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Hydrodynamic model of the Great Bay estuarine system. Part 1

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Hydrodynamic Model of The Great Bay Estuarine System

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HYDRODYNAMIC MODEL OF THE GREAT BAY ESTUARINE SYSTEM
PART I

by
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LIST OF NOTATION

A - Tidal amplitude
C - Generalized bottom friction coefficient
C_f - Connor and Wang bottom friction coefficient
C_h - Chezy bottom friction coefficient (Leendertse)
f - Coriolis effect ($f = 2\Omega \sin \phi$, where ϕ is the lattitude)
$F_{xx,\ yy,\ xy}$ Constitutive relations for eddy viscosity terms
F_p - Constitutive relation for pressure effects
g - Gravity
h - Water depth with respect to mean water level
H - Total water depth ($H = h + \eta$)
L - Tidal wavelength
p - Pressure
p' - Pressure fluctuation with respect to the ensemble average pressure
p'' - Pressure fluctuation with respect to the vertical average pressure
$\overline{p}$ - Ensemble average pressure
P - Vertical average of ensemble average pressure
P_a - Atmospheric pressure
$q_{x,\ y}$ - Vertical average velocity times water depth ($q_x = HU$)
r_{ij} - Reynolds stress ($r_{ij} = \overline{\rho_o u_i' u_j'}$)
r_{ij}'' - Fluctuation of Reynolds stress with respect to the vertical average Reynolds stress
R_{ij} - Vertical average Reynolds stress
t - Time
u_i - Tensor notation velocity component
u_i' - Fluctuation of the velocity component with respect to the ensemble average velocity component
u_i'' - Fluctuation of the velocity component with respect to the vertical average velocity component
$\overline{u}_i$ - Ensemble average velocity component
U_i - Vertical average of the ensemble average velocity component
U - Vertical average velocity component in the x direction
V - Vertical average velocity component in the y direction

x_i - Cartesian direction in tensor notation

x - Cartesian horizontal direction

y - Cartesian horizontal direction perpendicular to x

ε_{ij} - Eddy viscosity coefficient

μ - Viscosity coefficient in the Navier-Stokes Equation

η - Water surface elevation with respect to mean water level

ρ - Water density

ρ_o - Average water density

$\tau_{ij,\ xx,\ yy,xy}$ Internal stress term (vertical average of products of vertical average velocity fluctuations)

τ^b - Bottom stress term

τ^s - Surface stress term

ω - Tidal frequency

Ω - Earth's frequency of rotation

ξ - Viscosity coefficient in the Navier-Stokes Equation

ABSTRACT

A numerical hydrodynamic model developed by Connor and Wang has been applied to the Great Bay Estuary system. The model, using the finite element method, was found to be better suited to the complexities of the Great Bay Estuary system than Leendertse's finite difference model. Initial model development has been completed, and qualitatively acceptable results are presented. A numerical experiment was conducted to develop a procedure to be used for selection of critical model parameters in the calibration process. The general scheme for model calibration is presented, and is ready to be implemented, pending receipt of current data collected last summer by the National Ocean Survey.

INTRODUCTION

The Great Bay Estuary system and the surrounding area is a large part of the New Hampshire seacoast area. Much of the area immediately adjacent to the estuary is underdeveloped, and plans for future development and protection of the estuary are being considered at this time. The Great Bay Estuary System Modeling Project is an attempt to describe the dynamics of the estuary and to predict the effect on the estuary of possible development schemes, thus providing a quantitative basis for the decision-makers. The initial step in this program is the development of a computer-based numerical hydrodynamic model to predict the water movements in the estuary. Two mathematical models, based on the conservation of mass and momentum equations, have been studied in detail. Connor and Wang's two-dimensional finite element model was selected over Leendertse's two-dimensional finite difference model as being more suited for this particular application. Initial model application has been carried out, including a series of tests to establish a basis for selecting appropriate values of the various model parameters when calibrating the models. The models are qualitatively acceptable, and are ready to be calibrated quantitatively. A complete set of field data, from the UNH/NOS (National Ocean Survey) cooperative field program, will soon be available for use in the calibration process.

A PHYSICAL DESCRIPTION OF THE GREAT BAY ESTUARY SYSTEM

The Great Bay Estuary System is located in the New Hampshire seacoast region, and forms part of the New Hampshire-Maine boundary. Its area of 45 square kilometers makes it one of the largest estuaries opening on the Gulf of Maine. The Great Bay estuary system and its tributaries have a drainage area of about 2,410 kilometers.

The geometry of the estuary is complex, but lends itself to division of the estuary into segments (see Figure 1). Portsmouth Harbor is the mouth of the estuary and, together with the lower Piscataqua River, serves as the only seaport for New Hampshire. This area can be described as a channel, with several islands bordering the Portsmouth Harbor section. The channel is dredged in places to maintain a minimum 10.5 M (35 feet) depth, although it is 12 to 15 M deep for most of its length. This section's tidal prism is the lowest in the system, but the section is dominated by the tidal flow of the entire system. The currents are large, approaching a maximum of two to three meters per second at mid-ebb and mid-flood in the narrower sections. The average tidal range at Portsmouth is about 2.5 M, falling to 1.9 M at Dover Point.

The upper Piscataqua River is formed by the convergence of the Cocheco and Salmon Falls Rivers in Dover. It is the shallowest area in the estuary, with a mean depth of about two meters. The upper Piscataqua River is characterized by a channel approximately five meters deep, with tidal flats on both sides. The tidal currents are much weaker than the lower Piscataqua, as it is only affected by its own tidal prism. Little Bay is an L-shaped segment of the estuary joining the Piscataqua River at Dover Point, and the Great Bay at Adams Point. It is characterized by a channel with tidal flats on both sides. Two of the system's tributaries, the Bellamy and Oyster Rivers, flow into Little Bay. Little Bay turns sharply at Fox Point, creating complex flow patterns and a great deal of turbulence. It is dominated by tidal flow (including Great Bay effects), and has currents of two-three m/s at Dover Point due to the combined effect of large tidal prism and shallow depth at this point.

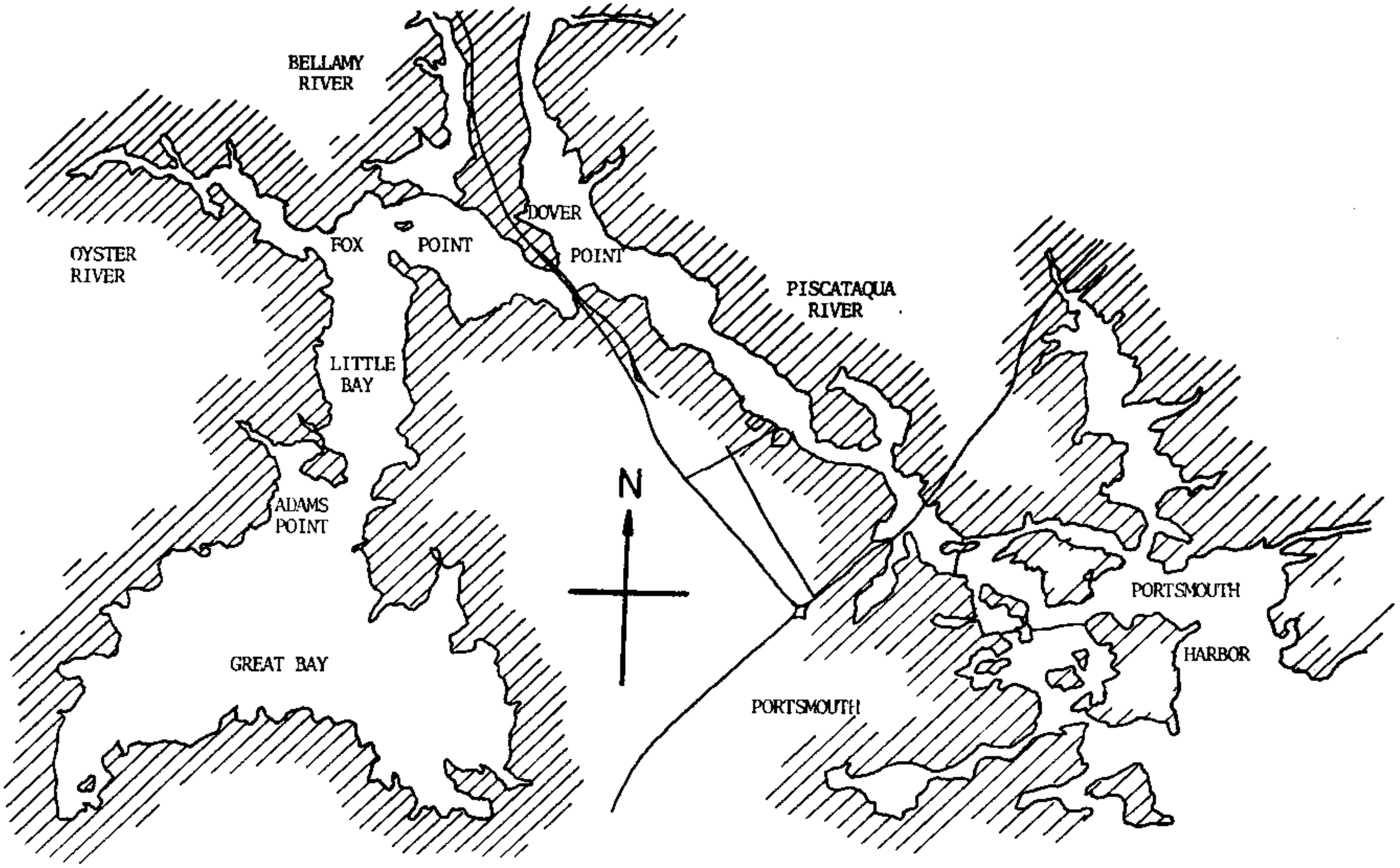
The last segment is Great Bay proper, a wide, shallow (2.7 M average) bay characterized by tidal flats, and a network of channels.

A small channel from the Winnicut River, and a larger one from the Squamscott and Lamprey Rivers join in the center of the Bay and form the main channel, which connects with Little Bay at Adams Point.

The freshwater discharge into the estuary varies greatly, with about half of the runoff in the months of March and April. Consequently, for the remainder of the year, freshwater discharge is of relatively minor importance when compared with tidal effects.

Appendix I contains details of the bathymetry of the Great Bay Estuary System (Shevenell). The data was obtained from U.S. Coast and Geodetic Survey maps 210 and 211. Areas of the segments and their depth contours were obtained through use of a planimeter. The bathymetry presented by these charts is the best complete set available, but a comprehensive bathymetric survey is needed.

FIGURE 1
GREAT BAY ESTUARY SYSTEM



PROJECT FORMULATION

The estuary is one of the most important recreational areas for the State of New Hampshire and southern Maine. Its relatively unpolluted waters are abundant with fish and other wildlife. Recently, a great deal of political and economic pressure has been brought to bear on the state to industrialize the land surrounding the estuary. The University of New Hampshire undertook a comprehensive study on the impact of an oil refinery located on the land adjacent to the estuary. One of the greatest problems the study team faced was the absence of a quantitative basis to determine the effects of such a development. Furthermore, the state is preparing a master plan for sewage control in the seacoast region. The plan deals with prediction of future sewage levels and treatment methods, but is based on qualitative understanding of the estuary, rather than a quantitative study.

To meet the needs of the state for better information on environmental effects of future development plans for the Great Bay Estuary system, a quantitative study is needed. The study must include description of present conditions, as well as predictive capabilities. Comprehensive data collection can be used to prescribe present conditions, but a model of the estuary is needed in order to predict changes resulting from environmental alterations.

At present, two types of models can be constructed for physcial and chemical predictions. The first is a scale physical model of the estuary. Boundary conditons are specified by pumping in water with appropriate physical and chemical properties. Data is then collected in the model by measuring various parameters with laboratory instruments. The model is modified until it can predict present conditions, and then altered to reflect development plans for prediction of the impact of these plans on the estuary. The physical model has been well-developed over the years, and its limitations, which are considerable, are well known.

The second type of model is a mathematical model. The geometry of the estuary is simulated through a series of three-dimensional, geometrically regular shapes called a grid. The equations representing the process are solved numerically for this grid. The model is calibrated to simulate present conditions; future conditions are simulated by altering the model in accordance with future development plans. Mathematical modeling of estuaries has developed rapidly in the last decade, and is now gaining acceptance. There is still much work to be done in this area, but mathematical models are already replacing physical models for several types of applications in estuarine and coastal waters.

Several mathematical models are currently available for estuarine processes. Hydrodynamic models, predicting the tides and currents, are the most advanced, and are used as a basis for dispersion models. Some hydrodynamic models have dispersion equations built in, while others have a companion dispersion model sharing the same grid and using the output of the hydrodynamic model. Most dispersion models predict concentrations of conservative and non-conservative substances. The theoretical basis of hydrodynamic models is reviewed in the next section.

GOVERNING EQUATIONS

The equations governing the motion in an estuary are the three momentum equations and the continuity equation. In their general form, the analytical solutions are not available. The differences in theory among investigators are the simplifying assumptions imposed to obtain a solvable set of equations.

In tensor notation the generalized equations of momentum and continuity for estuaries can be expressed by the following two equations:

a) The time rate of change of momentum of a moving fluid particle is equal to the sum of the forces acting on it:

$$\frac{\partial}{\partial t}(\rho u_i) + \frac{\partial}{\partial x_j}(\rho u_i u_j) = - \frac{\partial p}{\partial x_i} - 2\, \xi_{ij\ell}\, \Omega_j\, \rho u_\ell \; +$$

$$+ \rho g \delta_{i3} + \frac{\partial}{\partial x_j}\left[\mu \left(\frac{\partial u_i}{\partial x_j} - \frac{2}{3}\, \delta ij\, \frac{\partial u_k}{\partial x_k}\right)\right] + \frac{\partial}{\partial x_j}\left(\xi \frac{\partial u_k}{\partial x_k}\right)$$

b) The mass of a moving element of fluid remains constant:

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x_i}(\rho u_i) = 0$$

Where t is time, ρ density, u a velocity component, x a direction, P pressure, Ω the earth's rotation, g gravity, μ and ξ viscous coefficients.

Applying the following assumptions:

1) Incompressible flow $\left(\frac{\partial \rho}{\partial p} = 0\right)$

2) ρ(density) = ρ_o (constant) + $\delta\rho$ (a small perturbation term)

3) Viscosity coefficient is constant ($\mu = \mu_o$).

4) The second derivative of velocity with respect to perpendicular coordinates is small:

$$\left(\frac{\partial^2 u_i}{\partial x^2_j} = 0 \neq j\right).$$

The equations are simplified to obtain:

$$\frac{\partial u_i}{\partial t} + \frac{\partial}{\partial x_j}(u_i u_j) = - \frac{1}{\rho_o} \frac{\partial p}{\partial x_i} - 2\xi_{ij\ell}\Omega_j u_\ell + g\delta_{i3}$$

$$\frac{\partial u_i}{\partial x_i} = 0$$

Representing the variables as the sum of their ensemble average and a fluctuation about the ensemble average,

$$u_i = \overline{u}_i + u'$$

$$p = \overline{p} + p'$$

Where the overbar denotes the ensemble average, and the prime denotes the fluctuation term, the equations can be ensemble averaged to obtain:

$$\frac{\partial \bar{u}_i}{\partial t} + \frac{\partial}{\partial x_j}(\bar{u}_i \bar{u}_j) = -\frac{1}{\rho_o}\frac{\partial \bar{p}}{\partial x_i} - 2\epsilon_{ij\ell}\Omega_j \bar{u}_\ell + g\delta_{i3}$$

$$-\frac{1}{\rho_o}\frac{\partial}{\partial x_j}\overline{\rho_o u'_i u'_j}$$

$$\frac{\partial \bar{u}_i}{\partial x_i} = 0$$

This averaging technique smooths the stochastic processes while retaining the deterministic processes. The additional term is called the Reynolds stress, r, and is the ensemble average of the product of velocity fluctuations with respect to the ensemble average velocity, multiplied by density:

$$r_{ij} = \overline{\rho_o u'_i u'_j}$$

Assuming vertical variations of the various parameters are small, the equations may be vertically averaged, and the vertical momentum equation reduced to the hydrostatic relation, without loss of meaing. Representing the variables as the sum of their vertical average and a fluctuation about the vertical average:

$$\bar{u}_i = U_i + u''_i$$

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

$$r_{ij} = R_{ij} + r''_{ij}$$

Where capital letters indicate the vertical average values, and double prime denotes the fluctuation about the vertical average, the vertically averaged equations are:

$$\frac{\partial U}{\partial t} + \frac{\partial U^2}{\partial x} + \frac{\partial (UV)}{\partial y} = -\frac{1}{\rho_o}\frac{\partial P_a}{\partial x} + fV + g\frac{\partial \eta}{\partial x}$$

$$-\frac{1}{\rho_o}\frac{\partial R_{xx}}{\partial x} - \frac{1}{\rho_o}\frac{\partial R_{xy}}{\partial y} + \frac{1}{\rho_o}\frac{\partial \tau_{xx}}{\partial x} + \frac{1}{\rho_o}\frac{\partial \tau_{yx}}{\partial y} + \frac{(\tau_x^b + \tau_x^s)}{\rho_o h}$$

$$\frac{\partial V}{\partial t} + \frac{\partial (UV)}{\partial x} + \frac{\partial V^2}{\partial y} = -\frac{1}{\rho_o}\frac{\partial P_a}{\partial y} - fU + g\frac{\partial \eta}{\partial y}$$

$$-\frac{1}{\rho_o}\frac{\partial R_{yy}}{\partial y} - \frac{1}{\rho_o}\frac{\partial R_{xy}}{\partial x} + \frac{1}{\rho_o}\frac{\partial \tau_{yy}}{\partial y} + \frac{1}{\rho_o}\frac{\partial \tau_{yx}}{\partial x} + \frac{(\tau_y^b + \tau_y^s)}{\rho_o h}$$

$$\frac{1}{H}\frac{\partial \eta}{\partial t} + \frac{\partial U}{\partial x} + \frac{\partial V}{\partial y} = 0$$

Where U and V are horizontal velocity components, P_a atmospheric pressure, f the coriolis effect, η the water height above mean water level (MWL), R the Reynolds stress, and H the total water depth. The product of two velocity fluctuations (with respect to the vertical average) are represented as the internal stress terms τ_{xx}, τ_{yy}, τ_{xy}, and the bottom stress τ_x^s, τ_y^s. Reynolds and internal stress terms cannot be directly included in the equations, and are usually neglected as being small. These effects can be included by assuming a functional relationship with the horizontal velocity gradient as follows:

$$\frac{1}{\rho_o} (\tau_{ij} - R_{ij}) = \varepsilon_{ij} \left(\frac{\partial U_i}{\partial x_j} + \frac{\partial U_j}{\partial x_i}\right)$$

Where the coefficient ε is called the eddy viscosity coefficient. The bottom stress $\tau_x^{\ b}$, $\tau_y^{\ b}$ is assumed proportional to a quadratic function of velocity:

$$\frac{\tau_x{}^b}{\rho_o h} = \frac{CV\ (U^2 + V^2)^{1/2}}{h}$$

$$\frac{\tau_y{}^b}{\rho_o h} = \frac{CV\ (U^2 + V^2)^{1/2}}{h}$$

Where C is the bottom friction coefficient. The equations may now be expressed in the following form:

$$\frac{\partial U}{\partial t} + \frac{\partial U^2}{\partial x} + \frac{\partial (UV)}{\partial y} = fV + g\,\frac{\partial \eta}{\partial x}$$

$$+ \frac{\partial}{\partial x}\left(2\varepsilon_{xx}\,\frac{\partial U}{\partial x}\right) + \frac{\partial}{\partial y}\left[\varepsilon_{yx}\left(\frac{\partial V}{\partial x} + \frac{\partial U}{\partial y}\right)\right]$$

$$+ \frac{C\ U\ (U^2 + V^2)^{1/2}}{h}$$

$$\frac{\partial V}{\partial t} + \frac{\partial (UV)}{\partial x} + \frac{\partial V^2}{\partial y} = -\ fU + g\,\frac{\partial \eta}{\partial y}$$

$$+ \frac{\partial}{\partial y}\left(2\varepsilon_{yy}\,\frac{\partial V}{\partial y}\right) + \frac{\partial}{\partial x}\left[\varepsilon_{xy}\left(\frac{\partial U}{\partial y} + \frac{\partial V}{\partial x}\right)\right]$$

$$\frac{+\ CV\ (U^2 + V^2)^{1/2}}{h}$$

$$\frac{1}{H}\frac{\partial \eta}{\partial t} + \frac{\partial U}{\partial x} + \frac{\partial V}{\partial y} = 0$$

The atmospheric pressure gradient and the surface stress terms have been omitted. They can be important for specific atmospheric conditions, but in general they are not important, and the difficulty in specifying these terms makes their inclusion questionable at best.

The left hand side of the momentum equations is composed of the termporal and convective acceleration terms. The right hand side of the equations is composed of the forces acting on a fluid particle. The surface slope and bottom friction terms are the dominant forces, while the coriolis force and eddy viscosity term are secondary effects. The surface slope, acting as a hydraulic head, forces the flow, while the bottom friction is the primary resisting force.

LEENDERTSE'S FINITE DIFFERENCE MODEL

The two-dimensional finite difference solution technique developed by Leendertse is generally accepted and has broad application. The conservation of momentum and mass equations are reduced to a two-dimensional, vertically averaged form for solution:

$$\frac{\partial U}{\partial t} + U\frac{\partial U}{\partial x} + V\frac{\partial U}{\partial y} = fV + g\frac{\partial \eta}{\partial x} + g\frac{U(U^2+V^2)^{\frac{1}{2}}}{C_h^2\, H} + \frac{\tau_x^s}{\rho h}$$

$$\frac{\partial V}{\partial t} + U\frac{\partial V}{\partial x} + V\frac{\partial V}{\partial y} = -fU + g\frac{\partial \eta}{\partial y} + g\frac{V(U^2V^2)^{\frac{1}{2}}}{C_h^2\, H} + \frac{\tau_y^s}{\rho h}$$

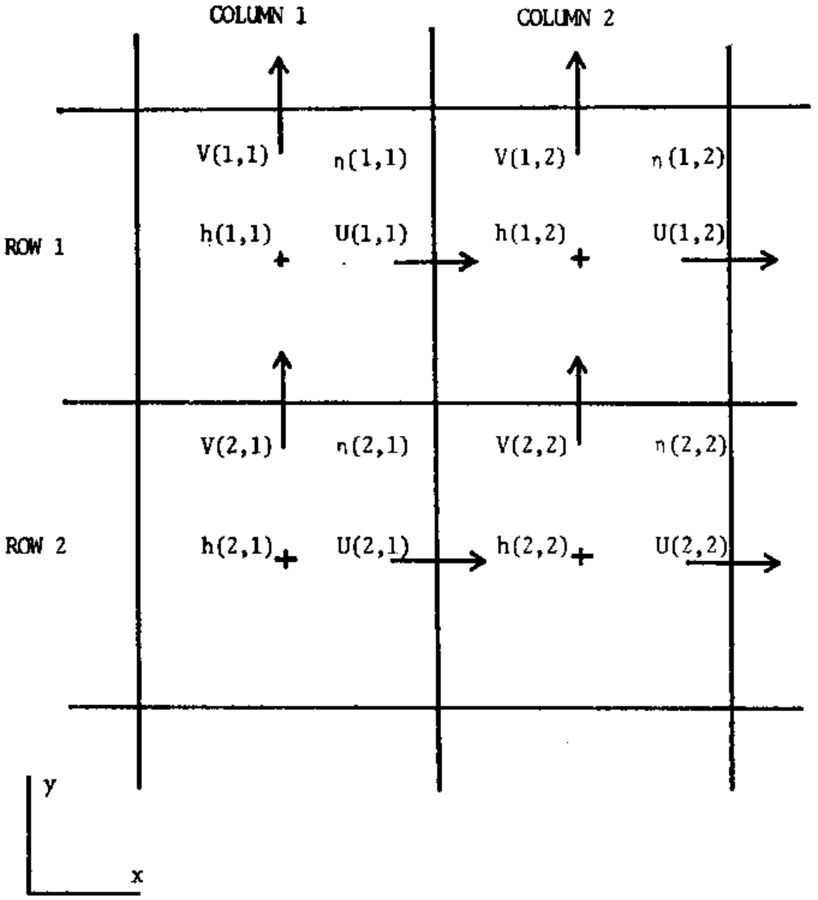
$$\frac{\partial \eta}{\partial t} + \frac{\partial}{\partial x}(HU) + \frac{\partial}{\partial y}(HV) = 0$$

U and V are the vertically averaged velocities in the x and y directions respectively, η is the elevation of the water surface above the mean water level (MWL), h is the depth of the water from MWL, H the total water depth which equals h + η, C_h the Chezy friction coefficient, τ_x and τ_y are the wind stress components.

A computational grid is selected to represent the geometry of the estuary. The various parameters are staggered on the grid as shown in Figure 2. The surface elevation is computed at the grid point, the U and V velocity components are computed midway between grid points, and the MWL depth h is selected for the center of every four grid points. The time step Δt is divided in half, with a solution obtained for each half time step. In the first solution, the U velocities are computed along each row using an implicit finite difference technique, and then the V velocities are computed explicitly along each column. The process is reversed in the second half time step, computing V velocities implicitly, and U velocities explicitly. The final result for the time step is obtained by averaging the explicit and implicit solution for velocity components at each point.

FIGURE 2

THE FINITE DIFFERENCE GRID AND THE PARAMETER STAGGERING SCHEME OF LEENDERTSE



Four elements, numbered by rows and columns, and the location of the variables in each element, are presented. Element (1,2) is complete, and shows the variables associated with it. In addition to its own variables, it is affected by all three of the other surface elevations, the U velocity of element (1,1), and the V velocity of element (2,2).

CONNOR AND WANG'S FINITE ELEMENT MODEL

The two-dimensional finite element solution technique developed by Connor and Wang is a unique and promising new approach. The two-dimensional vertically averaged conservation of momentum and mass equations used in the model are:

$$\frac{\partial q_x}{\partial t} + \frac{\partial (Uq_x)}{\partial x} + \frac{\partial (Uq_y)}{\partial y} = -\frac{\partial F_p}{\partial x} + g\frac{(h\eta)}{\partial x}$$

$$+ fq_y + \frac{\partial F_{xx}}{\partial x} + \frac{\partial F_{yx}}{\partial y} + (\tau_x^b - \tau_x^s)$$

$$\frac{\partial q_y}{\partial t} + \frac{\partial}{\partial x}(Vq_x) + \frac{\partial}{\partial y}(Vq_y) = -\frac{\partial F_p}{\partial y} + g\frac{\partial}{\partial y}(h\eta)$$

$$-fq_x + \frac{\partial F_{yy}}{\partial y} + \frac{\partial F_{xy}}{\partial x} + (\tau_y^b - \tau_y^s)$$

$$\frac{\partial \eta}{\partial t} + \frac{\partial q_x}{\partial x} + \frac{\partial q_y}{\partial y} = q_i$$

with the constitutive relations:

$$F_{xx} = \int_{-h}^{\eta} (\tau_{xx} - \rho(u')^2)\, dz = \xi_{xx}\frac{\partial q_x}{\partial x}$$

$$F_{yy} = \int_{-h}^{\eta} (\tau_{yy} - \rho(v')^2)\, dz = \xi_{yy}\frac{\partial q_y}{\partial y}$$

$$F_{xy} = F_{yx} = \int_{-h}^{\eta} (\tau_{xy} - \rho(u'v'))\, dz = \xi_{xy}\left(\frac{\partial q_y}{\partial x} + \frac{\partial q_x}{\partial y}\right)$$

$$F_p = gh\eta + 1/2\, g\eta^2 + \frac{\Delta\rho}{2\rho_o} g H^2 + \frac{p^s}{\rho_o} H$$

$$\tau_x^b = \frac{C_f q_x (q_x^2 + q_y^2)^{1/2}}{\rho H^2}$$

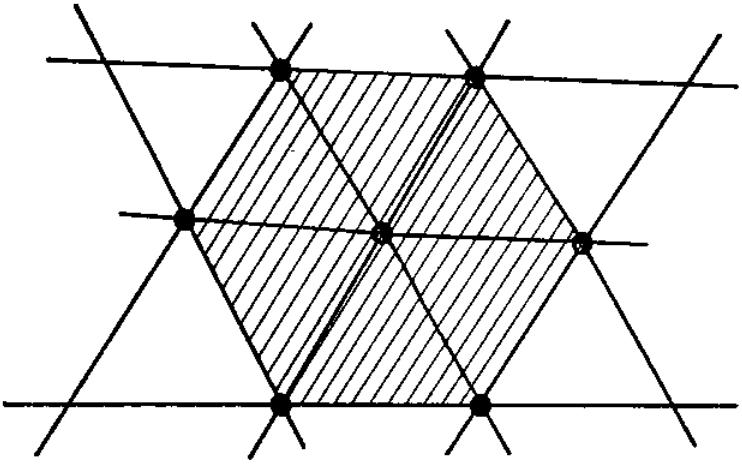
$$\tau_y^b = \frac{C_f q_y (q_x^2 + q_y^2)^{1/2}}{\rho H^2}$$

Where H is the total water depth, U and V the vertically averaged velocities, u' and v' the velocity fluctuations with respect to the ensemble average, q_x and q_y equal HU and HV respectively, h the depth of the water at MWL, η the height of the water surface above MWL, ρ_o the average density, $\Delta\rho$ the density fluctuation, C_f the bottom friction coefficient, τ_{xx}, τ_{yy}, τ_{xy} are internal stresses, and ξ_{xx}, ξ_{yy}, ξ_{xy} are eddy viscosity coefficients.

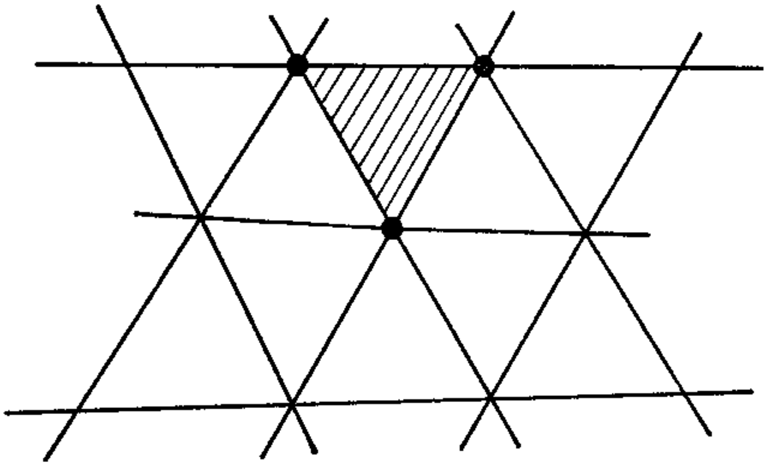
The finite element method approximates the solution of a boundary value problem with a function of piece-wise continuous polynomials. It is based on discretization of the continuum into an equivalent system of finite elements. Connor and Wang selected the simplest configuration, triangles with nodes at the angles. The values of the variables within the element have been assumed a linear function of the values at the nodes. The equations are transformed for application to an element using this linear polynominal representation. Treatment of the entire continuum is accomplished through summation of the contributions of each element. The domain of influence of a nodal value and an element value are graphically displayed in Figure 3. Solutions for q_x, q_y and η are obtained at each node. Depth is selected at each node point, while bottom friction and eddy viscosity are selected for each element.

