

WAVE HEIGHT ANALYSIS FOR FLOOD INSURANCE STUDIES

(TECHNICAL DOCUMENTATION FOR WHAFIS PROGRAM VERSION 3.0)

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1. INTRODUCTION

1.1 BACKGROUND

Under the National Flood Insurance Act of 1968 (as amended), the Federal Emergency Management Agency (FEMA) is responsible for promoting the public welfare by ensuring the availability of insurance protection against the risk of flood and mudslide losses and by encouraging sound floodplain management by communities as a condition for the insurance protection. In the context of those responsibilities, FEMA has considerable opportunity to develop programs that will reduce annual property losses resulting from floods and mudslides.

In the delineation of coastal high hazard zones, the Wave Height Analysis for Flood Insurance Studies (WHAFIS) model was developed to predict wave heights associated with hurricane coastal storm surge. The model was based on the methodology developed by the National Academy of Sciences (NAS) in 1977 (Reference 1). Since its completion in 1980, several revisions have been made to the model. The first version used approximate inland and overwater fetch growth curves, as recommended by the NAS, to evaluate wave heights over flooded land or open water without the presence of obstructions. In 1984, a procedure to compute wave height decay or growth in marsh grass areas was incorporated into the model. That procedure used the conservation of wave energy equation (Version 2.1, Reference 2). In 1987, during the preparation of the report entitled Guidelines and Specifications for

Wave Elevation Determination and V Zone Mapping (Reference 3), the model was updated to incorporate methodologies describe in the U.S. Army Corps of Engineers' 1984 Shore Protection Manual (SPM) (Reference 4). This report describes the methodologies incorporated in the latest revision (Version 3.0) of the WHAFIS model.

1.2 SCOPE OF REPORT

The major revisions of the WHAFIS model (Version 3.0, dated September 1988) reflect the inclusion of an approximate form of the conservation of wave action equation and the conservation of waves equation to calculate wave height and wave period change over shallow water areas (IF, OF, and VH Cards), and the application of an interpolation procedure for the input stillwater elevations.

The overwater and inland fetch growth fetch (F and G) curves for shallow water wave height calculation used in the previous model (Version 2.1) were based on the wave growth curves in the 1975 SPM (Reference 5). Those curves were revised significantly in the latest (1984) version of the SPM (Reference 4). The wave growth predicted using the latest SPM curves can be approximately reproduced using the conservation of wave action equation and conservation of waves equation. The wave energy equation used in the previous model (Version 2.1) to calculate wave-height modifications in wave transect segments containing marsh vegetation (VH Cards, Version 2.1) was also replaced

by a modified form of those two equations. However, for the transect segments containing buildings, dunes, and trees (BU, DU, and VE Cards), the computational procedure remains unchanged from the previous version of the model.

Very often, the 100-year stillwater elevations in backbay or inland areas differ from those along the open coast. In the previous model (Version 2.1), when a new stillwater elevation was given at a location along the transect, the model used an abrupt water-surface change at that location instead of a gradual decrease (or increase) between two given stillwater change locations. That method of interpolation between stillwater elevation changes resulted in a discontinuity of wave dynamics. The procedure of stillwater interpolation implemented in the current model (Version 3.0, dated September 1988) results in a gradual decrease (or increase) of the stillwater surface profile.

Chapter 2 describes the approximate conservation of wave action equation and conservation of waves equation for the computation of wave heights in inland and overwater fetch areas and marsh grass areas.

The conservation of wave action equation computes the wave action variations resulting from the wind energy input, wave energy redistribution, and dissipation. Wave action, short for wave action density, is a generalization of wave energy and is given by the wave energy density divided by the intrinsic (circular) frequency. When

time-mean currents are negligible, this frequency is given by $2\pi/T$ where T is the spectral peak wave period. Wave shoaling, but not wave refraction, is accounted for in the conservation of wave action equation. The conservation of wave action equation is more fundamental than the conservation of wave energy equation, because it applies to moving as well as stationary systems and to systems with a variable spectral peak wave period.

The conservation of waves equation states that under the slowly varying assumptions of wave ray theory, and in the absence of source terms, waves are neither destroyed or created. When source terms are present, the conservation of waves equation allows waves to, in effect, be created and destroyed through the action of the wind and various dissipation mechanisms. This equation is used in the present WHAFIS model (Version 3.0, dated September 1988) to calculate the change of peak spectral peak wave period in fetch and marsh grass areas.

A combined analytic finite difference numerical technique is used to solve the governing equations. The solution scheme is explained in detail, followed by the stillwater interpolation procedure used in obtaining the stillwater profile along the transect.

Chapter 3 summarizes the methodology used in the revision. Appendix A presents the derivation of the source term of the conservation of waves equation. Appendix B presents the derivation of the finite difference

form of the conservation of waves equation. The source program listing is presented in Appendix C. Finally, an example calculation including the input data and the model output data is covered in Appendix D to assist the user in using the model. To prepare the data and apply it to the model, the user should refer to the Guidelines and Specifications for Wave Elevation Determination and V Zone Mapping (Reference 3) for detailed information.

2. WAVE HEIGHT ANALYSIS FOR FETCHES AND MARSHES

The waves propagating inland from the coast receive wind energy input and/or dissipate wave energy due to overland obstructions. Waves also have their energy modified by the wave shoaling and refraction processes. Wave shoaling refers to variations of wave group velocity due to variations in the stillwater depth and spectral peak wave period. Wave refraction refers to changes in the direction of the waves. In the latest version of WHAFIS (Version 3.0, dated September 1988), wave shoaling, but not wave refraction effects, are accounted for. Wave refraction effects can be roughly parameterized by allowing a wave transect to change direction at a point (usually the National Geodetic Vertical Datum of 1929 (NGVD) shoreline) near where significant refraction effects occur. Such a direction change is not normally needed at the open coast since waves are assumed to travel perpendicularly to the open-coast NGVD shoreline at the shoreline.

The calculation of wave growth or decay along a wave ray (assumed to approximately coincide with a wave transect) requires the evaluation of wave dynamics pertinent to wave propagation. The conservation of wave action and conservation of waves equations have been developed and used to compute the wave characteristics for shallow water areas in the past (References 6 and 7). The equations approximately reproduce the wave-growth curves described in the current SPM for shallow-water waves and

appropriately describe the one-dimensional, general Stokes wave propagation associated with overland storm surge flooding. Section 2.1 explains the formulas in detail. The numerical technique used to solve the governing equations is described in Section 2.2. Section 2.3 briefly describes the procedures for stillwater interpolation implemented in the revision.

2.1 CONSERVATION OF WAVE ACTION AND CONSERVATION OF WAVES

Wave action, short for wave action density, is a generalization of wave energy and is given by E/Ω . Here E is the wave energy density and Ω is the intrinsic (circular) frequency. In general, Ω is a function of the spectral peak wave period T and the (time) mean current. In the present WHAFIS model, the mean current is assumed negligible compared to the wave-induced fluctuating current. Therefore Ω is assumed to be given by $2\pi/T$ which is the appropriate expression when the average current is negligible (Reference 7).

Wave energy propagates at the wave group velocity when the intrinsic frequency Ω is constant. When the spectral peak wave period T , and hence Ω , is not constant, wave action propagates at the wave group velocity (References 6 and 7). The intrinsic frequency Ω and spectral peak wave period T undergo significant changes when the net wind energy input to waves is significant, as in hurricanes.

When T and Ω are approximately constant, the conservation of wave energy equation can be used to model wave growth and decay. In hurricanes, T and Ω are usually not constant. Therefore, the conservation of wave energy equation cannot be used in general to model hurricane wave propagation. Rather, the conservation of wave action equation and conservation of waves equation must be used to model the propagation of these waves.

The conservation of wave action equation is the generalized version of the conservation of wave energy equation (References 2 and 6). Wave action variation can be expressed as a function of wind energy input (source), wave-wave interaction redistribution (source), and wave energy dissipation (sink) due to whitecapping, obstructions, and bottom friction. The conservation of wave action equation, taking into account the change in spectral peak wave period, is used to calculate the wave height of steady, slowly varying (in space) water waves.

The conservation of waves equation determines the change of wave spectral peak frequency as a function of the "source" term which, in turn, is a function of wave height, stillwater depth, and spectral peak wave period.

2.1.1 Governing Equations

2.1.1.A. Conservation of Wave Action Equation

The approximate conservation of wave action equation governing wave height variation along a wave transect (References 7 and 8), neglecting the mean current velocity and refraction effect is:

$$\frac{\partial}{\partial x} \left(\frac{C_g E}{\Omega} \right) = \frac{W_{net} - E_p}{\Omega} \quad (1)$$

where

- E = time averaged total wave energy per unit area (wave energy density)
- C_g = wave group velocity
- Ω = intrinsic angular frequency = $2\pi/T$
- T = spectral peak wave period, i.e., period of waves at the peak of the wave spectrum
- W_{net} = time-averaged rate of net wind energy input per unit area
- E_p = time-averaged rate of energy dissipation per unit area due to plants
- x = distance along the transect (waves are assumed to propagate in the direction of increasing x)

The factors E, W_{net} , and E_p are averaged over a wave period. W_{net} includes the effects of wind energy input, wave "whitecapping," wave-wave interaction, and bottom friction.

Equation 1 has been simplified by omitting the term involving the partial time derivative of action density, (E/Ω) . This omission is justified because FEMA is primarily concerned with maximum wave heights at a given shallow location for the storm or storms that produce the 100-year stillwater flood level (SWFL) at that location. Maximum wave heights occur at a shallow water location when the time derivative of the wave height and wave period is approximately zero there. Hence the time derivative of E is approximately zero there (since E is proportional to the wave height squared) and the time derivative of Ω is approximately zero there, too. (Because T is inversely proportional to Ω .) Because the time derivative of both E and Ω is zero, the time derivative of the action density will be zero at the location. The time derivative of the wave period is approximately zero at a shallow-water location when maximum wave heights occur because maximum wave heights and wave periods usually occur at nearly the same time. This near simultaneity arises from the shape-preserving nature of the wave spectrum (Reference 10) which directly couples the wave periods and wave heights together. The near simultaneity can also be justified a posteriori using equation A13 in Appendix A.

Expanding the derivative on the left side of Equation 1 and using $\Omega = 2\pi/T$, this equation can be expressed as:

$$(C_g T) \frac{\partial E}{\partial x} + E \frac{\partial (C_g T)}{\partial x} = T W_{net} - T E_p \quad (2)$$

This is the governing equation used for solving the wave heights along a wave transect. Equation 2 can also be derived from the spectral wave action equation by taking the zeroth moment in wave vector space and imposing the narrow spectrum approximation. The source term W_{net} is determined by using approximate differential forms of the "shallow water" wave height and wave period growth equations in the 1984 SPM (Reference 4).

2.1.1.B. Conservation of Waves Equation

In the conservation of wave action equation (Equation 2), the spectral peak wave period and its spatial variation need to be determined in order to evaluate the wave height changes. In this report, a differential equation that is equivalent to the conservation of waves (or crests) equation (References 6 and 9), with a source term, is used to calculate the spectral peak wave period.

The conservation of waves equation states that, if no new waves are being generated by a local disturbance, the time rate of change of wave number is balanced by the spatial rate of change of the angular frequency, that is

$$\frac{\partial k}{\partial t} + \frac{\partial \Omega}{\partial x} = 0 \quad (3)$$

where k is the wave number and $\Omega = 2\pi/T$ is as previously defined.

Omitting the time variation of the wave number, and considering the generation of near waves by the local wind, Equation 3 can be modified as

$$\frac{\partial \Omega}{\partial x} = S \quad (4)$$

where S is the source term as a function of water depth, wave height, windspeed, and the spectral peak wave period T itself. The source term is derived in a manner analogous to the W_{net} term in the conservation of wave action equation. Equation 4 can also be derived from the spectral wave action equation by taking the first moment in wave vector space and imposing the narrow spectrum approximation.

Equation 4 is further expanded in connection with the evaluation of the term $\frac{\partial(C_g T)}{\partial x}$ described in Section 2.1.2.B.

2.1.2 Wave Energy Density and Wave Group Velocity

The left hand side of Equation 2 involves the wave energy density E , the product of the wave group velocity C_g , and the spectral peak wave period T . It is preferable to express the wave energy and the wave group velocity as a function of wave height, wave period, and water depth.

2.1.2.A. Wave Energy Density (E)

If hurricane waves were monochromatic, the wave energy density E would be related to the wave height by

$$E = (1/8) (\rho) (g) (H^2) \quad (5)$$

where

ρ = water mass density = 1.99 slugs/ft³

g = gravitational acceleration = 32.2 ft/sec

H = the wave height.

However, monochromatic waves exist only in the laboratory. Real waves have a range of heights and periods, referred to as a "wave spectrum."

The spectrum can be modeled as if it were monochromatic if a properly defined "effective wave height" for the spectrum is used. If there were no interaction between waves of different periods and heights, then the higher waves in the spectrum would be attenuated more than the lower ones, effectively reshaping the spectrum. It has been observed (Reference 10) that real wave spectra tend to preserve their shapes when undergoing change. To account for this shape-preserving

characteristic of real spectra, the effective wave height for the spectra must be chosen as the root mean square (rms) wave height (H_{rms}). However, H_{rms} is related to the wave energy density E in the same manner as in Equation 5 but with H replaced by H_{rms} ; i.e., by

$$E = (1/8) (\rho) (g) (H_{rms})^2 \quad (6)$$

Physically, $(H_{rms})^2$ at a given location is eight times the variance of a wave record at that location. Rather than directly expressing E in terms of H_{rms} , it is more convenient to express it in terms of an energy-related wave height, the so-called "zero moment wave height" (H_{m0}). By definition, H_{m0} is proportional to the square root of the "zero frequency moment" of the wave energy spectral density, hence its name. H_{rms} is given in terms of H_{m0} by the approximate expression

$$H_{rms} = H_{m0}/\sqrt{2} \quad (7)$$

Equation 7 essentially defines H_{m0} and its relationship to H_{rms} . H_{m0} is convenient to use since it can be related directly (Reference 11) to the "significant wave height" (H_s), and H_s in turn can be related directly to FEMA's "controlling wave

height* (H_c). H_s is the average height of the highest (1/3) waves, and H_c is 1.6 times H_s (Reference 1). In deep water, H_{m0} and H_s are approximately equal. In shallow water, H_s can be up to 70 percent greater than H_{m0} . For Flood Insurance Studies, H_c is of primary interest.

By substituting Equation 7 for H_{rms} into Equation 6 for E , the following expression is obtained:

$$E = (1/16) (\rho) (g) (H_{m0})^2 \quad (8)$$

Equation 8 is used in the present study to calculate the wave energy density (E) and Equation 7 is used to calculate the effective wave height (H_{rms}).

Substituting Equation 8 into Equation 2 and rearranging, the wave action equation becomes

$$(C_g T) \frac{\partial (H_{m0})^2}{\partial x} + (H_{m0})^2 \frac{\partial (C_g T)}{\partial x} = \left(\frac{16}{\rho g} \right) (W_{net} T - TE_p) \quad (9)$$

2.1.2.B. Wave Group Velocity (C_g)

The expression used for the wave group velocity (C_g) also depends upon whether monochromatic waves or a spectrum of waves is being modeled. Because the present model is meant to represent a relatively narrow spectrum of waves, C_g is approximately equal to the average group velocity of waves near the spectral peak, which in turn is approximately equal to the group velocity at the spectral peak. (As noted at the beginning of Section 2.1, the wave action E/Ω , not the wave energy E , propagates at this group velocity). The approximate expression used to calculate C_g is therefore given as

$$C_g = \frac{L}{T} \left(\frac{1}{2} + \frac{kd}{\sinh(2kd)} \right) \quad (10)$$

where

k = wave number = $2\pi/L$

π = 3.14159

d = stillwater depth (including wave setup)

L = local wavelength of waves at spectral peak

$$= \left(\tanh \frac{2\pi d}{L_0} \right)^{1/2} \quad (11)$$

L_0 = equivalent deep water wavelength of waves at spectral peak

$$= \frac{g}{2\pi} T^2 \quad (12)$$

The expression for the local "peak wave length" (L) is given by Eckart (Reference 15) and is correct to within about 5 percent. The maximum

error of 5 percent occurs when $2\pi d/L$ is approximately equal to 1 (Reference 4, p 2-9). Equation 10 for C_g is the same as that for a monochromatic wave, except that the monochromatic wave period has been replaced by the spectral peak wave period (T).

To use Equation 10 for C_g , it must be assumed that the wave spectrum being modeled fulfills the "dominant peak" assumption, i.e., the frequency spectrum has one dominant, relatively sharp peak (and possibly several considerably smaller secondary peaks). Shallow areas with water depths of less than 30 feet are of primary interest to FEMA for calculations of wave-height variation. Hurricane spectra for those areas appear to fulfill the "dominant peak" assumption because the shallow water tends to amplify the spectral peak associated with the longest period wavetrain at the expense of the peak(s) associated with the shorter period wavetrain(s).

If Equation 10 is rearranged, the equation becomes

$$C_g T = \frac{L}{2} \left(1 + \frac{2kd}{\sinh(2kd)} \right) \quad (13)$$

Taking the partial derivative of Equation 13 with respect to x , we can evaluate the expression of $\frac{\partial(C_g T)}{\partial x}$ for Equation 9.

Let $\lambda = 2kd$ from Equation 12, and we have

$$\frac{\partial(C_g T)}{\partial x} = \frac{L}{2} \frac{\partial}{\partial x} \left(1 + \frac{\lambda}{\sinh \lambda} \right) + \frac{1}{2} \left(1 + \frac{\lambda}{\sinh \lambda} \right) \frac{\partial L}{\partial x} \quad (14)$$

Expanding the derivatives on the right hand side and using Equation 11,

we have

$$\begin{aligned} \frac{\partial(C_g T)}{\partial x} = & 2\pi \left(\frac{1 - \lambda \coth \lambda}{\sinh \lambda} \right) \frac{\partial d}{\partial x} + \left(\frac{\pi}{2} \right) \frac{T_2}{d^{1/2}} \left[1 + \left(\frac{\lambda}{\sinh \lambda} \right)^2 \cosh \lambda \right] \frac{\partial d}{\partial x} \\ & + \frac{T_3}{2} \left[1 + \left(\frac{\lambda}{\sinh \lambda} \right)^2 \cosh \lambda \right] \frac{\partial L_o}{\partial x} \end{aligned} \quad (15)$$

where

$$T_2 = \left(\frac{L_o}{2\pi} \right)^{1/2} \left[\frac{2\pi D}{(\sinh(2\pi D))(\cosh^3(2\pi D))} \right]^{1/2} \quad (16)$$

$$T_3 = (\tanh 2\pi D)^{1/2} \left(1 - \frac{2\pi D}{\sinh 4\pi D} \right) \quad (17)$$

$$D = \frac{d}{L_o} \quad (18)$$

Taking the partial derivative of Equation 12 with respect to x and introducing a parameter,

$$\tau = T^3 \quad (19a)$$

the $\frac{\partial L_o}{\partial x}$ in Equation 15 can be expressed as

$$\frac{\partial L_o}{\partial x} = \left(\frac{g}{3\pi T} \right) \frac{\partial \tau}{\partial x}$$

or

$$\frac{\partial L_o}{\partial x} = \left(\frac{g}{3\pi T} \right) S_{in} \quad (19b)$$

where $S_{in} = \frac{\partial \tau}{\partial x}$, involves the peak spectral period (T) and the water depth (d). From Equations 4 and 19b we have

$$S_{in} = - \frac{3T^4}{2\pi} S$$

where S and $\frac{\partial \Omega}{\partial x}$ are related by the conservation of waves equation, Equation 4.

$$S = \frac{\partial \Omega}{\partial x}$$

The equation for S_{in} is derived in Appendix A. Substituting Equations 15 and 19b into Equation 9, we have

$$(C_g T) \frac{\partial (H_{m0})^2}{\partial x} + (H_{m0})^2 \left(T_4 \frac{\partial d}{\partial x} + \frac{T_5}{d^{1/2}} \frac{\partial d}{\partial x} + T_6 S_{in} \right) = \left(\frac{16}{\rho g} \right) (W_{net} T - TE_p) \quad (20)$$

where

$$T_4 = 2\pi \left(\frac{1 - \lambda \coth \lambda}{\sinh \lambda} \right),$$

$$T_5 = \frac{\pi}{2} \left[1 + \left(\frac{\lambda}{\sinh \lambda} \right)^2 \cosh \lambda \right] T_2, \text{ and;}$$

$$T_6 = \frac{g}{6\pi T} \left[1 + \left(\frac{\lambda}{\sinh \lambda} \right)^2 \cosh \lambda \right] T_3$$

where T_2 and T_3 are described as Equations 16 and 17.

2.1.3 Net Wind Energy Input (W_{net})

The "wind input function" (W_{net}) accounts for the energy input from the wind to the waves, wave energy losses from whitecapping and bottom friction, and wave energy redistribution from wave-wave interaction. There is apparently no expression in the current literature that can be used to specify W_{net} for waves traveling

in shallow and intermediate water-depth areas. Several expressions do exist in the literature for the spectral W_{net} function associated with the full spectral wave action equation. One of these spectral W_{net} expressions must be integrated over wave vector space to arrive at an expression for the W_{net} function that can be used in the present model. Such an integration is quite complex and does not appear to have been done yet for waves in water of shallow and intermediate depth, an indirect approach must be used to determine the expression for W_{net} in the present model.

The expression for W_{net} was derived by requiring the solution of the conservation of wave action equation to approximately reproduce the wave-height spatial growth expressions in the current SPM when the conditions arise for which the SPM expressions are valid. These conditions are:

- a. Time dependence is absent.
- b. The plant dissipation function E_p is zero.
- c. The stillwater depth d and adjusted windspeed U_A are independent of space and time.
- d. H_{m0} and T are zero at the initial point of the fetch.

The requirement used to determine W_{net} is reasonable since the SPM expressions are widely recognized as good first approximations in situations where conditions a through d hold.

It is possible to derive an expression for W_{net} so that the current SPM wave height growth expressions and curves are reproduced exactly when conditions a through d hold. However, the resulting expression for W_{net} causes numerical problems when substituted into the wave action equation and the latter is numerically solved for H_{m0} . In particular, the expression for W_{net} becomes imaginary when H_{m0} is greater than $H_{m0,\infty}$. Here $H_{m0,\infty}$ is the infinite fetch value of the H_{m0} associated with the value of d and U_A . Since H_{m0} is larger than $H_{m0,\infty}$ in breaking and near-breaking areas, it was not possible to use the model in many areas with significant flooding potential. In addition, W_{net} becomes nearly singular for sufficiently small d and H_{m0} . This near singularity produces very erratic computed values of H_{m0} and T . To eliminate these numerical problems, a new parameterized form of the current SPM wave-height growth expression was devised and used to derive an expression for W_{net} .

In the current SPM, the expression for H_{m0} is given by

$$H_{m0} = \alpha_h \left(\frac{U_A^2}{g} \right) \beta_h \tanh q^m \quad (21)$$

where

$$\alpha_h = 0.283$$
$$\beta_h = \tanh \left\{ \gamma_h \left(\frac{gd}{U_A^2} \right)^{0.75} \right\} \quad (22)$$

$$\gamma_h = 0.53$$

$$m_h = 0.5$$

$$q = \left(\frac{\sigma_h}{\beta_h} \right)^{\frac{1}{m_h}} \left(\frac{gx}{U_A^2} \right) \quad (23)$$

x = fetch

$$\sigma_h = 0.00565$$

$$U_A = 0.589U^{1.23} = \text{"adjusted" windspeed}$$

U = wind speed (statute miles per hour)

The factor 0.589 relating U_A to $U^{1.23}$ accounts for the variation of the windstress coefficient with windspeed. U includes the effects of air-sea temperature difference. If U is derived from an observed windspeed, U also includes corrections to account for the location of the observation point compared to the overwater location where the wave calculation is being done.

An alternative, approximate form of Equation 21 can be derived by approximating $\tanh q^{m_h}$ by $(1-e^{-q})^{m_h}$, i.e., by replacing Equation 21 with

$$H_{m0} = \alpha_h \left(\frac{U_A^2}{g} \right) \beta_h (1 - e^{-q})^{m_h} \quad (24)$$

It can be shown that $(1 - e^{-q})^{m_h}$ differs from $\tanh q^{m_h}$ by no more than 4.8 percent for $m_h = 0.5$. Because this difference appears to be less than the scatter in the data used to construct Equation 21, Equation 24 is an equally valid and convenient alternative to the wave growth equation (Equation 21).

In order to obtain the expression for V_{nat} , we need to first evaluate the term $\frac{\partial(H_{m0})^2}{\partial x}$ under conditions for which the SPM expression for H_{m0} holds. Assuming for the moment that d and U_A are constant, and that H_{m0} is zero when x is zero, from Equation 24,

$$\frac{\partial(H_{m0})^2}{\partial x} = \left(\frac{U_A}{g} \right)^2 (\alpha_h \beta_h)^2 e^{-q} \frac{\partial q}{\partial x} \quad (25)$$

e^{-q} can be expressed as, from Equation 24,

$$e^{-q} = 1 - \left[\frac{H_{m0}}{\left(\frac{U_A^2}{g}\right) \alpha_h \beta_h} \right]^{\frac{1}{\beta_h}} \quad (26)$$

and from Equation 21

$$\frac{\partial q}{\partial x} = \left(\frac{\sigma_h}{\beta_h}\right)^{\frac{1}{\beta_h}} \left(\frac{g}{U_A^2}\right) \quad (27)$$

From Equation 24, as x approaches infinity,

$$H_{m0} = H_{m0,\infty}$$

where

$$H_{m0,\infty} = \left(\alpha_h \beta_h\right) \frac{U_A^2}{g} \quad (28)$$

Substituting Equations 26, 27, and 28 into Equation 25, and rearranging, the following expression is obtained:

$$\frac{\partial(H_{m0})^2}{\partial x} \Big|_{SPM} = (\sigma_h \alpha_h)^2 \frac{U_A^2}{g} \left\{ 1 - \left(\frac{(H_{m0})_{SPM}}{H_{m0,\infty}} \right)^2 \right\} \quad (29)$$

where the subscript "SPM" means evaluated using the reparameterized SPM formula, Equation 24.

Defining $\left(\frac{16}{\rho g}\right) W_{net} T$ as I_{net} Equation 20, the input factor I_{net} is given by

$$I_{net} = (C_g T)(\sigma_h \alpha_h)^2 \frac{U_A^2}{g} \left\{ 1 - \frac{(H_{m0})_{SPM}^2}{(H_{m0,\infty})^2} \right\} + (H_{m0})_{SPM}^2 T_6 S_{in} \quad (30a)$$

with

$$W_{net} = \frac{\rho g I_{net}}{16 T} \quad (30b)$$

Equations 30a and 30b give the expression for the wind input function (W_{net}) when marsh grass is absent and the 100-year stillwater depth (d) and adjusted windspeed (U_A) are constant and H_{m0} is zero at the beginning of the fetch. Since these equations do not involve the fetch distance (x) explicitly, they are also valid for situations where H_{m0} is nonzero at the beginning of the fetch.

When d and U_A are "slowly varying" with x , and H_{m0} is not zero at the beginning of the fetch, it is expected that Equations 30a and 30b, as a function of d , U , and H_{m0} , should still be a good approximate expression for W_{net} . It is also expected that these equations should be satisfactory when the energy dissipation due to marsh grass is modest, i.e., E_p is not very large. However, when the

dissipation due to marsh grass is strong, i.e., E_p is large, it is expected that Equations 30a and 30b may not be a good approximation for W_{net} under some circumstances. Nevertheless, because a better representation of W_{net} does not exist for shallow as well as deep areas, Equations 30a and 30b are assumed to be a valid approximate representation (as a function of U , d , and W_{net}) under all circumstances. Therefore Equations 30a and 30b with $H_{m0|SPM}$ replaced by H_{m0} is used in the present model to calculate W_{net} for all H_{m0} .

2.1.4 Plant-Induced Wave Energy Dissipation (E_p)

The wave energy dissipation through marshes is mainly the result of the drag force generated between the marsh plant and the wave current. The total energy dissipation through a predetermined marsh grass transect segment is also a function of the plant density within the segment and the individual plant geometry. In this section, the formulation of the wave energy dissipation E_p is summarized in terms of individual components that contribute to the total energy dissipation. For a detailed derivation and description of this concept, refer to References 2 and 12.

2.1.4.A. Density and Geometry of Marsh Plants

A transect segment containing marsh plants can be considered as a rectangular "swath" of ground. Within a swath, marsh grass usually grows in individual "patches" or "zones" (see Figure 1). Each patch may contain one or more plant types. To represent the relative areal extent of each plant type in a marsh grass transect swath, the parameter F_{cov} is used. For each species, F_{cov} is defined as the ratio of total patch area for that species to the total swath area for the transect segment (References 2 and 12).

Another parameter, N , is used for each plant type in a given transect segment to represent the average number of plants per square foot in a typical patch. F_{cov} and N for each plant type are related as shown below:

$$\text{Number of plants in segment} = (F_{cov})(N)(\text{area of segment swath}) \quad (31)$$

To produce realistic wave-marsh grass interactions, a detailed schematization must be developed for the marsh plant geometry. Each plant is assumed to consist of an "inflorescence," the flowering head; a "mainstem," the stem below the inflorescence; an "inflorescence stem," the part of the stem at the center of the inflorescence; and the leaves (see Figure 2). The leaves consist of cylindrical and flat parts. The cylindrical parts of all leaves essentially lie on the same plane, the unflexed "leaf plane," when the plants are erect. The

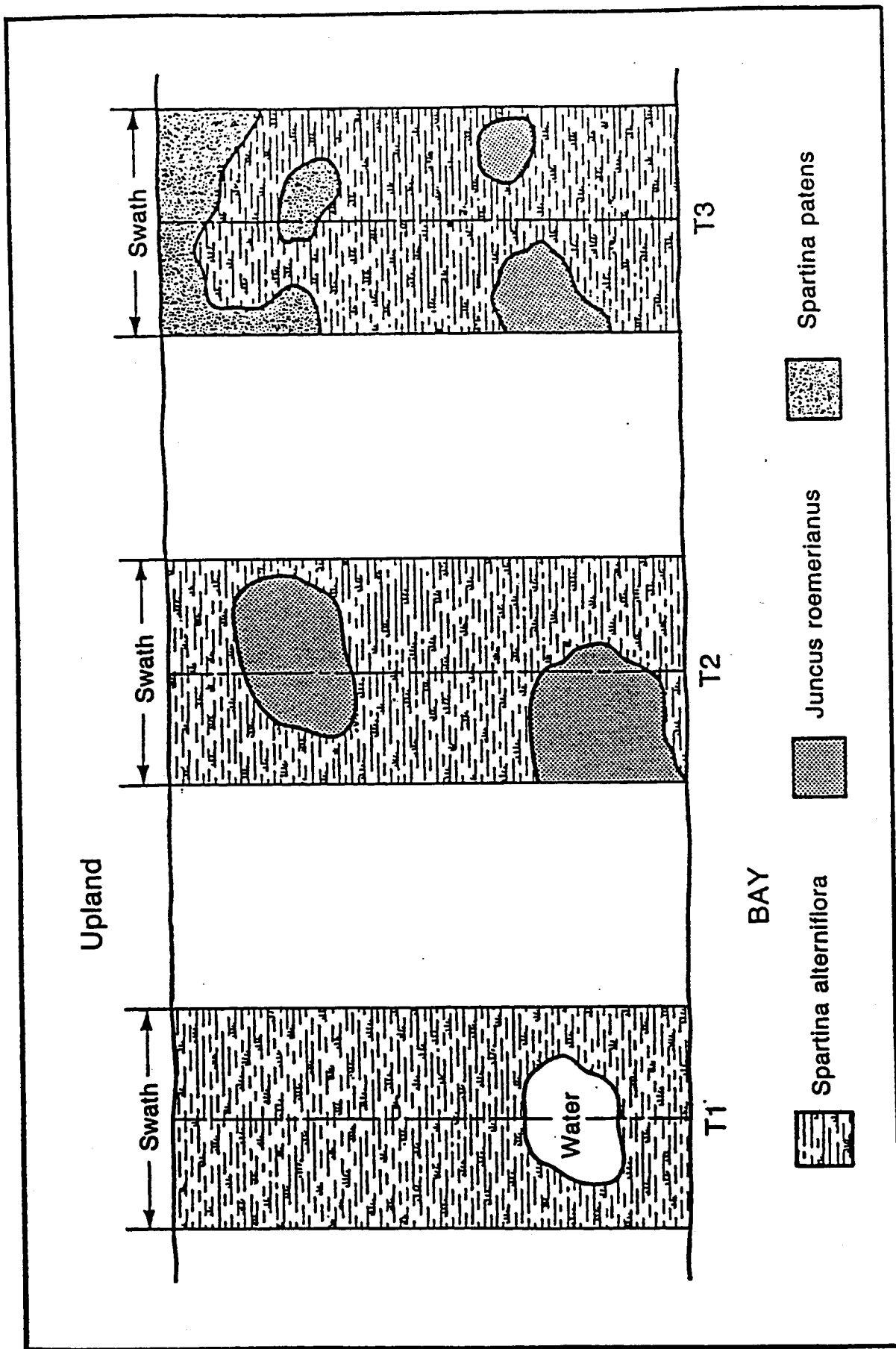


FIGURE 1. Three Examples of Ground Cover Variation Within Transect Swaths.

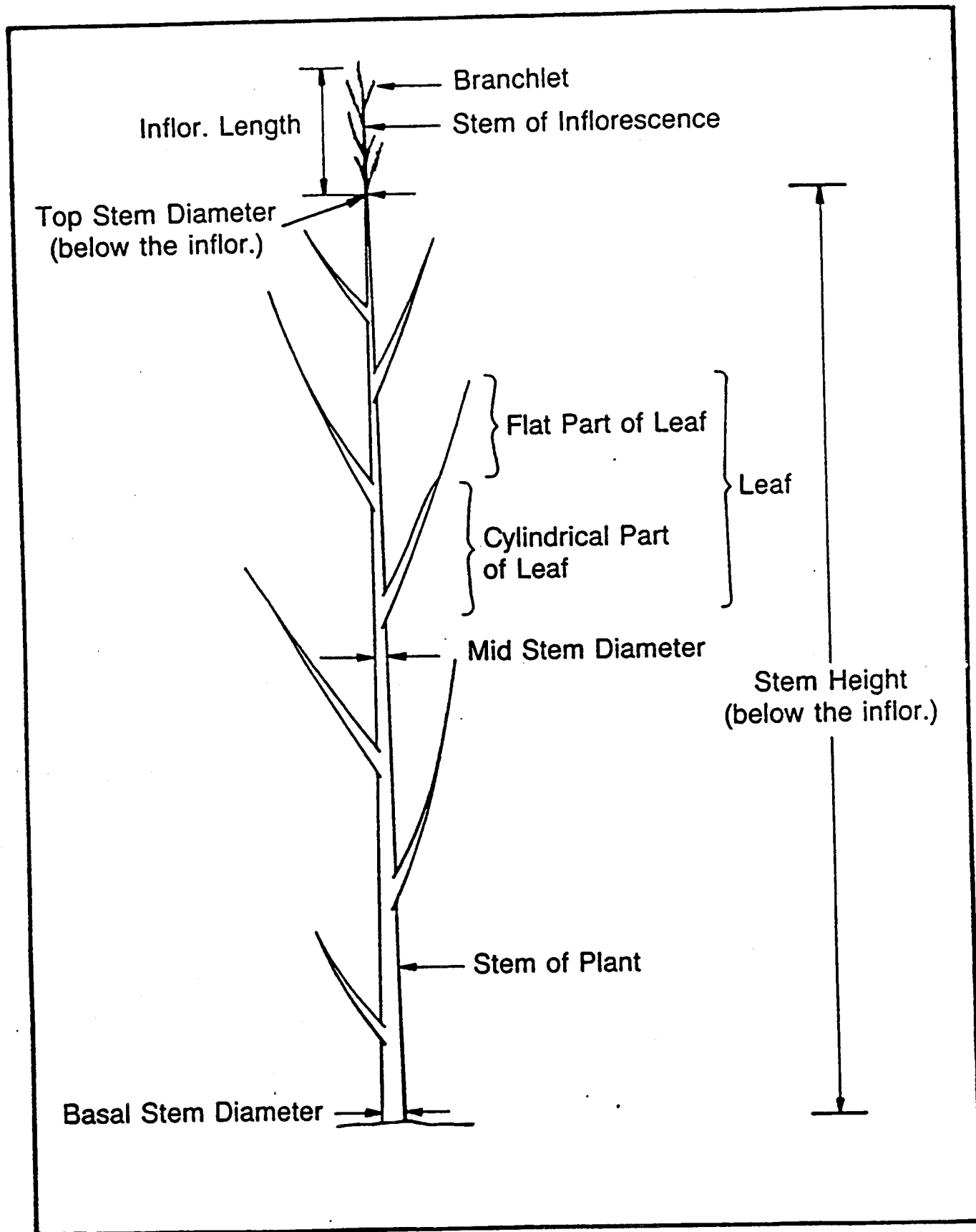


FIGURE 2. Schematic Diagram of Marsh Grass Plant Geometry.

inflorescence consists of discrete "branchlets" growing symmetrically from the stem. Field observation indicates that there is no preferred horizontal orientation for the leaf plane or the inflorescence branchlets.

2.1.4.B. Formulation of E_p

The plant energy dissipation E_p is the energy dissipated by marsh plants per second/square foot of ground area at a given point on a transect segment, which is averaged in time over a local spectral peak wave period T and in space over a rectangular ground area a_g surrounding the point. The ground area a_g , assumed to contain A_g square feet with $A_g > 1$, is referred to as the "averaging ground area" or just "averaging area." The averaging area is assumed to be large enough to contain many marsh plants of the various types found in the transect segment swath but small enough that the zero moment wave height (H_{m0}) does not change significantly within the area.

To calculate E_p , it is necessary to use a "plant statistical mechanics approach." This approach consists of summing and averaging the contributions to E_p from individual plants in the averaging ground area surrounding the arbitrary point on the transect segment. Use of a "plant statistical mechanics approach" is necessary because the contributions to E_p from an individual plant is a strong function of "leaf plane" orientation and inflorescence branchlet orientation of

the plant, and those change randomly from plant to plant. Since so few plants have an inflorescence, the effect of the inflorescence on wave energy dissipation is disregarded.

Let the value of E_p for the j^{th} member of the i^{th} plant type in the averaging ground area a_g be designated $E_{i,j}$. The range of a subscript j varies from plant type to plant type (i.e. depends on i) and is given by $1 < j < n_i$ where n_i is the number of "type i plants" in the averaging ground area a_g and the "plant type index" fulfills $1 < i < N_{p1}$. Here N_{p1} is the number of plant types in the transect segment assumed to be the same as the number of plant types in the averaging area A_g . The factor n_i is given in terms of averaging area size A_g and numerical density of type i plants N_i by

$$n_i = (N_i) (A_g) \quad (32)$$

Summing the energy dissipation per plant $E_{i,j}$ over the N_{p1} plant types and the individual plants in the averaging ground area, dividing the result sum by A_g , and simplifying, the plant dissipation function (E_p) is expressible as

$$E_p = \sum_{i=1}^{N_{p1}} (F_{cov,i})(N_i)E_i \quad (33)$$

where the following average has been introduced

$$E_i = \left(\frac{1}{n_i} \right) \sum_{j=1}^{n_i} E_{i,j} \quad (34)$$

and Equation 32 has been used to eliminate n_i in Equation 33 in favor of the number density N_i .

By definition, the time-average energy dissipation per plant ($E_{i,j}$) is given by the following double integral:

$$E_{i,j} = \left(\frac{1}{T} \right) \int_0^T \int_0^{h_i^*} | (F_{i,j})(u) | dz dt \quad (35)$$

where

z = elevation of some arbitrary point on a marsh plant, reference local ground elevation z_0 (positive values refer to values above ground)

F = instantaneous horizontal drag force (at elevation z), per unit of water depth, acting on a marsh plant in the averaging ground area A_g

$F_{i,j}$ = value of F for the j^{th} member of the i^{th} plant type in the averaging ground area A_g

h_i^* = h_i ; if $h_i \leq (d + \eta)$ i.e. plants submerged
 = $(d + \eta)$; if $h_i > (d + \eta)$ i.e. plants exposed

- $(d + \eta)$ = time-varying water depth
 η = Wave crest elevation references to the stillwater floodlevel (including wave setup)
 h_i = time varying stem top elevation of type "i" plants in the averaging ground area A_g
 u = horizontal current velocity produced by the waves at a given point in space and time above the averaging ground area A_g

The storm surge induced current is assumed to be negligible compared to the maximum value of wave induced current U at a given location.

2.1.4.C. Specification of Drag Forces

The product of drag force $(F_{i,j})$ and current velocity (u) in Equation 35 for $(E_{i,j})$ represents the instantaneous energy dissipated per second per unit depth of water by a marsh plant. The drag force per plant $(F_{i,j})$ is assumed to be caused by "profile drag" and can therefore be expressed as

$$F_{i,j} = 0.5 \rho C_D D'_{i,j} |u| u \quad (36)$$

where ρ is the water mass density, C_D is the "local drag coefficient," assumed to be 1.0, D' is the "local effective diameter" at elevation z of a marsh plant in the averaging ground area, and $D'_{i,j}$ is the value of D' for the j^{th} member of the i^{th} plant type in the averaging ground area. The contribution to the drag force

$$\begin{aligned}
R\cosh_1 &= \cosh[(k)(h_1^*)] / \cosh[kd] ; \text{ if } d \geq h_1^* \\
&= 1.0 && ; \text{ if } d < h_1^*
\end{aligned}
\tag{41}$$

$$\chi = (k x) - (\Omega t) = \text{wave phase} \tag{42}$$

$$k = (2 \pi) / L = \text{wave number of waves at spectral peak} \tag{43}$$

$$\Omega = (2 \pi) / T = \text{circular frequency of waves at spectral peak} \tag{44}$$

Substituting the equations for drag force per plant ($F_{1,j}$), rearranging and simplifying, it is seen that $E_{1,j}$ can be expressed as

$$E_{1,j} = (f_{1,j}) (H_{m0})^3 \tag{45}$$

where

$$f_{1,j} = \frac{1}{2\sqrt{2}} \frac{\rho}{12\pi} g^3 \left(\frac{T}{L}\right)^3 \left(\frac{C_D}{4}\right) G_{1,j} \tag{46}$$

$$G_{1,j} = \left(\frac{6\pi}{T}\right) \int_0^{T/2} (R\cosh_1)^3 \left[\int_0^{h_1^*} D'_{1,j} \left(\frac{z}{h_1^*}\right)^3 dz \right] \cos^3 \chi dt \tag{47}$$

Substituting the expressions for $E_{1,j}$, $f_{1,j}$, and $G_{1,j}$ into Equation 34 for E_1 , the resulting equation for E_1 into Equation 33 for E_p . rearranging and simplifying, it is found that the expression for the plant dissipation function E_p can be written as

$$E_p = (f_p) (H_{m0})^3 \quad (48)$$

where

$$f_p = \frac{1}{2\sqrt{2}}(\rho g) \left(\frac{\Omega}{12\pi} \right) \quad (49)$$

$$\Gamma = \sum_{i=1}^{N_{pl}} (F_{cov,i}) (C_{D,i}) (AW)_i (N_i) (F_{3,i}) \quad (50)$$

$$F_{3,i} = g^2 (T/L)^3 (rcosh_1)^3 \quad (51)$$

$$\begin{aligned} rcosh_1 &= [\cosh(0.5 k h_1)] / \cosh(k d); \quad d > (0.5h_1) \\ &= 1.0 \quad ; \quad d \leq (0.5h_1) \end{aligned} \quad (52)$$

$(AW)_i$ = average "wetted" frontal area per unflexed plant
for the i^{th} plant type in the marsh grass segment

$$(AW)_i = \frac{1}{N_i} \sum_{j=1}^{N_i} \left(\int_0^{h_i^*} (D'_{i,j}) dz \right)_{\text{plant unflexed}} \quad (53)$$

and N_{p1} is the number of plant types in a marsh grass segment, $F_{cov,i}$ is the coverage parameter for the i^{th} plant type in the marsh grass segment (i.e. the fraction of the segment covered by the i^{th} plant type), $C_{D,i}$ is the effective drag coefficient for the i^{th} plant type in the segment, N_i is the "number density" for the i^{th} plant type in the segment (i.e. the number of plants per square foot), and h_i is the stem height (i.e. "main stem height") of an unflexed type "i" plant in the averaging ground area. The equation for effective drag coefficient $C_{D,i}$ is extremely complex and is given in Procedures for Determining Wave Heights in Flood Marshes (Reference 12).

