# NUMERICAL MODEL FOR DESIGN OF IMPERMEABLE COASTAL STRUCTURES

BY
NOBUHISA KOBAYASHI AND ANDOJO WURJANTO



Sponsored by U.S. Army Coastal Engineering Research Center

RESEARCH REPORT NO. CE-89-75 JUNE, 1989

CENTER FOR APPLIED COASTAL RESEARCH
DEPARTMENT OF CIVIL ENGINEERING
UNIVERSITY OF DELAWARE
NEWARK, DELAWARE
19716

## NUMERICAL MODEL FOR DESIGN OF IMPERMEABLE COASTAL STRUCTURES

BY

NOBUHISA KOBAYASHI AND ANDOJO WURJANTO

Sponsored by U. S. Army Coastal Engineering Research Center

RESEARCH REPORT NO. CE-89-75 JUNE, 1989

CENTER FOR APPLIED COASTAL RESEARCH
DEPARTMENT OF CIVIL ENGINEERING
UNIVERSITY OF DELAWARE
NEWARK, DELAWARE
19716

#### ABSTRACT

A computer program called IBREAK is presented in this report. IBREAK may be used for the design of rough or smooth impermeable coastal structures of arbitrary geometry against normally incident waves. Any incident wave train can be specified as input at the seaward boundary of the computation domain, although the computation has been limited to monochromatic and transient waves. IBREAK computes the reflected wave train at the seaward boundary from which the reflection coefficient is predicted. For a subaerial structure, IBREAK computes wave runup on the seaward slope of the structure or wave overtopping over the crest of the structure if it is not high enough to prevent flow over its crest. For a submerged structure, IBREAK computes the transmitted wave train at the landward boundary of the computation domain from which the transmission coefficient is predicted. In addition to the equations of mass and momentum used to compute the flow field for any structure, an equation of energy is used in IBREAK to estimate the spatial variations of energy dissipation rates due to wave breaking and bottom friction. Furthermore, IBREAK computes the hydraulic stability and sliding motion of individual armor units under the action of the computed flow if the structure is protected with armor units. In addition to coastal structures, IBREAK can be used to predict the wave transformation in the surf zone and the resulting swash oscillation on a beach.

In this report, the equations and numerical procedures used in IBREAK are summarized by synthesizing the results published in various papers and reports. The essential parts of IBREAK are then explained to facilitate the use of IBREAK. The computer program IBREAK consists of the main program, 37

\*

subroutines and one function, which are written in self-explanatory manners. The common parameters and variables are listed and explained herein since a large number of parameters and variables are involved in IBREAK. The input parameters and variables together with various options are detailed so as to minimize the misuse of IBREAK. The output parameters and variables are also explained in detail since the proper interpretation of the computed results is essential. Several examples are presented herein, although the computed results were already published in various papers and reports. These examples may be used to get familiarized with IBREAK. The limitations and capabilities of IBREAK are discussed throughout this report. Users of IBREAK are strongly recommended to read the related papers quoted in the references of this report so that the degree of accuracy of the computed results may be inferred. It is also recommended to calibrate and verify IBREAK if it is to be applied to new problems. Our experiences with IBREAK for the last few years suggest that IBREAK is a fairly versatile computer program although it does not describe the detailed flow field associated with plunging breakers.

## ACKNOWLEDGEMENT

This is the third and final report resulting from research sponsored by the Coastal Engineering Research Center, U. S. Army Engineer Waterways

Experiment Station under Contract No. DACW 3988P0628. The authors would like to thank J. P. Ahrens and D. D. Davidson for their enthusiastic support of our continued efforts to develop a computer program for rubble structure design.

## TABLE OF CONTENTS

ABST	RACT	.1
ACKN	DWLEDGEMENT	. 2
TABL	E OF CONTENTS	. 3
PART	I: INTRODUCTION	. 5
	Background	. 5
	Scope	. 7
PART	II: NUMERICAL MODEL	12
	Governing Equations	12
	Numerical Method	16
	Incident Wave Profile	19
	Wave Reflection	22
	Wave Runup	23
	Wave Overtopping	26
	Wave Transmission	30
	Wave Energy Balance	33
	Hydraulic Stability of Armor Units	36
	Movement of Armor Units	38
PART	III: COMPUTER PROGRAM IBREAK	42
	Main Program	42
	Subroutines and Function	44
	Common Parameters and Variables	
	Input Parameters and Variables	
	Error and Warning Statements	
	Output Parameters and Variables	
	F1 6 T	85

				,
			SP	
			59	
			59	

PART IV: COM	NCLUSIONS.			٠			٠	٠		٠	•		•											. 88	
REFERENCES .																								. 90	,
APPENDIX A:	LISTING O	OF	IBRE	EAK					•	•			٠	٠	•	•				٠				.A-1	00
APPENDIX B:	EXAMPLE (	OF	WAVE	R	UNU	JP	AN	D	AR	MO	R	SI	'AF	BIL	ΙT	Y								.B-1	
APPENDIX C:	EXAMPLE C	OF	WAVE	R	UNU	JP	AN	D	AR	MO	R	MO	VE	ME	NT			٠						.C-1	25
APPENDIX D:	EXAMPLE C	F	WAVE	o'	VER	RTC	PP	IN	G	ON	S	UB	AE	RI	AL	S	TR	.UC	TU	IRE	:.			.D-1	
APPENDIX E:	EXAMPLE C	F	WAVE	T	RAN	ISM	IS	SI	ON	0	VE	R	SU	IBM	ER	GE	D	ST	RU	CT	'UR	EΕ		.E-1	

#### NUMERICAL MODEL FOR DESIGN OF IMPERMEABLE COASTAL STRUCTURES

## PART I: INTRODUCTION

#### Background

In the planning and design of rubble mound breakwaters and riprap revetments in the coastal environment, the effects of incident wind waves on these structures must be considered. The stability and damage of a rubble mound breakwater or a riprap revetment under wave attack is obviously an important aspect in its design. Wave runup and overtopping on a coastal structure are other important factors since they normally determine the required height of the coastal structure. Wave reflection and transmission are other important aspects for designing rubble mound breakwaters which protect harbors or coastlines from wave attack.

The present design practices of rubble mound breakwaters and riprap revetments are essentially based on hydraulic model tests and empirical formulas in spite of the fact that a very large number of papers were published and reviewed in coastal engineering journals and breakwater conferences (e.g., Bruun, 1985). The empirical formula proposed by Hudson (1959) for estimating the required weight of an individual armor unit in the primary cover layer of a rubble structure is still widely used in spite of its serious limitations as discussed in the Shore Protection Manual (1984), hereafter referred to as SPM. Various attempts were made to improve the Hudson formula by empirically including the neglected effects such as wave period, slope permeability, slope geometry and randomness of wind waves (Ahrens and McCartney, 1975; Bruun and Johannesson, 1976; Kobayashi and Jacobs, 1985; Van der Meer, 1987, 1988). Wave reflection and runup on coastal

structures were normally expressed as simple empirical functions of the surf similarity parameter (Battjes, 1974) which is useful for describing the gross characteristics of waves breaking or surging on uniform slopes (e.g., Ahrens and McCartney, 1975; Seelig, 1983; Ahrens and Martin, 1985). Empirical formulas for wave overtopping and transmission were also proposed (e.g., Cross and Sollitt, 1972; Weggel, 1976; Seelig, 1980; Jensen, 1983, 1984).

Mathematical models appear to have been used only for linear wave transmission through porous rubble-mound breakwaters (Madsen and White, 1975; Sulisz, 1985).

Empirical formulas are limited to the specific structure geometry and wave conditions examined in the experiments and are not versatile enough to deal with various combinations of different coastal structures and incident waves. Hydraulic model tests are time-consuming and scale effects such as viscous effects make it difficult to interpret the model test results unless expensive large-scale tests are performed. Furthermore, measurements are normally limited to free surface oscillations and slope profiles because of the difficulties of measuring fluid velocities and hydrodynamic forces acting on armor units. Generation of the specified incident waves is difficult because of wave reflection at the wavemaker and generation of parasitic waves (e.g., Mansard, 1988).

The need for numerical models for the rubble structure design may become obvious if one considers extensive use of numerical models for the design of offshore structures. Numerical models attempt to simulate the complicated wave motion and armor response in an approximate manner. Numerical models can hence be used to improve our quantitative understanding of the detailed mechanics as well as to interpret the model test results. Furthermore, a

hybrid approach based on empirical formulas, numerical models and hydraulic model tests will improve the efficiency and reliability of the design procedure.

#### Scope

This report synthesizes several computer programs developed previously for the projects funded by the National Science Foundation, the Delaware Sea Grant College Program, and the U.S. Army Coastal Engineering Research Center. A unified, user-friendly computer program called IBREAK is presented so that the single computer program with various computational options can be used for various coastal engineering problems. The capabilities and limitations of IBREAK are the same as those associated with the computer programs developed for the previous studies summarized in the following.

Kobayashi et al. (1986,1987) developed a numerical flow model to predict the flow characteristics on a rough impermeable slope for specified normally-incident monochromatic waves. The numerical flow model was based on the finite-amplitude shallow-water equations including the effects of bottom friction (Madsen and White, 1976) which were solved numerically in the time domain using an explicit dissipative Lax-Wendroff finite-difference method (Richtmyer and Morton, 1967; Hibberd and Peregrine, 1979; Packwood, 1980). A recent review of numerical methods developed for flows with shocks was given by Moretti (1987). The adopted numerical method is a shock-capturing method for which a separate treatment of a wave front (shock) is not required, although it can not describe the detailed behavior of waves plunging on the slope (e.g., Peregrine, 1983). The numerical flow model was developed in such a way that any incident wave train could be specified at the toe of the slope. The reflected wave train at the toe of the slope was computed from the

characteristics advancing seaward. Wave runup and run-down were predicted from the computed oscillation of the instantaneous waterline on the slope. Comparison was made with available monochromatic wave test data for large-scale uniform riprap slopes (Ahrens, 1975; Ahrens and McCartney, 1975) and small-scale composite riprap slopes (Kobayashi and Jacobs, 1985). The numerical model was shown to predict wave runup, run-down and reflection well except for some uncertainties associated with the friction factor for the rough impermeable slopes, the quantitative definition of visually-measured wave runup and the seaward boundary condition used in the model.

Kobayashi and Otta (1987) developed a numerical stability model to predict the hydraulic stability and sliding motion of armor units on a rough impermeable slope under the action of specified normally-incident monochromatic waves. The drag, lift and inertia forces acting on an armor unit were expressed in terms of the fluid velocity and acceleration predicted separately using the numerical flow model. The numerical stability model predicts the variation of the local stability number along the slope whose minimum value corresponds to the critical stability number for initiation of armor movement. The critical stability number computed for available riprap tests was shown to be in good agreement with the observed zero-damage stability number (Ahrens, 1975; Kobayashi and Jacobs, 1985), although the lift coefficient used in the model was calibrated within a reasonable range (Sleath, 1984). The critical hydrodynamic conditions for the minimum armor stability were shown to be different for plunging, collapsing and surging waves.

Kobayashi and Greenwald (1986,1988) performed an experiment to calibrate and evaluate the developed numerical models in more detail. Eight test runs

were conducted in a wave tank using a 1:3 glued gravel slope with an impermeable base. For each run with the specified monochromatic wave train generated in a burst, measurements were made of the free surface oscillation at the toe of the slope, the waterline oscillation on the slope, the temporal variations of dynamic pressure on the base of the slope and the displacements of loose gravel units placed on the glued gravel slope. The calibrated numerical models were shown to be capable of predicting the measured temporal variations of the hydrodynamic quantities and the measured spatial variations of the amount of the gravel movement.

Kobayashi and Watson (1987) applied the developed numerical flow model to predict wave reflection and runup on smooth impermeable slopes by adjusting the friction factor and the water depth specifying visually observed wave runup. Comparison with available empirical formulas (Seelig, 1983; Ahrens and Martin, 1985) indicated that the numerical flow model could also predict monochromatic wave reflection and runup on smooth slopes. Furthermore, the experiment conducted using the 1:3 glued gravel slope was repeated using a 1:3 plywood slope. The adjusted numerical flow model was shown to predict the measured temporal variations of the hydrodynamic quantities on the smooth slope as well. This comparison suggested that the numerical flow model developed for coastal structures might also be used to predict the flow characteristics in the swash zone on a beach. The applications of the numerical flow model for predicting the wave transformation and swash oscillation on beaches were presented by Kobayashi et al. (1988,1989), whereas the prediction of the sliding motion of individual sand particles was attempted by Kobayashi and DeSilva (1987).

Kobayashi and Wurjanto (1988,1989a) predicted the monochromatic wave overtopping over the crest of an impermeable coastal structure located on a sloping beach by modifying the numerical flow model. The modified model accounted for wave shoaling on the sloping beach in front of the structure located in relatively shallow water. The average overtopping rate per unit width was computed from the predicted temporal variations of the velocity and depth of the flow over the crest of the structure. The computed average overtopping rates were shown to be in agreement with the extensive small-scale test data of Saville (1955) for which smooth impermeable structures were fronted by a 1:10 slope. The numerical model also predicted the decrease of wave reflection due to the increase of wave overtopping.

Kobayashi and Wurjanto (1989b,1989c) and Wurjanto and Kobayashi (1989) predicted the monochromatic wave reflection and transmission over a submerged impermeable breakwater by modifying the numerical flow model. The modification was related to the landward boundary condition required for the transmitted wave propagating landward. In addition to the equations of mass and momentum used to compute the flow field, an equation of energy was derived to estimate the rate of energy dissipation due to wave breaking. The computed reflection and transmission coefficients were shown to be in agreement with the small-scale test data of Seelig (1980). The numerical model also predicted the spatial variation of the energy dissipation, the mean water level difference, and the time-averaged volume flux per unit width, although available measurements were not sufficient for evaluating the capabilities and limitations of the numerical model for predicting these quantities.

The numerical models discussed above are more versatile than empirical formulas but will need to be improved and expanded. Additional efforts will

be required to include the effects of incident random waves since wind waves are random (e.g., Battjes, 1984; Goda, 1985) and wave grouping may affect the design of coastal structures (e.g., Johnson et al., 1978; Burcharth, 1979). Oblique and directional waves will also need to be considered especially for the head of a mound breakwater (e.g., Losada and Gimenez-Curto, 1982; Christensen et al., 1984). The permeability of core materials will need to be included for the wave transmission through a porous breakwater (Madsen and White, 1975; Sulisz, 1985) and for the analysis of the geotechnical stability of such a breakwater (Barends et al., 1983; Hannoura and McCorquodale, 1985). The stability of the toe of a breakwater (e.g., Eckert, 1983) may also be affected by the permeability of the breakwater and its foundation. Furthermore, the adjustment of the geometry of a mound structure will need to be predicted for the design of berm and reef breakwaters (e.g., Baird and Hall, 1984; Ahrens, 1984). For large slender concrete armor units, their structural strength and breakage will become important design considerations (e.g., Port Sines Investigating Panel, 1982). Finally, an economical analysis for the design of a mound structure (e.g., Smith, 1986) will need to be improved on the basis of the improved quantitative understanding of the hydrodynamics and armor response.

It should be stated that the limitations of the computer program IBREAK presented herein will eventually be overcome in view of the rapid progress of the numerical models discussed above. Furthermore, more researchers are expected to apply and expand numerical models (Allsop et al., 1988; Thompson, 1988). This report will make the computer program IBREAK easily accessible to other researchers and engineers.

#### PART II: NUMERICAL MODEL

## Governing Equations

The wave motion on a rough or smooth impermeable slope is computed for the normally incident wave train specified at the seaward boundary of the computation domain as shown in Fig. 1 for the case of a rough slope. The prime indicates the dimensional variables in the following. The symbols shown in Fig. 1 are as follows: x' = horizontal coordinate taken to be positive landward with x'=0 at the seaward boundary; z' = vertical coordinate taken to be positive upward with z'=0 at the still water level (SWL);  $d'_t = \text{water depth}$  below SWL at the seaward boundary;  $\theta' = \text{local angle of the slope which may}$  vary along the slope;  $\eta' = \text{free surface elevation above SWL; } h' = \text{water depth}$  above the impermeable slope; and u' = depth-averaged horizontal velocity.

For the flow over the impermeable slope, the vertically-integrated equations for mass and x'-momentum may be expressed as (Kobayashi et al., 1987)

$$\frac{\partial h'}{\partial t'} + \frac{\partial}{\partial x'} (h'u') = 0 \tag{1}$$

$$\frac{\partial}{\partial t'} \left( h' u' \right) + \frac{\partial}{\partial x'} \left( h u'^{2} \right) = -g h' \frac{\partial \eta'}{\partial x'} - \frac{1}{2} f' \left| u' \right| u'$$
 (2)

where t' = time; g = gravitational acceleration; and f' = constant friction factor related to the shear stress acting on the slope. In this simplified analysis, the constant friction factor f' accounts for the roughness characteristics of the impermeable slope surface. Moreover, the theoretical bed level for the flow over the rough impermeable slope is difficult to

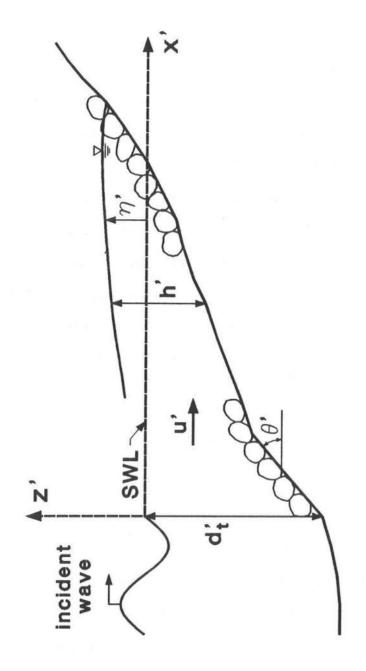


Figure 1. Wave Runup on a Rough Slope

pinpoint as is the case with oscillatory rough turbulent boundary layers (Jonsson, 1980).

The following dimensionless variables and parameters are introduced to normalize Eqs. 1 and 2:

$$t = t'/T'_r$$
;  $x = x'/[T'_r(gH'_r)^{1/2}]$ ;  $u = u'/(gH'_r)^{1/2}$  (3)

$$z = z'/H'_{r}$$
;  $h = h'/H'_{r}$ ;  $\eta = \eta'/H'_{r}$ ;  $d_{t} = d'_{t}/H'_{r}$  (4)

$$\sigma = T'_{r}(g/H'_{r})^{1/2} \quad ; \quad \theta = \sigma \, \tan\theta' \quad ; \quad f = \sigma f'/2 \tag{5}$$

where  $T_{r}'$  = representative wave period;  $H_{r}'$  = representative wave height;  $\sigma$  = dimensionless parameter related to wave steepness;  $\theta$  = dimensionless gradient of the slope; and f = normalized friction factor. The representative wave period and height used for the normalization can be taken as the period and height used to characterize the incident wave for a particular problem. Substitution of Eqs. 3-5 into Eqs. 1 and 2 yields

$$\frac{\partial \mathbf{h}}{\partial \mathbf{t}} + \frac{\partial}{\partial \mathbf{x}} (\mathbf{h}\mathbf{u}) = 0 \tag{6}$$

$$\frac{\partial}{\partial t} (hu) + \frac{\partial}{\partial x} (hu^2 + \frac{1}{2} h^2) = -\theta h - f |u| u$$
 (7)

where  $\theta$  and f express the effects of the slope and friction, respectively. For a uniform slope,  $\theta$  in Eq. 7 can be replaced by the surf similarity parameter,  $\xi = \theta/(2\pi)^{1/2}$ . In terms of the normalized coordinate system, the slope is located at

$$z = \int_0^x \theta dx - d_t \quad ; \quad x \ge 0$$
 (8)

which reduces to  $z = (\theta x - d_t)$  for a uniform slope.

The initial time t=0 for the computation marching forward in time is taken to be the time when the specified incident wave train arrives at the seaward boundary located at x=0 as shown in Fig. 1. The initial conditions for the computation are thus given by  $\eta$ =0 and u=0 at t=0 in the region x≥0. It is noted that h and  $\eta$  are uniquely related for given slope geometry expressed by Eq. 8.

In order to derive appropriate seaward and landward boundary conditions, Eqs. 6 and 7 are expressed in the following characteristic forms

$$\frac{\partial \alpha}{\partial t} + (u+c) \frac{\partial \alpha}{\partial x} = -\theta - \frac{f|u|u}{h} ; \quad \frac{dx}{dt} = u + c$$
 (9)

$$\frac{\partial \beta}{\partial t} + (u-c) \frac{\partial \beta}{\partial x} = \theta + \frac{f|u|u}{h} \qquad ; \qquad \frac{dx}{dt} = u - c \qquad (10)$$

with 
$$c = h^{1/2}$$
;  $\alpha = u + 2c$ ;  $\beta = -u + 2c$  (11)

where  $\alpha$  and  $\beta$  are the characteristic variables.

Assuming that u < c in the vicinity of the seaward boundary where the normalized water depth below SWL is  $d_t$ ,  $\alpha$  and  $\beta$  represent the characteristics advancing landward and seaward, respectively, in the vicinity of the seaward boundary. The total water depth at the seaward boundary is expressed in the form (Kobayashi et al., 1987)

$$h = d_t + \eta_1(t) + \eta_r(t)$$
 at  $x = 0$  (12)

where  $\eta_i$  and  $\eta_r$  are the free surface variations normalized by  $H'_r$  at x=0 due to the incident and reflected waves, respectively. The incident wave train is specified by prescribing the variation of  $\eta_i$  with respect to t  $\geq$  0. The normalized reflected wave train  $\eta_r$  is approximately expressed in terms of the seaward advancing characteristic  $\beta$  at x=0

$$\eta_{r}(t) \simeq \frac{1}{2} d_{t}^{1/2} \beta(t) - d_{t} - C_{t}$$
 at  $x = 0$  (13)

where  $\beta$  is given by Eq. 10. The correction term  $C_t$  in Eq. 13 introduced by Kobayashi et al. (1989) to predict wave set-down and set-up on a beach may be expressed as

$$C_t = \frac{1}{2} d_t^{1/2} (\eta - \overline{\eta}) (u - \overline{u}) (\overline{h})^{-1}$$
 at  $x = 0$  (14)

where the overbar denotes time averaging. For coastal structures, the nonlinear correction term  $C_{\mathsf{t}}$  expressed by Eq. 14 is normally negligible and use may be made of  $C_{\mathsf{t}} = 0$ .

The landward boundary condition of the numerical model depends on the crest height of a structure as will be explained in relation to the numerical procedures for wave runup, overtopping and transmission.

#### Numerical Method

Eqs. 6 and 7 are combined and expressed in the following vector form:

$$\frac{\partial \mathbf{U}}{\partial \mathbf{t}} + \frac{\partial \mathbf{F}}{\partial \mathbf{x}} + \mathbf{G} = 0 \tag{15}$$

with

$$U = \begin{bmatrix} m \\ h \end{bmatrix} ; F = \begin{bmatrix} mu+0.5h^2 \\ m \end{bmatrix} ; G = \begin{bmatrix} \theta h+f|u|u \\ 0 \end{bmatrix}$$
 (16)

where m = uh is the normalized volume flux per unit width. The vectors F and G depend on the vector U for given  $\theta$  and f.

Eq. 15 is discretized using a finite difference grid of constant space size  $\Delta x$  and constant time step  $\Delta t$  based on an explicit dissipative Lax-Wendroff method (e.g., Richtmeyer and Morton, 1967). In the following, the known quantities at the node located at  $x=(j-1)\Delta x$   $(j=1,2,\ldots,s)$  and at the

time  $t=(n-1)\Delta t$  are indicated by the subscript j without a superscript. The integer s indicates the wet node next to the moving waterline at  $t=(n-1)\Delta t$  for the case of wave runup and the node at the specified landward boundary for the case of wave overtopping or transmission. The unknown quantities at the node j and at the time  $t=n\Delta t$  are denoted by the subscript j with the superscript \* where the asterisk indicates the quantities at the next time level. The values of  $U_1^*$  and  $U_j^*$  for  $j \geq (s-1)$  are computed using the seaward and landward boundary conditions, respectively. The values of  $U_{j-1}^*$ ,  $U_j$  and  $U_{j+1}$  at the time  $t=(n-1)\Delta t$  (Kobayashi et al., 1987)

$$U_{j}^{*} = U_{j} - \lambda \left[ \frac{1}{2} (F_{j+1} - F_{j-1}) + \Delta x G_{j} \right]$$

$$+ \frac{\lambda^{2}}{2} (g_{j} - g_{j-1} - \Delta x S_{j}) + D_{j}$$
(17)

where  $\lambda = \Delta t/\Delta x$ . The vector  $g_j$  in Eq. 17 is given by

$$g_{j} = \frac{1}{2} \left[ A_{j+1} + A_{j} \right] \left[ F_{j+1} - F_{j} + \frac{\Delta x}{2} \left[ G_{j+1} + G_{j} \right] \right]$$
 (18)

with

$$\mathbf{A} = \begin{bmatrix} 2\mathbf{u} & ; & (\mathbf{h} - \mathbf{u}^2) \\ 1 & ; & 0 \end{bmatrix} \tag{19}$$

The vector S<sub>j</sub> in Eq. 17 is defined as

$$s_{j} = \left[ {^{\Delta xe_{j} - 0.5 \ \theta_{j_{0}}(m_{j+1} - m_{j-1})}} \right]$$
 (20)

with

$$e_{j} = 2f|u_{j}|h_{j}^{-1} \left[ \left( u_{j}^{2} - h_{j} \right) \left( h_{j+1} - h_{j-1} \right) \left( 2\Delta x \right)^{-1} - u_{j} \left( m_{j+1} - m_{j-1} \right) \left( 2\Delta x \right)^{-1} - \theta_{j}h_{j} - f|u_{j}|u_{j} \right]$$
(21)

The vector  $\mathbf{D}_{j}$  in Eq. 17 represents the additional term for damping high frequency parasitic waves, which tend to appear at the rear of a breaking wave, and is given by

$$D_{j} = \frac{\lambda}{2} \left[ Q_{j} \left[ U_{j+1} - U_{j} \right] - Q_{j-1} \left[ U_{j} - U_{j-1} \right] \right]$$
 (22)

with

$$Q_{j} = p_{j} I + \frac{1}{2} q_{j} \left( A_{j} + A_{j+1} \right)$$
 (23)

where I = unit matrix; and the coefficients  $p_j$  and  $q_j$  are given by

$$p_{j} = \frac{1}{2} \left( c_{j} + c_{j+1} \right)^{-1} \left[ \epsilon_{2} |w_{j+1} - w_{j}| \left( v_{j} + v_{j+1} \right) \right]$$

$$-\epsilon_{1}|v_{j+1}-v_{j}|\left(w_{j}+w_{j+1}\right)] \tag{24}$$

$$q_{j} = \left(c_{j} + c_{j+1}\right)^{-1} \left(\epsilon_{1} |v_{j+1} - v_{j}| - \epsilon_{2} |w_{j+1} - w_{j}|\right)$$
 (25)

with

$$c = h^{1/2}$$
 ;  $v = u + c$  ;  $w = u - c$  (26)

where  $\epsilon_1$  and  $\epsilon_2$  are the positive damping coefficients determining the amount of numerical damping of high frequency parasitic waves at the rear of a breaking wave.

The numerical stability criterion for this explicit finite difference method is given by (Packwood, 1980)

$$\frac{\Delta t}{\Delta x} < \left( \left| u_{m} \right| + c_{m} \right)^{-1} \quad \left[ \left( 1 + \frac{\epsilon^{2}}{4} \right)^{1/2} - \frac{\epsilon}{2} \right]$$
 (27)

where  $u_m$  = maximum value of u expected to be encountered in the flow field;  $c_m$  = maximum expected value of  $h^{1/2}$ ; and  $\epsilon$  = greatest coefficient of  $\epsilon_1$  and  $\epsilon_2$ . The values of  $\Delta t$ ,  $\Delta x$ ,  $\epsilon_1$  and  $\epsilon_2$  need to be specified, considering the

numerical stability criterion and desirable spatial and temporal accuracy as will be discussed in relation to the computer program IBREAK.

#### Incident Wave Profile

The normalized incident wave profile,  $\eta_{\mathbf{i}}(t) = \eta_{\mathbf{i}}'(t')/H_{\mathbf{r}}'$ , with  $t = t'/T_{\mathbf{r}}'$  at the seaward boundary of the computation domain needs to be specified as input where  $H_{\mathbf{r}}'$  and  $T_{\mathbf{r}}'$  are the representative wave height and period used for the normalization in Eqs. 3-5. The temporal variation of  $\eta_{\mathbf{i}}(t)$  can be the measured incident wave profile at the seaward boundary in the absence of a coastal structure (Kobayashi and Greenwald, 1986,1988). If no data on the incident wave profile is available, an appropriate wave theory may be used to specify  $\eta_{\mathbf{i}}(t)$  for  $t \geq 0$  such that  $\eta_{\mathbf{i}} = 0$  at t = 0 to be consistent with the assumed initial conditions of no wave action in the region of  $x \geq 0$  at t = 0.

For the case of incident monochromatic waves, the computer program IBREAK uses cnoidal or Stokes second-order wave theory to specify the periodic variation of  $\eta_1(t)$ . The height and period of the incident monochromatic wave at the seaward boundary located at x=0 are denoted by H' and T'. The reference wave period  $T_{\bf r}'$  is taken as  $T_{\bf r}'=T'$  for the incident monochromatic wave. The reference wave height  $H_{\bf r}'$  specified as input may be referred to deep water (Kobayashi and Wurjanto, 1988 and 1989a) or the location of wave measurement (Kobayashi et al, 1988). Since the numerical model is based on the finite-amplitude shallow-water equations given by Eqs. 1 and 2, the seaward boundary should be located in relatively shallow water. As a result, it is not always possible to take  $H_{\bf r}'=H'$ . Defining  $K_{\bf s}=H'/H_{\bf r}'$ , the height and period of the monochromatic wave profile  $\eta_1(t)$  at  ${\bf x}=0$  is  $K_{\bf s}$  and unity, respectively.

For Stokes second-order wave theory (e.g., SPM, 1984), the incident wave profile  $\eta_i(t)$  at x=0 is given by

$$\eta_1(t) = K_S \{0.5 \cos[2\pi(t+t_0)] + a_2 \cos[4\pi(t+t_0)]\}$$
 for  $t \ge 0$  (28)

with

$$a_2 = \frac{2\pi}{L} \cosh\left(\frac{2\pi}{L}\right) \left[2 + \cosh\left(\frac{4\pi}{L}\right)\right] \left[16\frac{d_t}{K_s} \sinh^3\left(\frac{2\pi}{L}\right)\right]^{-1}$$
 (29)

$$L = L_0 \tanh\left(\frac{2\pi}{L}\right) \tag{30}$$

where  $t_0$  = time shift computed to satisfy the conditions that  $\eta_{\hat{1}} = 0$  at t = 0 and  $\eta_{\hat{1}}$  decreases initially;  $a_2$  = normalized amplitude of the second-order harmonic;  $L = L'/d_t'$  with L' = dimensional wavelength at x = 0; and  $L_0 = L_0'/d_t'$  with  $L_0' = gT'^2/2\pi$  being the wavelength in deep water. The normalized wavelength L satisfying Eq. 30 for given  $L_0$  is computed using a Newton-Raphson iteration method. Eq. 29 yields the value of  $a_2$  for given  $d_t = d_t'/H_T'$ ,  $K_s$  and L. Since Eq. 28 satisfies  $\eta_{\hat{1}}(t+1) = \eta_{\hat{1}}(t)$  and  $\eta_{\hat{1}}(-t-t_0) = \eta_{\hat{1}}(t+t_0)$ , it is sufficient to compute the profile  $\eta_{\hat{1}}(t)$  for  $0 \le (t+t_0) \le 0.5$ . Eq. 28 may be appropriate if the Ursell parameter  $U_r < 26$  where  $U_r = (H'L'^2/d_t'^3) = (K_sL^2/d_t)$  at x = 0. It is noted that the value of  $U_r$  based on the normalized wavelength L computed from Eq. 30 is simply used to decide whether choidal or Stokes second-order wave theory is applied.

For the case of  $U_r \ge 26$ , choidal wave theory (e.g., Svendsen and Brink-Kjaer, 1972) is used to compute the incident wave profile  $\eta_i(t)$  at x=0

$$\eta_{i}(t) = \eta_{\min} + K_{s} \operatorname{cn}^{2}[2K(t+t_{0})] \quad \text{for } t \ge 0$$
(31)

with

$$\eta_{\min} = \frac{K_{s}}{m} \left( 1 - \frac{E}{K} \right) - K_{s} \tag{32}$$

where  $\eta_{\min}$  = normalized trough elevation below SWL; cn = Jacobian elliptic function; K = complete elliptic integral of the first kind; E = complete elliptic integral of the second kind; and m = parameter determining the complete elliptic integrals K(m) and E(m). The parameter m is related to the Ursell parameter  $U_r$ 

$$U_{r} = \frac{K_{s}L^{2}}{d_{t}} = \frac{16}{3} \text{ mK}^{2}$$
 (33)

For  $U_r \ge 26$ , the parameter m is in the range 0.8 < m < 1. The parameter m for given  $\sigma$ ,  $d_t$  and  $K_s$  is computed from

$$\frac{\sigma}{Ld_{t}^{1/2}} \left[ 1 + \frac{K_{s}}{md_{t}} \left( -m + 2 - 3 \frac{E}{K} \right) \right]^{1/2} - 1 = 0$$
 (34)

where the normalized wavelength L is given by Eq. 33 as a function of m for given  $d_t$  and  $K_s$ . The left hand side of Eq. 34 is a reasonably simple function of m in the range 0.8 < m < 1. As a result, Eq. 34 can be solved using an iteration method which successively narrows down the range of m bracketing the root of Eq. 34. After the value of m is computed for given  $\sigma$ ,  $d_t$  and  $K_s$ , the values of  $U_r$  and L are computed using Eq. 33, while Eq. 32 yields the value of  $\eta_{\min}$ . The incident wave profile  $\eta_i(t)$  is computed using Eq. 31 for  $0 \le (t+t_0) \le 0.5$  where the time shift  $t_0$  and the periodicity and symmetry of the cnoidal wave profile are used in the same manner as the Stokes second-order wave profile given by Eq. 28. It should be mentioned that the Jacobian elliptic function and the complete elliptic integrals of the first and second kinds are computed using the subroutines given by Press et al. (1986).

#### Wave Reflection

The normalized reflected wave train  $\eta_{r}(t)$  at the seaward boundary is computed using Eq. 13. It is also required to find the unknown value of the vector  $\mathbf{U}_{1}^{\star}$  at  $\mathbf{x}=0$  and the time  $\mathbf{t}=\mathbf{n}\Delta\mathbf{t}$  which can not be computed using Eq. 17.

A simple first-order finite difference equation corresponding to Eq. 10 with f=0 is used to find the value of  $\beta_1^*$  at x=0 and the time  $t=n\Delta t$ 

$$\beta_1^* = \beta_1 - \frac{\Delta t}{\Delta x} (u_1 - c_1)(\beta_2 - \beta_1) + \Delta t \theta_1$$
 (35)

where  $\beta_1 = (-u_1 + 2c_1)$  and  $\beta_2 = (-u_2 + 2c_2)$ . The right hand side of Eq. 35 can be computed for the known values of  $U_j$  with j=1 and 2 at the time  $t=(n-1)\Delta t$  where the spatial nodes are located at  $x=(j-1)\Delta x$ . The value of  $\eta_r$  at the time  $t=n\Delta t$  is calculated using Eq. 13. Eq. 12 yields the value of  $h_1^*$ , while  $u_1^* = [2(h_1^*)^{1/2} - \beta_1^*]$  using the definition of  $\beta$  given in Eq. 11. Thus, the values of  $h_1^*$ ,  $u_1^*$  and  $u_1^* = u_1^*h_1^*$  at x=0 and  $t=n\Delta t$  are obtained.

The nonlinear correction term  $C_t$  given by Eq. 14 needs to be estimated to compute  $\eta_r(t)$  using Eq. 13. For incident monochromatic waves on gentle slopes,  $C_t$  may be estimated by (Kobayashi et al., 1988)

$$C_t = K_s^2 (16d_t)^{-1}$$
 for gentle slopes (36)

where the assumptions of linear long wave and negligible wave reflection were made in Eq. 14 to derive Eq. 36. For coastal structures, wave reflection may not be negligible. It is hence suggested to choose the location of the seaward boundary so that  $C_{\mathsf{t}}$  may be assumed to be  $C_{\mathsf{t}} \simeq 0$  for coastal structures. This assumption may be checked using Eq. 36 as a rough guideline.

The reflection coefficient for incident monochromatic waves may be estimated using the following equations (Kobayashi and Wurjanto, 1989b,1989c)

$$r_1 = \left[ \left( \eta_r \right)_{\text{max}} - \left( \eta_r \right)_{\text{min}} \right] K_s^{-1}$$
 (37)

$$\mathbf{r}_2 = \left[ \overline{\eta_1^2} \left( \overline{\eta_1^2} \right)^{-1} \right]^{1/2} \tag{38}$$

$$r_3 = \left[ \overline{(\eta_r - \overline{\eta_r})^2} \left( \overline{\eta_i^2} \right)^{-1} \right]^{1/2}$$
(39)

where the subscripts max and min indicate the maximum and minimum values of  $\eta_{\mathtt{r}}(\mathtt{t})$  after the periodicity of  $\eta_{\mathtt{r}}(\mathtt{t})$  is established, whereas the overbar indicates the time averaging of the periodic variation. The normalized height of the periodic variation of  $\eta_{i}(t)$  is equal to  $K_{s}$ . Eq. 37 is based on the normalized height of the reflected wave train as compared to that of the incident wave train. Eqs. 38 and 39 are based on the time-averaged reflected wave energy as compared to the time-averaged incident wave energy,  $\eta_{i}^{2} = K_{S}^{2}/8$ , where the energy is estimated using linear wave theory. Eq. 39 accounts for the difference  $\overline{\eta_{\mathtt{r}}}$  between the still water level and the mean water level at x = 0 where  $\eta_i(t)$  is specified such that  $\overline{\eta_i}$  = 0. The method used to compute the reflection coefficient should be consistent with the method used to estimate the reflection coefficient from measured free surface oscillations. If the temporal variations of  $\eta_{\rm T}({\rm t})$  and  $\eta_{\rm i}({\rm t})$  are sinusoidal, Eqs. 37 and 38 yield  $r_1 = r_2$ . It may be noted that Eqs. 38 and 39 may also be used for incident random waves if the irregular variations of  $\eta_{1}(t)$  and  $\eta_{r}(t)$  are used to compute the time-averaged values.

#### Wave Runup

For the case of no wave overtopping on a subaerial coastal structure as shown in Fig. 1, the landward boundary of the numerical model is located at the moving waterline on the slope where the water depth is essentially zero.

The kinematic boundary condition requires that the horizontal waterline velocity is the same as the horizontal fluid velocity. In reality, it is difficult to pinpoint the exact location of the moving waterline on the slope. For the computation, the waterline is defined as the location where the normalized instantaneous water depth equals a small value  $\delta$  such as  $\delta = 10^{-3}$ .

The following numerical procedure dealing with the moving waterline located at  $h = \delta$  is used to compute the values of  $U_j^*$  at the time  $t = n\Delta t$  for the nodes  $j \geq (s-1)$  which are not computed by Eq. 17. It is noted that the procedure is somewhat intuitive and may be improved since the moving waterline tends to cause numerical instability.

- 1. Compute  $h_{S+1}=(2h_S-h_{S-1})$ ,  $u_{S+1}=(2u_S-u_{S-1})$ , and  $m_{S+1}=h_{S+1}u_{S+1}$  at the time  $t=(n-1)\Delta t \text{ where the integer s indicates the wet node next to the moving waterline at <math>t=(n-1)\Delta t$  such that  $h_S>\delta$  and  $h_{S+1}\leq \delta$ .
- 2. Compute  $h_j^*$  and  $m_j^*$  at t=n $\Delta$ t for the nodes j=(s-1) and s, using Eq. 17 without the damping term  $D_j$  since the water depth h can be very small at these nodes.
- 3. If  $h_{S-1}^* \leq \delta$ , the computation is aborted since the waterline should not move more than  $\Delta x$  because of the numerical stability criterion of the adopted explicit method given by Eq. 27. It is suggested to reduce  $\Delta t$  to avoid the numerical instability.
- 4. If  $h_S^* > h_{S-1}^*$ , use  $h_S^* = (2h_{S-1}^* h_{S-2}^*)$ , and  $u_S^* = (2u_{S-1}^* u_{S-2}^*)$ , so that the water depth near the waterline decreases landward. The following adjustments are made: if  $|u_S^*| > |u_{S-1}^*|$ , set  $u_S^* = 0.9 \ u_{S-1}^*$ ; if  $h_S^* < 0$ , set  $h_S^* = 0.5 \ h_{S-1}^*$ ; and if  $h_S^* > h_{S-1}^*$ , set  $h_S^* = 0.9 \ h_{S-1}^*$ . Then,  $m_S^* = h_S^* u_S^*$  based on the adjusted values of  $h_S^*$  and  $u_S^*$ .

- 5. If  $h_s^* \le \delta$ , set  $s^* = (s-1)$  and return where the integer  $s^*$  indicates the wet node next to the waterline at  $t=n\Delta t$ .
- 6. If  $h_{S}^{*} > \delta$ , compute  $h_{S+1}^{*} = (2h_{S}^{*} h_{S-1}^{*})$ ,  $u_{S+1}^{*} = (2u_{S}^{*} u_{S-1}^{*})$ , and  $m_{S+1}^{*} = h_{S+1}^{*} u_{S+1}^{*}$ .
- 7. If  $h_{S+1}^* \leq \delta$ , set  $s^* = s$  and return.
- 8. If  $h_{S+1}^* > \delta$ , compute  $U_S^{***}$  at the time  $t=(n+1)\Delta t$  using Eq. 17 without the damping term where  $U_J^*$  and  $U_J$  in Eq. 17 are replaced by  $U_S^{***}$  and  $U_S^*$ , respectively. Improve the linearly extrapolated values in Step 6 using the following finite difference equations derived from Eqs. 6 and 7 with f=0:

$$m_{S+1}^* = m_{S-1}^* - \frac{\Delta x}{\Delta t} (h_S^{**} - h_S)$$
 (40)

$$u_{S+1}^{*} = u_{S-1}^{*} - (u_{S}^{*})^{-1} \left[ \frac{\Delta x}{\Delta t} (u_{S}^{**} - u_{S}) + h_{S+1}^{*} - h_{S-1}^{*} + 2\Delta x \theta_{S} \right]$$
(41)

The upper limit of the absolute value of  $(u_S^*)^{-1}$  in Eq. 41 is taken as  $\delta^{-1}$  to avoid the division by the very small value. Calculate  $h_{S+1}^* = m_{S+1}^* / u_{S+1}^*$ 

- 9. If  $|u_{S+1}^*| \le \delta$ , set  $s^* = s$  and return.
- 10. If  $h_{S+1}^* \le h_S^*$  and  $h_{S+1}^* \le \delta$ , set  $s^* = s$  and return.
- 11. If  $h_{S+1}^* \le h_S^*$  and  $h_{S+1}^* > \delta$ , set  $s^* = (s+1)$  and return.
- 12. If  $h_{S+1}^* > h_S^*$ , the linearly extrapolated values of  $h_{S+1}^*$ ,  $u_{S+1}^*$  and  $m_{S+1}^*$  in step 6 are adopted in the following instead of those computed in step 8. Furthermore, set  $s^* = s$  if  $h_{S+1}^* > h_S^*$  and  $s^* = (s+1)$  if  $h_{S+1}^* \le h_S^*$  where  $h_{S+1}^*$  is the adopted value given by  $h_{S+1}^* = (2h_S^* h_{S-1}^*)$ .
- 13. Set  $h_j^* = 0$ ,  $u_j^* = 0$  and  $m_j^* = 0$  for  $j \ge (s*+1)$  since no water is present above the computational waterline.

Once the normalized water depth h at the given time is known as a function of x, the normalized free surface elevation,  $Z_r = Z_r'/H_r'$ , where the physical water depth equals a specified value  $\delta_{\mathtt{r}}'$ , can be computed as long as  $\delta_{\rm r}=(\delta_{\rm r}^{\,\prime}/{\rm H}_{\rm r}^{\,\prime})>\delta$  . The use of the physical depth  $\delta_{\rm r}^{\,\prime}$  is related to the use of a waterline meter to measure the waterline oscillation on the slope (e.g., Kobayashi and Greenwald, 1986,1988). The specified depth  $\delta_{\mathbf{r}}'$  can be regarded as the vertical distance between the waterline meter and the slope, while the corresponding elevation  $\mathbf{Z}_{\mathbf{r}}^{\prime}$  is the elevation above SWL of the intersection between the waterline meter and the free surface. The computed oscillations of  $Z_{\mathbf{r}}(\mathsf{t})$  for different values of  $\delta_{\mathbf{r}}'$  can be used to examine the sensitivity to  $\delta_{\mathtt{r}}^{'}$  of wave runup and run-down, which are normally defined as the maximum and minimum elevations relative to SWL reached by uprushing and downrushing water on the slope, respectively. For incident monochromatic waves, the normalized runup R, run-down Rd and setup  $\overline{Z_r}$  for given  $\delta_r'$  are obtained from the computed periodic oscillation of  $Z_r(t)$ . The computed results such as those presented by Kobayashi et al. (1989) indicate that wave runup is insensitive to  $\delta_{\mathtt{r}}'$  but wave run-down is very sensitive to  $\delta_{\mathtt{r}}'$  since a thin layer of water remains on the slope during wave downrush. This implies that wave run-down is difficult to measure visually or using a waterline meter.

## Wave Overtopping

Wave overtopping will occur if uprushing water reaches the landward edge of the crest of a subaerial structure as shown in Fig. 2 where  $x_e' = x'$ -coordinate of the landward edge of the crest. If wave overtopping occurs, the computation domain for the numerical model is limited to the region  $0 \le x \le x_e$  where  $x_e = x_e'/[T_r'(gH_r')^{1/2}]$  and the dimensionless variables defined in Eqs. 3-5

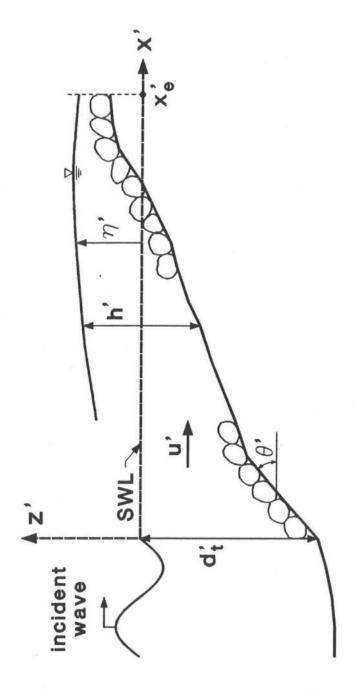


Figure 2. Wave Overtopping over a Subaerial Structure

remain the same. For the computation, wave overtopping is assumed to occur when the computed water depth h at  $x=x_e$  becomes greater than the small value  $\delta$  used for the location of the computational waterline on the slope. It is assumed that water flows over the landward edge freely. The flow approaching the landward edge can be supercritical as well as subcritical since the water depth at  $x=x_e$  is relatively small.

For the computation starting from the initial conditions of no wave action in the computation domain, wave overtopping occurs when the integer s indicating the wet node next to the computational waterline at  $t=(n-1)\Delta t$  becomes equal to the given integer  $j_e$  indicating the most landward node for the case of wave overtopping. When  $s=j_e$  at  $t=(n-1)\Delta t$ , the values of  $U_j^*$  at  $t=n\Delta t$  for the nodes j=(s-1) and s are computed as follows:

- 1. Compute  $U_{S-1}^*$  using Eq. 17 with j=(s-1) without the damping term  $D_{S-1}$  since the water depth h can be very small at this node.
- 2. If  $u_{S-1} > c_{S-1}$  where  $c_{S-1} = h_{S-1}^{1/2}$ , the flow approaching the landward edge is supercritical, and both characteristics given by Eqs. 9 and 10 advance to the landward edge from the computation domain. Since Eqs. 9 and 10 are equivalent to Eqs. 6 and 7, use is made of the following finite difference equations derived from Eqs. 6 and 7 with f=0:

$$h_{S}^{*} = h_{S} - \frac{\Delta t}{\Delta x} (m_{S} - m_{S-1})$$
 (42)

$$m_{S}^{*} = m_{S} - \frac{\Delta t}{\Delta x} \left[ \left[ m_{S} u_{S} + \frac{1}{2} h_{S}^{2} \right] - \left[ m_{S-1} u_{S-1} + \frac{1}{2} h_{S-1}^{2} \right] - \Delta t \theta_{S} h_{S} \right]$$
 (43)

Then,  $u_S^* = m_S^*/h_S^*$  and  $U_S^*$  is obtained.

3. If  $u_{S-1} \leq c_{S-1}$ , the flow approaching the landward edge is subcritical or critical, and only the characteristics  $\alpha$  given by Eq. 9 advances to the

landward edge from the computation domain. For this case, the flow at the landward edge node is assumed to be critical, that is,  $u_s^* = c_s^*$  at  $t = n\Delta t$ . Use is made of the following finite difference equation derived from Eq. 9 with f = 0:

$$\alpha_{S}^{*} = \alpha_{S} - \frac{\Delta t}{\Delta x} (u_{S} + c_{S}) (\alpha_{S} - \alpha_{S-1}) - \Delta t \theta_{S}$$
 (44)

where  $\alpha_S = (u_S + 2c_S)$  and  $\alpha_{S-1} = (u_{S-1} + 2c_{S-1})$ . Since  $u_S^* = c_S^* = (h_S^*)^{1/2}$ ,  $\alpha_S^* = (u_S^* + 2c_S^*) = 3u_S^*$ . Thus,  $u_S^* = \alpha_S^*/3$ ,  $h_S^* = (u_S^*)^2$ ,  $m_S^* = u_S^*h_S^*$  and  $U_S^*$  is obtained.

- 4. If  $h_s^* \leq \delta$ , wave overtopping is assumed to cease. Set  $s^* = (s-1)$  and return where the integer  $s^*$  indicates the wet node next to the waterline at  $t = n\Delta t$ .
- 5. If  $h_s^* > \delta$ , wave overtopping continues and  $s^* = j_e$ .

For incident monochromatic waves, the normalized average overtopping rate per unit width, Q, is obtained from the computed temporal variation of m=uh at  $x=x_e$ .

$$Q = Q'/[H'_r(gH'_r)^{1/2}] = \overline{m}$$
 at  $x = x_e$  (45)

where the overbar indicates the time averaging of m(t,x) at  $x=x_e$  after its periodicity is established. Eq. 45 does not include the volume flux during the interval when  $h \le \delta$  at  $x=x_e$  since the values of m at the nodes landward of the computational waterline are set to be zero during the computation. Eq. 45 can also be used to predict the value of Q for incident random waves for which the temporal variation of m at  $x=x_e$  is irregular.

#### Wave Transmission

For wave transmission over a submerged breakwater, the landward boundary is always located at  $x' = x'_e$  as shown in Fig. 3 where  $x'_e = x'$ -coordinate of the landward boundary which can be taken to be any convenient location such as the landward toe of the submerged breakwater. The computation domain for the numerical model is the fixed region  $0 \le x \le x_e$  where  $x_e = x'_e/[T'_r(gH'_r)^{1/2}]$  and the dimensionless variables defined in Eqs. 3-5 remain the same. To avoid the appearance of the waterline in the region  $0 \le x \le x_e$ , the normalized water depth h in the computation domain is taken as  $h = \delta$  if the computed value of h becomes less than  $\delta$ . It is assumed that the transmitted waves propagate landward without being reflected from the shoreline and the transmitted water flows landward without a return current. If the effects of the shoreline and return current need to be included, it will be required to extend the computation domain to the shoreline in a manner similar to the computations made by Kobayashi et al. (1988,1989) for the wave transformation over a shore-parallel bar and resulting swash oscillation on a beach.

Assuming that u < c in the vicinity of the landward boundary located at  $x = x_e$  where the normalized water depth below SWL is  $d_e = d_e'/H_r'$ ,  $\alpha$  and  $\beta$  represent the characteristics advancing landward and seaward, respectively, in the vicinity of the landward boundary. The boundary conditions at  $x = x_e$  may then be expressed as (Kobayashi and Wurjanto, 1989b,1989c)

$$h = d_e + \eta_t(t) \qquad \text{at } x = x_e \tag{46}$$

$$\eta_t(t) = \frac{1}{2} d_e^{1/2} \alpha(t) - d_e$$
 at  $x = x_e$  (47)

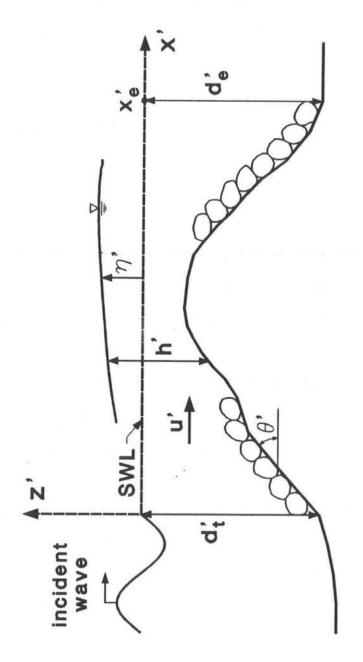


Figure 3. Wave Transmission over a Submerged Structure

where  $\eta_t$  is the free surface oscillation at  $x=x_e$  normalized by  $H_r'$  due to the transmitted wave, provided that no wave propagates seaward from the region  $x>x_e$ . Eq. 47 expresses the transmitted wave train  $\eta_t$  in terms of the landward-advancing characteristic  $\alpha$  given by Eq. 9 in a manner similar to Eq. 13 for the reflected wave train except that the nonlinear correction term is neglected in Eq. 47.

The following numerical procedure is used to compute the values of  $U_j^*$  at  $t=n\Delta t$  for the nodes j=(s-1) and s where the integer s for this case is the landward boundary node  $j_e$  located at  $x=x_e$ :

- 1. Compute  $U_{S-1}^*$  using Eq. 17 with j=(s-1) with the damping term  $D_{S-1}$  since the water depth h is large at this node.
- 2. Compute  $\alpha_s^*$  at  $t = n\Delta t$  using Eq. 44.
- 3. Compute  $\eta_t^*$  at  $t = n\Delta t$  using Eq. 47 with  $\alpha = \alpha_s^*$ . Then,  $h_s^* = (d_e + \eta_t^*)$  from Eq. 46, while  $u_s^* = [\alpha_s^* 2(h_s^*)^{1/2}]$ . Thus,  $m_s^* = h_s^* u_s^*$  and  $U_s^*$  is obtained.

For incident monochromatic waves, the transmission coefficient associated with the computed periodic wave train  $\eta_{t}(t)$  may be estimated using the following equations if  $d_{e} = d_{t}$ .

$$T_1 = [(\eta_t)_{max} - (\eta_t)_{min}] K_s^{-1}$$
 (48)

$$T_2 = \left[ \overline{\eta_t^2} \left( \overline{\eta_1^2} \right)^{-1} \right]^{1/2}$$
 (49)

$$T_3 = \left[ \overline{(\eta_{t} - \overline{\eta_{t}})^2} \left( \overline{\eta_{\underline{1}}^2} \right)^{-1} \right]^{1/2}$$
 (50)

Eqs. 48, 49 and 50 correspond to Eqs. 37, 38 and 39, respectively. Eq. 48 is based on the normalized height of the transmitted wave train as compared to that of the incident wave train. Eqs. 49 and 50 are based on the time-averaged transmitted wave energy as compared to the time-averaged incident wave energy,  $\overline{\eta_1^2} = K_S^2/8$ , based on linear wave theory. Eq. 50 accounts for the difference  $\overline{\eta_t}$  between the still water level and the mean water level at  $x = x_e$ .

#### Wave Energy Balance

The normalized equations of mass and x-momentum given by Eqs. 6 and 7 are used to compute the flow field. The normalized energy equation corresponding to Eqs. 6 and 7 may be expressed as (Kobayashi and Wurjanto, 1989b, 1989c)

$$\frac{\partial E}{\partial t} + \frac{\partial}{\partial x} (E_F) = -D_f - D_B$$
 (51)

with

$$E = \frac{1}{2} (hu^2 + \eta^2)$$
 for  $h > \eta$  (52a)

$$E = \frac{1}{2} [hu^2 + \eta^2 - (h-\eta)^2] \qquad \text{for } h < \eta$$
 (52b)

$$E_{\rm F} = \text{uh} \left( \frac{u^2}{2} + \eta \right) \tag{53}$$

$$D_{f} = f|u|u^{2} \tag{54}$$

where E = normalized specific energy defined as the sum of kinetic and potential energy per unit horizontal area;  $E_F$  = normalized energy flux per unit width;  $D_f$  = normalized rate of energy dissipation per unit horizontal area due to bottom friction; and  $D_B$  = normalized rate of energy dissipation per unit horizontal area due to wave breaking. The dimensional rate  $D_B'$  of energy dissipation due to wave breaking is given by  $D_B' = (\rho g H_T'^2/T_T') D_B$  where  $\rho$ 

= fluid density, which is assumed to be constant neglecting air bubbles. The normalized potential energy is taken to be relative to the normalized potential energy at t=0 when the incident wave train arrives at x=0 as shown in Figs. 1-3. Eqs. 52a and 52b are applicable for the portion of the structure below and above SWL, respectively.

Since the wave energy balance is normally analyzed in terms of the time-averaged quantities, the time-averaged dissipation rate,  $\overline{D_B}$ , due to wave breaking is computed using the time-averaged energy equation derived from Eq. 51

$$\overline{D}_{B} = -\frac{d}{dx} (\overline{E}_{F}) - \overline{D}_{f}$$
 (55)

The present numerical model needs to predict that  $\overline{D_B}$  is positive or zero depending on whether wave breaking occurs or not. The energy flux  $\overline{E_F}$  should decrease with the increase of x, while  $\overline{D_f} > 0$  since  $D_f$  defined in Eq. 54 is positive. It should be noted that Eq. 55 may be used even for the region which is not always exposed to water since h = 0 and u = 0 in the absence of water.

For the case of wave overtopping or transmission, integration of Eq. 55 from the seaward boundary to the landward boundary yields the time-averaged energy equation for the region  $0 \le x \le x_e$ 

$$\overline{E_F} (x=0) - \overline{E_F} (x = x_e) = \int_0^{x_e} (\overline{D_f} + \overline{D_B}) dx$$
 (56)

where the first and second terms on the left hand side of Eq. 56 are the values of  $\overline{E_F}$  at x=0 and  $x=x_e$ , respectively. Eq. 56 implies that the difference between the net energy fluxes at the seaward and landward boundaries equals the rate of energy dissipation between the two boundaries.

For the case of wave runup on a slope, Eq. 56 needs to be modified such that  $\overline{E_F}$  (x=x<sub>e</sub>) = 0 and x<sub>e</sub> should be interpreted as the maximum value of x reached by the waterline on the slope.

The specific energy  $\overline{E}$  and the energy flux  $\overline{E_F}$  at the seaward boundary where  $\eta = (\eta_1 + \eta_r)$  at x = 0 from Eq. 12 may approximately be given by (Kobayashi and Wurjanto, 1989b, 1989c)

$$\overline{E} \simeq \overline{\eta_1^2} + \overline{(\eta_r - \overline{\eta_r})^2} \qquad \text{at } x = 0$$
 (57)

$$\overline{E_F} \simeq d_t^{1/2} \left[ \overline{\eta_1^2} - (\overline{\eta_r} - \overline{\eta_r})^2 \right]$$
 at  $x = 0$  (58)

where  $d_t^{1/2}$  is the normalized group velocity at x=0 based on linear long wave theory. The reflection coefficient  $r_3$  given by Eq. 39 including the effect of  $\overline{\eta_r}$  is based on Eqs. 57 and 58. The reflection coefficient  $r_2$  given by Eq. 38 corresponds to Eqs. 57 and 58 with  $\overline{\eta_r}=0$ .

For the case of wave transmission over a submerged breakwater, the specific energy  $\overline{E}$  and the energy flux  $\overline{E_F}$  at the landward boundary where  $\eta=\eta_{t}$  at  $x=x_{e}$  may be approximated by

$$\overline{E} \simeq \overline{(\eta_t - \overline{\eta_t})^2}$$
 at  $x = x_e$  (59)

$$\overline{E_F} \simeq d_e^{1/2} (\overline{\eta_t - \overline{\eta_t}})^2$$
 at  $x = x_e$  (60)

where  $d_e^{1/2}$  is the normalized group velocity at  $x=x_e$  based on linear long wave theory. The transmission coefficient  $T_3$  given by Eq. 50 for the case of  $d_e=d_t$  is based on Eqs. 59 and 60, whereas the transmission coefficient  $T_2$  given by Eq. 49 does not include the wave setup  $\overline{\eta_t}$  at  $x=x_e$ .

#### Hydraulic Stability of Armor Units

The hydraulic stability of armor units is analyzed using the computed flow field on a rough impermeable slope. The drag, lift and inertia forces acting on individual armor units may be expressed in terms of the fluid velocity and acceleration on the rough impermeable slope. The normalized fluid acceleration, du/dt, is given by

$$\frac{d\mathbf{u}}{d\mathbf{t}} = \frac{\partial \mathbf{u}}{\partial \mathbf{t}} + \mathbf{u} \frac{\partial \mathbf{u}}{\partial \mathbf{x}} = -\frac{\partial \mathbf{h}}{\partial \mathbf{x}} - \theta - \frac{\mathbf{f} |\mathbf{u}| \mathbf{u}}{\mathbf{h}}$$
 (61)

where use is made of Eqs. 6 and 7.

Kobayashi and Otta (1987) expressed the stability condition against sliding or rolling of an armor unit located on the slope with its local slope angle  $\theta'$  as shown in Fig. 1 in the following form:

$$|N_S + E_1| + E_2 N_S \le E_3$$
 (62)

which is applicable for the case of  $u \neq 0$ . The stability number  $N_{\rm S}$  in Eq. 62 is defined as

$$N_s = H'_r (s_g - 1)^{-1} \left(\frac{W'}{\rho s_g}\right)^{-1/3}$$
 (63)

where  $H_{r}^{'}$  = reference wave height used for the normalization;  $s_{g}$  = specific gravity of the armor unit whose unit mass is given by  $\rho s_{g}$ ; and W' = median mass of the armor unit. If the stability number  $N_{s}$  required for the hydraulic stability of armor units is known, the required mass W' can be found using Eq. 63 for given  $H_{r}^{'}$ .  $E_{1}$ ,  $E_{2}$  and  $E_{3}$  in Eq. 62 are defined as

$$E_{1} = \frac{2C_{3}^{2/3}}{C_{2}C_{D}|u|u} \left[ \frac{C_{M}}{(s_{g}-1)\sigma} \frac{du}{dt} - \sin\theta' \right]$$
 (64)

$$E_2 = C_L \tan \phi / C_D \tag{65}$$

$$E_3 = \frac{2C_3^{2/3}}{C_2 C_D u^2} \cos \theta' \tan \phi$$
 (66)

where  $C_D$ ,  $C_L$  and  $C_M$  are the drag, lift and inertia coefficients, respectively, while  $C_2$ ,  $C_3$  and  $\phi$  are the area coefficient, volume coefficient and frictional angle of the armor unit, respectively. Eq. 62 can be solved in terms of  $N_S$ 

$$N_S \le N_R(t,x) = (E_1 + E_3)/(E_2 - 1); \text{ if } E_1 < 0, E_2 > 1 \text{ and } E_3 < (-E_1E_2)$$
 (67a)

$$N_S \le N_R(t,x) = (E_3 - E_1)/(E_2 + 1);$$
 otherwise (67b)

where  $N_R$  = dimensionless function expressing the degree of the armor unit stability as a function of t and x. For the computation, Eqs. 67a and 67b are used if  $\left|u\right| \geq 10^{-3}$  and  $N_R$  is set to be  $N_R$  = 1000 if  $\left|u\right| < 10^{-3}$ .

