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EROSION CONTROL OF SCOUR DURING CONSTRUCTION REPORT 7

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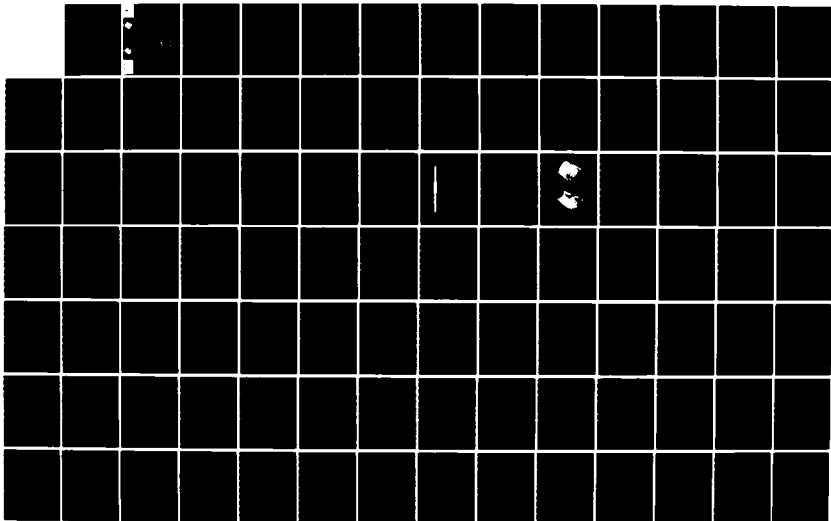
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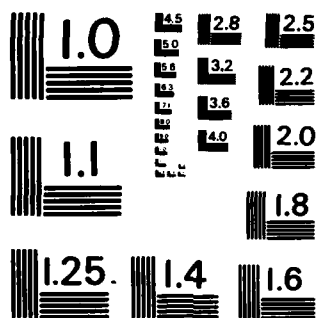
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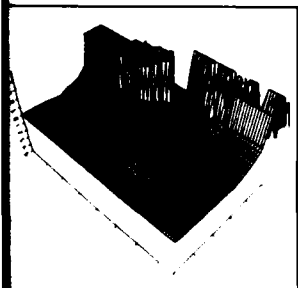
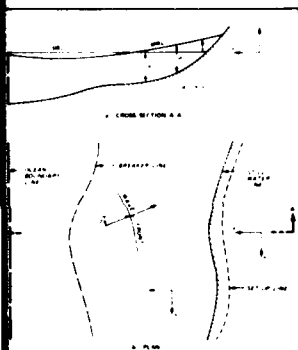
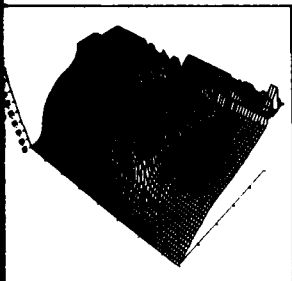




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TECHNICAL REPORT HL-80-3

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EROSION CONTROL OF SCOUR DURING CONSTRUCTION

Report 7
CURRENT — A WAVE-INDUCED
CURRENT MODEL

by

S. Rao Vemulakonda

Coastal Engineering Research Center

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
PO Box 631
Vicksburg, Mississippi 39180-0631



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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Often, large-scale engineering structures such as jetties or breakwaters are constructed in the nearshore region to stabilize navigation channels or protect harbor entrances and beaches. During construction, these structures may alter waves and currents. Waves break on such structures and the resulting turbulence causes material to be tossed into suspension and be transported from the region by wave-induced and other currents. This results in erosion at the toe of the structure since natural influx of material may not exist to (Continued)		

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20. ABSTRACT (Continued).

replace that removed from the region. In order to ensure structural stability, it is necessary to fill this area with nonerodible material. As a result, extra quantities of material may be required, and construction costs may be overrun. To minimize cost increases due to scour during construction, it is necessary to estimate the likelihood and amount of potential scour during construction. Since breaking waves and the currents induced by them play a vital role in transporting sediment away from coastal structures, thus resulting in scour, it is important to predict wave-induced currents, with and without structures.

The purpose of this study is to develop a generalized numerical model that will predict currents induced by breaking waves at locations with or without coastal structures. The model should be applicable to real-life bathymetries that are often arbitrary and irregular and must be computationally efficient and economical in view of the large numerical grids often required in engineering projects.

The numerical model called CURRENT developed in this study employs the radiation stress approach of Longuet-Higgins and solves the vertically integrated equations of momentum and continuity using an alternating direction implicit scheme. It includes mixing and advection terms.

The model has been applied to a case of normally incident waves on a plane beach. Results for setup matched the experimental data of Bowen, Inman, and Simmons. For obliquely incident waves on a plane beach, model results for longshore currents were compared with the analytical solution of Longuet-Higgins, first neglecting the effect of setup and later including the effect of setup. Agreement was excellent. As the numerical grid was made finer, the numerical results tended to converge toward the analytical solution.

The numerical model was applied to a field situation corresponding to Oregon Inlet, North Carolina. The bathymetry was very irregular and complex owing to the presence of channels, shoals, etc. A variable grid was used, and the significant wave during a part of the Ash Wednesday storm of March 1962 was simulated. The numerical results obtained for this case appeared to be reasonable, and the computer costs were modest.

For user convenience, model input, output, and files are described and two sample applications are presented.

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PREFACE

The study reported herein was authorized as a part of the Civil Works Research and Development Program by the Office, Chief of Engineers (OCE), US Army. This particular work unit, Erosion Control of Scour During Construction, is part of the Improvement of Operations and Maintenance Techniques (IOMT) Program. Mr. James L. Gottesman was the OCE Technical Monitor for the IOMT Program during preparation and publication of this report.

This study was conducted during the period 1 January 1981 through 31 March 1982 by personnel of the Hydraulics Laboratory of the US Army Engineer Waterways Experiment Station (WES) under the general supervision of Messrs. H. B. Simmons, Chief of the Hydraulics Laboratory; F. A. Herrmann, Jr., Assistant Chief of the Hydraulics Laboratory; R. A. Sager, Chief of the Estuaries Division and IOMT Program Manager; Dr. R. W. Whalin and Mr. C. E. Chatham, former and acting Chiefs of the Wave Dynamics Division, respectively; Mr. D. D. Davidson, Chief of the Wave Research Branch; and Dr. J. R. Houston, Research Hydraulic Engineer and Principal Investigator for the Erosion Control of Scour During Construction work unit. The Wave Dynamics Division was transferred to the Coastal Engineering Research Center (CERC) of WES on 1 July 1983 under the direction of Dr. R. W. Whalin, Chief of the Coastal Engineering Research Center. This report was prepared by Dr. S. Rao Vemulakonda, Research Hydraulic Engineer.

Commanders and Directors of WES during the conduct of this investigation and the preparation and publication of this report were COL Nelson P. Conover, CE, and COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.



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**CONVERSION FACTORS, US CUSTOMARY TO METRIC (SI)
UNITS OF MEASUREMENT**

US customary units of measurement used in this report can be converted to metric (SI) units as follows:

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
feet	0.3048	metres
feet per second	0.3048	metres per second
feet-feet per second	0.0929	metres-metres per second
feet per second per second	0.3048	metres per second per second
pounds (mass) per square foot	4.882428	kilograms per square metre
pounds per foot	1.488189	kilograms per metre
pounds-second-second per foot per foot per foot per foot	52.5540137	kilogram-second-second per metre per metre per metre per metre

EROSION CONTROL OF SCOUR DURING CONSTRUCTION

CURRENT--A WAVE-INDUCED CURRENT MODEL

PART I: INTRODUCTION

Statement of the Problem

1. Often, large-scale engineering structures such as jetties and breakwaters are constructed in the nearshore region to stabilize navigation channels or protect harbor entrances and beaches. The structures are usually built of rock or precast concrete. During construction, the massive structures alter the waves and currents near their location. Waves break on the toe of the structure and the resulting turbulence causes material from the bottom to be suspended. The suspended material in turn is moved away from the region by wave-induced and other currents. This results in erosion developing at the toe of the structure since the lost material may not be replaced by natural processes. In order to ensure that the structure will be stable and perform its function as desired, it will be necessary to fill with nonerodible material any scour hole that may have developed due to erosion. As a result, extra quantities of material may be required and construction costs may be overrun. To minimize cost increases due to scour during construction, it is necessary to estimate beforehand the likelihood and amount of potential scour during construction. This is a very complicated problem and the solution to it will depend strongly on the particular field site and the coastal environment.

2. Since breaking waves and the currents induced by them play a vital role in transporting sediment away from coastal structures resulting in scour, it is important to predict wave-induced currents, with and without structures. In view of the environment and site-specific nature of the problem, a generalized numerical model is needed. Results from such a model can be used as input to a sediment transport model to predict erosion during construction.

Purpose of the Study

3. The purpose of this study is to develop a generalized numerical model

that can predict currents induced by breaking waves at locations with or without coastal structures. The model should be applicable to real-life bathymetries that are often arbitrary and irregular and should be computationally efficient and economical in view of the large numerical grids often required in engineering projects.

PART II: THEORETICAL BACKGROUND

Review

4. In recent years, there has been a growing interest in the numerical modeling of longshore currents and nearshore circulation caused by the action of breaking waves. Results of such simulation, besides being useful on their own, form an essential input to numerical and physical models for nearshore processes such as sediment transport. The design and construction of large-scale engineering structures such as jetties require the determination of wave-induced currents not only near the open coast but also near inlets; in addition, the effects of the proposed or existing structures on these currents are required. Several publications on longshore currents and nearshore circulation have appeared in the literature during the past two decades. Some of these relate to experimental or field studies and others to analytic solutions and numerical models. Among the latter, mention must be made of Bowen (1969), Longuet-Higgins (1970), Thornton (1970), Noda (1974), Jonsson, Skovgaard, and Jacobsen (1974), Birkemeier and Dalrymple (1975), Liu and Mei (1976), Liu and Lennon (1978), Liu and Dalrymple (1978), Ebersole and Dalrymple (1980), and Vreugdenhil (1980). Several of these studies and models either consider only simple and idealized situations, for example, plane beaches and periodic bathymetries, or neglect terms of the governing equations involving unsteadiness, advection, and/or lateral mixing. Often, a linear friction is assumed. For practical engineering application, a generalized numerical model is needed that can handle real-life bathymetries. The model should be flexible in that one should be able to change easily the formulation of terms such as mixing and friction as improved understanding of these processes is gained in the future. It should be computationally efficient and economical for large numerical grids. This report describes one such numerical model for wave-induced currents developed at the US Army Engineer Waterways Experiment Station (WES). The model called "CURRENT" has been applied successfully to the determination of longshore currents near open coasts and wave-induced currents near inlets. It can handle impermeable nonoverlapping structures.

5. In terms of its analytic formulation the present model uses, to a large extent, the approach of Ebersole (1980), and Ebersole and Dalrymple (1980). Whereas their numerical model used an explicit method of solution,

the present model uses a highly efficient alternating direction, implicit, finite difference scheme. In view of the similarity between the equations for wave-induced currents and long waves, the present model was created by modifying an existing, well-tested WES shallow-water wave numerical model known as WIFM (WES Implicit Flooding Model) (Butler 1980). The velocity version of WIFM used here has nonlinear advective terms. The friction and mixing terms used in WIFM were modified to conform to the formulations normally used for wave-induced currents. Radiation stress terms were added to the model, since these are usually the "driving" terms for wave-induced currents. Certain capabilities of WIFM such as flooding/drying and wind-induced current calculation were not utilized in the model for wave-induced currents.

Equations of Motion

6. The hydrodynamic equations used in the model for wave-induced currents may be derived from the Navier-Stokes equations (for details, see Phillips (1969) and Ebersole (1980)). It is assumed in the derivation that the fluid is homogeneous and incompressible, and the vertical accelerations are negligible so that the pressure distribution is hydrostatic. By vertically integrating the three-dimensional form of the equations and applying appropriate boundary conditions, the depth-averaged two-dimensional form of the equations of motion and continuity are obtained. These equations are derived by time-averaging over a time interval corresponding to the period of the waves. Referring to a Cartesian coordinate scheme (Figure 1), these are:

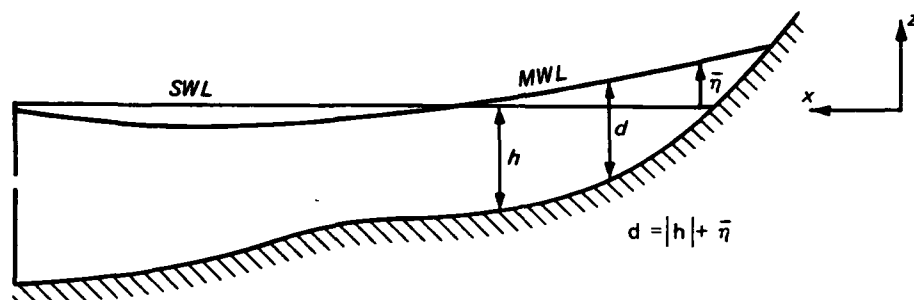
Momentum

$$\frac{\partial U}{\partial t} + U \frac{\partial U}{\partial x} + V \frac{\partial U}{\partial y} + g \frac{\partial \bar{\eta}}{\partial x} + \frac{1}{\rho d} \tau_{bx} + \frac{1}{\rho d} \left(\frac{\partial S_{xx}}{\partial x} + \frac{\partial S_{xy}}{\partial y} \right) - \frac{1}{\rho} \frac{\partial \tau_{xy}}{\partial y} = 0 \quad (1)$$

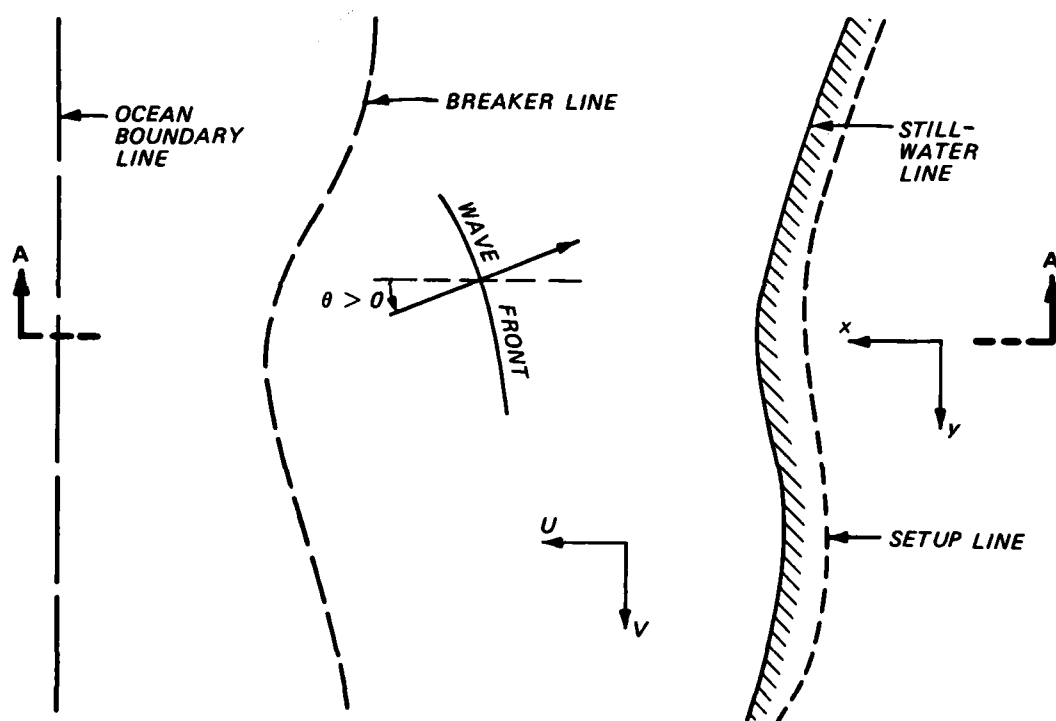
$$\frac{\partial V}{\partial t} + U \frac{\partial V}{\partial x} + V \frac{\partial V}{\partial y} + g \frac{\partial \bar{\eta}}{\partial y} + \frac{1}{\rho d} \tau_{by} + \frac{1}{\rho d} \left(\frac{\partial S_{xy}}{\partial x} + \frac{\partial S_{yy}}{\partial y} \right) - \frac{1}{\rho} \frac{\partial \tau_{xy}}{\partial x} = 0 \quad (2)$$

Continuity

$$\frac{\partial \bar{\eta}}{\partial t} + \frac{\partial}{\partial x} (Ud) + \frac{\partial}{\partial y} (Vd) = 0 \quad (3)$$



a. CROSS SECTION A-A



b. PLAN

Figure 1. Definition sketch for an irregular beach

where

U and V = depth-averaged horizontal velocity components at time t in the x - and y -directions, respectively, ft/sec*

$\bar{\eta}$ = displacement of the mean free surface with respect to the still-water level, ft

g = acceleration due to gravity, ft/sec²

ρ = mass density of seawater, lb-sec²/ft⁴

$d = \bar{\eta} - h$ = total water depth, ft

h = bed elevation with still-water level taken as zero (note h is negative for water cells and positive for land cells), ft

τ_{bx} and τ_{by} = bottom friction stresses in the x - and y -directions, respectively, lb/ft²

S_{xx} , S_{xy} , and S_{yy} = radiation stresses which arise because of the excess momentum flux due to waves (refer to Longuet-Higgins and Stewart (1964) for their significance), lb/ft

τ_{xy} = lateral shear stress due to turbulent mixing, lb/ft²

Note that the condition $\bar{\eta} > 0$ is known as "setup" and $\bar{\eta} < 0$ is called "setdown."

Bottom friction

7. At present, the numerical model uses a linear formulation for friction (Longuet-Higgins 1970). Thus

$$\tau_{bx} = \rho c \langle |u_{orb}| \rangle U \quad (4)$$

$$\tau_{by} = \rho c \langle |u_{orb}| \rangle V \quad (5)$$

where c is a drag coefficient (of the order of 0.01) and $\langle |u_{orb}| \rangle$ is the time average, over one wave period, of the absolute value of the wave orbital velocity at the bottom. From linear wave theory,

$$\langle |u_{orb}| \rangle = \frac{2H}{T \sinh k|h|} \quad (6)$$

* A table of factors for converting US customary units of measurement to metric (SI) units is presented on page 3.

where

H = local wave height, ft

T = wave period, sec

k = local wave number, $2\pi/L$, 1/ft

|h| = local still-water depth, ft

Equations 4 and 5 are based on the assumption that the velocity components U and V of the current are small compared with the wave orbital velocity, $\langle |u_{orb}| \rangle$. In the future, the numerical model can be easily adapted to other formulations for friction such as nonlinear friction.

Radiation stresses

8. As mentioned previously, the radiation stresses are of major importance since they furnish the main forces for creating wave-induced currents. Referring to Longuet-Higgins (1970), for monochromatic waves, they are defined in terms of the local wave climate as follows:

$$S_{xx} = E \left[\left(2n - \frac{1}{2} \right) \cos^2 \theta + \left(n - \frac{1}{2} \right) \sin^2 \theta \right] \quad (7)$$

$$S_{xy} = E n \cos \theta \sin \theta \quad (8)$$

$$S_{yy} = E \left[\left(2n - \frac{1}{2} \right) \sin^2 \theta + \left(n - \frac{1}{2} \right) \cos^2 \theta \right] \quad (9)$$

where

$$E = \frac{1}{8} \rho g H^2 \quad (10)$$

and

$$n = \frac{1}{2} \left(1 + \frac{2k|h|}{\sinh 2k|h|} \right) \quad (11)$$

Note that n is the ratio of wave group celerity to phase celerity, θ is the local wave direction defined as shown in Figure 1, and E is the wave energy density, lb/ft. For the numerical model described herein, the values of H, k, and θ are obtained by using a considerably modified form of the wave climate program developed by Noda et al. (1974). This particular program has the advantage that H, k, and θ can be computed at the centers of the cells of a rectangular numerical grid and wave breaking and decay are accounted for by a breaking index model for wave heights in the surf zone.

Lateral shear

9. In the numerical model, the coordinate scheme is chosen such that x is positive in the offshore direction and y is approximately in the along-shore direction. An eddy viscosity formulation is chosen for the lateral shear. The eddy viscosity is assumed to be anisotropic. Denoting ϵ_x and ϵ_y as the eddy viscosities in x - and y -directions, respectively, in general, ϵ_x is assumed to be a function of x and y and ϵ_y a constant. Accordingly,

$$\tau_{xy} = \rho \left(\epsilon_y \frac{\partial U}{\partial y} + \epsilon_x \frac{\partial V}{\partial x} \right) \quad (12)$$

For plane beach applications with lateral mixing, the eddy viscosity ϵ_x was assumed to vary within the surf zone in the manner suggested by Longuet-Higgins (1970):

$$\epsilon_x = N_{LH} x \sqrt{g|h|} \quad (13)$$

where

N_{LH} = an empirical coefficient that varies in the range 0.0 to 0.016

x = distance from the shoreline

For locations offshore of the breaker line, ϵ_x was kept constant and equal to its value at the breaker line. For field applications, the eddy viscosity ϵ_x was chosen according to the following relation given by Jonsson, Skovgaard, and Jacobsen (1974):

$$\epsilon_x = \frac{H^2 g T}{4\pi^2 |h|} \cos^2 \theta \quad (14)$$

This represents twice the value used by Thornton (1970). It was believed that for field situations, Equation 14 represented the eddy viscosities more realistically than the relation (Equation 13) for plane beaches. The value of ϵ_y was, in general, taken to be equal to the value of ϵ_x at the deepest part (usually near the offshore boundary) of the numerical grid. The numerical model is flexible enough to permit other formulations for eddy viscosity in the future, as our understanding improves.

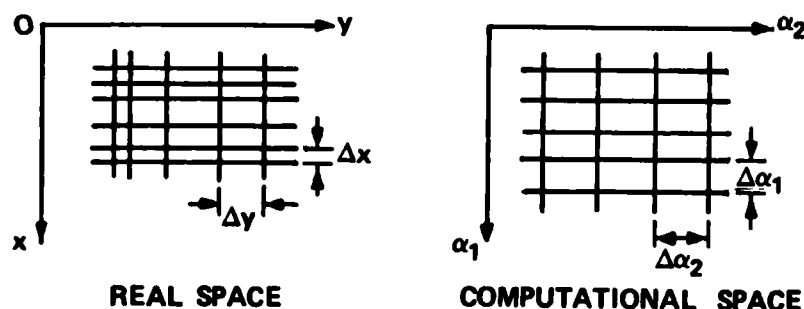
Variable grid

10. One major advantage of WIFM and therefore CURRENT is that the size of the grid cells may be varied smoothly in both horizontal directions. Thus

the grid may be made finer in regions of greater interest such as the surf zone, inlets, etc., and coarser in regions of less importance. For this purpose, a piecewise reversible transformation is used. The mapping for each coordinate direction is independent of the other. For mapping from the real or physical space (x, y) to the computational space (α_1, α_2) , a mapping function of the form

$$x = a_1 + b_1 \alpha_1^{c_1} \quad (15)$$

is used. A similar mapping function is employed for the y-direction. Here a_1 , b_1 , and c_1 are coefficients whose values change from region to region. The mapping transforms the variable grid in real space to a uniform grid in computational space. The transformation is such that all derivatives are centered in α -space. During the mapping process, both the variable and its derivative must match at the common boundary between two regions. The mapping is actually accomplished by an iterative procedure, using an interactive program called MAPIT developed at WES. Figure 2 shows an example of the variable grid.



MAPPING FUNCTIONS

$$\begin{aligned} x &= a_1 + b_1 \alpha_1^{c_1} \\ y &= a_2 + b_2 \alpha_2^{c_2} \end{aligned}$$

Figure 2. An example of variable grid

11. By using the mapping function in the x- and y-directions, the equations of motion in computational space may be written as:

Momentum

$$\begin{aligned}
 & u_t + \frac{1}{\mu_1} u u_{\alpha_1} + \frac{1}{\mu_2} v u_{\alpha_2} + \frac{g}{\mu_1} \bar{\eta}_{\alpha_1} + \frac{1}{\rho d} \tau_{bx} + \frac{1}{\rho d} \left[\frac{1}{\mu_1} (S_{xx})_{\alpha_1} + \frac{1}{\mu_2} (S_{xy})_{\alpha_2} \right] \\
 & - \epsilon_x \frac{1}{\mu_2} \frac{1}{\mu_1} v_{\alpha_2 \alpha_1} - \epsilon_y \frac{1}{\mu_2} \left[\frac{1}{\mu_2} u_{\alpha_2 \alpha_2} + \left(\frac{1}{\mu_2} \right)_{\alpha_2} u_{\alpha_2} \right] - \frac{1}{\mu_1 \mu_2} (\epsilon_x)_{\alpha_2} v_{\alpha_1} = 0 \quad (16)
 \end{aligned}$$

$$\begin{aligned}
 & v_t + \frac{1}{\mu_1} u v_{\alpha_1} + \frac{1}{\mu_2} v v_{\alpha_2} + \frac{g}{\mu_2} \bar{\eta}_{\alpha_2} + \frac{1}{\rho d} \tau_{by} + \frac{1}{\rho d} \left[\frac{1}{\mu_1} (S_{xy})_{\alpha_1} + \frac{1}{\mu_2} (S_{yy})_{\alpha_2} \right] \\
 & - \epsilon_x \frac{1}{\mu_1} \left[\frac{1}{\mu_1} v_{\alpha_1 \alpha_1} + \left(\frac{1}{\mu_1} \right)_{\alpha_1} v_{\alpha_1} \right] - \epsilon_y \frac{1}{\mu_1} \frac{1}{\mu_2} u_{\alpha_1 \alpha_2} - \frac{1}{\mu_1^2} (\epsilon_x)_{\alpha_1} v_{\alpha_1} = 0 \quad (17)
 \end{aligned}$$

Continuity

$$\bar{\eta}_t + \frac{1}{\mu_1} (Ud)_{\alpha_1} + \frac{1}{\mu_2} (Vd)_{\alpha_2} = 0 \quad (18)$$

where the subscripts t , α_1 , and α_2 indicate partial derivatives with respect to time, α_1 and α_2 , respectively, and

$$\mu_1 = \frac{\partial x}{\partial \alpha_1} = b_1 c_1^{\alpha_1 - 1} \quad (19)$$

and

$$\mu_2 = \frac{\partial y}{\partial \alpha_2} = b_2 c_2^{\alpha_2 - 1} \quad (20)$$

Variables μ_1 and μ_2 are expansion coefficients connected with the stretching of the uniform computational grid to the variable grid in real space. Note that in obtaining Equations 16 and 17, the assumptions made in paragraph 9 were used.

