TP 77-13

Development of Surge II Program With Application to the Sabine-Calcasieu Area for Hurricane Carla and Design Hurricanes

by

Robert O. Reid, Andrew C. Vastano, and Thomas J. Reid

TECHNICAL PAPER NO. 77-13
NOVEMBER 1977

Prepared for

U.S. ARMY, CORPS OF ENGINEERS
COASTAL ENGINEERING
RESEARCH CENTER

Kingman Building
Fort Belvoir, Va. 22060

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER TP 77-13	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) DEVELOPMENT OF SURGE II PROGRAM WITH APPLICATION TO THE SABINE-CALCASIEU AREA FOR HURRICANE CARLA AND DESIGN HURRICANES		5. TYPE OF REPORT & PERIOD COVERED Technical Paper 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Robert O. Reid, Andrew C. Vastano, and Thomas J. Reid		8. CONTRACT OR GRANT NUMBER(s) DACW64-74-C-0015
9. PERFORMING ORGANIZATION NAME AND ADDRESS Coastal Studies, Incorporated College Station, Texas 77843		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS A31231
11. CONTROLLING OFFICE NAME AND ADDRESS Department of the Army Coastal Engineering Research Center (CERRE-CO) Kingman Building, Fort Belvoir, Virginia 22060		12. REPORT DATE November 1977 13. NUMBER OF PAGES 218
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Design hurricane	Inland flooding model
Hurricane Carla	Sabine-Calcasieu region
Hurricane surge model	Surge II program

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

SURGE II is a program for calculation of storm surges and tides in a bay or estuary of the type where frictional resistance dominates over Coriolis force. It includes the provision for subgrid scale barriers and channels as well as allowing for overtopping of barriers and flooding of and recession from normally dry regions adjoining the bay or estuary. The theory and numerical algorithm is discussed in detail. A user's guide for the program is also provided. Application of the program, in respect to astronomical tides and

(continued)

hurricane surges, is made for the Sabine-Calcasieu region which straddles the Texas and Louisiana boundary. For normal tide conditions, cities such as Beaumont, Orange, and Lake Charles are connected to the sea via rivers, which in the numerical model must be represented as subgrid scale channels as long as the basic grid scale is of the order of a nautical mile. Under hurricane surge conditions, however, the overland flooding can greatly expand their connection to the sea.

Calibration of channel friction is carried out via the astronomical tide simulation. Calibration of the block friction is carried out using data on a previous storm of record, Hurricane Carla. An example application is provided for standard project hurricanes (SPH). The response for a large radius SPH of slow speed and one of moderate speed of translation is examined. Also, the effect of rainfall is examined by running the latter storm with and without rainfall.

PREFACE

This report is published to assist coastal engineers in the study of storm surge and inland flooding for use in the planning and design of protective coastal works. The work was carried out under the coastal processes program of the U.S. Army Coastal Engineering Research Center (CERC).

The report was prepared by Robert O. Reid, Andrew C. Vastano, and Thomas J. Reid, Coastal Studies, Inc., who are also on the staff of the Department of Oceanography, Texas A & M University, College Station, Texas, under CERC Contract No. DACW64-74-C-0015 to the U.S. Army Engineer District, Galveston.

The authors acknowledge the help of many individuals of the Galveston District, in providing most of the data necessary in schematizing the Sabine-Calcasieu system, the data for tidal calibration, the wind fields and observed water level data for Hurricane Carla, and the necessary input data for the Standard Project Hurricanes. G. Marinos and M. Choate assisted with various stages of the development and carried out the runs for the Standard Project Hurricane via the GE series 400 computer.

G. Marinos was the Galveston District contract monitor for the report under the general supervision of S. Tanner, Chief, Coastal Planning Section. Dr. Jon Hubertz was the CERC technical monitor of the report under the general supervision of Dr. D.L. Harris, Chief, Coastal Oceanography Branch, Research Division.

Comments on this publication are invited.

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

JOHN H. COUSINS
Colonel, Corps of Engineers
Commander and Director

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CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

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

Multiply	by	To obtain
inches	25.4	millimeters
	2.54	centimeters
square inches	6.452	square centimeters
cubic inches	16.39	cubic centimeters
feet	30.48	centimeters
	0.3048	meters
square feet	0.0929	square meters
cubic feet	0.0283	cubic meters
yards	0.9144	meters
square yards	0.836	square meters
cubic yards	0.7646	cubic meters
miles	1.6093	kilometers
square miles	259.0	hectares
knots	1.8532	kilometers per hour
acres	0.4047	hectares
foot-pounds	1.3558	newton meters
millibars	1.0197×10^{-3}	kilograms per square centimeter
ounces	28.35	grams
pounds	453.6	grams
	0.4536	kilograms
ton, long	1.0160	metric tons
ton, short	0.9072	metric tons
degrees (angle)	0.1745	radians
Fahrenheit degrees	5/9	Celsius degrees or Kelvins[1]

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[1] To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use formula: C = (5/9) (F -32).

To obtain Kelvin (K) readings, use formula: K = (5/9) (F -32) + 273.15.

