7.3.1 and 7.3.2, it is worthwhile mentioning some of the difficulties met before achieving them.

First, there was the problem of numerical instabilities. It was found that the solution of the model, when used to predict temperatures and mass concentrations only (that is, the water elevations and velocities have been prespecified), was numerically much more stable than when used as a full thermal-hydraulic model. It was possible to run the model, for thermal prediction only, with time steps in the order

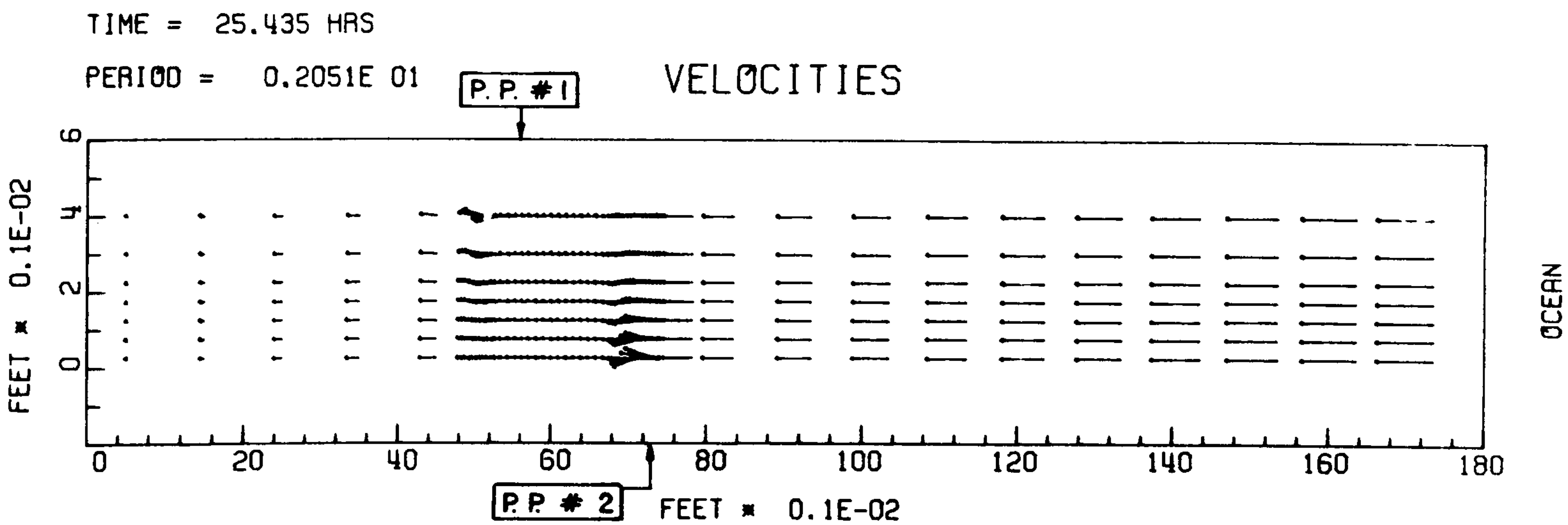


Figure 7.29. Velocity distribution (ft/hr) for sample problem No. 2 at time = 25.435 hr and period of tidal of 2.051.

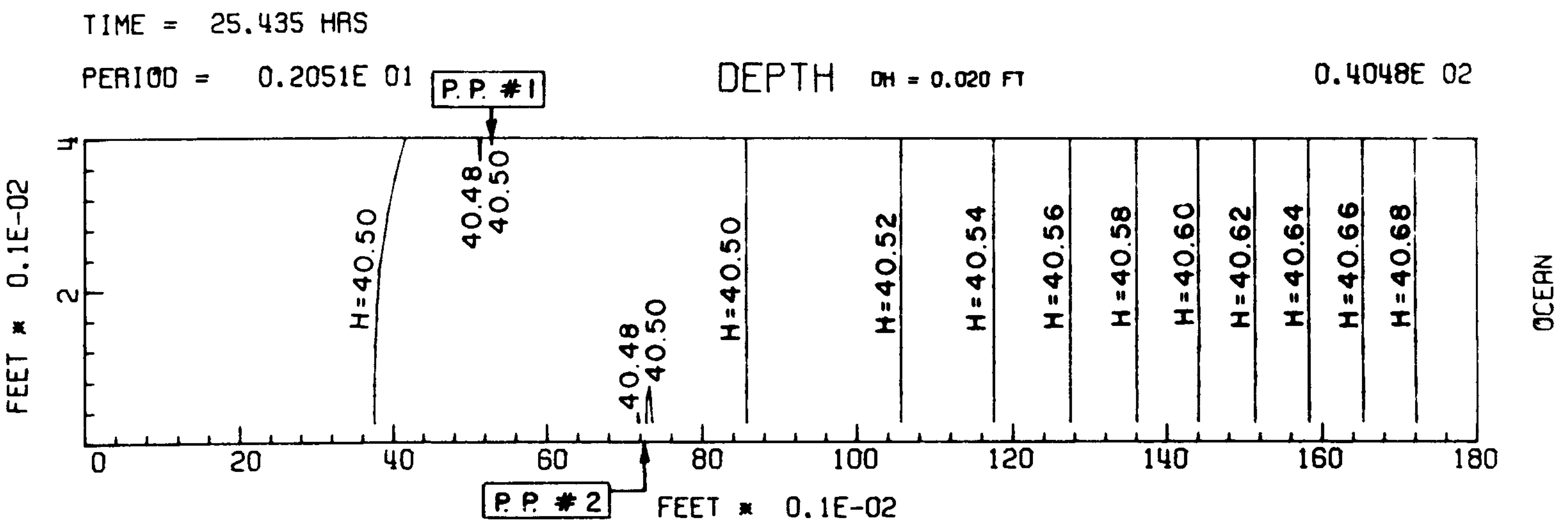


Figure 7.30. Water depth distribution (ft) for sample problem No. 2 at time = 25.435 hr and period of tidal of 2.051.

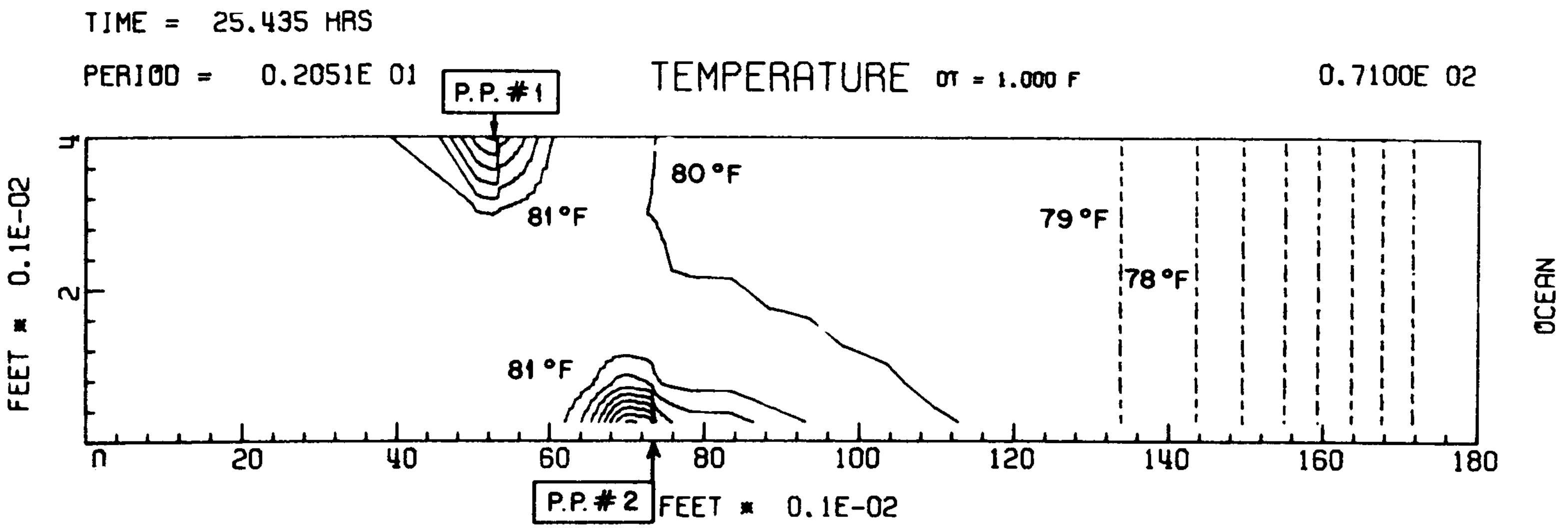


Figure 7.31. Temperature distribution (°F) for sample problem No. 2 at time = 25.435 hr and period of tidal of 2.051.

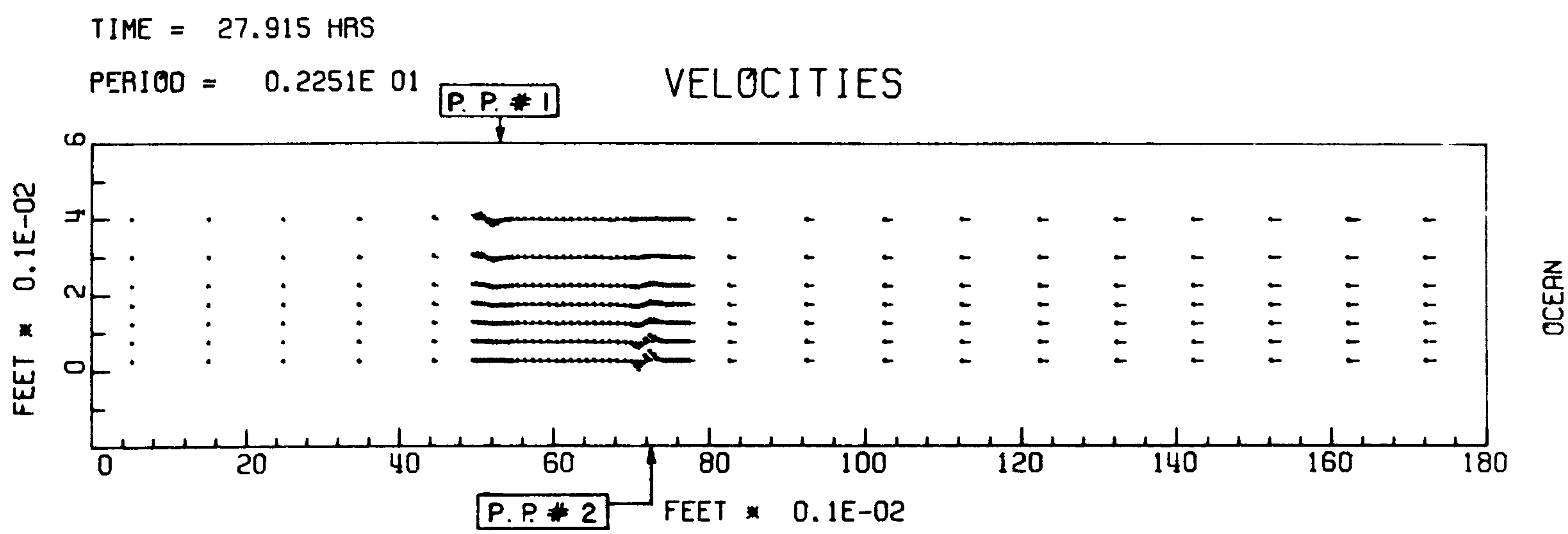


Figure 7.32. Velocity distribution (ft/hr) for sample problem No. 2 at time = 27.915 hr and period of tidal of 2.251.

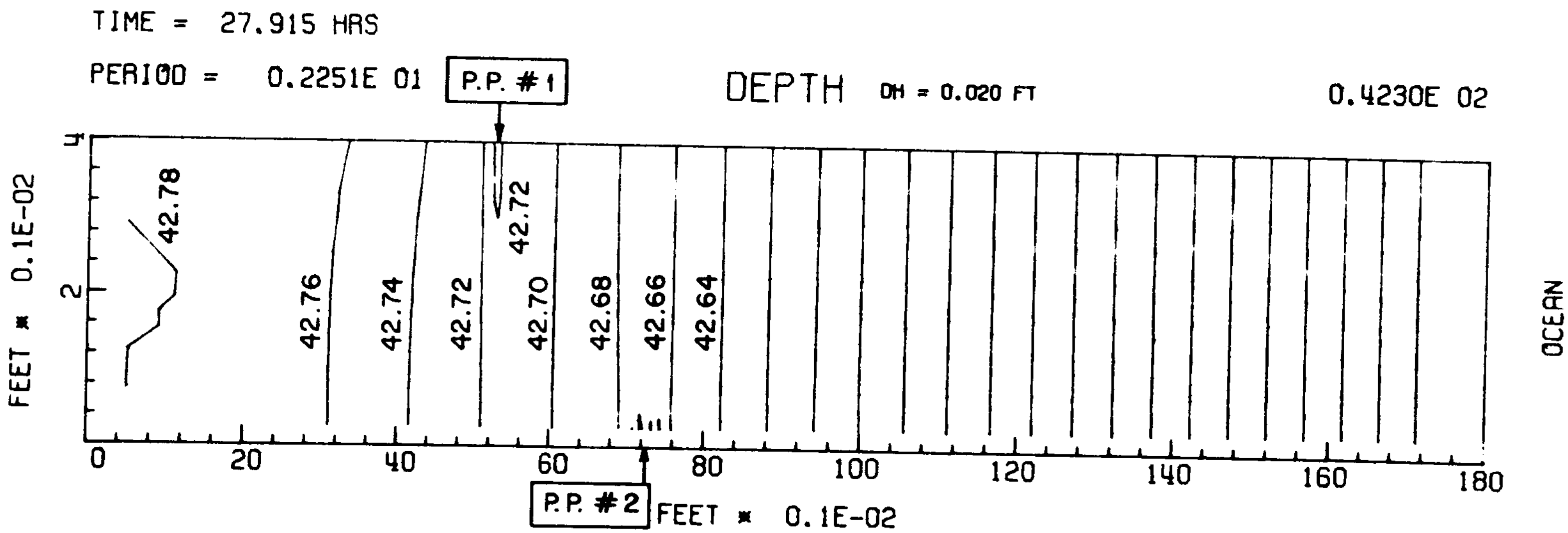


Figure 7.33. Water depth distribution (ft) for sample problem No. 2 at time = 27.915 hr and period of tidal of 2.251.

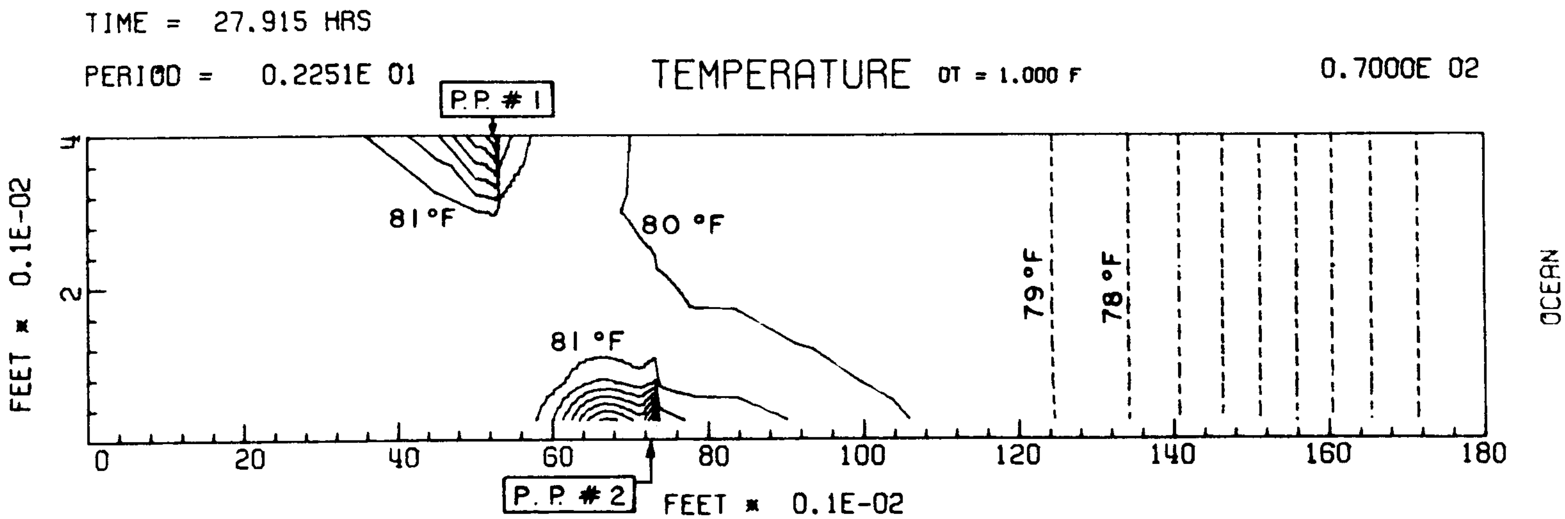


Figure 7.34. Temperature distribution (°F) for sample problem No. 2 at time = 27.915 hr and period of tidal of 2.251.

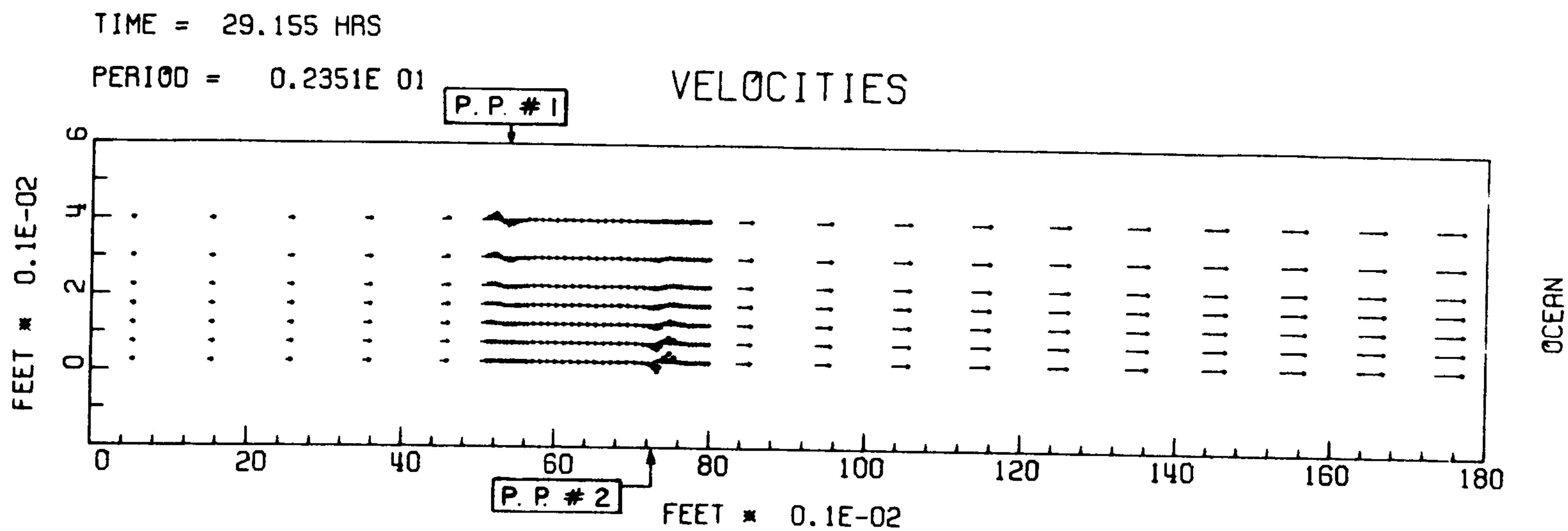


Figure 7.35. Velocity distribution (ft/hr) for sample problem No. 2 at time = 29.155 hr and period of tidal of 2.351.

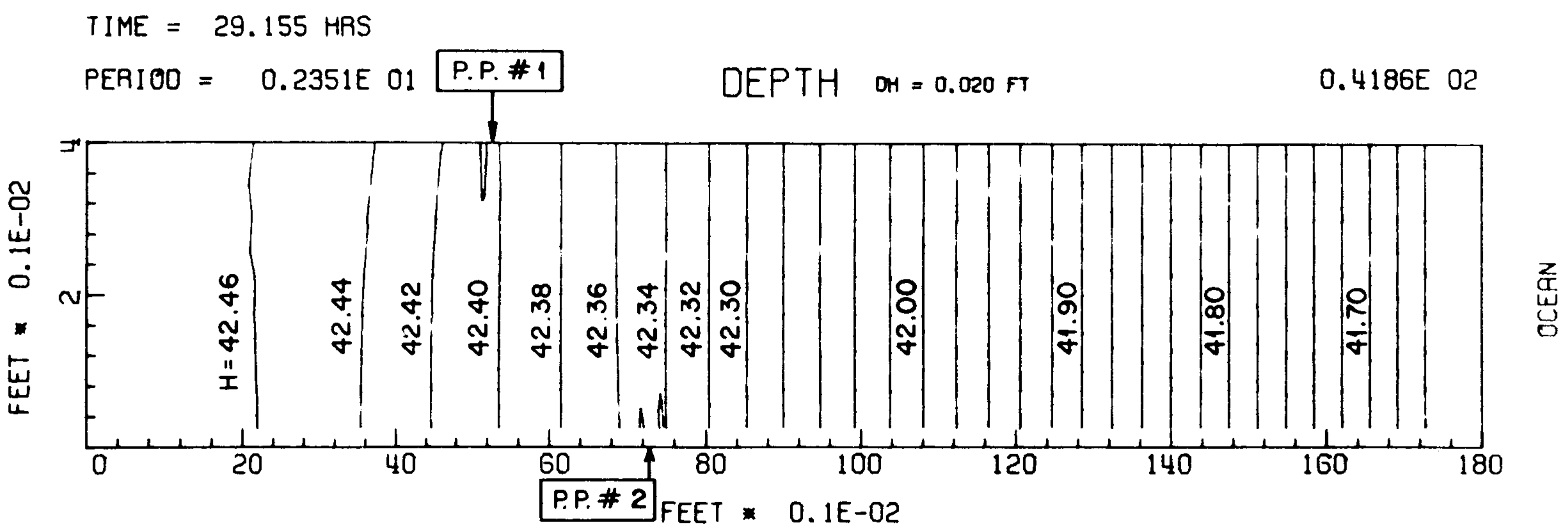


Figure 7.36. Water depth distribution (ft) for sample problem No. 2 at time = 29.155 hr and period of tidal of 2.351.

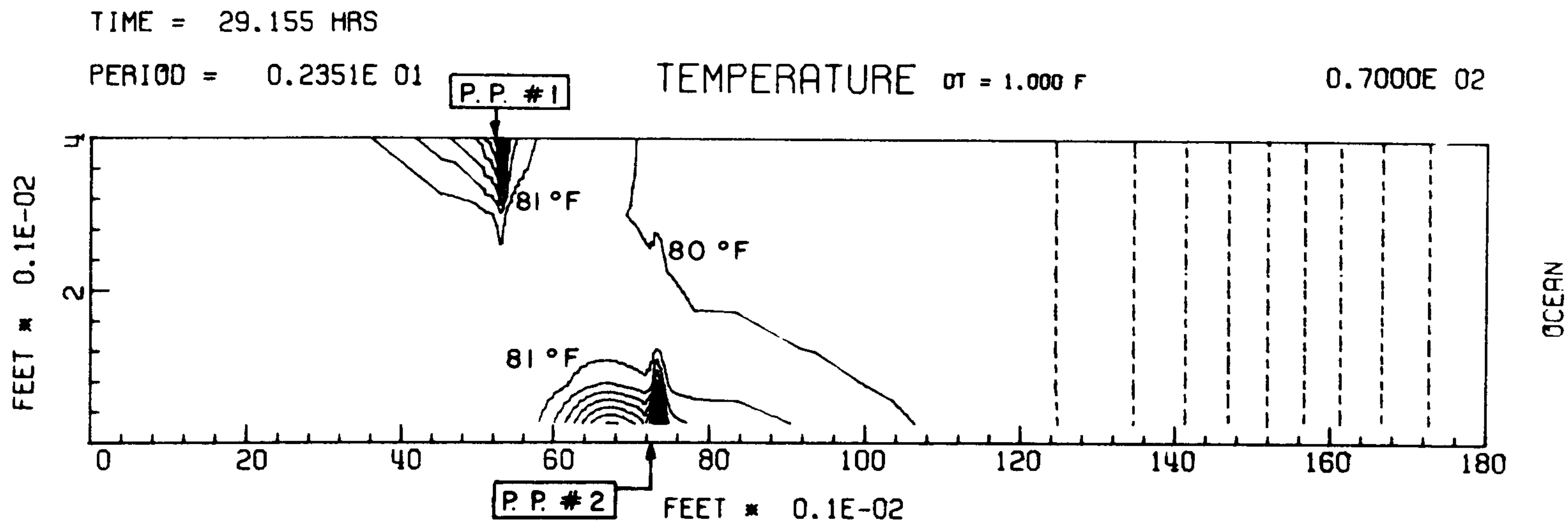


Figure 7.37. Temperature distribution (°F) for sample problem No. 2 at time = 29.155 hr and period of tidal of 2.351.

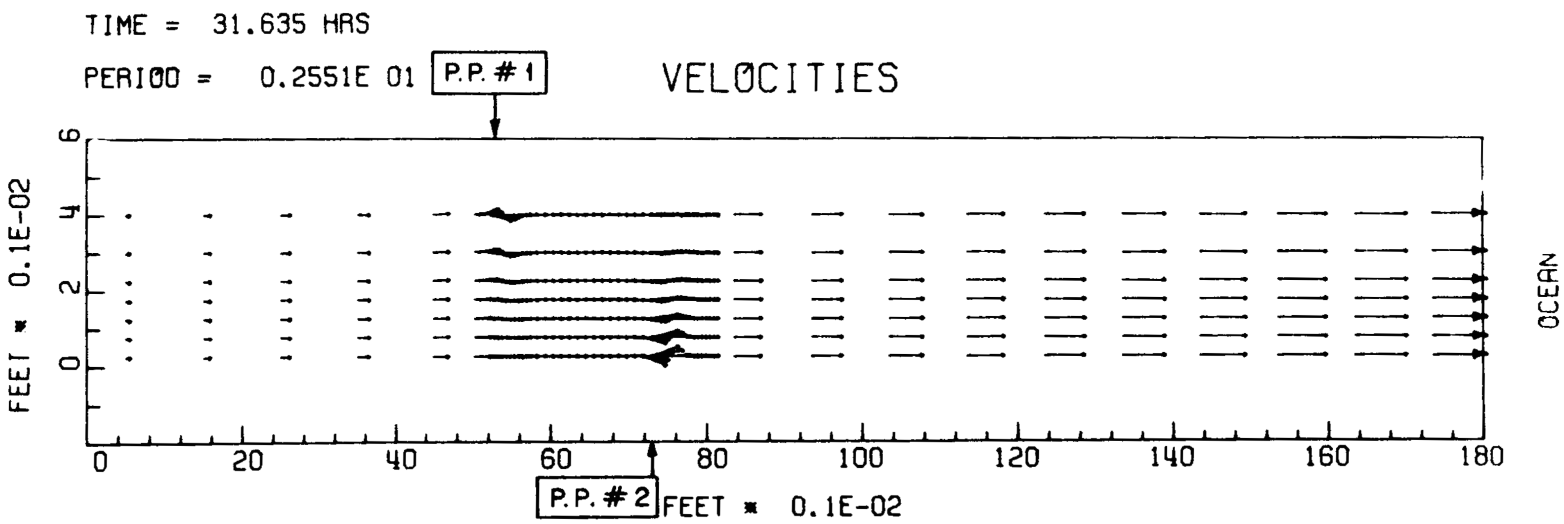


Figure 7.38. Velocity distribution (ft/hr) for sample problem No. 2 at time = 31.635 hr and period of tidal of 2.551.

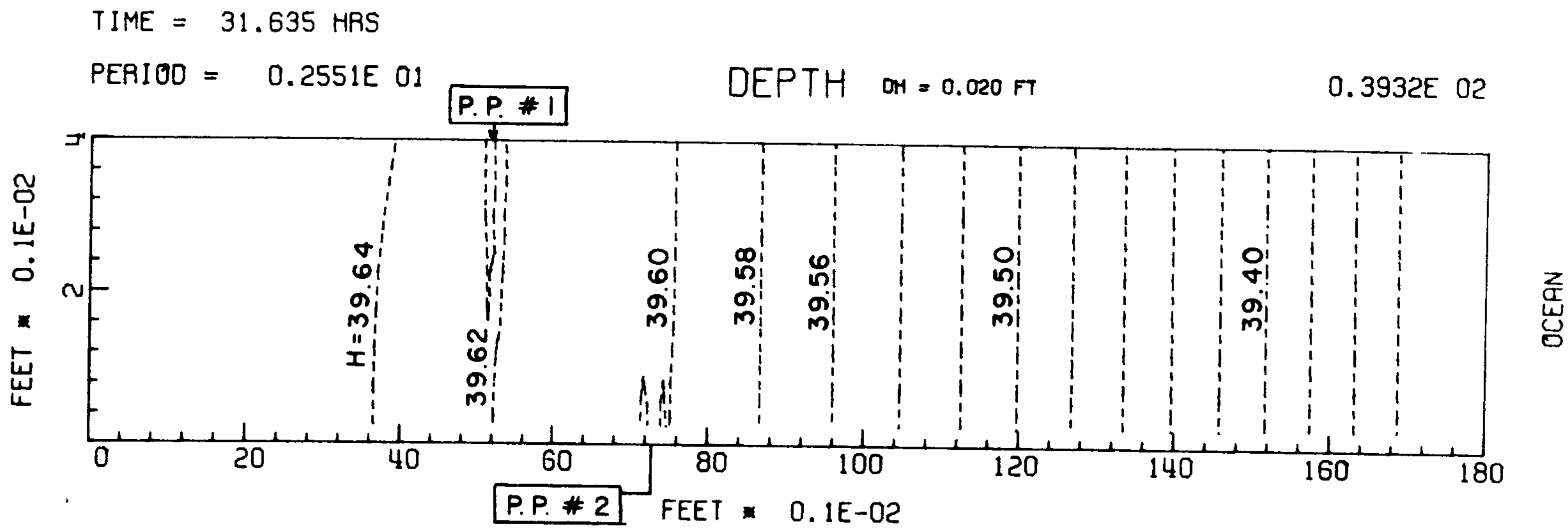


Figure 7.39. Water depth distribution (ft) for sample problem No. 2 at time = 31.635 hr and period of tidal of 2.551.

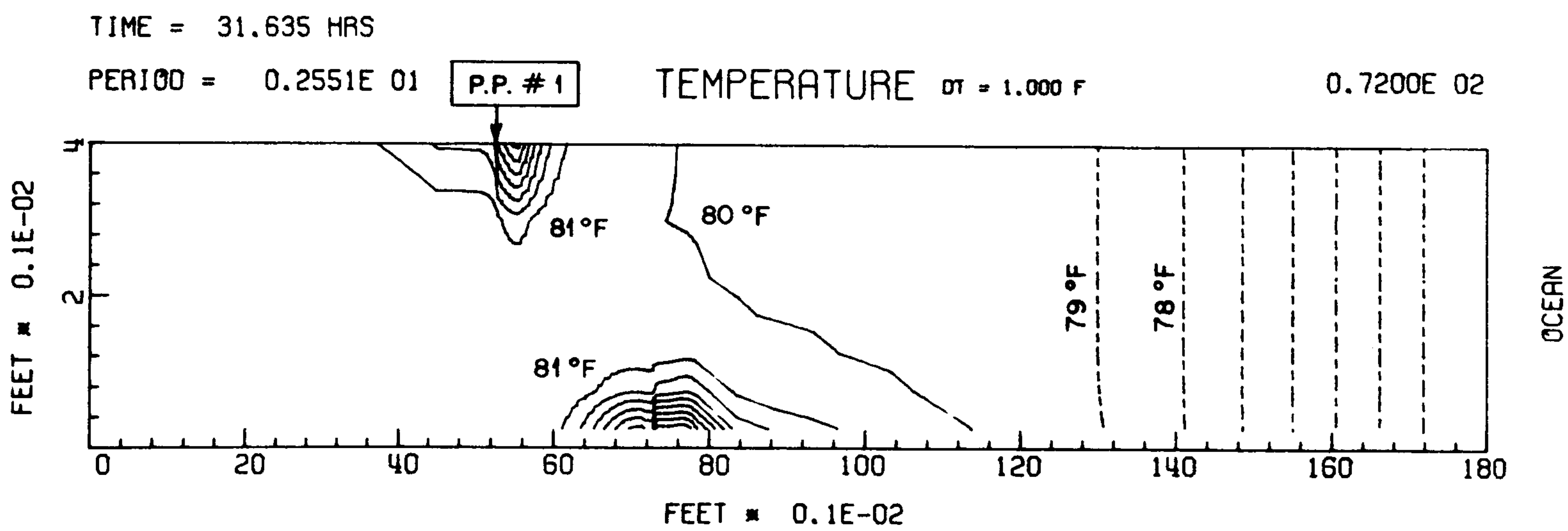


Figure 7.40. Temperature distribution (°F) for sample problem No. 2 at time = 31.635 hr and period of tidal of 2.551.

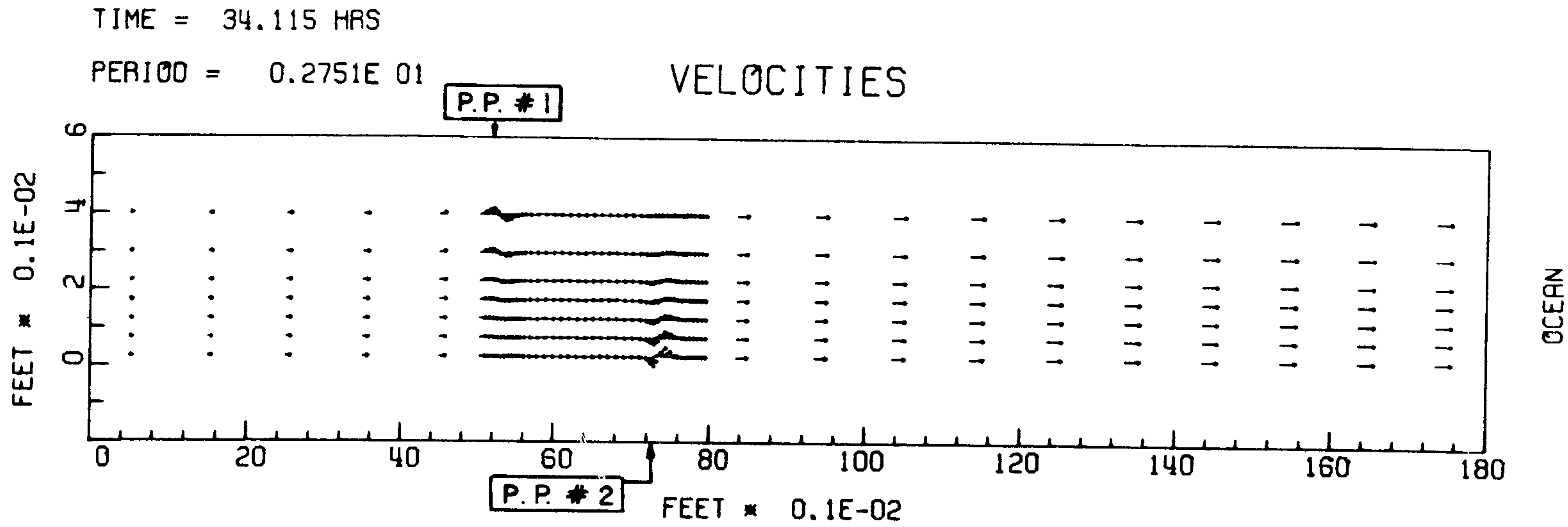


Figure 7.41. Velocity distribution (ft/hr) for sample problem No. 2 at time = 34.115 hr and period of tidal of 2.751.

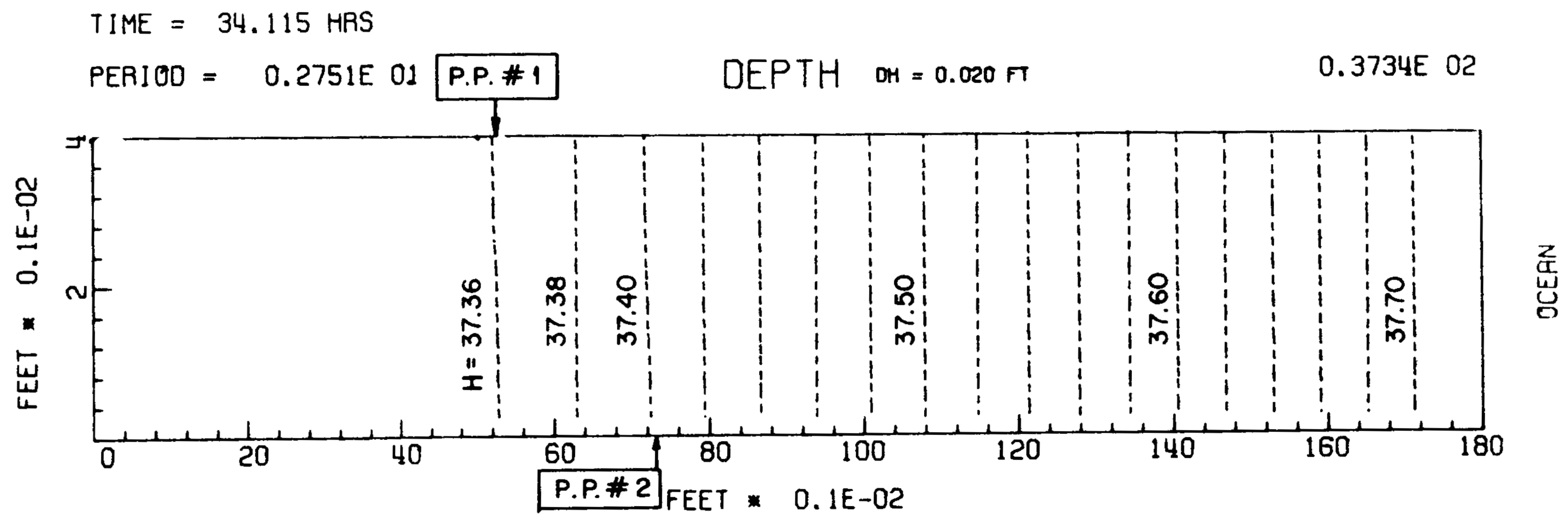


Figure 7.42. Water depth distribution (ft) for sample problem No. 2 at time = 34.115 hr and period of tidal of 2.751.

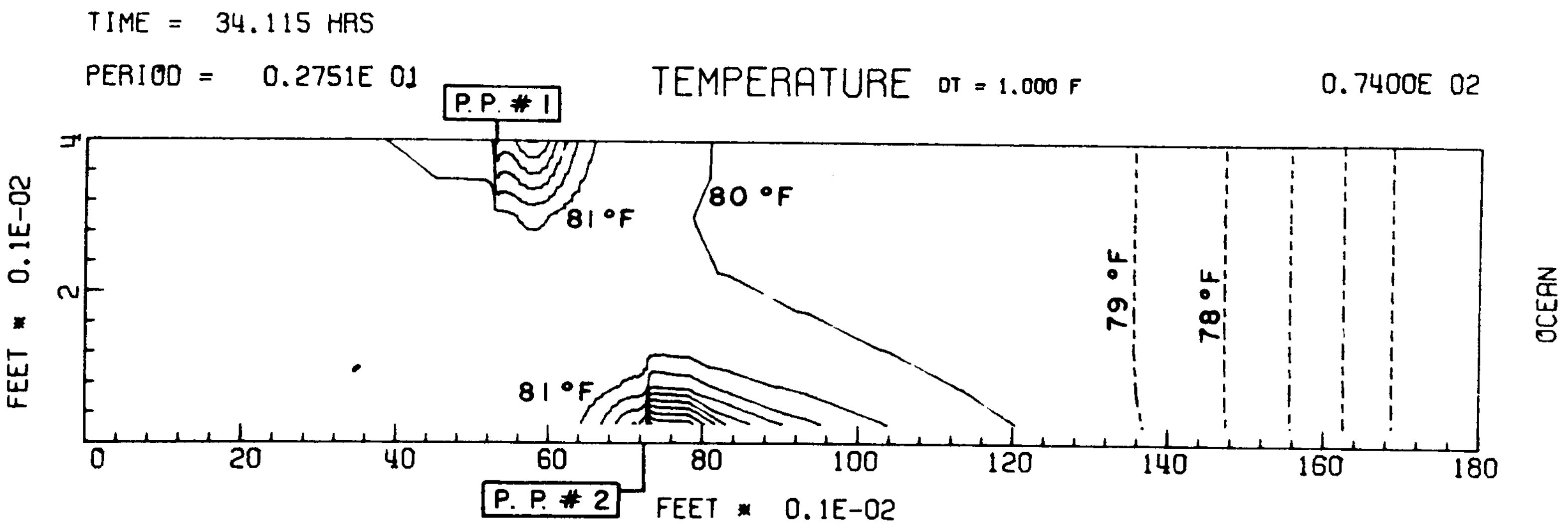


Figure 7.43. Temperature distribution (°F) for sample problem No. 2 at time = 34.115 hr and period of tidal of 2.751.

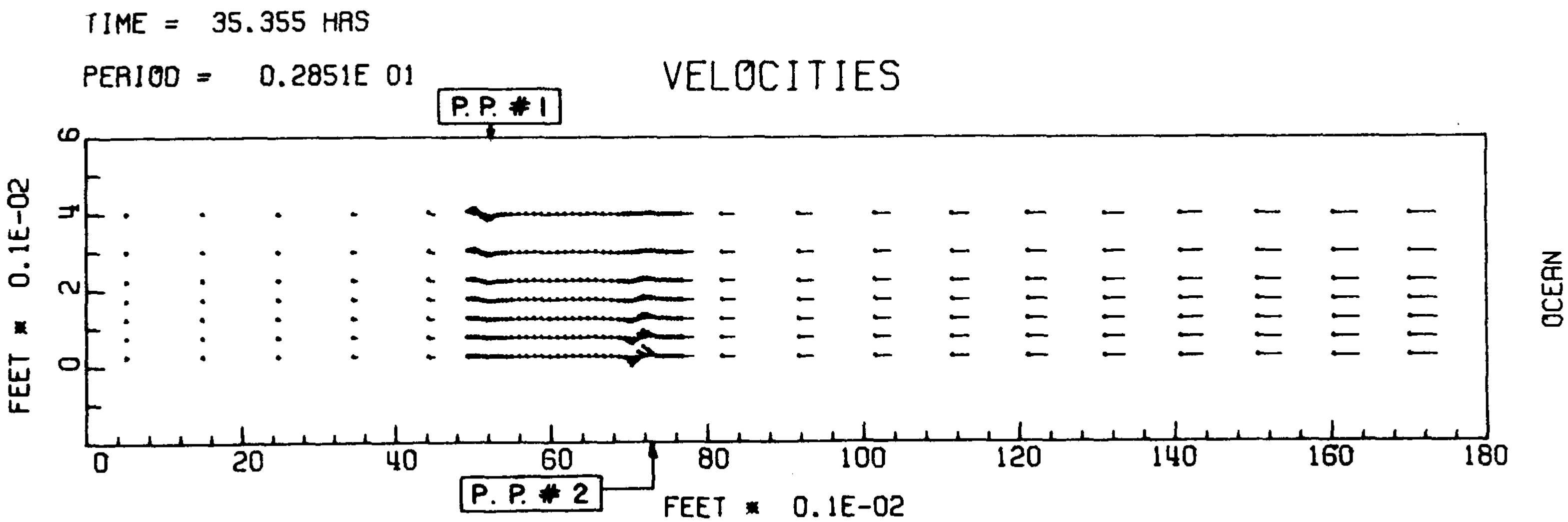


Figure 7.44. Velocity distribution (ft/hr) for sample problem No. 2 at time = 35.355 hr and period of tidal of 2.851.

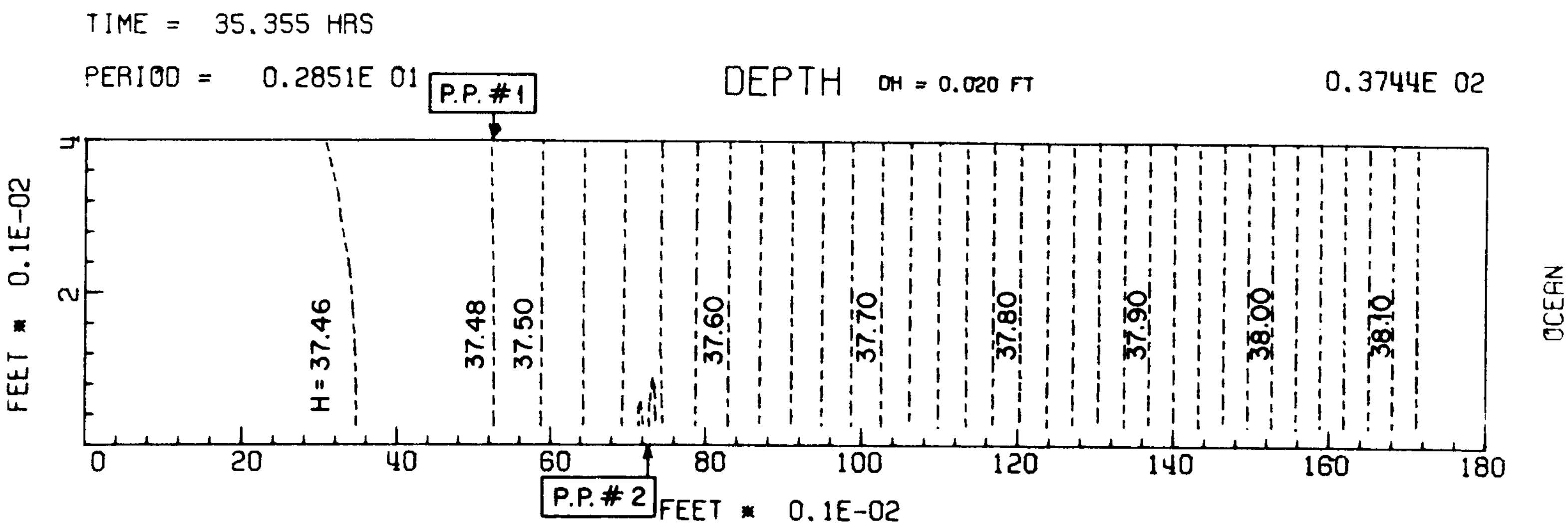


Figure 7.45. Water depth distribution (ft) for sample problem No. 2 at time = 35.355 hr and period of tidal of 2.851.

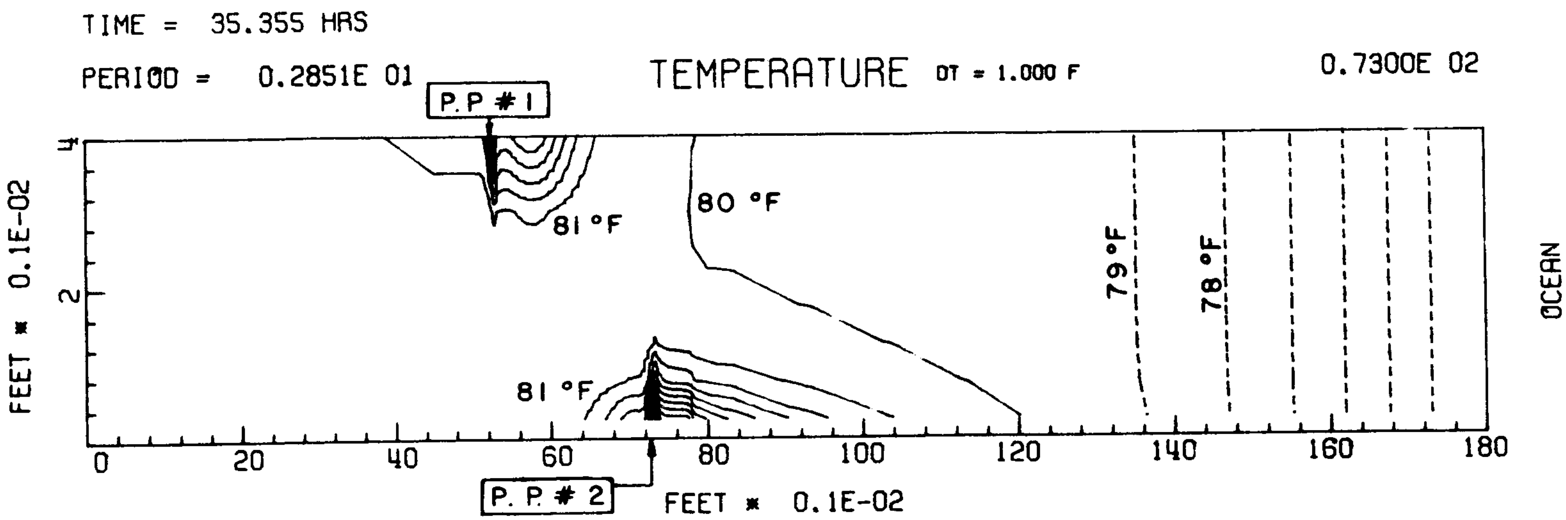


Figure 7.46. Temperature distribution (°F) for sample problem No. 2 at time = 35.355 hr and period of tidal of 2.851.

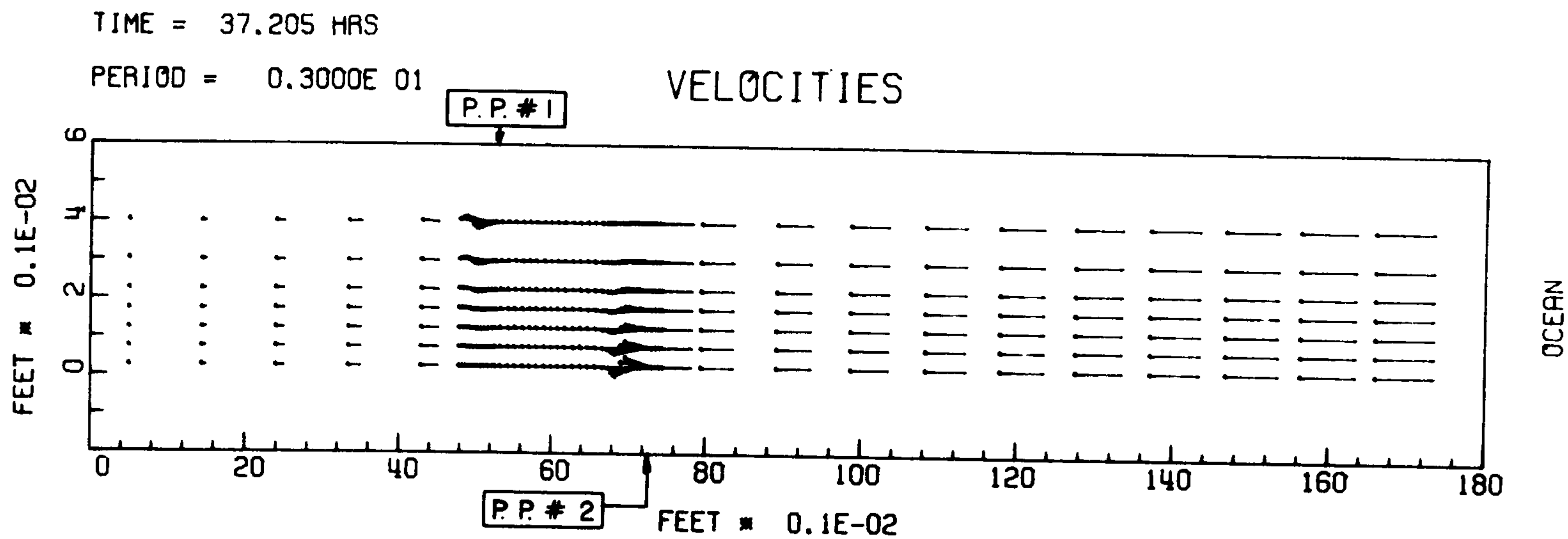


Figure 7.47. Velocity distribution (ft/hr) for sample problem No. 2 at time = 37.205 hr and period of tidal of 3.00.

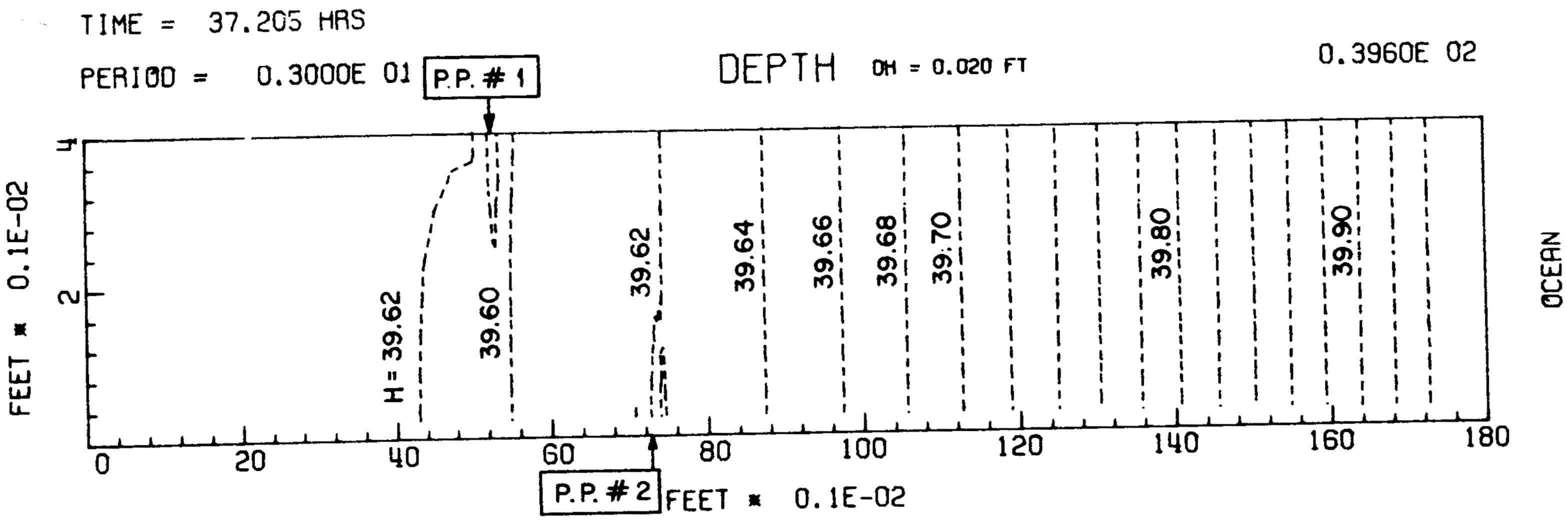


Figure 7.48. Water depth distribution (ft) for sample problem No. 2 at time = 37.205 hr and period of tidal of 3.00.

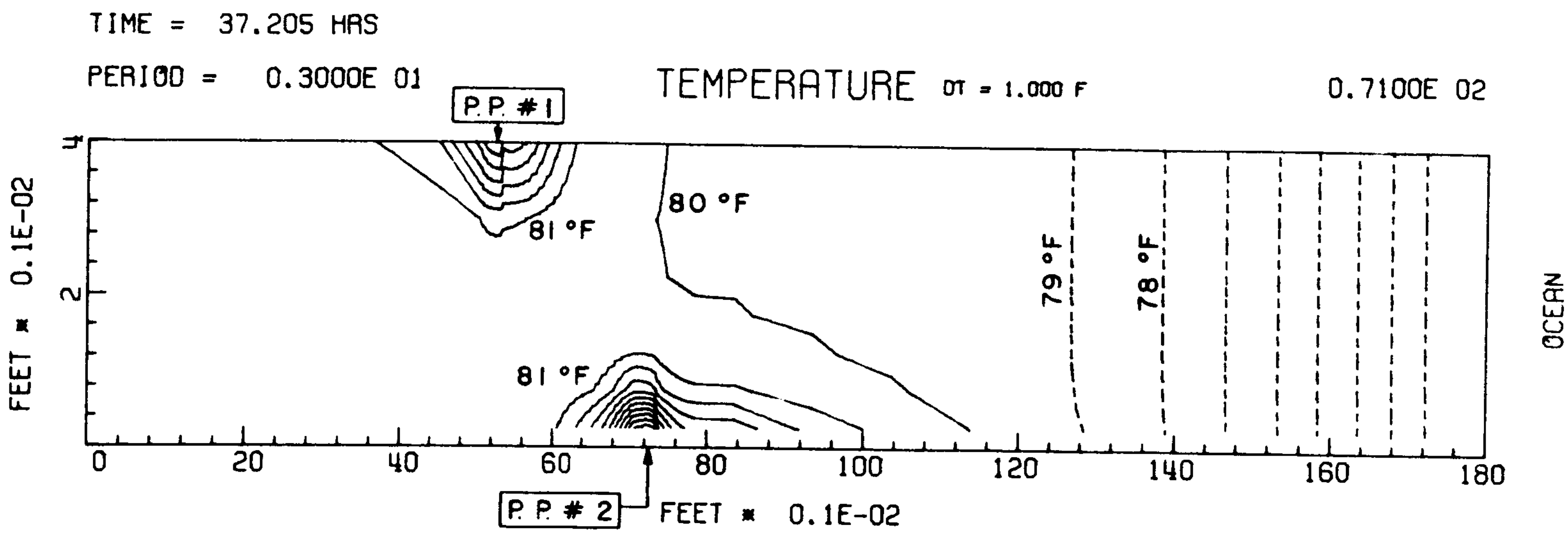


Figure 7.49. Temperature distribution (°F) for sample problem No. 2 at time = 37.205 hr and period of tidal of 3.00.

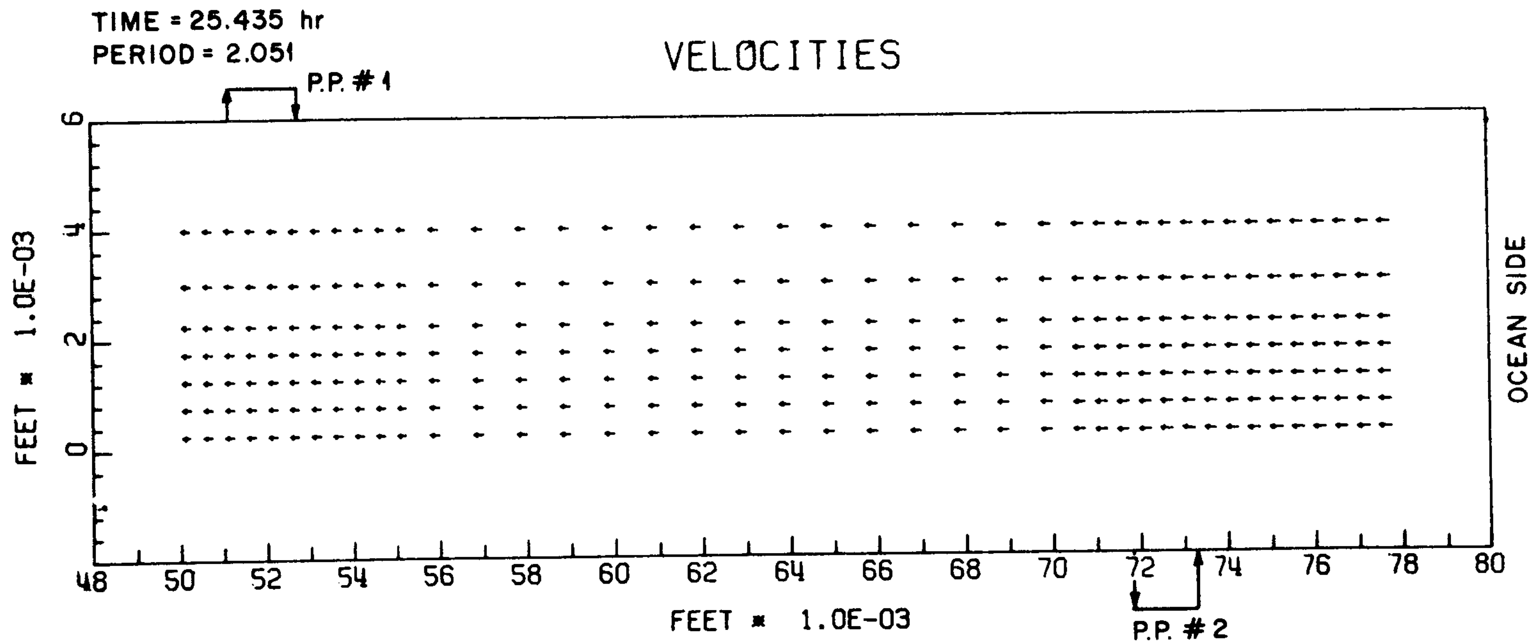


Figure 7.50. Velocity distribution (ft/hr), at the zone of power plant discharges, for sample problem No. 2 at time = 25.435 hr and period of tidal of 2.051.

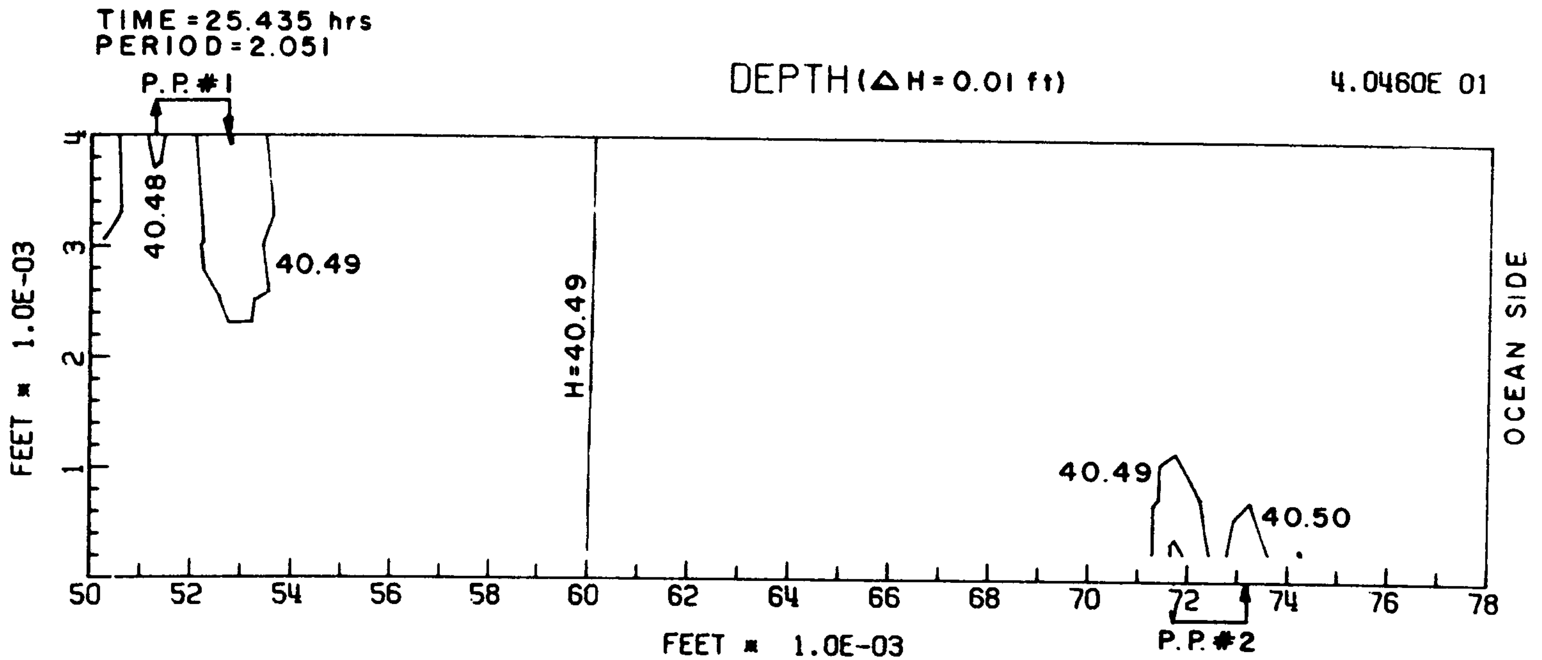


Figure 7.51. Water depth distribution (ft), at the zone of power plant discharges, for sample problem No. 2 at time = 25.435 hr and period of tidal of 2.051.

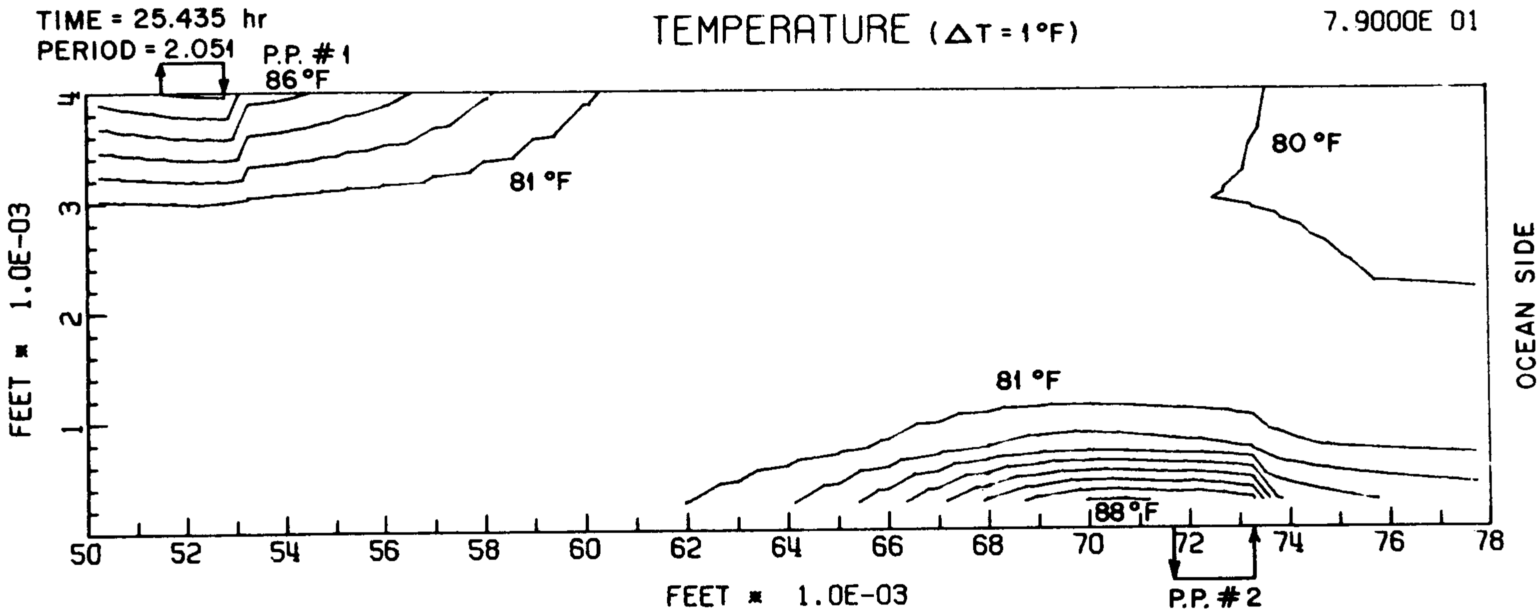


Figure 7.52. Temperature distribution (°F), at the zone of power plant discharges, for sample problem No. 2 at time = 25.435 hr and period of tidal of 2.051.

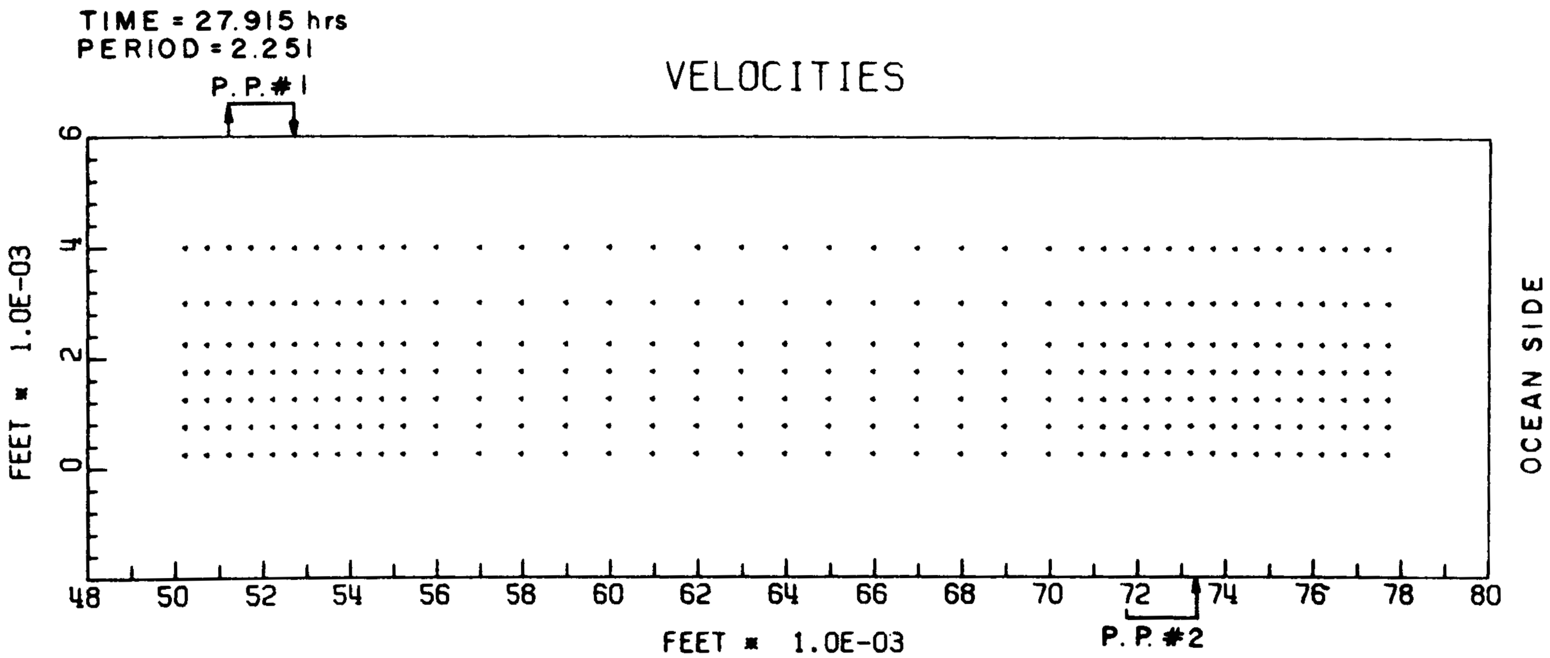


Figure 7.53. Velocity distribution (ft/hr), at the zone of power plant discharges, for sample problem No. 2 at time = 27.915 hr and period of tidal of 2.251.

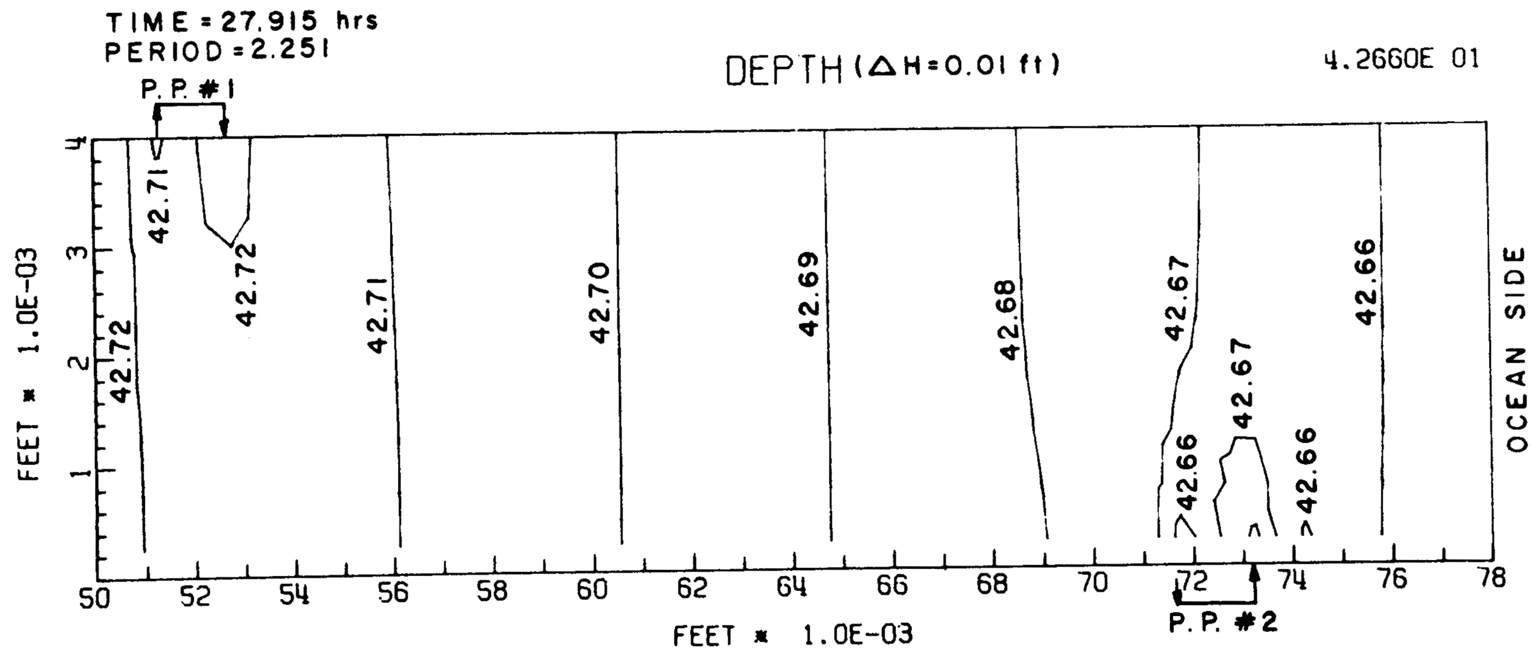


Figure 7.54. Water depth distribution (ft), at the zone of power plant discharges, for sample problem No. 2 at time = 27.915 hr and period of tidal of 2.251.

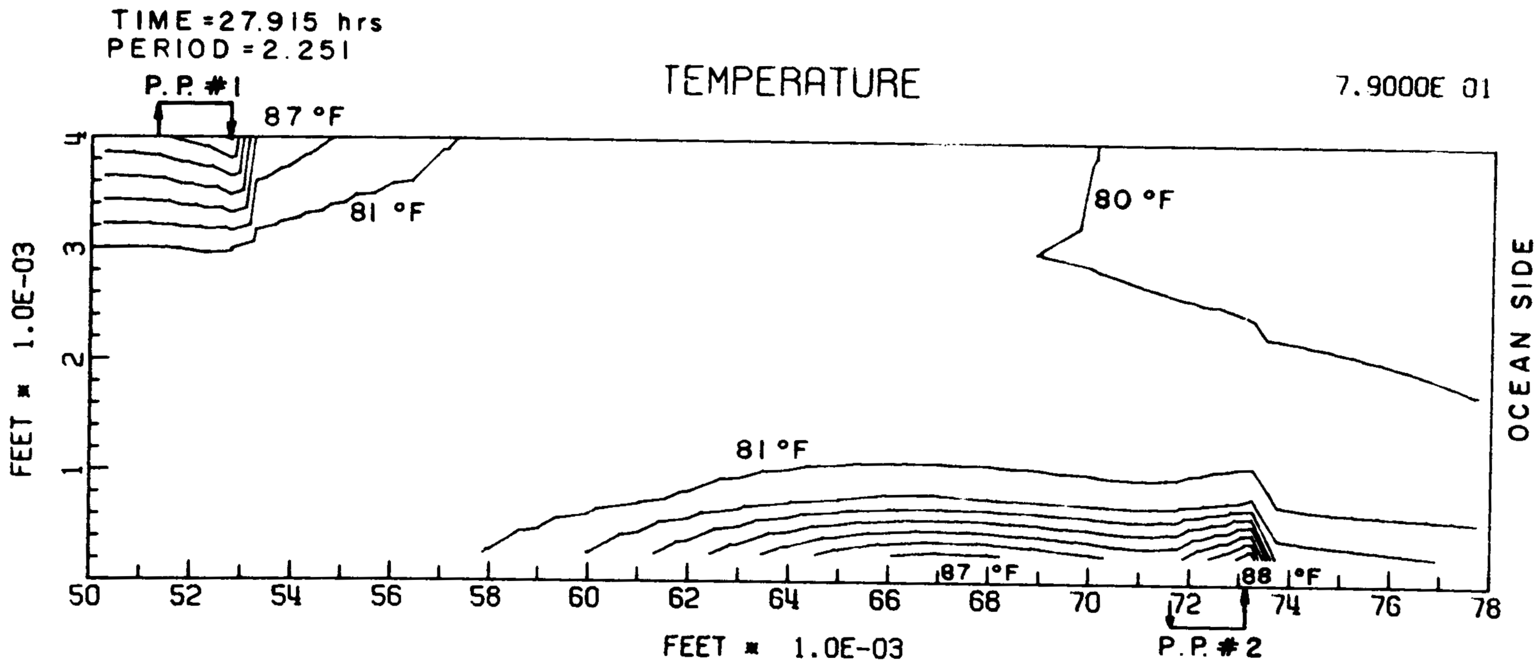


Figure 7.55. Temperature distribution (°F), at the zone of power plant discharges, for sample problem No. 2 at time = 27.915 hr and period of tidal of 2.251.

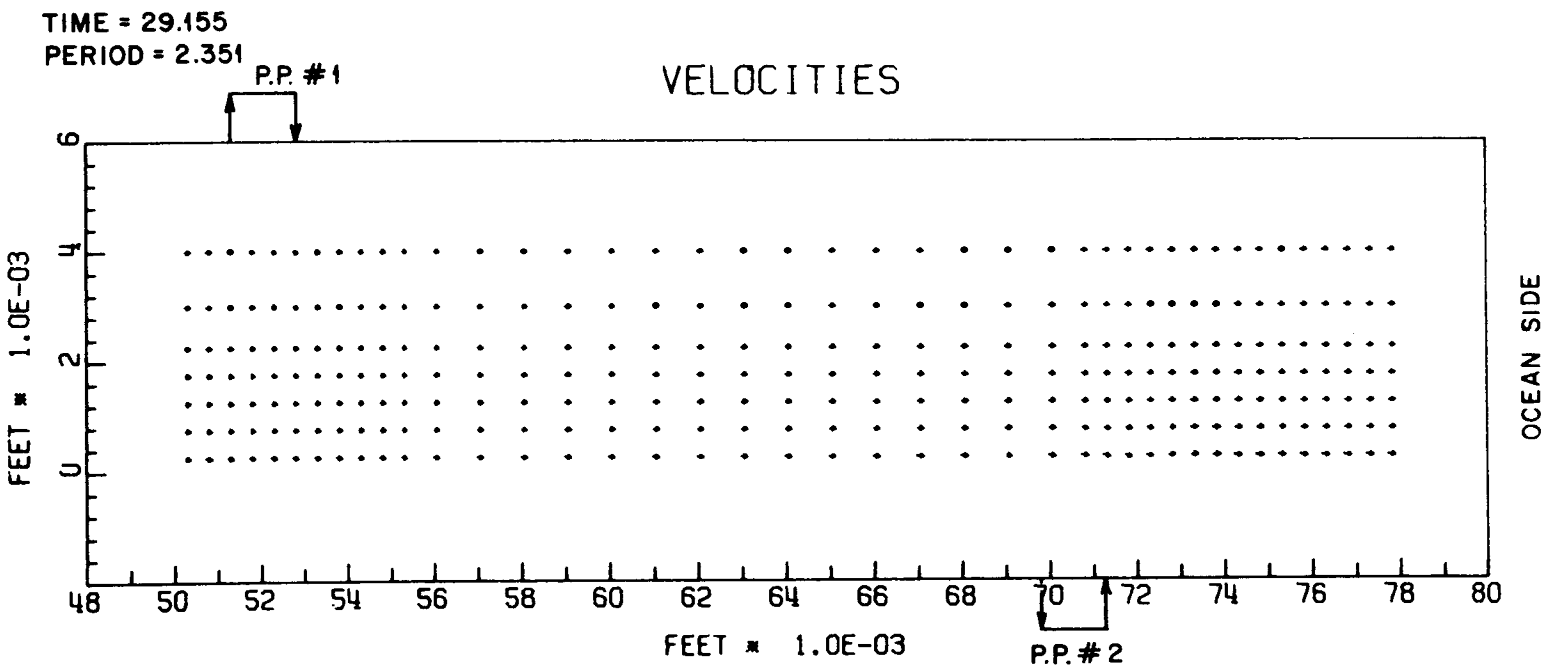


Figure 7.56. Velocity distribution (ft/hr), at the zone of power plant discharges, for sample problem No. 2 at time = 29.155 hr and period of tidal of 2.351.

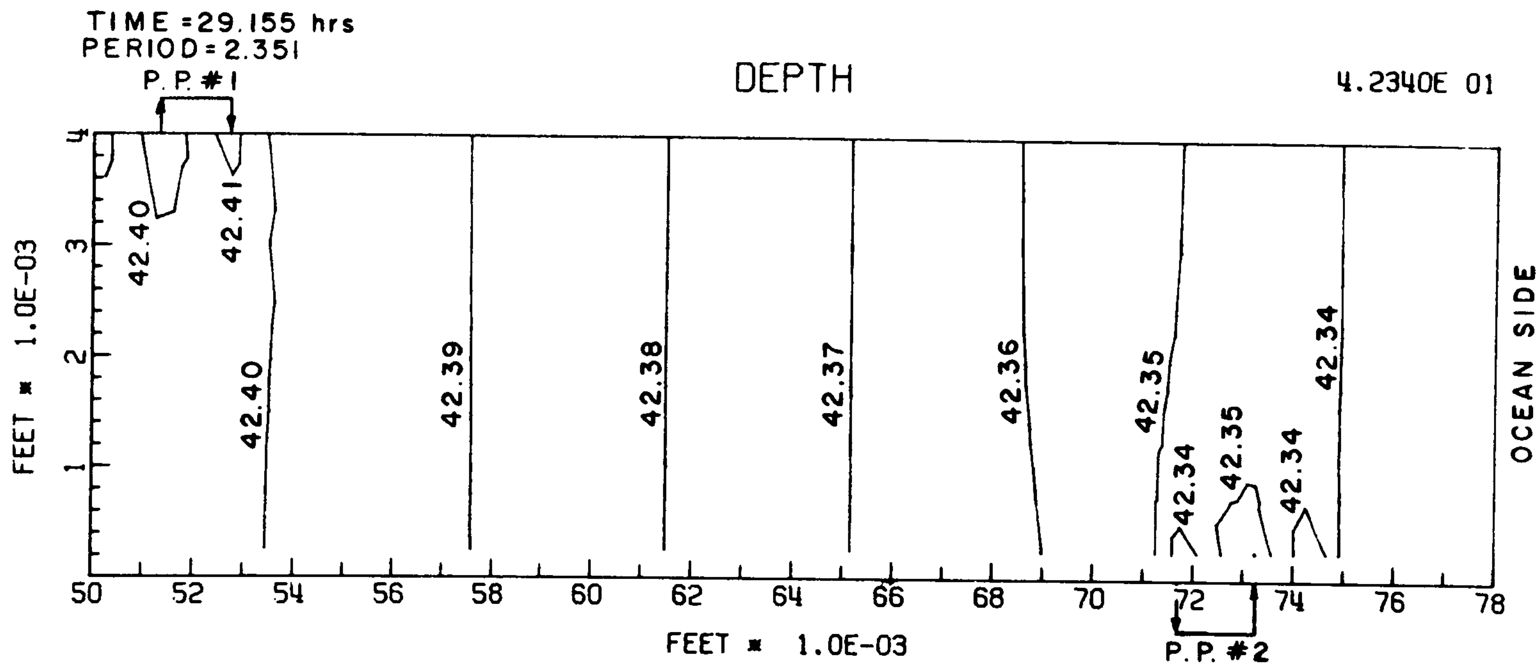


Figure 7.57. Water depth distribution (ft), at the zone of power plant discharges, for sample problem No. 2 at time = 29.155 hr and period of tidal of 2.351.

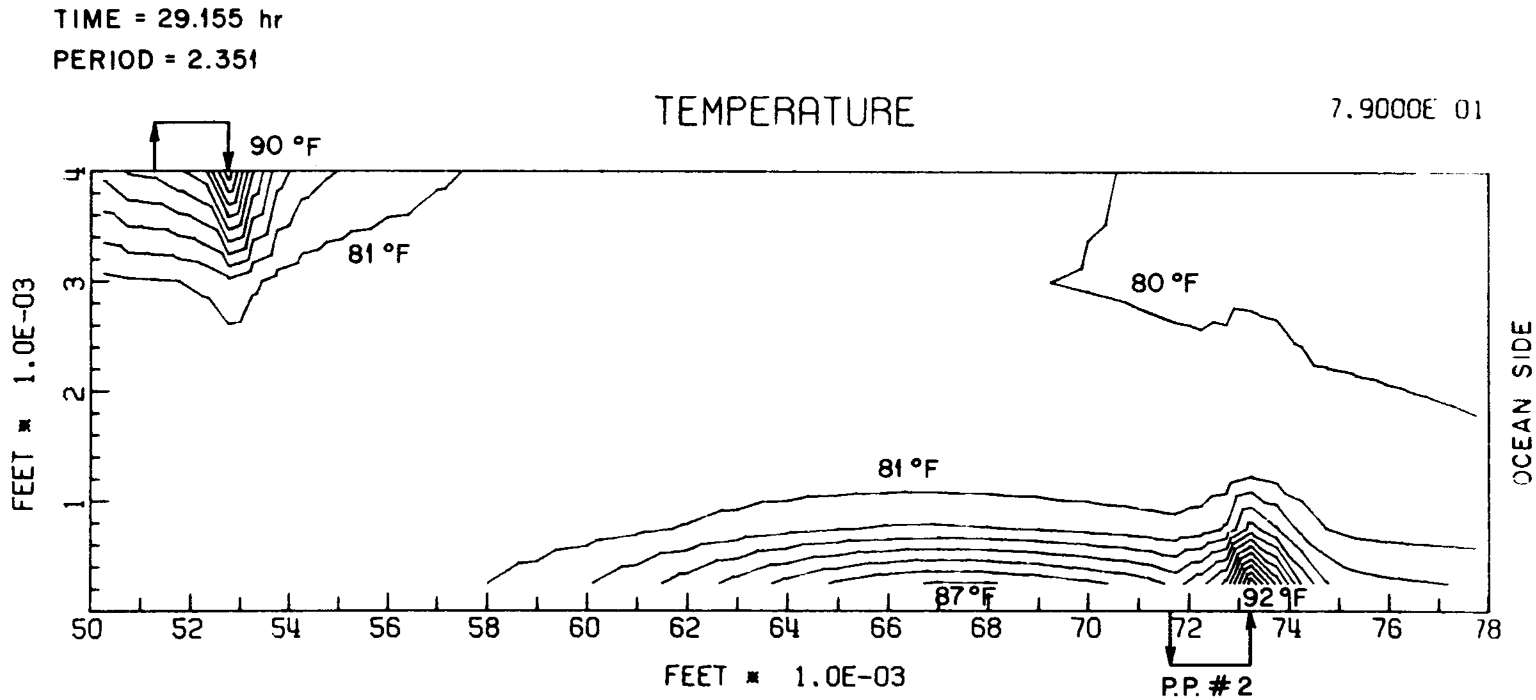


Figure 7.58. Temperature distribution (°F), at the zone of power plant discharges, for sample problem No. 2 at time = 29.155 hr and period of tidal of 2.351.

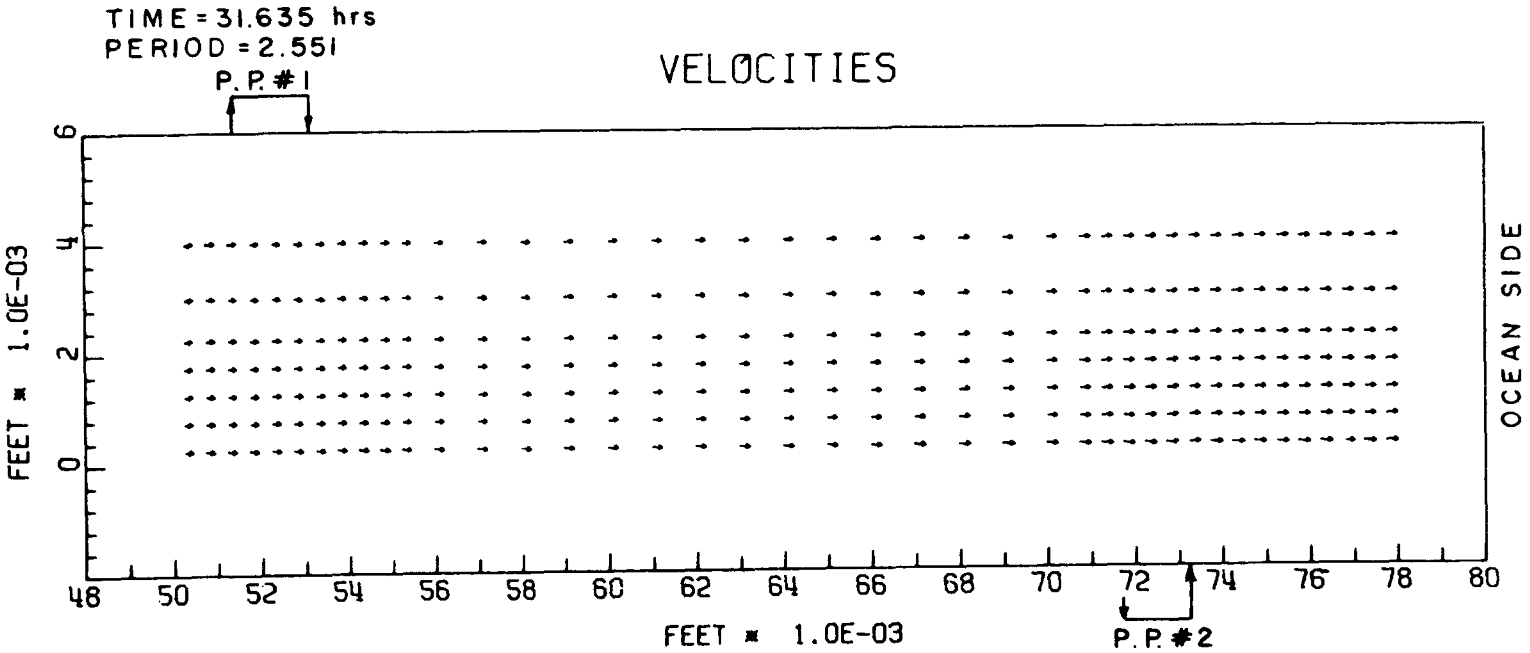


Figure 7.59. Velocity distribution (ft/hr), at the zone of power plant discharges, for sample problem No. 2 at time = 31.635 hr and period of tidal of 2.551.

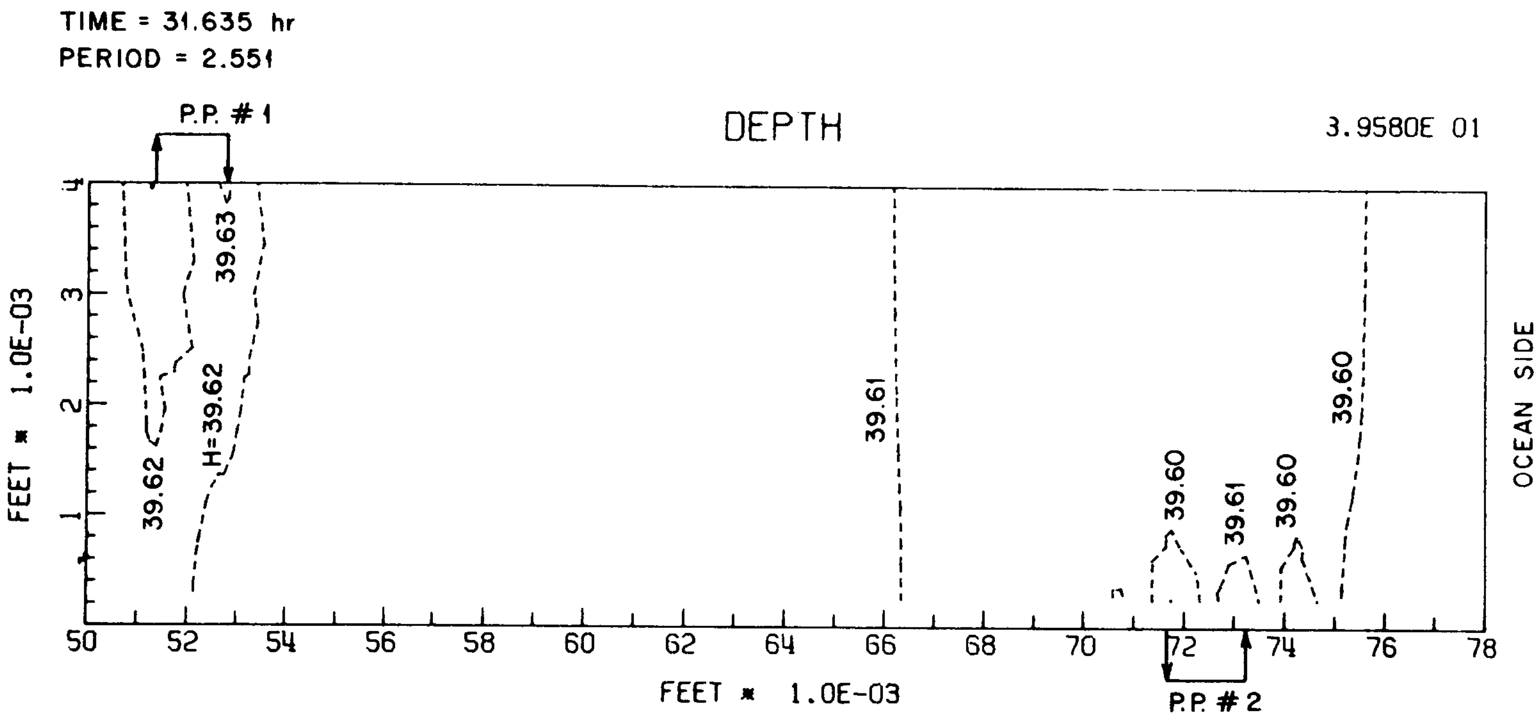


Figure 7.60. Water depth distribution (ft), at the zone of power plant discharges, for sample problem No. 2 at time = 31.635 hr and period of tidal of 2.551.

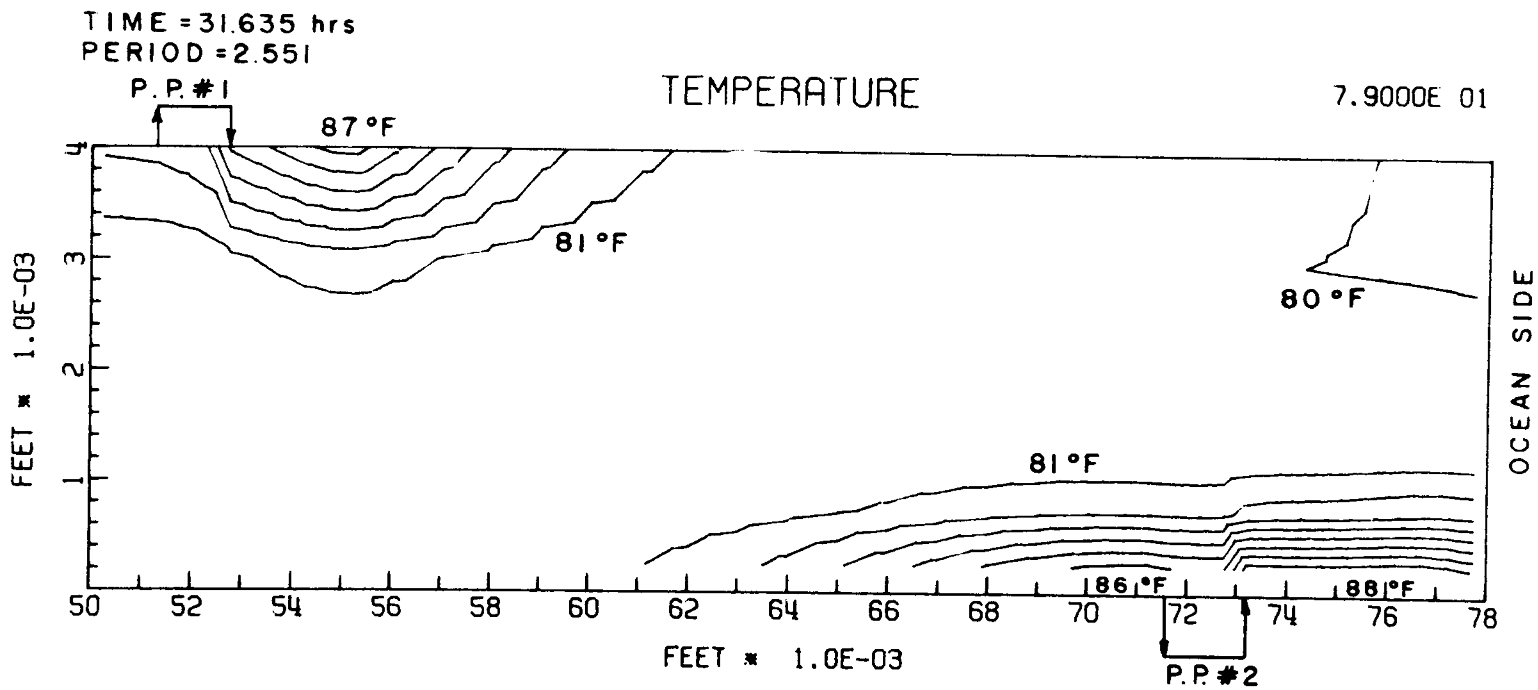


Figure 7.61. Temperature distribution (°F), at the zone of power plant discharges, for sample problem No. 2 at time = 31.635 hr and period of tidal of 2.551.