12. The nonlinear advective terms in the equations of motion often pose stability problems. These terms are handled in the present model by using the Stabilizing Correction (SC) scheme. This scheme will be described in a later

section. The eddy viscosity terms also can cause difficulties during the numerical computation. The finite difference scheme selected and the formulation for eddy viscosity adopted in the model will minimize such difficulties and stability problems. However, the user must exercise caution and judgment in selecting appropriate time- and space-steps, and eddy viscosity coefficients for the phenomena being simulated.

PART III: COMPUTATIONAL TECHNIQUES

Implicit Method

13. In order to solve the problem under consideration on a digital computer, the differential equations (Equations 16-18) have to be expressed in a finite difference form. In the present case, an alternating direction, implicit, finite difference scheme is employed. In view of the presence of the nonlinear advective terms, a particular implicit scheme known as the SC scheme is used. The basic idea of the scheme is as follows. The time level is indicated by a superscript k . The scheme involves variables at three time levels. The values of the variable at time levels $k-1$ and k are known from previous computations or prescribed initial conditions. To advance the solution from time level k to the new time level $k+1$, we introduce an intermediate time-level solution denoted by the superscript $*$. We operate on Equations 16-18 in a two-step procedure. In the first step, we sweep the rectangular grid in the $x(\alpha_1)$ direction, advancing the solution from time level k to $*$. Next, we sweep the grid in the $y(\alpha_2)$ direction, advancing the solution from time level $*$ to $k+1$. The two sweeps together constitute a full time-step, Δt .

Double-Sweep Technique

14. Before going into the details of the double sweep technique, the notation used for individual cells of the rectangular grid will be defined. Let Δx and Δy denote the cell dimensions in real space in the x - and y -directions, respectively. These dimensions may vary from cell to cell. Let the corresponding dimensions in computational space be $\Delta\alpha_1$ and $\Delta\alpha_2$. These dimensions are the same for all the cells in the grid. Let m and n denote indices corresponding to the center of an arbitrary cell (Figure 3). All the variables

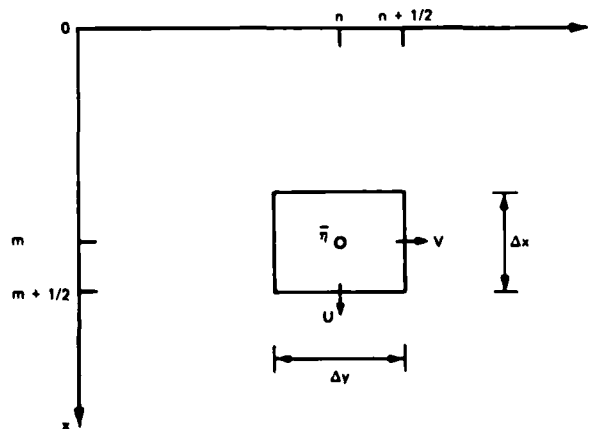


Figure 3. Cell notation

except the velocities U and V are defined at the cell centers. Velocities U and V are defined at cell faces $m+1/2$ and $n+1/2$, respectively. In the x -sweep, the x -momentum equation is centered about the cell face $m+1/2$ and the continuity equation is centered about the center of the cell and the two equations are solved, using in the process the result $U^* = U^{k+1}$. At the end of this sweep, $\bar{\eta}^*$ and U^{k+1} are known. Next, we sweep the grid in the y -direction. In this sweep, the y -momentum equation is centered about the cell face $n+1/2$ and the continuity equation about the cell center. Upon solving the two equations, $\bar{\eta}^{k+1}$ and V^{k+1} for each cell are obtained. Thus the two sweeps together complete the solution for $\bar{\eta}^{k+1}$, U^{k+1} , and V^{k+1} .

15. Even though the SC scheme has been described so far in terms of the (x, y) coordinate system for convenience, in reality we have to apply the technique to the equations of motion in the computational (α_1, α_2) space. After the application of the technique, the following finite difference equations result. For the rest of PART III, we will drop the bar over η for convenience. For the $\alpha_1(x)$ -sweep (taken along a grid cell column parallel to the α_1 -axis), we have

$$\begin{aligned}
& \frac{1}{2\Delta t} (U^{k+1} - U^{k-1}) + \frac{U^k}{2\mu_1\Delta\alpha_1} \delta_{2\alpha_1}(U^k) + \frac{\bar{v}^k}{2\mu_2\Delta\alpha_2} \delta_{2\alpha_2}(U^k) \\
& + \frac{g}{2\mu_1\Delta\alpha_1} \delta_{\alpha_1}(\eta^* + \eta^{k-1}) + \frac{c < \left| \frac{u}{orb} \right| > U^{k+1}}{\bar{d}} + \frac{1}{\rho\bar{d}} \left[\frac{1}{\mu_1\Delta\alpha_1} \delta_{\alpha_1}(S_{xx}^k) \right. \\
& + \left. \frac{1}{2\mu_2\Delta\alpha_2} \delta_{2\alpha_2}(\bar{S}_{xy}^k) \right] - \bar{\epsilon}_x \frac{1}{\mu_2} \frac{1}{\mu_1} \frac{1}{\Delta\alpha_2\Delta\alpha_1} \delta_{\alpha_2\alpha_1}(V^k) - \bar{\epsilon}_y \left[\frac{1}{(\mu_2\Delta\alpha_2)^2} \delta_{\alpha_2\alpha_2}(U^k) \right. \\
& + \left. \frac{1}{2\mu_2(\Delta\alpha_2)^2} \delta_{\alpha_2}\left(\frac{1}{\mu_2}\right) \delta_{2\alpha_2}(U^k) \right] - \frac{1}{2\mu_1\mu_2} \frac{1}{\Delta\alpha_2\Delta\alpha_1} \delta_{2\alpha_2}(\bar{\epsilon}_x) \delta_{\alpha_1}(\bar{v}^k) = 0 \\
& \text{at } (n, m+1/2)
\end{aligned} \tag{21}$$

$$\begin{aligned}
& \frac{1}{2\Delta t} (\eta^* - \eta^{k-1}) + \frac{1}{2\mu_1\Delta\alpha_1} \delta_{\alpha_1}(U^{k+1} \bar{d}^k + U^{k-1} \bar{d}^k) \\
& + \frac{1}{\mu_2\Delta\alpha_2} \delta_{\alpha_2}(V^{k-1} \bar{d}^k) = 0 \text{ at } (n, m)
\end{aligned} \tag{22}$$

In the above equations, a single bar represents a two-point average and a double bar a four-point average. The difference operator δ_{α_i} is defined as

$$\delta_{\alpha_i}(Z) = Z_{\alpha_{i+1/2}} - Z_{\alpha_{i-1/2}} \quad (23)$$

for any variable Z . The definition may be extended to the operators $\delta_{2\alpha_i}$ and $\delta_{\alpha_i\alpha_j}$.

16. Equations 21 and 22 may be rearranged so that the unknown quantities are to the left and the known quantities are to the right, as follows:

$$-a_m \eta_{n,m}^* + \bar{a}_{m+1/2} U_{n,m+1/2}^{k+1} + a_{m+1} \eta_{n,m+1}^* = B_{m+1/2} \quad (24)$$

$$-a_{m-1/2} U_{n,m-1/2}^{k+1} + \eta_{n,m}^* + a_{m+1/2} U_{n,m+1/2}^{k+1} = A_m \quad (25)$$

where

$$a_m = a_{m+1} = \frac{g\Delta t}{(\mu_1)_{m+1/2} \Delta \alpha_1} \quad (26)$$

$$\bar{a}_{m+1/2} = 1 + \frac{2\Delta t c < |u_{orb}|^k >_{n,m+1/2}}{\bar{d}_{n,m+1/2}^k} \quad (27)$$

$$\begin{aligned} B_{m+1/2} = U^{k-1} + \Delta t \left\{ -\frac{U^k}{\mu_1 \Delta \alpha_1} \delta_{2\alpha_1}(U^k) - \frac{\bar{V}^k}{\mu_2 \Delta \alpha_2} \delta_{2\alpha_2}(U^k) - \frac{g}{\mu_1 \Delta \alpha_1} \delta_{\alpha_1}(\eta^{k-1}) \right. \\ \left. - \frac{2}{\rho \bar{d}} \left[\frac{1}{\mu_1 \Delta \alpha_1} \delta_{\alpha_1}(S_{xx}^k) + \frac{1}{2\mu_2 \Delta \alpha_2} \delta_{2\alpha_2}(\bar{S}_{xy}^k) \right] + 2\bar{\epsilon}_x \frac{1}{\mu_2 \mu_1} \frac{1}{\Delta \alpha_2 \Delta \alpha_1} \delta_{\alpha_2 \alpha_1}(V^k) \right. \\ \left. + 2\bar{\epsilon}_y \left[\frac{1}{(\mu_2 \Delta \alpha_2)^2} \delta_{\alpha_2 \alpha_2}(U^k) + \frac{1}{2\mu_2 (\Delta \alpha_2)^2} \delta_{\alpha_2} \left(\frac{1}{\mu_2} \right) \delta_{2\alpha_2}(U^k) \right] \right. \\ \left. + \frac{1}{\mu_1 \mu_2} \frac{1}{\Delta \alpha_2 \Delta \alpha_1} \delta_{2\alpha_2}(\bar{\epsilon}_x) \delta_{\alpha_1}(\bar{V}^k) \right\} \text{ at } (n, m+1/2) \end{aligned} \quad (28)$$

$$a_{m\pm 1/2} = \frac{\Delta t}{(\mu_1)_m \Delta \alpha_1} \bar{d}_{n,m\pm 1/2}^k \quad (29)$$

$$A_m = \eta^{k-1} - \frac{\Delta t}{\mu_1 \Delta \alpha_1} \delta_{\alpha_1} (U^{k-1} \bar{d}^k) - \frac{2\Delta t}{\mu_2 \Delta \alpha_2} \delta_{\alpha_2} (V^{k-1} \bar{d}^k) \text{ at } (n,m) \quad (30)$$

$$\bar{v}_{n,m+1/2}^k = \frac{1}{4} \left(v_{n-1/2,m}^k + v_{n+1/2,m}^k + v_{n-1/2,m+1}^k + v_{n+1/2,m+1}^k \right) \quad (31)$$

17. Consider the set of cells for which the index n is constant and equal to N . Suppose at the upper boundary cell ($m = M$), the velocity $U_{N,M+1/2}$ is always known. Similarly suppose at the lower boundary cell ($m = L$) the water level $\eta_{N,L}$ is always known. Then the set of equations for all the cells may be written in the following matrix form if we drop the common subscript N :

$$\begin{bmatrix} \bar{a}_{M+1/2} & a_{M+1} & 0 & 0 & \dots & 0 \\ -a_{M+1/2} & 1 & a_{M+3/2} & 0 & \dots & 0 \\ 0 & -a_{M+1} & \bar{a}_{M+3/2} & a_{M+2} & \dots & 0 \\ & & & & \dots & \\ & & & & & \dots \\ & & & & & U_{L-1/2}^{k+1} \\ 0 & 0 & 0 & \dots & -a_{L-1/2} & 1 \end{bmatrix} \begin{bmatrix} U_{M+1/2}^{k+1} \\ \eta_{M+1}^* \\ U_{M+3/2}^{k+1} \\ . \\ . \\ U_{L-1/2}^{k+1} \\ \eta_L^* \end{bmatrix} = \begin{bmatrix} \hat{B}_{M+1/2} \\ A_{M+1} \\ B_{M+3/2} \\ . \\ . \\ B_{L-1/2} \\ \hat{A}_L \end{bmatrix} \quad (32)$$

where

$$\hat{B}_{m+1/2} \equiv B_{m+1/2} + a_m \eta_m^*$$

$$\hat{A}_L \equiv A_L - a_{L+1/2} U_{L+1/2}$$

18. Since the first matrix on the left-hand side of Equation 32 is tri-diagonal, the above matrix equation can be solved by recursion. In general, the recursion relations may be written as

$$\eta_m^* = -P_m U_{m+1/2}^{k+1} + Q_m \quad (33)$$

$$U_{m-1/2}^{k+1} = -R_{m-1} \eta_m^* + S_{m-1} \quad (34)$$

where

$$\begin{aligned} P_m &= \frac{a_{m+1/2}}{T_1} & Q_m &= \frac{A_m + a_{m-1/2} S_{m-1}}{T_1} \\ R_m &= \frac{a_{m+1}}{T_2} & S_m &= \frac{B_{m+1/2} + a_m Q_m}{T_2} \\ T_1 &= 1 + a_{m-1/2} R_{m-1} \\ T_2 &= \bar{a}_{m+1/2} + a_m P_m \end{aligned} \quad (35)$$

19. Since in the FORTRAN computer language, fractional indices are not possible, a new integer index system is adopted in the program. Thus all the variables defined at the center and the faces $m+1/2$ and $n+1/2$ of a cell (n,m) will be designated by the integer indices (N,M) . The only exceptions are the expansion coefficients μ_1 and μ_2 which are defined at cell centers and faces. For these, the following index system is adopted. For example, μ_1 at the center of cell (n,m) is designated by the index $2M-1$, whereas μ_1 at the face $m+1/2$ is denoted by the index $2M$, and similarly for μ_2 . Using this new notation, the expanded form of the recursion coefficients for the $\alpha_1(x)$ -sweep may be written as follows:

$$P_M = \frac{\Delta t \bar{d}_{N,M}^k}{(\mu_1)_{2M-1} \Delta \alpha_1 T_1} \quad (36)$$

$$Q_M = \frac{A_M + \frac{\Delta t \bar{d}_{N,M-1}^k}{(\mu_1)_{2M-1} \Delta \alpha_1} S_{M-1}}{T_1} \quad (37)$$

$$R_M = \frac{g \Delta t}{(\mu_1)_{2M} \Delta \alpha_1 T_2} \quad (38)$$

$$S_M = \frac{B_M + \frac{g\Delta t}{(\mu_1)_{2M}^{\Delta\alpha_1}} Q_M}{T_2} \quad (39)$$

where

$$T_1 = 1 + \frac{\Delta t \bar{d}_{N,M-1}^k}{(\mu_1)_{2M-1}^{\Delta\alpha_1}} R_{M-1} \quad (40)$$

$$T_2 = 1 + \frac{2\Delta t \cdot c \left| \overline{u_{orb}} \right|_{N,M}^k}{\bar{d}_{N,M}^k} + \frac{g\Delta t}{(\mu_1)_{2M}^{\Delta\alpha_1}} P_M \quad (41)$$

Using the same notation, the solution (Equations 33 and 34) may be written as

$$\eta_{N,M}^* = -P_M U_{N,M}^{k+1} + Q_M \quad (42)$$

$$U_{N,M-1}^{k+1} = -R_{M-1} \eta_{N,M}^* + S_{M-1} \quad (43)$$

For any given N , the recursion coefficients P , Q , R , and S are computed, using Equations 36-41, in succession between the boundaries in the direction of increasing $\alpha_1(x)$. The values of these coefficients at the boundaries depend on the types of boundary conditions encountered. Once all the coefficients for a given N have been determined, the values of η^* and U^{k+1} for all the cells in the column are computed, using Equations 41 and 42, in the direction of decreasing $\alpha_1(x)$. We next go to the next higher value of N , and so on until the whole grid is swept in the $\alpha_1(x)$ -direction.

20. The development of the finite difference equations and the recursion relations for the $\alpha_2(y)$ -sweep is similar to that for the $\alpha_1(x)$ -sweep. In this case, using the same notation as before, the recursion coefficients may be written as

$$P_N = \frac{\Delta t \bar{d}_{N,M}^k}{(\mu_2)_{2N-1}^{\Delta\alpha_2} T_1} \quad (44)$$

$$Q_N = \frac{A_N + \frac{\Delta t}{(\mu_2)_{2N-1}} \frac{\bar{d}_{N-1,M}^k}{\Delta \alpha_2} S_{N-1}}{T_1} \quad (45)$$

$$R_N = \frac{g \Delta t}{(\mu_2)_{2N} \Delta \alpha_2 T_2} \quad (46)$$

$$S_N = \frac{B_N + \frac{g \Delta t}{(\mu_2)_{2N} \Delta \alpha_2} Q_N}{T_2} \quad (47)$$

where

$$T_1 = 1 + \frac{\Delta t}{(\mu_2)_{2N-1}} \frac{\bar{d}_{N-1,M}^k}{\Delta \alpha_2} R_{N-1} \quad (48)$$

$$T_2 = \frac{1 + 2 \Delta t \, c \langle \overline{u_{orb}} \rangle_{N,M}^k}{\bar{d}_{N,M}^k} + \frac{g \Delta t}{(\mu_2)_{2N} \Delta \alpha_2} P_N \quad (49)$$

The corresponding solution may be expressed as

$$\eta_{N,M}^{k+1} = -P_N V_{N,M}^{k+1} + Q_N \quad (50)$$

$$V_{N-1,M}^{k+1} = -R_{N-1} \eta_{N,M}^{k+1} + S_{N-1} \quad (51)$$

Initial and Boundary Conditions

21. In order to solve the problem under consideration, appropriate initial and boundary conditions must be specified. For the examples reported here, an initial condition of rest was chosen so that η , U , and V are zero at the start of the calculations. To avoid shock, the radiation stress gradients were gradually built up to their full values over a number of time-steps. The numerical computation was stopped when a steady state was deemed to have been reached.

22. The numerical model permits different types of boundary conditions; among these are the following:

- a. "No flow" (wall). This type of boundary condition is used at closed boundaries such as the still-water line on beach and at impermeable structures. The normal velocity is set to zero in this case.
- b. Discharge. This type of condition is used by WIFM at open boundaries. The variation of discharge with time is prescribed along boundary cells. For the wave-induced current model, this condition is never used since the discharge is an unknown even at the boundaries.
- c. Elevation (tide). This type of condition is used by WIFM at open boundaries. The variation of the surface elevation with time is prescribed along boundary cells. For the wave-induced current model, this condition is never used except possibly at the offshore boundary since the setup is an unknown quantity. Even at the offshore boundary, a radiation boundary condition was found to be preferable.
- d. Uniform flux. In this type of open boundary condition, the flux at a boundary cell is made equal to that at the next interior cell. Thus the condition assumes $\partial(Ud)/\partial x = 0$ or $\partial(Vd)/\partial y = 0$ at the boundary. This type of condition is used for the lateral boundaries since it is a passive condition.
- e. Radiation. This open boundary condition requires that any transients developed initially inside the numerical grid should propagate out of the grid as gravity waves. It is of the form $\partial\eta/\partial t + C(\partial\eta/\partial x) = 0$ where C is the phase speed of a surface disturbance $\eta(x,t)$. It is often used by the wave-induced current at the offshore boundary and is found preferable to a wall or constant elevation condition there. Both of the latter conditions are highly reflective and as a result the transients tend to bounce back and forth between the offshore and nearshore boundaries and take a long time to damp out. On the other hand, the radiation condition seems to work quite well and allows the transients to propagate out of the grid which permits the set-down at the offshore boundary to assume an appropriate value.

23. The boundary conditions frequently used in the wave-induced current model are illustrated in Figure 4.

24. At present, the model allows for subgrid barriers such as jetties, provided they are impermeable and nonovertopping. The program essentially sets to zero the velocity component normal to the appropriate cell face.

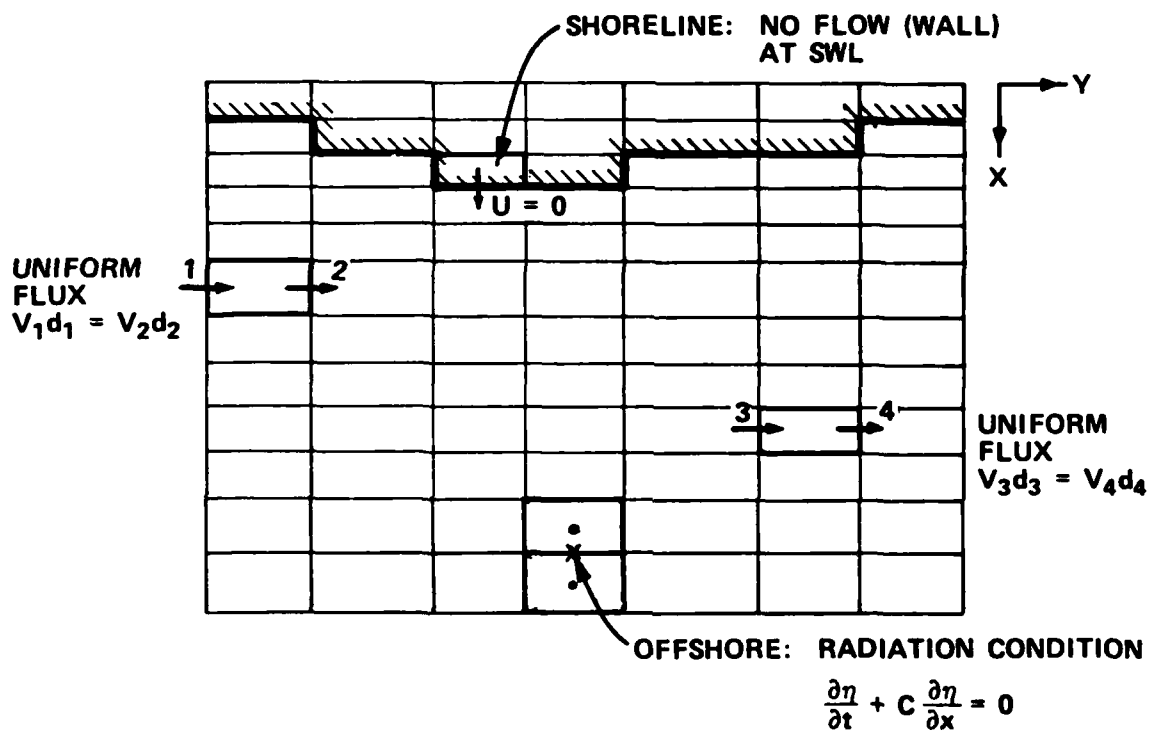


Figure 4. Boundary conditions used in numerical model CURRENT

PART IV: VALIDATION OF MODEL

Tests for Idealized Conditions

25. To develop confidence in the validity of the model and the accuracy of its results, several tests were run on the model and comparisons were made between model results and available laboratory data and analytic solutions. All of these tests were for plane beaches, for which the coordinate scheme is chosen such that the y-axis coincides with the still-water line in beach and the x-coordinate is measured from the still-water line (Figure 5). Note that for plane beaches, there is no variation in the alongshore (y) direction.

Plane beach: normal incidence

26. The model was run for a case of normal incidence on a plane smooth laboratory beach, reported by Bowen, Inman, and Simmons (1968). The conditions were as follows: $T = 1.14$ sec, deepwater wave height $H_0 = 6.45$ cm, and beach slope $s = 1:12$. To run this case on the model, a variable rectangular grid with overall dimensions of approximately 40 m by 30 cm (the laboratory channel was 40 m long) was used with $\Delta x_1 = \Delta x_2 = 10$ cm and $\Delta t = 0.05$ sec. The grid was 3 cells wide in the alongshore direction and 50 cells long in the offshore direction. In this example, walls were used for the lateral boundaries as well as the offshore boundary to correspond to the laboratory situation. Since for normal incidence, the velocities U and V would be zero everywhere corresponding to the steady state, advection, eddy viscosity, and friction terms were turned off in the model. The solution allowed for the effect of setup on the wave heights in the surf zone. As the solution proceeded, since $\bar{\eta}$ changed, the wave heights for cells in the surf zone were computed afresh for each time-step by using $H = \gamma(|h| + \bar{\eta})$, where γ is a breaking index and the radiation stresses were changed accordingly. As suggested by Bowen, Inman, and Simmons (1968), a γ of 1.15 was used. A buildup time of $10 \Delta t$ was used at the start. A comparison of the steady-state setup values from the model (after $150 \Delta t$) with those observed by Bowen, Inman, and Simmons (1968) is shown in Figure 6. As shown, there is excellent agreement in the offshore region. In the surf zone, the numerical model predicts higher setups than those observed. This is not surprising since the model does not allow flooding and runup. It is to be noted that the slope of the mean waterline in the surf zone is approximately the same in both cases.

