NOAA Technical Report NWS 17

Estimation of Hurricane Storm Surge In Apalachicola Bay, Florida

James E. Overland

June 1975

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Office of Hydrology
Silver Spring, Md.

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UNITED STATES DEPARTMENT OF COMMERCE
Rogers C. B. Morton, Secretary

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
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PREFACE

This report documents the formulation of a shallow bay hydrodynamic model and its application to Apalachicola Bay, Florida. The Apalachicola Bay model and the SPLASH model for estimating open coast surge (Jelesnianski 1972) were used as aids in determining total storm tide frequency information for Franklin County, Florida. The frequency analysis is presented in a separate report (Ho and Myers 1975). The present report is part of the study by the Special Studies Branch, Office of Hydrology, National Weather Service, for the Federal Insurance Administration, Department of Housing and Urban Development, under the National Flood Insurance Act of 1968.

ACKNOWLEDGMENTS

The formulation of the bay model has drawn upon the efforts of a large number of authors, most notably Hansen (1956), Jelesnianski (1967), Reid and Bodine (1968), and Laevastu and Stevens (1969). Their contribution is freely acknowledged. I extend my appreciation to the staff of the Special Studies Branch, all of whom contributed to the present project. I also thank E. Ramey and his staff at the National Ocean Survey for providing much useful information on Apalachicola Bay.

ESTIMATION OF HURRICANE STORM SURGE IN APALACHICOLA BAY, FLORIDA

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ABSTRACT. A vertically integrated two-dimensional numerical hydrodynamic model is developed for simulation of hurricane surge in Apalachicola Bay. Standard explicit time differencing is used in conjunction with a single Richardson lattice. Model features include finite amplitude effects, space variable wind velocities, and parameterization of flooding of terrain, overtopping of barrier islands and flow through narrow passes. The model utilizes the results of C. P. Jelesnianski's SPLASH model computation for open coast surge as input seaward of the Bay and continues the same storm track and wind field as used in the SPLASH computation across the Bay. The Bay model was calibrated for the astronomical tides and verified against hurricane Agnes.

The response of Apalachicola Bay has been determined from numerical computations for a variety of hypothetical hurricanes as specified by various storm parameters. Surge heights in the Bay increase with hurricane central pressure depression in a nearly linear fashion as does the open coast surge. An important parameter is the duration that the open coast surge remains high, a function of the forward speed of the storm and, to a lesser extent, the radius of maximum winds. Surge heights in the Bay increased relative to open coast surge values for slow moving storms. For bays of the extent of Apalachicola Bay, basin orientation relative to wind direction, headlands, and marsh areas can produce significant local variations in surge heights.

1. INTRODUCTION

The National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973 provide a National program for insuring residences and small businesses against damage and destruction by floods. As a part of this program it is necessary to provide frequency information for coastal areas on surges caused by hurricanes. For most areas, observed surge data alone is insufficient to determine expected flood levels. An additional source of frequency information is, however, provided by the specification of the hurricane climatology of a given region (Ho, Schwerdt, and Goodyear 1975). This information, combined with the use of a hydrodynamic surge calculation such as the SPLASH program for open coast surge (Jelesnianski 1972), can be used to estimate the surge response to an ensemble of hypothetical storms (Myers 1970, 1975). This report documents the modification and application of existing bay modeling techniques to the problem of estimating the response of a bay to hurricanes. An example of its utilization is given for Apalachicola Bay, Florida.

The approach to assessing the response of bays to hurricanes must be substantially different from assessing the response in unrestricted water and on the continental shelf. Variations in open water are, in general, of the same order as variations in the storm, while surge heights in a bay may vary greatly on the scale of a few miles. Dynamic processes also differ in their relative importance. An indication of the complexity of the time dependent response of continental shelf waters to storms of various tracks is given by Jelesnianski (1974); bathystrophic adjustment and excitation and subsequent propagation of forced and free inertial-gravitational modes are of primary importance. Bays provide walls for the wind to push water against, and their shallow depths introduce nonlinearities associated with bottom friction and finite-amplitude effects. Flooding of low terrain can greatly increase the surface areas of many bays and converging channels can produce dramatic local surge heights.

Dynamic coupling of a bay model with a shelf model that would permit direct interaction between them while spanning the diverse space scales and including relevant physical processes in both domains is beyond the scope of the present project. Instead, the results of a SPLASH computation for the open coast surge adjacent to the bay have been utilized as input with the same storm parameters and track as used in the SPLASH calculation continued over the bay. The present bay formulation simulates propagation of peak surge inland from the open coast, overtopping of barrier islands, local wind and pressure effects over the bay, and how these features are modified by basin orientation, bathymetry, bottom friction, and flooding. The results of the bay model confirm that timing of events is indeed critical, as high water in back bays may be the result of primarily the wind setup, landward propagation of open coast surge, or the two may combine or mitigate.

It is emphasized that the present formulation should not be considered operational for precise surge prediction, but provides a research tool to assist making quantitative estimates by combining the results of hydrodynamic simulations for a large number of hypothetical storms. The response of a bay to a particular storm is strongly dependent upon the landfall point and wind distribution within the storm, much more than for the open coast surge.

Technical formulation of the model is presented in sections 2, 3, and 4, and application to Apalachicola Bay is presented in section 5. A list of symbols is provided in Appendix B.

2. THEORETICAL CONSIDERATIONS

2.1 Basic Equations

Quantitative derivation is based upon conservation principles for momentum and fluid volume. A hydrostatic, incompressible fluid is assumed. A standard right-hand x, y, z coordinate system is used with z the vertical coordinate, but with y not necessarily northward, as in figure 1. Momentum and continuity equations are specified as follows:

$$\frac{\partial u}{\partial t} + \frac{\partial u^2}{\partial x} + \frac{\partial uv}{\partial y} + \frac{\partial uw}{\partial z} - fv = -\frac{1}{\rho_0}\frac{\partial p}{\partial x} + \frac{1}{\rho_0}\left[\frac{\partial \tau_{xx}}{\partial x} + \frac{\partial \tau_{xy}}{\partial y} + \frac{\partial \tau_{xz}}{\partial z}\right] \quad (1)$$

$$\frac{\partial v}{\partial t} + \frac{\partial uv}{\partial x} + \frac{\partial v^2}{\partial y} + \frac{\partial vw}{\partial z} + fu = -\frac{1}{\rho_0}\frac{\partial p}{\partial y} + \frac{1}{\rho_0}\left[\frac{\partial \tau_{yx}}{\partial x} + \frac{\partial \tau_{yy}}{\partial y} + \frac{\partial \tau_{yz}}{\partial z}\right] \quad (2)$$

$$\frac{1}{\rho_0}\frac{\partial p}{\partial z} + g = 0 \quad (3)$$

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0 \quad (4)$$

with ρ_0 density, p pressure, g acceleration of gravity, and f the Coriolis parameter. The component velocities, u, v, and w, represent deterministic variables that have been smoothed to filter small-scale turbulent features. The total velocity at an instant in time consists of this deterministic velocity, u, plus a random turbulent velocity, u', whose value is distributed according to a probability density function. Horizontal turbulent stresses are defined by the small-scale structure such that:

$$\tau_{xz} = -\rho_0 \langle u'w' \rangle_E, \text{ etc.} \quad (5)$$

where $\langle \quad \rangle_E$ is the smoothing operator, defined so that the average of the fluctuations, $\langle u' \rangle_E$ equals zero.

Following Hansen (1956) and Leendertse (1967), a total depth, H, horizontal volume transport per unit width, Q_x, and vertically averaged velocity, U, are introduced:

$$H = \eta - d \quad (6)$$

with η the surface elevation and d the depth with respect to z = 0 ,

$$Q_x = \int_d^\eta u \, dz, \quad (7)$$

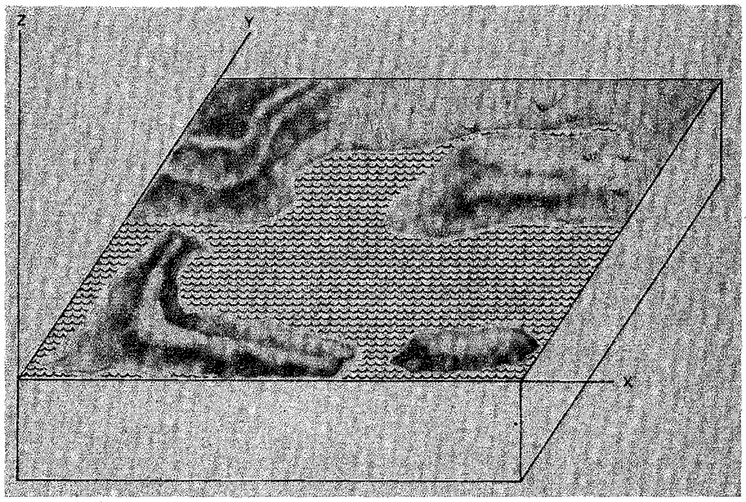

Figure 1.--Specification of coordinate system.

and

$$U = \frac{Q_x}{H} . \tag{8}$$

Assuming the deterministic velocities are related to their vertically averaged values

$$u(z) = U\ [1 + \alpha_u(z)] \tag{9}$$

and applying the kinematic condition at the surface and bottom, horizontal transport equations are derived in the following form:

$$\frac{\partial Q_x}{\partial t} + \frac{\partial(\alpha_{uu} U Q_x)}{\partial x} + \frac{\partial(\alpha_{uv} V Q_x)}{\partial y} - fQ_y = - gH \frac{\partial(\eta + \eta^*)}{\partial x} + \frac{\tau^S_{xz}}{\rho_0} - \frac{\tau^B_{xz}}{\rho_0} \tag{10}$$

$$\frac{\partial Q_y}{\partial t} + \frac{\partial(\alpha_{uv} U Q_y)}{\partial x} + \frac{\partial(\alpha_{vv} V Q_y)}{\partial y} + fQ_x = -gH \frac{\partial(\eta + \eta^*)}{\partial y} + \frac{\tau^S_{yz}}{\rho_0} - \frac{\tau^B_{yz}}{\rho_0} \tag{11}$$

$$\frac{\partial \eta}{\partial t} + \frac{\partial Q_x}{\partial x} + \frac{\partial Q_y}{\partial y} = 0 \tag{12}$$

with the velocity distribution functions defined by

$$\alpha_{uv} \equiv \frac{1}{H} \int_d^\eta (1 + \alpha_u \alpha_v)\ dz,\ \text{etc.} \tag{13}$$

These distribution functions approach 1.0 for small deviations of the velocity from the vertical mean. The term η^* is defined by $\eta^* = P_a/\rho_0 g$

with P_a the atmospheric pressure. The superscripts S and B indicate surface and bottom stress, respectively. Only the external contribution to the pressure field has been considered and lateral stress components are not explicitly included.

The field acceleration terms in eq (10) and (11) are notably important in two situations. They can be important in pollution dispersion calculations, as they are responsible for generating eddies through nonlinear interaction. They are also important where a fluid parcel may be rapidly accelerated, such as a flow impinging on a narrow opening. These terms will not be explicitly included in the interior of the bay; however, they are considered at low barriers and narrow entrance channels, which are treated as special cases, as outlined in sections 2.3 and 2.4.

The restriction to shallow bays implies that the water depth is much less than Ekman depth so that surface and bottom stress is rapidly diffused through the water column. The effect of the Coriolis terms in the vertically integrated equations will not be further considered.

2.2 Surface and Bottom Boundary Conditions

Stress from the wind at the free surface is related to the wind velocity by means of a drag coefficient C_d

$$\tau^S = \rho_a C_d W_a^2 \tag{14}$$

where ρ_a is the air density and W_a is the wind velocity at a given elevation, assumed to be 10 meters above the surface. The drag coefficient represents the bulk parameterization of very localized processes. The very large scatter in direct measurements is to be expected and even what bulk parameters, if any, determine its variation remains unclear. The problem is compounded as there is very little drag coefficient data for high wind speeds.

Wilson (1960), Roll (1965), and Wu (1969) have tabulated drag coefficient data from a wide variety of sources and methodologies. There is indication that a division is possible into "light" and "strong" winds around 30 knots with mean values of about 1.3×10^{-3} for light winds and 2.4×10^{-3} for strong winds. "Strong" winds imply less than 60 knots. For hurricane conditions Miller (1964) has computed drag coefficients from observations of ageostrophic atmospheric transports. While noting the large uncertainties in this approach, Miller suggests a weak increase with wind speed at very high wind speeds. We take some faith in the fact that many of the drag estimates were made in enclosed or semi-enclosed basins.

The present formulation divides the drag coefficient into three regions, a constant value of 1.2×10^{-3} below 15 knots, a linear increase to 2.1×10^{-3} at 30 knots and a weak linear increase to 2.65×10^{-3} at 90 knots. The SPLASH program assumes a constant drag coefficient of 2.4×10^{-3}. The ratio of the density of air to water has been taken as 1.25×10^{-3}.

The flux of rain water falling directly on the surface of the bay and stream runoff has not been included. It is quite possible, however, that for some basins, particularly narrow estuaries, if intense rains have occurred over the contributing watersheds well in advance of the hurricane, flood waters propagating down tributaries may arrive during the rising stages of the storm surge and thus alter the basin response.

Bottom stress (which in the present formulation implicitly includes all momentum loss to turbulent processes) is related to both the characteristics of the bottom and to features within the flow field. In a vertically integrated formulation the dependence must be parameterized in terms of the explicit model variables:

$$\tau^B = \tau^B \text{ (Bottom, } Q_x, Q_y, H, \tau^S) \tag{15}$$

For shallow flow, bottom stress has been related to a quadratic power law

$$\tau^{B*} = \frac{\rho_0 g \ |Q|Q}{C_H^2 \ H^2} \tag{16}$$

with a Chezy coefficient, C_H, specifying the type of bottom. As with the drag coefficient, bottom roughness coefficients parameterize the bulk effect of small-scale phenomena, thus the wide scatter in their estimation. Estimates are given by Chow (1959), Dronkers (1964), and Bruun (1967). Experience has also been obtained from modeling of tides in many areas. Reid and Bodine (1968) deduced a friction value corresponding to a Chezy coefficient of 62 $m^{\frac{1}{2}}/s$ (113 $ft^{\frac{1}{2}}/s$) from calibration for Galveston Bay, a bay that contains large areas with depths less than 12 feet similar to Apalachicola Bay.

Based upon these estimates the model provisionally specified three terrain-dependent Chezy coefficients for very shallow bays, 61 $m^{\frac{1}{2}}/s$ (110 $ft^{\frac{1}{2}}/s$) for areas normally below mlw, 44 $m^{\frac{1}{2}}/s$ (80 $ft^{\frac{1}{2}}/s$) on the tidal flats, and 14 $m^{\frac{1}{2}}/s$ (25 $ft^{\frac{1}{2}}/s$) for vegetated inland areas subject to flooding. In the tuning process (Chapter 5.2) it was found that a small increase in bottom friction provided a slight improvement in overall verification. A final deep water value of 55 $m^{\frac{1}{2}}/s$ (100 $ft^{\frac{1}{2}}/s$) was adopted for the study.

Equation (16) does not explicitly include the effect of wind stress on bottom stress. Reid (1956) has derived a generalized formulation of bottom stress for quasi-steady turbulent open channel flow which takes the influence of surface stress into account. Reid states that "in general, the effect of the wind stress is such that, for a given current, the effective resistance to flow is reduced for a following wind and increased for an opposing wind." His results show the correction to the bottom stress as a percentage of the surface stress to be a weak function of mean velocity and wind stress. However, over a wide variety of conditions this correction is less than 0.10 of the surface wind stress. This ratio is consistent with the few direct measurements of bottom stress available. As a first-order correction for the effect of wind on bottom stress, the following adjustment is made to the bottom stress:

$$\tau^B = \tau^{B*} - 0.06\tau^S. \tag{17}$$

2.3 Ocean Boundary Conditions and Narrow Inlets

Mathematical formulation of a bay model requires specification of driving forces and initial and boundary values. Specification of boundary values at an oceanic interface is available after the event from measurements such as tide gages, but for planning or forecasting purposes boundary input must be specified otherwise. Two approaches to providing boundary input are to extend the model seaward and thus also resolve continental shelf processes or to couple a shelf model to the bay model. In the latter case an artificial boundary is immersed into the fluid near the mouth of the bay that is charged with representing the interaction between the bay and the adjacent sea. An ideal artificial boundary would allow transient wave phenomena to propagate out of, as well as into, the bay, provide periodic forcing such as the tides, and allow for wind drift.

In this report the simplest type of coupling is considered in which the results of a SPLASH computation for open coast surge are used to specify water elevations seaward of the barrier islands and on the outside of inlets and passes. It is noted, however, that the SPLASH model does not account for the presence of entrances and broken features and does not include feedback from the bay model. Explicit specification of the oceanic sea level is useful to the extent that on the scale of model resolution the presence of entrances has only a minor influence on the development of surge along the open coast and amplitudes of long waves exiting through a channel are diminished by dispersion in two dimensions.

The SPLASH program specifies water elevations every 8 statute miles along the coast. Linear interpolation of these values was necessary for input at the finer resolution of the bay model. For storms whose paths are approximately normal to the coastline, it can be assumed that the peak surge arrives at nearly the same time for the stretch of coast adjacent to the bay and that the time history can be normalized at each location along the coast by

$$\eta_{open\ coast} = \eta_{max}(x)\ \text{sech}^2\ 0.33\left(\frac{T-T_{landfall}}{T_{2/3}}\right) \tag{18}$$

where $T_{2/3}$ is a width parameter defined by the duration that the water level remains above (2/3) η_{max}. Figure 2 shows the fit of eq (18) and an error function dependence against a hydrograph generated by the SPLASH program for a storm landfalling normal to the coast. For more complicated storm trajectories the results of a SPLASH II computation (Jelesnianski 1974) can be utilized, specifying the SPLASH-generated time histories of surge heights at the coastline.

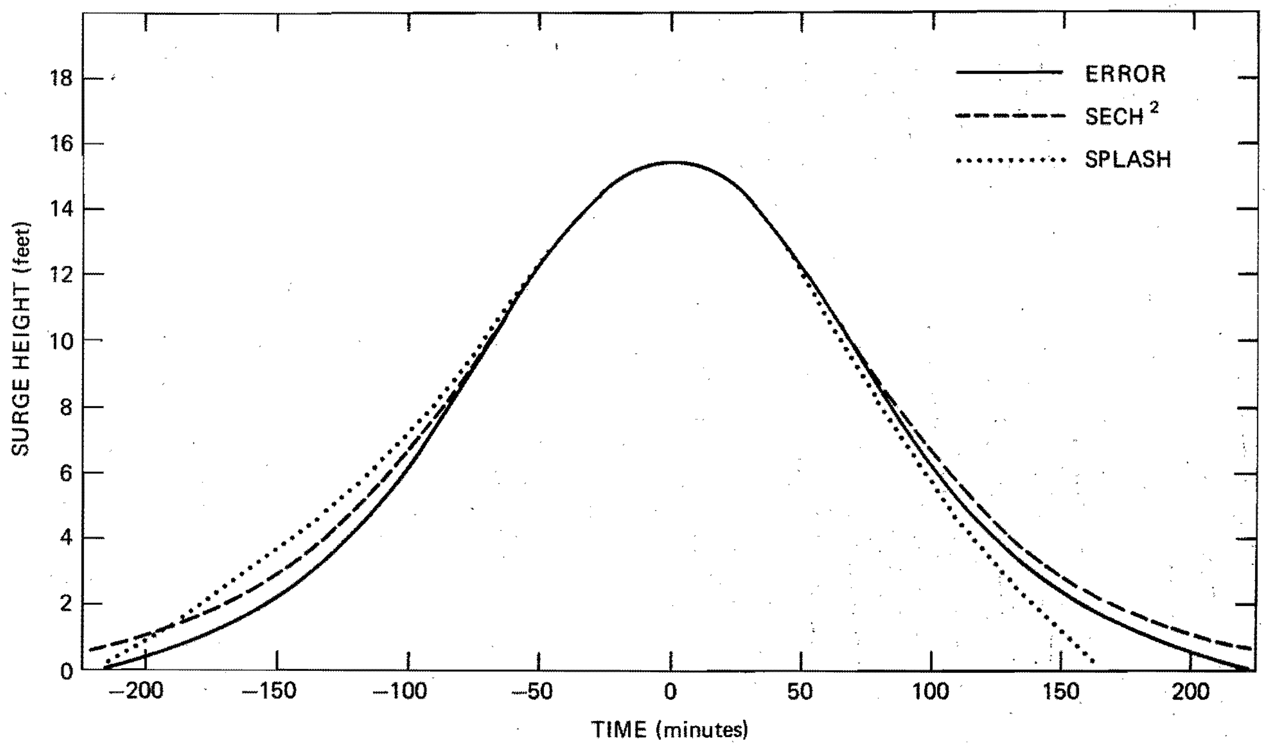

Figure 2.--Comparison of proposed functional dependences with a surge time-history at the coastline generated by the SPLASH model.

For application in the Gulf of Mexico, dynamics of tidal oscillations are not included.

Narrow entrance channels on the order of a few tenths of a mile in width which open into extensive bays are regions of high velocities and complicated flow patterns. The flow can experience accelerations both parallel and normal to the axis of the entrance. Transport through narrow passes is estimated from

$$Q_p = C_c A U_p \qquad (19)$$

with U_p the vertically averaged velocity near the axis of the channel, A(t) the geometric cross-sectional area, and C_c a contraction coefficient that excludes zones of eddying adjacent to lateral boundaries in the calculation of transport through the pass. The velocity is calculated from a momentum equation:

$$\frac{\partial U_p}{\partial t} + \frac{(1 + C_k)}{2} \frac{\partial U_p^2}{\partial x} + \frac{g U_p^2}{C_H^2 H} = - g \frac{\partial \eta}{\partial x} + \frac{\tau_{xz}^S}{H \rho_0} \qquad (20)$$

where C_k is the parameterization of momentum loss to turbulence and lateral acceleration. For large height differences between basins on either side of a pass, velocities through the constriction are limited by bottom friction and the field acceleration term. For this case Chow (1959, p. 479) indicates a C_k of order 0.25 to 0.8.

Equations (19) and (20) are utilized at narrow passes using the water elevations adjacent to the pass as input. From consideration of the geometry of the narrow entrances to Apalachicola Bay, the value of C_k was set at 0.35 and C_c is set at 0.90 (Chow 1959).

2.4 Flooding, Barriers, and Barrier Islands

Flooding is of primary importance. Concern is not only with possible reduction of surge heights in the bay through flooding but also the extent of flooding possible while the surge in the bay remains high. The model has a resolution on the order of 1 mile, and the effect of flooding of an area containing brush, trees, ponding areas, small channels, streets, buildings, etc., is parameterized as the average effect on the scale of this grid size. One can specify the average elevation, bottom friction, and parameterization of the physical processes of flooding.