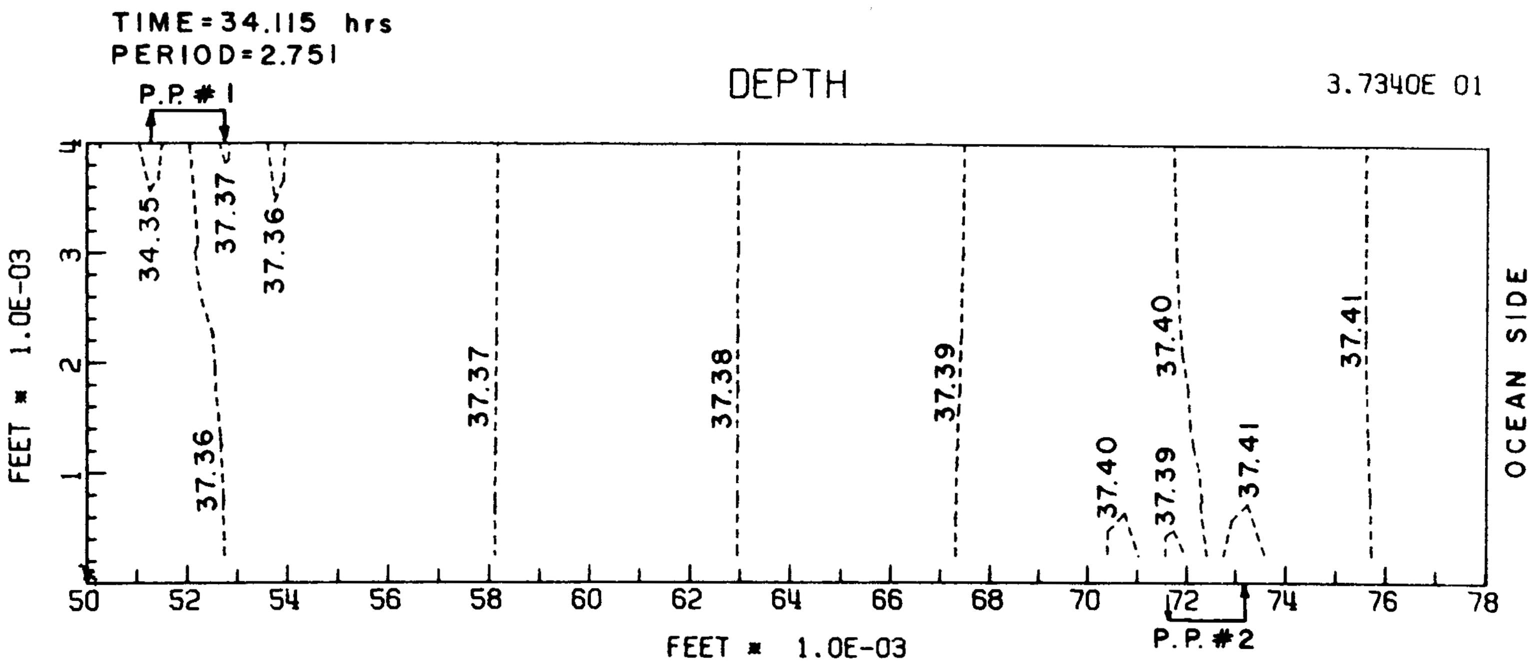


Figure 7.63. Water depth distribution (ft), at the zone of power plant discharges, for sample problem No. 2 at time = 34.115 hr and period of tidal of 2.751.

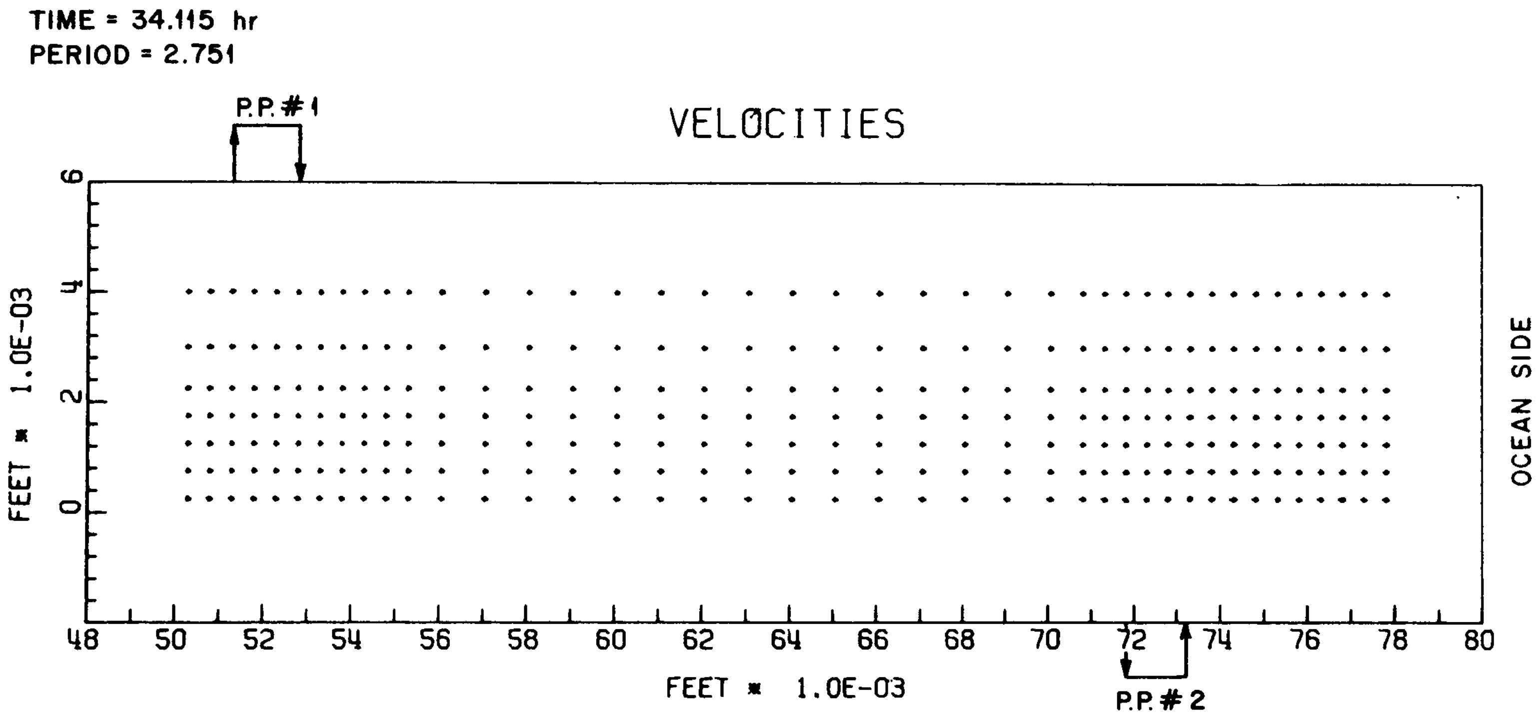


Figure 7.62. Velocity distribution (ft/hr), at the zone of power plant discharges, for sample problem No. 2 at time = 34.115 hr and period of tidal of 2.751.

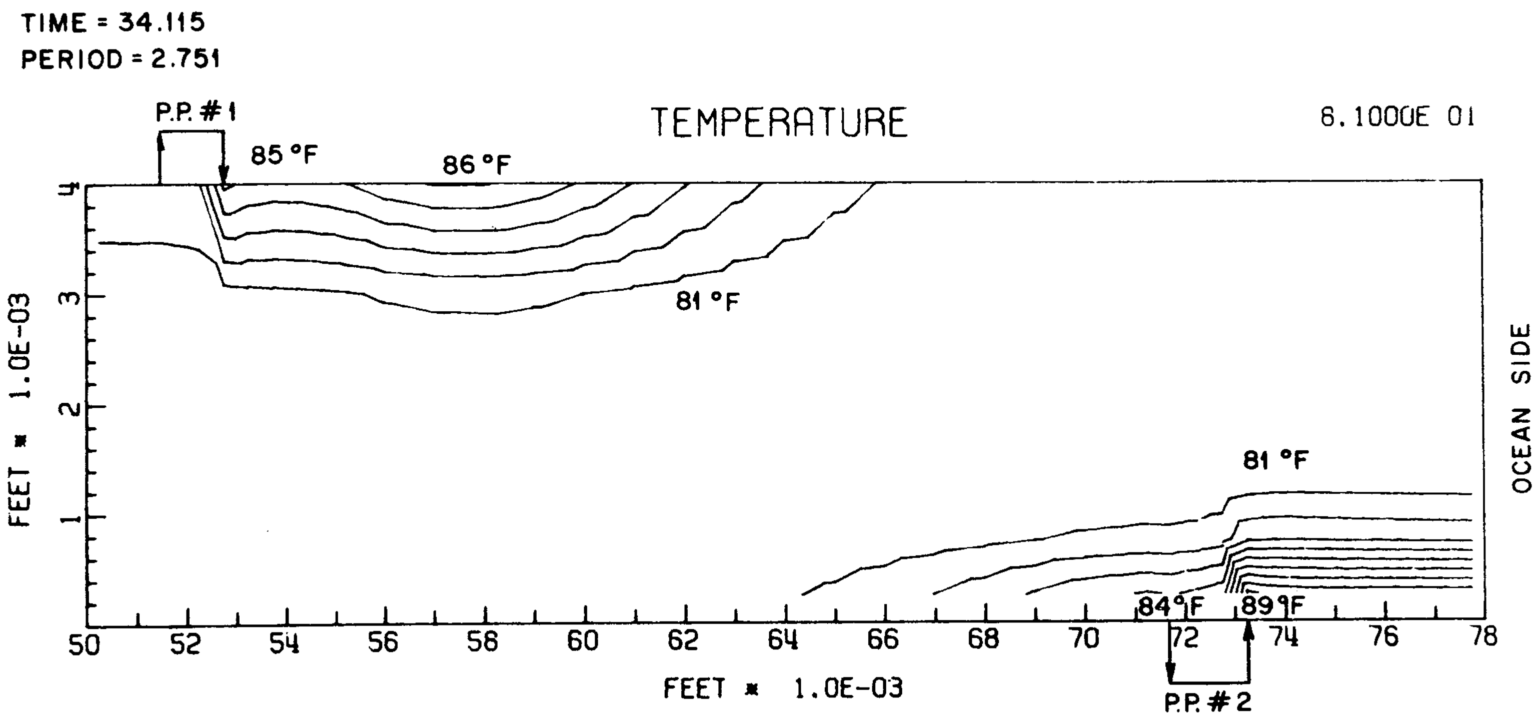


Figure 7.64. Temperature distribution (°F), at the zone of power plant discharges, for sample problem No. 2 at time = 34.115 hr and period of tidal of 2.751.

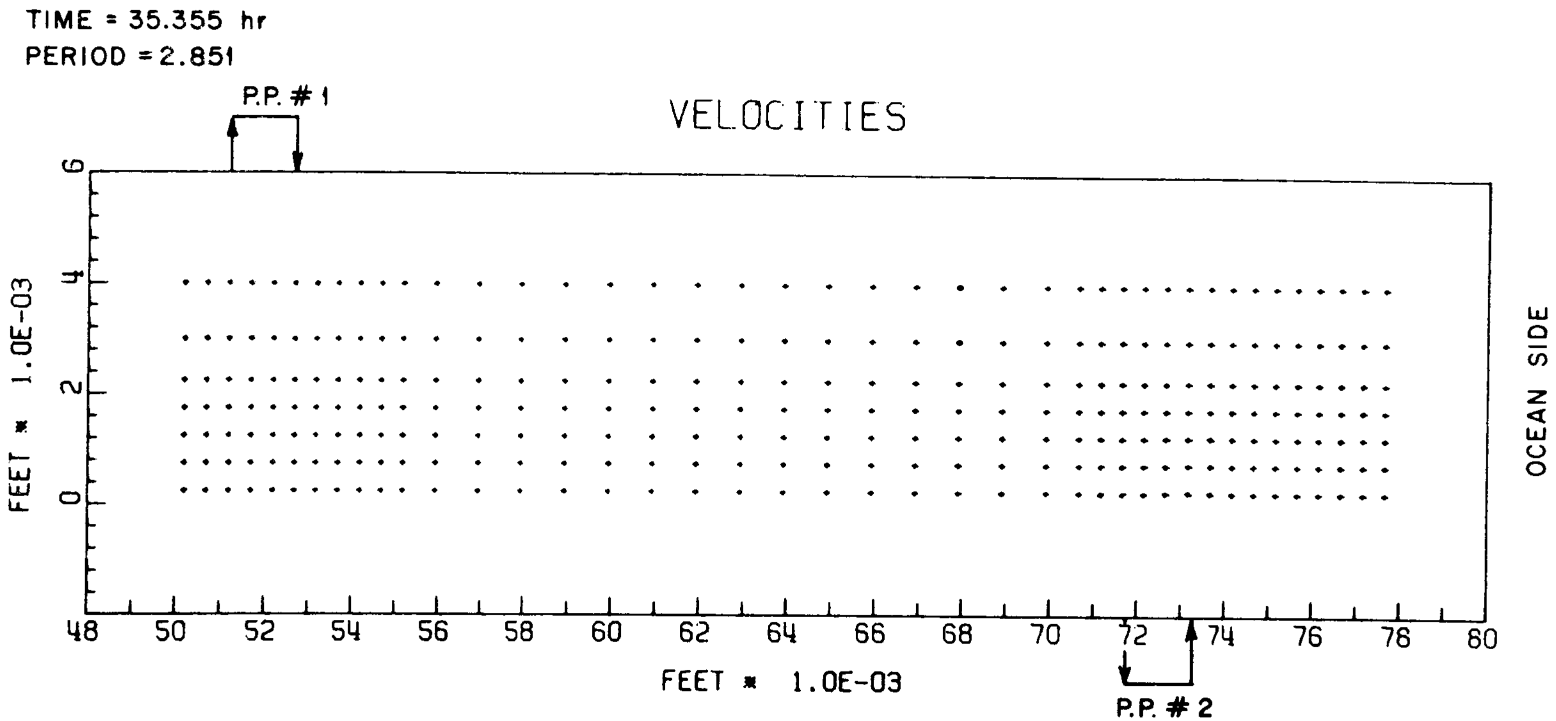


Figure 7.65. Velocity distribution (ft/hr), at the zone of power plant discharges, for sample problem No. 2 at time = 35.355 hr and period of tidal of 2.851.

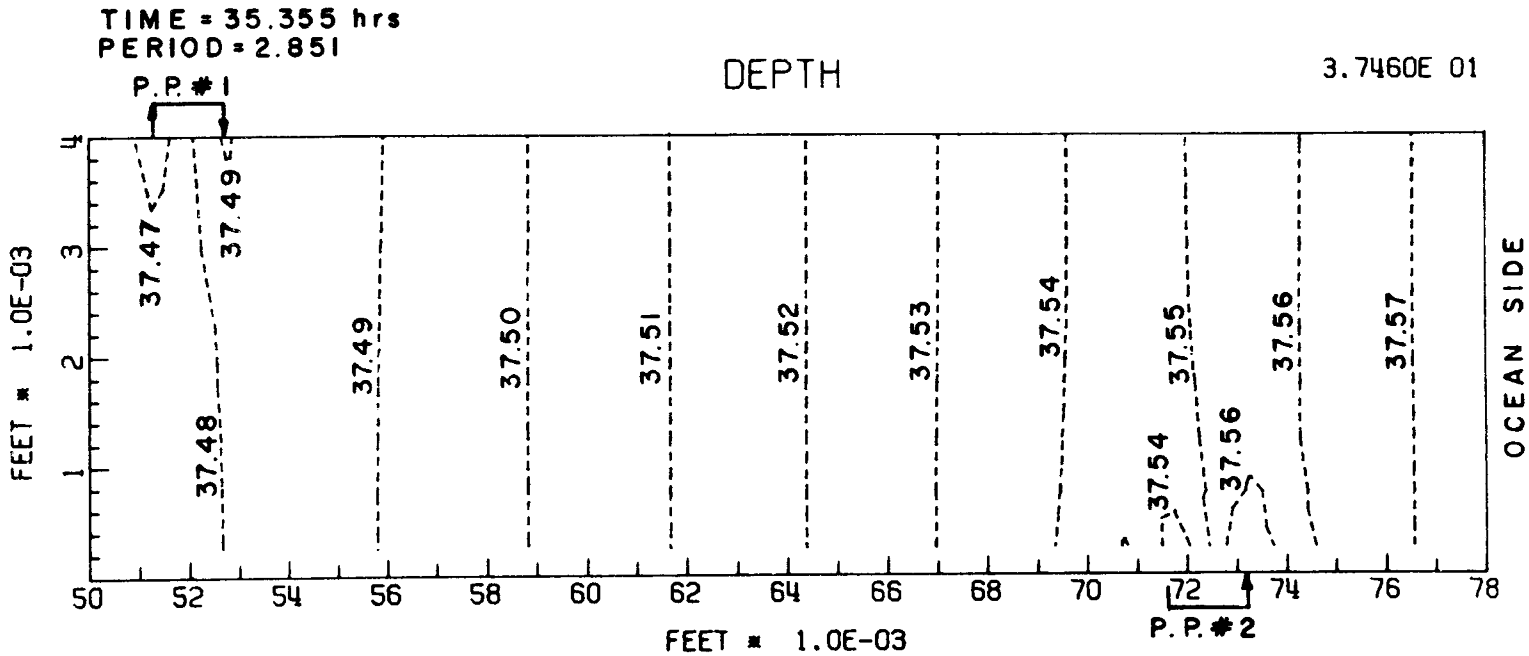


Figure 7.66. Water depth distribution (ft), at the zone of power plant discharges, for sample problem No. 2 at time = 35.355 hr and period of tidal of 2.851.

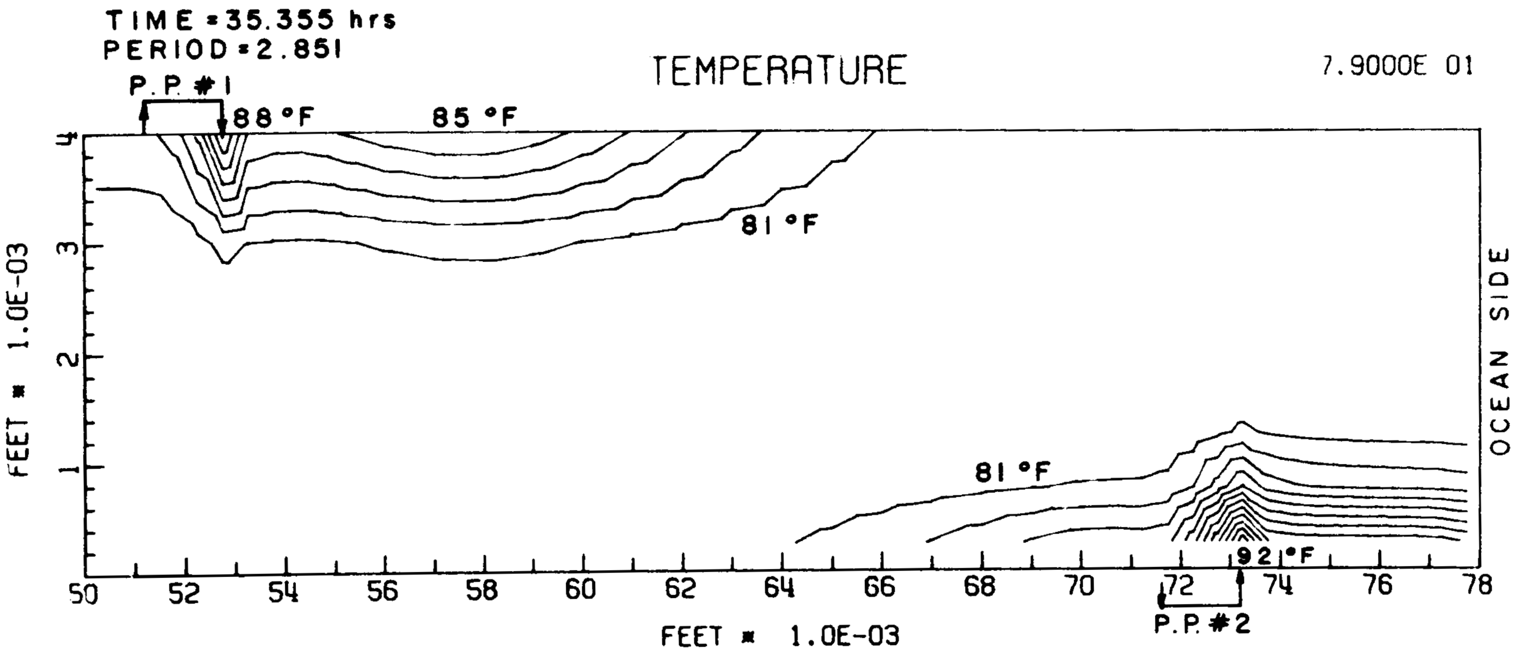


Figure 7.67. Temperature distribution (°F), at the zone of power plant discharges, for sample problem No. 2 at time = 35.355 hr and period of tidal of 2.851.

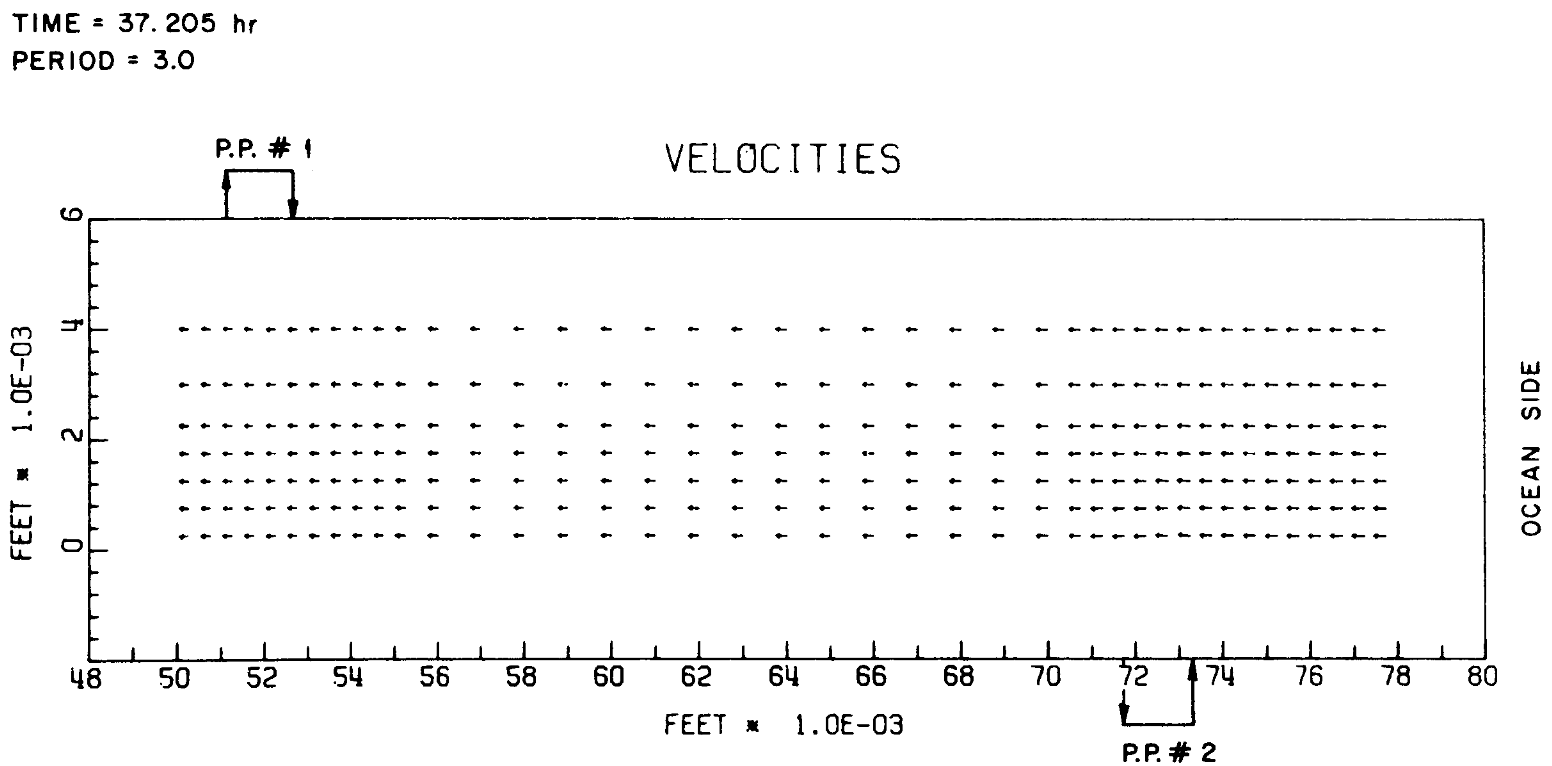


Figure 7.68. Velocity distribution (ft/hr), at the zone of power plant discharges, for sample problem No. 2 at time = 37.205 hr and period of tidal of 3.00.

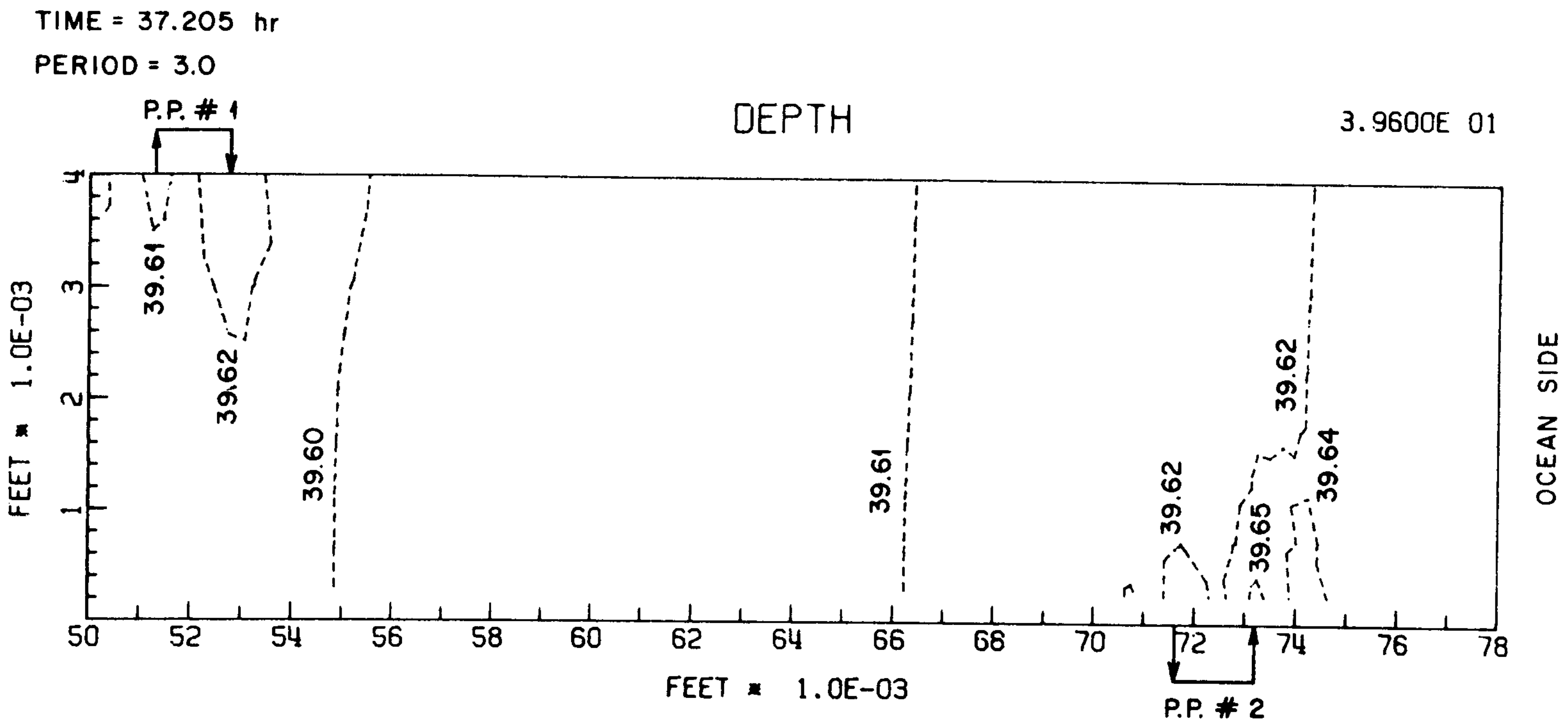


Figure 7.69. Water depth distribution (ft), at the zone of power plant discharges, for sample problem No. 2 at time = 37.205 hr and period of tidal of 3.00.

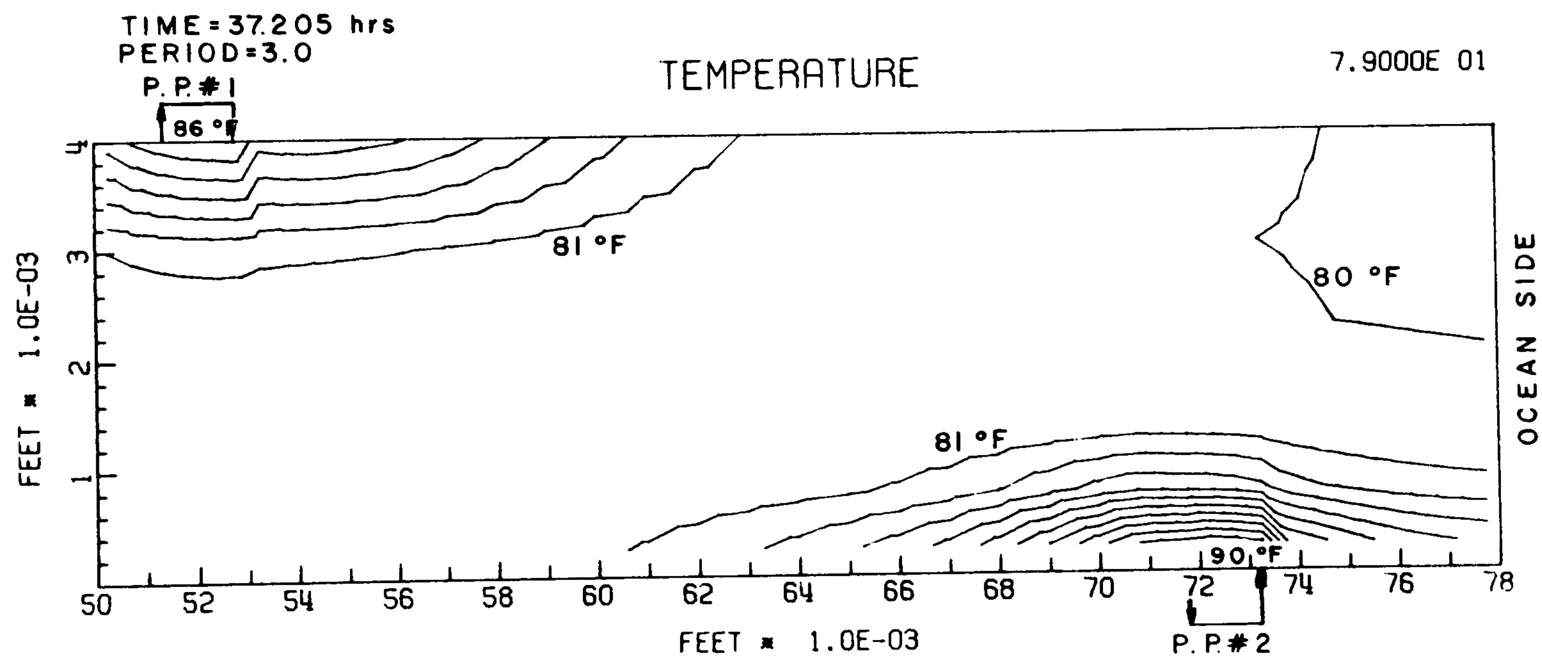


Figure 7.70. Temperature distribution (°F), at the zone of power plant discharges, for sample problem No. 2 at time = 37.205 hr and period of tidal of 3.00.

of hours, which seemed to be limited mainly by the diffusive part of the stability criteria developed in Section 6. On the other hand, the stable time step for the full thermal-hydraulic model was much smaller and was restricted mainly by the convective part of the stability criteria.

After gaining confidence with the use of the time step required for numerical stability, it was apparent that even when the solution was completely stable, it demonstrated oscillations with space; that is, the values of both water elevations and velocities were alternating for successive discrete elements. A close insight into the actual calculations performed by the computer program revealed that the problems come from the fact that both the water elevation (which is the driving force for the velocities) and the velocities (which are caused by water elevation differentials) are calculated at the same point (at the center of the discrete element). From the physical point of view the convecting fluxes must be evaluated on the half-point boundaries of each discrete element. This was indeed done, but the half-point values were based on linear interpolation between the two neighboring center values, which are the only ones calculated from the differential equations themselves. It seems more correct to evaluate the convective velocities at the half-point boundaries of each discrete element based on the differential equations themselves rather than on linear interpolation. To do this will require a staggered mesh, so that all the transported values will be calculated at the center point of each discrete element, while the convective velocities will be calculated (based on the actual differential equations and not linearly interpolated) at the half-point boundaries of each such discrete element. The use of such a double staggered mesh system will complicate the numerical solution considerably.

It is also clear that if the mesh size is then small enough so that any disturbance is well distributed between a number of discrete elements, the oscillations will be eliminated or at least minimized. However, such a course will dramatically increase the ratio of computer time to real time because of the effects of both increase in number of elements and decrease in the size of the time step required for numerical stability.

As a temporary measure, those oscillations were successfully eliminated by the use of an averaging technique between each two successive discrete elements. These averaging calculations are performed at the end of each complete time in a special subroutine called FILTER. It is recommended that the filtering technique, the staggered mesh system, and the reduced mesh size, as well as other possible solutions, be investigated for the best way to eliminate those oscillations.

As was mentioned before, the size of the time step must satisfy the stability criteria developed in Section 6. This, in addition to the fact that the computer time required for each time step for such an extensive model is understandably large, created a major financial obstacle to the ability to fully investigate the capabilities of the model by way of parametric studies under extensive sets of specified conditions. The two sample problems chosen here and presented in Sections 7.3.1 and 7.3.2 are designed to demonstrate the validity of the model (sample problem No. 1) and its capabilities (sample problem No. 2). Because of computer cost and financial limitations, both sample problems were run on a reduced version of the model which does not include the calculations of constituent mass concentration, and both sample problems were stopped before complete steady-state equilibrium had been achieved.

Figures 7.3 to 7.27 pages 102 to 206, show the results of the computer run for sample problem No. 1 in the form of plots for velocities (Figs. 7.3 to 7.6), water elevations (Figs. 7.7 to 7.22), and temperatures (Figs. 7.23 to 7.27). The symmetry of the flow around the discharge and intake points can be very well seen in all the above figures and specifically in the streak plots for velocities. In some cases the contour plots did not come up very smooth and the symmetry is not perfect in spite of the fact that corresponding printed output shows complete symmetry. That may be a result of the interpolation technique used in the plotting routines and the number of points available for this interpolation. It can be seen from Figs. 7.3 to 7.6 that hydraulic equilibrium at the inlet point is achieved rather fast. At the outlet point, it takes a few hours to achieve hydraulic equilibrium. Figure 7.6 shows a blown-up plot of the velocities at the vicinity of the inlet.

The mass balance has been checked by calculating the mass flows in the X direction at corss sections near the inlet and outlet points and comparing them with the total mass flow supplied at the inlet. At time 124.45 hours after initial conditions, the inlet flow was 30,080 cfs. At that same time the total flow in the X direction at a cross section 7,500 ft from the inlet point was 30100.7 cfs, which is an excellent agreement of +0.07%. The total flow in the X direction at a cross section 7,500 ft from the outlet point at the same time was 29,677.4 cfs which is also in a very good agreement of -1.3 percent, especially when the agreement might be further improved with time since complete hydraulic equilibrium was not yet achieved at the outlet.

Figures 7.7 to 7.15, pages 186 to 194, show the changes in water elevations with time over all the area modeled. Figures 7.16 to 7.22, pages 195 to 201, show a blown-up plot of the water elevations at the vicinity of the inlet. It is interesting in those plots to see the wave propagation and also the fact that the water elevations seem never to come to complete rest (at least not within the 124 hours of the run).

Figure 7.23 page 202, shows the temperature distribution and the spread of the heat around the discharge point. Since the farthest point to which change in temperature can be detected is less than 30,000 ft, Figures 7.24 to 7.27, pages 203 to 206, show blown-up plots of temperature distribution within this area. Thermal equilibrium was definitely not achieved. It must take more than 1,300 hours for a particle to move from the inlet point to the outlet point. That means that convection cannot be relied on for fast distribution of the heat, and diffusion is even a slower process. However, the heat balance has been checked based on transient conditions by comparing the total heat dumped into the water body to the heat absorbed by the water plus the heat lost to the atmosphere. The total heat dumped into the water body during the first 124.45 hours is

$$Q_{in} = G_{in} Cp_{in} \ \Delta T_{in} \ \Delta t = (540 \times 5000 \times 40.08 \times 62.2) \times 1.0 \times 15$$

$$\times 124.45$$

$$= 6.731 \times 10^{9} \times 1.0 \times 15 \times 124.45$$

$$= 12.565 \times 10^{12} \text{ Btu/hr} .$$

The total heat absorbed by the water during this period is

$$Q_{cap} = \sum_{i=1}^{N} A_i H_i \rho_i Cp_i \ \Delta T_i = AH_{av} \rho Cp \sum_{i=1}^{N} \Delta T_i$$

$$= 25 \times 10^{6} \times 40.08 \times 62.2 \times 159.2 = 9.922 \times 10^{12} \text{ Btu/hr} .$$

The total heat lost to the atmosphere must be calculated by increments of time. However, approximating it by the heat loss at the time 124.45 hours, one gets

$$Q_{lost} = \sum_{i=1}^{N} h_i A_i (T_i - T_E) \ t = h \cdot A \cdot \ t \sum_{i=1}^{N} (T_i - T_E)$$

$$= 5 \times 25 \times 10^{6} \times 124.45 \times 159.2 = 2.477 \times 10^{12} \text{ Btu/hr} ,$$

which gives an error of

$$\frac{Q_{lost} + Q_{cap}}{Q_{in}} = \frac{2.477 + 9.922}{12.565} = 1.3\% .$$

The heat lost to the atmosphere, however, is proportional to the excess temperature which itself changes with time. Performing the same calculations by increments of time gives an error of about 10 percent. In any case the agreement seems to be good considering the crude way the heat balance was performed.

Figures 7.29 to 7.70, pages 210 to 250, show the results of the computer run for sample problem No. 2 in a form of plots for velocities, water elevations, and temperatures at seven successive fractions of the tidal periods. Figures 7.29 to 7.49, pages 210 to 229, show the full area of the estuary modeled, and Figures 7.50 to 7.70, pages 230 to 250, show blown-up plots of the area around the two power plants, giving the changes of water velocities and water elevations with the tidal period. The dashed lines indicate water elevation below 40 ft. Unfortunately, the scale of the velocity vectors does not allow the direction of the flow to be seen clearly near the intake and discharge points of each power plant, although this is apparent in the plots for water elevations, and also in the printout of the results (see Appendix A). The interaction between the two power plants can be clearly seen in the plots for temperature distributions in both the full-area plots and the blown-up plots. Also, the cooling effects of the ocean temperature, which was set to 70°F, can be seen very clearly. The maximum temperature occurs at each power plant after slack water at the beginning of the ebb period. The maximum temperature at power plant No. 2, which is about 5 miles downstream of power plant No. 1, is higher because of the effect of heat convected downstream. It can be seen very clearly that the intake temperature of each power plant is much above ambient temperature. Recirculation of hot water from discharge to intake is properly taken into account. The full extent of the interaction between the two power plants may not yet have taken place, since the plots reflect only the third tidal cycle from the start of the problem. Quasi-steady-state conditions may not be achieved before at least 10 cycles. Nevertheless, most of the effects are already apparent. It is most satisfying to realize the capability of the model to handle such a complicated case of interacting power plants situated acorss from each other in an oscillating water body.

8. SUMMARY AND CONCLUSIONS

The objective of this study was to develop a time-dependent, two-dimensional mathematical model for predicting the velocities, water levels, temperature, and mass concentrations of various constituents in shallow vertically mixed water bodies. In order that such a model be useful, it must be capable of taking into account the very many complex contributors affecting the behavior and characteristics of such natural water bodies. Such a model must necessarily be highly nonlinear and is constrained by an extensive number of boundary conditions. For that reason the numerical approach is inescapable. In addition, it is recognized that for a prediction of various discharges into natural water bodies the model must incorporate both the immediate vicinity of the discharge point (nearfield) and the more distant zones (farfield), which are quite different in nature.

The model developed in this study meets most of those requirements although not all of them. The capability of the model to take into account complex factors affecting natural water bodies is almost unlimited. On the other hand, the use of the model for both the near field and the far field combined is limited mainly by our ability to understand and properly model the turbulent phenomena and the turbulent transport properties. The normal and shear stresses, which are properly included in the model, cannot be used to their full potential because of this basic limitation.

The major conclusions which can be derived from the present study are as follows.

1. The discrete element method can be successfully used for simulating natural water bodies based directly on the basic conservation principles of mass, momentum, and energy. This direct application of the conservation principles eliminates the need for first deriving complex partial differential equations and then integrating them numerically, based on rigid rules of differential calculus. Such an approach is very helpful to the practical engineer and scientist because of the clear identification of the various physical phenomena as well as the physical constraints expressed by the model boundaries.

2. It was demonstrated that the discrete element formulation of the conservation principles of mass, momentum, and energy can be easily reduced to the classical finite difference formulation of those principles by taking the limits as $\Delta X \to 0$, $\Delta Y \to 0$, and $\Delta t \to 0$, as is normally done in this formulation.

3. The time step criteria required to ensure numerical stability have been developed based on the discrete perturbation method for each one of the equations. These criteria include the effects of variable sizes of discrete elements, variable transport properties, convective effects, diffusion effects, surface heat and mass exchange on both bottom and top surfaces, and volumetric discharge and/or intake of both mass and heat. A more simplified but rather more conservative criterion commonly valid for all the equations has been developed for simpler and faster application.

4. Very complex factors affecting natural water bodies, such as wind, rain, evaporation, heat exchange with the atmosphere, seepage, bottom shear stresses, tributaries, tidal oscillation, and others, have been taken into account in a two-dimensional model. These factors can be realistically specified as both functions of space and time (although the time scale is smaller than turbulent time scale fluctuations).

5. The full simulation of normal and shear viscous stresses (laminar and turbulent) has been included in the momentum conservation equations. This allows the model to be potentially valid for simulating both near- and far-field regions. Full utilization of that potential is limited, however, by the limited capability to properly simulate and model turbulent transport properties.

6. The model is capable of simulating the mass transport of any number of constituents in the water body and the interaction between them. Full utilization of this capability is also limited by our present ability to model turbulent transport properties, specifically for more than two-component mixtures. However, used as such, the model can properly simulate salinity concentrations in salt intrusion zones in estuaries or mass concentrations of any number of noninteracting constituents discharged into a water body.

7. The model is capable of simulating discharges from a number of sources, including power plants, and properly takes into account the interactions between them as well as the recirculation effects between the intake and discharge structures. This capability is most valuable for assessing the impact of discharges from power plants or other sources

on the physical (and, therefore, also biological) environment of natural water bodies.

8. Because of its truly transient nature, the model is capable also of predicting rate of change of temperatures. Such information is very valuable for assessment of cold shock effects on aquatic biota when sharp discontinuities of start-up and shutdown in power plant operation occur.

9. Because of the inclusion of any number of constituents in the model and its capability to simulate intake structures, the model can potentially be extended to a full population distribution model for aquatic organisms in natural water bodies.

10. An extensive "decision making" network has been incorporated in the program for accepting the many possible physical boundary conditions. As can be imagined, with a minimum of six unknowns (assuming a mixture of two components only) and two space dimensions, such a logical network can be very complicated, and indeed it is. However, it allows the analyst to specify almost any realistic boundary conditions, which constitute, after all, the best chance to impose "reality" on a mathematical model.

11. The model was applied to two sample problems which demonstrated its workability and capabilities. The situation chosen in sample problem No. 2 is typical of realistic situations which are analyzed in environmental impact assessment and which definitely call for a time-dependent model like the one developed in this study. The ability to take into account the effects of interaction between two power plants situated

across from each other on the same water body under tidal conditions is most encouraging. Of course, a full verification of the validity of the model can be performed only by a very careful comparison with field data. Such a program is very strongly recommended for the future.

12. The application of the model with an extensive number of typical cases has shown that specification of a discontinuous function causes oscillations of the calculated velocities and water elevations with respect to space. These oscillations can be eliminated by the use of a finer mesh size which satisfies the cell Reynolds number.[78] However, satisfying this criterion requires the use of a very small grid mesh and, therefore, also a very small time step. The two requirements combined impose almost an impossible load on computer time. A temporary solution has been found by the use of the filtering subroutine, which eliminates these oscillations by an averaging technique. Another solution may be the use of a staggered mesh system. It is recommended that these and other methods be investigated to solve this problem.

13. Although the model is two dimensional and assumes vertically mixed conditions, this is not always the case found in reality. A three-dimensional model is very desirable from this point of view and will also reduce somewhat the necessity of using highly speculative shear flow dispersion coefficients to represent effects which are actually convective in nature. However, such models may be very costly to use, at least based on the presently available computing machines. Alternatively, an analytical method can be developed which will allow representation of vertical variations in a basically two-dimensional

model. It is strongly recommended that this be done as the very next step to the present study, specifically for cases where stratification and vertical variations do exist but are not necessarily predominant.

14. A computer program of the size and nature developed in this study is expected to be costly to run. The computer time required will depend on factors like number of elements, size of elements, velocities, diffusion coefficients, and others. These factors also determine the minimum time step required for numerical stability. The basic computer time required for the reduced version is about 0.00295 second of the IBM 360/91 computer for each time step and element. The full version, with two constituents, requires almost twice as much. This is indeed an obstacle, since it makes it expensive to run parametric studies, trial and error solutions, and verifications. Since the program is still in its exploratory form and no serious attempt has been made to optimize it, there is room for sharply improving this computing time performance. It is recommended that this be done, and other methods should be investigated to reduce computer time. The storage requirements are reasonable and do not cause any special problems.

15. The most apparent limitation for realization of the potential capabilities of mathematical models (analytical and numerical) is the very limited ability presently existing in realistically modeling turbulent transport properties. This fact is important especially when trying to simulate flow fields which are three dimensional in nature by two- or one-dimensional models. This limitation is a serious obstacle in a development of any model in fluid mechanics and seems to be the

"bottle neck" for the progress in this area. There is a great need for research, both theoretical and experimental, in turbulent transport modeling and its application in computational fluid mechanics.

16. A general computer program of the size and scope presented here requires constant usage, verification with field data, calibration, modifications, and capability improvements. A computer code of that nature does not become a truly reliable predictive tool unless evolutionized through use and experience. It is hoped that this computer model will indeed be adapted and used by careful thermal-hydraulic analysts who are fully aware of its capabilities, and most importantly, its limitations, until it is proven to be completely reliable and productive.

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APPENDIX A

COMPLETE INPUT AND OUTPUT FOR THE SAMPLE PROBLEMS

Table A.1. Input Data for Sample Problem No. 1

```
CASE TITLE: TEST PROBLEM NO.2:SQUARE POOL WITH FLOW IN AND OUT
--- --- ---

INPUT INFORMATION FROM SUBROUTINE INPUT:
--- --- --- --- --- --- --- --- --- ---

CARD NO. 1

TOTAL NUMBER OF CHEMICAL SPECIES CK CONSIDERED (NK) =   2

TOTAL NUMBER OF REGIONS (NREG) =   9

TOTAL NUMBER OF INITIAL CONDITIONS FUNCTIONS (NINTLF) =   2

TOTAL NUMBER OF VOLUMETRIC HEAT OR MASS GENERATION  FUNCTIONS (NGENF) =   1

TOTAL NUMBER OF BOUNDARY CONDITIONS FUNCTIONS (NBNDF) =   5

TOTAL NUMBER OF TOP CONDITIONS FUNCTIONS (NTOPF) =   2

TOTAL NUMBER OF BOTTOM CONDITIONS FUNCTIONS (NBOTF) =   2

TOTAL NUMBER OF ANALYTICAL FUNCTICNS (NANLFC) =   3

TOTAL NUMBER OF TABULATED FUNCTIONS (NTBLFC) =   1

TOTAL NUMBER OF GROSS LATTICE LINES IN X-DIRECTION (NXGRL) =   4

TOTAL NUMBER OF GROSS LATTICE LINES IN Y-DIRECTION (NYGRL) =   4

TOTAL NUMBER OF TEMP. MONITORING POINTS (NTMAX) =    3


CARD NO.  2

RESTART FLAG. IF EQUAL ZERO NO RESTART INFORMATION IS REQUIRED (ISTART) =   0

FINISH FLAG. IF EQUAL ZERO NO RESTART FILE IS CREATED (IFINIS) =   0

PLOTTING FLAG. IF EQUAL ZERO NO PLOTTING INFORMATION IS GENERATED. (IPLOT) =   0

FLAG FOR SELECTING THE NUMERICAL INTEGRATION PROCEDURE. (INTRT=1 SELECTS RUNGE-KUTTA-GILL METH
  INTRT=2 SELECTS EULER  METHOD.  INTRT=3 SELECTS ADAM-BASHWORTH METHOD.) (INTRT) =1


CARD NO. 3

STARTING TIME OF THIS CASE (STM) =   0.0

PROBLEM TIME FOR THIS CASE (PRBTM) = 124.0000

COMPUTER TIME CUTOFF LIMIT IN SECONDS (CPUSEC) =  295.00

TIME INCREMENT FOR PRINTED OUTPUT (DPRTTM) =    1.0000

TIDAL PERIOD IF AN ESTUARY (TIDAL) =   1.0000


CARD NO. 4
```

```
INITIAL TIME INCREMENT (SDTM) = 0.05000

LARGEST LIMIT FOR TIME INCREMENT (FDTM)=  0.05000

TIME INCREMENT IS MULTIPLIED EVERY NDTMC TIME STEPS BY (DTMIT)=     1.00

NUMBER OF TIME STEPS BEFORE PROCESS OF INCREASE IN TIME STEP SIZE BEGINS (INDTM)=  10

NUMBER OF TIME STEPS BETWEEN CHANGES IN TIME STEP SIZE (NDTMC) =    5

CRITERION TYPE (AS DEFINED IN SUBROUTINE CHKDTM) THAT EACH DTM WILL BE REQUIRED TO SATISFY (LDTMCR)=    0

TABULATED  FUNCTIONS

     TABLE NO.  1
   TABARG        TABFNC
0.0            0.0
1.0000D 00     4.0000D-01
3.0000D 00     8.0000D-01
6.0000D 00     9.5000D-01
8.0000D 00     1.0000D 00
1.0000D 01     1.0000D 00


INPUT INFORMATION FROM SUBROUTINE GEOM:
--- --- --- --- --- --- --- --- --- ---

XGRL(I)  - GROSS LATTICE LINE I IN THE X-DIRECTION

IXFD(I)  - NUMBER OF SUBDIVISIONS BETWEEN GROSS LATTICE LINES XGRL(I) AND XGRL(I+1).

YGRL(I)  - GROSS LATTICE LINE I IN Y-DIRECTION.

IYFD(I)  - NUMBER OF SUBDIVISIONS BETWEEN GROSS LATTICE LINES YGRL(I) AND YGRL(I+1).


I       XGRL         IXFD
1    0.0              10
2    5.00000D 04       1
3    5.50000D 04      10
4    1.05000D 05


I       YGRL         IYFD
1    0.0              10
2    5.00000D 04       1
3    5.50000D 04      10
4    1.05000D 05

                NODAL WIDTH                     NODAL CENTER
  I   X-DIRECTION    Y-DIRECTION    X-DIRECTION    Y-DIRECTION
  1   5000.00000     5000.00000    2.500000D 03   2.5000C0D 03
  2   5000.00000     5000.00000    7.500000D 03   7.5000C0D 03
  3   5000.00000     5000.00000    1.250000D 04   1.2500C0D 04
  4   5000.00000     5000.00000    1.750000D 04   1.7500C0D 04
  5   5000.00000     5000.00000    2.250000D 04   2.2500C0D 04
  6   5000.00000     5000.00000    2.750000D 04   2.7500C0D 04
  7   5000.00000     5000.00000    3.250000D 04   3.2500C0D 04
  8   5000.00000     5000.00000    3.750000D 04   3.7500C0D 04
```

Table A.1 (continued)

9	5000.00000	5000.00000	4.250000D 04	4.250000D 04
10	5000.00000	5000.00000	4.750000D 04	4.750000D 04
11	5000.00000	5000.00000	5.250000D 04	5.250000D 04
12	5000.00000	5000.00000	5.750000D 04	5.750000D 04
13	5000.00000	5000.00000	6.250000D 04	6.250000D 04
14	5000.00000	5000.00000	6.750000D 04	6.750000D 04
15	5000.00000	5000.00000	7.250000D 04	7.250000D 04
16	5000.00000	5000.00000	7.750000D 04	7.750000D 04
17	5000.00000	5000.00000	8.250000D 04	8.250000D 04
18	5000.00000	5000.00000	8.750000D 04	8.750000D 04
19	5000.00000	5000.00000	9.250000D 04	9.250000D 04
20	5000.00000	5000.00000	9.750000D 04	9.750000D 04
21	5000.00000	5000.00000	1.025000D 05	1.025000D 05

Table A.1 (continued)

GEOMETRIC DESCRIPTION OF REGIONS / INDEXICAL DESCRIPTION

REGION	UPX	DNX	UPY	DNY	DEPTH	AREA	I LOW	IHIGH	J LOW	JHIGH	NODES
1	0.0	50000.00	0.0	50000.00	40.000	2.5000D 09	1	10	1	10	100
2	0.0	50000.00	50000.00	55000.00	40.000	2.5000D 08	1	10	11	11	10
3	0.0	50000.00	55000.00	105000.00	40.000	2.5000D 09	1	10	12	21	100
4	50000.00	55000.00	0.0	50000.00	40.000	2.5000D 08	11	11	1	10	10
5	50000.00	55000.00	50000.00	55000.00	40.000	2.5000D 07	11	11	11	11	1
6	50000.00	55000.00	55000.00	105000.00	40.000	2.5000D 08	11	11	12	21	10
7	55000.00	105000.00	0.0	50000.00	40.000	2.5000D 09	12	21	1	10	100
8	55000.00	105000.00	50000.00	55000.00	40.000	2.5000D 08	12	21	11	11	10
9	55000.00	105000.00	55000.00	105000.00	40.000	2.5000D 09	12	21	12	21	100

TOTAL NO. OF NODES IN (INPUT) REGIONS= 441
MAX. NO. OF NODES IN GRID= 441

REGION	FUNCTION SELECTION INTF	IGENF	ITOPF	IBOTF	BOUNDARY SELECTION IUPXB	IDNXB	IUPYB	IDNYB
1	1	0	1	1	1	0	4	0
2	1	0	1	1	2	0	0	0
3	1	0	1	1	1	0	0	4
4	1	0	1	1	0	0	4	0
5	1	0	1	1	0	0	0	0
6	1	0	1	1	0	0	0	4
7	1	0	1	1	0	1	4	0
8	1	0	1	1	0	3	0	0
9	1	0	1	1	0	1	0	4

NUMBER OF ELEMENTS AVAILABLE IN ARRAY Z IN MAIN = 8600

NUMBER OF ELEMENTS NEEDED = 8547

POSITIONS TO MONITOR TEMPERATURE

M	REQUESTED LOCATION X	Y	SELECTED NODE I	J	NODE LOCATION X	Y	NODE REGION
1	2500.000	52500.000	1	11	2500.000	52500.000	2
2	102500.000	52500.000	21	11	102500.000	52500.000	8
3	52500.000	2500.000	11	1	52500.000	2500.000	4

```
NODAL DISPLAY FOR UPSTREAM BOUNDARIES IN X-DIRECTION,NPXM

J= 21**1
J= 20**1
J= 19**1
J= 18**1
J= 17**1
J= 16**1
J= 15**1
J= 14**1
J= 13**1
J= 12**1
J= 11**2
J= 10**1
J=  9**1
J=  8**1
J=  7**1
J=  6**1
J=  5**1
J=  4**1
J=  3**1
J=  2**1
J=  1**1
```

Table A.1 (continued)

NODAL DISPLAY FOR DOWNSTREAM BOUNDARIES IN X-DIRECTION,NBXP

J= 21**	1
J= 20**	1
J= 19**	1
J= 18**	1
J= 17**	1
J= 16**	1
J= 15**	1
J= 14**	1
J= 13**	1
J= 12**	1
J= 11**	3
J= 10**	1
J= 9**	1
J= 8**	1
J= 7**	1
J= 6**	1
J= 5**	1
J= 4**	1
J= 3**	1
J= 2**	1
J= 1**	1

Table A.1 (continued)

```
NODAL DISPLAY FOR UPSTREAM BOUNDARIES IN Y-DIRECTION,NEYM

J= 21**
J= 20**
J= 19**
J= 18**
J= 17**
J= 16**
J= 15**
J= 14**
J= 13**
J= 12**
J= 11**
J= 10**
J=  9**
J=  8**
J=  7**
J=  6**
J=  5**
J=  4**
J=  3**
J=  2**
J=  1**444444444444444444444
```

Table A.1 (continued)

```
NODAL DISPLAY FOR DOWNSTREAM BOUNDARIES IN Y-DIRECTION,NBYP

J= 21**444444444444444444444
J= 20**
J= 19**
J= 18**
J= 17**
J= 16**
J= 15**
J= 14**
J= 13**
J= 12**
J= 11**
J= 10**
J=  9**
J=  8**
J=  7**
J=  6**
J=  5**
J=  4**
J=  3**
J=  2**
J=  1**
```

Table A.1 (continued)

```
NODAL DISPLAY FOR REGIONS

J=  21**3333333333369999999999
J=  20**3333333333369999999999
J=  19**3333333333369999999999
J=  18**3333333333369999999999
J=  17**3333333333369999999999
J=  16**3333333333369999999999
J=  15**3333333333369999999999
J=  14**3333333333369999999999
J=  13**3333333333369999999999
J=  12**3333333333369999999999
J=  11**2222222222258888888888
J=  10**1111111111147777777777
J=   9**1111111111147777777777
J=   8**1111111111147777777777
J=   7**1111111111147777777777
J=   6**1111111111147777777777
J=   5**1111111111147777777777
J=   4**1111111111147777777777
J=   3**1111111111147777777777
J=   2**1111111111147777777777
J=   1**1111111111147777777777
```

Table A.1 (continued)

```
INPUT INFORMATION FROM SUBROUTINE GENCON:
--- --- --- --- --- --- --- --- --- ---

IGENFC - INTERNAL GENERATION FUNCTION (AN INDEX)
QDV - VALUE OF HEAT GENERATION PER UNIT VOLUME IN INTERNAL GENERATION FUNCTION
IQDVF - GENERAL PURPOSE FUNCTION TO BE USED ON QDV
GKDV(K) - VALUE OF MASS GENERATION PER UNIT VOLUME FOR SPECIE K IN INTERNAL GENERATION FUNCTION
IGKDVF(K) - GENERAL PURPOSE FUNCTION TO BE USED ON GKDV(K)
```

K	IGENFC	QDV	IQDVF	GKDV(1)	IGKDVF(1)	GKDV(2)	IGKDVF(2)
1	1	0.0	0	0.0	0	0.0	0

Table A.1 (continued)

INPUT INFORMATION FROM SUBROUTINE BNDCON:
--- --- --- --- --- --- --- --- ---

NBN - BOUNDARY CONDITION NUMBER
NHBDTP - TYPE OF BOUNDARY CONDITICN FOR WATER ELEVATICN H (NHBDTP)
NU - TYPE OF BOUNDARY CONDITION FCR VELOCITY U (NUBDTP)
NV - TYPE OF BCUNDARY CONDITION FCR VELOCITY V (NVBDTP)
NT - TYPE OF BOUNDARY CONDITION FOR TEMP. OR SPECIES CONCENTRATION (NBTDTP)
FH - VALUE OF BOUNDARY CONDITICN FOR WATER ELEVATION (FHBD)
FU - VALUE OF BOUNDARY CONDITION FOR VELOCITY U (FUBD)
FV - VALUE OF BOUNDARY CONDITION FOR VELOCITY V (FVBD)
FT - VALUE OF BOUNDARY CONDITION FOR TEMP. (FTBD)
FG - VALUE OF BOUNDARY CONDITION FOR MASS FLUX (FGBD)
FQ - VALUE OF BOUNDARY CONDITION FOR HEAT FLUX (FQBD)
FSBDN - VALUE OF BOUNDARY CONDITICN FCR NORMAL STRESSES
FGK(1) - VALUE OF BOUNDARY CONDITION FOR MASS FLUX OF SPECIE K (FGKBD)
FCK - VALUE OF BOUNDARY CONDITICN FOR SPECIES CONCENTRATION (FCKBD)
IHBDP - MULTIPLIER FUNCTION FOR FHBD
IU - MULTIPLIER FUNCTION FOR FUBD
IV - MULTIPLIER FUNCTION FOR FVBD
IT - MULTIPLIER FUNCTION FOR FTBD
IG - MULTIPLIER FUNCTION FOR FGBD
IQ - MULTIPLIER FUNCTICN FOR FQBD
ISN - MULTIPLIER FUNCTION FOR FSBDN
ISH - MULTIPLIER FUNCTION FOR FSBDSH

BOUNDARY CONDITIONS AT STARTING TIME

NBN	NHBDTP	NU	NV	NT	FH	FU	FV	FT
1	4	1	2	2	0.0	0.0	0.0	8.000000D 01
2	4	1	1	1	0.0	5.400000D 02	0.0	9.500000D 01
3	1	4	4	4	4.000000D 01	0.0	0.0	7.000000D 01
4	4	2	1	2	0.0	0.0	0.0	8.000000D 01
5	4	1	1	1	0.0	0.0	4.465800D 02	-1.500000D 01

NBN	FG	FQ	FSBDN	FSBDSH	FGK(1)	FGK(2)	FCK(1)	FCK(2)
1	0.0	0.0	0.0	0.0	0.0	0.0	1.000	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.923	0.027
3	0.0	0.0	0.0	0.0	0.0	0.0	0.973	0.027
4	0.0	0.0	0.0	0.0	0.0	0.0	1.000	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	1.000	0.0

MULTIPLIER FUNCTIONS FOR BOUNDARY CONDITIONS

NBN	IHBDP	IU	IV	IT	IG	IQ	ISN	ISH
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0

POWER PLANT ON BOUNDARY.

NBN	DTPP(NBN)	XINT	YINT	I	J
5	1.5000D 01	4.75000D 04	2.50000D 03	10	1

Table A.1 (continued)

INPUT INFORMATION FROM SUBROUTINE BOTCON:
--- --- --- --- --- --- --- --- --- ---

QB - HEAT COMING FROM THE BOTTOM
HCB - HEAT TRANSFER COEFFICIENT FOR THE BOTTOM
UB - VELOCITY OF MASS COMING FROM THE BOTTOM IN X-DIRECTION
VB - VELOCITY OF MASS COMING FROM THE BOTTOM IN Y-DIRECTION
WB - VELOCITY OF MASS COMING FROM THE BOTTOM IN Z-DIRECTION
TB - TEMPERATURE OF MASS COMING FROM THE BOTTOM
BMANGC - MANNING COEF. FOR FRICTION WITH THE BOTTOM
DCKB - MASS DIFFUSION COEFFICIENT FOR SPECIE K FROM BOTTOM
CKB - MASS CONCENTRATION OF SPECIES COMING FROM BOTTOM
IQB - MULTIPLIER FUNCTION FOR QB
IHCB - MULTIPLIER FUNCTION FOR HCB
IUB - MULTIPLIER FUNCTION FOR UB
IVB - MULTIPLIER FUNCTION FOR VB
IWB - MULTIPLIER FUNCTION FOR WB
ITB - MULTIPLIER FUNCTION FOR TB
IDCKB - MULTIPLIER FUNCTION FOR DCKB
ICKB - MULTIPLIER FUNCTION FOR CKB

BOTTOM CONDITIONS AT STARTING TIME

FCT. NO.	QB	HCB	UB	VB	WB	TB	BMANGC	DCKB(1)	CKB(1)	DCKB(2)	CKB(2)
1	0.0	0.0	0.0	0.0	0.0	8.00D 01	8.33D-06	0.0	10.00	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	8.00D 01	8.33D-06	0.0	10.00	0.0	0.0

MULTIPLIER FUNCTION FOR BOTTOM CONDITIONS

FCT.NO.	IQB	IHCB	IUB	IVB	IWB	ITB	IDCKB(1)	ICKB(1)	IDCKB(2)	ICKB(2)
1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0

INPUT INFORMATION FROM SUBROUTINE TOPCON:
--- --- --- --- --- --- --- --- --- ---

QT - HEAT COMING FROM THE TOP
HCT - HEAT TRANSFER COEFFICIENT FOR TOP
UT - VELOCITY OF MASS COMING FROM THE TOP IN X-DIRECTION
VT - VELOCITY OF MASS COMING FROM THE TOP IN Y-DIRECTION
WT - VELOCITY OF MASS COMING FROM THE TOP IN Z-DIRECTION
TT - TEMPERATURE OF MASS COMING FROM THE TOP
TD - DEW-POINT TEMPERATURE
QSOL - SOLAR HEAT FLUX
DCKT - MASS DIFFUSION COEFFICIENT FOR SPECIE K FROM TOP
CKT - MASS CONCENTRATION OF SPECIES COMING FROM THE TOP
IQT - MULTIPLIER FUNCTION FOR QT
IHCT - MULTIPLIER FUNCTION FOR HCT
IUT - MULTIPLIER FUNCTION FOR UT
IVT - MULTIPLIER FUNCTION FOR VT
IWT - MULTIPLIER FUNCTION FOR WT
ITT - MULTIPLIER FUNCTION FOR TT
ITD - MULTIPLIER FUNCTION FOR TD
IQSOL - MULTIPLIER FUNCTION FOR QSOL
IDCKT - MULTIPLIER FUNCTION FOR DCKT
ICKT - MULTIPLIER FUNCTION FOR CKT

TOP CONDITIONS AT STARTING TIME

FCT. NO.	QT	HCT	UT	VT	WT	TT	TD	QSOL	DCKT(1)	CKT(1)	DCKT(2)	CKT(2)

1	0.0	5.00	0.0	0.0	0.0	80.00	80.00	0.0	0.0	1.00	0.0	0.0
2	0.0	5.00	0.0	0.0	0.0	80.00	80.00	0.0	0.0	1.00	0.0	0.0

MULTIPLIER FUNCTION FOR TOP CONDITIONS

FCT. NO.	IQT	IHCT	IUT	IVT	IWT	ITT	ITD	IQSOL	IDCKT(1)	ICKT(1)	IDCKT(2)	ICKT(2)
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0

INPUT INFORMATION FROM SUBROUTINE FLXCON:
--- --- --- --- --- --- --- --- --- ---

COEFFICIENT FOR TOTAL EFFECTIVE THERMAL CONDUCTIVITY IN X-DIRECTION (XKPC) = 3.500000D-01
COEFFICIENT FOR TOTAL EFFECTIVE THERMAL CONDUCTIVITY IN Y-DIRECTION (YKPC) = 3.500000D-01
COEFFICIENT FOR TURBULENT VISCOSITY IN X-DIRECTION(XTVSC) = 2.000000D 00
COEFFICIENT FOR TURBULENT VISCOSITY IN Y-DIRECTION (YTVSC) = 2.000000D 00

DKXC - COEFFICIENT FOR TOTAL BINARY EFFECTIVE DIFFUSION COEFFICIENT OF SPECIE K IN X-DIRECTION
DKYC - COEFFICIENT FOR TOTAL BINARY EFFECTIVE DIFFUSION COEFFICIENT OF SPECIE K IN Y-DIRECTION

K	DKXC(K)	DKYC(K)
1	5.220000D-05	5.220000D-05
2	5.220000D-05	5.220000D-05

INPUT INFORMATION FROM SUBROUTINE INTCON:
--- --- --- --- --- --- --- --- --- ---

STH - INITIAL VALUE FOR WATER SURFACE ELEVATION, H, MEASURED FROM THE BOTTOM
STU - INITIAL VALUE FOR WATER VELOCITY, U, IN X-DIRECTION
STV - INITIAL VALUE FOR WATER VELOCITY, V, IN Y-DIRECTION
STWS - INITIAL VALUE FOR RATE OF CHANGE OF WATER ELEVATION WITH RESPECT TO TIME
STT - INITIAL VALUE FOR WATER TEMPERATURE, T.
STCK(I) - INITIAL VALUE FOR MASS CONCENTRATION OF SPECIES(I).
ISTHF - MULTIPLIER FUNCTION FOR STH
ISTUF - MULTIPLIER FUNCTION FOR STU
ISTVF - MULTIPLIER FUNCTION FOR STV
ISTWSF - MULTIPLIER FUNCTION FOR STWS
ISTTF - MULTIPLIER FUNCTION FOR STT
ISTCKF(I) - MULTIPLIER FUNCTION FOR STCK(I)

INITIAL CONDITIONS

FUNCTION NO.	STH	STU	STV	STT	STCK(1)	STCK(2)
1	40.00	0.0	0.0	80.00	1.00	0.0
2	40.00	0.0	0.0	80.00	1.00	0.0

MULTIPLIER FUNCTION FOR INITIAL CONDITIONS

FCT.NO.	ISTH	ISTU	ISTV	ISTT	ISTCK(1)	ISTCK(2)
1	0	0	0	0	0	0
2	0	0	0	0	0	0

Table A.2. Output Information for Sample Problem No. 1 at Time = 5.6 hr
Using the Fall Version of the Program

ITER.= 106 TIME=5.300000D 00 PERIOD=5.300000D 00 TIME INCREMENT=5.000000D-02

NODE	INDI- CES	X- LOCATION	Y- LOCATION	WATER ELEVATION	VELOCITY IN X-DIRECT.	VELOCITY IN Y-DIRECT.	WATER ELEV. RATE OF CHANGE	TEMP.	TEMP. RATE OF CHANGE	SUBSTANCE MASS CONCENTRATIONS CK(1)	CK(2)
1	1	2500.00	2500.00	4.01060D 01	2.237D 01	-2.150D 01	5.819D-03	8.000D 01	4.760D-12	1.000D 00	5.091D-15
1	2	2500.00	7500.00	4.01061D 01	2.254D 01	-6.505D 01	1.113D-02	8.000D 01	8.679D-10	1.000D 00	1.043D-12
1	3	2500.00	12500.00	4.01061D 01	2.448D 01	-1.114D 02	2.100D-02	8.000D 01	6.877D-08	1.000D 00	9.395D-11
1	4	2500.00	17500.00	4.01062D 01	3.211D 01	-1.639D 02	1.797D-02	8.000D 01	3.035D-06	1.000D 00	4.808D-09
1	5	2500.00	22500.00	4.01069D 01	5.072D 01	-2.260D 02	-4.265D-02	8.000D 01	7.880D-05	1.000D 00	1.515D-07
1	6	2500.00	27500.00	4.01089D 01	9.270D 01	-3.048D 02	-9.126D-02	8.000D 01	1.227D-03	1.000D 00	2.958D-06
1	7	2500.00	32500.00	4.01127D 01	1.832D 02	-4.242D 02	2.533D-01	8.002D 01	1.192D-02	9.999D-01	3.482D-05
1	8	2500.00	37500.00	4.01243D 01	3.553D 02	-6.218D 02	7.398D-01	8.012D 01	6.447D-02	9.993D-01	2.318D-04
1	9	2500.00	42500.00	4.01609D 01	3.667D 02	-8.848D 02	6.500D-01	8.046D 01	1.834D-01	9.975D-01	8.769D-04
1	10	2500.00	47500.00	4.03404D 01	-7.167D 02	-8.008D 02	-4.163D 00	8.110D 01	3.296D-01	9.941D-01	2.084D-03
1	11	2500.00	52500.00	4.04924D 01	-1.701D 03	3.325D-12	3.706D 00	8.313D 01	1.250D-01	9.832D-01	5.886D-03
1	12	2500.00	57500.00	4.03404D 01	-7.167D 02	8.008D 02	-4.163D 00	8.110D 01	3.296D-01	9.941D-01	2.084D-03
1	13	2500.00	62500.00	4.01609D 01	3.667D 02	8.848D 02	6.500D-01	8.046D 01	1.834D-01	9.975D-01	8.769D-04
1	14	2500.00	67500.00	4.01243D 01	3.553D 02	6.218D 02	7.398D-01	8.012D 01	6.447D-02	9.993D-01	2.318D-04
1	15	2500.00	72500.00	4.01127D 01	1.832D 02	4.242D 02	2.533D-01	8.002D 01	1.192D-02	9.999D-01	3.482D-05
1	16	2500.00	77500.00	4.01089D 01	9.270D 01	3.048D 02	-9.126D-02	8.000D 01	1.227D-03	1.000D 00	2.958D-06
1	17	2500.00	82500.00	4.01069D 01	5.072D 01	2.260D 02	-4.265D-02	8.000D 01	7.880D-05	1.000D 00	1.515D-07
1	18	2500.00	87500.00	4.01062D 01	3.211D 01	1.639D 02	1.797D-02	8.000D 01	3.035D-06	1.000D 00	4.808D-09
1	19	2500.00	92500.00	4.01061D 01	2.448D 01	1.114D 02	2.100D-02	8.000D 01	6.877D-08	1.000D 00	9.395D-11
1	20	2500.00	97500.00	4.01061D 01	2.254D 01	6.505D 01	1.113D-02	8.000D 01	8.679D-10	1.000D 00	1.043D-12
1	21	2500.00	102500.00	4.01060D 01	2.237D 01	2.150D 01	5.819D-03	8.000D 01	4.760D-12	1.000D 00	5.091D-15
2	1	7500.00	2500.00	4.01057D 01	6.250D 01	-1.927D 01	1.799D-02	8.000D 01	2.004D-13	1.000D 00	1.891D-16
2	2	7500.00	7500.00	4.01059D 01	6.468D 01	-5.740D 01	7.912D-03	8.000D 01	4.036D-11	1.000D 00	4.287D-14
2	3	7500.00	12500.00	4.01063D 01	7.018D 01	-9.721D 01	5.222D-03	8.000D 01	3.557D-09	1.000D 00	4.293D-12
2	4	7500.00	17500.00	4.01068D 01	8.147D 01	-1.405D 02	3.988D-02	8.000D 01	1.792D-07	1.000D 00	2.452D-10
2	5	7500.00	22500.00	4.01071D 01	1.024D 02	-1.890D 02	1.066D-01	8.000D 01	5.633D-06	1.000D 00	8.616D-09
2	6	7500.00	27500.00	4.01077D 01	1.375D 02	-2.418D 02	1.333D-01	8.000D 01	1.098D-04	1.000D 00	1.932D-07
2	7	7500.00	32500.00	4.01111D 01	1.882D 02	-2.814D 02	-3.951D-01	8.000D 01	1.159D-03	1.000D 00	2.735D-06
2	8	7500.00	37500.00	4.01172D 01	2.368D 02	-2.894D 02	-5.884D-01	8.001D 01	7.146D-03	9.999D-01	2.364D-05
2	9	7500.00	42500.00	4.01175D 01	1.679D 02	-2.422D 02	-4.689D-01	8.006D 01	3.343D-02	9.997D-01	1.065D-04
2	10	7500.00	47500.00	4.01094D 01	-2.328D 02	-1.296D 02	5.514D-01	8.000D 01	2.446D-03	1.000D 00	9.250D-06
2	11	7500.00	52500.00	4.01041D 01	-5.450D 02	-7.171D-12	-6.543D 00	8.000D 01	4.836D-04	1.000D 00	6.811D-07
2	12	7500.00	57500.00	4.01094D 01	-2.328D 02	1.296D 02	5.514D-01	8.000D 01	2.446D-03	1.000D 00	9.250D-06
2	13	7500.00	62500.00	4.01175D 01	1.679D 02	2.422D 02	-4.689D-01	8.006D 01	3.343D-02	9.997D-01	1.065D-04
2	14	7500.00	67500.00	4.01172D 01	2.368D 02	2.894D 02	-5.884D-01	8.001D 01	7.146D-03	9.999D-01	2.364D-05
2	15	7500.00	72500.00	4.01111D 01	1.882D 02	2.814D 02	-3.951D-01	8.000D 01	1.159D-03	1.000D 00	2.735D-06
2	16	7500.00	77500.00	4.01077D 01	1.375D 02	2.418D 02	1.333D-01	8.000D 01	1.098D-04	1.000D 00	1.932D-07
2	17	7500.00	82500.00	4.01071D 01	1.024D 02	1.890D 02	1.066D-01	8.000D 01	5.633D-06	1.000D 00	8.616D-09
2	18	7500.00	87500.00	4.01068D 01	8.147D 01	1.405D 02	3.988D-02	8.000D 01	1.792D-07	1.000D 00	2.452D-10
2	19	7500.00	92500.00	4.01063D 01	7.018D 01	9.721D 01	5.222D-03	8.000D 01	3.557D-09	1.000D 00	4.293D-12
2	20	7500.00	97500.00	4.01059D 01	6.468D 01	5.740D 01	7.912D-03	8.000D 01	4.036D-11	1.000D 00	4.287D-14
2	21	7500.00	102500.00	4.01057D 01	6.250D 01	1.927D 01	1.799D-02	8.000D 01	2.004D-13	1.000D 00	1.891D-16
3	1	12500.00	2500.00	4.01050D 01	9.528D 01	-1.427D 01	8.142D-03	8.000D 01	4.186D-15	1.000D 00	3.695D-18
3	2	12500.00	7500.00	4.01051D 01	9.819D 01	-4.229D 01	6.735D-03	8.000D 01	9.569D-13	1.000D 00	9.131D-16
3	3	12500.00	12500.00	4.01053D 01	1.046D 02	-7.007D 01	4.067D-03	8.000D 01	9.481D-11	1.000D 00	1.007D-13
3	4	12500.00	17500.00	4.01056D 01	1.153D 02	-9.656D 01	-1.080D-02	8.000D 01	5.343D-09	1.000D 00	6.419D-12
3	5	12500.00	22500.00	4.01057D 01	1.317D 02	-1.199D 02	-2.433D-04	8.000D 01	1.885D-07	1.000D 00	2.578D-10
3	6	12500.00	27500.00	4.01053D 01	1.525D 02	-1.349D 02	1.182D-02	8.000D 01	4.301D-06	1.000D 00	6.663D-09
3	7	12500.00	32500.00	4.01055D 01	1.678D 02	-1.202D 02	-2.277D-02	8.000D 01	6.090D-05	1.000D 00	1.085D-07
3	8	12500.00	37500.00	4.01066D 01	1.410D 02	-4.654D 01	-2.664D-01	8.000D 01	5.009D-04	1.000D 00	1.047D-06
3	9	12500.00	42500.00	4.01032D 01	2.306D 01	8.751D 01	9.331D-02	8.000D 01	1.198D-03	1.000D 00	2.907D-06
3	10	12500.00	47500.00	4.00784D 01	-1.664D 02	1.472D 02	1.017D 00	8.000D 01	4.114D-05	1.000D 00	7.546D-08
3	11	12500.00	52500.00	4.00575D 01	-2.690D 02	-4.097D-12	2.246D 00	8.000D 01	1.183D-06	1.000D 00	1.934D-09
3	12	12500.00	57500.00	4.00784D 01	-1.664D 02	-1.472D 02	1.017D 00	8.000D 01	4.114D-05	1.000D 00	7.546D-08
3	13	12500.00	62500.00	4.01032D 01	2.306D 01	-8.751D 01	9.331D-02	8.000D 01	1.198D-03	1.000D 00	2.907D-06
3	14	12500.00	67500.00	4.01066D 01	1.410D 02	4.654D 01	-2.664D-01	8.000D 01	5.009D-04	1.000D 00	1.047D-06

ITER.= 106 TIME=5.300000D 00 PERIOD=5.300000D 00 TIME INCREMENT=5.000000D-02

NODE	INDICES	X-LOCATION	Y-LOCATION	WATER ELEVATION	VELOCITY IN X-DIRECT.	VELOCITY IN Y-DIRECT.	WATER ELEV. RATE OF CHANGE	TEMP.	TEMP. RATE OF CHANGE	SUBSTANCE MASS CONCENTRATIONS CK(1)	CK(2)
3	15	12500.00	72500.00	4.01055D 01	1.678D 02	1.202D 02	-2.277D-02	8.000D 01	6.090D-05	1.000D 00	1.085D-07
3	16	12500.00	77500.00	4.01053D 01	1.525D 02	1.349D 02	1.182D-02	8.000D 01	4.301D-06	1.000D 00	6.663D-09
3	17	12500.00	82500.00	4.01057D 01	1.317D 02	1.199D 02	-2.433D-04	8.000D 01	1.885D-07	1.000D 00	2.578D-10
3	18	12500.00	87500.00	4.01056D 01	1.153D 02	9.656D 01	-1.080D-02	8.000D 01	5.343D-09	1.000D 00	6.419D-12
3	19	12500.00	92500.00	4.01053D 01	1.046D 02	7.007D 01	4.067D-03	8.000D 01	9.481D-11	1.000D 00	1.007D-13
3	20	12500.00	97500.00	4.01051D 01	9.819D 01	4.229D 01	6.735D-03	8.000D 01	9.569D-13	1.000D 00	9.131D-16
3	21	12500.00	102500.00	4.01050D 01	9.528D 01	1.427D 01	8.142D-03	8.000D 01	4.186D-15	1.000D 00	3.695D-18
4	1	17500.00	2500.00	4.01041D 01	1.163D 02	-8.385D 00	9.405D-03	8.000D 01	9.821D-19	1.000D 00	5.037D-20
4	2	17500.00	7500.00	4.01041D 01	1.184D 02	-2.458D 01	1.458D-02	8.000D 01	1.579D-14	1.000D 00	1.353D-17
4	3	17500.00	12500.00	4.01041D 01	1.225D 02	-3.913D 01	1.489D-02	8.000D 01	1.727D-12	1.000D 00	1.629D-15
4	4	17500.00	17500.00	4.01041D 01	1.284D 02	-4.948D 01	1.158D-02	8.000D 01	1.089D-10	1.000D 00	1.143D-13
4	5	17500.00	22500.00	4.01041D 01	1.342D 02	-5.179D 01	-8.567D-03	8.000D 01	4.268D-09	1.000D 00	5.082D-12
4	6	17500.00	27500.00	4.01038D 01	1.358D 02	-4.186D 01	3.461D-02	8.000D 01	1.085D-07	1.000D 00	1.456D-10
4	7	17500.00	32500.00	4.01026D 01	1.229D 02	-1.455D 01	9.450D-02	8.000D 01	1.740D-06	1.000D 00	2.561D-09
4	8	17500.00	37500.00	4.01011D 01	7.314D 01	3.522D 01	1.529D-01	8.000D 01	1.351D-05	1.000D 00	2.099D-08
4	9	17500.00	42500.00	4.01009D 01	-3.211D 01	9.282D 01	-2.558D-01	8.000D 01	1.556D-07	1.000D 00	3.335D-10
4	10	17500.00	47500.00	4.01014D 01	-1.727D 02	9.372D 01	-1.309D-01	8.000D 01	4.288D-09	1.000D 00	4.984D-12
4	11	17500.00	52500.00	4.01014D 01	-2.459D 02	-1.274D-12	-4.440D-01	8.000D 01	8.129D-11	1.000D 00	9.881D-14
4	12	17500.00	57500.00	4.01014D 01	-1.727D 02	-9.372D 01	-1.309D-01	8.000D 01	4.288D-09	1.000D 00	4.984D-12
4	13	17500.00	62500.00	4.01009D 01	-3.211D 01	-9.282D 01	-2.558D-01	8.000D 01	1.556D-07	1.000D 00	3.335D-10
4	14	17500.00	67500.00	4.01011D 01	7.314D 01	-3.522D 01	1.529D-01	8.000D 01	1.351D-05	1.000D 00	2.099D-08
4	15	17500.00	72500.00	4.01026D 01	1.229D 02	1.455D 01	9.450D-02	8.000D 01	1.740D-06	1.000D 00	2.561D-09
4	16	17500.00	77500.00	4.01038D 01	1.358D 02	4.186D 01	3.461D-02	8.000D 01	1.085D-07	1.000D 00	1.456D-10
4	17	17500.00	82500.00	4.01041D 01	1.342D 02	5.179D 01	-8.567D-03	8.000D 01	4.268D-09	1.000D 00	5.082D-12
4	18	17500.00	87500.00	4.01041D 01	1.284D 02	4.948D 01	1.158D-02	8.000D 01	1.089D-10	1.000D 00	1.143D-13
4	19	17500.00	92500.00	4.01041D 01	1.225D 02	3.913D 01	1.489D-02	8.000D 01	1.727D-12	1.000D 00	1.629D-15
4	20	17500.00	97500.00	4.01041D 01	1.184D 02	2.458D 01	1.458D-02	8.000D 01	1.579D-14	1.000D 00	1.353D-17
4	21	17500.00	102500.00	4.01041D 01	1.163D 02	8.385D 00	9.405D-03	8.000D 01	9.821D-19	1.000D 00	5.037D-20
5	1	22500.00	2500.00	4.01031D 01	1.257D 02	-3.360D 00	9.870D-03	8.000D 01	-1.124D-19	1.000D 00	5.228D-22
5	2	22500.00	7500.00	4.01031D 01	1.262D 02	-9.151D 00	1.076D-02	8.000D 01	6.946D-17	1.000D 00	1.512D-19
5	3	22500.00	12500.00	4.01031D 01	1.269D 02	-1.290D 01	1.246D-02	8.000D 01	2.307D-14	1.000D 00	1.967D-17
5	4	22500.00	17500.00	4.01030D 01	1.266D 02	-1.244D 01	1.323D-02	8.000D 01	1.588D-12	1.000D 00	1.485D-15
5	5	22500.00	22500.00	4.01029D 01	1.226D 02	-5.031D 00	1.278D-02	8.000D 01	6.896D-11	1.000D 00	7.163D-14
5	6	22500.00	27500.00	4.01027D 01	1.102D 02	1.169D 01	-3.942D-03	8.000D 01	1.884D-09	1.000D 00	2.195D-12
5	7	22500.00	32500.00	4.01022D 01	8.286D 01	3.763D 01	1.147D-02	8.000D 01	2.743D-08	1.000D 00	3.595D-11
5	8	22500.00	37500.00	4.01009D 01	3.406D 01	6.645D 01	3.485D-02	8.000D 01	1.203D-07	1.000D 00	1.610D-10
5	9	22500.00	42500.00	4.00996D 01	-3.704D 01	8.476D 01	6.456D-02	8.000D 01	1.426D-09	1.000D 00	1.897D-12
5	10	22500.00	47500.00	4.00985D 01	-1.127D 02	6.662D 01	-1.904D-02	8.000D 01	1.642D-11	1.000D 00	1.998D-14
5	11	22500.00	52500.00	4.00977D 01	-1.477D 02	-4.542D-12	2.793D-02	8.000D 01	1.495D-13	1.000D 00	1.689D-16
5	12	22500.00	57500.00	4.00985D 01	-1.127D 02	-6.662D 01	-1.904D-02	8.000D 01	1.642D-11	1.000D 00	1.998D-14
5	13	22500.00	62500.00	4.00996D 01	-3.704D 01	-8.476D 01	6.456D-02	8.000D 01	1.426D-09	1.000D 00	1.897D-12
5	14	22500.00	67500.00	4.01009D 01	3.406D 01	-6.645D 01	3.485D-02	8.000D 01	1.203D-07	1.000D 00	1.610D-10
5	15	22500.00	72500.00	4.01022D 01	8.286D 01	-3.763D 01	1.147D-02	8.000D 01	2.743D-08	1.000D 00	3.595D-11
5	16	22500.00	77500.00	4.01027D 01	1.102D 02	-1.169D 01	-3.942D-03	8.000D 01	1.884D-09	1.000D 00	2.195D-12
5	17	22500.00	82500.00	4.01029D 01	1.226D 02	5.031D 00	1.278D-02	8.000D 01	6.896D-11	1.000D 00	7.163D-14
5	18	22500.00	87500.00	4.01030D 01	1.266D 02	1.244D 01	1.323D-02	8.000D 01	1.588D-12	1.000D 00	1.485D-15
5	19	22500.00	92500.00	4.01031D 01	1.269D 02	1.290D 01	1.246D-02	8.000D 01	2.307D-14	1.000D 00	1.967D-17
5	20	22500.00	97500.00	4.01031D 01	1.262D 02	9.151D 00	1.076D-02	8.000D 01	6.946D-17	1.000D 00	1.512D-19
5	21	22500.00	102500.00	4.01031D 01	1.257D 02	3.360D 00	9.870D-03	8.000D 01	-1.124D-19	1.000D 00	5.228D-22
6	1	27500.00	2500.00	4.01021D 01	1.261D 02	4.215D-01	1.174D-02	8.000D 01	-1.061D-21	1.000D 00	4.502D-24
6	2	27500.00	7500.00	4.01021D 01	1.251D 02	2.220D 00	1.179D-02	8.000D 01	-3.060D-19	1.000D 00	1.408D-21
6	3	27500.00	12500.00	4.01021D 01	1.227D 02	5.731D 00	1.163D-02	8.000D 01	1.633D-16	1.000D 00	1.982D-19
6	4	27500.00	17500.00	4.01020D 01	1.175D 02	1.230D 01	1.547D-02	8.000D 01	1.901D-14	1.000D 00	1.607D-17
6	5	27500.00	22500.00	4.01018D 01	1.076D 02	2.299D 01	1.601D-02	8.000D 01	8.668D-13	1.000D 00	8.082D-16
6	6	27500.00	27500.00	4.01016D 01	8.951D 01	3.822D 01	1.600D-02	8.000D 01	2.310D-11	1.000D 00	2.370D-14
6	7	27500.00	32500.00	4.01013D 01	6.006D 01	5.622D 01	-2.152D-03	8.000D 01	2.674D-10	1.000D 00	3.018D-13

Table A.2 (continued)

ITER.= 106   TIME=5.300000D 00   PERIOD=5.300000D 00   TIME INCREMENT=5.000000D-02

NODE	INDI-CES	X-LOCATION	Y-LOCATION	WATER ELEVATION	VELOCITY IN X-DIRECT.	VELOCITY IN Y-DIRECT.	WATER ELEV. RATE OF CHANGE	TEMP.	TEMP. RATE OF CHANGE	SUBSTANCE MASS CONCENTRATIONS CK(1)	CK(2)
6	8	27500.00	37500.00	4.01009D 01	1.813D 01	7.043D 01	2.064D-02	8.000D 01	4.363D-10	1.000D 00	4.544D-13
6	9	27500.00	42500.00	4.01001D 01	-3.137D 01	7.019D 01	3.044D-02	8.000D 01	3.575D-12	1.000D 00	4.401D-15
6	10	27500.00	47500.00	4.00992D 01	-7.637D 01	4.585D 01	5.981D-02	8.000D 01	2.893D-14	1.000D 00	3.156D-17
6	11	27500.00	52500.00	4.00988D 01	-9.587D 01	-5.141D-12	-4.025D-02	8.000D 01	1.287D-16	1.000D 00	1.688D-19
6	12	27500.00	57500.00	4.00992D 01	-7.637D 01	-4.585D 01	5.981D-02	8.000D 01	2.893D-14	1.000D 00	3.156D-17
6	13	27500.00	62500.00	4.01001D 01	-3.137D 01	-7.019D 01	3.044D-02	8.000D 01	3.575D-12	1.000D 00	4.401D-15
6	14	27500.00	67500.00	4.01009D 01	1.813D 01	-7.043D 01	2.064D-02	8.000D 01	4.363D-10	1.000D 00	4.544D-13
6	15	27500.00	72500.00	4.01013D 01	6.006D 01	-5.622D 01	-2.152D-03	8.000D 01	2.674D-10	1.000D 00	3.018D-13
6	16	27500.00	77500.00	4.01016D 01	8.951D 01	-3.822D 01	1.600D-02	8.000D 01	2.310D-11	1.000D 00	2.370D-14
6	17	27500.00	82500.00	4.01018D 01	1.076D 02	-2.299D 01	1.601D-02	8.000D 01	8.668D-13	1.000D 00	8.082D-16
6	18	27500.00	87500.00	4.01020D 01	1.175D 02	-1.230D 01	1.547D-02	8.000D 01	1.901D-14	1.000D 00	1.607D-17
6	19	27500.00	92500.00	4.01021D 01	1.227D 02	-5.731D 00	1.163D-02	8.000D 01	1.633D-16	1.000D 00	1.982D-19
6	20	27500.00	97500.00	4.01021D 01	1.251D 02	-2.220D 00	1.179D-02	8.000D 01	-3.060D-19	1.000D 00	1.408D-21
6	21	27500.00	102500.00	4.01021D 01	1.261D 02	-4.215D-01	1.174D-02	8.000D 01	-1.061D-21	1.000D 00	4.502D-24
7	1	32500.00	2500.00	4.01012D 01	1.201D 02	2.933D 00	1.279D-02	8.000D 01	-8.909D-24	1.000D 00	3.507D-26
7	2	32500.00	7500.00	4.01012D 01	1.181D 02	9.400D 00	1.309D-02	8.000D 01	-2.750D-21	1.000D 00	1.167D-23
7	3	32500.00	12500.00	4.01012D 01	1.137D 02	1.691D 01	1.324D-02	8.000D 01	-3.760D-19	1.000D 00	1.731D-21
7	4	32500.00	17500.00	4.01011D 01	1.058D 02	2.607D 01	1.318D-02	8.000D 01	1.270D-16	1.000D 00	1.444D-19
7	5	32500.00	22500.00	4.01010D 01	9.320D 01	3.692D 01	1.566D-02	8.000D 01	8.502D-15	1.000D 00	7.159D-18
7	6	32500.00	27500.00	4.01008D 01	7.422D 01	4.860D 01	1.724D-02	8.000D 01	2.030D-13	1.000D 00	1.859D-16
7	7	32500.00	32500.00	4.01006D 01	4.777D 01	5.884D 01	1.882D-02	8.000D 01	1.703D-12	1.000D 00	1.654D-15
7	8	32500.00	37500.00	4.01003D 01	1.474D 01	6.323D 01	1.151D-02	8.000D 01	7.521D-13	1.000D 00	5.622D-16
7	9	32500.00	42500.00	4.01000D 01	-2.013D 01	5.616D 01	1.640D-02	8.000D 01	3.684D-15	1.000D 00	4.840D-18
7	10	32500.00	47500.00	4.00996D 01	-4.810D 01	3.405D 01	2.030D-02	8.000D 01	-2.714D-17	1.000D 00	2.615D-20
7	11	32500.00	52500.00	4.00994D 01	-5.907D 01	-5.745D-12	2.993D-02	8.000D 01	-1.519D-20	1.000D 00	9.200D-23
7	12	32500.00	57500.00	4.00996D 01	-4.810D 01	-3.405D 01	2.030D-02	8.000D 01	-2.714D-17	1.000D 00	2.615D-20
7	13	32500.00	62500.00	4.01000D 01	-2.013D 01	-5.616D 01	1.640D-02	8.000D 01	3.684D-15	1.000D 00	4.840D-18
7	14	32500.00	67500.00	4.01003D 01	1.474D 01	-6.323D 01	1.151D-02	8.000D 01	7.521D-13	1.000D 00	5.622D-16
7	15	32500.00	72500.00	4.01006D 01	4.777D 01	-5.884D 01	1.882D-02	8.000D 01	1.703D-12	1.000D 00	1.654D-15
7	16	32500.00	77500.00	4.01008D 01	7.422D 01	-4.860D 01	1.724D-02	8.000D 01	2.030D-13	1.000D 00	1.859D-16
7	17	32500.00	82500.00	4.01010D 01	9.320D 01	-3.692D 01	1.566D-02	8.000D 01	8.502D-15	1.000D 00	7.159D-18
7	18	32500.00	87500.00	4.01011D 01	1.058D 02	-2.607D 01	1.318D-02	8.000D 01	1.270D-16	1.000D 00	1.444D-19
7	19	32500.00	92500.00	4.01012D 01	1.137D 02	-1.691D 01	1.324D-02	8.000D 01	-3.760D-19	1.000D 00	1.731D-21
7	20	32500.00	97500.00	4.01012D 01	1.181D 02	-9.400D 00	1.309D-02	8.000D 01	-2.750D-21	1.000D 00	1.167D-23
7	21	32500.00	102500.00	4.01012D 01	1.201D 02	-2.933D 00	1.279D-02	8.000D 01	-8.909D-24	1.000D 00	3.507D-26
8	1	37500.00	2500.00	4.01003D 01	1.105D 02	4.333D 00	1.361D-02	8.000D 01	-6.491D-26	1.000D 00	2.381D-28
8	2	37500.00	7500.00	4.01003D 01	1.080D 02	1.318D 01	1.418D-02	8.000D 01	-2.116D-23	1.000D 00	8.326D-26
8	3	37500.00	12500.00	4.01003D 01	1.027D 02	2.240D 01	1.429D-02	8.000D 01	-3.000D-21	1.000D 00	1.272D-23
8	4	37500.00	17500.00	4.01002D 01	9.397D 01	3.202D 01	1.484D-02	8.000D 01	-2.310D-19	1.000D 00	1.061D-21
8	5	37500.00	22500.00	4.01002D 01	8.114D 01	4.159D 01	1.511D-02	8.000D 01	9.555D-18	1.000D 00	4.988D-20
8	6	37500.00	27500.00	4.01001D 01	6.366D 01	4.992D 01	1.774D-02	8.000D 01	1.342D-15	1.000D 00	1.103D-18
8	7	37500.00	32500.00	4.00999D 01	4.170D 01	5.497D 01	1.802D-02	8.000D 01	7.727D-15	1.000D 00	6.655D-18
8	8	37500.00	37500.00	4.00998D 01	1.678D 01	5.406D 01	1.999D-02	8.000D 01	8.608D-16	1.000D 00	7.239D-19
8	9	37500.00	42500.00	4.00997D 01	-7.491D 00	4.463D 01	1.405D-02	8.000D 01	-5.882D-19	1.000D 00	5.288D-21
8	10	37500.00	47500.00	4.00995D 01	-2.580D 01	2.572D 01	2.162D-02	8.000D 01	-3.082D-21	1.000D 00	2.141D-23
8	11	37500.00	52500.00	4.00994D 01	-3.275D 01	-7.299D-12	1.835D-02	8.000D 01	-9.245D-24	1.000D 00	5.427D-26
8	12	37500.00	57500.00	4.00995D 01	-2.580D 01	-2.572D 01	2.162D-02	8.000D 01	-3.082D-21	1.000D 00	2.141D-23
8	13	37500.00	62500.00	4.00997D 01	-7.491D 00	-4.463D 01	1.405D-02	8.000D 01	-5.882D-19	1.000D 00	5.288D-21
8	14	37500.00	67500.00	4.00998D 01	1.678D 01	-5.406D 01	1.999D-02	8.000D 01	8.608D-16	1.000D 00	7.239D-19
8	15	37500.00	72500.00	4.00999D 01	4.170D 01	-5.497D 01	1.802D-02	8.000D 01	7.727D-15	1.000D 00	6.655D-18
8	16	37500.00	77500.00	4.01001D 01	6.366D 01	-4.992D 01	1.774D-02	8.000D 01	1.342D-15	1.000D 00	1.103D-18
8	17	37500.00	82500.00	4.01002D 01	8.114D 01	-4.159D 01	1.511D-02	8.000D 01	9.555D-18	1.000D 00	4.988D-20
8	18	37500.00	87500.00	4.01002D 01	9.397D 01	-3.202D 01	1.484D-02	8.000D 01	-2.310D-19	1.000D 00	1.061D-21
8	19	37500.00	92500.00	4.01003D 01	1.027D 02	-2.240D 01	1.429D-02	8.000D 01	-3.000D-21	1.000D 00	1.272D-23
8	20	37500.00	97500.00	4.01003D 01	1.080D 02	-1.318D 01	1.418D-02	8.000D 01	-2.116D-23	1.000D 00	8.326D-26
8	21	37500.00	102500.00	4.01003D 01	1.105D 02	-4.333D 00	1.361D-02	8.000D 01	-6.491D-26	1.000D 00	2.381D-28