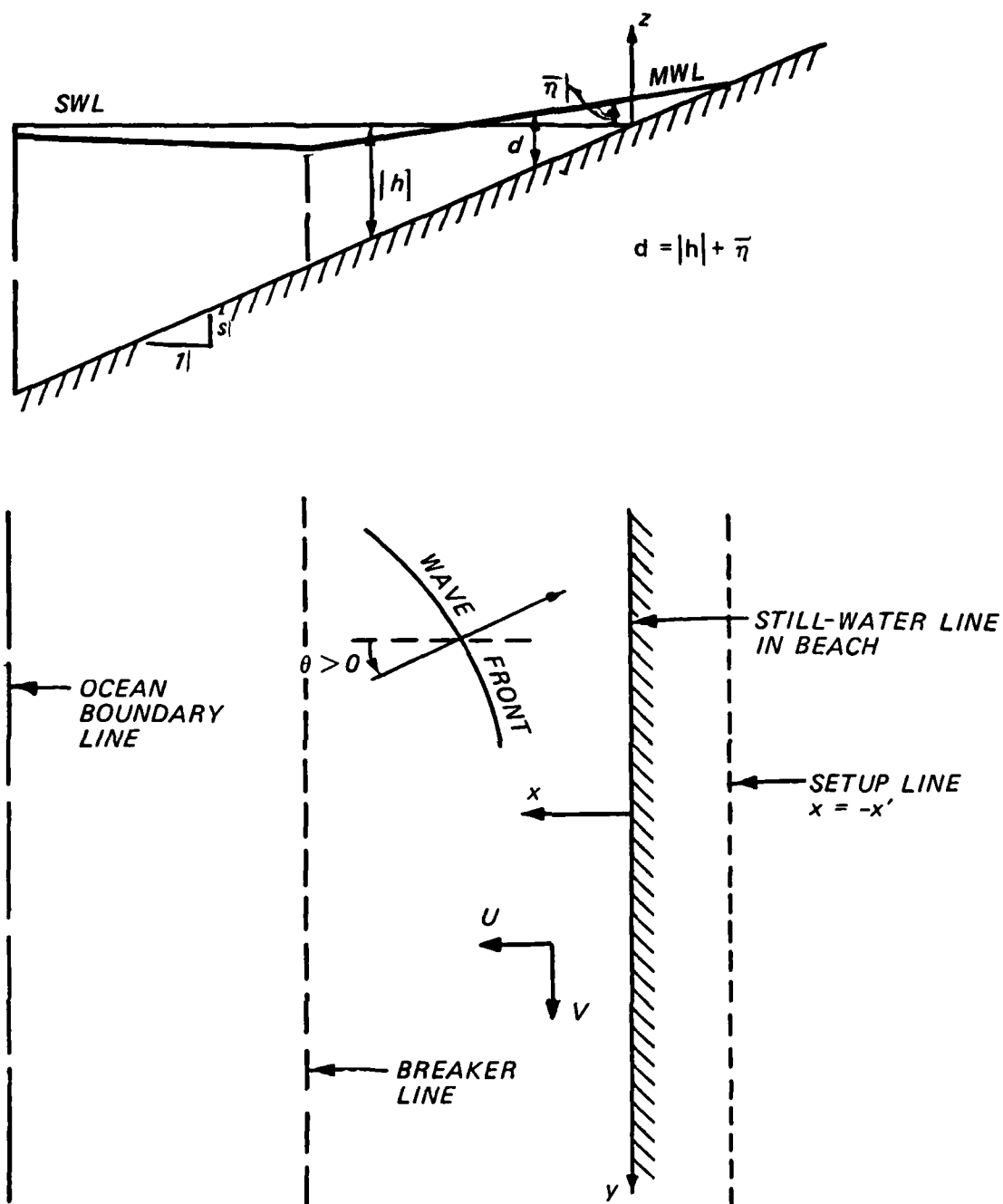


Figure 5. Definition sketch for a plane beach: cross section and plan

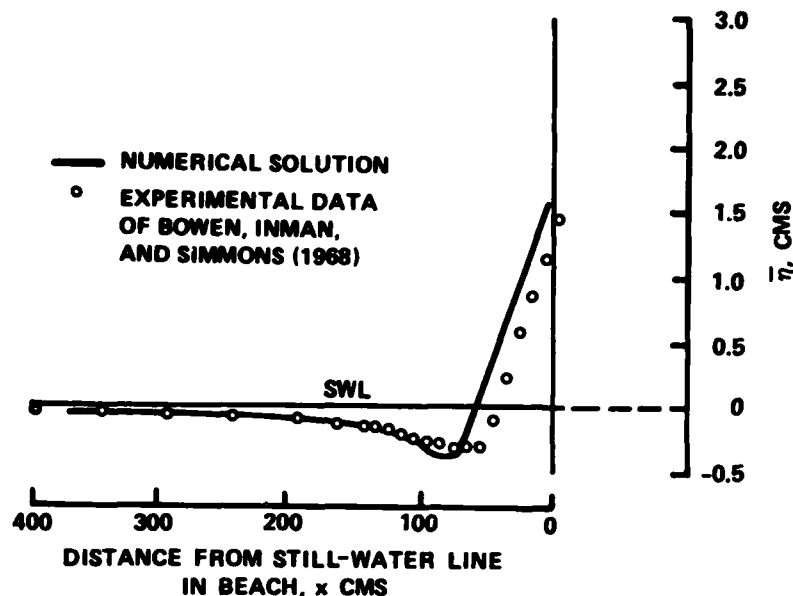


Figure 6. Comparison of numerical solution for setup with experimental data

Plane beach: oblique incidence

27. For this case, a plane beach of constant bottom slope $s = 1:30$ was selected. A monochromatic wave with the following deepwater characteristics was chosen: $T = 12$ sec, $H_0 = 10$ ft, and angle of incidence in deep water, $\theta_\infty = 20$ deg. A drag coefficient c of 0.01 and a breaking index γ of 0.82 were used in the model. A uniform grid with $\Delta x = \Delta y = 60$ ft was used for most of the runs. It was 6 cells wide in the alongshore direction and 100 cells long in the offshore direction. Uniform flux and radiation boundary conditions were used for the lateral and offshore boundaries, respectively. The buildup time varied from 15 to 50 Δt , depending on the time-step Δt used.

28. First the model was run without allowing for the effect of setup on wave heights and radiation stresses. Mixing and advection were ignored. A time-step of 0.5 sec was used. The steady-state velocity distribution obtained (after 800 Δt) is compared with the triangular distribution of Longuet-Higgins (1970) in Figure 7. There is good agreement. Note that for positive θ , V will be negative for our coordinate scheme. Later a finer grid ($\Delta x = \Delta y = 30$ ft) with a Δt of 0.25 sec was used. As shown in Figure 7, as the grid is made finer, the numerical solution tends to approach the analytic solution.

29. The effect of setup was taken into account next. A time-step of

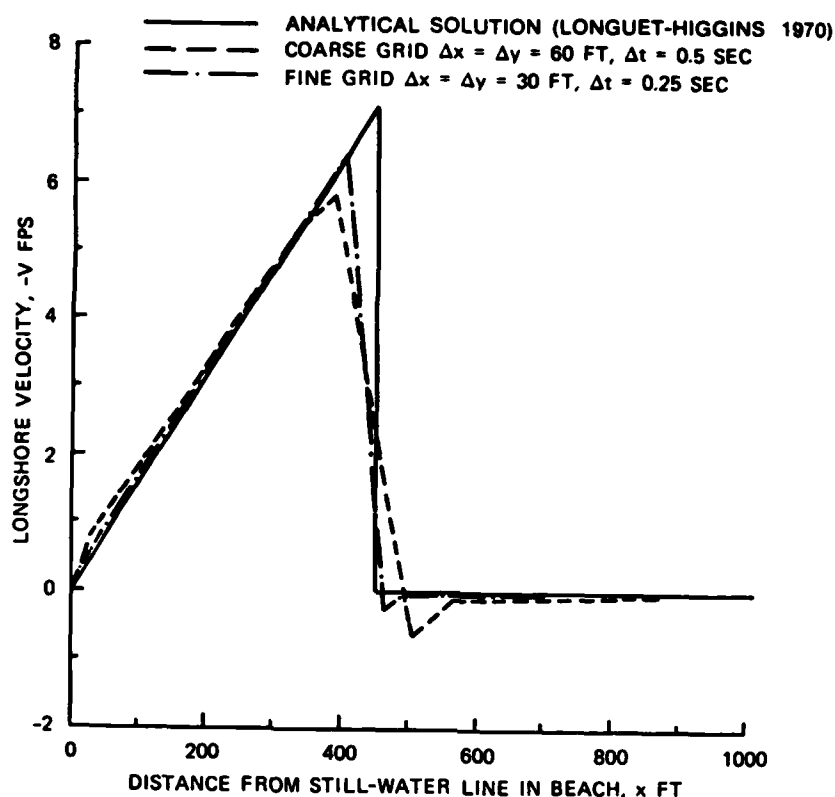


Figure 7. Plane beach: solution for longshore current neglecting the effect of setup

1.5 sec was used for this case. The velocity distribution from the model is compared with the corresponding analytic solution in Figure 8. There is good agreement. Note that the numerical solution goes to zero at the still-water line because a wall was assumed there. On the other hand, the Longuet-Higgins (1970) solution goes to zero at the setup line. To plot his solution, the distance from the still-water line to the setup line was estimated by using a relation provided by Dalrymple, Eubanks, and Birkemeier (1977).

30. The effect of lateral mixing was studied next, without taking the effect of setup into account. A time-step of 5.0 sec was used for these runs. The mixing parameter P of Longuet-Higgins (1970) was varied between 0.01 and 0.4. Note that P is defined as

$$P = \frac{\pi}{\gamma} \frac{sN_{LH}}{c} \quad (52)$$

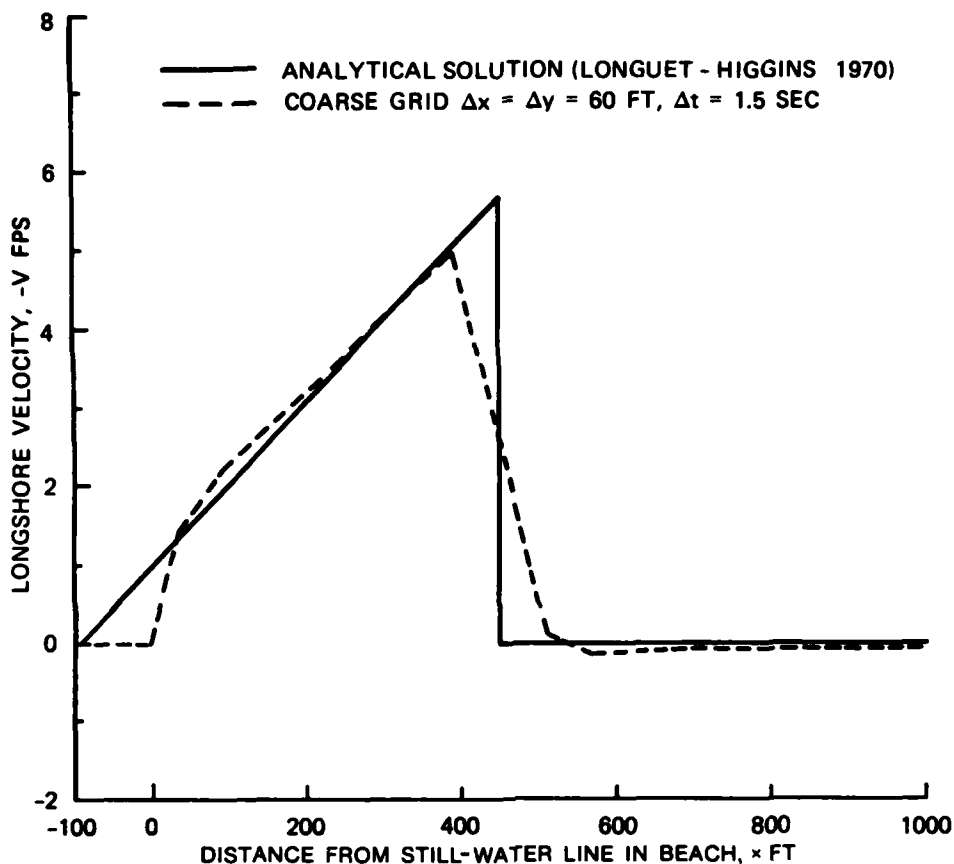


Figure 8. Plane beach: solution for longshore current considering the effect of setup

Figure 9 shows the effect of P on the numerical solution. As expected, the magnitude of the peak decreases, the peak moves closer to the shoreline, and the velocities offshore of the breaker line increase as P increases.

Difficulties Involved in Application to Field Situations

31. While it is relatively easy to apply a numerical current model to idealized cases, one must face several difficulties in applying the model to field situations. Among these is the highly irregular nature of the bathymetry, especially near inlets where channels and shoals exist. The topography must be smoothed to a certain extent in order for the wave climate and wave-induced current models to work properly; yet, one must be careful not to completely change the basic features of the topography. The shoreline as well as the breaker line may be irregular and may be oblique to the grid axes. There

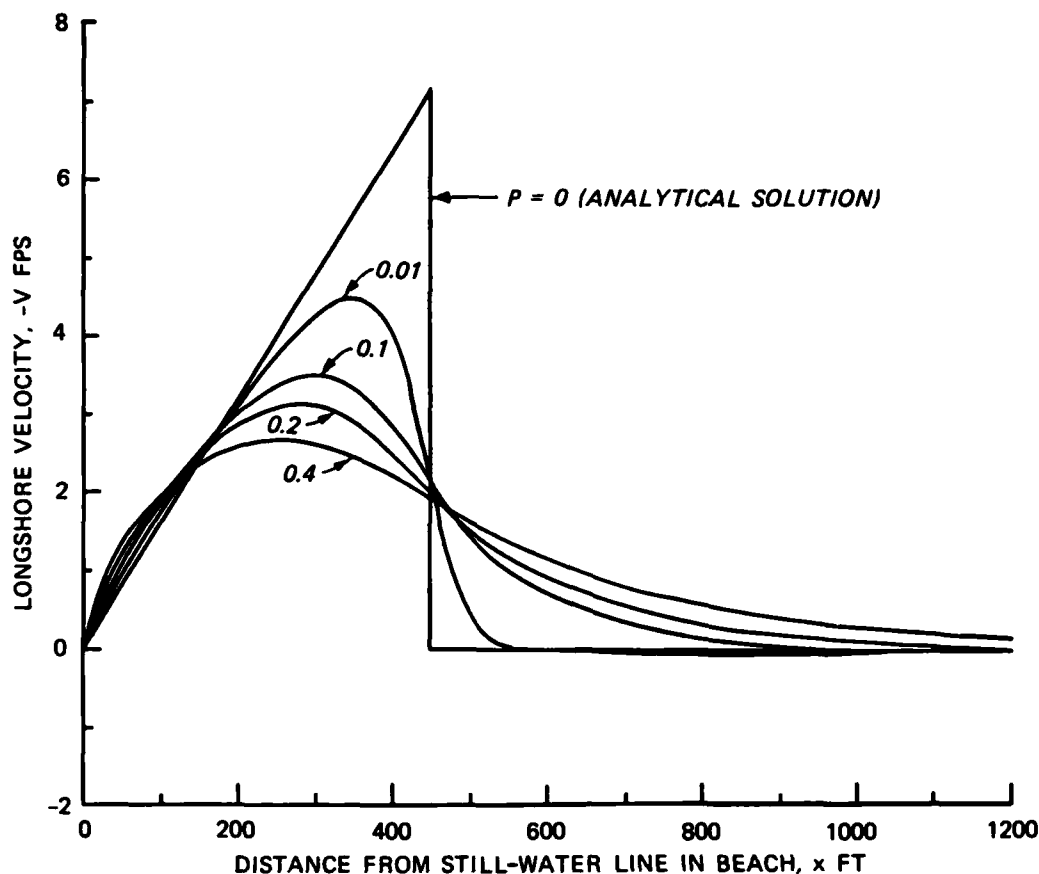


Figure 9. Plane beach: effect of mixing parameter P on the numerical solution

may be more than one breaker line. There are problems connected with discretization of the shoreline and breaker line(s). Selection of appropriate values for empirical coefficients such as friction and eddy viscosity coefficients and breaking index is not easy. There are problems in connection with the wave climate model also, especially if wave-current interactions are to be taken into account.

A Particular Field Application

32. In order to demonstrate the applicability of the numerical model to field situations, the case of Oregon Inlet, North Carolina, was selected. Oregon Inlet is a tidal inlet in a barrier island system. Behind the inlet toward the mainland is Pamlico Sound. Most of the problems mentioned in the previous paragraph had to be addressed and solved satisfactorily in this

application. For purposes of the numerical simulation, a rectangular region approximately 62,400 ft long in the alongshore direction and 29,400 ft wide in the offshore direction was considered. It included a portion of Pamlico Sound. The variable grid used for the simulation is shown in Figure 10. The grid was

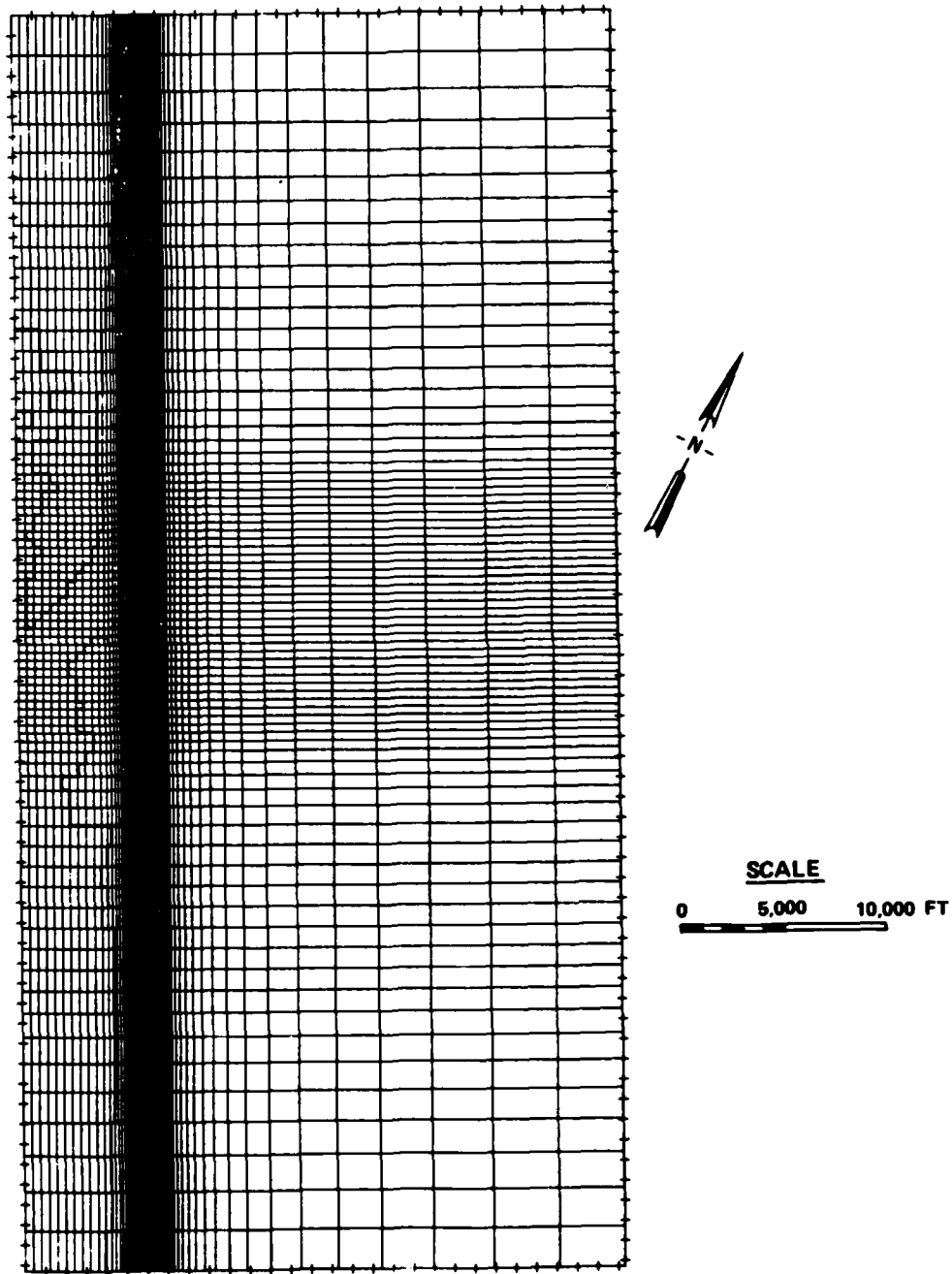


Figure 10. Numerical grid used for Oregon Inlet, North Carolina, simulation

77 cells long in the alongshore direction and 54 cells wide in the offshore direction. It may be noted that the minimum cell widths in the alongshore and offshore directions were 400 and 100 ft, respectively. These widths were used near the inlet and surf zone, respectively. Note that $\Delta\alpha_1 = \Delta\alpha_2 = 100$ ft. The topography used in the simulation corresponding to this grid is shown in Figure 11. The elevations are shown in feet and the datum is mean low water (mlw). Several points must be mentioned about this three-dimensional perspective plot. First, the vertical dimensions are highly exaggerated compared with the horizontal; secondly, the elevations are plotted in the computational space and not the physical space--so the horizontal dimensions are distorted. The topography was somewhat modified compared with the actual topography, with respect to the depths near the offshore boundary and the land elevations on the islands. In spite of these factors, Figure 11 helps one to visualize the irregular nature of the bathymetry. Also, the locations of the channels and shoals in the region of the inlet are shown clearly in the figure.

33. A monochromatic wave with a height of 11.39 ft, period of 8.0 sec, and $\theta = 51.1$ deg in 60-ft depth of water was selected for the simulation (the depth of water at the offshore boundary of the numerical grid was 60 ft). This wave corresponded to the significant wave during a part of the Ash Wednesday storm of March 1962 at the inlet. In this case, besides using "no flow" conditions at the shoreline, a radiation boundary condition offshore, and uniform flux boundary conditions at the lateral boundaries, a uniform flux boundary condition was used over a part of the inland side of the sound, while the rest of the sound was closed off. A time-step Δt of 18.0 sec and a drag coefficient c of 0.01 were used in the numerical model. The breaking index γ was chosen according to the breaking criterion employed by Noda (1974):

$$\frac{H_b}{L_b} = 0.12 \tanh \left(\frac{2\pi d_b}{L_b} \right) \quad (53)$$

where L corresponds to the wavelength and the subscript b indicates values at breaking. A buildup time of $15 \Delta t$ was used at the start. The eddy viscosity ε_x was chosen according to Equation 14 and the eddy viscosity ε_y was set equal to the value of ε_x at the offshore boundary. For the case under consideration, the complete equations (Equations 1, 2, and 3) were solved. An approximate steady state was reached after $67 \Delta t$. Figures 12 and 13 represent

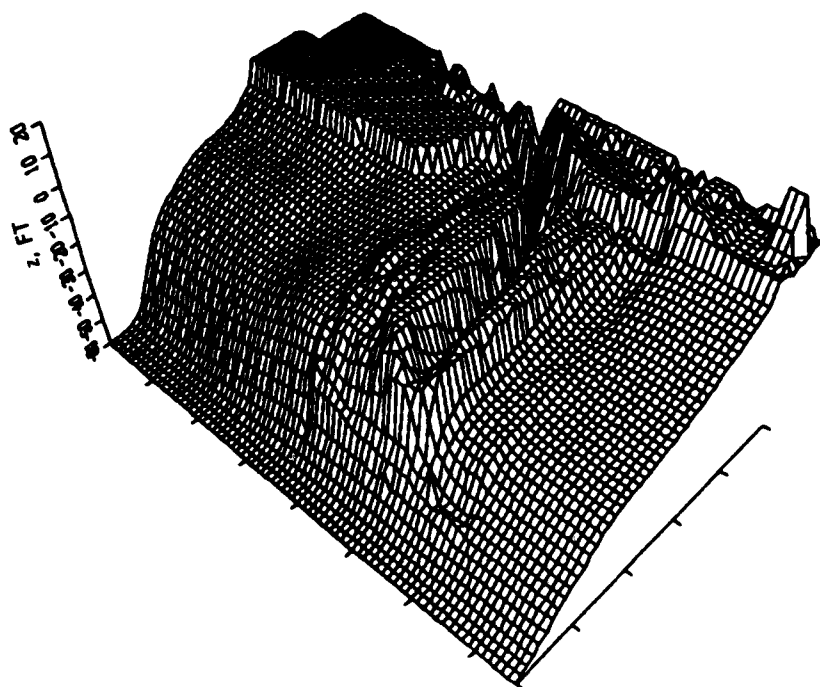


Figure 11. Topography used for Oregon Inlet,
North Carolina, simulation

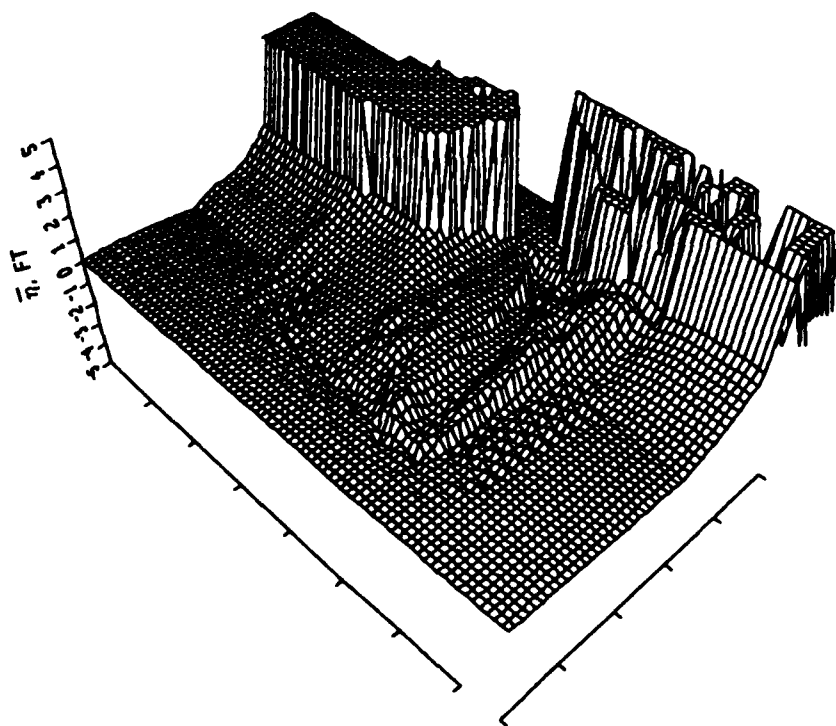


Figure 12. Water-surface elevation plot for Oregon Inlet,
North Carolina, simulation

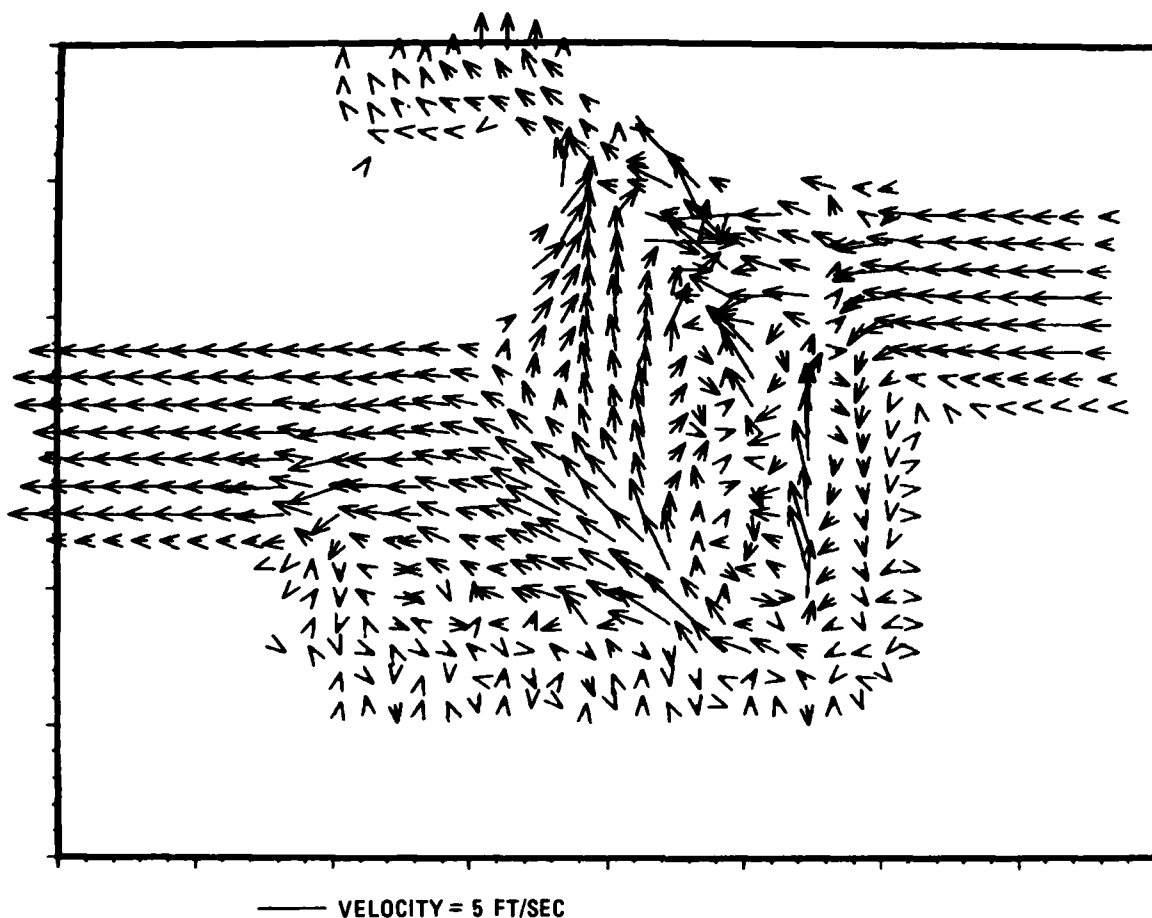


Figure 13. Velocity vector plot for Oregon Inlet, North Carolina, simulation

the corresponding mean water levels and velocity vectors plotted on the grid in the computational space. The velocity vectors are plotted for every other cell in each coordinate direction. To avoid confusion, the plotting of velocities with magnitudes less than 0.1 ft/sec is suppressed.