One mechanism for parameterizing flooding is given by Sielecki and Wurtele (1970) which represents flow up gradually sloping boundaries. Another approach was used by Reid and Bodine (1968) in which the land elevation is regarded as uniform over each grid square. If the elevation of the water is less than the land elevation at the junction of a flooded square and a dry square, zero water transport is taken.

$$Q_N = 0. \tag{21}$$

However, if the water level is greater than the adjacent dry land the rate of flooding per unit width is considered to be given by

$$Q_N = C_0 D_b \sqrt{g D_b} \tag{22}$$

where D_b is the depth of water above the level of the land and C_0 is a flooding coefficient. While the approach of Sielecki and Wurtele has an aesthetic appeal and could be of importance in open coast surge runup, for uneven terrain and marsh areas in bays Reid's approach is considered a better parameterization of flooding and is used in the present formulation with a C_0 of 0.7. The accuracy of the value of C_0 and the form of eq (22) is not considered critical, as eq (22) is applied for one time step and then the flooded square is considered part of the bay. If the water level in the bay drops so that water remains ponded inland, it is assumed to drain at the rate given by eq (22).

Very narrow geographic features can be treated as walls between adjacent grid squares. Causeways and dune ridge systems are treated in this manner. If the barrier is higher than the adjacent water levels, zero flow is specified. If the elevation on one side is in excess of the barrier height, eq (22) is assumed. If the barrier becomes submerged, transport toward the low head side is computed by

$$Q_N = C_s \, D_b \, \sqrt{g|H_1 - H_2|} \tag{23}$$

with C_s a discharge coefficient taken as 0.7 and D_b is the average depth, $(\eta_1 + \eta_2)/2 - z_b$, with z_b the height of the barrier.

3. NUMERICAL CONSIDERATIONS

3.1 Choice of Numerical Scheme

The primary variables are discretized on the well-known single Richardson lattice as shown in figure 3. Transport points lie midway between height points so that no averaging of spatial derivatives is required. For convenience, transport points at QX $(i - \frac{1}{2}, j)$ and QY $(i, j - \frac{1}{2})$ are assigned to box (i, j). The single Richardson lattice has the additional advantage of being able to collapse to a one-dimensional channel. Its main deficiency is, of course, that transport components are not defined at the same location, necessitating averaging in friction terms and Coriolis terms, if utilized. Discretization produces an error in wave propagation as wavelengths approach the grid dimensions. The dispersion relation for the linearized shallow water equations is

$$\sigma_E = \sqrt{gH} \; k. \tag{24}$$

with σ the frequency and k the wave number. The group velocity is non-zero unless H vanishes. The Richardson lattice gives the following relation

$$\sigma_R = \frac{2\sqrt{gH}}{\Delta x} \sin \left(\frac{k\Delta x}{2}\right) . \tag{25}$$

The shortest resolvable wave has wavelength $2\Delta X$ with corresponding wave number $k_c = \pi/\Delta X$; all waves lie between $0<k\Delta x<\pi$. A plot of the dispersion relations (24) and (25) is shown in figure 4, scaling $\Delta x/\sqrt{gh}$ as 1.0 arbitrary time units. For short waves the phase speed and group velocity are reduced compared with the analytical solution.

Simple explicit time differencing is used:

$$\frac{\partial\psi}{\partial t} (t + 1/2) \sim \frac{\psi (t + 1) - \psi (t)}{\Delta T} \tag{26}$$

where

$$\psi (t) \equiv \{QX(t+\tfrac{1}{2}),\ QY (t + \tfrac{1}{2}),\ \eta(t)\}^{-1} .$$

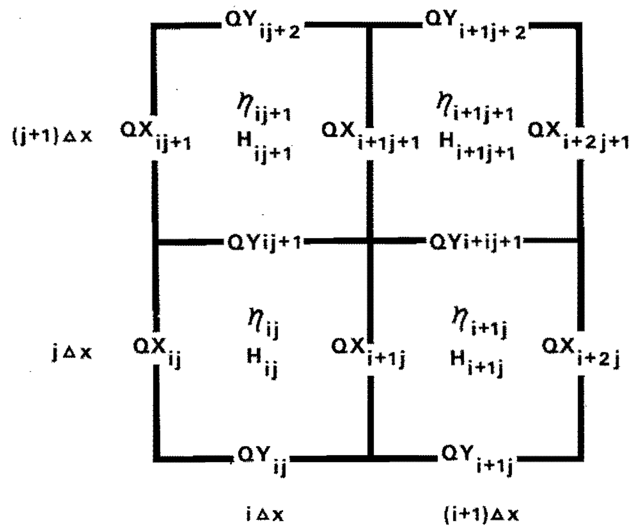

Figure 3.--Location of descretized variables on a Richardson lattice.

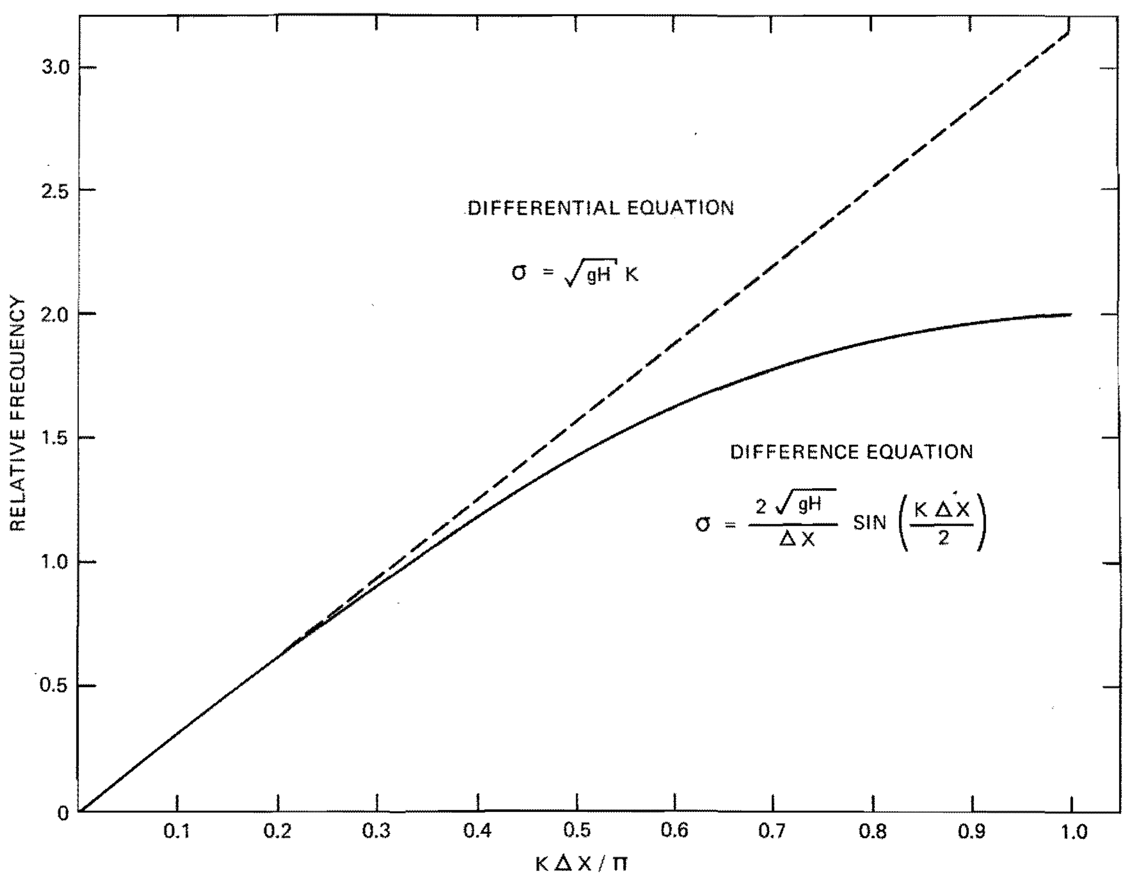

Figure 4.--Shallow water dispersion relation for solution on a Richardson lattice, compared to the analytic solution.

Transport variables are defined only at a level one-half time step ahead of water elevations, so that while eq (26) has the appearance of a "leap frog" formulation, it is equivalent to the forward scheme of Sielecki (1968), and does not experience separation of the solution at alternate time levels. Stability is governed by the Courant-Friedrich-Lewy condition (Platzman 1972),

$$\Delta T < \frac{\Delta x}{\sqrt{2gH_{max}}} \tag{27}$$

The scheme is computationally neutral, neither amplifying or damping wave modes. This is a desirable trait for surge computations, but it also implies that short wavelength noise is not dissipated.

3.2 Finite-Difference Formulation

The finite-difference formulation for the momentum equations is as follows:

$$\frac{QX_{ij}^{T+1} - QX_{ij}^{T}}{\Delta T} = -g\overline{H}_{ij} \left[\frac{\eta_{ij} - \eta_{i-1,j}}{\Delta X} + \frac{\eta^*_{ij} - \eta^*_{i-1,j}}{\Delta X} \right]^{T+\frac{1}{2}}$$

$$+ 1.06 \frac{\rho_a}{\rho_0} C_d |W| W_X^{T+\frac{1}{2}} - \frac{g\overline{Q}\, QX_{ij}^{T+1}}{C_H^2 \overline{H}_{ij}^2}, \tag{28}$$

with

$$\overline{H}_{ij} \equiv 0.5 \left[H_{ij} + H_{i-i,j} \right]^{T+\frac{1}{2}}$$

$$\overline{Q} \equiv \sqrt{QX_{ij}^2 + \frac{1}{16} (QY_{ij} + QY_{i,j+1} + QY_{i-1,j} + QY_{i-1,j+1})^2}^{\,T},$$

and

$$\frac{QY_{ij}^{T+1} - QY_{ij}^{T}}{\Delta T} = -g\overline{\overline{H}}_{ij} \left[\frac{\eta_{ij} - \eta_{i,j-1}}{\Delta X} + \frac{\eta^*_{ij} - \eta^*_{i,j-1}}{\Delta X} \right]^{T+\frac{1}{2}}$$

$$+ 1.06 \frac{\rho_a}{\rho_0} C_d |W| W_y^{T+\frac{1}{2}} - \frac{g\overline{\overline{Q}}\, QY_{ij}^{T+1}}{C_H^2 \overline{\overline{H}}_{ij}^2},$$

with

$$\overline{\overline{H}}_{ij} \equiv 0.5 \left[H_{ij} + H_{i,j-1} \right]^{T+\frac{1}{2}} \tag{29}$$

$$\overline{\overline{Q}} \equiv \sqrt{QY_{ij}^2 + \frac{1}{16} (QX_{ij} + QX_{i+1,j} + QX_{i,j-1} + QX_{i+1,j-1})^2}^{\,T}.$$

The wind speed $|\vec{W}|$ is given by $(W_x^2 + W_y^2)^{\frac{1}{2}}$ where W_x and W_y are component wind velocities.

The continuity equation is given by

$$\frac{\eta_{ij}^{T+\frac{1}{2}} - \eta^{T-\frac{1}{2}}}{\Delta T} = - \frac{QX_{i+1,j}^{T} - QX_{ij}^{T}}{\Delta X} - \frac{QY_{i,j+1}^{T} - QY_{ij}^{T}}{\Delta X} \quad . \tag{30}$$

In utilizing the transport formulation, interpolation of depth is not required in the continuity equation; this is preferred, as elevation changes are very sensitive to small errors in the horizontal divergence.

It has been shown that inclusion of an explicit friction term may reduce the permissible time step for stable computations (Holsters 1962); here, an implicit friction formulation is used. A stability analysis including implicit friction is presented in Appendix A. No smoothing of the primary variables, QY, QY, η, has been used with the present formulation.

Formulation at narrow passes is as follows:

$$\frac{U_p^{T+1} - U_p^{T}}{\Delta T} + \left[\frac{(1 + C_k)}{2\Delta X} + \frac{g}{C_H^2\, \overline{H}}\right] U_p^{T+1} U_p^{T} =$$

$$- g \left[\frac{\eta_p - \eta_{p-1}}{\Delta X}\right]^{T+\frac{1}{2}} + \frac{(1.06)}{\overline{H}} \frac{\rho_a}{\rho_0} C_d\, |\vec{W}| W_X^{T+\frac{1}{2}} \tag{31}$$

$$Q_p = C_c b\, \overline{H}\, U \tag{32}$$

where b is the ratio of pass width to grid length.

4. METEOROLOGICAL SPECIFICATION

Ho, et al. (1975) have classified hurricane occurrences in terms of five independent variables, P_0, the central pressure (an index of intensity of the storm), R, the radius to maximum winds (an index of storm size), F, the forward speed of the storm, θ, the direction of entry to the coast, and L, the landfall point of the storm center. In the SPLASH model, P_0, R, and an assumed wind speed variation with radial distance from the center are used as input to the steady-state momentum equations to derive a self-consistent meteorological input to the open coast surge model.

The same storm parameters as utilized in the SPLASH run to obtain open coast surge values are used as input to the bay model. The wind speed, inflow angle and atmospheric pressure gradient are given as a function of the radial distance from the center of the storm, r.

The wind speed profile is the same as specified in SPLASH model

$$W_S(r) = \frac{2Rr\ W_s\ max}{R^2 + r^2}. \tag{33}$$

W_s max, obtained from the SPLASH run, is the maximum wind speed if the storm was stationary and is a function of central pressure and radius of maximum wind. For use with the bay model the variations of the pressure gradient and inflow angle with radius are assumed rather than derived but are in qualitative agreement with derived SPLASH profiles. This assumption is expedient and reflects the fact that the extent of bays is small and the storm is, no doubt, modified during the transition from the sea to land. The inflow angle, ϕ, is assumed to have a maximum of 22° at 3 R and to approach 17° at large radius with the following dependence:

$$\phi = 0.2856 \left[\frac{r}{R}\right]^3 \exp\left[\frac{-r}{R}\right] \qquad r < 4.4R$$

$$\phi = 0.2967 \qquad r > 4.4R \tag{34}$$

The atmospheric pressure gradient has the following dependence with a maximum at 0.5 R (Myers 1954):

$$\frac{\partial P_a}{\partial r} = (P_N - P_0)\ \frac{R}{r^2} \exp\left[\frac{-R}{r}\right] \tag{35}$$

with P_N the pressure at some great distance from the center of the storm. Equation (35) represents a minor correction when applied over a bay and has usually been neglected in previous studies. Profiles of wind speed, inflow angle, and pressure gradient are plotted in figure 5.

The storm is moved across the grid with a given forward speed with the local wind velocities corrected for forward speed in the same manner as in the SPLASH storm

$$\vec{W} = \vec{W}_s(r) + \frac{Rr\vec{F}}{R^2 + r^2} \tag{36}$$

with $\vec{W}$ the composite wind velocity at a given location.

5. APPLICATION TO APALACHICOLA BAY AND FRANKLIN COUNTY

5.1 Description of the Area and Schematization

Franklin County is located in Northwest Florida on the northern edge of the Gulf of Mexico. The lateral extent is from Ochlockonee Point on Apalachee

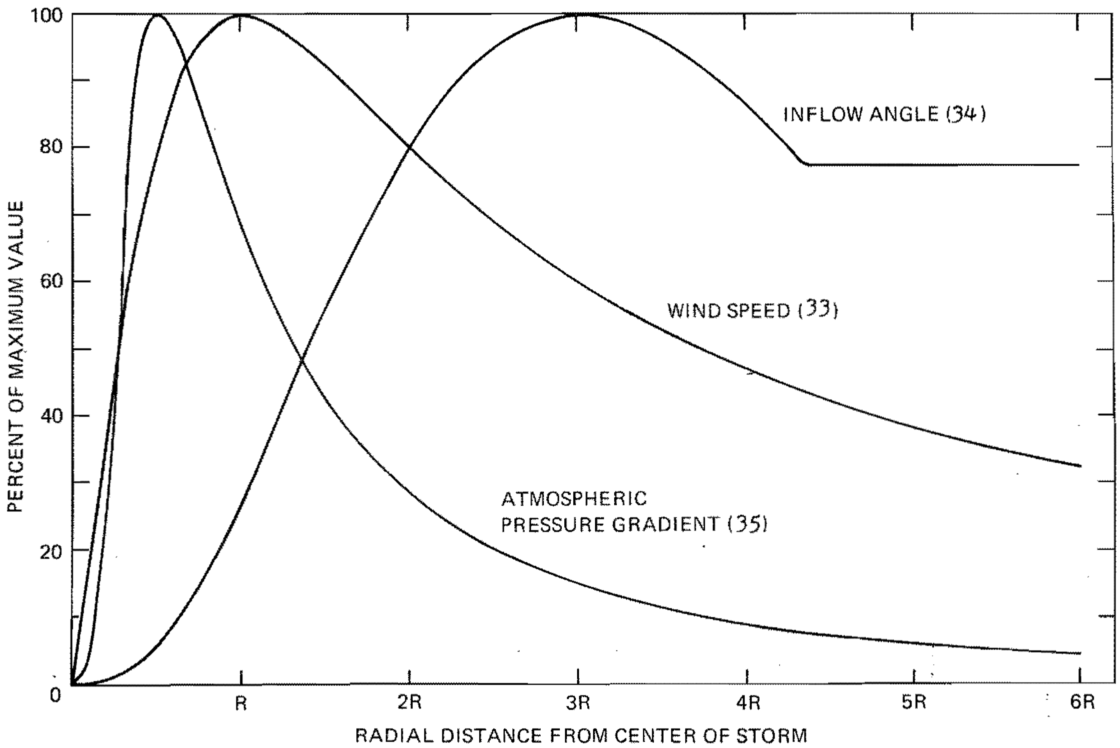

Figure 5.--Assumed dependence of wind speed, inflow angle, and atmospheric pressure gradient as a function of distance from the storm center scaled on the radius to maximum winds, R. Numbers in parentheses refer to equation numbers.

Bay to Indian Pass near Cape San Blas (fig. 6). The major geographic features are a 35-mile barrier island system, the 4-mile wide Saint George Sound, which opens into Apalachicola Bay, and the East Bay area, which is comprised of several bayous and low marsh areas. Saint George Sound has wide access to the Gulf through Duer Channel and East Pass. Major population centers are Apalachicola and Carrabelle, Fla., both located on minor rivers.

Apalachicola Bay is discretized with a horizontal resolution of 1 nautical mile as shown in figure 7. The shaded regions indicate areas normally above mean sea level. Dune ridges and causeways are specified by a heavier line with their average elevation given in feet. Reference datum is 1 foot below mean sea level; this level approximates the mean low water elevation throughout the region. Average elevation/depth of a grid square is given in figure 8. The letter S indicates location of sea points where the external water level is specified. Squares indicated with the letter X show the extent of computation landward. Possible flooding into these squares is computed with the volume of water considered lost from the system. Two narrow inlets are included, West Pass at location (6, 7) and Indian Pass at (2, 13) with widths of 0.30 nautical mile and 0.075 nautical mile, respectively. Water depths, land elevations, and terrain type were obtained from National Ocean Survey charts and Geological Survey 7½-minute quadrangles, supplemented by recent aerial photographs supplied by the National Ocean Survey.

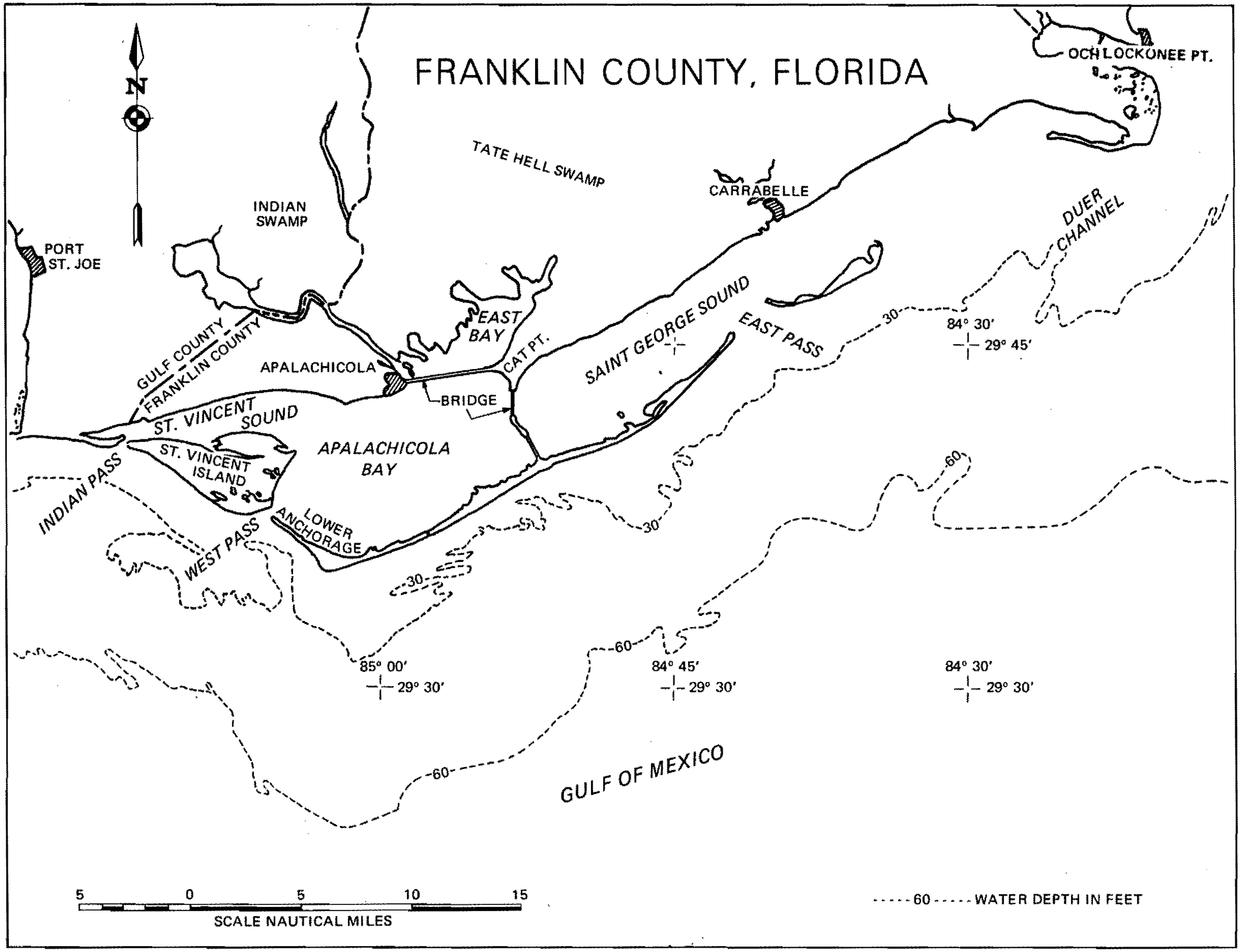

Figure 6.--Geographic locations in Franklin County, Fla.