2.1.4.E. Evaluation of Wetted Frontal Area per Unflexed Plant ((Aw)_i)

Before the above expression for $(Aw)_i$ can be evaluated, the local effective plant diameter ($D'_{i,j}$) must be specified for a plant in the unflexed state. Since the geometry of marsh grass is relatively sophisticated, the expression for $D'_{i,j}$ is relatively complicated and the evaluation of $(Aw)_i$ is quite tedious. The derivation of

expressions for $D'_{i,j}$ and $(Aw)_i$ is found in Procedures for Determining Wave Heights in Flood Marshes (Reference 12).

The final expression for $(Aw)_i$ is shown in that report to be

$$(Aw)_i = (Aw_s)_i + (2/\pi) (Aw_1)_i \quad (54)$$

where

$$\begin{aligned} (Aw_s)_i &= [(D_1)_i + [(D_2)_i - (D_1)_i]] (d); d \leq (h_i/2) \\ &= (1/4) [(D_1)_i + (D_2)_i] (h_i) + (D_2)_i (h_i) [(d/h_i) - 0.5] \\ &\quad + [(D_3)_i - (D_2)_i] [(d/h_i) - 0.5] z; \quad (h_i/2) < d \leq h_i \\ &= (A_s)_i \quad ; h_i < d \end{aligned} \quad (55)$$

$$(A_s)_i = (1/4) [(D_1)_i + (2)(D_2)_i (D_3)_i] (h_i) \quad (56)$$

$$(Aw_1)_i = (A_1)_i (d/h_i); d \leq h_i = (A_1)_i \quad ; d > h_i \quad (57)$$

$$(A_1)_i = (CA_p)_i (A_s)_i \quad (58)$$

and $(D_1)_i$ is the base stem diameter for plant type "i" in the averaging ground area, $(D_2)_i$ is the analogous diameter at the

midpoint of the "main stem" (the stem below the inflorescence), $(D_3)_i$ is the analogous diameter at the top of the main stem just below the inflorescence, and $(CA_b)_i$ is the value of the constant CA_b for plant type i . Equation 58 defines CA_b for the i^{th} plant type. Values of the three stem diameters and the CA_b parameter have been determined for the most common marsh grass species found along the Atlantic and Gulf coasts and are given in Procedures for Applying Marsh Grass Methodology (Reference 2) and Procedures for Determining Wave Heights in Flood Marshes (Reference 12).

2.1.4.F. Effective Drag Coefficient ($C_{D,i}$)

It is shown in an appendix to Reference 12 that $C_{D,i}$ ranges between approximately 0.069 and 0.25 for marsh grass plant types of interest to FEMA under various conditions of flexure. Focusing attention on only those situations where the flexing is near a maximum and ignoring "outlier" values of $C_{D,i}$, it is also shown in that appendix that $C_{D,i}$ ranges between approximately 0.069 and 0.121 for these same plant types. FEMA is primarily interested in the maximum flexure and near-maximum flexure situations associated with hurricane waves. Therefore, the expected range of $C_{D,i}$ for these situations, excluding "outlier" values, is 0.069 to 0.121. At present, our knowledge of plant flexure physics does not appear to warrant using anything other than a constant $C_{D,i}$. Consequently, the value of $C_{D,i}$ adopted by FEMA for all marsh grasses is the mean value of

this range after rounding, namely,

$$C_{D,i} = 0.1 \quad (59)$$

This value is also supported by estimates of $C_{D,i}$ from equivalent Manning's "n" values for steady uniform flow through marsh grass (Reference 12).

2.2 NUMERICAL SOLUTION SCHEME

A. Finite Difference Equation

Inserting Equation 30d (for the wind energy input) and Equation 48 (for the wave energy dissipation due to vegetation) into Equation 20 (the approximate conservation of wave action equation) and rearranging, we have

$$\begin{aligned} (C_g T) \frac{\partial (H_{m0})^2}{\partial x} + (H_{m0})^2 \left(T_4 \frac{\partial d}{\partial x} + T_5 d^{-1/2} \frac{\partial d}{\partial x} + (C_g T) (\sigma_h \alpha_h)^2 \frac{(U_A)^2}{g(H_{m0,-})^2} \right) \\ = (C_g T) (\sigma_h \alpha_h)^2 \frac{(U_A)^2}{g} - \left(\frac{16}{\rho g} \right) (f_p) T (H_{m0})^3 \end{aligned} \quad (60)$$

Note that the term $(H_{m0})^2 T_6 S_{in}$ has cancelled out. Letting $R = (H_{m0})^2$ and rearranging Equation 60, we have

$$\frac{\partial R}{\partial x} + R \left(T_7 \frac{\partial(d^{1/2})}{\partial x} + T_8 \frac{\partial(\ln d)}{\partial x} + b + cH_{m0} \right) = a \quad (61)$$

where

$$a = (\sigma_h \alpha_h)^2 \frac{(U_A)^2}{g} \quad (62)$$

$$b = \left(\frac{\sigma_h}{\beta_h} \right)^2 \frac{g}{(U_A)^2} \quad (63)$$

$$c = \left(\frac{16}{\rho g} \right) \frac{f_p}{C_g} \quad (64)$$

$$T_7 = \frac{2T_4 d^{1/2}}{C_g T} \quad (65)$$

$$T_8 = \frac{T_5 d^{1/2}}{C_g T} \quad (66)$$

This is the first-order differential equation to be solved for H_{m0} . All symbols in Equations 62 to 66 have been previously defined. The factors a , b , c , T_7 , and T_8 are functions of stillwater depth d , spectral peak wave period T , adjusted wind speed U_A , wave group velocity C_g , and the plant characteristics. In Equation 61, a accounts for wind energy input to the waves and wave-

wave interactions, b for wave energy dissipation due to whitecapping and bottom friction, c for wave energy dissipation due to marsh plants, and T_7 and T_8 for wave energy changes due to "shoaling" (i.e. due to spatial changes in the group velocity).

Equation 61 is solved using a combined analytic-finite difference numerical method. A transect segment for an inland or overwater fetch (IF or OF Cards) or containing marsh grasses (VH Card) is divided into one-dimensional grid cells of variable length. A grid point is at the boundary of each cell. The WHAFIS program solves Equation 61 for H_{m0} at the j^{th} grid point based on the value of H_{m0} at the $(j-1)^{\text{th}}$ grid point as shown in Figure 3. This computation is done for all grid points in the segment. Grid point $j=1$ corresponds to the beginning of the segment. The grid cell lengths are automatically set by WHAFIS in a manner explained in Section 2.2E.

The adjusted windspeed U_A is assumed to be a constant in an IF, OF, or VH transect segment. In the present WHAFIS program, the windspeed U is either 60 statute miles/hour (IF fetch segments and VH segments) or 80 statute miles/hour (OF fetch segments). U_A is related to U by $U_A = 0.589 U^{1.23}$ where U is in statute miles/hour. Therefore U_A takes on the value appropriate to the U_V value in a particular IF, OF, or VH segment.

Equation 61 may be rewritten as

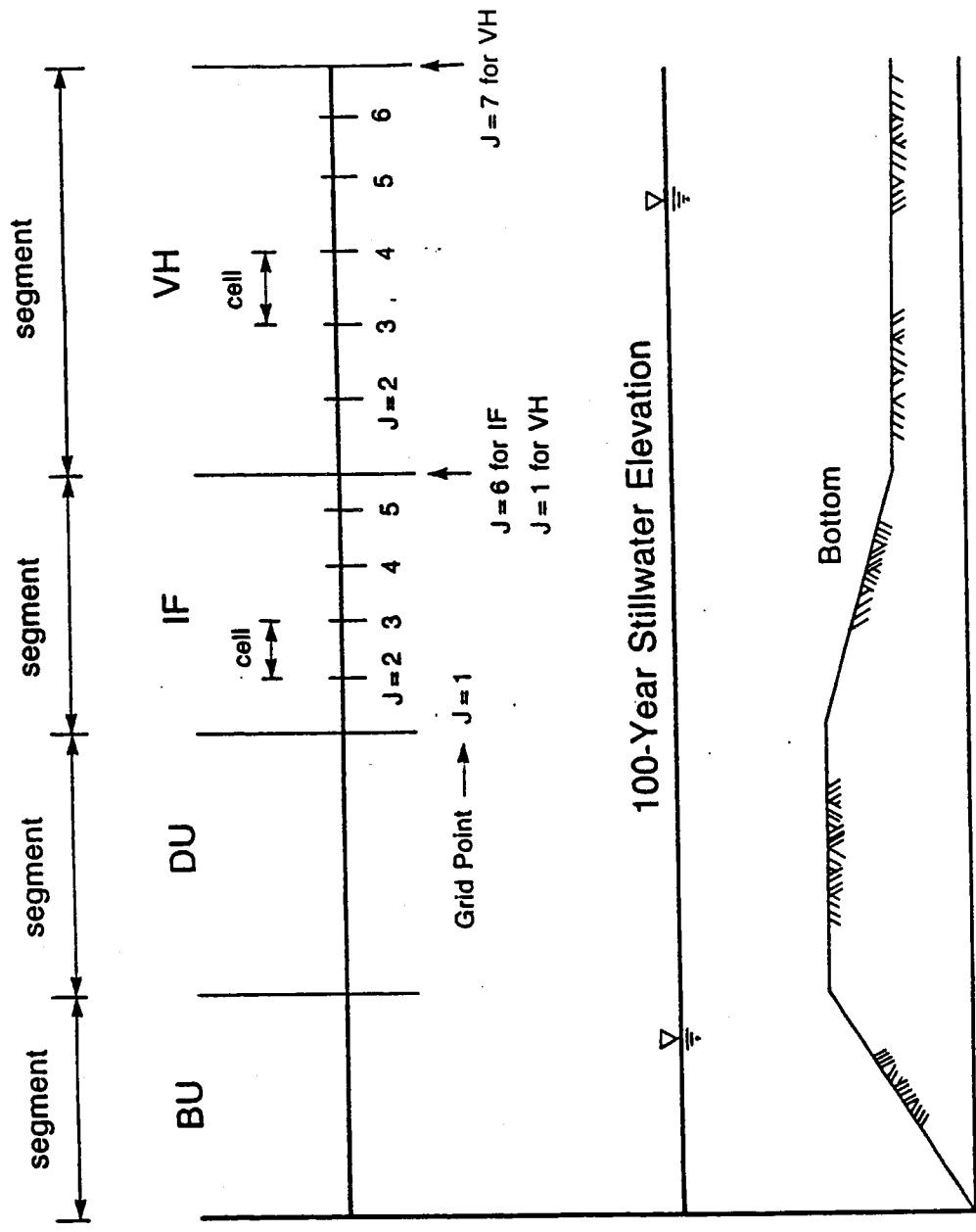


FIGURE 3. Finite Difference Grid for WHAFIS.

$$\frac{\partial R}{\partial x} + YR = a \quad (67)$$

where

$$Y = T_7 \frac{\partial(d^{1/2})}{\partial x} + T_8 \frac{\partial(\ln d)}{\partial x} + b + cH_{20} \quad (68)$$

Equation 67 is a first-order differential equation which can be solved analytically between grid points x_{j-1} and x_j by using the integrating factor.

$$\exp \left\{ \int_{x_{j-1}}^x Y dx \right\} \quad (69a)$$

Multiplying Equation 67 by Equation 69a and rearranging, it is found that Equation 67 can be rewritten as

$$\begin{aligned} \frac{\partial}{\partial x} \left(R \exp \left[\int_{x_{j-1}}^x Y dx \right] \right) \\ = a \exp \left[\int_{x_{j-1}}^x Y dx \right] \end{aligned} \quad (69b)$$

Integrating 69b from x_{j-1} to x_j within a grid cell of length

(Δx)

$$R_j \exp \left[\int_{x_{j-1}}^{x_j} Y dx \right] - R_{j-1} = a \int_{x_{j-1}}^{x_j} \exp \left[\int_{x_{j-1}}^{x'} Y dx' \right] dx'$$

or

$$R_j = R_{j-1} \exp \left[- \int_{x_{j-1}}^{x_j} Y dx \right] + a \exp \left[- \int_{x_{j-1}}^{x_j} Y dx \right] \int_{x_{j-1}}^{x_j} \exp \left[\int_{x_{j-1}}^{x'} Y dx' \right] dx \quad (70)$$

Evaluating the integration factor on the right side of Equation 70 and

assuming slowly varying wave motion within the grid cell, we have

$$R_j = R_{j-1} \left(\frac{d_{j-1}}{d_j} \right)^{T_8 |_{j-1/2}} \exp \left[-T_7 |_{j-1/2} (d_j^{1/2} - d_{j-1}^{1/2}) - b_{j-1/2} \Delta x \right]$$

$$+ a(\Delta x) \left(\frac{d_{j-1/2}}{d_j} \right)^{T_8 |_{j-1/2}} \exp \left[-T_7 |_{j-1/2} (d^{1/2} j - d_{j-1/2}^1) \right] \left(\frac{1 - \exp \left[-b'_{j-1/2} \Delta x \right]}{b'_{j-1/2} \Delta x} \right) \quad (71)$$

and

$$(H_{m0})_j = (R_j)^{1/2} \quad (72a)$$

This is the finite difference form of $H_{m0}|_j$ where

$$\Delta x = x_j - x_{j-1} \quad (72b)$$

$$b'_{j-1/2} = b_{j-1/2} + c_{j-1/2} H_{m0}|_{j-1} \quad (73)$$

$$b_{j-1/2} = \left(\frac{\sigma_h}{\beta_h |_{j-1/2}} \right)^2 \frac{g}{(U_\Delta)^2} \quad (74)$$

$$c_{j-1/2} = \left(\frac{16}{\rho g} \right) \frac{f_p}{C_g} = \frac{\Gamma_{j-1/2} (\tau_j + \tau_{j-1})}{3 \sqrt{2\pi} (C_g T)_{j-1/2}} \quad (75)$$

and

$$\tau = T^3$$

In Equations 71 through 75, the subscripts j , $j-1$, and $j-1/2$, respectively, denote the value to be determined at grid point j , the value at grid point $j-1$ (known), and the halfway value between j and $j-1$. The variables appear in Equations 71 through 75 and were explained previously. In solving for R_j , these variables were defined previously, based either on values calculated at previous grid point $j-1$ or on the predetermined stillwater elevation and bottom profile. The spectral peak wave period T_j , however, has to be solved using the conservation of waves equation described in Sections 2.1 and 2.1.3. The explicit form of the source term for this equation is derived in Appendix A. The finite difference form of the equation is derived in Appendix B.

B. FEMA's Controlling Wave Height

The zero moment wave height (H_{z0}) is not of direct interest in Flood Insurance Studies. For those studies, the controlling wave height (H_c) is used. H_c is approximately equal to the 1-percent waveheight, i.e., the average height of the highest 1-percent waves. As suggested by the NAS (1977), H_c is related to the significant wave height H_s by

$$H_c = 1.6 H_s \quad (76)$$

H_s , by definition, is the average height of the highest one-third of all waves. In relatively deep water, H_s is approximately equal to H_{m0} . In general, H_s is greater than H_{m0} . The two wave heights can be related (References 2, 11, and 12) to each other. The functional form of the relationship, when the wave is not breaking or just barely breaking, is:

$$H_s = [(R')_{av}] H_{m0} \quad ; \quad H_s \leq H_{sb} \quad (77)$$

where

$$H_{sb} = H_{cb}/1.6 \quad (78)$$

$$H_{cb} = S_b d \quad (79)$$

$$(R')_{av} = \text{smaller value of } R_{av} \text{ and } 1.7 \quad (80)$$

$$R_{av} = 1.477 + (0.477) [(d_0/d)^{0.8557} - 1.0] \quad (81)$$

and $d = d/(g T^2)$, $d_0 = 1.357 \times 10^{-3}$, and S_b , the breaking index for the controlling wave height, is approximately 0.78. Note that H_{sb} and H_{cb} are the breaking wave depth limited values of H_s and H_c respectively.

The value of H_{m0} calculated by equation 72 and H_s by equation 77 are accepted as long as the wave is not breaking, that is, H_s is less than or equal to H_{sb} . When H_s , calculated by equation 77, is greater than H_{sb} , H_s is reset to H_{sb} and H_{m0} a value H_{m0b} consistent with H_{sb} . H_{m0b} and H_{sb} are related to each other by:

$$H_{sb} = (S') H_{m0b} \quad (82)$$

where S' is a multiplicative factor that is a function of stillwater depth and H_{m0b} . S' takes on values ranging from 1.0 to 1.7. The approximate expression for S' is

$$\begin{aligned} S' &= (S')_{ac} && ; 1 \leq (S')_{ac} \leq (R')_{av} \\ &= 1.0 && ; (S')_{ac} < 1.0 \\ &= (R')_{av} && ; (S')_{ac} > (R')_{av} \end{aligned} \quad (83)$$

where

$$\begin{aligned} (S')_{ac} &= (S')_a && ; \epsilon' \leq 2.0 \\ &= (S')_c && ; \epsilon' > 2.0 \end{aligned} \quad (84)$$

$$(S')_a = (S')_{com} - (1.411) \log_{10}(\epsilon') \quad (85)$$

$$(S')_c = (S')_{com} - (.1188) - (1.017) \log_{10}(\epsilon') \quad (86)$$

$$(S')_{\text{com}} = 0.9 + (0.4271)\log_{10}(\bar{d}/\bar{d}_{\text{ref}}) \quad (87)$$

and \bar{d}_{ref} is 5.5722×10^{-5} , ϵ is $H_{m0} / 4 L$, and ϵ' is $\epsilon/0.002$. Equation 82 must be solved for H_{m0b} as a function of H_{sb} and spectral peak wavelength (L). The resulting expression for H_{m0b} is in the form of

$$H_{m0b} = (.008) (L) \epsilon^* \quad (88)$$

where ϵ^* fulfills the transcendental equation

$$(\epsilon')_{sb} = (\epsilon^*) [S'(\epsilon^*, \bar{d})] \quad (89)$$

where $(\epsilon')_{sb}$ is given in terms of breaking significant wave height (H_{sb}) and L by $(\epsilon')_{sb} = H_{sb}/(.008 L)$, and $S'(\epsilon^*, \bar{d})$ is the S' function defined by Equations 83 through 87 with ϵ' replaced by ϵ^* . Symbolically, S' is written in the transcendental equation as a function of the two arguments ϵ^* and \bar{d} to emphasize its dependence on these two parameters. The transcendental equation for ϵ^* is solved by an iterative procedure that is explained in detail in Procedures for Determining Wave Heights in Flood Marshes (Reference 12).

C. Initial Value of H_{m0}

An initial value of H_{m0} at the beginning of the IF, OF, or marsh grass segment is needed for the numerical scheme to solve Equations 71 and 72. However, such a value is not immediately available from the computations done before the segment. Instead, an initial value of controlling wave height (H_c) is available at the beginning of the segment. To generate an initial value of H_{m0} , Equations 76 through 89 are used. First, Equation 76 is solved for H_s in terms of the available value of H_c at the beginning of the segment. Then that value of H_s and Equations 77 through 81 are used to evaluate the initial value of H_{m0} if the wave is not breaking. The resulting expression for H_{m0} is :

$$H_{m0} = H_s / [(R')_{sv}] \quad (90)$$

If the wave is breaking, that is, if the H_s value computed from Equation 76 is greater than H_{sb} , then H_s is reset to H_{sb} , H_c to H_{cb} , and H_{m0} is set equal to H_{m0b} . H_{m0b} is determined by solving Equation 89 and evaluating Equation 88.

D. Wave Crest Elevation η

The National Academy of Science (NAS 1977) recommends approximating η for FISs in terms of controlling wave height H_c by the expression

$$\eta = \mu H_c \quad (91)$$

where $\mu = 0.7$ and η is measured relative to the stillwater elevation. In general, μ is a function of local wave period, stillwater depth, wave height, and bottom slope. It ranges from $\mu = 0.5$ for deepwater waves to almost 1.0 for breaking and near-breaking solitary and coincidental waves. The NAS recommends $\mu = 0.7$ as an average covering the range of conditions of primary interest to FEMA.

The present version of the WHAFIS program uses Equation 91 to calculate η . However, η is measured relative to the effective stillwater elevation, that is, the stillwater elevation which includes the effects of wave setup. WHAFIS does not calculate the wave setup. Rather, it assumes that the wave setup has been externally calculated and included in the stillwater elevation values input to the program.

E. Algorithm to Determine the Grid Cell Length Δx

The grid cell length Δx is automatically set by WHAFIS to efficiently

resolve the non-linear wave height variations within an IF or OF fetch segment or a VH segment.

At the beginning of the segment (see Figure 3), an initial value of Δx is calculated as the smaller of 50 feet or 1/10 the segment length (in feet). This Δx value is designated as Δx_2 since it is associated with calculations for $j=2$, the first grid point inside the segment. The full wave period, wave height, wave crest elevation calculation is then completed for $j=2$.

The value of Δx associated with grid point $j=3$, designated as Δx_3 is then calculated based on the absolute difference between the zero moment wave height values at the beginning and end of the previous grid cell, i.e. on the absolute difference between H_{m0} values at grid point $j=2$ and grid point $j=1$. Let us designate this absolute difference in H_{m0} values as $\text{diffH}(2,1)$. If this absolute difference is between 0.05 feet inclusive and 0.1 feet exclusive, then Δx_3 is unchanged from Δx_2 . If $\text{diffH}(2,1)$ is less than 0.05 feet Δx_3 is increased to twice that of Δx_2 . If $\text{diffH}(2,1)$ is greater than or equal to 0.1 foot, Δx_3 is reduced to half that of Δx_2 . The location (x coordinate) of grid point $j=3$, designated as x_3 is calculated from the value of Δx_3 using $x_3 = x_2 + \Delta x_3$, where x_2 is the location of grid point $j=2$.

The value of Δx for the j^{th} grid point, j greater than 3, is

determined in a manner similar to that for $j=3$. More explicitly, let Δx_{j-1} and Δx_j designate the Δx value for grid points $j-1$ and j respectively, and let $\text{diffH}(j-1, j-2)$ designate the absolute difference between the zero moment wave heights at grid points $j-1$ and $j-2$. The value of Δx_j is determined using the following expression:

$$\begin{aligned} \Delta x_j &= 0.5 (\Delta x_{j-1}) && \text{if } \text{diffH}(j-1, j-2) < 0.05 \text{ feet} \\ &= \Delta x_{j-1} && \text{if } 0.05 \text{ feet} \leq \text{diffH}(j-1, j-2) < 0.1 \text{ feet} \text{ (92)} \\ &= 2.0 (\Delta x_{j-1}) && \text{if } 0.1 \text{ feet} \leq \text{diffH}(j-1, j-1) \end{aligned}$$

The location (x coordinate) of grid point j , designated as x_j , is calculated from the value of Δx_j using $x_j = x_{j-1} + \Delta x_j$ where x_{j-1} is the location of grid point $j-1$.

If the location of grid point j , $j \geq 3$, based on the expression above is beyond the end of the segment, Δx_j is reduced to a value that will bring grid point j exactly to the end of the segment.

2.3 STILLWATER INTERPOLATION

In general, the 100-year stillwater flooding levels change inland from the open coast due to elevated ground, complicated geographic features, and different flooding sources or processes. The stillwaters taken from storm surge joint-probability modeling are the values at the center of a modeled grid cell. A wave height analysis transect commonly extends through more than one grid cell. However, the stillwater surface along a transect must have a gentle slope instead of an abrupt change experienced in the previous versions of the WHAFIS program, unless the new stillwater elevation exists behind high ground. In order to ensure a smooth water-surface profile, an interpolation scheme has been incorporated in the latest version (Version 3.0, dated September 1988) to perform the stillwater elevation interpolation along a transect if the stillwater input changes.

The linear interpolation is performed within a transect segment where the stillwater elevations at each end station differ. This linear interpolation scheme yields new stillwater elevations for stations within the segment. The interpolated stillwater elevation at each station within the segment is then compared with the corresponding ground elevation. If the interpolated stillwater elevation is above the corresponding ground elevation, i.e., without ground cut off, the interpolated stillwater values are used as the stillwater elevations for the computation of wave heights (Figure 4(a)). Otherwise, the

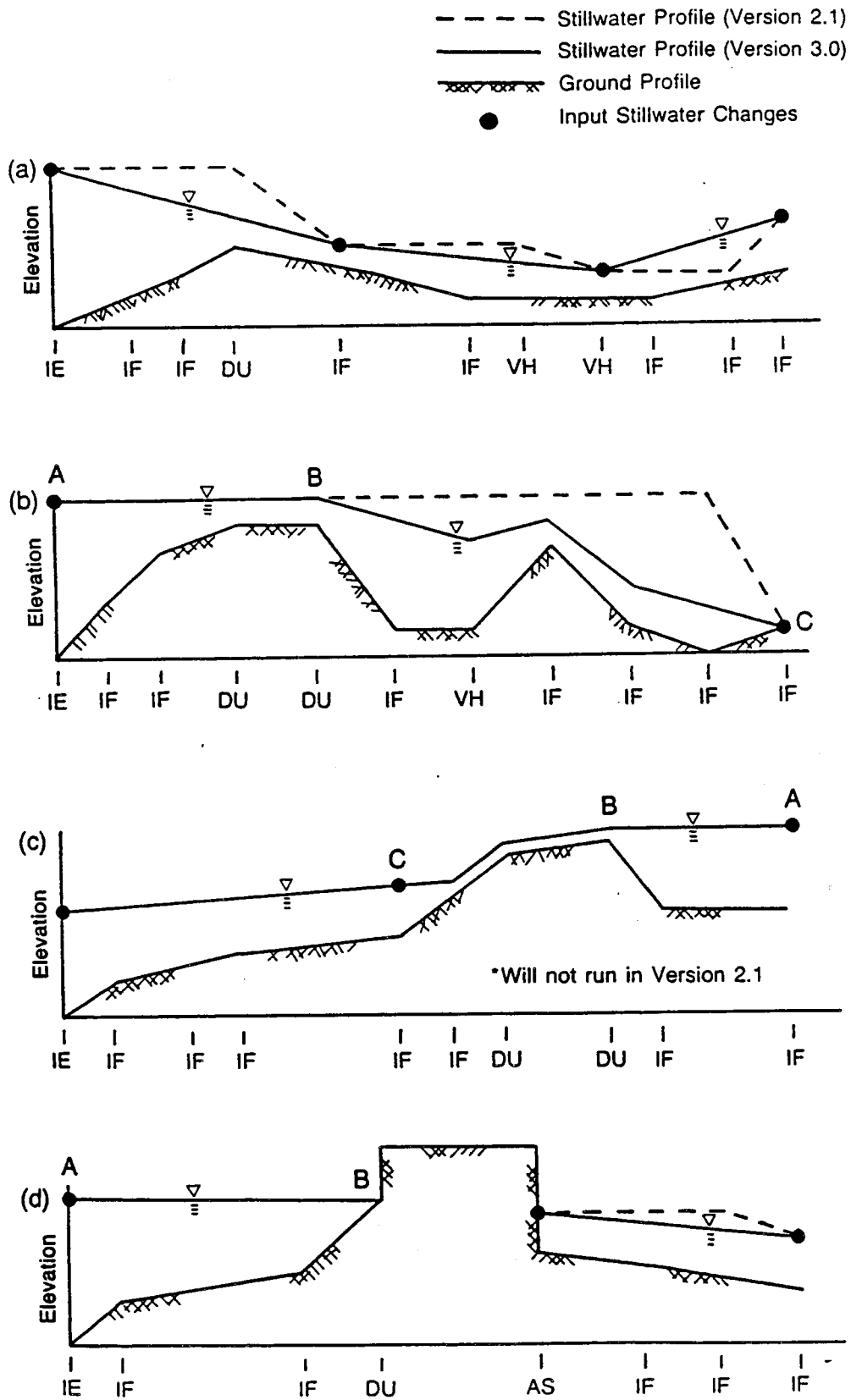


FIGURE 4. Stillwater Interpolation Examples

stillwater elevations will be determined by a method similar to the algorithm used in the FEMA SURGE Model (Reference 16) to determine flow over a barrier. In this method (Figures 4(b) and (c)), the higher stillwater elevation is held equal between the highest ground station (Station B) within the segment and the segment end station with the higher stillwater elevation (Station A). A linear interpolation is then performed within the subsegment between the highest ground station (Station B) and the segment end station with the lower stillwater elevation (Station C), using the given stillwater values at Stations B and C. If the interpolated stillwater elevation at any station in this subsegment is lower than the corresponding ground elevation, the new stillwater elevation at the station is set equal to the greatest of:

- a. The ground elevation plus the water depth at the highest ground station,
- b. The second interpolated value, or
- c. The stillwater elevation at the lower stillwater station in the segment.

This approach not only accounts for the surge flooding hydrodynamics but also resolves, to some extent, the stillwater distribution ambiguity inherent in the geographic discretization of the FEMA SURGE Model. However, note that the linear interpolation does not apply to the situation involving an above surge (AS) card. For that case (Figure 4(d)), the stillwater elevation remains unchanged between the last stillwater elevation input station (Station A) before the AS station and the beginning of the AS segment (Station B).

3. SUMMARY

The methodology revisions implemented in the WHAFIS Model (Version 3.0, dated September 1988) for inland fetch, overwater fetch, and marsh grass segments described in the previous sections are based on the conservation of wave action equation and the conservation of waves equation. These equations approximately reproduce the wave growth curves in the current SPM when the conditions arise for which the curves are valid. The revisions to WHAFIS make it a significantly improved wave model. The conservation of wave action equation and conservation of waves equation describe the wave propagation dynamics of slowly-varying wave motion. The waves associated with overland storm surge flooding fall into this category. The solution scheme involves analytical and finite difference techniques to obtain the wave heights and peak spectral wave period at any location. The scheme is stable and efficient. Finally, the new linear stillwater interpolation routine provides a procedure for obtaining a water-surface profile without abrupt changes for the calculation of wave heights along transects.

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APPENDIX A

DERIVATION OF THE SOURCE TERM IN THE CONSERVATION OF WAVES EQUATION

A.1 INTRODUCTION

The conservation of waves equation is given by Equation 4 in the main body of this report. This equation states that

$$\frac{\partial \Omega}{\partial x} = S \quad (A1)$$

where $\Omega = 2\pi/T$, T is the spectral peak wave period, x is the distance along the transect, and S is the source term.

S is determined in a manner similar to the net wind energy input per unit area W_{net} in the conservation of wave action equation. Below is a summary of the derivation.

A.2 REPARAMETERIZED SPM EXPRESSION FOR T

In order to minimize numerical problems and increase numerical efficiency, a reparameterized form of the SPM expression for T was devised and used to derive an expression for source term S .

The requirement was imposed that any reasonable expression for S produce values of T that differ little from those computed using wave period growth expressions in the current SPM when the following circumstances hold:

- a. The plant dissipation function (E_p), defined in Equation 48 of the main text, is zero.
- b. The stillwater depth d and adjusted windspeed U_A (see right below Equation 23 in main text) are independent of space and time, i.e. are constant.
- c. T and the zero moment wave height H_{m0} are zero at the beginning of the fetch.

In the current SPM, the expression for T is given by

$$T = \alpha_c \left\{ \frac{U_A}{g} \right\} \beta_c \tanh(q_c)^{m_c} \quad (A2)$$

where

$$\alpha_c = 7.54$$

$$\beta_c = \tanh \left\{ \gamma_c \left\{ \frac{gd}{U_A^2} \right\}^{3/8} \right\} \quad (A3)$$

$$\gamma_c = .833$$

$$m_c = 1./3.$$

g = gravitational acceleration

$$q_t = \left\{ \frac{\sigma_t}{\beta_t} \right\}^{1/m_t} \left\{ \frac{gx}{U_A^2} \right\} \quad (A4)$$

$$\sigma_t = .0379$$

$$U_A = 0.589 U^{1.23} = \text{adjusted windspeed}$$

U = windspeed (statute miles per hour)

An alternative approximate form of Equation A2 can be derived by approximating $\tanh(q_t)^{m_t}$ by $(1 - e^{-q_t})^{m_t}$, i.e. by replacing Equation A2 with

$$T = \alpha_t \left(\frac{U_A}{g} \right) \beta_t (1 - e^{-q_t})^{m_t} \quad (A5)$$

Equation A5 is analogous to Equation 24 for H_{m0} in the main text. It can be shown that $(1 - e^{-q_t})^{m_t}$ differs from $\tanh(q_t)^{m_t}$ by no more than 5.8% when $m_t = 1/3$. This reparameterized form of the SPM expression for T is inconvenient to use in practice since it does not explicitly

display the coupling of H_{m0} and T . Such a coupling occurs in the situations encountered in practice (d not constant, plant dissipation function E_p not zero) in FEMA FISSs.

To derive this second alternative "coupled" form of Equation A2, we proceed as follows. Eliminating gx/U_A^2 between Equation 23 of the main text and Equation A4, it is for that q and q_c in these two equations are related by

$$q_c = (v_c)q \quad (A6)$$

where

$$v_c = \left(\frac{\beta_h}{\sigma_h} \right)^{1/m_h} \left(\frac{\sigma_c}{\beta_c} \right)^{1/m_c} \quad (A7)$$

where σ_c , β_c , and m_c have already been defined in this appendix and

$$m_h = 0.5$$

$$\sigma_h = 0.00565$$

$$\beta_h = \tanh \left\{ \gamma_h \left\{ \frac{gd}{U_A^2} \right\}^{0.75} \right\} \quad (A8)$$

$$\gamma_h = 0.53$$

Solving Equation 24 in the main text for e^{-q} in terms of zero moment wave height H_{m0} , we find that

$$e^{-q} = 1 - \left[\frac{H_{m0}}{H_{m0,\infty}} \right]^{1/m_h} \quad (A9)$$

where $H_{m0,\infty}$ is given by Equation 28 in the main text, namely

$$H_{m0,\infty} = \left[\alpha_h \beta_h \right] \frac{U_A^2}{g} \quad (A10)$$

with

$$\alpha_h = 0.283,$$

and all other symbols have been previously defined in this Appendix. Substituting Equation A9 into Equation A6, the following equation for e^{-q_t} results:

$$e^{-q_t} = e^{-v_t q} \quad (A11)$$

Substituting Equation A9 into Equation A11, it is found that

$$e^{-q_t} = \left\{ 1 - \left[\frac{H_{m0}}{H_{m0,\infty}} \right]^{1/m_h} \right\}^{v_t} \quad (A12)$$

Finally substituting Equation A12 into Equation A5, the following equation for T results:

$$T = T_0 \left[1 - \left\{ 1 - \left[\frac{H_{m0}}{H_{m0,c}} \right]^{1/m_h} \right\}^{v_t} \right]^{m_t} \quad (\text{A13})$$

where

$$T_0 = \alpha_t \left[\frac{U_A}{g} \right] \beta_t \quad (\text{A14})$$

Equation A13 is the sought for "coupled" form of the SPM expression for spectral peak wave period T. It along with Equation A5 will be used to determine the source term S in Equation A1.

A.3 CONSTRUCTION OF SOURCE TERMS S_{1n} and S

The term $\frac{\partial \Omega}{\partial x}$ in Equation A1 can be rewritten in terms of T as

$$\frac{\partial \Omega}{\partial x} = - \frac{2\pi}{T^2} \frac{\partial T}{\partial x} \quad (\text{A15})$$

where the definition of Ω in terms of T, namely $\Omega = 2\pi/T$ has been used. Substituting Equation A15 into Equation A1, multiplying through

by $(1/m_t)T^{(1/m_t)-1}$ and introducing τ

where

$$\tau = T^{1/m_t} \quad (A16)$$

Equation A1 becomes

$$\frac{\partial \tau}{\partial x} = S_{in} \quad (A17)$$

where

$$S_{in} = - \frac{[T^{(1/m_t)+1}] S}{2\tau m_t} \quad (A18)$$

defines S_{in} in terms of T and S . Equation A17 is convenient for determining the source term S_{in} . S is then calculated by solving Equation A18 for S in terms of S_{in} giving

$$S = - \frac{(2\tau m_t) S_{in}}{T^{(1/m_t)+1}} \quad (A19)$$

In order to obtain an expression for the source term S_{in} in equation A17, we need to first determine the term $\frac{\partial \tau}{\partial x}$ under conditions for which the expressions for T and H_{m0} hold. Assume for the moment that stillwater depth d and adjusted windspeed

U_A are constant, and that T and hence r are zero when x is zero.

Therefore, from equation A5 and A14

$$\frac{\partial r}{\partial x} = (T_0)^{1/m_t} e^{-q_t} \frac{\partial q_t}{\partial x} \quad (\text{A20})$$

From Equation A4,

$$\frac{\partial q_t}{\partial x} = \frac{g}{U_A^2} \left[\frac{\sigma_t}{\beta_t} \right]^{1/m_t} \quad (\text{A21})$$

Substituting Equations A12 and A21 into Equation A20 and rearranging, the following expression is obtained:

$$\frac{\partial r}{\partial x} |_{\text{SPM}} = \frac{g}{U_A^2} \left[\frac{T_0 \sigma_t}{\beta_t} \right]^{1/m_t} \left\{ 1 - \left[\frac{H_{n0} |_{\text{SPM}}}{H_{n0,0}} \right]^{1/m_h} \right\}^{v_t} \quad (\text{A22})$$

where the subscript "SPM" means using the reparameterized SPM formula.

Using equation A14, the product of the first two terms in Equation A22

becomes

$$\begin{aligned} \frac{g}{U_A^2} \left[\frac{T_\infty \sigma_t}{\beta_t} \right]^{1/m_t} &= \frac{1}{g \left(\frac{U_A}{g} \right)^2} \left[\alpha_t \sigma_t \frac{U_A}{g} \right]^{1/m_t} \\ &= \frac{(\alpha_t \sigma_t)^{1/m_t}}{g} \left(\frac{U_A}{g} \right)^{(1/m_t)-2} \end{aligned} \quad (A23)$$

Substituting Equation A23 into Equation A22, the latter becomes

$$\frac{\partial \tau}{\partial x} \Big|_{SPM} = S_{in}^* \Big|_{SPM} \quad (A24)$$

where

$$S_{in}^* \Big|_{SPM} = \frac{(\alpha_t \sigma_t)^{1/m_t}}{g} \left(\frac{U_A}{g} \right)^{(1/m_t)-2} \left\{ 1 - \left[\frac{H_{m0} \Big|_{SPM}}{H_{m0,\infty}} \right]^{1/m_h} \right\}^{v_t} \quad (A25)$$

Observe that Equation A25 is only valid as long as $H_{m0} \Big|_{SPM}$ is $\leq H_{m0,\infty}$ and τ is $\leq \tau_\infty$ where

$$\tau_\infty = (T_\infty)^{1/m_t} \quad (A26)$$

Thus, it is convenient to define a new function $S_{in}^{**}|_{SPM}$

in terms of $S_{in}^*|_{SPM}$, $H_{m0,\infty}$, and τ_∞ as follows:

$$\begin{aligned} S_{in}^{**}|_{SPM} &= S_{in}^*|_{SPM} \quad \text{if } H_{m0}|_{SPM} \leq H_{m0,\infty} \text{ and } \tau \leq \tau_\infty \\ &= 0 \quad \text{if } H_{m0}|_{SPM} > H_{m0,\infty} \text{ or } \tau > \tau_\infty \end{aligned} \quad (A27)$$

In terms of $S_{in}^{**}|_{SPM}$, the expression for $\frac{\partial \tau}{\partial x}|_{SPM}$ becomes

$$\frac{\partial \tau}{\partial x}|_{SPM} = S_{in}^{**}|_{SPM} \quad (A28)$$

Comparing Equation A28 with Equation A17, it is seen that

$S_{in}^{**}|_{SPM}$ is the expression for the source function S_{in}

when marsh grass is absent, the stillwater depth d and windspeed U are

constant, and spectral peak wave period T (and hence $\tau = T^{1/m_t}$)

is zero at the beginning of the fetch. Since Equation A27 after substituting (Equations A10, A14, A25, and A26) does not involve the fetch distance (x) explicitly, it is valid for situations where T (and hence r) is non-zero at the beginning of the fetch.

When d and U are "slowly varying" with x , T (hence r) is not zero at the beginning of the fetch, and energy dissipation due to marsh grass is modest, i.e. E_p is not very large, it is expected that Equation A27 after substituting (Equations A10, A14, A25, and A26) should still be a good approximation for S_{in} . However, when dissipation due to marsh grass is strong, i.e. E_p is large, it is expected that Equation A27 may not be a good approximation for S_{in} . Nevertheless, because a better representation of S_{in} does not exist for shallow as well as deepwater areas, Equation A27 is assumed to be a valid approximate representation (as a function of U , d , H_{m0}) under all circumstances. Therefore Equation A27 (after substituting Equations A10, A14, A25 and A26) with $H_{m0}|_{SPM}$ replaced by H_{m0} is used in the present model to calculate the source function S_{in} for all H_{m0} . Equation A19 is then used to calculate S .

APPENDIX B

NUMERICAL SOLUTION OF CONSERVATION OF WAVES EQUATION

B.1 FORM OF CONSERVATION OF WAVES EQUATION TO BE SOLVED NUMERICALLY

Equation A1 of Appendix A (hereafter, all equations beginning with an A are from Appendix A), with $\frac{\partial \Omega}{\partial x}$ given by Equation A15 and S given in terms of S_{in} by Equation A19, governs the spectral peak wave period T. However, this equation produces numerical problems when discretized and then solved for small T since $\frac{\partial T}{\partial x}$ becomes unbounded as T approaches zero.

To overcome this numerical problem, it has been found that use of Equation A17 in discretized form leads to a numerically stable, well-behaved calculation of T for the full range of T. Thus the present model solves the following equations numerically for T:

$$\frac{\partial \tau}{\partial x} = S_{in} \quad (B1)$$

where T is determined from τ using

$$T = \tau^m \quad (B2)$$

with $m_t=1/3$, and the source term S_{in} in Equation B1 is given by

$$\begin{aligned}
 S_{in} &= S_{in}^* && \text{if } H_{m0} \leq H_{m0,*} \text{ and } r \leq r_* \\
 &= 0 && \text{if } H_{m0} > H_{m0,*} \text{ or } r > r_*
 \end{aligned}
 \tag{B3}$$

where

$$S_{in}^* = \frac{(\alpha_t \sigma_t)^{1/m_t}}{g} \left(\frac{U_A}{g} \right)^{(1/m_t)-2} \left\{ 1 - \left[\frac{H_{m0}}{H_{m0,*}} \right]^{1/m_h} \right\}^{v_t}
 \tag{B4}$$

$$\alpha_t = 7.54$$

$$\sigma_t = .0379$$

g = gravitational acceleration

$U_A = 0.589 U^{1.23}$ = adjusted windspeed

U = windspeed (statute miles per hour)

$$H_{m0,*} = \left[\alpha_h \beta_h \right] \frac{U_A^2}{g}
 \tag{B5}$$

$$\alpha_h = 0.283$$

$$\beta_h = \tanh \left\{ \gamma_h \left[\frac{gd}{U_A^2} \right]^{0.75} \right\} \quad (B6)$$

$$\gamma_h = 0.53$$

d = stillwater depth

$$m_h = 0.5$$

$$v_t = \left(\frac{\beta_h}{\sigma_h} \right)^{1/m_h} \left(\frac{\sigma_t}{\beta_t} \right)^{1/m_t} \quad (B7)$$

$$\sigma_h = 0.00565$$

$$\beta_t = \tanh \left\{ \gamma_t \left[\frac{gd}{U_A^2} \right]^{3/8} \right\} \quad (B8)$$

$$\gamma_t = .833$$

$$r_t = T_t^{1/m_t} \quad (B9)$$

$$T_t = \alpha_t \left(\frac{U_A}{g} \right) \beta_t \quad (B10)$$

Note that S_{in} is just $S_{in}^{**}|_{SPM}$ in Equation A27, generalized to hold for all H_{m0} , not just the SPM expression for H_{m0} . Similarly, S_{in}^* is

just $S_{in}^*|_{SPM}$ in equation A25 generalized to hold for all H_{m0} .