For the case of u=0, Kobayashi and Otta (1987) expressed the stability condition in the form

$$\left| \frac{c_{M}}{(s_{g}-1)\sigma} \frac{du}{dt} - \sin\theta' \right| \leq \cos\theta' \tan\phi \tag{68}$$

The condition given by Eq. 68 is satisfied if the normalized fluid acceleration remain within the following lower and upper bounds

$$\sigma a_{\min} \le du/dt \le \sigma a_{\max}$$
 (69)

with

$$a_{\min} \ge -\frac{s_g^{-1}}{c_M} \frac{\sin(\phi - \theta')}{\cos \phi}$$
;  $a_{\max} \le \frac{s_g^{-1}}{c_M} \frac{\sin(\phi + \theta')}{\cos \phi}$  (70)

In terms of the dimensional variables, Eq. 69 can be rewritten as  $ga_{\min} \le du'/dt' \le ga_{\max}$  where g = gravitational acceleration. The dimensionless

parameters  $a_{\min}$  and  $a_{\max}$  need to be chosen so as to satisfy the conditions given by Eq. 70 as discussed by Kobayashi and Otta (1987).

The local stability number  $N_{SX}(x)$  for initiation of armor movement at given location x is defined as the minimum value of  $N_R(t,x)$  at the same location for a specified duration. For incident monochromatic waves, this duration can be taken as one wave period after the establishment of the periodicity of  $N_R(t,x)$  with respect to t. If  $N_S \leq N_{SX}(x)$ , the armor unit located at given x will not move during the specified duration. The critical stability number  $N_{SC}$  for initiation of armor movement is defined as the minimum value of  $N_{SX}(x)$  with respect to x in the computation domain. If  $N_S \leq N_{SC}$ , no armor units in the computation domain will move during the specified duration.

#### Movement of Armor Units

Kobayashi and Otta (1987) also performed a simplified analysis to predict the sliding motion of armor units when the criterion for initiation of armor movement is exceeded. In the following, the results presented by Kobayashi and Otta (1987) are rearranged so that the computer program attached in Appendix A may be understood without difficulties.

The normalized forces acting on an armor unit are separated into

$$F_D = \frac{C_D C_2}{2C_3 d} \sigma |u - u_a| (u - u_a)$$
 (71)

$$F_{L} = \frac{C_{L}C_{2}}{2C_{3}d} \sigma(u - u_{a})^{2}$$
 (72)

$$F_{I} = c_{M} \frac{du}{dt}$$
 (73)

$$W_{c} = \sigma (s_{g} - 1) \cos \theta'$$
 (74)

$$W_{S} = \sigma (s_{g} - 1) \sin \theta'$$
 (75)

with

$$d = \frac{d'}{H'_{r}} = (H'_{r})^{-1} \left( \frac{W'}{C_{3} \rho s_{g}} \right)^{1/3} \qquad ; \qquad u_{a} = \frac{u'_{a}}{(gH'_{r})^{1/2}}$$
 (76)

where  $F_D$  = normalized drag force;  $F_L$  = normalized lift force;  $F_I$  = normalized inertia force due to the fluid acceleration only;  $W_C$  = component of the normalized submerged weight downward normal to the slope;  $W_S$  = component of the normalized submerged weight downward parallel to the slope; d = normalized length of the armor unit; and  $u_a$  = normalized velocity of the armor unit along the slope. The prime in Eq. 76 indicates the corresponding physical variable. It is simply assumed that the drag and inertia forces act upward or downward parallel to the slope, whereas the lift force acts upward normal to the slope. The normalized forces expressed by Eqs. 71-75 are based on the normalization by  $(gW'/\sigma s_g)$ . It is noted that the condition given by Eq. 69 is not imposed on the value of du/dt in Eq. 73 to account for possibly large fluid accelerations at the point of wave breaking.

The sliding motion of an armor unit starts if the following condition is satisfied

$$\left|F_{D} + F_{I} - W_{s}\right| > F_{R} \tag{77}$$

with 
$$F_{R} = (W_{c} - F_{L}) \tan \phi \ge 0$$
 (78)

where  $F_R$  = magnitude of the normalized frictional force acting on the armor unit which is zero if  $F_L \ge W_C$ . In Eqs. 77 and 78,  $F_D$  and  $F_L$  are given by Eqs 71 and 72 with  $u_a$  = 0, respectively, where  $u_a$  = 0 for a stationary armor unit.

The normalized equation of the sliding motion of the armor unit moving with the normalized velocity  $\mathbf{u}_a$  along the slope is given by

$$(s_g + C_m) \frac{du_a}{dt} = F_D + F_I - W_c - JF_R$$
 (79)

with

$$J = u_a / |u_a| \tag{80}$$

where  $C_m$  = added mass coefficient given by  $C_m$  =  $(C_M - 1)$  and  $F_R$  is assumed to act in the direction opposite to that of the armor movement. The displacement  $X_a'$  of the sliding unit along the slope from its initial location is normalized in the following two different ways:

$$X_{a}(t) = \frac{X'_{a}}{d'} = \frac{\sigma}{d} \int_{t_{0}}^{t} u_{a} dt$$
 (81a)

$$X_{aa}(t) = \frac{X'_a}{T'_r(gH'_r)^{1/2}} = \int_{t_0}^t u_a dt$$
 (81b)

where  $t_0$  = normalized time when the armor unit starts moving. Eq. 81a is used to estimate the degree of the armor movement relative its characteristic length d', whereas Eq. 81b is used to find the x-coordinate of the moving unit since the values of u and du/dt in Eqs. 71-73 should be those at the instantaneous location of the unit.

For the computation of the movement of individual armor units, the grid points used for the computation of the flow fields are used to specify the locations of the units before the armor movement computation. The movement of the armor unit located at the node j starts when the condition given by Eq. 77 is satisfied at the node j. If the armor unit located initially at the node j starts moving, a Lagrangian approach is used by tracking the location of the moving unit identified by its node number j. A forward difference equation in

the time t derived from Eq. 79 is used to find the normalized velocity  $u_a$  of the identified unit whose instantaneous location is computed using Eq. 81b. The values of u and du/dt in Eq. 71-73 are evaluated at the node closest to the instantaneous location of the moving unit. The moving unit is assumed to stop when the condition given by Eq. 77 is not satisfied. The stopped unit resumes its movement when the condition given by Eq. 77 is satisfied. The temporal variation of  $X_a$  defined by Eq. 81a is also computed for the armor unit identified by its initial location on the slope.

#### PART III: COMPUTER PROGRAM IBREAK

#### Main Program

The computer program IBREAK attached in Appendix A consists of the main program, 37 subroutines and one function, which are written in self-explanatory manners. Double precision is used throughout the program. IBREAK has been written for a mainframe computer, IBM 3090-180E as well as Sun workstations (Sun 3/60), which operates diskless in conjunction with a central file server, Sun 4/280. Consequently, IBREAK may not have to be modified much for other computers. The computation time of IBREAK for one wave period is on the order of a minute for the mainframe computer and on the order of ten minutes for the Sun workstation.

The main program lists all the important variables and parameters in the common statements. Before the time-marching computation based on Eq. 17, the main program performs the following tasks:

- Open files and read input data using the subroutines OPENER, INPUT1 and INPUT2.
- Process the input data for the time-marching computation using the subroutines BOTTOM, PARAM, INIT1 and INWAV.
- · Document the input and processed data using the subroutine DOC1

During the time-marching computation, the unknown quantities at the time  $t=n\Delta t$  are computed from the known quantities at the time  $t=(n-1)\Delta t$ . The computational procedure during the time-marching computation is as follows:

• Estimate  $h_{S+1}$ ,  $u_{S+1}$  and  $m_{S+1}$  at the time  $t=(n-1)\Delta t$  by linear extrapolation for the case of wave runup where the integer s indicates the wet node next to the moving waterline at  $t=(n-1)\Delta t$ .

- Retain the values of the quantities at the time  $t = (n-1)\Delta t$  which are required for the seaward and landward boundary computations.
- Compute  $c_j = h_j^{1/2}$  for j = 1, 2, ..., s used in the characteristic equations given by Eqs. 9 and 10 with Eq. 11.
- Compute the unknown quantities at the time  $t=n\Delta t$  using the subroutines MARCH, LANDBC and SEABC.
- Check the simplified condition of  $|u| < (\Delta x/\Delta t)$  that will be satisfied if the numerical stability criterion given by Eq. 27 is satisfied.
- Compute the quantities related to wave energy balance at the request of a user.
- Compute the statistics of  $\eta$ , u and m=uh so that the mean, maximum and minimum values can be found after the time-marching computation.
- Compute the hydraulic stability of armor units or the movement of armor units at the request of a user.
- Store the computed results during the time-marching computation using the subroutine DOC2 at the request of a user.
- Write the time level n every 500 time steps and the value of the normalized time,  $t=t'/T_{r}'$ , whenever t is an integer.

After the time-marching computation, the following tasks are performed:

- Compute the statistics of the quantities related to the flow field and armor stability using the subroutine STAT2.
- Compute the overall balance of wave energy using the subroutine BALANE at the request of a user.
- · Document the computed results using the subroutine DOC3.

#### Subroutines and Function

The 37 subroutines and one function arranged in numerical order in the computer program IBREAK are listed in Table 1. The page numbers for the subroutines and function listed in Table 1 correspond to the page numbers used for IBREAK attached in Appendix A. Each of the subroutines and function are explained concisely in the following:

- OPENER: this subroutine opens input and output files. Some of the files are opened on the basis of options selected by a user.
- INPUT1: this subroutine reads input data from the primary input data file and checks whether the options selected by a user are within the ranges available in IBREAK.
- 3. INPUT2: this subroutine reads the wave profile at the seaward boundary if the wave profile measured in a wave flume or generated numerically is specified as input.
- 4. BOTTOM: this subroutine computes the normalized structure geometry and the value of  $\Delta x$  from the dimensional structure geometry specified as input.
- 5. <u>PARAM</u>: this subroutine calculates the dimensionless parameters used in the other subroutines.
- 6. INIT1: this subroutine specifies the initial conditions given by  $\eta=0$  and u=0 at t=0 as well as the initial values of various quantities used for the subsequent computation.
- 7. <u>INIT2</u>: this subroutine facilitates the assignment of the initial values in the subroutine INIT1.

TABLE 1 - 37 Subroutines and One Function in Computer Program IBREAK

No.	Subroutine or Function	Page No. in IBREAK	No.	Subroutine or Function	Page No.
1	OPENER	7-11	20	MOVE	44-46
2	INPUT1	11-17	21	FORCES	46-47
3	INPUT2	17-18	22	ACCEL	47
4	воттом	18-21	23	STAT2	47-49
5	PARAM	21-24	24	COEF	49-50
6	INIT1	24-26	25	BALANE	50-52
7	INIT2	26	26	MATAFG	52
8	INWAV	26-29	27	MATGJR	52-53
9	FINDM	29-30	28	MATS	53
10	CEL	30-31	29	MATD	53-54
11	SNCNDN	31-32	30	MATU	54-55
12	MARCH	32-34	31	ASSIGN	55
13	LANDBC	34-37	32	DERIV	55
14	RUNUP	37-38	33	DOC1	55-60
15	OVERT	38-39	34	DOC2	60-63
16	SEABC	39-41	35	DOC3	63-67
17	ENERGY	41-42	36	CHEPAR	67-68
18	STAT1	42	37	CHEOPT	68
19	STABNO	42-44	38	STOPP	68-69

- 8. <u>INWAV</u>: this subroutine computes the incident wave profile at the seaward boundary using Eq. 28 or 31 if the wave profile is not specified as input.
- 9. <u>FINDM</u>: this subroutine computes the value of the parameter m which satisfies Eq. 34.
- 10. <u>CEL</u>: this function computes the values of the complete elliptic integrals K and E used in Eqs. 31-34 for given m.
- 11. <u>SNCNDN</u>: this subroutine computes the Jacobian elliptic function on used in Eq. 31.
- 12. MARCH: this subroutine performs the time-marching computation on the basis of Eq. 17.
- 13. <u>LANDBC</u>: this subroutine manages the landward boundary conditions for wave runup, overtopping or transmission as well as the computation of the normalized free surface elevation  $Z_r$  for given  $\delta_r'$  as discussed in relation to wave runup.
- 14. <u>RUNUP</u>: this subroutine computes the waterline movement on the slope of a subaerial structure on the basis of the procedure discussed in relation to wave runup.
- 15. OVERT: this subroutine computes the overtopping flow at the landward edge of the crest of a subaerial structure on the basis of the procedure discussed in relation to wave overtopping.
- 16. SEABC: this subroutine computes the flow at the seaward boundary using Eq. 35 and the reflected wave train  $\eta_{\rm r}({\rm t})$  using Eq. 13.
- 17. ENERGY: this subroutine computes the values of E,  $E_F$  and  $D_f$  defined by Eqs. 52, 53 and 54, respectively, in relation to the normalized equation of wave energy.

- 18. <u>STAT1</u>: this subroutine is used to calculate the sum, maximum and minimum values of quantities varying with time.
- 19. STABNO: this subroutine computes the armor stability function  $N_R(t,x)$  using Eqs. 64-67 and the local stability number  $N_{\rm SX}(x)$  defined as the minimum value of  $N_R(t,x)$  at given location.
- 20.  $\underline{\text{MOVE}}$ : this subroutine computes the displacement of armor units using Eqs. 77-81.
- 21. <u>FORCES</u>: this subroutine computes the normalized forces given by Eqs. 71-75.
- 22. ACCEL: this subroutine computes the value of du/dt using Eq. 61.
- 23. <u>STAT2</u>: this subroutine finds the statistical values of the computed variables after the time-marching computation.
- 24. <u>COEF</u>: this subroutine computes the wave reflection coefficients given by Eqs. 37-39 as well as the wave transmission coefficients given by Eqs. 48-50 for the case of a submerged structure.
- 25. <u>BALANE</u>: this subroutine checks the balance of wave energy using Eqs. 55 and 56 as well as the approximate expressions given by Eqs. 58 and 60 based on linear long wave theory.
- 26. MATAFG: this subroutine computes the values of the elements of the matrix
  A defined by Eq. 19 and the vectors F and G defined in Eq. 16.
- 27. MATGJR: this subroutine computes the values of the elements of the vector g defined by Eq. 18.
- 28. MATS: this subroutine computes the values of the elements of the vector  $\mathbf{s}_{j}$  at the node j defined by Eq. 20.
- 29.  $\underline{\text{MATD}}$ : this subroutine computes the values of the elements of the vector  $D_{\dot{1}}$  at the node j defined by Eq. 22.

- 30. MATU: this subroutine computes the values of the elements of the vector  $\mathbf{U}_{\mathbf{i}}^{*}$  at the node j and at the time  $\mathbf{t} = \mathbf{n}\Delta\mathbf{t}$  using Eq. 17.
- 31. <u>ASSIGN</u>: this subroutine changes a matrix to a vector or a vector to a matrix.
- 32. <u>DERIV</u>: this subroutine computes the first derivative of a function using a finite difference method.
- 33. <u>DOC1</u>: this subroutine documents the input data and dimensionless parameters before the time-marching computation.
- 34. <u>DOC2</u>: this subroutine stores some of the computed results at designated time levels during the time-marching computation.
- 35. <u>DOC3</u>: this subroutine documents the computed results after the timemarching computation.
- 36. CHEPAR: this subroutine checks whether the values of the integers N1, N2, N3, N4 and N5 used to specify the sizes of matrices and vectors in the main program are equal to the values of the corresponding integers N1R, N2R, N3R, N4R and N5R used in the subroutines.
- 37. <u>CHEOPT</u>: this subroutine checks whether the options selected by a user are within the ranges available in IBREAK.
- 38. <u>STOPP</u>: this subroutine executes a programmed stop if some of the input requirements for IBREAK are not satisfied.

#### Common Parameters and Variables

The parameters and variables included in the common statements in the main program are explained so that a user may be able to comprehend the computer program IBREAK and modify it if required. In the following, the common statements are explained one by one.

### /DIMENS/ integers used to specify the sizes of matrices and vectors:

- N1R = N1= maximum number of grid points allowed in the computation domain where N1R = N1 = 500 in IBREAK.
- N2R = N2 = maximum number of time steps allowed for the time-marching computation where N2R = N2 = 30000 in IBREAK.
- N3R = N3 = maximum number of different values of the physical water depth  $\delta_{\, {\rm r}}' \ {\rm allowed} \ {\rm for} \ {\rm wave} \ {\rm runup} \ {\rm where} \ {\rm N3R} \ = \ {\rm N3} \ = \ 3 \ {\rm in} \ {\rm IBREAK}.$
- N4R = N4 = maximum number of points allowed to specify the structure geometry consisting of linear segments where N4R = N4 = 100 in IBREAK.
- N5R = N5 = maximum number of time levels allowed for storing the spatial
  variations of the computed quantities as well as the maximum number
  of nodes allowed for storing the temporal variations of the computed
  quantities. N5R = N5 = 25 in IBREAK.

#### /CONSTA/ constants and input to the numerical model:

- PI  $= \pi = 3.141592$
- GRAV = gravitational acceleration  $g = 9.81 \text{ m/s}^2$  or  $32.2 \text{ ft/s}^2$ .
- DELTA = normalized water depth  $\delta$  used to define the computational waterline as discussed in relation to wave runup.
- X1 = damping coefficient  $\epsilon_1$  included in Eqs. 24 and 25.
- X2 = damping coefficient  $\epsilon_2$  included in Eqs. 24 and 25.

## /ID/ integers used to specify the options of a user:

IJOB = integer indicating the type of the landward boundary condition,
 where IJOB = 1 for wave runup on the seaward slope of a subaerial

- structure; IJOB = 2 for wave overtopping over a subaerial structure; and IJOB = 3 for wave transmission over a submerged structure.
- ISTAB = integer indicating the type of the armor analysis, where ISTAB = 0
  for no computation of armor stability or movement; ISTAB = 1 for
  the computation of armor stability; and ISTAB = 2 for the
  computation of armor movement.
- ISYST = integer indicating the system of units, where ISYST = 1 for the
   International System of Units; and ISYST = 2 for the U.S.
   Customary System of Units.
- IBOT = integer indicating the type of input data for the structure geometry, where IBOT = 1 for the width and slope of linear segments; and IBOT = 2 for the locations of end points of linear segments.
- INONCT = integer indicating whether the nonlinear correction term  $C_t$  is included in Eq. 13 for  $\eta_r(t)$ , where INONCT = 0 for  $C_t$  = 0; and INONCT = 1 for  $C_t$  given by Eq. 36.
- IENERG = integer indicating whether the quantities related to wave energy are computed or not, where IENERG = 0 for no computation; and IENERG = 1 for the computation of the energy quantities discussed in relation to Eqs. 51-60.
- IWAVE = integer indicating the type of the wave profile specified at the seaward boundary, where IWAVE = 1 for the incident wave profile  $\eta_{1}(t)$  computed using the subroutine INWAV; IWAVE = 2 for the incident wave profile  $\eta_{1}(t)$  read in the subroutine INPUT2; and IWAVE = 3 for the total wave profile  $[\eta_{1}(t) + \eta_{r}(t)]$  read in the

subroutine INPUT2. It is noted that IWAVE = 3 corresponds to the free surface oscillation measured at the seaward boundary in the presence of a coastal structure. However, this seaward boundary condition has been found to produce spurious long-period oscillations in the computation domain (Packwood, 1980).

- ISAVA = integer indicating the storage of the spatial variations of  $\eta$  and u in the computation domain at specified time levels if ISAVA = 1.
- ISAVB = integer indicating the storage of the temporal variation of h at specified nodes if ISAVB = 1.
- ISAVC = integer indicating the storage of the temporal variation of the displacement  $X_a$  given by Eq. 81a from specified initial nodal locations if ISAVC = 1.

# /IDREQ/ integers used for the special storage of the spatial variations of specified quantities:

- IREQ = integer indicating the option of the special storage, where IREQ =
   0 for no special storage; and IREQ = 1 for the special storage.
- IELEV = integer indicating the storage of the spatial variation of  $\eta$  at specified time levels if IELEV = 1.
- IV = integer indicating the storage of the spatial variation of u at specified time levels if IV = 1.
- IDUDT = integer indicating the storage of the spatial variation of du/dt given by Eq. 61 at specified time levels if IDUDT = 1.
- ISNR = integer indicating the storage of the spatial variation of  $N_{\rm R}$  given by Eq. 67 at specified time levels if ISNR = 1.

- NNREQ = number of the specified time levels at which the spatial variations of the requested quantities are stored. It is required that  $1 \leq \text{NNREQ} \leq \text{N5}$ .
- NREQ(i) = specified time levels with  $i=1,2,\ldots$ , NNREQ at which the spatial variations of the requested quantities are stored.

# /TLEVEL/ integers indicating specific time levels and time steps:

- •NTOP = last time level for the time-marching computation performed for the duration  $0 \le t \le \Delta t$  NTOP.
- •NONE = even number of time steps in one wave period where NONE =  $1/\Delta t$ .
- •NJUM1 = integer indicating the storage of the temporal variations of h and  $X_a$  every NJUM1 time steps if ISAVB = 1 and ISAVC = 1, respectively. NONE/NJUM1 must be an integer.
- NJUM2 = integer indicating the computation of  $N_R$  given by Eq. 67 every NJUM2 time steps if ISTAB = 1. NONE/NJUM2 must be an integer.
- NSAVA = time level at the beginning of the storage of the spatial variations of  $\eta$  and u if ISAVA = 1.
- NSTAB = time level when the computation of armor stability or movement begins if ISTAB = 1 or 2.
- NSTAT = time level at the beginning of the computation of the statistics such as the mean, maximum and minimum values after the establishment of the periodicity of the computed temporal variations.
- NTIMES = integer indicating the storage of the spatial variations of  $\eta$  and u NTIMES times at equal intervals from the time level NSAVA to the time level NTOP if ISAVA = 1.

# /NODES/ integers used to indicate specific nodal locations:

- S = integer s indicating the wet node next to the moving waterline at  $t=(n-1)\Delta t \text{ such that } h_S>\delta \text{ and } h_{S+1}\leq \delta \text{ except that } S=JE \text{ for }$   $IJOB=3 \text{ as discussed below.} \quad \text{It is required that } 1\leq S\leq N1.$
- JE = integer indicating the most landward node  $j_e$  of the structure geometry specified as input, where it is required that  $JE \leq N1$ . If IJOB = 1, S < JE all the time. If IJOB = 2, wave overtopping occurs when S = JE. If IJOB = 3, S is taken to be equal to the node JE at the landward boundary of the computation.
- JE1 = (JE-1)
- JSTAB = largest node number at each time level for which the computation
   of armor stability or movement is performed. JSTAB is taken as
   the largest node number based on DELTAR(1) in the subroutine
   LANDBC, although this can be modified easily.

# /GRID/ time step; grid size and related quantities:

- T = constant time step  $\Delta t$  used for the discretization of Eq. 15.
- X = constant space size  $\Delta x$  used for the discretization of Eq. 15.
- TX =  $\Delta t/\Delta x$
- XT =  $\Delta x/\Delta t$
- TTX =  $(\Delta t)^2/\Delta x$
- TTXX =  $(\Delta t)^2/(\Delta x)^2$
- TWOX =  $2\Delta x$

## /WAVE1/ dimensional incident wave characteristics:

- HREFP = representative wave height  $H_{\Gamma}'$  introduced in Eqs. 3-5 for the normalization of the governing equations.
- TP = representative wave period  $T_{r}'$  introduced in Eqs. 3-5 for the normalization of the governing equations.
- WLOP = dimensional deep water wavelength  $L'_0$  defined as  $L'_0 = gT'_r^2/2\pi$ .

# /WAVE2/ dimensionless incident wave characteristics:

- KS = normalized wave height,  $K_S = H'/H'_T$ , at the seaward boundary located at x = 0 where H' = wave height at x = 0.
- KSREF = shoaling coefficient,  $H'_r/H'_o$ , at the location where  $H'_r$  and  $T'_r$  are specified. It is noted that  $H'_o$  is the corresponding deep water wave height.
- KSSEA = shoaling coefficient,  $H'/H'_0$ , at the seaward boundary. It is noted that IBREAK requires only KS = KSSEA/KSREF. If  $H'_r$  = H', KS = 1 since KSSEA = KSREF.
- WLO = normalized deep water wavelength  $L_o$  given by  $L_o = L_o^\prime/d_t^\prime$  where  $d_t^\prime$  = water depth below SWL at the seaward boundary.
- WL = normalized wavelength L defined as L = L'/d'\_t with L' = dimensional wavelength at the seaward boundary based on linear wave theory except that the computed value of L is subsequently replaced by the value based on choidal wave theory if IWAVE = 1 and  $U_r \geq 26$ .
- UR = Ursell parameter  $U_r$  at the seaward boundary defined as  $U_r = (H'L'^2/d_t'^3) = (K_sL^2/d_t)$  based on linear wave theory except that the computed value of  $U_r$  is subsequently replaced by the value based on cnoidal wave theory if IWAVE = 1 and  $U_r \ge 26$ .

- URPRE = value of  ${\rm U_{r}}$  based on linear wave theory used to decide whether cnoidal or Stokes second-order wave theory is applied if IWAVE = 1.
- KSI = surf similarity parameter  $\xi$  defined as  $\xi = \sigma \tan\theta_{\xi}'/\sqrt{2\pi} = \tan\theta_{\xi}'/(H_{r}'/L_{0}')^{1/2}$  where  $\tan\theta_{\xi}' = \text{slope specified as input to define}$  the surf similarity parameter for a specific structure.
- SIGMA = dimensionless parameter  $\sigma$  defined as  $\sigma = T_r'(g/H_r')^{1/2}$ .

# /WAVE3/ normalized free surface elevations as a function of t:

- ETA(n) = time series with n = time level and n ≤ N2 of the free surface
   profile at the seaward boundary which is specified in the
   subroutine INPUT2 if IWAVE ≥ 2 or computed in the subroutine INWAV
   if IWAVE = 1.
- ETAIS( $n_S$ ) = time series of the incident wave train  $\eta_1$  at x=0 stored such that  $n_S$  = [(t/ $\Delta$ t) NSTAT + 1] where t = normalized time. It is required that  $n_S \le N2$ .
- ETARS( $n_{\rm S}$ ) = time series of the reflected wave train  $\eta_{\rm T}$  at x=0 stored in the same way as  $\eta_{\rm I}$  at x=0.
- ETATS  $(n_s)$  = time series of the transmitted wave train  $\eta_t$  at x=x<sub>e</sub> stored in the same way as  $\eta_i$  at x=0 if IJOB = 3.

# /WAVE4/ normalized maximum and minimum free surface elevations:

- ETAMAX = maximum value of the specified or computed time series ETA(n).
- ETAMIN = minimum value of the specified or computed time series ETA(n).

## /WAVE5/ parameters related to cnoidal wave theory:

- KCNO = complete elliptic integral of the first kind, K(m), used in Eqs. 31-34.
- ECNO = complete elliptic integral of the second kind, E(m), used in Eqs. 32-34.
- MCNO = parameter m computed from Eq. 34.
- KC2 = value of (1-m) used to compute the values of K(m) and E(m) using the function CEL.

## /BOT1/ dimensional parameters related to the structure:

- DSEAP = water depth  $d'_t$  below SWL at the seaward boundary.
- DLANDP = water depth  $d_e^\prime$  below SWL at the landward boundary used for IJOB = 3 only.
- FWP = constant friction factor f' used in Eq. 2.

### /BOT2/ normalized parameters related to the structure:

- DSEA = normalized water depth,  $d_t = d_t'/H_r'$ , at the seaward boundary.
- DSEAKS =  $d_t/K_s$  corresponding to the value of  $d_t'/H'$ .
- DSEA2 = normalized group velocity  $d_{\text{t}}^{1/2}$  at x = 0 based on linear long wave theory.
- DLAND = normalized water depth,  $d_e = d_e^\prime/H_r^\prime$ , at the landward boundary for IJOB = 3.
- DLAND2 = normalized group velocity  $d_e^{1/2}$  at  $x=x_e$  based on linear long wave theory.
- FW = normalized friction factor f given by  $f = \sigma f'/2$  and introduced in Eq. 7.
- TSLOPS = slope  $\tan \theta_{\xi}'$  used to define the surf similarity parameter  $\xi$  .

• WTOT = normalized horizontal width,  $(j_e^{-1})\Delta x$ , of the computation domain.

# /BOT3/ vectors related to the normalized structure geometry:

- U2INIT(j) = normalized water depth below SWL at the node j with  $j{=}1,2,\ldots, \text{JE located on the structure surface, corresponding to}$  the value of -z where z is given by Eq. 8.
- THETA(j) = dimensionless gradient of the slope,  $\theta_j$ , at the node j where  $\theta$  is defined in Eq. 5.
- SSLOPE(j) =  $\sin \theta_j'$  where  $\theta_j'$  = local angle of the slope at the node j required for the computation of armor stability and movement.
- XB(j) = normalized x-coordinate of the node j located on the structure surface.
- ZB(j) = normalized z-coordinate of the node j, corresponding to the normalized structure geometry given by Eq. 8.

# /BOT4/ input parameter for the structure geometry:

- NBSEG = number of linear segments of different inclinations used to specify the structure geometry. It is required that  $1 \le \text{NBSEG} \le (\text{N}4-1)$ .
- /BOT5/ dimensional quantities associated with linear segments of the structure:
  - WBSEG(i) = horizontal width of the segment i with i=1,2,...,NBSEG where the segment number i increases landward.
  - TBSLOP(i) = tangent of the slope of the segment i which is negative if the slope is downward in the landward direction.

- XBSEG(i) = horizontal distance from the seaward boundary located at x'=0 to the seaward end of the segment i.
- ZBSEG(i) = vertical distance below SWL at the seaward end of the segment i
  which is negative if the end point is located above SWL.

# /HYDRO/ hydrodynamic quantities computed by the numerical model:

- U(k,j) =values of the components of the vector  $U_j$  defined in Eq. 16 at the node j such that  $U(1,j)=m_j$  and  $U(2,j)=h_j$  where m= normalized volume flux per unit width; and h= normalized water depth below the instantaneous free surface.
- V(j) = value of the normalized depth-averaged velocity,  $u_j = m_j/h_j$ , at the node j.
- ELEV(j) = value of the normalized free surface elevation  $\eta_{\, j}$  above SWL at the node j.
- C(j) = value of  $c_j = h_j^{1/2}$  defined in Eq. 11 at the node j.
- DUDT(j) = value of the normalized fluid acceleration du/dt given by Eq. 61 at the node j.

# /MATRIX/ elements of matrices used in the numerical model:

- Al(k,j) = values of the elements of the first row of the matrix  $A_j$  defined by Eq. 19 at the node j such that Al(1,j) = 2u<sub>j</sub> and Al(2,j) =  $(h_j u_j^2)$ .
- F(k,j) = values of the elements of the vector  $F_j$  defined in Eq. 16 at the node j such that F(1,j) =  $(m_j u_j + 0.5 h_j^2)$  and F(2,j) =  $m_j$ .
- G1(j) = value of the non-zero element of the vector  $G_j$  defined in Eq. 16 at the node j such that G1(j) =  $\theta_j h_j + f|u_j|u_j$ .

- GJR(k,j) = values of the elements with k=1 and 2 of the vector  $\mathbf{g}_j$  defined by Eq. 18 at the node j.
- S1(j) = value of the non-zero element of the vector  $S_j$  given by Eq. 20 at the node j such that S1(j) =  $\Delta x e_j 0.5 \theta_j (m_{j+1} m_{j-1})$  where  $e_j$  is given by Eq. 21.
- D(k,j) = values of the elements with k=1 and 2 of the vector  $D_j$  defined by Eq. 22 at the node j.

## /RUNP1/ input parameter for wave runup computation:

• NDELR = number of different values of the physical water depth  $\delta_T'$  associated with the measured or visual waterline for which the normalized free surface elevation  $Z_T$  is computed as discussed in relation to wave runup. It is required that  $1 \leq \text{NDELR} \leq \text{N3}$ .

# /RUNP2/ quantities related to wave runup:

- DELRP(i) = different values of  $\delta_r'$  with  $1 \le i \le \text{NDELR}$  specified as input such that DELRP(i) < DELRP(i+1).
- DELTAR(i) = normalized water depth,  $\delta_r = \delta_r'/H_r'$ , corresponding to the different values of  $\delta_r'$ . It is required that  $\delta_r \geq \delta$  where the small value  $\delta$  is used to define the computational waterline.
- RUNUPS(i) = normalized free surface elevation  $Z_r$  above SWL at the location of  $h=\delta_r$  at each time level, where RUNUPS(i) corresponds to DELTAR(i).
- RSTAT(k,i) = mean, maximum and minimum values of RUNUPS(i) during the time levels between NSTAT and NTOP indicated by k=1,2 and 3, respectively.

#### /OVER/ quantities related to wave overtopping:

• OV(k) = quantities calculated from the computed values of m at  $x=x_e$  during the time levels between NSTAT and NTOP if IJOB=2, where OV(1) = Q given by Eq. 45; OV(2) = normalized time when the value of m at  $x=x_e$  is the maximum; OV(3) = normalized duration of wave overtopping; and OV(4) = maximum value of m at  $x=x_e$ . The normalized time and duration are taken to be relative to the duration from the time level NSTAT to the time level NTOP.

#### /COEFS/ reflection and transmission coefficients:

- RCOEF(k) = wave reflection coefficients defined by Eqs. 37, 38 and 39 for k=1, 2 and 3, respectively.
- TCOEF(k) = wave transmission coefficients defined by Eqs. 48, 49 and 50 for k=1, 2 and 3, respectively.

# /STAT/ statistics of the hydrodynamic quantities computed during the time levels between NSTAT and NTOP:

- ELSTAT(i) = time-averaged values  $\overline{\eta_i}$ ,  $\overline{\eta_r}$  and  $\overline{\eta_t}$  calculated from ETAIS( $n_s$ ), ETARS( $n_s$ ) and ETATS( $n_s$ ) for i=1, 2 and 3, respectively.
- UlSTAT(j) = mean value of  $m_j$  at the node j.
- ESTAT(k,j) = mean, maximum and minimum values of  $\eta_j$  at the node j indicated by k=1, 2 and 3, respectively.
- VSTAT(k,j) = mean, maximum and minimum values of  $u_j$  at the node j indicated by k=1, 2 and 3, respectively.

#### /ENERG/ quantities related to wave energy:

- ENER(i,j) = quantities related to the time-averaged energy equation expressed by Eq. 55 which are computed during the time levels between NSTAT and NTOP, where ENER(k,j) with i=1, 2, 3 and 4 correspond to the values of  $\overline{E}$ ,  $\overline{E_F}$ ,  $\overline{D_f}$  and  $\overline{D_B}$  at the node j, respectively.  $\overline{E}$ ,  $\overline{E_F}$  and  $\overline{D_f}$  are the time-averaged values of  $\overline{E}$ ,  $\overline{E_F}$  and  $\overline{D_f}$  is computed using Eq. 55.
- ENERB(k) = quantities related to the time-averaged energy balance in the computation domain expressed by Eq. 56, where ENERB(1) =  $\overline{E_F}(x=0)$ ; ENERB(2) =  $\overline{E_F}(x=x_e)$  which is zero if IJOB = 1; ENERB(3) =  $\int_0^{x_e} \overline{D_f} dx$ ; ENERB(4) =  $\int_0^{x_e} \overline{D_B} dx$ ; ENERB(5) = left hand side of Eq. 56; ENERB(6) = right hand side of Eq. 56, ENERB(7) = difference between the right and left hand sides of Eq. 56; ENERB (8) = percentage error defined as  $100 \times \text{ENERB}(7)/\text{ENERB}(5)$ ; ENERB(9) =  $d_t^{1/2} \frac{1}{\eta_1}$ ; ENERB(10) =  $d_t^{1/2} \frac{1}{(\eta_T \overline{\eta_T})^2}$ ; ENERB(11) =  $d_e^{1/2} \frac{1}{(\eta_T \overline{\eta_T})^2}$  only for IJOB = 3; ENERB(12) = right hand side of Eq. 58; ENERB(13) = percentage error in the approximate expression given by Eq. 58; and ENERB(14) = percentage error in the approximate expression given by Eq. 58; the uncertainties associated with the computed reflection and transmission coefficients.

# /STAB1/ input parameters related to armor stability and movement:

- C2 = area coefficient  $C_2$  of the armor unit.
- C3 = volume coefficient  $C_3$  of the armor unit.

- CD = drag coefficient  $C_D$  used in Eq. 71.
- CL = lift coefficient  $C_L$  used in Eq. 72.
- CM = inertia coefficient  $C_M$  used in Eq. 73.
- SG = specific gravity s<sub>g</sub> of the armor unit.
- TANPH1 =  $tan\phi$  with  $\phi$  = frictional angle of the armor unit.
- AMIN = parameter  $a_{\min}$  specified as input. The condition for  $a_{\min}$  given in Eq. 70 needs to be satisfied if ISTAB = 1.
- AMAX = parameter  $a_{max}$  specified as input. The condition for  $a_{max}$  given by Eq. 70 needs to be satisfied if ISTAB = 1.
- DAP = characteristic length d' of the armor unit defined in Eq. 76 which needs to be specified as input if ISTAB = 2.

# /STAB2/ computed parameters related to armor stability and movement:

- SG1 =  $(s_g-1)$  used in Eqs. 74 and 75.
- CTAN(j) = value of  $\cos\theta'_j$  tan $\phi$  at the node j where  $\theta'_j$  = local angle of the slope at the node j.

# /STAB3/ armor stability parameters used in the subroutine STABNO:

- CSTAB1 =  $2 C_3^{2/3}/(C_2C_D)$  used in Eq. 64.
- CSTAB2 =  $C_{M}/[(s_{g}-1) \sigma]$  used in Eq. 64.
- AMAXS =  $\sigma$  a used in Eq. 69.
- AMINS =  $\sigma$  a<sub>min</sub> used in Eq. 69.
- E2 =  $C_L \tan \phi / C_D$  used in Eq. 65.
- E3PRE(j) = value of 2  $C_3^{2/3} \cos \theta_j' \tan \phi/(C_2 C_D)$  at the node j used in Eq. 66.

# /STAB4/ armor movement parameters used in the subroutine MOVE:

- CSTAB3 =  $C_2C_D/(2C_3d)$  used in Eq. 71.
- CSTAB4 =  $C_2C_L/(2C_3d)$  used in Eq. 72.
- CM1 =  $(C_M 1)$  = added mass coefficient  $C_m$  used in Eq. 79.
- DA = normalized characteristic length d of the armor unit defined in Eq. 76.
- SIGDA =  $\sigma/d$  used in Eq. 81a.
- WEIG =  $\sigma(s_g 1)$  used in Eqs. 74 and 75.

# /STAB5/ node number and time levels related to armor stability:

- JSNSC = node number j where the critical stability number  $N_{\rm SC}$  for initiation of armor movement occurs.
- $\bullet$  NSNSC = time level n when the critical stability number  $N_{\mbox{\scriptsize SC}}$  for initiation of armor movement occurs.
- NSNSX(j) = time level n when the local stability number  $N_{SX}(x)$  at the node j occurs.

# /STAB6/ stability numbers for initiation of armor movement:

- SNSC = critical stability number  $N_{SC}$  defined as the minimum value of  $N_{SX}(x)$  with respect to x.
- SNR(j) = value of armor stability function  $N_R(t,x)$  at the node j and at the time  $t=n\Delta t$  computed during the time levels from n=NSTAB to n=NTOP if ISTAB=1.
- SNSX(j) = value of the local stability number  $N_{\rm SX}(x)$  at the node j defined as the minimum value of  $N_{\rm R}(t,x)$  at the node j.

### /STAB7/ integers related to armor movement:

- NMOVE = number of armor units moved from their initial locations where armor movement is computed during the time levels between NSTAB and NTOP if ISTAB = 2.
- · NSTOP = number of armor units stopped after their movement.
- ISTATE(j) = integer indicating the state of the armor unit initially
  located at the node j, where ISTATE(j) = 0, 1 or 2 depending on
  whether the armor unit is stationary, moving or stopped,
  respectively.
- NODIN(j) = node number at the initial location of the armor unit which
  must be equal to the node number j.
- NODFI(j) = node number closest to the armor unit at the end of each time step where each armor unit is identified by the node number j at the initial location of the armor unit.
- NDIS(j) = time level n when the armor unit identified by the node number j
  has started moving.

# /STAB8/ normalized velocity and displacement of moving or stopped armor units:

- VA(j) = normalized velocity  $u_a$  of the armor unit located initially at the node j which is computed using Eq. 79.
- XAA(j) = normalized displacement  $X_{aa}$  defined by Eq. 81b of the armor unit from its initial location at the node j.
- XA(j) = normalized displacement  $X_a$  defined by Eq. 81a of the armor unit from its initial location at the node j.

- /FILES/ file names and associated node numbers for ISAVB = 1 and ISAVC = 1:
  - NNOD1 = number of nodes where the temporal variation of h is stored if  $ISAVB = 1. \quad It is required that 1 \leq NNOD1 \leq N5.$
  - NNOD2 = number of nodes for which the temporal variation of the normalized displacement  $X_a$  is stored if ISAVC = 1. It is required that  $1 \le NNOD2 \le N5$ .
  - NODNO1(i) = i-the node number with  $i=1,2,\ldots,NNOD1$  where the temporal variation of h is stored.
  - NODNO2(k) = k-the node number with  $k=1,2,\ldots$ , NNOD2 for which the temporal variation of  $X_a$  is stored.
  - FNAME1(i) = file name associated with NODNO1(i).
  - FNAME2(k) = file name associated with NODNO2(k).
- /VALUEN/ values at the time  $t = (n-1)\Delta t$  stored at the beginning of each time step:
  - VSN =  $u_S$  used at the landward boundary computation.
  - USN(i) =  $U_S$  such that USN(1) =  $m_S$  and USN(2) =  $h_S$  used at the landward boundary computation.
  - VMN =  $u_{S-1}$  used at the landward boundary computation.
  - UMN(1) =  $m_{S-1}$  used at the landward boundary computation.
  - V1N =  $u_1$  used in Eq. 35.
  - V2N =  $u_2$  used in Eq. 35.

#### Input Parameters and Variables

The input parameters and variables are summaries in the sequence of the data input in IBREAK. First, the name of the primary input data file, FINP1, is read in the Main Program as follows:

```
WRITE(*,*) 'Name of Primary Input-Data-File?'
READ(*,5000) FINP1
5000 FORMAT(A20)
```

where some of the write statements are discussed here for convenience.

Almost all the input data are read in the subroutine INPUT1 from the input data file with its unit number = 11 and its file name = FINP1 as explained in the subroutine OPENER. The data input in the subroutine INPUT1 begins with the following comment lines:

```
READ(11,1110) NLINES
DO 110 I=1, NLINES
READ(11,1120) (COMMEN(J), J=1, 14)
WRITE(28,1120) (COMMEN(J), J=1, 14)
WRITE(29,1120) (COMMEN(J), J=1, 14)
110 CONTINUE
```

where NLINES = number of the comment lines proceeding the input data. The unit numbers 28 and 29 correspond to the file names ODOC and OMSG in the subroutine OPENER. The file ODOC stores the essential output for the concise documentation, while the file OMSG stores the messages written under special circumstances during the computation. The format statements used in the subroutine INPUT1 are listed in Table 2.

TABLE 2 - Format Statements Used in Subroutine INPUT1.

```
1110 FORMAT
              (18)
1120
              (14A5)
     FORMAT
1130
     FORMAT
              (211, 18)
1140 FORMAT
              (I1)
1150 FORMAT
             (I1, 2X, A20)
1160 FORMAT
              (311, 18, 314)
1170 FORMAT
             (511, 16)
1180 FORMAT
             (3F13.6)
1190 FORMAT
             (I6, 2X, A20)
```

The integers indicating the user's options and the related time levels and node locations are then read in the subroutine INPUT1.

```
READ(11,1130) IJOB, ISTAB, NSTAB
READ(11,1140) ISYST
READ(11,1140) IBOT
READ(11,1140) INONCT
READ(11,1140) IENERG
READ(11,1150) IWAVE, FINP2
READ(11,1160) ISAVA, ISAVB, ISAVC, NSAVA, NTIMES, NNOD1, NNOD2
READ(11,1170) IREQ, IELEV, IV, IDUDT, ISNR, NNREQ
```

where IJOB, ISTAB, ISYST, IBOT, INONCT, IENERG, IWAVE, ISAVA, ISAVB and ISAVC are explained in the common /ID/, whereas NSTAB, NSAVA and NTIMES are discussed in the common /TLEVEL/. On the other hand, NNOD1 and NNOD2 are explained in the common /FILES/, while IREQ, IELEV, IV, IDUDT, ISNR and NNREQ are discussed in the common /IDREQ/. If IWAVE=2 or 3, the file name FINP2 containing the data on the wave profile at the seaward boundary needs to be specified as input. The specified options are checked in the subroutine CHEOPT which writes the appropriate error message and correction instruction for each input parameter. If IREQ=1, at least one of IELEV, IV, IDUDT and ISNR must be unity. Furthermore, IDUDT=0 if ISTAB=0 and ISNR=0 if ISTAB ≠ 1. If IREQ=1, the following input is required:

READ(11,1110) (NREQ(I), I=1, NNREQ)

where NREQ is explained in the common /IDREQ/.

Some of the integers included in the common /TLEVEL/ are read as input

```
READ(11,1110) NTOP
READ(11,1110) NONE
READ(11,1110) NJUM1
```

The value of NSTAT is taken as NSTAT = (NTOP - NONE + 1) if IWAVE=1 corresponding to incident monochromatic waves, and NSTAT = NSAVA if IWAVE = 2 or 3. Furthermore, if ISAVA=0, NSAVA = (NTOP + 1) which has the same effect as ISAVA=0. Likewise, NSTAB = (NTOP + 1) if ISTAB=0. For incident monochromatic waves with IWAVE=1, use has been made of NTOP = NONE × (tp + 1), NSTAB = (NTOP - NONE + 1), NSAVA = (NTOP - NONE), NTIMES = 5 and NJUM1 - (NONE/100) where tp = normalized time when the periodicity is established. For coastal structures, tp = 4 and NONE = 2000 have been used typically. The computation of the armor stability has been made during the last wave period after the establishment of the periodicity. The spatial variations of  $\eta$  and u have been stored at the normalized time t = tp, (tp + 1/4), (tp + 1/2), (tp + 3/4) and t = (tp + 1) where the spatial variations of  $\eta$  and u must be the same at t = tp and (tp + 1) after the establishment of the periodicity.

Next, the following parameters are read:

```
READ(11,1110) S
READ(11,1180) FWP
READ(11,1180) X1, X2
READ(11,1180) DELTA
READ(11,1110) NDELR
DO 120 L=1, NDELR
READ(11,1180) DELRP(L) (units: mm or in)
120 CONTINUE
```

where DELTA, X1 and X2 are explained in the common /CONSTA/, whereas FWP is discussed in the common /BOT1/. The integer S included in the common /NODES/

is specified as input. The value of S specified as input corresponds to the number of spatial nodes from the seaward boundary to the wet node next to the initial waterline at SWL if IJOB = 1 or 2, whereas the input value of S is the number of spatial nodes from the seaward boundary to the landward boundary if IJOB = 3. On the other hand, NDELR and DELRP are explained in the common /RUNP1/ and /RUNP2/, respectively. If IJOB=3, NDELR=0 indicating no computation of wave runup. The physical values of DELRP(L) with  $1 \le L \le NDELR$  need to be specified in millimeters if ISYST = 1 and in inches if ISYST = 2 as indicated above.

The incident wave characteristics are specified as follows:

```
READ(11,1180) HREFP (units: m or ft), TP (units: sec)
READ(11,1180) KSREF, KSSEA
```

where HREFP and TP are explained in the common /WAVE1/, whereas KSREF and KSSEA are discussed in the common /WAVE2/. The value of TP is read in seconds, while the value of HREFP is read in meters if ISYST=1 and in feet if ISYST=2.

The input parameters related to the structure geometry are read as follows:

```
READ(11,1180) DSEAP (units: m or ft)
READ(11,1180) TSLOPS
READ(11,1110) NBSEG
```

where DSEAP, TSLOPS and NBSEG are explained in the common /BOT1/, /BOT2/ and /BOT4/, respectively. The dimensional quantities of the linear segments used to describe the structure geometry are explained in the common /BOT5/ as well as in Fig. 4. If IBOT=1, the width and slope of each segment need to be read as input.

```
DO 130 K=1, NBSEG
READ(11,1180) WBSEG(K) (units: m or ft), TBSLOP(K)
130 CONTINUE
```

On the other hand, if IBOT=2, the locations of the end points of the segments need to be read as input.

```
DO 140 K=1, NBSEG+1
READ(11,1180) XBSEG(K), ZBSEG(K) (units: m or ft)
140 CONTINUE
```

The dimensional quantities DSEAP, WBSEG(K), XBSEG(K) and ZBSEG(K) are read in meters if ISYST=1 and in feet if ISYST=2.

If ISAVB=1, the following quantities explained in the common /FILES/ need to be read as input:

```
DO 150 I=1, NNOD1
READ(11,1190) NODNO1(I), FNAME1(I)
150 CONTINUE
```

If ISTAB=1 or 2, the following parameters explained in the commons /TLEVEL/ and /STAB1/ need to be read as input:

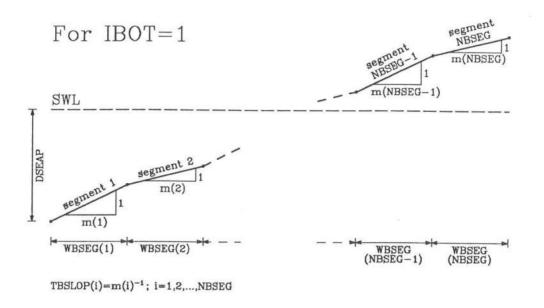
READ(11,1110) NJUM2
READ(11,1180) C2, C3, SG
READ(11,1180) CD, CL, CM
READ(11,1180) TANPHI
READ(11,1180) AMAX, AMIN

where AMAX and AMIN are used only for ISTAB=1.

If ISTAB=2, the characteristic length of the armor unit needs to be specified as well

READ(11,1180) DAP (units: m or ft)

where DAP is read in meters if ISYST=1 and in feet if ISYST=2.



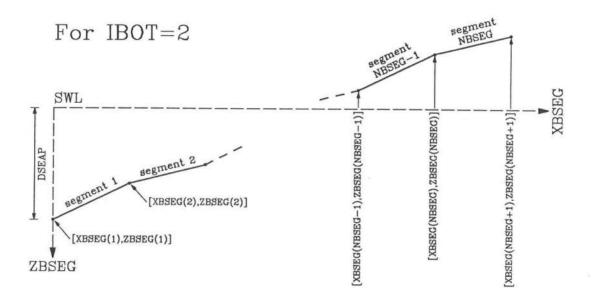


Figure 4. Input of Dimensional Structure Geometry for IBOT = 1 and 2

If ISAVC=1, the following quantities explained in the common /FILES/ needs to be read as input:

This is the end of the data input in the subroutine INPUT1.

If IWAVE=2 or 3, the time series associated with the normalized wave profile at the seaward boundary as explained in the commons /ID/ and /WAVE3/ are read from the file with its unit number = 12 and its file name = FINP2 in the subroutine INPUT2

The number of the data points read is written on the file OMSG with its unit number = 29 as explained in the subroutine OPENER. The time series read as input are reduced such that ETA(I) with I=1,2,...,NTOP where NTOP/NICE is an integer and NICE=500 is specified in the parameter statement of the subroutine INPUT2.

Finally, the numerical stability indicator ALPHAS is computed in the subroutine DOC1 before the time marching computation. This indicator is defined as

ALPHAS = 
$$\frac{\Delta x}{\Delta t} (1 + d_t^{1/2})^{-1} \left[ \left[ 1 + \frac{\epsilon^2}{4} \right]^{1/2} - \frac{\epsilon}{2} \right]$$
 (82)

The numerical stability criterion given by Eq. 27 requires that the value of ALPHAS should be greater than about unity where  $\left|u_{m}\right|=1$  and  $c_{m}=d_{t}^{1/2}$  are assumed in Eq. 27. As a result, the conditional stop before the time-marching computation is included in the subroutine DOC1 as follows:

```
WRITE(*,6010) ALPHAS
WRITE(*,6020)
READ(*,*) ISTOP
IF (ISTOP.EQ.1) STOP
6010 FORMAT ('Numerical stability indicator =', F7.2)
6020 FORMAT ('Time-marching computation is about to begin'/'l = stop here, else = proceed')
```

If ALPHAS < 1, it is suggested to increase the value of NONE =  $\Delta t^{-1}$  specified as input since the numerical instability is likely to occur during the timemarching computation.

#### Error and Warning Statements

The computer program IBREAK includes various error and warning statements, some of which have been discussed in relation to the data input for convenience.

In the main program of IBREAK, if the normalized water depth  $h_j = \text{U}(2,J)$  < 0, the following statement is written and the computation stops:

```
WRITE(*,2910) U(2,J), J, S, N
WRITE(29,2910) U(2,J), J, S, N
2910 FORMAT (/'From Main Program: Negative water depth
=',D12.3/'J=',I8,';S=',I8,';N=',I8)
```

where J = node number; S = waterline node number; and N = time level. Furthermore, if  $\left|u_{j}\right| > (\Delta x/\Delta t)$ , the following warning statement is written

```
WRITE(*,2920) V(J),XT,J,S,N

WRITE(29,2920) V(J),XT,J,S,N

2920 FORMAT(/'From Main Program: Abs(V(J)) > (X/T):','V(J)=',

D12.3,';X/T=',D12.3/'J=',18,';S=',18,';N=',18)
```

where V(J) = normalized fluid velocity  $u_j$ ; and  $XT = \Delta x/\Delta t$ . It may be shown that the numerical stability criterion given by Eq. 27 is violated if  $|u_j|$  >

 $(\Delta x/\Delta t)$ . In order to inform the progress of the time-marching computation, the following statement is written whenever the value of the time level N divided by 500 is an integer:

WRITE(\*,\*) 'N', N

Moreover, whenever IDUM = N/NONE is an integer, the following statement appears:

WRITE(\*,\*) 'Finished', IDUM, 'Wave Period(s)'

In the subroutine INPUT1, if none of IELEV, IV, IDUDT and ISNR are unity for the case of IREQ=1, the subroutine STOPP is called to write, 'Special storage requested, but pertinent identifiers not specified correctly. Check identifiers IREQ, IELEV, IV, IDUDT, ISNR.' Then, the computation stops.

Furthermore, the computation stops if the subroutine CHEOPT finds an input error in the options specified by a user. If ISTAB=2 and ISAVC=1, the number of the elements of the vectors NODNO2(I) and FNAME2(I) must be the same as NNOD2. The subroutine STOPP is called to write 'Need more data' if the number of the elements of these vectors is less than NNOD2.

In the subroutine BOTTOM, the computation stops if the structure geometry specified as input is not consistent with the specified value of IJOB. If IJOB=1 or 2, the structure must be subaerial. Otherwise, the subroutine STOPP is called to write 'SWL is always above the structure. RUNUP/OVERTOPPING computation can not be performed.' If IJOB=3, the structure must be submerged. Otherwise, the subroutine STOPP is called to write 'Part of the structure is above SWL. TRANSMISSION computation can not be performed.'

Furthermore, if the number of nodes in the computation domain, JE, becomes greater than N1 = 500 specified in IBREAK, the following statement is written:

WRITE(\*,2910) JE, N1
WRITE(29,2910) JE, N1
2910 FORMAT (/'End Node=', I8,'; N1=', I8/'Slope/Structure is too long.'/'Cut it, or change PARAMETER N1.')

It is noted that N1=500 should be sufficient for most applications where the values of JE in the range from 100 to 300 have been used.

In the subroutine FINDM, the following statement appears if the parameter m satisfying Eq. 34 is not obtained:

WRITE(\*,2910)
WRITE(29,2910)
2910 FORMAT('From Subr. 9 FINDM: '/'Criterion for parameter M not satisfied')

In the function CEL, the following statement appears if QQC =  $(1-m)^{1/2}$  equals zero where the value of m is obtained in the subroutine FINDM:

WRITE(\*,\*) 'Failure in Function CEL' WRITE(29,\*) 'Failure in Function CEL'

which stops the computation.

In the subroutine MARCH, the computation stops if  $h_{S-1}^* \leq \delta$ , corresponding to the third step in the numerical procedure dealing the moving waterline. The following statement is written:

WRITE(\*,2910) U(2,M), DELTA, S, N
WRITE(29,2910) U(2,M), DELTA, S, N

2910 FORMAT (/'From Subroutine 12 MARCH'/'U(2,S-1) is less than or equal to DELTA'/'U(2,S-1) =',D12.3/'DELTA =',D12.3/'S=',I8/'N=',
I8/'Program Aborted')

where  $U(2,M) = h_{S-1}^*$ ; DELTA =  $\delta$ ; S = waterline node number s; and N = time level. It is suggested to increase the value of NONE =  $\Delta t^{-1}$  to avoid the numerical instability which tends to occur near the moving waterline.

In the subroutine LANDBC, the following statement is written and the computation stops if IJOB=1 and  $S\geq JE$  where S = waterline node number and JE = most landward node number:

WRITE(\*,2910) N,S,JE WRITE(29,2910) N,S,JE

2910 FORMAT (/'From Subroutine 13 LANDBC:'/'N=', I8,';S=',I8, ';End Node=', I8/'Slope is not long enough to accommodate shoreline movement'/'Specify longer slope or choose overtopping computation')

This statement implies that wave overtopping over the specified structure geometry occurs even though IJOB=1 is specified. It is suggested to use IJOB=2 if the structure geometry is given or increase the crest height of the structure if no overtopping is allowed.

In the subroutine RUNUP, the following statement appears if  $h_s^* \ge h_{s-1}^*$  and the adjustment described in the fourth step of the numerical procedure dealing with the moving waterline is made:

where  $U(2,S) = h_S^*$ ; and  $U(2,M) = h_{S-1}^*$ . This statement does not stop the computation but suggests the numerical difficulty at the moving waterline which may eventually lead to the numerical instability.

In the subroutine STABNO, the following statement is written and the computation stops if the condition given by Eq. 68 is not satisfied:

WRITE(\*,2910) N,J
WRITE(29,2910) N,J
2910 FORMAT('From Subr. 19 STABNO'/'Armor Stability impossible'/'N=',
I8,';J=',I8)

where N = time level; and J = node number. This statement implies that the values of AMIN =  $a_{min}$  and AMAX =  $a_{max}$  specified as input do not satisfy the conditions given by Eq. 70.

In the subroutine DOC1, the following statement is written if the values of ALPHAS given by Eq. 82 is less than unity:

WRITE(\*,2910) ALPHAS
WRITE(29,2910) ALPHAS
2910 FORMAT(/'From Subr. 33 DOC1'/'Stability Indicator=', F9.3/'May
cause numerical instability. Increase NONE')

Furthermore, if NONE/NJUM1 and NONE/NJUM2 are not integers, the written statements instructing the changes of NJUM1 and NJUM2 appear in the manner similar to that for ALPHAS. The computation stops if the requirements for ALPHAS, NJUM1 and NJUM2 are not satisfied.

The subroutine CHEPAR checks whether the values of N1, N2, N3, N4 and N5 used to specify the sizes of matrices and vectors in the main program are equal to the corresponding values used in the subroutines. If this requirement is not satisfied, the computation stops and the instruction to correct the parameter error is written.

The subroutine CHEOPT checks the options selected by a user as well as the requirements of  $1 \le \text{NNOD1} \le \text{N5}$ ,  $1 \le \text{NNOD2} \le \text{N5}$ ,  $1 \le \text{NNREQ} \le \text{N5}$ ,  $1 \le \text{S} \le \text{N1}$ ,  $1 \le \text{NDELR} \le \text{N3}$  and  $1 \le \text{NBSEG} < \text{N4}$ . If there is an input error, the computation stops and the instruction to correct the input error is written.

The subroutine STOPP executes a programmed stop. This subroutine has already been explained when it is called in the subroutines INPUT1 and BOTTOM.

#### Output Parameters and Variables

The output of the input and computed results is made in the subroutines DOC1, DOC2 and DOC3 before, during and after the time-marching computation except that if IWAVE=1, the computed incident wave profile  $\eta_1(t)$  over one wave period is written in the subroutine INWAV as follows:

where ETA(I) =  $\eta_1(t)$  with t = (I-1) $\Delta t$  and NONE1=(NONE+1). The unit numbers and file names used in IBREAK are explained in the subroutine OPENER.

The output parameters and variables from the subroutines DOC1, DOC2 and DOC3 are summarized in the following. The format statements in these subroutines are lengthy but self-explanatory. As a result, these format statements are omitted in the following.

