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Verification Study of a Bathystrophic Storm Surge Model

by

George Pararas-Carayannis

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

A bathystrophic storm surge numerical model was verified, using data of historical hurricanes at selected traverses on the Gulf of Mexico and the east coast, by calibrating "coupled" values of wind and bottom stress coefficients in hydrodynamic equations for the numerical computation. These coefficients represented model calibration constants that included more than the physical effects of wind and seabed friction. Surge hydrographs were calculated and compared with observed or recorded surge hydrographs of: (a) Hurricane of 1949 at Galveston and Freeport, Texas; (b) Hurricane Carla at Galveston and Freeport, Texas; (c) Hurricane Audrey at Eugene Island, Louisiana; (d) Hurricane Camille at Biloxi, Mississippi; and (e) Hurricane Carol at Narragansett Pier, Rhode Island. Comparisons were made with theoretical results for several hypothetical storm surge problems for which analytical solutions could be obtained. Although reasonable empirical solutions were obtained by combining values of initial rise and of coefficients of bottom friction and wind stress, the significance, variation and interdependence of these parameters could not be determined adequately because of limited historical data. Extrapolation of empirically derived wind stress and bottom friction relationships, as determined from lower windspeeds, to extreme probable maximum conditions associated with the synthetic hurricanes, could not be conclusively verified. Because of the complexity of the problem, data limitations, and the variability of different factors entering the calibration process, correlation for all historical hurricanes at all traverses was difficult to obtain. However, overall evaluation indicates that when the assumptions used in developing the bathystrophic storm surge model are satisfied, the model reproduces theoretical solutions with an acceptable degree of accuracy.

PREFACE

This report is published to assist coastal engineers in the computation of design storm surge resulting from the combined meteorologic, oceanic, and astronomic effects coincident with the arrival of a hurricane at the coast for use in the planning and design of protective coastal works. The work was carried out under the coastal construction research program of the U.S. Army Coastal Engineering Research Center (CERC).

It was undertaken as a joint effort by CERC with support from the U.S. Atomic Energy Commission (AEC) under contract AT(49-1) 3318 to verify a CERC numerical model of hurricane surge prediction with data of historical hurricanes.

Construction of nuclear powerplants and superports and other large coastal installations have necessitated the development of conservative criteria in obtaining estimates of potential storm surges. Prediction of hurricane surge elevations is based primarily on the use of analytic and numerical models, since it is difficult to study these events in real time or with the use of physical models. The earliest and simplest of the numerical models for hurricane-induced storm surge, in which the most essential two-dimensional characteristics of the hurricane and the response of the sea are considered, is called the bathystrophic storm surge model. This model has been widely used because of its simplicity and relatively modest computer requirements, and is applied to several historical storms in this report to show its strengths and weaknesses. A computer program for simulating the hurricane wind and pressure fields from a few parameters, and for computing the bathystrophic storm surge is included. A variable astronomical tide may be used. The basic computer program was developed by Mr. B. R. Bodine of CERC. Changes were made to permit the use of wind data from both actual and simulated hurricanes.

Historical hurricane data for the calibration and verification of the model were developed by cooperative efforts with the AEC staff and the consultant firm of Nunn, Snyder and Associates; particularly, the preparation of wind-field data reductions for computer use for Hurricanes Carla and Audrey, and suggestions which were incorporated in this version of the model.

This report was prepared by Mr. George Pararas-Carayannis, Oceanographer, Design Branch, under the direct supervision of Mr. R. A. Jachowski, Chief, Design Branch, Engineering Development Division. Mr. H. D. McClung was responsible for organizing computer program documentation and making computer program revisions. Mr. J. C. Alquist assisted with programming revisions. The report was particularly benefited by comments and suggestions of Messrs. L. G. Hulman, E. Hawkins and W. S. Bevins, AEC, and from discussions with Messrs. B. R. Bodine and P. N. Stoa, and Drs. D. L. Harris, and B. E. Herchenroder, CERC.

A more powerful, fully two-dimensional, hurricane storm surge prediction model is used operationally by the National Weather Service, NOAA. Two versions of this model, called SPLASH I and SPLASH II, are available from the National Technical Information Service (NTIS), Springfield, Virginia 22151. The computer tape is listed as Number COM-75-101-80/AS and the Users Guide as COM-75-101-81/AS. Although the SPLASH models are considerably more complex and require more computer facilities than the bathystrophic models, they require fewer assumptions, and are valid for a wider range of considerations. They are undergoing continual development to increase the accuracy of the predictions.

Comments on this publication are invited.

Approved for publication in accordance with Public Law 166, 79*th* Congress, approved 31 July 1945, as supplemented by Public Law 172, 88*th* Congress, approved 7 November 1963.

James L. Trayers

JAMES L. TRAYERS
Colonel, Corps of Engineers
Commander and Director

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LIST OF SYMBOLS

A	kinematic form of wind stress
B	kinematic form of wind stress
C_1	dimensional constant
C_2	dimensional constant
C_3	dimensional constant
D	depth of water at edge of Continental Shelf
d	depth of water on the Continental Shelf (below SWL)
f	Coriolis parameter in radians per hour ($f = 2\omega \sin \theta$)
g	gravitational acceleration
in. hg.	inches of mercury
k	dimensionless surface stress coefficient
K	bottom friction coefficient (empirical constant)
K_1	constant part of the wind-stress coefficient
K_2	constant multiplier of the velocity-dependent part of wind-stress coefficient
L	length of disturbance
M_{xx}	momentum transport quantity
M_{xy}	momentum transport quantity
M_{yy}	momentum transport quantity
mb	millibar
p	precipitation rate (depth/time)
p_n	peripheral pressure (inches of mercury)
p_o	central pressure (inches of mercury)
R	radius of maximum winds (nautical miles)
r	distance from storm center to points on traverse
R_E	radius of the earth
S	setup (cumulative water elevation)
S_A	setup due to astronomical tide
S_e	initial setup of the water level at the time the storm surge computations are started
S_L	local setup or setdown due to such local effects as inland runoff or the coastal hydrography

LIST OF SYMBOLS—Continued

$S_{\Delta p}$	atmospheric pressure setup
S_T	total setup at shore
S_w	wave setup at shore due to breaking waves
S_x	x-component of storm setup
S_y	y-component of storm setup
T	shear stress at boundary
t	time
U	x-component of volume transport per unit width
u	x-component of current velocity
U_{max}	maximum gradient windspeed (miles per hour)
U_R	maximum windspeed 30 feet above the water (miles per hour)
V	y-component of volume transport per unit width
v	y-component of current velocity
V_F	forward speed (miles per hour or knots)
W	windspeed
W_c	critical windspeed taken as 16 miles per hour
W_o	wind velocity at a given location along the "prime vector"
W_x	x-component of windspeed
W_y	y-component of windspeed
X_n	distance of each point of the traverse from the shore intercept of the traverse
Δ_x	discrete increment of distance along x-axis
Δy	discrete increment of distance along y-axis
α	azimuth of traverse
β	azimuth of line referenced by r
γ	dimensionless resistance coefficient
δ	computed angle between the traverse and r
ϵ	angle between "prime vector" and the radius from storm center to any point on the traverse
ζ	astronomical tide potential in head of water
θ	angle of wind direction measured counterclockwise from the x-axis

LIST OF SYMBOLS—Continued

ξ	atmospheric pressure deficit in head of water
ρ	mass density of water
τ_{bx}	x-component of bottom stress
τ_{by}	y-component of bottom stress
τ_s	resultant of x- and y-components of surface wind stress
τ_{sx}	x-component of surface wind stress
τ_{sy}	y-component of surface wind stress
ϕ	geographical latitude in degrees
ω	angular velocity of earth equal to $2\pi/24$ radians per hour (7.29×10^5 radian/second)

VERIFICATION STUDY OF A BATHYSTROPHIC STORM SURGE MODEL

by

George Pararas-Carayannis

I. INTRODUCTION

1. General.

Hurricanes are severe tropical cyclones with winds spiraling inward toward a center or *eye* of low pressure at speeds which may reach more than 150 miles per hour (130 knots). Although usually erratic and unpredictable, hurricanes generally follow a westerly to northwesterly path toward the gulf or Atlantic coasts causing abnormal water level fluctuations. These water level fluctuations are called *storm surges* and are caused by an atmospheric pressure field and wind stress on the water surface, accompanying moving storm systems. Specific factors which can combine to produce extreme water fluctuations at a coast during the passage of a storm include: storm intensity, size, path, and duration over water; atmospheric pressure variation; speed of translation; winds and rainfall; bathymetry of the offshore region; astronomical tides; initial water level rise; surface waves and associated wave setup and runup.

Hurricane surge is an oceanographic phenomenon and constitutes a greater hazard to lives and coastal property than hurricane winds. Hurricane surges have been estimated to account for 75 to 90 percent of all deaths resulting from a hurricane. Surge inundation is also responsible for extensive damage to coastal property. Since 1900, hurricane damages to coastal property have averaged more than $50 million per year (Perdikes, 1967). The storm that hit Galveston in 1900 resulted in 6,000 deaths and the almost complete destruction of a large part of the city. Hurricane Camille, which struck the Mississippi coast in 1969, killed 262 persons and caused damages of nearly $1 billion (U.S. Army Engineer District, Mobile, 1970).

The development of an improved hurricane warning system has reduced the loss of life by recent large storms. Hurricane Carla, which struck the Texas coast in 1961, killed 32 persons. Hurricane Betsy hit near New Orleans in 1965, and was responsible for 81 deaths. However, the damage to property continued to rise because of the continuing development of the coastal zone. The damage from Hurricane Carla was more than $400 million (U.S. Army Engineer District, Galveston, 1962). Damages from Hurricane Betsy were estimated to be $372 million (Perdikes, 1967).

Increasing pressure for large coastal installations, such as powerplants, and superport terminals, and the increasing residential development of the coastal zones, have emphasized the need for more accurate estimates of potential storm surge hazards.

The prediction of storm surge resulting from the combined meteorologic, oceanic and astronomic effects coincident with the arrival of a hurricane at the coast is a very important problem, but rather a difficult one to solve. The present capability for the prediction of hurricane surge is based primarily on the use of analytic and numerical models, none of which have been adequately verified. Furthermore, the interactions between tide and storm surge in shallow waters are not well understood. Nonetheless, a consideration of water level fluctuation due to the passage of a hurricane is essential for the planning and design of coastal engineering works.

2. Design Storms.

The Corps of Engineers is interested in knowing the extent and elevation of flooding induced by hurricane surges for various reaches along the gulf and Atlantic coasts and in developing guidelines for determining engineering design criteria.

Hurricane wind and pressure field, and surge hydrograph data are not available for most of the gulf and Atlantic coasts. Therefore, design analysis for coastal structures requires that a uniform and conservative approach be taken based on statistical probabilities of hurricane occurrence. Based on this approach, and considering the degree of desired protection, the U.S. Army, Corps of Engineers established specific storm characteristics for use in the design of coastal structures (Graham and Nunn, 1959; U.S. Weather Bureau, HUR 7-97, 1968). The storms that are used for establishing design criteria are termed *hypothetical hurricanes*, or *hypohurricanes*.

Two hypothetical storm terms, dependent on geographical location, have been established for practical application in the analysis of the design of coastal structures. These are the *standard project hurricane* (SPH), and the *probable maximum hurricane* (PMH). The meteorological considerations for these hurricanes are based on central pressure index (CPI), peripheral pressure (p_n), radius to maximum winds (R), maximum gradient windspeed (U_{max}), maximum windspeed (U_R), and speed of translation (V_F). Generally, synthetic hurricanes are classified by speed of translation and length of the radius from the eye of the hurricane to the region of maximum winds. Specifically, synthetic hurricanes are classified as of large, medium, or small radius, each with a high, moderate, or slow speed of translation. The choice of which design hurricane to use for a coastal structure depends on economics and desired degree of protection.

Graham and Nunn (1959), from an analysis of historic hurricanes, developed criteria for a design storm where the CPI has an occurrence probability of once every 100 years. This is the storm termed *standard project hurricane* (SPH). It is defined as a *synthetic hurricane* intended to represent the most severe combination of hurricane parameters that are reasonably characteristic of a specified region, excluding rare combinations. The probability of the SPH occurrence would be less than the CPI probability as determined by Graham and Nunn (1959), because other parameters have also been selected from historical maximum values.

The maximum gradient windspeed (U_{max}) and maximum windspeed (U_R) in the zone of maximum winds in miles per hour of the SPH can be determined by the following equations:

$$U_{max} = K\left(p_n - p_o\right)^{1/2} - R\,(0.575\,f), \tag{1}$$

$$U_R = 0.865\,U_{max} + 0.5\,V_F, \tag{2}$$

where K is taken as 73 for the SPH; p_n and p_o are the peripheral and central pressures in inches of mercury, respectively; R is the radius of maximum winds in nautical miles; f is the Coriolis parameter (bathystrophic effect) in radians per hour; and V_F is the forward speed in miles per hour. U_R is the maximum windspeed 30 feet above the water in miles per hour.

Construction of nuclear powerplants in the coastal zone required the use by the Atomic Energy Commission (AEC) (function now assigned to the Nuclear Regulatory Commission) of an extreme hurricane termed the *probable maximum hurricane* (PMH). The PMH was selected by AEC to ensure that there would be no likelihood that the safety aspects of powerplants would be compromised during severe hurricane surges (including wind-generated surface waves). The AEC concluded that adequate safety against flooding would be provided if the safety-related facilities of powerplants were designed to withstand a flood protection level, based on the PMH surge. In a report by the U.S. Weather Bureau (HUR 7-97, 1968), and in the *Shore Protection Manual* (U.S. Army, Corps of Engineers, Coastal Engineering Research Center, 1973) the PMH is defined as "a hypothetical hurricane having that combination of characteristics which will make the most severe storm that is reasonably possible in the region involved, if the hurricane should approach the point under study along a critical path and at an optimum rate of movement."

This application of PMH parameters defined in HUR 7-97, is considered proper as such a hurricane is associated with conditions reasonably possible. The wind field development for the PMH as it relates to radius of maximum winds, windspeed (U_R and U_{max}), and forward speed of the storm, is described in HUR 7-97. One of the differences between the SPH and PMH parameters is that the peripheral pressure, p_n, for the SPH is taken as a constant value of 29.92 inches of mercury while, p_n, for the PMH varies as a function of latitude. In addition, the factor K is taken as a constant for the SPH and is considered a function of the latitude for the PMH. The CPI for the PMH was not assigned a particular probability of occurrence, but was taken as only an extreme event because of the relatively small amount of data available. Storms, other than the SPH, with different CPI probabilities of occurrence have been used to obtain hurricanes of various intensities for the design of coastal structures based on economics and the desired degree of protection.

3. Numerical Models.

Freeman, Baer, and Jung (1957) introduced a quasi-two-dimensional model by approximating the setup due to the alongshore transport of water and the bathystrophic flow, in addition to the setup normal to a coast.

The Bathystrophic Storm Tide Theory, developed by Freeman, Baer, and Jung, has been used by some investigators in predicting storm surge elevations. Bretschneider and Collins (1963) used the theory to predict the open-coast hurricane surge at Corpus Christi, Texas and vicinity. Marinos and Woodward (1968) modified the model used by Bretschneider and Collins to compute surge elevations for several locations along the Texas coast.

A quasi-two-dimensional mathematical model developed by Bodine (1971) has been used by the Coastal Engineering Research Center (CERC) to determine storm surge design water level elevations for coastal structures. This model is also based on theoretical approximations of the governing hydrodynamic equations, proposed by Freeman, Baer and Jung (1957); it calculates storm surge based on parameters of both actual and synthetic hurricanes. This numerical model was used in the verification study presented in this report.

4. Objective Scope and Significance of Present Investigation.

In CERC's bathystrophic storm surge model the basic equations describe in simplified form the water motions associated with nearly horizontal flows, as those of the hurricane surge, and provide a reasonable estimate of the surge. The mathematics, geometry and basic assumptions of the numerical method, have been presented by Bodine (1971) and are summarized later in this report. Because of the simplicity of this numerical model and the number of assumptions on which it is based, further verification was neccessary. The objective of the present investigation was to verify the model by comparing computed storm surge levels with those observed or recorded along the open coasts during the passage of actual storms.

Review of available hurricane data revealed that few significant hurricanes of record were sufficiently documented to provide a valid basis for analysis and verification. The following hurricanes and traverse lines (computational lines) along both the gulf and the Atlantic coasts were selected for verification: (a) Hurricane of 3 October 1949: Traverses at Galveston and Freeport, Texas, (b) Hurricane Carla, 1961: Traverses at Galveston and Freeport, Texas; (c) Hurricane Audrey, 1957: Traverse at Eugene Island, Louisiana; (d) Hurricane Camille, 1969: Traverse at Biloxi, Mississippi; and (e) Hurricane Carol, 1954: Traverse at Narragansett Pier, Rhode Island.

Wind stress and bottom friction coefficients are significant in the numerical model and affect the computation of surge. Of these two coefficients, wind stress has the more pronounced effect on surge elevation, and according to Van Dorn (1953), appears to vary with the windspeed. Initial rise and astronomical tide can also have a pronounced effect on final surge elevation. Proper determination of these parameters from tide gage recordings is necessary. No calibration of these parameters can be made. Therefore, the goal of the present investigation was limited in ascertaining which coefficients of wind stress and bottom friction when used in conjunction with the bathystrophic model of hurricane surge prediction, initial rise and astronomical tide, would yield surge levels comparable to those of historic hurricanes.

5. Data Limitations.

In engineering design, the normal practice is to use a hypothetical hurricane as the design storm to predict storm surge levels for various coastal locations. Such predictions are usually determined by mathematical models, because of the difficulty in simulating the complex surge generating processes with physical hydraulic models. In a physical model, it is difficult if not impossible, to duplicate the complex wind pattern of a hurricane, or the Coriolis effects. However, reasonable estimates of water level fluctuations at a coast due to hurricanes can be obtained in a numerical model by taking into account the physical laws governing the interactions between wind, water, land, and differences in atmospheric pressures. However, comparison and verification of the model are not simple due to the lack of sufficient historic hurricane wind field and surge hydrographic data. Only limited historic information is available for the gulf and Atlantic coasts.

a. Hurricane Data. Sufficient hurricane wind data is a prerequisite for reliable storm surge calculations. However, wind information on weather charts of most historic hurricanes is sporadic and is given for infrequent time intervals; therefore, the data cannot always permit the reduction of the wind field along a computational line (traverse).

b. Hydrographic Data. Reliable tide gage recordings of the hurricane surge are important in the verification of a numerical model. Most tide gages are located in sheltered areas and do not record nor represent the peak storm surge at the open coast. The few tide stations located on the open coast are widely separated and often are not near paths of hurricanes. Therefore, most tide gage data used in the calculations of surge on the open coast were from tide gages located some distance away. To avoid errors, corrections must be applied to account for phase differences in astronomical tides between the tide gage station and the point on the open coast where surge is computed. Similarly, corrections should be applied to the recorded hydrographs because of differences in the water level datum of tide gages, e.g., some of the recorded or observed surge data associated with hurricanes are reported in the literature relative to mean sea level (MSL). Other tide gage data are given relative to mean low water (MLW).

When tide gage records are not available, peak storm surge elevations on the open coast are often obtained visually from debris marks, which generally include wave-induced setup and runup. Then, it is impossible to determine accurately how much of the water level elevation is from surge and how much is from wave action. The observed levels in these cases are higher than those of the surge alone.

c. *Initial Water Levels.* Water levels along the coast have been observed for long periods of time before the arrival of a hurricane, and are different than the predicted astronomical tide. This difference in water level between observed and predicted tide appears to be independent of the storm or the astronomical forces, and is referred to as the *initial water level.* Harris (1963) has shown that such water level deviations can be as much as 2 feet above mean water level (MLW) preceding the approach of a hurricane. Others have attributed this initial rise to a "forerunner" of the storm, while Harris maintains that it is due to short-period anomalies in the mean sea level not related to the hurricane, and that predicted astronomical tides do not take this phenomenon into account. In some instances this initial rise is believed to be a significant factor in the total water level observed on the coast during the passage of storm systems and therefore cannot be ignored. This additional component is particularly important when determining the total water level for a synthetic hurricane as the PMH.

The initial water rise used as input to the numerical calculation of storm surge is usually the average difference between predicted astronomical and observed tides at a tide gage station at or closest to the shore intercept (open coast) of the traverse prior to the influencing effects of hurricane winds and pressures. In the numerical calculations, this value is treated as a constant and is added to the total water level. This may be an over-simplification, since the cause for such rise or its exact magnitude during the passage of the storm is unknown. Whatever the cause, however, the initial water level should be considered when evaluating the open-coast storm surge. This value is determined before the hurricane reaches the edge of the Continental Shelf or at a time when winds on the shore are less than 15 miles per hour. No available definition exists for identifying or measuring a value of initial rise for historic hurricanes. Because of the significance of the assumption of initial rise in hurricane verification, specific definition of initial rise for use in hurricane verification studies may be appropriate. Therefore, for the purpose of calibration, initial rise can be defined as "the average water level variation above the predicted astronomical tide at a station during the 2 days preceding the occurrence of a 15- to 20-mile per hour isovel of a hurricane advancing across the Continental Shelf."

Although there are numerous assumptions and data limitations, verification of the numerical computation of storm surge is possible with the data of a few recent hurricanes. In this study, the data were taken from a few well documented hurricanes. An important aspect of any future verification study will be the increased accuracy of basic data, the collection of additional historical data on storm surge wave action along coastlines, and data on the extent of coastal flooding.

II. THE BATHYSTROPHIC STORM SURGE MODEL

The numerical model described here is based on the Bathystrophic Storm Tide Theory and is used to estimate the rise of water on the open coast taking into account the combined effects of direct onshore and alongshore wind-stress components on the surface of the water, and the effects of the Coriolis force (bathystrophic effect), and the different pressure effects. This model can be described as a quasi-one-dimensional numerical scheme, which is a steady-state integration of the wind stresses of the hurricane winds on the surface of the water from the edge of the Continental Shelf to the shore, taking into consideration some of the effects of bottom friction and the alongshore flow caused by the earth's rotation. The bathystrophic contribution to hurricane surge can be explained as follows: In the northern hemisphere hurricane winds approaching the coast have a counterclockwise motion. Because of the Coriolis effect, the flow of water induced by the cyclonic winds will deflect to the right, causing a rise in the water level. The bathystrophic storm tide, therefore, is important in producing maximum surge even when winds blow parallel to the coast. Coastal morphology may also affect the extent of rise of water. However, in this model the surge is calculated only along a single traverse line at a time over the Continental Shelf for a straight open-ocean coast.

The model uses the onshore and alongshore wind-stress components of a moving wind field over the Continental Shelf, and a frictional component of bottom stress. The nonlinear storm surge is computed at selected points along the traverse by integrating numerically the one-dimensional hydrodynamic equations of motion and continuity.

The computed surge is a composite of water elevation obtained from components of the astronomical tide, the atmospheric pressure, the initial rise, the rises due to wind and bottom friction stresses, and wave setup.

1. Basic Assumptions, Conditions, and Limitations.

The bathystrophic theory on which this model is based, represents an approximation to the complete storm-generation process. Therefore, the model is limited by a number of initial conditions and assumptions. In most instances, the bathystrophic approximation appears to give a reasonable estimate of the open-coast surge; however, at times the surge estimate could be in error by a factor of 2 or more. The basic equations which govern the generation of storm surge will not be derived here, but to understand the bathystrophic approximation and its limitations, it is important to emphasize the assumptions, initial conditions, and the hydrodynamic processes neglected in development.

The following initial conditions are placed on the basic equations which govern storm surge generation (Bodine, 1971):

a. The hurricane creates a disturbance on the ocean surface of such horizontal dimensions so that $L >> D$ and $L << R_E$, where L is the length of the disturbance; D is the depth of the water (at the edge of the Continental Shelf), and R_E is the radius of the earth. It is also assumed that:

(1) The space derivatives of the current velocity and acceleration can be neglected. Thus, the vertical pressure gradient is hydrostatic, and vertical accelerations are negligible.

(2) The curvature of the earth can be neglected and a flat earth approximation can be used.

b. The acceleration due to the earth's rotation is a constant.

c. Water density ρ is a constant, and internal forces due to viscosity can be neglected.

d. The seabed is fixed, impermeable, and forms the lower boundary.

e. Surface storm waves are linearly superimposed on storm surge. A basic assumption of the model is that the surge involves only horizontal fluid motions. In respect to wave theory, such horizontal fluid motions are often referred to as *long waves*. The water motion associated with the propagation of long waves is in a continuous state of gradual change.

2. Hydrodynamic Equations.

Integrations of the primary hydrodynamic equations describing the storm surge problem have been shown by Haurwitz (1951), Welander (1961), Fortak (1962), Platzman (1963), Reid (1964), and Harris (1967). These derivations show the actual approximations involved. In the bathystrophic model by Bodine (1971), the basic equations are the simplified and vertically integrated equations of continuity expressing conservation of mass and motion, according to Newton's second law. The equations were taken directly from Bodine in integrated form for the purpose of illustrating the principal approximations of the bathystrophic model.

The governing two-dimensional hydrodynamic equations in a volume-transport form, appropriate for tropical or extratropical storm surge problems on the open coast and in enclosed or semienclosed basins, are as follows:

$$\frac{\partial U}{\partial t} + \underbrace{\frac{\partial M_{xx}}{\partial x} + \frac{\partial M_{xy}}{\partial y}}_{\text{Advection of Momentum}} = \underbrace{+ fV}_{\text{Coriolis}} - \underbrace{gD\frac{\partial S}{\partial x}}_{\text{Surface Slope}} + \underbrace{gD\frac{\partial \xi}{\partial x}}_{\text{Inverse Barometer}} + \underbrace{gD\frac{\partial \zeta}{\partial x}}_{\text{Astro. Tide Potential}} + \underbrace{\frac{\tau_{sx}}{\rho}}_{\text{Wind Stress}} - \underbrace{\frac{\tau_{bx}}{\rho}}_{\text{Bottom Stress}} + \underbrace{W_x P}_{\text{Rainfall Rate}} \tag{3}$$

$$\frac{\partial V}{\partial t} + \overbrace{\frac{\partial M_{yy}}{\partial y} + \frac{\partial M_{xy}}{\partial x}} = \overbrace{- fU} - \overbrace{gD\frac{\partial S}{\partial y}} + \overbrace{gD\frac{\partial \xi}{\partial y}} + \overbrace{gD\frac{\partial \zeta}{\partial y}} + \overbrace{\frac{\tau_{sy}}{\rho}} - \overbrace{\frac{\tau_{by}}{\rho}} + \overbrace{W_y P} \tag{4}$$

$$\frac{\partial S}{\partial t} + \frac{\partial U}{\partial x} + \frac{\partial V}{\partial y} = P\,. \tag{5}$$

where M_{xx}, M_{yy}, M_{xy}, U, and V are given by:

$$M_{xx} = \int_{-d}^{S} u^2\,dz; \quad M_{yy} = \int_{-d}^{S} v^2\,dz; \quad M_{xy} = \int_{-d}^{S} uv\,dz,$$

$$U = \int_{-d}^{S} u\,dz; \qquad V = \int_{-d}^{S} v\,dz\,.$$

where,

U, V = x and y components, respectively, of volume transport per unit width,

t = time,

M_{xx}, M_{yy}, M_{xy} = momentum transport quantities,

$f = 2\omega \sin\phi$ = Coriolis parameter,

ω = angular velocity of earth = $2\pi/24$ radians per hour (7.29×10^5 radians per second),

ϕ = geographical latitude,

τ_{sx}, τ_{sy} = x and y components of surface wind stress,

τ_{bx}, τ_{by} = x and y components of bottom stress,

ρ = mass density of water,

W_x, W_y = x and y components of windspeed,

ξ = atmospheric pressure deficit in head of water,

ζ = astronomical tide potential in head of water,

u, v = x and y components, respectively, of current velocity,

p = precipitation rate (depth/time),

S = setup of water surface above SWL,

g = gravitational acceleration,

D = depth of water at edge of Continental Shelf,

d = depth of water on the Continental Shelf,

and

θ = angle of wind measured counterclockwise from the x-axis.

Equations (3) and (4) are the equations of motion, while equation (5) is the continuity relation for a fluid of constant density. These basic equations provide a complete description of nearly all horizontal water motions resulting from hurricane surge. An exact solution of these equations would be very desirable for solving the surge problem; however, it is difficult to obtain. The model described here obtains only a useful approximation by ignoring some terms in the basic equations. Accurate solutions can only be acquired by retaining the full two-dimensional characteristics of the surge problem.

3. The Bathystrophic Model Approximation.

Application of the Bathystrophic Storm Tide Theory of Freeman, Baer, and Jung (1957) to the hydrodynamic equations of motion and continuity for the solution of the surge problem requires a number of assumptions. According to Bodine (1971) these assumptions imply that: (a) there is no volume transport normal to the shore, (b) the onshore wind setup responds instantaneously to the onshore wind stress, (c) advection of momentum (field acceleration) is negligible, (d) the alongshore sea surface height is uniform, and (e) precipitation can be neglected. When applied to the terms of the equations of motion and continuity (1), (2), and (3), according to Bodine these assumptions have the following physical significance:

$\frac{\partial U}{\partial t}, fU, \frac{\partial U}{\partial x}, \frac{\tau_{bx}}{\rho} \rightarrow 0$, (no onshore water volume transport),

$M_{xx}, M_{yy}, M_{xy} \rightarrow 0$, (the advection of momentum can be neglected),

$\frac{\partial S}{\partial y}, \frac{\partial V}{\partial y} \rightarrow 0$, (the alongshore sea surface and current are uniform),

$P \rightarrow 0$, (the precipitation can be neglected),

$\frac{\partial \xi}{\partial x}, \frac{\partial \xi}{\partial y} \rightarrow$ (The barometric effects are neglected in this approximation, but are accounted for elsewhere. These effects are discussed later.)

$\frac{\partial \zeta}{\partial x}, \frac{\partial \zeta}{\partial y} \rightarrow$ (The astronomical tide effects are neglected in this approximation but are accounted for in the final estimate of the surge on the coast. These effects are discussed later.)

Based on these assumptions, the motion equations (3) and (4), reduce to the following approximations:

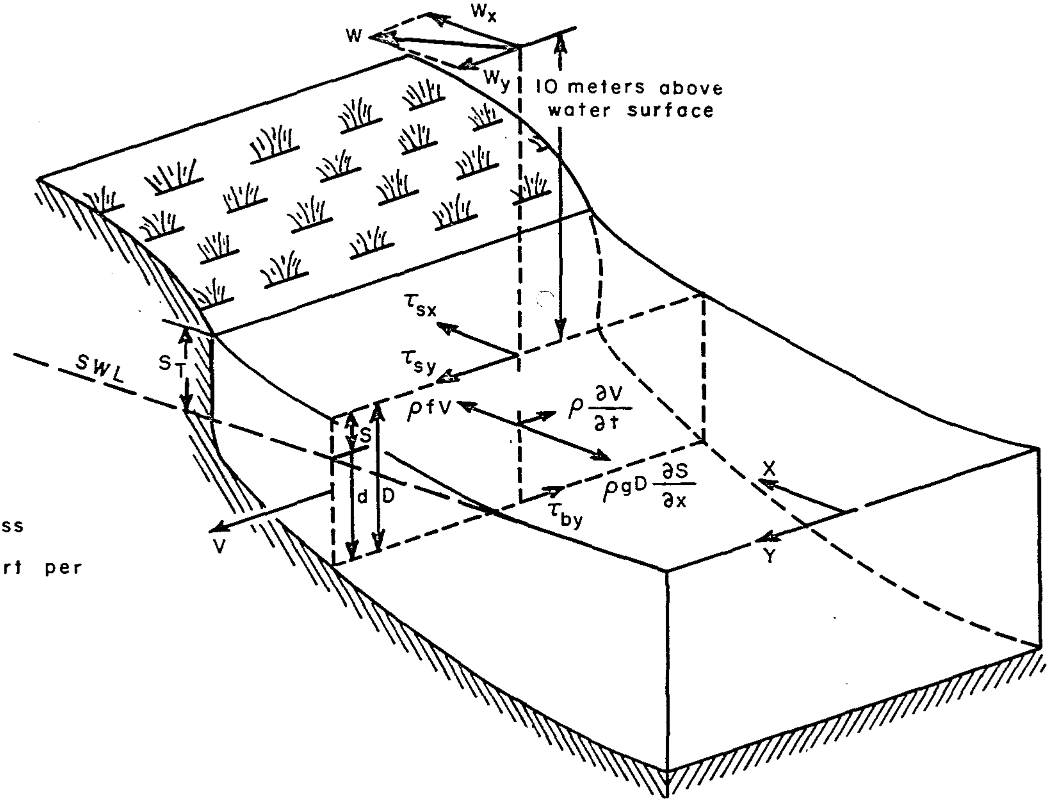
$$gD \frac{\partial S}{\partial x} = fV + \frac{\tau_{sx}}{\rho} , \tag{6}$$

$$\frac{\partial V}{\partial t} = \frac{\tau_{sy} - \tau_{by}}{\rho} . \tag{7}$$

The mass-continuity equation (5) is disregarded in the bathystrophic approximation because the assumptions make it unnecessary for a unique solution, and of no interest, for each term has been set equal to zero. The reduced equations (6) and (7) are now quasi-two-dimensional, since their solution can be obtained only along a single axis, the x-axis; however, the y-axis bathystrophic component of transport is retained and can be accounted for. The forces and responses for the bathystrophic approximation are shown in Figure 1. The weakness of the bathystrophic surge model lies on the numerous approximations outlined here. A reduction in the number of these approximations and the solution of the hydrodynamic equations in a more complete form may result in better estimates of storm surges.

4. Wind and Bottom Frictional Stresses.

Equations (6) and (7) include the x- and y-components of wind stress on the surface of the water, τ_{sx} and τ_{sy}, and the y component of bottom stress due to the water motion, τ_{by}. These are frictional stresses which need to be quantified for the solution of the surge problem. Formulas derived from theoretical solutions and physical experiments have been introduced which provide reasonable values of frictional forces at the bottom and water surface boundaries. However, these stress values have not been verified for the entire spectrum of conditions encountered in nature. Furthermore, the surface wind stresses and the bottom stresses must be "coupled" for the numerical computation of hurricane surge described in this report. Although surface and bottom stresses can be obtained individually from empirical experiments, the combined interaction of these stress factors does not obey a linear relationship. Friction models which take into account the interaction of surface wind and bottom friction stresses have been proposed by Reid (1957), Platzman (1963), and Jelesnianski (1967, 1970). These proposals, however, fail to describe the interactions of stresses in shallow water near the shore. Similarly, extrapolation of the surface wind stress relationship, as determined from lower windspeeds, to extreme wind conditions may not be realistic, as there may be interaction of other unknown or unmeasurable variables. Nonetheless, reasonable estimates of boundary stresses can be obtained if simplified stress laws are used, and the influence of vertical velocity distribution is neglected. Assuming horizontally uniform flows of wind and water at the water surface and seabed boundaries, NOTE: Various scales have been distorted to give a clearer pictorial representation.



LEGEND:

SWL = Stillwater Level
S_T = Total Setup at Shore
S = Setup
d = depth below SWL
D = Total depth
τ_{sx}, τ_{sy} = x, y components of wind stress
V = y-component of water transport per unit width (of x)
W = Windspeed
W_x, W_y = x, y components of windspeed
τ_{by} = y-component of bottom stress
f = Coriolis parameter
ρ = density of water
g = gravity
t = time

Figure 1. Schematic of forces and responses for bathystrophic approximation (U. S. Army, Corps of Engineers, Coastal Engineering Research Center, 1973).

respectively, similar formulas can be adopted for representing the wind and bottom friction stresses. Considering these flows, the mean shear stress at the boundary, τ relates to the mean velocity gradient $\bar{v}$ as follows:

$$\tau = \gamma \rho \bar{v}^2,$$

where ρ is the water density, and γ is a dimensionless resistance coefficient. To retain the proper sign consistent with the coordinate system used, the above equation can be written as follows:

$$\tau = \gamma \rho \bar{v} |\bar{v}| . \tag{8}$$

Accordingly, the shear stress at the bottom (τ_{by}) divided by water density, consistent with the stress term required for equation (7), is:

$$\frac{\tau_{by}}{\rho} = \mathrm{K} v |v| , \tag{9}$$

where the bed friction coefficient K, and the y-component of the water velocity, v, replace γ and $\bar{v}$ respectively, in equation (8). The bed friction coefficient K, as presented here, is dimensionless in accordance to the Prandtl-von Karman Boundary-Layer Theory (Prandtl, 1935; von Karman, 1930). In the bathystrophic model used in this study (Bodine, 1971), the Prandtl-von Karman Boundary-Layer Theory was chosen because of the simplicity in computation. In transport form, equation (9) is given by Bodine as:

$$\frac{\tau_{by}}{\rho} = \frac{\mathrm{K} \mathrm{V} |\mathrm{V}|}{\mathrm{D}^2} \text{ (bottom shear stress).} \tag{10}$$

For typical seabed conditions, the bottom friction coefficient K has been assigned values ranging from 2×10^{-3} and 5×10^{-3} . K is related to the coefficient of Chezy C and the Darcy-Weisbach friction factor f_f as follows:

$$\mathrm{K} = \frac{g}{\mathrm{C}^2} = \frac{f_f}{2} .$$

The wind-induced water surface stress, in accordance with equation (8), is given by:

$$\tau_s = \rho k \mathrm{W}^2 = \rho k \mathrm{W} |\mathrm{W}| , \tag{11}$$

where W is the wind velocity as given at standard anemometer level (30 feet above the wave surface, based on 10-minute averages), and k is a dimensionless surface friction coefficient. The square of the wind velocity is given as an absolute term W|W| rather than W^2 to retain the proper sign consistent with the coordinate system used. According to a relationship worked out by Van Dorn (1953), the wind-stress coefficient is a function of the windspeed given by:

$$k = K_1 + K_2 \left(1 - \frac{W_c}{W}\right)^2 \quad \text{for } W \geqslant W_c , \tag{12}$$

where the constants K_1 and K_2 were derived empirically by Van Dorn to be 1.1×10^{-6} and 2.5×10^{-6} respectively, and W_c is a critical windspeed taken as 14 knots (about 16 miles per hour). When $W \leqslant W_c$, equation (12), reduces to:

$$k = K_1 . \tag{13}$$

On the basis of equation (11), the x- and y-components of wind shear stress can be written as:

$$\left.\begin{aligned} \frac{\tau_{sx}}{\rho} &= kW^2 \cos\theta \\ \frac{\tau_{sy}}{\rho} &= kW^2 \sin\theta , \end{aligned}\right\} \quad \text{(wind shear stress)} \tag{14}$$

where θ is the angle between the x-axis and the local wind vector.

Equations (11) through (14) can now be introduced into the reduced equations of motion of the bathystrophic approximation; equations (6) and (7), can now be written as follows:

$$\frac{\partial S}{\partial x} = \frac{1}{gD}\left[fV + kW^2 \cos\theta\right], \tag{15}$$

$$\frac{\partial V}{\partial t} = kW^2 \sin\theta - \frac{KV^2}{D^2} \tag{16}$$

These equations are simplified forms of the hydrodynamic equations which are applied to the estimation of storm surge. The solution of these equations by numerical integration is given later in this report.

5. Numerical Solution of the Surge Problem.

A discussion of the numerical scheme for computing bathystrophic storm surge is given by Bodine (1971). The basic concepts are detailed here to show the geometry of the finite-difference numerical method and solution of the numerical equations of setup and flux.

Equations (15) and (16) giving setup and flux, respectively, can be solved in finite increments of time and space, assuming the functional relationships of the bathystrophic equations as continuous over the entire computing interval. The two-dimensional finite step method of the numerical scheme is illustrated in Figures 2 and 3 for discrete increments of space, $(\Delta_x)_i$ and time $(\Delta_t)_n$ along a single Cartesian axis, the computational plane represented by the traverse. For convenience, the seabed slope AB is shown to be uniform (Fig. 3). Point C represents position of the edge of the Continental Shelf or the most seaward point along the traverse, above point A. The line CB represents the equilibrium condition of the sea surface before being affected by the approaching hurricane winds. The line CD represents the sea surface altered by the cumulative effects of the winds, astronomical tide, initial rise, pressure differences and storm waves. A detailed explanation of the variables contributing to storm surge on the shore is discussed later. The cumulative water elevation (S) associated with the hurricane is DB, while point B represents the shore intercept of the traverse.

For convenience, a boundary condition is placed on the model at point B where the shoreline is represented by a vertical wall and surge is calculated at a one-half step increment in front of this wall. The model treats the final water elevation as a static condition, and the shoreline as a vertical impermeable boundary. However, in reality, the shore is a sloping surface and dynamic processes and momentum forces associated with water transport and storm waves may result in greater surge elevation along the coast.

An initial assumption of the numerical system is that, at the beginning of the calculation, when $t = t_o$, the system is in an equilibrium state, with a uniform water surface, and no currents. This implies that the water flux, V, is zero at $t = t_o$ and that S has a constant value for the system. Although in reality the system does not exist in a state of complete equilibrium, it is a reasonable assumption for the calculation. Later, this assumption is of little consequence, since the response of the system reflects only the effects of the input-forcing functions.

The discrete position x along the traverse line at any time level, t, is defined as:

$$x = x_o - \sum_{i=1}^{IM} (\Delta x)_i \ , \qquad (17)$$

and the time level t is given by:

$$t = t_o + \sum_{n=1}^{NM} (\Delta t)_n \ , \qquad (18)$$

where x_o as shown in Figure 3, is the distance from the shore intercept of the traverse to the most seaward point of the traverse. The summation of Δx is for all i intervals up to and including IM, so that at the shore $x = x_o$. Although x, according to the coordinate system shown here, would be negative, changing the sign of x to a positive value does not

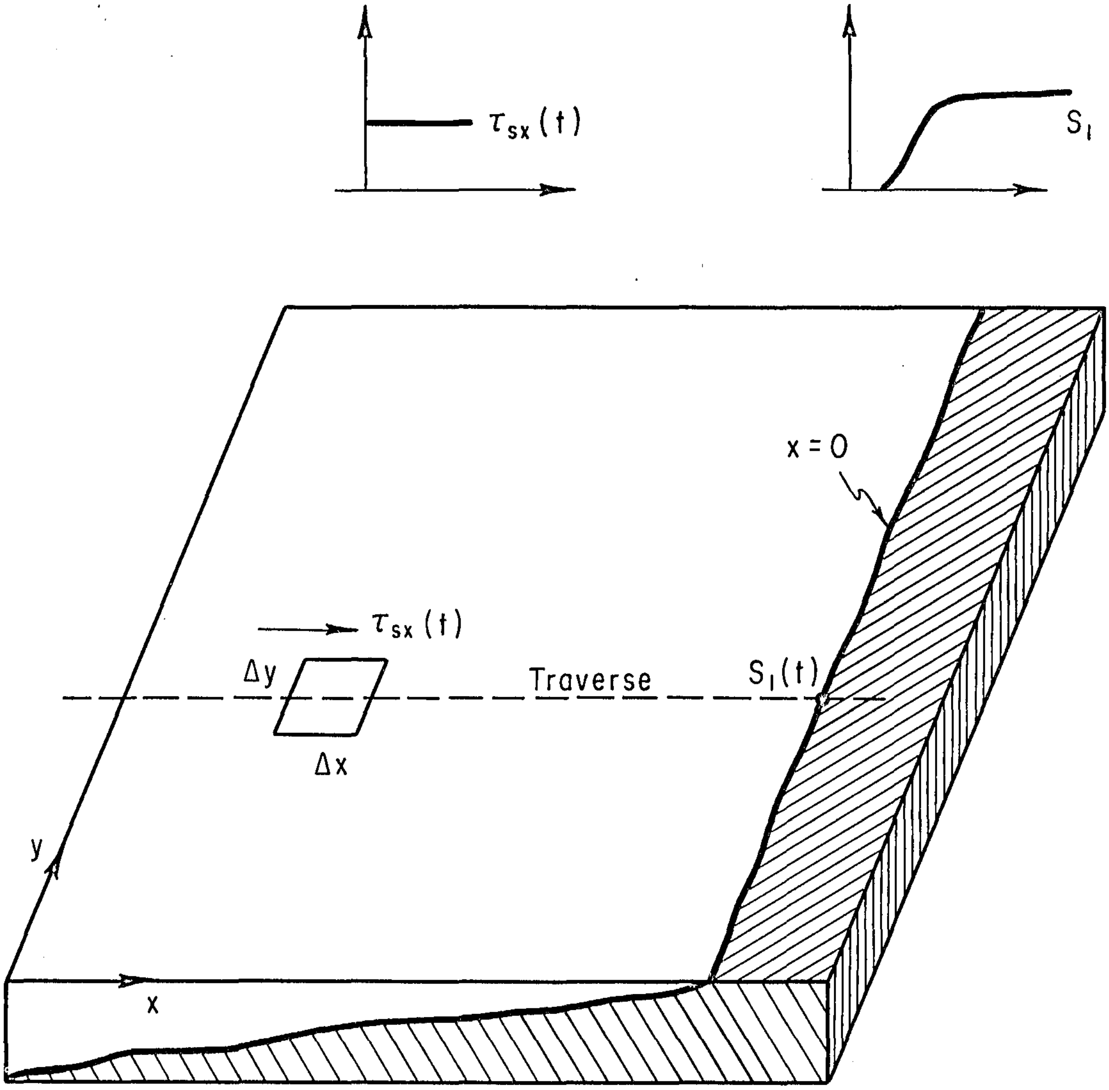


Figure 2. The response of sea level $S_1 \Delta x \Delta y$ due to a step function in the wind stress τ_{sx} acting over a unit area $\Delta x \Delta y$.

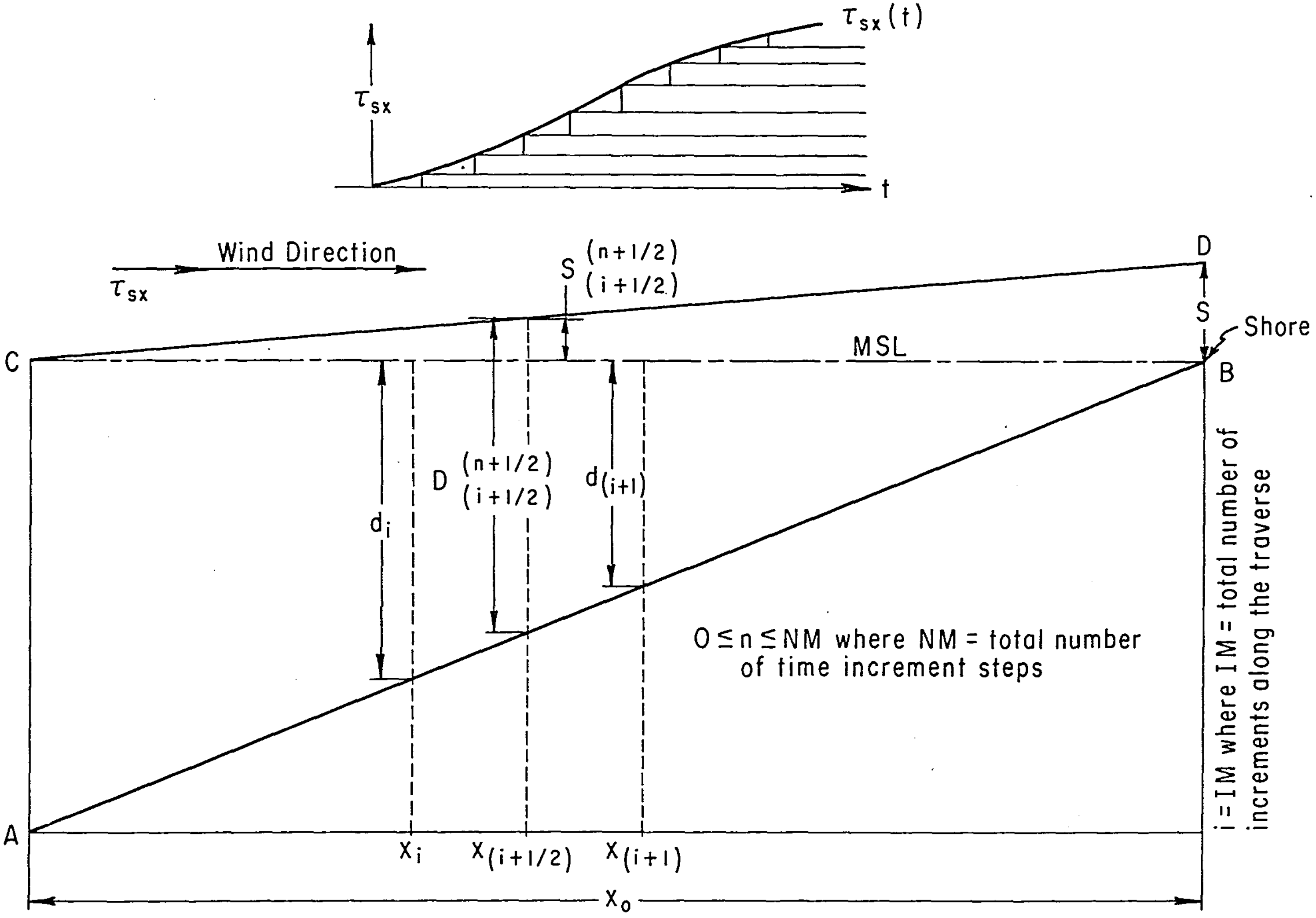


Figure 3. Numerical solution by summation of step functions.

change the computational method. The time scale at the beginning of the calculation at the seaward point of the computational line is t_o and the time level is the summation of Δ_t for all n's up to, and including a specified value n = NM.

From the chosen geometry of the present numerical scheme, the values of wind stress τ_s, seabed depths below the undisturbed level d, and the Coriolis effects are supplied at all discrete positions of i. The setup S, the total water depth at each increment, and the value of volume transport V, are evaluated at intervals, i + ½.

The total water depth $\left(D^{n+½}_{i+½}\right)$ midway between two time levels n and n + 1 is centered between the points x_i and x_{i+1}, and the cumulative water depth is given by:

$$D^{n+½}_{i+½} = \frac{d_i + d_{i+1}}{2} + S_e + \frac{S^n_A + S^{n+1}_A}{2} + \left(S_x + S_y\right)^n_{i+½}$$

$$+ \frac{1}{4}\left(\left[\left(S_{\Delta p}\right)_i + \left(S_{\Delta p}\right)_{i+1}\right]^n + \left[\left(S_{\Delta p}\right)_i + \left(S_{\Delta p}\right)_{i+1}\right]^{n+1}\right), \qquad (19)$$

where

S_e = initial rise in the water level at the time the storm surge computations are started,

S_A = setup due to astronomical tide,

$S_{\Delta p}$ = atmospheric pressure setup in feet, given by:

$$S_{\Delta p} = 1.14\left(p_n - p_o\right)\left(1 - e^{-R/r}\right),$$

which is an approximate relationship when pressure is expressed in inches of mercury and where p_n is the pressure at the periphery of the storm, and r is the radial distance from the storm center to the computation point on the traverse line and S_x and S_y are the components of the storm setup given by:

$$S_x = \sum_{j=1} \left(\Delta S_x\right)_j, \qquad (20)$$

$$S_y = \sum_{j=1} \left(\Delta S_y\right)_j. \qquad (21)$$

The physical significance of equations (20) and 21) is that total wind setup for any discrete position along the traverse is the setup in that reach superimposed cumulatively on the setups in all reaches seaward.

For a new time level, n + 1, the total water depth is given by:

$$D^{n+1}_{i+1/2} = \frac{d_i + d_{i+1}}{2} + S_e + S^{n+1}_A + \left(S_x + S_y\right)^n_{i+1/2}$$

$$+ \frac{1}{2}\left[\left(S_{\Delta p}\right)_i + \left(S_{\Delta p}\right)_{i+1}\right]^{n+1} . \tag{22}$$

From Figure 3 and equations (19) and (22) it is apparent that a small error is introduced each time D is calculated because the term $(S_x + S_y)$ is taken at the previous time level rather than at time (n + ½) for equation (19) and (n + 1) for equation (22). The reason is that the correct values are not known for these time intervals; therefore, an approximation is made. This error, however, is minimized by using small increments of time and space in the calculations.

The differential hydrodynamic equations (15) and (16) can now be solved by numerical integration. Equation (15) gives the cumulative setup resulting from onshore and alongshore effects. The onshore, wind-induced component, according to Bodine (1971) can be separated from the alongshore bathystrophic component and equation (15) can be written in its equivalent forms as follows:

$$\frac{\partial S_x}{\partial x} = \frac{kW^2 \cos\theta}{gD} , \tag{23}$$

$$\frac{\partial S_y}{\partial x} = \frac{fV}{gD} , \tag{24}$$

where the total setup along the x-axis is the sum of the two, given by

$$\frac{\partial S}{\partial x} = \frac{\partial S_x}{\partial x} + \frac{\partial S_y}{\partial x} .$$

Numerical integration of equations (23) and (24) will give the following numerical analogs (Bodine, 1971):

$$\left(\Delta S_x\right)^{n+1}_{i+1/2} = \frac{\Delta x}{2gD^{n+1}_{i+1/2}} \left(A_i + A_{i+1}\right)^{n+1} , \tag{25}$$

$$\left(\Delta S_y\right)^{n+1}_{i+1/2} = \frac{\Delta x}{2gD^{n+1}_{i+1/2}} \left(f_i + f_{i+1},\ V^{n+1}_{i+1/2}\right. , \tag{26}$$

where A is a Kinematic form of wind stress given by:

$$A = kW^2 \cos\theta .$$

Similarly, the alongshore differential equation (16) of water flux can be resolved by numerical integration as:

$$\frac{\partial V}{\partial t} = kW^2 \sin\theta - \frac{KV^2}{D^2},$$

or

$$\frac{\partial V}{\partial t} = kW^2 \sin\theta - KV|V|D^{-2}.$$

However,

$$\frac{\partial V}{\partial t} \simeq \frac{V_{i+1/2}^{n+1} - V_{i+1/2}^{n}}{\Delta t}. \tag{27}$$

The first term of equation (16), $kW^2 \sin\theta$ can be made equal to B, which is also a Kinematic form of the wind stress, so that,

$$B = kW^2 \sin\theta \simeq \frac{1}{4}\left[\left(B_i + B_{i+1}\right)^n + \left(B_i + B_{i+1}\right)^{n+1}\right]. \tag{28}$$

The second term of equation (16) can be approximated as follows:

$$KV|V|D^{-2} \simeq KV_{i+1/2}^{n+1}\left|V_{i+1/2}^{n}\right|\left(D^{-2}\right)_{i+1/2}^{n+1/2}. \tag{29}$$

Substituting equations (27), (28), and (29) into equation (16), yields:

$$\frac{V_{i+1/2}^{n+1} - V_{i+1/2}^{n}}{\Delta t} = \frac{1}{4}\left[\left(B_i + B_{i+1}\right)^n + \left(B_i + B_{i+1}\right)^{n+1}\right] - KV_{i+1/2}^{n+1}\left|V_{i+1/2}^{n}\right|\left(D^{-2}\right)_{i+1/2}^{n+1/2}. \tag{30}$$

Multiplying equation (30) by Δ_t and transposing the term $V_{i+1/2}^{n}$ yields:

$$V_{i+1/2}^{n+1} = \frac{1}{4}\left[\left(B_i + B_{i+1}\right)^n + \left(B_i + B_{i+1}\right)^{n+1}\right]\Delta t - KV_{i+1/2}^{n+1}\left|V_{i+1/2}^{n}\right|\left(D^{-2}\right)_{i+1/2}^{n+1/2}\Delta t + V_{i+1/2}^{n}, \tag{31}$$

transposing the term

$$KV_{i+½}^{n+1} \left|V_{i+½}^{n}\right| \left(D^{-2}\right)_{i+½}^{n+½} \Delta t,$$

yields:

$$V_{i+½}^{n+1} + KV_{i+½}^{n+1} \left|V_{i+½}^{n}\right| \left(D^{-2}\right)_{i+½}^{n+½} \Delta t$$

$$= V_{i+½}^{n} + \frac{1}{4} \left[\left(B_i + B_{i+1}\right)^n + \left(B_i + B_{i+1}\right)^{n+1}\right] \Delta t. \qquad (32)$$

Factoring out the term $V_{i+½}^{n+1}$ and dividing equation (32) by the term

$$1 + K\left|V_{i+½}^{n}\right| \left(D^{-2}\right)_{i+½}^{n+½} \Delta t,$$

becomes:

$$V_{i+½}^{n+1} = \frac{\left(\frac{1}{4}\right)\left[\left(B_i + B_{i+1}\right)^n + \left(B_i + B_{i+1}\right)^{n+1}\right] \Delta t + V_{i+½}^{n}}{1 + K\left|V_{i+½}^{n}\right| \Delta t \left(D^{-2}\right)_{i+½}^{n+½}}, \qquad (33)$$

which is the numerical analog of equation (16).

In the numerical analogs of the bathystrophic equations, nonuniform spacing Δx and time, Δt, steps can be taken. This permits coarse spacing, Δx, where the seabed is relatively flat, and fine spacing near the shore where the bed slope changes rapidly. Similarly, nonuniform time steps, Δt, permit more frequent storm-surge computations during the period when rapid water level changes are anticipated.

Based on this numerical scheme and logic, calculations of surge are started at the seaward boundary to the shore-intercept through all prescribed spatial positions on the traverse at the initial time level. The process is repeated for each prescribed time level, and continued for the entire temporal range. For each discrete position along the traverse line, the flux V, at each new time level, is evaluated based on the flux V at the previous time level. Similarly the stress term B, and depth D, are evaluated as the average values in the incremental domain of $(x + \Delta x)$ and $(t + \Delta t)$. Determination of V at each new time level can be made with equation (33), then using this value, determination of the x- and y-components of setup, ΔS_x and ΔS_y, can be made with equation (25) and (26), to obtain the total setups S_x and S_y.

As mentioned earlier, the total water level rise on the shore will be the summation of a number of components from the meteorological storm plus those unrelated to the storm. The total setup is given by:

$$S_T = S_x + S_y + S_{\Delta p} + S_e + S_A + S_W + S_L. \qquad (34)$$

Definitions of most components have been given. Some other components are related to the storm but some unrelated terms are provided as input to the surge computation. In equation (34), S_w is the wave setup at the shore due to breaking waves given (U.S. Army, Corps of Engineers, Coastal Engineering Research Center, 1973):

$$S_W = 0.19 \left[1 - 2.82 \left(\frac{H_b}{gT^2} \right)^{1/2} \right] H_b \, , \tag{35}$$

where H_b is the height of the breaking wave, g is the gravitational acceleration, and T is the wave period. The local setup or setdown S_L, is the deviation of the water surface from the computed water level due to such local effects as inland runoff inside the coastal barrier or the coastal hydrography. This component can only be estimated from full consideration of the influences of topography and hydrography not considered in the numerical computations. A schematic representation of the different setup components contributing to storm surge on the shore is shown in Figure 4.

Calculation of volume transport V, is based on repeated computations using the same formula, and can result in round-off errors, as each computed value will influence the values which remain to be determined. To ensure that the value of V does not exceed the maximum possible value, Bodine (1971) derived the following relationship. In an incremental form, equation (16) can be written as:

$$\Delta V = kW^2 \sin\theta \, \Delta t - KV^2 D^{-2} \, \Delta t \, ,$$

or

$$KV^2 D^{-2} \, \Delta t = kW^2 \sin\theta \, \Delta t - \Delta V \, .$$

For small

$$\Delta V, \; KV^2 D^{-2} \leqslant kW^2 \sin\theta \, .$$

Thus, the y-component of volume transport becomes

$$V \leqslant \sqrt{\frac{D^2 kW^2 \sin\theta}{K}} \, .$$

At the new time level, the above equation can be written in its numerical analog form, as:

$$V^{n+1}_{i+1/2} \leqslant \sqrt{\frac{\left|\left(B_i + B_{i+1}\right)^{n+1}\right| \left(D^2\right)^{n+1}_{i+1/2}}{2K}} \, . \tag{36}$$

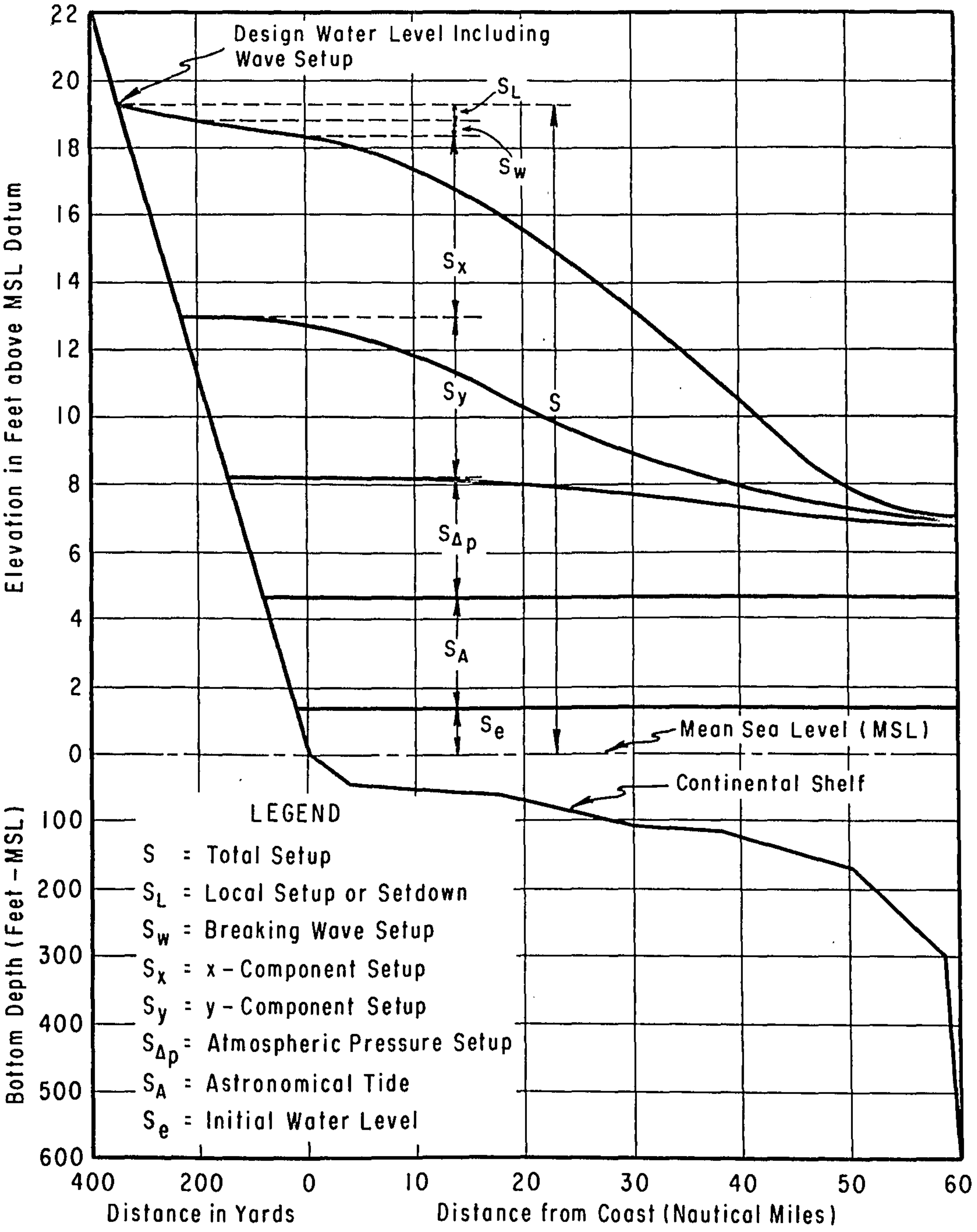


Figure 4. Various setup components over the Continental Shelf contributing to storm surge on the shore (Bodine, 1971).

According to this equation the absolute value of the flux must never exceed the term on the right-hand side. This relation is used as a check, and if this value is exceeded, the flux at the new time level, as an estimate, can be set equal to the value given by the right-hand side of equation (36). The integrated equations (25), (26), (33) and (36) can be used for the numerical solution of the surge problem. However, because of the inconsistency of units in the different terms used in these equations, it is desirable to absorb the invariant coefficients of these terms and substitute with constants. Such substitution reduces the possibility of errors and the equations are easier to use in the program. For example, weather charts usually present the wind data in knots. Distances taken from hydrographic maps are given in nautical miles, and depths in fathoms or feet. To eliminate conversion of units, Table 1 gives the dimensions of the variables used in the numerical scheme in four systems of units and the corresponding value of the constants for each system. The first column of units is given in the metric system while the other three are given in mixed units of the English system.

Table 1. Systems of Units for Storm Surge Computations

Parameters	Units and Constant Values			
	Metric	Mixed English		
Δx	km	nm	nm	mi
$\Delta S_x, \Delta S_y$	m	ft	ft	ft
g	m/sec^2	ft/sec^2	ft/sec^2	ft/sec^2
D	m	ft	ft	ft
A, B	$(km/hr)^2$	$(nm/hr)^2$	$(mi/hr)^2$	$(mi/hr)^2$
V	km^2/hr	nm^2/hr	mi^2/hr	mi^2/hr
f	hr^{-1}	hr^{-1}	hr^{-1}	hr^{-1}
Δt	hr	hr	hr	hr
C_1	3.94	269	203	176
C_2	2.06	141	106	92
C_3	$(1,000)^2$	$(6,080)^2$	$(5,280)^2$	$(5,280)^2$

(U.S. Army, Corps of Engineers, Coastal Engineering Research Center, 1973).

Equations (25), (26), (33), and (36) can now be given in a more simplified computational form, as follows:

$$\left(\Delta S_x\right)^{n+1}_{i+\frac{1}{2}} = \frac{C_1\,\Delta x}{D^{n+1}_{i+\frac{1}{2}}}\left(A_i + A_{i+1}\right)^{n+1}, \tag{37}$$

$$\left(\Delta S_y\right)^{n+1}_{i+\frac{1}{2}} = \frac{C_2\,\Delta x}{D^{n+1}_{i+\frac{1}{2}}}\left[\left(\sin\phi\right)_i + \left(\sin\phi\right)_{i+1}\right] V^{n+1}_{i+\frac{1}{2}}, \tag{38}$$

$$V^{n+1}_{i+\frac{1}{2}} = \frac{\left(\frac{1}{4}\right)\left[\left(B_i + B_{i+1}\right)^n + \left(B_i + B_{i+1}\right)^{n+1}\right]\left(\Delta t\right) + V^n_{i+\frac{1}{2}}}{1 + C_3\left|V^n_{i+\frac{1}{2}}\right|\Delta t\; K\left(D^{-2}\right)^{n+\frac{1}{2}}_{i+\frac{1}{2}}}, \tag{39}$$

$$V^{n+1}_{i+\frac{1}{2}} \leqslant \sqrt{\frac{\left|\left(B_i + B_{i+1}\right)^{n+1}\right|\left(D^2\right)^{n+1}_{i+\frac{1}{2}}}{2C_3 K}} \tag{40}$$

The values of the dimensional constants C_1, C_2, and C_3 in equations (37), (38), (39), and (40) will depend on the system of units used in performing the computations. In the present model, the English system of units is used, so $C_1 = 203$, $C_2 = 106$, and $C_3 = (5280)^2$.

III. HURRICANE AND HYDROGRAPHIC DATA

Verification of the bathystrophic model consisted of modeling surge response to the Continental Shelf at six locations for five historical hurricanes. Historical hurricanes and traverses used were: (a) Hurricane of 1949 at Galveston and Freeport, Texas; (b) Hurricane Carla at Galveston and Freeport, Texas; (c) Hurricane Audrey at Eugene Island, Louisiana; (d) Hurricane Camille at Biloxi, Mississippi; and (e) Hurricane Carol at Narragansett Pier, Rhode Island. The data describing these hurricanes, the resulting surges, and the traverses used in the verification, are presented in this section.

1. Hurricane of 3 October 1949.

a. Hurricane Data. This hurricane formed in the Bay of Campeche, Mexico, from a tropical depression which was observed 2 or 3 days before 1 October, over Yucatan, Honduras, and Guatemala. During the night of 30 September and 1 October, the center of the depression moved into the Gulf of Mexico near Carmen, Mexico and increased to hurricane intensity by 1045 hours Central Standard Time (CST), 2 October. The hurricane moved from Yucatan almost directly northward across the gulf and its center crossed the Texas coast 22 miles southwest of Freeport during the nights of 3 and 4 October. The storm passed Houston during the early morning of 4 October. Winds were estimated at 135 miles per hour, 5 miles west of Freeport (Zoch, 1949). The storm's center moved across southeastern Texas, northwestern Louisiana, eastern Arkansas, southeastern Missouri, western Illinois, southeastern Wisconsin, and northern lower Michigan. The intense winds and rainfall associated with this storm caused heavy damage to crops and property in Texas, Louisiana and Arkansas (Seamon, 1949).

Surface wind fields and pressure fields for this hurricane were obtained from the U.S. Weather Bureau (HUR 7-37, 1957). The report provides hourly wind fields from 1800 hours CST, 3 October to 0500 hours CST, 4 October 1949 (Fig. 5). Physical parameters generally describing the hurricanes are given in Table 2.

Table 2. Hurricane Parameters.

Parameter	Hurricane of 1949	Carla	Camille	Audrey	Carol
Central pressure (inches of mercury)	28.45	27.64	26.73	27.95	28.69
Peripheral pressure (inches of mercury)	29.95	29.92	29.92	29.70	29.92
Radius to maximum wind (nautical miles)	15.0	46.0	14.0	19.0	25.0
Translation speed[1] (knots)	11.0	3.0	13.0	13.0	33.3
Maximum gradient wind (miles per hour)	88.0	100.0	125.0	95.0	95.0

1. Average value

b. Hydrographic Data. The Hurricane of 3 October 1949 generated the following surges along the Texas coast: 11 feet at Velasco, 8 feet at Matagorda, 9 feet at Anahuac, and 11.4 feet at Harrisburg in the Houston Ship Channel (Zoch, 1949) (Figs. 6 and 7).

Hydrographs of surges associated with this hurricane, and used in this study, were recorded by the Brazos River and Galveston tide gages. The Brazos River station is located 1.2 nautical miles inland from the Gulf of Mexico, near Freeport where the Brazos River and the Intracoastal Waterway intersect. The Galveston gage used is located at Pier 21, Galveston Channel.

The method of hydrographic data reduction used for this study is given in Section IV.

2. Hurricane Carla.

a. Hurricane Data. Hurricane Carla has been described as one of the largest, most intense, and destructive hurricanes ever to strike the gulf coast. This hurricane evolved from a weak perturbation in the Intertropical Convergence Zone in the eastern Caribbean and was

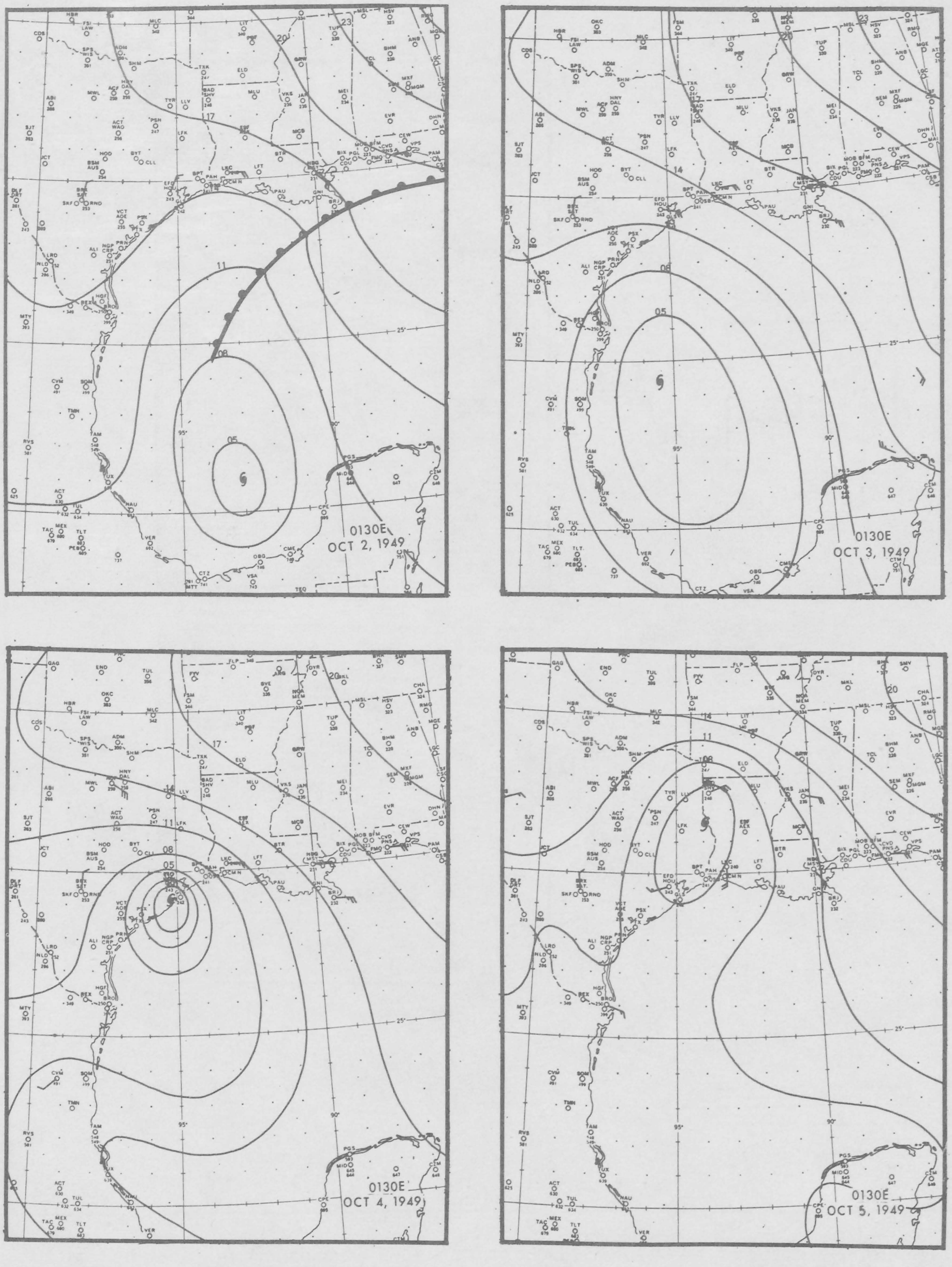


Figure 5. Hurricane of 3-4 October 1949. Synoptic charts (Harris, 1963).

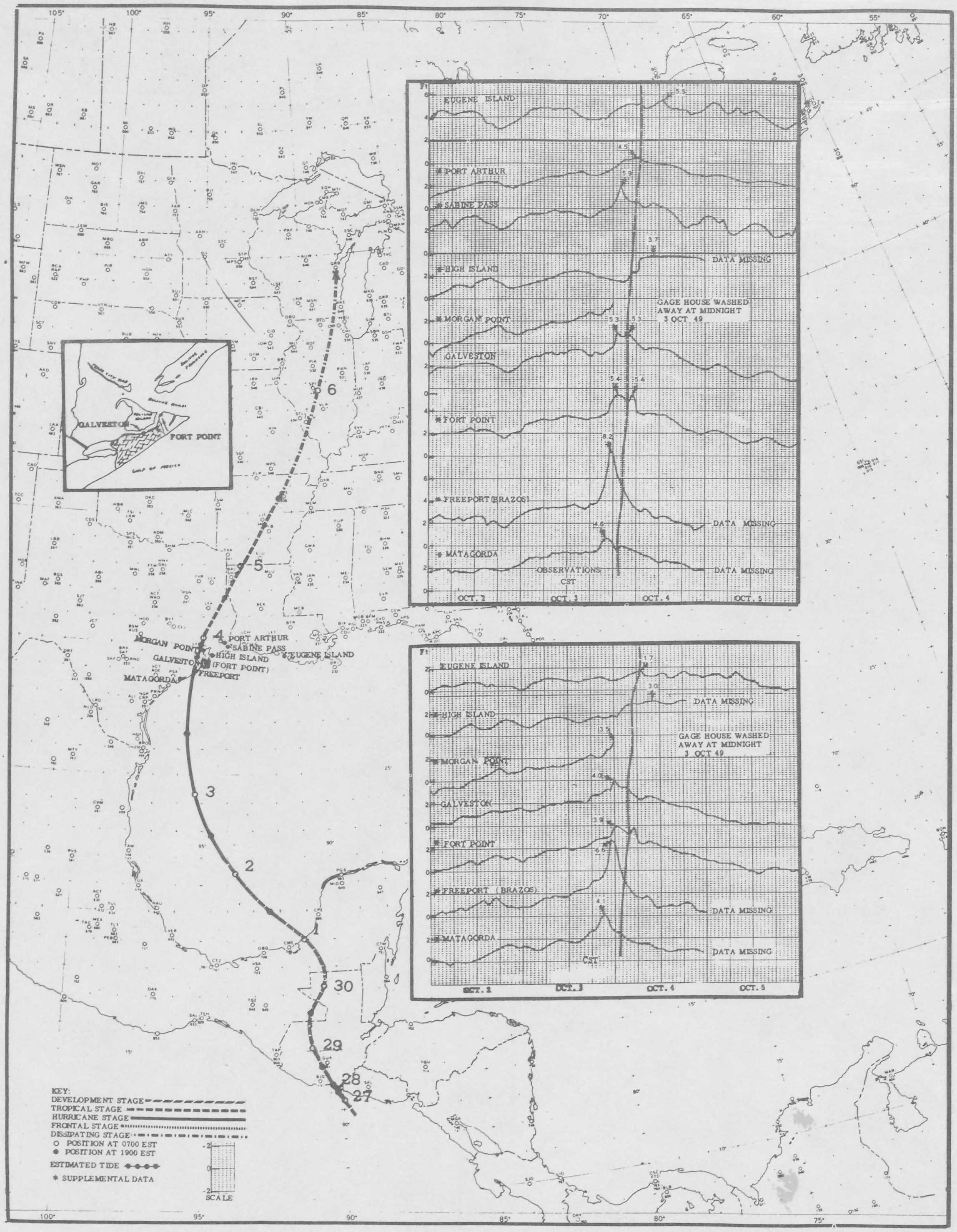


Figure 6. Hurricane of 3-4 October 1949. Storm surge (lower panel) and tide observations chart (hourly values only). Insert map for Galveston, Texas (Harris, 1963).

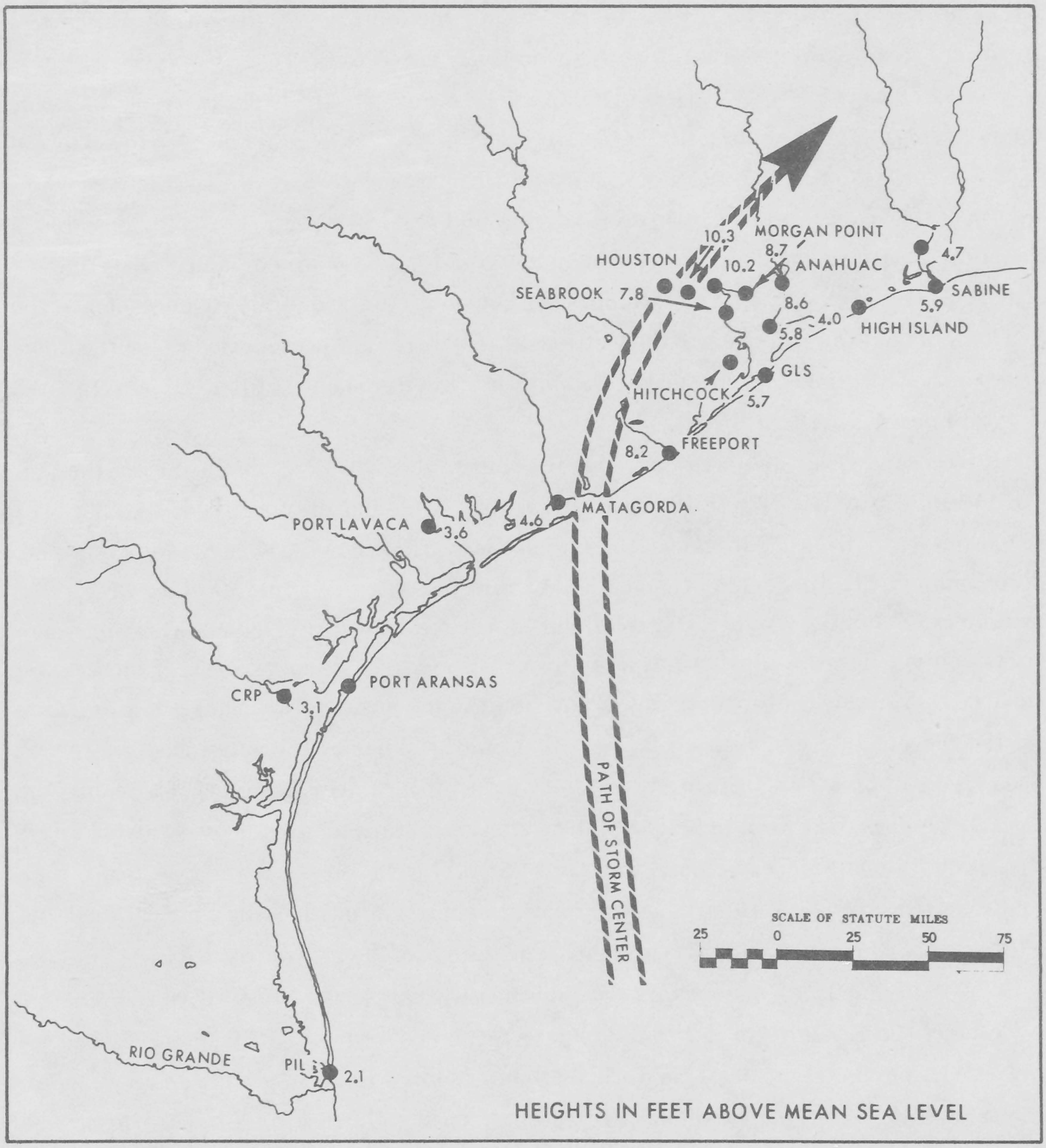


Figure 7. Hurricane of 3-4 October 1949. High water marks in Texas (Harris, 1963).

observed as early as 1 September 1961. By 0600 hours Central Standard Time (CST), 3 September, this disturbance intensified and developed a closed circulation. By 0600 hours CST, 4 September, the circulation increased to depression intensity with winds ranging from 32 to 38 miles per hour. By 1900 hours CST, of the same day, Carla was identified as a storm and an advisory was issued by the Miami Hurricane Center.

During the next several days, Carla continued to intensify gradually reaching hurricane force on the morning of the 6th. By the afternoon of the 11th, Carla's center moved inland over the Port O'Connor–Port Lavaca area on the central Texas coast. Hurricane force winds were reported from Corpus Christi to Galveston and hurricane gusts were felt along almost the entire length of the Texas coast. Maximum gusts of 175 miles per hour were estimated at Port Lavaca, Texas. A gust of 153 miles per hour was observed on the anemometer of the Bauer Dredging Company before the instrument failed. The lowest reported pressure at Port Lavaca was 27.61 inches of mercury (935 millibars) and it remained at that value from 1545 to 1735 hours CST (Dunn, 1962).

Surface wind fields and pressure fields for Hurricane Carla were obtained from the U.S. Weather Bureau (HUR 7-76A, 1964). In the report, wind and pressure fields were given at 6-hour intervals from 1200 hours Greenwich Mean Time (GMT), 9 September, through 1200 hours GMT, 10 September, and 3-hour intervals thereafter to 1500 hours GMT, 12 September. Synoptic weather charts of this storm are shown in Figures 8 and 9. These charts contain lines of equal windspeed (isotachs) and lines of equal angle of incurvature (isoangles). The angle of incurvature at any point is the angle between the wind direction and the tangent to a circle drawn through that point and concentric with the storm center.

b. Hydrographic Data. Storm surge associated with Hurricane Carla, began affecting the upper Texas coast on 8 September, until the center of the storm moved slowly inland 3 days later. Along the entire Texas coast, the storm surge began to develop when the winds were parallel to the coast at a distance of 100 miles, reaching a peak when the winds at the coast were from the north and actually had a slight offshore component (Harris, 1963).

Because of the storm's slow forward movement, water levels remained within about 1 foot of their peak values for nearly 24 hours. Surge levels were over 12 feet above mean sea level (MSL) on the open coast, and 20 feet above MSL within bays and estuaries. Storm surge and high water marks on the Texas coast during Hurricane Carla have been well documented (Cooperman and Sumner, 1961; Cry, 1961; Dunn, 1962). Reported surges were 16.6 feet above MSL at Port Lavaca, 14.5 feet above MSL at Port O'Connor, 15.2 feet above MSL at Matagorda, and 14.8 feet above MSL on the upper Houston Ship Channel. A high water line varying from 15.7 to 22 feet above MSL, established from debris near the head of Lavaca Bay, probably included the undetermined effects of wave setup and runup (Dunn, 1962).

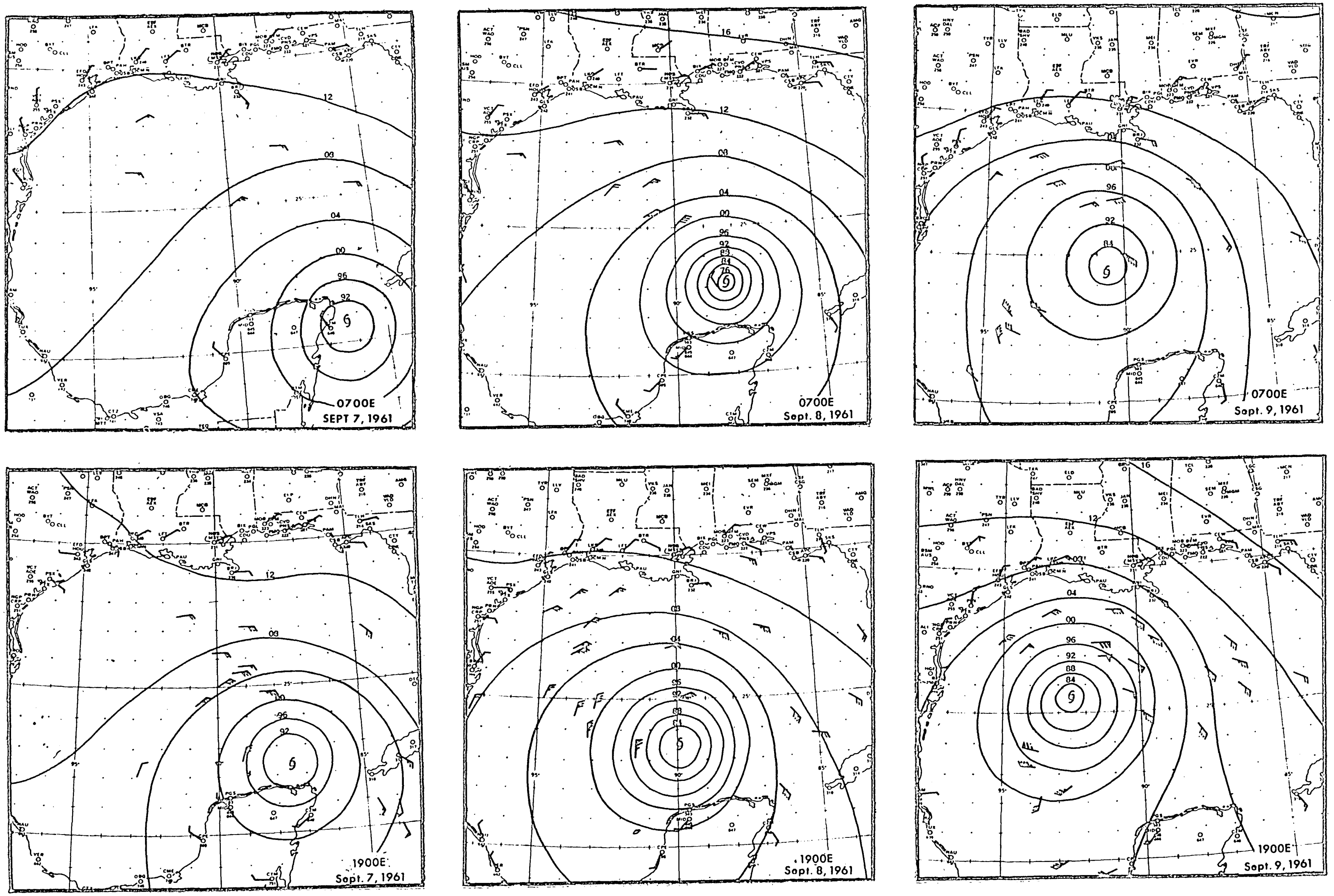


Figure 8. Hurricane Carla, 7-12 September 1961. Synoptic charts, 7-9 September (Harris, 1963).

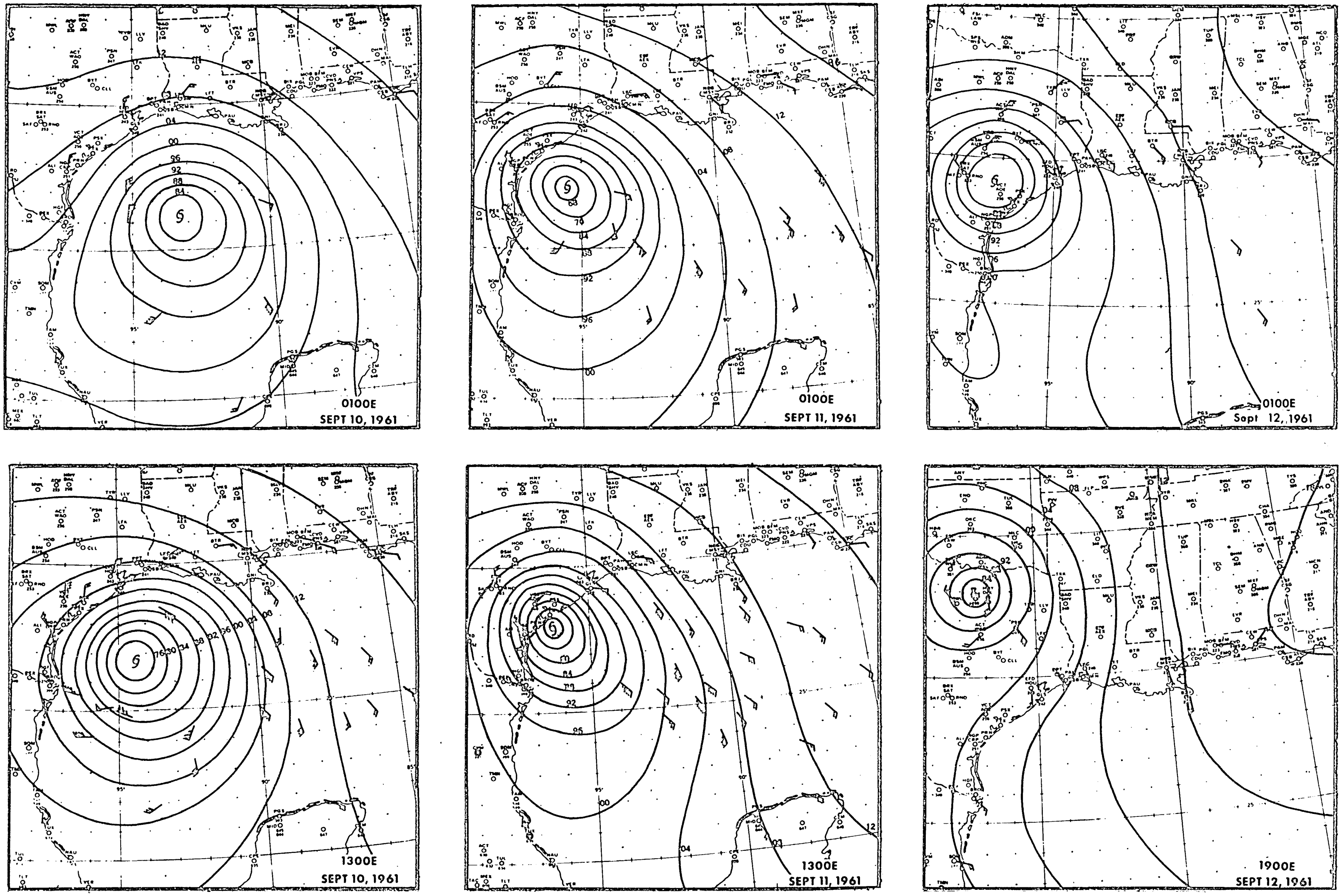


Figure 9. Hurricane Carla, 7-12 September 1961. Synoptic charts, 10-12 September (Harris, 1963).

Surge hydrograph data was taken from the U.S. Army Engineer District, Galveston (1962). Observed and recorded storm surges along the Texas coast and the predicted astronomical tide at Galveston are shown in Figures 10 and 11. Peak surge values along the Texas and Louisiana coasts are given in Figures 12 and 13.

3. Hurricane Audrey.

a. Hurricane Data. Hurricane Audrey developed from a tropical depression over the Bay of Campeche in southwestern Gulf of Mexico on 25 June 1954. The position of the tropical depression at that time was 22.5°N., 93°W., or about 380 miles southeast of Brownsville, Texas. Highest winds were estimated at 35 to 40 miles per hour.

By 1200 hours CST, 25 June, the tropical depression had reached hurricane strength with winds near the center increasing in speed from 75 to over 100 miles per hour. By 0600 hours CST on the 26th, Audrey was moving northward at about 10 miles per hour, and had reached a position 250 miles southeast of Brownsville. The hurricane's translational speed gradually increased until it reached 15 miles per hour early on the 27th. By 0700 hours CST, 27 June, the storm was centered near the Texas-Louisiana coast south of Port Arthur, Texas. Highest reported winds on the coast at that time were 75 miles per hour and surge elevation had reached 7 feet above MSL (Ross and Blum, 1957).

At 0930 hours CST on the 27th, a report from Orange, Texas stated that after experiencing winds of over 100 miles per hour the town was now experiencing the dead calm associated with the eye of the storm and was expecting the return of strong winds. Lake Charles, Louisiana, as the storm passed just to the west, reported maximum winds of 105 miles per hour. On land the storm rapidly increased forward momentum and continued in a northeast direction. On the morning of 28 June the storm was centered over west-central Tennessee and had lost its hurricane-strength winds. The storm, however, developed several tornadoes in Mississippi, Louisiana and Alabama. The following day when Audrey was expected to assume extratropical characteristics, it merged with a polar front which had formed in the vicinity of Chicago, Illinois on 28 June. The merge of these storms was complete and the new center was about 140 miles north of Buffalo, New York, in southwestern Quebec, Canada. At this time the storm had reached maximum intensity as an extratropical storm with a central pressure of 28.76 inches of mercury (974 millibars). Winds of 95 to 100 miles per hour were reported at Jamestown, New York (U.S. Weather Bureau, 1957). It then became difficult to differentiate between the contribution made by the remnants of Audrey and that of the polar trough. Meteorological discussions of the storm are given by Ross and Blum (1957), and by Moore (1957). A detailed analysis of the wind field as this storm crossed the coastline was made by Graham and Hudson (1960); additional historical data can be obtained from Sumner (1957a, 1957b). Other accounts of the storm have been presented in Klein (1957) and Morgan, Nichols, and Wright (1958).

Surface wind field data and central pressures describing Hurricane Audrey were obtained from Hydrometeorological Reports, HUR 7-51A, 7-57, and 7-57A (U.S. Weather Bureau,

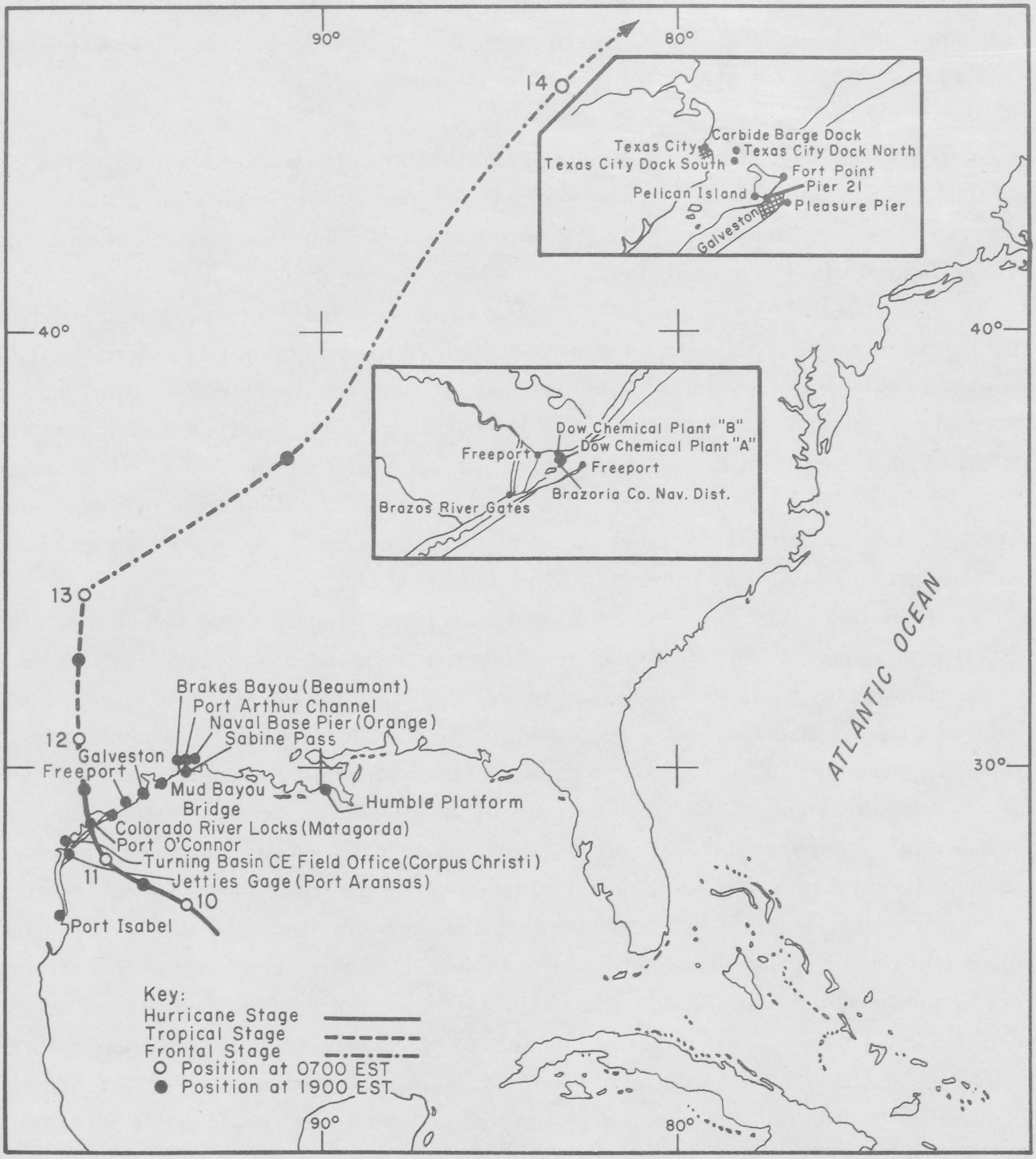


Figure 10. Hurricane Carla, 7-12 September 1961. Insert maps for Freeport and Galveston, Texas (Harris, 1963).

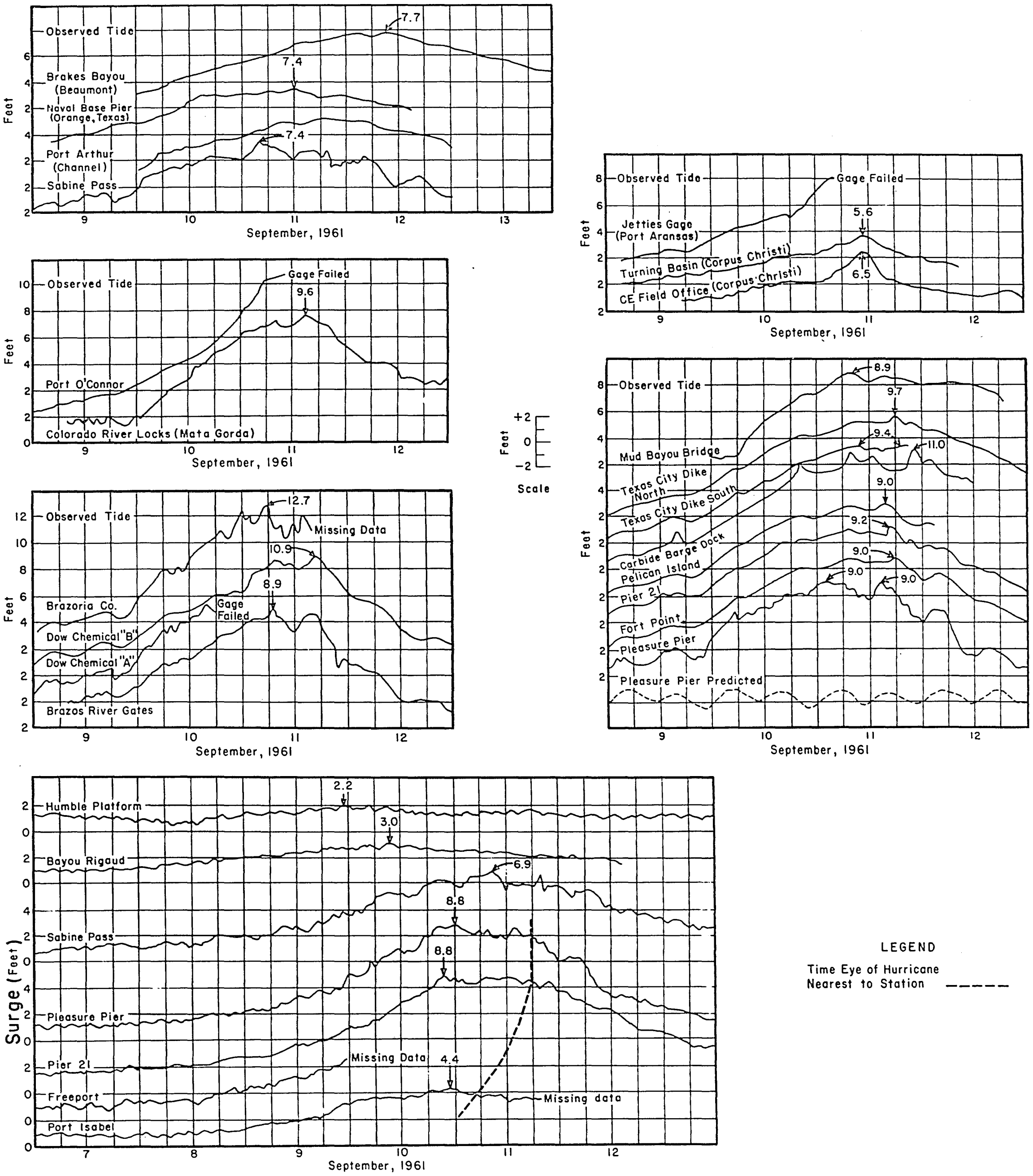


Figure 11. Hurricane Carla, 7-12 September 1961. Storm surge and observed tide chart (Harris, 1963).