B.2 NUMERICAL SCHEME

A. Finite Difference Equation

Equation B1 is solved numerically in each IF and OF fetch segment and VH segment using the same grid introduced to solve the conservation of wave action equation. This grid is discussed in the main body of this report (hereafter referred to as the main report) and illustrated schematically in Figure 3 of the report.

The WHAFIS program solves Equations B1 and B2 at the j^{th} grid point in a given transect segment based on the value of H_{m0} and T at the $(j-1)^{th}$ grid point, and the value of stillwater depth d halfway between the j^{th} and $(j-1)^{th}$ grid point. The adjusted windspeed U_A is constant in the segment, as discussed in the main report. The grid cell lengths, i.e. the distance between grid points j and $j-1$, are set in the manner described in the main report.

Integrating Equation B1 from x_{j-1} to x_j within grid cell Δx where

$$\Delta x = x_j - x_{j-1} \quad (B11)$$

$$\tau_j = \tau_{j-1} + \Delta x S'_{in}|_{j-1/2} \quad (B12)$$

and from Equation B2,

$$T_j = (\tau_j)^{m_t} \quad (B13)$$

This is the finite difference form of T_j where

$$\begin{aligned} S'_{in}|_{j-1/2} &= S^+_{in}|_{j-1/2} \quad \text{if } (H_{m0})_{j-1} \leq H_{m0,\infty}|_{j-1/2} \text{ and } \tau_{j-1} \leq \tau_{\infty}|_{j-1} \\ &= 0 \quad \text{otherwise} \end{aligned} \quad (B14)$$

$$S^+_{in}|_{j-1/2} = \frac{(\alpha_t \sigma_t)^{1/m_t}}{g} \left(\frac{U_A}{g} \right)^{(1/m_t)-2} \left\{ 1 - \frac{R_{j-1}}{R_{\infty}|_{j-1/2}} \right\}^{v_t|_{j-1/2}} \quad (B15)$$

$$R_{j-1} \equiv \left[(H_{m0})_{j-1} \right]^{1/m_h} \quad (B16)$$

$$R_{\infty}|_{j-1/2} \equiv \left[H_{m0,\infty}|_{j-1/2} \right]^{1/m_h} \quad (B17)$$

In Equations B12 through B17, the subscripts j , $j-1$, and $j-1/2$, respectively, denote the value to be determined at grid point j , the known value at grid point $j-1$, and the value halfway between j and $j-1$.

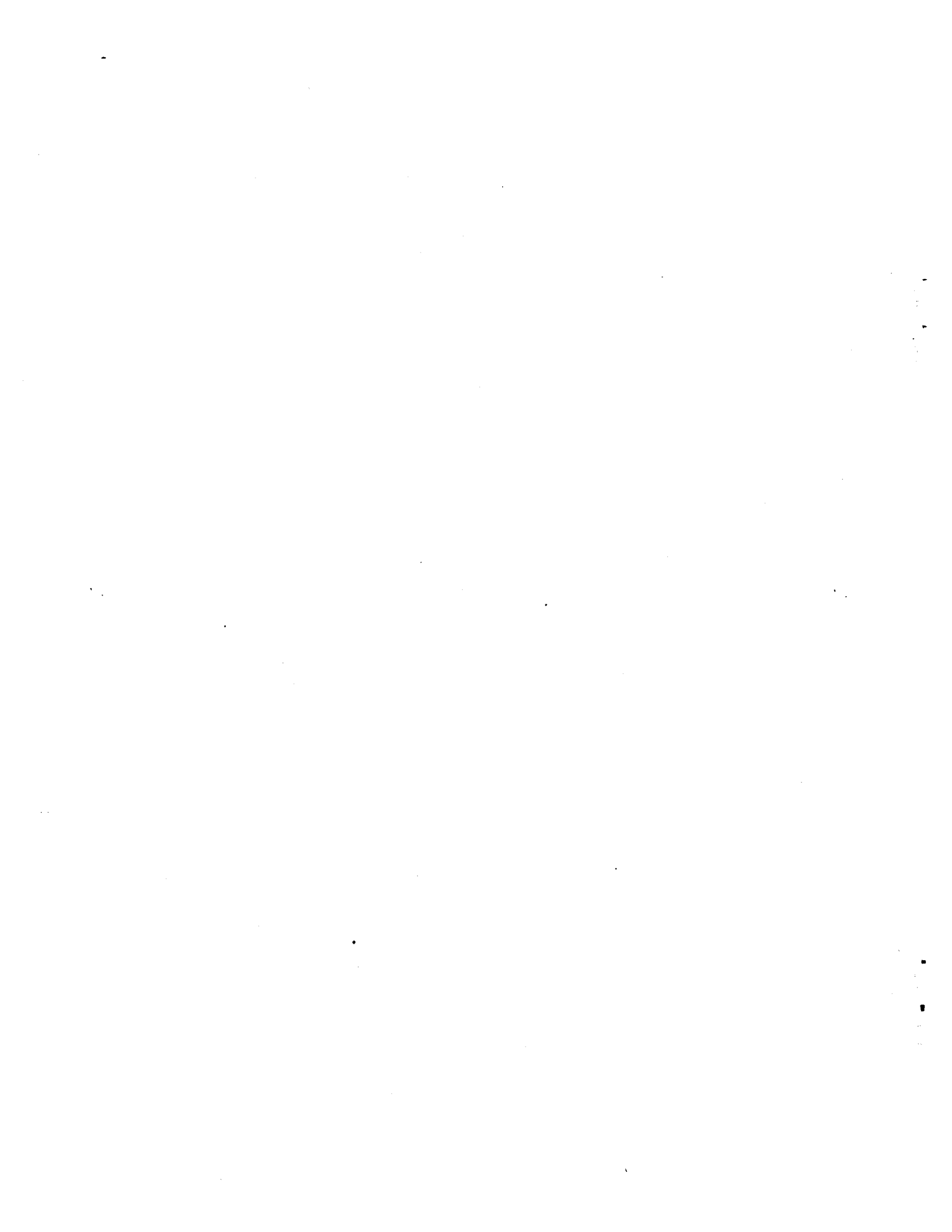
B. Computation Order

Assume that all variables have been calculated for grid point $j-1$ in an IF (inland), or OF (overwater), fetch segment or a VH (marsh grass) segment. To determine variable values at grid point j , the following computation sequence occurs:

1. The grid spacing Δx between grid points $j-1$ and j is determined. This Δx value is then used to determine location x_j of grid point j .
2. τ_j and spectral peak wave period $T_j = (\tau_j)^{0.8}$ are determined using the equations in this appendix.
3. R_j , zero moment wave height $(H_{m0})_j = (R_j)^{2.5}$, controlling wave height

and wave crest elevation $(\eta_c)_j$ are determined using the equations in the main report.

The WHAFIS program executes this sequence for all grid points in the segment. Grid point $j=1$ corresponds to the beginning of the segment.



APPENDIX C PROGRAM LISTING

1 C PROGRAM WHAFIS BY DAVID HARTY, DAMES AND MOORE, OCT. 20, 1980
2 C
3 *****
4 C
5 C FEMA WHAFIS MODEL, VERSION 3.0, SEPTEMBER 1988
6 C
7 C*****
8 C
9 C REVISED AUGUST 14, 1984
10 C
11 C
12 C REVISED AND CORRECTED ON 13 MARCH 1985 AND 22 MAY 1985
13 C BY DR. BARRY E. HERCHENRODER OF GREENHORNE AND O'MARA,
14 C INC., GREENBELT MD., 301-220-1868. THE RESULTING WHAFIS
15 C IS REFERRED TO AS WHAFIS2.1
16 C
17 C REVISED AND CORRECTED FEBRUARY 1987 BY DR. BARRY E. HERCHENRODER
18 C (SAME # AS ABOVE) OF GREENHORNE AND O'MARA, GREENBELT, MARYLAND.
19 C (301-220-1868) OF GREENHORNE AND O'MARA.
20 C REVISED AND CORRECTED FURTHER IN MAY AND JUNE 1987 BY
21 C DR. BARRY E. HERCHENRODER (SAME # AS ABOVE), OF
22 C GREENHORNE AND O'MARA.
23 C THE RESULTING WHAFIS IS REFERRED TO AS WHAFIS3, JUNE 1987.
24 C
25 C REVISED AND CORRECTED IN SEPTEMBER 1988 BY DR. BARRY E.
26 C HERCHENRODER (SAME # AS ABOVE), OF GREENHORNE & O'MARA. THE
27 C RESULTING WHAFIS IS REFERRED TO AS FEMA WHAFIS MODEL, VERSION 3.0,
28 C SEPTEMBER 1988.
29 C
30 C //////////////////////////////////////
31 C
32 C WAVE HEIGHT ANALYSIS FOR FLOOD INSURANCE STUDIES (WHAFIS) IS
33 C A PROGRAM WRITTEN TO ANALYZE THE DISSIPATION AND REGENERATION
34 C OF WIND WAVES ASSOCIATED WITH THE 100-YEAR STORM IN COASTAL AREAS.
35 C THE METHODOLOGY USED CONFORMS TO PROCEDURES REQUIRED BY THE FEDERAL
36 C INSURANCE ADMINISTRATION.
37 C THIS PROGRAM DETERMINES WAVE HEIGHTS AND ELEVATIONS, FLOOD HAZARD
38 C FACTORS, ZONE DESIGNATIONS, AND THE LOCATION OF ZONE BOUNDARIES
39 C FOR FLOOD INSURANCE STUDIES.
40 C
41 C
42 C
43 C PROGRAM WHAFIS3
44 C
45 C LOGICAL TEST, AZONE, VZONE
46 C
47 C DIMENSION FFL(10), FFF(10), GFL(10), GFF(10), PARAM(10),
48 C 1HBW(500), EW(500), TITLE(80),
49 C 1STVG(500), VZNE(500), STEG(500), ELZ(500), GS(500),


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50      LNSE(500),SELZ(500),SAVE(500),
51      1SA(500,5),AP(500),SBP(500),SEP(500)
52      DIMENSION HDN(8,8,7),PPSD(8,3),PLTYP(8)
53      C
54      C G&O SEPT 88
55      C
56      DIMENSION SPWP(500)
57      C
58      COMMON/ARRAY1/ SPWP
59      C
60      C END G&O SEPT 88
61      C
62      COMMON /PPT/HDN,PPSD,PLTYP
63      COMMON /FONLY/FFL,FFF,GFL,GFF
64      COMMON /AONLY/NFOM1
65      COMMON /AFGV/TOF,PARAM,BSFO,BEFO,WHI,WHT,NFO,
66      1HBW,AP,SET,SE,STEG,EL2,GS,EV,SA,M,NAP
67      CG&O 2/87
68      COMMON /BTSLOP/GSLB,GSLE
69      CG&O 2/87
70      DATA EI,DU,BU,VE,FI,FO,ET/2HIE,2H DU,2HBU,2HVE,2HIF,2HOF,2HET/
71      DATA WIND,WARD,BLEE,AS/4HWIND,4HWARD,4H LEE,2HAS/
72      DATA PI,BLANK/3.14159,1H /
73      DATA VH/2HVH/
74      C
75      C
76      C      UNIT 5 IS THE INPUT FILE
77      C      UNIT 6 IS THE OUTPUT FILE
78      C      UNIT 7 IS THE MARSH GRASS DATA FILE
79      C      UNIT 8 IS THE SCRATCH FILE FOR ECHOING THE INPUT
80      C      IN TABULAR FORM
81      C      UNIT 9 IS THE SCRATCH FILE USED TO WRITE MARSH
82      C      GRASS DEFAULT PARAMETERS WHEN THE LATTER
83      C      ARE OBTAINED BY REGRESSION AND INTERPOLATION.
84      C      UNIT 10 IS THE SCRATCH FILE USED TO STORE THE
85      C      RESULTED TRANSECT INFORMATION AFTER THE
86      C      STILLWATER SURGE ELEVATIONS BEEN INTERPOLATED
87      C      BY THE SUBROUTINE SCANE.
88      C
89      C      OPEN THE VARIOUS FILES
90      C
91      C      OPEN(5,FILE='@DATA',PAD='YES')
92      C
93      C G&O SEPT 88
94      C
95      C      OPEN(6,FILE='WHAFIS3.SEPT88.RESULTS',STATUS='FRESH'
96      C      1 , CARRIAGECONTROL='FORTRAN')
97      C
98      C END G&O SEPT 88
99      C
100     C      OPEN(7,FILE='MG.DF',STATUS='OLD',IOINTENT='INPUT')
101     C      OPEN(8,STATUS='SCRATCH',PAD='YES')

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102      CLOSE (9,ERR=9)
103    9   OPEN(9,STATUS='SCRATCH',PAD='YES')
104      CLOSE (10,ERR=1099)
105    1099 OPEN(10,STATUS='SCRATCH',PAD='YES')
106    C
107    C   READ IN TABULAR DATA FOR MARSH GRASS
108      CALL READIN
109    C
110    C           CALL SCANE TO INTERPOLATE 100-YR STILLWATER ELEVATIONS
111    C
112      CALL SCANE
113    C
114    C   READ THE TITLE CARD
115      READ(10,805)(TITLE(I),I=1,80)
116    C   PRINT HEADING AND TITLE
117    C   INITIALIZE VARIABLES FOR CURRENT TRANSECT
118    C
119    4   BSFO=0
120      N=0
121      M=0
122      NFO=0
123      NAP=0
124      WRITE(6,830)
125      WRITE(6,835)(TITLE(I),I=1,80)
126      WRITE(6,840)
127    C
128    C   READ DATA CARD DESCRIBING FETCH OR OBSTRUCTION
129    5   READ(10,810)TOF,(PARAM(I),I=1,10)
130    C   ECHO INPUT
131      WRITE(6,815)TOF,(PARAM(I),I=1,10)
132    C
133    C   WRITE INPUT TO SCRATCH FILE
134      WRITE(8,815)TOF,(PARAM(I),I=1,10)
135    C
136    C
137    C   BRANCH TO THE APPROPRIATE SEGMENT OF THE PROGRAM DEPENDING ON THE
138    C   TYPE OF FETCH OR OBSTRUCTION (TOF)
139      IF(TOF.EQ.DU)GO TO 50
140      IF(TOF.EQ.BU)GO TO 100
141      IF(TOF.EQ.VE)GO TO 125
142      IF(TOF.EQ.FI)GO TO 150
143      IF(TOF.EQ.FO)GO TO 200
144      IF(TOF.EQ.AS)GO TO 230
145      IF(TOF.EQ.VH)GO TO 240
146      IF(TOF.EQ.ET)GO TO 300
147    C
148    C   IF TOF IS ILLEGAL PRINT MESSAGE AND STOP
149      IF(TOF.NE.EI)WRITE(6,820)
150      IF(TOF.NE.EI)GO TO 1000
151    C
152    C
153    C   INITIAL ELEVATIONS PROGRAM SEGMENT

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154     ESFO=PARAM(1)
155     EEFO=PARAM(2)
156     FL=PARAM(3)
157     SET=PARAM(4)
158     SE=PARAM(5)
159     WHT=PARAM(6)
160     WPT=PARAM(7)
161 CG&O 2/87
162     WPI=WPT
163     WHI=WHT
164     GSLB=PARAM(9)
165     GSLE=GSLB
166 CG&O 2/87
167     ASE=SE
168 C
169 C     CHECK FOR MISSING AS CARD
170     IF(EEFO.GT.SE)WRITE(6,780)
171     IF(EEFO.GT.SE)GO TO 1000
172 C
173 C IF INITIAL WAVE HEIGHT IS KNOWN BRANCH TO ARRAY LOADING PROGRAM SEGMENT
174 CG&O 2/87 ** COMMENTED OUT ***
175 C     IF(WHT.NE.0)GO TO 250
176 C
177 C     IN CASE FETCH LENGTH IS NOT ON CURVE
178 C     IF(FL.GE.24.0)FF=1.0
179 C     IF(FL.LT..1) FF=(FL/0.1)*FFF(1)
180 C     IF(FL.LT..1.OR.FL.GE.24)GO TO 25
181 C
182 C     FIND FETCH LENGTH ON F CURVE
183 C     DO 20 I1=1,9
184 C     IF(FL.GE.FFL(I1).AND.FL.LT.FFL(I1+1))NF=I1
185 C 20 CONTINUE
186 C
187 C     INTERPOLATE BETWEEN POINTS ON F CURVE
188 C     DIFF1=FFF(NF+1)-FFF(NF)
189 C     DIFF2=ALOG10(FFL(NF+1))-ALOG10(FFL(NF))
190 C     DIFF3=ALOG10(FL)-ALOG10(FFL(NF))
191 C     FF=(DIFF1/DIFF2)*DIFF3+FFF(NF)
192 C
193 C     COMPUTE TRANSMITTED WAVE HEIGHT
194 C 25 WHT=.78*FF*SE
195 C     IF(EEFO.EQ.SE)WHT=0
196 CG&O 2/87 ** END OF COMMENTED OUT ***
197 C     COMPUTE WAVE PERIOD
198     IF(WPT.GT.0)GO TO 20
199     AFL=5280*FL
200     IF( AFL .EQ. 0.0 ) AFL=5280.*24.
201     WPT=T(0,AFL,117.0,26.0)
202 C
203 CG&O 2/87
204 C
205     20 CONTINUE

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206 C
207 C CALCULATE INITIAL TRANSMITTED CONTROLLING WAVE HEIGHT IF IT IS
208 C NOT KNOWN
209 C
210 IF(WHT. EQ. 0.0) THEN
211 AFL=5280.*FL
212 IF( AFL .EQ. 0.0 ) AFL=5280.*24.
213 WHT=HIN(0.0,AFL,117.0,26.0,WPT)
214 ENDIF
215 C
216 C CALCULATE BREAKING WAVE HEIGHT AND RESET WHT IF IT IS TOO LARGE
217 C
218 SDEB=AMAX1(0.0,SE-EEFO)
219 HB=SHBM(WPT,GSLE,SDEB)
220 WHT=AMIN1(WHT,HB)
221 CG&O 2/87 END
222 C
223 C BRANCH TO ARRAY LOADING PROGRAM SEGMENT
224 GO TO 250
225 C
226 C
227 C DUNE PROGRAM SEGMENT
228 50 ESFO=PARAM(1)
229 EEFO=PARAM(2)
230 AMMB=PARAM(3)
231 SETN=PARAM(4)
232 SEN=PARAM(5)
233 CG&O 2/87
234 GSLB=GSLE
235 WPI=WPT
236 WHI=WHT
237 GSLE=PARAM(9)
238 C
239 CG&O 2/87
240 C UPDATE SURGE ELEVATIONS
241 IF(SETN.NE.0)SET=SETN
242 IF(SEN.NE.0)SE=SEN
243 C CHECK FOR MISSING AS CARD
244 IF(EEFO.GT.SE.AND.AMMB.EQ.0)WRITE(6,780)
245 IF(EEFO.GT.SE.AND.AMMB.EQ.0)GO TO 1000
246 ASE=(SA(NFO,4)+SE)/2.0
247 EEB=EEFO
248 SDEB=SE-EEB
249 C COMPUTE TRANSMISSION COEFFICIENT B
250 CG&O 2/87
251 HBM=SHBM(WPI,GSLE,SDEB)
252 C IF(WHI.LT.SDEB*.78)B=1.0
253 IF(WHI.LT.HBM)B=1.0
254 CG&O 2/87 END
255 IF(WHI.EQ.0)GO TO 80
256 C CHECK FOR ARTIFICIAL OR MAN MADE BARRIERS
257 IF(AMMB.NE.0)GO TO 75

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258 CG&O 2/87
259 C IF(WHI.GE..78*SDEB)B=(.78*SDEB)/WHI
260 IF(WHI.GE.HBM)B=HBM/WHI
261 CG&O 2/87
262 GO TO 80
263 C COMPUTE B FOR ARTIFICIAL BARRIERS
264 75 IF(EEB.GE.SE+.5*WHI)B=0
265 IF(EEB.GE.SE+.5*WHI)GO TO 80
266 CG&O 2/87
267 C IF(WHI.GE.SDEB*.78)B=(1/(2*WHI))*(.78*SDEB+WHI)
268 IF(WHI.GE.HBM)B=(1/(2*WHI))*(HBM+WHI)
269 CG&O 2/87
270 IF(EEB.GT.SE)B=.5-((EEB-SE)/WHI)
271 C COMPUTE TRANSMITTED WAVE HEIGHT
272 80 WHT=B*WHI
273 C COMPUTE WAVE PERIOD AT END OF SEGMENT
274 WPT=WPI
275 C BRANCH TO ARRAY LOADING PROGRAM SEGMENT
276 C
277 GO TO 250
278 C
279 C BUILDING PROGRAM SEGMENT
280 100 ESFO=PARAM(1)
281 EEFO=PARAM(2)
282 R=PARAM(3)
283 RB=PARAM(4)
284 SETN=PARAM(5)
285 SEN=PARAM(6)
286 CG&O 2/87
287 GSLB=GSLE
288 WPI=WPT
289 WHI=WHT
290 GSLE=PARAM(9)
291 CG&O 2/87
292 C UPDATE SURGE ELEVATIONS
293 IF(SETN.NE.0)SET=SETN
294 IF(SEN.NE.0)SE=SEN
295 ASE=(SA(NFO,4)+SE)/2.0
296 C CHECK FOR MISSING AS CARD
297 IF(EEFO.GT.SE)WRITE(6,780)
298 IF(EEFO.GT.SE)GO TO 1000
299 C
300 C B IS A FUNCTION OF THE RATIO OF OPEN SPACE TO TOTAL TRANSVERSE WIDTH
301 C (R), AND THE NUMBER OF ROWS OF BUILDINGS (RB).
302 B=R**(RB/2.0)
303 WHT=WHI*B
304 IF(EEFO.EQ.SE)WHT=0
305 C COMPUTE WAVE PERIOD AT END OF SEGMENT
306 WPT=WPI
307 C BRANCH TO ARRAY LOADING PROGRAM SEGMENT
308 GO TO 250
309 C

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310 C
311 C VEGETATION PROGRAM SEGMENT
312 125 ESFO=PARAM(1)
313 EEFO=PARAM(2)
314 D=PARAM(3)
315 AH=PARAM(4)
316 AHS=PARAM(5)
317 DC=PARAM(6)
318 SETN=PARAM(7)
319 SEN=PARAM(8)
320 CG&O 2/87
321 GSLB=GSLE
322 WPI=WPT
323 WHI=WHT
324 GSLE=PARAM(9)
325 C
326 CG&O 2/87
327 IF(SETN.NE.0)SET=SETN
328 IF(SEN.NE.0)SE=SEN
329 ASE=(SA(NFO,4)+SE)/2.0
330 IF(DC.EQ.0)DC=1.0
331 W=ESFO-BSFO
332 C
333 C CHECK FOR MISSING AS CARD
334 IF(EEFO.GT.SE)WRITE(6,780)
335 IF(EEFO.GT.SE)GO TO 1000
336 C
337 C COMPUTE AVERAGE WETTED HEIGHT OF VEGETATION
338 AEG=(BEFO+EEFO)/2.0
339 ADV=ASE-AEG
340 C CHECK FOR NEGATIVE DEPTHS
341 IF(ADV.LE.0)WRITE(6,790)
342 IF(ADV.LE.0.) THEN
343 WRITE(6,791) TOF,PARAM(1)
344 ENDIF
345 791 FORMAT(/2X,'TOF= ',A2,2X,'STATION= ',F8.2/)
346 IF(ADV.LE.0)GO TO 1000
347 AWH=AMIN1(AH,ADV)
348 C
349 C
350 C COMPUTE TRANSMISSION COEFFICIENT, TRANSMITTED WAVE HEIGHT AND
351 C BRANCH TO ARRAY LOADING PROGRAM SEGMENT
352 PART1=DC*WHI*AWH*D*W
353 PART2=3*PI*(AHS**2)*(ADV**2)
354 B=1/(1+(PART1/PART2))
355 WHT=WHI*B
356 IF(EEFO.EQ.SE)WHT=0
357 C COMPUTE WAVE PERIOD AT END OF SEGMENT
358 WPT=WPI
359 C
360 GO TO 250
361 C

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362 C
363 C INLAND FETCH PROGRAM SEGMENT
364 150 ESFO=PARAM(1)
365 EEFO=PARAM(2)
366 SETN=PARAM(3)
367 SEN=PARAM(4)
368 CG&O 2/87
369 GSLB=GSLE
370 WPI=WPT
371 WHI=WHT
372 GSLE=PARAM(9)
373 CG&O 2/87
374 IF(SETN.NE.0)SET=SETN
375 IF(SEN.NE.0)SE=SEN
376 CG&O 2/87
377 C
378 C CHECK FOR MIISSING AS CARD
379 C
380 IF(EEFO. GT. SE) THEN
381 WRITE(6,780)
382 GO TO 1000
383 ENDIF
384 CG&O 2/87
385 C
386 ASE=(SA(NFO,4)+SE)/2.0
387 C
388 C THE SECTION THAT IGNORES REGENERATION FOR FETCHES
389 C SHORTER THAN 0.1 MILE IS DISABLED BELOW. INSTEAD,
390 C AN ESTIMATE OF THE G OR F FACTOR FOR FETCHES SHORTER
391 C THAN 0.1 MILES IS MADE USING LINEAR INTERPOLATION
392 C BETWEEN THE G OR F VALUE FOR 0.1 MILES AND F=0 OR
393 C G=0 FOR 0.0 MILES
394 C
395 C NO REGENERATION FOR FETCHES SHORTER THAN .1 MILE
396 CG&O 2/87 ** COMMENTED OUT ***
397 C AFL=ESFO-BSFO
398 C AFLHOLD= AFL
399 C IF(AFL.LT.528)WHT=WHI
400 C IF(AFL.LT.528)GO TO 250
401 C
402 C CHECK FOR MISSING AS CARD
403 C
404 C IF(EEFO.GT.SE)WRITE(6,780)
405 C IF(EEFO.GT.SE)GO TO 1000
406 CG&O 2/87 ** END OF COMMENTED OUT ***
407 C
408 C COMPUTE FETCH FACTOR
409 AEG=(EEFO+BEFO)/2.0
410 ADF=ASE-AEG
411 ADFHOLD= ADF
412 C CHECK FOR NEGATIVE DEPTHS
413 IF(ADF.LE.0)WRITE(6,790)

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414             IF(ADF.LE.0.) THEN
415                 WRITE(6,791) TOF,PARAM(1)
416             ENDIF
417         IF(ADF.LE.0)GO TO 1000
418     CG&O 2/87
419     C
420     C     INITIALIZE ERROR FLAG
421     C
422     C     TEST=.FALSE.
423     C
424     C     SET WINDSPEED W IN STATUTE MILES PER HOUR
425     C
426     C     W=60.0
427     C
428     C     NOTE THAT WHI AND WHT COMMUNICATE WITH MAIN PROGRAM THROUGH THE
429     C     AFGV COMMON BLOCK AND THAT WHT AND WPT ARE SET IN SUBROUTINE FETCH.
430     C
431     C     CALL FETCH(WPI,TEST,WPT,W)
432     C
433     CG&O 2/87 END
434     C
435     C     COMPUTE WAVE PERIOD
436     C
437     CG&O 2/87 ** COMMENTTED OUT AND INSERTED ***
438     C
439     C     AFL= AFLHOLD
440     C     ADF= ADFHOLD
441     C     WPI=T(WPI,AFL,88.0,ADF)
442     C     IF(HBW(NFO).LT..1)WPI=.1
443     C
444     C     SKIP TO NEXT TRANSECT IF ERROR FLAG IS SET
445     C
446     C     IF(TEST) GO TO 1000
447     C
448     CG&OO 2/87 ** END OF COMMENTTED OUT AND INSERTED ***
449     C
450     C     GO TO 5
451     C
452     C     OVER-WATER FETCH PROGRAM SEGMENT
453     C     SAME PROCEDURE AS INLAND FETCH EXCEPT FETCH FACTOR IS DEFINED
454     C     DIFFERENTLY AND F CURVES ARE USED INSTEAD OF G CURVES
455     C     200 ESFO=PARAM(1)
456     C     EEFO=PARAM(2)
457     C     SETN=PARAM(3)
458     C     SEN=PARAM(4)
459     CG&O 2/87
460     C     GSLB=GSLE
461     C     WPI=WPT
462     C     WHI=WHT
463     C     GSLE=PARAM(9)
464     CG&O 2/87
465     C     IF(SETN.NE.0)SET=SETN

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466         IF(SEN.NE.0)SE=SEN
467         ASE=(SA(NFO,4)+SE)/2.0
468 C        CHECK FOR MISSING AS CARD
469         IF(EEFO.GT.SE)WRITE(6,780)
470         IF(EEFO.GT.SE)GO TO 1000
471 C
472 CG&O 2/87 ** COMMENTTED OUT AND INSERTED ***
473 C
474 C        AFL=ESFO-BSFO
475 C        AFLHOLD= AFL
476         AEG=(EEFO+BEFO)/2.0
477         ADF=ASE-AEG
478 C        ADFHOLD= ADF
479         IF(ADF.LE.0)WRITE(6,790)
480             IF(ADF.LE.0.) THEN
481                 WRITE(6,791) TOF,PARAM(1)
482             ENDIF
483         IF(ADF.LE.0)GO TO 1000
484 C
485 C        INITIALIZE ERROR FLAG
486 C
487         TEST=.FALSE.
488 C
489 C        SET WINDSPEED W IN STATUTE MILES PER HOUR
490 C
491         W=80.0
492 C
493 C        NOTE THAT WHT AND WHI COMMUNICATED WITH MAIN PROGRAM THROUGH THE
494 C        AFGV COMMON BLOCK AND THAT WHT AND WPT ARE SET IN SUBROUTINE FETCH.
495 C
496         CALL FETCH(WPI,TEST,WPT,W)
497 C
498 C        COMPUTE WAVE PERIOD
499 C
500 C        AFL= AFLHOLD
501 C        ADF= ADFHOLD
502 C        WPI=T(WPI,AFL,117.0,ADF)
503 C        IF(HBW(NFO).LT..1)WPI=.1
504 C
505 C        SKIP TO NEXT TRANSECT IF ERROR FLAG IS SET
506 C
507         IF(TEST) GO TO 1000
508 C
509 CG&O 2/87 ** END OF COMMENTTED OUT AND INSERT ***
510 C
511         GO TO 5
512 C
513 C
514 C        ABOVE SURGE PROGRAM SEGMENT FOR B AND C ZONES
515 C        ESTABLISH GUTTERS AT BEGIN STATION AND END STATION
516 230 ESFO=PARAM(1)
517         EEFO=PARAM(2)

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518         SETN=PARAM(3)
519         SEN=PARAM(4)
520 CG&O 2/87
521 C
522         GSLB=GSLE
523         WPI=WPT
524         WHI=0.0
525         GSLE=PARAM(9)
526 CG&O 2/87
527 C      UPDATE SURGE ELEVATIONS
528         IF(SETN.NE.0)SET=SETN
529         IF(SEN.NE.0)SE=SEN
530         IF(EEFO. LT. SE) THEN
531             WRITE(6,785) TOF,PARAM(1),PARAM(2),SE
532 785     FORMAT(/LX,'*** AS CARD GROUND ELEVATION LESS THAN',
533 A      ' STILLWATER ELEVATION, SHOULD USE OTHER TYPE CARD, JOB',
534 B      ' DUMPED ***'/,
535 C      'TOF= ',A2,' STATION= ',F9.2,' GROUND ELEVATION= ',
536 D      F8.2,' STILLWATER ELEVATION= ',F8.2)
537         GO TO 1000
538         ENDIF
539         M=M+1
540         STEG(M)=BSFO
541         ELZ(M)=EW(NFO)
542         M=M+1
543         STEG(M)=ESFO
544         ELZ(M)=SE
545         WHT=0
546         WPT=0.1
547         GO TO 250
548 C
549 C
550 C      PROGRAM SEGMENT FOR MARSH GRASS OR OTHER COMPLEX PLANT COMMUNITY
551 240 ESFO=PARAM(1)
552         EEFO=PARAM(2)
553         SETN=PARAM(7)
554         SEN=PARAM(8)
555 CG&O 2/87
556         GSLB=GSLE
557         WPI=WPT
558         WHI=WHT
559         GSLE=PARAM(9)
560 CG&O 2/87
561 C      CHECK FOR SURGE CHANGE
562         IF(SETN.NE.0)SET=SETN
563         IF(SEN.NE.0)SE=SEN
564 C      CHECK FOR MISSING AS CARD
565         IF(EEFO.GT.SE)WRITE(6,780)
566         IF(EEFO.GT.SE)GO TO 1000
567 C      CHECK FOR NEGATIVE DEPTH
568         ASE=(SA(NFO,4)+SE)/2.0
569         AEG=(BEFO+EEFO)/2.0

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570         ADF=ASE-AEG
571         IF(ADF.LE.0)WRITE(6,790)
572             IF(ADF.LE.0.) THEN
573                 WRITE(6,791) TOF,PARAM(1)
574             ENDIF
575         IF(ADF.LE.0)GO TO 1000
576     C     INITIALIZE ERROR FLAG
577         TEST=.FALSE.
578     CG&O 2/87
579     C
580     C     SET WINDSPEED W IN STATUTE MILES PER HOUR
581     C
582         W=60.0
583     C
584     C     NOTE THAT WHI AND WHT COMMUNICATE WITH MAIN PROGRAM THROUGH THE
585     C     AFGV COMMON BLOCK AND THAT WHT AND WPT ARE SET IN SUBROUTINE VEG.
586     C
587     C     CALL SUBROUTINE
588         CALL VEG(WPI,TEST,WPT,W)
589     C
590     CG&O 2/87  END
591     C
592     C     SKIP TO NEXT TRANSECT IF ERROR FLAG IS SET
593         IF(TEST)GO TO 1000
594         GO TO 5
595     C
596     C
597     C     ARRAY LOADING PROGRAM SEGMENT
598     250 NFO=NFO+1
599         IF(NFO.GT.500)WRITE(6,995)
600         IF(NFO.GT.500)STOP
601         GS(NFO)=ESFO
602     C
603     C
604     CG&O 2/87
605         SDEB=AMAX1(0.0,SE-EEFO)
606     C
607     C     COMPUTE MAXIMUM WAVE HEIGHT
608     C     WHM=.78*(SE-EEFO)
609         WHM=SHBM(WPT,GSLE,SDEB)
610     C
611     CG&O 2/87
612         IF(TOF.EQ.DU.AND.AMMB.NE.0)WHM=WHT
613     C
614     C     COMPUTE WAVE HEIGHTS AND ELEVATIONS
615         HBW(NFO)=AMIN1(WHT,WHM)
616     CG&O 2/87
617         STMP = EEFO + SDEB
618     C     EW(NFO)=.7*HBW(NFO)+ASE
619         EW(NFO)=.7*HBW(NFO)+STMP
620     CG&O 2/87
621         IF(TOF.EQ.AS)EW(NFO)-EEFO

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622 C
623 C G&O SEPT 88
624 C
625 C          STORE SPECTRAL PEAK WAVE PERIOD IN THE
626 C          WPWP ARRAY
627 C
628 C          SPWP(NFO)= WPT
629 C
630 C END G&O SEPT 88
631 C
632 C          STORE INFORMATION NEEDED LATER FOR FLOOD INSURANCE ZONE DATA
633 C          SA(NFO,1)=BSFO
634 C          SA(NFO,2)=ESFO
635 C          SA(NFO,3)=SET
636 C          SA(NFO,4)=SE
637 C          SA(NFO,5)=TOF
638 C          IF(PARAM(10).NE.1)GO TO 275
639 C          NAP=NAP+1
640 C          AP(NAP)=ESFO
641 C          M=M+1
642 C          STEG(M)=GS(NFO)
643 C          ELZ(M)=EW(NFO)
644 C
645 C          INCIDENT WAVE HEIGHT AND PERIOD FOR NEXT OBSTRUCTION
646 C          EQUALS TRANSMITTED WAVE HEIGHT AND PERIOD OF CURRENT
647 C          OBSTRUCTION
648 C          275 WHT=HBW(NFO)
649 C          IF(HBW(NFO).LT..1)WPT=.1
650 C          CG&O 2/87 ** COMMENTED OUT ***
651 C          IF(HBW(NFO).LT..1)WPT=.1
652 C          WPI=WPT
653 C          CG&O 2/87 ** END OF COMMENTED OUT ***
654 C
655 C          BEGINNING POINT OF NEXT OBSTRUCTION IS END POINT OF CURRENT
656 C          OBSTRUCTION
657 C          BSFO=ESFO
658 C          BEFO=EEFO
659 C
660 C          BRANCH BACK TO READ STATEMENT AND READ ANOTHER CARD
661 C
662 C          GO TO 5
663 C
664 C
665 C          THIS POINT WILL BE REACHED IF THE LAST CARD WAS AN ET CARD
666 C          SIGNALING THE END OF THE TRANSECT.
667 C          CALL SUBROUTINE TO PRODUCE AN ANOTATED INPUT LISTING
668 C          300 CALL ECHO
669 C
670 C G&O SEPT 88
671 C
672 C          PRINT HEADINGS AND OUTPUT FOR PART2 (LOCATION, CONTROLLING
673 C          WAVE HEIGHT, SPECTRAL PEAK WAVE PERIOD, AND WAVE CREST

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674 C ELEVATION)
675 C
676 C WRITE(6,870)
677 C WRITE(6,880)
678 C
679 C WRITE( 6,875 )
680 875 FORMAT(///, 48X, ' PART2: CONTROLLING WAVE HEIGHTS, SPECTRAL '
681 1 , / 55X, 'PEAK WAVE PERIOD, AND WAVE CREST ELEVATIONS' )
682 C
683 C WRITE( 6,882 )
684 882 FORMAT( /, 42X, 10HLOCATION , 6X, 11HCONTROLLING, 2X
685 1 , 14HSPECTRAL PEAK , 2X, 10HWAVE CREST, / 58X, 11HWAVE HEIGHT
686 2 , 2X, 14HWAVE PERIOD , 2X, 10HELEVATION )
687 C
688 C END G&O SEPT 88
689 C
690 C DO 310 I=1,NFO
691 C
692 C G&O 3/87
693 C
694 C TEMP = SA(I,5)
695 C
696 C IF(SA(I,5).EQ.1.0.OR.SA(I,5).EQ.2.0) GO TO 310
697 C IF(SA(I,5).EQ.1.0.OR.SA(I,5).EQ.2.0) TEMP = 2H
698 C
699 C WRITE(6,890) SA(I,5),GS(I),HBW(I),EW(I)
700 C
701 C G&O SEPT 88
702 C
703 C WRITE(6,890) TEMP ,GS(I),HBW(I),EW(I)
704 C
705 C ZERO OUT SPECTRAL PEAK WAVE PERIOD
706 C APWP(I) IF CONTROLLING WAVE HEIGHT HBW(I)
707 C IS ZERO. THIS IS TO PREVENT WAVES WITH A
708 C NON-ZERO WAVE PERIOD FROM OCCURING WHEN THE
709 C WAVE HEIGHT IS ZERO.
710 C
711 C IF( HBW(I) .EQ. 0.0 ) SPWP(I) = 0.0
712 C
713 C WRITE( 6,892 ) TEMP, GS(I), HBW(I), SPWP(I), EW(I)
714 892 FORMAT( /, 40X, A2, F11.2, 3F13.2 )
715 C
716 C END G&O SEPT 88
717 C
718 C G&O 3/87 END
719 C
720 C 310 CONTINUE
721 C
722 C
723 C CHECK THAT WAVE IS NEARLY DAMPED OUT AT END OF TRANSECT
724 C IF(HBW(NFO).GT..5)WRITE(6,860)HBW(NFO)
725 C WRITE(6,895)

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726 C
727 C
728 C LIST LOCATION OF AREAS ABOVE SURGE
729 MM1=M-1
730 IF(M.EQ.0)GO TO 316
731 DO 315 I=1,NFO
732 IF(SA(I,5).EQ.AS)WRITE(6,950)SA(I,1),SA(I,2)
733 315 CONTINUE
734 316 IF(M.EQ.0)WRITE(6,970)
735 C
736 C
737 C LIST LOCATION OF SURGE CHANGES AND ESTABLISH GUTTERS AT THESE LOCATIONS
738 WRITE(6,885)
739 WRITE(6,985)
740 NFOM1=NFO-1
741 DO 318 I=1,NFOM1
742 IF(SA(I,3).EQ.SA(I+1,3).AND.SA(I,4).EQ.SA(I+1,4))GO TO 318
743 IF(SA(I,5).EQ.1.0.OR.SA(I,5).EQ.2.0)GO TO 317
744 M=M+1
745 STEG(M)=GS(I)
746 ELZ(M)=EW(I)
747 317 IF(SA(I+1,5).EQ.1.0.OR.SA(I+1,5).EQ.2.0)GO TO 318
748 M=M+1
749 STEG(M)=GS(I+1)
750 ELZ(M)=EW(I+1)
751 WRITE(6,960)STEG(M),SA(I+1,3),SA(I+1,4)
752 318 CONTINUE
753 IF(M-1.EQ.MM1)WRITE(6,975)
754 C
755 C
756 C FIND LOCATIONS WHERE THE HEIGHT OF THE BREAKING WAVE IS 3.0 FEET
757 C AND ESTABLISH GUTTERS AT THESE LOCATIONS
758 DO 330 I=1,NFOM1
759 TEST=.FALSE.
760 SLOPE=(HBW(I+1)-HBW(I))/(GS(I+1)-GS(I))
761 IF(I.EQ.1.AND.HBW(1).NE.3)GO TO 319
762 IF(I.NE.1)GO TO 319
763 N=N+1
764 M=M+1
765 STVG(N)=GS(1)
766 STEG(M)=GS(1)
767 ELZ(M)=EW(1)
768 TEST=.TRUE.
769 319 IF(SLOPE.EQ.0)GO TO 320
770 IF(HBW(1).EQ.3)GO TO 325
771 X=(3-HBW(I))/SLOPE+GS(I)
772 IF(X.LE.GS(I).OR.X.GT.GS(I+1))GO TO 330
773 N=N+1
774 M=M+1
775 STVG(N)=X
776 STEG(M)=X
777 ELZ(M)=2.1+((SA(I,4)+SA(I+1,4))/2.0)

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778     TEST=.TRUE.
779 320 IF(HBW(I).NE.3.AND.HBW(I+1).NE.3)GO TO 325
780     N=N+1
781     STVG(N)=GS(I+1)
782     TEST=.TRUE.
783 325 IF(TEST.AND.SLOPE.GT.0)VZNE(N)=BLEE
784     IF(TEST.AND.SLOPE.LE.0)VZNE(N)=WIND
785 330 CONTINUE
786     IF(N.EQ.0)GO TO 336
787 C
788 C
789 C     LIST LOCATIONS OF V ZONE GUTTERS AND V ZONES
790     WRITE(6,900)
791     WRITE(6,940)
792     DO 335 I=1,N
793     WRITE(6,905)STVG(I),VZNE(I),WARD
794 335 CONTINUE
795 C
796 C
797 C     FIND ELEVATION GUTTERS AT PLACES WHERE WAVE ELEVATION IS AN ODD MULTIPLE
798 C     OF .5 FEET
799 336 DO 370 I=1,NFOM1
800     BIG=AMAX1(EW(I),EW(I+1))
801     SMALL=AMIN1(EW(I),EW(I+1))
802     ITRNK=INT(SMALL)
803     TST=SMALL-ITRNK
804     IF(TST.LT..5)GTST=FLOAT(ITRNK)+.5
805     IF(TST.GT..5)GTST=FLOAT(ITRNK)+1.5
806     IF(TST.EQ..5)GTST=SMALL
807 340 IF(GTST.GT.BIG)GO TO 370
808     TEST=.FALSE.
809     SLOPE=(EW(I+1)-EW(I))/(GS(I+1)-GS(I))
810     IF(SLOPE.EQ.0)GO TO 370
811     M=M+1
812     STEG(M)=(GTST-EW(I))/SLOPE+GS(I)
813     ELZ(M)=GTST
814     GTST=GTST+1.0
815     GO TO 340
816 370 CONTINUE
817 C
818 C     AT LEAST TWO GUTTERS ARE NEEDED
819     M=M+1
820     STEG(M)=GS(1)
821     ELZ(M)=EW(1)
822     M=M+1
823     STEG(M)=GS(NFO)
824     ELZ(M)=EW(NFO)
825 C
826 C
827 C     SAVE LOCATION OF GUTTERS IN ORIGINAL ORDER
828     DO 382 I=1,M
829     SAVE(I)=STEG(I)