34. Referring to Figures 11, 12, and 13, let us first consider the two portions of the beach away from the inlet. The shorelines in these regions are approximately straight and the contours are approximately straight and parallel. As we approach the shoreline from offshore, there is a small setdown followed by a setup. The velocities are mainly alongshore and the velocity distribution is similar to that for a plane beach except that it exhibits two peaks at some locations.

35. The situation is more complicated in the region of the inlet (the central part of the grid). Here the breaker line is farther offshore. The

depth in the main channel decreases first and increases later as we go toward the inlet. Because of these factors, the water sets up around the inlet and tends to create a flow into the inlet through the various channels, as one would naturally expect. A part of the main alongshore flow goes around the channels and shoals to the other side.

36. Near the shoals, the patterns of mean water level and velocity are irregular. This is because the waves refract around the shoals and break, creating locally setups and currents that do not necessarily conform to the general patterns. As the waves go toward the islands, they re-form because the depth increases.

37. Figures 12 and 13 do not reflect the influence of tides and fresh-water flows through the inlet. In nature, these phenomena tend to modify the patterns shown in these figures.

Summary

38. The various tests for idealized situations and the successful comparisons to analytic solutions and experimental data indicate that the numerical model "behaves properly" and yields valid and accurate results. In the case of the field situation for Oregon Inlet, there are no field data available with which the model results can be compared. However, for this very complicated case, the model yields results that appear to be reasonable.

PART V: MODEL INPUT

General Description

39. The input data for CURRENT are discussed in this part. The model has been tested using the foot-pound-second system of units only. The number of time-steps computed is indicated by an integer variable ITIME. The grid index system is set up with N approximately in the alongshore direction and M increasing in the offshore direction. If a variable grid is used, the expansion coefficients must be defined for both cell centers and cell faces and are obtained from the programs MAPIT and GRID developed at WES.

Setting Matrix Dimensions

40. In the CRAY computer system on which the model was developed, matrix dimensions are changed for a particular application by using PARAMETER cards. The following parameters must always be set. This is done by using the UPDATE feature of CRAY. Using text editor, the following statements in *ID PARMRUN in update file UPDL2RV should be changed appropriately for the application:

```
PARAMETER(NDIM=   , MDIM=   , LDIM=   , IFRC=   )
```

```
PARAMETER(IPUT=   , ITDS=   , JPUT=   , JFLS=   )
```

```
PARAMETER(NGAGES=   , NBCELS=   , NBARCL=   )
```

The significance of the various parameters is explained below. Normally, only the parameters marked with an asterisk have to be changed. The rest may be left at the values given with the program.

NDIM* = Grid dimension (number of cells) in y-direction

MDIM* = Grid dimension (number of cells) in x-direction

LDIM* = Larger of NDIM and MDIM

IFRC* = Dimension of friction array for Chezy values ($>4 \cdot D_{MAXG}$, where D_{MAXG} is the maximum total water depth (ft) that will be experienced anywhere in the grid during the numerical simulation)

IPUT* = Dimension of elevation (tidal) forcing array--array must include a value for each time-step

ITDS* = Number of different elevation (tidal) forcing arrays

JPUT = Dimension of discharge forcing arrays
 JFLS = Number of different discharge forcing arrays
 NGAGES = Number of special gage locations for which results are to be printed
 NBCELS* = Number of boundary cells (where boundary conditions are to be applied)
 NBARCL* = Number of barrier cell faces

Input Data

41. The input data for CURRENT have been assembled into card groups that may consist of one or more data cards. Some groups are optional and thus each group is marked with an R (required) or O (optional). The following text indicates for each input card group the necessity code, FORTRAN format, the variables involved, and a brief description of the variables.

Necessity Code	Card Group (Format)	Variable	Description
R	1A (I5)	NDTAP	Number of file from which input data are to be read in--usually set to 95
NOTE: All the following card groups are on a separate file defined by NDTAP (if NDTAP≠5). Group 1A must be on the system input file (File 5, i.e. card reader)			
R	1B (8A8)	ITL	Identification title for run
R	1C (NAMELIST \$WAVE)	PER	Period of the wave
		HTO	Wave height at the offshore boundary--used for calculating ϵ_y
		THETAO	Angle of incidence of waves (in degrees) at the offshore boundary, measured with respect to the x-axis--used for calculating ϵ_y
		DEPMAX	Depth at the offshore boundary (ft)--used for calculating ϵ_y
		GAMMA	Breaking index (ratio of wave height to depth in surf zone)
R	2 (3I5)	NMAX	Grid dimension (number of cells) in y-direction
		MMAX	Grid dimension (number of cells) in x-direction

Necessity Code	Card Group (Format)	Variable	Description
R	3 (16I5)	ITID	Number of entries in input elevation (tidal) table
		JTID	Number of time-steps between entries in input elevation (tidal) table
		NTID	Number of distinct elevation (tidal) forcing functions
		MPR	Print control for initial conditions 1--print flag arrays only 2--print depth also <0--print in addition flood, barrier, and elevation (tidal) data
		MSURF	Print elevation (tidal) forcing function in steps of MSURF
R	4 (8E10.1)	TAU	Time-step, Δt (sec) for one full cycle
		DX	Cell dimension Δx_1 (ft)
		DY	Cell dimension Δx_2 (ft)
		G	Acceleration due to gravity (ft/sec^2)
		EPSD	Minimum amount of water defining a dry cell (ft)
		DCON1	Add DCON1 to water cell bed elevations to translate datum (ft)
		DMPX	Value of still-water land elevation assigned artificially to areas that will never flood (ft)
		VIS	A multiplier for eddy viscosity terms (can be set between 0 and 1)
		XLAND*	A value of bed elevation, $h > \text{XLAND}$ defines a cell that will never flood (ft) (positive)
		XSCOUR*	A value of $h < \text{XSCOUR}$ defines a cell that will never go dry (ft) (negative)
		SMAX	If $\eta > \text{SMAX}$, stop computations and print η ; caution: set SMAX higher than highest land cell elevation
		DMAXG	Positive bound on maximum total water depth that will be experienced during simulation (ft)--used for setting up size of friction matrix

* Caution: Select $\text{XLAND} <$ bed elevation of lowest land cell and $\text{XSCOUR} <$ depth $|h|$ of shallowest water cell if flooding/drying is not desirable. The flood/dry capabilities of the program have not been tested.

Necessity Code	Card Group (Format)	Variable	Description
R (Continued)	4 (8E10.1) (Continued)	DCON2	Add DCON2 to elevation (tidal) input values to correspond to model datum (ft)
		DLIMIT	Artificial cutoff value on bed elevation (h) for water cells (negative) (ft)
R	5 (16I5)	MAXTIM	Number of time-steps to run simulation
		INTAP	=m--save $\bar{\eta}$, U and V on file 1 every m Δt =-1--no data are saved on file 1
		IDELAY	Delay saving information on file 1 until ITIME= IDELAY (note ITIME counts the number of cycles)
		IXPAN	=0 uniform grid in real space #0 variable grid--read in expansion coefficients
		NGAGE	Number of special gage points (up to 20 gages are permitted)
		NFREQ	Information will be printed at gage points every NFREQ Δt 's-- <u>never set equal to zero!</u>
		NZP	Number of corrections to input depth matrix
R	7 (16I5)	NPRINT	Time-step index to print hydrodynamics ($\bar{\eta}$, U , and V) over the whole grid--up to 32 printouts are allowed--two cards must be included
O	8 (16I5)	NPOT	y-indices for special gage points (NGAGE in number)
		MPOT	x-indices for special gage points (NGAGE in number)--start on a new card
Note: Group 8 is omitted if NGAGE=0			
R	12 (10F8.3)	XMAN _i	Mannings's n for each code i, i=1,20--used for defining friction. Note: code 1 is used for all water outside computational boundaries--two cards must be included
		ZB	Heights (ft) for barrier cells (see card group 17)--start on a new card--two cards must be included
		CB	Chezy coefficients for barrier cells (see card group 17)--start on a new card--two cards must be included

Necessity Code	Card Group (Format)	Variable	Description
0	13 (2I5,F8.3)	N M DNM	Corrections to bed elevation matrix--grid indices N,M and corrected bed elevation DNM (ft)--NZP cards must be provided
Note: Group 13 is omitted if NZP=0			
R	14 (20I4)	ISHORE2 _N IBRK1 _N ISHORE3 _N IBRK2 _N	Matrix indicating shoreline position--for each N, read an M value corresponding to the last (seaward) land cell between beach and ocean. There are NMAX values Matrix indicating first breaker line position--for each N, read an M value corresponding to the breaker line Matrix indicating a fictitious shoreline position for a second surf zone Matrix indicating second breaker line position
Note: If there is no second surf zone, set all the values of ISHORE3 and IBRK2 to zero			
R	15 (35I2)	MAN _{N,M}	Friction codes (1 to 20)--for each N, read MAN _{N,M} , M = 1, MMAX (start a new card for each N)--use special code of 99 for all water cells outside of computational boundaries--code 99 corresponds to XMAN(1)
R	17 (3I2,4I4)	ITYP INDX IDIR I1 I2 } I3 }	Used for boundary data 1--impermeable nonoverlapping barrier 8--elevation (tidal) input boundary (used for radiation boundary) 9--flow input boundary (used for uniform flux boundary) 99--end of group 17 data 0--for flux boundary 1,2,3--used for indicating different elevation (tidal) boundaries 1--if flow or elevation (tide) is in the x-direction 2--if flow or elevation (tide) is in the y-direction Grid index (M or N value) of boundary line Boundary extends from N or M = I2 to I3

Necessity Code	Card Group (Format)	Variable	Description
R (Continued)	17 (3I2,4I4)	I4	0--for top or left boundary (low values of x or y) 1--for bottom or right boundary (high values of x or y)
Note: The termination of boundary data (group 17) is indicated by including at the end of the group a card containing 99 in columns 1 to 2. All other columns should be blank			
0	20 (10F8.4)	SURIN _i	Entries in input elevation (tidal) tables--there are NTID tables and for each table, there are ITID entries--the order in which the tables are read in de- pends on the sequence of the elevation (tidal) boundaries in group 17--start each table on a new card
Note: For radiation boundary, set ITID = 2, JTID > MAXTIM and SURIN ₁ = SURIN ₂ = 0.			
Note: Group 20 is omitted if NTID = 0			
R	23 (16I5)	JDELAY	Delay saving gage information until ITIME = JDELAY
R	32 (NAMELIST \$PAR)	RHO	Density of seawater (slugs/ft ³)--usually set to 1.99
		EY	Eddy viscosity ϵ_y (ft ² /sec)
		RAD	A weighting factor (between zero and one) for radiation stress gradient terms
		NTIMEB	Number of time-steps over which radiation terms are to be built up
		ADV1	A weighting factor (between zero and one) for advection terms
		FRC1	A weighting factor (between zero and one) for bottom friction terms
		ANLH	The parameter N_{LH} in Longuet-Higgins ex- pression for eddy viscosity (Equa- tion 13)--varies between 0 and 0.016
		CF	Drag coefficient c in the Longuet- Higgins linear relation for bed friction
		ITAVG	Number of time-steps over which the solu- tion (values of η , U , V , and dis- charges) is to be averaged. The program averages the solution starting with values from step MAXTIM-ITAVG + 1. These values are printed as well as saved on appropriate files

<u>Necessity Code</u>	<u>Card Group (Format)</u>	<u>Variable</u>	<u>Description</u>
R	33 (I2)	IEDDY	Index which indicates method of computing eddy viscosity ϵ_x 1 = Longuet-Higgins method 1 = Jonsson et al. method 3 = eddy viscosity ϵ_x is read in from file 40
0	34 (16F5.0)	XDIST _{N,M}	The matrix containing the distance from the shoreline to each cell for use in Longuet-Higgins formula for eddy viscosity ϵ_x . For each value of N, read MMAX values. Start each new N on a separate card. Note: For water cells offshore of breaker line, keep XDIST same as the value at the breaker line

Input Files

42. In Boeing Computer Services (BCS), the source deck for the program is on file WIFMSRC. It has to be updated first and a program library created. Then the program library should be updated again with the update file UPDL2RV.

43. The following input data files are often used. Some are optional depending on the run.

File FT 35

44. This file contains the wave data, usually the output from a numerical wave climate program. For each grid cell, the wave number AK, wave angle TH, and the wave height HT are read in sequence. The following statements are used to read the file in subroutine DEPTH:

```

      DO 10060 M=1, MMAX
      DO 10060 N=1, NMAX
      I = NMAX*(M-1) + N
      READ (35,10061) AK(I), TH(I), HT(I)
10060 CONTINUE
10061 FORMAT (F10.6, 2F10.3)

```

Note that in the program the same matrix may be used either as a double index, e.g., AK(N,M) or a single index, e.g., AK(I) array. The conversion from the two index to one index system is accomplished by the relation

$$I = NMAX*(M-1) + N$$

This file is always required.

File FT 36

45. This file contains the bed elevations $D(N,M)$ for grid cells. The following statements are used to read the file in subroutine DEPTH:

```
DO 99005 M=1,MMAX
  READ (36,99001) (D(N,M), N = 1,NMAX)
99001 FORMAT (10F8.3)
99005 CONTINUE
```

Note: Usually, if SWL is taken as the datum,

```
D(N,M) < 0 for water cells
          > 0 for land cells
```

This is a required file.

File FT 39

46. This file contains the grid expansion coefficients YNU and XMU for a variable grid. They correspond to μ_2 and μ_1 , respectively. There will be $NYN = 2 * NMAX$ values of YNU and $NXX = 2 * MMAX$ values of XMU. These coefficients are provided by a special program called GRID. The following statements are used to read the file in subroutine INTAKE:

```
READ (39,99002) (YNU(I), I = 1,NYY)
READ (39,99002) (XMU(I), I = 1,NXX)
99002 FORMAT (4G20.11)
```

This file is optional and required only for a variable grid ($IXPAN \neq 0$).

File FT 40

47. This file contains the eddy viscosity coefficients for the x-direction, EX. The following statements are used to read the coefficients in a string in subroutine EDDYVIS:

```
READ (40,115) (EX(I), I = 1,NMX)
115 FORMAT (16F5.1)
```

This file is optional and required only if IEDDY = 3.

File FT 95

48. This is a "card image" file. It contains the rest of the input data needed for running the program. The number of the file (NDTAP) may be other than 95. The number should be indicated always on the first input data card (card group 1A). This file is required.

PART VI: MODEL OUTPUT

General Description

49. This section describes the general output in the form of printed output and output files that may be obtained from the model and the controls one may exercise on the same. Most of the input data are printed as soon as they are read in so that errors in the input data may be easily detected and corrected by the user. By setting the variable MPR (card group 3) appropriately, the user may obtain as much information as he or she desires on the flag arrays, depths, flood, barrier, and tidal data. Similarly, by using the NPRINT (card group 7) option, the user may obtain detailed printout of $\bar{\eta}$, U , and V over the whole grid at intermediate times during the computation. By using the variables NGAGE, NFREQ, NPOT, and MPOT (card groups 5 and 8), the user may provide for special gages at several locations within the grid and obtain a time-history of water levels and velocities there either to check the results of the model or to compare model results with actual field gage data. The user must provide the necessary Job Control Language (JCL) to print the files FT 07 and FT 08. By setting the variable ITAVG (card group 32), the user may obtain a solution that is averaged over the last ITAVG time-steps. The program prints the averaged water levels and velocity components at the cell centers as well as the discharges across cell faces and stores them on file FT 20 for later use in a sediment transport model.

50. Program CURRENT constructs various arrays and tables packed with data to control double-sweep computation, forcing boundaries, barrier treatment, etc. There are two flag arrays ICU(N,M) and ICV(N,M) to control computation in x- and y-directions, respectively. Each element of ICU (ICV) consists of two digits: $n_1 n_2$. When the flags are printed, for any given cell (N,M) the values of ICU and ICV are printed together as a four-digit number ICF. The first digit n_1 in ICU (ICV) defines the character of the cell on the bottom (right) face of the cell. Digits n_1 and n_2 have the following significance:

n_1	Definition
1	Bottom (right) face of cell is an exposed barrier that cannot be overtopped. n_2 has no meaning. Note: The code ICU=10, ICV=10 is set by the program to indicate water cells outside computational boundaries.

(Continued)

n_1	Definition
5	No flow through bottom (right) face of cell. n_2 is set to zero.
6	Flow through bottom (right) face of cell. n_2 indicates the type of computation to use for advection. $n_2 = 0$ means no advection, $n_2 = 1$ advection in x-direction only, $n_2 = 2$ advection in y-direction only, and $n_2 = 3$ advection in both x- and y-directions.
7	Constructed by the program to indicate no computation for x-(y-) sweep. n_2 is set to zero to indicate a lower boundary, and 1 for an upper boundary, for the other sweep direction.
8	Elevation (tidal) or radiation boundary cell. n_2 indicates the number of the forcing elevation (tide) used.
9	Bottom (right) face is a discharge boundary. $n_2 = 0$ indicates a uniform flux boundary condition applied at cell center; otherwise n_2 indicates the number of the forcing discharge used.

Forcing elevation (tidal) boundary control vectors take the form:

$$\text{Vector } i : 1000000 * \text{INDX} + 1000 * N + M$$

and discharge boundary vectors the form:

$$\text{Vector } i : 1000000 * (\text{INDX} + 10 * \text{IDIR}) + 1000 * N + M$$

where i is the i^{th} element of the vector, N and M are indices of the grid cell and INDX and IDIR are defined in card group 17. The user is urged to set $\text{MAXTIM} = 0$ (card group 5) and $\text{MPR} = -1$ (card group 3) during the first run to check the accuracy of the input data, the flags, boundary vectors, etc. Once these are found to be correct, then MAXTIM and MPR may be set to desired values and the actual computations may be performed.

Output Files

51. Output may be stored by the model in the following files. Some are optional. The user must dispose the files with proper JCL if he or she wants to save the files for later use.

File FT 01

52. This file contains the bed elevations h , and $\bar{\eta}$, U , and V saved every INTAP time-steps in subroutine POUT . The reader is referred to that subroutine for details.

Files FT 07 and 08

53. These contain the results $\bar{\eta}$, U , and V for selected gages (see

card groups 5 and 8) stored at intervals of NFREQ, starting from time-step JDELAY. Each file contains information for up to 10 gages. It is convenient to copy these files to system OUTPUT file at the end of the run. The results will then be printed in a tabular form. Files FT 07 and FT 08 are written on in subroutine DRIVE.

File FT 11

54. This file contains the surface elevation $\bar{\eta}$ and the velocities U , V (averaged, respectively, at the center of the cell) for the special gage locations in a form that is convenient for plotting time series. The results are stored at intervals of NFREQ, starting from time-step JDELAY, using the following statements:

```
DO 10020 J=1, NGAGE
  N = NPOT(J)
  M = MPOT(J)
  II = NMAX*(M-1)+N
  WRITE(11)ITIME,J,N,M,SEP(II),UU,VV
```

10020 CONTINUE

where ITIME is the time-step number. This file is written on in subroutine DRIVE.

File FT 13

55. This file contains the surface elevations all over the grid at selected instants of time NPRINT during the course of the computation. The file is written on in subroutine POUT using the following statements:

```
WRITE(13) ITIME
DO 4800 M=1,MMAX
  DO 4800 N=1,NMAX
    I1 = (M-1)*NMAX+N
    WRITE(13)SEP(I1)
```

4800 CONTINUE

This file may be used for 3-D plotting.

File FT 14

56. This file contains the velocities U , V at the center of each grid cell for all the grid cells at selected instants of time NPRINT during the course of the computation. The file is written on in subroutine POUT using the following statements:

```

WRITE(14)ITIME
DO 4900 M=1,MMAX
DO 4900 N=1,NMAX
II=NMAX*(M-1)+N
WRITE(14) UU,VV

```

4900 CONTINUE

This file may be used for vector plotting.

File FT 15

57. This file contains the vertically integrated discharges DISCHX and DISCHY across the lower and right faces of each grid cell for all the grid cells at the end of the run (ITIME=MAXTIM). This file is written on in subroutine POUT using the following statements:

```

DO 31000 M=1, MMAX
DO 31000 N=1, NMAX
II = NMAX*(M-1)+N
WRITE(15)DISCHX(II),DISCHY(II)

```

31000 CONTINUE

File FT 20

58. This file contains some of the information needed for running a numerical sediment transport model subsequently, such as shoreline and breaker line positions, updated wave information, average values (averaged over ITAVG time-steps) of $\bar{\eta}$, U, V, and discharges across cell faces. It is written on in subroutines DEPTH, MOTN4, and POUT, respectively. The reader is referred to these subroutines for details.

PART VII: MODEL APPLICATION

Plane Beach: Longshore Currents

59. In order to demonstrate the use of the model for a simple situation, the case of monochromatic waves obliquely incident on a plane beach will be considered. This is the same case that was discussed in paragraphs 27-30 of PART IV except that the effect of setup, mixing, and advection are taken into account now during the course of the computation. The beach has a constant slope of 1:30. The wave characteristics in deep water are given by $T = 12$ sec, $H_0 = 10$ ft, and $\theta_\infty = 20$ deg. For purposes of the present simulation, a uniform grid with $\Delta x = \Delta y = 60$ ft, $NMAX = 6$, and $MMAX = 50$ is chosen. Also, let $c = 0.01$, $\gamma = 0.82$, $N_{LH} = 0.00783$, $\Delta t = 5.0$ sec, and $NTIMEB = 15$. Uniform flux boundary conditions are employed at the lateral boundaries and a radiation boundary condition at the offshore boundary. The simulation is run for 105 time-steps.

60. The CRAY JCL for running the program at BCS is shown in Figure 14. The user must supply his or her own user number (UN) and password (PW) and filename XXXLOG for dayfile. File WAVESRV has the results of a wave climate program for the case under consideration. File DEPBCH has the bathymetric information and file DATABCH most of the input data. No output files are saved.

61. The input data for the job from file DATABCH are shown in Figure 15. Note that the full print option $MPR=-1$ has been selected and $NGAGE$ has been set to 20 with $NFREQ=5$ and $JDELAY=0$. As for eddy viscosity, $IEDDY$ has been set to 1 (Longuet-Higgins formulation) so that both $ANLH$ and $XDIST$ have to be supplied. Note also that blank lines are used for input statements containing all zeros.

62. Figure 16 shows the "echo-print" of the input data by the program, Figure 17 the results of computation, and Figure 18 a sample printing of the results for selected gages. Note that the program prints the updated wave heights at the end of the run and the CPU time spent in the double-sweep computation.

Oregon Inlet

63. The next application to be considered is that of Oregon Inlet. This has been discussed at length in paragraphs 32-37 of PART IV. This is a

```

COEXX,P02,T40,STCA1.
USER,UN,PW.
FETCH,DN=AA,GDN=WIFMSRC,UN=CER0D2,DT=C,DS=FF.
UPDATE,F,I=AA,P=0,C=0,N,L=0.
FETCH,DN=A,GDN=UPDL2RV,UN=CER0D2,DT=C,DS=FF.
UPDATE,F,P=$NPL,IN.
CFT,I=$CPL,L=0.
FETCH,DN=FT35,GDN=WAVESRV,UN=CCCC26,DS=C1.
FETCH,DN=FT36,GDN=DEPBCH,UN=CER0D2,DT=C,DS=FF.
FETCH,DN=FT95,GDN=DATABCH,UN=CER0D2,DT=C,DS=FF.
LDR.
REWIND,DN=FT07.
COPYD,I=FT07,O=$OUT.
REWIND,DN=FT08.
COPYD,I=FT08,O=$OUT.
EXIT,U.
COST,LO=F.
LOGFILE,L=LOG,FULL.
STORE,DN=LOG,GDN=XXXLOG,DT=C,DS=FF,UN=XXXXXX.
◆MEOR
◆READ A
◆MEOR
    95
◆MEOF

```

Figure 14. Job Control Language (JCL) for plane beach application

SLAVE PER=12.0,HTD=10.0,THETA0=20.0,DEPMAX=97.,GAMMA=0.82, SEND

1 1 1 1 1 1
9 9 9 9 9 9

[illegible]

Figure 15. Input data for plane beach application

WAVE NUMBER AK
MULTIPLIED BY 10000.