The subroutine DOC1 documents the input data and calculated dimensionless parameters before the time-marching computation. First, the wave conditions at the seaward boundary specified as input are written depending on whether IWAVE=1, 2 or 3. If IWAVE=1, cnoidal or Stokes second-order wave theory is used to compute  $\eta_1(t)$  in the subroutine INWAV depending on URPRE  $\geq$  26 or URPRE < 26, respectively, where URPRE is the value of the Ursell parameter based on linear wave theory. If cnoidal wave theory is used, the following output is written:

WRITE(28,2813) KC2, ECNO, KCNO

where KC2, ECNO and KCNO are explained in the common /WAVE5/ as well as in the

corresponding format statement. The following quantities explained in the commons /WAVE1/, /WAVE2/, /WAVE4/, /BOT1/ and /BOT2/ are written

WRITE(28,2816) ETAMAX, ETAMIN
WRITE(28,2817) TP, HREFP, UL, DSEAP, UL, KSREF, KSSEA, KS
WRITE(28,2818) DSEA, WL, SIGMA, UR, KSI

where UL indicates the unit (m or ft) of the quantity in front of UL. If IJOB=3, DLANDP included in the common /BOT1/ is written

WRITE(28,2819) DLANDP, UL

The quantities explained in the commons /BOT1/, /BOT2/ and /BOT4/ are then written

WRITE(28,2821) FWP, FW, WTOT, NBSEG

If IBOT=1, the width and slope of each segment of the structure as shown in Fig. 4 are written

WRITE(28,2824) (K, WBSEG(K), TBSLOP(K), K=1, NBSEG)

If IBOT=2, the coordinates of the end points of linear segments of the structure as shown in Fig. 4 are written

WRITE(28,2824) (K,XBSEG(K),ZBSEG(K),K=1,NBSEG+1)

The quantities explained in the commons /CONSTA/, /TLEVEL/, /NODES/ and /GRID/ are written

WRITE(28,2841) X,T,DELTA,X1,X2,ALPHAS WRITE(28,2842) NTOP,NONE,JE WRITE(28,2843) S WRITE(28,2844) NJUM1 WRITE(28,2845) NJUM2 where ALPHAS is defined by Eq. 82 and the input value of S is written only if IJOB=1 or 2 since S =JE for IJOB=3. The value of NJUM2 is specified as input if ISTAB=1 or 2, but it is used only for ISTAB=1 in IBREAK. If ISTAB=1 or 2, the quantities explained in the common /STAB1/ are written

```
WRITE(28,2851) TANPHI,SG,C2,C3,CD,CL,CM
WRITE(28,2851) AMAX, AMIN
WRITE(28,2853) DAP,UL
```

where AMAX and AMIN are used and written only for ISTAB=1, while DAP (m or ft) is required only for ISTAB=2. Moreover, the normalized structure geometry is written as follows:

```
WRITE(22,2210) JE
WRITE(22,2220) (XB(J),ZB(J),J=1,JE)
```

where JE is discussed in the common /NODES/, whereas XB(J) and ZB(J) are explained in the common /BOT3/.

The subroutine DOC2 stores some of the computed results at designated time levels during the time-marching computation where use is made hereafter of N = current time level, S = most landward wet node at this time level, and J = node number in the range  $1 \le J \le S$ . If ICALL=1, corresponding to the specified time levels for the case of ISAVA=1, the spatial variations of the normalized free surface elevation  $\eta$  and the normalized fluid velocity u are stored

```
WRITE(22,2210) N,S
WRITE(22,2220) (ELEV(J),V(J),J=1,S)
```

If ICALL=2 in the subroutine DOC2, the computed temporal variations of certain quantities at specified nodes are stored every NJUM1 time steps

throughout the time-marching computation. If ISAVB=1, the temporal variation of the normalized water depth h is stored

WRITE(NUNIT, 5010) N, U(2,J)

where U(2,J) = value of h at the time level N and at the node J = NODNO1(I) with  $I=1,2,\ldots,NNOD1$ , as explained in the common /FILES/, whereas the unit number NUNIT = (49 + I) as explained in the subroutine OPENER. If ISAVC=1, the temporal variation of the normalized displacement of the armor unit,  $X_a$ , defined by Eq. 81a from its initial location is stored

WRITE(NUNIT, 7510) N, XA(J)

where XA(J) = value of  $X_a$  at the time level N of the armor unit initially located at the node J = NODNO2(I) with  $I=1,2,\ldots,NNOD2$  as explained in the common /FILES/, while the unit number NUNIT = (74 + I) as explained in the subroutine OPENER. It is noted that XA(J)=0 if ISTATE(J)=0, corresponding to the stationary armor unit at the node J. Furthermore, the computed temporal variations at the landward and seaward boundaries at the time level N are stored every NJUM1 time steps throughout the time-marching computation. If IJOB=1 or 2, the following quantities at the time level N are written

WRITE(31,3110) N,S WRITE(31,3120) (RUNUPS(L), L=1, NDELR)

where NDELR and RUNUPS(L) are explained in the commons /RUNP1/ and /RUNP2/. If IJOB=2, the hydrodynamic quantities at the most landward node JE are written

WRITE(32,3210) N,U(1,JE),U(2,JE),V(JE),C(JE)

where the hydrodynamic quantities are explained in the common /HYDRO/. It is noted that if IJOB=2 and wave overtopping occurs, S=JE and the hydrodynamic quantities at the node JE are non-zero. If IJOB=3, the hydrodynamic quantities at the fixed landward boundary located at the node J=JE are written

where ETAT = value of the normalized free surface elevation  $\eta_{t}$  due to the transmitted wave. On the other hand, the quantities at the seaward boundary located at the node J=1 are written as follows:

where ETAI, ETAR and ETATOT are the values of  $\eta_i$ ,  $\eta_r$  and  $(\eta_i + \eta_r)$  at the time level N, respectively, while  $\eta_i$  and  $\eta_r$  are the normalized free surface elevations due to the incident and reflected waves, respectively.

If ICALL=3 in the subroutine DOC2, the spatial variations of the requested quantities are stored at the specified time levels N=NREQ(I) with  $I=1,2,\ldots,NNREQ$  as explained in the common /IDREQ/. If IREQ=1 and the time level N=NREQ(I) in the main program, the following quantities are stored in the subroutine DOC2:

```
WRITE(40,4010) N,S

WRITE(40,4020) (ELEV(J),J=1,S)

WRITE(40,4020) (V(J),J=1,S)

WRITE(40,4020) (DUDT(J),J=1,S)

WRITE(40,4020) (SNR(J),J=1,S)
```

where S indicates the most landward wet node at the time level N. It is noted that ELEV(J), V(J), DUDT(J) and SNR(J) are stored only if IELEV, IV, IDUDT and ISNR are unity, respectively, as explained in the common /IDREQ/.

The subroutine DOC3 documents the computed results after the timemarching computation. The reflection coefficients defined by Eqs. 37, 38 and 39 for I=1,2 and 3, respectively, are written

$$WRITE(28, 2811)$$
 (RCOEF(I), I=1,3)

If IJOB=1 or 2, the normalized runup, run-down and setup for different values of  $\delta_{\rm r}'$  as explained in the common /RUNP2/ are written

WRITE(28,2821) JMAX
WRITE(28,2822) UL
DO 110 L=1, NDELR
WRITE(28,2823) L,DELRP(L),RSTAT(2,L),RSTAT(3,L),RSTAT(1,L)
110 CONTINUE

where JMAX is the largest node number reached by the computational waterline based on h= $\delta$  and UL indicates the unit (mm or inches) of DELRP(L) =  $\delta'_{r}$ . If IJOB=2, the wave overtopping quantities explained in the common /OVER/ are written

where U1STAT(1) = value of the time-averaged flux  $\overline{m}$  at the seaward boundary which should be equal to OV(1) = value of  $\overline{m}$  at the landward edge if the steady state is really established. If ISTAB=1, the armor stability quantities explained in the commons /STAB5/ and /STAB6/ are written

```
WRITE(28,2841) SNSC,JSNSC,NSNSC
WRITE(41,4110) JMAX
WRITE(41,4120) (XB(J),ZB(J),SNSX(J),J=1,JMAX)
```

where XB(J) and ZB(J) express the normalized structure geometry as explained

in the common /BOT3/. If ISTAB=2, the armor movement quantities explained in the commons /STAB7/ and /STAB8/ are written

WRITE(28,2842) NMOVE,NSTOP
WRITE(42,4210) NMOVE
DO 120 J=1, JMAX
IF(ISTATE(J).GE.1) WRITE(42,4220)
NODIN(J),NODFI(J),NDIS(J),ISTATE(J),XB(J),ZB(J),XA(J)
CONTINUE

where the armor unit initially located at the node J is stationary, moving or stopped after its movement depending on ISTATE(J)=0, 1 or 2, respectively. On the other hand, if IJOB=3, the time-averaged values of  $\eta_{\rm i}$ ,  $\eta_{\rm r}$  and  $\eta_{\rm t}$  are written as follows:

WRITE(28,2851) (ELSTAT(I), I=1,3), DELMWL

where ELSTAT(I) is explained in the common /STAT/ and DELMWL= $(\overline{\eta_t} - \overline{\eta_r})$  is the mean water level difference at the landward and seaward boundaries. If IJOB=1 or 2, the transmitted wave is not present and the following output is made:

WRITE(28,2852) (ELSTAT(I), I=1,2)

120

Moreover, if IJOB=3, the wave transmission coefficients defined by Eqs. 48, 49 and 50 for I=1, 2 and 3, respectively, are written

WRITE(28,2861) (TCOEF(I), I=1,3)
WRITE(28,2861) U1STAT(1),U1STAT(JE),QAVER

where UISTAT(1) and UISTAT(JE) are the values of m at the seaward and landward boundaries, respectively, while QAVER is the average of these two values. The statistics of the hydrodynamic quantities explained in the common /STAT/ are written as follows:

```
WRITE(23,2310) JMAX
WRITE(23,2320) (U1STAT(J),J=1,JMAX)
DO 130 I=1,3
WRITE(23,2320) (ESTAT(I,J),J=1,JMAX)
WRITE(23,2310) (VSTAT(I,J),J=1,JMAX)
130 CONTINUE
```

Finally, if IENERG=1, the wave energy quantities explained in the common /ENERG/ are written

WRITE(28,2872) (ENERB(I),I=1,10)
IF(IJOB.EQ.3) WRITE(28,2873) ENERB(11)
WRITE(28,2874) (ENERB(I),I=12,13)
IF(IJOB.EQ.3) WRITE(28,2875) ENERB(14)
WRITE(35,3510) JMAX
DO 140 I=1,4
WRITE(35,3520)(ENER(I,J),J=1,JMAX)
140 CONTINUE

## Examples of Input and Output

In order to illustrate the input and output of the computer program IBREAK, four examples are given in the following. All these examples correspond to the case of IWAVE=1 where the normalized incident wave profile  $\eta_{\rm i}({\rm t})$  is computed using Eq. 28 or 31. Use of IWAVE=2 was made for the comparisons of the numerical model with the experiments where measured incident wave trains were used as input by Kobayashi and Greenwald (1986,1988), Kobayashi and Watson (1987), and Kobayashi et al. (1989). If the free surface oscillation is measured at the seaward boundary of the computation domain in the presence of a coastal structure, use may be made of IWAVE=3, but this seaward boundary condition, which was used by Packwood (1980), has been found to produce spurious long-period oscillations in the computation domain.

The first example is the Test No. 12 of the large-scale riprap tests for uniform slopes conducted by Ahrens (1975). The structure was subaerial with no wave overtopping, corresponding to IJOB=1. Computation is made of the hydraulic stability of armor units by setting ISTAB=1. The tables and figures showing the input and output of the first example are given in Appendix B. Reference should be made to the papers of Kobayashi et al. (1987) and Kobayashi and Otta (1987) for the comparison of the numerical model with the large-scale riprap test data of Ahrens (1975) as well as the limitations and uncertainties of the numerical model.

The second example is the Test No. 32 of the large-scale riprap tests of Ahrens (1975) and is similar to the first example, where IJOB=1 for both examples. The major difference between the first and second examples is that the movement of individual armor units is computed in this example by setting ISTAB=2. The tables and figures showing the input and output of the second example are given in Appendix C.

The third example is one test run from the extensive small-scale test data of Saville (1955) for monochromatic wave overtopping over smooth impermeable structures fronted by a 1:10 slope. The structure was subaerial with wave overtopping, corresponding to IJOB=2. The structure was not protected with armor units. As a result, use is made if ISTAB=0, resulting in no computation of armor stability and movement. The tables and figures showing the input and output of the third example are given in Appendix D. Reference should be made to the report and paper of Kobayashi and Wurjanto (1988,1989a) for the comparison of the numerical model with the extensive small-scale test data of Saville (1955) as well as the difficulty associated

with the selection of an appropriate location of the seaward boundary on the 1:10 slope.

The fourth example is one test run from the small-scale test data of Seelig (1980) for monochromatic wave transmission over a submerged smooth impermeable structure, corresponding to IJOB=3 and ISTAB=0. The tables and figures showing the input and output of the fourth example are given in Appendix E. Reference should be made to the report and paper of Kobayashi and Wurjanto (1989b,1989c) for the comparison of the numerical model with one set of the small-scale test data of Seelig (1980) as well as the discussion on the computed wave energy balance, the mean water level difference and the time-averaged volume flux per unit width.

#### PART IV: CONCLUSIONS

The computer program IBREAK presented herein simulates the interaction of normally incident waves with a rough or smooth impermeable coastal structure in the manner similar to hydraulic model tests in a wave flume. This numerical model is expected to be less accurate than hydraulic model tests performed carefully because of various assumptions and coefficients employed in the numerical model. The advantages of the numerical model are low cost, little start-up time, and high spatial and temporal resolution. During a preliminary design, the numerical model may be used together with empirical formulas, if available, to reduce the number of feasible alternatives. During a detailed design, the numerical model may be used to reduce the number of hydraulic model tests as well as to estimate the quantities which can not be measured directly. Reversely, the hydraulic model test results may be used to calibrate the empirical coefficients included in the numerical model (Kobayashi and Greenwald, 1986,1988). In short, a hybrid approach based on empirical formulas, numerical models and hydraulic model tests will improve the efficiency and reliability of the design of coastal structures.

The numerical model is presently being improved to include the effects of normally incident random waves and permeable underlayers. Additional improvements will include oblique and directional waves, the permeability of core materials, the hydraulic and geotechnical stability of the toe and foundation of a breakwater, the adjustment of the geometry of a mound structure, and the structural strength and breakage of large slender concrete armor units. Numerical models for coastal structures are very new and expected to progress rapidly.

This report is intended to make the computer program IBREAK easily accessible to coastal engineers and researchers. This report emphasizes the usage of IBREAK. Users of IBREAK are strongly recommended to read the related papers which presented more detailed mathematical formulations and physical interpretations. Correct interpretations of the output of IBREAK are essential to avoid misuse of IBREAK. Furthermore, calibration and verification of IBREAK will be required if it is to be applied to situations different from those examined before.

#### REFERENCES

- Ahrens, J.P. (1975). "Large wave tank tests of riprap stability." <u>Tech.</u>

  <u>Memo. No. 51</u>, U. S. Army Coast. Engrg. Res. Ctr., Ft. Belvoir, Va.
- Ahrens, J.P. and McCartney, B.L. (1975). "Wave period effect on the stability of riprap." <a href="Proc. Civil Engrg">Proc. Civil Engrg</a>. in Oceans/III, ASCE, 1019-1034.
- Ahrens, J.P. (1984). "Reef type breakwaters." <u>Proc. 19th Coastal Engrg.</u>
  <a href="mailto:Conf.">Conf.</a>, ASCE, 2648-2662.
- Ahrens, J.P. and Martin, F.T. (1985). "Wave runup formulas for smooth slopes." J. Wtrway. Port Coast. and Oc. Engrg., ASCE, 111(1), 128-133.
- Allsop, N.W.H., Smallman, J.V. and Stephens, R.V. (1988). "Development and application of a mathematical model of wave action on steep slopes." <a href="Proc.21st Coast. Engrg. Conf.">Proc.21st Coast. Engrg. Conf.</a>, ASCE, 281-291.
- Baird, W.F. and Hall, K.R. (1984). "The design of breakwaters using quarried stones." Proc. 19th Coast. Engrg. Conf., ASCE, 1024-1031.
- Barends, B.J., van der Kogel, H., Uijttewaal, J. and Hagenaar, J. (1983).

  "West breakwater Sines, dynamic-geotechnical stability of breakwaters."

  Proc. Coastal Structures '83, ASCE, 31-44.
- Battjes, J.A. (1974). "Surf similarity." <u>Proc. 14th Coast. Engrg. Conf.</u>, ASCE, 466-480.
- Battjes, J.A. (1984). "A review of methods to establish the wave climate for breakwater design." <u>Coast. Engrg.</u>, 8, 141-160.
- Bruun, P. and Johannesson, P. (1976). "Parameters affecting stability of rubble mounds." J. Wtrway. Harbors Coast. Engrg. Div., ASCE, 102(WW2), 141-164.

- Bruun, P., ed. (1985). <u>The Design and Construction of Mounds for Breakwaters</u>
  and Coastal Protection. Elsevier, Amsterdam, The Netherlands.
- Burcharth, H.F. (1979). "The effect of wave grouping on on-shore structures."

  <u>Coast. Engrg.</u>, 2, 189-199.
- Christensen, F.T., Broberg, P.C., Sand, S.E. and Tryde, P. (1984). "Behavior of rubble-mound breakwater in directional and uni-directional waves."

  Coast. Engrg., 8, 265-278.
- Cross, R.H. and Sollitt, C.K. (1972). "Wave transmission by overtopping." J. Wtrway. Harbors Coast. Engrg. Div., ASCE, 98(WW3), 295-309.
- Eckert, J. (1983). "Design of toe protection for coastal structures." <u>Proc.</u>

  <u>Coastal Structures '83</u>, ASCE, 331-341.
- Goda, Y. (1985). Random Seas and Design of Maritime Structures, University of Tokyo Press, Tokyo, Japan.
- Hannoura, A.A. and McCorquodale, J.A. (1985). "Rubble mounds: Numerical modeling of wave motion." J. Wtrway. Port Coast. and Oc. Engrg., ASCE, 111(5), 800-816.
- Hibberd, S. and Peregrine, D.H. (1979). "Surf and run-up on a beach: A uniform bore." J. Fluid Mech., 95(2), 323-345.
- Hudson, R.Y. (1959). "Laboratory investigation of rubble-mound breakwaters."

  J. Wtrways. and Harbors Div., ASCE, 85(WW3), 93-120.
- Jensen, O.J. (1983). "Breakwater superstructures." <u>Proc. Coastal Structures</u>

  '83, ASCE, 272-285.
- Jensen, O.J. (1984). A Monograph of Rubble-Mound Breakwaters, Danish Hydraulic Institute, Horsholm, Denmark.

- Johnson, R.R., Mansard, E.P.D. and Ploeg, J. (1978). "Effects of wave grouping on breakwater stability." <a href="Proc. 16th Coast. Engrg. Conf.">Proc. 16th Coast. Engrg. Conf.</a>, 2228-2243.
- Jonsson, I.G. (1980). "A new approach to oscillatory rough turbulent boundary layers." Ocean Engrg., 7(1), 109-152.
- Kobayashi, N. and Jacobs, B.K. (1985). "Stability of armor units on composite slope." J. Wtrway. Port Coast. and Oc. Engrg., ASCE, 111(5), 880-894.
- Kobayashi, N., Roy, I. and Otta, A.K. (1986). "Numerical simulation of wave runup and armor stability." OTC Paper 5088, <u>18th Offshore Tech. Conf.</u>, 51-56.
- Kobayashi, N. and Greenwald, J.H. (1986). "Prediction of wave runup and riprap stability." Proc. 20th Coast. Engrg. Conf., ASCE, 1958-1971.
- Kobayashi, N. and DeSilva, G.S. (1987). "Motion of sediment particles in swash zone." <a href="Proc. Coastal Hydrodynamics">Proc. Coastal Hydrodynamics</a>, ASCE, 715-730.
- Kobayashi, N. and Otta, A.K. (1987). "Hydraulic stability analysis of armor units." J. Wtrway. Port Coast. and Oc. Engrg., ASCE, 113(2), 171-186.
- Kobayashi, N., Otta, A.K. and Roy, I. (1987). "Wave reflection and runup on rough slopes." J. Wtrway. Port Coast. and Oc. Engrg., ASCE, 113(3), 282-298.
- Kobayashi, N. and Watson, K.D. (1987). "Wave reflection and runup on smooth slopes." <a href="Proc. Coastal Hydrodynamics">Proc. Coastal Hydrodynamics</a>, ASCE, 548-563.
- Kobayashi, N. and Greenwald, J.H. (1988). "Waterline oscillation and riprap movement." J. Wtrway. Port Coast. and Oc. Engrg., ASCE, 114(3), 281-296.
- Kobayashi, N., Strzelecki, M.S. and Wurjanto, A. (1988). "Swash oscillation and resulting sediment movement." <u>Proc. 21st Coast. Engrg. Conf.</u>, ASCE, 1167-1181.

- Kobayashi, N. and Wurjanto, A. (1988). "Numerical prediction of wave overtopping on coastal structures." <u>Res. Rept. No. CE-88-72</u>, Ocean Engrg. Program, Univ. of Delaware, Newark, Delaware.
- Kobayashi, N., DeSilva, G.S. and Watson, K.D. (1989). "Wave transformation and swash oscillation on gentle and steep slopes." <u>J. Geophys. Res.</u>, 94(C1), 951-966.
- Kobayashi, N. and Wurjanto, A. (1989a). "Wave overtopping on coastal structures." J. Wtrway. Port Coast. and Oc. Engrg., ASCE, 115(2), 235-251.
- Kobayashi, N. and Wurjanto, A. (1989b). "Numerical prediction of wave transmission over submerged breakwaters." <u>Res. Rept. No. CE-89-73</u>, Center for Applied Coast. Res., Univ. of Delaware, Newark, Delaware.
- Kobayashi, N. and Wurjanto, A. (1989c). "Wave transmission over submerged breakwaters." J. Wtrway. Port Coast. and Oc. Engrg., ASCE, 115(5) (in press).
- Losada, M.A. and Gimenez-Curto, L.A. (1982). "Mound breakwaters under oblique wave attack: A working hypothesis." <u>Coast. Engrg.</u>, 6, 83-92.
- Madsen, O.S. and White, S.M. (1975). "Reflection and transmission characteristics of porous rubble-mound breakwaters." <u>Tech. Rept. No. 207</u>, R. M. Parsons Lab., Dept. of Civil Engrg., Mass. Inst. Tech., Cambridge, Mass.
- Madsen, O.S. and White, S.M. (1976). "Energy dissipation on a rough slope."

  J. Wtrways. and Harbors Coast. Engrg. Div., ASCE, 102(WW1), 31-48.
- Mansard, E.P.D. (1988). "Towards a better simulation of sea states for modelling of coastal structures." <a href="Proc. Berm Breakwaters">Proc. Berm Breakwaters</a>, ASCE, 1-20.
- Moretti, G. (1987). "Computation of flows with shocks." Ann. Rev. Fluid Mech., 19, 313-337.

- Packwood, A.R. (1980). "Surf and run-up on beaches." Ph.D. Thesis, School of Math., Univ. of Bristol, U.K.
- Peregrine, D.H. (1983). "Breaking waves on beaches." Ann. Rev. Fluid Mech., 15, 149-178.
- Port Sines Investigating Panel (1982). <u>Failure of the Breakwater at Port Sines</u>, <u>Portugal</u>. American Society of Civil Engineers, New York, NY.
- Press, W.H., et al. (1986). <u>Numerical Recipes: The Art of Scientific</u>

  <u>Computing</u>. Cambridge University Press, New York, NY.
- Richtmyer, R.D. and Morton, K.W. (1967). <u>Difference Methods for Initial-Value Problems</u>. 2nd ed., Interscience, New York, NY.
- Saville, T. (1955). "Laboratory data on wave runup and overtopping on shore structures." <u>Tech. Memo. No. 64</u>, U.S. Army Beach Erosion Board, Document Service Center, Dayton, Ohio.
- Seelig, W.N. (1980). "Two-dimensional tests of wave transmission and reflection characteristics of laboratory breakwaters." <u>Tech. Rept. 80-1</u>, U.S. Army Coast. Engrg. Res. Ctr., Ft. Belvoir, Va.
- Seelig, W.N. (1983). "Wave reflection from coastal structures." <u>Proc.</u>

  <u>Coastal Structures '83</u>, ASCE, 961-973.
- Shore Protection Manual (1984). U.S. Army Engineers Waterways Experiment Station, Coastal Engineering Research Center, U.S. Government Printing Office, Washington, D.C.
- Sleath, J.F.A. (1984). Sea Bed Mechanics, Wiley-Interscience, New York, NY.
- Smith, O.P. (1986). "Cost-effective optimization of rubble-mound breakwater
  cross sections." Tech. Rept. CERC-86-2, U.S. Army Coast. Engrg. Res. Ctr.,
  Vicksburg, Miss.

- Sulisz, W. (1985). "Wave reflection and transmission of permeable breakwaters of arbitrary cross-section." <u>Coast. Engrg.</u>, 9, 371-386.
- Svendsen, I.A. and Brink-Kjaer, O. (1972). "Shoaling of cnoidal waves."

  Proc. 13th Coast. Engrg. Conf., ASCE, 365-383.
- Thompson, A.C. (1988). "Numerical model of breakwater wave flows." Proc. 21st Coast. Engrg. Conf., ASCE, 2013-2027.
- Van der Meer, J.W. (1987). "Stability of breakwater armor layers design formulae." <u>Coast. Engrg.</u>, 11, 219-239.
- Van der Meer, J.W. (1988). "Deterministic and probabilistic design of breakwater armor layers." <u>J. Wtrway. Port Coast. and Oc. Engrg.</u>, ASCE, 114(1), 66-80.
- Weggel, J.R. (1976). "Wave overtopping equation." <u>Proc. 15th Coast. Engrg.</u>
  <u>Conf.</u>, ASCE, 2737-2755.
- Wurjanto, A. and Kobayashi, N. (1989). "Wave overtopping and transmission over breakwaters." <u>Proc. PORTS '89</u>, ASCE, 247-256.

# APPENDIX A: LISTING OF IBREAK

The computer program IBREAK is listed in the following. The page number is shown on the upper right corner and the number of pages of IBREAK is 69. The page number for the rest of this appendix is omitted since the page A-I with I=2,3,...70 corresponds to the page (I-1) of IBREAK.

The listed computer program together with the tabulated input and output for the four examples presented in Appendices B, C, D and E is available on a floppy disk. The computer program IBREAK has been run using a mainframe computer, IBM 3090-180E as well as Sun workstations (Sun 3/60), which operates in conjunction with a central file server, Sun 4/280. Some modifications may be required if other computers are used. The computer time and memory requirements appear to be prohibitive for personal computers.

C														IBR00010
C		##		####	44	#####		#######	###	###	##	##		IBR00020
C		##	##		##	##	##	##	##	##	##	##		IBR00030
C		##	##	·	##	##	##	##	##	##	##	##		IBR00040
C		##		###		#####		######	####	####	## #	#		IBR00050
C		##	##		##		#	##	##	##	####	##		IBR00060
C		##	##		##		##	##	##	##	###	##		IBR00070
C		##	##	###	##	##	##	#######	##	##	##	##		IBR00080
C												IBR00090		
C			Nun	eri	cal S	Simulat	ion f	or Imperme	ble B	reakwa	aters			IBR00100
			wave	Rui	nup a	and Ove	rtopp	ing on Suba	erial	Struc	ctures			IBR00110
C			. W	ave	Trai	nsmissi	on ov	er Submerge	ed Stru	acture	es .			IBR00120
C				. 51	cabi.	Lity an	d Mov	rement of A	mor Ur	nits .	•			IBR00130
C	Ta7 >>>	1++	h 7		1 - v.v.									IBR00140
C	WI	Occas	DY A	mao	JO WI	irjanto	unde	r Supervisi	on of	Nobuh	nisa Ko	baya	shi	IBR00150
C		ocea	II EII	gine	eri	ig Prog	ram,	Department	of Cit	il Er	nginee	ring		IBR00160
C			OII	Tve	rait	or be	lawar	e, Newark,	Delawa	are 19	9716			IBR00170
C							June	, 1989						IBR00180
C	###	######	####	***	нииил		CENTED	AT NOMBO						IBR00190
C	н н н	пппппп	nnnn	nnn1	****	*****	JENER	AL NOTES #	***	* # # # # #	+ # # # # #	f####	####	IBR00200
C	TЪ	e nurn	080	of c	aach	of 20	aba			C Fangara - construence		n vincenza		IBR00210
C	is	descr	ihed	in	each	OI 30 1	subro	utines arra	nged 1	n num	merical	. orde	er	IBR00220
C		GCDCI	TDCG	111	eaci	Subto	истпе	and where	11 18	calle	a.			IBR00230
C	A1	1 COMM	ON s	tate	ment	g anne:	ar in	the Main P	~~~~	(11-1	- 5			IBR00240
C	wi	ll be	refe	rrec	to	as 'Ma	in' h	ereafter).	Dogram	(Mai	n Prog	ram		IBR00250
C	COI	MMON s	tate	ment	is	given o	on lar	in Main.	Descri	ption	or ea	cn		IBR00260
C			0000			grven	лту	III Haili.						IBR00270
C	DO	UBLE P	RECI	SION	Iis	used th	roug	hout the pr	oaram					IBR00280
C							rroug	nout the pr	ogram.					IBR00290
C	#00	#####	####	####	####	#### N	MAIN	PROGRAM ##	######	****	****	***	###	IBR00300
C										инини	<b>нинини</b>	ппппп	***	IBR00310 IBR00320
C		Main	prog	ram	perf	orms ti	lme-m	arching com	putati	on us	ina			IBR00320
C		subro	utin	es	_						9			IBR00330
C														IBR00350
		PROGR	AM I	BREA	K									IBR00360
C														IBR00370
		IMPLI	CIT	DOUB	LE P	RECISIO	N (A	-H,O-Z)						IBR00380
		PARAM	ETER	(N1	=500	,N2=300	00, N	3=3,N4=100,	N5 = 25)					IBR00390
		DOUBL	E PR	ECIS	ION	KS, KSRE	F, KS	SEA, KSI						IBR00400
		DOUBL	E PR	ECIS	ION	KCNO, MC	CNO, KO	C2						IBR00410
		DIMEN												IBR00420
				*20	FINP	1,FINP2	, FNAI	ME1, FNAME2						IBR00430
~		INTEG	ER S											IBR00440
C		~~	_											IBR00450
C	• • •	COMMO	Ns											IBR00460
C		N	_	0										IBR00470
C		Name	=	Con	tent									IBR00480
C		/DIMES	TC /	mbe										IBR00490
C		/DIME	101	The	val	ues of	the '	'PARAMETER"	s spec	ified	in Ma	in.		IBR00500
C				NOC	e: M	ost sub	rout	ines have th	neir o	wn PAI	RAMETE	R sta	te-	IBR00510
C					m	ents. P	AKAMI	ETER values	speci	fied :	in sub	routi	nes	IBR00520
C					111	ubrout!	the s	same as the	r cour	nterpa	arts i	n Mai	n.	IBR00530
C		/CONST	ra/	Rae	ic c	onetant	ne 36	CHEPAR che	ecks th	nis re	equire	ment.		IBR00540
		, 00110.	/	Das		onscant	3 and	Tubut to I	umeri	cal mo	pdel			IBR00550

C	/ID/ Id	dentifiers specifying user's options	IBR00560
C	/IDREQ/ In	ntegers for special storing for armor stability	IBR00570
C	(s	see Subroutine 2 INPUT1 for special storing)	IBR00580
C		ntegers related to time levels	IBR00590
C		ntegers for spatial nodes	IBR00600
C	/GRID/ Ti	me step, grid size, and related quantities	IBR00610
C	/WAVE1/ Di	mensional wave data	IBR00620
C	/WAVE2/ Di	mensionless wave parameters	IBR00630
C	/WAVE3/ No	ormalized surface elevations	IBR00640
C	/WAVE4/ Ma	ax. and min. of normalized incident wave profile	IBR00650
C	/WAVE5/ Cn	noidal wave parameters (K, E, m and 1-m)	IBR00660
C	/BOT1/ Di	mensional parameters related to structure	IBR00670
C	/BOT2/ No	ermalized parameters related to structure	IBR00680
C	/BOT3/ No	ermalized structure geometry	IBR00690
C	/BOT4/ and /	BOT5/ Dimensional structure geometry	IBR00700
C	/HYDRO/ Hy	drodynamic quantities computed	IBR00710
C	/MATRIX/ El	ements of matrices used in numerical method	IBR00720
C	/RUNP1/ and	/RUNP2/ Quantities related to wave runup	IBR00730
C	/OVER/ Qu	antities related to wave overtopping	IBR00740
C	/COEFS/ Re	flection and transmission coefficients	IBR00750
C	/STAT/ Me	an, max. and min. of hydrodynamic quantities	IBR00760
C	/ENERG/ Qu	antities related to wave energy	IBR00770
C	/STAB1/ Ar	mor stability parameters read as input	IBR00780
C	/STAB2/ Co	mputed armor stability parameters	IBR00790
C	/STAB3/ Ar	mor stability parameters used in Subr. 19 STABNO	IBR00800
C	/STAB4/ Ar	mor movement parameters used in Subr. 20 MOVE	IBR00810
C	/STAB5/ and	/STAB6/ Stability numbers and associated quantities	IBR00820
C	in	Subr. 19 STABNO	IBR00830
C C C C	/STAB7/ and	/STAB8/ Quantities associated with armor movement	IBR00840
C	in	Subr. 20 MOVE	IBR00850
C	/FILES/ Fi	le names and associated node numbers related to	IBR00860
		tions ISAVB=1 and ISAVC=1	IBR00870
C	/VALUEN/ Va	lues at time level (N-1) stored during computation	IBR00880
	COMMON /DIME	NS/ N1R, N2R, N3R, N4R, N5R	IBR00890
	COMMON /CONS	TA/ PI,GRAV,DELTA,X1,X2	IBR00900
	COMMON /ID/	IJOB, ISTAB, ISYST, IBOT, INONCT, IENERG, IWAVE,	IBR00910
	+	ISAVA, ISAVB, ISAVC	IBR00920
	COMMON /IDRE		IBR00930
	COMMON /TLEVI	EL/ NTOP, NONE, NJUM1, NJUM2, NSAVA, NSTAB, NSTAT, NTIMES	IBR00940
	COMMON /NODE:	S/ S, JE, JE1, JSTAB, JMAX	IBR00950
	COMMON /GRID		IBR00960
	COMMON /WAVE:	54. No. 1 - 1 1 1 2 1 2 1 2 1 2 1 2 1 2 1 2 1 2	IBR00970
	COMMON /WAVE	, , , , , , , , , , , , , , , , , , , ,	IBR00980
	COMMON /WAVE:	, , , , , , , , , , , , , , , , , , , ,	IBR00990
	COMMON /WAVE		IBR01000
	COMMON /WAVE		IBR01010
	COMMON /BOT1,	1)	IBR01020
	COMMON /BOT2	, , , , , , , , , , , , , , , , , , , ,	IBR01030
	COMMON /BOT3,	/ U2INIT(N1), THETA(N1), SSLOPE(N1), XB(N1), ZB(N1)	IBR01040
	COMMON /BOT4/	/ NBSEG	IBR01050
	COMMON /BOT5/	, , , , , , , , , , , , , , , , , , , ,	IBR01060
	COMMON /HYDRO		IBR01070
	COMMON /MATRI	IX/ A1(2,N1),F(2,N1),G1(N1),GJR(2,N1),S1(N1),D(2,N1)	IBR01080
	COMMON /RUNP1	1/ NDELR	IBR01090
	COMMON /RUNP2	<pre>2/ DELRP(N3), DELTAR(N3), RUNUPS(N3), RSTAT(3,N3)</pre>	IBR01100

		COMMON /OVER/ OV(4)	IBR01110						
		COMMON /COEFS/ RCOEF(3), TCOEF(3)	IBR01120						
		COMMON /STAT/ ELSTAT(3), U1STAT(N1), ESTAT(3, N1), VSTAT(3, N1)	IBR01130						
		COMMON /ENERG/ ENER(4,N1), ENERB(14)	IBR01140						
		COMMON /STAB1/ C2, C3, CD, CL, CM, SG, TANPHI, AMIN, AMAX, DAP	IBR01150						
		COMMON /STAB2/ SG1, CTAN (N1)	IBR01160						
		COMMON /STAB3/ CSTAB1, CSTAB2, AMAXS, AMINS, E2, E3PRE (N1)	IBR01170						
		COMMON /STAB4/ CSTAB3, CSTAB4, CM1, DA, SIGDA, WEIG	IBR01180						
		COMMON /STAB5/ JSNSC, NSNSC, NSNSX (N1)	IBR01190						
		COMMON /STAB6/ SNSC, SNR(N1), SNSX(N1)	IBR01200						
		COMMON /STAB7/ NMOVE, NSTOP,	IBR01210						
		+ ISTATE (N1), NODIN (N1), NODFI (N1), NDIS (N1)	IBR01220						
		COMMON /STAB8/ VA(N1), XAA(N1), XA(N1)	IBR01230						
		COMMON /FILES/ NNOD1, NNOD2, NODNO1 (N5), NODNO2 (N5),	IBR01240						
		+ FNAME1 (N5), FNAME2 (N5)	IBR01250						
C		COMMON /VALUEN/ VSN, USN(2), VMN, UMN(1), V1N, V2N	IBR01260						
C		CAME A W M	IBR01270 IBR01280						
C		SAVE K,M,N							
C		VARIABLES ASSOCIATED WITH THE "PARAMETER"s	IBR01290						
C		VARIABLES ASSOCIATED WITH THE "PARAMETER"S	IBR01300 IBR01310						
C		Variables enecified in DADAMEMED							
CC		Variables specified in PARAMETER statement cannot be passed through COMMON statement. The following dummy integers are used in COMMON /DIMENS/.							
C		abed in common / Diriens/.	IBR01340						
		N1R = N1	IBR01350						
		N2R = N2	IBR01360						
		N3R = N3	IBR01370						
		N4R = N4	IBR01380						
		N5R = N5	IBR01390						
C			IBR01400 IBR01410						
C		OPEN FILES AND READ DATA							
C			IBR01420						
C		First call to Subr. 1 OPENER opens files unconditionally	IBR01430 IBR01440						
C		Second call to Subr. 1 OPENER opens files conditionally							
C		Subr. 2 INPUT1 reads primary input data	IBR01450 IBR01460						
C		Subr. 3 INPUT2 reads wave profile at seaward boundary if IWAVE>1	IBR01470						
C			IBR01480						
		WRITE (*,*) 'Name of Primary Input-Data-File?'	IBR01490						
		READ (*,5000) FINP1	IBR01500						
		CALL OPENER (1,FINP1,FINP2)	IBR01510						
		CALL INPUT1 (FINP2)	IBR01520						
		CALL OPENER (2,FINP1,FINP2)	IBR01530						
		IF (IWAVE.GT.1) CALL INPUT2							
C									
C	• • •	PRE-PROCESSING	IBR01550 IBR01560						
C			IBR01570						
C		Subr. 4 BOTTOM computes normalized structure geometry	IBR01580						
C		Subr. 5 PARAM calculates important parameters	IBR01590						
C		Subr. 6 INIT1 specifies initial conditions	IBR01600						
C		Subr. 8 INWAV computes incident wave profile if IWAVE=1	IBR01610						
C		C111 DAMPON	IBR01620						
		CALL BOTTOM	IBR01630						
		CALL PARAM	IBR01640						
		CALL INIT1	IBR01650						

```
IF (IWAVE.EQ.1) CALL INWAV
                                                                        IBR01660
C
                                                                        IBR01670
C ... PRE-LOOP DOCUMENTATION
                                                                        IBR01680
C
                                                                        IBR01690
      Subr. 33 DOC1 documents input data and related parameters
C
                                                                        IBR01700
C
       before time-marching computation
                                                                        IBR01710
C
      Subr. 34 DOC2 is checked using ICALL=0 before computation
                                                                        IBR01720
C
                                                                        IBR01730
      CALL DOC1
                                                                        IBR01740
      CALL DOC2 (0,0,DUM,DUM)
                                                                        IBR01750
      IF (IJOB.EQ.3) M=S-1
                                                                        IBR01760
C
                                                                        IBR01770
C ----- DO LOOP 500 BEGINS ----- IBR01780
                                                                        IBR01790
      For known hydrodynamic quantities at time level (N-1) compute
C
                                                                        IBR01800
      values of U(i,j) with i=1,2 and V(j) at node j for next time
C
                                                                        IBR01810
      level N where normalized time t=N*(time step size delta t)
C
                                                                        IBR01820
C
     with N=1,2,...,NTOP
                                                                        IBR01830
C
                                                                        IBR01840
  DO 500 N = 1, NTOP
                                                                        IBR01850
C
                                                                        IBR01860
  .... ESTIMATE U(2,K) AND V(K) WITH K=(S+1) BY EXTRAPOLATION
                                                                        IBR01870
C
                                                                        IBR01880
C
        S = most landward node at time level (N-1)
                                                                        IBR01890
        The following values at node j are known at time level (N-1)
C
                                                                        IBR01900
         U(1,j) = volume flux
                                                                        IBR01910
C
          U(2,j) = total water depth
                                                                        IBR01920
C
               = depth-averaged velocity
                                                                        IBR01930
C
                                                                        IBR01940
        IF (IJOB.LT.3) THEN
                                                                        IBR01950
          M = S-1
                                                                        IBR01960
          IF (S.LT.JE) THEN
                                                                        IBR01970
            K = S+1
                                                                        IBR01980
            V(K) = 2.D+00*V(S) - V(M)
                                                                        IBR01990
            U(2,K) = 2.D+00*U(2,S) - U(2,M)
                                                                        IBR02000
            U(1,K) = U(2,K)*V(K)
                                                                        IBR02010
            IF (U(2,K).GT.0.D+00) THEN
                                                                        IBR02020
             C(K) = DSQRT(U(2,K))
                                                                        IBR02030
                                                                        IBR02040
              C(K) = 0.D+00
                                                                        IBR02050
            ENDIF
                                                                        IBR02060
          ENDIF
                                                                        IBR02070
                                                                        IBR02080
                                                                        IBR02090
C ..... RETAIN SOME VALUES AT TIME LEVEL (N-1) AT LANDWARD AND
                                                                       IBR02100
C
        SEAWARD BOUNDARIES
                                                                       IBR02110
C
                                                                        IBR02120
        VSN
              = V(S)
                                                                        IBR02130
        USN(1) = U(1,S)
                                                                        IBR02140
        USN(2) = U(2,S)
                                                                        IBR02150
        VMN
              = V(M)
                                                                        IBR02160
       UMN(1) = U(1,M)
                                                                       IBR02170
       VIN
             = V(1)
                                                                       IBR02180
        V2N
             = V(2)
                                                                       IBR02190
C
                                                                       IBR02200
```

```
C ..... CRITICAL VELOCITIES USED IN CHARACTERISTIC VARIABLES
                                                                          IBR02210
                                                                          IBR02220
         DO 110 J = 1, S
                                                                         IBR02230
           IF (U(2,J).LT.0.D+00) THEN
                                                                         IBR02240
             WRITE (*,2910) U(2,J),J,S,N
                                                                         IBR02250
             WRITE (29,2910) U(2,J),J,S,N
                                                                         IBR02260
                                                                         IBR02270
           ELSE
                                                                         IBR02280
             C(J) = DSQRT(U(2,J))
                                                                          IBR02290
          ENDIF
                                                                          IBR02300
   110
        CONTINUE
                                                                          IBR02310
C
                                                                          IBR02320
C .... MARCH FROM TIME LEVEL (N-1) TO TIME LEVEL N
                                                                         IBR02330
                                                                         IBR02340
C
        Subr. 12 MARCH marches computation from time level (N-1) to N IBR02350
C
         excluding landward and seaward boundaries
                                                                         IBR02360
C
        Landward B.C. is in Subr. 13 LANDBC
                                                                         IBR02370
C
        Seaward B.C. is in Subr. 16 SEABC
                                                                         IBR02380
C
                                                                         IBR02390
        CALL MARCH (N, M)
                                                                         IBR02400
        CALL LANDBC (N, K, M, ETAT)
                                                                         IBR02410
        CALL SEABC (N, ETAR)
                                                                         IBR02420
C
                                                                         IBR02430
C ..... CHECK IF STABILITY CRITERION IS NOT VIOLATED
                                                                         IBR02440
                                                                         IBR02450
C
        T = time step; X = spatial grid size; XT = X/T
                                                                         IBR02460
C
                                                                         IBR02470
        DO 120 J = 1, S
                                                                         IBR02480
          IF (DABS(V(J)).GT.XT) THEN
                                                                         IBR02490
            WRITE (*,2920) V(J), XT, J, S, N
                                                                         IBR02500
            WRITE (29,2920) V(J), XT, J, S, N
                                                                         IBR02510
          ENDIF
                                                                         IBR02520
  120
        CONTINUE
                                                                         IBR02530
                                                                         IBR02540
C ..... WAVE ENERGY FLUX AND DISSIPATION
                                                                         IBR02550
       Computed in Subr. 17 ENERGY
                                                                         IBR02560
                                                                        IBR02570
        IF (IENERG.EQ.1.AND.N.GE.NSTAT) CALL ENERGY (N)
                                                                        IBR02580
                                                                        IBR02590
C .... STATISTICS OF HYDRODYNAMIC QUANTITIES
                                                                         IBR02600
C
                                                                         IBR02610
C
        Subr. 31 ASSIGN changes notions from matrix to vector or from IBR02620
C
         vector to matrix
                                                                        IBR02630
C
        Subr. 18 STAT1 finds mean, max. and min. values
                                                                        IBR02640
        NSTAT = time level when statistical calculations begin
C
                                                                        IBR02650
C
        At node j:
                                                                         IBR02660
C
          U1STAT(j) = mean volume flux
                                                                         IBR02670
C
          ELEV(j) = surface elevation above SWL
                                                                        IBR02680
C
                  = depth-averaged velocity
                                                                        IBR02690
C
        Mean, maximum, and minimum at node j:
                                                                        IBR02700
C
          ESTAT(1,j),ESTAT(2,j),ESTAT(3,j): for ELEV(j)
                                                                        IBR02710
C
         VSTAT(1, j), VSTAT(2, j), VSTAT(3, j): for V(j)
                                                                        IBR02720
C
        JMAX = the largest node number reached by the computational IBR02730
C
         waterline during N=NSTAT to N=NTOP
                                                                        IBR02740
C
       Note:
                                                                        IBR02750
```

C		For IJOB=3, JMAX=S was specified in Subr. 6 INIT1 as input	IBR02760
C		THE REPORT OF THE PROPERTY OF	IBR02770
		IF (N.GE.NSTAT) THEN	IBR02780
		CALL ASSIGN (1, VDUM ,U ,2,S,1)	IBR02790
		CALL STAT1 (1,U1STAT, VDUM, 1,S)	IBR02800
		CALL STAT1 (2, ESTAT , ELEV, 3, JE)	IBR02810
		CALL STAT1 (2, VSTAT , V , 3, S)	IBR02820
		IF (IJOB.LT.3.AND.S.GT.JMAX) JMAX=S	IBR02830
		ENDIF	IBR02840
C			IBR02850
C		COMPUTATION OF ARMOR STABILITY OR MOVEMENT	IBR02860
C		From N=NSTAB to N=NTOP	IBR02870
C			IBR02880
C		NSTAB = time level when computation of armor stability or	IBR02890
C		movement begins	IBR02900
C		ISTAB=1: INITIATION OF MOVEMENT OF ARMOR UNITS IN	IBR02910
C		SUBR. 19 STABNO	IBR02920
C		Computing SNR at every node at every NJUM2 time steps	IBR02930
С		<pre>SNR(j) = stability number against rolling/sliding at node j</pre>	IBR02940
C		ISTAB=2: SLIDING MOTION OF ARMOR UNITS IN SUBR. 20 MOVE	IBR02950
C		Tracking individual armor units	IBR02960
C		NMOVE = no. of units dislodged from their initial locations	IBR02970
C		NSTOP = no. of units stopped after moving	IBR02980
C		XAA(j),XA(j) = displacement of moving or stopped armor unit	IBR02990
C		number j from its initial location, normalized by	IBR03000
C		TP*sqrt(GRAV*HREFP) and DAP, respectively	IBR03010
C		THE ATOMAN COM A AND ALCO MADELLA COMMANDA	IBR03020
		IF (ISTAB.GT.O.AND.N.GE.NSTAB) THEN	IBR03030
		IF (ISTAB.EQ.1) THEN	IBR03040
		IDUM = MOD ((N-NSTAB), NJUM2)	IBR03050
		IF (IDUM.EQ.0) CALL STABNO (N) ELSE	IBR03060
		CALL MOVE (N)	IBR03070
		ENDIF	IBR03080
		ENDIF	IBR03090
C		DAD II	IBR03100
C	ranna van aman	DOCUMENTATION DURING TIME-MARCHING COMPUTATION	IBR03110
C		Subr. 34 DOC2 documents computed results at designated time	IBR03120
C		levels	IBR03130
C			IBR03140
C		Calling DOC2(1,) is for storing "A"	IBR03150
C		"A" = spatial variations of hydrodynamic quantities	IBR03160
C		Storing "A" is performed NTIMES (>1) times at equal	IBR03170
C		intervals from N=NSAVA to N=NTOP	IBR03180
CCC		NTOP = final time level	IBR03190
C		NSAVA = time level when storing "A" begins	IBR03200
C		Calling DOC2(2,) is for storing temporal variations at	IBR03210 IBR03220
C		specified nodes every NJUM1 time steps during N=1 to N=NTOP	IBR03230
C		Calling DOC2(3,) is for storing spatial variations at	IBR03240
C		specified time levels N=NREQ(i) with i=1,2,,NNREQ	IBR03250
C		a a fait it it in the	IBR03260
		IF (N.GE.NSAVA) THEN	IBR03270
		IDUM1 = (N-NSAVA) * (NTIMES-1)	IBR03280
		IDUM2 = NTOP-NSAVA	IBR03290
		IDUM3 = MOD(IDUM1, IDUM2)	IBR03300
			121103300

```
IF (IDUM3.EQ.0) CALL DOC2 (1, N, DUM, DUM)
                                                                    IBR03310
        ENDIF
                                                                    IBR03320
        IDUM4 = MOD(N, NJUM1)
                                                                    IBR03330
        IF (IDUM4.EQ.0) CALL DOC2 (2, N, ETAR, ETAT)
                                                                    IBR03340
        IF (IREQ.EQ.1) THEN
                                                                    IBR03350
          DO 130 I = 1, NNREO
                                                                    IBR03360
            IF (N.EQ.NREQ(I)) CALL DOC2 (3, N, DUM, DUM)
                                                                    IBR03370
  130
                                                                    IBR03380
        ENDIF
                                                                    IBR03390
C
                                                                    IBR03400
C
  .... HOW FAR THE COMPUTATION HAS BEEN
                                                                    IBR03410
                                                                    IBR03420
        IDUM = MOD(N, 500)
                                                                    IBR03430
        IF (IDUM.EQ.0) WRITE (*,*) 'N', N
                                                                    IBR03440
        IDUM = MOD(N, NONE)
                                                                    IBR03450
        IF (IDUM.EQ.0) THEN
                                                                    IBR03460
          IDUM = N/NONE
                                                                    IBR03470
          WRITE (*,*) ' Finished ', IDUM,' Wave Period(s)'
                                                                    IBR03480
        ENDIF
                                                                    IBR03490
                                                                    IBR03500
  500 CONTINUE
                                                                    IBR03510
                                                                    IBR03520
 ----- DO LOOP 500 ENDS ----- IBR03530
                                                                    IBR03540
  ... POST-PROCESSING
                                                                    IBR03550
C
                                                                    IBR03560
C
   Subr. 23 STAT2 calculates statistical values
                                                                    IBR03570
     Subr. 25 BALANE checks overall energy balance
C
                                                                    IBR03580
C
                                                                    IBR03590
     CALL STAT2
                                                                    IBR03600
     IF (IENERG.EQ.1) CALL BALANE
                                                                    IBR03610
C
                                                                   IBR03620
  ... POST-LOOP DOCUMENTATION
                                                                   IBR03630
C
     Subr. 35 DOC3 documents results after time-marching
                                                                   IBR03640
C
     computation
                                                                   IBR03650
C
                                                                    IBR03660
    CALL DOC3
                                                                   IBR03670
C
                                                                    IBR03680
 ... FORMATS
                                                                    IBR03690
                                                                   IBR03700
 2910 FORMAT (/' From Main Program: Negative water depth =',D12.3/
                                                                   IBR03710
             ' J =', I8,'; S =', I8,'; N = ', I8)
                                                                   IBR03720
 2920 FORMAT (/' From Main Program: Abs(V(J))>(X/T):',
                                                                   IBR03730
    +
              ' V(J) = ',D12.3,'; X/T = ',D12.3/
                                                                   IBR03740
              ' J = ', I8, '; S = ', I8, '; N = ', I8)
                                                                   IBR03750
 5000 FORMAT (A20)
                                                                   IBR03760
                                                                   IBR03770
     STOP
                                                                   IBR03780
     END
                                                                   IBR03790
                                                                   IBR03800
C -00----- END OF MAIN PROGRAM ----- IBR03810
C
                                                                   IBR03830
C
     This subroutine opens all input and output files
                                                                   IBR03840
C
                                                                   IBR03850
```

```
SUBROUTINE OPENER (ICALL, FINP1, FINP2)
                                                                              IBR03860
C
                                                                              IBR03870
       IMPLICIT DOUBLE PRECISION (A-H, O-Z)
                                                                              IBR03880
       PARAMETER (N1=500, N2=30000, N3=3, N4=100, N5=25)
                                                                              IBR03890
       CHARACTER*20 FINP1, FINP2, FNAME1, FNAME2
                                                                              IBR03900
       COMMON /DIMENS/ N1R, N2R, N3R, N4R, N5R
                                                                              IBR03910
       COMMON /ID/
                        IJOB, ISTAB, ISYST, IBOT, INONCT, IENERG, IWAVE,
                                                                             IBR03920
                        ISAVA, ISAVB, ISAVC
                                                                             IBR03930
       COMMON /IDREQ/
                        IREQ, IELEV, IV, IDUDT, ISNR, NNREQ, NREQ (N5)
                                                                             IBR03940
       COMMON /FILES/ NNOD1, NNOD2, NODNO1 (N5), NODNO2 (N5),
                                                                              IBR03950
                        FNAME1 (N5), FNAME2 (N5)
                                                                              IBR03960
C
                                                                              IBR03970
       IF (ICALL.EQ.1) THEN
                                                                              IBR03980
C
                                                                              IBR03990
C
         Subr. 36 CHEPAR (k,i,Ni,NiR) checks Ni=NiR with i=1,2,3,4 or 5 IBR04000
C
         in Subr. k
                                                                              IBR04010
C
                                                                              IBR04020
         CALL CHEPAR (1,5,N5,N5R)
                                                                              IBR04030
C
                                                                              IBR04040
  ..... UNCONDITIONAL OPENINGS
                                                                              IBR04050
                                                                             IBR04060
C
         Units 11-19 reserved for input data files
                                                                             IBR04070
C
         Units 21-29 reserved for unconditionally-opened files
                                                                             IBR04080
C
                                                                              IBR04090
C
  Unit Filename
                      Purpose
                                                                              IBR04100
C
                      ----- IBR04110
   ----
C
    11
        FINP1
                      Contains primary input data
                                                                             IBR04120
C
          OSEAWAV
                      Stores quantities at seaward boundary at every
                                                                             IBR04130
C
                      NJUM1 time steps
                                                                             IBR04140
C
                      --> N, ETAI, ETAR, ETATOT, V(1), U(1,1)
                                                                             IBR04150
C
   22 OSPACE
                   . Unconditionally, stores structure geometry
                                                                             IBR04160
C
                      --> JE, (XB(J), ZB(J), J=1, JE)
                                                                             IBR04170
C
                    . Conditionally, i.e., if ISAVA=1, stores spatial
                                                                             IBR04180
C
                      variations of flow quantities at designated time
                                                                             IBR04190
C
                      levels from N=NSAVA to N=NTOP
                                                                             IBR04200
C
                      --> N,S, (ELEV(J), V(J), J=1,S)
                                                                             IBR04210
C
    23
          OSTAT
                      Stores statistics of hydrodynamic quantities
                                                                             IBR04220
C
                      --> (U1STAT(J), J=1, JMAX)
                                                                             IBR04230
C
                      --> (ESTAT(i,J),J=1,JMAX)
                                                                             IBR04240
C
                      --> (VSTAT(i,J),J=1,JMAX)
                                                                             IBR04250
C
                          i=1,2,3
                                                                             IBR04260
C
    28
          ODOC
                      Stores essential output for concise documentation
                                                                             IBR04270
C
    29
                      Stores messages written under special
          OMSG
                                                                             IBR04280
C
                     circumstances during computation
                                                                             IBR04290
C
                                                                             IBR04300
                                      STATUS='OLD', ACCESS='SEQUENTIAL')
        OPEN (UNIT=11, FILE=FINP1,
                                                                             IBR04310
        OPEN (UNIT=21, FILE='OSEAWAV', STATUS='NEW', ACCESS='SEQUENTIAL')
                                                                             IBR04320
        OPEN (UNIT=22, FILE='OSPACE', STATUS='NEW', ACCESS='SEQUENTIAL')
                                                                             IBR04330
        OPEN (UNIT=23, FILE='OSTAT', STATUS='NEW', ACCESS='SEQUENTIAL')
OPEN (UNIT=28, FILE='ODOC', STATUS='NEW', ACCESS='SEQUENTIAL')
OPEN (UNIT=29, FILE='OMSG', STATUS='NEW', ACCESS='SEQUENTIAL')
                                                                             IBR04340
                                                                             IBR04350
                                                                             IBR04360
        RETURN
                                                                             IBR04370
C
                                                                             IBR04380
      ELSE
                                                                             IBR04390
C
                                                                             IBR04400
```