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830     382 CONTINUE
831     C
832     C
833     C     SORT GUTTERS BY INCREASING STATIONS
834         MM1=M-1
835         DO 386 J=1,M
836         DO 384 I=1,MM1
837             SMALL=AMIN1(STEG(I),STEG(I+1))
838             BIG=AMAX1(STEG(I),STEG(I+1))
839             STEG(I)=SMALL
840             STEG(I+1)=BIG
841     384 CONTINUE
842     386 CONTINUE
843     C
844     C
845     C     FIND THE ELEVATIONS ASSOCIATED WITH EACH OF THE GUTTERS
846         DO 390 J=1,M
847         DO 388 I=1,M
848             IF(SAVE(I).EQ.STEG(J))NS=I
849     388 CONTINUE
850         SELZ(J)=ELZ(NS)
851     390 CONTINUE
852     C
853     C
854     C     PRINT HEADING FOR PART6
855         WRITE(6,910)
856         WRITE(6,915)
857     C
858     C
859     C     FLAG GUTTERS LOCATED IN AREAS ABOVE SURGE FOR LATER ELIMINATION
860         DO 398 I1=1,NFO
861         DO 396 I2=1,M
862             IF(SA(I1,5).NE.AS)GO TO 396
863             IF(STEG(I2).GT.SA(I1,1).AND.STEG(I2).LT.SA(I1,2))STEG(I2)=-10.0
864     396 CONTINUE
865     398 CONTINUE
866     C
867     C
868     C     FLAG GUTTERS THAT ARE DUPLICATES FOR LATER ELIMINATION
869         DO 410 I=1,MM1
870             IF(STEG(M-I+1).EQ.STEG(M-I))STEG(M-I+1)=-10
871     410 CONTINUE
872     C
873     C
874     C     DETERMINE THE FETCH OR OBSTRUCTION ASSOCIATED WITH EACH GUTTER
875         DO 418 J=1,M
876             NSE(J)=0
877             DO 417 I=1,NFOM1
878                 IF(STEG(J).GE.GS(I).AND.STEG(J).LT.GS(I+1))NSE(J)=I
879     417 CONTINUE
880     418 CONTINUE
881         IF(STEG(M).EQ.GS(NFO))NSE(M)=NFOM1

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882 C
883 C
884 C FIND THE AREAS OVER WHICH THE WEIGHTED AVERAGE CALCULATIONS
885 C ARE TO BE MADE FOR A ZONE NUMBER DETERMINATIONS
886 C
887 K=0
888 IF(N.NE.0)GO TO 425
889 IF(HBW(1).GT.3.0)GO TO 445
890 K=1
891 SBP(K)=GS(1)
892 SEP(K)=GS(NFO)
893 GO TO 445
894 425 IF(VZNE(1).EQ.WIND)GO TO 430
895 K=1
896 SBP(K)=GS(1)
897 SEP(K)=STVG(1)
898 430 DO 440 I=1,N
899 IF(VZNE(I).EQ.BLEE)GO TO 440
900 K=K+1
901 SBP(K)=STVG(I)
902 IF(I.EQ.N)SEP(K)=GS(NFO)
903 IF(I.EQ.N)GO TO 440
904 SEP(K)=STVG(I+1)
905 440 CONTINUE
906 C
907 C
908 C DETERMINE THE ZONE DESIGNATION AND FLOOD HAZARD FACTOR FOR EACH ZONE
909 C AND PRINT THE RESULTS AS THEY ARE DETERMINED
910 C
911 445 WRITE(6,920)GS(1),EW(1)
912 DO 500 I=1,MM1
913 IF(STEG(I).EQ.-10)GO TO 500
914 INDEX=I+1
915 450 IF(INDEX.GT.M)GO TO 500
916 IF(INDEX.EQ.M.AND.STEG(INDEX).EQ.-10)GO TO 500
917 IF(STEG(INDEX).EQ.-10)INDEX=INDEX+1
918 IF(STEG(INDEX).EQ.-10)GO TO 450
919 INDX=NSE(I)+1
920 IF(SA(INDX,5).EQ.AS.AND.SA(INDX,1).EQ.STEG(I))WRITE(6,920)
921 1STEG(INDEX),SELZ(INDEX)
922 IF(SA(INDX,5).EQ.AS.AND.SA(INDX,1).EQ.STEG(I))GO TO 500
923 C
924 C G&O 3/87 COMMENTED OUT
925 C
926 C IF(K.EQ.0)GO TO 460
927 C
928 C G&O 3/87 END COMMENTED OUT
929 C
930 AZONE=.FALSE.
931 VZONE=.FALSE.
932 C
933 C G&O 3/87 INSERT

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934 C
935     IF(K.EQ.0)GO TO 460
936 C
937 C G&O 3/87 END INSERT
938 C
939     DO 455 J=1,K
940     IF(STEG(I).GE.SBP(J).AND.STEG(I).LT.SEP(J))AZONE=.TRUE.
941     IF(STEG(I).GE.SBP(J).AND.STEG(I).LT.SEP(J))INDX=J
942 455 CONTINUE
943     IF(AZONE)GO TO 462
944 460 VZONE=.TRUE.
945     TSG1=SA(NSE(I),3)+SA(NSE(I)+1,3)
946     TSG2=SA(NSE(INDEX),3)+SA(NSE(INDEX)+1,3)
947     HSG1=SA(NSE(I),4)+SA(NSE(I)+1,4)
948     HSG2=SA(NSE(INDEX),4)+SA(NSE(INDEX)+1,4)
949     TSG=(TSG1+TSG2)/4.0
950     HSG=(HSG1+HSG2)/4.0
951     DIFF=1.55*(HSG-TSG)
952     GO TO 470
953 462 BP=SBP(INDX)
954     EP=SEP(INDX)
955     START=BP
956     STOP=EP
957     IF(NAP.EQ.0)GO TO 468
958     DO 464 J=1,NAP
959     IF(AP(J).GT.BP.AND.AP(J).LE.STEG(I))START=AP(J)
960 464 CONTINUE
961     J=NAP
962 465 IF(AP(J).GE.STEG(INDEX).AND.AP(J).LT.EP)GO TO 466
963     IF(J.EQ.1)GO TO 468
964     J=J-1
965     GO TO 465
966 466 STOP=AP(J)
967 468 CALL AVG(START,STOP,AER,ATS)
968     DIFF=AER-ATS
969 470 BP=STEG(I)
970     EP=STEG(INDEX)
971     CALL AVG(BP,EP,AER,ATS)
972     ITRNK=INT(AER)
973     TST=AER-ITRNK
974     IF(TST.LT..5)IELZ=ITRNK
975     IF(TST.GE..5)IELZ=ITRNK+1
976     IF(DIFF.GE.0.AND.DIFF.LT..75)INSZ=1
977     BEG=.75
978     DO 480 I1=2,19
979     END=BEG+.5
980     IF(DIFF.GE.BEG.AND.DIFF.LT.END)INSZ=I1
981     BEG=BEG+.5
982 480 CONTINUE
983     IF(DIFF.GE.9.75.AND.DIFF.LT.10.5)INSZ=20
984     BEG=10.5
985     DO 490 I1=21,30

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986         END=BEG+1.0
987         IF(DIFF.GE.BEG.AND.DIFF.LT.END)INSZ=I1
988         BEG=BEG+1.0
989     490 CONTINUE
990         IF(DIFF.GE.20.5)INSZ=30
991         IF(INSZ.LE.20)IFHF=5*INSZ
992         IF(INSZ.GT.20)IFHF=100+(10*(INSZ-20))
993         IF(AZONE)WRITE(6,925) INSZ,IELZ,IFHF
994         IF(VZONE)WRITE(6,927) INSZ,IELZ,IFHF
995         WRITE(6,920)STEG(INDEX),SELZ(INDEX)
996     500 CONTINUE
997         WRITE(6,980)
998     C     CHECK FOR NON-BLANK TITLE CARD OF NEXT DATA SET
999     505 READ(10,805)(TITLE(I),I=1,80)
1000         TEST=.TRUE.
1001         DO 510 I=1,80
1002         IF(TITLE(I).NE.BLANK)TEST=.FALSE.
1003     510 CONTINUE
1004         IF(TEST)GO TO 1010
1005     C     IF THE TITLE CARD IS NOT BLANK READ IN THE NEXT TRANSECT
1006         GO TO 4
1007     780 FORMAT(5X,46H GROUND ELEVATION GREATER THAN SURGE ELEVATION,1X,
1008             124HENCOUNTERED. JOB DUMPED.)
1009     790 FORMAT(5X,42H AVERAGE DEPTH LESS THAN OR EQUAL TO ZERO.,1X,
1010             111HJOB DUMPED.)
1011     805 FORMAT(80A1)
1012     810 FORMAT(A2,F6.0,9F8.0)
1013     815 FORMAT(10X,A2,10F11.3)
1014     820 FORMAT(10X,39HTHE ABOVE CARD CONTAINS ILLEGAL DATA IN,1X,
1015             120HTHE FIRST 2 COLUMNS.)
1016     830 FORMAT(1H1,///,30X,29H WAVE HEIGHT COMPUTATIONS FOR,1X,
1017             153HFLOOD INSURANCE STUDIES (VERSION 3.0, SEPTEMBER 1988) )
1018     835 FORMAT(30X,80A1)
1019     840 FORMAT(///,60X,12H PART1 INPUT,/)
1020     860 FORMAT(5X,40HTRANSMITTED WAVE HEIGHT AT LAST FETCH OR,1X,
1021             113HOBSTRUCTION =F5.2,
1022             119H WHICH EXCEEDS 0.5.)
1023     870 FORMAT(///,48X,34H PART2 WAVE HEIGHTS AND ELEVATIONS)
1024     880 FORMAT(/,42X,10HLOCATION ,6X,11HWAVE HEIGHT,2X,
1025             114HWAVE ELEVATION)
1026     885 FORMAT(///,50X,31HPART4 LOCATION OF SURGE CHANGES)
1027     890 FORMAT(/,40X,A2,F11.2,2F13.2)
1028     895 FORMAT(///,40X,44HPART3 LOCATION OF AREAS ABOVE 100-YEAR SURGE)
1029     900 FORMAT(///,55X,26HPART5 LOCATION OF V ZONES)
1030     905 FORMAT(/,45X,F15.2,15X,2A4)
1031     910 FORMAT(///,51X,34HPART6 NUMBERED A ZONES AND V ZONES)
1032     915 FORMAT(/,40X,17HSTATION OF GUTTER,2X,9HELEVATION,2X,
1033             116HZONE DESIGNATION,3X,3HFHF,/)
1034     920 FORMAT(/,35X,F16.2,F15.2,/)
1035     925 FORMAT(74X,1HA,I2,2X,3HEL=,I2,5X,I3)
1036     927 FORMAT(74X,1HV,I2,2X,3HEL=,I2,5X,I3)
1037     940 FORMAT(/,45X,17HSTATION OF GUTTER,10X,

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1038      116HLOCATION OF ZONE)
1039      950 FORMAT(/,45X,7HBETWEEN,F10.2,1X,3HAND,F10.2)
1040      960 FORMAT(/,35X,F11.2,10X,F11.2,10X,F11.2)
1041      970 FORMAT(/,40X,46HNO AREAS ABOVE 100-YEAR SURGE IN THIS TRANSECT)
1042      975 FORMAT(/,50X,33HNO SURGE CHANGES IN THIS TRANSECT)
1043      980 FORMAT(/,50X,34HZONE TERMINATED AT END OF TRANSECT)
1044      985 FORMAT(/,40X,7HSTATION,10X,13H10-YEAR SURGE,10X,14H100-YEAR SURGE)
1045      990 FORMAT(A2,78A1)
1046      995 FORMAT(/,10X,38HARRAY DIMENSIONS EXCEEDED. JOB DUMPED.)
1047      C      IN CASE OF ERROR SKIP TO NEXT TRANSECT
1048      1000 READ(10,990)TOF,(TITLE(I),I=1,78)
1049      822 FORMAT(F10.2,6X,'V',I2,7X,I2)
1050      823 FORMAT(F10.2,6X,'A',I2,7X,I2)
1051      817 FORMAT(2F10.2)
1052      IF(TOF.NE.ET)GO TO 1000
1053      GO TO 505
1054      1010 STOP
1055      END
1056      SUBROUTINE FETCH(WPI,TEST,WPT,W)
1057      C
1058      C      THIS SUBROUTINE COMPUTES THE WAVE HEIGHTS AND ELEVATIONS FOR
1059      C      INLAND AND OVERWATER FETCHES AND STORES THE RESULTS FOR FURTHER
1060      C      ANALYSIS BY THE REST OF THE PROGRAM. WAVE HEIGHTS AND ELEVATIONS
1061      C      ARE COMPUTED USING THE CONSERVATION OF WAVE ACTION EQUATION WITH A
1062      C      VARIABLE GRID SPACING TO PERMIT ACCURATE LINEAR INTERPOLATION OF
1063      C      WAVE HEIGHTS AND
1064      C      ELEVATIONS FOR DETERMINING FLOOD INSURANCE DATA. THE CONSERVATION
1065      C      OF ACTION EQUATION IS IDENTICAL TO THE ONE USED FOR MARSH GRASS
1066      C      CALCULATION EXCEPT THAT THE PLANT ENERGY DISSIPATION IS ZERO.
1067      C      THE SPECTRAL PEAK WAVE PERIOD IS CALCULATED USING A
1068      C      DIFFERENTIAL FORM OF THE 1984 SPM WAVE PERIOD GROWTH
1069      C      EQUATIONS. THIS FORM IS EQUIVALENT TO THE CONSERVATION
1070      C      OF WAVES EQUATION. THE NET WIND ENERGY INPUT FUNCTION
1071      C      FOR THE WAVE ACTION EQUATION IS BASED ON THE 1984 SPM
1072      C      WAVE GROWTH EQUATIONS. THE SHOALING EFFECT IS INCLUDED
1073      C      IN THE WAVE ACTION EQUATION.
1074      C
1075      C G&O 2/87
1076      LOGICAL TEST
1077      C
1078      REAL NUTAVG
1079      C G&O 2/87 END
1080      C
1081      DIMENSION PARAM(10),FFL(10),GFL(10),GFF(10),FFF(10),HBW(500)
1082      C
1083      DIMENSION AP(500),SA(500,5),GS(500),EW(500),STEG(500),ELZ(500)
1084      C
1085      COMMON /FONLY/FFL,FFF,GFL,GFF
1086      C
1087      COMMON /AFGV/TOF,PARAM,BSFO,BEFO,WHI,WHT,NFO,
1088      1HBW,AP,SET,SE,STEG,ELZ,GS,EW,SA,M,NAP
1089      C

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1090 C G&O 2/87
1091     COMMON / BTSLOP / GSLB, GSLE
1092 C G&O 2/87 END
1093 C
1094 C G&O SEPT 88
1095 C
1096     DIMENSION SPWP(500)
1097 C
1098     COMMON/ARRAY1/ SPWP
1099 C
1100 C END G&O SEPT 88
1101 C
1102     FO=2HOF
1103     FI=2HIF
1104     DELTA1=0.0
1105     DELTA2=0.0
1106     DELTA3=0.0
1107     STOF=TOF
1108 C
1109 C     RETRIEVE DATA FROM ARRAY PARAM
1110 C
1111     ESFO=PARAM(1)
1112     EEFO=PARAM(2)
1113     SETN=PARAM(3)
1114     SEN=PARAM(4)
1115 C
1116 C G&O 2/87
1117     ABGF = PARAM(10)
1118 C G&O END
1119 C
1120 C
1121 C     SET TOF PARAMETER
1122 C
1123     IF( TOF .EQ. FI ) TOF= 1.0
1124     IF( TOF .EQ. FO ) TOF= 2.0
1125 C
1126 C** THE BOTTOM SLOPE AT END OF TRANSECT SEGMENT,GSLE, AND BOTTOM
1127 C** SLOPE AT BEGINNING OF SEGMENT, GSLB, HAVE BEEN SET PRIOR TO
1128 C** ENTERING THIS SUBROUTINE
1129 C
1130 C     CHECK FOR INVALID DATA
1131     IF(ESFO.GT.BSFO)GO TO 10
1132     IF( W .EQ. 60. ) WRITE(6,500)
1133     IF( W .EQ. 80. ) WRITE(6,500)
1134     TEST=.TRUE.
1135     10 CONTINUE
1136 C
1137     IF(TEST)GO TO 90
1138 C
1139 C     SET DEFAULT FOR WF1
1140     IF(WF1.EQ.0)WF1=1
1141 C

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1142 C   SET DEFAULT SURGE VALUES
1143     IF(SETN.EQ.0)SETN=SET
1144     IF(SEN.EQ.0)SEN=SE
1145 C
1146 C
1147 C   CHECK FOR ZERO WAVE PERIOD
1148     90 IF(WPI.GT.0)GO TO 95
1149     WRITE(6,600)
1150     TEST=.TRUE.
1151 C
1152 C   RETURN IF ERROR FLAG IS SET
1153     95 IF(.NOT.TEST)GO TO 100
1154     WRITE(6,580)
1155     REWIND 8
1156     REWIND 9
1157     RETURN
1158     100 CONTINUE
1159 C
1160 C   SET MINIMUM WAVE PERIOD TO .1 SECONDS
1161     IF(WPI.LT..1)WPI=.1
1162 C
1163 C G&O 2/87
1164 C
1165 C**  EVALUATE VARIOUS CONSTANTS NEEDED FOR EVALUATION
1166 C
1167 C   W = WINDSPEED IN STATUTE MILES PER HOUR. IT IS READ IN AS ONE OF
1168 C   THE SUBROUTINE ARGUMENTS.
1169 C
1170     CA = (5.28)*(.589)/3.6
1171 C
1172     UA = CA*(W**1.23)
1173 C
1174     ATS = 7.54
1175 C
1176     SIGT = .0379
1177 C
1178     G = 32.2
1179 C
1180     AH = 0.283
1181 C
1182     GAMH = 0.53
1183 C
1184     SIGH = .00565
1185 C
1186     GAMT = 0.833
1187 C
1188     PI = 3.1415926536
1189 C
1190 C
1191     CTAU = ((ATS*SIGT)**3)*UA/(G*G)
1192 C
1193     CRSTR = AH*UA*UA/G

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1194 C
1195 CWPFF = ATS*UA/G
1196 C
1197 CNUT = (SIGT**3)/(SIGH*SIGH)
1198 C
1199 CBETH = GAMH*((G/(UA*UA))**0.75)
1200 C
1201 CBETT = GAMT*((G/(UA*UA))**0.375)
1202 C
1203 PI2 = 2*PI
1204 C
1205 PID2 = PI * 0.5
1206 C
1207 CLO = G/PI2
1208 C
1209 PI4 = 4*PI
1210 C
1211 CAAVG = ((SIGH*AH)**2)*(UA*UA)/G
1212 C
1213 CBAVG = (SIGH**2)*G/(UA*UA)
1214 C
1215 CPAVG = ((SIGT*ATS)**2)/PI4
1216 C
1217 CCAVG = 1./(3.*PI*SQRT(2.0))
1218 C
1219 C1D3 =1./3.
1220 CFNUT = ( CBETH/(CBETT**2) )**2
1221 C G&O 2/87 END
1222 C
1223 C
1224 C SOLVE DIFFERENTIAL EQUATION
1225 C
1226 C DETERMINE DELTA X
1227 DX=25
1228 X=ESFO-BSFO
1229 IF(X.LT.500)DX=X/20.0
1230 C
1231 C EVALUATE COMMON FACTORS OUTSIDE THE LOOP
1232 DTS=DX*(SETN-SA(NFO,3))/X
1233 DS=DX*(SEN-SA(NFO,4))/X
1234 DG=DX*(EEFO-BEFO)/X
1235 C G&O 2/87
1236 DGSL=DX*(GSLE-GSLB)/X
1237 C G&O 2/87 END
1238 SIG=.0125
1239 GOU2=.00415806
1240 OOM=2.38095
1241 C PI=3.14159
1242 C G=32.2
1243 C1LOG= ALOG10(2.0)
1244 C2LOG= .394528 * C1LOG
1245 DSOOM=.68057

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1246 C
1247 C INITIALIZE VARIABLES
1248 XSUM=0
1249 XOLD=0
1250 TSOLD=SA(NFO,3)
1251 SOLD=SA(NFO,4)
1252 GOLD=BEFO
1253 C
1254 C G&O 2/87
1255 GSOLD=GSLE
1256 WPOLD=WPI
1257 DOLD=SOLD-GOLD
1258 DOLDSTR=AMAX1(0.01,SOLD-GOLD)
1259 IPASS = 0
1260 TDX = AMIN1( 2*DX, X )
1261 C G&O 2/87 END
1262 C
1263 YNEW=0
1264 C
1265 C CONVERT CONTROLLING WAVE HEIGHT TO
1266 C ZERO MOMENT WAVE HEIGHT
1267 C
1268 C G&O SEPT 88
1269 C
1270 C STATEMENT BELOW COMMENTED OUT AND THEN
1271 C CORRECTED
1272 C
1273 C YOLD=HMO(WHI,SOLD-BEFO,WPI)
1274 C
1275 C THERE ARE TWO CASES CORRESPONDING TO
1276 C BREAKING AND NON-BREAKING WAVES.
1277 C
1278 C HBM = SHBM( WPI, GSOLD, DOLDSTR )
1279 C
1280 C IF( WHI .GE. HBM ) THEN
1281 C
1282 C WAVE IS BREAKING
1283 C
1284 C WHI = HBM
1285 C YOLD = HMO( WHI, SOLD-BEFO, WPI)
1286 C
1287 C ELSE
1288 C
1289 C WAVE IS NOT BREAKING
1290 C
1291 C YOLD = HMONB( WHI, SOLD-BEFO , WPI )
1292 C
1293 C ENDIF
1294 C
1295 C END G&O SEPT 88
1296 C
1297 C CHECK FOR EXIT CONDITION

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1298 C
1299 C G&O COMMENT OUT 2/87
1300 C 110 XNEW=XOLD+2*DX
1301 C END G&O COMMENT OUT
1302 C
1303 C G&O 2/87
1304 110 CONTINUE
1305 C
1306 XNEW = XOLD + TDx
1307 C G&O 2/87 END
1308 C
1309 IF(XNEW.GT.X)GO TO 135
1310 C
1311 C G&O 2/87
1312 IF( XNEW .EQ. X ) IPASS = 1
1313 C G&O 2/87 END
1314 C
1315 C DETERMINE COEFFFFICIENTS
1316 TSAVG=TSOLD+DTS
1317 SAVG=SOLD+DS
1318 GAVG=GOLD+DG
1319 DAVG=SAVG-GAVG
1320 CG&O 2/87
1321 DAVGSTR=AMAX1(0.01,DAVG)
1322 GSLAVG=GSLOLD+DGSL
1323 GSLNEW=GSLAVG+DGSL
1324 DXN=2.*DX
1325 DNEW=DAVG+(DS-DG)
1326 DNEWSTR=AMAX1(0.01,DNEW)
1327 C
1328 TSNEW = TSAVG + DTS
1329 SNEW = SAVG + DS
1330 GNEW = GAVG + DG
1331 C
1332 C CALCULATE COEFFICIENTS PREPARATORY TO CALCULATING WPNEW
1333 C
1334 BETHAVG = TANH(CBETH*(DAVGSTR**0.75))
1335 C
1336 BETTAVG = TANH(CBETT*(DAVGSTR**0.375))
1337 IF(BETTAVG.GT.0.1)THEN
1338 FNUT = ( BETHAVG/(BETTAVG**2) )**2
1339 ELSE
1340 FNUT = CFNUT
1341 ENDIF
1342 C
1343 BETTOLD = TANH(CBETT*(DOLDSTR**0.375))
1344 WPFOLD = CWPF*BETTOLD
1345 C
1346 C
1347 NUTAVG = CNUT*(BETTAVG)*FNUT
1348 C
1349 RSTRAVG = ( CRSTR*BETHAVG )**2

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1350 C
1351 ROLD = YOLD*YOLD
1352 C RAT1 = AMIN1((ROLD/RSTRAVG),1.0)
1353 C
1354 RAT2 = ROLD/RSTRAVG
1355 RAT1= AMIN1(RAT2,1.0)
1356 FTAVG = (1.-RAT1)**NUTAVG
1357 C
1358 DLTAOLD=1
1359 IF((RAT2.GE.1) .OR. (WPOLD.GE.WPFOLD)) DLTAOLD=0.0
1360 C
1361 IF(RAT2. LE. 1.0) THEN
1362     DLTAPLD = 1.0
1363 ELSE
1364     DLTAPLD = 1.0/RAT2
1365 ENDIF
1366 C
1367 IF( RAT2 .LT. 1.0 ) THEN
1368     DLTAPPD = 1.0
1369 ELSE
1370     DLTAPPD = 0.0
1371 ENDIF
1372 C
1373 DELTAU = DXN*CTAU*FTAVG*DLTAOLD
1374 C
1375 TAUOLD = WPOLD**3
1376 C
1377 TAUNEW = TAUOLD+DELTAU
1378 C
1379 C     CALCULATE SPECTRAL PEAK WAVE PERIOD AT END OF GRID CELL, WPNEW
1380 C
1381 WPNEW = TAUNEW**C1D3
1382 C
1383 C     CALCULATE ADDITIONAL FACTORS PREPARATORY TO CALCULATING
1384 C     THE NEW HMO, YNEW
1385 C
1386 C     RESET DLTAOLD TO 1 AND SET DLTAPLD AND DLTAPPD TO 1
1387 C
1388 DLTAOLD = 1.0
1389 DLTAPLD = 1.0
1390 DLTAPPD = 1.0
1391 C
1392 C     CALCULATE OTHER FACTORS
1393 C
1394 BAVG = CBAVG / (BETHAVG**2)
1395 C
1396 WLOOLD = CLO*WPOLD*WPOLD
1397 WLOOLD = AMAX1(0.1,WLOOLD)
1398 C
1399 WLONEW = CLO*WPNEW*WPNEW
1400 WLONEW = AMAX1(0.1,WLONEW)
1401 C

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1402      CDNEW = DNEWSTR/WLONEW
1403      C
1404      CDOLD = DOLDSTR/WLOOLD
1405      C
1406      C      WLOLD IS THE SPECTRAL PEAK WAVE LENGTH AT THE BEGINNING OF THE
1407      C      SEGMENT
1408      C
1409      WLOLD = WLOOLD*SQRT(TANH(PI2*CDOLD))
1410      WLOLD = AMAX1(0.1,WLOLD)
1411      C
1412      C      WLNEW IS THE SPECTRAL PEAK WAVLENGTH AT THE END OF THE SEGMENT
1413      C
1414      WLNEW = WLONEW*SQRT(TANH(PI2*CDNEW))
1415      WLNEW = AMAX1(0.1,WLNEW)
1416      WLI-WLNEW
1417      C
1418      SLOLD = PI4*DOLDSTR/WLOLD
1419      SLOLD = AMAX1(0.01,SLOLD)
1420      C
1421      SLNEW = PI4*DNEWSTR/WLNEW
1422      SLNEW = AMAX1(0.01,SLNEW)
1423      C
1424      IF(SLOLD.GT.0.04)THEN
1425      FLOLD = SLOLD/SINH(AMIN1(50.0,SLOLD))
1426      ELSE
1427      FLOLD = 1.0
1428      ENDIF
1429      C
1430      IF(SLNEW.GT.0.04)THEN
1431      FLNEW = SLNEW/SINH(AMIN1(50.0,SLNEW))
1432      ELSE
1433      FLNEW = 1.0
1434      ENDIF
1435      C
1436      C      CGTOLD IS THE PRODUCT OF THE SPECTRAL PEAK PERIOD AND WAVE GROUP
1437      C      VELOCITY AT THE BEGINNING OF THE SEGMENT
1438      C
1439      C      CGTNEW IS THE PRODUCT AT THE END OF THE GRID
1440      C
1441      CGTOLD = 0.5*WLOLD*(1.0+FLOLD)
1442      C
1443      CGTNEW = 0.5*WLNEW*(1.0+FLNEW)
1444      C
1445      C      CALCULATE VARIOUS FACTORS AT THE MIDPOINT OF THE
1446      C      GRID CELL. THESE ARE DESIGNATED BY AN "AVG" AT THE
1447      C      END.
1448      C
1449      WLOAVG = 0.5*CLO*((WPOLD**2)+(WPNEW**2))
1450      WLOAVG = AMAX1(0.1,WLOAVG)
1451      C
1452      CDAVG = DAVGSTR/WLOAVG
1453      C

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1454      DPAVG = PI2 * CDAVG
1455      SDPAVG = AMIN1( 1.E9 , SINH( AMIN1(50.0,DPAVG) ) )
1456      CDPAVG = AMIN1( 1.E9 , COSH( AMIN1(50.0,DPAVG) ) )
1457      C
1458      FDAVG = SQRT(TANH(PI2*CDAVG))
1459      C
1460      WLAVG = WLOAVG*FDAVG
1461      WLAVG = AMAX1(0.1,WLAVG)
1462      C
1463      SLAVG = PI4*DAVGSTR/WLAVG
1464      SLAVG = AMAX1( 0.01 , SLAVG )
1465      C
1466      SSLAVG = AMIN1( 1.E9 , SINH(AMIN1(50.0,SLAVG) ) )
1467      CSLAVG = AMIN1( 1.E9 , COSH(AMIN1(50.0,SLAVG) ) )
1468      C
1469      IF(SLAVG.GT.0.04)THEN
1470      FLAVG = SLAVG/SSLAVG
1471      ELSE
1472      FLAVG = 1.0
1473      ENDIF
1474      C
1475      IF( SLAVG .GT. 0.04 ) THEN
1476          FL1AVG = (SSLAVG - (SLAVG*CSLAVG) ) / (SSLAVG**2)
1477          FL5AVG = 1.0 + ( (FLAVG**2)*CSLAVG )
1478      ELSE
1479          FL1AVG = 0.0
1480          FL5AVG = 2.0
1481      ENDIF
1482      C
1483      IF( DPAVG .GT. 0.04 ) THEN
1484          T2AVG = SQRT((WLOAVG*CDAVG)/(SDPAVG*(CDPAVG**3)))
1485      ELSE
1486          T2AVG = SQRT( WLOAVG/PI2 )
1487      ENDIF
1488      C
1489      T4AVG = PI2 * FL1AVG
1490      T5AVG = PID2 * FL5AVG * T2AVG
1491      C
1492      CGTAVG = 0.5*WLAVG*(1.+FLAVG)
1493      C
1494      IF( DPAVG .GT. 0.04 ) THEN
1495          T78AVG = ( SQRT(DAVGSTR) )/CGTAVG
1496      ELSE
1497          T78AVG = 1./SQRT( PI2*WLOAVG )
1498      ENDIF
1499      C
1500      T7AVG = 2. * T4AVG * T78AVG
1501      T8AVG = T5AVG * T78AVG
1502      C
1503      AAVG = CAAVG
1504      C
1505      C      WPAVG IS THE SPECTRAL PEAK PERIOD AT THE MIDPOINT OF THE SEGMENT

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1506 C
1507 WPAVG = 0.5*(WPOLD+WPNEW)
1508 C
1509 C CAPGAM IS CAPITAL GAMMA, THE PLANT PARAMETER FACTOR MULTIPLIES
1510 C HMO**3 IN THE EXPRESSION FOR THE WAVE ENERGY DISSIPATION DUE TO
1511 C MARSH GRASS
1512 C
1513 C ZERO OUT CAPGAM AND CAVG SINCE THIS SUBROUTINE DOES
1514 C NOT HANDLE MARSH PLANTS
1515 C
1516 CAPGAM = 0.0
1517 C
1518 CAVG = 0.0
1519 C
1520 BPAVG = ( BAVG + (CAVG*YOLD) ) * DXN
1521 C
1522 P = -BPAVG
1523 C
1524 Q2A = AAVG * DXN
1525 C
1526 EFAVG = EXP(P)
1527 C
1528 IF( ABS(P) .GT. 0.001 ) THEN
1529 Q3 = ( 1.-EFAVG )/BPAVG
1530 ELSE
1531 Q3 = 1.0
1532 ENDIF
1533 C
1534 Q27 = EXP( -T7AVG*( SQRT(DNEWSTR) - SQRT(DAVGSTR) ) )
1535 Q17 = EXP( -T7AVG*( SQRT(DNEWSTR) - SQRT(DOLDSTR) ) )
1536 C
1537 Q28 = (DAVGSTR/DNEWSTR)**T8AVG
1538 Q18 = (DOLDSTR/DNEWSTR)**T8AVG
1539 C
1540 C CALCULATE RNEW AND YNEW AT END OF GRID CELL
1541 C
1542 RNEW = (ROLD*Q18*Q17*EFAVG) + (Q2A*Q28*Q27*Q3)
1543 YNEW = SQRT(RNEW)
1544 C
1545 C YNEW IS THE HMO AT END OF GRID CELL
1546 C
1547 WPI=WPNEW
1548 C
1549 CG&O 2/87 END
1550 C
1551 CG&O 2/87 COMMENTED OUT *****
1552 C WLO=5.12*(WPI**2)
1553 C WL=SQRT(2*PI*DAVG*WLO)/(1+1.25*DAVG/WLO)
1554 C IF(DAVG/WL.LT..04)CG=SQRT(G*DAVG)
1555 C IF(DAVG/WL.GT..5)CG=G*WPI/(4*PI)
1556 C IF(DAVG/WL.GE..04.AND.DAVG/WL.LE..5)CG=
1557 C 1(.5+(2*PI*DAVG/WL)/SINH(4*PI*DAVG/WL))*(WL/WPI)

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1558 C CP=(1/(CG*3*PI))*APP(DEF,DAVG,NPLTS,WPI,WL)
1559 C BETA=TANH(.530*(GOU2*DAVG)**.75)
1560 C A=DSOOM*GOU2
1561 C B=((SIG/BETA)**OOM)*GOU2
1562 C
1563 C THE CONSTANT IN THE NEXT LINE IS THE PRODUCT OF SQUARE ROOT 2
1564 C AND M = 0.42.
1565 C
1566 C C=CP/0.5939696
1567 C P=- (B+C*YOLD)*2*DX
1568 C
1569 C DETERMINE NEW VALUES OF VARIABLES
1570 C
1571 C R=((YOLD**OOM)*EXP(P))+((A/(B+C*YOLD))*(1-EXP(P)))
1572 C YNEW=R**.42
1573 C IF(YNEW.LE.YOLD)GO TO 115
1574 C F1=EFL(YOLD,DAVG)
1575 C IF(F1.EQ.-1)GO TO 115
1576 C F2=EFL(YNEW,DAVG)
1577 C IF(F2.EQ.-1)GO TO 115
1578 C F=F2-F1
1579 C IF(F.GT.2*DX)F=2*DX
1580 C WPI=T(WPI,F,88.0,DAVG)
1581 C
1582 C
1583 C THE NEXT 5 LINES OF CODE HAVE BEEN COMMENTED OUT SINCE
1584 C THEY ARE IN THE WRONG PLACE. THEY HAVE BEEN REWRITTEN
1585 C IN THEIR PROPER PLACES.
1586 C
1587 C 115 TSNEW-TSAVG+DTS
1588 C SNEW-SAVG+DS
1589 C GNEW-GAVG+DG
1590 C
1591 C XSUM=XSUM+(2*DX)
1592 C
1593 C STORE RESULTS AT 100 FT. INTERVALS OR GREATER
1594 C
1595 C IF(XSUM.LT.100)GO TO 120
1596 C
1597 C CONVERT ZERO MOMENT WAVE HEIGHT TO
1598 C ZERO MOMENT WAVE HEIGHT
1599 C
1600 C COMMENT OUT NEXT 3 LINES SINCE WLI HAS PREVIOUSLY BEEN SET
1601 C
1602 C DNEW=SNEW-GNEW
1603 C WLO=5.12*(WPI**2)
1604 C WLI=SQRT(2*PI*DNEW*WLO)/(1+1.25*DNEW/WLO)
1605 C G&O 2/87 END COMMENTING OUT*****
1606 C
1607 C CONVERT ZERO MOMENT WAVE HEIGHT YNEW TO SIGNIFICANT
1608 C WAVE HEIGHT HS
1609 C

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1610          WLISTR = AMAX1( 0.1 , WLI )
1611      C
1612          EPP=YNEW/(4*WLISTR*.002)
1613          EPP = AMAX1( 1.0E-4 , EPP )
1614      C
1615          WPISTR = AMAX1( 0.1 , WPI )
1616      C
1617      C G&O 2/87 COMMENTED OUT
1618      C          DD=DNEW/(G*WPI**2)
1619      C G&O 2/87 END COMMENTED OUT
1620      C
1621          DD=DNEWSTR/(G*(WPISTR**2))
1622      C
1623      C
1624      C G&O SEPT 88
1625      C
1626      C          COMMENTED OUT TO MAKE EXPRESSION FOR HS CONSISTENT WITH
1627      C          THOMPSON & VINCENT'S HS EXPRESSION IN 1985 WATERWAYS & HARBOR
1628      C          ARTICLE
1629      C
1630      C          DC=5.5722E-5
1631      C          PART1=.9+(.42707*ALOG10(DD/DC))
1632      C          IF(EPP.LE.2)PHI=PART1-(1.411296*ALOG10(EPP))
1633      C          IF(EPP.GT.2)PHI=PART1-C2LOG-(1.016768*ALOG10(EPP))
1634      C
1635      C G&O 9/88 END
1636      C
1637          DO=1.357E-3
1638          RAV=1.477+.477*(((DO/DD)**.8557)-1)
1639          IF(RAV.GT.1.7)RAV=1.7
1640          IF( RAV .LT. 1.0 ) RAV= 1.0
1641      C
1642      C G&O SEPT 88
1643      C
1644      C          COMMENTED OUT TO MAKE EXPRESSION FOR HS CONSISTENT WITH
1645      C          THOMPSON & VINCENT'S HS EXPRESSION IN 1985 WATERWAYS & HARBOR
1646      C          ARTICLE
1647      C
1648      C          IF(PHI.LT.1)PHI=1
1649      C          IF(PHI.GT.RAV)PHI=RAV
1650      C
1651      C G&O 9/88 END
1652      C
1653      C G&O 9/88 SET PHI TO CORRECT EXPRESSION
1654      C
1655          PHI = RAV
1656      C
1657      C G&O 9/88 END
1658      C
1659          HS=PHI*YNEW
1660      C
1661      C          CONVERT SIGNIFICANT WAVE HEIGHT TO

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1662 C CONTROLLING WAVE HEIGHT WHT
1663 WHT=1.6*HS
1664 C
1665 C G&O 2/87
1666 C
1667 C IF THE CONTROLLING WAVE BREAKS, COMPUTE THE EQUIV-
1668 C ALENT ZERO MOMENT WAVE HEIGHT.
1669 C
1670 C HBM = SHBM( WPNEW, GSLNEW , DNEWSTR )
1671 C
1672 C G&O SEPT 88
1673 C
1674 C THE STATEMENT BELOW IS COMMENTED OUT AND
1675 C CORRECTED
1676 C
1677 C IF( WHT .GT. HBM ) THEN
1678 C
1679 C IF( WHT .GE. HBM ) THEN
1680 C
1681 C END G&O SEPT 88
1682 C
1683 C WHT = HBM
1684 C YNEW = HMO( WHT, DNEWSTR , WPI )
1685 C ENDIF
1686 C
1687 C 115 CONTINUE
1688 C
1689 C STORE RESULTS AT 100 FT. INTERVALS OR GREATER OR
1690 C AT END OF TRANSECT SEGMENT
1691 C
1692 C XSUM = XSUM + TDX
1693 C
1694 C IF(XSUM.LT.100)GO TO 120
1695 C G&O 2/87 END
1696 C
1697 C INCREMENT ARRAY SUBSCRIPT AND CHECK AGAINST
1698 C ARRAY DIMENSION
1699 C NFO=NFO+1
1700 C IF(NFO.GT.500)WRITE(6,995)
1701 C IF(NFO.GT.500)STOP
1702 C
1703 C COMPUTE NEW GROUND STATION,WAVE HEIGHT, AND
1704 C WAVE ELEVATION AND STORE RESULTS
1705 C GS(NFO)=BSFO+XNEW
1706 C
1707 C G&O 2/87
1708 C HBM=SHBM(WPNEW,GSLNEW,DNEWSTR)
1709 C WHM=HBM
1710 C WHM=.78*(SNEW-GNEW)
1711 C G&O 2/87 END
1712 C
1713 C IF(WHT.GT.WHM)WHT=WHM

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1714         HBW(NFO)=WHT
1715 C
1716 C G&O 2/87
1717         STMP=GNEW+DNEW
1718 C         EW(NFO)=.7*HBW(NFO)+SAVG
1719         EW(NFO)=.7*HBW(NFO)+STMP
1720 C G&O 2/87 END
1721 C
1722 C G&O SEPT 88
1723 C
1724         SPWP(NFO) = WPNEW
1725 C
1726 C END G&O SEPT 88
1727 C
1728         NFOM1=NFO-1
1729         SA(NFO,1)=GS(NFOM1)
1730         SA(NFO,2)=GS(NFO)
1731         SA(NFO,3)=TSNEW
1732         SA(NFO,4)=SNEW
1733 C
1734 C G&O 2/87
1735 C         SA(NFO,5)=1
1736 C
1737         IF( GS(NFO) .EQ. ESFO ) THEN
1738             SA( NFO,5 ) = STOF
1739         ELSE
1740             SA( NFO,5 ) = TOF
1741         ENDIF
1742 C G&O 2/87 END
1743 C
1744         XSUM=0
1745 C
1746 C G&O 2/87 COMMENTED OUT
1747 C
1748 C         THE NEXT TWO LINES ARE COMMENTED OUT SINCE THEY ARE
1749 C         IN THE WRONG PLACE
1750 C
1751 C         IF THE CONTROLLING WAVE BREAKS, COMPUTE THE
1752 C         EQUIVALENT ZERO MOMENT WAVE HEIGHT
1753 C
1754 C         IF(1.6*HS.LE.WHM)GO TO 120
1755 C         YNEW=HMO(WHT,DNEW,WPI)
1756 C G&O 2/87 END COMMENTED OUT
1757 C
1758         120 CONTINUE
1759 C
1760 C G&O 2/87
1761 C
1762 C         IF IPASS .EQ. 1, THEN THIS IS LAST PASS THROUGH THE
1763 C         LOOP. EXIT LOOP
1764 C
1765         IF( IPASS .EQ. 1 ) GO TO 135

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1766 C
1767 C G&O 2/87 END
1768 C
1769 C          ADJUST STEP SIZE
1770 C
1771 C          YTEST=ABS(YNEW-YOLD)
1772 C
1773 C G&O 2/87
1774 C          TDXMAX = X - XNEW
1775 C          DXMAX  = 0.5 * TDXMAX
1776 C G&O 2/87 END
1777 C
1778 C          IF( YTEST .GT. .05 ) GO TO 125
1779 C
1780 C G&O 2/87
1781 C          DX=2*DX
1782 C
1783 C          DXOLD = DX
1784 C          DXNEW = AMIN1( 2.*DX ,DXMAX )
1785 C          RATX  = 0.5 * DXNEW/DXOLD
1786 C          DX    = DXNEW
1787 C          TDX   = AMIN1( 2.*DX, TDXMAX)
1788 C
1789 C
1790 C          DTS=2*DTS*RATX
1791 C          DS=2*DS*RATX
1792 C          DG=2*DG*RATX
1793 C          DGSL=2.*DGSL*RATX
1794 C G&O 2/87 END
1795 C
1796 C          GO TO 130
1797 C
1798 C G&O 2/87
1799 C 125 IF( YTEST .LT. 0.1 ) GO TO 1000
1800 C          IF( DX    .LT. 5.0 ) GO TO 1000
1801 C
1802 C          DX=.5*DX
1803 C
1804 C          DXOLD = DX
1805 C          DXNEW = AMIN1( 0.5*DX,DXMAX )
1806 C          RATX  = 2. * DXNEW/DXOLD
1807 C          DX    = DXNEW
1808 C          TDX   = AMIN1( 2.*DX, TDXMAX )
1809 C
1810 C          DTS=.5*DTS*RATX
1811 C          DS=.5*DS*RATX
1812 C          DG=.5*DG*RATX
1813 C          DGSL=0.5*DGSL*RATX
1814 C
1815 C          GO TO 130
1816 C
1817 C 1000 CONTINUE