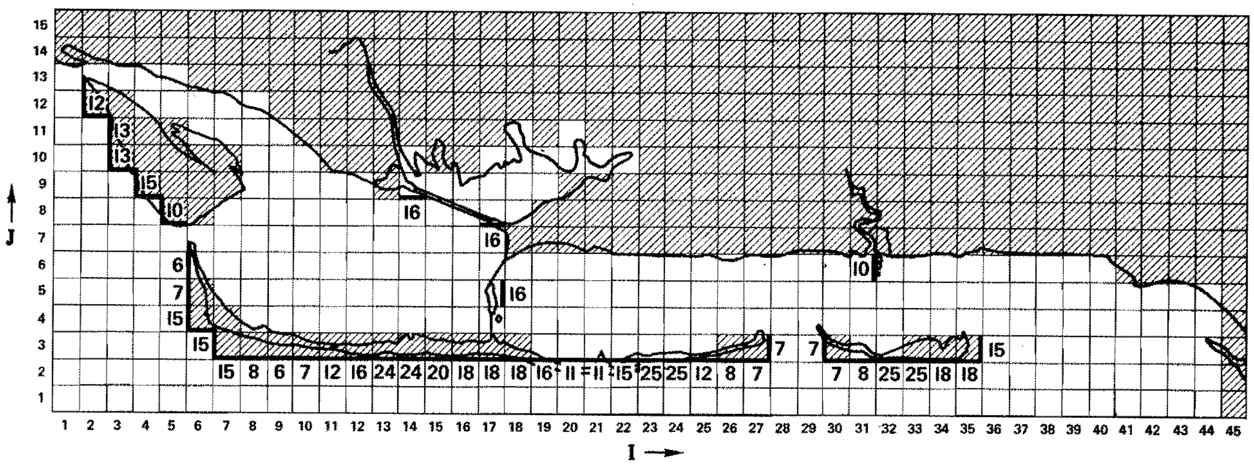

Figure 7.--Discretization of Apalachicola Bay, Fla. Figure also shows location of barriers with elevations in feet (MLW).

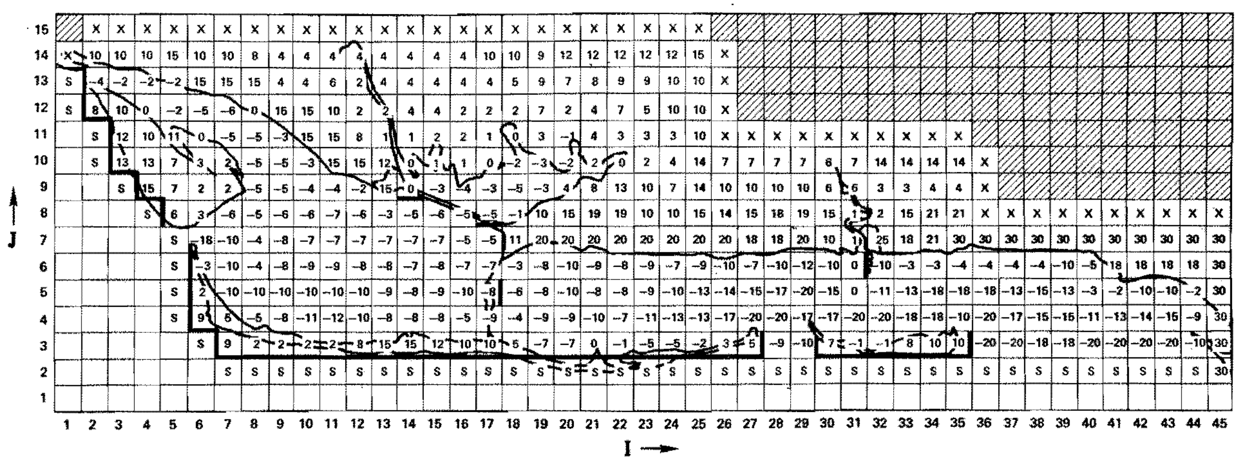

Figure 8.--Depth/elevation of grid squares in feet. "S" indicates location of sea points, and X points indicate landward extent of the computation.

5.2 Hindcasts--Astronomical Tides and Hurricane Agnes

In estimating what might happen, it is helpful to know how well we do by hindcasting what has already occurred.

For Apalachicola Bay a limited amount of astronomical tide data is available, and in 1972 Hurricane Agnes passed to the west of the Bay, providing a set of high-water marks throughout the Bay plus a single tide-gage record of the time history at Apalachicola.

Franklin County is in the region of transition between predominantly diurnal tides at Pensacola and predominantly semi-diurnal tides at Saint Marks and Cedar Keys. The tides at Apalachicola are influenced both by the main entrances and the small passes to the west, with the tide occurring earlier relative to the East Pass than if the small passes were closed.

As hourly values of water elevations at the passes were unavailable, the averaged tidal data obtained from the National Ocean Survey tide tables provided a first check on the overall model formulation. The tidal height and relative phase lag for high water was specified at East Pass and West Pass and the heights and phase lag computed at selected locations throughout the Bay assuming a semi-diurnal periodicity. The results for four values of the Chezy friction coefficient, 50, 100, 110, and 160 $ft^{1/2}/s$, are summarized in Table 1. The large coefficient, 160 $ft^{1/2}/s$, underestimated the damping of

Table 1.--Summary of tidal calibration

	East Pass		Carrabelle		Cat Point		Apalachicola		Lower Anchorage		West Pass	
	High Water (ft) MSL	Lag (hr)	High Water (ft) MSL	Lag (hr)	High Water (ft) MSL	Lag (hr)	High Water (ft) MSL	Lag (hr)	High Water (ft) MSL	Lag (hr)	High Water (ft) MSL	Lag (hr)
Observed	1.3	0.1	1.3	0.6	1.1	1.3	0.9	2.0	0.8	1.7	0.7	1.6
Friction Coef. 50 $ft^{1/2}/s$	PRESCRIBED	PRESCRIBED	1.25	1.0	0.85	2.2	0.65	3.2	0.60	2.7	PRESCRIBED	PRESCRIBED
Friction Coef. 100 $ft^{1/2}/s$	PRESCRIBED	PRESCRIBED	1.30	0.6	1.10	1.4	0.90	2.2	0.80	1.9	PRESCRIBED	PRESCRIBED
Friction Coef. 110 $ft^{1/2}/s$	PRESCRIBED	PRESCRIBED	1.30	0.6	1.15	1.4	0.95	2.1	0.80	1.9	PRESCRIBED	PRESCRIBED
Friction Coef. 160 $ft^{1/2}/s$	PRESCRIBED	PRESCRIBED	1.35	0.4	1.25	1.0	1.05	1.7	0.85	1.5	PRESCRIBED	PRESCRIBED

the heights in the Bay relative to East Pass, while strong friction, 50 $ft^{1/2}/s$, greatly retarded the propagation of the tide in Saint George Sound and underestimated the heights in the Bay.

Hurricane Agnes passed to the west of Franklin County on June 19, 1972 (fig. 9). The track was almost due north while in the Gulf of Mexico, curving to the north-northeast before landfalling near Panama City on the west side of Cape San Blas. Agnes was a relatively weak storm in the Gulf with a minimum pressure of 978 mb. An unfavorable environment led to its weakening before landfall (Simpson and Hebert 1973). Military reconnaissance indicated maximum sustained winds of 65 knots prior to landfall, while Apalachicola reported a maximum hourly wind speed of 34 knots and a fastest mile of 48 knots. Low-lying coastal villages between Carrabelle and Apalachicola suffered great damage. The estimated damage for Franklin County due to high tides was over $1 million (DeAngelis and Hodge 1972). Agnes is most noted, however, for reintensification of the storm center while over land with the attendant rainfall and floods over the Northeast United States. The total number of deaths attributed to Agnes was estimated at 124, and the total United States damage at $3,097 million (Simpson and Hebert 1973).

Figure 10 shows the location and magnitude (feet, MSL) of observed high watermarks in Franklin County for Agnes as supplied by the National Ocean Survey along with corrected values which remove the effects of the astronomical tide given in brackets. The highest values occur at Carrabelle. The elevation drops slightly westward along Saint George Sound with a large drop across the causeway near Cat Point to the high-water mark on the barrier island opposite Apalachicola. The water elevations increase again in East Bay to the north of Apalachicola.

A SPLASH computation for the outer coast surge height was made specifying the input meteorology for the storm while still at sea. Values consisted of a pressure drop of 35 mb and a radius of maximum winds of 21 nautical miles with the storm traveling north at 11.0 knots. The derived maximum wind speed corresponding to a stationary storm was computed to be 63 knots. Heights of 7 to 8 feet external to Apalachicola Bay were in agreement with the high watermarks on the outer coast.

Two runs on the bay model were made to simulate hurricane Agnes. The first case continued the wind field consistent with the SPLASH computation over the basin with the storm containing higher wind velocities than were observed at Apalachicola. The second case utilized a wind field obtained from the hourly winds at Apalachicola. In the latter case, the winds were uniform in speed and direction over the grid, changing in time.

The computed high-water envelope utilizing the SPLASH wind field is shown in figure 11, and the envelope using the local winds in figure 12. Lightly shaded squares indicate areas that became flooded during some part of the computation and dashed barrier lines indicate overtopping from the Gulf. Both runs show the qualitative trends of the observed high-water marks. In figure 13 the upper curves portray the observed hourly surge height at Apalachicola and the computed heights using the SPLASH and local winds. In the lower section the local and SPLASH winds at Apalachicola are also shown as a function of time. The use of the SPLASH wind field overestimated the onshore winds associated with the rear of the storm, resulting in higher than observed surge in East Bay. The observed wind field tended to underestimate the height variations in the Bay, perhaps in response to the smaller drag

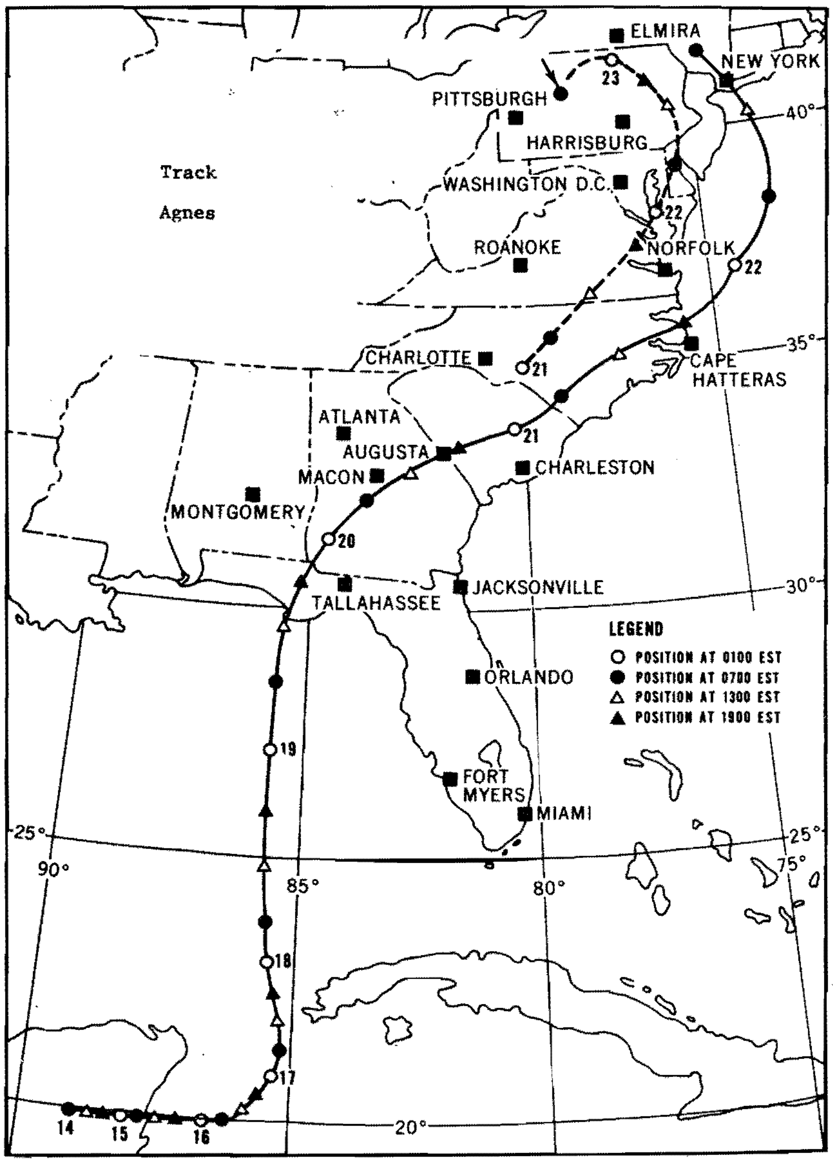

Figure 9.--Path of hurricane Agnes, June 14-23, 1972. (De Angelis and Hodge 1972)

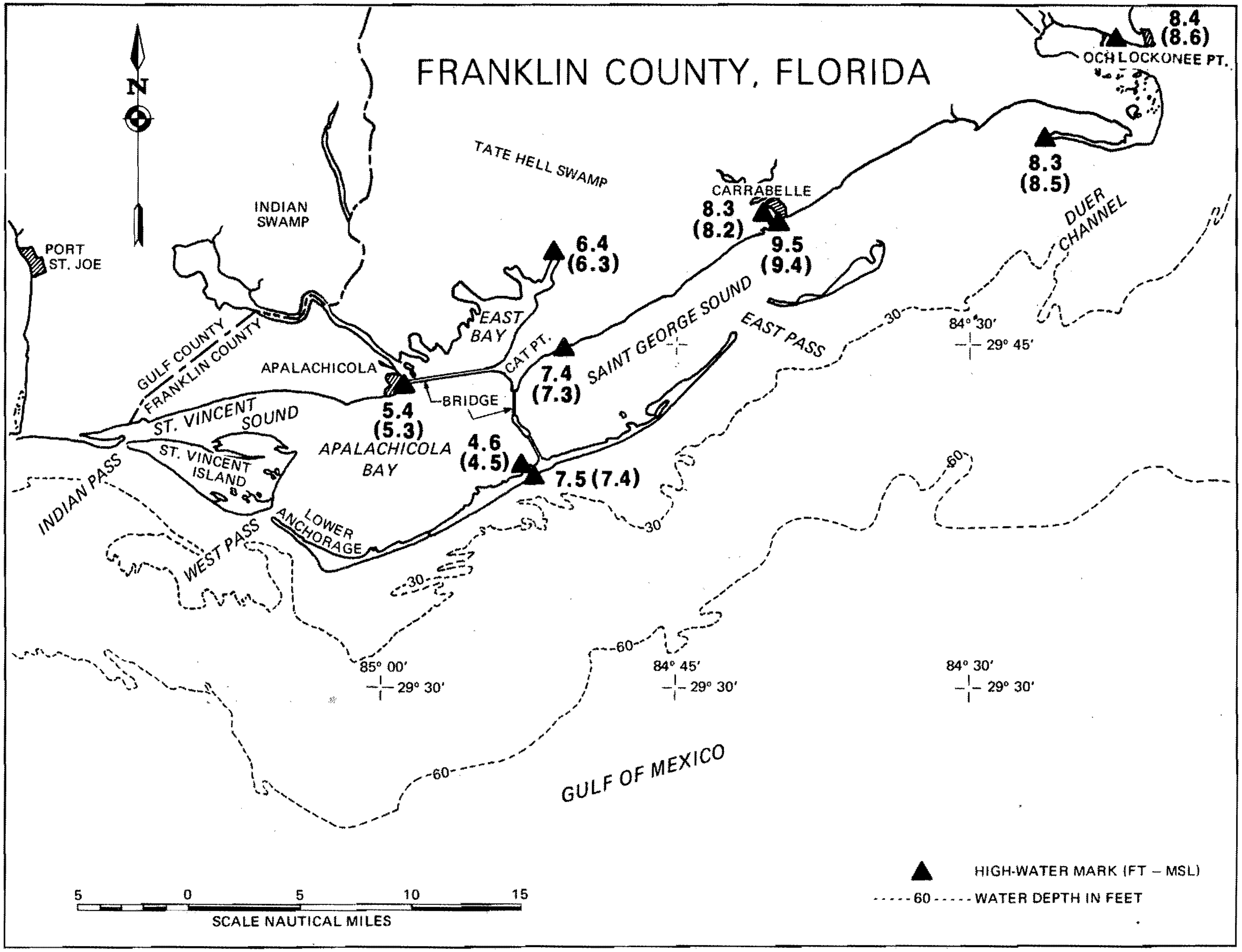

Figure 10.--Observed high-water marks for hurricane Agnes (ft, MSL).

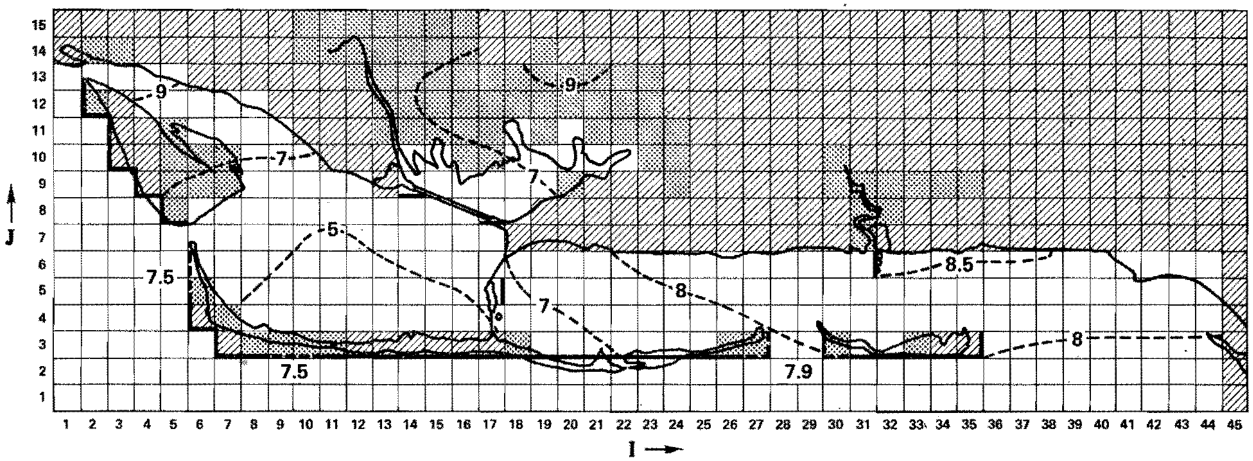

Figure 11.--Derived high-water envelope (ft) for hurricane Agnes continuing the SPLASH wind field across the Bay. Lightly shaded regions indicate flooded terrain.

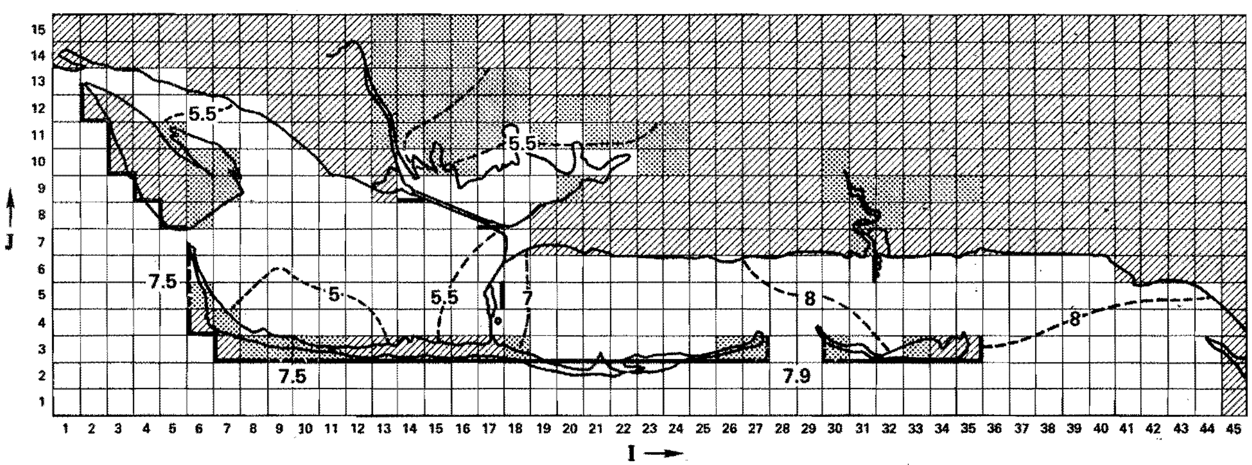

Figure 12.--Derived high-water envelope for hurricane Agnes utilizing local wind information.

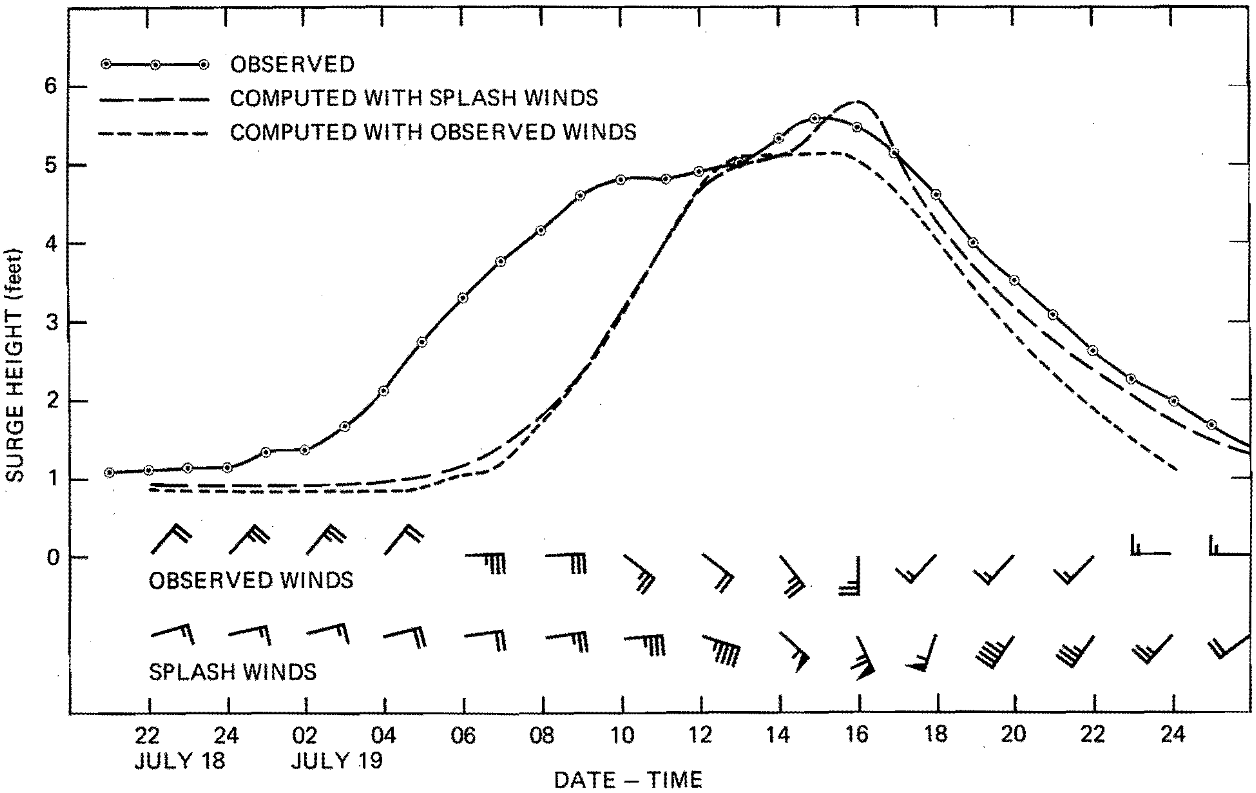

Figure 13.--(Top) Observed and derived time histories of the surge height at Apalachicola for Agnes. (Bottom) Observed and assumed SPLASH winds at Apalachicola.

coefficient assumed for lower wind speeds or to the Apalachicola winds not being representative over the entire region. The delayed maximum in the observed surge is evident in the SPLASH wind derived profile and in the latter case coincides with propagation of surge in from the east end of Saint George Sound and onshore winds.