I	J	1	2	3	4	5	6
1		0	0	0	0	0	0
2		924	924	924	924	924	924
3		535	535	535	535	535	535
4		416	416	416	416	416	416
5		352	352	352	352	352	352
6		312	312	312	312	312	312
7		283	283	283	283	283	283
8		261	261	261	261	261	261
9		243	243	243	243	243	243
10		229	229	229	229	229	229
11		218	218	218	218	218	218
12		208	208	208	208	208	208
13		199	199	199	199	199	199
14		191	191	191	191	191	191
15		185	185	185	185	185	185
16		179	179	179	179	179	179
17		173	173	173	173	173	173
18		169	169	169	169	169	169
19		164	164	164	164	164	164
20		160	160	160	160	160	160
21		156	156	156	156	156	156
22		153	153	153	153	153	153
23		150	150	150	150	150	150
24		147	147	147	147	147	147
25		144	144	144	144	144	144
26		142	142	142	142	142	142
27		139	139	139	139	139	139
28		137	137	137	137	137	137
29		135	135	135	135	135	135
30		133	133	133	133	133	133
31		131	131	131	131	131	131
32		129	129	129	129	129	129
33		128	128	128	128	128	128
34		126	126	126	126	126	126
35		125	125	125	125	125	125
36		123	123	123	123	123	123
37		122	122	122	122	122	122
38		121	121	121	121	121	121
39		119	119	119	119	119	119
40		118	118	118	118	118	118
41		117	117	117	117	117	117
42		116	116	116	116	116	116
43		115	115	115	115	115	115
44		114	114	114	114	114	114
45		113	113	113	113	113	113
46		112	112	112	112	112	112
47		111	111	111	111	111	111
48		110	110	110	110	110	110
49		109	109	109	109	109	109
50		109	109	109	109	109	109

Figure 16. (Sheet 2 of 8)

WAVE ANGLE DEG
MULTIPLIED BY 100.00

I	J	1	2	3	4	5	6
1		0	0	0	0	0	0
2		216	216	216	216	216	216
3		327	327	327	327	327	327
4		411	411	411	411	411	411
5		481	481	481	481	481	481
6		541	541	541	541	541	541
7		595	595	595	595	595	595
8		644	644	644	644	644	644
9		690	690	690	690	690	690
10		732	732	732	732	732	732
11		771	771	771	771	771	771
12		808	808	808	808	808	808
13		843	843	843	843	843	843
14		877	877	877	877	877	877
15		909	909	909	909	909	909
16		939	939	939	939	939	939
17		968	968	968	968	968	968
18		996	996	996	996	996	996
19		1023	1023	1023	1023	1023	1023
20		1049	1049	1049	1049	1049	1049
21		1074	1074	1074	1074	1074	1074
22		1098	1098	1098	1098	1098	1098
23		1121	1121	1121	1121	1121	1121
24		1143	1143	1143	1143	1143	1143
25		1165	1165	1165	1165	1165	1165
26		1186	1186	1186	1186	1186	1186
27		1207	1207	1207	1207	1207	1207
28		1227	1227	1227	1227	1227	1227
29		1246	1246	1246	1246	1246	1246
30		1265	1265	1265	1265	1265	1265
31		1283	1283	1283	1283	1283	1283
32		1301	1301	1301	1301	1301	1301
33		1318	1318	1318	1318	1318	1318
34		1335	1335	1335	1335	1335	1335
35		1352	1352	1352	1352	1352	1352
36		1368	1368	1368	1368	1368	1368
37		1383	1383	1383	1383	1383	1383
38		1398	1398	1398	1398	1398	1398
39		1413	1413	1413	1413	1413	1413
40		1428	1428	1428	1428	1428	1428
41		1442	1442	1442	1442	1442	1442
42		1456	1456	1456	1456	1456	1456
43		1469	1469	1469	1469	1469	1469
44		1482	1482	1482	1482	1482	1482
45		1495	1495	1495	1495	1495	1495
46		1507	1507	1507	1507	1507	1507
47		1520	1520	1520	1520	1520	1520
48		1531	1531	1531	1531	1531	1531
49		1543	1543	1543	1543	1543	1543
50		1554	1554	1554	1554	1554	1554

Figure 16. (Sheet 3 of 8)

WAVE HEIGHT HT
MULTIPLIED BY 100.00

I	J	1	2	3	4	5	6
1		0	0	0	0	0	0
2		82	82	82	82	82	82
3		246	246	246	246	246	246
4		410	410	410	410	410	410
5		574	574	574	574	574	574
6		738	738	738	738	738	738
7		902	902	902	902	902	902
8		1066	1066	1066	1066	1066	1066
9		1218	1218	1218	1218	1218	1218
10		1185	1185	1185	1185	1185	1185
11		1158	1158	1158	1158	1158	1158
12		1134	1134	1134	1134	1134	1134
13		1114	1114	1114	1114	1114	1114
14		1096	1096	1096	1096	1096	1096
15		1079	1079	1079	1079	1079	1079
16		1065	1065	1065	1065	1065	1065
17		1052	1052	1052	1052	1052	1052
18		1040	1040	1040	1040	1040	1040
19		1030	1030	1030	1030	1030	1030
20		1020	1020	1020	1020	1020	1020
21		1011	1011	1011	1011	1011	1011
22		1003	1003	1003	1003	1003	1003
23		995	995	995	995	995	995
24		989	989	989	989	989	989
25		982	982	982	982	982	982
26		976	976	976	976	976	976
27		971	971	971	971	971	971
28		966	966	966	966	966	966
29		961	961	961	961	961	961
30		957	957	957	957	957	957
31		953	953	953	953	953	953
32		949	949	949	949	949	949
33		946	946	946	946	946	946
34		943	943	943	943	943	943
35		940	940	940	940	940	940
36		937	937	937	937	937	937
37		934	934	934	934	934	934
38		932	932	932	932	932	932
39		930	930	930	930	930	930
40		928	928	928	928	928	928
41		926	926	926	926	926	926
42		924	924	924	924	924	924
43		923	923	923	923	923	923
44		921	921	921	921	921	921
45		920	920	920	920	920	920
46		919	919	919	919	919	919
47		918	918	918	918	918	918
48		917	917	917	917	917	917
49		916	916	916	916	916	916
50		915	915	915	915	915	915

Figure 16. (Sheet 4 of 8)

INPUT DATA--CARD GROUP 14

ISHORE2(N) MATRIX

1 1 1 1 1 1

IBRK1(N) MATRIX

9 9 9 9 9 9

ISHORE3(N) MATRIX

0 0 0 0 0 0

IBRK2(N) MATRIX

0 0 0 0 0 0

ADJ BED ELEV

MULTIPLIED BY 10.000

I	J	1	2	3	4	5	6
1		10	10	10	10	10	10
2		-10	-10	-10	-10	-10	-10
3		-30	-30	-30	-30	-30	-30
4		-50	-50	-50	-50	-50	-50
5		-70	-70	-70	-70	-70	-70
6		-90	-90	-90	-90	-90	-90
7		-110	-110	-110	-110	-110	-110
8		-130	-130	-130	-130	-130	-130
9		-150	-150	-150	-150	-150	-150
10		-170	-170	-170	-170	-170	-170
11		-190	-190	-190	-190	-190	-190
12		-210	-210	-210	-210	-210	-210
13		-230	-230	-230	-230	-230	-230
14		-250	-250	-250	-250	-250	-250
15		-270	-270	-270	-270	-270	-270
16		-290	-290	-290	-290	-290	-290
17		-310	-310	-310	-310	-310	-310
18		-330	-330	-330	-330	-330	-330
19		-350	-350	-350	-350	-350	-350
20		-370	-370	-370	-370	-370	-370
21		-390	-390	-390	-390	-390	-390
22		-410	-410	-410	-410	-410	-410
23		-430	-430	-430	-430	-430	-430
24		-450	-450	-450	-450	-450	-450
25		-470	-470	-470	-470	-470	-470
26		-490	-490	-490	-490	-490	-490
27		-510	-510	-510	-510	-510	-510
28		-530	-530	-530	-530	-530	-530
29		-550	-550	-550	-550	-550	-550
30		-570	-570	-570	-570	-570	-570
31		-590	-590	-590	-590	-590	-590

Figure 16. (Sheet 5 of 8)

32	-610	-610	-610	-610	-610	-610
33	-630	-630	-630	-630	-630	-630
34	-650	-650	-650	-650	-650	-650
35	-670	-670	-670	-670	-670	-670
36	-690	-690	-690	-690	-690	-690
37	-710	-710	-710	-710	-710	-710
38	-730	-730	-730	-730	-730	-730
39	-750	-750	-750	-750	-750	-750
40	-770	-770	-770	-770	-770	-770
41	-790	-790	-790	-790	-790	-790
42	-810	-810	-810	-810	-810	-810
43	-830	-830	-830	-830	-830	-830
44	-850	-850	-850	-850	-850	-850
45	-870	-870	-870	-870	-870	-870
46	-890	-890	-890	-890	-890	-890
47	-910	-910	-910	-910	-910	-910
48	-930	-930	-930	-930	-930	-930
49	-950	-950	-950	-950	-950	-950
50	-970	-970	-970	-970	-970	-970

SPECIAL PRINTOUT OF CODED FRICTION ARRAY -- CARD GROUP 15

M N 5 10

1	2	2	2	2	2	2
2	99	2	2	2	2	99
3	99	2	2	2	2	99
4	99	2	2	2	2	99
5	99	2	2	2	2	99
6	99	2	2	2	2	99
7	99	2	2	2	2	99
8	99	2	2	2	2	99
9	99	2	2	2	2	99
10	99	2	2	2	2	99
11	99	2	2	2	2	99
12	99	2	2	2	2	99
13	99	2	2	2	2	99
14	99	2	2	2	2	99
15	99	2	2	2	2	99
16	99	2	2	2	2	99
17	99	2	2	2	2	99
18	99	2	2	2	2	99
19	99	2	2	2	2	99
20	99	2	2	2	2	99
21	99	2	2	2	2	99
22	99	2	2	2	2	99
23	99	2	2	2	2	99
24	99	2	2	2	2	99
25	99	2	2	2	2	99
26	99	2	2	2	2	99
27	99	2	2	2	2	99
28	99	2	2	2	2	99
29	99	2	2	2	2	99
30	99	2	2	2	2	99

Figure 16. (Sheet 6 of 8)

31	99	2	2	2	2	99
32	99	2	2	2	2	99
33	99	2	2	2	2	99
34	99	2	2	2	2	99
35	99	2	2	2	2	99
36	99	2	2	2	2	99
37	99	2	2	2	2	99
38	99	2	2	2	2	99
39	99	2	2	2	2	99
40	99	2	2	2	2	99
41	99	2	2	2	2	99
42	99	2	2	2	2	99
43	99	2	2	2	2	99
44	99	2	2	2	2	99
45	99	2	2	2	2	99
46	99	2	2	2	2	99
47	99	2	2	2	2	99
48	99	2	2	2	2	99
49	99	2	2	2	2	99
50	99	2	2	2	2	99

NO. OF FLOOD CELLS

0

INPUT DATA--CARD GROUP 17
 ITP,INDX,IOIR,I1,I2,I3,I4
 1 1 1 50 2 5 1
 9 0 2 1 2 49 1
 9 0 2 5 2 49 1
 99 0 0 0 0 0 0 1

INPUT DATA--CARD GROUP 20 BOUNDARY ELEVATIONS
 6.6060 6.6080

INPUT DATA--CARD GROUP 23 JOELAY= 0

INPUT DATA--CARD GROUP 32
 GPFR RHO = 1.99, EV = 5.0, RAD = 1.0, NTIMEB = 15, ADV1 = 1.0, FNC1 = 1.0, ANLM = 7.83E-3, CF = 1.E-2, ITAVG = 1, BEND
 INPUT DATA CARD GROUP 33 ICDDY= 1

Figure 16. (Sheet 7 of 8)

DIST FROM BEACH

I	J	1	2	3	4	5	6
1		-30	-30	-30	-30	-30	-30
2		30	30	30	30	30	30
3		90	90	90	90	90	90
4		150	150	150	150	150	150
5		210	210	210	210	210	210
6		270	270	270	270	270	270
7		330	330	330	330	330	330
8		390	390	390	390	390	390
9		450	450	450	450	450	450
10		510	510	510	510	510	510
11		570	570	570	570	570	570
12		630	630	630	630	630	630
13		690	690	690	690	690	690
14		750	750	750	750	750	750
15		810	810	810	810	810	810
16		870	870	870	870	870	870
17		930	930	930	930	930	930
18		990	990	990	990	990	990
19		1050	1050	1050	1050	1050	1050
20		1110	1110	1110	1110	1110	1110
21		1170	1170	1170	1170	1170	1170
22		1230	1230	1230	1230	1230	1230
23		1290	1290	1290	1290	1290	1290
24		1350	1350	1350	1350	1350	1350
25		1410	1410	1410	1410	1410	1410
26		1470	1470	1470	1470	1470	1470
27		1530	1530	1530	1530	1530	1530
28		1590	1590	1590	1590	1590	1590
29		1650	1650	1650	1650	1650	1650
30		1710	1710	1710	1710	1710	1710
31		1770	1770	1770	1770	1770	1770
32		1830	1830	1830	1830	1830	1830
33		1890	1890	1890	1890	1890	1890
34		1950	1950	1950	1950	1950	1950
35		2010	2010	2010	2010	2010	2010
36		2070	2070	2070	2070	2070	2070
37		2130	2130	2130	2130	2130	2130
38		2190	2190	2190	2190	2190	2190
39		2250	2250	2250	2250	2250	2250
40		2310	2310	2310	2310	2310	2310
41		2370	2370	2370	2370	2370	2370
42		2430	2430	2430	2430	2430	2430
43		2490	2490	2490	2490	2490	2490
44		2550	2550	2550	2550	2550	2550
45		2610	2610	2610	2610	2610	2610
46		2670	2670	2670	2670	2670	2670
47		2730	2730	2730	2730	2730	2730
48		2790	2790	2790	2790	2790	2790
49		2850	2850	2850	2850	2850	2850
50		2910	2910	2910	2910	2910	2910

Figure 16. (Sheet 8 of 8)

EDDY VISC EX

I	J	1	2	3	4	5	6
1		0	0	0	J	0	0
2		1	1	1	1	1	1
3		7	7	7	7	7	7
4		15	15	15	15	15	15
5		25	25	25	25	25	25
6		36	36	36	36	36	36
7		49	49	49	49	49	49
8		62	62	62	62	62	62
9		77	77	77	77	77	77
10		77	77	77	77	77	77
11		77	77	77	77	77	77
12		77	77	77	77	77	77
13		77	77	77	77	77	77
14		77	77	77	77	77	77
15		77	77	77	77	77	77
16		77	77	77	77	77	77
17		77	77	77	77	77	77
18		77	77	77	77	77	77
19		77	77	77	77	77	77
20		77	77	77	77	77	77
21		77	77	77	77	77	77
22		77	77	77	77	77	77
23		77	77	77	77	77	77
24		77	77	77	77	77	77
25		77	77	77	77	77	77
26		77	77	77	77	77	77
27		77	77	77	77	77	77
28		77	77	77	77	77	77
29		77	77	77	77	77	77
30		77	77	77	77	77	77
31		77	77	77	77	77	77
32		77	77	77	77	77	77
33		77	77	77	77	77	77
34		77	77	77	77	77	77
35		77	77	77	77	77	77
36		77	77	77	77	77	77
37		77	77	77	77	77	77
38		77	77	77	77	77	77
39		77	77	77	77	77	77
40		77	77	77	77	77	77
41		77	77	77	77	77	77
42		77	77	77	77	77	77
43		77	77	77	77	77	77
44		77	77	77	77	77	77
45		77	77	77	77	77	77
46		77	77	77	77	77	77
47		77	77	77	77	77	77
48		77	77	77	77	77	77
49		77	77	77	77	77	77
50		77	77	77	77	77	77

Figure 17. Results of computation for plane beach (Sheet 1 of 11)

ICF FLAG ARRAY

M	N	1	2	3	4	5	6
1		5050	5050	5050	5050	5050	5050
2		7090	6062	6262	6262	6090	1010
3		7090	6163	6363	6363	6190	1010
4		7090	6163	6363	6363	6190	1010
5		7090	6163	6363	6363	6190	1010
6		7090	6163	6363	6363	6190	1010
7		7090	6163	6363	6363	6190	1010
8		7090	6163	6363	6363	6190	1010
9		7090	6163	6363	6363	6190	1010
10		7090	6163	6363	6363	6190	1010
11		7090	6163	6363	6363	6190	1010
12		7090	6163	6363	6363	6190	1010
13		7090	6163	6363	6363	6190	1010
14		7090	6163	6363	6363	6190	1010
15		7090	6163	6363	6363	6190	1010
16		7090	6163	6363	6363	6190	1010
17		7090	6163	6363	6363	6190	1010
18		7090	6163	6363	6363	6190	1010
19		7090	6163	6363	6363	6190	1010
20		7090	6163	6363	6363	6190	1010
21		7090	6163	6363	6363	6190	1010
22		7090	6163	6363	6363	6190	1010
23		7090	6163	6363	6363	6190	1010
24		7090	6163	6363	6363	6190	1010
25		7090	6163	6363	6363	6190	1010
26		7090	6163	6363	6363	6190	1010
27		7090	6163	6363	6363	6190	1010
28		7090	6163	6363	6363	6190	1010
29		7090	6163	6363	6363	6190	1010
30		7090	6163	6363	6363	6190	1010
31		7090	6163	6363	6363	6190	1010
32		7090	6163	6363	6363	6190	1010
33		7090	6163	6363	6363	6190	1010
34		7090	6163	6363	6363	6190	1010
35		7090	6163	6363	6363	6190	1010
36		7090	6163	6363	6363	6190	1010
37		7090	6163	6363	6363	6190	1010
38		7090	6163	6363	6363	6190	1010
39		7090	6163	6363	6363	6190	1010
40		7090	6163	6363	6363	6190	1010
41		7090	6163	6363	6363	6190	1010
42		7090	6163	6363	6363	6190	1010
43		7090	6163	6363	6363	6190	1010
44		7090	6163	6363	6363	6190	1010
45		7090	6163	6363	6363	6190	1010
46		7090	6163	6363	6363	6190	1010
47		7090	6163	6363	6363	6190	1010
48		7090	6163	6363	6363	6190	1010
49		7090	6062	6262	6262	6090	1010
50		1010	8171	8171	8171	8171	1010

Figure 17. (Sheet 2 of 11)

TIDAL AND DISCHARGE BOUNDARY VECTORS---TRANSMISSION BOUNDARY VECTOR

1	1002050	20001002	0
2	1003050	20001003	0
3	1004050	20001004	0
4	1005050	20001005	0
5		20001006	0
6		20001007	0
7		20001008	0
8		20001009	0
9		20001010	0
10		20001011	0
11		20001012	0
12		20001013	0
13		20001014	0
14		20001015	0
15		20001016	0
16		20001017	0
17		20001018	0
18		20001019	0
19		20001020	0
20		20001021	0
21		20001022	0
22		20001023	0
23		20001024	0
24		20001025	0
25		20001026	0
26		20001027	0
27		20001028	0
28		20001029	0
29		20001030	0
30		20001031	0
31		20001032	0
32		20001033	0
33		20001034	0
34		20001035	0
35		20001036	0
36		20001037	0
37		20001038	0
38		20001039	0
39		20001040	0
40		20001041	0
41		20001042	0
42		20001043	0
43		20001044	0
44		20001045	0
45		20001046	0
46		20001047	0
47		20001048	0
48		20001049	0
49		20005002	0
50		20005003	0
51		20005004	0
52		20005005	0
53		20005006	0
54		20005007	0
55		20005008	0
56		20005009	0
57		20005010	0
58		20005011	0
59		20005012	0

Figure 17. (Sheet 3 of 11)

60	20005013	0
61	20005014	0
62	20005015	0
63	20005016	0
64	20005017	0
65	20005018	0
66	20005019	0
67	20005020	0
68	20005021	0
69	20005022	0
70	20005023	0
71	20005024	0
72	20005025	0
73	20005026	0
74	20005027	0
75	20005028	0
76	20005029	0
77	20005030	0
78	20005031	0
79	20005032	0
80	20005033	0
81	20005034	0
82	20005035	0
83	20005036	0
84	20005037	0
85	20005038	0
86	20005039	0
87	20005040	0
88	20005041	0
89	20005042	0
90	20005043	0
91	20005044	0
92	20005045	0
93	20005046	0
94	20005047	0
95	20005048	0
96	20005049	0

BINARY INPUTS--SURF AND DCHRG ARRAYS--LINEAR INTERPOLATION HAS BEEN USED

T	I	1
1		0.000
101		0.000
201		0.000
301		0.000
401		0.000
501		0.000
601		0.000
701		0.000
801		0.000
901		0.000
1001		0.000
1101		0.000
1201		0.000
1301		0.000
1401		0.000
1501		0.000
1601		0.000
1701		0.000
1801		0.000
1901		0.000

END PRINTOUT OF INPUT DATA

Figure 17. (Sheet 4 of 11)

ORBITAL VEL UORB
MULTIPLIED BY 100.00

I	J	1	2	3	4	5	6
1		0	0	0	0	0	0
2		148	148	148	148	148	148
3		254	254	254	254	254	254
4		326	326	326	326	326	326
5		384	384	384	384	384	384
6		433	433	433	433	433	433
7		476	476	476	476	476	476
8		514	514	514	514	514	514
9		544	544	544	544	544	544
10		494	494	494	494	494	494
11		454	454	454	454	454	454
12		420	420	420	420	420	420
13		392	392	392	392	392	392
14		368	368	368	368	368	368
15		346	346	346	346	346	346
16		328	328	328	328	328	328
17		311	311	311	311	311	311
18		296	296	296	296	296	296
19		283	283	283	283	283	283
20		271	271	271	271	271	271
21		260	260	260	260	260	260
22		250	250	250	250	250	250
23		240	240	240	240	240	240
24		232	232	232	232	232	232
25		224	224	224	224	224	224
26		217	217	217	217	217	217
27		210	210	210	210	210	210
28		203	203	203	203	203	203
29		197	197	197	197	197	197
30		191	191	191	191	191	191
31		186	186	186	186	186	186
32		181	181	181	181	181	181
33		176	176	176	176	176	176
34		172	172	172	172	172	172
35		167	167	167	167	167	167
36		163	163	163	163	163	163
37		159	159	159	159	159	159
38		156	156	156	156	156	156
39		152	152	152	152	152	152
40		149	149	149	149	149	149
41		145	145	145	145	145	145
42		142	142	142	142	142	142
43		139	139	139	139	139	139
44		136	136	136	136	136	136
45		134	134	134	134	134	134
46		131	131	131	131	131	131
47		128	128	128	128	128	128
48		126	126	126	126	126	126
49		123	123	123	123	123	123
50		121	121	121	121	121	121

Figure 17. (Sheet 5 of 11)

WAVE HEIGHT HT
MULTIPLIED BY 100.00

I	J	1	2	3	4	5	6
1		0	0	0	0	0	0
2		228	228	228	228	228	228
3		355	355	355	355	355	355
4		484	484	484	484	484	484
5		613	613	613	613	613	613
6		742	742	742	742	742	742
7		870	870	870	870	870	870
8		997	997	997	997	997	997
9		1124	1124	1124	1124	1124	1124
10		1185	1185	1185	1185	1185	1185
11		1158	1158	1158	1158	1158	1158
12		1134	1134	1134	1134	1134	1134
13		1114	1114	1114	1114	1114	1114
14		1096	1096	1096	1096	1096	1096
15		1079	1079	1079	1079	1079	1079
16		1065	1065	1065	1065	1065	1065
17		1052	1052	1052	1052	1052	1052
18		1040	1040	1040	1040	1040	1040
19		1030	1030	1030	1030	1030	1030
20		1020	1020	1020	1020	1020	1020
21		1011	1011	1011	1011	1011	1011
22		1003	1003	1003	1003	1003	1003
23		995	995	995	995	995	995
24		989	989	989	989	989	989
25		982	982	982	982	982	982
26		976	976	976	976	976	976
27		971	971	971	971	971	971
28		966	966	966	966	966	966
29		961	961	961	961	961	961
30		957	957	957	957	957	957
31		953	953	953	953	953	953
32		949	949	949	949	949	949
33		946	946	946	946	946	946
34		943	943	943	943	943	943
35		940	940	940	940	940	940
36		937	937	937	937	937	937
37		934	934	934	934	934	934
38		932	932	932	932	932	932
39		930	930	930	930	930	930
40		928	928	928	928	928	928
41		926	926	926	926	926	926
42		924	924	924	924	924	924
43		923	923	923	923	923	923
44		921	921	921	921	921	921
45		920	920	920	920	920	920
46		919	919	919	919	919	919
47		918	918	918	918	918	918
48		917	917	917	917	917	917
49		916	916	916	916	916	916
50		915	915	915	915	915	915

ELEVATION AT T = 0.1458 HRS

ITIME = 105

Figure 17. (Sheet 6 of 11)

SURFACE ELEV
MULTIPLIED BY 100.00

I	J	1	2	3	4	5	6
1		100	100	100	100	100	100
2		183	183	183	183	183	183
3		141	141	141	141	141	141
4		103	103	103	103	103	103
5		66	66	66	66	66	66
6		29	29	29	29	29	29
7		-6	-6	-6	-6	-6	-6
8		-41	-41	-41	-41	-41	-41
9		-75	-75	-75	-75	-75	-75
10		-90	-90	-90	-90	-90	-90
11		-82	-82	-82	-82	-82	-82
12		-76	-76	-76	-76	-76	-76
13		-72	-72	-72	-72	-72	-72
14		-68	-68	-68	-68	-68	-68
15		-65	-65	-65	-65	-65	-65
16		-63	-63	-63	-63	-63	-63
17		-61	-61	-61	-61	-61	-61
18		-59	-59	-59	-59	-59	-59
19		-57	-57	-57	-57	-57	-57
20		-56	-56	-56	-56	-56	-56
21		-55	-55	-55	-55	-55	-55
22		-54	-54	-54	-54	-54	-54
23		-53	-53	-53	-53	-53	-53
24		-52	-52	-52	-52	-52	-52
25		-51	-51	-51	-51	-51	-51
26		-51	-51	-51	-51	-51	-51
27		-50	-50	-50	-50	-50	-50
28		-50	-50	-50	-50	-50	-50
29		-49	-49	-49	-49	-49	-49
30		-49	-49	-49	-49	-49	-49
31		-48	-48	-48	-48	-48	-48
32		-48	-48	-48	-48	-48	-48
33		-48	-48	-48	-48	-48	-48
34		-47	-47	-47	-47	-47	-47
35		-47	-47	-47	-47	-47	-47
36		-47	-47	-47	-47	-47	-47
37		-46	-46	-46	-46	-46	-46
38		-46	-46	-46	-46	-46	-46
39		-46	-46	-46	-46	-46	-46
40		-46	-46	-46	-46	-46	-46
41		-46	-46	-46	-46	-46	-46
42		-45	-45	-45	-45	-45	-45
43		-45	-45	-45	-45	-45	-45
44		-45	-45	-45	-45	-45	-45
45		-45	-45	-45	-45	-45	-45
46		-45	-45	-45	-45	-45	-45
47		-45	-45	-45	-45	-45	-45
48		-45	-45	-45	-45	-45	-45
49		-44	-44	-44	-44	-44	-44
50		0	-44	-44	-44	-44	0

Figure 17. (Sheet 7 of 11)

VELOCITY V
MULTIPLIED BY 100.00

I	J	1	2	3	4	5	6
1		0	0	0	0	0	0
2		-78	-78	-78	-78	-78	0
3		-142	-142	-142	-142	-142	0
4		-205	-205	-205	-205	-205	0
5		-254	-254	-254	-254	-254	0
6		-285	-285	-285	-285	-285	0
7		-294	-294	-294	-294	-294	0
8		-277	-277	-277	-277	-277	0
9		-232	-232	-232	-232	-232	0
10		-168	-168	-168	-168	-168	0
11		-111	-111	-111	-111	-111	0
12		-73	-73	-73	-73	-73	0
13		-47	-47	-47	-47	-47	0
14		-29	-29	-29	-29	-29	0
15		-18	-18	-18	-18	-18	0
16		-10	-10	-10	-10	-10	0
17		-6	-6	-6	-6	-6	0
18		-3	-3	-3	-3	-3	0
19		-1	-1	-1	-1	-1	0
20		0	0	0	0	0	0
21		0	0	0	0	0	0
22		1	1	1	1	1	0
23		1	1	1	1	1	0
24		1	1	1	1	1	0
25		1	1	1	1	1	0
26		1	1	1	1	1	0
27		1	1	1	1	1	0
28		1	1	1	1	1	0
29		1	1	1	1	1	0
30		1	1	1	1	1	0
31		1	1	1	1	1	0
32		1	1	1	1	1	0
33		1	1	1	1	1	0
34		1	1	1	1	1	0
35		1	1	1	0	0	0
36		0	0	0	0	0	0
37		0	0	0	0	0	0
38		0	0	0	0	0	0
39		0	0	0	0	0	0
40		0	0	0	0	0	0
41		0	0	0	0	0	0
42		0	0	0	0	0	0
43		0	0	0	0	0	0
44		0	0	0	0	0	0
45		0	0	0	0	0	0
46		0	0	0	0	0	0
47		0	0	0	0	0	0
48		0	0	0	0	0	0
49		0	0	0	0	0	0
50		0	0	0	0	0	0