FIGURE 3

CONNOR AND WANG'S DOMAIN OF INFLUENCE FOR NODE AND ELEMENT VALUES



Domain for Influence for Node Values



Domain of Influence for Element Values

A node variable or parameter affects all of the adjacent elements (six in this example), as the value of the variable or parameter within each element is a function of the values at the nodes. An element parameter affects the three nodes of the element.

MODEL APPLICATION

Connor and Wang's finite element model was chosen over Leendertse's finite difference model for this particular application because of the complexity of the geometry in the Great Bay Estuary system, and the need to model the estuary in segments, resulting from computational limitations. Connor and Wang's model has been applied to the Portsmouth Harbor, Piscataqua River, Little Bay and Great Bay segments of the estuary. A listing of the input data and a plot of the grid for each model are presented in Appendices III through VI respectively.

The grid was selected to coincide with the coastal and bathymetric features of the estuary as presented by United States Coast and Geodetic Survey chart No. 210. The model is not presently capable of handling mud flats, and these are, for the most part, neglected. The average distance between adjacent nodes is the characteristic length of the grid. The features included in the grid are at least as large as two characteristic lengths.

Several other factors, involving numerical stability, were considered when developing the grid. The size and shape of the elements may vary, but the most stable configuration is equilateral triangles of equal size. To preserve the grid stability, the general guidelines followed for these considerations are: (1) area of adjacent elements should vary less than 20 percent, and (2) angles of elements should be greater than 30 and less than 90 degrees. Another factor considered in selecting the grid is that an element may not have more than two of its three nodes on a land boundary. The final consideration is the number of nodes and elements to be included. The larger the number of nodes, the greater the detail, but computer core and time requirements are also increased. The maximum size of the time step is related to the characteristic length, and for this particular application the small characteristic lengths constrained the size of the time steps. As a result of these computational constraints, the grid was selected with as large a characteristic length as possible. The grids were modified several times to obtain an acceptable result.

Boundary conditions were set up as specified for the model. Land boundary conditions are handled internally by the model, forcing the flow to be tangential to the land. To accomplish this, normal angles (with respect to the land boundary) must be specified for each node on a land boundary. This task was simplified through the use of a simple auxiliary program listed in Appendix XI. Rivers are not considered in this preliminary development as their effect is secondary to the tidal prism, and are therefore treated as land boundaries. The open boundaries are treated by specifying the tidal amplitude, the tidal frequency and the phase lag. The tidal frequency was assumed standard, and is the same for all open boundaries. The tidal amplitude was selected for each open boundary, and the phase for each node on each open boundary. The values for these parameters were obtained from the Tide Tables of North America.

The bottom friction coefficient was assumed constant throughout the grid, and a medium value was chosen for preliminary runs. The eddy viscosity coefficient was assumed constant throughout the grid, with an arbitrary value selected for the ε_{xx} and ε_{yy} coefficients, and a smaller value for the ε_{xy} coefficient.

With the data for the model set up, the model was run using a constant depth (representative of the depth of the estuary) for initial runs, as the model is sensitive to this parameter. This allowed the stability of the grid to be tested, and approximate values for the friction and eddy viscosity coefficients to be found. After the grid had been evaluated and modified, and the coefficients evaluated, the depth of the estuary at each node was entered, again using chart No. 210. The chart data was supplemented for the Piscataqua River channel with data from a University of New Hampshire bathymetric survey. To preserve the cross sectional areas and volume characteristics of the estuary segment, slight modification of the depths was necessary. The model was run again, with varying depths, to test the stability of the fully three-dimensional grid. Large changes in depth within an element, and very shallow depths, cause numerical instabilities, requiring slight modifications. This initial development and testing has been completed, and the model is ready for calibration.

EVALUATION OF CRITICAL MODEL PARAMETERS

The model uses two parameters which must be evaluated for the estuary: the bottom friction coefficient and the eddy viscosity coefficient. Bottom friction plays a major role in estuary dynamics. This frictional effect is expressed in the model in the form CU^2/h, where C is the friction coefficient, U the vertically averaged velocity, and h the water depth. The eddy viscosity term is a combination of Reynolds Stress terms, resulting from ensemble averaging, and internal stress terms, resulting from the vertical averaging. It is expressed in the form $\frac{\partial}{\partial x} (\varepsilon_{xx} \frac{\partial u}{\partial x})$ where ε_{xx} is the eddy viscosity coefficient and $\partial u/\partial x$ is the horizontal current gradient. Both of the coefficients are assumed constant in time, and constant for an element. They may be specified for each element individually, however, allowing spatial changes in the coefficients from element to element. The values of these parameters are selected, in a process called model calibration, to cause model results to compare favorably with field data. A procedure for selection of these parameters would greatly assist in model calibration.

The initial step in the development of such a procedure is a review of the physical processes involved. Current velocity is a function of the tidal amplitude, bottom friction coefficient, and eddy viscosity coefficient. The tidal elevation at open boundaries is used as the forcing function for the model. It is specified as A cos (ωt), where A is the tidal amplitude, ω the frequency of the tide, and t the time. The current speed is proportional to the tidal elevation, and inversely proportional to the bottom friction coefficient. The primary effect of the eddy viscosity term on current velocity is to cause a phase shift, while its effect on the current magnitude is secondary.

A numerical experiment was conducted, consisting of a series of model simulations, to determine the effects of these three parameters on the model results. A simulation consisted of running the Little Bay model for one and one-half tidal cycles, allowing half a tidal cycle for the model to settle down numerically. Three sets of simulations were run, one for each of the parameters to be tested. Each set consisted of four simulations, holding two of the parameters constant while specifying a different value of the third parameter for each simulation. One simulation was common to all three sets, so a total of ten different simulations were carried out. Table 1 presents a list of all the coefficients used for the various simulations. Both u and v components of the velocity at a specific node were output every 20 minutes of simulation time, for a total of 37 current vectors over the tidal cycle for each simulation.

This data is presented as a series of graphs of current speed and direction plotted against time. Figure 4 presents these two plots for the simulation set in which amplitude was varied. The speed increases with increasing tidal amplitude, while slight variations in curve shape indicate the presence of phase variations. The direction plot indicates that the current direction is well-behaved, and the phase variation present. This confirms that current speed is proportional to tidal amplitude, and also indicates that phase varies with tidal amplitude.

The variation of friction coefficient simulation set results are presented in Figure 5. It can be seen from the speed plot that current velocity varies inversely with respect to the friction coefficient as expected. The direction plot indicates little or no phase variation for changing friction coefficients.

TABLE 1

SUMMARY OF PARAMETER VALUES FOR NUMERICAL EXPERIMENTS

	A	C	ξ_{xx}	ξ_{yy}	ξ_{xy}
Amplitude	0.8	0.020	18.0	18.0	8.0
	1.0	0.020	18.0	18.0	8.0
	1.2*	0.020	18.0	18.0	8.0
	1.4	0.020	18.0	18.0	8.0
Friction Coefficient	1.2	0.012	18.0	18.0	8.0
	1.2	0.016	18.0	18.0	8.0
	1.2*	0.020	18.0	18.0	8.0
	1.2	0.025	18.0	18.0	8.0
Eddy Viscosity Coefficient	1.2	0.020	9.0	9.0	4.0
	1.2*	0.020	18.0	18.0	8.0
	1.2	0.020	27.0	27.0	12.0
	1.2	0.020	36.0	36.0	16.0

*Simulation common to all three sets

The eddy viscosity simulation set results, presented in Figure 6, include one case ($\xi_{xx} = 36.0$) which is numerically unstable. Neglecting this case, the plots indicate a phase variation in speed with respect to the eddy viscosity coefficient.

Summarizing the results of these graphs, shows that the magnitude of the current velocity is a function of tidal amplitude and bottom friction coefficient, while the phase shift of the current is a function of tidal amplitude and the eddy viscosity coefficient. Since the tidal amplitude is determined by the physical conditions present at the boundary, calibration of the model with respect to current velocity magnitude is accomplished by changing the bottom friction coefficient, while calibration with respect to phase is carried out through modifications of the eddy viscosity coefficient.

To quantify the relations between tidal amplitude, bottom friction and current velocity, the data was normalized by dividing by a characteristic velocity. A characteristic velocity can be developed from the conservation of momentum equation for channel flow. For a one-dimensional, constant depth channel, neglecting the eddy viscosity term, the conservation of momentum equation can be written:

$$\frac{\partial U}{\partial t} + U\frac{\partial U}{\partial x} = -g\frac{\partial \eta}{\partial x} + \frac{CU^2}{h}$$

Where U is the vertically averaged current velocity, η the surface elevation, h the water depth, and C the friction coefficient. Evaluating the order of magnitude for each term in the equation for the Great Bay Estuary system:

$$\begin{array}{cccc} \dfrac{\partial U}{\partial t} + & U\dfrac{\partial U}{\partial x} = & -g\dfrac{\partial \eta}{\partial x} + & \dfrac{CU^2}{h} \\ 10^{-4} & 10^{-4} & 10^{-3} & 10^{-3} \end{array}$$

Neglecting the acceleration terms because they are an order of magnitude smaller yields:

$$g \frac{\partial\eta}{x} = \frac{CU^2}{h}$$

or

$$U = \left(\frac{gh}{C} \frac{\partial\eta}{\partial x}\right)^{\frac{1}{2}}$$

Where U is the characteristic velocity. For $\Delta x = L/4$, where L is the tidal wage length, $\Delta\eta = A$, the tidal amplitude:

$$U = \left(\frac{4ghA}{CL}\right)^{\frac{1}{2}} = \left(\frac{4gh}{L}\right)^{\frac{1}{2}} \left(\frac{A}{C}\right)^{\frac{1}{2}}$$

Evaluating to the order of magnitude:

$$\left(\frac{4gh}{L}\right)^{\frac{1}{2}} = 10^{-1}$$

and the characteristic velocity U can be expressed as:

$$U = 0.1 \left(\frac{A}{C}\right)^{\frac{1}{2}}$$

The variation of the maximum normalized velocity among the simulations (with the exception of the unstable case) is less than five percent. Therefore, for a given amplitude, this formula can be used in the selection of appropriate values for the bottom friction coefficient when calibrating the model.

The relations between tidal amplitude, eddy viscosity coefficient, and current phase are very complex. A qualitative, graphic approach was taken to provide insight into the selection of proper eddy viscosity coefficients. The numerical experiment data, normalized using the above procedure, is presented as phase plane plots, or hodographs. These are plots of one current component verses the other current component over the tidal cycle. The plots for the eddy viscosity coefficient set (Figure 7) show the increasing width of the curve as eddy viscosity increases, clearly delineating the phase effects of the eddy viscosity term. Note the plot shape for the unstable simulation ($\xi_{xx} = 36.0$). It can be seen that the eddy viscosity effects vary for the tidal amplitude (Figure 8) and bottom friction coefficient sets (Figure 9), despite the fact that the eddy viscosity coefficient is held constant. This occurs as the eddy viscosity term is a function of the second spatial derivative of the horizontal velocity and not the horizontal velocity itself. This indicates that the bottom friction coefficients must be evaluated first; then the eddy viscosity coefficients can be evaluated from comparison of phase plane plots of normalized model results and field data.

The results of these tests will facilitate the calibration of the models. The quantitative aspect in the relation of the tidal amplitude and friction coefficient to current velocity will eliminate much of the trial and error work previously associated with this step in the model development. The eddy viscosity coefficient must still be selected qualitatively, but this is the only parameter selected this way. Therefore, simple comparison of the shape of hodograph curves of normalized field data and model results at corresponding locations in the estuary should prove adequate.