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1818 C
1819 DXOLD = DX
1820 DXNEW = AMIN1( DX,DXMAX )
1821 RATX = DXNEW/DXOLD
1822 DX = DXNEW
1823 TDX = AMIN1( 2.*DX,TDXMAX )
1824 C
1825 DTS=DTS*RATX
1826 DS=DS*RATX
1827 DG=DG*RATX
1828 DGSL=DGSL*RATX
1829 C G&O 2/87 END
1830 C
1831 C UPDATE RECURSIVE VARIABLES AND LOOP BACK
1832 130 XOLD=XNEW
1833 YOLD=YNEW
1834 TSOLD=TSNEW
1835 SOLD=SNEW
1836 GOLD=GNEW
1837 C
1838 C G&O 2/87
1839 GSLOLD=GSLNEW
1840 WPOLD=WPNEW
1841 DOLD=DNEW
1842 DOLDSTR=AMAX1(0.01,DOLD)
1843 C G&O 2/87 END
1844 C
1845 GO TO 110
1846 C
1847 C STORE FINAL VALUE IF IT HAS NOT ALREADY BEEN STORED
1848 C
1849 135 IF(GS(NFO).EQ.ESFO)GO TO 140
1850 NFO=NFO+1
1851 GS(NFO)=ESFO
1852 C
1853 C G&O 2/87
1854 HBM=SHBM(WPNEW,GSLNEW,DNEWSTR)
1855 WHM=HBM
1856 C WHM=.78*(SE-EEFO)
1857 WHT=AMIN1(WHT,WHM)
1858 C G&O 2/87 END
1859 C
1860 HBW(NFO)=AMIN1(WHT,WHM)
1861 STMP=GNEW+DNEW
1862 C EW(NFO)=.7*HBW(NFO)+SAVG
1863 EW(NFO)=.7*HBW(NFO)+STMP
1864 C
1865 C
1866 C G&O SEPT 88
1867 C
1868 SPWP(NFO) = WPNEW
1869 C

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```

1870 C END G&O SEPT 88
1871 C
1872 C
1873 SA(NFO,1)=XOLD
1874 SA(NFO,2)=ESFO
1875 SA(NFO,3)=SETN
1876 SA(NFO,4)=SEN
1877 C
1878 C G&O 2/87
1879 C 140 SA(NFO,5)=2HVH
1880 C
1881 SA( NFO,5 ) = STOF
1882 C
1883 140 CONTINUE
1884 C G&O 2/87 END
1885 C
1886 C INSERT ABGF IF REQUIRED
1887 C
1888 IF(ABGF.NE.1)GO TO 150
1889 NAP=NAP+1
1890 AP(NAP)=ESFO
1891 M=M+1
1892 STEG(M)=GS(NFO)
1893 ELZ(M)=EW(NFO)
1894 C
1895 C GET READY FOR NEXT FETCH OR OBSTRUCTION AND RETURN
1896 150 BSFO=ESFO
1897 BEFO=EEFO
1898 C
1899 C G&O 2/87 ** COMMENTED OUT AND INSERT ***
1900 C WHI=HBW(NFO)
1901 WPT=WPNEW
1902 C G&O 2/87 ** END OF COMMENTED OUT AND INSERT ***
1903 RETURN
1904 500 FORMAT(/,10X,34HINVALID DATA IN FIELD 1 OF IF CARD)
1905 520 FORMAT(/,10X,34HINVALID DATA IN FIELD 1 OF OF CARD)
1906 580 FORMAT(/,10X,11HJOB DUMPED.)
1907 600 FORMAT(/,10X,'WAVE PERIOD LESS THAN OR EQUAL TO ZERO',/
1908 1 10X,'IN SUBROUTINE FETCH.ABORT RUN')
1909 995 FORMAT(/,10X,38HARRAY DIMENSIONS EXCEEDED. JOB DUMPED.)
1910 END
1911 SUBROUTINE VEG(WPI,TEST,WPT,W)
1912 C THIS SUBROUTINE READS MG CARDS ASSOCIATED WITH
1913 C MARSH GRASS OR OTHER PLANT COMMUNITIES AND DETERMINES
1914 C WAVE HEIGHTS AND ELEVATIONS.
1915 C
1916 C THIS VERSION OF VEG SOLVES THE WAVE ACTION EQUATION
1917 C WITH SHOALING EFFECTS. THE NET WIND ENERGY INPUT
1918 C FUNCTION IS BASED ON AN APPROXIMATE FORM OF THE 1984
1919 C SPM WAVE GROWTH EXPRESSIONS. THE SPECTRAL PEAK WAVE
1920 C PERIOD IS COMPUTED USING AN APPROXIMATE FORM OF 1984
1921 C SPM WAVE PERIOD GROWTH EXPRESSIONS IN DIFFERENTIAL

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1922 C          FORM. THE WAVE PERIOD APPROACH IS TANTAMOUNT TO USING
1923 C          THE CONSERVATION OF WAVES EQUATION IN DIFFERENTIAL FORM
1924 C
1925 C          LOGICAL TEST
1926 C
1927 C G&O 2/87
1928 C          REAL NUTAVG
1929 C G&O 2/87 END
1930 C
1931 C          DIMENSION CDE(10),FCOV(10),HBI(10),PPSF(10),SDB(10),
1932 C          1SDM(10),SDT(10),TYPE(10),FAR(10),DEF1(10,8),DEF2(10,8),DEF(10,8)
1933 C
1934 C          DIMENSION PARAM(10),HBW(500),AP(500),
1935 C          1STEG(500),ELZ(500),GS(500),EW(500),SA(500,5)
1936 C
1937 C          COMMON /AFGV/TOF,PARAM,BSFO,BEFO,WHI,WHT,NFO,
1938 C          1HBW,AP,SET,SE,STEG,ELZ,GS,EW,SA,M,NAP
1939 C
1940 C          COMMON /PP/NPLTS,TYPE,CDE,FCOV,HBI,PPSF,SDB,SDM,SDT,FAR
1941 C G&O 2/87
1942 C          COMMON /BTSLOP/GSLB,GSLE
1943 C G&O 2/87 END
1944 C
1945 C G&O SEPT 88
1946 C
1947 C          DIMENSION SPWP(500)
1948 C
1949 C          COMMON/ARRAY1/ SPWP
1950 C
1951 C END G&O SEPT 88
1952 C
1953 C          RETRIEVE DATA FROM ARRAY PARAM
1954 C          ESFO=PARAM(1)
1955 C          EEFO=PARAM(2)
1956 C          REG1=PARAM(3)
1957 C          WF1=PARAM(4)
1958 C          REG2=PARAM(5)
1959 C          NPLTS=PARAM(6)
1960 C          SETN=PARAM(7)
1961 C          SEN=PARAM(8)
1962 C          ABGF=PARAM(10)
1963 C G&O 2/87
1964 C
1965 C          SET STOF AND RESET TOF
1966 C
1967 C          STOF = TOF
1968 C          TOF = 1.0
1969 C
1970 C END G&O 2/87
1971 C
1972 C** THE BOTTOM SLOPE AT END OF TRANSECT SEGMENT,GSLE, AND BOTTOM
1973 C** SLOPE AT BEGINNING OF SEGMENT, GSLB, HAVE BEEN SET PRIOR TO

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1974 C** ENTERING THIS SUBROUTINE
1975 C
1976 C CHECK FOR INVALID DATA
1977 IF(ESFO.GT.BSFO)GO TO 10
1978 WRITE(6,500)
1979 TEST=.TRUE.
1980 10 IF(REG1.LE.8.AND.REG2.LE.8)GO TO 20
1981 WRITE(6,520)
1982 TEST=.TRUE.
1983 20 IF(REG1.EQ.INT(REG1).AND.REG2.EQ.INT(REG2))GO TO 25
1984 WRITE(6,520)
1985 TEST=.TRUE.
1986 25 IF(REG1.GE.1.AND.REG2.GE.0)GO TO 30
1987 WRITE(6,520)
1988 TEST=.TRUE.
1989 30 IF(WF1.LE.1.AND.WF1.GE.0)GO TO 40
1990 WRITE(6,530)
1991 TEST=.TRUE.
1992 40 IF(NPLTS.LE.10.AND.NPLTS.GT.0)GO TO 60
1993 WRITE(6,540)
1994 TEST=.TRUE.
1995 60 CONTINUE
1996 IF(TEST)GO TO 90
1997 C
1998 C SET DEFAULT FOR WF1
1999 IF(WF1.EQ.0)WF1=1
2000 C
2001 C SET DEFAULT SURGE VALUES
2002 IF(SETN.EQ.0)SETN=SET
2003 IF(SEN.EQ.0)SEN=SE
2004 C
2005 C READ MG CARDS
2006 DO 80 I=1,NPLTS
2007 READ(10,560)TOF,(PARAM(J),J=1,10)
2008 IF(TOF.EQ.2HMG)GO TO 70
2009 TEST=.TRUE.
2010 WRITE(6,570)
2011 BACKSPACE 5
2012 GO TO 90
2013 70 WRITE(6,590)TOF,(PARAM(J),J=1,10)
2014 WRITE(8,590)TOF,(PARAM(J),J=1,10)
2015 TYPE(I)=PARAM(1)
2016 CDE(I)=PARAM(2)
2017 FCOV(I)=PARAM(3)
2018 HBI(I)=PARAM(4)
2019 PPSF(I)=PARAM(5)
2020 SDB(I)=PARAM(6)/12.0
2021 SDM(I)=PARAM(7)/12.0
2022 SDT(I)=PARAM(8)/12.0
2023 FAR(I)=PARAM(9)
2024 IF(FCOV(I).LE.NPLTS)GO TO 80
2025 TEST=.TRUE.

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2026      WRITE(6,545)
2027  80   CONTINUE
2028  C
2029  C   LOOK UP DEFAULT PLANT PARAMETERS
2030      IF(REG2.NE.0)GO TO 85
2031      CALL LOOKUP(DEF,REG1,TEST)
2032      GO TO 90
2033  85   CALL LOOKUP(DEF1,REG1,TEST)
2034      CALL LOOKUP(DEF2,REG2,TEST)
2035  C
2036  C   COMPUTE WEIGHTED AVERAGE
2037      CALL WAVG(DEF1,DEF2,DEF,WF1,REG1,REG2,NPLTS,TYPE,TEST)
2038  C
2039  C   CHECK FOR ZERO WAVE PERIOD
2040  90   IF(WPI.GT.0)GO TO 95
2041      WRITE(6,600)
2042      TEST=.TRUE.
2043  C
2044  C   RETURN IF ERROR FLAG IS SET
2045  95   IF(.NOT.TEST)GO TO 100
2046      WRITE(6,580)
2047      REWIND 8
2048      REWIND 9
2049      RETURN
2050  100  CONTINUE
2051  C
2052  C   WRITE PLANT PARAMETERS TO SCRATCH FILE
2053      DO 105 I=1,NPLTS
2054      WRITE(9,610)TYPE(I),(DEF(I,J),J=1,8)
2055  105  CONTINUE
2056  C
2057  C   SET MINIMUM WAVE PERIOD TO .1 SECONDS
2058      IF(WPI.LT..1)WPI=.1
2059  C
2060  C G&O 2/87
2061  C
2062  C**  EVALUATE VARIOUS CONSTANTS NEEDED FOR EVALUATION
2063  C
2064  C   W = WINDSPEED IN STATUTE MILES PER HOUR. IT IS READ IN AS ONE OF
2065  C   THE SUBROUTINE ARGUMENTS.
2066  C
2067      CA = (5.28)*(.589)/3.6
2068  C
2069      UA = CA*(W**1.23)
2070  C
2071      ATS = 7.54
2072  C
2073      SIGT = .0379
2074  C
2075      G = 32.2
2076  C
2077      AH = 0.283

```

2078 C
2079 GAMH = 0.53
2080 C
2081 SIGH = .00565
2082 C
2083 GAMT = 0.833
2084 C
2085 PI = 3.1415926536
2086 C
2087 C
2088 CTAU = ((ATS*SIGT)**3)*UA/(G*G)
2089 C
2090 CRSTR = AH*UA*UA/G
2091 C
2092 CWPFF = ATS*UA/G
2093 C
2094 CNUT = (SIGT**3)/(SIGH*SIGH)
2095 C
2096 CBETH = GAMH*((G/(UA*UA))**0.75)
2097 C
2098 CBETT = GAMT*((G/(UA*UA))**0.375)
2099 C
2100 PI2 = 2*PI
2101 C
2102 PID2 = PI * 0.5
2103 C
2104 CLO = G/PI2
2105 C
2106 PI4 = 4*PI
2107 C
2108 CAAVG = ((SIGH*AH)**2)*(UA*UA)/G
2109 C
2110 CBAVG = (SIGH**2)*G/(UA*UA)
2111 C
2112 CPAVG = ((SIGT*ATS)**2)/PI4
2113 C
2114 CCAVG = 1./(3.*PI*SQRT(2.0))
2115 C
2116 C1D3 =1./3.
2117 CFNUT = (CBETH/(CBETT**2))**2
2118 C G&O 2/87 END
2119 C
2120 C
2121 C SOLVE DIFFERENTIAL EQUATION
2122 C
2123 C G&O SEPT 88
2124 C
2125 C CALCULATE INITIAL DELTA X. NOTE THAT THIS
2126 C INITIAL DELTA X STARTS OFF 5 TIME SMALLER FOR
2127 C VH CARDS THAN IF OR OF CARDS. COMMENT OUT
2128 C STATEMENTS WHICH WERE ORIGINALLY USED TO
2129 C SET INITIAL DELTA X AND REPLACE WITH REVISED


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2130 C STATEMENTS.
2131 C
2132 C DETERMINE DELTA X
2133 C DX=25
2134 C DX= 5
2135 C X=ESFO-BSFO
2136 C IF(X.LT.500)DX=X/20.0
2137 C IF(X.LT.100)DX=X/20.0
2138 C
2139 C END G&O SEPT 88
2140 C
2141 C EVALUATE COMMON FACTORS OUTSIDE THE LOOP
2142 C DTS=DX*(SETN-SA(NFO,3))/X
2143 C DS=DX*(SEN-SA(NFO,4))/X
2144 C DG=DX*(EEFO-BEFO)/X
2145 C G&O 2/87
2146 C DGSL=DX*(GSLE-GSLB)/X
2147 C G&O 2/87 END
2148 C SIG=.0125
2149 C GOU2=.00415806
2150 C OOM=2.38095
2151 C PI=3.14159
2152 C G=32.2
2153 C C1LOG= ALOG10(2.0)
2154 C C2LOG= .394528 * C1LOG
2155 C DSOOM=.68057
2156 C
2157 C INITIALIZE VARIABLES
2158 C XSUM=0
2159 C XOLD=0
2160 C TSOLD=SA(NFO,3)
2161 C SOLD=SA(NFO,4)
2162 C GOLD=BEFO
2163 C
2164 C G&O 2/87
2165 C GSLOLD=GSLB
2166 C WPOLD=WPI
2167 C DOLD=SOLD-GOLD
2168 C DOLDSTR=AMAX1(0.01,SOLD-GOLD)
2169 C IPASS = 0
2170 C TDX = AMIN1( 2*DX, X )
2171 C G&O 2/87 END
2172 C
2173 C YNEW=0
2174 C
2175 C CONVERT CONTROLLING WAVE HEIGHT TO
2176 C ZERO MOMENT WAVE HEIGHT
2177 C
2178 C G&O SEPT 88
2179 C
2180 C STATEMENT BELOW COMMENTED OUT AND THEN
2181 C CORRECTED

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2182 C
2183 C YOLD=HMO(WHI, SOLD-BEFO, WPI)
2184 C
2185 C THERE ARE TWO CASES CORRESPONDING TO
2186 C BREAKING AND NON-BREAKING WAVES.
2187 C
2188 C HBM = SHBM( WPI, GSLOLD, DOLDSTR )
2189 C
2190 C IF( WHI .GE. HBM ) THEN
2191 C
2192 C WAVE IS BREAKING
2193 C
2194 C WHI = HBM
2195 C YOLD = HMO( WHI, SOLD-BEFO, WPI)
2196 C
2197 C ELSE
2198 C
2199 C WAVE IS NOT BREAKING
2200 C
2201 C YOLD = HMONB( WHI, SOLD-BEFO , WPI )
2202 C
2203 C ENDIF
2204 C
2205 C END G&O SEPT 88
2206 C
2207 C CHECK FOR EXIT CONDITION
2208 C
2209 C G&O COMMENT OUT 2/87
2210 C 110 XNEW=XOLD+2*DX
2211 C END G&O COMMENT OUT
2212 C
2213 C G&O 2/87
2214 110 CONTINUE
2215 C
2216 C XNEW = XOLD + TDX
2217 C G&O 2/87 END
2218 C
2219 C IF(XNEW.GT.X)GO TO 135
2220 C
2221 C G&O 2/87
2222 C IF( XNEW .EQ. X ) IPASS = 1
2223 C G&O 2/87 END
2224 C
2225 C DETERMINE COEFFFFICIENTS
2226 C TSAVG=TSOLD+DTS
2227 C SAVG=SOLD+DS
2228 C GAVG=GOLD+DG
2229 C DAVG=SAVG-GAVG
2230 CG&O 2/87
2231 C DAVGSTR=AMAX1(0.01, DAVG)
2232 C GSLAVG=GSLOLD+DGSL
2233 C GSLNEW=GSLAVG+DGSL

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```

2234      DXN=2.*DX
2235      DNEW=DAVG+(DS-DG)
2236      DNEWSTR=AMAX1(0.01,DNEW)
2237      C
2238      TSNEW = TSAVG + DTS
2239      SNEW  = SAVG + DS
2240      GNEW  = GAVG + DG
2241      C
2242      C          CALCULATE COEFFICIENTS PREPARATORY TO CALCULATING WPNEW
2243      C
2244      BETHAVG = TANH(CBETH*(DAVGSTR**0.75))
2245      C
2246      BETTAVG = TANH(CBETT*(DAVGSTR**0.375))
2247      IF(BETTAVG.GT.0.1)THEN
2248      FNUT = ( BETHAVG/(BETTAVG**2) )**2
2249      ELSE
2250      FNUT = CFNUT
2251      ENDIF
2252      C
2253      BETTOLD = TANH(CBETT*(DOLDSTR**0.375))
2254      WPFOLD = CWPF*BETTOLD
2255      C
2256      C
2257      NUTAVG = CNUT*(BETTAVG)*FNUT
2258      C
2259      RSTRAVG = ( CRSTR*BETHAVG )**2
2260      C
2261      ROLD = YOLD*YOLD
2262      RAT1 = AMIN1((ROLD/RSTRAVG),1.0)
2263      C
2264      RAT2 = ROLD/RSTRAVG
2265      RAT1= AMIN1(RAT2,1.0)
2266      FTAVG = (1.-RAT1)**NUTAVG
2267      C
2268      DLTAOLD=1
2269      IF((RAT2.GE.1) .OR. (WPOLD.GE.WPFOLD)) DLTAOLD=0.0
2270      C
2271      IF(RAT2. LE. 1.0) THEN
2272      DLTAPLD = 1.0
2273      ELSE
2274      DLTAPLD = 1.0/RAT2
2275      ENDIF
2276      C
2277      IF( RAT2 .LT. 1.0 ) THEN
2278      DLTAPPD = 1.0
2279      ELSE
2280      DLTAPPD = 0.0
2281      ENDIF
2282      C
2283      DELTAU = DXN*CTAU*FTAVG*DLTAOLD
2284      C
2285      TAUOLD = WPOLD**3

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```

2286 C
2287 TAUNEW = TAUOLD+DELTAU
2288 C
2289 C CALCULATE SPECTRAL PEAK WAVE PERIOD AT END OF GRID CELL, WPNEW
2290 C
2291 WPNEW = TAUNEW**C1D3
2292 C
2293 C CALCULATE ADDITIONAL FACTORS PREPARATORY TO CALCULATING
2294 C THE NEW HMO, YNEW
2295 C
2296 C RESET DLTAOLD TO 1 AND SET DLTAOLD AND DLTAOLD TO 1
2297 C
2298 DLTAOLD = 1.0
2299 DLTAOLD = 1.0
2300 DLTAOLD = 1.0
2301 C
2302 C CALCULATE OTHER FACTORS
2303 C
2304 BAVG = CBAVG / (BETHAVG**2)
2305 C
2306 WLOOLD = CLO*WPOLD*WPOLD
2307 WLOOLD = AMAX1(0.1, WLOOLD)
2308 C
2309 WLONEW = CLO*WPNEW*WPNEW
2310 WLONEW = AMAX1(0.1, WLONEW)
2311 C
2312 CDNEW = DNEWSTR/WLONEW
2313 C
2314 CDOLD = DOLDSTR/WLOOLD
2315 C
2316 C WLOLD IS THE SPECTRAL PEAK WAVE LENGTH AT THE BEGINNING OF THE
2317 C SEGMENT
2318 C
2319 WLOLD = WLOOLD*SQRT(TANH(PI2*CDOLD))
2320 WLOLD = AMAX1(0.1, WLOLD)
2321 C
2322 C WLNEW IS THE SPECTRAL PEAK WAVLENGTH AT THE END OF THE SEGMENT
2323 C
2324 WLNEW = WLONEW*SQRT(TANH(PI2*CDNEW))
2325 WLNEW = AMAX1(0.1, WLNEW)
2326 WLI=WLNEW
2327 C
2328 SLOLD = PI4*DOLDSTR/WLOLD
2329 SLOLD = AMAX1(0.01, SLOLD)
2330 C
2331 SLNEW = PI4*DNEWSTR/WLNEW
2332 SLNEW = AMAX1(0.01, SLNEW)
2333 C
2334 IF(SLOLD.GT.0.04) THEN
2335 FLOLD = SLOLD/SINH(AMIN1(50.0, SLOLD))
2336 ELSE
2337 FLOLD = 1.0

```

```

2338      ENDIF
2339      C
2340      IF(SLNEW.GT.0.04) THEN
2341      FLNEW = SLNEW/SINH(AMIN1(50.0,SLNEW))
2342      ELSE
2343      FLNEW = 1.0
2344      ENDIF
2345      C
2346      C      CGTOLD IS THE PRODUCT OF THE SPECTRAL PEAK PERIOD AND WAVE GROUP
2347      C      VELOCITY AT THE BEGINNING OF THE SEGMENT
2348      C
2349      C      CGTNEW IS THE PRODUCT AT THE END OF THE GRID
2350      C
2351      CGTOLD = 0.5*WLOLD*(1.0+FLOLD)
2352      C
2353      CGTNEW = 0.5*WLNEW*(1.0+FLNEW)
2354      C
2355      C      CALCULATE VARIOUS FACTORS AT THE MIDPOINT OF THE
2356      C      GRID CELL. THESE ARE DESIGNATED BY AN "AVG" AT THE
2357      C      END.
2358      C
2359      WLOAVG = 0.5*CLO*((WPOLD**2)+(WPNEW**2))
2360      WLOAVG = AMAX1(0.1,WLOAVG)
2361      C
2362      CDAVG = DAVGSTR/WLOAVG
2363      C
2364      DPAVG = PI2 * CDAVG
2365      SDPAVG = AMIN1( 1.E9 ,  SINH( AMIN1(50.0,DPAVG) ) )
2366      CDPAVG = AMIN1( 1.E9 ,  COSH( AMIN1(50.0,DPAVG) ) )
2367      C
2368      FDAVG = SQRT(TANH(PI2*CDAVG))
2369      C
2370      WLAVG = WLOAVG*FDAVG
2371      WLAVG = AMAX1(0.1,WLAVG)
2372      C
2373      SLAVG = PI4*DAVGSTR/WLAVG
2374      SLAVG = AMAX1( 0.01 ,  SLAVG )
2375      C
2376      SSLAVG = SINH(AMIN1(50.0,SLAVG))
2377      CSLAVG = COSH(AMIN1(50.0,SLAVG))
2378      C
2379      IF(SLAVG.GT.0.04) THEN
2380      FLAVG = SLAVG/SSLAVG
2381      ELSE
2382      FLAVG = 1.0
2383      ENDIF
2384      C
2385      IF( SLAVG .GT. 0.04 ) THEN
2386      FL1AVG = (SSLAVG - (SLAVG*CSLAVG) ) / (SSLAVG**2)
2387      FL5AVG = 1.0 + ( (FLAVG**2)*CSLAVG )
2388      ELSE
2389      FL1AVG = 0.0

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```

2390         FL5AVG = 2.0
2391     ENDIF
2392 C
2393     IF( DPAVG .GT. 0.04 ) THEN
2394     T2AVG = SQRT((WLOAVG*CDAVG)/(SDPAVG*(CDPAVG**3)))
2395     ELSE
2396     T2AVG = SQRT( WLOAVG/PI2 )
2397     ENDIF
2398 C
2399     T4AVG = PI2 * FL1AVG
2400     T5AVG = PID2 * FL5AVG * T2AVG
2401 C
2402     CGTAVG = 0.5*WLAVG*(1.+FLAVG)
2403 C
2404     IF( DPAVG .GT. 0.04 ) THEN
2405     T78AVG = ( SQRT(DAVGSTR) )/CGTAVG
2406     ELSE
2407     T78AVG = 1./SQRT( PI2*WLOAVG )
2408     ENDIF
2409 C
2410     T7AVG = 2. * T4AVG * T78AVG
2411     T8AVG = T5AVG * T78AVG
2412 C
2413     AAVG = CAAVG
2414 C
2415 C     WPAVG IS THE SPECTRAL PEAK PERIOD AT THE MIDPOINT OF THE SEGMENT
2416 C
2417     WPAVG = 0.5*(WPOLD+WPNEW)
2418 C
2419 C     CAPGAM IS CAPITAL GAMMA, THE PLANT PARAMETER FACTOR MULTIPLIES
2420 C     HMO**3 IN THE EXPRESSION FOR THE WAVE ENERGY DISSIPATION DUE TO
2421 C     MARSH GRASS
2422 C
2423 CG&O END
2424 C
2425     CAPGAM = APP(DEF,DAVGSTR,NPLTS,WPAVG,WLAVG)
2426 C
2427     CAVG = CCAVG*CAPGAM*(WPOLD+WPNEW)/CGTAVG
2428 C
2429     BPAVG = ( BAVG + (CAVG*YOLD) ) * DXN
2430 C
2431     P = -BPAVG
2432 C
2433     Q2A = AAVG * DXN
2434 C
2435     EFAVG = EXP(P)
2436 C
2437     IF( ABS(P) .GT. 0.001 ) THEN
2438     Q3 = ( 1.-EFAVG )/BPAVG
2439     ELSE
2440     Q3 = 1.0
2441     ENDIF