ITER.= 106 TIME=5.300000D 00 PERIOD=5.300000D 00 TIME INCREMENT=5.000000D-02

NODE	INDI-CES	X-LOCATION	Y-LOCATION	WATER ELEVATION	VELOCITY IN X-DIRECT.	VELOCITY IN Y-DIRECT.	WATER ELEV. RATE OF CHANGE	TEMP.	TEMP. RATE OF CHANGE	SUBSTANCE MASS CONCENTRATIONS CK(1)	CK(2)
9	1	42500.00	2500.00	4.00995D 01	9.915D 01	4.885D 00	1.453D-02	8.000D 01	-4.003D-28	1.000D 00	1.370D-30
9	2	42500.00	7500.00	4.00995D 01	9.657D 01	1.457D 01	1.469D-02	8.000D 01	-1.364D-25	1.000D 00	4.983D-28
9	3	42500.00	12500.00	4.00995D 01	9.127D 01	2.412D 01	1.521D-02	8.000D 01	-1.975D-23	1.000D 00	7.736D-26
9	4	42500.00	17500.00	4.00994D 01	8.295D 01	3.318D 01	1.581D-02	8.000D 01	-1.501D-21	1.000D 00	6.338D-24
9	5	42500.00	22500.00	4.00994D 01	7.137D 01	4.111D 01	1.645D-02	8.000D 01	-6.074D-20	1.000D 00	2.776D-22
9	6	42500.00	27500.00	4.00994D 01	5.656D 01	4.683D 01	1.688D-02	8.000D 01	-3.052D-17	1.000D 00	5.188D-21
9	7	42500.00	32500.00	4.00993D 01	3.917D 01	4.884D 01	1.835D-02	8.000D 01	-2.397D-17	1.000D 00	2.215D-20
9	8	42500.00	37500.00	4.00993D 01	2.073D 01	4.553D 01	1.918D-02	8.000D 01	-2.275D-19	1.000D 00	1.297D-21
9	9	42500.00	42500.00	4.00992D 01	3.801D 00	3.583D 01	2.022D-02	8.000D 01	-8.634D-22	1.000D 00	7.339D-24
9	10	42500.00	47500.00	4.00991D 01	-8.408D 00	1.994D 01	1.929D-02	8.000D 01	-3.361D-24	1.000D 00	2.280D-26
9	11	42500.00	52500.00	4.00991D 01	-1.291D 01	-7.224D-12	1.991D-02	8.000D 01	-7.481D-27	1.000D 00	4.429D-29
9	12	42500.00	57500.00	4.00991D 01	-8.408D 00	-1.994D 01	1.929D-02	8.000D 01	-3.361D-24	1.000D 00	2.280D-26
9	13	42500.00	62500.00	4.00992D 01	3.801D 00	-3.583D 01	2.022D-02	8.000D 01	-8.634D-22	1.000D 00	7.339D-24
9	14	42500.00	67500.00	4.00993D 01	2.073D 01	-4.553D 01	1.918D-02	8.000D 01	-2.275D-19	1.000D 00	1.297D-21
9	15	42500.00	72500.00	4.00993D 01	3.917D 01	-4.884D 01	1.835D-02	8.000D 01	-2.397D-17	1.000D 00	2.215D-20
9	16	42500.00	77500.00	4.00994D 01	5.656D 01	-4.683D 01	1.688D-02	8.000D 01	-3.052D-17	1.000D 00	5.188D-21
9	17	42500.00	82500.00	4.00994D 01	7.137D 01	-4.111D 01	1.645D-02	8.000D 01	-6.074D-20	1.000D 00	2.776D-22
9	18	42500.00	87500.00	4.00994D 01	8.295D 01	-3.318D 01	1.581D-02	8.000D 01	-1.501D-21	1.000D 00	6.338D-24
9	19	42500.00	92500.00	4.00995D 01	9.127D 01	-2.412D 01	1.521D-02	8.000D 01	-1.975D-23	1.000D 00	7.736D-26
9	20	42500.00	97500.00	4.00995D 01	9.657D 01	-1.457D 01	1.469D-02	8.000D 01	-1.364D-25	1.000D 00	4.983D-28
9	21	42500.00	102500.00	4.00995D 01	9.915D 01	-4.885D 00	1.453D-02	8.000D 01	-4.003D-28	1.000D 00	1.370D-30
10	1	47500.00	2500.00	4.00987D 01	8.741D 01	4.911D 00	1.525D-02	8.000D 01	-2.047D-30	1.000D 00	6.544D-33
10	2	47500.00	7500.00	4.00987D 01	8.506D 01	1.451D 01	1.512D-02	8.000D 01	-7.246D-28	1.000D 00	2.463D-30
10	3	47500.00	12500.00	4.00987D 01	8.029D 01	2.365D 01	1.557D-02	8.000D 01	-1.062D-25	1.000D 00	3.857D-28
10	4	47500.00	17500.00	4.00987D 01	7.307D 01	3.179D 01	1.638D-02	8.000D 01	-7.901D-24	1.000D 00	3.086D-26
10	5	47500.00	22500.00	4.00987D 01	6.341D 01	3.826D 01	1.692D-02	8.000D 01	-2.986D-22	1.000D 00	1.258D-24
10	6	47500.00	27500.00	4.00987D 01	5.163D 01	4.217D 01	1.777D-02	8.000D 01	-4.470D-21	1.000D 00	2.024D-23
10	7	47500.00	32500.00	4.00987D 01	3.843D 01	4.249D 01	1.827D-02	8.000D 01	-1.363D-20	1.000D 00	6.601D-23
10	8	47500.00	37500.00	4.00987D 01	2.507D 01	3.832D 01	1.952D-02	8.000D 01	-5.085D-22	1.000D 00	2.882D-24
10	9	47500.00	42500.00	4.00987D 01	1.332D 01	2.928D 01	1.960D-02	8.000D 01	-2.512D-24	1.000D 00	1.392D-26
10	10	47500.00	47500.00	4.00986D 01	5.144D 00	1.594D 01	2.062D-02	8.000D 01	-5.140D-27	1.000D 00	3.557D-29
10	11	47500.00	52500.00	4.00986D 01	2.190D 00	-6.471D-12	1.956D-02	8.000D 01	-9.286D-30	1.000D 00	6.246D-32
10	12	47500.00	57500.00	4.00986D 01	5.144D 00	-1.594D 01	2.062D-02	8.000D 01	-5.140D-27	1.000D 00	3.557D-29
10	13	47500.00	62500.00	4.00987D 01	1.332D 01	-2.928D 01	1.960D-02	8.000D 01	-2.512D-24	1.000D 00	1.392D-26
10	14	47500.00	67500.00	4.00987D 01	2.507D 01	-3.832D 01	1.952D-02	8.000D 01	-5.085D-22	1.000D 00	2.882D-24
10	15	47500.00	72500.00	4.00987D 01	3.843D 01	-4.249D 01	1.827D-02	8.000D 01	-1.363D-20	1.000D 00	6.601D-23
10	16	47500.00	77500.00	4.00987D 01	5.163D 01	-4.217D 01	1.777D-02	8.000D 01	-4.470D-21	1.000D 00	2.024D-23
10	17	47500.00	82500.00	4.00987D 01	6.341D 01	-3.826D 01	1.692D-02	8.000D 01	-2.986D-22	1.000D 00	1.258D-24
10	18	47500.00	87500.00	4.00987D 01	7.307D 01	-3.179D 01	1.638D-02	8.000D 01	-7.901D-24	1.000D 00	3.086D-26
10	19	47500.00	92500.00	4.00987D 01	8.029D 01	-2.365D 01	1.557D-02	8.000D 01	-1.062D-25	1.000D 00	3.857D-28
10	20	47500.00	97500.00	4.00987D 01	8.506D 01	-1.451D 01	1.512D-02	8.000D 01	-7.246D-28	1.000D 00	2.463D-30
10	21	47500.00	102500.00	4.00987D 01	8.741D 01	-4.911D 00	1.525D-02	8.000D 01	-2.047D-30	1.000D 00	6.544D-33
11	1	52500.00	2500.00	4.00979D 01	7.599D 01	4.669D 00	1.555D-02	8.000D 01	-8.563D-33	1.000D 00	2.566D-35
11	2	52500.00	7500.00	4.00979D 01	7.402D 01	1.372D 01	1.531D-02	8.000D 01	-3.135D-30	1.000D 00	9.962D-33
11	3	52500.00	12500.00	4.00979D 01	7.010D 01	2.215D 01	1.580D-02	8.000D 01	-4.638D-28	1.000D 00	1.572D-30
11	4	52500.00	17500.00	4.00980D 01	6.429D 01	2.937D 01	1.646D-02	8.000D 01	-3.385D-26	1.000D 00	1.231D-28
11	5	52500.00	22500.00	4.00980D 01	5.678D 01	3.472D 01	1.718D-02	8.000D 01	-1.206D-24	1.000D 00	4.727D-27
11	6	52500.00	27500.00	4.00980D 01	4.795D 01	3.750D 01	1.791D-02	8.000D 01	-1.605D-23	1.000D 00	6.774D-26
11	7	52500.00	32500.00	4.00981D 01	3.842D 01	3.699D 01	1.860D-02	8.000D 01	-4.030D-23	1.000D 00	1.840D-25
11	8	52500.00	37500.00	4.00981D 01	2.914D 01	3.270D 01	1.921D-02	8.000D 01	-1.335D-24	1.000D 00	7.103D-27
11	9	52500.00	42500.00	4.00981D 01	2.124D 01	2.456D 01	1.982D-02	8.000D 01	-7.043D-27	1.000D 00	3.549D-29
11	10	52500.00	47500.00	4.00981D 01	1.589D 01	1.322D 01	2.017D-02	8.000D 01	-1.657D-29	1.000D 00	8.604D-32
11	11	52500.00	52500.00	4.00981D 01	1.399D 01	-3.705D-12	2.026D-02	8.000D 01	-2.599D-32	1.000D 00	1.558D-34
11	12	52500.00	57500.00	4.00981D 01	1.589D 01	-1.322D 01	2.017D-02	8.000D 01	-1.657D-29	1.000D 00	8.604D-32
11	13	52500.00	62500.00	4.00981D 01	2.124D 01	-2.456D 01	1.982D-02	8.000D 01	-7.043D-27	1.000D 00	3.549D-29
11	14	52500.00	67500.00	4.00981D 01	2.914D 01	-3.270D 01	1.921D-02	8.000D 01	-1.335D-24	1.000D 00	7.103D-27

296

Table A.2 (continued)

ITER.= 106 TIME=5.300000D 00 PERIOD=5.300000D 00 TIME INCREMENT=5.000000D-02

NODE	INDICES	X-LOCATION	Y-LOCATION	WATER ELEVATION	VELOCITY IN X-DIRECT.	VELOCITY IN Y-DIRECT.	WATER ELEV. RATE OF CHANGE	TEMP.	TEMP. RATE OF CHANGE	SUBSTANCE MASS CONCENTRATIONS CK(1)	CK(2)
11	15	52500.00	72500.00	4.00981D 01	3.842D 01	-3.699D 01	1.860D-02	8.000D 01	-4.030D-23	1.000D 00	1.840D-25
11	16	52500.00	77500.00	4.00980D 01	4.795D 01	-3.750D 01	1.791D-02	8.000D 01	-1.605D-23	1.000D 00	6.774D-26
11	17	52500.00	82500.00	4.00980D 01	5.678D 01	-3.472D 01	1.718D-02	8.000D 01	-1.206D-24	1.000D 00	4.727D-27
11	18	52500.00	87500.00	4.00980D 01	6.429D 01	-2.937D 01	1.646D-02	8.000D 01	-3.385D-26	1.000D 00	1.231D-28
11	19	52500.00	92500.00	4.00979D 01	7.010D 01	-2.215D 01	1.580D-02	8.000D 01	-4.638D-28	1.000D 00	1.572D-30
11	20	52500.00	97500.00	4.00979D 01	7.402D 01	-1.372D 01	1.531D-02	8.000D 01	-3.135D-30	1.000D 00	9.962D-33
11	21	52500.00	102500.00	4.00979D 01	7.599D 01	-4.669D 00	1.555D-02	8.000D 01	-8.563D-33	1.000D 00	2.566D-35
12	1	57500.00	2500.00	4.00972D 01	6.522D 01	4.328D 00	1.544D-02	8.000D 01	-2.900D-35	1.000D 00	8.186D-38
12	2	57500.00	7500.00	4.00972D 01	6.370D 01	1.269D 01	1.518D-02	8.000D 01	-1.097D-32	1.000D 00	3.278D-35
12	3	57500.00	12500.00	4.00972D 01	6.072D 01	2.039D 01	1.569D-02	8.000D 01	-1.643D-30	1.000D 00	5.226D-33
12	4	57500.00	17500.00	4.00973D 01	5.641D 01	2.683D 01	1.633D-02	8.000D 01	-1.186D-28	1.000D 00	4.046D-31
12	5	57500.00	22500.00	4.00974D 01	5.102D 01	3.144D 01	1.694D-02	8.000D 01	-4.064D-27	1.000D 00	1.492D-29
12	6	57500.00	27500.00	4.00974D 01	4.492D 01	3.362D 01	1.773D-02	8.000D 01	-5.009D-26	1.000D 00	1.986D-28
12	7	57500.00	32500.00	4.00975D 01	3.862D 01	3.284D 01	1.833D-02	8.000D 01	-1.127D-25	1.000D 00	4.866D-28
12	8	57500.00	37500.00	4.00975D 01	3.272D 01	2.876D 01	1.913D-02	8.000D 01	-3.720D-27	1.000D 00	1.856D-29
12	9	57500.00	42500.00	4.00975D 01	2.789D 01	2.144D 01	1.941D-02	8.000D 01	-2.127D-29	1.000D 00	1.060D-31
12	10	57500.00	47500.00	4.00976D 01	2.471D 01	1.148D 01	2.003D-02	8.000D 01	-5.565D-32	1.000D 00	2.968D-34
12	11	57500.00	52500.00	4.00976D 01	2.361D 01	-3.029D-12	1.978D-02	8.000D 01	-1.010D-34	1.000D 00	6.264D-37
12	12	57500.00	57500.00	4.00976D 01	2.471D 01	-1.148D 01	2.003D-02	8.000D 01	-5.565D-32	1.000D 00	2.968D-34
12	13	57500.00	62500.00	4.00975D 01	2.789D 01	-2.144D 01	1.941D-02	8.000D 01	-2.127D-29	1.000D 00	1.060D-31
12	14	57500.00	67500.00	4.00975D 01	3.272D 01	-2.876D 01	1.913D-02	8.000D 01	-3.720D-27	1.000D 00	1.856D-29
12	15	57500.00	72500.00	4.00975D 01	3.862D 01	-3.284D 01	1.833D-02	8.000D 01	-1.127D-25	1.000D 00	4.866D-28
12	16	57500.00	77500.00	4.00974D 01	4.492D 01	-3.362D 01	1.773D-02	8.000D 01	-5.009D-26	1.000D 00	1.986D-28
12	17	57500.00	82500.00	4.00974D 01	5.102D 01	-3.144D 01	1.694D-02	8.000D 01	-4.064D-27	1.000D 00	1.492D-29
12	18	57500.00	87500.00	4.00973D 01	5.641D 01	-2.683D 01	1.633D-02	8.000D 01	-1.186D-28	1.000D 00	4.046D-31
12	19	57500.00	92500.00	4.00972D 01	6.072D 01	-2.039D 01	1.569D-02	8.000D 01	-1.643D-30	1.000D 00	5.226D-33
12	20	57500.00	97500.00	4.00972D 01	6.370D 01	-1.269D 01	1.518D-02	8.000D 01	-1.097D-32	1.000D 00	3.278D-35
12	21	57500.00	102500.00	4.00972D 01	6.522D 01	-4.328D 00	1.544D-02	8.000D 01	-2.900D-35	1.000D 00	8.186D-38
13	1	62500.00	2500.00	4.00965D 01	5.519D 01	3.981D 00	1.495D-02	8.000D 01	-7.883D-38	1.000D 00	2.109D-40
13	2	62500.00	7500.00	4.00966D 01	5.412D 01	1.169D 01	1.468D-02	8.000D 01	-3.087D-35	1.000D 00	8.726D-38
13	3	62500.00	12500.00	4.00966D 01	5.206D 01	1.877D 01	1.523D-02	8.000D 01	-4.708D-33	1.000D 00	1.415D-35
13	4	62500.00	17500.00	4.00967D 01	4.919D 01	2.468D 01	1.582D-02	8.000D 01	-3.410D-31	1.000D 00	1.098D-33
13	5	62500.00	22500.00	4.00967D 01	4.577D 01	2.891D 01	1.638D-02	8.000D 01	-1.152D-29	1.000D 00	3.991D-32
13	6	62500.00	27500.00	4.00968D 01	4.216D 01	3.093D 01	1.718D-02	8.000D 01	-1.377D-28	1.000D 00	5.159D-31
13	7	62500.00	32500.00	4.00969D 01	3.873D 01	3.024D 01	1.779D-02	8.000D 01	-2.995D-28	1.000D 00	1.223D-30
13	8	62500.00	37500.00	4.00969D 01	3.582D 01	2.655D 01	1.863D-02	8.000D 01	-1.065D-29	1.000D 00	5.031D-32
13	9	62500.00	42500.00	4.00970D 01	3.368D 01	1.986D 01	1.873D-02	8.000D 01	-7.057D-32	1.000D 00	3.451D-34
13	10	62500.00	47500.00	4.00970D 01	3.241D 01	1.067D 01	1.957D-02	8.000D 01	-2.191D-34	1.000D 00	1.189D-36
13	11	62500.00	52500.00	4.00970D 01	3.201D 01	-6.867D-12	1.901D-02	8.000D 01	-4.810D-37	1.000D 00	3.025D-39
13	12	62500.00	57500.00	4.00970D 01	3.241D 01	-1.067D 01	1.957D-02	8.000D 01	-2.191D-34	1.000D 00	1.189D-36
13	13	62500.00	62500.00	4.00970D 01	3.368D 01	-1.986D 01	1.873D-02	8.000D 01	-7.057D-32	1.000D 00	3.451D-34
13	14	62500.00	67500.00	4.00969D 01	3.582D 01	-2.655D 01	1.863D-02	8.000D 01	-1.065D-29	1.000D 00	5.031D-32
13	15	62500.00	72500.00	4.00969D 01	3.873D 01	-3.024D 01	1.779D-02	8.000D 01	-2.995D-28	1.000D 00	1.223D-30
13	16	62500.00	77500.00	4.00968D 01	4.216D 01	-3.093D 01	1.718D-02	8.000D 01	-1.377D-28	1.000D 00	5.159D-31
13	17	62500.00	82500.00	4.00967D 01	4.577D 01	-2.891D 01	1.638D-02	8.000D 01	-1.152D-29	1.000D 00	3.991D-32
13	18	62500.00	87500.00	4.00967D 01	4.919D 01	-2.468D 01	1.582D-02	8.000D 01	-3.410D-31	1.000D 00	1.098D-33
13	19	62500.00	92500.00	4.00966D 01	5.206D 01	-1.877D 01	1.523D-02	8.000D 01	-4.708D-33	1.000D 00	1.415D-35
13	20	62500.00	97500.00	4.00966D 01	5.412D 01	-1.169D 01	1.468D-02	8.000D 01	-3.087D-35	1.000D 00	8.726D-38
13	21	62500.00	102500.00	4.00965D 01	5.519D 01	-3.981D 00	1.495D-02	8.000D 01	-7.883D-38	1.000D 00	2.109D-40
14	1	67500.00	2500.00	4.00960D 01	4.587D 01	3.671D 00	1.413D-02	8.000D 01	-1.703D-40	1.000D 00	4.346D-43
14	2	67500.00	7500.00	4.00960D 01	4.520D 01	1.084D 01	1.384D-02	8.000D 01	-6.923D-38	1.000D 00	1.864D-40
14	3	67500.00	12500.00	4.00960D 01	4.395D 01	1.746D 01	1.439D-02	8.000D 01	-1.085D-35	1.000D 00	3.102D-38
14	4	67500.00	17500.00	4.00961D 01	4.235D 01	2.309D 01	1.495D-02	8.000D 01	-8.018D-34	1.000D 00	2.455D-36
14	5	67500.00	22500.00	4.00962D 01	4.070D 01	2.728D 01	1.551D-02	8.000D 01	-2.750D-32	1.000D 00	9.049D-35
14	6	67500.00	27500.00	4.00962D 01	3.934D 01	2.952D 01	1.648D-02	8.000D 01	-3.347D-31	1.000D 00	1.189D-33
14	7	67500.00	32500.00	4.00963D 01	3.857D 01	2.929D 01	1.680D-02	8.000D 01	-7.527D-31	1.000D 00	2.910D-33

Table A.2 (continued)

ITER.= 106   TIME=5.300000D 00   PERIOD=5.300000D 00   TIME INCREMENT=5.000000D-02

NODE	INDI- CES	X- LOCATION	Y- LOCATION	WATER ELEVATION	VELOCITY IN X-DIRECT.	VELOCITY IN Y-DIRECT.	WATER ELEV. RATE OF CHANGE	TEMP.	TEMP. RATE OF CHANGE	SUBSTANCE MASS CONCENTRATIONS CK(1)	CK(2)
14	8	67500.00	37500.00	4.00964D 01	3.854D 01	2.614D 01	1.787D-02	8.000D 01	-3.100D-32	1.000D 00	1.395D-34
14	9	67500.00	42500.00	4.00964D 01	3.907D 01	1.988D C1	1.742D-02	8.000D 01	-2.514D-34	1.000D 00	1.206D-36
14	10	67500.00	47500.00	4.00964D 01	3.979D 01	1.084D 01	1.916D-02	8.000D 01	-9.798D-37	1.000D 00	5.316D-39
14	11	67500.00	52500.00	4.00964D 01	4.015D 01	-7.252D-12	1.755D-02	8.000D 01	-2.675D-39	1.000D 00	1.620D-41
14	12	67500.00	57500.00	4.00964D 01	3.979D 01	-1.084D C1	1.916D-02	8.000D 01	-9.798D-37	1.000D 00	5.316D-39
14	13	67500.00	62500.00	4.00964D 01	3.907D 01	-1.988D 01	1.742D-02	8.000D 01	-2.514D-34	1.000D 00	1.206D-36
14	14	67500.00	67500.00	4.00964D 01	3.854D 01	-2.614D 01	1.787D-02	8.000D 01	-3.100D-32	1.000D 00	1.395D-34
14	15	67500.00	72500.00	4.00963D 01	3.857D 01	-2.929D 01	1.680D-02	8.000D 01	-7.527D-31	1.000D 00	2.910D-33
14	16	67500.00	77500.00	4.00962D 01	3.934D 01	-2.952D 01	1.648D-02	8.000D 01	-3.347D-31	1.000D 00	1.189D-33
14	17	67500.00	82500.00	4.00962D 01	4.070D 01	-2.728D 01	1.551D-02	8.000D 01	-2.750D-32	1.000D 00	9.049D-35
14	18	67500.00	87500.00	4.00961D 01	4.235D 01	-2.309D 01	1.495D-02	8.000D 01	-8.018D-34	1.000D 00	2.455D-36
14	19	67500.00	92500.00	4.00960D 01	4.395D 01	-1.746D 01	1.439D-02	8.000D 01	-1.085D-35	1.000D 00	3.102D-38
14	20	67500.00	97500.00	4.00960D 01	4.520D 01	-1.084D 01	1.384D-02	8.000D 01	-6.923D-38	1.000D 00	1.864D-40
14	21	67500.00	102500.00	4.00960D 01	4.587D 01	-3.671D 00	1.413D-02	8.000D 01	-1.703D-40	1.000D 00	4.346D-43
15	1	72500.00	2500.00	4.00954D 01	3.720D 01	3.396D C0	1.300D-02	8.000D 01	-2.882D-43	1.000D 00	7.058D-46
15	2	72500.00	7500.00	4.00955D 01	3.684D 01	1.011D 01	1.273D-02	8.000D 01	-1.220D-40	1.000D 00	3.147D-43
15	3	72500.00	12500.00	4.00955D 01	3.624D 01	1.641D 01	1.323D-02	8.000D 01	-1.984D-38	1.000D 00	5.432D-41
15	4	72500.00	17500.00	4.00956D 01	3.565D 01	2.197D 01	1.388D-02	8.000D 01	-1.526D-36	1.000D 00	4.464D-39
15	5	72500.00	22500.00	4.00957D 01	3.547D 01	2.642D 01	1.442D-02	8.000D 01	-5.489D-35	1.000D 00	1.722D-37
15	6	72500.00	27500.00	4.00957D 01	3.611D 01	2.928D 01	1.548D-02	8.000D 01	-7.133D-34	1.000D 00	2.409D-36
15	7	72500.00	32500.00	4.00958D 01	3.790D 01	2.995D 01	1.519D-02	8.000D 01	-1.772D-33	1.000D 00	6.490D-36
15	8	72500.00	37500.00	4.00959D 01	4.089D 01	2.763D 01	1.735D-02	8.000D 01	-9.097D-35	1.000D 00	3.896D-37
15	9	72500.00	42500.00	4.00959D 01	4.451D 01	2.174D C1	1.511D-02	8.000D 01	-9.593D-37	1.000D 00	4.515D-39
15	10	72500.00	47500.00	4.00959D 01	4.771D 01	1.224D 01	1.960D-02	8.000D 01	-4.935D-39	1.000D 00	2.622D-41
15	11	72500.00	52500.00	4.00959D 01	4.909D 01	-3.665D-12	1.575D-02	8.000D 01	-1.688D-41	1.000D 00	9.533D-44
15	12	72500.00	57500.00	4.00959D 01	4.771D 01	-1.224D 01	1.960D-02	8.000D 01	-4.935D-39	1.000D 00	2.622D-41
15	13	72500.00	62500.00	4.00959D 01	4.451D 01	-2.174D 01	1.511D-02	8.000D 01	-9.593D-37	1.000D 00	4.515D-39
15	14	72500.00	67500.00	4.00959D 01	4.089D 01	-2.763D 01	1.735D-02	8.000D 01	-9.097D-35	1.000D 00	3.896D-37
15	15	72500.00	72500.00	4.00958D 01	3.790D 01	-2.995D 01	1.519D-02	8.000D 01	-1.772D-33	1.000D 00	6.490D-36
15	16	72500.00	77500.00	4.00957D 01	3.611D 01	-2.928D 01	1.548D-02	8.000D 01	-7.133D-34	1.000D 00	2.409D-36
15	17	72500.00	82500.00	4.00957D 01	3.547D 01	-2.642D 01	1.442D-02	8.000D 01	-5.489D-35	1.000D 00	1.722D-37
15	18	72500.00	87500.00	4.00956D 01	3.565D 01	-2.197D 01	1.388D-02	8.000D 01	-1.526D-36	1.000D 00	4.464D-39
15	19	72500.00	92500.00	4.00955D 01	3.624D 01	-1.641D 01	1.323D-02	8.000D 01	-1.984D-38	1.000D 00	5.432D-41
15	20	72500.00	97500.00	4.00955D 01	3.684D 01	-1.011D 01	1.273D-02	8.000D 01	-1.220D-40	1.000D 00	3.147D-43
15	21	72500.00	102500.00	4.00954D 01	3.720D 01	-3.396D 00	1.300D-02	8.000D 01	-2.882D-43	1.000D 00	7.058D-46
16	1	77500.00	2500.00	4.00950D 01	2.915D 01	3.121D 00	1.162D-02	8.000D 01	-3.731D-46	1.000D 00	8.823D-49
16	2	77500.00	7500.00	4.00950D 01	2.898D 01	9.389D 00	1.144D-02	8.000D 01	-1.650D-43	1.000D 00	4.105D-46
16	3	77500.00	12500.00	4.00951D 01	2.879D 01	1.540D 01	1.198D-02	8.000D 01	-2.812D-41	1.000D 00	7.409D-44
16	4	77500.00	17500.00	4.00951D 01	2.889D 01	2.098D 01	1.284D-02	8.000D 01	-2.291D-39	1.000D 00	6.435D-42
16	5	77500.00	22500.00	4.00952D 01	2.978D 01	2.592D C1	1.292D-02	8.000D 01	-8.930D-38	1.000D 00	2.679D-40
16	6	77500.00	27500.00	4.00953D 01	3.207D 01	2.979D 01	1.387D-02	8.000D 01	-1.303D-36	1.000D 00	4.190D-39
16	7	77500.00	32500.00	4.00954D 01	3.629D 01	3.194D 01	1.283D-02	8.000D 01	-3.834D-36	1.000D 00	1.331D-38
16	8	77500.00	37500.00	4.00954D 01	4.267D 01	3.108D 01	1.792D-02	8.000D 01	-2.648D-37	1.000D 00	1.075D-39
16	9	77500.00	42500.00	4.00954D 01	5.024D 01	2.586D 01	1.250D-02	8.000D 01	-3.925D-39	1.000D 00	1.800D-41
16	10	77500.00	47500.00	4.00953D 01	5.718D 01	1.536D 01	2.249D-02	8.000D 01	-2.784D-41	1.000D 00	1.415D-43
16	11	77500.00	52500.00	4.00953D 01	6.031D 01	-2.449D-12	8.742D-03	8.000D 01	-1.214D-43	1.000D 00	6.265D-46
16	12	77500.00	57500.00	4.00953D 01	5.718D 01	-1.536D 01	2.249D-02	8.000D 01	-2.784D-41	1.000D 00	1.415D-43
16	13	77500.00	62500.00	4.00954D 01	5.024D 01	-2.586D 01	1.250D-02	8.000D 01	-3.925D-39	1.000D 00	1.800D-41
16	14	77500.00	67500.00	4.00954D 01	4.267D 01	-3.108D 01	1.792D-02	8.000D 01	-2.648D-37	1.000D 00	1.075D-39
16	15	77500.00	72500.00	4.00954D 01	3.629D 01	-3.194D 01	1.283D-02	8.000D 01	-3.834D-36	1.000D 00	1.331D-38
16	16	77500.00	77500.00	4.00953D 01	3.207D 01	-2.979D 01	1.387D-02	8.000D 01	-1.303D-36	1.000D 00	4.190D-39
16	17	77500.00	82500.00	4.00952D 01	2.978D 01	-2.592D 01	1.292D-02	8.000D 01	-8.930D-38	1.000D 00	2.679D-40
16	18	77500.00	87500.00	4.00951D 01	2.889D 01	-2.098D 01	1.284D-02	8.000D 01	-2.291D-39	1.000D 00	6.435D-42
16	19	77500.00	92500.00	4.00951D 01	2.879D 01	-1.540D 01	1.198D-02	8.000D 01	-2.812D-41	1.000D 00	7.409D-44
16	20	77500.00	97500.00	4.00950D 01	2.898D 01	-9.389D C0	1.144D-02	8.000D 01	-1.650D-43	1.000D 00	4.105D-46
16	21	77500.00	102500.00	4.00950D 01	2.915D 01	-3.121D 00	1.162D-02	8.000D 01	-3.731D-46	1.000D 00	8.823D-49

Table A.2 (continued)

ITER.= 106 TIME=5.300000D 00 PERIOD=5.300000D 00 TIME INCREMENT=5.000000D-02

NODE	INDICES	X-LOCATION	Y-LOCATION	WATER ELEVATION	VELOCITY IN X-DIRECT.	VELOCITY IN Y-DIRECT.	WATER ELEV. RATE OF CHANGE	TEMP.	TEMP. RATE OF CHANGE	SUBSTANCE MASS CONCENTRATIONS CK(1)	CK(2)
17	1	82500.00	2500.00	4.00946D 01	2.178D 01	2.795D 00	1.014D-02	8.000D 01	-3.570D-49	1.000D 00	8.197D-52
17	2	82500.00	7500.00	4.00946D 01	2.169D 01	8.510D 00	1.016D-02	8.000D 01	-1.652D-46	1.000D 00	3.982D-49
17	3	82500.00	12500.00	4.00947D 01	2.164D 01	1.412D 01	1.072D-02	8.000D 01	-2.965D-44	1.000D 00	7.554D-47
17	4	82500.00	17500.00	4.00948D 01	2.201D 01	1.965D 01	1.134D-02	8.000D 01	-2.594D-42	1.000D 00	7.022D-45
17	5	82500.00	22500.00	4.00949D 01	2.339D 01	2.511D 01	1.053D-02	3.000D 01	-1.128D-40	1.000D 00	3.246D-43
17	6	82500.00	27500.00	4.00949D 01	2.673D 01	3.019D 01	1.385D-02	8.000D 01	-1.947D-39	1.000D 00	5.958D-42
17	7	82500.00	32500.00	4.00950D 01	3.297D 01	3.446D 01	1.025D-02	8.000D 01	-7.342D-39	1.000D 00	2.410D-41
17	8	82500.00	37500.00	4.00949D 01	4.311D 01	3.615D 01	2.105D-02	8.000D 01	-7.402D-40	1.000D 00	2.831D-42
17	9	82500.00	42500.00	4.00949D 01	5.610D 01	3.291D 01	7.819D-03	8.000D 01	-1.704D-41	1.000D 00	7.546D-44
17	10	82500.00	47500.00	4.00948D 01	6.950D 01	2.148D 01	3.079D-02	8.000D 01	-1.744D-43	1.000D 00	8.344D-46
17	11	82500.00	52500.00	4.00946D 01	7.613D 01	-3.760D-12	-1.026D-02	8.000D 01	-1.022D-45	1.000D 00	4.759D-48
17	12	82500.00	57500.00	4.00948D 01	6.950D 01	-2.148D 01	3.079D-02	8.000D 01	-1.744D-43	1.000D 00	8.344D-46
17	13	82500.00	62500.00	4.00949D 01	5.610D 01	-3.291D 01	7.819D-03	8.000D 01	-1.704D-41	1.000D 00	7.546D-44
17	14	82500.00	67500.00	4.00949D 01	4.311D 01	-3.615D 01	2.105D-02	8.000D 01	-7.402D-40	1.000D 00	2.831D-42
17	15	82500.00	72500.00	4.00950D 01	3.297D 01	-3.446D 01	1.025D-02	8.000D 01	-7.342D-39	1.000D 00	2.410D-41
17	16	82500.00	77500.00	4.00949D 01	2.673D 01	-3.019D 01	1.385D-02	8.000D 01	-1.947D-39	1.000D 00	5.958D-42
17	17	82500.00	82500.00	4.00949D 01	2.339D 01	-2.511D 01	1.053D-02	8.000D 01	-1.128D-40	1.000D 00	3.246D-43
17	18	82500.00	87500.00	4.00948D 01	2.201D 01	-1.965D 01	1.134D-02	8.000D 01	-2.594D-42	1.000D 00	7.022D-45
17	19	82500.00	92500.00	4.00947D 01	2.164D 01	-1.412D 01	1.072D-02	8.000D 01	-2.965D-44	1.000D 00	7.554D-47
17	20	82500.00	97500.00	4.00946D 01	2.169D 01	-8.510D 00	1.016D-02	8.000D 01	-1.652D-46	1.000D 00	3.982D-49
17	21	82500.00	102500.00	4.00946D 01	2.178D 01	-2.795D 00	1.014D-02	8.000D 01	-3.570D-49	1.000D 00	8.197D-52
18	1	87500.00	2500.00	4.00943D 01	1.525D 01	2.374D 00	8.948D-03	8.000D 01	-2.400D-52	1.000D 00	5.379D-55
18	2	87500.00	7500.00	4.00943D 01	1.512D 01	7.344D 00	9.126D-03	8.000D 01	-1.158D-49	1.000D 00	2.719D-52
18	3	87500.00	12500.00	4.00944D 01	1.498D 01	1.232D 01	9.348D-03	8.000D 01	-2.182D-47	1.000D 00	5.398D-50
18	4	87500.00	17500.00	4.00945D 01	1.517D 01	1.743D 01	9.476D-03	8.000D 01	-2.049D-45	1.000D 00	5.360D-48
18	5	87500.00	22500.00	4.00946D 01	1.627D 01	2.300D 01	8.873D-03	8.000D 01	-1.014D-43	1.000D 00	2.796D-46
18	6	87500.00	27500.00	4.00946D 01	1.954D 01	2.899D 01	1.767D-02	8.000D 01	-2.152D-42	1.000D 00	6.277D-45
18	7	87500.00	32500.00	4.00947D 01	2.678D 01	3.579D 01	9.081D-03	8.000D 01	-1.145D-41	1.000D 00	3.548D-44
18	8	87500.00	37500.00	4.00946D 01	4.096D 01	4.151D 01	2.397D-02	8.000D 01	-1.862D-42	1.000D 00	6.712D-45
18	9	87500.00	42500.00	4.00947D 01	6.186D 01	4.359D 01	-2.902D-02	8.000D 01	9.435D-44	1.000D 00	1.034D-43
18	10	87500.00	47500.00	4.00946D 01	8.759D 01	3.312D 01	2.892D-02	8.000D 01	-6.445D-44	1.000D 00	2.830D-45
18	11	87500.00	52500.00	4.00941D 01	1.018D 02	-4.674D-12	-5.281D-02	8.000D 01	3.762D-44	1.000D 00	1.805D-44
18	12	87500.00	57500.00	4.00946D 01	8.759D 01	-3.312D 01	2.892D-02	8.000D 01	-6.445D-44	1.000D 00	2.830D-45
18	13	87500.00	62500.00	4.00947D 01	6.186D 01	-4.359D 01	-2.902D-02	8.000D 01	9.435D-44	1.000D 00	1.034D-43
18	14	87500.00	67500.00	4.00946D 01	4.096D 01	-4.151D 01	2.397D-02	8.000D 01	-1.862D-42	1.000D 00	6.712D-45
18	15	87500.00	72500.00	4.00947D 01	2.678D 01	-3.579D 01	9.081D-03	8.000D 01	-1.145D-41	1.000D 00	3.548D-44
18	16	87500.00	77500.00	4.00946D 01	1.954D 01	-2.899D 01	1.767D-02	8.000D 01	-2.152D-42	1.000D 00	6.277D-45
18	17	87500.00	82500.00	4.00946D 01	1.627D 01	-2.300D 01	8.873D-03	8.000D 01	-1.014D-43	1.000D 00	2.796D-46
18	18	87500.00	87500.00	4.00945D 01	1.517D 01	-1.743D 01	9.476D-03	8.000D 01	-2.049D-45	1.000D 00	5.360D-48
18	19	87500.00	92500.00	4.00944D 01	1.498D 01	-1.232D 01	9.348D-03	8.000D 01	-2.182D-47	1.000D 00	5.398D-50
18	20	87500.00	97500.00	4.00943D 01	1.512D 01	-7.344D 00	9.126D-03	8.000D 01	-1.158D-49	1.000D 00	2.719D-52
18	21	87500.00	102500.00	4.00943D 01	1.525D 01	-2.374D 00	8.948D-03	8.000D 01	-2.400D-52	1.000D 00	5.379D-55
19	1	92500.00	2500.00	4.00941D 01	9.750D 00	1.871D 00	7.986D-03	8.000D 01	-1.055D-55	1.000D 00	2.320D-58
19	2	92500.00	7500.00	4.00942D 01	9.567D 00	5.928D 00	7.542D-03	8.000D 01	-5.255D-53	1.000D 00	1.209D-55
19	3	92500.00	12500.00	4.00942D 01	9.237D 00	9.962D 00	6.886D-03	8.000D 01	-1.017D-50	1.000D 00	2.456D-53
19	4	92500.00	17500.00	4.00944D 01	8.972D 00	1.404D 01	9.540D-03	8.000D 01	-9.943D-49	1.000D 00	2.524D-51
19	5	92500.00	22500.00	4.00945D 01	9.142D 00	1.872D 01	6.276D-03	8.000D 01	-5.458D-47	1.000D 00	2.252D-49
19	6	92500.00	27500.00	4.00945D 01	1.108D 01	2.453D 01	1.455D-02	8.000D 01	2.678D-46	1.000D 00	2.898D-45
19	7	92500.00	32500.00	4.00948D 01	1.709D 01	3.384D 01	-7.565D-03	8.000D 01	2.808D-41	1.000D 00	3.488D-41
19	8	92500.00	37500.00	4.00946D 01	3.313D 01	4.505D 01	4.147D-02	8.000D 01	8.740D-37	1.000D 00	7.228D-37
19	9	92500.00	42500.00	4.00943D 01	6.086D 01	5.888D 01	-5.088D-02	8.000D 01	1.942D-32	1.000D 00	1.040D-32
19	10	92500.00	47500.00	4.00924D 01	1.061D 02	5.495D 01	2.352D-01	8.000D 01	-9.664D-33	1.000D 00	3.589D-34
19	11	92500.00	52500.00	4.00902D 01	1.353D 02	-1.170D-12	1.982D-02	8.000D 01	-4.084D-19	1.000D 00	5.084D-33
19	12	92500.00	57500.00	4.00924D 01	1.061D 02	-5.495D 01	2.352D-01	8.000D 01	-9.664D-33	1.000D 00	3.589D-34
19	13	92500.00	62500.00	4.00943D 01	6.086D 01	-5.888D 01	-5.088D-02	8.000D 01	1.942D-32	1.000D 00	1.040D-32
19	14	92500.00	67500.00	4.00946D 01	3.313D 01	-4.505D 01	4.147D-02	8.000D 01	8.740D-37	1.000D 00	7.228D-37

Table A.2 (continued)

ITER.= 106 TIME=5.300000D 00 PERIOD=5.300000D 00 TIME INCREMENT=5.000000D-02

NODE	INDI- CES	X- LOCATION	Y- LOCATION	WATER ELEVATION	VELOCITY IN X-DIRECT.	VELOCITY IN Y-DIRECT.	WATER ELEV. RATE OF CHANGE	TEMP.	TEMP. RATE OF CHANGE	SUBSTANCE MASS CONCENTRATIONS CK(1)	CK(2)
19	15	92500.00	72500.00	4.00948D 01	1.709D 01	-3.384D 01	-7.565D-03	8.000D 01	2.808D-41	1.000D 00	3.488D-41
19	16	92500.00	77500.00	4.00945D 01	1.108D 01	-2.453D 01	1.455D-02	8.000D 01	2.678D-46	1.000D 00	2.898D-45
19	17	92500.00	82500.00	4.00945D 01	9.142D 00	-1.872D 01	6.276D-03	8.000D 01	-5.458D-47	1.000D 00	2.252D-49
19	18	92500.00	87500.00	4.00944D 01	8.972D 00	-1.404D 01	9.540D-03	8.000D 01	-9.943D-49	1.000D 00	2.524D-51
19	19	92500.00	92500.00	4.00942D 01	9.237D 00	-9.962D 00	6.886D-03	8.000D 01	-1.017D-50	1.000D 00	2.456D-53
19	20	92500.00	97500.00	4.00942D 01	9.567D 00	-5.928D 00	7.542D-03	8.000D 01	-5.255D-53	1.000D 00	1.209D-55
19	21	92500.00	102500.00	4.00941D 01	9.750D 00	-1.871D 00	7.986D-03	8.000D 01	-1.055D-55	1.000D 00	2.320D-58
20	1	97500.00	2500.00	4.00940D 01	5.367D 00	1.444D 00	7.332D-03	8.000D 01	1.814D-57	1.000D 00	1.570D-56
20	2	97500.00	7500.00	4.00940D 01	5.204D 00	4.648D 00	6.519D-03	8.000D 01	1.507D-52	1.000D 00	9.350D-52
20	3	97500.00	12500.00	4.00942D 01	4.786D 00	7.672D C0	6.729D-03	8.000D 01	4.401D-48	1.000D 00	2.182D-47
20	4	97500.00	17500.00	4.00943D 01	4.127D 00	1.035D 01	1.485D-02	8.000D 01	7.892D-44	1.000D 00	3.341D-43
20	5	97500.00	22500.00	4.00945D 01	3.271D 00	1.331D 01	8.428D-03	8.000D 01	9.810D-40	1.000D 00	3.717D-39
20	6	97500.00	27500.00	4.00946D 01	3.024D 00	1.663D 01	1.084D-02	8.000D 01	-6.255D-32	1.000D 00	1.293D-33
20	7	97500.00	32500.00	4.00952D 01	4.628D 00	2.448D 01	-4.927D-02	8.000D 01	-9.058D-28	1.000D 00	1.600D-29
20	8	97500.00	37500.00	4.00944D 01	1.669D 01	3.143D 01	5.108D-02	8.000D 01	-1.030D-23	1.000D 00	1.638D-25
20	9	97500.00	42500.00	4.00956D 01	4.607D 01	5.661D 01	-1.791D-01	8.000D 01	-1.154D-25	1.000D 00	1.552D-26
20	10	97500.00	47500.00	4.00918D 01	1.352D 02	7.591D 01	3.402D-01	8.000D 01	-1.205D-18	1.000D 00	1.168D-26
20	11	97500.00	52500.00	4.00855D 01	2.057D 02	3.934D-12	-6.318D-01	8.000D 01	-7.720D-14	1.000D 00	9.375D-22
20	12	97500.00	57500.00	4.00918D 01	1.352D 02	-7.591D 01	3.402D-01	8.000D 01	-1.205D-18	1.000D 00	1.168D-26
20	13	97500.00	62500.00	4.00956D 01	4.607D 01	-5.661D 01	-1.791D-01	8.000D 01	-1.154D-25	1.000D 00	1.552D-26
20	14	97500.00	67500.00	4.00944D 01	1.669D 01	-3.143D 01	5.108D-02	8.000D 01	-1.030D-23	1.000D 00	1.638D-25
20	15	97500.00	72500.00	4.00952D 01	4.628D 00	-2.448D 01	-4.927D-02	8.000D 01	-9.058D-28	1.000D 00	1.600D-29
20	16	97500.00	77500.00	4.00946D 01	3.024D 00	-1.663D 01	1.084D-02	8.000D 01	-6.255D-32	1.000D 00	1.293D-33
20	17	97500.00	82500.00	4.00945D 01	3.271D 00	-1.331D 01	8.428D-03	8.000D 01	9.810D-40	1.000D 00	3.717D-39
20	18	97500.00	87500.00	4.00943D 01	4.127D 00	-1.035D 01	1.485D-02	8.000D 01	7.892D-44	1.000D 00	3.341D-43
20	19	97500.00	92500.00	4.00942D 01	4.786D 00	-7.672D 00	6.729D-03	8.000D 01	4.401D-48	1.000D 00	2.182D-47
20	20	97500.00	97500.00	4.00940D 01	5.204D 00	-4.648D 00	6.519D-03	8.000D 01	1.507D-52	1.000D 00	9.350D-52
20	21	97500.00	102500.00	4.00940D 01	5.367D 00	-1.444D 00	7.332D-03	8.000D 01	1.814D-57	1.000D 00	1.570D-56
21	1	102500.00	2500.00	4.00939D 01	1.782D 00	1.257D 00	6.630D-03	8.000D 01	7.770D-53	1.000D 00	1.397D-51
21	2	102500.00	7500.00	4.00940D 01	1.717D 00	3.973D 00	8.222D-03	8.000D 01	6.112D-48	1.000D 00	6.337D-47
21	3	102500.00	12500.00	4.00941D 01	1.350D 00	6.368D 00	7.660D-03	8.000D 01	1.620D-43	1.000D 00	1.254D-42
21	4	102500.00	17500.00	4.00942D 01	4.870D-01	8.12CD 00	9.635D-03	8.000D 01	2.480D-39	1.000D 00	1.677D-38
21	5	102500.00	22500.00	4.00945D 01	-1.218D 00	9.721D 00	-2.705D-03	8.000D 01	2.310D-35	1.000D 00	1.573D-34
21	6	102500.00	27500.00	4.00948D 01	-4.037D 00	9.451D 00	3.161D-02	8.000D 01	4.941D-31	1.000D 00	3.245D-30
21	7	102500.00	32500.00	4.00955D 01	-9.101D 00	1.146D 01	-3.395D-02	8.000D 01	2.762D-27	1.000D 00	3.957D-26
21	8	102500.00	37500.00	4.00943D 01	-5.940D 00	2.055D 00	2.831D-01	8.000D 01	-1.555D-20	1.000D 00	1.517D-22
21	9	102500.00	42500.00	4.01026D 01	2.390D 01	2.881D 01	-4.381D-01	8.000D 01	-3.235D-19	1.000D 00	3.013D-20
21	10	102500.00	47500.00	4.01014D 01	1.993D 02	8.001D 01	2.754D-01	8.000D 01	-6.162D-14	1.000D 00	1.095D-15
21	11	102500.00	52500.00	4.00898D 01	3.515D 02	6.082D-12	-1.393D 00	8.000D 01	4.012D-09	1.000D 00	8.429D-11
21	12	102500.00	57500.00	4.01014D 01	1.993D 02	-8.001D 01	2.754D-01	8.000D 01	-6.162D-14	1.000D 00	1.095D-15
21	13	102500.00	62500.00	4.01026D 01	2.390D 01	-2.881D C1	-4.381D-01	8.000D 01	-3.235D-19	1.000D 00	3.013D-20
21	14	102500.00	67500.00	4.00943D 01	-5.940D 00	-2.055D 00	2.831D-01	8.000D 01	-1.555D-20	1.000D 00	1.517D-22
21	15	102500.00	72500.00	4.00955D 01	-9.101D 00	-1.146D 01	-3.395D-02	8.000D 01	2.762D-27	1.000D 00	3.957D-26
21	16	102500.00	77500.00	4.00948D 01	-4.037D 00	-9.451D 00	3.161D-02	8.000D 01	4.941D-31	1.000D 00	3.245D-30
21	17	102500.00	82500.00	4.00945D 01	-1.218D 00	-9.721D 00	-2.705D-03	8.000D 01	2.310D-35	1.000D 00	1.573D-34
21	18	102500.00	87500.00	4.00942D 01	4.870D-01	-8.120D 00	9.635D-03	8.000D 01	2.480D-39	1.000D 00	1.677D-38
21	19	102500.00	92500.00	4.00941D 01	1.350D 00	-6.368D 00	7.660D-03	8.000D 01	1.620D-43	1.000D 00	1.254D-42
21	20	102500.00	97500.00	4.00940D 01	1.717D 00	-3.973D C0	8.222D-03	8.000D 01	6.112D-48	1.000D 00	6.337D-47
21	21	102500.00	102500.00	4.00939D 01	1.782D 00	-1.257D 00	6.630D-03	8.000D 01	7.770D-53	1.000D 00	1.397D-51

IHC002I STOP 0

Table A.3. Output Information for Sample Problem No. 1 at Time = 124.45 hr Using the Reduced Version of the Program

ITER.= 913 TIME=1.244500D 02 PERIOD=1.244500D 02 TIME INCREMENT=5.000000D-02

NODE	INDI- CES	X- LOCATION	Y- LOCATION	WATER ELEVATION	VELOCITY IN X-DIRECT.	VELOCITY IN Y-DIRECT.	WATER ELEV. RATE OF CHANGE	TEMP.	TEMP. RATE OF CHANGE
1	1	2500.00	2500.00	4.00891D 01	8.079D-01	-7.868D-01	3.044D-05	8.000D 01	1.163D-12
1	2	2500.00	7500.00	4.00891D 01	8.652D-01	-2.518D 00	7.155D-05	8.000D 01	2.530D-10
1	3	2500.00	12500.00	4.00890D 01	9.664D-01	-4.404D 00	-3.128D-05	8.000D 01	2.334D-08
1	4	2500.00	17500.00	4.00890D 01	1.092D 00	-6.606D 00	-1.744D-04	8.000D 01	1.171D-06
1	5	2500.00	22500.00	4.00889D 01	1.190D 00	-9.361D 00	6.724D-04	8.000D 01	3.447D-05
1	6	2500.00	27500.00	4.00888D 01	1.450D 00	-1.304D 01	6.912D-04	8.002D 01	5.989D-04
1	7	2500.00	32500.00	4.00885D 01	2.287D 00	-1.858D 01	1.522D-03	8.023D 01	5.789D-03
1	8	2500.00	37500.00	4.00895D 01	7.941D 00	-2.239D 01	-1.028D-01	8.173D 01	1.766D-02
1	9	2500.00	42500.00	4.00820D 01	2.406D 01	-5.744D 01	4.314D-01	8.729D 01	6.429D-02
1	10	2500.00	47500.00	4.00901D 01	1.237D 02	-8.727D 01	-4.753D-01	9.113D 01	4.717D-02
1	11	2500.00	52500.00	4.01069D 01	2.123D 02	-6.839D-12	2.897D-01	9.473D 01	2.348D-05
1	12	2500.00	57500.00	4.00901D 01	1.237D 02	8.727D 01	-4.753D-01	9.113D 01	4.717D-02
1	13	2500.00	62500.00	4.00820D 01	2.406D 01	5.744D 01	4.314D-01	8.729D 01	6.429D-02
1	14	2500.00	67500.00	4.00895D 01	7.941D 00	2.239D 01	-1.028D-01	8.173D 01	1.766D-02
1	15	2500.00	72500.00	4.00885D 01	2.287D 00	1.858D 01	1.522D-03	8.023D 01	5.789D-03
1	16	2500.00	77500.00	4.00888D 01	1.450D 00	1.304D 01	6.912D-04	8.002D 01	5.989D-04
1	17	2500.00	82500.00	4.00889D 01	1.190D 00	9.361D 00	6.724D-04	8.000D 01	3.447D-05
1	18	2500.00	87500.00	4.00890D 01	1.092D 00	6.606D 00	-1.744D-04	8.000D 01	1.171D-06
1	19	2500.00	92500.00	4.00890D 01	9.664D-01	4.404D 00	-3.128D-05	8.000D 01	2.334D-08
1	20	2500.00	97500.00	4.00891D 01	8.652D-01	2.518D 00	7.155D-05	8.000D 01	2.530D-10
1	21	2500.00	102500.00	4.00891D 01	8.079D-01	7.668D-01	3.044D-05	8.000D 01	1.163D-12
2	1	7500.00	2500.00	4.00891D 01	2.507D 00	-8.088D-01	-8.621D-05	8.000D 01	7.132D-13
2	2	7500.00	7500.00	4.00891D 01	2.698D 00	-2.589D 00	-1.805D-05	8.000D 01	1.627D-10
2	3	7500.00	12500.00	4.00890D 01	3.097D 00	-4.543D 00	-1.936D-04	8.000D 01	1.581D-08
2	4	7500.00	17500.00	4.00890D 01	3.761D 00	-6.665D 00	-3.658D-04	8.000D 01	8.404D-07
2	5	7500.00	22500.00	4.00890D 01	4.836D 00	-9.818D 00	-6.668D-04	8.000D 01	2.603D-05
2	6	7500.00	27500.00	4.00889D 01	6.801D 00	-1.392D 01	2.316D-03	8.001D 01	4.777D-04
2	7	7500.00	32500.00	4.00887D 01	1.080D 01	-2.008D 01	6.604D-03	8.016D 01	4.923D-03
2	8	7500.00	37500.00	4.00894D 01	2.016D 01	-2.652D 01	-2.760D-02	8.118D 01	2.408D-02
2	9	7500.00	42500.00	4.00872D 01	3.738D 01	-4.727D 01	9.991D-02	8.488D 01	5.707D-02
2	10	7500.00	47500.00	4.00901D 01	1.011D 02	-5.777D 01	-2.543D-01	8.926D 01	4.068D-02
2	11	7500.00	52500.00	4.00960D 01	1.543D 02	-5.536D-12	3.526D-01	9.414D 01	8.511D-03
2	12	7500.00	57500.00	4.00901D 01	1.011D 02	5.777D 01	-2.543D-01	8.926D 01	4.068D-02
2	13	7500.00	62500.00	4.00872D 01	3.738D 01	4.727D 01	9.991D-02	8.488D 01	5.707D-02
2	14	7500.00	67500.00	4.00894D 01	2.016D 01	2.652D 01	-2.760D-02	8.118D 01	2.408D-02
2	15	7500.00	72500.00	4.00887D 01	1.080D 01	2.008D 01	6.604D-03	8.016D 01	4.923D-03
2	16	7500.00	77500.00	4.00889D 01	6.801D 00	1.392D 01	2.316D-03	8.001D 01	4.777D-04
2	17	7500.00	82500.00	4.00890D 01	4.836D 00	9.818D 00	-6.668D-04	8.000D 01	2.603D-05
2	18	7500.00	87500.00	4.00890D 01	3.761D 00	6.665D 00	-3.658D-04	8.000D 01	8.404D-07
2	19	7500.00	92500.00	4.00890D 01	3.097D 00	4.543D 00	-1.936D-04	8.000D 01	1.581D-08
2	20	7500.00	97500.00	4.00891D 01	2.698D 00	2.589D 00	-1.805D-05	8.000D 01	1.627D-10
2	21	7500.00	102500.00	4.00891D 01	2.507D 00	8.088D-01	-8.621D-05	8.000D 01	7.132D-13
3	1	12500.00	2500.00	4.00891D 01	4.256D 00	-8.443D-01	6.125D-05	8.000D 01	2.503D-13
3	2	12500.00	7500.00	4.00891D 01	4.592D 00	-2.692D 00	9.203D-05	8.000D 01	5.853D-11
3	3	12500.00	12500.00	4.00891D 01	5.305D 00	-4.734D 00	1.231D-04	8.000D 01	5.882D-09
3	4	12500.00	17500.00	4.00890D 01	6.517D 00	-7.179D 00	1.613D-04	8.000D 01	3.247D-07
3	5	12500.00	22500.00	4.00890D 01	8.500D 00	-1.027D 01	1.786D-04	8.000D 01	1.055D-05
3	6	12500.00	27500.00	4.00890D 01	1.187D 01	-1.440D 01	3.299D-04	8.000D 01	2.032D-04
3	7	12500.00	32500.00	4.00889D 01	1.796D 01	-2.010D 01	4.898D-03	8.006D 01	2.290D-03
3	8	12500.00	37500.00	4.00893D 01	2.917D 01	-2.631D 01	-1.505D-02	8.051D 01	1.376D-02
3	9	12500.00	42500.00	4.00890D 01	4.637D 01	-3.491D 01	3.156D-02	8.248D 01	4.512D-02
3	10	12500.00	47500.00	4.00900D 01	8.198D 01	-3.283D 01	-1.434D-01	8.627D 01	5.708D-02
3	11	12500.00	52500.00	4.00919D 01	1.077D 02	-5.275D-12	2.409D-01	9.270D 01	2.820D-02
3	12	12500.00	57500.00	4.00900D 01	8.198D 01	3.283D 01	-1.434D-01	8.627D 01	5.708D-02
3	13	12500.00	62500.00	4.00890D 01	4.637D 01	3.491D 01	3.156D-02	8.248D 01	4.512D-02
3	14	12500.00	67500.00	4.00893D 01	2.917D 01	2.631D 01	-1.505D-02	8.051D 01	1.376D-02

Table A.3 (continued)

ITER.= 913   TIME=1.244500D 02   PERIOD=1.244500D 02   TIME INCREMENT=5.000000D-02

NODE	INDICES	X-LOCATION	Y-LOCATION	WATER ELEVATION	VELOCITY IN X-DIRECT.	VELOCITY IN Y-DIRECT.	WATER ELEV. RATE OF CHANGE	TEMP.	TEMP. RATE OF CHANGE
3	15	12500.00	72500.00	4.00889D 01	1.796D 01	2.010D 01	4.898D-03	8.006D 01	2.290D-03
3	16	12500.00	77500.00	4.00890D 01	1.187D 01	1.440D 01	3.299D-04	8.000D 01	2.032D-04
3	17	12500.00	82500.00	4.00890D 01	8.500D 00	1.027D 01	1.786D-04	8.000D 01	1.055D-05
3	18	12500.00	87500.00	4.00890D 01	6.517D 00	7.179D 00	1.613D-04	8.000D 01	3.247D-07
3	19	12500.00	92500.00	4.00891D 01	5.305D 00	4.734D 00	1.231D-04	8.000D 01	5.882D-09
3	20	12500.00	97500.00	4.00891D 01	4.592D 00	2.692D 00	9.203D-05	8.000D 01	5.853D-11
3	21	12500.00	102500.00	4.00891D 01	4.256D 00	8.443D-01	6.125D-05	8.000D 01	2.503D-13
4	1	17500.00	2500.00	4.00891D 01	6.067D 00	-8.636D-01	1.506D-05	8.000D 01	5.208D-14
4	2	17500.00	7500.00	4.00891D 01	6.553D 00	-2.732D 00	-4.547D-06	8.000D 01	1.263D-11
4	3	17500.00	12500.00	4.00891D 01	7.582D 00	-4.790D 00	-6.318D-05	8.000D 01	1.328D-09
4	4	17500.00	17500.00	4.00891D 01	9.305D 00	-7.221D 00	7.216D-05	8.000D 01	7.756D-08
4	5	17500.00	22500.00	4.00891D 01	1.203D 01	-1.018D 01	-2.666D-04	8.000D 01	2.702D-06
4	6	17500.00	27500.00	4.00891D 01	1.630D 01	-1.381D 01	-2.991D-04	8.000D 01	5.734D-05
4	7	17500.00	32500.00	4.00891D 01	2.308D 01	-1.812D 01	1.415D-04	8.002D 01	7.346D-04
4	8	17500.00	37500.00	4.00893D 01	3.373D 01	-2.201D 01	-1.250D-03	8.016D 01	5.498D-03
4	9	17500.00	42500.00	4.00891D 01	4.813D 01	-2.487D 01	1.787D-02	8.093D 01	2.406D-02
4	10	17500.00	47500.00	4.00899D 01	6.782D 01	-2.010D 01	-3.389D-02	8.312D 01	5.124D-02
4	11	17500.00	52500.00	4.00909D 01	7.958D 01	-4.123D-12	3.583D-02	8.896D 01	6.423D-02
4	12	17500.00	57500.00	4.00899D 01	6.782D 01	2.010D 01	-3.389D-02	8.312D 01	5.124D-02
4	13	17500.00	62500.00	4.00891D 01	4.813D 01	2.487D 01	1.787D-02	8.093D 01	2.406D-02
4	14	17500.00	67500.00	4.00893D 01	3.373D 01	2.201D 01	-1.250D-03	8.016D 01	5.498D-03
4	15	17500.00	72500.00	4.00891D 01	2.308D 01	1.812D 01	1.415D-04	8.002D 01	7.346D-04
4	16	17500.00	77500.00	4.00891D 01	1.630D 01	1.381D 01	-2.991D-04	8.000D 01	5.734D-05
4	17	17500.00	82500.00	4.00891D 01	1.203D 01	1.018D 01	-2.666D-04	8.000D 01	2.702D-06
4	18	17500.00	87500.00	4.00891D 01	9.305D 00	7.221D 00	7.216D-05	8.000D 01	7.756D-08
4	19	17500.00	92500.00	4.00891D 01	7.582D 00	4.790D 00	-6.318D-05	8.000D 01	1.328D-09
4	20	17500.00	97500.00	4.00891D 01	6.553D 00	2.732D 00	-4.547D-06	8.000D 01	1.263D-11
4	21	17500.00	102500.00	4.00891D 01	6.067D 00	8.636D-01	1.506D-05	8.000D 01	5.208D-14
5	1	22500.00	2500.00	4.00891D 01	7.868D 00	-8.389D-01	3.619D-05	8.000D 01	6.688D-15
5	2	22500.00	7500.00	4.00891D 01	8.490D 00	-2.630D 00	9.988D-06	8.000D 01	1.722D-12
5	3	22500.00	12500.00	4.00891D 01	9.788D 00	-4.578D 00	-1.137D-05	8.000D 01	1.942D-10
5	4	22500.00	17500.00	4.00891D 01	1.191D 01	-6.812D 00	2.441D-05	8.000D 01	1.229D-08
5	5	22500.00	22500.00	4.00892D 01	1.510D 01	-9.400D 00	1.100D-04	8.000D 01	4.717D-07
5	6	22500.00	27500.00	4.00892D 01	1.973D 01	-1.230D 01	-1.232D-04	8.000D 01	1.127D-05
5	7	22500.00	32500.00	4.00892D 01	2.631D 01	-1.524D 01	2.324D-04	8.000D 01	1.681D-04
5	8	22500.00	37500.00	4.00893D 01	3.528D 01	-1.725D 01	-2.516D-03	8.004D 01	1.536D-03
5	9	22500.00	42500.00	4.00893D 01	4.598D 01	-1.734D 01	8.625D-03	8.026D 01	8.631D-03
5	10	22500.00	47500.00	4.00897D 01	5.785D 01	-1.240D 01	-1.782D-02	8.110D 01	2.692D-02
5	11	22500.00	52500.00	4.00901D 01	6.415D 01	-2.705D-12	2.285D-02	8.435D 01	6.530D-02
5	12	22500.00	57500.00	4.00897D 01	5.785D 01	1.240D 01	-1.782D-02	8.110D 01	2.692D-02
5	13	22500.00	62500.00	4.00893D 01	4.598D 01	1.734D 01	8.625D-03	8.026D 01	8.631D-03
5	14	22500.00	67500.00	4.00893D 01	3.528D 01	1.725D 01	-2.516D-03	8.004D 01	1.536D-03
5	15	22500.00	72500.00	4.00892D 01	2.631D 01	1.524D 01	2.324D-04	8.000D 01	1.681D-04
5	16	22500.00	77500.00	4.00892D 01	1.973D 01	1.230D 01	-1.232D-04	8.000D 01	1.127D-05
5	17	22500.00	82500.00	4.00892D 01	1.510D 01	9.400D 00	1.100D-04	8.000D 01	4.717D-07
5	18	22500.00	87500.00	4.00891D 01	1.191D 01	6.812D 00	2.441D-05	8.000D 01	1.229D-08
5	19	22500.00	92500.00	4.00891D 01	9.788D 00	4.578D 00	-1.137D-05	8.000D 01	1.942D-10
5	20	22500.00	97500.00	4.00891D 01	8.490D 00	2.630D 00	9.988D-06	8.000D 01	1.722D-12
5	21	22500.00	102500.00	4.00891D 01	7.868D 00	8.389D-01	3.619D-05	8.000D 01	6.688D-15
6	1	27500.00	2500.00	4.00892D 01	9.548D 00	-7.602D-01	2.815D-05	8.000D 01	5.563D-16
6	2	27500.00	7500.00	4.00892D 01	1.027D 01	-2.361D 00	9.276D-06	8.000D 01	1.563D-13
6	3	27500.00	12500.00	4.00892D 01	1.176D 01	-4.074D 00	-1.836D-05	8.000D 01	1.943D-11
6	4	27500.00	17500.00	4.00892D 01	1.413D 01	-5.975D 00	1.036D-05	8.000D 01	1.369D-09
6	5	27500.00	22500.00	4.00892D 01	1.752D 01	-8.058D 00	-1.682D-05	8.000D 01	5.925D-08
6	6	27500.00	27500.00	4.00892D 01	2.214D 01	-1.020D 01	1.486D-04	8.000D 01	1.624D-06
6	7	27500.00	32500.00	4.00892D 01	2.814D 01	-1.206D 01	-8.947D-05	8.000D 01	2.837D-05

Table A.3 (continued)

ITER.= 913 TIME=1.244500D C2 PERIOD=1.244500D C2 TIME INCREMENT=5.000000D-02

NODE	INDI-CES	X-LOCATION	Y-LOCATION	WATER ELEVATION	VELOCITY IN X-DIRECT.	VELOCITY IN Y-DIRECT.	WATER ELEV. RATE OF CHANGE	TEMP.	TEMP. RATE OF CHANGE
6	8	27500.00	37500.00	4.00893D 01	3.547D C1	-1.289D 01	-7.570D-04	8.001D 01	3.143D-04
6	9	27500.00	42500.00	4.00894D 01	4.339D C1	-1.194D 01	2.178D-03	8.005D 01	2.201D-03
6	10	27500.00	47500.00	4.00895D 01	5.083D 01	-7.847D 00	-4.894D-03	8.028D 01	9.275D-03
6	11	27500.00	52500.00	4.00897D 01	5.434D 01	-1.293D-12	6.859D-03	8.142D 01	3.374D-02
6	12	27500.00	57500.00	4.00895D 01	5.083D 01	7.847D 00	-4.894D-03	8.028D 01	9.275D-03
6	13	27500.00	62500.00	4.00894D 01	4.339D 01	1.194D 01	2.178D-03	8.005D 01	2.201D-03
6	14	27500.00	67500.00	4.00893D 01	3.547D 01	1.289D 01	-7.570D-04	8.001D 01	3.143D-04
6	15	27500.00	72500.00	4.00892D 01	2.814D 01	1.206D 01	-8.947D-05	8.000D 01	2.837D-05
6	16	27500.00	77500.00	4.00892D 01	2.214D 01	1.020D 01	1.486D-04	8.000D 01	1.624D-06
6	17	27500.00	82500.00	4.00892D 01	1.752D C1	8.058D 00	-1.682D-05	8.000D 01	5.925D-08
6	18	27500.00	87500.00	4.00892D 01	1.413D 01	5.975D 00	1.036D-05	8.000D 01	1.369D-09
6	19	27500.00	92500.00	4.00892D 01	1.176D C1	4.074D 00	-1.836D-05	8.000D 01	1.943D-11
6	20	27500.00	97500.00	4.00892D 01	1.027D 01	2.361D 00	9.276D-06	8.000D 01	1.563D-13
6	21	27500.00	102500.00	4.00892D 01	9.548D C0	7.602D-01	2.815D-05	8.000D 01	5.563D-16
7	1	32500.00	2500.00	4.00892D 01	1.100D 01	-6.288D-01	2.174D-05	8.000D 01	2.928D-17
7	2	32500.00	7500.00	4.00892D 01	1.179D C1	-1.937D 00	2.146D-06	8.000D 01	9.809D-15
7	3	32500.00	12500.00	4.00892D 01	1.340D C1	-3.318D 00	-2.208D-06	8.000D 01	1.382D-12
7	4	32500.00	17500.00	4.00892D 01	1.589D 01	-4.805D 00	-2.027D-06	8.000D 01	1.114D-10
7	5	32500.00	22500.00	4.00892D 01	1.931D 01	-6.358D 00	6.160D-08	8.000D 01	5.568D-09
7	6	32500.00	27500.00	4.00892D 01	2.372D 01	-7.833D 00	-1.179D-05	8.000D 01	1.778D-07
7	7	32500.00	32500.00	4.00893D 01	2.907D 01	-8.937D 00	1.256D-04	8.000D 01	3.667D-06
7	8	32500.00	37500.00	4.00893D 01	3.508D 01	-9.169D 00	-4.508D-04	8.000D 01	4.876D-05
7	9	32500.00	42500.00	4.00894D 01	4.104D 01	-8.033D 00	1.091D-03	8.001D 01	4.175D-04
7	10	32500.00	47500.00	4.00894D 01	4.601D C1	-4.972D 00	-2.670D-03	8.005D 01	2.240D-03
7	11	32500.00	52500.00	4.00895D 01	4.814D 01	1.442D-13	3.813D-03	8.033D 01	1.084D-02
7	12	32500.00	57500.00	4.00894D 01	4.601D 01	4.972D 00	-2.670D-03	8.005D 01	2.240D-03
7	13	32500.00	62500.00	4.00894D 01	4.104D 01	8.033D 00	1.091D-03	8.001D 01	4.175D-04
7	14	32500.00	67500.00	4.00893D 01	3.508D 01	9.169D 00	-4.508D-04	8.000D 01	4.876D-05
7	15	32500.00	72500.00	4.00893D 01	2.907D 01	8.937D 00	1.256D-04	8.000D 01	3.667D-06
7	16	32500.00	77500.00	4.00892D 01	2.372D C1	7.833D 00	-1.179D-05	8.000D 01	1.778D-07
7	17	32500.00	82500.00	4.00892D 01	1.931D 01	6.358D 00	6.160D-08	8.000D 01	5.568D-09
7	18	32500.00	87500.00	4.00892D 01	1.589D C1	4.805D 00	-2.027D-06	8.000D 01	1.114D-10
7	19	32500.00	92500.00	4.00892D 01	1.340D C1	3.318D 00	-2.208D-06	8.000D 01	1.382D-12
7	20	32500.00	97500.00	4.00892D 01	1.179D C1	1.937D 00	2.146D-06	8.000D 01	9.809D-15
7	21	32500.00	102500.00	4.00892D 01	1.100D 01	6.288D-01	2.174D-05	8.000D 01	2.928D-17
8	1	37500.00	2500.00	4.00892D 01	1.212D C1	-4.539D-01	1.455D-05	8.000D 01	6.617D-19
8	2	37500.00	7500.00	4.00892D 01	1.295D 01	-1.392D 00	1.696D-06	8.000D 01	4.289D-16
8	3	37500.00	12500.00	4.00892D 01	1.463D 01	-2.374D 00	-4.722D-06	8.000D 01	7.102D-14
8	4	37500.00	17500.00	4.00892D 01	1.717D 01	-3.412D 00	8.618D-06	8.000D 01	6.745D-12
8	5	37500.00	22500.00	4.00892D 01	2.055D C1	-4.461D 00	-1.235D-05	8.000D 01	3.993D-10
8	6	37500.00	27500.00	4.00893D 01	2.471D 01	-5.401D 00	1.016D-06	8.000D 01	1.516D-08
8	7	37500.00	32500.00	4.00893D 01	2.949D C1	-6.022D 00	-7.188D-06	8.000D 01	3.732D-07
8	8	37500.00	37500.00	4.00893D 01	3.455D 01	-6.013D 00	-4.426D-05	8.000D 01	5.958D-06
8	9	37500.00	42500.00	4.00893D 01	3.925D C1	-5.089D 00	2.584D-04	8.000D 01	6.153D-05
8	10	37500.00	47500.00	4.00894D 01	4.283D C1	-3.037D 00	-7.888D-04	8.001D 01	4.057D-04
8	11	37500.00	52500.00	4.00894D 01	4.425D C1	1.061D-12	1.166D-03	8.006D 01	2.445D-03
8	12	37500.00	57500.00	4.00894D 01	4.283D 01	3.037D 00	-7.888D-04	8.001D 01	4.057D-04
8	13	37500.00	62500.00	4.00893D 01	3.925D C1	5.089D 00	2.584D-04	8.000D 01	6.153D-05
8	14	37500.00	67500.00	4.00893D 01	3.455D C1	6.013D 00	-4.426D-05	8.000D 01	5.958D-06
8	15	37500.00	72500.00	4.00893D 01	2.949D C1	6.022D 00	-7.188D-06	8.000D 01	3.732D-07
8	16	37500.00	77500.00	4.00893D 01	2.471D 01	5.401D 00	1.016D-06	8.000D 01	1.516D-08
8	17	37500.00	82500.00	4.00892D 01	2.055D 01	4.461D 00	-1.235D-05	8.000D 01	3.993D-10
8	18	37500.00	87500.00	4.00892D 01	1.717D 01	3.412D 00	8.618D-06	8.000D 01	6.745D-12
8	19	37500.00	92500.00	4.00892D 01	1.463D 01	2.374D 00	-4.722D-06	8.000D 01	7.102D-14
8	20	37500.00	97500.00	4.00892D 01	1.295D 01	1.392D 00	1.696D-06	8.000D 01	4.289D-16
8	21	37500.00	102500.00	4.00892D 01	1.212D C1	4.539D-01	1.455D-05	8.000D 01	6.617D-19

Table A.3 (continued)

ITER.= 913 TIME=1.244500D 02 PERIOD=1.244500D 02 TIME INCREMENT=5.000000D-02

NODE	INDI-CES	X-LOCATION	Y-LOCATION	WATER ELEVATION	VELOCITY IN X-DIRECT.	VELOCITY IN Y-DIRECT.	WATER ELEV. RATE OF CHANGE	TEMP.	TEMP. RATE OF CHANGE
9	1	42500.00	2500.00	4.00893D 01	1.284D 01	-2.480D-01	8.292D-06	8.000D 01	0.0
9	2	42500.00	7500.00	4.00893D 01	1.370D 01	-7.645D-01	1.988D-06	8.000D 01	1.384D-17
9	3	42500.00	12500.00	4.00893D 01	1.542D 01	-1.309D 00	-3.046D-06	8.000D 01	2.618D-15
9	4	42500.00	17500.00	4.00893D 01	1.797D 01	-1.888D 00	1.554D-06	8.000D 01	3.028D-13
9	5	42500.00	22500.00	4.00893D 01	2.130D 01	-2.473D 00	2.803D-06	8.000D 01	2.193D-11
9	6	42500.00	27500.00	4.00893D 01	2.528D 01	-2.985D 00	-8.888D-06	8.000D 01	1.018D-09
9	7	42500.00	32500.00	4.00893D 01	2.968D 01	-3.313D 00	8.364D-06	8.000D 01	3.053D-08
9	8	42500.00	37500.00	4.00893D 01	3.413D 01	-3.276D 00	-6.304D-05	8.000D 01	5.903D-07
9	9	42500.00	42500.00	4.00893D 01	3.809D 01	-2.733D 00	1.737D-04	8.000D 01	7.344D-06
9	10	42500.00	47500.00	4.00893D 01	4.093D 01	-1.603D 00	-3.889D-04	8.000D 01	5.827D-05
9	11	42500.00	52500.00	4.00893D 01	4.200D 01	9.806D-13	5.464D-04	8.001D 01	4.222D-04
9	12	42500.00	57500.00	4.00893D 01	4.093D 01	1.603D 00	-3.889D-04	8.000D 01	5.827D-05
9	13	42500.00	62500.00	4.00893D 01	3.809D 01	2.733D 00	1.737D-04	8.000D 01	7.344D-06
9	14	42500.00	67500.00	4.00893D 01	3.413D 01	3.276D 00	-6.304D-05	8.000D 01	5.903D-07
9	15	42500.00	72500.00	4.00893D 01	2.968D 01	3.313D 00	8.364D-06	8.000D 01	3.053D-08
9	16	42500.00	77500.00	4.00893D 01	2.528D 01	2.985D 00	-8.888D-06	8.000D 01	1.018D-09
9	17	42500.00	82500.00	4.00893D 01	2.130D 01	2.473D 00	2.803D-06	8.000D 01	2.193D-11
9	18	42500.00	87500.00	4.00893D 01	1.797D 01	1.888D 00	1.554D-06	8.000D 01	3.028D-13
9	19	42500.00	92500.00	4.00893D 01	1.542D 01	1.309D 00	-3.046D-06	8.000D 01	2.618D-15
9	20	42500.00	97500.00	4.00893D 01	1.370D 01	7.645D-01	1.988D-06	8.000D 01	1.384D-17
9	21	42500.00	102500.00	4.00893D 01	1.284D 01	2.480D-01	8.292D-06	8.000D 01	0.0
10	1	47500.00	2500.00	4.00893D 01	1.313D 01	-2.414D-02	2.564D-06	8.000D 01	0.0
10	2	47500.00	7500.00	4.00893D 01	1.401D 01	-9.075D-02	4.428D-06	8.000D 01	0.0
10	3	47500.00	12500.00	4.00893D 01	1.576D 01	-1.780D-01	-4.889D-06	8.000D 01	6.972D-17
10	4	47500.00	17500.00	4.00893D 01	1.833D 01	-2.988D-01	2.608D-06	8.000D 01	9.863D-15
10	5	47500.00	22500.00	4.00893D 01	2.165D 01	-4.512D-01	-1.247D-06	8.000D 01	9.070D-13
10	6	47500.00	27500.00	4.00893D 01	2.555D 01	-6.145D-01	3.686D-06	8.000D 01	5.356D-11
10	7	47500.00	32500.00	4.00893D 01	2.978D 01	-7.486D-01	-5.174D-06	8.000D 01	2.021D-09
10	8	47500.00	37500.00	4.00893D 01	3.396D 01	-7.946D-01	-1.204D-05	8.000D 01	4.848D-08
10	9	47500.00	42500.00	4.00893D 01	3.758D 01	-6.975D-01	3.752D-05	8.000D 01	7.344D-07
10	10	47500.00	47500.00	4.00893D 01	4.010D 01	-4.230D-01	-8.848D-05	8.000D 01	6.965D-06
10	11	47500.00	52500.00	4.00893D 01	4.102D 01	-2.853D-14	1.285D-04	8.000D 01	5.944D-05
10	12	47500.00	57500.00	4.00893D 01	4.010D 01	4.230D-01	-8.848D-05	8.000D 01	6.965D-06
10	13	47500.00	62500.00	4.00893D 01	3.758D 01	6.975D-01	3.752D-05	8.000D 01	7.344D-07
10	14	47500.00	67500.00	4.00893D 01	3.396D 01	7.946D-01	-1.204D-05	8.000D 01	4.848D-08
10	15	47500.00	72500.00	4.00893D 01	2.978D 01	7.486D-01	-5.174D-06	8.000D 01	2.021D-09
10	16	47500.00	77500.00	4.00893D 01	2.555D 01	6.145D-01	3.686D-06	8.000D 01	5.356D-11
10	17	47500.00	82500.00	4.00893D 01	2.165D 01	4.512D-01	-1.247D-06	8.000D 01	9.070D-13
10	18	47500.00	87500.00	4.00893D 01	1.833D 01	2.988D-01	2.608D-06	8.000D 01	9.863D-15
10	19	47500.00	92500.00	4.00893D 01	1.576D 01	1.780D-01	-4.889D-06	8.000D 01	6.972D-17
10	20	47500.00	97500.00	4.00893D 01	1.401D 01	9.075D-02	4.428D-06	8.000D 01	0.0
10	21	47500.00	102500.00	4.00893D 01	1.313D 01	2.414D-02	2.564D-06	8.000D 01	0.0
11	1	52500.00	2500.00	4.00893D 01	1.296D 01	2.046D-01	-2.925D-06	8.000D 01	0.0
11	2	52500.00	7500.00	4.00893D 01	1.386D 01	5.953D-01	6.657D-06	8.000D 01	0.0
11	3	52500.00	12500.00	4.00893D 01	1.563D 01	9.700D-01	-5.929D-06	8.000D 01	0.0
11	4	52500.00	17500.00	4.00893D 01	1.825D 01	1.306D 00	2.186D-06	8.000D 01	2.847D-16
11	5	52500.00	22500.00	4.00893D 01	2.162D 01	1.574D 00	1.237D-06	8.000D 01	3.303D-14
11	6	52500.00	27500.00	4.00893D 01	2.558D 01	1.739D 00	1.068D-06	8.000D 01	2.476D-12
11	7	52500.00	32500.00	4.00893D 01	2.987D 01	1.758D 00	3.448D-06	8.000D 01	1.178D-10
11	8	52500.00	37500.00	4.00893D 01	3.408D 01	1.591D 00	-1.668D-06	8.000D 01	3.507D-09
11	9	52500.00	42500.00	4.00892D 01	3.772D 01	1.222D 00	1.399D-06	8.000D 01	6.458D-08
11	10	52500.00	47500.00	4.00892D 01	4.024D 01	6.681D-01	-6.050D-07	8.000D 01	7.256D-07
11	11	52500.00	52500.00	4.00892D 01	4.115D 01	-1.159D-13	-8.403D-06	8.000D 01	7.176D-06
11	12	52500.00	57500.00	4.00892D 01	4.024D 01	-6.681D-01	-6.050D-07	8.000D 01	7.256D-07
11	13	52500.00	62500.00	4.00892D 01	3.772D 01	-1.222D 00	1.399D-06	8.000D 01	6.458D-08
11	14	52500.00	67500.00	4.00893D 01	3.408D 01	-1.591D 00	-1.668D-06	8.000D 01	3.507D-09

Table A.3 (continued)

ITER.= 913   TIME=1.244500D 02   PERIOD=1.244500D 02   TIME INCREMENT=5.000000D-02

NODE	INDI-CES	X-LOCATION	Y-LOCATION	WATER ELEVATION	VELOCITY IN X-DIRECT.	VELOCITY IN Y-DIRECT.	WATER ELEV. RATE OF CHANGE	TEMP.	TEMP. RATE OF CHANGE
11	15	52500.00	72500.00	4.00893D 01	2.987D 01	-1.758D 00	3.448D-06	8.000D 01	1.178D-10
11	16	52500.00	77500.00	4.00893D 01	2.558D 01	-1.739D 00	1.068D-06	8.000D 01	2.476D-12
11	17	52500.00	82500.00	4.00893D 01	2.162D 01	-1.574D 00	1.237D-06	8.000D 01	3.303D-14
11	18	52500.00	87500.00	4.00893D 01	1.825D 01	-1.306D 00	2.186D-06	8.000D 01	2.847D-16
11	19	52500.00	92500.00	4.00893D 01	1.563D 01	-9.700D-01	-5.929D-06	8.000D 01	0.0
11	20	52500.00	97500.00	4.00893D 01	1.386D 01	-5.953D-01	6.657D-06	8.000D 01	0.0
11	21	52500.00	102500.00	4.00893D 01	1.296D 01	-2.046D-01	-2.925D-06	8.000D 01	0.0
12	1	57500.00	2500.00	4.00893D 01	1.233D 01	4.249D-01	-9.431D-06	8.000D 01	0.0
12	2	57500.00	7500.00	4.00893D 01	1.324D 01	1.259D 00	8.815D-06	8.000D 01	0.0
12	3	57500.00	12500.00	4.00893D 01	1.505D 01	2.087D 00	-6.889D-06	8.000D 01	0.0
12	4	57500.00	17500.00	4.00893D 01	1.773D 01	2.880D 00	2.800D-06	8.000D 01	9.942D-22
12	5	57500.00	22500.00	4.00893D 01	2.121D 01	3.581D 00	2.292D-06	8.000D 01	1.104D-15
12	6	57500.00	27500.00	4.00893D 01	2.537D 01	4.096D 00	1.886D-06	8.000D 01	1.055D-13
12	7	57500.00	32500.00	4.00893D 01	2.993D 01	4.295D 00	1.940D-06	8.000D 01	6.322D-12
12	8	57500.00	37500.00	4.00892D 01	3.450D 01	4.032D 00	2.296D-05	8.000D 01	2.331D-10
12	9	57500.00	42500.00	4.00892D 01	3.850D 01	3.203D 00	-4.847D-05	8.000D 01	5.193D-09
12	10	57500.00	47500.00	4.00892D 01	4.132D 01	1.801D 00	1.276D-04	8.000D 01	6.864D-08
12	11	57500.00	52500.00	4.00892D 01	4.236D 01	1.063D-12	-2.060D-04	8.000D 01	7.759D-07
12	12	57500.00	57500.00	4.00892D 01	4.132D 01	-1.801D 00	1.276D-04	8.000D 01	6.864D-08
12	13	57500.00	62500.00	4.00892D 01	3.850D 01	-3.203D 00	-4.847D-05	8.000D 01	5.193D-09
12	14	57500.00	67500.00	4.00892D 01	3.450D 01	-4.032D 00	2.296D-05	8.000D 01	2.331D-10
12	15	57500.00	72500.00	4.00893D 01	2.993D 01	-4.295D 00	1.940D-06	8.000D 01	6.322D-12
12	16	57500.00	77500.00	4.00893D 01	2.537D 01	-4.096D 00	1.886D-06	8.000D 01	1.055D-13
12	17	57500.00	82500.00	4.00893D 01	2.121D 01	-3.581D 00	2.292D-06	8.000D 01	1.104D-15
12	18	57500.00	87500.00	4.00893D 01	1.773D 01	-2.880D 00	2.800D-06	8.000D 01	9.942D-22
12	19	57500.00	92500.00	4.00893D 01	1.505D 01	-2.087D 00	-6.889D-06	8.000D 01	0.0
12	20	57500.00	97500.00	4.00893D 01	1.324D 01	-1.259D 00	8.815D-06	8.000D 01	0.0
12	21	57500.00	102500.00	4.00893D 01	1.233D 01	-4.249D-01	-9.431D-06	8.000D 01	0.0
13	1	62500.00	2500.00	4.00894D 01	1.128D 01	6.214D-01	-1.801D-05	8.000D 01	0.0
13	2	62500.00	7500.00	4.00894D 01	1.219D 01	1.662D 00	1.019D-05	8.000D 01	0.0
13	3	62500.00	12500.00	4.00893D 01	1.401D 01	3.117D 00	-5.979D-06	8.000D 01	0.0
13	4	62500.00	17500.00	4.00893D 01	1.675D 01	4.365D 00	1.963D-06	8.000D 01	0.0
13	5	62500.00	22500.00	4.00893D 01	2.040D 01	5.529D 00	1.040D-06	8.000D 01	2.946D-17
13	6	62500.00	27500.00	4.00893D 01	2.487D 01	6.462D 00	3.902D-06	8.000D 01	4.119D-15
13	7	62500.00	32500.00	4.00893D 01	2.993D 01	6.939D 00	2.711D-06	8.000D 01	3.142D-13
13	8	62500.00	37500.00	4.00892D 01	3.517D 01	6.673D 00	6.699D-05	8.000D 01	1.446D-11
13	9	62500.00	42500.00	4.00892D 01	3.995D 01	5.428D 00	-1.406D-04	8.000D 01	3.919D-10
13	10	62500.00	47500.00	4.00891D 01	4.344D 01	3.116D 00	3.866D-04	8.000D 01	6.095D-09
13	11	62500.00	52500.00	4.00891D 01	4.476D 01	2.352D-12	-6.061D-04	8.000D 01	7.824D-08
13	12	62500.00	57500.00	4.00891D 01	4.344D 01	-3.116D 00	3.866D-04	8.000D 01	6.095D-09
13	13	62500.00	62500.00	4.00892D 01	3.995D 01	-5.428D 00	-1.406D-04	8.000D 01	3.919D-10
13	14	62500.00	67500.00	4.00892D 01	3.517D 01	-6.673D 00	6.699D-05	8.000D 01	1.446D-11
13	15	62500.00	72500.00	4.00893D 01	2.993D 01	-6.939D 00	2.711D-06	8.000D 01	3.142D-13
13	16	62500.00	77500.00	4.00893D 01	2.487D 01	-6.462D 00	3.902D-06	8.000D 01	4.119D-15
13	17	62500.00	82500.00	4.00893D 01	2.040D 01	-5.529D 00	1.040D-06	8.000D 01	2.946D-17
13	18	62500.00	87500.00	4.00893D 01	1.675D 01	-4.365D 00	1.963D-06	8.000D 01	0.0
13	19	62500.00	92500.00	4.00893D 01	1.401D 01	-3.117D 00	-5.979D-06	8.000D 01	0.0
13	20	62500.00	97500.00	4.00894D 01	1.219D 01	-1.862D 00	1.019D-05	8.000D 01	0.0
13	21	62500.00	102500.00	4.00894D 01	1.128D 01	-6.214D-01	-1.801D-05	8.000D 01	0.0
14	1	67500.00	2500.00	4.00894D 01	9.857D 00	7.766D-01	-2.865D-05	8.000D 01	0.0
14	2	67500.00	7500.00	4.00894D 01	1.074D 01	2.354D 00	1.000D-05	8.000D 01	0.0
14	3	67500.00	12500.00	4.00894D 01	1.254D 01	3.984D 00	-2.131D-06	8.000D 01	0.0
14	4	67500.00	17500.00	4.00894D 01	1.531D 01	5.671D 00	-4.533D-06	8.000D 01	0.0
14	5	67500.00	22500.00	4.00893D 01	1.912D 01	7.339D 00	4.514D-06	8.000D 01	0.0
14	6	67500.00	27500.00	4.00893D 01	2.396D 01	8.802D 00	1.142D-05	8.000D 01	1.557D-16
14	7	67500.00	32500.00	4.00893D 01	2.972D 01	9.733D 00	2.157D-05	8.000D 01	1.450D-14

Table A.3 (continued)

ITER.= 913   TIME=1.244500D 02   PERIOD=1.244500D 02   TIME INCREMENT=5.000000D-02

NODE	INDICES	X-LOCATION	Y-LOCATION	WATER ELEVATION	VELOCITY IN X-DIRECT.	VELOCITY IN Y-DIRECT.	WATER ELEV. RATE OF CHANGE	TEMP.	TEMP. RATE OF CHANGE
14	8	67500.00	37500.00	4.00892D 01	3.601D 01	9.656D 00	1.337D-04	8.000D 01	8.473D-13
14	9	67500.00	42500.00	4.00891D 01	4.205D 01	8.113D 00	-4.152D-04	8.000D 01	2.837D-11
14	10	67500.00	47500.00	4.00891D 01	4.675D 01	4.795D 00	9.333D-04	8.000D 01	5.242D-10
14	11	67500.00	52500.00	4.00890D 01	4.862D 01	1.902D-12	-1.549D-03	8.000D 01	7.644D-09
14	12	67500.00	57500.00	4.00891D 01	4.675D 01	-4.795D 00	9.333D-04	8.000D 01	5.242D-10
14	13	67500.00	62500.00	4.00891D 01	4.205D 01	-8.113D 00	-4.152D-04	8.000D 01	2.837D-11
14	14	67500.00	67500.00	4.00892D 01	3.601D 01	-9.656D 00	1.337D-04	8.000D 01	8.473D-13
14	15	67500.00	72500.00	4.00893D 01	2.972D 01	-9.733D 00	2.157D-05	8.000D 01	1.450D-14
14	16	67500.00	77500.00	4.00893D 01	2.396D 01	-8.802D 00	1.142D-05	8.000D 01	1.557D-16
14	17	67500.00	82500.00	4.00893D 01	1.912D 01	-7.339D 00	4.514D-06	8.000D 01	0.0
14	18	67500.00	87500.00	4.00894D 01	1.531D 01	-5.671D 00	-4.533D-06	8.000D 01	0.0
14	19	67500.00	92500.00	4.00894D 01	1.254D 01	-3.984D 00	-2.131D-06	8.000D 01	0.0
14	20	67500.00	97500.00	4.00894D 01	1.074D 01	-2.354D 00	1.000D-05	8.000D 01	0.0
14	21	67500.00	102500.00	4.00894D 01	9.857D 00	-7.766D-01	-2.865D-05	8.000D 01	0.0
15	1	72500.00	2500.00	4.00894D 01	8.154D 00	8.711D-01	-3.996D-05	8.000D 01	0.0
15	2	72500.00	7500.00	4.00894D 01	8.984D 00	2.677D 00	7.222D-06	8.000D 01	0.0
15	3	72500.00	12500.00	4.00894D 01	1.069D 01	4.592D 00	2.141D-07	8.000D 01	0.0
15	4	72500.00	17500.00	4.00894D 01	1.340D 01	6.668D 00	-6.838D-06	8.000D 01	0.0
15	5	72500.00	22500.00	4.00894D 01	1.727D 01	8.865D 00	8.408D-06	8.000D 01	0.0
15	6	72500.00	27500.00	4.00893D 01	2.247D 01	1.100D 01	1.785D-05	8.000D 01	7.158D-22
15	7	72500.00	32500.00	4.00893D 01	2.906D 01	1.265D 01	-6.030D-05	8.000D 01	6.093D-16
15	8	72500.00	37500.00	4.00892D 01	3.681D 01	1.310D 01	3.075D-04	8.000D 01	4.721D-14
15	9	72500.00	42500.00	4.00891D 01	4.478D 01	1.154D 01	-1.192D-03	8.000D 01	2.008D-12
15	10	72500.00	47500.00	4.00890D 01	5.154D 01	7.131D 00	2.787D-03	8.000D 01	4.495D-11
15	11	72500.00	52500.00	4.00889D 01	5.442D 01	1.303D-12	-3.401D-03	8.000D 01	7.521D-10
15	12	72500.00	57500.00	4.00890D 01	5.154D 01	-7.131D 00	2.787D-03	8.000D 01	4.495D-11
15	13	72500.00	62500.00	4.00891D 01	4.478D 01	-1.154D 01	-1.192D-03	8.000D 01	2.008D-12
15	14	72500.00	67500.00	4.00892D 01	3.681D 01	-1.310D 01	3.075D-04	8.000D 01	4.721D-14
15	15	72500.00	72500.00	4.00893D 01	2.906D 01	-1.265D 01	-6.030D-05	8.000D 01	6.093D-16
15	16	72500.00	77500.00	4.00893D 01	2.247D 01	-1.100D 01	1.785D-05	8.000D 01	7.158D-22
15	17	72500.00	82500.00	4.00894D 01	1.727D 01	-8.865D 00	8.408D-06	8.000D 01	0.0
15	18	72500.00	87500.00	4.00894D 01	1.340D 01	-6.668D 00	-6.838D-06	8.000D 01	0.0
15	19	72500.00	92500.00	4.00894D 01	1.069D 01	-4.592D 00	2.141D-07	8.000D 01	0.0
15	20	72500.00	97500.00	4.00894D 01	8.984D 00	-2.677D 00	7.222D-06	8.000D 01	0.0
15	21	72500.00	102500.00	4.00894D 01	8.154D 00	-8.711D-01	-3.996D-05	8.000D 01	0.0
16	1	77500.00	2500.00	4.00895D 01	6.307D 00	8.875D-01	-4.787D-05	8.000D 01	0.0
16	2	77500.00	7500.00	4.00895D 01	7.032D 00	2.774D 00	-2.540D-06	8.000D 01	0.0
16	3	77500.00	12500.00	4.00895D 01	8.552D 00	4.832D 00	1.127D-05	8.000D 01	0.0
16	4	77500.00	17500.00	4.00894D 01	1.104D 01	7.188D 00	-7.448D-06	8.000D 01	0.0
16	5	77500.00	22500.00	4.00894D 01	1.479D 01	9.880D 00	3.075D-05	8.000D 01	0.0
16	6	77500.00	27500.00	4.00894D 01	2.018D 01	1.280D 01	-7.887D-05	8.000D 01	0.0
16	7	77500.00	32500.00	4.00893D 01	2.760D 01	1.552D 01	-1.728D-04	8.000D 01	2.002D-17
16	8	77500.00	37500.00	4.00892D 01	3.715D 01	1.704D 01	8.208D-04	8.000D 01	2.476D-15
16	9	77500.00	42500.00	4.00891D 01	4.794D 01	1.606D 01	-2.230D-03	8.000D 01	1.409D-13
16	10	77500.00	47500.00	4.00888D 01	5.823D 01	1.059D 01	7.467D-03	8.000D 01	3.941D-12
16	11	77500.00	52500.00	4.00886D 01	6.304D 01	1.619D-12	-1.047D-02	8.000D 01	7.762D-11
16	12	77500.00	57500.00	4.00888D 01	5.823D 01	-1.059D 01	7.467D-03	8.000D 01	3.941D-12
16	13	77500.00	62500.00	4.00891D 01	4.794D 01	-1.606D 01	-2.230D-03	8.000D 01	1.409D-13
16	14	77500.00	67500.00	4.00892D 01	3.715D 01	-1.704D 01	8.208D-04	8.000D 01	2.476D-15
16	15	77500.00	72500.00	4.00893D 01	2.760D 01	-1.552D 01	-1.728D-04	8.000D 01	2.002D-17
16	16	77500.00	77500.00	4.00894D 01	2.018D 01	-1.280D 01	-7.887D-05	8.000D 01	0.0
16	17	77500.00	82500.00	4.00894D 01	1.479D 01	-9.880D 00	3.075D-05	8.000D 01	0.0
16	18	77500.00	87500.00	4.00894D 01	1.104D 01	-7.188D 00	-7.448D-06	8.000D 01	0.0
16	19	77500.00	92500.00	4.00895D 01	8.552D 00	-4.832D 00	1.127D-05	8.000D 01	0.0
16	20	77500.00	97500.00	4.00895D 01	7.032D 00	-2.774D 00	-2.540D-06	8.000D 01	0.0
16	21	77500.00	102500.00	4.00895D 01	6.307D 00	-8.875D-01	-4.787D-05	8.000D 01	0.0

Table A.3 (continued)

ITER.= 913   TIME=1.244500D C2   PERIOD=1.244500D 02   TIME INCREMENT=5.000000D-02

NODE	INDI-CES	X-LOCATION	Y-LOCATION	WATER ELEVATION	VELOCITY IN X-DIRECT.	VELOCITY IN Y-DIRECT.	WATER ELEV. RATE OF CHANGE	TEMP.	TEMP. RATE OF CHANGE
17	1	82500.00	2500.00	4.00895D 01	4.486D 00	8.174D-01	-5.506D-05	8.000D 01	0.0
17	2	82500.00	7500.00	4.00895D 01	5.058D 00	2.605D 00	-1.742D-05	8.000D 01	0.0
17	3	82500.00	12500.00	4.00895D 01	6.279D 00	4.617D 00	1.002D-05	8.000D 01	0.0
17	4	82500.00	17500.00	4.00895D 01	8.353D 00	7.056D 00	-4.250D-05	8.000D 01	0.0
17	5	82500.00	22500.00	4.00895D 01	1.167D 01	1.009D 01	-1.140D-04	8.000D 01	0.0
17	6	82500.00	27500.00	4.00895D 01	1.685D 01	1.377D 01	-1.393D-04	8.000D 01	0.0
17	7	82500.00	32500.00	4.00894D 01	2.477D 01	1.789D 01	-3.428D-04	8.000D 01	0.0
17	8	82500.00	37500.00	4.00892D 01	3.631D 01	2.122D 01	2.869D-03	8.000D 01	1.297D-16
17	9	82500.00	42500.00	4.00891D 01	5.096D 01	2.212D 01	-6.105D-03	8.000D 01	9.793D-15
17	10	82500.00	47500.00	4.00886D 01	6.746D 01	1.607D 01	1.863D-02	8.000D 01	3.607D-13
17	11	82500.00	52500.00	4.00881D 01	7.607D 01	1.714D-13	-2.714D-02	8.000D 01	8.836D-12
17	12	82500.00	57500.00	4.00886D 01	6.746D 01	-1.607D 01	1.863D-02	8.000D 01	3.607D-13
17	13	82500.00	62500.00	4.00891D 01	5.096D 01	-2.212D 01	-6.105D-03	8.000D 01	9.793D-15
17	14	82500.00	67500.00	4.00892D 01	3.631D 01	-2.122D 01	2.869D-03	8.000D 01	1.297D-16
17	15	82500.00	72500.00	4.00894D 01	2.477D 01	-1.789D 01	-3.428D-04	8.000D 01	0.0
17	16	82500.00	77500.00	4.00895D 01	1.685D 01	-1.377D 01	-1.393D-04	8.000D 01	0.0
17	17	82500.00	82500.00	4.00895D 01	1.167D 01	-1.009D 01	-1.140D-04	8.000D 01	0.0
17	18	82500.00	87500.00	4.00895D 01	8.353D 00	-7.056D 00	-4.250D-05	8.000D 01	0.0
17	19	82500.00	92500.00	4.00895D 01	6.279D 00	-4.617D 00	1.002D-05	8.000D 01	0.0
17	20	82500.00	97500.00	4.00895D 01	5.058D 00	-2.605D 00	-1.742D-05	8.000D 01	0.0
17	21	82500.00	102500.00	4.00895D 01	4.486D 00	-8.174D-01	-5.506D-05	8.000D 01	0.0
18	1	87500.00	2500.00	4.00896D 01	2.868D 00	6.700D-01	-3.148D-06	8.000D 01	0.0
18	2	87500.00	7500.00	4.00896D 01	3.258D 00	2.184D 00	2.182D-05	8.000D 01	0.0
18	3	87500.00	12500.00	4.00896D 01	4.098D 00	3.934D 00	1.107D-04	8.000D 01	0.0
18	4	87500.00	17500.00	4.00896D 01	5.570D 00	6.176D 00	1.853D-05	8.000D 01	0.0
18	5	87500.00	22500.00	4.00896D 01	8.066D 00	9.197D 00	2.217D-04	8.000D 01	0.0
18	6	87500.00	27500.00	4.00896D 01	1.237D 01	1.333D 01	6.274D-04	8.000D 01	0.0
18	7	87500.00	32500.00	4.00895D 01	1.996D 01	1.886D 01	9.856D-04	8.000D 01	0.0
18	8	87500.00	37500.00	4.00893D 01	3.322D 01	2.478D 01	4.705D-03	8.000D 01	1.285D-21
18	9	87500.00	42500.00	4.00894D 01	5.316D 01	2.999D 01	-2.732D-02	8.000D 01	6.760D-16
18	10	87500.00	47500.00	4.00886D 01	8.120D 01	2.500D 01	2.328D-02	8.000D 01	3.490D-14
18	11	87500.00	52500.00	4.00875D 01	9.770D 01	-9.605D-13	-8.414D-02	8.000D 01	1.169D-12
18	12	87500.00	57500.00	4.00886D 01	8.120D 01	-2.500D 01	2.328D-02	8.000D 01	3.490D-14
18	13	87500.00	62500.00	4.00894D 01	5.316D 01	-2.999D 01	-2.732D-02	8.000D 01	6.760D-16
18	14	87500.00	67500.00	4.00893D 01	3.322D 01	-2.478D 01	4.705D-03	8.000D 01	1.285D-21
18	15	87500.00	72500.00	4.00895D 01	1.996D 01	-1.886D 01	9.856D-04	8.000D 01	0.0
18	16	87500.00	77500.00	4.00896D 01	1.237D 01	-1.333D 01	6.274D-04	8.000D 01	0.0
18	17	87500.00	82500.00	4.00896D 01	8.066D 00	-9.197D 00	2.217D-04	8.000D 01	0.0
18	18	87500.00	87500.00	4.00896D 01	5.570D 00	-6.176D 00	1.853D-05	8.000D 01	0.0
18	19	87500.00	92500.00	4.00896D 01	4.098D 00	-3.934D 00	1.107D-04	8.000D 01	0.0
18	20	87500.00	97500.00	4.00896D 01	3.258D 00	-2.184D 00	2.182D-05	8.000D 01	0.0
18	21	87500.00	102500.00	4.00896D 01	2.868D 00	-6.700D-01	-3.148D-06	8.000D 01	0.0
19	1	92500.00	2500.00	4.00896D 01	1.612D 00	4.776D-01	-1.018D-04	8.000D 01	0.0
19	2	92500.00	7500.00	4.00896D 01	1.831D 00	1.601D 00	-1.677D-04	8.000D 01	0.0
19	3	92500.00	12500.00	4.00896D 01	2.296D 00	2.913D 00	-2.158D-04	8.000D 01	0.0
19	4	92500.00	17500.00	4.00897D 01	3.110D 00	4.650D 00	-4.684D-04	8.000D 01	0.0
19	5	92500.00	22500.00	4.00897D 01	4.532D 00	7.137D 00	-7.272D-04	8.000D 01	0.0
19	6	92500.00	27500.00	4.00897D 01	7.258D 00	1.098D 01	-1.190D-03	8.000D 01	0.0
19	7	92500.00	32500.00	4.00898D 01	1.308D 01	1.732D 01	-5.297D-03	8.000D 01	0.0
19	8	92500.00	37500.00	4.00895D 01	2.604D 01	2.609D 01	1.054D-02	8.000D 01	0.0
19	9	92500.00	42500.00	4.00897D 01	4.913D 01	3.994D 01	-3.684D-02	8.000D 01	3.713D-17
19	10	92500.00	47500.00	4.00870D 01	9.430D 01	4.011D 01	2.101D-01	8.000D 01	3.626D-15
19	11	92500.00	52500.00	4.00838D 01	1.253D 02	-4.357D-13	-5.561D-02	8.000D 01	1.948D-13
19	12	92500.00	57500.00	4.00870D 01	9.430D 01	-4.011D 01	2.101D-01	8.000D 01	3.626D-15
19	13	92500.00	62500.00	4.00897D 01	4.913D 01	-3.994D 01	-3.684D-02	8.000D 01	3.713D-17
19	14	92500.00	67500.00	4.00895D 01	2.604D 01	-2.609D 01	1.054D-02	8.000D 01	0.0

Table A.3 (continued)

ITER.= 913   TIME=1.244500D 02   PERIOD=1.244500D 02   TIME INCREMENT=5.000000D-02

NODE	INDI-CES	X-LOCATION	Y-LOCATION	WATER ELEVATION	VELOCITY IN X-DIRECT.	VELOCITY IN Y-DIRECT.	WATER ELEV. RATE OF CHANGE	TEMP.	TEMP. RATE OF CHANGE
19	15	92500.00	72500.00	4.00898D 01	1.308D 01	-1.732D 01	-5.297D-03	8.000D 01	0.0
19	16	92500.00	77500.00	4.00897D 01	7.258D 00	-1.098D 01	-1.190D-03	8.000D 01	0.0
19	17	92500.00	82500.00	4.00897D 01	4.532D 00	-7.137D 00	-7.272D-04	8.000D 01	0.0
19	18	92500.00	87500.00	4.00897D 01	3.110D 00	-4.650D 00	-4.684D-04	8.000D 01	0.0
19	19	92500.00	92500.00	4.00896D 01	2.296D 00	-2.913D 00	-2.158D-04	8.000D 01	0.0
19	20	92500.00	97500.00	4.00896D 01	1.831D 00	-1.601D 00	-1.677D-04	8.000D 01	0.0
19	21	92500.00	102500.00	4.00896D 01	1.612D 00	-4.776D-01	-1.018D-04	8.000D 01	0.0
20	1	97500.00	2500.00	4.00896D 01	7.627D-01	3.017D-01	1.751D-04	8.000D 01	0.0
20	2	97500.00	7500.00	4.00897D 01	8.619D-01	1.051D 00	7.987D-05	8.000D 01	0.0
20	3	97500.00	12500.00	4.00897D 01	1.058D 00	1.911D 00	3.023D-04	8.000D 01	0.0
20	4	97500.00	17500.00	4.00897D 01	1.351D 00	3.027D 00	6.421D-04	8.000D 01	0.0
20	5	97500.00	22500.00	4.00898D 01	1.762D 00	4.615D 00	1.523D-03	8.000D 01	0.0
20	6	97500.00	27500.00	4.00900D 01	2.575D 00	7.203D 00	-4.359D-04	8.000D 01	0.0
20	7	97500.00	32500.00	4.00903D 01	4.919D 00	1.221D 01	-1.154D-02	8.000D 01	0.0
20	8	97500.00	37500.00	4.00896D 01	1.348D 01	1.849D 01	1.454D-02	8.000D 01	0.0
20	9	97500.00	42500.00	4.00917D 01	3.441D 01	4.146D 01	-1.434D-01	8.000D 01	0.0
20	10	97500.00	47500.00	4.00867D 01	1.148D 02	5.586D 01	3.084D-01	8.000D 01	3.745D-16
20	11	97500.00	52500.00	4.00789D 01	1.811D 02	-1.728D-13	-6.556D-01	8.000D 01	3.947D-14
20	12	97500.00	57500.00	4.00867D 01	1.148D 02	-5.586D 01	3.084D-01	8.000D 01	3.745D-16
20	13	97500.00	62500.00	4.00917D 01	3.441D 01	-4.146D 01	-1.434D-01	8.000D 01	0.0
20	14	97500.00	67500.00	4.00896D 01	1.348D 01	-1.849D 01	1.454D-02	8.000D 01	0.0
20	15	97500.00	72500.00	4.00903D 01	4.919D 00	-1.221D 01	-1.154D-02	8.000D 01	0.0
20	16	97500.00	77500.00	4.00900D 01	2.575D 00	-7.203D 00	-4.359D-04	8.000D 01	0.0
20	17	97500.00	82500.00	4.00898D 01	1.762D 00	-4.615D 00	1.523D-03	8.000D 01	0.0
20	18	97500.00	87500.00	4.00897D 01	1.351D 00	-3.027D 00	6.421D-04	8.000D 01	0.0
20	19	97500.00	92500.00	4.00897D 01	1.058D 00	-1.911D 00	3.023D-04	8.000D 01	0.0
20	20	97500.00	97500.00	4.00897D 01	8.619D-01	-1.051D 00	7.987D-05	8.000D 01	0.0
20	21	97500.00	102500.00	4.00896D 01	7.627D-01	-3.017D-01	1.751D-04	8.000D 01	0.0
21	1	102500.00	2500.00	4.00897D 01	1.722D-01	2.038D-01	1.864D-05	8.000D 01	0.0
21	2	102500.00	7500.00	4.00897D 01	1.983D-01	7.388D-01	-9.561D-05	8.000D 01	0.0
21	3	102500.00	12500.00	4.00897D 01	2.243D-01	1.336D 00	3.140D-05	8.000D 01	0.0
21	4	102500.00	17500.00	4.00897D 01	1.580D-01	2.059D 00	2.313D-04	8.000D 01	0.0
21	5	102500.00	22500.00	4.00898D 01	-2.770D-01	2.971D 00	-3.759D-04	8.000D 01	0.0
21	6	102500.00	27500.00	4.00900D 01	-1.444D 00	4.126D 00	-3.186D-04	8.000D 01	0.0
21	7	102500.00	32500.00	4.00905D 01	-3.742D 00	6.252D 00	-5.491D-03	8.000D 01	0.0
21	8	102500.00	37500.00	4.00897D 01	-2.692D 00	4.195D 00	1.249D-01	8.000D 01	0.0
21	9	102500.00	42500.00	4.00983D 01	1.489D 01	3.025D 01	-3.647D-01	8.000D 01	-1.762D-20
21	10	102500.00	47500.00	4.00950D 01	1.636D 02	6.203D 01	3.531D-01	8.000D 01	9.540D-16
21	11	102500.00	52500.00	4.00818D 01	2.972D 02	-8.544D-13	-1.337D 00	8.000D 01	1.141D-13
21	12	102500.00	57500.00	4.00950D 01	1.636D 02	-6.203D 01	3.531D-01	8.000D 01	9.540D-16
21	13	102500.00	62500.00	4.00983D 01	1.489D 01	-3.025D 01	-3.647D-01	8.000D 01	-1.762D-20
21	14	102500.00	67500.00	4.00897D 01	-2.692D 00	-4.195D 00	1.249D-01	8.000D 01	0.0
21	15	102500.00	72500.00	4.00905D 01	-3.742D 00	-6.252D 00	-5.491D-03	8.000D 01	0.0
21	16	102500.00	77500.00	4.00900D 01	-1.444D 00	-4.126D 00	-3.186D-04	8.000D 01	0.0
21	17	102500.00	82500.00	4.00898D 01	-2.770D-01	-2.971D 00	-3.759D-04	8.000D 01	0.0
21	18	102500.00	87500.00	4.00897D 01	1.580D-01	-2.059D 00	2.313D-04	8.000D 01	0.0
21	19	102500.00	92500.00	4.00897D 01	2.243D-01	-1.336D 00	3.140D-05	8.000D 01	0.0
21	20	102500.00	97500.00	4.00897D 01	1.983D-01	-7.388D-01	-9.561D-05	8.000D 01	0.0
21	21	102500.00	102500.00	4.00897D 01	1.722D-01	-2.038D-01	1.864D-05	8.000D 01	0.0

IHC002I STOP 0

Table A.4. Input Data for Sample Problem No. 2

CASE TITLE: TEST PROBLEM NO.2: TWO POWER PLANTS IN CROSS STREAM FLOW.