FIGURE 4

CURRENT SPEED AND DIRECTION PLOTS FOR THE TIDAL AMPLITUDE EXPERIMENT

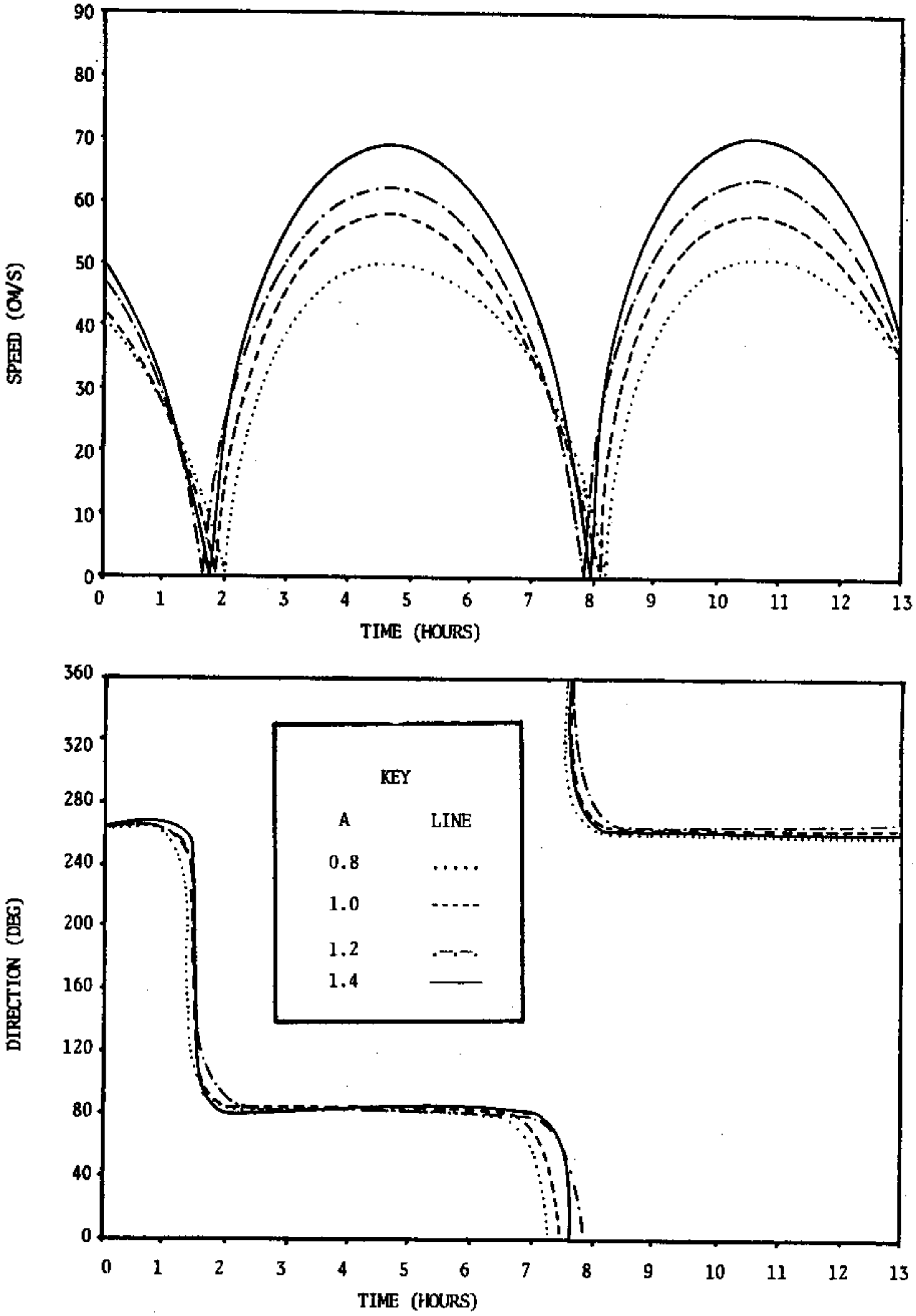


FIGURE 5

CURRENT SPEED AND DIRECTION PLOTS FOR THE BOTTOM FRICTION EXPERIMENT

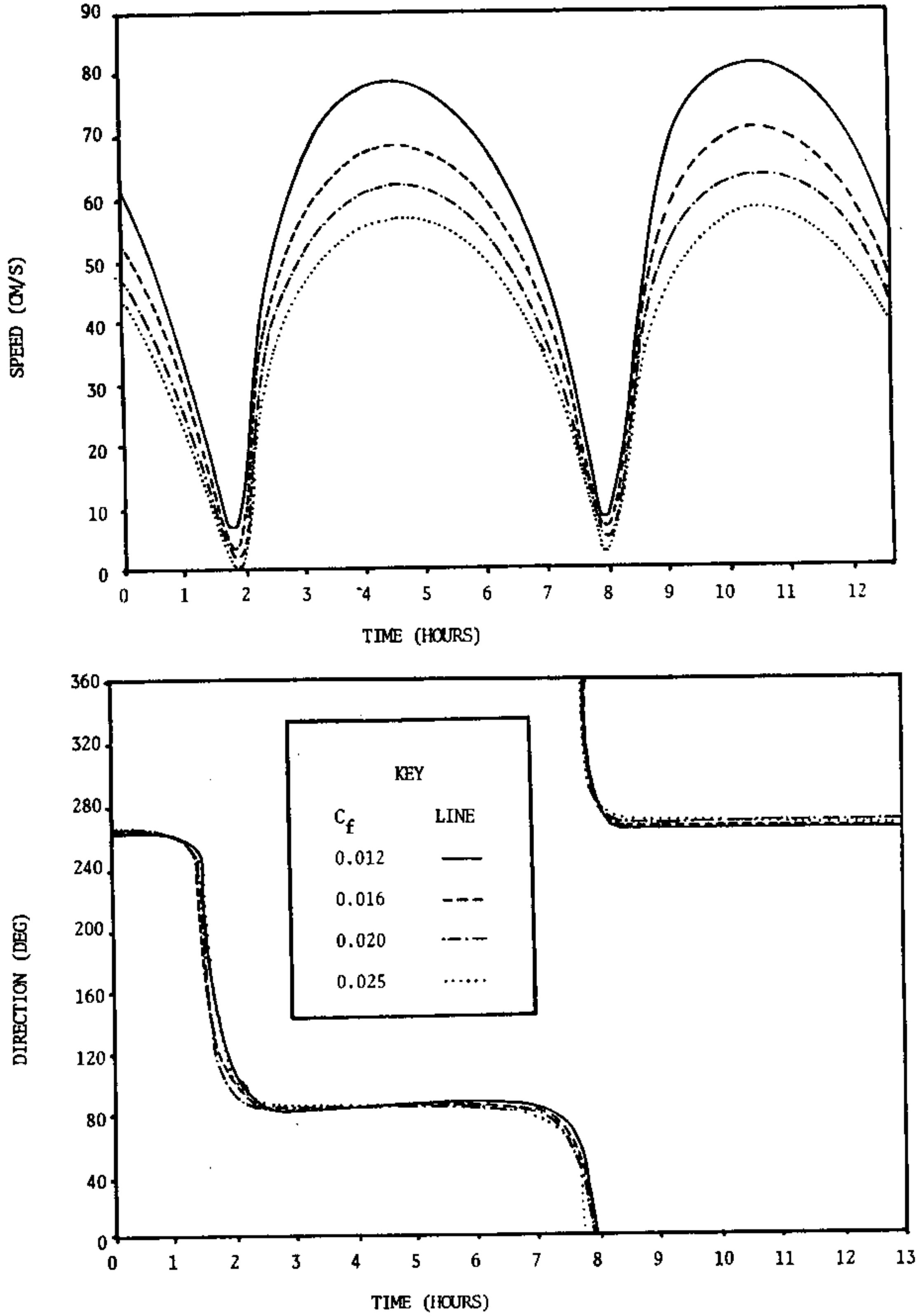


FIGURE 6

CURRENT SPEED AND DIRECTION PLOTS FOR THE EDDY VISCOSITY EXPERIMENT

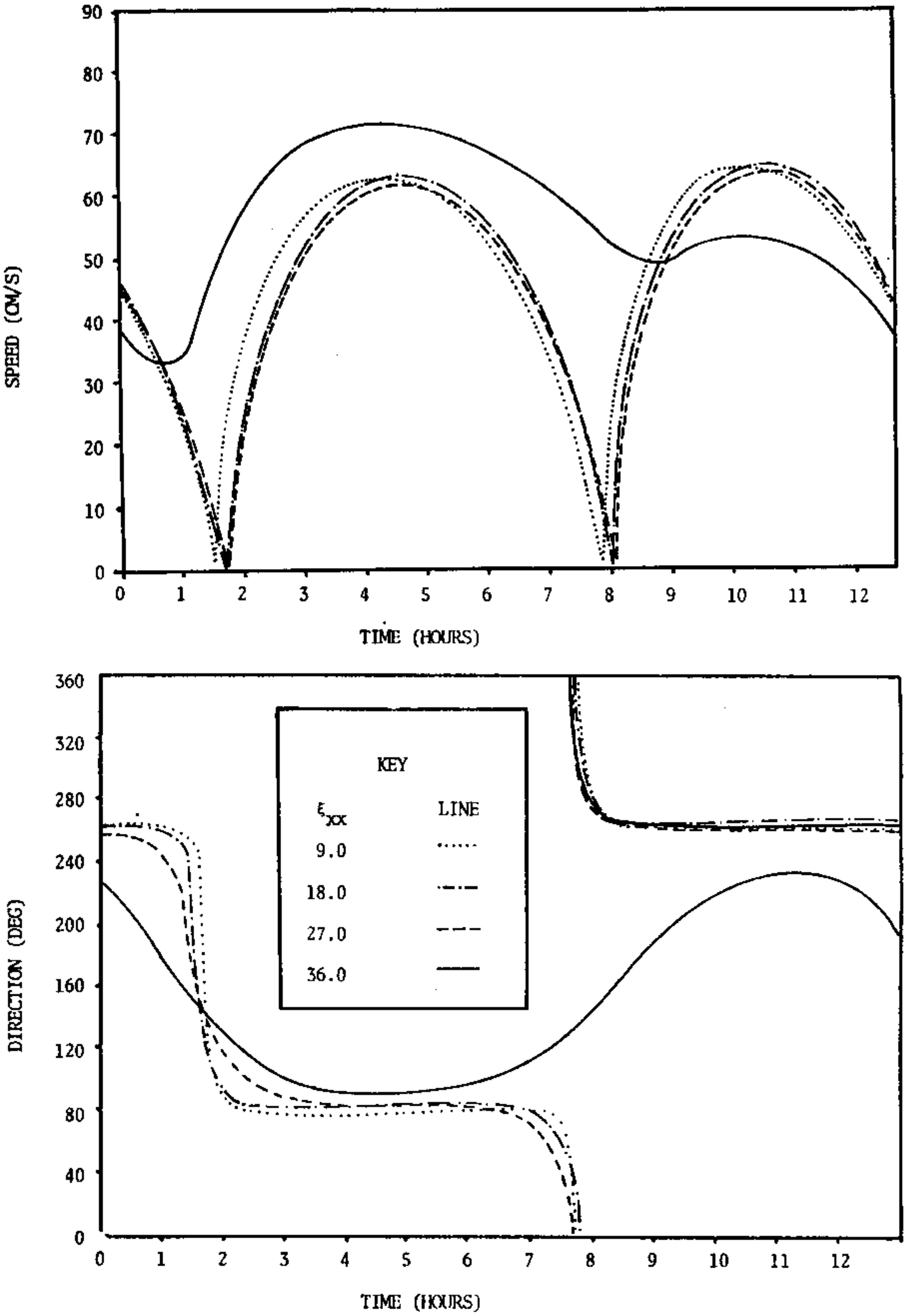


FIGURE 7

HODOGRAPH OF NORMALIZED CURRENT DATA FOR THE EDDY VISCOSITY COEFFICIENT EXPERIMENT

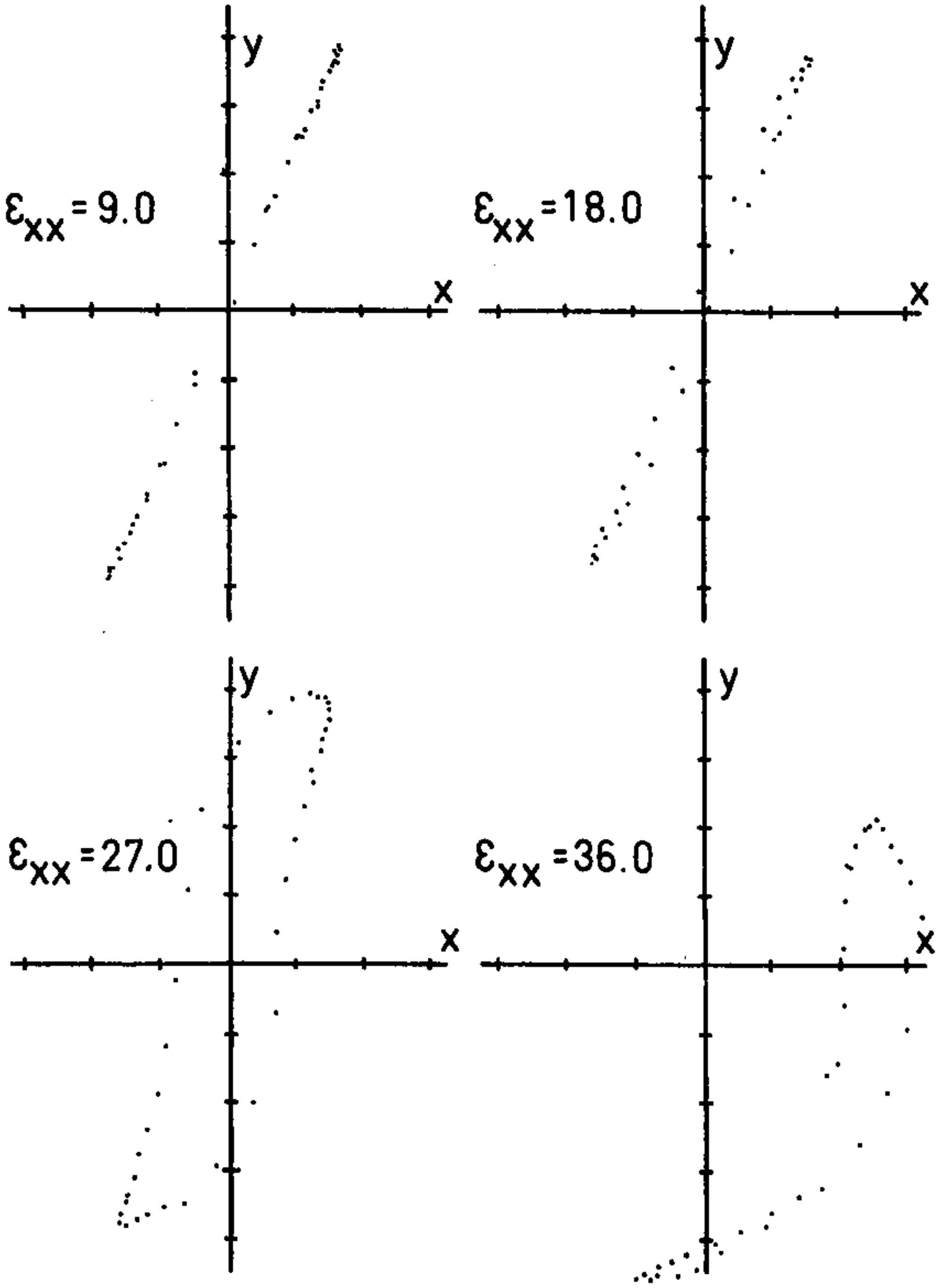


FIGURE 8

HODOGRAPH OF NORMALIZED CURRENT DATA FOR THE TIDAL AMPLITUDE EXPERIMENT

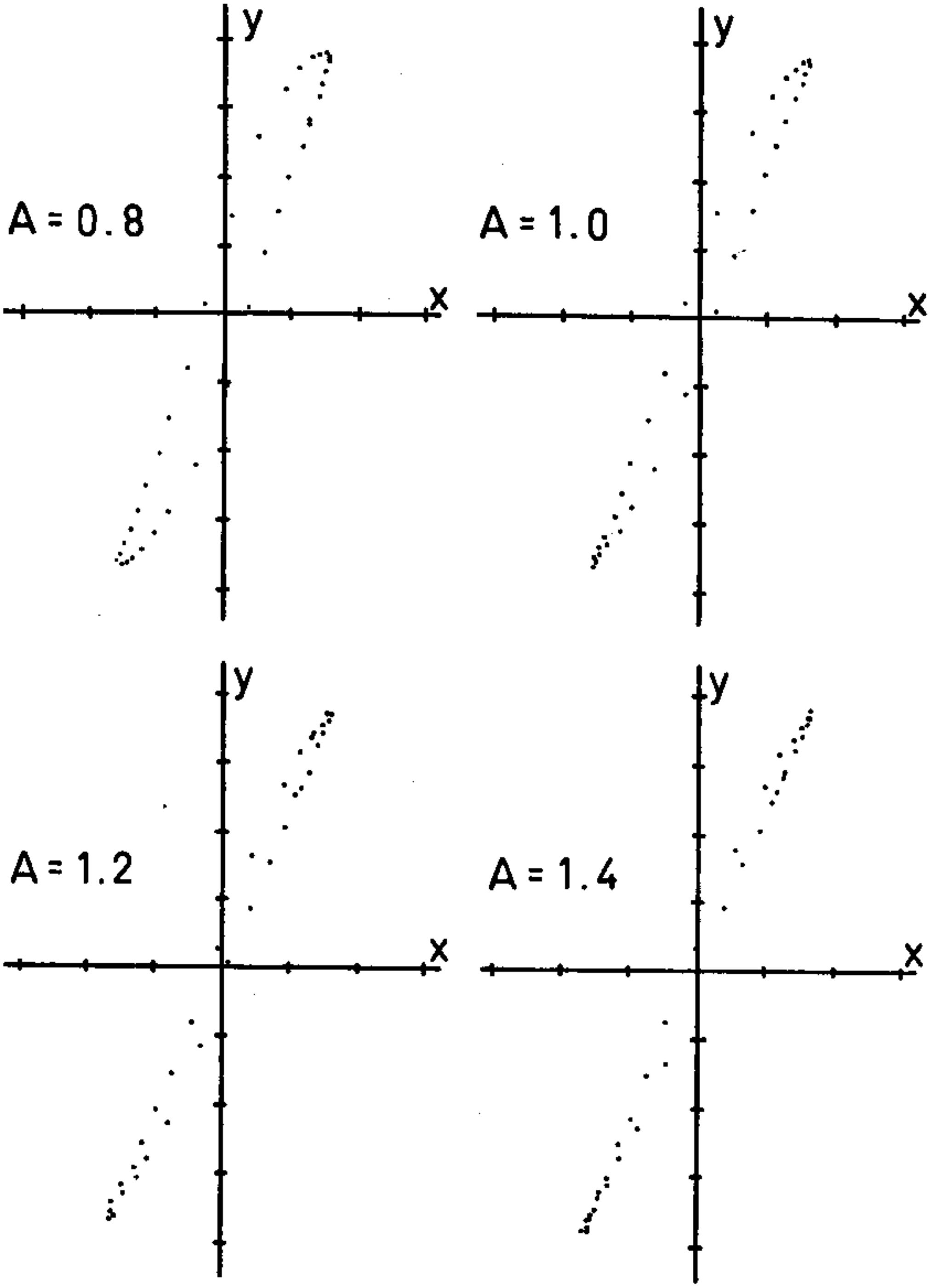
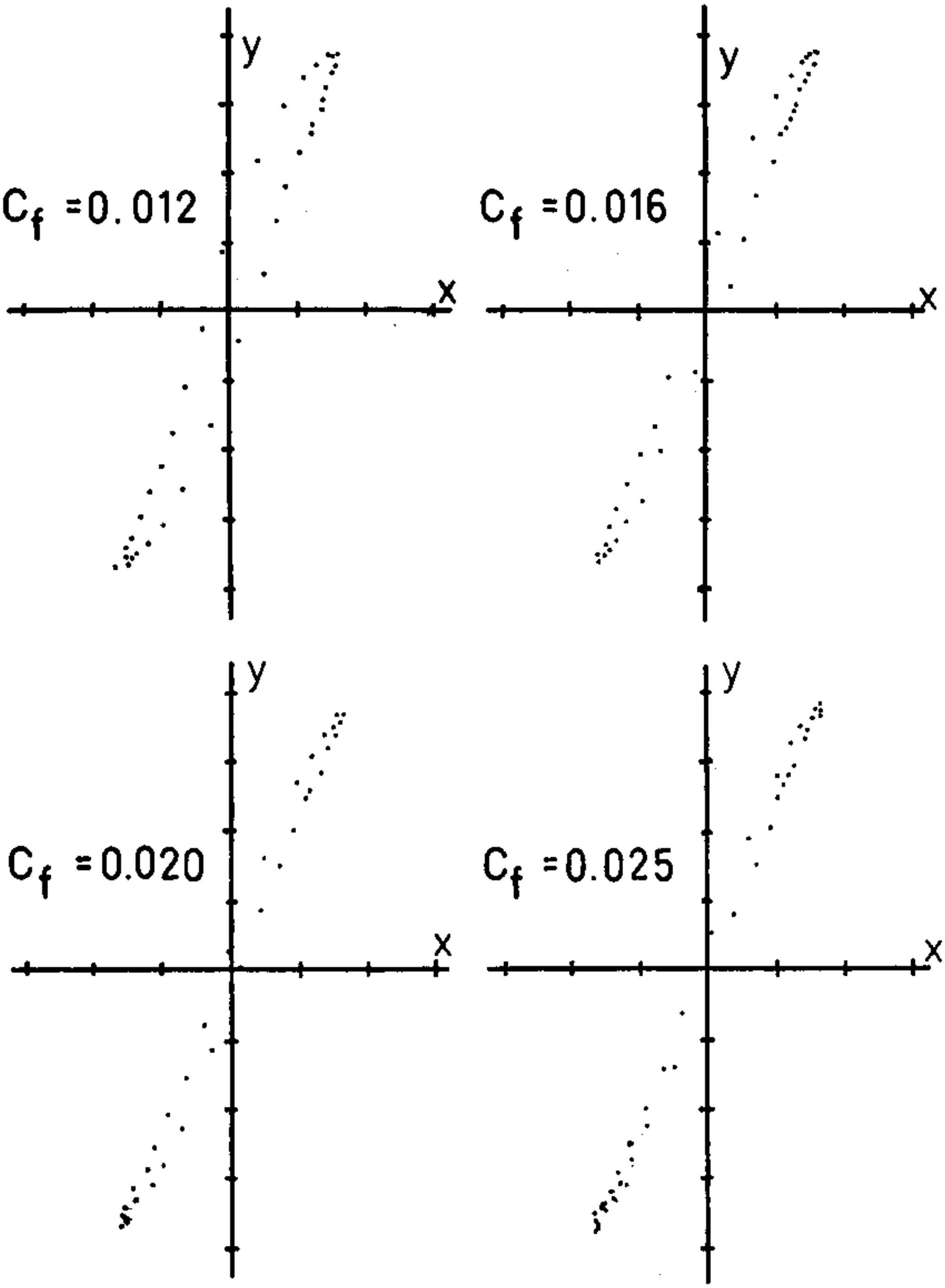


FIGURE 9

HODOGRAPH OF NORMALIZED CURRENT DATA FOR THE BOTTOM FRICTION COEFFICIENT EXPERIMENT



PRELIMINARY RESULTS

The model output is in the form of tidal elevation above mean water level and current velocity components at each node. Although the data in this form is important, it is difficult to develop an understanding of the overall flow characteristics from it. Therefore, graphical techniques have been applied to the model results to present a general picture of the characteristics. Surface elevation isoplots for individual time steps have been developed to illustrate the spatial gradients of surface elevation. Current vector plots for individual time steps illustrate the current patterns predicted by the model for any particular time in the tidal cycle. These plots are useful for evaluation of the model as well as presentation of final results for various applications.

Results for the Portsmouth Harbor, Piscataqua River, Little Bay and Great Bay models are presented in tabular and graphic form in Appendices VII through X respectively. These are only preliminary results, as the models have not been calibrated.

Qualitatively, the results of the models are acceptable for this stage of development. Current patterns and surface gradients are reasonable and compare favorably with the geometry of the basin. Higher currents and surface gradients are present in narrower and shallower parts of the estuary where the cross-sectional area is less. Comparison with preliminary field data indicates that appropriate current velocities can be predicted by the model. The models have been developed as completely as possible without detailed comparison with field data.

MODEL CALIBRATION

The model calibration is expected to be undertaken soon. The UNH/NOS cooperative field program was carried out successfully last summer for the majority of the Great Bay Estuary system, and the remainder of the program (the Portsmouth Harbor area) will be carried out this summer. Data analysis for the UNH portion of the program is nearly complete. Tide data has been received from NOS for the locations of importance for model calibration. The NOS current data is expected soon and will allow the model calibration process to begin.

Calibration of the model is the adjustment of bottom friction and eddy viscosity coefficients to cause the model results to compare more favorably with the data base. The comparisons of model results with the data base will take the following forms:

1) Comparison of tidal elevation and phase at points in the model corresponding to UNH/NOS tide stations.
2) Comparison of cross-sectional area mass flux at sections in the model corresponding to the UNH current data transects.
3) Comparison of current amplitude and phase at points in the model corresponding to NOS current stations and UNH transect stations.
4) Comparison of current hodographs at points in the model corresponding to NOS current stations and UNH transect stations.

The tidal elevation comparison will be helpful in evaluating spatial change in the bottom friction coefficient. Comparisons of cross-sectional mass flux and current data, together with tidal elevation data, will be used to calculate bottom friction coefficients, through the use of the parameter evaluation technique developed earlier. Comparison of hodographs will be used to evaluate eddy viscosity coefficients.

APPENDIX I

BATHYMETRY OF THE GREAT BAY ESTUARY SYSTEM

VOLUME DETERMINATIONS

Great Bay Estuary System

	Volume		Tidal Prism	
	$10^6 m^3$	%	$10^6 m^3$	%
Great Bay	42.8	16.2	28.2	29.3
Little Bay	59.7	22.6	22.6	23.5
Upper Piscataqua River	13.4	5.1	7.5	7.8
Lower Piscataqua River	147.7	56.0	37.8	39.3
Total	263.6	99.9	96.1	99.9

HYPSOMETRIC DATA
(Based on Area)

Area	Great Bay		Little Bay		Upper Piscataqua		Lower Piscataqua		Estuarine System	
Between	%	Cum%	%	Cum%	%	Cum%	%	Cum%	%	Cum%
Tidal Flat	46.2		29.4		48.1		27.2		35.6	
Low Tide	53.8		70.6		59.1		72.8		64.4	
0 - 1	52.8*	52.8								
1 - 6	25.2	78.0	36.8*	36.8	55.3*	55.3	21.9*	21.9	42.4*	42.4
6 - 12	13.2	91.2	12.9	49.7	27.0	82.3	12.1	34.0	13.6	56.0
12 - 18	3.8	95.0	8.6	58.3	11.3	93.6	10.1	44.1	8.2	64.2
18 - 24	1.7	96.7	9.7	68.0	6.3	99.9	16.7	60.8	12.4	76.6
24 - 30	0.7	97.4	8.7	76.7						
30 - 40	1.5	98.9	12.7	89.4			14.3	75.1	9.5	86.1
40 - 50	0.9	99.8	9.4	98.8			13.2	88.3	8.1	94.2
50 - 60	0.2	100.0	1.0	99.8			8.9	97.2	4.4	98.6
> 60							2.8	100.0	1.3	99.9

*% of low tide area

HYPSOMETRIC DATA
(Based on Volume)*

Interval	Great Bay		Little Bay		Upper Piscataqua		Lower Piscataqua		Estuarine System	
Frequency	%	Cum%	%	Cum%	%	Cum%	%	Cum%	%	Cum%
Tidal Prism	66.2		37.9		55.3		25.5		36.5	
Mean Low Tide	33.8		62.1		44.7		74.5		63.5	
0 - 1	19.4	19.4								
			27.2	27.2	60.9	60.9	21.3	21.3	26.8	26.8
1 - 6	37.0	56.4								
6 - 12	19.8	76.2	18.9	46.1	26.3	87.2	17.3	38.6	18.1	44.9
12 - 18	8.9	85.1	15.3	61.4	10.1	97.3	14.6	53.2	14.1	59.0
18 - 24	5.3	90.4	17.2	78.6	2.7	100.0				
							22.8	76.0	21.8	80.8
24 - 30	3.8	94.2	9.2	87.8						
30 - 40	4.0	98.2	9.3	97.1			12.8	88.8	10.9	91.7
40 - 50	1.4	99.6	2.7	99.8			7.3	96.1	5.6	97.3
50 - 60	0.4	100.0	0.3	100.1			2.9	99.0	2.0	99.3
> 60							1.0	100.0	0.7	100.0

*% of volume at mean low tide

APPENDIX II

ENSEMBLE AVERAGE DEFINITION

The major part of the dynamics of the estuary is deterministic, but part of the motion of the fluid is random in nature. The basic equations include all of the dynamics, both stochas stochastic and deterministic, but for a deterministic solution, the stochastic processes must be handled statistically.

Let us assume that the appropriate instantaneous motions and properties can be measured in detail for a period of time and that the external forcing processes are known. Assuming that the measurements have been taken for a number of these periods having the same external forces, the records can be analyzed to obtain the deterministic and stochastic modes. The deterministic value of a parameter at time t_o is obtained by averaging all the records of the parameter at time t_o. This averaging process is called the ensemble average.

APPENDIX III

PORTSMOUTH HARBOR INPUT DATA AND GRID

```
    2  127   134     2     1     2     2     2     1     1   360     1
MIT FINITE ELEMENT HYDRODYNAMIC MODEL - PORTSMOUTH HARBOR
     1     3     294.64    2540.00     16.74       1.25  1200.0      0.0     210.00
     2     2     431.80    2590.80     16.74       1.25  1200.0      0.0        0.0
     3     3     584.20    2646.68      3.33       1.25  1200.0      0.0      225.0
     4     1     254.00    2392.68      9.12      0.0     193.48     0.0        0.0
     5     0     406.40    2438.40     13.69      0.0       0.0      0.0        0.0
     6     0     558.80    2484.12     10.64      0.0       0.0      0.0        0.0
     7     1     731.52    2529.84      3.33      0.0      48.29     0.0        0.0
     8     1     360.68    2275.84      7.60      0.0     229.58     0.0        0.0
     9     0     523.32    2336.80     15.22      0.0       0.0      0.0        0.0
    10     0     685.80    2372.36      7.60      0.0       0.0      0.0        0.0
    11     1     863.60    2397.76      3.33      0.0      47.19     0.0        0.0
    12     1     508.00    2179.32      5.16      0.0     228.39     0.0        0.0
    13     0     650.24    2219.96     16.74      0.0       0.0      0.0        0.0
    14     0     812.80    2240.28      5.16      0.0       0.0      0.0        0.0
    15     1    1005.84    2275.84      3.94      0.0      15.73     0.0        0.0
    16     1     614.68    2052.32      6.07      0.0     214.32     0.0        0.0
    17     0     767.08    2077.72     18.87      0.0       0.0      0.0        0.0
    18     1     949.96    2103.12      3.33      0.0      17.25     0.0        0.0
    19     1     706.12    1884.68     12.17      0.0     213.17     0.0        0.0
    20     0     914.40    1899.92     16.74      0.0       0.0      0.0        0.0
    21     1    1082.04    2001.52      3.33      0.0      62.53     0.0        0.0
    22     1     828.04    1727.20      6.07      0.0     241.96     0.0        0.0
    23     1     980.44    1717.04      6.07      0.0     262.78     0.0        0.0
    24     0    1107.44    1838.96     16.74      0.0       0.0      0.0        0.0
    25     1    1244.60    1950.72      3.94      0.0      76.01     0.0        0.0
    26     1    1143.00    1686.56      3.94      0.0     258.25     0.0        0.0
    27     0    1280.16    1808.48     19.79      0.0       0.0      0.0        0.0
    28     1    1407.16    1920.24      5.16      0.0     105.88     0.0        0.0
    29     1    1524.00    2026.92      5.16      0.0     103.57     0.0        0.0
    30     1    1320.80    1645.92      3.33      0.0     257.76     0.0        0.0
    31     0    1457.96    1767.84     19.79      0.0       0.0      0.0        0.0
    32     0    1574.80    1879.60     10.64      0.0       0.0      0.0        0.0
    33     1    1691.64    1981.20      3.33      0.0      77.64     0.0        0.0
    34     1    1518.92    1605.28      5.16      0.0     256.79     0.0        0.0
    35     0    1635.76    1732.28     16.74      0.0       0.0      0.0        0.0
    36     0    1757.68    1844.04     12.47      0.0       0.0      0.0        0.0
    37     1    1874.52    1950.72      6.99      0.0      78.05     0.0        0.0
    38     1    1691.64    1559.56      5.16      0.0     254.23     0.0        0.0
    39     0    1818.64    1676.40      6.99      0.0       0.0      0.0        0.0
    40     0    1935.48    1793.24     16.74      0.0       0.0      0.0        0.0
    41     1    2052.32    1905.00     10.57      0.0      74.59     0.0        0.0
    42     1    1844.04    1513.84      6.07      0.0     252.43     0.0        0.0
```

43	0	1976.12	1625.60	7.60	0.0	0.0	0.0	0.0
44	0	2098.04	1737.36	14.91	0.0	0.0	0.0	0.0
45	1	2225.04	1854.20	21.01	0.0	73.95	0.0	0.0
46	1	2011.68	1457.96	6.07	0.0	251.84	0.0	0.0
47	0	2133.60	1569.72	7.60	0.0	0.0	0.0	0.0
48	0	2255.52	1686.56	13.69	0.0	0.0	0.0	0.0
49	1	2387.60	1808.48	18.26	0.0	42.80	0.0	0.0
50	1	2169.16	1407.16	3.33	0.0	249.07	0.0	0.0
51	0	2286.00	1524.00	22.84	0.0	0.0	0.0	0.0
52	1	2423.16	1625.60	16.74	0.0	29.4	0.0	0.0
53	1	2306.32	1346.20	6.07	0.0	239.17	0.0	0.0
54	0	2438.40	1437.64	23.75	0.0	0.0	0.0	0.0
55	1	2590.80	1473.20	6.07	0.0	72.80	0.0	0.0
56	1	2418.08	1259.84	6.07	0.0	222.06	0.0	0.0
57	0	2570.48	1285.24	23.45	0.0	0.0	0.0	0.0
58	1	2509.52	1112.52	19.79	0.0	246.73	0.0	0.0
59	1	2682.24	1148.08	16.74	0.0	285.80	0.0	0.0
60	0	2727.96	1325.88	23.45	0.0	0.0	0.0	0.0
61	1	2773.68	1498.60	13.69	0.0	98.26	0.0	0.0
62	1	2849.88	1209.04	6.07	0.0	285.64	0.0	0.0
63	0	2895.60	1361.44	23.45	0.0	0.0	0.0	0.0
64	1	2941.32	1524.00	8.21	0.0	98.49	0.0	0.0
65	1	3027.68	1244.60	6.07	0.0	282.86	0.0	0.0
66	0	3073.40	1402.08	23.45	0.0	0.0	0.0	0.0
67	1	3114.04	1549.40	7.60	0.0	100.99	0.0	0.0
68	1	3205.48	1290.32	6.07	0.0	287.48	0.0	0.0
69	0	3246.12	1442.72	18.26	0.0	0.0	0.0	0.0
70	1	3281.68	1590.04	13.69	0.0	106.03	0.0	0.0
71	1	3368.04	1351.28	6.07	0.0	289.24	0.0	0.0
72	0	3403.60	1498.60	22.84	0.0	0.0	0.0	0.0
73	1	3449.32	1645.92	15.22	0.0	109.67	0.0	0.0
74	1	3540.76	1407.16	6.07	0.0	286.59	0.0	0.0
75	0	3576.32	1549.40	19.79	0.0	0.0	0.0	0.0
76	1	3622.04	1711.96	6.07	0.0	114.76	0.0	0.0
77	1	3657.60	1981.20	9.73	0.0	196.35	0.0	0.0
78	1	3672.84	2204.72	3.94	0.0	148.08	0.0	0.0
79	1	3708.40	1452.88	6.07	0.0	280.41	0.0	0.0
80	0	3759.20	1620.52	19.79	0.0	0.0	0.0	0.0
81	1	3789.68	1803.40	14.61	0.0	167.60	0.0	0.0
82	0	3815.08	2062.48	10.64	0.0	0.0	0.0	0.0
83	1	3865.88	2316.48	10.64	0.0	110.68	0.0	0.0
84	1	3916.68	1473.20	6.07	0.0	279.80	0.0	0.0
85	0	3957.32	1681.48	18.26	0.0	0.0	0.0	0.0
86	0	3997.96	1915.16	18.87	0.0	0.0	0.0	0.0
97	0	4048.76	2153.92	6.07	0.0	0.0	0.0	0.0
88	1	4094.48	2362.20	3.33	0.0	75.67	0.0	0.0
89	1	4119.88	1524.00	6.07	0.0	280.41	0.0	0.0
90	0	4165.60	1742.44	19.79	0.0	0.0	0.0	0.0
91	0	4246.88	1971.04	22.84	0.0	0.0	0.0	0.0
92	1	4282.44	2204.72	3.33	0.0	47.91	0.0	0.0
93	1	4333.24	1549.40	6.07	0.0	275.43	0.0	0.0
94	0	4409.44	1780.16	18.26	0.0	0.0	0.0	0.0
95	1	4470.40	2021.84	21.01	0.0	101.99	0.0	0.0
96	1	4572.00	2275.84	3.94	0.0	149.19	0.0	0.0
97	1	4749.80	2489.20	3.33	0.0	114.57	0.0	0.0
98	1	4546.60	1564.64	13.08	0.0	270.53	0.0	0.0
99	0	4627.88	1808.48	16.74	0.0	0.0	0.0	0.0
100	0	4699.00	2062.48	21.31	0.0	0.0	0.0	0.0
101	0	4851.40	2280.92	8.82	0.0	0.0	0.0	0.0
102	1	5029.20	2484.12	5.16	0.0	84.56	0.0	0.0

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103    1   4739.64   1554.48      6.07      0.0     264.64      0.0       0.0
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105    0   4958.08   2032.00     17.35      0.0       0.0       0.0       0.0
106    0   5125.72   2240.28      5.16      0.0       0.0       0.0       0.0
107    1   5293.36   2438.40      3.94      0.0      45.51      0.0       0.0
108    1   4927.60   1529.08     11.56      0.0     229.45      0.0       0.0
109    0   5054.60   1762.76     18.57      0.0       0.0       0.0       0.0
110    1   5191.76   1986.28     14.61      0.0      22.03      0.0       0.0
111    1   5339.08   2199.64      3.33      0.0     348.10      0.0       0.0
112    1   4831.08    975.36      6.99      0.0     170.91      0.0       0.0
113    1   5013.96   1239.52      8.82      0.0     170.95      0.0       0.0
114    0   5135.88   1503.68     16.44      0.0       0.0       0.0       0.0
115    0   5298.44   1717.04     23.45      0.0       0.0       0.0       0.0
116    1   5471.16   1930.40      7.60      0.0      78.37      0.0       0.0
117    3   4927.60    650.24      8.82      1.25      0.0       0.0     165.0
118    0   5080.00    944.88      7.60      0.0       0.0       0.0       0.0
119    0   5232.40   1203.96     14.30      0.0       0.0       0.0       0.0
120    0   5389.88   1463.04     17.96      0.0       0.0       0.0       0.0
121    0   5552.44   1676.40     14.61      0.0       0.0       0.0       0.0
122    1   5735.32   1874.52      3.33      0.0      46.45      0.0       0.0
123    2   5166.36    614.68     12.17      1.25      0.0       0.0       0.0
124    0   5328.92    909.32     13.69      0.0       0.0       0.0       0.0
125    0   5486.40   1168.40     19.79      0.0       0.0       0.0       0.0
126    0   5638.80   1422.40     12.17      0.0       0.0       0.0       0.0
127    1   5801.36   1625.60      3.33      0.0      14.71      0.0       0.0
128    2   5430.52    574.04     14.61      1.25      0.0       0.0       0.0
129    0   5577.84    863.60     12.47      0.0       0.0       0.0       0.0
130    0   5720.08   1143.00     11.25      0.0       0.0       0.0       0.0
131    1   5867.40   1371.60      3.33      0.0      15.33      0.0       0.0
132    3   5684.52    543.56      6.07      1.25      0.0       0.0     165.0
133    1   5791.20    833.12     19.79      0.0     335.36      0.0       0.0
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       4         2         6         3
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       6         4         8         5
       7         5         8         9
       8         5         9         6
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  76  73  70  67  64  61  55  52  49  45  41  37  33  29
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        2         3         4
   3   2   1
 117 123 128 132
  -1
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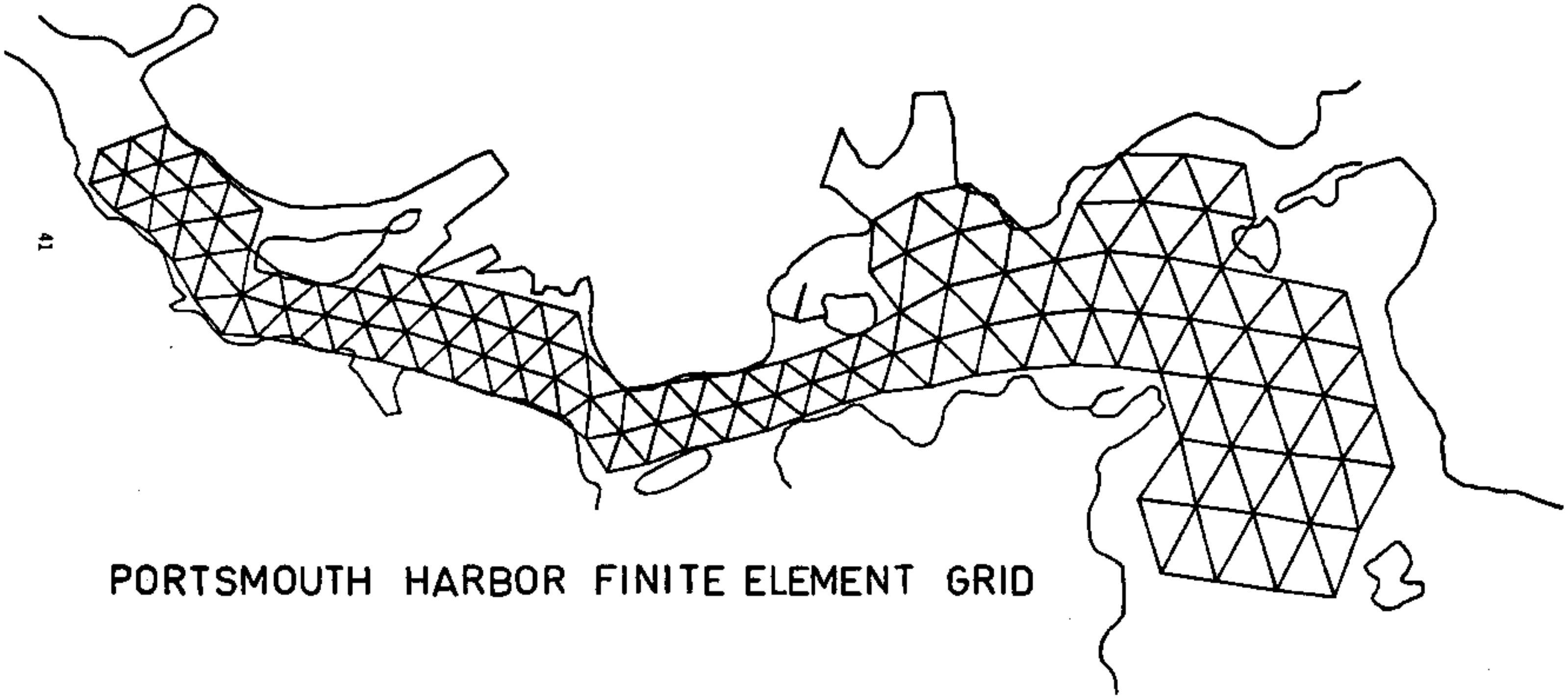