```

```

2442 C
2443 Q27 = EXP( -T7AVG*( SQRT(DNEWSTR) - SQRT(DAVGSTR) ) )
2444 Q17 = EXP( -T7AVG*( SQRT(DNEWSTR) - SQRT(DOLDSTR) ) )
2445 C
2446 Q28 = (DAVGSTR/DNEWSTR)**T8AVG
2447 Q18 = (DOLDSTR/DNEWSTR)**T8AVG
2448 C
2449 C CALCULATE RNEW AND YNEW AT END OF GRID CELL
2450 C
2451 RNEW = (ROLD*Q18*Q17*EFAVG) + (Q2A*Q28*Q27*Q3)
2452 YNEW = SQRT(RNEW)
2453 C
2454 C YNEW IS THE HMO AT END OF GRID CELL
2455 C
2456 WPI=WPNEW
2457 CG&O 2/87 END
2458 C
2459 C
2460 CG&O 2/87 COMMENTED OUT *****
2461 C WL0=5.12*(WPI**2)
2462 C WL=SQRT(2*PI*DAVG*WL0)/(1+1.25*DAVG/WL0)
2463 C IF(DAVG/WL.LT..04)CG=SQRT(G*DAVG)
2464 C IF(DAVG/WL.GT..5)CG=G*WPI/(4*PI)
2465 C IF(DAVG/WL.GE..04.AND.DAVG/WL.LE..5)CG=
2466 C 1(.5+(2*PI*DAVG/WL)/SINH(4*PI*DAVG/WL))*(WL/WPI)
2467 C CP=(1/(CG*3*PI))*APP(DEF,DAVG,NPLTS,WPI,WL)
2468 C BETA=TANH(.530*(GOU2*DAVG)**.75)
2469 C A=DSOOM*GOU2
2470 C B=((SIG/BETA)**OOM)*GOU2
2471 C
2472 C THE CONSTANT IN THE NEXT LINE IS THE PRODUCT OF SQUARE ROOT 2
2473 C AND M = 0.42.
2474 C
2475 C C=CP/0.5939696
2476 C P=- (B+C*YOLD)*2*DX
2477 C
2478 C DETERMINE NEW VALUES OF VARIABLES
2479 C
2480 C R=((YOLD**OOM)*EXP(P))+((A/(B+C*YOLD))*(1-EXP(P)))
2481 C YNEW=R**.42
2482 C IF(YNEW.LE.YOLD)GO TO 115
2483 C F1=EFL(YOLD,DAVG)
2484 C IF(F1.EQ.-1)GO TO 115
2485 C F2=EFL(YNEW,DAVG)
2486 C IF(F2.EQ.-1)GO TO 115
2487 C F=F2-F1
2488 C IF(F.GT.2*DX)F=2*DX
2489 C WPI=T(WPI,F,88.0,DAVG)
2490 C
2491 C
2492 C THE NEXT 5 LINES OF CODE HAVE BEEN COMMENTED OUT SINCE
2493 C THEY ARE IN THE WRONG PLACE. THEY HAVE BEEN REWRITTEN

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2494 C           IN THEIR PROPER PLACES.
2495 C
2496 C 115 TSNEW=TSAVG+DTS
2497 C           SNEW=SAVG+DS
2498 C           GNEW=GAVG+DG
2499 C
2500 C           XSUM=XSUM+(2*DX)
2501 C
2502 C           STORE RESULTS AT 100 FT. INTERVALS OR GREATER
2503 C
2504 C           IF(XSUM.LT.100)GO TO 120
2505 C
2506 C           CONVERT ZERO MOMENT WAVE HEIGHT TO
2507 C           ZERO MOMENT WAVE HEIGHT
2508 C
2509 C           COMMENT OUT NEXT 3 LINES SINCE WLI HAS PREVIOUSLY BEEN SET
2510 C
2511 C           DNEW=SNEW-GNEW
2512 C           WLO=5.12*(WPI**2)
2513 C           WLI=SQRT(2*PI*DNEW*WLO)/(1+1.25*DNEW/WLO)
2514 C G&O 2/87 END COMMENTING OUT*****
2515 C
2516 C           CONVERT ZERO MOMENT WAVE HEIGHT YNEW TO SIGNIFICANT
2517 C           WAVE HEIGHT HS
2518 C
2519 C           WLISTR = AMAX1( 0.1 , WLI )
2520 C
2521 C
2522 C           EPP=YNEW/(4*WLISTR*.002)
2523 C           EPP = AMAX1( 1.0E-4 , EPP )
2524 C
2525 C           WPISTR = AMAX1( 0.1 , WPI )
2526 C
2527 C G&O 2/87 COMMENTED OUT
2528 C           DD=DNEW/(G*WPI**2)
2529 C G&O 2/87 END COMMENTED OUT
2530 C
2531 C           DD=DNEWSTR/(G*(WPISTR**2))
2532 C
2533 CG&O 9/88 COMMENTED OUT TO MAKE EXPRESSION FOR HS CONSISTENT WITH
2534 C           THOMPSON & VINCENT'S HS EXPRESSION IN 1985 WATERWAYS & HARBOR
2535 C           ARTICLE
2536 C
2537 C           DC=5.5722E-5
2538 C           PART1=.9+(.42707*ALOG10(DD/DC))
2539 C           IF(EPP.LE.2)PHI=PART1-(1.411296*ALOG10(EPP))
2540 C           IF(EPP.GT.2)PHI=PART1-C2LOG-(1.016768*ALOG10(EPP))
2541 C
2542 CG&O 9/88 END
2543 C
2544 C           D0=1.357E-3
2545 C           RAV=1.477+.477*(((D0/DD)**.8557)-1)

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2546         IF(RAV.GT.1.7)RAV=1.7
2547         IF( RAV .LT. 1.0 ) RAV= 1.0
2548         C
2549         CG&O 9/88 COMMENTED OUT TO MAKE EXPRESSION FOR HS CONSISTENT WITH
2550         C           THOMPSON & VINCENT'S HS EXPRESSION IN 1985 WATERWAYS & HARBOR
2551         C           ARTICLE
2552         C
2553         C           IF(PHI.LT.1)PHI=1
2554         C           IF(PHI.GT.RAV)PHI=RAV
2555         C
2556         CG&O 9/88 END
2557         C
2558         CG&O 9/88   SET PHI TO CORRECT EXPRESSION
2559         C
2560         C           PHI = RAV
2561         C
2562         CG&O 9/88 END
2563         C
2564         C           HS=PHI*YNEW
2565         C
2566         C           CONVERT SIGNIFICANT WAVE HEIGHT TO
2567         C           CONTROLLING WAVE HEIGHT WHT
2568         C           WHT=1.6*HS
2569         C
2570         C G&O 2/87
2571         C
2572         C           IF THE CONTROLLING WAVE BREAKS, COMPUTE THE EQUIV-
2573         C           ALENT ZERO MOMENT WAVE HEIGHT.
2574         C
2575         C           HBM = SHBM( WPNEW, GSLNEW , DNEWSTR )
2576         C
2577         C
2578         C G&O SEPT 88
2579         C
2580         C           THE STATEMENT BELOW IS COMMENTED OUT AND
2581         C           CORRECTED
2582         C
2583         C           IF( WHT .GT. HBM ) THEN
2584         C
2585         C           IF( WHT .GE. HBM ) THEN
2586         C
2587         C END G&O SEPT 88
2588         C
2589         C           WHT = HBM
2590         C           YNEW = HMO( WHT, DNEWSTR , WPI )
2591         C           ENDIF
2592         C
2593         C 115 CONTINUE
2594         C
2595         C           STORE RESULTS AT 100 FT. INTERVALS OR GREATER OR
2596         C           AT END OF TRANSECT SEGMENT
2597         C

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2598      XSUM = XSUM + TDX
2599      C
2600      IF(XSUM.LT.100)GO TO 120
2601      C G&O 2/87 END
2602      C
2603      C      INCREMENT ARRAY SUBSCRIPT AND CHECK AGAINST
2604      C      ARRAY DIMENSION
2605      NFO=NFO+1
2606      IF(NFO.GT.500)WRITE(6,995)
2607      IF(NFO.GT.500)STOP
2608      C
2609      C      COMPUTE NEW GROUND STATION,WAVE HEIGHT, AND
2610      C      WAVE ELEVATION AND STORE RESULTS
2611      GS(NFO)=BSFO+XNEW
2612      C
2613      CG&O 2/87
2614      HBM=SHBM(WPNEW,GSLNEW,DNEWSTR)
2615      WHM=HBM
2616      C      WHM=.78*(SNEW-GNEW)
2617      CG&O 2/87 END
2618      C
2619      IF(WHT.GT.WHM)WHT=WHM
2620      HBW(NFO)=WHT
2621      C
2622      C G&O 2/87
2623      STMP=GNEW+DNEW
2624      C      EW(NFO)=.7*HBW(NFO)+SAVG
2625      EW(NFO)=.7*HBW(NFO)+STMP
2626      C G&O 2/87 END
2627      C
2628      C      G&O SEPT 88
2629      C
2630      SPWP(NFO) = WPNEW
2631      C
2632      C      END G&O SEPT 88
2633      C
2634      NFOM1=NFO-1
2635      SA(NFO,1)=GS(NFOM1)
2636      SA(NFO,2)=GS(NFO)
2637      SA(NFO,3)=TSNEW
2638      SA(NFO,4)=SNEW
2639      C
2640      C G&O 2/87
2641      C      SA(NFO,5)=1
2642      C
2643      IF( GS(NFO) .EQ. ESFO ) THEN
2644          SA( NFO,5 ) = STOF
2645      ELSE
2646          SA( NFO,5 ) = 1.0
2647      ENDIF
2648      C G&O 2/87 END
2649      C

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2650         XSUM=0
2651 C
2652 C G&O 2/87 COMMENTED OUT
2653 C
2654 C         THE NEXT TWO LINES ARE COMMENTED OUT SINCE THEY ARE
2655 C         IN THE WRONG PLACE
2656 C
2657 C         IF THE CONTROLLING WAVE BREAKS, COMPUTE THE
2658 C         EQUIVALENT ZERO MOMENT WAVE HEIGHT
2659 C
2660 C         IF(1.6*HS.LE.WHM)GO TO 120
2661 C         YNEW=HMO(WHT,DNEW,WPI)
2662 C G&O 2/87 END COMMENTED OUT
2663 C
2664 C         120 CONTINUE
2665 C
2666 C G&O 2/87
2667 C
2668 C         IF IPASS .EQ. 1, THEN THIS IS LAST PASS THROUGH THE
2669 C         LOOP. EXIT LOOP
2670 C
2671 C         IF( IPASS .EQ. 1 ) GO TO 135
2672 C
2673 C G&O 2/87 END
2674 C
2675 C         ADJUST STEP SIZE
2676 C
2677 C         YTEST=ABS(YNEW-YOLD)
2678 C
2679 C G&O 2/87
2680 C         TDXMAX = X - XNEW
2681 C         DXMAX = 0.5 * TDXMAX
2682 C G&O 2/87 END
2683 C
2684 C         IF( YTEST .GT. .05 ) GO TO 125
2685 C
2686 C G&O 2/87
2687 C         DX=2*DX
2688 C
2689 C         DXOLD = DX
2690 C         DXNEW = AMIN1( 2.*DX ,DXMAX )
2691 C         RATX = 0.5 * DXNEW/DXOLD
2692 C         DX = DXNEW
2693 C         TDX = AMIN1( 2.*DX, TDXMAX)
2694 C
2695 C
2696 C         DTS=2*DTS*RATX
2697 C         DS=2*DS*RATX
2698 C         DG=2*DG*RATX
2699 C         DGSL=2.*DGSL*RATX
2700 C G&O 2/87 END
2701 C

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2702          GO TO 130
2703      C
2704      C G&O 2/87
2705          125 IF( YTEST .LT. 0.1 ) GO TO 1000
2706          IF( DX .LT. 5.0 ) GO TO 1000
2707      C
2708      C      DX=.5*DX
2709      C
2710          DXOLD = DX
2711          DXNEW = AMIN1( 0.5*DX,DXMAX )
2712          RATX = 2. * DXNEW/DXOLD
2713          DX   = DXNEW
2714          TDX  = AMIN1( 2.*DX,TDXMAX )
2715      C
2716          DTS=.5*DTS*RATX
2717          DS=.5*DS*RATX
2718          DG=.5*DG*RATX
2719          DGSL=0.5*DGSL*RATX
2720      C
2721          GO TO 130
2722      C
2723          1000 CONTINUE
2724      C
2725          DXOLD = DX
2726          DXNEW = AMIN1( DX,DXMAX )
2727          RATX  = DXNEW/DXOLD
2728          DX   = DXNEW
2729          TDX  = AMIN1( 2.*DX,TDXMAX )
2730      C
2731          DTS=DTS*RATX
2732          DS=DS*RATX
2733          DG=DG*RATX
2734          DGSL=DGSL*RATX
2735      C G&O 2/87 END
2736      C
2737      C      UPDATE RECURSIVE VARIABLES AND LOOP BACK
2738          130 XOLD=XNEW
2739          YOLD=YNEW
2740          TSOLD=TSNEW
2741          SOLD=SNEW
2742          GOLD=GNEW
2743      C
2744      C G&O 2/87
2745          GSLOLD=GSLNEW
2746          WPOLD=WPNEW
2747          DOLD=DNEW
2748          DOLDSTR=AMAX1(0.01,DOLD)
2749      C G&O 2/87 END
2750      C
2751          GO TO 110
2752      C
2753      C      STORE FINAL VALUE IF IT HAS NOT ALREADY BEEN STORED

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2754 C
2755 135 IF(GS(NFO).EQ.ESFO)GO TO 140
2756 NFO=NFO+1
2757 GS(NFO)=ESFO
2758 C
2759 C G&O 2/87
2760 HBM=SHBM(WPNEW,GSLNEW,DNEWSTR)
2761 WHM=HBM
2762 C WHM=.78*(SE-EEFO)
2763 WHT=AMIN1(WHT,WHM)
2764 C G&O 2/87 END
2765 C
2766 HBW(NFO)=AMIN1(WHT,WHM)
2767 STMP=GNEW+DNEW
2768 C EW(NFO)=.7*HBW(NFO)+SAVG
2769 EW(NFO)=.7*HBW(NFO)+STMP
2770 C
2771 C G&O SEPT 88
2772 C
2773 SPWP(NFO) = WPNEW
2774 C
2775 C END G&O SEPT 88
2776 C
2777 SA(NFO,1)=XOLD
2778 SA(NFO,2)=ESFO
2779 SA(NFO,3)=SETN
2780 SA(NFO,4)=SEN
2781 C
2782 C G&O 2/87
2783 C 140 SA(NFO,5)=2HVH
2784 C
2785 SA( NFO,5 ) = 2HVH
2786 C
2787 140 CONTINUE
2788 C G&O 2/87 END
2789 C
2790 C INSERT ABGF IF REQUIRED
2791 C
2792 IF(ABGF.NE.1)GO TO 150
2793 NAP=NAP+1
2794 AP(NAP)=ESFO
2795 M=M+1
2796 STEG(M)=GS(NFO)
2797 ELZ(M)=EW(NFO)
2798 C
2799 C GET READY FOR NEXT FETCH OR OBSTRUCTION AND RETURN
2800 150 BSFO=ESFO
2801 BEFO=EEFO
2802 C
2803 C G&O 2/87 ** COMMENTED OUT AND INSERT ***
2804 C WHI=HBW(NFO)
2805 WPT=WPNEW

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2806 C G&O 2/87 ** END OF COMMENTED OUT AND INSERT ***
2807 RETURN
2808 500 FORMAT(/,10X,34HINVALID DATA IN FIELD 1 OF VH CARD)
2809 520 FORMAT(/,10X,45HINVALID DATA IN FIELD 3 OR FIELD 5 OF VH CARD)
2810 530 FORMAT(/,10X,34HINVALID DATA IN FIELD 4 OF VH CARD)
2811 540 FORMAT(/,10X,34HINVALID DATA IN FIELD 6 OF VH CARD)
2812 545 FORMAT(/,10X,34HINVALID DATA IN FILED 3 OF MG CARD)
2813 560 FORMAT(A2,2X,A4,9F8.0)
2814 570 FORMAT(/,10X,
2815 154HMISSING MG CARD OR INCORECT DATA IN FIELD 6 OF VH CARD)
2816 580 FORMAT(/,10X,11HJOB DUMPED.)
2817 590 FORMAT(10X,A2,7X,A4,9F11.3)
2818 600 FORMAT(/,10X,'WAVE PERIOD LESS THAN OR EQUAL TO ZERO',/
2819 1 10X,'IN SUBROUTINE VEG. ABORT RUN')
2820 610 FORMAT(A4,8F16.8)
2821 995 FORMAT(/,10X,38HARRAY DIMENSIONS EXCEEDED. JOB DUMPED.)
2822 END
2823 C
2824 C G&O 2/87 ** INSERT **
2825 C
2826 FUNCTION SHBM(WPI,SLOPE,DNEW)
2827 C
2828 C WRITTEN FEBRUARY 1987 BY:
2829 C
2830 C GREENHORNE AND O'MARA, INC.
2831 C GREENBELT, MARYLAND
2832 C
2833 C BASED ON IMPROVED BREAKING WAVE HEIGHT EQUATION SUPPLIED
2834 C BY DR. BARRY E. HERCHENRODER OF THE SAME FIRM.
2835 C
2836 C** THIS FUNCTION SUBROUTINE CALCULATES THE UPDATED MAXIMUM
2837 C** CONTROLLING BREAKING WAVE HEIGHT TAKING INTO ACCOUNT
2838 C** THE EFFECT OF BOTTOM SLOPE AND PEAK WAVE PERIOD.
2839 C** EQUATIONS 2-92 THROUGH 2-94 IN THE 1984 SHORE
2840 C** PROTECTION MANUAL (CERC, 1984) ARE USED. IT IS ASSUMED
2841 C** THAT THE BREAKING WAVE HEIGHT REFERRED TO IN THESE
2842 C** EQUATIONS IS THE 1% WAVEHEIGHT AND CAN THEREFORE BE
2843 C** EQUATED WITH FEMA'S CONTROLLING WAVE HEIGHT. THIS
2844 C** ASSUMPTION IS BACKED UP BY CALCULATIONS PERFORMED
2845 C** USING THORNTON AND GUZA'S DATA (JGR,1983) THAT SHOW
2846 C** THAT HRMS=0.42*(STILLWATER DEPTH) DERIVED BY THESE
2847 C** AUTHORS IS A DIRECT CONSEQUENCE OF USING THE BREAKING
2848 C** LAW IN THIS ROUTINE, AN OBSERVED BOTTOM SLOPE OF ZERO,
2849 C** AND A RATIO OF 1% WAVE HEIGHT TO SIGNIFICANT WAVE
2850 C** HEIGHT IN THE INNER SURF ZONE OF 1.3.
2851 C
2852 C** WPI: SPECTRAL PEAK WAVE PERIOD AT END OF TRANSECT
2853 C SEGMENT OR AT END OF GRID CELL WITHIN A TRANSECT
2854 C SEGMENT.
2855 C** SLOPE: BOTTOM SLOPE AT END OF TRANSECT SEGMENT OR AT
2856 C END OF GRID CELL WITHIN A TRANSECT SEGMENT
2857 C** DNEW: 100 YEAR STILL WATER DEPTH AT END OF TRANSECT

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2858 C          SEGMENT OR AT END OF GRID CELL WITHIN A TRANSECT
2859 C          SEGMENT.
2860 C
2861 C*****
2862 C
2863 C          REVISED IN JUNE AND JULY, 1987 TO RESTORE THE ORIGINAL 0.78
2864 C          BREAKING CRITERIA PER INSTRUCTION BY THE FEDERAL
2865 C          EMERGENCY MANAGEMENT AGENCY
2866 C
2867 C*****
2868 C
2869 C          SLOPE=ABS(SLOPE)
2870 C          AP=1.-EXP(-19.5*SLOPE)
2871 C          BP=1.-EXP(-19.0*SLOPE)
2872 C          AP=1.-0.5*AP
2873 C          WPI=AMAX1(0.1,WPI)
2874 C          BP=1.+1.36*BP*DNEW/(WPI**2)
2875 C          GAMA=0.78/(AP*BP)
2876 C          GAMMA = AMAX1( 0.78,GAMA )
2877 C          GAMMA=0.78
2878 C          SHBM=GAMMA*DNEW
2879 C          SHBM=AMAX1(0.0,SHBM)
2880 C          RETURN
2881 C          END
2882 C          FUNCTION HIN(WHI,AFL,W,D,WPT)
2883 C
2884 C          THIS FUNCTION COMPUTES THE TRANSMITTED CONTROLLING WAVE HEIGHT
2885 C          "HIN" FROM THE INCIDENT CONTROLLING WAVE HEIGHT "WHI", FETCH
2886 C          LENGTH "AFL", 10M 10MINUTE WIND SPEED "W", 100 YEAR STILLWATER
2887 C          DEPTH "D", AND TRANSMITTED WAVE PERIOD "WPT". THE 1984 SPM EQUA-
2888 C          TIONS ARE USED TO CALCULATE HMO, THE THOMPSON-VINCENT CURVES (IN
2889 C          PARAMETERIZED FORM) ARE USED TO CALCULATE THE SIGNIFICANT WAVE
2890 C          HEIGHT HS FROM HMO, AND THE CONTROLLING WAVE HEIGHT IS 1.6 TIMES
2891 C          HS.
2892 C
2893 C          PI=3.14159
2894 C          G=32.2
2895 C
2896 C          WPTSTR = AMAX1( .01 , WPT )
2897 C          DSTR   = AMAX1( .01 , D   )
2898 C
2899 C          IT IS ASSUMED THAT W IS INPUT AS UNADJUSTED WINDSPEED IN
2900 C          FEET PER SECOND
2901 C
2902 C          CALCULATE U, THE ADJUSTED WINDSPEED IN FEET PER SECOND
2903 C
2904 C          CA=(3.6/5.28)**0.23
2905 C          U=0.589*CA*(W**1.23)
2906 C
2907 C          CONVERT WHI TO ZERO MOMENT WAVEHEIGHT YI
2908 C
2909 C

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2910 C G&O SEPT 88
2911 C
2912 C THE STATEMENT BELOW IS COMMENTED OUT AND
2913 C CORRECTED
2914 C
2915 C YI = HMO( WHI , DSTR , WPTSTR )
2916 C
2917 C THERE ARE TWO CASES CORRESPONDING TO
2918 C BREAKING AND NON-BREAKING WAVES.
2919 C
2920 C HBM = 0.78 * DSTR
2921 C
2922 C IF( WHI .GE. HBM ) THEN
2923 C
2924 C WAVE IS BREAKING
2925 C
2926 C WHI = HBM
2927 C YI = HMO( WHI, DSTR, WPTSTR )
2928 C
2929 C ELSE
2930 C
2931 C WAVE IS NOT BREAKING
2932 C
2933 C YI = HMONB( WHI, DSTR, WPTSTR )
2934 C
2935 C ENDIF
2936 C
2937 C END G&O SEPT 88
2938 C
2939 C IT IS ALSO ASSUMED THAT AFL (FETCH DISTANCE), WHI (THE INCIDENT
2940 C WAVELENGTH), AND D (THE STILLWATER DEPTH) ARE IN FEET
2941 C
2942 C COMPUTE COMMON FACTORS
2943 C ALPHA=(.283/G)*U*U
2944 C BETA=TANH(.53*((G*D/(U**2))**.75))
2945 C X=YI/(ALPHA*BETA)
2946 C
2947 C CHECK TO SEE IF MAXIMUM WAVE HEIGHT HAS BEEN ACHIEVED
2948 C IF(X.LT.1)GO TO 20
2949 C YNEW = YI
2950 C GO TO 100
2951 C
2952 C COMPUTE EQUIVALENT FETCH LENGTH CORRESPONDING TO INCIDENT
2953 C WAVE HEIGHT
2954 C
2955 C 20 CONTINUE
2956 C TANHI=.5*LOG((1+X)/(1-X))
2957 C EFL=(((BETA/.00565)*TANHI)**2)*(U**2)/G
2958 C
2959 C COMPUTE TOTAL FETCH LENGTH
2960 C F=EFL+AFL
2961 C

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2962 C COMPUTE TRANSMITTED WAVE HEIGHT HMO
2963 YNEW=ALPHA*BETA*TANH((.00565/BETA)*SQRT((G*F/(U**2))))
2964 C
2965 100 CONTINUE
2966 C
2967 C CALCULATE THE WAVELENGTH WLNEW PREPARATORY TO CALCULATING HS
2968 C
2969 PI2=2.*PI
2970 WLONEW=(G/PI2)*WPTSTR*WPTSTR
2971 WLONEW=AMAX1(0.1,WLONEW)
2972 C
2973 DNEWSTR=AMAX1(0.01,D)
2974 CDNEW=DNEWSTR/WLONEW
2975 WLNEW=WLONEW*SQRT(TANH(PI2*CDNEW))
2976 WLNEW = AMAX1( 0.01 , WLNEW )
2977 C
2978 C CALCULATE REMAINING PARAMETERS
2979 C
2980 WPI = WPTSTR
2981 WLI=WLNEW
2982 C2LOG=.394528*ALOG10(2.0)
2983 C
2984 C CALCULATE HS AND CONTROLLING WAVE HEIGHT WHT
2985 C
2986 EPP=YNEW/(4*WLI*.002)
2987 EPP = AMAX1( 1.0E-4 , EPP )
2988 C
2989 DD=DNEWSTR/(G*(WPI**2))
2990 C
2991 CG&O 9/88 COMMENTED OUT TO MAKE EXPRESSION FOR HS CONSISTENT WITH
2992 C THOMPSON & VINCENT'S HS EXPRESSION IN 1985 WATERWAYS & HARBOR
2993 C ARTICLE
2994 C
2995 C DC=5.5722E-5
2996 C PART1=.9+(.42707*ALOG10(DD/DC))
2997 C IF(EPP.LE.2)PHI=PART1-(1.411296*ALOG10(EPP))
2998 C IF(EPP.GT.2)PHI=PART1-C2LOG-(1.016768*ALOG10(EPP))
2999 C
3000 CG&O 9/88 END
3001 C
3002 D0=1.357E-3
3003 RAV=1.477+.477*(((D0/DD)**.8557)-1)
3004 IF(RAV.GT.1.7)RAV=1.7
3005 IF( RAV .LT. 1.0 ) RAV= 1.0
3006 C
3007 CG&O 9/88 COMMENTED OUT TO MAKE EXPRESSION FOR HS CONSISTENT WITH
3008 C THOMPSON & VINCENT'S HS EXPRESSION IN 1985 WATERWAYS & HARBOR
3009 C ARTICLE
3010 C
3011 C IF(PHI.LT.1)PHI=1
3012 C IF(PHI.GT.RAV)PHI=RAV
3013 C

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3014 CG&O 9/88 END
3015 C
3016 CG&O 9/88 SET PHI TO CORRECT EXPRESSION
3017 C
3018 PHI = RAV
3019 C
3020 CG&O 9/88 END
3021 C
3022 HS=PHI*YNEW
3023 C
3024 C CONVERT SIGNIFICANT WAVE HEIGHT TO
3025 C CONTROLLING WAVE HEIGHT
3026 WHT=1.6*HS
3027 C
3028 C G&O SEPT 88
3029 C
3030 C IF THE CONTROLLING WAVEHEIGHT WHT BREAKS,
3031 C RESET IT TO THE BREAKING WAVEHEIGHT
3032 C
3033 HBM = 0.78 * DSTR
3034 WHT = AMIN1( WHT,HBM )
3035 C
3036 C END G&O SEPT 88
3037 C
3038 HIN=WHT
3039 C
3040 RETURN
3041 C
3042 C G&O 2/87 END INSERT
3043 C
3044 END
3045 SUBROUTINE AVG(BP,EP,AER,ATS)
3046 C THIS SUBROUTINE DETERMINES THE WEIGHTED AVERAGE 10 YEAR SURGE
3047 C ELEVATION (ATS) AND WEIGHTED AVERAGE 100 YEAR WAVE ELEVATION (AER)
3048 C GIVEN THE BEGIN POINT (BP) AND END POINT (EP) OVER WHICH THE
3049 C AVERAGE IS TO BE TAKEN.
3050 DIMENSION PARAM(10),HBW(500),STEG(500),ELZ(500),
3051 1GS(500),EW(500),SA(500,5),AP(500)
3052 COMMON /AONLY/NFOM1
3053 COMMON /AFGV/TOF,PARAM,BSFO,BEFO,WHI,WHT,NFO,
3054 1HBW,AP,SET,SE,STEG,ELZ,GS,EW,SA,M,NAP
3055 AS= 'AS'
3056 WT=0
3057 ICPS=0
3058 ICPE=0
3059 DO 10 I=1,NFOM1
3060 IF(BP.GE.GS(I).AND.BP.LT.GS(I+1))ICPS=I+1
3061 IF(EP.GT.GS(I).AND.EP.LE.GS(I+1))ICPE=I
3062 10 CONTINUE
3063 A1=0
3064 A2=0
3065 ICPEM1=ICPE-1

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3066     IF(ICPEM1.LE.ICPS)GO TO 25
3067     DO 20 I=ICPS,ICPEM1
3068     IF(SA(I+1,5).EQ.AS)GO TO 20
3069     HGHT1=SA(I,3)+SA(I+1,3)
3070     HGHT2=EW(I)+EW(I+1)
3071     WIDTH=GS(I+1)-GS(I)
3072     WT=WT+WIDTH
3073     A1=A1+(HGHT1*WIDTH/2.0)
3074     A2=A2+(HGHT2*WIDTH/2.0)
3075     20 CONTINUE
3076     25 IF(ICPS.EQ.ICPEM1)GO TO 30
3077     IF(ICPS.EQ.ICPE)GO TO 40
3078     IF(ICPS.GT.ICPE)GO TO 50
3079     GO TO 60
3080     30 IF(SA(ICPE,5).EQ.AS)GO TO 60
3081     HGHT1=SA(ICPS,3)+SA(ICPE,3)
3082     HGHT2=EW(ICPS)+EW(ICPE)
3083     WIDTH=GS(ICPE)-GS(ICPS)
3084     WT=WIDTH
3085     A1=HGHT1*WIDTH/2.0
3086     A2=HGHT2*WIDTH/2.0
3087     GO TO 60
3088     40 SLOPE1=(EW(ICPE)-EW(ICPEM1))/(GS(ICPE)-GS(ICPEM1))
3089     SLOPE2=(EW(ICPE+1)-EW(ICPE))/(GS(ICPE+1)-GS(ICPE))
3090     Y1=SLOPE1*(BP-GS(ICPEM1))+EW(ICPEM1)
3091     Y2=SLOPE2*(EP-GS(ICPE))+EW(ICPE)
3092     Y3=SA(ICPEM1,3)+SA(ICPE,3)
3093     Y4=SA(ICPE,3)+SA(ICPE+1,3)
3094     WIDTH1=GS(ICPE)-BP
3095     WIDTH2=EP-GS(ICPE)
3096     WT=WIDTH1+WIDTH2
3097     A1=((Y3*WIDTH1)+(Y4*WIDTH2))/2.0
3098     A2=((Y1+EW(ICPE))*WIDTH1+((Y2+EW(ICPE))*WIDTH2))/2.0
3099     GO TO 70
3100     50 X=((BP+EP)/2.0)-GS(ICPE)
3101     SLOPE=(EW(ICPS)-EW(ICPE))/(GS(ICPS)-GS(ICPE))
3102     Y1=(SA(ICPS,3)+SA(ICPE,3))/2.0
3103     Y2=SLOPE*X+EW(ICPE)
3104     WIDTH=EP-BP
3105     WT=WIDTH
3106     A1=Y1*WIDTH
3107     A2=Y2*WIDTH
3108     GO TO 70
3109     60 SLOPE1=(EW(ICPS)-EW(ICPS-1))/(GS(ICPS)-GS(ICPS-1))
3110     SLOPE2=(EW(ICPE+1)-EW(ICPE))/(GS(ICPE+1)-GS(ICPE))
3111     Y1=SLOPE1*(BP-GS(ICPS-1))+EW(ICPS-1)
3112     Y2=SLOPE2*(EP-GS(ICPE))+EW(ICPE)
3113     Y3=(SA(ICPS-1,3)+SA(ICPS,3))/2.0
3114     Y4=(SA(ICPE+1,3)+SA(ICPE,3))/2.0
3115     WIDTH1=GS(ICPS)-BP
3116     WIDTH2=EP-GS(ICPE)
3117     A1=A1+(Y3*WIDTH1+(Y4*WIDTH2))

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3118      A2=A2+((Y1+EW(ICPS))*WIDTH1/2.0)+((Y2+EW(ICPE))*WIDTH2/2.0)
3119      WT=WT+WIDTH1+WIDTH2
3120      70 ATS=A1/WT
3121      AER=A2/WT
3122      RETURN
3123      END
3124      SUBROUTINE READIN
3125      C      THIS SUBROUTINE READS IN TABULAR DATA ON MARSH GRASS
3126      DIMENSION HDN(8,8,7),PPSD(8,3),PLTYP(8)
3127      COMMON /PPT/HDN,PPSD,PLTYP
3128      C
3129      C      REWIND UNIT 7, THE UNIT WITH THE MARSH GRASS DATA
3130      C
3131      REWIND(7)
3132      C
3133      C      READ IN DATA FOR HEIGHT,DIAMETER,AND NUMBER DENSITY
3134      DO 20 I=1,7
3135      DO 20 J=1,8
3136      READ(7,500)(HDN(I,J,K),K=1,7)
3137      20 CONTINUE
3138      C
3139      C      NO MARSH GRASS IN REGION 8
3140      DO 30 I=1,8
3141      DO 30 J=1,7
3142      HDN(8,I,J)=0
3143      30 CONTINUE
3144      C
3145      C      READ IN DATA ON PLANT PARAMETERS THAT ARE SPECIES DEPENDENT
3146      DO 40 I=1,8
3147      READ(7,510)(PPSD(I,J),J=1,3)
3148      40 CONTINUE
3149      C
3150      C      READ IN MARSH GRASS PLANT TYPES
3151      READ(7,520)(PLTYP(I),I=1,8)
3152      C
3153      C      RETURN TO MAIN PROGRAM
3154      RETURN
3155      500 FORMAT(7F8.0)
3156      510 FORMAT(3F8.0)
3157      520 FORMAT(8(4X,A4))
3158      END
3159      FUNCTION APP(DEF,D,NPLTS,WPI,WL)
3160      C      THIS FUNCTION COMPUTES THE AVERAGE PLANT PARAMETER
3161      C      WHICH IS RELATED TO THE NET DRAG FORCE FOR ALL PLANT
3162      C      TYPES PRESENT FOR A GIVEN DEPTH
3163      C
3164      DIMENSION DEF(10,8)
3165      PI=3.14159
3166      G2=1036.84
3167      G=32.2
3168      C
3169      C      DETERMINE PLANT PARAMETERS

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3170      APP=0
3171      DO 60 I=1,NPLTS
3172      C
3173      C      UNLOAD DEF ARRAY
3174      CDE=DEF(I,1)
3175      FCOV=DEF(I,2)
3176      HBI=DEF(I,3)
3177      PPSF=DEF(I,4)
3178      SDB=DEF(I,5)
3179      SDM=DEF(I,6)
3180      SDT=DEF(I,7)
3181      FAR=DEF(I,8)
3182      C
3183      C      COMPUTE NON DEPTH DEPENDENT QUANTITIES
3184      ABMS=(SDB+SDM)*HBI*.25
3185      AAMS=(SDM+SDT)*HBI*.25
3186      TAS=ABMS+AAMS
3187      ACPL=(2/PI)*FAR*TAS
3188      C
3189      C      COMPUTE FACTOR WHICH ADJUSTS FOR THE EFFECTS
3190      C      OF WAVE PERIOD
3191      HF=.5*HBI
3192      IF(HF.GT.D)HF=D
3193      IF(D/WL.LT..04)GO TO 5
3194      IF(D/WL.GT..5)GO TO 10
3195      WPF=G2*((WPI/WL)*COSH(2*PI*HF/WL)/COSH(2*PI*D/WL))**3
3196      GO TO 15
3197      5 WPF=SQRT(G/D)
3198      GO TO 15
3199      10 Z=HF-D
3200      WPF=(8/G)*((PI/WPI)*EXP(2*PI*Z/WL))**3
3201      C
3202      C      COMPUTE FRONTAL AREA BELOW THE WATER SURFACE
3203      C      FOR EACH PLANT TYPE AND COMBINE WITH OTHER
3204      C      PLANT PARAMETERS
3205      15 IF(HBI.NE.0)GO TO 20
3206      AT=0
3207      GO TO 50
3208      20 IF(D.GT..5*HBI)GO TO 25
3209      SDI=SDB+((SDM-SDB)/(.5*HBI))
3210      A1=(SDB+SDI)*.5*D
3211      A2=ACPL*(D/HBI)
3212      AT=A1+A2
3213      GO TO 50
3214      25 IF(D.GT.HBI)GO TO 30
3215      SDI=SDM+(((SDT-SDM)/(HBI*.5))*(D-(HBI*.5)))
3216      A1=(SDM+SDI)*.5*(D-(.5*HBI))
3217      A2=ACPL*(D/HBI)
3218      AT=ABMS+A1+A2
3219      GO TO 50
3220      30 AT=TAS+ACPL
3221      50 APP=APP+(FCOV*PPSF*CDE*AT)*WPF

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3222      60 CONTINUE
3223      RETURN
3224      END
3225      SUBROUTINE ECHO
3226      C      THIS SUBROUTINE PRODUCES AN ANOTATED INPUT LISTING
3227      C
3228      DIMENSION PARAM(10)
3229      DATA EI,BU,DU,VE,FI,FO,AS,VH,GM,ET / 'IE','BU','DU',
3230      1'VE','IF','OF','AS','VH','MG','ET' /
3231      C
3232      C      REWIND SCRATCH FILES AND ADVANCE TO TOP OF PAGE
3233      REWIND 8
3234      REWIND 9
3235      WRITE(6,730)
3236      C
3237      C      READ CARD AND BRANCH TO APPROPRIATE PROGRAM SEGMENT
3238      10 READ(8,505)TOF,(PARAM(I),I=1,10)
3239      IF(TOF.EQ.EI)GO TO 50
3240      IF(TOF.EQ.BU)GO TO 100
3241      IF(TOF.EQ.DU)GO TO 150
3242      IF(TOF.EQ.VE)GO TO 200
3243      IF(TOF.EQ.FI)GO TO 250
3244      IF(TOF.EQ.FO)GO TO 250
3245      IF(TOF.EQ.AS)GO TO 250
3246      IF(TOF.EQ.VH)GO TO 300
3247      IF(TOF.EQ.ET)GO TO 350
3248      C
3249      C      PRINT INITIAL ELEVATIONS HEADINGS AND DATA
3250      50 WRITE(6,530)
3251      WRITE(6,540)
3252      WRITE(6,500)TOF,(PARAM(I),I=1,10)
3253      GO TO 10
3254      C
3255      C      PRINT BUILDING HEADINGS AND DATA
3256      100 WRITE(6,550)
3257      WRITE(6,560)
3258      WRITE(6,500)TOF,(PARAM(I),I=1,10)
3259      GO TO 10
3260      C
3261      C      PRINT DUNE HEADINGS AND DATA
3262      150 WRITE(6,565)
3263      WRITE(6,570)
3264      WRITE(6,500)TOF,(PARAM(I),I=1,10)
3265      GO TO 10
3266      C
3267      C      PRINT VEGETATION HEADINGS AND DATA
3268      200 WRITE(6,580)
3269      WRITE(6,590)
3270      WRITE(6,500)TOF,(PARAM(I),I=1,10)
3271      GO TO 10
3272      C
3273      C      PRINT FETCH OR ABOVE SURGE HEADINGS AND DATA

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3274      250 WRITE(6,600)
3275          WRITE(6,610)
3276          WRITE(6,500)TOF, (PARAM(I),I=1,10)
3277          GO TO 10
3278      C
3279      C      PRINT SPECIAL VEGETATION HEADINGS AND DATA
3280      300 WRITE(6,640)
3281          WRITE(6,650)
3282          WRITE(6,500)TOF, (PARAM(I),I=1,10)
3283          NPLTS=PARAM(6)
3284          DO 310 J=1,NPLTS
3285              READ(8,515)TOF, (PARAM(I),I=1,10)
3286              WRITE(6,660)
3287              WRITE(6,670)
3288              WRITE(6,510)TOF, (PARAM(I),I=1,10)
3289      310 CONTINUE
3290      C
3291      C      PRINT PLANT PARAMETERS INCLUDING DEFAULTS
3292          WRITE(6,700)
3293          DO 330 I=1,NPLTS
3294              WRITE(6,660)
3295              WRITE(6,670)
3296              READ(9,680)TYPE, (PARAM(J),J=1,8)
3297              PARAM(5)=PARAM(5)*12
3298              PARAM(6)=PARAM(6)*12
3299              PARAM(7)=PARAM(7)*12
3300              WRITE(6,520)TYPE, (PARAM(J),J=1,8)
3301      330 CONTINUE
3302          WRITE(6,710)
3303          GO TO 10
3304      C
3305      C      PRINT END OF TRANSECT MESSAGE AND EXPLANATORY NOTE
3306      350 WRITE(6,720)
3307          WRITE(6,740)
3308          WRITE(6,750)
3309      C
3310      C      REWIND SCRATCH FILES, ADVANCE PAGE, AND RETURN
3311          REWIND 8
3312          REWIND 9
3313          WRITE(6,730)
3314          RETURN
3315      500 FORMAT(2X,A2,10F11.3)
3316      505 FORMAT(10X,A2,10F11.3)
3317      510 FORMAT(2X,A2,7X,A4,9F11.3)
3318      515 FORMAT(10X,A2,7X,A4,9F11.3)
3319      520 FORMAT(11X,A4,9F11.3)
3320      530 FORMAT(/,T13,3HEND,T24,3HEND,T33,5HFETCH,T39,10HSURGE ELEV,
3321          1T50,10HSURGE ELEV,T64,7HINITIAL,T75,7HINITIAL,
3322          2T98,6HBOTTOM,T108,7HAVERAGE)
3323      540 FORMAT(T9,7HSTATION,T18,9HELEVATION,T32,6HLENGTH,T42,7H10-YEAR,
3324          1T52,8H100-YEAR,T61,11HWAVE HEIGHT,T74,9HW. PERIOD,
3325          1T99,5HSLOPE,T108,7HA-ZONES)

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3326 550 FORMAT(//, T13, 3HEND, T24, 3HEND, T28, 10HOPEN SPACE, T43, 6HNO. OF, T51,
3327 19HNEW SURGE, T62, 9HNEW SURGE, T98, 6HBOTTOM, T108, 7HAVERAGE)
3328 560 FORMAT(T9, 7HSTATION, T18, 9HELEVATION, T33, 5HRATIO, T45, 4HROWS, T53,
3329 17H10-YEAR, T63, 8H100-YEAR, T99, 5HSLOPE, T108, 7HA-ZONES)
3330 565 FORMAT(//, T6, 10HDUNE CREST, T17, 10HDUNE CREST, T31, 7HDUNE OR, T40,
3331 19HNEW SURGE, T51, 9HNEW SURGE, T98, 6HBOTTOM, T108, 7HAVERAGE)
3332 570 FORMAT(T9, 7HSTATION, T18, 9HELEVATION, T31, 7HSEAWALL, T42,
3333 17H10-YEAR, T52, 8H100-YEAR, T99, 5HSLOPE, T108, 7HA-ZONES)
3334 580 FORMAT(//, T13, 3HEND, T24, 3HEND, T31, 7HAVERAGE, T42, 7HAVERAGE, T53,
3335 17HAVERAGE, T67, 4HDRAG, T73, 9HNEW SURGE, T84, 9HNEW SURGE,
3336 1T98, 6HBOTTOM, T108, 7HAVERAGE)
3337 590 FORMAT(T9, 7HSTATION, T18, 9HELEVATION, T30, 8HDIAMETER, T43, 6HHEIGHT,
3338 1T53, 7HSPACING, T65, 6HCOEFF., T75, 7H10-YEAR, T85, 8H100-YEAR,
3339 1T99, 5HSLOPE, T108, 7HA-ZONES)
3340 600 FORMAT(//, T13, 3HEND, T24, 3HEND, T29, 9HNEW SURGE, T40, 9HNEW SURGE,
3341 1T98, 6HBOTTOM, T108, 7HAVERAGE)
3342 610 FORMAT(T9, 7HSTATION, T18, 9HELEVATION, T31, 7H10-YEAR, T41, 8H100-YEAR,
3343 1T99, 5HSLOPE, T108, 7HA-ZONES)
3344 640 FORMAT(//, T13, 3HEND, T24, 3HEND, T41, 8HREGION 1, T65, 6HNO. OF, T73,
3345 19HNEW SURGE, T84, 9HNEW SURGE, T98, 6HBOTTOM, T108, 7HAVERAGE)
3346 650 FORMAT(T9, 7HSTATION, T18, 9HELEVATION, T30, 8HREGION 1, T43, 6HWEIGHT,
3347 1T52, 8HREGION 2, T61, 11HPLANT TYPES, T75, 7H10-YEAR, T85, 8H100-YEAR,
3348 1T99, 5HSLOPE, T108, 7HA-ZONES)
3349 660 FORMAT(//, T11, 5HPLANT, T23, 4HDRAG, T30, 8HCOVERAGE, T40, 9HAVG. STEM,
3350 1T54, 6HNUMBERT62, 9HBASE STEM, T74, 8HMID STEM, T85, 8HTOP STEM,
3351 1T96, 9HLEAF-STEM)
3352 670 FORMAT(T12, 4HTYPE, T21, 6HCOEFF., T33, 5HRATIO, T43, 6HHEIGHT, T53,
3353 17HDENSITYT63, 8HDIAMETER, T74, 8HDIAMETER, T85, 8HDIAMETER,
3354 1T95, 10HAREA RATIO)
3355 680 FORMAT(A4, 8F16.8)
3356 700 FORMAT(//, 2X, 112(1H-), /, T27, 31HPLANT CHARACTERISTICS INCLUDING,
3357 1 31H VALUES SUPPLIED BY THE PROGRAM)
3358 710 FORMAT(//, 2X, 112(1H-))
3359 720 FORMAT(//, 2X, 48(1H-), 15HEND OF TRANSECT, 49(1H-))
3360 730 FORMAT(1H1)
3361 740 FORMAT(//, 2X, 5HNOTE:)
3362 750 FORMAT(/, 2X, 43HSURGE ELEVATION INCLUDES CONTRIBUTIONS FROM,
3363 11X, 29HASTRONOMICAL AND STORM TIDES.)
3364 END
3365 FUNCTION T(WPI, AFL, W, D)
3366 C
3367 C THIS FUNCTION COMPUTES THE TRANSMITTED WAVE PERIOD FROM
3368 C THE INCIDENT WAVE PERIOD, FETCH LENGTH, 10M. 10MIN. WIND-
3369 C SPEED AND 100 YEAR STILLWATER DEPTH.
3370 PI=3.14159
3371 G=32.2
3372 C13=.333333333
3373 C
3374 C IT IS ASSUMED THAT W IS INPUT AS UNADJUSTED WINDSPEED IN
3375 C FEET PER SECOND
3376 C
3377 C CALCULATE U, THE ADJUSTED WINDSPEED IN FEET PER SECOND

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3378 C
3379 CA=(3.6/5.28)**0.23
3380 U=0.589*CA*(W**1.23)
3381 C
3382 C IT IS ALSO ASSUMED THAT AFL, THE FETCH DISTANCE IS IN FEET AND
3383 C WPI IS IN SECONDS
3384 C
3385 C COMPUTE COMMON FACTORS
3386 ALPHA=(7.54/G)*U
3387 BETA=TANH(.833*((G*D/(U**2))**.375))
3388 X=WPI/(ALPHA*BETA)
3389 C
3390 C CHECK TO SEE IF MAXIMUM WAVE PERIOD HAS BEEN ACHIEVED
3391 IF(X.LT.1)GO TO 20
3392 T=WPI
3393 GO TO 100
3394 C
3395 C COMPUTE EQUIVELENT FETCH LENGTH CORESPONDING TO INCIDENT
3396 C WAVE PERIOD
3397 20 TANHI=.5*LOG((1+X)/(1-X))
3398 EFL=((BETA/.0379)*TANHI)**3*(U**2)/G
3399 C
3400 C COMPUTE TOTAL FETCH LENGTH
3401 F=EFL+AFL
3402 C
3403 C COMPUTE TRANSMITTED WAVE PERIOD
3404 T=ALPHA*BETA*TANH((.0379/BETA)*((G*F/(U**2))**C13))
3405 100 RETURN
3406 END
3407 SUBROUTINE WAVG(DEF1,DEF2,DEF,Wf1,REG1,REG2,NPLTS,TYPE,TEST)
3408 C THIS SUBROUTINE COMPUTES THE WEIGHTED AVERAGE VALUE OF PLANT
3409 C PARAMETERS COMBINING DATA FOR REGION 1 AND REGION 2
3410 C
3411 LOGICAL TEST
3412 DIMENSION DEF1(10,8),DEF2(10,8),DEF(10,8),TYPE(10)
3413 IREG1=REG1
3414 IREG2=REG2
3415 C
3416 C REPEAT COMPUTATIONS FOR EACH PLANT TYPE
3417 DO 90 I=1,NPLTS
3418 C
3419 C FOR STEM PARAMETERS WHICH SHOULD NOT BE ZERO USE RESULTS
3420 C FROM THE OTHER REGION
3421 DO 20 J=3,7
3422 IF(J.EQ.4)GO TO 20
3423 C
3424 C IF PARAMETERS ARE ZERO FOR BOTH REGIONS PRINT ERROR MESSAGE
3425 IF(DEF1(I,J).EQ.0.AND.DEF2(I,J).EQ.0)GO TO 10
3426 C
3427 C USE RESULTS FORM THE OTHER REGION
3428 IF(DEF1(I,J).EQ.0)DEF1(I,J)=DEF2(I,J)
3429 IF(DEF2(I,J).EQ.0)DEF2(I,J)=DEF1(I,J)

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3430      GO TO 20
3431      C
3432      C      SET ERROR FLAG AND PRINT ERROR MESSAGES
3433      10 TEST=.TRUE.
3434      IF(J.EQ.3)WRITE(6,110)TYPE(I),IREG1,IREG2
3435      IF(J.EQ.5)WRITE(6,120)TYPE(I),IREG1,IREG2
3436      IF(J.EQ.6)WRITE(6,130)TYPE(I),IREG1,IREG2
3437      IF(J.EQ.7)WRITE(6,140)TYPE(I),IREG1,IREG2
3438      WRITE(6,100)
3439      20 CONTINUE
3440      C
3441      C      COMPUTE WEIGHTED AVERAGE
3442      DO 90 J=1,8
3443      DEF(I,J)=WF1*DEF1(I,J)+(1-WF1)*DEF2(I,J)
3444      90 CONTINUE
3445      RETURN
3446      100 FORMAT(/,10X,19HINVALID INPUT DATA.)
3447      110 FORMAT(/,10X,45HHEIGHT BELOW INFLORESECE = 0 FOR PLANT TYPE ,
3448      1A4,10H IN REGION,I2,11H AND REGION,I2)
3449      120 FORMAT(/,10X,38HBASE STEM DIAMATER = 0 FOR PLANT TYPE ,
3450      1A4,10H IN REGION,I2,11H AND REGION,I2)
3451      130 FORMAT(/,10X,37HMID STEM DIAMATER = 0 FOR PLANT TYPE ,
3452      1A4,10H IN REGION,I2,11H AND REGION,I2)
3453      140 FORMAT(/,10X,37HTOP STEM DIAMATER = 0 FOR PLANT TYPE ,
3454      1A4,10H IN REGION,I2,11H AND REGION,I2)
3455      END
3456      C
3457      C      G&O SEPT 88
3458      C
3459      C      FUNCTION HMONB(WHI,DNEW,WPI)
3460      C
3461      C      THIS FUNCTION CONVERTS THE CONTROLLING WAVE HEIGHT, WHI
3462      C      TO THE ZERO MOMENT WAVE HEIGHT, HMO WHEN WAVE IS NOT BREAKING.
3463      C      DNEW IS THE STILLWATER DEPTH AND WPI IS THE SPECTRAL PEAK WAVE
3464      C      PERIOD AT THE LOCATION OF INTEREST.
3465      C
3466      IF(WHI.EQ.0)HMONB=0
3467      IF(WHI.EQ.0)RETURN
3468      C
3469      C      SET PRELIMINARY CONSTANTS OR FACTORS
3470      C
3471      G=32.2
3472      C
3473      C      CALCULATE THE SIGNIFICANT WAVE HEIGHT HS.
3474      C      NOTE THAT (1./1.6)=-.625
3475      C
3476      HS = WHI * 0.625
3477      C
3478      C      CALCULATE RAV
3479      C
3480      DNEWSTR = AMAX1( 0.01,DNEW )
3481      WPISTR = AMAX1( 0.1,WPI )

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3482 DD = DNEWSTR/( G*(WPISTR**2) )
3483 DO= 1.357E-3
3484 C
3485 RAV=1.477+.477*(((DO/DD)**.8557)-1)
3486 C
3487 IF(RAV.GT.1.7)RAV=1.7
3488 IF(RAV.LT.1)RAV=1
3489 C
3490 C CALCULATE HMO FROM HS AND RAV
3491 C
3492 HMO = HS/RAV
3493 C
3494 HMONB = HMO
3495 C
3496 RETURN
3497 END
3498 C
3499 C END G&O SEPT 88
3500 C
3501 FUNCTION HMO(WHI,DNEW,WPI)
3502 C
3503 C THIS FUNCTION CONVERTS THE CONTROLLING WAVE HEIGHT, WHI
3504 C TO THE ZERO MOMENT WAVE HEIGHT, HMO WHEN WAVE IS BREAKING
3505 C
3506 IF(WHI.EQ.0)HMO=0
3507 IF(WHI.EQ.0)RETURN
3508 C
3509 C SET PRELIMINARY CONSTANTS OR FACTORS
3510 C
3511 PI=3.14159
3512 G=32.2
3513 C
3514 C G&O 2/87
3515 DNEWSTR = AMAX1( 0.01,DNEW )
3516 PI2 = 2. * PI
3517 C G&O 2/87 END
3518 C
3519 HS=WHI/1.6
3520 NMAX= 25
3521 DO= 1.357E-3
3522 DC= 5.5722E-5
3523 C1LOG= ALOG10(2.0)
3524 C2LOG= .394528 * C1LOG
3525 C3LOG= 1.411296 * C1LOG
3526 C
3527 C CP1= 1.0/1.016768
3528 C
3529 CP1= .983508529
3530 C
3531 C CP2= 1.0/1.411296
3532 C
3533 CP2= .708568578

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3534 C
3535 C      CP3= 10**(-1.0/1.0167683)
3536 C
3537 C      CP3= .10387032
3538 C
3539 C      CP4= 10**(-1.0/1.411296)
3540 C
3541 C      CP4= .195628183
3542 C
3543 C G&O 2/87
3544 C      DD=DNEW/(G*WPI**2)
3545 C      WLO=5.12*(WPI**2)
3546 C      WLI=SQRT(2*PI*DNEW*WLO)/(1+1.25*DNEW/WLO)
3547 C      DD = DNEWSTR/(G*WPI*WPI)
3548 C      WLO = AMAX1( WLO,0.1 )
3549 C      CDNEW = DNEWSTR/WLO
3550 C      WLI = WLO * SQRT( TANH( PI2*CDNEW ) )
3551 C G&O 2/87 END
3552 C
3553 C      CL1= .008 * WLI
3554 C
3555 C      CL2= .016 * WLI
3556 C
3557 C      CL2= 2. * CL1
3558 C      CL3= 1.25/WLI
3559 C
3560 C      EPSP= HS/(.002*4*WLI)
3561 C
3562 C      EPSP= HS/CL1
3563 C
3564 C      CALC RAV AND PHIE
3565 C
3566 C      RAV=1.477+.477*((D0/DD)**.8557)-1)
3567 C      IF(RAV.GT.1.7)RAV=1.7
3568 C      IF(RAV.LT.1)RAV=1
3569 C
3570 C      PHIE= RAV
3571 C
3572 C      CALC DDP,PHIB,AKAPA,AKAPC
3573 C
3574 C      DDP= DD/DC
3575 C      PART1= .9 + ( .42707*ALOG10(DDP) )
3576 C      PHIB= PART1 - C3LOG
3577 C      AKAPA= .2303028/(DDP**.302608)
3578 C      AKAPC= .170474016/ (DDP**.420026987)
3579 C
3580 C      CALC HMOE. THERE ARE 2 CASES
3581 C
3582 C      IF( PHIB - PHIE ) 30 , 20 , 20
3583 C      20 CONTINUE
3584 C
3585 C      PHIB .GE. PHIE

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3586 C
3587 HMOE= (CL1/AKAPC) * (10**(-CP1*PHIE))
3588 GO TO 40
3589 C
3590 30 CONTINUE
3591 C
3592 PHIB .LT. PHIE
3593 C
3594 HMOE= (CL1/AKAPA) * (10**(-CP2*PHIE))
3595 C
3596 40 CONTINUE
3597 C
3598 CALC. HSE
3599 C
3600 HSE= PHIE * HMOE
3601 C
3602 SET PHID TO 1.0
3603 C
3604 PHID= 1.0
3605 C
3606 CALC HMOD. THERE ARE 2 CASES
3607 C
3608 IF( PHIB - 1.0 ) 60 , 50 , 50
3609 50 CONTINUE
3610 C
3611 PHIB .GE. 1.0
3612 C
3613 HMOD= (CL1/AKAPC) * CP3
3614 GO TO 70
3615 60 CONTINUE
3616 C
3617 PHIB .LT. 1.0
3618 C
3619 HMOD= (CL1/AKAPA) * CP4
3620 C
3621 70 CONTINUE
3622 C
3623 CALC HSD
3624 C
3625 HSD= HMOD
3626 C
3627 CALC HMOB AND HSB
3628 C
3629 HMOB= CL2
3630 HSB= HMOB * PHIB
3631 C
3632 CALC HMO AND EPP. THERE ARE 3 CASES.
3633 C
3634 IF( HS .GE. HSD ) GO TO 220
3635 IF( HS .LE. HSE ) GO TO 230
3636 C
3637 IF WE GET HERE, HSE .LT. HS .LT. HSD. JUMP TO THAT

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3638 C SECTION
3639 C
3640 GO TO 240
3641 C
3642 220 CONTINUE
3643 C
3644 C CASE 1--HS .GE. HSD. CALC HMO AND EPP.
3645 C
3646 HMO= HS
3647 EPP= HMO/CL1
3648 GO TO 320
3649 C
3650 230 CONTINUE
3651 C
3652 C CASE 2--HS .LE. HSE. CALC HMO AND EPP
3653 C
3654 HMO=HS/PHIE
3655 EPP= HMO/CL1
3656 GO TO 320
3657 C
3658 240 CONTINUE
3659 C
3660 C CASE 3--HSE .LT. HS .LT. HSD. CALC HMO AND EPP. THERE
3661 C ARE 3 SUBCASES.
3662 C
3663 IF( HSB - HS ) 80 , 140 , 150
3664 80 CONTINUE
3665 C
3666 C SUBCASE 1--HSB .LT. HS
3667 C
3668 C CALC RATSTAR. THERE ARE 2 SUB-SUB-CASES.
3669 C
3670 IF( PHIB - PHIE ) 90 , 100 , 100
3671 90 CONTINUE
3672 C
3673 C SUB-SUB-CASE 1--PHIB .LT. PHIE
3674 C
3675 RATSTAR= ( HMOB - HMOD )/( HSB - HSD )
3676 GO TO 110
3677 C
3678 100 CONTINUE
3679 C
3680 C SUB-SUB-CASE 2--PHIB .GE. PHIE
3681 C
3682 RATSTAR= ( HMOE - HMOD )/( HSE - HSD )
3683 110 CONTINUE
3684 C
3685 C USING RATSTAR, CALC INITIAL APPROX TO HMO, I.E.
3686 C HMOINIT
3687 C
3688 HMOINIT= HMOD + ( RATSTAR * ( HS - HSD ) )
3689 C

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3690 C      CALC INITIAL APPROX TO EPP, I.E. EPPINIT
3691 C
3692 C      EPPINIT= HMOINIT/CL1
3693 C
3694 C      INITIALIZE VARIABLES BEFORE NEWTON ITERATION WHICH
3695 C      CALCULATES EPP.
3696 C
3697 C      EPPN= EPPINIT
3698 C
3699 C      BEGIN ITERATION
3700 C
3701 C      DO 120 N = 1 , NMAX
3702 C
3703 C      PHIC= -1.016768 * ALOG10( AKAPC*EPPN )
3704 C      QC= (EPPN*PHIC) - EPSP
3705 C      DERIVQC= PHIC - .441576731
3706 C      DELEPPN= -QC/DERIVQC
3707 C      EPPNP1= EPPN + DELEPPN
3708 C
3709 C      CHECK AND SEE IF CONVERGENCE ACHIEVED.
3710 C
3711 C      IF( ABS(DELEPPN) .LT. CL3 ) GO TO 130
3712 C
3713 C      CONVERGENCE NOT ACHIEVED. RESET EPPN AND TRY AGAIN.
3714 C
3715 C      EPPN= EPPNP1
3716 C      120 CONTINUE
3717 C
3718 C      END OF ITERATION LOOP. IF WE GET HERE, CONVERGENCE
3719 C      NOT ACHIEVED. USE LATEST VALUE OF EPPNP1.
3720 C
3721 C      130 CONTINUE
3722 C
3723 C      IF WE JUMP HERE OUT OF ITERATION LOOP, THEN CONVERGENCE
3724 C      HAS BEEN ACHIEVED.
3725 C
3726 C      SET EPP AND HMO
3727 C
3728 C      EPP= EPPNP1
3729 C      HMO= CL1 * EPP
3730 C
3731 C      END OF CALC OF HMO AND EPP FOR SUB-CASE HSB .LT. HS.
3732 C
3733 C      GO TO 310
3734 C
3735 C      140 CONTINUE
3736 C
3737 C      HSB=HS SUB-CASE
3738 C
3739 C      CALC HMO AND EPP BY DEFINING RELATIONSHIPS FOR THIS
3740 C      SUB-CASE
3741 C

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3742      HMO= CL2
3743      EPP= 2.0
3744      C
3745      C      END OF CALC OF HMO FOR HSB=HS SUB-CASE
3746      C
3747      GO TO 310
3748      C
3749      150 CONTINUE
3750      C
3751      C      HSB .GT. HS SUB-CASE
3752      C
3753      C      CALC RATSTAR. THERE ARE 2 SUB-SUB-CASES.
3754      C
3755      IF( PHIB - PHID ) 160 , 160 , 170
3756      160 CONTINUE
3757      C
3758      C      PHIB .LE. PHID SUB-SUB-CASE
3759      C
3760      RATSTAR= ( HMOD - HMOE )/( HSD - HSE )
3761      GO TO 180
3762      C
3763      170 CONTINUE
3764      C
3765      C      PHIB .GT. PHID SUB-SUB-CASE
3766      C
3767      RATSTAR= ( HMOB - HMOE )/( HSB - HSE )
3768      180 CONTINUE
3769      C
3770      C      USING RATSTAR, CALC INITIAL APPROX TO HMO, I.E.
3771      C      HMOINIT
3772      C
3773      HMOINIT= HMOE + ( RATSTAR * ( HS - HSE ) )
3774      C
3775      C      CALC INITIAL APPROX TO EPP, I.E. EPPINIT
3776      C
3777      EPPINIT= HMOINIT/CL1
3778      C
3779      C      INITIALIZE VARIABLES BEFORE NEWTON ITERATION WHICH
3780      C      CALCULATES EPP.
3781      C
3782      EPPN= EPPINIT
3783      C
3784      C      BEGIN ITERATION
3785      C
3786      DO 190 N = 1 , NMAX
3787      C
3788      PHIA= -1.411296 * ALOG10( AKAPA*EPPN )
3789      QA= (EPPN*PHIA) - EPSP
3790      DERIVQA= PHIA - .612918065
3791      DELEPPN= -QA/DERIVQA
3792      EPPNPI= EPPN + DELEPPN
3793      C

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3794 C CHECK AND SEE OF CONVERGENCE ACHIEVED.
3795 C
3796 C IF( ABS(DELEPPN) .LT. CL3 ) GO TO 300
3797 C
3798 C CONVERGENCE NOT ACHIEVED. RESET EPPN AND TRY AGAIN.
3799 C
3800 C EPPN= EPPNP1
3801 C 190 CONTINUE
3802 C
3803 C END OF ITERATION LOOP. IF WE GET HERE, CONVERGENCE
3804 C NOT ACHIEVED. USE LATEST VALUE OF EPPNP1.
3805 C
3806 C 300 CONTINUE
3807 C
3808 C IF WE JUMP HERE OUT OF ITERATION LOOP, THEN CONVERGENCE
3809 C HAS BEEN ACHIEVED.
3810 C
3811 C SET EPP AND HMO
3812 C
3813 C EPP= EPPNP1
3814 C HMO= CL1 * EPP
3815 C
3816 C END OF CALC OF HMO AND EPP FOR SUB-CASE HSB .GT. HS.
3817 C
3818 C 310 CONTINUE
3819 C
3820 C END OF CALC OF HMO AND EPP FOR CASE
3821 C HSE .LT. HS .LT. HSD
3822 C
3823 C 320 CONTINUE
3824 C
3825 C END OF CALC OF HMO AND EPP
3826 C RETURN
3827 C END
3828 C
3829 C SUBROUTINE LOOKUP(DEF,REG,TEST)
3830 C
3831 C THIS SUBROUTINE BELONGS TO WHAFIS2.F77
3832 C
3833 C MODIFIED ON MAY 1985, BY AMIR RAZAVI PER RKC REQUEST.
3834 C
3835 C MODIFICATION WAS MADE TO MATCH W2.F77 OPERATION.
3836 C
3837 C THE COMMON STRUCTURE FOR /PP/ AND /PPT/ HAS ADDITIONAL VARIABLES IN
3838 C W2 PROGRAM. THOSE VARIABLES ARE NOT USED IN WHAFIS2.F77 AND THEREFORE
3839 C THE COMMON AREAS ARE NOT MODIFIED.
3840 C
3841 C THE MODIFIED LINES HAVE A "CAHR" AT THE BEGINING.
3842 C THE ADDED BLOCKS ARE IDENTIFIED BY "CAHR START" AND "CAHR END"
3843 C
3844 C LOGICAL TEST,TEST1,TEST2
3845 C THIS SUBROUTINE LOOKS UP DEFAULT MARSH GRASS PLANT PARAMETERS

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3846 C   FOR A GIVEN REGION AND PLANT TYPE
3847     DIMENSION CDE(10),FCOV(10),HBI(10),PPSF(10),SDB(10),
3848     1SDM(10),SDT(10),TYPE(10),FAR(10),DEF(10,8)
3849     DIMENSION HDN(8,8,7),PPSD(8,3),PLTYP(8)
3850     DIMENSION ITYP(10)
3851     COMMON /PP/NPLTS,TYPE,CDE,FCOV,HBI,PPSF,SDB,SDM,SDT,FAR
3852     COMMON /PPT/HDN,PPSD,PLTYP
3853     IREG=REG
3854 C
3855 C   SET DEFAULT VALUES FOR EACH PLANT TYPE
3856     TEST1=.FALSE.
3857 C
3858 CAHR START
3859     FCOVCUM=0.0
3860 CAHR END
3861 C
3862     DO 230 I1=1,NPLTS
3863 C
3864 C   INITIALIZE ARRAY DEF
3865     DEF(I1,1)=CDE(I1)
3866     DEF(I1,2)=FCOV(I1)
3867     DEF(I1,3)=HBI(I1)
3868     DEF(I1,4)=PPSF(I1)
3869     DEF(I1,5)=SDB(I1)
3870     DEF(I1,6)=SDM(I1)
3871     DEF(I1,7)=SDT(I1)
3872     DEF(I1,8)=FAR(I1)
3873 C
3874 C   INITIALIZE ERROR FLAG
3875     TEST2=.FALSE.
3876 C
3877 C   IF FCOV=0 REVISE DEFAULT
3878 CAHR START
3879 C   IF(COV(I1).EQ.0)TEST1=.TRUE.
3880 C
3881     IF(FCOV(I1)) 1000, 1010, 1020
3882 C
3883     1000 CONTINUE
3884 C
3885 C       FCOV(I) IS NEGATIVE. SET ERROR FLAG AND PRINT
3886 C       MESSAGE.
3887 C
3888     TEST2=.TRUE.
3889     WRITE(6,1005)I
3890     1005 FORMAT(/10X,"FCOV WAS FOUND TO BE NEGATIVE FOR PLANT TYPE=",
3891     1 I2)
3892     GOTO 1030
3893 C
3894     1010 CONTINUE
3895 C
3896 C       FCOV=0. USE DEFAULT FCOV FOR THIS PLANT TYPE.
3897 C

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3898         TEST1=.TRUE.
3899         NCOV=NCOV+1
3900         GOTO 1030
3901     C
3902     1020     CONTINUE
3903     C
3904     C         FCOV IS GREATER THAN ZERO
3905     C
3906     C         FCOVCUM=FCOVCUM+FCOV(I1)
3907     C
3908     1030 CONTINUE
3909     C
3910     C         CHECK AND SEE IF PLANT TYPE I1 IS MARSH GRASS. IF IT IS,
3911     C         CONTINUE ON. IF IT IS NOT, JUMP TO LABEL 225, IE.
3912     C         RIGHT ABOVE END OF LOOP.
3913     C
3914     C         DO 1040 I2=1,8
3915     C         IF(TYPE(I1).EQ.PLTYP(I2)) GOTO 1050
3916     1040 CONTINUE
3917     C
3918     C         IF WE GET HERE PLANT TYPE IS NOT MARSH GRASS. JUMP TO
3919     C         END OF LOOP.
3920     C
3921     C         GOTO 225
3922     C
3923     1050 CONTINUE
3924     C
3925     C         IF WE GET HERE, PLANT TYPE IS MARSH GRASS. CONTINUE ON.
3926     C
3927     C         NEXT LINE IS FOR DIAGNOSTIC PURPOSES.
3928     C         WRITE(6,1060)
3929     C1060 FORMAT(1X/1X,"PLANT TYPE IS RECOGNIZED AS MARSH GRASS",/)
3930     C
3931     CAHR END
3932     C
3933     CAHR IF(FCOV(I1).EQ.0)TEST1=.TRUE.
3934     C
3935     C         IF CDE=0 REVISE DEFAULT
3936     C         IF(CDE(I1).EQ.0)DEF(I1,1)=.1
3937     C
3938     C         RELATE PLANT TYPE TO ARRAY INDEX
3939     C         ITYP(I1)=9
3940     C         DO 20 I2=1,8
3941     C         IF(TYPE(I1).EQ.PLTYP(I2))ITYP(I1)=I2
3942     20 CONTINUE
3943     C
3944     C         IF SDB=0 REVISE DEFAULT
3945     C         IF(SDB(I1).NE.0)GO TO 120
3946     C         IF(ITYP(I1).LT.9.AND.REG.NE.0)GO TO 90
3947     C         TEST2=.TRUE.
3948     C         GO TO 120
3949     90 IF(HBI(I1).NE.0)GO TO 100

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3950         DEF(I1,5)=HDN(IREG,ITYP(I1),2)
3951         GO TO 120
3952     100 A=HDN(IREG,ITYP(I1),3)
3953         B=HDN(IREG,ITYP(I1),4)
3954         DEF(I1,5)=A*HBI(I1)**B
3955     120 CONTINUE
3956     C
3957     C     IF PPSF=0 REVISE DEFAULT
3958         IF(PPSF(I1).NE.0)GO TO 150
3959         IF(ITYP(I1).LT.9.AND.REG.NE.0)GO TO 130
3960         TEST2=.TRUE.
3961         GO TO 150
3962     130 IF(HBI(I1).NE.0)GO TO 140
3963         DEF(I1,4)=HDN(IREG,ITYP(I1),5)
3964         GO TO 150
3965     140 A=HDN(IREG,ITYP(I1),6)
3966         B=HDN(IREG,ITYP(I1),7)
3967         DEF(I1,4)=A*HBI(I1)**B
3968     150 CONTINUE
3969     C
3970     C     IF HBI=0 REVISE DEFAULT
3971         IF(HBI(I1).NE.0)GO TO 160
3972         IF(ITYP(I1).LT.9.AND.REG.NE.0)GO TO 155
3973         TEST2=.TRUE.
3974         GO TO 160
3975     155 DEF(I1,3)=HDN(IREG,ITYP(I1),1)
3976     160 CONTINUE
3977     C
3978     C     IF SDM=0 REVISE DEFAULT
3979         IF(SDM(I1).NE.0)GO TO 180
3980         IF(ITYP(I1).LT.9)GO TO 170
3981         TEST2=.TRUE.
3982         GO TO 180
3983     170 DEF(I1,6)=DEF(I1,5)*PPSD(ITYP(I1),1)
3984     180 CONTINUE
3985     C
3986     C     IF SDT=0 REVISE DEFAULT
3987         IF(SDT(I1).NE.0)GO TO 200
3988         IF(ITYP(I1).LT.9)GO TO 190
3989         TEST2=.TRUE.
3990         GO TO 200
3991     190 DEF(I1,7)=DEF(I1,5)*PPSD(ITYP(I1),2)
3992     200 CONTINUE
3993     C
3994     C     IF FAR=0 REVISE DEFAULT
3995         IF(FAR(I1).NE.0)GO TO 220
3996         IF(ITYP(I1).LT.9)GO TO 210
3997         TEST2=.TRUE.
3998         GO TO 220
3999     210 DEF(I1,8)=PPSD(ITYP(I1),3)
4000     220 CONTINUE
4001     CAHR START

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4002      225 CONTINUE
4003 CAHR END
4004 C
4005 C      PRINT ERROR MESSAGE IF REQUIRED
4006      IF(TEST2)WRITE(6,500)TYPE(I1),IREG
4007 C
4008 C      SET ERROR FLAG IF REQUIRED
4009      IF(TEST2)TEST=.TRUE.
4010 C
4011 C      CLOSE OFF MAIN DO LOOP
4012      230 CONTINUE
4013 C
4014 C      REVISE FCOV IF REQUIRED AND RETURN
4015 CAHR  IF(.NOT.TEST1)GO TO 250
4016      IF(.NOT.TEST1)GO TO 270
4017 CAHR START
4018 C
4019 C      IF WE GET HERE, NCOV SHOULD BE GREATER THAN ZERO.
4020 C      TEST AND MAKE SURE.
4021 C
4022      IF(NCOV.GT.0)GOTO 2010
4023 C
4024      WRITE(6,2000)
4025      2000 FORMAT(/10X,"NCOV IS .LE. ZERO IN SUB. LOOKUP WHEN IT SHOULD",
4026      1 " BE .GT. ZERO. ABORT RUN.")
4027      STOP
4028 C
4029      2010 CONTINUE
4030      IF(FCOVCUM.GT.0.0)GOTO 250
4031 C
4032 C      IF WE GET HERE, ALL PLANTS USE DEFAULT FCOV VALUE.
4033 C
4034      FCOVFLT=1.0/FLOAT(NPLTS)
4035 C
4036 CAHR END
4037      DO 240 I2=1,NPLTS
4038 CAHR  DEF(I2,2)=1/FLOAT(NPLTS)
4039      DEF(I2,2)=FCOVFLT
4040      240 CONTINUE
4041 CAHR START
4042 C
4043      GOTO 270
4044      250 CONTINUE
4045 C
4046 C      AT LEAST ONE PLANT SPECIES DOES NOT HAVE A DEFAULT
4047 C      FCOV VALUE. WE ASSUME MULTIPLE COVERGE SO THAT SUM
4048 C      OF FCOV FOR SPECIES WITH DEFAULT IS 1.0
4049 C
4050      FCOVFLT=1.0/FLOAT(NCOV)
4051 C
4052      DO 260 I2=1, NPLTS
4053      IF(FCOV(I2).EQ.0.0)DEF(I2,2)=FCOVFLT

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4054 260 CONTINUE
4055 270 CONTINUE
4056 C
4057 CAHR END
4058
4059 CAHR 250 RETURN
4060 500 FORMAT(/,10X,41HNO DEFAULT DATA AVAILABLE FOR PLANT TYPE ,A4,
4061 110H IN REGION,I2)
4062 END
4063 C
4064 C*****
4065 SUBROUTINE SCANE
4066 C*****
4067 C
4068 C DEVELOPED FEBRUARY 1987 BY
4069 C
4070 C GREENHORNE AND O'MARA, INC.
4071 C GREENBELT, MARYLAND
4072 C
4073 C THIS SUBROUTINE IS CALLED AT THE BEGINNING OF THE MAIN PROGRAM
4074 C TO PERFORM THE STILLWATER ELEVATION INTERPOLATION.
4075 C
4076 C THE INTERPOLATION SCHEME IS PERFORMED WITHIN A TRANSECT SEGMENT
4077 C DEFINED AS THE STATIONING INTERVAL OF SURGE ELEVATION CHANGES.
4078 C THE STILLWATER ELEVATIONS IN THE SEGMENT ARE LINEAR INTERPOLATED
4079 C USING TWO GIVEN SURGES AT THE BEGINNING AND THE END OF A SEGMENT.
4080 C
4081 C THE LINEAR INTERPOLATED VALUES AT EACH STATION WITHIN THIS SEGMENT
4082 C ARE THEN COMPARED WITH THE CORRESPONDING GROUND ELEVATIONS. IF THE
4083 C INTERPOLATED ELEVATION ARE ABOVE THE CORRESPONDING GROUND
4084 C ELEVATIONS (I.E., NO GROUND CUT OFF), THE INTERPOLATED VALUES
4085 C ARE USED AS THE STILLWATER ELEVATIONS FOR THE COMPUTATION OF
4086 C THE WAVE HEIGHT.
4087 C OTHERWISE, THE STILLWATER ELEVATIONS WILL BE DETERMINED BY
4088 C THE CONCEPT SIMILAR TO THE "FLOW OVER A BARRIER" ALGORITHM USED
4089 C IN THE FEMA'S SURGE MODEL.
4090 C
4091 C AT THE END OF THIS SUBROUTINE, THE WEIGHT AVERAGED BOTTOM SLOPE
4092 C AT EACH STATION ARE COMPUTED AND STORED IN THE NINETH PARAMETER,
4093 C I.E., PARAM(J,9), WHICH WILL BE UTILIZED IN THE WAVE ENERGY
4094 C EQUATION PERFORMED IN THE MAIN PROGRAM
4095 C
4096 C*****
4097 C
4098 C LOGICAL TEST,TEST1
4099 C DIMENSION TOF(500),PARAM(500,10),TITLE(80),SGOLD(200),
4100 C A SGNEW(200),JM(2),ELMX(2)
4101 C
4102 C DATA EI,DU,BU,VE,FI,FO,ET/ 'IE','DU','BU','VE','IF','OF','ET'/
4103 C DATA AS,VH,GM,BLANK/ 'AS','VH','MG',' '/
4104 C
4105 C NPLTS=0

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4106         NVH=0
4107         NVH1=0
4108         NVH2=0
4109     C
4110     1  READ(5,805)  (TITLE(I),I=1,80)
4111         TEST=.TRUE.
4112     C
4113         DO 510 I=1,80
4114         IF(TITLE(I). NE. BLANK) TEST=.FALSE.
4115     510 CONTINUE
4116     C
4117         IF(TEST) THEN
4118         WRITE(10,805) BLANK
4119         REWIND 10
4120         RETURN
4121         ENDIF
4122     C
4123         WRITE(6,806)  (TITLE(I),I=1,80)
4124     806 FORMAT(1H1,10X, '*** THE FOLLOWING MESSAGES ARE THE RESULTS ',
4125     A      'FROM THE 100-YR ELEVATION INTERPOLATION FOR THE ',
4126     B      'TRANSECT:',//,10X,80A1)
4127     C
4128     C** CHECK IF THE FIRST CARD IS EI CARD
4129     C
4130         READ(5,810) TOF(1),(PARAM(1,I),I=1,10)
4131         NB=1
4132         IF(TOF(1). NE. EI) THEN
4133         WRITE(6,820)
4134     820 FORMAT(10X, ' THE FIRST CARD IS NOT AN IE CARD, THIS'
4135     A ' TRANSECT IS ABORTED. CONTINUED TO NEXT TRANSECT'/)
4136         DO 3 J=1,500
4137         READ(5,810) TOF(J)
4138         IF(TOF(J).EQ.ET) GO TO 1
4139     3  CONTINUE
4140         ENDIF
4141     C
4142     C** GIVING INITIAL STATIONING, BED ELEVATION, AND 100-YEAR ELEVATION
4143     C
4144         BFO=PARAM(1,1)
4145         BEL=PARAM(1,2)
4146         BSEN=PARAM(1,5)
4147         SGOLD(1)=BSEN
4148         SGNEW(1)=BSEN
4149     C
4150     C** CHECK IF BED ELEVATION BEL IS GREATER THAN 100-YEAR ELEVATION BSEN
4151     C** ON EI CARD
4152     C
4153         IF(BEL. GT. BSEN) THEN
4154         WRITE(6,780)
4155     780 FORMAT(5X, 'GROUND ELEVATION GREATER THAN SURGE ELEVATION AT'
4156     A ' IE CARD. JOB DUMPED.'/)
4157         DO 4 J=1,500

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4158         READ(5,810) TOF(J)
4159         IF(TOF(J).EQ.ET) GO TO 1
4160     4     CONTINUE
4161     ENDIF
4162 C
4163 C*****      START SCANNING 100-YR ELE. CHANGES      *****
4164 C
4165 C**  ASSUMING THE CURRENT STATION IS THE END STATION OF THE
4166 C**  INTERPOLATION SEGMENT
4167 C
4168 C**  FIRST READ INPUT FROM UNIT N5
4169 C
4170         NFO=1
4171     5     NFO = NFO + 1
4172         READ(5,810) TOF(NFO), (PARAM(NFO,I), I=1,10)
4173 C
4174 C**  SET END SEGMENT STATIONING AND CORRESPONDING BED ELEVATION
4175 C
4176         EFO=PARAM(NFO,1)
4177         EEL=PARAM(NFO,2)
4178 C
4179 C**  BRANCH TO VARIOUS PROGRAM SEGMENT ACCORDING TO CARD TYPE & SET THE
4180 C**  READ IN 100 YEAR STILLWATER ELEVATION ESEN
4181 C
4182         IF(TOF(NFO).EQ.DU) GO TO 50
4183         IF(TOF(NFO).EQ.BU) GO TO 100
4184         IF(TOF(NFO).EQ.VE. OR. TOF(NFO).EQ.VH) GO TO 150
4185         IF(TOF(NFO).EQ.FI. OR. TOF(NFO).EQ.FO) GO TO 200
4186         IF(TOF(NFO).EQ.AS) GO TO 250
4187         IF(TOF(NFO).EQ.ET) THEN
4188             NE=NFO
4189             GO TO 400
4190         ENDIF
4191 C
4192 C**  DUNE (DU) CARD
4193 C
4194     50     ESEN=PARAM(NFO,5)
4195           GO TO 350
4196 C
4197 C**  BUILDING (BU) CARD
4198 C
4199     100    ESEN=PARAM(NFO,6)
4200           GO TO 350
4201 C
4202 C**  VEGETATION (VE) OR MARSH GRASS (VH) CARD
4203 C
4204     150    ESEN=PARAM(NFO,8)
4205 C
4206           IF(TOF(NFO).EQ.VE) GO TO 350
4207 C
4208 C*  FOR VH CARD, READ NPLTS TIMES OF MG CARDS
4209 C

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4210      HIGH=AMAX1(BSEN,ESEN)
4211      IF(EEL. GT. HIGH) THEN
4212          WRITE(6,781) EFO,TOF(NFO)
4213      ENDIF
4214      C
4215      SGOLD(NFO)=ESEN
4216      SGNEW(NFO)=ESEN
4217      C
4218      IF(ESEN.EQ.0.) THEN
4219          SGOLD(NFO)=SGOLD(NFO-1)
4220          SGNEW(NFO)=SGOLD(NFO)
4221      ENDIF
4222      C
4223      KPLTS=NPLTS
4224      C
4225      NPLTS=PARAM(NFO,6)
4226      DO 155 I=1,NPLTS
4227          NFO = NFO + 1
4228          READ(5,560) TOF(NFO),(PARAM(NFO,K),K=1,10)
4229          SGOLD(NFO)=SGOLD(NFO-1)
4230          SGNEW(NFO)=SGOLD(NFO)
4231      155 CONTINUE
4232      C
4233      IF(ESEN.NE.0.) THEN
4234          NVH=1
4235          NE=NFO-NPLTS
4236      C
4237      IF(NE. EQ. 2) THEN
4238          NVH1=NE
4239          GO TO 400
4240      ENDIF
4241      C
4242      ENDIF
4243      C
4244      IF(NVH. EQ. 1) THEN
4245          NVH=0
4246          NVH2=NFO-NPLTS-KPLTS
4247      C
4248      IF(NVH2. EQ. NVH1+1) THEN
4249          NVH1=NE
4250          GO TO 400
4251      ENDIF
4252      C
4253          NVH1=NE
4254      C
4255      ENDIF
4256      C
4257      IF(ESEN.EQ.0.) GO TO 5
4258      GO TO 351
4259      C
4260      C** INLAND FETCH (IF) OR OVER-WATER FETCH (OF) CARD
4261      C

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4262     200 ESEN=PARAM(NFO,4)
4263     GO TO 350
4264     C
4265     C** ABOVE SURGE (AS) CARD
4266     C
4267     250 ESEN=PARAM(NFO,4)
4268     C
4269     C FOR AS CARD RESET BEGINNING SEGMENT COUNTER
4270     C
4271     NE=NFO
4272     C
4273     C** AND RESET 100-YR ELEVATION
4274     C
4275     IF(ESEN.EQ.0.) THEN
4276         SGOLD(NFO)=SGOLD(NFO-1)
4277         SGNEW(NFO)=SGOLD(NFO)
4278     ELSE
4279         SGOLD(NFO)=ESEN
4280         SGNEW(NFO)=ESEN
4281     ENDIF
4282     GO TO 400
4283     C
4284     C*****
4285     C** SCANNING FOR 100-YR SURGE ELEVATION CHANGES *
4286     C*****
4287     C
4288     C** FIRST CHECK WHETHER THE GROUND ELEVATION IS GREATER THAN
4289     C** THE STILLWATER ELEVATION. IF IT IS, THEN FLAG THE MESSAGE.
4290     C
4291     350 CONTINUE
4292     HIGH=AMAX1(BSEN,ESEN)
4293     IF(EEL. GT. HIGH) THEN
4294         WRITE(6,781) EFO,TOF(NFO)
4295     781     FORMAT(10X,'**** THE SURGE ELEVATION AT THIS STATION',
4296     A         '(STATIONING ',F8.0,' ), WHICH IS ',A2,' CARD,',
4297     B         ' IS LESS THAN THE GROUND ELEVATION.',/,
4298     C         10X,'THE INTERPOLATION PROCESS CONTINUED.',//
4299     D         5X,'*** PLEASE DOUBLE-CHECK THE SURGE AND GROUND',
4300     E         ' ELEVATIONS IN THE VICINITY OF THIS STATION',
4301     F         ' !!!!!!!'//)
4302     C
4303     END IF
4304     C
4305     C** SECOND, IF THERE IS NO SURGE ELEVATION CHANGE, GO TO 5 TO
4306     C** READ NEXT CARD.
4307     C** IF THE SURGE ELEVATION CHANGES, DO INTERPOLATION
4308     C
4309     SGOLD(NFO)=ESEN
4310     SGNEW(NFO)=ESEN
4311     IF(ESEN.EQ.0.) THEN
4312         SGOLD(NFO)=SGOLD(NFO-1)
4313         SGNEW(NFO)=SGOLD(NFO)

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4314         GO TO 5
4315         ENDIF
4316     C
4317     C*****
4318     C**  PREPARING FOR LINEAR INTERPOLATION  *
4319     C*****
4320     C
4321         NE=NFO
4322         351 DX=EFO-BFO
4323         DSG=ESEN-BSEN
4324         DDSG=DSG/DX
4325     C
4326     C*****
4327     C**  LINEAR INTERPOLATION  *
4328     C*****
4329     C
4330         NME=NE-1
4331         NMB=NB+1
4332     C
4333         IF(NME. LT. NMB) GO TO 400
4334     C
4335         DO 360 J=NMB,NME
4336         IF(TOF(J). EQ. GM) THEN
4337             SGNEW(J)=SGNEW(J-1)
4338         ELSE
4339             SGNEW(J)=SGOLD(J)+DDSG*(PARAM(J,1)-BFO)
4340         ENDIF
4341         360 CONTINUE
4342     C
4343     C** CHECK IF THE LINEAR INTERPOLATION LINE CUT OFF ANY
4344     C** HIGH GROUND BED ELEVATION BELOW FOR STATIONS
4345     C** BETWEEN NB AND NE
4346     C
4347         NK=0
4348         ELMX(1)=0.
4349         ELMX(2)=0.
4350         TEST1=.TRUE.
4351     C
4352         DO 370 J=NMB,NME
4353     C
4354         IF(TOF(J). EQ. GM) GO TO 370
4355         IF(SGNEW(J). GE. PARAM(J,2)) GO TO 365
4356     C
4357         IF(TEST1) THEN
4358             NK=NK+1
4359             TEST1=.FALSE.
4360         ENDIF
4361     C
4362     C*  IF THE INTERPOLATION LINE CUTS MORE THAN TWO PORTIONS OF
4363     C*  HIGH GROUND RIDGE, STOP THIS TRANSECT, GO TO NEXT TRANSECT
4364     C
4365         IF(NK. GT. 2) THEN

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4366      WRITE(6,899)
4367      899  FORMAT(10X,'INTERPOLATION LINE CUTS OFF MORE THAN',
4368      A    ' TWO PORTIONS OF HIGH GROUND RIDGE'//,
4369      B    10X,'THIS TRANSECT IS ABORTED, RE-ASSIGN 100-YR ',
4370      C    'ELEVATIONS AT HIGH GROUND STATIONS'///)
4371      DO 363 I = 1, 500
4372      READ(5,810) TOF(I)
4373      IF(TOF(I). EQ. ET) GO TO 1
4374      363  CONTINUE
4375      END IF
4376      C
4377      IF(PARAM(J,2). GE. ELMX(NK)) THEN
4378      ELMX(NK)=PARAM(J,2)
4379      JM(NK)=J
4380      ENDIF
4381      GO TO 370
4382      C
4383      365 TEST1=.TRUE.
4384      C
4385      370 CONTINUE
4386      C
4387      C** IF THERE IS NO CUT OFF FROM INTERPOLATION LINE THEN
4388      C** GO TO WRITE TO SCRATCH FILE SEGMENT
4389      C
4390      IF(NK. EQ. 0) GO TO 400
4391      C
4392      C** IF THE 100-YR ELE. AT STATION NE IS GREATER THAN THE
4393      C** 100-YR ELE. AT STATION NB, THEN BRANCH TO 600
4394      C
4395      IF(DSG. GT. 0.) GO TO 600
4396      C
4397      C** THE FOLLOWING SEGMENT FOR THE CASE THAT THE 100-YR ELE. AT
4398      C** STATION NE IS LESS THAN OR EQUAL TO THE 100-YR ELE. AT
4399      C** STATION NB.
4400      C
4401      IF(NK. EQ. 1) GO TO 380
4402      C
4403      C** IF THE HIGHEST GROUND ELEVATIONS OF THE SECOND HUMP IS LOWER
4404      C** THAN THE FIRST HIGHEST HUMP GROUND ELEVATION, THEN BRANCH TO
4405      C** STATEMENT 390
4406      C
4407      IF(PARAM(JM(2),2). LT. PARAM(JM(1),2)) GO TO 390
4408      JM(1)=JM(2)
4409      C
4410      C** RESET 100-YR ELE. TO BE THE SAME AS BSEN, THE ELE. AT
4411      C** THE BEGINING OF THIS INTERPOLATION SEGMENT
4412      C
4413      C** FOR STATIONS FROM NMB TO THE HIGHEST BED STATION, JM(1)
4414      C
4415      380 DO 373 J=NMB,JM(1)
4416      SGNEW(J)=BSEN
4417      IF(TOF(J). EQ. GM) GO TO 373

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4418 C
4419 C** IF THE NEW SURGE ELEVATION IS STILL LESS THEN THE BED
4420 C** ELEVATION, ABORT THIS TRANSECT, GIVING ERROR MESSAGE.
4421 C
4422 IF(SGNEW(J).GE.PARAM(J,2)) GO TO 373
4423 WRITE(6,782) PARAM(J,1),TOF(J)
4424 782 FORMAT(/10X,'**** UNREASONABLE HIGH GROUND ELEVATION',
4425 A ' AT STATION (' ,F8.2,' ) WHICH IS ',A2,' CARD.'/,10X,
4426 B 'THIS TRANSECT IS ABORTED, CONTINUED TO NEXT TRANSECT'//,
4427 C 10X,'*** DOUBLE-CHECK THE SURGE AND GROUND ELEVATIONS',
4428 D ' IN THE VICINITY OF THIS STATION. IF THE GROUND'/,
4429 E 15X,' ELEVATIONS ARE CORRECT, EITHER ASSIGN A HIGHER',
4430 F ' SURGE ELEVATION OR USE AS CARDS !!!!!'//)
4431 C
4432 DO 371 KK=1,500
4433 READ(5,810) TOF(KK)
4434 IF(TOF(KK).EQ.ET) GO TO 1
4435 371 CONTINUE
4436 C
4437 373 CONTINUE
4438 C
4439 C** FOR THE REST STATIONS AFTER JM(1) TO THE END STATION OF
4440 C** THIS SEGMENT, THE 100-YR ELE. WILL BE THE BED ELEVATION,
4441 C** PARAM(J,2), PLUS THE WATER DEPTH, D, SITTING ON THE HIGHEST
4442 C** BED ELEVATION STATION
4443 C** UNTIL THE 100-YR ELE. AT THE END STATION OF THIS SEGMENT
4444 C** IS MET
4445 C
4446 D=SGNEW(JM(1))-PARAM(JM(1),2)
4447 JMB=JM(1)+1
4448 C
4449 DO 375 J=JMB,NME
4450 IF(TOF(J).EQ.GM) THEN
4451 SGNEW(J)=SGNEW(J-1)
4452 ELSE
4453 SGNEW(J)=AMAX1(PARAM(J,2)+D,ESEN)
4454 ENDIF
4455 375 CONTINUE
4456 C
4457 GO TO 400
4458 C
4459 390 CONTINUE
4460 C
4461 C** THE FOLLOWING PROGRAM SEGMENT IS FOR THE CASE THAT THE
4462 C** INTERPOLATION LINE CUTS BED ELEVATIONS TWO PORTIONS IN
4463 C** THIS TRANSECT SEGMENT, AND THE HIGHER BED ELEVATION
4464 C** STATION IS BEFORE THE OTHER ONE, I.E., THE BED ELE. AT
4465 C** JM(1) IS GREATER THAN THE BED ELE. AT JM(2)
4466 C
4467 C** FIRST RESET THE 100-YR ELE. FOR STATIONS BEFORE JM(1)
4468 C
4469 DO 393 J=NMB,JM(1)

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4470      SGNEW(J)=BSEN
4471      IF(SGNEW(J).GE.PARAM(J,2)) GO TO 393
4472      WRITE(6,782) PARAM(J,1),TOF(J)
4473      393 CONTINUE
4474      C
4475      C** THEN LINEAR INTERPOLATION 100-YR ELE. FROM JM(1)+1 TO
4476      C** THE END STATION, NE, OF THIS INTERPOLATION SEGMENT
4477      C
4478      D=SGNEW(JM(1))-PARAM(JM(1),2)
4479      DX=EFO-PARAM(JM(1),1)
4480      DDSG=(ESEN-BSEN)/DX
4481      C
4482      JMB=JM(1)+1
4483      DO 395 J=JMB, NME
4484      IF(TOF(J). EQ. GM) THEN
4485          SGNEW(J)=SGNEW(J-1)
4486      ELSE
4487          SGNEW(J)=SGOLD(J)+DDSG*(PARAM(J,1)-PARAM(JM(1),1))
4488      ENDIF
4489      395 CONTINUE
4490      C
4491      C** SET THE 100-YR ELE. AT STATIONS BETWEEN STATION JM(1)
4492      C** AND NE AS THE MAXIMUM OF: SECOND INTERPOLATION VALUE,
4493      C** THE BED ELEVATIONS PLUS THE WATER DEPTH AT JM(1),
4494      C** AND THE 100-YR ELE. AT THE END STATION OF THIS SEGMENT
4495      C
4496      DO 397 J=JMB,NME
4497      IF(TOF(J). EQ. GM) THEN
4498          SGNEW(J)=SGNEW(J-1)
4499      ELSE
4500          SGNEW(J)=AMAX1(SGNEW(J),PARAM(J,2)+D,ESEN)
4501      ENDIF
4502      397 CONTINUE
4503      C
4504      GO TO 400
4505      C
4506      C***** END OF INTERPOLATION FOR DSG IS LESS THAN ZERO CASE
4507      C
4508      600 CONTINUE
4509      C
4510      C*** THE FOLLOWING PROGRAM SEGMENT IS FOR THE CASE OF 100-YR ELE.
4511      C*** AT NE IS GREATER THAN THE 100-YR ELE. AT NB. AND THERE IS AT
4512      C*** LEAST ONE CUT OFF PORTION FROM THE LINEAR INTERPOLATION LINE.
4513      C
4514      IF(NK. EQ. 1) GO TO 605
4515      C
4516      IF(PARAM(JM(1),2). LT. PARAM(JM(2),2)) GO TO 620
4517      C
4518      605 CONTINUE
4519      C
4520      C** RESET 100-YR ELE. TO BE THE SAME AS ESEN, THE ELE. AT THE END
4521      C** OF THIS INTERPOLATION SEGMENT, I.E., AT STATION NE.

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4522 C
4523     DO 610 J=JM(1),NME
4524     SGNEW(J)=ESEN
4525     610 CONTINUE
4526 C
4527 C** FOR THE REST OF STATIONS FROM NMB (I.E., NB+1) TO JM(1)-1 OF
4528 C** THIS SEGMENT, THE 100-YR ELE. WILL BE THE GROUND ELEVATION,
4529 C** PARAM(JP,2), PLUS THE WATER DEPTH, D, SITTING ON THE HIGHEST
4530 C** GROUND ELEVATION STATION JM(1), UNTIL THE BSEN IS MET.
4531 C
4532     D=SGNEW(JM(1))-PARAM(JM(1),2)
4533 C
4534     JP=JM(1)-1
4535     DO 615 J = NMB, JP
4536     IF(TOF(J). EQ. GM) THEN
4537         SGNEW(J)=SGNEW(J-1)
4538     ELSE
4539         SGNEW(J)=AMAX1(PARAM(J,2)+D,BSEN)
4540     ENDIF
4541     615 CONTINUE
4542 C
4543     GO TO 400
4544 C
4545     620 CONTINUE
4546 C
4547 C** THE FOLLOWING PROGRAM SEGMENT IS FOR THE CASE THAT THE
4548 C** INTERPOLATION LINE CUTS BED ELEVATIONS TWO PORTIONS IN
4549 C** THIS TRANSECT SEGMENT, AND THE HIGHER BED ELEVATION
4550 C** STATION IS AFTER THE OTHER ONE, I.E., THE BED ELE. AT
4551 C** JM(1) IS LOWER THAN THE BED ELE. AT JM(2).
4552 C
4553     DO 630 J=JM(2),NME
4554     SGNEW(J)=ESEN
4555     630 CONTINUE
4556 C
4557 C** THEN LINEAR INTERPOLATION 100-YR ELE. FOR STATIONS BETWEEN
4558 C** NB AND JM(2)
4559 C
4560     D=SGNEW(JM(2))-PARAM(JM(2),2)
4561     DX=PARAM(JM(2),1)-BFO
4562     DDSG=(ESEN-BSEN)/DX
4563 C
4564     JP=JM(2)-1
4565     DO 635 J = NMB, JP
4566     IF(TOF(J). EQ. GM) THEN
4567         SGNEW(J)=SGNEW(J-1)
4568     ELSE
4569         SGNEW(J)=ESEN+DDSG*(PARAM(J,1)-PARAM(JM(2),1))
4570     ENDIF
4571     635 CONTINUE
4572 C
4573     640 CONTINUE

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4574 C
4575 C** SET THE 100-YR ELE. AT STATIONS BETWEEN STATIONS NB AND
4576 C** JM(2) AS THE MAXIMUM OF: SECOND INTERPOLATION VALUE (SGNEW),
4577 C** THE BED ELEVATION PLUS THE WATER DEPTH AT JM(2) (D), AND
4578 C** THE 100-YR ELE. AT THE BEGINNING STATION OF THIS SEGMENT
4579 C** BSEN (=SGNEW(NB)).
4580 C
4581 JP=JM(2)-1
4582 DO 645 J = NMB, JP
4583 IF(TOF(J). EQ. GM) THEN
4584 SGNEW(J)=SGNEW(J-1)
4585 ELSE
4586 SGNEW(J)=AMAX1(SGNEW(J), PARAM(J, 2)+D, BSEN)
4587 ENDIF
4588 645 CONTINUE
4589 C
4590 C***** END OF DSG GREATER THAN ZERO CASE *****
4591 C
4592 C*****
4593 C***** END OF INTERPOLATION PROCESS *****
4594 C*****
4595 C
4596 C**** STORING NEW 100-YR ELE. TO THE CORRESPONDING FILED PARAMETER
4597 C
4598 400 IF(NB. NE. 1) GO TO 402
4599 WRITE(10,805) (TITLE(I),I=1,80)
4600 C WRITE(10,815) TOF(1), (PARAM(1,I),I=1,10)
4601 402 CONTINUE
4602 C
4603 J=NB
4604 410 J=J+1
4605 IF(TOF(J). EQ. GM) GO TO 410
4606 IF(TOF(J). EQ. DU) GO TO 450
4607 IF(TOF(J). EQ. BU) GO TO 460
4608 IF(TOF(J). EQ. VE. OR. TOF(J). EQ. VH) GO TO 470
4609 IF(TOF(J). EQ. FI. OR. TOF(J). EQ. FO) GO TO 480
4610 IF(TOF(J). EQ. AS) GO TO 480
4611 GO TO 490
4612 C
4613 C** DUNE (DU) CARD
4614 C
4615 450 PARAM(J,5)=SGNEW(J)
4616 GO TO 490
4617 C
4618 C** BUILDING (BU) CARD
4619 C
4620 460 PARAM(J,6)=SGNEW(J)
4621 GO TO 490
4622 C
4623 C** VEGETATION (VE) OR MARSH GRASH (VH) CARD
4624 C
4625 470 PARAM(J,8)=SGNEW(J)

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4626         GO TO 490
4627     C
4628     C** INLAND FETCH (IF) OR OVER-WATER FETCH (OF) CARD
4629     C
4630         480 PARAM(J,4)=SGNEW(J)
4631     C
4632         490 IF(TOF(J).EQ.ET) GO TO 700
4633     C
4634         IF(J.EQ.NE) THEN
4635             BSEN=SGNEW(J)
4636             BFO=PARAM(J,1)
4637             NB=NE
4638             GO TO 5
4639         ELSE
4640             GO TO 410
4641         ENDIF
4642     C
4643     C*****
4644     C
4645     C** THE FOLLOWING SEGMENT IS FOR COMPUTING THE AVERAGE BOTTOM
4646     C** SLOPE AT EACH STATION FOR THE PURPOSE OF WAVE COMPUTATION
4647     C** BY WAVE ENERGY EQUATION IN THE MAIN PROGRAM
4648     C
4649     C** THE BOTTOM SLOPE IS STORED AS PARAM(J,9) OF EACH STATION
4650     C** EXCEPT FOR MG CARD
4651     C
4652     C*****
4653     C
4654         700 CONTINUE
4655     C
4656     C** STARTING FROM THE FIRST CARD, FIRST COMPUTE THE SLOPE BETWEEN
4657     C** STATION J AND J-1. THE SLOPE FOR IE CARD IS THE SLOPE BETWEEN
4658     C** THE IE CARD AND THE SECOND CARD
4659     C
4660         J=2
4661     C
4662         SA=(PARAM(J,2)-PARAM(J-1,2))/(PARAM(J,1)-PARAM(J-1,1))
4663     C
4664         PARAM(J-1,9)=SA
4665     C
4666         JA=J-1
4667         JB=J+1
4668     C
4669     C** IF THE NEXT CARD IS AS CARD, THE AVERAGE SLOPE IS THE SLOPE SA
4670     C
4671         705 IF(TOF(JB).EQ.AS) THEN
4672             PARAM(J,9)=SA
4673             GO TO 720
4674         ENDIF
4675     C
4676     C** IF TOF(J) IS VH CARD, SKIP ALL MG CARDS
4677     C

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4678         IF(TOF(J). EQ. VH) THEN
4679             NPLTS=PARAM(J,6)
4680             JB=JB+NPLTS
4681         ENDIF
4682     C
4683     C** COMPUTE THE BOTTOM SLOPE BETWEEN THIS STATION, J, AND THE
4684     C** NEXT STATION, JB
4685     C
4686     C** HOWEVER,IF THE NEXT STATION IS ET, END OF THE TRANSECT,
4687     C** THEN THE AVERAGED SLOPE IS SA
4688     C
4689         IF(TOF(JB). EQ. ET) THEN
4690             PARAM(J,9)=-SA
4691             GO TO 770
4692         ENDIF
4693     C
4694         SB=(PARAM(JB,2)-PARAM(J,2))/(PARAM(JB,1)-PARAM(J,1))
4695     C
4696     C** IF TOF(J) IS AS CARD, THE AVERAGE SLOPE OF THIS CARD IS THE
4697     C** SLOPE OF SB
4698     C
4699         IF(TOF(J). EQ. AS) THEN
4700             PARAM(J,9)=-SB
4701             GO TO 710
4702         ENDIF
4703     C
4704     C** WEIGHT AVERAGED SLOPE FOR THIS STATION FROM SA AND SB
4705     C
4706         SS=(PARAM(J,1)-PARAM(JA,1))*SA + (PARAM(JB,1)-PARAM(J,1))*SB
4707         PARAM(J,9)=-SS/(PARAM(JB,1)-PARAM(JA,1))
4708     C
4709     C** REPLACE SA WITH SB, AND CONTINUE TO NEXT STATION
4710     C
4711     710 SA=SB
4712     C
4713     C** FOR VH CARD, REARRANGE PREVIOUS AND LATER STATION COUNT
4714     C
4715         IF(TOF(J).EQ. VH) THEN
4716             JA=J
4717             J=JB
4718             JB=J+1
4719             GO TO 705
4720         ENDIF
4721     C
4722     720 J=J+1
4723         JA=J-1
4724         JB=J+1
4725         GO TO 705
4726     C
4727     C*****
4728     C
4729     C** COMPLETE CALCULATING AVERAGED BOTTOM SLOPE FOR THIS TRANSECT *

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4730 C
4731 C*****
4732 C
4733 C*****
4734 C
4735 C** START WRITING TO SCRATCH FILE -- UNIT 10
4736 C
4737 C*****
4738 C
4739 C 770 CONTINUE
4740 C
4741 C DO 775 J=1,500
4742 C
4743 C IF(TOF(J).EQ.GM) THEN
4744 C WRITE(10,565) TOF(J),(PARAM(J,I),I=1,10)
4745 C ELSE
4746 C
4747 C IF((PARAM(J,1).GE. 9999.9).OR.(PARAM(J,1).LE.-1000.)) THEN
4748 C WRITE(10,816) TOF(J),(PARAM(J,I),I=1,10)
4749 C ELSE
4750 C WRITE(10,815) TOF(J),(PARAM(J,I),I=1,10)
4751 C ENDIF
4752 C
4753 C ENDIF
4754 C
4755 C IF(TOF(J). EQ. ET) GO TO 1
4756 C 775 CONTINUE
4757 C
4758 C 560 FORMAT(A2,2X,A4,9F8.0)
4759 C 565 FORMAT(A2,2X,A4,9F8.2)
4760 C 805 FORMAT(80A1)
4761 C 810 FORMAT(A2,F6.0,9F8.0)
4762 C
4763 C G&O SEPT 88
4764 C
4765 C
4766 C 815 FORMAT(A2,F6.1,7F8.2,F8.4,F8.2)
4767 C 816 FORMAT(A2,F6.0,7F8.2,F8.4,F8.2)
4768 C
4769 C 815 FORMAT(A2,F6.1,7F8.3,F8.4,F8.3)
4770 C 816 FORMAT(A2,F6.0,7F8.3,F8.4,F8.3)
4771 C
4772 C END G&O SEPT 88
4773 C
4774 C END