SYMBOLS AND DEFINITIONS

A	cross-sectional area of a channel
A_b	effective surface area of a block
A_c	cross-sectional area of a channel
A_s	surface area of an estuary at MSL
a_o	amplitude of input tide to an estuary
B	$8/3\pi\ m(A_s\omega)^2\ a_o$, a parameter which determines the phase lag of tidal response in an estuary
BN	right-hand side of equation (48)
BP	right-hand side of equation (46)
b	$(\partial A/\partial s)_H$ const., a characteristic of a channel
C_d	dimensionless discharge coefficient characterizing a constricted opening between bay and sea
C_g	admittance coefficient (with dimensions of velocity); nominally represents the wave speed in the sea
C_o	dimensionless overflow coefficient (generally less than 0.5 for a broad-crested barrier)
C_s	dimensionless discharge coefficient for a submerged barrier (generally less than $\sqrt{2}$)
D	total depth of water at position x,y at time t
$\overline{D}$	a mean depth for the effective fetch across a block; also mean depth for a channel $(D_N + D_P)/2$
D_b	depth of water over the crest of a barrier
D_c	effective depth of a channel A_c/w
D_{max}	maximum depth to be expected anywhere in the system during a storm surge
F_L	contribution to the forcing term in equation (17) due to lateral transfer of mass and momentum
f	dimensionless bed resistance coefficient for blocks
f_c	channel bed friction coefficient

G	damping factor for channels, see equation (44)
G_1	damping factor for x-transport on blocks, see equation (35)
G_2	damping factor for y-transport on blocks, see equation (36)
g	acceleration due to gravity
H	water level elevation relative to local MSL datum
HB	water elevation on the water-connected block of a channel
HC	common water elevation for a channel junction
HM	mean water level anomaly of connected channel and blocks
HX	water level at the lower end of an x-channel
HY	water level at the left end of a y-channel
H_A	H at point B in a channel
H_b	water level on the high side of a barrier
H_g	input tide level at time t outside a bay entrance
H(i,j)	water level anomaly H for block identified by x and y indexes i,j
H*	tentative predicted H for a ponding block in the absence of any contribution by longitudinal discharge to or from the channel which terminates adjacent to that block
H'	value of H at new time level
H'_p	new H value at point P in channel
H_1 & H_2	water levels on the two sides of a barrier (both of which exceed Z_b), equation (10)
i	x-index for grid blocks
j	y-index for grid blocks
K	dimensionless wind-stress coefficient, equation (6)
L	effective fetch length

L_f	net time rate of gain of water volume per unit distance along the channel by lateral transfer and rainfall
L_m	net time rate of gain of momentum (divided by water density) per unit distance along channel
m	$fL/gD_cA_c^2$ or $1/g(C_dA_d)^2$
N	denotes negative characteristic
n	time index
P	wind "push" term $X\Delta t$ or $Y\Delta t$; also denotes positive characteristic
Q	volume transport through cross-sectional area of a channel
$\overline{Q}$	mean Q value for channel, equation (45)
$QCXP_K$	flow at the upper end of an x-channel for channel block K
$QCYN_K$	flow at the left end of a y-channel for channel block K
$QCYP_K$	flow at the right end of a y-channel for channel block K
$QCXN_K$	flow at the lower end of an x-channel for channel block K
Q_A	Q at point A of positive characteristic
Q_B	Q at point B of negative characteristic
Q_d	discharge from channel to ponding block
q_f	the flow (per unit length of channel) from the channel to the adjacent block
q_i	lateral volume flux per unit length into the channel
q_n	outward component of volume flux at a boundary
q_o	lateral volume flux per unit length out of the channel
q_t	flow (per unit length of channel) from the channel block to the channel (across the interior side of the channel)
Q'	new Q value
Q'_N	new Q at point N

SYMBOLS AND DEFINITIONS--Continued

Q'_P	new Q at point P
Q'_r	specified river discharge
R	rainfall rate
R(i,j)	rainfall rate for block i,j
r	relative amplitude response
s	distance along the axis of a channel
T	tidal period
T_s	longitudinal component of wind stress (divided by water density) or appropriate wind-stress component (X or Y) corresponding to time level t for the associated channel block
t	time
U	vertically integrated x-component of volume transport per unit width
UCF(K)	lateral transport, per unit width per unit time, nominally from an x-channel of block K to an adjacent block; also denoted UCF_K
UCT(K)	lateral transport, per unit width per unit time, nominally to an x-channel from the interior of block I; also denoted UCT_K
UN	U value on left side of block
U(i,j)	value of U at the left side of block i,j
U(i+1,j)	value of U at the right side of block i,j
u	typical fluid speed in the bay
U'	value of U at new time level
V	vertically integrated y component of volume transport per unit width
VCF(K)	lateral transport per unit width per unit time, nominally from an y-channel of block K to an adjacent block; also denoted VCF_K

SYMBOLS AND DEFINITIONS--Continued

$VCT(K)$	lateral transport per unit width per unit time, nominally to an y-channel from the interior of block K; also denoted VCT_K
VN_I	value of V at the lower side of a block
$V(i,j)$	value of V at the lower side of block i,j
$V(i,j+1)$	value of V at the upper side of block i,j
V'	value of V at new time level
W	windspeed at 10-meter elevation over the water
W_c	a critical speed taken as 14 knots (7 meters per second)
w	surface width of a channel (conveyance width)
X	x-component of the wind stress divided by the density of the water
$X(i+1,j)$	value of X for right side of block i,j
x	horizontal Cartesian coordinate nominally alongshore, positive to the right when facing shore
Y	y-component of the wind stress divided by the density of the water
$Y(i,j+1)$	value of Y for top side of block i,j
y	horizontal Cartesian coordinate nominally normal to shore, positive landward
Z	elevation of the seabed relative to MSL datum
$Z(i,j)$	value of Z for block i,j
Z_b	barrier crest elevation
Z_c	channel bed elevation
α	$(gD)^{\frac{1}{2}} \Delta t/\Delta s$ (Courant number); also L_c/D_cA_c, equation (77)
Γ	$L(C_bD_b)^2/\overline{D}\Delta t$
ΔH	a head differential dependent upon barrier type
Δq	net lateral flow to the channel per unit length of channel