PORTSMOUTH HARBOR FINITE ELEMENT GRID

APPENDIX IV

PISCATAQUA RIVER INPUT DATA AND GRID

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   2  128    94     2     1     2     2     2     1     1   240     0
MIT FINITE ELEMENT HYDRODYNAMIC MODEL - PISCATAQUA RIVER
     1     3    152.54    507.95     15.00      1.25   3600.00      0.0     -92.00
     2     2     66.03    685.73     11.00      1.25   3600.00      0.0       0.0
     3     3    152.38    863.51      5.52      1.25   3600.00      0.0      88.00
     4     0    253.97    685.73     13.44      0.0       0.0       0.0       0.0
     5     1    330.17    507.95      7.35      0.0    -114.00      0.0       0.0
     6     0    436.84    695.89     11.92      0.0       0.0       0.0       0.0
     7     1    344.77    863.51      5.52      0.0      90.00      0.0       0.0
     8     1    451.60    356.36      3.08      0.0    -130.00      0.0       0.0
     9     0    507.95    507.95     10.39      0.0       0.0       0.0       0.0
    10     1    523.19    863.51      4.30      0.0      97.00      0.0       0.0
    11     1    609.54    341.92      3.08      0.0     -98.00      0.0       0.0
    12     0    700.97    507.95     10.39      0.0       0.0       0.0       0.0
    13     0    624.78    706.05     11.92      0.0       0.0       0.0       0.0
    14     1    721.29    914.31      4.30      0.0      98.00      0.0       0.0
    15     1    802.56    345.41      3.08      0.0    -109.00      0.0       0.0
    16     0    919.39    507.95      7.35      0.0       0.0       0.0       0.0
    17     0    822.88    711.13     11.92      0.0       0.0       0.0       0.0
    18     1    944.79    924.47      4.30      0.0      89.00      0.0       0.0
    19     1   1026.06    299.69      3.08      0.0     -89.00      0.0       0.0
    20     0   1147.96    507.95      7.35      0.0       0.0       0.0       0.0
    21     0   1046.38    711.13     11.92      0.0       0.0       0.0       0.0
    22     1   1168.28    904.15      4.30      0.0      85.00      0.0       0.0
    23     1   1224.16    335.25      3.08      0.0     -85.00      0.0       0.0
    24     0   1356.22    507.95      8.87      0.0       0.0       0.0       0.0
    25     0   1264.79    706.84     11.92      0.0       0.0       0.0       0.0
    26     1   1391.78    888.91      4.30      0.0      88.00      0.0       0.0
    27     1   1422.26    333.25      4.30      0.0     -92.00      0.0       0.0
    28     0   1569.56    507.95      8.87      0.0       0.0       0.0       0.0
    29     0   1513.69    695.89     11.92      0.0       0.0       0.0       0.0
    30     1   1671.15    888.91      3.08      0.0      84.00      0.0       0.0
    31     1   1615.28    320.01      4.30      0.0     -95.00      0.0       0.0
    32     0   1762.58    497.79      9.48      0.0       0.0       0.0       0.0
    33     0   1727.03    690.81     11.92      0.0       0.0       0.0       0.0
    34     1   1899.73    843.20      3.08      0.0      70.00      0.0       0.0
    35     1   1813.38    299.69      3.08      0.0     -87.00      0.0       0.0
    36     0   1909.89    452.07     11.92      0.0       0.0       0.0       0.0
    37     0   1930.21    645.10     11.92      0.0       0.0       0.0       0.0
    38     1   2041.95    767.00      4.30      0.0      46.00      0.0       0.0
    39     1   2036.88    345.41      7.35      0.0     -96.00      0.0       0.0
    40     0   2067.35    492.71     11.92      0.0       0.0       0.0       0.0
    41     1   2123.23    629.86      7.35      0.0      35.00      0.0       0.0
    42     1   2163.86    289.53      7.35      0.0    -112.00      0.0       0.0
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 43     0    2163.70     406.60      11.92       0.0       0.0        0.0        0.0
 44     1    2224.82     513.03       7.35       0.0      67.00       0.0        0.0
 45     1    2290.85     243.82       7.35       0.0    -116.00       0.0        0.0
 46     0    2301.01     386.04      11.92       0.0       0.0        0.0        0.0
 47     1    2356.88     518.11       7.35       0.0      71.00       0.0        0.0
 48     1    2407.68     167.62       7.35       0.0     -99.00       0.0        0.0
 49     0    2433.08     299.69      11.92       0.0       0.0        0.0        0.0
 50     1    2463.55     426.68       7.35       0.0      84.00       0.0        0.0
 51     1    2539.75     203.18       7.35       0.0     -70.00       0.0        0.0
 52     0    2549.90     335.25      11.92       0.0       0.0        0.0        0.0
 53     1    2570.22     482.55       7.35       0.0     111.00       0.0        0.0
 54     1    2661.65     259.05       7.35       0.0     -64.00       0.0        0.0
 55     0    2661.65     396.20      11.92       0.0       0.0        0.0        0.0
 56     1    2697.21     513.03       7.35       0.0     114.00       0.0        0.0
 57     1    2768.32     314.93       7.35       0.0     -62.00       0.0        0.0
 58     0    2788.64     452.07      11.92       0.0       0.0        0.0        0.0
 59     1    2803.88     584.14       7.35       0.0     126.00       0.0        0.0
 60     1    2880.07     375.88       7.35       0.0     -63.00       0.0        0.0
 61     0    2895.31     507.95      11.92       0.0       0.0        0.0        0.0
 62     1    2895.31     655.25       7.35       0.0     121.00       0.0        0.0
 63     1    2996.90     431.76       7.35       0.0     -63.00       0.0        0.0
 64     0    3007.06     558.74      11.92       0.0       0.0        0.0        0.0
 65     1    3022.30     711.13       3.08       0.0     107.00       0.0        0.0
 66     1    3098.90     462.26       7.35       0.0     -68.00       0.0        0.0
 67     0    3128.97     604.46      11.92       0.0       0.0        0.0        0.0
 68     1    3159.44     736.53       3.08       0.0     132.00       0.0        0.0
 69     1    3195.00     858.43       3.08       0.0     136.00       0.0        0.0
 70     1    3200.08     492.71       7.35       0.0     -73.00       0.0        0.0
 71     0    3240.71     629.86      11.92       0.0       0.0        0.0        0.0
 72     0    3281.35     772.08       8.87       0.0       0.0        0.0        0.0
 73     1    3327.07     904.15       3.08       0.0     100.00       0.0        0.0
 74     1    3316.91     528.27       7.35       0.0     -76.00       0.0        0.0
 75     0    3352.46     660.33      11.92       0.0       0.0        0.0        0.0
 76     0    3398.18     787.32      13.44       0.0       0.0        0.0        0.0
 77     1    3469.29     904.15       3.08       0.0      61.00       0.0        0.0
 78     1    3418.50     548.58       7.35       0.0     -83.00       0.0        0.0
 79     0    3484.53     665.41      11.92       0.0       0.0        0.0        0.0
 80     1    3540.40     782.24       7.35       0.0      56.00       0.0        0.0
 81     1    3535.33     553.66       7.35       0.0    -101.00       0.0        0.0
 82     0    3611.52     650.17      11.92       0.0       0.0        0.0        0.0
 83     1    3697.87     756.84       7.35       0.0      86.00       0.0        0.0
 84     1    3657.23     497.79       7.35       0.0    -115.00       0.0        0.0
 85     0    3758.82     604.46      11.92       0.0       0.0        0.0        0.0
 86     1    3860.41     761.92       7.35       0.0      76.00       0.0        0.0
 87     1    3774.06     441.92       7.35       0.0    -120.00       0.0        0.0
 88     0    3911.21     538.43      15.92       0.0       0.0        0.0        0.0
 89     1    4063.59     650.17       7.35       0.0      62.00       0.0        0.0
 90     1    3916.29     345.41       7.35       0.0    -129.00       0.0        0.0
 91     0    4078.83     441.92      15.92       0.0       0.0        0.0        0.0
 92     3    4255.61     558.74       7.35       1.25      0.0        0.0       60.00
 93     3    4068.67     203.18       7.35       1.25      0.0        0.0     -135.00
 94     2    4251.53     325.09      51.92       1.25      0.0        0.0        0.0
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  37         27          28         24 0.028     18.0      18.0       3.0
  38         24          28         29 0.028     18.0      18.0       3.0
  39         29          30         26 0.028     18.0      18.0       3.0
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  41         28          33         29 0.028     18.0      18.0       3.0
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  43         31          32         28 0.028     18.0      18.0       3.0
  44         28          32         33 0.028     18.0      18.0       3.0
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  47         32          37         33 0.028     18.0      18.0       3.0
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  50         32          36         37 0.028     18.0      18.0       3.0
  51         37          38         34 0.028     18.0      18.0       3.0
  52         35          39         36 0.028     18.0      18.0       3.0
  53         39          40         36 0.028     18.0      18.0       3.0
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  55         40          41         37 0.028     18.0      18.0       3.0
  56         37          41         38 0.028     18.0      18.0       3.0
  57         39          42         43 0.028     18.0      18.0       3.0
  58         39          43         40 0.028     18.0      18.0       3.0
  59         43          44         40 0.028     18.0      18.0       3.0
  60         40          44         41 0.028     18.0      18.0       3.0
  61         42          45         46 0.028     18.0      18.0       3.0
  62         42          46         43 0.028     18.0      18.0       3.0
  63         43          46         44 0.028     18.0      18.0       3.0
  64         46          47         44 0.028     18.0      18.0       3.0
  65         45          48         49 0.028     18.0      18.0       3.0
  66         45          49         46 0.028     18.0      18.0       3.0
  67         49          50         46 0.028     18.0      18.0       3.0
  68         46          50         47 0.028     18.0      18.0       3.0
```

69	48	51	49	0.028	18.0	18.0	3.0
70	51	52	49	0.028	18.0	18.0	3.0
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74	54	55	52	0.028	18.0	18.0	3.0
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83	58	61	59	0.028	18.0	18.0	3.0
84	61	62	59	0.028	18.0	18.0	3.0
85	60	63	61	0.028	18.0	18.0	3.0
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91	64	67	65	0.028	18.0	18.0	3.0
92	67	68	65	0.028	18.0	18.0	3.0
93	66	70	67	0.028	18.0	18.0	3.0
94	70	71	67	0.028	18.0	18.0	3.0
95	67	71	68	0.028	18.0	18.0	3.0
96	71	72	68	0.028	18.0	18.0	3.0
97	68	72	69	0.028	18.0	18.0	3.0
98	72	73	69	0.028	18.0	18.0	3.0
99	70	74	71	0.028	18.0	18.0	3.0
100	74	75	71	0.028	18.0	18.0	3.0
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105	74	78	75	0.028	18.0	18.0	3.0
106	78	79	75	0.028	18.0	18.0	3.0
107	75	79	76	0.028	18.0	18.0	3.0
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122	88	89	86	0.028	18.0	18.0	3.0
123	90	91	88	0.028	18.0	18.0	3.0
124	91	89	88	0.028	18.0	18.0	3.0
125	93	91	90	0.028	18.0	18.0	3.0
126	91	92	89	0.028	18.0	18.0	3.0
127	93	94	91	0.028	18.0	18.0	3.0
128	94	92	91	0.028	18.0	18.0	3.0

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        2          28          28
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70  74  78  81  84  87  90  93
92  89  86  83  80  77  73  69  68  65  62  59  56  53  50  47  44  41  38  34
30  26  22  18  14  10   7   3
        2           3           3
93  94  92
 3   2   1
```

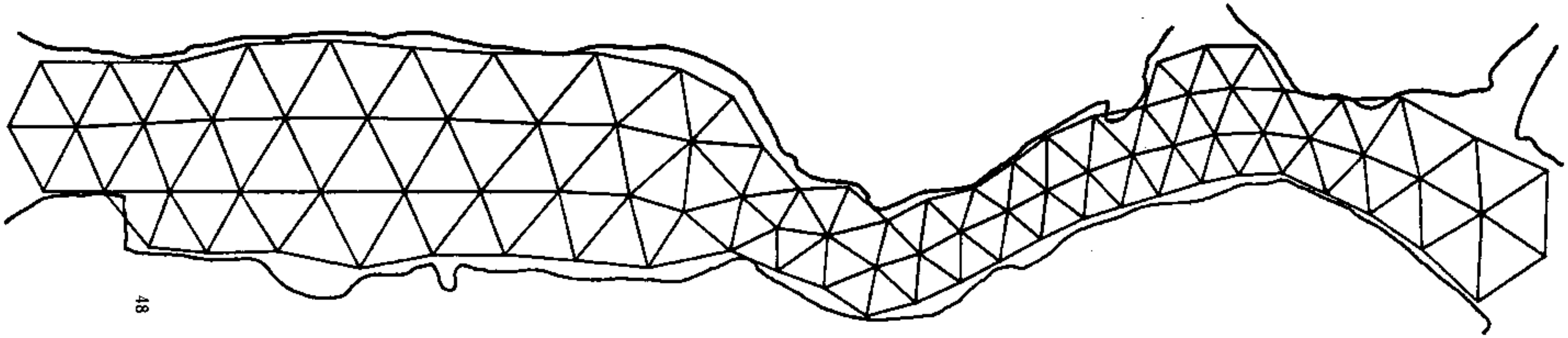

PISCATAQUA RIVER FINITE ELEMENT GRID

APPENDIX V

LITTLE BAY INPUT DATA AND GRID

```
   2  171   118     2      1     2      2     2      1     1   360
IT FINITE ELEMENT HYDRODYNAMIC MODEL - LITTLE BAY
   1      2    1697.81    3440.25         9.0         1.20       0.0        0.0        0.0
   2      3    1921.33    3364.05         7.0         1.20       0.0        0.0       -2.00
   3      3    1489.53    3277.69         7.0         1.20       0.0        0.0      177.00
   4      0    1697.81    3201.49         9.0         0.0        0.0        0.0        0.0
   5      1    1916.25    3099.89         7.0         0.0       -2.00       0.0        0.0
   6      1    1474.29    3038.93         7.03        0.0      158.00       0.0        0.0
   7      0    1687.65    2947.49        11.0         0.0        0.0        0.0        0.0
   8      1    1906.09    2891.61         7.0         0.0      -19.00       0.0        0.0
   9      1    1291.41    2830.65         9.0         0.0      140.00       0.0        0.0
  10      0    1514.93    2749.37         9.0         0.0        0.0        0.0        0.0
  11      1    1774.01    2698.57         7.0         0.0       -4.00       0.0        0.0
  12      1    1144.09    2642.69         9.0         0.0      135.00       0.0        0.0
  13      0    1372.69    2581.73        13.0         0.0        0.0        0.0        0.0
  14      0    1606.37    2510.61         9.0         0.0        0.0        0.0        0.0
  15      1    1890.85    2469.97         6.0         0.0       -1.00       0.0        0.0
  16      1     915.49    2459.81         8.0         0.0      131.00       0.0        0.0
  17      0    1220.29    2388.69        11.0         0.0        0.0        0.0        0.0
  18      0    1469.21    2317.57        13.0         0.0        0.0        0.0        0.0
  19      1    1763.85    2236.29         9.0         0.0      -34.00       0.0        0.0
  20      1     707.21    2256.61         7.0         0.0      142.00       0.0        0.0
  21      0    1027.25    2195.65         9.0         0.0        0.0        0.0        0.0
  22      0    1321.89    2094.05        16.0         0.0        0.0        0.0        0.0
  23      1    1601.29    2043.25        10.0         0.0      -36.00       0.0        0.0
  24      1     310.97    1880.69         5.0         0.0      141.00       0.0        0.0
  25      1     539.57    1961.97         7.0         0.0      130.00       0.0        0.0
  26      0     834.21    1997.53        10.0         0.0        0.0        0.0        0.0
  27      0    1149.17    1926.41        14.0         0.0        0.0        0.0        0.0
  28      1    1464.13    1819.73        10.0         0.0      -42.00       0.0        0.0
  29      1     275.41    1621.61         7.0         0.0      175.00       0.0        0.0
  30      0     498.93    1713.05         7.0         0.0        0.0        0.0        0.0
  31      0     752.93    1774.01        11.0         0.0        0.0        0.0        0.0
  32      0    1006.93    1768.93        18.0         0.0        0.0        0.0        0.0
  33      1    1220.29    1626.69        11.0         0.0      -36.00       0.0        0.0
  34      1     275.41    1377.77         8.0         0.0      178.00       0.0        0.0
  35      0     463.37    1453.97        11.0         0.0        0.0        0.0        0.0
  36      0     691.97    1640.33         9.0         0.0        0.0        0.0        0.0
  37      0     935.81    1560.65        15.0         0.0        0.0        0.0        0.0
  38      1    1128.85    1377.77        10.0         0.0      -17.00       0.0        0.0
  39      1     265.25    1169.49         8.0         0.0     -172.00       0.0        0.0
  40      0     458.29    1250.77        12.0         0.0        0.0        0.0        0.0
  41      0     646.25    1326.97        10.0         0.0      100.00       0.0        0.0
  42      0     864.69    1321.89        12.0         0.0        0.0        0.0        0.0
```

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 43    1   1078.05   1169.49     8.0     0.0    -13.00    0.0    0.0
 44    1    326.21    981.53     8.0     0.0   -146.00    0.0    0.0
 45    0    468.45   1078.05    12.0     0.0      0.0     0.0    0.0
 47    0    663.97   1165.49     7.0     0.0     10.00    0.0    0.0
 48    0    874.85   1067.89    12.0     0.0      0.0     0.0    0.0
 49    1   1037.41    966.29     8.0     0.0     -4.00    0.0    0.0
 50    1    458.29    869.77     9.0     0.0   -159.00    0.0    0.0
 51    0    671.65    976.45     8.0     0.0    -87.00    0.0    0.0
 52    0    859.61    864.69    13.0     0.0      0.0     0.0    0.0
 53    0    656.41    742.77    14.0     0.0      0.0     0.0    0.0
 54    1    427.81    625.93    12.0     0.0    180.00    0.0    0.0
 55    1   1047.57    803.73     8.0     0.0     19.00    0.0    0.0
 56    0    879.93    661.49    11.0     0.0      0.0     0.0    0.0
 57    0    717.37    458.29    12.0     0.0      0.0     0.0    0.0
 58    1    458.29    356.69     9.0     0.0   -155.00    0.0    0.0
 59    1    620.85    183.97     8.0     0.0   -141.00    0.0    0.0
 60    1   1276.17    869.77     9.0     0.0    130.00    0.0    0.0
 61    1   1144.09    661.49     8.0     0.0     91.00    0.0    0.0
 62    0   1017.09    448.13    11.0     0.0      0.0     0.0    0.0
 63    0    874.85    234.77    14.0     0.0      0.0     0.0    0.0
 64    1    747.85      6.17     8.0     0.0   -115.00    0.0    0.0
 65    1   1514.93    966.29     9.0     0.0    107.00    0.0    0.0
 66    0   1413.33    691.97    11.0     0.0      0.0     0.0    0.0
 67    0   1245.69    458.29    11.0     0.0      0.0     0.0    0.0
 68    0   1164.41    229.69    11.0     0.0      0.0     0.0    0.0
 69    1    996.77     21.41     8.0     0.0    -89.00    0.0    0.0
 70    1   1763.85   1017.09     8.0     0.0    101.00    0.0    0.0
 71    0   1672.41    752.93    13.0     0.0      0.0     0.0    0.0
 72    0   1550.49    504.01     6.0     0.0      0.0     0.0    0.0
 73    1   1393.01    260.17     6.0     0.0    -55.00    0.0    0.0
 74    1   1286.33     16.33     7.0     0.0    -57.00    0.0    0.0
 75    1   2033.09   1067.89     7.0     0.0     94.00    0.0    0.0
 76    0   1931.49    773.25    12.0     0.0      0.0     0.0    0.0
 77    0   1814.65    529.41    12.0     0.0      0.0     0.0    0.0
 78    1   1713.05    285.57     7.0     0.0    -89.00    0.0    0.0
 79    1   2322.65   1057.73     7.0     0.0     85.00    0.0    0.0
 80    0   2210.89    803.73    11.0     0.0      0.0     0.0    0.0
 81    0   2094.03    534.49    11.0     0.0      0.0     0.0    0.0
 82    1   1987.37    270.33     8.0     0.0    -93.00    0.0    0.0
 83    1   2607.13   1022.17     6.0     0.0     84.00    0.0    0.0
 84    0   2485.21    763.09     9.0     0.0      0.0     0.0    0.0
 85    0   2363.29    524.33    11.0     0.0      0.0     0.0    0.0
 86    1   2226.13    255.09     7.0     0.0    -93.00    0.0    0.0
 87    1   2947.49    991.69     6.0     0.0     84.00    0.0    0.0
 88    0   2749.37    727.53     9.0     0.0      0.0     0.0    0.0
 89    0   2617.29    504.01    11.0     0.0      0.0     0.0    0.0
 90    1   2495.37    244.93     7.0     0.0    -94.00    0.0    0.0
 91    1   3226.89    956.13     6.0     0.0     83.00    0.0    0.0
 92    0   3059.25    702.13     9.0     0.0      0.0     0.0    0.0
 93    0   2891.61    473.53    11.0     0.0      0.0     0.0    0.0
 94    1   2764.61    219.53     7.0     0.0    -95.00    0.0    0.0
 95    1   3501.21    920.57     6.0     0.0     78.00    0.0    0.0
 96    0   3353.89    686.89     9.0     0.0      0.0     0.0    0.0
 97    0   3186.25    453.21    11.0     0.0      0.0     0.0    0.0
 98    1   3008.45    199.21     7.0     0.0    -94.00    0.0    0.0
 99    1   3775.53    839.29     6.0     0.0     70.00    0.0    0.0
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101    0   3440.25    407.49    11.0     0.0      0.0     0.0    0.0
102    1   3252.29    183.97     7.0     0.0    -94.00    0.0    0.0
103    1   4065.09    712.29     8.0     0.0     59.00    0.0    0.0
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104    0   3821.25    539.57     9.0     0.0      0.0     0.0      0.0
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106    1   3485.97    168.73     7.0     0.0   -100.00    0.0      0.0
107    1   4303.84    519.25     8.0     0.0     52.00    0.0      0.0
108    0   4065.09    407.49    13.0     0.0      0.0     0.0      0.0
109    0   3851.73    280.49    13.0     0.0      0.0     0.0      0.0
110    1   3673.93    112.85     8.0     0.0   -112.00    0.0      0.0
111    1   4466.40    392.25     7.0     0.0     61.00    0.0      0.0
112    0   4253.04    285.57    14.0     0.0      0.0     0.0      0.0
113    1   4065.09    158.57    10.0     0.0    -84.00    0.0      0.0
114    1   3866.97     16.33     8.0     0.0    -85.00    0.0      0.0
115    3   4628.96    331.29     8.0     1.10  3600.00    0.0     69.00
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140	93	94	98
141	95	100	99
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143	96	101	100
144	96	97	101
145	97	102	101
146	97	98	102
147	99	104	103
148	99	100	104
149	100	105	104
150	100	101	105
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153	103	108	107
154	103	104	108
155	104	109	108
156	104	105	109
157	105	110	109
158	105	106	110
159	107	112	111
160	107	108	112
161	108	113	112
162	108	109	113
163	109	114	113
164	109	110	114

```
      165       111       116       115
      166       111       112       116
      167       112       117       116
      168       112       113       117
      169       115       116       118
      170       116       119       118
      171       116       117       119
    43.1 .72722E-04   9.81    44640.00  1030.0
 11160.0  78120.0    10.0               18    5.0              1       120
        2        28        33
115 111 107 103  99  95  91  87  83  79  75  70  65  60  61  55  49  43  38  33
 28  23  19  15  11   8   5   2
  3   6   9  12  16  20  25  24  29  34  39  44  50  54  58  59  64  69  74  73
 78  82  86  90  94  98 102 106 110 114 113 117 119
        2         3         3
  2   1   3
119 118 115
   0
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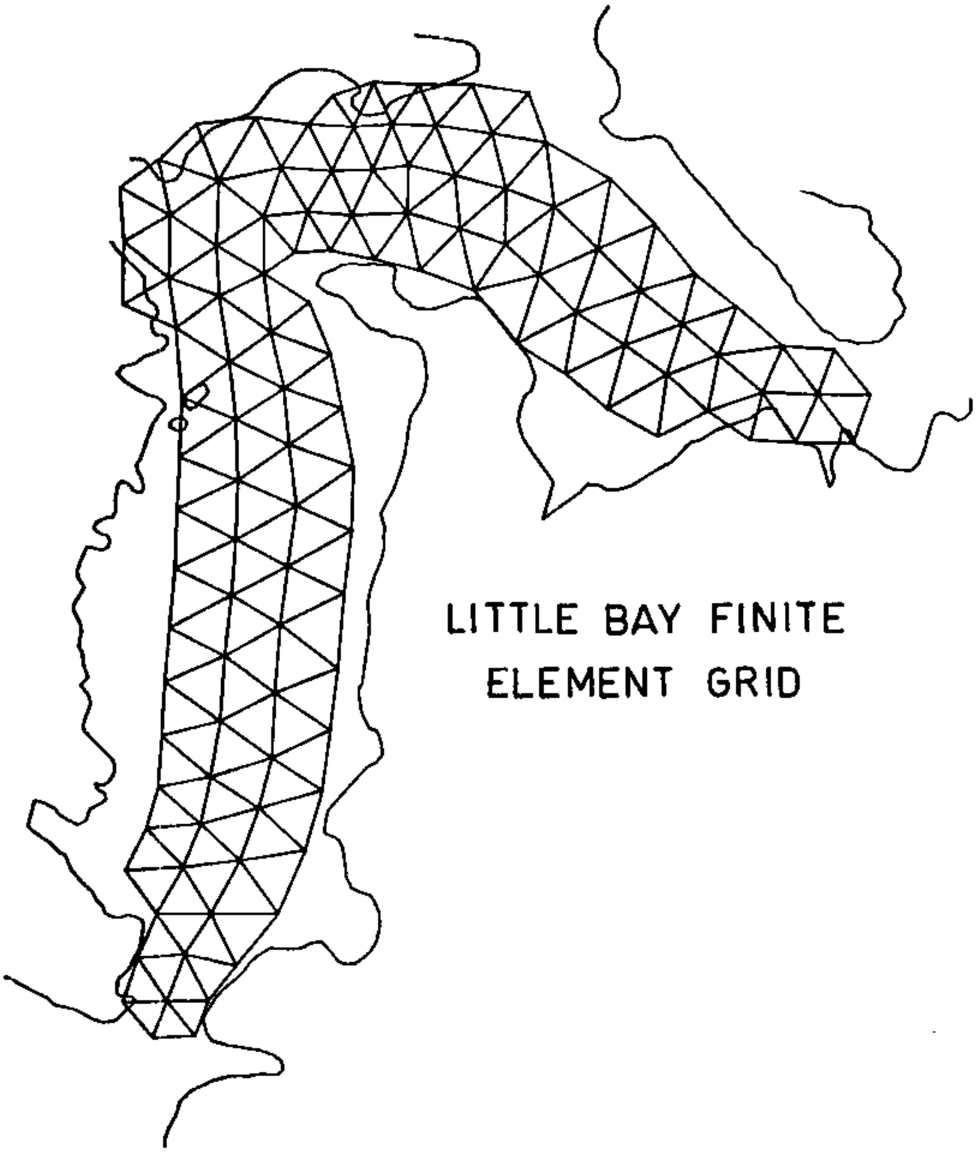

LITTLE BAY FINITE ELEMENT GRID

APPENDIX VI

GREAT BAY INPUT DATA AND GRID

```
    2  129    87     2     1     2     2     2     1     1   240     1
 IT FINITE ELEMENT HYDRODYNAMIC MODEL - GREAT BAY
    1     1   6045.00    574.00        1.50                 303.1
    2     1   6273.00   1143.00        1.50                   6.8
    3     1   5588.00    589.00        1.50                 269.3
    4     0   5760.00   1117.00        1.50                     .
    5     1   5892.00   1676.00        1.50                  38.0
    6     1   5110.00    584.00        1.50                 269.3
    7     0   5283.00   1087.00        1.80                     .
    8     0   5425.00   1605.00        1.80                     .
    9     1   5537.00   2092.00        1.50                  38.3
   10     1   4673.00    599.00        1.50                 238.3
   11     0   4851.00   1066.00        2.11                     .
   12     0   4978.00   1544.00        2.41                     .
   13     0   5100.00   2001.00        2.11                     .
   14     1   5232.00   2509.00        1.50                  67.6
   15     1   4434.00   1036.00        1.80                 241.0
   16     0   4577.00   1483.00        3.02                     .
   17     0   4673.00   1925.00        4.55                     .
   18     1   4785.00   2438.00        1.50                  99.3
   19     1   4094.00   1016.00        1.80                 246.9
   20     0   4185.00   1432.00        3.33                     .
   21     0   4338.00   1854.00        2.41                     .
   22     1   4389.00   2372.00        1.80                 102.8
   23     1   3794.00   1356.00        3.02                 249.1
   24     0   3891.00   1803.00        3.63                     .
   25     1   3987.00   2255.00        2.72                  43.8
   26     1   4140.00   2707.00        1.80                 337.8
   27     1   4328.00   3098.00        1.50                   1.1
   28     1   3352.00   1295.00        1.50                 278.2
   29     0   3505.00   1752.00        3.94                     .
   30     0   3606.00   2209.00        3.63                     .
   31     0   3733.00   2692.00        2.72                     .
   32     0   3937.00   3098.00        1.80                     .
   33     1   4130.00   3474.00        1.50                  58.5
   34     1   2951.00   1234.00        1.50                 277.5
   35     0   3098.00   1696.00        1.50                     .
   36     0   3215.00   2164.00        1.80                     .
   37     0   3332.00   2656.00        5.16                     .
   38     0   3525.00   3093.00        6.99                     .
   39     1   3733.00   3479.00       10.64                  28.7
   40     1   3942.00   3815.00       13.69                 329.1
   41     1   4114.00   4114.00       15.52                 330.9
   42     3   4277.00   4414.00        3.02       1.10       0.00                     331.5
```

```
43      1   2540.00    1188.00       1.80                 277.4
44      0   2682.00    1656.00       1.80                    .
45      0   2824.00    2133.00       3.33                    .
46      0   2946.00    2600.00       5.16                    .
47      0   3129.00    3063.00       7.60                    .
48      0   3332.00    3469.00      10.64                    .
49      0   3556.00    3825.00       7.60                    .
50      0   3804.00    4150.00      10.64
51      2   3982.00    4434.00      15.22       1.10       0.00
52      1   2057.00    1117.00       1.80                 277.8
53      0   2245.00    1605.00       1.80
54      0   2397.00    2077.00       3.33                    .
55      0   2560.00    2565.00       1.80                    .
56      0   2702.00    3027.00       1.80                    .
57      0   2987.00    3454.00       3.33                    .
58      0   3169.00    3830.00       3.33                    .
59      1   3423.00    4185.00       2.11                 109.9
60      3   3703.00    4455.00       3.02       1.10       0.00                 133.9
61      1   1569.00    1056.00       1.50                 277.3
62      0   1752.00    1534.00       1.80                    .
63      0   1935.00    2026.00       3.33                    .
64      0   2108.00    2529.00       2.72                    .
65      0   2286.00    2981.00       2.11                    .
66      1   2463.00    3439.00       2.11                 120.2
67      1   2712.00    3835.00       1.80                 145.5
68      1   2997.00    4216.00       1.50                 114.6
69      1    756.00     482.00       1.50                 304.5
70      1   1021.00     985.00       1.50                 304.8
71      0   1259.00    1473.00       2.11                    .
72      0   1447.00    1955.00       3.02                    .
73      0   1630.00    2473.00       1.50                    .
74      0   1833.00    2931.00       1.50                    .
75      1   2006.00    3418.00       1.50                  93.2
76      1    233.00     421.00       1.50                 245.9
77      0    452.00     909.00       1.50                    .
78      0    670.00    1402.00       3.33                    .
79      0    934.00    1899.00       2.11                    .
80      0   1117.00    2413.00       1.50                    .
81      1   1336.00    2885.00       1.50                 126.1
82      1   1554.00    3388.00       1.50                 125.2
83      1    -71.00     853.00       3.63                 185.2
84      1    157.00    1346.00       3.33                 155.2
85      1    386.00    1844.00       1.50                 156.2
86      1    604.00    2362.00       1.50                 156.4
87      1    817.00    2834.00       1.50                 125.6
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        2         1          2          4
        3         2          5          4
        4         3          7          6
        5         3          4          7
        6         4          8          7
        7         4          5          8
        8         5          9          8
        9         6         11         10
       10         6          7         11
       11         7         12         11
       12         7          8         12
       13         8         13         12
       14         8          9         13
       15         9         14         13
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73	45	55	54
74	45	46	55
75	46	56	55

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        94            56            57            66
        95            57            67            66
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        99            61            71            70
       100            61            62            71
       101            62            72            71
       102            62            63            72
       103            63            73            72
       104            63            64            73
       105            64            74            73
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       107            65            75            74
       108            65            66            75
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       110            69            70            77
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       116            72            73            80
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       121            76            77            83
       122            77            84            83
       123            77            78            84
       124            78            85            84
       125            78            79            85
       126            79            86            85
       127            79            80            86
       128            80            87            86
       129            80            81            87
   43.1 .72722E-04    9.81      44640.0     1030.0
11160.0  12480.0      10.0                18   5.0               1        240
      1           42
60   59   68   67   66   75   82   81   87   86   85   84   83   76   69   70   61   52   43   34
28   23   19   15   10    6    3    1    2    5    9   14   18   22   25   26   27   33   39   40
41   42
```