C	• • • • •	. CONDITIO	NAL OPENINGS FOR ICALL=2	IBR04410
C		** '. 21	20	IBR04420
C		Units 31	-39 reserved for files containing hydrodynamic and	IBR04430
C		II-1 41	energy quantities	IBR04440
C		Units 41	-49 reserved for files containing armor stability and	IBR04450
C		II-14- FO	movement quantities	IBR04460
C		Units 50	-74 reserved for saving "B"	IBR04470
C		Units /5	-99 reserved for saving "C"	IBR04480
		"B" = te	mporal variations of normalized total water depth	IBR04490
C		at	specified nodes	IBR04500
C		"C" = te	mporal variations of normalized displacement of	IBR04510
0		ar	mor units from specified initial nodal locations	IBR04520
C	77 J.A.	P/3		IBR04530
C	Unit		e Purpose	IBR04540
				IBR04550
C	12	FINP2	Contains input data precsribing water surface	IBR04560
C	21	ODIMINE	elevations at seaward boundary if IWAVE>1	IBR04570
0	31	ORUNUP	Stores waterline node and runup elevations	IBR04580
C			associated with (DELTAR(L), L=1, NDELR), if IJOB<3,	IBR04590
C			at every NJUM1 time steps	IBR04600
0	20	0011111	> N,S, (RUNUPS(L), L=1, NDELR)	IBR04610
C	32	OOVER	Stores quantities at landward edge node, if	IBR04620
C			IJOB=2, at every NJUM1 time steps	IBR04630
C	33	OMPANIC	> N,U(1,JE),U(2,JE),V(JE),C(JE)	IBR04640
C	33	OTRANS	Stores values at landward boundary, if IJOB=3,	IBR04650
C			at every NJUM1 time steps	IBR04660
C	34	OINWAV	> N,U(1,JE),V(JE),C(JE),ETAT	IBR04670
C	34	OINWAV	Stores incident wave profile at seaward boundary	IBR04680
C	35	OENERG	if IWAVE=1	IBR04690
C	33	OENERG	Stores time-averaged energy quantities if IENERG=1	IBR04700
C			> JMAX, (ENER(i, J), J=1, JMAX)	IBR04710
C	40	ODEO	i=1,2,3,4	IBR04720
C	40	OREQ	Stores spatial variation at designated time levels	IBR04730
C	41	OSTAB1	(e.g., at time of minimum stability) if IREQ=1	IBR04740
C	41	OSTABL	Stores local stability number at each node	IBR04750
C	42	OCHADA	> JMAX, (XB(J), ZB(J), SNSX(J), J=1, JMAX)	IBR04760
C	42	OSTAB2	Stores quantities related to armor movement	IBR04770
c	50	ENTRACE 1 / 1 \	1	IBR04780
C		FNAME1(1)		IBR04790
23.ET()	31 1	FNAME1(2)		IBR04800
C	•		! total water depth at specified nodes at every	IBR04810
			! NJUM1 time steps if ISAVB=1	IBR04820
C	and	so on		IBR04830
C	75 1		r .	IBR04840
C		FNAME2(1)		IBR04850
C	101	FNAME2(2)	! Store "C", i.e., temporal variations of normalized	IBR04860
C	•		! displacement, XA, of armor units from specified	IBR04870
C			! initial nodal locations at every NJUM1 time steps	IBR04880
C	and	so on	! if ISAVC=1	IBR04890
		WATER AG	CHAMADD DOWNSAN	IBR04900
C		WAVES AT	SEAWARD BOUNDARY	IBR04910
C		TE /TUBE	DO 1) mumu	IBR04920
			.EQ.1) THEN	IBR04930
		OPEN (U	NIT=34, FILE='OINWAV', STATUS='NEW', ACCESS='SEQUENTIAL')	IBR04940
		ELSE		IBR04950

```
OPEN (UNIT=12, FILE=FINP2, STATUS='OLD', ACCESS='SEQUENTIAL')
                                                                             IBR04960
         ENDIF
                                                                             IBR04970
C
                                                                             IBR04980
  ---- RUNUP-OVERTOPPING-TRANSMISSION
                                                                             IBR04990
C
                                                                             IBR05000
         IF (IJOB.LT.3) THEN
                                                                             IBR05010
           OPEN (UNIT=31, FILE='ORUNUP', STATUS='NEW', ACCESS='SEQUENTIAL') IBR05020
           IF (IJOB.EQ.2) OPEN
                                                                            IBR05030
              (UNIT=32, FILE='OOVER', STATUS='NEW', ACCESS='SEQUENTIAL')
                                                                            IBR05040
         ELSE
                                                                            IBR05050
           OPEN (UNIT=33, FILE='OTRANS', STATUS='NEW', ACCESS='SEQUENTIAL') IBR05060
         ENDIF
                                                                            IBR05070
C
                                                                            IBR05080
C ---- WAVE ENERGY
                                                                            IBR05090
C
                                                                            IBR05100
         IF (IENERG.EQ.1)
                                                                            IBR05110
          OPEN (UNIT=35, FILE='OENERG', STATUS='NEW', ACCESS='SEQUENTIAL') IBR05120
C
                                                                            IBR05130
C
  ---- FOR SAVING "B"
                                                                            IBR05140
C
                                                                            IBR05150
         IF (ISAVB.EQ.1) THEN
                                                                            IBR05160
          DO 110 I = 1, NNOD1
                                                                            IBR05170
             NUNIT = 49 + I
                                                                            IBR05180
             OPEN (UNIT=NUNIT, FILE=FNAME1(I), STATUS='NEW',
                                                                            IBR05190
                   ACCESS='SEQUENTIAL')
                                                                            IBR05200
  110
           CONTINUE
                                                                            IBR05210
         ENDIF
                                                                            IBR05220
C
                                                                            IBR05230
  ---- ARMOR STABILITY
C
                                                                            IBR05240
C
                                                                            IBR05250
        IF (ISTAB.EQ.1) THEN
                                                                            IBR05260
          OPEN (UNIT=41,FILE='OSTAB1',STATUS='NEW',ACCESS='SEQUENTIAL') IBR05270
        ELSEIF (ISTAB.EQ.2) THEN
                                                                            IBR05280
          OPEN (UNIT=42,FILE='OSTAB2',STATUS='NEW',ACCESS='SEQUENTIAL') IBR05290
C
           ----- The following is for saving "C"
                                                                            IBR05300
          IF (ISAVC.EQ.1) THEN
                                                                            IBR05310
            DO 120 I = 1, NNOD2
                                                                            IBR05320
              NUNIT = 74 + I
                                                                            IBR05330
               OPEN (UNIT=NUNIT, FILE=FNAME2(I), STATUS='NEW',
                                                                            IBR05340
                     ACCESS='SEQUENTIAL')
                                                                            IBR05350
  120
            CONTINUE
                                                                            IBR05360
          ENDIF
                                                                            IBR05370
        ENDIF
                                                                            IBR05380
C
                                                                            IBR05390
C
  ---- SPECIAL STORING AT SPECIFIED TIME LEVELS
                                                                            IBR05400
C
                                                                           IBR05410
        IF (IREQ.EQ.1)
                                                                           IBR05420
          OPEN (UNIT=40, FILE='OREQ', STATUS='NEW', ACCESS='SEQUENTIAL')
                                                                           IBR05430
C
                                                                           IBR05440
        RETURN
                                                                           IBR05450
C
                                                                           IBR05460
      ENDIF
                                                                           IBR05470
C
                                                                           IBR05480
      END
                                                                           IBR05490
C
                                                                           IBR05500
```

```
C -01----- END OF SUBROUTINE OPENER ----
                                                                           IBR05510
 IBR05530
       This subroutine reads data from primary input data file and
 C
                                                                            IBR05540
 C
       checks some of them
                                                                            IBR05550
 C
                                                                            IBR05560
       SUBROUTINE INPUT1 (FINP2)
                                                                            IBR05570
 C
                                                                            IBR05580
       IMPLICIT DOUBLE PRECISION (A-H, O-Z)
                                                                            IBR05590
       PARAMETER (N1=500, N2=30000, N3=3, N4=100, N5=25)
                                                                            IBR05600
       DOUBLE PRECISION KS, KSREF, KSSEA, KSI
                                                                            IBR05610
       CHARACTER*5 COMMEN(14)
                                                                            IBR05620
       CHARACTER*20 FINP2, FNAME1, FNAME2
                                                                           IBR05630
       INTEGER S
                                                                           IBR05640
       COMMON /DIMENS/ N1R, N2R, N3R, N4R, N5R
                                                                           IBR05650
       COMMON /CONSTA/ PI, GRAV, DELTA, X1, X2
                                                                           IBR05660
       COMMON /ID/
                       IJOB, ISTAB, ISYST, IBOT, INONCT, IENERG, IWAVE,
                                                                           IBR05670
                       ISAVA, ISAVB, ISAVC
                                                                           IBR05680
       COMMON /IDREQ/ IREQ, IELEV, IV, IDUDT, ISNR, NNREQ, NREQ (N5)
                                                                           IBR05690
       COMMON /TLEVEL/ NTOP, NONE, NJUM1, NJUM2, NSAVA, NSTAB, NSTAT, NTIMES
                                                                           IBR05700
      COMMON /NODES/ S, JE, JE1, JSTAB, JMAX
COMMON /WAVE1/ HREFP, TP, WLOP
COMMON /WAVE2/ KS, KSREF, KSSEA, WLO, WL, UR, URPRE, KSI, SIGMA
                                                                           IBR05710
                                                                           IBR05720
                                                                           IBR05730
      COMMON /BOT1/ DSEAP, DLANDP, FWP
COMMON /BOT2/ DSEA, DSEAKS, DSEA2, DLAND, DLAND2, FW, TSLOPS, WTOT
                                                                           IBR05740
                                                                           IBR05750
       COMMON /BOT4/ NBSEG
                                                                           IBR05760
      COMMON /BOT5/
                       WBSEG (N4), TBSLOP (N4), XBSEG (N4), ZBSEG (N4)
                                                                           IBR05770
      COMMON /RUNP1/ NDELR
                                                                           IBR05780
      COMMON /RUNP2/ DELRP(N3), DELTAR(N3), RUNUPS(N3), RSTAT(3, N3)
                                                                           IBR05790
      COMMON /STAB1/ C2,C3,CD,CL,CM,SG,TANPHI,AMIN,AMAX,DAP
                                                                           IBR05800
      COMMON /FILES/ NNOD1, NNOD2, NODNO1 (N5), NODNO2 (N5),
                                                                           IBR05810
                       FNAME1 (N5), FNAME2 (N5)
                                                                           IBR05820
      DATA INDIC /0/
                                                                           IBR05830
      CALL CHEPAR (2,1,N1,N1R)
                                                                           IBR05840
      CALL CHEPAR (2,3,N3,N3R)
                                                                           IBR05850
      CALL CHEPAR (2,4,N4,N4R)
                                                                           IBR05860
      CALL CHEPAR (2,5,N5,N5R)
                                                                           IBR05870
C
                                                                           IBR05880
C ..... COMMENT LINES
                                                                           IBR05890
           NLINES = number of comment lines preceding input data
                                                                           IBR05900
      READ (11, 1110) NLINES
                                                                           IBR05910
      DO 110 I = 1, NLINES
                                                                           IBR05920
        READ (11,1120) (COMMEN(J), J=1,14)
                                                                          IBR05930
        WRITE (28,1120) (COMMEN(J), J=1,14)
                                                                           IBR05940
        WRITE (29,1120) (COMMEN(J), J=1,14)
                                                                           IBR05950
  110 CONTINUE
                                                                           IBR05960
C
                                                                           IBR05970
  ···· OPTIONS
                                                                          IBR05980
C
            IJOB=1: RUNUP on impermeable slope
                                                                          IBR05990
C
                =2: OVERTOPPING over subaerial structure
                                                                          IBR06000
C
                =3: TRANSMISSION over submerged structure
                                                                          IBR06010
C
            ISTAB=0: No computation of armor stability or movement
                                                                          IBR06020
C
                 =1: Armor stability computation
                                                                          IBR06030
C
                 =2: Armor movement computation
                                                                          IBR06040
            If ISTAB>0 --> Must specify NSTAB
                                                                          IBR06050
```

C		Armor stability or movement is computed from N=NSTAB	IBR06060
C		to N=NTOP	IBR06070
C		ISYST=1: International System of Units (SI) is used	IBR06080
C		=2: US Customary System of Units (USCS) is used	IBR06090
C		<pre>IBOT=1: "Type 1" bottom data (width-slope)</pre>	IBR06100
C		=2: "Type 2" bottom data (coordinates)	IBR06110
CCC		INONCT=0: No correction term in computing ETAR	IBR06120
0		=1: Correction term for ETAR recommended for	IBR06130
0		beaches	IBR06140
C		IENERG=0: Energy quantities NOT computed	IBR06150
C		=1: Energy quantities computed	IBR06160
C		IWAVE=1: Incident waves at seaward boundary computed	IBR06170
C		=2: Incident waves at seaward boundary given as input =3: Total waves at seaward boundary given as input	IBR06180
C		If IWAVE>1> Must specify FINP2 = name of input data	IBR06190
C		file containing the given wave	IBR06200
C		"A" = Spatial variations of hydrodynamic quantities	IBR06210
00000		"B" = Temporal variations of total water depth at	IBR06220
C		specified nodes at every NJUM1 time steps	IBR06230
C		"C" = Temporal variations of displacement of armor units	IBR06240 IBR06250
C		from specified initial nodal locations at every	IBR06260
C		NJUM1 time steps	IBR06270
C		ISAVA, ISAVB, ISAVC are identifiers associated with saving	IBR06280
C		"A", "B", "C", respectively (1=save; 0=no)	IBR06290
C		NSAVA AND NTIMES:	IBR06300
C		If ISAVA=1, "A" is saved NTIMES (>1) times at equal	IBR06310
0000		intervals from N=NSAVA to N=NTOP	IBR06320
C		If ISAVB=1> Must specify NNOD1, i.e, the number of	IBR06330
		nodes for which "B" is to be saved	IBR06340
C		If ISAVC=1> Must specify NNOD2, i.e., the number of	IBR06350
C		nodes for which "C" is to be saved	IBR06360
CCC		IREQ=0: No special storing	IBR06370
C		=1: Special storing requested	IBR06380
C		Special storing = storing spatial variations of requested quantities at time levels N=NREQ(i)	IBR06390
C		with i=1,2,,NNREQ	IBR06400
C		Quantities available for request:	IBR06410
C		. ELEV = surface elevation	IBR06420
C		. V = depth-averaged velocity	IBR06430
C		. DUDT = total fluid acceleration	IBR06440 IBR06450
C		. SNR = stability number against rolling/sliding	IBR06460
C		> requested by IELEV=1, IV=1, IDUDT=1, and ISNR=1,	IBR06470
C		respectively	IBR06480
C		Note: DUDT can be requested only if ISTAB>0	IBR06490
C		SNR can be requested only if ISTAB=1	IBR06500
	READ	(11,1130) IJOB, ISTAB, NSTAB	IBR06510
		(11,1140) ISYST	IBR06520
		(11,1140) IBOT	IBR06530
		(11,1140) INONCT	IBR06540
		(11,1140) IENERG	IBR06550
		(11,1150) IWAVE,FINP2	IBR06560
	READ	(11, 1160) ISAVA, ISAVB, ISAVC, NSAVA, NTIMES, NNOD1, NNOD2	IBR06570
С	READ	(11,1170) IREQ, IELEV, IV, IDUDT, ISNR, NNREQ	IBR06580
c.		CHECK OBLIONS	IBR06590
		CHECK OPTIONS	IBR06600

```
C
             Subr. 37 CHEOPT is to check if user's options are within
                                                                              IBR06610
 C
             the ranges available
                                                                              IBR06620
       CALL CHEOPT ( 1, INDIC, IJOB , 1, 3)
                                                                              IBR06630
       CALL CHEOPT ( 2, INDIC, ISTAB , 0, 2)
                                                                              IBR06640
       CALL CHEOPT ( 3, INDIC, ISYST ,1,2)
                                                                              IBR06650
       CALL CHEOPT ( 4, INDIC, IBOT ,1,2)
                                                                             IBR06660
       CALL CHEOPT ( 5, INDIC, INONCT, 0, 1)
                                                                             IBR06670
       CALL CHEOPT ( 6, INDIC, IENERG, 0, 1)
                                                                             IBR06680
       CALL CHEOPT ( 7, INDIC, IWAVE , 1, 3)
                                                                             IBR06690
       CALL CHEOPT ( 8, INDIC, ISAVA , 0, 1)
                                                                             IBR06700
       CALL CHEOPT ( 9, INDIC, ISAVB , 0, 1)
                                                                             IBR06710
       CALL CHEOPT (10, INDIC, ISAVC , 0, 1)
                                                                             IBR06720
       CALL CHEOPT (11, INDIC, IREQ ,0,1)
CALL CHEOPT (12, INDIC, IELEV ,0,1)
                                                                             IBR06730
                                                                             IBR06740
       CALL CHEOPT (13, INDIC, IV ,0,1)
                                                                             IBR06750
       CALL CHEOPT (14, INDIC, IDUDT , 0, 1)
                                                                             IBR06760
       CALL CHEOPT (15, INDIC, ISNR ,0,1)
                                                                             IBR06770
       IF (ISAVB.EQ.1) CALL CHEOPT (16, IDUM, NNOD1, 1, N5)
                                                                             IBR06780
       IF (ISAVC.EQ.1) CALL CHEOPT (17, IDUM, NNOD2, 1, N5)
                                                                             IBR06790
C
                                                                             IBR06800
  ..... PRE-PROCESS SPECIAL STORING
                                                                             IBR06810
             Subr. 38 STOPP stops execution of the computation
                                                                             IBR06820
      IF (IREQ.EQ.1) THEN
                                                                             IBR06830
         IF (ISTAB.EQ.O.AND.IDUDT.NE.O) IDUDT=0
                                                                             IBR06840
         IF (ISTAB.NE.1.AND.ISNR.NE.0) ISNR=0
                                                                             IBR06850
        NOREQ = IELEV+IV+IDUDT+ISNR
                                                                             IBR06860
         IF (NOREQ.EQ.0) THEN
                                                                             IBR06870
           CALL STOPP (1,3)
                                                                             IBR06880
        ELSE
                                                                             IBR06890
           CALL CHEOPT (18, IDUM, NNREQ, 1, N5)
                                                                             IBR06900
           READ (11,1110) (NREQ(I), I=1, NNREO)
                                                                             IBR06910
        ENDIF
                                                                             IBR06920
      ENDIF
                                                                             IBR06930
C
                                                                             IBR06940
  ..... CONSTANTS
                                                                             IBR06950
C
           PI = 3.141592...
                                                                            IBR06960
C
            GRAV = gravitational acceleration
                                                                            IBR06970
C
                    . in m/sec**2 if ISYST=1 (SI)
                                                                            IBR06980
C
                    . in ft/sec**2 if ISYST=2 (USCS)
                                                                            IBR06990
      PI = 4.D+00*DATAN(1.D+00)
                                                                            IBR07000
      IF (ISYST.EQ.1) THEN
                                                                            IBR07010
        GRAV = 9.81D+00
                                                                            IBR07020
      ELSE
                                                                            IBR07030
        GRAV = 32.2D+00
                                                                            IBR07040
      ENDIF
                                                                            IBR07050
C
                                                                            IBR07060
 ..... DATA RELATED TO TIME STEPPING
                                                                            IBR07070
            NTOP = total number of time steps for computation
                                                                            IBR07080
C
            NONE = even number of time steps in one wave period
                                                                           IBR07090
C
            The wave period is the reference period used for the
                                                                           IBR07100
C
                    normalization of the governing equations
                                                                            IBR07110
C
            NJUM1: Temporal variations at specified nodes are stored
                                                                            IBR07120
                    at every NJUM1 time steps
                                                                            IBR07130
      READ (11,1110) NTOP
                                                                            IBR07140
      READ (11, 1110) NONE
                                                                            IBR07150
```

_	READ (11,1110) NJUM1	IBR07160
C		IBR07170
C	IMPORTANT TIME LEVELS INCLUDED IN COMMON /TLEVEL/	IBR07180
C	NTOP = final time level	IBR07190
C	NONE = even number of time steps in one wave period	IBR07200
C	NSAVA = time level when saving "A" begins	IBR07210
0	NTIMES = number of time levels when "A" is saved	IBR07220
C	NSTAB = time level when computation of armor stability	IBR07230
C	or movement begins	IBR07240
C	<pre>NSTAT = time level when statistical calculations begin Used: NSTAT=(NTOP-NONE+1) for IWAVE=1</pre>	IBR07250
C	NSTAT=NSAVA for IWAVE>1	IBR07260
C	Note: The value of NTOP for IWAVE>1 will be adjusted in	IBR07270
C	Subr. 3 INPUT2	IBR07280
CCC		IBR07290 IBR07300
C	For monochromatic incident waves with IWAVE=1, use has	IBR07310
C	been made of the following guideline:	IBR07310
C	. Let tp = normalized time when periodicity is established	IBR07330
CCC	. Specify:	IBR07340
C	tp=integer which is 4 or greater for coastal structures	IBR07350
C	NONE=on the order of 2000	IBR07360
C	. Calculate:	IBR07370
C	NTOP=(tp+1) *NONE for (tp+1) wave periods	IBR07380
C	NSTAB=(NTOP-NONE+1) for armor stability during the last	IBR07390
C	one wave period	IBR07400
C	NSAVA=(NTOP-NONE)	IBR07410
C	NTIMES=5 to save "A" at normalized time $t=tp$ , $(tp+1/4)$ , $(tp+2/4)$ , $(tp+3/4)$ and $(tp+1)$ where "A" at $t=tp$ must	IBR07420
C	be the same as "A" at t=(tp+1) if "A" is periodic	IBR07430
C	Moreover, NJUM1 = on the order of NONE/100 so that	IBR07440 IBR07450
C	temporal variations are stored (NONE/NJUM1) times in	IBR07460
C	one wave period	IBR07470
C		IBR07480
	IF (IWAVE.EQ.1) THEN	IBR07490
	NSTAT = NTOP-NONE+1	IBR07500
	ELSE	IBR07510
	NSTAT = NSAVA	IBR07520
	ENDIF	IBR07530
	IF (ISAVA.EQ.0) NSAVA=NTOP+1 IF (ISTAB.EQ.0) NSTAB=NTOP+1	IBR07540
C	II (IOIAD.EQ.V) NSIAD-NIOPTI	IBR07550
C	GENERAL DATA	IBR07560
C	S as input:	IBR07570
C	. for IJOB<3: number of spatial nodes along the bottom	IBR07580 IBR07590
C	below SWL	IBR07600
C	. for IJOB=3: number of nodes between seaward and	IBR07610
C	landward boundaries	IBR07620
C	Note: S should be so large that delta x between two	IBR07630
C	adjacent nodes is sufficiently small.	IBR07640
C	S=100 to 300 has been used.	IBR07650
CCC	FWP = bottom friction factor	IBR07660
C	X1, X2 = damping coefficients	IBR07670
C	<pre>DELTA = normalized water depth defining computational    waterline</pre>	IBR07680
C	NDELR = number of "DELRP"s to be specified	IBR07690
	mander of build 5 to be specified	IBR07700

```
C
             DELRP = physical water depth associated with visual or
                                                                           IBR07710
C
                     measured waterline
                                                                           IBR07720
C
                     . in millimeters if ISYST=1 (SI)
                                                                           IBR07730
C
                      . in inches if ISYST=2 (USCS)
                                                                           IBR07740
       READ (11,1110) S
                                                                           IBR07750
       READ (11,1180) FWP
                                                                           IBR07760
       READ (11,1180) X1,X2
                                                                           IBR07770
      READ (11,1180) DELTA
                                                                           IBR07780
      READ (11,1110) NDELR
                                                                           IBR07790
      CALL CHEOPT (19, IDUM, S, 1, N1-1)
                                                                           IBR07800
       IF (IJOB.LT.3) THEN
                                                                           IBR07810
         CALL CHEOPT (20, IDUM, NDELR, 1, N3)
                                                                           IBR07820
      ELSE
                                                                           IBR07830
        NDELR = 0
                                                                           IBR07840
      ENDIF
                                                                           IBR07850
      DO 120 L = 1, NDELR
                                                                           IBR07860
         READ (11, 1180) DELRP (L)
                                                                           IBR07870
  120 CONTINUE
                                                                           IBR07880
C
                                                                           IBR07890
  ..... WAVE PROPERTIES
                                                                           IBR07900
            HREFP = physical wave height at "reference" location
                                                                           IBR07910
C
                     . in meters if ISYST=1 (SI)
                                                                           IBR07920
C
                     . in feet if ISYST=2 (USCS)
                                                                          IBR07930
                  = physical reference wave period, in seconds
                                                                         IBR07940
C
            HREFP and TP are used to normalize the governing
                                                                          IBR07950
C
                    equations
                                                                          IBR07960
C
            KSREF = shoaling coefficient at "reference" location
                                                                          IBR07970
C
             KSSEA = shoaling coefficient at seaward boundary
                                                                           IBR07980
C
            SIGMA is a measure of wave steepness
                                                                           IBR07990
      READ (11,1180) HREFP, TP
                                                                           IBR08000
      READ (11,1180) KSREF, KSSEA
                                                                           IBR08010
      SIGMA = TP*DSQRT(GRAV/HREFP)
                                                                           IBR08020
C
                                                                           IBR08030
  ..... STRUCTURE GEOMETRY
                                                                           IBR08040
C
            The structure geometry is divided into segments of
                                                                          IBR08050
            different inclination
                                                                          IBR08060
C
            NBSEG = number of segments
                                                                          IBR08070
C
            DSEAP = physical water depth below SWL at seaward
                                                                          IBR08080
C
                     boundary
                                                                          IBR08090
C
            TSLOPS = tangent of slope used to define
                                                                          IBR08100
C
                      "surf similarity parameter"
                                                                          IBR08110
C
            For segment i starting from the seaward boundary:
                                                                          IBR08120
C
              WBSEG(i) = physical horizontal width
                                                                          IBR08130
C
              TBSLOP(i) = tangent of slope (+ upslope, - downslope)
              XBSEG(i) = tangent of slope (+ upslope, - downslope)
XBSEG(i) = physical horizontal distance from seaward
                                                                          IBR08140
C
                                                                          IBR08150
C
                          boundary to the segment's seaward-end
                                                                          IBR08160
C
              ZBSEG(i) = physical water depth below SWL (+ below SWL) IBR08170
C
                          at the segment's seaward-end
                                                                          IBR08180
C
            DSEAP, WBSEG, XBSEG, ZBSEG are in meters if ISYST=1 (SI),
                                                                          IBR08190
C
                                           feet if ISYST=2 (USCS)
                                                                          IBR08200
      READ (11,1180) DSEAP
                                                                          IBR08210
      READ (11,1180) TSLOPS
                                                                          IBR08220
      READ (11,1110) NBSEG
                                                                          IBR08230
      CALL CHEOPT (21, IDUM, NBSEG, 1, N4)
                                                                          IBR08240
      IF (IBOT.EQ.1) THEN
                                                                          IBR08250
```

```
DO 130 K = 1, NBSEG
                                                                           IBR08260
           READ (11,1180) WBSEG(K), TBSLOP(K)
                                                                           IBR08270
         CONTINUE
                                                                           IBR08280
       ELSE
                                                                           IBR08290
         DO 140 K = 1, NBSEG+1
                                                                           IBR08300
           READ (11,1180) XBSEG(K), ZBSEG(K)
                                                                           IBR08310
         CONTINUE
                                                                           IBR08320
       ENDIF
                                                                           IBR08330
                                                                           IBR08340
  ..... DATA RELATED TO SAVING "B", i.e., temporal variations of
                                                                           IBR08350
               total water depth at specified nodes
                                                                           IBR08360
 C
                     = no. of nodes for which "B" is to be saved
                                                                           IBR08370
 C
             NODNO1(I) = I-th node number for which "B" is to be saved
                                                                          IBR08380
 C
             FNAME1(I) = name of file associated with NODNO1(I)
                                                                           IBR08390
       IF (ISAVB.EQ.1) THEN
                                                                           IBR08400
        DO 150 I = 1, NNOD1
                                                                           IBR08410
           READ (11,1190) NODNO1(I), FNAME1(I)
                                                                           IBR08420
  150
         CONTINUE
                                                                           IBR08430
      ENDIF
                                                                           IBR08440
C
                                                                          IBR08450
  ..... DATA RELATED TO ARMOR STABILITY AND MOVEMENT
                                                                          IBR08460
             NJUM2:
                      stability number SNR is computed at every NJUM2
                                                                          IBR08470
C
                      time steps (NJUM2=1 has been used)
                                                                          IBR08480
C
             SG
                    = specific gravity
                                                                           IBR08490
C
            C2
                   = area coefficient
                                                                          IBR08500
C
            C3
                   = volume coefficient
                                                                          IBR08510
C
            CD
                   = drag coefficient
                                                                          IBR08520
C
            CL
                   = lift coefficient
                                                                          IBR08530
C
           CM
                   = inertia coefficient
                                                                          IBR08540
C
           TANPHI = armor friction factor
                                                                          IBR08550
C
           AMAX, AMIN = upper and lower bounds of fluid acceleration,
                                                                          IBR08560
C
                     normalized by gravitational acceleration, used
                                                                          IBR08570
C
                      only for ISTAB=1
                                                                          IBR08580
C
            DAP
                   = physical armor diameter
                                                                          IBR08590
C
                      . in meters IF ISYST=1 (SI)
                                                                          IBR08600
C
                      . in feet IF ISYST=2 (USCS)
                                                                          IBR08610
C
            NNOD2
                      = no. of nodes for which "C" is to be saved
                                                                          IBR08620
            NODNO2(I) = I-th node number for which "C" is to be saved
                                                                          IBR08630
C
            FNAME2(I) = name of file associated with NODNO2(I)
                                                                          IBR08640
            "C" = temporal variations of displacement of armor units
C
                                                                          IBR08650
C
                  from specified initial nodal locations
                                                                          IBR08660
C --- To compute SNR = stability number against rolling/sliding:
                                                                          IBR08670
      IF (ISTAB.GT.0) THEN
                                                                          IBR08680
        READ (11,1110) NJUM2
                                                                          IBR08690
        READ (11,1180) C2,C3,SG
                                                                          IBR08700
        READ (11,1180) CD, CL, CM
                                                                          IBR08710
        READ (11,1180) TANPHI
                                                                          IBR08720
        READ (11,1180) AMAX, AMIN
                                                                          IBR08730
C --- To compute movement of armor units, additional input is required: IBR08750
      IF (ISTAB.EQ.2) THEN
                                                                          IBR08760
        READ (11,1180) DAP
                                                                          IBR08770
        IF (ISAVC.EQ.1) THEN
                                                                          IBR08780
          DO 160 I = 1, NNOD2
                                                                         IBR08790
            READ (11,1190,END=990) NODNO2(I),FNAME2(I)
                                                                         IBR08800
```

	1.00		
1	160		IBR08810
		ENDIF	IBR08820
	0	ENDIF	IBR08830
	C	TE (TNDTC OF A) OFFICE	IBR08840
		IF (INDIC.GT.0) STOP RETURN	IBR08850
	990	CONTINUE	IBR08860
	330	CALL STOPP (4,4)	IBR08870
	C	CALL STOPP (4,4)	IBR08880
	c	FORMATS	IBR08890
	С	FORMIS	IBR08900
		FORMAT (18)	IBR08910
		FORMAT (14A5)	IBR08920
		FORMAT (211,18)	IBR08930
		FORMAT (I1)	IBR08940
		FORMAT (I1,2X,A20)	IBR08950
		FORMAT (311,18,314)	IBR08960
		FORMAT (511,16)	IBR08970
		FORMAT (3F13.6)	IBR08980
		FORMAT (16,2X,A20)	IBR08990 IBR09000
	C		IBR09010
		END	IBR09020
	C		IBR09030
	C -02	END OF SUBROUTINE INPUT1	IBR09040
	C #03	##################### SUBROUTINE INPUT2 ####################################	IBR09050
	C		IBR09060
	C	This subroutine reads seaward boundary wave profile data	IBR09070
	C	if IWAVE>1	IBR09080
	C		IBR09090
		SUBROUTINE INPUT2	IBR09100
	C		IBR09110
		IMPLICIT DOUBLE PRECISION (A-H,O-Z)	IBR09120
		PARAMETER (N1=500, N2=30000, N3=3, N4=100, N5=25)	IBR09130
		PARAMETER (NICE=500)	IBR09140
		COMMON /DIMENS/ N1R, N2R, N3R, N4R, N5R	IBR09150
		COMMON /ID/ IJOB, ISTAB, ISYST, IBOT, INONCT, IENERG, IWAVE,	IBR09160
		ISAVA, ISAVB, ISAVC	IBR09170
		COMMON /TLEVEL/ NTOP, NONE, NJUM1, NJUM2, NSAVA, NSTAB, NSTAT, NTIMES	IBR09180
		COMMON /WAVE3/ ETA(N2), ETAIS(N2), ETARS(N2), ETATS(N2)	IBR09190
		COMMON /WAVE4/ ETAMAX, ETAMIN CALL CHEPAR (3,2,N2,N2R)	IBR09200
	С	CADD CHEFAR (3,2,N2,N2R)	IBR09210
	C	ETA = given time series of free surface profile (IWAVE>1)	IBR09220
-	C	ETAMAX and ETAMIN are its maximum and minimum, respectively	IBR09230
(	C	billing and billing are its maximum and minimum, respectively	IBR09240
(	C	In order to get 'nice' time levels for storage of computed	IBR09250
(	C	results, NTOP is taken to be a multiplication of NICE specified	IBR09260
(	C	in the PARAMETER statement of this subroutine	IBR09270
	C	or ours surrentile	IBR09280
		READ (12,1210,END=910) (IDUM,ETA(I),I=1,N2)	IBR09290 IBR09300
	910	CONTINUE	IBR09310
		IDUM = I-1	IBR09320
		WRITE (*,2910) IDUM	IBR09330
		WRITE (29,2910) IDUM	IBR09340
		NTOP = IDUM+1	IBR09350

```
920 CONTINUE
                                                                          IBR09360
        NTOP = NTOP-1
                                                                          IBR09370
        IDUM = MOD(NTOP, NICE)
                                                                          IBR09380
      IF (IDUM.NE.0) GOTO 920
                                                                          IBR09390
      ETAMAX = -1.D+03
                                                                         IBR09400
      ETAMIN = 1.D+03
                                                                         IBR09410
      DO 100 I = 1, NTOP
                                                                         IBR09420
        IF (ETA(I).GT.ETAMAX) ETAMAX=ETA(I)
                                                                         IBR09430
        IF (ETA(I).LT.ETAMIN) ETAMIN=ETA(I)
                                                                        IBR09440
  100 CONTINUE
                                                                         IBR09450
      IF (ISAVA.EQ.0) NSAVA=NTOP+1
                                                                         IBR09460
      IF (ISTAB.EQ.0) NSTAB=NTOP+1
                                                                         IBR09470
 1210 FORMAT (I10, F10.6)
                                                                         IBR09480
 2910 FORMAT (/' From Subroutine 3 INPUT2'/
                                                                         TBR09490
     +' Seaward boundary wave profile has been read from a data file'/ IBR09500
     +' Number of data points read =', 18)
                                                                         IBR09510
C
                                                                         IBR09520
      RETURN
                                                                         IBR09530
      END
                                                                         IBR09540
                                                                         IBR09550
C -03----- END OF SUBROUTINE INPUT2 ----- IBR09560
C
                                                                         IBR09580
C
      This subroutine calculates normalized structure geometry and
                                                                         IBR09590
C
      delta x between two adjacent nodes
                                                                         IBR09600
C
                                                                         IBR09610
      SUBROUTINE BOTTOM
                                                                         IBR09620
C
                                                                         IBR09630
      IMPLICIT DOUBLE PRECISION (A-H, O-Z)
      PARAMETER (N1=500, N2=30000, N3=3, N4=100, N5=25)
                                                                         IBR09650
      DOUBLE PRECISION KS, KSREF, KSSEA, KSI
                                                                         IBR09660
      DIMENSION TSLOPE (N1)
                                                                         IBR09670
      INTEGER S
                                                                         IBR09680
      COMMON /DIMENS/ N1R, N2R, N3R, N4R, N5R
                                                                         IBR09690
      COMMON /CONSTA/ PI, GRAV, DELTA, X1, X2
                                                                         IBR09700
                     IJOB, ISTAB, ISYST, IBOT, INONCT, IENERG, IWAVE,
      COMMON /ID/
                                                                         IBR09710
                      ISAVA, ISAVB, ISAVC
                                                                         IBR09720
      COMMON /TLEVEL/ NTOP, NONE, NJUM1, NJUM2, NSAVA, NSTAB, NSTAT, NTIMES
                                                                         IBR09730
      COMMON /NODES/ S, JE, JE1, JSTAB, JMAX
                                                                         IBR09740
      COMMON /GRID/
                      T, X, TX, XT, TTX, TTXX, TWOX
                                                                         IBR09750
      COMMON /WAVE1/ HREFP, TP, WLOP
                                                                         IBR09760
      COMMON /WAVE2/ KS, KSREF, KSSEA, WLO, WL, UR, URPRE, KSI, SIGMA
                                                                         IBR09770
      COMMON /BOT1/ DSEAP, DLANDP, FWP
COMMON /BOT2/ DSEA, DSEAKS, DSEA2, DLAND, DLAND2, FW, TSLOPS, WTOT
                                                                         IBR09780
                                                                         IBR09790
      COMMON /BOT3/ U2INIT(N1), THETA(N1), SSLOPE(N1), XB(N1), ZB(N1)
                                                                         IBR09800
      COMMON /BOT4/ NBSEG
                                                                         IBR09810
      COMMON /BOT5/ WBSEG(N4), TBSLOP(N4), XBSEG(N4), ZBSEG(N4)
                                                                         IBR09820
      COMMON /STAB1/ C2,C3,CD,CL,CM,SG,TANPHI,AMIN,AMAX,DAP
                                                                         IBR09830
      COMMON /STAB2/ SG1, CTAN (N1)
                                                                         IBR09840
      CALL CHEPAR (4,1,N1,N1R)
                                                                         IBR09850
      CALL CHEPAR (4,4,N4,N4R)
                                                                         IBR09860
C
                                                                         IBR09870
C
 ... THE FOLLOWING VARIABLES ARE DIMENSIONAL
                                                                         IBR09880
                                                                         IBR09890
      TSLOPS = tangent of slope used to define
                                                                         IBR09900
```

```
C
                "surf similarity parameter"
                                                                            IBR09910
      BSWL: . for IJOB<3: physical horizontal distance between seaward boundary and initial waterline on slope . for IJOB=3: physical horizontal distance between
                                                                           IBR09920
C
                                                                           IBR09930
C
                                                                           IBR09940
C
               seaward and landward boundaries
                                                                            IBR09950
C
      DSEAP = water depth below SWL at seaward boundary
                                                                            IBR09960
C
                                                                            IBR09970
C
      The structure geometry is divided into segments of different
                                                                            IBR09980
C
      inclination
                                                                            IBR09990
C
      NBSEG = number of segments
                                                                            IBR10000
C
      For segment i starting from the seaward boundary:
                                                                            IBR10010
C
        WBSEG(i) = physical horizontal width
                                                                            IBR10020
C
        TBSLOP(i) = tangent of slope (+ upslope, - downslope)
                                                                            IBR10030
C
        XBSEG(i) = physical horizontal distance from seaward boundary IBR10040
C
                     to the segment's seaward-end
                                                                            IBR10050
       ZBSEG(i) = physical water depth below SWL (+ below SWL)
C
                                                                            IBR10060
C
                     at the segment's seaward-end
                                                                           IBR10070
C
     BSWL, DSEAP, WBSEG, XBSEG, ZBSEG are in meters if ISYST=1 (SI),
                                                                           IBR10080
                                            feet if ISYST=2 (USCS)
                                                                            IBR10090
                                                                            IBR10100
C ... COMPLETE SEGMENT DATA NOT SPECIFIED AS INPUT
                                                                            IBR10110
                                                                            IBR10120
      IF (IBOT.EQ.1) THEN
                                                                            IBR10130
               = 0.D + 00
                                                                            IBR10140
        XBSEG(1) = 0.D+00
                                                                            IBR10150
        ZBSEG(1) = DSEAP
                                                                            IBR10160
        DO 110 K = 2, NBSEG+1
                                                                            IBR10170
          DCUM = DCUM + WBSEG(K-1) *TBSLOP(K-1)
                                                                            IBR10180
          XBSEG(K) = XBSEG(K-1) + WBSEG(K-1)
                                                                            IBR10190
          ZBSEG(K) = DSEAP - DCUM
                                                                            IBR10200
        CONTINUE
                                                                            IBR10210
      ELSE
                                                                            IBR10220
        DO 120 K = 1, NBSEG
                                                                            IBR10230
          TBSLOP(K) = -(ZBSEG(K+1)-ZBSEG(K))/(XBSEG(K+1)-XBSEG(K))
                                                                            IBR10240
  120
        CONTINUE
                                                                            IBR10250
      ENDIF
                                                                            IBR10260
C
                                                                           IBR10270
  ... CALCULATE GRID SPACING X BETWEEN TWO ADJACENT NODES
                                                                           IBR10280
C
      (dimensional)
                                                                           IBR10290
C
                                                                           IBR10300
C
      The value of S specified as input corresponds to
                                                                           IBR10310
      . for IJOB<3: number of nodes along the bottom below SWL
C
                                                                           IBR10320
C
      . for IJOB=3: number of nodes between seaward and landward
                                                                           IBR10330
C
                     boundaries
                                                                            IBR10340
C
                                                                            IBR10350
      IF (IJOB.LT.3) THEN
                                                                            IBR10360
       K = 0
                                                                            IBR10370
  900
      CONTINUE
                                                                            IBR10380
          IF (K.EQ.NBSEG) CALL STOPP (5,6)
                                                                           IBR10390
          K = K+1
                                                                           IBR10400
          CROSS = ZBSEG(K) * ZBSEG(K+1)
                                                                           IBR10410
        IF (CROSS.GT.0.D+00) GOTO 900
                                                                           IBR10420
        BSWL = XBSEG(K+1) + ZBSEG(K+1)/TBSLOP(K)
                                                                           IBR10430
           = BSWL/DBLE(S)
                                                                           IBR10440
      ELSE
                                                                           IBR10450
```

IBREAK FORTRAN

```
BSWL = XBSEG (NBSEG+1)
                                                                          IBR10460
         X = BSWL/DBLE(S-1)
                                                                          IBR10470
         DO 130 K = 1, NBSEG+1
                                                                          IBR10480
           IF (ZBSEG(K).LT.O.D+00) CALL STOPP (7,8)
                                                                         IBR10490
         CONTINUE
                                                                         IBR10500
       ENDIF
                                                                         IBR10510
 C
                                                                         IBR10520
 C ... CALCULATE STRUCTURE GEOMETRY AT EACH NODE (dimensional)
                                                                         IBR10530
 C
                                                                         IBR10540
C
       JE = landward edge node (IJOB<3) or landward boundary node
                                                                         IBR10550
C
            (IJOB=3)
                                                                         IBR10560
C
      U2INIT(j) = water depth below SWL at node j (+ below SWL)
                                                                         IBR10570
C
                 = total water depth U(2,j) at time t=0
                                                                         IBR10580
C
                   (physical, later normalized under the same name)
                                                                     IBR10590
C
      TSLOPE(j) = tangent of local slope at node j
                                                                         IBR10600
C
                                                                         IBR10610
      IF (IJOB.LT.3) THEN
                                                                         IBR10620
        DUM = XBSEG(NBSEG+1)/X
                                                                          IBR10630
        JE = INT(DUM) + 1
                                                                          IBR10640
      ELSE
                                                                         IBR10650
        JE = S
                                                                          IBR10660
      ENDIF
                                                                          IBR10670
      IF (JE.GT.N1) THEN
                                                                          IBR10680
        WRITE (*,2910) JE,N1
                                                                         IBR10690
        WRITE (29,2910) JE,N1
                                                                         IBR10700
        STOP
                                                                         IBR10710
      ELSE
                                                                         IBR10720
        JE1 = JE-1
                                                                         IBR10730
      ENDIF
                                                                         IBR10740
 2910 FORMAT (/' End Node =', I8,'; N1 =', I8/
                                                                         IBR10750
              ' Slope/Structure is too long.'/
                                                                         IBR10760
               ' Cut it, or change PARAMETER N1.')
                                                                         IBR10770
C
                                                                         IBR10780
      DIST = -X
                                                                         IBR10790
      K = 1
                                                                         IBR10800
      XCUM = XBSEG(K+1)
                                                                         IBR10810
      DO 140 J = 1, JE
                                                                         IBR10820
        DIST = DIST + X
                                                                         IBR10830
        IF (DIST.GT.XCUM.AND.K.LT.NBSEG) THEN
                                                                         IBR10840
          K
             = K+1
                                                                         IBR10850
          XCUM = XBSEG(K+1)
                                                                         IBR10860
                                                                         IBR10870
        U2INIT(J) = ZBSEG(K) - (DIST-XBSEG(K))*TBSLOP(K)
                                                                         IBR10880
        TSLOPE(J) = TBSLOP(K)
                                                                         IBR10890
  140 CONTINUE
                                                                         IBR10900
C
                                                                         IBR10910
C ... NORMALIZATION
                                                                         IBR10920
C
                                                                         IBR10930
C
      WTOT = normalized width of computation domain
                                                                         IBR10940
C
      At node j:
                                                                         IBR10950
C
       U2INIT(j) = normalized water depth below SWL (+ below SWL)
                                                                       IBR10960
C
        THETA(j) = normalized tangent of local slope
                                                                         IBR10970
C
        (XB(j), ZB(j)) = normalized coordinates of the structure
                                                                        IBR10980
C
                                                                         IBR10990
     DUM = TP*DSQRT(GRAV*HREFP)
                                                                         IBR11000
```

```
X = X/DUM
                                                                       IBR11010
      DIST = -X
                                                                       IBR11020
      WTOT = DBLE(JE1) *X
                                                                       IBR11030
      DO 150 J = 1, JE
                                                                       IBR11040
        U2INIT(J) = U2INIT(J)/HREFP
                                                                       IBR11050
        THETA(J) = TSLOPE(J) *SIGMA
                                                                       IBR11060
                = DIST + X
                                                                       IBR11070
        XB(J)
                = DIST
                                                                       IBR11080
        ZB(J)
                 = -U2INIT(J)
                                                                       IBR11090
  150 CONTINUE
                                                                       IBR11100
C
                                                                       IBR11110
  ... QUANTITIES NEEDED FOR COMPUTATION OF ARMOR STABILITY AND
                                                                       IBR11120
C
      MOVEMENT
                                                                       IBR11130
                                                                       IBR11140
C
     TSLOPE(j) = tangent of local slope at node j
                                                                       IBR11150
C
      SSLOPE(j) = sine of local slope at node j
                                                                       IBR11160
C
     CSLOPE = cosine of local slope
                                                                       IBR11170
C
     TANPHI = armor friction factor
                                                                       IBR11180
C
                                                                       IBR11190
      IF (ISTAB.GT.0) THEN
                                                                       IBR11200
       DO 160 J = 1, JE
                                                                       IBR11210
         ANGLE
                  = DATAN (TSLOPE (J))
                                                                       IBR11220
          CSLOPE = DCOS (ANGLE)
                                                                       IBR11230
          SSLOPE(J) = DSIN(ANGLE)
                                                                       IBR11240
         CTAN(J) = CSLOPE*TANPHI
                                                                       IBR11250
  160
      CONTINUE
                                                                       IBR11260
     ENDIF
                                                                       IBR11270
C
                                                                       IBR11280
     RETURN
                                                                       IBR11290
                                                                       IBR11300
C
                                                                       IBR11310
C -04----- END OF SUBROUTINE BOTTOM ----- IBR11320
C
                                                                       IBR11340
C
     This subroutine calculates parameters used in other subroutines IBR11350
C
                                                                      IBR11360
     SUBROUTINE PARAM
                                                                      IBR11370
C
                                                                      IBR11380
     IMPLICIT DOUBLE PRECISION (A-H, O-Z)
                                                                      IBR11390
     PARAMETER (N1=500, N2=30000, N3=3, N4=100, N5=25)
                                                                      IBR11400
     DOUBLE PRECISION KS, KSREF, KSSEA, KSI
                                                                      IBR11410
     INTEGER S
                                                                      IBR11420
     COMMON /DIMENS/ N1R, N2R, N3R, N4R, N5R
                                                                      IBR11430
     COMMON /CONSTA/ PI, GRAV, DELTA, X1, X2
                                                                      IBR11440
     COMMON /ID/
                     IJOB, ISTAB, ISYST, IBOT, INONCT, IENERG, IWAVE,
                                                                      IBR11450
                     ISAVA, ISAVB, ISAVC
                                                                      IBR11460
     COMMON /TLEVEL/ NTOP, NONE, NJUM1, NJUM2, NSAVA, NSTAB, NSTAT, NTIMES
     COMMON /GRID/
                    T, X, TX, XT, TTX, TTXX, TWOX
                                                                      IBR11480
     COMMON /WAVE1/ HREFP, TP, WLOP
                                                                      IBR11490
     COMMON /WAVE2/ KS, KSREF, KSSEA, WLO, WL, UR, URPRE, KSI, SIGMA
                                                                      IBR11500
     COMMON /NODES/ S, JE, JE1, JSTAB, JMAX
                                                                      IBR11510
     COMMON /BOT1/ DSEAP, DLANDP, FWP
                                                                      IBR11520
     COMMON /BOT2/ DSEA, DSEAKS, DSEA2, DLAND, DLAND2, FW, TSLOPS, WTOT
                                                                      IBR11530
     COMMON /BOT3/ U2INIT(N1), THETA(N1), SSLOPE(N1), XB(N1), ZB(N1)
                                                                      IBR11540
     COMMON /RUNP1/ NDELR
                                                                      IBR11550
```

```
COMMON /RUNP2/ DELRP(N3), DELTAR(N3), RUNUPS(N3), RSTAT(3, N3)
                                                                       IBR11560
      COMMON /STAB1/ C2,C3,CD,CL,CM,SG,TANPHI,AMIN,AMAX,DAP
                                                                        IBR11570
      COMMON /STAB2/ SG1, CTAN (N1)
                                                                        IBR11580
      COMMON /STAB3/ CSTAB1, CSTAB2, AMAXS, AMINS, E2, E3PRE (N1)
                                                                        IBR11590
      COMMON /STAB4/ CSTAB3, CSTAB4, CM1, DA, SIGDA, WEIG
                                                                        IBR11600
      CALL CHEPAR (5,1,N1,N1R)
                                                                        IBR11610
      CALL CHEPAR (5,3,N3,N3R)
                                                                       IBR11620
C
                                                                        IBR11630
C ... PARAMETERS RELATED TO FINITE DIFFERENCE GRIDDING
                                                                       IBR11640
                                                                       IBR11650
C
      T = delta t = constant time step
                                                                        IBR11660
C
      X = delta x = constant grid spacing between two adjacent nodes
                                                                       IBR11670
C
      NTOP = final time level
                                                                        IBR11680
      NONE = number of time steps in one wave period
C
                                                                        IBR11690
C
                                                                        IBR11700
          = 1.D + 00/DBLE (NONE)
                                                                        IBR11710
      TX = T/X
                                                                        IBR11720
      XT = X/T
                                                                        IBR11730
      TTX = T*T/X
                                                                        IBR11740
      TTXX = T*T/(X*X)
                                                                        IBR11750
      TWOX = 2.D+00*X
                                                                        IBR11760
                                                                       IBR11770
C ... PARAMETERS RELATED TO WAVE AND SLOPE CHARACTERISTICS
                                                                       IBR11780
C
                                                                       IBR11790
C
     KSI
                  = surf similarity parameter
                                                                        IBR11800
C
                 = deep-water wavelengths, physical and normalized,
     WLOP, WLO
                                                                       IBR11810
C
                   respectively
                                                                       IBR11820
     DSEAP, DSEA = water depths below SWL at seaward boundary,
C
                                                                       IBR11830
C
                    physical and normalized, respectively
                                                                       IBR11840
C
     DLANDP, DLAND = water depths below SWL at landward boundary,
                                                                      IBR11850
C
                   physical and normalized, respectively
                                                                       IBR11860
C
                     (only for IJOB=3)
                                                                       IBR11870
C
    FWP, FW
                  = slope friction factors, physical and normalized, IBR11880
                    respectively
                                                                       IBR11890
C
     DELRP, DELTAR = water depths associated with visual or measured
                                                                       IBR11900
C
                    waterline, physical and normalized, respectively IBR11910
C
                                                                       IBR11920
     WLOP = GRAV*(TP*TP)/(2.D+00*PI)
                                                                       IBR11930
           = WLOP/DSEAP
                                                                       IBR11940
            = KSSEA/KSREF
     KS
                                                                       IBR11950
     KSI
           = SIGMA*TSLOPS/DSQRT(2.D+00*PI)
                                                                       IBR11960
     DSEA = DSEAP/HREFP
                                                                       IBR11970
     DSEAKS = DSEA/KS
                                                                       IBR11980
     DSEA2 = DSORT(DSEA)
                                                                       IBR11990
            = .5D+00*FWP*SIGMA
                                                                       IBR12000
     DO 110 L = 1, NDELR
                                                                       IBR12010
       IF (ISYST.EQ.1) THEN
                                                                       IBR12020
         DELTAR(L) = DELRP(L)/(1.D+03*HREFP)
                                                                       IBR12030
                                                                       IBR12040
         DELTAR(L) = DELRP(L)/(12.D+00*HREFP)
                                                                       IBR12050
       ENDIF
                                                                       IBR12060
 110 CONTINUE
                                                                       IBR12070
     IF (IJOB.EQ.3) THEN
                                                                       IBR12080
       DLAND = U2INIT(S)
                                                                       IBR12090
       DLANDP = DLAND*HREFP
                                                                       IBR12100
```

		DLAND2 = DSQRT (DLAND)	IBR12110
-		ENDIF	IBR12120
C		T TAIDAD MANIET BAOMY AND DOGGE	IBR12130
C		LINEAR WAVELENGTH AND PRELIMINARY URSELL NUMBER	IBR12140
C		WY	IBR12150
C		WL = normalized linear wavelength at seaward boundary	IBR12160
C		UR = Ursell number at seaward boundary based on linear wavelength	IBR12170
C		MWORT - 0 DIOOFRI	IBR12180
		TWOPI = 2.D+00*PI $WL = WL0$	IBR12190
			IBR12200
	000	FUN1 = WL - WLO*DTANH(TWOPI/WL)	IBR12210
	900	IF (DABS (FUN1) .GT.1.D-04) THEN	IBR12220
		FUN2 = 1.D+00 + WLO*TWOPI/(WL*DCOSH(TWOPI/WL))**2	IBR12230
		WL = WL - FUN1/FUN2	IBR12240
		FUN1 = WL - WLO*DTANH(TWOPI/WL)	IBR12250
		GOTO 900 ENDIF	IBR12260
		UR = WL*WL/DSEAKS	IBR12270
		URPRE = UR	IBR12280
C		ORPRE = UR	IBR12290
C		PARAMETERS FOR ARMOR STABILITY AND MOVEMENT	IBR12300
C		FARAMETERS FOR ARMOR STABILITY AND MOVEMENT	IBR12310
C		JSTAB = the largest node number for which computation of armor	IBR12320
C		JSTAB = the largest node number for which computation of armor stability or movement will be performed	IBR12330
C		SG = specific gravity	IBR12340
C		C2 = area coefficient	IBR12350
C		C3 = volume coefficient	IBR12360
C		CD = drag coefficient	IBR12370
C		CL = lift coefficient	IBR12380
C		CM = inertia coefficient	IBR12390
C		TANDUT - armor frietien forten	IBR12400
C		AMAY AMIN = upper and lever haveds as said	IBR12410
C		normalized by annuitational	IBR12420
C		ESPDE is propared for computing ES !	IBR12430
C		DAP DA = armor diameters whereight	IBR12440
C		used in Cube 20 Morre	IBR12450
C		WETC - normalized subsequent	IBR12460
C		Cube 21 EODGEC	IBR12470
C			IBR12480
		TE /TCTAD CT A) TUENT	IBR12490
		SG1 = SG-1 D+00	IBR12500
		TE (TIOD EO 2) TOMAD-TO	IBR12510
		ENDIE	IBR12520
		TE (TEMAD EO 1) MUENT	IBR12530 IBR12540
		CSTAR1 - 2 D+00+C3++/2 D100/2 D100/	IBR12550
		CSTAR? - CM//SCI+CTCMA	IBR12560
		F2 - CI *TANDUT (CD	IBR12570
		$\Delta M \Delta V C = \Delta M \Delta V + C T C M \Delta$	IBR12580
		AMTNC - AMTNI+CTCMA	IBR12590
		DO 120 T = 1 TE	IBR12600
		E3DDE/TV - CCMAD1+CMAY/TV	IBR12610
	120	CONTINUE	IBR12620
		FISETE /TOURD EO 21 MUENT	IBR12630
			BR12640
		DA - DAD (UDEED	BR12650

```
SIGDA = SIGMA/DA
                                                                        IBR12660
        CSTAB3 = C2*CD/(2.D+00*C3*DA)
                                                                        IBR12670
        CSTAB4 = C2*CL/(2.D+00*C3*DA)
                                                                        IBR12680
        WEIG = SIGMA*SG1
                                                                        IBR12690
      ENDIF
                                                                        IBR12700
C
                                                                        IBR12710
      RETURN
                                                                        IBR12720
      END
                                                                        IBR12730
C
                                                                       IBR12740
C -05----- END OF SUBROUTINE PARAM ----- IBR12750
C
                                                                        IBR12770
C
      This subroutine assigns initial values
                                                                        IBR12780
C
                                                                        IBR12790
      SUBROUTINE INIT1
                                                                        IBR12800
C
                                                                        IBR12810
      IMPLICIT DOUBLE PRECISION (A-H, O-Z)
                                                                        IBR12820
      PARAMETER (N1=500, N2=30000, N3=3, N4=100, N5=25)
                                                                       IBR12830
      INTEGER S
                                                                       IBR12840
      COMMON /DIMENS/ N1R, N2R, N3R, N4R, N5R
                                                                       IBR12850
      COMMON /CONSTA/ PI, GRAV, DELTA, X1, X2
                                                                       IBR12860
      COMMON /ID/
                      IJOB, ISTAB, ISYST, IBOT, INONCT, IENERG, IWAVE,
                                                                       IBR12870
                      ISAVA, ISAVB, ISAVC
                                                                       IBR12880
      COMMON /NODES/ S, JE, JE1, JSTAB, JMAX
                                                                       IBR12890
      COMMON /BOT3/ U2INIT(N1), THETA(N1), SSLOPE(N1), XB(N1), ZB(N1)
                                                                       IBR12900
      COMMON /HYDRO/ U(2,N1),V(N1),ELEV(N1),C(N1),DUDT(N1)
                                                                       IBR12910
      COMMON /RUNP1/ NDELR
                                                                       IBR12920
      COMMON /RUNP2/ DELRP(N3), DELTAR(N3), RUNUPS(N3), RSTAT(3, N3)
                                                                       IBR12930
      COMMON /OVER/
                      OV (4)
                                                                       IBR12940
      COMMON /STAT/
                      ELSTAT(3), U1STAT(N1), ESTAT(3, N1), VSTAT(3, N1)
                                                                       IBR12950
      COMMON /ENERG/ ENER(4,N1), ENERB(14)
                                                                       IBR12960
      COMMON /STAB5/ JSNSC, NSNSC, NSNSX (N1)
                                                                       IBR12970
      COMMON /STAB6/ SNSC, SNR(N1), SNSX(N1)
                                                                       IBR12980
      COMMON /STAB7/ NMOVE, NSTOP,
                                                                       IBR12990
                      ISTATE (N1), NODIN (N1), NODFI (N1), NDIS (N1)
                                                                       IBR13000
      CALL CHEPAR (6,1,N1,N1R)
                                                                       IBR13010
      CALL CHEPAR (6,3,N3,N3R)
                                                                       IBR13020
C
                                                                       IBR13030
C ... INSTANTANEOUS HYDRODYNAMIC QUANTITIES
                                                                       IBR13040
                                                                       IBR13050
C
     Hydrodynamic quantities at node j:
                                                                       IBR13060
C
       U(1,j) = volume flux
                                                                       IBR13070
C
       U(2,j) = total water depth (not less than DELTA for IJOB=3)
                                                                       IBR13080
C
       V(j) = depth-averaged velocity
                                                                       IBR13090
       ELEV(j) = surface elevation above SWL
C
                                                                       IBR13100
                                                                       IBR13110
     DO 110 J = 1, JE
                                                                       IBR13120
       U(1,J) = 0.D+00
                                                                       IBR13130
       IF (J.LE.S) THEN
                                                                       IBR13140
         U(2,J) = U2INIT(J)
                                                                       IBR13150
         ELEV(J) = 0.D+00
                                                                       IBR13160
       ELSE
                                                                       IBR13170
         U(2,J) = 0.D+00
                                                                       IBR13180
         ELEV(J) = ZB(J)
                                                                       IBR13190
       ENDIF
                                                                       IBR13200
```