SYMBOLS AND DEFINITIONS--Continued

Δs	grid size for blocks (distance between successive H values in both the x and y directions); also written ΔS or DELS
Δt	time step (time interval between successive H values at given location); also written DELT
θ	the angle between the wind velocity vector and the x-axis
λ	$w\,(g\bar{D})^{1/2}/G$
π	3.14159 ...
σ	$wf\lvert Q\rvert/A^2$
ϕ	latitude
Ω	absolute angular speed of the earth
ω	radian frequency $2\pi/T$

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I. INTRODUCTION

Numerical techniques for the solution of equations representing storm surges in coastal areas were significantly augmented in 1966 by the development of a two-dimensional model (referred to in this study as the SURGE I program) for the U.S. Army Engineer District, Galveston (Reid and Bodine, 1968). At about the same time a number of bay models emerged. Notable among these are the models of Leenderste (1967) and Masch, et al. (1969), which have been applied to problems of both surge and circulation in bays. These models include the Coriolis force which is neglected in the Reid-Bodine model. However, the Reid-Bodine model produced the first successful inclusion of flooding, recession, barriers, and flow over barriers in the study of inundation of low-lying coasts. The actual model is a nonlinear system of equations and boundary conditions solved by numerical integration of time-dependent, forced motion. Its use produces the water response to stormwinds over the region for a given storm tide at the seaward boundary. The initial application was a hindcast of the Hurricane Carla surge generated in Galveston Bay during 9 to 12 September 1961.

During Hurricane Carla, the wetted perimeter of Galveston Bay essentially doubled, as accurately reproduced in the hindcast computations. Serial observations of water levels for the storm period available from stations throughout the bay were compared to levels computed with the numerical algorithm. These records produced a standard deviation of less than 4 inches, overall. The maximum deviation of the water level prediction was 1.5 feet and occurred at the grid square corresponding to the location of the Pelican Island Bridge which spans the channel between Galveston and the Pelican Islands. Although this disparity was relatively large, its effect on the computations was effectively reduced by the smoothing operation of the numerical integration. However, this difference points out a basic problem confronting any model--the minimum definition of topographic features.

The basic problem of indicating subgrid scale effects in numerical modeling is normally solved by parameterization of the omitted physical mechanism. Often, an analytic relationship is introduced that requires the specification of empirically derived constants; e.g., the wind-stress equation for the transfer of momentum from wind to water. Another simple and pertinent instance is the *a priori* rotation of wind vectors over certain grid squares in the Hurricane Carla computations for Galveston Bay. The model Galveston entrance channel was not in the proper orientation on the Cartesian numerical grid system and, as a result, did not admit a realistic amount of water to the bay. A programed shift in the wind vectors indicated this subgrid scale feature.

SURGE I has been applied to the study of Texas coastline surge susceptibility. The topographic features of this region are characterized by barrier islands and shallow, river-fed bay systems surrounded by near sea level land and marshes. The specific applications of the program have therefore centered interest on the immediate environs of a bay. The requirement for surge studies of appreciable distances inland from the bay system has only recently been placed on the numerical model. The propagation of the surge to higher ground through necessary subgrid scale topographic features has required an extension of the basic algorithm.

The new algorithm developed for the study of the Sabine-Calcasieu region is referred to as the SURGE II program. This program incorporates all the features of SURGE I with the further option of representing variable depth and width channels along the sides of each grid square. The flow computations for the channels interact with the normal grid square computations and permit a complete suite of flooding conditions for overtopping of levees. In this manner SURGE II provides a time-dependent, subgrid scale transport of water through the model.

II. THEORETICAL DEVELOPMENT FOR SURGE II

1. Summary of Two-Dimensional Theory.

The development of SURGE II was based on the SURGE I concept by Reid and Bodine (1968). A part of this study is presented here to provide a complete description of SURGE II.

The advection of momentum (or field acceleration) is considered negligible except at singular regions of the bay (submerged barriers and narrow channels) where the effect is included implicitly through the use of appropriate nonlinear discharge relations. The effect of the earth's rotation is also neglected; this approximation appears justifiable for systems of small spatial scale and shallow depth where frictional forces are more dominant.

Within the normal domain of the bay and immediate adjoining sea, the vertically integrated equations of motion and of continuity appropriate to the problem are taken as follows:

$$\frac{\partial U}{\partial t} + gD\,\frac{\partial H}{\partial x} = X - fqUD^{-2} \tag{1}$$

$$\frac{\partial V}{\partial t} + gD\,\frac{\partial H}{\partial y} = Y - fqVD^{-2} \tag{2}$$

$$\frac{\partial H}{\partial t} + \frac{\partial U}{\partial x} + \frac{\partial V}{\partial y} = R\,, \tag{3}$$

where

x and y = horizontal Cartesian coordinates;

t = time;

U and V = vertically integrated x and y components, respectively, of transport per unit width;

g = gravity;

H = water level elevation relative to the local mean sea level (MSL) datum;

D = depth of water at position x, y at time t;

q = magnitude of the transport per unit width;

f = dimensionless bed-resistance coefficient;

R = rainfall rate;

X and Y = x and y components of the wind stress divided by the density of the water (the density assumed constant).