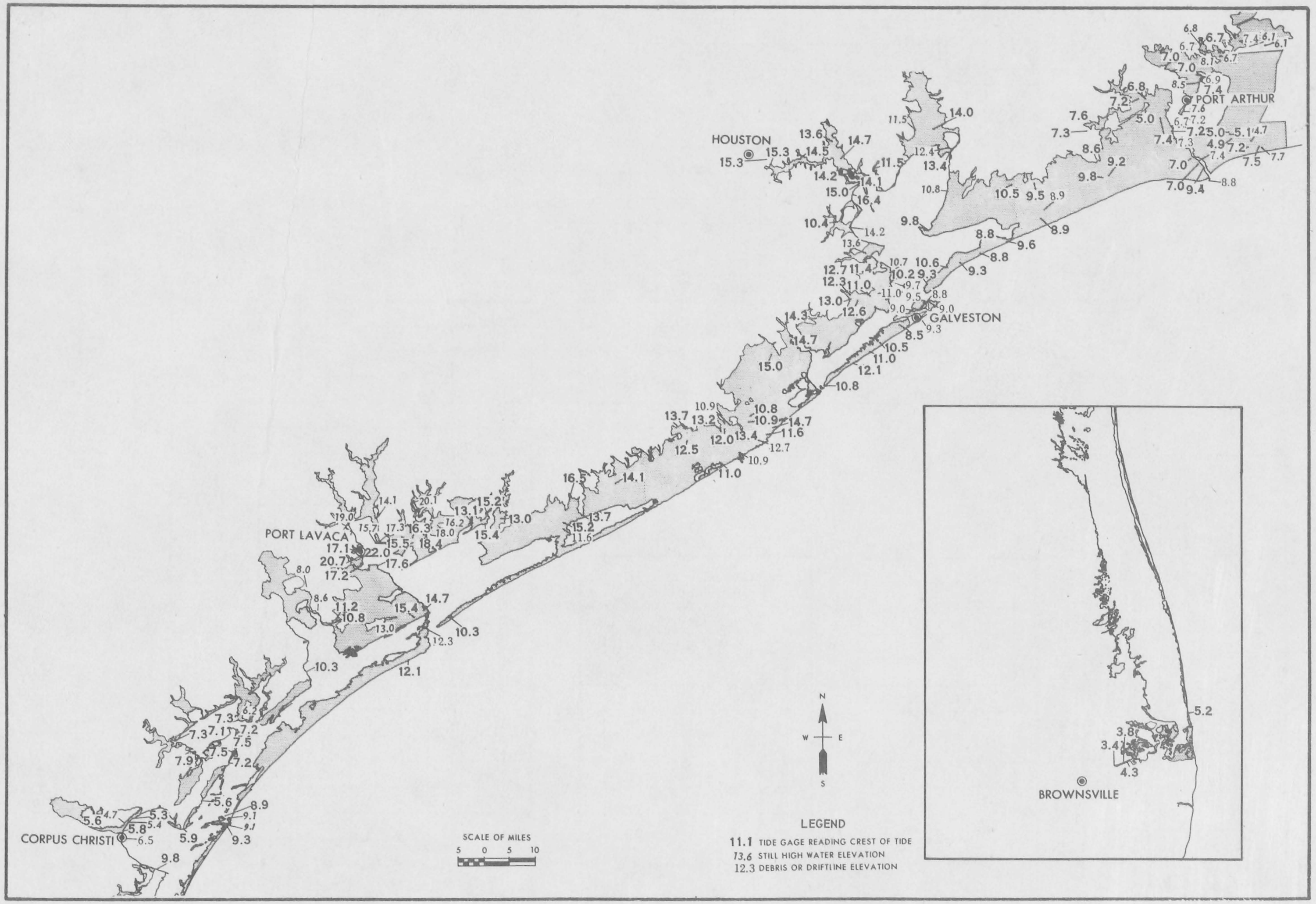


Figure 12. Hurricane Carla, 7-12 September 1961. High water mark chart for Texas. Shaded area indicates the extent of flooding (Harris, 1963).

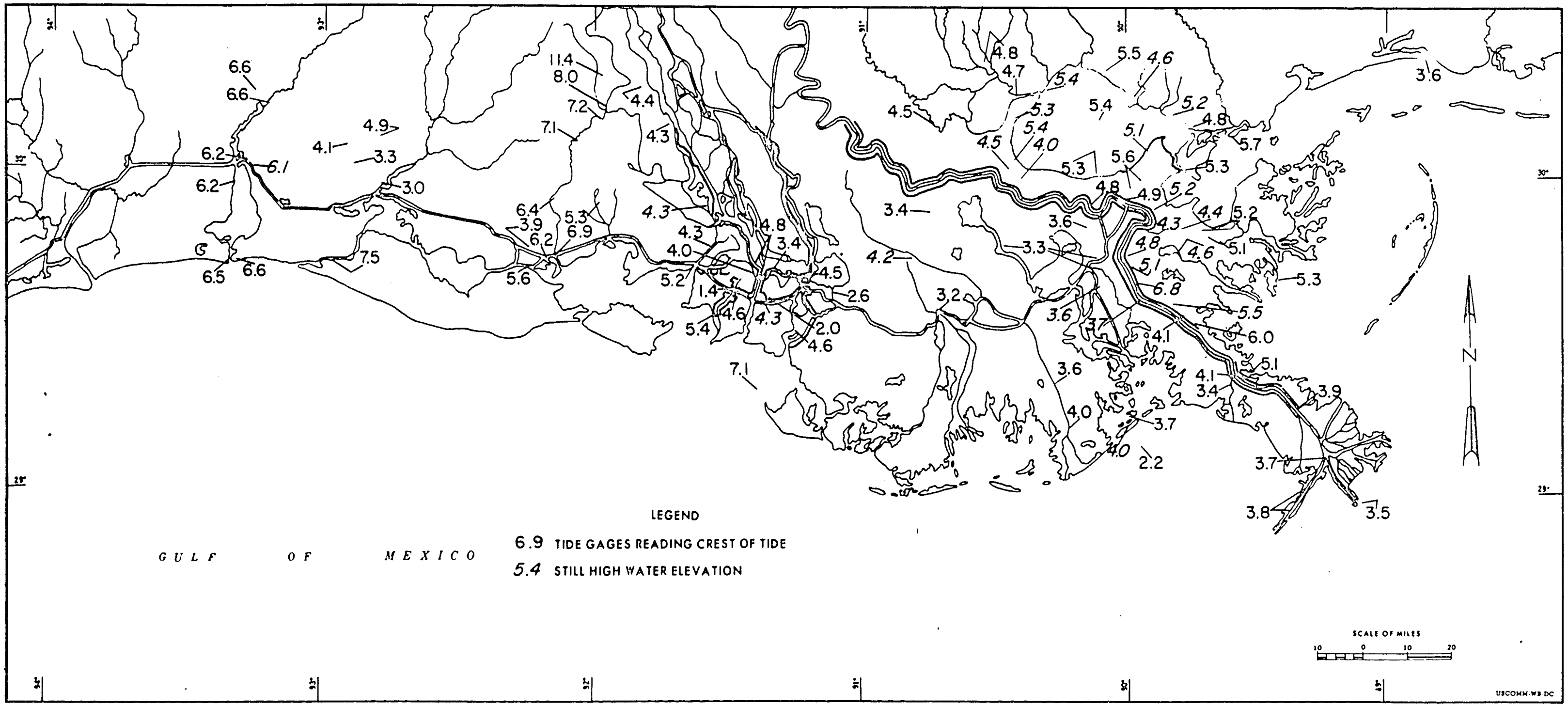


Figure 13. Hurricane Carla, 7-12 September 1961. High water mark chart for southern Louisiana (Harris, 1963).

1964). In these reports, wind fields are given in 2-hour intervals from 0000 to 0600 hours CST and 1200 to 2400 hours CST, and at 1-hour intervals from 0600 to 1200 hour CST. The charts contain windspeeds shown by isotachs and directions shown by arrows. Physical parameters describing Hurricane Audrey are given in Table 2; synoptic weather charts are shown in Figure 14, and Figure 15 shows the hurricane track.

b. Hydrographic Data. Most damage by Hurricane Audrey along the gulf coast resulted from high surges. The normal diurnal tidal range for this area is 1 to 2 feet. The coast of Louisiana where the hurricane struck is near sea level, and in places is below sea level for considerable distances inland. Therefore, the area affected by high water was extensive, and low lying regions were inundated as far as 10 to 20 miles inland. The limits of flooding along the coast have been documented by the U.S. Army Engineer District, New Orleans.

Hurricane surges of 6 feet or more above MSL extended from Galveston, Texas to a point 330 miles eastward. These have been documented by Harris (1958, 1963). The observed storm water levels of about 30 recording stations effected by Hurricane Audrey are shown in Figures 16 and 17 (Harris, 1963). These water level records were obtained from tide gage records by plotting hourly values of water elevation, and reduced to a common scale for showing peak values where available. Maximum surge observations along the Texas and Louisiana coasts are shown in Figures 18 and 19. At Galveston, observed water levels reached a peak of 6.2 feet above MSL at 0430 hours CST on 27 June (Fig. 20).

The storm center's landfall point was about 23 miles to the west of Cameron, Louisiana. The highest surge occurred 40 miles to the east of the storm's landfall point, about 3 miles east of Creole. No records of surge for that area were made. Although the tide gage near Cameron, Louisiana was destroyed by the storm, a part of the record was reconstructed from a U.S. Coast Guard Station log on Monkey Island. At that station, the water began to rise at the rate of 1.5 feet per hour by 0400 hours CST, 27 June, reaching a peak elevation of 10.6 feet above MSL between 1000 and 1100 hours CST on the 27th. Storm waves between 4 and 5 feet high with a few peaks possibly reaching 8 to 10 feet, were superimposed on the surge at Cameron. High water remained in the area until 1400 hours CST, then began to recede when winds shifted to an offshore direction (Ross and Blum, 1957). At the Eugene Island tide station, the recording pen of the tide gage went off scale shortly after 0600 hours CST, came back on scale briefly between 0700 and 0800 hours CST, and went off scale again after 0800 hours CST. The recording pen returned to the recording position shortly after 1000 hours CST inferring a peak surge elevation of 7.3 feet MSL. This may be in error by a few tenths of a foot. The Eugene Island gage record is shown in Figure 21.

4. Hurricane Camille.

a. Hurricane Data. Hurricane Camille originated off the coast of Africa on 5 August 1969, and was recognized as a tropical disturbance on the 9th, about 480 miles east of the northern Leeward Islands. By 14 August, near the island of Grand Cayman in the Caribbean,

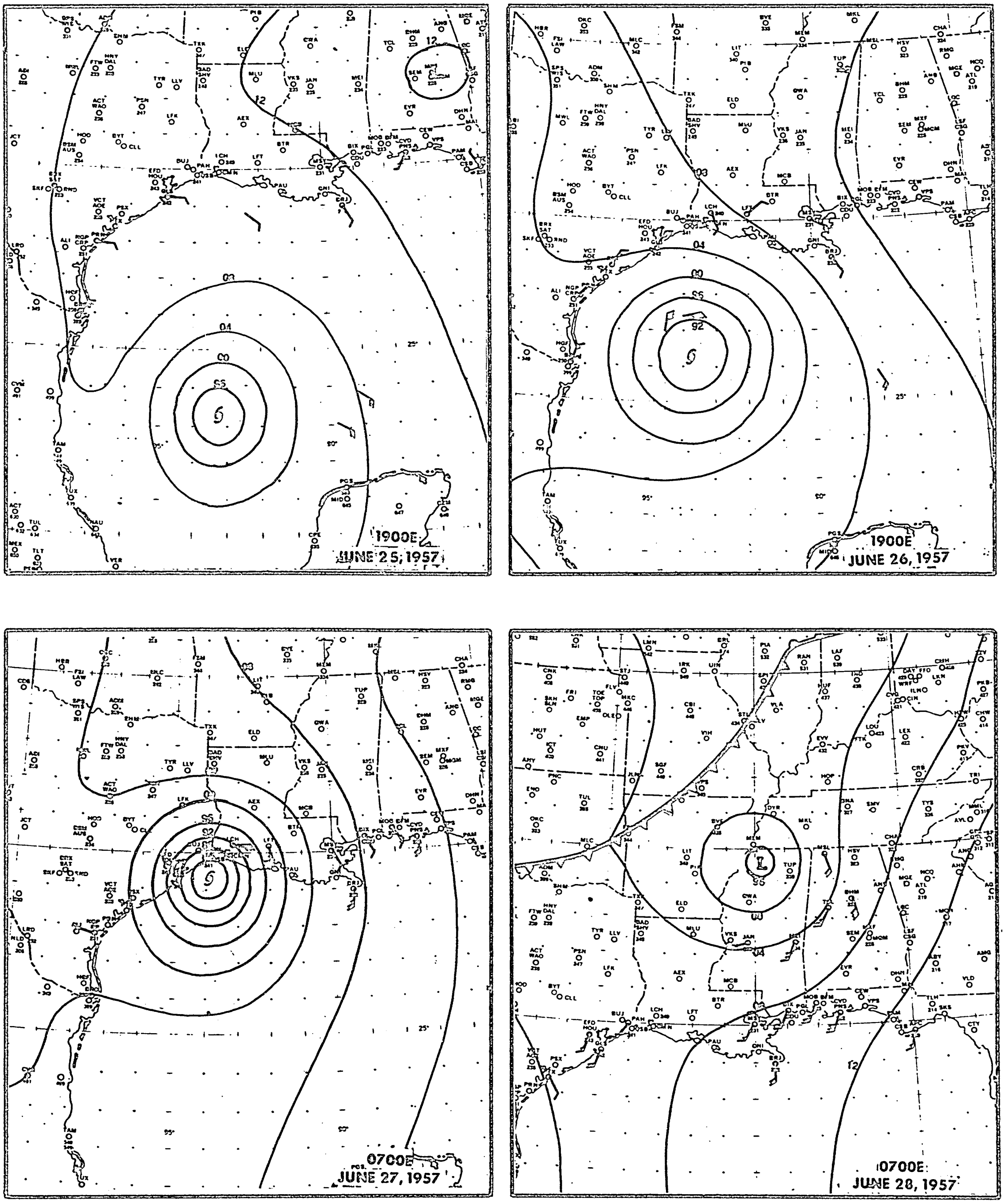


Figure 14. Hurricane Audrey, 26-27 June 1957. Synoptic charts (Harris, 1963).

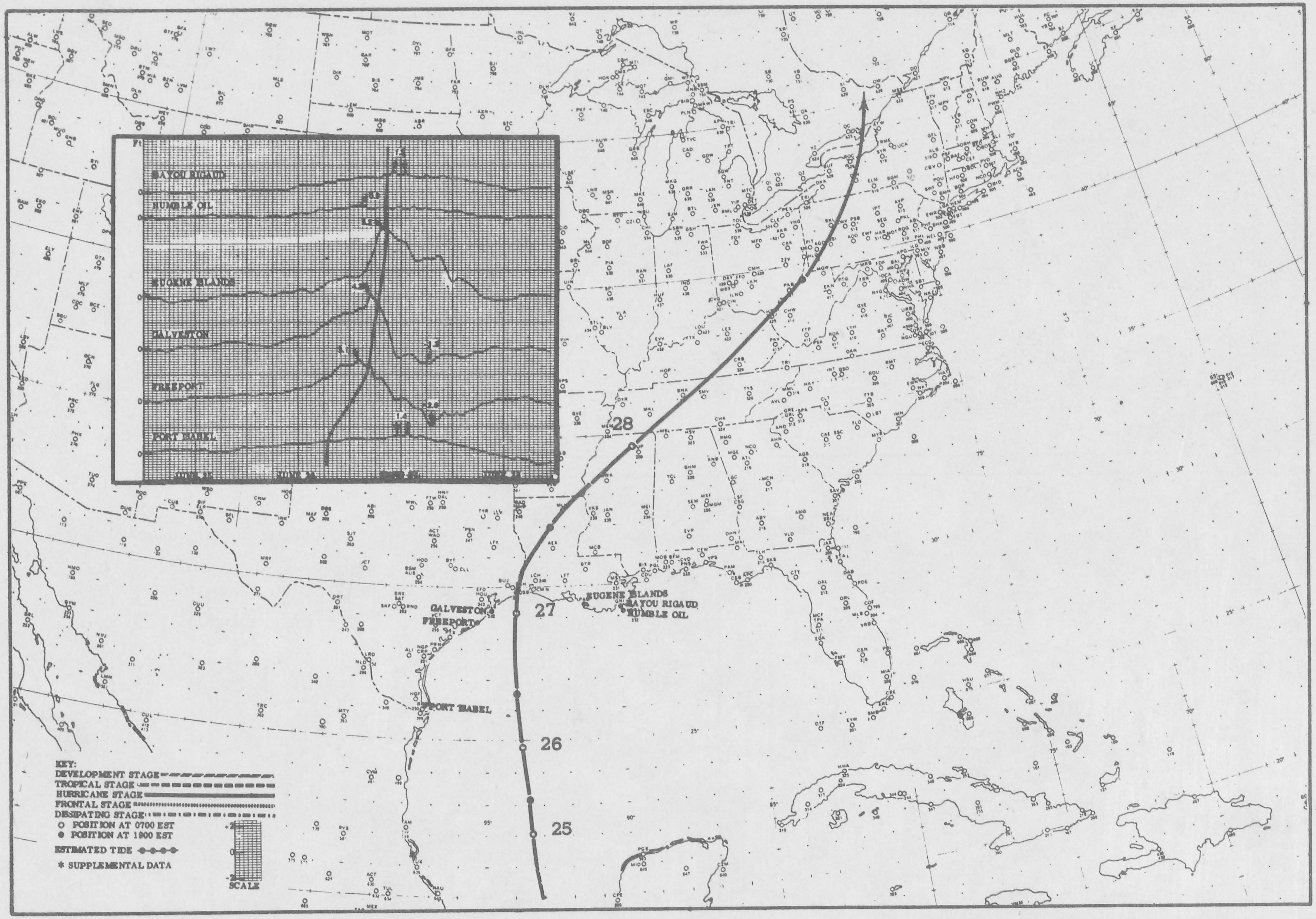


Figure 15. Hurricane Audrey, 26-27 June 1957. Storm surge chart (Harris, 1963).

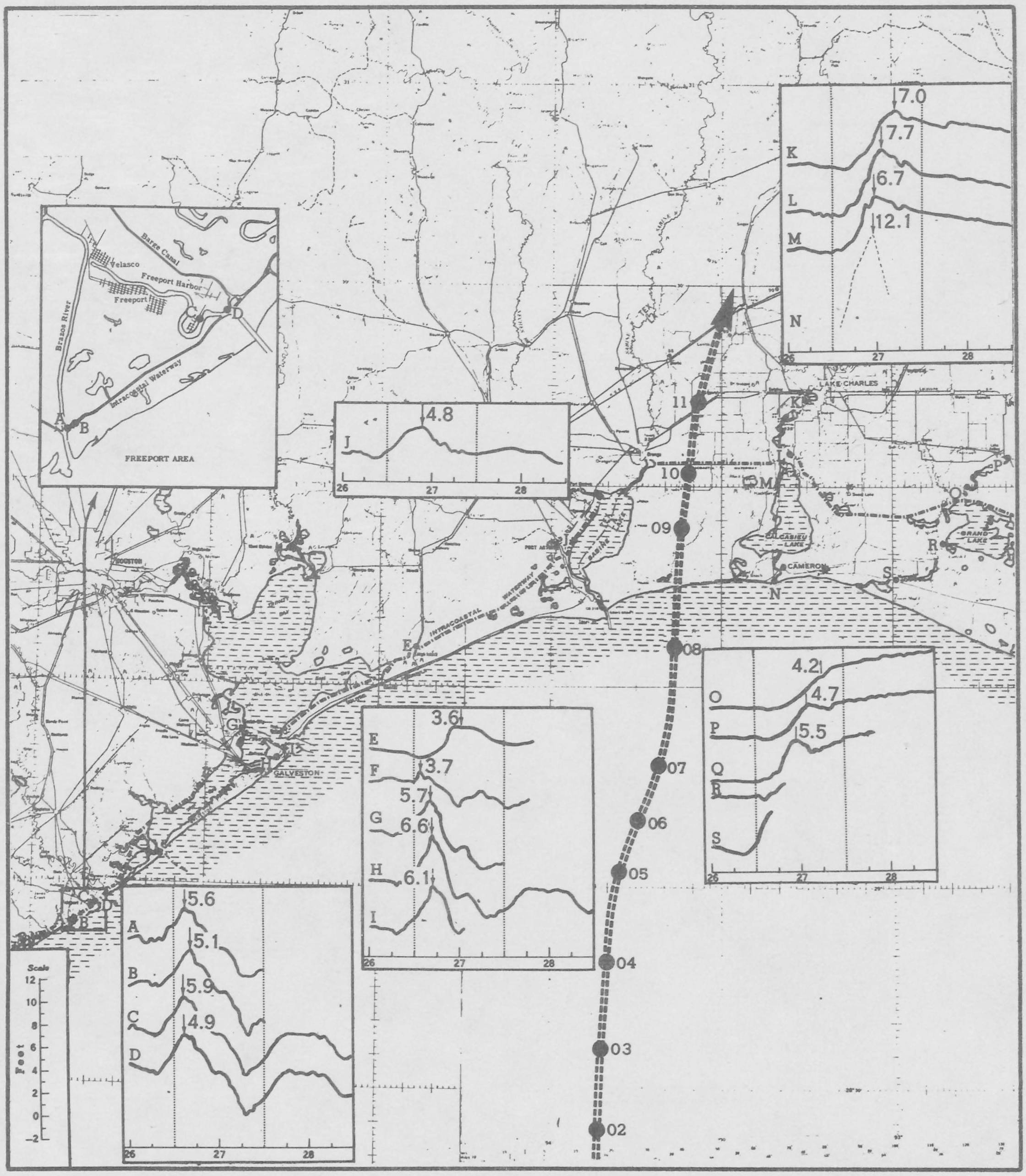


Figure 16. Hurricane Audrey, 26-27 June 1957. Observed tides, Texas and western Louisiana. Insert map of Freeport, Texas (Harris, 1963).

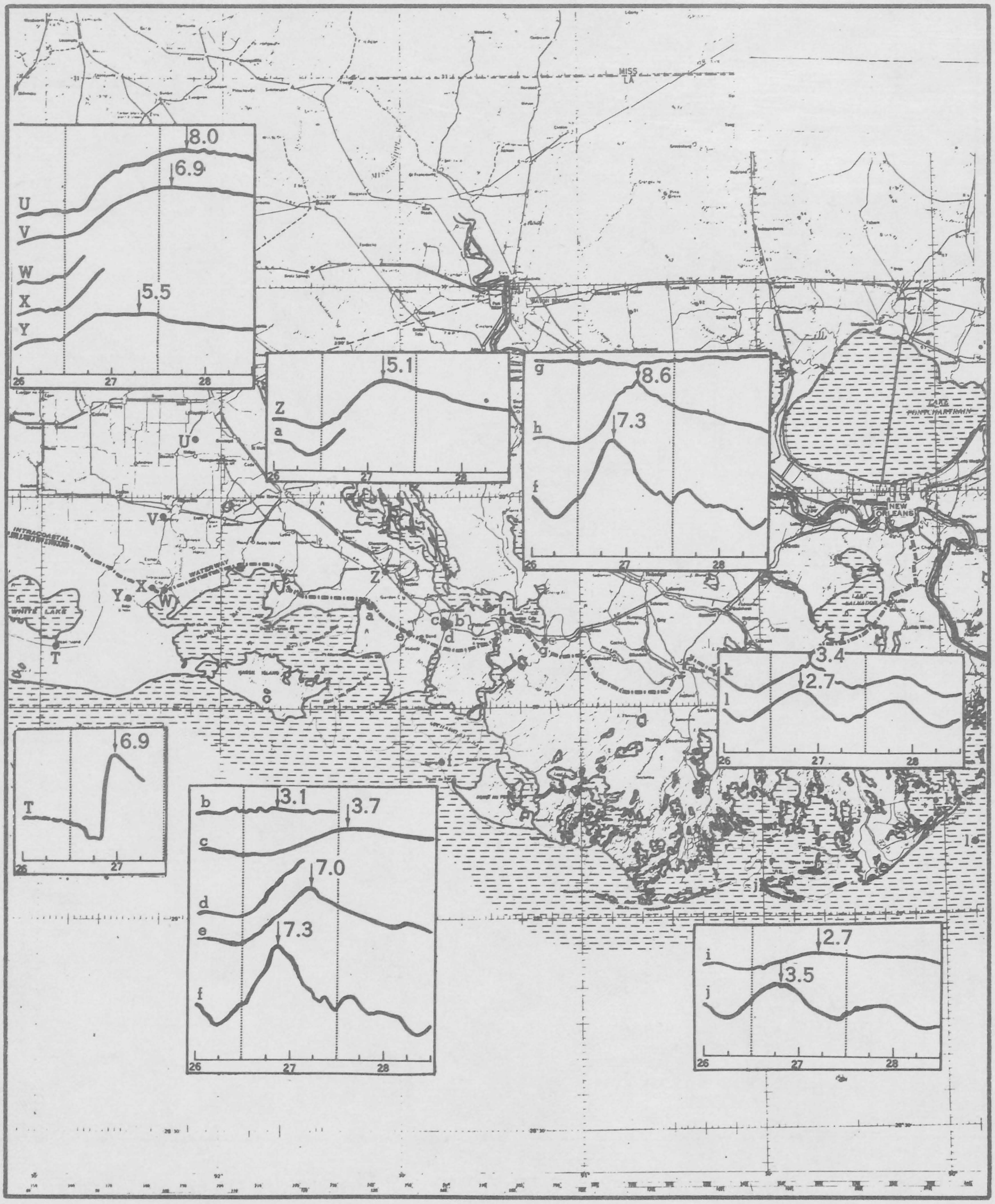


Figure 17. Hurricane Audrey, 26-27 June 1957. Observed tides, eastern Louisiana (Harris 1963).

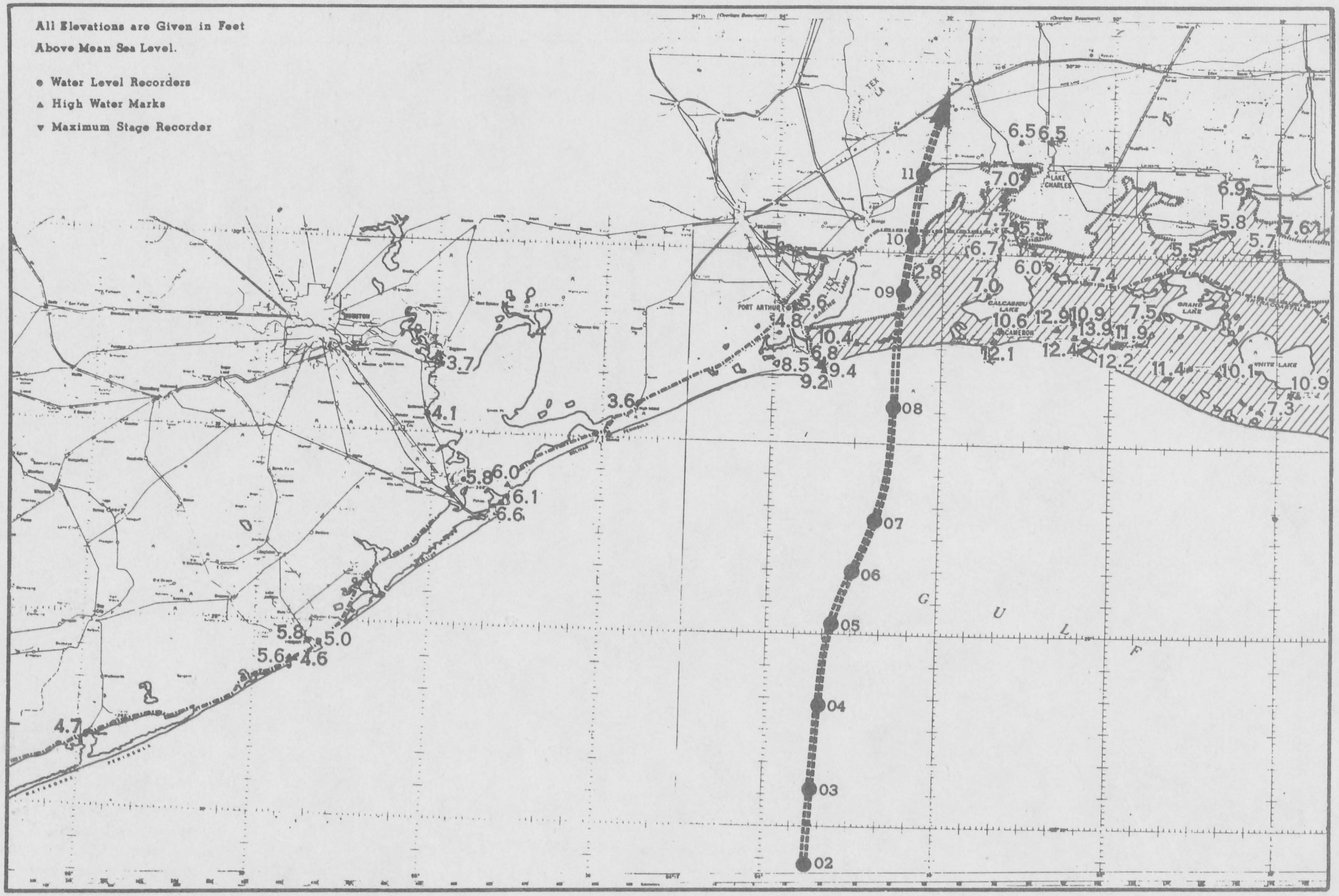


Figure 18. Hurricane Audrey, 26-27 June 1957. High water mark chart for Texas and western Louisiana. Hatched area gives limit of inundation in Louisiana (Harris, 1963).

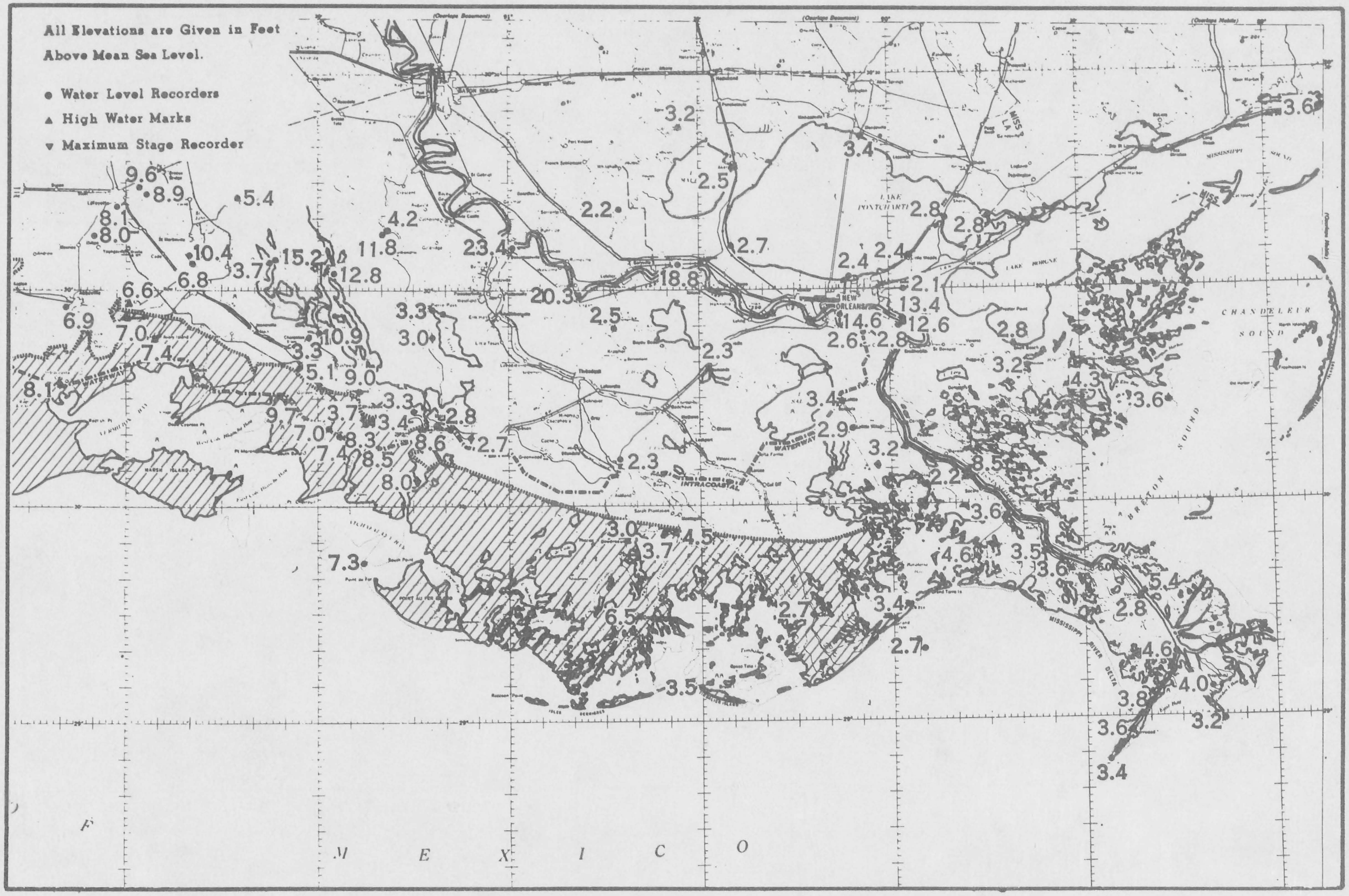


Figure 19. Hurricane Audrey, 26-27 June 1957. High water mark chart, eastern Louisiana. Hatched area gives limit of inundation in Louisiana (Harris, 1963).

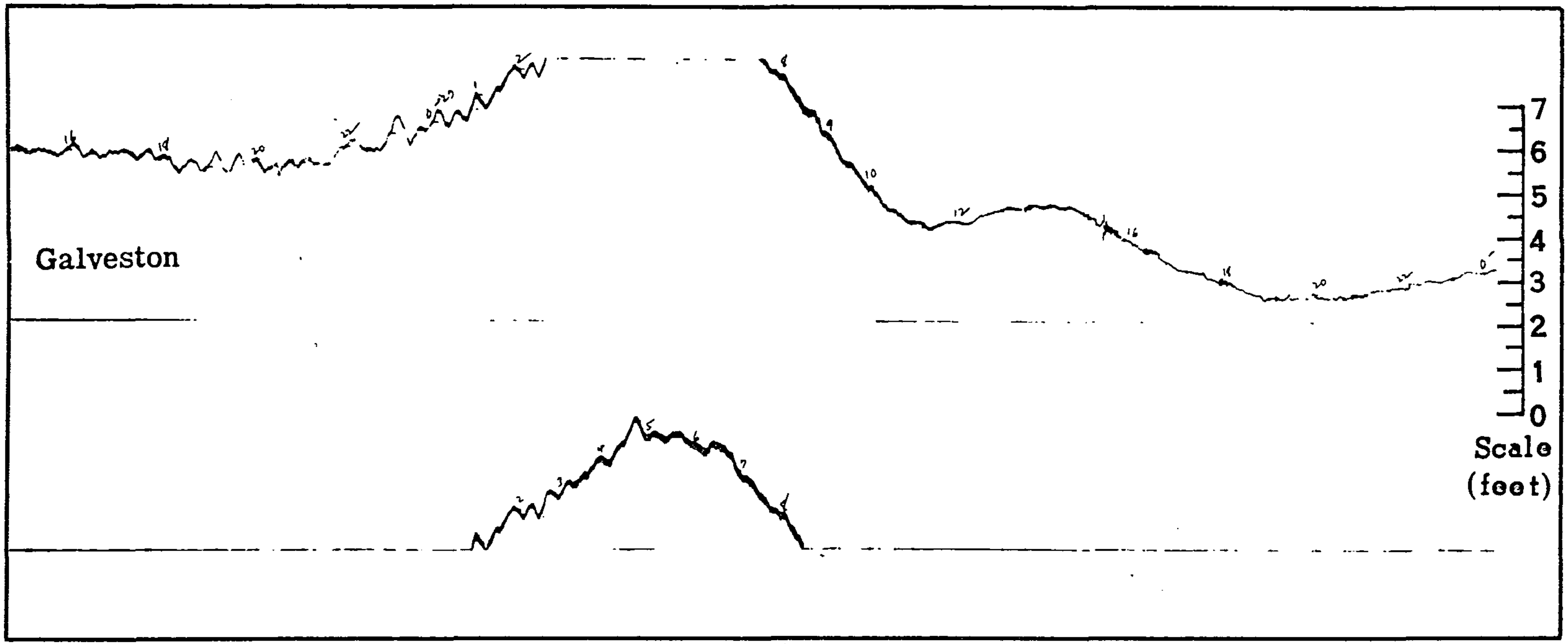


Figure 20. Hurricane Audrey, 26-27 June 1957. Observed tide records for Galveston, Texas, and U.S. Coast and Geodetic Survey tide station (Harris, 1963).

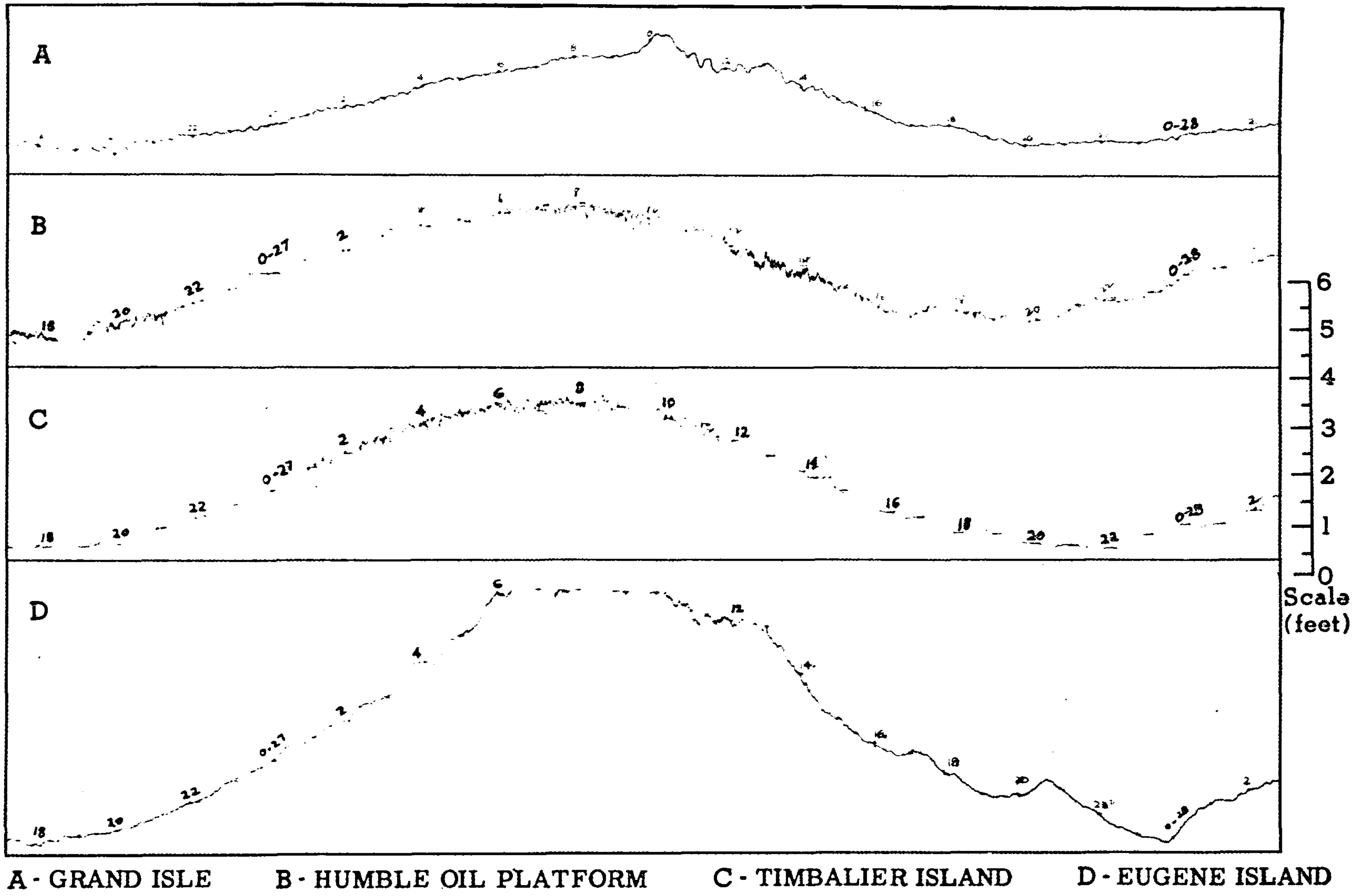


Figure 21. Hurricane Audrey, 26-27 June 1957. Observed tide records at U.S. Coast and Geodetic Survey tide stations in Louisiana (Harris, 1963).

the storm had developed a 29.50 inches of mercury (999 millibars) pressure center and surface winds of 55 miles per hour. The disturbance was christened Tropical Storm Camille.

The storm moved northwestward at 9 miles per hour and its central pressure dropped to 29.26 inches of mercury (991 millibars) late on the 14th. By 15 August, Camille was located 60 miles southeast of Cape San Antonio, Cuba, and had developed into a full hurricane with 28.47 inches of mercury (964 millibars) central pressure and winds of 115 miles per hour (De Angelis, 1969). The storm moved into the Gulf of Mexico on the 16th and changed to a north-northwestward direction with a translational speed of 14 miles per hour. Its central pressure had dropped to 26.72 inches of mercury (905 millibars). Hurricane watches were set up from Biloxi, Mississippi, to St. Marks, Florida. On 17 August, Camille was 250 miles south of Mobile, Alabama with surface winds near the center estimated at more than 201.5 miles per hour. Hurricane warnings were issued for the Mississippi coastal areas extending westward to New Orleans.

The center of Hurricane Camille made landfall at Clermont Harbor, Waveland, and Bay St. Louis, Louisiana at about 2330 hours CDT on the 17th. There were no records of winds near the center, but estimates ranged up to 201.5 miles per hour. At the west end of the Bay St. Louis Bridge a pressure of 26.85 inches of mercury (909.3 millibars) was reported. At Boothville, Louisiana, winds of 107 miles per hour were recorded before a power failure; at Pilottown, Louisiana, the *S.S. Cristobal* estimated winds at 160 miles per hour. Winds at Keesler Air Force Base, Biloxi, Mississippi were measured at 81 miles per hour with gusts to 129 miles per hour. At Ingalls Shipyard, Pascagoula, Mississippi the highest sustained wind reached 81 miles per hour while a local radio station reported 104 miles per hour winds before power failure.

Hurricane-force winds were concentrated close to the storm's center as it moved inland. These winds extended from east of New Orleans to Pascagoula, while gusts of hurricane force winds extended along the coast from New Orleans to west of Mobile Bay.

Once over land, Hurricane Camille weakened considerably moving northward through Mississippi passing close to Columbia, Prentis, Jackson, Canton, and Greenwood. At Jackson, winds gusted to 67 miles per hour as the storm center passed 10 miles west of the city. The storm was only identifiable as a depression by the time it reached the northern Mississippi border and was tracked northward to southern Virginia.

Torrential rainfall caused devastating flash floods and landslides along the eastern slopes of the Blue Ridge Mountains and record flooding along the James River.

Surface wind fields and pressure fields of Hurricane Camille were obtained from the Hydrometeorological Reports HUR 7-113, and 7-113A (Environmental Science Services Administration, 1969 and 1970). In the latter report wind fields are given at 6-hour intervals from 0000 hours through 1800 hours GMT, 17 August, then at 3-hour intervals through 0500 hours GMT, 18 August, and then at 6-hour intervals until 0000 hours GMT, 19 August. The track for Hurricane Camille is given in Figure 22; Figures 23, 24, and 25 are the synoptic weather charts used in this study.

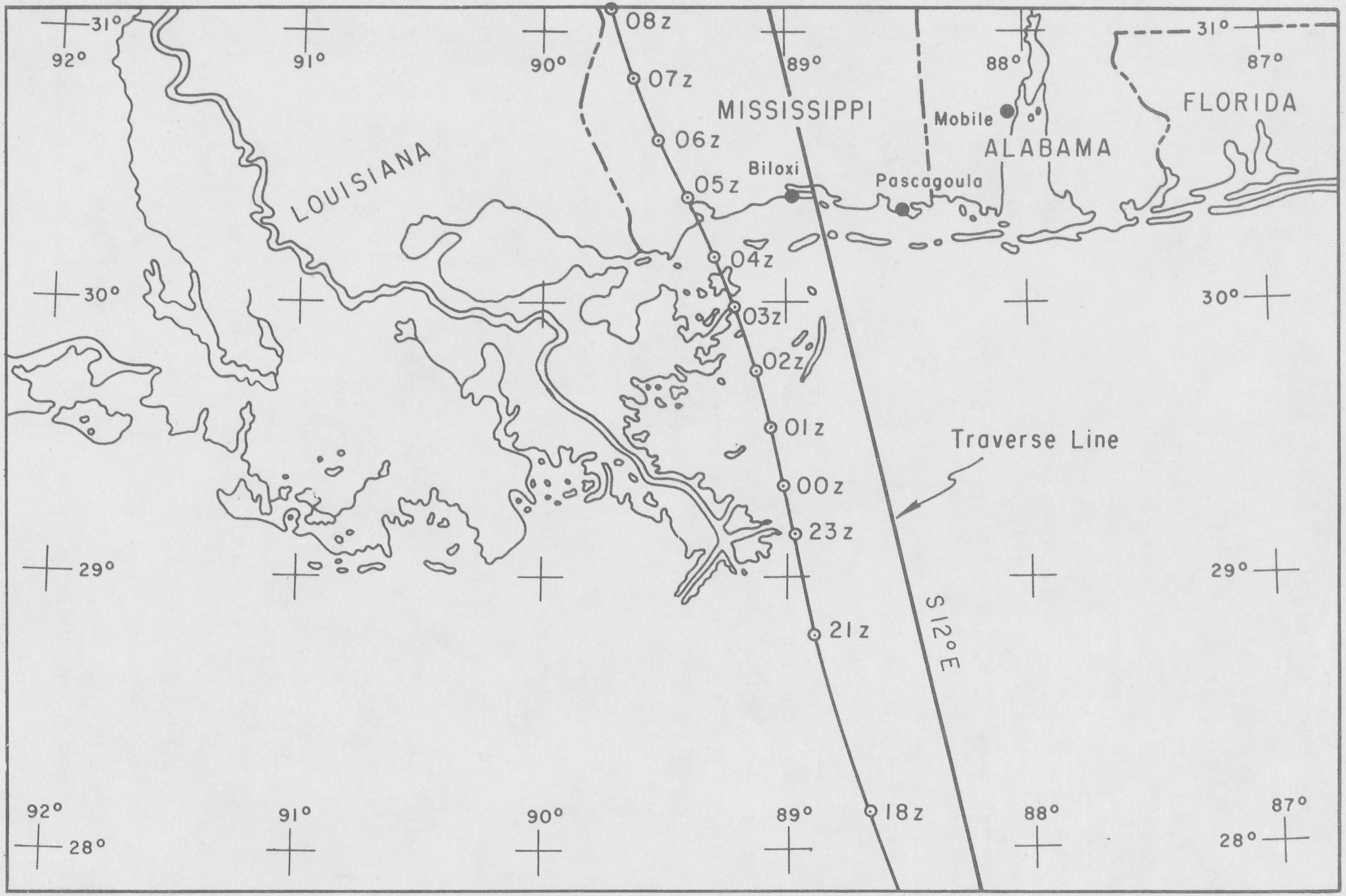
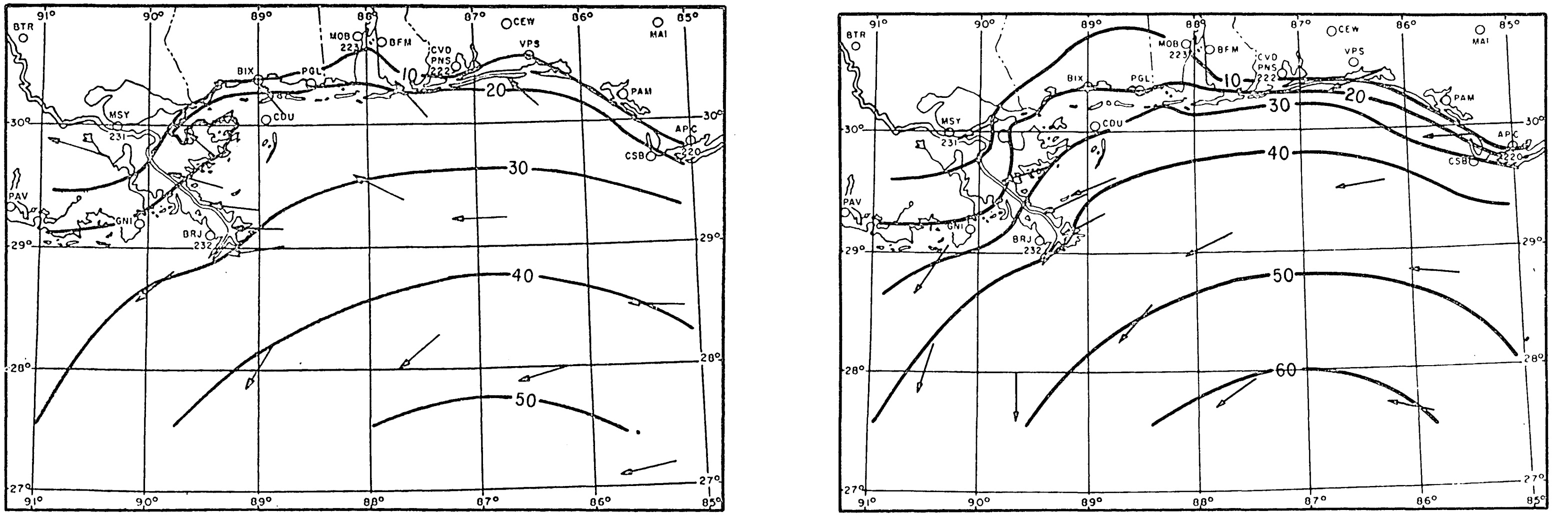
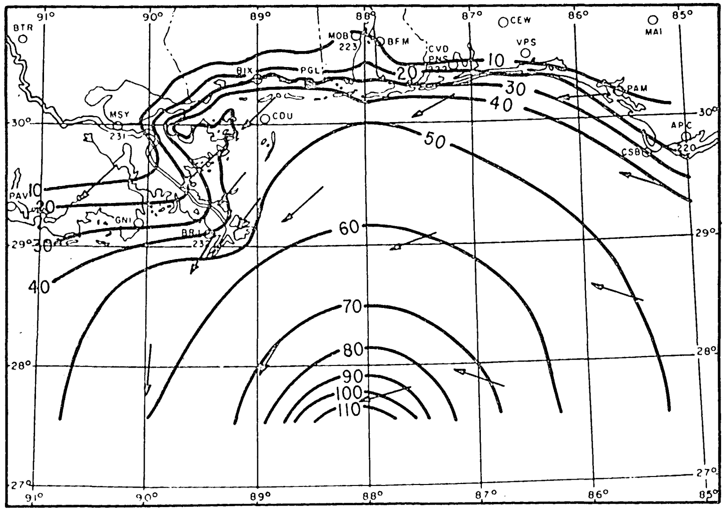


Figure 22. Track for Hurricane Camille, August 1969 (Environmental Science Services Administration; HUR 7-113A, 1970).



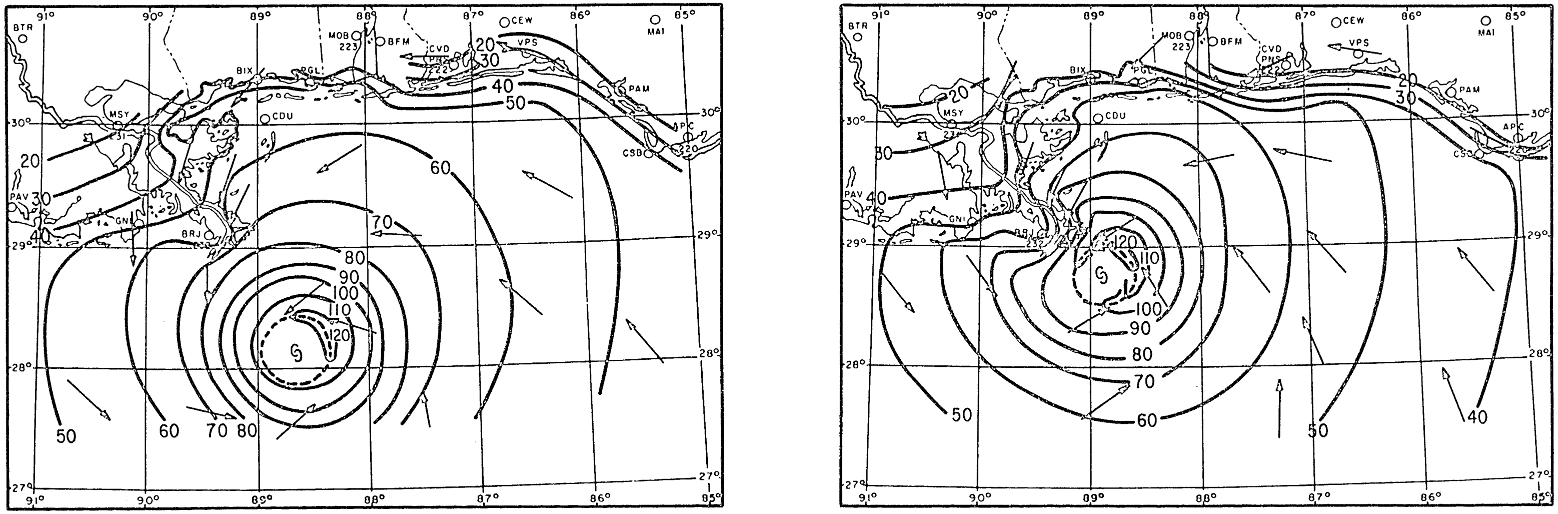
A 0000 GMT – 17 Aug 69

B 0600 GMT – 17 Aug 69



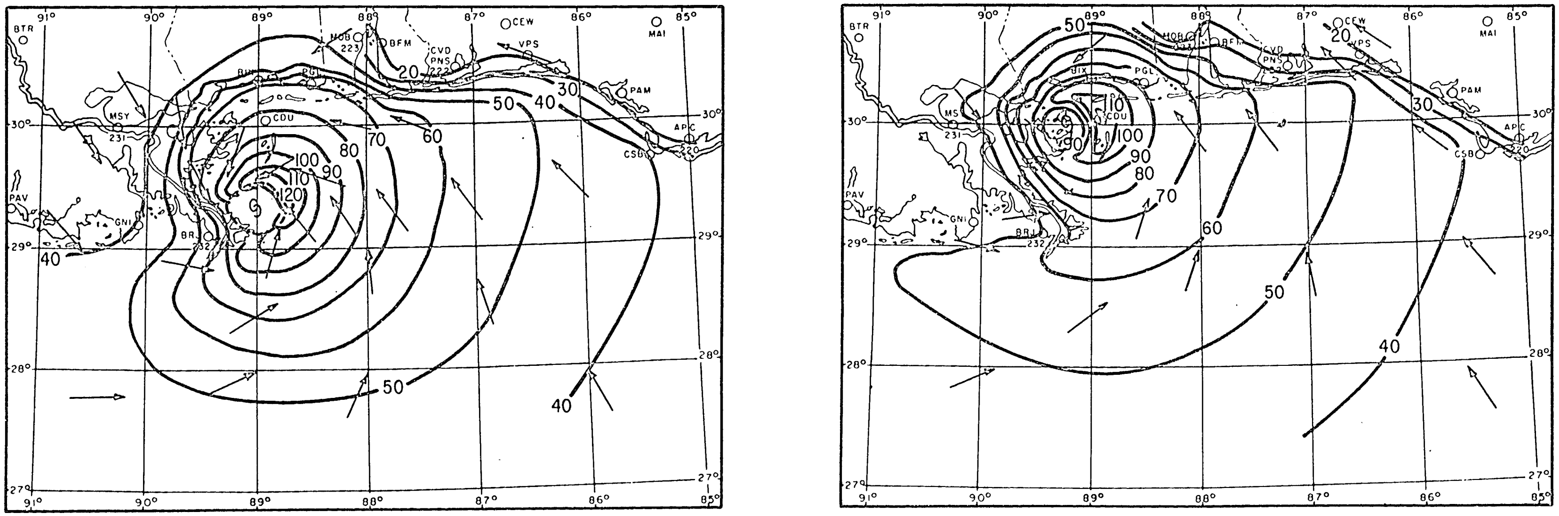
C 1200 GMT – 17 Aug 69

Figure 23. 30-foot surface isovels (knots), Hurricane Camille (Environmental Science Services Administration; HUR 7-113A, 1970).



D 1800 GMT – 17 Aug 69

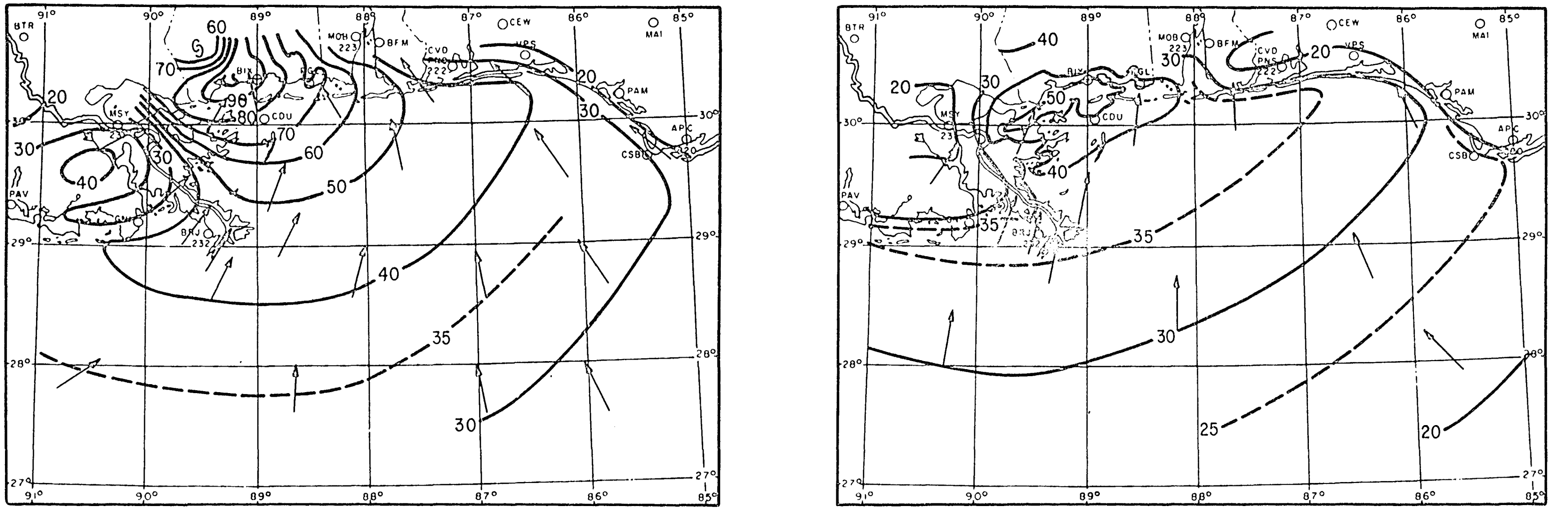
E 2100 GMT – 17 Aug 69



F 0000 GMT – 18 Aug 69

G 0300 GMT – 18 Aug 69

Figure 24. 30-foot surface isovels (knots), Hurricane Camille (Environmental Science Services Administration; HUR 7-113A, 1970).



H 0600 GMT – 18 Aug 69

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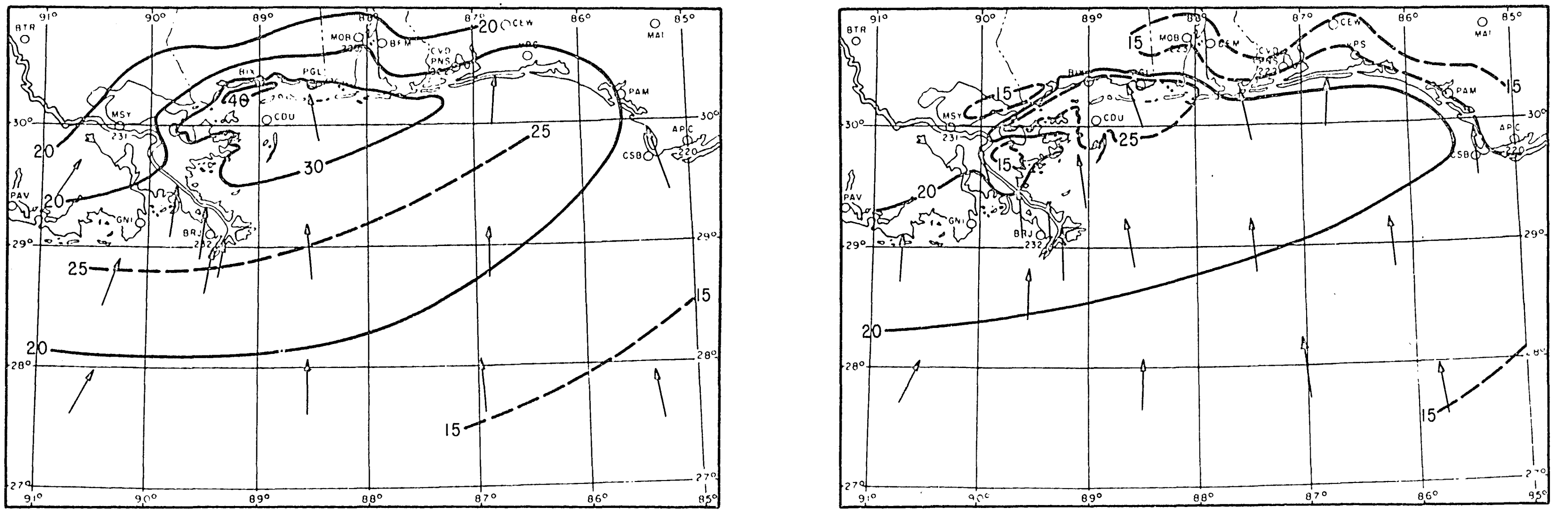


J 1800 GMT – 18 Aug 69

K 0000 GMT – 19 Aug 69

Figure 25. 30-foot surface isovels (knots), Hurricane Camille (Environmental Science Services Administration; HUR 7-113A, 1970).

b. Hydrographic Data. The storm surge generated by Camille flooded coastal regions from lower Plaquemines Parish in Louisiana, to Perido Pass, Alabama. Maximum storm surge of 24.6 feet above MSL was measured in the Pass Christian-Long Beach, Mississippi, area. In St. Louis Bay, maximum surge was 18 feet above MSL. At Back Bay of Biloxi, Mississippi, the surge elevation reached about 15 feet above MSL (U.S. Army Engineer District, Mobile, 1970), and near 10 feet above MSL as far east as the Mississippi-Alabama border.

Along the Louisiana coast, the storm surge was 15 feet above MSL at Boothville, and 9 feet above MSL near the mouth of the Mississippi, at Garden Island. At Alluvial City surge height reached 7.97 feet above MSL, at Chef Menteur Pass 11.06 feet, at Shell Beach 11.06 feet, and at Rigolets 9 feet. Detailed maps of areas flooded and surge measurements of Hurricane Camille are presented by Wilson and Hudson (1969). Additional surge elevations along the Louisiana and Mississippi coasts are shown in Figure 26.

Surge data along the coast of Louisiana, Mississippi and Alabama, were obtained from the U.S. Army Engineer District, Mobile Report (1970). The surge elevation of 19.5 feet above MSL used for the calibration is based on a visual observation of high water mark at Biloxi, Mississippi (Fig. 27). This value may include runup due to wave action. The reduction of tide data is discussed in Section IV.

5. Hurricane Carol.

a. Hurricane Data. Hurricane Carol formed near the northeastern Bahama Islands on 26 and 27 August 1954. Then, it moved northward to a position near 30°N., 76°W., and became nearly stationary. For the next three days the storm drifted very slowly and by 30 August had moved to about 32.5°N., 77.5°W. Then, it began accelerating in a north-northeast direction passing near Cape Hatteras at about 2100 or 2200 hours EST, 30 August (Fig. 28). Highest winds were estimated to vary from 75 to 125 miles per hour.

During the morning of the 31st, Carol moved very rapidly in a north-northeast direction from Cape Hatteras, crossed over the eastern end of Long Island and entered the New England area at the south shore of Rhode Island. From there, Carol crossed Rhode Island, eastern Massachusetts and along the Maine-New Hampshire border into Canada through the St. Lawrence Valley. The storm left 60 dead and over $460 million damage to property and crops in the North Atlantic States (Davis, 1954).

Carol struck the Rhode Island area in full strength at about 1030 hours EST, 31 August, with sustained winds up to 90 miles per hour and gusts up to 105 miles per hour. Highest winds were at Block Island, Rhode Island, where 130 miles per hour was measured in gusts.

In the vicinity of Narragansett Bay, at Point Judith, Rhode Island, maximum hurricane winds with velocities of 73 to 82 miles per hour were observed about 1100 hours EST. At the entrance of Narragansett Bay near Brenton Point winds with velocities from 73 to 82 miles per hour were observed between 1100 and 1200 hours EST.

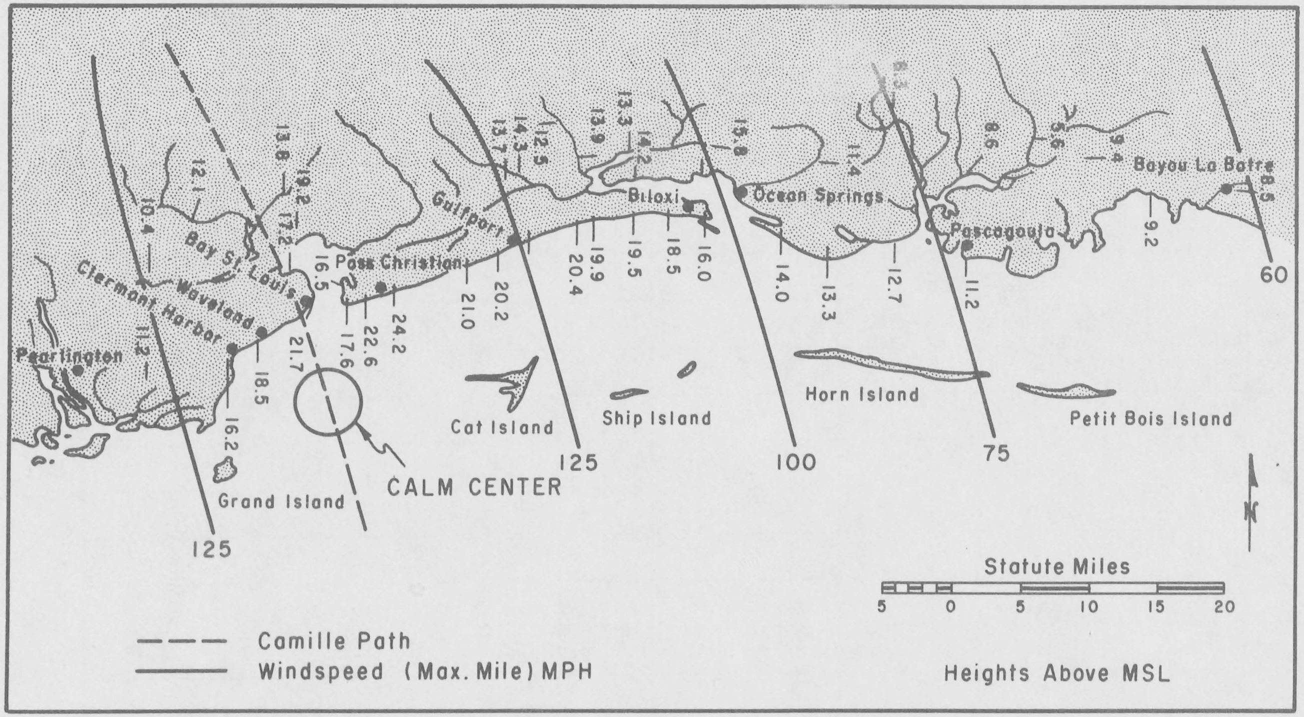


Figure 26. Hurricane Camille track, windspeeds and resultings surges along the Mississippi coast.

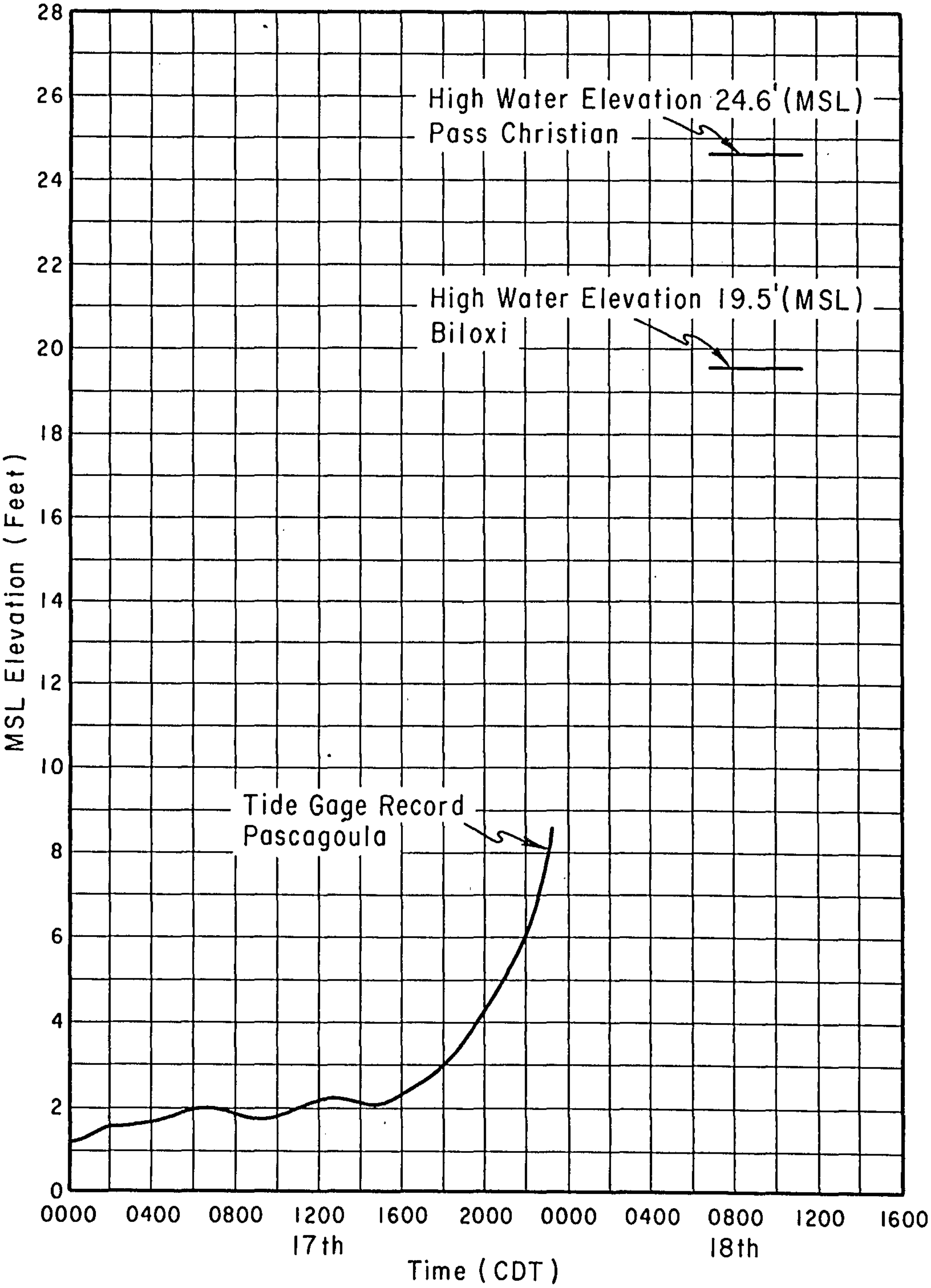


Figure 27. Hurricane Camille, August 1969. Storm surge chart.

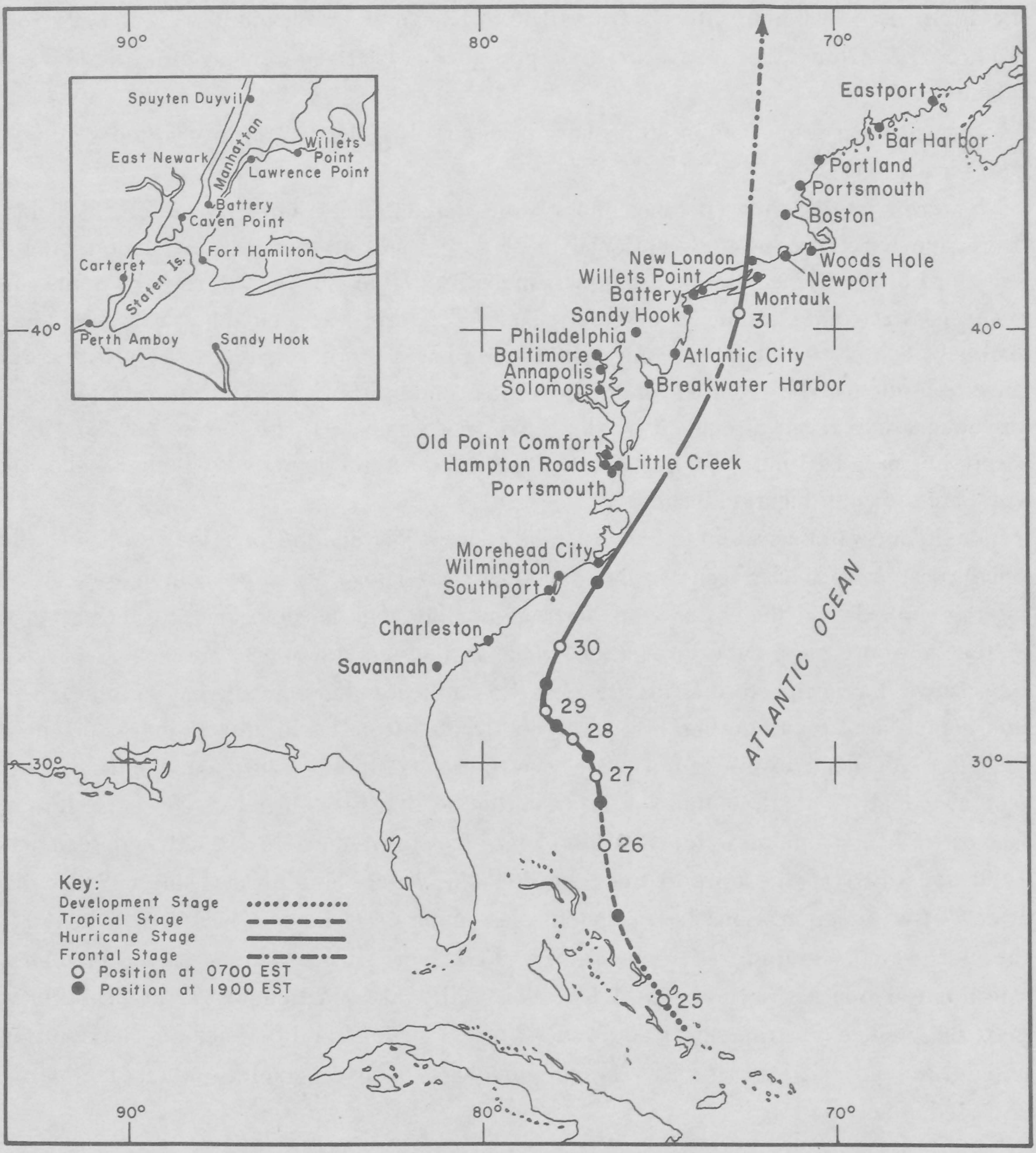


Figure 28. Storm track of Hurricane Carol, 30-31 August 1951. Insert map for New York Harbor (Harris, 1963).

Surface wind field and pressure fields for Hurricane Carol were obtained from the Hydrometeorological Report HUR 7-54 (U.S. Weather Bureau, 1959). In the report, wind fields are given at 3-hour intervals from 0130 to 1330 hours EST, and 2-hour intervals from 1330 to 1730 hours EST, 31 August. Synoptic weather charts of the hurricane are shown in Figure 29.

Historical accounts for this storm have been given by McGuire (1954), Rhodes (1954), and Davis (1954).

b. Hydrographic Data. Because of forward speed, intensity, and arrival during high tide, Hurricane Carol produced exceptionally high surges and destructive wave action. About one-third of Providence, Rhode Island, was under 8 to 10 feet of water for several hours and many coastal communities were severely damaged. Storm waves outside Narragansett Bay had heights over 40 feet approaching from the southeast. Storm surges associated with Carol have been discussed by Redfield and Miller (1957) and by Harris (1963). Surge data in these discussions have been assembled by the U.S. Army Engineer District, New York and U.S. Army Engineer Division, New England. Peak surge values and surge hydrographs for the east coast are shown in Figures 30 and 31.

Maximum water elevation observed at Narragansett Pier due to Hurricane Carol along the open coast outside Narragansett Bay was 12.8 feet above MSL. No complete recorded hydrograph exists at the entrance to Narragansett Bay, and the closest gage to the entrance is the Newport gage on Constellation Dock at Coasters Harbor Island, which became inoperative during the storm. This gage was 4.5 nautical miles from the bay entrance. The hydrograph used for the calibration was reconstructed from visual observations which may include runup due to wave action. Water elevation at Newport reached a maximum of 11.6 feet above MLW at 1230 hours EST (reported by the City Engineer, Newport, Rhode Island) while a maximum water elevation of 12.5 feet above the gage datum was observed at 1100 hours EST at the Newport tide gage site. This water elevation probably includes the effects of wave action. Considering that the gage datum was 1.4 feet below MLW in 1954, the net water elevation at Newport was 11.1 feet MLW. The maximum predicted astronomical tide at Newport was 4 feet above MLW at 0917 hours EST. At 1100 hours EST, the predicted astronomical tide was 3.2 feet. The 7.9 feet difference was the result of initial rise and hurricane surge. The methodology of hydrographic data reduction is discussed in Section IV.

IV. DATA REDUCTION

1. Wind Data Reduction.

A prerequisite of accurate storm surge calculation is the availability of good wind field data along a selected computational traverse. Most wind field data of hurricanes are given in 3- and 6-hour weather charts; however, critical hurricane surge effects may be experienced at a coastline between time intervals for which wind field charts are available. Drastic changes in windspeed and direction can occur during these widely separated time intervals

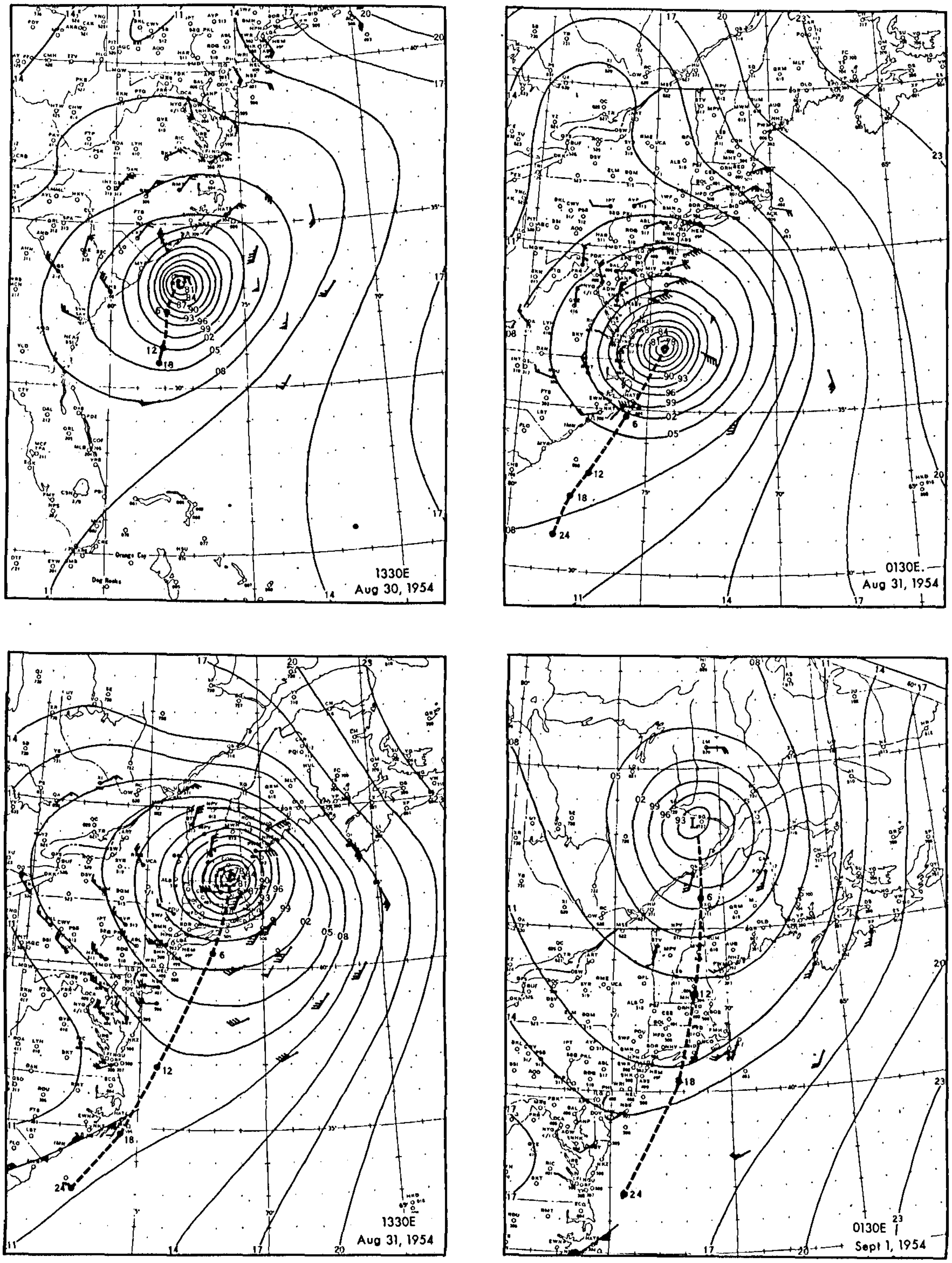


Figure 29. Hurricane Carol, 30-31 August 1954. Synoptic charts (Harris, 1963).

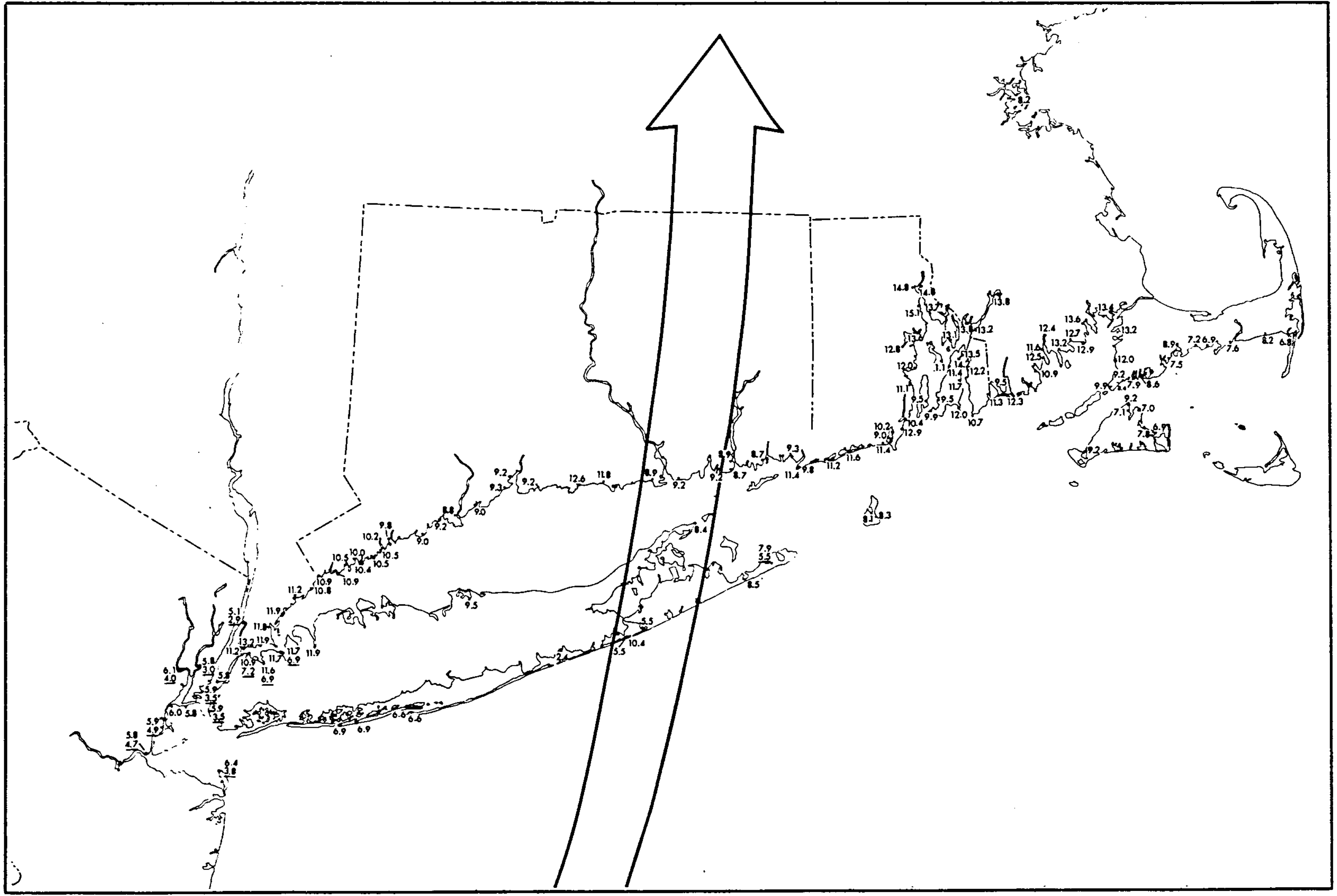


Figure 30. Hurricane Carol, 30-31 August 1954. High water marks in New York and New England (Harris, 1963).

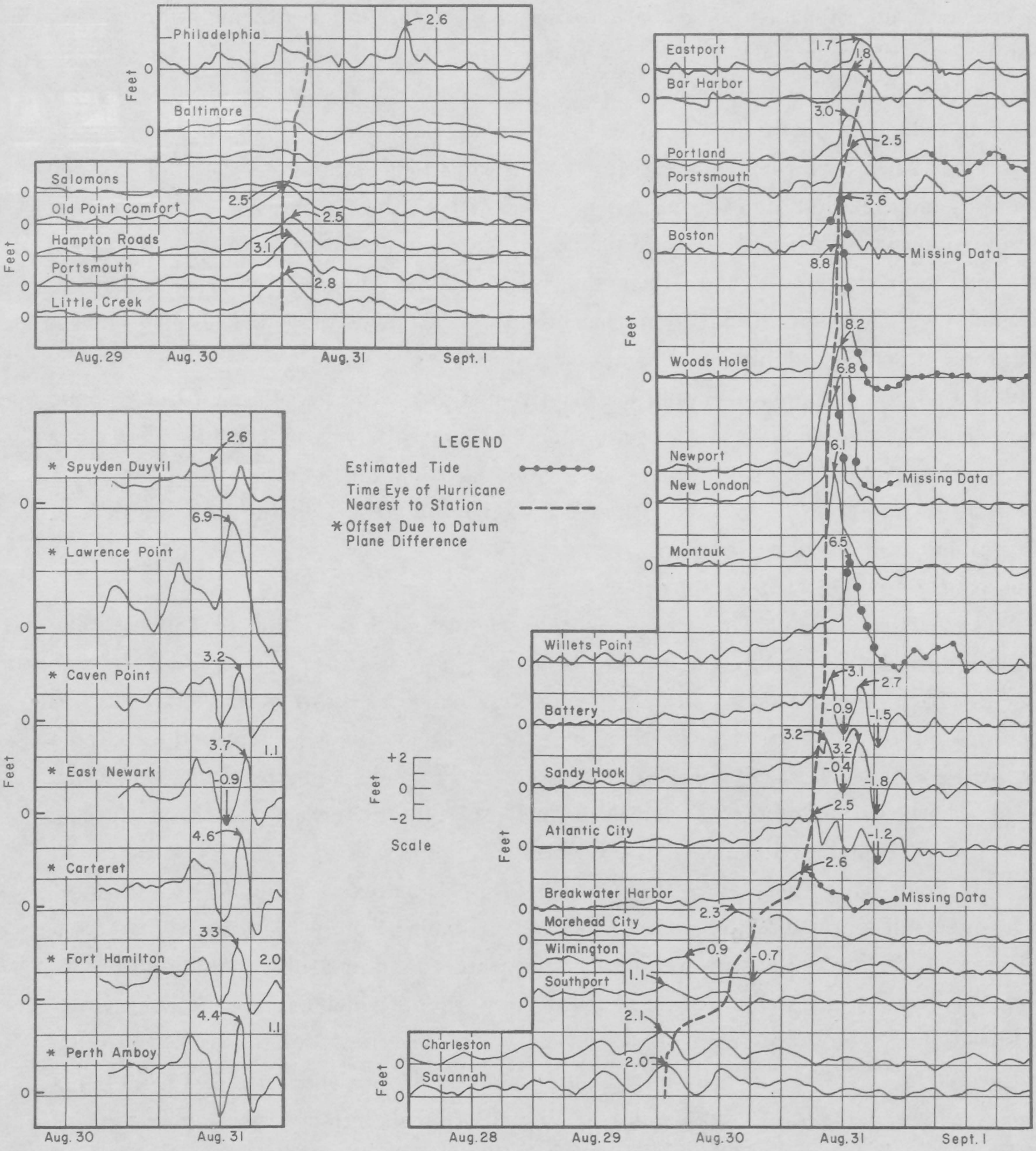


Figure 31. Hurricane Carol, 30-31 August 1951. Storm surge chart (Harris, 1963).

which may render storm surge calculations invalid. Therefore, frequent wind information is desirable, at least along traverses where storm surge calculations are made. An accurate interpolation procedure must be used to generate additional temporal wind information. This data reduction can be done graphically or by computer. However, both schemes have limitations. When a storm is moving slowly, the wind field data may be voluminous and graphical interpolation time consuming. When the storm is moving rapidly, linear interpolation may give inaccurate wind field data, especially in situations where abrupt wind direction reversals occur, and when the hurricane center crosses the coastline. In interpolating, abrupt wind direction changes often require a subjective evaluation and interpretation, or very sophisticated computer programs.

In this study, a graphical, nonlinear, data reduction method was used to interpolate windspeeds, W, and wind vector directions, o, for time intervals of 1 hour or less along each traverse. A computer subroutine was introduced to obtain the distances of the storm center, r, to points on the traverse. The methodology used for reduction of wind data of historical hurricanes is discussed below.

a. Windspeeds and Wind Vector Directions.

(1) A computational line (traverse) was selected and drawn on a chart of the same scale as the wind charts in the same geographical area (Fig. 32).

(2) Each traverse was plotted, or a transparency showing the traverse was superimposed, on all appropriate weather charts of the same scale which covered the chosen time period for which calculations of surge were to be made, for a particular hurricane. Weather charts with contours of windspeeds in knots (30-foot surface isotachs or isovels), and vectors of wind directions, were used in this study.

(3) Points along the traverse were selected for calculations at different time stages of the storm. Wind vector directions and speeds were obtained from each weather chart for a time interval starting at the seaward point of the traverse and at a subsequent point on the traverse. This was done at the earliest phase of the storm for which data was available if the windspeeds at the seaward point exceeded the critical value of 14 knots. Windspeeds, W, were obtained by interpolation between isovels and converted from knots to miles per hour (1 knot = 1.15 miles per hour). Wind direction angles, θ, (the angles between traverse line and wind direction) were obtained by averaging two or more wind vectors on either side of the traverse and these measured counterclockwise from the traverse line from 0° to 360°. Also, the initial distance values, r_{LM}, of the storm center to the traverse shore-intercept were obtained in nautical miles for each position of the storm given on the weather charts (Fig. 32). Subsequent values of distances r to all other points on the traverse were developed internally by the program, according to the method given in Section VI. This data reduction procedure was repeated for each time step in the development of the storm (using a 6-, 3-, or 1-hour weather chart). The process of interpolation was subjective, and attention was given in developing the data in a reasonable fashion.

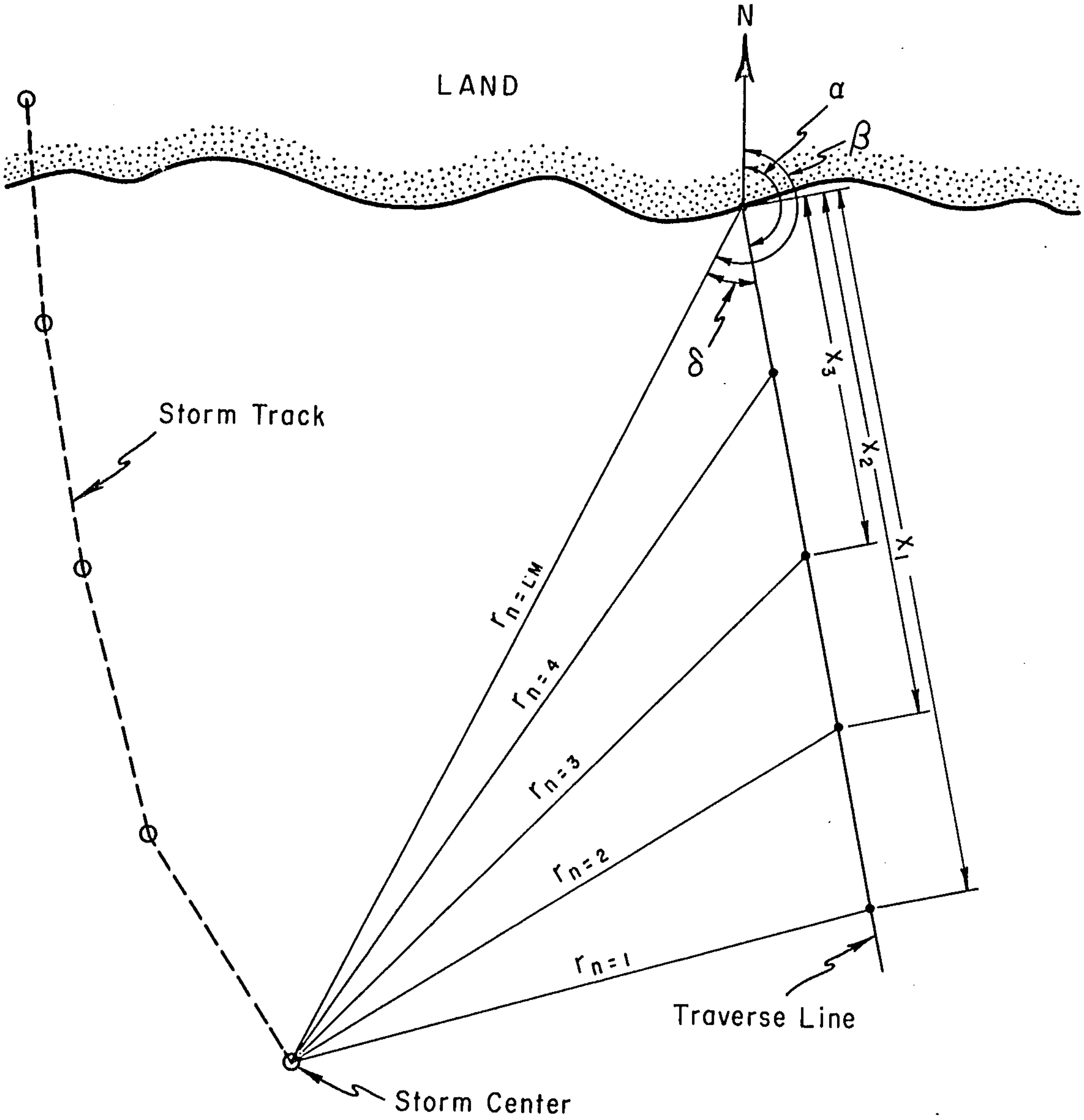


Figure 32. Schematic of nonlinear graphical interpolation of wind data and distance of the storm center to points on the traverse.

(4) If the data obtained by this procedure were from hourly wind charts, it was tabulated and then punched directly on computer cards without further reduction. This form provided an input for the numerical surge calculations. An example of the input data format is shown in Appendix A.

(5) If data were obtained from 3- or 6-hour weather charts, then graphs were prepared of: windspeed changes with time for points on the traverse, wind direction changes with time for points on the traverse, wind direction changes along the traverse for each 3- or 6-hour interval, and changes with time in the distance of the hurricane center with each point on the traverse. Examples of graphs used for reduction of the 3- and 6-hour wind data are given in Figures 33 through 36. Hourly wind directions and speeds were obtained from the graphs by nonlinear interpolation for all points along each traverse, and for each hurricane. In addition, r values were obtained. Finally, all values were tabulated, punched on cards, and used as input for surge calculations.

b. Storm Center Distance, r, to Traverse. Values of distances r between points along the traverse and the moving storm center were calculated internally by a routine added to the computer program. Given the azimuth a of the traverse, the initial distance, r_{LM}, between the storm center and shore-intercept of the traverse, and azimuth β of this line, subsequent values of r for each point on the traverse were calculated by the program for each time interval. From geometry shown in Figure 32, the value of r_n was determined each time using the law of cosines. Accordingly:

$$r_n = \sqrt{X_n^2 + r_{LM}^2 - 2X_n r_{LM} \cos \delta} \qquad (41)$$

where

X_n = the distance of each point of the traverse from the shore intercept of that traverse,

and

δ = the computed angle between the traverse and r_{LM} .

2. Hydrographic Data Reduction.

Tide gage hydrographs of historic hurricane surges are important in the calibration and verification of a numerical model. The importance of such data was discussed in Section I. For the purpose of this study, corrections and adjustments were applied to the hydrographic data to account for tide gage locations, tide phases, water level datums of tide gages, and initial rise preceding the arrival of hurricanes.

a. Tide Gage Locations. In the discussion of data limitations, it was pointed out that most tide gage stations are situated in protected areas of the coast and do not record storm

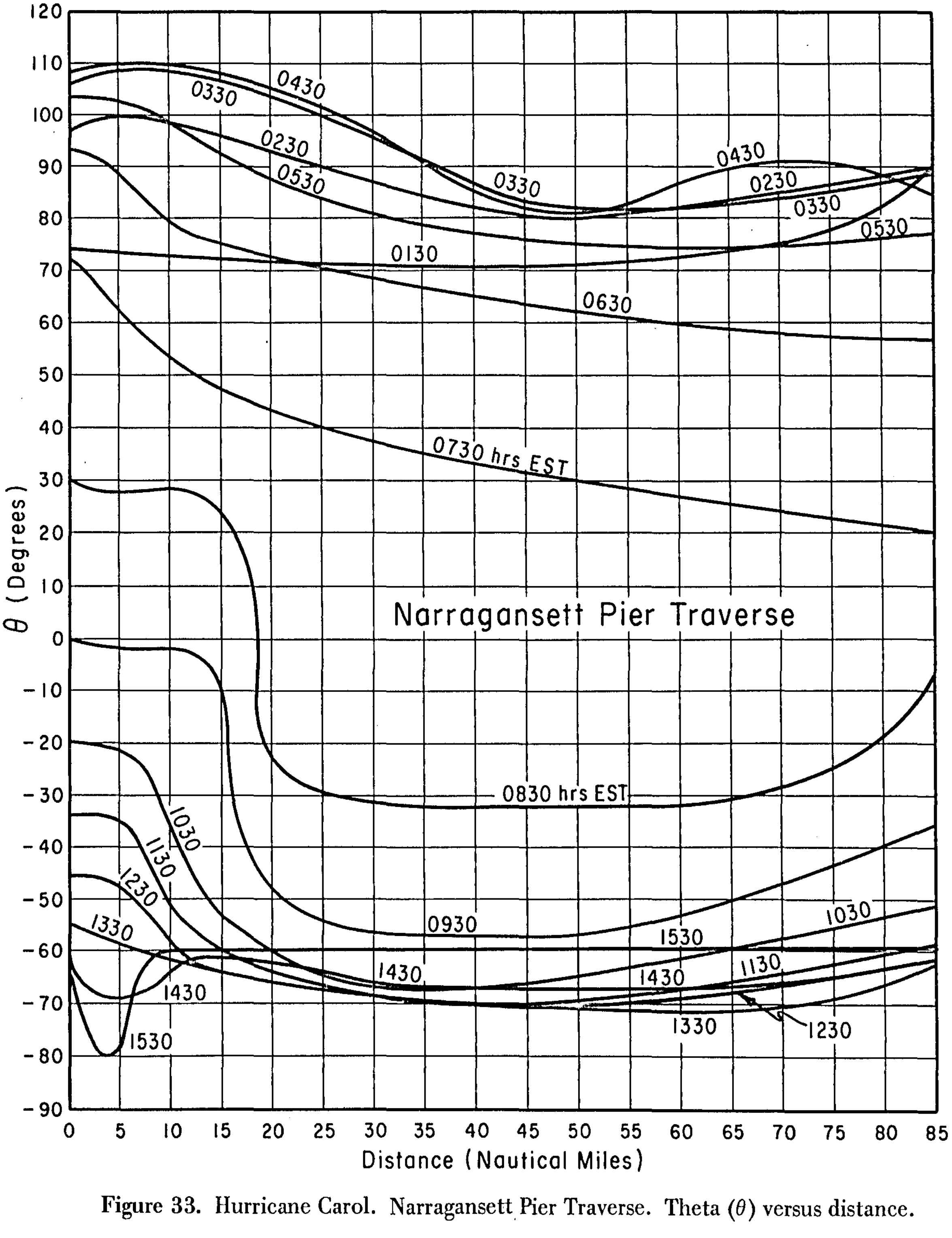


Figure 33. Hurricane Carol. Narragansett Pier Traverse. Theta (θ) versus distance.

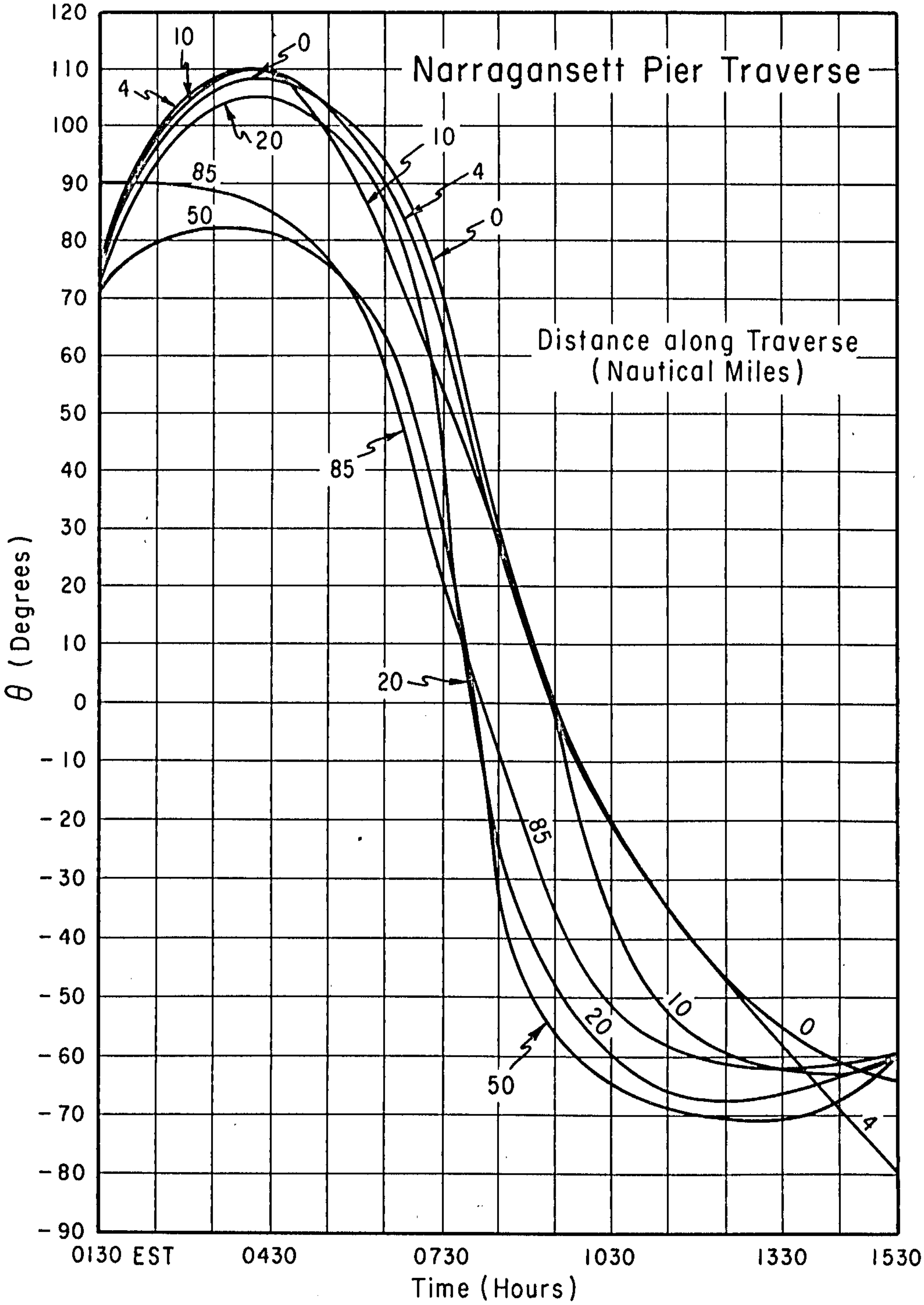


Figure 34. Hurricane Carol. Narragansett Pier Traverse. Theta (θ) versus time.