```
       1         3
42  51  60
  1.1       1.1       1.1       1.1       1.1       1.1       1.1       1.1
  1.1       1.1       1.1       1.1       1.1       1.1       1.1       1.1
  1.1       1.1       1.1       1.1       1.1       1.1       1.1       1.1
  1.1       1.1       1.1       1.1       1.1       1.1       1.1       1.1
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  1.1       1.1       1.1       1.1       1.1       1.1       1.1       1.1
  1.1       1.1       1.1       1.1       1.1       1.1       1.1       1.1
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  1.1       1.1       1.1       1.1       1.1       1.1       1.1       1.1
  1.1       1.1       1.1       1.1       1.1       1.1       1.1       1.1
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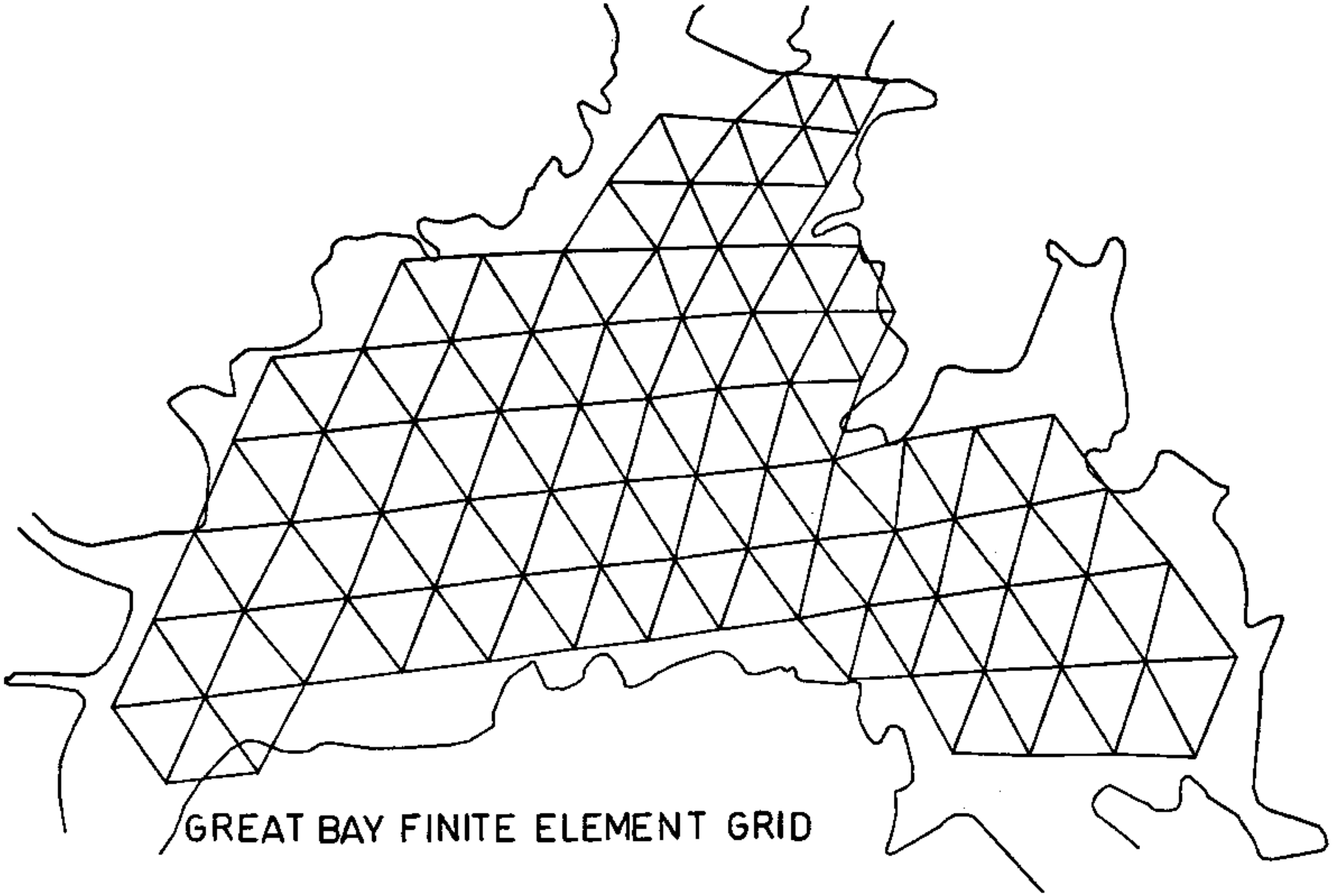


GREAT BAY FINITE ELEMENT GRID

APPENDIX VII

PORTSMOUTH HARBOR MODEL RESULTS

```
RESULTS OF THE MODEL AT  4.1 HOURS AFTER HIGH TIDE
                        MKS UNITS

             WATER              *       U           V
NODE         DEPTH           ETA    VELOCITY    VELOCITY

   1         16.46         -0.28        0.28       -0.49
   2         16.46         -0.28        0.28       -0.50
   3          3.05         -0.28        0.65       -0.65
   4          8.85         -0.27        0.13       -0.52
   5         13.40         -0.29        0.13       -0.36
   6         10.36         -0.28        0.23       -0.36
   7          3.04         -0.29        0.41       -0.37
   8          7.31         -0.29        0.43       -0.37
   9         14.94         -0.28        0.38       -0.40
  10          7.30         -0.30        0.33       -0.37
  11          3.05         -0.28        0.41       -0.39
  12          4.88         -0.28        0.36       -0.32
  13         16.45         -0.29        0.37       -0.36
  14          4.87         -0.29        0.19       -0.34
  15          3.63         -0.31        0.16       -0.57
  16          5.77         -0.30        0.38       -0.55
  17         18.57         -0.30        0.28       -0.55
  18          3.03         -0.30        0.18       -0.58
  19         11.85         -0.32        0.66       -0.38
  20         16.45         -0.29        0.25       -0.38
  21          3.02         -0.31        0.63       -0.33
  22          5.75         -0.32        0.17       -0.09
  23          5.76         -0.31        0.41       -0.05
  24         16.41         -0.33        0.83       -0.26
  25          3.61         -0.33        0.69       -0.17
  26          3.61         -0.33        0.60       -0.12
  27         19.45         -0.34        0.87       -0.23
  28          4.82         -0.34        0.57        0.16
  29          4.79         -0.37        0.35        0.09
  30          2.99         -0.34        0.62       -0.13
  31         19.44         -0.35        0.76       -0.04
  32         10.29         -0.35        0.45        0.03
  33          2.97         -0.36        0.52       -0.11
  34          4.81         -0.35        0.59       -0.14
  35         16.38         -0.36        0.57       -0.13
  36         12.11         -0.35        0.46       -0.08
  37          6.62         -0.37        0.48       -0.10
  38          4.81         -0.35        0.53       -0.15
  39          6.62         -0.37        0.59       -0.12
  40         16.37         -0.37        0.44       -0.14

*
 ETA = WATER SURFACE DEVIATION FROM MSL
```

RESULTS OF THE MODEL AT 4.1 HOURS AFTER HIGH TIDE

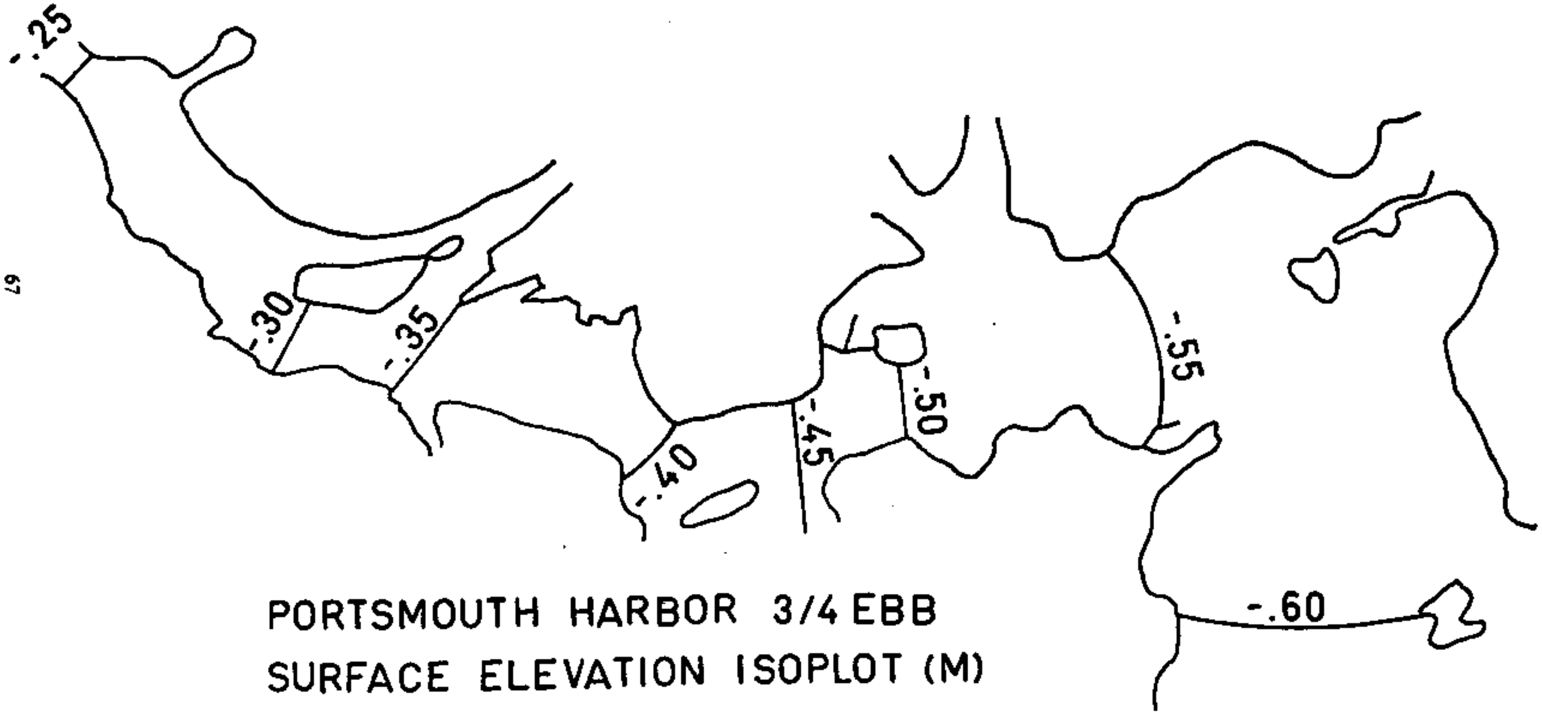
MKS UNITS

NODE	WATER DEPTH	ETA*	U VELOCITY	V VELOCITY
41	18.21	-0.36	0.48	-0.13
42	5.70	-0.37	0.46	-0.15
43	7.24	-0.36	0.56	-0.19
44	14.54	-0.37	0.44	-0.16
45	20.64	-0.37	0.37	-0.11
46	5.70	-0.37	0.47	-0.15
47	7.23	-0.37	0.58	-0.23
48	13.32	-0.37	0.39	-0.23
49	17.83	-0.38	0.29	-0.32
50	2.96	-0.37	0.50	-0.19
51	22.46	-0.38	0.58	-0.39
52	16.36	-0.38	0.27	-0.49
53	5.69	-0.38	0.58	-0.34
54	23.36	-0.39	0.72	-0.49
55	5.66	-0.41	0.77	-0.24
56	5.67	-0.40	0.35	-0.38
57	23.05	-0.40	0.57	-0.15
58	19.38	-0.41	0.27	-0.12
59	16.32	-0.42	0.39	0.11
60	23.03	-0.42	0.75	0.08
61	13.27	-0.42	0.74	0.11
62	5.65	-0.42	0.63	0.18
63	23.01	-0.44	0.79	0.11
64	7.78	-0.43	0.78	0.12
65	5.63	-0.44	0.73	0.17
66	23.00	-0.45	0.80	0.20
67	7.14	-0.46	0.83	0.16
68	5.63	-0.44	0.74	0.23
69	17.80	-0.46	0.88	0.23
70	13.24	-0.45	0.84	0.24
71	5.61	-0.46	0.78	0.27
72	22.35	-0.49	0.88	0.30
73	14.75	-0.47	0.81	0.29
74	5.62	-0.45	0.85	0.25
75	19.28	-0.51	0.86	0.24
76	5.58	-0.49	0.68	0.32
77	9.20	-0.53	-0.05	0.18
78	3.41	-0.52	0.02	0.03
79	5.57	-0.50	0.81	0.15
80	19.27	-0.52	0.73	0.19

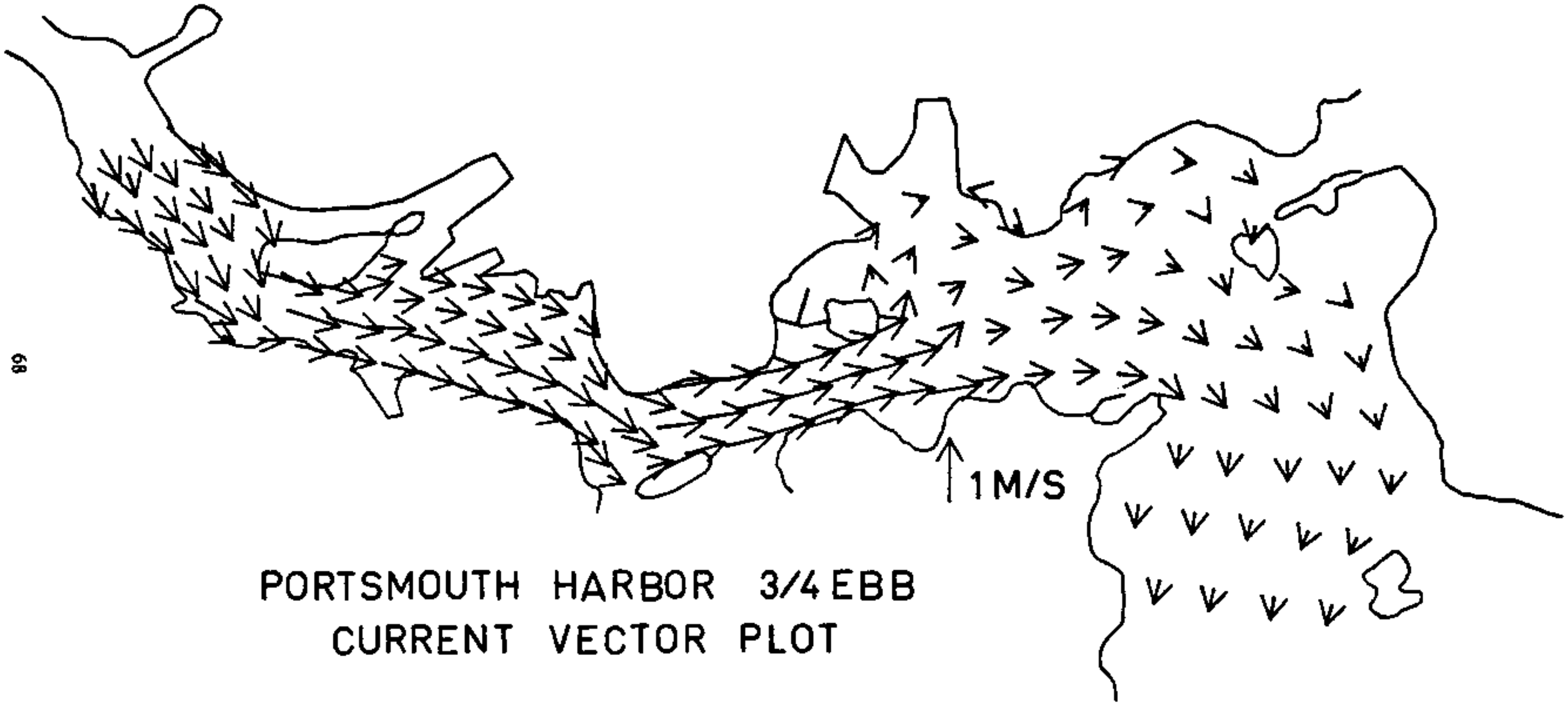
*ETA = WATER SURFACE DEVIATION FROM MSL

```
RESULTS OF THE MODEL AT  4.1 HOURS AFTER HIGH TIDE

                         MKS UNITS

            WATER                *        U          V
   NODE     DEPTH         ETA       VELOCITY   VELOCITY

    81      14.09        -0.52        0.09       0.43
    82      10.11        -0.53        0.09       0.17
    83      10.12        -0.52        0.12       0.05
    84       5.56        -0.51        0.81       0.14
    85      17.73        -0.53        0.35       0.37
    86      18.35        -0.52        0.23       0.16
    87       5.54        -0.53        0.23      -0.04
    88       2.80        -0.53       -0.06       0.02
    89       5.54        -0.53        0.48       0.09
    90      19.27        -0.52        0.34       0.05
    91      22.31        -0.53        0.40      -0.09
    92       2.80        -0.53        0.12      -0.11
    93       5.54        -0.53        0.44       0.04
    94      17.72        -0.54        0.43       0.06
    95      20.46        -0.55        0.41       0.09
    96       3.38        -0.56        0.09       0.16
    97       2.77        -0.56        0.07       0.03
    98      12.55        -0.53        0.39       0.00
    99      15.20        -0.54        0.40      -0.02
   100      20.76        -0.55        0.28       0.08
   101       8.26        -0.56        0.13       0.04
   102       4.62        -0.54        0.16      -0.02
   103       5.52        -0.55        0.46      -0.04
   104      18.31        -0.56        0.35      -0.05
   105      16.80        -0.55        0.21      -0.08
   106       4.59        -0.57        0.05      -0.07
   107       3.40        -0.54        0.19      -0.19
   108      11.01        -0.55        0.36      -0.31
   109      18.01        -0.56        0.28      -0.29
   110      14.05        -0.56        0.12      -0.29
   111       2.77        -0.56       -0.06      -0.27
   112       6.40        -0.59       -0.05      -0.33
   113       8.26        -0.56       -0.05      -0.34
   114      15.87        -0.57        0.29      -0.35
   115      22.88        -0.57        0.27      -0.20
   116       7.03        -0.57        0.22      -0.05
   117       8.22        -0.60       -0.10      -0.36
   118       7.02        -0.58       -0.05      -0.33
   119      13.72        -0.58       -0.04      -0.34
   120      17.38        -0.58        0.18      -0.27

*
 ETA = WATER SURFACE DEVIATION FROM MSL
```

```
RESULTS OF THE MODEL AT  4.1 HOURS AFTER HIGH TIDE

                     MKS UNITS

              WATER            *        U          V
   NODE       DEPTH          ETA    VELOCITY   VELOCITY

   121        14.03        -0.58       0.13      -0.15
   122         2.75        -0.58       0.10      -0.10
   123        11.57        -0.60      -0.08      -0.34
   124        13.09        -0.60      -0.07      -0.29
   125        10.20        -0.59       0.00      -0.30
   126        11.59        -0.58       0.10      -0.23
   127         2.74        -0.59       0.05      -0.20
   128        14.01        -0.60      -0.05      -0.33
   129        11.88        -0.59      -0.11      -0.26
   130        10.68        -0.57      -0.01      -0.26
   131         2.76        -0.57       0.06      -0.22
   132         5.47        -0.60      -0.08      -0.31
   133        10.21        -0.58      -0.11      -0.24
   134         2.76        -0.57      -0.03      -0.28

*
 ETA = WATER SURFACE DEVIATION FROM MSL
```



PORTSMOUTH HARBOR 3/4 EBB
SURFACE ELEVATION ISOPLOT (M)



PORTSMOUTH HARBOR 3/4 EBB
CURRENT VECTOR PLOT

PISCATAQUA RIVER MODEL RESULTS

RESULTS OF THE MODEL AT 10.3 HOURS AFTER HIGH TIDE

MKS UNITS

NODE	WATER DEPTH	ETA*	U VELOCITY	V VELOCITY
1	14.82	-0.18	-0.43	0.01
2	10.81	-0.19	-0.69	0.13
3	5.34	-0.18	-0.30	0.01
4	13.26	-0.18	-0.62	0.02
5	7.18	-0.17	-0.53	0.23
6	11.76	-0.16	-0.61	0.00
7	5.35	-0.17	-0.35	0.00
8	2.94	-0.14	-0.18	0.15
9	10.23	-0.16	-0.43	0.07
10	4.14	-0.15	-0.39	-0.04
11	2.93	-0.15	-0.21	0.03
12	10.24	-0.15	-0.39	0.00
13	11.78	-0.14	-0.51	0.00
14	4.16	-0.14	-0.22	-0.03
15	2.95	-0.13	-0.40	0.13
16	7.21	-0.14	-0.41	0.02
17	11.78	-0.14	-0.54	-0.08
18	4.18	-0.12	-0.22	0.00
19	2.97	-0.11	-0.23	0.00
20	7.22	-0.13	-0.51	-0.05
21	11.81	-0.11	-0.52	0.07
22	4.16	-0.14	-0.39	0.03
23	3.00	-0.08	-0.05	0.00
24	8.77	-0.10	-0.46	0.06
25	11.83	-0.09	-0.53	-0.02
26	4.22	-0.08	-0.28	0.01
27	4.19	-0.11	-0.32	0.01
28	8.80	-0.07	-0.45	-0.01
29	11.83	-0.09	-0.54	0.12
30	3.00	-0.08	0.01	0.00
31	4.23	-0.07	-0.23	0.02
32	9.39	-0.09	-0.58	0.14
33	11.85	-0.07	-0.56	0.05
34	3.02	-0.06	0.40	-0.14
35	3.03	-0.05	-0.16	0.00
36	11.88	-0.04	-0.47	0.09
37	11.87	-0.05	-0.46	0.28
38	4.22	-0.08	0.04	-0.04
39	7.29	-0.06	-0.66	0.06
40	11.87	-0.05	-0.75	0.45

* ETA = WATER SURFACE DEVIATION FROM MSL

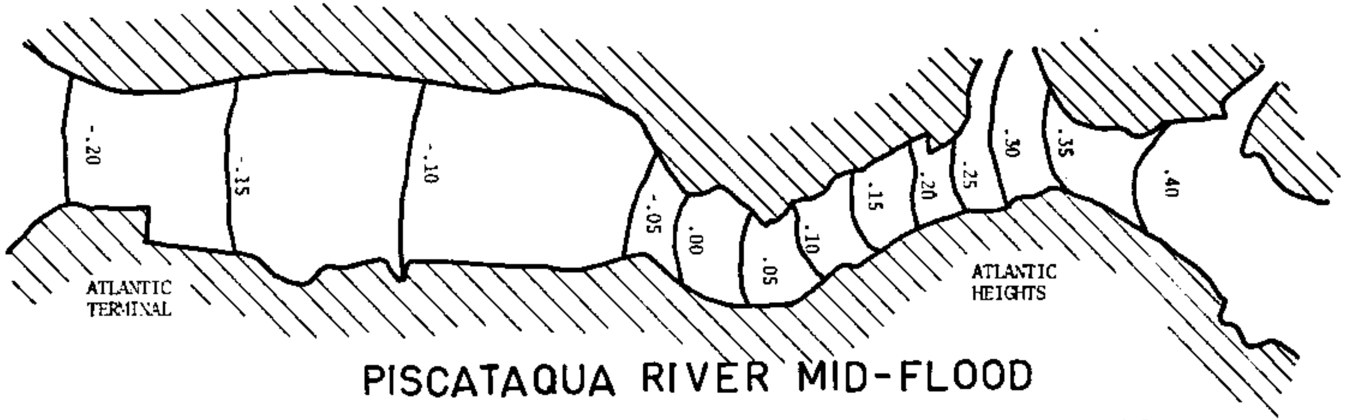
RESULTS OF THE MODEL AT 10.3 HOURS AFTER HIGH TIDE

MKS UNITS

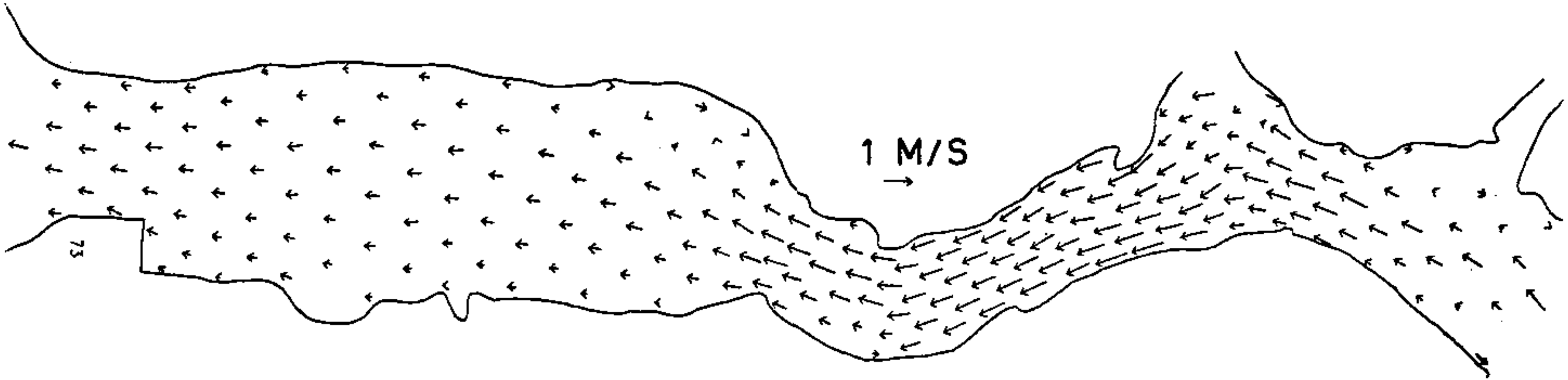
NODE	WATER DEPTH	ETA*	U VELOCITY	V VELOCITY
41	7.30	-0.05	-0.12	0.17
42	7.32	-0.03	-0.51	0.20
43	11.93	0.01	-0.89	0.25
44	7.32	-0.03	-0.85	0.36
45	7.38	0.03	-0.39	0.19
46	11.92	0.00	-0.97	0.36
47	7.41	0.06	-0.28	0.09
48	7.32	-0.03	0.27	-0.04
49	11.97	0.05	-0.88	0.22
50	7.36	0.01	-0.91	0.09
51	7.42	0.07	-0.72	-0.26
52	11.96	0.04	-0.86	-0.30
53	7.46	0.11	-0.86	-0.33
54	7.40	0.05	-0.79	-0.38
55	12.03	0.11	-0.83	-0.40
56	7.38	0.03	-1.01	-0.45
57	7.42	0.07	-0.91	-0.48
58	12.09	0.17	-0.85	-0.37
59	7.51	0.16	-0.74	-0.54
60	7.44	0.09	-0.95	-0.48
61	12.07	0.15	-0.78	-0.51
62	7.51	0.16	-0.63	-0.38
63	7.56	0.21	-0.83	-0.42
64	12.14	0.22	-0.90	-0.19
65	3.24	0.16	-0.93	-0.28
66	7.47	0.12	-1.14	-0.46
67	12.20	0.28	-0.86	-0.32
68	3.31	0.23	-0.78	-0.71
69	3.34	0.26	-0.23	-0.24
70	7.61	0.26	-1.18	-0.36
71	12.16	0.24	-0.86	-0.29
72	9.23	0.36	-0.33	-0.23
73	3.33	0.25	-0.79	-0.14
74	7.65	0.30	-0.96	-0.24
75	12.21	0.29	-0.73	-0.50
76	13.71	0.27	-0.44	0.04
77	3.52	0.44	0.65	-0.36
78	7.63	0.28	-0.52	-0.06
79	12.29	0.37	-0.96	0.26
80	7.62	0.27	-0.72	0.48

* ETA = WATER SURFACE DEVIATION FROM MSL

```
RESULTS OF THE MODEL AT 10.3 HOURS AFTER HIGH TIDE

                    MKS UNITS

            WATER             *        U          V
NODE        DEPTH           ETA    VELOCITY   VELOCITY

 81          7.59           0.24     -0.49       0.09
 82         12.30           0.38     -1.12       0.29
 83          7.68           0.33     -0.25       0.01
 84          7.69           0.34     -0.62       0.28
 85         12.31           0.39     -1.02       0.46
 86          7.72           0.37      0.22      -0.05
 87          7.71           0.36     -0.27       0.16
 88         16.34           0.42     -0.77       0.34
 89          7.74           0.39      0.25      -0.13
 90          7.73           0.38     -0.21       0.17
 91         16.35           0.43     -0.73       0.42
 92          7.76           0.41      0.08      -0.04
 93          7.76           0.41      0.39      -0.39
 94         52.35           0.43     -0.19       0.21

*
 ETA = WATER SURFACE DEVIATION FROM MSL
```



PISCATAQUA RIVER MID-FLOOD
SURFACE ELEVATION ISOPLOT (M)



PISCATAQUA RIVER MID-FLOOD
CURRENT VECTOR PLOT

APPENDIX IX

LITTLE BAY MODEL RESULTS

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RESULTS OF THE MODEL AT  3.0 HOURS AFTER HIGH TIDE

                 MKS UNITS

           WATER                 *      U          V
 NODE      DEPTH          ETA     VELOCITY   VELOCITY

    1       5.06          0.06     -0.24       1.13
    2       3.77          0.06      0.04       1.14
    3       4.07          0.06      0.07       1.31
    4      12.67          0.12     -0.02       1.16
    5       3.84          0.13      0.04       1.09
    6       5.39          0.16      0.44       1.08
    7      13.33          0.17      0.33       0.86
    8       3.88          0.17      0.32       0.94
    9       3.96          0.25      0.50       0.60
   10      12.76          0.21      0.45       0.89
   11       4.22          0.21      0.37       0.97
   12       3.95          0.24      0.44       0.44
   13      15.21          0.22      0.26       0.43
   14       9.45          0.25      0.27       0.61
   15       3.93          0.22      0.01       0.43
   16       3.97          0.26      0.29       0.74
   17      10.96          0.24      0.26       0.44
   18      15.54          0.25      0.18       0.43
   19       4.24          0.23      0.21       0.31
   20       3.98          0.27      0.21       0.20
   21       5.17          0.24      0.27       0.41
   22      20.11          0.25      0.22       0.33
   23       4.56          0.24      0.26       0.35
   24       3.97          0.25      0.17       0.21
   25       3.07          0.26      0.28       0.24
   26       4.63          0.26      0.31       0.31
   27      16.17          0.27      0.30       0.35
   28       9.45          0.25      0.36       0.40
   29       6.42          0.27      0.03       0.35
   30       6.43          0.28      0.20       0.32
   31       7.64          0.27      0.17       0.34
   32      21.65          0.26      0.20       0.29
   33      12.50          0.26      0.28       0.30
   34       3.98          0.27      0.01       0.36
   35      11.00          0.29      0.05       0.28
   36       9.15          0.25      0.22       0.42
   37      15.57          0.28      0.19       0.39
   38       9.77          0.27      0.14       0.46
   39       4.00          0.29     -0.06       0.44
   40      15.27          0.28      0.07       0.35

*ETA = WATER SURFACE DEVIATION FROM MSL
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```
RESULTS OF THE MODEL AT  3.0 HOURS AFTER HIGH TIDE .