```

APPENDIX D Example Calculations

	DUVAL COUNTY, FLORIDA		T-1		12/03/87		
IE	0.0	0.0	24.0	7.0	11.60	0.0	13.0
OF 350.	9.4						
DU 351.	11.6						
AS 1345.	8.85	4.0	8.85				
VE 1445.	8.52	0.3	15.0	6.0			
VE 1600.	8.0	0.3	15.0	6.0			
VE 1800.	7.3	0.3	15.0	6.0			
VE 2000.	6.7	0.3	15.0	6.0			
VE 2200.	6.0	0.3	15.0	6.0			
VE 2500.	5.0	0.3	15.0	6.0			
VH 7000.	0.0	3.0	0.0	0.0	1.0		
MG SALT	0.0	1.0					
OF 7200.	-6.0						
OF 8300.	-6.0						
OF 8900.	-12.0						
OF 9100.	-6.0						
OF 9350.	0.0						
VH10500.	2.5	3.0	0.0	0.0	1.0		
MG SALT	0.0	1.0					
OF11300.	-6.0						
OF11800.	0.0						
VH13300.	2.5	3.0	0.0	0.0	1.0		
MG SALT	0.0	1.0					
OF13700.	-6.0						
OF14700.	-18.0						
OF16000.	0.0						
VH18500.	2.5	3.0	0.0	0.0	1.0		
MG SALT	0.0	1.0					
OF19000.	-12.0						
OF19600.	0.0						
VH25000.	2.5	3.0	0.0	0.0	1.0	2.5	7.25
MG SALT	0.0	1.0					
OF26000.	-12.0						
OF27200.	0.0						
VH35200.	2.5	3.0	0.0	0.0	1.0		
MG SALT	0.0	1.0					
OF35700.	-12.0						
OF37900.	-9.0						
OF38000.	0.0						
VH47200.	2.5	3.0	0.0	0.0	1.0		
MG SALT	0.0	1.0					
OF47700.	-12.0						
OF48100.	0.0	3.0	6.45				
VH49750.	2.5	3.0	0.0	0.0	1.0		
MG SALT	0.0	1.0					
IF49850.	6.45						
ET							