INPUT INFORMATION FROM SUBROUTINE INPUT:

CARD NO. 1

TOTAL NUMBER OF CHEMICAL SPECIES CK CONSIDERED (NK) = 2

TOTAL NUMBER OF REGIONS (NREG) = 11

TOTAL NUMBER OF INITIAL CONDITIONS FUNCTIONS (NINTLF) = 2

TOTAL NUMBER OF VOLUMETRIC HEAT OR MASS GENERATION FUNCTIONS (NGENF) = 1

TOTAL NUMBER OF BOUNDARY CONDITIONS FUNCTIONS (NBNDF) = 8

TOTAL NUMBER OF TOP CONDITIONS FUNCTIONS (NTOPF) = 2

TOTAL NUMBER OF BOTTOM CONDITIONS FUNCTIONS (NBOTF) = 2

TOTAL NUMBER OF ANALYTICAL FUNCTIONS (NANLFC) = 3

TOTAL NUMBER OF TABULATED FUNCTIONS (NTBLFC) = 1

TOTAL NUMBER OF GROSS LATTICE LINES IN X-DIRECTION (NXGRL) = 14

TOTAL NUMBER OF GROSS LATTICE LINES IN Y-DIRECTION (NYGRL) = 4

TOTAL NUMBER OF TEMP. MONITORING POINTS (NTMAX) = 3

CARD NO. 2

RESTART FLAG. IF EQUAL ZERO NO RESTART INFORMATION IS REQUIRED (ISTART) = [illegible]

FINISH FLAG. IF EQUAL ZERO NO RESTART FILE IS CREATED (IFINTS) = 0

PLOTTING FLAG. IF EQUAL ZERO NO PLOTTING INFORMATION IS GENERATED. (IPLOT) = 0

FLAG FOR SELECTING THE NUMERICAL INTEGRATION PROCEDURE. (INTRT=1 SELECTS RUNGE-KUTTA-GILL METHOD.
INTRT=2 SELECTS EULER METHOD. INTRT=3 SELECTS ADAM-BASHWORTH METHOD.) (INTRT) =1

CARD NO. 3

STARTING TIME OF THIS CASE (STM) = 0.0

PROBLEM TIME FOR THIS CASE (PRBTM) = 12.4000

COMPUTER TIME CUTOFF LIMIT IN SECONDS (CPUSEC) = 295.00

TIME INCREMENT FOR PRINTED OUTPUT (DPRTTM) = 0.1000

TIDAL PERIOD IF AN ESTUARY (TIDAL) = 12.4000

CARD NO. 4

Table A.4 (continued)

```
INITIAL TIME INCREMENT (SDTM) = 0.00500

LARGEST LIMIT FOR TIME INCREMENT (FDTM)=  0.00500

TIME INCREMENT IS MULTIPLIED EVERY NDTMC TIME STEPS BY (DTMLT)=     1.00

NUMBER OF TIME STEPS BEFORE PROCESS OF INCREASE IN TIME STEP SIZE BEGINS (INDTM)=  10

NUMBER OF TIME STEPS BETWEEN CHANGES IN TIME STEP SIZE (NDTMC) =   5

CRITERION TYPE (AS DEFINED IN SUBROUTINE CHKDTM) THAT EACH DTM WILL BE REQUIRED TO SATISFY (LDTMCR)=   0

TABULATED  FUNCTIONS

     TABLE NO.  1
  TABARG         TABFNC
0.0            0.0
1.0000D 00     4.0000D-01
3.0000D 00     8.0000D-01
6.0000D 00     9.5000D-01
8.0000D 00     1.0000D 00
1.0000D 01     1.0000D 00


INPUT INFORMATION FROM SUBROUTINE GEOM:
--- --- --- --- --- --- --- --- --- ---

XGRL(I)  - GROSS LATTICE LINE I IN THE X-DIRECTION

IXFD(I)  - NUMBER OF SUBDIVISIONS BETWEEN GROSS LATTICE LINES XGRL(I) AND XGRL(I+1).

YGRL(I)  - GROSS LATTICE LINE I IN Y-DIRECTION.

IYFD(I)  - NUMBER OF SUBDIVISIONS BETWEEN GROSS LATTICE LINES YGRL(I) AND YGRL(I+1).


 I       XGRL        IXFD
 1    0.0              5
 2    5.00000D 04      2
 3    5.10000D 04      1
 4    5.15000D 04      2
 5    5.25000D 04      1
 6    5.30000D 04      5
 7    5.55000D 04     15
 8    7.05000D 04      2
 9    7.15000D 04      1
10    7.20000D 04      2
11    7.30000D 04      1
12    7.35000D 04     10
13    7.85000D 04     10
14    1.78500D 05


 I       YGRL        IYFD
 1    0.0              4
 2    2.00000D 03      1
 3    2.50000D 03      2
 4    4.50000D 03
```

Table A.4 (continued)

	NODAL WIDTH		NODAL CENTER	
I	X-DIRECTION	Y-DIRECTION	X-DIRECTION	Y-DIRECTION
1	10000.00000	500.00000	5.000000D 03	2.500000D 02
2	10000.00000	500.00000	1.500000D 04	7.500000D 02
3	10000.00000	500.00000	2.500000D 04	1.250000D 03
4	10000.00000	500.00000	3.500000D 04	1.750000D 03
5	10000.00000	500.00000	4.500000D 04	2.250000D 03
6	500.00000	1000.00000	5.025000D 04	3.000000D 03
7	500.00000	1000.00000	5.075000D 04	4.000000D 03
8	500.00000		5.125000D 04	
9	500.00000		5.175000D 04	
10	500.00000		5.225000D 04	
11	500.00000		5.275000D 04	
12	500.00000		5.325000D 04	
13	500.00000		5.375000D 04	
14	500.00000		5.425000D 04	
15	500.00000		5.475000D 04	
16	500.00000		5.525000D 04	
17	1000.00000		5.600000D 04	
18	1000.00000		5.700000D 04	
19	1000.00000		5.800000D 04	
20	1000.00000		5.900000D 04	
21	1000.00000		6.000000D 04	
22	1000.00000		6.100000D 04	
23	1000.00000		6.200000D 04	
24	1000.00000		6.300000D 04	
25	1000.00000		6.400000D 04	
26	1000.00000		6.500000D 04	
27	1000.00000		6.600000D 04	
28	1000.00000		6.700000D 04	
29	1000.00000		6.800000D 04	
30	1000.00000		6.900000D 04	
31	1000.00000		7.000000D 04	
32	500.00000		7.075000D 04	
33	500.00000		7.125000D 04	
34	500.00000		7.175000D 04	
35	500.00000		7.225000D 04	
36	500.00000		7.275000D 04	
37	500.00000		7.325000D 04	
38	500.00000		7.375000D 04	
39	500.00000		7.425000D 04	
40	500.00000		7.475000D 04	
41	500.00000		7.525000D 04	
42	500.00000		7.575000D 04	
43	500.00000		7.625000D 04	
44	500.00000		7.675000D 04	
45	500.00000		7.725000D 04	
46	500.00000		7.775000D 04	
47	500.00000		7.825000D 04	
48	10000.00000		8.350000D 04	
49	10000.00000		9.350000D 04	
50	10000.00000		1.035000D 05	
51	10000.00000		1.135000D 05	
52	10000.00000		1.235000D 05	
53	10000.00000		1.335000D 05	
54	10000.00000		1.435000D 05	
55	10000.00000		1.535000D 05	
56	10000.00000		1.635000D 05	
57	10000.00000		1.735000D 05	

Table A.4 (continued)

	GEOMETRIC DESCRIPTION OF REGIONS						INDEXICAL DESCRIPTION				
REGION	UPX	DNX	UPY	DNY	DEPTH	AREA	I LOW	IHIGH	J LOW	JHIGH	NODES
1	0.0	51000.00	0.0	2000.00	40.000	1.0200D 08	1	7	1	4	28
2	0.0	51000.00	2000.00	2500.00	40.000	2.5500D 07	1	7	5	5	7
3	0.0	51000.00	2500.00	4500.00	40.000	1.0200D 08	1	7	6	7	14
4	51000.00	51500.00	0.0	4500.00	40.000	2.2500D 06	8	8	1	7	7
5	51500.00	52500.00	0.0	4500.00	40.000	4.5000D 06	9	10	1	7	14
6	52500.00	53000.00	0.0	4500.00	40.000	2.2500D 06	11	11	1	7	7
7	53000.00	71500.00	0.0	4500.00	40.000	8.3250D 07	12	33	1	7	154
8	71500.00	72000.00	0.0	4500.00	40.000	2.2500D 06	34	34	1	7	7
9	72000.00	73000.00	0.0	4500.00	40.000	4.5000D 06	35	36	1	7	14
10	73000.00	73500.00	0.0	4500.00	40.000	2.2500D 06	37	37	1	7	7
11	73500.00	178500.00	0.0	4500.00	40.000	4.7250D 08	38	57	1	7	140

TOTAL NO. OF NODES IN (INPUT) REGIONS= 399
MAX. NO. OF NODES IN GRID= 399

	FUNCTION SELECTION				BOUNDARY SELECTION			
REGION	INTF	IGENF	ITOPF	IBOTF	IUPXB	IDNXB	IUPYB	IDNYB
1	1	0	1	1	1	0	4	0
2	1	0	1	1	2	0	0	0
3	1	0	1	1	1	0	0	4
4	1	0	1	1	0	0	4	5
5	1	0	1	1	0	0	4	4
6	1	0	1	1	0	0	4	6
7	1	0	1	1	0	0	4	4
8	1	0	1	1	0	0	7	4
9	1	0	1	1	0	0	4	4
10	1	0	1	1	0	0	8	4
11	1	0	1	1	0	3	4	4

NUMBER OF ELEMENTS AVAILABLE IN ARRAY Z IN MAIN = 8600

NUMBER OF ELEMENTS NEEDED = 7837

POSITIONS TO MONITOR TEMPERATURE

N	REQUESTED LOCATION		SELECTED NODE		NODE LOCATION		NODE
	X	Y	I	J	X	Y	REGION
1	73250.000	250.000	37	1	73250.000	250.000	10
2	73250.000	2250.000	37	5	73250.000	2250.000	10
3	73250.000	3000.000	37	6	73250.000	3000.000	10

Table A.4 (continued)

```
NODAL DISPLAY FOR UPSTREAM BOUNDARIES IN X-DI    ON,NEXM

J=  7**1
J=  6**1
J=  5**2
J=  4**1
J=  3**1
J=  2**1
J=  1**1
```

```
NODAL DISPLAY FOR DOWNSTREAM BOUNDARIES IN X-DIRECTION,NBYP

J=   7**                                                   3
J=   6**                                                   3
J=   5**                                                   3
J=   4**.                                                  3
J=   3**
J=   2**
J=   1**
```

Table A.4 (continued)

```
NODAL DISPLAY FOR UPSTREAM BOUNDARIES IN Y-DIRECTION,NBYM

J=   7**
J=   6**
J=   5**
J=   4**
J=   3**
J=   2**
J=   1**44444444444444444444444444444447448444444444444444444444
```

```
NODAL DISPLAY FOR DOWNSTREAM BOUNDARIES IN Y-DIRECTION,NBYP

J=   7**44444445446444444444444444444444444444444444444444444
J=   6**
J=   5**
J=   4**
J=   3**
J=   2**
J=   1**
```

Table A.4 (continued)

```
NODAL DISPLAY FOR REGIONS

J=   7**33333334556777777777777777777777777899ABBBBBBBBBBBBBBBBBBBBBBB
J=   6**33333334556777777777777777777777777899ABBBBBBBBBBBBBBBBBBBBBBB
J=   5**22222224556777777777777777777777777899ABBBBBBBBBBBBBBBBBBBBBBB
J=   4**11111114556777777777777777777777777899ABBBBBBBBBBBBBBBBBBBBBBB
J=   3**11111114556777777777777777777777777899ABBBBBBBBBBBBBBBBBBBBBBB
J=   2**11111114556777777777777777777777777899ABBBBBBBBBBBBBBBBBBBBBBB
J=   1**11111114556777777777777777777777777899ABBBBBBBBBBBBBBBBBBBBBBB
```

Table A.4 (continued)

```
INPUT INFORMATION FROM SUBROUTINE GENCON:
--- --- --- --- --- --- --- --- --- ---

IGENFC - INTERNAL GENERATION FUNCTION (AN INDEX)
QDV - VALUE OF HEAT GENERATION PER UNIT VOLUME IN INTERNAL GENERATION FUNCTION
IQDVF - GENERAL PURPOSE FUNCTION TO BE USED ON QDV
GKDV(K) - VALUE OF MASS GENERATION PER UNIT VOLUME FOR SPECIE K IN INTERNAL GENERATION FUNCTION
IGKDVF(K) - GENERAL PURPOSE FUNCTION TO BE USED ON GKDV(K)
```

K	IGENFC	QDV	IQDVF	GKDV(1)	IGKDVF(1)	GKDV(2)	IGKDVF(2)
1	1	0.0	0	0.0	0	0.0	0

Table A.4 (continued)

```
INPUT INFORMATION FROM SUBROUTINE BNDCON:
--- --- --- --- --- --- --- --- --- ---

NBN - BOUNDARY CONDITION NUMBER
NHBDTP - TYPE OF BOUNDARY CONDITION FOR WATER ELEVATION H (NHBDTP)
NU - TYPE OF BOUNDARY CONDITION FOR VELOCITY U (NUBDTP)
NV - TYPE OF BOUNDARY CONDITION FOR VELOCITY V ( NVBDTP)
NT - TYPE OF BOUNDARY CONDITION FOR TEMP. OR SPECIES CONCENTRATION (NBTDTP)
FH -  VALUE OF BOUNDARY CONDITION FOR WATER ELEVATION (FHBD)
FU - VALUE OF BOUNDARY CONDITION FOR VELOCITY U (FUBD)
FV - VALUE OF BOUNDARY CONDITION FOR VELOCITY V (FVBD)
FT - VALUE OF BOUNDARY CONDITION FOR TEMP. (FTBD)
FG - VALUE OF BOUNDARY CONDITION FOR MASS FLUX (FGBD)
FQ - VALUE OF BOUNDARY CONDITION FOR HEAT FLUX (FQBD)
FSBDN - VALUE OF BOUNDARY CONDITION FOR NORMAL STRESSES
FGK(1) - VALUE OF BOUNDARY CONDITION FOR MASS FLUX OF SPECIE K (FGKBD)
FCK - VALUE OF BOUNDARY CONDITION FOR SPECIES CONCENTRATION (FCKBD)
IHBDF - MULTIPLIER FUNCTION FOR FHBD
IU    - MULTIPLIER FUNCTION FOR FUBD
IV    - MULTIPLIER FUNCTION FOR FVBD
IT    - MULTIPLIER FUNCTION FOR FTBD
IG    - MULTIPLIER FUNCTION FOR FGBD
IQ    - MULTIPLIER FUNCTION FOR FQBD
ISN   - MULTIPLIER FUNCTION FOR FSBDN
ISH   - MULTIPLIER FUNCTION FOR FSBDSH
```

BOUNDARY CONDITIONS AT STARTING TIME

NBN	NHBDTP	NU	NV	NT	FH	FU	FV	FT
1	4	1	2	2	0.0	0.0	0.0	8.000000D 01
2	4	1	1	1	0.0	7.200000D 02	0.0	8.000000D 01
3	1	4	4	4	1.000000D 00	0.0	0.0	7.000000D 01
4	4	2	1	2	0.0	0.0	0.0	8.000000D 01
5	4	4	1	4	0.0	0.0	4.465800D 02	8.000000D 01
6	4	1	1	1	0.0	0.0	-4.465800D 02	-1.500000D 01
7	4	4	1	4	0.0	0.0	-4.465800D 02	8.000000D 01
8	4	1	1	1	0.0	0.0	4.465800D 02	-1.500000D 01

NBN	FG	FQ	FSBDN	FSBDSH	FGK(1)	FGK(2)	FCK(1)	FCK(2)
1	0.0	0.0	0.0	0.0	0.0	0.0	1.000	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	1.000	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.973	0.027
4	0.0	0.0	0.0	0.0	0.0	0.0	1.000	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.993	0.007
6	0.0	0.0	0.0	0.0	0.0	0.0	0.993	0.007
7	0.0	0.0	0.0	0.0	0.0	0.0	0.993	0.007
8	0.0	0.0	0.0	0.0	0.0	0.0	0.993	0.007

MULTIPLIER FUNCTIONS FOR BOUNDARY CONDITIONS

NBN	IHBDF	IU	IV	IT	IG	IQ	ISN	ISH
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	-2	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0

Table A.4 (continued)

POWER PLANT ON BOUNDARY.

NBN	DTPP(NBN)	XINT	YINT	I	J
6	1.500D 01	5.12500D 04	4.25000D 03	8	7
8	1.500D 01	7.17500D 04	2.50000D 02	34	1

INPUT INFORMATION FROM SUBROUTINE BOTCON:
--- --- --- --- --- --- --- --- --- ---

QB - HEAT COMING FROM THE BOTTOM
HCB - HEAT TRANSFER COEFFICIENT FOR THE BOTTOM
UB - VELOCITY OF MASS COMING FROM THE BOTTOM IN X-DIRECTION
VB - VELOCITY OF MASS COMING FROM THE BOTTOM IN Y-DIRECTION
WB - VELOCITY OF MASS COMING FROM THE BOTTOM IN Z-DIRECTION
TB - TEMPERATURE OF MASS COMING FROM THE BOTTOM
BMANGC - MANNING COEF. FOR FRICTION WITH THE BOTTOM
DCKB - MASS DIFFUSION COEFFICIENT FOR SPECIE K FROM BOTTOM
CKB - MASS CONCENTRATION OF SPECIES COMING FROM BOTTOM
IQB - MULTIPLIER FUNCTION FOR QB
IHCB - MULTIPLIER FUNCTION FOR HCB
IUB - MULTIPLIER FUNCTION FOR UB
IVB - MULTIPLIER FUNCTION FOR VB
IWB - MULTIPLIER FUNCTION FOR WB
ITB - MULTIPLIER FUNCTION FOR TB
IDCKB - MULTIPLIER FUNCTION FOR DCKB
ICKB - MULTIPLIER FUNCTION FOR CKB

BOTTOM CONDITIONS AT STARTING TIME

FCT. NO.	QB	HCB	UB	VB	WB	TB	BMANGC	DCKB(1)	CKB(1)	DCKB(2)	CKB(2)
1	0.0	0.0	0.0	0.0	0.0	8.00D 01	8.33D-06	0.0	10.00	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	8.00D 01	8.33D-06	0.0	10.00	0.0	0.0

MULTIPLIER FUNCTION FOR BOTTOM CONDITIONS

FCT.NO.	IQB	IHCB	IUB	IVB	IWB	ITB	IDCKB(1)	ICKB(1)	IDCKB(2)	ICKB(2)
1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0

INPUT INFORMATION FROM SUBROUTINE TOPCON:
--- --- --- --- --- --- --- --- --- ---

QT - HEAT COMING FROM THE TOP
HCT - HEAT TRANSFER COEFFICIENT FOR TOP
UT - VELOCITY OF MASS COMING FROM THE TOP IN X-DIRECTION
VT - VELOCITY OF MASS COMING FROM THE TOP IN Y-DIRECTION
WT - VELOCITY OF MASS COMING FROM THE TOP IN Z-DIRECTION
TT - TEMPERATURE OF MASS COMING FROM THE TOP
TD - DEW-POINT TEMPERATURE
QSOL - SOLAR HEAT FLUX
DCKT - MASS DIFFUSION COEFFICIENT FOR SPECIE K FROM TOP
CKT - MASS CONCENTRATION OF SPECIES COMING FROM THE TOP
IQT - MULTIPLIER FUNCTION FOR QT
IHCT - MULTIPLIER FUNCTION FOR HCT
IUT - MULTIPLIER FUNCTION FOR UT
IVT - MULTIPLIER FUNCTION FOR VT

Table A.4 (continued)

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IWT - MULTIPLIER FUNCTION FOR WT
ITT - MULTIPLIER FUNCTION FOR TT
ITD - MULTIPLIER FUNCTION FOR TD
IQSOL - MULTIPLIER FUNCTION FOR QSOL
IDCKT - MULTIPLIER FUNCTION FOR DCKT
ICKT - MULTIPLIER FUNCTION FOR CKT
```

TOP CONDITIONS AT STARTING TIME

FCT. NO.	QT	HCT	UT	VT	WT	TT	TD	QSOL	DCKT(1)	CKT(1)	DCKT(2)	CKT(2)
1	0.0	5.00	0.0	0.0	0.0	80.00	80.00	0.0	0.0	1.00	0.0	0.0
2	0.0	5.00	0.0	0.0	0.0	80.00	80.00	0.0	0.0	1.00	0.0	0.0

MULTIPLIER FUNCTION FOR TOP CONDITIONS

FCT. NO.	IQT	IHCT	IUT	IVT	IWT	ITT	ITD	IQSOL	IDCKT(1)	ICKT(1)	IDCKT(2)	ICKT(2)
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0

INPUT INFORMATION FROM SUBROUTINE FLXCON:
--- --- --- --- --- --- --- --- --- ---

```
COEFFICIENT FOR TOTAL EFFECTIVE THERMAL CONDUCTIVITY IN X-DIRECTION (XKPC) =  3.500000D-01
COEFFICIENT FOR TOTAL EFFECTIVE THERMAL CONDUCTIVITY IN Y-DIRECTION (YKPC) =  3.500000D-01
COEFFICIENT FOR TURBULENT VISCOSITY IN X-DIRECTION(XTVSC) =  2.000000D 00
COEFFICIENT FOR TURBULENT VISCOSITY IN Y-DIRECTION (YTVSC) =  2.000000D 00

DKXC - COEFFICIENT FOR TOTAL BINARY EFFECTIVE DIFFUSION COEFFICIENT OF SPECIE K IN X-DIRECTION
DKYC - COEFFICIENT FOR TOTAL BINARY EFFECTIVE DIFFUSION COEFFICIENT OF SPECIE K IN Y-DIRECTION
```

K	DKXC(K)	DKYC(K)
1	5.220000D-05	5.220000D-05
2	5.220000D-05	5.220000D-05

INPUT INFORMATION FROM SUBROUTINE INTCON:
--- --- --- --- --- --- --- --- --- ---