It is a long progression from specifying several generalized storm parameters for Agnes to obtaining a surge height at Apalachicola. Observed hourly values at the Pass entrances would have shortened the number of links and thus might have increased the agreement with data, particularly the time history. However, the intent was a check upon the entire procedure. Even with the highly generalized input, the overall results are encouraging, particularly in the estimation of the reduction in surge height from Carrabelle to Cat Point and Cat Point to Apalachicola as seen by comparing figures 11 and 12 with the high-water marks in figure 10.

5.3 Response of the Apalachicola Bay Model to a Major Hypothetical Storm

This section discusses the results of the model for simulation of a major storm. The storm is specified by a pressure drop of 52 mb, a radius of maximum winds of 23 nautical miles, a forward speed of 13 knots with a maximum stationary storm wind speed of 77 knots. The storm travels perpendicular to the coastline with the center of the storm passing 28 nautical miles to the west of Apalachicola. While this storm is considerably less intense than a Camille (1969) type storm, it represents an unfavorable storm track for Apalachicola Bay. Figures 14, 15, and 16 portray the instantaneous water heights in the Bay at 4 hours before the storm passes close to Apalachicola, while the storm passes, and 3 hours later. Wind arrows are included at Carrabelle and Apalachicola with one bar representing 10 knots. Flooded regions are again specified by lighter shading.

Before the storm hits (fig. 14) strong east winds blow down Saint George Sound and across Apalachicola Bay with wind setup in Saint Vincent Sound and on the west side of the Bay. The setup, however, does not build substantially until the water level external to the Bay begins to rise and negate the flow through the passes driven by the inside-outside height difference. Water is blown out of East Bay. This figure also portrays the effect of the initial rise of the open coast surge propagating into Saint George Sound.

Figure 15 shows the water elevations an hour after the open coast surge has peaked at 11.7 feet near East Pass. Water heights in Apalachicola Bay and East Bay are rapidly increasing as the surge propagates down Saint George Sound. Maximum winds over Apalachicola Bay have produced a strong height gradient towards the north side of the Bay. Overtopping of sections of the barrier island is occurring, but the strong onshore winds maintain the strong inside-outside height difference across the barrier island opposite Apalachicola.

After landfall (fig. 16) the open coast surge is decreasing, draining the Bay while the strong winds in the rear of the storm drive the water up against the higher topography in East Bay.

The composite high-water envelope for this storm is shown in figure 17. It is evident that the maximum elevations are dependent upon the timing of the wind direction and magnitude and propagation of the open coast surge with the occurrence of maximum surge greatly separated in time for different parts of the region.

As a further check on the model formulation, the effect of low-elevation flooding was investigated. Figure 18 shows the high-water envelope generated by rerunning the same storm but assuming that the lateral boundaries of the basin are held fixed so that the surface area does not increase with increasing water elevation. Most areas are not overly sensitive to this assumption except East Bay. In this region heights are 2 feet higher than in the case including flooding. This is the result of neglecting the large extent of low swamp area north of East Bay.

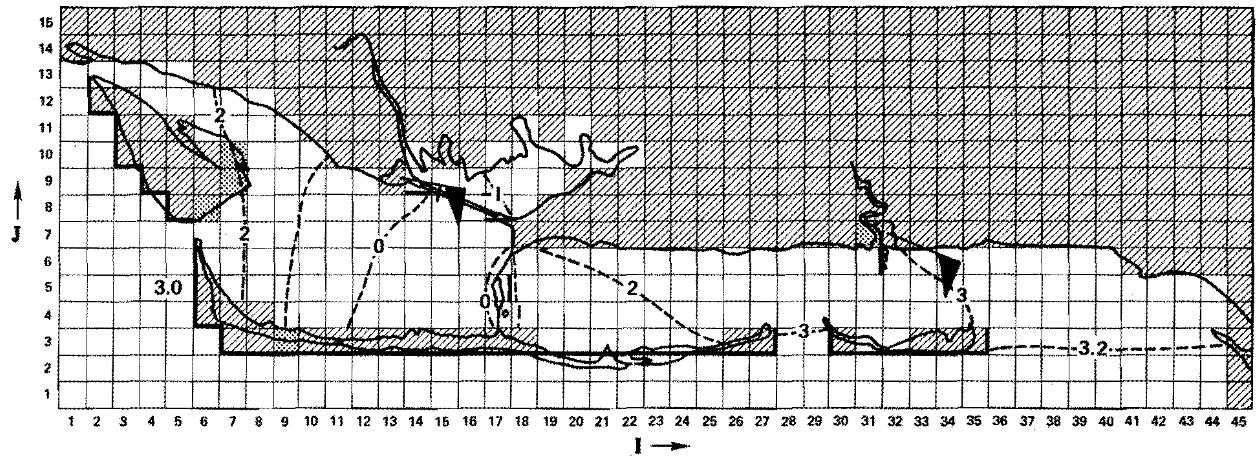

Figure 14.--Instantaneous water heights for a hypothetical storm, 4 hr before landfall. Wind velocities are given for Apalachicola and Carrabelle.

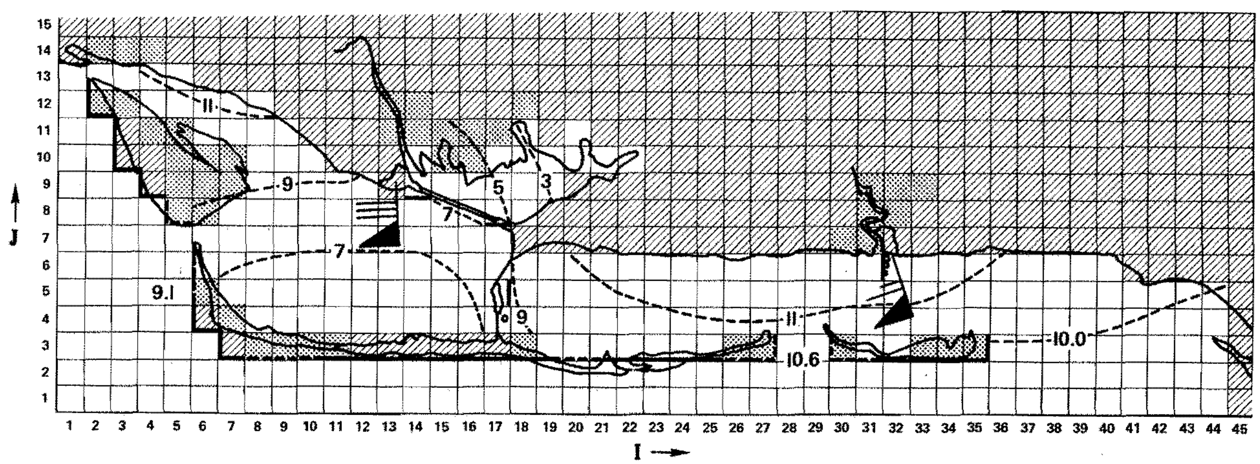

Figure 15.--Instantaneous water heights for a hypothetical storm at closest approach to Apalachicola.

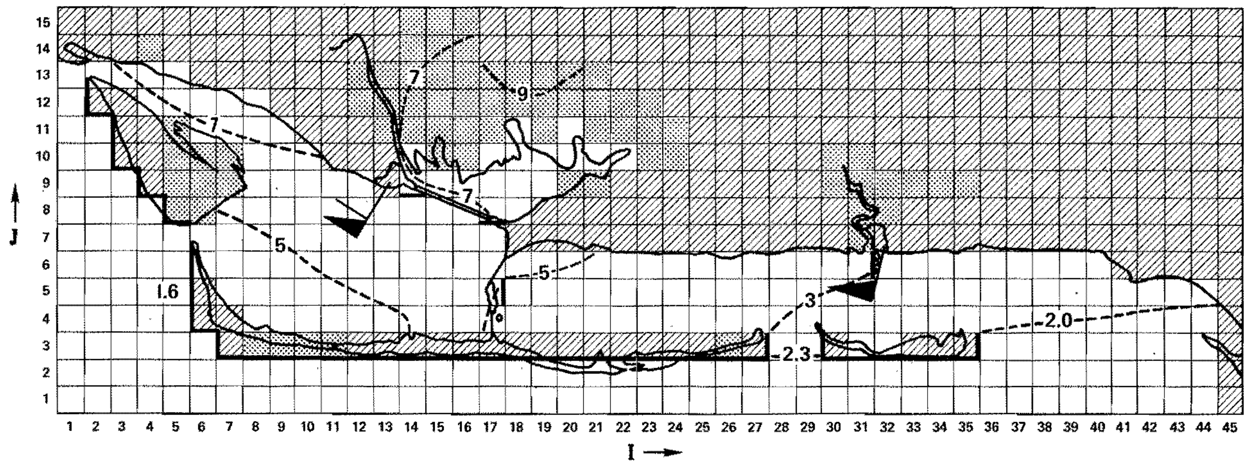

Figure 16.--Instantaneous water heights for a hypothetical storm 3 hr after landfall.

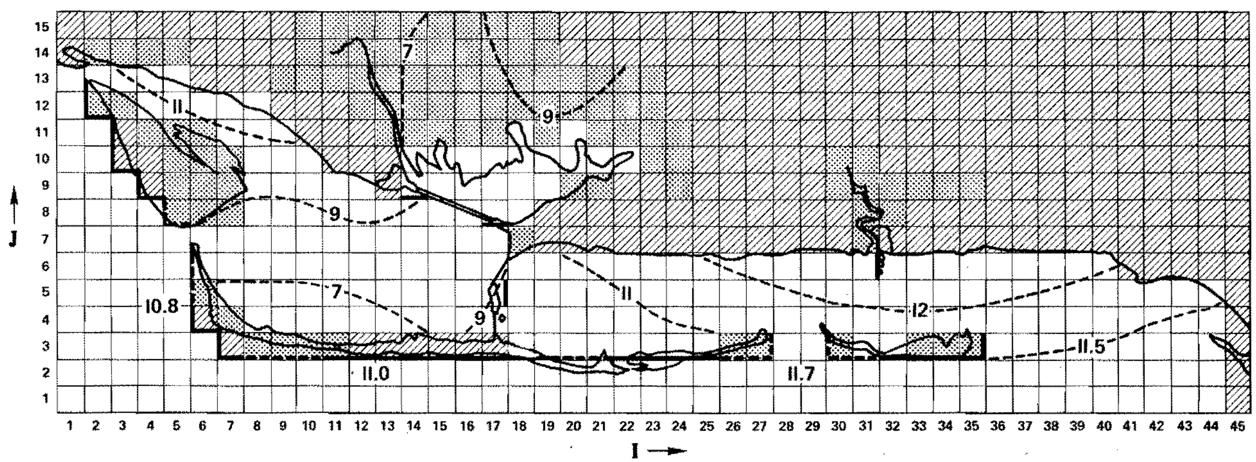

Figure 17.--Composite high-water envelope for hypothetical storm.

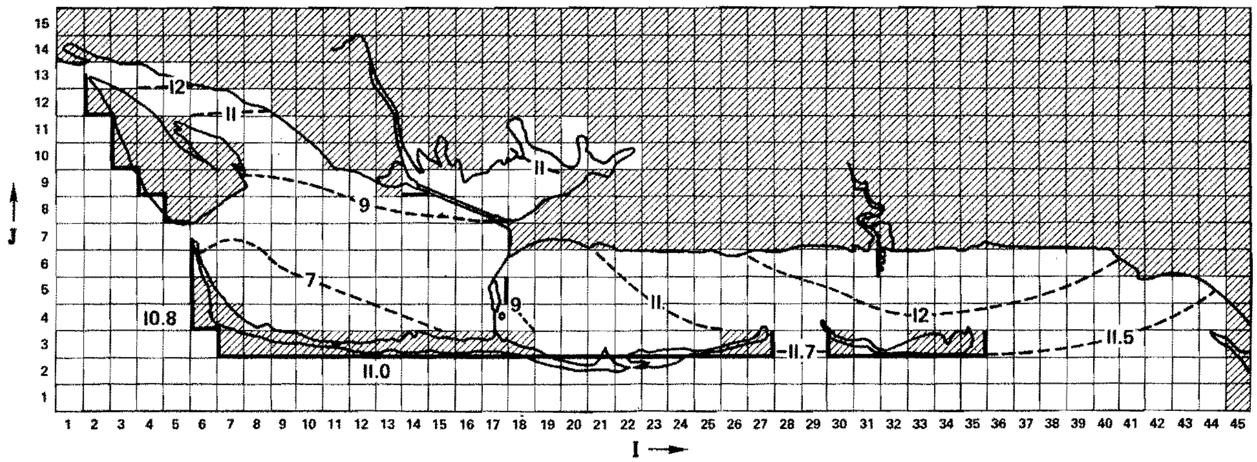

Figure 18.--Composite high-water envelope for hypothetical storm
assuming fixed lateral boundaries.

5.4 Response of Apalachicola Bay to an Ensemble of Climatological Storms

While in sections 5.2 and 5.3 the height values at a given location for a particular storm are subject to the absolute error in estimation of the model coefficients as well as how close the model storm simulates the actual hurricane, analysis of the sensitivity of the model to systematic variations in storm parameters while maintaining the same model assumptions should be indicative of the general response of the Bay. To this end a series of major storms were investigated, with results analyzed for various locations throughout the Bay.

The results are summarized here for four geographic locations A, B, C, D as shown in figure 19. Point A indicates the variation of the open coast value derived from the SPLASH run used as input for the bay model. Saint George Sound showed similar variation as point A with the height value at Carrabelle slightly greater than for the open coast with heights decreasing toward Cat Point. Points B and C show the response inside Apalachicola Bay. Point C is considered representative of the vicinity of Apalachicola. Heights generally increased across the Bay and continued to increase into Saint Vincent Sound. Point D is representative of the East Bay region. Maximum water levels in this region were mostly associated with southwest winds in the rear of storms, coinciding with high surge in Apalachicola Bay. Heights east of point D generally increased until they intersected topography, while in the region to the west of point D and north of Apalachicola, maximum heights generally decreased over the large areas of low terrain.

Figures 20 and 21 show the variation of surge height with variations in central pressure and forward speed, respectively, for a storm with a maximum wind radius of 23 nautical miles traveling perpendicular to the coastline with the center of the storm passing 28 nautical miles to the west of Apalachicola. For variation in central pressure all storms had a forward speed of 13 knots and for variation of forward speed all storms had a central pressure depression of 62 mb.

The response of surge height in the Bay to increasing storm intensity is nearly linear with pressure, as is the open-coast surge, with the inside-outside height difference increasing slightly with storm intensity. A major feature of figure 20 is the response of East Bay. For low open coast surge wind effects over the East Bay become relatively more important, and as the surge increases above 7 feet large areas become subject to flooding, reducing the surge heights relative to other locations.

For a fixed storm size, curve A in figure 21 shows the increase in open coast surge height as the speed of the storm increases. The remaining curves are indicative of two opposing influences in the interior to the Bay. As forward speed decreases, the open coast surge and thus the heights near the entrances decrease. However, with slower speeds, the wind duration and time for filling the basin and back bays are increased. The net effect is that the open coast surge height and storm duration tend to cancel in Apalachicola Bay, producing an almost flat response with forward speed. East Bay is more sensitive than Apalachicola Bay to the duration of high water. In general,

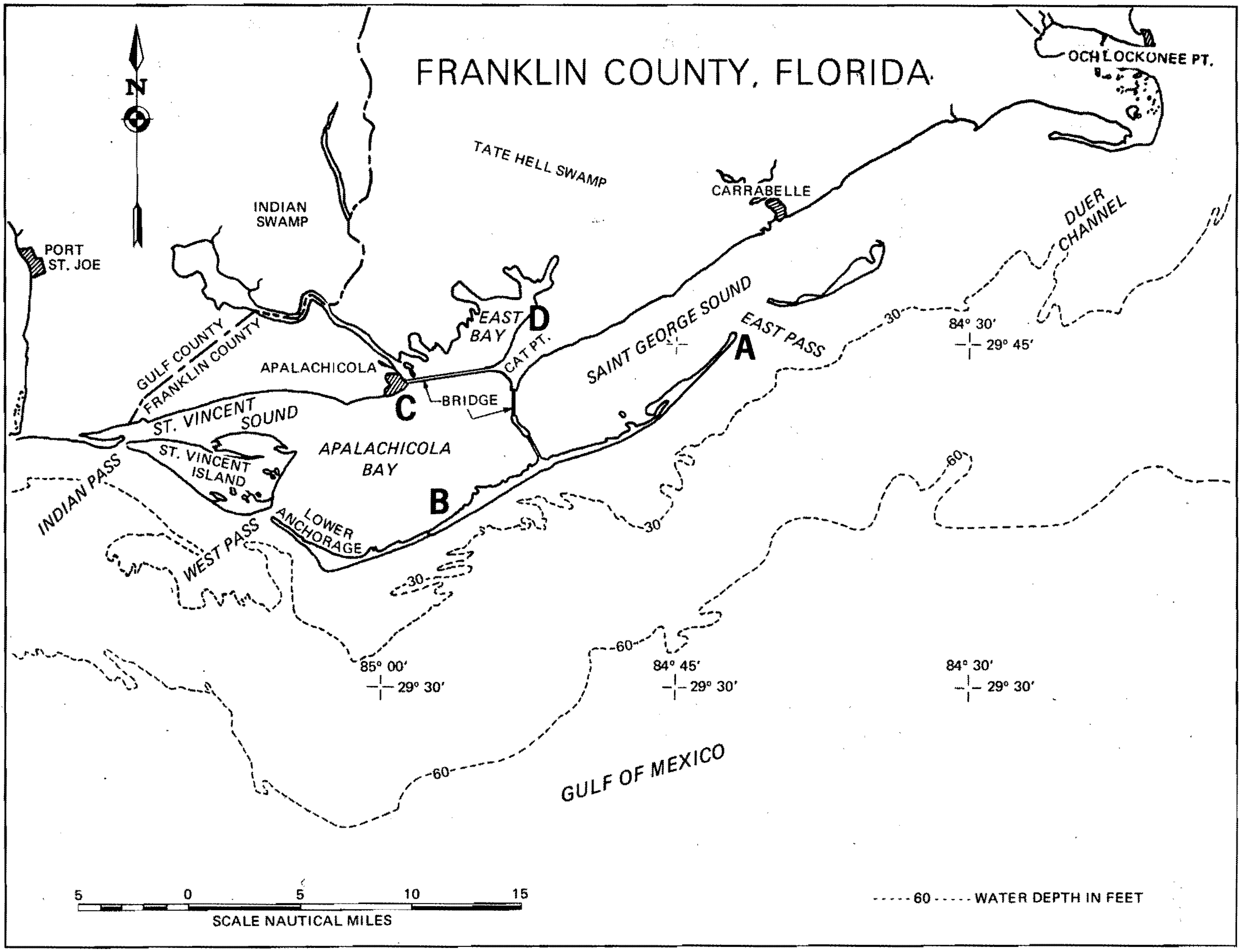

Figure 19.--Reference locations A, B, C, D for figures 20, 21, 22.

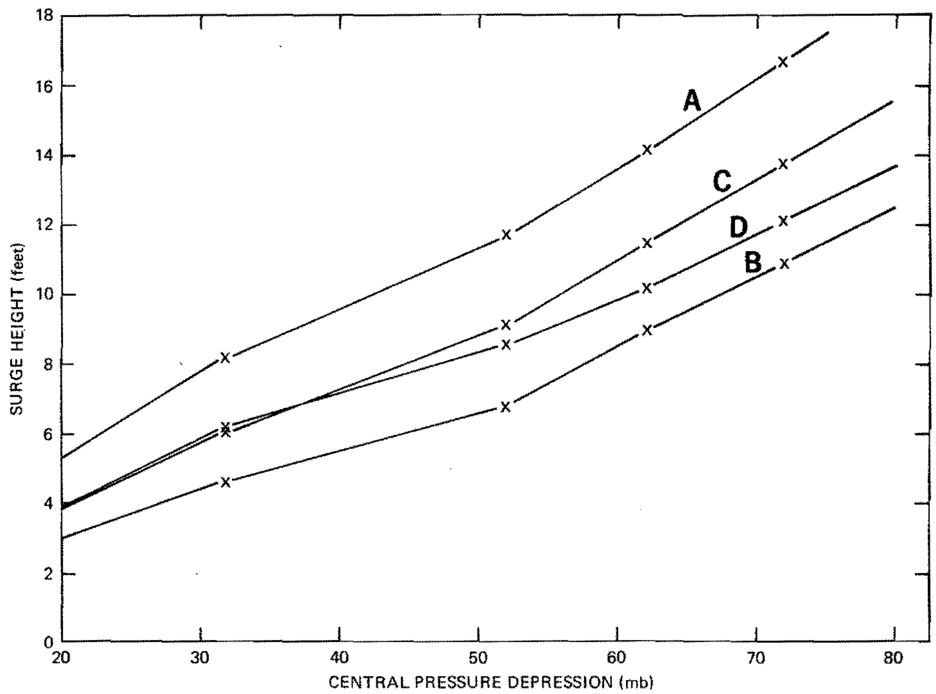

Figure 20.--Surge elevations at four locations as a function of increasing hurricane central pressure with other parameters held fixed.