Normal values of f are in the range 10^{-3} to 10^{-2} for typical seabed conditions.

The value of q is obtained from U and V by

$$q = (U^2 + V^2)^{\frac{1}{2}} \tag{4}$$

which is a positive quantity.

The kinematic forms of the wind-stress components in the absence of rainfall are taken as

$$\begin{aligned} X &= K\,W^2 \cos\theta \\ Y &= K\,W^2 \sin\theta\ , \end{aligned} \tag{5}$$

where W is the windspeed at a 10-meter elevation over the water, and θ is the angle between the wind velocity vector and the x-axis. The dimensionless coefficient, K, used in the calculations is presumed to be a function of windspeed as implied by the van Dorn (1953) relation for wind stress. Specifically, it is assumed that

$$\begin{aligned} K &= K_1 && \text{for } W \le W_c \\ K &= K_1 + K_2 \left(1 - \frac{W_c}{W}\right)^2 && \text{for } W \ge W_c\ , \end{aligned} \tag{6}$$

where the constants K_1 and K_2 are taken as 1.2×10^{-6} and 1.8×10^{-6}, respectively, and W_c is a critical speed which is taken as 14 knots (7 meters per second). For large windspeeds, K approaches the limiting value of 3.6×10^{-6} which corresponds to a resistance coefficient of about 3.0×10^{-3} if the ratio of air density to water density is taken as 1.2×10^{-3}.

In the presence of rainfall an added flux of momentum proportional to RW occurs (van Dorn, 1953). The effect can be included by augmenting K by R/W. For heavy rainfall, the resulting K is increased about 10 percent.

The variables H and D are related by the simple expression,

$$D = H - Z \quad , \tag{7}$$

where Z is the elevation of the seabed relative to the MSL datum. Presumably, Z is a function of x and y only; i.e., the time-dependent scour of the seabed is ignored.

The above equations ignore the direct effect of variable atmospheric pressure which is relatively minor in a small, shallow bay. The effect over the sea is included implicitly through the specification of an appropriate surge height versus time in the adjoining sea where the combined effects of winds and differential atmospheric pressure give rise to a coastal storm surge. This is presumed to be determined independently of the detailed calculations for the bay and enters as a boundary condition.

a. Boundary Conditions. Four different types of boundary conditions are used in this system of computations. Two of these conditions apply to the water-land boundary, one condition applies to the artificial boundary representing the seaward end of the bay system, and one applies at partial barriers internal to the system. (Additional internal conditions are needed in the presence of imbedded channels as discussed later in Section III,2.) All four conditions relate the normal component of flow at the boundary to the state of the water level at the boundary.

In general, the boundary between bay water and land depends on the water elevation and the land topography. The shoreline for different uniform elevations of the surface of the bay is readily established from a knowledge of the topography. For a bay with low-lying terrain, the rate of increase of surface area of water per unit increase of water level can be considerable. In the actual rising stage of storm tide the amount of inundation is controlled by the rate at which the water can flow into the potential ponding areas. In the present scheme, which uses a representation of the bay in terms of a discrete grid, the elevation of the seabed or land is regarded as uniform over each grid square, thus forming a two-dimensional, stairstep-type approximation of the actual topography. The boundary condition on the normal component of flow, q_n, at the juncture of a flooded square and a dry square is taken as

$$q_n = 0 , \tag{8}$$

if the elevation, H, of the water is less than that of the adjacent dryland. However, if the water level is greater than that of the dryland, then the rate of flooding, q_n, per unit length of land barrier, is given by

$$q_n = \pm C_o D_b (gD_b)^{\frac{1}{2}} , \tag{9}$$

where D_b is water depth over the crest of the barrier, and C_o is an appropriate dimensionless overflow coefficient, generally less than 0.5 for a broad-crested barrier. The choice of sign depends on whether the flooding is from bay to land or from flooded land back to the bay during the recession stage.

Equation (9) is considered valid for any barrier within or at the boundary of the system for which the water level on one side of the barrier is greater than the barrier crest elevation, Z_b, and for which the water level on the other side is less than Z_b. Moreover, D_b is simply $H_b - Z_b$, where H_b is the water level on the high side.

In the case where the water level on both sides of an internal barrier exceeds the barrier-crest elevation, the discharge is taken as that for a submerged wier,

$$q_n = \pm C_s D_b (g|H_1 - H_2|)^{\frac{1}{2}} , \tag{10}$$

where D_b is the water depth over the crest of the barrier, H_1 and H_2 are the water levels on the two sides of the barrier (both of which exceed Z_b), and C_s is an appropriate dimensionless discharge coefficient for the submerged barrier (generally less than $\sqrt{2}$). In this case, D_b is taken as $(H_1 + H_2)/2 - Z_b$. Again, the sign is taken such that the flow is directed toward the low-head side of the barrier. Both equations (9) and (10) presume that the velocity of approach to the barrier is much less than the velocity over the barrier.

In the numerical computational scheme, emphasis is placed on the evaluation of flow and water levels within a bay which is connected to a sea of essentially unlimited extent. An appropriate boundary condition is required either at the mouth of the bay system or along some line within the sea which delineates the outer limit of the computational grid. The correct approach would be to treat the development of the surge in the sea and bay as a single problem. However, the difference in spatial resolution required for the two different regions of the system, as well as computer storage limitations, makes this impractical. The assumption is made that the effect of the conditions in the bay has only a minor influence on the development of the surge in the sea and over the Continental Shelf. The evaluation of the latter can be determined independently of the bay problem or obtained from observation and used as an outer boundary condition for the bay.