                 MKS UNITS

           WATER                 *      U          V
 NODE      DEPTH          ETA     VELOCITY   VELOCITY

   41      15.58          0.06      0.12       0.22
   42       3.08          0.05      0.24       0.44
   43       1.90          0.10     -0.05      -0.01
   44       1.90          0.08      0.06       0.05
   45       3.45          0.12      0.08       0.04
   46       5.27          0.11      0.07       0.16
   47       7.66          0.06      0.08       0.14
   48      10.75          0.11      0.06       0.20
   49       7.67          0.07      0.25       0.30
   50      10.72          0.08      0.27       0.21
   51      13.28          0.06      0.03       0.32
   52       1.83          0.08      0.13       0.02
   53       1.95          0.15      0.03       0.05
   54       3.45          0.12      0.15       0.06
   55       1.87          0.07      0.04       0.14
   56       1.92          0.12      0.24       0.01
   57       3.43          0.10      0.10       0.15
   58       3.40          0.07      0.13       0.21
   59       2.21          0.10      0.23       0.09
   60       3.08          0.06      0.26       0.25
   61       1.64          0.14      0.12       0.01
   62       1.92          0.12     -0.02       0.07
   63       3.40          0.07      0.09       0.00
   64       2.86          0.14      0.02       0.03
   65       2.22          0.11      0.11       0.02
   66       2.19          0.07      0.10       0.06
   67       1.49          0.09     -0.08      -0.12
   68       1.59          0.09      0.10       0.05
   69       1.66          0.16     -0.10      -0.07
   70       1.64          0.14      0.04       0.03
   71       2.19          0.08      0.02      -0.05
   72       3.17          0.15      0.08       0.05
   73       1.63          0.13      0.08       0.03
   74       1.57          0.07      0.08       0.07
   75       1.64          0.14      0.15       0.01
   76       1.63          0.13     -0.07       0.03
   77       1.58          0.08      0.08       0.04
   78       3.47          0.14     -0.01       0.06
   79       2.23          0.12      0.09       0.01
   80       1.57          0.07      0.01       0.02

*ETA = WATER SURFACE DEVIATION FROM MSL
```

RESULTS OF THE MODEL AT 3.0 HOURS AFTER HIGH TIDE

MKS UNITS

NODE	WATER DEPTH	ETA*	U VELOCITY	V VELOCITY
81	9.56	0.33	-0.43	0.02
82	4.12	0.41	-0.38	0.04
83	4.16	0.45	-0.64	0.03
84	18.74	0.40	-0.53	0.05
85	9.59	0.39	-0.46	0.02
86	4.19	0.43	-0.26	0.03
87	4.14	0.43	-0.54	0.03
88	10.65	0.43	-0.55	0.05
89	12.69	0.45	-0.61	0.04
90	4.15	0.44	-0.22	0.03
91	4.16	0.45	-0.63	0.11
92	10.88	0.46	-0.57	0.08
93	12.37	0.43	-0.45	0.04
94	4.17	0.46	-0.01	0.00
95	4.22	0.51	-0.67	0.10
96	10.76	0.45	-0.55	0.01
97	12.69	0.45	-0.64	0.04
98	4.20	0.49	-0.09	0.03
99	4.23	0.49	-0.61	0.26
100	10.87	0.45	-0.64	0.16
101	12.74	0.50	-0.52	0.04
102	4.22	0.51	0.36	-0.21
103	4.22	0.51	-0.72	0.36
104	10.92	0.50	-0.64	0.06
105	12.73	0.49	-0.55	0.10
106	4.23	0.49	-0.24	0.19
107	4.25	0.54	-0.76	0.26
108	15.78	0.49	-0.62	0.13
109	15.78	0.49	-0.42	0.17
110	4.26	0.55	-0.76	0.42
111	4.26	0.55	-0.93	0.27
112	16.03	0.49	-0.72	-0.08
113	10.97	0.55	0.35	0.03
114	4.29	0.53	-0.63	0.24
115	9.76	0.56	-1.03	0.44
116	14.29	0.52	-0.88	0.34
117	4.29	0.58	-0.96	0.59
118	15.97	0.58	-0.77	0.25
119	3.71	0.00	0.00	0.00

*ETA = WATER SURFACE DEVIATION FROM MSL

RESULTS OF THE MODEL AT 3.0 HOURS AFTER HIGH TIDE

MKS UNITS

NODE	WATER DEPTH	ETA*	U VELOCITY	V VELOCITY
1	1.57	0.07	-0.08	-0.05
2	1.67	0.17	-0.02	0.15
3	1.65	0.15	0.01	-0.00
4	1.64	0.14	-0.01	0.01
5	1.55	0.05	0.01	-0.01
6	1.64	0.14	-0.12	0.00
7	1.87	0.07	-0.03	-0.01
8	1.97	0.17	-0.09	0.01
9	1.63	0.13	0.03	-0.03
10	1.55	0.05	-0.18	0.11
11	2.27	0.16	-0.00	-0.00
12	2.52	0.11	-0.05	0.02
13	2.18	0.07	0.02	0.04
14	1.65	0.15	-0.14	0.06
15	1.93	0.13	-0.12	0.07
16	3.10	0.08	-0.06	0.00
17	4.70	0.15	-0.03	0.00
18	1.63	0.13	-0.13	-0.02
19	1.87	0.07	-0.11	0.05
20	3.47	0.14	-0.05	0.05
21	2.53	0.12	-0.05	0.06
22	1.86	0.05	-0.14	-0.03
23	3.15	0.13	-0.07	0.03
24	3.71	0.08	0.01	0.12
25	2.87	0.15	-0.20	0.21
26	1.92	0.12	0.03	0.03
27	1.61	0.11	-0.01	0.31
28	1.55	0.05	-0.19	-0.03
29	4.08	0.14	0.11	-0.00
30	3.73	0.10	-0.16	0.10
31	2.80	0.08	0.04	0.20
32	1.89	0.09	-0.00	0.25
33	1.57	0.07	-0.03	0.16
34	1.66	0.16	0.04	0.01
35	1.62	0.12	0.03	0.11
36	1.87	0.07	0.03	0.09
37	5.29	0.12	-0.03	0.20
38	7.10	0.11	0.09	0.14
39	10.71	0.07	-0.07	0.13
40	13.70	0.01	0.13	0.22

*ETA = WATER SURFACE DEVIATION FROM MSL

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RESULTS OF THE MODEL AT  3.0 HOURS AFTER HIGH TIDE

                    MKS UNITS

           WATER              *       U          V
  NODE     DEPTH          ETA    VELOCITY   VELOCITY

   41      10.70          0.29      0.11       0.41
   42      12.22          0.28      0.08       0.50
   43       5.21          0.28      0.15       0.66
   44       3.97          0.26     -0.32       0.48
   45      14.97          0.29     -0.14       0.39
   46       3.98          0.27      0.11       0.51
   47       4.01          0.30      0.07       0.51
   48      14.06          0.29      0.05       0.57
   49       4.01          0.30     -0.23       0.60
   50       9.49          0.29     -0.09       0.71
   51       4.01          0.30     -0.02       0.48
   52      16.82          0.31     -0.12       0.46
   53      14.07          0.30      0.00       0.41
   54      12.35          0.31     -0.20       0.57
   55       4.02          0.31     -0.33       0.58
   56      12.53          0.31     -0.24       0.32
   57      12.56          0.32     -0.13       0.28
   58       9.20          0.31     -0.22       0.27
   59       6.57          0.42     -0.51      -0.43
   60       4.03          0.32     -0.90      -0.02
   61       4.04          0.33     -0.35       0.14
   62      11.04          0.32     -0.35       0.10
   63      18.05          0.32      0.27      -0.13
   64       5.29          0.36     -0.46      -0.14
   65       4.08          0.37     -0.63      -0.43
   66      12.59          0.35     -0.60      -0.33
   67      12.26          0.32     -0.41      -0.07
   68      16.83          0.32     -0.25      -0.30
   69       4.12          0.41     -0.51      -0.10
   70       4.12          0.41     -0.59       0.01
   71      17.20          0.38     -0.89      -0.29
   72       4.64          0.32     -0.63      -0.44
   73       4.06          0.35      0.02       0.01
   74       4.14          0.43     -0.29      -0.02
   75       4.09          0.38     -0.50      -0.01
   76      15.68          0.39     -0.49       0.04
   77      18.75          0.41     -0.42      -0.01
   78       4.12          0.41     -0.20       0.02
   79       4.11          0.40     -0.57       0.07
   80      13.48          0.44     -0.56       0.05

*
 ETA = WATER SURFACE DEVIATION FROM MSL
```

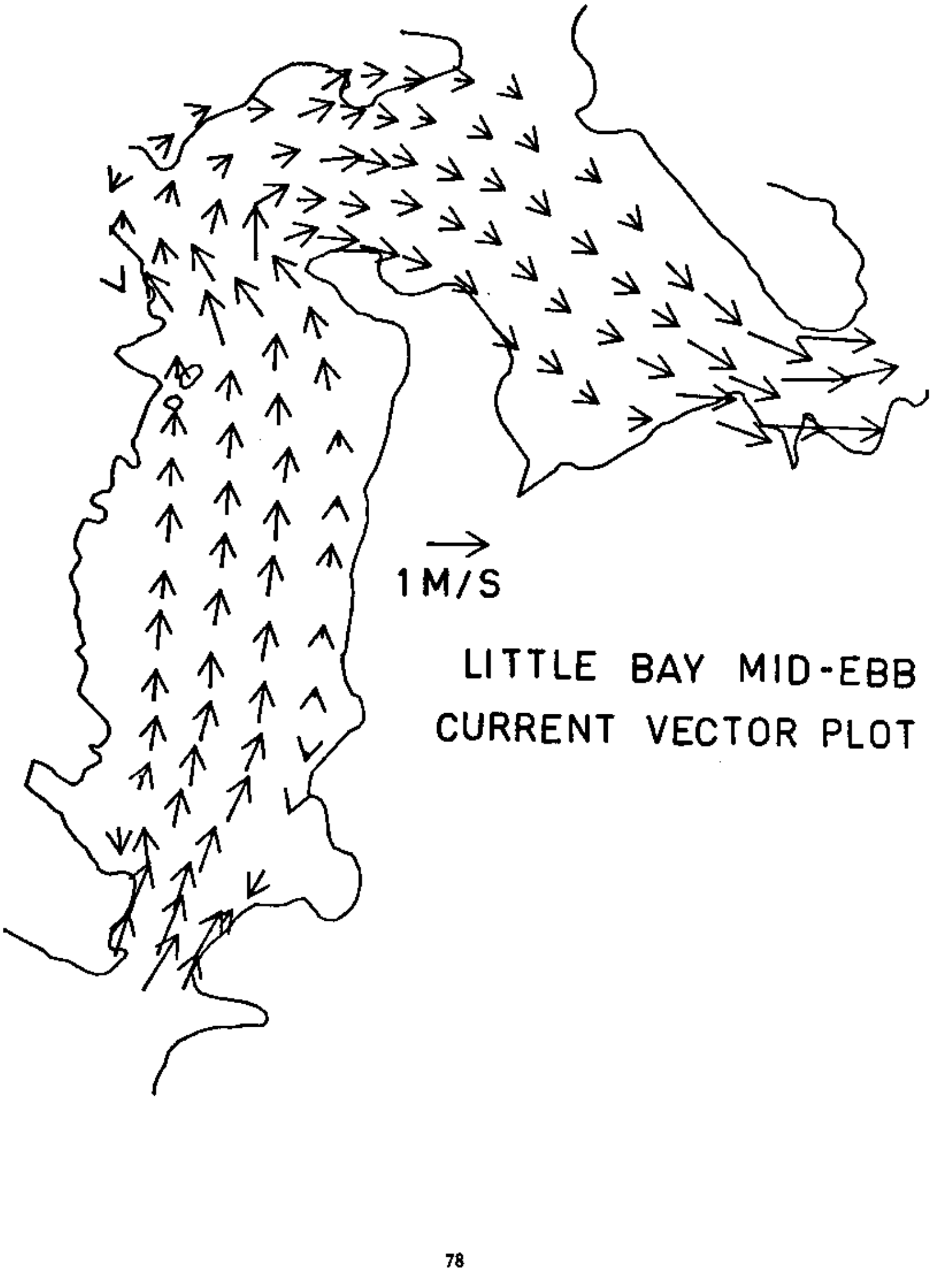
```
RESULTS OF THE MODEL AT  3.0 HOURS AFTER HIGH TIDE

                    MKS UNITS

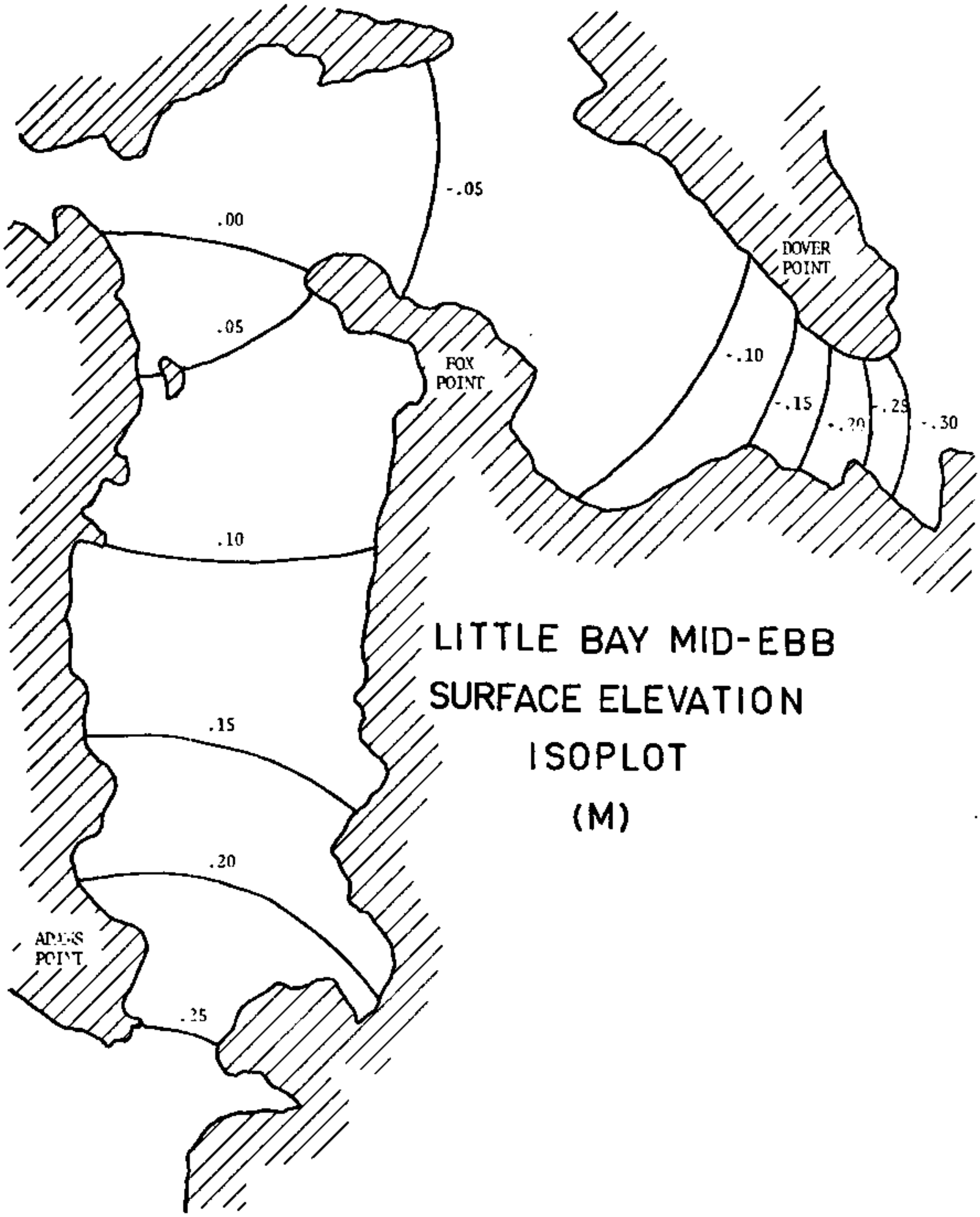
           WATER              *       U          V
  NODE     DEPTH          ETA    VELOCITY   VELOCITY

   81       1.64          0.14      0.06       0.04
   82       1.62          0.12      0.03       0.02
   83       3.78          0.15     -0.00       0.00
   84       3.46          0.13     -0.02      -0.04
   85       1.59          0.09      0.04       0.08
   86       1.65          0.15     -0.00      -0.00
   87       1.64          0.14      0.09       0.05

*
 ETA = WATER SURFACE DEVIATION FROM MSL
```



LITTLE BAY MID-EBB
CURRENT VECTOR PLOT



LITTLE BAY MID-EBB
SURFACE ELEVATION
ISOPLOT
(M)

APPENDIX X

GREAT BAY MODEL RESULTS

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RESULTS OF THE MODEL AT  3.0 HOURS AFTER HIGH TIDE

                    MKS UNITS

           WATER            *         U          V
NODE       DEPTH          ETA    VELOCITY   VELOCITY

  1         1.57          0.07      -0.08      -0.05
  2         1.67          0.17      -0.02       0.15
  3         1.65          0.15       0.01      -0.00
  4         1.64          0.14      -0.01       0.01
  5         1.55          0.05       0.01      -0.01
  6         1.64          0.14      -0.12       0.00
  7         1.87          0.07      -0.03      -0.01
  8         1.97          0.17      -0.09       0.01
  9         1.63          0.13       0.03      -0.03
 10         1.55          0.05      -0.18       0.11
 11         2.27          0.16      -0.00      -0.00
 12         2.52          0.11      -0.05       0.02
 13         2.18          0.07       0.02       0.04
 14         1.65          0.15      -0.14       0.06
 15         1.93          0.13      -0.12       0.07
 16         3.10          0.08      -0.06       0.00
 17         4.70          0.15      -0.03       0.00
 18         1.63          0.13      -0.13      -0.02
 19         1.87          0.07      -0.11       0.05
 20         3.47          0.14      -0.05       0.05
 21         2.53          0.12      -0.05       0.06
 22         1.86          0.06      -0.14      -0.03
 23         3.15          0.13      -0.07       0.03
 24         3.71          0.08       0.01       0.12
 25         2.87          0.15      -0.20       0.21
 26         1.92          0.12       0.03       0.08
 27         1.61          0.11      -0.01       0.31
 28         1.55          0.05      -0.19      -0.03
 29         4.08          0.14       0.11      -0.00
 30         3.73          0.10      -0.16       0.10
 31         2.80          0.08       0.04       0.20
 32         1.89          0.09      -0.00       0.25
 33         1.57          0.07      -0.25       0.16
 34         1.66          0.16       0.04       0.01
 35         1.62          0.12       0.03       0.11
 36         1.87          0.07       0.03       0.09
 37         5.28          0.12      -0.03       0.20
 38         7.10          0.11       0.09       0.14
 39        10.71          0.07      -0.07       0.13
 40        13.70          0.01       0.13       0.22

*
 ETA = WATER SURFACE DEVIATION FROM MSL
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RESULTS OF THE MODEL AT  3.0 HOURS AFTER HIGH TIDE .

                          MKS UNITS

              WATER             *         U           V
   NODE       DEPTH           ETA     VELOCITY    VELOCITY

    41        15.58           0.06      0.12        0.22
    42         3.08           0.06      0.24        0.44
    43         1.90           0.10     -0.05       -0.01
    44         1.88           0.08      0.06        0.05
    45         3.45           0.12      0.08        0.04
    46         5.27           0.11      0.07        0.16
    47         7.66           0.06      0.08        0.14
    48        10.75           0.11      0.06        0.20
    49         7.67           0.07      0.25        0.30
    50        10.72           0.08      0.27        0.21
    51        15.28           0.06      0.03        0.32
    52         1.88           0.08      0.13        0.02
    53         1.95           0.15      0.03        0.05
    54         3.45           0.12      0.15        0.06
    55         1.87           0.07      0.04        0.14
    56         1.92           0.12      0.24        0.01
    57         3.43           0.10      0.10        0.15
    58         3.40           0.07      0.13        0.21
    59         2.21           0.10      0.23        0.09
    60         3.08           0.06      0.26        0.25
    61         1.64           0.14      0.12        0.01
    62         1.92           0.12     -0.02        0.07
    63         3.40           0.07      0.09        0.00
    64         2.86           0.14      0.02        0.03
    65         2.22           0.11      0.11        0.02
    66         2.18           0.07      0.10        0.06
    67         1.89           0.09     -0.08       -0.12
    68         1.59           0.09      0.10        0.05
    69         1.66           0.16     -0.10       -0.07
    70         1.64           0.14      0.04        0.03
    71         2.19           0.08      0.02       -0.05
    72         3.17           0.15      0.08        0.05
    73         1.63           0.13      0.08        0.03
    74         1.57           0.07      0.08        0.07
    75         1.64           0.14      0.15        0.01
    76         1.63           0.13     -0.07        0.03
    77         1.58           0.08      0.08        0.04
    78         3.47           0.14     -0.01        0.06
    79         2.23           0.12      0.09        0.01
    80         1.57           0.07      0.01        0.02

*
ETA = WATER SURFACE DEVIATION FROM MSL
```
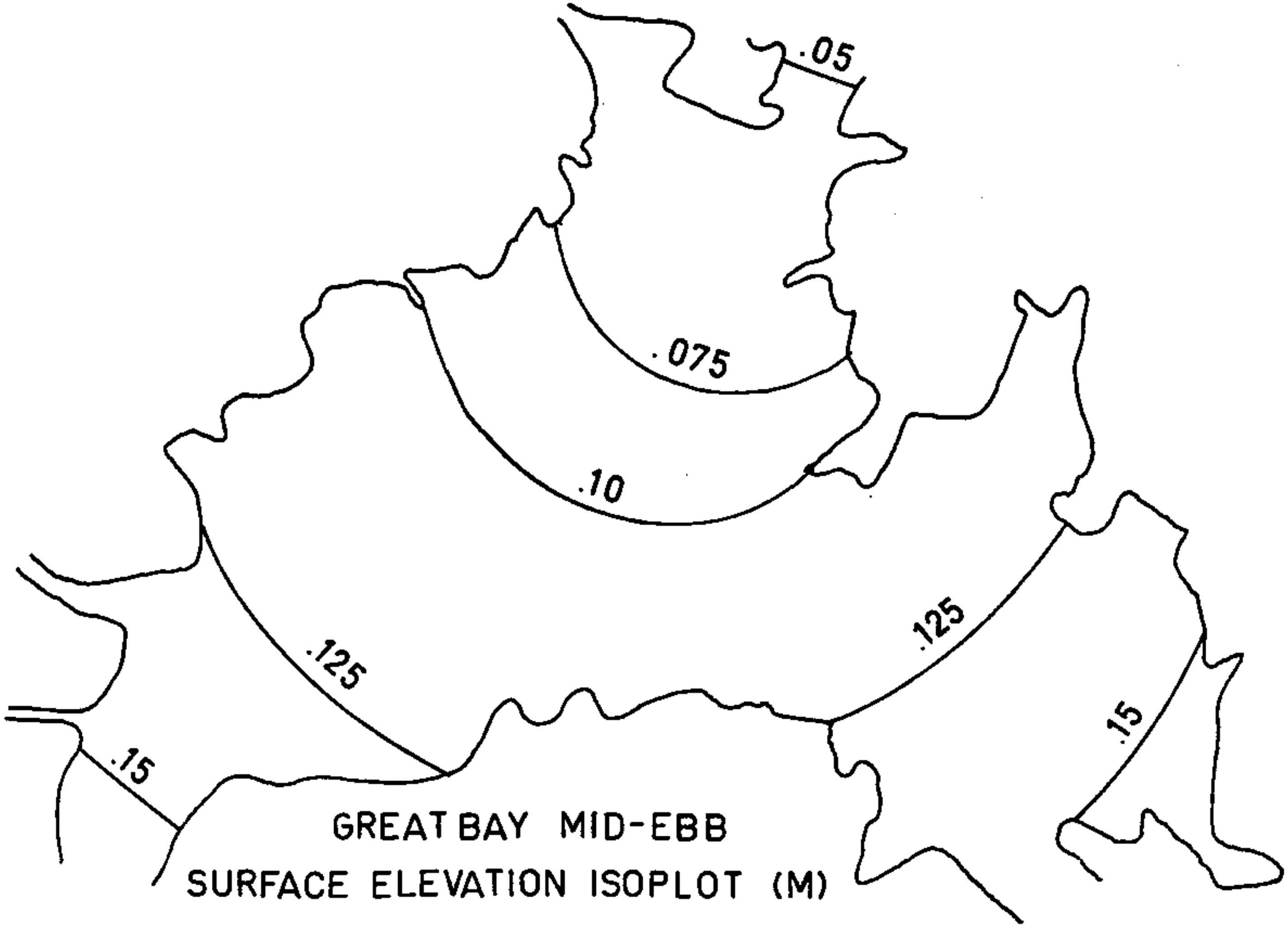
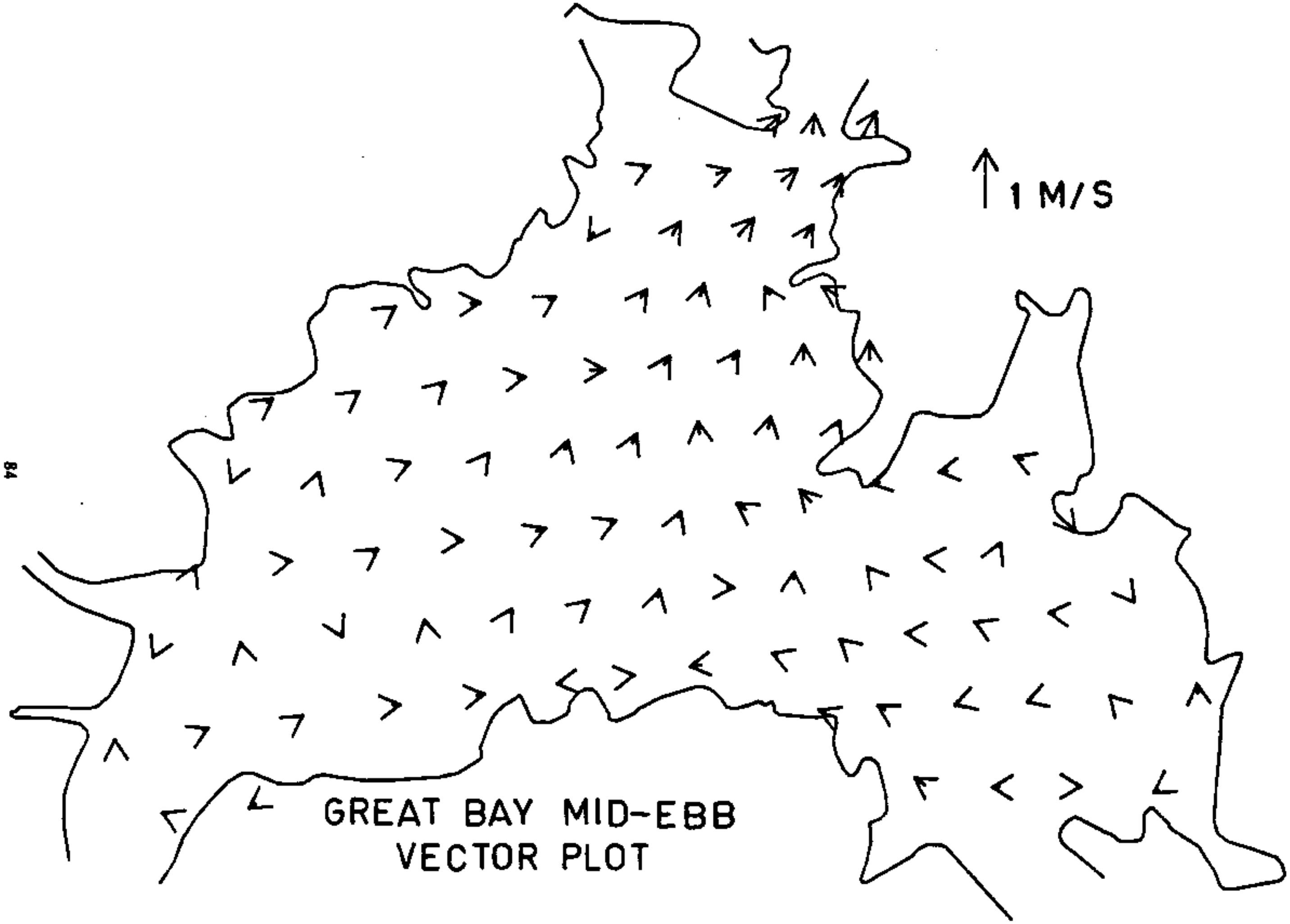



GREAT BAY MID-EBB
SURFACE ELEVATION ISOPLOT (M)



GREAT BAY MID-EBB
VECTOR PLOT

APPENDIX XI

PROGRAM FOR CALCULATING NORMAL ANGLES FOR LAND BOUNDARY ANGLES

```
C     CAFE (CIRCULATION ANALYSIS BY FINITE ELEMENTS) DATA ASSIST PROGRAM
C     PROGRAM CALCULATES NORMAL ANGLES FOR LAND BOUNDARY NODES
C
C     INPUT: CARD GROUP 1 (1 CARD) NUMBER OF NODE POINTS NMNP (I10)
C            CARD GROUP 2 (NMNP CARDS) NODE DATA CARDS AS USED IN CAFE
C            CARD GROUP 3 LAND BOUNDARY DATA AS USED IN CAFE
C
C     OUTPUT: NODE NUMBER, NORMAL ANGLE,ANGLE FORMED BY NODE AND
C             PRECEDING NODE, ANGLE FORMED BY NODE AND FOLLOWING NODE
C
C
      DIMENSION N(10),NODES(100),X(200),Y(200)
      DIMENSION ANGLE(200),DEPTH(200),I1(200),I2(200)
        OPEN(UNIT=5,DEVICE='DSK',ACCESS='SEQIN',FILE='PORT.DAT')
        OPEN(UNIT=7,DEVICE='DSK',ACCESS='SEQOUT',FILE='PORTS.DAT')
      PI=3.14159
      DEG=360./(2.*PI)
C
C     READ NUMBER OF NODES
      READ(5,100) NMNP
      DO 10 I=1,NMNP
10    ANGLE(I)=0.0
C
C     READ X AND Y COORDINATES OF NODES
      READ(5,150) (I1(I),I2(I),X(I),Y(I),DEPTH(I),I=1,NMNP)
150   FORMAT(2I5,3F10.0)
C
C     READ NUMBER OF LAND BOUNDARY STRINGS (NUM) AND NUMBER OF NODES
C     IN EACH STRING (N(I))
      READ(5,100) NUM,(N(I),I=1,NUM)
100   FORMAT(8I10)
C
      DO 99 K=1,NUM
      IEND=N(K)
C
C     READ NODES IN STRING (K)
      READ(5,101) (NODES(I),I=1,IEND)
101   FORMAT(20I4)
C
      JEND=IEND-1
      WRITE(6,200)
200   FORMAT(1H1,5X,'NORMAL ANGLES FOR LAND BOUNDARY'//11X,'NODE',10X,
     1   'ANGLE',9X,'ANGLE1',9X,'ANGLE2'/)
C
C     SET UP LOOP TO CALCULATE NORMAL ANGLES FOR ALL NODES EXCEPT
```