		V(J) = 0.D+00	TDD12010
		IF (IJOB.EQ.3.AND.U(2,J).LT.DELTA) U(2,J)=DELTA	IBR13210
	110	CONTINUE	IBR13220
C			IBR13230
C		HYDRODYNAMIC QUANTITIES FOR STATISTICAL CALCULATIONS	IBR13240 IBR13250
C			
C		Subr. 7 INIT2 is used to specify initial values for statistical	IBR13260
C		quantities	IBR13270 IBR13280
C		ELSTAT(1) = mean surface elev. of incident wave at seaw. bdry.	IBR13290
C		At node j:	IBR13300
C		U1STAT(j) = mean volume flux	IBR13310
C		Mean, maximum, and minimum at node j:	IBR13320
C		ESTAT(1,j), ESTAT(2,j), ESTAT(3,j): for ELEV(j)	IBR13330
C		VSTAT(1,j), VSTAT(2,j), VSTAT(3,j): for V(j)	IBR13340
C		1	IBR13350
		ELSTAT(1) = 0.D+00	IBR13360
		CALL INIT2 (1,U1STAT,1,JE)	IBR13370
		CALL INIT2 (2, ESTAT, 3, JE)	IBR13380
		CALL INIT2 (2, VSTAT, 3, JE)	IBR13390
C			IBR13400
C		RUNUP	IBR13410
C			IBR13420
C		JMAX = the largest node number reached by computational	IBR13430
C		waterline	IBR13440
C		RSTAT(1), RSTAT(2), RSTAT(3) = mean, maximum, and minimum RUNUPS	IBR13450
C		(See Subr. 13 LANDBC for RUNUPS)	IBR13460
C		JMAX = S	IBR13470
			IBR13480
C		IF (IJOB.LT.3) CALL INIT2 (2, RSTAT, 3, NDELR)	IBR13490
C		OVERTOPPING	IBR13500
C		Computed during N=NSTAT to N=NTOP in Subr. 15 OVERT	IBR13510
C		compared during N-NSTAT to N-NTOP in Subr. 15 OVERT	IBR13520
C		OV(1) = normalized average overtopping rate	IBR13530
C		OV(2) = normalized time when OV(4) occurs after time of N=NSTAT	IBR13540
C		OV(3) = normalized overtopping duration	IBR13550
C		OV(4) = normalized maximum overtopping rate	IBR13560
C		OV(2) and OV(3) will eventually be normalized in Subr. 23 STAT2	IBR13570
C		or to, and or to, will evenedally be normalized in Subr. 23 STAT2	IBR13580
		IF (IJOB.EQ.2) CALL INIT2 (1,0V,1,4)	IBR13590
C		(2/01/2/1/	IBR13600
C		ARMOR STABILITY AND MOVEMENT	IBR13610
C			IBR13620
C		Stability numbers:	IBR13630 IBR13640
C		<pre>SNR(j) = stability number against rolling/sliding at node j</pre>	IBR13650
C		SNSX(j) = local stability number = minimum of SNR at node i	IBR13660
C		SNSC = critical stab. number = min. of SNSX along the slope	IBR13670
C		Armor units movement:	IBR13680
C		NMOVE = no. of units dislodged from their initial locations	IBR13690
C		NSTOP = no. of units stopped after moving	IBR13700
C		ISTATE(j) indicates the state of armor unit initially located	IBR13710
C		at node j: 0=stationary, 1=moving, 2=stopped	IBR13720
C			IBR13730
		IF (ISTAB.EQ.1) THEN	IBR13740
		SNSC = 1.D+03	IBR13750

```
DO 120 J = 1, JE
                                                                   IBR13760
          SNSX(J) = 1.D+03
                                                                   IBR13770
  120
        CONTINUE
                                                                   IBR13780
      ELSEIF (ISTAB.EQ.2) THEN
                                                                   IBR13790
        NMOVE = 0
                                                                   IBR13800
        NSTOP = 0
                                                                   IBR13810
        DO 130 J = 1, JE
                                                                   IBR13820
         ISTATE(J) = 0
                                                                   IBR13830
      CONTINUE
  130
                                                                   IBR13840
      ENDIF
                                                                   IBR13850
                                                                   IBR13860
C ... WAVE ENERGY (normalized time-averaged quantities)
                                                                   IBR13870
C
                                                                   IBR13880
C
      At node j:
                                                                   IBR13890
C
       ENER(1,j) = energy per unit surface area
                                                                   IBR13900
C
       ENER(2,j) = energy flux per unit width
                                                                  IBR13910
      Rate of energy dissipation, at node j:
                                                                  IBR13920
      ENER(3,j): due to bottom friction, per unit bottom area ENER(4,j): due to wave breaking, per unit surface area
C
                                                                 IBR13930
C
                                                                  IBR13940
C
                                                                  IBR13950
     IF (IENERG.EQ.1) CALL INIT2 (1, ENER, 4, JE)
                                                                  IBR13960
C
                                                                   IBR13970
      RETURN
                                                                   IBR13980
      END
                                                                  IBR13990
C
                                                                   IBR14000
C -06----- END OF SUBROUTINE INIT1 ----- IBR14010
IBR14030
     This subroutine facilitates assignment of initial values in
C
                                                                  IBR14040
C
     Subr. 6 INIT1
                                                                  IBR14050
C
                                                                  IBR14060
     SUBROUTINE INIT2 (MODE, VAL, ND1, ND2)
                                                                  IBR14070
C
                                                                  IBR14080
     IMPLICIT DOUBLE PRECISION (A-H, O-Z)
                                                                  IBR14090
     DIMENSION VAL (ND1, ND2)
                                                                  IBR14100
     IF (MODE.EQ.1) THEN
                                                                  IBR14110
       DO 120 I = 1, ND1
                                                                  IBR14120
         DO 110 J = 1,ND2
                                                                   IBR14130
           VAL(I,J) = 0.D+00
                                                                  IBR14140
  110
         CONTINUE
                                                                  IBR14150
  120
       CONTINUE
                                                                  IBR14160
     ELSE
                                                                  IBR14170
       DO 130 J = 1,ND2
                                                                  IBR14180
         VAL(1,J) = 0.D+00
                                                                  IBR14190
         VAL(2,J) = -1.D+03
                                                                  IBR14200
         VAL(3,J) = 1.D+03
                                                                  IBR14210
  130
       CONTINUE
                                                                  IBR14220
     ENDIF
                                                                  IBR14230
C
                                                                  IBR14240
     RETURN
                                                                  IBR14250
                                                                  IBR14260
                                                                  IBR14270
C -07----- END OF SUBROUTINE INIT2 ----- IBR14280
C
                                                                  IBR14300
```

```
This subroutine computes incident wave profile at seaward
C
                                                                         IBR14310
C
      boundary if IWAVE=1
                                                                          IBR14320
C
      Wave Profile: Stokes II if UR<26
                                                                          IBR14330
C
                    Cnoidal otherwise
                                                                          IBR14340
                                                                          IBR14350
      SUBROUTINE INWAV
                                                                          IBR14360
C
                                                                          IBR14370
      IMPLICIT DOUBLE PRECISION (A-H, O-Z)
                                                                          IBR14380
      PARAMETER (N1=500, N2=30000, N3=3, N4=100, N5=25)
                                                                          IBR14390
      DOUBLE PRECISION K, M, KC2, KC, KS, KSREF, KSSEA, KSI
                                                                          IBR14400
      DIMENSION ETAU(N2)
                                                                          IBR14410
      COMMON /DIMENS/ N1R, N2R, N3R, N4R, N5R
                                                                          IBR14420
      COMMON /CONSTA/ PI, GRAV, DELTA, X1, X2
                                                                          IBR14430
      COMMON /ID/
                   IJOB, ISTAB, ISYST, IBOT, INONCT, IENERG, IWAVE,
                                                                         IBR14440
                      ISAVA, ISAVB, ISAVC
                                                                         IBR14450
      COMMON /TLEVEL/ NTOP, NONE, NJUM1, NJUM2, NSAVA, NSTAB, NSTAT, NTIMES IBR14460
      COMMON /GRID/ T, X, TX, XT, TTX, TTXX, TWOX
                                                                          IBR14470
      COMMON /WAVE2/ KS, KSREF, KSSEA, WLO, WL, UR, URPRE, KSI, SIGMA
                                                                          IBR14480
      COMMON /WAVE3/ ETA(N2), ETAIS(N2), ETARS(N2), ETATS(N2)
                                                                          IBR14490
      COMMON /WAVE4/ ETAMAX, ETAMIN
                                                                          IBR14500
      COMMON /WAVE5/ K,E,M,KC2
                                                                          IBR14510
      COMMON /BOT2/ DSEA, DSEAKS, DSEA2, DLAND, DLAND2, FW, TSLOPS, WTOT
                                                                          IBR14520
      CALL CHEPAR (8,2,N2,N2R)
                                                                          IBR14530
C
                                                                          IBR14540
C ... CONSTANTS
                                                                          IBR14550
C
                                                                          IBR14560
      TWOPI = 2.D+00*PI
                                                                          IBR14570
      FOURPI = 4.D+00*PI
                                                                          IBR14580
      HALFPI = PI/2.D+00
                                                                          IBR14590
      NONE1 = NONE+1
                                                                          IBR14600
      NHALF = NONE/2
                                                                          IBR14610
      NHALF1 = NHALF+1
                                                                          IBR14620
C
                                                                          IBR14630
 ... COMPUTE HALF OF WAVE PROFILE (unadjusted)
                                                                          IBR14640
                                                                          IBR14650
C
      ETAMAX = normalized maximum surface elevation
                                                                         IBR14660
C
      ETAMIN = normalized minimum surface elevation
                                                                         IBR14670
C
      ETAU = unadjusted surface elevation
                                                                         IBR14680
C
      NO = approximate time level at which surface elevation is zero IBR14690
C
      UR based on linear wave theory is used in the following
                                                                         IBR14700
C
         criterion
                                                                          IBR14710
C
                                                                          IBR14720
     IF (UR.LT.26.) THEN
                                                                          IBR14730
C
                                                                          IBR14740
C ---- Stokes II Wave Profile
                                                                          IBR14750
                                                                          IBR14760
       ARG = TWOPI/WL
                                                                          IBR14770
       ARG2 = 2.D+00*ARG
                                                                          IBR14780
        DUM = 16.D+00*DSEAKS*DSINH(ARG)**3.D+00
                                                                         IBR14790
        AMP2 = ARG*DCOSH(ARG) * (2.D+00+DCOSH(ARG2))/DUM
                                                                         IBR14800
         DO 110 N = 1, NHALF1
                                                                         IBR14810
          TIME = DBLE(N-1) *T
                                                                         IBR14820
          ETAU(N) = .5D+00*DCOS(TWOPI*TIME)+AMP2*DCOS(FOURPI*TIME)
                                                                         IBR14830
         ETAU(N) = KS*ETAU(N)
                                                                          IBR14840
         IF (N.GT.1) THEN
                                                                          IBR14850
```

```
IF (ETAU (N) .LE.0.D+00.AND.ETAU (N-1).GT.0.D+00) NO=N
                                                                            IBR14860
           ENDIF
                                                                            IBR14870
  110
         CONTINUE
                                                                            IBR14880
         ETAMIN = ETAU(NHALF1)
                                                                             IBR14890
         ETAMAX = ETAU(1)
                                                                             IBR14900
C
                                                                            IBR14910
       ELSE
                                                                            IBR14920
C
                                                                            IBR14930
C ---- Cnoidal Wave Profile
                                                                            IBR14940
C
                                                                            IBR14950
C
         FINDM is to find the parameter M of the Jacobian elliptic func. IBR14960
C
         See Func. 10 CEL and Subr. 11 SNCNDN
                                                                            IBR14970
C
                                                                            IBR14980
         CALL FINDM (M)
                                                                            IBR14990
        KC2 = 1.D + 00 - M
                                                                            IBR15000
        KC = DSQRT(KC2)
                                                                            IBR15010
           = CEL(KC, 1.D+00, 1.D+00, 1.D+00)
                                                                            IBR15020
        E = CEL(KC, 1.D+00, 1.D+00, KC2)
                                                                            IBR15030
        UR = 16.D+00*M*K*K/3.D+00
                                                                            IBR15040
        WL = DSQRT (UR*DSEAKS)
                                                                            IBR15050
        ETAMIN = (1.D+00-E/K)/M - 1.D+00
                                                                            IBR15060
        ETAMIN = KS*ETAMIN
                                                                            IBR15070
        ETAMAX = ETAMIN + KS
                                                                            IBR15080
        DO 120 N = 1, NHALF1
                                                                            IBR15090
          TIME = DBLE(N-1)*T
                                                                            IBR15100
          TETA = 2.D + 00 * K * TIME
                                                                            IBR15110
          CALL SNCNDN (TETA, KC2, SNU, CNU, DNU)
                                                                            IBR15120
          ETAU(N) = ETAMIN + KS*CNU*CNU
                                                                            IBR15130
           IF (N.GT.1) THEN
                                                                            IBR15140
            IF (ETAU(N).LE.O.D+00.AND.ETAU(N-1).GT.O.D+00) NO=N
                                                                            IBR15150
          ENDIF
                                                                            IBR15160
  120
        CONTINUE
                                                                            IBR15170
        ETAU (NHALF1) = ETAMIN
                                                                            IBR15180
C
                                                                            IBR15190
                                                                            IBR15200
C
                                                                            IBR15210
C ... THE OTHER HALF OF WAVE PROFILE
                                                                            IBR15220
                                                                            IBR15230
      DO 130 N = NHALF+2, NONE1
                                                                            IBR15240
        ETAU(N) = ETAU(NONE+2-N)
                                                                            IBR15250
  130 CONTINUE
                                                                            IBR15260
                                                                            IBR15270
C
  ... ADJUST WAVE PROFILE
                                                                           IBR15280
C
      so that elevation=0 at time=0 and decreases initially with time
                                                                           IBR15290
C
                                                                            IBR15300
      ETAU = unadjusted surface elevation
                                                                            IBR15310
C
      ETA = adjusted surface elevation
                                                                            IBR15320
                                                                            IBR15330
      NMARK = NONE-N0+2
                                                                           IBR15340
      DO 140 N = 1, NONE1
                                                                           IBR15350
        IF (N.LE.NMARK) THEN
                                                                           IBR15360
          ETA(N) = ETAU(N+N0-1)
                                                                           IBR15370
                                                                           IBR15380
          ETA(N) = ETAU(N-NMARK+1)
                                                                           IBR15390
        ENDIF
                                                                           IBR15400
```

```
140 CONTINUE
                                                                      IBR15410
C
                                                                      IBR15420
C ... SAVE COMPUTED WAVE PROFILE
                                                                      IBR15430
                                                                      IBR15440
      WRITE (34,3410) (ETA(I), I=1, NONE1)
                                                                      IBR15450
 3410 FORMAT (8F9.6)
                                                                      IBR15460
                                                                      IBR15470
      RETURN
                                                                      IBR15480
      END
                                                                      IBR15490
C
                                                                      IBR15500
C -08----- END OF SUBROUTINE INWAV -----
                                                                      IBR15510
C
                                                                      IBR15530
C
     This subroutine computes the parameter M (MLIL<M<MBIG) of the
                                                                      IBR15540
C
     Jacobian elliptic functions
                                                                      IBR15550
C
                                                                      IBR15560
     SUBROUTINE FINDM (M)
                                                                      IBR15570
C
                                                                      IBR15580
     IMPLICIT DOUBLE PRECISION (A-H, O-Z)
                                                                      IBR15590
     DOUBLE PRECISION K, M, KC2, KC, MSAV, MLIL, MBIG
                                                                      IBR15600
     DOUBLE PRECISION KS, KSREF, KSSEA, KSI
                                                                      IBR15610
     COMMON /CONSTA/ PI, GRAV, DELTA, X1, X2
                                                                      IBR15620
     COMMON /WAVE2/ KS, KSREF, KSSEA, WLO, WL, UR, URPRE, KSI, SIGMA
                                                                      IBR15630
     COMMON /BOT2/ DSEA, DSEAKS, DSEA2, DLAND, DLAND2, FW, TSLOPS, WTOT
                                                                     IBR15640
     DATA SMALL, MLIL /1.D-07, .8D+00/
                                                                     IBR15650
     DATA INDI, I /0,0/
                                                                      IBR15660
     SIGDT = DSQRT(2.D+00*PI*WL0)
                                                                      IBR15670
     MBIG = 1.00D+00 - 1.00D-15
                                                                      IBR15680
          = .95D+00
                                                                      IBR15690
 900 CONTINUE
                                                                      IBR15700
       I = I+1
                                                                     IBR15710
       MSAV = M
                                                                      IBR15720
       KC2 = 1.D+00-M
                                                                      IBR15730
           = DSQRT (KC2)
                                                                      IBR15740
           = CEL(KC, 1.D+00, 1.D+00, 1.D+00)
                                                                     IBR15750
           = CEL(KC, 1.D+00, 1.D+00, KC2)
                                                                     IBR15760
       UR = 16.D+00*M*K*K/3.D+00
                                                                     IBR15770
       WL = DSQRT (UR*DSEAKS)
                                                                     IBR15780
          = 1.D+00 + (-M+2.D+00-3.D+00*E/K)/(M*DSEAKS)
                                                                     IBR15790
          = SIGDT*DSQRT(F)/WL - 1.D+00
                                                                     IBR15800
       IF (F.LT.0.D+00) THEN
                                                                     IBR15810
         MBIG = M
                                                                     IBR15820
       ELSEIF (F.GT.O.D+00) THEN
                                                                     IBR15830
         MLIL = M
                                                                     IBR15840
       ELSE
                                                                     IBR15850
        RETURN
                                                                     IBR15860
                                                                     IBR15870
       M = (MLIL+MBIG)/2.D+00
                                                                     IBR15880
       DIF = DABS (MSAV-M)
                                                                     IBR15890
       IF (DIF.LT.SMALL) RETURN
                                                                     IBR15900
       IF (INDI.EQ.0) THEN
                                                                     IBR15910
         IF (I.EO.50) THEN
                                                                     IBR15920
          SMALL = 1.D-13
                                                                     IBR15930
          INDI = 1
                                                                     IBR15940
        ELSE
                                                                     IBR15950
```

```
IF (M.GT..9999D+00) THEN
                                                                         IBR15960
              SMALL = 1.D-13
                                                                         IBR15970
              INDI = 1
                                                                         IBR15980
            ENDIF
                                                                         IBR15990
          ENDIF
                                                                         IBR16000
        ENDIF
                                                                         IBR16010
      IF (I.LT.100) GOTO 900
                                                                         IBR16020
      WRITE (*,2910)
                                                                         IBR16030
      WRITE (29,2910)
                                                                        IBR16040
 2910 FORMAT (/' From Subr. 9 FINDM:'/
                                                                        IBR16050
               ' Criterion for parameter M not satisfied')
                                                                        IBR16060
C
                                                                        IBR16070
      RETURN
                                                                        IBR16080
      END
                                                                         IBR16090
C
                                                                         IBR16100
C -09----- END OF SUBROUTINE FINDM ----- IBR16110
C #10################ DOUBLE PRECISION FUNCTION CEL ############## IBR16120
                                                                        IBR16130
C
      This function computes the general complete elliptic integral,
                                                                        IBR16140
C
  and is a double precision version of the "Function CEL" from
                                                                        IBR16150
C
      the book:
                                                                        IBR16160
       William H. Press, et. al.
C
                                                                        IBR16170
       Numerical Recipes: The Art of Scientific Computing.
                                                                        IBR16180
C
       Cambridge University Press, New York, 1986.
                                                                        IBR16190
C
       Pages 187-188.
                                                                        IBR16200
C
                                                                        IBR16210
      DOUBLE PRECISION FUNCTION CEL (QQC, PP, AA, BB)
                                                                        IBR16220
C
                                                                        IBR16230
      IMPLICIT DOUBLE PRECISION (A-H, O-Z)
                                                                        IBR16240
      PARAMETER (CA=1.D-06, PIO2=1.5707963268D+00)
                                                                        IBR16250
      IF (QQC.EQ.0.D+00) THEN
                                                                        IBR16260
       WRITE (*,*) 'Failure in Function CEL'
                                                                        IBR16270
       WRITE (29,*) 'Failure in Function CEL'
                                                                        IBR16280
       STOP
                                                                        IBR16290
      ENDIF
                                                                        IBR16300
     QC = DABS(QQC)
                                                                        IBR16310
     A = AA
                                                                        IBR16320
     B = BB
                                                                        IBR16330
     P = PP
                                                                        IBR16340
     E = QC
                                                                        IBR16350
     EM = 1.D+00
                                                                        IBR16360
     IF (P.GT.0.D+00) THEN
                                                                        IBR16370
       P = DSQRT(P)
                                                                        IBR16380
       B = B/P
                                                                        IBR16390
     ELSE
                                                                        IBR16400
       F = QC*QC
                                                                        IBR16410
       O = 1.D + 00 - F
                                                                        IBR16420
       G = 1.D + 00 - P
                                                                        IBR16430
       F = F-P
                                                                        IBR16440
       Q = Q*(B-A*P)
                                                                        IBR16450
       P = DSORT(F/G)
                                                                        IBR16460
       A = (A-B)/G
                                                                        IBR16470
       B = -Q/(G*G*P) + A*P
                                                                        IBR16480
     ENDIF
                                                                        IBR16490
 900 F = A
                                                                        IBR16500
```

```
A = A+B/P
                                                                      IBR16510
      G = E/P
                                                                      IBR16520
      B = B + F * G
                                                                      IBR16530
      B = B + B
                                                                      IBR16540
      P = G+P
                                                                      IBR16550
      G = EM
                                                                      IBR16560
      EM = QC + EM
                                                                      IBR16570
      IF (DABS (G-QC) .GT.G*CA) THEN
                                                                      IBR16580
        QC = DSQRT(E)
                                                                      IBR16590
        QC = QC+QC
                                                                      IBR16600
       E = QC*EM
                                                                      IBR16610
       GOTO 900
                                                                      IBR16620
      ENDIF
                                                                      IBR16630
      CEL = PIO2*(B+A*EM)/(EM*(EM+P))
                                                                      IBR16640
C
                                                                      IBR16650
                                                                      IBR16660
      END
                                                                      IBR16670
C
                                                                      IBR16680
C -10----- END OF DOUBLE PRECISION FUNCTION CEL ----- IBR16690
IBR16710
C
      This subroutine computes the Jacobian elliptic functions,
                                                                     IBR16720
     and is a double precision version of the "Subroutine SNCNDN"
                                                                     IBR16730
C
     from the book:
                                                                     IBR16740
C
       William H. Press, et. al.
                                                                     IBR16750
C
       Numerical Recipes: The Art of Scientific Computing.
                                                                     IBR16760
      Cambridge University Press, New York, 1986.
                                                                     IBR16770
      Page 189.
                                                                     IBR16780
                                                                     IBR16790
     SUBROUTINE SNCNDN (UU, EMMC, SN, CN, DN)
                                                                     IBR16800
C
                                                                     IBR16810
     IMPLICIT DOUBLE PRECISION (A-H, O-Z)
                                                                     IBR16820
     PARAMETER (CA=1.D-06)
                                                                     IBR16830
     DIMENSION EM(13), EN(13)
                                                                     IBR16840
     LOGICAL BO
                                                                     IBR16850
     EMC = EMMC
                                                                     IBR16860
     U = UU
                                                                     IBR16870
     IF (EMC.NE.O.D+00) THEN
                                                                     IBR16880
       BO = (EMC.LT.0.D+00)
                                                                     IBR16890
       IF (BO) THEN
                                                                     IBR16900
         D = 1.D + 00 - EMC
                                                                     IBR16910
         EMC = -EMC/D
                                                                     IBR16920
         D = DSQRT(D)
                                                                     IBR16930
         U = D*U
                                                                     IBR16940
       ENDIF
                                                                     IBR16950
       A = 1.D+00
                                                                     IBR16960
       DN = 1.D+00
                                                                     IBR16970
       DO 110 I = 1,13
                                                                     IBR16980
         L = I
                                                                     IBR16990
         EM(I) = A
                                                                     IBR17000
         EMC = DSQRT (EMC)
                                                                     IBR17010
         EN(I) = EMC
                                                                     IBR17020
         C = .5D+00*(A+EMC)
                                                                     IBR17030
         IF (DABS (A-EMC) . LE . CA*A) GOTO 910
                                                                     IBR17040
         EMC = A \times EMC
                                                                     IBR17050
```

```
A = C
                                                                       IBR17060
  110
       CONTINUE
                                                                       IBR17070
  910 U = C*U
                                                                       IBR17080
        SN = DSIN(U)
                                                                       IBR17090
        CN = DCOS(U)
                                                                       IBR17100
        IF (SN.EQ.0.D+00) GOTO 920
                                                                       IBR17110
        A = CN/SN
                                                                       IBR17120
        C = A*C
                                                                       IBR17130
        DO 120 II = L, 1, -1
                                                                       IBR17140
          B = EM(II)
                                                                       IBR17150
          A = C*A
                                                                       IBR17160
          C = DN*C
                                                                      IBR17170
          DN = (EN(II) + A)/(B+A)
                                                                      IBR17180
          A = C/B
                                                                      IBR17190
  120
        CONTINUE
                                                                      IBR17200
        A = 1.D + 00/DSQRT(C*C+1.D+00)
                                                                      IBR17210
        IF (SN.LT.O.D+00) THEN
                                                                      IBR17220
          SN = -A
                                                                      IBR17230
        ELSE
                                                                      IBR17240
         SN = A
                                                                      IBR17250
        ENDIF
                                                                      IBR17260
       CN = C*SN
                                                                      IBR17270
  920 IF (BO) THEN
                                                                      IBR17280
          A = DN
                                                                      IBR17290
          DN = CN
                                                                      IBR17300
          CN = A
                                                                      IBR17310
          SN = SN/D
                                                                      IBR17320
        ENDIF
                                                                      IBR17330
      ELSE
                                                                      IBR17340
        CN = 1.D + 00/DCOSH(U)
                                                                      IBR17350
        DN = CN
                                                                      IBR17360
        SN = DTANH(U)
                                                                      IBR17370
      ENDIF
                                                                      IBR17380
C
                                                                      IBR17390
      RETURN
                                                                      IBR17400
      END
                                                                      IBR17410
C
                                                                      IBR17420
C -11----- END OF SUBROUTINE SNCNDN ----- IBR17430
C
                                                                      IBR17450
      This subroutine marches the computation from time level (N-1)
C
                                                                      IBR17460
      to time level N excluding seaward and landward boundaries
C
                                                                      IBR17470
C
     which are treated separately
                                                                      IBR17480
C
                                                                      IBR17490
      SUBROUTINE MARCH (N, M)
                                                                      IBR17500
C
                                                                      IBR17510
      IMPLICIT DOUBLE PRECISION (A-H, O-Z)
                                                                      IBR17520
     PARAMETER (N1=500, N2=30000, N3=3, N4=100, N5=25)
                                                                      IBR17530
      INTEGER S
                                                                      IBR17540
      COMMON /DIMENS/ N1R, N2R, N3R, N4R, N5R
                                                                      IBR17550
     COMMON /CONSTA/ PI, GRAV, DELTA, X1, X2
                                                                      IBR17560
                   IJOB, ISTAB, ISYST, IBOT, INONCT, IENERG, IWAVE,
                                                                      IBR17570
                     ISAVA, ISAVB, ISAVC
                                                                      IBR17580
     COMMON /NODES/ S, JE, JE1, JSTAB, JMAX
                                                                      IBR17590
     COMMON /BOT2/ DSEA, DSEAKS, DSEA2, DLAND, DLAND2, FW, TSLOPS, WTOT
                                                                      IBR17600
```

```
COMMON /BOT3/
                     U2INIT(N1), THETA(N1), SSLOPE(N1), XB(N1), ZB(N1)
                                                                         IBR17610
      COMMON /HYDRO/ U(2,N1),V(N1),ELEV(N1),C(N1),DUDT(N1)
                                                                         IBR17620
      IF (N.EQ.1) CALL CHEPAR (12,1,N1,N1R)
                                                                         IBR17630
C
                                                                         IBR17640
      U(1,j) and U(2,j) at time level N are computed as follows:
                                                                         IBR17650
C
      . at j=2,3,...,JDAM : WITH numerical damping term
                                                                         IBR17660
       . at j=(JDAM+1),(JDAM+2),...,JLAX : NO numerical damping term
C
                                                                         IBR17670
C
      JE1=(JE-1) indicates the node next to the landward edge node
                                                                         IBR17680
                                                                         IBR17690
      IF (IJOB.LT.3) THEN
                                                                         IBR17700
        JDAM = S-2
                                                                         IBR17710
        JLAX = S
                                                                         IBR17720
        IF (IJOB.EQ.2.AND.S.EQ.JE) JLAX=JE1
                                                                         IBR17730
                                                                         IBR17740
        JDAM = JE1
                                                                         IBR17750
        JLAX = JE1
                                                                         IBR17760
      ENDIF
                                                                         IBR17770
      JLAX1 = JLAX+1
                                                                         IBR17780
C
                                                                         IBR17790
  ... COMPUTE ELEMENTS OF MATRICES
                                                                         IBR17800
                                                                         IBR17810
C
      Subr. 26 MATAFG computes non-constant elements of Matrices A
                                                                         IBR17820
C
            and G, and the elements of Matrix F
                                                                         IBR17830
C
      Subr. 28 MATS computes the first element of Matrix S
                                                                         IBR17840
C
      Subr. 27 MATGJR, Subr. 29 MATD, and Subr. 30 MATU compute
                                                                        IBR17850
C
            the elements of Matrices g, D, and U, respectively
                                                                        IBR17860
      Subr. 30 MATU computes values of U at time level N using
C
                                                                        IBR17870
            the results obtained from the other four subroutines
C
                                                                         IBR17880
C
                                                                         IBR17890
      CALL MATAFG (N, 1, JLAX1)
                                                                         IBR17900
      CALL MATGJR (N, 1, JLAX)
                                                                         IBR17910
      CALL MATS (N, 2, JLAX)
                                                                         IBR17920
      CALL MATD (N, JDAM, JLAX)
                                                                         IBR17930
      CALL MATU (N, 2, JLAX)
                                                                         IBR17940
C
                                                                         IBR17950
C ... ABORT COMPUTATION IF WATER DEPTH AT (S-1) <or= DELTA
                                                                         IBR17960
                                                                         IBR17970
      IF (U(2,M).LE.DELTA) THEN
                                                                         IBR17980
        WRITE (*,2910) U(2,M), DELTA, S, N
                                                                         IBR17990
        WRITE (29,2910) U(2,M), DELTA, S, N
                                                                         IBR18000
        STOP
                                                                         IBR18010
      ENDIF
                                                                         IBR18020
 2910 FORMAT (/' From Subroutine 12 MARCH'/
                                                                         IBR18030
     +' U(2,S-1) is less than or equal to DELTA'/' U(2,S-1) =',D12.3/
                                                                         IBR18040
     +' DELTA
                =',D12.3/' S =',I8/' N =',I8/' Program Aborted')
                                                                        IBR18050
C
                                                                        IBR18060
  ... COMPLETE THE COMPUTATION OF HYDRODYNAMIC QUANTITIES
                                                                        IBR18070
                                                                        IBR18080
C
      Water depth h is taken to be not less than DELTA
                                                                        IBR18090
C
     for submerged structures
                                                                        IBR18100
C
                                                                        IBR18110
     DO 100 J = 2, JLAX
                                                                        IBR18120
        IF (IJOB.EQ.3.AND.U(2,J).LT.DELTA) U(2,J)=DELTA
                                                                        IBR18130
             = U(1,J)/U(2,J)
                                                                        IBR18140
       ELEV(J) = U(2,J) - U2INIT(J)
                                                                        IBR18150
```

```
100 CONTINUE
                                                                         IBR18160
C
                                                                         IBR18170
      RETURN
                                                                         IBR18180
      END
                                                                         IBR18190
C
                                                                         IBR18200
C -12----- END OF SUBROUTINE MARCH ----- IBR18210
C
                                                                         IBR18230
C
      This subroutine manages the computation for
                                                                         IBR18240
C
      landward boundary conditions
                                                                         IBR18250
C
                                                                         IBR18260
      SUBROUTINE LANDBC (N, K, M, ETAT)
                                                                         IBR18270
C
                                                                         IBR18280
      IMPLICIT DOUBLE PRECISION (A-H, O-Z)
                                                                         IBR18290
      PARAMETER (N1=500, N2=30000, N3=3, N4=100, N5=25)
                                                                         IBR18300
                                                                        IBR18310
      COMMON /DIMENS/ N1R, N2R, N3R, N4R, N5R
                                                                        IBR18320
                      IJOB, ISTAB, ISYST, IBOT, INONCT, IENERG, IWAVE,
      COMMON /ID/
                                                                        IBR18330
                      ISAVA, ISAVB, ISAVC
                                                                        IBR18340
      COMMON /TLEVEL/ NTOP, NONE, NJUM1, NJUM2, NSAVA, NSTAB, NSTAT, NTIMES
                                                                        IBR18350
     COMMON /NODES/ S, JE, JE1, JSTAB, JMAX COMMON /GRID/ T, X, TX, XT, TTX, TTXX, TWOX
                                                                        IBR18360
                                                                         IBR18370
      COMMON /WAVE3/ ETA(N2), ETAIS(N2), ETARS(N2), ETATS(N2)
                                                                         IBR18380
      COMMON /BOT2/ DSEA, DSEAKS, DSEA2, DLAND, DLAND2, FW, TSLOPS, WTOT
                                                                         IBR18390
      COMMON /BOT3/ U2INIT(N1), THETA(N1), SSLOPE(N1), XB(N1), ZB(N1)
                                                                         IBR18400
      COMMON /HYDRO/ U(2,N1),V(N1),ELEV(N1),C(N1),DUDT(N1)
                                                                        IBR18410
     COMMON /RUNP1/ NDELR
                                                                        IBR18420
    COMMON /RUNP2/ DELRP(N3), DELTAR(N3), RUNUPS(N3), RSTAT(3,N3)
                                                                        IBR18430
      COMMON /OVER/
                      OV (4)
                                                                        IBR18440
      COMMON /VALUEN/ VSN, USN(2), VMN, UMN(1), V1N, V2N
                                                                        IBR18450
      IF (N.EQ.1) THEN
                                                                        IBR18460
        CALL CHEPAR (13,1,N1,N1R)
                                                                        IBR18470
        CALL CHEPAR (13,2,N2,N2R)
                                                                        IBR18480
        CALL CHEPAR (13, 3, N3, N3R)
                                                                        IBR18490
                                                                         IBR18500
C
                                                                         IBR18510
C
 ... MANAGE LANDWARD B.C.
                                                                        IBR18520
C
                                                                        IBR18530
C
      Subr. 14 RUNUP computes shoreline movement if computational
                                                                        IBR18540
C
            waterline is on the slope (IJOB<3)
                                                                        IBR18550
C
      Subr. 15 OVERT computes hydrodynamic quantities at landward edge IBR18560
C
            node if overtopping occurs (IJOB=2)
                                                                        IBR18570
C
      ALPHA = landward-advancing characteristics
                                                                        IBR18580
C
      ETAT = surface elevation due to transmitted wave at
                                                                        IBR18590
C
              landward boundary (IJOB=3)
                                                                        IBR18600
C
     DLAND = norm. water depth below SWL at landw. boundary (IJOB=3)
                                                                        IBR18610
C
     S used in Subr. 14 RUNUP is the value at time level (N-1)
                                                                        IBR18620
C
                                                                        IBR18630
     IF (IJOB.EQ.1) THEN
                                                                        IBR18640
       CALL RUNUP (N, K, M)
                                                                        IBR18650
        IF (S.GT.JE1) THEN
                                                                        IBR18660
         WRITE (*,2910) N,S,JE
                                                                        IBR18670
          WRITE (29,2910) N,S,JE
                                                                        IBR18680
          STOP
                                                                        IBR18690
       ENDIF
                                                                        IBR18700
```

```
ELSEIF (IJOB.EQ.2) THEN
                                                                         IBR18710
        IF (S.LT.JE) THEN
                                                                         IBR18720
          CALL RUNUP (N, K, M)
                                                                         IBR18730
        ELSE
                                                                         IBR18740
          CALL OVERT (N, M)
                                                                         IBR18750
        ENDIF
                                                                         IBR18760
      ELSE
                                                                         IBR18770
C
        For IJOB=3: Wave Transmission over Submerged Breakwater
                                                                        IBR18780
             = TX*(VSN+C(S))*(VSN-VMN+2.D+00*(C(S)-C(M)))
                                                                        IBR18790
               = VSN+2.D+00*C(S) - DUM - T*THETA(S)
                                                                         IBR18800
                = ALPHA*DLAND2/2.D+00 - DLAND
                                                                         IBR18810
        U(2,S) = DLAND + ETAT
                                                                         IBR18820
                = ALPHA - 2.D+00*DSQRT(U(2,S))
                                                                         IBR18830
        U(1,S) = U(2,S) *V(S)
                                                                         IBR18840
        ELEV(S) = U(2,S) - U2INIT(S)
                                                                         IBR18850
      ENDIF
                                                                         IBR18860
 2910 FORMAT (/' From Subroutine 13 LANDBC:'/
                                                                         IBR18870
     + 'N =', I8,'; S =', I8,'; End Node =', I8/
                                                                        IBR18880
         ' Slope is not long enough to accomodate shoreline movement'/ IBR18890
         ' Specify longer slope or choose overtopping computation')
                                                                        IBR18900
C
                                                                        IBR18910
  ... CONDITIONS LANDWARD OF NEW WATERLINE NODE S AT TIME LEVEL N
                                                                         IBR18920
                                                                         IBR18930
      IF (IJOB.LT.3) THEN
                                                                         IBR18940
        L = S+1
                                                                         IBR18950
        U(1,L) = 0.D+00
                                                                         IBR18960
        U(2,L) = 0.D+00
                                                                         IBR18970
        V(L)
               = 0.D + 00
                                                                         IBR18980
        ELEV(L) = ZB(L)
                                                                         IBR18990
      ENDIF
                                                                        IBR19000
C
                                                                        IBR19010
  ... COMPUTE RUNUPS ASSOCIATED WITH DEPTHS (DELTAR(L), L=1, NDELR)
C
                                                                        IBR19020
      (Assume water depth decreases landward and U(2,S+1)=0.)
                                                                        IBR19030
C
      If IJOB<3, NDELR>0, DO 100 performed
                                                                        IBR19040
C
      If IJOB=3, NDELR=0, DO 100 void
                                                                        IBR19050
C
                                                                        IBR19060
C
      NSTAB = time level when computation of armor stability or
                                                                       IBR19070
C
             movement begins
                                                                       IBR19080
C
      JSTAB = the largest node number based on DELTAR(1)
                                                                       IBR19090
C
              for armor stability or movement
                                                                       IBR19100
C
                                                                       IBR19110
C
               For IJOB=3, JSTAB=JE was defined in Subr. 5 PARAM
                                                                       IBR19120
C
      DELTAR = water depth associated with visual or measured
                                                                       IBR19130
C
               waterline
                                                                        IBR19140
C
      RUNUPS = free surface elevation where the water depth equals
                                                                        IBR19150
C
              DELTAR
                                                                        IBR19160
C
      NDELR = number of DELTARs
                                                                        IBR19170
C
                                                                        IBR19180
      IF (NDELR.GE.1) THEN
                                                                        IBR19190
       DO 100 L = 1, NDELR
                                                                        IBR19200
          IF (IJOB.EQ.2.AND.S.EQ.JE.AND.U(2,S).GE.DELTAR(L)) THEN
                                                                       IBR19210
           IF (L.EQ.1.AND.N.GE.NSTAB) JSTAB=S
                                                                        IBR19220
           RUNUPS(L) = ZB(S) + U(2,S)
                                                                        IBR19230
         ELSE
                                                                        IBR19240
           INDIC = 0
                                                                        IBR19250
```

```
J = -1
                                                                            IBR19260
   900
             CONTINUE
                                                                            IBR19270
               J = J + 1
                                                                           IBR19280
               IF (U(2,S-J).GE.DELTAR(L)) THEN
                                                                           IBR19290
                 INDIC = 1
                                                                           IBR19300
                 NRUN1 = S-J
                                                                           IBR19310
                 NRUN2 = S-J+1
                                                                           IBR19320
                 IF (L.EQ.1.AND.N.GE.NSTAB) JSTAB=NRUN1
                                                                           IBR19330
                 DEL1 = U(2, S-J)
                                                                           IBR19340
                 DEL2 = U(2, S-J+1)
                                                                           IBR19350
                      = (ZB(NRUN2)-ZB(NRUN1))*(DEL1-DELTAR(L))
                 RUN
                                                                           IBR19360
                      = RUN/(DEL1-DEL2)
                                                                           IBR19370
                 RUN = RUN + ZB(NRUN1)
                                                                           IBR19380
                 RUNUPS (L) = RUN + DELTAR (L)
                                                                           IBR19390
                                                                           IBR19400
             IF (INDIC.EQ.0) GOTO 900
                                                                           IBR19410
           ENDIF
                                                                           IBR19420
  100
        CONTINUE
                                                                           IBR19430
       ENDIF
                                                                           IBR19440
                                                                           IBR19450
C ... STATISTICAL CALCULATIONS
                                                                           IBR19460
C
                                                                           IBR19470
C
      NSTAT = time level when statistical calculations begin
                                                                           IBR19480
C
                                                                           IBR19490
C
        RSTAT(1,L), RSTAT(2,L), RSTAT(3,L) = mean, max. and min.
                                                                           IBR19500
C
           RUNUPS(L), respectively
                                                                           IBR19510
C
      IJOB=2: Overtopping computed during N=NSTAT to N=NTOP
                                                                           IBR19520
C
        OV(1) = normalized average overtopping rate
                                                                           IBR19530
C
        OV(2) = normalized time when OV(4) occurs after time of N=NSTAT IBR19540
C
        OV(3) = normalized overtopping duration
                                                                           IBR19550
C
        OV(4) = normalized maximum overtopping rate
                                                                           IBR19560
C
        OV(2) and OV(3) will be normalized in Subr 23 STAT2
                                                                           IBR19570
C
      IJOB=3:
                                                                           IBR19580
C
        ETAT = surface elevation due to transmitted wave at
                                                                           IBR19590
C
          landward boundary
                                                                           IBR19600
C
        ETAT is saved in a time-array as ETATS starting from N=NSTAT
                                                                           IBR19610
                                                                           IBR19620
      IF (N.GE.NSTAT) THEN
                                                                           IBR19630
        IF (IJOB.LT.3) THEN
                                                                           IBR19640
          CALL STAT1 (2, RSTAT, RUNUPS, 3, NDELR)
                                                                           IBR19650
          IF (IJOB.EQ.2) THEN
                                                                           IBR19660
            OV(1) = OV(1) + U(1, JE)
                                                                           IBR19670
            IF (U(1, JE) .GT.0.D+00) OV(3) = OV(3) + 1.D+00
                                                                           IBR19680
            IF (U(1, JE).GT.OV(4)) THEN
                                                                           IBR19690
              OV(2) = DBLE(N-NSTAT+1)
                                                                           IBR19700
              OV(4) = U(1, JE)
                                                                           IBR19710
            ENDIF
                                                                           IBR19720
          ENDIF
                                                                           IBR19730
                                                                           IBR19740
          ETATS(N-NSTAT+1) = ETAT
                                                                           IBR19750
        ENDIF
                                                                          IBR19760
      ENDIF
                                                                          IBR19770
C
                                                                          IBR19780
      RETURN
                                                                          IBR19790
      END
                                                                          IBR19800
```

```
C
                                                                    IBR19810
C -13----- END OF SUBROUTINE LANDBC ----- IBR19820
IBR19840
 C
      This subroutine computes waterline movement for IJOB=1 and if
                                                                    IBR19850
 C
      no overtopping occurs for IJOB=2
                                                                    IBR19860
 C
                                                                    IBR19870
      SUBROUTINE RUNUP (N, K, M)
                                                                    IBR19880
C
                                                                    IBR19890
      IMPLICIT DOUBLE PRECISION (A-H, O-Z)
                                                                    IBR19900
      PARAMETER (N1=500, N2=30000, N3=3, N4=100, N5=25)
                                                                    IBR19910
      DIMENSION USN2(2), US1N1(2)
                                                                    IBR19920
      INTEGER S, SNEW
                                                                    IBR19930
      COMMON /DIMENS/ N1R, N2R, N3R, N4R, N5R
                                                                    IBR19940
      COMMON /CONSTA/ PI, GRAV, DELTA, X1, X2
                                                                    IBR19950
      COMMON /NODES/ S, JE, JE1, JSTAB, JMAX
                                                                    IBR19960
      COMMON /GRID/ T, X, TX, XT, TTX, TTXX, TWOX
                                                                    IBR19970
      COMMON /BOT3/ U2INIT(N1), THETA(N1), SSLOPE(N1), XB(N1), ZB(N1) IBR19980
      COMMON /HYDRO/ U(2,N1),V(N1),ELEV(N1),C(N1),DUDT(N1)
                                                                    IBR19990
      COMMON /MATRIX/ A1(2,N1),F(2,N1),G1(N1),GJR(2,N1),S1(N1),D(2,N1) IBR20000
      COMMON /VALUEN/ VSN, USN (2), VMN, UMN (1), V1N, V2N
                                                                    IBR20010
      IF (N.EQ.1) CALL CHEPAR (14,1,N1,N1R)
                                                                    IBR20020
C
                                                                    IBR20030
C ... ADJUST VALUES AT S IF U(2,S)>U(2,S-1)
                                                                    IBR20040
                                                                    IBR20050
      IF (U(2,S).GE.U(2,M)) THEN
                                                                    IBR20060
       V(S) = 2.D+00*V(M) - V(S-2)
                                                                    IBR20070
        U(2,S) = 2.D+00*U(2,M) - U(2,S-2)
                                                                    IBR20080
        IF (ABS(V(S)).GT.ABS(V(M))) V(S)=.9*V(M)
                                                                   IBR20090
        IF (U(2,S).LT.0.D+00) U(2,S)=.5*U(2,M)
                                                                   IBR20100
        IF (U(2,S).GT.U(2,M)) U(2,S)=.9*U(2,M)
                                                                   IBR20110
        U(1,S) = V(S) *U(2,S)
                                                                   IBR20120
       ELEV(S) = U(2,S) - U2INIT(S)
                                                                   IBR20130
       WRITE (*,2910) S,N,U(2,S),U(2,M)
                                                                   IBR20140
       WRITE (29,2910) S,N,U(2,S),U(2,M)
                                                                   IBR20150
     ENDIF
                                                                   IBR20160
 2910 FORMAT (/' From Subroutine 14 RUNUP: U(2,S)>U(2,S-1) at',
                                                                   IBR20170
             ' S =', I8,'; N =', I8/' Adjusted values:',
    +
                                                                   IBR20180
             ' U(2,S) =',E12.3,'; U(2,S-1) =',E12.3)
                                                                   IBR20190
C
                                                                   IBR20200
C ... DETERMINE THE NEXT WATERLINE NODE
                                                                   IBR20210
                                                                   IBR20220
     IF (U(2,S).LE.DELTA) THEN
                                                                   IBR20230
       SNEW = M
                                                                   IBR20240
     ELSE
                                                                   IBR20250
       V(K) = 2.D+00*V(S) - V(M)
                                                                   IBR20260
       U(2,K) = 2.D+00*U(2,S) - U(2,M)
                                                                   IBR20270
       U(1,K) = V(K) *U(2,K)
                                                                   IBR20280
       IF (U(2,K).LE.DELTA) THEN
                                                                   IBR20290
         SNEW = S
                                                                   IBR20300
       ELSE
                                                                   IBR20310
         IBR20320
C
                USN2(i), VSN2 = U(i,S) and V(S), respectively,
C
                                                                  IBR20330
C
                at time level (N+1), i=1,2
                                                                   IBR20340
        CALL MATAFG (2, M, K)
                                                                   IBR20350
```

```
CALL MATGJR (2, M, S)
                                                                   IBR20360
          CALL MATS (2,S,S)
                                                                  IBR20370
         DUM1 = TX*((F(1,K)-F(1,M))/2.D+00+X*G1(S))
                                                                  IBR20380
         DUM2 = TTXX*(GJR(1,S)-GJR(1,M))
                                                                  IBR20390
         DUM3 = TX*(F(2,K)-F(2,M))
                                                                  IBR20400
         DUM4 = TTXX*(GJR(2,S)-GJR(2,M))
                                                                  IBR20410
         USN2(1) = U(1,S) - DUM1 + (DUM2 - TTX * S1(S)) / 2.D + 00
                                                                  IBR20420
         USN2(2) = U(2,S) - (DUM3 - DUM4)/2.D+00
                                                                  IBR20430
         VSN2 = USN2(1)/USN2(2)
                                                                  IBR20440
         ----- IBR20450
C
C
                 US1N1(i), VS1N1 = U(i, S+1) and V(S+1), respectively,
                                                                  IBR20460
C
                 at time level N, i=1,2
                                                                  IBR20470
         VS = V(S)
                                                                  IBR20480
         IF (DABS (VS) .LT.DELTA) VS=DSIGN (DELTA, VS)
                                                                  IBR20490
         VS1N1 = V(M) - (XT*(VSN2-VSN)+U(2,K)-U(2,M)+TWOX*THETA(S))/VS
                                                                  IBR20500
         US1N1(1) = U(1,M) - XT*(USN2(2)-USN(2))
                                                                  IBR20510
         US1N1(2) = US1N1(1)/VS1N1
                                                                  IBR20520
C
         ______
                                                                  IBR20530
         IF (DABS (VS1N1).LE.DELTA) THEN
                                                                  IBR20540
           SNEW = S
                                                                  IBR20550
         ELSE
                                                                  IBR20560
           IF (US1N1(2).LE.U(2,S)) THEN
                                                                  IBR20570
             IF (US1N1(2).LE.DELTA) THEN
                                                                  IBR20580
               SNEW = S
                                                                  IBR20590
             ELSE
                                                                  IBR20600
               SNEW = K
                                                                  IBR20610
               U(2,K) = US1N1(2)
                                                                  IBR20620
               U(1,K) = US1N1(1)
                                                                  IBR20630
                   = VS1N1
              V(K)
                                                                  IBR20640
             ENDIF
                                                                  IBR20650
           ELSE
                                                                  IBR20660
             IF (U(2,K).LE.U(2,S)) THEN
                                                                  IBR20670
              SNEW = K
                                                                  IBR20680
             ELSE
                                                                  IBR20690
              SNEW = S
                                                                  IBR20700
             ENDIF
                                                                  IBR20710
           ENDIF
                                                                  IBR20720
         ENDIF
                                                                  IBR20730
       ENDIF
                                                                  IBR20740
                                                                  IBR20750
     IF (SNEW.EQ.K) ELEV(K)=U(2,K)-U2INIT(K)
                                                                  IBR20760
     S = SNEW
                                                                  IBR20770
C
                                                                  IBR20780
C
     S at time level N has been found
                                                                  IBR20790
C
                                                                  IBR20800
     RETURN
                                                                  IBR20810
                                                                  IBR20820
C
                                                                  IBR20830
C -14----- END OF SUBROUTINE RUNUP ----- IBR20840
C
                                                                  IBR20860
C
     This subroutine computes quantities at landward-end node for
                                                                 IBR20870
C
     IJOB=2 if overtopping occurs, that is, S=JE and M=(S-1)=JE1
                                                                 IBR20880
C
                                                                  IBR20890
     SUBROUTINE OVERT (N, M)
                                                                  IBR20900
```

```
C
                                                                         IBR20910
      IMPLICIT DOUBLE PRECISION (A-H, O-Z)
                                                                         IBR20920
      PARAMETER (N1=500, N2=30000, N3=3, N4=100, N5=25)
                                                                         IBR20930
      INTEGER S
                                                                         IBR20940
      COMMON /DIMENS/ N1R, N2R, N3R, N4R, N5R
                                                                         IBR20950
      COMMON /ID/ IJOB, ISTAB, ISYST, IBOT, INONCT, IENERG, IWAVE,
                                                                         IBR20960
                      ISAVA, ISAVB, ISAVC
                                                                         IBR20970
      COMMON /CONSTA/ PI, GRAV, DELTA, X1, X2
                                                                         IBR20980
      COMMON /NODES/ S, JE, JE1, JSTAB, JMAX
                                                                         IBR20990
      COMMON /GRID/ T, X, TX, XT, TTX, TTXX, TWOX
                                                                         IBR21000
      COMMON /BOT3/ U2INIT(N1), THETA(N1), SSLOPE(N1), XB(N1), ZB(N1)
                                                                        IBR21010
      COMMON /HYDRO/ U(2,N1),V(N1),ELEV(N1),C(N1),DUDT(N1)
                                                                         IBR21020
      COMMON /MATRIX/ A1(2,N1),F(2,N1),G1(N1),GJR(2,N1),S1(N1),D(2,N1) IBR21030
      COMMON /VALUEN/ VSN, USN(2), VMN, UMN(1), V1N, V2N
                                                                        IBR21040
      DATA INDI /0/
                                                                        IBR21050
      SAVE INDI
                                                                        IBR21060
      IF (INDI.EQ.0) THEN
                                                                        IBR21070
        CALL CHEPAR (15,1,N1,N1R)
                                                                        IBR21080
        INDI = 1
                                                                        IBR21090
      ENDIF
                                                                        IBR21100
      IF (VMN.GT.C(M)) THEN
                                                                        IBR21110
        U(1,S) = USN(1) - TX*(F(1,S)-F(1,M)) - T*(THETA(S)*USN(2))
                                                                        IBR21120
        U(2,S) = USN(2) - TX*(USN(1)-UMN(1))
                                                                        IBR21130
        V(S)
             = U(1,S)/U(2,S)
                                                                        IBR21140
      ELSE
                                                                        IBR21150
        VCS = VSN + 2.D+00*C(S)
                                                                        IBR21160
        VCM = VMN + 2.D+00*C(M)
                                                                        IBR21170
        V(S) = (VCS-TX*(VSN+C(S))*(VCS-VCM)-T*(THETA(S)))/3.D+00
                                                                        IBR21180
        U(2,S) = V(S) *V(S)
                                                                        IBR21190
        U(1,S) = V(S) *U(2,S)
                                                                        IBR21200
      ENDIF
                                                                        IBR21210
      IF (U(2,S).LE.DELTA) THEN
                                                                        IBR21220
        S = M
                                                                        IBR21230
      ELSE
                                                                        IBR21240
        ELEV(S) = U(2,S) - U2INIT(S)
                                                                        IBR21250
      ENDIF
                                                                        IBR21260
C
                                                                        IBR21270
      RETURN
                                                                        IBR21280
                                                                        IBR21290
                                                                        IBR21300
C -15----- END OF SUBROUTINE OVERT ----- IBR21310
IBR21330
     This subroutine treats seaward boundary conditions at node j=1
C
                                                                        IBR21340
C
                                                                        IBR21350
      SUBROUTINE SEABC (N, ETAR)
                                                                        IBR21360
C
                                                                        IBR21370
     IMPLICIT DOUBLE PRECISION (A-H, O-Z)
                                                                        IBR21380
     PARAMETER (N1=500, N2=30000, N3=3, N4=100, N5=25)
                                                                        IBR21390
     DOUBLE PRECISION KS, KSREF, KSSEA, KSI
                                                                        IBR21400
     COMMON /DIMENS/ N1R, N2R, N3R, N4R, N5R
                                                                       IBR21410
                     IJOB, ISTAB, ISYST, IBOT, INONCT, IENERG, IWAVE,
     COMMON /ID/
                                                                       IBR21420
                     ISAVA, ISAVB, ISAVC
                                                                       IBR21430
     COMMON /TLEVEL/ NTOP, NONE, NJUM1, NJUM2, NSAVA, NSTAB, NSTAT, NTIMES
                                                                       IBR21440
     COMMON /GRID/ T, X, TX, XT, TTX, TTXX, TWOX
                                                                        IBR21450
```

```
COMMON /WAVE2/ KS, KSREF, KSSEA, WLO, WL, UR, URPRE, KSI, SIGMA
                                                                        IBR21460
      COMMON /WAVE3/ ETA(N2), ETAIS(N2), ETARS(N2), ETATS(N2)
                                                                         IBR21470
      COMMON /BOT1/ DSEAP, DLANDP, FWP
                                                                         IBR21480
      COMMON /BOT2/ DSEA, DSEAKS, DSEA2, DLAND, DLAND2, FW, TSLOPS, WTOT
                                                                          IBR21490
      COMMON /BOT3/ U2INIT(N1), THETA(N1), SSLOPE(N1), XB(N1), ZB(N1)

COMMON /HYDRO/ U(2.N1), V(N1), ELEV(N1), C(N1), DUDT(N1)
                                                                          IBR21500
      COMMON /HYDRO/ U(2,N1),V(N1),ELEV(N1),C(N1),DUDT(N1)
                                                                          IBR21510
      COMMON /VALUEN/ VSN, USN(2), VMN, UMN(1), V1N, V2N
                                                                          IBR21520
      IF (N.EQ.1) THEN
                                                                          IBR21530
        CALL CHEPAR (16,1,N1,N1R)
                                                                          IBR21540
        CALL CHEPAR (16,2,N2,N2R)
                                                                          IBR21550
      ENDIF
                                                                          IBR21560
C
                                                                          IBR21570
C ... ESTIMATE ETAR
                                                                          IBR21580
C
                                                                          IBR21590
C
     BETA = seaward-advancing characteristics
                                                                          IBR21600
C
      ETAR = surface elevation due to reflected wave at
                                                                          IBR21610
C
             seaward boundary
                                                                          IBR21620
      A correction term included in ETAR if INONCT=1 to improve
C
                                                                         IBR21630
C
             prediction of wave set-down and setup on beach
                                                                         IBR21640
C
                                                                         IBR21650
      VC1 = -V1N+2.D+00*C(1)
                                                                         IBR21660
 VC2 = -V2N+2.D+00*C(2)
                                                                         IBR21670
      BETA = VC1 - TX*(V1N-C(1))*(VC2-VC1) + T*THETA(1)
                                                                         IBR21680
      ETAR = BETA*DSEA2/2.D+00 - DSEA
                                                                         IBR21690
      IF (INONCT.EQ.1) ETAR=ETAR-KS*KS/(16.D+00*DSEA)
                                                                         IBR21700
C
                                                                          IBR21710
C ... VALUES AT NODE ONE
                                                                          IBR21720
                                                                          IBR21730
      IF (IWAVE.EQ.1) THEN
                                                                          IBR21740
       NWAVE = MOD(N, NONE) + 1
                                                                          IBR21750
        U(2,1) = DSEA + ETAR + ETA (NWAVE)
                                                                          IBR21760
        ELEV(1) = ETA(NWAVE) + ETAR
                                                                          IBR21770
      ELSEIF (IWAVE.EQ.2) THEN
                                                                          IBR21780
        U(2,1) = DSEA + ETAR + ETA(N)
                                                                          IBR21790
        ELEV(1) = ETA(N) + ETAR
                                                                         IBR21800
                                                                         IBR21810
        U(2,1) = DSEA + ETA(N)
                                                                         IBR21820
        ELEV(1) = ETA(N)
                                                                          IBR21830
                                                                          IBR21840
      V(1) = 2.D+00*DSQRT(U(2,1))-BETA
                                                                          IBR21850
      U(1,1) = U(2,1) *V(1)
                                                                          IBR21860
                                                                          IBR21870
C ... STATISTICAL CALCULATIONS
                                                                         IBR21880
C
                                                                         IBR21890
C
      NSTAT = time level when statistical calculations begin
                                                                         IBR21900
C
      ETAI = surface elevation associated with incident wave at
                                                                         IBR21910
C
             seaward boundary
                                                                         TBR21920
C
      ETAR = surface elevation associated with reflected wave at
                                                                          IBR21930
C
             seaward boundary
                                                                         IBR21940
C
     ETAI is saved in a time-array as ETAIS starting from N=NSTAT
                                                                          IBR21950
C
     ETAR is saved in a time-array as ETARS starting from N=NSTAT
                                                                          IBR21960
C
                                                                          TBR21970
      IF (N.GE.NSTAT) THEN
                                                                          IBR21980
       IF (IWAVE.EQ.1) THEN
                                                                          IBR21990
          NWAVE = MOD(N, NONE) + 1
                                                                          IBR22000
```

```
ETAI = ETA(NWAVE)
                                                                       IBR22010
        ELSEIF (IWAVE.EQ.2) THEN
                                                                       IBR22020
          ETAI = ETA(N)
                                                                       IBR22030
        ELSE
                                                                       IBR22040
          ETAI = ETA(N)-ETAR
                                                                       IBR22050
        ENDIF
                                                                       IBR22060
        ETAIS(N-NSTAT+1) = ETAI
                                                                       IBR22070
        ETARS(N-NSTAT+1) = ETAR
                                                                       IBR22080
                                                                       IBR22090
C
                                                                       IBR22100
      RETURN
                                                                       IBR22110
      END
                                                                      IBR22120
C
                                                                      IBR22130
C -16----- END OF SUBROUTINE SEABC -----
                                                                      IBR22140
IBR22160
C
      This subroutine computes quantities related to wave energy
                                                                      IBR22170
C
                                                                      IBR22180
      SUBROUTINE ENERGY (N)
                                                                      IBR22190
C
                                                                      IBR22200
      IMPLICIT DOUBLE PRECISION (A-H, O-Z)
                                                                      IBR22210
      PARAMETER (N1=500, N2=30000, N3=3, N4=100, N5=25)
                                                                      IBR22220
      DIMENSION E(3)
                                                                      IBR22230
      INTEGER S
                                                                      IBR22240
      COMMON /DIMENS/ N1R, N2R, N3R, N4R, N5R
                                                                      IBR22250
      COMMON /ID/ IJOB, ISTAB, ISYST, IBOT, INONCT, IENERG, IWAVE,
                                                                      IBR22260
                     ISAVA, ISAVB, ISAVC
                                                                      IBR22270
      COMMON /TLEVEL/ NTOP, NONE, NJUM1, NJUM2, NSAVA, NSTAB, NSTAT, NTIMES
                                                                      IBR22280
      COMMON /NODES/ S, JE, JE1, JSTAB, JMAX
                                                                      IBR22290
      COMMON /HYDRO/ U(2,N1),V(N1),ELEV(N1),C(N1),DUDT(N1)
                                                                      IBR22300
      COMMON /BOT2/ DSEA, DSEAKS, DSEA2, DLAND, DLAND2, FW, TSLOPS, WTOT
                                                                      IBR22310
      COMMON /ENERG/ ENER(4,N1), ENERB(14)
                                                                      IBR22320
      IF (N.EQ.NSTAT) CALL CHEPAR (17,1,N1,N1R)
                                                                      IBR22330
                                                                      IBR22340
      E's are instantaneous quantities, ENER's time-averaged
                                                                      IBR22350
C
     quantities
                                                                      IBR22360
C
                                                                      IBR22370
C
     At node j:
                                                                      IBR22380
C
       E(1), ENER(1, j) = norm. energy per unit surface area
                                                                      IBR22390
C
       E(2), ENER(2,j) = norm. energy flux per unit width
                                                                     IBR22400
C
      Normalized rate of energy dissipation at node j:
                                                                     IBR22410
C
       E(3), ENER(3, j): due to bottom friction, per unit bottom area IBR22420
C
            ENER(4,j): due to wave breaking, per unit surface area
                                                                     IBR22430
C
                                                                      IBR22440
     DO 120 J = 1.5
                                                                      IBR22450
       E(1) = (U(1,J)*V(J)+ELEV(J)*ELEV(J))/2.D+00
                                                                      IBR22460
       IF (U(2,J).LT.ELEV(J)) E(1)=E(1)-(U(2,J)-ELEV(J))**2/2.D+00
                                                                      IBR22470
       E(2) = U(1,J)*(V(J)*V(J)/2.D+00+ELEV(J))
                                                                      IBR22480
       E(3) = FW*DABS(V(J))*V(J)*V(J)
                                                                      IBR22490
       DO 110 I = 1.3
                                                                      IBR22500
         ENER(I,J) = ENER(I,J) + E(I)
                                                                      IBR22510
       CONTINUE
                                                                      IBR22520
  120 CONTINUE
                                                                      IBR22530
C
                                                                      IBR22540
C
     ENER's are time-averaged in Subr. 25 BALANE
                                                                     IBR22550
```

```
C
                                                                    IBR22560
      RETURN
                                                                    IBR22570
      END
                                                                    IBR22580
C
                                                                    IBR22590
C -17----- END OF SUBROUTINE ENERGY -----
                                                                   IBR22600
C
                                                                    IBR22620
C
      For MODE=1, VAL1(1,J) is sum of VAL2(J)
                                                                    IBR22630
      For MODE=2, VAL1(1,J) is sum of VAL2(J)
C
                                                                   IBR22640
C
                 VAL1(2,J) is maximum of VAL2(J)
                                                                   IBR22650
C
                 VAL1(3,J) is minimum of VAL2(J)
                                                                   IBR22660
C
                                                                   IBR22670
      SUBROUTINE STAT1 (MODE, VAL1, VAL2, ND1, ND2)
                                                                   IBR22680
C
                                                                    IBR22690
     IMPLICIT DOUBLE PRECISION (A-H, O-Z)
                                                                    IBR22700
     DIMENSION VAL1 (ND1, ND2), VAL2 (ND2)
                                                                   IBR22710
     IF (MODE.EO.1) THEN
                                                                   IBR22720
       DO 120 I = 1, ND1
                                                                   IBR22730
         DO 110 J = 1, ND2
                                                                   IBR22740
           VAL1(I,J) = VAL1(I,J) + VAL2(J)
                                                                   IBR22750
  110
         CONTINUE
                                                                   IBR22760
  120
       CONTINUE
                                                                   IBR22770
     ELSE
                                                                   IBR22780
       DO 130 J = 1, ND2
                                                                   IBR22790
         VAL1(1,J) = VAL1(1,J) + VAL2(J)
                                                                   IBR22800
         IF (VAL2(J).GT.VAL1(2,J)) VAL1(2,J)=VAL2(J)
                                                                   IBR22810
         IF (VAL2(J).LT.VAL1(3,J)) VAL1(3,J)=VAL2(J)
                                                                   IBR22820
  130
       CONTINUE
                                                                   IBR22830
     ENDIF
                                                                   IBR22840
C
                                                                   IBR22850
     RETURN
                                                                   IBR22860
                                                                   IBR22870
C
                                                                   IBR22880
C -18----- END OF SUBROUTINE STAT1 ----- IBR22890
IBR22910
C
     This subroutine computes stability number against
                                                                   IBR22920
C
     rolling/sliding, SNR
                                                                   IBR22930
C
                                                                   IBR22940
     SUBROUTINE STABNO (N)
                                                                   IBR22950
C
                                                                   IBR22960
     IMPLICIT DOUBLE PRECISION (A-H, O-Z)
                                                                   IBR22970
     PARAMETER (N1=500, N2=30000, N3=3, N4=100, N5=25)
                                                                   IBR22980
     INTEGER S
                                                                   IBR22990
     COMMON /DIMENS/ N1R, N2R, N3R, N4R, N5R
                                                                   IBR23000
     COMMON /TLEVEL/ NTOP, NONE, NJUM1, NJUM2, NSAVA, NSTAB, NSTAT, NTIMES
                                                                   IBR23010
     COMMON /NODES/ S, JE, JE1, JSTAB, JMAX
                                                                   IBR23020
     COMMON /BOT2/ DSEA, DSEAKS, DSEA2, DLAND, DLAND2, FW, TSLOPS, WTOT
                                                                   IBR23030
     COMMON /BOT3/ U2INIT(N1), THETA(N1), SSLOPE(N1), XB(N1), ZB(N1)
                                                                   IBR23040
     COMMON /HYDRO/ U(2,N1),V(N1),ELEV(N1),C(N1),DUDT(N1)
                                                                   IBR23050
     COMMON /STAB2/ SG1, CTAN(N1)
                                                                   IBR23060
     COMMON /STAB3/ CSTAB1, CSTAB2, AMAXS, AMINS, E2, E3PRE (N1)
                                                                   IBR23070
     COMMON /STAB5/ JSNSC, NSNSC, NSNSX (N1)
                                                                   IBR23080
     COMMON /STAB6/ SNSC, SNR(N1), SNSX(N1)
                                                                   IBR23090
     IF (N.EQ.NSTAB) CALL CHEPAR (19,1,N1,N1R)
                                                                   IBR23100
```

```
C
                                                                          IBR23110
C ... FLUID ACCELERATION
                                                                          IBR23120
C
      Computed in Subr. 22 ACCEL
                                                                          IBR23130
C
                                                                          IBR23140
      CALL ACCEL (N)
                                                                          IBR23150
C
                                                                          IBR23160
C
  ... STABILITY NUMBER SNR
                                                                          IBR23170
C
                                                                          IBR23180
      SNR(j) = stability number against rolling/sliding at node j
C
                                                                         IBR23190
C
      SNR is computed for j=1,2,..., JSTAB where JSTAB is defined
                                                                          IBR23200
C
       in Subr. 13 LANDBC
                                                                          IBR23210
C
                                                                          IBR23220
      DO 110 J = 1, JSTAB
                                                                          IBR23230
C
                                                                         IBR23240
        IF (DABS(V(J)).LT.1.D-03) THEN
                                                                         IBR23250
C
          ----- Avoid having very small velocity values
                                                                         IBR23260
C
                       SNR=1000 indicates very stable units
                                                                         IBR23270
          SNR(J) = 1.D+03
                                                                         IBR23280
        ELSE
                                                                         IBR23290
          ----- Impose lower and upper bounds of fluid
C
                                                                         IBR23300
C
                       acceleration
                                                                         IBR23310
          IF (DUDT(J).GT.AMAXS) DUDT(J)=AMAXS
                                                                         IBR23320
          IF (DUDT(J).LT.AMINS) DUDT(J)=AMINS
                                                                         IBR23330
C
          ----- SNR=-1000 indicates that AMAX and AMIN
                                                                         IBR23340
C
                       specified in Subr. 2 INPUT1 needs to be
                                                                         IBR23350
C
                       modified
                                                                         IBR23360
          VALUE = CSTAB2*DUDT(J)-SSLOPE(J)
                                                                         IBR23370
          ABSV = DABS (VALUE)
                                                                         IBR23380
          IF (ABSV.GT.CTAN(J)) THEN
                                                                         IBR23390
            SNR(J) = -1.D+03
                                                                         IBR23400
            WRITE (*,2910) N,J
                                                                         IBR23410
            WRITE (29, 2910) N, J
                                                                         IBR23420
                                                                         IBR23430
          ENDIF
                                                                         IBR23440
          ----- Compute SNR
C
                                                                         IBR23450
          E1 = VALUE*CSTAB1/(V(J)*DABS(V(J)))
                                                                         IBR23460
          E3 = E3PRE(J)/(V(J)*V(J))
                                                                         IBR23470
          E1E2 = -E1 \times E2
                                                                         IBR23480
          IF (E1.LT.0.D+00.AND.E2.GT.1.D+00.AND.E3.LT.E1E2) THEN
                                                                         IBR23490
            SNR(J) = (E3+E1)/(E2-1.D+00)
                                                                         IBR23500
                                                                         IBR23510
            SNR(J) = (E3-E1)/(E2+1.D+00)
                                                                         IBR23520
          ENDIF
                                                                         IBR23530
        ENDIF
                                                                         IBR23540
 2910 FORMAT (' From Subr. 19 STABNO'/' Armor stability impossible'/
                                                                         IBR23550
              ' N = ', I8, '; J = ', I8)
                                                                         IBR23560
                                                                         IBR23570
  110 CONTINUE
                                                                         IBR23580
C
                                                                         IBR23590
C
 ... FIND SNSX
                                                                         IBR23600
C
                                                                         IBR23610
C
      SNSX(j) = local stability number = minimum of SNR at node j
                                                                         IBR23620
C
     NSNSX(j) = time level when SNSX(j) occurs
                                                                         IBR23630
C
                                                                         IBR23640
     DO 120 J = 1, JSTAB
                                                                         IBR23650
```

```
IF (SNR(J).LT.SNSX(J)) THEN
                                                                                                                                                        IBR23660
                      SNSX(J) = SNR(J)
                                                                                                                                                        IBR23670
                      NSNSX(J) = N
                                                                                                                                                        IBR23680
                  ENDIF
                                                                                                                                                        IBR23690
     120 CONTINUE
                                                                                                                                                        IBR23700
 C
                                                                                                                                                        IBR23710
             RETURN
                                                                                                                                                        IBR23720
             END
                                                                                                                                                        IBR23730
 C
                                                                                                                                                       IBR23740
 C -19----- END OF SUBROUTINE STABNO ----- IBR23750
 IBR23770
 C
             This subroutine computes movement of armor units
                                                                                                                                                        TBR23780
 C
                                                                                                                                                        IBR23790
             SUBROUTINE MOVE (N)
                                                                                                                                                        IBR23800
 C
                                                                                                                                                       IBR23810
             IMPLICIT DOUBLE PRECISION (A-H, O-Z)
                                                                                                                                                       IBR23820
             PARAMETER (N1=500, N2=30000, N3=3, N4=100, N5=25)
                                                                                                                                                       IBR23830
             DOUBLE PRECISION KS, KSREF, KSSEA, KSI
                                                                                                                                                       IBR23840
     INTEGER S
                                                                                                                                                       IBR23850
             COMMON /DIMENS/ N1R, N2R, N3R, N4R, N5R
                                                                                                                                                       IBR23860
             COMMON /ID/ IJOB, ISTAB, ISYST, IBOT, INONCT, IENERG, IWAVE,
                                                                                                                                                       IBR23870
                                               ISAVA, ISAVB, ISAVC
                                                                                                                                                       IBR23880
             COMMON /NODES/ S, JE, JE1, JSTAB, JMAX
                                                                                                                                                       IBR23890
             COMMON /TLEVEL/ NTOP, NONE, NJUM1, NJUM2, NSAVA, NSTAB, NSTAT, NTIMES
                                                                                                                                                       IBR23900
             COMMON /GRID/ T, X, TX, XT, TTX, TTXX, TWOX
            COMMON /WAVE2/ KS, KSREF, KSSEA, WLO, WL, UR, URPRE, KSI, SIGMA COMMON /HYDRO/ U(2,N1), V(N1), ELEV(N1), C(N1), DUDT(N1) COMMON /BOT3/ U2INIT(N1), THETA(N1), SSLOPE(N1), VR(N1), THETA(N1), THETA(N1), SSLOPE(N1), VR(N1), THETA(N1), SSLOPE(N1), VR(N1), THETA(N1), SSLOPE(N1), VR(N1), THETA(N1), 
                                                                                                                                                       IBR23910
                                                                                                                                                       IBR23920
                                                                                                                                                       IBR23930
                                             U2INIT(N1), THETA(N1), SSLOPE(N1), XB(N1), ZB(N1)
                                                                                                                                                      IBR23940
             COMMON /STAB1/ C2, C3, CD, CL, CM, SG, TANPHI, AMIN, AMAX, DAP
                                                                                                                                                       IBR23950
             COMMON /STAB2/ SG1, CTAN (N1)
                                                                                                                                                       IBR23960
             COMMON /STAB4/ CSTAB3, CSTAB4, CM1, DA, SIGDA, WEIG
                                                                                                                                                       IBR23970
             COMMON /STAB5/ JSNSC, NSNSC, NSNSX (N1)
                                                                                                                                                       IBR23980
            COMMON /STAB6/ SNSC, SNR (N1), SNSX (N1)
                                                                                                                                                       IBR23990
            COMMON /STAB7/ NMOVE, NSTOP,
                                                                                                                                                       IBR24000
                                              ISTATE (N1), NODIN (N1), NODFI (N1), NDIS (N1)
                                                                                                                                                       IBR24010
            COMMON /STAB8/ VA(N1), XAA(N1), XA(N1)
                                                                                                                                                       IBR24020
            IF (N.EQ.NSTAB) THEN
                                                                                                                                                       IBR24030
                CALL CHEPAR (20,1,N1,N1R)
                                                                                                                                                       IBR24040
                CALL CHEPAR (20,5,N5,N5R)
                                                                                                                                                       IBR24050
                DO 110 J = 1, JE
                                                                                                                                                       IBR24060
                     NODIN(J) = J
                                                                                                                                                       IBR24070
                     NODFI(J) = J
                                                                                                                                                       IBR24080
                                     = 0.D + 00
                     VA(J)
                                                                                                                                                       IBR24090
                     XAA(J)
                                    = 0.D + 00
                                                                                                                                                       IBR24100
    110
                CONTINUE
                                                                                                                                                       IBR24110
            ENDIF
                                                                                                                                                       IBR24120
C
                                                                                                                                                       IBR24130
C ... FLUID ACCELERATION
                                                                                                                                                       IBR24140
C
            Computed in Subr. 22 ACCEL
                                                                                                                                                       IBR24150
C
                                                                                                                                                       IBR24160
            CALL ACCEL (N)
                                                                                                                                                       IBR24170
C
                                                                                                                                                       IBR24180
C ... GENERAL TERMS
                                                                                                                                                       IBR24190
                                                                                                                                                       IBR24200
```