```
STH - INITIAL VALUE FOR WATER SURFACE ELEVATION, H, MEASURED FROM THE BOTTOM
STU - INITIAL VALUE FOR WATER VELOCITY, U, IN X-DIRECTION
STV - INITIAL VALUE FOR WATER VELOCITY, V, IN Y-DIRECTION
STWS - INITIAL VALUE FOR RATE OF CHANGE OF WATER ELEVATION WITH RESPECT TO TIME
STT - INITIAL VALUE FOR WATER TEMPERATURE, T.
STCK(I) - INITIAL VALUE FOR MASS CONCENTRATION OF SPECIES(I).
ISTHF - MULTIPLIER FUNCTION FOR STH
ISTUF - MULTIPLIER FUNCTION FOR STU
ISTVF - MULTIPLIER FUNCTION FOR STV
ISTWSF - MULTIPLIER FUNCTION FOR STWS
ISTTF - MULTIPLIER FUNCTION FOR STT
ISTCKF(I) - MULTIPLIER FUNCTION FOR STCK(I)
```

INITIAL CONDITIONS

FUNCTION NO.	STH	STU	STV	STT	STCK(1)	STCK(2)
1	40.00	0.0	0.0	80.00	1.00	0.0
2	40.00	0.0	0.0	80.00	1.00	0.0

Table A.4 (continued)

MULTIPLIER FUNCTION FOR INITIAL CONDITIONS

PCT.NO.	ISTH	ISTU	ISTV	ISTT	ISTCK(1)	ISTCK(2)
1	0	0	0	0	0	0
2	0	0	0	0	0	0

Table A.5. Output Information for Sample Problem No. 2 at Time = 0.61 hr Using the Full Version of the Program

ITEP.= 118 TIME=5.900000D-01 PERIOD=4.758065D-02 TIME INCREMENT=5.000000D-03

NODE	INDICES	X-LOCATION	Y-LOCATION	WATER ELEVATION	VELOCITY IN X-DIRECT.	VELOCITY IN Y-DIRECT.	WATER ELEV. RATE OF CHANGE	TEMP.	TEMP. RATE OF CHANGE	SUBSTANCE MASS CONCENTRATIONS CK(1)	CK(2)
1	1	5000.00	250.00	4.00131D 01	1.467D 02	-1.582D 00	-1.665D-02	8.000D 01	-2.821D-71	1.000D 00	2.195D-74
1	2	5000.00	750.00	4.00134D 01	1.477D 02	-6.658D 00	-2.294D-01	8.000D 01	-2.556D-68	1.000D 00	2.706D-71
1	3	5000.00	1250.00	4.00134D 01	1.494D 02	-1.252D 01	3.782D-01	8.000D 01	-1.373D-65	1.000D 00	1.536D-68
1	4	5000.00	1750.00	4.00143D 01	1.516D 02	-1.667D 01	-5.727D-01	8.000D 01	-2.630D-63	1.000D 00	3.920D-66
1	5	5000.00	2250.00	4.00158D 01	1.528D 02	-8.535D 00	2.173D-01	8.000D 01	4.385D-63	1.000D 00	7.613D-64
1	6	5000.00	3000.00	4.00125D 01	1.510D 02	8.231D 00	-9.937D-01	8.000D 01	1.151D-60	1.000D 00	3.110D-60
1	7	5000.00	4000.00	4.00099D 01	1.485D 02	-1.508D-01	1.005D-01	8.000D 01	2.259D-56	1.000D 00	1.779D-56
2	1	15000.00	250.00	4.00190D 01	1.224D 02	-7.591D-01	1.832D-01	8.000D 01	-5.162D-61	1.000D 00	6.314D-64
2	2	15000.00	750.00	4.00190D 01	1.228D 02	-2.687D 00	1.266D-01	8.000D 01	-1.424D-57	1.000D 00	3.040D-60
2	3	15000.00	1250.00	4.00188D 01	1.233D 02	-4.723D 00	1.227D-01	8.000D 01	-1.967D-54	1.000D 00	6.424D-57
2	4	15000.00	1750.00	4.00187D 01	1.238D 02	-6.004D 00	4.623D-02	8.000D 01	-1.113D-51	1.000D 00	7.704D-54
2	5	15000.00	2250.00	4.00188D 01	1.237D 02	-1.915D 00	-8.370D-02	8.000D 01	9.895D-51	1.000D 00	8.881D-51
2	6	15000.00	3000.00	4.00180D 01	1.216D 02	3.534D 00	8.392D-02	8.000D 01	3.980D-47	1.000D 00	3.242D-47
2	7	15000.00	4000.00	4.00174D 01	1.194D 02	3.767D-03	2.223D-01	8.000D 01	1.716D-43	1.000D 00	1.344D-43
3	1	25000.00	250.00	4.00214D 01	9.622D 01	-1.595D-01	1.023D-01	8.000D 01	4.085D-54	1.000D 00	4.641D-54
3	2	25000.00	750.00	4.00214D 01	9.602D 01	-2.864D-01	1.006D-01	8.000D 01	1.054D-49	1.000D 00	1.175D-49
3	3	25000.00	1250.00	4.00213D 01	9.553D 01	-3.516D-01	1.083D-01	8.000D 01	1.412D-45	1.000D 00	1.534D-45
3	4	25000.00	1750.00	4.00212D 01	9.463D 01	-4.016D-01	1.422D-01	8.000D 01	1.245D-41	1.000D 00	1.332D-41
3	5	25000.00	2250.00	4.00211D 01	9.319D 01	-2.261D-01	1.541D-01	8.000D 01	-8.722D-36	1.000D 00	6.961D-38
3	6	25000.00	3000.00	4.00212D 01	9.048D 01	-1.020D-01	1.475D-01	8.000D 01	-2.729D-32	1.000D 00	2.172D-34
3	7	25000.00	4000.00	4.00213D 01	8.790D 01	-8.109D-01	1.080D-01	8.000D 01	4.233D-31	1.000D 00	5.087D-31
4	1	35000.00	250.00	4.00200D 01	6.560D 01	1.023D-01	1.484D-01	8.000D 01	-6.588D-42	1.000D 00	5.758D-45
4	2	35000.00	750.00	4.00201D 01	6.498D 01	4.692D-01	1.490D-01	8.000D 01	-2.631D-37	1.000D 00	2.279D-40
4	3	35000.00	1250.00	4.00202D 01	6.369D 01	7.219D-01	1.624D-01	8.000D 01	-5.114D-33	1.000D 00	4.699D-36
4	4	35000.00	1750.00	4.00203D 01	6.168D 01	8.441D-01	1.713D-01	8.000D 01	-4.269D-29	1.000D 00	4.897D-32
4	5	35000.00	2250.00	4.00205D 01	5.897D 01	7.700D-01	1.783D-01	8.000D 01	-1.535D-25	1.000D 00	2.625D-28
4	6	35000.00	3000.00	4.00209D 01	5.449D 01	4.106D-01	1.773D-01	8.000D 01	-2.002D-22	1.000D 00	6.821D-25
4	7	35000.00	4000.00	4.00216D 01	5.023D 01	-1.907D-02	9.472D-02	8.000D 01	1.641D-19	1.000D 00	1.318D-21
5	1	45000.00	250.00	4.00163D 01	2.798D 01	8.810D-01	4.586D-02	8.000D 01	6.186D-44	1.000D 00	1.635D-43
5	2	45000.00	750.00	4.00163D 01	2.703D 01	3.022D 00	5.125D-02	8.000D 01	3.277D-39	1.000D 00	5.366D-39
5	3	45000.00	1250.00	4.00164D 01	2.511D 01	4.998D 00	6.899D-02	8.000D 01	9.258D-35	1.000D 00	1.114D-34
5	4	45000.00	1750.00	4.00166D 01	2.215D 01	6.864D 00	7.594D-02	8.000D 01	1.822D-30	1.000D 00	1.787D-30
5	5	45000.00	2250.00	4.00167D 01	1.818D 01	8.211D 00	1.553D-01	8.000D 01	-1.216D-23	1.000D 00	5.642D-26
5	6	45000.00	3000.00	4.00169D 01	1.011D 01	9.549D 00	2.116D-01	8.000D 01	1.417D-16	1.000D 00	8.086D-21
5	7	45000.00	4000.00	4.00175D 01	7.607D-01	1.183D 01	4.464D-01	8.000D 01	1.782D-11	1.000D 00	1.553D-15
6	1	50250.00	250.00	4.00141D 01	5.258D 00	1.659D 00	2.530D-02	8.000D 01	2.825D-39	1.000D 00	2.386D-39
6	2	50250.00	750.00	4.00142D 01	4.228D 00	5.433D 00	1.986D-02	8.000D 01	1.109D-34	1.000D 00	7.057D-35
6	3	50250.00	1250.00	4.00143D 01	2.182D 00	9.057D 00	-2.174D-02	8.000D 01	2.144D-30	1.000D 00	1.222D-30
6	4	50250.00	1750.00	4.00144D 01	-8.602D-01	1.254D 01	-2.067D-02	8.000D 01	-1.817D-24	1.000D 00	1.494D-26
6	5	50250.00	2250.00	4.00145D 01	-4.702D 00	1.524D 01	-7.451D-02	8.000D 01	8.578D-19	1.000D 00	3.652D-22
6	6	50250.00	3000.00	4.00155D 01	-9.985D 00	1.892D 01	-3.210D-01	8.000D 01	1.595D-12	1.000D 00	4.272D-17
6	7	50250.00	4000.00	4.00184D 01	-1.433D 01	2.568D 01	-2.021D 00	8.000D 01	-2.840D-11	1.000D 00	2.509D-12
7	1	50750.00	250.00	4.00144D 01	4.361D-01	2.248D 00	1.290D-01	8.000D 01	-1.801D-34	1.000D 00	1.379D-36
7	2	50750.00	750.00	4.00144D 01	-5.938D-01	7.084D 00	1.299D-01	8.000D 01	-6.669D-30	1.000D 00	3.696D-32
7	3	50750.00	1250.00	4.00145D 01	-2.714D 00	1.212D 01	1.778D-01	8.000D 01	-1.523D-25	1.000D 00	5.634D-28
7	4	50750.00	1750.00	4.00144D 01	-5.962D 00	1.753D 01	2.795D-01	8.000D 01	-2.112D-21	1.000D 00	5.562D-24
7	5	50750.00	2250.00	4.00145D 01	-1.020D 01	2.462D 01	5.595D-01	8.000D 01	5.366D-15	1.000D 00	1.420D-19
7	6	50750.00	3000.00	4.00149D 01	-1.280D 01	4.304D 01	8.792D-01	8.000D 01	9.123D-10	1.000D 00	2.751D-14
7	7	50750.00	4000.00	4.00148D 01	-1.286D 01	7.311D 01	2.809D 00	8.000D 01	2.345D-05	1.000D 00	2.030D-09
8	1	51250.00	250.00	4.00147D 01	-5.948D 00	2.888D 00	-4.419D-03	8.000D 01	-1.435D-31	1.000D 00	5.098D-34
8	2	51250.00	750.00	4.00147D 01	-7.313D 00	8.638D 00	2.015D-02	8.000D 01	-3.800D-27	1.000D 00	1.260D-29
8	3	51250.00	1250.00	4.00146D 01	-1.031D 01	1.483D 01	-8.283D-02	8.000D 01	-6.009D-23	1.000D 00	1.735D-25
8	4	51250.00	1750.00	4.00144D 01	-1.568D 01	2.174D 01	-3.291D-02	8.000D 01	4.010D-18	1.000D 00	1.412D-21
8	5	51250.00	2250.00	4.00143D 01	-2.450D 01	3.229D 01	-8.186D-01	8.000D 01	1.481D-12	1.000D 00	3.475D-17
8	6	51250.00	3000.00	4.00130D 01	-4.504D 01	6.196D 01	-8.261D-01	8.000D 01	1.791D-07	1.000D 00	6.640D-12
8	7	51250.00	4000.00	4.00078D 01	-7.296D 01	1.090D 02	-2.394D 00	8.000D 01	3.872D-03	1.000D 00	2.904D-07

Table A.5 (continued)

ITER.= 118 TIME=5.900000D-01 PERIOD=4.758065D-02 TIME INCREMENT=5.000000D-03

NODE	INDICES	X-LOCATION	Y-LOCATION	WATER ELEVATION	VELOCITY IN X-DIRECT.	VELOCITY IN Y-DIRECT.	WATER ELEV. RATE OF CHANGE	TEMP.	TEMP. RATE OF CHANGE	SUBSTANCE MASS CONCENTRATIONS CK(1)	CK(2)
9	1	51750.00	250.00	4.00151D 01	-1.265D 01	2.846D 00	1.081D-01	8.000D 01	-2.266D-29	1.000D 00	1.000D-31
9	2	51750.00	750.00	4.00151D 01	-1.426D 01	8.051D 00	1.450D-01	8.000D 01	-5.233D-25	1.000D 00	2.276D-27
9	3	51750.00	1250.00	4.00151D 01	-1.779D 01	1.326D 01	2.343D-01	8.000D 01	-6.342D-21	1.000D 00	2.718D-23
9	4	51750.00	1750.00	4.00150D 01	-2.458D 01	1.836D 01	2.387D-01	8.000D 01	1.842D-15	1.000D 00	1.547D-19
9	5	51750.00	2250.00	4.00150D 01	-3.690D 01	2.312D 01	6.662D-01	8.000D 01	1.958D-10	1.000D 00	3.782D-15
9	6	51750.00	3000.00	4.00150D 01	-7.879D 01	3.319D 01	8.748D-01	8.000D 01	1.252D-05	1.000D 00	5.940D-10
9	7	51750.00	4000.00	4.00156D 01	-1.395D 02	5.200D 01	4.396D 00	8.002D 01	7.244D-02	1.000D 00	7.107D-06
10	1	52250.00	250.00	4.00156D 01	-1.861D 01	2.300D 00	6.702D-02	8.000D 01	-1.157D-27	1.000D 00	9.220D-30
10	2	52250.00	750.00	4.00156D 01	-1.994D 01	6.229D 00	5.567D-02	8.000D 01	-2.214D-23	1.000D 00	1.949D-25
10	3	52250.00	1250.00	4.00155D 01	-2.267D 01	9.780D 00	-4.892D-02	8.000D 01	4.098D-19	1.000D 00	1.979D-21
10	4	52250.00	1750.00	4.00157D 01	-2.783D 01	1.274D 01	-1.736D-01	8.000D 01	8.085D-13	1.000D 00	1.229D-17
10	5	52250.00	2250.00	4.00151D 01	-3.698D 01	9.156D 00	6.734D-02	8.000D 01	5.122D-08	1.000D 00	7.757D-13
10	6	52250.00	3000.00	4.00188D 01	-7.234D 01	3.781D 00	-1.353D 00	8.000D 01	3.836D-05	1.000D 00	4.256D-08
10	7	52250.00	4000.00	4.00364D 01	-1.251D 02	2.675D 01	-6.361D 00	8.021D 01	6.964D-01	9.999D-01	9.705D-05
11	1	52750.00	250.00	4.00161D 01	-2.329D 01	1.530D 00	1.481D-01	8.000D 01	-1.425D-25	1.000D 00	3.526D-28
11	2	52750.00	750.00	4.00161D 01	-2.398D 01	3.728D 00	5.156D-02	8.000D 01	-6.220D-22	1.000D 00	6.509D-24
11	3	52750.00	1250.00	4.00160D 01	-2.534D 01	5.448D 00	1.596D-01	8.000D 01	2.660D-16	1.000D 00	6.043D-20
11	4	52750.00	1750.00	4.00163D 01	-2.731D 01	6.615D 00	-1.242D-01	8.000D 01	2.096D-11	1.000D 00	5.818D-15
11	5	52750.00	2250.00	4.00151D 01	-2.954D 01	-1.380D 00	1.515D 00	8.000D 01	2.006D-05	1.000D 00	3.207D-10
11	6	52750.00	3000.00	4.00213D 01	-3.123D 01	-6.362D 00	-3.011D 00	8.000D 01	7.893D-06	1.000D 00	2.225D-07
11	7	52750.00	4000.00	4.00511D 01	-3.136D 01	4.354D 01	5.811D 00	8.343D 01	5.125D 00	9.984D-01	1.603D-03
12	1	53250.00	250.00	4.00167D 01	-2.608D 01	4.444D-01	8.650D-02	8.000D 01	-8.598D-23	1.000D 00	3.574D-26
12	2	53250.00	750.00	4.00167D 01	-2.608D 01	3.843D-01	9.237D-02	8.000D 01	-3.396D-19	1.000D 00	1.593D-22
12	3	53250.00	1250.00	4.00166D 01	-2.604D 01	-3.106D-01	1.324D-02	8.000D 01	1.512D-14	1.000D 00	1.295D-18
12	4	53250.00	1750.00	4.00168D 01	-2.498D 01	-1.965D 00	-8.694D-02	8.000D 01	9.594D-10	1.000D 00	5.389D-14
12	5	53250.00	2250.00	4.00162D 01	-2.117D 01	-9.816D 00	1.865D-01	8.000D 01	4.218D-06	1.000D 00	1.830D-10
12	6	53250.00	3000.00	4.00192D 01	5.126D 00	-1.947D 01	-9.302D-01	8.000D 01	1.956D-03	1.000D 00	9.435D-08
12	7	53250.00	4000.00	4.00344D 01	4.861D 01	-1.477D 00	-4.556D 00	8.008D 01	3.112D-01	1.000D 00	3.661D-05
13	1	53750.00	250.00	4.00174D 01	-2.642D 01	-7.581D-01	1.010D-01	8.000D 01	-2.607D-20	1.000D 00	1.997D-23
13	2	53750.00	750.00	4.00174D 01	-2.581D 01	-3.086D 00	1.280D-01	8.000D 01	2.509D-15	1.000D 00	7.968D-20
13	3	53750.00	1250.00	4.00174D 01	-2.436D 01	-6.232D 00	1.655D-01	8.000D 01	3.374D-12	1.000D 00	1.184D-16
13	4	53750.00	1750.00	4.00174D 01	-2.104D 01	-1.083D 01	1.042D-01	8.000D 01	2.046D-09	1.000D 00	8.193D-14
13	5	53750.00	2250.00	4.00175D 01	-1.400D 01	-1.781D 01	2.194D-01	8.000D 01	6.409D-07	1.000D 00	2.980D-11
13	6	53750.00	3000.00	4.00178D 01	1.317D 01	-2.971D 01	9.538D-02	8.000D 01	1.018D-04	1.000D 00	5.992D-09
13	7	53750.00	4000.00	4.00187D 01	5.219D 01	-4.221D 01	1.724D 00	8.000D 01	1.386D-02	1.000D 00	1.047D-06
14	1	54250.00	250.00	4.00180D 01	-2.466D 01	-1.707D 00	1.079D-01	8.000D 01	-1.089D-21	1.000D 00	7.931D-25
14	2	54250.00	750.00	4.00180D 01	-2.350D 01	-5.456D 00	1.092D-01	8.000D 01	5.551D-17	1.000D 00	1.795D-21
14	3	54250.00	1250.00	4.00181D 01	-2.087D 01	-9.929D 00	1.075D-01	8.000D 01	5.919D-14	1.000D 00	1.801D-18
14	4	54250.00	1750.00	4.00182D 01	-1.606D 01	-1.569D 01	1.683D-01	8.000D 01	3.108D-11	1.000D 00	1.026D-15
14	5	54250.00	2250.00	4.00184D 01	-8.101D 00	-2.217D 01	4.266D-02	8.000D 01	8.762D-09	1.000D 00	3.483D-13
14	6	54250.00	3000.00	4.00191D 01	1.006D 01	-2.925D 01	1.363D-02	8.000D 01	1.228D-06	1.000D 00	7.456D-11
14	7	54250.00	4000.00	4.00197D 01	3.079D 01	-3.576D 01	8.212D-04	8.000D 01	2.060D-04	1.000D 00	1.479D-08
15	1	54750.00	250.00	4.00186D 01	-2.197D 01	-2.054D 00	1.157D-01	8.000D 01	-3.122D-24	1.000D 00	1.674D-27
15	2	54750.00	750.00	4.00186D 01	-2.046D 01	-6.056D 00	1.067D-01	8.000D 01	-8.061D-21	1.000D 00	4.663D-24
15	3	54750.00	1250.00	4.00187D 01	-1.725D 01	-1.034D 01	1.026D-01	8.000D 01	1.126D-16	1.000D 00	5.942D-21
15	4	54750.00	1750.00	4.00187D 01	-1.201D 01	-1.509D 01	1.413D-01	8.000D 01	1.408D-13	1.000D 00	4.280D-18
15	5	54750.00	2250.00	4.00188D 01	-4.634D 00	-1.942D 01	1.079D-01	8.000D 01	4.457D-11	1.000D 00	1.819D-15
15	6	54750.00	3000.00	4.00191D 01	7.950D 00	-2.133D 01	1.253D-01	8.000D 01	8.502D-09	1.000D 00	4.894D-13
15	7	54750.00	4000.00	4.00190D 01	2.008D 01	-2.033D 01	1.527D-01	8.000D 01	1.884D-06	1.000D 00	1.225D-10
16	1	55250.00	250.00	4.00192D 01	-1.948D 01	-1.900D 00	1.228D-01	8.000D 01	-3.938D-27	1.000D 00	1.710D-30
16	2	55250.00	750.00	4.00192D 01	-1.793D 01	-5.507D 00	1.238D-01	8.000D 01	-1.289D-23	1.000D 00	6.604D-27
16	3	55250.00	1250.00	4.00192D 01	-1.477D 01	-9.025D 00	1.110D-01	8.000D 01	-1.713D-20	1.000D 00	1.092D-23
16	4	55250.00	1750.00	4.00193D 01	-1.005D 01	-1.232D 01	1.359D-01	8.000D 01	2.111D-16	1.000D 00	1.005D-20
16	5	55250.00	2250.00	4.00193D 01	-4.077D 00	-1.467D 01	1.105D-01	8.000D 01	1.221D-13	1.000D 00	5.558D-18
16	6	55250.00	3000.00	4.00193D 01	4.536D 00	-1.415D 01	1.850D-01	8.000D 01	3.163D-11	1.000D 00	1.937D-15
16	7	55250.00	4000.00	4.00191D 01	1.194D 01	-1.061D 01	1.470D-01	8.000D 01	9.281D-09	1.000D 00	6.174D-13

Table A.5 (continued)

ITER.= 118 TIME=5.900000D-01 PERIOD=4.758065D-02 TIME INCREMENT=5.000000D-03

NODE	INDICES	X-LOCATION	Y-LOCATION	WATER ELEVATION	VELOCITY IN X-DIRECT.	VELOCITY IN Y-DIRECT.	WATER ELEV. RATE OF CHANGE	TEMP.	TEMP. RATE OF CHANGE	SUBSTANCE MASS CONCENTRATIONS CK(1)	CK(2)
17	1	56000.00	250.00	4.00200D 01	-1.731D 01	-1.450D 00	1.308D-01	8.000D 01	-1.107D-30	1.000D 00	4.820D-34
17	2	56000.00	750.00	4.00200D 01	-1.601D 01	-4.170D 00	1.334D-01	8.000D 01	-4.791D-27	1.000D 00	2.512D-30
17	3	56000.00	1250.00	4.00200D 01	-1.346D 01	-6.645D 00	1.266D-01	8.000D 01	-8.296D-24	1.000D 00	5.595D-27
17	4	56000.00	1750.00	4.00200D 01	-9.857D 00	-8.642D 00	1.346D-01	8.000D 01	-7.449D-21	1.000D 00	6.977D-24
17	5	56000.00	2250.00	4.00200D 01	-5.701D 00	-9.739D 00	1.219D-01	8.000D 01	6.113D-17	1.000D 00	5.242D-21
17	6	56000.00	3000.00	4.00200D 01	-3.069D-01	-8.595D 00	1.479D-01	8.000D 01	2.998D-14	1.000D 00	2.449D-18
17	7	56000.00	4000.00	4.00198D 01	4.107D 00	-5.200D 00	1.437D-01	8.000D 01	1.346D-11	1.000D 00	1.028D-15
18	1	57000.00	250.00	4.00210D 01	-1.627D 01	-9.239D-01	1.369D-01	8.000D 01	-1.623D-34	1.000D 00	8.494D-38
18	2	57000.00	750.00	4.00210D 01	-1.536D 01	-2.638D 00	1.392D-01	8.000D 01	-9.268D-31	1.000D 00	5.910D-34
18	3	57000.00	1250.00	4.00210D 01	-1.362D 01	-4.101D 00	1.362D-01	8.000D 01	-2.083D-27	1.000D 00	1.765D-30
18	4	57000.00	1750.00	4.00210D 01	-1.131D 01	-5.125D 00	1.431D-01	8.000D 01	-2.351D-24	1.000D 00	2.931D-27
18	5	57000.00	2250.00	4.00210D 01	-8.876D 00	-5.519D 00	1.395D-01	8.000D 01	-1.374D-21	1.000D 00	2.873D-24
18	6	57000.00	3000.00	4.00210D 01	-6.015D 00	-4.572D 00	1.541D-01	8.000D 01	-2.335D-19	1.000D 00	1.698D-21
18	7	57000.00	4000.00	4.00209D 01	-3.767D 00	-2.323D 00	1.544D-01	8.000D 01	7.975D-16	1.000D 00	9.211D-19
19	1	58000.00	250.00	4.00222D 01	-1.725D 01	-5.631D-01	1.557D-01	8.000D 01	-1.660D-38	1.000D 00	1.143D-41
19	2	58000.00	750.00	4.00222D 01	-1.665D 01	-1.586D 00	1.571D-01	8.000D 01	-1.195D-34	1.000D 00	1.005D-37
19	3	58000.00	1250.00	4.00222D 01	-1.554D 01	-2.426D 00	1.562D-01	8.000D 01	-3.351D-31	1.000D 00	3.835D-34
19	4	58000.00	1750.00	4.00221D 01	-1.413D 01	-2.960D 00	1.599D-01	8.000D 01	-4.616D-28	1.000D 00	8.096D-31
19	5	58000.00	2250.00	4.00221D 01	-1.273D 01	-3.110D 00	1.589D-01	8.000D 01	-3.240D-25	1.000D 00	9.925D-28
19	6	58000.00	3000.00	4.00221D 01	-1.117D 01	-2.509D 00	1.639D-01	8.000D 01	-6.669D-23	1.000D 00	7.185D-25
19	7	58000.00	4000.00	4.00221D 01	-9.972D 00	-1.191D 00	1.621D-01	8.000D 01	4.775D-22	1.000D 00	4.748D-22
20	1	59000.00	250.00	4.00234D 01	-1.977D 01	-3.302D-01	1.716D-01	8.000D 01	-1.096D-42	1.000D 00	1.065D-45
20	2	59000.00	750.00	4.00234D 01	-1.938D 01	-9.192D-01	1.725D-01	8.000D 01	-9.739D-39	1.000D 00	1.146D-41
20	3	59000.00	1250.00	4.00234D 01	-1.869D 01	-1.389D 00	1.721D-01	8.000D 01	-3.350D-35	1.000D 00	5.453D-38
20	4	59000.00	1750.00	4.00234D 01	-1.783D 01	-1.668D 00	1.742D-01	8.000D 01	-5.574D-32	1.000D 00	1.431D-34
20	5	59000.00	2250.00	4.00234D 01	-1.701D 01	-1.725D 00	1.741D-01	8.000D 01	-4.726D-29	1.000D 00	2.157D-31
20	6	59000.00	3000.00	4.00234D 01	-1.613D 01	-1.375D 00	1.770D-01	8.000D 01	-1.151D-26	1.000D 00	1.913D-28
20	7	59000.00	4000.00	4.00234D 01	-1.544D 01	-6.417D-01	1.766D-01	8.000D 01	2.186D-25	1.000D 00	1.522D-25
21	1	60000.00	250.00	4.00247D 01	-2.336D 01	-1.823D-01	1.872D-01	8.000D 01	-7.985D-42	1.000D 00	5.984D-46
21	2	60000.00	750.00	4.00247D 01	-2.311D 01	-5.035D-01	1.878D-01	8.000D 01	-5.216D-43	1.000D 00	8.084D-46
21	3	60000.00	1250.00	4.00247D 01	-2.267D 01	-7.548D-01	1.878D-01	8.000D 01	-1.935D-39	1.000D 00	4.716D-42
21	4	60000.00	1750.00	4.00247D 01	-2.214D 01	-8.965D-01	1.891D-01	8.000D 01	-3.905D-36	1.000D 00	1.537D-38
21	5	60000.00	2250.00	4.00247D 01	-2.164D 01	-9.174D-01	1.895D-01	8.000D 01	-4.007D-33	1.000D 00	2.845D-35
21	6	60000.00	3000.00	4.00247D 01	-2.111D 01	-7.262D-01	1.912D-01	8.000D 01	-1.139D-30	1.000D 00	3.084D-32
21	7	60000.00	4000.00	4.00247D 01	-2.071D 01	-3.359D-01	1.915D-01	8.000D 01	5.460D-29	1.000D 00	2.936D-29
22	1	61000.00	250.00	4.00261D 01	-2.777D 01	-8.652D-02	2.032D-01	8.000D 01	-4.371D-38	1.000D 00	3.925D-42
22	2	61000.00	750.00	4.00261D 01	-2.760D 01	-2.387D-01	2.036D-01	8.000D 01	-3.746D-40	1.000D 00	3.199D-44
22	3	61000.00	1250.00	4.00261D 01	-2.731D 01	-3.559D-01	2.037D-01	8.000D 01	-2.037D-42	1.000D 00	3.725D-46
22	4	61000.00	1750.00	4.00261D 01	-2.695D 01	-4.195D-01	2.046D-01	8.000D 01	-1.296D-40	1.000D 00	8.902D-43
22	5	61000.00	2250.00	4.00261D 01	-2.662D 01	-4.274D-01	2.051D-01	8.000D 01	-1.623D-37	1.000D 00	2.054D-39
22	6	61000.00	3000.00	4.00261D 01	-2.628D 01	-3.367D-01	2.061D-01	8.000D 01	-5.201D-35	1.000D 00	2.745D-36
22	7	61000.00	4000.00	4.00261D 01	-2.602D 01	-1.524D-01	2.066D-01	8.000D 01	7.152D-33	1.000D 00	3.121D-33
23	1	62000.00	250.00	4.00276D 01	-3.287D 01	-1.882D-02	2.195D-01	8.000D 01	-1.686D-34	1.000D 00	1.809D-38
23	2	62000.00	750.00	4.00276D 01	-3.274D 01	-5.411D-02	2.197D-01	8.000D 01	-1.549D-36	1.000D 00	1.558D-40
23	3	62000.00	1250.00	4.00276D 01	-3.250D 01	-8.056D-02	2.199D-01	8.000D 01	-9.067D-39	1.000D 00	8.332D-43
23	4	62000.00	1750.00	4.00276D 01	-3.222D 01	-9.515D-02	2.205D-01	8.000D 01	-1.802D-41	1.000D 00	1.537D-45
23	5	62000.00	2250.00	4.00276D 01	-3.196D 01	-9.780D-02	2.210D-01	8.000D 01	-1.311D-42	1.000D 00	6.421D-44
23	6	62000.00	3000.00	4.00276D 01	-3.170D 01	-7.680D-02	2.215D-01	8.000D 01	-2.877D-40	1.000D 00	1.114D-40
23	7	62000.00	4000.00	4.00276D 01	-3.150D 01	-2.963D-02	2.222D-01	8.000D 01	4.225D-37	1.000D 00	1.542D-37
24	1	63000.00	250.00	4.00292D 01	-3.860D 01	3.812D-02	2.360D-01	8.000D 01	-4.643D-31	1.000D 00	5.918D-35
24	2	63000.00	750.00	4.00292D 01	-3.846D 01	9.907D-02	2.361D-01	8.000D 01	-4.649D-33	1.000D 00	5.460D-37
24	3	63000.00	1250.00	4.00292D 01	-3.822D 01	1.458D-01	2.363D-01	8.000D 01	-3.038D-35	1.000D 00	3.217D-39
24	4	63000.00	1750.00	4.00292D 01	-3.793D 01	1.686D-01	2.367D-01	8.000D 01	-6.694D-38	1.000D 00	6.443D-42
24	5	63000.00	2250.00	4.00292D 01	-3.767D 01	1.663D-01	2.372D-01	8.000D 01	-1.332D-40	1.000D 00	1.193D-44
24	6	63000.00	3000.00	4.00292D 01	-3.741D 01	1.292D-01	2.373D-01	8.000D 01	-5.823D-44	1.000D 00	1.275D-45
24	7	63000.00	4000.00	4.00292D 01	-3.722D 01	6.719D-02	2.382D-01	8.000D 01	7.258D-42	1.000D 00	2.258D-42

Table A.5 (continued)

ITER.= 118   TIME=5.900000D-01   PERIOD=4.758065D-02   TIME INCREMENT=5.000000D-03

NODE	INDI-CES	X-LOCATION	Y-LOCATION	WATER ELEVATION	VELOCITY IN X-DIRECT.	VELOCITY IN Y-DIRECT.	WATER ELEV. RATE OF CHANGE	TEMP.	TEMP. RATE OF CHANGE	SUBSTANCE MASS CONCENTRATIONS CK(1)	CK(2)
25	1	64000.00	250.00	4.00308D 01	-4.493D 01	9.695D-02	2.526D-01	8.000D 01	-9.315D-28	1.000D 00	1.394D-31
25	2	64000.00	750.00	4.00308D 01	-4.475D 01	2.554D-01	2.526D-01	8.000D 01	-1.032D-29	1.000D 00	1.401D-33
25	3	64000.00	1250.00	4.00308D 01	-4.445D 01	3.743D-01	2.528D-01	8.000D 01	-7.610D-32	1.000D 00	9.214D-36
25	4	64000.00	1750.00	4.00308D 01	-4.408D 01	4.303D-01	2.531D-01	8.000D 01	-1.866D-34	1.000D 00	2.044D-38
25	5	64000.00	2250.00	4.00308D 01	-4.376D 01	4.235D-01	2.536D-01	8.000D 01	-4.022D-37	1.000D 00	4.098D-41
25	6	64000.00	3000.00	4.00308D 01	-4.344D 01	3.261D-01	2.534D-01	8.000D 01	-2.012D-40	1.000D 00	1.929D-44
25	7	64000.00	4000.00	4.00308D 01	-4.321D 01	1.578D-01	2.545D-01	8.000D 01	-4.234D-44	1.000D 00	5.042D-48
26	1	65000.00	250.00	4.00325D 01	-5.191D 01	1.690D-01	2.694D-01	8.000D 01	-1.397D-24	1.000D 00	2.412D-28
26	2	65000.00	750.00	4.00325D 01	-5.165D 01	4.383D-01	2.692D-01	8.000D 01	-1.731D-26	1.000D 00	2.683D-30
26	3	65000.00	1250.00	4.00325D 01	-5.120D 01	6.349D-01	2.694D-01	8.000D 01	-1.447D-28	1.000D 00	1.993D-32
26	4	65000.00	1750.00	4.00325D 01	-5.068D 01	7.199D-01	2.698D-01	8.000D 01	-3.956D-31	1.000D 00	4.921D-35
26	5	65000.00	2250.00	4.00325D 01	-5.022D 01	6.989D-01	2.704D-01	8.000D 01	-9.223D-34	1.000D 00	1.069D-37
26	6	65000.00	3000.00	4.00325D 01	-4.979D 01	5.302D-01	2.699D-01	8.000D 01	-4.942D-37	1.000D 00	5.377D-41
26	7	65000.00	4000.00	4.00325D 01	-4.947D 01	2.478D-01	2.712D-01	8.000D 01	-1.094D-40	1.000D 00	1.136D-44
27	1	66000.00	250.00	4.00344D 01	-5.958D 01	2.627D-01	2.864D-01	8.000D 01	-1.621D-21	1.000D 00	3.142D-25
27	2	66000.00	750.00	4.00344D 01	-5.917D 01	6.522D-01	2.871D-01	8.000D 01	-2.230D-23	1.000D 00	3.911D-27
27	3	66000.00	1250.00	4.00343D 01	-5.848D 01	9.192D-01	2.867D-01	8.000D 01	-2.112D-25	1.000D 00	3.302D-29
27	4	66000.00	1750.00	4.00343D 01	-5.770D 01	1.011D 00	2.870D-01	8.000D 01	-6.432D-28	1.000D 00	9.100D-32
27	5	66000.00	2250.00	4.00343D 01	-5.704D 01	9.553D-01	2.876D-01	8.000D 01	-1.621D-30	1.000D 00	2.143D-34
27	6	66000.00	3000.00	4.00343D 01	-5.644D 01	7.067D-01	2.868D-01	8.000D 01	-9.333D-34	1.000D 00	1.154D-37
27	7	66000.00	4000.00	4.00343D 01	-5.601D 01	3.194D-01	2.885D-01	8.000D 01	-2.179D-37	1.000D 00	2.562D-41
28	1	67000.00	250.00	4.00363D 01	-6.798D 01	3.438D-01	3.014D-01	8.000D 01	-1.506D-18	1.000D 00	3.182D-22
28	2	67000.00	750.00	4.00363D 01	-6.733D 01	8.396D-01	3.051D-01	8.000D 01	-2.240D-20	1.000D 00	4.411D-24
28	3	67000.00	1250.00	4.00362D 01	-6.624D 01	1.136D 00	3.039D-01	8.000D 01	-2.377D-22	1.000D 00	4.232D-26
28	4	67000.00	1750.00	4.00362D 01	-6.508D 01	1.166D 00	3.043D-01	8.000D 01	-8.054D-25	1.000D 00	1.302D-28
28	5	67000.00	2250.00	4.00362D 01	-6.416D 01	1.023D 00	3.037D-01	8.000D 01	-2.195D-27	1.000D 00	3.324D-31
28	6	67000.00	3000.00	4.00362D 01	-6.340D 01	7.154D-01	3.028D-01	8.000D 01	-1.363D-30	1.000D 00	1.921D-34
28	7	67000.00	4000.00	4.00361D 01	-6.288D 01	3.129D-01	3.055D-01	8.000D 01	-3.372D-34	1.000D 00	4.496D-38
29	1	68000.00	250.00	4.00384D 01	-7.683D 01	4.070D-01	3.125D-01	8.000D 01	3.025D-14	1.000D 00	2.597D-19
29	2	68000.00	750.00	4.00384D 01	-7.572D 01	7.627D-01	2.894D-01	8.000D 01	2.665D-16	1.000D 00	3.902D-21
29	3	68000.00	1250.00	4.00383D 01	-7.409D 01	8.972D-01	3.023D-01	8.000D 01	-2.062D-19	1.000D 00	4.222D-23
29	4	68000.00	1750.00	4.00382D 01	-7.258D 01	7.114D-01	3.199D-01	8.000D 01	-7.771D-22	1.000D 00	1.449D-25
29	5	68000.00	2250.00	4.00382D 01	-7.151D 01	4.125D-01	3.204D-01	8.000D 01	-2.294D-24	1.000D 00	4.011D-28
29	6	68000.00	3000.00	4.00381D 01	-7.075D 01	1.742D-01	3.176D-01	8.000D 01	-1.547D-27	1.000D 00	2.500D-31
29	7	68000.00	4000.00	4.00380D 01	-7.028D 01	8.563D-02	3.245D-01	8.000D 01	-4.080D-31	1.000D 00	6.194D-35
30	1	69000.00	250.00	4.00407D 01	-8.580D 01	1.034D 00	3.497D-01	8.000D 01	1.861D-11	1.000D 00	1.746D-16
30	2	69000.00	750.00	4.00407D 01	-8.379D 01	-5.129D-01	3.184D-01	8.000D 01	2.892D-13	1.000D 00	2.746D-18
30	3	69000.00	1250.00	4.00406D 01	-8.151D 01	-1.623D 00	3.070D-01	8.000D 01	3.359D-15	1.000D 00	3.303D-20
30	4	69000.00	1750.00	4.00403D 01	-8.005D 01	-2.202D 00	3.507D-01	8.000D 01	-5.744D-19	1.000D 00	1.263D-22
30	5	69000.00	2250.00	4.00401D 01	-7.934D 01	-2.362D 00	3.577D-01	8.000D 01	-1.847D-21	1.000D 00	3.787D-25
30	6	69000.00	3000.00	4.00400D 01	-7.905D 01	-1.885D 00	3.536D-01	8.000D 01	-1.369D-24	1.000D 00	2.567D-28
30	7	69000.00	4000.00	4.00399D 01	-7.896D 01	-6.955D-01	3.543D-01	8.000D 01	-3.883D-28	1.000D 00	6.789D-32
31	1	70000.00	250.00	4.00418D 01	-9.869D 01	-1.633D 00	8.329D-01	8.000D 01	9.376D-09	1.000D 00	9.498D-14
31	2	70000.00	750.00	4.00419D 01	-9.355D 01	-6.673D 00	8.121D-01	8.000D 01	1.367D-10	1.000D 00	1.534D-15
31	3	70000.00	1250.00	4.00420D 01	-8.980D 01	-1.016D 01	5.764D-01	8.000D 01	1.891D-12	1.000D 00	2.029D-17
31	4	70000.00	1750.00	4.00421D 01	-8.889D 01	-1.107D 01	3.688D-01	8.000D 01	8.382D-15	1.000D 00	8.603D-20
31	5	70000.00	2250.00	4.00419D 01	-8.916D 01	-1.000D 01	3.908D-01	8.000D 01	-1.146D-18	1.000D 00	2.773D-22
31	6	70000.00	3000.00	4.00418D 01	-8.983D 01	-6.941D 00	3.727D-01	8.000D 01	-9.387D-22	1.000D 00	2.050D-25
31	7	70000.00	4000.00	4.00417D 01	-9.032D 01	-2.199D 00	3.644D-01	8.000D 01	-2.880D-25	1.000D 00	5.797D-29
32	1	70750.00	250.00	4.00495D 01	-8.681D 01	-7.857D 00	-2.950D 00	8.000D 01	2.417D-06	1.000D 00	3.951D-11
32	2	70750.00	750.00	4.00447D 01	-8.930D 01	-1.567D 01	-6.007D-01	8.000D 01	4.537D-08	1.000D 00	6.601D-13
32	3	70750.00	1250.00	4.00435D 01	-9.262D 01	-2.141D 01	6.189D-02	8.000D 01	6.831D-10	1.000D 00	9.345D-15
32	4	70750.00	1750.00	4.00438D 01	-9.565D 01	-2.218D 01	2.428D-01	8.000D 01	3.644D-12	1.000D 00	4.392D-17
32	5	70750.00	2250.00	4.00436D 01	-9.810D 01	-1.926D 01	2.210D-01	8.000D 01	1.370D-14	1.000D 00	1.508D-19
32	6	70750.00	3000.00	4.00433D 01	-9.999D 01	-1.277D 01	3.034D-01	8.000D 01	-4.761D-19	1.000D 00	1.221D-22
32	7	70750.00	4000.00	4.00432D 01	-1.011D 02	-3.593D 00	3.523D-01	8.000D 01	-1.597D-22	1.000D 00	3.714D-26

Table A.5 (continued)

ITER.= 118   TIME=5.900000D-01   PERIOD=4.758065D-02   TIME INCREMENT=5.000000D-03

NODE	INDI-CES	X-LOCATION	Y-LOCATION	WATER ELEVATION	VELOCITY IN X-DIRECT.	VELOCITY IN Y-DIRECT.	WATER ELEV. RATE OF CHANGE	TEMP.	TEMP. RATE OF CHANGE	SUBSTANCE MASS CONCENTRATIONS CK(1)	CK(2)
33	1	71250.00	250.00	4.00447D 01	-7.628D 01	-1.016D 02	2.759D 00	8.000D 01	2.939D-04	1.000D 00	9.207D-09
33	2	71250.00	750.00	4.00439D 01	-8.953D 01	-7.606D 01	2.746D 00	8.000D 01	5.822D-06	1.000D 00	1.292D-10
33	3	71250.00	1250.00	4.00438D 01	-1.009D 02	-5.521D 01	2.020D 00	8.000D 01	9.371D-08	1.000D 00	1.746D-12
33	4	71250.00	1750.00	4.00440D 01	-1.062D 02	-4.063D 01	1.078D 00	8.000D 01	5.682D-10	1.000D 00	8.686D-15
33	5	71250.00	2250.00	4.00442D 01	-1.088D 02	-3.019D 01	7.400D-01	8.000D 01	2.419D-12	1.000D 00	3.198D-17
33	6	71250.00	3000.00	4.00443D 01	-1.102D 02	-1.839D 01	4.313D-01	8.000D 01	1.826D-15	1.000D 00	2.861D-20
33	7	71250.00	4000.00	4.00443D 01	-1.109D 02	-4.756D 00	4.289D-01	8.000D 01	-3.476D-20	1.000D 00	9.485D-24
34	1	71750.00	250.00	4.00326D 01	-1.523D 02	-1.832D 02	8.219D-01	8.000D 01	1.801D-02	1.000D 00	8.845D-07
34	2	71750.00	750.00	4.00413D 01	-1.444D 02	-1.267D 02	-3.979D 00	8.000D 01	3.937D-04	1.000D 00	1.313D-08
34	3	71750.00	1250.00	4.00438D 01	-1.372D 02	-7.968D 01	-2.618D 00	8.000D 01	7.842D-06	1.000D 00	1.966D-10
34	4	71750.00	1750.00	4.00439D 01	-1.318D 02	-5.019D 01	-4.171D-01	8.000D 01	5.970D-08	1.000D 00	1.151D-12
34	5	71750.00	2250.00	4.00446D 01	-1.277D 02	-3.368D 01	-4.278D-02	8.000D 01	2.989D-10	1.000D 00	4.860D-15
34	6	71750.00	3000.00	4.00452D 01	-1.246D 02	-1.943D 01	3.284D-01	8.000D 01	3.646D-13	1.000D 00	5.035D-18
34	7	71750.00	4000.00	4.00454D 01	-1.226D 02	-5.047D 00	3.143D-01	8.000D 01	-5.515D-18	1.000D 00	1.877D-21
35	1	72250.00	250.00	4.00415D 01	-2.498D 02	-6.804D 01	5.153D 00	8.004D 01	3.012D-01	1.000D 00	2.036D-05
35	2	72250.00	750.00	4.00453D 01	-2.083D 02	-5.187D 01	3.998D 00	8.000D 01	1.270D-02	1.000D 00	5.277D-07
35	3	72250.00	1250.00	4.00464D 01	-1.744D 02	-3.714D 01	2.349D 00	8.000D 01	3.579D-04	1.000D 00	1.159D-08
35	4	72250.00	1750.00	4.00462D 01	-1.563D 02	-2.487D 01	7.802D-01	8.000D 01	3.860D-06	1.000D 00	9.588D-11
35	5	72250.00	2250.00	4.00464D 01	-1.452D 02	-1.650D 01	8.630D-01	8.000D 01	2.477D-08	1.000D 00	5.092D-13
35	6	72250.00	3000.00	4.00466D 01	-1.378D 02	-9.758D 00	5.152D-01	8.000D 01	3.757D-11	1.000D 00	6.497D-16
35	7	72250.00	4000.00	4.00467D 01	-1.330D 02	-3.000D 00	4.523D-01	8.000D 01	1.766D-14	1.000D 00	2.831D-19
36	1	72750.00	250.00	4.00712D 01	-2.466D 02	5.652D 01	-9.898D 00	8.054D 01	2.468D 00	9.997D-01	2.512D-04
36	2	72750.00	750.00	4.00517D 01	-2.062D 02	5.875D 01	-1.282D 00	8.003D 01	2.138D-01	1.000D 00	1.362D-05
36	3	72750.00	1250.00	4.00481D 01	-1.753D 02	3.365D 01	-1.854D-01	8.000D 01	9.570D-03	1.000D 00	4.617D-07
36	4	72750.00	1750.00	4.00491D 01	-1.597D 02	1.479D 01	-5.393D-01	8.000D 01	1.504D-04	1.000D 00	5.701D-09
36	5	72750.00	2250.00	4.00485D 01	-1.499D 02	8.680D 00	-1.001D-01	8.000D 01	1.344D-06	1.000D 00	3.888D-11
36	6	72750.00	3000.00	4.00481D 01	-1.435D 02	3.889D 00	3.354D-01	8.000D 01	2.688D-09	1.000D 00	6.245D-14
36	7	72750.00	4000.00	4.00479D 01	-1.390D 02	9.358D-02	3.738D-01	8.000D 01	1.619D-12	1.000D 00	3.241D-17
37	1	73250.00	250.00	4.00935D 01	-1.438D 02	7.767D 01	8.853D 00	8.602D 01	7.295D 00	9.972D-01	2.808D-03
37	2	73250.00	750.00	4.00564D 01	-1.460D 02	1.052D 02	-3.260D 00	8.051D 01	1.766D 00	9.998D-01	2.400D-04
37	3	73250.00	1250.00	4.00492D 01	-1.469D 02	7.194D 01	3.865D 00	8.003D 01	1.508D-01	1.000D 00	1.189D-05
37	4	73250.00	1750.00	4.00511D 01	-1.456D 02	3.889D 01	1.014D 00	8.000D 01	3.490D-03	1.000D 00	2.108D-07
37	5	73250.00	2250.00	4.00501D 01	-1.438D 02	2.512D 01	1.170D 00	8.000D 01	4.009D-05	1.000D 00	1.880D-09
37	6	73250.00	3000.00	4.00495D 01	-1.420D 02	1.324D 01	2.525D-01	8.000D 01	8.578D-08	1.000D 00	3.561D-12
37	7	73250.00	4000.00	4.00492D 01	-1.407D 02	2.427D 00	4.818D-01	8.000D 01	7.930D-11	1.000D 00	2.356D-15
38	1	73750.00	250.00	4.00672D 01	-6.242D 01	6.555D 01	-7.217D 00	8.010D 01	-5.640D-03	1.000D 00	4.553D-05
38	2	73750.00	750.00	4.00529D 01	-9.819D 01	7.598D 01	-8.915D-02	8.000D 01	1.079D-02	1.000D 00	1.710D-06
38	3	73750.00	1250.00	4.00507D 01	-1.225D 02	5.529D 01	2.437D-01	8.000D 01	3.199D-04	1.000D 00	3.167D-08
38	4	73750.00	1750.00	4.00515D 01	-1.318D 02	3.629D 01	-4.706D-01	8.000D 01	4.124D-06	1.000D 00	2.860D-10
38	5	73750.00	2250.00	4.00509D 01	-1.366D 02	2.715D 01	4.482D-02	8.000D 01	3.477D-08	1.000D 00	1.534D-12
38	6	73750.00	3000.00	4.00507D 01	-1.389D 02	1.600D 01	4.248D-01	8.000D 01	7.794D-11	1.000D 00	2.606D-15
38	7	73750.00	4000.00	4.00506D 01	-1.405D 02	3.560D 00	4.092D-01	8.000D 01	5.584D-14	1.000D 00	1.578D-18
39	1	74250.00	250.00	4.00464D 01	-7.741D 01	3.573D 01	2.929D 00	8.000D 01	-6.707D-04	1.000D 00	1.545D-06
39	2	74250.00	750.00	4.00510D 01	-1.022D 02	3.214D 01	1.526D 00	8.000D 01	2.022D-04	1.000D 00	3.173D-08
39	3	74250.00	1250.00	4.00523D 01	-1.205D 02	2.846D 01	7.681D-01	8.000D 01	3.522D-06	1.000D 00	3.265D-10
39	4	74250.00	1750.00	4.00519D 01	-1.290D 02	2.562D 01	1.718D-01	8.000D 01	3.685D-08	1.000D 00	2.302D-12
39	5	74250.00	2250.00	4.00518D 01	-1.346D 02	2.189D 01	5.622D-01	8.000D 01	2.442D-10	1.000D 00	1.114D-14
39	6	74250.00	3000.00	4.00519D 01	-1.384D 02	1.422D 01	4.864D-01	8.000D 01	4.690D-13	1.000D 00	1.742D-17
39	7	74250.00	4000.00	4.00519D 01	-1.409D 02	3.873D 00	4.498D-01	8.000D 01	3.074D-16	1.000D 00	1.117D-20
40	1	74750.00	250.00	4.00537D 01	-1.132D 02	1.173D 01	8.231D-01	8.000D 01	-3.162D-06	1.000D 00	6.536D-09
40	2	74750.00	750.00	4.00540D 01	-1.198D 02	1.681D 01	-3.576D-01	8.000D 01	2.133D-07	1.000D 00	7.353D-11
40	3	74750.00	1250.00	4.00537D 01	-1.267D 02	2.006D 01	1.090D-01	8.000D 01	5.814D-09	1.000D 00	5.803D-13
40	4	74750.00	1750.00	4.00534D 01	-1.322D 02	1.959D 01	6.137D-01	8.000D 01	5.275D-11	1.000D 00	3.368D-15
40	5	74750.00	2250.00	4.00534D 01	-1.366D 02	1.651D 01	4.862D-01	8.000D 01	2.582D-13	1.000D 00	1.372D-17
40	6	74750.00	3000.00	4.00534D 01	-1.400D 02	1.115D 01	4.251D-01	8.000D 01	3.641D-16	1.000D 00	1.878D-20
40	7	74750.00	4000.00	4.00534D 01	-1.422D 02	3.812D 00	4.368D-01	8.000D 01	-1.115D-20	1.000D 00	1.103D-23

Table A.5 (continued)

ITER.= 118 TIME=5.900000D-01 PERIOD=4.758065D-02 TIME INCREMENT=5.000000D-03

NODE	INDI-CES	X-LOCATION	Y-LOCATION	WATER ELEVATION	VELOCITY IN X-DIRECT.	VELOCITY IN Y-DIRECT.	WATER ELEV. RATE OF CHANGE	TEMP.	TEMP. RATE OF CHANGE	SUBSTANCE MASS CONCENTRATIONS CK(1)	CK(2)
41	1	75250.00	250.00	4.00550D 01	-1.266D 02	2.820D 00	4.349D-01	8.000D 01	-3.840D-09	1.000D 00	8.790D-12
41	2	75250.00	750.00	4.00548D 01	-1.287D 02	9.152D 00	2.935D-01	8.000D 01	2.077D-10	1.000D 00	7.020D-14
41	3	75250.00	1250.00	4.00547D 01	-1.326D 02	1.281D 01	4.961D-01	8.000D 01	3.223D-12	1.000D 00	4.448D-16
41	4	75250.00	1750.00	4.00547D 01	-1.369D 02	1.298D 01	5.128D-01	8.000D 01	2.425D-14	1.000D 00	2.105D-18
41	5	75250.00	2250.00	4.00548D 01	-1.401D 02	1.135D 01	4.614D-01	8.000D 01	8.272D-17	1.000D 00	6.964D-21
41	6	75250.00	3000.00	4.00548D 01	-1.427D 02	8.085D 00	4.292D-01	8.000D 01	-5.441D-21	1.000D 00	7.779D-24
41	7	75250.00	4000.00	4.00548D 01	-1.445D 02	3.233D 00	4.533D-01	8.000D 01	-3.487D-24	1.000D 00	3.965D-27
42	1	75750.00	250.00	4.00562D 01	-1.365D 02	2.381D 00	3.773D-01	8.000D 01	-4.609D-12	1.000D 00	1.042D-14
42	2	75750.00	750.00	4.00561D 01	-1.376D 02	5.513D 00	5.653D-01	8.000D 01	1.659D-13	1.000D 00	5.704D-17
42	3	75750.00	1250.00	4.00561D 01	-1.399D 02	7.489D 00	4.993D-01	8.000D 01	1.622D-15	1.000D 00	2.601D-19
42	4	75750.00	1750.00	4.00562D 01	-1.426D 02	8.038D 00	4.415D-01	8.000D 01	6.393D-20	1.000D 00	8.994D-22
42	5	75750.00	2250.00	4.00562D 01	-1.447D 02	7.551D 00	4.436D-01	8.000D 01	-1.052D-21	1.000D 00	2.227D-24
42	6	75750.00	3000.00	4.00562D 01	-1.465D 02	5.596D 00	4.587D-01	8.000D 01	-1.191D-24	1.000D 00	1.901D-27
42	7	75750.00	4000.00	4.00562D 01	-1.479D 02	2.362D 00	4.594D-01	8.000D 01	-5.894D-28	1.000D 00	7.603D-31
43	1	76250.00	250.00	4.00576D 01	-1.449D 02	1.444D 00	4.659D-01	8.000D 01	-2.136D-15	1.000D 00	8.837D-18
43	2	76250.00	750.00	4.00576D 01	-1.457D 02	3.186D 00	4.948D-01	8.000D 01	7.795D-17	1.000D 00	3.588D-20
43	3	76250.00	1250.00	4.00576D 01	-1.470D 02	4.429D 00	4.666D-01	8.000D 01	-1.849D-20	1.000D 00	1.123D-22
43	4	76250.00	1750.00	4.00576D 01	-1.486D 02	4.979D 00	4.552D-01	8.000D 01	-7.673D-23	1.000D 00	2.700D-25
43	5	76250.00	2250.00	4.00576D 01	-1.499D 02	4.850D 00	4.691D-01	8.000D 01	-1.984D-25	1.000D 00	4.788D-28
43	6	76250.00	3000.00	4.00576D 01	-1.511D 02	3.657D 00	4.664D-01	8.000D 01	-1.626D-28	1.000D 00	2.965D-31
43	7	76250.00	4000.00	4.00576D 01	-1.521D 02	1.588D 00	4.670D-01	8.000D 01	-5.970D-32	1.000D 00	6.696D-35
44	1	76750.00	250.00	4.00590D 01	-1.524D 02	6.927D-01	4.829D-01	8.000D 01	2.009D-18	1.000D 00	5.397D-21
44	2	76750.00	750.00	4.00591D 01	-1.528D 02	1.773D 00	4.743D-01	8.000D 01	-5.968D-22	1.000D 00	1.611D-23
44	3	76750.00	1250.00	4.00591D 01	-1.537D 02	2.583D 00	4.730D-01	8.000D 01	-4.595D-24	1.000D 00	3.546D-26
44	4	76750.00	1750.00	4.00591D 01	-1.546D 02	2.970D 00	4.759D-01	8.000D 01	-1.391D-26	1.000D 00	5.912D-29
44	5	76750.00	2250.00	4.00591D 01	-1.555D 02	2.926D 00	4.778D-01	8.000D 01	-2.548D-29	1.000D 00	7.290D-32
44	6	76750.00	3000.00	4.00591D 01	-1.564D 02	2.232D 00	4.756D-01	8.000D 01	-9.748D-32	1.000D 00	4.151D-35
44	7	76750.00	4000.00	4.00591D 01	-1.570D 02	9.903D-01	4.758D-01	8.000D 01	-8.389D-32	1.000D 00	1.031D-35
45	1	77250.00	250.00	4.00605D 01	-1.592D 02	3.212D-01	4.873D-01	8.000D 01	6.669D-23	1.000D 00	2.566D-24
45	2	77250.00	750.00	4.00605D 01	-1.595D 02	9.481D-01	4.813D-01	8.000D 01	-9.252D-26	1.000D 00	5.776D-27
45	3	77250.00	1250.00	4.00605D 01	-1.601D 02	1.414D 00	4.849D-01	8.000D 01	-8.455D-28	1.000D 00	9.008D-30
45	4	77250.00	1750.00	4.00605D 01	-1.607D 02	1.637D 00	4.855D-01	8.000D 01	-2.530D-29	1.000D 00	1.344D-32
45	5	77250.00	2250.00	4.00605D 01	-1.613D 02	1.624D 00	4.852D-01	8.000D 01	-2.372D-29	1.000D 00	3.226D-33
45	6	77250.00	3000.00	4.00605D 01	-1.620D 02	1.253D 00	4.830D-01	8.000D 01	-2.400D-29	1.000D 00	3.260D-33
45	7	77250.00	4000.00	4.00605D 01	-1.624D 02	5.672D-01	4.845D-01	8.000D 01	-2.422D-29	1.000D 00	3.292D-33
46	1	77750.00	250.00	4.00620D 01	-1.658D 02	1.454D-01	4.959D-01	8.000D 01	2.166D-26	1.000D 00	1.017D-27
46	2	77750.00	750.00	4.00620D 01	-1.660D 02	4.597D-01	4.937D-01	8.000D 01	-5.824D-27	1.000D 00	2.701D-30
46	3	77750.00	1250.00	4.00620D 01	-1.664D 02	6.911D-01	4.951D-01	8.000D 01	-5.867D-27	1.000D 00	8.920D-31
46	4	77750.00	1750.00	4.00620D 01	-1.669D 02	8.025D-01	4.948D-01	8.000D 01	-5.914D-27	1.000D 00	8.979D-31
46	5	77750.00	2250.00	4.00620D 01	-1.674D 02	8.020D-01	4.942D-01	8.000D 01	-5.957D-27	1.000D 00	9.052D-31
46	6	77750.00	3000.00	4.00620D 01	-1.679D 02	6.240D-01	4.931D-01	8.000D 01	-6.002D-27	1.000D 00	9.128D-31
46	7	77750.00	4000.00	4.00620D 01	-1.682D 02	2.805D-01	4.936D-01	8.000D 01	-6.037D-27	1.000D 00	9.187D-31
47	1	78250.00	250.00	4.00635D 01	-1.722D 02	7.026D-02	5.025D-01	8.000D 01	-1.252D-24	1.000D 00	2.161D-28
47	2	78250.00	750.00	4.00635D 01	-1.724D 02	2.152D-01	5.027D-01	8.000D 01	-1.255D-24	1.000D 00	2.162D-28
47	3	78250.00	1250.00	4.00635D 01	-1.727D 02	3.210D-01	5.029D-01	8.000D 01	-1.259D-24	1.000D 00	2.171D-28
47	4	78250.00	1750.00	4.00635D 01	-1.731D 02	3.752D-01	5.021D-01	8.000D 01	-1.265D-24	1.000D 00	2.183D-28
47	5	78250.00	2250.00	4.00635D 01	-1.735D 02	3.804D-01	5.023D-01	8.000D 01	-1.270D-24	1.000D 00	2.193D-28
47	6	78250.00	3000.00	4.00635D 01	-1.740D 02	2.976D-01	5.023D-01	8.000D 01	-1.276D-24	1.000D 00	2.204D-28
47	7	78250.00	4000.00	4.00635D 01	-1.743D 02	1.260D-01	5.024D-01	8.000D 01	-1.280D-24	1.000D 00	2.212D-28
48	1	83500.00	250.00	4.00795D 01	-2.383D 02	2.788D-02	5.044D-01	8.000D 01	-2.243D-22	1.000D 00	4.486D-26
48	2	83500.00	750.00	4.00795D 01	-2.385D 02	8.369D-02	5.041D-01	8.000D 01	-2.245D-22	1.000D 00	4.490D-26
48	3	83500.00	1250.00	4.00795D 01	-2.388D 02	1.240D-01	5.044D-01	8.000D 01	-2.248D-22	1.000D 00	4.498D-26
48	4	83500.00	1750.00	4.00795D 01	-2.391D 02	1.459D-01	5.041D-01	8.000D 01	-2.253D-22	1.000D 00	4.508D-26
48	5	83500.00	2250.00	4.00795D 01	-2.394D 02	1.501D-01	5.041D-01	8.000D 01	-2.257D-22	1.000D 00	4.517D-26
48	6	83500.00	3000.00	4.00795D 01	-2.397D 02	1.183D-01	5.046D-01	8.000D 01	-2.261D-22	1.000D 00	4.525D-26
48	7	83500.00	4000.00	4.00795D 01	-2.400D 02	4.637D-02	5.045D-01	8.000D 01	-2.264D-22	1.000D 00	4.532D-26

Table A.5 (continued)

ITER.= 118 TIME=5.900000D-01 PERIOD=4.758065D-02 TIME INCREMENT=5.000000D-03

NODE	INDICES	X-LOCATION	Y-LOCATION	WATER ELEVATION	VELOCITY IN X-DIRECT.	VELOCITY IN Y-DIRECT.	WATER ELEV. RATE OF CHANGE	TEMP.	TEMP. RATE OF CHANGE	SUBSTANCE MASS CONCENTRATIONS CK(1)	CK(2)
49	1	93500.00	250.00	4.01111D 01	-3.685D 02	4.310D-03	5.399D-01	8.000D 01	-1.552D-16	1.000D 00	9.305D-23
49	2	93500.00	750.00	4.01111D 01	-3.686D 02	1.169D-02	5.399D-01	8.000D 01	-1.553D-16	1.000D 00	9.310D-23
49	3	93500.00	1250.00	4.01111D 01	-3.688D 02	1.713D-02	5.395D-01	8.000D 01	-1.553D-16	1.000D 00	9.317D-23
49	4	93500.00	1750.00	4.01111D 01	-3.690D 02	2.002D-02	5.392D-01	8.000D 01	-1.554D-16	1.000D 00	9.326D-23
49	5	93500.00	2250.00	4.01111D 01	-3.692D 02	2.067D-02	5.388D-01	8.000D 01	-1.554D-16	1.000D 00	9.334D-23
49	6	93500.00	3000.00	4.01111D 01	-3.694D 02	1.767D-02	5.383D-01	8.000D 01	-1.555D-16	1.000D 00	9.343D-23
49	7	93500.00	4000.00	4.01111D 01	-3.695D 02	1.001D-02	5.382D-01	8.000D 01	-1.555D-16	1.000D 00	9.349D-23
50	1	103500.00	250.00	4.01457D 01	-5.104D 02	4.921D-03	6.020D-01	8.000D 01	-2.042D-15	1.000D 00	1.152D-19
50	2	103500.00	750.00	4.01457D 01	-5.105D 02	7.326D-03	6.022D-01	8.000D 01	-2.042D-15	1.000D 00	1.152D-19
50	3	103500.00	1250.00	4.01457D 01	-5.106D 02	1.028D-02	6.020D-01	8.000D 01	-2.042D-15	1.000D 00	1.153D-19
50	4	103500.00	1750.00	4.01457D 01	-5.107D 02	1.176D-02	6.020D-01	8.000D 01	-2.043D-15	1.000D 00	1.153D-19
50	5	103500.00	2250.00	4.01457D 01	-5.108D 02	1.125D-02	6.019D-01	8.000D 01	-2.043D-15	1.000D 00	1.154D-19
50	6	103500.00	3000.00	4.01457D 01	-5.109D 02	1.098D-02	6.015D-01	8.000D 01	-2.044D-15	1.000D 00	1.154D-19
50	7	103500.00	4000.00	4.01457D 01	-5.110D 02	1.321D-02	6.018D-01	8.000D 01	-2.044D-15	1.000D 00	1.155D-19
51	1	113500.00	250.00	4.01844D 01	-6.705D 02	5.553D-03	6.884D-01	8.000D 01	-1.293D-12	1.000D 00	9.062D-17
51	2	113500.00	750.00	4.01844D 01	-6.705D 02	9.044D-03	6.885D-01	8.000D 01	-1.293D-12	1.000D 00	9.063D-17
51	3	113500.00	1250.00	4.01844D 01	-6.706D 02	1.316D-02	6.884D-01	8.000D 01	-1.293D-12	1.000D 00	9.064D-17
51	4	113500.00	1750.00	4.01844D 01	-6.707D 02	1.549D-02	6.885D-01	8.000D 01	-1.294D-12	1.000D 00	9.066D-17
51	5	113500.00	2250.00	4.01844D 01	-6.707D 02	1.519D-02	6.886D-01	8.000D 01	-1.294D-12	1.000D 00	9.068D-17
51	6	113500.00	3000.00	4.01844D 01	-6.708D 02	1.425D-02	6.884D-01	8.000D 01	-1.294D-12	1.000D 00	9.070D-17
51	7	113500.00	4000.00	4.01844D 01	-6.709D 02	1.570D-02	6.888D-01	8.000D 01	-1.294D-12	1.000D 00	9.072D-17
52	1	123500.00	250.00	4.02277D 01	-8.540D 02	4.502D-03	7.945D-01	8.000D 01	-5.411D-10	1.000D 00	4.629D-14
52	2	123500.00	750.00	4.02277D 01	-8.541D 02	7.556D-03	7.946D-01	8.000D 01	-5.411D-10	1.000D 00	4.629D-14
52	3	123500.00	1250.00	4.02277D 01	-8.541D 02	1.116D-02	7.945D-01	8.000D 01	-5.412D-10	1.000D 00	4.629D-14
52	4	123500.00	1750.00	4.02277D 01	-8.542D 02	1.331D-02	7.946D-01	8.000D 01	-5.412D-10	1.000D 00	4.630D-14
52	5	123500.00	2250.00	4.02277D 01	-8.542D 02	1.320D-02	7.947D-01	8.000D 01	-5.413D-10	1.000D 00	4.630D-14
52	6	123500.00	3000.00	4.02277D 01	-8.542D 02	1.239D-02	7.945D-01	8.000D 01	-5.413D-10	1.000D 00	4.631D-14
52	7	123500.00	4000.00	4.02277D 01	-8.543D 02	1.351D-02	7.949D-01	8.000D 01	-5.414D-10	1.000D 00	4.631D-14
53	1	133500.00	250.00	4.02755D 01	-1.065D 03	3.319D-03	9.153D-01	8.000D 01	-1.429D-07	1.000D 00	1.539D-11
53	2	133500.00	750.00	4.02755D 01	-1.065D 03	5.364D-03	9.154D-01	8.000D 01	-1.429D-07	1.000D 00	1.539D-11
53	3	133500.00	1250.00	4.02755D 01	-1.065D 03	7.936D-03	9.154D-01	8.000D 01	-1.429D-07	1.000D 00	1.539D-11
53	4	133500.00	1750.00	4.02754D 01	-1.065D 03	9.505D-03	9.155D-01	8.000D 01	-1.429D-07	1.000D 00	1.539D-11
53	5	133500.00	2250.00	4.02754D 01	-1.065D 03	9.441D-03	9.155D-01	8.000D 01	-1.429D-07	1.000D 00	1.539D-11
53	6	133500.00	3000.00	4.02754D 01	-1.065D 03	9.032D-03	9.154D-01	8.000D 01	-1.429D-07	1.000D 00	1.539D-11
53	7	133500.00	4000.00	4.02754D 01	-1.065D 03	1.035D-02	9.157D-01	8.000D 01	-1.429D-07	1.000D 00	1.539D-11
54	1	143500.00	250.00	4.03271D 01	-1.307D 03	2.371D-03	1.046D 00	8.000D 01	-2.323D-05	1.000D 00	3.289D-09
54	2	143500.00	750.00	4.03271D 01	-1.307D 03	3.674D-03	1.046D 00	8.000D 01	-2.323D-05	1.000D 00	3.289D-09
54	3	143500.00	1250.00	4.03271D 01	-1.307D 03	5.428D-03	1.046D 00	8.000D 01	-2.323D-05	1.000D 00	3.290D-09
54	4	143500.00	1750.00	4.03271D 01	-1.307D 03	6.514D-03	1.046D 00	8.000D 01	-2.323D-05	1.000D 00	3.290D-09
54	5	143500.00	2250.00	4.03271D 01	-1.307D 03	6.459D-03	1.046D 00	8.000D 01	-2.323D-05	1.000D 00	3.290D-09
54	6	143500.00	3000.00	4.03271D 01	-1.307D 03	6.294D-03	1.046D 00	8.000D 01	-2.323D-05	1.000D 00	3.290D-09
54	7	143500.00	4000.00	4.03271D 01	-1.307D 03	7.563D-03	1.046D 00	8.000D 01	-2.323D-05	1.000D 00	3.290D-09
55	1	153500.00	250.00	4.03818D 01	-1.580D 03	1.589D-03	1.178D 00	8.000D 01	-2.210D-03	1.000D 00	4.401D-07
55	2	153500.00	750.00	4.03817D 01	-1.580D 03	2.440D-03	1.178D 00	8.000D 01	-2.210D-03	1.000D 00	4.401D-07
55	3	153500.00	1250.00	4.03817D 01	-1.580D 03	3.600D-03	1.178D 00	8.000D 01	-2.210D-03	1.000D 00	4.401D-07
55	4	153500.00	1750.00	4.03817D 01	-1.580D 03	4.316D-03	1.178D 00	8.000D 01	-2.210D-03	1.000D 00	4.401D-07
55	5	153500.00	2250.00	4.03817D 01	-1.580D 03	4.272D-03	1.178D 00	8.000D 01	-2.210D-03	1.000D 00	4.402D-07
55	6	153500.00	3000.00	4.03817D 01	-1.580D 03	4.176D-03	1.178D 00	8.000D 01	-2.210D-03	1.000D 00	4.402D-07
55	7	153500.00	4000.00	4.03817D 01	-1.580D 03	5.065D-03	1.178D 00	8.000D 01	-2.210D-03	1.000D 00	4.402D-07
56	1	163500.00	250.00	4.04381D 01	-1.885D 03	8.914D-04	1.309D 00	7.999D 01	-1.110D-01	1.000D 00	3.503D-05
56	2	163500.00	750.00	4.04381D 01	-1.885D 03	1.446D-03	1.309D 00	7.999D 01	-1.110D-01	1.000D 00	3.503D-05
56	3	163500.00	1250.00	4.04381D 01	-1.885D 03	2.123D-03	1.309D 00	7.999D 01	-1.110D-01	1.000D 00	3.503D-05
56	4	163500.00	1750.00	4.04381D 01	-1.885D 03	2.521D-03	1.309D 00	7.999D 01	-1.110D-01	1.000D 00	3.503D-05
56	5	163500.00	2250.00	4.04381D 01	-1.885D 03	2.486D-03	1.309D 00	7.999D 01	-1.110D-01	1.000D 00	3.503D-05
56	6	163500.00	3000.00	4.04381D 01	-1.885D 03	2.358D-03	1.309D 00	7.999D 01	-1.110D-01	1.000D 00	3.503D-05
56	7	163500.00	4000.00	4.04381D 01	-1.885D 03	2.668D-03	1.309D 00	7.999D 01	-1.110D-01	1.000D 00	3.503D-05

Table A.5 (continued)

ITER.= 118 TIME=5.900000D-01 PERIOD=4.758065D-02 TIME INCREMENT=5.000000D-03

NODE	INDICES	X-LOCATION	Y-LOCATION	WATER ELEVATION	VELOCITY IN X-DIRECT.	VELOCITY IN Y-DIRECT.	WATER ELEV. RATE OF CHANGE	TEMP.	TEMP. RATE OF CHANGE	SUBSTANCE MASS CONCENTRATIONS CK(1)	CK(2)
57	1	173500.00	250.00	4.04950D 01	-2.214D 03	2.360D-04	1.401D 00	7.944D 01	-2.246D 00	9.985D-01	1.500D-03
57	2	173500.00	750.00	4.04950D 01	-2.214D 03	5.555D-04	1.401D 00	7.944D 01	-2.246D 00	9.985D-01	1.500D-03
57	3	173500.00	1250.00	4.04950D 01	-2.214D 03	7.941D-04	1.401D 00	7.944D 01	-2.246D 00	9.985D-01	1.500D-03
57	4	173500.00	1750.00	4.04950D 01	-2.214D 03	8.924D-04	1.401D 00	7.944D 01	-2.246D 00	9.985D-01	1.500D-03
57	5	173500.00	2250.00	4.04950D 01	-2.214D 03	8.603D-04	1.401D 00	7.944D 01	-2.246D 00	9.985D-01	1.500D-03
57	6	173500.00	3000.00	4.04950D 01	-2.214D 03	6.585D-04	1.401D 00	7.944D 01	-2.246D 00	9.985D-01	1.500D-03
57	7	173500.00	4000.00	4.04950D 01	-2.214D 03	3.071D-04	1.401D 00	7.944D 01	-2.246D 00	9.985D-01	1.500D-03

IHC002I STOP 0

Table A.6. Output Information for Sample Problem No. 2 at Time = 37.205 hr
the Reduced Version of the Program

ITER.=2479 TIME=3.720500D 01 PERIOD=3.000403D 00 TIME INCREMENT=5.000000D-03

NODE	INDICES	X-LOCATION	Y-LOCATION	WATER ELEVATION	VELOCITY IN X-DIRECT.	VELOCITY IN Y-DIRECT.	WATER ELEV. RATE OF CHANGE	TEMP.	TEMP. RATE OF CHANGE
1	1	5000.00	250.00	3.96310D 01	-5.176D 01	-2.685D 00	1.457D 00	8.000D 01	3.861D-08
1	2	5000.00	750.00	3.96314D 01	-5.014D 01	-7.269D 00	1.347D 00	8.000D 01	2.693D-08
1	3	5000.00	1250.00	3.96314D 01	-4.726D 01	-1.344D 01	1.776D 00	8.000D 01	1.973D-07
1	4	5000.00	1750.00	3.96332D 01	-4.361D 01	-1.680D 01	7.985D-01	8.000D 01	1.479D-06
1	5	5000.00	2250.00	3.96354D 01	-4.133D 01	-9.781D 00	2.085D 00	8.000D 01	8.665D-06
1	6	5000.00	3000.00	3.96310D 01	-4.324D 01	6.579D 00	3.421D-01	8.000D 01	8.605D-05
1	7	5000.00	4000.00	3.96269D 01	-4.627D 01	6.944D 00	1.543D 00	8.000D 01	6.331D-04
2	1	15000.00	250.00	3.96315D 01	-4.292D 02	-1.306D 00	1.639D 00	8.000D 01	2.033D-06
2	2	15000.00	750.00	3.96315D 01	-4.279D 02	-3.464D 00	1.610D 00	8.000D 01	6.471D-07
2	3	15000.00	1250.00	3.96313D 01	-4.256D 02	-6.057D 00	1.589D 00	8.000D 01	1.365D-06
2	4	15000.00	1750.00	3.96312D 01	-4.228D 02	-7.181D 00	1.402D 00	8.000D 01	1.858D-05
2	5	15000.00	2250.00	3.96314D 01	-4.208D 02	-3.229D 00	1.234D 00	8.000D 01	1.939D-04
2	6	15000.00	3000.00	3.96302D 01	-4.211D 02	2.786D 00	1.373D 00	8.000D 01	1.632D-03
2	7	15000.00	4000.00	3.96294D 01	-4.222D 02	3.335D 00	1.625D 00	8.003D 01	1.111D-02
3	1	25000.00	250.00	3.96292D 01	-8.087D 02	-1.797D-01	1.509D 00	8.000D 01	3.018D-05
3	2	25000.00	750.00	3.96292D 01	-8.075D 02	-4.161D-01	1.511D 00	8.000D 01	9.448D-06
3	3	25000.00	1250.00	3.96290D 01	-8.055D 02	-6.596D-01	1.513D 00	8.000D 01	9.510D-06
3	4	25000.00	1750.00	3.96288D 01	-8.029D 02	-7.329D-01	1.530D 00	8.000D 01	1.180D-04
3	5	25000.00	2250.00	3.96287D 01	-8.006D 02	-4.302D-01	1.534D 00	8.000D 01	1.205D-03
3	6	25000.00	3000.00	3.96290D 01	-7.991D 02	-7.330D-02	1.513D 00	8.003D 01	9.467D-03
3	7	25000.00	4000.00	3.96296D 01	-7.982D 02	-2.202D-01	1.446D 00	8.021D 01	5.912D-02
4	1	35000.00	250.00	3.96244D 01	-1.193D 03	4.550D-01	1.488D 00	8.000D 01	1.646D-04
4	2	35000.00	750.00	3.96245D 01	-1.192D 03	1.438D 00	1.492D 00	8.000D 01	5.255D-05
4	3	35000.00	1250.00	3.96246D 01	-1.189D 03	2.255D 00	1.518D 00	8.000D 01	4.451D-05
4	4	35000.00	1750.00	3.96248D 01	-1.186D 03	2.766D 00	1.552D 00	8.000D 01	4.571D-04
4	5	35000.00	2250.00	3.96251D 01	-1.182D 03	2.789D 00	1.583D 00	8.002D 01	4.131D-03
4	6	35000.00	3000.00	3.96261D 01	-1.178D 03	2.398D 00	1.556D 00	8.013D 01	2.923D-02
4	7	35000.00	4000.00	3.96281D 01	-1.175D 03	2.200D 00	1.441D 00	8.082D 01	1.595D-01
5	1	45000.00	250.00	3.96188D 01	-1.584D 03	1.425D 00	1.352D 00	8.000D 01	5.827D-04
5	2	45000.00	750.00	3.96188D 01	-1.583D 03	4.345D 00	1.356D 00	8.000D 01	1.712D-04
5	3	45000.00	1250.00	3.96189D 01	-1.581D 03	7.312D 00	1.370D 00	8.000D 01	2.112D-04
5	4	45000.00	1750.00	3.96190D 01	-1.576D 03	1.029D 01	1.394D 00	8.000D 01	2.329D-03
5	5	45000.00	2250.00	3.96191D 01	-1.570D 03	1.291D 01	1.483D 00	8.005D 01	2.006D-02
5	6	45000.00	3000.00	3.96201D 01	-1.560D 03	1.665D 01	1.466D 00	8.033D 01	1.146D-01
5	7	45000.00	4000.00	3.96224D 01	-1.552D 03	2.255D 01	1.972D 00	8.200D 01	5.712D-01
6	1	50250.00	250.00	3.96161D 01	-1.793D 03	1.989D 00	1.367D 00	8.000D 01	8.898D-03
6	2	50250.00	750.00	3.96161D 01	-1.792D 03	6.064D 00	1.372D 00	8.000D 01	2.469D-03
6	3	50250.00	1250.00	3.96160D 01	-1.789D 03	1.053D 01	1.349D 00	8.000D 01	1.768D-03
6	4	50250.00	1750.00	3.96160D 01	-1.784D 03	1.562D 01	1.359D 00	8.002D 01	1.576D-02
6	5	50250.00	2250.00	3.96160D 01	-1.776D 03	2.107D 01	1.325D 00	8.016D 01	1.124D-01
6	6	50250.00	3000.00	3.96174D 01	-1.756D 03	3.055D 01	1.020D 00	8.101D 01	4.959D-01
6	7	50250.00	4000.00	3.96215D 01	-1.734D 03	4.526D 01	-6.027D-01	8.543D 01	2.188D 00
7	1	50750.00	250.00	3.96165D 01	-1.815D 03	1.658D 00	1.439D 00	8.001D 01	1.430D-02
7	2	50750.00	750.00	3.96164D 01	-1.814D 03	5.275D 00	1.446D 00	8.000D 01	3.928D-03
7	3	50750.00	1250.00	3.96164D 01	-1.812D 03	9.673D 00	1.463D 00	8.000D 01	2.042D-03
7	4	50750.00	1750.00	3.96163D 01	-1.808D 03	1.553D 01	1.515D 00	8.002D 01	1.505D-02
7	5	50750.00	2250.00	3.96163D 01	-1.801D 03	2.449D 01	1.658D 00	8.020D 01	9.313D-02
7	6	50750.00	3000.00	3.96163D 01	-1.777D 03	4.639D 01	1.994D 00	8.116D 01	3.244D-01
7	7	50750.00	4000.00	3.96153D 01	-1.744D 03	8.031D 01	4.541D 00	8.611D 01	1.243D 00
8	1	51250.00	250.00	3.96169D 01	-1.836D 03	9.305D-01	1.378D 00	8.001D 01	2.194D-02
8	2	51250.00	750.00	3.96169D 01	-1.836D 03	3.208D 00	1.380D 00	8.000D 01	5.983D-03
8	3	51250.00	1250.00	3.96168D 01	-1.835D 03	6.471D 00	1.332D 00	8.000D 01	2.293D-03
8	4	51250.00	1750.00	3.96166D 01	-1.835D 03	1.165D 01	1.373D 00	8.003D 01	1.320D-02
8	5	51250.00	2250.00	3.96165D 01	-1.833D 03	2.220D 01	8.228D-01	8.022D 01	6.988D-02
8	6	51250.00	3000.00	3.96142D 01	-1.828D 03	5.271D 01	1.320D 00	8.125D 01	1.711D-01
8	7	51250.00	4000.00	3.96058D 01	-1.819D 03	9.996D 01	-2.032D 00	8.654D 01	4.287D-01

Table A.6 (continued)

ITER.=2479   TIME=3.720500D 01   PERIOD=3.000403D 00   TIME INCREMENT=5.000000D-03

NODE	INDICES	X-LOCATION	Y-LOCATION	WATER ELEVATION	VELOCITY IN X-DIRECT.	VELOCITY IN Y-DIRECT.	WATER ELEV. RATE OF CHANGE	TEMP.	TEMP. RATE OF CHANGE
9	1	51750.00	250.00	3.96174D 01	-1.854D 03	-1.613D-01	1.411D 00	8.002D 01	3.199D-02
9	2	51750.00	750.00	3.96174D 01	-1.855D 03	-2.720D-01	1.416D 00	8.000D 01	8.696D-03
9	3	51750.00	1250.00	3.96173D 01	-1.856D 03	1.026D-01	1.450D 00	8.000D 01	2.577D-03
9	4	51750.00	1750.00	3.96172D 01	-1.859D 03	1.452D 00	1.515D 00	8.003D 01	1.121D-02
9	5	51750.00	2250.00	3.96172D 01	-1.864D 03	5.691D 00	1.690D 00	8.024D 01	5.444D-02
9	6	51750.00	3000.00	3.96161D 01	-1.883D 03	1.998D 01	2.366D 00	8.131D 01	1.173D-01
9	7	51750.00	4000.00	3.96116D 01	-1.910D 03	4.253D 01	6.510D 00	8.683D 01	3.266D-01
10	1	52250.00	250.00	3.96179D 01	-1.871D 03	-1.350D 00	1.394D 00	8.003D 01	4.436D-02
10	2	52250.00	750.00	3.96179D 01	-1.871D 03	-4.194D 00	1.389D 00	8.001D 01	1.208D-02
10	3	52250.00	1250.00	3.96179D 01	-1.872D 03	-7.407D 00	1.352D 00	8.000D 01	2.950D-03
10	4	52250.00	1750.00	3.96181D 01	-1.875D 03	-1.130D 01	1.298D 00	8.003D 01	9.315D-03
10	5	52250.00	2250.00	3.96181D 01	-1.881D 03	-1.720D 01	1.093D 00	8.026D 01	4.403D-02
10	6	52250.00	3000.00	3.96191D 01	-1.901D 03	-3.155D 01	4.923D-01	8.134D 01	1.034D-01
10	7	52250.00	4000.00	3.96228D 01	-1.929D 03	-5.298D 01	-3.797D 00	8.694D 01	3.778D-01
11	1	52750.00	250.00	3.96184D 01	-1.884D 03	-2.233D 00	1.414D 00	8.004D 01	5.877D-02
11	2	52750.00	750.00	3.96184D 01	-1.884D 03	-7.077D 00	1.412D 00	8.001D 01	1.610D-02
11	3	52750.00	1250.00	3.96185D 01	-1.884D 03	-1.283D 01	1.456D 00	8.000D 01	3.443D-03
11	4	52750.00	1750.00	3.96188D 01	-1.884D 03	-2.030D 01	1.430D 00	8.003D 01	8.174D-03
11	5	52750.00	2250.00	3.96189D 01	-1.885D 03	-3.237D 01	1.953D 00	8.026D 01	5.232D-02
11	6	52750.00	3000.00	3.96214D 01	-1.882D 03	-6.260D 01	1.554D 00	8.133D 01	2.458D-01
11	7	52750.00	4000.00	3.96298D 01	-1.877D 03	-1.079D 02	4.915D 00	8.704D 01	4.964D-01
12	1	53250.00	250.00	3.96188D 01	-1.897D 03	-2.559D 00	1.396D 00	8.005D 01	7.500D-02
12	2	53250.00	750.00	3.96188D 01	-1.896D 03	-8.000D 00	1.391D 00	8.001D 01	2.074D-02
12	3	53250.00	1250.00	3.96189D 01	-1.894D 03	-1.420D 01	1.369D 00	8.001D 01	3.947D-03
12	4	53250.00	1750.00	3.96190D 01	-1.892D 03	-2.178D 01	1.333D 00	8.003D 01	5.506D-03
12	5	53250.00	2250.00	3.96192D 01	-1.887D 03	-3.190D 01	1.153D 00	8.024D 01	3.086D-02
12	6	53250.00	3000.00	3.96199D 01	-1.869D 03	-5.277D 01	8.318D-01	8.120D 01	1.107D-01
12	7	53250.00	4000.00	3.96219D 01	-1.842D 03	-8.319D 01	-1.715D 00	8.541D 01	3.913D-01
13	1	53750.00	250.00	3.96192D 01	-1.909D 03	-2.405D 00	1.404D 00	8.007D 01	9.312D-02
13	2	53750.00	750.00	3.96192D 01	-1.908D 03	-7.338D 00	1.402D 00	8.002D 01	2.605D-02
13	3	53750.00	1250.00	3.96192D 01	-1.906D 03	-1.259D 01	1.416D 00	8.001D 01	4.640D-03
13	4	53750.00	1750.00	3.96193D 01	-1.902D 03	-1.834D 01	1.439D 00	8.003D 01	3.044D-03
13	5	53750.00	2250.00	3.96194D 01	-1.897D 03	-2.391D 01	1.447D 00	8.023D 01	1.674D-02
13	6	53750.00	3000.00	3.96189D 01	-1.884D 03	-3.035D 01	1.767D 00	8.117D 01	6.024D-02
13	7	53750.00	4000.00	3.96163D 01	-1.869D 03	-3.818D 01	3.369D 00	8.552D 01	9.759D-02
14	1	54250.00	250.00	3.96195D 01	-1.922D 03	-1.981D 00	1.399D 00	8.010D 01	1.137D-01
14	2	54250.00	750.00	3.96196D 01	-1.921D 03	-5.897D 00	1.397D 00	8.003D 01	3.223D-02
14	3	54250.00	1250.00	3.96196D 01	-1.919D 03	-9.799D 00	1.391D 00	8.001D 01	5.544D-03
14	4	54250.00	1750.00	3.96196D 01	-1.915D 03	-1.360D 01	1.411D 00	8.003D 01	4.168D-04
14	5	54250.00	2250.00	3.96197D 01	-1.911D 03	-1.649D 01	1.341D 00	8.023D 01	-2.232D-03
14	6	54250.00	3000.00	3.96199D 01	-1.906D 03	-1.760D 01	1.406D 00	8.115D 01	-2.347D-02
14	7	54250.00	4000.00	3.96194D 01	-1.903D 03	-1.731D 01	9.635D-01	8.555D 01	-2.565D-01
15	1	54750.00	250.00	3.96199D 01	-1.936D 03	-1.458D 00	1.399D 00	8.013D 01	1.374D-01
15	2	54750.00	750.00	3.96199D 01	-1.935D 03	-4.243D 00	1.399D 00	8.004D 01	3.948D-02
15	3	54750.00	1250.00	3.96199D 01	-1.933D 03	-6.606D 00	1.398D 00	8.001D 01	6.739D-03
15	4	54750.00	1750.00	3.96199D 01	-1.931D 03	-8.919D 00	1.405D 00	8.003D 01	-1.715D-03
15	5	54750.00	2250.00	3.96199D 01	-1.928D 03	-1.001D 01	1.394D 00	8.022D 01	-1.936D-02
15	6	54750.00	3000.00	3.96198D 01	-1.925D 03	-8.951D 00	1.454D 00	8.112D 01	-1.033D-01
15	7	54750.00	4000.00	3.96192D 01	-1.924D 03	-6.094D 00	1.459D 00	8.548D 01	-5.995D-01
16	1	55250.00	250.00	3.96203D 01	-1.952D 03	-1.012D 00	1.397D 00	8.016D 01	1.648D-01
16	2	55250.00	750.00	3.96203D 01	-1.951D 03	-2.901D 00	1.399D 00	8.005D 01	4.801D-02
16	3	55250.00	1250.00	3.96203D 01	-1.949D 03	-4.507D 00	1.396D 00	8.001D 01	8.263D-03
16	4	55250.00	1750.00	3.96202D 01	-1.947D 03	-5.600D 00	1.402D 00	8.003D 01	-3.249D-03
16	5	55250.00	2250.00	3.96202D 01	-1.946D 03	-5.879D 00	1.392D 00	8.021D 01	-3.306D-02
16	6	55250.00	3000.00	3.96201D 01	-1.944D 03	-4.547D 00	1.436D 00	8.109D 01	-1.724D-01
16	7	55250.00	4000.00	3.96198D 01	-1.944D 03	-1.855D 00	1.400D 00	8.533D 01	-8.920D-01

Table A.6 (continued)

ITER.=2479   TIME=3.720500D 01   PERIOD=3.000403D 00   TIME INCREMENT=5.000000D-03

NODE	INDICES	X-LOCATION	Y-LOCATION	WATER ELEVATION	VELOCITY IN X-DIRECT.	VELOCITY IN Y-DIRECT.	WATER ELEV. RATE OF CHANGE	TEMP.	TEMP. RATE OF CHANGE
17	1	56000.00	250.00	3.96208D 01	-1.976D 03	-6.235D-01	1.392D 00	8.021D 01	1.963D-01
17	2	56000.00	750.00	3.96208D 01	-1.975D 03	-1.772D 00	1.393D 00	8.006D 01	5.795D-02
17	3	56000.00	1250.00	3.96207D 01	-1.975D 03	-2.685D 00	1.391D 00	8.001D 01	1.014D-02
17	4	56000.00	1750.00	3.96207D 01	-1.973D 03	-3.205D 00	1.392D 00	8.003D 01	-4.280D-03
17	5	56000.00	2250.00	3.96206D 01	-1.972D 03	-3.211D 00	1.388D 00	8.020D 01	-4.351D-02
17	6	56000.00	3000.00	3.96206D 01	-1.972D 03	-2.250D 00	1.390D 00	8.104D 01	-2.267D-01
17	7	56000.00	4000.00	3.96204D 01	-1.972D 03	-4.571D-01	1.399D 00	8.511D 01	-1.122D 00
18	1	57000.00	250.00	3.96215D 01	-2.010D 03	-3.082D-01	1.391D 00	8.030D 01	2.677D-01
18	2	57000.00	750.00	3.96215D 01	-2.009D 03	-8.686D-01	1.393D 00	8.009D 01	8.075D-02
18	3	57000.00	1250.00	3.96214D 01	-2.009D 03	-1.281D 00	1.392D 00	8.002D 01	1.462D-02
18	4	57000.00	1750.00	3.96214D 01	-2.008D 03	-1.468D 00	1.394D 00	8.002D 01	-5.487D-03
18	5	57000.00	2250.00	3.96214D 01	-2.008D 03	-1.410D 00	1.395D 00	8.017D 01	-5.848D-02
18	6	57000.00	3000.00	3.96213D 01	-2.008D 03	-9.323D-01	1.395D 00	8.093D 01	-3.065D-01
18	7	57000.00	4000.00	3.96213D 01	-2.008D 03	-8.681D-02	1.398D 00	8.455D 01	-1.456D 00
19	1	58000.00	250.00	3.96222D 01	-2.044D 03	-1.395D-01	1.393D 00	8.044D 01	3.579D-01
19	2	58000.00	750.00	3.96222D 01	-2.044D 03	-3.882D-01	1.393D 00	8.013D 01	1.101D-01
19	3	58000.00	1250.00	3.96222D 01	-2.044D 03	-5.598D-01	1.393D 00	8.002D 01	2.068D-02
19	4	58000.00	1750.00	3.96222D 01	-2.043D 03	-6.205D-01	1.394D 00	8.002D 01	-5.162D-03
19	5	58000.00	2250.00	3.96222D 01	-2.043D 03	-5.782D-01	1.394D 00	8.014D 01	-6.283D-02
19	6	58000.00	3000.00	3.96222D 01	-2.043D 03	-3.733D-01	1.392D 00	8.078D 01	-3.318D-01
19	7	58000.00	4000.00	3.96221D 01	-2.043D 03	-2.226D-02	1.394D 00	8.383D 01	-1.558D 00
20	1	59000.00	250.00	3.96230D 01	-2.079D 03	-5.283D-02	1.392D 00	8.061D 01	4.685D-01
20	2	59000.00	750.00	3.96230D 01	-2.079D 03	-1.461D-01	1.392D 00	8.018D 01	1.466D-01
20	3	59000.00	1250.00	3.96230D 01	-2.079D 03	-2.049D-01	1.392D 00	8.003D 01	2.846D-02
20	4	59000.00	1750.00	3.96230D 01	-2.078D 03	-2.178D-01	1.392D 00	8.002D 01	-3.553D-03
20	5	59000.00	2250.00	3.96230D 01	-2.078D 03	-1.949D-01	1.392D 00	8.011D 01	-5.854D-02
20	6	59000.00	3000.00	3.96230D 01	-2.078D 03	-1.206D-01	1.391D 00	8.061D 01	-3.118D-01
20	7	59000.00	4000.00	3.96230D 01	-2.078D 03	2.055D-03	1.392D 00	8.308D 01	-1.467D 00
21	1	60000.00	250.00	3.96239D 01	-2.114D 03	-9.650D-03	1.391D 00	8.084D 01	5.982D-01
21	2	60000.00	750.00	3.96239D 01	-2.114D 03	-2.753D-02	1.391D 00	8.025D 01	1.896D-01
21	3	60000.00	1250.00	3.96239D 01	-2.114D 03	-3.401D-02	1.391D 00	8.005D 01	3.784D-02
21	4	60000.00	1750.00	3.96239D 01	-2.114D 03	-2.817D-02	1.391D 00	8.002D 01	-1.092D-03
21	5	60000.00	2250.00	3.96239D 01	-2.113D 03	-1.728D-02	1.391D 00	8.008D 01	-4.915D-02
21	6	60000.00	3000.00	3.96239D 01	-2.113D 03	-1.297D-03	1.391D 00	8.047D 01	-2.652D-01
21	7	60000.00	4000.00	3.96239D 01	-2.113D 03	2.206D-02	1.391D 00	8.239D 01	-1.263D 00
22	1	61000.00	250.00	3.96248D 01	-2.149D 03	1.196D-02	1.389D 00	8.112D 01	7.402D-01
22	2	61000.00	750.00	3.96248D 01	-2.149D 03	3.079D-02	1.390D 00	8.034D 01	2.370D-01
22	3	61000.00	1250.00	3.96248D 01	-2.149D 03	4.904D-02	1.390D 00	8.007D 01	4.840D-02
22	4	61000.00	1750.00	3.96248D 01	-2.149D 03	6.281D-02	1.390D 00	8.001D 01	1.781D-03
22	5	61000.00	2250.00	3.96248D 01	-2.149D 03	6.743D-02	1.390D 00	8.006D 01	-3.804D-02
22	6	61000.00	3000.00	3.96248D 01	-2.149D 03	5.739D-02	1.389D 00	8.034D 01	-2.099D-01
22	7	61000.00	4000.00	3.96248D 01	-2.148D 03	3.756D-02	1.390D 00	8.180D 01	-1.021D 00
23	1	62000.00	250.00	3.96257D 01	-2.184D 03	2.331D-02	1.388D 00	8.146D 01	8.834D-01
23	2	62000.00	750.00	3.96257D 01	-2.184D 03	5.998D-02	1.388D 00	8.045D 01	2.860D-01
23	3	62000.00	1250.00	3.96257D 01	-2.184D 03	8.989D-02	1.388D 00	8.009D 01	5.978D-02
23	4	62000.00	1750.00	3.96257D 01	-2.184D 03	1.065D-01	1.388D 00	8.002D 01	4.780D-03
23	5	62000.00	2250.00	3.96257D 01	-2.184D 03	1.070D-01	1.388D 00	8.004D 01	-2.752D-02
23	6	62000.00	3000.00	3.96257D 01	-2.183D 03	8.479D-02	1.388D 00	8.025D 01	-1.577D-01
23	7	62000.00	4000.00	3.96257D 01	-2.183D 03	4.687D-02	1.388D 00	8.133D 01	-7.912D-01
24	1	63000.00	250.00	3.96266D 01	-2.219D 03	2.819D-02	1.387D 00	8.186D 01	1.021D 00
24	2	63000.00	750.00	3.96266D 01	-2.219D 03	6.941D-02	1.387D 00	8.058D 01	3.382D-01
24	3	63000.00	1250.00	3.96266D 01	-2.219D 03	1.008D-01	1.387D 00	8.011D 01	7.301D-02
24	4	63000.00	1750.00	3.96266D 01	-2.219D 03	1.142D-01	1.387D 00	8.002D 01	7.982D-03
24	5	63000.00	2250.00	3.96266D 01	-2.218D 03	1.091D-01	1.387D 00	8.003D 01	-1.871D-02
24	6	63000.00	3000.00	3.96266D 01	-2.218D 03	8.282D-02	1.387D 00	8.017D 01	-1.144D-01
24	7	63000.00	4000.00	3.96266D 01	-2.218D 03	4.449D-02	1.387D 00	8.097D 01	-5.978D-01

Table A.6 (continued)

ITER.=2479   TIME=3.720500D 01   PERIOD=3.000403D 00   TIME INCREMENT=5.000000D-03

NODE	INDI-CES	X-LOCATION	Y-LOCATION	WATER ELEVATION	VELOCITY IN X-DIRECT.	VELOCITY IN Y-DIRECT.	WATER ELEV. RATE OF CHANGE	TEMP.	TEMP. RATE OF CHANGE
25	1	64000.00	250.00	3.96276D 01	-2.254D 03	2.449D-02	1.385D 00	8.232D 01	1.176D 00
25	2	64000.00	750.00	3.96276D 01	-2.254D 03	5.005D-02	1.385D 00	8.073D 01	4.094D-01
25	3	64000.00	1250.00	3.96276D 01	-2.254D 03	6.532D-02	1.385D 00	8.015D 01	9.307D-02
25	4	64000.00	1750.00	3.96276D 01	-2.253D 03	6.198D-02	1.386D 00	8.002D 01	1.219D-02
25	5	64000.00	2250.00	3.96276D 01	-2.253D 03	4.539D-02	1.386D 00	8.002D 01	-1.184D-02
25	6	64000.00	3000.00	3.96276D 01	-2.253D 03	2.602D-02	1.385D 00	8.012D 01	-8.117D-02
25	7	64000.00	4000.00	3.96276D 01	-2.253D 03	1.507D-02	1.386D 00	8.070D 01	-4.451D-01
26	1	65000.00	250.00	3.96287D 01	-2.289D 03	4.600D-03	1.383D 00	8.284D 01	1.430D 00
26	2	65000.00	750.00	3.96287D 01	-2.289D 03	-3.072D-02	1.384D 00	8.091D 01	5.411D-01
26	3	65000.00	1250.00	3.96286D 01	-2.288D 03	-7.230D-02	1.383D 00	8.019D 01	1.315D-01
26	4	65000.00	1750.00	3.96286D 01	-2.288D 03	-1.237D-01	1.384D 00	8.003D 01	1.931D-02
26	5	65000.00	2250.00	3.96286D 01	-2.288D 03	-1.645D-01	1.384D 00	8.002D 01	-6.670D-03
26	6	65000.00	3000.00	3.96286D 01	-2.288D 03	-1.515D-01	1.384D 00	8.009D 01	-5.718D-02
26	7	65000.00	4000.00	3.96286D 01	-2.288D 03	-7.423D-02	1.385D 00	8.051D 01	-3.290D-01
27	1	66000.00	250.00	3.96297D 01	-2.323D 03	-4.352D-02	1.382D 00	8.347D 01	1.931D 00
27	2	66000.00	750.00	3.96297D 01	-2.323D 03	-2.478D-01	1.383D 00	8.114D 01	7.928D-01
27	3	66000.00	1250.00	3.96297D 01	-2.323D 03	-4.405D-01	1.381D 00	8.024D 01	2.043D-01
27	4	66000.00	1750.00	3.96297D 01	-2.323D 03	-6.064D-01	1.384D 00	8.003D 01	3.209D-02
27	5	66000.00	2250.00	3.96296D 01	-2.323D 03	-6.908D-01	1.383D 00	8.001D 01	-2.631D-03
27	6	66000.00	3000.00	3.96296D 01	-2.323D 03	-5.820D-01	1.383D 00	8.006D 01	-4.083D-02
27	7	66000.00	4000.00	3.96296D 01	-2.323D 03	-2.808D-01	1.384D 00	8.037D 01	-2.434D-01
28	1	67000.00	250.00	3.96309D 01	-2.358D 03	-1.141D-01	1.381D 00	8.430D 01	2.771D 00
28	2	67000.00	750.00	3.96309D 01	-2.358D 03	-7.534D-01	1.381D 00	8.148D 01	1.181D 00
28	3	67000.00	1250.00	3.96308D 01	-2.357D 03	-1.308D 00	1.377D 00	8.033D 01	3.156D-01
28	4	67000.00	1750.00	3.96308D 01	-2.357D 03	-1.713D 00	1.382D 00	8.005D 01	5.171D-02
28	5	67000.00	2250.00	3.96307D 01	-2.358D 03	-1.856D 00	1.380D 00	8.001D 01	8.552D-04
28	6	67000.00	3000.00	3.96307D 01	-2.358D 03	-1.500D 00	1.381D 00	8.004D 01	-3.035D-02
28	7	67000.00	4000.00	3.96306D 01	-2.359D 03	-6.875D-01	1.383D 00	8.026D 01	-1.828D-01
29	1	68000.00	250.00	3.96323D 01	-2.391D 03	-1.919D-01	1.357D 00	8.547D 01	3.726D 00
29	2	68000.00	750.00	3.96322D 01	-2.390D 03	-1.911D 00	1.359D 00	8.198D 01	1.565D 00
29	3	68000.00	1250.00	3.96321D 01	-2.391D 03	-3.287D 00	1.364D 00	8.046D 01	4.274D-01
29	4	68000.00	1750.00	3.96319D 01	-2.391D 03	-4.114D 00	1.378D 00	8.007D 01	7.296D-02
29	5	68000.00	2250.00	3.96318D 01	-2.393D 03	-4.254D 00	1.378D 00	8.001D 01	3.940D-03
29	6	68000.00	3000.00	3.96317D 01	-2.394D 03	-3.293D 00	1.379D 00	8.003D 01	-2.366D-02
29	7	68000.00	4000.00	3.96317D 01	-2.395D 03	-1.394D 00	1.383D 00	8.019D 01	-1.403D-01
30	1	69000.00	250.00	3.96340D 01	-2.421D 03	-9.940D-01	1.339D 00	8.703D 01	4.072D 00
30	2	69000.00	750.00	3.96337D 01	-2.421D 03	-5.211D 00	1.387D 00	8.264D 01	1.591D 00
30	3	69000.00	1250.00	3.96334D 01	-2.422D 03	-8.155D 00	1.383D 00	8.064D 01	4.427D-01
30	4	69000.00	1750.00	3.96331D 01	-2.425D 03	-9.291D 00	1.402D 00	8.010D 01	8.043D-02
30	5	69000.00	2250.00	3.96329D 01	-2.428D 03	-8.898D 00	1.390D 00	8.001D 01	5.763D-03
30	6	69000.00	3000.00	3.96328D 01	-2.431D 03	-6.502D 00	1.384D 00	8.002D 01	-1.859D-02
30	7	69000.00	4000.00	3.96327D 01	-2.433D 03	-2.473D 00	1.382D 00	8.013D 01	-1.079D-01
31	1	70000.00	250.00	3.96344D 01	-2.452D 03	-8.172D 00	1.978D 00	8.872D 01	3.016D 00
31	2	70000.00	750.00	3.96340D 01	-2.450D 03	-1.513D 01	1.591D 00	8.330D 01	9.267D-01
31	3	70000.00	1250.00	3.96340D 01	-2.454D 03	-1.919D 01	1.517D 00	8.083D 01	2.629D-01
31	4	70000.00	1750.00	3.96339D 01	-2.460D 03	-1.917D 01	1.391D 00	8.013D 01	5.546D-02
31	5	70000.00	2250.00	3.96338D 01	-2.466D 03	-1.659D 01	1.393D 00	8.002D 01	4.511D-03
31	6	70000.00	3000.00	3.96338D 01	-2.470D 03	-1.127D 01	1.371D 00	8.001D 01	-1.375D-02
31	7	70000.00	4000.00	3.96338D 01	-2.473D 03	-3.708D 00	1.371D 00	8.008D 01	-7.954D-02
32	1	70750.00	250.00	3.96411D 01	-2.448D 03	-2.311D 01	-2.110D 00	8.998D 01	7.108D-01
32	2	70750.00	750.00	3.96364D 01	-2.460D 03	-2.968D 01	6.741D-01	8.371D 01	-2.286D-01
32	3	70750.00	1250.00	3.96349D 01	-2.476D 03	-3.263D 01	1.191D 00	8.094D 01	-7.376D-02
32	4	70750.00	1750.00	3.96348D 01	-2.488D 03	-2.953D 01	1.253D 00	8.016D 01	-1.998D-03
32	5	70750.00	2250.00	3.96347D 01	-2.497D 03	-2.357D 01	1.317D 00	8.002D 01	-8.678D-04
32	6	70750.00	3000.00	3.96347D 01	-2.502D 03	-1.509D 01	1.366D 00	8.001D 01	-9.481D-03
32	7	70750.00	4000.00	3.96348D 01	-2.505D 03	-4.313D 00	1.371D 00	8.005D 01	-5.462D-02

Table A.6 (continued)

ITER.=2479 TIME=3.720500D 01 PERIOD=3.000403D 00 TIME INCREMENT=5.000000D-03

NODE	INDICES	X-LOCATION	Y-LOCATION	WATER ELEVATION	VELOCITY IN X-DIRECT.	VELOCITY IN Y-DIRECT.	WATER ELEV. RATE OF CHANGE	TEMP.	TEMP. RATE OF CHANGE
33	1	71250.00	250.00	3.96342D 01	-2.443D 03	-1.026D 02	5.184D 00	9.020D 01	-1.039D-01
33	2	71250.00	750.00	3.96343D 01	-2.474D 03	-7.716D 01	3.446D 00	8.370D 01	-5.977D-01
33	3	71250.00	1250.00	3.96345D 01	-2.500D 03	-5.539D 01	2.535D 00	8.094D 01	-2.031D-01
33	4	71250.00	1750.00	3.96349D 01	-2.514D 03	-3.904D 01	1.608D 00	8.016D 01	-3.007D-02
33	5	71250.00	2250.00	3.96352D 01	-2.522D 03	-2.758D 01	1.508D 00	8.002D 01	-4.605D-03
33	6	71250.00	3000.00	3.96354D 01	-2.526D 03	-1.632D 01	1.400D 00	8.001D 01	-8.336D-03
33	7	71250.00	4000.00	3.96355D 01	-2.528D 03	-3.954D 00	1.384D 00	8.004D 01	-4.552D-02
34	1	71750.00	250.00	3.96209D 01	-2.534D 03	-1.684D 02	-1.681D 00	9.030D 01	-1.634D 00
34	2	71750.00	750.00	3.96302D 01	-2.544D 03	-1.111D 02	-1.586D 00	8.363D 01	-9.163D-01
34	3	71750.00	1250.00	3.96338D 01	-2.550D 03	-6.536D 01	-6.394D-01	8.091D 01	-2.720D-01
34	4	71750.00	1750.00	3.96348D 01	-2.551D 03	-3.837D 01	1.106D 00	8.015D 01	-4.819D-02
34	5	71750.00	2250.00	3.96356D 01	-2.552D 03	-2.440D 01	1.199D 00	8.002D 01	-7.763D-03
34	6	71750.00	3000.00	3.96360D 01	-2.551D 03	-1.336D 01	1.346D 00	8.000D 01	-7.857D-03
34	7	71750.00	4000.00	3.96362D 01	-2.551D 03	-2.733D 00	1.354D 00	8.003D 01	-3.853D-02
35	1	72250.00	250.00	3.96285D 01	-2.652D 03	-8.195D 01	8.580D 00	9.062D 01	-1.283D 00
35	2	72250.00	750.00	3.96336D 01	-2.626D 03	-5.232D 01	4.128D 00	8.359D 01	-8.705D-01
35	3	72250.00	1250.00	3.96356D 01	-2.601D 03	-2.872D 01	2.709D 00	8.088D 01	-2.866D-01
35	4	72250.00	1750.00	3.96361D 01	-2.587D 03	-1.525D 01	1.751D 00	8.015D 01	-5.615D-02
35	5	72250.00	2250.00	3.96366D 01	-2.579D 03	-8.852D 00	1.563D 00	8.002D 01	-1.014D-02
35	6	72250.00	3000.00	3.96368D 01	-2.574D 03	-4.445D 00	1.407D 00	8.000D 01	-7.989D-03
35	7	72250.00	4000.00	3.96369D 01	-2.571D 03	-6.942D-01	1.384D 00	8.002D 01	-3.333D-02
36	1	72750.00	250.00	3.96431D 01	-2.667D 03	8.131D 01	-5.990D 00	9.044D 01	-1.969D 00
36	2	72750.00	750.00	3.96394D 01	-2.643D 03	5.292D 01	-1.422D 00	8.345D 01	-1.226D 00
36	3	72750.00	1250.00	3.96382D 01	-2.619D 03	3.095D 01	4.849D-03	8.083D 01	-3.323D-01
36	4	72750.00	1750.00	3.96381D 01	-2.605D 03	1.859D 01	9.943D-01	8.014D 01	-6.150D-02
36	5	72750.00	2250.00	3.96378D 01	-2.596D 03	1.236D 01	1.184D 00	8.001D 01	-1.208D-02
36	6	72750.00	3000.00	3.96377D 01	-2.591D 03	7.088D 00	1.343D 00	8.000D 01	-8.580D-03
36	7	72750.00	4000.00	3.96376D 01	-2.588D 03	1.650D 00	1.363D 00	8.002D 01	-2.954D-02
37	1	73250.00	250.00	3.96531D 01	-2.582D 03	1.689D 02	4.504D 00	9.008D 01	-2.240D 00
37	2	73250.00	750.00	3.96440D 01	-2.596D 03	1.125D 02	4.425D 00	8.316D 01	-4.091D-01
37	3	73250.00	1250.00	3.96406D 01	-2.603D 03	6.769D 01	3.404D 00	8.074D 01	-2.084D-01
37	4	73250.00	1750.00	3.96397D 01	-2.604D 03	4.129D 01	1.645D 00	8.012D 01	-5.575D-02
37	5	73250.00	2250.00	3.96389D 01	-2.603D 03	2.734D 01	1.550D 00	8.001D 01	-1.280D-02
37	6	73250.00	3000.00	3.96385D 01	-2.602D 03	1.555D 01	1.403D 00	8.000D 01	-9.383D-03
37	7	73250.00	4000.00	3.96384D 01	-2.601D 03	3.573D 00	1.392D 00	8.001D 01	-2.667D-02
38	1	73750.00	250.00	3.96418D 01	-2.529D 03	1.033D 02	-2.282D 00	8.692D 01	-2.902D 00
38	2	73750.00	750.00	3.96410D 01	-2.562D 03	7.863D 01	-6.677D-01	8.242D 01	-1.197D 00
38	3	73750.00	1250.00	3.96404D 01	-2.589D 03	5.722D 01	2.248D-01	8.057D 01	-2.937D-01
38	4	73750.00	1750.00	3.96399D 01	-2.601D 03	4.099D 01	1.134D 00	8.009D 01	-5.557D-02
38	5	73750.00	2250.00	3.96395D 01	-2.608D 03	2.945D 01	1.242D 00	8.001D 01	-1.374D-02
38	6	73750.00	3000.00	3.96393D 01	-2.611D 03	1.771D 01	1.354D 00	8.000D 01	-1.014D-02
38	7	73750.00	4000.00	3.96391D 01	-2.612D 03	4.570D 00	1.368D 00	8.001D 01	-2.416D-02
39	1	74250.00	250.00	3.96352D 01	-2.572D 03	2.208D 01	4.740D 00	8.635D 01	-3.096D 00
39	2	74250.00	750.00	3.96391D 01	-2.584D 03	2.951D 01	2.064D 00	8.211D 01	-1.025D 00
39	3	74250.00	1250.00	3.96402D 01	-2.599D 03	3.280D 01	1.571D 00	8.048D 01	-2.517D-01
39	4	74250.00	1750.00	3.96401D 01	-2.610D 03	2.984D 01	1.516D 00	8.007D 01	-5.023D-02
39	5	74250.00	2250.00	3.96401D 01	-2.617D 03	2.399D 01	1.434D 00	8.000D 01	-1.377D-02
39	6	74250.00	3000.00	3.96400D 01	-2.622D 03	1.552D 01	1.380D 00	8.000D 01	-1.057D-02
39	7	74250.00	4000.00	3.96399D 01	-2.624D 03	4.700D 00	1.378D 00	8.000D 01	-2.156D-02
40	1	74750.00	250.00	3.96415D 01	-2.617D 03	7.551D 00	5.755D-01	8.576D 01	-2.931D 00
40	2	74750.00	750.00	3.96414D 01	-2.616D 03	1.550D 01	1.185D 00	8.187D 01	-9.235D-01
40	3	74750.00	1250.00	3.96411D 01	-2.620D 03	2.006D 01	1.258D 00	8.041D 01	-2.235D-01
40	4	74750.00	1750.00	3.96409D 01	-2.626D 03	2.015D 01	1.370D 00	8.006D 01	-4.483D-02
40	5	74750.00	2250.00	3.96409D 01	-2.631D 03	1.752D 01	1.350D 00	8.000D 01	-1.330D-02
40	6	74750.00	3000.00	3.96408D 01	-2.634D 03	1.200D 01	1.363D 00	7.999D 01	-1.053D-02
40	7	74750.00	4000.00	3.96407D 01	-2.637D 03	4.226D 00	1.371D 00	8.000D 01	-1.865D-02

Table A.6 (continued)

ITER.=2479 TIME=3.720500D 01 PERIOD=3.000403D 00 TIME INCREMENT=5.000000D-03

NODE	INDI- CES	X- LOCATION	Y- LOCATION	WATER ELEVATION	VELOCITY IN X-DIRECT.	VELOCITY IN Y-DIRECT.	WATER ELEV. RATE OF CHANGE	TEMP.	TEMP. RATE OF CHANGE
41	1	75250.00	250.00	3.96413D 01	-2.637D 03	2.096D 00	1.375D 00	8.521D 01	-2.491D 00
41	2	75250.00	750.00	3.96414D 01	-2.637D 03	7.542D 00	1.426D 00	8.168D 01	-7.763D-01
41	3	75250.00	1250.00	3.96415D 01	-2.639D 03	1.121D 01	1.400D 00	8.036D 01	-1.850D-01
41	4	75250.00	1750.00	3.96416D 01	-2.643D 03	1.240D 01	1.368D 00	8.005D 01	-3.742D-02
41	5	75250.00	2250.00	3.96416D 01	-2.646D 03	1.160D 01	1.371D 00	8.000D 01	-1.229D-02
41	6	75250.00	3000.00	3.96415D 01	-2.649D 03	8.394D 00	1.364D 00	7.999D 01	-1.007D-02
41	7	75250.00	4000.00	3.96415D 01	-2.651D 03	3.366D 00	1.369D 00	7.999D 01	-1.558D-02
42	1	75750.00	250.00	3.96421D 01	-2.658D 03	9.141D-01	1.380D 00	8.474D 01	-1.911D 00
42	2	75750.00	750.00	3.96422D 01	-2.658D 03	3.933D 00	1.391D 00	8.152D 01	-5.967D-01
42	3	75750.00	1250.00	3.96422D 01	-2.659D 03	6.219D 00	1.369D 00	8.032D 01	-1.411D-01
42	4	75750.00	1750.00	3.96423D 01	-2.661D 03	7.334D 00	1.366D 00	8.004D 01	-2.956D-02
42	5	75750.00	2250.00	3.96423D 01	-2.662D 03	7.231D 00	1.369D 00	7.999D 01	-1.112D-02
42	6	75750.00	3000.00	3.96423D 01	-2.664D 03	5.464D 00	1.366D 00	7.999D 01	-9.462D-03
42	7	75750.00	4000.00	3.96422D 01	-2.665D 03	2.423D 00	1.368D 00	7.999D 01	-1.281D-02
43	1	76250.00	250.00	3.96429D 01	-2.677D 03	4.928D-01	1.373D 00	8.439D 01	-1.364D 00
43	2	76250.00	750.00	3.96429D 01	-2.677D 03	2.133D 00	1.364D 00	8.141D 01	-4.300D-01
43	3	76250.00	1250.00	3.96430D 01	-2.677D 03	3.449D 00	1.368D 00	8.029D 01	-1.023D-01
43	4	76250.00	1750.00	3.96430D 01	-2.678D 03	4.203D 00	1.365D 00	8.003D 01	-2.297D-02
43	5	76250.00	2250.00	3.96430D 01	-2.679D 03	4.278D 00	1.370D 00	7.999D 01	-1.019D-02
43	6	76250.00	3000.00	3.96430D 01	-2.680D 03	3.340D 00	1.364D 00	7.999D 01	-9.023D-03
43	7	76250.00	4000.00	3.96430D 01	-2.681D 03	1.594D 00	1.367D 00	7.999D 01	-1.081D-02
44	1	76750.00	250.00	3.96436D 01	-2.695D 03	3.256D-01	1.373D 00	8.413D 01	-9.679D-01
44	2	76750.00	750.00	3.96436D 01	-2.695D 03	1.166D 00	1.372D 00	8.133D 01	-3.110D-01
44	3	76750.00	1250.00	3.96437D 01	-2.695D 03	1.863D 00	1.375D 00	8.027D 01	-7.533D-02
44	4	76750.00	1750.00	3.96437D 01	-2.696D 03	2.300D 00	1.374D 00	8.003D 01	-1.870D-02
44	5	76750.00	2250.00	3.96437D 01	-2.696D 03	2.389D 00	1.375D 00	7.999D 01	-9.817D-03
44	6	76750.00	3000.00	3.96437D 01	-2.697D 03	1.908D 00	1.372D 00	7.999D 01	-8.981D-03
44	7	76750.00	4000.00	3.96437D 01	-2.698D 03	9.531D-01	1.373D 00	7.999D 01	-9.819D-03
45	1	77250.00	250.00	3.96444D 01	-2.713D 03	1.876D-01	1.335D 00	8.396D 01	-7.472D-01
45	2	77250.00	750.00	3.96444D 01	-2.713D 03	5.991D-01	1.334D 00	8.127D 01	-2.449D-01
45	3	77250.00	1250.00	3.96444D 01	-2.713D 03	9.443D-01	1.336D 00	8.026D 01	-6.080D-02
45	4	77250.00	1750.00	3.96445D 01	-2.713D 03	1.172D 00	1.334D 00	8.002D 01	-1.678D-02
45	5	77250.00	2250.00	3.96445D 01	-2.713D 03	1.235D 00	1.336D 00	7.999D 01	-1.002D-02
45	6	77250.00	3000.00	3.96445D 01	-2.714D 03	1.001D 00	1.334D 00	7.998D 01	-9.373D-03
45	7	77250.00	4000.00	3.96445D 01	-2.714D 03	5.075D-01	1.335D 00	7.999D 01	-9.751D-03
46	1	77750.00	250.00	3.96451D 01	-2.730D 03	9.020D-02	1.442D 00	8.382D 01	-6.521D-01
46	2	77750.00	750.00	3.96451D 01	-2.730D 03	2.754D-01	1.441D 00	8.122D 01	-2.166D-01
46	3	77750.00	1250.00	3.96451D 01	-2.730D 03	4.305D-01	1.442D 00	8.025D 01	-5.501D-02
46	4	77750.00	1750.00	3.96451D 01	-2.731D 03	5.371D-01	1.441D 00	8.002D 01	-1.650D-02
46	5	77750.00	2250.00	3.96451D 01	-2.731D 03	5.729D-01	1.441D 00	7.999D 01	-1.066D-02
46	6	77750.00	3000.00	3.96451D 01	-2.731D 03	4.672D-01	1.440D 00	7.998D 01	-1.009D-02
46	7	77750.00	4000.00	3.96452D 01	-2.731D 03	2.292D-01	1.440D 00	7.998D 01	-1.030D-02
47	1	78250.00	250.00	3.96455D 01	-2.748D 03	3.711D-02	1.362D 00	8.371D 01	-6.169D-01
47	2	78250.00	750.00	3.96455D 01	-2.748D 03	1.228D-01	1.362D 00	8.119D 01	-2.063D-01
47	3	78250.00	1250.00	3.96455D 01	-2.748D 03	1.923D-01	1.362D 00	8.024D 01	-5.340D-02
47	4	78250.00	1750.00	3.96455D 01	-2.748D 03	2.413D-01	1.362D 00	8.002D 01	-1.703D-02
47	5	78250.00	2250.00	3.96455D 01	-2.748D 03	2.612D-01	1.362D 00	7.998D 01	-1.154D-02
47	6	78250.00	3000.00	3.96455D 01	-2.749D 03	2.121D-01	1.362D 00	7.998D 01	-1.101D-02
47	7	78250.00	4000.00	3.96455D 01	-2.749D 03	9.192D-02	1.362D 00	7.998D 01	-1.117D-02
48	1	83500.00	250.00	3.96531D 01	-2.890D 03	1.096D-02	1.062D 00	8.360D 01	-5.996D-01
48	2	83500.00	750.00	3.96531D 01	-2.890D 03	4.578D-02	1.061D 00	8.115D 01	-2.014D-01
48	3	83500.00	1250.00	3.96531D 01	-2.890D 03	7.216D-02	1.062D 00	8.023D 01	-5.307D-02
48	4	83500.00	1750.00	3.96531D 01	-2.890D 03	9.096D-02	1.062D 00	8.001D 01	-1.785D-02
48	5	83500.00	2250.00	3.96531D 01	-2.890D 03	1.000D-01	1.062D 00	7.998D 01	-1.254D-02
48	6	83500.00	3000.00	3.96532D 01	-2.890D 03	7.946D-02	1.063D 00	7.998D 01	-1.203D-02
48	7	83500.00	4000.00	3.96532D 01	-2.890D 03	2.454D-02	1.062D 00	7.998D 01	-1.218D-02

Table A.6 (continued)

ITER.=2479 TIME=3.720500D 01 PERIOD=3.000403D 00 TIME INCREMENT=5.000000D-03

NODE	INDICES	X-LOCATION	Y-LOCATION	WATER ELEVATION	VELOCITY IN X-DIRECT.	VELOCITY IN Y-DIRECT.	WATER ELEV. RATE OF CHANGE	TEMP.	TEMP. RATE OF CHANGE
49	1	93500.00	250.00	3.96710D 01	-3.157D 03	-1.746D-03	1.070D 00	8.165D 01	-3.335D-01
49	2	93500.00	750.00	3.96710D 01	-3.157D 03	1.661D-03	1.069D 00	8.048D 01	-1.279D-01
49	3	93500.00	1250.00	3.96710D 01	-3.157D 03	2.829D-03	1.069D 00	8.005D 01	-5.184D-02
49	4	93500.00	1750.00	3.96710D 01	-3.157D 03	3.661D-03	1.069D 00	7.995D 01	-3.470D-02
49	5	93500.00	2250.00	3.96710D 01	-3.157D 03	4.933D-03	1.069D 00	7.994D 01	-3.227D-02
49	6	93500.00	3000.00	3.96710D 01	-3.157D 03	2.081D-03	1.069D 00	7.994D 01	-3.204D-02
49	7	93500.00	4000.00	3.96710D 01	-3.157D 03	-8.202D-03	1.068D 00	7.994D 01	-3.205D-02
50	1	103500.00	250.00	3.96942D 01	-3.424D 03	-1.297D-03	1.072D 00	8.066D 01	-2.313D-01
50	2	103500.00	750.00	3.96942D 01	-3.424D 03	-2.408D-03	1.072D 00	8.009D 01	-1.224D-01
50	3	103500.00	1250.00	3.96942D 01	-3.424D 03	-3.882D-03	1.072D 00	7.989D 01	-8.431D-02
50	4	103500.00	1750.00	3.96942D 01	-3.424D 03	-4.979D-03	1.072D 00	7.985D 01	-7.637D-02
50	5	103500.00	2250.00	3.96942D 01	-3.424D 03	-5.168D-03	1.072D 00	7.984D 01	-7.533D-02
50	6	103500.00	3000.00	3.96942D 01	-3.424D 03	-4.927D-03	1.072D 00	7.984D 01	-7.523D-02
50	7	103500.00	4000.00	3.96942D 01	-3.424D 03	-5.363D-03	1.072D 00	7.984D 01	-7.523D-02
51	1	113500.00	250.00	3.97223D 01	-3.692D 03	2.695D-04	1.073D 00	8.002D 01	-2.370D-01
51	2	113500.00	750.00	3.97223D 01	-3.692D 03	4.989D-04	1.073D 00	7.974D 01	-1.790D-01
51	3	113500.00	1250.00	3.97223D 01	-3.692D 03	5.681D-04	1.073D 00	7.965D 01	-1.597D-01
51	4	113500.00	1750.00	3.97223D 01	-3.692D 03	5.024D-04	1.073D 00	7.963D 01	-1.559D-01
51	5	113500.00	2250.00	3.97223D 01	-3.692D 03	3.997D-04	1.073D 00	7.963D 01	-1.554D-01
51	6	113500.00	3000.00	3.97223D 01	-3.692D 03	2.779D-04	1.073D 00	7.963D 01	-1.554D-01
51	7	113500.00	4000.00	3.97223D 01	-3.692D 03	1.066D-04	1.073D 00	7.963D 01	-1.554D-01
52	1	123500.00	250.00	3.97549D 01	-3.959D 03	6.294D-04	1.075D 00	7.940D 01	-3.255D-01
52	2	123500.00	750.00	3.97549D 01	-3.959D 03	1.625D-03	1.075D 00	7.927D 01	-2.956D-01
52	3	123500.00	1250.00	3.97549D 01	-3.959D 03	2.381D-03	1.075D 00	7.923D 01	-2.860D-01
52	4	123500.00	1750.00	3.97549D 01	-3.959D 03	2.787D-03	1.075D 00	7.922D 01	-2.843D-01
52	5	123500.00	2250.00	3.97549D 01	-3.959D 03	2.807D-03	1.075D 00	7.922D 01	-2.840D-01
52	6	123500.00	3000.00	3.97549D 01	-3.959D 03	2.344D-03	1.075D 00	7.922D 01	-2.840D-01
52	7	123500.00	4000.00	3.97549D 01	-3.959D 03	1.611D-03	1.075D 00	7.922D 01	-2.840D-01
53	1	133500.00	250.00	3.97914D 01	-4.225D 03	4.204D-04	1.080D 00	7.860D 01	-4.830D-01
53	2	133500.00	750.00	3.97914D 01	-4.225D 03	1.311D-03	1.080D 00	7.855D 01	-4.684D-01
53	3	133500.00	1250.00	3.97914D 01	-4.225D 03	1.951D-03	1.080D 00	7.853D 01	-4.638D-01
53	4	133500.00	1750.00	3.97914D 01	-4.225D 03	2.297D-03	1.080D 00	7.852D 01	-4.630D-01
53	5	133500.00	2250.00	3.97914D 01	-4.225D 03	2.326D-03	1.080D 00	7.852D 01	-4.629D-01
53	6	133500.00	3000.00	3.97914D 01	-4.226D 03	1.902D-03	1.080D 00	7.852D 01	-4.629D-01
53	7	133500.00	4000.00	3.97914D 01	-4.226D 03	1.201D-03	1.080D 00	7.852D 01	-4.629D-01
54	1	143500.00	250.00	3.98314D 01	-4.494D 03	1.854D-04	1.091D 00	7.749D 01	-6.955D-01
54	2	143500.00	750.00	3.98314D 01	-4.494D 03	7.727D-04	1.091D 00	7.746D 01	-6.887D-01
54	3	143500.00	1250.00	3.98314D 01	-4.494D 03	1.145D-03	1.091D 00	7.746D 01	-6.866D-01
54	4	143500.00	1750.00	3.98314D 01	-4.494D 03	1.331D-03	1.091D 00	7.746D 01	-6.863D-01
54	5	143500.00	2250.00	3.98314D 01	-4.494D 03	1.339D-03	1.091D 00	7.746D 01	-6.862D-01
54	6	143500.00	3000.00	3.98314D 01	-4.494D 03	1.071D-03	1.091D 00	7.746D 01	-6.862D-01
54	7	143500.00	4000.00	3.98314D 01	-4.494D 03	6.442D-04	1.091D 00	7.746D 01	-6.862D-01
55	1	153500.00	250.00	3.98741D 01	-4.765D 03	5.193D-05	1.111D 00	7.598D 01	-9.566D-01
55	2	153500.00	750.00	3.98741D 01	-4.765D 03	4.389D-04	1.111D 00	7.597D 01	-9.535D-01
55	3	153500.00	1250.00	3.98741D 01	-4.765D 03	6.427D-04	1.111D 00	7.596D 01	-9.526D-01
55	4	153500.00	1750.00	3.98741D 01	-4.765D 03	7.300D-04	1.111D 00	7.596D 01	-9.524D-01
55	5	153500.00	2250.00	3.98741D 01	-4.765D 03	7.251D-04	1.111D 00	7.596D 01	-9.524D-01
55	6	153500.00	3000.00	3.98741D 01	-4.765D 03	5.759D-04	1.111D 00	7.596D 01	-9.524D-01
55	7	153500.00	4000.00	3.98741D 01	-4.765D 03	3.714D-04	1.111D 00	7.596D 01	-9.524D-01
56	1	163500.00	250.00	3.99186D 01	-5.042D 03	9.028D-06	1.144D 00	7.401D 01	-1.178D 00
56	2	163500.00	750.00	3.99186D 01	-5.042D 03	2.951D-04	1.144D 00	7.401D 01	-1.176D 00
56	3	163500.00	1250.00	3.99186D 01	-5.042D 03	4.300D-04	1.144D 00	7.400D 01	-1.176D 00
56	4	163500.00	1750.00	3.99186D 01	-5.042D 03	4.810D-04	1.144D 00	7.400D 01	-1.176D 00
56	5	163500.00	2250.00	3.99186D 01	-5.042D 03	4.737D-04	1.144D 00	7.400D 01	-1.176D 00
56	6	163500.00	3000.00	3.99186D 01	-5.042D 03	3.806D-04	1.144D 00	7.400D 01	-1.176D 00
56	7	163500.00	4000.00	3.99186D 01	-5.042D 03	2.772D-04	1.144D 00	7.400D 01	-1.176D 00

Table A.6 (continued)

ITER.=2479   TIME=3.720500D 01   PERIOD=3.000403D 00   TIME INCREMENT=5.000000D-03

NODE	INDI-CES	X-LOCATION	Y-LOCATION	WATER ELEVATION	VELOCITY IN X-DIRECT.	VELOCITY IN Y-DIRECT.	WATER ELEV. RATE OF CHANGE	TEMP.	TEMP. RATE OF CHANGE
57	1	173500.00	250.00	3.99640D 01	-5.324D 03	3.631D-05	1.163D 00	7.171D 01	-9.213D-01
57	2	173500.00	750.00	3.99640D 01	-5.324D 03	2.448D-04	1.163D 00	7.171D 01	-9.207D-01
57	3	173500.00	1250.00	3.99640D 01	-5.324D 03	3.541D-04	1.163D 00	7.171D 01	-9.206D-01
57	4	173500.00	1750.00	3.99640D 01	-5.324D 03	3.989D-04	1.163D 00	7.171D 01	-9.205D-01
57	5	173500.00	2250.00	3.99640D 01	-5.324D 03	3.923D-04	1.163D 00	7.171D 01	-9.205D-01
57	6	173500.00	3000.00	3.99640D 01	-5.324D 03	3.146D-04	1.163D 00	7.171D 01	-9.205D-01
57	7	173500.00	4000.00	3.99640D 01	-5.324D 03	2.217D-04	1.163D 00	7.171D 01	-9.205D-01

IHC002I STOP 0

APPENDIX B

COMPUTER PROGRAM NOMENCLATURE

AND FORTRAN IV LISTING

OS/360 FORTRAN H

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COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,
                   SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *  * *
C                 N   O   T   A   T   I   O   N   S                     * *
C                                                                       * *
C      C O N V E N T I O N   U S E D                                    * *
C    THE INDICES I,J ARE USED TO LOCATE A POINT IN THE AREA XY BY       * *
C    INDICATING THE I AND J GRID LINES WHICH CROSS EACH OTHER AT THAT   * *
C    POINT.   MID POINTS ARE INDICATED BY THE USE OF                    * *
C    I + OR - 1/2 AND J + OR - 1/2 INDICES.  MOST VARIABLE NAMES THEN   * *
C    HAVE A BASIC PART MARKED HERE BY XXX AND AN INDEX PART WHICH       * *
C    HAVE THE FOLLOWING MEANING---                                      * *
C    XXXIJ ---VALUE AT (I,J) LOCATION                                   * *
C    XXXIMJ---VALUE AT (I-1/2,J) LOCATION                               * *
C    XXXIPJ---VALUE AT (I+1/2,J) LOCATION                               * *
C    XXXIJM---VALUE AT (I,J-1/2) LOCATION                               * *
C    XXXIJP---VALUE AT (I,J+1/2) LOCATION                               * *
C    XXIMJM---VALUE AT (I-1/2,J-1/2) LOCATION                           * *
C    XXIPJM---VALUE AT (I+1/2,J-1/2) LOCATION                           * *
C    XXIMJP---VALUE AT (I-1/2,J+1/2) LOCATION                           * *
C    XXIPJP---VALUE AT (I+1/2,J+1/2) LOCATION                           * *
C                                                                       * *
C    HALFVALUES OF THE ABOVE ARE NAMED ACCORDING TO THE I,J INDICES     * *
C    CONCEPT EXPLAINED ABOVE.  THEY ARE NOT DIMENSIONED FOR I AND J     * *
C    SINCE THEY ARE BEING RE-CALCULATED FOR EVERY POINT AND EVERY TIME  * *
C    STEP.  FOR INSTANCE, THE TEMPERATURE AT POINT I+1/2,J IS MARKED    * *
C    TIPJ(NON-DIMENSIONAL) AND MASS CONCENTRATION AT POINT              * *
C    I,J-1/2 IS MARKED CKIJM(K) (DIMENSIONED ONLY FOR K BUT NOT FOR I,J).* *
C                                                                       * *
C    I---SUBSCRIPT IN X DIRECTION FOR GRID LINE I(X=0 AT I=1+1/2        * *
C         AND X=LX AT I=NX+1/2).                                        * *
C    J---SUBSCRIPT IN Y DIRECTION FOR GRID LINE J(Y=0 AT J=1+1/2        * *
C         AND Y=LY AT J=NY+1/2).                                        * *
C    K---INDEX FOR THE SPECIFIC CHEMICAL SPECIES CK (K=1...NK).         * *
C                                                                       * *
C                                                                       * *
C    BKIJ---CONSTANT BASED ON THE SLOPE OF THE BOTTOM.  (SEE NOTES)     * *
C   *BMANGC(M)---MANNING COEFF. FOR FRICTION IN THE BOTTOM.-INPUT       * *
C    BMDIJ---MASS FLUX RATE COMING FROM THE BOTTOM.                     * *
C    CIJ---CHEZY COEFFICIENT FOR BOTTOM FRICTION CALCULATIONS           * *
C    CK(K,I,J)---SPECIES MASS CONCENTRATION                             * *
C*   CKTIJ(K)---MASS CONCENTRATION OF SPECIES COMING FROM THE TOP       * *
C*   CKBIJ(K)---MASS CONCENTRATION OF SPECIES COMING FROM THE BOTTOM.   * *
C    CKTMD(K,I,J)---TIME DERIVIATIVE OF SPECIES MASS CONCENTRATION.     * *
C    CP---MIXTURE SPECIFIC HEAT                                         * *
C    CPK(K)---SPECIFIC HEAT                                             * *
C   *CPUSEC---COMPUTER TIME CUT-OFF LIMIT IN SEC.-INPUT                 * *
C   *DCKB(K,M)---MASS COEFFICIENT FOR SPECIES K FROM BOTTOM.-INPUT      * *
C   *DCKT(K,M)---MASS COEFFICIENT FOR SPECIES K FROM TOP.-INPUT         * *
C   *DEPTH(I)---THE UNIFORM DEPTH OF REGION I.                          * *
C   *DKXC---COEFFICIENT FOR DKXIJ-INPUT                                 * *
C    DKXIJ(K)---TOTAL BINARY EFFECTIVE DIFFUSION COEFFICIENT FOR        * *
C               SPECIES K IN X-DIRECTION.                               * *
C   *DKYC---COEFFICIENT FOR DKYIJ-INPUT                                 * *
C    DKYIJ(K)---TOTAL BINARY EFFECTIVE DIFFUSION COEFFICIENT FOR        * *
C               SPECIES K IN Y-DIRECTION.                               * *
C   *DNX(I)---DOWNSTREAM GROSS LATTICE LINE BOUNDING REGION I IN        * *
C             X DIRECTION.                                              * *
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C  *DNY(I)---DOWNSTREAM GROSS LATTICE LINE BOUNDING REGION I IN          * *
C           Y DIRECTION.                                                 * *
C  *DPRTTM---TIME INCREMENT FOR PRINTING OUTPUT IN ADDITION TO INITIAL   * *
C           AND FINAL PRINTOUTS.-INPUT                                   * *
C   DTM---TIME INCREMENT FOR NUMERICAL CALCULATIONS.                     * *
C  *DTMLT---TIME INCREMENT IS MULTIPLIED BY DTMLT EVERY                  * *
C           NDTMC TIME STEPS.-INPUT                                      * *
C   DX(I)---DISTANCE INCREMENT IN X DIRECTION AT GRID LINE I.            * *
C   DY(J)---DISTNCE INCREMENT IN Y DIRECTION AT GRID LINE J.             * *
C  *FCKBD(K,M)---VALUE OF BOUNDARY CONDITION FOR SPECIES CONCENTRATION. * *
C  *FDTM---LARGEST LIMIT FOR TIME INCREMENT.-INPUT                       * *
C  *FGBD(N)---VALUE OF BOUNDARY CONDITION FOR SPECIES MASS FLUX          * *
C  *FGKBD(K,M)---VALUE OF BOUNDARY CONDITION FOR MASS FLUX OF SPECIE K. * *
C  *FHBD(M)---VALUE OF BOUNDARY CONDITION FOR WATER ELEVATION.           * *
C  *FQBD(M)---VALUE OF BOUNDARY CONDITION FOR HEAT FLUX                  * *
C  *FSBDN(M)---VALUE OF BOUNDARY CONDITION FOR NORMAL STRESSES           * *
C  *FSBDSH(M)---VALUE OF BOUNDARY CONDITION FOR SHEAR STRESSES           * *
C  *FTBD(M)---VALUE OF BOUNDARY CONDITION FOR TEMP.                      * *
C  *FTM---FINAL TIME OF THE CASE                                         * *
C  *FUBD(M)---VALUE OF BOUNDARY CONDITION FOR U VELOCITY                 * *
C  *FVBD(M)---VALUE OF BOUNDARY CONDITION FOR V VELOCITY                 * *
C   GKBIJ---MASS DIFFUSION OF SPECIES K FROM BOTTOM                      * *
C  *GKDV(K,I)---VALUE OF MASS GENERATION PER UNIT VOLUME FOR SPECIE K    * *
C              IN INTERNAL GENERATION FUNCTION NUMBER I.                 * *
C   GKTIJ---MASS DIFFUSION OF SPECIES K FROM TOP.                        * *
C   GKXIJ(K)---MASS FLUX OF SPECIES K IN X-DIRECTION.                    * *
C   GKYIJ(K)---MASS FLUX OF SPECIES K IN Y-DIRECTION.                    * *
C   GR---EARTH'S GRAVITY, 32.2 FT-SQ/SEC                                 * *
C   GRC---CONVERSION UNIT, 32.2 LB-MASS FT/LB-FORCE SEC-SQ.              * *
C   H(I,J)---WATER SURFACE ELEVATION MEASURED FROM THE BOTTOM.           * *
C   HB(I,J)---ELEVATION OF BOTTOM FROM A REFERENCE DATUM.                * *
C   HC(I,J)---ELEVATION OF THE CENTROID OF THE ELEMENT FROM A            * *
C            REFERENCE DATUM                                             * *
C  *HCB(M)---HEAT COEFFICIENT FOR BOTTOM.-INPUT                          * *
C  *HCT(M)---HEAT COEFFICIENT FOR TOP.-INPUT                             * *
C   HS(I,J)---ELEVATION OF WATER SURFACE FROM A REFERENCE DATUM.         * *
C   HT---MIXTURE ENTHALPY                                                * *
C*  HTBIJ---ENTHALPY OF FLUID COMING FROM BOTTOM.                        * *
C   HTK(K)---SPECIES ENTHALPY                                            * *
C   HTMD(I,J)---TIME DERIVIATIVE OF WATER SURFACE ELEVATION              * *
C*  HTTIJ---ENTHALPY OF FLUID COMING FROM THE TOP.                       * *
C  *IBNDFC---BOUNDARY CONDITIONS FUNCTION NUMBER(AN INDEX)               * *
C  *IBOTF(I)---BOTTOM CONDITIONS FUNCTION NUMBER WHICH WILL BE USED      * *
C             FOR THE REGION I.                                          * *
C  *IBOTFC---BOTTOM CONDITIONS FUNCTION NUMBER(AN INDEX)                 * *
C  *ICKBDF(K,M)---MULTIPLIER FUNCTION FOR FCKBD(K,M)                     * *
C  *ICKBF(K,M)---MULTIPLER FUNCTION FOR CKB(K,M)                         * *
C  *ICKTF(K,M)---MULTIPLER FUNCTION FOR CKT(K,M)                         * *
C  *IDCKB(K,M)---MULTIPLIER FUNCTION FOR DCKB(K,M)                       * *
C  *IDCKT(K,M)---MULTIPLIER FUNCTION FOR DCKT(K,M)                       * *
C  *IDNXB(I)---BOUNDARY CONDITIONS FUNCTIONS NUMBER TO BE IMPOSED ON     * *
C             FACE DNX(I) OF REGION I.                                   * *
C  *IDNYB(I)---BOUNDARY CONDITIONS FUNCTIONS NUMBER TO BE IMPOSED ON     * *
C             FACE DNY(I) OF REGION I.                                   * *
C  *IFINIS---IF EQUAL ZERO NO RESTART FILE IS CREATED.-INPUT             * *
C  *IGENF(I)---INTERNAL GENERATION FUNCTION NUMBER WHICH WILL BE USED    * *
C             FOR THE REGION I.                                          * *
C  *IGBDF(N)---MULTIPLIER FUNCTION FOR FGBD(N)                           * *
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C  *IGKBDF(K,M)---MULTIPLIER FUNCTION FOR FGKBD(K,M) SPE39E K#          * *
C  *IGKDVF(K,I)---GENERAL PURPOSE FUNCTION TO BE USED ON GKDV(K,I)       * *
C  *IGENFC---INTERNAL GENERATION FUNCTION NUMBER (AN INDEX)             * *
C  *IHBDF(M)---MULTIPLIER FUNCTION FOR FHBD(M)                          * *
C  *IHCB(M)---MULTIPLIER FUNCTION FOR HCB(M)                            * *
C  *IHCT(M)---MULTIPLIER FUNCTION FOR HCT(M)                            * *
C  *INDTM---NUMBER OF TIME STEPS BEFORE PROCESS OF INCREASE IN TIME STEP* *
C           SIZE BEGINS.-INPUT                                          * *
C  *INTF(I)---INITIAL CONDITION FUNCTION NUMBER WHICH WILL BE USED FOR  * *
C             THE REGION I.-INPUT                                       * *
C  *INTFC---INITIAL CONDITIONS FUNCTION NUMBER(AN INDEX)                * *
C  *INTRT---NUMERICAL INTEGRATION PROCEDURE SELECTION                   * *
C           (1) SELECTS RUNGE-KUTTA-GILL METHOD                         * *
C           (2) SELECTS EULER METHOD                                    * *
C           (3) SELECTS ADAM-BASWORTH METHOD                            * *
C  *IPLOT---IF EQUAL ZERO NO PLOTTING INFORMATION IS GENERATED.-INPUT   * *
C  *IQBDF(M)---MULTIPLIER FUNCTION FOR FQBD(M)                          * *
C  *IQBF(M)---MULTIPLIER FUNCTION FOR QE(M)                             * *
C  *IQDVF(I)---GENERAL PURPOSE FUNCTION TO BE USED ON QDV(I)            * *
C  *IQTF(M)---MULTIPLIER FUNCTION FOR QT(M)                             * *
C  *IREG----REGION NUMBER (AN INDEX)-INPUT                              * *
C  *ISHBDF(M)---MULTIPLIER FUNCTION FOR FSBDSH(M)                       * *
C  *ISNBDF(M)---MULTIPLIER FUNCTION FOR FSBDN(M)                        * *
C  *ISTART---IF EQUAL ZERO NO RESTART INFORMATION IS REQUIRED.-INPUT    * *
C  *ISTCKF(K,M)---MULTIPLIER FUNCTION FOR STCK(K,M)-INPUT               * *
C  *ISTHF(M)---MULTIPLIER FUNCTION FOR STH(M)-INPUT                     * *
C  *ISTTF(M)---MULTIPLIER FUNCTION FOR STT(M)-INPUT                     * *
C  *ISTUF(M)---MULTIPLIER FUNCTION FOR STU(M)-INPUT                     * *
C  *ISTVF(M)---MULTIPLIER FUNCTION FOR STV(M)-INPUT                     * *
C  *ISTWSF(M)---MULTIPLIER FUNCTION FOR STWS(M)-INPUT                   * *
C  *ITBDF(M)---MULTIPLIER FUNCTION FOR FTBD(M)                          * *
C  *ITBF(M)---MULTIPLER FUNCTION FOR TE(M)                              * *
C  *ITOPF(I)---TOP CONDITIONS FUNCTION NUMBER WHICH WILL BE USED FOR    * *
C              THE REGION I.                                            * *
C  *ITOPFC---TOP CONDITIONS FUNCTION NUMBER(AN INDEX)                   * *
C  *ITTF(M)---MULTIPLER FUNCTION FOR TT(M)                              * *
C  *IUBF(M)---MULTIPLER FUNCTION FOR UE(M)                              * *
C  *IUBDF(M)---MULTIPLIER FUNCTION FOR FUBD(M)                          * *
C  *IUPXB(I)---BOUNDARY CONDITIONS FUNCTIONS NUMBER TO BE IMPOSED ON    * *
C              FACE UPX(I) OF REGION I.                                 * *
C  *IUPYB(I)---BOUNDARY CONDITIONS FUNCTIONS NUMBER TO BE IMPOSED ON    * *
C              FACE UPY(I) OF REGION I.                                 * *
C  *IUTF(M)---MULTIPLER FUNCTION FOR UT(M)                              * *
C  *IVBDF(M)---MULTIPLIER FUNCTION FOR FVBD(M)                          * *
C  *IVBF(M)---MULTIPLER FUNCTION FOR VE(M)                              * *
C  *IVTF(M)---MULTIPLER FUNCTION FOR VT(M)                              * *
C  *IWBF(M)---MULTIPLER FUNCTION FOR WE(M)                              * *
C  *IWTF(M)---MULTIPLER FUNCTION FOR WT(M)                              * *
C  *IXFD(I)---NUMBER OF SUBDIVISIONS BETWEEN GROSS LATTICE LINES XGRL(I)* *
C             AND XGRL(I+1).-INPUT                                      * *
C  *IYFD(I)---NUMBER OF SUBDIVISIONS BETWEEN GROSS LATTICE LINES YGRL(I)* *
C             AND YGRL(I+1).-INPUT                                      * *
C  *LDTMCR---SELECTS THE DESIRED CRITERION TO DETERMINE THE SUITABILITY * *
C            OF THE PROPOSED DTM.-INPUT                                 * *
C  *NANLFC---TOTAL NUMBER OF ANALYTICAL  FUNCTIONS  - INPUT             * *
C  *NBN---BOUNDARY CONDITION NUMBER                                     * *
C  *NBNDF---TOTAL NUMBER OF BOUNDARY CONDITIONS FUNCTIONS.-INPUT        * *
C  *NBOTF---TOTAL NUMBER OF BOTTOM CONDITIONS FUNCTIONS.-INPUT          * *
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C    NBXM---NODAL DISPLAY FOR UPSTREAM ECUNDARIES IN X-DIRECTION.          * *
C    NBXP---NODAL DISPLAY FOR DOWNSTREAM BOUNCARIES IN X-DIRECTION.        * *
C    NBYM---NODAL DISPLAY FOR UPSTREAM EOUNDARIES IN Y-DIRECTION.          * *
C    NBYP---NODAL CISPLAY FOR DOWNSTREAM BOUNCARIES IN Y-DIRECTION.        * *
C   *NDTMC---NUMBER OF TIME STEPS BETWEEN CHANGES IN TIME STEP SIZE.-INPU* *
C   *NGENF---TOTAL NUMBER OF VOLUMETRIC HEAT OR MASS GENERATION            * *
C           FUNCTIONS.-INPUT                                               * *
C   *NHBDTP(M)---TYPE OF BOUNCARY CONDITION F    'EVATION                  * *
C   *NINTLF---TOTAL NUMEER OF INITIAL CCNDIT'  . FUNCTIONS.-INPUT          * *
C   *NK---TOTAL NUMBER OF CHEMICAL SPECIES CK ..NSIDERED.-INPUT            * *
C   *NREG---TOTAL NUMBER OF REGIONS.-INF.                                  * *
C   *NTBDTP(M)---TYPE OF BOUNDARY CONDITION FCR TEMP. OR S..CIES           * *
C                CONCENTRATION.                                            * *
C   *NTBLFC---TOTAL NUMBER OF TABULATED FUNCTIONS - :NPUT                  * *
C   *NTMAX---TOTAI NUMBER OF TEMPERATURE MONITORING POINTS.-INPUT          * *
C    NTOPF---TOTAI NUMBER OF TOP CONDITIONS FUNCTIONS.-INPUT               * *
C   *NUBDTP(M)---TYPE OF BOUNDARY CONDITICN FCR VELOCITY U                 * *
C   *NVBDTP(M)---TYPE CF BOUNDARY CONDITION FCR VELOCITY V                 * *
C   *NXGRL---TOTAL NUMBER OF GROSS LATTICE LINES IN X DIRECTION.-INPUT     * *
C   *NYGRL---TOTAL NUMBER OF GROSS LATTICE LINES IN Y DIRECTION.-INPUT     * *
C   *PRBTM---PROBLEM TIME FOR THIS CASE.-INPUT                             * *
C   *QB(M)---HEAT COMING FROM THE BOTTOM.                                  * *
C   *QDV(I)---VALUE OF HEAT GENERATION PER UNIT VOLUME IN INTERNAL         * *
C            GENERATION FUNCTION NUMBER I                                  * *
C    QKBIJ---HEAT COMING FROM BOTTOM BECAUSE CF MASS DIFFUSION.            * *
C    QKTIJ---HEAT COMING FROM TOP BECAUSE OF MASS DIFFUSION.               * *
C   *QSOL---SOLAR HEAT FLUX-INPUT                                          * *
C   *QT(M)---HEAT COMING FROM THE TOP.                                     * *
C    QXIJ---HEAT FLUX IN X-DIRECTION.                                      * *
C    QYIJ---HEAT FLUX IN Y-DIRECTION.                                      * *
C    RO---MIXTURE DENSITY                                                  * *
C    ROK(K)---SPECIES DENSITY                                              * *
C    ROKTD---TEMPERATURE DERIVIATIVE OF THE SPECIES DENSITY.               * *
C    ROTD---TEMPERATURE DERIVIATIVE OF THE MIXTURE DENSITY.                * *
C    SBXIJ---STRESS AT THE BOTTOM IN X-CIRECTION.                          * *
C    SBYIJ---STRESS AT THE BOTTOM IN Y-CIRECTION.                          * *
C    SDTM---INITIAL TIME INCREMENT-INPUT                                   * *
C   *STCK(K,M)---INITIAL VALUE FOR CK(K,I,J)-INPUT                         * *
C   *STH(M)---INITIAL VALUE FOR H(I,J)-INPUT                               * *
C   *STM---STARTING TIME OF THIS CASE.-INPUT                               * *
C   *STT(M)---INITIAL VALUE FOR T(I,J)-INPUT                               * *
C   *STU(M)---INITIAL VALUE FOR U(I,J)-INPUT                               * *
C   *STV(M)---INITIAL VALUE FOR V(I,J)-INPUT                               * *
C   *STWS(M)---INITIAL VALUE FOR WS(I,J)-INPUT                             * *
C    STXIJ---STRESS AT THE TOP IN X-DIRECTION.                             * *
C    STYIJ---STRESS AT THE TOP IN X-DIRECTION.                             * *
C    SXXIJ---NORMAL STRESS IN X-CIRECTICN.                                 * *
C    SXYIJ---SHEAR STRESS IN X- OR Y-DIRECTION.                            * *
C    SYYIJ---NORMAL STRESS IN Y-DIRECTICN.                                 * *
C    TABARG---                                                             * *
C    TABFNC---                                                             * *
C    T(I,J)---WATER TEMPERATURE.                                           * *
C   *TB(M)---TEMPERATURE OF MASS COMING FROM THE BOTTOM.                   * *
C   *TD---DEW-POINT TEMP.-INPUT                                            * *
C   *TIDAL---TIDAL PERIOD IF AN ESTUARY.                                   * *
C    TKIJ---CONSTANT BASED ON THE SLOPE OF THE TCP WATER SURFACE.          * *
C    TM---CURRENT TIME                                                     * *
C    TMDIJ---MASS FLUX RATE COMING FRCM THE TCP.                           * *
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          C  *TT(M)---TEMPERATURE OF MASS COMING FROM THE TOP.                  * *
          C   TTMD(I,J)---TIME DERIVIATIVE OF WATER TEMPERATURE.                * *
          C   U(I,J)---WATER VELOCITY IN X DIRECTICN.                           * *
          C  *UB(M)---VELOCITY OF MASS COMING FROM THE BOTTOM IN X-DIRECTION-INPUT* *
          C  *UPX(I)---UPSTREAM GROSS LATTICE LINE BOUNDING REGION I IN         * *
          C            X DIRECTION.                                             * *
          C  *UPY(I)---UPSTREAM GROSS LATTICE LINE BOUNDING REGION I IN         * *
          C            Y DIRECTION.                                             * *
          C  *UT(M)---VELOCITY OF MASS COMING FRCM THE TCP IN X-DIRECTION.-INPUT * *
          C   UTMD(I,J)---TIME DERIVIATIVE OF VELOCITY IN X-DIRECTION.          * *
          C   V(I,J)---WATER VELOCITY IN Y DIRECTICN.                           * *
          C  *VB(M)---VELOCITY OF MASS COMING FRCM THE BOTTOM IN Y-DIRECTION-INPUT* *
          C  *VT(M)---VELOCITY OF MASS COMING FRCM THE TCP IN Y-DIRECTION.-INPUT * *
          C   VTMD(I,J)---TIME DERIVIATIVE OF VELOCITY IN Y-DIRECTION.          * *
          C  *WB(M)---VELOCITY OF MASS COMING FRCM THE BOTTOM IN Z-DIRECTION-INPUT* *
          C   WS(I,J)---RATE OF CHANGE OF WATER ELEVATION WITH RESPECT TO       * *
          C     TIME, THAT IS ALSO WATER VERTICAL VELOCITY AT THE SURFACE.      * *
          C  *WT(M)---VELOCITY OF MASS COMING FRCM THE TCP IN Z-DIRECTION.-INPUT * *
          C            XGRL(I) AND XGRL(I+1).-INPUT                             * *
          C   X(I)---DISTANCE IN X DIRECTION UP TO THE I GRID LINE.             * *
          C  *XGRL(I)---GRCSS LATTICE LINE I IN X DIREC.-INPUT                  * *
          C            XGRL(I) AND XGRL(I+1).-INPUT                             * *
          C  *XKPC---CONSTANT PART OF THERMAL CONDUCTIVITY IN                   * *
          C            X DIRECTION -INPUT                                       * *
          C   XKPIJ---TOTAL EFFECTIVE HEAT DISPERSICN COEFFICIENT IN X-DIRECTION. * *
          C  *XTMAX(I)---X LCCATION OF POINT AT WHICH TIDAL MADE AVERAGE AND    * *
          C              MINIMUM TEMPERATURE SHOULD BE CALCULATED               * *
          C  *XTVSC---CONSTANT PART OF DYNAMIC VISCOSITY IN                     * *
          C            X DIRECTION -INPUT                                       * *
          C   XTVSIJ---TURBULENT VISCOSITY IN X-CIRC                            * *
          C   Y(J)---DISTANCE IN Y DIRECTICN UP TO THE J GRID LINE              * *
          C  *YGRL(I)---GROSS LATTICE  LINE I IN Y DIREC.-INPUT                 * *
          C  *YKPC---CONSTANT PART OF THERMAL CONDUCTIVITY IN                   * *
          C            Y DIRECTION -INPUT                                       * *
          C   YKPIJ---TOTAL EFFECTIVE HEAT DISPERSICN COEFFICIENT IN Y-DIRECTION. * *
          C  *YTMAX(I)    Y LOCATION OF ABOVE POINT.                            * *
          C   YTVS---TURBULENT VISCOSITY IN Y-DIRECTION.                        * *
          C  *YTVSC---CONSTANT PART OF DYNAMIC VISCOSITY IN                     * *
          C            Y DIRECTION -INPUT                                       * *
          C                                                                     * *
          C******************************************************************** * *
          C                                                                     * *
          C                                                                     * *
          C                                                                     * *
ISN 0002        IMPLICIT REAL*8(A-H,O-Z)                                        * *
ISN 0003        COMMON/COMBIN/ ANL,ATMP,CPIJ,CKIJ(4),CKIPJ(4),CKIMJ(4),CKIJP(4) ,* *
               > CKIJM(4),DXM,DXP,DYM,DYP,DXIP1,DYJP1,DXLI,DXRI,DXLI1,DXRI1,DYLJ ,* *
               > DYRJ,DYLJ1,DYRJ1,GBIJ,GKBIJ(4),QBIJ,QKBIJ(4),SBXIJ,SBYIJ,GXIMJ , * *
               > GXIPJ,GYIJM,GYIJP,GTIJ,GKTIJ(4),QTIJ,QKTIJ(4),STXIJ,STYIJ,QDVIJ ,* *
               > QXIMJ,QXIPJ,QYIJM.QYIJP,GKXIMJ(4),GKXIPJ(4),GKYIJM(4),GKYIJP(4) ,* *
               > HTKIJ(4),HTKIJM(4),HTKIPJ(4),HTKIMJ(4),HTKIJP(4),HIJ,HIJM,HIPJ , * *
               > HIMJ,HIJP,UIJ,UIJM,UIPJ,UIMJ,UIJP,VIJ,VIJM,VIPJ,VIMJ,VIJP,TIJ ,  * *
               > TIJM,TIPJ,TIMJ,TIJP,ROKTPD(4),RCIJ,ROIJM,ROIPJ,ROIMJ,ROIJP ,     * *
               > SHKTPD(4),SHTCKD(4),SHTTPD,SXXIMJ,SXXIPJ,SYYIJM,SYYIJP,SXYIJM ,  * *
               > SXYIPJ,SXYIMJ,SXYIJP,ROIMJD,RCIPJD,ROIJMD,ROIJPD,EQTMP,TDIJ ,    * *
               > HCIMJ,HCIPJ,HCIJM,HCIJP,GR,ROCKD(4),SPHTK(4),DENSK(4),RODKIJ(4) ,* *
               > GKDVIJ(4),DXI,DYJ ,QDV(25),HBD(25),UBD(25),VBD(25),TBD(25),      * *
               > CKBD(4,25),TBIJ,HCBIJ ,DCKBIJ(4),HTKBIJ(4),BNIJ,UBIJ,VBIJ,WBIJ,  * *
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                    > ROBIJ,HTBIJ,CKBIJ(4),TTIJ,HCTIJ,CCKTIJ(4),HTKTIJ(4),UTIJ,VTIJ,
                    > WTIJ,ROTIJ,HTTIJ,CKTIJ(4)  ,QBD(25),GBC(25),GKBD(4,25),SBDN(25),
                    > SBDSH(25),WIND,WINDX,WINDY ,IJ,IM1J,IP1J,IJM1,IJP1,INTRT,KOIJ,
                    > KOIM1J,KOIP1J,KOIJM1,KOIJP1  ,NBXM,NBXP,NBYM,NBYP,NREGIN,NBNDF ,
                    > IXQV(25),JYQV(25),NHBDTP(25),NUEDTP(25),NVBDTP(25),NTBDTP(25)  ,
                    > NXGRL,NYGRL,NREG,NINTLP,NTOPF,NECTF,NTEIFC,NTMAX,NGENF
ISN 0004              COMMON/Z/NZSP,NDUM,Z(1)
ISN 0005              COMMON/DROU/TIM,DTM,TM,PERIOD,IT,NMOVE,LMOVE,N
ISN 0006              COMMON/OUT/NK,KX,KY,NKKX,IXO,IYO,IHO,IUO,IVO,IWSO,ITO,ITTMDO,ICKO
ISN 0007              DIMENSION IXT(10),JYT(10)
ISN 0008              CALL SETZ
                C***   SUBR.SETZ DEFINES FULLY THE SIZE OF Z ARRAY AND THE VALUE
                C      OF NZSP.
ISN 0009              CALL INPUT(NK)
ISN 0010              CALL GEOM(KX,KY,Z,Z(2000),Z(4000),Z(6000),IXT,JYT)
                C   Z=DX,Z(2000)=DY,Z(4000)=X,Z(6000)=Y
                C *** PARTITION 1-DIM. ARRAY Z INTO SUBARRAYS OF THE
                C *** CORRECT SIZE FOR THE ASSOCIATED 1-, 2-, 3-
                C *** DIMENSIONAL ARRAY.
ISN 0011              N=KX*KY
ISN 0012              M=NK*N
                C *** THE DIMENSIONED ARRAYS A(KX,KY) AND B(NK,KX,KY) CONTAIN N AND
                C     M ELEMENTS RESPECTIVELY.
ISN 0013              IF (KX.LE.1999.AND.KY.LE.1999.AND.NZSP.GE.MAX0(6000+KY-1,N+4*(KX+
                    > KY))) GO TO 10
ISN 0015              PRINT 1000,KX,KY,NZSP
ISN 0016              CALL EXIT
ISN 0017           10 IDX=1
ISN 0018              IDY=KX+1
ISN 0019              IX=IDY+KY
ISN 0020              IY=IX+KX
ISN 0021              DO 12 I=1,KY
ISN 0022           12 Z(IDY-1+I)=Z(1999+I)
ISN 0023              DO 14 I=1,KX
ISN 0024           14 Z(IX-1+I)=Z(3999+I)
ISN 0025              DO 16 I=1,KY
ISN 0026           16 Z(IY-1+I)=Z(5999+I)
ISN 0027              LMOVE=(4+NK)*N
                C *** HAVE LMOVE UNKNOWNS
ISN 0028              GO TO (18,20,18),INTRT
ISN 0029           18 NMOVE=LMOVE+LMOVE
                C *** SAVE MEANS SAVING IN A RESTART FILE AT END OF THIS RUN
                C *** SAVE UNKNOWNS AND ROUNDING ERR.EST., O.     R-K-G.
                C ***
                C *** SAVE UNKNOWNS AND DERIVATIVES AT PREVIOUS TIME STEP (DER. IN Q).
                C *** ADAMS-BASHFORTH
ISN 0030              GO TO 22
ISN 0031           20 NMOVE=LMOVE
                C *** SAVE UNKNOWNS ONLY, EULER.
ISN 0032           22 CONTINUE
ISN 0033              IDXL=IY+KY
ISN 0034              IDXR=IDXL+KX
ISN 0035              IDYL=IDXR+KX
ISN 0036              IDYR=IDYL+KY
                C *** DXL(I+1)=DX(I)/(DX(I)+DX(I+1))          I=1,...,KX-1
                C *** DXR(I+1)=DX(I+1)/(DX(I)+DX(I+1))        I=1,...,KX-1
                C *** DYL(I+1)=DY(I)/(DY(I)+DY(I+1))          I=1,...,KY-1
                C *** DYR(I+1)=DY(I+1)/(DY(I)+DY(I+1))        I=1,...,KY-1
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 ISN 0037          KXM1=KX-1
 ISN 0038          DO 24 I=1,KXM1
 ISN 0039          D=Z(IDX+I)+Z(IDX-1+I)
 ISN 0040          Z(IDXL+I)=Z(IDX-1+I)/D
 ISN 0041       24 Z(IDXR+I)=Z(IDX+I)/D
 ISN 0042          KYM1=KY-1
 ISN 0043          DO 26 I=1,KYM1
 ISN 0044          D=Z(IDY+I)+Z(IDY-1+I)
 ISN 0045          Z(IDYL+I)=Z(IDY-1+I)/D
 ISN 0046       26 Z(IDYR+I)=Z(IDY+I)/D
 ISN 0047          INFLG=IDYR+KY
 ISN 0048          IH=INFLG+N
 ISN 0049          IU=IH+N
 ISN 0050          IV=IU+N
 ISN 0051          IT=IV+N
 ISN 0052          ICK=IT+N
 ISN 0053          IEHSR=ICK+M
 ISN 0054          IEUPL=IEHSR+N
 ISN 0055          IEVPL=IEUPL+N
 ISN 0056          IETMP=IEVPL+N
 ISN 0057          IECSK=IETMP+N
 ISN 0058          IHTMD=IECSK+M
 ISN 0059          IUTMD=IHTMD+N
 ISN 0060          IVTMD=IUTMD+N
 ISN 0061          ITTMD=IVTMD+N
 ISN 0062          ICKTMD=ITTMD+N
 ISN 0063          NSPACE=ICKTMD+M-1
 ISN 0064          CALL GEOMFG(Z(INFLG),KX,KY,Z(IDX),Z(IDY),Z(IX),Z(IY),IXT,JYT,
                  > NCHECK,NZSP,NSPACE)
            C *** SET CONSTANTS NEEDED IN SUBR.OUTPRT.
 ISN 0065          NKKX=NK*KX
 ISN 0066          IX0=IX-1
 ISN 0067          IY0=IY-1
 ISN 0068          IH0=IH-1
 ISN 0069          IU0=IU-1
 ISN 0070          IV0=IV-1
 ISN 0071          IWS0=IHTMD-1
 ISN 0072          IT0=IT-1
 ISN 0073          ITTMD0=ITTMD-1
 ISN 0074          ICK0=ICK-1
 ISN 0075          IF (NSPACE.GT.NZSP) NCHECK=NCHECK+10000
 ISN 0077          CALL DRIVE(KX,KY,NK,Z(IX),Z(IY),Z(IDX),Z(IDY),Z(IDXL),Z(IDXR),
                  > Z(IDYL),Z(IDYR),Z(IH),Z(IU),Z(IV),Z(IT),Z(ICK),Z(IEHSR),Z(IHTMD),
                  >  Z(IUTMD),Z(IVTMD),Z(ITTMD),Z(ICKTMD),Z(INFLG),IXT,JYT,NCHECK,
                  > Z(IH))
 ISN 0078          RETURN
 ISN 0079     1000 FORMAT('1EITHER KX.GT.1999'/8X,'KY.GT.1999'/ ,5X,
                  > 'OR NZSP.LT.MAX(6000+KY-1,N+4(KX+KY))'/// ' KX=',I4/' KY=',I4/
                  > ' NZSP=',I6//' N=KX*KY'//' CP.SUBR.MAIN')
 ISN 0080          END
```