*** THE FOLLOWING MESSAGES ARE THE RESULTS FROM THE 100-YR ELEVATION INTERPOLATION FOR THE TRANSECT:

DUVAL COUNTY, FLORIDA T-1 12/03/87

WAVE HEIGHT COMPUTATIONS FOR FLOOD INSURANCE STUDIES (VERSION 3.0, SEPTEMBER 1988)
DUVAL COUNTY, FLORIDA T-1 12/03/87

PARTIAL INPUT

IE	.000	.000	24.000	7.000	11.600	.000	13.000	.000	.027	.000
CF	350.000	9.400	.000	.000	.000	.000	.000	.000	.033	.000
DU	351.000	11.600	.000	.000	.000	.000	.000	.000	2.200	.000
AS	1345.000	8.850	4.000	8.850	.000	.000	.000	.000	-.003	.000
VE	1445.000	8.520	.300	15.000	6.000	.000	.000	8.843	-.003	.000
VE	1600.000	8.000	.300	15.000	6.000	.000	.000	8.833	-.003	.000
VE	1800.000	7.300	.300	15.000	6.000	.000	.000	8.819	-.003	.000
VE	2000.000	6.700	.300	15.000	6.000	.000	.000	8.806	-.003	.000
VE	2200.000	6.000	.300	15.000	6.000	.000	.000	8.792	-.003	.000
VE	2500.000	5.000	.300	15.000	6.000	.000	.000	8.772	-.001	.000
VH	7000.000	.000	3.000	.000	.000	1.000	.000	8.468	-.002	.000
MG	SALT	.000	1.000	.000	.000	.000	.000	.000	.000	.000
CF	7200.000	-6.000	.000	8.454	.000	.000	.000	.000	-.005	.000
CF	8300.000	-6.000	.000	8.380	.000	.000	.000	.000	-.004	.000
CF	8900.000	-12.000	.000	8.339	.000	.000	.000	.000	.000	.000
CF	9100.000	-6.000	.000	8.325	.000	.000	.000	.000	.027	.000
CF	9350.000	.000	.000	8.309	.000	.000	.000	.000	.006	.000
VH	10500.000	2.500	3.000	.000	.000	1.000	.000	8.231	-.003	.000
MG	SALT	.000	1.000	.000	.000	.000	.000	.000	.000	.000
CF	11300.000	-6.000	.000	8.177	.000	.000	.000	.000	-.002	.000
CF	11800.000	.000	.000	8.143	.000	.000	.000	.000	.004	.000
VH	13300.000	2.500	3.000	.000	.000	1.000	.000	8.041	-.003	.000
MG	SALT	.000	1.000	.000	.000	.000	.000	.000	.000	.000
CF	13700.000	-6.000	.000	8.014	.000	.000	.000	.000	-.015	.000
CF	14700.000	-18.000	.000	7.947	.000	.000	.000	.000	.003	.000
CF	16000.000	.000	.000	7.859	.000	.000	.000	.000	.005	.000
VH	18500.000	2.500	3.000	.000	.000	1.000	.000	7.690	-.004	.000
MG	SALT	.000	1.000	.000	.000	.000	.000	.000	.000	.000
CF	19000.000	-12.000	.000	7.656	.000	.000	.000	.000	-.002	.000
CF	19600.000	.000	.000	7.615	.000	.000	.000	.000	.002	.000
VH	25000.000	2.500	3.000	.000	.000	1.000	2.500	7.250	-.002	.000
MG	SALT	.000	1.000	.000	.000	.000	.000	.000	.000	.000
CF	26000.000	-12.000	.000	7.215	.000	.000	.000	.000	-.001	.000
CF	27200.000	.000	.000	7.174	.000	.000	.000	.000	.002	.000
VH	35200.000	2.500	3.000	.000	.000	1.000	.000	6.897	-.001	.000
MG	SALT	.000	1.000	.000	.000	.000	.000	.000	.000	.000
CF	35700.000	-12.000	.000	6.879	.000	.000	.000	.000	-.004	.000

CF	35700.000	-12.000	.000	6.879	.000	.000	.000	.000	-.004	.000
CF	37900.000	-9.000	.000	6.803	.000	.000	.000	.000	.005	.000
CF	38000.000	.000	.000	6.800	.000	.000	.000	.000	.001	.000
VH	47200.000	2.500	3.000	.000	.000	1.000	.000	6.481	-.001	.000
MG	SALT	.000	1.000	.000	.000	.000	.000	.000	.000	.000
CF	47700.000	-12.000	.000	6.464	.000	.000	.000	.000	-.003	.000
CF	48100.000	.000	3.000	6.450	.000	.000	.000	.000	.007	.000
VH	49750.000	2.500	3.000	.000	.000	1.000	.000	.000	.004	.000
MG	SALT	.000	1.000	.000	.000	.000	.000	.000	.000	.000
IF	49850.000	6.450	.000	.000	.000	.000	.000	.000	.040	.000
ET	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

END STATION	END ELEVATION	FEICH LENGTH	SURGE 10-YEAR	ELEV SURGE 100-YEAR	INITIAL WAVE HEIGHT	INITIAL W. PERIOD	BOTTOM SLOPE	AVERAGE A-ZONES
.000	.000	24.000	7.000	11.600	.000	13.000	.000	.027

END STATION	END ELEVATION	NEW SURGE 10-YEAR	NEW SURGE 100-YEAR	BOTTOM SLOPE	AVERAGE A-ZONES
350.000	9.400	.000	.000	.000	.000

LINE STATION	CREST ELEVATION	LINE OR SEAWALL	NEW SURGE 10-YEAR	NEW SURGE 100-YEAR	BOTTOM SLOPE	AVERAGE A-ZONES
351.000	11.600	.000	.000	.000	.000	.000

END STATION	END ELEVATION	NEW SURGE 10-YEAR	NEW SURGE 100-YEAR	BOTTOM SLOPE	AVERAGE A-ZONES
1345.000	8.850	4.000	8.850	.000	.000

END STATION	END ELEVATION	AVERAGE DIAMETER	AVERAGE HEIGHT	AVERAGE SPACING	DRAG COEFF.	NEW SURGE 10-YEAR	NEW SURGE 100-YEAR	BOTTOM SLOPE	AVERAGE A-ZONES
1445.000	8.520	.300	15.000	6.000	.000	.000	8.843	-.003	.000

END STATION	END ELEVATION	AVERAGE DIAMETER	AVERAGE HEIGHT	AVERAGE SPACING	DRAG COEFF.	NEW SURGE 10-YEAR	NEW SURGE 100-YEAR	BOTTOM SLOPE	AVERAGE A-ZONES
1600.000	8.000	.300	15.000	6.000	.000	.000	8.833	-.003	.000

END STATION	END ELEVATION	AVERAGE DIAMETER	AVERAGE HEIGHT	AVERAGE SPACING	DRAG COEFF.	NEW SURGE 10-YEAR	NEW SURGE 100-YEAR	BOTTOM SLOPE	AVERAGE A-ZONES
1800.000	7.300	.300	15.000	6.000	.000	.000	8.819	-.003	.000

END STATION	END ELEVATION	AVERAGE DIAMETER	AVERAGE HEIGHT	AVERAGE SPACING	DRAG COEFF.	NEW SURGE 10-YEAR	NEW SURGE 100-YEAR	BOTTOM SLOPE	AVERAGE A-ZONES
2000.000	6.700	.300	15.000	6.000	.000	.000	8.806	-.003	.000

END STATION	END ELEVATION	AVERAGE DIAMETER	AVERAGE HEIGHT	AVERAGE SPACING	DRAG COEFF.	NEW SURGE 10-YEAR	NEW SURGE 100-YEAR	BOTTOM SLOPE	AVERAGE A-ZONES
2200.000	6.000	.300	15.000	6.000	.000	.000	8.792	-.003	.000

END STATION	END ELEVATION	AVERAGE DIAMETER	AVERAGE HEIGHT	AVERAGE SPACING	DRAG COEFF.	NEW SURGE 10-YEAR	NEW SURGE 100-YEAR	BOTTOM SLOPE	AVERAGE A-ZONES
2500.000	5.000	.300	15.000	6.000	.000	.000	8.772	-.001	.000

END STATION	END ELEVATION	REGION 1	REGION 1 WEIGHT	REGION 2	NO. OF PLANT TYPES	NEW SURGE 10-YEAR	NEW SURGE 100-YEAR	BOTTOM SLOPE	AVERAGE A-ZONES
7000.000	.000	3.000	.000	.000	1.000	.000	8.468	-.002	.000

PLANT TYPE	DRAG COEFF.	COVERAGE RATIO	AVG. STEM HEIGHT	NUMBER DENSITY	BASE STEM DIAMETER	MID STEM DIAMETER	TOP STEM DIAMETER	LEAF-STEM AREA RATIO	
SALT	.000	1.000	.000	.000	.000	.000	.000	.000	.000

PLANT CHARACTERISTICS INCLUDING VALUES SUPPLIED BY THE PROGRAM

PLANT TYPE	DRAG COEFF.	COVERAGE RATIO	AVG. STEM HEIGHT	NUMBER DENSITY	BASE STEM DIAMETER	MID STEM DIAMETER	TOP STEM DIAMETER	LEAF-STEM AREA RATIO
SALT	.100	1.000	3.200	10.000	.220	.088	.044	1.590

END STATION	END ELEVATION	NEW SURGE 10-YEAR	NEW SURGE 100-YEAR					BOTTOM SLOPE	AVERAGE A-ZONES
7200.000	-6.000	.000	8.454	.000	.000	.000	.000	-.005	.000

END STATION	END ELEVATION	NEW SURGE 10-YEAR	NEW SURGE 100-YEAR					BOTTOM SLOPE	AVERAGE A-ZONES
8300.000	-6.000	.000	8.380	.000	.000	.000	.000	-.004	.000

END STATION	END ELEVATION	NEW SURGE 10-YEAR	NEW SURGE 100-YEAR					BOTTOM SLOPE	AVERAGE A-ZONES
8900.000	-12.000	.000	8.339	.000	.000	.000	.000	.000	.000

END STATION	END ELEVATION	NEW SURGE 10-YEAR	NEW SURGE 100-YEAR					BOTTOM SLOPE	AVERAGE A-ZONES
9100.000	-6.000	.000	8.325	.000	.000	.000	.000	.027	.000

END STATION	END ELEVATION	NEW SURGE 10-YEAR	NEW SURGE 100-YEAR					BOTTOM SLOPE	AVERAGE A-ZONES
9350.000	.000	.000	8.309	.000	.000	.000	.000	.006	.000

END STATION	END ELEVATION	REGION 1	REGION 1 WEIGHT	REGION 2	NO. OF PLANT TYPES	NEW SURGE 10-YEAR	NEW SURGE 100-YEAR	BOTTOM SLOPE	AVERAGE A-ZONES
10500.000	2.500	3.000	.000	.000	1.000	.000	8.231	-.003	.000

PLANT TYPE	DRAG COEFF.	COVERAGE RATIO	AVG. STEM HEIGHT	NUMBER DENSITY	BASE STEM DIAMETER	MID STEM DIAMETER	TOP STEM DIAMETER	LEAF-STEM AREA RATIO	
SALT	.000	1.000	.000	.000	.000	.000	.000	.000	.000

PLANT CHARACTERISTICS INCLUDING VALUES SUPPLIED BY THE PROGRAM

PLANT TYPE	DRAG COEFF.	COVERAGE RATIO	AVG. STEM HEIGHT	NUMBER DENSITY	BASE STEM DIAMETER	MID STEM DIAMETER	TOP STEM DIAMETER	LEAF-STEM AREA RATIO	
SALT	.100	1.000	3.200	10.000	.220	.088	.044	1.590	

END STATION	END ELEVATION	NEW SURGE 10-YEAR	NEW SURGE 100-YEAR					BOTTOM SLOPE	AVERAGE A-ZONES
11300.000	-6.000	.000	8.177	.000	.000	.000	.000	-.002	.000

END STATION	END ELEVATION	NEW SURGE 10-YEAR	NEW SURGE 100-YEAR					BOTTOM SLOPE	AVERAGE A-ZONES
11800.000	.000	.000	8.143	.000	.000	.000	.000	.004	.000

END STATION	END ELEVATION	REGION 1	REGION 1 WEIGHT	REGION 2	NO. OF PLANT TYPES	NEW SURGE 10-YEAR	NEW SURGE 100-YEAR	BOTTOM SLOPE	AVERAGE A-ZONES
13300.000	2.500	3.000	.000	.000	1.000	.000	8.041	-.003	.000

PLANT TYPE	DRAG COEFF.	COVERAGE RATIO	AVG. STEM HEIGHT	NUMBER DENSITY	BASE STEM DIAMETER	MID STEM DIAMETER	TOP STEM DIAMETER	LEAF-STEM AREA RATIO	
SALT	.000	1.000	.000	.000	.000	.000	.000	.000	.000

PLANT CHARACTERISTICS INCLUDING VALUES SUPPLIED BY THE PROGRAM

PLANT TYPE	DRAG COEFF.	COVERAGE RATIO	AVG. STEM HEIGHT	NUMBER DENSITY	BASE STEM DIAMETER	MID STEM DIAMETER	TOP STEM DIAMETER	LEAF-STEM AREA RATIO
SALT	.100	1.000	3.200	10.000	.220	.088	.044	1.590

END STATION	END ELEVATION	NEW SURGE 10-YEAR	NEW SURGE 100-YEAR					BOTTOM SLOPE	AVERAGE A-ZONES
13700.000	-6.000	.000	8.014	.000	.000	.000	.000	-.015	.000

END STATION	END ELEVATION	NEW SURGE 10-YEAR	NEW SURGE 100-YEAR					BOTTOM SLOPE	AVERAGE A-ZONES
14700.000	-18.000	.000	7.947	.000	.000	.000	.000	.003	.000

END STATION	END ELEVATION	NEW SURGE 10-YEAR	NEW SURGE 100-YEAR					BOTTOM SLOPE	AVERAGE A-ZONES
16000.000	.000	.000	7.859	.000	.000	.000	.000	.005	.000

END STATION	END ELEVATION	REGION 1	REGION 1 WEIGHT	REGION 2	NO. OF PLANT TYPES	NEW SURGE 10-YEAR	NEW SURGE 100-YEAR	BOTTOM SLOPE	AVERAGE A-ZONES
18500.000	2.500	3.000	.000	.000	1.000	.000	7.690	-.004	.000

PLANT TYPE	DRAG COEFF.	COVERAGE RATIO	AVG. STEM HEIGHT	NUMBER DENSITY	BASE STEM DIAMETER	MID STEM DIAMETER	TOP STEM DIAMETER	LEAF-STEM AREA RATIO
SALT	.000	1.000	.000	.000	.000	.000	.000	.000

PLANT CHARACTERISTICS INCLUDING VALUES SUPPLIED BY THE PROGRAM

PLANT TYPE	DRAG COEFF.	COVERAGE RATIO	AVG. STEM HEIGHT	NUMBER DENSITY	BASE STEM DIAMETER	MID STEM DIAMETER	TOP STEM DIAMETER	LEAF-STEM AREA RATIO
SALT	.100	1.000	3.200	10.000	.220	.088	.044	1.590

END STATION	END ELEVATION	NEW SURGE 10-YEAR	NEW SURGE 100-YEAR					BOTTOM SLOPE	AVERAGE A-ZONES
19000.000	-12.000	.000	7.656	.000	.000	.000	.000	-.002	.000

END STATION	END ELEVATION	NEW SURGE 10-YEAR	NEW SURGE 100-YEAR					BOTTOM SLOPE	AVERAGE A-ZONES

STATION	ELEVATION	10-YEAR	100-YEAR					SLOPE	A-ZONES
19600.000	.000	.000	7.615	.000	.000	.000	.000	.002	.000

END	END		REGION 1		NO. OF	NEW SURGE	NEW SURGE	BOTTOM	AVERAGE
STATION	ELEVATION	REGION 1	WEIGHT	REGION 2	PLANT TYPES	10-YEAR	100-YEAR	SLOPE	A-ZONES
25000.000	2.500	3.000	.000	.000	1.000	2.500	7.250	-.002	.000

PLANT	DRAG	COVERAGE	AVG. STEM	NUMBER	BASE STEM	MID STEM	TOP STEM	LEAF-STEM	
TYPE	COEFF.	RATIO	HEIGHT	DENSITY	DIAMETER	DIAMETER	DIAMETER	AREA RATIO	
SALT	.000	1.000	.000	.000	.000	.000	.000	.000	.000

PLANT CHARACTERISTICS INCLUDING VALUES SUPPLIED BY THE PROGRAM

PLANT	DRAG	COVERAGE	AVG. STEM	NUMBER	BASE STEM	MID STEM	TOP STEM	LEAF-STEM	
TYPE	COEFF.	RATIO	HEIGHT	DENSITY	DIAMETER	DIAMETER	DIAMETER	AREA RATIO	
SALT	.100	1.000	3.200	10.000	.220	.088	.044	1.590	

END	END	NEW SURGE	NEW SURGE					BOTTOM	AVERAGE
STATION	ELEVATION	10-YEAR	100-YEAR					SLOPE	A-ZONES
26000.000	-12.000	.000	7.215	.000	.000	.000	.000	-.001	.000

END	END	NEW SURGE	NEW SURGE					BOTTOM	AVERAGE
STATION	ELEVATION	10-YEAR	100-YEAR					SLOPE	A-ZONES
27200.000	.000	.000	7.174	.000	.000	.000	.000	.002	.000

END	END		REGION 1		NO. OF	NEW SURGE	NEW SURGE	BOTTOM	AVERAGE
STATION	ELEVATION	REGION 1	WEIGHT	REGION 2	PLANT TYPES	10-YEAR	100-YEAR	SLOPE	A-ZONES
35200.000	2.500	3.000	.000	.000	1.000	.000	6.897	-.001	.000

PLANT	DRAG	COVERAGE	AVG. STEM	NUMBER	BASE STEM	MID STEM	TOP STEM	LEAF-STEM	
TYPE	COEFF.	RATIO	HEIGHT	DENSITY	DIAMETER	DIAMETER	DIAMETER	AREA RATIO	
SALT	.000	1.000	.000	.000	.000	.000	.000	.000	.000

PLANT CHARACTERISTICS INCLUDING VALUES SUPPLIED BY THE PROGRAM

PLANT	DRAG	COVERAGE	AVG. STEM	NUMBER	BASE STEM	MID STEM	TOP STEM	LEAF-STEM	
TYPE	COEFF.	RATIO	HEIGHT	DENSITY	DIAMETER	DIAMETER	DIAMETER	AREA RATIO	

SALT .100 1.000 3.200 10.000 .220 .088 .044 1.590

END STATION	END ELEVATION	NEW SURGE 10-YEAR	NEW SURGE 100-YEAR					BOTTOM SLOPE	AVERAGE A-ZONES
35700.000	-12.000	.000	6.879	.000	.000	.000	.000	-.004	.000

END STATION	END ELEVATION	NEW SURGE 10-YEAR	NEW SURGE 100-YEAR					BOTTOM SLOPE	AVERAGE A-ZONES
37900.000	-9.000	.000	6.803	.000	.000	.000	.000	.005	.000

END STATION	END ELEVATION	NEW SURGE 10-YEAR	NEW SURGE 100-YEAR					BOTTOM SLOPE	AVERAGE A-ZONES
38000.000	.000	.000	6.800	.000	.000	.000	.000	.001	.000

END STATION	END ELEVATION	REGION 1	REGION 1 WEIGHT	REGION 2	NO. OF PLANT TYPES	NEW SURGE 10-YEAR	NEW SURGE 100-YEAR	BOTTOM SLOPE	AVERAGE A-ZONES
47200.000	2.500	3.000	.000	.000	1.000	.000	6.481	-.001	.000

PLANT TYPE	DRAG COEFF.	COVERAGE RATIO	AVG. STEM HEIGHT	NUMBER DENSITY	BASE STEM DIAMETER	MID-STEM DIAMETER	TOP STEM DIAMETER	LEAF-STEM AREA RATIO
SALT	.000	1.000	.000	.000	.000	.000	.000	.000

PLANT CHARACTERISTICS INCLUDING VALUES SUPPLIED BY THE PROGRAM

PLANT TYPE	DRAG COEFF.	COVERAGE RATIO	AVG. STEM HEIGHT	NUMBER DENSITY	BASE STEM DIAMETER	MID-STEM DIAMETER	TOP STEM DIAMETER	LEAF-STEM AREA RATIO
SALT	.100	1.000	3.200	10.000	.220	.088	.044	1.590

END STATION	END ELEVATION	NEW SURGE 10-YEAR	NEW SURGE 100-YEAR					BOTTOM SLOPE	AVERAGE A-ZONES
47700.000	-12.000	.000	6.464	.000	.000	.000	.000	-.003	.000

END STATION	END ELEVATION	NEW SURGE 10-YEAR	NEW SURGE 100-YEAR					BOTTOM SLOPE	AVERAGE A-ZONES
48100.000	.000	3.000	6.450	.000	.000	.000	.000	.007	.000

END STATION	END ELEVATION	REGION 1	REGION 1 WEIGHT	REGION 2	NO. OF PLANT TYPES	NEW SURGE 10-YEAR	NEW SURGE 100-YEAR	BOTTOM SLOPE	AVERAGE A-ZONES
49750.000	2.500	3.000	.000	.000	1.000	.000	.000	.004	.000

PLANT TYPE	DRAG COEFF.	COVERAGE RATIO	AVG. STEM HEIGHT	NUMBER DENSITY	BASE STEM DIAMETER	MID STEM DIAMETER	TOP STEM DIAMETER	LEAF-STEM AREA RATIO	
SALT	.000	1.000	.000	.000	.000	.000	.000	.000	.000

PLANT CHARACTERISTICS INCLUDING VALUES SUPPLIED BY THE PROGRAM

PLANT TYPE	DRAG COEFF.	COVERAGE RATIO	AVG. STEM HEIGHT	NUMBER DENSITY	BASE STEM DIAMETER	MID STEM DIAMETER	TOP STEM DIAMETER	LEAF-STEM AREA RATIO
SALT	.100	1.000	3.200	10.000	.220	.088	.044	1.590

END STATION	END ELEVATION	NEW SURGE 10-YEAR	NEW SURGE 100-YEAR					BOTTOM SLOPE	AVERAGE A-ZONES
49850.000	6.450	.000	.000	.000	.000	.000	.000	.040	.000

END OF TRANSECT

E ELEVATION INCLUDES CONTRIBUTIONS FROM ASTRONOMICAL AND STORM TIDES.

PART 2: CONTROLLING WAVE HEIGHTS, SPECTRAL PEAK WAVE PERIOD, AND WAVE CREST ELEVATIONS

LOCATION	CONTROLLING WAVE HEIGHT	SPECTRAL PEAK WAVE PERIOD	WAVE CREST ELEVATION
1E .00	9.05	13.00	17.93
105.00	6.85	13.00	16.39
210.00	4.65	13.00	14.85
315.00	2.45	13.00	13.31

OF	350.00	1.72	13.00	12.80
DJ	351.00	.00	.00	11.60
AS	1345.00	.00	.00	8.85
VE	1445.00	.00	.00	8.84
VE	1600.00	.00	.00	8.83
VE	1800.00	.00	.00	8.82
VE	2000.00	.00	.00	8.81
VE	2200.00	.00	.00	8.79
VE	2500.00	.00	.00	8.77
	2605.00	.61	.68	9.19
	2725.00	.89	.88	9.38
	2885.00	1.15	1.05	9.55
	3045.00	1.36	1.17	9.69
	3205.00	1.53	1.28	9.80
	3445.00	1.75	1.41	9.93
	3605.00	1.88	1.48	10.01
	3765.00	2.00	1.55	10.09
	3925.00	2.11	1.61	10.15
	4085.00	2.21	1.67	10.21
	4245.00	2.30	1.72	10.27
	4405.00	2.39	1.77	10.32
	4565.00	2.48	1.82	10.37
	4725.00	2.56	1.86	10.41
	5045.00	2.71	1.94	10.50
	5365.00	2.85	2.02	10.57
	5685.00	2.98	2.09	10.64

	6005.00	3.11	2.16	10.71
	6325.00	3.23	2.22	10.77
	6645.00	3.34	2.28	10.83
	6965.00	3.45	2.33	10.88
VH	7000.00	3.46	2.34	10.89
	7100.00	3.66	2.37	11.02
CF	7200.00	3.80	2.39	11.12
	7350.00	3.93	2.43	11.20
	7450.00	4.01	2.45	11.25
	7650.00	4.17	2.50	11.34
	7850.00	4.32	2.54	11.43
	8050.00	4.46	2.59	11.52
	8250.00	4.60	2.63	11.60
CF	8300.00	4.63	2.64	11.62
	8450.00	4.77	2.67	11.71
	8550.00	4.85	2.69	11.76
	8650.00	4.93	2.71	11.81
	8750.00	5.01	2.73	11.86
CF	8900.00	5.12	2.76	11.92
	9040.00	5.14	2.78	11.93
CF	9100.00	5.11	2.79	11.91
	9275.00	5.00	2.82	11.82
CF	9350.00	4.96	2.84	11.78
	9500.00	4.90	2.85	11.73
	9660.00	4.84	2.87	11.68
	9980.00	4.69	2.90	11.55

	10140.00	4.60	2.91	11.48
	10300.00	4.50	2.92	11.40
	10460.00	4.39	2.93	11.31
VH	10500.00	4.36	2.94	11.29
	10650.00	4.38	2.96	11.29
	10850.00	4.52	2.99	11.37
	10950.00	4.62	3.01	11.43
	11050.00	4.72	3.02	11.50
	11150.00	4.83	3.04	11.56
	11250.00	4.93	3.06	11.63
CF	11300.00	4.98	3.06	11.67
	11450.00	4.99	3.09	11.66
	11650.00	5.00	3.11	11.66
CF	11800.00	5.05	3.14	11.68
	11950.00	4.99	3.15	11.62
	12110.00	4.92	3.16	11.57
	12430.00	4.76	3.18	11.44
	12590.00	4.68	3.20	11.36
	12750.00	4.59	3.21	11.29
	12910.00	4.49	3.22	11.21
	13070.00	4.38	3.23	11.13
	13230.00	4.27	3.24	11.04
VH	13300.00	4.22	3.24	10.99
	13420.00	4.14	3.26	10.93
	13580.00	4.28	3.28	11.02
CF	13700.00	4.44	3.30	11.12

	13850.00	4.61	3.32	11.23
	13950.00	4.72	3.33	11.30
	14050.00	4.82	3.34	11.37
	14150.00	4.93	3.35	11.43
	14250.00	5.03	3.37	11.50
	14350.00	5.12	3.38	11.56
	14450.00	5.21	3.39	11.61
	14550.00	5.30	3.40	11.67
	14650.00	5.38	3.42	11.72
CF	14700.00	5.42	3.42	11.74
	14850.00	5.48	3.44	11.77
	15050.00	5.53	3.46	11.79
	15450.00	5.55	3.51	11.78
CF	16000.00	5.72	3.57	11.86
	16150.00	5.61	3.57	11.78
	16310.00	5.49	3.57	11.68
	16470.00	5.38	3.58	11.59
	16630.00	5.26	3.58	11.50
	16790.00	5.14	3.59	11.40
	16950.00	5.02	3.60	11.31
	17110.00	4.90	3.60	11.21
	17270.00	4.78	3.61	11.12
	17430.00	4.66	3.62	11.03
	17590.00	4.54	3.63	10.93
	17750.00	4.42	3.64	10.84
	17910.00	4.30	3.65	10.74

	18070.00	4.18	3.65	10.65
	18230.00	4.06	3.66	10.55
	18390.00	3.94	3.67	10.45
VH	18500.00	3.86	3.68	10.39
	18600.00	3.66	3.69	10.25
	18700.00	3.68	3.70	10.25
	18900.00	3.93	3.72	10.41
CF	19000.00	4.09	3.73	10.52
	19150.00	4.14	3.75	10.54
	19350.00	4.23	3.77	10.59
CF	19600.00	4.53	3.79	10.79
	19750.00	4.48	3.80	10.74
	19910.00	4.42	3.81	10.69
	20230.00	4.31	3.83	10.59
	20550.00	4.20	3.84	10.49
	20870.00	4.09	3.86	10.39
	21190.00	3.98	3.88	10.29
	21510.00	3.88	3.90	10.20
	21830.00	3.78	3.92	10.11
	22150.00	3.68	3.94	10.02
	22470.00	3.58	3.95	9.93
	22790.00	3.49	3.97	9.84
	23110.00	3.40	3.99	9.76
	23430.00	3.31	4.01	9.67
	23750.00	3.22	4.02	9.59
	24070.00	3.13	4.04	9.51

	24390.00	3.05	4.06	9.42
	24710.00	2.96	4.08	9.34
VH	25000.00	2.89	4.09	9.27
	25150.00	2.82	4.11	9.22
	25350.00	2.90	4.12	9.27
	25550.00	3.08	4.14	9.39
	25650.00	3.19	4.15	9.46
	25750.00	3.30	4.16	9.53
	25850.00	3.41	4.16	9.61
	25950.00	3.53	4.17	9.69
CF	26000.00	3.59	4.18	9.73
	26150.00	3.72	4.19	9.81
	26350.00	3.89	4.20	9.93
	26550.00	4.07	4.22	10.04
	26750.00	4.26	4.24	10.17
	26850.00	4.37	4.24	10.25
	26950.00	4.49	4.25	10.33
	27050.00	4.62	4.26	10.42
	27150.00	4.78	4.27	10.52
CF	27200.00	4.86	4.27	10.58
	27350.00	4.76	4.28	10.50
	27510.00	4.66	4.28	10.43
	27670.00	4.57	4.29	10.35
	27830.00	4.48	4.30	10.29
	27990.00	4.39	4.31	10.22
	28150.00	4.31	4.31	10.16

	28470.00	4.15	4.33	10.04
	28790.00	4.01	4.34	9.93
	29110.00	3.89	4.36	9.83
	29430.00	3.77	4.37	9.74
	29750.00	3.67	4.38	9.65
	30070.00	3.57	4.40	9.57
	30390.00	3.48	4.41	9.50
	30710.00	3.40	4.43	9.43
	31030.00	3.32	4.44	9.37
	31670.00	3.18	4.47	9.25
	32310.00	3.06	4.50	9.14
	32950.00	2.95	4.53	9.04
	33590.00	2.84	4.53	8.94
	34230.00	2.74	4.53	8.85
	34870.00	2.64	4.53	8.76
VH	35200.00	2.59	4.53	8.71
	35350.00	2.40	4.54	8.57
	35550.00	2.55	4.55	8.67
	35650.00	2.68	4.56	8.76
OF	35700.00	2.75	4.56	8.80
	35850.00	2.95	4.57	8.94
	35950.00	3.07	4.58	9.02
	36050.00	3.19	4.59	9.10
	36150.00	3.30	4.59	9.17
	36250.00	3.41	4.60	9.25
	36350.00	3.51	4.61	9.32

	36450.00	3.62	4.61	9.38
	36550.00	3.71	4.62	9.45
	36650.00	3.81	4.63	9.51
	36750.00	3.90	4.63	9.57
	36850.00	3.99	4.64	9.63
	36950.00	4.08	4.65	9.69
	37050.00	4.17	4.65	9.75
	37150.00	4.25	4.66	9.80
	37350.00	4.41	4.67	9.91
	37550.00	4.57	4.69	10.01
	37750.00	4.71	4.70	10.11
CF	37900.00	4.82	4.71	10.18
CF	38000.00	5.30	4.72	10.51
	38150.00	5.27	4.72	10.48
	38310.00	5.23	4.72	10.45
	38630.00	5.15	4.72	10.39
	39270.00	4.83	4.72	10.14
	39590.00	4.54	4.73	9.92
	39750.00	4.41	4.73	9.83
	39910.00	4.29	4.74	9.74
	40070.00	4.18	4.74	9.65
	40230.00	4.08	4.75	9.58
	40390.00	3.98	4.75	9.50
	40550.00	3.89	4.75	9.44
	40710.00	3.81	4.75	9.37
	41030.00	3.65	4.75	9.25

	41350.00	3.52	4.75	9.15
	41670.00	3.40	4.75	9.05
	41990.00	3.30	4.75	8.97
	42310.00	3.21	4.75	8.90
	42630.00	3.13	4.75	8.83
	43270.00	2.98	4.75	8.71
	43910.00	2.86	4.75	8.60
	44550.00	2.76	4.75	8.51
	45190.00	2.67	4.75	8.42
	45830.00	2.58	4.75	8.34
	46470.00	2.50	4.75	8.26
	47110.00	2.42	4.75	8.18
VH	47200.00	2.41	4.75	8.17
	47350.00	2.21	4.76	8.02
	47550.00	2.36	4.77	8.12
	47650.00	2.49	4.78	8.21
CF	47700.00	2.56	4.78	8.25
	47820.00	2.76	4.79	8.39
	47980.00	3.11	4.80	8.63
CF	48100.00	3.56	4.81	8.94
	48250.00	3.55	4.81	8.94
	48410.00	3.54	4.81	8.92
	48730.00	3.48	4.81	8.88
	49370.00	3.25	4.81	8.73
	49690.00	3.08	4.81	8.61
VH	49750.00	3.05	4.81	8.58

IF 49850.00 .01 4.81 6.46

PART3 LOCATION OF AREAS ABOVE 100-YEAR SURGE

BETWEEN 351.00 AND 1345.00

PART4 LOCATION OF SURGE CHANGES

STATION	10-YEAR SURGE	100-YEAR SURGE
1345.00	4.00	8.85
1445.00	4.00	8.84
1600.00	4.00	8.83
1800.00	4.00	8.82
2000.00	4.00	8.81
2200.00	4.00	8.79
2500.00	4.00	8.77
7000.00	4.00	8.47
7200.00	4.00	8.45
8300.00	4.00	8.38
8900.00	4.00	8.34
9100.00	4.00	8.32
9350.00	4.00	8.31
10500.00	4.00	8.23
11300.00	4.00	8.18
11800.00	4.00	8.14
13300.00	4.00	8.04
13700.00	4.00	8.01
14700.00	4.00	7.95

16000.00	4.00	7.86
18500.00	4.00	7.69
19000.00	4.00	7.66
19600.00	4.00	7.61
25000.00	2.50	7.25
26000.00	2.50	7.22
27200.00	2.50	7.17
35200.00	2.50	6.90
35700.00	2.50	6.88
37900.00	2.50	6.80
38000.00	2.50	6.80
47200.00	2.50	6.48
47700.00	2.50	6.46
48100.00	3.00	6.45

PARTS LOCATION OF V ZONES

STATION OF GUTTER	LOCATION OF ZONE
288.71	WINDWARD
5731.23	LEEWARD
24564.27	WINDWARD
25457.99	LEEWARD
32636.62	WINDWARD
35894.29	LEEWARD
43191.50	WINDWARD
47929.02	LEEWARD
49751.53	WINDWARD

PART 6 NUMBERED A ZONES AND V ZONES

STATION OF GUTTER	ELEVATION	ZONE DESIGNATION	EHF
.00	17.93		
		V14 EL=18	70
29.57	17.50		
		V14 EL=17	70
97.76	16.50		
		V14 EL=16	70
165.96	15.50		
		V14 EL=15	70
234.15	14.50		
		V14 EL=14	70
288.71	13.70		
		A12 EL=14	60
302.35	13.50		
		A12 EL=13	60
350.25	12.50		
		A12 EL=12	60
351.00	11.60		
1345.00	8.85		
		A12 EL= 9	60
1445.00	8.84		
		A12 EL= 9	60
1600.00	8.83		

		A12 EL= 9	60
1800.00	8.82		
		A12 EL= 9	60
2000.00	8.81		
		A12 EL= 9	60
2200.00	8.79		
		A12 EL= 9	60
2500.00	8.77		
		A12 EL= 9	60
2836.89	9.50		
		A12 EL=10	60
5057.99	10.50		
		A12 EL=11	60
5731.23	10.65		
		V14 EL=11	70
7000.00	10.89		
		V14 EL=11	70
7200.00	11.12		
		V14 EL=11	70
8001.87	11.50		
		V14 EL=12	70
8300.00	11.62		
		V13 EL=12	65
8900.00	11.92		
		V13 EL=12	65
9100.00	11.91		

		V13 EL=12	65
9350.00	11.78		
		V13 EL=12	65
10086.32	11.50		
		V13 EL=11	65
10500.00	11.29		
		V13 EL=11	65
11053.35	11.50		
		V13 EL=12	65
11300.00	11.67		
		V13 EL=12	65
11800.00	11.68		
		V13 EL=12	65
12270.56	11.50		
		V13 EL=11	65
13300.00	10.99		
		V12 EL=11	60
13700.00	11.12		
		V12 EL=11	60
14255.73	11.50		
		V12 EL=12	60
14700.00	11.74		
		V12 EL=12	60
16000.00	11.86		
		V12 EL=12	60
16625.18	11.50		

		V12 EL=11	60
18314.20	10.50		
		V11 EL=10	55
18500.00	10.39		
		V11 EL=10	55
18984.81	10.50		
		V11 EL=11	55
19000.00	10.52		
		V11 EL=11	55
19600.00	10.79		
		V11 EL=11	55
20511.00	10.50		
		V13 EL=10	65
24090.23	9.50		
		V14 EL= 9	70
24564.27	9.38		
		A14 EL= 9	70
25000.00	9.27		
		A14 EL= 9	70
25457.99	9.33		
		V15 EL= 9	75
25707.39	9.50		
		V15 EL=10	75
26000.00	9.73		
		V15 EL=10	75
27132.21	10.50		

		V14 EL=11	70
27200.00	10.58		
		V14 EL=11	70
27354.08	10.50		
		V14 EL=10	70
30389.39	9.50		
		V14 EL= 9	70
32636.62	9.09		
		A13 EL= 9	65
35200.00	8.71		
		A13 EL= 9	65
35700.00	8.80		
		A13 EL= 9	65
35894.29	8.97		
		V14 EL= 9	70
36630.08	9.50		
		V13 EL=10	65
37900.00	10.18		
		V13 EL=10	65
37996.17	10.50		
		V13 EL=11	65
38000.00	10.51		
		V13 EL=11	65
38063.37	10.50		
		V13 EL=10	65
40399.32	9.50		

		V13 EL= 9	65
43191.50	8.73		
		A12 EL= 9	60
44600.66	8.50		
		A12 EL= 8	60
47200.00	8.17		
		A12 EL= 8	60
47700.00	8.25		
		A12 EL= 8	60
47892.44	8.50		
		A12 EL= 9	60
47929.02	8.56		
		V11 EL= 9	55
48100.00	8.94		
		V11 EL= 9	55
49751.53	8.55		
		A 9 EL= 9	45
49753.88	8.50		
		A 9 EL= 8	45
49800.89	7.50		
		A 9 EL= 7	45
49847.91	6.50		
		A 9 EL= 6	45
49850.00	6.46		

ZONE TERMINATED AT END OF TRANSECT