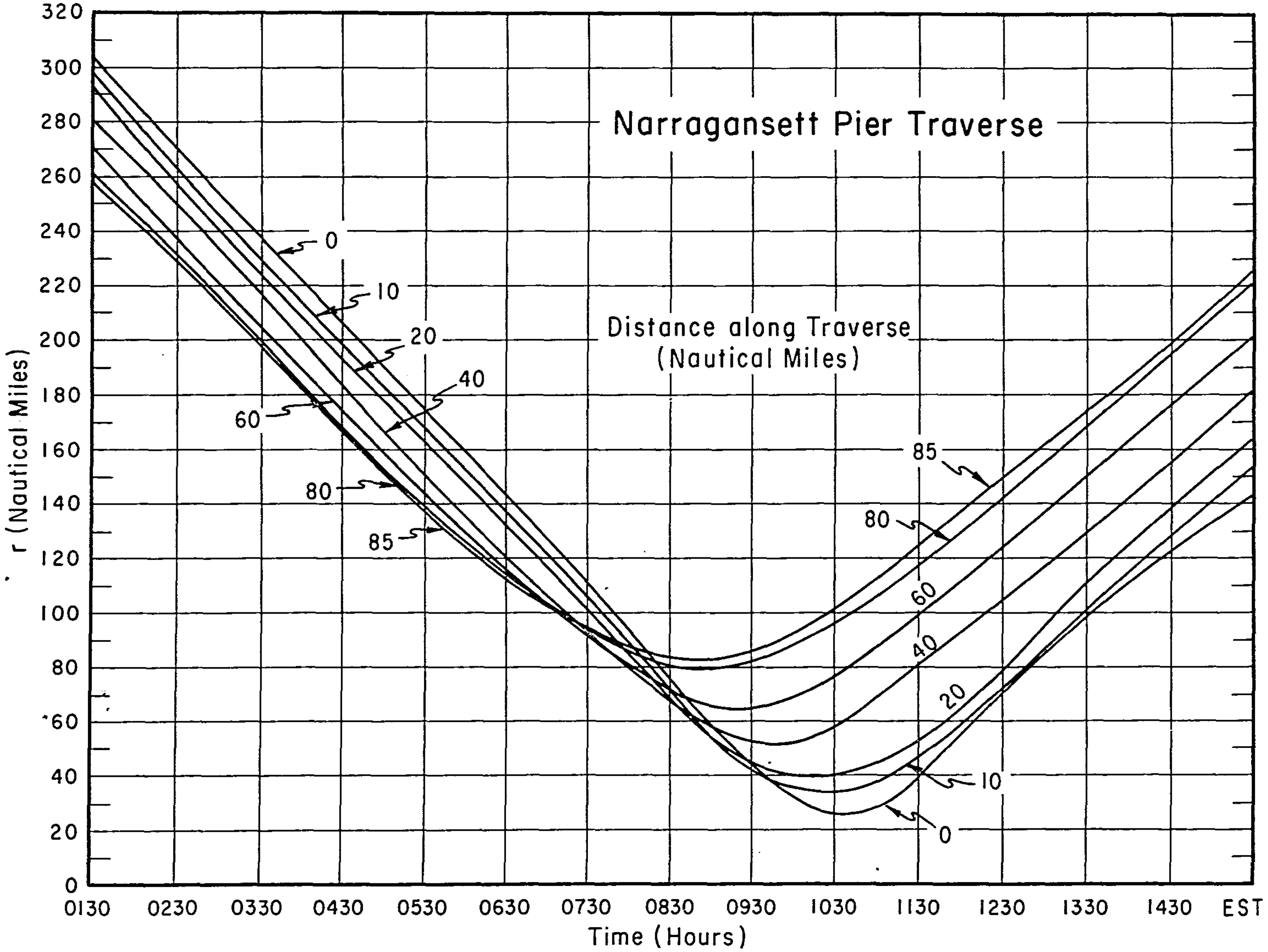


Figure 35. Hurricane Carol. Radius (r) versus time.

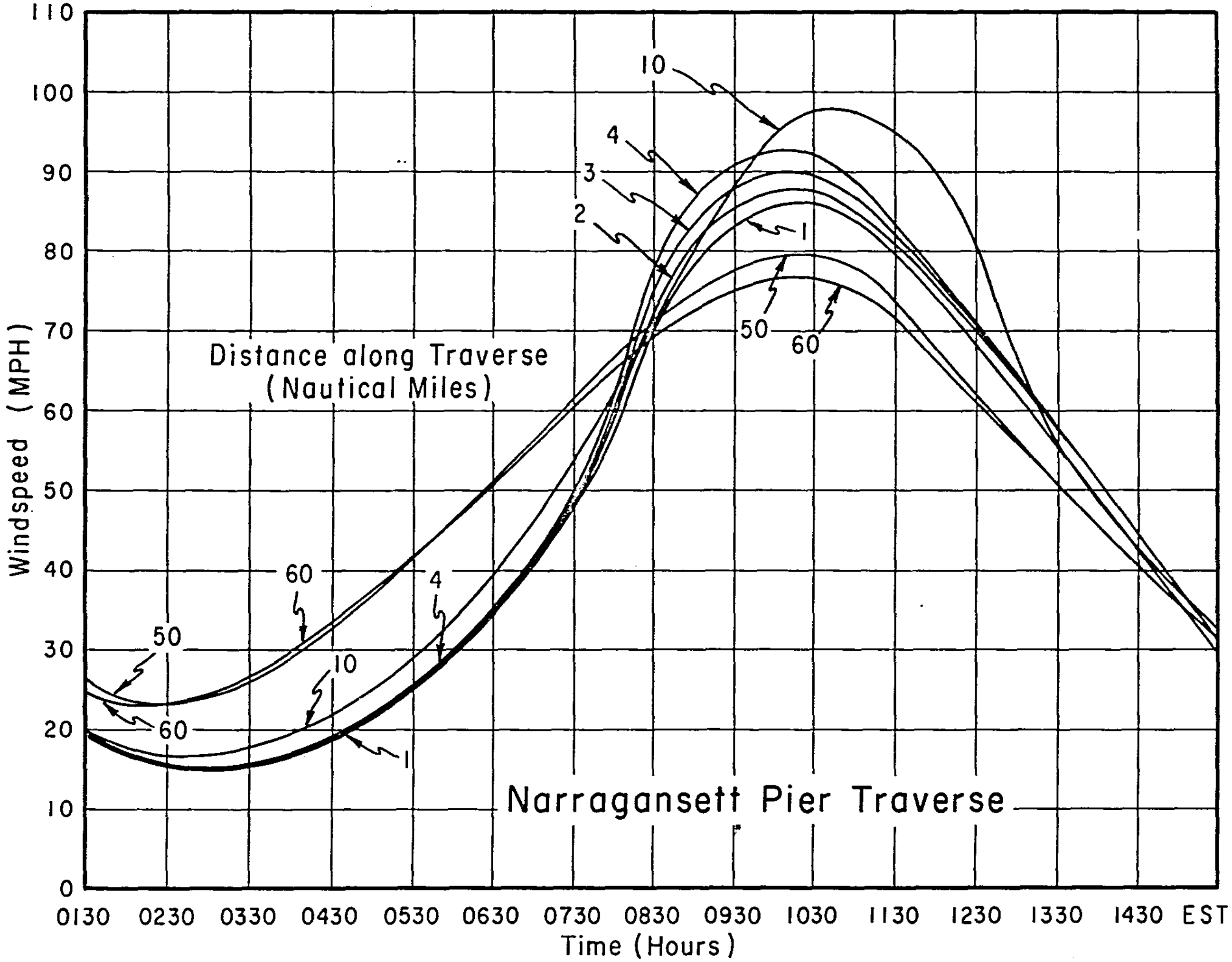


Figure 36. Hurricane Carol. Windspeed versus time.

surge at the open coast. The few tide gage stations located on the open coast are widely separated and often are not near paths of hurricanes. Some tide gage data used in the computation of surge on the open coast can only be estimated from tide gages located a distance away. The following tide gages were used for each hurricane:

(1) Hurricane of 1949. For the Freeport traverse the nearest tidal station which recorded the surge of this hurricane, was at Brazos River Gates. Brazos River Gates is located inland of the Gulf of Mexico at the intersection of the Brazos River and the Intracoastal Waterway (Fig. 37). For the Galveston traverse the nearest tidal station was located at Galveston's Pier 21, adjacent to Galveston Channel. This station provided the best recorded data.

(2) Hurricane Carla. For the Freeport and Galveston traverses, the nearest tidal stations recording surge from Carla were the Brazos River Gates and the Pleasure Pier gages, respectively.

(3) Hurricane Audrey. Eugene Island, Louisiana was selected as the traverse for calculation of surge from Audrey because this island is located on the seaward side of Atchafalaya Bay and represents an open coast situation. The Eugene Island tide gage station operated by the National Ocean Survey only partially recorded this event.

(4) Hurricane Camille. No complete surge hydrograph exists. The Biloxi, Mississippi, traverse used for computation of surge did not have a tide gage. The peak surge for this location (19.5 feet above MSL) is based on a visual observation. The nearest tide gage station from which a partial record of this event could be obtained, was at Pascagoula, Mississippi.

(5) Hurricane Carol. The Narragansett Pier, selected as the traverse in computing surge from Carol, represents an open-coast location which experienced maximum surge. The nearest tide gage station was at Coasters Harbor Island, Newport, Rhode Island (Fig. 38). Corrections were applied to the records from this gage, accounting for phase differences in the astronomical tide values used in the computation, e.g., the maximum water level due to Carol at the Newport gage (11.61 feet above MLW) occurred at 1100 hours EST. The high tide of 4 feet above MLW was predicted to occur at 0917 hours EST, for that location. Therefore, at the time of maximum surge at Newport, the predicted tide elevation was 3.2 feet above MLW, the difference (observed minus predicted) in tide being 7.9 feet. The tide tables were consulted for Narragansett Pier; however, no corrections were applied for tidal time and height differences between this station and Newport as these differences were relatively insignificant.

When tide gage records were not available, peak storm surge elevations on the open coast were obtained from visual observations of debris marks, which generally include the effects of wave-induced setup and runup. However, it was not possible to determine accurately how much of the water level elevation was due to surge and to wave action. The observed levels

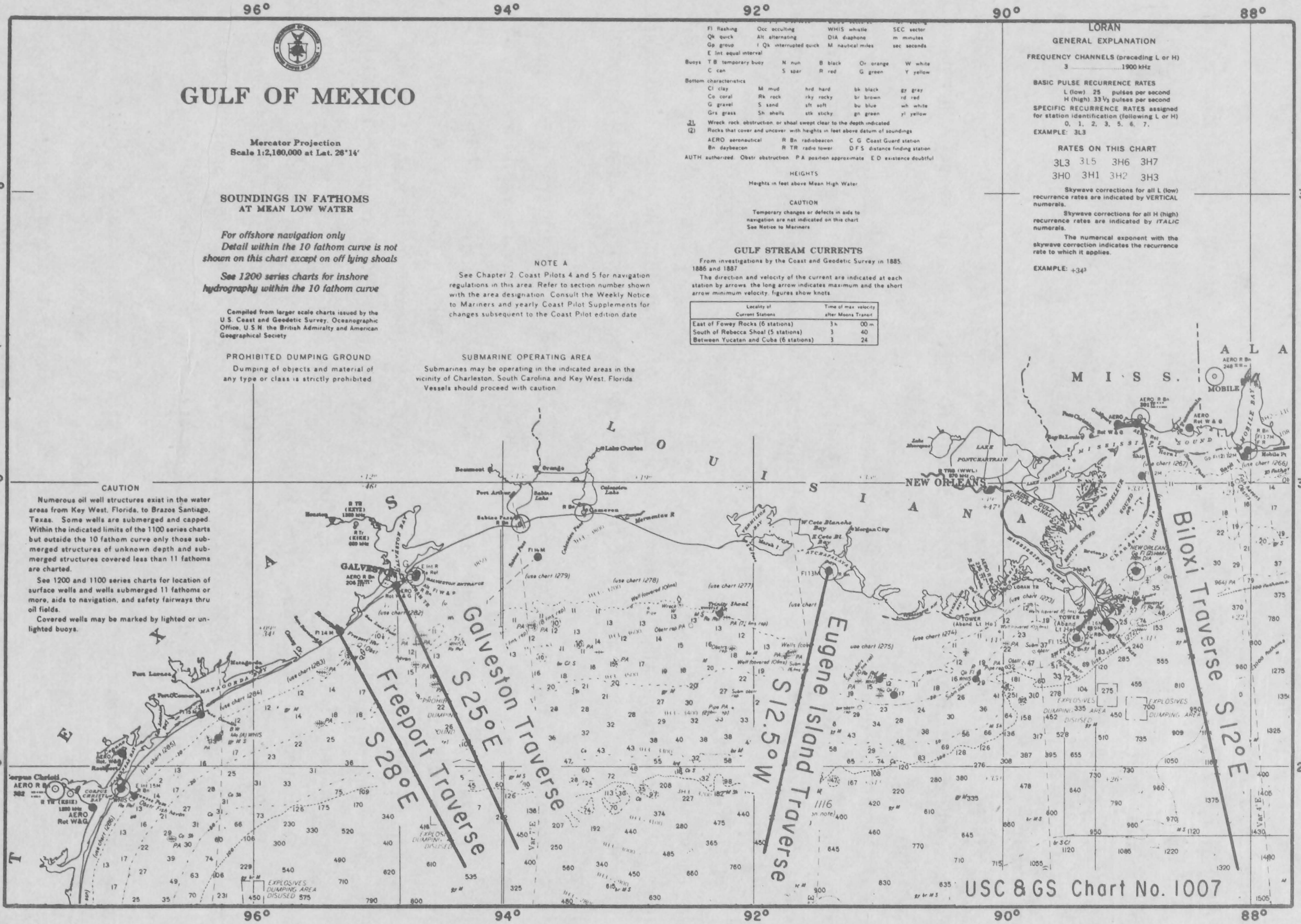


Figure 37. Galveston and Freeport, Texas; Eugene Island, Louisiana; and Biloxi, Mississippi, traverses.

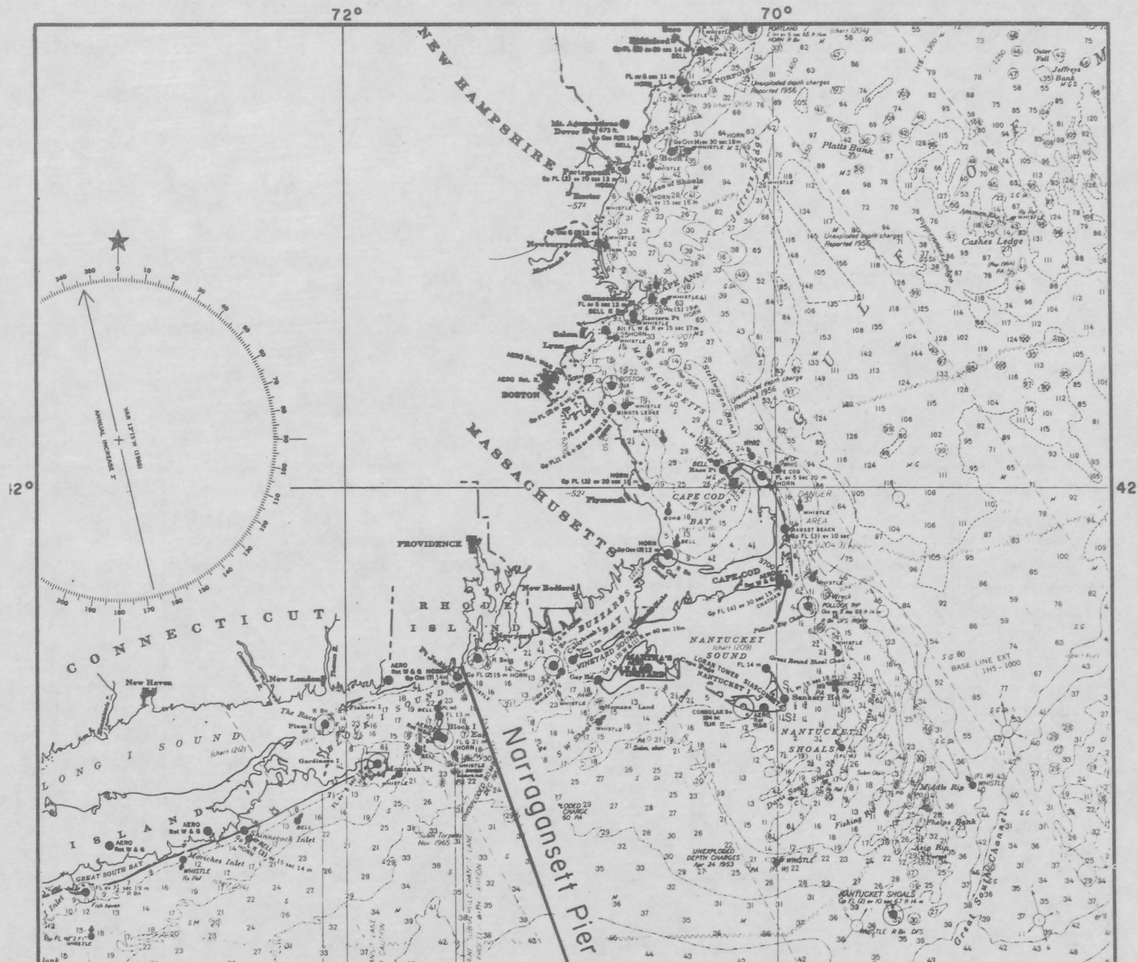


Figure 38. The Narragansett Pier traverse.

in these cases may be higher than those of the surge alone, e.g., for Camille, the surge elevation of 19.5 feet above MSL used for the calibration was based on a visual observation of high water marks at Biloxi, Mississippi. Without a better record, the observed surge hydrograph for Carol at Newport, used in the calibration for the Narragansett Pier traverse, was reconstructed from visual observations which may have also included wave runup. In both instances there was no logical way of correcting for the wave runup.

The predicted astronomical tide elevations for the tide gage station nearest to the traverses used for the computation at the time maximum surges occurred for each hurricane is given in Table 3.

Table 3. Hydrographic Data.

Parameter (feet MLW)	Hurricane of 1949 Texas		Carla Texas		Camille Mississippi	Audrey Louisiana	Carol Rhode Island
Traverse	Freeport	Galveston	Freeport	Galveston	Biloxi	Eugene Island	Narragansett Pier
Tide Station	Brazos River	Pier 21 Galveston Channel	Brazos River	Pleasure Pier	Pascagoula		Coaster Island
Initial rise	2.00	2.00	2.50	1.90	1.20	1.00	1.20
Astronomical tide at time of maximum observed surge	1.42	1.02	1.19	1.10	1.60	0.81	3.2

b. Sea Level Datum Corrections. Some recorded or observed surge data associated with hurricanes were referenced to MSL. Other tide gage data referred to MLW, or SLD. Therefore, corrections were applied for differences in the water level datum. Also, corrections were applied for tide gage datums, e.g., the gage datum at Newport, Rhode Island (Constellation Dock at Coasters Harbor Island) was 1.4 feet below MLW; therefore, the maximum gage value was corrected to 11.1 feet MLW. A correction was also applied for the phase of the tide and at 1100 hours EST the predicted astronomical tide should have been 3.2 feet. The surge for that location was 7.9 feet.

Predicted tides for the various locations at or near the traverses used in the calibration were obtained from tide tables which are referenced to MLW. The tide tables give maximum and minimum heights of tides and the times of respective occurrences. Height values were plotted and smooth curves fitted to obtain continuous values of astronomical tides (Figs. 39 through 71). These tide curves represent projected astronomical tides used for estimating the initial rise and for computing the surge hydrographs. All reported water level values refer to MLW datum.

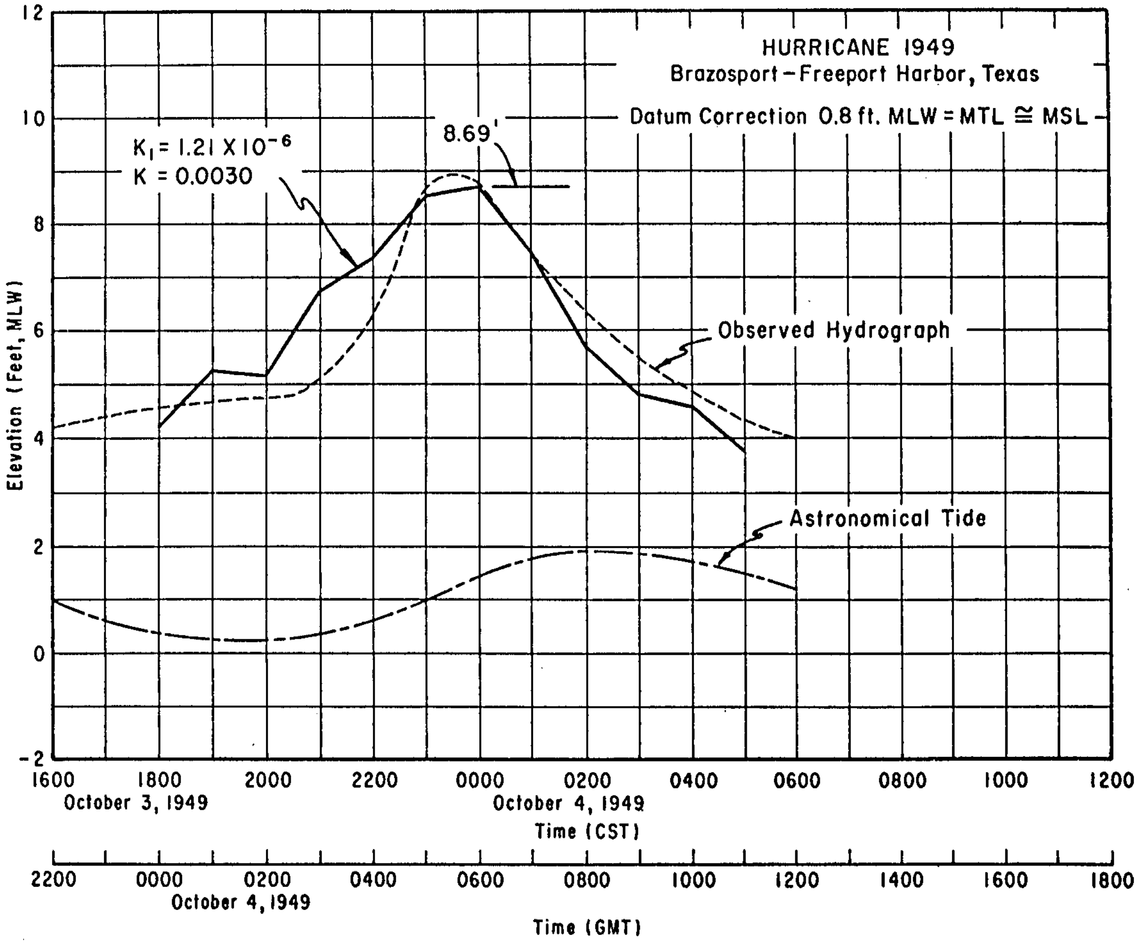


Figure 39. Observed and computed surge hydrographs for the Hurricane of 1949 at Freeport, Texas, $K_1 = 1.21 \times 10^{-6}$, $K_2 = 2.75 \times 10^{-6}$, K = 0.0030.

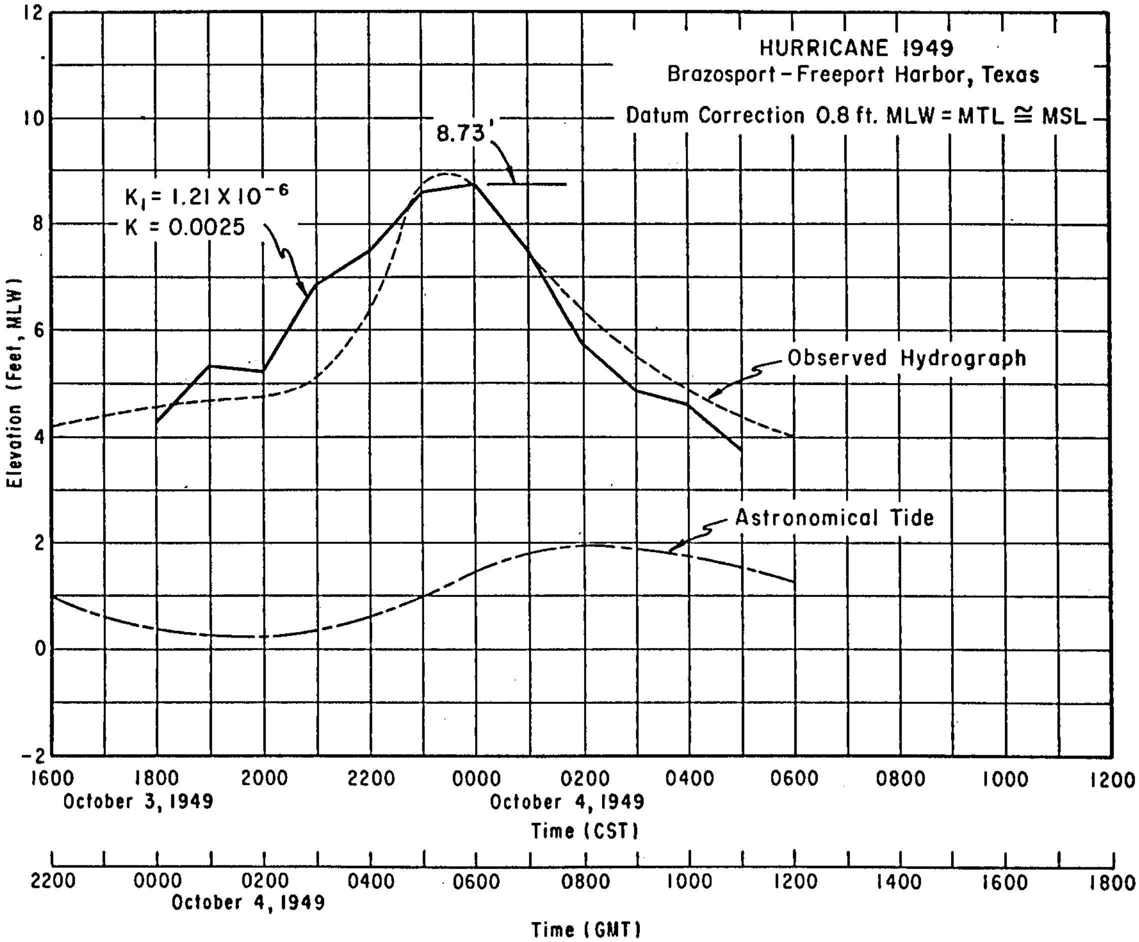


Figure 40. Observed and computed surge hydrographs for the Hurricane of 1949 at Freeport, Texas, $K_1 = 1.21 \times 10^{-6}$, $K_2 = 2.75 \times 10^{-6}$, $K = 0.0025$.

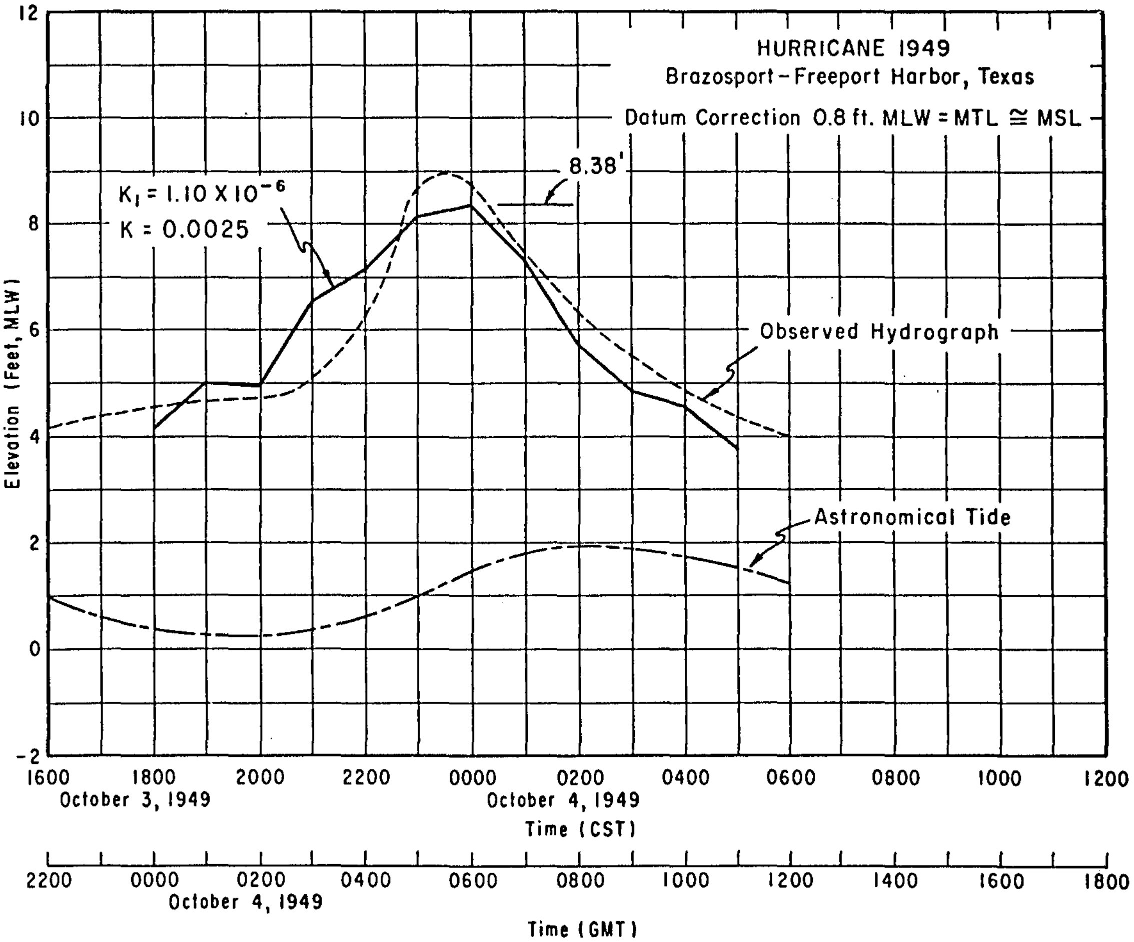


Figure 41. Observed and computed surge hydrographs for the Hurricane of 1949 at Freeport, Texas, $K_1 = 1.10 \times 10^{-6}$, $K_2 = 2.50 \times 10^{-6}$, $K = 0.0025$.

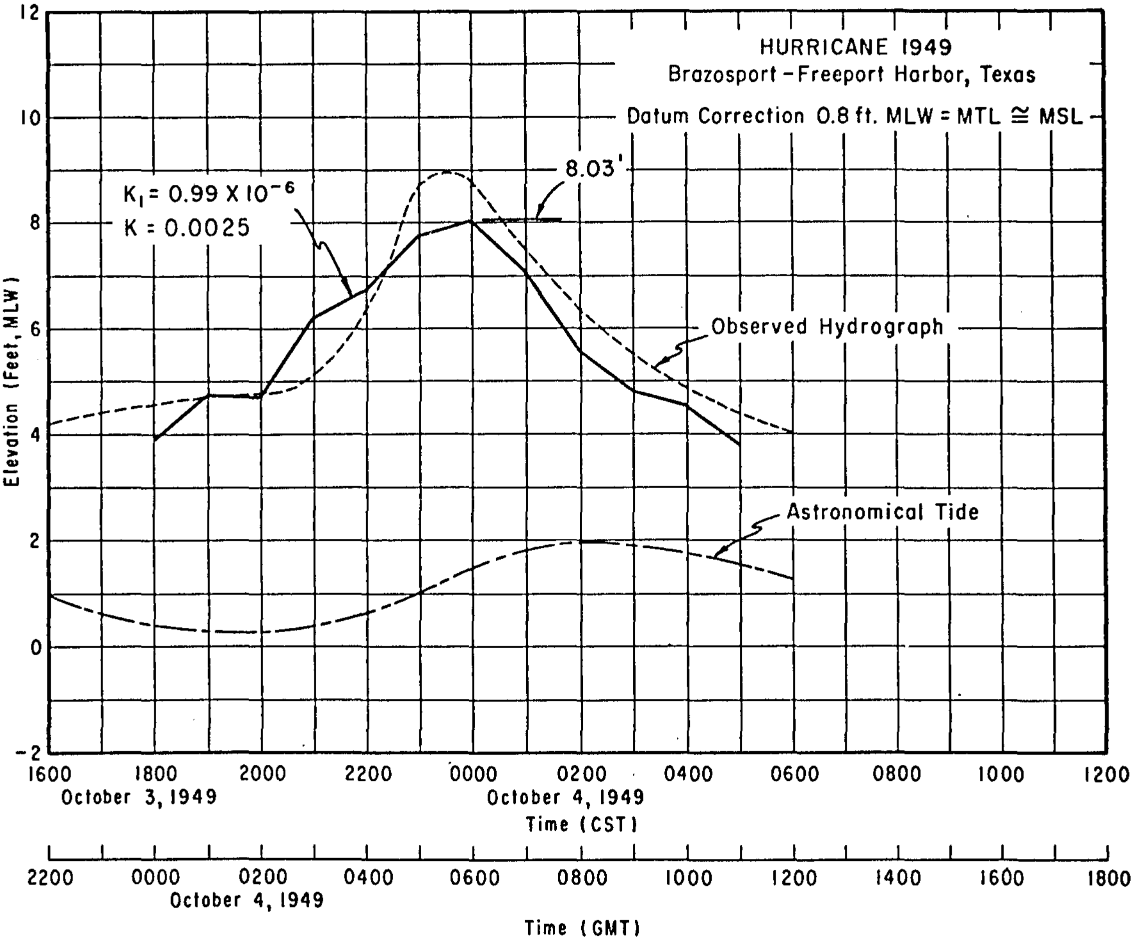


Figure 42. Observed and computed surge hydrographs for the Hurricane of 1949 at Freeport, Texas, $K_1 = 0.99 \times 10^{-6}$, $K_2 = 2.25 \times 10^{-6}$, K = 0.0025.

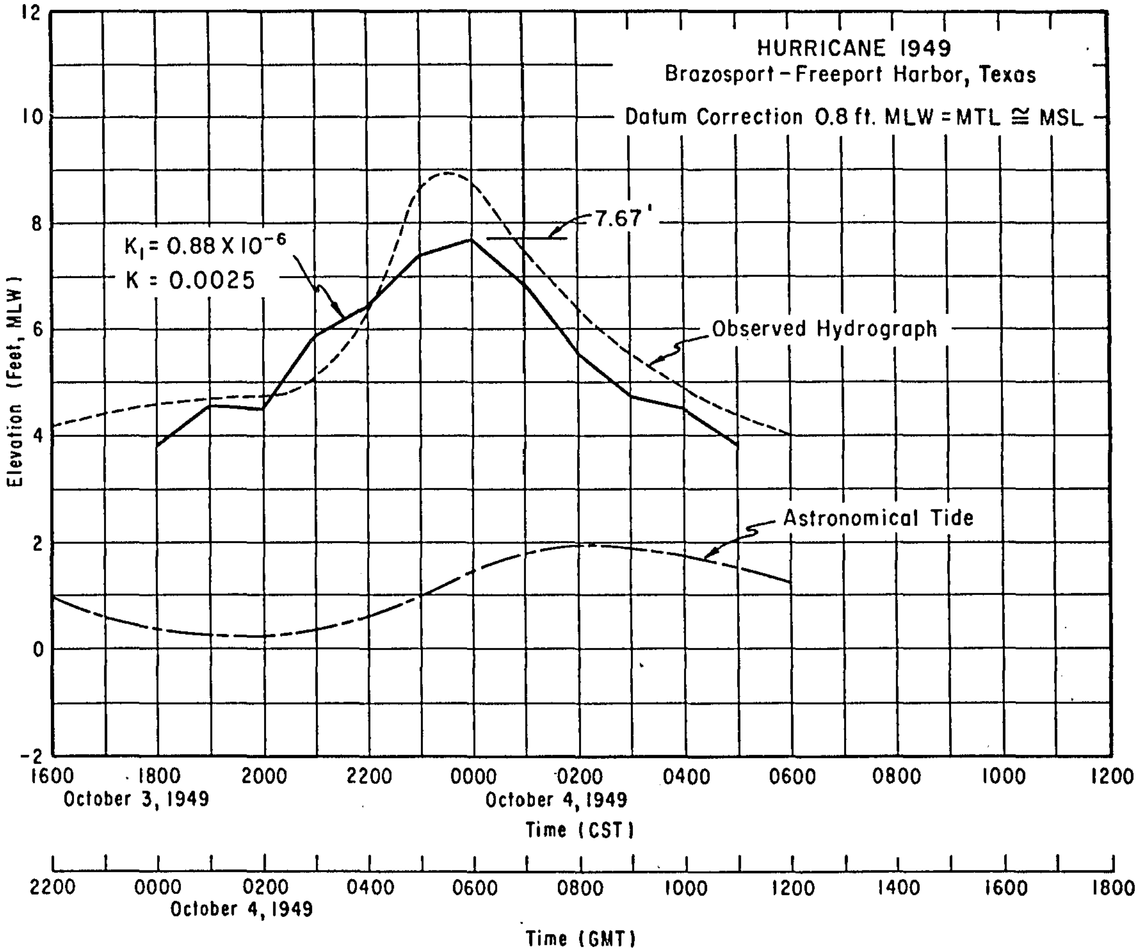


Figure 43. Observed and computed surge hydrographs for the Hurricane of 1949 at Freeport, Texas, $K_1 = 0.88 \times 10^{-6}$, $K_2 = 2.00 \times 10^{-6}$, $K = 0.0025$.

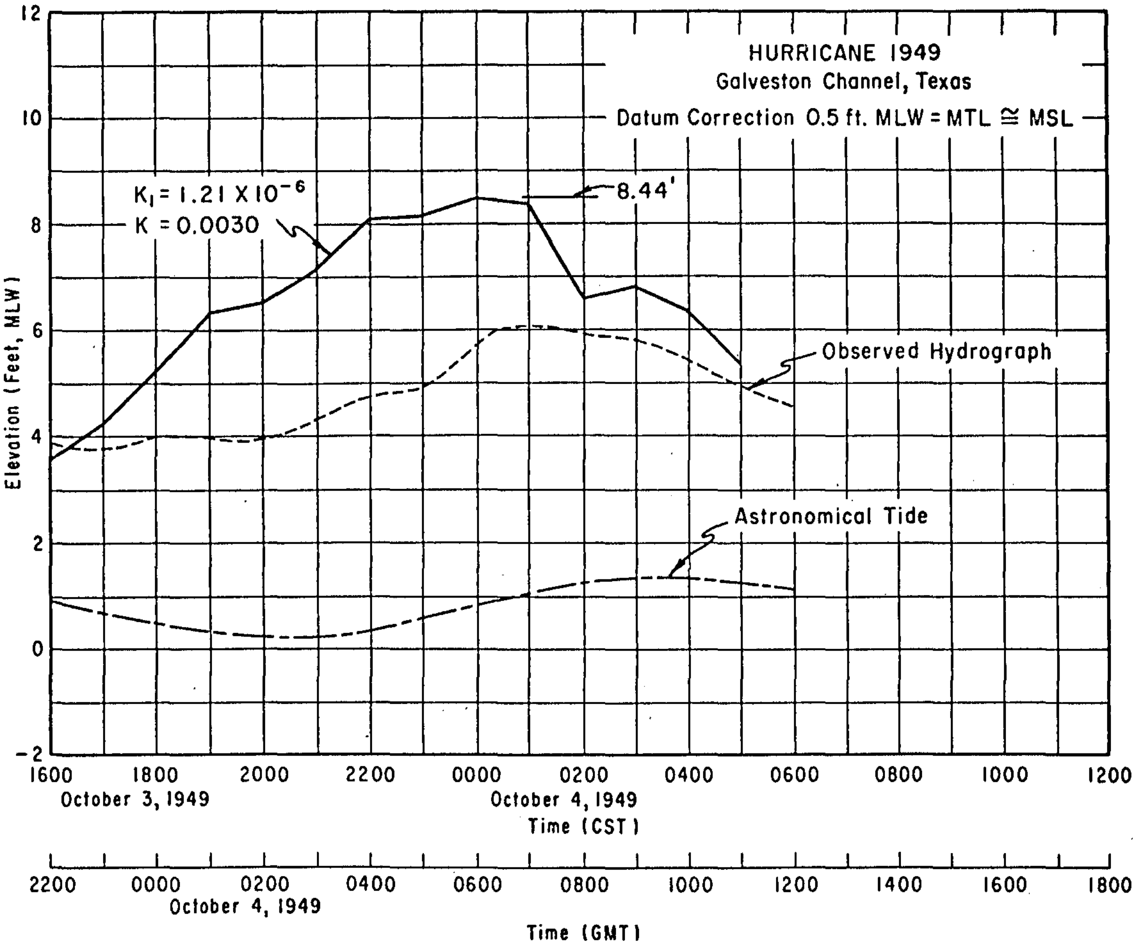


Figure 44. Observed and computed surge hydrographs for the Hurricane of 1949 at Galveston, Texas, $K_1 = 1.21 \times 10^{-6}$, $K_2 = 2.75 \times 10^{-6}$, $K = 0.0030$.

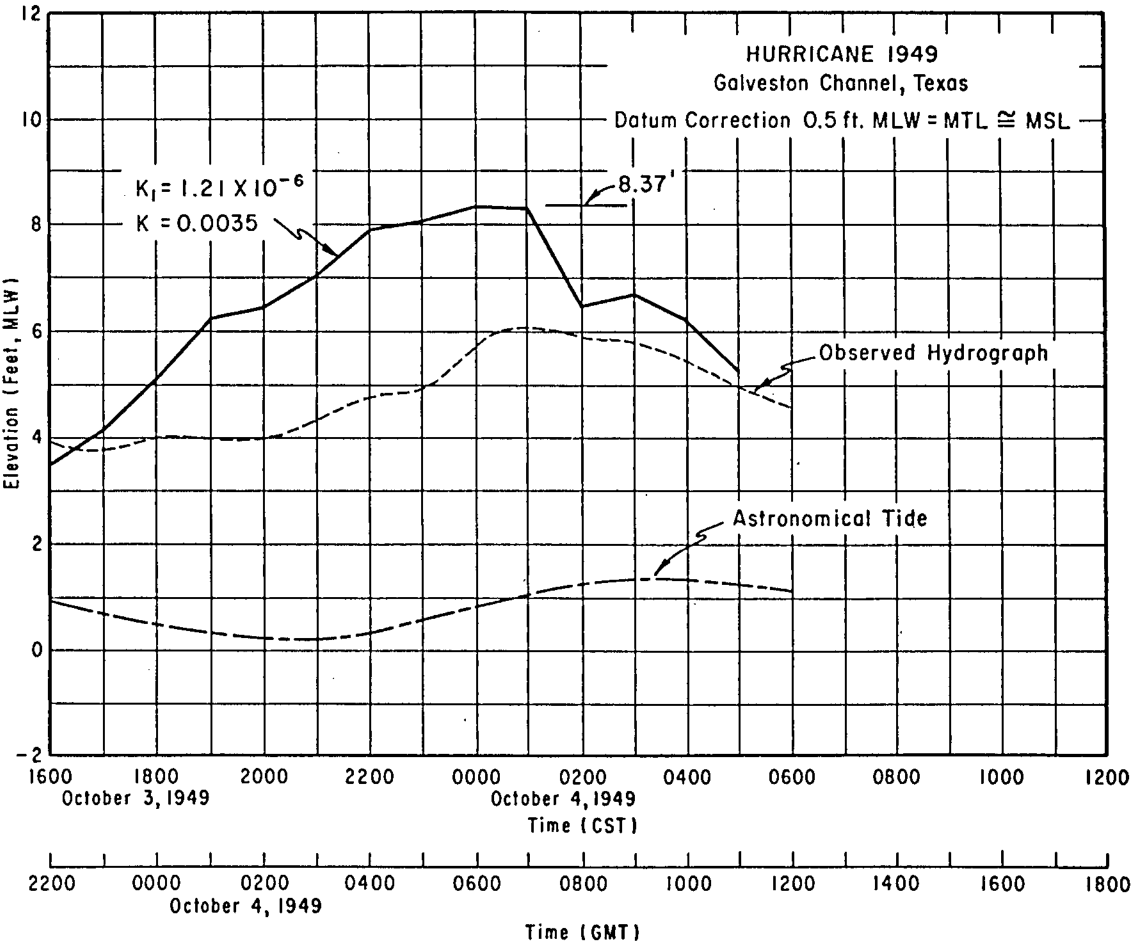


Figure 45. Observed and computed surge hydrographs for the Hurricane of 1949 at Galveston, Texas, $K_1 = 1.21 \times 10^{-6}$, $K_2 = 2.75 \times 10^{-6}$, $K = 0.0035$.

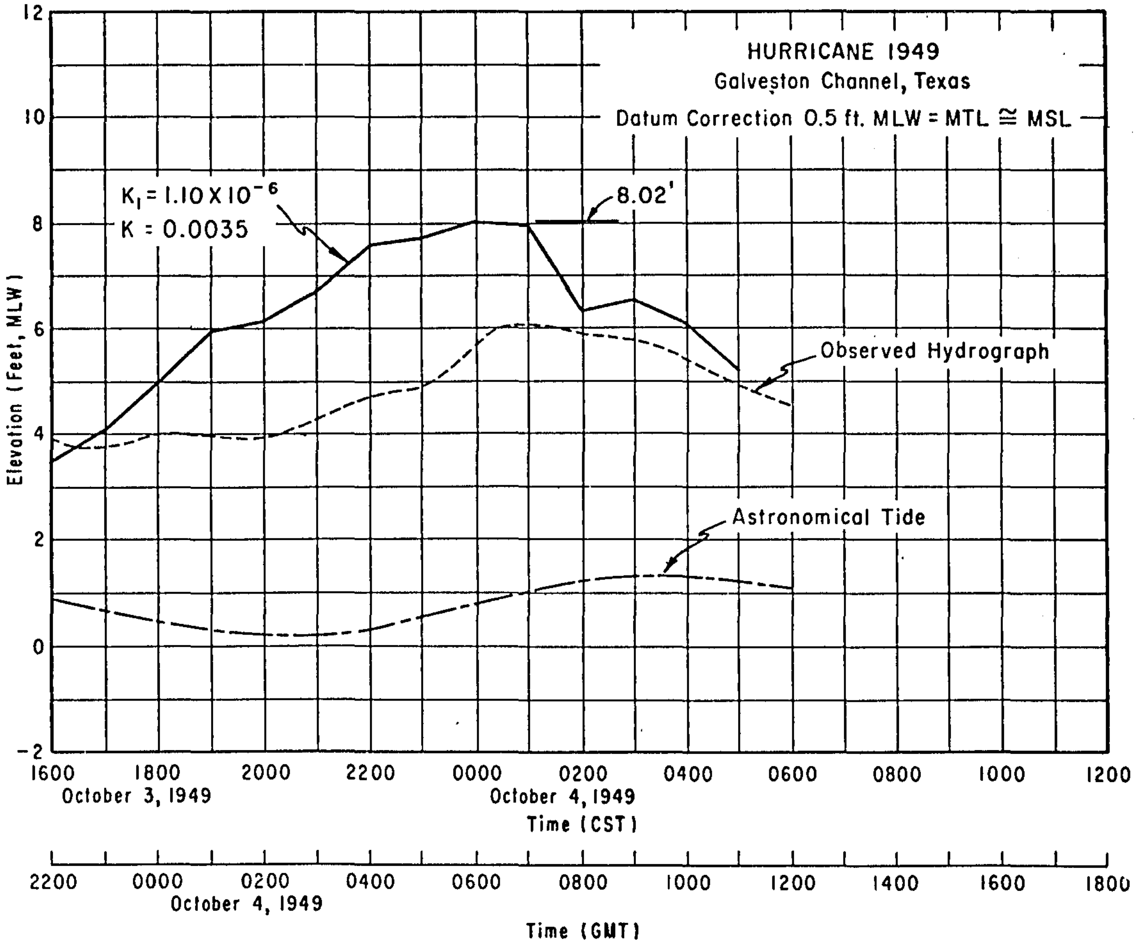


Figure 46. Observed and computed surge hydrographs for the Hurricane of 1949 at Galveston, Texas, $K_1 = 1.10 \times 10^{-6}$, $K_2 = 2.50 \times 10^{-6}$, K = 0.0035.

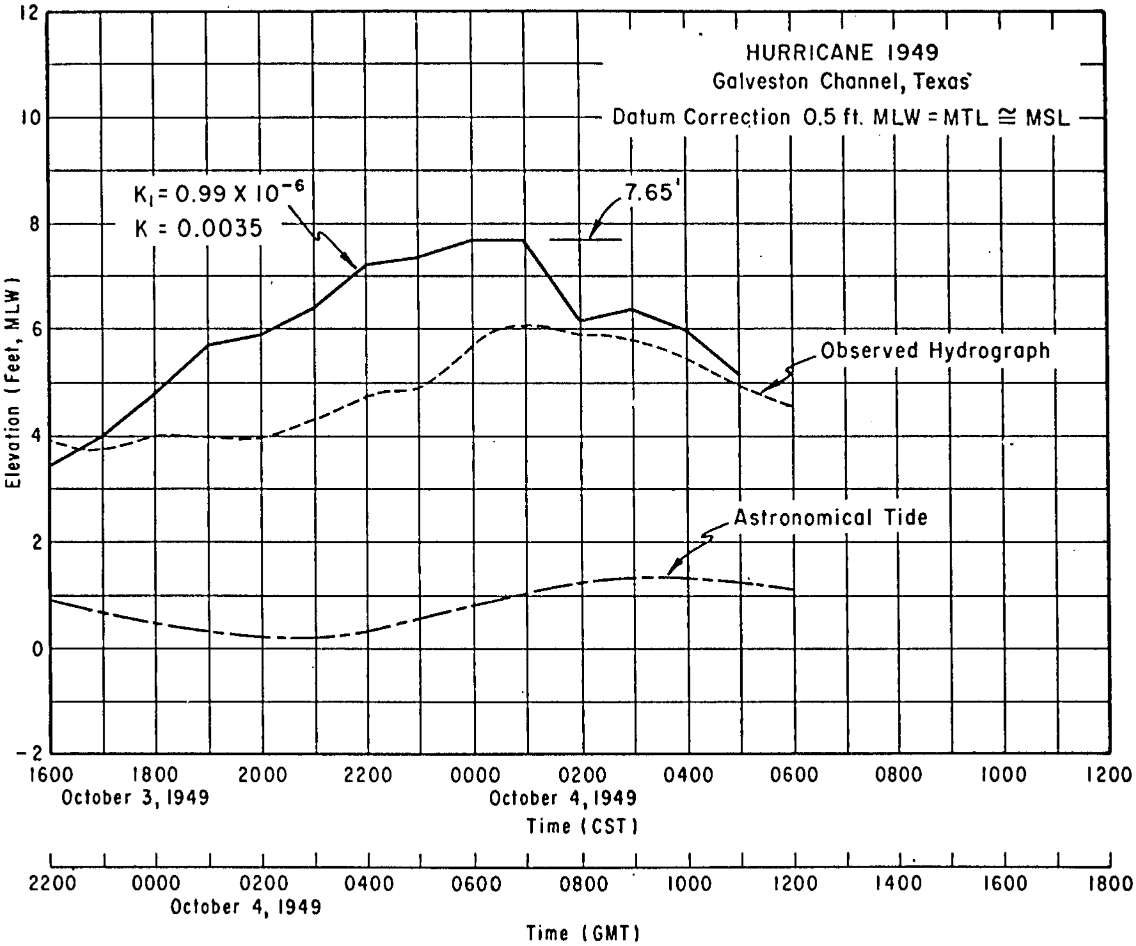


Figure 47. Observed and computed surge hydrographs for the Hurricane of 1949 at Galveston, Texas, $K_1 = 0.99 \times 10^{-6}$, $K_2 = 2.25 \times 10^{-6}$, $K = 0.0035$.

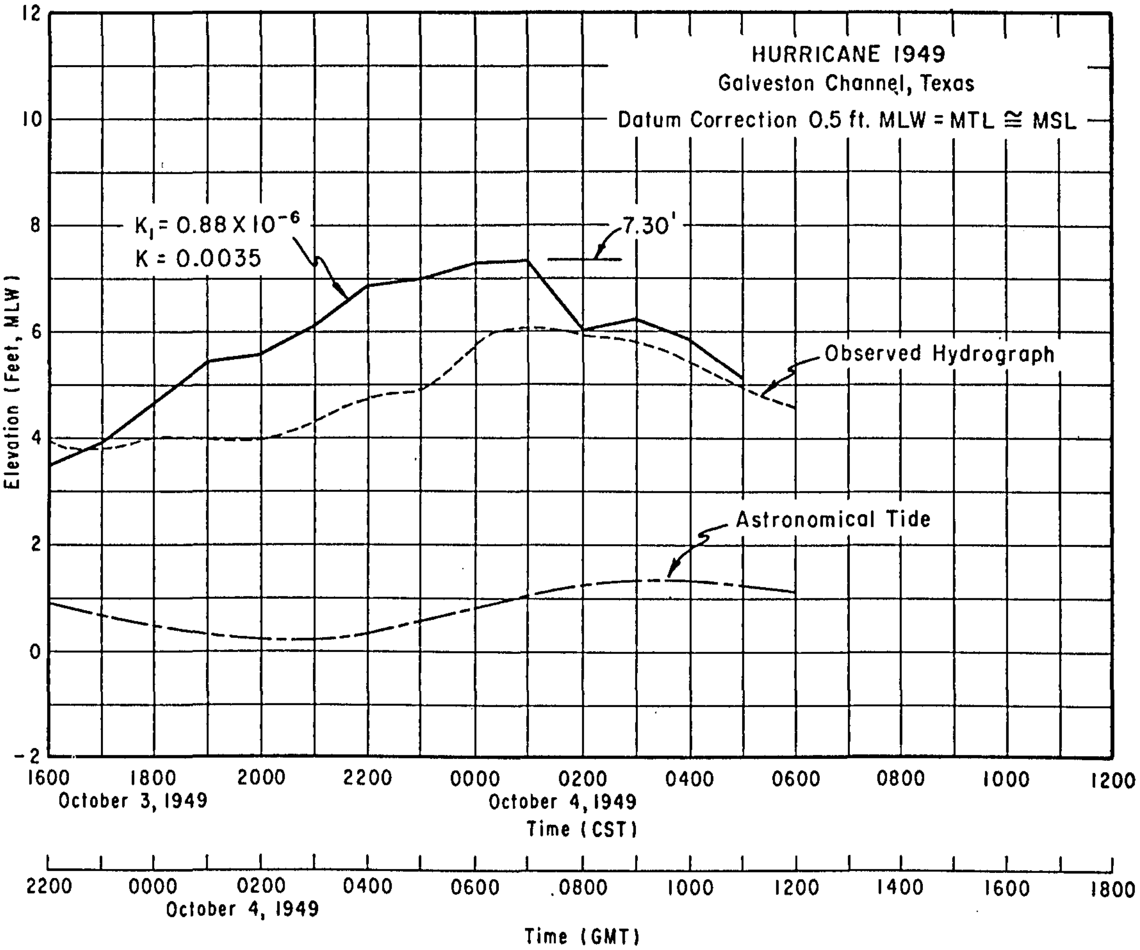


Figure 48. Observed and computed surge hydrographs for the Hurricane of 1949 at Galveston, Texas, $K_1 = 0.88 \times 10^{-6}$, $K_2 = 2.00 \times 10^{-6}$, $K = 0.0035$.

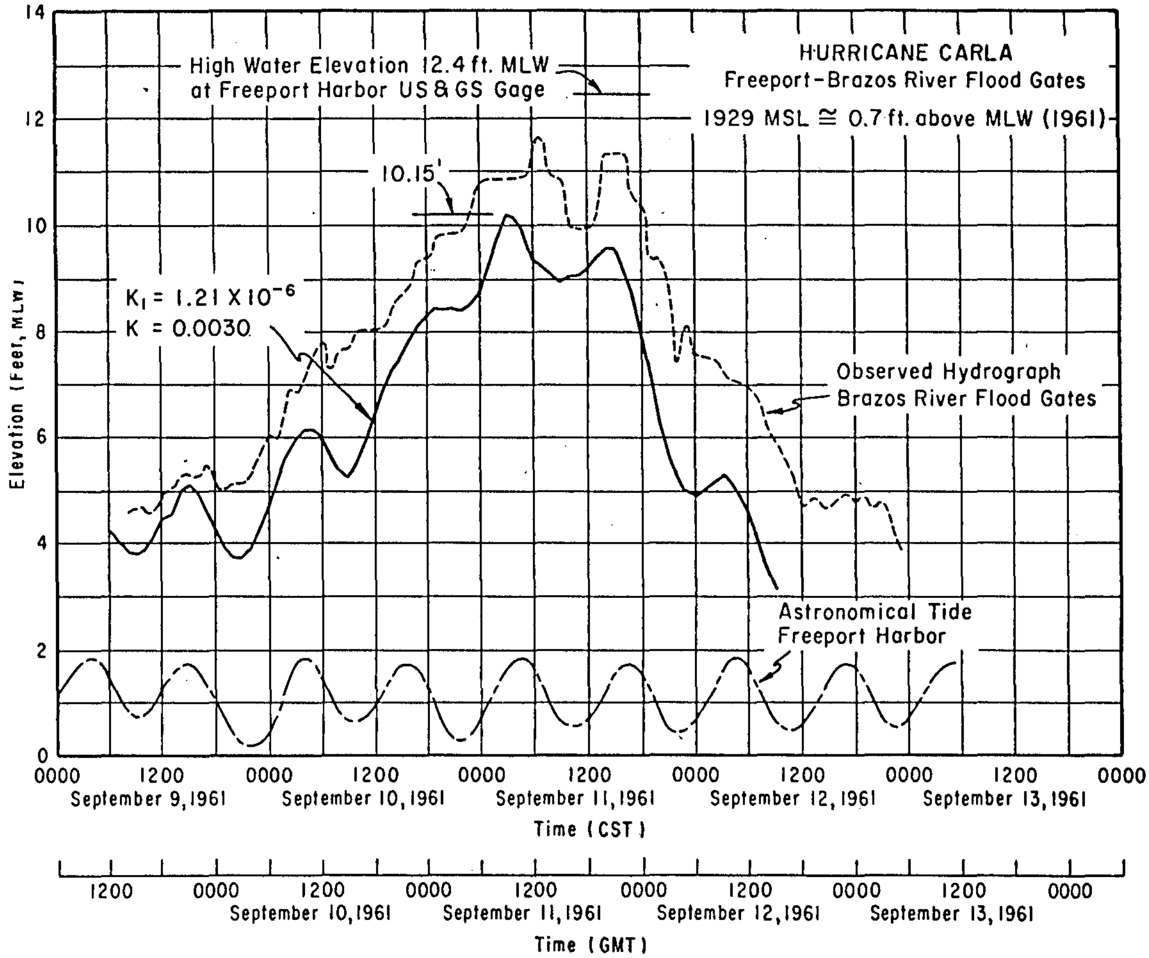


Figure 49. Observed and computed surge hydrographs for Hurricane Carla at Freeport, Texas, $K_1 = 1.21 \times 10^{-6}$, $K_2 = 2.75 \times 10^{-6}$, $K = 0.0030$.

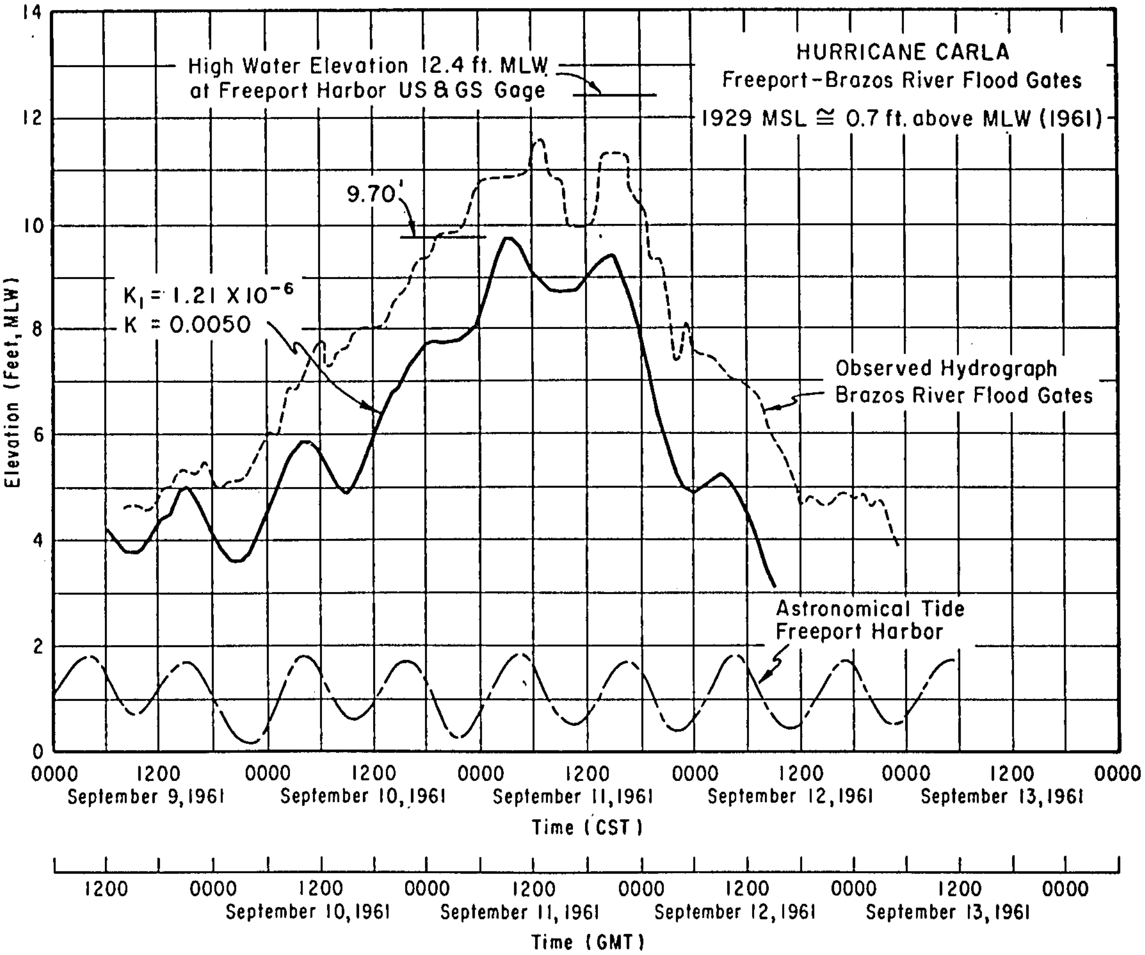


Figure 50. Observed and computed surge hydrographs for Hurricane Carla at Freeport, Texas, $K_1 = 1.21 \times 10^{-6}$, $K_2 = 2.75 \times 10^{-6}$, $K = 0.0050$.

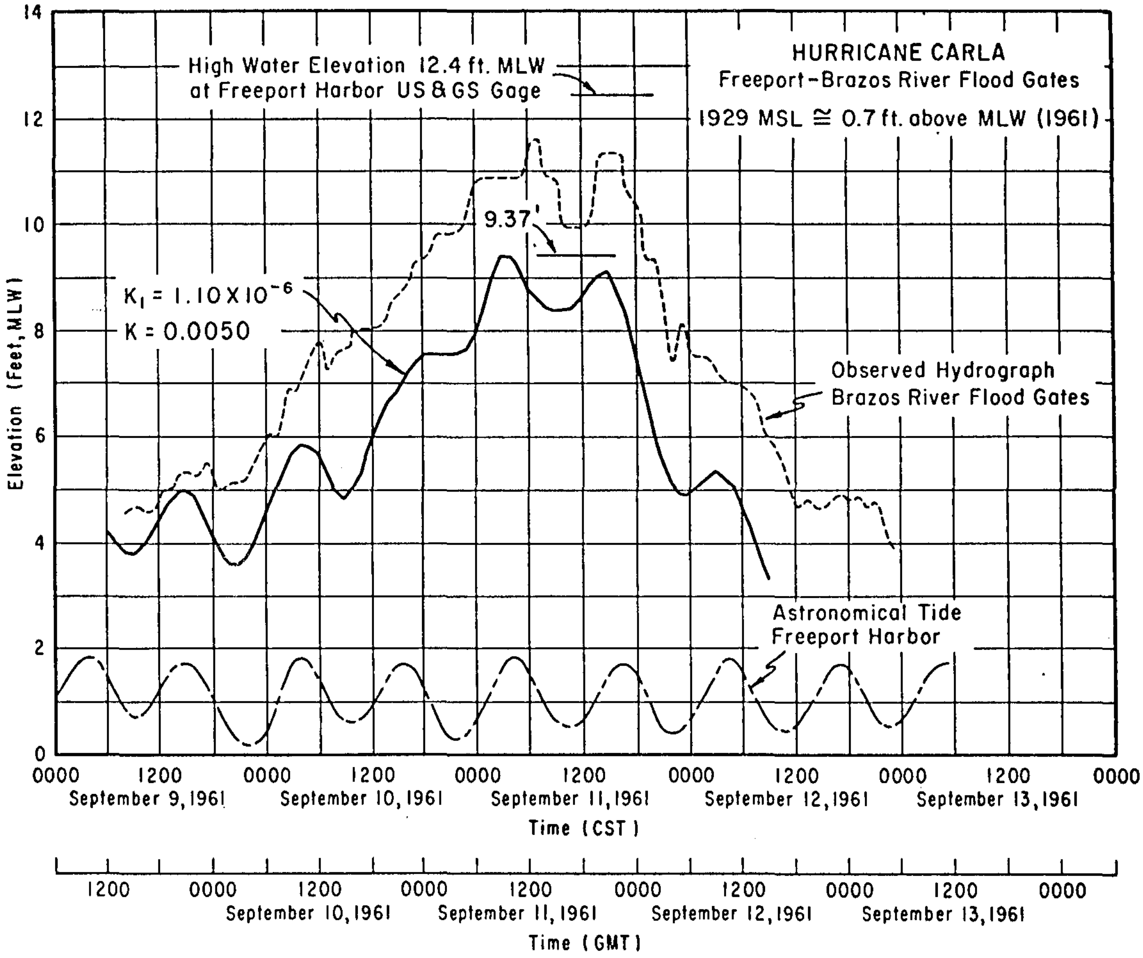


Figure 51. Observed and computed surge hydrographs for Hurricane Carla at Freeport, Texas, $K_1 = 1.10 \times 10^{-6}$, $K_2 = 2.50 \times 10^{-6}$, $K = 0.0050$.

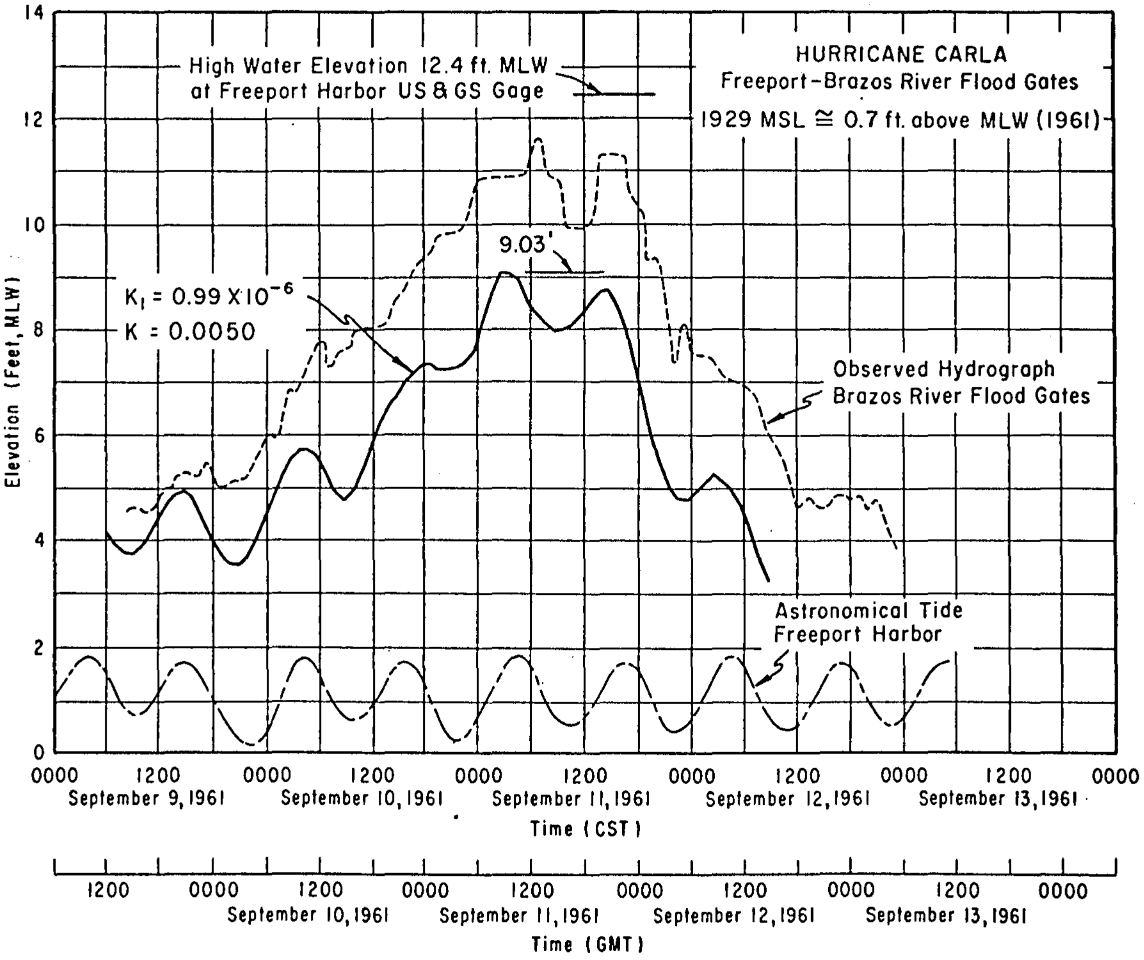


Figure 52. Observed and computed surge hydrographs for Hurricane Carla at Freeport, Texas, $K_1 = 0.99 \times 10^{-6}$, $K_2 = 2.25 \times 10^{-6}$, $K = 0.0050$.

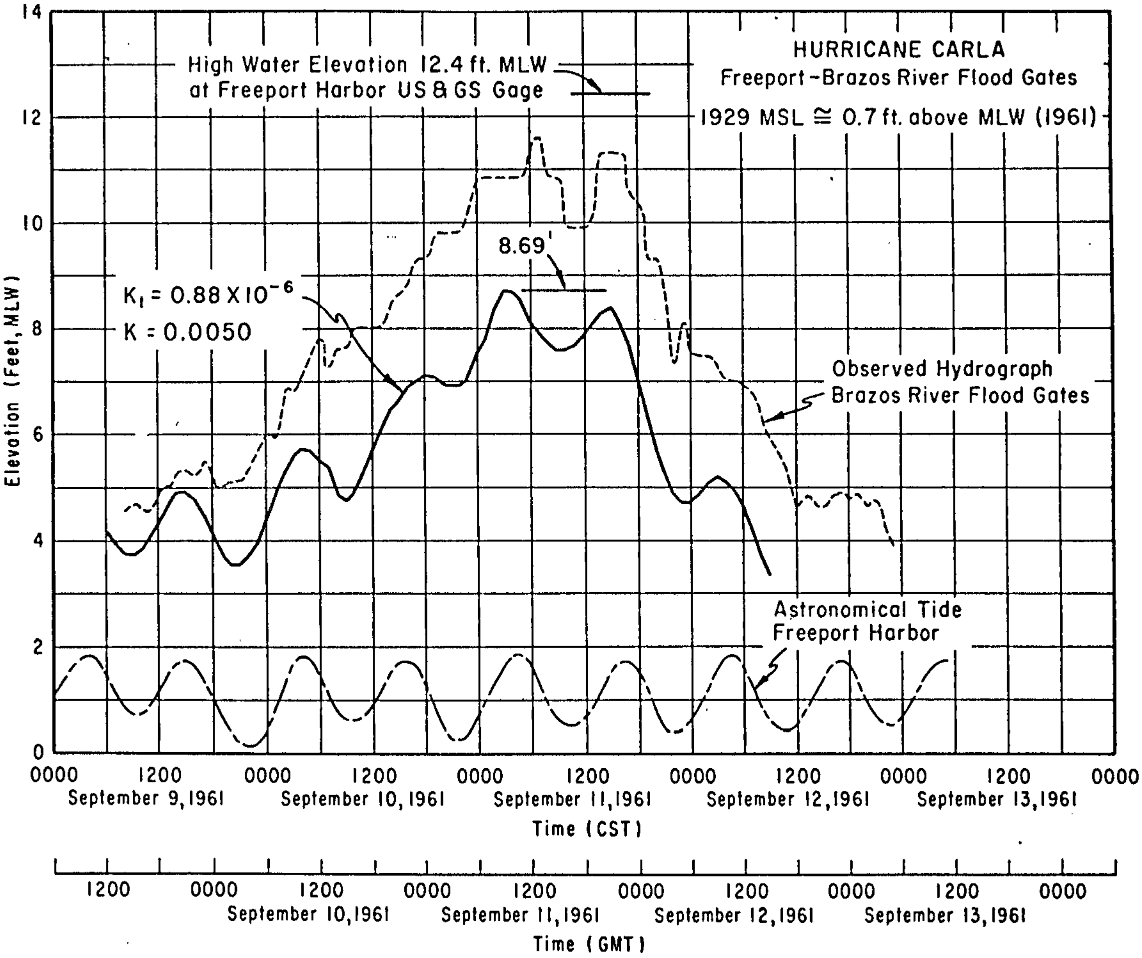


Figure 53. Observed and computed surge hydrographs for Hurricane Carla at Freeport, Texas, $K_1 = 0.88 \times 10^{-6}$, $K_2 = 2.00 \times 10^{-6}$, $K = 0.0050$.

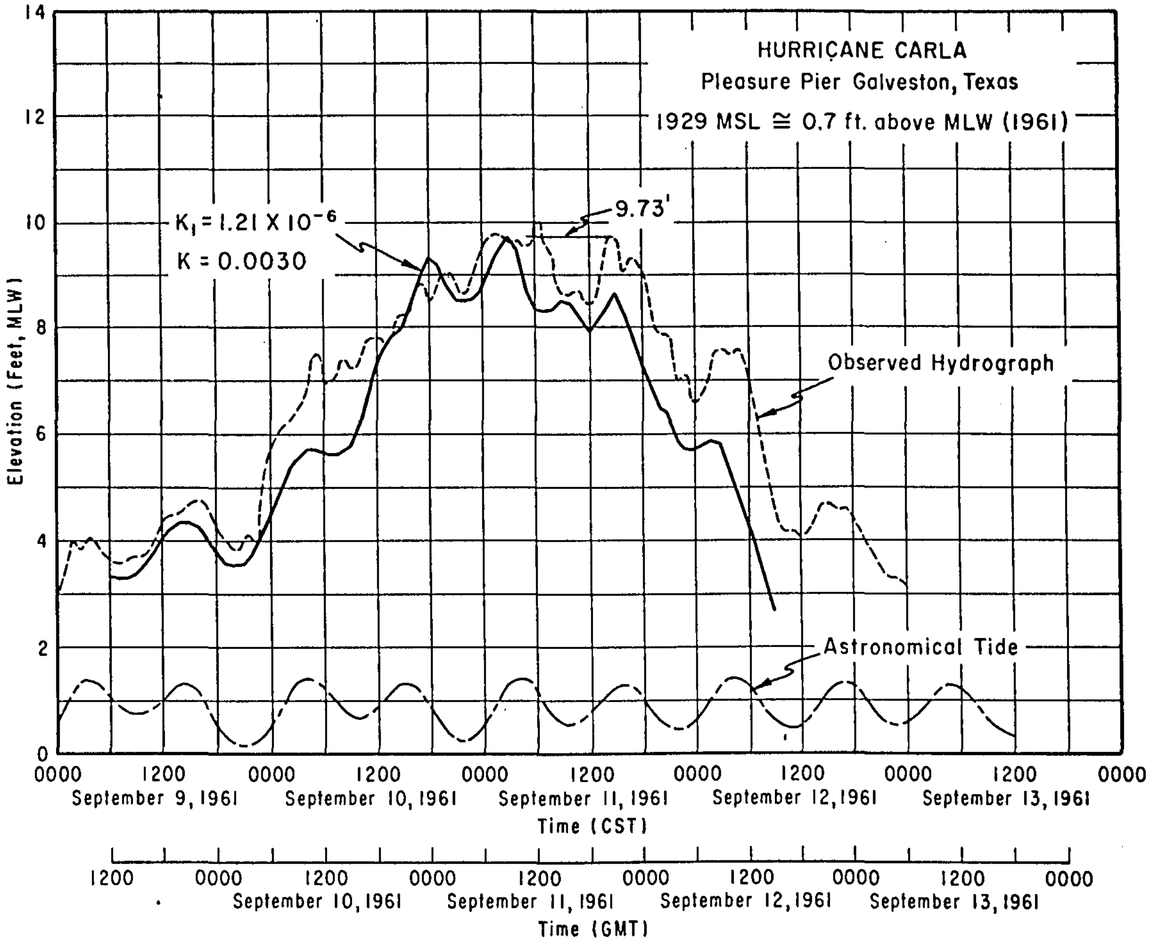


Figure 54. Observed and computed surge hydrographs for Hurricane Carla at Galveston, Texas, $K_1 = 1.21 \times 10^{-6}$, $K_2 = 2.75 \times 10^{-6}$, $K = 0.0030$.

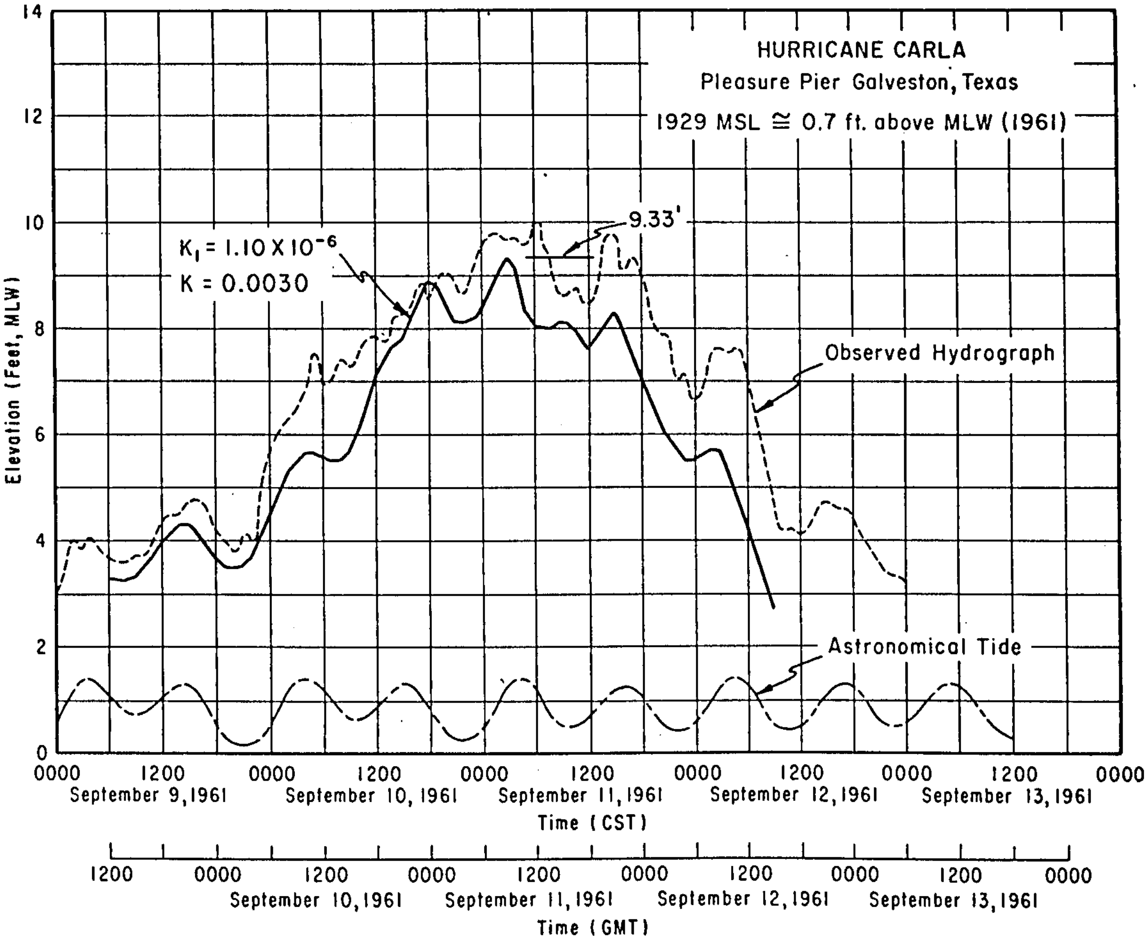


Figure 55. Observed and computed surge hydrographs for Hurricane Carla at Galveston, Texas, $K_1 = 1.10 \times 10^{-6}$, $K_2 = 2.50 \times 10^{-6}$, $K = 0.0030$.

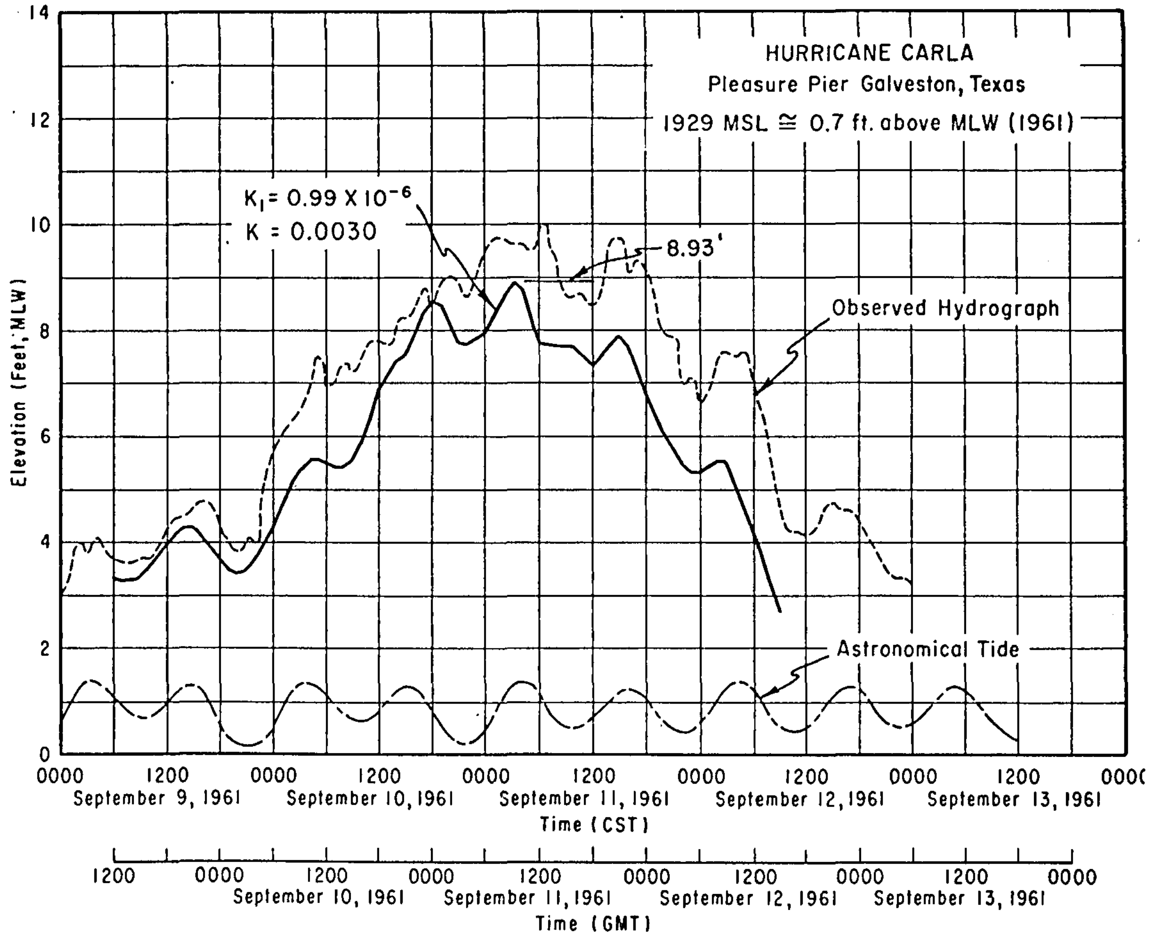


Figure 56. Observed and computed surge hydrographs for Hurricane Carla at Galveston, Texas, $K_1 = 0.99 \times 10^{-6}$, $K_2 = 2.25 \times 10^{-6}$, $K = 0.0030$.

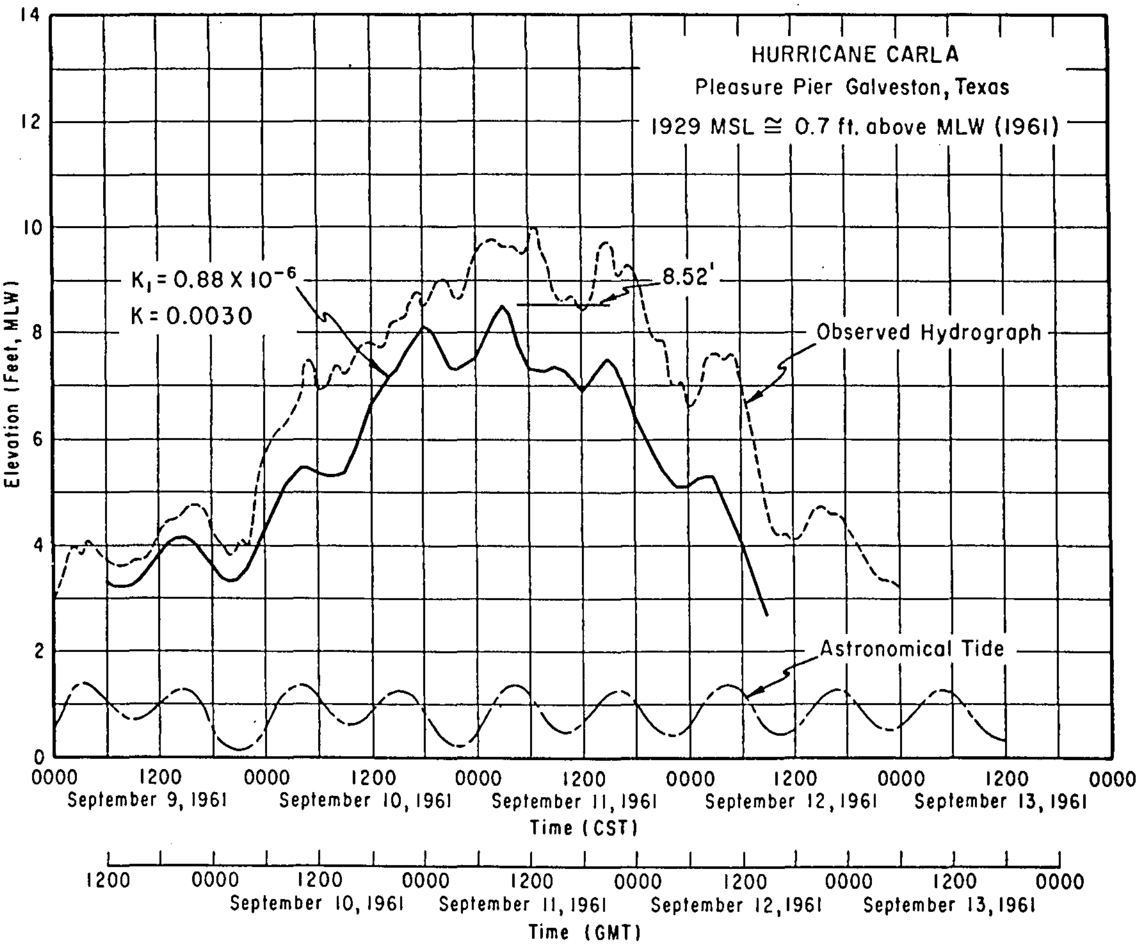


Figure 57. Observed and computed surge hydrographs for Hurricane Carla at Galveston, Texas, $K_1 = 0.88 \times 10^{-6}$, $K_2 = 2.00 \times 10^{-6}$, $K = 0.0030$.

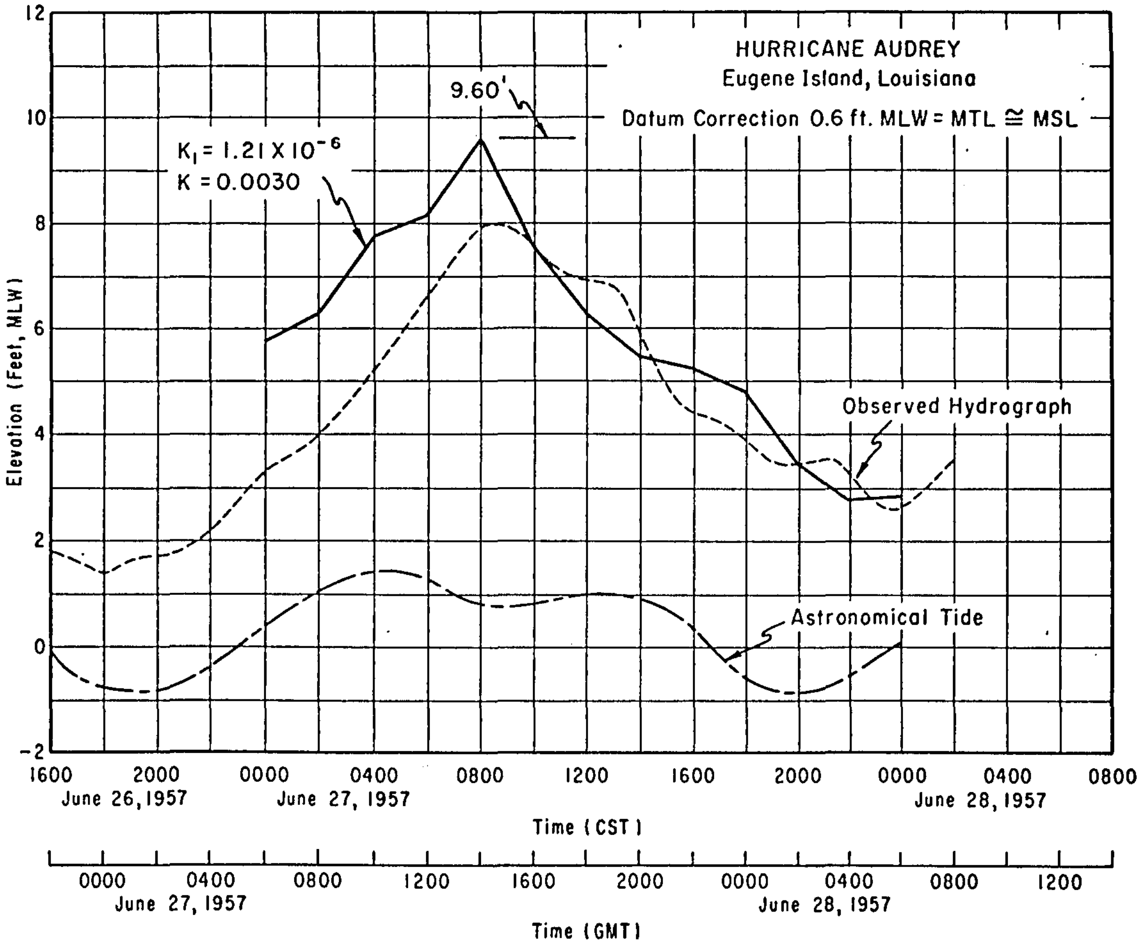


Figure 58. Observed and computed surge hydrographs for Hurricane Audrey at Eugene Island, Louisiana, $K_1 = 1.21 \times 10^{-6}$, $K_2 = 2.75 \times 10^{-6}$, $K = 0.0030$.

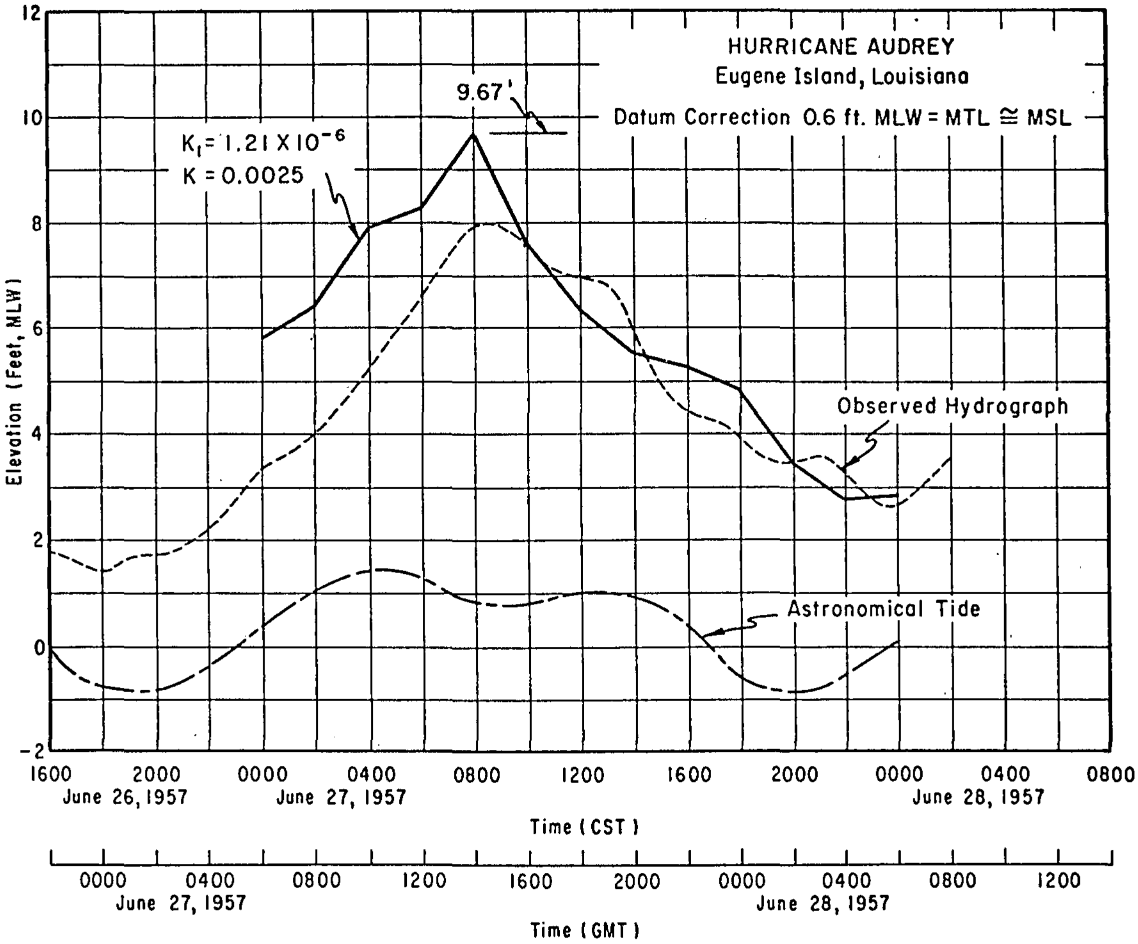


Figure 59. Observed and computed surge hydrographs for Hurricane Audrey at Eugene Island, Louisiana, $K_1 = 1.21 \times 10^{-6}$, $K_2 = 2.75 \times 10^{-6}$, $K = 0.0025$.

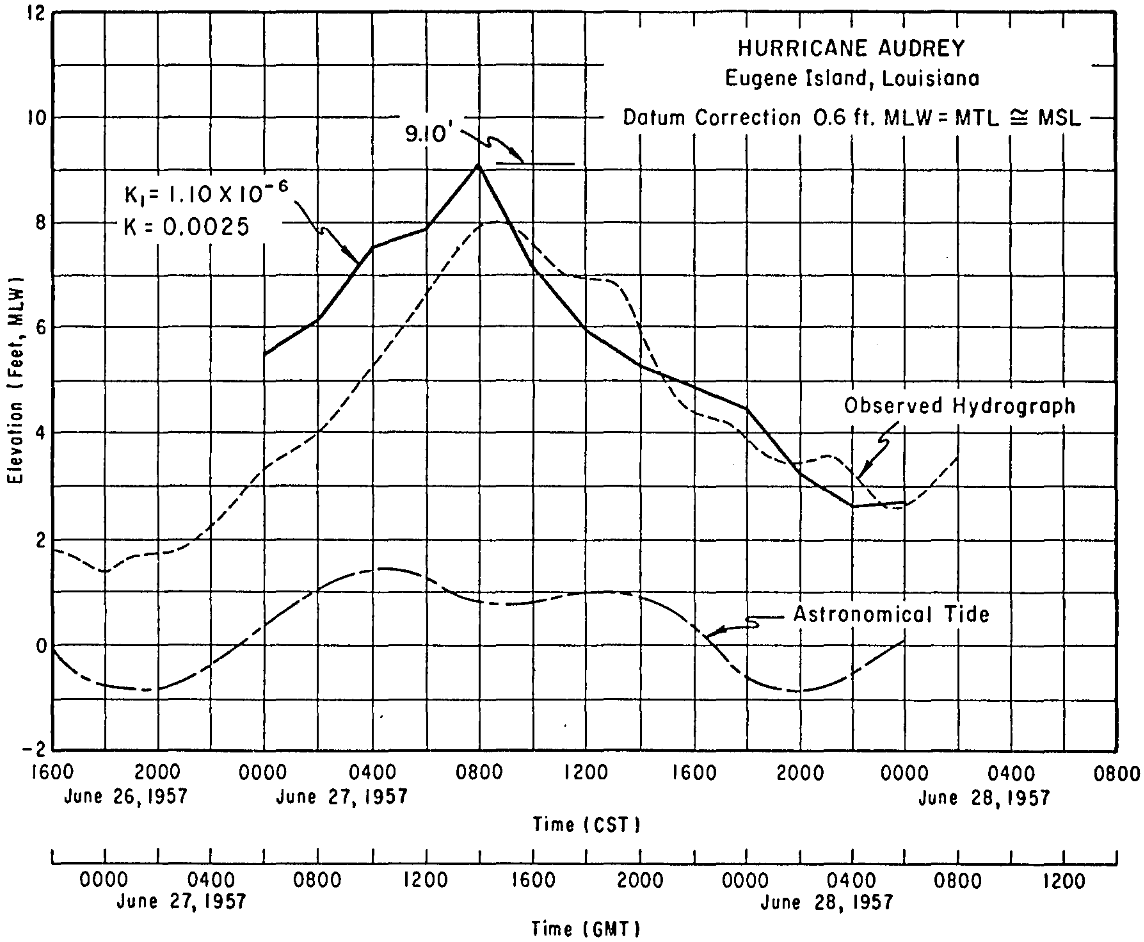


Figure 60. Observed and computed surge hydrographs for Hurricane Audrey at Eugene Island, Louisiana, $K_1 = 1.10 \times 10^{-6}$, $K_2 = 2.50 \times 10^{-6}$, $K = 0.0025$.

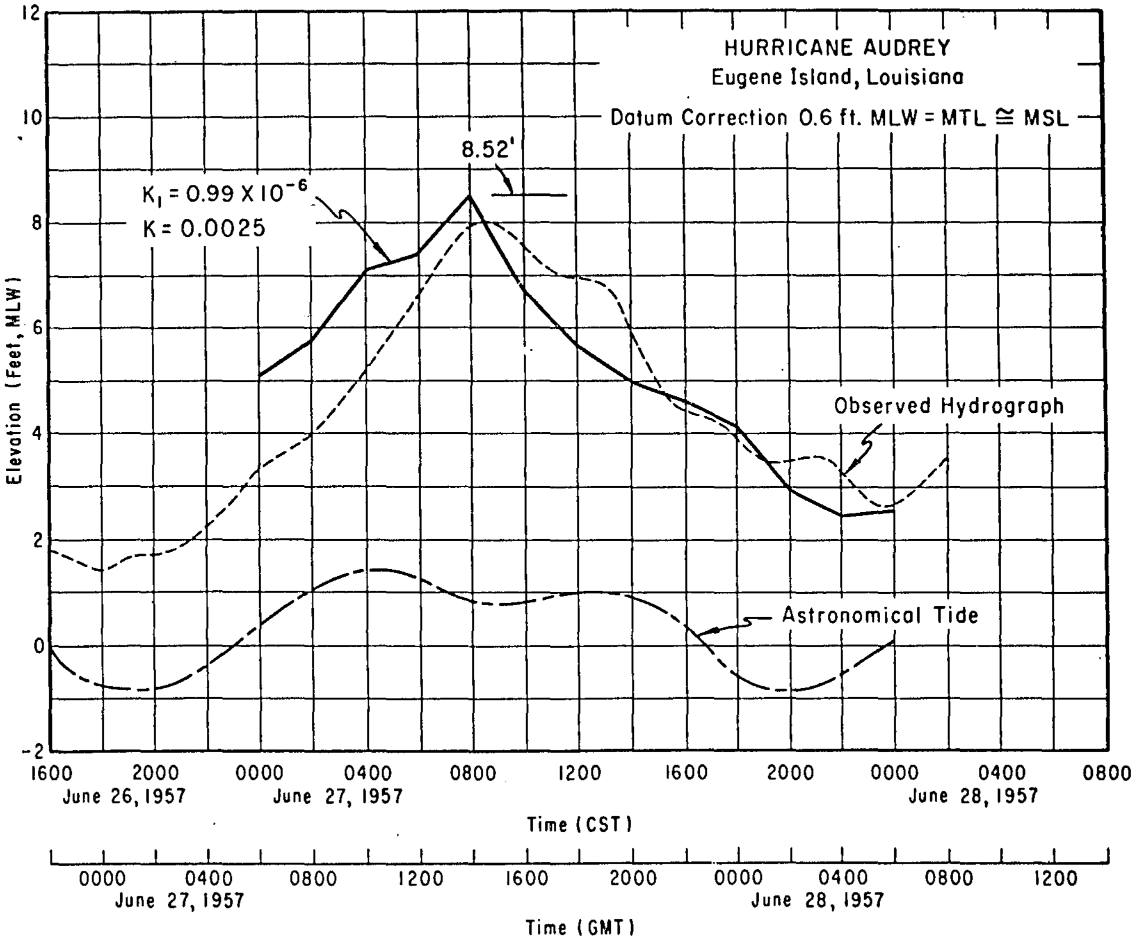


Figure 61. Observed and computed surge hydrographs for Hurricane Audrey at Eugene Island, Louisiana, $K_1 = 0.99 \times 10^{-6}$, $K_2 = 2.25 \times 10^{-6}$, K = 0.0025.