The simplest condition at the seaward boundary is of the form

$$H = H_g , \qquad (11)$$

where H_g is the prescribed water level which would exist in the absence of the bay at time t at the outer boundary of the bay system. SURGE II presently uses this condition at the seaward boundary and at lateral boundaries on the limited shelf part of the system. An alternative condition for the lateral boundaries on the shelf is to prescribe that $\partial U/\partial x = 0$ at these boundaries where x is taken alongshore (Jelesnianski, 1966, 1967). An alternative condition for the seaward boundary is one which allows for radiation of energy to the sea. The latter condition is of the form

$$H = H_g + q_n/C_g , \qquad (12)$$

where q_n is taken positive outwards from the bay to the sea, and C_g is an appropriate admittance coefficient (with dimensions of velocity). Nominally, C_g represents the wave speed in the sea. The generalized condition (eq. 12) is nearly equivalent to the simplest condition (eq. 11) if C_g greatly exceeds the wave speed for the bay.

b. Initial Conditions. Since the system includes allowance for frictional dissipation as well as radiation of energy, the solution for given fields of X and Y and given boundary function, H_g, should be reasonably insensitive to the nature of the initial conditions after a suitable lapse of time from the initial state. Thus, the initial conditions can be somewhat arbitrary. As in the laboratory model experiments, it is reasonable to start from a state of equilibrium in which U and V are zero and H is uniform throughout the system, in order to minimize the introduction of transient oscillations related to the starting conditions. Moreover, a reasonable period (depending on the characteristic decay time) can be allowed for the system to reach that state where its response reflects only the effect of the forcing functions.

2. Theory of Embedded Channels.

Let s denote distance along the axis of a channel whose cross-sectional area is A and surface width is w at position s and time t. Let Q be the volume transport through A in the positive sense of s, and let H be the water elevation above MSL datum at the same section. In general, A and w are known functions of H for a given cross section, as determined by the geometry of the cross section (Fig. 1). In particular, $\partial A/\partial H = w$ for given s. The width w is to be the "conveyance" width, as used by Dronkers (1964).

The channel is considered an "open system" in the sense that water and momentum may enter or leave the channel laterally; i.e., exchange of fluid with adjacent bay area or flooded land can exist. If the longitudinal velocity in the channel is considered uniform for evaluating the

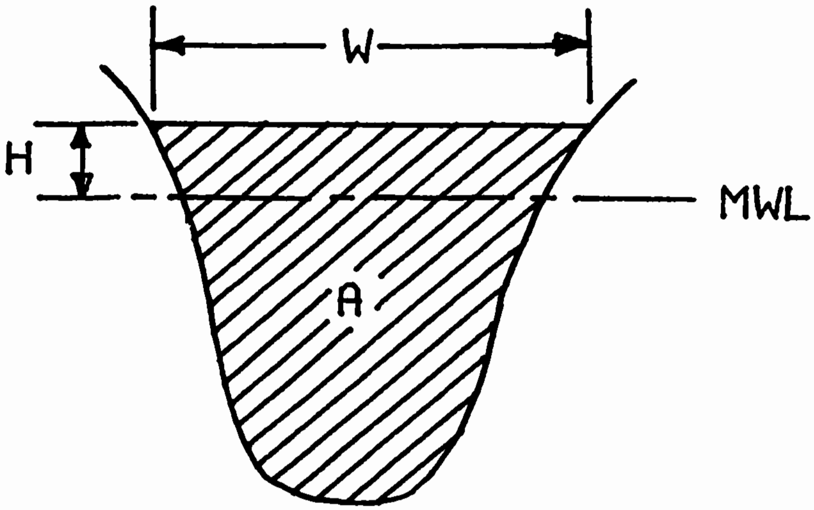

Figure 1. Schematic channel cross section showing pertinent parameters.

longitudinal transport of momentum, then the equations of motion and continuity for a given channel reach are (Stoker, 1957, Ch. 11; Dronkers, 1964, Ch. 9)

$$\frac{\partial Q}{\partial t} + \frac{\partial}{\partial s}(Q^2/A) + gA\frac{\partial H}{\partial s} = wT_s - \sigma Q + L_m \tag{13}$$

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial s} = L_f , \tag{14}$$

where

T_s = longitudinal component of wind stress (divided by water density);

σ = $wf|Q|/A^2$ where f is a dimensionless channel-friction coefficient;

L_f = net time rate for gain of water volume per unit distance along the channel by lateral transfer and rainfall;

L_m = associated net time rate of gain of momentum (divided by water density) per unit distance along channel.

The units of L_f are square feet per second; L_m has the units cubic feet per second squared.

It is convenient in the analysis of the channel dynamics to transform the above equations into a characteristic form. There are several different possible characteristic forms. The approach used by Stoker (1957) is to work with u and H (where $u \equiv Q/A$) as the dependent variables. Dronkers (1964) works with either Q and H directly or with Q and total head $(H + (Q/A)^2/2g)$. Each method has certain advantages and disadvantages. In the present analysis, the variables Q and H are used to be as consistent as possible with the computations in the two-dimensional regions of the system.