C	Counters:	IBR24210
C	NMOVE = number of armor units dislodged from their initial	IBR24220
C	locations	IBR24230
C	NSTOP = number of armor units stopped after moving	IBR24240
C	Node numbers:	IBR24250
C	JSTAB = the largest node number for which armor movement	IBR24260
С	is computed	IBR24270
C C	For moving/stopped armor unit number j:	IBR24280
C	NODIN(j) = node number where it was initially located	IBR24290
C	NODFI(j) = node number closest to the armor unit at the end	IBR24300
C	of each time step	IBR24310
C	Dynamics:	IBR24320
C	FDES = normalized destabilizing force	IBR24330
C	FR = normalized resistance force	IBR24340
C	FDES and FR are computed in Subr. 21 FORCES	IBR24350
C	ISTATE(j) indicates the state of armor unit initially located	IBR24360
C	at node j: 0=stationary, 1=moving, 2=stopped For moving/stopped armor unit number j:	IBR24370
C	VA(j) = normalized velocity	IBR24380
C	XAA(j), XA(j) = displacement from its initial location,	IBR24390
C	normalized by TP*sqrt(GRAV*HREFP) and DAP, respectively	IBR24400
C	NDIS(j) = time level N when it starts moving the first time	IBR24410
C	It is assumed that once an armor unit is dislodged from a node,	IBR24420
C	no other unit will be dislodged from the same node.	IBR24430
C	and the same node.	IBR24440 IBR24450
	DO 120 $J = 1$ , JSTAB	IBR24450
	IF (ISTATE(J).EQ.0) THEN	IBR24470
C	STATIONARY ARMOR UNIT	IBR24480
C	Check whether the unit at node j starts moving	IBR24490
	CALL FORCES (V(J), J, FDES, FR, DUDT, SSLOPE, CTAN)	IBR24500
	IF (DABS (FDES) .GT.FR) THEN	IBR24510
	IF (FDES.LT.0.D+00) FR=-FR	IBR24520
	NMOVE = NMOVE+1	IBR24530
	ISTATE(J) = 1	IBR24540
	NDIS(J) = N	IBR24550
	VA(J) = (FDES-FR) *T/(SG+CM1)	IBR24560
	XAA(J) = .5D+00*VA(J)*T	IBR24570
	NODFI(J) = J + NINT(XAA(J)/X)	IBR24580
	ENDIF	IBR24590
С	ELSEIF (ISTATE(J).EQ.1) THEN	IBR24600
C	MOVING ARMOR UNIT	IBR24610
	Follow the moving unit initially located at node j NOD = NODFI(J)	IBR24620
	VREL = V(NOD) - VA(J)	IBR24630
	CALL FORCES (VREL, NOD, FDES, FR, DUDT, SSLOPE, CTAN)	IBR24640
	FR = $FR*(VA(J)/DABS(VA(J)))$	IBR24650
	DVA = (FDES-FR) *T/(SG+CM1)	IBR24660
	DXAA = (VA(J) + .5D + 00 * DVA) *T	IBR24670
	VA(J) = VA(J) + DVA	IBR24680
	XAA(J) = XAA(J) + DXAA	IBR24690
	NODFI(J) = NODIN(J) + NINT(XAA(J)/X)	IBR24700 IBR24710
C	Check whether the moving unit identified by the	IBR24710
C	initial node j stops at the end of each time step	IBR24720
	IF (DABS(VA(J)).LT.1.D-06.AND.DABS(FDES).LT.DABS(FR)) THEN	IBR24740
	ISTATE(J) = 2	IBR24750

```
NSTOP
                     = NSTOP+1
                                                                      IBR24760
          ENDIF
                                                                     IBR24770
        ELSE
                                                                     IBR24780
C
        ..... STOPPED ARMOR UNIT ..... IBR24790
                 Check whether the stopped armor unit located
C
                                                                     IBR24800
C
                  initially at node j resumes movement
                                                                     IBR24810
          NOD = NODFI(J)
                                                                     IBR24820
          CALL FORCES (V(NOD), NOD, FDES, FR, DUDT, SSLOPE, CTAN)
                                                                     IBR24830
          IF (DABS (FDES) .GT.FR) THEN
                                                                     IBR24840
            IF (FDES.LT.0.D+00) FR=-FR
                                                                     IBR24850
            VA(J)
                   = (FDES-FR) *T/(SG+CM1)
                                                                     IBR24860
                     = XAA(J) + .5D+00*VA(J)*T
            XAA(J)
                                                                     IBR24870
            NODFI(J) = NODIN(J) + NINT(XAA(J)/X)
                                                                     IBR24880
           NSTOP = NSTOP-1
                                                                     IBR24890
            ISTATE(J) = 1
                                                                     IBR24900
          ENDIF
                                                                     IBR24910
        ENDIF
                                                                     IBR24920
  120 CONTINUE
                                                                     IBR24930
C
                                                                     IBR24940
 ... COMPUTE XA
                                                                     IBR24950
C
                                                                     IBR24960
     DO 130 J = 1, JSTAB
                                                                     IBR24970
       IF (ISTATE(J).GE.1) XA(J)=XAA(J)*SIGDA
                                                                     IBR24980
  130 CONTINUE
                                                                     IBR24990
                                                                     IBR25000
      RETURN
                                                                     IBR25010
      END
                                                                     IBR25020
C
                                                                     IBR25030
C -20----- END OF SUBROUTINE MOVE ----- IBR25040
C
                                                                     IBR25060
C
     This subroutine computes destabilizing force FDES
                                                                    IBR25070
C
     and resistance force FR used in Subr. 20 MOVE
                                                                    IBR25080
C
                                                                    IBR25090
     SUBROUTINE FORCES (VELO, NODE, FDES, FR, DUDT, SSLOPE, CTAN)
                                                                    IBR25100
C
                                                                    IBR25110
     IMPLICIT DOUBLE PRECISION (A-H, O-Z)
                                                                    IBR25120
     DOUBLE PRECISION KS, KSREF, KSSEA, KSI
                                                                    IBR25130
     DIMENSION DUDT (N1R), SSLOPE (N1R), CTAN (N1R)
                                                                    IBR25140
     COMMON /DIMENS/ N1R, N2R, N3R, N4R, N5R
                                                                     IBR25150
     COMMON /WAVE2/ KS, KSREF, KSSEA, WLO, WL, UR, URPRE, KSI, SIGMA COMMON /STAB1/ C2, C3, CD, CL, CM, SG, TANPHI, AMIN, AMAX, DAP
                                                                   IBR25160
                                                                    IBR25170
     COMMON /STAB4/ CSTAB3, CSTAB4, CM1, DA, SIGDA, WEIG
                                                                    IBR25180
C
                                                                    IBR25190
C
     WEIG = normalized submerged weight of armor unit defined in
                                                                   IBR25200
C
            Subr. 5 PARAM
                                                                    IBR25210
C
     WSIN = component of WEIG parallel to local slope
                                                                    IBR25220
C
     WCOS = component of WEIG normal to local slope
                                                                    IBR25230
C
     FD = normalized drag force
                                                                    IBR25240
C
     FL = normalized lift force
                                                                    IBR25250
C
     FI = normalized inertia force due to fluid only
                                                                    IBR25260
C
     FDES = normalized destabilizing force = FD+FI-WSIN
                                                                    IBR25270
     FR = normalized resistance or friction force
C
                                                                    IBR25280
C
         = 0 if (WCOS-FL)<0; no contact with other units
                                                                   IBR25290
    Note: FR returned to Subr. 20 MOVE is positive or zero IBR25300
```

------

```
C
                                                                      IBR25310
      WSIN = WEIG*SSLOPE (NODE)
                                                                     IBR25320
      WCOS = WEIG*CTAN(NODE)/TANPHI
                                                                     IBR25330
         = SIGMA*CSTAB3*VELO*DABS(VELO)
                                                                     IBR25340
      FL
          = SIGMA*CSTAB4*VELO*VELO
                                                                     IBR25350
      FI
          = CM*DUDT (NODE)
                                                                     IBR25360
      FDES = FD + FI - WSIN
                                                                     IBR25370
      FR = (WCOS-FL)*TANPHI
                                                                     IBR25380
      IF (FR.LE.0.D+00) FR=0.D+00
                                                                     IBR25390
C
                                                                      IBR25400
      RETURN
                                                                     IBR25410
      END
                                                                     IBR25420
                                                                     TBR25430
C -21----- END OF SUBROUTINE FORCES ----- IBR25440
C
      This subroutine computes total fluid acceleration using
                                                                     IBR25470
C
      Subr. 31 ASSIGN and Subr. 32 DERIV
                                                                     IBR25480
C
                                                                     IBR25490
      SUBROUTINE ACCEL (N)
                                                                     IBR25500
C
                                                                     IBR25510
      IMPLICIT DOUBLE PRECISION (A-H, O-Z)
                                                                     IBR25520
      PARAMETER (N1=500, N2=30000, N3=3, N4=100, N5=25)
                                                                     IBR25530
     DIMENSION VDUM1 (N1), VDUM2 (N1)
                                                                     IBR25540
      INTEGER S
                                                                     IBR25550
      COMMON /DIMENS/ N1R, N2R, N3R, N4R, N5R
                                                                     IBR25560
      COMMON /NODES/ S, JE, JE1, JSTAB, JMAX
                                                                     IBR25570
     COMMON /TLEVEL/ NTOP, NONE, NJUM1, NJUM2, NSAVA, NSTAB, NSTAT, NTIMES
                                                                    IBR25580
      COMMON /GRID/ T, X, TX, XT, TTX, TTXX, TWOX
                                                                     IBR25590
     COMMON /BOT2/ DSEA, DSEAKS, DSEA2, DLAND, DLAND2, FW, TSLOPS, WTOT IBR25600 COMMON /BOT3/ U2INIT(N1), THETA(N1), SSLOPE(N1), XB(N1), ZB(N1) IBR25610
     COMMON /HYDRO/ U(2,N1),V(N1),ELEV(N1),C(N1),DUDT(N1)
                                                                     IBR25620
      IF (N.EQ.NSTAB) CALL CHEPAR (22,1,N1,N1R)
                                                                     IBR25630
     CALL ASSIGN (1, VDUM1, U, 2, S, 2)
                                                                     IBR25640
     CALL DERIV (VDUM1, VDUM2, X, S)
                                                                     IBR25650
     DO 100 J = 1, S
                                                                     IBR25660
       DUDT(J) = -VDUM2(J) - THETA(J) - FW*V(J)*DABS(V(J))/U(2,J)
                                                                     IBR25670
                                                                     IBR25680
                                                                     IBR25690
     RETURN
                                                                     IBR25700
     END
C
                                                                     IBR25720
C -22----- END OF SUBROUTINE ACCEL ----- IBR25730
C
                                                                     IBR25750
C
     This subroutine computes statistical values after time-marching
                                                                     IBR25760
C
     computation
                                                                     IBR25770
C
                                                                     IBR25780
     SUBROUTINE STAT2
                                                                     IBR25790
C
                                                                     IBR25800
     IMPLICIT DOUBLE PRECISION (A-H, O-Z)
                                                                    IBR25810
     PARAMETER (N1=500, N2=30000, N3=3, N4=100, N5=25)
                                                                    IBR25820
     INTEGER S
                                                                    IBR25830
     COMMON /DIMENS/ N1R, N2R, N3R, N4R, N5R
                                                                    IBR25840
     COMMON /ID/ IJOB, ISTAB, ISYST, IBOT, INONCT, IENERG, IWAVE,
                                                                   IBR25850
```

```
ISAVA, ISAVB, ISAVC
                                                                             IBR25860
       COMMON /TLEVEL/ NTOP, NONE, NJUM1, NJUM2, NSAVA, NSTAB, NSTAT, NTIMES
                                                                            IBR25870
       COMMON /NODES/ S, JE, JE1, JSTAB, JMAX
                                                                             IBR25880
       COMMON /WAVE3/ ETA(N2), ETAIS(N2), ETARS(N2), ETATS(N2)
                                                                             IBR25890
       COMMON /RUNP1/ NDELR
                                                                             IBR25900
       COMMON /RUNP2/ DELRP(N3), DELTAR(N3), RUNUPS(N3), RSTAT(3, N3)
                                                                             IBR25910
       COMMON /OVER/ OV(4)
                                                                             IBR25920
       COMMON /COEFS/ RCOEF(3), TCOEF(3)
                                                                            IBR25930
       COMMON /STAT/ ELSTAT(3), U1STAT(N1), ESTAT(3, N1), VSTAT(3, N1)
                                                                            IBR25940
      COMMON /STAB5/ JSNSC, NSNSC, NSNSX(N1)
COMMON /STAB6/ SNSC, SNR(N1), SNSX(N1)
                                                                            IBR25950
                                                                            IBR25960
       CALL CHEPAR (23, 1, N1, N1R)
                                                                            IBR25970
       CALL CHEPAR (23, 2, N2, N2R)
                                                                            IBR25980
       CALL CHEPAR (23,3,N3,N3R)
                                                                            IBR25990
      NDENOM = NTOP-NSTAT+1
                                                                             IBR26000
      DENOM = DBLE (NDENOM)
                                                                             IBR26010
C
                                                                             IBR26020
  ... REFLECTION AND TRANSMISSION COEFFICIENTS AND
C
                                                                            IBR26030
      MEAN SURFACE ELEVATIONS AT BOUNDARIES
                                                                            IBR26040
C
      Using Subr. 24 COEF
                                                                            IBR26050
C
                                                                            IBR26060
C
      RCOEF(i) = reflection coefficient of the i-th kind
                                                                           IBR26070
      TCOEF(i) = transmission coefficient of the i-th kind
C
                                                                          IBR26080
                  i=1,2,3 for monochromatic incident waves
C
                                                                           IBR26090
C
      Mean surface elevations:
                                                                           IBR26100
      ELSTAT(1): due to incident wave ETAIS (Subr. 16 SEABC) ELSTAT(2): due to reflected wave ETARS (Subr. 16 SEABC)
C
                                                                          IBR26110
IBR26120
C
      ELSTAT(3): due to transmitted wave ETATS (Subr. 13 LANDBC)
C
                                                                            IBR26130
C
                                                                            IBR26140
      CALL COEF (1, DUM , ELSTAT(1), ETAIS, NDENOM)
                                                                            IBR26150
      CALL COEF (2, RCOEF, ELSTAT(2), ETARS, NDENOM)
                                                                            IBR26160
      IF (IJOB.EQ.3) CALL COEF (2, TCOEF, ELSTAT(3), ETATS, NDENOM)
                                                                           IBR26170
C
                                                                            IBR26180
C
 ... WAVE SETUP ON SLOPE COMPUTED FROM WATERLINE MOTION
                                                                            IBR26190
C
      (Subr. 13 LANDBC)
                                                                            IBR26200
C
                                                                            IBR26210
      IF (IJOB.LT.3) THEN
                                                                            IBR26220
        DO 110 L = 1, NDELR
                                                                            IBR26230
          RSTAT(1,L) = RSTAT(1,L)/DENOM
                                                                            IBR26240
  110
        CONTINUE
                                                                            IBR26250
      ENDIF
                                                                            IBR26260
C
                                                                            IBR26270
C ... OVERTOPPING
                                                                            IBR26280
      Computed in Subr. 13 LANDBC
                                                                            IBR26290
C
      OV(2) and OV(3) are relative to the interval of N=NSTAT to
                                                                           IBR26300
C
      N=NTOP which is taken to be unity
                                                                            IBR26310
C
                                                                            IBR26320
      IF (IJOB.EQ.2) THEN
                                                                            IBR26330
        DO 120 I = 1,3
                                                                            IBR26340
          OV(I) = OV(I)/DENOM
                                                                            IBR26350
  120
      CONTINUE
                                                                            IBR26360
      ENDIF
                                                                            IBR26370
                                                                            IBR26380
C ... MEAN HYDRODYNAMIC QUANTITIES
                                                                            IBR26390
                                                                            IBR26400
```

-----

```
C
      Mean value at node j (from Main):
                                                                      IBR26410
C
       U1STAT(j): volume flux
                                                                      IBR26420
C
        ESTAT(1, j): surface elevation above SWL
                                                                      IBR26430
C
       VSTAT(1, j): depth-averaged velocity
                                                                      IBR26440
C
                                                                      IBR26450
     DO 130 J = 1, JMAX
                                                                      IBR26460
        U1STAT(J) = U1STAT(J)/DENOM
                                                                      IBR26470
        ESTAT(1,J) = ESTAT(1,J)/DENOM
                                                                      IBR26480
        VSTAT(1,J) = VSTAT(1,J)/DENOM
                                                                      IBR26490
  130 CONTINUE
                                                                      IBR26500
C
                                                                      IBR26510
C ... CRITICAL STABILITY NUMBER, SNSC
                                                                      IBR26520
C
                                                                      IBR26530
      SNSC = critical stability number = min. of SNSX along the slope IBR26540
C
C
     NSNSC = time level N when SNSC occurs
                                                                      IBR26550
C
     JSNSC = node number where SNSC occurs
                                                                      IBR26560
C
     SNSX(j) = local stability number (Subr. 19 STABNO)
                                                                      IBR26570
C
    NSNSX(j) = time level N when <math>SNSX(j) occurs
                                                                     IBR26580
C
     SNR(j) = stability number against rolling/sliding at node j
                                                                     IBR26590
                                                                     IBR26600
     IF (ISTAB.EQ.1) THEN
                                                                      IBR26610
       DO 140 J = 1, JMAX
                                                                      IBR26620
         IF (SNSX(J).LT.SNSC) THEN
                                                                      IBR26630
           SNSC = SNSX(J)
                                                                      IBR26640
           JSNSC = J
                                                                     IBR26650
           NSNSC = NSNSX(J)
                                                                     IBR26660
         ENDIF
                                                                     IBR26670
       CONTINUE
                                                                     IBR26680
     ENDIF
                                                                      IBR26690
C
                                                                      IBR26700
     RETURN
                                                                     IBR26710
                                                                     IBR26720
C
                                                                     IBR26730
C -23----- END OF SUBROUTINE STAT2 ----- IBR26740
C
                                                                     IBR26760
C
     This subroutine computes:
                                                                     IBR26770
C
     . time-averaged value of given quantity, VAL (MODE=1)
                                                                     IBR26780
     . reflection or transmission coefficients (three kinds) (MODE=2) IBR26790
      for monochromatic incident waves
                                                                     IBR26800
                                                                     IBR26810
     SUBROUTINE COEF (MODE, COE, AVER1, VAL, ND)
                                                                     IBR26820
C
                                                                     IBR26830
     IMPLICIT DOUBLE PRECISION (A-H, O-Z)
                                                                     IBR26840
     DOUBLE PRECISION KS, KSREF, KSSEA, KSI
                                                                     IBR26850
     DIMENSION COE(3), VAL(ND)
                                                                     IBR26860
     COMMON /WAVE2/ KS, KSREF, KSSEA, WLO, WL, UR, URPRE, KSI, SIGMA
                                                                     IBR26870
     SUM1 = 0.D+00
                                                                     IBR26880
     DO 110 I = 1, ND
                                                                     IBR26890
       SUM1 = SUM1 + VAL(I)
                                                                     IBR26900
 110 CONTINUE
                                                                     IBR26910
     AVER1 = SUM1/DBLE(ND)
                                                                     IBR26920
     IF (MODE.EQ.2) THEN
                                                                     IBR26930
       VALMAX = -1.D+03
                                                                     IBR26940
       VALMIN = 1.D+03
                                                                     IBR26950
```

```
SUM2 = 0.D+00
                                                                                                                                          IBR26960
                SUM3 = 0.D+00
                                                                                                                                          IBR26970
                DO 120 I = 1, ND
                                                                                                                                          IBR26980
                    IF (VAL(I).GT.VALMAX) VALMAX = VAL(I)
                                                                                                                                          IBR26990
                    IF (VAL(I).LT.VALMIN) VALMIN = VAL(I)
                                                                                                                                          IBR27000
                    SUM2 = SUM2 + VAL(I)*VAL(I)
                                                                                                                                          IBR27010
                    SUM3 = SUM3 + (VAL(I) - AVER1) **2
                                                                                                                                          IBR27020
     120
                CONTINUE
                                                                                                                                          IBR27030
                AVER2 = SUM2/DBLE(ND)
                                                                                                                                          IBR27040
                AVER3 = SUM3/DBLE(ND)
                                                                                                                                         IBR27050
 C
                               Monochromatic incident wave plottle to describe given by ETAI=(KS/2)COS[2*PI*(t+t0)] since linear monochromatic incident wave plottle to describe a since linear given by ETAI=(KS/2)COS[2*PI*(t+t0)] since linear monochromatic incident wave plottle to describe the since linear given by ETAI=(KS/2)COS[2*PI*(t+t0)] since linear monochromatic incident wave plottle to describe the since linear given by ETAI=(KS/2)COS[2*PI*(t+t0)] since linear monochromatic incident wave plottle to describe the since linear monochromatic incident wave plottle to describe the since linear monochromatic incident wave plottle to describe the since linear monochromatic incident wave plottle to describe the since linear monochromatic incident wave plottle to describe the since linear monochromatic incident wave plottle to describe the since linear monochromatic incident wave plottle to describe the since linear monochromatic incident wave plottle to describe the since linear monochromatic incident wave plottle to describe the since linear monochromatic incident wave plottle to describe the since linear monochromatic incident wave plottle to describe the since linear monochromatic incident wave plottle to describe the since linear monochromatic incident wave plottle to describe the since linear monochromatic incident wave plottle to describe the since linear monochromatic incident wave plottle to describe the since linear monochromatic incident wave plottle to describe the since linear monochromatic incident wave plottle to describe the since linear monochromatic incident wave plottle to describe the since linear monochromatic incident wave plottle to describe the since linear monochromatic incident wave plottle to describe the since linear monochromatic incident wave plottle to describe the since linear monochromatic incident wave plottle to describe the since linear monochromatic incident wave plottle to describe the since linear monochromatic incident wave plottle to describe the since linear monochromatic incident wave plottle to descri
                              Monochromatic incident wave profile is assumed to be
                                                                                                                                         IBR27060
 C
                                                                                                                                         IBR27070
 C
                                                                                                                                         IBR27080
 C
                               and transmission coefficients
                                                                                                                                          IBR27090
                COE(1) = (VALMAX-VALMIN)/KS
                                                                                                                                          IBR27100
                COE(2) = DSQRT(8.D+00*AVER2)/KS
                                                                                                                                         IBR27110
                COE(3) = DSQRT(8.D+00*AVER3)/KS
                                                                                                                                         IBR27120
            ENDIF
                                                                                                                                         IBR27130
 C
                                                                                                                                          IBR27140
            RETURN
                                                                                                                                         IBR27150
            END
                                                                                                                                          IBR27160
 C
                                                                                                                                         IBR27170
C -24----- END OF SUBROUTINE COEF ----- IBR27180
IBR27200
C
            This subroutine checks overall energy balance
                                                                                                                                         IBR27210
C
                                                                                                                                         IBR27220
            SUBROUTINE BALANE
                                                                                                                                         IBR27230
C
                                                                                                                                         IBR27240
            IMPLICIT DOUBLE PRECISION (A-H, O-Z)
                                                                                                                                         IBR27250
           PARAMETER (N1=500, N2=30000, N3=3, N4=100, N5=25)
                                                                                                                                         IBR27260
           DOUBLE PRECISION KS, KSREF, KSSEA, KSI
                                                                                                                                         IBR27270
           DIMENSION VDUM1 (N1), VDUM2 (N1)
                                                                                                                                         IBR27280
            INTEGER S
                                                                                                                                         IBR27290
           COMMON /DIMENS/ N1R, N2R, N3R, N4R, N5R
                                                                                                                                         IBR27300
           COMMON /ID/ IJOB, ISTAB, ISYST, IBOT, INONCT, IENERG, IWAVE,
                                                                                                                                        IBR27310
                                         ISAVA, ISAVB, ISAVC
                                                                                                                                         IBR27320
           COMMON /TLEVEL/ NTOP, NONE, NJUM1, NJUM2, NSAVA, NSTAB, NSTAT, NTIMES
                                                                                                                                         IBR27330
           COMMON /NODES/ S, JE, JE1, JSTAB, JMAX
                                                                                                                                         IBR27340
           COMMON /GRID/ T, X, TX, XT, TTX, TTXX, TWOX
                                                                                                                                         IBR27350
           COMMON /BOT2/ DSEA, DSEAKS, DSEA2, DLAND, DLAND2, FW, TSLOPS, WTOT
                                                                                                                                        IBR27360
           COMMON /WAVE2/ KS, KSREF, KSSEA, WLO, WL, UR, URPRE, KSI, SIGMA
                                                                                                                                        IBR27370
           COMMON /COEFS/ RCOEF(3), TCOEF(3)
                                                                                                                                        IBR27380
           COMMON /ENERG/ ENER(4,N1), ENERB(14)
                                                                                                                                         IBR27390
           CALL CHEPAR (25,1,N1,N1R)
                                                                                                                                         IBR27400
           CALL CHEPAR (25,3,N3,N3R)
                                                                                                                                         IBR27410
C
                                                                                                                                         IBR27420
C
           All quantities involved herein are time-averaged quantities
                                                                                                                                        IBR27430
C
                                                                                                                                        IBR27440
C
           At node j:
                                                                                                                                        IBR27450
C
              ENER(1,j) = norm. energy per unit surface area
                                                                                                                                        IBR27460
C
              ENER(2,j) = norm. energy flux per unit width
                                                                                                                                       IBR27470
C
           Norm. rate of energy dissipation, at node j:
                                                                                                                                       IBR27480
C
              ENER(3,j): due to bottom friction, per unit bottom area
                                                                                                                                      IBR27490
              ENER(4, j): due to wave breaking, per unit surface area IBR27500
C
```

```
C
                                                                          IBR27510
      DENOM = DBLE (NTOP-NSTAT+1)
                                                                          IBR27520
      DO 120 J = 1, JMAX
                                                                          IBR27530
        DO 110 I = 1,3
                                                                          IBR27540
          ENER(I,J) = ENER(I,J)/DENOM
                                                                          IBR27550
  110
        CONTINUE
                                                                          IBR27560
  120 CONTINUE
                                                                          IBR27570
      ----- Use Subr. 31 ASSIGN and Subr. 32 DERIV
                                                                          IBR27580
      CALL ASSIGN (1, VDUM1, ENER, 4, JMAX, 2)
                                                                          IBR27590
      CALL DERIV (VDUM1, VDUM2, X, JMAX)
                                                                          IBR27600
      DO 130 J = 1, JMAX
                                                                          IBR27610
        ENER(4,J) = -VDUM2(J) - ENER(3,J)
                                                                          IBR27620
  130 CONTINUE
                                                                          IBR27630
C
                                                                          IBR27640
C
      Normalized energy flux at boundaries:
                                                                          IBR27650
C
        ENERB(1): at seaward boundary
                                                                          IBR27660
C
       ENERB(2): at landward boundary
                                                                          IBR27670
      Normalized rate of energy dissipation in the computation domain: IBR27680
C
C
      ENERB(3): due to bottom friction
                                                                          IBR27690
C
        ENERB (4): due to wave breaking
                                                                          IBR27700
C
                                                                          IBR27710
      ENERB(1) = ENER(2,1)
                                                                          IBR27720
      IF (IJOB.EQ.1) THEN
                                                                          IBR27730
        ENERB(2) = 0.D+00
                                                                          IBR27740
                                                                          IBR27750
        ENERB(2) = ENER(2, JMAX)
                                                                          IBR27760
      ENDIF
                                                                          IBR27770
      DO 150 I = 3,4
                                                                          IBR27780
        ENERB(I) = (ENER(I, 1) + ENER(I, JMAX))/2.D+00
                                                                          IBR27790
        DO 140 J = 2, JMAX-1
                                                                          IBR27800
          ENERB(I) = ENERB(I) + ENER(I,J)
                                                                          IBR27810
        CONTINUE
                                                                          IBR27820
        ENERB(I) = ENERB(I) *X
                                                                          IBR27830
  150 CONTINUE
                                                                          IBR27840
                                                                          IBR27850
      ENERB(5) = ENERB(1) - ENERB(2)
                                                                          IBR27860
      ENERB(6) = ENERB(3) + ENERB(4)
                                                                          IBR27870
      ENERB(7) = ENERB(6) - ENERB(5)
                                                                          IBR27880
      ENERB(8) = 100.D+00*ENERB(7)/ENERB(5)
                                                                          IBR27890
                                                                          IBR27900
C
     Approximate energy flux based on linear long wave:
                                                                         IBR27910
C
        ENERB(9): due to incident wave at seaward boundary
                                                                         IBR27920
        ENERB(10): due to reflected wave at seaward boundary
C
                                                                         IBR27930
C
       ENERB(11): due to transmitted wave at landward boundary
                                                                        IBR27940
                                                                          IBR27950
     ENERB(9) = KS*KS*DSEA2/8.D+00
                                                                          IBR27960
      ENERB(10) = DSEA2*(KS*RCOEF(3))**2/8.D+00
                                                                          IBR27970
      ENERB(12) = ENERB(9) - ENERB(10)
                                                                          IBR27980
      ENERB (13) = 100.D + 00* (ENERB (12) - ENERB (1)) / ENERB (1)
                                                                         IBR27990
      IF (IJOB.EQ.3) THEN
                                                                          IBR28000
        ENERB(11) = DLAND2*(KS*TCOEF(3))**2/8.D+00
                                                                          IBR28010
        ENERB (14) = 100.D+00* (ENERB (11) -ENERB (2)) /ENERB (2)
                                                                          IBR28020
     ENDIF
                                                                         IBR28030
C
                                                                         IBR28040
     RETURN
                                                                          IBR28050
```

```
END
                                                                     TBR28060
C
                                                                     IBR28070
C -25----- END OF SUBROUTINE BALANE ----- IBR28080
C
                                                                     IBR28100
C
      This subroutine computes, for each node,
                                                                    IBR28110
C
     . the elements of the the first row of Matrix A (2x2)
                                                                    IBR28120
     . the elements of Matrix F (2x1) \longrightarrow F(1,j) and F(2,j) IBR28130 IBR28140
C
C
C
      . the first element of Matrix G (2x1) --> G1(j)
                                                                    IBR28150
C
     j=node number
                                                                    IBR28160
C
                                                                    IBR28170
     SUBROUTINE MATAFG (N, JBEGIN, JEND)
                                                                    IBR28180
C
                                                                    IBR28190
     IMPLICIT DOUBLE PRECISION (A-H, O-Z)
                                                                    IBR28200
     PARAMETER (N1=500, N2=30000, N3=3, N4=100, N5=25)
                                                                    IBR28210
     COMMON /DIMENS/ N1R, N2R, N3R, N4R, N5R
                                                                    IBR28220
     COMMON /BOT2/ DSEA, DSEAKS, DSEA2, DLAND, DLAND2, FW, TSLOPS, WTOT IBR28230 COMMON /BOT3/ U2INIT(N1), THETA(N1), SSLOPE(N1), XB(N1), ZB(N1) IBR28240
     COMMON /BOT3/
     COMMON /HYDRO/ U(2,N1),V(N1),ELEV(N1),C(N1),DUDT(N1)
                                                                    IBR28250
     COMMON /MATRIX/ A1(2,N1),F(2,N1),G1(N1),GJR(2,N1),S1(N1),D(2,N1) IBR28260
     IF (N.EQ.1) CALL CHEPAR (26,1,N1,N1R)
                                                                    IBR28270
     DO 100 J = JBEGIN, JEND
                                                                    IBR28280
       A1(1,J) = 2.D+00*V(J)
                                                                    IBR28290
       A1(2,J) = U(2,J) - V(J) * V(J)
                                                                    IBR28300
       F(1,J) = V(J) *U(1,J) + U(2,J) *U(2,J)/2.D+00
                                                                    IBR28310
       F(2,J) = U(1,J)
                                                                    IBR28320
       G1(J) = THETA(J)*U(2,J) + FW*DABS(V(J))*V(J)
                                                                    IBR28330
 100 CONTINUE
                                                                    IBR28340
                                                                    IBR28350
     RETURN
                                                                    IBR28360
                                                                    IBR28370
C
                                                                    IBR28380
C -26----- END OF SUBROUTINE MATAFG ----- IBR28390
C
                                                                    IBR28410
C
     This subroutine computes, for each node, the elements of
                                                                    IBR28420
C
     Matrix g (2x1) --> GJR(1,j) and GJR(2,j), j=node number
                                                                    IBR28430
C
                                                                    IBR28440
     SUBROUTINE MATGJR (N, JBEGIN, JEND)
                                                                    IBR28450
C
                                                                    IBR28460
     IMPLICIT DOUBLE PRECISION (A-H, O-Z)
                                                                    IBR28470
     PARAMETER (N1=500, N2=30000, N3=3, N4=100, N5=25)
                                                                    IBR28480
     COMMON /DIMENS/ N1R, N2R, N3R, N4R, N5R
                                                                    IBR28490
     COMMON /GRID/ T, X, TX, XT, TTX, TTXX, TWOX
                                                                   IBR28500
     COMMON /HYDRO/ U(2,N1),V(N1),ELEV(N1),C(N1),DUDT(N1)
                                                                    IBR28510
     COMMON /MATRIX/ A1(2,N1),F(2,N1),G1(N1),GJR(2,N1),S1(N1),D(2,N1) IBR28520
     IF (N.EQ.1) CALL CHEPAR (27,1,N1,N1R)
                                                                    IBR28530
     DO 100 J = JBEGIN, JEND
                                                                    IBR28540
       FG1 = F(1,J+1)-F(1,J) + X*(G1(J+1)+G1(J))/2.D+00
                                                                    IBR28550
       FG2 = F(2,J+1)-F(2,J)
                                                                    IBR28560
       DUM = (A1(1,J+1)+A1(1,J))*FG1 + (A1(2,J+1)+A1(2,J))*FG2
                                                                    IBR28570
       GJR(1,J) = DUM/2.D+00
                                                                    IBR28580
       GJR(2,J) = FG1
                                                                    IBR28590
 100 CONTINUE
                                                                    IBR28600
```

```
C
                                                                    IBR28610
      RETURN
                                                                    IBR28620
                                                                    IBR28630
C
                                                                   IBR28640
C -27----- END OF SUBROUTINE MATGJR ----- IBR28650
IBR28670
C
     This subroutine computes, for each node, the first element of
                                                                   IBR28680
C
     Matrix S (2x1) --> S1(j), j=node number
                                                                   IBR28690
C
                                                                    IBR28700
     SUBROUTINE MATS (N, JBEGIN, JEND)
                                                                    IBR28710
C
                                                                    IBR28720
     IMPLICIT DOUBLE PRECISION (A-H, O-Z)
                                                                   IBR28730
     PARAMETER (N1=500, N2=30000, N3=3, N4=100, N5=25)
                                                                   IBR28740
     COMMON /DIMENS/ N1R, N2R, N3R, N4R, N5R
                                                                   IBR28750
     COMMON /GRID/
                   T, X, TX, XT, TTX, TTXX, TWOX
                                                                   IBR28760
     COMMON /BOT2/
                   DSEA, DSEAKS, DSEA2, DLAND, DLAND2, FW, TSLOPS, WTOT
                                                                  IBR28770
     COMMON /BOT3/
                    U2INIT(N1), THETA(N1), SSLOPE(N1), XB(N1), ZB(N1)
                                                                   IBR28780
     COMMON /HYDRO/ U(2,N1),V(N1),ELEV(N1),C(N1),DUDT(N1)
                                                                   IBR28790
     COMMON /MATRIX/ A1(2,N1),F(2,N1),G1(N1),GJR(2,N1),S1(N1),D(2,N1) IBR28800
     IF (N.EQ.1) CALL CHEPAR (28,1,N1,N1R)
                                                                   IBR28810
     DO 100 J = JBEGIN, JEND
                                                                   IBR28820
       DUM1 = (V(J)*V(J)-U(2,J))*(U(2,J+1)-U(2,J-1))/TWOX
                                                                   IBR28830
       DUM2 = V(J) * (U(1,J+1) - U(1,J-1)) / TWOX
                                                                   IBR28840
       DUM3 = THETA(J) *U(2,J)
                                                                   IBR28850
       DUM4 = FW*DABS(V(J))*V(J)
                                                                   IBR28860
       DUM5 = 2.D+00*FW*DABS(V(J))/U(2,J)
                                                                   IBR28870
       EJN = DUM5*(DUM1-DUM2-DUM3-DUM4)
                                                                   IBR28880
       S1(J) = X*EJN - THETA(J)*(U(1,J+1)-U(1,J-1))/2.D+00
                                                                   IBR28890
 100 CONTINUE
                                                                   IBR28900
C
                                                                   IBR28910
     RETURN
                                                                   IBR28920
                                                                   IBR28930
C
                                                                   IBR28940
C -28----- END OF SUBROUTINE MATS ----- IBR28950
C
                                                                   IBR28970
C
     This subroutine computes, for each node, the elements of
                                                                   IBR28980
C
     Matrix D (2x1) --> D(1,j) and D(2,j), j=node number
                                                                   IBR28990
C
                                                                   IBR29000
     SUBROUTINE MATD (N, JDAM, JEND)
                                                                   IBR29010
C
                                                                   IBR29020
     IMPLICIT DOUBLE PRECISION (A-H, O-Z)
                                                                   IBR29030
     PARAMETER (N1=500, N2=30000, N3=3, N4=100, N5=25)
                                                                   IBR29040
     DIMENSION Q(2,2,N1),UU(2,N1)
                                                                   IBR29050
     COMMON /DIMENS/ N1R, N2R, N3R, N4R, N5R
                                                                   IBR29060
     COMMON /CONSTA/ PI, GRAV, DELTA, X1, X2
                                                                   IBR29070
     COMMON /GRID/ T, X, TX, XT, TTX, TTXX, TWOX
                                                                   IBR29080
     COMMON /HYDRO/ U(2,N1),V(N1),ELEV(N1),C(N1),DUDT(N1)
                                                                   IBR29090
     COMMON /MATRIX/ A1(2,N1),F(2,N1),G1(N1),GJR(2,N1),S1(N1),D(2,N1)
                                                                   IBR29100
     IF (N.EQ.1) CALL CHEPAR (29,1,N1,N1R)
                                                                   IBR29110
     DO 120 J = 1, JDAM
                                                                   IBR29120
       CC1 = C(J+1) + C(J)
                                                                   IBR29130
       CC2 = C(J+1) - C(J)
                                                                   IBR29140
       VC1 = V(J+1) + V(J) + CC1
                                                                   IBR29150
```

```
VC2 = V(J+1) - V(J) + CC2
                                                                      IBR29160
        VC3 = V(J+1) + V(J) - CC1
                                                                      IBR29170
        VC4 = V(J+1) - V(J) - CC2
                                                                      IBR29180
        PPP = (-X1*DABS(VC2)*VC3+X2*DABS(VC4)*VC1)/(2.D+00*CC1)
                                                                      IBR29190
        QQQ = (X1*DABS(VC2)-X2*DABS(VC4))/CC1
                                                                      IBR29200
        Q(1,1,J) = QQQ*(A1(1,J+1)+A1(1,J))/2.D+00 + PPP
                                                                     IBR29210
        Q(1,2,J) = QQQ*(A1(2,J+1)+A1(2,J))/2.D+00
        Q(2,1,J) = QQQ
                                                                     IBR29230
        Q(2,2,J) = PPP
                                                                     IBR29240
        DO 110 I = 1,2
                                                                     IBR29250
         UU(I,J) = U(I,J+1)-U(I,J)
                                                                      IBR29260
  110
        CONTINUE
                                                                      IBR29270
  120 CONTINUE
                                                                      IBR29280
      DO 150 I = 1,2
                                                                      IBR29290
       DO 140 J = 2, JDAM
                                                                      IBR29300
          D(I,J) = 0.D+00
                                                                      IBR29310
         DO 130 L = 1,2
                                                                      IBR29320
           D(I,J) = D(I,J) + Q(I,L,J) * UU(L,J) - Q(I,L,J-1) * UU(L,J-1)
                                                                     IBR29330
  130
         D(I,J) = TX*D(I,J)/2.D+00
                                                                      IBR29350
  140
      CONTINUE
                                                                     IBR29360
  150 CONTINUE
                                                                      IBR29370
      IF (JEND.GT.JDAM) THEN
                                                                      IBR29380
       DO 170 I = 1,2
                                                                     IBR29390
         DO 160 J = JDAM+1, JEND
                                                                      IBR29400
           D(I,J) = 0.D+00
                                                                     IBR29410
  160
         CONTINUE
                                                                     TBR29420
170
       CONTINUE
                                                                     IBR29430
     ENDIF
                                                                     IBR29440
C
                                                                     IBR29450
      RETURN
                                                                     IBR29460
                                                                     IBR29470
C
                                                                     IBR29480
C -29----- END OF SUBROUTINE MATD ----- IBR29490
C
                                                                     IBR29510
C
      This subroutine computes the elements of Matrix U (2x1)
                                                                     IBR29520
C
     --> U(1,j) and U(2,j) with j=node number at next time level
                                                                     IBR29530
C
                                                                     IBR29540
     SUBROUTINE MATU (N, JBEGIN, JEND)
                                                                     IBR29550
C
                                                                     IBR29560
     IMPLICIT DOUBLE PRECISION (A-H, O-Z)
                                                                     IBR29570
     PARAMETER (N1=500, N2=30000, N3=3, N4=100, N5=25)
                                                                     IBR29580
     COMMON /DIMENS/ N1R, N2R, N3R, N4R, N5R
                                                                     IBR29590
     COMMON /GRID/ T, X, TX, XT, TTX, TTXX, TWOX
                                                                     IBR29600
     COMMON /HYDRO/ U(2,N1),V(N1),ELEV(N1),C(N1),DUDT(N1)
                                                                     IBR29610
     COMMON /MATRIX/ A1(2,N1),F(2,N1),G1(N1),GJR(2,N1),S1(N1),D(2,N1) IBR29620
     IF (N.EQ.1) CALL CHEPAR (30,1,N1,N1R)
                                                                     IBR29630
     DO 100 J = JBEGIN, JEND
                                                                     IBR29640
       DUM1 = TX*((F(1,J+1)-F(1,J-1))/2.D+00+X*G1(J))
                                                                     IBR29650
       DUM2 = TTXX*(GJR(1,J)-GJR(1,J-1))
                                                                     IBR29660
       DUM3 = TX*(F(2,J+1)-F(2,J-1))
                                                                     IBR29670
       DUM4 = TTXX*(GJR(2,J)-GJR(2,J-1))
                                                                     IBR29680
       U(1,J) = U(1,J) - DUM1 + (DUM2-TTX*S1(J))/2.D+00 + D(1,J)
                                                                   IBR29690
       U(2,J) = U(2,J) - (DUM3-DUM4)/2.D+00 + D(2,J)
                                                                    IBR29700
```