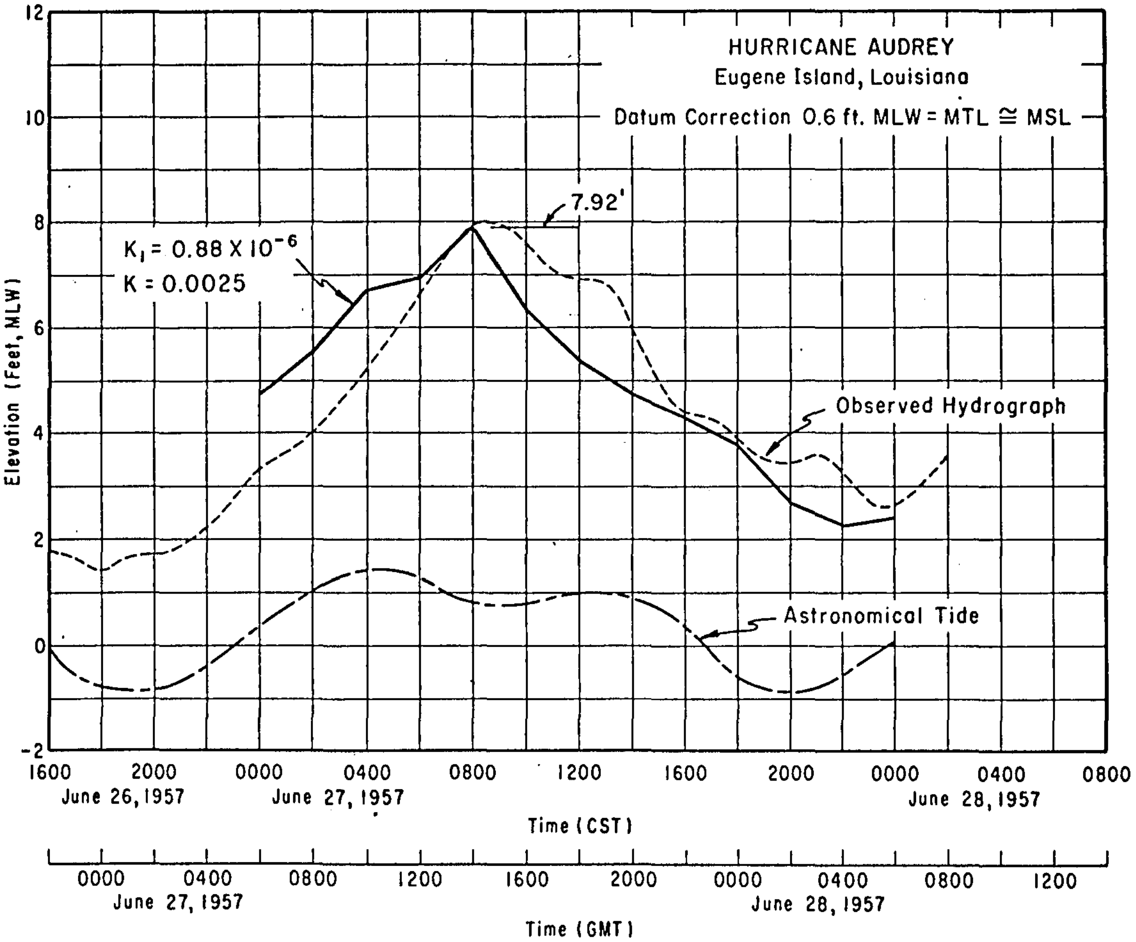


Figure 62. Observed and computed surge hydrographs for Hurricane Audrey at Eugene Island, Louisiana, $K_1 = 0.88 \times 10^{-6}$, $K_2 = 2.00 \times 10^{-6}$ $K = 0.0025$.

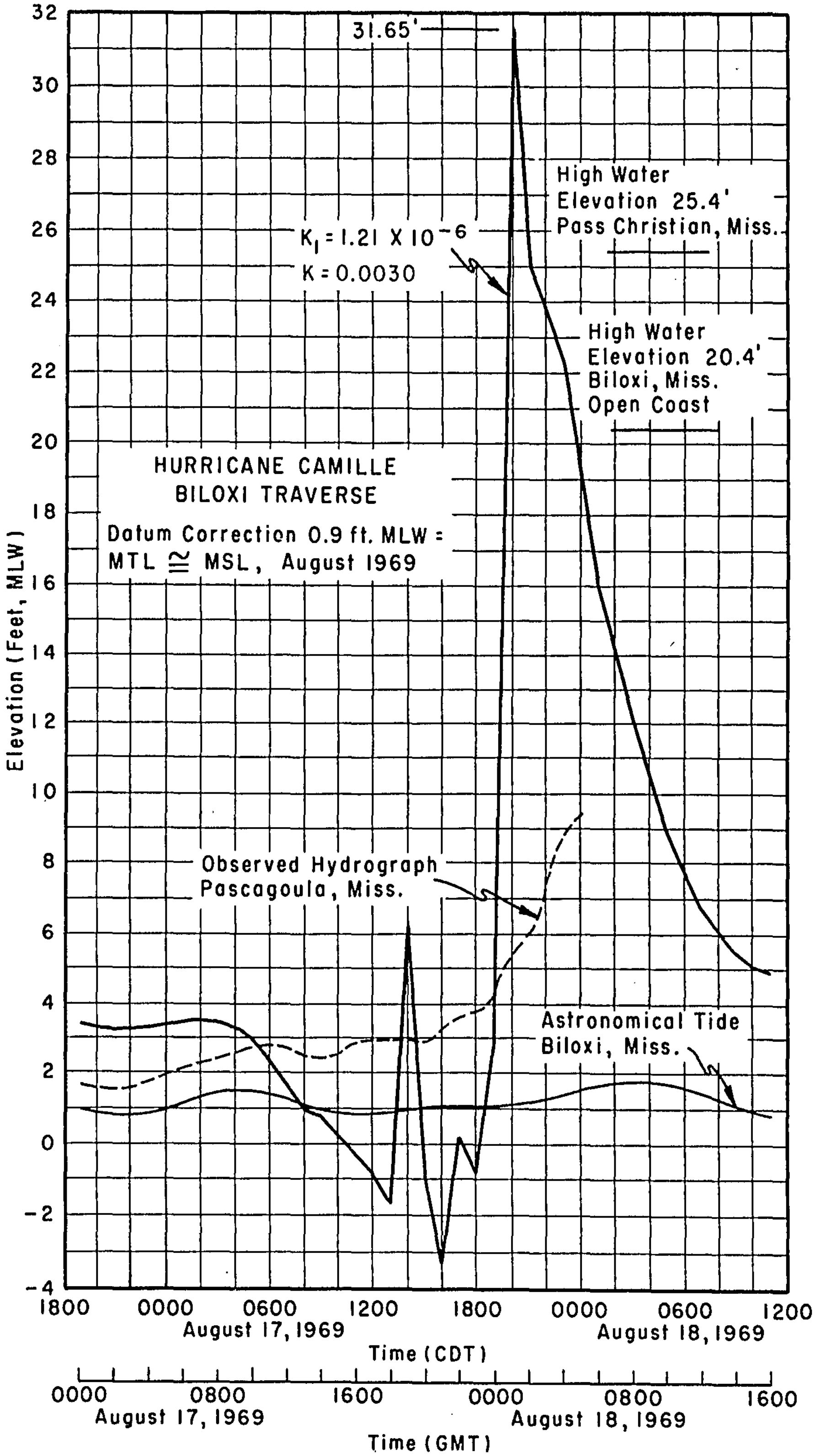


Figure 63. Observed and computed surge hydrographs for Hurricane Camille at Biloxi, Mississippi, $K_1 = 1.21 \times 10^{-6}$, $K_2 = 2.75 \times 10^{-6}$, $K = 0.0030$.

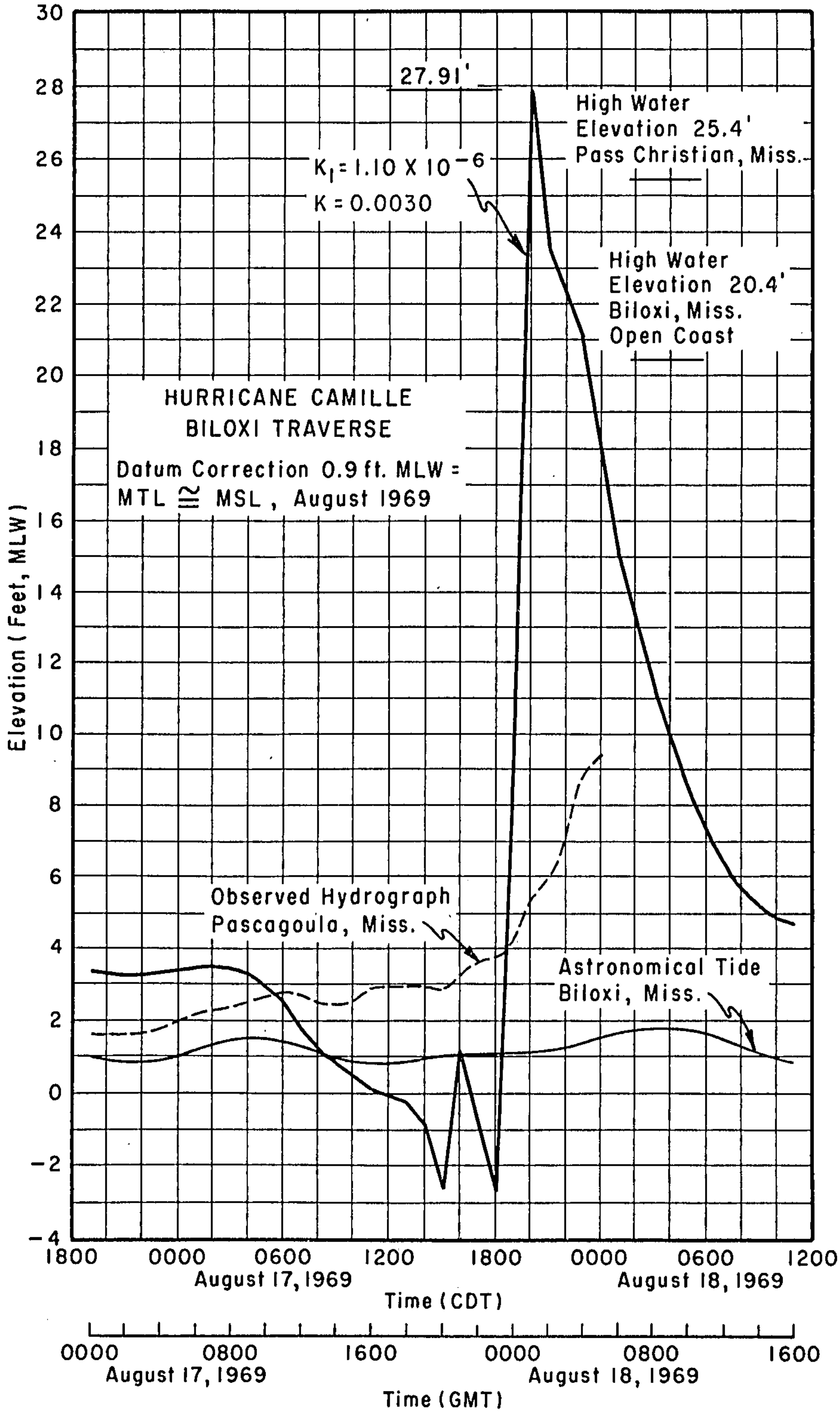


Figure 64. Observed and computed surge hydrographs for Hurricane Camille at Biloxi, Mississippi, $K_1 = 1.10 \times 10^{-6}$, $K_2 = 2.50 \times 10^{-6}$, $K = 0.0030$.

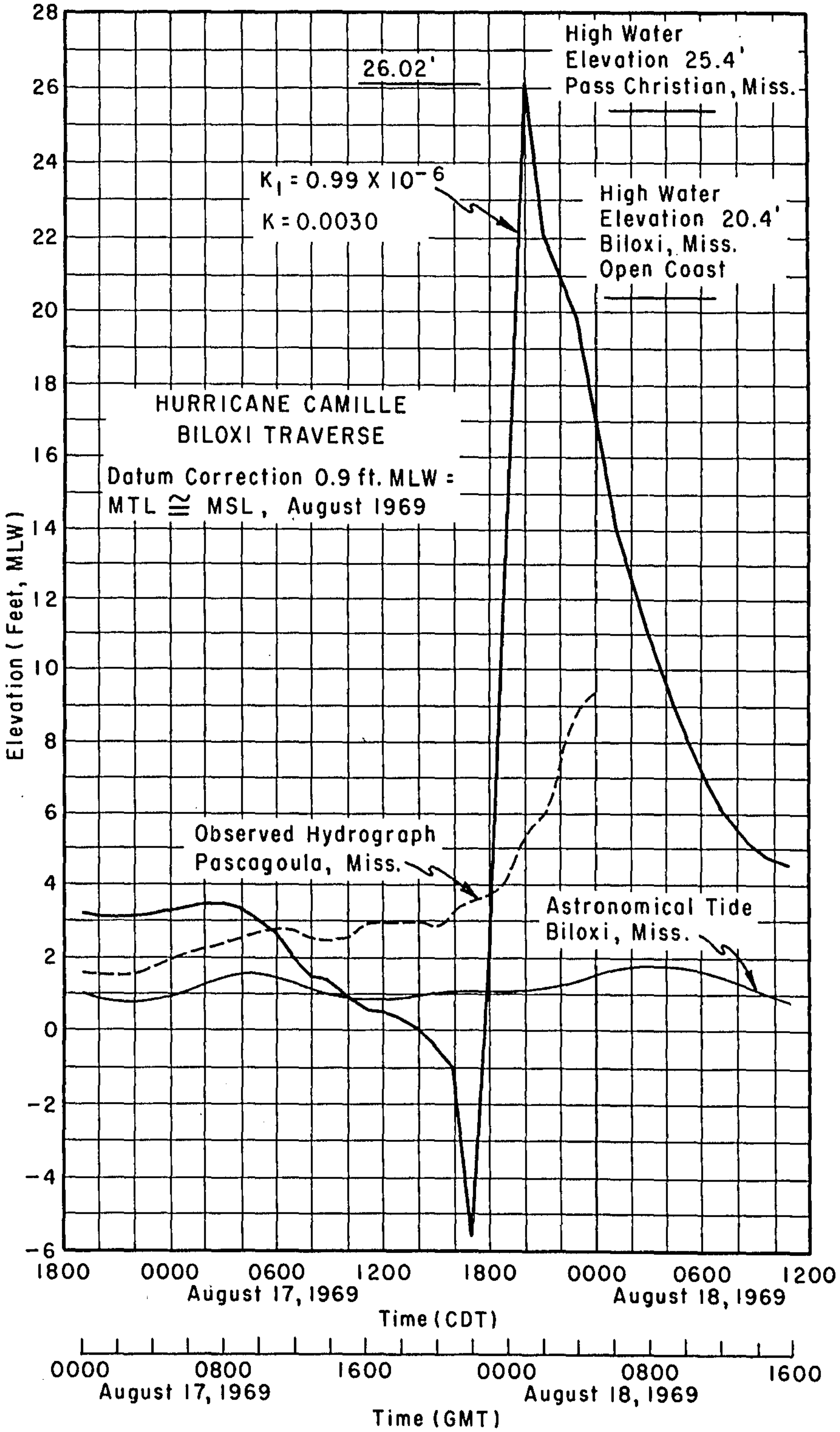


Figure 65. Observed and computed surge hydrographs for Hurricane Camille at Biloxi, Mississippi, $K_1 = 0.99 \times 10^{-6}$, $K_2 = 2.25 \times 10^{-6}$, $K = 0.0030$.

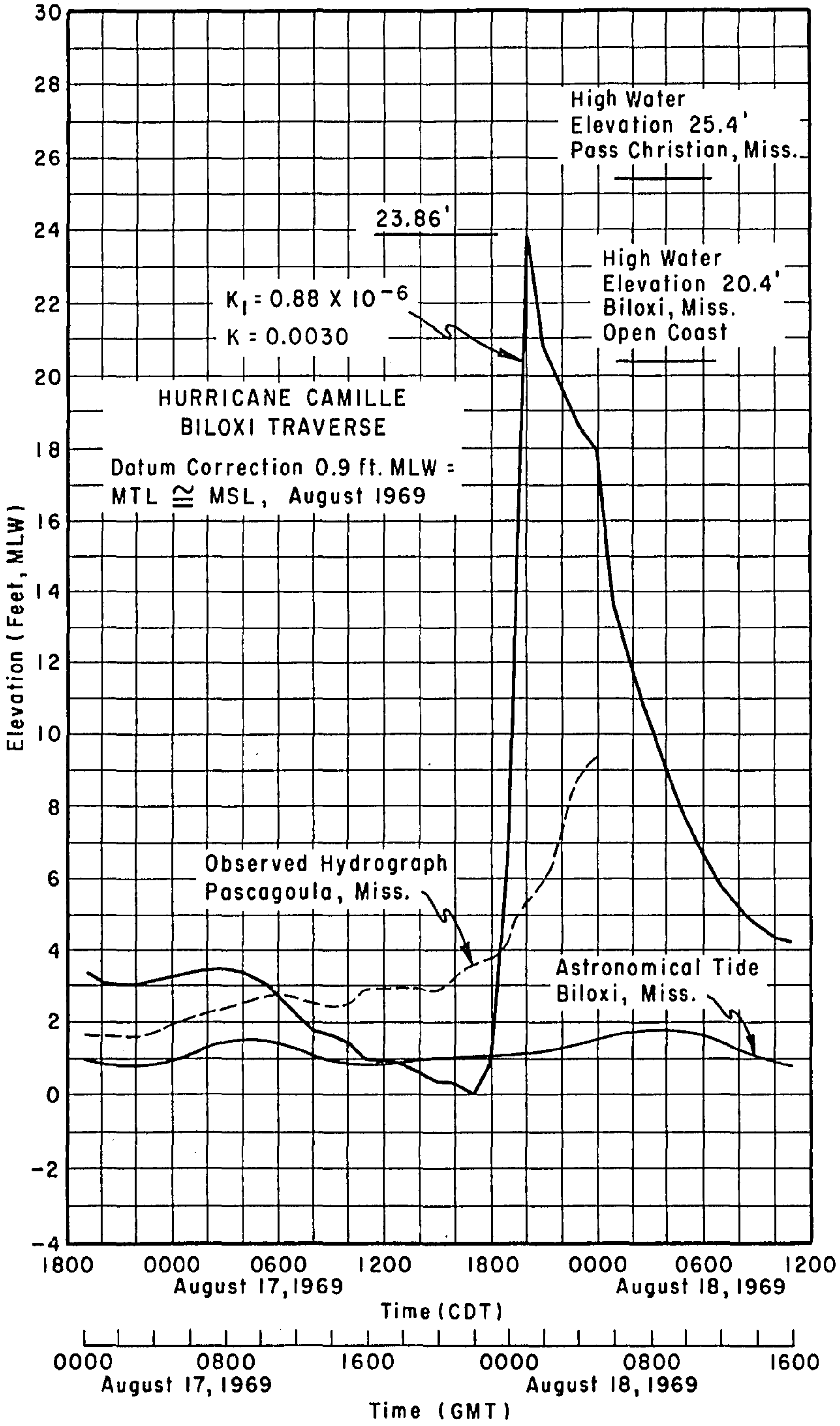


Figure 66. Observed and computed surge hydrographs for Hurricane Camille at Biloxi, Mississippi, $K_1 = 0.88 \times 10^{-6}$, $K_2 = 2.00 \times 10^{-6}$, K = 0.0030.

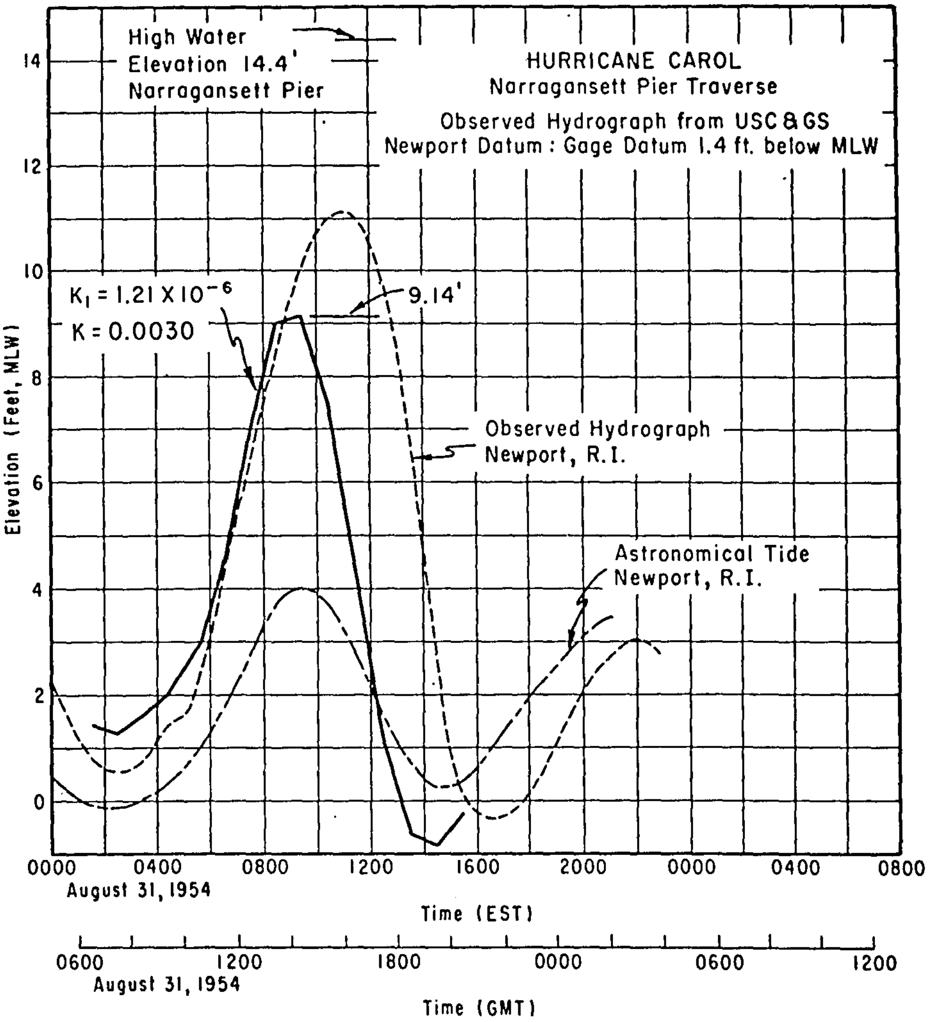


Figure 67. Reconstructed and computed surge hydrographs for Hurricane Carol at Narragansett Pier, Rhode Island, $K_1 = 1.21 \times 10^{-6}$, $K_2 = 2.75 \times 10^{-6}$, $K = 0.0030$.

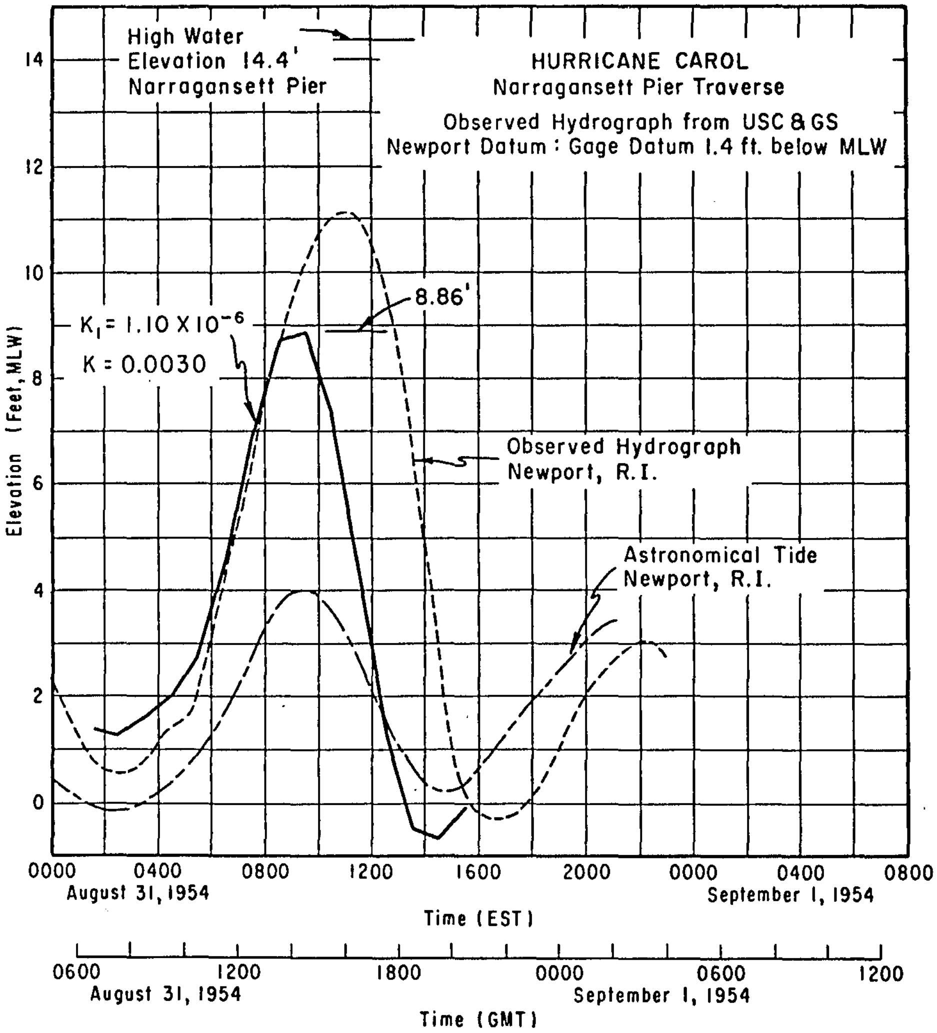


Figure 68. Reconstructed and computed surge hydrographs for Hurricane Carol at Narragansett Pier, Rhode Island, $K_1 = 1.10 \times 10^{-6}$, $K_2 = 2.50 \times 10^{-6}$, $K = 0.0030$.

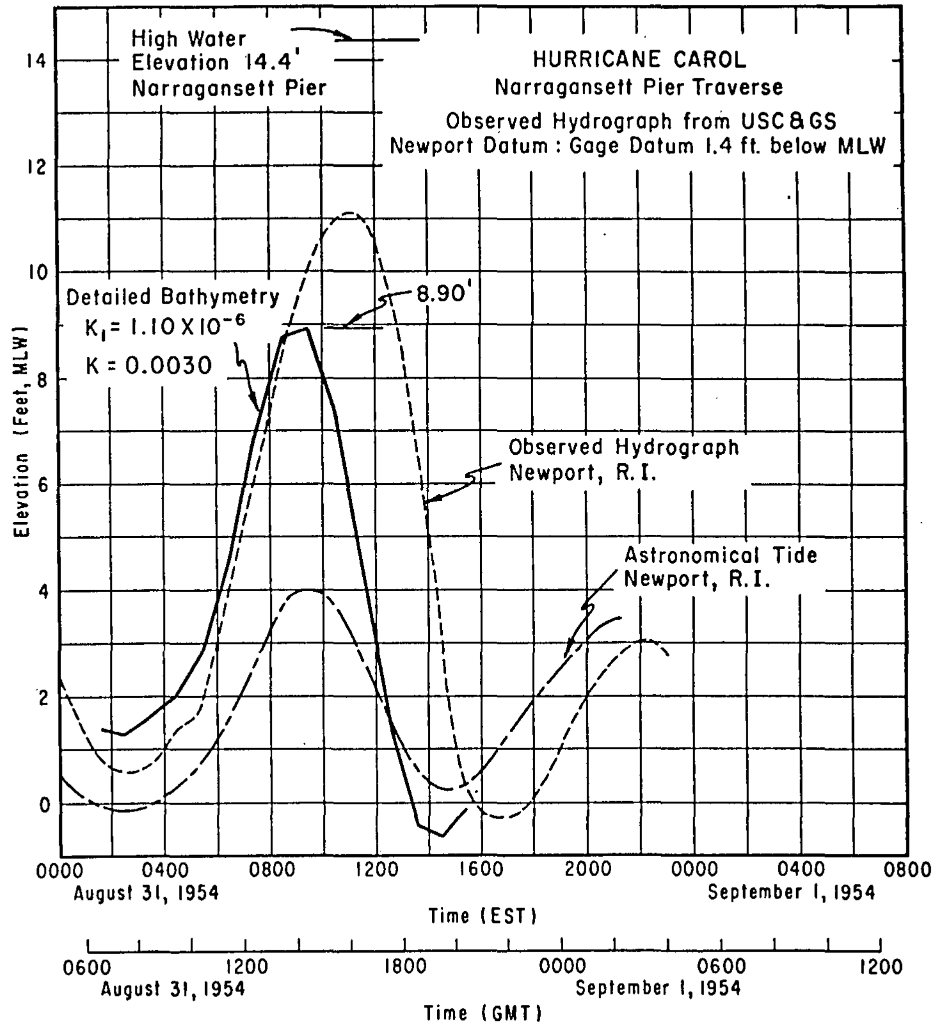


Figure 69. Reconstructed and computed surge hydrographs for Hurricane Carol at Narragansett Pier, Rhode Island, $K_1 = 1.10 \times 10^{-6}$, $K_2 = 2.50 \times 10^{-6}$, $K = 0.0030$.

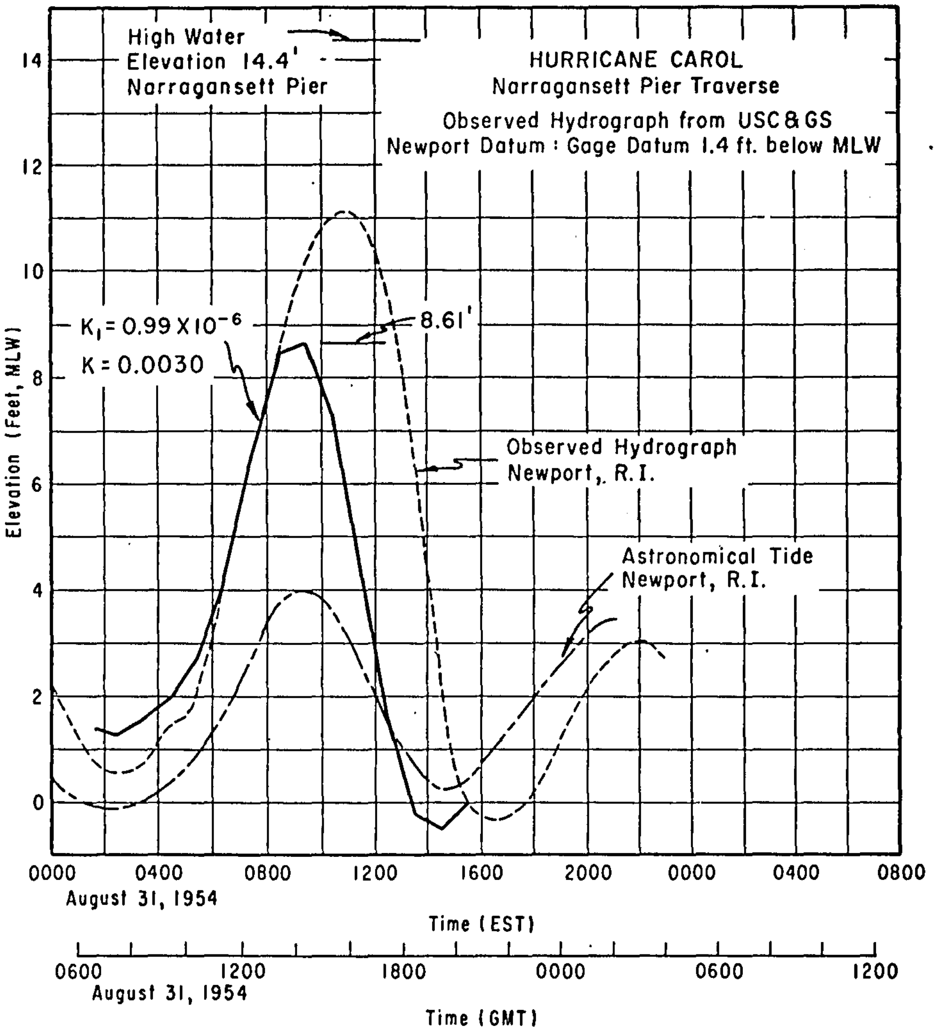


Figure 70. Reconstructed and computed surge hydrographs for Hurricane Carol at Narragansett Pier, Rhode Island, $K_1 = 0.99 \times 10^{-6}$, $K_2 = 2.25 \times 10^{-6}$, $K = 0.0030$.

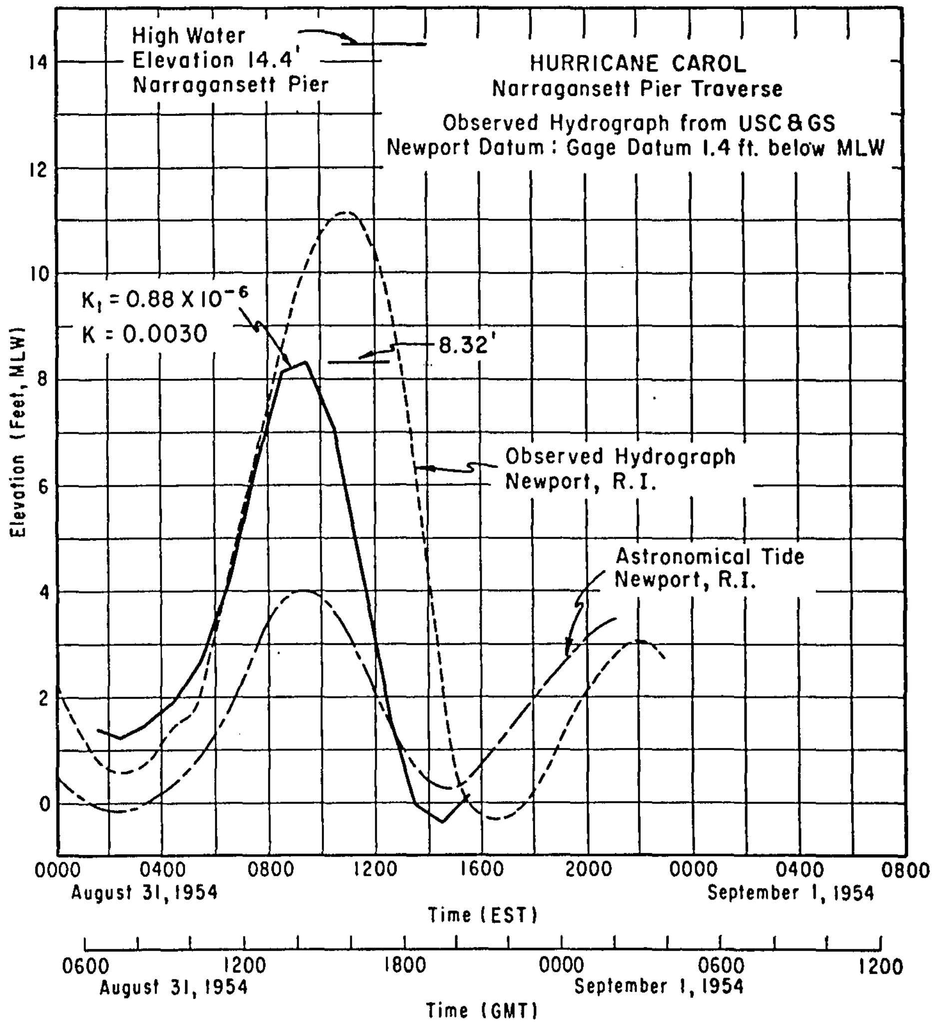


Figure 71. Reconstructed and computed surge hydrographs for Hurricane Carol at Narragansett Pier, Rhode Island, $K_1 = 0.88 \times 10^{-6}$, $K_2 = 2.00 \times 10^{-6}$, $K = 0.0030$.

c. Initial Rise. Other hydrographic data of major importance in the calculation of storm surge with a numerical model involves the initial rise in water level preceding the arrival of a hurricane. At such times, water levels along the coast have been observed to be different than the predicted astronomical tide. This difference in water levels between observed and predicted tides appears to be in many cases, independent of the storm or the astronomical forces. The significance of initial rise was discussed in Section I. Examination of prestorm tide gage records (from which initial rise is obtained) indicates that a considerable range of values may be selected. Harris (1963) has shown that such water level deviations can be as much as 2 feet.

The initial rise used as input to the numerical calculation of storm surge is usually the average difference between predicted astronomical and observed tides at a tide gage station at or closest to the shore-intercept (open coast) of the traverse before the influencing effects of hurricane winds and pressures. In the numerical calculations, this value should be treated as a constant and added to the total water level. This may be an oversimplification, since the cause for such rise or its exact magnitude during the passage of the storm is not known with certainty. For the purpose of calibration, initial rise was defined in Section I as "the average water level variation above the predicted astronomical tide at a station during the 2 days preceding the occurrence of a 15 to 20 miles per hour isovel of a hurricane advancing across the Continental Shelf." Based on this definition, the initial rise in water levels used in the calculation of surges at Galveston, Freeport, Eugene Island, Biloxi and Narragansett Pier for the selected hurricanes, were estimated using the predicted tides shown in Figures 39 through 71, taken from the tide tables and the observed or recorded hydrographs of water levels at the nearest tide gage stations. Because of these limitations, the initial rises in water levels used in this study may represent rough approximations.

3. Computational Traverses.

Computational traverses, used for surge calculation of each selected hurricane, were chosen on the basis of their proximity to hurricane tracks, to recording tide gages on relatively open coasts, and to points on the coast where maximum, well documented observations of historic surge water levels were available. The selected traverses were also situated, in each case, to the right of the hurricane tracks, to accommodate a limitation of the bathystrophic numerical model for surge computation (preferably at a distance of about 1 to 3 times the radius to maximum winds away from the path of the hurricane center, in order to intercept the maximum effect of the hurricane).

For the Hurricane of 3 October 1949 and Hurricane Carla, traverses were selected at Galveston and Freeport, Texas, for which tide gage records and good historical accounts of surges were available. A traverse for Hurricane Audrey was selected at Eugene Island, Louisiana, a relatively open-coast location which experienced maximum surges and where a semicomplete tide gage record and visual measurement of peak surge existed. For Hurricane Camille, a traverse at Biloxi, Mississippi was selected; this location was on the open coast where large surge water levels were observed and documented and was nearer the tide gage at Pascagoula, Mississippi, where some tidal information could be obtained. A better traverse may have been Pass Christian, Mississippi, where maximum surge for this hurricane occurred; however, it was not selected because of the unusual coastal configuration of the region and the presence of offshore islands.

A traverse was selected at Narragansett Pier, Rhode Island for Hurricane Carol, the only hurricane chosen on the open Atlantic coast which experienced maximum surge. Although the data for Narragansett Pier were based on a peak value which may have included some storm wave setup and runup, and the nearest tide gage along the coast was at Newport, Rhode Island, in a semisheltered area, this was the only location unobstructed by offshore islands and where the open-coast condition could best be met.

The traverses at Galveston, Freeport, Eugene Island, Biloxi and Narragansett Pier are given in Figures 37 and 38. The bathymetric profiles for all traverses and the coordinates of the shore-intercepts and orientation of the traverses used in the computations are summarized in Table 4. The bearings of the traverses were established by a perpendicular orientation to the bathymetric contours between the tide gage stations on the open coast (shore-intercept) or nearby points and the 600-foot depth contour on the Continental Shelf. The bathymetry for the profiles was taken from detailed nautical charts.

V. MODEL VERIFICATION

1. Calibration.

The ability of the numerical model to reproduce historical hurricane surges or to adequately calculate hypothetical hurricane surges depends primarily on proper selection of values of specific parameters such as wind stress and bottom friction. Selection of specific calibration coefficients and establishing their relationship to each other is important to verification of the model. Both wind and bottom friction (stress) coefficients can be calibrated for use in the hydrodynamic equations of the surge estimate. However, it should be emphasized that because hurricane surge is a complex phenomenon, the wind stress and bottom friction coefficients obtained through calibration actually represent model calibration coefficients which include more than the physical effects of wind stress and bottom friction. Therefore, these model coefficients are considered to be representative of all the remaining unknowns contributing to storm surge.

In reconstituting the historical surge data, difficulties were encountered with establishing values of initial rise which varied with location of each particular hurricane. Since it was difficult to calibrate for such an initial rise, an attempt was made to standardize the method of measurement and to assign a consistent value in each case, independent of wind stress and bottom friction. This was added to the final estimate of surge. A definition of initial rise and method of measurement is discussed in Sections I and IV. For the calibration, raw data describing historical hurricanes were corrected, reduced, digitized, and used with the model to calculate surge hydrographs and then compared to the observed or recorded surges of these hurricanes. Methods of data reduction were discussed in Section IV.

Table 4. Data Used for Calibration.

Texas				Mississippi		Rhode Island		Louisiana	
Freeport		Galveston		Biloxi		Narragansett Pier		Eugene Island	
Coordinates of Shore Intercept									
28°55.5′N 95°17.25′W		29°15.4′N 94°48.75′W		30°23′N 88°52′W		41°25.65′N 71°27.35′W		29°21′N 91°22.5′W	
Orientation of Traverse									
S 28°E		S 25°E		S 12°E		S 20°E		S 12.5°W	
DFS	DIF	DFS	DIF	DFS	DIF	DFS	DIF	DFS	DIF
0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
0.05	1	0.1	4	1.0	3	0.1	15	1.0	5
0.1	5	0.2	6	2.0	9	0.2	25	2.0	10
0.4	10	0.4	12	3.0	9	0.3	30	3.0	12
0.5	20	0.5	16	5.0	12	0.4	40	5.0	15
1.0	30	1.0	18	10.0	13	0.5	45	10.0	15
2.0	32	2.0	29	15.0	35	0.6	47	15.0	18
3.0	37	3.0	34	20.0	36	0.7	49	20.0	20
4.0	40	4.0	40	30.0	40	0.8	55	30.0	50
5.0	47	5.0	45	40.0	52	0.9	57	40.0	60
10.0	66	10.0	57	50.0	90	1.0	60	50.0	140
15.0	78	15.0	60	60.0	160	2.0	80	60.0	200
20.0	90	20.0	54	70.0	235	3.0	90	70.0	260
30.0	114	30.0	72	77.0	600	4.0	103	80.0	320
40.0	132	40.0	95	—	—	5.0	107	90.0	600
50.0	168	50.0	123	—	—	10.0	120	—	—
60.0	240	60.0	150	—	—	15.0	120	—	—
70.0	570	70.0	180	—	—	20.0	150	—	—
70.9	600	80.0	230	—	—	30.0	160	—	—
—	—	90.0	348	—	—	40.0	192	—	—
—	—	92.5	600	—	—	50.0	215	—	—
—	—	—	—	—	—	60.0	270	—	—
—	—	—	—	—	—	70.0	370	—	—
—	—	—	—	—	—	80.0	450	—	—
—	—	—	—	—	—	85.0	600	—	—

DFS = Distance From Shore (nautical miles)
DIF = Depth In Feet (mean low water)

Calibration was achieved by varying the values of the relative wind stress, k, and bottom friction, K, coefficients in the numerical equations used for surge computation. These coefficients are interdependent (coupled) in the basic equations (15) and (16) of the model, and were adjusted so that computed surges reproduced, as well as possible, the observed or recorded storm surges of historic hurricanes.

Emphasis was placed on calibrating the constants in Van Dorn's (1953) wind-stress relationship, which has the following forms in the numerical model:

$$k = K_1 + K_2 \left[1 - \left(\frac{W_c}{W}\right)^2\right] \text{ for } W \geqslant W_c , \qquad (12)$$

and

$$k = K_1 \text{ when } W \leqslant W_c , \qquad (13)$$

where,

k = wind-stress coefficient,

K_1 = the constant part of the wind-stress coefficient,

K_2 = the constant multiplier of the velocity-dependent part of the wind-stress coefficient,

W = windspeed in miles per hour,

W_c = critical windspeed taken about 16 miles per hour (14 knots).

In equations (12) and (13) the constants K_1 and K_2 account for pressure, density, precipitation, temperature and other factors of a hurricane system which are not easily measured. These factors effect the wind stress and the model as a whole and can only be obtained empirically.

In verifying the bathystrophic model, the wind-stress constants were varied until reasonable agreement of the peak values for the calculated and observed or recorded surge hydrographs were obtained at each traverse for each hurricane. Similarly, the value of the bottom friction coefficient was varied for each pair of constants in the wind-stress relationship to determine the effects of bottom friction on the overall surge computation. This procedure was continued until the entire range of values for K_1, K_2 and bottom friction, K, were analyzed, and an optimal condition of *best fit* was obtained between observed and computed surge hydrographs. *Best fit* can be best described as a condition of reasonable agreement between observed or recorded and computed surge hydrographs in shape, height, and time of peak surge values. Because of complexities in the shapes of both computed and observed or recorded surge hydrographs, no attempts were made to perform statistical correlation studies of the entire hydrographs. In each case, best fit was obtained when maximum computed surge reached a value slightly greater than the observed maximum surge value. To ensure that the maximum computed surge was reasonable and conservative, a 5-percent limit was placed on the difference with the peak observed surge.

The results of calibration with historical hurricanes are shown in Figures 39 through 71. In these figures, computed surge hydrographs of each hurricane at each traverse are shown for different values of wind-stress constants and bottom friction. Observed or recorded surge hydrographs and predicted astronomical tides are also shown. Computed surge hydrographs incorporate the varying predicted tides and values of initial rise. Computer outputs of surge estimates for each hurricane are summarized in Appendix B. Initial conditions used and the results of calibration obtained for historical hurricanes are summarized in Table 5. Only peak values of surge are given in the table.

2. Evaluation of Calibration.

Data reliability from an evaluation of the results obtained through calibration of each hurricane follows:

a. *Hurricane of 1949.* The computed surge hydrograph of the Hurricane of 1949 at Galveston showed poor correlation to the recorded surge hydrograph; this may be due to lack of wind data for this traverse. A fair correlation was obtained for the Freeport traverse.

b. *Hurricane Carla.* Good results were obtained using Hurricane Carla data for the Galveston traverse which provided most of the desired conditions for an open-coast station. Good results were obtained for the Freeport traverse.

c. *Hurricane Audrey.* The computed surge hydrograph of Hurricane Audrey for the Eugene Island traverse showed a good degree of correlation to the observed surge hydrograph.

d. *Hurricane Camille.* Inadequate correlation between the computed hurricane surge hydrograph and the observed high water elevation at the Biloxi, Mississippi, traverse for Hurricane Camille, is attributed to insufficient wind-field information and the irregularity of the coastline. Furthermore, Camille's wind-field charts were available for only 6-hour intervals and the highest surge occurred sometime between charts. The interpolated wind field for that period probably does not accurately represent actual wind conditions which produced the maximum surge. Similarly, there is no hydrograph at the point of the coast where the maximum surge occurred. The value provided is an observed elevation extrapolated from debris and high water marks and may include the effects of wave-induced runup. Because of the Mississippi River Delta and the offshore islands, and lack of sufficient wind field and hydrograph data, Biloxi was a poor site for numerical calculations of surge.

e. *Hurricane Carol.* Poor correlation was obtained for computed and reconstructed surge hydrographs of the Narragansett Pier traverse using data of Hurricane Carol. There was one limitation with the available wind data—the maximum surge occurred between the 3-hour time interval for which wind data were available, and since Carol crossed the coast at

Table 5. Effect of Wind Stress and Bottom Friction on Calculated Surge Values of Historic Hurricanes

Hurricane Traverse	Wind Equation	Stress Constants	Bottom Friction	Initial Rise	Surge Peak Height		Percent Difference
	K_1	K_2	K		Calculated	Observed	
October 1949 Freeport, Texas	1.21×10^{-6}	2.75×10^{-6}	0.0030	2.00	8.69	8.9	– 2.4
	1.21×10^{-6}	2.75×10^{-6}	0.0025	2.00	8.83	8.9	– 1.9
	1.10×10^{-6}	2.50×10^{-6}	0.0025	2.00	8.38	8.9	– 5.8
	0.99×10^{-6}	2.25×10^{-6}	0.0025	2.00	8.03	8.9	– 9.8
	0.88×10^{-6}	2.00×10^{-6}	0.0025	2.00	7.67	8.9	–13.8
October 1949 Galveston, Texas	1.21×10^{-6}	2.75×10^{-6}	0.0030	2.00	8.44	6.0	40.7
	1.21×10^{-6}	2.75×10^{-6}	0.0035	2.00	8.37	6.0	39.5
	1.10×10^{-6}	2.50×10^{-6}	0.0035	2.00	8.02	6.0	33.7
	0.99×10^{-6}	2.25×10^{-6}	0.0035	2.00	7.65	6.0	27.5
	0.88×10^{-6}	2.00×10^{-6}	0.0035	2.00	7.30	6.0	21.7
Carla Freeport, Texas	1.21×10^{-6}	2.75×10^{-6}	0.0030	2.50	10.15	11.6	–12.5
	1.21×10^{-6}	2.75×10^{-6}	0.0050	2.50	9.70	11.6	–16.4
	1.10×10^{-6}	2.50×10^{-6}	0.0050	2.50	9.37	11.6	–19.2
	0.99×10^{-6}	2.25×10^{-6}	0.0050	2.50	9.03	11.6	–22.2
	0.88×10^{-6}	2.00×10^{-6}	0.0050	2.50	8.69	11.6	–25.1
Carla Galveston, Texas	1.21×10^{-6}	2.75×10^{-6}	0.0030	1.90	9.73	10.0	– 2.7
	1.10×10^{-6}	2.50×10^{-6}	0.0030	1.90	9.33	10.0	– 6.7
	0.99×10^{-6}	2.25×10^{-6}	0.0030	1.90	8.93	10.0	–10.7
	0.88×10^{-6}	2.00×10^{-6}	0.0030	1.90	8.52	10.0	–14.8
Audrey Eugene Island, Louisiana	1.21×10^{-6}	2.75×10^{-6}	0.0030	1.00	9.60	7.9	21.5
	1.21×10^{-6}	2.75×10^{-6}	0.0025	1.00	9.67	7.9	22.4
	1.10×10^{-6}	2.50×10^{-6}	0.0025	1.00	9.10	7.9	15.2
	0.99×10^{-6}	2.25×10^{-6}	0.0025	1.00	8.52	7.9	7.8
	0.88×10^{-6}	2.00×10^{-6}	0.0025	1.00	7.92	7.9	0.3
Camille Biloxi, Mississippi	1.21×10^{-6}	2.75×10^{-6}	0.0030	1.20	31.65	20.4	55.1
	1.10×10^{-6}	2.50×10^{-6}	0.0030	1.20	27.91	20.4	36.8
	0.99×10^{-6}	2.25×10^{-6}	0.0030	1.20	26.02	20.4	27.5
	0.88×10^{-6}	2.00×10^{-6}	0.0030	1.20	23.86	20.4	17.0
Carol Narragansett Pier, Rhode Island	1.21×10^{-6}	2.75×10^{-6}	0.0030	1.20	9.14	11.1[1]	–17.7
	1.10×10^{-6}	2.50×10^{-6}	0.0030	1.20	8.86	11.1	–20.2
	1.10×10^{-6}	2.50×10^{-6}	0.0030	1.20	8.90[2]	11.1	–19.8
	0.99×10^{-6}	2.25×10^{-6}	0.0030	1.20	8.61	11.1	–22.4
	0.88×10^{-6}	2.00×10^{-6}	0.0030	1.20	8.32	11.1	–25.0

[1] Newport peak value.

[2] Detail bathymetry.

a high translational velocity, the interpolated wind values used for the calculation may be underestimates of the actual windspeeds. Therefore, the calculated surge may be less than what it would have been calculated if the actual wind field was more accurately described. The maximum observed surge runup obtained for this site may include some storm-wave setup and runup with the surge. However, both the predicted tide and the observed surge hydrograph were obtained for the Coasters Island tide gage at Newport, Rhode Island, a site inside Narragansett Bay. The observed hydrograph at Newport may reflect frictional and restricted entrance effects not representative of the open-coast surge. In addition, the hydrograph was not a gage recording, as the gage became inoperative during the storm, but the hydrograph is a composite of visual observations and a survey of high water marks.

Examination of computed hydrographs for historic hurricanes in Figures 39 through 71, and of the summary of peak surges and calibration variables given in Table 5, show that best results were obtained when the K_1 and K_2 coefficients in the wind-stress relationship were 1.21×10^{-6} and 2.75×10^{-6} respectively, and when the bottom friction (K) was given values ranging from 0.0025 to 0.003. Based on these results the wind-stress equation was given the following numerical form:

$$k = \left[1.21 + 2.75\left(1 - \frac{16}{W}\right)^2\right] 10^{-6} \qquad (42)$$

This combination of wind stress and bottom friction coefficients gave optimum results with the bathystrophic numerical model. Of the two coefficients, the wind-stress coefficient was more important and had the most pronounced effect on the final surge computation. Large changes in the value of bottom friction coefficient did not appreciably change the final estimate of surge, while small changes in wind-stress coefficient produced large changes in the surge estimate. The values for K_1 and K_2, in the wind-stress relationship obtained through the calibration procedure are not appreciably different from those used previously with this model, e.g., Reid and Bodine (1968) used values of $K_1 = 1.1 \times 10^{-6}$ and $K_2 = 2.5 \times 10^{-6}$ in the wind-stress equation used in their study of Galveston Bay. The form of equation (42) is empirically derived for low windspeeds. It is extrapolated here for use at the high windspeeds of hurricanes and indicates a nonlinear relation between windspeed and wind stress. This may be due to decapitation of the wave tops at higher windspeeds, increased turbulence, or some other unknown or unmeasurable factors.

To check on the relationship of the wind stress and windspeed using the coefficients given above, the following test was applied. Using the parameters of the probable maximum hurricane (PMH), ($p_o = 26.7$ inches of mercury, $p_n = 31.25$ inches of mercury, $R = 24$ nautical miles, $V_t = 20$ knots, and $U_{max} = 149.8$ miles per hour) windspeeds and pressure were calculated along the hurricane's prime vector for increasing integer distance intervals of the ratio, r/R. Utilizing these data, the wind-stress equation was solved and values of wind-stress coefficient were tabulated (Table 6). A plot was prepared to show the

Table 6. Change in the Wind-Stress Coefficient with Windspeed and Pressure.

r/R	Windspeed, W (miles per hour)	Atmospheric Pressure, p (inches of mercury)	Wind-Stress Coefficient, k
1	149.9	28.4	3.40×10^{-6}
2	137.9	29.5	3.36×10^{-6}
3	100.0	30.0	3.15×10^{-6}
4	86.6	30.2	3.04×10^{-6}
5	76.4	30.4	2.93×10^{-6}
6	68.2	30.6	2.82×10^{-6}
7	60.6	30.6	2.70×10^{-6}
8	53.7	30.7	2.57×10^{-6}
9	48.0	30.8	2.43×10^{-6}
10	43.0	30.8	2.29×10^{-6}
12	34.8	30.9	2.01×10^{-6}
14	28.9	30.9	1.76×10^{-6}
16	24.3	31.0	1.53×10^{-6}
18	20.5	31.0	1.34×10^{-6}
20	16.9	31.0	1.22×10^{-6}
22	13.8	31.0	1.21×10^{-6}

Wind-Stress Equation: $k = 1.21 \times 10^{-6} + 2.75 \times 10^{-6} \left(1 - \frac{16}{W}\right)^2$

Atmospheric pressure Equation: $p = p_o + p_n = p_o \big) e^{-R/r}$

change of the wind-stress coefficients with increasing windspeeds (Fig. 72). As shown in the figure, at higher windspeeds the wind-stress coefficient increases but at a slower rate than at lower speeds.

VI. DESIGN STORM WIND FIELD REDUCTION

The meteorological considerations leading to development of wind field data for synthetic hurricanes such as the SPH and the PMH, have been discussed by Myers (1954), Graham and Nunn (1959) and U.S. Weather Bureau (HUR 7-97, 1968). Definitions of design storms have been given previously in this report. The development of model winds and pressure fields of hurricanes along the lines presented by Myers is summarized in the *Shore Protection Manual* (U.S. Army, Corps of Engineers, Coastal Engineering Research Center, 1973).

The numerical model used in this study is capable of developing internally the wind velocity field of a synthetic hurricane, and of using this data for surge calculations. The methodology of wind data reduction and pressure field development for synthetic hurricanes are included as an example. The hurricane pressure field can be obtained by the following equation:

$$\frac{p - p_o}{p_n - p_o} = e^{-R/r}, \qquad (43)$$

where,

p = pressure anywhere in the storm system,
p_o = pressure at center of storm,
p_n = pressure at the periphery of the storm,
r = the radial distance from the storm center to the computation point on the traverse line,

and

R = radius to maximum winds.

Equation (43) is the model's radial profile of sea level pressure developed empirically from hurricane data in Schloemer (1954). Another form of equation (43) used in this model is:

$$p_n - p = \left(p_n - p_o\right)\left(1 - e^{-R/r}\right). \qquad (44)$$

The same equation can be used for estimating the pressure setup, $S_{\Delta p}$, contribution to the surge with the following equation:

$$S_{\Delta p} = 1.14\ (p_n - p_{o,}\ (1 - e^{-R/r}), \qquad (45)$$

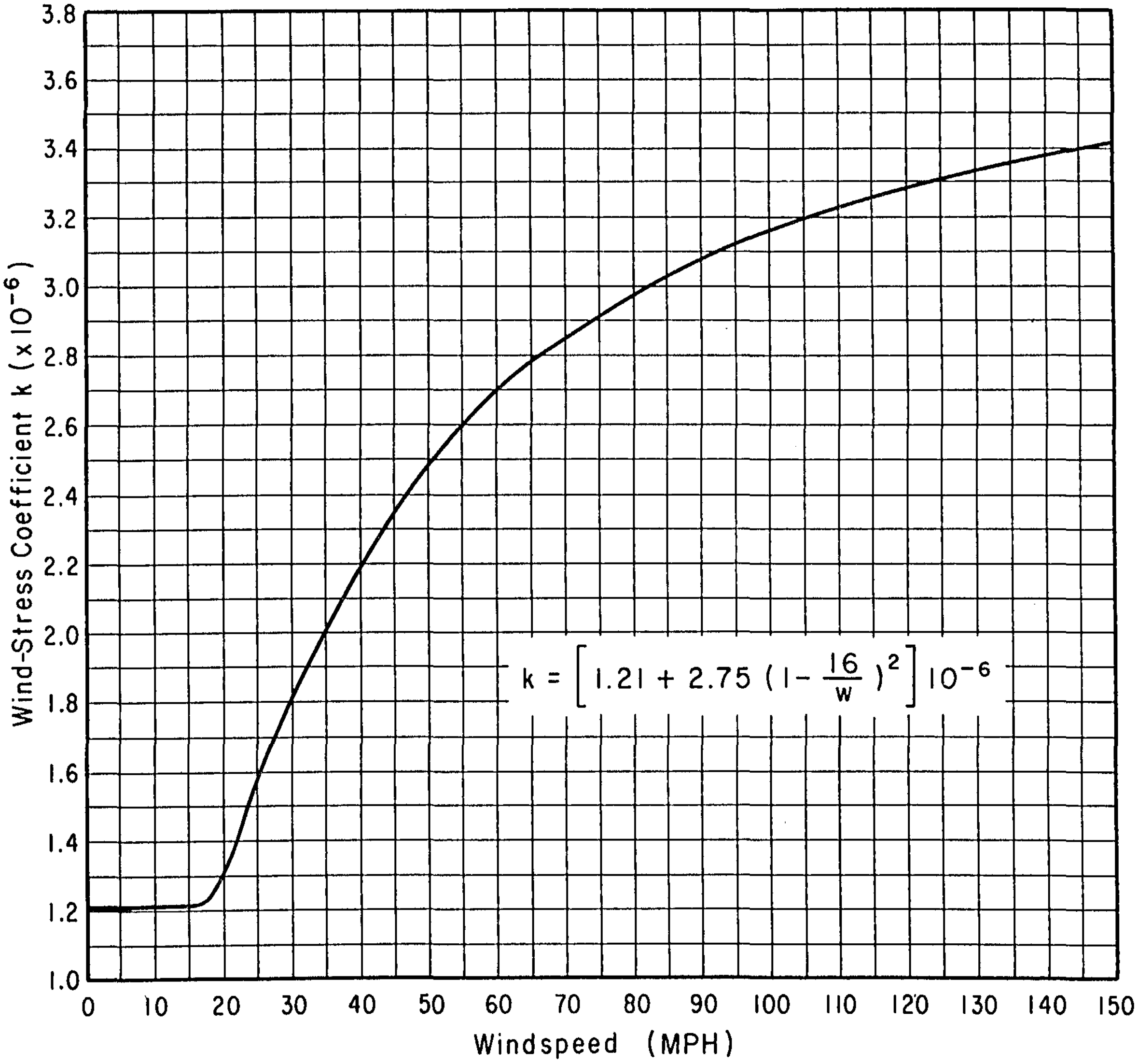


Figure 72. Relationship of wind-stress coefficient to windspeed along the prime vector of PMH.

where 1.14 is a conversion constant changing pressure in inches of mercury to feet of setup, accounting also for density effects.

The maximum gradient windspeed (U_{max}), the maximum wind (U_R) in the belt of maximum winds, and the windspeed (U) anywhere along a computational traverse, can be determined by the following equations:

$$U_{max} = K\left(p_n - p_o\right)^{1/2} - R\,(0.576\,f)\,, \tag{46}$$

$$U_R = 0.865\ U_{max} + 0.576\ V_F, \tag{47}$$

$$U = \left(\frac{U_o}{U_R}\right) U_R - 0.576\ V_F\ \left(1 - \cos\epsilon\right), \tag{48}$$

where

U_{max} = maximum gradient windspeed in miles per hour for a symmetical, synthetic hurricane,

U_R = maximum windspeed at the radius to maximum winds (R) given in miles per hour, 30 feet above the water,

K = empirical constant; units are miles per hour per inches of mercury$^{1/2}$ (a function of latitude for the PMH),

P_n = asymptotic pressure (inches of mercury),

p_o = central pressure (inches of mercury),

p = pressure at a given location (inches of mercury),

R = radius to maximum winds (nautical miles),

f = Coriolis parameter = $2\omega \sin\phi$,

ϕ = north latitude (degrees),

ω = 0.2625 radians per hour,

V_F = forward speed of the storm (knots),

U_o = wind velocity at a given location along the "prime vector." This is a function of r and R (see U.S. Weather Bureau, HUR 7-97, 1968),

ϵ = the angle between the prime vector and the radius to station location,

0.576 = the dimensionless product of 0.5, a fundamental factor in equations 46, 47, and 48, and the conversion from nautical to statute miles (1 nautical mile = 1.1515 statute mile),

and

0.865 = dimensionless empirical reduction factor from U_{max} to U_R for all zones except zone B where a value of 0.885 is used.

Figure 73 shows hurricane zones for the Atlantic and gulf coasts.

Equations (46) and (47) relate the maximum gradient and sustained winds to the hurricane pressure field, the Coriolis force, and the storm's translational velocity or forward speed. The wind velocity field for any design (hypothetical) hurricane can be computed and graphically constructed by solving the equations given above. However, for both the PMH and SPH, the values of gradient windspeed, U_{max}, and the maximum sustained wind, U_R, are given by definition, so for these hurricanes, only equation (48) is solved internally to develop the wind field along the traverse. The geometry of a synthetic hurricane system for which the wind field is calculated is shown in Figure 74. At any time, the hurricane wind field can be depicted as near-symmetrical and characterized by a storm center at point O and an approximate zero-windspeed isovel. The computational traverse is placed by definition through the radius of maximum winds and parallel to the storm track indicated by the line ABC (Fig. 74). The storm's track is indicated by line OD′. The hurricane's *prime vector*, indicated by the line OBE, forms an angle of 115° with the track and traverse. The wind field of only a stationary hurricane is symmetrical on both sides of this line. The wind field of a moving hurricane is distorted by the forward velocity of the storm. The shore-intercept of the traverse indicated by point A, is placed initially at the zero-wind isovel, at zero time in the computation. At this time, the theoretical wind direction at point A forms a deflection angle of 25° with a line normal to the radius through the point. This is the deflection angle γ shown in Figure 74 and at this point has a maximum value. From geometry shown in the figure it becomes apparent that the wind vector θ, the angle formed between the traverse and the wind vector, is given by:

$$\theta = \epsilon - 25^\circ + \gamma , \tag{49}$$

where γ = the angle of wind vector deflection, will vary as follows:

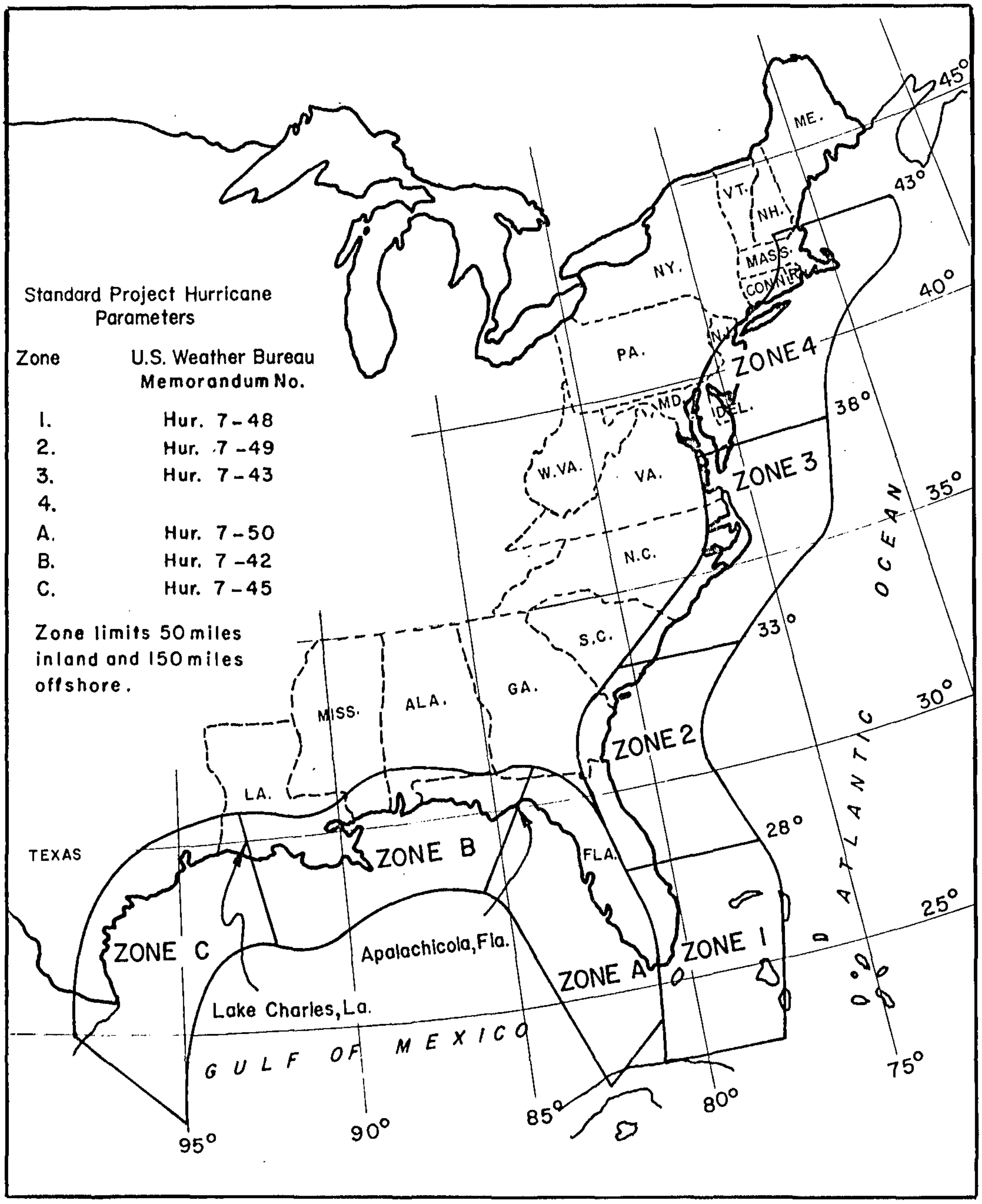
$$0 \leqslant \frac{r}{R} < 1, \gamma \text{ will vary from } 0^\circ \text{ to } 10^\circ,$$

$$1 \leqslant \frac{r}{R} < 1.2, \gamma \text{ will vary from } 10^\circ \text{ to } 25^\circ,$$

$$1.2 \leqslant \frac{r}{R} \text{, the } \gamma = 25^\circ,$$

and ϵ = the angle between the prime vector and the line drawn from the storm center to any point on the traverse.

The storm is not stationary, and as it moves towards the coast, the windspeeds may increase and wind vectors will change direction for the shore-intercept point and all other points on the traverse. However, windspeeds are adjusted to account for frictional effects of



Standard Project Hurricane Parameters

Zone	U.S. Weather Bureau Memorandum No.
1.	Hur. 7-48
2.	Hur. 7-49
3.	Hur. 7-43
4.	
A.	Hur. 7-50
B.	Hur. 7-42
C.	Hur. 7-45

Zone limits 50 miles inland and 150 miles offshore.

Figure 73. Atlantic and gulf coasts—hurricane zones (U.S. Army, Corps of Engineers, Coastal Engineering Research Center, 1973).

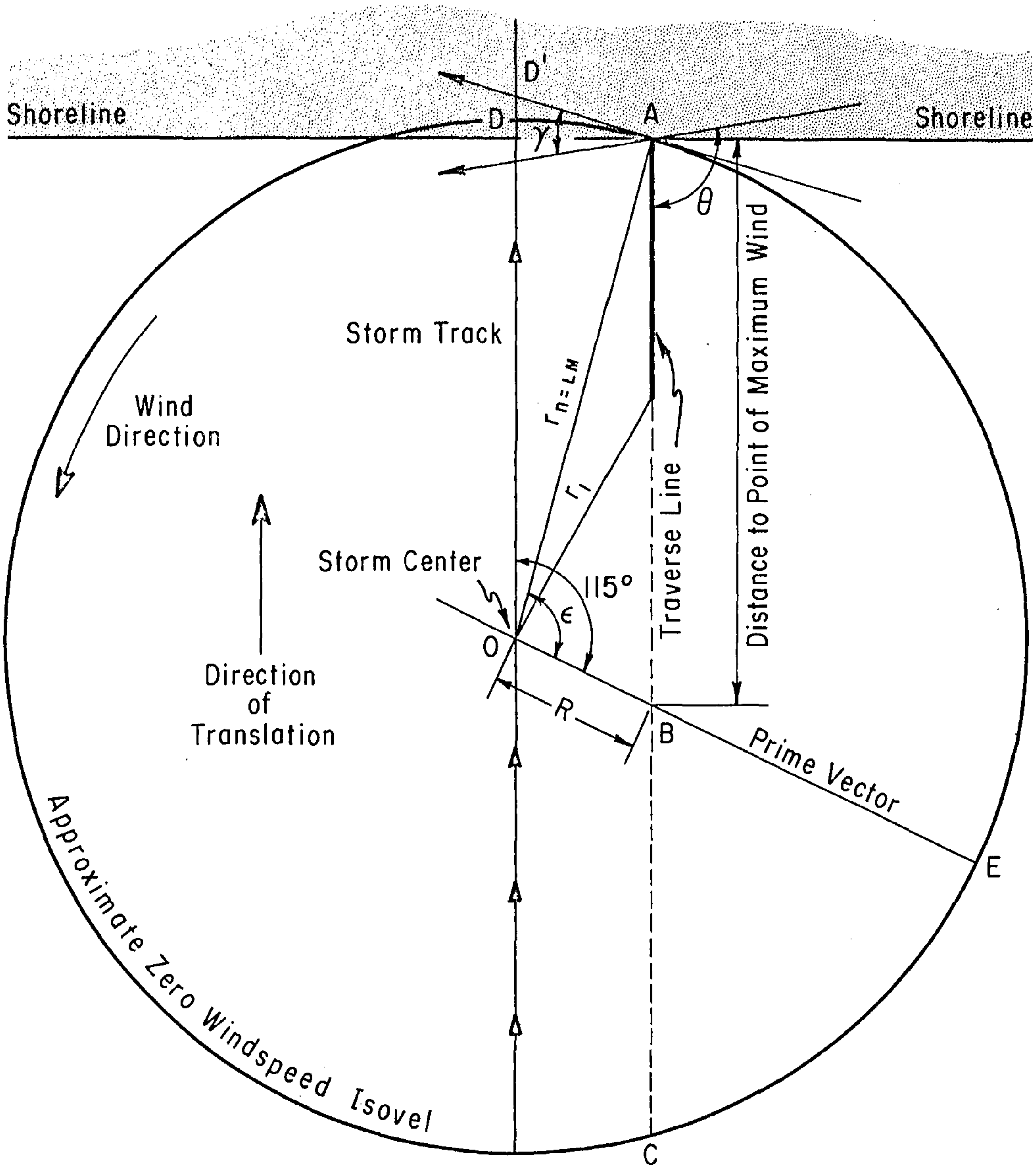


Figure 74. Wind field of a synthetic hurricane at time, t = o.

land within 2 nautical miles of the shore; windspeeds are multiplied by a filling factor which varies linearly from 1.00 at 2 nautical miles to 0.89 at the shore. The maximum windspeed is experienced at the shore-intercept of the traverse when point B along the prime vector has moved to position A (Fig. 74). Similarly, the direction of winds along the traverse change as the hurricane moves shoreward. Following passage of the hurricane, the winds decrease, and wind vectors reverse direction.

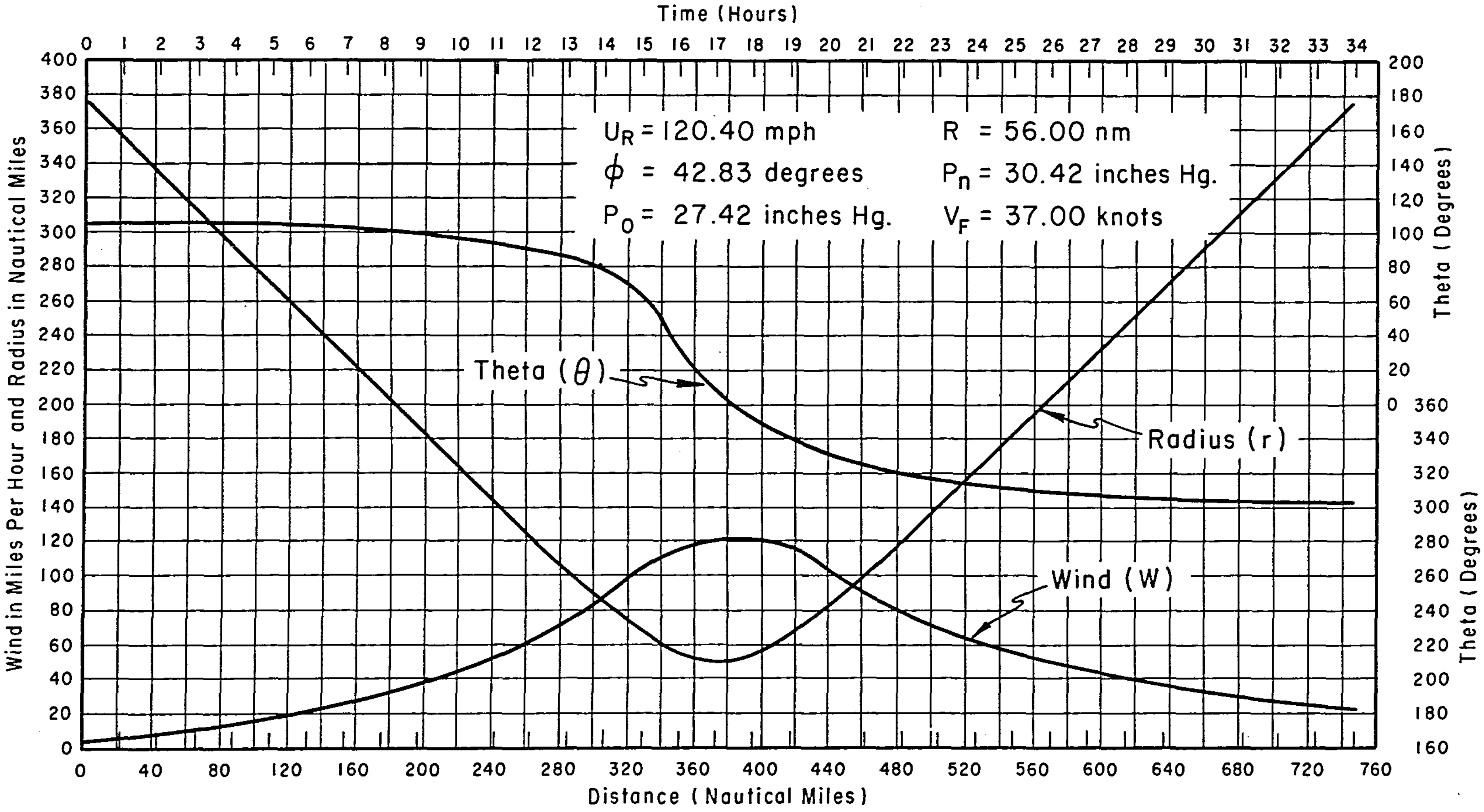
Windspeeds and directions are obtained for the traverse and extension of the traverse, BC. Considering the geometry of the system and the equations given earlier, the model develops the complete wind field of a synthetic hurricane. Characteristics of a hypothetical hurricane developed internally by the computer program are shown graphically in Figure 75.

The following input parameters are assigned to the hypothetical hurricane: radius of maximum winds, forward speed of the storm, asymptotic pressure, central pressure, maximum windspeed at R, latitude of traverse line at the shore, initial rise, astronomical tide (constant), hurricane zone, and bottom profile data. With these parameters, the program computes the wind profile along the prime vector as a function of the radius of maximum wind and then the wind profile and wind vector angle (wind field) along the traverse line as a function of forward speed. The windspeed is also corrected for filling within 2 nautical miles of shore. The internal computer calculations are in accordance with procedures described in HUR 7-79.

VII. SUMMARY AND CONCLUSIONS

The prediction of storm surge resulting from the combined meteorologic, oceanic, and astronomic effects coincident with the arrival of a hurricane at the coast is important in planning and the design of coastal structures. Increasing requirements for large coastal installations, such as nuclear powerplants and superport terminals, have required conservative criteria in obtaining estimates of potential storm surges. The present capability for prediction of hurricane surge is based primarily on the use of analytic and numerical models, none of which have been adequately verified. This study was undertaken for the purpose of further verifying a numerical model of hurricane surge prediction using data of historical hurricanes at selected traverses of the Gulf of Mexico and the Atlantic Coast. The numerical model used in this report is based on the *Bathystrophic Storm Tide Theory* and used to estimate the rise of water on the open coast by taking into account the combined effects of direct onshore and alongshore wind-stress components on the water surface and the effects of the Coriolis force to integrate numerically the one-dimensional hydrodynamic equations of motion and continuity.

Verification was achieved empirically in the model by varying the values of coefficients in the wind stress relationship and bottom friction. Surge hydrographs were calculated and compared with the observed or recorded surge hydrographs of the following hurricanes and traverses: (a) Hurricane of 1949 at Galveston and Freeport, Texas; (b) Hurricane Carla at



U_R = 120.40 mph
ϕ = 42.83 degrees
P_0 = 27.42 inches Hg.
R = 56.00 nm
P_n = 30.42 inches Hg.
V_F = 37.00 knots

Figure 75. Hypohurricane characteristics (PMH).

Galveston and Freeport, Texas; (c) Hurricane Audrey at Eugene Island, Louisiana; (d) Hurricane Camille at Biloxi, Mississippi; and (e) Hurricane Carol at Narragansett Pier, Rhode Island.

The calibration of the coefficients and verification of the numerical model was somewhat limited by the quantity and quality of the historical hurricane data available. Only the Galveston traverse for Hurricane Carla and the Eugene Island traverse for Hurricane Audrey were satisfactory open-coast locations. Of the two traverses, the Galveston traverse provided the best data for calibration. The computed hydrograph for the Galveston traverse satisfied the *best-fit* condition, while a fair degree of correlation was obtained for the Freeport traverse with data from Hurricane Carla and the Hurricane of 1949. Poor correlation at other traverses with the other hurricanes is attributed to lack of sufficient data and to a deficiency of the numerical model. Where both hurricane wind and hydrographic data were of fair or good quality, and where the condition of open coast was met (Hurricane Carla at Galveston), the model reproduced the recorded historical surges satisfactorily.

The best results were obtained when the coefficients K_1 and K_2 in the wind stress relationship were set equal to 1.21×10^{-6}, and 2.75×10^{-6} respectively, when bottom friction ranged from 0.0025 to 0.003, and when the wind-stress equation was given the following numerical form:

$$K = \left[1.21 + 2.75\left(1 - \frac{16}{W}\right)^2\right] 10^{-6}.$$

These results indicate that the numerical model can be used for estimating realistically the values of surges from both actual and synthetic hurricanes. However, certain parameters used in the calculations, such as initial rise, wind stress, and bottom friction, and their interrelationships cannot be adequately determined at the present time. The reasons are the following:

a. No standardized method exists for measuring the values of initial rises associated with historic hurricanes from tide gage records. Such initial rises appear to occur independently of hurricanes.

b. It is generally believed that bottom friction as used in the hurricane surge computations, is a function of depth and offshore bottom topography. No specific method exists for determining a value of bottom friction coefficient for use in the model which is not dependent on other factors.

c. Bottom friction and wind stress are combined in the numerical computation of hurricane surge. However, accurate determination of wind stress is not presently possible. The magnitude of wind-stress coefficient has been determined empirically with actual storms having windspeeds of less than 90 miles per hour. Extrapolation of the wind stress relationship, as determined from lower windspeeds, to extreme probable maximum conditions may be introducing an error. There is a basis for suggesting that the wind stress magnitude at high windspeeds may be lower than that obtained by extrapolation. Decapitation of the wave tops at high speeds may be the mechanism responsible for lower wind stress values. Correlation of the hurricanes at all traverses was difficult to obtain because of the complexity of the problem, data limitations, the variability and the unknown relationship between wind and bottom stress coefficients, of the factors entering the calibration process. Reliable results obtained with a part of the historical data, support the conclusions that the quasi-two-dimensional bathystrophic storm surge model can be reasonably applied to synthetic hurricane problems; also, the combined values of wind stress and bottom friction coefficients of the bathystrophic numerical model which were obtained through calibration are conservative. However, the results of this study indicated a combination of wind stress and bottom friction coefficients which should be used with the model. Because of the coupled nature of wind stress and bottom friction coefficients, the results of the study did not conclusively determine individual values of these parameters which can be extrapolated to PMH conditions at locations where no historical records exist. Therefore, it is recommended that the most conservative estimates of each parameter be used in the model for computing surges of synthetic hurricanes required for the design of coastal structures; and when additional data becomes available on future hurricanes, further testing and verification of the model be undertaken.

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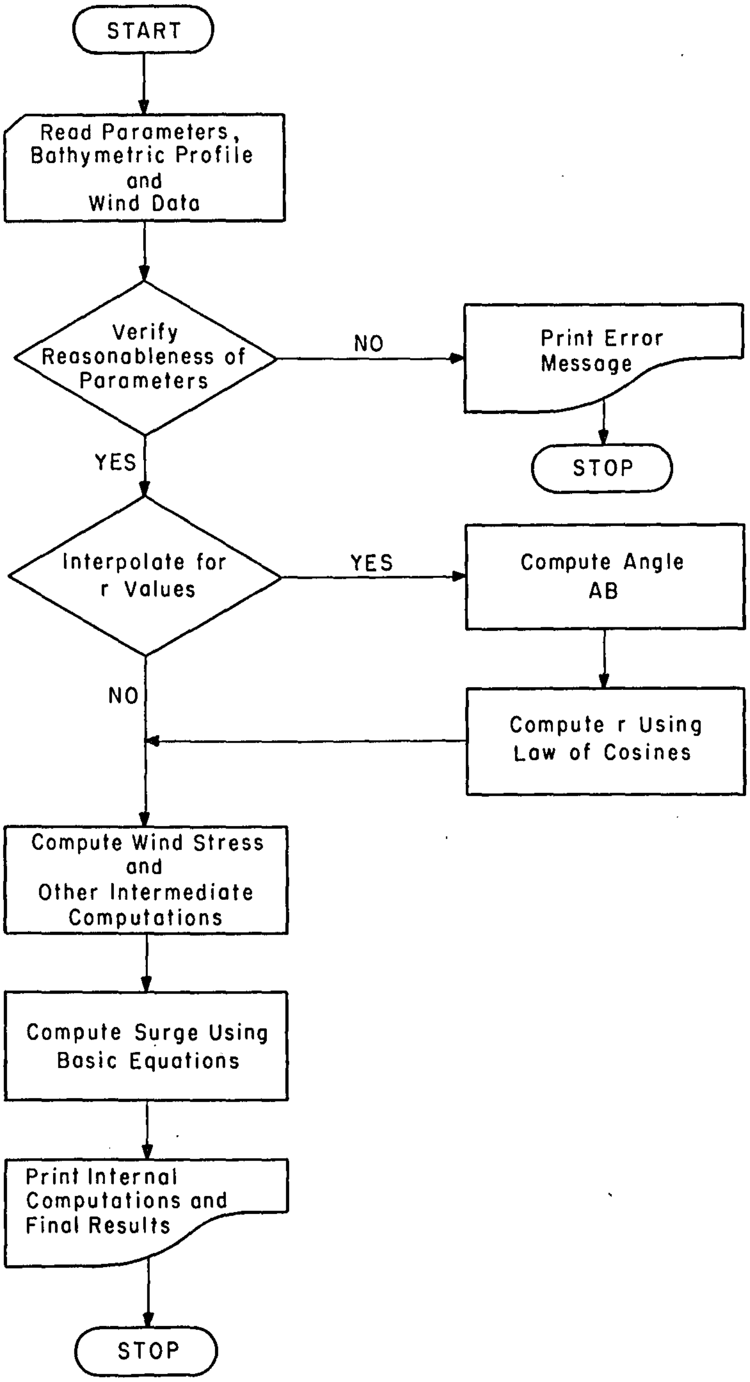
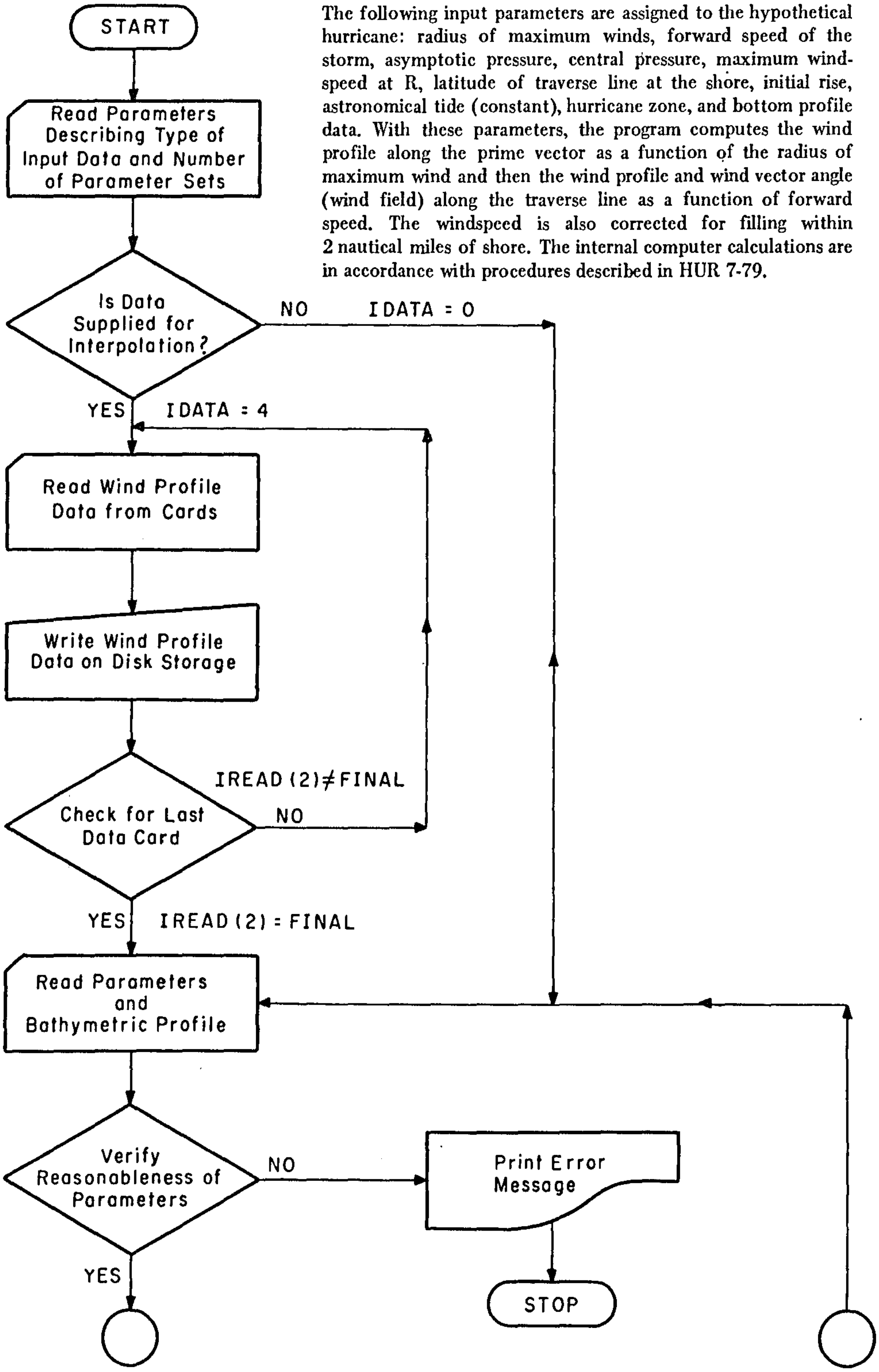
APPENDIX A. COMPUTER PROGRAM DOCUMENTATION

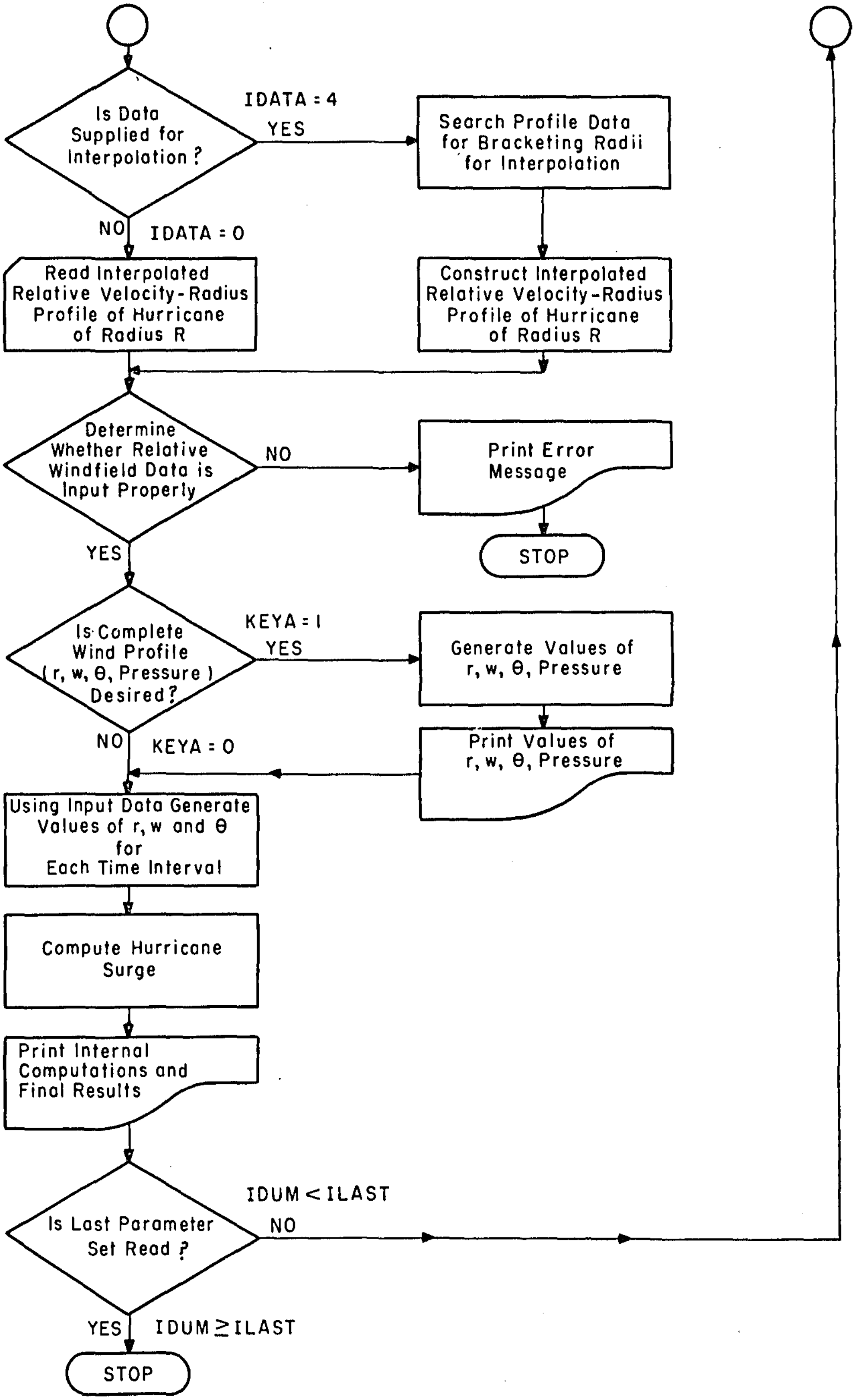
APPENDIX A-1. FLOW CHARTS FOR ACTUAL HURRICANES



APPENDIX A-1. FLOW CHARTS FOR HYPOTHETICAL HURRICANES

The following input parameters are assigned to the hypothetical hurricane: radius of maximum winds, forward speed of the storm, asymptotic pressure, central pressure, maximum windspeed at R, latitude of traverse line at the shore, initial rise, astronomical tide (constant), hurricane zone, and bottom profile data. With these parameters, the program computes the wind profile along the prime vector as a function of the radius of maximum wind and then the wind profile and wind vector angle (wind field) along the traverse line as a function of forward speed. The windspeed is also corrected for filling within 2 nautical miles of shore. The internal computer calculations are in accordance with procedures described in HUR 7-79.