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*OPTIONS IN EFFECT*       NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,

*OPTIONS IN EFFECT*       SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF

*STATISTICS*     SOURCE STATEMENTS =       79 ,PROGRAM SIZE =     2526

*STATISTICS*  NO  DIAGNOSTICS GENERATED
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****** END OF COMPILATION ******                105K BYTES OF CORE NOT USED
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OS/360 FORTRAN H

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      COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,
                       SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF
ISN 0002            SUBROUTINE INPUT(NK)
ISN 0003            IMPLICIT REAL*8 (A-H,O-Z)
ISN 0004            REAL*4 TODAY,TITIE
ISN 0005            COMMON/COMBIN/ ANL,ATMP,CPIJ,CKIJ(4),CKIPJ(4),CKIMJ(4),CKIJP(4) ,
                  > CKIJM(4),DXM,DXP,DYM,DYP,DXIP1,DYJP1,DXLI,DXRI,DXLI1,DXRI1,DYLJ ,
                  > DYRJ,DYLJ1,DYRJ1,GBIJ,GKBIJ(4),QBIJ,QKBIJ(4),SBXIJ,SBYIJ,GXIMJ ,
                  > GXIPJ,GYIJM,GYIJP,GTIJ,GKTIJ(4) ,QTIJ,QKTIJ(4) ,STXIJ,STYIJ,QDVIJ ,
                  > QXIMJ,QXIPJ,QYIJM,QYIJP,GKXIMJ(4),GKXIPJ(4),GKYIJM(4),GKYIJP(4) ,
                  > HTKIJ(4),HTKIJM(4),HTKIPJ(4),HTKIMJ(4),HTKIJP(4),HIJ,HIJM,HIPJ ,
                  > HIMJ,HIJP,UIJ,UIJM,UIPJ,UIMJ,UIJP,VIJ,VIJM,VIPJ,VIMJ,VIJP,TIJ ,
                  > TIJM,TIPJ,TIMJ,TIJP,ROKTPD(4),RCIJ,ROIJM,ROIPJ,ROIMJ,ROIJP ,
                  > SHKTPD(4),SHTCKD(4),SHTTPD,SXXIMJ,SXXIPJ,SYYIJM,SYYIJP,SXYIJM ,
                  > SXYIPJ,SXYIMJ,SXYIJP,ROIMJD,ROIPJD,ROIJMD,ROIJPD,EQTMP,TDIJ ,
                  > HCIMJ,HCIPJ,HCIJM,HCIJP,GR,ROCKD(4),SPHTK(4),DENSK(4),RODKIJ(4) ,
                  > GKDVIJ(4),DXI,DYJ ,QDV(25),HBD(25),UBD(25),VBD(25),TBD(25),
                  > CKBD(4,25),TBIJ,HCBIJ ,DCKBIJ(4),HTKBIJ(4),BNIJ,UBIJ,VBIJ,WBIJ,
                  > ROBIJ,HTBIJ,CKBIJ(4),TTIJ,HCTIJ,DCKTIJ(4),HTKTIJ(4),UTIJ,VTIJ,
                  > WTIJ,ROTIJ,HTTIJ,CKTIJ(4) ,QBD(25),GBD(25),GKBD(4,25),SBDN(25),
                  > SBDSH(25),WIND,WINDX,WINDY ,IJ,IM1J,IP1J,IJM1,IJP1,INTRT,KOIJ,
                  > KOIM1J,KOIP1J,KOIJM1,KOIJP1 ,NBXM,NBXP,NBYM,NBYP,NREGIN,NBNDF ,
                  > IXQV(25),JYQV(25),NHBDTP(25),NUBDTP(25),NVBDTP(25),NTBDTP(25) ,
                  > NXGRL,NYGRL,NREG,NINTLP,NTOPF,NBOTF,NTBLFC,NTMAX,NGENF
ISN 0006            DIMENSION TITLE(18),TODAY(2),NOW(2)
ISN 0007            COMMON/INDBIT/DTMLT,STM,SDTM,PRBTM,DPRTTM,CPUSEC,TIDAL,FDTM,
                  > INDTM,NDTMC,IFINIS,LDTMCR,ISTART,IPLOT,NCPU
ISN 0008            COMMON/TABLE/NTBLP(10),TABARG(25,10),TABFNC(25,10)
ISN 0009            COMMON/SCRATH/KTAB(10)
ISN 0010            READ(50,1000) TITLE
              C * * * THESE CALLS GET THE DATE AND TIME AND PRINT THEM * * * * * *
ISN 0011            CALL IDAY(TODAY)
ISN 0012            CALL TIME(NOW)
ISN 0013            PRINT 1010, (TITLE(I),I=1,18),(TODAY(I),I=1,2),(NOW(I),I=1,2)
              C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
ISN 0014            PRINT 1020
ISN 0015            READ(50,1030) NK,NREG,NINTLP,NGENF,NBNDF,NTOPF,NBOTF,NANLFC,
                  > NTBLFC,NXGRL,NYGRL,NTMAX
ISN 0016            READ(50,1030) ISTART,IFINIS ,IPLOT,INTRT
ISN 0017            READ(50,1040) STM,PRBTM,CPUSEC,DPRTTM,TIDAL
ISN 0018            READ(50,1050) SDTM,FDTM,DTMLT,INDTM,NDTMC,LDTMCR
ISN 0019            PRINT 1060, NK,NREG,NINTLP,NGENF,NBNDF,NTOPF,NBOTF,NANLFC, NTBLFC,
                  > NXGRL,NYGRL,NTMAX
ISN 0020            PRINT 1070, ISTART,IFINIS ,IPLOT,INTRT
ISN 0021            PRINT 1080, STM,PRBTM,CPUSEC,DPRTTM,TIDAL
ISN 0022            PRINT 1090, SDTM,FDTM,DTMLT,INDTM,NDTMC,LDTMCR
ISN 0023            IF (NTBLFC.LE.0) GO TO 22
ISN 0025            IF (NTBLFC.LE.10) GO TO 10
ISN 0027            PRINT 1100,NTBLFC
ISN 0028            GO TO 14
ISN 0029         10 DO 12 J=1,NTBLFC
ISN 0030         12 KTAB(J)=-1
ISN 0031            PRINT 1110
ISN 0032            DO 18 I=1,NTBLFC
ISN 0033            READ(50,1120) ITBLFC,NTEMP,(TABARG(J,ITBLFC),TABFNC(J,ITBLFC), J=
                  > 1,NTEMP)
ISN 0034            NTBLP(ITBLFC)=NTEMP
ISN 0035            IF (1.LE.ITBLFC.AND.ITBLFC.LE.NTBLFC) GO TO 16
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ISN 0037          PRINT 1130,ITBLFC,NTBLFC
ISN 0038       14 CALL EXIT
ISN 0039       16 IF (KTAB(ITBLFC).EQ.-1) GO TO 18
ISN 0041          PRINT 1140,ITBLFC
ISN 0042          GO TO 14
ISN 0043       18 KTAB(ITBLFC)=ITBLFC
ISN 0044          DO 20 I=1,NTBLFC
ISN 0045          NTEMP=NTBLF(I)
ISN 0046       20 PRINT 1150,I,(TABARG(J,I),TABFNC(J,I),J=1,NTEMP)
ISN 0047       22 RETURN
ISN 0048     1000 FORMAT(18A4)
ISN 0049     1010 FORMAT(1H1,' CASE TITLE: ',18A4,23X,2A4,4X,2A4/1X,' --- --- ---'/)
ISN 0050     1020 FORMAT(1X,' INPUT INFORMATION FRCM SUBROUTINE INPUT:'/1X,
                 > ' --- --- --- --- --- --- --- --- --- ---')
ISN 0051     1030 FORMAT(14I5)
ISN 0052     1040 FORMAT(8E10.2)
ISN 0053     1050 FORMAT(3E10.2,3I5)
ISN 0054     1060 FORMAT (/'0',1X,'CARD NO. 1'/
                 >'0',1X,'TOTAL NUMBER OF CHEMICAL SPECIES CK CONSIDERED (NK)= ',I3
                 > /'0',1X,'TCTAL NUMBER OF REGIONS (NREG)= '
                 >,I3/'0',1X,'TOTAL NUMBER OF INITIAL CONDITIONS FUNCTIONS (NINTLF)
                 >= ',I3/'0',1X,'TOTAL NUMBER OF VCLUMETRIC HEAT OR MASS GENERATION
                 > FUNCTIONS (NGENF)= ',I3/'0',1X'TOTAL NUMBER OF BOUNDARY CONDITION
                 >S FUNCTIONS (NBNDF)= ',I3/'0',1X,'TOTAL NUMBER OF TOP CONDITIONS F
                 >UNCTIONS (NTOPF)= ',I3/'0'1X,'TCTAL NUMBER OF BOTTOM CONDITIONS FU
                 >NCTIONS (NBOTF)= ',I3/'0',1X,'TOTAL NUMBER OF ANALYTICAL FUNCTIONS
                 > (NANLFC)= ',I3/'0',1X,'TOTAL NUMBER OF TABULATED FUNCTIONS (NTBLF
                 >C)= ',I3/'0',1X,'TOTAL NUMBER CF GROSS LATTICE LINES IN X-DIRECTIO
                 >N (NXGRL)= ',I3/'0',1X,'TOTAL NUMBER OF GROSS LATTICE LINES IN Y-D
                 >IRECTION (NYGRL)= ',I3/'0',1X,'TCTAL NUMBER OF TEMP. MONITORING PO
                 >INTS (NTMAX) =  ',I3)
ISN 0055     1070 FORMAT (//'0',1X,'CARD NO.  2',
                 >      /'0',1X,'RESTART FLAG. IF EQUAL ZERC NO RESTART INFORMATION
                 >IS REQUIREC (ISTART)= ',I3/'0',1X,'FINISH FLAG. IF EQUAL ZERO NO R
                 >ESTART FILE IS CREATED (IFINIS)= ',I3/'0',1X,'PLOTTING FLAG. IF EQ
                 >UAL ZERO NC PLOTTING INFORMATION IS GENERATED. (IPLOT) = ',I3/
                 >'0 FLAG FOR SELECTING THE NUMERICAL INTEGRATION PROCEDURE. (INTRT=
                 >1 SELECTS RUNGE-KUTTA-GILL METHOC.'/1H ,3X,'INTRT=2 SELECTS EULER
                 > METHOD.  INTRT=3 SELECTS ADAM-BASHWORTH METHOD.) (INTRT) =',I1)
ISN 0056     1080 FORMAT(///02X,'CARD NO. 3'/'0',1X,
                 > 'STARTING TIME OF THIS CASE (STM)= ',F8.4/'0',1X,
                 > 'PROBLEM TIME FOR THIS CASE (PRETM)= ',F8.4/'0',1X,
                 > 'COMPUTER TIME CUTOFF LIMIT IN SECONDS (CPUSEC)= ',F7.2/'0',1X,
                 > 'TIME INCREMENT FOR PRINTED OUTPUT (DPRTIM)=  ',F8.4/ '0',1X,
                 > 'TIDAL PERIOD IF AN ESTUARY (TIDAL) = ',F8.4)
ISN 0057     1090 FORMAT(//'0',1X,'CARD NO. 4'/'0',' INITIAL TIME INCREMENT (SDTM) =
                 >' ,F8.5/'0',1X,'LARGEST LIMIT FOR TIME INCREMENT (FDTM)= ',F8.5/'0
                 >',1X,'TIME INCREMENT IS MULTIPLIED EVERY NDTMC TIME STEPS BY (DTML
                 >T)=  ',F6.2/'0',1X,'NUMBER OF TIME STEPS BEFORE PROCESS OF INCREAS
                 >E IN TIME STEP SIZE BEGINS (INDTM)= ',I3/'0',1X,'NUMBER OF TIME ST
                 >EPS BETWEEN CHANGES IN TIME STEP SIZE (NCTMC) = ',I3/'0',1X,'CRITE
                 >RION TYPE (AS DEFINED IN SUBROUTINE CHKDIM) THAT EACH DTM WILL BE
                 >REQUIRED TO SATISFY (LDTMCR)= ',I3)
ISN 0058     1100 FORMAT(' NTBLFC='I2,1X'IS GREATER THAN MAX.ALLOWED VALUE OF 10.')
ISN 0059     1110 FORMAT (//2X,'TABULATED  FUNCTIONS')
ISN 0060     1120 FORMAT(2I5,6E10.5,10X/(10X,6E10.5,10X))
ISN 0061     1130 FORMAT(' ITBLFC='I2,1X'IS NOT IN THE RANGE 1 TO NTBLFC='I2)
ISN 0062     1140 FORMAT(' TABLE NC. = ITBLFC = ' I2,1X'HAS ALREADY BEEN USED.')
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   ISN 0063       1150 FORMAT(//7X'TABLE NO.'I3/4X'TABARG'8X'TABFNC'/(1PE12.4,3X,E11.4))  INPU1150
   ISN 0064            END                                                                 INPU1160

*OPTIONS IN EFFECT*       NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,

*OPTIONS IN EFFECT*       SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF

*STATISTICS*      SOURCE STATEMENTS =       63 ,PROGRAM SIZE =      4236

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                                      105K BYTES OF CORE NOT USED
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CS/360 FORTRAN H

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        COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,
                         SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF
ISN 0002          SUBROUTINE GEOM(KX,KY,DX,DY,X,Y,IXT,JYT)
ISN 0003          IMPLICIT REAL*8 (A-H,O-Z)
ISN 0004          COMMON/REGION/DEPTH(25),SM(25),ILREG(25),IHREG(25),JLREG(25),
                > JHREG(25),INTF(25),IGENF(25),ITOPF(25),IBOTF(25)
ISN 0005          INTEGER*2 ILREG,IHREG,JLREG,JHREG
ISN 0006          INTEGER*2 INTF,IGENF,ITOPF,IBOTF
ISN 0007          COMMON/COMBIN/ ANL,ATMP,CPIJ,CKIJ(4),CKIPJ(4),CKIMJ(4),CKIJP(4) ,
                > CKIJM(4),DXM,DXP,DYM,DYP,DXIP1,DYJP1,DXLI,DXRI,DXLI1,DXRI1,DYLJ ,
                > DYRJ,DYLJ1,DYRJ1,GBIJ,GKBIJ(4),QBIJ,QKBIJ(4),SBXIJ,SBYIJ,GXIMJ ,
                > GXIPJ,GYIJM,GYIJP,GTIJ,GKTIJ(4),QTIJ,QKTIJ(4),STXIJ,STYIJ,QDVIJ ,
                > QXIMJ,QXIPJ,QYIJM,QYIJP,GKXIMJ(4),GKXIPJ(4),GKYIJM(4),GKYIJP(4) ,
                > HTKIJ(4),HTKIJM(4),HTKIPJ(4),HTKIMJ(4),HTKIJP(4),HIJ,HIJM,HIPJ ,
                > HIMJ,HIJP,UIJ,UIJM,UIPJ,UIMJ,UIJP,VIJ,VIJM,VIPJ,VIMJ,VIJP,TIJ ,
                > TIJM,TIPJ,TIMJ,TIJP,ROKTPD(4),RCIJ,ROIJM,ROIPJ,ROIMJ,ROIJP ,
                > SHKTPD(4),SHTCKD(4),SHTTPD,SXXIMJ,SXXIPJ,SYYIJM,SYYIJP,SXYIJM ,
                > SXYIPJ,SXYIMJ,SXYIJP,ROIMJD,ROIPJD,ROIJMD,ROIJPD,EQTMP,TDIJ ,
                > HCIMJ,HCIPJ,HCIJM,HCIJP,GR,ROCKD(4),SPHTR(4),DENSK(4),RODKIJ(4) ,
                > GKDVIJ(4),DXI,DYJ ,QDV(25),HBD(25),UBD(25),VBD(25),TBD(25),
                > CKBD(4,25),TBIJ,HCBIJ ,DCKBIJ(4),HTKBIJ(4),BNIJ,UBIJ,VBIJ,WBIJ,
                > ROBIJ,HTBIJ,CKBIJ(4),TTIJ,HCTIJ,DCKTIJ(4),HTKTIJ(4),UTIJ,VTIJ,
                > WTIJ,ROTIJ,HTTIJ,CKTIJ(4) ,QBD(25),GBD(25),GKBD(4,25),SBDN(25),
                > SBDSH(25),WIND,WINDX,WINDY ,IJ,IM1J,IP1J,IJM1,IJP1,INTRT,KOIJ,
                > KOIM1J,KOIP1J,KOIJM1,KOIJP1 ,NBXM,NBXP,NBYM,NBYP,NREGIN,NBNDF ,
                > IXQV(25),JYQV(25),NHBDTP(25),NUBDTP(25),NVBDTP(25),NTBDTP(25) ,
                > NXGRL,NYGRL,NREG,NINTLF,NTOPF,NBOTF,NTEIFC,NTMAX,NGENF
ISN 0008          LOGICAL*1 TABLE(32),STRING(132)
ISN 0009          INTEGER*4 NCR(5),KFLG(5)
ISN 0010          REAL*4 FLAG(5),XNAME,YNAME
ISN 0011          EQUIVALENCE (TABLE(1),TAB(1))
ISN 0012          DIMENSION DX(1),DY(1),X(1),Y(1)
ISN 0013          COMMON/SCRATH/XGRL(50),YGRL(50),ARAREG(25),UPX(25),DNX(25),UPY(25)
                > ,DNY(25),IXFD(49),IYFD(49),IXGRL(50),JYGRL(50),NODREG(25)
                > IUPXB(25),IDNXB(25),IUPYB(25),IDNYB(25),KREG(25)
ISN 0014          INTEGER*2 IXFD,IYFD,IXGRL,JYGRL,NODREG
ISN 0015          INTEGER*2 IUPXB,IDNXB,IUPYB,IDNYB,KREG
ISN 0016          DIMENSION IXT(1),JYT(1)
ISN 0017          DIMENSION XTMAX(10),YTMAX(10),TAB(4)
ISN 0018          DATA XNAME/' X  '/,YNAME/' Y  '/
ISN 0019          DATA NSCALE/Z01000000/
ISN 0020          DATA TAB/' 1234567','89ABCDEF','GHIJKLMN','OPQRSTUV'/
ISN 0021          DATA FLAG/'NBXM','NBXP','NBYM','NBYP','REG.'/
            C ***
            C ***
ISN 0022          READ(50,1000) (XGRL(M),M=1,NXGRL)
ISN 0023          NXL=NXGRL-1
ISN 0024          READ(50,1010) (IXFD(M),M=1,NXL)
ISN 0025          PRINT 1020
ISN 0026          PRINT 1030
ISN 0027          PRINT 1040,(M,XGRL(M),IXFD(M),M=1,NXL)
ISN 0028          PRINT 1040,NXGRL,XGRL(NXGRL)
ISN 0029          READ(50,1000) (YGRL(M),M=1,NYGRL)
ISN 0030          NYL=NYGRL-1
ISN 0031          READ(50,1010) (IYFD(M),M=1,NYL)
ISN 0032          PRINT 1050
ISN 0033          PRINT 1040,(M,YGRL(M),IYFD(M),M=1,NYL)
ISN 0034          PRINT 1040,NYGRL,YGRL(NYGRL)
```

```
ISN 0035          LASTI=0                                                  GEOM  570
ISN 0036          DO 12 M=1,NXI                                            GEOM  580
ISN 0037          INTI=LASTI+1                                             GEOM  590
ISN 0038          LASTI=LASTI+IXFD(M)                                      GEOM  600
ISN 0039          WIDTH=(XGRL(M+1)-XGRL(M))/IXFD(M)                        GEOM  610
ISN 0040          XL=XGRL(M)-.5*WIDTH                                      GEOM  620
ISN 0041          IXGRL(M)=INTI                                            GEOM  630
ISN 0042          DO 10 I=INTI,LASTI                                       GEOM  640
ISN 0043          DX(I)=WIDTH                                              GEOM  650
ISN 0044          XL=XL+WIDTH                                              GEOM  660
ISN 0045       10 X(I)=XL                                                  GEOM  670
ISN 0046       12 CONTINUE                                                 GEOM  680
ISN 0047          IXGRL(NXGRL)=LASTI+1                                     GEOM  690
            C *** IXGRL(M) IS THE 1ST I SUBSCRIPT TO THE RIGHT OF THE X-GROSS  GEOM  700
            C *** LATTICE LINE, XGRL(M).                                   GEOM  710
ISN 0048          LASTJ=0                                                  GEOM  720
ISN 0049          DO 16 M=1,NYL                                            GEOM  730
ISN 0050          INTJ=LASTJ+1                                             GEOM  740
ISN 0051          LASTJ=LASTJ+IYFD(M)                                      GEOM  750
ISN 0052          WIDTH=(YGRL(M+1)-YGRL(M))/IYFD(M)                        GEOM  760
ISN 0053          YL=YGRL(M)-.5*WIDTH                                      GEOM  770
ISN 0054          JYGRL(M)=INTJ                                            GEOM  780
ISN 0055          DO 14 J=INTJ,LASTJ                                       GEOM  790
ISN 0056          DY(J)=WIDTH                                              GEOM  800
ISN 0057          YL=YL+WIDTH                                              GEOM  810
ISN 0058       14 Y(J)=YL                                                  GEOM  820
ISN 0059       16 CONTINUE                                                 GEOM  830
ISN 0060          JYGRL(NYGRL)=LASTJ+1                                     GEOM  840
ISN 0061          KX=LASTI                                                 GEOM  850
ISN 0062          KY=LASTJ                                                 GEOM  860
ISN 0063          PRINT 1060                                               GEOM  870
            CW 10 FORMAT(//' ',7X'NODE WIDTH'3X'NODAL CENTER')             GEOM  880
            CW    PRINT 11                                                 GEOM  890
            CW 11 FORMAT(4X'I'2X'X-DIRECTION'3X'X-DIRECTION'/)             GEOM  900
            CW    PRINT 12,(I,DX(I),X(I),I=1,LASTI)                        GEOM  910
            CW 12 FORMAT(I5,0PF13.5,1PE15.6)                               GEOM  920
            CW    PRINT 10                                                 GEOM  930
            CW    PRINT 13                                                 GEOM  940
            CW 13 FORMAT(4X'J'2X'Y-DIRECTION'3X'Y-DIRECTION'/)             GEOM  950
            CW    PRINT 12,(J,DY(J),Y(J),J=1,LASTJ)                        GEOM  960
ISN 0064          LASTK=LASTI                                              GEOM  970
ISN 0065          IF (LASTJ.GT.LASTI) LASTK=LASTJ                          GEOM  980
ISN 0067          DO 22 K=1,LASTK                                          GEOM  990
ISN 0068          IF (K.GT.LASTI) GO TO 18                                 GEOM 1000
ISN 0070          IF (K.GT.LASTJ) GO TO 20                                 GEOM 1010
ISN 0072          PRINT 1070,K,DX(K),DY(K),X(K),Y(K)                       GEOM 1020
ISN 0073          GO TO 22                                                 GEOM 1030
ISN 0074       18 PRINT 1080,K,DY(K),Y(K)                                  GEOM 1040
ISN 0075          GO TO 22                                                 GEOM 1050
ISN 0076       20 PRINT 1090,K,DX(K),X(K)                                  GEOM 1060
ISN 0077       22 CONTINUE                                                 GEOM 1070
            C *** ASSUME XGRL AND YGRL ARE ORDERED IN ASCENDING ORDER.     GEOM 1080
ISN 0078          PRINT 1100                                               GEOM 1090
            C *** NODEXP=TOTAL NUMBER OF NODES DETERMINED BY THE RECTANGULAR GRID  GEOM 1100
ISN 0079          NODEXP=LASTI*LASTJ                                       GEOM 1110
            C *** NODTOT=TOTAL NUMBER OF NODES IN THE DESCRIBED REGIONS.   GEOM 1120
ISN 0080          NODTOT=0                                                 GEOM 1130
ISN 0081          NSK=0                                                    GEOM 1140
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                C *** NSK SET TO 1 IF A REGION EDGE DOESN'T LIE CLOSE ENOUGH TO A GROSS
                C *** LATTICE LINE.  THIS INDICATES THAT A MESSAGE HAS BEEN PRINTED.
ISN 0082              DO 24 M=1,NREG
ISN 0083           24 KREG(M)=-1
                C *** INITIALIZATION OF KREG.  WILL CHECK THAT SAME REGION NUMBER ISN'T
                C *** ASSIGNED MORE THAN ONCE.
ISN 0084              DO 34 M=1,NREG
ISN 0085              READ(50,1110) IREG,INTF(IREG),IGENF(IREG),DEPTH(IREG),UPX(IREG),
                     > DNX(IREG),UPY(IREG),DNY(IREG),ITOPF(IREG),I[illegible]IREG),IUPXB(IREG)
                     > ,IDNXB(IREG),IUPYB(IREG),IDNYB(IREG)
ISN 0086              IF (1.LE.IREG.AND.IREG.LE.25) GO TO 28
ISN 0088              PRINT 1120,IREG
ISN 0089           26 CALL EXIT
ISN 0090           28 IF (KREG(IREG).EQ.-1) GO TO 30
ISN 0092              PRINT 1130,IREG
ISN 0093              GO TO 26
ISN 0094           30 KREG(IREG)=IREG
ISN 0095              IF (UPX(IREG).LT.DNX(IREG).AND.UPY(IREG).LT.DNY(IREG)) GO TO 32
ISN 0097              PRINT 1140,IREG,UPX(IREG),DNX(IREG),UPY(IREG),DNY(IREG)
ISN 0098              GO TO 26
                C *** A REGION EDGE SHOULD LIE ON A GROSS LATTICE LINE. THIS IS
                C *** CHECKED IN SUBR.CHEKED (CHECK EDGE)
                C *** UPON EXIT FROM SUBR.CHEKED, THE VALUE OF THE REGION EDGE
                C *** WILL CORRESPOND EXACTLY WITH THE GROSS LATTICE LINE NEAREST
                C *** THE REGION EDGE UPON ENTRY.
ISN 0099           32 CALL CHEKED(UPX(IREG),XGRL,NXGRL,NSK,' UPX',MC,IREG)
ISN 0100              ILREG(IREG)=IXGRL(MC)
ISN 0101              CALL CHEKED(DNX(IREG),XGRL,NXGRL,NSK,' DNX',MC,IREG)
ISN 0102              IHREG(IREG)=IXGRL(MC)-1
ISN 0103              CALL CHEKED(UPY(IREG),YGRL,NYGRL,NSK,' UPY',MC,IREG)
ISN 0104              JLREG(IREG)=JYGRL(MC)
ISN 0105              CALL CHEKED(DNY(IREG),YGRL,NYGRL,NSK,' DNY',MC,IREG)
ISN 0106              JHREG(IREG)=JYGRL(MC)-1
ISN 0107              ARAREG(IREG)=(DNX(IREG)-UPX(IREG))*(DNY(IREG)-UPY(IREG))
ISN 0108              NODREG(IREG)=(IHREG(IREG)-ILREG(IREG)+1)* (JHREG(IREG)-JLREG(IREG)
                     > +1)
ISN 0109              NODTOT=NODTOT+NODREG(IREG)
ISN 0110           34 CONTINUE
ISN 0111              IF (NSK.EQ.1) PRINT 1100
ISN 0113              PRINT 1150
ISN 0114              PRINT 1160,(I,UPX(I),DNX(I),UPY(I),DNY(I),DEPTH(I),ARAREG(I),
                     > ILREG(I),IHREG(I),JLREG(I),JHREG(I),NODREG(I),I=1,NREG)
ISN 0115              PRINT 1170,NODTOT,NODEXP
ISN 0116              PRINT 1180
ISN 0117              PRINT 1190,(I,INTF(I),IGENF(I),ITOPF(I),IBOTF(I),IUPXB(I),
                     > IDNXB(I),IUPYB(I),IDNYB(I),I=1,NREG)
                C *** CHECK THAT THE REGIONS ARE PAIRWISE DISJOINT.
                C *** WHEN PAINTING OF ONE REGION UPON ANOTHER IS ALLOWED,THIS
                C *** DISJOINTNESS TEST MUST BE ALTERED.
ISN 0118              NDISJT=0
ISN 0119              NREGM1=NREG-1
ISN 0120              IF (NREGM1.EQ.0) GO TO 40
ISN 0122              DO 38 I=1,NREGM1
ISN 0123              IP1=I+1
ISN 0124              DO 36 J=IP1,NREG
ISN 0125              IF (IHREG(J).LT.ILREG(I)) GO TO 36
ISN 0127              IF (ILREG(J).GT.IHREG(I)) GO TO 36
ISN 0129              IF (JHREG(J).LT.JLREG(I)) GO TO 36
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ISN 0131          IF (JLREG(J).GT.JHREG(I)) GO TO 36                             GEOM1730
            C *** IF HERE 2 REGIONS OVERLAP.                                      GEOM1740
ISN 0133          IF (NDISJT.EQ.0) PRINT 1100                                     GEOM1750
ISN 0135          NDISJT=1                                                         GEOM1760
ISN 0136          PRINT 1200,I,J                                                   GEOM1770
ISN 0137       36 CONTINUE                                                         GEOM1780
ISN 0138       38 CONTINUE                                                         GEOM1790
ISN 0139       40 CONTINUE                                                         GEOM1800
ISN 0140          RETURN                                                           GEOM1810
            C ***                                                                  GEOM1820
            C ***                                                                  GEOM1830
ISN 0141          ENTRY GEOMFG(NFLG,KX,KY,DX,DY,X,Y,IXT,JYT,NCHECK,NZSP,NSPACE)   GEOM1840
            C ***                                                                  GEOM1850
            C ***                                                                  GEOM1860
ISN 0142          DIMENSION NFLG(KX,1)                                             GEOM1870
ISN 0143          PRINT 1210,NZSP,NSPACE                                           GEOM1880
            C *** 1ST ZERO ALL FLAGS                                               GEOM1890
ISN 0144          DO 44 I=1,KX                                                     GEOM1900
ISN 0145          DO 42 J=1,KY                                                     GEOM1910
ISN 0146       42 NFLG(I,J)=0                                                      GEOM1920
ISN 0147       44 CONTINUE                                                         GEOM1930
            C *** A NFLG WORD IS PARTITIONED AS FOLLOWS. THE 1ST 8 BITS (FROM LEFT) GEOM1940
            C *** CONTAIN THE REGION NUMBER.  THE NEXT 4 BITS ARE UNUSED. THE NEXT 5GEOM1950
            C *** ARE NBYP, NEXT 5 NBYM, NEXT 5 NBXP, NEXT 5 NBXM                  GEOM1960
ISN 0148          DO 52 M=1,NREG                                                   GEOM1970
ISN 0149          IL=ILREG(M)                                                      GEOM1980
ISN 0150          IH=IHREG(M)                                                      GEOM1990
ISN 0151          JL=JLREG(M)                                                      GEOM2000
ISN 0152          JH=JHREG(M)                                                      GEOM2010
            C *** SM USED IN SUBR.CHKDTM TO ASSESS OR DETERMINE THE TIME STEP, DTM. GEOM2020
ISN 0153          SM(M)=DMIN1(DX(IL),DY(JL))                                       GEOM2030
ISN 0154          DO 46 I=IL,IH                                                    GEOM2040
ISN 0155          DO 46 J=JL,JH                                                    GEOM2050
            C *** SET THE REGION FLAG IN NFLG(I,J) TO BE M                         GEOM2060
ISN 0156          CALL REGFLG(NFLG(I,J),M)                                         GEOM2070
ISN 0157       46 CONTINUE                                                         GEOM2080
ISN 0158          DO 48 I=IL,IH                                                    GEOM2090
            C *** SET Y- BOUNDARY FOR REGION M    (UPY)                            GEOM2100
ISN 0159          CALL PACFLG(NFLG(I,JL),IUPYB(M), 3)                              GEOM2110
            C *** SET Y+ BOUNDARY FOR REGION M    (DNY)                            GEOM2120
ISN 0160       48 CALL PACFLG(NFLG(I,JH),IDNYB(M), 4)                              GEOM2130
ISN 0161          DO 50 J=JL,JH                                                    GEOM2140
            C *** SET X- BOUNDARY FOR REGION M    (UPX)                            GEOM2150
ISN 0162          CALL PACFLG(NFLG(IL,J),IUPXB(M), 1)                              GEOM2160
            C *** SET X+ BOUNDARY FOR REGION M    (DNX)                            GEOM2170
ISN 0163       50 CALL PACFLG(NFLG(IH,J),IDNXB(M), 2)                              GEOM2180
ISN 0164       52 CONTINUE                                                         GEOM2190
ISN 0165          NLAND=0                                                          GEOM2200
ISN 0166          NTEM=0                                                           GEOM2210
ISN 0167          IF (NTMAX.LE.0) GO TO 70                                         GEOM2220
ISN 0169          IF (NTMAX.LE.10) GO TO 54                                        GEOM2230
            C *** NTMAX IS RESTRICTED BY THE DIMENSIONING OF THE ARRAYS IXT AND JYT GEOM2240
            C *** IN SUBR. MAIN. AND THE ARRAY XTMAX AND YTMAX IN THIS SUBR.       GEOM2250
            C *** AND ARRAYS TMAX,TMIN,SMTDTM IN SUBR.DRIVE.                       GEOM2260
ISN 0171          PRINT 1220,NTMAX                                                 GEOM2270
ISN 0172          CALL EXIT                                                        GEOM2280
ISN 0173       54 READ(50,1230) (XTMAX(M),YTMAX(M),M=1,NTMAX)                      GEOM2290
            C *** DETERMINE NODES AT WHICH TEMPERATURE WILL BE MONITORED.          GEOM2300
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              C *** CF. SUBR.DRIVE.
ISN 0174            DO 56 M=1,NTMAX
ISN 0175            CALL BSERCH(IXT(M),XTMAX(M),X,LASTI,DX,XNAME,M,NTEM,0)
ISN 0176            CALL BSERCH(JYT(M),YTMAX(M),Y,LASTJ,DY,YNAME,M,NTEM,0)
ISN 0177         56 CONTINUE
ISN 0178            PRINT 1240
ISN 0179            DO 68 M=1,NTMAX
ISN 0180            IXTM=IXT(M)
ISN 0181            JYTM=JYT(M)
ISN 0182            LREG=NFLG(IXTM,JYTM)/NSCALE
ISN 0183         58 PRINT 1250,M,XTMAX(M),YTMAX(M),IXTM,JYTM,X(IXTM),Y(JYTM),LREG
ISN 0184            IF (LREG.GT.0) GO TO 68
              C *** IF NODE ON LAND, CHECK NEIGHBORING (IN INDEXICAL SENSE) NODES TO
              C *** SEE IF ONE IS IN WATER. IF THERE IS, USE IT.
ISN 0186            IF (IXTM.EQ.1) GO TO 60
ISN 0188            LREG=NFLG(IXTM-1,JYTM)/NSCALE
ISN 0189            IF (LREG.EQ.0) GO TO 60
ISN 0191            IXTM=IXTM-1
ISN 0192            IXT(M)=IXTM
ISN 0193            GO TO 58
ISN 0194         60 IF (IXTM.EQ.LASTI) GO TO 62
ISN 0196            LREG=NFLG(IXTM+1,JYTM)/NSCALE
ISN 0197            IF (LREG.EQ.0) GO TO 62
ISN 0199            IXTM=IXTM+1
ISN 0200            IXT(M)=IXTM
ISN 0201            GO TO 58
ISN 0202         62 IF (JYTM.EQ.1) GO TO 64
ISN 0204            LREG=NFLG(IXTM,JYTM-1)/NSCALE
ISN 0205            IF (LREG.EQ.0) GO TO 64
ISN 0207            JYTM=JYTM-1
ISN 0208            JYT(M)=JYTM
ISN 0209            GO TO 58
ISN 0210         64 IF (JYTM.EQ.LASTJ) GO TO 66
ISN 0212            LREG=NFLG(IXTM,JYTM+1)/NSCALE
ISN 0213            IF (LREG.EQ.0) GO TO 66
ISN 0215            JYTM=JYTM+1
ISN 0216            JYT(M)=JYTM
ISN 0217            GO TO 58
ISN 0218         66 NLAND=1
ISN 0219            PRINT 1260
ISN 0220         68 CONTINUE
ISN 0221         70 CONTINUE
              C *** VISUAL DISPLAY OF BOUNDARY FLAGS AND REGICN IDENTIFIERS.
ISN 0222            DO 90 K0=1,5
              CW    PRINT 601,FLAG(K0)
              CW601 FORMAT('1'///' NODAL DISPLAY FOR 'A4//)
ISN 0223            GO TO (72,74,76,78,80),K0
ISN 0224         72 PRINT 1270,FLAG(1)
ISN 0225            GO TO 82
ISN 0226         74 PRINT 1280,FLAG(2)
ISN 0227            GO TO 82
ISN 0228         76 PRINT 1290,FLAG(3)
ISN 0229            GO TO 82
ISN 0230         78 PRINT 1300,FLAG(4)
ISN 0231            GO TO 82
ISN 0232         80 PRINT 1310
ISN 0233         82 IH=0
ISN 0234         84 IL=IH+1
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ISN 0235          IH=MINO(LASTI,IH+122)
ISN 0236          DO 88 JR=1,LASTJ
ISN 0237          J=(LASTJ+1)-JR
ISN 0238          IS=0
ISN 0239          DO 86 I=IL,IH
ISN 0240          IS=IS+1
ISN 0241          CALL GTFLGS(NOR,NFLG(I,J))
ISN 0242          STRING(IS)=TABLE(NOR(KC)+1)
ISN 0243       86 CONTINUE
ISN 0244          PRINT 1320,J,(STRING(I),I=1,IS)
ISN 0245       88 CONTINUE
ISN 0246          PRINT 1330
ISN 0247          IF (IH.LT.LASTI) GO TO 84
ISN 0249       90 CONTINUE
ISN 0250          NCHECK=NDISJT+10*NSK+100*NTEM+1000*NLAND
ISN 0251          RETURN
ISN 0252     1000 FORMAT(7E10.2,10X)
ISN 0253     1010 FORMAT(14I5,10X)
ISN 0254     1020 FORMAT(//'0',1X,'INPUT INFORMATION FROM SUBROUTINE GEOM:'/1X,
                 >' --- --- --- --- --- --- --- --- --- ---'/'0',1X,'XGRL(I) - GROSS
                 > LATTICE LINE I IN THE X-DIRECTION'/'0',1X,'IXFD(I) - NUMBER OF SU
                 >BDIVISIONS BETWEEN GROSS LATTICE LINES XGRL(I) AND XGRL(I+1).'
                 >/'0',1X,'YGRL(I) - GROSS LATTICE LINE I IN Y-DIRECTION.'/'0',1X,
                 >'IYFD(I) - NUMBER OF SUBDIVISIONS BETWEEN GROSS LATTICE LINES YGRL
                 >(I) AND YGRL(I+1).')
ISN 0255     1030 FORMAT(//'0',1X'I'6X'XGRL'7X'IXFD')
ISN 0256     1040 FORMAT(I3,1PE14.5,I6)
ISN 0257     1050 FORMAT(///2X'I'6X'YGRL'7X'IYFD')
ISN 0258     1060 FORMAT(//' ',13X,'NODAL WIDTH',17X,'NODAL CENTER'/4X,'I',2X,
                 > 'X-DIRECTION',3X,'Y-DIRECTION',3X,'X-DIRECTION',3X,'Y-DIRECTION')
ISN 0259     1070 FORMAT(I5,0P2F13.5,1P2E15.6)
ISN 0260     1080 FORMAT(I5,13X,0PF13.5,15X,1PE15.6)
ISN 0261     1090 FORMAT(I5,0PF13.5,13X,1PE15.6)
ISN 0262     1100 FORMAT('1')
ISN 0263     1110 FORMAT(3I5,5X,5E10.2/2I5,20X,4(5X,I5))
ISN 0264     1120 FORMAT('1REGION NUMBER IS OUTSIDE THE RANGE OF 1 TO 25',1X
                 > 'IREG='I2)
ISN 0265     1130 FORMAT('1REGION NO.=IREG='I3,1X'HAS ALREADY BEEN DEFINED.')
ISN 0266     1140 FORMAT('1THE UP- AND DOWN-STREAM VALUES ARE INCORRECTLY ORDERED IN
                 > REGION 'I2/' UPX='F11.5/' DNX='F11.5/' UPY='F11.5/' DNY='F11.5)
ISN 0267     1150 FORMAT(///19X'GEOMETRIC DESCRIPTION OF REGIONS',36X,
                 > 'INDEXICAL DESCRIPTION'/' REGION'6X'UPX'8X'DNX'8X'UPY'8X'DNY'8X
                 > 'DEPTH'8X'AREA'7X'I LOW'2X'IHIGH'2X'J LOW'2X'JHIGH'3X 'NODES'//)
ISN 0268     1160 FORMAT(I5,0PF13.2,3F11.2,F11.3,1PE13.4,3X,4I7,I8)
ISN 0269     1170 FORMAT(' ',68X,
                 > '-----------------------------------------------------'/
                 > 68X'TOTAL NO. OF NODES IN (INPUT) REGIONS='I8/
                 > 68X'MAX. NO. OF NODES IN GRID='12X,I8)
ISN 0270     1180 FORMAT(//////13X'FUNCTION SELECTION'13X'BOUNDARY SELECTION'/
                 > ' REGION'3X'INTF'2X'IGENF'2X'ITCPF'2X'IBCTF'5X'IUPXB'2X'IDNXB'
                 > 2X'IUPYB'2X'IDNYB')
ISN 0271     1190 FORMAT(I5,I8,I6,2I7,I10,3I7)
ISN 0272     1200 FORMAT(///' THE REGIONS 'I2,1X'AND'I3,1X'OVERLAP.')
ISN 0273     1210 FORMAT(//////' NUMBER OF ELEMENTS AVAILABLE IN ARRAY Z IN MAIN =',
                 > I7//' NUMBER OF ELEMENTS NEEDED =',I7)
ISN 0274     1220 FORMAT('1NTMAX EXCEEDS 10. CF.SUER GEOM.  NTMAX='I3)
ISN 0275     1230 FORMAT(6E10.2,20X)
ISN 0276     1240 FORMAT(//'0',T23,'POSITIONS TO MONITOR TEMPERATURE' //
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                    > 3X'M'2X'REQUESTED LOCATION'9X'SELECTED NODE'9X'NODE LOCATION',    GEOM3470
                    > T76,'NODE'/11X'X'11X'Y'12X'I'7X'J'10X'X'11X'Y'7X'REGION'/)        GEOM3480
  ISN 0277     1250 FORMAT(I4,2F12.3,5X,I4,4X,I4,3X,2F12.3,I7)                          GEOM3490
  ISN 0278     1260 FORMAT(/' LAND NODE SELECTED.  NEED ONE IN WATER.'/)                GEOM3500
  ISN 0279     1270 FORMAT('1'///                                                       GEOM3510
                    > ' NODAL DISPLAY FOR UPSTREAM BOUNDARIES IN X-DIRECTION,',A4//)    GEOM3520
  ISN 0280     1280 FORMAT('1'///' NODAL DISPLAY FOR DOWNSTREAM BOUNDARIES IN X-DIRECTGEOM3530
                    >ION,',A4//)                                                        GEOM3540
  ISN 0281     1290 FORMAT('1'///                                                       GEOM3550
                    > ' NODAL DISPLAY FOR UPSTREAM BOUNDARIES IN Y-DIRECTION,',A4//)    GEOM3560
  ISN 0282     1300 FORMAT('1'///' NODAL DISPLAY FOR DOWNSTREAM BOUNDARIES IN Y-DIRECTGEOM3570
                    >ION,',A4//)                                                        GEOM3580
  ISN 0283     1310 FORMAT('1'///' NODAL DISPLAY FOR REGIONS'//)                        GEOM3590
  ISN 0284     1320 FORMAT(' J='I3,'**'122A1)                                           GEOM3600
  ISN 0285     1330 FORMAT(//)                                                          GEOM3610
  ISN 0286          END                                                                 GEOM3620

*OPTIONS IN EFFECT*      NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,

*OPTIONS IN EFFECT*      SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF

*STATISTICS*     SOURCE STATEMENTS =     285 ,PROGRAM SIZE =     9180

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                                    53K BYTES OF CORE NOT USED
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OS/360 FORTRAN H

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COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,
                         SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF
ISN 0002            SUBROUTINE SOLRKG(KX,KY,NK,Y,Q,F,H,U,V,T,CK,HTMD,UTMD, VTMD,TTMD,
                   > CKTMD,DX,DY,DXL,DXR,DYL,DYR,NFLG)
              C ***
              C ***
              C *** NUMERICAL INTEGRATION OF THE SYSTEM OF DIFFERENTIAL EQUATIONS.
              C *** VIA RUNGE-KUTTA-GILL'S METHOD.
              C ***
              C ***
              C *** R-K-G METHOD  COMPUTATIONALLY EXECUTED AS DESCRIBED BY
              C ***  ROBERT J.THOMPSON IN VOL.12/NUMBER 12/ DECEMBER, 1970 OF THE
              C ***  COMMUNICATIONS OF THE ACM.
              C ***
              C ***
ISN 0003            IMPLICIT REAL*8 (A-H,O-Z)
ISN 0004            COMMON/COMBIN/ ANL,ATMP,CPIJ,CKIJ(4),CKIPJ(4),CKIMJ(4),CKIJP(4)  ,
                  > CKIJM(4),DXM,DXP,DYM,DYP,DXIP1,DYJP1,DXII,DXRI,DXLI1,DXRI1,DYLJ ,
                  > DYRJ,DYLJ1,DYRJ1,GBIJ,GKBIJ(4),QBIJ,QKBIJ(4),SBXIJ,SBYIJ,GXIMJ ,
                  > GXIPJ,GYIJM,GYIJP,GTIJ,GKTIJ(4) ,QTIJ,QKTIJ(4),STXIJ,STYIJ,QDVIJ ,
                  > QXIMJ,QXIPJ,QYIJM,QYIJP,GKXIMJ(4),GKXIPJ(4),GKYIJM(4),GKYIJP(4) ,
                  > HTKIJ(4),HTKIJM(4),HTKIPJ(4),HTKIMJ(4),HTKIJP(4),HIJ,HIJM,HIPJ ,
                  > HIMJ,HIJP,UIJ,UIJM,UIPJ,UIMJ,UIJP,VIJ,VIJM,VIPJ,VIMJ,VIJP,TIJ ,
                  > TIJM,TIPJ,TIMJ,TIJP,ROKTPD(4),RCIJ,ROIJM,ROIPJ,ROIMJ,ROIJP ,
                  > SHKTPD(4),SHTCKD(4),SHTTPD,SXXIMJ,SXXIPJ,SYYIJM,SYYIJP,SXYIJM ,
                  > SXYIPJ,SXYIMJ,SXYIJP,ROIMJD,ROIPJD,ROIJMD,ROIJPD,EQTMP,TDIJ ,
                  > HCIMJ,HCIPJ,HCIJM,HCIJP,GR,ROCKD(4),SPHTK(4),DENSK(4),RODKIJ(4) ,
                  > GKDVIJ(4),DXI,DYJ ,QDV(25),HBD(25),UBD(25),VBD(25),TBD(25),
                  > CKBD(4,25),TBIJ,HCBIJ ,DCKBIJ(4),HTKBIJ(4),BNIJ,UBIJ,VBIJ,WBIJ,
                  > ROBIJ,HTBIJ,CKBIJ(4),TTIJ,HCTIJ,DCKTIJ(4),HTKTIJ(4),UTIJ,VTIJ,
                  > WTIJ,ROTIJ,HTTIJ,CKTIJ(4)  ,QBD(25),GBD(25),GKBD(4,25),SBDN(25),
                  > SBDSH(25),WIND,WINDX,WINDY ,IJ,IM1J,IP1J,IJM1,IJP1,INTRT,KOIJ,
                  > KOIM1J,KOIP1J,KOIJM1,KOIJP1 ,NBXM,NBXP,NBYM,NBYP,NREGIN,NBNDP ,
                  > IXQV(25),JYQV(25),NHBDTP(25),NUBDTP(25),NVBDTP(25),NTBDTP(25)  ,
                  > NXGRL,NYGRL,NREG,NINTLP,NTOPF,NECTF,NTELEC,NTMAX,NGENF
ISN 0005            COMMON/DROC/TIM,DTM,TM,PERIOD,IT,NMCVE,LMCVE,N
ISN 0006            DIMENSION Y(1),Q(1),F(1)
ISN 0007            DIMENSION H(1),U(1),V(1),T(1),CK(1),ERRHSR(1),HTMD(1),UTMD(1),
                  > VTMD(1),TTMD(1),CKTMD(1),DX(1),DY(1),DXL(1),DXR(1),DYL(1),DYR(1),
                  >  NFLG(1)
              C *** 404AFB0CCC06219B = 1-1/SQRT(2)          IN HEXADECIMAL  A1
              C *** 411B504F333F9DE6 = 1+1/SQRT(2)          IN HEXADECIMAL  A2
              C *** 402AAAAAAAAAAAAB = 1/6                  IN HEXADECIMAL  A3
ISN 0008            DATA A1/Z404AFB0CCC06219B/,A2/Z411B504F333F9DE6/ ,A3/
                  > Z402AAAAAAAAAAAAB/,NSW/1/
              C *** BOUNDARY CONDITIONS MAY VARY WITH TIME.
              C *** MOREOVER, BOUNDARY CONDITIONS MAY DEPEND ON Y (I.E., CURRENT
              C *** VALUES OF VARIABLES).
ISN 0009            ODDTM=1.D0/DTM
ISN 0010            IF (NSW.EQ.0) GO TO 14
              C *** THE VERY 1ST CALL TO SOLVET IS SPECIAL.  SPECIAL IN ORDER TO
              C *** OBTAIN WS AS WE DO.
ISN 0012         10 TIM=TM
ISN 0013            GO TO 28
ISN 0014         12 NSW=0
ISN 0015            IF (IT.EQ.0) CALL OUTPRT
ISN 0017         14 DO 16 K=1,LMCVE
ISN 0018            TEMP=.5D0*(F(K)-2.D0*Q(K))
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ISN 0019          SAVE=Y(K)
ISN 0020          Y(K)=Y(K)+DTM*TEMP
ISN 0021          TEMP=(Y(K)-SAVE)*ODDTM
ISN 0022       16 Q(K)=Q(K)+3.D0*TEMP-.5D0*F(K)
ISN 0023          TIM=TM+.5D0*DTM
ISN 0024          CALL BNDCON(KX,NK,T,CK)
ISN 0025          CALL SOLFNC( HTMD,UTMD,VTMD,TTMD,CKTMD,H,U,V,T,CK, DX,DY,DXL,DXR,
                > DYL,DYR,NFLG)
ISN 0026          DO 18 K=1,LMOVE
ISN 0027          TEMP=A1*(F(K)-Q(K))
ISN 0028          SAVE=Y(K)
ISN 0029          Y(K)=Y(K)+DTM*TEMP
ISN 0030          TEMP=(Y(K)-SAVE)*ODDTM
ISN 0031       18 Q(K)=Q(K)+3.D0*TEMP-A1*F(K)
ISN 0032          CALL BNDCON(KX,NK,T,CK)
ISN 0033          CALL SOLFNC( HTMD,UTMD,VTMD,TTMD,CKTMD,H,U,V,T,CK, DX,DY,DXL,DXR,
                > DYL,DYR,NFLG)
ISN 0034       20 DO 22 K=1,LMOVE
ISN 0035          TEMP=A2*(F(K)-Q(K))
ISN 0036          SAVE=Y(K)
ISN 0037          Y(K)=Y(K)+DTM*TEMP
ISN 0038          TEMP=(Y(K)-SAVE)*ODDTM
ISN 0039       22 Q(K)=Q(K)+3.D0*TEMP-A2*F(K)
ISN 0040       24 TIM=TM+DTM
ISN 0041          CALL BNDCON(KX,NK,T,CK)
ISN 0042          CALL SOLFNC( HTMD,UTMD,VTMD,TTMD,CKTMD,H,U,V,T,CK, DX,DY,DXL,DXR,
                > DYL,DYR,NFLG)
ISN 0043          DO 26 K=1,LMOVE
ISN 0044          TEMP=A3*(F(K)-2.D0*Q(K))
ISN 0045          SAVE=Y(K)
ISN 0046          Y(K)=Y(K)+DTM*TEMP
ISN 0047          TEMP=(Y(K)-SAVE)*ODDTM
ISN 0048       26 Q(K)=Q(K)+3.D0*TEMP-.5D0*F(K)
ISN 0049       28 CONTINUE
ISN 0050          CALL BNDCON(KX,NK,T,CK)
ISN 0051          CALL SOLFNC( HTMD,UTMD,VTMD,TTMD,CKTMD,H,U,V,T,CK, DX,DY,DXL,DXR,
                > DYL,DYR,NFLG)
ISN 0052          IF (NSW.EQ.1) GO TO 12
ISN 0054          TM=TIM
ISN 0055       30 RETURN
ISN 0056          END

*OPTIONS IN EFFECT*     NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,

*OPTIONS IN EFFECT*     SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF

*STATISTICS*    SOURCE STATEMENTS =      55 ,PROGRAM SIZE =     2056

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                              105K BYTES OF CORE NOT USED
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OS/360 FORTRAN H

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      COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,
                         SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF
ISN 0002              SUBROUTINE SOLEUL(KX,KY,NK,Y,Q,F,H,U,V,T,CK,HTMD,UTMD, VTMD,TTMD,
                    > CKTMD,DX,DY,DXL,DXR,DYL,DYR,NFLG)
              C ***
              C ***
              C *** NUMERICAL INTEGRATION OF THE SYSTEM OF DIFFERENTIAL EQUATIONS.
              C *** VIA EULER'S METHOD.
              C ***
              C *** Y(TM+DTM) = Y(TM) + DTM*Y'(TM)
              C ***
              C ***
ISN 0003              IMPLICIT REAL*8 (A-H,O-Z)
ISN 0004              COMMON/COMBIN/ ANL,ATMP,CPIJ,CKIJ(4),CKIPJ(4),CKIMJ(4),CKIJP(4) ,
                    > CKIJM(4),DXM,DXP,DYM,DYP,DXIP1,DYJP1,DXII,DXRI,DXLI1,DXRI1,DYLJ ,
                    > DYRJ,DYLJ1,DYRJ1,GBIJ,GKBIJ(4),CBIJ,QKBIJ(4),SBXIJ,SBYIJ,GXIMJ ,
                    > GXIPJ,GYIJM,GYIJP,GTIJ,GKTIJ(4),QTIJ,CKTIJ(4),STXIJ,STYIJ,QDVIJ ,
                    > QXIMJ,QXIPJ,QYIJM,QYIJP,GKXIMJ(4),GKXIPJ(4),GKYIJM(4),GKYIJP(4) ,
                    > HTKIJ(4),HTKIJM(4),HTKIPJ(4),HTKIMJ(4),HTKIJP(4),HIJ,HIJM,HIPJ ,
                    > HIMJ,HIJP,UIJ,UIJM,UIPJ,UIMJ,UIJP,VIJ,VIJM,VIPJ,VIMJ,VIJP,TIJ ,
                    > TIJM,TIPJ,TIMJ,TIJP,ROKTPD(4),ROIJ,ROIJM,ROIPJ,ROIMJ,ROIJP ,
                    > SHKTPD(4),SHTCKD(4),SHTTPD,SXXIMJ,SXXIPJ,SYYIJM,SYYIJP,SXYIJM ,
                    > SXYIPJ,SXYIMJ,SXYIJP,ROIMJD,ROIPJD,ROIJMD,ROIJPD,EQTMP,TDIJ ,
                    > HCIMJ,HCIPJ,HCIJM,HCIJP,GR,ROCKD(4),SPHTK(4),DENSK(4),RODKIJ(4) ,
                    > GKDVIJ(4),DXI,DYJ ,QDV(25),HBD(25),UBD(25),VBD(25),TBD(25),
                    > CKBD(4,25),TBIJ,HCBIJ ,DCKBIJ(4),HTKBIJ(4),BNIJ,UBIJ,VBIJ,WBIJ,
                    > ROBIJ,HTBIJ,CKBIJ(4),TTIJ,HCTIJ,DCKTIJ(4),HTKTIJ(4),UTIJ,VTIJ,
                    > WTIJ,ROTIJ,HTTIJ,CKTIJ(4) ,QBD(25),GBD(25),GKBD(4,25),SBDN(25),
                    > SBDSH(25),WIND,WINDX,WINDY ,IJ,IM1J,IP1J,IJM1,IJP1,INTRT,KOIJ,
                    > KOIM1J,KOIP1J,KOIJM1,KOIJP1 ,NBXM,NBXP,NBYM,NBYP,NREGIN,NBNDF ,
                    > IXQV(25),JYQV(25),NHBDTP(25),NUBDTP(25),NVBDTP(25),NTBDTP(25) ,
                    > NXGRL,NYGRL,NREG,NINTLF,NTOPF,NEQTP,NTBIFC,NTMAX,NGENF
ISN 0005              COMMON/DROC/TIM,DTM,TM,PERIOD,IT,NMOVE,LMOVE,N
ISN 0006              DIMENSION Y(1),Q(1),F(1),H(1),U(1),V(1),T(1),CK(1),HTMD(1),UTMD(1)
                    > ,VTMD(1),TTMD(1),CKTMD(1),DX(1),DY(1),DXL(1),DXR(1),DYL(1),DYR(1)
                    > ,NFLG(1)
ISN 0007              IF (IT.GT.0) GO TO 10
ISN 0009              TIM=TM
ISN 0010              CALL BNDCON(KX,NK,T,CK)
ISN 0011              CALL SOLFNC(HTMD,UTMD,VTMD,TTMD,CKTMD,H,U,V,T,CK,DX,DY,DXL, DXR,
                    > DYL,DYR,NFLG)
ISN 0012              CALL OUTPRT
ISN 0013           10 DO 12 K=1,LMOVE
ISN 0014           12 Y(K)=Y(K) + DTM*F(K)
ISN 0015              TM=TM+DTM
ISN 0016              TIM=TM
ISN 0017              CALL BNDCON(KX,NK,T,CK)
ISN 0018              CALL SOLFNC(HTMD,UTMD,VTMD,TTMD,CKTMD,H,U,V,T,CK,DX,DY,DXL, DXR,
                    > DYL,DYR,NFLG)
ISN 0019              RETURN
ISN 0020              END

*OPTIONS IN EFFECT*       NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,

*OPTIONS IN EFFECT*       SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF

*STATISTICS*     SOURCE STATEMENTS =       19 ,PROGRAM SIZE =      1252

*STATISTICS*  NO  DIAGNOSTICS GENERATED
```

****** END OF COMPIILATION ******

121K BYTES OF CORE NOT USED

OS/360 FORTRAN H

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        COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,
                     SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF
ISN 0002          SUBROUTINE SCLFNI(NK,KX,KY)
ISN 0003          IMPLICIT REAL*8 (A-H,O-Z)
ISN 0004          COMMON/COMBIN/ ANL,ATMP,CPIJ,CKIJ(4),CKIPJ(4),CKIMJ(4),CKIJP(4) ,
                > CKIJM(4),DXM,DXP,DYM,DYP,DXIP1,DYJP1,DXLI,DXRI,DXLI1,DXRI1,DYLJ ,
                > DYRJ,DYLJ1,DYRJ1,GBIJ,GKBIJ(4),QBIJ,QKBIJ(4),SBXIJ,SBYIJ,GXIMJ ,
                > GXIPJ,GYIJM,GYIJP,GTIJ,GKTIJ(4),QTIJ,QKTIJ(4),STXIJ,STYIJ,QDVIJ ,
                > QXIMJ,QXIPJ,QYIJM,QYIJP,GKXIMJ(4),GKXIPJ(4),GKYIJM(4),GKYIJP(4) ,
                > HTKIJ(4),HTKIJM(4),HTKIPJ(4),HTKIMJ(4),HTKIJP(4),HIJ,HIJM,HIPJ ,
                > HIMJ,HIJP,UIJ,UIJM,UIPJ,UIMJ,UIJP,VIJ,VIJM,VIPJ,VIMJ,VIJP,TIJ ,
                > TIJM,TIPJ,TIMJ,TIJP,ROKTPD(4),RCIJ,ROIJM,ROIPJ,ROIMJ,ROIJP ,
                > SHKTPD(4),SHTCKD(4),SHTTPD,SXXIMJ,SXXIPJ,SYYIJM,SYYIJP,SXYIJM ,
                > SXYIPJ,SXYIMJ,SXYIJP,ROIMJD,ROIPJD,ROIJMD,ROIJPD,EQTMP,TDIJ ,
                > HCIMJ,HCIPJ,HCIJM,HCIJP,GR,ROCKD(4),SPHTK(4),DENSK(4),RODKIJ(4) ,
                > GKDVIJ(4),DXI,DYJ ,QDV(25),HBD(25),UBD(25),VBD(25),TBD(25),
                > CKBD(4,25),TBIJ,HCBIJ ,DCKBIJ(4),HTKBIJ(4),BNIJ,UBIJ,VBIJ,WBIJ,
                > ROBIJ,HTBIJ,CKBIJ(4),TTIJ,HCTIJ,DCKTIJ(4),HTKTIJ(4),UTIJ,VTIJ,
                > WTIJ,ROTIJ,HTTIJ,CKTIJ(4) ,QBD(25),GBD(25),GKBD(4,25),SBDN(25),
                > SBDSH(25),WIND,WINDX,WINDY ,IJ,IM1J,IP1J,IJM1,IJP1,INTRT,KOIJ,
                > KOIM1J,KOIP1J,KOIJM1,KOIJP1 ,NBXM,NBXP,NBYM,NBYP,NREGIN,NBNDF ,
                > IXQV(25),JYQV(25),NHBDTP(25),NUBDTP(25),NVBDTP(25),NTBDTP(25) ,
                > NXGRL,NYGRL,NREG,NINTLF,NTOPF,NEOTF,NTBIFC,NTMAX,NGENF
ISN 0005          DIMENSION CKIMJD(4),CKIPJD(4),CKIJMD(4),CKIJPD(4)
            C *** INSERT 9/12/73
ISN 0006          COMMON/DROC/TIM,DTM,TM,PERIOD,IT,NMOVE,LMOVE,N
ISN 0007          COMMON/INDRIT/DTMLT,STM,SDTM,PRBTM,DPRTTM,CPUSEC,TIDAL,FDTM,
                > INDTM,NDTMC,IFINIS,LDTMCR,ISTART,IPLOT,NCPU
            C *** END INSERT
ISN 0008          DATA MASK/Z000FFFFF/
ISN 0009          DATA MASK/Z000FFFFF/
ISN 0010          ATMP=2116.224D0*GR
            C *** 1'S IN MASK COVER TOTALLY SPACE FOR NBXM,NBXP,NBYM,NBYP IN FLAG,
            C *** NFLG.
ISN 0011          DENS=62.2DC
ISN 0012          SPHT=1.D0
ISN 0013          KXNK=KX*NK
ISN 0014          KXNK=KX*NK
ISN 0015          CALL FLXCNI(NK)
ISN 0016          RETURN
ISN 0017          ENTRY SOLFNC( HTMD,UTMD,VTMD,TTMD,CKTMD,H,U,V,T,CK,DX,DY,DXL, DXR,
                > DYL,DYR,NFLG)
ISN 0018          DIMENSION HTMD(1),UTMD(1),VTMD(1),TTMD(1),CKTMD(1),H(1),U(1),V(1),
                > T(1),CK(1),DX(1),DY(1),DXL(1),DXR(1),DYL(1),DYR(1),NFLG(1)
ISN 0019          KOIJS=0
ISN 0020          DO 282 I=1,KX
ISN 0021          IJ=I
ISN 0022          DXLI=DXL(I)
ISN 0023          DXRI=DXR(I)
ISN 0024          DXRI1=DXR(I+1)
ISN 0025          DXLI1=DXL(I+1)
            C *** DXMU (DXPU) NOT USED WHEN I=1 (I=KX)
            C *** DYMU (DYPU) NOT USED WHEN J=1 (J=KY)
ISN 0026          DXMU=DXPU
ISN 0027          DXI=DX(I)
ISN 0028          DXPU=DX(I)+DX(I+1)
ISN 0029          KOIJ=KOIJS
ISN 0030          DO 280 J=1,KY
```

```
ISN 0031          DYMU=DYPU
ISN 0032          DYJ=DY(J)
ISN 0033          DYPU=DY(J)+DY(J+1)
            C *** OFTENTIMES WE VIEW 2- AND 3- DIMENSIONAL ARRAYS AS 1- DIMENSIONAL
            C *** ARRAYS.  THIS OFTEN EXPEDITES THE MACHINE EXECUTION OF THE PROG.
            C *** SUPPOSE DIMENSION A(KX,KY),C(NK,KX,KY) AND
            C *** SUPPOSE EQUIVALENCE (B(1),A(1,1),C(1,1,1)).
            C *** THEN
            C ***            A(I,J)=B((J-1)*KX+I)
            C ***         C(K,I,J)=D((J-1)*NK*KX+(I-1)*NK+K)
ISN 0034          IJP1=IJ+KX
ISN 0035          KOIJP1=KOIJ+KXNK
ISN 0036          CALL GTFLGS(NBXM,NFLG(IJ))
            C     ALL FLAGS ARE OBTAINED WITH CALL TO GTFLGS.  THEY ARE STORED IN
            C     NBXM(1), NBXM(2), NBXM(3),...NBXM(5)
            C     NOTE THAT COMMON/COMBIN/ IS ARRANGED SO THAT
            C     NBXM(2)=NBXP, NBXM(3)=NBYM, NBXM(4)=NBYP, NBXM(5)=NREGIN
            C     NREGIN=REGION NUMBER FOR (I,J)-NODE
            C     NREGIN=0 IMPLIES NODE (I,J) IS A NONWATER NODE
ISN 0037          IF (NREGIN.EQ.0) GO TO 278
ISN 0039          DYLJ=DYL(J)
ISN 0040          DYRJ=DYR(J)
ISN 0041          DYLJ1=DYL(J+1)
ISN 0042          DYRJ1=DYR(J+1)
            C *** A(IJ)=A(I,J)              IJ=(J-1)*KX+I
            C *** A(IM1J)=A(I-1,J)          IM1J=IJ-1
            C *** A(IP1J)=A(I+1,J)          IP1J=IJ+1
            C *** A(IJM1)=A(I,J-1)          IJM1=IJ-KX
            C *** A(IJP1)=A(I,J+1)          IJP1=IJ+KX
            C *** C(KOIJ+K)=C(K,I,J)        KOIJ=(J-1)*NK*KX+(I-1)*NK    (=(0,I,J)
            C *** C(KOIM1J+K)=C(K,I-1,J)   KOIM1J=KOIJ-NK
            C *** C(KOIP1J+K)=C(K,I+1,J)   KOIP1J=KOIJ+NK
            C *** C(KOIJM1+K)=C(K,I,J-1)   KOIJM1=KOIJ-(NK*KX)
            C *** C(KOIJP1+K)=C(K,I,J+1)   KOIJP1=KOIJ+(NK*KX)
ISN 0043          KOIM1J=KOIJ-NK
ISN 0044          KOIP1J=KOIJ+NK
ISN 0045          KOIJM1=KOIJ-KXNK
ISN 0046          IM1J=IJ-1
ISN 0047          IP1J=IJ+1
ISN 0048          IJM1=IJ-KX
ISN 0049          DXM=DXMU
ISN 0050          DXP=DXPU
ISN 0051          DYM=DYMU
ISN 0052          DYP=DYPU
            C *** DXM=DX(I-1)+DX(I)     IF(NBXM.EQ.0)
            C *** DXM=2*DX(I)           IF(NBXM.GT.0)
            C *** DXP=DX(I)+DX(I+1)     IF(NBXP.EQ.0)
            C *** DXP=2*DX(I)           IF(NBXP.GT.0)
            C *** DYM=DY(J-1)+DY(J)     IF(NBYM.EQ.0)
            C *** DYM=2*DY(J)           IF(NBYM.GT.0)
            C *** DYP=DY(J)+DY(J+I)     IF(NBYP.EQ.0)
            C *** DYP=2*DY(J)           IF(NBYP.GT.0)
ISN 0053          HIJ=H(IJ)
ISN 0054          UIJ=U(IJ)
ISN 0055          VIJ=V(IJ)
ISN 0056          TIJ=T(IJ)
ISN 0057          DO 10 K=1,NK
ISN 0058       10 CKIJ(K)=CK(KOIJ+K)
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```
               C *** IF NBXM=NBXP=NBYM=NBYP=0, THEN GC TO 440 (AN INTERIOR NODE)
ISN 0059             INSIDE=IAND(MASK,NFLG(IJ))
ISN 0060             IF (INSIDE.EQ.0) GO TO 200
ISN 0062             IF (NBXM) 12,12,16
ISN 0063          12 HIMJ=HIJ + DXRI*(H(IM1J)-HIJ)
ISN 0064             UIMJ=UIJ + DXRI*(U(IM1J)-UIJ)
ISN 0065             VIMJ=VIJ + DXRI*(V(IM1J)-VIJ)
ISN 0066             TIMJ=TIJ + DXRI*(T(IM1J)-TIJ)
ISN 0067             DO 14 K=1,NK
ISN 0068          14 CKIMJ(K)=CK(KOIJ+K) + DXRI*(CK(KOIM1J+K)-CK(KOIJ+K))
ISN 0069             GO TO 58
ISN 0070          16 NH=NHBDTP(NBXM)
ISN 0071             DXM=DXI+DXI
ISN 0072             GO TO (22,20,284,18),NH
ISN 0073             GO TO 284
ISN 0074          18 HIMJ=HIJ+DXLI1*(HIJ-H(IP1J))
ISN 0075             GO TO 24
ISN 0076          20 HIMJ=HIJ
ISN 0077             GO TO 24
ISN 0078          22 HIMJ=HBD(NBXM)
ISN 0079          24 NU=NUBDTP(NBXM)
ISN 0080             GO TO (30,28,284,26),NU
ISN 0081             GO TO 284
ISN 0082          26 UIMJ=UIJ+DXLI1*(UIJ-U(IP1J))
ISN 0083             GO TO 32
ISN 0084          28 UIMJ=UIJ
ISN 0085             GO TO 32
ISN 0086          30 UIMJ=UBD(NBXM)
ISN 0087          32 NV=NVBDTP(NBXM)
ISN 0088             GO TO (38,36,284,34),NV
ISN 0089             GO TO 284
ISN 0090          34 VIMJ=VIJ+DXLI1*(VIJ-V(IP1J))
ISN 0091             GO TO 40
ISN 0092          36 VIMJ=VIJ
ISN 0093             GO TO 40
ISN 0094          38 VIMJ=VBD(NBXM)
ISN 0095          40 NT=NTBDTP(NBXM)
ISN 0096             GO TO (52,48,284,42),NT
ISN 0097             GO TO 284
ISN 0098          42 IF (UIMJ) 44,44,52
ISN 0099          44 TIMJ=TIJ+DXLI1*(TIJ-T(IP1J))
ISN 0100             DO 46 K=1,NK
ISN 0101          46 CKIMJ(K)=CK(KOIJ+K)+DXLI1*(CK(KOIJ+K)-CK(KOIP1J+K))
ISN 0102             GO TO 56
ISN 0103          48 TIMJ=TIJ
ISN 0104             DO 50 K=1,NK
ISN 0105          50 CKIMJ(K)=CK(KOIJ+K)
ISN 0106             GO TO 56
ISN 0107          52 TIMJ=TBD(NBXM)
ISN 0108             DO 54 K=1,NK
ISN 0109          54 CKIMJ(K)=CKBD(K,NBXM)
ISN 0110          56 CONTINUE
ISN 0111          58 IF (NBXP) 60,60,64
ISN 0112          60 HIPJ=HIJ+DXLI1*(H(IP1J)-HIJ)
ISN 0113             UIPJ=UIJ+DXLI1*(U(IP1J)-UIJ)
ISN 0114             VIPJ=VIJ+DXLI1*(V(IP1J)-VIJ)
ISN 0115             TIPJ=TIJ+DXLI1*(T(IP1J)-TIJ)
ISN 0116             DO 62 K=1,NK
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   62 CKIPJ(K)=CK(KOIJ+K)+DXLI1*(CK(KOIP1J+K)-CK(KOIJ+K))
      GO TO 106
   64 NH=NHBDTP(NEXP)
      DXP=DXI+DXI
      GO TO (70,68,284,66),NH
      GO TO 284
   66 HIPJ=HIJ+DXPI*(HIJ-H(IM1J))
      GO TO 72
   68 HIPJ=HIJ
      GO TO 72
   70 HIPJ=HBD(NEXP)
   72 NU=NUBDTP(NEXP)
      GO TO (78,76,284,74),NU
      GO TO 284
   74 UIPJ=UIJ+DXPI*(UIJ-U(IM1J))
      GO TO 80
   76 UIPJ=UIJ
      GO TO 80
   78 UIPJ=UBD(NEXP)
   80 NV=NVBDTP(NEXP)
      GO TO (86,84,284,82),NV
      GO TO 284
   82 VIPJ=VIJ+DXPI*(VIJ-V(IM1J))
      GO TO 88
   84 VIPJ=VIJ
      GO TO 88
   86 VIPJ=VBD(NEXP)
   88 NT=NTBDTP(NEXP)
      GO TO (100,96,284,90),NT
      GO TO 284
   90 IF (UIPJ) 100,92,92
   92 TIPJ=TIJ+DXPI*(TIJ-T(IM1J))
      DO 94 K=1,NK
   94 CKIPJ(K)=CK(KOIJ+K)+DXPI*(CK(KOIJ+K)-CK(KOIM1J+K))
      GO TO 104
   96 TIPJ=TIJ
      DO 98 K=1,NK
   98 CKIPJ(K)=CK(KOIJ+K)
      GO TO 104
  100 TIPJ=TBD(NEXP)
      DO 102 K=1,NK
  102 CKIPJ(K)=CKBD(K,NEXP)
  104 CONTINUE
  106 IF (NBYM) 108,108,112
  108 HIJM=HIJ + DYPJ*(H(IJM1)-HIJ)
      UIJM=UIJ + DYPJ*(U(IJM1)-UIJ)
      VIJM=VIJ + DYPJ*(V(IJM1)-VIJ)
      TIJM=TIJ + DYPJ*(T(IJM1)-TIJ)
      DO 110 K=1,NK
  110 CKIJM(K)=CK(KOIJ+K) + DYPJ*(CK(KOIJM1+K)-CK(KOIJ+K))
      GO TO 154
  112 NH=NHBDTP(NBYM)
      DYM=DYJ+DYJ
      GO TO (118,116,284,114),NH
      GO TO 284
  114 HIJM=HIJ+DYIJ1*(HIJ-H(IJP1))
      GO TO 120
  116 HIJM=HIJ
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ISN 0175          GO TO 120                                                  SOLF2310
ISN 0176      118 HIJM=HBD(NBYM)                                             SOLF2320
ISN 0177      120 NU=NUBDTP(NBYM)                                            SOLF2330
ISN 0178          GO TO (126,124,284,122),NU                                 SOLF2340
ISN 0179          GO TO 284                                                  SOLF2350
ISN 0180      122 UIJM=UIJ+DYLJ1*(UIJ-U(IJP1))                               SOLF2360
ISN 0181          GO TO 128                                                  SOLF2370
ISN 0182      124 UIJM=UIJ                                                   SOLF2380
ISN 0183          GO TO 128                                                  SOLF2390
ISN 0184      126 UIJM=UBD(NBYM)                                             SOLF2400
ISN 0185      128 NV=NVBDTP(NBYM)                                            SOLF2410
ISN 0186          GO TO (134,132,284,130),NV                                 SOLF2420
ISN 0187          GO TO 284                                                  SOLF2430
ISN 0188      130 VIJM=VIJ+DYLJ1*(VIJ-V(IJP1))                               SOLF2440
ISN 0189          GO TO 136                                                  SOLF2450
ISN 0190      132 VIJM=VIJ                                                   SOLF2460
ISN 0191          GO TO 136                                                  SOLF2470
ISN 0192      134 VIJM=VBD(NBYM)                                             SOLF2480
ISN 0193      136 NT=NTBDTP(NBYM)                                            SOLF2490
ISN 0194          GO TO (148,144,284,138),NT                                 SOLF2500
ISN 0195          GO TO 284                                                  SOLF2510
ISN 0196      138 IF (VIJM) 140,140,148                                      SOLF2520
ISN 0197      140 TIJM=TIJ+DYLJ1*(TIJ-T(IJP1))                               SOLF2530
ISN 0198          DO 142 K=1,NK                                              SOLF2540
ISN 0199      142 CKIJM(K)=CK(KOIJ+K)+DYLJ1*(CK(KOIJ+K)-CK(KOIJP1+K))        SOLF2550
ISN 0200          GO TO 152                                                  SOLF2560
ISN 0201      144 TIJM=TIJ                                                   SOLF2570
ISN 0202          DO 146 K=1,NK                                              SOLF2580
ISN 0203      146 CKIJM(K)=CK(KOIJ+K)                                        SOLF2590
ISN 0204          GO TO 152                                                  SOLF2600
ISN 0205      148 TIJM=TBD(NBYM)                                             SOLF2610
ISN 0206          DO 150 K=1,NK                                              SOLF2620
ISN 0207      150 CKIJM(K)=CKBD(K,NBYM)                                      SOLF2630
ISN 0208      152 CONTINUE                                                   SOLF2640
ISN 0209      154 IF (NBYP) 156,156,160                                      SOLF2650
ISN 0210      156 HIJP=HIJ+DYLJ1*(H(IJP1)-HIJ)                               SOLF2660
ISN 0211          UIJP=UIJ+DYLJ1*(U(IJP1)-UIJ)                               SOLF2670
ISN 0212          VIJP=VIJ+DYLJ1*(V(IJP1)-VIJ)                               SOLF2680
ISN 0213          TIJP=TIJ+DYLJ1*(T(IJP1)-TIJ)                               SOLF2690
ISN 0214          DO 158 K=1,NK                                              SOLF2700
ISN 0215      158 CKIJP(K)=CK(KOIJ+K)+DYLJ1*(CK(KOIJP1+K)-CK(KOIJ+K))        SOLF2710
ISN 0216          GO TO 204                                                  SOLF2720
ISN 0217      160 NH=NHBDTP(NBYP)                                            SOLF2730
ISN 0218          DYP=DYJ+DYJ                                                SOLF2740
ISN 0219          GO TO (166,164,284,162),NH                                 SOLF2750
ISN 0220          GO TO 284                                                  SOLF2760
ISN 0221      162 HIJP=HIJ+DYRJ*(HIJ-H(IJM1))                                SOLF2770
ISN 0222          GO TO 168                                                  SOLF2780
ISN 0223      164 HIJP=HIJ                                                   SOLF2790
ISN 0224          GO TO 168                                                  SOLF2800
ISN 0225      166 HIJP=HBD(NBYP)                                             SOLF2810
ISN 0226      168 NU=NUBDTP(NBYP)                                            SOLF2820
ISN 0227          GO TO (174,172,284,170),NU                                 SOLF2830
ISN 0228          GO TO 284                                                  SOLF2840
ISN 0229      170 UIJP=UIJ+DYRJ*(UIJ-U(IJM1))                                SOLF2850
ISN 0230          GO TO 176                                                  SOLF2860
ISN 0231      172 UIJP=UIJ                                                   SOLF2870
ISN 0232          GO TO 176                                                  SOLF2880
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ISN 0233        174 UIJP=UBD(NBYP)
ISN 0234        176 NV=NVBDTP(NBYP)
ISN 0235            GO TO (182,180,284,178),NV
ISN 0236            GO TO 284
ISN 0237        178 VIJP=VIJ+DYRJ*(VIJ-V(IJM1))
ISN 0238            GO TO 184
ISN 0239        180 VIJP=VIJ
ISN 0240            GO TO 184
ISN 0241        182 VIJP=VBD(NBYP)
ISN 0242        184 NT=NTBDTP(NBYP)
ISN 0243            GO TO (196,192,284,186),NT
ISN 0244            GO TO 284
ISN 0245        186 IF (VIJP) 196,188,188
ISN 0246        188 TIJP=TIJ+DYRJ*(TIJ-T(IJM1))
ISN 0247            DO 190 K=1,NK
ISN 0248        190 CKIJP(K)=CK(KOIJ+K)+DYRJ*(CK(KOIJ+K)-CK(KOIJM1+K))
ISN 0249            GO TO 204
ISN 0250        192 TIJP=TIJ
ISN 0251            DO 194 K=1,NK
ISN 0252        194 CKIJP(K)=CK(KOIJ+K)
ISN 0253            GO TO 204
ISN 0254        196 TIJP=TBD(NBYP)
ISN 0255            DO 198 K=1,NK
ISN 0256        198 CKIJP(K)=CKBD(K,NBYP)
ISN 0257            GO TO 204
              C *** BEGIN CALCULATION FOR INTERIOR NODE.
ISN 0258        200 DO 202 K=1,NK
ISN 0259            CKIJ(K)=CK(KOIJ+K)
ISN 0260            CKIMJ(K)=CKIJ(K)  + DXRI *(CK(KOIM1J+K)-CKIJ(K))
ISN 0261            CKIPJ(K)=CKIJ(K)  + DXLI1*(CK(KOIP1J+K)-CKIJ(K))
ISN 0262            CKIJM(K)=CKIJ(K)  + DYRJ *(CK(KOIJM1+K)-CKIJ(K))
ISN 0263            CKIJP(K)=CKIJ(K)  + DYLJ1*(CK(KOIJP1+K)-CKIJ(K))
ISN 0264        202 CONTINUE
ISN 0265            HIMJ=HIJ + DXRI *(H(IM1J)-HIJ)
ISN 0266            HIPJ=HIJ + DXLI1*(H(IP1J)-HIJ)
ISN 0267            HIJM=HIJ + DYRJ *(H(IJM1)-HIJ)
ISN 0268            HIJP=HIJ + DYLJ1*(H(IJP1)-HIJ)
ISN 0269            UIMJ=UIJ + DXRI *(U(IM1J)-UIJ)
ISN 0270            UIPJ=UIJ + DXLI1*(U(IP1J)-UIJ)
ISN 0271            UIJM=UIJ + DYRJ *(U(IJM1)-UIJ)
ISN 0272            UIJP=UIJ + DYLJ1*(U(IJP1)-UIJ)
ISN 0273            VIMJ=VIJ + DXRI *(V(IM1J)-VIJ)
ISN 0274            VIPJ=VIJ + DXLI1*(V(IP1J)-VIJ)
ISN 0275            VIJM=VIJ + DYRJ *(V(IJM1)-VIJ)
ISN 0276            VIJP=VIJ + DYLJ1*(V(IJP1)-VIJ)
ISN 0277            TIMJ=TIJ + DXRI *(T(IM1J)-TIJ)
ISN 0278            TIPJ=TIJ + DXLI1*(T(IP1J)-TIJ)
ISN 0279            TIJM=TIJ + DYRJ *(T(IJM1)-TIJ)
ISN 0280            TIJP=TIJ + DYLJ1*(T(IJP1)-TIJ)
              C *** END CALCULATION FOR INTERIOR NODE.
ISN 0281        204 CONTINUE
ISN 0282            IF (UIMJ) 206,210,214
ISN 0283        206 UIMJD=UIJ
ISN 0284            VIMJD=VIJ
ISN 0285            TIMJD=TIJ
ISN 0286            HIMJD=HIJ
ISN 0287            DO 208 K=1,NK
ISN 0288        208 CKIMJD(K)=CKIJ(K)
```

```
ISN 0289          GO TO 218                                                  SOLF3470
ISN 0290      210 UIMJD=UIMJ                                                 SOLF3480
ISN 0291          VIMJD=VIMJ                                                 SOLF3490
ISN 0292          TIMJD=TIMJ                                                 SOLF3500
ISN 0293          HIMJD=HIMJ                                                 SOLF3510
ISN 0294          DO 212 K=1,NK                                              SOLF3520
ISN 0295      212 CKIMJD(K)=CKIMJ(K)                                         SOLF3530
ISN 0296          GO TO 218                                                  SOLF3540
ISN 0297      214 IF (NBXM.GT.0) GO TO 210                                   SOLF3550
ISN 0299          UIMJD=U(IM1J)                                              SOLF3560
ISN 0300          VIMJD=V(IM1J)                                              SOLF3570
ISN 0301          TIMJD=T(IM1J)                                              SOLF3580
ISN 0302          HIMJD=H(IM1J)                                              SOLF3590
ISN 0303          DO 216 K=1,NK                                              SOLF3600
ISN 0304      216 CKIMJD(K)=CK(KOIM1J+K)                                     SOLF3610
ISN 0305      218 IF (UIPJ) 228,224,220                                      SOLF3620
ISN 0306      220 UIPJD=UIJ                                                  SOLF3630
ISN 0307          VIPJD=VIJ                                                  SOLF3640
ISN 0308          TIPJD=TIJ                                                  SOLF3650
ISN 0309          HIPJD=HIJ                                                  SOLF3660
ISN 0310          DO 222 K=1,NK                                              SOLF3670
ISN 0311      222 CKIPJD(K)=CKIJ(K)                                          SOLF3680
ISN 0312          GO TO 232                                                  SOLF3690
ISN 0313      224 UIPJD=UIPJ                                                 SOLF3700
ISN 0314          VIPJD=VIPJ                                                 SOLF3710
ISN 0315          TIPJD=TIPJ                                                 SOLF3720
ISN 0316          HIPJD=HIPJ                                                 SOLF3730
ISN 0317          DO 226 K=1,NK                                              SOLF3740
ISN 0318      226 CKIPJD(K)=CKIPJ(K)                                         SOLF3750
ISN 0319          GO TO 232                                                  SOLF3760
ISN 0320      228 IF (NBXP.GT.0) GO TO 224                                   SOLF3770
ISN 0322          UIPJD=U(IP1J)                                              SOLF3780
ISN 0323          VIPJD=V(IP1J)                                              SOLF3790
ISN 0324          TIPJD=T(IP1J)                                              SOLF3800
ISN 0325          HIPJD=H(IP1J)                                              SOLF3810
ISN 0326          DO 230 K=1,NK                                              SOLF3820
ISN 0327      230 CKIPJD(K)=CK(KOIP1J+K)                                     SOLF3830
ISN 0328      232 IF (VIJM) 234,238,242                                      SOLF3840
ISN 0329      234 UIJMD=UIJ                                                  SOLF3850
ISN 0330          VIJMD=VIJ                                                  SOLF3860
ISN 0331          TIJMD=TIJ                                                  SOLF3870
ISN 0332          HIJMD=HIJ                                                  SOLF3880
ISN 0333          DO 236 K=1,NK                                              SOLF3890
ISN 0334      236 CKIJMD(K)=CKIJ(K)                                          SOLF3900
ISN 0335          GO TO 246                                                  SOLF3910
ISN 0336      238 UIJMD=UIJM                                                 SOLF3920
ISN 0337          VIJMD=VIJM                                                 SOLF3930
ISN 0338          TIJMD=TIJM                                                 SOLF3940
ISN 0339          HIJMD=HIJM                                                 SOLF3950
ISN 0340          DO 240 K=1,NK                                              SOLF3960
ISN 0341      240 CKIJMD(K)=CKIJM(K)                                         SOLF3970
ISN 0342          GO TO 246                                                  SOLF3980
ISN 0343      242 IF (NBYM.GT.0) GO TO 238                                   SOLF3990
ISN 0345          UIJMD=U(IJM1)                                              SOLF4000
ISN 0346          VIJMD=V(IJM1)                                              SOLF4010
ISN 0347          TIJMD=T(IJM1)                                              SOLF4020
ISN 0348          HIJMD=H(IJM1)                                              SOLF4030
ISN 0349          DO 244 K=1,NK                                              SOLF4040
```

```
ISN 0350      244 CKIJMD(K)=CK(KOIJM1+K)                                                SOLF4050
ISN 0351      246 IF (VIJP) 256,252,248                                                 SOLF4060
ISN 0352      248 UIJPD=UIJ                                                             SOLF4070
ISN 0353          VIJPD=VIJ                                                             SOLF4080
ISN 0354          TIJPD=TIJ                                                             SOLF4090
ISN 0355          HIJPD=HIJ                                                             SOLF4100
ISN 0356          DO 250 K=1,NK                                                         SOLF4110
ISN 0357      250 CKIJPD(K)=CKIJ(K)                                                     SOLF4120
ISN 0358          GO TO 260                                                             SOLF4130
ISN 0359      252 UIJPD=UIJP                                                            SOLF4140
ISN 0360          VIJPD=VIJP                                                            SOLF4150
ISN 0361          TIJPD=TIJP                                                            SOLF4160
ISN 0362          HIJPD=HIJP                                                            SOLF4170
ISN 0363          DO 254 K=1,NK                                                         SOLF4180
ISN 0364      254 CKIJPD(K)=CKIJP(K)                                                    SOLF4190
ISN 0365          GO TO 260                                                             SOLF4200
ISN 0366      256 IF (NBYP.GT.0) GO TO 252                                              SOLF4210
ISN 0368          UIJPD=U(IJP1)                                                         SOLF4220
ISN 0369          VIJPD=V(IJP1)                                                         SOLF4230
ISN 0370          TIJPD=T(IJP1)                                                         SOLF4240
ISN 0371          HIJPD=H(IJP1)                                                         SOLF4250
ISN 0372          DO 258 K=1,NK                                                         SOLF4260
ISN 0373      258 CKIJPD(K)=CK(KOIJP1+K)                                                SOLF4270
ISN 0374      260 CONTINUE                                                              SOLF4280
            C                                                                           SOLF4290
            C   THE CENTROIDAL ELEVATION HC CAN BE CALCULATED FOR THE TIME BEING        SOLF4300
            C                 FOR UNIFORM DEPTH AS                                      SOLF4310
ISN 0375          HCIPJ=0.5D0*HIPJ                                                      SOLF4320
ISN 0376          HCIMJ=0.5D0*HIMJ                                                      SOLF4330
ISN 0377          HCIJP=0.5D0*HIJP                                                      SOLF4340
ISN 0378          HCIJM=0.5D0*HIJM                                                      SOLF4350
            C                                                                           SOLF4360
            C                                                                           SOLF4370
            C   EVALUATE PHYSICAL PROPERTIES BY CALLING THE MATPR SUBROUTINE            SOLF4380
            C            WITH THE APPROPRIATE ARGUMENTS                                 SOLF4390
            C                                                                           SOLF4400
            C   AT POINT I+1/2,J                                                        SOLF4410
            C                                                                           SOLF4420
ISN 0379          CALL MATPRP( CKIPJ,TIPJ,DENS,SPHT,ROTPD)                              SOLF4430
ISN 0380          ROIPJ=DENS                                                            SOLF4440
ISN 0381          HTIPJ=SPHT*TIPJ                                                       SOLF4450
            C                                                                           SOLF4460
            C   AT POINT I-1/2,J                                                        SOLF4470
            C                                                                           SOLF4480
ISN 0382          CALL MATPRP( CKIMJ,TIMJ,DENS,SPHT,ROTPD)                              SOLF4490
ISN 0383          ROIMJ=DENS                                                            SOLF4500
ISN 0384          HTIMJ=SPHT*TIMJ                                                       SOLF4510
            C                                                                           SOLF4520
            C   AT POINT I,J+1/2                                                        SOLF4530
            C                                                                           SOLF4540
ISN 0385          CALL MATPRP( CKIJP,TIJP,DENS,SPHT,ROTPD)                              SOLF4550
ISN 0386          ROIJP=DENS                                                            SOLF4560
ISN 0387          HTIJP=SPHT*TIJP                                                       SOLF4570
            C                                                                           SOLF4580
            C   AT POINT I,J-1/2                                                        SOLF4590
            C                                                                           SOLF4600
ISN 0388          CALL MATPRP( CKIJM,TIJM,DENS,SPHT,ROTPD)                              SOLF4610
ISN 0389          ROIJM=DENS                                                            SOLF4620
```

```
ISN 0390          HTIJM=SPHT*TIJM
           C
           C   AT POINT I+1/2,J
           C
ISN 0391      262 CALL MATPRP( CKIPJD,TIPJD,DENS,SPHT,ROTPD)
ISN 0392          ROIPJD=DENS
ISN 0393          HTIPJD=SPHT*TIPJD
           C
           C   AT POINT I-1/2,J
           C
ISN 0394          CALL MATPRP( CKIMJD,TIMJD,DENS,SPHT,ROTPD)
ISN 0395          ROIMJD=DENS
ISN 0396          HTIMJD=SPHT*TIMJD
           C
           C   AT POINT I,J+1/2
           C
ISN 0397          CALL MATPRP( CKIJPD,TIJPD,DENS,SPHT,ROTPD)
ISN 0398          ROIJPD=DENS
ISN 0399          HTIJPD=SPHT*TIJPD
           C
           C   AT POINT I,J-1/2
           C
ISN 0400          CALL MATPRP( CKIJMD,TIJMD,DENS,SPHT,ROTPD)
ISN 0401          ROIJMD=DENS
ISN 0402          HTIJMD=SPHT*TIJMD
           C
           C
           C
           C   AT POINT I,J
           C
ISN 0403      264 CALL MATPRP( CKIJ,TIJ,DENS,SPHT,ROTPD)
ISN 0404          ROIJ=DENS
ISN 0405          CPIJ=SPHT
ISN 0406          HTIJ=SPHT*TIJ
ISN 0407          DO 266 K=1,NK
ISN 0408      266 HTKIJ(K)=SPHTK(K)*TIJ
           C
           C   CALCULATES VOLUMETRIC HEAT GENERATION AND SPECIES MASS
           C   GENERATION IF NEEDED.
ISN 0409          IF (NGENF.EQ.0) GO TO 268
ISN 0411          CALL GENCON
ISN 0412          GO TO 272
ISN 0413      268 CONTINUE
ISN 0414          QDVIJ=0.0D0
ISN 0415          DO 270 K=1,NK
ISN 0416      270 GKDVIJ(K)=0.0D0
ISN 0417      272 CONTINUE
           C
           C
           C
ISN 0418          CALL FLXCON(CK,U,V,T,NFLG)
           C   FLXCON CALLS TOPCON AND BOTCON SUBROUTINES
           C
           C*****THIS IS A DUMY PROCEDURE FOR TESTING SOLVET
           C****
           C*     DO 206 K=1,NK
           C*206 CKTMD(KOIJ+K)=.001
           C*     TTMD(IJ)=10.
```

```
               C*     HTMP(IJ)=10.                                                    SOLF5210
               C*     VTMD(IJ)= C.D0                                                  SOLF5220
               C      UTMD(IJ)=0.0D0                                                  SOLF5230
               C*     GO TO 211                                                       SOLF5240
ISN 0419              SXXIMJ=0.                                                       SOLF5250
ISN 0420              SXXIPJ=0.                                                       SOLF5260
ISN 0421              SYYIJM=0.                                                       SOLF5270
ISN 0422              SYYIJP=0.                                                       SOLF5280
ISN 0423              SXYIMJ=0.                                                       SOLF5290
ISN 0424              SXYIPJ=0.                                                       SOLF5300
ISN 0425              SXYIJM=0.                                                       SOLF5310
ISN 0426              SXYIJP=0.                                                       SOLF5320
               C*     IF (IJ.EQ.199.OR.IJ.EQ.201.OR.IJ.EQ.241.OR.IJ.EQ.243) GBIJ=233. SOLF5330
               C*     IF (IJ.EQ.200.OR.IJ.EQ.220.OR.IJ.EQ.222.OR.IJ.EQ.242) GBIJ=233. SOLF5340
               C*     IF(IJ.EQ.211)GBIJ=179.135D0                                     SOLF5350
               C*     IF(IJ.EQ.211)QBIJ=333.333D0                                     SOLF5360
               C*     IF(IJ.EQ.145) GBIJ=80.448D0                                     SOLF5370
               C*     IF(IJ.EQ.73) QBIJ=748.48D0                                      SOLF5380
               C    CALCULATE THE TIME DERIVIATIES OF ALL THE UNKNOWNS BY USING       SOLF5390
               C                 THE MAJOR EQUATIONS                                  SOLF5400
               C                                                                      SOLF5410
               C                                                                      SOLF5420
               C      BASIC CONTINUITY EQUATION                                       SOLF5430
               C                                                                      SOLF5440
ISN 0427              HROTMD =GBIJ+GTIJ -(HIPJD*GXIPJ-HIMJD*GXIMJ)/DXI -(HIJPD*GYIJP- SOLF5450
                     > HIJMD*GYIJM)/DYJ                                               SOLF5460
               C                                                                      SOLF5470
               C                                                                      SOLF5480
               C      SPECIES MASS CONCENTRATION EQUATION                             SOLF5490
               C                                                                      SOLF5500
ISN 0428              SUMK=0.0D0                                                      SOLF5510
ISN 0429              DO 274 K=1,NK                                                   SOLF5520
ISN 0430              CKTMD(KOIJ+K)= GKDVIJ(K)/ROIJ+( -(+HIPJ*(GXIPJ*(CKIPJD(K)-CKIJ(K))) SOLF5530
                     > +GKXIPJ(K)) -HIMJ*(GXIMJ*(CKIMJD(K)-CKIJ(K))+GKXIMJ(K)))/DXI -(+ SOLF5540
                     > HIJP*(GYIJP*(CKIJPD(K)-CKIJ(K))+GKYIJP(K)) -HIJM*(GYIJM*       SOLF5550
                     > (CKIJMD(K)-CKIJ(K))+GKYIJM(K)))/DYJ +GBIJ*(CKBIJ(K)-CKIJ(K))+  SOLF5560
                     > GKBIJ(K)  +GTIJ*(CKTIJ(K)-CKIJ(K))+GKTIJ(K)  )/(ROIJ*HIJ)      SOLF5570
               C                                                                      SOLF5580
ISN 0431         274  SUMK=SUMK+RCCKD(K)*CKTMD(KOIJ+K)                                SOLF5590
               C                                                                      SOLF5600
               C                                                                      SOLF5610
               C      ENERGY EQUATION                                                 SOLF5620
               C                                                                      SOLF5630
ISN 0432              SQCKGN=0.0D0                                                    SOLF5640
ISN 0433              SQKXIP=0.0D0                                                    SOLF5650
ISN 0434              SQKXIM=0.0D0                                                    SOLF5660
ISN 0435              SQKYJP=0.0D0                                                    SOLF5670
ISN 0436              SQKYJM=0.0D0                                                    SOLF5680
ISN 0437              SQKBIJ=0.0D0                                                    SOLF5690
ISN 0438              SQKTIJ=0.0D0                                                    SOLF5700
ISN 0439              DO 276 K=1,NK                                                   SOLF5710
ISN 0440              SQCKGN=SQCKGN+HTKIJ(K)*CKTMD(KOIJ+K)                            SOLF5720
ISN 0441              SQKBIJ=SQKBIJ+QKBIJ(K)                                          SOLF5730
ISN 0442              SQKTIJ=SQKTIJ+QKTIJ(K)                                          SOLF5740
ISN 0443              SQKXIP=SQKXIP+GKXIPJ(K)*(HTKIJ(K))                              SOLF5750
ISN 0444              SQKXIM=SQKXIM+GKXIMJ(K)*(HTKIJ(K))                              SOLF5760
ISN 0445              SQKYJP=SQKYJP+GKYIJP(K)*(HTKIJ(K))                              SOLF5770
ISN 0446         276  SQKYJM=SQKYJM+GKYIJM(K)*(HTKIJ(K))                              SOLF5780
```

```
              C
ISN 0447            TTMD(IJ)=-SQCKGN/CPIJ +( -(+HIPJ*(GXIPJ*(HTIPJD-HTIJ)+QXIPJ+
                  > SQKXIP) -HIMJ*(GXIMJ*(HTIMJD-HTIJ)+QXIMJ+SQKXIM))/DXI -(+HIJP*
                  > (GYIJP*(HTIJPD-HTIJ)+QYIJP+SQKYJP) -HIJM*(GYIJM*(HTIJMD-HTIJ)+
                  > QYIJM+SQKYJM))/DYJ +GBIJ*(HTBIJ-HTIJ)+QBIJ+SQKBIJ +GTIJ*(HTTIJ-
                  > HTIJ)+QTIJ+SQKTIJ )/(ROIJ*CPIJ*HIJ) +QDVIJ/(ROIJ*CPIJ)
              C
              C
              C     CONTINUITY EQUATION FOR WATER ELEVATION H
              C
ISN 0448            ROTMD=ROIPD*TTMD(IJ)+SUMK
              C
ISN 0449            HTMD(IJ)=(-HIJ*ROTMD+HROTMD)/ROIJ
              C
              C
              C     MOMENTUM EQUATION IN X-DIRECTION
              C
ISN 0450            HYPIPJ=GR*RCIPJ*(HIPJ-HCIPJ)
ISN 0451            HYPIJP=GR*RCIJP*(HIJP-HCIJP)
ISN 0452            HYPIMJ=GR*RCIMJ*(HIMJ-HCIMJ)
ISN 0453            HYPIJM=GR*RCIJM*(HIJM-HCIJM)
              C
              C
ISN 0454            UTMD(IJ)=-(HIPJ*HYPIPJ-HIMJ*HYPIMJ)/(DXI*ROIJ*HIJ)+( -(+HIPJ*
                  > (GXIPJ*(UIPJD-UIJ)-SXXIPJ) -HIMJ*(GXIMJ*(UIMJD-UIJ)-SXXIMJ))/DXI
                  > -(+HIJP*(GYIJP*(UIJPD-UIJ)-SXYIJP) -HIJM*(GYIJM*(UIJMD-UIJ)-
                  > SXYIJM))/DYJ +GBIJ*(UBIJ-UIJ)+SBXIJ+GTIJ*(UTIJ-UIJ)+STXIJ )/
                  > (ROIJ*HIJ)
              CW * * * DEBUGGING * * *
              CW    IF(I.EQ.1.AND.J.EQ.1) PRINT 10,I,J,UTMD(IJ),UIJ,HROTMD,
              CW   1HIPJ,GXIPJ,UIPJD,SXXIPJ,HYPIPJ,HIMJ,GXIMJ,UIMJD,SXXIMJ,HYPIMJ,
              CW   2DXI,HIJP,GYIJP,UIJPD,SXYIJP,HIJM,GYIJM,UIJMD,SXYIJM,DYJ,GBIJ,
              CW   3UBIJ,SBXIJ,GTIJ,UTIJ,STXIJ,ROIJ,HIJ
              CW 10 FORMAT(///' U''(I,J),I=',I3,3X,'J=',I3/(13Z10))
              CW    IF(I.EQ.1.AND.J.EQ.1) PRINT 11,DCUT,DIN
              CW 11 FORMAT(10Z10)
              CW * * * DEBUGGING * * *
              C
              C
              C     MOMENTUM EQUATION IN Y-DIRECTION
              C
ISN 0455            VTMD(IJ)=-(HIJP*HYPIJP-HIJM*HYPIJM)/(DYJ*ROIJ*HIJ)+( -(+HIPJ*
                  > (GXIPJ*(VIPJD-VIJ)-SXYIPJ) -HIMJ*(GXIMJ*(VIMJD-VIJ)-SXYIMJ))/DXI
                  > -(+HIJP*(GYIJP*(VIJPD-VIJ)-SYYIJP+HYPIJP) -HIJM*(GYIJM*(VIJMD-
                  > VIJ)-SYYIJM+HYPIJM))/DYJ +GBIJ*(VBIJ-VIJ)+SBYIJ+GTIJ*(VTIJ-VIJ)+
                  > STYIJ )/(ROIJ*HIJ)
ISN 0456        278 CONTINUE
              C
              C
ISN 0457            IJ=IJP1
ISN 0458            KOIJ=KOIJP1
              CW * * * DEBUGGING * * *
              CW    IF(I.EQ.1.AND.J.EQ.1.AND.NCOUNT.EQ.3) CALL EXIT
              CW * * * DEBUGGING * * *
ISN 0459        280 CONTINUE
ISN 0460            KOIJS=KOIJS+NK
ISN 0461        282 CONTINUE
ISN 0462            GO TO 286
```