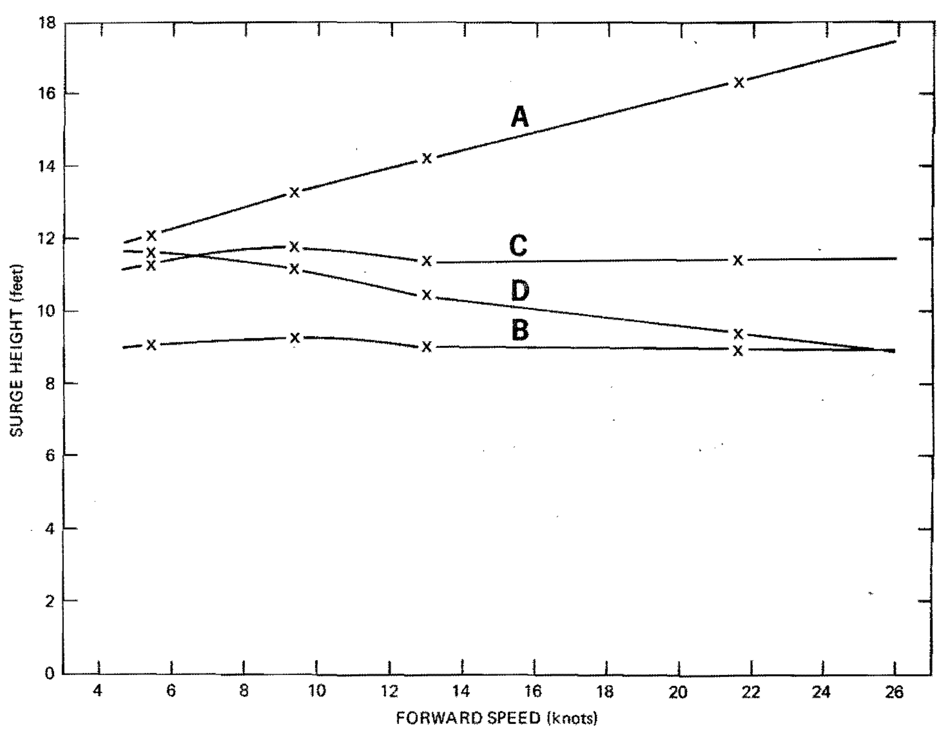

Figure 21.--Surge elevations at four locations as a function of the forward speed of the storm.

as forward speed increases, the outside-inside height difference continually increases.

Figure 22 summarizes the response of the same four locations to an increase of the distance from the storm center to the Bay. The same storm was used at all locations, having a 62-mb drop, a forward speed of 13 knots traveling

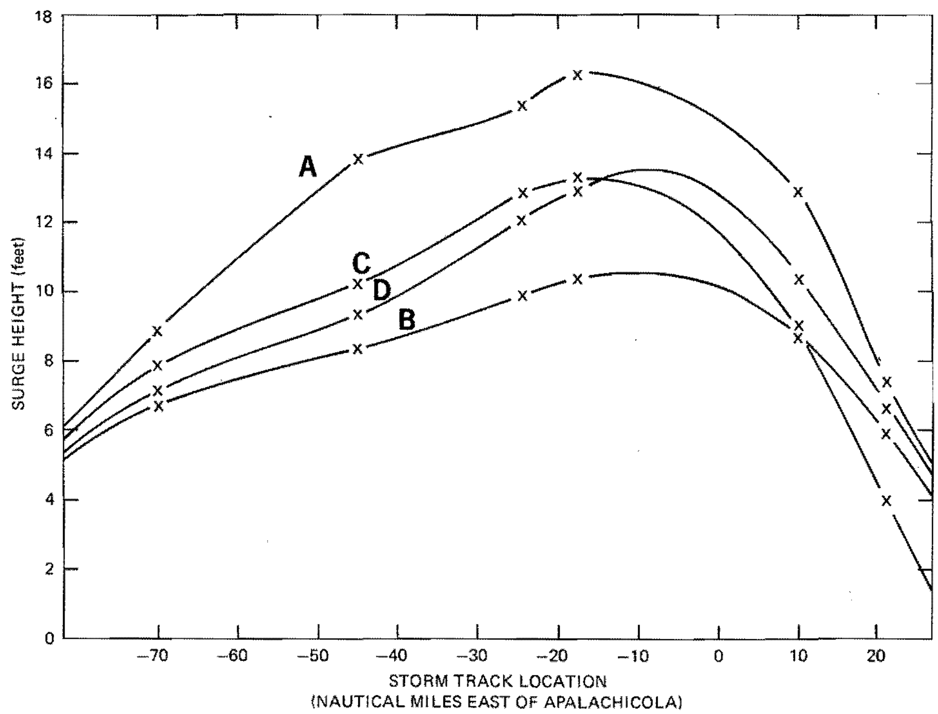

Figure 22.--Surge height variation at four locations as a function of distance of closest approach to Apalachicola.

normal to the coastline, and a radius of maximum winds of 26 nautical miles. The surge heights for storms passing to the west of the Bay exhibited the same general trends as the open coast surge gradient outside the Bay; wind speed and direction are qualitatively similar for these storms. When a storm passes over the Bay, the open coast surge outside the west end of the Bay is reduced and the winds over Apalachicola Bay have an offshore component before landfall, both factors reducing the surge height at Apalachicola and in Saint Vincent Sound. East Bay experiences maximum surge corresponding to maximum southwest winds.

The bay model formulation specifies a unique surge height at each location for a given storm. Sensitivities at points A, B, C, and D to storm parameters of the type suggested in figures 20, 21, and 22 and for other points throughout Franklin County have been utilized as an aid in assessing tide height potential from the hurricane climatology of the region. The results of this work are in a separate report (Ho and Myers 1975). The basic approach is to sum over the combination of storm parameters, each with its own probability of occurence per year, that contribute to giving a certain surge elevation at a particular location. The results of this methodology are summarized by figure 23, which depicts the estimated tidal elevations at the 0.01 per year probability level for Franklin County.

6. CONCLUSIONS AND RECOMMENDATIONS

The primary objective to recommend expected tide height frequencies, especially at the 0.01 per year probability level, is summarized by figure 23.

The present model can be considered the simplest two-dimensional formulation that is capable of resolving the major influences in the Bay. Possible directions for further refinement are specification of meteorological input that accounts for transition over land and a more sophisticated treatment of the bay-ocean interface, particularly in situations in which the interaction with the astronomical tides must be considered. The hydrodynamics of these entrances, with their associated high velocities, strains the assumptions viable in both the bay and on the adjacent shelf.

However, as tools, the best improvement to bay models of this type is their continued consistent application and refinement in different locations and situations. This provides improved insight into the physical phenomena, interpretation of the mathematical and parametric formulation, and experience in application necessary for providing improved estimates.

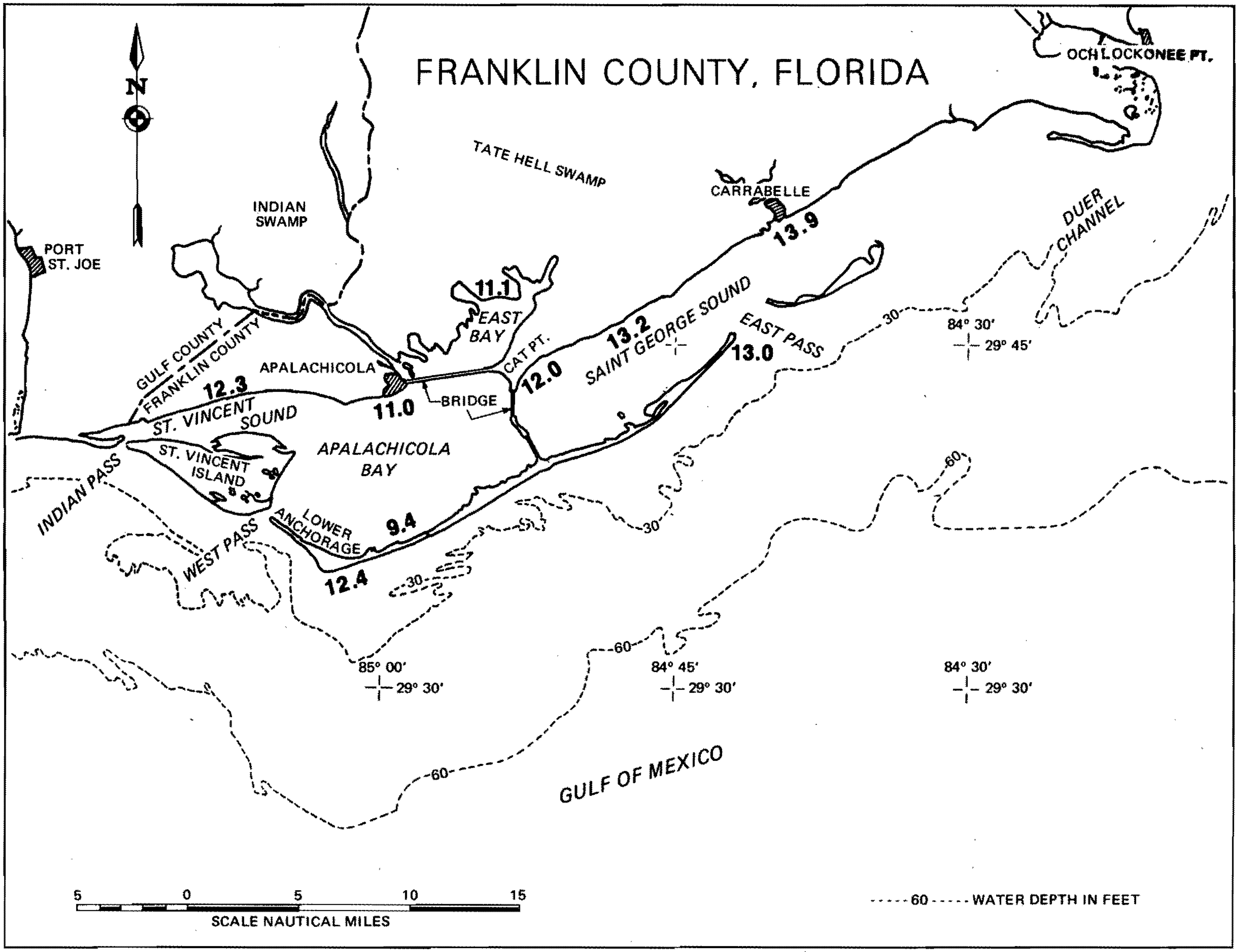

Figure 23.--Estimated tide levels (ft, MSL) at the 0.01 per year probability level. Values represent composite water elevations derived from an ensemble of hypothetical storms.

APPENDIX A: STABILITY ANALYSIS OF IMPLICIT BOTTOM FRICTION

Express the momentum equation in the following form:

$$Q_j^{T+1} - Q_j^{T} + \frac{\Delta X}{\Delta T} C_r^{\,2} \left[\eta_{j+1/2} - \eta_{j-1/2} \right]^{T+\frac{1}{2}} + f_r Q_j^{T+1} = 0 \tag{37}$$

where C_r is the Courant number

$$C_r = \frac{\Delta T}{\Delta X} \sqrt{gH} \tag{38}$$

and f_r is the friction term

$$f_r = \frac{g \Delta T Q avg.}{C_H^{\,2} H_j^{\,2}} \tag{39}$$

The continuity equation is

$$\eta_{j+1/2}^{T+1/2} - \eta_{j+1/2}^{T-1/2} + \frac{\Delta T}{\Delta X} \left[Q_{j+1} - Q_j \right]^{T} = 0. \tag{40}$$

Assume a truncated Fourier solution

$$\begin{Bmatrix} Q \\ \eta \end{Bmatrix} = \begin{Bmatrix} Q \\ \eta \end{Bmatrix}^{*} \exp\,(ijk\Delta X + iT\sigma\Delta T)\,, \quad i \equiv \sqrt{-1} \tag{41}$$

Upon substitution of (41) into (37) and (40),

$$Q^{*} \left[(1 + f_r)\, e^{i\sigma\Delta T} - 1 \right] + \frac{\Delta X}{\Delta T} C_r^{\,2} \eta^{*} e^{(i\sigma\Delta T)/2} \left[e^{(ik\Delta X)/2} - e^{-(ik\Delta X)/2} \right] = 0 \tag{42}$$

and

$$\eta^{*} \left[e^{i\sigma\Delta T} - 1 \right] + Q^{*} \frac{\Delta T}{\Delta X} e^{(i\sigma\Delta T)/2} \left[e^{(ik\Delta X)/2} - e^{-(ik\Delta X)/2} \right] = 0. \tag{43}$$

Setting $\lambda = e^{i\sigma\Delta T}$ and combining gives:

$$(\lambda - 1) \left[(1 + f_r)\, \lambda - 1 \right] + 4 C_r^{\,2} \lambda \sin^2 \left(\frac{k\Delta X}{2}\right) = 0 \tag{44}$$

with roots

$$\lambda_{1,2} = \frac{B \pm \sqrt{B^2 - (1 + f_r)}}{1 + f_r} \tag{45}$$

where

$$B = 1 + \frac{f_r}{2} - 2\, C_r^{\,2} \sin^2 \left(\frac{k\Delta X}{2}\right). \tag{46}$$

The requirement $|\lambda| \leq 1$ is satisfied by $1 + \frac{f_r}{2} \geq |B|$ or

$$C_r = \frac{\Delta T}{\Delta X} \sqrt{gH_j} \leq \left(1 + \frac{f_r}{2}\right)^{1/2} . \tag{47}$$

APPENDIX B: LIST OF SYMBOLS

Symbol	Definitions
A	Cross sectional area of entrance
b	Ratio of pass width to grid length
C_c	Entrance flow contraction coefficient
C_d	Drag coefficient
C_H	Chezy bottom friction coefficient
C_k	Entrance momentum loss coefficient
C_0	Flooding coefficient
C_s	Barrier coefficient
d	Land elevation/depth relative to MLW
D_b	Depth of water over a barrier
E	Ensemble averaging operator
f	Coriolis parameter
F	Forward speed of hurricane
g	Acceleration of gravity
H	Local water depth
I	X grid point location
J	Y grid point location
k	Wave number
L	Hurricane landfall point
MLW	Mean low water
MSL	Mean sea level
p	Pressure
P_a	Atmospheric Pressure
P_0	Central pressure in hurricane
Q_p	Total volume transport through a narrow entrance
Q_n	Q_x or Q_y
Q_x	X component of horizontal transport per unit width
Q_y	Y component of horizontal transport per unit width
r	radial distance from center of storm
R	Radius to maximum winds in hurricane
T	Time

Symbol	Definitions
$T_{2/3}$	Time open coast surge remains above 2/3 its maximum value
u	X component of velocity
u'	Component of turbulent velocity fluctuation
U	Vertically integrated velocity, X component
U_p	Vertically integrated velocity near axis of a narrow channel
v	Y component of velocity
V	Vertically integrated velocity Y component
w	Vertical component of velocity
W	Composite wind velocity
W_a	Wind speed
W_{max}	Maximum wind speed for stationary storm
W_x	X component of wind velocity
W_y	Y component of wind velocity
z_b	Barrier height
α_i	Vertical dependence function of horizontal velocity (9)
α_{ij}	Velocity distribution function (13)
ΔX	Grid length
ΔT	Time step
η	Water elevation relative to datum
η^*	Equivalent height of atmospheric pressure
η_{max}	Maximum open coast surge at a given location
θ	Direction of entry of hurricane relative to coastline
π	3.1416
ρ_a	Density of air
ρ_0	Density of water
σ_E	Frequency-analytical solution
σ_R	Frequency-Richardson lattice
τ_{ij}	Stress component
τ^S	Surface stress
τ^B	Bottom stress
τ^{B*}	Bottom stress with τ^S=0
ϕ	Inflow angle
ψ	Discretized vector variable composed of x and y volume transport components and water surface displacement

APPENDIX C: DOCUMENTATION OF COMPUTER PROGRAM

This section provides a listing of the model program and sample output which was run on the CDC 6600 at the NOAA computer facility at Suitland, Md. Compilation time is 8 seconds, and 24 hours of simulation required 83 seconds of CPU time with a CM requirement of 62K octal.

A list of variable definitions is given in Section C.1. All input except bathymetry is internal to the program. Storm input consists of forward speed, FRDS; radius to maximum winds, RM; central pressure deficit, PD; maximum stationary storm wind speed, VR; landfall location, LNDFL; path orientation, ALPHA; maximum open coast surge amplitude, A; and surge duration parameter, T23.

The program listing is provided for completeness; it has not been optimized nor specifically programed for operational use or modification. Any changes such as application to other bays should be made with care.

C.1 List of Program Variables

"IV" specifies intermediate variables. Dimensions are given in comments in the listing.

Variables	Definitions
A	Amplitude of open coast surge
AH	IV
ALPHA	Angle--Storm path and J-Axis
AR	IV
ARG	IV
ARGMAX	IV
AWPASS	Depth of West Pass
AXPASS	Depth of Indian Pass
CALPHA	IV
CC	Contraction coefficient for narrow passes
CD	Drag coefficient
CHEZY	IV
CH1	Chezy coefficient--deep water
CH2	Chezy coefficient--tidal flats
CH3	Chezy coefficient--land
CH4	IV
CK	Momentum loss coefficient for narrow passes
CO	Flooding constant
CPHI	IV
CS	Barrier constant
CTHETA	IV
C2	IV
D	Land elevation--MLW
DT	Time step
DTD	IV
DWPASS	Mean Depth--West Pass
DX	Grid length

Variables	Definitions	Variables	Definitions
DXPASS	Mean Depth--Indian Pass	RAIN	Rainfall
ETA	Water elevation	RM	Radius maximum wind
ETAMAX	Maximum surge	SALPHA	IV
F	IV	SPHI	IV
FLUX	IV	SSSG	IV
FLUXX	IV	STHETA	IV
FLUXY	IV	T	Time
FORCE	IV	TEXIT	IV
FR	IV	TIME	IV
FRDS	Storm speed	TMLDF	Time before landfall
FX	IV	TMN	MSL-MLW difference
G	Acceleration of gravity	TSTA	IV
GAGE	Storage for gages	TSTB	IV
GPAD	IV	TSTC	IV
H	Water depths	TSTD	IV
HMAX	Maximum water depth	TSTOP	Termination time
I, J, K	Counters	T23	Time during which A is greater than 0.66A
IMAX	Maximum grid point	V	Wind speed
IM1	IV	VR	Maximum wind speed
INDEX	Counter	VY	IV
JM1	IV	VX	IV
JMAX	Maximum grid point	WDIS	IV
LGAGE	IV	W	Height barrier normal to coast
LNDFL	Landfall location	WX	IV
NTLDF	IV	WPASS	Velocity through West Pass
OMEGA	IV	X	I component of distance from storm center
PD	Central pressure depression	WY	IV
PG	IV	XPASS	Velocity through Indian Pass
PGX	IV	Y	J component of distance from storm center
PGY	IV	Z	Height of barrier parallel to coast
PHI	Inflow angle		
QX	X-transport		
QY	Y-transport		
R	Distance from storm center		