Is Data Supplied for Interpolation ?
IDATA = 4
YES
Search Profile Data for Bracketing Radii for Interpolation
NO
IDATA = 0
Read Interpolated Relative Velocity-Radius Profile of Hurricane of Radius R
Construct Interpolated Relative Velocity-Radius Profile of Hurricane of Radius R
Determine Whether Relative Windfield Data is Input Properly
NO
Print Error Message
STOP
YES
Is Complete Wind Profile (r, w, θ, Pressure) Desired?
KEYA = 1
YES
Generate Values of r, w, θ, Pressure
NO
KEYA = 0
Print Values of r, w, θ, Pressure
Using Input Data Generate Values of r, w and θ for Each Time Interval
Compute Hurricane Surge
Print Internal Computations and Final Results
Is Last Parameter Set Read ?
IDUM < ILAST
NO
YES
IDUM ≥ ILAST
STOP

APPENDIX A-2. PROGRAM LISTINGS FOR ACTUAL HURRICANES

```
      PROGRAM SURGEA(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE39,TAPE38SGA00100
     2)                                                                 SGA00150
C****************** ADPO FILE IDENTIFICATION ***************************SGA00200
C    752X6R17G0 (SURGEA)  COMPUTES STORM SURGE BY BATHYSTROPHIC METHOD  SGA00300
C        (ACTUAL HURRICANES)                                            SGA00400
C                                                                       SGA00500
C     *****************************************************************SGA00600
C                                                                       SGA00700
C                     QUASI-TWO-DIMENSIONAL OPEN COAST STORM SURGE PROGRAM SGA00800
C                                                                       SGA00900
C  NOTATION USEDA                                                       SGA01000
C       AB = CALCULATED ANGLE BETWEEN THE TRAVERSE AND INITIAL STORM    SGA01100
C            CENTER LINE (RS(1))                                        SGA01200
C    AHOUR = VARIABLE USED TO ESTABLISH STORM TIME.                     SGA01300
C    ALPHA = AZIMUTH OF THE TRAVERSE (DEGREES)                          SGA01400
C       AN = INTERMEDIATE VALUE OF WIND STRESS AND SETUP FOR X-COMPONENT.SGA01500
C     BEAR = BEARING OF TRAVERSE IN DEGREES. DOES NOT ENTER COMPUTATIONS.SGA01600
C    BETAO = AZIMUTH OF THE STORM CENTER LINE (RS(1)) (DEGREES)         SGA01700
C      BFF = BOTTOM FRICTION FACTOR.                                    SGA01800
C       BN = INTERMEDIATE VALUE OF WIND STRESS AND SETUP FOR Y-COMPONENT.SGA01900
C       BP = AN ARRAY USED TO STORE SUCESSIVE VALUES OF BN.             SGA02000
C       BY = ABSOLUTE VALUE OF BN.                                      SGA02100
CC1,C2,C3 = DIMENSION CORRECTION FACTORS.                               SGA02200
C        D = DEPTH BELOW MEAN WATER LEVEL IN FEET.                       SGA02300
C     DASQ = TOTAL WATER DEPTH SQUARED AT EACH TIME LEVEL.              SGA02400
C     DAVG = AVERAGE BOTTOM DEPTH AT EACH TIME LEVEL.                   SGA02500
C     DELT = TIME INCREMENTS IN HOURS.                                  SGA02600
C   DELSXN = INCREMENTAL X-COMP SETUP IN FEET.                          SGA02700
C   DELSYN = INCREMENTAL Y-COMP SETUP IN FEET.                          SGA02800
C      DEN = INTERMEDIATE COMPUTATION FOR DENOMINATOR OF FLUX EQUATION  SGA02900
C            AT EACH TIME LEVEL                                         SGA03000
C     DIST = DISTANCE FROM COAST IN N.M.                                SGA03100
C    DIST(1) AND DEPTH(1) ARE FARTHEST POINTS FROM SHORE WITH           SGA03200
C    SUCESSIVE VALUES TAKEN SHOREWARD OF THESE POINTS                   SGA03300
C      DTH = TOTAL WATER DEPTH AT EACH TIME LEVEL (FEET).               SGA03400
C      DTN = INTERMEDIATE COMPUTATION OF WATER DEPTH                    SGA03500
C      DTS = INTERMEDIATE COMPUTATION OF TOTAL WATER DEPTH (DTH)        SGA03600
C   ICHECK = SENTINEL USED TO INDICATE ERRORS.                          SGA03700
C       ID = IDENTIFIES TYPE OF DATA ON CARD                            SGA03800
C   IOMITD = PRINT OPTION PARAMETER (DESCRIBED IN DETAIL WHEN REFERENCED)SGA03900
C    IOMIT = PRINT OPTION PARAMETER (DESCRIBED IN DETAIL WHEN REFERENCED)SGA04000
C    ISKIP = PRINT OPTION                                               SGA04100
C    ITYPE = THE FIRST 3 LETTERS OF THE HURRICANE NAME.                 SGA04200
C       LM = MAX. NO. OF SHELF REACHES (LIMIT OF 50)                    SGA04300
C       NM = MAX. NO. OF TIME INCREMENTS (LIMIT OF 50)                  SGA04400
C       NN = CARD NUMBER READ FROM CARD                                 SGA04500
C      PHI = GEOGRAPHICAL LATITUDE IN DEGREES GIVEN BY PHII.            SGA04600
C     PHII = GEOGRAPHICAL LATITUDE IN DEGREES SUPPLIED AS INPUT         SGA04700
C       PI = 3.14159                                                    SGA04800
C       PN = PERIPHERAL PRESSUE IN INCHES OF HG.                        SGA04900
C       PO = CENTRAL PRESSURE INCHES OF HG.                             SGA05000
C        R = RADIUS OF MAX. WINDS IN N.M.                               SGA05100
C       RS = RADII MEASURES FROM STORM CENTER TO POINT ON TRAVERSE IN NM.SGA05200
C    RS(1) = DISTANCE (N.M.) FROM STORM CENTER TO SHORE INTERSECTION OF SGA05300
C            THE TRAVERSE                                               SGA05400
C       SA = SETUP DUE TO ASTRONOMICAL FORCES IN FEET.                  SGA05500
C      SAP = OLD VALUE OF ASTRONOMICAL TIDE                             SGA05600
C       SE = INITIAL SETUP IN FEET.                                     SGA05700
C   SINPHI = SINE OF GEOGRAPHICAL LATITUDE                              SGA05800
C       SP = SETUP DUE TO PRESSURE IN FEET.                             SGA05900
C      SPN = PRESSURE SETUP AT NEW TIME LEVEL.                          SGA06000
C      SPP = PRESSURE SETUP AT PREVIOUS TIME LEVEL.                     SGA06100
C    SPRES = SUCESSIVE VALUES OF PRESSURE SETUP AT EACH TIME LEVEL      SGA06200
C       ST = SUCESSIVE VALUES OF TOTAL SURGE ALONG TRAVERSE LINE        SGA06300
C     STOT = VALUE OF TOTAL SURGE AT SHORE FOR EACH TIME LEVEL.         SGA06400
C    SUMSX = SUCESSIVE VALUES OF X-COMPONENT OF SURGE ALONG TRAVERSE    SGA06500
C            LINE                                                       SGA06600
C    SUMSY = SUCESSIVE VALUES OF Y-COMPONENT OF SURGE ALONG TRAVERSE    SGA06700
C            LINE                                                       SGA06800
C       SW = SUCESSIVE VALUES OF SUMSX + SUMSY ALONG TRAVERSE LINE      SGA06900
C      SWW = SUCESSIVE VALUES OF SW FOR EACH TIME LEVEL AT SHORE        SGA07000
C       SX = TOTAL X-COMP SETUP AT SHORE IN FEET.                       SGA07100
C      SXP = SUCESSIVE VALUES OF SUMSX                                  SGA07200
C       SY = TOTAL Y-COMP SETUP AT SHORE IN FEET.                       SGA07300
C      SYP = SUCESSIVE VALUES OF SUMSY                                  SGA07400
C        T = ANGLE MEASURED FROM THE POSTIVE X-AXIS COUNTER CLOCKWISE TO SGA07500
C              THE WIND VECTOR,(THETA).                                 SGA07600
C       VF = FORWARD SPEED OF STORM IN KNOTS.                           SGA07700
C    VN, VNN, VNTEST, VP AND VS REFER TO Y-COMPONENT OF VOLUME TRANSPORT SGA07800
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C       VN = SUCESSIVE VALUES OF FLUX ALONG TRAVERSE LINE                 SGA07900
C      VNN = ABSOLUTE VALUE OF FLUX                                       SGA08000
C   VNTEST = CHECK ON VALUE OF FLUX                                       SGA08100
C       VP = FLUX AT PREVIOUS TIME LEVEL                                  SGA08200
C       VS = Y-FLUX (FT*FT/SEC)                                           SGA08300
C        W = WIND SPEED IN MPH.                                           SGA08400
C       WK = VAN DORNS WIND STRESS FACTOR.                                SGA08500
C    WKCOR = CORRECTION FACTOR FOR WIND STRESS COEFFICIENT.               SGA08600
C      WSQ = WIND (W) SQUARED                                             SGA08700
C      WWX = W * W * COS(THETA) IN MPH SQ.                                SGA08800
C      WWY = W * W * SIN(THETA) IN MPH SQ.                                SGA08900
C       WX = MAXIMUM WIND SPEED (MPH).                                    SGA09000
      DIMENSION SP(50),WWX(50),WWY(50),WK(50),D(50),DIST(50),RS(50),      SGA09100
     2 W(50),A(20),SA(200),DELT(200),PHI(50),T(50),DAVG(50),DELX(50),     SGA09200
     3 SX(200),SY(200),SWW(200),SPRES(200),STOT(200),SINPHI(50),SXP(100)SGA09300
     4,SYP(100),SPP(100),VP(100),BP(100)                                  SGA09400
      DIMENSION VX(2000),BEAR(2)                                          SGA09500
      DATA C1,C2,C3 /203.,106.,5280./                                     SGA09600
C  READ STORM IDENTIFICATION TITLE.                                       SGA09700
      READ (5,10) (A(I),I=1,20)                                           SGA09800
10    FORMAT (20A4)                                                       SGA09900
C   READ PARAMETERS AND CHECK IDENTIFICATION DATA.                        SGA10000
C                                                                         SGA10100
C***NOTE.   IDENTIFICATION DATA IS CHECKED ON EACH DATA CARD TO           SGA10200
C   AVOID MISREADING INPUT DATA.                                          SGA10300
C                                                                         SGA10400
      READ (5,20) NM,LM,ISKIP,IOMIT,IOMITD,ID                             SGA10500
20    FORMAT (5I5,50X,A5)                                                 SGA10600
C     FLAG IS SET                                                         SGA10700
      ICHECK=0                                                            SGA10800
C   CHECK FOR EXCEEDED DIMENSIONS.                                        SGA10900
      IF (NM-200) 30,30,40                                                SGA11000
30    IF (LM-50) 90,90,40                                                 SGA11100
C                                                                         SGA11200
C   ERROR MESSAGE 01 WRITTEN                                              SGA11300
40    WRITE (6,730)                                                       SGA11400
      ERROR=2H01                                                          SGA11500
      ICHECK=1                                                            SGA11600
      WRITE (6,50)                                                        SGA11700
50    FORMAT (50X,13HERROR MESSAGE,///)                                   SGA11800
      WRITE (6,60) ERROR                                                  SGA11900
60    FORMAT (1X,6HERROR ,A2,/)                                           SGA12000
      WRITE (6,70)                                                        SGA12100
70    FORMAT (/,3X,88H SEE ERROR TABLE IN CERC TM TITLE VERIFICATION STUSGA12200
     2DY OF A BATHYSTROPIC STORM SURGE MODEL/)                            SGA12300
      WRITE (6,80) NM,LM                                                  SGA12400
80    FORMAT (1H ,68HMAX. NO. OF TIME INCREMENTS = 200     MAX. NO. OF SSGA12500
     2HELF REACHES = 50,//,60H THE VALUE OF TIME INCREMENTS OR SHELF REASGA12600
     3CHES WAS TOO LARGE,//,41H YOUR VALUE FOR TIME INCREMENTS(NM) WAS =SGA12700
     4,I5,/,39H YOUR VALUE FOR SHELF REACHES(LM) WAS =,I5)                SGA12800
      WRITE (6,730)                                                       SGA12900
C                                                                         SGA13000
90    IF (ID.EQ.5HPAR 1) GO TO 110                                        SGA13100
C                                                                         SGA13200
C   ERROR MESSAGE 02 WRITTEN                                              SGA13300
      IDA=1                                                               SGA13400
      WRITE (6,730)                                                       SGA13500
      ERROR=2H02                                                          SGA13600
      WRITE (6,50)                                                        SGA13700
      WRITE (6,60) ERROR                                                  SGA13800
      WRITE (6,70)                                                        SGA13900
      WRITE (6,100) ID,IDA                                                SGA14000
100   FORMAT (23H ID IN ERROR * ID GIVEN,1X,A5,/,18H ID SHOULD BE PAR ,ISGA14100
     21)                                                                  SGA14200
      WRITE (6,730)                                                       SGA14300
C                                                                         SGA14400
      ICHECK=1                                                            SGA14500
110   LMM=LM-1                                                            SGA14600
      PI=3.14159                                                          SGA14700
      READ (5,120) PHII,ITYPE,BEAR,ID                                     SGA14800
120   FORMAT (10X,F10.2,27X,A3,2A5,15X,A5)                                SGA14900
      IF (ID.EQ.5HPAR 2) GO TO 130                                        SGA15000
C                                                                         SGA15100
C   ERROR MESSAGE 02 WRITTEN                                              SGA15200
      IDA=2                                                               SGA15300
      WRITE (6,730)                                                       SGA15400
      ERROR=2H02                                                          SGA15500
      WRITE (6,50)                                                        SGA15600
      WRITE (6,60) ERROR                                                  SGA15700
      WRITE (6,70)                                                        SGA15800
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      WRITE (6,100) ID,IDA                                              SGA15900
      WRITE (6,730)                                                     SGA16000
C                                                                       SGA16100
      ICHECK=1                                                          SGA16200
  130 DO 140 I=1,LM                                                     SGA16300
  140 PHI(I)=PHII                                                       SGA16400
      READ (5,150) R,PO,PN,VF,SE,WKCOR,ID                               SGA16500
  150 FORMAT (5F7.2,21X,F7.2,12X,A5)                                    SGA16600
      IF (ID.EQ.5HPAR 3) GO TO 160                                      SGA16700
C                                                                       SGA16800
C   ERROR MESSAGE 02 WRITTEN                                            SGA16900
      IDA=3                                                             SGA17000
      WRITE (6,730)                                                     SGA17100
      ERROR=2H02                                                        SGA17200
      WRITE (6,50)                                                      SGA17300
      WRITE (6,60) ERROR                                                SGA17400
      WRITE (6,70)                                                      SGA17500
      WRITE (6,100) ID,IDA                                              SGA17600
      WRITE (6,730)                                                     SGA17700
C                                                                       SGA17800
      ICHECK=1                                                          SGA17900
C   READ MAXIMUM WIND VELOCITY AND BOTTOM FRICTION FACTOR.              SGA18000
  160 READ (5,170) WX,BFF,ID                                            SGA18100
  170 FORMAT (2F7.1,61X,A5)                                             SGA18200
      IF (ID.EQ.5HPAR 4) GO TO 180                                      SGA18300
C                                                                       SGA18400
C   ERROR MESSAGE 02 WRITTEN                                            SGA18500
      IDA=4                                                             SGA18600
      WRITE (6,730)                                                     SGA18700
      ERROR=2H02                                                        SGA18800
      WRITE (6,50)                                                      SGA18900
      WRITE (6,60) ERROR                                                SGA19000
      WRITE (6,70)                                                      SGA19100
      WRITE (6,100) ID,IDA                                              SGA19200
      WRITE (6,730)                                                     SGA19300
C                                                                       SGA19400
      ICHECK=1                                                          SGA19500
C   READ DISTANCE VALUES AND CHECK IDENTIFICATION DATA.                 SGA19600
  180 NC=1                                                              SGA19700
      IB=1                                                              SGA19800
  190 IE=IB+5                                                           SGA19900
      IF (IE.GE.LM) IE=LM                                               SGA20000
      READ (5,240) ID,NN,(DIST(L),L=IB,IE)                              SGA20100
      IF (ID.EQ.6HDIST  .AND.NN.EQ.NC) GO TO 210                        SGA20200
C                                                                       SGA20300
C   ERROR MESSAGE 03 WRITTEN                                            SGA20400
      WRITE (6,730)                                                     SGA20500
      ERROR=2H03                                                        SGA20600
      WRITE (6,50)                                                      SGA20700
      WRITE (6,60) ERROR                                                SGA20800
      WRITE (6,70)                                                      SGA20900
      WRITE (6,200) ID,NN                                               SGA21000
  200 FORMAT (23H ID IN ERROR * ID GIVEN,1X,A6,/,20H ID SHOULD BE DIST  SGA21100
     2,12HCARD NUMBER ,I5)                                              SGA21200
      WRITE (6,730)                                                     SGA21300
C                                                                       SGA21400
      ICHECK=1                                                          SGA21500
  210 IF (IE.GE.LM) GO TO 220                                           SGA21600
      IB=IB+6                                                           SGA21700
      NC=NC+1                                                           SGA21800
      GO TO 190                                                         SGA21900
C   READ DEPTH VALUES AND CHECK IDENTICATION DATA.                      SGA22000
  220 IB=1                                                              SGA22100
      NC=1                                                              SGA22200
  230 IE=IB+5                                                           SGA22300
      IF (IE.GE.LM) IE=LM                                               SGA22400
      READ (5,240) ID,NN,(D(L),L=IB,IE)                                 SGA22500
  240 FORMAT (A6,4X,I5,5X,6F10.2)                                       SGA22600
      IF (ID.EQ.6HDEPTH .AND.NN.EQ.NC) GO TO 260                        SGA22700
C                                                                       SGA22800
C   ERROR MESSAGE 04 WRITTEN                                            SGA22900
      WRITE (6,730)                                                     SGA23000
      ERROR=2H04                                                        SGA23100
      WRITE (6,50)                                                      SGA23200
      WRITE (6,60) ERROR                                                SGA23300
      WRITE (6,70)                                                      SGA23400
      WRITE (6,250) ID,NN                                               SGA23500
  250 FORMAT (23H ID IN ERROR * ID GIVEN,1X,A6,/,20H ID SHOULD BE DEPTH SGA23600
     2,12HCARD NUMBER ,I5)                                              SGA23700
      WRITE (6,730)                                                     SGA23800
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C                                                                       SGA23900
      ICHECK=1                                                          SGA24000
260   IF (IF.GE.LM) GO TO 270                                           SGA24100
      IB=IB+6                                                           SGA24200
      NC=NC+1                                                           SGA24300
      GO TO 230                                                         SGA24400
C                                                                       SGA24500
C                                                                       SGA24600
270   REWIND 38                                                         SGA24700
C   INITIALIZE SENTINEL ITPP AND INDEX VARIABLE NTP                     SGA24800
      ITPP=0                                                            SGA24900
      NTP=LM+1                                                          SGA25000
      DO 590 N=1,NM                                                     SGA25100
C   READ TIME INCREMENT, ASTRO TIDE, AZIMUTH TRAVERSE, AND AZIMUTH RS(1)SGA25200
      READ (5,320) IHUR,NN,LX,DELT(N),SA(N),ALPHA,BETA0                 SGA25300
C   WHEN ISKIP = 1 OR 2 ORIGINAL WIND FIELD INPUT DATA ARE NOT PRINTED  SGA25400
      IF (ISKIP.EQ.1.OR.ISKIP.EQ.2) GO TO 300                           SGA25500
C   PRINT HEADING, TIME INCREMENT, ASTRO TIDE, AZIMUTH TRAVERSE, AND    SGA25600
C   AZIMUTH RS(1)                                                       SGA25700
      WRITE (6,280)                                                     SGA25800
280   FORMAT (/,16X,7HDELT(N),4X,5HSA(N),4X,5HALPHA,5X,5HBETA0,/)       SGA25900
      WRITE (6,290) IHUR,NN,LX,DELT(N),SA(N),ALPHA,BETA0                SGA26000
290   FORMAT (1X,A3,I2,I5,4F10.1)                                       SGA26100
C   CHECK IDENTIFICATION.                                               SGA26200
300   IF (IHUR.EQ.ITYPE.AND.NN.EQ.N) GO TO 310                          SGA26300
C                                                                       SGA26400
C    IDENTIFICATION ERROR MESSAGE 05 WRITTEN                            SGA26500
      WRITE (6,730)                                                     SGA26600
      ERROR=2H05                                                        SGA26700
      WRITE (6,50)                                                      SGA26800
      WRITE (6,60) ERROR                                                SGA26900
      WRITE (6,70)                                                      SGA27000
      WRITE (6,330) IHUR,NN,LX                                          SGA27100
      WRITE (6,340) ITYPE,N                                             SGA27200
      WRITE (6,730)                                                     SGA27300
C                                                                       SGA27400
      ICHECK=1                                                          SGA27500
C                                                                       SGA27600
C                                                                       SGA27700
310   DO 520 L=1,LM                                                     SGA27800
C   READ RADII, MAGNITUDES, AND ANGLES FOR WIND FOR SUBSEQUENT TIMES,   SGA27900
      READ (5,320) IHUR,NN,LX,RS(L),W(L),T(L)                           SGA28000
320   FORMAT (A3,I2,I5,4F10.1)                                          SGA28100
C   CHECK IDENTIFICATION DATA,                                          SGA28200
      IF (IHUR.EQ.ITYPE.AND.NN.EQ.N.AND.LX.EQ.L) GO TO 350              SGA28300
C                                                                       SGA28400
C                                                                       SGA28500
C    IDENTIFICATION ERROR MESSAGE 05 WRITTEN                            SGA28600
      WRITE (6,730)                                                     SGA28700
      ERROR=2H05                                                        SGA28800
      WRITE (6,50)                                                      SGA28900
      WRITE (6,60) ERROR                                                SGA29000
      WRITE (6,70)                                                      SGA29100
      WRITE (6,330) IHUR,NN,LX,RS(L),W(L),T(L)                          SGA29200
330   FORMAT (25X,18HTHIS CARD IN ERROR,2X,A3,I2,I5,3F10.1)             SGA29300
      WRITE (6,340) ITYPE,N,L                                           SGA29400
340   FORMAT (1X,42HTHESE VALUES SHOULD AGREE WITH THOSE ABOVE,2X,A3,I2,SGA29500
     2I5)                                                               SGA29600
      WRITE (6,730)                                                     SGA29700
C                                                                       SGA29800
      ICHECK=1                                                          SGA29900
C   CHECK IS MADE TO SEE IF ERRORS WERE ENCOUNTERED IN INPUT DATA       SGA30000
      IF (ICHECK.EQ.1) GO TO 1030                                       SGA30100
C                                                                       SGA30200
350   IF (RS(L).GT..00001) GO TO 510                                    SGA30300
C                                                                       SGA30400
C   THE FOLLOWING STEPS PERFORM INTERPOLATION OF RS                     SGA30500
C   WHEN INTERPOLATION PROCEDURE FOR RS IS USED, WIND DATA (RS,W,T)     SGA30600
C   MUST BE SUPPLIED IN AN ORDER BEGINNING WITH SHOREWARD MOST POINT    SGA30700
C   AND ENDING WITH SEAWARD MOST POINT FOR EACH TIME PERIOD.            SGA30800
C                                                                       SGA30900
C                                                                       SGA31000
C                TO COMPUTE RS GIVEN AZIMUTHS IN DEGREES OF THE TRAVERSESGA31100
C     AND AZIMUTH IN DEGREES OF THE LINE CONNECTING THE STORM CENTER    SGA31200
C     TO THE SHORE INTERSECTION OF THE TRAVERSE                         SGA31300
C     AB= CALCULATED ANGLE BETWEEN THE TRAVERSE AND INITIAL STORM       SGA31400
C         CENTER LINE (RS(1))                                           SGA31500
C     ALPHA = AZIMUTH OF THE TRAVERSE (DEGREES)                         SGA31600
C     RS(1)  = DISTANCE (N.M.) FROM STORM CENTER TO SHORE INTERSECTION  SGA31700
C           OF THE TRAVERSE                                             SGA31800
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C                                                                       SGA31900
C     BETAO = AZIMUTH OF THE STORM CENTER LINE (RS(1)) (DEGREES)        SGA32000
      ITPP=1                                                            SGA32100
C                                                                       SGA32200
C    CHECK IS MADE TO SEE WHAT QUADRANT  ANGLES ALPHA AND BETAO ARE     SGA32300
C    LOCATED.  ANGLE AB IS CALCULATED AND CONVERTED TO RADIANS.         SGA32400
C    THIS CONVERTION IS DONE BECAUSE THE ARGUMENTS OF TRIG FUNCTIONS    SGA32500
C    FOR COMPUTER CALCULATION MUST BE IN RADIANS.                       SGA32600
C                                                                       SGA32700
C                                                                       SGA32800
      IF (BETAO.LT.0.OR.ALPHA.LT.0.) GO TO 360                          SGA32900
      IF (BETAO.GT.360.OR.ALPHA.GT.360.) GO TO 360                      SGA33000
      GO TO 380                                                         SGA33100
C                                                                       SGA33200
C    ERROR MESSAGE 06 WRITTEN                                           SGA33300
360   WRITE (6,730)                                                     SGA33400
      ERROR=2H06                                                        SGA33500
      WRITE (6,60) ERROR                                                SGA33600
      WRITE (6,70)                                                      SGA33700
      WRITE (6,370) ALPHA,BETAO                                         SGA33800
370   FORMAT (//,1X,89HTHE AZIMUTHS ALPHA AND BETAO CANNOT BE GREATER THSGA33900
     2AN 360 DEGREES OR BE LESS THAN 0 DEGREES,/,30X,17HALPHA GIVEN WAS SGA34000
     3=,F10.1,2X,17HBETAO GIVEN WAS =,F10.1)                            SGA34100
      WRITE (6,730)                                                     SGA34200
C                                                                       SGA34300
      GO TO 1030                                                        SGA34400
380   IF (ALPHA.GT.180.) GO TO 420                                      SGA34500
      IF (BETAO.GT.90.) GO TO 400                                       SGA34600
390   AB=(BETAO-ALPHA+180.)*PI/180.                                     SGA34700
      GO TO 480                                                         SGA34800
400   IF (BETAO.GT.ALPHA) GO TO 410                                     SGA34900
      GO TO 390                                                         SGA35000
410   AB=(ALPHA-BETAO+180.)*PI/180.                                     SGA35100
      GO TO 480                                                         SGA35200
420   IF (BETAO.GT.ALPHA) GO TO 440                                     SGA35300
      IF (BETAO.GT.90.) GO TO 430                                       SGA35400
      IF ((ALPHA-180.).GT.BETAO) GO TO 470                              SGA35500
      AB=(BETAO-ALPHA-180.)*PI/180.                                     SGA35600
      GO TO 480                                                         SGA35700
430   IF (BETAO.LT.180.) GO TO 390                                      SGA35800
      IF (BETAO.LT.270.) GO TO 390                                      SGA35900
440   IF (BETAO.GT.270.) GO TO 450                                      SGA36000
      IF (BETAO.LT.90.) GO TO 460                                       SGA36100
      GO TO 410                                                         SGA36200
450   BETAO=BETAO-180.                                                  SGA36300
      AB=(ALPHA+BETAO-180.)*PI/180.                                     SGA36400
      GO TO 480                                                         SGA36500
460   AB=(ALPHA-BETAO-180.)*PI/180.                                     SGA36600
      GO TO 480                                                         SGA36700
470   AB=(ALPHA-BETAO-180.)*PI/180.                                     SGA36800
C    THE EQUATION AT STATEMENT 480 IS OF THE BASIC FORM                 SGA36900
C            C=(A**2+B**2-2*A*B*COS(CC))**.5                            SGA37000
C                                                                       SGA37100
C                   LAW OF COSINES                                      SGA37200
C                                                                       SGA37300
480   RS(L)=(DIST(NTP-L)**2.+RS(1)**2.-2.*DIST(NTP-L)*RS(1)*COS(AB))**.5SGA37400
C    WHEN ISKIP = 1 OR 2 COMPUTATIONAL AND RELATED INTERMEDIATE INPUT   SGA37500
C    DATA ARE NOT PRINTED                                               SGA37600
      IF (ISKIP.EQ.1.OR.ISKIP.EQ.2) GO TO 510                           SGA37700
      FUD=COS(AB)                                                       SGA37800
      IF (L.EQ.2) WRITE (6,490)                                         SGA37900
490   FORMAT (/,11X,1HL,5X,4HDIST,5X,5HRS(1),8X,3HFUD,4X,5HRS(L),/)     SGA38000
      WRITE (6,500) NTP,L,DIST(NTP-L),RS(1),FUD,RS(L)                   SGA38100
500   FORMAT (2X,2I5,4F10.3)                                            SGA38200
510   T(L)=PI*T(L)/180.                                                 SGA38300
520   CONTINUE                                                          SGA38400
C                                                                       SGA38500
      IF (ITPP.EQ.0) GO TO 550                                          SGA38600
C                                                                       SGA38700
C    RE-ORDERS DATA SO MOST SEAWARD POINT IS FIRST AND MOST LANDWARD    SGA38800
C    POINT IS LAST.                                                     SGA38900
C                                                                       SGA39000
      DO 530 L=1,LM                                                     SGA39100
      VX(L)=RS(L)                                                       SGA39200
      VX(500+L)=W(L)                                                    SGA39300
      VX(1000+L)=T(L)                                                   SGA39400
530   CONTINUE                                                          SGA39500
C                                                                       SGA39600
      DO 540 L=1,LM                                                     SGA39700
      RS(L)=VX(NTP-L)                                                   SGA39800
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      W(L)=VX(500+NTP-L)                                                SGA39900
      T(L)=VX(1000+NTP-L)                                               SGA40000
540   CONTINUE                                                          SGA40100
C                                                                       SGA40200
C   WHEN ISKIP = 2 WIND FIELD DATA IN FINAL FORM ARE NOT PRINTED        SGA40300
550   IF (ISKIP.EQ.2) GO TO 580                                         SGA40400
      DO 570 L=1,LM                                                     SGA40500
      LX=L                                                              SGA40600
      IF (L.EQ.1) WRITE (6,560)                                         SGA40700
560   FORMAT (/,1X,21HACTUAL INPUT OF RS(L),5X,4HW(L),6X,4HT(L),/)      SGA40800
      WRITE (6,290) IHUR,NN,LX,RS(L),W(L),T(L)                          SGA40900
570   CONTINUE                                                          SGA41000
C                                                                       SGA41100
580   WRITE (38) (W(L),RS(L),T(L),L=1,LM)                               SGA41200
C                                                                       SGA41300
590   CONTINUE                                                          SGA41400
C                                                                       SGA41500
C                                                                       SGA41600
      REWIND 38                                                         SGA41700
      REWIND 39                                                         SGA41800
      DO 630 N=1,NM                                                     SGA41900
C                                                                       SGA42000
      READ (38) (W(L),RS(L),T(L),L=1,LM)                                SGA42100
C                                                                       SGA42200
      DO 610 L=1,LM                                                     SGA42300
      SP(L)=1.14*(PN-PO)*(1.0-EXP(-R/RS(L)))                            SGA42400
      WSQ=W(L)*W(L)                                                     SGA42500
      WWX(L)=WSQ*COS(T(L))                                              SGA42600
      WWY(L)=WSQ*SIN(T(L))                                              SGA42700
C   VAN DORN\S WIND STRESS COEFFICIENT IS DETERMINED.                   SGA42800
      IF (W(L).LE.16.0) GO TO 600                                       SGA42900
      WK(L)=0.0000011+0.0000025*(1.0-16.0/W(L))**2                      SGA43000
      GO TO 610                                                         SGA43100
600   WK(L)=0.0000011                                                   SGA43200
610   CONTINUE                                                          SGA43300
      DO 620 LL=1,LMM                                                   SGA43400
      WRITE (39) WWX(LL+1),WWX(LL),WWY(LL+1),WWY(LL),SA(N),SP(LL+1),SP(LSGA43500
     2L),WK(LL)                                                         SGA43600
620   CONTINUE                                                          SGA43700
630   CONTINUE                                                          SGA43800
      WRITE (6,640)                                                     SGA43900
C  THE BASIC INFORMATION OF THE STORM PROBLEM IS WRITTEN OUT.           SGA44000
640   FORMAT (1H1,30X,52HQUASI-TWO-DIMENSIONAL OPEN COAST STORM SURGE PRSGA44100
     2OGRAM///)                                                         SGA44200
      WRITE (6,10) (A(I),I=1,20)                                        SGA44300
      WRITE (6,650)                                                     SGA44400
650   FORMAT (54X,10HINPUT DATA,/,54X,10H----- ----,///)                SGA44500
      WRITE (6,660) ITYPE                                               SGA44600
660   FORMAT (/,29X,46HFIRST THREE LETTERS OF HURRICANE NAME (ITYPE) ,A3SGA44700
     2,/,75X,3H---//)                                                   SGA44800
      WRITE (6,670) PO,PN,R,WX,VF,SE,BFF,WKCOR                          SGA44900
670   FORMAT (6X,24HCENTRAL PRESSURE (PO) = ,F5.2,8H IN. HG.,17X,27HPERISGA45000
     2PHERAL PRESSURE (PN) = ,F5.2,8H IN. HG.//,1X,29HRADIUS TO MAXIMUM SGA45100
     3WIND (R) = ,F4.1,5H N.M.,28X,20HMAXIMUM WIND (WX) = ,F5.1,7H MI/HRSGA45200
     4.,//,5X,25HTRANSLATION SPEED (VF )= ,F4.1,6H KNOTS,27X,20HINITIAL SGA45300
     5RISE (SE) = ,F4.2,5H FEET,//,1X,31HBOTTOM FRICTION FACTOR (BFF) = SGA45400
     6,F6.4,9X,40HWIND STRESS CORRECTION FACTOR (WKCOR) = ,F4.2,/)      SGA45500
      WRITE (6,680) PHII,BEAR                                           SGA45600
680   FORMAT (1X,29HGEOGRAPHICAL LATITUDE(PHII) =,F10.2,21X,26HTRAVERSE SGA45700
     2BEARING (BEAR) = ,2A5,///)                                        SGA45800
      WRITE (6,690)                                                     SGA45900
690   FORMAT (40X,41HBOTTOM PROFILE OVER THE CONTINENTAL SHELF,//,46X,13SGA46000
     2HDISTANCE FROM,8X,5HDEPTH,/,47X,12HSHORE (N.M.),8X,6H(FEET))      SGA46100
      DO 710 L=1,LM                                                     SGA46200
      WRITE (6,700) DIST(L),D(L)                                        SGA46300
700   FORMAT (49X,F6.2,9X,F5.1)                                         SGA46400
710   CONTINUE                                                          SGA46500
      WRITE (6,720) ISKIP,IOMIT,IOMITD                                  SGA46600
720   FORMAT (//,10X,24HINPUT AND OUTPUT CONTROL,/,10X,24(1H-),//,1X,7HISGA46700
     2SKIP =,I5,67H  0 = ALL WIND FIELD DATA BEFORE AND AFTER INTERPOLATSGA46800
     3ION IS PRINTED,/,15X,57H1 = WIND FIELD DATA USED FOR INTERPOLATIONSGA46900
     4 IS NOT PRINTED/,15X,35H2 = ALL WIND FIELD DATA NOT PRINTED//,1X,7SGA47000
     5HIOMIT =,I5,3X,21H0 = DETAILED PRINTING,/,1X,8HIOMITD =,I5,2X,26H1SGA47100
     6 = SKIP DETAILED PRINTING,//)                                     SGA47200
      REWIND 39                                                         SGA47300
      TII=0.0                                                           SGA47400
      IF (IOMITD.EQ.1) GO TO 790                                        SGA47500
C  IF IOMITD NOT EQUAL 1, INPUT COMPUTATIONAL DATA PRINTED OUT.         SGA47600
      DO 780 N=1,NM                                                     SGA47700
      WRITE (6,730)                                                     SGA47800
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730   FORMAT (///,1X,119H***********************************************SGA47900
     2******************************************************************SGA48000
     3******)                                                           SGA48100
      TI=TII                                                            SGA48200
      TII=TI+DELT(N)                                                    SGA48300
      WRITE (6,740) TI,TII                                              SGA48400
740   FORMAT (1X,/1X11HTIME (T) = ,F6.2,6X,16HTIME (T+DELT) = ,F6.2,//) SGA48500
      WRITE (6,750)                                                     SGA48600
750   FORMAT (10X,8HWWX(I+1),7X,6HWWX(I),7X,8HWWY(I+1),8X,6HWWY(I),5X,11SGA48700
     2HASTRO. TIDE,4X,7HSP(I+1),8X,5HSP(I),5X11HWIND STRESS,/,67X,6H(FEESGA48800
     3T),9X,4H(FT),10X,4H(FT),6X,9HPARAMETER,//)                        SGA48900
      DO 770 LL=1,LMM                                                   SGA49000
      READ (39) WWX(LL+1),WWX(LL),WWY(LL+1),WWY(LL),SA(N),SP(LL+1),SP(LLSGA49100
     2),WK(LL)                                                          SGA49200
      WRITE (6,760) WWX(LL+1),WWX(LL),WWY(LL+1),WWY(LL),SA(N),SP(LL+1),SSGA49300
     2P(LL),WK(LL)                                                      SGA49400
760   FORMAT (10X,F7.1,8X,F7.1,7X,F7.1,8X,F7.1,7X,F4.2,10X,F4.2,10X,F4.2SGA49500
     2,5X,F10.8)                                                        SGA49600
770   CONTINUE                                                          SGA49700
780   CONTINUF                                                          SGA49800
C   DUMMY CONTINUF                                                      SGA49900
790   CONTINUF                                                          SGA50000
      REWIND 39                                                         SGA50100
      WRITE (6,800)                                                     SGA50200
      IF (IOMIT.EQ.1) GO TO 820                                         SGA50300
800   FORMAT (1H1)                                                      SGA50400
      WRITE (6,810)                                                     SGA50500
810   FORMAT (54X,11HOUTPUT DATA,/,54X,11H------ ----,///)              SGA50600
      WRITE (6,660) ITYPE                                               SGA50700
      WRITE (6,670) PO,PN,R,WX,VF,SE,BFF,WKCOR                          SGA50800
      WRITE (6,680) PHII,BEAR                                           SGA50900
C   DUMMY CONTINUE                                                      SGA51000
820   CONTINUF                                                          SGA51100
      DO 830 L=1,LMM                                                    SGA51200
C  INCREMFNTAL X-VALUFS AND AVG. DEPTHS ARE COMPUTED.                   SGA51300
      DFLX(L)=DIST(L)-DIST(L+1)                                         SGA51400
      DAVG(L)=(D(L)+D(L+1))/2.0                                         SGA51500
830   CONTINUE                                                          SGA51600
      DO 840 L=1,LM                                                     SGA51700
      PHI(L)=(PHI(L)*PI)/180.0                                          SGA51800
C  THF SINF OF THE LATITUDE IS FVALUATED.                               SGA51900
      SINPHI(L)=SIN(PHI(L))                                             SGA52000
840   CONTINUF                                                          SGA52100
      TII=0.0                                                           SGA52200
      DO 970 N=1,NM                                                     SGA52300
      IF (IOMIT.EQ.1) GO TO 850                                         SGA52400
      WRITE (6,800)                                                     SGA52500
C   DUMMY CONTINUE                                                      SGA52600
850   CONTINUF                                                          SGA52700
      SUMSX=0.0                                                         SGA52800
      SUMSY=0.0                                                         SGA52900
      IF (IOMIT.EQ.1) GO TO 870                                         SGA53000
      TI=TII                                                            SGA53100
      TII=TI+DELT(N)                                                    SGA53200
      WRITE (6,740) TT,TII                                              SGA53300
      WRITE (6,860)                                                     SGA53400
860   FORMAT (1X,5HDIST.,3X,5HDEPTH,5X,6HD AVG.,3X,9HPRES.RISE,2X,10HASTSGA53500
     2RO.TIDE,3X,7HINITIAL,5X,6HY-FLUX,5X,7HONSHORE,4X,10HALONGSHORE,2X,SGA53600
     310HTOTAL WIND,3X,5HTOTAL,/,1X,4H(NM),3X,8H(FT.MLW),2X,8H(FT.MLW),4SGA53700
     4X,4H(FT),7X,4H(FT),6X,10HLEVEL(FT),1X,11H(FT*FT/SEC),1X,10HSETUP (SGA53800
     5FT),2X,10HSETUP (FT),2X,10HSETUP (FT),2X,10HSURGE (FT),//)        SGA53900
C   DUMMY CONTINUE                                                      SGA54000
870   CONTINUE                                                          SGA54100
      DO 950 L=1,LMM                                                    SGA54200
C  STORM SURGF COMPUTATIONS BEGIN.                                      SGA54300
      READ (39) WWX(L+1),WWX(L),WWY(L+1),WWY(L),SA(N),SP(L+1),SP(L),WK(LSGA54400
     2)                                                                 SGA54500
      AN=WK(L)*(WWX(L)+WWX(L+1))*WKCOR                                  SGA54600
      BN=WK(L)*(WWY(L)+WWY(L+1))*0.5*WKCOR                              SGA54700
      SPN=(SP(L)+SP(L+1))/2.0                                           SGA54800
      IF (N.NF.1) GO TO 880                                             SGA54900
C  PROBLFM IS INIALIZED FOR FIRST TIMF LEVEL.                           SGA55000
      SXP(L)=0.0                                                        SGA55100
      SYP(L)=0.0                                                        SGA55200
      SPP(L)=SPN                                                        SGA55300
      VP(L)=0.0                                                         SGA55400
      HP(L)=BN                                                          SGA55500
      SAP=SA(N)                                                         SGA55600
880   DTS=DAVG(L)+SE+SXP(L)+SYP(L)                                      SGA55700
      DTN=DTS+SA(N)+SPN                                                 SGA55800
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      DTH=DTS+((SA(N)+SAP)/2.0)+((SPP(L)+SPN)/2.0)
      DASQ=(C3/DTH)**2
      DEN=BFF*ABS(VP(L))*DELT(N)*DASQ
      VN=((BN+BP(L))*DELT(N)*0.5+VP(L))/(1.0+DEN)
      BY=ABS(BN)
      VNTEST=SQRT(BY/(BFF*DASQ))
      VNN=ABS(VN)
C  A CHECK IS MADE TO INSURE THAT THE ALONGSHORE DOES NOT EXCEED THE
C     LIMITING VALUE.
      IF (VNTEST.GT.VNN) GO TO 910
      IF (VN) 890,900,900
890   VN=-VNTEST
      GO TO 910
900   VN=VNTEST
910   DELSYN=(C2*DELX(L)*(SINPHI(L)+SINPHI(L+1))*VN)/DTN
      DELSXN=(C1*DELX(L)*AN)/DTN
      SUMSX=SUMSX+DELSXN
      SUMSY=SUMSY+DELSYN
      VS=7744.0*VN
      ST=SA(N)+SE+SUMSX+SUMSY+SPN
      SW=SUMSX+SUMSY
      IF (IOMIT.EQ.1) GO TO 940
C  IF IOMIT NOT EQUAL 1, OUTPUT RESULTS ARE PRINTED OUT IN DETAIL FOR
C     EACH TIME LEVEL.
      WRITE (6,920) DIST(L),D(L)
920   FORMAT (1X,F5.1,5X,F5.1)
      WRITE (6,930) DAVG(L),SPN,SA(N),SE,VS,SUMSX,SUMSY,SW,ST
930   FORMAT (21X,F5.1,5X,F4.2,8X,F4.2,7X,F4.2,8X,F7.1,5X,F6.3,6X,F7.3,6
     2X,F6.3,5X,F5.2)
940   SXP(L)=SUMSX
      SYP(L)=SUMSY
      SPP(L)=SPN
      VP(L)=VN
      BP(L)=BN
950   CONTINUE
      IF (IOMIT.EQ.1) GO TO 960
      WRITE (6,920) DIST(LM),D(LM)
C  NEW VALUES ARE SET EQUAL TO PREVIOUS VALUES.
960   SX(N)=SUMSX
      SY(N)=SUMSY
      SWW(N)=SW
      SPRES(N)=SPN
      STOT(N)=ST
      SAP=SA(N)
970   CONTINUE
      K=1
C   DUMMY CONTINUE
980   CONTINUE
      WRITE (6,800)
      WRITE (6,990)
C  THE RESULTS ARE SUMMARIZED FOR ALL TIME LEVELS.
990   FORMAT (38X,41HSUMMARY OF OPEN COAST STORM SURGE PROBLEM,///)
      WRITE (6,10) (A(I),I=1,20)
      WRITE (6,660) ITYPE
      WRITE (6,670) PO,PN,R,WX,VF,SE,BFF,WKCOR
      WRITE (6,680) PHIT,BEAR
      WRITE (6,1000)
1000  FORMAT (,///,2X,4HTIME,6X,5HSETUP,5X,5HSETUP,4X,9HTOT. WIND,3X,9HA
     2ST. TIDE,3X,13HINITIAL WATER,4X,8HPRESSURE,3X,11HTOTAL WATER,/,1X,
     37H(HOURS),3X,7HX-COMP.,3X,7HY-COMP.,4X,5HSETUP,7X,5HLEVEL,9X,5HLEV
     4EL,10X,5HSETUP,7X,5HLEVEL,/,12X,5H(FT.),5X,5H(FT.),5X,5H(FT.),6X,9
     5H(FT. MLW),6X,5H(FT.),10X,9H(FT.),6X,9H(FT. MLW),//)
C
      AHOUR=0.0
      DO 1020 N=1,NM
      AHOUR=AHOUR+DELT(N)
      WRITE (6,1010) AHOUR,SX(N),SY(N),SWW(N),SA(N),SE,SPRES(N),STOT(N)
1010  FORMAT (2X,F6.2,,5X,F6.2,4X,F6.2,4X,F6.2,6X,F6.2,8X,F6.2,9X,F6.2,7
     2X,F6.2)
1020  CONTINUE
      IF (K.EQ.3) GO TO 1040
      K=K+1
      GO TO 980
C   IF STOP APPEARS IN DAYFILE AN ERROR WAS ENCOUNTERED
1030  STOP
C   IF STOP 00000 APPEARS IN DAYFILE PROGRAM TERMINATED PROPERLY
C   AND OUTPUT WAS GENERATED.
1040  STOP 00000
      END
```

APPENDIX A-2. PROGRAM LISTINGS FOR HYPOTHETICAL HURRICANES

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      PROGRAM SURGE(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE39,TAPE4) SRG00100
C     752X6R1590 (SURGE) COMPUTES STORM SURGE BY BATHYSTROPHIC METHOD   SRG00200
C                  QUASI-TWO-DIMENSIONAL OPEN COAST STORM SURGE PROGRAM SRG00300
C                                                                       SRG00400
C **************************************                                SRG00500
C **(SURGE FOR HYPOTHETICAL HURRICANE)**                                SRG00600
C **************************************                                SRG00700
C                                                                       SRG00800
C      *****REVISIONS*****                                              SRG00900
C                                                                       SRG01000
C     ALL REVISIONS SHOULD BE LISTED BELOW BY ADDING A COMMENT CARD     SRG01100
C     SIMILAR TO THE FIRST REVISION (0).                                SRG01200
C     0 IN COLUMN 80 INDICATES INITIAL REVISION.                        SRG01300
C     A TO Z IN COLUMN 80 INDICATES SUBSEQUENT REVISIONS.               SRG01400
C                                                                       SRG01500
C     REVISION   DATE       NAME OF INDIVIDUAL RESPONSIBLE FOR REVISION SRG01600
C                                                                       SRG01700
C        0      4-29-74     HAROLD D. MCCLUNG                           SRG01800
C        A                                                              SRG01900
C        B                                                              SRG02000
C        C                                                              SRG02100
C        D                                                              SRG02200
C        E                                                              SRG02300
C        F                                                              SRG02400
C        G                                                              SRG02500
C                                                                       SRG02600
C    NOTATION USED IN ALPHABETICAL ORDER<                               SRG02700
C   AHOUR = VARIABLE USED TO ESTABLISH STORM TIME.                      SRG02800
C      AN = INTERMEDIATE VALUE OF WIND STRESS AND SETUP FOR X-COMPONENT.SRG02900
C    BEAR = BEARING OF TRAVERSE IN DEGREES. DOES NOT ENTER COMPUTATIONS.SRG03000
C     BFF = BOTTOM FRICTION FACTOR.                                     SRG03100
C      BN = INTERMEDIATE VALUE OF WIND STRESS AND SETUP FOR Y-COMPONENT.SRG03200
C      BP = AN ARRAY USED TO STORE SUCESSIVE VALUES OF BN.              SRG03300
C      BY = ABSOLUTE VALUE OF BN.                                       SRG03400
CC1,C2,C3 = DIMENSION CORRECTION FACTORS.                               SRG03500
C       D = DEPTH BELOW MEAN WATER LEVEL IN FEET.                       SRG03600
C    DASQ = TOTAL WATER DEPTH SQUARED AT EACH TIME LEVEL.               SRG03700
C    DAVG = AVERAGE BOTTOM DEPTH AT EACH TIME LEVEL.                    SRG03800
C  DELSXN = INCREMENTAL X-COMP SETUP IN FEET.                           SRG03900
C  DELSYN = INCREMENTAL Y-COMP SETUP IN FEET.                           SRG04000
C    DELT = TIME INCREMENTS IN HOURS.                                   SRG04100
C   DELTT = TIME INCREMENT USED FOR COMPUTATIONS.                       SRG04200
C    DELX = DIFFERENCE BETWEEN TRAVERSE DISTANCES AT EACH TIME LEVEL.   SRG04300
C     DEN = INTERMEDIATE COMPUTATION FOR DENOMINATOR OF FLUX EQUATION   SRG04400
C           AT EACH TIME LEVEL                                          SRG04500
C    DIST = DISTANCE FROM COAST IN N.M.                                 SRG04600
C   DIST(1) AND DEPTH(1) ARE FARTHEST POINTS FROM SHORE WITH            SRG04700
C   SUCESSIVE VALUES TAKEN SHOREWARD OF THESE POINTS                    SRG04800
C   DISTO = INITIAL DISTANCE ALONG TRAVERSE LINE TO POINT OF MAXIMUM    SRG04900
C           WIND VELOCITY.                                              SRG05000
C     DTH = TOTAL WATER DEPTH AT EACH TIME LEVEL (FEET).                SRG05100
C     DTN = INTERMEDIATE COMPUTATION OF WATER DEPTH                     SRG05200
C     DTS = INTERMEDIATE COMPUTATION OF TOTAL WATER DEPTH (DTH)         SRG05300
C       E = PARAMETER USED TO CHECK CONVERGENCE                         SRG05400
C      EE = PARAMETER USED TO CHECK CONVERGENCE                         SRG05500
C  ICHECK = SENTINEL USED TO INDICATE ERRORS.                           SRG05600
C      ID = IDENTIFIES TYPE OF DATA ON CARD.                            SRG05700
C   IDATA = IDENTIFIES TYPE OF WIND DATA SUPPLIED AS INPUT (DESCRIBED   SRG05800
C   IN DETAIL WHEN REFERENCED)                                          SRG05900
C    IDUM = DUMMY VARIABLE NAME                                         SRG06000
C   ILAST = INDICATES NUMBER OF DIFFERENT PARAMETER SETS TO BE READ     SRG06100
C   IOMIT = PRINT OPTION PARAMETER (DESCRIBED IN DETAIL WHEN REFERENCED)SRG06200
C  IOMITD = PRINT OPTION PARAMETER (DESCRIBED IN DETAIL WHEN REFERENCED)SRG06300
C   IREAD = USED TO READ ALL DIGITIZED WIND DATA ONTO DISK STORAGE      SRG06400
C   ITYPE = THE TYPE OF HURRICANE MODEL. (PMH OR SPH)                   SRG06500
C     IVX = INTERPOLATED WIND DATA GENERATED IN SUBROUTINE PROFIL       SRG06600
C   IZONE = HURRICANE ZONE                                              SRG06700
C     KEY = PRINT OPTION FOR SUBROUTINE HRWDPF (DESCRIBED IN DETAIL WHENSRG06800
C   REFERENCED)                                                         SRG06900
C    KEYA = OPTION WHICH DETERMINES WHETHER SUBROUTINE ZERWND IS TO BE  SRG07000
C           CALLED (DESCRIBED IN DETAIL WHEN REFERENCED)                SRG07100
C    LIST = PRINT OPTION FOR SUBROUTINE PROFIL (DESCRIBED IN DETAIL WHENSRG07200
C   REFERENCED)                                                         SRG07300
C      LM = MAX. NO. OF SHELF REACHES.                                  SRG07400
C      NM = MAX. NO. OF TIME INCREMENTS.                                SRG07500
C      NN = CARD NUMBER READ FROM CARD                                  SRG07600
C    NPTS = THE NUMBER OF POINTS ALONG THE PMH PROFILE                  SRG07700
C     PHI = GEOGRAPHICAL LATITUDE IN DEGREES GIVEN BY PHII.             SRG07800
C    PHII = GEOGRAPHICAL LATITUDE IN DEGREES SUPPLIED AS INPUT          SRG07900
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C   PHIIA = LATITUDE LIMIT FOR HURRICANE ZONE                           SRG08000
C   PHIIB = LATITUDE LIMIT FOR HURRICANE ZONE                           SRG08100
C      PI = 3.14159                                                     SRG08200
C      PN = PERIPHERAL PRESSUF IN INCHES OF HG.                         SRG08300
C      PO = CENTRAL PRESSURE INCHES OF HG.                              SRG08400
C       R = RADIUS OF MAX. WINDS IN N.M.                                SRG08500
C      RR = RADIUS TO MAXIMUM WIND OF WIND FIELD DATA SUPPLIED AS INPUT SRG08600
C      RS = RADII MEASURES FROM STORM CENTER TO POINT ON TRAVERSE IN NM.SRG08700
C      SA = SETUP DUE TO ASTRONOMICAL FORCES IN FEET.                   SRG08800
C     SAA = VALUE OF ASTRONOMICAL TIDE SUPPLIED AS INPUT                SRG08900
C     SAP = OLD VALUE OF ASTRONOMICAL TIDE                              SRG09000
C      SE = INITIAL SETUP IN FEET.                                      SRG09100
C  SINPHI = SINE OF GEOGRAPHICAL LATITUDE                               SRG09200
C      SP = SETUP DUE TO PRESSURE IN FEET.                              SRG09300
C     SPN = PRESSURE SETUP AT NEW TIME LEVEL.                           SRG09400
C     SPP = PRESSURE SETUP AT PREVIOUS TIME LEVEL.                      SRG09500
C   SPRES = SUCESSIVE VALUES OF PRESSURE SETUP AT EACH TIME LEVEL       SRG09600
C      ST = SUCESSIVE VALUES OF TOTAL SURGE ALONG TRAVERSE LINE         SRG09700
C    STOT = VALUE OF TOTAL SURGE AT SHORE FOR EACH TIME LEVEL.          SRG09800
C   SUMSX = SUCESSIVE VALUES OF X-COMPONENT OF SURGE ALONG TRAVERSE     SRG09900
C           LINE                                                        SRG10000
C   SUMSY = SUCESSIVE VALUES OF Y-COMPONENT OF SURGE ALONG TRAVERSE     SRG10100
C           LINE                                                        SRG10200
C      SW = SUCESSIVE VALUES OF SUMSX + SUMSY ALONG TRAVERSE LINE       SRG10300
C     SWW = SUCESSIVE VALUES OF SW FOR EACH TIME LEVEL AT SHORE         SRG10400
C      SX = TOTAL X-COMP SETUP AT SHORE IN FEET.                        SRG10500
C     SXP = SUCESSIVE VALUES OF SUMSX                                   SRG10600
C      SY = TOTAL Y-COMP SETUP AT SHORE IN FEET.                        SRG10700
C     SYP = SUCESSIVE VALUES OF SUMSY                                   SRG10800
C       T = ANGLE MEASURED FROM THE POSTIVE X-AXIS COUNTER CLOCKWISE TO SRG10900
C           THE WIND VECTOR,(THETA).                                    SRG11000
C      VF = FORWARD SPEED OF STORM IN KNOTS.                            SRG11100
C   VN, VNN, VNTEST, VP AND VS REFER TO Y-COMPONENT OF VOLUME TRANSPORT SRG11200
C      VN = SUCESSIVE VALUES OF FLUX ALONG TRAVERSE LINE                SRG11300
C     VNN = ABSOLUTE VALUE OF FLUX                                      SRG11400
C  VNTEST = CHECK ON VALUE OF FLUX                                      SRG11500
C      VP = FLUX AT PREVIOUS TIME LEVEL                                 SRG11600
C      VS = Y-FLUX (FT*FT/SEC)                                          SRG11700
C      VX = THE VALUES OF RELATIVE WIND VELOCITY ALONG THE              SRG11800
C           AXIS OF SYMMETRY OF THE HURRICANE.                          SRG11900
C   AXIS OF SYMMETRY IS LINE THROUGH STORM CENTER AND RADIUS TO         SRG12000
C   MAX WINDS DRAWEN 115 DEGREES FROM DIRECTION OF FORWARD MOTION       SRG12100
C       W = WIND SPEED IN MPH.                                          SRG12200
C    WIND = ADJUSTED WIND SPEED NEAR SHORE DUE TO INTERFERENCE WITH     SRG12300
C           LAND MASS                                                   SRG12400
C      WK = VAN DORNS WIND STRESS FACTOR.                               SRG12500
C   WKCOR = CORRECTION FACTOR FOR WIND STRESS COEFFICIENT WHICH         SRG12600
C           ADJUSTS STRESS FACTORS UPWARD BY 10 PERCENT.  THIS ADJUSTMENSRG12700
C           PROVIDES FOR MORE ACCURATE ESTIMATE OF ACTUAL SURGE.        SRG12800
C     WSQ = WIND SQUARED                                                SRG12900
C     WWX = W * W * COS(THETA) IN MPH SQ.                               SRG13000
C     WWY = W * W * SIN(THETA) IN MPH SQ.                               SRG13100
C   VARIABLES NOT DEFINED IN THIS ROUTINE WILL BE DEFINED IN ANOTHER    SRG13200
C   ROUTINE                                                             SRG13300
      DIMENSION SP(50),WWX(50),WWY(50),WK(50),D(50),DIST(50),RS(1500),  SRG13400
     2 W(1500),A(20),SA(200),DELT(200),PHI(50),T(1500),DAVG(50),BEAR(2),SRG13500
     3 DELX(50),SX(200),SY(200),SWW(200),SPRES(200),STOT(200),IVX(1600),SRG13600
     4 SINPHI(50),SXP(100),SYP(100),SPP(100),VP(100),BP(100),VX(1600)   SRG13700
      DIMENSION IREAD(16)                                               SRG13800
      COMMON /WND/ W,T,DELT,DIST,VX,RS                                  SRG13900
      COMMON /PAR/ LM,VF,WX,R,DISTO,XP                                  SRG14000
      COMMON /PTS/ NPTS                                                 SRG14100
      COMMON /PFF/ KEY                                                  SRG14200
      COMMON /ATM/ PN,PO                                                SRG14300
      COMMON /TES/ HOMB                                                 SRG14400
C   NPTS IS THE NUMBER OF POINTS ALONG THE PMH PROFILE COMMENCING AT    SRG14500
C   RHO/R = .8, TERMINATING AT RHO/R = 30., SPACED AT INCREMENTS OF .02.SRG14600
C   WARNING.  DO NOT INCREASE NPTS ABOVE  1600 WITOUT INCREASING THE    SRG14700
C   DIMENSION OF VX ACCORDINGLY, OR SOMETHING WILL BE CLOBBERED.        SRG14800
      DATA NPTS,E /1461,.000005/                                        SRG14900
      DATA C1,C2,C3 /203.,.106,.5280./                                  SRG15000
      DATA WKCUR /1.10/                                                 SRG15100
C   READ LOOP PARAMETER AND DATA TYPE PARAMETER                         SRG15200
      READ (5,10) ILAST,IDATA                                           SRG15300
10    FORMAT (2I5)                                                      SRG15400
C   INITIALIZE COUNTER IDUM                                             SRG15500
      IDUM=1                                                            SRG15600
C   CHECK TO SEE IF DATA SUPPLIED IS TO BE INTERPOLATED.                SRG15700
C   IF IDATA = 0 THESE STEPS ARE SKIPPED.                               SRG15800
      IF (IDATA.EQ.0) GO TO 40                                          SRG15900
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C   DATA IS READ IN AND WRITTEN OUT ON DISK REFERENCED BY IDATA         SRG16000
C   (NORMALLY IDATA = 4 WHEN DATA IS TO BE INTERPOLATED)                SRG16100
20    READ (5,30) IREAD                                                 SRG16200
30    FORMAT (16A5)                                                     SRG16300
      WRITE (IDATA,30) IREAD                                            SRG16400
      IF (IREAD(2).EQ.5HFINAL) GO TO 40                                 SRG16500
      GO TO 20                                                          SRG16600
40    WRITE (6,50) IDUM                                                 SRG16700
50    FORMAT (1H1,38(1H*),/,1X,36HTHIS IS THE BEGINNING OF RUN NUMBER ,ISRG16800
     22,/,1X,38(1H*),/)                                                 SRG16900
C                                                                       SRG17000
C  READ STORM IDENTIFICATION TITLE.                                     SRG17100
C                                                                       SRG17200
      READ (5,60) (A(I),I=1,20)                                         SRG17300
60    FORMAT (20A4)                                                     SRG17400
C                                                                       SRG17500
C   READ PARAMETERS AND CHECK IDENTIFICATION DATA.                      SRG17600
C                                                                       SRG17700
C   NOTE.   IDENTIFICATION DATA IS CHECKED ON EACH DATA CARD TO         SRG17800
C   AVOID MISREADING INPUT DATA.                                        SRG17900
C                                                                       SRG18000
      READ (5,70) NM,LM,IOMIT,IOMITD,KEY,KEYA,LIST,ID                   SRG18100
70    FORMAT (2I5,5X,5I5,35X,A5)                                        SRG18200
C                                                                       SRG18300
C     FLAG IS SET                                                       SRG18400
C                                                                       SRG18500
      ICHECK=0                                                          SRG18600
C                                                                       SRG18700
C   CHECK FOR EXCEEDED DIMENSIONS.                                      SRG18800
C                                                                       SRG18900
      IF (NM-200) 80,80,90                                              SRG19000
80    IF (LM-50) 130,130,90                                             SRG19100
90    WRITE (6,690)                                                     SRG19200
      ICHECK=1                                                          SRG19300
C                                                                       SRG19400
C   WRITE ERROR MESSAGE                                                 SRG19500
C                                                                       SRG19600
      WRITE (6,100)                                                     SRG19700
100   FORMAT (50X,13HERROR MESSAGE,///)                                 SRG19800
      WRITE (6,110) NM,LM                                               SRG19900
110   FORMAT (1H ,68HMAX. NO. OF TIME INCREMENTS = 200     MAX. NO. OF SSRG20000
     2HELF REACHES = 50,//,60H THE VALUE OF TIME INCREMENTS OR SHELF REASRG20100
     3CHES WAS TOO LARGE,//,41H YOUR VALUE FOR TIME INCREMENTS(NM) WAS =SRG20200
     4,I5,/,39H YOUR VALUE FOR SHELF REACHES(LM) WAS =,I5,//,1X,8HERROR SRG20300
     501)                                                               SRG20400
      WRITE (6,120)                                                     SRG20500
120   FORMAT (3X,88H SEE ERROR TABLE IN CERC TM TITLE VERIFICATION STUDYSRG20600
     2 OF A BATHYSTROPIC STORM SURGE MODEL)                             SRG20700
      WRITE (6,690)                                                     SRG20800
C                                                                       SRG20900
C   CHECK FOR CARD ID                                                   SRG21000
C                                                                       SRG21100
130   IF (ID.EQ.5HPAR 1) GO TO 150                                      SRG21200
      IDA=1                                                             SRG21300
C                                                                       SRG21400
C   WRITE ERROR MESSAGE                                                 SRG21500
C                                                                       SRG21600
      WRITE (6,690)                                                     SRG21700
      WRITE (6,100)                                                     SRG21800
      WRITE (6,140) ID,IDA                                              SRG21900
140   FORMAT (23H ID IN ERROR * ID GIVEN,1X,A5,/,18H ID SHOULD BE PAR ,ISRG22000
     21,//,1X,8HERROR 02)                                               SRG22100
      WRITE (6,120)                                                     SRG22200
      WRITE (6,690)                                                     SRG22300
      ICHECK=1                                                          SRG22400
C                                                                       SRG22500
150   LMM=LM-1                                                          SRG22600
      PI=3.14159                                                        SRG22700
      READ (5,160) DELTT,PHII,SAA,IZONE,ITYPE,BEAR,ID                   SRG22800
160   FORMAT (3F10.2,8X,A2,7X,A3,2A5,15X,A5)                            SRG22900
C                                                                       SRG23000
C   VERIFY ZONE AND LATITUDE SPECIFICATIONS                             SRG23100
C                                                                       SRG23200
      IF (IZONE.NE.2H 1) GO TO 170                                      SRG23300
      IF (PHII.GE.25.00.AND.PHII.LE.28.00) GO TO 250                    SRG23400
      PHIIA=25.00                                                       SRG23500
      PHIIB=28.00                                                       SRG23600
      GO TO 230                                                         SRG23700
170   IF (IZONE.NE.2H 2) GO TO 180                                      SRG23800
      IF (PHII.GE.28.00.AND.PHII.LE.33.00) GO TO 250                    SRG23900
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      PHIIA=28.00                                                       SRG24000
      PHIIB=33.00                                                       SRG24100
      GO TO 230                                                         SRG24200
180   IF (IZONE.NE.2H 3) GO TO 190                                      SRG24300
      IF (PHII.GE.33.00.AND.PHII.LE.38.00) GO TO 250                    SRG24400
      PHIIA=33.00                                                       SRG24500
      PHIIB=38.00                                                       SRG24600
      GO TO 230                                                         SRG24700
190   IF (IZONE.NE.2H 4) GO TO 200                                      SRG24800
      IF (PHII.GE.38.00.AND.PHII.LE.43.00) GO TO 250                    SRG24900
      PHIIA=38.00                                                       SRG25000
      PHIIB=43.00                                                       SRG25100
      GO TO 230                                                         SRG25200
200   IF (IZONE.NE.2H A.AND.IZONE.NE.2H B.AND.IZONE.NE.2H C) GO TO 210  SRG25300
      IF (PHII.GE.25.00.AND.PHII.LE.31.00) GO TO 250                    SRG25400
      PHIIA=25.00                                                       SRG25500
      PHIIB=31.00                                                       SRG25600
      GO TO 230                                                         SRG25700
210   ICHECK=1                                                          SRG25800
C                                                                       SRG25900
C   WRITE ERROR MESSAGE                                                 SRG26000
C                                                                       SRG26100
      WRITE (6,690)                                                     SRG26200
      WRITE (6,100)                                                     SRG26300
      WRITE (6,220) IZONE                                               SRG26400
220   FORMAT (60H ZONE REQUESTED NOT VALID, VALID ZONES ARE A,B,C,1,2,3 SRG26500
     2AND 4,/,20H YOU REQUESTED ZONE ,A2,//,1X,8HERROR 03)              SRG26600
      WRITE (6,120)                                                     SRG26700
      WRITE (6,690)                                                     SRG26800
      GO TO 250                                                         SRG26900
230   ICHECK=1                                                          SRG27000
C                                                                       SRG27100
C   WRITE ERROR MESSAGE                                                 SRG27200
C                                                                       SRG27300
      WRITE (6,690)                                                     SRG27400
      WRITE (6,100)                                                     SRG27500
      WRITE (6,240) IZONE,PHIIA,PHIIB,PHII                              SRG27600
240   FORMAT (26H LATITUDE LIMITS FOR ZONE ,A2,4H ARE,1X,F5.2,3H TO,1X,FSRG27700
     25.2,8H DEGREES,//,24H YOU REQUESTED LATITUDE ,F6.2,//,1X,8HERROR 0SRG27800
     34)                                                                SRG27900
      WRITE (6,120)                                                     SRG28000
      WRITE (6,690)                                                     SRG28100
C                                                                       SRG28200
C   CHECK FOR CARD ID                                                   SRG28300
C                                                                       SRG28400
250   IF (ID.EQ.5HPAR 2) GO TO 260                                      SRG28500
      IDA=2                                                             SRG28600
C                                                                       SRG28700
C   WRITE ERROR MESSAGE                                                 SRG28800
C                                                                       SRG28900
      WRITE (6,690)                                                     SRG29000
      WRITE (6,100)                                                     SRG29100
      WRITE (6,140) ID,IDA                                              SRG29200
      WRITE (6,120)                                                     SRG29300
      WRITE (6,690)                                                     SRG29400
      ICHECK=1                                                          SRG29500
260   DO 270 I=1,LM                                                     SRG29600
270   PHI(I)=PHII                                                       SRG29700
      DO 280 I=1,NM                                                     SRG29800
      SA(I)=SAA                                                         SRG29900
280   DELT(I)=DELTT                                                     SRG30000
      READ (5,290) R,PO,PN,VF,SE,ID                                     SRG30100
290   FORMAT (5F7.2,40X,A5)                                             SRG30200
C                                                                       SRG30300
C   CHECK FOR CARD ID                                                   SRG30400
C                                                                       SRG30500
      IF (ID.EQ.5HPAR 3) GO TO 300                                      SRG30600
      IDA=3                                                             SRG30700
C                                                                       SRG30800
C   WRITE ERROR MESSAGE                                                 SRG30900
C                                                                       SRG31000
      WRITE (6,690)                                                     SRG31100
      WRITE (6,100)                                                     SRG31200
      WRITE (6,140) ID,IDA                                              SRG31300
      WRITE (6,120)                                                     SRG31400
      WRITE (6,690)                                                     SRG31500
      ICHECK=1                                                          SRG31600
C                                                                       SRG31700
C   READ MAXIMUM WIND VELOCITY AND BOTTOM FRICTION FACTOR.              SRG31800
C                                                                       SRG31900
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  300 READ (5,310) WX,BFF,ID                                            SRG32000
  310 FORMAT (2F7.1,61X,A5)                                             SRG32100
C                                                                       SRG32200
C   CHECK FOR CARD ID                                                   SRG32300
C                                                                       SRG32400
      IF (ID.EQ.5HPAR 4) GO TO 320                                      SRG32500
      IDA=4                                                             SRG32600
C                                                                       SRG32700
C   WRITE ERROR MESSAGE                                                 SRG32800
C                                                                       SRG32900
      WRITE (6,690)                                                     SRG33000
      WRITE (6,100)                                                     SRG33100
      WRITE (6,140) ID,IDA                                              SRG33200
      WRITE (6,120)                                                     SRG33300
      WRITE (6,690)                                                     SRG33400
      ICHECK=1                                                          SRG33500
C                                                                       SRG33600
C   READ DISTANCE VALUES AND CHECK IDENTIFICATION DATA.                 SRG33700
C                                                                       SRG33800
  320 NC=1                                                              SRG33900
      IB=1                                                              SRG34000
  330 IE=IB+5                                                           SRG34100
C                                                                       SRG34200
C   LOOP LENGTH IS CORRECTED                                            SRG34300
C                                                                       SRG34400
      IF (IE.GE.LM) IE=LM                                               SRG34500
      READ (5,380) ID,NN,(DIST(L),L=IB,IE)                              SRG34600
C                                                                       SRG34700
C   CHECK FOR CARD ID AND CARD NUMBER                                   SRG34800
C                                                                       SRG34900
      IF (ID.EQ.6HDIST  .AND.NN.EQ.NC) GO TO 350                        SRG35000
C                                                                       SRG35100
C   WRITE ERROR MESSAGE                                                 SRG35200
C                                                                       SRG35300
      WRITE (6,690)                                                     SRG35400
      WRITE (6,100)                                                     SRG35500
      WRITE (6,340) ID,NN                                               SRG35600
  340 FORMAT (23H ID IN ERROR * ID GIVEN,1X,A6,/,20H ID SHOULD BE DIST  SRG35700
     2,12HCARD NUMBER ,I5,//,1X,8HERROR 05)                             SRG35800
      WRITE (6,120)                                                     SRG35900
      WRITE (6,690)                                                     SRG36000
      ICHECK=1                                                          SRG36100
C                                                                       SRG36200
C   CHECK FOR LAST SHELF REACH DISTANCE                                 SRG36300
C                                                                       SRG36400
  350 IF (IE.GE.LM) GO TO 360                                           SRG36500
      IB=IB+6                                                           SRG36600
      NC=NC+1                                                           SRG36700
      GO TO 330                                                         SRG36800
C                                                                       SRG36900
C   READ DEPTH VALUES AND CHECK IDENTICATION DATA.                      SRG37000
C                                                                       SRG37100
  360 IB=1                                                              SRG37200
      NC=1                                                              SRG37300
  370 IE=IB+5                                                           SRG37400
C                                                                       SRG37500
C   LOOP LENGTH IS CORRECTED                                            SRG37600
C                                                                       SRG37700
      IF (IE.GE.LM) IE=LM                                               SRG37800
      READ (5,380) ID,NN,(D(L),L=IB,IE)                                 SRG37900
  380 FORMAT (A6,4X,I5,5X,6F10.2)                                       SRG38000
C                                                                       SRG38100
C   CHECK FOR CARD ID AND CARD NUMBER                                   SRG38200
C                                                                       SRG38300
      IF (ID.EQ.6HDEPTH .AND.NN.EQ.NC) GO TO 400                        SRG38400
C                                                                       SRG38500
C   WRITE ERROR MESSAGE                                                 SRG38600
C                                                                       SRG38700
      WRITE (6,690)                                                     SRG38800
      WRITE (6,100)                                                     SRG38900
      WRITE (6,390) ID,NN                                               SRG39000
  390 FORMAT (23H ID IN ERROR * ID GIVEN,1X,A6,/,20H ID SHOULD BE DEPTH SRG39100
     2,12HCARD NUMBER ,I5,//,1X,8HERROR 06)                             SRG39200
      WRITE (6,120)                                                     SRG39300
      WRITE (6,690)                                                     SRG39400
      ICHECK=1                                                          SRG39500
C                                                                       SRG39600
C   CHECK FOR LAST SHELF REACH DEPTH                                    SRG39700
C                                                                       SRG39800
  400 IF (IE.GE.LM) GO TO 410                                           SRG39900
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         IB=IB+6                                                        SRG40000
         NC=NC+1                                                        SRG40100
         GO TO 370                                                      SRG40200
C                                                                       SRG40300
C    READ RELATIVE WIND VELOCITY ALONG AXIS OF SYMMETRY AND CHECK       SRG40400
C    IDENTIFICATION DATA.                                               SRG40500
C    CHECK IS MADE TO SEE IF ERRORS WERE ENCOUNTERED IN INPUT DATA      SRG40600
C                                                                       SRG40700
410      IF (ICHECK.EQ.1) GO TO 1020                                    SRG40800
         IB=1                                                           SRG40900
         NC=1                                                           SRG41000
420      IE=IB+11                                                       SRG41100
C                                                                       SRG41200
C    LOOP LENGTH IS CORRECTED                                           SRG41300
C                                                                       SRG41400
         IF (IE.GE.NPTS) IE=NPTS                                        SRG41500
C                                                                       SRG41600
C    CHECK IS MADE TO SEE HOW PROFILE DATA IS SUPPLIED.                 SRG41700
C    IF IDATA = 0 DATA SUPPLIED IS IN INTERPOLATED FORM.  SUBROUTINE    SRG41800
C    PROFIL IS NOT CALLED.                                              SRG41900
C    IF IDATA = 4 DATA SUPPLIED IS A SET OF BRACKETING RADII FOR        SRG42000
C    HURRICANE ZONE OF INTEREST OR IS COMPLETE SET OF PROFIL DATA       SRG42100
C    (DATA FOR ALL ZONES AND RADII).  WHEN COMPLETE SET OF PROFIL       SRG42200
C    DATA IS SUPPLIED A SEARCH IS MADE FOR BRACKETING RADII FOR         SRG42300
C    REQUESTED ZONE.                                                    SRG42400
C    WHEN IDATA = 4 INTERPOLATION IS DONE INTERNALLY BY SPECIFING       SRG42500
C    ZONE, HURRICANE TYPE, AND RADIUS                                   SRG42600
C    TO MAX. WIND.                                                      SRG42700
C                                                                       SRG42800
         IF (IDATA.EQ.4) GO TO 440                                      SRG42900
         READ (5,430) ID1,ID2,ID3,RR,NN,(VX(I),I=IB,IE)                 SRG43000
430      FORMAT (A4,A2,1X,A3,F5.1,I5,12F5.3)                            SRG43100
         GO TO 460                                                      SRG43200
440      CALL PROFIL (IZONE,ITYPE,R,IVX,IDATA,LIST)                     SRG43300
C                                                                       SRG43400
C    CHECK IS MADE FOR ERROR  FROM SUBROUTINE PROFIL                    SRG43500
C                                                                       SRG43600
         IF (HOMB.EQ.5HERROR) GO TO 660                                 SRG43700
C                                                                       SRG43800
C    DATA THAT WAS ROUNDED=OFF IN SUBROUTINE PROFIL IS CONVERTED TO     SRG43900
C    REAL NUMBERS                                                       SRG44000
C                                                                       SRG44100
         DO 450 I=1,NPTS                                                SRG44200
         VX(I)=IVX(I)/1000.                                             SRG44300
450      CONTINUE                                                       SRG44400
         GO TO 500                                                      SRG44500
460      EE=ABS(RR=R)                                                   SRG44600
C                                                                       SRG44700
C    CHECK AGREMENT OF HURRICANE IDENTIFICATION TO SEE IF IT AGREES     SRG44800
C    WITH DATA IDENTIFICATION                                           SRG44900
C                                                                       SRG45000
         IF (ID1.EQ.4HZONE.AND.ID2.EQ.IZONE.AND.ID3.EQ.ITYPE.AND.EE.LT.E.ANSRG45100
        2D.NN.EQ.NC) GO TO 490                                          SRG45200
         ICHECK=1                                                       SRG45300
C                                                                       SRG45400
C    WRITE ERROR MESSAGE                                                SRG45500
C                                                                       SRG45600
         WRITE (6,690)                                                  SRG45700
         WRITE (6,470)                                                  SRG45800
470      FORMAT (40X,38HRELATIVE WIND FIELD DATA CARD IN ERROR,/)       SRG45900
         WRITE (6,480) ID1,ID2,IZONE,ID3,ITYPE,RR,NN                    SRG46000
480      FORMAT (1X,34H[[ZONE[[ SHOULD = YOUR VALUE OF [[,A4,2H[[,4X,2H[[,ASRG46100
        22,12H[[ SHOULD = ,A2,17HHURRICANE TYPE [[,A3,12H[[ SHOULD = ,A3,/,SRG46200
        321HRADIUS TO MAX. WIND =,F5.1,19H CHECK CARD NUMBER ,I5,//,1X,8HERSRG46300
        4ROR 07)                                                        SRG46400
         WRITE (6,120)                                                  SRG46500
C                                                                       SRG46600
C    CHECK SENTINEL TO SEE IF ERRORS WERE ENCOUNTERED.                  SRG46700
C                                                                       SRG46800
         IF (ICHECK.EQ.1) GO TO 1020                                    SRG46900
C                                                                       SRG47000
C    CHECK FOR LAST WIND PROFILE POINT                                  SRG47100
C                                                                       SRG47200
490      IF (IE.EQ.NPTS) GO TO 500                                      SRG47300
         IB=IB+12                                                       SRG47400
         NC=NC+1                                                        SRG47500
         GO TO 420                                                      SRG47600
C                                                                       SRG47700
C                                                                       SRG47800
C    COMPUTE MIN. DIST. FROM TRAVERSE LINE TO HUR. CENTER.              SRG47900
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C   COMPUTE INITIAL LOCATION ON TRAVERSE LINE,                          SRG48000
500   CALL STRTPT                                                       SRG48100
C                                                                       SRG48200
C                                                                       SRG48300
      DO 570 N=1,NM                                                     SRG48400
C                                                                       SRG48500
C    IF KEYA = 1  SUBROUTINE ZERWND IS CALLED,  IF KEYA = 0 SUBROUTINE  SRG48600
C    ZERWND IS NOT CALLED,                                              SRG48700
C                                                                       SRG48800
      IF (KEYA,EQ,1,AND,N,EQ,1) CALL ZERWND                             SRG48900
      CALL HRWDPF (N)                                                   SRG49000
C                                                                       SRG49100
C   THE STORMS POSITION RELATIVE TO THE SHORELINE IS DETERMINED,        SRG49200
C                                                                       SRG49300
      DO 550 L=1,LM                                                     SRG49400
C                                                                       SRG49500
C   SETUP DUE TO THE ATMOSPHERIC PRESSURE DIFFERENTIAL IS EVALUATED,    SRG49600
C                                                                       SRG49700
      SP(L)=1,14*(PN=PO)*(1,0=EXP(=R/RS(L)))                            SRG49800
      IF (DIST(L)=2,0) 510,510,520                                      SRG49900
C                                                                       SRG50000
C   THE WIND SPEED NEAR SHORE DUE TO THE STORMS INTERFERENCE WITH THE   SRG50100
C      LAND MASS,                                                       SRG50200
C                                                                       SRG50300
510   WIND=W(L)*,89                                                     SRG50400
      GO TO 530                                                         SRG50500
520   WIND=W(L)                                                         SRG50600
530   WSQ=WIND*WIND                                                     SRG50700
      WWX(L)=WSQ*COS(T(L))                                              SRG50800
      WWY(L)=WSQ*SIN(T(L))                                              SRG50900
      IF (W(L),LE,16,0) GO TO 540                                       SRG51000
C                                                                       SRG51100
C   VAN DORNS WIND STRESS COEFFICIENT IS DETERMINED,                    SRG51200
C                                                                       SRG51300
      WK(L)=0,0000011+0,0000025*(1,0=16,0/W(L))**2                      SRG51400
      GO TO 550                                                         SRG51500
540   WK(L)=0,0000011                                                   SRG51600
550   CONTINUE                                                          SRG51700
      WRITE (39) DELT(N)                                                SRG51800
      DO 560 LL=1,LMM                                                   SRG51900
      WRITE (39) WWX(LL+1),WWX(LL),WWY(LL+1),WWY(LL),SA(N),SP(LL+1),SP(LSRG52000
     2L),WK(LL)                                                         SRG52100
560   CONTINUE                                                          SRG52200
570   CONTINUE                                                          SRG52300
C                                                                       SRG52400
C   THE BASIC INFORMATION OF THE STORM PROBLEM IS WRITTEN OUT,          SRG52500
C                                                                       SRG52600
      WRITE (6,580)                                                     SRG52700
580   FORMAT (1H1,30X,52HQUASI=TWO=DIMENSIONAL OPEN COAST STORM SURGE PRSRG52800
     2OGRAM///)                                                         SRG52900
      WRITE (6,60) (A(I),I=1,20)                                        SRG53000
      WRITE (6,590)                                                     SRG53100
590   FORMAT (54X,10HINPUT DATA,/,54X,10H===== ====,///)                SRG53200
      WRITE (6,600) ITYPE,PHII,IZONE                                    SRG53300
600   FORMAT (/,36X,32HTYPE OF HURRICANE MODEL (ITYPE) ,A3,/,68X,3H===,/SRG53400
     2/,1X,30HGEOGRAPHICAL LATITUDE (PHII) =,F10,2,8H DEGREES,15X,22HHURSRG53500
     3RICANE ZONE (IZONE),A2,/)                                         SRG53600
      WRITE (6,610) PO,PN,R,WX,VF,SE,BEAR,BFF                           SRG53700
610   FORMAT (6X,24HCENTRAL PRESSURE (PO) = ,F5,2,8H IN, HG,,17X,27HPERISRG53800
     2PHERAL PRESSURE (PN) = ,F5,2,8H IN, HG,//,1X,29HRADIUS TO MAXIMUM SRG53900
     3WIND (R) = ,F4,1,5H N,M,,28X,20HMAXIMUM WIND (WX) = ,F5,1,7H MI/HRSRG54000
     4,,//,5X,25HTRANSLATION SPEED (VF) = ,F4,1,6H KNOTS,27X,20HINITIAL SRG54100
     5RISE (SE) = ,F4,2,5H FEET,//,4X,26HTRAVERSE BEARING (BEAR) = ,2A5,SRG54200
     616X,31HBOTTOM FRICTION FACTOR (BFF) = ,F6,4)                      SRG54300
      WRITE (6,970)                                                     SRG54400
      WRITE (6,620)                                                     SRG54500
620   FORMAT (1X,90HSURGE TRAVERSE IS PARALLEL TO STORM TRACK AND 115 DESRG54600
     2GREES FROM THE LINE OF STRONGEST WINDS//)                         SRG54700
      WRITE (6,630)                                                     SRG54800
630   FORMAT (40X,41HBOTTOM PROFILE OVER THE CONTINENTAL SHELF,//,46X,13SRG54900
     2HDISTANCE FROM,8X,5HDEPTH,/,47X,12HSHORE (N,M,),8X,6H(FEET))      SRG55000
      DO 640 L=1,LM                                                     SRG55100
      WRITE (6,650) DIST(L),D(L)                                        SRG55200
640   CONTINUE                                                          SRG55300
650   FORMAT (49X,F6,2,9X,F5,1)                                         SRG55400
660   WRITE (6,670) IDATA,IOMIT,IOMITD,KEY                              SRG55500
670   FORMAT (//,10X,24HINPUT AND OUTPUT CONTROL,/,10X,24(1H=),//,1X,7HISRG55600
     2DATA =,I5,50H  0 = WIND FIELD DATA INPUT BY CARDS IN FINAL FORM,/,SRG55700
     315X,57H4 = WIND FIELD DATA INPUT BY CARDS AND TRANSFERED TO DISK//SRG55800
     4,1X,7HIOMIT =,I5,3X,21H0 = DETAILED PRINTING,/,1X,8HIOMITD =,I5,2XSRG55900
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     5,26H1 = SKIP DETAILED PRINTING,//,3X,6HKEY  =,I5,69H  0 = WIND DATSRG56000
     6A(PROFILE DISTANCE, RADIUS, WIND,AND THETA) NOT PRINTED,/,16X,63H1SRG56100
     7 = WIND DATA(PROFILE DISTANCE, RADIUS, WIND,AND THETA) PRINTED,//)SRG56200
      WRITE (6,680) LIST,KEYA,DELTT                                     SRG56300
  680 FORMAT (3X,6HLIST =,I5,42H  0 = DATA GENERATED IN PROFIL NOT PRINTSRG56400
     2ED,/,16X,36H1 = DATA GENERATED IN PROFIL PRINTED,//,3X,6HKEYA =,I5SRG56500
     3,34H  0 = SUBROUTINE ZERWND NOT CALLED,/,16X,31H1 = SUBROUTINE ZERSRG56600
     4WND IS CALLED,//,1X,8HDELT.T  =,F10.2,1X,33HHOUR INITIAL COMPUTATIOSRG56700
     5N INTERVAL)                                                       SRG56800
C                                                                       SRG56900
C   CHECK IS MADE FOR ERROR  FROM SUBROUTINE PROFIL                     SRG57000
C                                                                       SRG57100
      IF (BOMB.EQ.5HERROR) GO TO 1020                                   SRG57200
      REWIND 39                                                         SRG57300
      TII=0.0                                                           SRG57400
C                                                                       SRG57500
      IF (IOMITD.EQ.1) GO TO 750                                        SRG57600
C  IF IOMITD NOT EQUAL 1, INPUT COMPUTATIONAL DATA PRINTED OUT,         SRG57700
C                                                                       SRG57800
      DO 740 N=1,NM                                                     SRG57900
      WRITE (6,690)                                                     SRG58000
  690 FORMAT (///,1X,119H***********************************************SRG58100
     2******************************************************************SRG58200
     3******)                                                           SRG58300
      READ (39) DELT(N)                                                 SRG58400
      TI=TII                                                            SRG58500
      TII=TI+DELT(N)                                                    SRG58600
      WRITE (6,700) TI,TII                                              SRG58700
  700 FORMAT (1X,/1X11HTIME (T) = ,F6.2,6X,16HTIME (T+DELT) = ,F6.2,//) SRG58800
      WRITE (6,710)                                                     SRG58900
  710 FORMAT (10X,8HWWX(I+1),7X,6HWWX(I),7X,8HWWY(I+1),8X,6HWWY(I),5X,11SRG59000
     2HASTRO. TIDE,4X,7HSP(I+1),8X,5HSP(I),5X11HWIND STRESS,/,67X,6H(FEESRG59100
     3T),9X,4H(FT),10X,4H(FT),6X,9HPARAMETER,//)                        SRG59200
      DO 730 LL=1,LMM                                                   SRG59300
      READ (39) WWX(LL+1),WWX(LL),WWY(LL+1),WWY(LL),SA(N),SP(LL+1),SP(LLSRG59400
     2),WK(LL)                                                          SRG59500
      WRITE (6,720) WWX(LL+1),WWX(LL),WWY(LL+1),WWY(LL),SA(N),SP(LL+1),SSRG59600
     2P(LL),WK(LL)                                                      SRG59700
  720 FORMAT (10X,F7.1,8X,F7.1,7X,F7.1,8X,F7.1,7X,F4.2,10X,F4.2,10X,F4.2SRG59800
     2,5X,F10.8)                                                        SRG59900
  730 CONTINUE                                                          SRG60000
  740 CONTINUE                                                          SRG60100
C   DUMMY CONTINUE                                                      SRG60200
  750 CONTINUE                                                          SRG60300
      REWIND 39                                                         SRG60400
      WRITE (6,760)                                                     SRG60500
C                                                                       SRG60600
C   CHECK TO SEE IF INPUT COMPUTATIONAL DATA IS PRINTED                 SRG60700
      IF (IOMIT.EQ.1) GO TO 780                                         SRG60800
C                                                                       SRG60900
  760 FORMAT (1H1)                                                      SRG61000
      WRITE (6,770)                                                     SRG61100
  770 FORMAT (54X,11HOUTPUT DATA,/,54X,11H------ ----,///)              SRG61200
      WRITE (6,600) ITYPE,PHII,IZONE                                    SRG61300
      WRITE (6,610) PO,PN,R,WX,VF,SE,BEAR,SFF                           SRG61400
  780 CONTINUE                                                          SRG61500
      DO 790 L=1,LMM                                                    SRG61600
C                                                                       SRG61700
C  INCREMENTAL X-VALUES AND AVG, DEPTHS ARE COMPUTED,                   SRG61800
C                                                                       SRG61900
      DELX(L)=DIST(L)-DIST(L+1)                                         SRG62000
      DAVG(L)=(D(L)+D(L+1))/2.0                                         SRG62100
  790 CONTINUE                                                          SRG62200
      DO 800 L=1,LM                                                     SRG62300
      PHI(L)=(PHI(L)*PI)/180.0                                          SRG62400
C                                                                       SRG62500
C  THE SINE OF THE LATITUDE IS EVALUATED,                               SRG62600
C                                                                       SRG62700
      SINPHI(L)=SIN(PHI(L))                                             SRG62800
  800 CONTINUE                                                          SRG62900
      TII=0.0                                                           SRG63000
      DO 930 N=1,NM                                                     SRG63100
C                                                                       SRG63200
C   CHECK TO SEE IF INPUT COMPUTATIONAL DATA IS PRINTED                 SRG63300
C                                                                       SRG63400
      IF (IOMIT.EQ.1) GO TO 810                                         SRG63500
      WRITE (6,760)                                                     SRG63600
C   DUMMY CONTINUE                                                      SRG63700
  810 CONTINUE                                                          SRG63800
      READ (39) DELT(N)                                                 SRG63900
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      SUMSX=0.0                                                         SRG64000
      SUMSY=0.0                                                         SRG64100
C                                                                       SRG64200
C   CHECK TO SEE IF INPUT COMPUTATIONAL DATA IS PRINTED                 SRG64300
      IF (IOMIT.EQ.1) GO TO 830                                         SRG64400
C                                                                       SRG64500
      TI=TII                                                            SRG64600
      TII=TI+DELT(N)                                                    SRG64700
      WRITE (6,700) TI,TII                                              SRG64800
      WRITE (6,820)                                                     SRG64900
820   FORMAT (1X,5HDIST.,3X,5HDEPTH,5X,6HD AVG.,3X,9HPRES.RISE,2X,10HASTSRG65000
     2RO.TIDE,3X,7HINITIAL,5X,6HY-FLUX,5X,7HONSHORE,4X,10HALONGSHORE,2X,SRG65100
     310HTOTAL WIND,3X,5HTOTAL,/,1X,4H(NM),3X,8H(FT.MLW),2X,8H(FT.MLW),4SRG65200
     44X,4H(FT),7X,4H(FT),6X,10HLEVEL(FT),1X,11H(FT*FT/SEC),1X,10HSETUP (SRG65300
     5FT),2X,10HSETUP (FT),2X,10HSETUP (FT),2X,10HSURGE (FT),//)        SRG65400
C   DUMMY CONTINUE                                                      SRG65500
830   CONTINUE                                                          SRG65600
      DO 910 L=1,LMM                                                    SRG65700
C                                                                       SRG65800
C                                                                       SRG65900
C  STORM SURGE COMPUTATIONS BEGIN.                                      SRG66000
C                                                                       SRG66100
C                                                                       SRG66200
      READ (39) WWX(L+1),WWX(L),WWY(L+1),WWY(L),SA(N),SP(L+1),SP(L),WK(LSRG66300
     2)                                                                 SRG66400
      AN=WK(L)*(WWX(L)+WWX(L+1))*WKCOR                                  SRG66500
      BN=WK(L)*(WWY(L)+WWY(L+1))*0.5*WKCOR                              SRG66600
      SPN=(SP(L)+SP(L+1))/2.0                                           SRG66700
      IF (N.NE.1) GO TO 840                                             SRG66800
C                                                                       SRG66900
C  PROBLEM IS INIALIZED FOR FIRST TIME LEVEL.                           SRG67000
C                                                                       SRG67100
      SXP(L)=0.0                                                        SRG67200
      SYP(L)=0.0                                                        SRG67300
      SPP(L)=SPN                                                        SRG67400
      VP(L)=0.0                                                         SRG67500
      BP(L)=BN                                                          SRG67600
      SAP=SA(N)                                                         SRG67700
840   DTS=DAVG(L)+SE+SXP(L)+SYP(L)                                      SRG67800
      DTN=DTS+SA(N)+SPN                                                 SRG67900
      DTH=DTS+((SA(N)+SAP)/2.0)+((SPP(L)+SPN)/2.0)                      SRG68000
      DASQ=(C3/DTH)**2                                                  SRG68100
      DEN=BFF*ABS(VP(L))*DELT(N)*DASQ                                   SRG68200
      VN=((BN+BP(L))*DELT(N)*0.5+VP(L))/(1.0+DEN)                       SRG68300
      BY=ABS(BN)                                                        SRG68400
      VNTEST=SQRT(BY/(BFF*DASQ))                                        SRG68500
      VNN=ABS(VN)                                                       SRG68600
C                                                                       SRG68700
C  A CHECK IS MADE TO INSURE THAT THE ALONGSHORE DOES NOT EXCEED THE    SRG68800
C    LIMITING VALUE.                                                    SRG68900
C                                                                       SRG69000
      IF (VNTEST.GT.VNN) GO TO 870                                      SRG69100
      IF (VN) 850,860,860                                               SRG69200
850   VN=-VNTEST                                                        SRG69300
      GO TO 870                                                         SRG69400
860   VN=VNTEST                                                         SRG69500
870   DELSYN=(C2*DELX(L)*(SINPHI(L)+SINPHI(L+1))*VN)/DTN                SRG69600
      DELSXN=(C1*DELX(L)*AN)/DTN                                        SRG69700
      SUMSX=SUMSX+DELSXN                                                SRG69800
      SUMSY=SUMSY+DELSYN                                                SRG69900
      VS=7744.0*VN                                                      SRG70000
      ST=SA(N)+SE+SUMSX+SUMSY+SPN                                       SRG70100
      SW=SUMSX+SUMSY                                                    SRG70200
C                                                                       SRG70300
      IF (IOMIT.EQ.1) GO TO 900                                         SRG70400
C  IF IOMIT NOT EQUAL 1, OUTPUT RESULTS ARE PRINTED OUT IN DETAIL FOR   SRG70500
C    EACH TIME LEVEL.                                                   SRG70600
C                                                                       SRG70700
      WRITE (6,880) DIST(L),D(L)                                        SRG70800
880   FORMAT (1X,F5.1,5X,F5.1)                                          SRG70900
      WRITE (6,890) DAVG(L),SPN,SA(N),SE,VS,SUMSX,SUMSY,SW,ST           SRG71000
890   FORMAT (21X,F5.1,5X,F4.2,8X,F4.2,7X,F4.2,8X,F7.1,5X,F6.3,6X,F7.3,6SRG71100
     2X,F6.3,5X,F5.2)                                                   SRG71200
900   SXP(L)=SUMSX                                                      SRG71300
      SYP(L)=SUMSY                                                      SRG71400
      SPP(L)=SPN                                                        SRG71500
      VP(L)=VN                                                          SRG71600
      BP(L)=BN                                                          SRG71700
910   CONTINUE                                                          SRG71800
C                                                                       SRG71900
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C   CHECK TO SEE IF OUTPUT RESULTS ARE TO BE PRINTED                    SRG72000
      IF (IOMIT.EQ.1) GO TO 920                                         SRG72100
C                                                                       SRG72200
      WRITE (6,880) DIST(LM),D(LM)                                      SRG72300
C                                                                       SRG72400
C  NEW VALUES ARE SET EQUAL TO PREVIOUS VALUES.                         SRG72500
C                                                                       SRG72600
920   SX(N)=SUMSX                                                       SRG72700
      SY(N)=SUMSY                                                       SRG72800
      SWW(N)=SW                                                         SRG72900
      SPRES(N)=SPN                                                      SRG73000
      STOT(N)=ST                                                        SRG73100
      SAP=SA(N)                                                         SRG73200
930   CONTINUE                                                          SRG73300
      K=1                                                               SRG73400
C   DUMMY CONTINUE                                                      SRG73500
940   CONTINUE                                                          SRG73600
      WRITE (6,760)                                                     SRG73700
      WRITE (6,950)                                                     SRG73800
C                                                                       SRG73900
C  THE RESULTS ARE SUMMARIZED FOR ALL TIME LEVELS.                      SRG74000
C                                                                       SRG74100
950   FORMAT (38X,41HSUMMARY OF OPEN COAST STORM SURGE PROBLEM,///)     SRG74200
      WRITE (6,960)                                                     SRG74300
960   FORMAT (40X,38HPROJECT ELEMENT 151001 AEC STORM SURGE,//).        SRG74400
      WRITE (6,60) (A(I),I=1,20)                                        SRG74500
      WRITE (6,600) ITYPE,PHII,IZONE                                    SRG74600
      WRITE (6,610) PO,PN,R,WX,VF,SE,BEAR,BFF                           SRG74700
      WRITE (6,970)                                                     SRG74800
970   FORMAT (/,20X,74HWIND STRESS EQUATION  WK(L) = 0.00000121+ 0.00000SRG74900
     2275* (1.0 - 16.0/W(L))**2,/)                                      SRG75000
      WRITE (6,620)                                                     SRG75100
      WRITE (6,980)                                                     SRG75200
980   FORMAT (,///,2X,4HTIME,6X,5HSETUP,5X,5HSETUP,4X,9HTOT. WIND,3X,9HASRG75300
     2ST. TIDE,3X,13HINITIAL WATER,4X,8HPRESSURE,3X,11HTOTAL WATER,7X,14SRG75400
     3HTIDE CORRECTED/,1X,7H(HOURS),3X,7HX-COMP.,3X,7HY-COMP.,4X,5HSETUPSRG75500
     4,7X,5HLEVEL,9X,5HLEVEL,10X,5HSETUP,7X,5HLEVEL,10X,17HTOTAL WATER LSRG75600
     5EVEL/,12X,5H(FT.),5X,5H(FT.),5X,5H(FT.),6X,9H(FT. MLW),6X,5H(FT.),SRG75700
     610X,5H(FT.),6X,9H(FT. MLW),11X,9H(FT. MLW)//)                     SRG75800
      AHOUR=0.0                                                         SRG75900
      DO 1000 N=1,NM                                                    SRG76000
      AHOUR=AHOUR+DELT(N)                                               SRG76100
      WRITE (6,990) AHOUR,SX(N),SY(N),SWW(N),SA(N),SE,SPRES(N),STOT(N)  SRG76200
990   FORMAT (2X,F6.2,,5X,F6.2,4X,F6.2,4X,F6.2,6X,F6.2,8X,F6.2,9X,F6.2,7SRG76300
     2X,F6.2,15X,1H.)                                                   SRG76400
1000  CONTINUE                                                          SRG76500
      IF (K.EQ.3) GO TO 1010                                            SRG76600
      K=K+1                                                             SRG76700
      GO TO 940                                                         SRG76800
C   DUMMY CONTINUE                                                      SRG76900
1010  CONTINUE                                                          SRG77000
      IF (IDUM.GE.ILAST) STOP 00000                                     SRG77100
      REWIND 39                                                         SRG77200
      IDUM=IDUM+1                                                       SRG77300
      GO TO 40                                                          SRG77400
1020  STOP                                                              SRG77500
      END                                                               SRG77600
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      SUBROUTINE HRWDPF (M)                                              HRW00100
C                                                                        HRW00200
C     *******************************************************************HRW00300
C                                                                        HRW00400
C   THIS ROUTINE COMPUTES WIND VELOCITY MAGNITUDE AND DIRECTION ALONG A HRW00500
C   TRAVERSE LINE WHICH PASSES THRU A PROBABLE MAXIMUM HURRICANE AT THE HRW00600
C   POINT WHERE WIND VELOCITY IS GREATEST. THIS TRAVERSE IS 115.         HRW00700
C   DEG.COUNTERCLOCKWISE TO THE LINE OF SYMMETRY OF THE P.M.H. ISOVELS. HRW00800
C                                                                        HRW00900
C   VARIABLES NOT DEFINED IN THIS ROUTINE WILL BE DEFINED IN ANOTHER     HRW01000
C   ROUTINE                                                              HRW01100
C                                                                        HRW01200
C     THE MAGNITUDE OF THE WIND VELOCITY, W(L), IS ASSUMED TO BE GIVEN   HRW01300
C     BY THE FORMULA                                                     HRW01400
C           W(L) = WX*VXX(RHO/R) - .5*(1.-COS(THETA))*VF*1.151           HRW01500
C   WHERE                                                                HRW01600
C     RS(L) AND THETA ARE POLAR COORDINATES OF DISTANCE AND ANGLE RE-    HRW01700
C     SPECTIVELY. (THE INITIAL RAY OF THE COORDINATE SYSTEM IS ALONG     HRW01800
C     THE ISOVEL AXIS OF SYMMETRY AND PASSES THRU THE MAXIMUM VELOCITY   HRW01900
C     POINT. THE ORIGIN IS AT THE HURRICANE CENTER.)                     HRW02000
C   AND WHERE VXX IS THE                                                 HRW02100
C       RELATIVE WIND VELOCITY DISTRIBUTION ALONG THE POLAR COORD.       HRW02200
C     INITIAL RAY,   R IS THE DISTANCE FROM THE ORIGIN TO THE MAXIMUM    HRW02300
C     VELOCITY POINT.   WX IS THE MAXIMUM WIND VELOCITY. VF IS THE       HRW02400
C     VELOCITY AT WHICH THE ENTIRE HURRICANE IS MOVING,                  HRW02500
C     (DISTANCES ARE IN NAUTICAL MILES. VF IS IN KNOTS. W(L) AND WX      HRW02600
C   ARE IN M.P.H.)                                                       HRW02700
C                                                                        HRW02800
C   THE VARIABLES THETA AND THETAD ARE USED FOR CLARITY TO ILLUSTRATE    HRW02900
C   CHANGES IN THE VALUE OF TH.  THESE VARIABLES DO NOT APPEAR IN        HRW03000
C   THE ROUTINE.  TH IS USED TO REPRESENT THETA AND THETAD.              HRW03100
C   TH IS ORIGINALLY THETA IN RADIANS WHICH IS THE POLAR COORDINATE      HRW03200
C   OF LOCATION FOR RS(L).  TH IS CONVERTED TO THETAD(ANGLE WHICH        HRW03300
C   INCLUDES DEFLECTION),  THEN TH IS CONVERTED TO THETAD - 25. DEGREES.HRW03400
C   THE SUBTRACTION OF 25. DEGREES WAS A CORRECTION  FOR GEOMETRY.       HRW03500
C   THE WIND DIRECTION, THETAD, IS GIVEN BY THE FOLLOWING FORMULAS       HRW03600
C     THETAD=THETA+25.                           IF RS(L)/R LT 1.2       HRW03700
C     THETAD=THETA+15.*(RS(L)-R)/(1.2*R-R)+10.   IF 1. LT RS(L)/R LT 1.2 HRW03800
C     THETAD=THETA+10.*RS(L)/R                   IF RS(L)/R LT 1.        HRW03900
C                                                                        HRW04000
C     (ANGLES ARE IN DEGREES.  COUNTERCLOCKWISE IS POS.)                 HRW04100
C                                                                        HRW04200
C   OTHER FORTRAN VARIABLES ARE AS FOLLOWS,                              HRW04300
C     DEL = DIFFERENCE BETWEEN POINTS ON THE TRAVERSE.                   HRW04400
C   DISTO = INITIAL DISTANCE ALONG TRAVERSE LINE TO POINT OF MAXIMUM     HRW04500
C           WIND VELOCITY.                                               HRW04600
C      HR = TIME STEP                                                    HRW04700
C    RAD2 = NUMBER OF DEGREES EQUAL TO ONE RADIAN (CONVERSION FACTOR)    HRW04800
C     X AND Y ARE CARTESIAN COORDINATES CORRESPONDING TO THE POLAR       HRW04900
C     COORDINATES.   XX(S ARE RHO/R RATIOS ALONG THE INITIAL             HRW05000
C     RAY. VX(S ARE DIGITIZED WIND SPEEDS CORRESPONDING TO THE XX(S.     HRW05100
C     DX AND DY ARE INCREMENTS OF X                                      HRW05200
C     AND Y ALONG THE VELOCITY PROFILE.                                  HRW05300
C     AL IS A DISTANCE ALONG THE VELOCITY PROFILE AT WHICH COMPUTATIONS  HRW05400
C     BEGIN.                                                             HRW05500
C     XP IS THE MIN. DISTANCE FROM THE HURRICANE CENTER TO THE  TRAVERSEHRW05600
C     LINE.                                                              HRW05700
C                                                                        HRW05800
C                                                                        HRW05900
      DIMENSION W(1500),T(1500),DELT(200),DIST(50),RS(1500),VX(1600)     HRW06000
      COMMON /PFF/ KEY                                                   HRW06100
      COMMON /WND/ W,T,DELT,DIST,VX,RS                                   HRW06200
      COMMON /PAR/ LM,VF,WX,R,DISTO,XP                                   HRW06300
C   SN AND CS ARE SIN(115) AND COS(115). RAD1 IS  25 DEG. IN RADIANS.    HRW06400
      DATA SN,CS,RAD1,RAD2,PI /.90631,.42262,.436332,57.29577867,        HRW06500
     2 3.1415927/                                                        HRW06600
C                                                                        HRW06700
C  COMPUTE PROFILE PARAMETERS.                                           HRW06800
C   COMPUTE TIME ELAPSED.                                                HRW06900
      HR=0.                                                              HRW07000
      MX=M-1                                                             HRW07100
      IF (MX.LE.0) GO TO 20                                              HRW07200
      DO 10 L=1,MX                                                       HRW07300
10    HR=HR+DELT(L)                                                      HRW07400
20    AL=DISTO-DIST(1)-HR*VF                                             HRW07500
      IF (KEY.EQ.1) WRITE (6,30) M,HR                                    HRW07600
30    FORMAT (15H TIME INCREMENT,I3,5X,F5.1,6H HOURS)                    HRW07700
C  COMPUTE INITIAL X AND Y.                                              HRW07800
      X=R-AL*CS                                                          HRW07900
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      Y=AL*SN                                                           HRW08000
C                                                                       HRW08100
      IF (KEY.EQ.0) GO TO 70                                            HRW08200
C   PRINT PARAMETERS.                                                   HRW08300
      WRITE (6,40) R,VF,WX,XP                                           HRW08400
40    FORMAT (1X,5X,3HR =,F6.2,9H N. MILES,4X,4HVF =,F6.2,6H KNOTS,4X,5HHRW08500
     2 WX =,F7.2,7H M.P.H./1X,12HX DISTANCE =,F5.2,9H N. MILES)         HRW08600
      WRITE (6,50)                                                      HRW08700
50    FORMAT (///)                                                      HRW08800
C   PRINT TITLE.                                                        HRW08900
      WRITE (6,60)                                                      HRW09000
60    FORMAT (1X,6X,13HDISTANCE FROM,6X,6HRADIAL,10X,4HWIND,5X,24HANGLE HRW09100
     2FROM TRAVERSE LINE/1X,8X,10HCOAST LINE,6X,8HDISTANCE,7X,8HVELOCITYHRW09200
     3,4X,21HCOUNTERCLOCKWISE POS./1X,9X,8HN. MILES,7X,8HN. MILES,9X,6HMHRW09300
     4.P.H.,5X,9H(DEGREES))                                             HRW09400
      WRITE (6,50)                                                      HRW09500
C  REPETETIVE COMPUTATION OF WIND VELOCITY AND DIRECTION VERSUS X AND Y.HRW09600
70    DO 90 L=1,LM                                                      HRW09700
      RS(L)=SQRT(X**2+Y**2)                                             HRW09800
      CALL QUAD (X,Y,TH)                                                HRW09900
C   TH = ANGLE FROM LINE OF SYMMETRY TO RADIUS VECTOR (RS(L))           HRW10000
      CALL VEL (RS(L),VXX)                                              HRW10100
      W(L)=WX*VXX+.5*(1.-COS(TH))*VF*1.151                              HRW10200
      CALL DEFL (TH,RS(L))                                              HRW10300
C   TH = WIND ANGLE WITH CORRECTION FOR DEFLECTION                      HRW10400
C   T(L) = WIND ANGLE - 25 DEGREES FOR GEOMETRY                         HRW10500
      T(L)=TH-RAD1                                                      HRW10600
C   CONVERT WIND VELOCITY ANGLE TO DEG. FROM 115 DEG. LINE.             HRW10700
      TH=RAD2*T(L)                                                      HRW10800
C                                                                       HRW10900
C   IF KEY = 1, WIND VELOCITY PRINTOUT IS INCLUDED.  IF KEY = 0, WIND   HRW11000
C   VELOCITY PRINTOUT IS SUPRESSED.                                     HRW11100
C                                                                       HRW11200
      IF (KEY.EQ.1) WRITE (6,80) DIST(L),RS(L),W(L),TH                  HRW11300
80    FORMAT (1X,4F15.2)                                                HRW11400
      IF (L.GE.LM) GO TO 90                                             HRW11500
      DEL=DIST(L)-DIST(L+1)                                             HRW11600
      X=X-DEL*CS                                                        HRW11700
      Y=Y+DEL*SN                                                        HRW11800
90    CONTINUE                                                          HRW11900
      IF (KEY.EQ.0) RETURN                                              HRW12000
      WRITE (6,100)                                                     HRW12100
100   FORMAT (//1X,49HX AXIS IS ALONG HURRICANE ISOVEL AXIS OF SYMMETRY)HRW12200
      WRITE (6,110)                                                     HRW12300
110   FORMAT (1H1)                                                      HRW12400
      RETURN                                                            HRW12500
      END                                                               HRW12600
```

```
      SUBROUTINE QUAD (X,Y,TH)                                          QUD00100
C                                                                       QUD00200
C     ******************************************************************QUD00300
C                                                                       QUD00400
C   THIS ROUTINE COMPUTES ARCTANGENTS AND DETERMINES THE APPROPRIATE    QUD00500
C   QUADRANT.                                                           QUD00600
C                                                                       QUD00700
C   VARIABLES NOT DEFINED IN THIS ROUTINE WILL BE DEFINED IN ANOTHER    QUD00800
C   ROUTINE                                                             QUD00900
C                                                                       QUD01000
C   X IS ALONG THE P.M.H. AXIS OF SYMMETRY THRU THE CENTER.             QUD01100
C   Y IS PERPENDICULAR TO X.                                            QUD01200
C                                                                       QUD01300
      DATA PI /3.1415927/                                               QUD01400
C   ERROR IS GIVEN AN INITIAL VALUE.                                    QUD01500
      DATA ERROR /2H00/                                                 QUD01600
C   TEST FOR + OR - PI/2                                                QUD01700
      IF (ABS(X).GT..00001) GO TO 40                                    QUD01800
      IF (ABS(Y).LT..00001) ERROR=2H08                                  QUD01900
      IF (ERROR.EQ.2H08) GO TO 10                                       QUD02000
      GO TO 40                                                          QUD02100
C   PRINT ERROR MESSAGE                                                 QUD02200
10    WRITE (6,20) ERROR                                                QUD02300
20    FORMAT (/,1X,38H***** ERROR FROM SUBROUTINE QUAD *****,//,1X,6HERRQUD02400
     2OR ,A2)                                                           QUD02500
      WRITE (6,30)                                                      QUD02600
30    FORMAT (3X,88H SEE ERROR TABLE IN CERC TM TITLE VERIFICATION STUDYQUD02700
     2 OF A BATHYSTROPIC STORM SURGE MODEL)                             QUD02800
      STOP                                                              QUD02900
C   TEST FOR QUADRANT.                                                  QUD03000
40    IF (X.LT.0..AND.Y.GT.0.) GO TO 60                                 QUD03100
      IF (X.EQ.0..AND.Y.GT.0.) GO TO 70                                 QUD03200
      IF (X.GT.0..AND.Y.GE.0.) GO TO 80                                 QUD03300
      IF (X.GT.0..AND.Y.LT.0.) GO TO 90                                 QUD03400
      ERROR=2H10                                                        QUD03500
C   PRINT ERROR MESSAGE                                                 QUD03600
      WRITE (6,20) ERROR                                                QUD03700
      WRITE (6,30)                                                      QUD03800
      WRITE (6,50) X,Y                                                  QUD03900
50    FORMAT (1X,2F10.3)                                                QUD04000
      STOP                                                              QUD04100
C                                                                       QUD04200
C   2ND QUADRANT.                                                       QUD04300
60    TH=PI-ATAN(-Y/X)                                                  QUD04400
      GO TO 100                                                         QUD04500
70    TH=PI/2.                                                          QUD04600
      GO TO 100                                                         QUD04700
C   1ST QUADRANT.                                                       QUD04800
80    TH=ATAN(Y/X)                                                      QUD04900
      GO TO 100                                                         QUD05000
C   4TH QUADRANT.                                                       QUD05100
90    TH=-ATAN(-Y/X)                                                    QUD05200
C   TEST FOR REASONABLENESS.                                            QUD05300
C   THE VALUE OF THETA (TH) SHOULD BE BETWEEN 115. DEG. AND             QUD05400
C   -65. DEG. ALONG THE WIND VELOCITY PROFILE.                          QUD05500
100   IF (TH.LT.(115./180.)*PI.AND.TH.GT.-(65./180.)*PI) RETURN         QUD05600
      ERROR=2H11                                                        QUD05700
C   PRINT ERROR MESSAGE                                                 QUD05800
      WRITE (6,20) ERROR                                                QUD05900
      WRITE (6,30)                                                      QUD06000
      WRITE (6,50) TH                                                   QUD06100
      STOP                                                              QUD06200
      END                                                               QUD06300
```