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   ISN 0463        284 PRINT 1000                                                         SOLF6370
   ISN 0464            STOP 2                                                             SOLF6380
   ISN 0465        286 RETURN                                                             SOLF6390
   ISN 0466       1000 FORMAT(//'0******************************************'/ ,          SOLF6400
                      > '0 PROGRAM IS NOT SET TO HANDLE THIS TYPE OF BOUNDARY' ,          SOLF6410
                      > ' CONDITION'//,'0******************************************'/)    SOLF6420
   ISN 0467            END                                                                SOLF6430

*OPTIONS IN EFFECT*      NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,

*OPTIONS IN EFFECT*      SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF

*STATISTICS*     SOURCE STATEMENTS =     466 ,PROGRAM SIZE =    10062

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                                          21K BYTES OF CORE NOT USED
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OS/360 FORTRAN H

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COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,
                   SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF
ISN 0002        SUBROUTINE FILTER(NK,KX,KY)
ISN 0003        IMPLICIT REAL*8 (A-H,O-Z)
ISN 0004        COMMON/COMBIN/ ANL,ATMP,CBIJ,CKIJ(4),CKIPJ(4),CKIMJ(4),CKIJP(4) ,
               > CKIJM(4),DXM,DXP,DYM,DYP,DXIP1,DYJP1,DXLI,DXRI,DXLI1,DXRI1,DYLJ ,
               > DYRJ,DYLJ1,DYRJ1,GBIJ,GKBIJ(4),QBIJ,QKBIJ(4),SBXIJ,SBYIJ,GXIMJ ,
               > GXIPJ,GYIJM,GYIJP,GTIJ,GKTIJ(4),QTIJ,QKTIJ(4),STXIJ,STYIJ,QDVIJ ,
               > QXIMJ,QXIPJ,QYIJM,QYIJP,GKXIMJ(4),GKXIPJ(4),GKYIJM(4),GKYIJP(4) ,
               > HTKIJ(4),HTKIJM(4),HTKIPJ(4),HTKIMJ(4),HTKIJP(4),HIJ,HIJM,HIPJ ,
               > HIMJ,HIJP,UIJ,UIJM,UIPJ,UIMJ,UIJP,VIJ,VIJM,VIPJ,VIMJ,VIJP,TIJ ,
               > TIJM,TIPJ,TIMJ,TIJP,ROKTPD(4),RCIJ,ROIJM,ROIPJ,ROIMJ,ROIJP ,
               > SHKTPD(4),SHTCKD(4),SHTTPD,SXXIMJ,SXXIPJ,SYYIJM,SYYIJP,SXYIJM ,
               > SXYIPJ,SXYIMJ,SXYIJP,ROIMJD,ROIPJD,ROIJMD,ROIJPD,EQTMP,TDIJ ,
               > HCIMJ,HCIPJ,HCIJM,HCIJP,GR,ROCKD(4),SEHTK(4),DENSK(4),RODKIJ(4) ,
               > GKDVIJ(4),DXI,DYJ ,QDV(25),HBD(25),UBD(25),VBD(25),TBD(25),
               > CKBD(4,25),TBIJ,HCBIJ ,DCKBIJ(4),HTKBIJ(4),BNIJ,UBIJ,VBIJ,WBIJ,
               > ROBIJ,HTBIJ,CKBIJ(4),TTIJ,HCTIJ,DCKTIJ(4),HTKTIJ(4),UTIJ,VTIJ,
               > WTIJ,ROTIJ,HTTIJ,CKTIJ(4) ,QBD(25),GBD(25),GKBD(4,25),SBDN(25),
               > SBDSH(25),WIND,WINDX,WINDY ,IJ,IM1J,IP1J,IJM1,IJP1,INTRT,KOIJ,
               > KOIM1J,KOIP1J,KOIJM1,KOIJP1 ,NBXM,NBXP,NBYM,NBYP,NREGIN,NBNDF ,
               > IXQV(25),JYQV(25),NHBDTP(25),NUBDTP(25),NVBDTP(25),NTBDTP(25) ,
               > NXGRL,NYGRL,NREG,NINTLF,NTOPF,NEQTF,NTEIFC,NTMAX,NGENF
ISN 0005        DIMENSION CKIMJD(4),CKIPJD(4),CKIJMD(4),CKIJPD(4)
ISN 0006        COMMON/DROU/TIM,DTM,TM,PERIOD,TT,NMCVF,LMCVF,N
ISN 0007        COMMON/INDFIT/DTMLT,STM,SDTM,PRBTM,DPRITM,CPUSEC,TIDAL,FDTM,
               > INDTM,NDTMC,IFINIS,LDTMCR,ISTART,IPLOT,NCPU
ISN 0008        DATA MASK/Z00FFFFFF/
            C *** 1'S IN MASK COVER TOTALLY SPACE FOR NBXM,NBXP,NBYM,NBYP IN FLAG,
            C *** NFLG.
ISN 0009        RETURN
ISN 0010        ENTRY FILTEN( HTMD,UTMD,VTMD,TTMD,CKTMD,H,U,V,T,CK,DX,DY,DXL, DXR,
               > DYL,DYR,NFLG)
ISN 0011        DIMENSION HTMD(1),UTMD(1),VTMD(1),TTMD(1),CKTMD(1),H(1),U(1),V(1),
               > T(1),CK(1),DX(1),DY(1),DXL(1),DXR(1),DYL(1),DYR(1),NFLG(1)
ISN 0012     10 DO 94 I=1,KX
ISN 0013        IJ=I
ISN 0014        DXRI=DXR(I)
ISN 0015        DXLI1=DXL(I+1)
ISN 0016        DO 92 J=1,KY
ISN 0017        DYRJ=DYR(J)
ISN 0018        DYLJ1=DYL(J+1)
ISN 0019        CALL GTFLGS(NBXM,NFLG(IJ))
ISN 0020        IF (NREGIN.EQ.0) GO TO 90
ISN 0022        IP1J=IJ+1
ISN 0023        IJP1=IJ+KX
            C*      IF(I.GE.1.AND.I.LE.5.AND.J.GE.1.AND.J.LE.5.AND.IT.LE.3)
            C*     1PRINT 20,I,J,IJ,HTMD(IJ),H(IJ),HIMJ ,HIPJ ,HIJM ,HIJP ,
            C*     2UTMD(IJ),VTMD(IJ),U(IJ),V(IJ),UIMJ ,VIMJ ,UIPJ ,VIPJ ,
            C*     3UIJM ,VIJM ,UIJP ,VIJP
ISN 0024        HIJ=H(IJ)
ISN 0025        UIJ=U(IJ)
ISN 0026        VIJ=V(IJ)
ISN 0027        TIJ=T(IJ)
            C *** IF NBXM=NBXP=NBYM=NBYP=0, THEN GO TO 440 (AN INTERIOR NODE)
ISN 0028        INSIDE=IAND(MASK,NFLG(IJ))
ISN 0029        IF (INSIDE.EQ.0) GO TO 86
ISN 0031        IF (NBYM) 12,12,14
```

```
   12 HIJMF=HIJPFC
      UIJMF=UIJPFC
      VIJMF=VIJPFC
      TIJMF=TIJPFC
      GO TO 48
   14 NH=NHBDTP(NBYM)
      GO TO (20,18,180,16),NH
      GO TO 180
   16 HIJMF=HIJ+DYLJ1*(HIJ-H(IJP1))
      GO TO 22
   18 HIJMF=HIJ
      GO TO 22
   20 HIJMF=HBD(NBYM)
   22 NU=NUBDTP(NBYM)
      GO TO (28,26,180,24),NU
      GO TO 180
   24 UIJMF=UIJ+DYLJ1*(UIJ-U(IJP1))
      GO TO 30
   26 UIJMF=UIJ
      GO TO 30
   28 UIJMF=UBD(NBYM)
   30 NV=NVBDTP(NBYM)
      GO TO (36,34,180,32),NV
      GO TO 180
   32 VIJMF=VIJ+DYLJ1*(VIJ-V(IJP1))
      GO TO 38
   34 VIJMF=VIJ
      GO TO 38
   36 VIJMF=VBD(NBYM)
   38 NT=NTBDTP(NBYM)
      GO TO (46,44,180,40),NT
      GO TO 180
   40 IF (VIJMF) 42,42,46
   42 TIJMF=TIJ+DYLJ1*(TIJ-T(IJP1))
      GO TO 48
   44 TIJMF=TIJ
      GO TO 48
   46 TIJMF=TBD(NBYM)
   48 CONTINUE
      IF (NBYP) 50,50,52
   50 HIJPFC=HIJ+DYLJ1*(H(IJP1)-HIJ)
      HIJPF=HIJPFC
      UIJPFC=UIJ+DYLJ1*(U(IJP1)-UIJ)
      UIJPF=UIJPFC
      VIJPFC=VIJ+DYLJ1*(V(IJP1)-VIJ)
      VIJPF=VIJPFC
      TIJPFC=TIJ+DYLJ1*(T(IJP1)-TIJ)
      TIJPF=TIJPFC
      GO TO 98
   52 NH=NHBDTP(NBYP)
      GO TO (58,56,180,54),NH
      GO TO 180
   54 HIJPF=HIJ+DYBJ*(HIJ-HIJM1)
      GO TO 60
   56 HIJPF=HIJ
      GO TO 60
   58 HIJPF=HBD(NBYP)
   60 NU=NUBDTP(NBYP)
```

```
ISN 0090          GO TO (66,64,180,62),NU
ISN 0091          GO TO 180
ISN 0092       62 UIJPF=UIJ+DYRJ*(UIJ-UIJM1)
ISN 0093          GO TO 68
ISN 0094       64 UIJPF=UIJ
ISN 0095          GO TO 68
ISN 0096       66 UIJPF=UBD(NBYP)
ISN 0097       68 NV=NVBDTP(NBYP)
ISN 0098          GO TO (74,72,180,70),NV
ISN 0099          GO TO 180
ISN 0100       70 VIJPF=VIJ+DYRJ*(VIJ-VIJM1)
ISN 0101          GO TO 76
ISN 0102       72 VIJPF=VIJ
ISN 0103          GO TO 76
ISN 0104       74 VIJPF=VBD(NBYP)
ISN 0105       76 NT=NTBDTP(NBYP)
ISN 0106          GO TO (84,82,180,78),NT
ISN 0107          GO TO 180
ISN 0108       78 IF (VIJPF) 84,80,80
ISN 0109       80 TIJPF=TIJ+DYRJ*(TIJ-TIJM1)
ISN 0110          GO TO 88
ISN 0111       82 TIJPF=TIJ
ISN 0112          GO TO 88
ISN 0113       84 TIJPF=TBD(NBYP)
ISN 0114          GO TO 88
            C *** BEGIN CALCULATION FOR INTERIOR NODE.
ISN 0115       86 CONTINUE
ISN 0116          HIJMF=HIJPFC
ISN 0117          HIJPFC=HIJ + DYLJ1*(H(IJP1)-HIJ)
ISN 0118          HIJPF=HIJPFC
ISN 0119          UIJMF=UIJPFC
ISN 0120          UIJPFC=UIJ + DYLJ1*(U(IJP1)-UIJ)
ISN 0121          UIJPF=UIJPFC
ISN 0122          VIJMF=VIJPFC
ISN 0123          VIJPFC=VIJ + DYLJ1*(V(IJP1)-VIJ)
ISN 0124          VIJPF=VIJPFC
ISN 0125          TIJMF=TIJPFC
ISN 0126          TIJPFC=TIJ + DYLJ1*(T(IJP1)-TIJ)
ISN 0127          TIJPF=TIJPFC
            C *** END CALCULATION FOR INTERIOR NODE.
ISN 0128       88 CONTINUE
ISN 0129          HIJM1=HIJ
ISN 0130          UIJM1=UIJ
ISN 0131          VIJM1=VIJ
ISN 0132          TIJM1=TIJ
ISN 0133          H(IJ)=0.5D0*(HIJMF+HIJPF)
ISN 0134          U(IJ)=0.5D0*(UIJMF+UIJPF)
            C*        IF(DABS(U(IJ)).LT.1.0D-14)U(IJ)=0.0
ISN 0135          V(IJ)=0.5D0*(VIJMF+VIJPF)
            C*        IF(DABS(V(IJ)).LT.1.0D-14)V(IJ)=C.0
ISN 0136          T(IJ)=0.5D0*(TIJMF+TIJPF)
            C*        IF(I.GE.1.AND.I.LE.5.AND.J.GE.1.AND.J.LE.5.AND.IT.LE.3)
            C*       1PRINT 20,I,J,IJ,HTMD(IJ),H(IJ),HIMJ ,HIPJ ,HIJMF ,HIJPF
            C*       2UTMD(IJ),VTMD(IJ),U(IJ),V(IJ),UIMJ ,VIMJ ,UIPJ ,VIPJ ,
            C*       3UIJMF,VIJMF,UIJPF,VIJPF
ISN 0137       90 CONTINUE
            C
            C
```

```
ISN 0138          IJ=IJP1                                                   FILT1730
ISN 0139       92 CONTINUE                                                  FILT1740
ISN 0140       94 CONTINUE                                                  FILT1750
ISN 0141          IJ=0                                                      FILT1760
ISN 0142          DO 178 J=1,KY                                             FILT1770
ISN 0143          DYRJ=DYR(J)                                               FILT1780
ISN 0144          DYLJ1=DYL(J+1)                                            FILT1790
ISN 0145          DO 176 I=1,KX                                             FILT1800
ISN 0146          IJ=IJ+1                                                   FILT1810
ISN 0147          DXRI=DXR(I)                                               FILT1820
ISN 0148          DXLI1=DXL(I+1)                                            FILT1830
ISN 0149          CALL GTFLGS(NBXM,NFLG(IJ))                                FILT1840
ISN 0150          IF (NRFGIN.EQ.0) GO TO 174                                FILT1850
ISN 0152          IP1J=IJ+1                                                 FILT1860
ISN 0153          IJP1=IJ+KX                                                FILT1870
         C*       IF(I.GE.1.AND.I.LE.5.AND.J.GE.1.AND.J.LE.5.AND.IT.LE.3)   FILT1880
         C*      1PRINT 20,I,J,IJ,HTMD(IJ),H(IJ),HIMJ ,HIPJ ,HIJMF ,HIJPF , FILT1890
         C*      2UTMD(IJ),VTMD(IJ),U(IJ),V(IJ),UIMJ ,VIMJ ,UIPJ ,VIPJ ,    FILT1900
         C*      3UIJMF,VIJMF,UIJPF,VIJPF                                   FILT1910
ISN 0154          HIJ=H(IJ)                                                 FILT1920
ISN 0155          UIJ=U(IJ)                                                 FILT1930
ISN 0156          VIJ=V(IJ)                                                 FILT1940
ISN 0157          TIJ=T(IJ)                                                 FILT1950
         C *** IF NBXM=NBXP=NBYM=NBYP=0, THEN GO TO 450 (AN INTERIOR NODE)  FILT1960
ISN 0158          INSIDE=IAND(MASK,NFLG(IJ))                                FILT1970
ISN 0159          IF (INSIDE.EQ.0) GO TO 170                                FILT1980
ISN 0161          IF (NBXM) 96,96,98                                        FILT1990
ISN 0162       96 HIMJF=HIPJFC                                              FILT2000
ISN 0163          UIMJF=UIPJFC                                              FILT2010
ISN 0164          VIMJF=VIPJFC                                              FILT2020
ISN 0165          TIMJF=TIPJFC                                              FILT2030
ISN 0166          GO TO 132                                                 FILT2040
ISN 0167       98 NH=NHBDTP(NBXM)                                           FILT2050
ISN 0168          GO TO (104,102,180,100),NH                                FILT2060
ISN 0169          GO TO 180                                                 FILT2070
ISN 0170      100 HIMJF=HIJ+DXLI1*(HIJ-H(IP1J))                             FILT2080
ISN 0171          GO TO 106                                                 FILT2090
ISN 0172      102 HIMJF=HIJ                                                 FILT2100
ISN 0173          GO TO 106                                                 FILT2110
ISN 0174      104 HIMJF=HBD(NBXM)                                           FILT2120
ISN 0175      106 NU=NUBDTP(NBXM)                                           FILT2130
ISN 0176          GO TO (112,110,180,108),NU                                FILT2140
ISN 0177          GO TO 180                                                 FILT2150
ISN 0178      108 UIMJF=UIJ+DXLI1*(UIJ-U(IP1J))                             FILT2160
ISN 0179          GO TO 114                                                 FILT2170
ISN 0180      110 UIMJF=UIJ                                                 FILT2180
ISN 0181          GO TO 114                                                 FILT2190
ISN 0182      112 UIMJF=UBD(NBXM)                                           FILT2200
ISN 0183      114 NV=NVBDTP(NBXM)                                           FILT2210
ISN 0184          GO TO (120,118,180,116),NV                                FILT2220
ISN 0185          GO TO 180                                                 FILT2230
ISN 0186      116 VIMJF=VIJ+DXLI1*(VIJ-V(IP1J))                             FILT2240
ISN 0187          GO TO 122                                                 FILT2250
ISN 0188      118 VIMJF=VIJ                                                 FILT2260
ISN 0189          GO TO 122                                                 FILT2270
ISN 0190      120 VIMJF=VBD(NBXM)                                           FILT2280
ISN 0191      122 NT=NTBDTP(NBXM)                                           FILT2290
ISN 0192          GO TO (130,128,180,124),NT                                FILT2300
```

```
            GO TO 180
        124 IF (UIMJE) 126,126,130
        126 TIMJE=TIJ+DXLI1*(TIJ-T(IP1J))
            GO TO 132
        128 TIMJE=TIJ
            GO TO 132
        130 TIMJE=TBD(NBXM)
        132 CONTINUE
            IF (NBXP) 134,134,136
        134 HIPJEC=HIJ+DXLI1*(H(IP1J)-HIJ)
            HIPJE=HIPJEC
            UIPJEC=UIJ+DXLI1*(U(IP1J)-UIJ)
            UIPJE=UIPJEC
            VIPJEC=VIJ+DXLI1*(V(IP1J)-VIJ)
            VIPJE=VIPJEC
            TIPJEC=TIJ+DXLI1*(T(IP1J)-TIJ)
            TIPJE=TIPJEC
            GO TO 172
        136 NH=NHBDTP(NBXP)
            GO TO (142,140,180,138),NH
            GO TO 180
        138 HIPJE=HIJ+DXRI*(HIJ-HIM1J)
            GO TO 144
        140 HIPJE=HIJ
            GO TO 144
        142 HIPJE=HBD(NBXP)
        144 NU=NUBDTP(NBXP)
            GO TO (150,148,180,146),NU
            GO TO 180
        146 UIPJE=UIJ+DXRI*(UIJ-UIM1J)
            GO TO 152
        148 UIPJE=UIJ
            GO TO 152
        150 UIPJE=UBD(NBXP)
        152 NV=NVBDTP(NBXP)
            GO TO (158,156,180,154),NV
            GO TO 180
        154 VIPJE=VIJ+DXRI*(VIJ-VIM1J)
            GO TO 160
        156 VIPJE=VIJ
            GO TO 160
        158 VIPJE=VBD(NBXP)
        160 NT=NTBDTP(NBXP)
            GO TO (168,166,180,162),NT
            GO TO 180
        162 IF (UIPJE) 168,164,164
        164 TIPJE=TIJ+DXRI*(TIJ-TIM1J)
            GO TO 172
        166 TIPJE=TIJ
            GO TO 172
        168 TIPJE=TBD(NBXP)
            GO TO 172
C *** BEGIN CALCULATION FOR INTERIOR NODE.
        170 CONTINUE
            HIMJE=HIPJEC
            HIPJEC=HIJ + DXLI1*(H(IP1J)-HIJ)
            HIPJE=HIPJEC
            UIMJE=UIPJEC
```

```
 ISN 0250             UIPJFC=UIJ + DXLI1*(U(IP1J)-UIJ)
 ISN 0251             UIPJF=UIPJFC
 ISN 0252             VIMJF=VIPJFC
 ISN 0253             VIPJFC=VIJ + DXLI1*(V(IP1J)-VIJ)
 ISN 0254             VIPJF=VIPJFC
 ISN 0255             TIMJF=TIPJFC
 ISN 0256             TIPJFC=TIJ + DXLI1*(T(IP1J)-TIJ)
 ISN 0257             TIPJF=TIPJFC
                C *** END CALCULATION FOR INTERIOR NODE.
 ISN 0258         172 CONTINUE
 ISN 0259             HIM1J=HIJ
 ISN 0260             UIM1J=UIJ
 ISN 0261             VIM1J=VIJ
 ISN 0262             TIM1J=TIJ
 ISN 0263             H(IJ)=0.5D0*(HIMJF+HIPJF)
 ISN 0264             U(IJ)=0.5D0*(UIMJF+UIPJF)
                C*    IF(DABS(U(IJ)).LT.1.0D-14)U(IJ)=0.0
 ISN 0265             V(IJ)=0.5D0*(VIMJF+VIPJF)
                C*    IF(DABS(V(IJ)).LT.1.0D-14)V(IJ)=0.0
 ISN 0266             T(IJ)=0.5D0*(TIMJF+TIPJF)
                C*    IF(I.GE.1.AND.I.LE.5.AND.J.GE.1.AND.J.LE.5.AND.IT.LE.3)
                C*   1PRINT 20,I,J,IJ,HTMD(IJ),H(IJ),HIMJF,HIPJF,HIJMF,HIJPF,
                C*   2UTMD(IJ),VTMD(IJ),U(IJ),V(IJ),UIMJF,VIMJF,UIPJF,VIPJF,
                C*   3UIJMF,VIJMF,UIJPF,VIJPF
 ISN 0267         174 CONTINUE
                C
                C
 ISN 0268         176 CONTINUE
 ISN 0269         178 CONTINUE
 ISN 0270             GO TO 182
 ISN 0271         180 PRINT 1010
 ISN 0272             STOP 2
 ISN 0273         182 RETURN
 ISN 0274        1000 FORMAT(///' U''(I,J),I=',I3,3X,'J=',I3,3X,'IJ=',I3/(4E26.18))
 ISN 0275        1010 FORMAT(//'0******************************************'/ ,
                    > '0 PROGRAM IS NOT SET TO HANDLE THIS TYPE OF BOUNDARY' ,
                    > ' CONDITION'//,'0******************************************'/)
 ISN 0276             END

*OPTIONS IN EFFECT*       NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,

*OPTIONS IN EFFECT*       SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF

*STATISTICS*     SOURCE STATEMENTS =      275 ,PROGRAM SIZE =      4726

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                                77K BYTES OF CORE NOT USED
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OS/360 FORTRAN H

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        COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,
                           SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF
ISN 0002                SUBROUTINE GENCNI(NK)
ISN 0003                IMPLICIT REAL*8 (A-H,O-Z)
ISN 0004                DIMENSION IQDVF(25),IGKDVF(4,25),GKDV(4,25)
ISN 0005                COMMON/REGION/DEPTH(25),SM(25),ILREG(25),IHREG(25),JLREG(25),
                       > JHREG(25),INTF(25),IGENF(25),ITOPF(25),IBOTF(25)
ISN 0006                INTEGER*2 ILREG,IHREG,JLREG,JHREG
ISN 0007                INTEGER*2 INTF,IGENF,ITOPF,IBOTF
ISN 0008                COMMON/COMBIN/ ANL,ATMP,CPIJ,CKIJ(4),CKIPJ(4),CKIMJ(4),CKIJP(4) ,
                       > CKIJM(4),DXM,DXP,DYM,DYP,DXIP1,DYJP1,DXII,DXRI,DXLI1,DXRI1,DYLJ ,
                       > DYRJ,DYLJ1,DYRJ1,GBIJ,GKBIJ(4),QBIJ,QKBIJ(4),SBXIJ,SBYIJ,GXIMJ ,
                       > GXIPJ,GYIJM,GYIJP,GTIJ,GKTIJ(4),QTIJ,QKTIJ(4),STXIJ,STYIJ,QDVIJ ,
                       > QXIMJ,QXIPJ,QYIJM,QYIJP,GKXIMJ(4),GKXIPJ(4),GKYIJM(4),GKYIJP(4) ,
                       > HTKIJ(4),HTKIJM(4),HTKIPJ(4),HTKIMJ(4),HTKIJP(4),HIJ,HIJM,HIPJ ,
                       > HIMJ,HIJP,UIJ,UIJM,UIPJ,UIMJ,UIJP,VIJ,VIJM,VIPJ,VIMJ,VIJP,TIJ ,
                       > TIJM,TIPJ,TIMJ,TIJP,RCKTPD(4),RCIJ,ROIJM,ROIPJ,ROIMJ,ROIJP ,
                       > SHKTPD(4),SHTCKD(4),SHTTPD,SXXIMJ,SXXIPJ,SYYIJM,SYYIJP,SXYIJM ,
                       > SXYIPJ,SXYIMJ,SXYIJP,ROIMJD,RCIPJD,RCIJMD,ROIJPD,EQTMP,TDIJ ,
                       > HCIMJ,HCIPJ,HCIJM,HCIJP,GR,ROCKD(4),SPHTK(4),DENSK(4),RODKIJ(4) ,
                       > GKDVIJ(4),DXI,DYJ ,QDV(25),HBD(25),UBD(25),VBD(25),TBD(25),
                       > CKBD(4,25),TBIJ,HCBIJ ,DCKBIJ(4),HTKBIJ(4),BNIJ,UBIJ,VBIJ,WBIJ,
                       > ROBIJ,HTBIJ,CKBIJ(4),TTIJ,HCTIJ,DCKTIJ(4),HTKTIJ(4),UTIJ,VTIJ,
                       > WTIJ,ROTIJ,HTTIJ,CKTIJ(4) ,QBD(25),GBD(25),GKBD(4,25),SBDN(25),
                       > SBDSH(25),WIND,WINDX,WINDY ,IJ,IM1J,IP1J,IJM1,IJP1,INTRT,KOIJ,
                       > KOIM1J,KOIP1J,KOIJM1,KOIJP1 ,NBXM,NBXP,NBYM,NBYP,NREGIN,NBNDF ,
                       > IXQV(25),JYQV(25),NHBDTP(25),NUBDTP(25),NVBDTP(25),NTBDTP(25) ,
                       > NXGRL,NYGRL,NREG,NINTLF,NTOPF,NBOTF,NTELEC,NTMAX,NGENF
ISN 0009                IF (NGENF.EQ.0) GO TO 14
                   C   ANY INPUT VARIABLE CAN BE SET HERE
ISN 0011                PRINT 1000
ISN 0012                DO 10 I=1,NGENF
ISN 0013                READ(50,1010) IGENFC,QDV(IGENFC),IQDVF(IGENFC),(GKDV(K,IGENFC),
                       > IGKDVF(K,IGENFC),K=1,NK)
ISN 0014             10 CONTINUE
ISN 0015                PRINT 1020
ISN 0016                DO 12 K=1,NGENF
ISN 0017                PRINT 1030,K,IGENFC,QDV(K),IQDVF(K),GKDV(1,K),IGKDVF(1,K),GKDV(2,
                       > K),IGKDVF(2,K)
ISN 0018             12 CONTINUE
ISN 0019             14 CONTINUE
ISN 0020                RETURN
                   C * * * * * * * * * * * * * * * * * * * * * *
ISN 0021                ENTRY GENCCN
                   C * * * * * * * * * * * * * * * * * * * * * *
ISN 0022                IQVA=IGENF(NREGIN)
ISN 0023                IF (IQVA.LE.0) GO TO 22
ISN 0025             16 DO 18 K=1,NK
ISN 0026             18 GKDVIJ(K)=GKDV(K,IQVA)*GNRLFC(IGKDVF(K,IQVA),X)
ISN 0027                QDVIJ=QDV(IQVA)*GNRLFC(IQDVF(IQVA),X)
                   CC  IF GKDVIJ(K) WERE DIFFERENT THAN ABOVE. SOME EVALUATION COULD HAVE
                   CC  COME HERE.
ISN 0028             20 RETURN
ISN 0029             22 QDVIJ=0.D0
ISN 0030                DO 24 K=1,NK
ISN 0031             24 GKDVIJ(K)=0.D0
ISN 0032                RETURN
ISN 0033           1000 FORMAT(////'1',1X,'INPUT INFORMATION FROM SUBROUTINE GENCON:'/1X,
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                  >' --- --- --- --- --- --- --- --- --- --- '//2X,'IGENFC - INTERNALGENC 570
                  > GENERATION FUNCTION (AN INDEX)'/2X,'QDV - VALUE OF HEAT GENERATIOGENC 580
                  >N PER UNIT VOLUME IN INTERNAL GENERATION FUNCTION'/2X,'IQDVF - GENGENC 590
                  >ERAL PURPOSE FUNCTION TO BE USED ON QDV'/2X,'GKDV(K) - VALUE OF MAGENC 600
                  >SS GENERATION PER UNIT VOLUME FOR SPECIE K IN INTERNAL GENERATION GENC 610
                  >FUNCTION'/2X,'IGKDVF(K) - GENERAL PURPOSE FUNCTION TO BE USED ON GGENC 620
                  >KDV(K)'/)                                                         GENC 630
  ISN 0034      1010 FORMAT(I5,5X,3(E10.2,I5,5X),10X/(10X,3(E10.2,I5,5X),10X))       GENC 640
  ISN 0035      1020 FORMAT(//5X,'K',6X,'IGENFC',5X,'QDV',10X,'IQDVF',5X,'GKDV(1)',5X, GENC 650
                  > 'IGKDVF(1)',5X,'GKDV(2)',5X,'IGKDVF(2)')                         GENC 660
  ISN 0036      1030 FORMAT(4X,I2,5X,I5,5X,E10.2,3X,I5,2(8X,E10.2,1X,I5))            GENC 670
  ISN 0037           END                                                             GENC 680

*OPTIONS IN EFFECT*      NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,

*OPTIONS IN EFFECT*      SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF

*STATISTICS*     SOURCE STATEMENTS =      36 ,PROGRAM SIZE =     3020

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                                   117K BYTES OF CORE NOT USED
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CS/360 FORTRAN H

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         COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,
                            SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF
ISN 0002            SUBROUTINE ENDCNI(NK,Z,DX,Y,DY,KX,KY,NCHECK)                          BNDC
ISN 0003            IMPLICIT REAL*8 (A-H,O-Z)                                             BNDC
ISN 0004            DIMENSION FHBD(25),FUBD(25),FVBD(25),FTBD(25),FCKBD(4,25) ,           BNDC
                   > FQBD(25),FGBD(25),FSBDN(25),FSBDSH(25),FGKBD(4,25),RO(25)            BNDC
ISN 0005            DIMFNSION IHBDF(25),IUBDF(25),IVBDF(25),ITBDF(25),IGBDF(25),          BNDC
                   > IQBDF(25),ISNBDF(25),ISHBDF(25),ICKBDF(4,25),IGKBDF(4,25)            BNDC
ISN 0006            DIMENSION IINT(25),JINT(25)                                           BNDC
               C *** Z IS REALLY CUR X ARRAY, BUT THE NAME X IS USED AFTER THE ENTRY      BNDC
               C *** FOR ANCTHEF FURPOSE.                                                 BNDC
ISN 0007            DIMENSION Z(1),DX(1),Y(1),DY(1)                                       BNDC
ISN 0008            COMMON/COMBIN/ ANL,ATMP,CPIJ,CKIJ(4),CKIPJ(4),CKIMJ(4),CKIJP(4) ,     BNDC
                   > CKIJM(4),DXM,DXP,DYM,DYP,DXIP1,DYJP1,DXLI,DXRI,DXLI1,DXRI1,DYLJ ,BNDC
                   > DYRJ,DYLJ1,DYRJ1,GBIJ,GKBIJ(4),QBIJ,QKBIJ(4),SBXIJ,SBYIJ,GXIMJ ,  BNDC
                   > GXIPJ,GYIJM,GYIJP,GTIJ,GKTIJ(4),QTIJ,QKTIJ(4),STXIJ,STYIJ,QDVIJ ,BNDC
                   > QXIMJ,QXIPJ,QYIJM,QYIJP,GKXIMJ(4),GKXIPJ(4),GKYIJM(4),GKYIJP(4) ,BNDC
                   > HTKIJ(4),HTKIJM(4),HTKIPJ(4),HTKIMJ(4),HTKIJP(4),HIJ,HIJM,HIPJ ,  BNDC
                   > HIMJ,HIJP,UIJ,UIJM,UIPJ,UIMJ,UIJP,VIJ,VIJM,VIPJ,VIMJ,VIJP,TIJ ,    BNDC
                   > TIJM,TIPJ,TIMJ,TIJP,ROKTPD(4),RCIJ,ROIJE,ROIPJ,ROIMJ,ROIJP ,       BNDC
                   > SHKTPD(4),SHTCKD(4),SHTTPD,SXXIMJ,SXXIPJ,SYYIJM,SYYIJP,SXYIJM ,    BNDC
                   > SXYIPJ,SXYIMJ,SXYIJP,ROIMJD,RCIPJD,ROIJMD,ROIJPD,EQTMP,TDIJ ,      BNDC
                   > HCIMJ,HCIPJ,HCIJM,HCIJP,GR,ROCKD(4),SPHTK(4),DENSK(4),RODKIJ(4) ,BNDC
                   > GKDVIJ(4),DXI,DYJ ,QDV(25),HBD(25),UBD(25),VBD(25),TBD(25),       BNDC
                   > CKBD(4,25),TBIJ,HCBIJ ,DCKBIJ(4),HTKBIJ(4),BNIJ,UBIJ,VBIJ,WBIJ,    BNDC
                   > ROBIJ,HTBIJ,CKBIJ(4),TTIJ,HCTIJ,DCKTIJ(4),HTKTIJ(4),UTIJ,VTIJ,     BNDC
                   > WTIJ,ROTIJ,HTTIJ,CKTIJ(4) ,QBD(25),GBD(25),GKBD(4,25),SBDN(25),    BNDC
                   > SBDSH(25),WIND,WINDX,WINDY ,IJ,IM1J,IP1J,IJM1,IJP1,INTRT,KOIJ,     BNDC
                   > KOIM1J,KOIP1J,KOIJM1,KOIJP1 ,NBXM,NBXP,NEYM,NBYP,NREGIN,NBNDF ,   BNDC
                   > IXQV(25),JYQV(25),NHBDTP(25),NUEDTP(25),NVBDTP(25),NTBDTP(25) ,   BNDC
                   > NXGRL,NYGRL,NREG,NINTLF,NTOPF,NEOTF,NTBIFC,NTMAX,NGENF             BNDC
ISN 0009            COMMON/SCRATH/XINT(25),YINT(25)                                       BNDC
ISN 0010            PRINT 1000                                                            BNDC
ISN 0011            PRINT 1010                                                            BNDC
ISN 0012            PRINT 1020                                                            BNDC
ISN 0013            NPOW=0                                                                BNDC
ISN 0014            NPRI=0                                                                BNDC
ISN 0015            DO 10 I=1,NBNDF                                                       BNDC
ISN 0016            READ(50,1030)NBN,NHBDTP(NBN),NUBDTF(NBN),NVBDTP(NBN),NTBDTP(NBN)      BNDC
               C    NBTYP=1, CONSTANT FLUX GOING OUT (OPEN CHANNEL FLOWING OUT FOR TEMPBNDC
               C    NBTYP=2, ADIABATIC (NO HEAT DIFFUSION FCR TEMPERATURE,                BNDC
               C             OPEN CHANNEL FLOWING OUT FOR VELOCITY)                       BNDC
               C    NBTYP=3, ISCTHERMAL (OPEN CHANNEL FLCWING IN FOR TEMF AND VELOCITY)BNDC
               C    NBTYP=4, CONSTANT FLUX COMING IN (CONSTANT EXTERNAL HEAT FLUX         BNDC
               C             WITH KNOWN HEAT TRANSFER COEFFICIENT FOR TEMPERATURE         BNDC
               C             AND EXTERNAL KNOWN STRESS, LIKE FRICTION, FOR VELOCITY)      BNDC
ISN 0017            READ(50,1040) FHBD(NBN),FUBD(NBN),FVBD(NEN),FTBD(NBN),XINT(NBN),      BNDC
                   > YINT(NBN)                                                            BNDC
ISN 0018            READ(50,1040) FGBD(NBN),FQBD(NBN),FSBDN(NBN),FSBDSH(NBN)              BNDC
ISN 0019            READ(50,1040)(FCKBD(K,NBN),FGKBD(K,NBN),K=1,NK)                       BNDC
ISN 0020            READ(50,1030)IHBDF(NBN),IUBDF(NBN),IVBDF(NBN),ITBDF(NBN),             BNDC
                   > IGBDF(NBN),IQBDF(NBN),ISNBDF(NBN),ISHBDF(NBN), (ICKBDF(K,NBN),      BNDC
                   > IGKBDF(K,NBN),K=1,NK)                                                BNDC
ISN 0021            IF (FTBD(NBN).GE.0.) GO TO 10                                         BNDC
ISN 0023            NPRI=1                                                                BNDC
               C *** CALCULATE NODE CONTAINING THE POINT (XINT,YINT).                     BNDC
ISN 0024            CALL BSERCH(IINT(NBN),XINT(NBN),Z,KX,DX,'  X ',NBN,NPOW,1)            BNDC
ISN 0025            CALL BSERCH(JINT(NBN),YINT(NBN),Y,KY,DY,'  Y ',NBN,NPOW,1)            BNDC
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ISN 0026       10 CONTINUE                                                        BNDC 570
ISN 0027          NCHECK=NCHECK+100000*NPOW                                       BNDC 580
ISN 0028          PRINT 1050,(NBN,NHBDTP(NBN),NUBDTP(NBN),NVBDTP(NBN),NTBDTP(NBN),  BNDC 590
                > FHBD(NBN),FUBD(NBN),FVBD(NBN),FTBD(NBN),NBN=1,NBNDF)           BNDC 600
               C  REALLY DESIGNED FOR NK=2                                        BNDC 610
ISN 0029          PRINT 1060,(NBN,FGBD(NBN),FQBD(NBN),FSBDN(NBN),FSBDSH(NBN),     BNDC 620
                > FGKBD(1,NBN),FGKBD(2,NBN),FCKBD(1,NBN),FCKBD(2,NBN),NBN=1,NBNDF)  BNDC 630
ISN 0030          PRINT 1070,(NBN,IHBDF(NBN),IUBDF(NBN),IVBDF(NBN),ITBDF(NBN),    BNDC 640
                > IGBDF(NBN),IQBDF(NBN),ISNBDF(NBN),ISHBDF(NBN),NBN=1,NBNDF)     BNDC 650
ISN 0031          IF (NPRI.EQ.0) GO TO 14                                         BNDC 660
ISN 0033          PRINT 1080                                                      BNDC 670
ISN 0034          DO 12 NBN=1,NBNDF                                               BNDC 680
ISN 0035          IF (FTBD(NBN).GE.0.) GO TO 12                                   BNDC 690
ISN 0037          DTPP=-FTBD(NBN)                                                 BNDC 700
ISN 0038          PRINT 1090, NBN,DTPP,XINT(NBN),YINT(NBN),IINT(NBN),JINT(NBN)   BNDC 710
ISN 0039       12 CONTINUE                                                        BNDC 720
ISN 0040       14 CONTINUE                                                        BNDC 730
ISN 0041          DENS=62.2D0                                                     BNDC 740
ISN 0042          SPHT=1.D0                                                       BNDC 750
ISN 0043          RETURN                                                          BNDC 760
               C * * * * * * * * * * * * * * * * * * * * * * *                    BNDC 770
ISN 0044          ENTRY BNDCON(KX,NK,T,CK)                                        BNDC 780
               C * * * * * * * * * * * * * * * * * * * * * * *                    BNDC 790
ISN 0045          DIMENSION T(KX,1),CK(NK,KX,1)                                   BNDC 800
ISN 0046          DO 26 NBN=1,NBNDF                                               BNDC 810
ISN 0047          HBD(NBN)=FHBD(NBN)*GNRLFC(IHBDF(NBN),X)                         BNDC 820
ISN 0048          UBD(NBN)=FUBD(NBN)*GNRLFC(IUBDF(NBN),X)                         BNDC 830
ISN 0049          VBD(NBN)=FVBD(NBN)*GNRLFC(IVBDF(NBN),X)                         BNDC 840
ISN 0050          DO 16 K=1,NK                                                    BNDC 850
ISN 0051       16 CKBD(K,NBN)=FCKBD(K,NBN)*GNRLFC(ICKBDF(K,NBN),X)               BNDC 860
ISN 0052          GBD(NBN)=FGBD(NBN)*GNRLFC(IGBDF(NBN),X)                         BNDC 870
ISN 0053          IF (FTBD(NBN).LT.0.) GO TO 20                                   BNDC 880
ISN 0055       18 TBD(NBN)=FTBD(NBN)*GNRLFC(ITBDF(NBN),X)                         BNDC 890
ISN 0056          CALL MATPRP(CKBD(1,NBN),TBD(NBN),DENS,SPHT,ROTPD)              BNDC 900
ISN 0057          RO(NBN)=DENS                                                    BNDC 910
ISN 0058          GO TO 22                                                        BNDC 920
ISN 0059       20 FLPP=GBD(NBN)                                                   BNDC 930
ISN 0060          I=IINT(NBN)                                                     BNDC 940
ISN 0061          J=JINT(NBN)                                                     BNDC 950
ISN 0062          CALL MATPRP(CK(1,I,J),T(I,J),DENS,SPHT,ROTPD)                   BNDC 960
               C *** -FTBD(NBN)=QPP(NBN)                                          BNDC 970
ISN 0063          TBD(NBN)=T(I,J)+(-FTBD(NBN))                                    BNDC 980
ISN 0064          RO(NBN)=DENS                                                    BNDC 990
ISN 0065       22 CONTINUE                                                        BNDC1000
ISN 0066          QBD(NBN)=FQBD(NBN)*GNRLFC(IQBDF(NBN),X)                         BNDC1010
ISN 0067          DO 24 K=1,NK                                                    BNDC1020
ISN 0068       24 GKBD(K,NBN)=FGKBD(K,NBN)*GNRLFC(IGKBDF(K,NBN),X)               BNDC1030
ISN 0069          SBDN(NBN)=FSBDN(NBN)*GNRLFC(ISNBDF(NBN),X)                      BNDC1040
ISN 0070          SBDSH(NBN)=FSBDSH(NBN)*GNRLFC(ISHBDF(NBN),X)                    BNDC1050
ISN 0071       26 CONTINUE                                                        BNDC1060
ISN 0072          RETURN                                                          BNDC1070
ISN 0073     1000 FORMAT(////'1',1X,'INPUT INFORMATION FROM SUBROUTINE BNDCON:'/1X,  BNDC1080
                > ' --- --- --- --- --- --- --- --- --- ---')                     BNDC1090
ISN 0074     1010 FORMAT ('0',1X,'NBN - BOUNDARY CONDITION NUMBER'/                BNDC1100
                >' ',1X,'NHBDTP - TYPE OF BOUNDARY CONDITION FOR WATER ELEVATION H BNDC1110
                >(NHBDTP)'/' ',1X,'NU - TYPE OF BOUNDARY CONDITION FOR VELOCITY U (BNDC1120
                >NUBDTP)'/' ',1X,'NV - TYPE OF BOUNDARY CONDITION FOR VELOCITY V ( BNDC1130
                >NVBDTP)'/' ',1X,'NT - TYPE OF BOUNDARY CONDITION FOR TEMP. OR SPECBNDC1140
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                >IES CONCENTRATION (NBTDTP)'/' ',1X,'FH -  VALUE OF BOUNDARY CONDITBNDC1150
                >ION FOR WATER ELEVATION (FHBD)'/                                  BNDC1160
                >' ',1X,'FU - VALUE OF BOUNDARY CONDITION FOR VELOCITY U (FUBD)'/  BNDC1170
                >' ',1X,'FV - VALUE OF BOUNDARY CONDITION FOR VELOCITY V (FVBD)'/  BNDC1180
                >' ',1X,'FT - VALUE OF BOUNDARY CONDITION FOR TEMP. (FTBD)'/       BNDC1190
                >' ',1X,'FG - VALUE OF BOUNDARY CONDITION FOR MASS FLUX (FGBD)'/   BNDC1200
                >' ',1X,'FQ - VALUE OF BOUNDARY CONDITION FOR HEAT FLUX (FQBD)'/   BNDC1210
                >' ',1X,'FSBDN - VALUE OF BOUNDARY CONDITION FOR NORMAL STRESSES'/ BNDC1220
                >' ',1X,'FGK(1) - VALUE OF BOUNDARY CONDITION FOR MASS FLUX OF SPECBNDC1230
                >IE K (FGKBD)'/ ' ',1X,'FCK - VALUE OF BOUNDARY CONDITION FOR SPECIBNDC1240
                >ES CONCENTRATION (FCKBD)')                                        BNDC1250
  ISN 0075      1020 FORMAT(' ',1X,'IHBDF - MULTIPLIER FUNCTION FOR FHBD'/ ' ',1X, BNDC1260
                > 'IU    - MULTIPLIER FUNCTION FOR FUBD'/ ' ',1X,                  BNDC1270
                > 'IV    - MULTIPLIER FUNCTION FOR FVBD'/ ' ',1X,                  BNDC1280
                > 'IT    - MULTIPLIER FUNCTION FOR FTBD'/ ' ',1X,                  BNDC1290
                > 'IG    - MULTIPLIER FUNCTION FOR FGBD'/ ' ',1X,                  BNDC1300
                > 'IQ    - MULTIPLIER FUNCTION FOR FQBD'/ ' ',1X,                  BNDC1310
                > 'ISN   - MULTIPLIER FUNCTION FOR FSBDN'/ ' ',1X,                 BNDC1320
                > 'ISH   - MULTIPLIER FUNCTION FOR FSBDSH')                        BNDC1330
  ISN 0076      1030 FORMAT(14I5,10X)                                              BNDC1340
  ISN 0077      1040 FORMAT(7E10.3,10X)                                            BNDC1350
  ISN 0078      1050 FORMAT(//'  BOUNDARY CONDITIONS AT STARTING TIME'/'  NBN',2X, BNDC1360
                > 'NHBDTP',3X,'NU',3X,'NV',3X,'NT',23X,'FH',13X,                   BNDC1370
                > 'FU'13X'FV'13X'FT'/(I3,I8,I6,2I5,15X,1P4E15.6))                  BNDC1380
  ISN 0079      1060 FORMAT(//'0 NBN'7X'FG'12X'FQ'12X'FSBDN'10X'FSBDSH'9X'FGK(1)'9X, BNDC1390
                > 'FGK(2)'6X'FCK(1)'3X'FCK(2)'/ (I3,1X,1P6E15.6,0P2F9.3))          BNDC1400
  ISN 0080      1070 FORMAT(//'  MULTIPLIER FUNCTIONS FOR BOUNDARY CONDITIONS'/'  NBN',BNDC1410
                > 4X,'IHBDF',2X,'IU',3X,'IV',3X,'IT',3X,'IG',3X,'IQ',3X,'ISN',2X,  BNDC1420
                > 'ISH'/(I3,I8,I6,6I5))                                            BNDC1430
  ISN 0081      1080 FORMAT(///' POWER PLANT ON BOUNDARY.'// ' NBN',4X,'DTPP(NBN)',6X, BNDC1440
                > 'XINT',10X,'YINT',9X,'I',5X,'J'/)                                BNDC1450
  ISN 0082      1090 FORMAT(I4,1PE13.3,2E14.5,2I6)                                 BNDC1460
  ISN 0083           END                                                           BNDC1470

*OPTIONS IN EFFECT*      NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,

*OPTIONS IN EFFECT*      SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF

*STATISTICS*     SOURCE STATEMENTS =      82 ,PROGRAM SIZE =     10102

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                                  93K BYTES OF CORE NOT USED
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OS/360 FORTRAN H

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COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,
                         SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF
ISN 0002        SUBROUTINE BCTCNI(NK)
ISN 0003        IMPLICIT REAL*8 (A-H,O-Z)
ISN 0004        DIMENSION UB(25),VB(25),WB(25),TB(25),QB(25),HCB(25),BMANGC(25),
               > CKB(4,25),DCKB(4,25),ICKBF(4,25),IDCKBF(4,25), IUBF(25),IVBF(25),
               > IWBF(25),ITBF(25),IQBF(25),IHCBF(25)
ISN 0005        COMMON/REGICN/DEPTH(25),SM(25),IIREG(25),IHREG(25),JLREG(25),
               > JHREG(25),INTF(25),IGENF(25),ITCPF(25),IBOTF(25)
ISN 0006        INTEGER*2 IIREG,IHREG,JLREG,JHREG
ISN 0007        INTEGER*2 INTF,IGENF,ITCPF,IBOTF
ISN 0008        COMMON/COMBIN/ ANL,ATMP,CPIJ,CKIJ(4),CKIPJ(4),CKIMJ(4),CKIJP(4)  ,
               > CKIJM(4),DXM,DXP,DYM,DYP,DXIP1,DYJP1,DXLI,DXRI,DXLI1,DXRI1,DYLJ ,
               > DYRJ,DYLJ1,DYRJ1,GBIJ,GKBIJ(4),QBIJ,QKBIJ(4),SBXIJ,SBYIJ,GXIMJ ,
               > GXIPJ,GYIJM,GYIJP,GTIJ,GKTIJ(4),QTIJ,QKTIJ(4),STXIJ,STYIJ,QDVIJ ,
               > QXIMJ,QXIPJ,QYIJM,QYIJP,GKXIMJ(4),GKXIPJ(4),GKYIJM(4),GKYIJP(4)  ,
               > HTKIJ(4),HTKIJM(4),HTKIPJ(4),HTKIMJ(4),HTKIJP(4),HIJ,HIJM,HIPJ ,
               > HIMJ,HIJP,UIJ,UIJM,UIPJ,UIMJ,UIJP,VIJ,VIJM,VIPJ,VIMJ,VIJP,TIJ ,
               > TIJM,TIPJ,TIMJ,TIJP,RCKTPD(4),RCIJ,ROIJM,ROIPJ,ROIMJ,ROIJP ,
               > SHKTPD(4),SHTCKD(4),SHTTPD,SXXIMJ,SXXIPJ,SYYIJM,SYYIJP,SXYIJM ,
               > SXYIPJ,SXYIMJ,SXYIJP,ROIMJD,ROIPJD,ROIJMD,ROIJPD,EQTMP,TDIJ ,
               > HCIMJ,HCIPJ,HCIJM,HCIJP,GR,ROCKD(4),SPHTK(4),DENSK(4),RODKIJ(4)  ,
               > GKDVIJ(4),DXI,DYJ ,QDV(25),HBD(25),UBD(25),VBD(25),TBD(25),
               > CKBD(4,25),TBIJ,HCBIJ ,DCKBIJ(4),HTKBIJ(4),BNIJ,UBIJ,VBIJ,WBIJ,
               > ROBIJ,HTBIJ,CKBIJ(4),TTIJ,HCTIJ,DCKTIJ(4),HTKTIJ(4),UTIJ,VTIJ,
               > WTIJ,ROTIJ,HTTIJ,CKTIJ(4) ,QBD(25),GBD(25),GKBD(4,25),SBDN(25),
               > SBDSH(25),WIND,WINDX,WINDY ,IJ,IM1J,IP1J,IJM1,IJP1,INTRT,KOIJ,
               > KOIM1J,KOIP1J,KOIJM1,KOIJP1 ,NBXM,NBXP,NBYM,NBYP,NREGIN,NBNDF ,
               > IXQV(25),JYQV(25),NHBDTP(25),NUBDTP(25),NVBDTP(25),NTBDTP(25)  ,
               > NXGRL,NYGRL,NREG,NINTLF,NTOPF,NBOTF,NTBIFC,NTMAX,NGENF
ISN 0009        PRINT 1000
ISN 0010        PRINT 1010
ISN 0011        PRINT 1020
ISN 0012        DO 10 I=1,NBCTF
ISN 0013        READ(50,1030) I,UB(I),VB(I),WB(I),TB(I),QB(I),HCB(I),BMANGC(I)
ISN 0014        READ(50,1050) (CKB(K,I),DCKB(K,I),K=1,NK)
ISN 0015        READ(50,1040) IUBF(I),IVBF(I),IWBF(I),ITBF(I),IQBF(I), IHCBF(I),
               > (ICKBF(K,I),IDCKBF(K,I),K=1,NK)
ISN 0016     10 CONTINUE
ISN 0017        PRINT 1060
ISN 0018        DO 12 I=1,NBCTF
ISN 0019        PRINT 1070,I,QB(I),HCB(I),UB(I),VB(I),WB(I),TB(I),BMANGC(I),
               > (DCKB(K,I),CKB(K,I),K=1,NK)
ISN 0020     12 CONTINUE
ISN 0021        PRINT 1080
ISN 0022        DO 14 I=1,NBOTF
ISN 0023        PRINT 1090,I,IQBF(I),IHCBF(I),IUBF(I),IVBF(I),IWBF(I),ITBF(I),
               > (IDCKBF(K,I),ICKBF(K,I),K=1,NK)
ISN 0024     14 CONTINUE
ISN 0025        DENS=62.2D0
ISN 0026        SPHT=1.D0
ISN 0027        RETURN
          C * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
ISN 0028        ENTRY BOTCON
          C * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
ISN 0029        NBT=IBOTF(NREGIN)
ISN 0030        TBIJ=TB(NBT)*GNRLFC(ITBF(NBT),X)
          C     DO 201 K=1,NK
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              C 201 CKBIJ(K)=CKB(K,NBT)*GNRLFC(ICKBF(K,NBT),X)
   ISN 0031         CALL MATPRF(CKE,TBIJ,DENS,SPHT,FCTPH)
   ISN 0032         ROBIJ=DENS
   ISN 0033         HTBIJ=SPHT*TBIJ
   ISN 0034         DO 16 K=1,NK
              C *** NOTE REARRANGEMENT.
   ISN 0035         CKBIJ(K)=CKB(K,NBT)*GNRLFC(ICKBF(K,NBT),X)
   ISN 0036         DCKBIJ(K)=DCKB(K,NBT)*GNRLFC(IDCKBF(K,NBT),X)
   ISN 0037      16 HTKBIJ(K)=SPHTK(K)*TBIJ
   ISN 0038         BNIJ=BMANGC(NBT)
   ISN 0039         QBIJ=QB(NBT)*GNRLFC(IQBF(NBT),X)
   ISN 0040         HCBIJ=HCB(NBT)*GNRLFC(IHCBF(NBT),X)
   ISN 0041         UBIJ=UB(NBT)*GNRLFC(IUBF(NBT),X)
   ISN 0042         VBIJ=VB(NBT)*GNRLFC(IVBF(NBT),X)
   ISN 0043         WBIJ=WB(NBT)*GNRLFC(IWBF(NBT),X)
   ISN 0044         RETURN
   ISN 0045    1000 FORMAT(////'0',1X,'INPUT INFORMATION FROM SUBROUTINE BOTCON:'/1X,
                   > ' --- --- --- --- --- --- --- --- --- ---')
   ISN 0046    1010 FORMAT ('0',1X,'QB - HEAT COMING FROM THE BOTTOM'/
                   >' ',1X,'HCB - HEAT TRANSFER COEFFICIENT FOR THE BOTTOM'/
                   >' ',1X,'UB - VELOCITY OF MASS COMING FROM THE BOTTOM IN X-DIRECTIO
                   >N'/' ',1X,'VB - VELOCITY OF MASS COMING FROM THE BOTTOM IN Y-DIREC
                   >TION'/' ',1X,'WB - VELOCITY OF MASS COMING FROM THE BOTTOM IN Z-DI
                   >RECTION'/' ',1X,'TB - TEMPERATURE OF MASS COMING FROM THE BOTTOM'/
                   >' ',1X,'BMANGC - MANNING COEF. FOR FRICTION WITH THE BOTTOM'/
                   >' ',1X,'DCKB - MASS DIFFUSION COEFFICIENT FOR SPECIE K FROM BOTTOM
                   >'/' ',1X,'CKB - MASS CONCENTRATION OF SPECIES COMING FROM BOTTOM')
   ISN 0047    1020 FORMAT(' ',1X,'IQB - MULTIPLIER FUNCTION FOR QB'/ ' ',1X,
                   > 'IHCB - MULTIPLIER FUNCTION FOR HCB'/ ' ',1X,
                   > 'IUB - MULTIPLIER FUNCTION FOR UB'/ ' ',1X,
                   > 'IVB - MULTIPLIER FUNCTION FOR VB'/ ' ',1X,
                   > 'IWB - MULTIPLIER FUNCTION FOR WB'/ ' ',1X,
                   > 'ITB - MULTIPLIER FUNCTION FOR TB'/ ' ',1X,
                   > 'IDCKB - MULTIPLIER FUNCTION FOR DCKB'/ ' ',1X,
                   > 'ICKB - MULTIPLIER FUNCTION FOR CKB')
   ISN 0048    1030 FORMAT(I5,5X,6E10.5,10X/(7E10.5,10X))
   ISN 0049    1040 FORMAT (14I5,10X)
   ISN 0050    1050 FORMAT(7E10.5,10X)
   ISN 0051    1060 FORMAT(//'  BOTTOM CONDITIONS AT STARTING TIME'/'  FCT. NO.',5X,
                   > 'QB',7X,'HCB',6X,'UB',6X,'VB',6X,'WB',6X,'TB',7X,'BMANGC',5X,
                   > 'DCKB(1)',6X,'CKB(1)',4X,'DCKB(2)',6X,'CKB(2)')
   ISN 0052    1070 FORMAT(1X,I5,4X,3F9.2,1P4E9.2,1X,4F11.2)
   ISN 0053    1080 FORMAT(//'  MULTIPLIER FUNCTION FOR BOTTOM CONDITIONS'/
                   > '  FCT.NO.',4X,'IQB',2X,'IHCB',1X,'IUB',2X,'IVB',2X,'IWB',2X,
                   > 'ITB',2X, 'IDCKB(1)',1X,'ICKB(1)',1X,'IDCKB(2)',1X,'ICKB(2)')
   ISN 0054    1090 FORMAT(2X,I3,1X,I8,5I5,1X,4(I5,4X))
   ISN 0055         END

*OPTIONS IN EFFECT*     NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,

*OPTIONS IN EFFECT*     SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF

*STATISTICS*     SOURCE STATEMENTS =      54 ,PROGRAM SIZE =     7604

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                              105K BYTES OF CORE NOT USED
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CS/360 FORTRAN H

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       COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,
                         SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF
ISN 0002              SUBROUTINE TOPCNI(NK)
ISN 0003              IMPLICIT REAL*8 (A-H,O-Z)
ISN 0004              DIMENSION UT(25),VT(25),WT(25),TT(25),CT(25),HCT(25), TD(25),
                     > QSOL(25),CKT(4,25),DCKT(4,25),ICKTF(4,25),IDCKTF(4,25), IUTF(25),
                     > IVTF(25),IWTF(25),ITTF(25),IQTF(25),IHCTF(25), ITDF(25),
                     > IQSOLF(25),WNDX(25),WNDY(25)
ISN 0005              COMMON/REGION/DEPTH(25),SM(25),ILREG(25),IHREG(25),JLREG(25),
                     > JHREG(25),INTF(25),IGENF(25),ITOPF(25),IBOTF(25)
ISN 0006              INTEGER*2 ILREG,IHREG,JLREG,JHREG
ISN 0007              INTEGER*2 INTF,IGENF,ITOPF,IBOTF
ISN 0008              COMMON/COMBIN/ ANL,ATMP,CPIJ,CKIJ(4),CKIPJ(4),CKIMJ(4),CKIJP(4) ,
                     > CKIJM(4),DXM,DXP,DYM,DYP,DXIP1,DYJP1,DXLI,DXRI,DXLI1,DXRI1,DYLJ ,
                     > DYRJ,DYLJ1,DYRJ1,GBIJ,GKBIJ(4),QBIJ,QKBIJ(4),SBXIJ,SBYIJ,GXIMJ ,
                     > GXIPJ,GYIJM,GYIJP,GTIJ,GKTIJ(4),QTIJ,QKTIJ(4),STXIJ,STYIJ,QDVIJ ,
                     > QXIMJ,QXIPJ,QYIJM,QYIJP,GKXIMJ(4),GKXIPJ(4),GKYIJM(4),GKYIJP(4) ,
                     > HTKIJ(4),HTKIJM(4),HTKIPJ(4),HTKIMJ(4),HTKIJP(4),HIJ,HIJM,HIPJ ,
                     > HIMJ,HIJP,UIJ,UIJM,UIPJ,UIMJ,UIJP,VIJ,VIJM,VIPJ,VIMJ,VIJP,TIJ ,
                     > TIJM,TIPJ,TIMJ,TIJP,ROKTPD(4),ROIJ,ROIJM,ROIPJ,ROIMJ,ROIJP ,
                     > SHKTPD(4),SHTCKD(4),SHTTPD,SXXIMJ,SXXIPJ,SYYIJM,SYYIJP,SXYIJM ,
                     > SXYIPJ,SXYIMJ,SXYIJP,ROIMJD,ROIPJD,ROIJMD,ROIJPD,EQTMP,TDIJ ,
                     > HCIMJ,HCIPJ,HCIJM,HCIJP,GR,ROCKD(4),SPHTK(4),DENSK(4),RODKIJ(4) ,
                     > GKDVIJ(4),DXI,DYJ ,QDV(25),HBD(25),UBD(25),VBD(25),TBD(25),
                     > CKBD(4,25),TBIJ,HCBIJ ,DCKBIJ(4),HTKBIJ(4),BNIJ,UBIJ,VBIJ,WBIJ,
                     > ROBIJ,HTBIJ,CKBIJ(4),TTIJ,HCTIJ,DCKTIJ(4),HTKTIJ(4),UTIJ,VTIJ,
                     > WTIJ,ROTIJ,HTTIJ,CKTIJ(4) ,QBD(25),GBD(25),GKBD(4,25),SBDN(25),
                     > SBDSH(25),WIND,WINDX,WINDY ,IJ,IM1J,IP1J,IJM1,IJP1,INTRT,KOIJ,
                     > KOIM1J,KOIP1J,KOIJM1,KOIJP1 ,NBXM,NBXP,NBYM,NBYP,NREGIN,NBNDF ,
                     > IXQV(25),JYQV(25),NHBDTP(25),NUBDTP(25),NVBDTP(25),NTBDTP(25) ,
                     > NXGRL,NYGRL,NREG,NINTLF,NTOPF,NBOTF,NTBIFC,NTMAX,NGENF
ISN 0009              PRINT 1000
ISN 0010              PRINT 1010
ISN 0011              PRINT 1020
ISN 0012              DO 10 L=1,NTOPF
ISN 0013              READ(50,1030) I,UT(I),VT(I),WT(I),TT(I),CT(I),HCT(I),TD(I),QSOL(I)
                     >  ,WNDX(I),WNDY(I)
ISN 0014              READ(50,1050) (CKT(K,I),DCKT(K,I),K=1,NK)
ISN 0015              READ(50,1040)IUTF(I),IVTF(I),IWTF(I),ITTF(I),IQTF(I),IHCTF(I),
                     > ITDF(I),IQSCLF(I),(ICKTF(K,I),IDCKTF(K,I),K=1,NK)
ISN 0016           10 CONTINUE
ISN 0017              PRINT 1060
ISN 0018              DO 12 I=1,NTOPF
ISN 0019              PRINT 1070,I,QT(I),HCT(I),UT(I),VT(I),WT(I),TT(I),TD(I),QSOL(I),
                     > (DCKT(K,I),CKT(K,I),K=1,2)
ISN 0020           12 CONTINUE
ISN 0021              PRINT 1080,(I,IQTF(I),IHCTF(I),IUTF(I),IVTF(I),IWTF(I),ITTF(I),
                     > ITDF(I),IQSCLF(I),(IDCKTF(K,I),ICKTF(K,I),K=1,NK),I=1,NTOPF)
ISN 0022              DENS=62.2D0
ISN 0023              SPHT=1.D0
ISN 0024              RETURN
                C * * * * * * * * * * * * * * * * * * * * *
ISN 0025              ENTRY TOPCCN
                C * * * * * * * * * * * * * * * * * * * * *
ISN 0026              NTP=ITOPF(NREGIN)
ISN 0027              TTIJ=TT(NTP)*GNRLFC(ITTF(NTP),X)
                C     DO 201 K=1,NK
                C 201 CKTIJ(K)=CKT(K,NTP)*GNRLFC(ICKTF(K,NTP),X)
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ISN 0028          CALL MATPRP(CKT,TTIJ,DENS,SPHT,RCTPD)
ISN 0029          ROTIJ=DENS
ISN 0030          HTTIJ=SPHT*TTIJ
ISN 0031          DO 14 K=1,NK
         C *** NOTE REARRANGEMENT.
ISN 0032          CKTIJ(K)=CKT(K,NTP)
ISN 0033          DCKTIJ(K)=DCKT(K,NTP)*GNRLFC(IDCKTF(K,NTP),X)
ISN 0034       14 HTKTIJ(K)=SPHTK(K)*TTIJ
ISN 0035          QTIJ=QT(NTP)*GNRLFC(IQTF(NTP),X)
ISN 0036          TDIJ=TD(NTP)*GNRLFC(ITDF(NTP),X)
ISN 0037          QSOLIJ=QSOL(NTP)*GNRLFC(IQSOLF(NTP),X)
ISN 0038          UTIJ=UT(NTP)*GNRLFC(IUTF(NTP),X)
ISN 0039          VTIJ=VT(NTP)*GNRLFC(IVTF(NTP),X)
ISN 0040          WTIJ=WT(NTP)*GNRLFC(IWTF(NTP),X)
ISN 0041          WINDX=WNDX(NTP)
ISN 0042          WINDY=WNDY(NTP)
ISN 0043          WIND=DSQRT(WINDX**2+WINDY**2)
ISN 0044          IF (HCT(NTP).GE.0.) GO TO 16
         C *** CALCULATE HEAT EXCHANGE COEFF. AND EQUILIBRIUM TEMP. BASED ON THE
         C *** EDINGER AND GEYER METHOD.
ISN 0046          BETA=(TIJ+TDIJ)*(5.1D-5*(TIJ+TDIJ)-0.0042D0)+0.255D0
         C *** 1/5280 = .1893939D-3
         C *** 1/24 = .4166667D-1
ISN 0047          HCTIJ=.4166667D-1*(15.7D0+(BETA+0.26D0)*(70.D0+0.7D0 *(0.1893939D-
                > 3*WIND)**2D0))
ISN 0048          EQTMP=TDIJ+QSOLIJ/HCTIJ
ISN 0049          GO TO 18
ISN 0050       16 HCTIJ=HCT(NTP)*GNRLFC(IHCTF(NTP),X)
ISN 0051          EQTMP=TDIJ
ISN 0052       18 RETURN
ISN 0053     1000 FORMAT(////'0',1X,'INPUT INFORMATION FROM SUBROUTINE TOPCON:'/1X,
                > ' --- --- --- --- --- --- --- --- --- ---')
ISN 0054     1010 FORMAT ('0',1X,'QT - HEAT COMING FROM THE TOP'/
                >' ',1X,'HCT - HEAT TRANSFER COEFFICIENT FOR TOP'/
                >' ',1X,'UT  - VELOCITY OF MASS COMING FROM THE TOP IN X-DIRECTION'
                >/' ',1X,'VT  - VELOCITY OF MASS COMING FROM THE TOP IN Y-DIRECTION
                >'/' ',1X,'WT  - VELOCITY OF MASS COMING FROM THE TOP IN Z-DIRECTIO
                >N'/' ',1X,'TT  - TEMPERATURE OF MASS COMING FROM THE TOP'/
                >' ',1X,'TD  - DEW-POINT TEMPERATURE'/
                >' ',1X,'QSOL - SOLAR HEAT FLUX'/
                >' ',1X,'DCKT - MASS DIFFUSION COEFFICIENT FOR SPECIE K FROM TOP'/
                >' ',1X,'CKT - MASS CONCENTRATION OF SPECIES COMING FROM THE TOP')
ISN 0055     1020 FORMAT (' ',1X,'IQT - MULTIPLIER FUNCTION FOR QT'/ ' ',1X,
                > 'IHCT - MULTIPLIER FUNCTION FOR HCT'/ ' ',1X,
                > 'IUT - MULTIPLIER FUNCTION FOR UT'/ ' ',1X,
                > 'IVT - MULTIPLIER FUNCTION FOR VT'/ ' ',1X,
                > 'IWT - MULTIPLIER FUNCTION FOR WT'/ ' ',1X,
                > 'ITT - MULTIPLIER FUNCTION FOR TT'/ ' ',1X,
                > 'ITD - MULTIPLIER FUNCTION FOR TD'/ ' ',1X,
                > 'IQSOL - MULTIPLIER FUNCTION FOR QSOL'/ ' ',1X,
                > 'IDCKT - MULTIPLIER FUNCTION FOR DCKT'/ ' ',1X,
                > 'ICKT - MULTIPLIER FUNCTION FOR CKT')
ISN 0056     1030 FORMAT(I5,5X,6E10.5,10X/(7F10.5,10X))
ISN 0057     1040 FORMAT(14I5,10X)
ISN 0058     1050 FORMAT(7E10.5,10X)
ISN 0059     1060 FORMAT(//'  TOP CONDITIONS AT STARTING TIME'/'  FCT. NO.',6X,'QT',
                > 6X,'HCT',5X,'UT',6X,'VT',6X,'WT',6X,'TT',6X,'TD',6X,'QSOL',5X,
                > 'DCKT(1)',3X,'CKT(1)',3X,'DCKT(2)',3X,'CKT(2)')
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   ISN 0060       1070 FORMAT(1X,I5,6X,8F8.2,4F10.2)                                       TOPC1150
   ISN 0061       1080 FORMAT(//'  MULTIPLIER FUNCTION FOR TOF CONDITIONS'/'  FCT. NO.', TOPC1160
                      > 4X,'IQT',2X,'IHCT',1X,'IUT',2X,'IVT',2X,'IWT',2X,'ITT',2X,'ITD',   TOPC1170
                      > 2X,'IQSOL',1X,'IDCKT(1)',1X,'ICKT(1)',1X,'IDCKT(2)',1X,'ICKT(2)'/TOPC1180
                      >  (3X,I3,6X,7(I3,2X),2X,I3,3X,4(I4,4X)))                            TOPC1190
   ISN 0062            END                                                                 TOPC1200

*OPTIONS IN EFFECT*      NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,

*OPTIONS IN EFFECT*      SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT NOID,NOXREF

*STATISTICS*     SOURCE STATEMENTS =      61 ,PROGRAM SIZE =     8920

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                                   105K BYTES OF CORE NOT USED
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CS/360 FORTRAN H

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COMPIIER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,
                        SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF
ISN 0002            SUBROUTINE INTCON(NK,KX,KY,H,U,V,T,CK,Q,REST)
                C *** Q=(ERRHSR,ERRUFL,ERRVFL,ERRTMP,ERRCSK)
                C *** REST=(H,U,V,T,CK,ERRHSR,ERRUFL,ERRVFL,ERRTMP,ERRCSK)
ISN 0003            IMPLICIT REAL*8 (A-H,O-Z)
ISN 0004            DIMENSION H(KX,KY),U(KX,KY),V(KX,KY),T(KX,KY), CK(NK,KX,KY),
                   > REST(NMOVE),Q(1)
ISN 0005            COMMON/REGICN/DEPTH(25),SM(25),ILREG(25),IHREG(25),JLREG(25),
                   > JHREG(25),INTF(25),IGENF(25),ITOPF(25),IBOTF(25)
ISN 0006            INTEGER*2 ILREG,IHREG,JLREG,JHREG
ISN 0007            INTEGER*2 INTF,IGENF,ITOPF,IBOTF
ISN 0008            COMMON/COMBIN/ ANL,ATMP,CPIJ,CKIJ(4),CKIPJ(4),CKIMJ(4),CKIJP(4) ,
                   > CKIJM(4),DXM,DXP,DYM,DYP,DXIP1,DYJP1,DXII,DXRI,DXLI1,DXRI1,DYLJ ,
                   > DYRJ,DYLJ1,DYRJ1,GBIJ,GKBIJ(4),QBIJ,QKBIJ(4),SBXIJ,SBYIJ,GXIMJ ,
                   > GXIPJ,GYIJM,GYIJP,GTIJ,GKTIJ(4),QTIJ,QKTIJ(4),STXIJ,STYIJ,QDVIJ ,
                   > QXIMJ,QXIPJ,QYIJM,QYIJP,GKXIMJ(4),GKXIPJ(4),GKYIJM(4),GKYIJP(4) ,
                   > HTKIJ(4),HTKIJM(4),HTKIPJ(4),HTKIMJ(4),HTKIJP(4),HIJ,HIJM,HIPJ ,
                   > HIMJ,HIJP,UIJ,UIJM,UIPJ,UIMJ,UIJP,VIJ,VIJM,VIPJ,VIMJ,VIJP,TIJ ,
                   > TIJM,TIPJ,TIMJ,TIJP,ROKTPD(4),RCIJ,RCIJM,ROIPJ,ROIMJ,ROIJP ,
                   > SHKTPD(4),SHTCKD(4),SHTTPD,SXXIMJ,SXXIPJ,SYYIJM,SYYIJP,SXYIJM ,
                   > SXYIPJ,SXYIMJ,SXYIJP,ROIMJD,RCIPJD,RCIJMD,ROIJPD,EQTMP,TDIJ ,
                   > HCIMJ,HCIPJ,HCIJM,HCIJP,GR,ROCKD(4),SPHTK(4),DENSK(4),RODKIJ(4) ,
                   > GKDVIJ(4),DXI,DYJ ,QDV(25),HBD(25),UBD(25),VBD(25),TBD(25),
                   > CKBD(4,25),TBIJ,HCBIJ ,DCKBIJ(4),HTKBIJ(4),BNIJ,UBIJ,VBIJ,WBIJ,
                   > ROBIJ,HTBIJ,CKBIJ(4),TTIJ,HCTIJ,DCKTIJ(4),HTKTIJ(4),UTIJ,VTIJ,
                   > WTIJ,ROTIJ,HTTIJ,CKTIJ(4) ,QBD(25),GBD(25),GKBD(4,25),SBDN(25),
                   > SBDSH(25),WIND,WINDX,WINDY ,IJ,IM1J,IP1J,IJM1,IJP1,INTRT,KOIJ,
                   > KOIM1J,KOIP1J,KOIJM1,KOIJP1 ,NBXM,NBXP,NBYM,NBYP,NREGIN,NBNDF ,
                   > IXQV(25),JYQV(25),NHBDTP(25),NUBDTP(25),NVBDTP(25),NTBDTP(25) ,
                   > NXGRL,NYGRL,NREG,NINTLF,NTOPF,NBOTF,NTBIFC,NTMAX,NGENF
ISN 0009            COMMON/DROU/TIM,DTM,TM,PERIOD,IT,NMOVE,LMOVE,N
ISN 0010            COMMON/INDPIT/DTMLT,STM,SPTM,PRBTM,DPRTTM,CPUSEC,TIDAL,PDTM,
                   > INDTM,NDTMC,IFINIS,LDTMCR,ISTART,IPLOT,NCPU
ISN 0011            COMMON/SCRATH/STH(25),STU(25),STV(25),STT(25),STCK(4,25),
                   > ISTHF(25),ISTUF(25),ISTVF(25),ISTTF(25),ISTCKF(4,25),KINT(25)
ISN 0012            IF (ISTART.NE.0) GO TO 32
ISN 0014            PRINT 1000
ISN 0015            IF (NINTLF.LE.25.AND.1.LE.NINTLF) GO TO 12
ISN 0017            PRINT 1010,NINTLF
ISN 0018         10 CALL EXIT
ISN 0019         12 DO 14 M=1,NINTLF
ISN 0020         14 KINT(M)=-1
ISN 0021            DO 20 I=1,NINTLF
ISN 0022            READ(50,1050) INTFC,STH(INTFC),STU(INTFC),STV(INTFC),STT(INTFC)
ISN 0023            IF (1.LE.INTFC.AND.INTFC.LE.NINTIF) GO TO 16
ISN 0025            PRINT 1020,INTFC,NINTLF
ISN 0026            GO TO 10
ISN 0027         16 IF (KINT(INTFC).EQ.-1) GO TO 18
ISN 0029            PRINT 1030,INTFC
ISN 0030            GO TO 10
ISN 0031         18 READ(50,1060) (STCK(K,INTFC),K=1,NK)
ISN 0032            READ(50,1040) ISTHF(INTFC),ISTUF(INTFC),ISTVF(INTFC),ISTTF(INTFC),
                   >  (ISTCKF(K,INTFC),K=1,NK)
ISN 0033         20 KINT(INTFC)=INTFC
ISN 0034            DO 26 L=1,NREG
ISN 0035            NINL=INTF(I)
ISN 0036            IL=ILREG(L)
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ISN 0037          IH=IHREG(L)
ISN 0038          JL=JLREG(L)
ISN 0039          JH=JHREG(L)
ISN 0040          DO 24 I=IL,IH
ISN 0041          DO 24 J=JL,JH
ISN 0042          H(I,J)=STH(NINL)*GNRLFC(ISTHF(NINL),X)
ISN 0043          U(I,J)=STU(NINL)*GNRLFC(ISTUF(NINL),X)
ISN 0044          V(I,J)=STV(NINL)*GNRLFC(ISTVF(NINL),X)
ISN 0045          T(I,J)=STT(NINL)*GNRLFC(ISTTF(NINL),X)
ISN 0046          DO 22 K=1,NK
ISN 0047          CK(K,I,J)=STCK(K,NINL)*GNRLFC(ISTCKF(K,NINL),X)
ISN 0048       22 CONTINUE
ISN 0049       24 CONTINUE
ISN 0050       26 CONTINUE
ISN 0051          DO 28 I=1,LMCVE
ISN 0052       28 Q(I)=0.
            C*   READ HERE ANY SPECIAL INITIAL VARIABLES THAT ARE NOT AS
            C*   SPECIFIED ABOVE
ISN 0053          PRINT 1070
ISN 0054          DO 30 I=1,NINTLF
ISN 0055       30 PRINT 1080,I,STH(I),STU(I),STV(I),STT(I),(STCK(K,I),K=1,NK)
ISN 0056          PRINT 1090,(I,ISTHF(I),ISTUF(I),ISTVF(I),ISTTF(I),(ISTCKF(K,I), K=
         > 1,NK),I=1,NINTLF)
ISN 0057          RETURN
            C   READ INITIAL CONDITIONS FROM RESTART FILE
ISN 0058       32 READ(11) STM,SDTI,KXL,KYL,NKL
ISN 0059          IF (KX.EQ.KXL.AND.KY.EQ.KYL.AND.NK.EQ.NKL) GO TO 34
ISN 0061          PRINT 1100,KXL,KYL,NKL,STM,KX,KY,NK
ISN 0062          CALL EXIT
ISN 0063       34 CONTINUE
            C *** ALLOWS AN INPUT DTM TO BE USED WITH A RESTART FILE
ISN 0064          IF (SDTM.LT.0.) GO TO 36
ISN 0065          SDTM=SDTL
ISN 0067          GO TO 38
ISN 0068       36 SDTM=-SDTM
ISN 0069       38 CONTINUE
ISN 0070          READ(11) REST
ISN 0071          REWIND 11
            C***  THIS FREES THE BUFFERS ASSOCIATED WITH 11 AT THIS
            C***  POINT.( 11 REFERS TO DISK)
ISN 0072          RETURN
ISN 0073     1000 FORMAT(////'0',1X,'INPUT INFORMATION FROM SUBROUTINE INTCON:'/1X,
          >' --- --- --- --- --- --- --- --- --- ---'//
          >2X,'STH - INITIAL VALUE FOR WATER SURFACE ELEVATION, H, MEASURED F
          >ROM THE BOTTOM'/2X,'STU - INITIAL VALUE FOR WATER VELOCITY, U, IN
          >X-DIRECTION'/2X,'STV - INITIAL VALUE FOR WATER VELOCITY, V, IN Y-DI
          >IRECTION'/2X,'STWS - INITIAL VALUE FOR RATE OF CHANGE OF WATER ELE
          >VATION WITH RESPECT TO TIME'/
          >2X,'STT - INITIAL VALUE FOR WATER TEMPERATURE, T.'/2X,
          >'STCK(I) - INITIAL VALUE FOR MASS CONCENTRATION OF SPECIES(I).'/2X
          >,'ISTHF - MULTIPLIER FUNCTION FOR STH'/
          >2X,'ISTUF - MULTIPLIER FUNCTION FOR STU'/2X,'ISTVF - MULTIPLIER FU
          >NCTION FOR STV'/2X,'ISTWSF - MULTIPLIER FUNCTION FOR STWS'/
          >2X,'ISTTF - MULTIPLIER FUNCTION FOR STT'/2X,'ISTCKF(I) - MULTIPLIE
          >R FUNCTION FOR STCK(I)'/)
ISN 0074     1010 FORMAT(' NINTLF='I2,1X'IS NOT IN THE RANGE 1 TO 25.')
ISN 0075     1020 FORMAT(' INTFC='I2,1X'IS NOT IN THE RANGE 1 TO NINTLF='I2)
ISN 0076     1030 FORMAT(' THE INITIAL CONDITION FUNCTION VALUE INTFC='I2,
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                    > 1X'HAS    ALREADY BEEN USED.')                                INTC1150
  ISN 0077      1040 FORMAT(14I5,10X)                                               INTC1160
  ISN 0078      1050 FORMAT(I5,5X,6E10.5,10X/(7E10.5,10X))                          INTC1170
  ISN 0079      1060 FORMAT(7E10.5,10X)                                             INTC1180
  ISN 0080      1070 FORMAT(//'  INITIAL CONDITIONS'/'  FUNCTION NO.'5X'STH'6X'STU',6X,INTC1190
                    > 'STV'6X'STT'3X'STCK(1)'2X'STCK(2)')                           INTC1200
  ISN 0081      1080 FORMAT(1X,I7,6X,9F9.2)                                         INTC1210
  ISN 0082      1090 FORMAT(//'  MULTIPLIER FUNCTION FOR INITIAL CONDITIONS'/       INTC1220
                    > '  FCT.NO.',4X'ISTH',2X,'ISTU',2X,'ISTV',2X,'ISTT',2X,'ISTCK(1)',INTC1230
                    > 'ISTCK(2)'/(4X,I3,5X,4(I3,3X),2(I5,5X)))                      INTC1240
  ISN 0083      1100 FORMAT('1PARAMETER DISAGREEMENT IN RESTART'//                  INTC1250
                    > ' FROM RESTART FILE,  KX='I4,2X'KY='I4,2X'NK='I1,2X'STM='1PE10.4/INTC1260
                    >  ' FROM INPUT FILE,    KX='I4,2X'KY='I4,2X'NK='I1)            INTC1270
  ISN 0084           END                                                            INTC1280