C.2 Program Listing

```
PROGRAM      APLCH                                   CDC 6600 FTN V3.0-324  OPT=2  01/10/75  12.03.03.      PAGE     1

                 PROGRAM APLCH(INPUT,OUTPUT)
                DIMENSION QX(46,15),QY(46,15),ETA(46,15),H(46,15),D(46,15),
               1F(46,15)          ,Z(46,15),W(46,15),ETAMAX(46,15)
               2,WY(46,15),WX(46,15)
               3,PGX(46,15),PGY(46,15),CHEZY(46,15)
               7,GAGE(900,7)
         CCC  MODEL COMPUTES IN ENGLISH UNITS
         CCCC     LOAD DATA
                DATA IMAX,JMAX/46,15/
                IM1=IMAX-1
                JM1=JMAX-1
                DATA G,CO,CS,CH1,CH2,CH3/32.2,0.70,0.70,100.,80.,25./
                SSSG=SQRT(G)
                TMN=0.9
                DX=6076.
                 HMAX=40.
                DTD=G*HMAX
                DTD=SQRT(DTD)
                DT=DX/(1.414214*DTD)
         CCCBATHYMETRY
                DO 2 I=1,IMAX
                READ 2222,(D(I,J),J=1,JMAX)
            2    CONTINUE
          2222 FORMAT(15F3.0)
         CCCC     PASS PARAMETERS ****
                CC=0.9
                CK=0.35
                CH4=G/CH1**2
                DWPASS=38.
                DXPASS=15.
                K=0
          108     CONTINUE
                K=K+1
         CC         STORM PARAMETERS
         CCC    FORWARD SPEED STMPH, RM NAUTICAL MILES VR STMPH
         CCC  PRESSURE DROP IN MB
         CCC     CCC LNDFL IN NAUTICAL MILES ALONG X AXIS
         CCC    TMLDF  IS HRS BEFORE  LANDFALL
         CCC SURGE PAR---IS A+20 GT HMAX$$    T23 IS FUNCTION OF RM AND FRDS
         CCC      ANGLE MEASURED LEFT FROM NORMAL
                FRDS=15.
                RM=22.85
                T23=3.2
                LNDFL=-21
                PD=52.
                A=11.7
                VR=88.9
                TMLDF=16.
                RAIN=0.
                ALPHA=0.
         CCC    PRINT PARAMETERS
                PRINT 4,((D(I,J),J=1,JMAX),I=1,IMAX)
            4   FORMAT(1H1,10X,*TOPOGRAPHY*/(10X,15F5.0))
                PRINT 5,DX,DT,CH1,CH2,CH3,CO,CS,CK,
               1FRDS,VR,RM,LNDFL,PD,T23,A,ALPHA
```

```
      5   FORMAT(5X,*PARAMETERS---UNITS ARE IN  FOOT-SECONDS*/10X,*SPACE
         1GRID  TIME STEP FRICTION-DEEP,FLATS,WOODS  FLOODING CONSTANTS
         ACO,CS    ENTRANCE COEF CK*/
         210X,8(6X,F7.2),//,20X,* STORM PARAMETERS*/,
         32X,* FSPEED(MPH) MXVELOCITY(MPH) RADIUS M WIND(NM) LANDFALL(NM)
         4PRESS(MB)    T23(HRS)    AMP(FT)  ALPHA(RAD)*/
         55X,3(F6.1,9X),I7,9X,4(F7.3,6X))
CCCCCSCALE VARIABLES
          RM=RM*6076.
          FRDS=1.4666667*FRDS
          VR=1.4666667*VR
          CALPHA=COS(ALPHA)
          SALPHA=SIN(ALPHA)
          NTLDF=FRDS*CALPHA*3600.*TMLDF/DX
          TSTOP=1.5*3600.*TMLDF
          TEXIT=3600.*TMLDF
          T23=0.5*T23*3600.
          OMEGA=0.66/T23
          PD=0.033455*PD
CCCCINITIALIZE ARRAYS
          T=0.
          INDEX=0
          ARGMAX=0.
          LGAGE=0
          WPASS=0.
          XPASS=0.
          DO 1 I=1,IMAX
          DO 1 J=1,JMAX
          QX(I,J)=QY(I,J)=0.
          PGY(I,J)=0.
          PGX(I,J)=0.
          WX(I,J)=WY(I,J)=0.
          ETAMAX(I,J)=-0.00001
          ETA(I,J)=TMN
          H(I,J)=TMN-D(I,J)
          IF(D(I,J).GT.TMN) ETA(I,J)=D(I,J)-0.00001
          CHEZY(I,J)=CH1/SSSG
          IF(D(I,J).GT.-2.5) CHEZY(I,J)=CH2/SSSG
          IF(D(I,J).GT.0.5) CHEZY(I,J)=CH3/SSSG
CCC        SET BARRIERS
          Z(I,J)=-1.
          W(I,J)=-1.
          IF(J.EQ.JMAX) Z(I,J)=D(I,J)
          IF(I.EQ.2) W(I,J)=D(I,J)
          IF(I.EQ.IMAX) W(I,J)=100.
      1    CONTINUE
          DO 6 I=2,IMAX
          DO 6 J=2,JMAX
          IF(D(I,J).GT.23.5.OR.D(I,J).LT.22.5) GO TO 6
          IF(D(I-1,J).LT.22.5) W(I,J)=D(I-1,J)
          IF(D(I,J-1).LT.22.5) Z(I,J)=D(I,J-1)
          IF(D(I-1,J).LT.22.5.OR. D(I,J-1).LT.22.5) ETA(I,J)=0.98
      6    CONTINUE
          Z(17,8) = 16.
          Z(14,9)=16.
```

```
      W(18,5)=16.
      W(32,6)=10.
      Z(35,3) = 18.
      Z(34,3) = 18.
      Z(33,3) = 25.
      Z(32,3) = 25.
      Z(31,3) =  8.
      Z(30,3)=7.
      Z(27,3)=7.
      Z(26,3)=8.
      Z(25,3) = 12.
      Z(24,3) = 25.
      Z(23,3) = 25.
      Z(22,3) = 15.
      Z(21,3)=11.
      Z(20,3)=11.
      Z(19,3)=16.
      Z(18,3) = 18.
      Z(17,3) = 18.
      Z(16,3)=18.
      Z(15,3) = 20.
      Z(14,3) = 24.
      Z(13,3) = 24.
      Z(12,3) = 16.
      Z(11,3) = 12.
      Z(10,3)=7.
      Z( 9,3) =  6.
      Z( 8,3) =  8.
      Z(7,3)=15.
      Z(6,4)=15.
      Z( 5,8) = 10.
      Z(4,9)=15.
      Z(3,10)=13.
      Z(2,12)=12.
      W(36,3) = 15.
      W(30,3)=7.
      W(28,3)=7.
      W(7,3)=15.
      W(6,4)=15.
      W(6,5)=7.
      W(6,6)=6.
      W(5,8)=10.
      W(4,9)=15.
      W(3,10)=13.
      W(3,11)=13.
      W(2,12)=12.
CCC   LOOP FOR INTEGRATION
 100    CONTINUE
      T=T+DT
      INDEX=INDEX+1
CCCC    NEW ETA
      DO 20 I=2,IM1
      DO 20 J=3,JM1
      IF(D(I,J).GT.22.5)  GO TO 20
      FLUXX=QX(I+1,J)-QX(I,J)
```

```
      FLUXY=QY(I,J+1)-QY(I,J)
      FLUX=FLUXX/DX+FLUXY/DX-RAIN
      ETA(I,J)=ETA(I,J)-DT*FLUX
   20  CONTINUE
      AR=OMEGA*(T-TEXIT)
      AR=A*(1.0-TANH(AR)**2)
      DO 22 I=1,IMAX
      GRAD=1.0
      IF(I.GT.30) GRAD=1.0-0.06*(I-30)/15
      IF(I.LT.20)   GRAD=0.90+0.005*I
      ARG=TMN+GRAD*AR
      ETA(I,1) =ARG
      ETA(I,2)=ARG
      DO 22 J=2,JMAX
      IF(D(I,J).GT.800.) ETA(I,J)=ARG
  22   CONTINUE
C     OUTPUT ***********
      IF(MOD(INDEX,100).EQ.0) GO TO 900
 901   CONTINUE
      IF(MOD(INDEX,4).NE.0) GO TO 951
      TIME=T/3600.
      LGAGE=LGAGE+1
      GAGE(LGAGE,1)=TIME
      GAGE(LGAGE,2)=ETA(29,4)
      GAGE(LGAGE,3)=ETA(31,6)
      GAGE(LGAGE,4)=ETA(18,6)
      GAGE(LGAGE,5)=ETA(13,8)
      GAGE(LGAGE,6)=ETA( 8,4)
      GAGE(LGAGE,7)=ETA( 6,7)
 951       CONTINUE
CCC  NEW DEPTHS
      DO 94 I=2,IM1
      DO 94 J=2,JM1
      IF(D(I,J).GT.22.5)  GO TO 94
      H(I,J)=ETA(I,J)-D(I,J)
      IF(H(I,J).LT.0.) GO TO 94
      IF(ETA(I,J).GT.ETAMAX(I,J)) ETAMAX(I,J)=ETA(I,J)
  94   CONTINUE
CCCCC WIND FIELD COMPUTATION
      IF(MOD(INDEX,4).NE.3) GO TO 49
      DO  41 J=3,JM1
      DO 41 I=2,IM1
      IF(H(I,J).LT.0.99) GO TO 42
      Y=(J+NTLDF)*DX-CALPHA*FRDS*T
      X=(I-LNDFL)*DX-SALPHA*FRDS*(T-TEXIT)
      R=X**2+Y**2
      IF(R.LT.10.) R=10.
      WDIS=R+RM**2
      R=SQRT(R)
      CTHETA=X/R
      STHETA=Y/R
CC    INFLOW  ANGLE OF 22DEGREES
CCCC AT LARGE R  PHI  IS 17DEGREES
      PHI=R/RM
      IF(PHI.GT.4.4) GO TO 44
```

```
          PHI=0.28564*PHI**3*EXP(-PHI)
    44    IF(PHI.GT.4.4) PHI=0.29670597
          CPHI=COS(PHI)
          SPHI=SIN(PHI)
          PG=PD*RM*EXP(-RM/R)/R**2
          PG=PG*DX
          PGX(I,J)=PG*X/R
          PGY(I,J)=PG*Y/R
          WDIS=R*RM/WDIS
          VX=-WDIS*(2.0*VR*(STHETA*CPHI+CTHETA*SPHI)-FRDS*SALPHA)
          VY=WDIS*(2.0*VR*(CTHETA*CPHI-STHETA*SPHI)+FRDS*CALPHA)
          V=VX**2+VY**2
          V=SQRT(V)
          CD=1.62
          IF(V.GT.25.) CD=1.62+1.13*(V-25.)/25.
          IF(V.GT.50.) CD=2.75+0.75*(V-50.)/100.
          CD=CD*0.000001
          WX(I,J)=CD*V*VX
          WY(I,J)=CD*V*VY
          GO TO 43
    42     CONTINUE
          WX(I,J)=0.
          WY(I,J)=0.
     43     CONTINUE
     41    CONTINUE
     49    CONTINUE
   CCC   FRICTION FACTOR FOR QY
          DO 61 J=3,JM1
          DO 61 I=2,IM1
          IF(D(I,J).GT.22.5) GO TO 61
          F(I,J)=QX(I,J)+QX(I+1,J)+QX(I,J-1)+QX(I+1,J-1)
          F(I,J)=(0.25*F(I,J))**2
     61     CONTINUE
   CC    QX DETERMINATION
          DO 50 I=2,IM1
          DO 50  J=3,JM1
   CCC    FLOODING ROUTINE FOR QX
          IF(W(I,J).GT.  0.) GO TO 55
   CCCC   BOTH AREAS DRY
          IF(H(I,J).LT.0..AND.H(I-1,J).LT.0.)QX(I,J)=0.
          IF(H(I,J).LT.0..AND.H(I-1,J).LT.0.) GO TO 59
   CCCC     NORMAL CASE
          TSTB=ETA(I-1,J)-D(I,J)
          TSTC=ETA(I,J)-D(I-1,J)
          IF(H(I,J).GT.0..AND.H(I-1,J).GT.0..AND.TSTB.GT.0..AND.TSTC.GT.0.)
         1 GO TO 57
   CCC     ADVANCING OR RECEEDING TIDE
          IF(H(I,J).LT.0.) GO TO 501
          IF(H(I-1,J).LT.0.) GO TO 503
          QX(I,J)=CO*H(I-1,J)*SQRT(G*H(I-1,J))
          IF(TSTC.GT.0.) QX(I,J)=-CO*H(I,J)*SQRT(G*H(I,J))
          GO TO 59
   501     CONTINUE
          IF(TSTB.LT.0.) QX(I,J)=0.
          IF(TSTB.LT.0.) GO TO 59
```

```
      IF(TSTB.GT.H(I-1,J)) TSTB=H(I-1,J)
      QX(I,J)=CO*TSTB*SQRT(G*TSTB)
      GO TO 59
  503   CONTINUE
      IF(TSTC.LT.0.) QX(I,J)=0.
      IF(TSTC.LT.0.) GO TO 59
      IF(TSTC.GT.H(I,J)) TSTC=H(I,J)
      QX(I,J)=-CO*TSTC*SQRT(G*TSTC)
      GO TO 59
   55  CONTINUE
CCC   BARRIER TEST
      TSTC=ETA(I,J)-W(I,J)
      TSTB=ETA(I-1,J)-W(I,J)
      IF(TSTB.LT.0..AND.TSTC.LT. 0.)QX(I,J)=0.
      IF(TSTB.LT.0..AND.TSTC.LT. 0.) GO TO 59
      IF(TSTB.GT.0..AND.TSTC.GT.0.) GO TO 555
      IF(TSTB.GT.0.) QX(I,J)=CO*TSTB*SQRT(G*TSTB)
      IF(TSTC.GT.0.) QX(I,J)=-CO*TSTC*SQRT(G*TSTC)
      GO TO 59
  555    CONTINUE
      TSTA=ETA(I,J)-ETA(I-1,J)
      TSTD=ABS(TSTA)
      TSTB=(TSTB+TSTC)/2.
      QX(I,J)=CS*TSTB*SQRT(G*TSTD)
      IF(TSTA.GT.0.) QX(I,J)=-QX(I,J)
      GO T0 59
   57  CONTINUE
CCCC  NORMAL CASE
      IF(H(I,J).LT.0.99) WX(I,J)=0.
      IF(H(I-1,J).LT.0.99) WX(I,J)=0.
      AH=H(I,J)+H(I-1,J)
      AH=AH/2.
      CZ=CHEZY(I,J)*CHEZY(I-1,J)
      FORCE=ETA(I,J)-ETA(I-1,J)+PGX(I,J)
      FORCE=-G*AH*FORCE/DX+WX(I,J)
      FORCE=DT*FORCE
      FR=QY(I,J)+QY(I-1,J)+QY(I,J+1)+QY(I-1,J+1)
      FR=(0.25*FR)**2
      FX=QX(I,J)**2
      FX=SQRT(FR+FX)/(CZ*AH**2)
      FX=1.+DT*FX
      QX(I,J)=QX(I,J)+FORCE
      QX(I,J)=QX(I,J)/FX
   59  CONTINUE
   50   CONTINUE
CCC   QY DETERMINATION
      DO  60 J=3,JMAX
      DO 60 I=2,IM1
CCCC   FLOODING ROUTINE QY
      IF(Z(I,J).GT.0.) GO TO 65
CCC    BOTH AREAS DRY
      IF(H(I,J).LT.0..AND.H(I,J-1).LT.0.) QY(I,J)=0.
      IF(H(I,J).LT.0..AND.H(I,J-1).LT.0.) GO TO 69
      TSTB=ETA(I,J-1)-D(I,J)
      TSTC=ETA(I,J)-D(I,J-1)
```

```
CCC    NORMAL CASE
       IF(H(I,J).GT.0..AND.H(I,J-1).GT.0..AND.TSTB.GT.0..AND.TSTC.GT.0.)
      1 GO TO  67
CCC     ADVANCING OR RECEEDING TIDE
       IF(H(I,J).LT.0.) GO TO 601
       IF(H(I,J-1).LT.0.) GO TO 603
       QY(I,J)=CO*H(I,J-1)*SQRT(G*H(I,J-1))
       IF(TSTC.GT.0.) QY(I,J)=-CO*H(I,J)*SQRT(G*H(I,J))
       GO TO 69
  601   CONTINUE
       IF(TSTB.LT.0.) QY(I,J)=0.
       IF(TSTB.LT.0.) GO TO 69
       IF(TSTB.GT.H(I,J-1)) TSTB=H(I,J-1)
       QY(I,J)=CO*TSTB*SQRT(G*TSTB)
       GO TO 69
  603     CONTINUE
       IF(TSTC.LT.0.) QY(I,J)=0.
       IF(TSTC.LT.0.) GO TO 69
       IF(TSTC.GT.H(I,J)) TSTC=H(I,J)
       QY(I,J)=-CO*TSTC*SQRT(G*TSTC)
       GO TO  69
   65     CONTINUE
CCC    BARRIER TEST
       TSTB=ETA(I,J-1)-Z(I,J)
       TSTC=ETA(I,J)-Z(I,J)
       IF(TSTB.LT.0..AND.TSTC.LT.0.) QY(I,J)=0.
       IF(TSTB.LT.0..AND.TSTC.LT.0.) GO TO 69
       IF(TSTB.GT.0..AND.TSTC.GT.0.) GO TO 655
       IF(TSTC.GT.0.) QY(I,J)=-CO*TSTC*SQRT(G*TSTC)
       IF(TSTB.GT.0.) QY(I,J)=CO*TSTB*SQRT(G*TSTB)
       GO TO 69
  655   CONTINUE
       TSTA=ETA(I,J)-ETA(I,J-1)
       TSTD=ABS(TSTA)
       TSTB=(TSTB+TSTC)/2.
       QY(I,J)=CS*TSTB*SQRT(G*TSTD)
       IF(TSTA.GT.0.) QY(I,J)=-QY(I,J)
       GO TO 69
   67  CONTINUE
CCCC   NORMAL CASE
       IF(H(I,J-1).LT.0.99) WY(I,J)=0.
       IF(H(I,J).LT.0.99) WY(I,J)=0.
       AH=H(I,J)+H(I,J-1)
       AH=AH/2.
       C2=CHEZY(I,J)*CHEZY(I,J-1)
       FORCE=ETA(I,J)-ETA(I,J-1)+PGY(I,J)
       FORCE=-G*AH*FORCE/DX+WY(I,J)
       FX=QY(I,J)**2
       FX=SQRT(FX+F(I,J))/(C2*AH**2)
       FX=1.+DT*FX
       QY(I,J)=QY(I,J)+DT*FORCE
       QY(I,J)=QY(I,J)/FX
   69   CONTINUE
    60  CONTINUE
CCC     BOUNDARY FLUX DETERMINATION
```

```
            AWPASS=DWPASS+0.5*(ETA(5,7)+ETA(6,7))
            FORCE=ETA(6, 7)-ETA(5, 7)+PGX(6, 7)
            FORCE=-G*FORCE/DX+WX(6 ,7)/AWPASS
            FORCE=DT*FORCE
            FX=ABS(WPASS)
            FX=1.0+DT*FX*(0.5*(1.+CK)/DX+CH4/AWPASS)
            WPASS=WPASS+FORCE
            WPASS=WPASS/FX
            QX(6, 7)=CC*0.30*AWPASS*WPASS
            AXPASS=DXPASS+0.5*(ETA(1,13)+ETA(2,13))
            FORCE=ETA(2,13)-ETA(1,13)+PGX(2,13)
            FORCE=-G*FORCE/DX+WX(2,13)/AXPASS
            FORCE=DT*FORCE
            FX=ABS(XPASS)
            FX=1.0+DT*FX*(0.5*(1.+CK)/DX+CH4/AXPASS)
            XPASS=XPASS+FORCE
            XPASS=XPASS/FX
            QX(2,13)=CC*0.075*AXPASS*XPASS
            IF(T.LT.TSTOP) GO TO 100
            GO TO 101
      C     OUTPUT ***********
       900    CONTINUE
            TIME=T/3600.
            DO 920 I=2,IM1
            DO 920 J=1,JMAX
            F(I,J)=ETA(I,J)
            IF(H(I,J).LT.0.15)  F(I,J)=88.8
       920  CONTINUE
            PRINT 1040,TIME,((F(I,J),J=1,JMAX),I=2,IM1)
       1040 FORMAT(1H1,10X,*TIME IN HRS.*,F10.2,/,(2X,F5.1,10X,14F5.1))
            GO TO 901
       101   CONTINUE
            DO 910 I=2,IM1
            GRAD=1.0
            IF(I.GT.30) GRAD=1.0-0.06*(I-30)/15
            IF(I.LT.20)    GRAD=0.90+0.005*I
            DO 910 J=2,JMAX
            IF(D(I,J).GT.99.) ETAMAX(I,J)=TMN+GRAD*A
       910    CONTINUE
            PRINT 1043,((D(I,J),J=2,JMAX),I=2,IM1)
       1043  FORMAT(1H1,*    TOPOGRAPHY   VALUES ABOVE MLW
           1*,(//2X,14F5.1))
            PRINT 1045,((ETAMAX(I,J),J=2,JMAX),I=2,IM1)
       1045  FORMAT(1H1,*      MAXIMUMUM WATER LEVEL PRODUCED BY THIS STORM
           1*,(//2X,14F5.1))
            DO 103 I=2,IM1
            DO 103 J=2,JMAX
            F(I,J)=ETAMAX(I,J)-D(I,J)
            IF(F(I,J).LT.0.) F(I,J)=0.0
            IF(D(I,J).LT.0.) F(I,J)=888.8
       103    CONTINUE
            PRINT 1048,((F(I,J),J=2,JMAX),I=2,IM1)
       1048 FORMAT(1H1,*    FLOODING DEPTH   888.8 INDICATES BELOW MLW*
           1 ,(//2X,14F5.1))
            PRINT 1049,(GAGE(I,1),GAGE(I,2),GAGE(I,3),GAGE(I,4),GAGE(I,5),
```

```
         1GAGE(I,6),GAGE(I,7),I=1,LGAGE)
    1049 FORMAT(1H1,* TIME      DOG ID     CARBELE    CAT PT    APLCLA     L
         1ANCHR  W PASS*,/,(7(2X,F8.2)))
         STOP
445      END
```

TOPOGRAPHY

999.	999.	999.	999.	999.	999.	999.	999.	999.	999.	999.	999.	999.	10.	10.
999.	999.	999.	999.	999.	999.	999.	999.	999.	999.	999.	8.	-4.	10.	10.
999.	999.	999.	999.	999.	999.	999.	999.	999.	13.	12.	10.	-2.	10.	10.
999.	999.	999.	999.	999.	999.	999.	999.	15.	13.	10.	0.	-2.	10.	10.
999.	999.	999.	999.	999.	999.	999.	6.	7.	7.	4.	-2.	-2.	15.	10.
999.	999.	999.	9.	2.	-3.	-18.	3.	2.	3.	0.	-5.	15.	10.	4.
999.	999.	9.	5.	-10.	-10.	-10.	-6.	2.	2.	-5.	-6.	15.	10.	4.
999.	999.	2.	-5.	-10.	-4.	-4.	-5.	-5.	-5.	-5.	0.	15.	8.	4.
999.	999.	2.	-8.	-10.	-8.	-8.	-6.	-5.	-5.	-3.	15.	4.	4.	4.
999.	999.	2.	-11.	-10.	-9.	-7.	-6.	-4.	-3.	15.	15.	4.	4.	4.
999.	999.	2.	-12.	-10.	-9.	-7.	-7.	-4.	15.	15.	10.	6.	4.	4.
999.	999.	8.	-10.	-10.	-8.	-7.	-6.	-2.	15.	8.	2.	2.	4.	4.
999.	999.	15.	-8.	-9.	-8.	-7.	-3.	15.	12.	1.	2.	4.	4.	4.
999.	999.	15.	-8.	-8.	-7.	-7.	-5.	0.	0.	1.	4.	4.	4.	4.
99.	999.	12.	-8.	-9.	-8.	-7.	-6.	-3.	1.	2.	4.	4.	4.	4.
999.	999.	10.	-5.	-10.	-7.	-5.	-5.	-4.	1.	2.	2.	4.	4.	4.
999.	999.	10.	-9.	-8.	-7.	-5.	-5.	-3.	0.	1.	2.	4.	10.	13.
999.	999.	5.	-4.	-6.	-3.	11.	-1.	-5.	-2.	0.	2.	5.	10.	13.
999.	999.	-7.	-9.	-8.	-8.	20.	10.	-3.	-3.	3.	7.	9.	9.	13.
999.	999.	-7.	-9.	-10.	-10.	20.	15.	4.	-2.	-1.	2.	7.	12.	15.
999.	999.	0.	-10.	-8.	-9.	20.	19.	8.	-2.	4.	4.	8.	12.	15.
999.	999.	-1.	-7.	-8.	-8.	20.	19.	13.	0.	3.	7.	9.	12.	15.
999.	999.	-5.	-11.	-9.	-9.	20.	10.	10.	2.	3.	6.	9.	12.	17.
999.	999.	-5.	-13.	-10.	-7.	20.	10.	7.	4.	3.	10.	10.	12.	17.
999.	999.	-2.	-13.	-13.	-9.	20.	15.	14.	14.	10.	10.	10.	15.	18.
999.	999.	3.	-17.	-14.	-10.	20.	14.	10.	7.	23.	23.	23.	23.	23.
999.	999.	5.	-20.	-15.	-7.	18.	15.	10.	7.	23.	23.	23.	23.	23.
-20.	-20.	-9.	-20.	-17.	-10.	18.	18.	10.	7.	23.	23.	23.	23.	23.
-20.	-20.	-10.	-17.	-20.	-12.	20.	19.	10.	7.	23.	23.	23.	23.	23.
999.	999.	7.	-17.	-15.	-10.	10.	15.	6.	6.	23.	23.	23.	23.	23.
999.	999.	-1.	-20.	0.	0.	1.	1.	6.	7.	23.	23.	23.	23.	23.
999.	999.	-1.	-20.	-11.	-10.	25.	2.	3.	14.	23.	23.	23.	23.	23.
999.	999.	8.	-18.	-13.	-3.	18.	15.	3.	14.	23.	23.	23.	23.	23.
999.	999.	10.	-18.	-18.	-3.	21.	21.	4.	14.	23.	23.	23.	23.	23.
999.	999.	10.	-10.	-18.	-4.	30.	21.	4.	14.	23.	23.	23.	23.	23.
-20.	-20.	-20.	-20.	-18.	-4.	30.	23.	23.	23.	23.	23.	23.	23.	23.
-20.	-20.	-20.	-17.	-13.	-4.	30.	23.	23.	23.	23.	23.	23.	23.	23.
-20.	-20.	-18.	-15.	-15.	-4.	30.	23.	23.	23.	23.	23.	23.	23.	23.
-20.	-20.	-18.	-15.	-13.	-10.	30.	23.	23.	23.	23.	23.	23.	23.	23.
-20.	-20.	-20.	-11.	-3.	-5.	30.	23.	23.	23.	23.	23.	23.	23.	23.
-20.	-20.	-20.	-13.	-2.	18.	30.	23.	23.	23.	23.	23.	23.	23.	23.
-20.	-20.	-20.	-14.	-10.	18.	30.	23.	23.	23.	23.	23.	23.	23.	23.
-20.	-20.	-20.	-15.	-10.	18.	30.	23.	23.	23.	23.	23.	23.	23.	23.
-20.	-20.	-10.	-9.	-2.	18.	30.	23.	23.	23.	23.	23.	23.	23.	23.
75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.
75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.