```
C      FIRST AND LAST
       DO 50 J=2,JEND
C
       NP1=NODES(J-1)
       NP0=NODES(J)
       NP2=NODES(J+1)
       Y1=Y(NP1)-Y(NP0)
       Y2=Y(NP2)-Y(NP0)
       X1=X(NP1)-X(NP0)
       X2=X(NP2)-X(NP0)
C
C      CALCULATE PRECEDING ANGLE (ANG1)
       ANG1=ATAN(Y1/X1)*DEG
C
C      CALCULATE FOLLOWING ANGLE (ANG2)
       ANG2=ATAN(Y2/X2)*DEG
C
       IF(X1.LT.0.0) ANG1=180.+ANG1
       IF(X2.LT.0.0) ANG2=180.+ANG2
       IF(ANG1.LT.0.0) ANG1=ANG1+360.
       IF(ANG2.LT.0.0) ANG2=ANG2+360.
C
C      CALCULATE NORMAL ANGLE
       ANG=(ANG2+ANG1)/2.
C
C      CORRECT ANGLE TO OUTWARD NORMAL IF NECESSARY
       IF(ANG1.GT.ANG2) ANG=ANG+180.
C
       IF(ANG.GT.360.) ANG=ANG-360.
       NODEJ=NODES(J)
       ANGLE(NODEJ)=ANG
50     WRITE(6,201) NODES(J),ANG,ANG1,ANG2
201    FORMAT(5X,I10,3(5X,F10.4))
99     CONTINUE
       WRITE(7,202) (I1(I),I2(I),X(I),Y(I),DEPTH(I),ANGLE(I),I=1,NMNP)
202    FORMAT(2I5,3F10.2,10X,F10.2)
       STOP
       END
```

APPENDIX XII

PROGRAM FOR CALCULATING NORMAL ANGLES FOR LAND BOUNDARY ANGLES

```
      DIMENSION TITLE(20),TEXT1(2,2),TEXT2(2,2),TEXT3(2,2),
     1  ICON(190,3),A(190,3),B(190,3),AREA(190),
     2  NEXT(135),NINT(135),XORD(135),YORD(135),DEPTH(135),NBC(135),
     3  SYSMH(135,12),SYSMQ(270,24),
     4  H(135),Q(270),HPREV(135),QPREV(270),HOLD(135),QOLD(270),
     5  H2(135),Q2(270),SYSFH(135),SYSFQ(270),SYSFHB(135),SYSFQB(270),
     6 SYSBMH(12,12),SYSBMQ(112,24),NHN(25),NCN(135),NVN(135),
     7  HB(25),ALAG(25),QB(135),QBANG(135),TAUWX(135),TAUWY(135),
     8  PSPLUS(135),CF(190),EDXX(190),EDYY(190),
     9  EDXY(190), NFLUX(30),FLUX(30)
      DIMENSION ETA(135),U(135),V(135),ETAPRV(135),
     1  NMLBN(3),ICONL(3,70),NMHNPB(3),ICONB(3,70)
      EQUIVALENCE(HPREV(1),ETAPRV(1))
      COMMON/SORTNO/K1,K2,K3
      COMMON/CGRID/NMNP,NMNP2,NBANDH,NBANDQ,MAXNOD,MAXMQ,MAXBWH,
     1  MAXBWQ,NMHBN,NMQBN,NMVBN,MAXHBN,MAXQBN,MAXEL,NMEL,
     2  MAXQBM,MAXHBM
      COMMON/COUTP/NOUT
      COMMON/CINTEG/TIME,TINC,RKFACT,RKFAC,ISTEP,PHASE,ITIME
      COMMON/CCPT/ IDFRIC,IDEPTH,IEDVIS,ICNVEC,IWIND,IVERSN
      COMMON/CPROP/GRAVT,CORIO,DENSTY
      DATA TEXT1,TEXT2,TEXT3/4HVARY,4HCONS,3HING,4HTANT,4HSET ,4HREAD,
     1  4HTO 0,3H IN,4HIGNO,4HINCL,4HRED ,4HUDED/
C     MAXHBN=NMHBN
C     MAXQBN=NMQBN
C     MAXL.GE.MAX(NMLBN); MAXO.GE.MAX(NMHNPB)
C     DIMENSION SYSMH(MAXNOD,MAXBWH),SYSMQ(MAXMQ,MAXBWQ),
C     SYSBMH(MAXHBM,MAXBWM),SYSBMQ(MAXQBM,MAXBWQ),ICONL(3,MAXL),ICONB(3,
        OPEN(UNIT=5,ACCESS='SEQIN',DEVICE='DSK',FILE='PORTSH')
        OPEN(UNIT=6,DEVICE='DSK',ACCESS='SEQOUT',DISPOSE='RENAME',
     1  FILE='PORTSH.LPT')
        OPEN(UNIT=8,DEVICE='DSK',ACCESS='SEQOUT',FILE='PHOUT')
        OPEN(UNIT=4,DEVICE='DSK',ACCESS='SEQIN',FILE='CONDIN')
      MAXO=70
      MAXL=70
      MAXNOD=135
      MAXEL=190
      MAXBWH=12
      MAXBWQ=24
      MAXHBN=6
      MAXQBN=56
      MAXMQ=2*MAXNOD
      MAXQBM=MAXQBN*2
      MAXHBM=MAXHBN*2
  320 NBANDH=0
```

```
      READ(5,1001)IVERSN,NMEL,NMNP,IBFRIC,IDEPTH,IEDVIS,IWIND,INPUTH,
     1    INPUTQ,ICNVEC,IPLOT
 1001 FORMAT(16I5)
      IF(IVERSN .NE. 2) STOP
      LENGTH=MAXNOD*MAXBWH
      CALL AMATZR(SYSMH,LENGTH)
      LENGTH=MAXMQ*MAXBWQ
      CALL AMATZR(SYSMQ,LENGTH)
      LENGTH=MAXHBM*MAXBWH
      CALL AMATZR(SYSBMH,LENGTH)
      LENGTH=MAXQBM*MAXBWQ
      CALL AMATZR(SYSBMQ,LENGTH)
      CALL AMATZR(PSPLUS,NMNP)
      CALL AMATZR(ETA,MAXNOD)
      CALL AMATZR(Q,MAXMQ)
      CALL AMATZR(QPREV,MAXMQ)
      TUPI=6.28318
      NMHBN=0
      NMVBN=0
      NMQBN=0
      IFLUX=0
      READ(5,1003) TITLE
 1003 FORMAT(20A4)
      WRITE(6,1002) TITLE
 1002 FORMAT(1H1//1H-,25X,20A4)
      CALL SLINE(36)
      WRITE(6,1004)NMEL,NMNP,IVERSN,(TEXT1(IBFRIC,I),I=1,2),
     1  (TEXT1(IDEPTH,I),I=1,2),(TEXT1(IEDVIS,I),I=1,2),
     2  (TEXT1(IWIND,I),I=1,2),(TEXT2(INPUTH,I),I=1,2),
     3  (TEXT2(INPUTQ,I),I=1,2),(TEXT3(ICNVEC,I),I=1,2)
 1004 FORMAT(1H0,5X,'THIS PROBLEM HAS THE FOLLOWING CHARACTERISTICS:'/
     1  1H0,10X,'NUMBER OF ELEMENTS, NMEL = ',I5/1H ,
     2  10X,'NUMBER OF NODES, NMNP = ',I5/1H ,
     3  10X,'THE MODEL APPLIED IS VERSION ',I1/1H ,
     4  10X,'IT IS ASSUMED THAT SPATIALLY,'/1H ,
     5  40X,'BOTTOM FRICTION IS ',2A4/1H ,
     6  40X,'MEAN LOW WATER DEPTH IS ',2A4/1H ,
     7  40X,'EDDY VISCOSITY IS ',2A4/1H ,
     8  40X,'WIND STRESS IS ',2A4/1H ,
     9  10X,'INITIAL VALUES OF H ARE ',2A4/1H ,
     A  10X,'INITIAL VALUES OF Q ARE ',2A4/1H ,
     B  10X,'CONVECTIVE ACCELERATIONS ARE ',2A4/1H )
      CALL SLINE(36)
      NMNP2=NMNP*2
      CALL AMATZR(ETA,NMNP)
      CALL AMATZR(Q,NMNP2)
      WRITE(6,1010)
 1010 FORMAT(1H0,6X,'NODE',8X,'X-',11X,'Y-',8X,'DEPTH',4X,'NODE',5X,
     1  'TIDAL',5X,'TIME',5X,'LOCAL X',6X,'FLUX',5X,' LOCAL Y',4X,
     3  'SOURCE'/1H ,5X,'NUMBER',3X,'COORDINATE',3X,'COORDINATE',4X,
     4  '(MWL)',4X,'CODE',3X,'AMPLITUDE',4X,'LAG',6X,'FLUX',7X,'ANGLE',
     5  7X,'FLUX',7X,'FLUX'/1H ,18X,'(M)',10X,'(M)',8X,'(M)',15X,
     6  '(M)',6X,'(SEC)',3X,'(M2/SEC)',3X,'(DEGREES)',3X,'(M2/SEC)',
     7  4X,'(M/SEC)'/1H0)
      DO 10 I=1,NMNP
      READ(5,1005)NEXT(I),NBC(I),XORD(I),YORD(I),DEPTH(I),DUM1,DUM2,
     1  DUM3,DUM4
 1005 FORMAT(2I5,7F10.0)
      NINT(NEXT(I))=I
      I1=NBC(I)
```

```
      N=NEXT(I)
      IF(IDEPTH .EQ. 1) GO TO 60
      DEPTH(I)=DEPTH(1)
60    IF(I1 .EQ. 0) GO TO 70
      IF(I1 .EQ. 1) GO TO 80
      IF(I1 .EQ. 2) GO TO 90
      IF(I1 .EQ. 3) GO TO 100
      IF(I1 .EQ. 6) GO TO 50
      IF(I1 .EQ. 4) GO TO 110
      NMHBN=NMHBN+1
      NMQBN=NMQBN+1
      NMVBN=NMVBN+1
      NHN(NMHBN)=I
      NQN(NMQBN)=I
      NVN(NMVBN)=I
      HB(NMHBN)=DUM1
      ALAG(NMHBN)=DUM2
      QB(NMQBN)=DUM3
      QBANG(NMQBN)=DUM4
      DUM4=0.
      WRITE(6,1006) N,XORD(I),YORD(I),DEPTH(I),NBC(I),HB(NMHBN),
     1  ALAG(NMHBN),QB(NMQBN),QBANG(NMQBN),DUM4
1006 FORMAT(1H ,5X,I4,5X,F10.2,3X,F10.2,3X,F6.2,3X,I6,4X,F5.2,4X,
     1  F6.0,4X,F8.4,5X,F6.1,6X,F3.1)
      QBANG(NMQBN)=QBANG(NMQBN)*3.14159/180.
      GO TO 10
110   NMQBN=NMQBN+1
      NMVBN=NMVBN+1
      NQN(NMQBN)=I
      NVN(NMVBN)=I
      QB(NMQBN)=DUM1
      QBANG(NMQBN)=DUM2
      WRITE(6,1008)N,XORD(I),YORD(I),DEPTH(I),NBC(I),QB(NMQBN),
     1  QBANG(NMQBN),DUM3
1008 FORMAT(1H ,5X,I4,5X,F10.2,3X,F10.2,3X,F6.2,3X,I5,24X,F8.4,
     1  5X,F6.1,6X,F3.1)
      GO TO 10
100   NMHBN=NMHBN+1
      NMQBN=NMQBN+1
      NHN(NMHBN)=I
      NQN(NMQBN)=I
      HB(NMHBN)=DUM1
      ALAG(NMHBN)=DUM2
      QB(NMQBN)=DUM3
      QBANG(NMQBN)=DUM4
      WRITE(6,1012)N,XORD(I),YORD(I),DEPTH(I),NBC(I),HB(NMHBN),
     1  ALAG(NMHBN),QB(NMQBN),QBANG(NMQBN)
1012 FORMAT(1H ,5X,I4,5X,F10.2,3X,F10.2,3X,F6.2,3X,I4,6X,F5.2,4X,
     1  F6.0,4X,F8.4,5X,F6.1)
      QBANG(NMQBN)=QBANG(NMQBN)*3.14159/180.
      GO TO 10
90    NMHBN=NMHBN+1
      NHN(NMHBN)=I
      HB(NMHBN)=DUM1
      ALAG(NMHBN)=DUM2
      WRITE(6,1014)N,XORD(I),YORD(I),DEPTH(I),NBC(I),HB(NMHBN),
     1  ALAG(NMHBN)
1014 FORMAT(1H ,5X,I4,5X,F10.2,3X,F10.2,3X,F6.2,3X,I3,7X,F5.2,4X,F6.0)
      GO TO 10
80    NMQBN=NMQBN+1
```

```
      NQN(NMQBN)=I
      QB(NMQBN)=DUM1
      QBANG(NMQBN)=DUM2
      WRITE(6,1016)N,XORD(I),YORD(I),DEPTH(I),NBC(I),QB(NMQBN),
     1   QBANG(NMQBN)
 1016 FORMAT(1H ,5X,I4,5X,F10.2,3X,F10.2,3X,F6.2,3X,I2,27X,F8.4,
     1   5X,F6.1)
      QBANG(NMQBN)=QBANG(NMQBN)*3.14159/180.
      GO TO 10
 70   WRITE(6,1018) N,XORD(I),YORD(I),DEPTH(I),NBC(I)
 1018 FORMAT(1H ,5X,I4,5X,F10.2,3X,F10.2,3X,F6.2,3X,I1)
      GO TO 10
 50   IFLUX=IFLUX+1
      NFLUX(IFLUX)=I
      FLUX(IFLUX)=DUM1
      WRITE(6,1020)N,XCRD(I),YORD(I),DEPTH(I),NBC(I),FLUX(IFLUX)
 1020 FORMAT(1H ,5X,I4,5X,F10.2,3X,F10.2,3X,F6.2,3X,I6,56X,F8.4)
 10   CONTINUE
      CALL SLINE(15)
      WRITE(6,1030)NMHBN,NMQBN,NMVBN,IFLUX
 1030 FORMAT(1H0,5X,'NUMBER OF PRESCRIBED BOUNDARY AND INTERNAL FLUX NOD
     1ES'/1H0,10X,'PRESCRIBED HEIGHTS, NMHBN =',I5/1H ,10X,
     2   'PRESCRIBED LOCAL X FLUX, NMQBN =',I5/1H ,10X,
     3   'PRESCRIBED X AND Y FLUX, NMVBN =',I5/1H ,10X,
     4   'INTERNAL FLUX NODES, IFLUX =',I5)
      CALL SLINE(36)
      READ(5,1007)(N,(ICON(N,J),J=1,3),CF(N),EDXX(N),EDYY(N),EDXY(N),
     1   L=1,NMEL)
 1007 FORMAT(4I10,4F10.0)
      WRITE(6,1022)
 1022 FORMAT(1H0,5X,'ELEMENT CONNECTIVITIES.'/1H0,10X,'ELEMENT NUMBER',
     1   3X,'NODE 1',3X,'NODE 2',3X,'NODE 3',3X,'FRICTION COEFFICIENT',
     2   3X,'EDDY XX',3X,'EDDY YY',3X,'EDDY XY'/1H0)
      IF(IBFRIC .EQ. 1) GO TO 130
      DO 120 I=2,NMEL
      CF(I)=CF(1)
 120  CONTINUE
 130  IF(IVERSN .EQ. 1 .OR. IEDVIS .EQ. 1) GO TO 200
      DO 210 I=2,NMEL
      EDXX(I)=EDXX(1)
      EDYY(I)=EDYY(1)
      EDXY(I)=EDXY(1)
 210  CONTINUE
 200  DO 220 I=1,NMEL
      WRITE(6,1024)I,(ICON(I,J),J=1,3),CF(I),EDXX(I),EDYY(I),EDXY(I)
 1024 FORMAT(1H ,16X,I3,10X,I3,6X,I3,6X,I3,12X,F10.6,3X,F9.2,
     1   1X,F9.2,1X,F9.2)
 220  CONTINUE
      CALL SLINE(36)
      CALL GEOM(NINT,ICON,A,B,AREA,XORD,YORD,SYSMH)
      NBANDQ=2*NBANDH
      CALL QMAT(SYSMQ,SYSMH)
      IF(NMQBN .GT. 0) CALL ROTMQ(SYSMQ,NQN,QBANG)
      READ(5,1009) ALATT,OMEGA,GRAVT,PERIOD,DENSTY
 1009 FORMAT(F9.1,E11.5,F7.2,F11.1,F9.1)
      CORIO=2.*OMEGA*SIN(ALATT*3.14159/180.)
      PHASE=TUPI/PERIOD
      WRITE(6,1026)ALATT,CORIO,GRAVT,OMEGA,PERIOD,DENSTY
 1026 FORMAT(1H0,5X,'SYSTEM PROPERTIES.'/1H0,10X,
     1   'AVERAGE LATITUDE, ALATT = ',F7.2,2X,'(DEGREES N)'/1H ,
```

```
     2  10X,'CORIOLIS PARAMETER, CORIO = 2*OMEGA*SIN(ALATT) = ',E10.3,
     3  2X,'(SEC-1)'/1H ,10X,'GRAVITATIONAL ACCELERATION, GRAVT = ',F6.3
     5  , 2X,'(M/SEC2)'/1H ,10X,'ANGULAR VELOCITY OF EARTH ROTATION, OME
     6GA = ',E10.3,2X,'(SEC-1)'/1H ,10X,
     7  'PERIOD OF HARMONIC TIDAL EXCITATION, PERIOD = ',F6.0,2X,
     8  '(SEC)'/1H 10X,'DENSITY OF WATER, DENSTY = ',F7.2,' (KG/M3)')
      CALL SLINE(36)
      READ(5,1011)STRTIM,ENDTIM,TINC,NO,BOUND,IDT,NOUT
 1011 FORMAT(2F9.1,F8.1,4X,I10,F6.1,4X,2I10)
      IF(IDT.EQ.1) GOTO 450
450   IF(NMHBN.EQ.0) GOTO 400
      CALL STORNO(MAXNOD,MAXBWH,MAXHBM,MAXBWH,NBANDH,NMHBN,1,
     1   SYSMH,NHN,SYSBMH,0)
 400  IF(NMVBN .EQ. 0) GO TO 410
      CALL STORNO(MAXMQ,MAXBWQ,MAXQBM,MAXBWQ,NBANDQ,NMVBN,2,SYSMQ,NVN,
     1   SYSBMQ,1)
      LENGTH=MAXQBN*MAXBWQ
      CALL AMATZP(SYSBMQ,LENGTH)
 410  IF(NMQBN .EQ. 0) GO TO 170
      CALL STORNO(MAXMQ,MAXBWQ,MAXQBM,MAXBWQ,NBANDQ,NMQBN,2,SYSMQ,
     1   NQN,SYSBMQ,0)
 170  CALL DECOMP(NMNP,MAXNOD,MAXBWH,NBANDH,SYSMH)
      CALL DECOMP(NMNP2,MAXMQ,MAXBWQ,NBANDQ,SYSMQ)
        TINC2=TINC/2
        IF( INPUTQ.EQ.2) READ(4,9940) STRTIM
9940    FORMAT(F10.0)
      TIME=STRTIM
      WRITE(6,1028)STRTIM,ENDTIM,TINC,NO,BCUND,(TEXT1(IDT,J),J=1,2),
     1   NOUT,IPLOT
 1028 FORMAT(1H0,5X,'INTEGRATION PARAMETERS,'/1H0,10X,
     1   'START TIME OF INTEGRATION, STRTIM = ',F9.1,2X,'SEC'/
     2   1H ,10X,'END TIME OF INTEGRATION, ENDTIM = ',F9.1,2X,'SEC'/
     3   1H ,10X,'CONSTANT TIME INCREMENT, TINC = ',F7.1,2X,'SEC'/1H ,10X
     4   ,'EXTERNAL NODE AT WHICH VARIATION IS BOUNDED BY BOUND, NO = ',
     5   I4/1H ,10X,'CRUDE STABILITY CONTROL,BOUND = ',F6.2/1H ,10X,
     6   'THE TIME INCREMENT IS ASSUMED ',2A4/1H ,10X,
     7   'OUTPUT WILL BE PRINTED FOR EVERY ',I3,' TIMESTEPS',
     8   'OUTPUT WILL BE STORED FOR EVERY ',I3,' TIMESTEPS')
      NO=NINT(NO)
      CALL SLINE(36)
      READ(5,1015) NMLB,(NMLBN(L), L=1,NMLB)
      DO 350 I=1,NMLB
      JEND=NMLBN(I)
      READ(5,1013)(ICONL(I,J), J=1,JEND)
 1015 FORMAT(8I10)
 350  CONTINUE
      DO 360 I=1,NMLB
      WRITE(6,1052) I,NMLBN(I),(ICONL(I,J), J=1,JEND)
 1052 FORMAT(1H0,5X,'LAND SEGMENT ',I2,5X,'# NODES, NMLBN = ',I2/1H ,5X,
     1   'EXTERNAL NODE NUMBERS: ',25(I3,'-')/1H ,20X,25(I3,'-'))
      DO 370 J=1,JEND
      ICONL(I,J)=NINT(ICONL(I,J))
 370  CONTINUE
      WRITE(6,1054) (ICONL(I,J), J=1,JEND)
 1054 FORMAT(1H ,5X,'INTERNAL NODE NUMBERS: ',25(I3,'-')/1H ,
     120X,25(I3,'-'))
 360  CONTINUE
      CALL SLINE(36)
      IF( IVERSN .EQ. 1) GO TO 20
      READ(5,1015) NSEGMT,(NMHNPB(I), I=1,NSEGMT)
```

```
1013 FORMAT(20I4)
      WRITE(6,1046) NSEGMT
1046 FORMAT(1H0,10X,'MODEL VERSION 2 CHOSEN. THE ADDITIONAL',
     1   ' BOUNDARY INFORMATION IS:'/1H0,15X,
     2   'NUMBER OF BOUNDARY SEGMENTS, NSEGMT = ',I5/1H0)
      IF(NSEGMT .EQ. 0) GO TO 40
      DO 30 I=1,NSEGMT
      J1=NMHNPB(I)
      READ(5,1013)(ICONB(I,J), J=1,J1)
      WRITE(6,1048)I,NMHNPB(I),(ICONB(I,J), J=1,J1)
1048 FORMAT(1H ,5X,'SEGMENT ',I3,',  NUMBER OF NODES, NMHNPB = ',
     1  I3,',  EXTERNAL NODE NUMBERS: ',15('-',I3))
      DO 140 J=1,J1
      ICONB(I,J)=NINT(ICONB(I,J))
140   CONTINUE
      WRITE(6,1050) (ICONB(I,J), J=1,J1)
1050 FORMAT(1H ,51X,'INTERNAL NODE NUMBERS: ',15('-',I3)/1H0)
30    CONTINUE
40    CALL SLINE(36)
20    ITIME=0
      IF(INPUTH .EQ. 1) GO TO 230
      CALL READX(ETA,NMNP)
      WRITE(6,1042)
1042 FORMAT(1H0,'INITIAL VALUES OF SURFACE ELEVATIONS ARE:'/1H )
      WRITE(6,1040)(ETA(I), I=1,NMNP)
1040 FORMAT(1H ,10(2X,E10.3))
      CALL SLINE(40)
230   IF(INPUTQ .EQ. 1) GO TO 270
      CALL READX(QPREV,NMNP2)
      DO 190 I=1,NMNP2
      Q(I)=QPREV(I)
190   CONTINUE
      IF(NMQBN .GT. 0) CALL LOCGLO(QBANG,NQN,QPREV,1.)
      WRITE(6,1044)
1044 FORMAT(1H0,10X,'INITIAL VALUES OF THE FLUXES ARE:'/1H )
      WRITE(6,1040) (Q(I), I=1,NMNP2)
      CALL SLINE(40)
270   TIME=TIME+TINC2
240   CALL STETAB(ETA,HB,NHN,ALAG)
      CALL CETA(H,DEPTH,ETA)
      CALL INTIME(ETA,ETAPRV,NMNP,SYSFQ,NMNP2)
      ITIME =ITIME+1
      TIME=TIME+TINC2
      CALL FORCEQ(H,Q,TAUWX,TAUWY,DEPTH,AREA,CF,EDXX,EDYY,EDXY,ICON,
     1  A,B,PSPLUS,SYSFQ,ETA)
      IF(IVERSN .EQ. 1) GO TO 250
      CALL BOUNDF(SYSFQ,XORD,YORD,NMLB,NMLBN,ICONL,ETA,DEPTH,MAXL)
      IF(NSEGMT .EQ. 0) GO TO 250
      CALL BOUNDF(SYSFQ,XORD,YORD,NSEGMT,NMHNPB,ICONB,ETA,DEPTH,MAXD)
250   IF(NMQBN .GT. 0) CALL LOCGLO(QBANG,NQN,SYSFQ,1.)
      CALL SOLVX(Q,SYSFQ,QPREV,SYSMQ,NMNP2,NBANDQ,MAXMQ,MAXBWQ)
      IF(NMQBN .EQ. 0) GO TO 180
      CALL STQB(Q,QB,NQN,NVN)
180   DO 150 I=1,NMNP2
      QPREV(I)=Q(I)
150   CONTINUE
      IF(NMQBN .GT. 0) CALL LOCGLO(QBANG,NQN,Q,-1.)
      CALL OUTPUT(H,Q,ETA,U,V,DEPTH,ISTAT)
      GO TO (330,300),ISTAT
260   IF(IDT.NE.1) CALL VARTIM(TIME)
```

```
      TINC2=TINC/2.
      TIME=TIME+TINC2
      CALL AMATZR(SYSFH,NMNP)
      CALL FCRCEH(Q,SYSFH,A,B,ICON)
      IF(NMHBN .EQ. 0) GO TO 160
      CALL STETAB(ETA,HB,NHN,ALAG)
      CALL SUBOUN(NMHBN,NHN,NBANDH,SYSFH,SYSBMH,ETA,ETAPRV,NMNP,
     1  MAXHBM,MAXBWH,1)
C     CALL NOFLOW(Q,QB,QBANG,XORD,YORD,SYSFH,NMLBN,ICONL,NMLB,
C    1  NMNP,NMNP2,NMQBN,MAXL)
 160  CALL SOLVX(ETA,SYSFH,ETAPRV,SYSMH,NMNP,NBANDH,MAXNOD,MAXBWH)
      GO TO 240
 300  CALL STETAB(ETA,HB,NHN,ALAG)
      CALL CETA(H,DEPTH,ETA)
      CALL VOLUME(ETA,AREA,ICON,VOL)
      WRITE(6,1034) TIME,TINC,ITIME,VOL
 1034 FORMAT(1H0,10X,'TIME = ',F12.2,' SEC',5X,'DELTA T WAS, TINC = ',
     1  F8.2,1X,'SEC.',5X,'TIME STEP, ITIME = ',I5/1H0,10X,
     2  'NET VOLUME ABOVE MLW, VOL = ',E13.6)
      CALL SLINE(15)
      WRITE(6,1021)
 1021 FORMAT(1H0,'INTERNAL',2X,'EXTERNAL',6X,'H',11X,'QX',10X,'QY',10X,
     1  'ETA',10X,'U',11X,'V',9X,'SYSFH',8X,'SYSFQ',8X,'SYSFQ'/1H ,2X,'N
     2  E',6X,'NODE'/1H ,1X,'NUMBER',4X,'NUMBER'/1H )
      DO 310 I=1,NMNP
      WRITE(6,1032)I,NEXT(I),H(I),Q(2*I-1),Q(2*I),ETA(I),U(I),V(I),
     1  SYSFH(I),SYSFO(2*I-1),SYSFQ(2*I)
 1032 FORMAT(1H ,2X,I4,6X,I4,4X,6(F10.5,2X),2(E11.4,2X),E11.4)
 310  CONTINUE
      CALL SLINE(36)
      CALL GRAPH(XORD,YORD,ETA,NMNP)
 330  CALL CHECKS(H(NO),DEPTH(NO),BOUND,ICHECK)
      IF(ICHECK.EQ.1) GOTO 320
      IF(TIME+TINC .GT. ENDTIM+0.001) GO TO 320
      IF(IPLOT.EQ.0) GOTO 260
        IF(ITIME/IPLOT*IPLOT.NE.ITIME) GOTO 260
        CALL PLOTOT(ETA,U,V)
        CALL INITCD(ETA,Q)
      GO TO 260
      END
C
C
      SUBROUTINE AMATZR(AMAT,N)
      DIMENSION AMAT(N)
      DO 10 I=1,N
      AMAT(I)=0.
 10   CONTINUE
      RETURN
      END
C
C
      SUBROUTINE BAKSUB(NE,INDX1,INDX2,NBAND,B,X)
      DIMENSION B(INDX1,INDX2), X(INDX1)
      X(NE)=X(NE)/B(NE,1)
      NDIF=NBAND-1
      DO 10 N=1,NDIF
      J=NE-N
      J1=J+1
      A=0.
      DO 20 K=J1,NE
```

```
      KJR=K-J+1
      A=A+B(J,KJR)*X(K)
 20   CONTINUE
      X(J)=(X(J)-A)/B(J,1)
 10   CONTINUE
      NE1=NE-1
      DO 30 N=NBAND,NE1
      J=NE-N
      J1=J+1
      A=0.
      KT=J+NDIF
      DO 40 K=J1,KT
      KJR=K-J+1
      A=A+B(J,KJR)*X(K)
 40   CONTINUE
      X(J)=(X(J)-A)/B(J,1)
 30   CONTINUE
      RETURN
      END
C
C
      SUBROUTINE BOUNDF(SYSFQ,XORD,YORD,NMB,NMN,ICONB,ETA,DEPTH,MAX)
      COMMON/CPROP/GRAVT,CORIO,DENSTY
      COMMON/CGRID/NMNP,NMNP2,NBANDH,NBANDQ,MAXNOD,MAXMQ,MAXBWH,
     1  MAXBWQ,NMHBN,NMCBN,NMVBN,MAXHBN,MAXQBN,MAXEL,NMEL,
     2  MAXQBM,MAXHBM
      DIMENSION SYSFQ(NMNP2),XORD(NMNP),YORD(NMNP),NMN(NMB),
     1  ICONB(3,MAX),ETA(NMNP),DEPTH(NMNP)
      DO 10 I=1,NMB
      JEND=NMN(I)
      DO 20 J=2,JEND
      K1=ICONB(I,J-1)
      K2=ICONB(I,J)
      ANX=(YORD(K2)-YORD(K1))*GRAVT/12.
      ANY=(XORD(K1)-XORD(K2))*GRAVT/12.
      DSEGMT=DEPTH(K1)+DEPTH(K2)
      ESEGMT=ETA(K1)+ETA(K2)
      VAR1=DSEGMT*ESEGMT+ESEGMT**2/2.
      VAR2=2.*DEPTH(K1)*ETA(K1)+ETA(K1)**2
      VAR3=2.*DEPTH(K2)*ETA(K2)+ETA(K2)**2
      SYSFQ(2*K1-1)=SYSFQ(2*K1-1)-ANX*(VAR1+VAR2)
      SYSFQ(2*K1)=SYSFQ(2*K1)-ANY*(VAR1+VAR2)
      SYSFQ(2*K2-1)=SYSFQ(2*K2-1)-ANX*(VAR1+VAR3)
      SYSFQ(2*K2)=SYSFQ(2*K2)-ANY*(VAR1+VAR3)
 20   CONTINUE
 10   CONTINUE
      RETURN
      END
C
C
      SUBROUTINE CETA(H,DEPTH,ETA)
      COMMON/CGRID/NMNP,NMNP2,NBANDH,NBANDQ,MAXNOD,MAXMQ,MAXBWH,
     1  MAXBWQ,NMHBN,NMCBN,NMVBN,MAXHBN,MAXQBN,MAXEL,NMEL,
     2  MAXQBM,MAXHBM
      DIMENSION H(NMNP),DEPTH(NMNP),ETA(NMNP)
      DO 10 I=1,NMNP
      H(I)=DEPTH(I)+ETA(I)
 10   CONTINUE
      RETURN
      END
```