```
      SUBROUTINE DEFL (TH,RHO)                                          DEF00100
C                                                                       DEF00200
C     ******************************************************************DEF00300
C                                                                       DEF00400
C   THIS ROUTINE COMPUTES THE WIND DIRECTION AS A FUNCTION OF THETA     DEF00500
C   AND RHO/R.   THE FORMULAS ARE EXPLAINED ELSEWHERE.                  DEF00600
C                                                                       DEF00700
C   VARIABLES NOT DEFINED IN THIS ROUTINE WILL BE DEFINED IN ANOTHER    DEF00800
C   ROUTINE                                                             DEF00900
C                                                                       DEF01000
C     RHO = RADIAL DISTANCE FOR PRESENT POINT ON TRAVERSE               DEF01100
      COMMON /PAR/ LM,VF,WX,R,DISTO,XP                                  DEF01200
      DATA PI /3.1415927/                                               DEF01300
      IF (RHO.GE.1.2*R) GO TO 10                                        DEF01400
      IF (RHO.LT.R) GO TO 20                                            DEF01500
      TH=TH+(10./180.)*PI+(15./180.)*PI*(RHO-R)/(.2*R)                  DEF01600
      RETURN                                                            DEF01700
10    TH=TH+(25./180.)*PI                                               DEF01800
      RETURN                                                            DEF01900
C                                                                       DEF02000
20    TH=TH+(RHO/R)*(10./180.)*PI                                       DEF02100
      RETURN                                                            DEF02200
      END                                                               DEF02300
```

```
      SUBROUTINE VEL (RHO,VXX)                                          VEL00100
C                                                                       VEL00200
C     ******************************************************************VEL00300
C                                                                       VEL00400
C   THIS ROUTINE MAKES AN INTERPOLATION OF WIND VELOCITY ALONG THE      VEL00500
C   P.M.H. AXIS OF SYMMETRY.                                            VEL00600
C                                                                       VEL00700
C   VARIABLES NOT DEFINED IN THIS ROUTINE WILL BE DEFINED IN ANOTHER    VEL00800
C   ROUTINE                                                             VEL00900
C                                                                       VEL01000
C     RHO = RADIAL DISTANCE FOR PRESENT POINT ON TRAVERSE               VEL01100
      DIMENSION W(1500),T(1500),DELT(200),DIST(50),RS(1500),VX(1600)    VEL01200
      COMMON /WND/ W,T,DELT,DIST,VX,RS                                  VEL01300
      COMMON /PAR/ LM,VF,WX,R,DISTO,XP                                  VEL01400
      COMMON /PTS/ NPTS                                                 VEL01500
C                                                                       VEL01600
C   XX AND XI ARE DISTANCES ALONG THE P.M.H. AXIS OF SYMMETRY.          VEL01700
      XI=RHO/R                                                          VEL01800
C   CHECK RHO/R FOR REASONABLENESS.                                     VEL01900
      IF (XI.GT..84.AND.XI.LT.29.1) GO TO 50                            VEL02000
C   PRINT ERROR MESSAGE                                                 VEL02100
10    WRITE (6,20)                                                      VEL02200
20    FORMAT (/,1X,37H***** ERROR FROM SUBROUTINE VEL *****,//,1X,8HERROVEL02300
     2R 12)                                                             VEL02400
      WRITE (6,30)                                                      VEL02500
30    FORMAT (3X,88H SEE ERROR TABLE IN CERC TM TITLE VERIFICATION STUDYVEL02600
     2 OF A BATHYSTROPIC STORM SURGE MODEL)                             VEL02700
      WRITE (6,40) XI                                                   VEL02800
40    FORMAT (1X,4HXI =,F10.3,19H UNREASONABLE INPUT)                   VEL02900
      VXX=-999.                                                         VEL03000
      STOP                                                              VEL03100
C   SEARCH FOR APPROPRIATE VX POINTS.                                   VEL03200
50    DO 60 I=1,NPTS                                                    VEL03300
      XX=.78+.02*I                                                      VEL03400
      IF (XI.GT.XX) GO TO 60                                            VEL03500
      M=I                                                               VEL03600
      GO TO 70                                                          VEL03700
60    CONTINUE                                                          VEL03800
      GO TO 10                                                          VEL03900
C                                                                       VEL04000
70    XM=50.*(VX(M)-VX(M-1))                                            VEL04100
      VXX=XM*(XI-XX)+VX(M-1)                                            VEL04200
      RETURN                                                            VEL04300
      END                                                               VEL04400
```

```
      SUBROUTINE STRTPT                                                 STR00100
C                                                                       STR00200
C     ******************************************************************STR00300
C                                                                       STR00400
C   THIS SUBROUTINE COMPUTES THE RADIAL DISTANCE AT WHICH WIND VELOCITY STR00500
C   FOR A P.M.H. EQUALS 0.  THIS IS USED TO COMPUTE THE STARTING POINT  STR00600
C   ON THE TRAVERSE LINE.                                               STR00700
C                                                                       STR00800
C   VARIABLES NOT DEFINED IN THIS ROUTINE WILL BE DEFINED IN ANOTHER    STR00900
C   ROUTINE                                                             STR01000
C                                                                       STR01100
C   DISTO = INITIAL DISTANCE ALONG TRAVERSE LINE TO POINT OF MAXIMUM    STR01200
C           WIND VELOCITY.                                              STR01300
C     RHO = RADIAL DISTANCE AT WHICH WIND VELOCITY EQUALS ZERO          STR01400
C     YPP = DISTANCE ALONG TRAVERSE FROM POINT OF MAXIMUM WIND TO POINT STR01500
C           WHERE XP INTERSECTS TRAVERSE LINE.                          STR01600
      DIMENSION W(1500),T(1500),DELT(200),DIST(50),RS(1500),VX(1600)    STR01700
      COMMON /PAR/ LM,VF,WX,R,DISTO,XP                                  STR01800
      COMMON /PTS/ NPTS                                                 STR01900
      COMMON /WND/ W,T,DELT,DIST,VX,RS                                  STR02000
C   SN AND CS ARE SIN(115) AND COS(115).                                STR02100
      DATA SN,CS /.90631,.42262/                                        STR02200
C                                                                       STR02300
      VXZ=.5*(1.+CS)*VF*1.151/WX                                        STR02400
C                                                                       STR02500
      DO 70 I=1,NPTS                                                    STR02600
      IF (VX(I).GT.VXZ) GO TO 70                                        STR02700
C   COMPUTE RADIAL DISTANCE AT WHICH WIND VELOCITY EQUALS 0.            STR02800
      RHO=.76+I*.02                                                     STR02900
C   CHECK TO AVOID DIVISION BY ZERO.                                    STR03000
      EE=ABS(VX(I)-VX(I-1))                                             STR03100
      IF (EE.GT..00001) GO TO 50                                        STR03200
      EE=ABS(VXZ-VX(I-1))                                               STR03300
      IF (EE.LT..00001) GO TO 40                                        STR03400
C   PRINT ERROR MESSAGE                                                 STR03500
      WRITE (6,10)                                                      STR03600
   10 FORMAT (/,1X,40H***** ERROR FROM SUBROUTINE STRTPT *****,//,1X,8HESTR03700
     2RROR 13)                                                          STR03800
      WRITE (6,20)                                                      STR03900
   20 FORMAT (3X,88H SEE ERROR TABLE IN CERC TM TITLE VERIFICATION STUDYSTR04000
     2 OF A BATHYSTROPIC STORM SURGE MODEL)                             STR04100
      WRITE (6,30) VX(I-1),VX(I),VXZ,I                                  STR04200
   30 FORMAT (1X,25HTILT YOU DIVIDED BY ZERO,/3F10.5,I5)                STR04300
      STOP                                                              STR04400
C                                                                       STR04500
   40 XM=.5                                                             STR04600
      GO TO 60                                                          STR04700
   50 XM=(VXZ-VX(I-1))/(VX(I)-VX(I-1))                                  STR04800
C   MAKE FINAL INTERPOLATION.                                           STR04900
   60 RHO=RHO+XM*.02                                                    STR05000
C   RHO IS INITIAL DIST. FROM P.M.H. CENTER.                            STR05100
      RHO=RHO*R                                                         STR05200
      GO TO 80                                                          STR05300
   70 CONTINUE                                                          STR05400
C                                                                       STR05500
   80 YPP=R*CS                                                          STR05600
C   XP IS THE HORIZONTAL DISTANCE FROM THE P.M.H. CENTER TO THE         STR05700
      XP=R*SN                                                           STR05800
C   TRAVERSE LINE.                                                      STR05900
C   COMPUTE INITIAL POINT ALONG TRAVERSE LINE.                          STR06000
      DISTO=YPP+SQRT(RHO**2-XP**2)                                      STR06100
      WRITE (6,90) RHO,DISTO                                            STR06200
   90 FORMAT (/1X,61HRADIAL DISTANCE AT WHICH WIND VELOCITY FOR A P.M.H.STR06300
     2 EQUALS 0.,F9.1/1H ,73HINITIAL DISTANCE ALONG TRAVERSE LINE FROM PSTR06400
     3OINT OF MAX. WIND VEL. EQUALS ,F9.1)                              STR06500
      WRITE (6,100)                                                     STR06600
  100 FORMAT (1H057HRADIAL DISTANCE MEANS DISTANCE FROM CENTER OF HURRICSTR06700
     2ANE. )                                                            STR06800
      WRITE (6,110)                                                     STR06900
  110 FORMAT (1X,65HDISTANCE FROM COASTLINE MEANS DISTANCE PARALLEL TO TSTR07000
     2RAVERSE LINE.)                                                    STR07100
      WRITE (6,120)                                                     STR07200
  120 FORMAT (1H1)                                                      STR07300
      RETURN                                                            STR07400
      END                                                               STR07500
```

```
      SUBROUTINE PROFIL (IZONE,ITYPE,RR,IRR,IDATA,LIST)                 PRO00100
C                                                                       PRO00200
C     ******************************************************************PRO00300
C                                                                       PRO00400
C   FORMERLY PROGRAM PROFIL                                             PRO00500
C                                                                       PRO00600
C   722S8R12M0 (PROFIL) INTERPOLATION OF HURRIANE VELOCITY PROFILES.    PRO00700
      DIMENSION R(2),IRR(2000),VR2(2,750),XR2(2,750),VTMP(2,2000),XXA(2)PRO00800
     2,YYA(2),AX(2),IAX(16)                                             PRO00900
      DIMENSION ERR(9),DUM(16)                                          PRO01000
      COMMON /PTS/ NPTS                                                 PRO01100
      COMMON /TES/ BOMB                                                 PRO01200
      REWIND IDATA                                                      PRO01300
C                                                                       PRO01400
C   VARIABLES NOT DEFINED IN THIS ROUTINE WILL BE DEFINED IN ANOTHER    PRO01500
C   ROUTINE                                                             PRO01600
C                                                                       PRO01700
C   THIS PROGRAM INTERPOLATES A PROFILE FOR A PMH WITH SIZE PARAMETER,  PRO01800
C   RR, BETWEEN 2 DIGITIZED PMH PROFILES WITH SIZE PARAMETERS, R(1)     PRO01900
C   AND R(2) AND PRINTS THE OUTPUT IF REQUESTED.  THIS OUTPUT IS PART OFPRO02000
C   THE INPUT FOR PROGRAM SURGE.                                        PRO02100
C                                                                       PRO02200
C   RELATIVE VELOCITY VALUES ARE INTERPOLATED ALONG THE PMH PROFILES    PRO02300
C   WHICH WERE READ IN, AT INTERVALS OF .02.  THESE VALUES ARE STORED   PRO02400
C   IN THE VTMP ARRAY.  THEN THE VALUES STORED IN VTMP ARE USED TO MAKE PRO02500
C   INTERPOLATIONS FOR THE CONSTRUCTION OF A PMH WITH  A SIZE           PRO02600
C   PARAMETER OF RR NAUTICAL MILES.  THESE FINAL INTERPOLATIONS ARE     PRO02700
C   STORED IN IRR.                                                      PRO02800
C                                                                       PRO02900
C   CAUTION.    THE LOGIC OF THIS PROGRAM IS RATHER DELICATE IN         PRO03000
C               PLACES.  BEFORE MAKING ANY PROGRAM CHANGES IT WOULD     PRO03100
C               BE WISE TO READ THE WARNINGS INDICATED BELOW.           PRO03200
C                                                                       PRO03300
C                                                                       PRO03400
C   DEFINITION OF FORTRAN VARIABLES IS AS FOLLOWS.                      PRO03500
C      R IS THE DISTANCE FROM THE PMH CENTER TO THE POINT OF MAX WIND   PRO03600
C      VELOCITY.  R IS A PARAMETER FOR THE PMH PROFILES WHICH WERE      PRO03700
C      DIGITIZED.  RR IS THE DISTANCE FROM THE PMH CENTER TO THE POINT  PRO03800
C      OF MAX WIND VELOCITY FOR THE PMH PROFILE BEING CONSTRUCTED.      PRO03900
C      IRR IS THE FINAL INTERPOLATED VALUES OF THE PMH PROFILE BEING    PRO04000
C      CONSTRUCTED, AS A FUNCTION OF RELATIVE DISTANCE. VR2 IS REL. VELOPRO04100
C     -CITY VALUES OF THE DIGITIZED PMH PROFILES.  XR2 IS DIGITIZED     PRO04200
C      VALUES OF RELATIVE DISTANCE CORRESPONDING TO THE VR2IS.          PRO04300
C      VTMP IS INTERPOLATED VALUES OF RELATIVE VELOCITY ALONG THE DIGIT-PRO04400
C      IZED PROFILES. (XXA(I),YYA(I),I=1,2) ARE (X,Y) POINTS USED TO    PRO04500
C      MAKE LINEAR INTERPOLATIONS.                                      PRO04600
C   NPTS IS THE NUMBER OF POINTS BETWEEN X = .8 AND  X = 30, SPACED AT  PRO04700
C   INCREMENTS OF X EQUAL TO .02.                                       PRO04800
C            IB AND IE ARE USED TO READ AND PRINT OUT DATA CARD BY      PRO04900
C            CARD OR LINE BY LINE.                                      PRO05000
C   ITYPE IS THE TYPE OF HURRICANE MODEL. (PMH OR SPH)                  PRO05100
C                                                                       PRO05200
C                                                                       PRO05300
C   NOTE.  PMH MEANS PROBABLE MAXIMUM HURRICANE.                        PRO05400
C                                                                       PRO05500
C                                                                       PRO05600
      DATA E,KX /.00001,5H...../                                        PRO05700
C      WARNING.     NPTS SHOULD ALWAYS BE LESS THAN 2000.  OTHERWISE    PRO05800
C                   THE DIMENSIONS OF VTMP AND IRP WILL BE EXCEEDED AND PRO05900
C                   SOMETHING WILL BE CLOBBERED.                        PRO06000
C                                                                       PRO06100
      DATA ERR /5HERR14,5HERR15,5HERR16,5HERR17,5HERR18,5HERR19,5HERR20,PRO06200
     2 5HERR21,5HERR22/                                                 PRO06300
C                                                                       PRO06400
C   ID IS GIVEN AN INITIAL VALUE .  IF ID REMAINS = AAAAA THEN YOU      PRO06500
C   KNOW IZONE WAS NOT A LEGAL VALUE FOR THIS PROGRAM                   PRO06600
      ID=5HAAAAA                                                        PRO06700
      IF (IZONE.EQ.2H A) ID=5H00001                                     PRO06800
      IF (IZONE.EQ.2H 1) ID=5H00001                                     PRO06900
      IF (IZONE.EQ.2H 2) ID=5H00001                                     PRO07000
      IF (IZONE.EQ.2H 4) ID=5H00001                                     PRO07100
      IF (IZONE.EQ.2H B) ID=5H00002                                     PRO07200
      IF (IZONE.EQ.2H C) ID=5H00002                                     PRO07300
      IF (IZONE.EQ.2H 3) ID=5H00003                                     PRO07400
C   VERIFY THAT ZONE REQUESTED IS CORRECT                               PRO07500
      IF (ID.EQ.5HAAAAA) GO TO 10                                       PRO07600
      GO TO 30                                                          PRO07700
C   WRITE ERROR MESSAGE                                                 PRO07800
10    BOMB=ERR(1)                                                       PRO07900
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         WRITE (6,20) IZONE                                             PRO08000
 20      FORMAT (1X,45HZONE REQUESTED IS NOT VALID FOR THIS PROGRAM,/,1X,51PRO08100
        2HVALID ZONES ARE A,B,C,1,2,3,4,  YOU REQUESTED ZONE ,A2)      PRO08200
         GO TO 420                                                      PRO08300
 C                                                                      PRO08400
 C    READ VELOCITY PROFILES FOR RHO/R FROM .8 TO 30.                   PRO08500
 C    INITIALIZE KK AND IFLAG                                           PRO08600
 30      KK=1                                                           PRO08700
         IFLAG=0                                                        PRO08800
 40      READ (IDATA,50) JID,R(KK)                                      PRO08900
 50      FORMAT (5X,A5,F5.1,2X,A3)                                      PRO09000
 C    CHECK FOR CORRECT ZONE                                            PRO09100
         BOMB=ERR(2)                                                    PRO09200
         IF (JID.EQ.5HFINAL) GO TO 420                                  PRO09300
         BOMB=ERR(3)                                                    PRO09400
         IF (JID.NE.ID.AND.KK.EQ.2) GO TO 420                           PRO09500
         IF (JID.NE.ID) GO TO 60                                        PRO09600
         GO TO 70                                                       PRO09700
 60      READ (IDATA,160) DUM                                           PRO09800
         IF (DUM(1).EQ.5H.....) GO TO 30                                PRO09900
         GO TO 60                                                       PRO10000
 70      BOMB=ERR(4)                                                    PRO10100
         IF (R(KK).LT.2.0.OR.R(KK).GT.80.0) GO TO 80                    PRO10200
 C    CHECK FOR BRACKETING RADII                                        PRO10300
         IF (R(KK).LE.RR) GO TO 100                                     PRO10400
         IF (R(KK).GT.RR) GO TO 110                                     PRO10500
 80      WRITE (6,90) R(KK)                                             PRO10600
 90      FORMAT (1X,39HINTERPOLATION RANGE FOR R = 2.0 TO 80.0,/,1X,17HYOU PRO10700
        2REQUESTED R =,1X,F5.1)                                         PRO10800
         GO TO 420                                                      PRO10900
 C                                                                      PRO11000
 100     R(1)=R(KK)                                                     PRO11100
         KK=1                                                           PRO11200
         GO TO 120                                                      PRO11300
 110     BOMB=ERR(5)                                                    PRO11400
         IF (KK.EQ.1) GO TO 420                                         PRO11500
 C    SET FLAG TO END READING                                           PRO11600
         IFLAG=1                                                        PRO11700
 C                                                                      PRO11800
 120     IB=1                                                           PRO11900
 130     IE=IB+7                                                        PRO12000
         READ (IDATA,140) (XR2(KK,K),VR2(KK,K),K=IB,IE)                 PRO12100
 140     FORMAT (8(F5.2,F5.3))                                          PRO12200
 C    TEST FOR LAST CARD.                                               PRO12300
 C    ALL 9(S IN COLS 1-5 INDICATES END OF DATA.                        PRO12400
         EE=ABS(XR2(KK,IB)-999.99)                                      PRO12500
         IF (EE.LT.E) GO TO 150                                         PRO12600
         IB=IB+8                                                        PRO12700
         GO TO 130                                                      PRO12800
 C                                                                      PRO12900
 C                                                                      PRO13000
 C    CHECK TO MAKE CERTAIN THAT IE DOES NOT EXCEED 750,                PRO13100
 C        WARNING.     IF IE EXCEEDS 750, THE DIMENSIONS OF XR2 AND VR2 PRO13200
 C                     WILL BE EXCEEDED, AND SOMETHING WILL BE CLOBBERED. PRO13300
 150     BOMB=ERR(6)                                                    PRO13400
         IF (IE.GT.750) GO TO 420                                       PRO13500
 C    DECREASE IE BY 8 BECAUSE 1 EXTRA CARD WAS READ.                   PRO13600
         IE=IE-8                                                        PRO13700
 C    READ PERIODS.                                                     PRO13800
         READ (IDATA,160) IAX                                           PRO13900
 160     FORMAT (16A5)                                                  PRO14000
 C                                                                      PRO14100
 C    COUNT EXACT NO OF DATA POINTS.                                    PRO14200
         DO 170 K=1,8                                                   PRO14300
         IF (ABS(XR2(KK,IE-K+1)).LT.E.AND.ABS(VR2(KK,IE-K+1)).LT.E) GO TO 1PRO14400
        270                                                             PRO14500
 C    CHECK TO MAKE CERTAIN THAT LAST XR2 VALUE EXCEEDS 30.             PRO14600
 C        WARNING.     IF NO VALUE OF XR2 EXCEEDS 30, THE LOGIC IN THE DO PRO14700
 C                     LOOP ENDING AT STATEMENT 220 IS BOOBY TRAPPED.   PRO14800
 C                                                                      PRO14900
         BOMB=ERR(7)                                                    PRO15000
         IF (XR2(KK,IE-K+1).LT.30.) GO TO 420                           PRO15100
         MP=IE-K+1                                                      PRO15200
         GO TO 180                                                      PRO15300
 170     CONTINUE                                                       PRO15400
 C    IMPOSSIBLE.                                                       PRO15500
         BOMB=ERR(8)                                                    PRO15600
         GO TO 420                                                      PRO15700
 C                                                                      PRO15800
 180     DO 210 I=1,16                                                  PRO15900
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      BOMB=ERR(9)                                                       PRO16000
      IF (IAX(I).NE.KX) GO TO 190                                       PRO16100
      GO TO 210                                                         PRO16200
190   WRITE (6,200) IAX                                                 PRO16300
200   FORMAT (1X,16A5)                                                  PRO16400
      GO TO 420                                                         PRO16500
210   CONTINUE                                                          PRO16600
C                                                                       PRO16700
C    NOTE***** ONLY ONE SET OF DIGITIZED DATA IS USED WHEN R(KK) = RR   PRO16800
C    SET FLAG TO END READING ONLY IF R(KK) EQUALS RR                    PRO16900
      IF (R(KK).EQ.RR) IFLAG=1                                          PRO17000
C    CHECK FLAG TO END READING                                          PRO17100
      IF (IFLAG.EQ.1) GO TO 220                                         PRO17200
      KK=2                                                              PRO17300
      GO TO 40                                                          PRO17400
C                                                                       PRO17500
C    INPUT AND INTERNAL COMPUTATIONS ARE PRINTED OUT FOR DEBUGGING PUR- PRO17600
C    POSES IF LIST = 1.  IF LIST = 0  INPUT AND INTERNAL COMPUTATIONS   PRO17700
C    NOT PRINTED.                                                       PRO17800
C                                                                       PRO17900
C    CHECK PRINT OPTION.                                                PRO18000
220   IF (LIST.NE.1) GO TO 270                                          PRO18100
      DO 260 KK=1,2                                                     PRO18200
      WRITE (6,230)                                                     PRO18300
230   FORMAT (1H0,3HXR2//)                                              PRO18400
      WRITE (6,240) (XR2(KK,L),L=1,MP)                                  PRO18500
240   FORMAT (1X,16F7.3)                                                PRO18600
      WRITE (6,250)                                                     PRO18700
250   FORMAT (1H0,3HVR2//)                                              PRO18800
      WRITE (6,240) (VR2(KK,L),L=1,MP)                                  PRO18900
C    SKIP OUT OF LOOP ONLY WHEN R(KK) = RR                              PRO19000
      IF (R(KK).EQ.RR) GO TO 270                                        PRO19100
260   CONTINUE                                                          PRO19200
C                                                                       PRO19300
C                                                                       PRO19400
C    CONSTRUCT INTERPOLATED RELATIVE VELOCITY PROFILE.                  PRO19500
C                                                                       PRO19600
C                                                                       PRO19700
C    IN THE DO LOOP ENDING AT STATEMENT 250,VALUES OF RELATIVE VELOCITY PRO19800
C    ARE INTERPOLATED STARTING AT X = .8 AND ENDING AT X = 30. BY       PRO19900
C    INCREMENTS OF X,EQUAL TO .02.                                      PRO20000
C                                                                       PRO20100
270    DO 340 KK=1,2                                                    PRO20200
C                                                                       PRO20300
C    THIS DO LOOP REFINES SPACING BETWEEN DIGITIZED DATA POINTS         PRO20400
C                                                                       PRO20500
      X=.8                                                              PRO20600
      IA=-1                                                             PRO20700
      IFUD=0                                                            PRO20800
C    SELECT DIGITIZED VALUES OF (X,Y) FOR INTERPOLATION.  IA IS A       PRO20900
C    COUNTER.   WHEN IA = -1, THE SUBSCRIPT IA+2 (BELOW) EQUALS 1.      PRO21000
C    THE TEST VARIABLE,IFUD, IS USED BECAUSE THE INTERPOLATION          PRO21100
C    COEFFICIENTS MUST BE COMPUTED AT LEAST ONCE BEFORE USING THE       PRO21200
C    INTERPOLATION FORMULA.                                             PRO21300
      DO 310 I=1,NPTS                                                   PRO21400
      IF (X.LE.XR2(KK,IA+2).AND.IFUD.EQ.1) GO TO 300                    PRO21500
      IFUD=1                                                            PRO21600
280   IA=IA+1                                                           PRO21700
      IF (X.GT.XR2(KK,IA+2)) GO TO 280                                  PRO21800
C                                                                       PRO21900
C    X SHOULD BE BETWEEN XXA(1) AND XXA(2).                             PRO22000
C    SUBSTITUTE APPROPRIATE (X,Y) VALUES FOR INTERPOLATION.             PRO22100
      DO 290 L=1,2                                                      PRO22200
      XXA(L)=XR2(KK,IA+L)                                               PRO22300
290   YYA(L)=VR2(KK,IA+L)                                               PRO22400
      CALL INTERP (XXA,YYA,AX)                                          PRO22500
300   VTMP(KK,I)=AX(1)*X+AX(2)                                          PRO22600
310   X=X+.02                                                           PRO22700
C    CHECK PRINT OPTION.                                                PRO22800
      IF (LIST.NE.1) GO TO 330                                          PRO22900
      WRITE (6,320)                                                     PRO23000
320   FORMAT (1H0,5HVTMP //)                                            PRO23100
      WRITE (6,240) (VTMP(KK,L),L=1,NPTS)                               PRO23200
C    SKIP OUT OF LOOP ONLY WHEN R(KK) = RR                              PRO23300
330   IF (R(KK).EQ.RR) GO TO 350                                        PRO23400
340   CONTINUE                                                          PRO23500
C                                                                       PRO23600
350   DO 380 I=1,NPTS                                                   PRO23700
C                                                                       PRO23800
C    THIS DO LOOP INTERPOLATES BETWEEN TWO SETS OF DIGITIZED DATA       PRO23900
```

```
C    AND STORES INTERPOLATED VALUES IN A NEW ARRAY (IRR).               PRO24000
C                                                                       PRO24100
C    SKIP FOLLOWING LOOP ONLY WHEN R(KK) = RR                           PRO24200
      IF (R(KK).EQ.RR) GO TO 370                                        PRO24300
      DO 360 KK=1,2                                                     PRO24400
      YYA(KK)=VTMP(KK,I)                                                PRO24500
      XXA(KK)=R(KK)                                                     PRO24600
360   CONTINUE                                                          PRO24700
      CALL INTERP (XXA,YYA,AX)                                          PRO24800
      IRR(I)=(AX(1)*RR+AX(2))*1000.+.5                                  PRO24900
      GO TO 380                                                         PRO25000
C    EXECUTE THE FOLLOWING STATEMENT ONLY WHEN R(KK) = RR               PRO25100
370   IRR(I)=VTMP(1,I)*1000.+.5                                         PRO25200
380   CONTINUE                                                          PRO25300
C                                                                       PRO25400
C    CHECK PRINT OPTION.                                                PRO25500
      IF (LIST.NE.1) GO TO 470                                          PRO25600
      WRITE (6,390) RR                                                  PRO25700
390   FORMAT (3H0R=,F5.1,//4H IRR,//)                                   PRO25800
C                                                                       PRO25900
C    PRINT FINAL INTERPOLATED VALUES OF RELATIVE VELOCITY.              PRO26000
      IB=1                                                              PRO26100
      NC=1                                                              PRO26200
400   IE=IB+11                                                          PRO26300
      IF (IE.GT.NPTS) IE=NPTS                                           PRO26400
      WRITE (6,410) IZONE,ITYPE,RR,NC,(IRR(I),I=IB,IE)                  PRO26500
410   FORMAT (1X,4HZONE,A2,1X,A3,F5.1,13I5)                             PRO26600
      IF (IE.EQ.NPTS) GO TO 470                                         PRO26700
      IB=IB+12                                                          PRO26800
      NC=NC+1                                                           PRO26900
      GO TO 400                                                         PRO27000
C  ERROR MESSAGE IS WRITTEN                                             PRO27100
420   WRITE (6,430)                                                     PRO27200
430   FORMAT (/,1X,40H***** ERROR FROM SUBROUTINE PROFIL *****)         PRO27300
      WRITE (6,440) BOMB                                                PRO27400
440   FORMAT (//,1X,A5)                                                 PRO27500
      WRITE (6,450)                                                     PRO27600
450   FORMAT (3X,88H SEE ERROR TABLE IN CERC TM TITLE VERIFICATION STUDYPRO27700
     2 OF A BATHYSTROPIC STORM SURGE MODEL)                             PRO27800
      WRITE (6,460)                                                     PRO27900
460   FORMAT (1X,86H****************************************************PRO28000
     2**********************************)                               PRO28100
C    IF BOMB = ANY ERROR RETURN IS MADE TO MAIN PROGRAM SURGE WHERE THE PRO28200
C    VALUES OF IDATA, KEY, KEYA, AND ETC. ARE WRITTEN BEFORE RUN        PRO28300
C    TERMINATION.                                                       PRO28400
      BOMB=5HERROR                                                      PRO28500
470   RETURN                                                            PRO28600
      END                                                               PRO28700
```

```
      SUBROUTINE INTERP (XXA,YYA,AX)                                    INT00100
C                                                                       INT00200
C     ******************************************************************INT00300
C                                                                       INT00400
C   THIS SUBROUTINE MAKES LINEAR INTERPOLATIONS BETWEEN DIGITIZED (X,Y) INT00500
C   DATA POINTS AND BETWEEN PROFILE CURVES OF DIFFERENT SIZE HURRICANES.INT00600
C                                                                       INT00700
C   VARIABLES NOT DEFINED IN THIS ROUTINE WILL BE DEFINED IN ANOTHER    INT00800
C   ROUTINE                                                             INT00900
C                                                                       INT01000
C      (XXA,YYA)(S ARE THE DATA POINTS. AX(S ARE THE INTERPOLATION COEF-INT01100
C      ICIENTS.                                                         INT01200
C   AX(S ARE DETERMINED BY USING THE STANDARD SLOPE INTERCEPT FORM      INT01300
C   AX(1) IS THE SLOPE,  AX(2) IS THE INTERCEPT.                        INT01400
C                                                                       INT01500
      DIMENSION XXA(2),YYA(2),AX(2)                                     INT01600
      DATA E /.000005/                                                  INT01700
C                                                                       INT01800
C   CHECK TO SEE IF XXA POINTS ARE,EVER INCREASING.                     INT01900
      IF (XXA(2)-XXA(1).GT.E) GO TO 40                                  INT02000
C   UNREASONABLE INPUT.                                                 INT02100
C   PRINT ERROR MESSAGE                                                 INT02200
      WRITE (6,10)                                                      INT02300
10    FORMAT (/,1X,40H***** ERROR FROM SUBROUTINE INTERP *****,//,1X,8HEINT02400
     2RROR 23)                                                          INT02500
      WRITE (6,20)                                                      INT02600
20    FORMAT (3X,88H SEE ERROR TABLE IN CERC TM TITLE VERIFICATION STUDYINT02700
     2 OF A BATHYSTROPIC STORM SURGE MODEL)                             INT02800
      WRITE (6,30) XXA                                                  INT02900
30    FORMAT (1X,2F10.3,41H  TILT, X DATA SHOULD BE EVER INCREASING.)   INT03000
      STOP                                                              INT03100
C                                                                       INT03200
C   NORMAL INPUT                                                        INT03300
C   COMPUTE INTERPOLATION COEFFICIENTS.                                 INT03400
C                                                                       INT03500
40    AX(1)=(YYA(2)-YYA(1))/(XXA(2)-XXA(1))                             INT03600
      AX(2)=YYA(1)-AX(1)*XXA(1)                                         INT03700
      RETURN                                                            INT03800
      END                                                               INT03900
```

```
      SUBROUTINE ZERWND                                                 ZWD00100
C                                                                       ZWD00200
C     *****************************************************************ZWD00300
C                                                                       ZWD00400
C    THIS ROUTINE COMPUTES WIND VELOCITY MAGNITUDE AND DIRECTION ALONG A ZWD00500
C    TRAVERSE LINE WHICH PASSES THRU A PROBABLE MAXIMUM HURRICANE AT THE ZWD00600
C    POINT WHERE WIND VELOCITY IS GREATEST. THIS TRAVERSE IS 115.       ZWD00700
C    DEG.COUNTERCLOCKWISE TO THE LINE OF SYMMETRY OF THE P.M.H. ISOVELS. ZWD00800
C                                                                       ZWD00900
C    THIS ROUTINE DOES COMPUTATION FOR RS, W, AND TH ALONG A TRAVERSE   ZWD01000
C    DRAWN FROM THE ZERO WIND ISOVEL AT SHORE TO THE POINT WHERE        ZWD01100
C    THE TRAVERSE INTERSECTS WITH THE ZERO WIND ISOVEL AT THE TAIL      ZWD01200
C    OF THE STORM.                                                      ZWD01300
C                                                                       ZWD01400
C    COMPUTATIONS ARE DONE SHOREWARD-SEAWARD FOR THIS ROUTINE           ZWD01500
C                                                                       ZWD01600
C     ******************************************************            ZWD01700
C                                   NOTE                                ZWD01800
C    NONE OF THE RESULTS FROM THIS ROUTINE ARE CARRIED TO THE MAIN      ZWD01900
C    PROGRAM OR ANY OTHER ROUTINE.                                      ZWD02000
C    THE ONLY PURPOSE OF THIS ROUTINE IS TO SUPPLY A COMPLETE DESCRIPTIONZWD02100
C    OF THE WIND FIELD USED IS COMPUTING SURGE.                         ZWD02200
C     ******************************************************            ZWD02300
C                                                                       ZWD02400
C    VARIABLES NOT DEFINED IN THIS ROUTINE WILL BE DEFINED IN ANOTHER   ZWD02500
C    ROUTINE                                                            ZWD02600
C                                                                       ZWD02700
C    THE VARIABLES THETA AND THETAD ARE USED FOR CLARITY TO ILLUSTRATE  ZWD02800
C    CHANGES IN THE VALUE OF TH.  THESE VARIABLES DO NOT APPEAR IN      ZWD02900
C    THE ROUTINE.  TH IS USED TO REPRESENT THETA AND THETAD.            ZWD03000
C    TH IS ORIGINALLY THETA IN RADIANS WHICH IS THE POLAR COORDINATE    ZWD03100
C    OF LOCATION FOR RS(L).  TH IS CONVERTED TO THETAD(ANGLE WHICH      ZWD03200
C    INCLUDES DEFLECTION).  THEN TH IS CONVERTED TO THETAD - 25. DEGREES.ZWD03300
C    THE SUBTRACTION OF 25. DEGREES WAS A CORRECTION  FOR GEOMETRY.     ZWD03400
C    THE WIND DIRECTION, THETAD, IS GIVEN BY THE FOLLOWING FORMULAS     ZWD03500
C      THETAD=THETA+25.                          IF RS(L)/R LT 1.2      ZWD03600
C      THETAD=THETA+15.*(RS(L)-R)/(1.2*R-R)+10.  IF 1. LT RS(L)/R LT 1.2 ZWD03700
C      THETAD=THETA+10.*RS(L)/R                  IF RS(L)/R LT 1.       ZWD03800
C                                                                       ZWD03900
C      (DISTANCES ARE IN NAUTICAL MILES, VF IS IN KNOTS, W(L) AND WX    ZWD04000
C    ARE IN M.P.H.)                                                     ZWD04100
C      (ANGLES ARE IN DEGREES,  COUNTERCLOCKWISE IS POS.)               ZWD04200
C     VARIABLES ARE AS FOLLOWS.                                         ZWD04300
C      AL IS A DISTANCE ALONG THE VELOCITY PROFILE AT WHICH COMPUTATIONS ZWD04400
C      BEGIN.                                                           ZWD04500
C      DEL = DIFFERENCE BETWEEN DELA AND DELB.                          ZWD04600
C      DELA = DISTANCE TO POINT ON TRAVERSE WHERE COMPUTATIONS TAKE PLACEZWD04700
C      DELB = DISTANCE TO POINT ON TRAVERSE 10 N.M. FARTHER FROM SHORE  ZWD04800
C    DISTO = INITIAL DISTANCE ALONG TRAVERSE LINE TO POINT OF MAXIMUM   ZWD04900
C             WIND VELOCITY.                                            ZWD05000
C    PRESS = ATMOSPHERIC PRESSURE DIFFERENTIAL.                         ZWD05100
C      R = DISTANCE FROM ORIGIN TO THE MAXIMUM WIND.                    ZWD05200
C    RAD2 = THE NUMBER OF DEGREES IN ONE RADIAN (CONVERSION FACTOR)     ZWD05300
C      RS= THE LENGTH OF THE RAY FROM THE STROM CENTER TO ANY POINT     ZWD05400
C          ON THE TRAVERSE.                                             ZWD05500
C    SN AND CS ARE SIN(115) AND COS(115). RAD1 IS  25 DEG. IN RADIANS.  ZWD05600
C   SNTF = SINE OF 25 DEGREES                                           ZWD05700
C      TH = THE ANGLE (DEGREES) BETWEEN 115 DEG. LINE AND THE RAY DRAWN ZWD05800
C             BETWEEN THE STORM CENTER AND ANY POINT ON THE TRAVERSE.   ZWD05900
C    TEST = VALUE USED TO TEST FOR END OF TRAVERSE DRAWN FROM ZERO WIND ZWD06000
C             TO ZERO WIND.                                             ZWD06100
C      VF = SPEED OF TRANSLATION OF ENTIRE HURRICANE.                   ZWD06200
C      W= MAGNITUDE OF WIND VELOCITY AT ANY POINT ALONG THE TRAVERSE LINEZWD06300
C      WX = MAXIMUM WIND VELOCITY                                       ZWD06400
C      X AND Y = CARTESIAN COORDINATES OF EACH RAY RS. THE STORM        ZWD06500
C      CENTER IS THE ORIGIN TO WHICH X AND Y VALUES ARE REFERENCED.     ZWD06600
C      THE X- AXIS IS ALONG THE RADIUS TO MAX. WINDS (R).               ZWD06700
C                                                                       ZWD06800
      COMMON /PAR/ LM,VF,WX,R,DISTO,XP                                  ZWD06900
      COMMON /ATM/ PN,PO                                                ZWD07000
      DATA SN,CS,RAD1,RAD2 /.90631,.42262,.436332,57.29577867/          ZWD07100
      DATA SNTF /.42262/                                                ZWD07200
C                                                                       ZWD07300
      TEST=2.*(DISTO-R*SNTF)                                            ZWD07400
      DELA=0.                                                           ZWD07500
      AL=DISTO                                                          ZWD07600
      WRITE (6,10)                                                      ZWD07700
10    FORMAT (18H TIME INCREMENT  1,5X,11H  0.0 HOURS)                  ZWD07800
C  COMPUTE INITIAL X AND Y.                                             ZWD07900
```

```
      X=H-AL*CS                                                         ZWD08000
      Y=AL*SN                                                           ZWD08100
C                                                                       ZWD08200
C   PRINT PARAMETERS.                                                   ZWD08300
      WRITE (6,20) R,VF,WX,XP                                           ZWD08400
20    FORMAT (1X,5X,3HR =,F6.2,9H N. MILES,4X,4HVF =,F6.2,6H KNOTS,4X,5HZWD08500
     2 WX =,F7.2,7H M.P.H./1X,12HX DISTANCE =,F5.2,9H N. MILES)         ZWD08600
      WRITE (6,30)                                                      ZWD08700
30    FORMAT (//)                                                       ZWD08800
C   PRINT TITLE.                                                        ZWD08900
      WRITE (6,40)                                                      ZWD09000
40    FORMAT (27X,4H(RS),12X,3H(W),10X,4H(TH),19X,7H(PRESS))            ZWD09100
      WRITE (6,50)                                                      ZWD09200
50    FORMAT (1X,6X,13HDISTANCE FROM,6X,6HRADIAL,10X,4HWIND,5X,24HANGLE ZWD09300
     2FROM TRAVERSE LINE,3X,8HPRESSURE/5X,16HZERO VELOCITY AT,4X,8HDISTAZWD09400
     3NCE,7X,8HVELOCITY,4X,21HCOUNTERCLOCKWISE POS.,6X,5HSETUP/4X,18HFROZWD09500
     4NT OF HURRICANE,3X,8HN. MILES,9X,6HM.P.H.,5X,9H(DEGREES),19X,3HFT.ZWD09600
     5/,10X,8HN. MILES)                                                 ZWD09700
      WRITE (6,30)                                                      ZWD09800
C  REPETETIVE COMPUTATION OF WIND VELOCITY AND DIRECTION VERSUS X AND Y.ZWD09900
60    RS=SQRT(X**2+Y**2)                                                ZWD10000
      CALL QUAD (X,Y,TH)                                                ZWD10100
C   TH = ANGLE FROM LINE OF SYMMETRY TO RADIUS VECTOR (RS(L))           ZWD10200
      CALL VEL (RS,VXX)                                                 ZWD10300
      W=WX*VXX-.5*(1.-COS(TH))*VF*1.151                                 ZWD10400
      CALL DEFL (TH,RS)                                                 ZWD10500
C   TH = WIND ANGLE WITH CORRECTION FOR DEFLECTION                      ZWD10600
C   SUBTRACT 25 DEGREES FOR GEOMETRY.                                   ZWD10700
C   CONVERT WIND VELOCITY ANGLE TO DEG. FROM 115 DEG. LINE.             ZWD10800
      TH=RAD2*(TH-RAD1)                                                 ZWD10900
      IF (TH.LE.0.) TH=TH+360.                                          ZWD11000
      PRESS=(PN-P0)*(1.0-EXP(-R/RS))                                    ZWD11100
      WRITE (6,70) DELA,RS,W,TH,PRESS                                   ZWD11200
70    FORMAT (1X,4F15.2,10X,F15.2)                                      ZWD11300
      IF (DELA.GE.TEST) GO TO 80                                        ZWD11400
      DELB=DELA+10.                                                     ZWD11500
      IF (DELB.GE.TEST) DELB=TEST                                       ZWD11600
      DEL=DELB-DELA                                                     ZWD11700
      X=X+DEL*CS                                                        ZWD11800
      Y=Y-DEL*SN                                                        ZWD11900
      DELA=DELB                                                         ZWD12000
      GO TO 60                                                          ZWD12100
80    WRITE (6,90)                                                      ZWD12200
90    FORMAT (//1X,49HX AXIS IS ALONG HURRICANE ISOVEL AXIS OF SYMMETRY)ZWD12300
      WRITE (6,100)                                                     ZWD12400
100   FORMAT (1H1)                                                      ZWD12500
      RETURN                                                            ZWD12600
      END                                                               ZWD12700
```

APPENDIX A-3. DEFINITION OF SYMBOLS AND COMPUTER PROGRAM VARIABLES FOR ACTUAL HURRICANES

AB	Calculated angle between the traverse and initial storm centerline, RS (1).
AHOUR	Variable used to establish storm time.
ALPHA	Azimuth of the traverse (degrees).
AN	Intermediate value of wind stress and setup for x-component.
BEAR	Bearing of traverse in degrees. Not used for computations.
BETA 0	Azimuth of the storm centerline, RS (1) (degrees).
BFF	Bottom friction factor.
BN	Intermediate value of wind stress and setup for y-component.
BP	An array used to store successive values of BN.
BY	Absolute value of BN.
C1, C2, C3	Dimension correction factors.
D	Depth below mean water level in feet.
DASQ	Total water depth squared at each time level.
DAVG	Average bottom depth at each time level.
DELSXN	Incremental x-component setup in feet.
DELSYN	Incremental y-component setup in feet.
DELT	Time increments in hours.
DELX	Difference between traverse distances at each time level.
DEN	Intermediate computation for denominator of flux equation at each time level.
DIST	Distance from coast (nautical miles). DIST (1) and D (1) are farthest points from shore with successive values taken shoreward of these points.

DTH	Total water depth at each time level (feet).
DTN	Intermediate computation of water depth.
DTS	Intermediate computation of total water depth (DTH).
FUD	Cosine (AB).
IB, IE	Used to read and print out data; card-by-card or line-by-line.
ICHECK	Sentinel used to indicate errors.
ID	Identifies type of data on card.
IHUR	First three letters of hurricane punched on input data.
IOMIT	Print option parameter. If IOMIT equals 1, detailed printing is omitted. If IOMIT equals 0, detailed printing of type shown in example output for actual hurricane of Appendix A-7 is supplied.
IOMITD	Print option parameter. If IOMITD equals 1, detailed printing is omitted. If IOMITD equals 0, detailed printing of type shown in example output for actual hurricane of Appendix A-7 is supplied.
ISKIP	Print option parameter. If parameter equals 0, all wind data before and after interpolation is printed. If parameter equals 1, input wind-field data is omitted. If parameter equals 2, all wind-field data is omitted. See example output for actual hurricane in Appendix A-7.
ITYPE	First three letters of hurricane name.
ITPP	Sentinel used to verify interpolation of wind-field data.
LM	Number of shelf reaches for input supplied (maximum 50).
NM	Number of time increments for input supplied (maximum 200).
NN	Card number read from card.
NTP	Equals LM + 1.
PHI	Geographical latitude in degrees of traverse (given by PHII).
PHII	Geographical latitude in degrees of traverse (supplied as input).

PI	3.14159
PN	Peripheral pressure (inches of HG).
PO	Central pressure (inches of HG).
R	Radius of maximum winds (nautical miles).
RS	Length of ray from storm center to any point on the traverse (nautical miles). Polar coordinate of distance.
SA	Setup due to astronomical forces (feet).
SAP	Old value of astronomical tide.
SE	Initial setup (feet).
SINPHI	Sine of geographical latitude.
SP	Setup due to pressure (feet).
SPN	Pressure setup at new time level.
SPRES	Successive values of pressure setup at each time level.
ST	Successive values of total surge along traverse line.
Storm Center	Origin to which x- and y-values are referenced.
STOT	Value of total surge at shore for each time level.
SUMSX	Successive values of x-component of surge along traverse line.
SUMSY	Successive values of y-component of surge along traverse line.
SW	Successive values of SUMSX + SUMSY along traverse line.
SWW	Successive values of SW for each time level at shore.
SX	Total x-component setup at shore (feet).
SXP	Successive values of SUMSX.
SY	Total y-component setup at shore (feet).

SYP	Successive values of SUMSY.
T	Angle measured from the positive x-axis counterclockwise to the wind vector. Polar coordinate of angle.
VF	Forward speed of storm (knots).
VN, VNN, VNTEST, VP, VS	y-component of volume transport.
VN	Successive values of flux along traverse line.
VNN	Absolute value of flux.
VNTEST	Check on value of flux.
VP	Flux at previous time level.
VS	Y-flux (ft × ft/sec).
W	Magnitude of wind velocity at any point along the traverse line in miles per hour.
WK	Van Dorn's wind-stress factor.
WKCOR	Empirical calibration factor for wind-stress coefficient.
WSQ	W squared.
WWX	WSQ × cosine (T) in miles per hour squared.
WWY	WSQ × sine (T) in miles per hour squared.
WX	Maximum windspeed in miles per hour. Does not enter into computations for actual hurricane.
X-axis	Along the radius to maximum winds (R).

APPENDIX A-3. DEFINITION OF SYMBOLS AND COMPUTER PROGRAM VARIABLES FOR HYPOTHETICAL HURRICANES

AHOUR	Variable used to establish storm time.
AL	Distance along the velocity profile at which computations begin for each time step. Measured from point of maximum wind to most seaward point on traverse.
AN	Intermediate value of wind stress and setup for x-component.
AX	Interpolation coefficients determined by using the slope intercept form. AX (1) is the slope. AX (2) is the intercept.
BEAR	Bearing of traverse in degrees. Not used for computations.
BFF	Bottom friction factor.
BN	Intermediate value of wind stress and setup for y-component.
BP	An array used to store successive values of BN.
BY	Absolute value of BN.
C1, C2, C3	Dimension correction factors.
CS	Cosine 115°.
D	Depth below mean low water datum in feet.
DASQ	Total water depth squared at each time level.
DAVG	Average bottom depth at each time level.
DEL	Difference between points on the traverse.
DELA	Distance to point on traverse where computations take place.
DELB	Distance to point on traverse 10 nautical miles farther from shore than DELA.
DELSXN	Incremental x-component setup in feet.
DELSYN	Incremental y-component setup in feet.

DELT	Time increments in hours.
DELTT	Time increment used for computations.
DELX	Difference between traverse distances at each time level.
DEN	Intermediate computation for denominator of flux equation at each time level.
DIST	Distance from coast (nautical miles). DIST (1) and D (1) are farthest points from shore with successive values taken shoreward of these points.
DIST 0	Initial distance along traverse line to point of maximum wind velocity.
DTH	Total water depth at each time level (feet).
DTN	Intermediate computation of water depth.
DTS	Intermediate computation of total water depth (DTH).
E	Parameter used to check convergence.
EE	Parameter used to check convergence.
HR	Time step.
IB, IE	Used to read and print out data, card-by-card or line-by-line.
ICHECK	Sentinel used to indicate errors.
ID	Identifies type of data on card.
IDATA	Identifies type of wind data supplied as input. If IDATA equals 4 or 5, relative wind velocity data is supplied for interpolation. If IDATA equals 0, interpolated relative wind velocity data is supplied. See sample input sheet of Appendix A-6 for data format.
ILAST	Indicates number of different parameter sets to be read.
IOMIT	Print option parameter. If IOMIT equals 1, detailed printing is omitted. If IOMIT equals 0, detailed printing of type shown in example output for hypothetical hurricane of Appendix A-7 is supplied.

IOMITD	Print option parameter. If IOMITD equals 1, detailed printing is omitted. If IOMITD equals 0, detailed printing of type shown in example output for hypothetical hurricane of Appendix A-7 is supplied.
IREAD	Used to read all digitized wind data onto disk storage.
IRR	Final interpolated values of PMH profile being constructed as a function of relative distance.
ITYPE	Type of hurricane model (PMH or SPH).
IVX	Interpolated wind data generated in subroutine PROFIL.
IZONE	Hurricane zone.
KEY	Print option for subroutine HRWDPF. If KEY equals 0, detailed printing is omitted. If KEY equals 1, detailed printing of type shown in example output of this appendix is supplied.
KEYA	If KEYA equals 0, subroutine ZERWND is not called. If KEYA equals 1, subroutine ZERWND is called and printing of type shown in example output of Appendix A-7 is supplied.
LIST	Print option for subroutine PROFIL. If LIST equals 0, detailed printing is omitted. If LIST equals 1, detailed printing of type shown in example output of Appendix A-7 is supplied.
LM	Maximum number of 50 shelf reaches for input supplied.
NM	Maximum number of 200 time increments for input supplied.
NN	Card number read from card.
NPTS	Number of points along the PMH profile.
PHI	Geographical latitude in degrees of traverse (given by PHII).
PHII	Geographical latitude in degrees of traverse (supplied as input).
PHIIA	Latitude limit for hurricane zone.
PHIIB	Latitude limit for hurricane zone.
PI	3.14159.

PN	Peripheral pressure (inches of HG).
PO	Central pressure (inches of HG).
PRESS	Atmospheric pressure differential.
R	Radius to maximum wind in nautical miles (input parameter) or (subroutine PROFIL) radius to maximum wind for the PMH profiles which were digitized.
RAD 1	25° in Radians.
RAD 2	Number of degrees equal to one radian (conversion factor).
RHO	Each successive value of RS (L) along the traverse line or (subroutine STRTPT) initial distance from PMH center to shore intersection of traverse line.
RR	Radius to maximum winds of wind-field data supplied as input or (subroutine PROFIL) radius to maximum wind for the PMH profile being constructed.
RS	Length of the ray from the storm center to any point on the traverse (nautical miles). Polar coordinate of distance.
SA	Setup due to astronomical forces (feet).
SAA	Value of astronomical tide (input parameter in feet).
SAP	Old value of astronomical tide.
SE	Initial setup (feet).
SINPHI	Sine of geographical latitude.
SN	Sine 115°.
SNTF	Sine of 25°.
SP	Setup due to pressure (feet).
SPN	Pressure setup at new time level.
SPRES	Successive values of pressure setup at each time level.

ST	Successive values of total surge along traverse line.
STOT	Value of total surge at shore for each time level.
SUMSX	Successive values of x-component of surge along traverse line.
SUMSY	Successive values of y-component of surge along traverse line.
SW	Successive values of SUMSX + SUMSY along traverse line.
SWW	Successive values of SW for each time level at shore.
SX	Total x-component of setup at shore (feet).
SXP	Successive values of SUMSX.
SY	Total y-component of setup at shore (feet).
SYP	Successive values of SUMSY.
T	Angle measured from the positive x-axis counterclockwise to the wind vector. Polar coordinate of angle.
TEST	Value used to test for end of traverse which was drawn from zero to zero wind.
TH	Has three different values: (1) angle in radians between 115° line and the the ray drawn between the storm center and any point on the traverse similarly referred to as the polar coordinate of location for RS (L). (2) Wind angle with correction for deflection. (3) Wind angle less 25° correction for geometry.
VF	Forward speed of storm (knots).
VN, VNN, VNTEST, VP, VS	y-component of volume transport.
VN	Successive values of flux along traverse line.
VNN	Absolute value of flux.
VNTEST	Check on value of flux.

VP	Flux at previous time level.
VR2	Relative velocity values of digitized PMH profiles.
VS	Y-flux (ft + ft/sec).
VTMP	Interpolated values of relative velocity along each digitized profile.
VX	Values of digitized relative wind velocity along the axis of symmetry.
VXX	Relative wind velocity distribution along the polar coordinate initial ray RS (L).
W	Windspeed before adjustment due to interference with land mass. Magnitude of wind velocity at any point along the traverse line in miles per hour.
WIND	Adjusted windspeed near shore due to interference with land mass.
WK	Van Dorn's wind-stress factor.
WKCOR	Empirical calibration factor for wind-stress coefficient (constant).
WSQ	WIND squared.
WWX	WSQ × cosine (T) in miles per hour squared.
WWY	WSQ × sine (T) in miles per hour squared.
WX	Maximum windspeed in miles per hour.
X	Along the PMH axis of symmetry through the storm center.
XP	Minimum distance from hurricane center to traverse line.
XR2	Digitized values of relative distance corresponding to VR2 .
XX, XI	Distances along the PMH axis of symmetry.
XXA, YYA	(x, y) points used to make linear interpolations.
X, Y	Cartesian coordinates corresponding to the polar coordinates RS (L) and T. Storm center is the origin to which x- and y-values are referenced. The x-axis is along the radius to maximum winds (R).

Y	Perpendicular to X.
YPP	Distance along traverse from point of maximum wind to point where XP intersects traverse line.

APPENDIX A-4. INDEX OF VARIABLES FOR COMPUTER PROGRAMS

Index is to be used in locating and defining variables in the computer program. Variables are listed in alphabetical order with locations and definitions indicated by line number.

ACTUAL HURRICANES

PROGRAM SURGE A

```
A            REFS       92      444      612  DEFINED       99
AB           REFS      375      379  DEFINED      348      352      357      365
              367      369
AHOUR        REFS      625      626  DEFINED      623      625
ALPHA        REFS      261      330      331      339      346      348      350
              352      354      356      357      365      367      369
          DEFINED      254
AN           REFS      575  DEFINED      547
BEAR         REFS       96      457      510      615  DEFINED      149
BETA0        REFS      261      330      331      339      347      348      350
              352      354      355      356      357      359      360      361
              362      364      365      367      369  DEFINED      254      364
BFF          REFS      450      509      562      565      614
          DEFINED      182
BN           REFS      556      563      564      593  DEFINED      548
BP           REFS       92      563  DEFINED      556      593
BY           REFS      565  DEFINED      564
C1           REFS      575  DEFINED       97
C2           REFS      574  DEFINED       97
C3           REFS      561  DEFINED       97
D            REFS       92      464    2*516      584      596
          DEFINED      226
DASQ         REFS      562      565  DEFINED      561
DAVG         REFS       92      558      586  DEFINED      516
DELSXN       REFS      576  DEFINED      575
DELSYN       REFS      577  DEFINED      574
DELT         REFS       92      261      484      533      562      563      625
          DEFINED      254
DELX         REFS       92      574      575  DEFINED      515
DEN          REFS      563  DEFINED      562
DIST         REFS       92    2*375      382      464    2*515      584      596
          DEFINED      202
DTH          REFS      561  DEFINED      560
DTN          REFS      574      575  DEFINED      559
DTS          REFS      559      560  DEFINED      558
ERROR        REFS      120      139      158      175      191      209      234
              270      291      337  DEFINED      116      137      156      173
              189      207      232      268      289      336
FUD          REFS      382  DEFINED      379
I            REFS       99      165      444      612  DEFINED       99      164
              444      612
IB           REFS      200      202      218      224      226      243
          DEFINED      199      218      222      243
ICHECK       REFS      302  DEFINED      109      117      146      163      180
              196      216      241      276      300
ID           REFS      132      141      151      160      168      177      184
              193      203      211      228      236  DEFINED      106      149
              166      182      202      226
IDA          REFS      141      160      177      193  DEFINED      135      154
              171      187
IK           REFS      201      202      217      225      226      242
          DEFINED      200      201      224      225
IHUR         REFS      261      264      272      284      293      410
          DEFINED      254      281
IOMIT        REFS      467      504      525      531      581      595
          DEFINED      106
IOMITD       REFS      467      476  DEFINED      106
ISKIP        REFS    2*256    2*378      405      467  DEFINED      106
ITPP.        REFS      387  DEFINED      250      322
ITYPE        REFS      264      273      284      295      447      508      613
```

```
             DEFINED       149
K               REFS       630       631   DEFINED       605       631
L               REFS       202       226     3*281       284     3*293       295       304
               3*375       380     3*382     2*384     2*393     2*394     2*395     2*399
               2*400     2*401       407       408     3*410     3*413     3*422     2*425
               2*426     2*427     2*428       430     2*431       433     2*464     3*515
               3*516     2*519     2*521     7*545     3*547     3*548     2*549       552
                 553       554       555       556     3*558       560       562     2*563
               3*574       575     2*584       586       589       590       591       592
                 593   DEFINED       202       226       279       392       398       406
                 413       422       424       463       513       518       543
LL              REFS     7*436     7*492     7*494   DEFINED       435       491
LM              REFS       112       125       147       164     2*201       217     2*225
                 242       251       279       392       398       406       413       422
                 424       463       518     2*596   DEFINED       106
LMM             REFS       435       491       513       543   DEFINED       147
LX              REFS       261       272       284       293       410
             DEFINED       254       281       407
N               REFS     2*254     2*261       264       273       284       295       436
                 484       492       494       533       545       550       557       559
                 560       562       563       579       586       598       599       600
                 601       602       603       625     6*626   DEFINED       252       420
                 478       524       624
NC              REFS       203       219       228       244   DEFINED       198       219
                 225       244
NM              REFS       111       125       252       420       478       524       624
             DEFINED       106
NN              REFS       203       211       228       236       261       264       272
                 284       293       410   DEFINED       202       226       254       281
NTP             REFS     2*375     2*382       399       400       401
             DEFINED       251
PHI             REFS        92       519       521   DEFINED       165       519
PHII            REFS       165       457       510       615   DEFINED       149
PI              REFS       348       352       357       365       367       369       384
                 519   DEFINED       148
PN              REFS       425       450       509       614   DEFINED       166
PO              REFS       425       450       509       614   DEFINED       166
R               REFS       425       450       509       614   DEFINED       166
RS              REFS        92       293       304     2*375     2*382       393       410
                 413       425   DEFINED       281       375       399       422
SA              REFS        92       261       436       494       557       559       560
                 579       586       603       626   DEFINED       254       492       545
SAP             REFS       560   DEFINED       557       603
SE              REFS       450       509       558       579       586       614       626
             DEFINED       166
SINPHI          REFS        92     2*574   DEFINED       521
SP              REFS        92     2*436     2*494     2*549   DEFINED       425     2*492
               2*545
SPN             REFS       554       559       560       579       586       591       601
             DEFINED       549
SPP             REFS        92       560   DEFINED       554       591
SPRES           REFS        92       626   DEFINED       601
ST              REFS       586       602   DEFINED       579
STOT            REFS        92       626   DEFINED       602
SUMSX           REFS       576       579       580       586       589       598
             DEFINED       529       576
SUMSY           REFS       577       579       580       586       590       599
             DEFINED       530       577
SW              REFS       586       600   DEFINED       580
SWW             REFS        92       626   DEFINED       600
SX              REFS        92       626   DEFINED       598
SXP             REFS        92       558   DEFINED       552       589
SY              REFS        92       626   DEFINED       599
SYP             REFS        92       558   DEFINED       553       590
T               REFS        92       293       384       395       410       413       427
                 428   DEFINED       281       384       401       422
TI              REFS       484       485       533       534   DEFINED       483       532
TII             REFS       483       485       532       534   DEFINED       475       484
                 523       533
VF              REFS       450       509       614   DEFINED       166
VN              REFS       566       570       574       578       592
             DEFINED       563       571       573
VNN             REFS       569   DEFINED       566
VNTEST          REFS       569       571       573   DEFINED       565
VP              REFS        92       562       563   DEFINED       555       592
VS              REFS       586   DEFINED       578
VX              REFS        96       399       400       401   DEFINED       393       394
                 395
```

```
W                 REFS       92       293       394       410       413     2*426       430
                   431  DEFINED       281       400       422
WK                REFS       92       436       494       547       548
               DEFINED      431       433       492       545
WKCOR             REFS      450       509       547       548       614
               DEFINED      166
W80               REFS      427       428   DEFINED       426
WWX               REFS       92     2*436     2*494     2*547   DEFINED       427     2*492
                 2*545
WWY               REFS       92     2*436     2*494     2*548   DEFINED       428     2*492
                 2*545
WX                REFS      450       509       614   DEFINED       182
```

APPENDIX A-4. INDEX OF VARIABLES FOR COMPUTER PROGRAMS FOR HYPOTHETICAL HURRICANES

PROGRAM SURGE

```
VARIABLES
        A           REFS      134       530       745       DEFINED   173
        AHOUR       REFS      761       762       DEFINED   759       761
        AN          REFS      697       DEFINED   665
        BEAR        REFS      134       537       614       747       DEFINED   228
        BFF         REFS      537       614       682       685       747
                    DEFINED   320
        BN          REFS      676       683       684       717       DEFINED   666
        BOMB        REFS      144       437       572
        BP          REFS      134       683       DEFINED   676       717
        BY          REFS      685       DEFINED   684
        C1          REFS      697       DEFINED   150
        C2          REFS      696       DEFINED   150
        C3          REFS      681       DEFINED   150
        D           REFS      134       552       621       708       723
                    DEFINED   379
        DASQ        REFS      682       685       DEFINED   681
        DAVG        REFS      134       678       710       DEFINED   621
        DELSXN      REFS      698       DEFINED   697
        DELSYN      REFS      699       DEFINED   696
        DELT        REFS      134       139       518       586       647       682       683
                    761       DEFINED   300       584       639
        DELTT       REFS      300       563       DEFINED   228
        DELX        REFS      134       696       697       DEFINED   620
        DEN         REFS      683       DEFINED   682
        DIST        REFS      134       139       499       552       620       708       723
                    DEFINED   346
        DISTO       REFS      140
        DTH         REFS      681       DEFINED   680
        DTN         REFS      696       697       DEFINED   679
        DTS         REFS      679       680       DEFINED   678
        E           REFS      451       DEFINED   149
        EE          REFS      451       DEFINED   446
        I           REFS      173       297       299       300       430       443       530
                    745       DEFINED   173       296       298       430       442       530
                    745
        IB          REFS      341       346       366       374       379       400       411
                    430       474       DEFINED   340       366       372       400       409
                    474
        ICHECK      REFS      408       469       DEFINED   186       193       224       258
                    270       295       316       335       361       395       453
        ID          REFS      212       219       285       292       306       313       325
                    332       350       356       384       390       DEFINED   181       228
                    301       320       346       379
        IDA         REFS      219       292       313       332       DEFINED   213       286
                    307       326
        IDATA       REFS      159       429       433       555       DEFINED   153
                      REFS    164
        IDUM        REFS      167       771       773       DEFINED   156       773
        ID1         REFS      451       460       DEFINED   430
        ID2         REFS      451       460       DEFINED   430
        ID3         REFS      451       460       DEFINED   430
        IE          REFS      345       346       365       378       379       399       415
                    430       473       DEFINED   341       345       374       378       411
                    415
        ILAST       REFS      771       DEFINED   153
        IOMIT       REFS      555       608       635       644       704       721
                    DEFINED   181
        IOMITD      REFS      555       576       DEFINED   181
        IREAD       REFS      138       164       165       DEFINED   162
        ITYPE       REFS      433       451       460       533       613       746
                    DEFINED   228
        IVX         REFS      134       433       443
        IZONE       REFS      233       238       243       248       253       264       276
                    433       451       460       533       613       746
                    DEFINED   228
        K           REFS      766       767       DEFINED   734       767
        KEY         REFS      142       555       DEFINED   181
        KEYA        REFS      489       563       DEFINED   181
        L           REFS      346       379       498       499       504       506       508
                    509       510       514       516       552       620       621       624
                    628       663       665       666       667       672       673       674
                    675       676       678       680       682       683       696       697
                    708       710       713       714       715       716       717
```

```
VARIABLES
                     DEFINED       346       379       494       551       616       623       657
          LIST          REFS       433       563   DEFINED       181
          LL            REFS       520       594       596   DEFINED       519       593
          LM            REFS       140       191       199       226       296       345       365
                         378       399       494       551       623       723
                     DEFINED       181
          LMM           REFS       519       593       616       657   DEFINED       226
          N             REFS       489       490       518       520       584       586       594
                         596       639       647       663       668       677       679       680
                         682       683       701       710       727       728       729       730
                         731       732       761       762   DEFINED       484       579       631
                         760
          NC            REFS       350       367       384       401       451       475
                     DEFINED       339       367       373       401       410       475
          NM            REFS       190       199       298       484       579       631       760
                     DEFINED       181
          NN            REFS       350       356       384       390       451       460
                     DEFINED       346       379       430
          NPTS          REFS       141       415       442       473   DEFINED       149
          PHI           REFS       134       624       628   DEFINED       297       624
          PHII          REFS       234       239       244       249       254       276       297
                         533       613       746   DEFINED       228
          PHIIA         REFS       276   DEFINED       235       240       245       250       255
          PHIIB         REFS       276   DEFINED       236       241       246       251       256
          PI            REFS       624   DEFINED       227
          PN            REFS       143       498       537       614       747
                     DEFINED       301
          PO            REFS       143       498       537       614       747
                     DEFINED       301
          R             REFS       140       433       446       498       537       614       747
                     DEFINED       301
          RR            REFS       446       460   DEFINED       430
          RS            REFS       134       139       498
          SA            REFS       134       520       596       677       679       680       701
                         710       732       762   DEFINED       299       594       663
          SAA           REFS       299   DEFINED       228
          SAP           REFS       680   DEFINED       677       732
          SE            REFS       537       614       678       701       710       747       762
                     DEFINED       301
          SINPHI        REFS       134       696   DEFINED      628.
          SP            REFS       134       520       596       667   DEFINED       498       594
                         663
          SPN           REFS       674       679       680       701       710       715       730
                     DEFINED       667
          SPP           REFS       134       680   DEFINED       674       715
          SPRES         REFS       134       762   DEFINED       730
          ST            REFS       710       731   DEFINED       701
          STOT          REFS       134       762   DEFINED       731
          SUMSX         REFS       698       701       702       710       713       727
                     DEFINED       640       698
          SUMSY         REFS       699       701       702       710       714       728
                     DEFINED       641       699
          SW            REFS       710       729   DEFINED       702
          SWW           REFS       134       762   DEFINED       729
          SX            REFS       134       762   DEFINED       727
          SXP           REFS       134       678   DEFINED       672       713
          SY            REFS       134       762   DEFINED       728
          SYP           REFS       134       678   DEFINED       673       714
          T             REFS       134       139       508       509
          TI            REFS       586       587       647       648   DEFINED       585       646
          TII           REFS       585       587       646       648   DEFINED       574       586
                         630       647
          VF            REFS       140       537       614       747   DEFINED       301
          VN            REFS       686       692       696       700       716
                     DEFINED       683       693       695
          VNN           REFS       691   DEFINED       686
          VNTEST        REFS       691       693       695   DEFINED       685
          VP            REFS       134       682       683   DEFINED       675       716
          VS            REFS       710   DEFINED       700
          VX            REFS       134       139   DEFINED       430       443
          W             REFS       134       139       504       506       510       514
          WIND          REFS       507   DEFINED       504       506
          WK            REFS       134       520       596       665       666
                     DEFINED       514       516       594       663
          WKCOR         REFS       665       666   DEFINED       151
          WSQ           REFS       508       509   DEFINED       507
          WWX           REFS       134       520       596       665   DEFINED       508       594
                         663
          WWY           REFS       134       520       596       666   DEFINED       509       594
                         663
          WX            REFS       140       537       614       747   DEFINED       320
          XP            REFS       140
```

SUBROUTINE HRWDPF

```
VARIABLES
        AL                   REFS         80         81    DEFINED         76
        CS                   REFS         80        118    DEFINED         71
        DEL                  REFS        118        119    DEFINED        117
        DELA                 REFS        112        114        115        117    DEFINED         75        120
        DELB                 REFS        116        117        120    DEFINED        115        116
        DISTO                REFS         69         74         76
        LM                   REFS         69
        PN                   REFS         70        111
        PO                   REFS         70        111
        PRESS                REFS        112    DEFINED        111
        R                    REFS         69         74         80         84        111
        RAD1                 REFS        109    DEFINED         71
        RAD2                 REFS        109    DEFINED         71
        RS                   REFS        103        105        111        112    DEFINED        100
        SN                   REFS         81        119    DEFINED         71
        SNTF                 REFS         74    DEFINED         72
        TEST                 REFS        114        116    DEFINED         74
        TH                   REFS        101        104        105        109        110        112
                          DEFINED        109        110
        VF                   REFS         69         84        104
        VXX                  REFS        103        104
        W                    REFS        112    DEFINED        104
        WX                   REFS         69         84        104
        X                    REFS        100        101        118    DEFINED         80        118
        XP                   REFS         69         84
        Y                    REFS        100        101        119    DEFINED         81        119
```

SUBROUTINE QUAD

```
VARIABLES
        ERROR                REFS         20         23         37         59    DEFINED         16         19
                               35         57
        PI                   REFS         44         46         56    DEFINED         14
        TH                   REFS         56         61    DEFINED          1         44         46         49
                               52
        X                    REFS         18         31         32         33         34         39         44
                               49         52    DEFINED          1
        Y                    REFS         19         31         32         33         34         39         44
                               49         52    DEFINED          1
```

SUBROUTINE DEFL

```
VARIABLES
        DISTO                REFS         12
        LM                   REFS         12
        PI                   REFS         16         18         21    DEFINED         13
        R                    REFS         12         14         15         16         21
        RHO                  REFS         14         15         16         21    DEFINED          1
        TH                   REFS         16         18         21    DEFINED          1         16         18
                               21
        VF                   REFS         12
        WX                   REFS         12
        XP                   REFS         12
```

SUBROUTINE VEL

```
VARIABLES
        DELT                      REFS            12        13
        DIST                      REFS            12        13
        DISTO                     REFS            14
        I                         REFS            34        36   DEFINED        33
        LM                        REFS            14
        M                         REFS            41        42   DEFINED        36
        NPTS                      REFS            15        33
        R                         REFS            14        18
        RHO                       REFS            18   DEFINED         1
        RS                        REFS            12        13
        T                         REFS            12        13
        VF                        REFS            14
        VX                        REFS            12        13        41        42
        VXX                     DEFINED            1        30        42
        W                         REFS            12        13
        WX                        REFS            14
        XI                        REFS            20        28        35        42   DEFINED        18
        XM                        REFS            42   DEFINED        41
        XP                        REFS            14
        XX                        REFS            35        42   DEFINED        34
```

SUBROUTINE STRIPT

```
VARIABLES
        CS             REFS            24        56   DEFINED        22
        DELT           REFS            17        20
        DIST           REFS            17        20
        DISTO          REFS            18        62   DEFINED        61
        EE             REFS            32        34   DEFINED        31        33
        I              REFS            27        29        31        33        42        48
                     DEFINED           26
        LM             REFS            18
        NPTS           REFS            19        26
        R              REFS            18        52        56        58
        RHO            REFS            50        52        61        62   DEFINED        29        50
                         52
        RS             REFS            17        20
        SN             REFS            58   DEFINED        22
        T              REFS            17        20
        VF             REFS            18        24
        VX             REFS            17        20        27        31        33        42        48
        VXZ            REFS            27        33        42        48   DEFINED        24
        W              REFS            17        20
        WX             REFS            18        24
        XM             REFS            50   DEFINED        46        48
        XP             REFS            18        61   DEFINED        58
        YPP            REFS            61   DEFINED        56
```

SUBROUTINE PROFIL

```
VARIABLES
        AX                REFS         8       225       226       248       249
        BOMB              REFS        12       274   DEFINED        79        92        94       101
                           114       134       150       156       160       285
        DUM               REFS        10        99   DEFINED        98
        E                 REFS       126       144   DEFINED        57
        EE                REFS       126   DEFINED       125
        ERR               REFS        10        79        92        94       101       114       134
                           150       156       160   DEFINED        62
        I                 REFS       161       226       245       249       252       265
                       DEFINED       159       214       237       265
        IA                REFS       215       217       218       223       224
                       DEFINED       207       217
        IAX               REFS         8       161       163   DEFINED       139
        IB                REFS       120       121       125       127       263       265       268
                       DEFINED       119       127       261       268
        ID                REFS        76        95        96   DEFINED        67        68        69
                            70        71        72        73        74
        IDATA          DEFINED         1      REFS        13        89        98       121       139
        IE                REFS       121       135       137       144       151       152       264
                           265       267   DEFINED       120       137       263       264
        IFLAG             REFS       172   DEFINED        88       117       170
        IFUD              REFS       215   DEFINED       208       216
        IRR               REFS         8       265   DEFINED         1       249       252
        ITYPE             REFS       265   DEFINED         1
        IZONE             REFS        68        69        70        71        72        73        74
                            80       265   DEFINED         1
        JID               REFS        93        95        96   DEFINED        89
        K                 REFS       121       144       151       152   DEFINED       121       143
        KK                REFS        89        95       102       104       105       106       111
                           115       121       125       144       151       170       185       189
                           191       215       218       223       224       226       232       234
                           243       245       246   DEFINED        87       112       173       182
                           202       244
        KX                REFS       161   DEFINED        57
        L                 REFS       185       189       223       224       232
                       DEFINED       185       189       222       232
        LIST              REFS       181       229       256   DEFINED         1
        MP                REFS       185       189   DEFINED       152
        NC                REFS       265       269   DEFINED       262       269
        NPTS              REFS        11       214       232       237       264       267
        R                 REFS         8       102       104       105       106       111       170
                           191       234       243       246   DEFINED        89       111
        RR                REFS       104       105       170       191       234       243       249
                           257       265   DEFINED         1
        VR2               REFS         8       144       189       224   DEFINED       121
        VTMP              REFS         8       232       245       252   DEFINED       226
        X                 REFS       215       218       226       227   DEFINED       206       227
        XR2               REFS         8       125       144       151       185       215       218
                           223   DEFINED       121
        XXA               REFS         8       225       248   DEFINED       223       246
        YYA               REFS         8       225       248   DEFINED       224       245
```

SUBROUTINE INTERP

```
VARIABLES
        AX                          REFS        16        37   DEFINED         1        36        37
        E                           REFS        20   DEFINED        17
        XXA                         REFS        16        20        29        36        37
                                 DEFINED         1
        YYA                         REFS        16        36        37   DEFINED         1
```

SUBROUTINE ZERWND

```
VARIABLES
       AL              REFS         79         80   DEFINED       75
       CS              REFS         79        117   DEFINED       65
       DEL             REFS        117        118   DEFINED      114
       DELT            REFS         60         62        74
       DIST            REFS         60         62        75       113       116
       DISTO           REFS         63         75
       HR              REFS         74         75        76   DEFINED        70        74
       KEY             REFS         61         76        82       113       120
       L               REFS         74         98       101       102       103       106       108
                         113       115        116   DEFINED       73        97
       LM              REFS         63         97       115
       M               REFS         71         76   DEFINED        1
       MX              REFS         72         73   DEFINED       71
       PI           DEFINED         65
       R               REFS         63         79        84
       RAD1            REFS        106    DEFINED        65
       RAD2            REFS        108    DEFINED        65
       RS              REFS         60         62       101       103       113
                    DEFINED         98
       SN              REFS         80        118   DEFINED       65
       T               REFS         60         62       108   DEFINED       106
       TH              REFS         99        102       103       106       113
                    DEFINED        108
       VF              REFS         63         75        84       102
       VX              REFS         60         62
       VXX             REFS        101        102
       W               REFS         60         62       113   DEFINED       102
       WX              REFS         63         84       102
       X.              REFS         98         99       117   DEFINED        79       117
       XP              REFS         63         84
       Y               REFS         98         99       118   DEFINED        80       118
```

APPENDIX A-5. PROGRAM DECK STRUCTURE FOR ACTUAL HURRICANES

ACTUAL HURRICANE DECK STRUCTURE

1.	0J590) MCCLUNG 752X6R1590 162 PAGES	JOB CARD
2.	TASK(TNQ072648,PWCERC1,TRTS)MCCLUNG AEC SURGE	JOB DEFINITION CARD
3.	FTN(OPT=0,PL=10000)	COMPILE USING FORTRAN COMPILER
4.	REDUCE.	REDUCE CORE SPACE MINIMUM VALUE
5.	LGO.	LOAD AND RUN PROGRAM
6.	7/8/9	END OF CONTROL CARD DECK
7.	MAIN PROGRAM DECK FOR SURGE	
8.	7/8/9	END OF PROGRAM DECK
9.	DATA DECK	
10.	7/8/9	END OF DATA DECK
11.	6/7/8/9	END OF JOB

APPENDIX A-5. PROGRAM DECK STRUCTURE FOR HYPOTHETICAL HURRICANES

HYPOTHETICAL HURRICANE DECK STRUCTURE

```
 1. QJ590)              MCCLUNG  752X6R1590        162  PAGES       JOB CARD

 2. TASK(TNQ072648,PWCERC1,TRTS)MCCLUNG AEC SURGE            JOB DEFINITION CARD

 3. FTN(OPT=0,PL=10000)  COMPILE IN FORTRAN COMPILER

 4. REDUCE.              REDUCE CORE SPACE TO MINIMUM VALUE

 5. LGO.                 LOAD AND RUN PROGRAM

 6. 7/8/9                END OF CONTROL CARD DECK

 7. MAIN PROGRAM DECK FOR SURGE

 8.        SUBROUTINE HRWDPF(M)

 9.        SUBROUTINE QUAD(X,Y,TH)

10.        SUBROUTINE DEFL(TH,RHO)

11.        SUBROUTINE VEL(RHO,VXX)

12.        SUBROUTINE STRTPT

13.        SUBROUTINE PROFIL(IZONE,ITYPE,RR,IRR,IDATA,LIST)

14.        SUBROUTINE INTERP(XXA,YYA,AX)

15.        SUBROUTINE ZERWND

16.  7/8/9              END OF PROGRAM DECK

17.  DATA DECK

18.  7/8/9              END OF DATA DECK

19.  6/7/8/9            END OF JOB
```

APPENDIX A-6. DATA INPUT CODING SHEETS AND EXAMPLES FOR ACTUAL HURRICANES

1 2 3 4 5 6 7 8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

Storm Identification Title Card

1 — 2 ☐☐☐ … 20 … 40 … 60 … 80 ☐ — 1

2 — NM 3 5 ☐☐☐ LM 9 10 ☐☐ ISKIP 15 ☐ IOMIT 20 ☐ IOMITD 25 ☐ ID 76 80 PAR 1 — 2

3 — PHII 15 20 ☐☐☐.☐☐ ITYPE 48 50 ☐☐☐ BEAR 52 60 ☐☐☐☐.☐☐☐☐ ID 76 80 PAR 2 — 3

4 — R 2 7 ☐☐☐.☐☐ PO 9 14 ☐☐☐.☐☐ PN 16 21 ☐☐☐.☐☐ VF 23 28 ☐☐☐.☐☐ SE 30 35 ☐☐☐.☐☐ WKCOR 58 63 ☐☐☐☐☐ ID 76 80 PAR 3 — 4

5 — WX 1 7 ☐☐☐☐.☐☐ BFF 9 14 ☐☐☐☐☐☐ ID 76 80 PAR 4 — 5

Bottom profile distances from shore (values taken seaward — shoreward)

ID 1 4 — NN 15 — DIST(L) 23 30 — DIST(L) 33 40 — DIST(L) 43 50 — DIST(L) 53 60 — DIST(L) 63 70 — DIST(L) 73 80

6 DIST 1 ☐☐☐☐☐.☐☐ … 6
7 DIST 2 … 7
8 DIST 3 … 8
9 DIST 4 … 9
10 DIST 5 … 10
11 DIST 6 … 11
12 DIST 7 … 12
13 DIST 8 … 13
14 DIST 9 … 14

Where L=1 to LM (maximum of 50)

Bottom profile depths (values taken seaward — shoreward)

ID 1 5 — NN 15 — 23 D(L) 30 — 33 D(L) 40 — 43 D(L) 50 — 53 D(L) 60 — 63 D(L) 70 — 73 D(L) 80

15 DEPTH 1 ☐☐☐☐☐.☐☐ … 15
16 DEPTH 2 … 16
17 DEPTH 3 … 17
18 DEPTH 4 … 18
19 DEPTH 5 … 19
20 DEPTH 6 … 20
21 DEPTH 7 … 21
22 DEPTH 8 … 22
23 DEPTH 9 … 23

Where L=1 to LM (maximum of 50)

Wind field data where N=1 to NM

ALPHA and BETA0 are supplied if interpolation for RS is required

24 — IHUR NN 1 345 ☐☐☐☐☐ LX 7 10 ☐☐☐☐ DELT(N) 17 20 ☐☐.☐ SA(N) 27 30 ☐☐.☐ ALPHA 35 40 ☐☐☐.☐ BETA0 45 50 ☐☐☐☐.☐ — 24

Wind field data where L=1 to LM

25 — IHUR NN 1 345 ☐☐☐☐☐ LX 7 10 ☐☐☐☐ RS(L) 15 20 ☐☐☐☐.☐ W(L) 25 30 ☐☐☐☐.☐ T(L) 35 40 ☐☐☐.☐ — 25

1 2 3 4 5 6 7 8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

12345678901234567890123456789012345678901234567890123456789012345678901234567890

Storm Identification Title Card

1 CAMILLE VF=13.0 KNOTS (APPROX.) R=24. N. MILES (APPROX.)

Card	Field	Columns	Value
2	NM	3–5	43
2	LM	9–10	14
2	ISKIP	15	0
2	IOMIT	20	0
2	IOMITD	25	0
2	ID	76–80	PAR 1
3	PHII	15–20	30.00
3	ITYPE	48–50	CAM
3	BEAR	52–60	S 12.00 E
3	ID	76–80	PAR 2
4	R	2–7	24.00
4	PO	9–14	27.63
4	PN	16–21	29.92
4	VF	23–28	13.00
4	SE	30–35	1.20
4	WKCOR	58–63	1.10
4	ID	76–80	PAR 3
5	WX	1–7	125.00
5	BFF	9–14	.0050
5	ID	76–80	PAR 4

Bottom profile distances from shore (values taken seaward — shoreward)

Card	ID 1–4	NN 15	DIST(L) 23–30	DIST(L) 33–40	DIST(L) 43–50	DIST(L) 53–60	DIST(L) 63–70	DIST(L) 73–80
6	DIST	1	77.	70.	60.	50.	40.	30.
7	DIST	2	20.	15.	10.	5.	3.	2.
8	DIST	3	1.	0.	.	.	.	.
9	DIST	4	.	.	.	.	.	.
10	DIST	5	.	.	.	.	.	.
11	DIST	6	.	.	.	.	.	.
12	DIST	7	.	.	.	.	.	.
13	DIST	8	.	.	.	.	.	.
14	DIST	9	.	.	.	.	.	.

Where L=1 to LM (maximum of 50)

Bottom profile depths (values taken seaward — shoreward)

Card	ID 1–5	NN 15	D(L) 23–30	D(L) 33–40	D(L) 43–50	D(L) 53–60	D(L) 63–70	D(L) 73–80
15	DEPTH	1	600.	235.	160.	90.	52.	40.
16	DEPTH	2	36.	35.	13.	12.	9.	9.
17	DEPTH	3	3.	0.	.	.	.	.
18	DEPTH	4	.	.	.	.	.	.
19	DEPTH	5	.	.	.	.	.	.
20	DEPTH	6	.	.	.	.	.	.
21	DEPTH	7	.	.	.	.	.	.
22	DEPTH	8	.	.	.	.	.	.
23	DEPTH	9	.	.	.	.	.	.

Where L=1 to LM (maximum of 50)

Wind field data where N=1 to NM

ALPHA and BETAØ are supplied if interpolation for RS is required

Card	IHUR 1–3	NN 4–5	LX 7–10	DELT(N) 17–20	SA(N) 27–30	ALPHA 35–40	BETAØ 45–50
24	CAM	1		1.	.8	.	.

Wind field data where L=1 to LM

Card	IHUR 1–3	NN 4–5	LX 7–10	RS(L) 15–20	W(L) 25–30	T(L) 35–40
25	CAM		1	274.	37.	86.

12345678901234567890123456789012345678901234567890123456789012345678901234567890

SAMPLE

ACTUAL HURRICANE DATA DECK

```
                                  Storm Identification Title
1.     CAMILLE   VF=13.0 KNOTS (APPROX.)    R=24. N. MILES (APPROX.)   HEADER CARD

        NM    LM   ISKIP IOMIT IOMITD                                               ID    ─┐
2.      43    14     0     0     0                                                  PAR 1   │
                                                                                            │
                       PHII                                 ITYPE    BEAR               ID      │
3.                     30.00                                 CAM S 12.00 E           PAR 2   │  HURRICANE PARAMETER CARDS
                                                                                            │
         R       PO      PN      VF       SE                          WKCOR             ID      │
4.     14.00   27.63   29.92   13.00    1.20                          1.10            PAR 3   │
                                                                                            │
        WX      BFF                                                                  ID      │
5.     125.0   .0030                                                                 PAR 4  ─┘

        ID           NN        DIST(L)   DIST(L)   DIST(L)   DIST(L)   DIST(L)   DIST(L)─┐
6.     DIST           1          77.       70.       60.       50.       40.       30.     │
                                                                                            │
7.     DIST           2          20.       15.       10.        5.        3.        2.     │
                                                                                            │  THESE CARDS DEFINE
8.     DIST           3           1.        0.                                             │  BATHYMETRIC PROFILE
                                                                                            │
        ID           NN         D(L)      D(L)      D(L)      D(L)      D(L)      D(L)     │
9.     DEPTH          1         600.      235.      160.       90.       52.       40.     │
                                                                                            │
10.    DEPTH          2          36.       35.       13.       12.        9.        9.     │
                                                                                            │
11.    DEPTH          3           3.        0.                                            ─┘
      IHUR  NN              DELT(L)      SA(L)
12.    CAM  1                  1.          .8

      IHUR  NN   LX          RS(L)      W(L)      T(L)  ┐
13.    CAM  1    1           274.        37.       86.  ┘  THESE CARDS GIVE DATA
                                                            TAKEN FROM ISOVEL CHARTS
```

APPENDIX A-6. DATA INPUT CODING SHEETS AND EXAMPLES FOR HYPOTHETICAL HURRICANES

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

1 ILAST 5 ☐ IDATA 10 ☐ 1

2 If IDATA = 4 pre-punched digitized wind field data decks are supplied for input 2

Storm Identification Title Card

3 2 ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐ 20 ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐ 40 ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐ 60 ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐ 80 3

4 NM 3 5 ☐☐☐ LM 9 10 ☐☐ IOMIT 20 ☐ IOMITD 25 ☐ KEY 30 ☐ KEYA 35 ☐ LIST 40 ☐ ID 76 80 PAR 1 4

5 DELTT 5 10 ☐☐☐.☐☐ PHII 15 20 ☐☐☐.☐☐ SAA 25 30 ☐☐☐.☐☐ IZONE 40 ☐ ITYPE 48 50 ☐☐☐ BEAR 52 60 ☐☐☐☐.☐☐☐☐ ID 76 80 PAR 2 5

6 R 2 7 ☐☐☐.☐☐ PO 9 14 ☐☐☐.☐☐ PN 16 21 ☐☐☐.☐☐ VF 23 28 ☐☐☐.☐☐ SE 30 35 ☐☐☐.☐☐ ID 76 80 PAR 3 6

7 WX 1 7 ☐☐☐☐.☐☐ BFF 9 14 ☐.☐☐☐☐ ID 76 80 PAR 4 7

Bottom profile distances from shore (values taken seaward – shoreward)

	ID 1 4	NN 15	DIST(L) 23 30	DIST(L) 33 40	DIST(L) 43 50	DIST(L) 53 60	DIST(L) 63 70	DIST(L) 73 80	
8	DIST	1	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	8
9	DIST	2	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	9
10	DIST	3	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	10
11	DIST	4	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	11
12	DIST	5	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	12
13	DIST	6	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	13
14	DIST	7	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	14
15	DIST	8	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	15
16	DIST	9	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐					16

Where L = 1 to LM (maximum of 50)

Bottom profile depths (values taken seaward — shoreward)

	ID 1 5	NN 15	D(L) 23 30	D(L) 33 40	D(L) 43 50	D(L) 53 60	D(L) 63 70	D(L) 73 80	
17	DEPTH	1	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	17
18	DEPTH	2	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	18
19	DEPTH	3	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	19
20	DEPTH	4	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	20
21	DEPTH	5	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	21
22	DEPTH	6	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	22
23	DEPTH	7	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	23
24	DEPTH	8	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐	
25	DEPTH	9	☐☐☐☐☐.☐☐	☐☐☐☐☐.☐☐					25

Where L = 1 to LM (maximum of 50)

26 If IDATA = 0 pre – punched relative wind field data deck is supplied for input 26

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

1 2 3 4 5 6 7 8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

1 ILAST (5): 1 IDATA (10): 4 1

2 If [✓ IDATA = 4] pre-punched digitized wind field data decks are supplied for input 2

Storm Identification Title Card

3 (2–80): SAMPLE STORM SURGE PROBLEM HAMPTON BEACH, N.H. HUR. H PMH 2-28-74 BY HDM 3

4 NM (3–5): 44 LM (9–10): 49 IOMIT (20): 0 IOMITD (25): 0 KEY (30): 1 KEYA (35): 1 LIST (40): 1 ID (76–80): PAR 1 4

5 DELTT (5–10): .50 PHII (15–20): 42.83 SAA (25–30): 11.2 IZONE (40): 4 ITYPE (48–50): PHM BEAR (52–60): N 75.00 W ID (76–80): PAR 2 5

6 R (2–7): 56. PO (9–14): 27.42 PN (16–21): 30.42 VF (23–28): 37. SE (30–35): .6 ID (76–80): PAR 3 6

7 WX (1–7): 120.4 BFF (9–14): .0025 ID (76–80): PAR 4 7

Bottom profile distances from shore (values taken seaward — shoreward)

	ID (1–4)	NN (15)	DIST (L) (23–30)	DIST (L) (33–40)	DIST (L) (43–50)	DIST (L) (53–60)	DIST (L) (63–70)	DIST (L) (73–80)	
8	DIST	1	47.6	46.6	43.6	40.6	39.6	38.6	8
9	DIST	2	37.6	36.6	35.6	31.6	30.6	29.6	9
10	DIST	3	28.6	27.	26.	25.5	25.	24.5	10
11	DIST	4	24.	23.5	22.5	21.5	20.5	20.	11
12	DIST	5	19.	16.	15.	14.	12.5	10.	12
13	DIST	6	8.5	5.	3.	2.	1.8	1.6	13
14	DIST	7	1.4	1.2	1.	.9	.8	.7	14
15	DIST	8	.6	.5	.4	.3	.2	.1	15
16	DIST	9	0.0	.					16

Where L = 1 to LM (maximum of 50)

Bottom profile depths (values taken seaward — shoreward)

	ID (1–5)	NN (15)	D(L) (23–30)	D(L) (33–40)	D(L) (43–50)	D(L) (53–60)	D(L) (63–70)	D(L) (73–80)	
17	DEPTH	1	600.	580.	456.	446.	410.	420.	17
18	DEPTH	2	432.	416.	402.	226.	230.	266.	18
19	DEPTH	3	324.	300.	190.	189.	196.	194.	19
20	DEPTH	4	186.	167.	165.	278.	296.	294.	20
21	DEPTH	5	397.	382.	365.	365.	317.	175.	21
22	DEPTH	6	249.	156.	69.	64.	60.	60.	22
23	DEPTH	7	49.	41.	33.	30.	28.	16.	23
24	DEPTH	8	15.	13.	11.	10.	9.	4.	24
25	DEPTH	9	0.0	.					25

Where L = 1 to LM (maximum of 50)

26 If IDATA = 0 pre-punched relative wind field data deck is supplied for input 26

1 2 3 4 5 6 7 8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

HYPOTHETICAL HURRICANE DATA DECK

```
       ILAST IDATA
 1.      1     4

             JID  R(KK)
 2.  0000000001005000

      XR2   VR2   XR2   VR2   XR2   VR2   XR2   VR2   XR2   VR2   XR2   VR2   XR2   VR2   XR2   VR2
 3.  +0000+0000+0001+0000+0002+0001+0003+0002+0004+0002+0005+0004+0006+0006+0007+0006

 4.  +0008+0007+0009+0008+0010+0009+0011+0011+0012+0012+0013+0013+0014+0015+0015+0016

 5.  +0016+0018+0017   ETC.

 6.  99999

                IAX
 7.  ...........................................................................

             JID  R(KK)
 8.  000000000100660

      XR2   VR2   XR2   VR2   XR2   VR2   XR2   VR2   XR2   VR2   XR2   VR2   XR2   VR2   XR2   VR2
 9.  +0000+0000+0001+0000+0002+0001+0003+0002+0004+0002+0005+0004+0006+0006+0007+0006

10.  +0008+0007+0009+0008+0010+0009+0011+0011+0012+0012+0013+0013+0014+0015+0015+0016

11.  +0016+0018+0017   ETC.

12.  99999

                IAX
13.  ...........................................................................

14.       FINAL
```

When IDATA = 4 this type of data is supplied as input for interpolation; then wind field data is computed

```
                                          Storm Identification Title
15.  SAMPLE STORM SURGE PROBLEM    HAMPTON BEACH.N.H.   HUR. H PMH 2-28-74 BY HDM       HEADER CARD

      NM    LM          IOMIT IOMITD KEY   KEYA LIST                                ID
16.   44    49            0     0     1     1    1                                 PAR 1

          DELTT      PHII       SAA          IZONE     ITYPE    BEAR                ID
17.        .50      42.83      11.2            4        PMH N 75.00 W              PAR 2

       R         PO       PN      VF          SE                                    ID
18.   56.       27.42   30.42   37.          .6                                    PAR 3

      WX        BFF                                                                 ID
19.  120.4     .0025                                                               PAR 4
```

HURRICANE PARAMETER CARDS

```
      ID         NN     DIST(L)  DIST(L)  DIST(L)  DIST(L)  DIST(L)  DIST(L)
20.  DIST        1       47.6     46.6     43.6     40.6     39.6     38.6

21.  DIST        2       37.6     36.6     35.6     31.6     30.6     29.6

22.  DIST        3       28.6     27.      26.      25.5     25.      24.5

23.  DIST        4       24.      23.5     22.5     21.5     20.5     20.

24.  DIST        5       19.      16.      15.      14.      12.5     10.

25.  DIST        6        8.5      5.       3.       2.       1.8      1.6

26.  DIST        7        1.4      1.2      1.        .9       .8       .7

27.  DIST        8         .6       .5       .4       .3       .2       .1

28.  DIST        9        0.0
      ID         NN     D(L)     D(L)     D(L)     D(L)     D(L)     D(L)
29.  DEPTH       1      600.     580.     456.     446.     410.     420.

30.  DEPTH       2      432.     416.     402.     226.     230.     266.

31.  DEPTH       3      324.     300.     190.     189.     196.     194.

32.  DEPTH       4      186.     167.     165.     278.     296.     294.

33.  DEPTH       5      397.     382.     365.     365.     317.     175.

34.  DEPTH       6      249.     156.      69.      64.      60.      60.

35.  DEPTH       7       49.      41.      33.      30.      28.      16.

36.  DEPTH       8       15.      13.      11.      10.       9.       4.

37.  DEPTH       9       0.0
```

THESE CARDS DEFINE BATHYMETRIC PROFILE

HYPOTHETICAL HURRICANE DATA DECK

```
      ILAST IDATA
 1.     1     0
                                       Storm Identification Title
 2.   SAMPLE STORM SURGE PROBLEM     HAMPTON BEACH,N.H.    HUR. H PMH 2-28-74 BY MDM

       NM    LM           IOMIT IOMITD  KEY   KEYA  LIST                          ID
 3.    44    49             0      0     1     1     1                           PAR 1

             DELTT        PHII        SAA            IZONE       ITYPE   BEAR           ID
 4.           .50        42.83       11.2              4          PMH N 75.00 W        PAR 2

        R         PO       PN      VF         SE                                         ID
 5.    56.       27.42   30.42    37.         .6                                        PAR 3

        WX        BFF                                                                    ID
 6.   120.4      .0025                                                                  PAR 4
        ID                 NN           DIST(L)     DIST(L)     DIST(L)     DIST(L)     DIST(L)     DIST(L)
 7.   DIST                  1            47.6        46.6        43.6        40.6        39.6        38.6

 8.   DIST                  2            37.6        36.6        35.6        31.6        30.6        29.6

 9.   DIST                  3            28.6        27.         26.         25.5        25.         24.5

10.   DIST                  4            24.         23.5        22.5        21.5        20.5        20.

11.   DIST                  5            19.         16.         15.         14.         12.5        10.

12.   DIST                  6             8.5         5.          3.          2.          1.8         1.6

13.   DIST                  7             1.4         1.2         1.           .9          .8          .7

14.   DIST                  8              .6          .5          .4          .3          .2          .1

15.   DIST                  9             0.0
```

HEADER CARD

HURRICANE PARAMETER CARDS

THESE CARDS DEFINE BATHYMETRIC PROFILE

```
      ID                 NN            D(L)      D(L)      D(L)      D(L)      D(L)      D(L)
16.  DEPTH               1            600.      580.      456.      446.      410.      420.

17.  DEPTH               2            432.      416.      402.      226.      230.      266.

18.  DEPTH               2            432.      416.      402.      226.      230.      266.

19.  DEPTH               3            324.      300.      190.      189.      196.      194.

20.  DEPTH               4            186.      167.      165.      278.      296.      294.

21.  DEPTH               5            397.      382.      365.      365.      317.      175.

22.  DEPTH               6            249.      156.       69.       64.       60.       60.

23.  DEPTH               7             49.       41.       33.       30.       28.       16.

24.  DEPTH               8             15.       13.       11.       10.        9.        4.

25.  DEPTH               9             0.0

     ID1  ID2 ID3    RR     NN VX(I) VX(I) VX(I) VX(I) VX(I) VX(I) VX(I) VX(I) VX(I) VX(I) VX(I) VX(I)
26.  ZONE  4  PMH   56.0    1   896   917   930   945   954   965   972   981   986   991   999   998

27.  ZONE  4  PMH   56.0    2   998   997   996   995   993   991   989   986   982   976   970   965

28.  ZONE  4  PMH   56.0    3    ETC.
```

When IDATA = 0 this type of data is supplied as input for computing wind field data

APPENDIX A-7. OUTPUT LISTING EXAMPLES FOR ACTUAL HURRICANES*

Output for ISKIP = 0

```
                  DELT(N)     SA(N)     ALPHA     BETAO

AUD 1     1         2.0        -.4      194.0      60.0

          L        DIST       RS(1)       FUD      RS(L)

    16    2        1.000     148.000     .695    147.307
    16    3        2.000     148.000     .695    146.618
    16    4        3.000     148.000     .695    145.932
    16    5        5.000     148.000     .695    144.571
    16    6       10.000     148.000     .695    141.237
    16    7       15.000     148.000     .695    138.003
    16    8       20.000     148.000     .695    134.876
    16    9       30.000     148.000     .695    128.979
    16   10       40.000     148.000     .695    123.609
    16   11       50.000     148.000     .695    118.841
    16   12       60.000     148.000     .695    114.747
    16   13       70.000     148.000     .695    111.404
    16   14       80.000     148.000     .695    108.879
    16   15       90.000     148.000     .695    107.231
```

Output for ISKIP = 0 or 1

```
ACTUAL INPUT OF RS(L)        W(L)       T(L)

AUD 1     1      107.2       30.0       1.1
AUD 1     2      108.9       33.4       1.1
AUD 1     3      111.4       35.3       1.1
AUD 1     4      114.7       36.7       1.1
AUD 1     5      118.8       38.7       1.1
AUD 1     6      123.6       41.0       1.1
AUD 1     7      129.0       42.2       1.1
AUD 1     8      134.9       43.3       1.0
AUD 1     9      138.0       45.7       1.0
AUD 1    10      141.2       48.1        .9
AUD 1    11      144.6       50.2        .8
AUD 1    12      145.9       52.7        .8
AUD 1    13      146.6       55.2        .7
AUD 1    14      147.3       57.6        .6
AUD 1    15      148.0       59.6        .5

                  DELT(N)     SA(N)     ALPHA     BETAO

AUD 2     2         2.0         .1      194.0      67.0

          L        DIST       RS(1)       FUD      RS(L)

    16    2        1.000     140.000     .602    139.400
    16    3        2.000     140.000     .602    138.806
    16    4        3.000     140.000     .602    138.215
    16    5        5.000     140.000     .602    137.049
    16    6       10.000     140.000     .602    134.220
    16    7       15.000     140.000     .602    131.520
    16    8       20.000     140.000     .602    128.957
    16    9       30.000     140.000     .602    124.277
    16   10       40.000     140.000     .602    120.249
    16   11       50.000     140.000     .602    116.939
    16   12       60.000     140.000     .602    114.410
    16   13       70.000     140.000     .602    112.714
    16   14       80.000     140.000     .602    111.890
    16   15       90.000     140.000     .602    111.957

ACTUAL INPUT OF RS(L)        W(L)       T(L)

AUD 2     1      112.0       41.0       1.0
AUD 2     2      111.9       41.1       1.1
AUD 2     3      112.7       41.2       1.1
AUD 2     4      114.8       41.5       1.1
AUD 2     5      116.9       41.9       1.0
AUD 2     6      120.2       43.1       1.0
AUD 2     7      124.3       44.2       1.0
AUD 2     8      129.0       45.4       1.0
AUD 2     9      131.5       47.7        .9
AUD 2    10      134.2       50.0        .8
AUD 2    11      137.0       52.4        .8
AUD 2    12      138.2       54.7        .7
AUD 2    13      138.8       57.0        .6
AUD 2    14      139.4       59.2        .5
AUD 2    15      140.0       60.0        .4
```

---

*See Appendix A-3 for definition of variables.

Standard Program Output

```
                         QUASI-TWO-DIMENSIONAL OPEN COAST STORM SURGE PROGRAM


HURRICANE AUDREY VERIFICATION AT EUGENE ISLAND LA.          JUN 1957    AEC 7/73
                                                       INPUT DATA
                                                       ----- ----


                       FIRST THREE LETTERS OF HURRICANE NAME (ITYPE) AUD
                                                                     ---

     CENTRAL PRESSURE (PO) = 27.95 IN. HG.                PERIPHERAL PRESSURE (PN) = 29.70 IN. HG.

RADIUS TO MAXIMUM WIND (R) = 19.0 N.M.                           MAXIMUM WIND (WX) =  95.0 MI/HR.