Figure 17. (Sheet 8 of 11)

VELOCITY U
MULTIPLIED BY 100.00

I	J	1	2	3	4	5	6
1		0	0	0	0	0	0
2		0	2	2	2	2	0
3		0	2	2	2	2	0
4		0	2	2	2	2	0
5		0	2	2	2	2	0
6		0	2	2	2	2	0
7		0	2	2	2	2	0
8		0	3	3	3	3	0
9		0	2	2	2	2	0
10		0	3	3	3	3	0
11		0	3	3	3	3	0
12		0	3	3	3	3	0
13		0	3	3	3	3	0
14		0	3	3	3	3	0
15		0	3	3	3	3	0
16		0	3	3	3	3	0
17		0	3	3	3	3	0
18		0	3	3	3	3	0
19		0	3	3	3	3	0
20		0	3	3	3	3	0
21		0	3	3	3	3	0
22		0	3	3	3	3	0
23		0	3	3	3	3	0
24		0	3	3	3	3	0
25		0	3	3	3	3	0
26		0	3	3	3	3	0
27		0	3	3	3	3	0
28		0	3	3	3	3	0
29		0	3	3	3	3	0
30		0	3	3	3	3	0
31		0	3	3	3	3	0
32		0	3	3	3	3	0
33		0	3	3	3	3	0
34		0	3	3	3	3	0
35		0	3	3	3	3	0
36		0	3	3	3	3	0
37		0	3	3	3	3	0
38		0	3	3	3	3	0
39		0	3	3	3	3	0
40		0	3	3	3	3	0
41		0	3	3	3	3	0
42		0	3	3	3	3	0
43		0	3	3	3	3	0
44		0	3	3	3	3	0
45		0	3	3	3	3	0
46		0	3	3	3	3	0
47		0	3	3	3	3	0
48		0	3	3	3	3	0
49		0	3	4	4	3	0
50		0	0	0	0	0	0

Figure 17. (Sheet 9 of 11)

DISCHARGE Y DIR
MULTIPLIED BY 0.10000E-01

I	J	1	2	3	4	5	6
1		0	0	0	0	0	0
2		-1	-1	-1	-1	-1	0
3		-4	-4	-4	-4	-4	0
4		-7	-7	-7	-7	-7	0
5		-12	-12	-12	-12	-12	0
6		-16	-16	-16	-16	-16	0
7		-19	-19	-19	-19	-19	0
8		-21	-21	-21	-21	-21	0
9		-20	-20	-20	-20	-20	0
10		-16	-16	-16	-16	-16	0
11		-12	-12	-12	-12	-12	0
12		-9	-9	-9	-9	-9	0
13		-6	-6	-6	-6	-6	0
14		-4	-4	-4	-4	-4	0
15		-3	-3	-3	-3	-3	0
16		-2	-2	-2	-2	-2	0
17		-1	-1	-1	-1	-1	0
18		-1	-1	-1	-1	-1	0
19		0	0	0	0	0	0
20		0	0	0	0	0	0
21		0	0	0	0	0	0
22		0	0	0	0	0	0
23		0	0	0	0	0	0
24		0	0	0	0	0	0
25		0	0	0	0	0	0
26		0	0	0	0	0	0
27		0	0	0	0	0	0
28		0	0	0	0	0	0
29		0	0	0	0	0	0
30		0	0	0	0	0	0
31		0	0	0	0	0	0
32		0	0	0	0	0	0
33		0	0	0	0	0	0
34		0	0	0	0	0	0
35		0	0	0	0	0	0
36		0	0	0	0	0	0
37		0	0	0	0	0	0
38		0	0	0	0	0	0
39		0	0	0	0	0	0
40		0	0	0	0	0	0
41		0	0	0	0	0	0
42		0	0	0	0	0	0
43		0	0	0	0	0	0
44		0	0	0	0	0	0
45		0	0	0	0	0	0
46		0	0	0	0	0	0
47		0	0	0	0	0	0
48		0	0	0	0	0	0
49		0	0	0	0	0	0
50		0	0	0	0	0	0

Figure 17. (Sheet 10 of 11)

DISCHARGE X DIR
MULTIPLIED BY 0.10000E-J1

I	J	1	2	3	4	5	6
1		0	0	0	0	0	0
2		0	0	0	0	0	0
3		0	0	0	0	0	0
4		0	0	0	0	0	0
5		0	0	0	0	0	0
6		0	0	0	0	0	0
7		0	0	0	0	0	0
8		0	0	0	0	0	0
9		0	0	0	0	0	0
10		0	0	0	0	0	0
11		0	0	0	0	0	0
12		0	0	0	0	0	0
13		0	0	0	0	0	0
14		0	0	0	0	0	0
15		0	0	0	0	0	0
16		0	0	0	0	0	0
17		0	0	0	0	0	0
18		0	1	1	1	1	0
19		0	1	1	1	1	0
20		0	1	1	1	1	0
21		0	1	1	1	1	0
22		0	1	1	1	1	0
23		0	1	1	1	1	0
24		0	1	1	1	1	0
25		0	1	1	1	1	0
26		0	1	1	1	1	0
27		0	1	1	1	1	0
28		0	1	1	1	1	0
29		0	1	1	1	1	0
30		0	1	1	1	1	0
31		0	1	1	1	1	0
32		0	1	1	1	1	0
33		0	1	1	1	1	0
34		0	1	1	1	1	0
35		0	1	1	1	1	0
36		0	1	1	1	1	0
37		0	1	1	1	1	0
38		0	1	1	1	1	0
39		0	1	1	1	1	0
40		0	1	1	1	1	0
41		0	1	1	1	1	0
42		0	1	1	1	1	0
43		0	1	2	2	1	0
44		0	1	2	2	1	0
45		0	2	2	2	2	0
46		0	2	2	2	2	0
47		0	2	2	2	2	0
48		0	2	2	2	2	0
49		0	2	2	2	2	0
50		0	0	0	0	0	0

TIMES FOR START, STOP, AND EXECUTION -- 5.186 7.175 2.000

Figure 17. (Sheet 11 of 11)

TIME	GAGE NO.	1	2	3	4	5	6	7	8	9	10
	QUANTITY	4	4	4	4	4	4	4	4	4	4
0	SURF ELY	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	WVEL F/S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	WVEL F/S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	GRD ELEV	-1.00	-3.00	-5.00	-7.00	-9.00	-11.00	-13.00	-15.00	-17.00	-19.00
	WCTR F/S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5	SURF ELY	0.0263	0.3065	0.2934	0.1857	0.0693	-0.0485	-0.1641	-0.2810	-0.2754	-0.2192
	WVEL F/S	-0.5155	-1.0000	-0.9141	-0.7975	-0.6742	-0.5567	-0.4449	-0.3447	-0.2555	-0.1855
	WVEL F/S	-0.0736	-0.0672	-0.0832	-0.0951	-0.1045	-0.1116	-0.1109	-0.0693	-0.0184	-0.0000
	GRD ELEV	-1.00	-3.00	-5.00	-7.00	-9.00	-11.00	-13.00	-15.00	-17.00	-19.00
	WCTR F/S	0.5206	1.0022	0.9178	0.8036	0.6823	0.5678	0.4624	0.3515	0.2561	0.1855
10	SURF ELY	1.6435	1.2335	0.8700	0.5587	0.2766	0.0043	-0.2628	-0.5111	-0.5759	-0.5044
	WVEL F/S	-0.3025	-0.7349	-0.9010	-0.9305	-0.8933	-0.8174	-0.7253	-0.6331	-0.5425	-0.4574
	WVEL F/S	-0.1810	-0.2063	-0.2587	-0.2943	-0.3226	-0.3394	-0.3228	-0.2163	-0.0785	-0.0184
	GRD ELEV	-1.00	-3.00	-5.00	-7.00	-9.00	-11.00	-13.00	-15.00	-17.00	-19.00
	WCTR F/S	0.3525	0.7633	0.9374	0.9759	0.9498	0.8651	0.7939	0.6641	0.5481	0.4575
15	SURF ELY	2.3364	1.8388	1.4550	1.0908	0.7119	0.3163	-0.0710	-0.4513	-0.5804	-0.5253
	WVEL F/S	-0.2410	-0.4991	-0.4951	-0.4657	-0.4517	-0.4405	-0.4333	-0.4153	-0.3896	-0.3662
	WVEL F/S	-0.3347	-0.4074	-0.5022	-0.5796	-0.6346	-0.6590	-0.6128	-0.4221	-0.1739	-0.0354
	GRD ELEV	-1.00	-3.00	-5.00	-7.00	-9.00	-11.00	-13.00	-15.00	-17.00	-19.00
	WCTR F/S	0.4157	0.6443	0.7095	0.7435	0.7789	0.7926	0.7505	0.5922	0.4266	0.3685
20	SURF ELY	2.4766	2.0132	1.6152	1.2119	0.8076	0.4233	0.0553	-0.3006	-0.3732	-0.3087
	WVEL F/S	0.0835	0.2005	0.2226	0.1754	0.1030	0.0442	0.0143	0.0052	0.0012	-0.0040
	WVEL F/S	-0.4635	-0.5836	-0.7347	-0.8470	-0.9299	-0.9617	-0.8907	-0.6242	-0.2883	-0.0842
	GRD ELEV	-1.00	-3.00	-5.00	-7.00	-9.00	-11.00	-13.00	-15.00	-17.00	-19.00
	WCTR F/S	0.4774	0.6171	0.7677	0.8650	0.9356	0.9627	0.8908	0.6242	0.2883	0.0844
25	SURF ELY	2.2301	1.6163	1.4504	1.0798	0.7318	0.3979	0.0759	-0.2429	-0.2869	-0.2215
	WVEL F/S	0.0402	0.0871	0.1063	0.1265	0.1482	0.1814	0.2113	0.2247	0.2227	0.1992
	WVEL F/S	-0.5634	-0.7263	-0.9266	-1.1825	-1.1959	-1.2406	-1.1534	-0.8319	-0.4266	-0.1590
	GRD ELEV	-1.00	-3.00	-5.00	-7.00	-9.00	-11.00	-13.00	-15.00	-17.00	-19.00
	WCTR F/S	0.5634	0.7315	0.9326	1.0895	1.2050	1.2538	1.1725	0.8612	0.4812	0.2545
30	SURF ELY	2.1477	1.7476	1.3670	0.9596	0.6348	0.2874	-0.0461	-0.3913	-0.4726	-0.4015
	WVEL F/S	0.0331	0.0529	0.0348	0.0261	0.0308	0.0426	0.0499	0.0537	0.0503	0.0480
	WVEL F/S	-0.6330	-0.8463	-1.0933	-1.2874	-1.3264	-1.4766	-1.3689	-1.0144	-0.5621	-0.2410
	GRD ELEV	-1.00	-3.00	-5.00	-7.00	-9.00	-11.00	-13.00	-15.00	-17.00	-19.00
	WCTR F/S	0.6335	0.8479	1.0939	1.2876	1.4267	1.4773	1.3698	1.0158	0.5643	0.2457
35	SURF ELY	2.1669	1.7026	1.3305	0.9643	0.6807	0.2506	-0.1019	-0.4452	-0.5422	-0.4692
	WVEL F/S	-0.0015	0.0025	0.0200	0.0414	0.0528	0.0530	0.0506	0.0468	0.0419	0.0435
	WVEL F/S	-0.6810	-0.9501	-1.2428	-1.4736	-1.6346	-1.6859	-1.5586	-1.1767	-0.6861	-0.3204
	GRD ELEV	-1.00	-3.00	-5.00	-7.00	-9.00	-11.00	-13.00	-15.00	-17.00	-19.00
	WCTR F/S	0.6810	0.9501	1.2430	1.4742	1.6355	1.6667	1.5554	1.1776	0.6874	0.3233
40	SURF ELY	2.1126	1.6597	1.2924	0.9237	0.5610	0.1959	-0.1520	-0.4948	-0.5952	-0.5142
	WVEL F/S	0.0183	0.0442	0.0653	0.0789	0.0765	0.0669	0.0558	0.0510	0.0518	0.0540
	WVEL F/S	-0.7151	-1.0295	-1.3647	-1.6293	-1.8097	-1.8629	-1.7231	-1.3231	-0.8029	-0.4000
	GRD ELEV	-1.00	-3.00	-5.00	-7.00	-9.00	-11.00	-13.00	-15.00	-17.00	-19.00
	WCTR F/S	0.7133	1.0304	1.3662	1.6312	1.8115	1.8641	1.7242	1.3241	0.8046	0.4044
45	SURF ELY	2.0506	1.6104	1.2348	0.8710	0.5047	0.1563	-0.1869	-0.5248	-0.6240	-0.5426
	WVEL F/S	0.0175	0.0370	0.0398	0.0391	0.0425	0.0435	0.0444	0.0470	0.0474	0.0500
	WVEL F/S	-0.7359	-1.0977	-1.4726	-1.7689	-1.9677	-2.0236	-1.8753	-1.4556	-0.9140	-0.4792

Figure 18. Sample results for selected gages for plane beach computation

more complicated situation. A variable grid is employed, with NMAX=77 and MMAX=54, so as to have a greater resolution near the inlet and the surf zone. The JCL for this case is shown in Figure 19. In addition to files FT 35, 36, and 95, file FT 39 containing the grid expansion coefficients is needed. In this case, output files FT 11, 13, 14, 15, and 20 are being saved at the end of the run for later use.

64. Part of the input data from file DATAW3L is shown in Figure 20. Note that MPR is set to -1 for full printout, $\Delta\alpha_1 = \Delta\alpha_2 = 100$ ft and $\Delta t = 18$ sec. The simulation is run for 67 time-steps. Twenty special gages are used with NFREQ=2. A printout of results is desired at ITIME=67. There are two surf zones over a part of the grid. JDELAY is set to 15 to delay printing of gage information. It is desired to build up the radiation stress terms over 15 time-steps (NTIMEB=15). γ is set to 0.754. Averaging of results over the last 10 time-steps is required (ITAVG=10). Jonsson-type eddy viscosity formulation is desired so IEDDY is set to 2.

65. Figure 21 shows the coded friction array and the flags for this application. A sampling of the averaged results for $\bar{\eta}$, U, and V at the end is also shown.