In transforming equations (13) and (14) to characteristic form, it is noted that

$$\frac{\partial A}{\partial t} = w \frac{\partial H}{\partial t}$$

$$\frac{\partial A}{\partial s} = w \frac{\partial H}{\partial s} + b , \tag{15}$$

where

$$b \equiv \left(\frac{\partial A}{\partial s}\right)_{H \text{ const}} . \tag{16}$$

(For a channel of uniform cross section the latter quantity would be zero.) It can be shown, following Dronkers' (1964) analysis and considering equation (15), that a characteristic form of equations (13) and (14) is

$$\frac{dQ}{dt} + w\left(- \frac{Q}{A} \pm \sqrt{\frac{gA}{w}}\right) \frac{dH}{dt} = \left\{wT_s - \sigma Q + L_m + b \left(\frac{Q}{A}\right)^2 + \left(- \frac{Q}{A} \pm \sqrt{\frac{gA}{w}}\right) L_f\right\} \tag{17}$$

along the path s(t) where

$$\frac{ds}{dt} = \frac{Q}{A} \pm \sqrt{\frac{gA}{w}} . \tag{18}$$

The path line where the plus or minus sign is taken in equation (18) is referred to as the positive P characteristic or the negative N characteristic path, respectively. These are illustrated in Figure 2 where x corresponds to s, the two paths having point C in common. Equation (17) with the upper sign applies along P and equation (17)

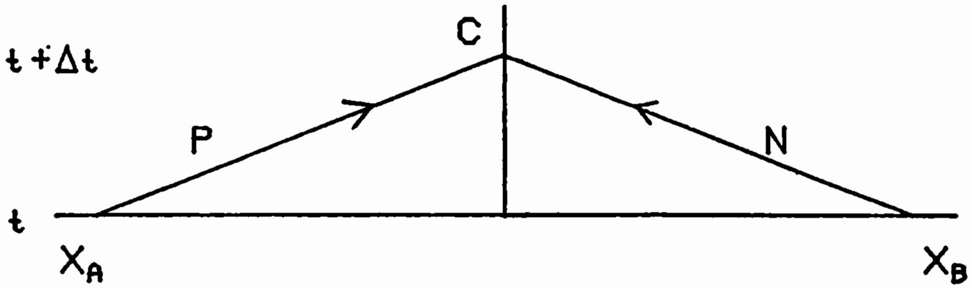

Figure 2. Schematic positive and negative characteristic paths to a common point in the x, t diagram.

with the lower sign applies on path N. Thus, information with regard to Q and H at points x_A and x_B at time t and along the two paths can, in principle, be used to predict the values of Q and H at point C from two equations.

For a laterally closed channel (L_f, $L_m = 0$) of a uniform cross section ($b = 0$) without friction ($\sigma = 0$), in the absence of wind stress ($T_s = 0$), then the quantity in braces on the right-hand side of equation (17) vanishes. In this case only the information at points A and B of Figure 2 is needed to predict values of H and Q at C. To show that equation (17) is consistent with Stoker's (1957) analysis for this special case, let $u = Q/A$ and $D = A/w$. For a uniform cross section at given H, $dH/dt = dD/dt$, so equation (17) reduces to

$$\frac{d(DU)}{dt} + (-u \pm \sqrt{gD}) \frac{dD}{dt} = 0 \tag{19}$$

along

$$\frac{ds}{dt} = u \pm \sqrt{gD}. \tag{20}$$

Equation (19) simplifies further to

$$wD \frac{d}{dt} (u \pm 2\sqrt{gD}) = 0. \tag{21}$$

Thus, for this special case $(u + 2\sqrt{gD})$ is conserved along P where $dx/dt = u + \sqrt{gD}$, while $(u - 2\sqrt{gD})$ is conserved along N where $dx/dt = u - \sqrt{gD}$. Thus, u and D (hence, Q and H) can readily be evaluated at C.

In the more general case the time integral of the right-hand side of equation (17) must be estimated in a rational way. This is considered later in Section III,2. Also, in the general case it is usually not possible to put the left-hand side of equation (17) in the simple form shown in equation (21).

a. Lateral Transfer Terms. In the absence of direct rainfall, L_f must equal the net gain of volume per unit length per unit time due to lateral flow into the channel on either or both sides. Let q_i and q_o, respectively, represent the volume fluxes per unit length into and out of the channel. Then, $L_f = q_i - q_o$ in the absence of rainfall, or

$$L_f = q_i - q_o + wR \tag{22}$$

with rainfall. The corresponding lateral transfer of momentum (divided by water density) is

$$L_m = q_i u_i - q_o u_o, \tag{23}$$

the transfer from rainfall being included in the wind-stress term as discussed in Section II,1. In equation (23) the quantity u_o is simply Q/A for the channel while u_i is the channel-directed component of velocity of fluid from the adjoining block water area. In equation (17) the terms L_m and L_f contribute to the right-hand side the quantity,

$$F_L \equiv L_m - \frac{Q}{A} L_f \pm \sqrt{\frac{gA}{w}}\, L_f \, . \tag{24}$$

Using equations (22) and (23) yields

$$F_L = q_i \,(u_i - u_o) - wRu_o \pm \left(\frac{gA}{w}\right)^{\frac{1}{2}} (q_i - q_o + wR). \tag{25}$$

The lateral flows into or out of the channel can be evaluated by relations such as equations (8), (9), and (10). This is also discussed in Section III,2.