PARAMETERS---UNITS ARE IN FOOT-SECONDS

SPACE GRID	TIME STEP	FRICTION-DEEP,FLATS,WOODS			FLOODING CONSTANTS CO,CS		ENTRANCE COEF CK
6076.00	119.71	100.00	80.00	25.00	.70	.70	.35

STORM PARAMETERS

FSPEED(MPH)	MXVELOCITY(MPH)	RADIUS M WIND(NM)	LANDFALL(NM)	PRESS(MB)	T23(HRS)	AMP(FT)	ALPHA(RAD)
15.0	88.9	22.9	-21	52.000	3.200	11.700	0.000

TIME IN HRS. 3.33

88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	1.1	88.8	88.8
88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	1.1	88.8	88.8
88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	1.2	1.1	88.8	88.8
88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	1.2	1.1	88.8	88.8
88.8	88.8	88.8	88.8	88.8	1.1	1.0	88.8	88.8	88.8	1.2	1.1	88.8	88.8	88.8
88.8	88.8	88.8	88.8	1.1	1.1	1.0	1.1	88.8	88.8	1.1	1.0	88.8	88.8	88.8
88.8	88.8	88.8	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.1	88.8	88.8	88.8
88.8	88.8	88.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	88.8	88.8	88.8	88.8
88.8	88.8	88.8	1.0	1.0	1.0	1.0	1.0	.9	.9	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	1.0	1.0	.9	.9	.9	.9	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	.9	.9	.9	.9	.9	.9	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	.9	.9	.9	.9	.9	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	.9	.9	.9	.9	.9	.9	.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	.9	.9	.8	.8	.8	.9	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	.8	.8	.8	.8	.8	.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	.9	.8	.8	.8	.7	.7	.7	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	1.0	1.1	1.0	88.8	.6	.6	.6	.6	88.8	88.8	88.8	88.8
88.8	88.8	1.1	1.0	1.1	1.1	88.8	88.8	.5	.5	88.8	88.8	88.8	88.8	88.8
88.8	88.8	1.1	1.0	1.0	1.0	88.8	88.8	88.8	.4	.4	88.8	88.8	88.8	88.8
88.8	88.8	1.0	1.0	1.0	1.0	88.8	88.8	88.8	.2	88.8	88.8	88.8	88.8	88.8
88.8	88.8	1.1	1.0	1.0	1.0	88.8	88.8	88.8	.3	88.8	88.8	88.8	88.8	88.8
88.8	88.8	1.0	1.0	1.0	1.0	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	1.0	1.0	1.0	1.0	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	.9	1.0	1.0	1.0	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	.9	1.0	1.0	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	.9	.9	.9	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
.9	.9	.9	.9	.9	.9	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
.9	.9	.9	.9	.9	.9	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	.9	.9	.9	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	.9	.9	.9	.9	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	.9	.9	.9	1.0	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	.9	.9	.9	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	.9	.9	.9	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	.9	.9	.9	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
.9	.9	.9	.9	.9	.9	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
.9	.9	.9	.9	.9	.9	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
.9	.9	.9	.9	.9	.9	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
.9	.9	.9	.9	.9	.9	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
.9	.9	.9	.9	.9	.9	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
.9	.9	.9	.9	.9	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
.9	.9	.9	.9	.9	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
.9	.9	.9	.9	.9	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
.9	.9	.9	.9	.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8

TIME IN HRS. 6.65

88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	1.3	88.8	88.8
88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	1.2	88.8	88.8
88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	1.5	1.3	88.8	88.8
88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	1.4	1.2	88.8	88.8
88.8	88.8	88.8	88.8	88.8	1.2	1.2	88.8	88.8	88.8	1.4	1.3	88.8	88.8	88.8
88.8	88.8	88.8	88.8	1.2	1.2	1.2	1.2	88.8	88.8	1.3	1.2	88.8	88.8	88.8
88.8	88.8	88.8	1.2	1.2	1.2	1.1	1.2	1.2	1.2	1.1	1.1	88.8	88.8	88.8
88.8	88.8	88.8	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.0	88.8	88.8	88.8	88.8
88.8	88.8	88.8	1.0	1.0	1.0	1.0	1.0	1.0	.9	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	1.0	1.0	1.0	1.0	1.0	.9	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	.9	.9	.9	.9	.9	.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	.9	.9	.9	.9	.9	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	.8	.8	.8	.8	.8	.8	.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	.8	.8	.8	.8	.8	.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	.8	.7	.7	.7	.7	.7	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	.8	.7	.7	.6	.5	.5	.5	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	1.1	1.2	1.1	88.8	.3	.4	.4	.4	88.8	88.8	88.8	88.8
88.8	88.8	1.2	1.2	1.2	1.2	88.8	88.8	.2	.2	88.8	88.8	88.8	88.8	88.8
88.8	88.8	1.1	1.2	1.2	1.2	88.8	88.8	88.8	-.0	.0	88.8	88.8	88.8	88.8
88.8	88.8	1.1	1.1	1.1	1.1	88.8	88.8	88.8	-.4	88.8	88.8	88.8	88.8	88.8
88.8	88.8	1.2	1.1	1.1	1.1	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	1.1	1.1	1.1	1.1	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	1.0	1.1	1.1	1.1	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	1.0	1.0	1.0	1.0	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	1.0	1.0	1.0	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	1.0	1.0	1.0	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
.9	.9	.9	.9	1.0	1.0	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
.9	.9	.9	.9	.9	.9	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	.9	.9	.9	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	1.0	1.0	.9	.9	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	1.0	1.0	1.0	1.1	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	1.0	1.0	1.0	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	1.0	1.0	1.0	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	1.0	1.0	1.0	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
.9	.9	.9	1.0	1.0	1.0	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
.9	.9	.9	.9	.9	1.0	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
.9	.9	.9	.9	.9	.9	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
.9	.9	.9	.9	.9	.9	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
.9	.9	.9	.9	.9	.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
.9	.9	.9	.9	1.0	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
.9	.9	.9	.9	.9	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
.9	.9	.9	.9	.9	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
.9	.9	.9	.9	.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8

TIME IN HRS. 9.98

88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	2.0	88.8	88.8
88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	1.8	88.8	88.8
88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	2.2	1.9	88.8	88.8
88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	2.0	1.6	88.8	88.8
88.8	88.8	88.8	88.8	88.8	1.7	1.6	88.8	88.8	88.8	2.0	1.9	88.8	88.8	88.8
88.8	88.8	88.8	88.8	1.7	1.6	1.6	1.7	88.8	88.8	1.7	1.7	88.8	88.8	88.8
88.8	88.8	88.8	1.6	1.5	1.5	1.5	1.5	1.6	1.6	1.5	1.4	88.8	88.8	88.8
88.8	88.8	88.8	1.3	1.4	1.4	1.3	1.3	1.3	1.3	1.2	88.8	88.8	88.8	88.8
88.8	88.8	88.8	1.2	1.2	1.2	1.2	1.2	1.1	1.0	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	1.0	1.1	1.1	1.0	1.0	1.0	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	.9	.9	.9	.9	.9	.7	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	.8	.8	.8	.8	.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	.7	.7	.7	.7	.8	.8	.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	.6	.6	.6	.6	.7	.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	.5	.5	.5	.5	.4	.5	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	.6	.5	.5	.3	.0	.2	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	1.4	1.7	1.5	88.8	-.1	-.2	.0	88.8	88.8	88.8	88.8	88.8
88.8	88.8	1.6	1.6	1.6	1.7	88.8	88.8	-.7	-.7	88.8	88.8	88.8	88.8	88.8
88.8	88.8	1.5	1.5	1.6	1.6	88.8	88.8	88.8	-.9	-.8	88.8	88.8	88.8	88.8
88.8	88.8	1.3	1.5	1.5	1.6	88.8	88.8	88.8	-1.0	88.8	88.8	88.8	88.8	88.8
88.8	88.8	1.5	1.5	1.5	1.5	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	1.4	1.5	1.5	1.5	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	1.3	1.4	1.4	1.5	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	1.2	1.4	1.4	1.4	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	1.3	1.3	1.4	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	1.3	1.3	1.3	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
1.2	1.2	1.2	1.3	1.3	1.3	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
1.2	1.2	1.2	1.2	1.2	1.2	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	1.2	1.1	1.1	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	1.2	1.3	1.2	1.1	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	1.2	1.3	1.4	1.5	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	1.3	1.3	1.4	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	1.3	1.3	1.4	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	1.3	1.3	1.4	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
1.2	1.2	1.3	1.3	1.3	1.3	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
1.2	1.2	1.2	1.2	1.3	1.3	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
1.2	1.2	1.2	1.2	1.3	1.3	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
1.2	1.2	1.2	1.2	1.2	1.2	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
1.2	1.2	1.2	1.2	1.1	1.1	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
1.2	1.2	1.2	1.3	1.4	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
1.2	1.2	1.2	1.2	1.3	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
1.2	1.2	1.2	1.2	1.2	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
1.2	1.2	1.1	1.1	1.1	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8

TIME IN HRS. 13.30

88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	4.8	88.8	88.8
88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	4.2	88.8	88.8
88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	4.0	3.8	88.8	88.8
88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	3.5	3.1	88.8	88.8
88.8	88.8	88.8	88.8	4.0	4.0	4.2	4.0	2.6	88.8	3.5	3.5	88.8	88.8	88.8
88.8	88.8	88.8	88.8	3.3	3.5	3.7	3.8	4.1	2.9	3.0	3.0	88.8	88.8	88.8
88.8	88.8	2.5	2.5	2.7	2.8	3.0	3.1	3.2	3.0	2.8	2.4	88.8	88.8	88.8
88.8	88.8	88.8	2.0	2.2	2.3	2.5	2.5	2.5	2.5	2.4	88.8	88.8	88.8	88.8
88.8	88.8	88.8	1.6	1.7	1.9	2.0	2.1	2.1	2.0	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	1.2	1.4	1.5	1.6	1.7	1.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	.8	1.0	1.2	1.3	1.4	1.2	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	.5	.7	.9	1.0	1.2	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	.2	.5	.6	.8	1.0	2.0	1.1	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	.1	.3	.4	.5	.7	1.1	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	.2	.3	.4	.2	.0	.3	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	.6	.2	.6	.2	-1.0	-.5	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	2.6	3.4	3.2	88.8	88.8	-1.6	-.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	3.1	3.2	3.3	3.5	88.8	88.8	-2.2	-1.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	2.8	3.1	3.3	3.5	88.8	88.8	88.8	-1.5	88.8	88.8	88.8	88.8	88.8
88.8	88.8	2.6	3.1	3.3	3.5	88.8	88.8	88.8	-1.3	88.8	88.8	88.8	88.8	88.8
88.8	88.8	3.2	3.3	3.4	3.6	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	3.3	3.4	3.6	3.7	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	3.2	3.5	3.7	3.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	3.1	3.7	3.8	4.0	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	3.6	3.9	4.0	4.1	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	4.0	4.1	4.2	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
5.0	5.0	4.7	4.3	4.3	4.3	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
5.0	5.0	4.6	4.3	4.2	4.3	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	4.2	4.1	4.2	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	4.1	4.2	4.2	3.8	2.0	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	4.0	4.3	4.5	4.7	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	4.4	4.5	4.6	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	4.4	4.6	4.7	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	4.6	4.7	4.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
4.9	4.9	4.9	4.8	4.8	4.9	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
4.9	4.9	4.9	4.9	4.9	5.0	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
4.9	4.9	4.9	4.9	4.9	5.0	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
4.9	4.9	4.9	4.9	4.8	4.9	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
4.9	4.9	4.9	4.9	4.8	4.7	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
4.8	4.8	4.9	4.9	5.0	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
4.8	4.8	4.8	4.9	5.0	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
4.8	4.8	4.8	4.8	4.9	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
4.8	4.8	4.7	4.7	4.7	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8

TIME IN HRS. 16.63

88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	10.5	11.9	11.7	88.8
88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	11.0	11.6	11.2	88.8
88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	10.9	11.0	11.8	11.6	88.8
88.8	88.8	88.8	88.8	88.8	88.8	88.8	10.7	9.8	8.8	10.8	11.3	11.7	88.8	88.8
88.8	88.8	88.8	88.8	7.4	8.4	9.0	9.5	9.7	9.9	11.0	11.6	88.8	88.8	88.8
88.8	88.8	88.8	6.3	6.9	7.8	8.7	9.2	9.9	10.2	10.9	11.6	88.8	88.8	88.8
88.8	88.8	7.5	6.1	6.7	7.5	8.4	9.0	9.6	10.3	10.9	11.4	88.8	88.8	88.8
88.8	88.8	6.9	6.0	6.6	7.4	8.1	8.8	9.5	10.2	10.8	88.8	88.8	88.8	88.8
88.8	88.8	6.7	5.8	6.5	7.2	7.9	8.5	9.3	10.1	88.8	88.8	88.8	88.8	88.8
88.8	88.8	4.3	5.6	6.3	7.0	7.7	8.4	9.2	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	5.5	6.2	6.9	7.5	8.2	9.0	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	5.4	6.1	6.7	7.3	8.1	88.8	88.8	2.5	2.3	88.8	88.8	88.8
88.8	88.8	88.8	5.3	6.0	6.6	7.1	7.7	6.1	6.9	6.7	4.5	88.8	88.8	88.8
88.8	88.8	88.8	5.4	6.1	6.6	6.9	6.9	6.6	6.8	4.6	88.8	88.8	88.8	88.8
88.8	88.8	88.8	5.9	6.4	6.8	6.9	6.1	6.1	6.3	2.5	88.8	88.8	88.8	88.8
88.8	88.8	88.8	6.9	6.8	7.5	7.4	4.2	4.6	4.8	2.1	88.8	88.8	88.8	88.8
88.8	88.8	10.1	9.6	10.5	10.6	88.8	2.3	2.7	2.9	2.3	88.8	88.8	88.8	88.8
88.8	88.8	10.2	10.5	11.0	11.4	88.8	88.8	.8	2.0	88.8	88.8	88.8	88.8	88.8
88.8	88.8	10.3	10.8	11.3	11.7	88.8	88.8	88.8	-.3	88.8	88.8	88.8	88.8	88.8
88.8	88.8	10.5	11.1	11.5	12.0	88.8	88.8	88.8	-1.4	88.8	88.8	88.8	88.8	88.8
88.8	88.8	11.1	11.5	11.9	12.3	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	11.4	11.8	12.2	12.5	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	11.6	12.0	12.4	12.7	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	11.7	12.2	12.5	12.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	11.8	12.3	12.6	12.9	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	12.1	12.4	12.7	13.0	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
11.9	11.9	12.1	12.5	12.7	13.0	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
11.9	11.9	12.3	12.5	12.7	13.0	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	11.9	12.5	12.7	13.0	13.5	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	12.2	12.5	12.7	12.9	13.0	10.6	7.5	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	12.3	12.5	12.8	13.1	88.8	7.1	5.4	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	12.2	12.5	12.7	13.0	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	12.1	12.4	12.6	12.9	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	12.0	12.3	12.5	12.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
11.6	11.6	11.9	12.2	12.4	12.7	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
11.5	11.5	11.8	12.1	12.3	12.6	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
11.5	11.5	11.7	12.0	12.2	12.5	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
11.5	11.5	11.7	11.9	12.2	12.4	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
11.4	11.4	11.6	11.8	12.1	12.3	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
11.4	11.4	11.6	11.8	12.0	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
11.3	11.3	11.5	11.7	11.9	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
11.3	11.3	11.5	11.7	11.9	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
11.2	11.2	11.4	11.6	11.9	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8

TIME IN HRS. 19.95

88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	7.3	88.8	88.8
88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	7.9	88.8	88.8
88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	7.8	8.5	10.2	88.8
88.8	88.8	88.8	88.8	88.8	88.8	88.8	6.6	7.2	7.8	7.3	8.2	8.7	88.8	88.8
88.8	88.8	88.8	88.8	4.2	4.6	4.8	5.3	6.5	7.2	7.9	8.5	88.8	88.8	88.8
88.8	88.8	88.8	88.8	4.7	5.0	5.3	5.8	6.6	7.5	8.1	8.6	88.8	88.8	88.8
88.8	88.8	3.8	4.6	5.0	5.3	5.7	6.3	6.9	7.5	8.2	8.9	88.8	88.8	88.8
88.8	88.8	4.3	4.9	5.3	5.6	6.1	6.6	7.2	7.8	8.4	88.8	88.8	88.8	88.8
88.8	88.8	4.7	5.2	5.5	5.8	6.2	6.7	7.3	7.9	88.8	88.8	88.8	88.8	88.8
88.8	88.8	5.0	5.4	5.7	6.0	6.5	6.9	7.5	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	5.6	5.9	6.3	6.7	7.1	7.6	88.8	88.8	5.0	4.2	88.8	88.8
88.8	88.8	88.8	5.8	6.1	6.4	6.7	7.2	88.8	88.8	7.6	7.6	5.0	88.8	88.8
88.8	88.8	88.8	5.9	6.2	6.6	6.9	7.3	7.5	8.1	8.5	8.5	7.0	4.3	88.8
88.8	88.8	88.8	6.0	6.3	6.7	7.1	7.5	7.9	8.4	8.8	9.0	7.7	4.3	88.8
88.8	88.8	88.8	6.0	6.4	6.7	7.2	7.6	8.0	8.5	9.0	9.3	9.0	4.6	88.8
88.8	88.8	88.8	6.1	6.5	6.8	7.3	7.8	8.2	8.7	9.2	9.6	10.0	88.8	88.8
88.8	88.8	88.8	5.5	5.7	6.3	88.8	8.0	8.5	8.9	9.4	9.9	10.4	88.8	88.8
88.8	88.8	5.0	5.3	5.7	6.0	88.8	88.8	8.6	9.0	9.5	10.1	9.4	88.8	88.8
88.8	88.8	5.0	5.3	5.6	5.9	88.8	88.8	8.8	9.0	9.5	9.9	9.7	88.8	88.8
88.8	88.8	5.0	5.3	5.6	5.9	88.8	88.8	8.8	9.0	9.5	9.6	8.2	88.8	88.8
88.8	88.8	4.6	5.1	5.4	5.7	88.8	88.8	88.8	8.9	9.2	7.7	88.8	88.8	88.8
88.8	88.8	4.5	4.9	5.2	5.5	88.8	88.8	88.8	8.4	6.6	6.3	88.8	88.8	88.8
88.8	88.8	4.5	4.7	5.0	5.3	88.8	88.8	88.8	4.8	3.7	88.8	88.8	88.8	88.8
88.8	88.8	4.4	4.5	4.8	5.0	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	4.2	4.3	4.5	4.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	4.1	4.3	4.6	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
2.6	2.6	3.2	3.9	4.1	4.4	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
2.6	2.6	3.2	3.8	4.1	4.3	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	3.7	4.1	4.3	88.8	88.8	7.7	6.3	88.8	88.8	88.8	88.8	88.8
88.8	88.8	3.3	3.6	3.9	4.5	6.0	7.2	8.2	7.2	88.8	88.8	88.8	88.8	88.8
88.8	88.8	3.2	3.5	3.6	3.8	88.8	7.4	8.2	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	3.4	3.5	3.9	88.8	88.8	8.0	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	3.3	3.4	3.7	88.8	88.8	6.4	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	3.1	3.3	3.6	88.8	88.8	4.2	88.8	88.8	88.8	88.8	88.8	88.8
2.5	2.5	2.7	2.9	3.2	3.5	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
2.5	2.5	2.7	2.9	3.1	3.4	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
2.5	2.5	2.7	2.9	3.1	3.4	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
2.5	2.5	2.7	2.8	3.1	3.4	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
2.5	2.5	2.6	2.8	3.1	3.5	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
2.5	2.5	2.6	2.8	3.1	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
2.5	2.5	2.6	2.8	3.0	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
2.5	2.5	2.6	2.8	3.0	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
2.5	2.5	2.6	2.9	3.2	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8