Cost of Computation

66. In general, the cost of running the model depends on the number of grid points used, the number of time-steps of simulation run, amount of input and output, the job priority, the computer, and the computer vendor used. The following total cost information was for running the model at standard priority on the CRAY computer of BCS. For the plane beach application, described in paragraphs 59-62, involving 300 grid points and 105 time-steps, the total cost was approximately \$7. For the Oregon Inlet application, described in paragraphs 63-65, involving 4,158 grid points and 67 time-steps, the total cost was approximately \$23. Therefore the computation costs for the model may be considered modest.

```

CODEXX,P02,T40,STCR1.
USER,UN,PW.
FETCH,DN=AA,GDN=WIFMSRC,UN=CER0D2,DT=C,DS=FF.
UPDATE,F,I=AA,P=0,C=0,N,L=0.
FETCH,DN=A,GDN=UPDL2RV,UN=CER0D2,DT=C,DS=FF.
UPDATE,F,P=$NPL,IN.
CFT,I=$CPL,L=0.
FETCH,DN=FT35,GDN=AWED3M,UN=CCCC26,DS=CI.
FETCH,DN=FT36,GDN=ORDPRV1,UN=CER0D2,DT=C,DS=FF.
FETCH,DN=FT39,GDN=EXPCFRV,UN=CER0D2,DT=C,DS=FF.
FETCH,DN=FT95,GDN=DATAW3L,UN=CER0D2,DT=C,DS=FF.
LDR.
REWIND,DN=FT07.
COPYD,I=FT07,O=$OUT.
REWIND,DN=FT08.
COPYD,I=FT08,O=$OUT.
REWIND,DN=FT11.
STORE,DN=FT11,GDN=OREGAGE,PAM=R,DS=CI,NEW,NA.
REWIND,DN=FT13.
STORE,DN=FT13,GDN=ORESUFF,PAM=R,DS=CI,NEW,NA.
REWIND,DN=FT14.
STORE,DN=FT14,GDN=OREVEL,PAM=R,DS=CI,NEW,NA.
REWIND,DN=FT15.
STORE,DN=FT15,GDN=OREDIS,PAM=R,DS=CI,NEW,NA.
REWIND,DN=FT20.
STORE,DN=FT20,GDN=ORESEDI,PAM=R,DS=CI,NEW,NA.
EXIT,U.
COST,LO=F.
LOGFILE,L=LOG,FULL.
STORE,DN=LOG,GDN=XXXLOG,DT=C,DS=FF,UN=XXXXXX.
◆WEOF
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Figure 19. Job Control Language (JCL) for Oregon Inlet,
North Carolina, application

SHOVE PER=8.0,HTO=11.39,THETA0=51.1,DEPMAX=61.,GAMMA=0.754, SEND

[illegible]

44 45 46 47 48

[illegible]

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Figure 20. Input data from file DATAW3L for Oregon Inlet, North Carolina, application

SPECIAL PRINTOUT OF CODED FRICTION ARRAY -- CARD GROUP 15

M	N	5	10	15	20	25	30	35	40
1	99	99	99	99	99	99	99	99	99
2	99	99	99	99	99	99	99	99	99
3	99	99	99	99	99	99	99	99	99
4	99	99	99	99	99	99	99	99	99
5	99	99	99	99	99	99	99	99	99
6	99	99	99	99	99	99	99	99	99
7	99	99	99	99	99	99	99	99	99
8	99	99	99	99	99	99	99	99	99
9	99	99	99	99	99	99	99	99	99
10	99	99	99	99	99	99	99	99	99
11	99	99	99	99	99	99	99	99	99
12	99	99	99	99	99	99	99	99	99
13	99	99	99	99	99	99	99	99	99
14	99	99	99	99	99	99	99	99	99
15	99	99	99	99	99	99	99	99	99
16	99	99	99	99	99	99	99	99	99
17	99	99	99	99	99	99	99	99	99
18	99	99	99	99	99	99	99	99	99
19	99	99	99	99	99	99	99	99	99
20	99	99	99	99	99	99	99	99	99
21	99	99	99	99	99	99	99	99	99
22	99	99	99	99	99	99	99	99	99
23	99	99	99	99	99	99	99	99	99
24	99	99	99	99	99	99	99	99	99
25	99	99	99	99	99	99	99	99	99
26	99	99	99	99	99	99	99	99	99
27	99	99	99	99	99	99	99	99	99
28	99	99	99	99	99	99	99	99	99
29	99	99	99	99	99	99	99	99	99
30	99	99	99	99	99	99	99	99	99
31	99	99	99	99	99	99	99	99	99
32	99	99	99	99	99	99	99	99	99
33	99	99	99	99	99	99	99	99	99
34	99	99	99	99	99	99	99	99	99
35	99	99	99	99	99	99	99	99	99
36	99	99	99	99	99	99	99	99	99
37	99	99	99	99	99	99	99	99	99
38	99	99	99	99	99	99	99	99	99
39	99	99	99	99	99	99	99	99	99
40	99	99	99	99	99	99	99	99	99
41	99	99	99	99	99	99	99	99	99
42	99	99	99	99	99	99	99	99	99
43	99	99	99	99	99	99	99	99	99
44	99	99	99	99	99	99	99	99	99
45	99	99	99	99	99	99	99	99	99
46	99	99	99	99	99	99	99	99	99
47	99	99	99	99	99	99	99	99	99
48	99	99	99	99	99	99	99	99	99
49	99	99	99	99	99	99	99	99	99
50	99	99	99	99	99	99	99	99	99
51	99	99	99	99	99	99	99	99	99
52	99	99	99	99	99	99	99	99	99
53	99	99	99	99	99	99	99	99	99
54	99	99	99	99	99	99	99	99	99

Figure 21. Coded friction array, flags, and a sample of averaged results for Oregon Inlet, North Carolina, application (Sheet 1 of 26)

[illegible]

Figure 21. (Sheet 2 of 26)

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Figure 21. (Sheet 3 of 26)

SURFACE ELEV AVG
MULTIPLIED BY 100.00

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 21. (Sheet 7 of 26)

I	J	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1	1	0	0	-1	-1	-2	-2	-2	-3	-3	-4	-4	-5	-6	-5	-4	0	0	500	500	500
2	2	0	0	0	1	0	0	0	0	0	4	4	5	0	0	0	0	0	300	310	210
3	3	0	0	0	1	1	2	2	3	3	4	4	5	5	5	3	0	0	6	40	450
4	4	-1	-1	1	2	2	3	3	5	5	6	6	7	7	7	6	5	6	8	8	500
5	5	-1	-1	1	2	3	4	5	6	6	7	8	9	9	8	8	6	9	11	11	11
6	6	-1	-1	0	2	3	5	6	7	7	8	9	9	7	7	8	6	9	11	11	11
7	7	150	-2	0	1	3	5	6	7	7	8	8	500	500	500	2	9	9	10	11	10
8	8	300	-3	-2	-1	150	300	600	700	700	600	700	700	700	500	700	110	7	10	10	8
9	9	500	300	-3	-2	300	500	750	600	500	400	400	650	720	700	700	110	-1	14	9	8
10	10	350	500	500	500	500	1000	800	700	400	400	750	900	750	800	700	750	10	11	13	14
11	11	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	5	-5	11	-7
12	12	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	17	6	13	12
13	13	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	29	13	14	22
14	14	500	500	500	500	500	500	500	500	500	500	500	500	500	500	79	43	24	24	18	15
15	15	500	500	500	500	500	500	500	500	500	500	500	500	500	500	68	41	31	25	21	20
16	16	500	500	500	500	500	500	500	500	500	500	500	500	500	500	64	42	27	27	21	23
17	17	500	500	500	500	500	500	500	500	500	500	500	500	500	500	102	63	42	29	30	26
18	18	500	500	500	500	500	500	500	500	500	500	500	500	500	99	63	43	27	13	25	27
19	19	500	500	500	500	500	500	500	500	500	500	500	500	500	87	64	44	30	15	30	28
20	20	500	500	500	500	500	500	500	500	500	500	500	500	500	86	62	44	34	24	33	32
21	21	500	500	500	500	500	500	500	500	500	500	500	125	107	85	63	45	37	23	35	36
22	22	500	139	147	142	139	137	136	135	136	137	136	114	103	82	62	46	40	21	37	38
23	23	136	121	111	105	101	99	99	99	102	104	105	105	96	79	62	47	30	22	40	42
24	24	57	97	89	83	79	77	77	79	84	88	91	94	68	77	61	47	39	29	43	47
25	25	76	96	69	64	61	60	61	65	64	67	63	67	71	71	66	56	44	37	32	39
26	26	56	60	55	51	48	44	49	52	57	57	51	56	60	62	58	52	43	39	41	36
27	27	43	47	43	38	34	39	41	43	46	51	45	45	50	50	46	41	41	41	42	44
28	28	30	37	34	29	25	30	31	33	37	41	45	45	50	50	46	41	41	41	42	44
29	29	20	21	25	19	20	23	23	24	27	31	35	38	40	42	40	37	36	42	46	50
30	30	9	17	15	9	9	14	14	14	19	23	26	29	32	34	35	34	39	42	46	50
31	31	-2	7	5	-4	-2	5	5	6	10	15	18	20	23	26	29	30	35	57	53	55
32	32	-16	-4	-5	-10	-13	-4	-4	-2	3	8	11	13	15	18	21	26	37	51	55	55
33	33	-29	-14	-13	-19	-24	-12	-11	-15	-4	3	5	7	9	10	14	20	47	54	55	53
34	34	-20	-23	-22	-30	-34	-19	-18	-15	-6	-2	1	2	4	7	13	31	50	55	55	39
35	35	-23	-33	-30	-35	-39	-25	-24	-21	-14	-6	-3	-4	-8	-8	-6	24	47	46	39	39
36	36	-17	-24	-24	-29	-42	-30	-16	-26	-18	-9	-7	-6	-12	-13	-11	7	6	18	32	53
37	37	-19	-42	-36	-41	-53	-36	-27	-17	-15	-13	-10	-11	-12	-13	-11	-14	-1	1	19	24
38	38	-12	-17	-22	-24	-34	-24	-13	-27	-23	-21	-18	-18	-18	-19	-20	-15	-17	0	11	11
39	39	-14	-34	-33	-27	-37	-10	-36	-19	-11	-26	-22	-22	-23	-24	-25	-24	-16	-5	-9	2
40	40	-7	-10	-24	-27	-22	-15	-13	-13	-9	-38	-22	-22	-23	-24	-25	-27	-32	-14	-7	-5
41	41	-11	-23	-24	-21	-19	-30	-32	-9	-4	-32	-33	-33	-30	-29	-22	-27	-32	-17	-7	-5
42	42	-3	-5	-24	-10	-6	-19	-30	-32	-26	-28	-28	-25	-35	-33	-41	-26	-27	-32	-18	-5
43	43	-8	-10	-11	-5	-10	-17	-18	-3	-10	-40	-44	-27	-25	-34	-15	-28	-33	-44	-31	-35
44	44	-4	-3	-19	-14	-1	-5	-22	-23	-16	-7	-23	-15	-15	-22	-37	-11	-15	-23	-41	-38
45	45	-6	-1	0	-17	-17	-2	-3	-10	-18	-21	-22	-20	-12	-12	-17	-30	-12	-10	-34	-34
46	46	-12	-7	-1	-4	-16	-16	-8	-4	-2	-2	-18	-19	-19	-19	-10	-14	-29	-10	-6	-5
47	47	-11	-12	-9	-2	-4	-8	-15	-12	-14	-1	-5	-5	-16	-18	-6	-6	-6	-25	-17	-5
48	48	-1	-10	-12	-13	1	0	0	-5	-11	-13	-5	0	-7	-13	-14	-7	-6	-2	-7	-4
49	49	-2	-2	-4	-8	-7	-2	-1	-1	-1	-2	-3	-2	-2	-3	-5	-9	-6	-6	-6	-6
50	50	-1	-1	-1	-1	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
51	51	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
52	52	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-2
53	53	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-2
54	54	-2	-2	-2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

I	J	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77
1	200	500	500	500	500	500	200	200	200	500	500	500	500	500	500	500	200	200
2	200	500	500	500	500	500	250	250	250	200	200	200	200	200	500	500	200	200
3	150	500	500	500	500	500	300	300	300	250	250	250	250	1000	1000	1000	220	520
4	500	500	500	500	500	400	200	200	200	300	300	300	300	1500	1500	1500	230	500
5	500	120	500	500	500	500	300	300	300	270	270	270	270	2000	2000	2000	240	350
6	500	140	500	500	500	500	500	500	500	220	220	220	220	1300	1000	1000	250	320
7	500	200	500	500	500	500	500	500	500	200	200	200	200	200	200	200	500	500
8	260	300	300	500	500	500	400	400	400	500	500	500	500	200	200	200	200	400
9	1760	860	600	700	700	700	400	400	400	400	400	300	300	300	300	300	300	400
10	400	1300	1200	1000	1000	1000	800	800	800	500	500	500	500	500	500	500	500	500
11	115	112	500	500	500	500	500	500	500	147	147	148	150	152	153	154	153	148
12	67	68	121	130	138	142	145	147	149	111	112	113	115	116	117	118	115	113
13	52	72	77	80	99	104	109	111	112	91	93	95	97	97	97	97	94	92
14	41	54	58	64	77	83	88	91	91	74	75	77	79	80	81	80	76	76
15	19	22	41	53	59	65	71	74	75	60	61	63	65	66	66	63	63	60
16	3	11	27	34	44	49	56	63	65	43	44	46	48	49	50	49	47	45
17	-12	5	13	20	28	34	41	43	44	29	30	31	33	34	35	34	32	30
18	-18	-5	1	8	14	20	25	29	30	15	16	17	19	20	21	20	18	16
19	-26	-22	-10	-7	1	7	12	15	16	3	4	6	7	8	7	7	5	3
20	-30	-26	-19	-17	-10	-5	0	2	2	-9	-7	-6	-5	-4	-5	-5	-7	-9
21	-39	-31	-27	-24	-19	-16	-12	-9	-9	-19	-18	-16	-15	-15	-15	-16	-17	-19
22	-17	-31	-34	-34	-28	-25	-22	-19	-19	-28	-27	-26	-25	-25	-25	-25	-27	-29
23	-35	-39	-42	-40	-36	-34	-30	-28	-26	-36	-35	-34	-32	-32	-33	-33	-35	-36
24	-16	-43	-39	-38	-32	-29	-28	-27	-27	-31	-27	-28	-28	-28	-28	-29	-35	-40
25	-46	-32	-19	-24	-32	-29	-28	-27	-27	-22	-26	-25	-25	-25	-24	-28	-31	-35
26	-14	-40	-48	-53	-27	-25	-24	-24	-24	-27	-23	-24	-24	-23	-24	-25	-30	-35
27	-41	-27	-17	-21	-29	-25	-24	-24	-24	-19	-22	-21	-22	-22	-21	-24	-27	-30
28	-12	-38	-46	-50	-24	-22	-20	-20	-21	-23	-19	-21	-20	-20	-21	-22	-26	-31
29	-40	-23	-15	-17	-26	-22	-22	-22	-22	-17	-20	-19	-19	-19	-21	-21	-24	-27
30	-11	-38	-42	-46	-21	-20	-20	-20	-20	-18	-18	-18	-18	-18	-19	-19	-23	-28
31	-36	-20	-14	-19	-23	-19	-18	-18	-18	-15	-15	-16	-17	-17	-16	-19	-22	-24
32	-10	-36	-39	-43	-19	-18	-17	-16	-16	-17	-15	-15	-16	-16	-17	-17	-21	-25
33	-32	-16	-13	-17	-21	-17	-16	-16	-16	-17	-15	-15	-16	-16	-17	-17	-20	-22
34	-10	-35	-36	-41	-17	-17	-16	-15	-15	-16	-15	-15	-15	-15	-15	-16	-20	-24
35	-30	-13	-12	-16	-20	-16	-15	-15	-15	-16	-15	-15	-15	-14	-15	-16	-20	-24
36	-10	-34	-34	-41	-16	-15	-15	-14	-14	-12	-12	-12	-13	-13	-14	-16	-21	-24
37	-26	-11	-11	-15	-18	-14	-13	-13	-13	-14	-15	-15	-15	-13	-14	-14	-16	-21
38	-10	-33	-31	-36	-14	-14	-14	-14	-13	-11	-13	-13	-13	-12	-12	-12	-15	-19
39	-22	-8	-10	-14	-16	-12	-11	-11	-12	-13	-13	-11	-11	-11	-11	-12	-15	-19
40	-11	-30	-26	-33	-12	-12	-11	-11	-10	-8	-10	-9	-9	-9	-9	-11	-13	-15
41	-16	-5	-9	-12	-12	-9	-8	-7	-7	-6	-7	-6	-6	-6	-6	-7	-10	-12
42	-13	-24	-19	-24	-9	-9	-8	-7	-7	-6	-7	-6	-6	-5	-5	-6	-7	-11
43	-7	-1	-8	-10	-9	-6	-6	-6	-7	-4	-5	-3	-4	-4	-4	-5	-6	-7
44	-13	-13	-10	-9	-7	-6	-5	-4	-4	-4	-3	-3	-3	-4	-4	-5	-7	-9
45	0	-1	-9	-7	-5	-4	-4	-4	-5	-4	-3	-4	-3	-4	-4	-5	-7	-9
46	-15	-5	-4	-5	-5	-4	-3	-3	-3	-3	-3	-2	-3	-3	-3	-4	-5	-6
47	-9	-7	-5	-4	-4	-4	-3	-3	-2	-2	-2	-2	-2	-2	-3	-4	-5	-6
48	-5	-4	-4	-3	-3	-3	-3	-2	-2	-2	-2	-2	-2	-2	-2	-3	-4	-5
49	-3	-3	-3	-2	-2	-2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-2	-3	-4
50	-2	-2	-2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-2	-3	-4
51	-1	-1	-1	-1	-1	-1	0	0	0	1	1	1	1	0	0	1	-1	-1
52	-1	-1	-1	-1	-1	-1	0	0	0	0	0	0	0	0	0	0	-1	-1
53	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-2
54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 21. (Sheet 10 of 26)

DISCHARGE AVG
MULTIPLIED BY 0.10000E-01

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	-19	-19	-20	-19	-19	-19	-19	-19	-19	-19	-19	-19	-19	-19	-19	-19	-19	-19	-19
24	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25
25	-33	-33	-34	-33	-34	-34	-34	-33	-33	-33	-33	-32	-31	-30	-31	-31	-26	-23	-27
26	-40	-40	-41	-41	-40	-40	-40	-40	-40	-40	-40	-39	-38	-37	-37	-38	-31	-26	-31
27	-42	-42	-43	-42	-42	-42	-42	-41	-41	-41	-41	-41	-40	-41	-42	-41	-33	-27	-33
28	-37	-37	-38	-37	-37	-37	-37	-36	-36	-36	-36	-35	-34	-34	-35	-34	-26	-24	-34
29	-30	-30	-32	-31	-31	-31	-31	-31	-31	-31	-31	-30	-29	-29	-30	-29	-25	-21	-26
30	-26	-26	-27	-26	-27	-27	-27	-27	-27	-27	-27	-26	-25	-25	-26	-25	-21	-17	-21
31	-27	-27	-28	-27	-28	-28	-28	-28	-28	-28	-28	-27	-26	-26	-27	-26	-21	-17	-21
32	-34	-34	-35	-35	-35	-35	-35	-35	-35	-35	-35	-34	-33	-33	-34	-33	-27	-23	-27
33	-45	-45	-47	-45	-46	-46	-46	-45	-45	-45	-45	-44	-43	-43	-44	-43	-37	-31	-36
34	-55	-55	-57	-55	-56	-56	-56	-55	-55	-55	-55	-54	-53	-53	-54	-53	-47	-41	-46
35	-53	-53	-55	-53	-54	-54	-54	-53	-53	-53	-53	-52	-51	-51	-52	-51	-45	-39	-44
36	-37	-37	-38	-37	-38	-38	-38	-37	-37	-37	-37	-36	-35	-35	-36	-35	-29	-23	-28
37	-18	-18	-19	-18	-19	-19	-19	-18	-18	-18	-18	-17	-16	-16	-17	-16	-11	-7	-11
38	-7	-7	-8	-7	-8	-8	-8	-7	-7	-7	-7	-6	-5	-5	-6	-5	-1	3	7
39	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
40	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
41	3	3	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
42	3	3	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
43	9	9	10	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
44	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
45	25	25	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26
46	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29
47	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41
48	42	42	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45
49	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45
50	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58
51	55	55	57	56	57	57	57	56	56	56	56	55	54	54	55	54	50	46	50
52	57	57	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56
53	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54
54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 21. (Sheet 11 of 26)

[illegible]

DISCHARGE AVG
MULTIPLIED BY 0.10000E-01

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 21. (Sheet 15 of 26)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-13	-14	-15	-16	-17	-18	-19	-20	-21	-22	-23	-24	-25	-26	-27	-28	-29	-30	-31	-32	-33	-34	-35	-36	-37	-38	-39	-40	
2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-13	-14	-15	-16	-17	-18	-19	-20	-21	-22	-23	-24	-25	-26	-27	-28	-29	-30	-31	-32	-33	-34	-35	-36	-37	-38	-39	-40	
3	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-13	-14	-15	-16	-17	-18	-19	-20	-21	-22	-23	-24	-25	-26	-27	-28	-29	-30	-31	-32	-33	-34	-35	-36	-37	-38	-39	-40	
4	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-13	-14	-15	-16	-17	-18	-19	-20	-21	-22	-23	-24	-25	-26	-27	-28	-29	-30	-31	-32	-33	-34	-35	-36	-37	-38	-39	-40	
5	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-13	-14	-15	-16	-17	-18	-19	-20	-21	-22	-23	-24	-25	-26	-27	-28	-29	-30	-31	-32	-33	-34	-35	-36	-37	-38	-39	-40	
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7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
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14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
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17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
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19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
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21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
23	-1	23	-5	7	-2	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			
24	3	19	0	3	-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			
25	5	12	5	3	0	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			
26	7	4	10	5	3	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			
27	5	-8	16	14	-2	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			
28	14	-23	21	18	-5	-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				
29	22	-41	26	25	-11	-4	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			
30	34	-62	32	37	-21	-10	4	16	25	-29	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28			
31	50	-88	38	54	-33	-19	9	16	30	-32	-27	-29	-29	-29	-29	-29	-29	-29	-29	-29	-29	-29	-29	-29	-29	-29	-29	-29	-29	-29	-29	-29	-29	-29	-29	-29			
32	64	-115	38	77	-47	-32	14	-21	-37	-36	-27	-35	-35	-35	-35	-35	-35	-35	-35	-35	-35	-35	-35	-35	-35	-35	-35	-35	-35	-35	-35	-35	-35	-35	-35	-35			
33	78	-132	36	13	-53	-48	20	-23	-44	-42	-23	-31	-31	-31	-31	-31	-31	-31	-31	-31	-31	-31	-31	-31	-31	-31	-31	-31	-31	-31	-31	-31	-31	-31	-31	-31			
34	77	-134	22	108	-47	-58	24	-22	-53	-50	-21	-27	-27	-27	-27	-27	-27	-27	-27	-27	-27	-27	-27	-27	-27	-27	-27	-27	-27	-27	-27	-27	-27	-27	-27	-27			
35	67	-129	18	114	-49	-63	23	-11	-61	-58	-21	-24	-24	-24	-24	-24	-24	-24	-24	-24	-24	-24	-24	-24	-24	-24	-24	-24	-24	-24	-24	-24	-24	-24	-24	-24			
36	66	-123	1	116	-33	-62	2	10	-65	-65	-22	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20			
37	52	-107	4	116	-37	-44	-6	23	-68	-70	-26	-17	-17	-17	-17	-17	-17	-17	-17	-17	-17	-17	-17	-17	-17	-17	-17	-17	-17	-17	-17	-17	-17	-17	-17	-17			
38	50	-101	-11	103	-10	-41	-26	48	-69	-76	-31	-15	-15	-15	-15	-15	-15	-15	-15	-15	-15	-15	-15	-15	-15	-15	-15	-15	-15	-15	-15	-15	-15	-15	-15	-15			
39	30	-68	7	66	-29	-12	28	35	-75	-80	-39	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11			
40	48	-96	-36	117	39	-57	-36	70	-73	-101	-46	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4			
41	38	-11	-32	-6	-2	45	77	-6	-73	-43	-68	72	-40	-33	-37	17	4	104	105	105	105	105	105	105	105	105	105	105	105	105	105	105	105	105	105	105			
42	60	-50	-26	143	18	-91	-21	107	81	-127	-115	92	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12			
43	97	29	-132	-77	106	122	-25	-75	-99	10	-2	106	6	23	160	91	57	41	186	98	4	100	80	100	80	100	80	100	80	100	80	100	80	100	80	100			
44	60	42	95	-54	-114	21	115	156	-32	-27	-50	18	73	52	78	158	4	100	80	100	80	100	80	100	80	100	80	100	80	100	80	100	80	100	80	100			
45	-61	17	25	40	1	-63	-50	36	115	48	-131	-15	-22	22	47	75	-123	-1	22	37	1	22	37	1	22	37	1	22	37	1	22	37	1	22	37	1			
46	-63	35	80	-11	32	74	-29	-62	-2	37	-82	-60	-5	39	112	-21	26	-25	147	1	22	37	1	22	37	1	22	37	1	22	37	1	22	37	1	22			
47	-147	-79	76	134	172	-59	13	-105	32	83	0	-53	-215	20	95	88	-68	-65	153	184	1	22	37	1	22	37	1	22	37	1	22	37	1	22	37	1			
48	-156	-165	-112	13	318	57	-108	-186	-62	137	213	-56	-229	-115	64	195	77	-122	-27	115	1	22	37	1	22	37	1	22	37	1	22	37	1	22	37	1			
49	-38	-93	-163	-17	205	151	10	-49	-61	-27	36	29	-34	-83																									

I	J	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
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7	-53	-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	-100	-19	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	-139	-32	2	-37	-23	-157	-86	-49	-43	0	0	0	0	0	0	0	0	0	0	0	0
10	-65	59	-18	-93	-148	-157	-86	-49	-43	0	0	0	0	0	0	0	0	0	0	0	0
11	-17	60	-5	-75	-68	-123	-208	-124	-124	-131	57	-37	-36	-7	-13	-21	-96	-61	-19	23	5
12	-74	95	64	-40	-15	-134	-157	-106	-111	28	-35	-36	-36	-7	-10	-23	76	-53	-23	18	23
13	-69	24	96	29	46	-123	-226	-106	-111	30	-24	-17	-26	-26	-2	-18	65	-41	-46	14	36
14	-62	-9	27	149	63	-118	-214	-114	-57	50	-24	-17	-26	-26	-5	-14	55	-29	-35	48	43
15	-73	-23	4	50	122	-49	-238	-68	-63	26	-11	-5	-7	-23	-9	-15	52	-36	-13	76	52
16	-71	-27	-3	13	83	34	-234	-20	-181	10	-5	-4	-4	-21	-14	-11	32	-34	12	103	68
17	-68	-32	-1	14	28	50	-176	-6	-59	-31	8	4	5	-12	-27	-4	9	-37	41	135	77
18	-66	-35	-4	-4	-37	2	-67	-39	-17	-74	14	5	12	-27	-4	9	5	-37	41	135	77
19	-66	-37	-4	-7	-23	8	-8	-41	-45	12	-81	6	17	4	-29	-10	-24	-35	64	165	83
20	-66	-38	-5	-7	-23	20	-17	-23	-1	-115	-8	22	28	-18	-24	-0	-42	-42	84	202	89
21	-67	-39	-6	-10	-14	29	-2	-8	-31	-92	-42	19	43	-7	-26	-85	-45	-45	93	238	84
22	-67	-41	-7	-13	-15	27	20	12	-24	-118	-58	12	34	16	-29	-102	-85	-45	93	238	84
23	-65	-45	-9	-11	-11	16	40	19	-27	-90	-93	4	24	22	-26	-116	-102	-85	93	238	84
24	-59	-50	-11	-12	-10	11	42	26	-24	-74	-105	-6	16	27	-37	-132	-102	-85	93	238	84
25	-51	-55	-14	-13	-9	-20	49	43	-15	-51	-118	-15	13	18	-45	-139	-102	-85	93	238	84
26	-50	-56	-19	-14	-9	-14	38	40	-12	-33	-109	-27	16	10	-62	-156	-102	-85	93	238	84
27	-41	-55	-26	-15	-9	-15	35	31	-9	-20	-87	-44	21	6	-81	-121	-11	-11	151	223	116
28	-50	-47	-35	-17	-9	-10	11	17	26	-5	-16	-54	-52	17	1	-94	-113	-15	203	224	114
29	-52	-39	-45	-20	-9	-10	11	11	18	-6	-21	-22	-50	15	-3	-106	-112	-15	221	200	113
30	-57	-34	-50	-27	-9	-4	3	23	-26	-9	-56	22	-5	-113	-111	-1	206	208	106	106	106
31	-62	-30	-56	-33	-9	-7	-3	32	-36	-46	57	-68	27	-10	-106	-103	3	204	185	106	106
32	-66	-35	-54	-43	-10	-5	-10	20	-42	-46	90	-71	26	-14	-110	-10	18	173	195	96	96
33	-68	-41	-59	-46	-13	-3	-9	1	-40	-40	97	-50	14	-16	-103	-105	51	161	169	103	103
34	-74	-48	-59	-52	-18	0	-7	-4	-44	-32	98	-34	6	-28	-85	-135	50	147	182	92	92
35	-71	-57	-67	-49	-28	1	-7	-11	-39	-37	94	-5	-11	-39	-89	-91	58	145	157	99	99
36	-71	-61	-70	-64	-33	3	-6	-8	-29	-47	56	47	-16	-47	-93	-93	60	141	173	85	85
37	-59	-69	-73	-67	-49	7	-6	0	-13	-56	29	60	-2	-53	-92	-97	72	137	147	97	97
38	-71	-60	-73	-66	-71	10	-10	11	13	-46	-32	102	-11	-58	-96	-101	64	134	176	72	72
39	-57	-70	-58	-104	-115	14	-12	-6	30	4	-51	93	-12	-56	-105	-94	88	111	114	114	117
40	-51	-71	-26	-142	-115	-37	-16	-13	-13	-28	-3	66	29	-43	-96	-115	63	142	186	50	50
41	-55	-46	-11	-126	-173	-91	-31	-12	-20	-91	21	104	13	-1	-109	-94	96	65	98	160	160
42	-22	-77	7	-45	-177	-153	-116	-48	-17	-79	-1	58	64	0	-119	-57	75	166	138	10	10
43	-128	-104	-103	-133	-159	-208	-175	-140	-74	-4	-38	16	31	12	-7	13	34	-15	115	185	185
44	-135	94	99	-51	-158	-157	-252	-309	-165	-22	-10	7	-79	-44	45	112	86	43	-57	-27	0
45	-48	-98	-6	1	52	80	-52	-272	-613	-8	155	0	-35	-76	-115	26	103	41	80	-18	0
46	-17	-17	-79	-1	132	106	173	-290	-557	-124	729	-169	-46	-180	-232	-94	117	65	-66	65	0
47	-54	-43	-97	-153	-46	6	118	138	-648	-23	669	-14	35	-32	-145	-211	58	93	-44	-166	0
48	67	15	-189	-140	-75	-65	187	254	-9	-144	-139	-56	-104	-3	296	75	-161	17	110	-35	0
49	61	59	-32	-103	-140	-117	6	129	106	1	-61	-93	-233	-58	316	214	-116	-106	21	34	0
50	9	16	8	-7	-27	-35	-27	-4	10	7	-6	-14	-34	-39	24	70	23	-7	-7	-2	0
51	-2	-1	-1	-1	-2	-3	-4	-4	-3	-1	-1	-1	-1	-1	-1	2	1	1	1	0	0
52	-2	-2	-1	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-1	0	0	0	0	0
53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 21. (Sheet 17 of 26)

I	J	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77
1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	11	34	-58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	12	61	-19	-26	-7	-5	-2	-3	-2	-1	-1	0	0	0	0	0	0	0
13	13	70	0	-23	-13	-10	-5	-6	-3	-2	-1	0	0	0	0	0	0	0
14	14	71	-7	-28	-16	-15	-7	-9	-5	-3	-2	0	0	0	0	0	0	0
15	15	73	-17	-41	-19	-21	-9	-13	-7	-3	-2	-1	0	0	0	0	0	0
16	16	69	-29	-43	-22	-26	-12	-17	-9	-4	-4	-2	-1	0	0	0	0	0
17	17	66	-42	-48	-25	-31	-14	-22	-11	-4	-5	-2	-1	0	0	0	0	0
18	18	74	-53	-57	-24	-36	-15	-26	-14	-4	-5	-2	-1	0	0	0	0	0
19	19	84	-60	-35	-21	-41	-16	-29	-15	-4	-5	-3	-2	0	0	0	0	0
20	20	66	-62	-24	-15	-43	-14	-33	-15	-2	-7	-3	-2	0	0	0	0	0
21	21	85	-54	-13	-4	-42	-10	-35	-15	-2	-7	-4	-3	0	0	0	0	0
22	22	78	-46	-12	14	-36	-4	-36	-15	0	-6	-5	-3	0	0	0	0	0
23	23	64	-34	-20	22	-32	6	-31	-16	2	0	-6	-3	0	0	0	0	0
24	24	67	-24	-23	26	-31	7	-24	-5	-2	3	-5	-3	0	0	0	0	0
25	25	69	-13	-26	19	-27	5	-24	-5	-2	1	-2	-1	0	0	0	0	0
26	26	55	-3	-20	14	-27	2	-22	-2	-2	2	-2	-1	0	0	0	0	0
27	27	62	1	-20	11	-24	1	-22	-2	-2	0	-1	0	0	0	0	0	0
28	28	51	8	-12	3	-24	-1	-20	-2	-4	1	-2	0	0	0	0	0	0