	100	CONTINUE	IBR29710
C			IBR29720
		RETURN	IBR29730
		END	IBR29740
C			IBR29750
		END OF SUBROUTINE MATU	IBR29760
	#31	#################### SUBROUTINE ASSIGN #########################	IBR29770
C			IBR29780
C		This subroutine changes notations from matrix to vector or	IBR29790
C		from vector to matrix	IBR29800
C		CURROUMTNE ACCION (MODE MAIL MAIL MR. ARROWS	IBR29810
С		SUBROUTINE ASSIGN (MODE, VAL1, VAL2, ND1, ND2, NROW)	IBR29820
C		IMPLICIT DOUBLE PRECISION (A-H,O-Z)	IBR29830
		DIMENSION VAL1 (ND2), VAL2 (ND1, ND2)	IBR29840
		IF (MODE.EQ.1) THEN	IBR29850 IBR29860
		DO 110 J = 1, ND2	IBR29870
		VAL1(J) = VAL2(NROW, J)	IBR29880
	110		IBR29890
		ELSE	IBR29900
		DO 120 $J = 1,ND2$	IBR29910
		VAL2 (NROW, J) = VAL1 (J)	IBR29920
	120	CONTINUE	IBR29930
		ENDIF	IBR29940
C			IBR29950
		RETURN	IBR29960
~		END	IBR29970
C	21	END OF SUBROUTINE ASSIGN	IBR29980
		###################### SUBROUTINE ASSIGN	IBR29990
C	#32	**************************************	IBR30000
C		This subroutine computes the first derivative, DER, of given	IBR30010
C		quantity, FUN, with respect to given variable, VAR, for	IBR30020 IBR30030
C		J=1,2,,ND	IBR30030
C			IBR30050
		SUBROUTINE DERIV (FUN, DER, VAR, ND)	IBR30060
C			IBR30070
		IMPLICIT DOUBLE PRECISION (A-H,O-Z)	IBR30080
		DIMENSION FUN (ND), DER (ND)	IBR30090
		VAR2 = 2.D + 00*VAR	IBR30100
		DER(1) = (FUN(2) - FUN(1)) / VAR	IBR30110
		DER(ND) = (FUN(ND) - FUN(ND-1)) / VAR	IBR30120
		DO 100 $J = 2$ , ND-1	IBR30130
	100	DER(J) = (FUN(J+1)-FUN(J-1))/VAR2	IBR30140
С	100	CONTINUE	IBR30150
C		RETURN	IBR30160
		END	IBR30170
C		Test a Test	IBR30180
	-32-	END OF SUBROUTINE DERIV	IBR30190 IBR30200
C	#33	######################################	IBR30210
C			IBR30220
C		This subroutine documents input data and related parameters	IBR30230
C		before time-marching computation	IBR30240
C			IBR30250

```
SUBROUTINE DOC1
                                                                             IBR30260
C
                                                                             IBR30270
      IMPLICIT DOUBLE PRECISION (A-H, O-Z)
                                                                             IBR30280
      PARAMETER (N1=500, N2=30000, N3=3, N4=100, N5=25)
                                                                             IBR30290
      DOUBLE PRECISION KCNO, MCNO, KC2
                                                                             IBR30300
      DOUBLE PRECISION KS, KSREF, KSSEA, KSI
                                                                             IBR30310
      CHARACTER*7 UL
                                                                             IBR30320
      INTEGER S
                                                                             IBR30330
      COMMON /DIMENS/ N1R, N2R, N3R, N4R, N5R
                                                                             IBR30340
      COMMON /CONSTA/ PI, GRAV, DELTA, X1, X2
                                                                             IBR30350
      COMMON /ID/
                     IJOB, ISTAB, ISYST, IBOT, INONCT, IENERG, IWAVE,
                                                                            IBR30360
                        ISAVA, ISAVB, ISAVC
                                                                             IBR30370
      COMMON /TLEVEL/ NTOP, NONE, NJUM1, NJUM2, NSAVA, NSTAB, NSTAT, NTIMES
                                                                             IBR30380
      COMMON /NODES/ S, JE, JE1, JSTAB, JMAX
                                                                             TBR30390
      COMMON /GRID/
                       T, X, TX, XT, TTX, TTXX, TWOX
                                                                             IBR30400
      COMMON /WAVE1/ HREFP, TP, WLOP
                                                                             IBR30410
      COMMON /WAVE2/ KS, KSREF, KSSEA, WLO, WL, UR, URPRE, KSI, SIGMA COMMON /WAVE4/ ETAMAX, ETAMIN
                                                                             IBR30420
                                                                             IBR30430
      COMMON /WAVE5/ KCNO, ECNO, MCNO, KC2
                                                                             IBR30440
      COMMON /BOT1/ DSEAP, DLANDP, FWP
                                                                             IBR30450
      COMMON /BOT2/ DSEA, DSEAKS, DSEA2, DLAND, DLAND2, FW, TSLOPS, WTOT
                                                                             IBR30460
      COMMON /BOT3/ U2INIT(N1), THETA(N1), SSLOPE(N1), XB(N1), ZB(N1)
                                                                             IBR30470
      COMMON /BOT4/ NBSEG
                                                                             IBR30480
      COMMON /BOT5/ WBSEG(N4), TBSLOP(N4), XBSEG(N4), ZBSEG(N4)
                                                                             IBR30490
      COMMON /STAB1/ C2,C3,CD,CL,CM,SG,TANPHI,AMIN,AMAX,DAP
                                                                             IBR30500
      CALL CHEPAR (33, 1, N1, N1R)
                                                                             TBR30510
      CALL CHEPAR (33, 4, N4, N4R)
                                                                             IBR30520
      ISTOP = 0
                                                                             IBR30530
C
                                                                             IBR30540
C ... SYSTEM OF UNITS
                                                                             IBR30550
                                                                             IBR30560
      IF (ISYST.EQ.1) THEN
                                                                             IBR30570
        UL = ' meters'
                                                                             IBR30580
                                                                             IBR30590
        UL = ' feet '
                                                                             IBR30600
      ENDIF
                                                                             IBR30610
C
                                                                             IBR30620
C
  ... NUMERICAL STABILITY INDICATOR, ALPHAS
                                                                             IBR30630
                                                                             IBR30640
      EPSI
             = DMAX1(X1, X2)
                                                                             IBR30650
             = 1.D+00 + EPSI*EPSI/4.D+00
      DUM1
                                                                             IBR30660
             = DSQRT(DUM1) - EPSI/2.D+00
                                                                             IBR30670
      ALPHAS = DUM2*X*DBLE(NONE)/(1.D+00+DSQRT(DSEA))
                                                                             IBR30680
C
                                                                             IBR30690
C
 ... WAVE CONDITION
                                                                             IBR30700
                                                                             IBR30710
      WRITE (28, 2811)
                                                                             IBR30720
      IF (IWAVE.EQ.1) THEN
                                                                             IBR30730
        IF (URPRE.LT.26) THEN
                                                                             IBR30740
          WRITE (28, 2812)
                                                                             IBR30750
        ELSE
                                                                             IBR30760
          WRITE (28,2813) KC2, ECNO, KCNO
                                                                             IBR30770
        ENDIF
                                                                             IBR30780
      ELSEIF (IWAVE.EQ.2) THEN
                                                                             IBR30790
        WRITE (28,2814)
                                                                             IBR30800
```

```
ELSE
                                                                                IBR30810
         WRITE (28, 2815)
                                                                                IBR30820
       ENDIF
                                                                                IBR30830
       WRITE (28,2816) ETAMAX, ETAMIN
                                                                                IBR30840
       WRITE (28,2817) TP, HREFP, UL, DSEAP, UL, KSREF, KSSEA, KS
                                                                                IBR30850
       WRITE (28,2818) DSEA, WL, SIGMA, UR, KSI
                                                                               IBR30860
       IF (IJOB.EQ.3) WRITE (28,2819) DLANDP, UL
 2811 FORMAT (/'WAVE CONDITION')
                                                                                IBR30880
 2812 FORMAT (/'Stokes II Incident Wave at Seaward Boundary')
                                                                               IBR30890
 2813 FORMAT (/'Cnoidal Incident Wave at Seaward Boundary'/
                                                                               IBR30900
         '1-m = ',D20.9/
                                                                                IBR30910
               'E = ',D20.9/
     +
                                                                                IBR30920
              'K = ', D20.9)
 2814 FORMAT (/'Incident Wave at Seaward Boundary Given as Input')
2815 FORMAT (/'Total Wave at Seaward Boundary Given as Input')
                                                                                IBR30930
                                                                             IBR30940
                                                                              IBR30950
+ 'Norm. Minimum Surface Elev. = ',F12.6/ IBR30960
2817 FORMAT ('Reference Wave Period = ',F12.6,' sec.'/ IBR30980
+ 'Reference Wave Height = ',F12.6,A7/ IBR30990
+ 'Depth at Seaward Boundary = ',F12.6,A7/ IBR31000
+ 'Shoal. Coef. at Reference Ks1 = ',F0.2/
 2816 FORMAT ('Norm. Maximum Surface Elev. = ',F12.6/
+ 'Norm. Minimum Surface Elev. = ',F12.6/)
            'Shoal. Coef. at Reference Ks1 = ',F9.3/
                              at Seaw. Bdr. Ks2 = ', F9.3/
                                                                               IBR31020
                              Ks = Ks2/Ks1 = ', F9.3
                                                                             IBR31030
IBR31040
IBR31050
IBR31060
IBR31070
IBR31080
                                                                              IBR31030
 2818 FORMAT ('Norm. Depth at Seaw. Bdr.
                                                 = ', F9.3/
     + 'Normalized Wave Length
                                               = ', F9.3/
+ '"Sigma" = ',F9.3/

+ 'Ursell Number = ',F9.3/

+ 'Surf Similarity Parameter = ',F9.3)

2819 FORMAT ('Depth at Landward Boundary = ',F12.6,A7)
                                                                              IBR31090
                                                                               IBR31100
C ... STRUCTURE PROPERTIES
                                                                               IBR31110
                                                                               IBR31120
      WRITE (28,2821) FWP, FW, WTOT, NBSEG
                                                                               IBR31130
      IF (IBOT.EQ.1) THEN
                                                                               IBR31140
        WRITE (28,2822) UL
                                                                               IBR31150
        WRITE (28,2824) (K, WBSEG(K), TBSLOP(K), K=1, NBSEG)
                                                                               IBR31160
                                                                               IBR31170
        WRITE (28,2823) UL, UL
                                                                               IBR31180
        WRITE (28,2824) (K, XBSEG(K), ZBSEG(K), K=1, NBSEG+1)
                                                                               IBR31190
      ENDIF
                                                                               IBR31200
2821 FORMAT (/'SLOPE PROPERTIES'//
                                                                               IBR31210
              'Friction Factor = ',F12.6/
'Norm. Friction Factor = ',F12.6/
                                                                              IBR31220
                                                                              IBR31230
              'Norm. Horiz. Length of'/
                                                                              IBR31240
              Computation Domain = ',F12.6/
                                                                               IBR31250
        'Number of Segments = ', 18)
                                                                               IBR31260
2822 FORMAT ('-----'/
                                                                               IBR31270
              ' SEGMENT WBSEG(I) TBSLOP(I)'/
                                                                              IBR31280
              ' I ',A7/
                                                                               IBR31290
              IBR31300
2823 FORMAT ('-----'/
                                                                               IBR31310
    + 'SEGMENT XBSEG(I) ZBSEG(I)'/
                                                                              IBR31320
              ' I ',A7,' ',A7/
                                                                              IBR31330
             ′-----')
                                                                              IBR31340
2824 FORMAT (18,2F12.6)
                                                                              IBR31350
```

```
IBR31360
C ... COMPUTATION PARAMETERS
                                                                          IBR31370
                                                                          IBR31380
      WRITE (28,2841) X,T,DELTA,X1,X2,ALPHAS
                                                                         IBR31390
      WRITE (28,2842) NTOP, NONE, JE
                                                                         IBR31400
      IF (IJOB.LT.3) WRITE (28,2843) S
                                                                         IBR31410
      WRITE (28,2844) NJUM1
                                                                         IBR31420
      IF (ISTAB.GT.0) WRITE (28,2845) NJUM2
                                                                         IBR31430
 2841 FORMAT (/'COMPUTATION PARAMETERS'//
                                                                          IBR31440
     + 'Normalized Delta x = ',D14.6/
                                                                          IBR31450
     + 'Normalized Delta t = ',D14.6/
+ 'Normalized DELTA = ',E14.6/
                                                                         IBR31460
                                                                         IBR31470
     + 'Damping Coeff. x1 = ',F9.3/
                                                                         IBR31480
     + '
                           x2 = ', F9.3/
                                                                         IBR31490
     + 'Num. Stab. Indicator = ',F9.3)
                                                                         IBR31500
 2842 FORMAT (
                                                                         IBR31510
     + 'Total Number of Time Steps
                                         NTOP = ', 18/
                                                                        IBR31520
     + 'Number of Time Steps in 1 Wave Period'/
                                                                        IBR31530
                                          NONE = ', 18/
                                                                        IBR31540
     + 'Total Number of Spatial Nodes
                                           JE = ', I8)
                                                                         IBR31550
 2843 FORMAT (
                                                                         IBR31560
     + 'Number of Nodes Along Bottom Below SWL'/
                                                                         IBR31570
                                              S = ', I8)
                                                                         IBR31580
 2844 FORMAT (
                                                                        IBR31590
     + 'Storing Temporal Variations at Every'/
                                                                        IBR31600
                                         NJUM1 = ', 18,' Time Steps') IBR31610
 2845 FORMAT (
                                                                         IBR31620
    + 'Armor Stability Number Computed'/
                                                                         IBR31630
                             at Every NJUM2 = ', I8,' Time Steps')
                                                                         IBR31640
C
                                                                         IBR31650
C ... PARAMETERS FOR ARMOR STABILITY AND MOVEMENT
                                                                         IBR31660
                                                                         IBR31670
      IF (ISTAB.GT.0) WRITE (28,2851) TANPHI, SG, C2, C3, CD, CL, CM
                                                                         IBR31680
      IF (ISTAB.EQ.1) WRITE (28,2852) AMAX, AMIN
                                                                       IBR31690
      IF (ISTAB.EQ.2) WRITE (28,2853) DAP,UL
                                                                        IBR31700
 2851 FORMAT (/'PARAMETERS FOR ARMOR STABILITY AND MOVEMENT'//
                                                                       IBR31710
            'Armor Friction Factor = ',F9.3/
'Specific Gravity = ',F9.3/
                                                                        IBR31720
     +
             'Area Coefficient C2 = ',F9.3/
     +
                                                                         IBR31740
             'Volume Coefficient C3 = ',F9.3/
                                                                         IBR31750
             'Drag Coefficient CD = ',F9.3/
'Lift Coefficient CL = ',F9.3/
                                                                         IBR31760
                                                                         IBR31770
          'Inertia Coefficient CM = ',F9.3)
                                                                         IBR31780
 2852 FORMAT ('Norm. Upper and Lower Bounds of du/dt'/
                                                                         IBR31790
                                  AMAX = ',F9.3/
                                                                        IBR31800
                                   AMIN = ', F9.3)
                                                                        IBR31810
 2853 FORMAT ('Armor Diameter
                                        = ',F12.6,A7)
                                                                        IBR31820
                                                                         IBR31830
 ... NORMALIZED STRUCTURE GEOMETRY
                                                                         IBR31840
C
                                                                         IBR31850
C
      File 22 = 'OSPACE'
                                                                        IBR31860
     (XB(j), ZB(j)) = normalized coordinates of the structure
C
                                                                        IBR31870
C
                      at node j
                                                                         IBR31880
C
    ZB negative below SWL
                                                                         IBR31890
C
                                                                         IBR31900
```

```
WRITE (22,2210) JE
                                                                            IBR31910
      WRITE (22,2220) (XB(J),ZB(J),J=1,JE)
                                                                            IBR31920
 2210 FORMAT (18)
                                                                            IBR31930
 2220 FORMAT (6D12.4)
                                                                            IBR31940
                                                                            IBR31950
C ... SOME CHECKINGS
                                                                            IBR31960
                                                                            IBR31970
     ---- Numerical stability criterion requires ALPHAS > about 1
                                                                            IBR31980
C
                                                                            IBR31990
      IF (ALPHAS.LE.1.) THEN
                                                                            IBR32000
        WRITE (*,2910) ALPHAS
                                                                            IBR32010
        WRITE (29,2910) ALPHAS
                                                                            IBR32020
        ISTOP = ISTOP+1
                                                                            IBR32030
                                                                            IBR32040
 2910 FORMAT (/' From Subr. 33 DOC1'/' Stability Indicator =',F9.3/
                                                                           IBR32050
               ' May cause numerical instability. Increase NONE')
                                                                           IBR32060
                                                                           IBR32070
      --- Temporal variations are stored at every NJUM1 time steps.
          Stability number SNR is computed at every NJUM1 time steps. IBR32080 (SNR is stability number against rolling/sliding)
          (SNR is stability number against rolling/sliding).
C
                                                                          IBR32100
C
          For plotting the results, the values of NONE/NJUM1 and
                                                                           IBR32110
C
          NONE/NJUM2 should be integers.
                                                                           IBR32120
C
                                                                           IBR32130
      VAL1 = DBLE (NONE) / DBLE (NJUM1)
                                                                           IBR32140
      RES1 = DMOD (VAL1, 1.D+00)
                                                                           IBR32150
      IF (RES1.NE.O.D+00) THEN
                                                                           IBR32160
        WRITE (*,2920) NONE, NJUM1, VAL1
                                                                           IBR32170
        WRITE (29,2920) NONE, NJUM1, VAL1
        ISTOP = ISTOP+1
                                                                           IBR32190
      ENDIF
                                                                           IBR32200
      IF (ISTAB.EQ.1) THEN
                                                                           IBR32210
        VAL2 = DBLE (NONE) / DBLE (NJUM2)
                                                                           IBR32220
        RES2 = DMOD(VAL2, 1.D+00)
                                                                           IBR32230
        IF (RES2.NE.O.D+00) THEN
                                                                           IBR32240
          WRITE (*, 2930) NONE, NJUM2, VAL2
                                                                           IBR32250
          WRITE (29,2930) NONE, NJUM2, VAL2
                                                                           IBR32260
          ISTOP = ISTOP+1
                                                                           IBR32270
        ENDIF
                                                                           IBR32280
      ENDIF
                                                                           IBR32290
 2920 FORMAT (/' From Subr. 33 DOC1'/' NONE =', I8/' NJUM1 =', I8/
                                                                          IBR32300
               ' NONE/NJUM1 =',F12.3,', not an integer'/
                                                                          IBR32310
              ' Change NJUM1')
                                                                          IBR32320
 2930 FORMAT (/' From Subr. 33 DOC1'/' NONE =', 18/' NJUM2 =', 18/
                                                                          IBR32330
               ' NONE/NJUM2 =',F12.3,', not an integer'/
                                                                           IBR32340
               ' Change NJUM2')
                                                                           IBR32350
C
                                                                           IBR32360
      IF (ISTOP.GT.0) STOP
                                                                           IBR32370
C
                                                                           IBR32380
C ... CONDITIONAL STOP BEFORE TIME-MARCHING COMPUTATION
                                                                           IBR32390
                                                                           IBR32400
      WRITE (*,6010) ALPHAS
                                                                           IBR32410
      WRITE (*,6020)
                                                                           IBR32420
      READ (*,*) ISTOP
                                                                           IBR32430
      IF (ISTOP.EQ.1) STOP
                                                                          IBR32440
 6010 FORMAT (' Numerical stability indicator =',F7.2)
                                                                          IBR32450
```

```
6020 FORMAT (' Time-marching computation is about to begin'/
                                                                          IBR32460
              ' 1 = stop here, else = proceed')
                                                                          IBR32470
                                                                          IBR32480
      RETURN
                                                                          IBR32490
                                                                          IBR32500
C
                                                                          IBR32510
C -33----- END OF SUBROUTINE DOC1 ----- IBR32520
C
                                                                          IBR32540
C
      This subroutine stores computed results at designated time
                                                                          IBR32550
C
      levels during time-marching computation
                                                                          IBR32560
C
                                                                          IBR32570
      SUBROUTINE DOC2 (ICALL, N, ETAR, ETAT)
C
                                                                          IBR32590
      IMPLICIT DOUBLE PRECISION (A-H, O-Z)
                                                                          IBR32600
      PARAMETER (N1=500, N2=30000, N3=3, N4=100, N5=25)
                                                                          IBR32610
      CHARACTER*20 FNAME1, FNAME2
                                                                          IBR32620
      INTEGER S
                                                                          IBR32630
      COMMON /DIMENS/ N1R, N2R, N3R, N4R, N5R
                                                                          IBR32640
      COMMON /ID/ IJOB, ISTAB, ISYST, IBOT, INONCT, IENERG, IWAVE,
                                                                         IBR32650
                      ISAVA, ISAVB, ISAVC
                                                                         IBR32660
      COMMON /IDREQ/ IREQ, IELEV, IV, IDUDT, ISNR, NNREQ, NREQ (N5)
                                                                         IBR32670
      COMMON /TLEVEL/ NTOP, NONE, NJUM1, NJUM2, NSAVA, NSTAB, NSTAT, NTIMES IBR32680
      COMMON /NODES/ S,JE,JE1,JSTAB,JMAX
COMMON /WAVE3/ ETA(N2),ETAIS(N2),ETARS(N2),ETATS(N2)
COMMON /HYDRO/ U(2,N1),V(N1),ELEV(N1),C(N1),DUDT(N1)
                                                                         IBR32690
                                                                         IBR32700
                                                                         IBR32710
      COMMON /RUNP1/ NDELR
                                                                         IBR32720
      COMMON /RUNP2/ DELRP (N3), DELTAR (N3), RUNUPS (N3), RSTAT (3, N3)
                                                                         IBR32730
      COMMON /STAB5/ JSNSC, NSNSC, NSNSX (N1)
                                                                         IBR32740
      COMMON /STAB6/ SNSC, SNR(N1), SNSX(N1)
                                                                         IBR32750
      COMMON /STAB7/ NMOVE, NSTOP,
                                                                          IBR32760
                      ISTATE (N1), NODIN (N1), NODFI (N1), NDIS (N1)
                                                                         IBR32770
      COMMON /STAB8/ VA(N1), XAA(N1), XA(N1)
                                                                         IBR32780
      COMMON /FILES/ NNOD1, NNOD2, NODNO1 (N5), NODNO2 (N5),
                                                                         IBR32790
                      FNAME1 (N5), FNAME2 (N5)
                                                                         IBR32800
      DATA ZERO /0.D+00/
                                                                         IBR32810
C
                                                                          IBR32820
      IF (ICALL.EQ.0) THEN
                                                                          IBR32830
C
                                                                          IBR32840
C
 .... CHECKING PARAMETERS
                                                                          IBR32850
                                                                          IBR32860
        CALL CHEPAR (34,1,N1,N1R)
                                                                          IBR32870
        CALL CHEPAR (34,2,N2,N2R)
                                                                         TBR32880
        CALL CHEPAR (34,3,N3,N3R)
                                                                         IBR32890
        CALL CHEPAR (34,5,N5,N5R)
                                                                         IBR32900
C
                                                                         IBR32910
     ELSEIF (ICALL.EQ.1) THEN
                                                                         IBR32920
C
                                                                         IBR32930
C ..... STORING "A"
                                                                         IBR32940
        "A" = spatial variations of hydrodynamic quantities
                                                                         IBR32950
C
                                                                         IBR32960
C
       File 22 = 'OSPACE'
                                                                         IBR32970
C
       N = current time level
                                                                         IBR32980
C
       S = waterline node (IJOB<3) or landward-end node (IJOB=3)
                                                                         IBR32990
       At node j:
                                                                         IBR33000
```

```
C
           ELEV(j) = surface elevation above SWL
                                                                          IBR33010
 C
           V(j) = depth-averaged velocity
                                                                          IBR33020
 C
                                                                          IBR33030
         WRITE (22,2210) N,S
                                                                          IBR33040
        WRITE (22,2220) (ELEV(J), V(J), J=1, S)
                                                                          IBR33050
 C
                                                                        IBR33060
      ELSEIF (ICALL.EQ.2) THEN
                                                                          IBR33070
 C
                                                                          IBR33080
C ..... STORING "B"
                                                                          IBR33090
C
        "B" = temporal variations of total water depth at specified
                                                                          IBR33100
C
              nodes
                                                                          IBR33110
C
                                                                          IBR33120
        IF (ISAVB.EQ.1) THEN
                                                                          IBR33130
          DO 110 I = 1, NNOD1
                                                                          IBR33140
            NUNIT = 49+I
                                                                          IBR33150
                  = NODNO1(I)
                                                                          IBR33160
             WRITE (NUNIT, 5010) N, U(2, J)
                                                                          IBR33170
  110
          CONTINUE
                                                                          IBR33180
        ENDIF
                                                                          IBR33190
C
                                                                          IBR33200
  .... STORING "C"
                                                                          IBR33210
        "C" = temporal variations of displacement of armor units
                                                                          IBR33220
C
               from specified initial nodal locations
                                                                          IBR33230
C
                                                                          IBR33240
        IF (ISAVC.EQ.1) THEN
                                                                          IBR33250
          DO 210 I = 1, NNOD2
                                                                          IBR33260
            NUNIT = 74+I
                                                                          IBR33270
            J = NODNO2(I)
                                                                          IBR33280
            IF (ISTATE(J).EQ.0) THEN
                                                                          IBR33290
              WRITE (NUNIT, 7510) N, ZERO
                                                                          IBR33300
                                                                          IBR33310
              WRITE (NUNIT, 7510) N, XA(J)
                                                                          IBR33320
            ENDIF
                                                                          IBR33330
  210
          CONTINUE
                                                                          IBR33340
        ENDIF
                                                                          IBR33350
C
                                                                          IBR33360
  .... STORING VALUES AT LANDWARD-END NODE
                                                                          IBR33370
C
                                                                          IBR33380
C
        File 31 = 'ORUNUP'
                                                                          IBR33390
C
        File 32 = 'OOVER'
                                                                          IBR33400
C
        File 33 = 'OTRANS'
                                                                          IBR33410
C
        JE = landward-end node
                                                                         IBR33420
C
        N = current time level
                                                                         IBR33430
C
        S = waterline node
                                                                         IBR33440
C
        RUNUPS = free surface elevation where the water depth equals
                                                                         IBR33450
C
                 DELTAR
                                                                         IBR33460
C
        DELTAR = water depth associated with visual or measured
                                                                         IBR33470
C
                 waterline
                                                                         IBR33480
C
        NDELR = number of DELTARs
                                                                         IBR33490
C
        ETAT = surface elevation due to transmitted wave at
                                                                         IBR33500
C
                 landward boundary
                                                                         IBR33510
C
      At node j:
                                                                         IBR33520
C
         U(1,j) = volume flux
                                                                         IBR33530
C
         U(2,j) = total water depth
                                                                         IBR33540
C
         V(j) = depth-averaged velocity
                                                                         IBR33550
```

```
C
          C(j) = critical velocity
                                                                          IBR33560
C
                                                                          IBR33570
        IF (IJOB.GT.1) C(JE) = DSQRT(U(2, JE))
                                                                          IBR33580
        IF (IJOB.LT.3) THEN
                                                                          IBR33590
          WRITE (31, 3110) N,S
                                                                          IBR33600
          WRITE (31,3120) (RUNUPS(L), L=1, NDELR)
                                                                          IBR33610
          IF (IJOB.EQ.2) WRITE (32,3210) N,U(1,JE),U(2,JE),V(JE),C(JE) IBR33620
                                                                          IBR33630
          WRITE (33,3310) N,U(1,JE),V(JE),C(JE),ETAT
                                                                          IBR33640
                                                                          IBR33650
C
                                                                          IBR33660
C .... STORING VALUES AT SEAWARD BOUNDARY
                                                                          IBR33670
C
                                                                          IBR33680
C
        File 21 = 'OSEAWAV'
                                                                          IBR33690
C
        N = current time level
                                                                          IBR33700
C
        Surface elevations at seaward boundary:
                                                                          IBR33710
C
        . ETAI --> due to incident wave
                                                                          IBR33720
C
        . ETAR --> due to reflected wave
                                                                          IBR33730
C
        . ETATOT = ETAI+ETAR
                                                                          IBR33740
C
        At node j:
                                                                          IBR33750
C
          V(j) = depth-averaged velocity
                                                                          IBR33760
C
          U(1,j) = volume flux
                                                                          IBR33770
                                                                          IBR33780
        IF (IWAVE.EQ.1) THEN
                                                                          IBR33790
          NWAVE = MOD(N, NONE) + 1
                                                                          IBR33800
          ETAI = ETA(NWAVE)
                                                                          IBR33810
          ETATOT = ETAI+ETAR
                                                                          IBR33820
        ELSEIF (IWAVE.EQ.2) THEN
                                                                          IBR33830
          ETAI
               = ETA(N)
                                                                          IBR33840
          ETATOT = ETAI + ETAR
                                                                          IBR33850
        ELSE
                                                                          IBR33860
                = ETA(N)-ETAR
                                                                          IBR33870
          ETATOT = ETA(N)
                                                                          IBR33880
                                                                          IBR33890
        WRITE (21,2110) N, ETAI, ETAR, ETATOT, V(1), U(1,1)
                                                                          IBR33900
C
                                                                          IBR33910
      ELSE
                                                                          IBR33920
C
                                                                          IBR33930
C ..... SPECIAL STORING IF ICALL=3
                                                                          IBR33940
                                                                          IBR33950
C
       File 40 = 'OREO'
                                                                         IBR33960
C
        S = waterline node (IJOB<3) or landward-end node (IJOB=3)
                                                                         IBR33970
C
        At node j for specified time level N:
                                                                         IBR33980
C
          ELEV(j) = surface elevation above SWL
                                                                         IBR33990
                = depth-averaged velocity
                                                                         IBR34000
C
          DUDT(j) = total fluid acceleration
                                                                         IBR34010
C
         SNR(j) = stability number against rolling/sliding
                                                                         IBR34020
C
                                                                         IBR34030
        WRITE (40,4010) N.S
                                                                         IBR34040
        IF (IELEV.EQ.1) WRITE (40,4020) (ELEV(J), J=1,S)
                                                                         IBR34050
        IF (IV.EQ.1) WRITE (40,4020) (V(J),J=1,S)
                                                                         IBR34060
        IF (IDUDT.EQ.1) WRITE (40,4020) (DUDT(J), J=1, S)
                                                                         IBR34070
        IF (ISNR.EQ.1) WRITE (40,4020) (SNR(J), J=1,S)
                                                                         IBR34080
C
                                                                         IBR34090
      ENDIF
                                                                         IBR34100
```

```
C
                                                                         IBR34110
C ... FORMATS
                                                                         IBR34120
                                                                         IBR34130
 2110 FORMAT (18,5D12.4)
                                                                         IBR34140
 2210 FORMAT (218)
                                                                         IBR34150
 2220 FORMAT (6D12.4)
                                                                         IBR34160
 3110 FORMAT (218)
                                                                         IBR34170
 3120 FORMAT (6D12.4)
                                                                         IBR34180
 3210 FORMAT (18,5D12.4)
                                                                         IBR34190
 3310 FORMAT (18,5D12.4)
                                                                         IBR34200
 4010 FORMAT (218)
                                                                         IBR34210
 4020 FORMAT (6D12.4)
                                                                         IBR34220
 5010 FORMAT (18, D12.4)
                                                                         IBR34230
 7510 FORMAT (18, D12.4)
                                                                         IBR34240
                                                                         IBR34250
      RETURN
                                                                         IBR34260
      END
                                                                         IBR34270
C
                                                                        IBR34280
C -34----- END OF SUBROUTINE DOC2 ----- IBR34290
IBR34310
      This subroutine documents results after time-marching
                                                                         IBR34320
     computation
                                                                         IBR34330
C
                                                                         IBR34340
      SUBROUTINE DOC3
                                                                        TBR34350
C
                                                                        IBR34360
      IMPLICIT DOUBLE PRECISION (A-H, O-Z)
                                                                        IBR34370
      PARAMETER (N1=500, N2=30000, N3=3, N4=100, N5=25)
                                                                        IBR34380
      CHARACTER*7 UL
                                                                        IBR34390
      INTEGER S
                                                                        IBR34400
      COMMON /DIMENS/ N1R, N2R, N3R, N4R, N5R
                                                                        IBR34410
      COMMON /CONSTA/ PI, GRAV, DELTA, X1, X2
                                                                        IBR34420
      COMMON /ID/ IJOB, ISTAB, ISYST, IBOT, INONCT, IENERG, IWAVE,
                                                                        IBR34430
                     ISAVA, ISAVB, ISAVC
                                                                        IBR34440
     COMMON /NODES/ S, JE, JE1, JSTAB, JMAX
                                                                        IBR34450
      COMMON /BOT3/ U2INIT(N1), THETA(N1), SSLOPE(N1), XB(N1), ZB(N1)
                                                                        IBR34460
      COMMON /COEFS/ RCOEF(3), TCOEF(3)
                                                                        IBR34470
      COMMON /STAT/ ELSTAT(3), U1STAT(N1), ESTAT(3, N1), VSTAT(3, N1)
                                                                        IBR34480
     COMMON /RUNP1/ NDELR
COMMON /RUNP2/ DELRP(N3), DELTAR(N3), RUNUPS(N3), RSTAT(3,N3)
COMMON /OVER/ OV(4)
                                                                        IBR34490
                                                                        IBR34500
                                                                        IBR34510
      COMMON /STAB5/ JSNSC, NSNSC, NSNSX(N1)
                                                                        IBR34520
     COMMON /STAB6/ SNSC, SNR(N1), SNSX(N1)
                                                                        IBR34530
     COMMON /STAB7/ NMOVE, NSTOP,
                                                                        IBR34540
                     ISTATE (N1), NODIN (N1), NODFI (N1), NDIS (N1)
                                                                        IBR34550
      COMMON /STAB8/ VA(N1), XAA(N1), XA(N1)
                                                                        IBR34560
      COMMON /ENERG/ ENER(4,N1), ENERB(14)
                                                                        IBR34570
      CALL CHEPAR (35,1,N1,N1R)
                                                                        IBR34580
     CALL CHEPAR (35,3,N3,N3R)
                                                                        IBR34590
C
                                                                        IBR34600
C ... SYSTEM OF UNITS
                                                                        IBR34610
                                                                        IBR34620
      IF (ISYST.EQ.1) THEN
                                                                        IBR34630
       UL = ' [mm]'
                                                                        IBR34640
     ELSE
                                                                        IBR34650
```

```
UL = ' [inch]'
                                                                    IBR34660
      ENDIF
                                                                    IBR34670
C
                                                                    IBR34680
C ... REFLECTION COEFFICIENTS
                                                                    IBR34690
                                                                    IBR34700
      WRITE (28,2811) (RCOEF(I), I=1,3)
                                                                    IBR34710
 2811 FORMAT (/'REFLECTION COEFFICIENTS'//
                                                                    IBR34720
    'r1 = ',F9.3/
                                                                    IBR34730
              'r2 = ',F9.3/
     +
                                                                    IBR34740
              'r3 = ', F9.3)
     +
                                                                    IBR34750
C
                                                                    IBR34760
C ... RUNUP, RUNDOWN, SETUP
                                                                    IBR34770
                                                                    IBR34780
     IF (IJOB.LT.3) THEN
                                                                    IBR34790
       WRITE (28,2821) JMAX
                                                                    IBR34800
       WRITE (28,2822) UL
                                                                    IBR34810
       DO 110 L = 1, NDELR
                                                                    IBR34820
         WRITE (28, 2823) L, DELRP (L), RSTAT (2, L), RSTAT (3, L), RSTAT (1, L)
                                                                   IBR34830
  110
       CONTINUE
                                                                    IBR34840
                                                                    IBR34850
 2821 FORMAT (/'RUNUP, RUNDOWN, SETUP'//
                                                                    IBR34860
     +'Largest Node Number Reached by Computational Waterline'/
                                                                   IBR34870
                                                                   IBR34880
 2822 FORMAT (
                                                                    IBR34890
    +'-----'/
                                                                    IBR34900
     +'
            I DELTAR(I) RUNUP(I) RUNDOWN(I) SETUP(I)'/
                                                                   IBR34910
            ', A7,' R
                                       Rd Zr'/
                                                                   IBR34920
     +'-----
                                                                    IBR34930
 2823 FORMAT (18,1X,F9.3,3(3X,F9.3))
                                                                    IBR34940
C
                                                                    IBR34950
C ... OVERTOPPING
                                                                    IBR34960
                                                                    IBR34970
     IF (IJOB.EQ.2) THEN
                                                                    IBR34980
       WRITE (28,2831) OV(1), U1STAT(1), OV(4), OV(2), OV(3)
                                                                    IBR34990
     ENDIF
                                                                    IBR35000
 2831 FORMAT (/'OVERTOPPING'//
                                                                    IBR35010
             'Norm. Avg. Overtopping Rate = ',D14.6/
                                                                    IBR35020
             'Norm. Avg. Flow at Seaw. Bdr. = ',D14.6/
                                                                   IBR35030
             'Norm. Max. Overtopping Rate = ',D14.6/
                                                                   IBR35040
    +'Max. Rate Occurs at ',F8.6,' Within Interval [NSTAT,NTOP]'/ IBR35050
    +'Overtopping Duration = ',F8.6,' Within Interval [NSTAT,NTOP]'/ IBR35060
    +'The last two quantities are relative to the specified'/
                                                                   IBR35070
    +' interval taken as unity')
                                                                    IBR35080
                                                                    IBR35090
 ... QUANTITIES FOR ARMOR STABILITY AND MOVEMENT
                                                                    IBR35100
                                                                    IBR35110
C
     File 41 = 'OSTAB1'
                                                                    IBR35120
C
    File 42 = 'OSTAB2'
                                                                    IBR35130
     (XB(j), ZB(j)) = normalized coordinates of the structure at
C
                                                                    IBR35140
                   node j
                                                                    IBR35150
                                                                    IBR35160
C
      SNSX(j) = local stability number = minimum of SNR at a node j
                                                                    IBR35170
      SNR(j) = stability number against rolling/sliding at node j
C
                                                                   IBR35180
C
                                                                    IBR35190
       ISTATE(j) indicates the state of armor unit initially located IBR35200
```

```
at node j: 0=stationary, 1=moving, 2=stopped For moving/stopped armor unit number j:
                                                                           IBR35210
                                                                          IBR35220
         NODIN(j) = its initial location (i.e., node number)
NODFI(j) = node closest to its final location
C
                                                                        IBR35230
IBR35240
          NDIS(j) = time level N when it started moving
                                                                         IBR35250
C
          XA(j) = displacement from its initial location,
                                                                         IBR35260
                     normalized by DAP
                                                                          IBR35270
                                                                          IBR35280
      IF (ISTAB.EQ.1) THEN
                                                                           IBR35290
        WRITE (28,2841) SNSC, JSNSC, NSNSC
                                                                           IBR35300
        WRITE (41,4110) JMAX
                                                                          IBR35310
        WRITE (41, 4120) (XB(J), ZB(J), SNSX(J), J=1, JMAX)
                                                                          IBR35320
      ELSEIF (ISTAB.EQ.2) THEN
                                                                          IBR35330
        WRITE (28,2842) NMOVE, NSTOP
                                                                          IBR35340
        WRITE (42,4210) NMOVE
                                                                          IBR35350
        DO 120 J = 1, JMAX
                                                                          IBR35360
          IF (ISTATE(J).GE.1) WRITE (42,4220)
             NODIN(J), NODFI(J), NDIS(J), ISTATE(J), XB(J), ZB(J), XA(J)
                                                                         IBR35380
  120 CONTINUE
                                                                          IBR35390
      ENDIF
                                                                          IBR35400
 2841 FORMAT (/'STABILITY NUMBER'//
                                                                          IBR35410
     +
               'Critical Stability Number Nsc = ',F9.3/
                                                                          IBR35420
               'At Node Number J = ', 19/
                                                                         IBR35430
    + 'At Time Level
                                            N = ', 19)
                                                                          IBR35440
 2842 FORMAT (/'ARMOR UNITS MOVEMENT'//
                                                                          IBR35450
    + 'Number of Units Moved
              'Number of Units Moved = ',18/
'Number of Units Stopped = ',18)
                                              = ', 18/
                                                                         IBR35460
                                                                          IBR35470
 4110 FORMAT (18)
                                                                          IBR35480
 4120 FORMAT (6D12.4)
                                                                          IBR35490
 4210 FORMAT (18)
                                                                          IBR35500
 4220 FORMAT (318, 13, 3D12.4)
                                                                          IBR35510
                                                                          IBR35520
C ... WAVE SET-DOWN OR SETUP
                                                                          IBR35530
                                                                          IBR35540
      IF (IJOB.EQ.3) THEN
                                                                          IBR35550
       DELMWL = ELSTAT(3) - ELSTAT(2)
                                                                          IBR35560
        WRITE (28,2851) (ELSTAT(I), I=1,3), DELMWL
                                                                          IBR35570
                                                                          IBR35580
        WRITE (28,2852) (ELSTAT(I), I=1,2)
                                                                          IBR35590
      ENDIF
                                                                          IBR35600
 2851 FORMAT (/'WAVE SET-DOWN OR SETUP'//
                                                                         IBR35610
             'Average value of ETAI = ',F12.6/
                                                                         IBR35620
                                ETAR = ', F12.6/
                                                                         IBR35630
                                ETAT = ', F12.6/
                                                                         IBR35640
         'MWL Difference = ',F12.6)
                                                                          IBR35650
 2852 FORMAT (/'WAVE SET-DOWN OR SETUP'//
                                                                          IBR35660
               'Average value of ETAI = ',F12.6/
                                                                          IBR35670
                                ETAR = ', F12.6
                                                                          IBR35680
C
                                                                          IBR35690
C ... TRANSMISSION
                                                                          IBR35700
                                                                          IBR35710
      IF (IJOB.EQ.3) THEN
                                                                          IBR35720
        QAVER = .5*(U1STAT(1)+U1STAT(JE))
        WRITE (28,2861) (TCOEF(I), I=1,3)
                                                                         IBR35740
        WRITE (28,2862) U1STAT(1), U1STAT(JE), QAVER
                                                                         IBR35750
```

```
ENDIF
                                                                         IBR35760
 2861 FORMAT (/'TRANSMISSION'//
                                                                        IBR35770
             'Transmission Coefficient T1 = ',F9.3/
                                                                        IBR35780
                                        T2 = ', F9.3/
                                                                        IBR35790
                                        T3 = ', F9.3)
                                                                        IBR35800
 2862 FORMAT ('Norm. Avg. Flow at Seaw. Bdr. = ',F12.6/
                                                                        IBR35810
             'Norm. Avg. Flow at Landw. Bdr. = ',F12.6/
                                                                        IBR35820
              'Average of the Above Two = ',F12.6)
                                                                        IBR35830
C
                                                                        IBR35840
C ... STATISTICS OF HYDRODYNAMIC QUANTITIES
                                                                        IBR35850
                                                                        IBR35860
C
    File 23 = 'OSTAT'
C
      JMAX = the largest node number reached by computational
                                                                        IBR35880
C
                                                                        IBR35890
C
       At node j:
                                                                        IBR35900
C
         ELEV(j) = surface elevation above SWL
                                                                        IBR35910
C
                   = depth-averaged velocity
         V(j)
                                                                        IBR35920
C
         U1STAT(j) = mean volume flux
                                                                        IBR35930
C
      Mean, maximum, and minimum at node j:
                                                                        IBR35940
C
         ESTAT(1,j), ESTAT(2,j), ESTAT(3,j): for ELEV(j)
                                                                        IBR35950
C
          VSTAT(1, j), VSTAT(2, j), VSTAT(3, j): for V(j)
                                                                        IBR35960
C
                                                                        IBR35970
     WRITE (23,2310) JMAX
                                                                        IBR35980
     WRITE (23,2320) (U1STAT(J), J=1, JMAX)
                                                                        IBR35990
      DO 130 I = 1,3
                                                                        IBR36000
        WRITE (23, 2320) (ESTAT(I, J), J=1, JMAX)
                                                                        IBR36010
        WRITE (23, 2320) (VSTAT (I, J), J=1, JMAX)
                                                                        IBR36020
  130 CONTINUE
                                                                        IBR36030
 2310 FORMAT (18)
                                                                        IBR36040
2320 FORMAT (6D12.4)
                                                                        IBR36050
                                                                        IBR36060
C ... QUANTITIES FOR TIME-AVERAGED ENERGY BALANCE
                                                                        IBR36070
C
                                                                        IBR36080
C
     File 35 = 'OENERG'
                                                                        IBR36090
C
     At node j:
                                                                        IBR36100
C
      ENER(1, j) = norm. energy per unit surface area
                                                                       IBR36110
C
       ENER(2,j) = norm. energy flux per unit width
                                                                       IBR36120
C
     Normalized rate of energy dissipation at node j:
                                                                       IBR36130
C
      ENER(3, j): due to bottom friction, per unit bottom area
                                                                       IBR36140
C
      ENER(4, j): due to wave breaking, per unit surface area
                                                                       IBR36150
                                                                        IBR36160
     IF (IENERG.EQ.1) THEN
                                                                        IBR36170
       WRITE (28, 2871)
                                                                        IBR36180
        WRITE (28,2872) (ENERB(I), I=1,10)
                                                                        IBR36190
        IF (IJOB.EQ.3) WRITE (28,2873) ENERB(11)
                                                                        IBR36200
       WRITE (28,2874) (ENERB(I), I=12,13)
                                                                        IBR36210
       IF (IJOB.EQ.3) WRITE (28,2875) ENERB(14)
                                                                        IBR36220
       WRITE (35, 3510) JMAX
                                                                        IBR36230
        DO 140 I = 1,4
                                                                        IBR36240
          WRITE (35, 3520) (ENER(I, J), J=1, JMAX)
                                                                        IBR36250
       CONTINUE
                                                                        IBR36260
     ENDIF
                                                                        IBR36270
2871 FORMAT (/'TIME-AVERAGED ENERGY BALANCE'//
                                                                        IBR36280
             'Normalized Energy Flux:')
                                                                        IBR36290
2872 FORMAT ('. at Seaw. Boundary A =',D14.6/
                                                                        IBR36300
```

------

```
'. at Landw. Boundary B =', D14.6/
                                                                           IBR36310
              'Normalized Rate of Energy Dissipation'/
                                                                          IBR36320
              'in the Computation Domain, Due to: '/
                                                                          IBR36330
             '. bottom friction C = ', D14.6/
                                                                          IBR36340
             '. wave breaking
                                    D = ', D14.6/
                                                                          IBR36350
             'Calculation 1:'/
                                                                          IBR36360
                               E = A-B =', D14.6/
                                                                          IBR36370
                               F = C+D =', D14.6/
                                                                          IBR36380
          ' Must G=0, but G = F-E =',D14.6/
' % error 100G/E =',F14.2/
'Approximate Energy Flux, Based on'/
                                                                          IBR36390
                                                                          IBR36400
                                                                          IBR36410
            'Linear Long Wave, Due to:'/
                                                                          IBR36420
             '. incident wave at seaw. boundary P =',D14.6/
'. reflected wave at seaw. boundary Q =',D14.6)
                                                                          IBR36430
                                                                          IBR36440
 2873 FORMAT ('. transmitted wave at landw. bndry. R =',D14.6)
                                                                          IBR36450
 2874 FORMAT ('Calculation 2:'/
                                                                          IBR36460
              'Net Energy Flux at Seaw. Bndry. S = P-Q =', D14.6/
                                                                          IBR36470
              '% Error at Seaward Boundary 100(S-A)/A =',F14.2)
                                                                          IBR36480
 2875 FORMAT ('% Error at Landward Boundary 100(R-B)/B =',F14.2)
 3510 FORMAT (18)
                                                                          IBR36500
 3520 FORMAT (5D15.6)
                                                                          IBR36510
                                                                          IBR36520
      RETURN
                                                                          IBR36530
                                                                          IBR36540
C
                                                                          IBR36550
C -35----- END OF SUBROUTINE DOC3 -----
                                                                          IBR36560
IBR36580
      This subroutine checks PARAMETER NCHEK=N1, N2, N3, N4, N5 specified
C
                                                                          IBR36590
C
      in given subroutine (ICALL) match NREF=N1R, N2R, N3R, N4R, N5R
                                                                          IBR36600
C
                                                                          IBR36610
      SUBROUTINE CHEPAR (ICALL, NW, NCHEK, NREF)
                                                                          IBR36620
C
                                                                          IBR36630
      CHARACTER*2 WHICH (5)
                                                                          IBR36640
      CHARACTER*6 SUBR (38)
                                                                          IBR36650
      DATA WHICH /'N1','N2','N3','N4','N5'/
                                                                          IBR36660
      DATA SUBR /'OPENER', 'INPUT1', 'INPUT2', 'BOTTOM', 'PARAM',
                                                                          IBR36670
                  'INIT1 ','INIT2 ','INWAV ','FINDM ','CEL ',
                                                                          IBR36680
                  'SNCNDN', 'MARCH', 'LANDBC', 'RUNUP', 'OVERT',
'SEABC', 'ENERGY', 'STAT1', 'STABNO', 'MOVE',
                                                                         IBR36690
                                                                         IBR36700
                  'FORCES', 'ACCEL ', 'STAT2' , 'COEF ', 'BALANE',
                                                                         IBR36710
                  'MATAFG','MATGJR','MATS ','MATD ','MATU ',
                                                                         IBR36720
                  'ASSIGN', 'DERIV', 'DOC1 ', 'DOC2 ', 'DOC3 ',
                                                                         IBR36730
                  'CHEPAR', 'CHEOPT', 'STOPP '/
                                                                          IBR36740
      IF (NCHEK.NE.NREF) THEN
                                                                          IBR36750
        WRITE (*,2910)
                                                                          IBR36760
               WHICH (NW), NCHEK, ICALL, SUBR (ICALL), WHICH (NW), NREF
                                                                          IBR36770
        WRITE (29,2910)
                                                                          IBR36780
               WHICH (NW), NCHEK, ICALL, SUBR (ICALL), WHICH (NW), NREF
                                                                          IBR36790
        STOP
                                                                          IBR36800
     ENDIF
                                                                          IBR36810
 2910 FORMAT (/
                                                                          IBR36820
     +' PARAMETER Error: ',A2,' =',I8,' in Subroutine',I3,' ',A6/
                                                                          IBR36830
     +' Correct Value: ',A2,' =',I8)
                                                                          IBR36840
C
                                                                          IBR36850
```

```
RETURN
                                                                   IBR36860
      END
                                                                   IBR36870
                                                                   IBR36880
C -36----- END OF SUBROUTINE CHEPAR ----- IBR36890
C
                                                                   IBR36910
C
      This subroutine checks user's options
                                                                   IBR36920
C
                                                                   IBR36930
      SUBROUTINE CHEOPT (ICALL, INDIC, ITEM, ILOW, IUP)
                                                                   IBR36940
C
                                                                   IBR36950
      CHARACTER*2 WHICH(6)
                                                                   IBR36960
      CHARACTER*6 OPTI(21)
                                                                   IBR36970
      DATA WHICH /'N5','N5','N5','N1','N3','N4'/
                                                                  IBR36980
     DATA OPTI /'IJOB ','ISTAB ','ISYST ','IBOT ','INONCT',
                                                                 IBR36990
                'IENERG','IWAVE ','ISAVA ','ISAVB ','ISAVC ',
                                                                 IBR37000
                 'IREQ ','IELEV ','IV ','IDUDT ','ISNR ',
     2
                                                                 IBR37010
                 'NNOD1 ','NNOD2 ','NNREQ ','S ','NDELR ',
     3
                                                                  IBR37020
                 'NBSEG '/
                                                                   IBR37030
      IF (ICALL.LE.15) THEN
                                                                   IBR37040
       IF (ITEM.LT.ILOW.OR.ITEM.GT.IUP) THEN
                                                                  IBR37050
         WRITE (*,2910) OPTI(ICALL), ITEM, OPTI(ICALL), ILOW, IUP
                                                                  IBR37060
         WRITE (29,2910) OPTI(ICALL), ITEM, OPTI(ICALL), ILOW, IUP
                                                                  IBR37070
         INDIC = INDIC + 1
                                                                  IBR37080
       ENDIF
                                                                   IBR37090
     ELSE
                                                                   IBR37100
       IF (ITEM.LT.ILOW.OR.ITEM.GT.IUP) THEN
                                                                   IBR37110
         I = ICALL-15
                                                                   IBR37120
         WRITE (*,2920) OPTI(ICALL), ITEM, OPTI(ICALL), IUP, WHICH(I)
                                                                  IBR37130
         WRITE (29,2920) OPTI(ICALL), ITEM, OPTI(ICALL), IUP, WHICH(I)
                                                                   IBR37140
         STOP
                                                                   IBR37150
       ENDIF
                                                                   IBR37160
     ENDIF
                                                                   IBR37170
 2910 FORMAT (/' Input Error: ', A6,'=', I1/
                                                                  IBR37180
              ' Specify ', A6,' in the range of [', I1,',', I1,']')
                                                                  IBR37190
 2920 FORMAT (/' Input Error: ',A6,'=',I8/
+ 'Specify ',A6,' in the range of [1,',I8,']'/
                                                                  IBR37200
                                                                  IBR37210
              ' Change PARAMETER ', A2,' if necessary')
                                                                  IBR37220
C
                                                                  IBR37230
     RETURN
                                                                  IBR37240
     END
                                                                  IBR37250
C
                                                                  IBR37260
C -37----- END OF SUBROUTINE CHEOPT -----
                                                                  IBR37270
C
                                                                  IBR37290
     This subroutine executes a programmed stop
C
                                                                  IBR37300
C
                                                                  IBR37310
     SUBROUTINE STOPP (IBEGIN, IEND)
                                                                  IBR37320
C
                                                                  IBR37330
     CHARACTER*55 MSG(8)
                                                                  IBR37340
     DATA MSG /
                                                                  IBR37350
    1 ' Special storing requested,',
                                                                  IBR37360
    2 ' but pertinent identifiers not specified correctly.',
                                                                  IBR37370
    3 ' Check identifiers IREQ, IELEV, IV, IDUDT, ISNR.',
                                                                  IBR37380
    4 ' Need more data.',
                                                                  IBR37390
    5 ' SWL is always above the structure.',
                                                                  IBR37400
```

6 ' RUNUP/OVERTOPPING computation can not be performed.',	IBR37410
7 ' Part of the structure is above SWL.',	IBR37420
8 ' TRANSMISSION computation can not be performed.'/	IBR37430
DO 100 I = IBEGIN, IEND	IBR37440
WRITE (*,2910) MSG(I)	IBR37450
WRITE (29,2910) MSG(I)	IBR37460
100 CONTINUE	IBR37470
WRITE (*,2920)	IBR37480
WRITE (29,2920)	IBR37490
2910 FORMAT (A55)	IBR37500
2920 FORMAT (' Programmed Stop.')	IBR37510
C	IBR37520
STOP	IBR37530
END	IBR37540
C	IBR37550
C -38 END OF SUBROUTINE STOPP	IBR37560

t

## APPENDIX B: EXAMPLE OF WAVE RUNUP AND ARMOR STABILITY

The first example of the input and output of IBREAK is the Test No. 12 of the large-scale riprap tests conducted by Ahrens (1975).

Table B-1 lists the input data written from the file with its unit number = 11 and its file name FINP1 specified by a user. It is noted that IBREAK requires only the value of KS=KSSEA/KSREF as explained in the common /WAVE2/. For this example, the representative wave height  $H_{\rm r}'$  = HREFP is taken as the wave height H' measured at the toe of the 1:2.5 riprap slope. For the case of  $H_{\rm r}'$  = H', KSSEA=KSREF and KS=1. As a result, KSSEA=KSREF=1.0 could also be used as input instead of KSSEA=KSREF=1.0614 calculated using an available table for cnoidal wave shoaling (Svendsen and Brink-Kjaer, 1972).

Table B-2 lists the warning messages written from the file with its unit number = 29 and its file name = OMSG. These messages tend to appear during the transient period starting from the initial conditions of no wave action in the computation domain until the establishment of the periodic wave motion in the computation domain.

Table B-3 lists the concise output written from the file with its unit number = 28 and its file name = ODOC. The concise output is used to check the accuracy of the input data as well as to obtain important design parameters regarding wave reflection, runup, run-down, setup and armor stability.

Fig. B-1 shows the dimensional structure geometry specified as input. Since IJOB=1 and no wave overtopping is allowed, the width of the 1:2.5 slope must be chosen so that wave runup will not reach the landward edge of the slope.

Fig. B-2 shows the variations of  $\eta_{\dot{1}}$  = ETAI,  $\eta_{\dot{r}}$  = ETAR and  $\eta_{\dot{tot}}$  = ( $\eta_{\dot{1}}$  +  $\eta_{\dot{r}}$ ) = ETATOT as a function of the normalized time t = N/NONE plotted from the

file with its unit number = 21 and its file name = OSEAWAV. It is noted that the incident wave profile  $\eta_{\rm I}(t)$  and the reflected wave profile  $\eta_{\rm T}(t)$  are approximately 180° out of phase for this example.

Fig. B-3 shows the variations of the normalized waterline elevation  $Z_r = RUNUPS(i)$  with i=1,2 and 3 corresponding to the physical depth  $\delta_r' = 0.157$ , 0.787 and 1.575 inches, respectively, as a function of the normalized time t=N/NONE plotted from the file with its unit number = 31 and its file name = ORUNUP. Wave runup is not sensitive to  $\delta_r'$  but wave run-down is very sensitive to  $\delta_r'$  as shown in Fig. B-3.

Fig. B-4 shows the variations of the normalized mean water level  $\overline{\eta}=$  ESTAT(1,j), the normalized crest elevation  $\eta_{\max}=$  ESTAT(2,j) and the normalized trough elevation  $\eta_{\min}=$  ESTAT(3,j) as a function of the normalized horizontal coordinate  $x=(j-1)\Delta x$  plotted from the file with its unit number = 23 and its file name = OSTAT. Fig. B-4 also shows the normalized structure geometry described by the nodal locations XB(j) and ZB(j) which are stored in the file with its unit number = 22 and its file name = OSPACE.

Fig. B-5 shows the variations of the time-averaged fluid velocity  $\overline{u}=VSTAT(1,j)$ , the maximum fluid velocity  $u_{max}=VSTAT(2,j)$  and the minimum fluid velocity  $u_{min}=VSTAT(3,j)$  as a function of the normalized horizontal coordinate  $x=(j-1)\Delta x$  plotted from the file with its unit number = 23 and its file name = OSPACE. It is noted that  $\overline{u}$  is negative as explained by Kobayashi et al. (1989).

Fig. B-6 shows the variation of the time-averaged volume flux per unit width  $\overline{m} = \text{U1STAT}(j)$ , as a function of the normalized horizontal coordinate  $x = (j-1)\Delta x$  plotted from the file with its unit number = 23 and its file name = OSPACE. It is noted that the time-averaged continuity equation requires  $\overline{m}=0$ 

(Kobayashi et al., 1989) while the computed values of  $\overline{m}$  are on the order of  $10^{-3}$  or less.

Fig. B-7 shows the variations of the time-averaged wave energy per unit horizontal area,  $\overline{E} = \text{ENER}(1,j)$ , the time-averaged energy flux per unit width,  $\overline{E_F} = \text{ENER}(2,j)$ , the time-averaged rate of energy dissipation per unit horizontal area due to bottom friction,  $\overline{D_f} = \text{ENER}(3,j)$ , and the time-averaged rate of energy dissipation per unit horizontal area due to wave breaking,  $\overline{D_B} = \text{ENER}(4,j)$ , as a function of the normalized horizontal coordinate  $\mathbf{x} = (j-1)\Delta\mathbf{x}$ . Fig. B-7 is plotted from the file with its unit number = 35 and its file name = OENERG. Fig. B-7 indicates that the wave energy dissipation due to wave breaking is small for this example with the surf similarity parameter  $\xi = 4.40$  as listed in Table B-3.

Fig. B-8 shows the variations of the normalized free surface elevation  $\eta = \text{ELEV}(j)$  as a function of the normalized horizontal coordinate  $x = (j-1)\Delta x$  at the normalized time t = (N/NONE) = 5, 5.25, 5.5, 5.75 and 6 plotted from the file with its unit number = 22 and its file name = OSPACE. Fig. B-8 also shows the normalized structure geometry in the same way as Fig. B-4. It is noted that the spatial variation of  $\eta$  at t=6 is the same as that at t=5 because of the periodicity.

Fig. B-9 shows the variations of the normalized fluid velocity u=V(j) as a function of the normalized horizontal coordinate  $x=(j-1)\Delta x$  at the normalized time t=(N/NONE)=5, 5.25. 5.5, 5.75 and 6 plotted from the file with its unit number = 22 and its file name = OSPACE. The spatial variation of u at t=6 is the same as that at t=5 because of the periodicity.

Fig. B-10 shows the variations of the normalized horizontal velocity, u = V(j), the normalized fluid acceleration, du/dt = DUDT(j), and the armor

stability function  $N_R = SNR(j)$  as a function of the normalized vertical location on the slope, z = ZB(j), at the time level N = NSNSC = 21492corresponding to the time when the minimum value of  $N_{\mbox{\scriptsize R}}$  shown in Fig. B-10 is equal to the critical stability number  $N_{\text{sc}}$  = 2.401. Fig. B-10 is plotted from the file with its unit number = 40 and its file name = OREQ together with the file containing ZB(j). The values of  $N_{\rm SC}$  and NSNSC are listed in Table B-3. In order to plot Fig. B-10, IREQ=1, IELEV=1, IV=1, IDUDT=1, ISNR=1, NNREQ=1 and NREQ(1) = 21492 are specified as input as shown in Table B-1. The critical time level NSNSC=21492 was computed beforehand using IREQ=0. implies that computation needs to be made twice to plot a figure similar to Fig. B-10. IBREAK could be modified without difficulties so as to store the requested quantities at the time when the critical stability number  ${\rm N}_{\rm SC}$ occurs. The special storage option included in IBREAK allows the storage of the requested quantities at the specified time levels N=NREQ(i) with i=1,2,...,NNREQ. Consequently, this option can be used for other purposes as well.

Fig. B-11 shows the variation of the local stability number,  $N_{\rm SX}=$  SNSX(j), as a function of the normalized vertical location on the slope z=ZB(j) plotted from the file with its unit number = 41 and its file name = OSTAB1. The minimum value of  $N_{\rm SX}$  shown in Fig. B-11 is equal to  $N_{\rm SC}=2.401$ .

## TABLE B-1

```
3 = number of comment lines
 2
      Ahrens (1975) Test 12 (Zero Damage)
 3
      4
 5
      11 20001
                                 --> IJOB, ISTAB, NSTAB
 6
      2
                                --> ISYST
 7
                                --> IBOT
 8
      0
                                --> INONCT
 9
      1
                                --> IENERG
10
     1 no wave data file
                                --> IWAVE, FINP2
11
     100 20000 5 0 0
                               --> ISAVA-B-C, NSAVA, NTIMES, NNOD1, NNOD2
12
     11111 1
                                --> IREQ, IELEV, IV, IDUDT, ISNR, NNREQ
13
     21492
                                --> NREQ (1)
        24000
14
                                --> NTOP
15
         4000
                                --> NONE
16
           20
                                --> NJUM1
17
          100
                                --> S
18
           .300000
                                --> FWP
19
          1.000000
                       1.000000 --> X1,X2
20
           .001000
                                --> DELTA(normalized)
                                --> NDELR
21
            3
           .157480
                                --> DELRP(1) (inches)
22
23
                                --> DELRP(2)
           .787402
24
          1.574803
                                --> DELRP (3)
25
          3.060000
                      8.500000 --> HREFP (feet), TP (seconds)
26
          1.061400
                      1.061400 --> KSREF, KSSEA
27
                                --> DSEAP (feet)
         15.000000
28
           .400000
                                --> TSLOPS
29
           1
                                --> NBSEG
30
         60.000000
                       .400000 --> WBSEG(1) (feet), TBSLOP(1)
31
           1
                                            --> NJUM2
                       .660000 2.710000 --> C2,C3,SG
.180000 1.500000 --> CD,CL,CM
32
           .900000
                      .660000
33
           .500000
34
         1.191754
                                            --> TANPHI
          1.000000
                      -.800000
                                            --> AMAX, AMIN
```

## TABLE B-2

1			
2	Ahrens (1975) Test 12 (Zero Damage)		
3			
4			
5	From Subroutine 14 RUNUP: $U(2,S)>U(2,S-1)$ at $S=$	100: N =	1806
6	Adjusted values: $U(2,S) = 0.974E-03$ ; $U(2,S-1) =$	0.195E-02	1000
8	From Subroutine 14 RUNUP: $U(2,S)>U(2,S-1)$ at $S=$	138; N =	5293
9	Adjusted values: $U(2,S) = 0.809E-03$ ; $U(2,S-1) =$	0.162E-02	0233

#### TABLE B-3

```
Ahrens (1975) Test 12 (Zero Damage)
 2
 3
 4
 5
       WAVE CONDITION
 6
 7
      Cnoidal Incident Wave at Seaward Boundary
 8
      1-m = 0.112815261D+00
 9
                0.111509461D+01
      K =
10
                0.252149782D+01
      Norm. Maximum Surface Elev.
11
                                         0.628691
       Norm. Minimum Surface Elev. = -0.371309
12
13
14
      Reference Wave Period
                                         8.500000 sec.
      Reference Wave Height
15
                                         3.060000 feet
       Depth at Seaward Boundary = 15.000000 feet
16
       Shoal. Coef. at Reference Ks1 = 1.061
at Seaw. Bdr. Ks2 = 1.061
17
18
19
                  Ks = Ks2/Ks1 =
20
       Norm. Depth at Seaw. Bdr.
                                         4.902
       Normalized Wave Length
21
                                       12.144
22
       "Sigma"
                                       27.573
                                       30.084
23
       Ursell Number
24
       Surf Similarity Parameter
                                         4.400
25
26
      SLOPE PROPERTIES
27
28
      Friction Factor
                               = 0.300000
     Norm. Friction Factor = Norm. Horiz. Length of
29
                                     4.135970
30
        Computation Domain =
31
                                   0.711121
     Number of Segments
32
33
      -----
      SEGMENT WBSEG(I) TBSLOP(I)
34
       I feet
35
36
37
            1 60.000000 0.400000
38
39
      COMPUTATION PARAMETERS
40
41
      Normalized Delta x = 0.444451D-02
      Normalized Delta t = 0.250000D-03
Normalized DELTA = 0.100000E-02
42
43
      Normalized DELIA
Damping Coeff. x1 = x2 =
44
                              1.000
      x2 = 1.000
Num. Stab. Indicator = 3.419
45
46
      Total Number of Time Steps NTOP =
47
                                               24000
48
      Number of Time Steps in 1 Wave Period
49
                                    NONE =
                                                4000
      Total Number of Spatial Nodes
50
                                     JE =
51
      Number of Nodes Along Bottom Below SWL
52
                                        S =
                                                100
53
      Storing Temporal Variations at Every
54
                                     NJUM1 =
                                                20 Time Steps
55
      Armor Stability Number Computed
                          at Every NJUM2 = 1 Time Steps
56
57
```

```
58
      PARAMETERS FOR ARMOR STABILITY AND MOVEMENT
59
     Armor Friction Factor
60
                                 1.192
61
     Specific Gravity
                                2.710
                       C2 = 0.900
62
      Area Coefficient
63
      Volume Coefficient C3 = 0.660
                               0.500
      Drag Coefficient CD =
64
65
      Lift Coefficient
                        CL =
66
      Inertia Coefficient CM =
                                 1.500
67
      Norm. Upper and Lower Bounds of du/dt
68
                       AMAX = 1.000
69
                       AMIN = -0.800
70
71
      REFLECTION COEFFICIENTS
72
73
     r1 = 0.553
           0.546
74
     r2 =
75
      r3 =
76
77
     RUNUP, RUNDOWN, SETUP
78
     Largest Node Number Reached by Computational Waterline
79
80
81
82
          I DELTAR(I) RUNUP(I) RUNDOWN(I) SETUP(I)
83
               [inch]
                          R
                                   Rd
      ______
84
85
               0.157 1.864 0.656
0.787 1.853 -0.283
1.575 1.842 -0.714
          1
                                           1.318
                                            0.909
86
           2
87
           3
                                               0.705
88
89
      STABILITY NUMBER
90
91
     Critical Stability Number Nsc =
                                   2.401
92
     At Node Number J =
                                    85
93
     At Time Level
                             N =
                                   21492
94
95
     WAVE SET-DOWN OR SETUP
96
97
     Average value of ETAI =
                            0.000000
98
                    ETAR =
                            0.015310
99
```

```
100
        TIME-AVERAGED ENERGY BALANCE
101
102
        Normalized Energy Flux:
103
        at Seaw. Boundary A = 0.202324D+00 at Landw. Boundary B = 0.000000D+00
104
105
        Normalized Rate of Energy Dissipation
        in the Computation Domain, Due to:
106
107
        . bottom friction C = 0.197916D+00
108
         . wave breaking
                               D = 0.440842D - 02
109
        Calculation 1:
110
                         E = A-B = 0.202324D+00
                         F = C+D = 0.202324D+00
111
112
          Must G=0, but G = F-E = 0.345043D-06
113
          % error 100G/E =
                                      0.00
114
        Approximate Energy Flux, Based on
115
        Linear Long Wave, Due to:
116
        . incident wave at seaw. boundary
                                              P = 0.276755D+00

Q = 0.818700D-01
        . reflected wave at seaw. boundary
117
118
        Calculation 2:
        Net Energy Flux at Seaw. Bndry. S = P-Q = 0.194885D+00
119
120
        % Error at Seaward Boundary 100(S-A)/A =
```

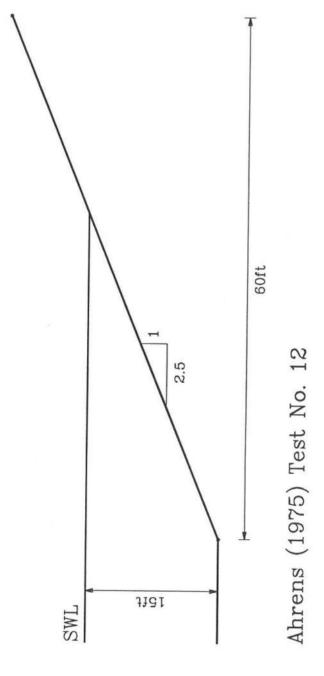
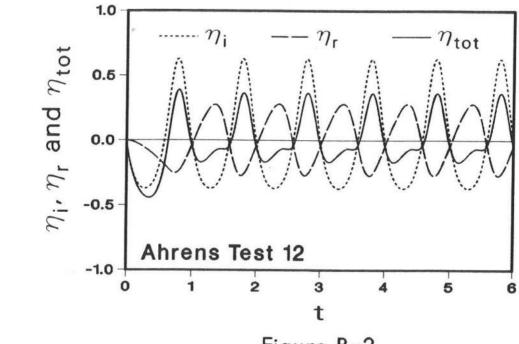
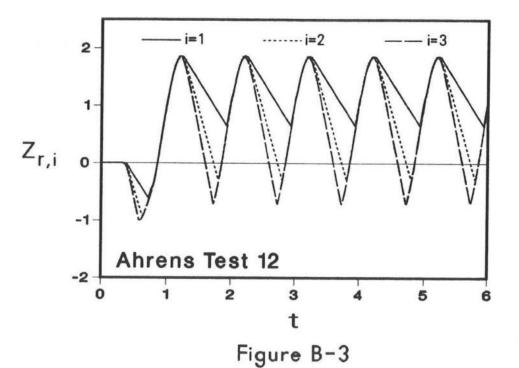


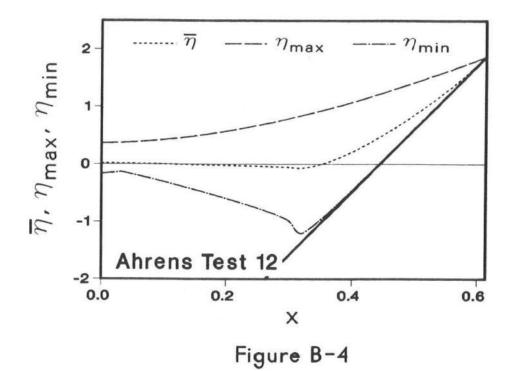
Figure B-1

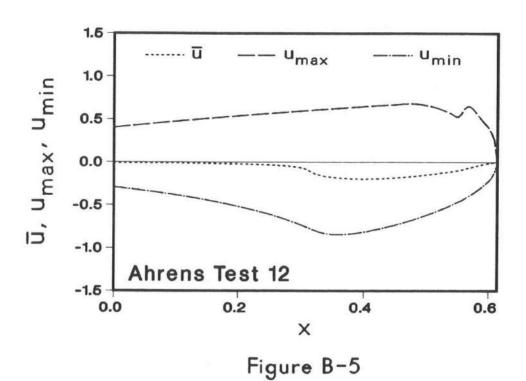


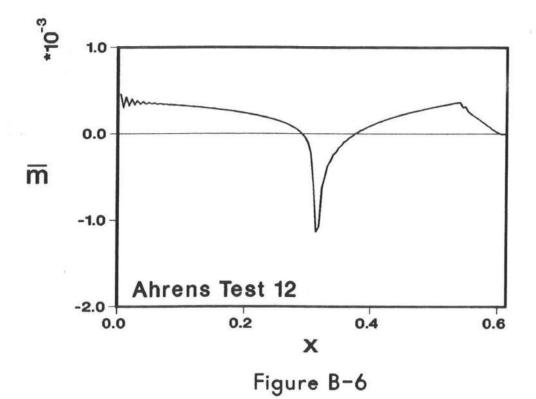


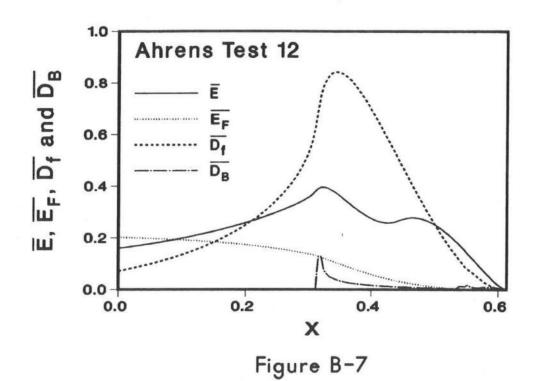


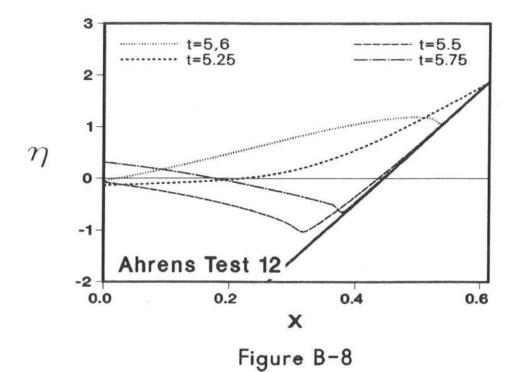
B-11

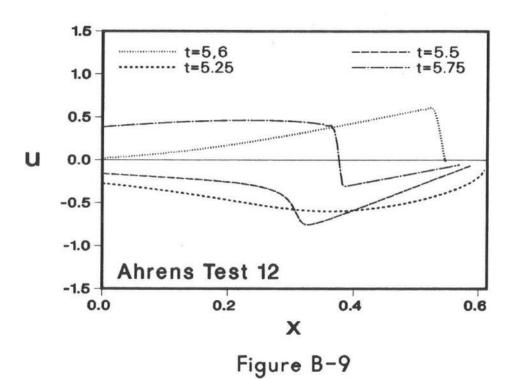












# Ahrens Test 12

## Critical Conditions:

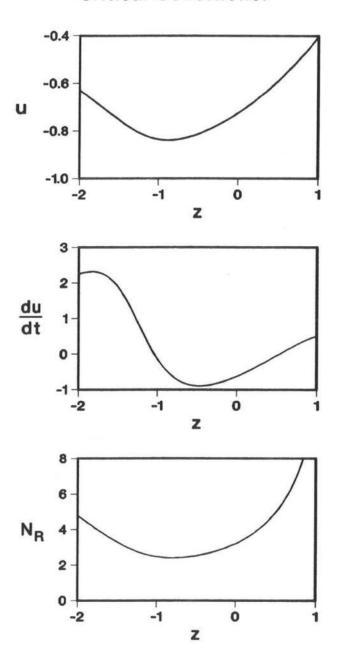
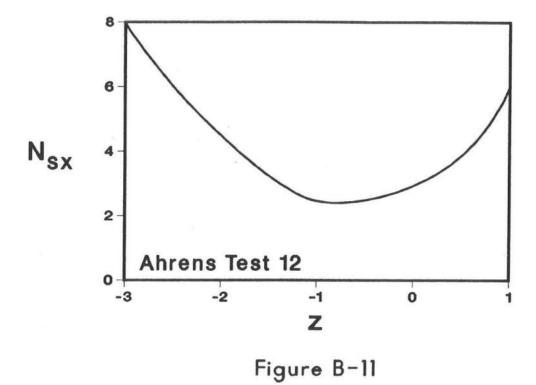


Figure B-10



#### APPENDIX C: EXAMPLE OF WAVE RUNUP AND ARMOR MOVEMENT

The second example is the Test No. 32 of the large-scale riprap tests of Ahrens (1975) and is similar to the first example, where IJOB=1 for both examples.