b. <u>Simplifications</u>. The SURGE II program uses certain simplifications of the above equations. For normal conditions, the propagational speed $(gA/w)^{\frac{1}{2}}$ significantly exceeds the speeds u_i or u_o; i.e., Q/A. Accordingly, F is approximated by

$$F_L = \pm \left(\frac{gA}{w}\right)^{\frac{1}{2}} L_f \, . \tag{26}$$

Elsewhere in equations (17) and (18), Q/A is neglected compared with $(gA/w)^{\frac{1}{2}}$. Moreover, each channel reach within a grid block is considered of uniform width and bottom elevation Z_c; however, w and Z_c vary from one reach to another. Thus, b = 0 for each reach and

$$A/w = D = H - Z_c \, . \tag{27}$$

Under these conditions equations (17) and (18) take the form,

$$\frac{dQ}{dt} \pm w\sqrt{gD}\,\frac{dH}{dt} = \left\{wT_s - f\,|Q|\,Q/(D^2 w) \pm \sqrt{gD}\,(q_i - q_o + wR)\right\} \tag{28}$$

along

$$\frac{ds}{dt} = \pm \sqrt{gD} \tag{29}$$

where T_s = X or Y as s = x or y, depending on channel orientation. Equation (28) can also be expressed in the form,

$$\frac{d}{dt}\,(Q \pm \frac{2}{3}\, wD\sqrt{gD}\,) = F \tag{30}$$

for a given channel reach where F is the right-hand side of equation (28). The neglect of Q/A relative to $\sqrt{gD}$ in the above approximate channel equations is tantamount to neglect of longitudinal advection of momentum in the original equation (13), an approximation already made in the two-dimensional equations in Section II, 1.

III. SURGE II PROGRAM

Numerical algorithms for two-dimensional blocks and subgrid scale channels are given in this section, and the coupling between these is discussed. A complete listing of the SURGE II program is in Appendix A. A description of the program, as adapted for the GE-400 computer, and the required input and output options are discussed in Appendix B. Appendix C is a user's guide to the SURGE II program. The block algorithm is essentially as discussed by Reid and Bodine (1968) except for a change in the barrier computation and incorporation of coupling with the subgrid scale channels.

1. Block Algorithm.

In the numerical analog of the prognostic equations (1), (2), and (3), values of H are evaluated on a uniform Cartesian mesh at spacing, Δs, for uniform time steps, Δt. The values of H are representative of the water level for the grid square i, j which is centered at $x = (i - 1/2)\ \Delta s$, $y = (j - 1/2)\ \Delta s$, at time $n\Delta t$, in which i, j, and n are integers. Values of Z are specified as permanent storage for the same locations as H so that D can be evaluated as needed at these locations. Values of U are evaluated at even half steps of x, odd half steps of y, and odd half steps of t (Fig. 3). This staggered system gives the least storage consistent with a given spatial resolution. It corresponds to the simplest scheme discussed by Platzman (1958) and requires only half the storage compared with the coupled scheme used by Miyazaki (1963).

The variables X and Y are supplied at spatial locations consistent with U and V, respectively, but at even half steps of t. Values of H_g are supplied for positions and times on the outer boundary of the bay consistent with the locations and times for the H values on that line. Values of R are supplied at locations consistent with H but at a one-half time step out of phase with H. Arrays of X, Y, and R, for a single value of j and n, and the array of H_g values for given n are read from tape as required. The fields of X and Y are generated from a coarse spatial and temporal array evaluated from the basic meteorological data and then evaluated for the detailed mesh by linear interpolation.