    TRANSLATION SPEED (VF )= 14.0 KNOTS                          INITIAL RISE (SE) = 1.00 FEET

BOTTOM FRICTION FACTOR (BFF) =  .0025        WIND STRESS CORRECTION FACTOR (WKCOR) = 1.10

GEOGRAPHICAL LATITUDE(PHII) =     29.30                 TRAVERSE BEARING (BEAR) =  S 12.5 W


                                     BOTTOM PROFILE OVER THE CONTINENTAL SHELF

                                          DISTANCE FROM        DEPTH
                                           SHORE (N.M.)        (FEET)
                                              90.00          600.0
                                              80.00          320.0
                                              70.00          260.0
                                              60.00          200.0
                                              50.00          140.0
                                              40.00           60.0
                                              30.00           50.0
                                              20.00           20.0
                                              15.00           18.0
                                              10.00           15.0
                                               5.00           15.0
                                               3.00           12.0
                                               2.00           10.0
                                               1.00            5.0
                                               0.00            0.0


          INPUT AND OUTPUT CONTROL
          ------------------------

ISKIP =     0   0 = ALL WIND FIELD DATA BEFORE AND AFTER INTERPOLATION IS PRINTED
                1 = WIND FIELD DATA USED FOR INTERPOLATION IS NOT PRINTED
                2 = ALL WIND FIELD DATA NOT PRINTED

IOMIT =     0   0 = DETAILED PRINTING
IOMITD =     0  1 = SKIP DETAILED PRINTING
```

Output when control parameter IØMITD = 0

```
****************************************************************************************************
TIME (T) =    0.00       TIME (T+DELT) =    2.00

        WWX(I+1)    WWX(I)     WWY(I+1)      WWY(I)   ASTRO. TIDE  SP(I+1)     SP(I)    WIND STRESS
                                                        (FEET)      (FT)        (FT)     PARAMETER


         471.5        380.4     1011.0       815.7      -.40        .32         .32    .00000164
         526.6        471.5     1129.3      1011.0      -.40        .31         .32    .00000178
         571.4        526.6     1219.7      1129.3      -.40        .30         .31    .00000185
         635.3        571.4     1356.3      1219.7      -.40        .29         .30    .00000190
         736.9        635.3     1510.9      1356.3      -.40        .28         .29    .00000196
         830.6        736.9     1575.3      1510.9      -.40        .27         .28    .00000203
         937.4        830.6     1623.7      1575.3      -.40        .26         .27    .00000206
        1173.9        937.4     1727.3      1623.7      -.40        .26         .26    .00000209
        1446.6       1173.9     1805.6      1727.3      -.40        .25         .26    .00000216
        1709.0       1446.6     1852.0      1805.6      -.40        .25         .25    .00000221
        2024.6       1709.0     1901.2      1852.0      -.40        .24         .25    .00000226
        2361.3       2024.6     1925.8      1901.2      -.40        .24         .24    .00000231
        2711.1       2361.3     1912.9      1925.8      -.40        .24         .24    .00000236
        3038.4       2711.1     1840.1      1912.5      -.40        .24         .24    .00000240


****************************************************************************************************
TIME (T) =    2.00       TIME (T+DELT) =    4.00

        WWX(I+1)    WWX(I)     WWY(I+1)      WWY(I)   ASTRO. TIDE  SP(I+1)     SP(I)    WIND STRESS
                                                        (FEET)      (FT)        (FT)     PARAMETER


         821.5        840.5     1476.0      1455.8       .10        .31         .31    .00000203
         830.7        821.5     1480.3      1476.0       .10        .31         .31    .00000203
         850.7        830.7     1497.5      1480.3       .10        .31         .31    .00000204
         877.8        850.7     1520.4      1497.5       .10        .30         .31    .00000204
         956.7        877.8     1592.3      1520.4       .10        .29         .30    .00000206
        1049.7        956.7     1647.7      1592.3       .10        .28         .29    .00000209
        1158.5       1049.7     1704.7      1647.7       .10        .27         .28    .00000212
        1397.7       1158.5     1795.4      1704.7       .10        .27         .27    .00000215
        1672.8       1397.7     1857.9      1795.4       .10        .26         .27    .00000220
        1998.3       1672.8     1883.1      1857.9       .10        .26         .26    .00000226
        2344.9       1998.3     1858.5      1883.1       .10        .26         .26    .00000231
        2715.5       2344.9     1783.8      1858.5       .10        .26         .26    .00000235
        3094.4       2715.5     1645.3      1783.8       .10        .25         .26    .00000239
        3326.0       3094.4     1377.7      1645.3       .10        .25         .25    .00000243


****************************************************************************************************
```

Output when control parameter IØMIT = 0

```
                                              OUTPUT DATA
                                              ------ ----

                          FIRST THREE LETTERS OF HURRICANE NAME (ITYPE) AUD
                                                                        ---

         CENTRAL PRESSURE (PO) = 27.95 IN. HG.              PERIPHERAL PRESSURE (PN) = 29.70 IN. HG.

     RADIUS TO MAXIMUM WIND (R) = 19.0 N.M.                       MAXIMUM WIND (WX) =  95.0 MI/HR.

        TRANSLATION SPEED (VF )= 14.0 KNOTS                       INITIAL RISE (SE) = 1.00 FEET

     BOTTOM FRICTION FACTOR (BFF) =  .0025         WIND STRESS CORRECTION FACTOR (WKCOR) = 1.10

     GEOGRAPHICAL LATITUDE(PHII) =     29.30                  TRAVERSE BEARING (BEAR) =  S 12.5 W


TIME (T) =   0.00      TIME (T+DELT) =   2.00

DIST.   DEPTH    D AVG.   PRES.RISE  ASTRO.TIDE   INITIAL     Y-FLUX .  ONSHORE    ALONGSHORE  TOTAL WIND   TOTAL
(NM)   (FT.MLW) (FT.MLW)    (FT)       (FT)     LEVEL(FT). (FT*FT/SEC) SETUP (FT)  SETUP (FT)  SETUP (FT)  SURGE (FT)

 90.0   600.0
                 460.0      .32        -.40       1.00         25.6      .007        .007        .014        .94
 80.0   320.0
                 290.0      .32        -.40       1.00         32.4      .020        .022        .043        .96
 70.0   260.0
                 230.0      .31        -.40       1.00         37.0      .040        .044        .084        .99
 60.0   200.0
                 170.0      .30        -.40       1.00         41.6      .070        .076        .146       1.05
 50.0   140.0
                 100.0      .29        -.40       1.00         47.9      .129        .140        .269       1.16
 40.0    60.0
                  55.0      .28        -.40       1.00         53.4      .257        .268        .524       1.40
 30.0    50.0
                  35.0      .27        -.40       1.00         56.2      .484        .478        .962       1.83
 20.0    20.0
                  19.0      .26        -.40       1.00         36.2      .732        .600       1.332       2.19
 15.0    18.0
                  16.5      .25        -.40       1.00         32.9     1.096        .727       1.823       2.68
 10.0    15.0
                  15.0      .25        -.40       1.00         31.0     1.588        .858       2.446       3.29
  5.0    15.0
                  13.5      .24        -.40       1.00         28.7     1.851        .912       2.763       3.61
  3.0    12.0
                  11.0      .24        -.40       1.00         24.2     2.042        .939       2.981       3.82
  2.0    10.0
                   7.5      .24        -.40       1.00         17.3     2.362        .967       3.329       4.17
  1.0     5.0
                   2.5      .24        -.40       1.00          6.9     3.286        .995       4.281       5.12
  0.0     0.0
```

Output when control parameter IØMIT = 0

```
TIME (T) =   2.00        TIME (T+DELT) =   4.00

DIST.    DEPTH     D AVG.    PRES.RISE  ASTRO.TIDE    INITIAL       Y-FLUX       ONSHORE      ALONGSHORE   TOTAL WIND    TOTAL
(NM)    (FT.MLW)  (FT.MLW)     (FT)       (FT)       LEVEL(FT).  (FT*FT/SEC)  SETUP (FT)    SETUP (FT)   SETUP (FT)  SURGE (FT)

 90.0     600.0
                    460.0       .31        .10         1.00          63.6          .016          .018         .035        1.45
 80.0     320.0
                    290.0       .31        .10         1.00          73.7          .042          .052         .094        1.50
 70.0     260.0
                    230.0       .31        .10         1.00          80.3          .075          .099         .174        1.58
 60.0     200.0
                    170.0       .30        .10         1.00          86.5          .121          .166         .287        1.69
 50.0     140.0
                    100.0       .30        .10         1.00          91.4          .204          .287         .491        1.89
 40.0      60.0
                     55.0       .29        .10         1.00          83.8          .368          .484         .852        2.24
 30.0      50.0
                     35.0       .28        .10         1.00          66.0          .648          .721        1.369        2.75
 20.0      20.0
                     19.0       .27        .10         1.00          40.5          .930          .846        1.776        3.15
 15.0      18.0
                     16.5       .27        .10         1.00          37.9         1.314          .975        2.289        3.65
 10.0      15.0
                     15.0       .26        .10         1.00          37.1         1.806         1.107        2.913        4.27
  5.0      15.0
                     13.5       .26        .10         1.00          35.1         2.060         1.160        3.220        4.58
  3.0      12.0
                     11.0       .26        .10         1.00          30.4         2.233         1.187        3.420        4.78
  2.0      10.0
                      7.5       .25        .10         1.00          23.5         2.488         1.213        3.700        5.06
  1.0       5.0
                      2.5       .25        .10         1.00          14.7         2.916         1.237        4.153        5.51
  0.0       0.0
```

Standard Program Output

```
                                        SUMMARY OF OPEN COAST STORM SURGE PROBLEM


HURRICANE AUDREY VERIFICATION AT EUGENE ISLAND LA.          JUN 1957    AEC 7/73

                          FIRST THREE LETTERS OF HURRICANE NAME (ITYPE) AUD
                                                                        ---

     CENTRAL PRESSURE (PO) = 27.95 IN. HG.                     PERIPHERAL PRESSURE (PN) = 29.70 IN. HG.

RADIUS TO MAXIMUM WIND (R) = 19.0 N.M.                                 MAXIMUM WIND (WX) =  95.0 MI/HR.

    TRANSLATION SPEED (VF )= 14.0 KNOTS                                INITIAL RISE (SE) = 1.00 FEET

BOTTOM FRICTION FACTOR (BFF) =  .0025       WIND STRESS CORRECTION FACTOR (*KCOR) = 1.10

GEOGRAPHICAL LATITUDE(PHII) =     29.30                           TRAVERSE BEARING (BEAR) =  S 12.5 W



 TIME       SETUP      SETUP     TOT. WIND    AST. TIDE   INITIAL WATER     PRESSURE   TOTAL WATER
(HOURS)    X-COMP.    Y-COMP.     SETUP        LEVEL         LEVEL           SETUP        LEVEL
          (FT. MLW)  (FT. MLW)  (FT. MLW)    (FT. MLW)     (FT. MLW)       (FT. MLW)    (FT. MLW)


   2.00       3.29        .99       4.28         -.40          1.00             .24         5.12
   4.00       2.92       1.24       4.15          .10          1.00             .25         5.51
   6.00       3.84       1.38       5.22          .52          1.00             .27         7.01
   8.00       4.26       1.45       5.70          .32          1.00             .28         7.30
  10.00       6.11       1.44       7.56         -.12          1.00             .30         8.73
  12.00       4.77        .74       5.50         -.05          1.00             .29         6.74
  14.00       3.50        .53       4.03          .08          1.00             .28         5.39
  16.00       3.13        .25       3.37         -.18          1.00             .26         4.45
  18.00       3.62        .10       3.71         -.80          1.00             .23         4.14
  20.00       4.09        .14       4.23        -1.60          1.00             .21         3.84
  22.00       3.21       -.04       3.18        -1.90          1.00             .20         2.47
  24.00       2.29       -.08       2.21        -1.40          1.00             .18         1.99
  26.00       1.81       -.18       1.62         -.60          1.00             .16         2.19
```

APPENDIX A-7. OUTPUT LISTING EXAMPLES FOR HYPOTHETICAL HURRICANES*

Standard Program Output

```
****************************************
THIS IS THE BEGINNING OF RUN NUMBER  1
****************************************
```

Output when control parameter LIST = 1

```
XR2

   0.000    .010    .020    .030    .040    .050    .060    .070    .080    .090    .100    .110    .120    .130    .140    .150
    .160    .170    .180    .190    .200    .210    .220    .230    .240    .250    .260    .270    .280    .290    .300    .310
    .320    .330    .340    .350    .360    .370    .380    .390    .400    .410    .420    .430    .440    .450    .460    .470
    .480    .490    .500    .510    .520    .530    .540    .550    .560    .570    .580    .590    .600    .610    .620    .630
    .640    .650    .660    .670    .680    .690    .700    .710    .720    .730    .740    .750    .760    .770    .780    .790
    .800    .810    .820    .830    .840    .850    .860    .870    .880    .890    .900    .910    .920    .930    .940    .950
    .960    .970    .980    .990   1.000   1.070   1.100   1.130   1.170   1.200   1.230   1.270   1.300   1.330   1.370   1.400
   1.430   1.470   1.500   1.530   1.570   1.600   1.630   1.670   1.700   1.730   1.770   1.800   1.830   1.870   1.900   1.930
   1.970   2.000   2.030   2.070   2.100   2.130   2.170   2.250   2.350   2.450   2.550   2.650   2.750   2.850   2.950   3.050
   3.150   3.250   3.350   3.450   3.550   3.650   3.750   3.850   3.950   4.050   4.150   4.250   4.350   4.450   4.550   4.650
   4.750   4.850   4.950   5.050   5.150   5.250   5.350   5.450   5.550   5.650   5.750   5.850   5.950   6.050   6.150   6.250
   6.350   6.450   6.550   6.650   6.750   6.850   6.950   7.050   7.150   7.250   7.350   7.450   7.550   7.650   7.750   7.850
   7.950   8.050   8.150   8.250   8.350   8.450   8.550   8.650   8.750   8.850   8.950   9.050   9.150   9.250   9.350   9.450
   9.550   9.650   9.750   9.850   9.950  10.050  10.150  10.250  10.350  10.450  10.550  10.650  10.750  10.850  10.950  11.050
  11.150  11.250  11.350  11.450  11.550  11.650  11.750  11.850  11.950  12.050  12.150  12.250  12.350  12.450  12.550  12.650
  12.750  12.850  12.950  13.050  13.150  13.250  13.350  13.450  13.550  13.650  13.750  13.850  13.950  14.050  14.150  14.250
  14.350  14.450  14.550  14.650  14.750  14.850  14.950  15.050  15.150  15.250  15.350  15.450

VR2

   0.000   0.000    .001    .002    .002    .004    .006    .006    .007    .008    .009    .011    .012    .013    .015    .016
    .018    .018    .020    .023    .024    .027    .028    .031    .033    .036    .040    .043    .045    .048    .055    .058
    .063    .066    .075    .080    .086    .091    .102    .108    .115    .122    .136    .143    .152    .161    .178    .188
    .198    .207    .231    .243    .258    .271    .300    .315    .334    .355    .395    .418    .446    .471    .523    .547
    .570    .594    .637    .658    .681    .702    .738    .760    .780    .794    .822    .834    .845    .857    .875    .885
    .896    .904    .917    .924    .930    .934    .945    .950    .954    .959    .965    .970    .972    .976    .981    .984
    .986    .989    .991    .992    .999    .997    .995    .992    .989    .984    .976    .966    .950    .938    .928    .916
    .903    .892    .882    .872    .863    .851    .841    .830    .821    .809    .800    .791    .785    .772    .763    .756
    .748    .739    .732    .725    .716    .710    .702    .684    .665    .645    .626    .612    .593    .579    .568    .555
    .542    .531    .518    .508    .498    .490    .480    .469    .459    .451    .443    .434    .425    .417    .409    .402
    .394    .386    .377    .371    .365    .358    .351    .346    .339    .333    .327    .321    .313    .307    .302    .295
    .289    .284    .277    .274    .268    .264    .257    .251    .246    .241    .238    .230    .225    .220    .215    .210
    .206    .200    .195    .191    .186    .181    .177    .175    .169    .165    .161    .158    .154    .151    .148    .144
    .140    .137    .134    .131    .128    .125    .122    .120    .117    .115    .112    .110    .107    .104    .104    .102
    .099    .096    .094    .092    .090    .089    .086    .083    .082    .081    .080    .078    .075    .075    .073    .071
    .069    .067    .066    .065    .063    .063    .062    .060    .060    .059    .057    .056    .056    .054    .053    .053
    .050    .049    .048    .048    .048    .048    .047    .045    .045    .043    .043    .043

XR2

   0.000    .010    .020    .030    .040    .050    .060    .070    .080    .090    .100    .110    .120    .130    .140    .150
    .160    .170    .180    .190    .200    .210    .220    .230    .240    .250    .260    .270    .280    .290    .300    .310
    .320    .330    .340    .350    .360    .370    .380    .390    .400    .410    .420    .430    .440    .450    .460    .470
    .480    .490    .500    .510    .520    .530    .540    .550    .560    .570    .580    .590    .600    .610    .620    .630
    .640    .650    .660    .670    .680    .690    .700    .710    .720    .730    .740    .750    .760    .770    .780    .790
    .800    .810    .820    .830    .840    .850    .860    .870    .880    .890    .900    .910    .920    .930    .940    .950
    .960    .970    .980    .990   1.000   1.030   1.070   1.100   1.130   1.170   1.200   1.230   1.270   1.300   1.330   1.370
   1.400   1.430   1.470   1.500   1.530   1.570   1.600   1.630   1.670   1.700   1.730   1.770   1.800   1.830   1.870   1.900
   1.930   1.970   2.000   2.030   2.060   2.140   2.240   2.340   2.440   2.540   2.640   2.740   2.840   2.940   3.040   3.140
   3.240   3.340   3.440   3.540   3.640   3.740   3.840   3.940   4.040   4.140   4.240   4.340   4.440   4.540   4.640   4.740
   4.840   4.940   5.040   5.140   5.240   5.340   5.440   5.540   5.640   5.740   5.840   5.940   6.040   6.140   6.240   6.340
   6.440   6.540   6.640   6.740   6.840   6.940   7.040   7.140   7.240   7.340   7.440   7.540   7.640   7.740   7.840   7.940
   8.040   8.140   8.240   8.340   8.440   8.540   8.640   8.740   8.840   8.940   9.040   9.140   9.240   9.340   9.440   9.540
   9.640   9.740   9.840   9.940  10.040  10.140  10.240  10.340  10.440  10.540  10.640  10.740  10.840  10.940  11.040  11.140
  11.240  11.340  11.440  11.540  11.640  11.740  11.840  11.940  12.040  12.140  12.240  12.340  12.440  12.540  12.640  12.740
  12.840  12.940  13.040  13.140  13.240  13.340  13.440  13.540  13.640  13.740  13.840  13.940  14.040  14.140  14.240  14.340
  14.440  14.540  14.640  14.740  14.840  14.940  15.040  15.140  15.240  15.340  15.440  30.050

VR2

   0.000   0.000    .001    .002    .002    .004    .006    .006    .007    .008    .009    .011    .012    .013    .015    .016
    .018    .018    .020    .023    .024    .027    .028    .031    .033    .036    .040    .043    .045    .048    .055    .058
    .063    .066    .075    .080    .086    .091    .102    .108    .115    .122    .136    .143    .152    .161    .178    .188
    .198    .207    .231    .243    .258    .271    .300    .315    .334    .353    .395    .418    .446    .471    .523    .547
    .570    .594    .637    .658    .681    .702    .738    .760    .780    .794    .822    .834    .845    .857    .875    .885
    .896    .904    .917    .924    .930    .934    .945    .950    .954    .959    .965    .970    .972    .976    .981    .984
    .986    .989    .991    .992    .999    .998    .996    .994    .991    .986    .979    .968    .956    .942    .929    .914
    .903    .890    .881    .868    .855    .845    .833    .822    .813    .803    .791    .781    .769    .760    .750    .741
    .734    .725    .715    .707    .701    .683    .660    .638    .620    .604    .584    .571    .558    .543    .530    .517
    .505    .493    .483    .473    .462    .451    .441    .431    .420    .412    .402    .392    .381    .374    .365    .357
    .347    .338    .331    .324    .316    .310    .303    .296    .289    .282    .274    .269    .264    .259    .253    .250
    .244    .237    .229    .224    .218    .213    .207    .201    .196    .189    .184    .180    .174    .171    .167    .161
    .156    .153    .147    .143    .138    .133    .129    .124    .120    .116    .112    .109    .106    .102    .098    .095
    .091    .089    .086    .083    .079    .077    .075    .072    .069    .065    .062    .059    .058    .056    .054    .052
    .050    .048    .045    .044    .042    .039    .038    .036    .035    .033    .032    .029    .028    .026    .024    .023
    .021    .021    .020    .018    .017    .016    .015    .015    .013    .012    .011    .011    .010    .008    .008    .008
    .007    .006    .005    .004    .003    .003    .002    .002    .001    .001   0.000   0.000
```

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*See Appendix A-3 for definition of variables.

Output when control parameter LIST = 1

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VTMP

 .896    .917    .930    .945    .954    .965    .972    .981    .986    .991    .999    .998    .998    .997    .996    .995
 .993    .991    .990    .987    .984    .979    .974    .969    .961    .950    .942    .936    .931    .924    .916    .907
 .900    .895    .889    .882    .875    .870    .865    .859    .851    .844    .838    .833    .827    .821    .813    .807
 .802    .797    .791    .787    .782    .775    .769    .763    .758    .754    .750    .745    .739    .734    .730    .727
 .722    .716    .712    .708    .704    .700    .695    .691    .686    .682    .678    .675    .671    .667    .663    .659
 .655    .651    .647    .643    .639    .636    .632    .628    .625    .622    .619    .616    .613    .610    .606    .603
 .599    .595    .592    .589    .586    .583    .580    .578    .576    .574    .571    .569    .567    .564    .562    .559
 .556    .554    .551    .549    .546    .543    .541    .539    .537    .534    .532    .530    .527    .525    .522    .519
 .517    .515    .513    .511    .509    .507    .505    .503    .501    .499    .497    .496    .494    .492    .491    .489
 .487    .485    .483    .481    .479    .477    .475    .472    .470    .468    .466    .464    .462    .460    .458    .457
 .455    .453    .452    .450    .449    .447    .445    .444    .442    .440    .439    .437    .435    .433    .431    .430
 .428    .426    .424    .423    .421    .419    .418    .416    .415    .413    .411    .410    .408    .407    .406    .404
 .403    .401    .400    .398    .396    .395    .393    .392    .390    .388    .387    .385    .383    .382    .380    .378
 .376    .375    .374    .373    .372    .370    .369    .368    .367    .366    .364    .363    .362    .360    .359    .357
 .356    .355    .353    .352    .351    .350    .349    .348    .347    .345    .344    .343    .341    .340    .338    .337
 .336    .335    .334    .332    .331    .330    .329    .328    .326    .325    .324    .323    .322    .320    .319    .317
 .315    .314    .312    .311    .310    .309    .308    .307    .306    .305    .304    .303    .301    .300    .299    .297
 .296    .294    .293    .292    .291    .290    .289    .288    .287    .286    .285    .283    .282    .281    .279    .278
 .277    .276    .276    .275    .274    .273    .272    .271    .270    .269    .268    .267    .266    .265    .264    .263
 .262    .261    .259    .258    .256    .255    .254    .253    .252    .251    .250    .249    .248    .247    .246    .245
 .244    .243    .242    .241    .240    .240    .239    .238    .237    .236    .234    .232    .231    .230    .229    .228
 .227    .226    .225    .224    .223    .222    .221    .220    .219    .218    .217    .216    .215    .214    .213    .212
 .211    .210    .209    .208    .207    .206    .205    .204    .203    .202    .201    .200    .199    .198    .197    .196
 .195    .194    .193    .192    .191    .191    .190    .189    .188    .187    .186    .185    .184    .183    .182    .181
 .180    .179    .178    .177    .177    .176    .176    .176    .175    .174    .173    .172    .171    .170    .169    .168
 .167    .166    .165    .165    .164    .163    .162    .161    .161    .160    .160    .159    .158    .158    .157    .156
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 .144    .144    .143    .142    .141    .140    .140    .139    .139    .138    .137    .137    .136    .136    .135    .134
 .134    .133    .133    .132    .131    .131    .130    .130    .129    .128    .128    .127    .127    .126    .125    .125
 .124    .124    .123    .122    .122    .121    .121    .121    .120    .120    .119    .119    .118    .117    .117    .116
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0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000
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Output when control parameter LIST = 1

```
VTMP

 .896    .917    .930    .945    .954    .965    .972    .981    .986    .991    .999    .998    .997    .996    .995    .994
 .992    .990    .987    .984    .979    .972    .965    .959    .951    .942    .933    .925    .918    .910    .903    .894
 .888    .883    .877    .868    .859    .853    .848    .841    .833    .826    .820    .815    .810    .803    .795    .789
 .784    .777    .769    .763    .758    .753    .747    .741    .736    .732    .727    .722    .715    .710    .705    .701
 .697    .692    .688    .683    .678    .674    .669    .665    .660    .656    .651    .647    .642    .638    .634    .631
 .627    .624    .620    .617    .614    .610    .607    .604    .600    .596    .592    .588    .584    .581    .579    .576
 .574    .571    .568    .566    .563    .561    .558    .555    .552    .549    .546    .543    .540    .538    .535    .533
 .530    .527    .525    .522    .520    .517    .515    .512    .510    .507    .505    .503    .500    .498    .495    .493
 .491    .489    .487    .485    .483    .481    .479    .477    .475    .473    .471    .469    .466    .464    .462    .460
 .458    .455    .453    .451    .449    .447    .445    .443    .441    .439    .437    .435    .433    .431    .429    .427
 .424    .422    .420    .418    .417    .415    .414    .412    .410    .408    .406    .404    .402    .400    .398    .396
 .394    .392    .390    .388    .385    .383    .381    .380    .378    .377    .375    .374    .372    .370    .369    .367
 .365    .363    .362    .360    .359    .357    .355    .353    .351    .349    .347    .345    .343    .342    .340    .338
 .337    .335    .334    .332    .331    .330    .328    .327    .325    .324    .322    .321    .319    .318    .316    .315
 .314    .312    .311    .310    .309    .307    .306    .304    .303    .302    .300    .299    .297    .296    .295    .293
 .292    .290    .289    .288    .286    .285    .283    .282    .280    .279    .277    .276    .274    .273    .272    .271
 .270    .269    .268    .267    .266    .265    .264    .263    .262    .261    .260    .259    .258    .257    .255    .254
 .253    .252    .252    .251    .251    .250    .249    .248    .246    .245    .244    .243    .241    .240    .238    .237
 .235    .234    .232    .231    .229    .228    .227    .226    .225    .224    .223    .222    .220    .219    .218    .217
 .216    .215    .214    .213    .212    .211    .209    .208    .207    .206    .205    .203    .202    .201    .200    .199
 .198    .197    .196    .195    .193    .192    .190    .189    .188    .187    .186    .185    .184    .183    .182    .182
 .181    .180    .179    .178    .176    .175    .174    .173    .173    .172    .172    .171    .170    .169    .169    .168
 .167    .166    .165    .163    .162    .161    .160    .159    .158    .157    .156    .155    .155    .154    .154    .153
 .152    .151    .149    .148    .147    .146    .145    .145    .144    .143    .142    .141    .140    .139    .138    .137
 .136    .135    .134    .133    .132    .131    .131    .130    .129    .128    .127    .126    .125    .124    .123    .122
 .122    .121    .120    .119    .118    .118    .117    .116    .115    .114    .114    .113    .112    .111    .111    .110
 .110    .109    .108    .108    .107    .107    .106    .105    .104    .104    .103    .102    .101    .100    .100    .099
 .098    .097    .097    .096    .096    .095    .094    .093    .093    .092    .091    .091    .090    .090    .089    .089
 .088    .088    .087    .087    .086    .085    .085    .084    .084    .083    .082    .081    .081    .080    .079    .079
 .078    .078    .077    .077    .077    .076    .076    .075    .075    .074    .074    .073    .073    .072    .071    .071
 .070    .070    .069    .068    .067    .067    .066    .065    .064    .064    .063    .063    .062    .061    .061    .060
 .060    .059    .059    .059    .058    .058    .058    .058    .057    .057    .056    .056    .056    .055    .055    .054
 .054    .054    .053    .053    .052    .052    .052    .051    .051    .050    .050    .050    .049    .049    .048    .048
 .047    .047    .046    .046    .045    .045    .045    .044    .044    .044    .044    .043    .043    .042    .042    .041
 .041    .040    .040    .039    .039    .039    .038    .038    .038    .038    .037    .037    .036    .036    .036    .036
 .035    .035    .035    .035    .034    .034    .033    .033    .033    .033    .032    .032    .032    .031    .031    .030
 .030    .029    .029    .029    .028    .028    .028    .028    .027    .027    .026    .026    .026    .025    .025    .024
 .024    .024    .024    .023    .023    .023    .023    .022    .022    .021    .021    .021    .021    .021    .021    .021
 .021    .021    .020    .020    .020    .020    .019    .019    .018    .018    .018    .018    .017    .017    .017    .017
 .017    .016    .016    .016    .016    .016    .015    .015    .015    .015    .015    .015    .015    .015    .015    .014
 .014    .013    .013    .013    .013    .012    .012    .012    .012    .012    .011    .011    .011    .011    .011    .011
 .011    .011    .011    .011    .010    .010    .010    .010    .009    .009    .008    .008    .008    .008    .008    .008
 .008    .008    .008    .008    .008    .008    .008    .008    .007    .007    .007    .007    .007    .006    .006    .006
 .006    .006    .005    .005    .005    .005    .005    .004    .004    .004    .004    .004    .003    .003    .003    .003
 .003    .003    .003    .003    .003    .003    .002    .002    .002    .002    .002    .002    .002    .002    .002    .002
 .001    .001    .001    .001    .001    .001    .001    .001    .001    .001    .000    .000    .000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
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0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
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0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000   0.000   0.000   0.000
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Output when control parameter LIST = 1

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R= 56.0

IRR

ZONE 4 PMH 56.0    1  896  917  930  945  954  965  972  981  986  991  999  998
ZONE 4 PMH 56.0    2  998  997  996  995  993  991  989  986  982  976  970  965
ZONE 4 PMH 56.0    3  957  947  939  932  926  919  911  902  896  890  884  877
ZONE 4 PMH 56.0    4  869  863  859  852  844  837  831  826  821  814  806  800
ZONE 4 PMH 56.0    5  795  790  783  778  773  767  761  755  750  746  741  736
ZONE 4 PMH 56.0    6  730  725  721  717  712  707  703  699  694  690  685  681
ZONE 4 PMH 56.0    7  676  672  668  664  660  656  652  648  645  641  637  633
ZONE 4 PMH 56.0    8  630  626  623  619  615  612  609  606  602  599  596  593
ZONE 4 PMH 56.0    9  589  586  583  580  577  575  572  569  567  564  562  559
ZONE 4 PMH 56.0   10  557  554  552  549  546  544  541  539  536  533  531  529
ZONE 4 PMH 56.0   11  526  524  522  520  517  514  512  509  507  505  503  501
ZONE 4 PMH 56.0   12  499  497  495  493  491  489  487  485  484  482  480  478
ZONE 4 PMH 56.0   13  476  474  472  470  468  466  463  461  459  457  455  453
ZONE 4 PMH 56.0   14  451  449  447  445  444  442  440  438  437  435  433  432
ZONE 4 PMH 56.0   15  430  428  426  424  423  421  419  417  415  413  411  409
ZONE 4 PMH 56.0   16  408  406  404  402  401  399  398  396  395  393  392  390
ZONE 4 PMH 56.0   17  389  387  385  384  382  381  379  377  375  374  372  370
ZONE 4 PMH 56.0   18  368  367  365  363  361  360  359  358  356  355  354  353
ZONE 4 PMH 56.0   19  351  350  349  347  346  344  343  341  340  339  337  336
ZONE 4 PMH 56.0   20  335  334  332  331  330  329  328  326  325  323  322  321
ZONE 4 PMH 56.0   21  319  318  317  316  314  313  312  311  309  308  306  305
ZONE 4 PMH 56.0   22  304  303  301  300  298  297  296  295  294  292  291  290
ZONE 4 PMH 56.0   23  289  288  287  286  285  284  282  281  280  279  278  277
ZONE 4 PMH 56.0   24  276  275  274  273  271  270  269  268  267  265  264  262
ZONE 4 PMH 56.0   25  261  260  259  258  257  256  255  254  253  252  251  250
ZONE 4 PMH 56.0   26  249  248  247  246  245  243  242  241  240  238  237  236
ZONE 4 PMH 56.0   27  235  234  233  232  231  229  228  227  226  225  224  223
ZONE 4 PMH 56.0   28  223  222  221  220  219  217  216  215  213  212  211  210
ZONE 4 PMH 56.0   29  209  208  207  206  205  204  203  202  201  201  200  199
ZONE 4 PMH 56.0   30  198  197  196  195  194  193  192  191  190  189  188  187
ZONE 4 PMH 56.0   31  186  185  184  183  182  181  180  180  179  178  177  176
ZONE 4 PMH 56.0   32  175  174  173  172  171  170  169  168  167  166  165  164
ZONE 4 PMH 56.0   33  163  163  162  161  160  160  159  158  158  157  156  155
ZONE 4 PMH 56.0   34  154  153  152  151  150  149  148  148  147  146  145  144
ZONE 4 PMH 56.0   35  144  143  142  142  141  140  140  139  138  137  137  136
ZONE 4 PMH 56.0   36  136  135  134  134  133  132  132  131  130  129  129  128
ZONE 4 PMH 56.0   37  127  126  126  125  124  123  123  122  121  121  120  119
ZONE 4 PMH 56.0   38  119  118  118  117  117  116  116  115  114  114  113  113
ZONE 4 PMH 56.0   39  112  111  111  110  109  109  108  107  107  106  106  105
ZONE 4 PMH 56.0   40  105  104  104  104  103  103  102  102  101  100  100   99
ZONE 4 PMH 56.0   41   99   98   98   97   97   96   95   95   94   94   93   93
ZONE 4 PMH 56.0   42   92   92   91   90   90   89   89   88   88   87   87   87
ZONE 4 PMH 56.0   43   86   86   86   86   86   85   85   85   84   84   83   83
ZONE 4 PMH 56.0   44   82   82   81   81   80   79   79   78   78   78   77   77
ZONE 4 PMH 56.0   45   76   76   75   75   75   74   74   74   73   73   73   72
ZONE 4 PMH 56.0   46   72   72   71   71   70   70   69   69   68   68   67   67
ZONE 4 PMH 56.0   47   66   66   66   65   65   65   65   64   64   64   64   64
ZONE 4 PMH 56.0   48   63   63   63   62   62   62   62   61   61   60   60   59
ZONE 4 PMH 56.0   49   59   58   58   58   58   57   57   57   57   56   56   56
ZONE 4 PMH 56.0   50   55   55   54   54   54   53   53   53   52   52   51   51
ZONE 4 PMH 56.0   51   51   50   50   50   50   49   49   49   49   49   49   48
ZONE 4 PMH 56.0   52   48   48   47   47   47   46   46   46   46   46   46   46
ZONE 4 PMH 56.0   53   45   45   45   45   45   44   44   44   43   43   43   43
ZONE 4 PMH 56.0   54   43   43   43   43   42   42   42   42   41   41   41   40
ZONE 4 PMH 56.0   55   40   40   40   39   39   39   39   39   39   39   39   39
ZONE 4 PMH 56.0   56   38   38   38   37   37   37   36   36   36   36   36   36
ZONE 4 PMH 56.0   57   36   36   36   35   35   34   34   34   34   34   33   33
ZONE 4 PMH 56.0   58   33   33   33   32   32   32   32   32   32   32   32   32
ZONE 4 PMH 56.0   59   32   32   31   31   31   31   31   31   31   31   31   31
ZONE 4 PMH 56.0   60   30   30   30   29   29   29   29   29   29   29   29   28
ZONE 4 PMH 56.0   61   28   28   27   27   27   27   27   27   27   27   27   27
ZONE 4 PMH 56.0   62   27   27   27   27   27   27   27   27   26   26   26   26
ZONE 4 PMH 56.0   63   25   25   25   25   25   25   25   25   24   24   24   24
ZONE 4 PMH 56.0   64   24   24   24   24   24   24   24   24   24   24   24   24
ZONE 4 PMH 56.0   65   24   24   24   24   24   24   24   23   23   23   23   23
ZONE 4 PMH 56.0   66   23   23   23   22   22   22   22   22   22   22   22   22
ZONE 4 PMH 56.0   67   22   22   22   22   22   22   22   22   22   22   22   22
ZONE 4 PMH 56.0   68   22   22   22   22   22   22   22   21   21   21   21   21
ZONE 4 PMH 56.0   69   21   21   21   21   21   21   21   21   21   21   21   21
ZONE 4 PMH 56.0   70   21   21   21   21   21   21   20   20   20   20   20   20
ZONE 4 PMH 56.0   71   20   20   19   19   19   19   19   19   19   19   19   19
ZONE 4 PMH 56.0   72   19   19   19   18   18   18   18   18   18   18   18   18
ZONE 4 PMH 56.0   73   18   18   18   18   18   18   18   18   18   17   17   17
ZONE 4 PMH 56.0   74   17   17   17   17   17   17   17   17   17   17   17   17
ZONE 4 PMH 56.0   75   17   17   17   17   17   17   17   17   16   16   16   16
ZONE 4 PMH 56.0   76   16   15   15   15   15   15   15   15   15   15   14   14
ZONE 4 PMH 56.0   77   14   14   14   14   14   14   14   14   14   14   14   14
ZONE 4 PMH 56.0   78   14   14   14   14   14   14   14   14   14   14   14   14
ZONE 4 PMH 56.0   79   14   14   14   14   13   13   13   13   13   13   13   13
```

Output when control parameter LIST = 1

```
ZONE 4 PMH 56.0   80   13   13   13   13   13   13   13   13   13   13   12   12
ZONE 4 PMH 56.0   81   12   12   12   12   12   11   11   11   11   10   10   10
ZONE 4 PMH 56.0   82   10   10   10   10   10   10   10   10   10   10    9    9
ZONE 4 PMH 56.0   83    9    9    9    9    9    9    9    9    9    9    9    9
ZONE 4 PMH 56.0   84    9    9    9    9    9    9    9    9    9    9    9    9
ZONE 4 PMH 56.0   85    9    9    8    8    8    8    8    8    8    8    7    7
ZONE 4 PMH 56.0   86    7    7    7    7    7    7    7    7    7    7    7    7
ZONE 4 PMH 56.0   87    7    7    7    7    7    7    7    7    7    6    6    6
ZONE 4 PMH 56.0   88    6    6    6    6    6    6    6    6    6    6    5    5
ZONE 4 PMH 56.0   89    5    5    5    5    5    5    5    5    5    5    5    4
ZONE 4 PMH 56.0   90    4    5    5    5    5    5    5    5    5    4    4    4
ZONE 4 PMH 56.0   91    4    4    4    4    3    3    3    3    2    2    2    2
ZONE 4 PMH 56.0   92    2    2    2    2    2    2    2    2    2    2    2    2
ZONE 4 PMH 56.0   93    2    2    2    2    2    2    2    2    2    2    2    2
ZONE 4 PMH 56.0   94    2    2    2    2    2    2    2    2    2    1    1    1
ZONE 4 PMH 56.0   95    1    1    1    1    1    1    1    1    1    1    1    0
ZONE 4 PMH 56.0   96    0    0    0    0    0    0    0    0    0    0    0    0
ZONE 4 PMH 56.0   97    0    0    0    0    0    0    0    0    0    0    0    0
ZONE 4 PMH 56.0   98    0    0    0    0    0    0    0    0    0    0    0    0
ZONE 4 PMH 56.0   99    0    0    0    0    0    0    0    0    0    0    0    0
ZONE 4 PMH 56.0  100    0    0    0    0    0    0    0    0    0    0    0    0
ZONE 4 PMH 56.0  101    0    0    0    0    0    0    0    0    0    0    0    0
ZONE 4 PMH 56.0  102    0    0    0    0    0    0    0    0    0    0    0    0
ZONE 4 PMH 56.0  103    0    0    0    0    0    0    0    0    0    0    0    0
ZONE 4 PMH 56.0  104    0    0    0    0    0    0    0    0    0    0    0    0
ZONE 4 PMH 56.0  105    0    0    0    0    0    0    0    0    0    0    0    0
ZONE 4 PMH 56.0  106    0    0    0    0    0    0    0    0    0    0    0    0
ZONE 4 PMH 56.0  107    0    0    0    0    0    0    0    0    0    0    0    0
ZONE 4 PMH 56.0  108    0    0    0    0    0    0    0    0    0    0    0    0
ZONE 4 PMH 56.0  109    0    0    0    0    0    0    0    0    0    0    0    0
ZONE 4 PMH 56.0  110    0    0    0    0    0    0    0    0    0    0    0    0
ZONE 4 PMH 56.0  111    0    0    0    0    0    0    0    0    0    0    0    0
ZONE 4 PMH 56.0  112    0    0    0    0    0    0    0    0    0    0    0    0
ZONE 4 PMH 56.0  113    0    0    0    0    0    0    0    0    0    0    0    0
ZONE 4 PMH 56.0  114    0    0    0    0    0    0    0    0    0    0    0    0
ZONE 4 PMH 56.0  115    0    0    0    0    0    0    0    0    0    0    0    0
ZONE 4 PMH 56.0  116    0    0    0    0    0    0    0    0    0    0    0    0
ZONE 4 PMH 56.0  117    0    0    0    0    0    0    0    0    0    0    0    0
ZONE 4 PMH 56.0  118    0    0    0    0    0    0    0    0    0    0    0    0
ZONE 4 PMH 56.0  119    0    0    0    0    0    0    0    0    0    0    0    0
ZONE 4 PMH 56.0  120    0    0    0    0    0    0    0    0    0    0    0    0
ZONE 4 PMH 56.0  121    0    0    0    0    0    0    0    0    0    0    0    0
ZONE 4 PMH 56.0  122    0    0    0    0    0    0    0    0    0
```

Standard Program Output

```
RADIAL DISTANCE AT WHICH WIND VELOCITY FOR A P.M.H. EQUALS 0.    377.9
INITIAL DISTANCE ALONG TRAVERSE LINE FROM POINT OF MAX. WIND VEL. EQUALS        398.1

RADIAL DISTANCE MEANS DISTANCE FROM CENTER OF HURRICANE.
DISTANCE FROM COASTLINE MEANS DISTANCE PARALLEL TO TRAVERSE LINE.
```

Output when control parameter KEYA = 1

```
TIME INCREMENT  1        0.0 HOURS
    R = 56.00 N. MILES    VF = 37.00 KNOTS      WX = 120.40 M.P.H.
X DISTANCE =50.75 N. MILES


                         (RS)            (W)           (TH)                    (PRESS)
    DISTANCE FROM       RADIAL          WIND    ANGLE FROM TRAVERSE LINE      PRESSURE
   ZERO VELOCITY AT    DISTANCE       VELOCITY   COUNTERCLOCKWISE POS.         SETUP
  FRONT OF HURRICANE   N. MILES         M.P.H.    (DEGREES)                      FT.
       N. MILES


          0.00          377.89           2.79       107.28                       .41
         10.00          367.98           3.93       107.07                       .42
         20.00          358.08           5.47       106.85                       .43
         30.00          348.18           6.58       106.62                       .45
         40.00          338.29           7.86       106.37                       .46
         50.00          328.41           9.47       106.11                       .47
         60.00          318.54          10.77       105.83                       .48
         70.00          308.67          12.30       105.54                       .50
         80.00          298.81          13.72       105.22                       .51
         90.00          288.96          15.38       104.88                       .53
        100.00          279.12          16.81       104.52                       .55
        110.00          269.29          18.72       104.14                       .56
        120.00          259.48          20.65       103.72                       .58
        130.00          249.68          22.48       103.27                       .60
        140.00          239.90          24.60       102.79                       .62
        150.00          230.13          26.69       102.26                       .65
        160.00          220.39          28.75       101.69                       .67
        170.00          210.67          31.19       101.06                       .70
        180.00          200.98          33.33       100.37                       .73
        190.00          191.32          35.75        99.62                       .76
        200.00          181.70          38.49        98.78                       .80
        210.00          172.12          41.41        97.85                       .83
        220.00          162.59          44.29        96.81                       .87
        230.00          153.12          47.63        95.64                       .92
        240.00          143.72          51.39        94.32                       .97
        250.00          134.42          55.79        92.82                      1.02
        260.00          125.21          60.42        91.09                      1.08
        270.00          116.14          65.55        89.09                      1.15
        280.00          107.24          70.97        86.75                      1.22
        290.00           98.54          77.26        84.00                      1.30
        300.00           90.12          84.21        80.72                      1.39
        310.00           82.05          91.27        76.79                      1.48
        320.00           74.45          98.78        72.02                      1.59
        330.00           67.48         106.07        66.22                      1.69
        340.00           61.35         109.56        51.34                      1.80
        350.00           56.34         112.55        36.19                      1.89
        360.00           52.77         112.38        25.33                      1.96
        370.00           50.95         112.90        14.13                      2.00
        380.00           51.05         114.70         2.89                      2.00
        390.00           53.08         117.54       352.46                      1.96
        400.00           56.81         120.30       344.38                      1.88
        410.00           61.96         119.64       342.98                      1.78
        420.00           68.19         117.40       343.10                      1.68
        430.00           75.23         111.18       337.42                      1.57
        440.00           82.89         104.91       332.76                      1.47
        450.00           91.00          98.25       328.90                      1.38
        460.00           99.46          92.13       325.68                      1.29
        470.00          108.18          86.21       322.98                      1.21
        480.00          117.10          81.17       320.68                      1.14
        490.00          126.19          76.26       318.72                      1.08
        500.00          135.41          71.99       317.01                      1.02
        510.00          144.73          67.87       315.53                       .96
        520.00          154.13          64.25       314.23                       .91
        530.00          163.61          61.25       313.07                       .87
        540.00          173.14          58.20       312.05                       .83
        550.00          182.73          55.63       311.13                       .79
        560.00          192.35          52.86       310.30                       .76
        570.00          202.01          50.69       309.55                       .73
        580.00          211.71          48.53       308.87                       .70
        590.00          221.43          46.02       308.25                       .67
        600.00          231.18          43.93       307.68                       .65
        610.00          240.94          41.99       307.16                       .62
        620.00          250.73          39.84       306.68                       .60
        630.00          260.53          38.22       306.23                       .58
        640.00          270.34          36.35       305.82                       .56
        650.00          280.17          34.38       305.44                       .54
        660.00          290.01          32.98       305.08                       .53
        670.00          299.86          31.33       304.74                       .51
        680.00          309.72          29.99       304.43                       .50
        690.00          319.59          28.42       304.14                       .48
        700.00          329.47          26.91       303.86                       .47
        710.00          339.35          25.53       303.60                       .46
        720.00          349.24          24.27       303.36                       .44
        730.00          359.14          23.01       303.12                       .43
        740.00          369.04          21.64       302.90                       .42
        748.93          377.89          20.63       302.72                       .41

X AXIS IS ALONG HURRICANE ISOVEL AXIS OF SYMMETRY
```

Output when control parameter KEY = 1

```
TIME INCREMENT  1          0.0 HOURS
     R = 56.00 N. MILES    VF = 37.00 KNOTS       WX = 120.40 M.P.H.
X DISTANCE =50.75 N. MILES


       DISTANCE FROM        RADIAL              WIND      ANGLE FROM TRAVERSE LINE
        COAST LINE         DISTANCE           VELOCITY     COUNTERCLOCKWISE POS.
         N. MILES          N. MILES             M.P.H.      (DEGREES)



          47.60             330.78               9.05          106.17
          46.60             331.77               8.74          106.20
          43.60             334.74               8.39          106.28
          40.60             337.70               7.92          106.36
          39.60             338.69               7.81          106.38
          38.60             339.68               7.69          106.41
          37.60             340.67               7.58          106.43
          36.60             341.66               7.46          106.46
          35.60             342.65               7.35          106.48
          31.60             346.60               6.95          106.58
          30.60             347.59               6.65          106.60
          29.60             348.58               6.54          106.63
          28.60             349.57               6.42          106.65
          27.00             351.15               6.24          106.69
          26.00             352.14               6.12          106.71
          25.50             352.64               6.07          106.73
          25.00             353.13               6.01          106.74
          24.50             353.63               5.95          106.75
          24.00             354.12               5.90          106.76
          23.50             354.62               5.84          106.77
          22.50             355.61               5.72          106.79
          21.50             356.60               5.61          106.82
          20.50             357.59               5.58          106.84
          20.00             358.08               5.47          106.85
          19.00             359.07               5.20          106.87
          16.00             362.04               4.86          106.94
          15.00             363.03               4.85          106.96
          14.00             364.02               4.51          106.99
          12.50             365.51               4.42          107.02
          10.00             367.98               3.93          107.07
           8.50             369.47               3.76          107.10
           5.00             372.94               3.36          107.18
           3.00             374.92               3.14          107.22
           2.00             375.91               3.02          107.24
           1.80             376.11               3.00          107.24
           1.60             376.30               2.98          107.25
           1.40             376.50               2.95          107.25
           1.20             376.70               2.93          107.26
           1.00             376.90               2.91          107.26
            .90             377.00               2.90          107.26
            .80             377.10               2.88          107.27
            .70             377.20               2.87          107.27
            .60             377.30               2.86          107.27
            .50             377.39               2.85          107.27
            .40             377.49               2.84          107.27
            .30             377.59               2.83          107.28
            .20             377.69               2.82          107.28
            .10             377.79               2.81          107.28
           0.00             377.89               2.79          107.28

X AXIS IS ALONG HURRICANE ISOVEL AXIS OF SYMMETRY
```

Output when control parameter KEY = 1

```
TIME INCREMENT  2          .5 HOURS
    R = 56.00 N. MILES    VF = 37.00 KNOTS      WX = 120.40 M.P.H.
X DISTANCE =50.75 N. MILES


     DISTANCE FROM       RADIAL           WIND    ANGLE FROM TRAVERSE LINE
       COAST LINE       DISTANCE        VELOCITY   COUNTERCLOCKWISE POS.
        N. MILES        N. MILES          M.P.H.     (DEGREES)


          47.60          312.51           11.84         105.65
          46.60          313.50           11.62         105.68
          43.60          316.46           11.14         105.77
          40.60          319.42           10.67         105.86
          39.60          320.41           10.55         105.89
          38.60          321.40           10.44         105.91
          37.60          322.39           10.34         105.94
          36.60          323.37           10.08         105.97
          35.60          324.36           10.02         106.00
          31.60          328.31            9.49         106.11
          30.60          329.30            9.15         106.13
          29.60          330.29            9.03         106.16
          28.60          331.28            8.94         106.19
          27.00          332.86            8.61         106.23
          26.00          333.85            8.50         106.26
          25.50          334.34            8.44         106.27
          25.00          334.83            8.38         106.28
          24.50          335.33            8.32         106.29
          24.00          335.82            8.26         106.31
          23.50          336.32            8.29         106.32
          22.50          337.31            7.97         106.35
          21.50          338.29            7.86         106.37
          20.50          339.29            7.74         106.40
          20.00          339.78            7.68         106.41
          19.00          340.77            7.57         106.43
          16.00          343.73            7.22         106.51
          15.00          344.72            7.11         106.53
          14.00          345.71            6.99         106.56
          12.50          347.20            6.82         106.59
          10.00          349.67            6.41         106.65
           8.50          351.15            6.24         106.69
           5.00          354.62            5.84         106.77
           3.00          356.60            5.61         106.82
           2.00          357.59            5.58         106.84
           1.80          357.78            5.54         106.84
           1.60          357.98            5.49         106.85
           1.40          358.18            5.45         106.85
           1.20          358.38            5.41         106.86
           1.00          358.58            5.26         106.86
            .90          358.68            5.25         106.87
            .80          358.77            5.24         106.87
            .70          358.87            5.23         106.87
            .60          358.97            5.21         106.87
            .50          359.07            5.20         106.87
            .40          359.17            5.19         106.88
            .30          359.27            5.18         106.88
            .20          359.37            5.17         106.88
            .10          359.47            5.16         106.88
           0.00          359.57            5.15         106.89

X AXIS IS ALONG HURRICANE ISOVEL AXIS OF SYMMETRY
```

Standard Program Output

```
                                  QUASI-TWO-DIMENSIONAL OPEN COAST STORM SURGE PROGRAM

SAMPLE   NUCLEAR POWER STATION  HAMPTON BEACH,N.H. HUR. H PMH 2-28-74 BY HDM
                                                  INPUT DATA
                                                  ----- ----

                                     TYPE OF HURRICANE MODEL (ITYPE) PMH
                                                                     ---

GEOGRAPHICAL LATITUDE (PHII) =     42.83 DEGREES              HURRICANE ZONE (IZONE) 4

    CENTRAL PRESSURE (PO) = 27.42 IN. HG.              PERIPHERAL PRESSURE (PN) = 30.42 IN. HG.

RADIUS TO MAXIMUM WIND (R) = 56.0 N.M.                         MAXIMUM WIND (WX) = 120.6 MI/HR.

   TRANSLATION SPEED (VF) = 37.0 KNOTS                          INITIAL RISE (SE) =  .60 FEET

  TRAVERSE BEARING (BEAR) =  S 12  E                 BOTTOM FRICTION FACTOR (BFF) =  .0025

                WIND STRESS EQUATION  WK(L) = 0.00000121+ 0.00000275* (1.0 - 16.0/W(L))**2

SURGE TRAVERSE IS PARALLEL TO STORM TRACK AND 115 DEGREES FROM THE LINE OF STRONGEST WINDS


                                         BOTTOM PROFILE OVER THE CONTINENTAL SHELF

                                            DISTANCE FROM       DEPTH
                                             SHORE (N.M.)       (FEET)
                                                47.60           600.0
                                                46.60           580.0
                                                43.60           456.0
                                                40.60           446.0
                                                39.60           410.0
                                                38.60           420.0
                                                37.60           432.0
                                                36.60           416.0
                                                35.60           402.0
                                                31.60           226.0
                                                30.60           230.0
                                                29.60           266.0
                                                28.60           324.0
                                                27.00           300.0
                                                26.00           190.0
                                                25.50           189.0
                                                25.00           196.0
                                                24.50           194.0
                                                24.00           186.0
                                                23.50           167.0
                                                22.50           165.0
                                                21.50           278.0
                                                20.50           296.0
                                                20.00           294.0
                                                19.00           397.0
                                                16.00           382.0
                                                15.00           365.0
                                                14.00           365.0
                                                12.50           317.0
                                                10.00           175.0
                                                 8.50           249.0
                                                 5.00           156.0
                                                 3.00            69.0
                                                 2.00            64.0
                                                 1.80            60.0
                                                 1.60            60.0
                                                 1.40            49.0
                                                 1.20            41.0
                                                 1.00            33.0
                                                  .90            30.0
                                                  .80            28.0
                                                  .70            16.0
                                                  .60            15.0
                                                  .50            13.0
                                                  .40            11.0
                                                  .30            10.0
                                                  .20             9.0
                                                  .10             4.0
                                                 0.00             0.0


      INPUT AND OUTPUT CONTROL
      ------------------------

IDATA =     4  0 = WIND FIELD DATA INPUT BY CARDS IN FINAL FORM
               4 = WIND FIELD DATA INPUT BY CARDS AND TRANSFERED TO DISK

IOMIT =     0   0 = DETAILED PRINTING
IOMITD =     0  1 = SKIP DETAILED PRINTING

  KEY  =     1  0 = WIND DATA(PROFILE DISTANCE, RADIUS, WIND,AND THETA) NOT PRINTED
                1 = WIND DATA(PROFILE DISTANCE, RADIUS, WIND,AND THETA) PRINTED


  LIST =     1  0 = DATA GENERATED IN PROFIL NOT PRINTED
                1 = DATA GENERATED IN PROFIL PRINTED

  KEYA =     1  0 = SUBROUTINE ZERWND NOT CALLED
                1 = SUBROUTINE ZERWND IS CALLED

DELTT  =        .50 HOUR INITIAL COMPUTATION INTERVAL
```

Output when control parameter IOMITD = 0

```
****************************************************************************************************************
TIME (T) =   0.00       TIME (T+DELT) =      .50

        WWX(I+1)        WWX(I)        WWY(I+1)          WWY(I)      ASTRO. TIDE     SP(I+1)          SP(I)      WIND STRESS
                                                                      (FEET)         (FT)            (FT)        PARAMETER


          -21.3          -22.8            73.3            78.7          *.20           .53             .53        .00000110
          -19.7          -21.3            67.6            73.3          *.20           .53             .53        .00000110
          -17.7          -19.7            60.3            67.6          *.20           .52             .53        .00000110
          -17.2          -17.7            58.5            60.3          *.20           .52             .52        .00000110
          -16.7          -17.2            56.8            58.5          *.20           .52             .52        .00000110
          -16.2          -16.7            55.1            56.8          *.20           .52             .52        .00000110
          -15.8          -16.2            53.4            55.1          *.20           .52             .52        .00000110
          -15.3          -15.8            51.8            53.4          *.20           .52             .52        .00000110
          -13.8          -15.3            46.3            51.8          *.20           .51             .52        .00000110
          -12.6          -13.8            42.4            46.3          *.20           .51             .51        .00000110
          -12.2          -12.6            41.0            42.4          *.20           .51             .51        .00000110
          -11.8          -12.2            39.5            41.0          *.20           .51             .51        .00000110
          -11.2          -11.8            37.3            39.5          *.20           .50             .51        .00000110
          -10.8          -11.2            35.9            37.3          *.20           .50             .50        .00000110
          -10.6          -10.8            35.3            35.9          *.20           .50             .50        .00000110
          -10.4          -10.6            34.6            35.3          *.20           .50             .50        .00000110
          -10.2          -10.4            33.9            34.6          *.20           .50             .50        .00000110
          -10.0          -10.2            33.3            33.9          *.20           .50             .50        .00000110
           -9.8          -10.0            32.6            33.3          *.20           .50             .50        .00000110
           -9.5           -9.8            31.4            32.6          *.20           .50             .50        .00000110
           -9.1           -9.5            30.1            31.4          *.20           .50             .50        .00000110
           -9.0           -9.1            29.8            30.1          *.20           .50             .50        .00000110
           -8.7           -9.0            28.7            29.8          *.20           .50             .50        .00000110
           -7.9           -8.7            25.9            28.7          *.20           .49             .50        .00000110
           -6.9           -7.9            22.6            25.9          *.20           .49             .49        .00000110
           -6.9           -6.9            22.5            22.6          *.20           .49             .49        .00000110
           -5.9           -6.9            19.5            22.5          *.20           .49             .49        .00000110
           -5.7           -5.9            18.7            19.5          *.20           .49             .49        .00000110
           -4.5           -5.7            14.8            18.7          *.20           .48             .49        .00000110
           -4.2           -4.5            13.5            14.8          *.20           .48             .48        .00000110
           -3.3           -4.2            10.8            13.5          *.20           .48             .48        .00000110
           -2.9           -3.3             9.4            10.8          *.20           .47             .48        .00000110
           -2.1           -2.9             6.9             9.4          *.20           .47             .47        .00000110
           -2.1           -2.1             6.8             6.9          *.20           .47             .47        .00000110
           -2.1           -2.1             6.7             6.8          *.20           .47             .47        .00000110
           -2.0           -2.1             6.6             6.7          *.20           .47             .47        .00000110
           -2.0           -2.0             6.5             6.6          *.20           .47             .47        .00000110
           -2.0           -2.0             6.4             6.5          *.20           .47             .47        .00000110
           -2.0           -2.0             6.3             6.4          *.20           .47             .47        .00000110
           -2.0           -2.0             6.3             6.3          *.20           .47             .47        .00000110
           -1.9           -2.0             6.2             6.3          *.20           .47             .47        .00000110
           -1.9           -1.9             6.2             6.2          *.20           .47             .47        .00000110
           -1.9           -1.9             6.1             6.2          *.20           .47             .47        .00000110
           -1.9           -1.9             6.1             6.1          *.20           .47             .47        .00000110
           -1.9           -1.9             6.0             6.1          *.20           .47             .47        .00000110
           -1.9           -1.9             6.0             6.0          *.20           .47             .47        .00000110
           -1.9           -1.9             6.0             6.0          *.20           .47             .47        .00000110
           -1.8           -1.9             5.9             6.0          *.20           .47             .47        .00000110
```

Output when control parameter IOMITD = 0

```
****************************************************************************************************************
TIME (T) =    .50      TIME (T+DELT) =   1.00

     WWX(I+1)      WWX(I)      WWY(I+1)        WWY(I)     ASTRO. TIDE     SP(I+1)        SP(I)     WIND STRESS
                                                            (FEET)         (FT)          (FT)      PARAMETER

      -36.5        -37.8        130.0          135.0        *.20           .56           .56        .00000110
      -33.7        -36.5        119.4          130.0        *.20           .55           .56        .00000110
      -31.1        -33.7        109.5          119.4        *.20           .55           .55        .00000110
      -30.5        -31.1        107.1          109.5        *.20           .55           .55        .00000110
      -29.9        -30.5        104.8          107.1        *.20           .55           .55        .00000110
      -29.4        -29.9        102.8          104.8        *.20           .55           .55        .00000110
      -28.0        -29.4         97.8          102.8        *.20           .54           .55        .00000110
      -27.6        -28.0         96.4           97.8        *.20           .54           .54        .00000110
      -25.0        -27.6         86.5           96.4        *.20           .54           .54        .00000110
      -23.3        -25.0         80.4           86.5        *.20           .53           .54        .00000110
      -22.7        -23.3         78.4           80.4        *.20           .53           .53        .00000110
      -22.3        -22.7         76.8           78.4        *.20           .53           .53        .00000110
      -20.7        -22.3         71.2           76.8        *.20           .53           .53        .00000110
      -20.2        -20.7         69.3           71.2        *.20           .53           .53        .00000110
      -19.9        -20.2         68.3           69.3        *.20           .53           .53        .00000110
      -19.7        -19.9         67.4           68.3        *.20           .53           .53        .00000110
      -19.4        -19.7         66.5           67.4        *.20           .53           .53        .00000110
      -19.2        -19.4         65.6           66.5        *.20           .53           .53        .00000110
      -19.3        -19.2         66.0           65.6        *.20           .52           .53        .00000110
      -17.9        -19.3         61.0           66.0        *.20           .52           .52        .00000110
      -17.4        -17.9         59.2           61.0        *.20           .52           .52        .00000110
      -16.9        -17.4         57.5           59.2        *.20           .52           .52        .00000110
      -16.7        -16.9         56.6           57.5        *.20           .52           .52        .00000110
      -16.2        -16.7         54.9           56.6        *.20           .52           .52        .00000110
      -14.8        -16.2         50.0           54.9        *.20           .51           .52        .00000110
      -14.4        -14.8         48.4           50.0        *.20           .51           .51        .00000110
      -13.9        -14.4         46.9           48.4        *.20           .51           .51        .00000110
      -13.3        -13.9         44.6           46.9        *.20           .51           .51        .00000110
      -11.8        -13.3         39.4           44.6        *.20           .51           .51        .00000110
      -11.2        -11.8         37.3           39.4        *.20           .50           .51        .00000110
       -9.8        -11.2         32.6           37.3        *.20           .50           .50        .00000110
       -9.1         -9.8         30.1           32.6        *.20           .50           .50        .00000110
       -7.1         -9.1         23.6           30.1        *.20           .50           .50        .00000110
       -7.0         -7.1         23.2           23.6        *.20           .50           .50        .00000110
       -6.9         -7.0         22.9           23.2        *.20           .50           .50        .00000110
       -6.8         -6.9         22.5           22.9        *.20           .49           .50        .00000110
       -6.7         -6.8         22.1           22.5        *.20           .49           .49        .00000110
       -6.4         -6.7         21.0           22.1        *.20           .49           .49        .00000110
       -6.3         -6.4         20.9           21.0        *.20           .49           .49        .00000110
       -6.3         -6.3         20.8           20.9        *.20           .49           .49        .00000110
       -6.3         -6.3         20.7           20.8        *.20           .49           .49        .00000110
       -6.2         -6.3         20.6           20.7        *.20           .49           .49        .00000110
       -6.2         -6.2         20.5           20.6        *.20           .49           .49        .00000110
       -6.2         -6.2         20.4           20.5        *.20           .49           .49        .00000110
       -6.2         -6.2         20.3           20.4        *.20           .49           .49        .00000110
       -6.1         -6.2         20.2           20.3        *.20           .49           .49        .00000110
       -6.1         -6.1         20.2           20.2        *.20           .49           .49        .00000110
       -6.1         -6.1         20.1           20.2        *.20           .49           .49        .00000110

****************************************************************************************************************
```

Output when control parameter IOMIT = 0

```
                                                   OUTPUT DATA
                                                   ------ ----


                                  TYPE OF HURRICANE MODEL (ITYPE) PMH
                                                                  ---
GEOGRAPHICAL LATITUDE (PHII) =     42.83 DEGREES              HURRICANE ZONE (IZONE) 4

     CENTRAL PRESSURE (PO) = 27.42 IN. HG.          PERIPHERAL PRESSURE (PN) = 30.42 IN. HG.

RADIUS TO MAXIMUM WIND (R) = 56.0 N.M.                      MAXIMUM WIND (WX) = 120.4 MI/HR.

    TRANSLATION SPEED (VF) = 37.0 KNOTS                    INITIAL RISE (SE) =  .60 FEET

    TRAVERSE BEARING (BEAR) =  N 75.00 W         BOTTOM FRICTION FACTOR (BFF) =  .0025
```

Output when control parameter IOMIT = 0

```
TIME (T) =   0.00       TIME (T+DELT) =    .50

DIST.    DEPTH     D AVG.   PRES.RISE  ASTRO.TIDE   INITIAL      Y-FLUX      ONSHORE    ALONGSHORE  TOTAL WIND   TOTAL
(NM)   (FT.MLW)  (FT.MLW)     (FT)        (FT)     LEVEL(FT). (FT*FT/SEC) SETUP (FT)  SETUP (FT)  SETUP (FT) SURGE (FT)

 47.6    600.0
                   590.0      .53        9.20        .60           .4      -.000        .000        -.000      12.33
 46.6    580.0
                   518.0      .53        9.20        .60           .3      -.000        .000        -.000      12.33
 43.6    456.0
                   451.0      .52        9.20        .60           .3      -.000        .000        -.000      12.32
 40.6    446.0
                   428.0      .52        9.20        .60           .3      -.000        .000        -.000      12.32
 39.6    410.0
                   415.0      .52        9.20        .60           .3      -.000        .000        -.000      12.32
 38.6    420.0
                   426.0      .52        9.20        .60           .3      -.000        .000        -.000      12.32
 37.6    432.0
                   424.0      .52        9.20        .60           .3      -.000        .000        -.000      12.32
 36.6    416.0
                   409.0      .52        9.20        .60           .2      -.000        .000        -.000      12.32
 35.6    402.0
                   314.0      .51        9.20        .60           .2      -.000        .000        -.000      12.31
 31.6    226.0
                   228.0      .51        9.20        .60           .2      -.000        .000        -.000      12.31
 30.6    230.0
                   248.0      .51        9.20        .60           .2      -.000        .000        -.000      12.31
 29.6    266.0
                   295.0      .51        9.20        .60           .2      -.000        .000        -.000      12.31
 28.6    324.0
                   312.0      .51        9.20        .60           .2      -.000        .000        -.000      12.31
 27.0    300.0
                   245.0      .50        9.20        .60           .2      -.000        .000        -.000      12.30
 26.0    190.0
                   189.5      .50        9.20        .60           .2      -.000        .000        -.000      12.30
 25.5    189.0
                   192.5      .50        9.20        .60           .2      -.000        .000        -.000      12.30
 25.0    196.0
                   195.0      .50        9.20        .60           .2      -.000        .000        -.000      12.30
 24.5    194.0
                   190.0      .50        9.20        .60           .2      -.000        .000        -.000      12.30
 24.0    186.0
                   176.5      .50        9.20        .60           .2      -.000        .000        -.000      12.30
 23.5    167.0
                   166.0      .50        9.20        .60           .1      -.001        .000        -.000      12.30
 22.5    165.0
                   221.5      .50        9.20        .60           .1      -.001        .000        -.000      12.30
 21.5    278.0
                   287.0      .50        9.20        .60           .1      -.001        .000        -.000      12.30
 20.5    296.0
                   295.0      .50        9.20        .60           .1      -.001        .000        -.000      12.30
 20.0    294.0
                   345.5      .49        9.20        .60           .1      -.001        .000        -.000      12.29
 19.0    397.0
                   389.5      .49        9.20        .60           .1      -.001        .000        -.000      12.29
 16.0    382.0
                   373.5      .49        9.20        .60           .1      -.001        .000        -.000      12.29
 15.0    365.0
                   365.0      .49        9.20        .60           .1      -.001        .000        -.000      12.29
 14.0    365.0
                   341.0      .49        9.20        .60           .1      -.001        .000        -.000      12.29
 12.5    317.0
                   246.0      .48        9.20        .60           .1      -.001        .000        -.000      12.28
 10.0    175.0
                   212.0      .48        9.20        .60           .1      -.001        .000        -.000      12.28
  8.5    249.0
                   202.5      .48        9.20        .60           .1      -.001        .000        -.000      12.28
  5.0    156.0
                   112.5      .48        9.20        .60           .0      -.001        .000        -.000      12.28
  3.0     69.0
                    66.5      .47        9.20        .60           .0      -.001        .000        -.000      12.27
  2.0     64.0
                    62.0      .47        9.20        .60           .0      -.001        .000        -.000      12.27
  1.8     60.0
                    60.0      .47        9.20        .60           .0      -.001        .000        -.000      12.27
  1.6     60.0
                    54.5      .47        9.20        .60           .0      -.001        .000        -.000      12.27
  1.4     49.0
                    45.0      .47        9.20        .60           .0      -.001        .000        -.000      12.27
  1.2     41.0
                    37.0      .47        9.20        .60           .0      -.001        .000        -.000      12.27
  1.0     33.0
                    31.5      .47        9.20        .60           .0      -.001        .000        -.000      12.27
   .9     30.0
                    29.0      .47        9.20        .60           .0      -.001        .000        -.000      12.27
   .8     28.0
                    22.0      .47        9.20        .60           .0      -.001        .000        -.000      12.27
   .7     16.0
                    15.5      .47        9.20        .60           .0      -.001        .000        -.000      12.27
   .6     15.0
                    14.0      .47        9.20        .60           .0      -.001        .000        -.000      12.27
   .5     13.0
                    12.0      .47        9.20        .60           .0      -.001        .000        -.000      12.27
   .4     11.0
                    10.5      .47        9.20        .60           .0      -.001        .000        -.000      12.27
   .3     10.0
                     9.5      .47        9.20        .60           .0      -.001        .000        -.000      12.27
   .2      9.0
                     6.5      .47        9.20        .60           .0      -.001        .000        -.000      12.27
   .1      4.0
                     2.0      .47        9.20        .60           .0      -.001        .000        -.000      12.27
  0.0      0.0
```

Output when control parameter IOMIT = 0

```
TIME (T) =     .50      TIME (T+DELT) =   1.00

DIST.    DEPTH     D AVG.   PRES.RISE  ASTRO.TIDE   INITIAL      Y-FLUX      ONSHORE      ALONGSHORE  TOTAL WIND   TOTAL
(NM)   (FT.MLW)  (FT.MLW)     (FT)       (FT)     LEVEL(FT), (FT*FT/SEC) SETUP (FT)   SETUP (FT)  SETUP (FT)  SURGE (FT)

 47.6     600.0
                   590.0      .56      *.20       .60           .8     -.000          .000       -.000      12.36
 46.6     580.0
                   518.0      .56      *.20       .60           .8     -.000          .000       -.000      12.36
 43.6     456.0
                   451.0      .55      *.20       .60           .7     -.000          .000       -.000      12.35
 40.6     446.0
                   428.0      .55      *.20       .60           .7     -.000          .000       -.000      12.35
 39.6     410.0
                   415.0      .55      *.20       .60           .7     -.000          .000       -.000      12.35
 38.6     420.0
                   426.0      .55      *.20       .60           .6     -.000          .000       -.000      12.35
 37.6     432.0
                   424.0      .54      *.20       .60           .6     -.000          .000       -.000      12.34
 36.6     416.0
                   409.0      .54      *.20       .60           .6     -.000          .000       -.000      12.34
 35.6     402.0
                   314.0      .54      *.20       .60           .6     -.001          .000       -.000      12.34
 31.6     226.0
                   228.0      .54      *.20       .60           .5     -.001          .000       -.000      12.34
 30.6     230.0
                   248.0      .53      *.20       .60           .5     -.001          .001       -.000      12.33
 29.6     266.0
                   295.0      .53      *.20       .60           .5     -.001          .001       -.000      12.33
 28.6     324.0
                   312.0      .53      *.20       .60           .4     -.001          .001       -.000      12.33
 27.0     300.0
                   245.0      .53      *.20       .60           .4     -.001          .001       -.000      12.33
 26.0     190.0
                   189.5      .53      *.20       .60           .4     -.001          .001       -.000      12.33
 25.5     189.0
                   192.5      .53      *.20       .60           .4     -.001          .001       -.000      12.33
 25.0     196.0
                   195.0      .53      *.20       .60           .4     -.001          .001       -.000      12.33
 24.5     194.0
                   190.0      .53      *.20       .60           .4     -.001          .001       -.000      12.33
 24.0     186.0
                   176.5      .52      *.20       .60           .4     -.001          .001       -.000      12.32
 23.5     167.0
                   166.0      .52      *.20       .60           .4     -.001          .001       -.000      12.32
 22.5     165.0
                   221.5      .52      *.20       .60           .4     -.001          .001       -.000      12.32
 21.5     278.0
                   287.0      .52      *.20       .60           .3     -.001          .001       -.000      12.32
 20.5     296.0
                   295.0      .52      *.20       .60           .3     -.001          .001       -.000      12.32
 20.0     294.0
                   345.5      .52      *.20       .60           .3     -.001          .001       -.000      12.32
 19.0     397.0
                   389.5      .52      *.20       .60           .3     -.001          .001       -.000      12.32
 16.0     382.0
                   373.5      .51      *.20       .60           .3     -.001          .001       -.000      12.31
 15.0     365.0
                   365.0      .51      *.20       .60           .3     -.001          .001       -.000      12.31
 14.0     365.0
                   341.0      .51      *.20       .60           .2     -.001          .001       -.000      12.31
 12.5     317.0
                   246.0      .51      *.20       .60           .2     -.001          .001       -.000      12.31
 10.0     175.0
                   212.0      .51      *.20       .60           .2     -.001          .001       -.000      12.30
  8.5     249.0
                   202.5      .50      *.20       .60           .2     -.001          .001       -.000      12.30
  5.0     156.0
                   112.5      .50      *.20       .60           .1     -.001          .001       -.000      12.30
  3.0      69.0
                    66.5      .50      *.20       .60           .1     -.001          .001       -.000      12.30
  2.0      64.0
                    62.0      .50      *.20       .60           .1     -.001          .001       -.000      12.30
  1.8      60.0
                    60.0      .50      *.20       .60           .1     -.001          .001       -.000      12.30
  1.6      60.0
                    54.5      .50      *.20       .60           .1     -.002          .001       -.000      12.29
  1.4      49.0
                    45.0      .49      *.20       .60           .1     -.002          .001       -.000      12.29
  1.2      41.0
                    37.0      .49      *.20       .60           .1     -.002          .001       -.000      12.29
  1.0      33.0
                    31.5      .49      *.20       .60           .1     -.002          .001       -.000      12.29
   .9      30.0
                    29.0      .49      *.20       .60           .1     -.002          .001       -.000      12.29
   .8      28.0
                    22.0      .49      *.20       .60           .1     -.002          .001       -.000      12.29
   .7      16.0
                    15.5      .49      *.20       .60           .1     -.002          .001       -.000      12.29
   .6      15.0
                    14.0      .49      *.20       .60           .1     -.002          .001       -.000      12.29
   .5      13.0
                    12.0      .49      *.20       .60           .1     -.002          .001       -.000      12.29
   .4      11.0
                    10.5      .49      *.20       .60           .1     -.002          .001       -.000      12.29
   .3      10.0
                     9.5      .49      *.20       .60           .1     -.002          .001       -.000      12.29
   .2       9.0
                     6.5      .49      *.20       .60           .1     -.002          .001       -.000      12.29
   .1       4.0
                     2.0      .49      *.20       .60           .1     -.002          .001       -.000      12.29
  0.0       0.0
```

Standard Program Output

```
                                    SUMMARY OF OPEN COAST STORM SURGE PROBLEM

                                         PROJECT ELEMENT ------------------

SAMPLE   NUCLEAR POWER STATION  HAMPTON BEACH,N.H. HUR. H PMH 2-28-74 BY HDM
                                   TYPE OF HURRICANE MODEL (ITYPE) PMH
                                                                   ---
GEOGRAPHICAL LATITUDE (PHII) =     42.83 DEGREES               HURRICANE ZONE (IZONE) 4

     CENTRAL PRESSURE (PO) = 27.42 IN. HG.                 PERIPHERAL PRESSURE (PN) = 30.42 IN. HG.

RADIUS TO MAXIMUM WIND (R) = 56.0 N.M.                              MAXIMUM WIND (WX) = 120.4 MI/HR.

    TRANSLATION SPEED (VF) = 37.0 KNOTS                             INITIAL RISE (SE) =  .60 FEET

   TRAVERSE BEARING (BEAR) =  S 12  E                   BOTTOM FRICTION FACTOR (BFF) =  .0025

                       WIND STRESS EQUATION  WK(L) = 0.00000121+ 0.00000275* (1.0 - 16.0/W(L))**2

SURGE TRAVERSE IS PARALLEL TO STORM TRACK AND 115 DEGREES FROM THE LINE OF STRONGEST WINDS


 TIME      SETUP     SETUP    TOT. WIND   AST. TIDE   INITIAL WATER     PRESSURE   TOTAL WATER        TIDE CORRECTED
(HOURS)   X-COMP.   Y-COMP.    SETUP       LEVEL         LEVEL          SETUP       LEVEL         TOTAL WATER LEVEL
           (FT.)     (FT.)     (FT.)     (FT. MLW)       (FT.)          (FT.)     (FT. MLW)            (FT. MLW)

    .50     -.00       .00      -.00       11.20           .60             .47      12.27                 .
   1.00     -.00       .00      -.00       11.20           .60             .49      12.29                 .
   1.50     -.00       .00      -.00       11.20           .60             .52      12.32                 .
   2.00     -.00       .00       .00       11.20           .60             .54      12.34                 .
   2.50     -.01       .01       .00       11.20           .60             .57      12.38                 .
   3.00     -.01       .01       .00       11.20           .60             .61      12.41                 .
   3.50     -.01       .02       .01       11.20           .60             .64      12.45                 .
   4.00     -.02       .04       .02       11.20           .60             .69      12.50                 .
   4.50     -.03       .06       .03       11.20           .60             .73      12.56                 .
   5.00     -.03       .09       .05       11.20           .60             .79      12.64                 .
   5.50     -.04       .13       .09       11.20           .60             .85      12.74                 .
   6.00     -.04       .18       .14       11.20           .60             .92      12.86                 .
   6.50     -.04       .27       .23       11.20           .60            1.01      13.03                 .
   7.00     -.01       .38       .37       11.20           .60            1.11      13.28                 .
   7.50      .07       .54       .61       11.20           .60            1.23      13.63                 .
   8.00      .26       .75      1.02       11.20           .60            1.37      14.19                 .
   8.50      .68      1.04      1.72       11.20           .60            1.54      15.06                 .
   9.00     1.46      1.35      2.81       11.20           .60            1.74      16.36                 .
   9.50     2.39      1.61      4.00       11.20           .60            1.97      17.77                 .
  10.00     3.13      1.57      4.70       11.20           .60            2.17      18.67                 .
  10.50     3.46      1.29      4.75       11.20           .60            2.28      18.84                 .
  11.00     3.51      1.14      4.65       11.20           .60            2.24      18.69                 .
  11.50     3.15       .93      4.07       11.20           .60            2.07      17.94                 .
  12.00     2.49       .70      3.18       11.20           .60            1.85      16.83                 .
  12.50     1.81       .48      2.29       11.20           .60            1.63      15.73                 .
  13.00     1.32       .30      1.61       11.20           .60            1.45      14.86                 .
  13.50      .97       .15      1.12       11.20           .60            1.29      14.21                 .
  14.00      .73       .04       .77       11.20           .60            1.16      13.73                 .
  14.50      .56      -.05       .51       11.20           .60            1.05      13.36                 .
  15.00      .44      -.11       .32       11.20           .60             .96      13.08                 .
  15.50      .34      -.16       .18       11.20           .60             .88      12.86                 .
  16.00      .27      -.20       .07       11.20           .60             .82      12.68                 .
  16.50      .21      -.23      -.02       11.20           .60             .76      12.54                 .
  17.00      .16      -.24      -.08       11.20           .60             .71      12.43                 .
  17.50      .13      -.25      -.13       11.20           .60             .66      12.34                 .
  18.00      .10      -.26      -.16       11.20           .60             .62      12.27                 .
  18.50      .08      -.25      -.18       11.20           .60             .59      12.21                 .
  19.00      .06      -.25      -.19       11.20           .60             .56      12.17                 .
  19.50      .04      -.24      -.19       11.20           .60             .53      12.14                 .
  20.00      .03      -.22      -.19       11.20           .60             .50      12.11                 .
  20.50      .02      -.21      -.18       11.20           .60             .48      12.10                 .
  21.00      .02      -.18      -.17       11.20           .60             .46      12.09                 .
  21.50      .01      -.17      -.15       11.20           .60             .44      12.09                 .
  22.00      .01      -.15      -.14       11.20           .60             .42      12.09                 .
```

APPENDIX A-8. ERROR TABLES FOR ACTUAL AND HYPOTHETICAL HURRICANES

Error

Actual Hurricanes

01 The value of NM or LM has exceeded the maximum value allowable for the program.

02 The card ID in columns 76 through 80 is incorrect. Check 10 FORMAT in main program to make sure it reads: 10 FORMAT (8I5, 35X, A5).

03 ID in columns 1 through 6 is incorrect. It should be DIST starting in column 1.

04 ID in columns 1 through 6 is incorrect. It should be DEPTH starting in column 1.

05 Wind-field data card in error. The card should be of the form: three letters of hurricane name in columns 1 through 3; card set number in columns 4 and 5; and card number in columns 7 through 10. Three letters of hurricane name should agree with the value of ITYPE; card set number should agree with the value of N; and card number should agree with the value of L.

06 The values of ALPHA and BETA 0 read in where smaller than 0° or greater than 360°.

Hypothetical Hurricanes

01 The value of NM or LM has exceeded the maximum value allowable for the program.

02 The card ID in columns 76 through 80 is incorrect. Check 10 FORMAT in main program to make sure it reads: 10 FORMAT (815, 35X, A5).

03 A hurricane zone (IZONE) other than A, B, C, 1, 2, 3, or 4 was requested.

04 A latitude (PHII) outside the limits of the zone was requested.

05 ID in columns 1 through 6 is incorrect. It should be DIST starting in column 1.

06 ID in columns 1 through 6 is incorrect. It should be DEPTH starting in column 1.

07 Relative wind-field data card in error. The card should be of the form: ZONE in columns 1 through 4; hurricane zone ID in column 6; hurricane type in columns 8 through 10; RR in columns 11 through 15; card number right justified in columns 16 through 20; and VX values follow in five column fields starting in column 21 and ending in column 80. The zone ID (ID2) on the card should agree with the zone (IZONE) requested. The hurricane type (ID3) on the card should agree with hurricane type (ITYPE) requested. The value of radius to maximum wind (RR) on the card should equal ±0.000005 the radius to maximum wind (R) requested. The card number on the card (NN) should equal the number of cards read (NC).

Error	Hypothetical Hurricanes—Continued
08	Both values of X and Y in subroutine QUAD are zero or nearly equal to zero. Check the values of DIST, VF, and R for validity.
09	None.
10	The values of X and Y in subroutine QUAD must fall in the first, second, or fourth quadrant. The values of X and Y were negative. Check the values of DIST, VF, and R for validity.
11	The value of TH in subroutine QUAD must fall between 115° and –65°. The value computed was unreasonable.
12	The value of RHO/R in subroutine VEL is unreasonable. The value must be between 0.84 and 29.1. Check the value of R and RHO for validity.
13	The value of VX defined in subroutine STRTPT is not valid. Check the relative wind-field data given in the main program.
14	The zone identification defined in the main program does not match the zone identification in columns 6 through 10 of one of the header cards of the digitized (X,Y) data. Error from subroutine PROFIL.
15	Final digitized wind-field deck was read without matching zone ID. Check input data.
16	Second digitized wind-field deck was not found for zone requested. Check input data.
17	The value of R on one of the header cards of the digitized (X,Y) data is unreasonable. The value must be between 2.0 and 80.0. Error from subroutine PROFIL.
18	First deck of digitized wind-field data [R (KK)] has a larger radius than radius (RR) requested. First deck of digitized wind-field data must have a radius [R(KK)] less than or equal to radius (RR) requested.
19	The number of digitized (X,Y) points for one of the input hurricane profiles exceeds 750. The maximum number of points for each profile is 750. Error from subroutine PROFIL.
20	The last digitized X value for one of the input profiles is less than 30. The value must exceed 30. Error from subroutine PROFIL.

Error	Hypothetical Hurricanes—Continued
21	The impossible has occurred. Execution was terminated by dropping through the loop at statement 40. Check the program deck for correct statement sequence or for missing statements prior to statement 40 in subroutine PROFIL.
22	The end card following the digitized (X,Y) data for one of the input profiles does not contain periods in columns 1 through 80 as it should. Error from subroutine PROFIL.
23	The values of X are not in an increasing order; therefore, data must be supplied in increasing order. Error from subroutine INTERP.

PRECAUTIONS

1. For detailed output listing, run the program with only one parameter set at a time; otherwise run will be terminated for maximum number of lines of output.

2. When using digitized wind profile data deck, the last card of the digitized data deck should have the word FINAL punched in columns 6 through 10. See Appendix A-6., Input Coding Sheet for Hypothetical Hurricanes.

3. Other precautions and general information are given in Appendixes A-2 and A-3.

4. It is important to fully understand the precautions and to format the data properly before attempting to use this program.

APPENDIX B. WIND FIELD AND COMPUTED HYDROGRAPHIC DATA OF HISTORIC HURRICANES

The wind field data is voluminous and for this reason it has not been included in this report. However it can be provided to potential users upon request. A computer summary of input and output computer data is given in this section. The computed hydrographs of storm surges have been depicted graphically in Figures 39 through 71.

APPENDIX B-1. HURRICANE OF OCTOBER 1949, FREEPORT, TEXAS

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                                        SUMMARY OF OPEN COAST STORM SURGE PROBLEM


OCT 1949 HURRICANE VERIFICATION AT FREEPORT. TEXAS                                 AEC 6/73
       CENTRAL PRESSURE = 28.45 IN. HG.                                 PERIPHERAL PRESSURE = 29.95 IN. HG.

   RADIUS TO MAXIMUM WIND = 15.0 N.M.                                   MAXIMUM          WIND =  88.0 MI/HR.

       TRANSLATION SPEED = 11.0 KNOTS                                              INITIAL RISF = 2.00 FEET

   BOTTOM FRICTION FACTOR =  .0030                          WIND STRESS CORRECTION FACTOR = 1.10

              C1 =  203.0                          C2 =  106.0                         C3 =  5280.0



 TIME      SETUP     SETUP    TOT. WIND   AST. TIDE   INITIAL WATER    PRESSURE   TOTAL WATER
(HOURS)   X-COMP.   Y-COMP.    SETUP       LFVEL         LEVEL          SETUP       LEVEL
           (FT.)     (FT.)     (FT.)     (FT. MLW)       (FT.)          (FT.)     (FT. MLW)


  1.00      1.12       .40      1.52         .37          2.00            .32          4.21
  2.00      1.90       .71      2.61         .24          2.00            .38          5.23
  3.00      1.52       .98      2.50         .22          2.00            .44          5.15
  4.00      2.88      1.04      3.92         .35          2.00            .52          6.78
  5.00      3.00      1.11      4.11         .60          2.00            .65          7.36
  6.00      3.83       .81      4.64         .95          2.00            .89          8.48
  7.00      3.80       .41      4.21        1.42          2.00           1.07          8.69
  8.00      2.56       .08      2.64        1.80          2.00           1.02          7.47
  9.00      1.27      -.30       .97        1.90          2.00            .82          5.69
 10.00       .74      -.47       .26        1.89          2.00            .65          4.80
 11.00       .85      -.51       .34        1.74          2.00            .53          4.60
 12.00       .36      -.58      -.22        1.54          2.00            .43          3.75
```

```
                                  SUMMARY OF OPEN COAST STORM SURGE PROBLEM


OCT 1949 HURRICANE VERIFICATION AT FREEPORT, TEXAS                          AEC 6/73
         CENTRAL PRESSURE = 28.45 IN. HG.                         PERIPHERAL PRESSURE = 29.95 IN. HG.

    RADIUS TO MAXIMUM WIND = 15.0 N.M.                            MAXIMUM          WIND =  88.0 MI/HR.

         TRANSLATION SPEED = 11.0 KNOTS                                      INITIAL RISE = 2.00 FEET

    BOTTOM FRICTION FACTOR =  .0025                       WIND STRESS CORRECTION FACTOR = 1.10

              C1 =  203.0                      C2 =  106.0                      C3 =  5280.0



 TIME       SETUP       SETUP     TOT. WIND    AST. TIDE    INITIAL WATER     PRESSURE    TOTAL WATER
(HOURS)    X-COMP.     Y-COMP.      SETUP        LEVEL          LEVEL           SETUP        LEVEL
            (FT.)       (FT.)       (FT.)     (FT. MLW)         (FT.)           (FT.)      (FT. MLW)


   1.00       1.12         .40       1.52          .37          2.00             .32          4.21
   2.00       1.90         .72       2.62          .24          2.00             .38          5.24
   3.00       1.52        1.00       2.52          .22          2.00             .44          5.18
   4.00       2.88        1.11       3.99          .35          2.00             .52          6.86
   5.00       3.00        1.19       4.19          .60          2.00             .65          7.44
   6.00       3.82         .88       4.71          .95          2.00             .89          8.55
   7.00       3.79         .45       4.25         1.42          2.00            1.07          8.73
   8.00       2.56         .13       2.68         1.80          2.00            1.02          7.51
   9.00       1.27        -.27       1.00         1.90          2.00             .82          5.72
  10.00        .74        -.45        .28         1.89          2.00             .65          4.82
  11.00        .85        -.50        .34         1.74          2.00             .53          4.61
  12.00        .36        -.58       -.22         1.54          2.00             .43          3.75
```

```
                                  SUMMARY OF OPEN COAST STORM SURGE PROBLEM


OCT 1949 HURRICANE VERIFICATION AT FREEPORT, TEXAS                          AEC 6/73
         CENTRAL PRESSURE = 28.45 IN. HG.                         PERIPHERAL PRESSURE = 29.95 IN. HG.

    RADIUS TO MAXIMUM WIND = 15.0 N.M.                            MAXIMUM          WIND =  88.0 MI/HR.

         TRANSLATION SPEED = 11.0 KNOTS                                      INITIAL RISE = 2.00 FEET

    BOTTOM FRICTION FACTOR =  .0025                       WIND STRESS CORRECTION FACTOR = 1.00

              C1 =  203.0                      C2 =  106.0                      C3 =  5280.0



 TIME       SETUP       SETUP     TOT. WIND    AST. TIDE    INITIAL WATER     PRESSURE    TOTAL WATER
(HOURS)    X-COMP.     Y-COMP.      SETUP        LEVEL          LEVEL           SETUP        LEVEL
            (FT.)       (FT.)       (FT.)     (FT. MLW)         (FT.)           (FT.)      (FT. MLW)


   1.00       1.02         .36       1.38          .37          2.00             .32          4.08
   2.00       1.73         .66       2.39          .24          2.00             .38          5.01
   3.00       1.38         .93       2.31          .22          2.00             .44          4.97
   4.00       2.62        1.04       3.66          .35          2.00             .52          6.53
   5.00       2.73        1.12       3.85          .60          2.00             .65          7.10
   6.00       3.49         .84       4.33          .95          2.00             .89          8.17
   7.00       3.46         .43       3.90         1.42          2.00            1.07          8.38
   8.00       2.33         .13       2.47         1.80          2.00            1.02          7.29
   9.00       1.16        -.23        .93         1.90          2.00             .82          5.65
  10.00        .67        -.40        .27         1.89          2.00             .65          4.80
  11.00        .77        -.46        .31         1.74          2.00             .53          4.58
  12.00        .33        -.53       -.20         1.54          2.00             .43          3.77
```

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                              SUMMARY OF OPEN COAST STORM SURGE PROBLEM


OCT 1949 HURRICANE VERIFICATION AT FREEPORT, TEXAS                          AEC 6/73
          CENTRAL PRESSURE = 28.45 IN. HG.                         PERIPHERAL PRESSURE = 29.95 IN. HG.

    RADIUS TO MAXIMUM WIND = 15.0 N.M.                               MAXIMUM          WIND =  88.0 MI/HR.

         TRANSLATION SPEED = 11.0 KNOTS                                         INITIAL RISE = 2.00 FEET

    BOTTOM FRICTION FACTOR =  .0025                         WIND STRESS CORRECTION FACTOR =  .90

                  C1 =  203.0                     C2 =  106.0                        C3 =  5280.0



 TIME       SETUP      SETUP     TOT. WIND    AST. TIDE    INITIAL WATER    PRESSURE    TOTAL WATER
(HOURS)    X-COMP.    Y-COMP.     SETUP        LEVEL          LEVEL          SETUP        LEVEL
            (FT.)      (FT.)      (FT.)      (FT. MLW)        (FT.)          (FT.)      (FT. MLW)


  1.00        .92        .33       1.25          .37           2.00           .32         3.94
  2.00       1.56        .60       2.16          .24           2.00           .38         4.78
  3.00       1.25        .85       2.09          .22           2.00           .44         4.75
  4.00       2.37        .97       3.33          .35           2.00           .52         6.20
  5.00       2.47       1.04       3.51          .60           2.00           .65         6.76
  6.00       3.16        .79       3.94          .95           2.00           .89         7.78
  7.00       3.13        .41       3.54         1.42           2.00          1.07         8.03
  8.00       2.11        .14       2.25         1.80           2.00          1.02         7.07
  9.00       1.04       -.19        .86         1.90           2.00           .82         5.58
 10.00        .60       -.35        .25         1.89           2.00           .65         4.79
 11.00        .69       -.41        .29         1.74           2.00           .53         4.55
 12.00        .29       -.47       -.18         1.54           2.00           .43         3.79
```

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                              SUMMARY OF OPEN COAST STORM SURGE PROBLEM


OCT 1949 HURRICANE VERIFICATION AT FREEPORT, TEXAS                          AEC 6/73
          CENTRAL PRESSURE = 28.45 IN. HG.                         PERIPHERAL PRESSURE = 29.95 IN. HG.

    RADIUS TO MAXIMUM WIND = 15.0 N.M.                               MAXIMUM          WIND =  88.0 MI/HR.

         TRANSLATION SPEED = 11.0 KNOTS                                         INITIAL RISE = 2.00 FEET

    BOTTOM FRICTION FACTOR =  .0025                         WIND STRESS CORRECTION FACTOR =  .80

                  C1 =  203.0                     C2 =  106.0                        C3 =  5280.0



 TIME       SETUP      SETUP     TOT. WIND    AST. TIDE    INITIAL WATER    PRESSURE    TOTAL WATER
(HOURS)    X-COMP.    Y-COMP.     SETUP        LEVEL          LEVEL          SETUP        LEVEL
            (FT.)      (FT.)      (FT.)      (FT. MLW)        (FT.)          (FT.)      (FT. MLW)


  1.00        .82        .29       1.11          .37           2.00           .32         3.80
  2.00       1.39        .53       1.92          .24           2.00           .38         4.55
  3.00       1.11        .77       1.88          .22           2.00           .44         4.53
  4.00       2.11        .89       3.00          .35           2.00           .52         5.87
  5.00       2.20        .97       3.17          .60           2.00           .65         6.42
  6.00       2.82        .73       3.55          .95           2.00           .89         7.39
  7.00       2.79        .39       3.18         1.42           2.00          1.07         7.67
  8.00       1.88        .14       2.03         1.80           2.00          1.02         6.85
  9.00        .93       -.15        .78         1.90           2.00           .82         5.50
 10.00        .54       -.30        .24         1.89           2.00           .65         4.77
 11.00        .62       -.36        .26         1.74           2.00           .53         4.53
 12.00        .26       -.42       -.16         1.54           2.00           .43         3.82
```

APPENDIX B-1. HURRICANE OF OCTOBER 1949, GALVESTON, TEXAS

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                                          SUMMARY OF OPEN COAST STORM SURGE PROBLEM


OCT 1949 HURRICANE VERIFICATION AT GALVESTON, TEXAS                               AEC 6/73
           CENTRAL PRESSURE = 28.45 IN. HG.                     PERIPHERAL PRESSURE = 29.95 IN. HG.

    RADIUS TO MAXIMUM WIND = 46.0 N.M.                           MAXIMUM           WIND =  88.0 MI/HR.

         TRANSLATION SPEED = 11.0 KNOTS                                    INITIAL RISE = 2.00 FEET

    BOTTOM FRICTION FACTOR =  .0030                        WIND STRESS CORRECTION FACTOR = 1.10

                 C1 =  203.0                      C2 =  106.0                          C3 =  5280.0



 TIME      SETUP      SETUP     TOT. WIND    AST. TIDE   INITIAL WATER    PRESSURE    TOTAL WATER
(HOURS)   X-COMP.    Y-COMP.     SETUP        LEVEL         LEVEL          SETUP        LEVEL
           (FT.)      (FT.)      (FT.)      (FT. MLW)       (FT.)          (FT.)      (FT. MLW)


  1.00      -.37        .36       -.01        1.20          2.00            .25          3.43
  2.00      -.26        .65        .39         .87          2.00            .28          3.54
  3.00       .32        .91       1.23         .67          2.00            .32          4.22
  4.00       .99       1.13       2.12         .46          2.00            .62          5.20
  5.00      1.99       1.31       3.30         .30          2.00            .68          6.28
  6.00      2.06       1.48       3.54         .22          2.00            .73          6.49
  7.00      2.45       1.67       4.12         .20          2.00            .79          7.11
  8.00      3.23       1.63       4.85         .33          2.00            .87          8.06
  9.00      3.26       1.37       4.63         .52          2.00            .98          8.13
 10.00      3.66        .92       4.59         .77          2.00           1.08          8.44
 11.00      3.51        .66       4.17        1.02          2.00           1.17          8.36
 12.00      1.66        .40       2.06        1.19          2.00           1.26          6.51
 13.00      1.96        .22       2.19        1.29          2.00           1.30          6.77
 14.00      1.68        .04       1.72        1.29          2.00           1.29          6.30
 15.00      1.01       -.19        .83        1.25          2.00           1.22          5.28
```

```
                                        SUMMARY OF OPEN COAST STORM SURGE PROBLEM


OCT 1949 HURRICANE VERIFICATION AT GALVESTON, TEXAS                                 AEC 6/73
        CENTRAL PRESSURE = 28.45 IN. HG.                                 PERIPHERAL PRESSURE = 29.95 IN. HG.

    RADIUS TO MAXIMUM WIND = 46.0 N.M.                                   MAXIMUM          WIND =  88.0 MI/HR.

        TRANSLATION SPEED = 11.0 KNOTS                                             INITIAL RISE = 2.00 FEET

    BOTTOM FRICTION FACTOR =   .0035                              WIND STRESS CORRECTION FACTOR = 1.10

                  C1 =  203.0                         C2 =  106.0                        C3 =  5280.0



  TIME      SETUP      SETUP     TOT. WIND    AST. TIDE   INITIAL WATER     PRESSURE   TOTAL WATER
 (HOURS)   X-COMP.    Y-COMP.     SETUP        LEVEL         LEVEL           SETUP        LEVEL
            (FT.)      (FT.)      (FT.)      (FT. MLW)       (FT.)           (FT.)      (FT. MLW)


   1.00      -.37        .35       -.02         1.20          2.00             .25         3.43
   2.00      -.26        .65        .38          .87          2.00             .28         3.53
   3.00       .32        .89       1.21          .67          2.00             .32         4.20
   4.00       .99       1.10       2.08          .46          2.00             .62         5.17
   5.00      1.99       1.26       3.26          .30          2.00             .68         6.24
   6.00      2.06       1.42       3.48          .22          2.00             .73         6.43
   7.00      2.45       1.60       4.05          .20          2.00             .79         7.04
   8.00      3.23       1.52       4.75          .33          2.00             .87         7.95
   9.00      3.27       1.27       4.54          .52          2.00             .98         8.04
  10.00      3.67        .85       4.52          .77          2.00            1.08         8.37
  11.00      3.52        .60       4.12         1.02          2.00            1.17         8.31
  12.00      1.66        .36       2.01         1.19          2.00            1.26         6.47
  13.00      1.96        .18       2.15         1.29          2.00            1.30         6.73
  14.00      1.68        .00       1.68         1.29          2.00            1.29         6.26
  15.00      1.01       -.22        .79         1.23          2.00            1.22         5.24
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                                        SUMMARY OF OPEN COAST STORM SURGE PROBLEM


OCT 1949 HURRICANE VERIFICATION AT GALVESTON, TEXAS                                 AEC 6/73
        CENTRAL PRESSURE = 28.45 IN. HG.                                 PERIPHERAL PRESSURE = 29.95 IN. HG.

    RADIUS TO MAXIMUM WIND = 46.0 N.M.                                   MAXIMUM          WIND =  88.0 MI/HR.

        TRANSLATION SPEED = 11.0 KNOTS                                             INITIAL RISE = 2.00 FEET

    BOTTOM FRICTION FACTOR =   .0035                              WIND STRESS CORRECTION FACTOR = 1.00

                  C1 =  203.0                         C2 =  106.0                        C3 =  5280.0



  TIME      SETUP      SETUP     TOT. WIND    AST. TIDE   INITIAL WATER     PRESSURE   TOTAL WATER
 (HOURS)   X-COMP.    Y-COMP.     SETUP        LEVEL         LEVEL           SETUP        LEVEL
            (FT.)      (FT.)      (FT.)      (FT. MLW)       (FT.)           (FT.)      (FT. MLW)


   1.00      -.34        .32       -.01         1.20          2.00             .25         3.43
   2.00      -.24        .59        .35          .87          2.00             .28         3.50
   3.00       .29        .82       1.11          .67          2.00             .32         4.10
   4.00       .90       1.02       1.91          .46          2.00             .62         5.00
   5.00      1.81       1.18       2.99          .30          2.00             .68         5.97
   6.00      1.87       1.33       3.20          .22          2.00             .73         6.15
   7.00      2.23       1.50       3.73          .20          2.00             .79         6.72
   8.00      2.95       1.44       4.39          .33          2.00             .87         7.59
   9.00      2.98       1.21       4.19          .52          2.00             .98         7.69
  10.00      3.35        .81       4.16          .77          2.00            1.08         8.02
  11.00      3.21        .58       3.79         1.02          2.00            1.17         7.98
  12.00      1.51        .35       1.86         1.19          2.00            1.26         6.32
  13.00      1.79        .19       1.98         1.29          2.00            1.30         6.56
  14.00      1.53        .02       1.55         1.29          2.00            1.29         6.13
  15.00       .92       -.18        .74         1.23          2.00            1.22         5.19
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                                   SUMMARY OF OPEN COAST STORM SURGE PROBLEM


OCT 1949 HURRICANE VERIFICATION AT GALVESTON, TEXAS                          AEC 6/73
        CENTRAL PRESSURE = 28.45 IN. HG.                          PERIPHERAL PRESSURE = 29.95 IN. HG.

    RADIUS TO MAXIMUM WIND = 46.0 N.M.                           MAXIMUM          WIND =  88.0 MI/HR.