Table C-1 lists the input data used for the second example and is similar to Table B-1. Use is made of ISTAB=2 and the movement of individual armor units is computed unlike the first example for which ISTAB=1 as shown in Table B-1. The representative wave height  $H_{\Gamma}' = HREFP$  is taken as the wave height  $H_{\Gamma}'$  measured at the toe of the 1:3.5 riprap slope. Since  $H_{\Gamma}' = H'$ , KSSEA=KSREF=1.0 could also be used instead of KSSEA=KSREF=0.9421 used in Table C-1 on the basis of linear wave shoaling.

Table C-2 lists the warning messages written during the time-marching computation in the same way as Table B-2.

Table C-3 lists the concise output for the second example. Table C-3 includes the quantities related to the armor movement unlike Table B-3 in which the quantities related to the armor stability have been written.

Table C-4 lists the values of ISTATE(j), NODIN(j), NODFI(j), NDIS(j), XB(j), ZB(j) and XA(j) explained in the commons /STAB7/, /STAB8/ and /BOT3/ at the time level N = NTOP = 14000, that is, the normalized time t = (NTOP/NONE) = 7 for the armor units located at the node j at t=0 and moved during  $0 < t \le 7$ . Table C-4 is written from the file with its unit number = 42 and its file name = OSTAB2. The normalized armor displacement  $X_a$  defined by Eq. 81a is small for this example. This suggests that armor units may move but may not be dislodged from their initial locations.

Fig. C-1 shows the dimensional structure geometry specified as input in Table C-1.

Fig. C-2 shows the temporal variations of the incident wave profile  $\eta_{\rm i}$ , the reflected wave profile  $\eta_{\rm r}$  and the total wave profile  $\eta_{\rm tot} = (\eta_{\rm i} + \eta_{\rm r})$ . Fig. C-2 is similar to Fig. B-2 except that wave reflection for the second example with the surf similarity parameter  $\xi = 2.00$  is less than that for the first example with  $\xi = 4.40$ .

Fig. C-3 shows the temporal variations of the normalized waterline elevation  $Z_r$  with i=1,2 and 3 corresponding to the physical depth  $\delta_r'=0.157$ , 0.787 and 1.575 inches. The waterline oscillations for the second example with  $\xi=2.00$  are less than those shown in Fig. B-3 for the first example with  $\xi=4.40$ .

Fig. C-4 shows the spatial variations of the mean water level  $\overline{\eta}$ , the crest elevation  $\eta_{\max}$ , and the trough elevation  $\eta_{\min}$  in the same way as Fig. B-4.

Fig. C-5 shows the spatial variations of the time-averaged velocity  $\overline{u}$ , the maximum velocity  $u_{max}$  and the minimum velocity  $u_{min}$  in the same as Fig. B-5.

Fig. C-6 shows the spatial variation of the time-averaged volume flux per unit width  $\overline{m}$  in the same way as Fig. B-6. The computed values of  $\overline{m}$ , which are on the order of  $10^{-3}$  or less, satisfy the time-averaged continuity equation  $\overline{m}$  = 0 almost exactly.

Fig. C-7 shows the spatial variations of the time-averaged energy quantities  $\overline{E}$ ,  $\overline{E_F}$ ,  $\overline{D_f}$  and  $\overline{D_B}$  in the same way as Fig. B-7. The wave energy dissipation due to wave breaking for the second example with  $\xi = 2.00$  is larger than that for the first example with  $\xi = 4.40$ .

Fig. C-8 shows the spatial variations of the free surface elevation  $\eta$  at the time t = 6, 6.25, 6.5, 6.75 and 7. Fig. C-8 indicates wave breaking for

the second example with  $\xi = 2.00$  unlike Fig. B-8 for the first example with  $\xi = 4.40$ . It is noted that the numerical method used for IBREAK produces a steep wave front whenever wave breaking occurs. A two-dimensional model would be required to simulate the wave breaking process in a more realistic manner.

Fig. C-9 shows the spatial variations of the horizontal velocity u at the time t = 6, 6.25, 6.5, 6.75 and 7 in the same way as Fig. B-9 except that the computation duration  $0 \le t \le 7$  for the second example is taken to be longer because of the computation of the armor movement which will not become periodic even after the establishment of the periodic flow field.

Fig. C-10 plots the values of the normalized displacement  $X_a$  at t=7 as a function of the corresponding values of the initial vertical location on the slope z.

Fig. C-11 shows the temporal variations of  $X_a$  for the two armor units initially located at z=-1.283 and z=0.797, corresponding to the node number j=72 and j=119, respectively, as listed in Table C-4. The temporal variations of  $X_a$  for j=72 and 119 are plotted from the files with their unit numbers = 75 and 76, respectively. The corresponding file names specified as input are 0072 and 0119 as listed in Table C-1.

#### TABLE C-1

```
1
           3 = number of comment lines
2
     3
    Ahrens (1975) Test 32 (Zero Damage)
 4
 5
                              --> IJOB, ISTAB, NSTAB
     2
 6
                              --> ISYST
                              --> IBOT
 7
     1
                              --> INONCT
8
     0
 9
                              --> IENERG
     1
10
     1 no wave data file
                             --> IWAVE, FINP2
    101 12000 5 0 2
11
                             --> ISAVA-B-C, NSAVA, NTIMES, NNOD1, NNOD2
    00000 0
12
                              --> IREQ, IELEV, IV, IDUDT, ISNR, NNREQ
      14000
13
                              --> NTOP
        2000
                              --> NONE
14
15
          10
                              --> NJUM1
         100
                              --> S
16
                              --> FWP
17
          .300000
18
         1.000000 1.000000 --> X1,X2
          .001000
                              --> DELTA(normalized)
19
          3
20
                              --> NDELR
          .157480
21
                              --> DELRP(1) (inches)
          .787402
                              --> DELRP (2)
22
23
         1.574803
                              --> DELRP (3)
         3.390000
24
                    5.700000 --> HREFP (feet), TP (seconds)
                     .942100 --> KSREF, KSSEA
25
           .942100
                              --> DSEAP (feet)
26
        15.000000
         .285714
                              --> TSLOPS
27
28
                              --> NBSEG
           1
29
        85.000000
                     .285714 --> WBSEG(1) (feet), TBSLOP(1)
30
          1
                                         --> NJUM2
          .900000
                     .660000
                              2.710000 --> C2,C3,SG
31
          .500000
                     .400000
32
                                1.500000 --> CD, CL, CM
33
         1.191754
                                         --> TANPHI
         1.000000
                     -.800000
34
                                         --> AMAX, AMIN
         1.030000
35
                                         --> DAP (feet)
        72 0072
                                  --> NODNO2(1), FNAME2(I)
36
37
     119 0119
                                  -->
                                        (2) (2)
```

## TABLE C-2

1			
2	Ahrens (1975) Test 32 (Zero Damage)		
3			
4			
5	From Subroutine 14 RUNUP: $U(2,S)>U(2,S-1)$ at $S=$	130; N =	3706
6	Adjusted values: $U(2,S) = 0.112E-02$ ; $U(2,S-1) =$	0.224E-02	
7			
8	From Subroutine 14 RUNUP: $U(2,S)>U(2,S-1)$ at $S=$	130; N =	5616
9	Adjusted values: $U(2,S) = 0.145E-02$ ; $U(2,S-1) =$	0.290E-02	
10			
11	From Subroutine 14 RUNUP: $U(2,S)>U(2,S-1)$ at $S=$	130; N =	5702
12	Adjusted values: $U(2,S) = 0.639E-03$ ; $U(2,S-1) =$	0.128E-02	

#### TABLE C-3

```
1
 2
      Ahrens (1975) Test 32 (Zero Damage)
 3
 4
 5
      WAVE CONDITION
 6
      Stokes II Incident Wave at Seaward Boundary
 7
      Norm. Maximum Surface Elev. = 0.594242
 8
 9
      Norm. Minimum Surface Elev.
                                        -0.405758
10
     Reference Wave Period
Reference Wave Height
11
                                  = 5.700000 sec.
      Depth at Seaward Boundary = 15.000000 feet Shoal. Coef. at Reference Ks1 = 0.942
12
13
14
15
16
                  Ks = Ks2/Ks1 =
                                        1.000
17
     Norm. Depth at Seaw. Bdr.
                                        4.425
     Normalized Wave Length
18
                                        7.560
      "Sigma"
19
                                  = 17.567
20
      Ursell Number
                                  = 12.917
      Surf Similarity Parameter =
21
                                       2.002
22
      SLOPE PROPERTIES
23
24
      Friction Factor
25
                              = 0.300000
= 2.635082
     Norm. Friction Factor =
26
27
     Norm. Horiz. Length of
28
       Computation Domain = 1.419329
29 Number of Segments =
30
      -----
       SEGMENT WBSEG(I) TBSLOP(I)
I feet
31
32
33
      _____
34
           1 85.000000 0.285714
35
36
      COMPUTATION PARAMETERS
37
38
      Normalized Delta x = 0.881571D-02
      Normalized Delta t = 0.500000D-03
39
40
      Normalized DELTA = 0.100000E-02
     Damping Coeff. x1 = 1.000
x2 = 1.000
Num. Stab. Indicator = 3.511
41
42
43
     Total Number of Time Steps NTOP =
44
                                            14000
      Number of Time Steps in 1 Wave Period
45
46
                                   NONE =
                                              2000
47
      Total Number of Spatial Nodes
                                    JE =
                                               162
48
      Number of Nodes Along Bottom Below SWL
49
                                               100
                                       S =
50
      Storing Temporal Variations at Every
51
                                    NJUM1 =
                                               10 Time Steps
52
     Armor Stability Number Computed
53
                         at Every NJUM2 = 1 Time Steps
```

54

```
55
      PARAMETERS FOR ARMOR STABILITY AND MOVEMENT
56
      Armor Friction Factor =
57
                                  1.192
     Specific Gravity
                                  2.710
58
     Area Coefficient
                        C2 =
59
                                  0.900
60
     Volume Coefficient C3 =
                                  0.660
     Drag Coefficient CD = Lift Coefficient CL =
61
                                  0.500
62
                                  0.400
63
      Inertia Coefficient CM =
                                  1.500
      Armor Diameter
64
                                  1.030000 feet
65
     REFLECTION COEFFICIENTS
66
67
     r1 =
68
             0.173
     r2 = 0.185

r3 = 0.176
69
70
71
72
      RUNUP, RUNDOWN, SETUP
73
74
      Largest Node Number Reached by Computational Waterline
75
                            JMAX = 130
76
           I DELTAR(I) RUNUP(I) RUNDOWN(I) SETUP(I)
77
78
                [inch]
                           R
                                      Rd
79
                                    -----
           1 0.157 1.284 0.892 1.116
2 0.787 1.275 0.538 0.976
80
81
82
            3
                1.575
                           1.265
                                      0.309
                                                 0.887
83
84
      ARMOR UNITS MOVEMENT
85
     Number of Units Moved
86
                                        64
      Number of Units Stopped =
87
                                       34
88
89
      WAVE SET-DOWN OR SETUP
90
    Average value of ETAI = 0.000000
ETAR = 0.019853
91
92
93
```

```
94
        TIME-AVERAGED ENERGY BALANCE
 95
 96
        Normalized Energy Flux:
        . at Seaw. Boundary A = 0.271704D+00 at Landw. Boundary B = 0.000000D+00
 97
 98
 99
        Normalized Rate of Energy Dissipation
100
        in the Computation Domain, Due to:
101
        . bottom friction C = 0.205248D+00
. wave breaking D = 0.664560D-01
102
103
      Calculation 1:
104
                         E = A-B = 0.271704D+00
105
                         F = C+D = 0.271704D+00
          Must G=0, but G = F-E = 0.512847D-07
106
107
          % error 100G/E = 0.00
108
        Approximate Energy Flux, Based on
109
        Linear Long Wave, Due to:
110
        . incident wave at seaw. boundary
                                              P = 0.262939D+00
111
        . reflected wave at seaw. boundary Q = 0.814467D-02
112
       Calculation 2:
113
       Net Energy Flux at Seaw. Bndry. S = P-Q = 0.254795D+00
114
       % Error at Seaward Boundary 100(S-A)/A =
```

TABLE C-4

No.	Status	Node No.	Node No.	Time	Coordinates of		Xa	
	at $t=7$	at		Step	Initial Location		at t=7	
		Initial	Final	When				
		Location	Location	Start	x	Z		
				Moving				
1	stopped	67	66	3806	0.582	-1.504	-0.26	
2	moving	68	68	3819	0.591	-1.460	-0.09	
3	moving	69	69	3835	0.600	-1.416	0.03	
4	moving	70	70	1830	0.608	-1.372	0.21	
5	moving	71	71	1840	0.617	-1.327	0.14	
6	moving	72	72	1856	0.626	-1.283	0.12	
7	moving	73	74	1873	0.635	-1.239	0.41	
8	moving	74	74	1891	0.643	-1.195	0.18	
9	moving	75	76	1909	0.652	-1.150	0.42	
10	moving	76	76	1926	0.661	-1.106	-0.03	
11	moving	77	77	1943	0.670	-1.062	0.04	
12	moving	78	78	1959	0.679	-1.018	-0.16	
13	moving	79	79	1975	0.688	-0.974	-0.15	
14	stopped	80	80	1991	0.696	-0.929	-0.05	
15	stopped	81	81	2006	0.705	-0.885	-0.128	
16	moving	82	82	2021	0.714	-0.841	-0.16	
17	moving	83	83	2036	0.723	-0.797	-0.182	
18	moving	84	84	2051	0.732	-0.752	-0.250	
19	moving	85	85	2065	0.740	-0.708	-0.023	
20	moving	86	85	2080	0.749	-0.664	-0.302	
21	stopped	87	87	2094	0.758	-0.619	-0.173	
22	stopped	88	87	2109	0.767	-0.575	-0.27	
23	stopped	89	89	2123	0.776	-0.531	-0.245	
24	stopped	90	90	2138	0.785	-0.487	-0.119	
25	moving	91	90	2153	0.793	-0.442	-0.322	
26	moving	92	91	2168	0.802	-0.398	-0.391	
27	stopped	93	92	2183	0.811	-0.354	-0.396	
28	moving	94	93	2199	0.820	-0.310	-0.308	
29	moving	95	94	2215	0.829	-0.266	-0.545	
30	moving	96	95	2231	0.837	-0.221	-0.477	
31	moving	97	96	2201	0.846	-0.177	-0.598	
32	moving	98	97	2217	0.855	-0.133	-0.640	
33	stopped	99	98	2255	0.864	-0.089	-0.449	
34	moving	100	99	2276	0.873	-0.044	-0.561	
35	stopped	101	101	2295	0.882	0.000	-0.179	
36	stopped	102	102	2313	0.890	0.044	-0.089	
37	stopped	103	103	2330	0.899	0.089	-0.172	
38	stopped	104	103	2346	0.908	0.133	-0.286	
39	stopped	105	104	2363	0.917	0.177	-0.332	
40	stopped	106	105	2380	0.926	0.221	-0.293	
41	stopped	107	107	2398	0.934	0.266	-0.241	
42	stopped	108	108	2417	0.943	0.310	-0.186	
43	stopped	109	108	2437	0.952	0.354	-0.344	
44	stopped	110	109	2459	0.961	0.398	-0.359	
45	stopped	111	110	2482	0.970	0.442	-0.265	
46	stopped	112	111	2506	0.979	0.487	-0.328	
47	stopped	113	113	2531	0.987	0.531	-0.201	
48	stopped	114	114	2556	0.996	0.575	-0.186	
49	stopped	115	114	2581	1.005	0.619	-0.288	
50	stopped	116	115	2607	1.014	0.664	-0.474	

No.	Status	Node No. at Initial Location	Node No. at Final Location	Time Step When Start Moving	Coordinates of		Xa	
	at t=7				Initial Location		at t=7	
					х	z		
51	stopped	117	117	2633	1.023	0.708	-0.132	
52	stopped	118	117	2661	1.031	0.752	-0.282	
, 53	stopped	119	119	2690	1.040	0.797	-0.045	
54	stopped	120	119	2720	1.049	0.841	-0.473	
55	stopped	121	121	2752	1.058	0.885	-0.047	
56	stopped	122	122	2785	1.067	0.929	-0.172	
57	stopped	123	123	2821	1.076	0.974	-0.132	
58	stopped	124	123	2860	1.084	1.018	-0.267	
59	moving	125	124	2901	1.093	1.062	-0.345	
60	moving	126	125	2948	1.102	1.106	-0.349	
61	stopped	127	126	3000	1.111	1.150	-0.275	
62	moving	128	128	3061	1.120	1.195	-0.221	
63	moving	129	129	3138	1.128	1.239	-0.135	
64	moving	130	130	5471	1.137	1.283	-0.042	

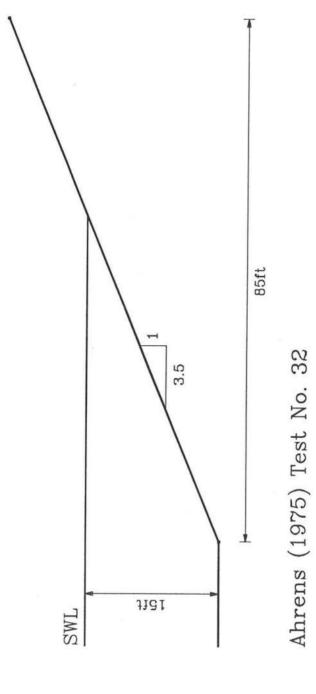
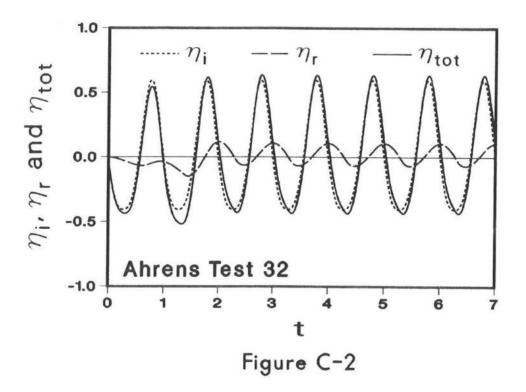
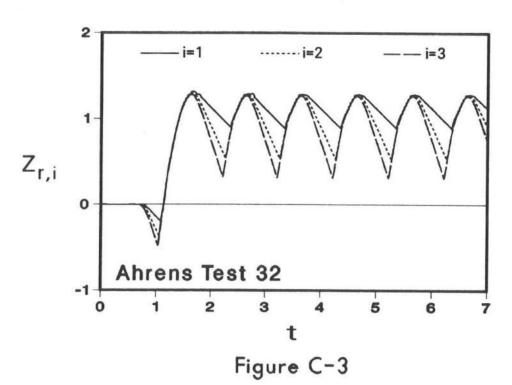
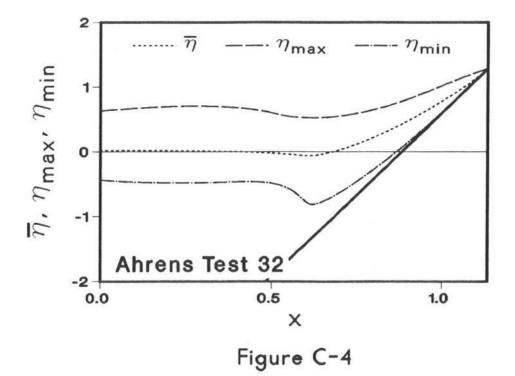
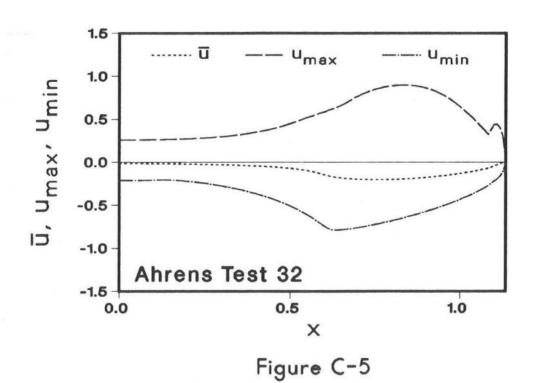


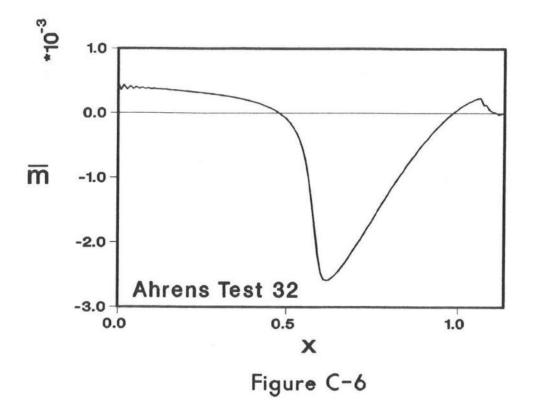
Figure C-1

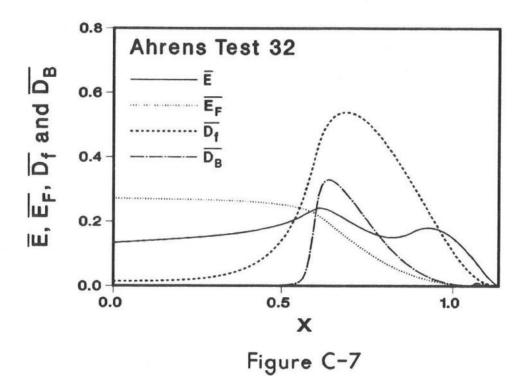


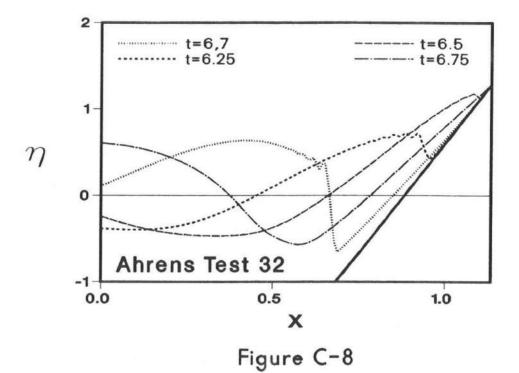


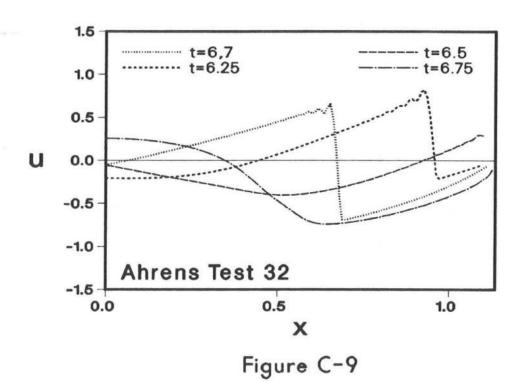


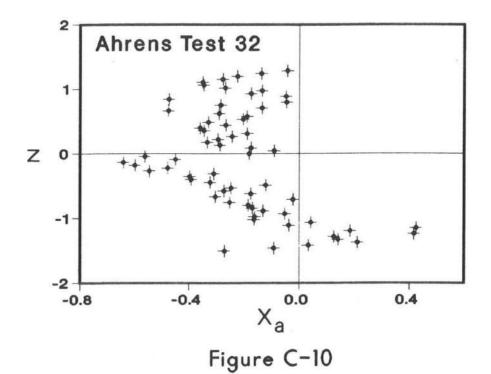


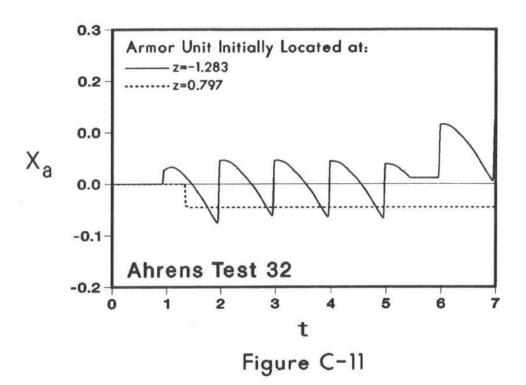












### APPENDIX D: EXAMPLE OF WAVE OVERTOPPING ON SUBAERIAL STRUCTURE

The third example is one test run from the extensive small-scale test data of Saville (1955) for monochromatic wave overtopping over smooth impermeable structures fronted by a 1:10 slope. This test run corresponds to the Run No. 10 in the report of Kobayashi and Wurjanto (1988).

Table D-1 lists the input data for the third example where IJOB=2 for the computation of wave overtopping over a subaerial structure and ISTAB=0 since armor stability and movement are not computed for this smooth impermeable structure. The representative wave height  $H_{\rm r}' = {\rm HREFP}$  is taken as the deep water wave height  $H_{\rm o}'$  given in the report of Saville (1955). As a result, KSREF =  $H_{\rm r}'/H_{\rm o}'$  is unity, while KSSEA =  $H_{\rm o}'/H_{\rm o}' = 1.034$  is the shoaling coefficient at the seaward boundary estimated using cnoidal wave theory as discussed in the report of Kobayashi and Wurjanto (1988). It is noted that the friction factor f' = FWP is reduced from 0.3 in Tables B-1 and C-1 for the rough slopes to 0.05 in Table D-1 for the smooth slope.

Table D-2 lists the warning messages written during the time-marching computation in the same way as Tables B-2 and C-2.

Table D-3 lists the concise output for the third example and includes the quantities related to wave overtopping and explained in the common /OVER/ unlike Tables B-3 and C-3.

Fig. D-1 shows the dimensional structure geometry specified as input in Table D-1. The structure consists of three linear segments.

Fig. D-2 shows the temporal variations of the incident wave profile  $\eta_{1}$ , the reflected wave profile  $\eta_{r}$  and the total wave profile  $\eta_{tot} = (\eta_{1} + \eta_{r})$ . The asymmetry of the reflected wave profile in Fig. D-2 appears to be related

to wave overtopping since the reflected wave profiles shown in Figs. B-2 and C-2 are more symmetric.

Fig. D-3 shows the temporal variations of the normalized waterline elevation  $Z_r$  with i=1, 2 and 3 corresponding to the physical depth  $\delta_r'=1$ , 3 and 5 mm. These values of  $\delta_r'$  for the small-scale test are taken to be smaller than those for the large-scale test where  $\delta_r'=4$ ,20 and 40mm in Figs. B-3 and C-3. It should be noted that  $Z_r$  is taken to be the normalized free surface elevation at the landward edge of the structure when wave overtopping occurs and the normalized water depth h exceeds the value of  $\delta_r=\delta_r'/H_r'$ . The normalized elevation of the crest of the structure shown in Fig. D-1 corresponds to  $Z_r=1.0$  in Fig. D-3. As a result, the portion of the three curves above  $Z_r=1.0$  in Fig. D-3 indicates the free surface elevation at the landward edge. Fig. D-3 also suggests that a thin layer of water, whose thickness is greater than 1 mm but less than 3 mm, remains on the crest of the structure when the water depth at the landward edge decreases.

Fig. D-4 shows the temporal variations of u and  $c = h^{1/2}$  at the landward edge located at  $x = x_e$  which have been denoted by V(JE) and C(JE) and stored as a function of the time level N with t = N/NONE in the subroutine DOC2. Fig. D-4 is plotted from the file with its unit number = 32 and its file name = OOVER. Fig. D-4 indicates that wave overtopping starts suddenly as a supercritical flow for which u > c and decreases gradually as a critical flow for which u = c.

Fig. D-5 shows the temporal variations of m and h at the landward edge located at  $x = x_e$  which have been denoted by U(1,JE) and U(2,JE) and stored together with V(JE) and C(JE) in the subroutine DOC2. Figs. 4 and 5 show that the overtopping flow is highly unsteady. The maximum and time-averaged values

of m during  $4 \le t \le 5$  are 0.2564 and 0.0455, respectively, as listed in Table D-3. The temporal variation of h at  $x = x_e$  may be useful for interpreting the temporal variations of  $Z_r$  shown in Fig. D-3.

Fig. D-6 shows the temporal variation of u at the seaward boundary located at x=0 which has been denoted by V(1) and stored as a function of the time level N with t=N/NONE in the subroutine DOC2. Fig. D-6 is plotted from the file with its unit number = 21 and its file name = OSEAWAV. Fig. D-6 is plotted to check the periodicity of u at x=0.

Fig. D-7 shows the spatial variations of the mean water level  $\overline{\eta}$ , the crest elevation  $\eta_{\rm max}$ , and the trough elevation  $\eta_{\rm min}$ . Formation of the standing wave on the 1:10 slope in front of the structure is apparent in Fig. D-7 whereas this is not apparent in Figs. B-4 and C-4 for which the computation domain has been limited to the region landward of the toe of the structure.

Fig. D-8 shows the spatial variations of the time-averaged velocity  $\overline{u}$ , the maximum velocity  $u_{max}$  and the minimum velocity  $u_{min}$ . The maximum and minimum velocity variations on the 1:10 slope appear to be consistent with the standing wave envelope shown in Fig. D-7. Comparison of Fig. D-8 with Figs. B-5 and C-5 indicates that wave overtopping results in unidirectional landward flow on the crest of the structure.

Fig. D-9 shows the spatial variation of the time-averaged volume flux per unit width  $\overline{m}$ . The time-averaged continuity equation requires  $\overline{m} = \text{constant}$ . For the case of no wave overtopping,  $\overline{m}=0$  as shown in Figs. B-6 and C-6. For the case of wave overtopping shown in Fig. D-9, the computed values of  $\overline{m}$  are 0.45 on the average but fluctuates due to the high-frequency numerical oscillations which tend to occur at the locations where the slope is

discontinuous. The dimensional structure geometry shown in Fig. D-1 and the normalized structure geometry shown in Fig. D-7 indicate that the slope changes suddenly from 1:10 to 1:3 in the vicinity of x=1.0 where the spatial variation of  $\overline{m}$  shown in Fig. D-9 fluctuates greatly. The computed variation of  $\overline{m}$  could be smoothed using the smoothing procedure applied by Kobayashi and Wurjanto (1989b,1989c). The smoothed variation of  $\overline{m}$  will still yield  $\overline{m} \simeq 0.45$ . It is noted that the time-averaged quantities are more difficult to compute accurately and more influenced by the numerical high-frequency oscillations than the instantaneous quantities.

Fig. D-10 shows the spatial variations of the time-averaged energy quantities  $\overline{E}$ ,  $\overline{E_F}$ ,  $\overline{D_f}$  and  $\overline{D_B}$  in the same way as Figs. B-7 and C-7. The numerical high-frequency oscillations are apparent especially for  $\overline{D_B}$ . This is because the spatial variation of  $\overline{D_B}$  computed using Eq. 55 is strongly affected by the apparently small high-frequency oscillations in the spatial variation of  $\overline{E_F}$  which would be required to be smoothed before the computation of  $\overline{D_B}$  (Kobayashi and Wurjanto, 1989b,1989c).

Fig. D-11 shows the spatial variations of the free surface elevation  $\eta$  at the time t=4, 4.25, 4.5, 4.75 and 5. The numerical high-frequency oscillations are apparent especially in the vicinity of x = 1.0 in Fig. D-11 as compared to Figs. B-8 and C-8.

Fig. D-12 shows the spatial variations of the horizontal velocity u at the time t = 4, 4.25, 4.5, 4.75 and 5. The numerical high-frequency oscillations are apparent in Fig. D-12 as compared to Figs. B-9 and C-9. It is noted that no measurements are available on the detailed spatial and temporal velocity field on a coastal structure. It might be possible that the high-frequency oscillations are related to the actual flow phenomena in the vicinity of the slope discontinuity.

#### TABLE D-1

```
1
            3 = number of comment lines
 3
      Saville (1955) Run 10
 4
      5
      20
             0
                               --> IJOB, ISTAB, NSTAB
 6
      1
                               --> ISYST
 7
      1
                               --> IBOT
 8
                               --> INONCT
 9
                               --> IENERG
     1 no wave data file
10
                               --> IWAVE, FINP2
11
     100 32000 5 0 0
                               --> ISAVA-B-C, NSAVA, NTIMES, NNOD1, NNOD2
12
     00000 0
                               --> IREQ, IELEV, IV, IDUDT, ISNR, NNREQ
13
        40000
                               --> NTOP
14
          8000
                               --> NONE
           40
15
                               --> NJUM1
          120
16
                               --> S
17
           .050000
                               --> FWP
                      1.000000 --> X1,X2
18
          1.000000
          .001000
19
                               --> DELTA(normalized)
20
            3
                               --> NDELR
21
          1.000000
                               --> DELRP(1) (mm)
22
          3.000000
                               --> (2)
                                       (3)
23
          5.000000
                               -->
24
           .107576
                     2.621810 --> HREFP (m), TP (seconds)
25
          1.000000
                     1.034000 --> KSREF, KSSEA
          .430000
26
                               --> DSEAP (m)
          .333333
27
                               --> TSLOPS
28
           3
                               --> NBSEG
29
          2.689000
                       .100000 --> WBSEG(1) (m), TBSLOP(1)
30
           .807000
                       .333333 -->
                                      (2)
                                                  (2)
31
                       .000000 -->
           .090000
                                       (3)
                                                  (3)
```

### TABLE D-2

1			
2	Saville (1955) Run 10		
3			
3 4 5			
	From Subroutine 14 RUNUP: $U(2,S)>U(2,S-1)$ at $S=$	121; N =	7536
6	Adjusted values: $U(2,S) = 0.221E-02$ ; $U(2,S-1) =$	0.245E-02	7550
8	From Subroutine 14 RUNUP: $U(2,S)>U(2,S-1)$ at $S=$	121; N =	7575
9	Adjusted values: $U(2,S) = 0.203E-02$ ; $U(2,S-1) =$	0.225E-02	7575
11	From Subroutine 14 RUNUP: $U(2,S)>U(2,S-1)$ at $S=$	121; $N =$	7645
12 13	Adjusted values: $U(2,S) = 0.187E-02$ ; $U(2,S-1) =$	0.207E-02	7045
14	From Subroutine 14 RUNUP: $U(2,S)>U(2,S-1)$ at $S=$	122: N =	8367
15	Adjusted values: $U(2,S) = 0.127E-02$ ; $U(2,S-1) =$	0.171E-02	0307
16		0.1.12	
17	From Subroutine 14 RUNUP: $U(2,S)>U(2,S-1)$ at $S=$	120; N =	8834
18	Adjusted values: $U(2,S) = 0.168E-02$ ; $U(2,S-1) =$	0.175E-02	0004

#### TABLE D-3

```
2
      Saville (1955) Run 10
 3
      5
      WAVE CONDITION
 6
 7
      Cnoidal Incident Wave at Seaward Boundary
 8
      1-m = 0.608412027D-01
 9
               0.107076819D+01
      K =
10
               0.281408330D+01
11
      Norm. Maximum Surface Elev.
                                      0.682057
12
      Norm. Minimum Surface Elev.
                                     -0.351943
13
14
     Reference Wave Period
                                      2.621810 sec.
      Reference Wave Height
15
                                      0.107576 meters
      Depth at Seaward Boundary = 0.430000 meters
16
17
      Shoal. Coef. at Reference Ks1 = 1.000
18
                 at Seaw. Bdr. Ks2 =
                                     1.034
19
                 Ks = Ks2/Ks1 =
                                     1.034
      Norm. Depth at Seaw. Bdr.
20
                                      3.997
      Normalized Wave Length
21
                                    12.383
22
      "Sigma"
                                     25.037
      Ursell Number
23
                                    39.665
     Surf Similarity Parameter
24
                                      3.329
25
26
     SLOPE PROPERTIES
27
28
     Friction Factor
                                 0.050000
      Norm. Friction Factor =
29
                                  0.625919
      Norm. Horiz. Length of
30
31
      Computation Domain =
                                 1.325054
32
      Number of Segments
33
      ______
34
      SEGMENT WBSEG(I) TBSLOP(I)
35
       I meters
36
      -----
37
           1 2.689000 0.100000
               0.807000 0.333333
0.090000 0.000000
38
            2
39
            3
40
41
     COMPUTATION PARAMETERS
42
43
     Normalized Delta x = 0.981521D-02
     Normalized Delta t = 0.125000D-03
Normalized DELTA = 0.100000E-02
44
45
                          1.000
46
     Damping Coeff. x1 =
                    x2 =
47
                            1.000
48
      Num. Stab. Indicator =
                           16.180
49
      Total Number of Time Steps NTOP =
                                           40000
50
     Number of Time Steps in 1 Wave Period
51
     Total Number of Spatial Nodes JE =
                                            8000
52
                                            136
     Number of Nodes Along Bottom Below SWL
53
54
                                    S =
                                            120
55
     Storing Temporal Variations at Every
56
                                  NJUM1 =
                                            40 Time Steps
57
```

```
58
        REFLECTION COEFFICIENTS
                0.606
  60
        r1 =
 61
        r2 =
                 0.579
 62
        r3 =
                 0.579
 63
        RUNUP, RUNDOWN, SETUP
 65
        Largest Node Number Reached by Computational Waterline
 66
 67
                                 JMAX = 136
 68
        -----
 69
             I DELTAR(I) RUNUP(I) RUNDOWN(I) SETUP(I)
 70
                  [mm]
                               R
 71

    1
    1.000
    1.297
    0.130
    1.048

    2
    3.000
    1.297
    -0.937
    0.423

    3
    5.000
    1.297
    -0.958
    0.327

 72
 73
 74
 75
 76
        OVERTOPPING
 77
 78
        Norm. Avg. Overtopping Rate = 0.455369D-01
 79
        Norm. Avg. Flow at Seaw. Bdr. = 0.453231D-01
Norm. Max. Overtopping Rate = 0.256392D+00
 80
        Max. Rate Occurs at 0.439000 Within Interval [NSTAT, NTOP]
 81
 82
        Overtopping Duration = 1.000000 Within Interval [NSTAT, NTOP]
 83
        The last two quantities are relative to the specified
          interval taken as unity
 85
 86
        WAVE SET-DOWN OR SETUP
 87
 88
        Average value of ETAI =
                                   0.000000
 89
                         ETAR =
                                  -0.005894
 90
 91
      TIME-AVERAGED ENERGY BALANCE
 92
      Normalized Energy Flux:
 93
 94
       . at Seaw. Boundary A = 0.186835D+00
 95
        . at Landw. Boundary B = 0.698877D-01
 96
       Normalized Rate of Energy Dissipation
 97
       in the Computation Domain, Due to:
 98
       . bottom friction C = 0.846857D-01
 99
                              D = 0.322616D-01
        . wave breaking
100
       Calculation 1:
101
                        E = A-B = 0.116947D+00
102
                       F = C+D = 0.116947D+00
        Must G=0, but G = F-E = 0.277556D-16
103
104
         % error 100G/E =
105
       Approximate Energy Flux, Based on
106
       Linear Long Wave, Due to:
107
       . incident wave at seaw. boundary P = 0.267195D+00
108
        . reflected wave at seaw. boundary Q = 0.895412D-01
109
       Calculation 2:
110
       Net Energy Flux at Seaw. Bndry. S = P-Q = 0.177653D+00
       % Error at Seaward Boundary 100(S-A)/A =
111
```

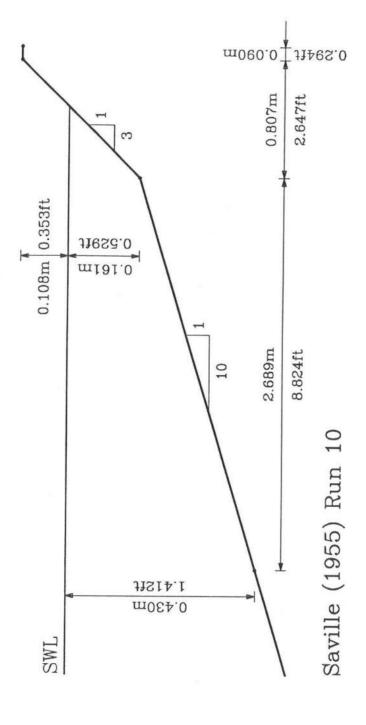
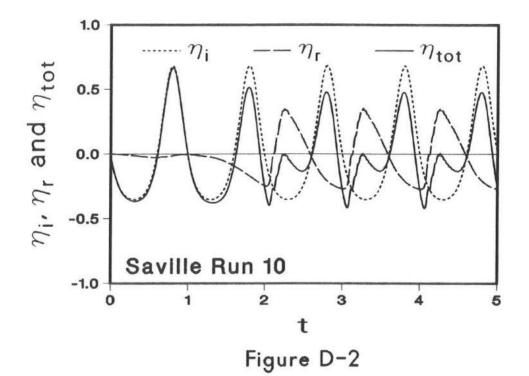
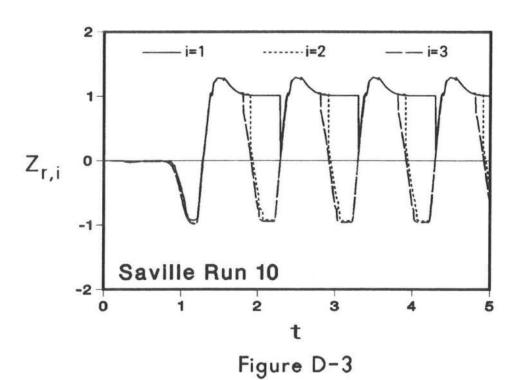
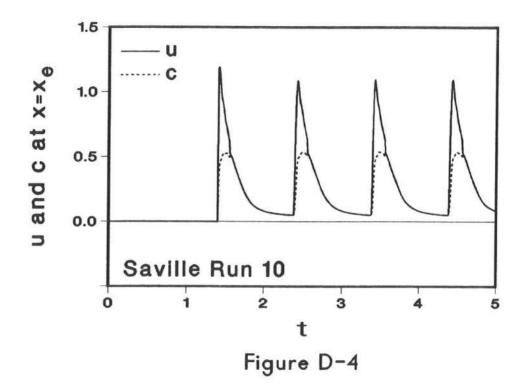
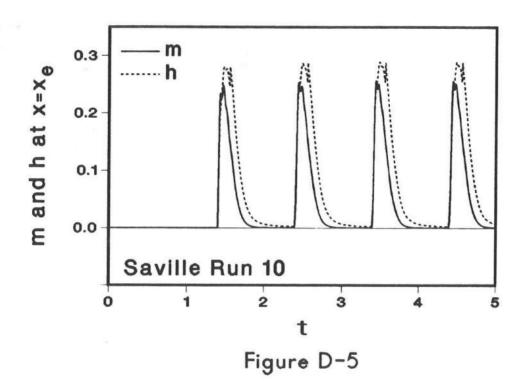


Figure D-1









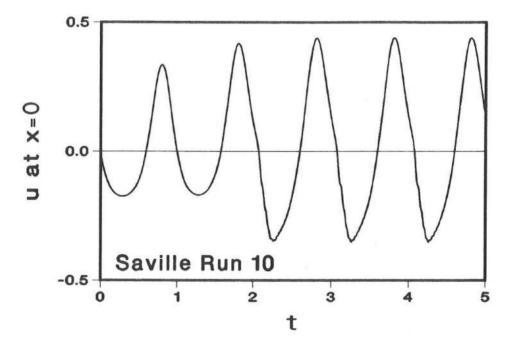
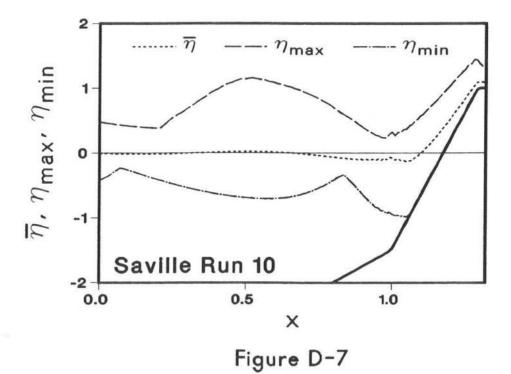
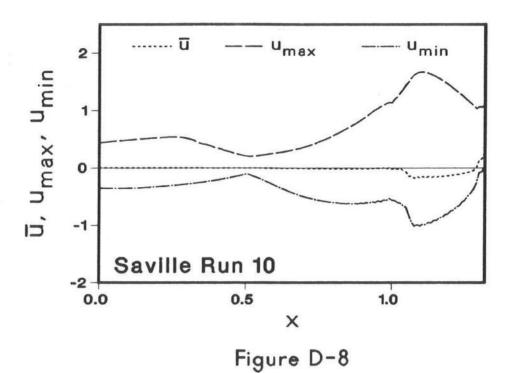


Figure D-6





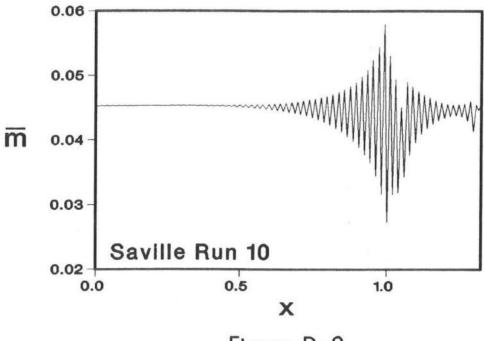
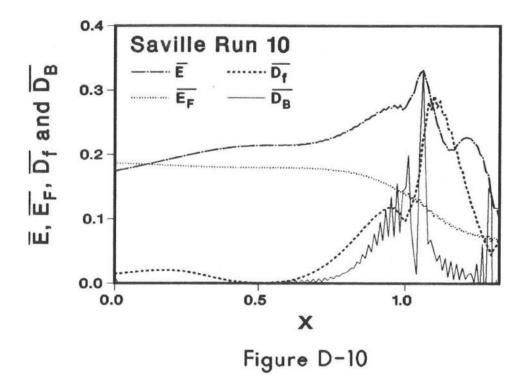
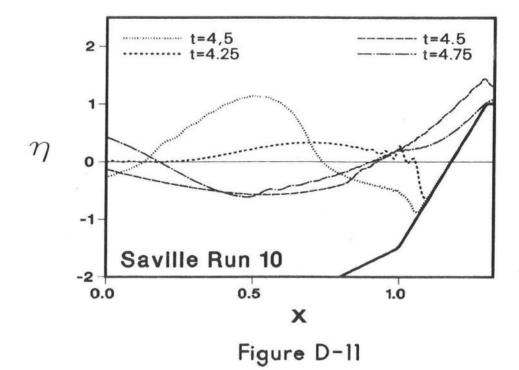
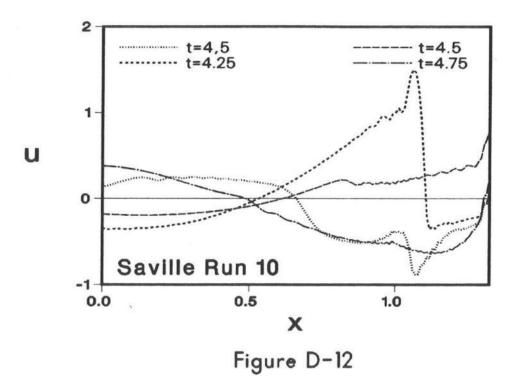


Figure D-9



D-14





## APPENDIX E: EXAMPLE OF WAVE TRANSMISSION OVER SUBMERGED STRUCTURE

The fourth example is one test run from the small-scale test data of Seelig (1980) for monochromatic wave transmission over a submerged smooth impermeable structure. This test run corresponds to the Run No. 2 in the report of Kobayashi and Wurjanto (1989b).

Table E-1 lists the input data for the fourth example where IJOB=3 for the computation of wave transmission over a submerged breakwater and ISTAB=0 since armor stability and movement are not computed for this smooth impermeable structure. The representative wave height  $H_{r}^{\prime}$  = HREFP is taken as the wave height  ${\tt H}'$  measured at the seaward toe of the structure. Since  ${\tt H}'_{\tt T}=$ H', KSSEA = KSREF = 1.0 could also be used in Table E-1 as discussed in relation to Table B-1. The number of nodes used for the computation is S =300 and greater than those used for the other examples. The damping coefficients X1=2 and X2=2 are specified as input in Table E-1 as compared to X1=1 and X2=1 used for the other examples. These changes of the data input are thought to reduce the numerical high frequency oscillations which tend to occur at the sharp corners of the submerged structure. It is also noted that the input format for the dimensional structure geometry is changed because of the use of IBOT=2 used in Table E-1 instead of IBOT=1 used in Tables B-1, C-1 and D-1. There are no warning messages written during the time-marching computation unlike the other examples as shown in Tables B-2, C-2 and D-2.

Table E-2 lists the concise output for the fourth example and includes the quantities related to wave transmission unlike Tables B-3, C-3 and D-3.

Fig. E-1 shows the dimensional structure geometry consisting of three linear segments specified as input in Table E-1.

Fig. E-2 shows the temporal variations of the incident wave profile  $\eta_i$ , the reflected wave profile  $\eta_r$ , and the total wave profile  $\eta_{\text{tot}} = (\eta_i + \eta_r)$ . The asymmetry of the reflected wave profile shown in Fig. E-2 is similar to that shown in Fig. D-2.

Fig. E-3 shows the temporal variation of the transmitted wave train  $\eta_{t}$  at the landward toe of the structure which has been denoted by ETAT and stored as a function of the time level N with t = N/NONE in the subroutine DOC2. Fig. E-3 is plotted from the file with its unit number = 33 and its file name = OTRANS. The computed transmitted wave profile exhibits a bore-like profile as discussed by Kobayashi and Wurjanto (1989b).

Fig. E-4 shows the spatial variations of the mean water level  $\overline{\eta}$ , the crest elevation  $\eta_{\rm max}$ , and the trough elevation  $\eta_{\rm min}$  together with the normalized geometry of the submerged breakwater. The mean water level  $\overline{\eta}$  increases landward except in the vicinity of the sharp corners of the submerged structure where the computed results may not be very reliable. The increase of the mean water level from the seaward boundary to the landward boundary is 0.15 as listed in Table E-2.

Fig. E-5 shows the spatial variations of the time-averaged velocity  $\overline{u}$ , the maximum velocity  $u_{max}$  and the minimum velocity  $u_{min}$ . Figs. E-4 and E-5 may be compared with Figs. D-7 and D-8 to examine the similarity and difference between wave overtopping over a subaerial structure and wave transmission over a submerged structure.

Fig. E-6 shows the spatial variation of the time averaged volume flux per unit width,  $\overline{m}$ , which is required to be constant. The oscillations of the computed values of  $\overline{m}$  shown in Fig. E-6 are reduced as compared to those shown in Fig. D-9, although the increases of the number of nodes and the damping

coefficients do not eliminate this problem. The approximate value of  $\overline{m}=0.196$  listed in Table E-2 may still be used as the required constant value of  $\overline{m}$  caused by wave transmission.

Fig. E-7 shows the spatial variations of the time-averaged energy quantities  $\overline{E}$ ,  $\overline{E_F}$  and  $\overline{D_f}$  where the spatial variation of  $\overline{D_B}$  is not shown because of the numerical high-frequency oscillations similar to those shown in Fig. D-10. The spatial variation of  $\overline{D_B}$  computed using the smoothed variation of  $\overline{E_F}$  was presented in the report of Kobayashi and Wurjanto (1989b).

Fig. E-8 shows the spatial variations of the free surface elevation  $\eta$  at the time t=4, 4.25, 4.5, 4.75 and 5 in the same way as Fig. D-11.

Fig. E-9 shows the spatial variations of the horizontal velocity u at the time t = 4, 4.25, 4.5, 4.75 and 5 in the same way as Fig. D-12.

## TABLE E-1

```
1
            3 = number of comment lines
 2
 3
      Seelig (1980) Run 2
 5
      30
                                --> IJOB, ISTAB, NSTAB
 6
      1
                                --> ISYST
 7
                                --> IBOT
      2
                                --> INONCT
 8
                               --> IENERG
 9
10
     1 no wave data file
                               --> IWAVE, FINP2
     100 12000 5 0 0
11
                               --> ISAVA-B-C, NSAVA, NTIMES, NNOD1, NNOD2
     00000 0
12
                                --> IREQ, IELEV, IV, IDUDT, ISNR, NNREQ
      15000
13
                                --> NTOP
14
         3000
                                --> NONE
15
           15
                                --> NJUM1
          300
16
                                --> S
           .050000
17
                                --> FWP
         2.000000 2.000000 --> X1,X2
18
           .001000
                                --> DELTA(normalized)
19
20
           0
                                --> NDELR
           .193000
21
                    2.390000 --> HREFP (m), TP (seconds)
           .931989
22
                       .931989 --> KSREF, KSSEA
23
           .900000
                                --> DSEAP (m)
           .666667
24
                                --> TSLOPS
           3.000000
25
                                --> NBSEG
26
                       .900000 --> XBSEG(1) (m), ZBSEG(1) (m)
                       .150000 --> (2)
.150000 --> (3)
27
         1.125000
                                             (2)
28
          1.425000
                                                    (3)
                       .900000 --> (4)
29
          2.550000
                                                    (4)
```

## TABLE E-2

```
1
 2
       Seelig (1980) Run 2
 3
  4
 5
       WAVE CONDITION
 6
 7
       Stokes II Incident Wave at Seaward Boundary
       Norm. Maximum Surface Elev. = 0.582547
 8
 9
       Norm. Minimum Surface Elev. = -0.417453
10
       Reference Wave Period = 2.390000 sec.
Reference Wave Height = 0.193000 meters
Depth at Seaward Boundary = 0.900000 meters
11
12
13
       Shoal. Coef. at Reference Ks1 = 0.932
14
15
                    at Seaw. Bdr. Ks2 = 0.932
16
                    Ks = Ks2/Ks1 = 1.000
17
       Norm. Depth at Seaw. Bdr.
                                            4.663
18
       Normalized Wave Length
                                            7.053
19
       "Sigma"
                                          17.039
20
       Ursell Number
                                          10.669
       Surf Similarity Parameter = Depth at Landward Boundary =
21
                                          4.532
0.900000 meters
22
23
24
       SLOPE PROPERTIES
25
26
       Friction Factor
                                  - 0.050000
       Norm. Friction Factor = Norm. Horiz. Length of
27
                                       0.425984
28
29
        Computation Domain = 0.775406
30
      Number of Segments
31
       _____
       SEGMENT XBSEG(I) ZBSEG(I)
I meters meters
32
33
34
35
             1 0.000000 0.900000
36
             2 1.125000 0.150000
37
              3 1.425000 0.150000
38
              4 2.550000 0.900000
39
40
       COMPUTATION PARAMETERS
41
42
      Normalized Delta x = 0.259333D-02
       Normalized Delta t = 0.333333D-03
Normalized DELTA = 0.100000E-02
43
44
45
       Damping Coeff. x1 =
                               2.000
46
       x2 = 2.000
Num. Stab. Indicator = 1.020
47
48
       Total Number of Time Steps NTOP =
                                                  15000
49
       Number of Time Steps in 1 Wave Period
50
                                       NONE =
                                                  3000
51
      Total Number of Spatial Nodes
                                       JE =
       Storing Temporal Variations at Every
52
                                       NJUM1 = 15 Time Steps
53
54
```

```
55
       REFLECTION COEFFICIENTS
56
57
       r1 =
                0.494
58
       r2 =
                0.550
59
       r3 =
                0.504
60
61
       WAVE SET-DOWN OR SETUP
62
63
       Average value of ETAI =
                                   0.000000
64
                        ETAR =
                                  -0.077559
65
                        ETAT =
                                   0.073361
66
       MWL Difference
                                   0.150920
67
68
       TRANSMISSION
69
70
       Transmission Coefficient T1 =
                                        0.741
71
                                T2 =
                                         0.722
72
                                T3 =
                                          0.691
73
       Norm. Avg. Flow at Seaw. Bdr. =
                                            0.196176
       Norm. Avg. Flow at Landw. Bdr. =
74
                                            0.196442
75
       Average of the Above Two
                                            0.196309
76
77
       TIME-AVERAGED ENERGY BALANCE
78
79
      Normalized Energy Flux:
80
      . at Seaw. Boundary A = 0.219144D+00
. at Landw. Boundary B = 0.163349D+00
81
      Normalized Rate of Energy Dissipation
83
      in the Computation Domain, Due to:
84
      . bottom friction C = 0.141936D-01
85
       . wave breaking
                            D = 0.416010D-01
86
      Calculation 1:
87
                       E = A-B = 0.557946D-01
88
                       F = C+D = 0.557946D-01
89
        Must G=0, but G = F-E = -0.138778D-16
        % error 100G/E =
90
91
      Approximate Energy Flux, Based on
92
      Linear Long Wave, Due to:
      . incident wave at seaw. boundary P = 0.269931D+00
93
94
      . reflected wave at seaw. boundary Q = 0.685893D-01
95
       . transmitted wave at landw. bndry. R = 0.129051D+00
96
      Calculation 2:
      Net Energy Flux at Seaw. Bndry. S = P-Q = 0.201342D+00
97
98
      % Error at Seaward Boundary 100(S-A)/A =
99
      % Error at Landward Boundary 100 (R-B) /B =
                                                       -21.00
```

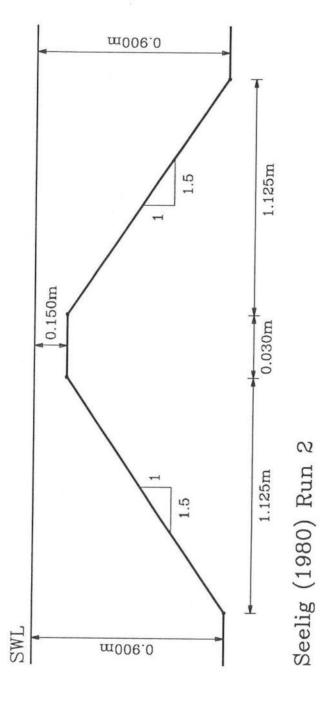
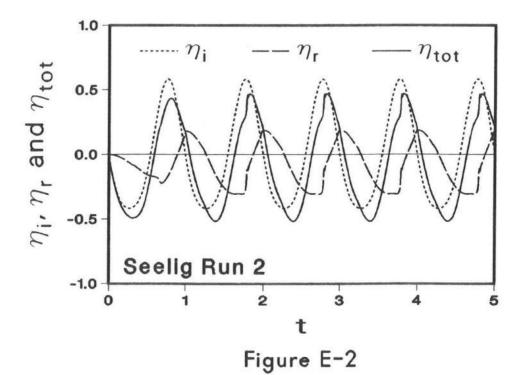
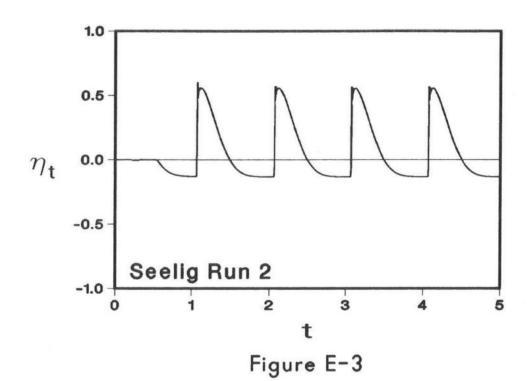
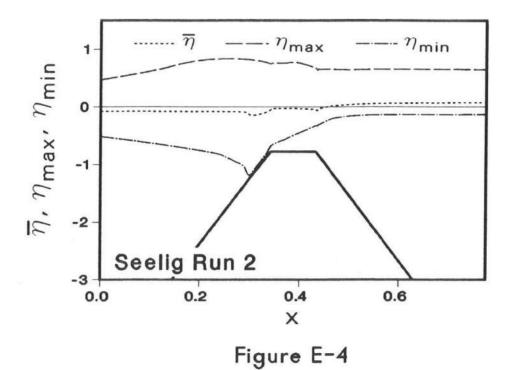
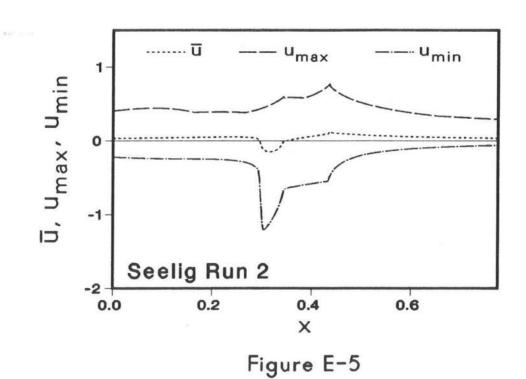


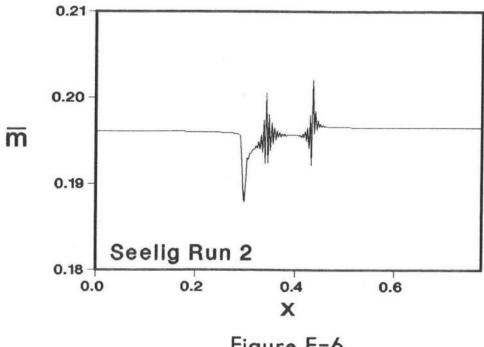
Figure E-1













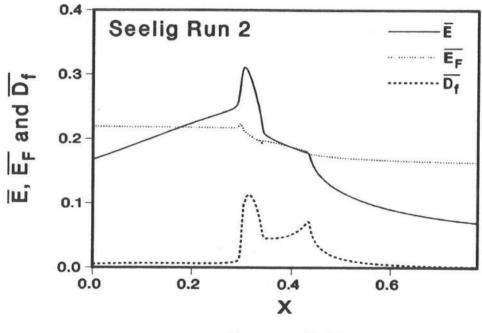
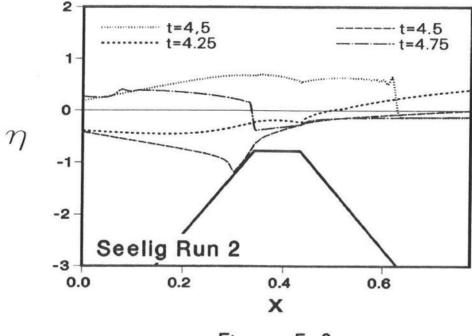
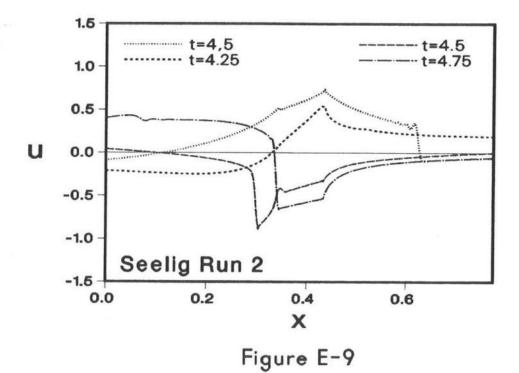


Figure E-7







E-11