```
C
C
      SUBROUTINE CHECKS(H,D,BOUND,ICHECK)
      ICHECK=0
      IF(ABS(H-D) .LT. BOUND) RETURN
      ICHECK=1
      WRITE(6,1002) H,D,BOUND
 1002 FORMAT(1H0,15X,'STABILITY CHECK: BOUND EXCEEDED AT NODE ',/
     1  1H ,5X,'HEIGHT WAS ',E11.4,5X,'DEPTH ',F6.2,5X,'BOUND = ',F6.2)
      RETURN
      END
C
C
      SUBROUTINE DECOMP(NEQT,INDX1,INDX2,NBAND,A)
      DIMENSION A(INDX1,INDX2)
      I=1
 70   DIAG=A(I,1)
      IF(DIAG .LT. 1.E-30) GO TO 10
      DIAG =SQRT(DIAG)
      DO 20 K=1,NBAND
      A(I,K)=A(I,K)/DIAG
 20   CONTINUE
      I=I+1
      IF(I .GT. NEQT) RETURN
      LIM=NBAND-1
      I4=I-LIM
      I3=I-1
 50   DO 30 J=1,LIM
      IF(I+J .GT. NEQT+1) GO TO 70
      I2=I4+J-1
      IF(I .LT. NBAND) I2=1
      DO 40 I1=I2,I3
      IF(I-I1+J .GT. NBAND) GO TO 40
      K=I-I1
      A(I,J)= A(I,J)-A(I1,K+1)*A(I1,K+J)
 40   CONTINUE
 30   CONTINUE
      GO TO 70
 10   WRITE(6,1002) I
 1002 FORMAT(1H-,5X,'SINGULAR ELEMENT IN ROW',I3)
      STOP
      END
C
C
      SUBROUTINE FORCEH(Q,SYSFH,A,B,ICON)
      COMMON/CGRID/NMNP,NMNP2,NBANDH,NBANDQ,MAXNOD,MAXMQ,MAXBWH,
     1  MAXBWQ,NMHBN,NMQBN,NMVBN,MAXHBN,MAXQBN,MAXEL,NMEL,
     2  MAXQBM,MAXHBM
      COMMON/SORTNO/K(3)
      DIMENSION Q(NMNP2),SYSFH(NMNP),ICON(MAXEL,3),A(MAXEL,3),
     1  B(MAXEL,3)
      DO 10 I=1,NMEL
      VAR=0.
      DO 20 J=1,3
      K(J)=ICON(I,J)
      VAR=VAR+B(I,J)*Q(2*K(J)-1)+A(I,J)*Q(2*K(J))
 20   CONTINUE
      VAR=-VAR/6.
      DO 30 J=1,3
      SYSFH(K(J))=VAR+SYSFH(K(J))
```

```
 30     CONTINUE
 10     CONTINUE
        RETURN
        END
C
C
        SUBROUTINE FORCEQ(H,Q,TAUWX,TAUWY,DEPTH,AREA,CF,EDXX,EDYY,
       1  EDXY,ICON,A,B,PSPLUS,SYSFQ,ETA)
        COMMON/CPROP/GRAVT,CORIO,DENSTY
        COMMON/CGRID/NMNP,NMNP2,NBANDH,NBANDQ,MAXNOD,MAXMQ,MAXBWH,
       1  MAXBWQ,NMHBN,NMQBN,NMVBN,MAXHBN,MAXQBN,MAXEL,NMEL,
       2  MAXQBM,MAXHBM
        COMMON/COPT/ IBFRIC,IDEPTH,IEDVIS,ICNVEC,IWIND,IVERSN
        DIMENSION H(NMNP),Q(NMNP2),TAUWX(NMNP),TAUWY(NMNP),DEPTH(NMNP),
       1  AREA(NMEL),CF(NMEL),EDXX(NMEL),EDYY(NMEL),EDXY(NMEL),ICON(MAXEL,
       2  3),A(MAXEL,3),B(MAXEL,3),PSPLUS(NMNP),SYSFQ(NMNP2),ETA(NMNP),
       3  SX(200),SY(200),CXX(200),CYY(200),CXY(200),K(3),
       4  SBX(200),SBY(200)
        CALL WINDS(TAUWX,TAUWY)
        DO 10 I=1,NMNP
        SX(I)=TAUWX(I)+CORIO*Q(2*I)
        SY(I)=TAUWY(I)-CORIO*Q(2*I-1)
        VAR=SQRT(Q(2*I-1)**2+Q(2*I)**2)/H(I)**2
        SBX(I)=Q(2*I-1)*VAR
        SBY(I)=VAR*Q(2*I)
 10     CONTINUE
        IF(ICNVEC .EQ. 1) GO TO 40
        DO 90 I=1,NMNP
        CXX(I)=Q(2*I-1)**2/H(I)
        CYY(I)=Q(2*I)**2/H(I)
        CXY(I)=Q(2*I)*Q(2*I-1)/H(I)
 90     CONTINUE
 40     DO 20 I=1,NMEL
        A12=AREA(I)/12.
        ETAEMT=0.
        DEMT=0.
        BDEMT=0.
        EDEMT=0.
        E2EMT=0.
        FXX=0.
        FXY=0.
        FYY=0.
        DO 30 J=1,3
        K(J)=ICON(I,J)
        ETAEMT=ETAEMT+ETA(K(J))
        DEMT=DEMT+DEPTH(K(J))
        BDEMT=BDEMT+B(I,J)*DEPTH(K(J))
        EDEMT=EDEMT+ETA(K(J))*DEPTH(K(J))
        E2EMT=E2EMT+ETA(K(J))**2
        FXX=FXX+Q(2*K(J)-1)*B(I,J)
        FXY=FXY+Q(2*K(J)-1)*A(I,J)+Q(2*K(J))*B(I,J)
        FYY=FYY+Q(2*K(J))*A(I,J)
 30     CONTINUE
        PRESS=((DEMT*ETAEMT+EDEMT)*2+ETAEMT**2+E2EMT)*GRAVT/48.
        VAR=(B(I,1)*DEPTH(K(1))+B(I,2)*DEPTH(K(2))+B(I,3)*DEPTH(K(3)))
       1  *GRAVT/24.
        SXX=(SX(K(1))+SX(K(2))+SX(K(3)))*A12
        SBXX=-(SBX(K(1))+SBX(K(2))+SBX(K(3)))*A12*CF(I)
        CONVEC=0.
        DO 50 J=1,3
```

```
      COLL=PRESS*B(I,J)+SXX+SBXX+A12*SX(K(J))-A12*SBX(K(J))*CF(I)
     1  +VAR*ETAEMT+VAR*ETA(K(J))-(EDXX(I)*FXX*B(I,J)
     2  +EDYY(I)*FYY*A(I,J))/AREA(I)/4.
      SYSFQ(2*K(J)-1)=SYSFQ(2*K(J)-1)+COLL
      IF(ICNVEC .EQ. 1) GO TO 50
      CONVEC=CONVEC+B(I,J)*CXX(K(J))+A(I,J)*CXY(K(J))
50    CONTINUE
      IF(ICNVEC .EQ. 1) GO TO 60
      CONVEC=-CONVEC/6.
      DO 70 J=1,3
      SYSFQ(2*K(J)-1)=SYSFQ(2*K(J)-1)+CONVEC
70    CONTINUE
60    CONVEC=0.
      VAR=(A(I,1)*DEPTH(K(1))+A(I,2)*DEPTH(K(2))+A(I,3)*DEPTH(K(3)))
     1  *GRAVT/24.
      SXX=(SY(K(1))+SY(K(2))+SY(K(3)))*A12
      SBXX=-(SBY(K(1))+SBY(K(2))+SBY(K(3)))*A12*CF(I)
      DO 80 J=1,3
      COLL=PRESS*A(I,J)+SXX+SBXX+A12*SY(K(J))-A12*SBY(K(J))*CF(I)
     1  +VAR*ETAEMT+VAR*ETA(K(J))-(EDXY(I)*FXY*B(I,J)
     2  +EDXY(I)*FXY*A(I,J))/AREA(I)/4.
      SYSFQ(2*K(J))=SYSFQ(2*K(J))+COLL
      IF(ICNVEC .EQ. 1) GO TO 80
      CONVEC=CONVEC+B(I,J)*CXY(K(J))+A(I,J)*CYY(K(J))
80    CONTINUE
      IF(ICNVEC .EQ. 1) GO TO 20
      CONVEC=-CONVEC/6.
      DO 100 J=1,3
      SYSFQ(2*K(J))=SYSFQ(2*K(J))+CONVEC
100   CONTINUE
20    CONTINUE
      RETURN
      END
C
C
      SUBROUTINE FORSUB(NE,INDX1,INDX2,NBAND,B,C)
      DIMENSION B(INDX1,INDX2),C(INDX1)
      C(1)=C(1)/B(1,1)
      DO 10 J=2,NBAND
      A=0.
      J1=J-1
      DO 20 L=1,J1
      LJR=J-L+1
      A=A+B(L,LJR)*C(L)
20    CONTINUE
      C(J)=(C(J)-A)/B(J,1)
10    CONTINUE
      NDIF=NBAND-1
      NN=NBAND+1
      DO 30 J=NN,NE
      A=0.
      J1=J-1
      LT=J-NDIF
      DO 40 L=LT,J1
      LJR=J-L+1
      A=A+B(L,LJR)*C(L)
40    CONTINUE
      C(J)=(C(J)-A)/B(J,1)
30    CONTINUE
      RETURN
```

```
      END
C
C
      SUBROUTINE GEOM(NINT,ICON,A,B,AREA,XORD,YORD,SYSMH)
      COMMON/CGRID/NMNP,NMNP2,NBANDH,NBANDQ,MAXNOD,MAXMQ,MAXBWH,
     1  MAXBWQ,NMHBN,NMQBN,NMVBN,MAXHBN,MAXQBN,MAXEL,NMEL,
     2  MAXQBM,MAXHBM
      COMMON/SORTNO/K(3)
      DIMENSION NINT(NMNP),ICON(MAXEL,3),A(MAXEL,3),B(MAXEL,3),
     1  AREA(NMEL),SYSMH(MAXNOD,MAXBWH),XORD(NMNP),YORD(NMNP)
      DIMENSION IPERM(3,2)
      DATA IPERM/3,1,2,2,3,1/
      WRITE(6,1002)
 1002 FORMAT(1H0,5X,'GEOMETRICAL RELATIONS'/1H ,10X,
     2  'ELEMENT'/1H ,10X,'NUMBER',4X,'A1',8X,'B1',
     3  8X,'A2',8X,'B2',8X,'A3',8X,'B3',8X,'AREA'/1H )
      DO 10 I=1,NMEL
      DO 20 J=1,3
      K(J)=NINT(ICON(I,J))
      ICON(I,J)=K(J)
 20   CONTINUE
      DO 40 J=1,3
      A(I,J)=XORD(K(IPERM(J,1)))-XORD(K(IPERM(J,2)))
      B(I,J)=YORD(K(IPERM(J,2)))-YORD(K(IPERM(J,1)))
 40   CONTINUE
      AREA(I)=0.5*(B(I,1)*A(I,2)-B(I,2)*A(I,1))
      IF(AREA(I) .GT. 0.) GO TO 30
      WRITE(6,1004) I
 1004 FORMAT(1H0,5X,'NEGATIVE AREA IN ELEMENT:',I4)
      STOP
 30   VAR=AREA(I)/12.
      CALL SORTN
      K1=K(1)
      K2=K(2)
      K3=K(3)
      SYSMH(K1,1)=SYSMH(K1,1)+2.*VAR
      K21=K2-K1+1
      SYSMH(K1,K21)=SYSMH(K1,K21)+VAR
      K31=K3-K1+1
      SYSMH(K1,K31)=SYSMH(K1,K31)+VAR
      SYSMH(K2,1)=SYSMH(K2,1)+2.*VAR
      K32=K3-K2+1
      SYSMH(K2,K32)=SYSMH(K2,K32)+VAR
      SYSMH(K3,1)=SYSMH(K3,1)+2.*VAR
      WRITE(6,1006)I,A(I,1),B(I,1),A(I,2),B(I,2),A(I,3),B(I,3),AREA(I)
 1006 FORMAT(1H ,5X,I6,2X,6(F9.1,1X),F12.1)
      IF(K31 .LT. NBANDH) GO TO 10
      NBANDH=K31
 10   CONTINUE
      WRITE(6,1010) NBANDH
 1010 FORMAT(1H0,10X,'BANDWIDTH OF THIS GRID IS, NBANDH = ',I4)
      CALL SLINE(36)
      IF(NBANDH .LE. MAXBWH) RETURN
      WRITE(6,1008) NBANDH
 1008 FORMAT(1H0,5X,'BANDWIDTH IS TOO LARGE, NBANDH = ',I5)
      STOP
      END
C
C
      SUBROUTINE GRAPH(XORD,YORD,ETA,NMNP)
```

```
      DIMENSION  XORD(1),YORD(1),ETA(1)
      RETURN
      END
C
C
        SUBROUTINE INITCD(ETA,Q)
        COMMON/CGRID/NMNP,NMNP2 ,NBANDH,NBANDQ,MAXNOD,MAXMQ,MAXBWH,
     1  MAXBWQ,NMHBN,NMQBN,NMVBN,MAXHBN,MAXQBN,MAXEL,NMEL,MAXQBM
        COMMON/CINTEG/TIME,TINC,RKFACT,RKFAC,ISTEP,PHASE,ITIME
        DIMENSION ETA(NMNP),Q(NMNP2)
        OPEN(UNIT=9,DEVICE='DSK',ACCESS='SEQOUT',FILE='INCOND')
        WRITE(9,200) TIME
        WRITE(9,200) (ETA(I),I=1,NMNP)
        WRITE(9,200) (Q(I),I=1,NMNP2)
200     FORMAT(8F10.4)
        RETURN
        END
C
C
      SUBROUTINE INTIME(ETA,ETAPRV,NMNP,SYSFQ,NMNP2)
      DIMENSION ETA(NMNP),ETAPRV(NMNP),SYSFQ(NMNP2)
      DO 10 I=1,NMNP
      ETAPRV(I)=ETA(I)
      SYSFQ(I)=0.
 10   CONTINUE
      I1=NMNP+1
      DO 20 I=I1,NMNP2
      SYSFQ(I)=0.
 20   CONTINUE
      RETURN
      END
C
C
      SUBROUTINE LCCGLO(QBANG,NQN,Q,GLTOLC)
      COMMON/ANGLE/S,C
      COMMON/CGRID/NMNP,NMNP2,NBANDH,NBANDQ,MAXNOD,MAXMQ,MAXBWH,
     1  MAXBWQ,NMHBN,NMQBN,NMVBN,MAXHBN,MAXQBN,MAXEL,NMEL,
     2  MAXQBM,MAXHBM
      DIMENSION QBANG(MAXNOD),Q(NMNP2),NQN(MAXNOD)
      DO 10 I=1,NMQBN
      I1=NQN(I)
      ANG=GLTOLC*QBANG(I)
      CALL TRIGO(ANG)
      CALL ROTV(Q(2*I1-1),Q(2*I1))
 10   CONTINUE
      RETURN
      END
C
C
      SUBROUTINE OUTPUT(H,Q,ETA,U,V,DEPTH,ISTAT)
      COMMON/CINTEG/TIME,TINC,RKFACT,RKFAC,ISTEP,PHASE,ITIME
      COMMON/COUTP/NOUT
      COMMON/CGRID/NMNP,NMNP2,NBANDH,NBANDQ,MAXNOD,MAXMQ,MAXBWH,
     1  MAXBWQ,NMHBN,NMQBN,NMVBN,MAXHBN,MAXQBN,MAXEL,NMEL,
     2  MAXQBM,MAXHBM
      DIMENSION H(NMNP),Q(NMNP2),ETA(NMNP),U(NMNP),V(NMNP),DEPTH(NMNP)
      ISTAT=1
      IF(ITIME/NOUT*NCUT .EQ. ITIME) GO TO 10
      IF(ITIME .EQ. 2) GO TO 10
      IF(ITIME .EQ. 5) GO TO 10
```

```
      RETURN
 10   CALL CETA(H,DEPTH,ETA)
      CALL VEL(H,Q,U,V)
      ISTAT=2
      RETURN
      END
C
C
        SUBROUTINE PLOTOT(ETA,U,V)
        DIMENSION ETA(NMNP),U(NMNP),V(NMNP)
        COMMON/CGRID/NMNP,NMNP2,NBANDH,NBANDQ,MAXNOD,MAXMQ,MAXBWH,
     1  MAXBWQ,NMNBN,NMQBN,NMVBN,MAXHBN,MAXQBN,MAXEL,NMEL,MAXQBM,MAXHBM
        COMMON/CINTEG/TIME,TINC,RKFACT,RKFAC,ISTEP,PHASE,ITIME
        WRITE(8,200) TIME
        WRITE(8,200) (ETA(I),I=1,NMNP)
        WRITE(8,200) (U(I),V(I),I=1,NMNP)
200     FORMAT(8F10.4)
      RETURN
      END
C
C
      SUBROUTINE POSTTT(A,B,C,D)
      COMMON/ANGLE/SIN,COS
      A1=A*COS+B*SIN
      B=-A*SIN+B*COS
      C1=C*COS+D*SIN
      D=-C*SIN+D*COS
      A=A1
      C=C1
      RETURN
      END
C
C
      SUBROUTINE PRET(A,B,C,D)
      COMMON/ANGLE/SIN,COS
      A1=A*COS+C*SIN
      B1=B*COS+D*SIN
      C=-A*SIN+C*COS
      D=-B*SIN+D*COS
      A=A1
      B=B1
      RETURN
      END
C
C
      SUBROUTINE QMAT(SYSMQ,SYSMH)
      COMMON/CGRID/NMNP,NMNP2,NBANDH,NBANDQ,MAXNOD,MAXMQ,MAXBWH,
     1  MAXBWQ,NMHBN,NMQBN,NMVBN,MAXHBN,MAXQBN,MAXEL,NMEL,
     2  MAXQBM,MAXHBM
      DIMENSION SYSMQ(MAXMQ,MAXBWQ),SYSMH(MAXNOD,MAXBWH)
      NDIF=NMNP-NBANDH+1
      DO 10 IR=1,NDIF
      DO 20 IC=1,NBANDH
      SYSMQ(2*IR-1,2*IC-1)=SYSMH(IR,IC)
      SYSMQ(2*IR,2*IC-1)=SYSMH(IR,IC)
 20   CONTINUE
 10   CONTINUE
      N1=NDIF+1
      J1=0
      DO 30 IR=N1,NMNP
```

```
      J1=J1+1
      LIM=NBANDH-J1
      DO 40 IC=1,LIM
      SYSMQ(2*IR-1,2*IC-1)=SYSMH(IR,IC)
      SYSMQ(2*IR,2*IC-1)=SYSMH(IR,IC)
 40   CONTINUE
 30   CONTINUE
      RETURN
      END
C
C
      SUBROUTINE READX(X,NMN)
      DIMENSION X(NMN)
      READ(4,1001)X
 1001 FORMAT(8F10.0)
      RETURN
      END
C
C
      SUBROUTINE ROTMQ(SYSMQ,NQN,QBANG)
      COMMON/ANGLE/S,C
      COMMON/CGRID/NMNP,NMNP2,NBANDH,NBANDQ,MAXNOD,MAXMQ,MAXBWH,
     1  MAXBWQ,NMHBN,NMQBN,NMVBN,MAXHBN,MAXQBN,MAXEL,NMEL,
     2  MAXQBM,MAXHBM
      DIMENSION SYSMQ(MAXMQ,MAXBWQ),NQN(NMQBN),QBANG(NMQBN)
      LIM1=NBANDG/2-1
      DO 10 I=1,NMQBN
      IR=NQN(I)
      LIM=LIM1
      IF(IR .LE. LIM) GO TO 20
      CALL TRIGO(QBANG(I))
 40   DO 30 IC=1,LIM
      IR1=IR-IC
      CALL POSTTT(SYSMQ(2*IR1-1,2*IC+1),SYSMQ(2*IR1-1,2*IC+2),
     1  SYSMQ(2*IR1,2*IC),SYSMQ(2*IR1,2*IC+1))
 30   CONTINUE
      GO TO 10
 20   IF(IR .EQ. 1) GO TO 10
      CALL TRIGO(QBANG(I))
      LIM=IR-1
      GO TO 40
 10   CONTINUE
      NDIF=(NMNP2-NBANDG+2)/2
      LIM1=NBANDQ/2
      DO 50 I=1,NMQBN
      IR=NQN(I)
      LIM=LIM1
      IF(IR .GT. NDIF) GO TO 60
      CALL TRIGO(QBANG(I))
 80   DO 70 IC=2,LIM
      CALL PRET(SYSMQ(2*IR-1,2*IC-1),SYSMQ(2*IR-1,2*IC),
     1  SYSMQ(2*IR,2*IC-2),SYSMQ(2*IR,2*IC-1))
 70   CONTINUE
      GO TO 50
 60   IF(IR .EQ. NMNP) GO TO 50
      CALL TRIGO(QBANG(I))
      LIM=LIM-(IR-NDIF)
      GO TO 80
 50   CONTINUE
      RETURN
```

```
      END
C
C
      SUBROUTINE ROTV(A,B)
      COMMON/ANGLE/ S,C
      X=A*C+B*S
      B=-A*S+B*C
      A=X
      RETURN
      END
C
C
      SUBROUTINE SLINE(N)
      DATA STAR/3H* */
      WRITE(6,1002)(STAR,I=1,N)
 1002 FORMAT(1H0,5X,42A3)
      RETURN
      END
C
C
      SUBROUTINE SOLVX(X,SYSFX,XPREV,SYSMX,NMN,NBAND,INDEX1,INDEX2)
      COMMON/CGRID/NMNP,NMNP2,NBANDH,NBANDQ,MAXNOD,MAXMQ,MAXBWH,
     1  MAXBWQ,NMHBN,NMQBN,NMVBN,MAXHBN,MAXQBN,MAXEL,NMEL,
     2  MAXQBM,MAXHBM
      COMMON/CINTEG/TIME,TINC,RKFACT,RKFAC,ISTEP,PHASE,ITIME
      DIMENSION X(NMN),SYSFX(NMN),SYSMX(INDEX1,INDEX2),
     1  XPREV(NMN)
      DO 10 I=1,NMN
      X(I)=TINC*SYSFX(I)
 10   CONTINUE
      CALL FORSUB(NMN,INDEX1,INDEX2,NBAND,SYSMX,X)
      CALL BAKSUB(NMN,INDEX1,INDEX2,NBAND,SYSMX,X)
      DO 20 I=1,NMN
      X(I)=X(I)+XPREV(I)
 20   CONTINUE
      RETURN
      END
C
C
      SUBROUTINE SORTN
      COMMON/SORTNO/K1,K2,K3
      IF(K1 .LT. K3)  GO TO 10
      K=K3
      K3=K1
      K1=K
 10   IF(K2 .LT. K3)  GO TO 20
      K=K3
      K3=K2
      K2=K
 20   IF(K1 .LT. K2)  RETURN
      K=K2
      K2=K1
      K1=K
      RETURN
      END
C
C
      SUBROUTINE STETAB(ETA,HB,NHN,ALAG)
      COMMON/CGRID/NMNP,NMNP2,NBANDH,NBANDQ,MAXNOD,MAXMQ,MAXBWH,
     1  MAXBWQ,NMHBN,NMQBN,NMVBN,MAXHBN,MAXQBN,MAXEL,NMEL,
```

```
     2   MAXQBM,MAXHBM
      COMMON/CINTEG/TIME,TINC,RKFACT,RKFAC,ISTEP,PHASE,ITIME
      DIMENSION ETA(NMNP),HB(NMHBN),NHN(NMHBN),ALAG(NMHBN)
      DO 10 I=1,NMHBN
      I1=NHN(I)
      ETA(I1)=HB(I)*SIN(PHASE*(TIME-ALAG(I)))
 10   CONTINUE
      RETURN
      END
C
C
      SUBROUTINE STORNO(INDX1,INDX2,INDX3,INDX4,NBAND,NMBN,NN,A,NB,C,
     1   NV)
      COMMON/CINTEG/TIME,TINC,RKFACT,RKFAC,ISTEP,PHASE,ITIME
      DIMENSION A(INDX1,INDX2),C(INDX3,INDX4),NB(NMBN)
      NDIF=NBAND-1
      DO 10 I=1,NMBN
      IR=NB(I)
      IR1=NN*(IR-1)+1+NV
      IF(IR1 .EQ. 1) GO TO 20
      IF(IR1 .LE. NDIF) NDIF=NN*(IR-1)+NV
      DO 30 IC=1,NDIF
      IR2=IR1-IC
      C(2*I-1,IC)=-A(IR2,IC+1)/TINC
      A(IR2,IC+1)=0.
 30   CONTINUE
      NDIF=NBAND-1
 20   DO 40 IC=1,NDIF
      C(2*I,IC)=-A(IR1,IC+1)/TINC
      A(IR1,IC+1)=0.
 40   CONTINUE
      A(IR1,1)=1.
 10   CONTINUE
      RETURN
      END
C
C
      SUBROUTINE STQB(Q,QB,NQN,NVN)
      COMMON/CGRID/NMNP,NMNP2,NBANDH,NBANDQ,MAXNOD,MAXMQ,MAXBWH,
     1MAXBWQ,NMHBN,NMQBN,NMVBN,MAXHBN,MAXQBN,MAXEL,NMEL,
     2MAXQBM,MAXHBM
      COMMON/CINTEG/TIME,TINC,RKFACT,RKFAC,ISTEP,PHASE,ITIME
      DIMENSION Q(NMNP2),QB(MAXNOD),NQN(MAXNOD),NVN(MAXNOD)
      DO 10 I=1,NMQBN
      I1=2*NQN(I)-1
C     IF(I1.LE.0) I1=1
      Q(I1)=QB(I)
 10   CONTINUE
      IF(NMVBN.EQ.0) GO TO 30
      DO 20 I=1,NMVBN
      I1=2*NVN(I)
      Q(I1)=0.
 20   CONTINUE
 30   CONTINUE
      RETURN
      END
C
C
      SUBROUTINE SUBOUN(NMBN,NN,NBAND,SYSFXB,SYSBMX,X,XPREV,
     1   NEQT,INDX1,INDX2,NV)
```

```
      DIMENSION SYSBMX(INCX1,INDX2),NN(NMBN),SYSFXB(NEQT),X(NEQT),
     1  XPREV(NEQT)
      DO 10 I=1,NMBN
      I1=NV*NN(I)-1
      IF(I1.LT.1)I1=1
      NDIF=NBAND-1
      IF(I1.LE.1)GO TO 20
      IF(I1 .LT. NBAND) NDIF=I1-1
      DO 30 J=1,NDIF
      SYSFXB(I1-J)=SYSFXB(I1-J)+SYSBMX(2*I-1,J)*(X(I1)-XPREV(I1))
 30   CONTINUE
      NDIF=NBAND-1
 20   IF(I1+NDIF .GT. NEQT) NDIF=NEQT-I1
      DO 40 J=1,NDIF
      SYSFXB(I1+J)=SYSFXB(I1+J)+SYSBMX(2*I,J)*(X(I1)-XPREV(I1))
 40   CONTINUE
 10   CONTINUE
      RETURN
      END
C
C
      SUBROUTINE TIMEN
      COMMON/CINTEG/TIME,TINC,RKFACT,RKFAC,ISTEP,PHASE,ITIME
      TIME=TIME+TINC
      RETURN
      END
C
C
      SUBROUTINE TRIGO(A)
      COMMON/ANGLE/S,C
      S=SIN(A)
      C=COS(A)
      RETURN
      END
C
C
      SUBROUTINE VARTIM(TIME)
      RETURN
      END
C
C
      SUBROUTINE VEL(H,Q,U,V)
      COMMON/CGRID/NMNP,NMNP2,NBANDH,NBANDQ,MAXNOD,MAXMQ,MAXBWH,
     1  MAXBWQ,NMHBN,NMQBN,NMVBN,MAXHBN,MAXQBN,MAXEL,NMEL,
     2  MAXQBM,MAXHBM
      DIMENSION H(NMNP),Q(NMNP2),U(NMNP),V(NMNP)
      DO 10 I=1,NMNP
      U(I)=Q(2*I-1)/H(I)
      V(I)=Q(2*I)/H(I)
 10   CONTINUE
      RETURN
      END
C
C
      SUBROUTINE VOLUME(ETA,AREA,ICON,VOL)
      COMMON/CGRID/NMNP,NMNP2,NBANDH,NBANDQ,MAXNOD,MAXMQ,MAXBWH,
     1  MAXBWQ,NMHBN,NMQBN,NMVBN,MAXHBN,MAXQBN,MAXEL,NMEL,
     2  MAXQBM,MAXHBM
      DIMENSION ETA(NMNP),AREA(NMEL),ICON(MAXEL,3)
      VOL=0.
```

```
      DO 10 I=1,NMEL
      SUM=0.
      DO 20 J=1,3
      SUM=SUM+ETA(ICON(I,J))
 20   CONTINUE
      VOL=AREA(I)*SUM/3.+VOL
 10   CONTINUE
      RETURN
      END
C
C
      SUBROUTINE WINDS(TAUWX,TAUWY)
      COMMON/CINTEG/TIME,TINC,RKFACT,RKFAC,ISTEP,PHASE,ITIME
      COMMON/COPT/ IBFRIC,IDEPTH,IEDVIS,ICNVEC,IWIND,IVERSN
      COMMON/CGRID/NMNP,NMNP2,NBANDH,NBANDQ,MAXNOD,MAXMQ,MAXBWH,
     1   MAXBWQ,NMHBN,NMQBN,NMVBN,MAXHBN,MAXQBN,MAXEL,NMEL,
     2   MAXQBM,MAXHBM
      DIMENSION TAUWX(NMNP),TAUWY(NMNP)
      IF(IWIND .EQ. 4) RETURN
      DO 10 I=1,NMNP
      TAUWX(I)=0.
      TAUWY(I)=0.
 10   CONTINUE
      IWIND=4
      RETURN
      END
C
C
```

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