TIME IN HRS. 23.28

88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	2.5	88.8	88.8
88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	2.9	88.8	88.8
88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	3.0	3.4	88.8	88.8
88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	3.4	3.8	88.8	88.8
88.8	88.8	88.8	88.8	2.6	2.2	2.2	88.8	3.3	3.6	3.4	3.7	88.8	88.8	88.8
88.8	88.8	88.8	88.8	2.6	2.6	2.6	2.9	3.1	3.3	3.7	3.9	88.8	88.8	88.8
88.8	88.8	2.8	2.7	2.8	2.9	3.0	3.2	3.4	3.6	3.8	4.1	88.8	88.8	88.8
88.8	88.8	3.0	2.9	3.0	3.1	3.2	3.4	3.6	3.8	4.0	88.8	88.8	88.8	88.8
88.8	88.8	3.0	3.1	3.2	3.3	3.4	3.6	3.7	4.0	88.8	88.8	88.8	88.8	88.8
88.8	88.8	3.0	3.2	3.3	3.4	3.6	3.7	3.9	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	3.3	3.4	3.6	3.7	3.9	4.1	88.8	88.8	5.5	5.9	4.5	88.8
88.8	88.8	88.8	3.4	3.6	3.7	3.9	4.0	88.8	88.8	5.4	5.9	6.4	4.4	88.8
88.8	88.8	88.8	3.6	3.7	3.8	4.0	4.3	4.8	5.1	5.7	6.3	6.9	4.5	88.8
88.8	88.8	88.8	3.7	3.8	4.0	4.2	4.5	4.9	5.4	6.0	6.6	7.1	4.5	88.8
88.8	88.8	88.8	3.7	3.9	4.0	4.3	4.9	5.2	5.7	6.4	6.9	7.4	4.6	88.8
88.8	88.8	88.8	3.6	3.9	4.0	4.3	5.3	5.6	6.0	6.5	7.2	7.7	88.8	88.8
88.8	88.8	88.8	2.9	2.7	3.2	88.8	5.7	6.0	6.3	6.7	7.3	8.1	88.8	88.8
88.8	88.8	2.2	2.5	2.6	2.7	88.8	88.8	6.3	6.6	7.0	7.6	88.8	9.4	88.8
88.8	88.8	2.3	2.4	2.5	2.7	88.8	88.8	6.6	7.0	7.3	7.6	8.5	88.8	88.8
88.8	88.8	2.3	2.3	2.4	2.6	88.8	88.8	88.8	7.3	7.6	8.2	9.3	88.8	88.8
88.8	88.8	1.7	2.1	2.2	2.4	88.8	88.8	88.8	7.6	8.0	8.7	9.2	88.8	88.8
88.8	88.8	1.7	1.8	2.0	2.2	88.8	88.8	88.8	7.9	8.4	9.1	9.3	88.8	88.8
88.8	88.8	1.6	1.7	1.8	2.0	88.8	88.8	8.0	8.3	8.7	88.8	88.8	88.8	88.8
88.8	88.8	1.6	1.6	1.7	1.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	1.5	1.6	1.7	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	1.4	1.5	1.6	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
1.0	1.0	1.2	1.4	1.5	1.6	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
1.0	1.0	1.2	1.4	1.5	1.6	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	1.4	1.5	1.6	88.8	88.8	6.9	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	1.1	1.3	1.4	1.9	4.1	5.5	6.3	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	1.1	1.2	1.3	1.3	88.8	5.9	6.4	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	1.2	1.3	1.4	88.8	88.8	6.7	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	1.2	1.2	1.4	88.8	88.8	7.0	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	1.2	1.2	1.4	88.8	88.8	4.5	88.8	88.8	88.8	88.8	88.8	88.8
1.0	1.0	1.1	1.1	1.2	1.3	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
1.0	1.0	1.1	1.2	1.2	1.4	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
1.0	1.0	1.1	1.2	1.3	1.4	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
1.0	1.0	1.1	1.2	1.3	1.5	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
1.0	1.0	1.1	1.2	1.3	1.6	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
1.0	1.0	1.1	1.1	1.3	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
1.0	1.0	1.1	1.2	1.3	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
1.0	1.0	1.1	1.2	1.3	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
1.0	1.0	1.1	1.3	1.4	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8

MAXIMUMUM WATER LEVEL PRODUCED BY THIS STORM

11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	10.6	11.9	11.8	-.0
11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	-.0	-.0	11.3	12.0	12.0	-.0
11.7	11.7	11.7	11.7	11.7	11.7	11.7	-.0	-.0	11.3	11.9	12.4	12.3	-.0
11.7	11.7	11.7	11.7	11.7	11.7	11.3	10.1	10.1	11.4	12.2	12.7	-.0	-.0
11.8	11.8	-.0	7.6	8.4	9.1	9.6	10.1	10.7	11.8	12.5	-.0	-.0	-.0
11.8	-.0	6.7	7.4	8.0	8.7	9.4	10.3	11.1	11.9	12.6	-.0	-.0	-.0
11.9	7.9	6.8	7.5	8.2	8.9	9.6	10.4	11.2	12.0	12.7	-.0	-.0	-.0
12.0	7.0	7.0	7.7	8.3	9.0	9.7	10.5	11.3	12.0	-.0	4.0	-.0	-.0
12.0	7.1	7.3	7.8	8.4	9.1	9.9	10.6	11.4	-.0	-.0	4.0	4.0	-.0
12.1	6.8	7.5	8.0	8.5	9.2	9.9	10.7	-.0	-.0	-.0	6.1	4.0	-.0
12.1	-.0	7.6	8.1	8.7	9.3	10.0	10.8	-.0	-.0	5.8	6.2	4.5	-.0
12.2	-.0	7.8	8.3	8.8	9.4	10.0	-.0	-.0	7.7	7.6	7.1	4.4	-.0
12.2	-.0	7.9	8.4	8.9	9.4	9.9	9.1	9.7	9.4	8.7	8.0	4.6	-.0
12.3	-.0	8.0	8.5	9.0	9.4	9.6	9.5	10.0	9.5	9.1	8.7	4.8	-.0
12.4	10.0	8.2	8.7	9.1	9.5	9.3	9.4	9.6	9.4	9.3	9.4	5.0	-.0
12.4	10.1	8.5	8.9	9.4	9.7	8.7	9.1	9.3	9.6	9.6	10.1	10.1	-.0
12.5	10.4	10.1	11.0	11.1	11.0	8.6	8.9	9.2	9.7	10.0	10.5	10.2	-.0
12.5	10.5	10.9	11.3	11.7	-.0	-.0	8.8	9.2	9.6	10.1	10.4	9.4	-.0
12.6	10.6	11.1	11.5	11.9	-.0	-.0	8.8	9.1	9.5	10.0	10.5	-.0	-.0
12.6	10.8	11.3	11.7	12.1	-.0	-.0	9.0	9.1	9.6	10.0	10.5	-.0	-.0
12.6	11.2	11.6	12.0	12.4	-.0	-.0	-.0	9.1	9.4	9.8	9.5	-.0	-.0
12.6	11.5	11.9	12.2	12.5	-.0	-.0	-.0	8.8	9.0	9.6	9.3	-.0	-.0
12.6	11.6	12.0	12.4	12.7	-.0	-.0	8.0	8.8	9.2	-.0	-.0	-.0	-.0

12.6	11.7	12.2	12.5	12.8	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0
12.6	11.9	12.4	12.7	12.9	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0
12.6	12.4	12.6	12.8	13.1	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0
12.6	12.6	12.7	12.9	13.2	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0
12.6	12.8	12.8	13.0	13.2	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0
12.6	12.7	12.8	12.9	13.2	13.6	-.0	7.7	6.3	-.0	-.0	-.0	-.0	-.0
12.6	12.5	12.8	13.0	13.1	13.0	10.7	9.8	7.3	-.0	-.0	-.0	-.0	-.0
12.5	12.6	12.9	13.1	13.4	-.0	9.2	9.3	-.0	-.0	-.0	-.0	-.0	-.0
12.5	12.5	12.9	13.1	13.4	-.0	-.0	8.0	-.0	-.0	-.0	-.0	-.0	-.0
12.4	12.6	12.9	13.1	13.3	-.0	-.0	7.4	-.0	-.0	-.0	-.0	-.0	-.0
12.4	12.4	12.8	13.0	13.3	-.0	-.0	4.5	-.0	-.0	-.0	-.0	-.0	-.0
12.3	12.6	12.8	13.0	13.2	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0
12.3	12.5	12.7	12.9	13.2	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0
12.2	12.4	12.6	12.8	13.1	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0
12.2	12.4	12.6	12.8	13.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0
12.1	12.3	12.5	12.7	12.9	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0
12.1	12.3	12.5	12.7	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0
12.0	12.2	12.4	12.6	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0
12.0	12.2	12.3	12.5	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0
11.9	12.1	12.3	12.5	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0
-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0

FLOODING DEPTH 888.8 INDICATES BELOW MLW

```
0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  2.6888.8  1.8  0.0
0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  1.3888.8  2.0  0.0
0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  1.3 11.9888.8  2.3  0.0
0.0  0.0  0.0  0.0  0.0  0.0  5.3  3.1  3.1  7.4888.8888.8  0.0  0.0
0.0  0.0  0.0  5.6888.8888.8  6.6  8.1  7.7 11.8888.8  0.0  0.0  0.0
0.0  0.0  1.7888.8888.8888.8888.8  8.3  9.1888.8888.8  0.0  0.0  0.0
0.0  5.9888.8888.8888.8888.8888.8888.8888.8888.8 12.7  0.0  0.0  0.0
0.0  5.0888.8888.8888.8888.8888.8888.8888.8888.8  0.0   .0  0.0  0.0
0.0  5.1888.8888.8888.8888.8888.8888.8888.8  0.0  0.0   .0   .0  0.0
0.0  4.8888.8888.8888.8888.8888.8888.8  0.0  0.0  0.0   .1   .0  0.0
0.0  0.0888.8888.8888.8888.8888.8888.8  0.0  0.0  3.8  4.2   .5  0.0
0.0  0.0888.8888.8888.8888.8888.8  0.0  0.0  6.7  5.6  3.1   .4  0.0
0.0  0.0888.8888.8888.8888.8888.8  9.1  9.7  8.4  4.7  4.0   .6  0.0
0.0  0.0888.8888.8888.8888.8888.8888.8  9.0  7.5  5.1  4.7   .8  0.0
0.0   .0888.8888.8888.8888.8888.8888.8  8.6  7.4  7.3  5.4  1.0  0.0
0.0   .1888.8888.8888.8888.8888.8888.8  9.3  8.6  7.6  6.1   .1  0.0
0.0  5.4888.8888.8888.8   .0888.8888.8888.8  9.7  8.0  5.5   .2  0.0
0.0888.8888.8888.8888.8  0.0  0.0888.8888.8  6.6  3.1  1.4   .4  0.0
0.0888.8888.8888.8888.8  0.0  0.0  4.8888.8888.8  8.0  3.5  0.0  0.0
0.0 10.8888.8888.8888.8  0.0  0.0  1.0888.8  5.6  6.0  2.5  0.0  0.0
0.0888.8888.8888.8888.8  0.0  0.0  0.0  9.1  6.4  2.8   .5  0.0  0.0
0.0888.8888.8888.8888.8  0.0  0.0  0.0  6.8  6.0  3.6   .3  0.0  0.0
0.0888.8888.8888.8888.8  0.0  0.0  1.0  4.8  6.2  0.0  0.0  0.0  0.0
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  0.0888.8888.8888.8888.8  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  8.9888.8888.8888.8  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  7.4888.8888.8888.8  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
888.8888.8888.8888.8888.8  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
888.8888.8888.8888.8888.8  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  5.7888.8888.8888.8  3.6  0.0  1.7   .3  0.0  0.0  0.0  0.0  0.0
  0.0888.8888.8 13.0 13.1 12.0  9.7  3.8   .3  0.0  0.0  0.0  0.0  0.0
  0.0888.8888.8888.8888.8  0.0  7.2  6.3  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  4.5888.8888.8888.8  0.0  0.0  5.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  2.6888.8888.8888.8  0.0  0.0  3.4  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  2.4888.8888.8888.8  0.0  0.0   .5  0.0  0.0  0.0  0.0  0.0  0.0
888.8888.8888.8888.8888.8  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
888.8888.8888.8888.8888.8  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
888.8888.8888.8888.8888.8  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
888.8888.8888.8888.8888.8  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
888.8888.8888.8888.8888.8  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
888.8888.8888.8888.8  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
888.8888.8888.8888.8  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
888.8888.8888.8888.8  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
888.8888.8888.8888.8  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
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TIME	DOG ID	CARBELE	CAT PT	APLCLA	L ANCHR	W PASS
.13	.90	.90	.90	.90	.90	.90
.27	.89	.89	.90	.90	.93	.92
.40	.89	.87	.91	.89	.96	.94
.53	.88	.85	.90	.88	.98	.96
.67	.88	.85	.90	.88	1.01	.97
.80	.88	.86	.91	.87	1.03	.98
.93	.88	.86	.92	.88	1.04	.97
1.06	.89	.87	.92	.91	1.01	.96
1.20	.89	.88	.92	.92	.99	.96
1.33	.89	.88	.92	.92	.99	.98
1.46	.89	.88	.92	.92	1.00	.98
1.60	.89	.87	.94	.91	1.03	.98
1.73	.90	.86	.95	.90	1.04	.98
1.86	.90	.86	.95	.89	1.05	1.00
2.00	.90	.88	.96	.89	1.04	1.00
2.13	.90	.89	.97	.89	1.04	1.00
2.26	.90	.89	.97	.90	1.05	1.00
2.39	.91	.89	.97	.90	1.04	1.00
2.53	.91	.88	.98	.89	1.04	1.00
2.66	.91	.88	.99	.89	1.04	1.00
2.79	.91	.88	.99	.89	1.04	1.01
2.93	.91	.89	.99	.89	1.05	1.01
3.06	.91	.90	1.01	.88	1.06	1.02
3.19	.91	.90	1.01	.88	1.06	1.02
3.33	.91	.89	1.01	.88	1.07	1.02
3.46	.90	.88	1.02	.88	1.07	1.03
3.59	.90	.86	1.01	.89	1.07	1.03
3.72	.90	.86	1.01	.89	1.07	1.03
3.86	.90	.87	1.03	.88	1.07	1.03
3.99	.90	.88	1.03	.88	1.08	1.04
4.12	.91	.89	1.02	.88	1.09	1.04
4.26	.91	.89	1.02	.88	1.09	1.05
4.39	.91	.88	1.03	.88	1.10	1.05
4.52	.91	.87	1.03	.88	1.10	1.06
4.66	.91	.86	1.03	.88	1.10	1.06
4.79	.91	.87	1.03	.88	1.11	1.06
4.92	.90	.87	1.04	.88	1.11	1.07
5.05	.91	.88	1.04	.88	1.12	1.07
5.19	.91	.88	1.05	.88	1.13	1.08
5.32	.91	.88	1.06	.87	1.13	1.08
5.45	.91	.87	1.06	.87	1.14	1.09
5.59	.91	.87	1.07	.87	1.15	1.09
5.72	.91	.87	1.07	.87	1.15	1.10
5.85	.91	.87	1.08	.87	1.16	1.11
5.99	.91	.87	1.08	.87	1.17	1.11
6.12	.92	.87	1.09	.87	1.17	1.12
6.25	.92	.88	1.10	.87	1.18	1.13
6.38	.92	.88	1.10	.87	1.19	1.14
6.52	.92	.88	1.11	.87	1.20	1.15
6.65	.92	.88	1.12	.86	1.21	1.15
6.78	.93	.88	1.13	.86	1.22	1.16
6.92	.93	.88	1.14	.86	1.23	1.17
7.05	.93	.88	1.15	.86	1.23	1.18
7.18	.94	.89	1.15	.86	1.24	1.20
7.32	.94	.89	1.17	.86	1.26	1.21
7.45	.94	.89	1.18	.86	1.27	1.22
7.58	.95	.90	1.19	.86	1.28	1.23
7.71	.95	.90	1.20	.86	1.29	1.25
7.85	.96	.90	1.21	.86	1.30	1.26
7.98	.96	.91	1.23	.86	1.32	1.28
8.11	.98	.92	1.24	.86	1.33	1.29
8.25	.99	.95	1.25	.86	1.34	1.31
8.38	1.01	.98	1.27	.86	1.36	1.32
8.51	1.01	.99	1.28	.86	1.37	1.34
8.65	1.02	.98	1.30	.86	1.38	1.36
8.78	1.03	.96	1.32	.86	1.39	1.38
8.91	1.04	.96	1.34	.85	1.41	1.40
9.05	1.05	.98	1.36	.85	1.42	1.42
9.18	1.07	.99	1.38	.85	1.44	1.44

9.31	1.09	.99	1.40	.85	1.45	1.46
9.44	1.12	1.01	1.42	.85	1.47	1.49
9.58	1.13	.98	1.44	.85	1.49	1.51
9.71	1.17	1.03	1.46	.85	1.51	1.54
9.84	1.17	.98	1.48	.84	1.53	1.57
9.98	1.23	1.05	1.51	.84	1.55	1.60
10.11	1.22	.97	1.53	.84	1.58	1.64
10.24	1.30	1.01	1.56	.84	1.61	1.68
10.38	1.29	.98	1.59	.85	1.63	1.72
10.51	1.37	1.08	1.62	.84	1.66	1.77
10.64	1.37	1.08	1.66	.84	1.69	1.81
10.77	1.47	1.04	1.69	.84	1.71	1.87
10.91	1.51	1.03	1.73	.85	1.76	1.92
11.04	1.57	1.07	1.77	.85	1.79	1.98
11.17	1.63	1.17	1.82	.86	1.81	2.05
11.31	1.71	1.27	1.86	.86	1.86	2.11
11.44	1.81	1.36	1.91	.87	1.89	2.18
11.57	1.89	1.43	1.97	.88	1.92	2.26
11.71	2.01	1.51	2.03	.89	1.96	2.35
11.84	2.12	1.61	2.09	.90	2.00	2.45
11.97	2.24	1.73	2.16	.92	2.04	2.55
12.10	2.38	1.87	2.23	.93	2.08	2.66
12.24	2.52	2.02	2.31	.95	2.13	2.78
12.37	2.69	2.17	2.39	.97	2.18	2.91
12.50	2.87	2.34	2.48	1.00	2.23	3.05
12.64	3.06	2.53	2.58	1.03	2.28	3.17
12.77	3.27	2.74	2.69	1.06	2.34	3.33
12.90	3.49	2.97	2.80	1.10	2.40	3.51
13.04	3.73	3.22	2.91	1.14	2.45	3.71
13.17	3.99	3.48	3.04	1.19	2.50	3.96
13.30	4.27	3.76	3.18	1.23	2.50	4.16
13.43	4.58	4.05	3.32	1.28	2.66	4.44
13.57	4.91	4.36	3.47	1.36	2.78	4.81
13.70	5.25	4.73	3.63	1.43	2.86	5.07
13.83	5.62	5.13	3.81	1.52	2.98	5 24
13.97	6.00	5.55	3.99	1.65	3.12	5.43
14.10	6.41	5.98	4.18	1.79	3.29	5.71
14.23	6.83	6.40	4.39	1.95	3.41	5.96
14.37	7.30	6.87	4.62	2.15	3.40	6.22
14.50	7.78	7.39	4.85	2.36	3.71	6.52
14.63	8.29	7.97	5.09	2.57	3.65	6.72
14.76	8.83	8.52	5.35	2.85	4.27	7.08
14.90	9.34	9.09	5.63	3.12	4.22	7.28
15.03	9.86	9.64	5.93	3.40	4.45	7.62
15.16	10.39	10.30	6.24	3.74	4.61	7.89
15.30	10.84	10.74	6.57	4.05	4.78	8.12
15.43	11.24	11.18	6.93	4.47	4.96	8.31
15.56	11.62	11.62	7.34	4.75	5.16	8.46
15.70	12.01	12.15	7.78	5.19	5.24	8.62
15.83	12.32	12.50	8.20	5.54	5.38	8.76
15.96	12.55	12.76	8.67	5.98	5.48	8.89
16.09	12.68	12.95	9.10	6.35	5.66	9.03
16.23	12.74	13.07	9.53	6.77	5.78	9.04
16.36	12.71	13.08	9.92	7.20	5.90	9.09
16.49	12.61	13.01	10.27	7.61	5.93	8.98
16.63	12.46	12.89	10.58	8.05	6.11	9.05
16.76	12.24	12.70	10.81	8.38	6.06	8.88
16.89	11.95	12.44	10.98	8.77	6.24	8.92
17.03	11.62	12.13	11.08	9.05	6.26	8.72
17.16	11.23	11.76	11.12	9.37	6.37	8.70
17.29	10.82	11.38	11.10	9.55	6.44	8.49
17.43	10.37	10.95	11.02	9.75	6.48	8.51
17.56	9.91	10.55	10.91	9.82	6.49	8.30
17.69	9.49	10.10	10.74	9.96	6.58	8.17
17.82	9.07	9.72	10.53	9.96	6.52	7.91
17.96	8.56	9.08	10.28	9.99	6.76	7.60
18.09	8.18	8.86	9.99	9.92	6.52	7.52
18.22	7.77	8.39	9.64	9.82	6.66	7.28
18.36	7.39	7.98	9.28	9.72	6.50	7.16
18.49	7.03	7.75	8.87	9.60	6.46	6.98

18.62	6.62	7.36	8.48	9.41	6.34	6.92
18.76	6.32	7.03	8.10	9.25	6.26	6.74
18.89	5.92	6.70	7.80	9.00	6.13	6.65
19.02	5.62	6.42	7.49	8.77	6.03	6.38
19.15	5.28	6.08	7.30	8.52	5.79	6.20
19.29	5.01	5.76	7.15	8.25	5.79	5.97
19.42	4.71	5.47	6.96	8.01	5.39	5.73
19.55	4.47	5.25	6.77	7.74	5.32	5.52
19.69	4.21	4.98	6.66	7.63	5.02	5.27
19.82	3.99	4.74	6.45	7.38	4.74	5.04
19.95	3.80	4.52	6.32	7.23	4.64	4.80
20.09	3.62	4.37	6.15	7.03	4.46	4.52
20.22	3.42	4.21	5.99	6.87	4.35	4.35
20.35	3.26	4.03	5.81	6.68	4.27	4.18
20.48	3.11	3.86	5.65	6.51	4.13	4.04
20.62	2.96	3.70	5.51	6.33	4.07	3.88
20.75	2.82	3.54	5.37	6.18	3.94	3.75
20.88	2.70	3.42	5.22	6.06	3.85	3.60
21.02	2.57	3.28	5.09	5.94	3.73	3.56
21.15	2.45	3.15	4.94	5.82	3.67	3.42
21.28	2.34	3.02	4.82	5.68	3.57	3.32
21.42	2.23	2.90	4.69	5.55	3.43	3.20
21.55	2.13	2.78	4.57	5.42	3.58	3.12
21.68	2.04	2.68	4.44	5.30	3.47	3.00
21.81	1.96	2.59	4.32	5.20	3.27	2.83
21.95	1.88	2.50	4.19	5.04	3.37	2.92
22.08	1.81	2.42	4.07	4.98	3.20	2.77
22.21	1.75	2.34	3.95	4.83	3.25	2.73
22.35	1.69	2.27	3.85	4.72	3.09	2.65
22.48	1.63	2.20	3.74	4.64	3.07	2.63
22.61	1.58	2.14	3.64	4.51	3.06	2.52
22.75	1.53	2.08	3.54	4.44	2.88	2.46
22.88	1.49	2.02	3.44	4.34	2.91	2.41
23.01	1.45	1.96	3.36	4.22	2.88	2.34
23.14	1.41	1.91	3.27	4.17	2.74	2.26
23.28	1.37	1.86	3.19	4.04	2.73	2.23
23.41	1.34	1.82	3.11	3.98	2.67	2.16
23.54	1.31	1.77	3.02	3.87	2.61	2.11
23.68	1.28	1.73	2.94	3.78	2.55	2.06
23.81	1.26	1.70	2.87	3.71	2.50	2.04
23.94	1.23	1.66	2.79	3.62	2.47	1.99

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