         TRANSLATION SPEED = 11.0 KNOTS                                         INITIAL RISE = 2.00 FEET

    BOTTOM FRICTION FACTOR =  .0035                        WIND STRESS CORRECTION FACTOR =  .90

                C1 =  203.0                         C2 =  106.0                     C3 =  5280.0



 TIME      SETUP      SETUP     TOT. WIND   AST. TIDE    INITIAL WATER    PRESSURE   TOTAL WATER
(HOURS)   X-COMP.    Y-COMP.     SETUP       LEVEL          LEVEL          SETUP        LEVEL
           (FT.)      (FT.)      (FT.)     (FT. MLW)        (FT.)          (FT.)      (FT. MLW)


  1.00      -.30        .29       -.01        1.20           2.00            .25         3.44
  2.00      -.21        .54        .32         .87           2.00            .28         3.47
  3.00       .26        .75       1.01         .67           2.00            .32         4.00
  4.00       .81        .93       1.74         .46           2.00            .62         4.82
  5.00      1.63       1.08       2.72         .30           2.00            .68         5.70
  6.00      1.69       1.23       2.92         .22           2.00            .73         5.87
  7.00      2.02       1.39       3.41         .20           2.00            .79         6.40
  8.00      2.66       1.36       4.02         .33           2.00            .87         7.22
  9.00      2.69       1.15       3.84         .52           2.00            .98         7.34
 10.00      3.03        .77       3.80         .77           2.00           1.08         7.65
 11.00      2.90        .55       3.45        1.02           2.00           1.17         7.64
 12.00      1.37        .34       1.71        1.19           2.00           1.26         6.16
 13.00      1.62        .19       1.81        1.29           2.00           1.30         6.39
 14.00      1.38        .04       1.42        1.29           2.00           1.29         6.00
 15.00       .83       -.14        .69        1.23           2.00           1.22         5.14
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                                   SUMMARY OF OPEN COAST STORM SURGE PROBLEM


OCT 1949 HURRICANE VERIFICATION AT GALVESTON, TEXAS                          AEC 6/73
        CENTRAL PRESSURE = 28.45 IN. HG.                          PERIPHERAL PRESSURE = 29.95 IN. HG.

    RADIUS TO MAXIMUM WIND = 46.0 N.M.                           MAXIMUM          WIND =  88.0 MI/HR.

         TRANSLATION SPEED = 11.0 KNOTS                                         INITIAL RISE = 2.00 FEET

    BOTTOM FRICTION FACTOR =  .0035                        WIND STRESS CORRECTION FACTOR =  .80

                C1 =  203.0                         C2 =  106.0                     C3 =  5280.0



 TIME      SETUP      SETUP     TOT. WIND   AST. TIDE    INITIAL WATER    PRESSURE   TOTAL WATER
(HOURS)   X-COMP.    Y-COMP.     SETUP       LEVEL          LEVEL          SETUP        LEVEL
           (FT.)      (FT.)      (FT.)     (FT. MLW)        (FT.)          (FT.)      (FT. MLW)


  1.00      -.27        .26       -.01        1.20           2.00            .25         3.44
  2.00      -.19        .48        .29         .87           2.00            .28         3.44
  3.00       .23        .68        .91         .67           2.00            .32         3.90
  4.00       .72        .85       1.56         .46           2.00            .62         4.65
  5.00      1.46        .99       2.44         .30           2.00            .68         5.43
  6.00      1.51       1.13       2.63         .22           2.00            .73         5.58
  7.00      1.80       1.28       3.08         .20           2.00            .79         6.06
  8.00      2.37       1.26       3.64         .33           2.00            .87         6.84
  9.00      2.41       1.06       3.48         .52           2.00            .98         6.99
 10.00      2.70        .73       3.43         .77           2.00           1.08         7.29
 11.00      2.59        .52       3.11        1.02           2.00           1.17         7.30
 12.00      1.22        .33       1.55        1.19           2.00           1.26         6.01
 13.00      1.44        .20       1.64        1.29           2.00           1.30         6.22
 14.00      1.23        .06       1.29        1.29           2.00           1.29         5.87
 15.00       .74       -.11        .64        1.23           2.00           1.22         5.09
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APPENDIX B-2. HURRICANE CARLA, FREEPORT, TEXAS

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                                        SUMMARY OF OPEN COAST STORM SURGE PROBLEM


HURRICANE CARLA VERIFICATION AT FREEPORT, TEXAS                    SEP 1961     AEC 6/73
          CENTRAL PRESSURE = 27.64 IN. HG.                                PERIPHERAL PRESSURE = 29.92 IN. HG.

    RADIUS TO MAXIMUM WIND = 46.0 N.M.                                  MAXIMUM          WIND =  88.0 MI/HR.

        TRANSLATION SPEED =  3.0 KNOTS                                               INITIAL RISE = 2.50 FEET

    BOTTOM FRICTION FACTOR =  .0030                         WIND STRESS CORRECTION FACTOR = 1.10

                C1 =  203.0                            C2 =  106.0                          C3 =  5280.0


  TIME      SETUP      SETUP    TOT. WIND   AST. TIDE   INITIAL WATER   PRESSURE   TOTAL WATER
(HOURS)    X-COMP.    Y-COMP.     SETUP       LEVEL         LEVEL         SETUP        LEVEL
            (FT.)      (FT.)      (FT.)     (FT. MLW)       (FT.)         (FT.)      (FT. MLW)


   1.00       -.04        .07        .04       1.36          2.50           .32        4.22
   2.00       -.02        .14        .12       1.05          2.50           .33        4.00
   3.00       -.01        .20        .20        .80          2.50           .34        3.83
   4.00        .01        .26        .27        .70          2.50           .35        3.81
   5.00       -.02        .32        .30        .77          2.50           .36        3.93
   6.00       -.05        .37        .33        .97          2.50           .37        4.16
   7.00       -.08        .42        .34       1.25          2.50           .38        4.47
   8.00       -.08        .47        .39       1.51          2.50           .39        4.79
   9.00       -.09        .53        .44       1.67          2.50           .40        5.00
  10.00       -.10        .59        .48       1.69          2.50           .41        5.08
  11.00       -.15        .65        .51       1.51          2.50           .42        4.94
  12.00       -.20        .71        .51       1.18          2.50           .43        4.62
  13.00       -.26        .78        .51        .79          2.50           .44        4.25
  14.00       -.29        .85        .56        .42          2.50           .46        3.93
  15.00       -.31        .92        .61        .17          2.50           .47        3.75
  16.00       -.33       1.00        .67        .10          2.50           .48        3.75
  17.00       -.36       1.09        .73        .21          2.50           .50        3.93
  18.00       -.38       1.18        .80        .46          2.50           .48        4.24
  19.00       -.40       1.28        .88        .80          2.50           .53        4.70
  20.00       -.40       1.37        .98       1.16          2.50           .54        5.17
  21.00       -.39       1.46       1.07       1.49          2.50           .55        5.61
  22.00       -.39       1.55       1.16       1.72          2.50           .56        5.94
  23.00       -.37       1.63       1.27       1.80          2.50           .57        6.13
  24.00       -.34       1.71       1.37       1.70          2.50           .58        6.15
  25.00       -.31       1.79       1.49       1.44          2.50           .59        6.01
  26.00       -.38       1.87       1.49       1.10          2.50           .61        5.70
  27.00       -.48       1.96       1.48        .79          2.50           .63        5.39
  28.00       -.58       2.05       1.47        .62          2.50           .65        5.24
  29.00       -.49       2.16       1.67        .63          2.50           .67        5.47
  30.00       -.38       2.28       1.90        .78          2.50           .70        5.88
  31.00       -.23       2.41       2.18       1.03          2.50           .72        6.43
  32.00       -.22       2.53       2.31       1.32          2.50           .74        6.87
  33.00       -.21       2.62       2.41       1.56          2.50           .77        7.24
  34.00       -.21       2.69       2.49       1.69          2.50           .79        7.46
  35.00        .03       2.78       2.81       1.67          2.50           .83        7.81
  36.00        .36       2.90       3.25       1.45          2.50           .87        8.08
  37.00        .72       3.03       3.76       1.10          2.50           .93        8.28
  38.00       1.16       3.12       4.29        .71          2.50           .92        8.42
  39.00       1.55       3.05       4.60        .38          2.50           .92        8.40
  40.00       1.91       2.88       4.79        .21          2.50           .91        8.41
  41.00       2.00       2.74       4.74        .24          2.50           .91        8.39
  42.00       2.08       2.58       4.65        .41          2.50           .90        8.47
  43.00       2.15       2.43       4.58        .70          2.50           .90        8.69
  44.00       2.40       2.33       4.74       1.05          2.50           .95        9.23
  45.00       2.67       2.22       4.89       1.39          2.50           .99        9.78
  46.00       2.92       2.04       4.95       1.65          2.50          1.04       10.15
  47.00       2.94       1.81       4.75       1.79          2.50          1.03       10.07
  48.00       2.94       1.62       4.56       1.76          2.50          1.03        9.85
  49.00       2.92       1.40       4.33       1.54          2.50          1.00        9.36
  50.00       3.08       1.41       4.50       1.19          2.50          1.01        9.19
  51.00       3.26       1.44       4.70        .83          2.50          1.02        9.04
  52.00       3.41       1.48       4.89        .57          2.50          1.03        8.98
  53.00       3.53       1.41       4.93        .50          2.50          1.07        9.00
  54.00       3.59       1.18       4.77        .60          2.50          1.13        9.00
  55.00       3.67        .98       4.65        .81          2.50          1.18        9.14
  56.00       3.80        .75       4.55       1.09          2.50          1.22        9.35
  57.00       3.85        .51       4.36       1.37          2.50          1.24        9.47
  58.00       3.89        .26       4.14       1.59          2.50          1.28        9.51
  59.00       3.61        .08       3.69       1.69          2.50          1.24        9.12
  60.00       3.36       -.09       3.27       1.65          2.50          1.21        8.64
  61.00       3.10       -.25       2.84       1.42          2.50          1.18        7.94
  62.00       2.84       -.41       2.43       1.08          2.50          1.13        7.14
  63.00       2.62       -.56       2.06        .73          2.50          1.08        6.37
  64.00       2.39       -.69       1.70        .48          2.50          1.05        5.72
  65.00       2.17       -.81       1.36        .40          2.50          1.00        5.26
  66.00       1.96       -.91       1.04        .49          2.50           .96        4.99
  67.00       1.76      -1.00        .76        .71          2.50           .92        4.89
  68.00       1.70      -1.08        .62       1.00          2.50           .87        5.00
  69.00       1.66      -1.16        .50       1.31          2.50           .84        5.15
  70.00       1.59      -1.23        .36       1.59          2.50           .80        5.25
  71.00       1.34      -1.29        .05       1.76          2.50           .75        5.06
  72.00       1.10      -1.28       -.18       1.79          2.50           .72        4.83
  73.00        .90      -1.21       -.32       1.64          2.50           .68        4.50
  74.00        .71      -1.15       -.44       1.31          2.50           .66        4.04
  75.00        .55      -1.10       -.55        .92          2.50           .64        3.51
  76.00        .43      -1.03       -.60        .59          2.50           .62        3.11
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                              SUMMARY OF OPEN COAST STORM SURGE PROBLEM

HURRICANE CARLA VERIFICATION AT FREEPORT, TEXAS           SEP 1961    AEC 6/73
          CENTRAL PRESSURE = 27.64 IN. HG.                          PERIPHERAL PRESSURE = 29.92 IN. HG.

    RADIUS TO MAXIMUM WIND = 46.0 N.M.                            MAXIMUM          WIND =  88.0 MI/HR.

        TRANSLATION SPEED =  3.0 KNOTS                                     INITIAL RISE = 2.50 FEET

    BOTTOM FRICTION FACTOR =  .0050                       WIND STRESS CORRECTION FACTOR = 1.10

              C1 =  203.0                        C2 =  106.0                        C3 =  5280.0



 TIME       SETUP      SETUP     TOT. WIND   AST. TIDE   INITIAL WATER     PRESSURE    TOTAL WATER
(HOURS)    X-COMP.    Y-COMP.     SETUP       LEVEL          LEVEL           SETUP         LEVEL
           (FT.)      (FT.)       (FT.)     (FT. MLW)        (FT.)           (FT.)       (FT. MLW)


  1.00       -.04        .07         .04        1.36           2.50             .32          4.22
  2.00       -.02        .14         .12        1.05           2.50             .33          3.99
  3.00       -.01        .20         .19         .80           2.50             .34          3.83
  4.00        .01        .25         .26         .70           2.50             .35          3.81
  5.00       -.02        .30         .29         .77           2.50             .36          3.91
  6.00       -.05        .35         .31         .97           2.50             .37          4.14
  7.00       -.08        .40         .32        1.25           2.50             .38          4.45
  8.00       -.08        .44         .35        1.51           2.50             .39          4.75
  9.00       -.09        .48         .39        1.67           2.50             .40          4.96
 10.00       -.10        .53         .43        1.69           2.50             .41          5.03
 11.00       -.15        .58         .44        1.51           2.50             .42          4.87
 12.00       -.20        .63         .43        1.18           2.50             .43          4.54
 13.00       -.26        .68         .42         .79           2.50             .44          4.15
 14.00       -.29        .74         .45         .42           2.50             .46          3.82
 15.00       -.31        .79         .48         .17           2.50             .47          3.62
 16.00       -.33        .86         .52         .10           2.50             .48          3.61
 17.00       -.36        .92         .57         .21           2.50             .50          3.77
 18.00       -.38       1.00         .62         .46           2.50             .48          4.06
 19.00       -.40       1.07         .67         .80           2.50             .53          4.50
 20.00       -.40       1.15         .75        1.16           2.50             .54          4.95
 21.00       -.39       1.21         .82        1.49           2.50             .55          5.36
 22.00       -.39       1.28         .89        1.72           2.50             .56          5.67
 23.00       -.37       1.34         .97        1.80           2.50             .57          5.84
 24.00       -.34       1.40        1.06        1.70           2.50             .58          5.83
 25.00       -.31       1.46        1.15        1.44           2.50             .59          5.68
 26.00       -.38       1.52        1.14        1.10           2.50             .61          5.35
 27.00       -.48       1.58        1.10         .79           2.50             .63          5.02
 28.00       -.59       1.65        1.07         .62           2.50             .65          4.84
 29.00       -.49       1.74        1.25         .63           2.50             .67          5.06
 30.00       -.38       1.84        1.46         .78           2.50             .70          5.43
 31.00       -.23       1.94        1.71        1.03           2.50             .72          5.96
 32.00       -.22       2.03        1.81        1.32           2.50             .74          6.37
 33.00       -.21       2.09        1.88        1.56           2.50             .77          6.71
 34.00       -.21       2.14        1.93        1.69           2.50             .79          6.91
 35.00        .03       2.20        2.23        1.67           2.50             .83          7.23
 36.00        .35       2.30        2.65        1.45           2.50             .87          7.48
 37.00        .72       2.41        3.13        1.10           2.50             .93          7.66
 38.00       1.17       2.46        3.63         .71           2.50             .92          7.75
 39.00       1.55       2.37        3.92         .38           2.50             .92          7.72
 40.00       1.92       2.23        4.15         .21           2.50             .91          7.77
 41.00       2.01       2.12        4.13         .24           2.50             .91          7.79
 42.00       2.08       2.00        4.08         .41           2.50             .90          7.90
 43.00       2.16       1.86        4.05         .70           2.50             .90          8.15
 44.00       2.42       1.81        4.22        1.05           2.50             .95          8.72
 45.00       2.68       1.72        4.41        1.39           2.50             .99          9.29
 46.00       2.93       1.58        4.51        1.65           2.50            1.04          9.70
 47.00       2.95       1.40        4.35        1.79           2.50            1.03          9.67
 48.00       2.95       1.25        4.21        1.76           2.50            1.03          9.49
 49.00       2.93       1.09        4.02        1.54           2.50            1.00          9.06
 50.00       3.09       1.09        4.19        1.19           2.50            1.01          8.88
 51.00       3.27       1.12        4.38         .83           2.50            1.02          8.73
 52.00       3.42       1.15        4.57         .57           2.50            1.03          8.67
 53.00       3.54       1.09        4.62         .50           2.50            1.07          8.69
 54.00       3.60        .91        4.51         .60           2.50            1.13          8.73
 55.00       3.68        .75        4.43         .81           2.50            1.18          8.92
 56.00       3.81        .56        4.36        1.09           2.50            1.22          9.17
 57.00       3.86        .35        4.21        1.37           2.50            1.24          9.32
 58.00       3.89        .14        4.03        1.59           2.50            1.28          9.40
 59.00       3.62       -.03        3.59        1.69           2.50            1.24          9.01
 60.00       3.37       -.19        3.17        1.65           2.50            1.21          8.54
 61.00       3.10       -.35        2.75        1.42           2.50            1.18          7.85
 62.00       2.85       -.49        2.36        1.08           2.50            1.13          7.07
 63.00       2.63       -.62        2.01         .73           2.50            1.08          6.32
 64.00       2.39       -.71        1.68         .48           2.50            1.05          5.70
 65.00       2.17       -.79        1.38         .40           2.50            1.00          5.28
 66.00       1.95       -.86        1.10         .49           2.50             .96          5.04
 67.00       1.75       -.91         .85         .71           2.50             .92          4.98
 68.00       1.70       -.95         .75        1.00           2.50             .87          5.12
 69.00       1.66      -1.00         .66        1.31           2.50             .84          5.30
 70.00       1.59      -1.05         .54        1.59           2.50             .80          5.43
 71.00       1.33      -1.08         .26        1.76           2.50             .75          5.27
 72.00       1.10      -1.03         .07        1.79           2.50             .72          5.08
 73.00        .89       -.97        -.07        1.64           2.50             .68          4.75
 74.00        .71       -.92        -.20        1.31           2.50             .66          4.27
 75.00        .55       -.88        -.32         .92           2.50             .64          3.74
 76.00        .43       -.82        -.40         .59           2.50             .62          3.32
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                                SUMMARY OF OPEN COAST STORM SURGE PROBLEM


HURRICANE CARLA VERIFICATION AT FREEPORT, TEXAS              SEP 1961     AEC 6/73
           CENTRAL PRESSURE = 27.64 IN. HG.                          PERIPHERAL PRESSURE = 29.92 IN. HG.

    RADIUS TO MAXIMUM WIND = 46.0 N.M.                             MAXIMUM         WIND =  88.0 MI/HR.

         TRANSLATION SPEED =  3.0 KNOTS                                      INITIAL RISE = 2.50 FEET

    BOTTOM FRICTION FACTOR =  .0050                     WIND STRESS CORRECTION FACTOR = 1.00

               C1 =  203.0                        C2 =  106.0                        C3 =  5280.0



  TIME      SETUP      SETUP    TOT. WIND   AST. TIDE   INITIAL WATER   PRESSURE   TOTAL WATER
(HOURS)    X-COMP     Y-COMP     SETUP       LEVEL         LEVEL         SETUP       LEVEL
            (FT.)      (FT.)     (FT.)     (FT. MLW)       (FT.)         (FT.)     (FT. MLW)


    1.00       -.03        .06        .03        1.36          2.50        .32        4.21
    2.00       -.02        .13        .11        1.05          2.50        .33        3.98
    3.00       -.01        .18        .18         .80          2.50        .34        3.81
    4.00        .00        .23        .24         .70          2.50        .35        3.78
    5.00       -.02        .28        .26         .77          2.50        .36        3.89
    6.00       -.04        .32        .28         .97          2.50        .37        4.12
    7.00       -.07        .37        .29        1.25          2.50        .38        4.42
    8.00       -.08        .40        .33        1.51          2.50        .39        4.73
    9.00       -.09        .45        .36        1.67          2.50        .40        4.93
   10.00       -.10        .49        .40        1.69          2.50        .41        5.00
   11.00       -.13        .54        .41        1.51          2.50        .42        4.84
   12.00       -.18        .59        .41        1.18          2.50        .43        4.52
   13.00       -.24        .64        .40         .79          2.50        .44        4.13
   14.00       -.26        .69        .43         .42          2.50        .46        3.80
   15.00       -.28        .74        .46         .17          2.50        .47        3.60
   16.00       -.30        .80        .50         .10          2.50        .48        3.58
   17.00       -.33        .87        .54         .21          2.50        .50        3.75
   18.00       -.35        .94        .59         .46          2.50        .48        4.03
   19.00       -.36       1.01        .65         .80          2.50        .53        4.47
   20.00       -.36       1.08        .72        1.16          2.50        .54        4.92
   21.00       -.36       1.14        .79        1.49          2.50        .55        5.32
   22.00       -.35       1.21        .85        1.72          2.50        .56        5.63
   23.00       -.33       1.26        .93        1.80          2.50        .57        5.80
   24.00       -.31       1.32       1.01        1.70          2.50        .58        5.79
   25.00       -.28       1.38       1.10        1.44          2.50        .59        5.63
   26.00       -.35       1.44       1.09        1.10          2.50        .61        5.30
   27.00       -.44       1.50       1.06         .79          2.50        .63        4.98
   28.00       -.53       1.57       1.03         .62          2.50        .65        4.81
   29.00       -.44       1.65       1.20         .63          2.50        .67        5.01
   30.00       -.34       1.74       1.39         .78          2.50        .70        5.37
   31.00       -.21       1.84       1.63        1.03          2.50        .72        5.88
   32.00       -.20       1.92       1.72        1.32          2.50        .74        6.29
   33.00       -.20       1.99       1.79        1.56          2.50        .77        6.62
   34.00       -.19       2.03       1.84        1.69          2.50        .79        6.82
   35.00        .03       2.09       2.12        1.67          2.50        .83        7.12
   36.00        .32       2.18       2.51        1.45          2.50        .87        7.33
   37.00        .66       2.29       2.95        1.10          2.50        .93        7.47
   38.00       1.06       2.34       3.40         .71          2.50        .92        7.53
   39.00       1.41       2.26       3.67         .38          2.50        .92        7.47
   40.00       1.75       2.13       3.88         .21          2.50        .91        7.50
   41.00       1.83       2.02       3.86         .24          2.50        .91        7.51
   42.00       1.90       1.90       3.80         .41          2.50        .90        7.62
   43.00       1.97       1.80       3.77         .70          2.50        .90        7.87
   44.00       2.20       1.72       3.92        1.05          2.50        .95        8.42
   45.00       2.44       1.64       4.09        1.39          2.50        .99        8.97
   46.00       2.67       1.51       4.18        1.65          2.50       1.04        9.37
   47.00       2.69       1.34       4.03        1.79          2.50       1.03        9.34
   48.00       2.69       1.19       3.89        1.76          2.50       1.03        9.17
   49.00       2.67       1.04       3.71        1.54          2.50       1.00        8.75
   50.00       2.82       1.04       3.86        1.19          2.50       1.01        8.56
   51.00       2.98       1.07       4.04         .83          2.50       1.02        8.39
   52.00       3.12       1.10       4.22         .57          2.50       1.03        8.31
   53.00       3.23       1.04       4.26         .50          2.50       1.07        8.33
   54.00       3.28        .87       4.15         .60          2.50       1.13        8.38
   55.00       3.36        .71       4.07         .81          2.50       1.18        8.56
   56.00       3.47        .54       4.01        1.09          2.50       1.22        8.81
   57.00       3.52        .34       3.87        1.37          2.50       1.24        8.98
   58.00       3.55        .14       3.69        1.59          2.50       1.28        9.06
   59.00       3.30       -.01       3.29        1.69          2.50       1.24        8.72
   60.00       3.07       -.16       2.91        1.65          2.50       1.21        8.27
   61.00       2.83       -.30       2.52        1.42          2.50       1.18        7.62
   62.00       2.59       -.44       2.16        1.08          2.50       1.13        6.87
   63.00       2.39       -.55       1.84         .73          2.50       1.08        6.15
   64.00       2.18       -.65       1.53         .48          2.50       1.05        5.55
   65.00       1.97       -.73       1.24         .40          2.50       1.00        5.15
   66.00       1.78       -.79        .99         .49          2.50        .96        4.93
   67.00       1.60       -.84        .75         .71          2.50        .92        4.88
   68.00       1.55       -.89        .66        1.00          2.50        .87        5.03
   69.00       1.51       -.94        .57        1.31          2.50        .84        5.21
   70.00       1.45       -.99        .46        1.59          2.50        .80        5.35
   71.00       1.21      -1.02        .20        1.76          2.50        .75        5.21
   72.00       1.00       -.97        .03        1.79          2.50        .72        5.03
   73.00        .81       -.92       -.10        1.64          2.50        .68        4.72
   74.00        .65       -.87       -.22        1.31          2.50        .66        4.25
   75.00        .50       -.83       -.33         .92          2.50        .64        3.73
   76.00        .39       -.78       -.39         .59          2.50        .62        3.32
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                         SUMMARY OF OPEN COAST STORM SURGE PROBLEM

HURRICANE CARLA VERIFICATION AT FREEPORT, TEXAS              SEP 1961    AEC 6/73
        CENTRAL PRESSURE = 27.64 IN. HG.                        PERIPHERAL PRESSURE = 29.92 IN. HG.

   RADIUS TO MAXIMUM WIND = 46.0 N.M.                          MAXIMUM          WIND =  88.0 MI/HR.

       TRANSLATION SPEED =  3.0 KNOTS                                     INITIAL RISE = 2.50 FEET

   BOTTOM FRICTION FACTOR =  .0050                  WIND STRESS CORRECTION FACTOR =  .90

            C1 =  203.0                     C2 =  106.0                     C3 =  5280.0



  TIME      SETUP      SETUP    TOT. WIND   AST. TIDE   INITIAL WATER    PRESSURE   TOTAL WATER
(HOURS)    X-COMP.    Y-COMP.     SETUP       LEVEL         LEVEL          SETUP       LEVEL
            (FT.)      (FT.)      (FT.)     (FT. MLW)       (FT.)          (FT.)     (FT. MLW)


   1.00       -.03        .06        .03        1.36          2.50            .32         4.21
   2.00       -.02        .11        .09        1.05          2.50            .33         3.97
   3.00       -.01        .16        .16         .80          2.50            .34         3.80
   4.00        .00        .21        .21         .70          2.50            .35         3.76
   5.00       -.02        .25        .24         .77          2.50            .36         3.87
   6.00       -.04        .30        .26         .97          2.50            .37         4.10
   7.00       -.06        .33        .27        1.25          2.50            .38         4.40
   8.00       -.07        .37        .30        1.51          2.50            .39         4.70
   9.00       -.08        .41        .33        1.67          2.50            .40         4.90
  10.00       -.09        .46        .37        1.69          2.50            .41         4.97
  11.00       -.12        .50        .38        1.51          2.50            .42         4.81
  12.00       -.17        .55        .38        1.18          2.50            .43         4.49
  13.00       -.22        .59        .37         .79          2.50            .44         4.11
  14.00       -.24        .64        .40         .42          2.50            .46         3.78
  15.00       -.26        .69        .44         .17          2.50            .47         3.57
  16.00       -.27        .75        .47         .10          2.50            .48         3.56
  17.00       -.29        .81        .51         .21          2.50            .50         3.72
  18.00       -.31        .88        .56         .46          2.50            .48         4.01
  19.00       -.33        .94        .61         .80          2.50            .53         4.44
  20.00       -.32       1.01        .69        1.16          2.50            .54         4.88
  21.00       -.32       1.07        .75        1.49          2.50            .55         5.29
  22.00       -.32       1.13        .81        1.72          2.50            .56         5.59
  23.00       -.30       1.19        .89        1.80          2.50            .57         5.75
  24.00       -.28       1.24        .96        1.70          2.50            .58         5.74
  25.00       -.25       1.30       1.05        1.44          2.50            .59         5.57
  26.00       -.31       1.35       1.04        1.10          2.50            .61         5.25
  27.00       -.39       1.41       1.02         .79          2.50            .63         4.93
  28.00       -.48       1.47       1.00         .62          2.50            .65         4.77
  29.00       -.40       1.55       1.15         .63          2.50            .67         4.95
  30.00       -.31       1.64       1.33         .78          2.50            .70         5.30
  31.00       -.19       1.73       1.54        1.03          2.50            .72         5.79
  32.00       -.18       1.81       1.63        1.32          2.50            .74         6.19
  33.00       -.18       1.87       1.70        1.56          2.50            .77         6.52
  34.00       -.17       1.92       1.75        1.69          2.50            .78         6.72
  35.00        .02       1.98       2.00        1.67          2.50            .83         7.00
  36.00        .29       2.06       2.35        1.45          2.50            .87         7.17
  37.00        .59       2.16       2.75        1.10          2.50            .93         7.28
  38.00        .96       2.22       3.17         .71          2.50            .92         7.30
  39.00       1.27       2.14       3.42         .38          2.50            .92         7.21
  40.00       1.57       2.02       3.59         .21          2.50            .91         7.21
  41.00       1.65       1.92       3.57         .24          2.50            .91         7.22
  42.00       1.71       1.81       3.52         .41          2.50            .90         7.33
  43.00       1.78       1.70       3.48         .70          2.50            .90         7.59
  44.00       1.98       1.63       3.62        1.05          2.50            .95         8.12
  45.00       2.21       1.56       3.76        1.39          2.50            .99         8.65
  46.00       2.41       1.43       3.84        1.65          2.50           1.04         9.03
  47.00       2.43       1.27       3.70        1.79          2.50           1.03         9.01
  48.00       2.43       1.13       3.56        1.76          2.50           1.03         8.85
  49.00       2.41        .98       3.39        1.54          2.50           1.00         8.43
  50.00       2.54        .99       3.53        1.19          2.50           1.01         8.23
  51.00       2.69       1.01       3.70         .83          2.50           1.02         8.04
  52.00       2.81       1.04       3.85         .57          2.50           1.03         7.95
  53.00       2.91        .98       3.90         .50          2.50           1.07         7.97
  54.00       2.96        .82       3.79         .60          2.50           1.13         8.02
  55.00       3.03        .68       3.71         .81          2.50           1.18         8.20
  56.00       3.14        .51       3.65        1.09          2.50           1.22         8.46
  57.00       3.18        .33       3.52        1.37          2.50           1.24         8.63
  58.00       3.21        .15       3.36        1.59          2.50           1.28         8.72
  59.00       2.98        .00       2.99        1.69          2.50           1.24         8.42
  60.00       2.77       -.13       2.64        1.65          2.50           1.21         8.01
  61.00       2.55       -.26       2.29        1.42          2.50           1.18         7.39
  62.00       2.34       -.38       1.96        1.08          2.50           1.13         6.67
  63.00       2.16       -.50       1.66         .73          2.50           1.08         5.98
  64.00       1.96       -.59       1.38         .48          2.50           1.05         5.40
  65.00       1.78       -.66       1.12         .40          2.50           1.00         5.02
  66.00       1.60       -.73        .88         .49          2.50            .96         4.82
  67.00       1.44       -.78        .66         .71          2.50            .92         4.79
  68.00       1.39       -.82        .57        1.00          2.50            .87         4.94
  69.00       1.36       -.87        .48        1.31          2.50            .84         5.13
  70.00       1.30       -.92        .38        1.59          2.50            .80         5.27
  71.00       1.09       -.95        .14        1.76          2.50            .75         5.16
  72.00        .90       -.92       -.02        1.79          2.50            .72         4.99
  73.00        .73       -.86       -.13        1.64          2.50            .68         4.69
  74.00        .58       -.82       -.24        1.31          2.50            .66         4.24
  75.00        .45       -.79       -.33         .92          2.50            .64         3.73
  76.00        .35       -.74       -.39         .59          2.50            .62         3.33
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                              SUMMARY OF OPEN COAST STORM SURGE PROBLEM


HURRICANE CARLA VERIFICATION AT FREEPORT, TEXAS            SEP 1961     AEC 6/73
          CENTRAL PRESSURE = 27.64 IN. HG.                      PERIPHERAL PRESSURE = 29.92 IN. HG.

   RADIUS TO MAXIMUM WIND = 46.0 N.M.                      MAXIMUM           WIND =  88.0 MI/HR.

       TRANSLATION SPEED =  3.0 KNOTS                                   INITIAL RISE = 2.50 FEET

   BOTTOM FRICTION FACTOR =  .0050                      WIND STRESS CORRECTION FACTOR =  .80

              C1 =  203.0                       C2 =  106.0                       C3 =  5280.0


 TIME      SETUP     SETUP    TOT. WIND   AST. TIDE   INITIAL WATER    PRESSURE   TOTAL WATER
(HOURS)   X-COMP.   Y-COMP.    SETUP       LEVEL          LEVEL         SETUP        LEVEL
           (FT.)     (FT.)     (FT.)     (FT. MLW)        (FT.)         (FT.)      (FT. MLW)


  1.00       -.03       .05       .03       1.36          2.50           .32          4.21
  2.00       -.02       .10       .08       1.05          2.50           .33          3.96
  3.00       -.00       .15       .14        .80          2.50           .34          3.78
  4.00        .00       .19       .19        .70          2.50           .35          3.74
  5.00       -.01       .23       .21        .77          2.50           .36          3.84
  6.00       -.03       .27       .23        .97          2.50           .37          4.07
  7.00       -.06       .30       .24       1.25          2.50           .38          4.37
  8.00       -.06       .34       .28       1.51          2.50           .39          4.67
  9.00       -.07       .37       .31       1.67          2.50           .40          4.87
 10.00       -.08       .41       .34       1.69          2.50           .41          4.94
 11.00       -.11       .46       .35       1.51          2.50           .42          4.78
 12.00       -.15       .50       .35       1.18          2.50           .43          4.46
 13.00       -.19       .54       .35        .79          2.50           .44          4.08
 14.00       -.21       .59       .38        .42          2.50           .46          3.75
 15.00       -.23       .63       .41        .17          2.50           .47          3.55
 16.00       -.24       .69       .45        .10          2.50           .48          3.53
 17.00       -.26       .75       .48        .21          2.50           .50          3.69
 18.00       -.28       .81       .53        .46          2.50           .48          3.97
 19.00       -.29       .87       .58        .80          2.50           .53          4.41
 20.00       -.29       .94       .65       1.16          2.50           .54          4.85
 21.00       -.29       .99       .71       1.49          2.50           .55          5.25
 22.00       -.28      1.05       .77       1.72          2.50           .56          5.55
 23.00       -.27      1.10       .84       1.80          2.50           .57          5.71
 24.00       -.25      1.16       .91       1.70          2.50           .58          5.68
 25.00       -.22      1.21       .99       1.44          2.50           .59          5.51
 26.00       -.28      1.26       .98       1.10          2.50           .61          5.19
 27.00       -.35      1.32       .97        .79          2.50           .63          4.88
 28.00       -.43      1.38       .95        .62          2.50           .65          4.72
 29.00       -.35      1.45      1.09        .63          2.50           .67          4.90
 30.00       -.28      1.53      1.25        .78          2.50           .70          5.23
 31.00       -.17      1.62      1.45       1.03          2.50           .72          5.70
 32.00       -.16      1.70      1.53       1.32          2.50           .74          6.10
 33.00       -.16      1.75      1.60       1.56          2.50           .77          6.42
 34.00       -.15      1.80      1.65       1.69          2.50           .79          6.62
 35.00        .02      1.85      1.87       1.67          2.50           .83          6.87
 36.00        .26      1.93      2.19       1.45          2.50           .87          7.01
 37.00        .53      2.03      2.55       1.10          2.50           .93          7.08
 38.00        .85      2.08      2.93        .71          2.50           .93          7.06
 39.00       1.13      2.02      3.15        .38          2.50           .92          6.95
 40.00       1.40      1.90      3.30        .21          2.50           .91          6.93
 41.00       1.47      1.81      3.28        .24          2.50           .91          6.93
 42.00       1.53      1.70      3.23        .41          2.50           .90          7.04
 43.00       1.58      1.61      3.19        .70          2.50           .90          7.29
 44.00       1.77      1.54      3.31       1.05          2.50           .95          7.81
 45.00       1.97      1.47      3.43       1.39          2.50           .99          8.32
 46.00       2.15      1.35      3.49       1.65          2.50          1.04          8.69
 47.00       2.16      1.20      3.36       1.79          2.50          1.03          8.68
 48.00       2.17      1.07      3.23       1.76          2.50          1.03          8.52
 49.00       2.15       .93      3.08       1.54          2.50          1.00          8.12
 50.00       2.27       .93      3.20       1.19          2.50          1.01          7.90
 51.00       2.40       .95      3.35        .83          2.50          1.02          7.69
 52.00       2.51       .98      3.49        .57          2.50          1.03          7.58
 53.00       2.60       .93      3.52        .50          2.50          1.07          7.59
 54.00       2.64       .78      3.42        .60          2.50          1.13          7.65
 55.00       2.70       .64      3.35        .81          2.50          1.18          7.84
 56.00       2.80       .49      3.29       1.09          2.50          1.22          8.09
 57.00       2.84       .32      3.16       1.37          2.50          1.24          8.27
 58.00       2.86       .15      3.01       1.59          2.50          1.28          8.38
 59.00       2.66       .02      2.68       1.69          2.50          1.24          8.11
 60.00       2.47      -.10      2.37       1.65          2.50          1.21          7.74
 61.00       2.27      -.21      2.06       1.42          2.50          1.18          7.16
 62.00       2.09      -.33      1.76       1.08          2.50          1.13          6.47
 63.00       1.92      -.43      1.49        .73          2.50          1.08          5.80
 64.00       1.75      -.52      1.23        .48          2.50          1.05          5.26
 65.00       1.58      -.59       .99        .40          2.50          1.00          4.89
 66.00       1.43      -.65       .77        .49          2.50           .96          4.72
 67.00       1.28      -.71       .57        .71          2.50           .92          4.70
 68.00       1.24      -.75       .48       1.00          2.50           .87          4.86
 69.00       1.21      -.80       .41       1.31          2.50           .84          5.05
 70.00       1.16      -.85       .31       1.59          2.50           .80          5.20
 71.00        .97      -.88       .09       1.76          2.50           .75          5.11
 72.00        .80      -.86      -.06       1.79          2.50           .72          4.95
 73.00        .65      -.81      -.16       1.64          2.50           .68          4.66
 74.00        .52      -.77      -.25       1.31          2.50           .66          4.22
 75.00        .40      -.74      -.33        .92          2.50           .64          3.73
 76.00        .31      -.69      -.38        .59          2.50           .62          3.33
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APPENDIX B-2. HURRICANE CARLA, GALVESTON, TEXAS

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                              SUMMARY OF OPEN COAST STORM SURGE PROBLEM

HURRICANE CARLA VERIFICATION AT GALVESTON,  TEXAS           SEP 1961    AEC 6/73
          CENTRAL PRESSURE = 27.64 IN. HG.                          PERIPHERAL PRESSURE = 29.92 IN. HG.

    RADIUS TO MAXIMUM WIND = 46.0 N.M.                            MAXIMUM          WIND =  88.0 MI/HR.

         TRANSLATION SPEED =  3.0 KNOTS                                      INITIAL RISE = 1.90 FEET

    BOTTOM FRICTION FACTOR =  .0030                         WIND STRESS CORRECTION FACTOR = 1.10

              C1 =  203.0                      C2 =  106.0                        C3 =  5280.0


  TIME      SETUP      SETUP     TOT. WIND    AST. TIDE   INITIAL WATER     PRESSURE   TOTAL WATER
 (HOURS)   X-COMP.    Y-COMP.     SETUP        LEVEL         LEVEL          SETUP       LEVEL
            (FT.)      (FT.)      (FT.)      (FT. MLW)       (FT.)          (FT.)     (FT. MLW)

    1.00      -.12        .13        .01        1.07          1.90            .32        3.31
    2.00      -.11        .26        .15         .89          1.90            .33        3.27
    3.00      -.10        .37        .27         .75          1.90            .34        3.26
    4.00      -.09        .48        .39         .70          1.90            .35        3.34
    5.00      -.08        .57        .49         .75          1.90            .36        3.50
    6.00      -.08        .66        .58         .89          1.90            .37        3.74
    7.00      -.07        .74        .67        1.07          1.90            .38        4.02
    8.00      -.10        .81        .71        1.22          1.90            .39        4.21
    9.00      -.15        .89        .74        1.30          1.90            .39        4.33
   10.00      -.20        .98        .78        1.26          1.90            .40        4.33
   11.00      -.25       1.06        .81        1.10          1.90            .41        4.22
   12.00      -.33       1.15        .82         .84          1.90            .42        3.98
   13.00      -.39       1.24        .84         .56          1.90            .44        3.74
   14.00      -.42       1.33        .90         .30          1.90            .45        3.55
   15.00      -.44       1.43        .99         .14          1.90            .46        3.49
   16.00      -.47       1.54       1.07         .10          1.90            .47        3.54
   17.00      -.50       1.66       1.16         .20          1.90            .48        3.75
   18.00      -.49       1.79       1.30         .41          1.90            .50        4.10
   19.00      -.51       1.93       1.42         .69          1.90            .51        4.51
   20.00      -.52       2.06       1.54         .98          1.90            .51        4.93
   21.00      -.52       2.18       1.66        1.23          1.90            .52        5.32
   22.00      -.53       2.30       1.77        1.37          1.90            .53        5.57
   23.00      -.52       2.40       1.88        1.39          1.90            .54        5.71
   24.00      -.52       2.50       1.99        1.29          1.90            .55        5.72
   25.00      -.51       2.60       2.09        1.11          1.90            .56        5.66
   26.00      -.45       2.70       2.26         .89          1.90            .57        5.62
   27.00      -.37       2.81       2.44         .70          1.90            .59        5.63
   28.00      -.28       2.93       2.65         .61          1.90            .61        5.77
   29.00      -.03       3.05       3.02         .62          1.90            .63        6.17
   30.00       .26       3.17       3.43         .74          1.90            .64        6.71
   31.00       .58       3.28       3.86         .91          1.90            .66        7.32
   32.00       .60       3.36       3.96        1.10          1.90            .67        7.63
   33.00       .62       3.43       4.04        1.24          1.90            .69        7.88
   34.00       .64       3.47       4.12        1.30          1.90            .71        8.02
   35.00      1.04       3.54       4.58        1.24          1.90            .74        8.46
   36.00      1.50       3.64       5.14        1.06          1.90            .77        8.87
   37.00      2.03       3.75       5.78         .80          1.90            .81        9.29
   38.00      2.29       3.65       5.94         .53          1.90            .80        9.17
   39.00      2.39       3.38       5.77         .31          1.90            .79        8.78
   40.00      2.49       3.08       5.57         .21          1.90            .78        8.46
   41.00      2.61       2.94       5.55         .24          1.90            .75        8.44
   42.00      2.73       2.79       5.52         .39          1.90            .73        8.54
   43.00      2.82       2.63       5.45         .62          1.90            .70        8.68
   44.00      2.97       2.57       5.53         .90          1.90            .74        9.07
   45.00      3.07       2.51       5.58        1.16          1.90            .79        9.43
   46.00      3.19       2.46       5.65        1.33          1.90            .84        9.73
   47.00      3.06       2.25       5.30        1.40          1.90            .83        9.43
   48.00      2.56       2.05       4.61        1.34          1.90            .81        8.67
   49.00      2.76       1.74       4.50        1.16          1.90            .80        8.36
   50.00      2.96       1.76       4.71         .92          1.90            .81        8.34
   51.00      3.14       1.81       4.95         .69          1.90            .81        8.35
   52.00      3.32       1.90       5.22         .54          1.90            .81        8.47
   53.00      3.33       1.86       5.19         .50          1.90            .85        8.43
   54.00      3.29       1.56       4.85         .58          1.90            .88        8.21
   55.00      3.18       1.19       4.37         .74          1.90            .92        7.94
   56.00      3.35       1.03       4.37         .93          1.90            .94        8.14
   57.00      3.51        .90       4.40        1.12          1.90            .96        8.38
   58.00      3.71        .77       4.49        1.26          1.90            .97        8.62
   59.00      3.50        .63       4.13        1.30          1.90            .95        8.28
   60.00      3.26        .48       3.73        1.23          1.90            .94        7.80
   61.00      3.05        .37       3.42        1.05          1.90            .91        7.28
   62.00      3.02        .27       3.29         .82          1.90            .89        6.90
   63.00      2.94        .19       3.12         .59          1.90            .88        6.50
   64.00      2.90        .09       2.99         .44          1.90            .86        6.19
   65.00      2.80       -.04       2.76         .40          1.90            .85        5.91
   66.00      2.63       -.14       2.48         .48          1.90            .84        5.70
   67.00      2.53       -.23       2.30         .65          1.90            .83        5.68
   68.00      2.57       -.35       2.22         .88          1.90            .79        5.79
   69.00      2.63       -.52       2.11        1.11          1.90            .76        5.87
   70.00      2.63       -.72       1.91        1.29          1.90            .73        5.83
   71.00      2.28       -.91       1.37        1.39          1.90            .70        5.36
   72.00      2.00      -1.04        .96        1.37          1.90            .67        4.89
   73.00      1.71      -1.13        .58        1.23          1.90            .64        4.35
   74.00      1.43      -1.19        .24         .99          1.90            .63        3.76
   75.00      1.18      -1.23       -.05         .73          1.90            .62        3.20
   76.00       .96      -1.25       -.29         .51          1.90            .61        2.73
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                          SUMMARY OF OPEN COAST STORM SURGE PROBLEM

HURRICANE CARLA VERIFICATION AT GALVESTON, TEXAS          SEP 1961     AEC 6/73
        CENTRAL PRESSURE = 27.64 IN. HG.                     PERIPHERAL PRESSURE = 29.92 IN. HG.

   RADIUS TO MAXIMUM WIND = 46.0 N.M.                     MAXIMUM          WIND =  88.0 MI/HR.

       TRANSLATION SPEED =  3.0 KNOTS                               INITIAL RISE = 1.90 FEET

   BOTTOM FRICTION FACTOR =  .0030              WIND STRESS CORRECTION FACTOR = 1.00

              C1 =  203.0                    C2 =  106.0                     C3 =  5280.0


  TIME      SETUP     SETUP    TOT. WIND   AST. TIDE   INITIAL WATER   PRESSURE   TOTAL WATER
(HOURS)   X-COMP.   Y-COMP.     SETUP       LEVEL         LEVEL         SETUP       LEVEL
           (FT.)     (FT.)      (FT.)    (FT. MLW)        (FT.)         (FT.)     (FT. MLW)

   1.00      -.11       .12        .01       1.07          1.90           .32        3.30
   2.00      -.10       .23        .14        .89          1.90           .33        3.26
   3.00      -.09       .34        .25        .75          1.90           .34        3.24
   4.00      -.08       .44        .36        .70          1.90           .35        3.30
   5.00      -.08       .52        .45        .75          1.90           .36        3.46
   6.00      -.07       .61        .54        .89          1.90           .37        3.70
   7.00      -.06       .68        .62       1.07          1.90           .38        3.97
   8.00      -.10       .75        .65       1.22          1.90           .39        4.16
   9.00      -.14       .83        .69       1.30          1.90           .39        4.28
  10.00      -.18       .91        .72       1.26          1.90           .40        4.28
  11.00      -.23       .99        .76       1.10          1.90           .41        4.17
  12.00      -.30      1.07        .77        .84          1.90           .42        3.93
  13.00      -.36      1.15        .80        .56          1.90           .44        3.69
  14.00      -.39      1.24        .86        .30          1.90           .45        3.50
  15.00      -.40      1.34        .94        .14          1.90           .46        3.44
  16.00      -.43      1.44       1.02        .10          1.90           .47        3.49
  17.00      -.45      1.56       1.11        .20          1.90           .48        3.69
  18.00      -.45      1.68       1.23        .41          1.90           .50        4.04
  19.00      -.46      1.81       1.35        .69          1.90           .51        4.44
  20.00      -.48      1.94       1.46        .98          1.90           .51        4.86
  21.00      -.47      2.05       1.58       1.23          1.90           .52        5.24
  22.00      -.48      2.16       1.68       1.37          1.90           .53        5.48
  23.00      -.47      2.27       1.80       1.39          1.90           .54        5.62
  24.00      -.47      2.37       1.89       1.29          1.90           .55        5.63
  25.00      -.46      2.46       2.00       1.11          1.90           .56        5.56
  26.00      -.41      2.56       2.15        .89          1.90           .57        5.51
  27.00      -.34      2.66       2.33        .70          1.90           .59        5.52
  28.00      -.26      2.78       2.52        .61          1.90           .61        5.64
  29.00      -.03      2.89       2.86        .62          1.90           .63        6.01
  30.00       .24      3.00       3.24        .74          1.90           .64        6.52
  31.00       .53      3.11       3.63        .91          1.90           .66        7.10
  32.00       .54      3.19       3.74       1.10          1.90           .67        7.41
  33.00       .56      3.25       3.82       1.24          1.90           .69        7.65
  34.00       .59      3.30       3.89       1.30          1.90           .71        7.79
  35.00       .94      3.37       4.31       1.24          1.90           .74        8.19
  36.00      1.36      3.46       4.83       1.06          1.90           .77        8.56
  37.00      1.85      3.57       5.41        .80          1.90           .81        8.92
  38.00      2.08      3.48       5.57        .53          1.90           .80        8.79
  39.00      2.18      3.22       5.40        .31          1.90           .79        8.41
  40.00      2.27      2.94       5.20        .21          1.90           .78        8.09
  41.00      2.38      2.80       5.18        .24          1.90           .75        8.08
  42.00      2.49      2.66       5.15        .39          1.90           .73        8.17
  43.00      2.57      2.51       5.08        .62          1.90           .70        8.31
  44.00      2.71      2.45       5.15        .90          1.90           .74        8.69
  45.00      2.80      2.40       5.20       1.16          1.90           .79        9.05
  46.00      2.91      2.35       5.26       1.33          1.90           .84        9.33
  47.00      2.79      2.14       4.93       1.40          1.90           .83        9.06
  48.00      2.34      1.95       4.29       1.34          1.90           .81        8.34
  49.00      2.52      1.66       4.18       1.16          1.90           .80        8.04
  50.00      2.69      1.67       4.37        .92          1.90           .81        7.99
  51.00      2.86      1.72       4.59        .69          1.90           .81        7.99
  52.00      3.03      1.80       4.83        .54          1.90           .81        8.08
  53.00      3.03      1.77       4.80        .50          1.90           .85        8.05
  54.00      3.00      1.49       4.48        .58          1.90           .88        7.85
  55.00      2.90      1.14       4.04        .74          1.90           .92        7.60
  56.00      3.05       .98       4.03        .93          1.90           .94        7.80
  57.00      3.20       .86       4.05       1.12          1.90           .96        8.03
  58.00      3.39       .74       4.13       1.26          1.90           .97        8.26
  59.00      3.19       .61       3.81       1.30          1.90           .95        7.96
  60.00      2.97       .46       3.43       1.23          1.90           .94        7.50
  61.00      2.78       .36       3.14       1.05          1.90           .91        7.01
  62.00      2.75       .27       3.02        .82          1.90           .89        6.64
  63.00      2.68       .19       2.87        .59          1.90           .88        6.24
  64.00      2.64       .10       2.74        .44          1.90           .86        5.94
  65.00      2.55      -.02       2.53        .40          1.90           .85        5.68
  66.00      2.39      -.12       2.28        .48          1.90           .84        5.49
  67.00      2.31      -.20       2.11        .65          1.90           .83        5.49
  68.00      2.34      -.31       2.03        .88          1.90           .79        5.60
  69.00      2.39      -.47       1.93       1.11          1.90           .76        5.70
  70.00      2.40      -.65       1.75       1.29          1.90           .73        5.66
  71.00      2.08      -.83       1.25       1.39          1.90           .70        5.24
  72.00      1.82      -.96        .86       1.37          1.90           .67        4.80
  73.00      1.55     -1.04        .51       1.23          1.90           .64        4.28
  74.00      1.30     -1.10        .20        .99          1.90           .63        3.72
  75.00      1.07     -1.14       -.07        .73          1.90           .62        3.18
  76.00       .87     -1.17       -.30        .51          1.90           .61        2.72
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                                        SUMMARY OF OPEN COAST STORM SURGE PROBLEM


HURRICANE CARLA VERIFICATION AT GALVESTON,  TEXAS           SEP 1961    AEC 6/73
          CENTRAL PRESSURE = 27.64 IN. HG.                     PERIPHERAL PRESSURE = 29.92 IN. HG.

    RADIUS TO MAXIMUM WIND = 46.0 N.M.                         MAXIMUM          WIND =  88.0 MI/HR.

         TRANSLATION SPEED =  3.0 KNOTS                                     INITIAL RISE = 1.90 FEET

    BOTTOM FRICTION FACTOR =  .0030                    WIND STRESS CORRECTION FACTOR =  .90

                C1 =  203.0                     C2 =  106.0                          C3 =  5280.0



  TIME       SETUP      SETUP     TOT. WIND   AST. TIDE   INITIAL WATER     PRESSURE   TOTAL WATER
 (HOURS)    X-COMP.    Y-COMP.     SETUP       LEVEL         LEVEL           SETUP       LEVEL
             (FT.)      (FT.)      (FT.)     (FT. MLW)       (FT.)           (FT.)     (FT. MLW)


   1.00       -.10        .11        .01        1.07          1.90             .32        3.30
   2.00       -.09        .21        .12         .89          1.90             .33        3.24
   3.00       -.08        .31        .23         .75          1.90             .34        3.22
   4.00       -.07        .39        .32         .70          1.90             .35        3.27
   5.00       -.07        .48        .41         .75          1.90             .36        3.42
   6.00       -.06        .55        .49         .89          1.90             .37        3.65
   7.00       -.06        .62        .56        1.07          1.90             .38        3.91
   8.00       -.09        .69        .60        1.22          1.90             .39        4.11
   9.00       -.12        .76        .64        1.30          1.90             .39        4.23
  10.00       -.17        .83        .67        1.26          1.90             .40        4.23
  11.00       -.21        .91        .70        1.10          1.90             .41        4.11
  12.00       -.27        .99        .72         .84          1.90             .42        3.88
  13.00       -.32       1.07        .74         .56          1.90             .44        3.64
  14.00       -.35       1.15        .80         .30          1.90             .45        3.45
  15.00       -.36       1.24        .88         .14          1.90             .46        3.38
  16.00       -.38       1.34        .96         .10          1.90             .47        3.43
  17.00       -.41       1.45       1.04         .20          1.90             .48        3.62
  18.00       -.41       1.57       1.16         .41          1.90             .50        3.97
  19.00       -.42       1.69       1.27         .69          1.90             .51        4.37
  20.00       -.43       1.81       1.38         .98          1.90             .51        4.78
  21.00       -.42       1.92       1.50        1.23          1.90             .52        5.15
  22.00       -.43       2.03       1.59        1.37          1.90             .53        5.39
  23.00       -.43       2.13       1.70        1.39          1.90             .54        5.53
  24.00       -.42       2.22       1.80        1.29          1.90             .55        5.53
  25.00       -.42       2.31       1.89        1.11          1.90             .56        5.46
  26.00       -.37       2.41       2.04         .89          1.90             .57        5.40
  27.00       -.30       2.51       2.20         .70          1.90             .59        5.39
  28.00       -.23       2.61       2.38         .61          1.90             .61        5.50
  29.00       -.02       2.72       2.70         .62          1.90             .63        5.85
  30.00        .22       2.83       3.05         .74          1.90             .64        6.33
  31.00        .47       2.93       3.41         .91          1.90             .66        6.87
  32.00        .49       3.01       3.50        1.10          1.90             .67        7.17
  33.00        .51       3.07       3.58        1.24          1.90             .69        7.41
  34.00        .53       3.12       3.65        1.30          1.90             .71        7.56
  35.00        .85       3.19       4.04        1.24          1.90             .74        7.92
  36.00       1.23       3.27       4.50        1.06          1.90             .77        8.23
  37.00       1.66       3.37       5.04         .80          1.90             .81        8.55
  38.00       1.88       3.30       5.18         .53          1.90             .80        8.41
  39.00       1.97       3.06       5.02         .31          1.90             .79        8.03
  40.00       2.04       2.79       4.83         .21          1.90             .78        7.72
  41.00       2.15       2.66       4.81         .24          1.90             .75        7.70
  42.00       2.25       2.52       4.77         .39          1.90             .73        7.79
  43.00       2.32       2.38       4.70         .62          1.90             .70        7.93
  44.00       2.44       2.32       4.76         .90          1.90             .74        8.31
  45.00       2.53       2.27       4.80        1.16          1.90             .79        8.65
  46.00       2.63       2.23       4.86        1.33          1.90             .84        8.93
  47.00       2.52       2.03       4.55        1.40          1.90             .83        8.68
  48.00       2.11       1.85       3.97        1.34          1.90             .81        8.02
  49.00       2.28       1.57       3.85        1.16          1.90             .80        7.71
  50.00       2.43       1.59       4.02         .92          1.90             .81        7.65
  51.00       2.59       1.63       4.22         .69          1.90             .81        7.62
  52.00       2.74       1.71       4.44         .54          1.90             .81        7.69
  53.00       2.74       1.68       4.42         .50          1.90             .85        7.66
  54.00       2.71       1.41       4.12         .58          1.90             .88        7.48
  55.00       2.62       1.08       3.70         .74          1.90             .92        7.26
  56.00       2.76        .93       3.69         .93          1.90             .94        7.45
  57.00       2.89        .81       3.70        1.12          1.90             .96        7.68
  58.00       3.06        .71       3.77        1.26          1.90             .97        7.91
  59.00       2.89        .59       3.47        1.30          1.90             .95        7.62
  60.00       2.68        .45       3.13        1.23          1.90             .94        7.20
  61.00       2.51        .35       2.86        1.05          1.90             .91        6.73
  62.00       2.48        .27       2.75         .82          1.90             .89        6.37
  63.00       2.42        .20       2.61         .59          1.90             .88        5.99
  64.00       2.39        .11       2.49         .44          1.90             .86        5.70
  65.00       2.30       -.00       2.30         .40          1.90             .85        5.45
  66.00       2.16       -.09       2.07         .48          1.90             .84        5.29
  67.00       2.08       -.17       1.92         .65          1.90             .83        5.29
  68.00       2.12       -.27       1.85         .88          1.90             .79        5.41
  69.00       2.16       -.41       1.75        1.11          1.90             .76        5.52
  70.00       2.16       -.58       1.58        1.29          1.90             .73        5.50
  71.00       1.87       -.74       1.13        1.39          1.90             .70        5.12
  72.00       1.64       -.86        .77        1.37          1.90             .67        4.71
  73.00       1.40       -.95        .45        1.23          1.90             .64        4.22
  74.00       1.17      -1.01        .16         .99          1.90             .63        3.68
  75.00        .97      -1.05       -.09         .73          1.90             .62        3.16
  76.00        .78      -1.08       -.30         .51          1.90             .61        2.72
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                              SUMMARY OF OPEN COAST STORM SURGE PROBLEM


HURRICANE CARLA VERIFICATION AT GALVESTON,  TEXAS            SEP 1961    AEC 6/73
          CENTRAL PRESSURE = 27.64 IN. HG.                          PERIPHERAL PRESSURE = 29.92 IN. HG.

    RADIUS TO MAXIMUM WIND = 46.0 N.M.                          MAXIMUM          WIND =  88.0 MI/HR.

         TRANSLATION SPEED =  3.0 KNOTS                                     INITIAL RISE = 1.90 FEET

    BOTTOM FRICTION FACTOR =  .0030                        WIND STRESS CORRECTION FACTOR =  .80

                   C1 =  203.0                      C2 =  106.0                       C3 =  5280.0



  TIME      SETUP      SETUP    TOT. WIND   AST. TIDE   INITIAL WATER    PRESSURE   TOTAL WATER
(HOURS)    X-COMP.    Y-COMP.    SETUP       LEVEL          LEVEL         SETUP        LEVEL
            (FT.)      (FT.)     (FT.)    (FT. MLW)        (FT.)         (FT.)     (FT. MLW)


   1.00       -.09        .10        .01       1.07          1.90           .32         3.30
   2.00       -.08        .19        .11        .89          1.90           .33         3.23
   3.00       -.07        .27        .20        .75          1.90           .34         3.19
   4.00       -.06        .35        .29        .70          1.90           .35         3.24
   5.00       -.06        .43        .37        .75          1.90           .36         3.37
   6.00       -.05        .50        .44        .89          1.90           .37         3.60
   7.00       -.05        .56        .51       1.07          1.90           .38         3.86
   8.00       -.08        .62        .54       1.22          1.90           .39         4.05
   9.00       -.11        .69        .58       1.30          1.90           .39         4.17
  10.00       -.15        .76        .61       1.26          1.90           .40         4.17
  11.00       -.18        .83        .65       1.10          1.90           .41         4.06
  12.00       -.24        .90        .66        .84          1.90           .42         3.82
  13.00       -.29        .98        .69        .56          1.90           .44         3.59
  14.00       -.31       1.05        .75        .30          1.90           .45         3.39
  15.00       -.32       1.14        .82        .14          1.90           .46         3.32
  16.00       -.34       1.23        .89        .10          1.90           .47         3.36
  17.00       -.36       1.34        .97        .20          1.90           .48         3.56
  18.00       -.36       1.45       1.09        .41          1.90           .50         3.89
  19.00       -.37       1.56       1.19        .69          1.90           .51         4.29
  20.00       -.38       1.67       1.29        .98          1.90           .51         4.69
  21.00       -.38       1.78       1.40       1.23          1.90           .52         5.06
  22.00       -.39       1.88       1.50       1.37          1.90           .53         5.30
  23.00       -.38       1.98       1.60       1.39          1.90           .54         5.43
  24.00       -.38       2.07       1.69       1.29          1.90           .55         5.43
  25.00       -.37       2.15       1.78       1.11          1.90           .56         5.35
  26.00       -.33       2.24       1.92        .89          1.90           .57         5.28
  27.00       -.27       2.34       2.07        .70          1.90           .59         5.26
  28.00       -.21       2.44       2.23        .61          1.90           .61         5.36
  29.00       -.02       2.54       2.52        .62          1.90           .63         5.67
  30.00        .19       2.65       2.84        .74          1.90           .64         6.12
  31.00        .42       2.74       3.17        .91          1.90           .66         6.63
  32.00        .44       2.82       3.26       1.10          1.90           .67         6.93
  33.00        .45       2.88       3.33       1.24          1.90           .69         7.17
  34.00        .47       2.93       3.40       1.30          1.90           .71         7.31
  35.00        .76       2.99       3.75       1.24          1.90           .74         7.63
  36.00       1.09       3.07       4.17       1.06          1.90           .77         7.90
  37.00       1.48       3.17       4.65        .80          1.90           .81         8.16
  38.00       1.67       3.11       4.79        .53          1.90           .80         8.01
  39.00       1.75       2.88       4.64        .31          1.90           .79         7.64
  40.00       1.82       2.63       4.45        .21          1.90           .78         7.34
  41.00       1.92       2.51       4.42        .24          1.90           .75         7.31
  42.00       2.01       2.38       4.39        .39          1.90           .73         7.41
  43.00       2.07       2.25       4.32        .62          1.90           .70         7.54
  44.00       2.18       2.19       4.37        .90          1.90           .74         7.91
  45.00       2.25       2.14       4.40       1.16          1.90           .79         8.25
  46.00       2.35       2.10       4.44       1.33          1.90           .84         8.52
  47.00       2.25       1.92       4.16       1.40          1.90           .83         8.29
  48.00       1.89       1.75       3.63       1.34          1.90           .81         7.68
  49.00       2.03       1.48       3.51       1.16          1.90           .80         7.37
  50.00       2.17       1.49       3.66        .92          1.90           .81         7.29
  51.00       2.31       1.54       3.84        .69          1.90           .81         7.25
  52.00       2.44       1.60       4.04        .54          1.90           .81         7.38
  53.00       2.45       1.58       4.02        .50          1.90           .85         7.27
  54.00       2.42       1.33       3.74        .58          1.90           .88         7.11
  55.00       2.34       1.02       3.35        .74          1.90           .92         6.92
  56.00       2.46        .88       3.34        .93          1.90           .94         7.10
  57.00       2.58        .77       3.35       1.12          1.90           .96         7.33
  58.00       2.74        .67       3.41       1.26          1.90           .97         7.54
  59.00       2.58        .56       3.14       1.30          1.90           .95         7.29
  60.00       2.40        .43       2.83       1.23          1.90           .94         6.89
  61.00       2.24        .34       2.58       1.05          1.90           .91         6.45
  62.00       2.22        .27       2.48        .82          1.90           .89         6.10
  63.00       2.16        .20       2.36        .59          1.90           .88         5.73
  64.00       2.13        .12       2.24        .44          1.90           .86         5.45
  65.00       2.05        .01       2.07        .40          1.90           .85         5.22
  66.00       1.93       -.07       1.86        .48          1.90           .84         5.08
  67.00       1.86       -.13       1.72        .65          1.90           .83         5.10
  68.00       1.88       -.23       1.66        .88          1.90           .79         5.23
  69.00       1.92       -.35       1.57       1.11          1.90           .76         5.34
  70.00       1.93       -.51       1.42       1.29          1.90           .73         5.34
  71.00       1.67       -.66       1.01       1.39          1.90           .70         5.00
  72.00       1.46       -.77        .69       1.37          1.90           .67         4.62
  73.00       1.25       -.85        .39       1.23          1.90           .64         4.16
  74.00       1.04       -.91        .13        .99          1.90           .63         3.65
  75.00        .86       -.96       -.10        .73          1.90           .62         3.15
  76.00        .70       -.99       -.29        .51          1.90           .61         2.72
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APPENDIX B-3. HURRICANE AUDREY, EUGENE ISLAND, LOUISIANA

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                                      SUMMARY OF OPEN COAST STORM SURGE PROBLEM


HURRICANE AUDREY VERIFICATION AT EUGENE ISLAND LA.         JUN 1957     AEC 7/73
          CENTRAL PRESSURE = 27.95 IN. HG.                       PERIPHERAL PRESSURE = 29.70 IN. HG.

    RADIUS TO MAXIMUM WIND = 19.0 N.M.                         MAXIMUM           WIND =  95.0 MI/HR.

         TRANSLATION SPEED = 14.0 KNOTS                                  INITIAL RISE = 1.00 FEET

    BOTTOM FRICTION FACTOR =  .0030                    WIND STRESS CORRECTION FACTOR = 1.10

                C1 =  203.0                      C2 =  106.0                      C3 =  5280.0



 TIME      SETUP     SETUP    TOT. WIND   AST. TIDE   INITIAL WATER     PRESSURE   TOTAL WATER
(HOURS)   X-COMP.    Y-COMP.    SETUP      LEVEL         LEVEL          SETUP       LEVEL
           (FT.)      (FT.)     (FT.)      (FT. MLW)      (FT.)           (FT.)      (FT. MLW)


    2.00        3.29       .95      4.24         .32          1.00             .24         5.80
    4.00        2.92      1.16      4.08        1.00          1.00             .25         6.34
    6.00        3.85      1.30      5.14        1.40          1.00             .27         7.81
    8.00        4.27      1.36      5.63        1.27          1.00             .28         8.17
   10.00        6.13      1.35      7.49         .82          1.00             .30         9.60
   12.00        4.78       .69      5.47         .80          1.00             .29         7.55
   14.00        3.51       .48      3.99         .98          1.00             .28         6.25
   16.00        3.13       .20      3.34         .90          1.00             .26         5.50
   18.00        3.62       .07      3.70         .30          1.00             .23         5.23
   20.00        4.09       .12      4.22        -.60          1.00             .21         4.83
   22.00        3.22      -.04      3.18        -.88          1.00             .20         3.49
   24.00        2.29      -.08      2.21        -.58          1.00             .18         2.81
   26.00        1.81      -.18      1.63         .07          1.00             .16         2.86
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                              SUMMARY OF OPEN COAST STORM SURGE PROBLEM


HURRICANE AUDREY VERIFICATION AT EUGENE ISLAND LA.          JUN 1957    AEC 7/73
        CENTRAL PRESSURE = 27.95 IN. HG.                          PERIPHERAL PRESSURE = 29.70 IN. HG.

    RADIUS TO MAXIMUM WIND = 19.0 N.M.                           MAXIMUM          WIND =  95.0 MI/HR.

        TRANSLATION SPEED = 14.0 KNOTS                                  INITIAL RISE = 1.00 FEET

    BOTTOM FRICTION FACTOR =  .0025                       WIND STRESS CORRECTION FACTOR = 1.10

                 C1 =  203.0                     C2 =  106.0                   C3 =  5280.0



 TIME       SFTUP     SETUP    TOT. WIND   AST. TIDE   INITIAL WATER   PRESSURE   TOTAL WATER
(HOURS)    X-COMP.   Y-COMP.    SETUP       LFVEL         LEVEL         SETUP       LEVEL
            (FT.)     (FT.)     (FT.)     (FT. MLW)       (FT.)         (FT.)     (FT. MLW)


   2.00      3.29       .99      4.28        .32          1.00           .24        5.84
   4.00      2.92      1.24      4.15       1.00          1.00           .25        6.41
   6.00      3.84      1.38      5.22       1.40          1.00           .27        7.89
   8.00      4.26      1.45      5.70       1.27          1.00           .28        8.25
  10.00      6.11      1.44      7.56        .82          1.00           .30        9.67
  12.00      4.77       .74      5.50        .80          1.00           .29        7.59
  14.00      3.50       .53      4.03        .98          1.00           .28        6.29
  16.00      3.13       .25      3.37        .90          1.00           .26        5.53
  18.00      3.62       .10      3.71        .30          1.00           .23        5.24
  20.00      4.09       .14      4.23       -.60          1.00           .21        4.84
  22.00      3.21      -.04      3.18       -.88          1.00           .20        3.49
  24.00      2.29      -.06      2.21       -.58          1.00           .18        2.81
  26.00      1.81      -.18      1.62        .07          1.00           .16        2.86
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                              SUMMARY OF OPEN COAST STORM SURGE PROBLEM


HURRICANE AUDREY VERIFICATION AT EUGENE ISLAND LA.           JUN 1957    AEC 7/73
        CENTRAL PRESSURE = 27.95 IN. HG.                           PERIPHERAL PRESSURE = 29.70 IN. HG.

    RADIUS TO MAXIMUM WIND = 19.0 N.M.                            MAXIMUM          WIND =  95.0 MI/HR.

        TRANSLATION SPEED = 14.0 KNOTS                                   INITIAL RISE = 1.00 FEET

    BOTTOM FRICTION FACTOR =  .0025                        WIND STRESS CORRECTION FACTOR = 1.00

                 C1 =  203.0                      C2 =  106.0                   C3 =  5280.0



 TIME       SFTUP     SETUP    TOT. WIND   AST. TIDE   INITIAL WATER    PRESSURE   TOTAL WATER
(HOURS)    X-COMP.   Y-COMP.    SETUP       LEVEL         LEVFL          SETUP       LEVEL
            (FT.)     (FT.)     (FT.)     (FT. MLW)       (FT.)          (FT.)     (FT. MLW)


   2.00      2.99       .93      3.91        .32          1.00            .24        5.48
   4.00      2.69      1.16      3.85       1.00          1.00            .25        6.11
   6.00      3.53      1.30      4.83       1.40          1.00            .27        7.50
   8.00      3.92      1.36      5.28       1.27          1.00            .28        7.83
  10.00      5.63      1.36      6.99        .82          1.00            .30        9.10
  12.00      4.40       .70      5.09        .80          1.00            .29        7.18
  14.00      3.22       .50      3.72        .98          1.00            .28        5.98
  16.00      2.87       .24      3.11        .90          1.00            .26        5.27
  18.00      3.31       .10      3.41        .30          1.00            .23        4.94
  20.00      3.75       .14      3.89       -.60          1.00            .21        4.50
  22.00      2.95      -.03      2.92       -.88          1.00            .20        3.24
  24.00      2.10      -.08      2.03       -.58          1.00            .18        2.63
  26.00      1.66      -.17      1.49        .07          1.00            .16        2.72
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                              SUMMARY OF OPEN COAST STORM SURGE PROBLEM

HURRICANE AUDREY VERIFICATION AT EUGENE ISLAND LA.            JUN 1957    AEC 7/73
          CENTRAL PRESSURE = 27.95 IN. HG.                            PERIPHERAL PRESSURE = 29.70 IN. HG.

    RADIUS TO MAXIMUM WIND = 19.0 N.M.                           MAXIMUM           WIND =  95.0 MI/HR.

         TRANSLATION SPEED = 14.0 KNOTS                                      INITIAL RISE = 1.00 FEET

    BOTTOM FRICTION FACTOR =  .0025                        WIND STRESS CORRECTION FACTOR =  .90

              C1 =  203.0                        C2 =  106.0                          C3 =  5280.0



 TIME       SETUP      SETUP     TOT. WIND    AST. TIDE    INITIAL WATER    PRESSURE    TOTAL WATER
(HOURS)    X-COMP.    Y-COMP.     SETUP        LEVEL          LEVEL          SETUP        LEVEL
            (FT.)      (FT.)      (FT.)      (FT. MLW)        (FT.)          (FT.)      (FT. MLW)

  2.00       2.69        .86       3.55         .32           1.00            .24          5.11
  4.00       2.46       1.08       3.54        1.00           1.00            .25          5.79
  6.00       3.21       1.21       4.42        1.40           1.00            .27          7.09
  8.00       3.58       1.27       4.85        1.27           1.00            .28          7.40
 10.00       5.14       1.27       6.40         .82           1.00            .30          8.52
 12.00       4.02        .65       4.67         .80           1.00            .29          6.76
 14.00       2.93        .48       3.41         .98           1.00            .28          5.67
 16.00       2.61        .24       2.84         .90           1.00            .26          5.00
 18.00       3.01        .10       3.11         .30           1.00            .23          4.64
 20.00       3.40        .13       3.54        -.60           1.00            .21          4.15
 22.00       2.69       -.03       2.66        -.88           1.00            .20          2.98
 24.00       1.91       -.07       1.85        -.58           1.00            .18          2.45
 26.00       1.50       -.15       1.35         .07           1.00            .16          2.58
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                              SUMMARY OF OPEN COAST STORM SURGE PROBLEM

HURRICANE AUDREY VERIFICATION AT EUGENE ISLAND LA.            JUN 1957    AEC 7/73
          CENTRAL PRESSURE = 27.95 IN. HG.                            PERIPHERAL PRESSURE = 29.70 IN. HG.

    RADIUS TO MAXIMUM WIND = 19.0 N.M.                           MAXIMUM           WIND =  95.0 MI/HR.

         TRANSLATION SPEED = 14.0 KNOTS                                      INITIAL RISE = 1.00 FEET

    BOTTOM FRICTION FACTOR =  .0025                        WIND STRESS CORRECTION FACTOR =  .80

              C1 =  203.0                        C2 =  106.0                          C3 =  5280.0



 TIME       SETUP      SETUP     TOT. WIND    AST. TIDE    INITIAL WATER    PRESSURE    TOTAL WATER
(HOURS)    X-COMP.    Y-COMP.     SETUP        LEVEL          LEVEL          SETUP        LEVEL
            (FT.)      (FT.)      (FT.)      (FT. MLW)        (FT.)          (FT.)      (FT. MLW)

  2.00       2.39        .79       3.18         .32           1.00            .24          4.74
  4.00       2.22       1.00       3.22        1.00           1.00            .25          5.47
  6.00       2.89       1.12       4.01        1.40           1.00            .27          6.68
  8.00       3.23       1.18       4.41        1.27           1.00            .28          6.96
 10.00       4.64       1.17       5.81         .82           1.00            .30          7.92
 12.00       3.63        .61       4.24         .80           1.00            .29          6.32
 14.00       2.64        .45       3.09         .98           1.00            .28          5.35
 16.00       2.34        .23       2.57         .90           1.00            .26          4.73
 18.00       2.70        .10       2.80         .30           1.00            .23          4.33
 20.00       3.05        .13       3.18        -.60           1.00            .21          3.80
 22.00       2.42       -.03       2.39        -.88           1.00            .20          2.71
 24.00       1.72       -.06       1.66        -.58           1.00            .18          2.26
 26.00       1.35       -.14       1.21         .07           1.00            .16          2.44
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APPENDIX B-4. HURRICANE CAMILLE, BILOXI, MISSISSIPPI

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                                SUMMARY OF OPEN COAST STORM SURGE PROBLEM


 CAMILLE   VF=13.0 KNOTS (APPROX.)     R=24. N. MILES (APPROX.)
                           FIRST THREE LETTERS OF HURRICANE NAME (ITYPE) CAM
                                                                         ---

    CENTRAL PRESSURE (PO) = 26.73 IN. HG.                 PERIPHERAL PRESSURE (PN) = 29.92 IN. HG.

RADIUS TO MAXIMUM WIND (R) = 24.0 N.M.                           MAXIMUM WIND (WX) = 125.0 MI/HR.

   TRANSLATION SPEED (VF )= 13.0 KNOTS                           INITIAL RISE (SE) = 1.20 FEET

BOTTOM FRICTION FACTOR (BFF) =  .0030        WIND STRESS CORRECTION FACTOR (WKCOR) = 1.10

GEOGRAPHICAL LATITUDE(PHII) =     30.00                    TRAVERSE BEARING (BEAR) =  S 12.0 E



 TIME      SETUP     SETUP    TOT. WIND   AST. TIDE   INITIAL WATER    PRESSURE   TOTAL WATER
(HOURS)   X-COMP.   Y-COMP.    SETUP       LEVEL         LEVEL          SETUP       LEVEL
           (FT.)     (FT.)     (FT.)     (FT. MLW)       (FT.)          (FT.)     (FT. MLW)

  1.00       .81       .16       .97       1.04           1.20            .24        3.46
  2.00       .65       .32       .98        .92           1.20            .25        3.35
  3.00       .51       .49      1.00        .84           1.20            .27        3.31
  4.00       .36       .67      1.03        .80           1.20            .28        3.31
  5.00       .20       .84      1.04        .83           1.20            .29        3.36
  6.00      -.00      1.00       .99        .94           1.20            .30        3.44
  7.00      -.29      1.16       .87       1.10           1.20            .31        3.49
  8.00      -.58      1.33       .74       1.28           1.20            .33        3.55
  9.00      -.96      1.48       .52       1.42           1.20            .34        3.48
 10.00     -1.37      1.63       .26       1.49           1.20            .36        3.31
 11.00     -1.93      1.77      -.16       1.49           1.20            .37        2.90
 12.00     -2.52      1.90      -.63       1.40           1.20            .39        2.36
 13.00     -3.35      2.01     -1.34       1.27           1.20            .41        1.54
 14.00     -4.00      2.14     -1.85       1.10           1.20            .43         .87
 15.00     -4.15      2.28     -1.87        .95           1.20            .45         .73
 16.00     -4.79      2.37     -2.42        .84           1.20            .47         .09
 17.00     -5.35      2.45     -2.90        .80           1.20            .50        -.40
 18.00     -5.92      2.56     -3.35        .81           1.20            .54        -.81
 19.00     -7.03      2.67     -4.36        .86           1.20            .58       -1.72
 20.00       .74      2.80      3.54        .92           1.20            .63        6.29
 21.00     -6.66      3.07     -3.59        .98           1.20            .69        -.72
 22.00     -9.63      3.59     -6.24       1.02           1.20            .78       -3.24
 23.00     -6.73      3.84     -2.88       1.03           1.20            .85         .20
 24.00     -8.58      4.48     -4.10       1.03           1.20            .96        -.92
 25.00     -5.18      4.84      -.34       1.03           1.20           1.09        2.98
 26.00     25.43      2.70     28.13       1.05           1.20           1.27       31.65
 27.00     19.87      1.29     21.16       1.11           1.20           1.52       24.98
 28.00     18.78       .53     19.30       1.21           1.20           1.90       23.61
 29.00     17.56      -.02     17.54       1.33           1.20           2.06       22.13
 30.00     14.42      -.20     14.22       1.45           1.20           2.07       18.94
 31.00     11.54      -.34     11.20       1.56           1.20           1.94       15.90
 32.00     10.00      -.48      9.52       1.65           1.20           1.63       14.01
 33.00      8.41      -.61      7.80       1.69           1.20           1.40       12.08
 34.00      7.10      -.74      6.36       1.70           1.20           1.18       10.44
 35.00      5.94      -.84      5.10       1.64           1.20            .99        8.93
 36.00      5.07      -.88      4.19       1.54           1.20            .84        7.77
 37.00      4.31      -.88      3.44       1.39           1.20            .70        6.72
 38.00      3.80      -.79      3.01       1.22           1.20            .61        6.04
 39.00      3.35      -.72      2.63       1.05           1.20            .55        5.43
 40.00      3.09      -.63      2.45        .88           1.20            .51        5.04
 41.00      3.03      -.58      2.44        .74           1.20            .47        4.85
 42.00      2.86      -.50      2.36        .65           1.20            .44        4.65
 43.00      2.94      -.43      2.51        .60           1.20            .42        4.74
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                              SUMMARY OF OPEN COAST STORM SURGE PROBLEM

CAMILLE    VF=13.0 KNOTS (APPROX.)    R=24. N. MILES (APPROX.)
       CENTRAL PRESSURE = 26.73 IN. HG.                          PERIPHERAL PRESSURE = 29.92 IN. HG.

  RADIUS TO MAXIMUM WIND = 24.0 N.M.                             MAXIMUM         WIND = 125.0 MI/HR.

       TRANSLATION SPEED = 13.0 KNOTS                                    INITIAL RISE = 1.20 FEET

  BOTTOM FRICTION FACTOR =  .0030                      WIND STRESS CORRECTION FACTOR = 1.00

               C1 =  203.0                   C2 =  106.0                   C3 =  5280.0



  TIME      SETUP      SETUP    TOT. WIND  AST. TIDE  INITIAL WATER    PRESSURE  TOTAL WATER
(HOURS)    X-COMP.    Y-COMP.     SETUP      LEVEL        LEVEL          SETUP      LEVEL
            (FT.)      (FT.)      (FT.)   (FT. MLW)      (FT.)          (FT.)    (FT. MLW)

   1.00        .74        .15        .89      1.04         1.20            .24       3.37
   2.00        .60        .29        .89       .92         1.20            .25       3.26
   3.00        .46        .45        .92       .84         1.20            .27       3.22
   4.00        .33        .62        .95       .80         1.20            .28       3.23
   5.00        .18        .78        .96       .83         1.20            .29       3.28
   6.00      -.00         .93        .93       .94         1.20            .30       3.37
   7.00      -.26        1.09        .83      1.10         1.20            .31       3.44
   8.00      -.53        1.24        .71      1.28         1.20            .33       3.52
   9.00      -.87        1.39        .52      1.42         1.20            .34       3.48
  10.00     -1.24        1.53        .29      1.49         1.20            .36       3.34
  11.00     -1.75        1.67       -.09      1.49         1.20            .37       2.98
  12.00     -2.29        1.79       -.50      1.40         1.20            .39       2.49
  13.00     -3.03        1.90      -1.13      1.27         1.20            .41       1.75
  14.00     -3.59        2.03      -1.56      1.10         1.20            .43       1.17
  15.00     -3.70        2.16      -1.54       .95         1.20            .45        .86
  16.00     -4.26        2.24      -2.01       .84         1.20            .47        .50
  17.00     -4.68        2.32      -2.36       .80         1.20            .50        .14
  18.00     -5.03        2.43      -2.59       .81         1.20            .54       -.05
  19.00     -5.50        2.54      -2.95       .86         1.20            .58       -.32
  20.00     -6.33        2.69      -3.64       .92         1.20            .63       -.88
  21.00     -8.51        2.90      -5.61       .98         1.20            .69      -2.74
  22.00     -4.96        3.16      -1.79      1.02         1.20            .78       1.21
  23.00     -7.65        3.70      -3.95      1.03         1.20            .85       -.88
  24.00    -10.14        4.22      -5.92      1.03         1.20            .96      -2.73
  25.00      1.72        4.54       6.27      1.03         1.20           1.09       9.58
  26.00     21.82        2.58      24.39      1.05         1.20           1.27      27.91
  27.00     18.55        1.23      19.78      1.11         1.20           1.52      23.61
  28.00     17.47         .52      18.00      1.21         1.20           1.90      22.30
  29.00     16.32         .02      16.34      1.33         1.20           2.06      20.93
  30.00     13.40        -.15      13.25      1.45         1.20           2.07      17.97
  31.00     10.70        -.28      10.42      1.56         1.20           1.94      15.12
  32.00      9.26        -.42       8.84      1.65         1.20           1.63      13.32
  33.00      7.78        -.55       7.23      1.69         1.20           1.40      11.51
  34.00      6.56        -.67       5.88      1.70         1.20           1.18       9.96
  35.00      5.48        -.77       4.71      1.64         1.20            .99       8.54
  36.00      4.67        -.82       3.85      1.54         1.20            .84       7.43
  37.00      3.97        -.82       3.15      1.39         1.20            .70       6.44
  38.00      3.49        -.75       2.74      1.22         1.20            .61       5.78
  39.00      3.08        -.68       2.39      1.05         1.20            .55       5.20
  40.00      2.83        -.60       2.23       .88         1.20            .51       4.82
  41.00      2.78        -.56       2.22       .74         1.20            .47       4.63
  42.00      2.62        -.48       2.14       .65         1.20            .44       4.44
  43.00      2.70        -.41       2.29       .60         1.20            .42       4.51
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                              SUMMARY OF OPEN COAST STORM SURGE PROBLEM


CAMILLE   VF=13.0 KNOTS (APPROX.)    H=24. N. MILES (APPROX.)
        CENTRAL PRESSURE = 26.73 IN. HG.                            PERIPHERAL PRESSURE = 29.92 IN. HG.

  RADIUS TO MAXIMUM WIND = 24.0 N.M.                                MAXIMUM           WIND = 125.0 MI/HR.

       TRANSLATION SPEED = 13.0 KNOTS                                         INITIAL RISE = 1.20 FEET

  BOTTOM FRICTION FACTOR =  .0030                        WIND STRESS CORRECTION FACTOR =  .90

            C1 =  203.0                        C2 =  106.0                        C3 =  5280.0



 TIME      SETUP      SETUP     TOT. WIND   AST. TIDE   INITIAL WATER    PRESSURE   TOTAL WATER
(HOURS)   X-COMP.    Y-COMP.     SETUP        LEVEL         LEVEL          SETUP        LEVEL
           (FT.)      (FT.)      (FT.)     (FT. MLW)        (FT.)          (FT.)     (FT. MLW)


  1.00        .66        .13        .80        1.04          1.20            .24         3.28
  2.00        .54        .27        .80         .92          1.20            .25         3.18
  3.00        .42        .41        .83         .84          1.20            .27         3.14
  4.00        .30        .57        .86         .80          1.20            .28         3.14
  5.00        .16        .72        .88         .83          1.20            .29         3.20
  6.00       -.00        .86        .86         .94          1.20            .30         3.30
  7.00       -.24       1.01        .77        1.10          1.20            .31         3.39
  8.00       -.48       1.16        .68        1.28          1.20            .33         3.49
  9.00       -.79       1.30        .51        1.42          1.20            .34         3.47
 10.00      -1.12       1.43        .32        1.49          1.20            .36         3.36
 11.00      -1.58       1.56       -.02        1.49          1.20            .37         3.05
 12.00      -2.05       1.68       -.37        1.40          1.20            .39         2.62
 13.00      -2.71       1.79       -.92        1.27          1.20            .41         1.96
 14.00      -3.19       1.91      -1.29        1.10          1.20            .43         1.44
 15.00      -3.28       2.03      -1.24         .95          1.20            .45         1.35
 16.00      -3.76       2.11      -1.65         .84          1.20            .47          .86
 17.00      -4.11       2.19      -1.92         .80          1.20            .50          .58
 18.00      -4.37       2.29      -2.07         .81          1.20            .54          .47
 19.00      -4.72       2.40      -2.32         .86          1.20            .58          .32
 20.00      -5.29       2.54      -2.75         .92          1.20            .63          .00
 21.00      -6.08       2.74      -3.34         .98          1.20            .69         -.47
 22.00      -7.12       3.04      -4.08        1.02          1.20            .78        -1.08
 23.00     -12.25       3.46      -8.79        1.03          1.20            .85        -5.71
 24.00      -5.38       3.93      -1.45        1.03          1.20            .96         1.74
 25.00       -.57       4.37       3.79        1.03          1.20           1.09         7.11
 26.00      20.05       2.44      22.50        1.05          1.20           1.27        26.02
 27.00      17.15       1.17      18.32        1.11          1.20           1.52        22.15
 28.00      16.13        .52      16.64        1.21          1.20           1.90        20.95
 29.00      15.05        .06      15.11        1.33          1.20           2.06        19.70
 30.00      12.35       -.10      12.25        1.45          1.20           2.07        16.97
 31.00       9.84       -.23       9.61        1.56          1.20           1.94        14.31
 32.00       8.50       -.36       8.14        1.65          1.20           1.63        12.62
 33.00       7.13       -.49       6.64        1.69          1.20           1.40        10.93
 34.00       6.00       -.60       5.39        1.70          1.20           1.18         9.48
 35.00       5.01       -.70       4.30        1.64          1.20            .99         8.14
 36.00       4.26       -.75       3.51        1.54          1.20            .84         7.09
 37.00       3.62       -.76       2.86        1.39          1.20            .70         6.15
 38.00       3.18       -.70       2.48        1.22          1.20            .61         5.52
 39.00       2.80       -.64       2.15        1.05          1.20            .55         4.96
 40.00       2.56       -.57       2.01         .88          1.20            .51         4.59
 41.00       2.53       -.53       2.00         .74          1.20            .47         4.41
 42.00       2.39       -.46       1.93         .65          1.20            .44         4.22
 43.00       2.45       -.39       2.07         .60          1.20            .42         4.29
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                         SUMMARY OF OPEN COAST STORM SURGE PROBLEM


CAMILLE   VF=13.0 KNOTS (APPROX.)    R=24. N. MILES (APPROX.)
      CENTRAL PRESSURE = 26.73 IN. HG.                          PERIPHERAL PRESSURE = 29.92 IN. HG.

  RADIUS TO MAXIMUM WIND = 24.0 N.M.                       MAXIMUM         WIND = 125.0 MI/HR.

      TRANSLATION SPEED = 13.0 KNOTS                                 INITIAL RISE = 1.20 FEET

  BOTTOM FRICTION FACTOR =  .0030                    WIND STRESS CORRECTION FACTOR =  .80

            C1 =  203.0                      C2 =  106.0                      C3 =  5280.0



  TIME      SETUP      SETUP    TOT. WIND   AST. TIDE   INITIAL WATER    PRESSURE   TOTAL WATER
 (HOURS)   X-COMP.    Y-COMP.    SETUP       LEVEL         LEVEL          SETUP       LEVEL
            (FT.)      (FT.)     (FT.)     (FT. MLW)       (FT.)          (FT.)     (FT. MLW)


   1.00        .59        .12        .71       1.04          1.20           .24        3.19
   2.00        .48        .24        .72        .92          1.20           .25        3.09
   3.00        .37        .37        .74        .84          1.20           .27        3.05
   4.00        .27        .51        .78        .80          1.20           .28        3.05
   5.00        .15        .65        .80        .83          1.20           .29        3.12
   6.00       -.00        .79        .79        .94          1.20           .30        3.23
   7.00       -.21        .93        .72       1.10          1.20           .31        3.33
   8.00       -.43       1.07        .64       1.28          1.20           .33        3.45
   9.00       -.70       1.20        .50       1.42          1.20           .34        3.46
  10.00       -.99       1.33        .34       1.49          1.20           .36        3.38
  11.00      -1.40       1.45        .05       1.49          1.20           .37        3.11
  12.00      -1.82       1.57       -.26       1.40          1.20           .39        2.73
  13.00      -2.40       1.67       -.73       1.27          1.20           .41        2.15
  14.00      -2.81       1.78      -1.03       1.10          1.20           .43        1.70
  15.00      -2.87       1.90       -.98        .95          1.20           .45        1.62
  16.00      -3.30       1.98      -1.32        .84          1.20           .47        1.19
  17.00      -3.58       2.05      -1.53        .80          1.20           .50         .97
  18.00      -3.79       2.15      -1.64        .81          1.20           .54         .90
  19.00      -4.08       2.25      -1.83        .86          1.20           .58         .81
  20.00      -4.54       2.38      -2.16        .92          1.20           .63         .59
  21.00      -5.11       2.57      -2.54        .98          1.20           .69         .33
  22.00      -5.61       2.85      -2.76       1.02          1.20           .78         .24
  23.00      -6.32       3.25      -3.07       1.03          1.20           .85         .00
  24.00      -6.10       3.73      -2.37       1.03          1.20           .96         .82
  25.00       -.71       4.11       3.40       1.03          1.20          1.09        6.71
  26.00      18.03       2.30      20.33       1.05          1.20          1.27       23.86
  27.00      15.70       1.11      16.81       1.11          1.20          1.52       20.63
  28.00      14.73        .51      15.24       1.21          1.20          1.90       19.55
  29.00      13.72        .10      13.83       1.33          1.20          2.06       18.42
  30.00      11.26       -.05      11.21       1.45          1.20          2.07       15.93
  31.00       8.96       -.18       8.78       1.56          1.20          1.94       13.48
  32.00       7.72       -.30       7.42       1.65          1.20          1.63       11.90
  33.00       6.46       -.42       6.04       1.69          1.20          1.40       10.33
  34.00       5.43       -.54       4.89       1.70          1.20          1.18        8.97
  35.00       4.53       -.63       3.89       1.64          1.20           .99        7.72
  36.00       3.84       -.68       3.16       1.54          1.20           .84        6.74
  37.00       3.26       -.69       2.57       1.39          1.20           .70        5.85
  38.00       2.86       -.64       2.22       1.22          1.20           .61        5.26
  39.00       2.52       -.60       1.92       1.05          1.20           .55        4.72
  40.00       2.32       -.54       1.78        .88          1.20           .51        4.36
  41.00       2.27       -.50       1.77        .74          1.20           .47        4.19
  42.00       2.14       -.43       1.71        .65          1.20           .44        4.01
  43.00       2.20       -.37       1.84        .60          1.20           .42        4.06
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APPENDIX B-5. HURRICANE CAROL, NARRAGANSETT PIER, RHODE ISLAND

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                                    SUMMARY OF OPEN COAST STORM SURGE PROBLEM


CAROL       VF = 33.3 KNOTS         R = 25. N. MILES
        CENTRAL PRESSURE = 28.69 IN. HG.                          PERIPHERAL PRESSURE = 29.92 IN. HG.

   RADIUS TO MAXIMUM WIND = 25.0 N.M.                         MAXIMUM          WIND =  95.0 MI/HR.

       TRANSLATION SPEED = 33.3 KNOTS                                    INITIAL RISE =  .50 FEET

   BOTTOM FRICTION FACTOR =  .0030                      WIND STRESS CORRECTION FACTOR = 1.10

              C1 =  203.0                      C2 =  106.0                       C3 =  5280.0



 TIME      SETUP      SETUP     TOT. WIND    AST. TIDE   INITIAL WATER     PRESSURE   TOTAL WATER
(HOURS)   X-COMP.    Y-COMP.     SETUP        LEVEL          LEVEL          SETUP        LEVEL
           (FT.)      (FT.)      (FT.)     (FT. MLW)        (FT.)          (FT.)     (FT. MLW)


  1.00        .04        .06        .10          .00          1.20            .11         1.41
  2.00        .00        .12        .12        -.20           1.20            .12         1.25
  3.00       -.00        .18        .18          .10          1.20            .14         1.62
  4.00       -.01        .28        .27          .40          1.20            .16         2.03
  5.00        .07        .48        .55          .90          1.20            .19         2.84
  6.00        .30        .79       1.09         1.99          1.20            .23         4.51
  7.00       1.18       1.20       2.38         3.10          1.20            .29         6.96
  8.00       2.30       1.21       3.50         3.90          1.20            .40         9.00
  9.00       2.83        .50       3.33         4.00          1.20            .61         9.14
 10.00       2.53       -.71       1.82         3.60          1.20            .87         7.48
 11.00       1.94      -2.16       -.22         2.70          1.20            .63         4.31
 12.00       1.19      -3.21      -2.02         1.50          1.20            .41         1.09
 13.00        .57      -3.46      -2.88          .70          1.20            .34         -.65
 14.00        .29      -2.91      -2.62          .30          1.20            .27         -.86
 15.00        .16      -2.22      -2.07          .40          1.20            .22         -.24
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                                   SUMMARY OF OPEN COAST STORM SURGE PROBLEM


CAROL        VF = 33.3 KNOTS        R = 25. N. MILES
       CENTRAL PRESSURE = 28.69 IN. HG.                        PERIPHERAL PRESSURE = 29.92 IN. HG.

    RADIUS TO MAXIMUM WIND = 25.0 N.M.                        MAXIMUM          WIND =  95.0 MI/HR.

          TRANSLATION SPEED = 33.3 KNOTS                               INITIAL RISE =  .50 FEET

    BOTTOM FRICTION FACTOR =  .0030                    WIND STRESS CORRECTION FACTOR = 1.00

               C1 =  203.0                      C2 =  106.0                        C3 =  5280.0



 TIME       SETUP       SETUP      TOT. WIND     AST. TIDE     INITIAL WATER      PRESSURE    TOTAL WATER
(HOURS)    X-COMP.     Y-COMP.      SETUP         LEVEL           LEVEL            SETUP         LEVEL
            (FT.)       (FT.)       (FT.)       (FT. MLW)         (FT.)            (FT.)       (FT. MLW)


  1.00         .03         .06         .09          .00           1.20              .11          1.40
  2.00         .00         .11         .11         -.20           1.20              .12          1.24
  3.00        -.00         .16         .16          .10           1.20              .14          1.60
  4.00        -.01         .26         .25          .40           1.20              .16          2.01
  5.00         .07         .43         .50          .90           1.20              .19          2.79
  6.00         .27         .72        1.00         1.99           1.20              .23          4.41
  7.00        1.07        1.09        2.17         3.10           1.20              .29          6.75
  8.00        2.09        1.11        3.20         3.90           1.20              .40          8.70
  9.00        2.58         .47        3.05         4.00           1.20              .61          8.86
 10.00        2.30        -.63        1.67         3.60           1.20              .87          7.34
 11.00        1.76       -1.96        -.19         2.70           1.20              .63          4.33
 12.00        1.08       -2.93       -1.85         1.50           1.20              .41          1.26
 13.00         .52       -3.21       -2.69          .70           1.20              .34          -.46
 14.00         .26       -2.75       -2.48          .30           1.20              .27          -.71
 15.00         .14       -2.10       -1.96          .40           1.20              .22          -.13
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                                   SUMMARY OF OPEN COAST STORM SURGE PROBLEM


CAROL        VF = 33.3 KNOTS        R = 25. N. MILES
       CENTRAL PRESSURE = 28.69 IN. HG.                        PERIPHERAL PRESSURE = 29.92 IN. HG.

    RADIUS TO MAXIMUM WIND = 25.0 N.M.                        MAXIMUM          WIND =  95.0 MI/HR.

          TRANSLATION SPEED = 33.3 KNOTS                               INITIAL RISE =  .50 FEET

    BOTTOM FRICTION FACTOR =  .0030                    WIND STRESS CORRECTION FACTOR = 1.00

               C1 =  203.0                      C2 =  106.0                        C3 =  5280.0



 TIME       SETUP       SETUP      TOT. WIND     AST. TIDE     INITIAL WATER      PRESSURE    TOTAL WATER
(HOURS)    X-COMP.     Y-COMP.      SETUP         LEVEL           LEVEL            SETUP         LEVEL
            (FT.)       (FT.)       (FT.)       (FT. MLW)         (FT.)            (FT.)       (FT. MLW)


  1.00         .04         .06         .09          .00           1.20              .11          1.40
  2.00         .00         .11         .11         -.20           1.20              .12          1.24
  3.00        -.00         .16         .16          .10           1.20              .14          1.60
  4.00        -.01         .26         .25          .40           1.20              .16          2.01
  5.00         .07         .43         .50          .90           1.20              .19          2.79
  6.00         .27         .72        1.00         1.99           1.20              .23          4.42
  7.00        1.08        1.10        2.17         3.10           1.20              .29          6.76
  8.00        2.12        1.11        3.23         3.90           1.20              .40          8.73
  9.00        2.62         .47        3.09         4.00           1.20              .61          8.90
 10.00        2.35        -.64        1.71         3.60           1.20              .87          7.38
 11.00        1.80       -1.96        -.16         2.70           1.20              .64          4.38
 12.00        1.10       -2.94       -1.84         1.50           1.20              .42          1.28
 13.00         .53       -3.22       -2.69          .70           1.20              .34          -.45
 14.00         .27       -2.75       -2.48          .30           1.20              .27          -.71
 15.00         .15       -2.10       -1.96          .40           1.20              .22          -.13
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                          SUMMARY OF OPEN COAST STORM SURGE PROBLEM


CAROL        VF = 33.3 KNOTS        R = 25. N. MILES
        CENTRAL PRESSURE = 28.69 IN. HG.                      PERIPHERAL PRESSURE = 29.92 IN. HG.

    RADIUS TO MAXIMUM WIND = 25.0 N.M.                    MAXIMUM          WIND =  95.0 MI/HR.

         TRANSLATION SPEED = 33.3 KNOTS                                  INITIAL RISE =  .50 FEET

    BOTTOM FRICTION FACTOR =  .0030                   WIND STRESS CORRECTION FACTOR =  .90

               C1 =  203.0                    C2 =  106.0                    C3 =  5280.0



 TIME       SETUP      SETUP     TOT. WIND    AST. TIDE    INITIAL WATER    PRESSURE   TOTAL WATER
(HOURS)    X-COMP.    Y-COMP.     SETUP        LEVEL          LEVEL          SETUP       LEVEL
            (FT.)      (FT.)      (FT.)      (FT. MLW)        (FT.)          (FT.)     (FT. MLW)


  1.00        .03        .05        .08         .00           1.20            .11         1.39
  2.00        .00        .10        .10        -.20           1.20            .12         1.23
  3.00       -.00        .15        .15         .10           1.20            .14         1.59
  4.00       -.01        .23        .22         .40           1.20            .16         1.98
  5.00        .06        .39        .45         .90           1.20            .19         2.74
  6.00        .25        .65        .90        1.99           1.20            .23         4.32
  7.00        .97        .99       1.96        3.10           1.20            .29         6.55
  8.00       1.91       1.01       2.92        3.90           1.20            .40         8.42
  9.00       2.36        .44       2.80        4.00           1.20            .61         8.61
 10.00       2.12       -.56       1.56        3.60           1.20            .87         7.22
 11.00       1.62      -1.76       -.14        2.70           1.20            .64         4.40
 12.00        .99      -2.66      -1.67        1.50           1.20            .42         1.45
 13.00        .48      -2.96      -2.49         .70           1.20            .34         -.25
 14.00        .24      -2.57      -2.33         .30           1.20            .27         -.56
 15.00        .13      -1.98      -1.84         .40           1.20            .22         -.02
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                          SUMMARY OF OPEN COAST STORM SURGE PROBLEM


CAROL        VF = 33.3 KNOTS        R = 25. N. MILES
        CENTRAL PRESSURE = 28.69 IN. HG.                      PERIPHERAL PRESSURE = 29.92 IN. HG.

    RADIUS TO MAXIMUM WIND = 25.0 N.M.                    MAXIMUM          WIND =  95.0 MI/HR.

         TRANSLATION SPEED = 33.3 KNOTS                                  INITIAL RISE =  .50 FEET

    BOTTOM FRICTION FACTOR =  .0030                   WIND STRESS CORRECTION FACTOR =  .80

               C1 =  203.0                    C2 =  106.0                    C3 =  5280.0



 TIME       SETUP      SETUP     TOT. WIND    AST. TIDE    INITIAL WATER    PRESSURE   TOTAL WATER
(HOURS)    X-COMP.    Y-COMP.     SETUP        LEVEL          LEVEL          SETUP       LEVEL
            (FT.)      (FT.)      (FT.)      (FT. MLW)        (FT.)          (FT.)     (FT. MLW)


  1.00        .03        .05        .07         .00           1.20            .11         1.39
  2.00        .00        .09        .09        -.20           1.20            .12         1.21
  3.00       -.00        .13        .13         .10           1.20            .14         1.57
  4.00       -.01        .21        .20         .40           1.20            .16         1.96
  5.00        .05        .35        .40         .90           1.20            .19         2.69
  6.00        .22        .58        .80        1.99           1.20            .23         4.22
  7.00        .86        .88       1.75        3.10           1.20            .29         6.35
  8.00       1.70        .91       2.61        3.90           1.20            .40         8.10
  9.00       2.11        .41       2.51        4.00           1.20            .61         8.32
 10.00       1.88       -.48       1.40        3.60           1.20            .87         7.07
 11.00       1.44      -1.55       -.11        2.70           1.20            .64         4.43
 12.00        .88      -2.37      -1.49        1.50           1.20            .42         1.63
 13.00        .42      -2.69      -2.27         .70           1.20            .34         -.03
 14.00        .21      -2.38      -2.17         .30           1.20            .27         -.40
 15.00        .12      -1.84      -1.72         .40           1.20            .22          .10
```

Pararas-Carayannis, George
Verification study of a bathystrophic storm surge model. Fort Belvoir, Va., U.S. Coastal Engineering Research Center, 1975.

248 p. illus. (U.S. Coastal Engineering Research Center. Technical memorandum no. 50).

Bibliography: p. 132-136.

Verification of a bathystrophic storm surge numerical model is presented. Historical hurricane data from traverses on the gulf and east coasts were used to calibrate combined values of wind and bottom-stress coefficients in hydrodynamic equations for a numerical computation.

1. Hurricane data—Data processing. 2. Coastal engineering. 3. Hurricanes. 4. Storm surges. I. Title. (Series)

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Pararas-Carayannis, George
Verification study of a bathystrophic storm surge model. Fort Belvoir, Va., U.S. Coastal Engineering Research Center, 1975.

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