29	29	62	6	-13	3	-21	-2	-20	-3	-3	-1	-1	0	0	0	0	0	0
30	30	52	13	-6	8	-22	-3	-18	-4	-4	0	-2	0	0	0	0	0	0
31	31	63	10	-7	4	-19	-3	-19	-5	-3	-1	-2	0	0	0	0	0	0
32	32	53	16	0	7	-21	-4	-17	-5	-5	-1	-2	0	0	0	0	0	0
33	33	64	14	-1	3	-18	-4	-18	-6	-5	-1	-2	-1	0	0	0	0	0
34	34	55	22	6	8	-20	-5	-16	-6	-5	-1	-3	-1	0	0	0	0	0
35	35	67	16	5	14	-17	-5	-17	-6	-3	-1	-3	-1	0	0	0	0	0
36	36	59	25	11	3	-19	-5	-16	-7	-3	-1	-3	-1	0	0	0	0	0
37	37	69	19	10	14	-17	-6	-16	-7	-4	-1	-3	-1	0	0	0	0	0
38	38	55	34	16	7	-20	-6	-15	-8	-1	-1	-3	-1	0	0	0	0	0
39	39	90	2	16	16	-13	-8	-18	-8	-1	-5	-2	-2	0	0	0	0	0
40	40	58	60	25	7	-13	-8	-18	-10	-9	2	-5	-2	0	0	0	0	0
41	41	66	-29	5	27	-7	-12	-19	-7	1	-10	-1	-1	0	0	0	0	0
42	42	71	95	13	-14	-25	0	-11	-16	-11	6	-8	-2	0	0	0	0	0
43	43	28	-43	12	47	-5	-16	-16	-3	-2	-14	-6	-2	0	0	0	0	0
44	44	152	113	-19	-24	-8	8	-12	-21	-7	10	-11	-1	0	0	0	0	0
45	45	175	3	58	41	-22	-15	1	-13	-13	-13	-9	-10	0	0	0	0	0
46	46	129	-36	-77	5	11	-7	-20	-10	3	-2	-13	4	0	0	0	0	0
47	47	-15	75	-16	-33	-14	6	-2	-11	-12	0	-10	-10	0	0	0	0	0
48	48	-97	-31	-5	-3	-17	-12	0	3	-3	-8	-1	-4	0	0	0	0	0
49	49	5	-7	-6	3	0	-5	-6	-2	1	-1	-2	-2	0	0	0	0	0
50	50	0	-2	-6	-5	-3	-2	-3	3	-3	-1	-2	-4	0	0	0	0	0
51	51	-1	-1	0	1	1	2	3	3	3	3	3	3	0	0	0	0	0
52	52	0	0	1	2	2	3	3	3	3	3	3	3	0	0	0	0	0
53	53	2	4	5	5	7	8	8	8	8	8	8	8	0	0	0	0	0
54	54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 21. (Sheet 18 of 26)

VELOCITY V AVG
MULTIPLIED BY 100.00

I	J	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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23	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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29	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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31	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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36	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
47	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
48	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
49	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
52	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
53	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 21. (Sheet 19 of 26)

I	J	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3		-2	-5	-11	-16	-22	-30	-31	-46	-61	-110	-120	-114	-96	-62	-107	-168	-177	-76	0	0
4		-8	-12	-18	-24	-30	-37	-50	-56	-66	-90	-100	-98	-100	-99	-96	-102	-113	-102	-42	0
5		-15	-15	-12	-20	-38	-46	-53	-67	-96	-115	-117	-121	-133	-144	-149	-157	-165	-132	-93	-43
6		-9	-16	-18	-23	-37	-54	-64	-69	-84	-106	-120	-134	-152	-160	-155	-154	-157	-134	-104	-83
7		0	-6	-14	-17	-28	-42	-51	-59	-57	-41	-15	0	0	-73	-136	-132	-143	-122	-87	-66
8		0	-5	-9	-4	0	0	0	0	0	0	0	0	0	0	-55	-125	-147	-121	-80	-64
9		0	0	-2	-2	0	0	0	0	0	0	0	0	0	0	0	0	-46	-116	-130	-131
10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	83	-47	-227	-226
11		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	51	1	-63
12		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	107	13	158
13		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	151	192	55	-48
14		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	123	304	235	43
15		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	184	134	23	-49
16		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	117	261	190	15
17		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	118	236	209	138
18		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	87	183	185	165
19		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	99	198	174	116
20		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	182	171	135	121
21		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	136	132	128	106
22		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	56	106	110	101
23		-361	-340	-345	-364	-367	-360	-340	-313	-273	-320	-174	-94	0	48	73	113	89	-7	-53	-54
24		-362	-339	-326	-344	-345	-342	-331	-312	-283	-240	-192	-124	-47	2	39	65	53	-7	-51	-46
25		-359	-320	-298	-318	-315	-316	-314	-304	-286	-260	-224	-165	-97	-44	-3	56	37	-37	-57	-34
26		-345	-298	-267	-278	-286	-286	-296	-301	-294	-274	-246	-202	-144	-95	-47	-13	21	20	-39	-82
27		-334	-282	-246	-273	-281	-275	-285	-295	-295	-286	-267	-231	-186	-133	-100	-56	-33	6	-34	-71
28		-334	-286	-240	-250	-293	-277	-289	-300	-294	-285	-275	-253	-222	-190	-152	-111	-78	-53	-57	-98
29		-351	-308	-253	-314	-322	-295	-290	-303	-292	-279	-272	-263	-246	-229	-203	-159	-132	-86	-45	-120
30		-378	-337	-272	-343	-355	-297	-290	-302	-266	-266	-266	-266	-266	-266	-257	-223	-174	-132	-115	-146
31		-405	-361	-285	-363	-362	-301	-286	-297	-274	-248	-247	-261	-275	-251	-302	-282	-232	-163	-140	-184
32		-413	-364	-270	-353	-369	-297	-274	-290	-261	-226	-223	-224	-266	-298	-334	-346	-275	-201	-174	-159
33		-346	-331	-263	-312	-351	-281	-253	-274	-248	-204	-195	-220	-247	-284	-335	-395	-367	-277	-219	-226
34		-265	-352	-202	-175	-250	-239	-227	-253	-236	-168	-168	-191	-223	-259	-308	-367	-406	-355	-263	-263
35		-179	-163	-164	-178	-158	-163	-165	-205	-215	-168	-143	-154	-186	-226	-279	-345	-402	-396	-330	-277
36		-117	-130	-104	-66	-120	-172	-117	-125	-182	-150	-122	-129	-153	-185	-233	-286	-346	-382	-381	-355
37		-31	-37	-86	-63	-27	-67	-96	-119	-158	-137	-108	-106	-123	-149	-203	-255	-302	-321	-369	-326
38		-15	-22	1	32	-32	-102	-64	-82	-146	-129	-100	-92	-103	-119	-172	-236	-289	-290	-323	-371
39		35	16	-62	-23	73	59	-84	-160	-132	-118	-97	-92	-97	-95	-143	-233	-280	-247	-257	-279
40		2	12	90	63	-53	-80	55	95	-50	-123	-84	-99	-114	-86	-102	-227	-295	-252	-227	-227
41		36	-21	-90	0	145	96	-93	-128	10	21	-15	-65	-130	-121	-69	-116	-281	-311	-224	-205
42		26	59	102	13	-86	-15	133	128	-63	-104	-8	13	-46	-46	-87	-141	-146	-254	-270	-202
43		-12	-73	-79	54	107	-15	-110	-27	147	173	49	-19	-23	-86	-15	97	28	-94	-141	-96
44		61	69	3	-67	-11	84	74	-41	-137	-80	16	66	75	40	-63	-57	66	103	-5	-131
45		-12	16	35	27	-12	-18	34	95	91	-3	-46	-20	11	27	133	-24	-52	-11	19	-6
46		7	8	-1	-1	3	-20	-43	-29	5	24	19	19	24	29	26	33	25	0	-22	-22
47		10	27	38	23	-1	-2	7	5	4	-3	-16	-21	4	28	33	23	24	44	46	18
48		-4	5	24	33	19	1	1	16	30	34	15	-3	-4	7	19	14	-5	-11	8	30
49		3	-9	-10	4	20	21	10	-3	-11	-3	14	14	5	-7	-2	13	21	13	4	6
50		1	-2	-10	-14	-6	7	11	6	3	0	0	3	3	1	-5	-4	1	6	6	7
51		1	0	-2	-4	-4	-2	0	1	1	1	1	1	1	1	1	0	-1	-2	-1	-1
52		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
53		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 21. (Sheet 20 of 26)

AD-A148 102

EROSION CONTROL OF SCOUR DURING CONSTRUCTION REPORT 7

2/2

CURRENT--A WAVE-IND. (U) ARMY ENGINEER WATERWAYS

EXPERIMENT STATION VICKSBURG MS HYDRA.

UNCLASSIFIED

S R VEMULAKONDA SEP 84 WES/TR/HL-80-3-7

F/G 10/3

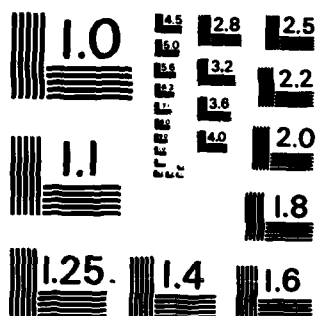
NL



END

FORMED

DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

I	J	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	6	-35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	7	-32	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	8	-28	15	27	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	9	-115	-102	-112	-67	-37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	10	-107	-95	-58	-55	-68	-36	-14	0	0	0	0	0	0	0	0	0	0	0	0	0
11	11	-103	-127	-110	-129	-229	-461	-520	-374	-156	0	0	0	0	0	0	-215	-302	-162	-116	-86
12	12	414	384	134	-11	-107	-180	-444	-523	-617	-492	-434	-557	-330	-258	-108	-16	-7	56	127	88
13	13	96	681	431	17	-144	-275	-191	-281	90	-379	-784	-323	-358	-255	-358	-116	-74	-57	-55	-94
14	14	0	196	659	390	-110	-155	-259	-416	-277	-72	-185	-316	-319	-259	-303	-225	-216	-212	-201	-369
15	15	-78	-20	465	840	545	53	8	-155	-263	-119	-159	-241	-263	-269	-250	-175	-165	-207	-296	-408
16	16	-23	-3	299	575	514	250	53	-155	-361	-225	-135	-217	-268	-247	-180	-125	-65	-134	-315	-420
17	17	-48	-11	9	537	848	472	186	36	-332	-347	-154	-282	-301	-260	-217	-104	9	-101	-281	-397
18	18	-36	-14	131	-1	-65	449	283	47	-221	-382	-226	-305	-403	-367	-268	-148	-3	-70	-248	-369
19	19	-36	-21	17	159	42	-171	-110	-157	-200	-296	-256	-244	-400	-436	-493	-121	36	-54	-223	-326
20	20	-41	-26	27	4	57	42	-134	-240	-357	-369	-232	-114	-251	-369	-355	-121	71	21	-161	-285
21	21	-48	-31	7	114	53	-79	-97	-152	-133	-183	-263	-6	-64	-180	-207	-78	41	17	-117	-204
22	22	-65	-49	-2	51	44	17	-43	-141	-237	-294	-184	-5	122	35	-84	6	41	16	-44	-137
23	23	-82	-83	-15	61	15	34	39	-69	-80	-254	-288	-62	89	109	29	62	58	-17	-49	-64
24	24	-97	-128	-34	43	51	13	28	-5	-31	-130	-213	-116	44	71	72	116	73	21	-10	-75
25	25	-80	-150	-57	43	58	201	249	77	5	-128	-220	-134	-44	47	120	140	92	-25	-32	6
26	26	-183	-166	-80	43	54	72	43	54	64	26	-159	-175	-105	-105	-60	113	85	17	-30	-22
27	27	-74	-166	-127	50	54	72	43	54	64	26	-159	-175	-105	-105	-60	113	85	17	-30	-22
28	28	-76	-153	-168	17	105	35	47	121	56	89	-12	-185	-151	-72	41	63	37	17	-10	-12
29	29	-87	-171	-177	12	146	62	48	75	53	108	19	-134	-176	-140	-27	37	16	-40	-24	41
30	30	-132	-129	-161	-26	107	61	61	67	50	106	25	-60	-150	-77	-14	-39	-27	-12	-16	-16
31	31	-161	-158	-170	-20	141	76	73	48	34	143	59	-39	-26	-24	-12	-56	-76	-73	-11	43
32	32	-225	-165	-150	-5	42	60	89	155	128	126	29	-75	-77	-49	-1	-22	-97	-57	-5	-11
33	33	-261	-213	-127	-64	48	53	-28	51	114	65	35	-82	-133	-59	-60	-24	-47	-93	-3	47
34	34	-291	-224	-165	-124	19	68	-7	24	70	48	32	-43	-89	19	13	-55	-45	-16	-9	-13
35	35	-318	-292	-154	-126	-38	56	6	9	3	-2	26	-91	-150	-5	70	28	-31	-4	4	45
36	36	-333	-326	-231	-113	3	37	5	-25	-64	-52	93	29	-161	-120	-38	-3	-3	-11	-15	-15
37	37	-325	-374	-298	-217	-33	60	7	-43	-128	-122	1	41	-80	-141	-80	-35	-42	-66	10	39
38	38	-317	-310	-333	-261	-64	32	44	6	-158	-224	-70	-50	-104	-165	-100	-34	-5	17	-29	-34
39	39	-300	-313	-320	-367	-174	-37	-52	111	119	-90	-151	-102	-104	-132	-100	-51	-61	-77	34	57
40	40	-245	-258	-323	-335	-344	-266	-28	64	134	188	136	94	75	-28	-65	-29	37	31	-68	-54
41	41	-222	-249	-314	-354	-437	-381	-175	-30	66	221	210	117	115	82	26	-19	-97	-62	54	26
42	42	-224	-224	-212	-325	-459	-508	-409	-189	-51	-45	-20	54	99	-2	8	16	25	-16	-85	-21
43	43	-174	-359	-176	-243	-416	-459	-442	-363	-156	-92	-121	-31	35	54	-30	-115	-105	-15	52	-7
44	44	-29	-2	-175	-1	-261	-474	-542	-468	-315	-224	-198	-153	-60	37	36	-19	-57	-80	-51	38
45	45	-72	-43	33	-2	-46	-97	-242	-231	-114	-235	-251	-219	-156	-97	-60	-26	-10	-13	3	12
46	46	-18	-36	-36	25	67	58	16	-16	-24	-14	-98	-157	-122	-97	-72	-62	-50	-45	-50	-23
47	47	-1	7	13	24	46	76	93	51	14	13	6	-2	-27	-50	-72	-62	-50	-45	-50	-23
48	48	26	12	15	25	30	38	35	25	-32	-71	-1	63	75	83	49	-5	-9	12	5	16
49	49	15	13	2	-11	-12	-6	7	24	4	16	19	10	1	5	16	19	10	1	5	16
50	50	10	14	14	4	-1	-9	-11	-4	6	10	7	2	-4	-19	-9	9	-1	-4	-2	-1
51	51	0	1	2	2	1	-1	-1	-4	-3	-2	-2	-2	-2	-2	-2	-2	-2	-2	-1	-1
52	52	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
53	53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54	54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 21. (Sheet 21 of 26)

I	J	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77
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2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	11	-153	-107	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	12	-42	-268	-357	-275	-222	-192	-175	-162	-157	-155	-155	-151	-149	-147	-146	-147	-74
13	13	-105	-227	-340	-346	-308	-282	-263	-245	-245	-244	-243	-241	-239	-236	-232	-232	-116
14	14	-372	-376	-356	-343	-320	-293	-278	-259	-255	-253	-249	-247	-245	-246	-246	-246	-123
15	15	-434	-433	-398	-372	-350	-325	-306	-284	-264	-243	-278	-274	-272	-272	-273	-273	-136
16	16	-436	-415	-413	-421	-376	-375	-356	-337	-332	-333	-330	-325	-323	-324	-324	-324	-162
17	17	-441	-426	-431	-435	-440	-426	-411	-392	-387	-387	-384	-381	-379	-368	-368	-368	-140
18	18	-426	-437	-436	-468	-462	-453	-445	-431	-428	-430	-425	-421	-419	-420	-421	-421	-211
19	19	-371	-392	-407	-454	-460	-457	-455	-446	-448	-448	-447	-447	-445	-448	-448	-448	-224
20	20	-301	-304	-346	-412	-434	-443	-448	-443	-443	-443	-443	-443	-443	-443	-443	-443	-224
21	21	-144	-207	-278	-335	-347	-410	-422	-435	-437	-435	-430	-430	-430	-430	-430	-430	-217
22	22	-133	-136	-163	-224	-301	-344	-367	-371	-382	-398	-400	-396	-397	-401	-403	-404	-212
23	23	-79	-129	-140	-144	-176	-230	-267	-284	-289	-312	-326	-324	-326	-331	-337	-337	-170
24	24	-68	-66	-66	-74	-64	-90	-112	-131	-163	-165	-180	-185	-187	-194	-207	-215	-108
25	25	-18	-52	-60	-33	-20	-33	-30	-45	-60	-50	-60	-70	-72	-76	-69	-97	-48
26	26	6	19	-24	-24	-18	-11	-11	-11	-24	-26	-23	-27	-30	-32	-35	-39	-19
27	27	21	-6	-12	-1	-2	-7	-6	-6	-12	-13	-11	-14	-14	-13	-13	-12	-6
28	28	27	39	1	-16	-7	-1	-2	-1	-6	-4	-6	-6	-6	-5	-2	-1	0
29	29	18	-5	4	7	2	-4	-3	-1	-3	-4	-2	-3	-2	-1	2	5	3
30	30	27	36	3	14	-4	0	-1	-3	-1	-2	-1	-2	-1	1	4	6	3
31	31	16	-3	8	14	2	-3	-2	0	-2	-3	-1	-1	0	1	4	7	4
32	32	31	37	3	14	-4	1	-1	-5	-1	-5	0	0	0	1	5	6	3
33	33	12	-4	10	14	2	-3	-1	1	-2	-3	0	-1	1	2	5	7	4
34	34	32	34	1	-14	-4	1	-2	-4	-1	-2	-1	-2	-1	1	4	5	3
35	35	6	-6	11	7	0	-3	-2	-1	-4	-5	-2	-3	-2	-1	2	4	2
36	36	33	38	-4	-13	-6	-2	-5	-7	-3	-5	-6	-4	-3	-2	0	2	1
37	37	-9	-15	4	-9	-5	-7	-5	-7	-3	-5	-6	-4	-4	-2	-1	2	1
38	38	36	22	-14	-13	-7	-2	-5	-7	-3	-5	-6	-4	-2	-1	2	2	1
39	39	-39	-36	15	15	-3	-6	-2	1	-4	-5	-1	-2	-1	0	2	4	2
40	40	58	35	-32	-34	-5	2	-5	-7	2	2	2	0	2	2	3	3	2
41	41	-60	-38	34	23	0	-6	2	4	-4	-3	-2	0	1	2	3	6	3
42	42	69	17	-44	-27	1	4	-5	-5	4	-2	-2	1	1	2	2	1	1
43	43	-58	2	47	26	-1	-2	-5	-5	-5	-2	-2	-1	-1	1	2	4	2
44	44	58	-5	-33	-11	5	1	-5	-2	3	0	-2	1	-1	1	0	-1	0
45	45	-34	19	24	2	-5	1	3	-3	-6	-1	-1	-3	-2	-2	-1	0	-2
46	46	-22	-42	-22	-7	0	-3	-4	0	-3	-1	-3	-3	-2	-3	-3	-2	-1
47	47	6	11	-9	-7	-1	0	-3	-4	-3	-1	-1	-2	-2	-2	-2	-2	-1
48	48	-20	-4	8	-2	-3	-2	0	-1	-2	-2	-1	-2	-1	-2	-2	-2	-1
49	49	9	2	1	1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-2	-2	-2	-1
50	50	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-2	-2	-2	-1
51	51	-1	-1	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-3	-3	-3	-2
52	52	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-3	-3	-3	-2
53	53	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-2	-2	-2	-1
54	54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 21. (Sheet 22 of 26)

[illegible]

Figure 21. (Sheet 23 of 26)

I	J	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1	1	-12	-9	-9	-36	-66	-137	-62	-62	-109	-103	-269	-315	-276	-201	-239	-207	-121			
2	2	-11	-19	-14	-32	-57	-55	-71	-77	-117	-151	-203	-229	-220	-197	-242	-217	-106		0	0
3	3	-13	-18	-24	-39	-45	-54	-69	-82	-110	-122	-119	-134	-102	-135	-224	-217	-154		0	0
4	4	-17	-25	-25	-37	-41	-52	-58	-57	-72	-85	-86	-91	-102	-134	-173	-166	-181		-51	3
5	5	-17	-21	-16	-29	-34	-39	-36	-36	-40	-41	-40	-35	-62	-94	-120	-139	-141		-182	-30
6	6	-8	-10	-14	-16	-19	-22	-21	-20	-6	-8	-15	-21	-25	-101	-133	-128	-130		-84	-68
7	7	0	-9	-7	1	-2	-5	-7	-6	-6	3	12	0	0	-47	-101	-85	-121		-101	-46
8	8	0	-4	-3	1	0	0	0	0	0	0	0	0	0	0	-48	-37	-133		-252	-103
9	9	0	0	-3	1	0	0	0	0	0	0	0	0	0	0	0	0	-219		-381	-166
10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-924		-991	-218
11	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-512		-664	-229
12	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-930		-662	-221
13	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-73		-359	-203
14	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-42	-173	-286		-381	-198
15	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-110	-193	-350		-316	-289
16	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-168	-195	-299		-317	-285
17	17	0	0	0	0	0	0	0	0	0	0	0	0	0	-31	-196	-186	-250		-317	-261
18	18	0	0	0	0	0	0	0	0	0	0	0	0	0	-83	-197	-177	-223		-285	-277
19	19	0	0	0	0	0	0	0	0	0	0	0	0	0	-137	-197	-166	-211		-262	-279
20	20	0	0	0	0	0	0	0	0	0	0	0	0	-21	-151	-190	-154	-203		-132	-205
21	21	0	0	0	0	0	0	0	0	0	0	-1	-57	-188	-183	-166	-199	-135		-296	-385
22	22	0	36	-12	15	-5	0	-4	-4	-7	-18	-22	-1	-75	-183	-179	-182	-185		-95	-311
23	23	-1	71	-19	23	-6	-1	-12	-11	-21	-25	-47	-14	-82	-183	-176	-184	-158		-66	-327
24	24	5	5	-7	20	-5	-2	-15	-12	-31	-36	-52	-37	-89	-144	-175	-156	-133		-62	-330
25	25	8	39	6	23	-2	-3	-17	-23	-37	-55	-58	-34	-95	-144	-173	-155	-116		-82	-318
26	26	11	16	24	-1	-1	-3	-15	-26	-48	-61	-63	-66	-99	-144	-173	-112	-95		-33	-302
27	27	13	-4	24	21	-2	-3	-12	-27	-41	-55	-66	-74	-102	-143	-173	-112	-102		-37	-277
28	28	17	-25	33	27	-7	-3	-7	-7	-41	-56	-67	-79	-103	-182	-172	-174	-104		-53	-255
29	29	25	-48	39	34	-16	-9	-1	-28	-43	-57	-66	-82	-102	-159	-171	-178	-106		-67	-244
30	30	36	-72	45	54	-29	-13	5	-29	-47	-58	-62	-79	-99	-134	-170	-184	-113		-86	-236
31	31	50	-98	51	74	-47	-25	12	-32	-53	-60	-57	-76	-94	-137	-165	-151	-132		-115	-225
32	32	63	-134	52	133	-65	-42	19	-35	-61	-64	-51	-70	-86	-117	-155	-155	-169		-12	-226
33	33	70	-141	48	135	-77	-53	28	-37	-70	-71	-44	-53	-77	-103	-141	-131	-216		-131	-238
34	34	75	-153	35	135	-73	-88	34	-37	-81	-88	-39	-53	-68	-120	-125	-175	-232		-155	-227
35	35	65	-139	23	134	-67	-87	35	-46	-92	-91	-36	-45	-59	-78	-108	-165	-217		-166	-205
36	36	57	-121	11	134	-55	-86	18	-2	-99	-101	-37	-50	-57	-91	-159	-191	-154		-191	-137
37	37	46	-105	3	134	-44	-70	3	24	-102	-108	-40	-32	-45	-56	-75	-135	-164		-152	-175
38	38	39	-98	3	113	-29	-53	-21	50	-101	-114	-47	-27	-41	-77	-54	-130	-148		-167	-140
39	39	29	-70	-2	4	-22	-32	0	56	-103	-117	-55	-21	-40	-82	-25	-94	-147		-180	-92
40	40	26	-63	-12	1	4	-38	-4	66	-54	-138	-64	-5	-45	-50	10	-93	-163		-204	-67
41	41	27	-59	-28	9	20	-6	20	40	-46	-99	-81	54	-53	-60	-1	63	-129		-225	-92
42	42	28	-53	-22	50	7	-19	31	52	0	-102	-117	110	-21	-44	30	68	-54		-181	-166
43	43	42	-50	-53	34	51	9	32	21	-3	-99	-72	17	11	-50	-41	83	26		-13	-232
44	44	38	19	-16	-7	2	59	33	28	-63	-82	-23	67	38	38	-55	-5	41		3	-70
45	45	1	15	35	-3	-41	-13	25	74	25	-88	-71	3	26	58	-58	-6	-55		-3	65
46	46	-27	11	25	11	9	1	-25	-12	40	29	-75	-23	-10	46	57	24	-47		-21	64
47	47	-39	-6	34	23	52	6	-5	-52	8	34	-26	-85	-62	19	65	12	-10		-43	119
48	48	-53	-43	-6	72	115	-4	-22	-1	-11	55	51	-5	-117	-23	43	75	-1		-54	52
49	49	-35	-33	-51	50	116	45	-23	-55	-33	27	59	-7	-64	-37	3	55	37		-25	-9
50	50	-7	-16	-36	-19	46	39	7	-6	-13	-7	7	6	-9	-22	-17	6	18		7	-1
51	51	-3	-4	-7	-7	1	7	5	2	0	0	-1	0	-1	-4	-5	-4	-1		-1	0
52	52	-2	-1	-1	-1	-1	-1	0	0	0	0	-1	0	-1	-1	-1	-1	-1		-1	-1
53	53	-1	-1	-1	-1	-1	-1	0	0	0	0	0	0	0	0	0	0	0		0	0
54	54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0

PART VIII: SUMMARY AND CONCLUSIONS

67. This report describes the development of a generalized numerical model for coastal currents induced by breaking waves. The model employs the radiation stress approach of Longuet-Higgins and solves the vertically integrated equations of momentum and continuity using an alternating direction implicit scheme. It includes mixing and advection terms.

68. The model has the following desired features in terms of application to engineering projects: the ability to handle real-life bathymetries, flexibility in terms of formulation of mixing and friction terms, computational efficiency, and economy.

69. The model was applied to a case of normally incident waves on a plane beach. The results for setup matched the experimental data of Bowen, Inman, and Simmons (1968).

70. For oblique incidence of waves on a plane beach, model results for longshore currents were compared with the analytical solution of Longuet-Higgins, first neglecting the effect of setup and later including the effect of setup. Agreement was excellent. As the numerical grid was made finer, the numerical results tended to converge toward the analytical solution. Next, the effect of lateral mixing on the velocity distribution was studied. As the mixing parameter P increased, the numerical solution exhibited the proper behavior, since the magnitude of the peak decreased, the peak moved closer to the shoreline, and the velocities offshore of the breaker line increased.

71. The model was finally applied to a field situation corresponding to Oregon Inlet, North Carolina. The bathymetry was very irregular and complex owing to the presence of channels and shoals. A variable grid was used. The significant wave condition during a part of the Ash Wednesday storm of March 1962 was selected for simulation. The numerical results obtained for this case appeared to be reasonable and the computer costs were modest.

72. For the convenience of the potential user, model input, output, and files are described and two sample applications are presented.

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APPENDIX A: NOTATION

a_1	Mapping function, dimensionless
a_{m+1}	Coefficients, 1/sec
$a_{m+1/2}$	Coefficients, sec
$a_{m-1/2}$	Coefficient, dimensionless
A_m	Computational parameter, ft
b_1	Mapping function, dimensionless
$B_{m+1/2}$	Computational parameter, ft/sec
c	Drag coefficient (of the order of 0.01), dimensionless
c_1	Mapping function, dimensionless
C	Phase speed, ft/sec
d	Total water depth including setup, ft
d_b	Water depth at wave breaking, ft
E	Wave energy density, lb/ft
g	Acceleration due to gravity, 32.174 ft/sec ²
h	Bed elevation with still-water level taken as zero, ft
$ h $	Local still-water depth, ft
H	Local wave height, ft
H_b	Breaking wave height, ft
H_o	Deepwater wave height, ft
k	Local wave number, $2\pi/L$, 1/ft
L	Local wavelength, ft
L_b	Breaking wavelength, ft
m	x-index of arbitrary cell center
n	y-index of arbitrary cell center
n	Ratio of wave group celerity to wave phase celerity, dimensionless
N_{LH}	Empirical coefficient that varies from 0.000 to 0.016, dimensionless
P	Mixing parameter which varies between 0 and 0.40, dimensionless
P_m	Recursion coefficient, sec
P_M	Recursion coefficient, sec
Q_m	Recursion coefficient, ft
Q_M	Recursion coefficient, ft

R_m	Recursion coefficient, 1/sec
R_M	Recursion coefficient, 1/sec
s	Beach slope, dimensionless
S_m	Recursion coefficient, ft/sec
S_M	Recursion coefficient, ft/sec
S_{xx}	Radiation stress in the x-direction (normal to the y-z plane), lb/ft
S_{xy}	Radiation stress in the y-direction in the x-z plane, lb/ft
S_{yy}	Radiation stress in the y-direction (normal to the x-z plane), lb/ft
t	Time, sec
T	Wave period, sec
$T1$	Computational parameter, dimensionless
$T2$	Computational parameter, dimensionless
U	Depth-averaged horizontal velocity in x-direction, ft/sec
$\langle U_{orb} \rangle$	Time-averaged wave orbital velocity at the bottom, ft/sec
V	Depth-averaged horizontal velocity in y-direction, ft/sec
x	Horizontal Cartesian coordinate, ft
y	Horizontal Cartesian coordinate, ft
z	Vertical Cartesian coordinate, ft
Z	Arbitrary variable
α_1	Computational space coordinate, ft
α_2	Computational space coordinate, ft
γ	Wave breaking index on the order of 1.0, dimensionless
δ_{α_i}	Difference operator
Δt	Time increment, sec
Δx	Cell dimension in x-direction in real space, ft
Δy	Cell dimension in y-direction in real space, ft
$\Delta \alpha_1$	Cell dimension in α_1 -direction in computational space, ft
$\Delta \alpha_2$	Cell dimension in α_2 -direction in computational space, ft
ϵ_x	Eddy viscosity in the x-direction, ft ² /sec
ϵ_y	Eddy viscosity in the y-direction, ft ² /sec
η^*	Water-surface elevation at intermediate time level, ft
$\bar{\eta}$	Displacement of the mean free surface with respect to still-water level, ft
θ	Local wave direction, deg

μ_1	Expansion coefficient, dimensionless
μ_2	Expansion coefficient, dimensionless
π	3.14159, dimensionless
ρ	Mass density of seawater, 1.99 lb-sec ² /ft ⁴
τ_{bx}	Bottom friction stress in the x-direction, lb/ft ²
τ_{by}	Bottom friction stress in the y-direction, lb/ft ²
τ_{xy}	Lateral shear stress due to turbulent mixing, lb/ft ²

Symbol

∂	Partial derivative symbol, dimensionless
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