*OPTIONS IN EFFECT*      NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,

*OPTIONS IN EFFECT*      SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF

*STATISTICS*     SOURCE STATEMENTS =      83 ,PROGRAM SIZE =     4054

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                                 101K BYTES OF CORE NOT USED
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      COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,
                         SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF
ISN 0002             SUBROUTINE FIXCNI(NK)
ISN 0003             IMPLICIT REAL*8 (A-H,O-Z)
ISN 0004             COMMON/COMBIN/ ANL,ATMF,CPIJ,CKIJ(4),CKIPJ(4),CKIMJ(4),CKIJP(4) ,
                    > CKIJM(4),DXM,DXP,DYM,DYP,DXIP1,DYJP1,DXLI,DXRI,DXLI1,DXRI1,DYLJ ,
                    > DYRJ,DYLJ1,DYRJ1,GBIJ,GKBIJ(4),QBIJ,QKBIJ(4),SBXIJ,SBYIJ,GXIMJ ,
                    > GXIPJ,GYIJM,GYIJP,GTIJ,GKTIJ(4),QTIJ,QKTIJ(4),STXIJ,STYIJ,QDVIJ ,
                    > QXIMJ,QXIPJ,QYIJM,QYIJP,GKXIMJ(4),GKXIPJ(4),GKYIJM(4),GKYIJP(4) ,
                    > HTKIJ(4),HTKIJM(4),HTKIPJ(4),HTKIMJ(4),HTKIJP(4),HIJ,HIJM,HIPJ ,
                    > HIMJ,HIJP,UIJ,UIJM,UIPJ,UIMJ,UIJP,VIJ,VIJM,VIPJ,VIMJ,VIJP,TIJ ,
                    > TIJM,TIPJ,TIMJ,TIJP,ROKTPD(4),RCIJ,RCIJM,ROIPJ,ROIMJ,ROIJP ,
                    > SHKTPD(4),SHTCKD(4),SHTTPD,SXXIMJ,SXXIPJ,SYYIJM,SYYIJP,SXYIJM ,
                    > SXYIPJ,SXYIMJ,SXYIJP,ROIMJD,RCIPJD,RCIJMD,ROIJPD,EQTMP,TDIJ ,
                    > HCIMJ,HCIPJ,HCIJM,HCIJP,GR,ROCKD(4),SPHTK(4),DENSK(4),RODKIJ(4) ,
                    > GKDVIJ(4),DXI,DYJ ,QDV(25),HBD(25),UBD(25),VBD(25),TBD(25),
                    > CKBD(4,25),TBIJ,HCBIJ ,DCKBIJ(4),HTKBIJ(4),BNIJ,UBIJ,VBIJ,WBIJ,
                    > ROBIJ,HTBIJ,CKBIJ(4),TTIJ,HCTIJ,DCKTIJ(4),HTKTIJ(4),UTIJ,VTIJ,
                    > WTIJ,ROTIJ,HTTIJ,CKTIJ(4) ,QBD(25),GBD(25),GKBD(4,25),SBDN(25),
                    > SBDSH(25),WIND,WINDX,WINDY ,IJ,IM1J,IP1J,IJM1,IJP1,INTRT,KOIJ,
                    > KOIM1J,KOIP1J,KOIJM1,KOIJP1 ,NBXM,NBXP,NBYM,NBYP,NREGIN,NBNDF ,
                    > IXQV(25),JYQV(25),NHBDTP(25),NUBDTP(25),NVBDTP(25),NTBDTP(25) ,
                    > NXGRL,NYGRL,NREG,NINTLF,NTOPF,NEOTF,NTBIFC,NTMAX,NGENP
ISN 0005             DATA O6TH/Z402AAAAAAAAAAAAB/
ISN 0006             DIMENSION DKXC(4),DKYC(4),DKXIMJ(4),DKXIPJ(4),DKYIJM(4),DKYIJP(4)
ISN 0007             DIMENSION MBXM(5)
ISN 0008             EQUIVALENCE(MBXP,MBXM(2)),(MBYM,MBXM(3)),(MBYP,MBXM(4))
ISN 0009             ABS(X)=DABS(X)
ISN 0010             SQRT(X)=DSQRT(X)
ISN 0011             READ(50,1000) XKPC,YKPC,XTVSC,YTVSC
ISN 0012             PRINT 1010,XKPC,YKPC,XTVSC,YTVSC
ISN 0013             PRINT 1020
ISN 0014             READ(50,1000)( DKXC(K),DKYC(K),K=1,NK)
ISN 0015             DO 10 K=1,NK
ISN 0016          10 PRINT 1030,K,DKXC(K),DKYC(K)
ISN 0017             RETURN
                C * * * * * * * * * * * * * * * * * * * * * * * * * * * *
ISN 0018             ENTRY FLXCCN(CK,U,V,T,NFLG)
                C * * * * * * * * * * * * * * * * * * * * * * * * * * * *
ISN 0019             DIMENSION CK(1),U(1),V(1),T(1),NFLG(1)
                CC   THE TRANSPORT COEFFICIENTS SHOULD BE CALCULATED BASED ON
                CC VELOCITIES AND VELOCITY GRADIENTS.  FOR THE TIME BEING THEY WILL BE
                CC SET EQUAL TO THE INPUT COEFFICIENTS THEMSELVES.
                C   CALCULATION OF ALL THE INTERNAL FLUXES
ISN 0020             TEM=0.00443D0*HIMJ*ROIMJ*SQRT(UIMJ*UIMJ+VIMJ*VIMJ)
ISN 0021             XKPIMJ=XKPC+TEM*CPIJ
ISN 0022             XTVIMJ=XTVSC+TEM
ISN 0023             YTVIMJ=YTVSC+TEM
ISN 0024             DO 12 K=1,NK
ISN 0025          12 DKXIMJ(K)=DKXC(K)
ISN 0026             IF (NBXM) 14,14,30
ISN 0027          14 QXIMJ = 2.*XKPIMJ*(T(IM1J)-TIJ)/DXM
ISN 0028             GXIMJ=ROIMJD*UIMJ
ISN 0029             DO 16 K=1,NK
ISN 0030          16 GKXIMJ(K)=2.*RCIMJ*DKXIMJ(K)*(CK(KOIM1J+K)-CKIJ(K))/DXM
ISN 0031             SXXIMJ=4.*XTVIMJ*(UIJ-U(IM1J))/DXM
ISN 0032             IF (NBYM) 18,18,20
ISN 0033          18 UIMJM1=DXLI*U(IJM1)+DXRI*U(IJM1-1)
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ISN 0034          UIM1JM=DYLJ*U(IM1J)+DYRJ*U(IJM1-1)
ISN 0035          UIMJM=UIJ-DXRI*(UIJM-UIM1JM)-DYRJ*(UIMJ-UIMJM1)
ISN 0036          GO TO 22
          CC   IT WILL BE ASSUMED HERE THAT UIMB(NBYM)=UIE(NBYM)=VB(NBYM)
          CC   THE SAME FOR OTHER SUCH HALF POINT BOUNDARY VELOCITIES.
ISN 0037       20 UIMJM=UIJM
ISN 0038       22 IF (NBYP) 24,24,26
ISN 0039       24 UIMJP1=DXLI*U(IJP1)+DXRI*U(IJP1-1)
ISN 0040          UIM1JP=DYLJ1*U(IJP1-1)+DYRJ1*U(IM1J)
ISN 0041          UIMJP=UIJ-DXRI*(UIJP-UIM1JP)+DYRJ1*(UIMJP1-UIMJ)
ISN 0042          GO TO 28
ISN 0043       26 UIMJP=UIJP
ISN 0044       28 SXYIMJ=YTVIMJ*(UIMJP-UIMJM)/DYJ +2.*XTVIMJ*(VIJ-V(IM1J))/DXM
ISN 0045          GO TO 62
ISN 0046       30 QXIMJ=QBD(NBXM)+4.*XKPIMJ*(TIMJ-TIJ)/DXM
ISN 0047          GXIMJ=GBD(NBXM)+ROIMJD*UIMJ
ISN 0048          DO 32 K=1,NK
ISN 0049       32 GKXIMJ(K)=GKBD(K,NBXM)+4.*ROIMJ*DKXIMJ(K)*(CKIMJ(K)-CKIJ(K))/DXM
ISN 0050          SXXIMJ=SBDN(NBXM)+8.*XTVIMJ*(UIJ-UIMJ)/DXM
ISN 0051          IF (NBYM) 34,34,44
ISN 0052       34 CALL GTFLGS(MBXM,NFLG(IJM1))
ISN 0053          NUJM=NUBDTP(MBXM(1))
ISN 0054          GO TO (40,38,216,36),NUJM
ISN 0055          GO TO 216
ISN 0056       36 UIMJM1=U(IJM1)+DXLI1*(U(IJM1)-U(IJM1+1))
ISN 0057          GO TO 42
ISN 0058       38 UIMJM1=U(IJM1)
ISN 0059          GO TO 42
ISN 0060       40 UIMJM1=UBD(MBXM(1))
ISN 0061       42 UIMJM=DYLJ*UIMJ+DYRJ*UIMJM1
ISN 0062          GO TO 46
ISN 0063       44 UIMJM=UIMJ
ISN 0064       46 IF (NBYP) 48,48,58
ISN 0065       48 CALL GTFLGS(MBXM,NFLG(IJP1))
ISN 0066          NUJP=NUBDTP(MBXM(1))
ISN 0067          GO TO (54,52,216,50),NUJP
ISN 0068          GO TO 216
ISN 0069       50 UIMJP1=U(IJP1)+DXLI1*(U(IJP1)-U(IJP1+1))
ISN 0070          GO TO 56
ISN 0071       52 UIMJP1=U(IJP1)
ISN 0072          GO TO 56
ISN 0073       54 UIMJP1=UBD(MBXM(1))
ISN 0074       56 UIMJP=DYLJ1*UIMJP1+DYRJ1*UIMJ
ISN 0075          GO TO 60
ISN 0076       58 UIMJP=UIMJ
ISN 0077       60 SXYIMJ=SBDSH(NBXM)+YTVIMJ*(UIMJP-UIMJM)/DYJ+4.*XTVIMJ*(VIJ-VIMJ) /
                > DXM
ISN 0078       62 TEM=0.00443D0*HIPJ *ROIPJ *SQRT(UIPJ *UIPJ +VIPJ *VIPJ )
ISN 0079          XKPIPJ =XKPC+TEM*CPIJ
ISN 0080          XTVIPJ =XTVSC+TEM
ISN 0081          YTVIPJ =YTVSC+TEM
ISN 0082          DO 64 K=1,NK
ISN 0083       64 DKXIPJ(K)=DKXC(K)
ISN 0084          IF (NBXP) 66,66,82
ISN 0085       66 QXIPJ=2.*XKPIPJ*(TIJ-T(IP1J ))/DXP
ISN 0086          GXIPJ=ROIPJD*UIPJ
ISN 0087          DO 68 K=1,NK
ISN 0088       68 GKXIPJ(K)=2.*ROIPJ*DKXIPJ(K)*(CKIJ(K)-CK(KOIP1J+K))/DXP
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ISN 0089          SXXIPJ=4.*XTVIPJ*(U(IP1J )-UIJ)/DXP
ISN 0090          IF (NBYM) 70,70,72
ISN 0091       70 UIPJM1=DXLI1*U(IJM1+1) + DXRI1*U(IJM1)
ISN 0092          UIP1JM=DYLJ*U(IP1J) + DYRJ*U(IJM1+1)
ISN 0093          UIPJM=UIJ+DXRI1*(UIP1JM-UIJM)-DYRJ*(UIPJ-UIPJM1)
ISN 0094          GO TO 74
ISN 0095       72 UIPJM=UIJM
ISN 0096       74 IF (NBYP) 76,76,78
ISN 0097       76 UIPJP1=DXLI1*U(IJP1+1) + DXRI1*U(IJP1)
ISN 0098          UIP1JP=DYLJ1*U(IJP1+1) + DYRJ1*U(IP1J)
ISN 0099          UIPJP=UIJ+DXRI1*(UIP1JP-UIJP)+DYRJ1*(UIPJP1-UIPJ)
ISN 0100          GO TO 80
ISN 0101       78 UIPJP=UIJP
ISN 0102       80 SXYIPJ=YTVIPJ*(UIPJP-UIPJM)/DYJ +2.*XTVIPJ*(V(IP1J)-VIJ)/DXP
ISN 0103          GO TO 114
ISN 0104       82 QXIPJ=QBD(NBXP)+4.*XKPIPJ*(TIJ-TIPJ)/DXP
ISN 0105          GXIPJ=GBD(NBXP)+ROIPJD*UIPJ
ISN 0106          DO 84 K=1,NK
ISN 0107       84 GKXIPJ(K)=GKBD(K,NBXP)+4.*ROIPJ*DKXIPJ(K)*(CKIJ(K)-CKIPJ(K))/DXP
ISN 0108          SXXIPJ=SBDN(NBXP)+8.*XTVIPJ*(UIPJ-UIJ)/DXP
ISN 0109          IF (NBYM) 86,86,96
ISN 0110       86 CALL GTFLGS(MBXM,NFLG(IJM1))
ISN 0111          NUJM=NUBDTP(MBXP)
ISN 0112          GO TO (92,90,216,88),NUJM
ISN 0113          GO TO 216
ISN 0114       88 UIPJM1=U(IJM1)+DXRI*(U(IJM1)-U(IJM1-1))
ISN 0115          GO TO 94
ISN 0116       90 UIPJM1=U(IJM1)
ISN 0117          GO TO 94
ISN 0118       92 UIPJM1=UBD(MBXP)
ISN 0119       94 UIPJM=DYLJ*UIPJ+DYRJ*UIPJM1
ISN 0120          GO TO 98
ISN 0121       96 UIPJM=UIPJ
ISN 0122       98 IF (NBYP) 100,100,110
ISN 0123      100 CALL GTFLGS(MBXP,NFLG(IJP1))
ISN 0124          NUJP=NUBDTP(MBXP)
ISN 0125          GO TO (106,104,216,102),NUJP
ISN 0126          GO TO 216
ISN 0127      102 UIPJP1=U(IJP1)+DXRI*(U(IJP1)-U(IJP1-1))
ISN 0128          GO TO 108
ISN 0129      104 UIPJP1=U(IJP1)
ISN 0130          GO TO 108
ISN 0131      106 UIPJP1=UBD(MBXP)
ISN 0132      108 UIPJP=DYLJ1*UIPJP1+DYRJ1*UIPJ
ISN 0133          GO TO 112
ISN 0134      110 UIPJP=UIPJ
ISN 0135      112 SXYIPJ=SBDSH(NBXP)+YTVIPJ*(UIPJP-UIPJM)/DYJ+4.*XTVIPJ*(VIPJ-VIJ) /
                > DXP
ISN 0136      114 TEM=0.00443D0*HIJM*ROIJM*SQRT(UIJM*UIJM+VIJM*VIJM)
ISN 0137          YKPIJM=YKPC+TEM*CPIJ
ISN 0138          XTVIJM=XTVSC+TEM
ISN 0139          YTVIJM=YTVSC+TEM
ISN 0140          DO 116 K=1,NK
ISN 0141      116 DKYIJM(K)=DKYC(K)
ISN 0142          IF (NBYM) 118,118,134
ISN 0143      118 QYIJM=2.*YKPIJM*(T(IJM1 )-TIJ)/DYM
ISN 0144          GYIJM=ROIJMD*VIJM
ISN 0145          DO 120 K=1,NK
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ISN 0146       120 GKYIJM(K)=2.*ROIJM*DKYIJM(K)*(CK(KOIJM1+K)-CKIJ(K))/DYM             FLXC1730
ISN 0147           SYYIJM=4.*YTVIJM*(VIJ-V(IJM1 ))/DYM                                 FLXC1740
ISN 0148           IF (NBXM) 122,122,124                                               FLXC1750
ISN 0149       122 VIMJM1=DXLI*V(IJM1)+DXRI*V(IJM1-1)                                  FLXC1760
ISN 0150           VIM1JM=DYLJ*V(IM1J)+DYRJ*V(IJM1-1)                                  FLXC1770
ISN 0151           VIMJM=VIJ-DXRI*(VIJM-VIM1JM)-DYRJ*(VIMJ-VIMJM1)                     FLXC1780
ISN 0152           GO TO 126                                                           FLXC1790
ISN 0153       124 VIMJM=VIMJ                                                          FLXC1800
ISN 0154       126 IF (NBXP) 128,128,130                                               FLXC1810
ISN 0155       128 VIPJM1=DXLI1*V(IJM1+1) + DXRI1*V(IJM1)                              FLXC1820
ISN 0156           VIP1JM=DYLJ*V(IP1J) + DYRJ*V(IJM1+1)                                FLXC1830
ISN 0157           VIPJM=VIJ+DXRI1*(VIP1JM-VIJM)-DYRJ*(VIPJ-VIPJM1)                    FLXC1840
ISN 0158           GO TO 132                                                           FLXC1850
ISN 0159       130 VIPJM=VIPJ                                                          FLXC1860
ISN 0160       132 SXYIJM=2.*YTVIJM*(UIJ-U(IJM1))/DYM+XTVIJM*(VIPJM-VIMJM)/DXI         FLXC1870
ISN 0161           GO TO 162                                                           FLXC1880
ISN 0162       134 QYIJM=QBD(NBYM)+4.*YKPIJM*(TIJM-TIJ)/DYM                            FLXC1890
ISN 0163           GYIJM=GBD(NBYM)+ROIJMD*VIJM                                         FLXC1900
ISN 0164           DO 136 K=1,NK                                                       FLXC1910
ISN 0165       136 GKYIJM(K)=GKBD(K,NBYM)+4.*ROIJM*DKYIJM(K)*(CKIJM(K)-CKIJ(K))/DYM    FLXC1920
ISN 0166           SYYIJM=SBDN(NBYM)+8.*YTVIJM*(VIJ-VIJM)/DYM                          FLXC1930
ISN 0167           IF (NBXM.GT.0) GO TO 146                                            FLXC1940
ISN 0169           CALL GTFLGS(MBXM,NFLG(IM1J))                                        FLXC1950
ISN 0170           NVIM=NVBDTF(MBYM)                                                   FLXC1960
ISN 0171           GO TO (142,140,216,138),NVIM                                        FLXC1970
ISN 0172           GO TO 216                                                           FLXC1980
ISN 0173       138 VIM1JM=V(IM1J)+DYLJ1*(V(IM1J)-V(IJP1-1))                            FLXC1990
ISN 0174           GO TO 144                                                           FLXC2000
ISN 0175       140 VIM1JM=VIM1J                                                        FLXC2010
ISN 0176           GO TO 144                                                           FLXC2020
ISN 0177       142 VIM1JM=VBD(MBYM)                                                    FLXC2030
ISN 0178       144 VIMJM=DXLI*VIJM + DXRI*VIM1JM                                       FLXC2040
ISN 0179           GO TO 148                                                           FLXC2050
ISN 0180       146 VIMJM=VIJM                                                          FLXC2060
ISN 0181       148 IF (NBXP.GT.0) GO TO 158                                            FLXC2070
ISN 0183           CALL GTFLGS(MBXM,NFLG(IP1J))                                        FLXC2080
ISN 0184           NVIP=NVBDTF(MBYM)                                                   FLXC2090
ISN 0185           GO TO (154,152,216,150),NVIP                                        FLXC2100
ISN 0186           GO TO 216                                                           FLXC2110
ISN 0187       150 VIP1JM=V(IP1J)+DYLJ1*(V(IP1J)-V(IJP1+1))                            FLXC2120
ISN 0188           GO TO 156                                                           FLXC2130
ISN 0189       152 VIP1JM=VIP1J                                                        FLXC2140
ISN 0190           GO TO 156                                                           FLXC2150
ISN 0191       154 VIP1JM=VBD(MBYM)                                                    FLXC2160
ISN 0192       156 VIPJM=DXLI1*VIP1JM + DXRI1*VIJM                                     FLXC2170
ISN 0193           GO TO 160                                                           FLXC2180
ISN 0194       158 VIPJM=VIJM                                                          FLXC2190
ISN 0195       160 SXYIJM=SBDSH(NBYM)+4.*YTVIJM*(UIJ-UIJM)/DYM+XTVIJM*(VIPJM-VIMJM)    FLXC2200
                 > DXI                                                                 FLXC2210
ISN 0196       162 TEM=0.00443D0*HIJP*ROIJP*SQRT(UIJP*UIJP+VIJP*VIJP)                  FLXC2220
ISN 0197           YKPIJP=YKPC+TEM*CPIJ                                                FLXC2230
ISN 0198           XTVIJP=XTVSC+TEM                                                    FLXC2240
ISN 0199           YTVIJP=YTVSC+TEM                                                    FLXC2250
ISN 0200           DO 164 K=1,NK                                                       FLXC2260
ISN 0201       164 DKYIJP(K)=DKYC(K)                                                   FLXC2270
ISN 0202           IF (NBYP) 166,166,182                                               FLXC2280
ISN 0203       166 QYIJP=2.*YKPIJP*(TIJ-T(IJP1 ))/DYP                                  FLXC2290
ISN 0204           GYIJP=ROIJPD*VIJP                                                   FLXC2300
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ISN 0205          DO 168 K=1,NK
ISN 0206      168 GKYIJP(K)=2.*ROIJP*DKYIJP(K)*(CKIJ(K)-CK(KOIJP1+K))/DYP
ISN 0207          SYYIJP=4.*YTVIJP*(V(IJP1 )-VIJ)/DYP
ISN 0208          IF (NBXM) 170,170,172
ISN 0209      170 VIMJP1=DXLI*V(IJP1)+DXRI*V(IJP1-1)
ISN 0210          VIM1JP=DYIJ1*V(IJP1-1)+DYPJ1*V(IM1J)
ISN 0211          VIMJP=VIJ-DXRI*(VIJP-VIM1JP)+DYRJ1*(VIMJP1-VIMJ)
ISN 0212          GO TO 174
ISN 0213      172 VIMJP=VIMJ
ISN 0214      174 IF (NBXP) 176,176,178
ISN 0215      176 VIPJP1=DXLI1*V(IJP1+1) + DXRI1*V(IJP1)
ISN 0216          VIP1JP=DYLJ1*V(IJP1+1) + DYRJ1*V(IP1J)
ISN 0217          VIPJP=VIJ+DXRI1*(VIP1JP-VIJP)+DYRJ1*(VIPJP1-VIPJ)
ISN 0218          GO TO 180
ISN 0219      178 VIPJP=VIPJ
ISN 0220      180 SXYIJP=2.*YTVIJP*(U(IJP1)-UIJ)/DYP+XTVIJP*(VIPJP-VIMJP)/DXI
ISN 0221          GO TO 210
ISN 0222      182 QYIJP=QBD(NBYP)+4.*YKPIJP*(TIJ-TIJP)/DYP
ISN 0223          GYIJP=GBD(NBYP)+ROIJPD*VIJP
ISN 0224          DO 184 K=1,NK
ISN 0225      184 GKYIJP(K)=GKBD(K,NBYP)+4.*ROIJP*DKYIJP(K)*(CKIJ(K)-CKIJP(K))/DYP
ISN 0226          SYYIJP=SBDN(NBYP)+8.*YTVIJP*(VIJP-VIJ)/DYP
ISN 0227          IF (NBXM.GT.0) GO TO 194
ISN 0229          CALL GTFLGS(MBXM,NFLG(IM1J))
ISN 0230          NVIM=NVBDTP(MBYP)
ISN 0231          GO TO (190,188,216,186),NVIM
ISN 0232          GO TO 216
ISN 0233      186 VIM1JP=V(IM1J)+DYRJ*(V(IM1J)-V(IJM1-1))
ISN 0234          GO TO 192
ISN 0235      188 VIM1JP=VIM1J
ISN 0236          GO TO 192
ISN 0237      190 VIM1JP=VBD(MBYP)
ISN 0238      192 VIMJP=DXLI*VIJP + DXRI*VIM1JP
ISN 0239          GO TO 196
ISN 0240      194 VIMJP=VIJP
ISN 0241      196 IF (NBXP.GT.0) GO TO 206
ISN 0243          CALL GTFLGS(MBXM,NFLG(IP1J))
ISN 0244          NVIP=NVBDTP(MBYP)
ISN 0245          GO TO (202,200,216,198),NVIP
ISN 0246          GO TO 216
ISN 0247      198 VIP1JP=V(IP1J)+DYRJ*(V(IP1J)-V(IJM1+1))
ISN 0248          GO TO 204
ISN 0249      200 VIP1JP=VIP1J
ISN 0250          GO TO 204
ISN 0251      202 VIP1JP=VBD(MBYP)
ISN 0252      204 VIPJP=DXLI1*VIP1JP + DXRI1*VIJP
ISN 0253          GO TO 208
ISN 0254      206 VIPJP=VIJP
ISN 0255      208 SXYIJP=SBDSH(NBYP)+4.*YTVIJP*(UIJP-UIJ)/DYP+XTVIJP*(VIPJP-VIMJP) /
                > DXI
ISN 0256      210 CONTINUE
ISN 0257          HXDRIJ=(HIPJ-HIMJ)/DXI
ISN 0258          HYDRIJ=(HIJP-HIJM)/DYJ
              C
              C   CALCULATION OF BOTTOM FLUXES
ISN 0259          CALL BOTCON
ISN 0260          GBIJ=ROBIJ*SQRT(WBIJ*WBIJ+UBIJ*UBIJ+VBIJ*VBIJ)
ISN 0261          DO 212 K=1,NK
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ISN 0262          GKBIJ(K)=-DCKBIJ(K)*(CKIJ(K)-CKBIJ(K))                     FLXC2890
ISN 0263      212 QKBIJ(K)= GKBIJ(K)*HTKBIJ(K)                               FLXC2900
ISN 0264          QBIJ=-HCBIJ*(TIJ-TBIJ)                                     FLXC2910
ISN 0265          BCIJ=1.49D0*HIJ**06TH/BNIJ                                 FLXC2920
            C *** CALCULATE STRESSES FROM BOTTOM FRICTION.                   FLXC2930
ISN 0266          CON=(GR*ROIJ*SQRT(UIJ*UIJ+VIJ*VIJ))/(BCIJ*BCIJ)            FLXC2940
ISN 0267          SBXIJ=-CON*UIJ                                             FLXC2950
ISN 0268          SBYIJ=-CON*VIJ                                             FLXC2960
            C                                                                FLXC2970
            C   CALCULATION OF TOP FLUXES                                    FLXC2980
ISN 0269          CALL TOPCON                                                FLXC2990
            C *** CALCULATE WIND STRESSES                                    FLXC3000
ISN 0270          STXIJ=3.2D-6*WIND*WINDX                                    FLXC3010
ISN 0271          STYIJ=3.2D-6*WIND*WINDY                                    FLXC3020
ISN 0272          GTIJ=ROTIJ*SQRT(WTIJ*WTIJ+UTIJ*UTIJ+VTIJ*VTIJ)             FLXC3030
ISN 0273          DO 214 K=1,NK                                              FLXC3040
ISN 0274          GKTIJ(K)=-DCKTIJ(K)*(CKIJ(K)-CKTIJ(K))                     FLXC3050
ISN 0275      214 QKTIJ(K)= GKTIJ(K)*HTKTIJ(K)                               FLXC3060
            C *** HEAT EXCHANGE WITH THE ATMOSPHERE                          FLXC3070
ISN 0276          QTIJ=-HCTIJ*(TIJ-EQTMP)                                    FLXC3080
ISN 0277          RETURN                                                     FLXC3090
ISN 0278      216 STOP 7777                                                  FLXC3100
ISN 0279     1000 FORMAT(7E10.3,10X)                                         FLXC3110
ISN 0280     1010 FORMAT(////'0',1X,'INPUT INFORMATION FROM SUBROUTINE FLXCON:'/1X, FLXC3120
                 >' --- --- --- --- --- --- --- --- --- ---'//,             FLXC3130
                 >2X,'COEFFICIENT FOR TOTAL EFFECTIVE THERMAL CONDUCTIVITY IN X-DIREFLXC3140
                 >CTION (XKPC) = ',1PE13.6/                                  FLXC3150
                 >2X,'COEFFICIENT FOR TOTAL EFFECTIVE THERMAL CONDUCTIVITY IN Y-DIREFLXC3160
                 >CTION (YKPC) = ',E13.6/                                    FLXC3170
                 >2X,'COEFFICIENT FOR TURBULENT VISCOSITY IN X-DIRECTION(XTVSC) = ',FLXC3180
                 >E13.6/                                                     FLXC3190
                 >2X,'COEFFICIENT FOR TURBULENT VISCOSITY IN Y-DIRECTION (YTVSC) = 'FLXC3200
                 >,E13.6//                                                   FLXC3210
                 >2X,'DKXC - COEFFICIENT FOR TOTAL BINARY EFFECTIVE DIFFUSION COEFFIFLXC3220
                 >CIENT OF SPECIE K IN X-DIRECTION'/                         FLXC3230
                 >2X,'DKYC - COEFFICIENT FOR TOTAL BINARY EFFECTIVE DIFFUSION COEFFIFLXC3240
                 >CIENT OF SPECIE K IN Y-DIRECTION')                         FLXC3250
ISN 0281     1020 FORMAT('0  K',6X,'DKXC(K)',8X,'DKYC(K)'/)                  FLXC3260
ISN 0282     1030 FORMAT(I5,2(2X,1PE13.6))                                   FLXC3270
ISN 0283          END                                                        FLXC3280

*OPTIONS IN EFFECT*      NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,

*OPTIONS IN EFFECT*      SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF

*STATISTICS*     SOURCE STATEMENTS =      282 ,PROGRAM SIZE =     7626

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                              53K BYTES OF CORE NOT USED
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                                        OS/360  FORTRAN H

          COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,
                             SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF
 ISN 0002           SUBROUTINE SETZ                                              SETZ   10
 ISN 0003           IMPLICIT REAL*8 (A-H,O-Z)                                    SETZ   20
              C *** THE VALUE OF NZSP MUST BE SET HERE.  THIS VALUE SHOULD       SETZ   30
              C *** CORRESPOND TO THE NUMBER OF ELEMENTS THAT ARE IN THE ARRAY   SETZ   40
              C *** Z AS DEFINED HERE.  MOREOVER, EACH CASE RUN REQUIRES EXACTLY SETZ   50
              C ***      (13+3NK)(KX)(KY)+4(KX+KY)                               SETZ   60
              C *** ELEMENTS IN THE ARRAY Z.                                     SETZ   70
 ISN 0004           COMMON/Z/NZSP,NDUM,Z(8600)                                   SETZ   80
 ISN 0005           NZSP=8600                                                    SETZ   90
              C *** N.B., IN MAIN Z(6000) IS PASSED TO GEOM AS THE ADDRESS OF Y(1).  SETZ  100
              C *** CONSEQUENTLY GEOM STORES INTO Z(6000),...,Z(6000+KY-1).      SETZ  110
              C *** THUS NEED NZSP.GE.6000+KY-1.  PROGRAM TERMINATES IN MAIN IF THIS SETZ  120
              C *** CONDITION IS NOT MET.                                        SETZ  130
 ISN 0006           RETURN                                                       SETZ  140
 ISN 0007           END                                                          SETZ  150

*OPTIONS IN EFFECT*      NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,

*OPTIONS IN EFFECT*      SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF

*STATISTICS*     SOURCE STATEMENTS =       6 ,PROGRAM SIZE =       196

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                                   129K BYTES OF CORE NOT USED
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                                         OS/360  FORTRAN H

         COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,
                                  SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF
   ISN 0002            SUBROUTINE CHKDTM(DTM,NREG,KX,H,U,IDTMCR)
   ISN 0003            IMPLICIT REAL*8 (A-H,O-Z)
   ISN 0004            COMMON/REGION/DEPTH(25),SM(25),ILREG(25),IHREG(25),JLREG(25),
                     > JHREG(25),INTF(25),IGENF(25),ITOPF(25),IECTF(25)
   ISN 0005            INTEGER*2 ILREG,IHREG,JLREG,JHREG
   ISN 0006            INTEGER*2 INTF,IGENF,ITOPF,IECTF
   ISN 0007            DIMENSION H(KX,1),U(KX,1)
                 C *** IDTMCR SELECTS THE DESIRED CRITERION TO DETERMINE THE SUITABILITY
                 C     OF THE PROPOSED DTM.
                 C     GR=32.2*3600.*3600.
   ISN 0008            GR=4.17312D8
   ISN 0009            HTIM=1.D20
   ISN 0010            UTIM=1.D20
   ISN 0011            PRINT 1000
   ISN 0012            DO 18 M=1,NREG
   ISN 0013            IL=ILREG(M)
   ISN 0014            IH=IHREG(M)
   ISN 0015            JL=JLREG(M)
   ISN 0016            JH=JHREG(M)
   ISN 0017            HTIML=0.D0
   ISN 0018            UTIML=0.D0
   ISN 0019            DO 12 I=IL,IH
   ISN 0020            DO 10 J=JL,JH
                 C *** A NEG. H WILL CAUSE ABNORMAL END IN H**(1/6) IN FLXCON
   ISN 0021            HTIML=DMAX1(HTIML,H(I,J))
   ISN 0022         10 UTIML=DMAX1(UTIML,DABS(U(I,J)))
   ISN 0023         12 CONTINUE
   ISN 0024            HTIM=DMIN1(HTIM,SM(M)/DSQRT((GR+GR)*HTIML))
   ISN 0025            IF (UTIML.NE.0.) GO TO 14
   ISN 0027            Q=1.D20
   ISN 0028            GO TO 16
   ISN 0029         14 Q=SM(M)/UTIML
   ISN 0030         16 UTIM=DMIN1(UTIM,Q)
   ISN 0031         18 CONTINUE
   ISN 0032            PRINT 1010,HTIM,UTIM
   ISN 0033            DTM=DMIN1(DTM,HTIM,UTIM)
   ISN 0034            RETURN
   ISN 0035       1000 FORMAT(///2X,'TIME INCREMENT CRITERIA'/1X,
                     > '---- ---- ---- ---- ---- ----')
   ISN 0036       1010 FORMAT('   DTM.LE.DTM(H)=',1PE8.2,5X,'DTM.LE.DTM(U)=',E8.2)
   ISN 0037            END

*OPTIONS IN EFFECT*       NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,

*OPTIONS IN EFFECT*       SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF

*STATISTICS*     SOURCE STATEMENTS =       36 ,PROGRAM SIZE =      1108

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                                  125K BYTES OF CORE NOT USED
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OS/360 FORTRAN H

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        COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,
                           SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF
  ISN 0002             FUNCTION ANLFNC(M)
  ISN 0003             IMPLICIT REAL*8 (A-H,O-Z)
  ISN 0004             COMMON/COMBIN/ ANL,ATMP,CPIJ,CKIJ(4),CKIPJ(4),CKIMJ(4),CKIJP(4) ,
                      > CKIJM(4),DXM,DXP,DYM,DYP,DXIP1,DYJP1,DXLI,DXRI,DXLI1,DXRI1,DYLJ ,
                      > DYRJ,DYLJ1,DYRJ1,GBIJ,GKBIJ(4),QBIJ,QKBIJ(4),SBXIJ,SBYIJ,GXIMJ ,
                      > GXIPJ,GYIJM,GYIJP,GTIJ,GKTIJ(4),QTIJ,CKTIJ(4),STXIJ,STYIJ,QDVIJ ,
                      > QXIMJ,QXIPJ,QYIJM,QYIJP,GKXIMJ(4),GKXIPJ(4),GKYIJM(4),GKYIJP(4) ,
                      > HTKIJ(4),HTKIJM(4),HTKIPJ(4),HTKIMJ(4),HTKIJP(4),HIJ,HIJM,HIPJ ,
                      > HIMJ,HIJP,UIJ,UIJM,UIPJ,UIMJ,UIJP,VIJ,VIJM,VIPJ,VIMJ,VIJP,TIJ ,
                      > TIJM,TIPJ,TIMJ,TIJP,RCKTPD(4),RCIJ,ROIJM,ROIPJ,ROIMJ,ROIJP ,
                      > SHKTPD(4),SHTCKD(4),SHTTPD,SXXIMJ,SXXIPJ,SYYIJM,SYYIJP,SXYIJM ,
                      > SXYIPJ,SXYIMJ,SXYIJP,ROIMJD,RCIPJD,ROIJMD,ROIJPD,EQTMP,TDIJ ,
                      > HCIMJ,HCIPJ,HCIJM,HCIJP,GR,ROCKD(4),SPHTK(4),DENSK(4),RODKIJ(4) ,
                      > GKDVIJ(4),DXI,DYJ ,QDV(25),HBD(25),UBD(25),VBD(25),TBD(25),
                      > CKBD(4,25),TBIJ,HCBIJ ,DCKBIJ(4),HTKBIJ(4),BNIJ,UBIJ,VBIJ,WBIJ,
                      > ROBIJ,HTBIJ,CKBIJ(4),TTIJ,HCTIJ,DCKTIJ(4),HTKTIJ(4),UTIJ,VTIJ,
                      > WTIJ,ROTIJ,HTTIJ,CKTIJ(4) ,QBD(25),GBD(25),GKBD(4,25),SBDN(25),
                      > SBDSH(25),WIND,WINDX,WINDY ,IJ,IM1J,IP1J,IJM1,IJP1,INTRT,KOIJ,
                      > KOIM1J,KOIP1J,KOIJM1,KOIJP1 ,NBXM,NBXP,NBYM,NBYP,NREGIN,NBNDF ,
                      > IXQV(25),JYQV(25),NHBDTP(25),NUBDTP(25),NVBDTP(25),NTBDTP(25) ,
                      > NXGRL,NYGRL,NREG,NINTLF,NTOPF,NEOTF,NTEIFC,NTMAX,NGENF
  ISN 0005             COMMON/DROD/TIM,DTM,TM,PERIOD,NMCVE,LMCVE,N
  ISN 0006             COMMON/INDRIT/DTMLT,STM,SDTM,PRBTM,DPRTTM,CPUSEC,TIDAL,FDTM,
                      > INDTM,NDTMC,IFINIS,LDTMCR,ISTART,IPLCT,KCPU
  ISN 0007             IF (M.GT.10) GO TO 30
  ISN 0009             GO TO (10,12,14,16,18,20,22,24,26,28), M
  ISN 0010          10 ANLFNC=1.0D0
  ISN 0011             RETURN
  ISN 0012          12 ANLFNC=40.0D0+2.25D0*DSIN(6.2831854D0*TIM/TIDAL)
  ISN 0013             RETURN
  ISN 0014          14 IF (TIM.GT.5.) GO TO 28
  ISN 0016             ANLFNC=(1.D0-DEXP(2.0*TIM**1.5))
  ISN 0017             RETURN
  ISN 0018          16 IF (TIM.GT.5.) GO TO 28
  ISN 0020             ANLFNC=(1.D0-DEXP(0.1*TIM**1.5))
  ISN 0021             RETURN
  ISN 0022          18 ANLFNC=1.0D0
  ISN 0023             RETURN
  ISN 0024          20 ANLFNC=1.0D0
  ISN 0025             RETURN
  ISN 0026          22 ANLFNC=1.0D0
  ISN 0027             RETURN
  ISN 0028          24 ANLFNC=1.0D0
  ISN 0029             RETURN
  ISN 0030          26 ANLFNC=1.0D0
  ISN 0031             RETURN
  ISN 0032          28 ANLFNC=1.0D0
  ISN 0033          30 RETURN
  ISN 0034             END

*OPTIONS IN EFFECT*      NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,

*OPTIONS IN EFFECT*      SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF

*STATISTICS*     SOURCE STATEMENTS =       33 ,PROGRAM SIZE =       750

*STATISTICS*  NO  DIAGNOSTICS GENERATED
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****** END OF COMPILATION ******   121K BYTES OF CORE NOT USED

OS/360 FORTRAN H

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        COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,
                           SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF
ISN 0002             SUBROUTINE DRIVE(KX,KY,NK,X,Y,DX,DY,DXL,DXR,DYL,DYR,H,U,V,T, CK,
                   > ERRHSR,HTMD,UTMD,VTMD,TTMD,CKTMD,NFLG,IXT,JYT,NCHECK,HH)
ISN 0003             IMPLICIT REAL*8 (A-H,O-Z)
ISN 0004             COMMON/REGION/DEPTH(25),SM(25),ILREG(25),IHREG(25),JLREG(25),
                   > JHREG(25),INTF(25),IGENF(25),ITOPF(25),IBOTF(25)
ISN 0005             INTEGER*2 ILREG,IHREG,JLREG,JHREG
ISN 0006             INTEGER*2 INTF,IGENF,ITOPF,IBOTF
ISN 0007             COMMON/COMBIN/ ANL,ATMP,CPIJ,CKIJ(4),CKIPJ(4),CKIMJ(4),CKIJP(4) ,
                   > CKIJM(4),DXM,DXP,DYM,DYP,DXIP1,DYJP1,DXLI,DXRI,DXLI1,DXRI1,DYLJ ,
                   > DYRJ,DYLJ1,DYRJ1,GBIJ,GKBIJ(4),QBIJ,QKBIJ(4),SBXIJ,SBYIJ,GXIMJ ,
                   > GXIPJ,GYIJM,GYIJP,GTIJ,GKTIJ(4),QTIJ,QKTIJ(4),STXIJ,STYIJ,QDVIJ ,
                   > QXIMJ,QXIPJ,QYIJM,QYIJP,GKXIMJ(4),GKXIPJ(4),GKYIJM(4),GKYIJP(4) ,
                   > HTKIJ(4),HTKIJM(4),HTKIPJ(4),HTKIMJ(4),HTKIJP(4),HIJ,HIJM,HIPJ ,
                   > HIMJ,HIJP,UIJ,UIJM,UIPJ,UIMJ,UIJP,VIJ,VIJM,VIPJ,VIMJ,VIJP,TIJ ,
                   > TIJM,TIPJ,TIMJ,TIJP,RCKTPD(4),RCIJ,ROIJM,ROIPJ,ROIMJ,ROIJP ,
                   > SHKTPD(4),SHTCKD(4),SHTTPD,SXXIMJ,SXXIPJ,SYYIJM,SYYIJP,SXYIJM ,
                   > SXYIPJ,SXYIMJ,SXYIJP,ROIMJD,RCIPJD,RCIJMD,ROIJPD,EQTMP,TDIJ ,
                   > HCIMJ,HCIPJ,HCIJM,HCIJP,GR,ROCKD(4),SPHTK(4),DENSK(4),RODKIJ(4) ,
                   > GKDVIJ(4),DXI,DYJ ,QDV(25),HBD(25),UBD(25),VBD(25),TBD(25),
                   > CKBD(4,25),TBIJ,HCBIJ ,CCKBIJ(4),HTKBIJ(4),BNIJ,UBIJ,VBIJ,WBIJ,
                   > ROBIJ,HTBIJ,CKBIJ(4),TTIJ,HCTIJ,CCKTIJ(4),HTKTIJ(4),UTIJ,VTIJ,
                   > WTIJ,ROTIJ,HTTIJ,CKTIJ(4) ,QBD(25),GBD(25),GKBD(4,25),SBDN(25),
                   > SBDSH(25),WIND,WINDX,WINDY ,IJ,IM1J,IP1J,IJM1,IJP1,INTRT,KOIJ,
                   > KOIM1J,KOIP1J,KOIJM1,KOIJP1 ,NBXM,NBXP,NBYM,NBYP,NREGIN,NBNDF ,
                   > IXQV(25),JYQV(25),NHBDTP(25),NUBDTP(25),NVBDTP(25),NTBDTP(25) ,
                   > NXGRL,NYGRL,NREG,NINTLF,NTOPF,NBOTF,NTBLFC,NTMAX,NGENF
ISN 0008             DIMENSION NFLG(KX,KY),T(KX,KY),H(NMOVE),U(KX,KY),HH(KX,KY)
ISN 0009             COMMON/INDPIT/DTMLT,STM,SDTM,PRBTM,DPRTTM,CPUSEC,TIDAL,FDTM,
                   > INDTM,NDTMC,IFINIS,LDTMCR,ISTART,IPLOT,NCPU
ISN 0010             COMMON/DROU/TIM,DTM,TM,PERIOD,IT,NMOVE,LMCVE,N
ISN 0011             DIMENSION X(1),Y(1),DX(1),DY(1),V(1),CK(1),ERRHSR(1),HTMD(1),
                   > UTMD(1),VTMD(1),TTMD(1),CKTMD(1)
ISN 0012             DIMENSION DXL(1),DXR(1),DYL(1),DYR(1)
ISN 0013             DIMENSION TMAX(10),TMIN(10),SMTDTM(10)
ISN 0014             DIMENSION IXT(1),JYT(1)
ISN 0015             IPLTP=8
              C      GR=32.2*3600.*3600.
ISN 0016             GR=4.17312D8
ISN 0017             NCPU=100.*CPUSEC
              C ***  ICLOCK(0) RETURNS TIME IN .01 SEC..
ISN 0018             ITIME=ICLOCK(0)
ISN 0019             ISTOP=0
ISN 0020             CALL GENCNI(NK)
ISN 0021             CALL MATPRI(NK)
ISN 0022             CALL BNDCNI(NK,X,DX,Y,DY,KX,KY,NCHECK)
ISN 0023             CALL BOTCNI(NK)
ISN 0024             CALL TOPCNI(NK)
ISN 0025             CALL SOLFNI(NK,KX,KY)
              C ***  SOLFNI CALLS FLXCNI.  INITIALIZATION ROUTINES.
ISN 0026             CALL FILTER(NK,KX,KY)
ISN 0027             CALL INTCON(NK,KX,KY,H,U,V,T,CK,ERRHSR,H)
ISN 0028             IF (NCHECK.EQ.0) GO TO 10
ISN 0030             PRINT 1000,NCHECK
ISN 0031             CALL EXIT
ISN 0032          10 CONTINUE
ISN 0033             DTM=SDTM
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ISN 0034          TM=STM
ISN 0035          PERIOD=TM/TIDAL
ISN 0036          FTM=STM+PRFTM
ISN 0037          PRTTM=TM+DPRTTM
ISN 0038          IF (IPLOT.EQ.0) GO TO 12
ISN 0040          IF (ISTART.EQ.0) CALL PLCTX(0)
           C   IT IS USED TO KEEP THE DELTA TIME FROM CHANGING INITIALLY.
ISN 0042       12 IT=0
           C     ISS IS SWITCH USED TO ZERO TAVG CALCULATION BETWEEN TIDAL PERIODS
ISN 0043          ISS=0
ISN 0044          NDTM=0
           C     STARTS MAJOR DO LOOP OF THE PROGRAM
ISN 0045       14 IF (LDTMCR.GT.0) CALL CHKDTM(DTM,NREG,KX,H,U,LDTMCR)
ISN 0047          IF (INTRT.EQ.3) GO TO 20
ISN 0049          DTM=DMIN1(DTM,FDTM)
ISN 0050          GO TO (16,18,20),INTRT
ISN 0051       16 CALL SOLRKG(KX,KY,NK,H,ERRHSR,HTMD,H,U,V,T,CK,HTMD,UTMD, VTMD,
                > TTMD,CKTMD,DX,DY,DXL,DXR,DYL,DYR,NFLG)
ISN 0052          GO TO 22
ISN 0053       18 CALL SOLEUI(KX,KY,NK,H,ERRHSR,HTMD,H,U,V,T,CK,HTMD,UTMD, VTMD,
                > TTMD,CKTMD,DX,DY,DXL,DXR,DYL,DYR,NFLG)
ISN 0054          GO TO 22
ISN 0055       20 CALL SOLAB (KX,KY,NK,H,ERRHSR,HTMD,H,U,V,T,CK,HTMD,UTMD, VTMD,
                > TTMD,CKTMD,DX,DY,DXL,DXR,DYL,DYR,NFLG)
           C *** WHEN SOLAB SELECTED, DON'T WANT DTM MODIFIED EXTERNAL TO
           C *** SUBROUTINE SOLAB.
           C *** SUBROUTINE CHKDTM, IN THE FUTURE (AFTER 9/27/73), MAY ALTER DTM.
ISN 0056       22 CALL FILTEN(HTMD,UTMD,VTMD,TTMD,CKTMD,H,U,V,T,CK, DX,DY,DXL,DXR,
                > DYL,DYR,NFLG)
ISN 0057          PERIOD=TM/TIDAL
ISN 0058          IT=IT+1
ISN 0059          IF (ISS.NE.0) GO TO 26
           C      INITIALIZE THE REQUIRED ARRAYS.
ISN 0061          DO 24 L=1,NTMAX
ISN 0062          SMTDTM(L)=0.
ISN 0063          TMAX(L)=0.
ISN 0064       24 TMIN(L)=10000.
ISN 0065          SMDTM=0.
ISN 0066          ISS=1
ISN 0067       26 DO 28 L=1,NTMAX
ISN 0068          SMTDTM(L)=SMTDTM(L)+DTM*T(IXT(L),JYT(L))
ISN 0069          IF (TMAX(L).LT.T(IXT(L),JYT(L))) TMAX(L)=T(IXT(L),JYT(L))
ISN 0071       28 IF (TMIN(L).GT.T(IXT(L),JYT(L))) TMIN(L)=T(IXT(L),JYT(L))
ISN 0073          SMDTM=SMDTM+DTM
ISN 0074          IF (SMDTM.LT.TIDAL) GO TO 32
ISN 0076          PRINT 1010
ISN 0077          DO 30 L=1,NTMAX
ISN 0078          TAVG=SMTDTM(L)/SMDTM
ISN 0079       30 PRINT 1020,IXT(L),JYT(L),TMIN(L),TMAX(L),TAVG
ISN 0080          ISS=0
ISN 0081       32 IF ((ICLOCK(0)-ITIME).LT.NCPU) GO TO 36
ISN 0083       34 PRINT 1030
ISN 0084          ISTOP=1
ISN 0085          GO TO 40
ISN 0086       36 IF (FTM.GT.TM) GO TO 38
ISN 0088          ISTOP=1
ISN 0089          GO TO 40
ISN 0090       38 IF (PRTTM.GT.TM) GO TO 46
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ISN 0092          40 IF (IPLOT.EQ.0) GO TO 42
ISN 0094             CALL PLOTX(1)
ISN 0095          42 CALL OUTPRT
ISN 0096          44 PRTTM=PRTTM+DPRTTM
ISN 0097             IF (ISTOP.EQ.1) GO TO 48
ISN 0099          46 CONTINUE
ISN 0100             IF (IT.LT.INDTM) GO TO 14
ISN 0102             IF (DTM.GE.FDTM) GO TO 14
ISN 0104             NDTM=NDTM+1
ISN 0105             IF (NDTM.LT.NDTMC) GO TO 14
ISN 0107             NDTM=0
ISN 0108             IF (INTPT.EQ.3) GO TO 14
ISN 0110             DTM=DTMLT*DTM
ISN 0111             GO TO 14
ISN 0112          48 IF (IFINIS.EQ.0) GO TO 50
                C    CREATE A RESTART FILE
ISN 0114             WRITE(10) TM,DTM,KX,KY,NK
ISN 0115             WRITE(10) H
ISN 0116          50 WRITE(52,1040) TM,DTM,IT,KX,KY,NK
ISN 0117             WRITE(52,1050) HH(1,1),HH(5,1),HH(9,1),HH(11,1),HH(21,1),HH(37,1),
                    >  HH(56,1),HH(57,1),U(1,1),U(5,1),U(9,1),U(11,1),U(21,1),U(37,1),
                    > U(56,1),U(57,1)
ISN 0118             IF (IPLOT.NE.0) END FILE IPLTP
ISN 0120          52 RETURN
ISN 0121        1000 FORMAT('1'///' IT HAS BEEN DECIDED THAT THIS CASE CANNOT BE
                    > RUN.'//' CHECK PRINTED OUTPUT.'//' NCHECK = ' I6)
ISN 0122        1010 FORMAT('1  NODE ID.'/2X'IXT'4X'JXT'7X'TMIN'8X'TMAX'8X'TAVG'/)
ISN 0123        1020 FORMAT(I5,I7,F13.4,2F12.4)
ISN 0124        1030 FORMAT('1 HAVE EXCEEDED THE MAX.REQUESTED CPU TIME.')
ISN 0125        1040 FORMAT(' TM='1PE10.3,1X,'DTM='1PE10.3,1X,'IT=',I5,1X,'KX=',I5,1X,
                    > 'KY=',I5,1X,'NK=',I5)
ISN 0126        1050 FORMAT(///1H ,'THE HH AND U VALUES ARE (1,1),(5,1),(9,1),(11,1),(2
                    >1,1),(37,1),(56,1),(57,1)'/1P6E11.4/6E11.4/4E11.4)
ISN 0127             END

*OPTIONS IN EFFECT*      NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,

*OPTIONS IN EFFECT*      SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF

*STATISTICS*     SOURCE STATEMENTS =      126 ,PROGRAM SIZE =      4182

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                                  93K BYTES OF CORE NOT USED
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CS/360 FORTRAN H

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        COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,
                          SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF
ISN 0002            SUBROUTINE SOLAB (KX,KY,NK,Y,Q,F,H,U,V,T,CK,HTMD,UTMD, VTMD,TTMD,
                   > CKTMD,DX,DY,DXL,DXR,DYL,DYR,NFLG)
              C ***
              C ***
              C *** NUMERICAL INTEGRATION OF THE SYSTEM OF DIFFERENTIAL EQUATIONS.
              C *** VIA ADAMS-BASHFORTH METHOD.
              C ***
              C *** Y(TM+DTM) = Y(TM) +  (DTM/2)*(3*Y'(TM)-Y'(TM-DTM))
              C ***
              C ***
ISN 0003            IMPLICIT REAL*8 (A-H,O-Z)
ISN 0004            COMMON/COMBIN/ ANL,ATMP,CPIJ,CKIJ(4),CKIPJ(4),CKIMJ(4),CKIJP(4) ,
                   > CKIJM(4),DXM,DXP,DYM,DYP,DXIP1,DYJP1,DXLI,DXRI,DXLI1,DXRI1,DYLJ ,
                   > DYRJ,DYLJ1,DYRJ1,GBIJ,GKBIJ(4),QBIJ,QKBIJ(4),SBXIJ,SBYIJ,GXIMJ ,
                   > GXIPJ,GYIJM,GYIJP,GTIJ,GKTIJ(4),QTIJ,QKTIJ(4),STXIJ,STYIJ,QDVIJ ,
                   > QXIMJ,QXIPJ,QYIJM,QYIJP,GKXIMJ(4),GKXIPJ(4),GKYIJM(4),GKYIJP(4) ,
                   > HTKIJ(4),HTKIJM(4),HTKIPJ(4),HTKIMJ(4),HTKIJP(4),HIJ,HIJM,HIPJ ,
                   > HIMJ,HIJP,UIJ,UIJM,UIPJ,UIMJ,UIJP,VIJ,VIJM,VIPJ,VIMJ,VIJP,TIJ ,
                   > TIJM,TIPJ,TIMJ,TIJP,ROKTPD(4),ROIJ,ROIJM,ROIPJ,ROIMJ,ROIJP ,
                   > SHKTPD(4),SHTCKD(4),SHTTPD,SXXIMJ,SXXIPJ,SYYIJM,SYYIJP,SXYIJM ,
                   > SXYIPJ,SXYIMJ,SXYIJP,ROIMJD,ROIPJD,ROIJMD,ROIJPD,EQTMP,TDIJ ,
                   > HCIMJ,HCIPJ,HCIJM,HCIJP,GR,ROCKD(4),SPHTK(4),DENSK(4),RODKIJ(4) ,
                   > GKDVIJ(4),DXI,DYJ ,QDV(25),HBD(25),UBD(25),VBD(25),TBD(25),
                   > CKBD(4,25),TBIJ,HCBIJ ,DCKBIJ(4),HTKBIJ(4),BNIJ,UBIJ,VBIJ,WBIJ,
                   > ROBIJ,HTBIJ,CKBIJ(4),TTIJ,HCTIJ,DCKTIJ(4),HTKTIJ(4),UTIJ,VTIJ,
                   > WTIJ,ROTIJ,HTTIJ,CKTIJ(4) ,QBD(25),GBD(25),GKBD(4,25),SBDN(25),
                   > SBDSH(25),WIND,WINDX,WINDY ,IJ,IM1J,IP1J,IJM1,IJP1,INTRT,KOIJ,
                   > KOIM1J,KOIP1J,KOIJM1,KOIJP1 ,NBXM,NBXP,NBYM,NBYP,NREGIN,NBNDF ,
                   > IXQV(25),JYQV(25),NHBDTP(25),NUBDTP(25),NVBDTP(25),NTBDTP(25) ,
                   > NXGRL,NYGRL,NREG,NINTLF,NTOPF,NEOTF,NTBIFC,NTMAX,NGENF
ISN 0005            COMMON/DROC/TIM,DTM,TM,PERIOD,IT,NMOVE,LMOVE,N
ISN 0006            DIMENSION Y(1),H(1),U(1),V(1),T(1),CK(1),HTMD(1),UTMD(1) ,VTMD(1),
                   > TTMD(1),CKTMD(1),DX(1),DY(1),DXL(1),DXR(1),DYL(1),DYR(1),NFLG(1),
                   > Q(LMOVE),F(LMOVE)
ISN 0007            DATA NO1STP/10/,NSVDER/01/
              C *** WILL PERFORM NO1STP ONE-STEP INTEGRATIONS PRIOR TO APPLYING THE
              C *** ADAMS-BASHFORTH PROCEDURE.   INITIAL STEPSIZE = DTM.
              C *** THE A-B PROCEDURE WILL COMMENCE WITH A STEPSIZE = L * DTM
              C *** WHERE THE INTEGER L SATISFIES
              C ***                    L = NO1STP - (NSVDER + 1)
              C *** CURRENTLY, WHEN THE A-B PROCEDURE COMMENCES, THE STEPSIZE  DTM MAY
              C *** NOT BE ALTERED.
ISN 0008            IF (IT.GT.NO1STP) GO TO 12
ISN 0010            IF (IT.EQ.NO1STP) GO TO 10
ISN 0012            CALL SOLRKG(KX,KY,NK,Y,Q,F,H,U,V,T,CK,HTMD,UTMD,VTMD,TTMD,CKTMD,
                   > DX,DY,DXL,DXR,DYL,DYR,NFLG)
              C *** CAN'T CHANGE SOLEUL TO SOLRKG UNLESS GET AN ADDITIONAL SPACE
              C *** ALLOCATION IN THE Z ARRAY.
              C *** HERE THE Q OF RKG IS USED TO HOLD Y'(TM-DTM)
ISN 0013            IF (IT.NE.NSVDER) GO TO 16
ISN 0015            WRITE(13)F
ISN 0016            REWIND 13
ISN 0017            GO TO 16
ISN 0018         10 DTM=(NO1STP-(NSVDER+1))*DTM
ISN 0019            DTMD2=.5D0*DTM
ISN 0020            READ(13)Q
```

```
                C *** NOTE WELL, PROGRAMMED SO DTMD2 CAN'T BE CHANGED IN IT'S VALUE
                C *** HERE.
   ISN 0021        12 DO 14 K=1,IMOVE
   ISN 0022           Y(K)=Y(K)+DTMD2*(3.D0*F(K)-Q(K))
   ISN 0023        14 Q(K)=F(K)
   ISN 0024           TM=TM+DTM
   ISN 0025           TIM=TM
   ISN 0026           CALL BNDCON(KX,NK,T,CK)
   ISN 0027           CALL SOLFNC(HTMD,UTMD,VTMD,TTMD,CKTMD,H,U,V,T,CK,DX,DY,DXL, DXR,
                     > DYL,DYR,NFIG)
   ISN 0028        16 RETURN
   ISN 0029           END

*OPTIONS IN EFFECT*      NAME=  MAIN,OPT=02,LINECNT=60,SIZE=COOCK,

*OPTIONS IN EFFECT*      SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NCMAE,NOEDIT,NOID,NOXREF

*STATISTICS*     SOURCE STATEMENTS =       28 ,PROGRAM SIZE =      1702

*STATISTICS*  NO  DIAGNOSTICS GENERATEC

****** END OF COMPILATION ******                                121K BYTES OF CORE NOT USED
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                                 OS/360  FORTRAN H

        COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,
                                  SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF
  ISN 0002              SUBROUTINE MATPRI(NK)
  ISN 0003              IMPLICIT REAL*8 (A-H,O-Z)
  ISN 0004              COMMON/COMBIN/ ANL,ATMP,CPIJ,CKIJ(4),CKIPJ(4),CKIMJ(4),CKIJP(4) ,
                       > CKIJM(4),DXM,DXP,DYM,DYP,DXIP1,DYJP1,DXLI,DXRI,DXLI1,DXRI1,DYLJ ,
                       > DYRJ,DYLJ1,DYRJ1,GBIJ,GKBIJ(4),QBIJ,QKBIJ(4),SBXIJ,SBYIJ,GXIMJ ,
                       > GXIPJ,GYIJM,GYIJP,GTIJ,GKTIJ(4),QTIJ,QKTIJ(4),STXIJ,STYIJ,QDVIJ ,
                       > QXIMJ,QXIPJ,QYIJM,QYIJP,GKXIMJ(4),GKXIPJ(4),GKYIJM(4),GKYIJP(4) ,
                       > HTKIJ(4),HTKIJM(4),HTKIPJ(4),HTKIMJ(4),HTKIJP(4),HIJ,HIJM,HIPJ ,
                       > HIMJ,HIJP,UIJ,UIJM,UIPJ,UIMJ,UIJP,VIJ,VIJM,VIPJ,VIMJ,VIJP,TIJ ,
                       > TIJM,TIPJ,TIMJ,TIJP,ROKTPD(4),ROIJ,ROIJM,ROIPJ,ROIMJ,ROIJP ,
                       > SHKTPD(4),SHTCKD(4),SHTTPD,SXXIMJ,SXXIPJ,SYYIJM,SYYIJP,SXYIJM ,
                       > SXYIPJ,SXYIMJ,SXYIJP,ROIMJD,ROIPJD,ROIJMD,ROIJPD,EQTMP,TDIJ ,
                       > HCIMJ,HCIPJ,HCIJM,HCIJP,GR,ROCKD(4),SPHTK(4),DENSK(4),RODKIJ(4) ,
                       > GKDVIJ(4),DXI,DYJ ,QDV(25),HBD(25),UBD(25),VBD(25),TBD(25),
                       > CKBD(4,25),TBIJ,HCBIJ ,DCKBIJ(4),HTKBIJ(4),BNIJ,UBIJ,VBIJ,WBIJ,
                       > ROBIJ,HTBIJ,CKBIJ(4),TTIJ,HCTIJ,DCKTIJ(4),HTKTIJ(4),UTIJ,VTIJ,
                       > WTIJ,ROTIJ,HTTIJ,CKTIJ(4) ,QBD(25),GBD(25),GKBD(4,25),SBDN(25),
                       > SBDSH(25),WIND,WINDX,WINDY ,IJ,IM1J,IP1J,IJM1,IJP1,INTRT,KOIJ,
                       > KOIM1J,KOIP1J,KOIJM1,KOIJP1 ,NBXM,NBXP,NBYM,NBYP,NREGIN,NBNDF ,
                       > IXQV(25),JYQV(25),NHBDTP(25),NUBDTP(25),NVBDTP(25),NTBDTP(25) ,
                       > NXGRL,NYGRL,NREG,NINTLP,NTOPF,NECTF,NTBIFC,NTMAX,NGENF
  ISN 0005              DIMENSION CKIMJD(4),CKIPJD(4),CKIJMD(4),CKIJPD(4)
  ISN 0006              DIMENSION CONCK(1)
  ISN 0007              RETURN
  ISN 0008              ENTRY MATPRP(CONCK,TEMP,DENS,SPHT,ROTPD)
  ISN 0009           10 DENS=0.D00
  ISN 0010              SPHT=0.D00
  ISN 0011              ROTPD=0.D00
  ISN 0012              SHTTPD=0.D00
                CC   EQUATIONS OF DENSITY AND SPECIFIC HEAT AS FUNCTIONS OF TEMPERATURE
                CC   AND CONCENTRATION WILL BE GIVEN HERE
                C       MEANTIME K=1 IS WATER AND K=2 IS SALT.
  ISN 0013              DENSK(1)=62.6651D0-0.000062338D0*TEMP**2
  ISN 0014              DENSK(2)=46.013D0
  ISN 0015              SPHTK(1)=1.0D0
  ISN 0016              SPHTK(2)=1.0D0
  ISN 0017              ROKTPD(1)=-0.000124676D0*TEMP
  ISN 0018              ROKTPD(2)=0.0D0
  ISN 0019              SHKTPD(1)=0.0D0
  ISN 0020              SHKTPD(2)=0.0D0
  ISN 0021              DO 12 K=1,NK
  ISN 0022              ROCKD(K)=DENSK(K)
  ISN 0023              SHTCKD(K)=SPHTK(K)
  ISN 0024              ROTPD=ROTPD+CONCK(K)*ROKTPD(K)
  ISN 0025              SHTTPD=SHTTPD+CONCK(K)*SHKTPD(K)
  ISN 0026              DENS=DENS+CONCK(K)*DENSK(K)
  ISN 0027           12 SPHT=SPHT + CONCK(K)*SPHTK(K)
  ISN 0028              RETURN
  ISN 0029              END

*OPTIONS IN EFFECT*       NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,

*OPTIONS IN EFFECT*       SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF

*STATISTICS*     SOURCE STATEMENTS =       28 ,PROGRAM SIZE =       742

*STATISTICS*  NO  DIAGNOSTICS GENERATED
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****** END OF COMPILATION ******

121K BYTES OF CORE NOT USED

OS/360 FORTRAN H

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COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,
                   SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF
ISN 0002          SUBROUTINE OUTPRT
ISN 0003          IMPLICIT REAL*8 (A-H,O-Z)
ISN 0004          COMMON/OUT/NK,KX,KY,NKKX,IXO,IYO,IHO,IUO,IVO,IWSO,ITO,ITTMDO,ICKO
ISN 0005          COMMON/DROU/TIM,DTM,TM,PERIOD,IT,NMOVE,LMCVE,N
ISN 0006          COMMON/COMBIN/ ANL,ATMP,CPIJ,CKIJ(4),CKIPJ(4),CKIMJ(4),CKIJP(4) ,
                > CKIJM(4),DXM,DXP,DYM,DYP,DXIP1,DYJP1,DXLI,DXRI,DXLI1,DXRI1,DYLJ ,
                > DYRJ,DYLJ1,DYRJ1,GBIJ,GKBIJ(4),QBIJ,QKBIJ(4),SBXIJ,SBYIJ,GXIMJ ,
                > GXIPJ,GYIJM,GYIJP,GTIJ,GKTIJ(4),QTIJ,CKTIJ(4),STXIJ,STYIJ,QDVIJ ,
                > QXIMJ,QXIPJ,QYIJM,QYIJP,GKXIMJ(4),GKXIPJ(4),GKYIJM(4),GKYIJP(4) ,
                > HTKIJ(4),HTKIJM(4),HTKIPJ(4),HTKIMJ(4),HTKIJP(4),HIJ,HIJM,HIPJ ,
                > HIMJ,HIJP,UIJ,UIJM,UIPJ,UIMJ,UIJP,VIJ,VIJM,VIPJ,VIMJ,VIJP,TIJ ,
                > TIJM,TIPJ,TIMJ,TIJP,ROKTPD(4),RCIJ,ROIJM,ROIPJ,ROIMJ,ROIJP ,
                > SHKTPD(4),SHTCKD(4),SHTTPD,SXXIMJ,SXXIPJ,SYYIJM,SYYIJP,SXYIJM ,
                > SXYIPJ,SXYIMJ,SXYIJP,ROIMJD,RCIPJD,RCIJMD,ROIJPD,EQTMP,TDIJ ,
                > HCIMJ,HCIPJ,HCIJM,HCIJP,GR,ROCKD(4),SPHTK(4),DENSK(4),RODKIJ(4) ,
                > GKDVIJ(4),DXI,DYJ ,QDV(25),HBD(25),UBD(25),VBD(25),TBD(25),
                > CKBD(4,25),TBIJ,HCBIJ ,DCKBIJ(4),HTKBIJ(4),BNIJ,UBIJ,VBIJ,WBIJ,
                > ROBIJ,HTBIJ,CKBIJ(4),TTIJ,HCTIJ,DCKTIJ(4),HTKTIJ(4),UTIJ,VTIJ,
                > WTIJ,ROTIJ,HTTIJ,CKTIJ(4) ,QBD(25),GBD(25),GKBD(4,25),SBDN(25),
                > SBDSH(25),WIND,WINDX,WINDY ,IJ,IM1J,IP1J,IJM1,IJP1,INTRT,KOIJ,
                > KOIM1J,KOIP1J,KOIJM1,KOIJP1 ,NBXM,NBXP,NBYM,NBYP,NREGIN,NBNDF ,
                > IXQV(25),JYQV(25),NHBDTP(25),NUBDTP(25),NVBDTP(25),NTBDTP(25) ,
                > NXGRL,NYGRL,NREG,NINTLF,NTOPF,NECTF,NTBIFC,NTMAX,NGENF
ISN 0007          DATA NOLINE/55/
ISN 0008          DATA NC/03/
ISN 0009          COMMON/Z/NZSP,NDUM,Z(1)
ISN 0010          NPOS=NOLINE
ISN 0011          KOIJS=ICKO
ISN 0012          DO 14 I=1,KX
ISN 0013          IJ=I
ISN 0014          KOIJ=KOIJS
ISN 0015          DO 12 J=1,KY
ISN 0016          NPOS=NPOS+1
ISN 0017          IF (NPOS.LE.NOLINE) GO TO 10
ISN 0019          NPOS=0
ISN 0020          PRINT 1000,IT,TM,PERIOD,DTM
ISN 0021       10 PRINT 1010,I,J,Z(IXO+I),Z(IYO+J),Z(IHO+IJ),Z(IUO+IJ),Z(IVO+IJ),
                > Z(IWSO+IJ),Z(ITO+IJ),Z(ITTMDO+IJ),(Z(KOIJ+K),K=1,NK)
ISN 0022          KOIJ=KOIJ+NKKX
ISN 0023       12 IJ=IJ+KX
ISN 0024       14 KOIJS=KOIJS+NK
ISN 0025          IF (INTRT.NE.1) GO TO 22
ISN 0027          IF (NC.LE.0) GO TO 22
ISN 0029          IQHO=IHO+LMCVE
ISN 0030          NC=NC-1
ISN 0031          IQUO=IUO+LMCVE
ISN 0032          IQVO=IVO+LMCVE
ISN 0033          IQTO=ITO+LMOVE
ISN 0034          IQCKO=ICKO+LMOVE
ISN 0035          NPOS=NOLINE
ISN 0036          KOIJS=IQCKO
ISN 0037          DO 20 I=1,KX
ISN 0038          IJ=I
ISN 0039          KOIJ=KOIJS
ISN 0040          DO 18 J=1,KY
ISN 0041          NPOS=NPOS+1
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ISN 0042          IF (NPOS.LE.NOLINE) GO TO 16
ISN 0044          NPOS=0
ISN 0045          PRINT 1020,IT
ISN 0046       16 PRINT 1030,I,J,Z(IQHO+IJ),Z(IQUO+IJ),Z(IQVO+IJ),Z(IQTO+IJ),
                 > (Z(KOIJ+K),K=1,NK)
ISN 0047          KOIJ=KOIJ+NKKX
ISN 0048       18 IJ=IJ+KX
ISN 0049       20 KOIJS=KOIJS+NK
ISN 0050       22 RETURN
ISN 0051     1000 FORMAT('1 ITER.=',I4,3X,'TIME=',1PE12.6,3X,'PERIOD=',E12.6,3X,
                 >'TIME INCREMENT=',E12.6//,
                 >45X,'VELOCITY',3X,'VELOCITY',2X,'WATER ELEV.',14X,'TEMP.',4X,
                 >'SUBSTANCE MASS CONCENTRATIONS'/6X,'INDI-',4X,'X-',9X,'Y-',7X,
                 >'WATER',8X,'IN',9X,'IN',8X,'RATE',18X,'RATE'/,2X,'NODE CES',2X,
                 >'LOCATION   LOCATION  ELEVATION   X-DIRECT.  Y-DIRECT.  OF CHANGE
                 >     TEMP.    OF CHANGE',4X,'CK(1)',6X,'CK(2)'/)
ISN 0052     1010 FORMAT(2(1X,I3),1X,2F11.2,1PE13.5,1P8E11.3)
ISN 0053     1020 FORMAT('1IT=',I3,5X,'ROUNDING ERROR ESTIMATES, Q.'/ 3X,'I',5X,'J',
                 > 8X,'QH',11X,'QU',11X,'QV',11X,'QT')
ISN 0054     1030 FORMAT(I5,2X,I4,1P6E11.3)
ISN 0055          END

*OPTIONS IN EFFECT*      NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,

*OPTIONS IN EFFECT*      SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF

*STATISTICS*     SOURCE STATEMENTS =       54 ,PROGRAM SIZE =      1588

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                              113K BYTES OF CORE NOT USED
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                                 OS/360  FORTRAN H

        COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,
                           SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF
   ISN 0002            SUBROUTINE CHEKED(UPX,XGRL,NXGRL,NSK,NAME,MC,IREG)
   ISN 0003            IMPLICIT REAL*8 (A-H,O-Z)
   ISN 0004            DIMENSION XGRL(1)
   ISN 0005            DATA DEL/Z3C1000C00000C000/
                 C *** DEL=16**-5
   ISN 0006            DO 20 M=1,NXGRL
   ISN 0007            IF (UPX-XGRL(M)) 10,22,20
   ISN 0008         10 IF (M.GT.1) GO TO 12
   ISN 0010            MC=1
   ISN 0011            GO TO 16
   ISN 0012         12 IF (UPX.LE..5*(XGRL(M)+XGRL(M-1))) GO TO 14
   ISN 0014            MC=M
   ISN 0015            GO TO 16
   ISN 0016         14 MC=M-1
                 C *** IF UPX IS SUFFICIENTLY CLOSE TO XGRL(MC) IN A RELATIVE SENSE,
                 C *** THEN DON'T PRINT REPLACEMENT MESSAGE.  HOWEVER, THE REPLACEMENT
                 C *** DOES OCCUR.
   ISN 0017         16 IF (DABS(UPX-XGRL(MC)).LE.DEL*XGRL(MC)) GO TO 18
   ISN 0019            PRINT 1000, IREG,NAME,UPX,XGRL(MC)
   ISN 0020            NSK=1
   ISN 0021         18 UPX=XGRL(MC)
   ISN 0022            GO TO 24
   ISN 0023         20 CONTINUE
   ISN 0024            MC=NXGRL
   ISN 0025            GO TO 16
   ISN 0026         22 MC=M
   ISN 0027         24 RETURN
   ISN 0028       1000 FORMAT(' IN REGION = 'I2,1X'THE'A4,1X'EDGE WAS CHANGED FROM'F11.5,
                      > 1X'TO 'F11.5)
   ISN 0029            END

*OPTIONS IN EFFECT*       NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,

*OPTIONS IN EFFECT*       SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF

*STATISTICS*     SOURCE STATEMENTS =       28 ,PROGRAM SIZE =       714

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                              129K BYTES OF CORE NOT USED
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                                   CS/360  FCRTRAN H

        COMPILER CPTIONS - NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,
                              SOURCE,EBCDIC,NOLIST,NCDECK,LCAD,NOMAP,NOEDIT,NOID,NOXREF
  ISN 0002          SUBROUTINE ESRRCH(IXT,XTMAX,X,LASTI,DX,XNAME,M,NTEM,NS)
  ISN 0003          IMPLICIT REAL*8 (A-H,O-Z)
  ISN 0004          REAL*4 XNAME
  ISN 0005          DIMENSION X(1),DX(1)
              C *** BINARY SEARCH THRU ORDERED ARRAY.
  ISN 0006          DATA DEL/Z3C10000000000000/
  ISN 0007          IF (XTMAX.GT.X(1)) GO TC 10
  ISN 0009          IXT=1
  ISN 0010          IF (XTMAX.GE.X(1)-.5D0*DX(1)) GO TC 26
  ISN 0012          IF ((X(1)-.5D0*DX(1))-XTMAX.LE.DEL*DABS(XTMAX)) GO TO 26
  ISN 0014          GO TO 28
  ISN 0015       10 IF (XTMAX.LT.X(LASTI)) GO TO 12
  ISN 0017          IXT =LASTI
  ISN 0018          IF (XTMAX.LE.X(LASTI)+.5D0*DX(LASTI)) GO TO 26
  ISN 0020          IF (XTMAX-(X(LASTI)+.5D0*DX(LASTI)).LE.DEL*DABS(XTMAX)) GO TO 26
  ISN 0022          GO TO 28
  ISN 0023       12 ML=1
  ISN 0024          MH=LASTI
  ISN 0025       14 IF (MH-ML.EQ.1) GO TO 22
  ISN 0027          N=(ML+MH)/2
  ISN 0028          IF (XTMAX-X(N)) 16,20,18
  ISN 0029       16 MH=N
  ISN 0030          GO TO 14
  ISN 0031       18 ML=N
  ISN 0032          GO TO 14
  ISN 0033       20 IXT=N
  ISN 0034          GO TO 26
  ISN 0035       22 IF (XTMAX.LE..5*(X(ML)+X(ML+1))) GC TC 24
  ISN 0037          IXT=MH
  ISN 0038          GO TO 26
  ISN 0039       24 IXT=ML
  ISN 0040       26 RETURN
  ISN 0041       28 IF (NTEM.EQ.0) PRINT 1000
  ISN 0043          NTEM=1
  ISN 0044          IF (NS.NE.0) GO TO 30
  ISN 0046          PRINT 1010,XNAME,XNAME,M
  ISN 0047          GO TO 26
  ISN 0048       30 PRINT 1020,XNAME,M
  ISN 0049          GO TO 26
  ISN 0050     1000 FORMAT(' 1'//)
  ISN 0051     1010 FORMAT(' THE'A3,'CORDINATE OF THE M-TH TEMPERATURE MONITORING
                   >POINT IS OUTSIDETHE'A3,'GRID.  M='I2)
  ISN 0052     1020 FORMAT(' THE',A3,'CORDINATE IS NCT IN THE GRID STRUCTURE.'/
                   > ' THE BOUNDARY FCN. NO = NBN = ',I2)
  ISN 0053          END

*OPTIONS IN EFFECT*      NAME=  MAIN,OPT=02,LINECNT=60,SIZE=COCCK,

*OPTIONS IN EFFECT*      SOURCE,EBCDIC,NOLIST,NCDECK,LCAD,NOMAP,NOEDIT,NOID,NOXREF

*STATISTICS*     SOURCE STATEMENTS =       52 ,PROGRAM SIZE =      1108

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                                 121K BYTES OF CORE NOT USED
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                              OS/360  FORTRAN H

        COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,
                           SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF
  ISN 0002            FUNCTION GNRLFC(N,X)
  ISN 0003            IMPLICIT REAL*8 (A-H,O-Z)
  ISN 0004            COMMON/COMBIN/ ANL,ATMP,CPIJ,CKIJ(4),CKIPJ(4),CKIMJ(4),CKIJP(4) ,
                     > CKIJM(4),DXM,DXP,DYM,DYP,DXIP1,DYJP1,DXLI,DXRI,DXLI1,DXRI1,DYLJ ,
                     > DYRJ,DYIJ1,DYRJ1,GBIJ,GKBIJ(4),QBIJ,QKBIJ(4),SBXIJ,SBYIJ,GXIMJ ,
                     > GXIPJ,GYIJM,GYIJP,GTIJ,GKTIJ(4),QTIJ,QKTIJ(4),STXIJ,STYIJ,QDVIJ ,
                     > QXIMJ,QXIPJ,QYIJM,QYIJP,GKXIMJ(4),GKXIPJ(4),GKYIJM(4),GKYIJP(4) ,
                     > HTKIJ(4),HTKIJM(4),HTKIPJ(4),HTKIMJ(4),HTKIJP(4),HIJ,HIJM,HIPJ ,
                     > HIMJ,HIJP,UIJ,UIJM,UIPJ,UIMJ,UIJP,VIJ,VIJM,VIPJ,VIMJ,VIJP,TIJ ,
                     > TIJM,TIPJ,TIMJ,TIJP,RCKTPD(4),RCIJ,ROIJM,ROIPJ,ROIMJ,ROIJP ,
                     > SHKTPD(4),SHTCKD(4),SHTTPD,SXXIMJ,SXXIPJ,SYYIJM,SYYIJP,SXYIJM ,
                     > SXYIPJ,SXYIMJ,SXYIJP,ROIMJD,RCIPJD,RCIJMD,ROIJPD,EQTMP,TDIJ ,
                     > HCIMJ,HCIPJ,HCIJM,HCIJP,GR,ROCKD(4),SPHTK(4),DENSK(4),RODKIJ(4) ,
                     > GKDVIJ(4),DXI,DYJ ,QDV(25),HBD(25),UBD(25),VBD(25),TBD(25),
                     > CKBD(4,25),TBIJ,HCBIJ ,DCKBIJ(4),HTKBIJ(4),BNIJ,UBIJ,VBIJ,WBIJ,
                     > ROBIJ,HTBIJ,CKBIJ(4),TTIJ,HCTIJ,DCKTIJ(4),HTKTIJ(4),UTIJ,VTIJ,
                     > WTIJ,ROTIJ,HTTIJ,CKTIJ(4) ,QBD(25),GBD(25),GKBD(4,25),SBDN(25),
                     > SBDSH(25),WIND,WINDX,WINDY ,IJ,IM1J,IP1J,IJM1,IJP1,INTRT,KOIJ,
                     > KOIM1J,KOIP1J,KOIJM1,KOIJP1 ,NBXM,NBXP,NBYM,NBYP,NREGIN,NBNDF ,
                     > IXQV(25),JYQV(25),NHBDTP(25),NUBDTP(25),NVBDTP(25),NTBDTP(25) ,
                     > NXGRL,NYGRL,NREG,NINTLP,NTOPF,NBOTF,NTBLFC,NTMAX,NGENF
  ISN 0005            COMMON/TABLE/NTBLP(10),TABARG(25,10),TABFNC(25,10)
                C*****THIS VALUE FOR X IS INSERTED HERE TO TEST THE PROGRAM FOR
                C     WORKABILITY.
  ISN 0006            X = 1.D0
  ISN 0007            IF (N) 14,10,12
  ISN 0008         10 GNRLFC=1.0D0
  ISN 0009            RETURN
  ISN 0010         12 CALL ATSM(X,TABARG(1,N),TABFNC(1,N),NTBLE(N),1,ARG,VAL,5)
  ISN 0011            CALL ALI(X,ARG,VAL,Y,5,0.01,IER)
  ISN 0012            GNRLFC=Y
  ISN 0013            RETURN
  ISN 0014         14 N=-N
  ISN 0015            GNRLFC=ANLFNC(N)
  ISN 0016            N=-N
  ISN 0017            RETURN
  ISN 0018            END

*OPTIONS IN EFFECT*      NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,

*OPTIONS IN EFFECT*      SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF

*STATISTICS*     SOURCE STATEMENTS =       17 ,PROGRAM SIZE =       548

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                                121K BYTES OF CORE NOT USED
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OS/360 FORTRAN H

COMPILER OPTIONS - NAME= MAIN,OPT=02,LINECNT=60,SIZE=0000K,
SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF

```
C
C     ..................................................................
C
C        SUBROUTINE ALI
C
C        PURPOSE
C           TO INTERPOLATE FUNCTION VALUE Y FOR A GIVEN ARGUMENT VALUE
C           X USING A GIVEN TABLE (ARG,VAL) OF ARGUMENT AND FUNCTION
C           VALUES.
C
C        USAGE
C           CALL ALI (X,ARG,VAL,Y,NDIM,EPS,IER)
C
C        DESCRIPTION OF PARAMETERS
C           X      - THE ARGUMENT VALUE SPECIFIED BY INPUT.
C           ARG    - THE INPUT VECTOR (DIMENSION NDIM) OF ARGUMENT
C                    VALUES OF THE TABLE (NOT DESTROYED).
C           VAL    - THE INPUT VECTOR (DIMENSION NDIM) OF FUNCTION
C                    VALUES OF THE TABLE (DESTROYED).
C           Y      - THE RESULTING INTERPOLATED FUNCTION VALUE.
C           NDIM   - AN INPUT VALUE WHICH SPECIFIES THE NUMBER OF
C                    POINTS IN TABLE (ARG,VAL).
C           EPS    - AN INPUT CONSTANT WHICH IS USED AS UPPER BOUND
C                    FOR THE ABSOLUTE ERROR.
C           IER    - A RESULTING ERROR PARAMETER.
C
C        REMARKS
C           (1) TABLE (ARG,VAL) SHOULD REPRESENT A SINGLE-VALUED
C               FUNCTION AND SHOULD BE STORED IN SUCH A WAY, THAT THE
C               DISTANCES ABS(ARG(I)-X) INCREASE WITH INCREASING
C               SUBSCRIPT I. TO GENERATE THIS ORDER IN TABLE (ARG,VAL),
C               SUBROUTINES ATSG, ATSM OR ATSE COULD BE USED IN A
C               PREVIOUS STAGE.
C           (2) NO ACTION BESIDES ERROR MESSAGE IN CASE NDIM LESS
C               THAN 1.
C           (3) INTERPOLATION IS TERMINATED EITHER IF THE DIFFERENCE
C               BETWEEN TWO SUCCESSIVE INTERPOLATED VALUES IS
C               ABSOLUTELY LESS THAN TOLERANCE EPS, OR IF THE ABSOLUTE
C               VALUE OF THIS DIFFERENCE STOPS DIMINISHING, OR AFTER
C               (NDIM-1) STEPS. FURTHER IT IS TERMINATED IF THE
C               PROCEDURE DISCOVERS TWO ARGUMENT VALUES IN VECTOR ARG
C               WHICH ARE IDENTICAL. DEPENDENT ON THESE FOUR CASES,
C               ERROR PARAMETER IER IS CODED IN THE FOLLOWING FORM
C                IER=0 - IT WAS POSSIBLE TO REACH THE REQUIRED
C                        ACCURACY (NO ERROR).
C                IER=1 - IT WAS IMPOSSIBLE TO REACH THE REQUIRED
C                        ACCURACY BECAUSE OF ROUNDING ERRORS.
C                IER=2 - IT WAS IMPOSSIBLE TO CHECK ACCURACY BECAUSE
C                        NDIM IS LESS THAN 3, OR THE REQUIRED ACCURACY
C                        COULD NOT BE REACHED BY MEANS OF THE GIVEN
C                        TABLE. NDIM SHOULD BE INCREASED.
C                IER=3 - THE PROCEDURE DISCOVERED TWO ARGUMENT VALUES
C                        IN VECTOR ARG WHICH ARE IDENTICAL.
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           NONE
```

```
              C
              C        METHOD
              C           INTERPOLATION IS DONE BY MEANS OF AITKENS SCHEME OF
              C           LAGRANGE INTERPOLATION. ON RETURN Y CONTAINS AN INTERPOLATED
              C           FUNCTION VALUE AT POINT X, WHICH IS IN THE SENSE OF REMARK
              C           (3) OPTIMAL WITH RESPECT TO GIVEN TABLE. FOR REFERENCE, SEE
              C           F.B.HILDEBRAND, INTRODUCTION TO NUMERICAL ANALYSIS,
              C           MCGRAW-HILL, NEW YORK/TORONTO/LONDON, 1956, PP.49-50.
              C
              C     ..............................................................
              C
  ISN 0002          SUBROUTINE ALI(X,ARG,VAL,Y,NDIM,EPS,IER)
              C
              C
  ISN 0003          IMPLICIT REAL*8 (A-H,O-Z)
  ISN 0004          DIMENSION ARG(1),VAL(1)
  ISN 0005          IER=2
  ISN 0006          DELT2=0.D0
  ISN 0007          IF (NDIM-1) 26,22,10
              C
              C     START OF AITKEN-LOOP
  ISN 0008       10 DO 20 J=2,NDIM
  ISN 0009          DELT1=DELT2
  ISN 0010          IEND=J-1
  ISN 0011          DO 12 I=1,IEND
  ISN 0012          H=ARG(I)-ARG(J)
  ISN 0013          IF (H) 12,34,12
  ISN 0014       12 VAL(J)=(VAL(I)*(X-ARG(J))-VAL(J)*(X-ARG(I)))/H
  ISN 0015          DELT2=DABS(VAL(J)-VAL(IEND))
  ISN 0016          IF (J-2) 20,20,14
  ISN 0017       14 IF (DELT2-EPS) 28,28,16
  ISN 0018       16 IF (J-5) 20,18,18
  ISN 0019       18 IF (DELT2-DELT1) 20,30,30
  ISN 0020       20 CONTINUE
              C     END OF AITKEN-LOOP
              C
  ISN 0021       22 J=NDIM
  ISN 0022       24 Y=VAL(J)
  ISN 0023       26 RETURN
              C
              C     THERE IS SUFFICIENT ACCURACY WITHIN NDIM-1 ITERATION STEPS
  ISN 0024       28 IER=0
  ISN 0025          GO TO 24
              C
              C     TEST VALUE DELT2 STARTS OSCILLATING
  ISN 0026       30 IER=1
  ISN 0027       32 J=IEND
  ISN 0028          GO TO 24
              C
              C     THERE ARE TWO IDENTICAL ARGUMENT VALUES IN VECTOR ARG
  ISN 0029       34 IER=3
  ISN 0030          GO TO 32
  ISN 0031          END

*OPTIONS IN EFFECT*      NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,

*OPTIONS IN EFFECT*      SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF

*STATISTICS*     SOURCE STATEMENTS =       30 ,PROGRAM SIZE =       738
```

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*STATISTICS*  NO  DIAGNOSTICS GENERATED
****** END OF COMPILATION ******                                  129K BYTES OF CORE NOT USED
```

```
                                   OS/360  FORTRAN H

COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,
                   SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF
C
C     ..............................................................
C
C        SUBROUTINE ATSM
C
C        PURPOSE
C           NDIM POINTS OF A GIVEN TABLE WITH MONOTONIC ARGUMENTS ARE
C           SELECTED AND ORDERED SUCH THAT
C           ABS(ARG(I)-X).GE.ABS(ARG(J)-X) IF I.GT.J.
C
C        USAGE
C           CALL ATSM (X,Z,F,IROW,ICOL,ARG,VAL,NDIM)
C
C        DESCRIPTION OF PARAMETERS
C           X      - THE SEARCH ARGUMENT.
C           Z      - THE VECTOR OF ARGUMENT VALUES (DIMENSION IROW).
C                    THE ARGUMENT VALUES MUST BE STORED IN INCREASING
C                    OR DECREASING SEQUENCE.
C           F      - IN CASE ICOL=1, F IS THE VECTOR OF FUNCTION VALUES
C                    (DIMENSION IROW).
C                    IN CASE ICOL=2, F IS AN IROW BY 2 MATRIX. THE FIRST
C                    COLUMN SPECIFIES THE VECTOR OF FUNCTION VALUES AND
C                    THE SECOND THE VECTOR OF DERIVATIVES.
C           IROW   - THE DIMENSION OF VECTOR Z AND OF EACH COLUMN
C                    IN MATRIX F.
C           ICOL   - THE NUMBER OF COLUMNS IN F (I.E. 1 OR 2).
C           ARG    - THE RESULTING VECTOR OF SELECTED AND ORDERED
C                    ARGUMENT VALUES (DIMENSION NDIM).
C           VAL    - THE RESULTING VECTOR OF SELECTED FUNCTION VALUES
C                    (DIMENSION NDIM) IN CASE ICOL=1. IN CASE ICOL=2,
C                    VAL IS THE VECTOR OF FUNCTION AND DERIVATIVE VALUES
C                    (DIMENSION 2*NDIM) WHICH ARE STORED IN PAIRS (I.E.
C                    EACH FUNCTION VALUE IS FOLLOWED BY ITS DERIVATIVE
C                    VALUE).
C           NDIM   - THE NUMBER OF POINTS WHICH MUST BE SELECTED OUT OF
C                    THE GIVEN TABLE (Z,F).
C
C        REMARKS
C           NO ACTION IN CASE IROW LESS THAN 1.
C           IF INPUT VALUE NDIM IS GREATER THAN IROW, THE PROGRAM
C           SELECTS ONLY A MAXIMUM TABLE OF IROW POINTS.  THEREFORE THE
C           USER OUGHT TO CHECK CORRESPONDENCE BETWEEN TABLE (ARG,VAL)
C           AND ITS DIMENSION BY COMPARISON OF NDIM AND IROW, IN ORDER
C           TO GET CORRECT RESULTS IN FURTHER WORK WITH TABLE (ARG,VAL).
C           THIS TEST MAY BE DONE BEFORE OR AFTER CALLING
C           SUBROUTINE ATSM.
C           SUBROUTINE ATSM ESPECIALLY CAN BE USED FOR GENERATING THE
C           TABLE (ARG,VAL) NEEDED IN SUBROUTINES ALI, AHI, AND ACFI.
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           NONE
C
C        METHOD
C           SELECTION IS DONE BY SEARCHING THE SUBSCRIPT J OF THAT
C           ARGUMENT, WHICH IS NEXT TO X (BINARY SEARCH).
C           AFTERWARDS NEIGHBOURING ARGUMENT VALUES ARE TESTED AND
```

```
              C          SELECTED IN THE ABOVE SENSE.
              C
              C     ..............................................................
              C
ISN 0002            SUBROUTINE AISM(X,Z,F,IROW,ICOL,ARG,VAL,NDIM)
              C
              C
ISN 0003            IMPLICIT REAL*8 (A-H,O-Z)
ISN 0004            DIMENSION Z(1),F(1),ARG(1),VAL(1)
              C
              C     CASE IROW=1 IS CHECKED OUT
ISN 0005            IF (IROW-1) 54,50,10
ISN 0006         10 N=NDIM
              C
              C     IF N IS GREATER THAN IROW, N IS SET EQUAL TO IROW.
ISN 0007            IF (N-IROW) 14,14,12
ISN 0008         12 N=IROW
              C
              C     CASE IROW.GE.2
              C     SEARCHING FOR SUBSCRIPT J SUCH THAT Z(J) IS NEXT TO X.
ISN 0009         14 IF (Z(IROW)-Z(1)) 18,16,16
ISN 0010         16 J=IROW
ISN 0011            I=1
ISN 0012            GO TO 20
ISN 0013         18 I=IROW
ISN 0014            J=1
ISN 0015         20 K=(J+I)/2
ISN 0016            IF (X-Z(K)) 22,22,24
ISN 0017         22 J=K
ISN 0018            GO TO 26
ISN 0019         24 I=K
ISN 0020         26 IF (IABS(J-I)-1) 28,28,20
ISN 0021         28 IF (DABS(Z(J)-X)-DABS(Z(I)-X)) 32,32,30
ISN 0022         30 J=I
              C
              C     TABLE SELECTION
ISN 0023         32 K=J
ISN 0024            JL=0
ISN 0025            JR=0
ISN 0026            DO 48 I=1,N
ISN 0027            ARG(I)=Z(K)
ISN 0028            IF (ICOL-1) 36,36,34
ISN 0029         34 VAL(2*I-1)=F(K)
ISN 0030            KK=K+IROW
ISN 0031            VAL(2*I)=F(KK)
ISN 0032            GO TO 38
ISN 0033         36 VAL(I)=F(K)
ISN 0034         38 JJR=J+JR
ISN 0035            IF (JJR-IROW) 40,44,44
ISN 0036         40 JJL=J-JL
ISN 0037            IF (JJL-1) 46,46,42
ISN 0038         42 IF (DABS(Z(JJR+1)-X)-DABS(Z(JJL-1)-X)) 46,46,44
ISN 0039         44 JL=JL+1
ISN 0040            K=J-JL
ISN 0041            GO TO 48
ISN 0042         46 JR=JR+1
ISN 0043            K=J+JR
ISN 0044         48 CONTINUE
```

```
  ISN 0045          RETURN
               C
               C    CASE IROW=1
  ISN 0046       50 ARG(1)=Z(1)
  ISN 0047          VAL(1)=F(1)
  ISN 0048          IF (ICOL-2) 54,52,54
  ISN 0049       52 VAL(2)=F(2)
  ISN 0050       54 RETURN
  ISN 0051          END

*OPTIONS IN EFFECT*      NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,

*OPTIONS IN EFFECT*      SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF

*STATISTICS*     SOURCE STATEMENTS =      50 ,PROGRAM SIZE =      980

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                                121K BYTES OF CORE NOT USED
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                                                              OS/360  FORTRAN H

                   COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,
                                      SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF
   ISN 0002           SUBROUTINE OUTZ(NK,KX,KY)                                          OUTZ   10
   ISN 0003           IMPLICIT REAL*8 (A-H,O-Z)                                          OUTZ   20
   ISN 0004           COMMON/Z/NZSP,NDUM,Z(1)                                            OUTZ   30
   ISN 0005           REAL*4 ANAM                                                        OUTZ   40
   ISN 0006           DIMENSION ANAM(8)                                                  OUTZ   50
   ISN 0007           DATA ANAM/'H','U','V','T','CK1','CK2','CK3','CK4'/                 OUTZ   60
   ISN 0008           N=KX*KY                                                            OUTZ   70
   ISN 0009           M=NK*N                                                             OUTZ   80
   ISN 0010           IH=4*(KX+KY)+N                                                     OUTZ   90
   ISN 0011           IH1=8*N+2*M+IH                                                     OUTZ  100
   ISN 0012           L=NK+4                                                             OUTZ  110
   ISN 0013           DO 12 K=1,2                                                        OUTZ  120
   ISN 0014           PRINT 1000,K                                                       OUTZ  130
   ISN 0015           DO 10 J=1,L                                                        OUTZ  140
   ISN 0016           IL=IH+1                                                            OUTZ  150
   ISN 0017           IH=IH+N                                                            OUTZ  160
   ISN 0018           PRINT 1010,ANAM(J),(Z(I),I=IL,IH)                                  OUTZ  170
   ISN 0019        10 CONTINUE                                                           OUTZ  180
   ISN 0020        12 IH=IH1                                                             OUTZ  190
   ISN 0021           RETURN                                                             OUTZ  200
   ISN 0022      1000 FORMAT('1VALUES WHEN K=1, DERIVATIVES WHEN K=2.  K='I2)            OUTZ  210
   ISN 0023      1010 FORMAT(//1X,A4/(1P10E13.5))                                        OUTZ  220
   ISN 0024           END                                                                OUTZ  230

*OPTIONS IN EFFECT*     NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,

*OPTIONS IN EFFECT*     SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF

*STATISTICS*     SOURCE STATEMENTS =      23 ,PROGRAM SIZE =      654

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                                       129K BYTES OF CORE NOT USED
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                              OS/360  FORTRAN H

        COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,
                             SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF
  ISN 0002              SUBROUTINE PLOTX(INPLT)
  ISN 0003              IMPLICIT REAL*8 (A-H,O-Z)
  ISN 0004              COMMON/OUT/NK,KX,KY,NKKX,IXO,IYO,IHO,IUO,IVO,IWSO,ITO,ITTMDO,ICKO
  ISN 0005              COMMON/DROU/TIM,DTM,TM,PERIOD,IT,NMOVE,LMOVE,N
  ISN 0006              COMMON/COMBIK/ ANL,ATMP,CPIJ,CKIJ(4),CKIPJ(4),CKIMJ(4),CKIJP(4) ,
                       > CKIJM(4),DXM,DXP,DYM,DYP,DXIP1,DYJP1,DXLI,DXRI,DXLI1,DXRI1,DYLJ ,
                       > DYRJ,DYLJ1,DYRJ1,GBIJ,GKBIJ(4),QBIJ,QKBIJ(4),SBXIJ,SBYIJ,GXIMJ ,
                       > GXIPJ,GYIJM,GYIJP,GTIJ,GKTIJ(4),QTIJ,QKTIJ(4),STXIJ,STYIJ,QDVIJ ,
                       > QXIMJ,QXIPJ,QYIJM,QYIJP,GKXIMJ(4),GKXIPJ(4),GKYIJM(4),GKYIJP(4) ,
                       > HTKIJ(4),HTKIJM(4),HTKIPJ(4),HTKIMJ(4),HTKIJP(4),HIJ,HIJM,HIPJ ,
                       > HIMJ,HIJP,UIJ,UIJM,UIPJ,UIMJ,UIJP,VIJ,VIJM,VIPJ,VIMJ,VIJP,TIJ ,
                       > TIJM,TIPJ,TIMJ,TIJP,RCKTPD(4),RCIJ,ROIJM,ROIPJ,ROIMJ,ROIJP ,
                       > SHKTPD(4),SHTCKD(4),SHTTPD,SXXIPJ,SXXIPJ,SYYIJM,SYYIJP,SXYIJM ,
                       > SXYIPJ,SXYIMJ,SXYIJP,RCIMJD,RCIPJD,RCIJPD,ROIJPD,EQTMP,TDIJ ,
                       > HCIMJ,HCIPJ,HCIJM,HCIJP,GB,ROCKD(4),SPHTR(4),DENSK(4),RODKIJ(4) ,
                       > GKDVIJ(4),DXI,DYJ ,QDV(25),HBD(25),UBD(25),VBD(25),TBD(25),
                       > CKBD(4,25),TBIJ,HCBIJ ,DCKBIJ(4),HTKBIJ(4),BNIJ,UBIJ,VBIJ,WBIJ,
                       > ROBIJ,HTBIJ,CKBIJ(4),TTIJ,HCTIJ,DCKTIJ(4),HTKTIJ(4),UTIJ,VTIJ,
                       > WTIJ,ROTIJ,HTTIJ,CKTIJ(4) ,QBD(25),GBD(25),GKBD(4,25),SBDN(25),
                       > SBDSH(25),WIND,WINDX,WINDY ,IJ,IM1J,IP1J,IJM1,IJP1,INTRT,KOIJ,
                       > KOIM1J,KOIP1J,KOIJM1,KOIJP1 ,NBXM,NBXP,NBYM,NBYP,NREGIN,NBNDF ,
                       > IXQV(25),JYQV(25),NHBDTP(25),NUBDTP(25),NVBDTP(25),NTBDTP(25) ,
                       > NXGRL,NYGRL,NREG,NINTLF,NTOPF,NBCTF,NTBIFC,NTMAX,NGENF
  ISN 0007              COMMON/Z/NZSF,NDUM,Z(1)
               C
  ISN 0008              IPLTP=8
  ISN 0009              IF (INPLT.NE.0) GO TO 14
  ISN 0011              DO 10 I=1,KX
  ISN 0012              WRITE(IPLTP)I,Z(IXO+I)
  ISN 0013           10 CONTINUE
  ISN 0014              DO 12 J=1,KY
  ISN 0015              WRITE(IPLTP)J,Z(IYO+J)
  ISN 0016           12 CONTINUE
  ISN 0017           14 WRITE(IPLTP)TM,PERIOD,IT,DTM
  ISN 0018              KOIJS=ICKO
  ISN 0019              DO 20 I=1,KX
  ISN 0020              IJ=I
  ISN 0021              KOIJ=KOIJS
  ISN 0022              DO 18 J=1,KY
  ISN 0023           16 WRITE(IPLTP)Z(IHO+IJ),Z(IUO+IJ),Z(IVO+IJ), Z(IWSO+IJ),Z(ITO+IJ),
                       > Z(ITTMDO+IJ),(Z(KOIJ+K),K=1,NK)
  ISN 0024              KOIJ=KOIJ+NKKX
  ISN 0025           18 IJ=IJ+KX
  ISN 0026           20 KOIJS=KOIJS+NK
  ISN 0027              RETURN
  ISN 0028              END

*OPTIONS IN EFFECT*      NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,

*OPTIONS IN EFFECT*      SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,NOID,NOXREF

*STATISTICS*     SOURCE STATEMENTS =       27 ,PROGRAM SIZE =       736

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                                121K BYTES OF CORE NOT USED

*STATISTICS*  NO  DIAGNOSTICS THIS STEP
```

ORNL-TM-4626

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