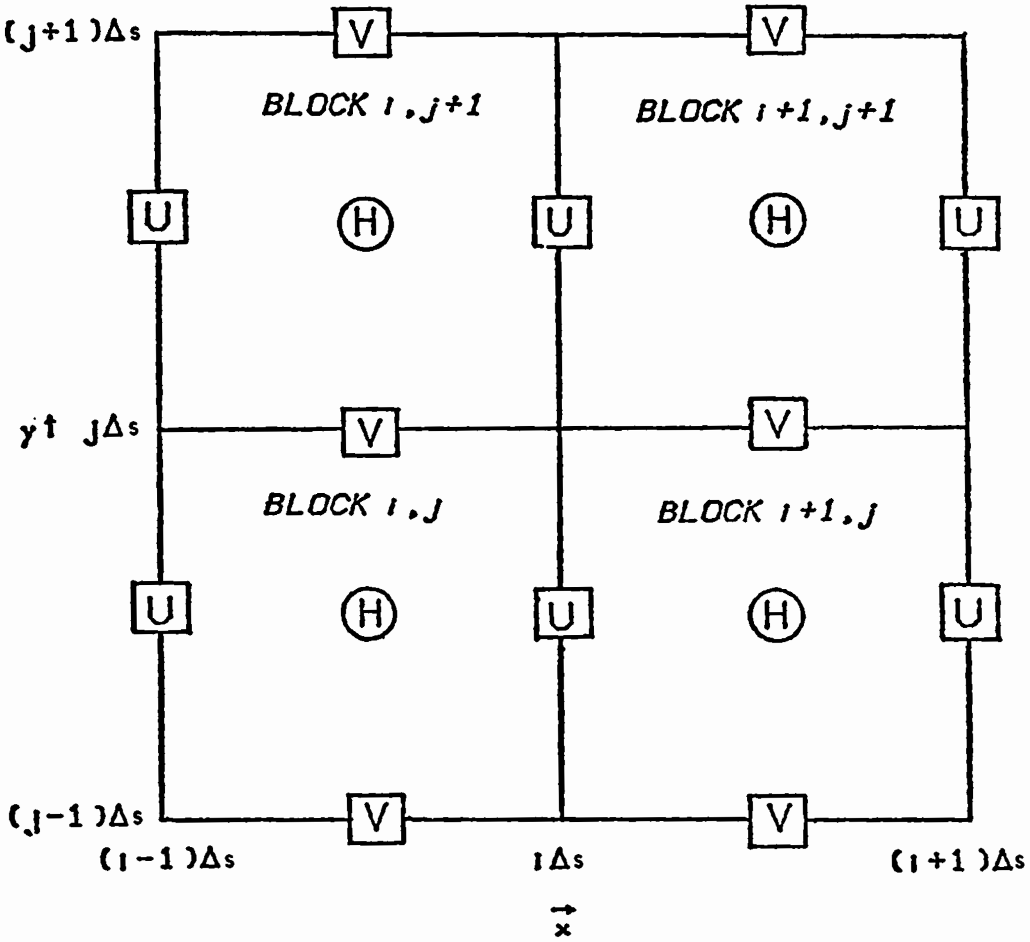

Figure 3. Example of grid blocks showing staggered arrangement of variables U, V, and H.

Information pertinent to the position, elevations, and discharge coefficients for barriers (those not resolved by the limitations of the grid system) is stored as permanent storage along with the field of Z.

The numerical analogs of equations (1), (2), and (3) use values of U, V, H, Z, X, Y, and R at locations shown in Figure 4 for a typical calculation. In the present application a common value of R for given time is used for the whole spatial array. The following notation is used in the recursion equations: H(i,j) represents H centered in block i, j at t = nΔt; U(i,j) represents U for the left side of block i,j at t = (n - 1/2) Δt; v(i,j) represents V for the lower side of block i,j at t = (n - 1/2) Δt.

Primed symbols are used to denote values of these variables at time step Δt later. Thus, the difference U' - U is centered in time at the level of H, and the difference H' - H is centered in time at the level of U' or V'. The notation for Z or D is consistent with that of H.

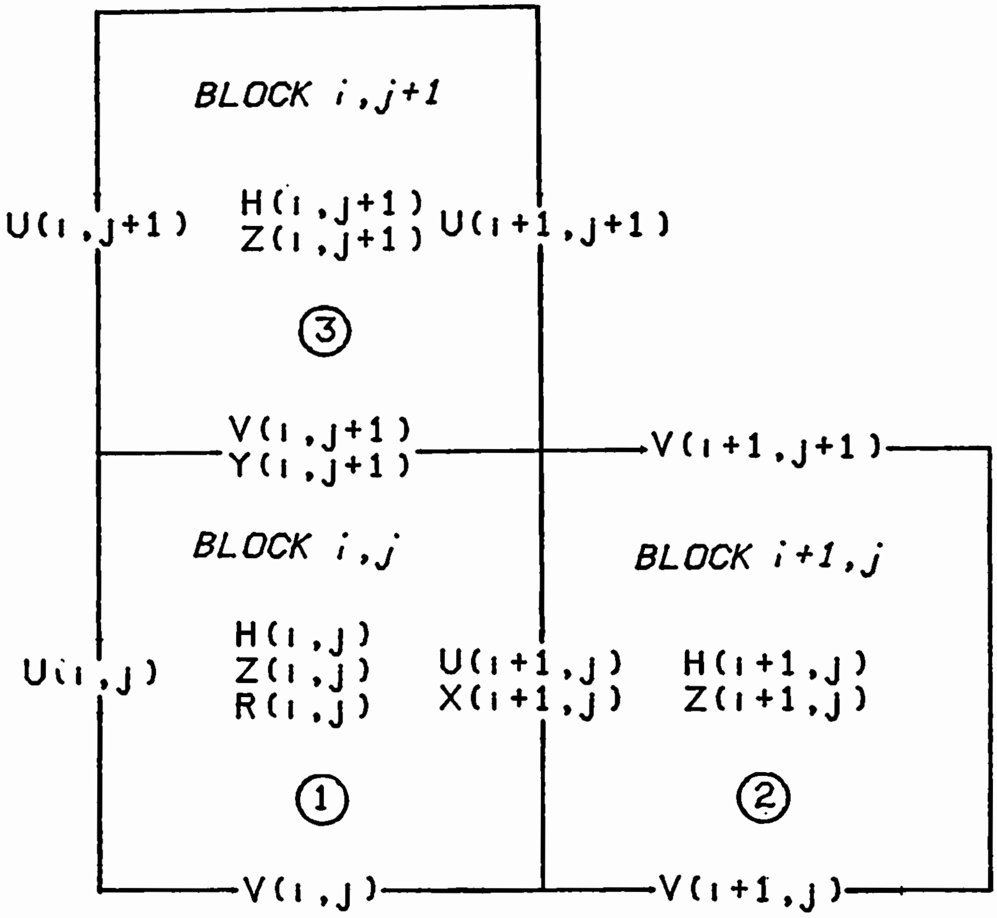

Figure 4. Basic block triad showing variables used in computation of U, V, and H for block 1.

The frictional terms in equations (1) and (2) are represented by $fAU'D^{-2}$ and $fQV'D^{-2}$, respectively, where the estimation of Q and D is centered spatially at the position for U' or V'. Since U, V, and D are not available at common locations, this requires a suitable spatial average in order to obtain centered values of Q and D. The resulting recursion equations for U, V, and H, using centered differences for the spatial derivatives, are as follows:

$$U'(i+1,j) = \frac{1}{G_1(i,j)} \Big\{U(i+1,j) + \frac{g\Delta t}{2\Delta s} [D(i+1,j) + D(i,j)] [H(i,j) - H(i+1,j)] + X(i+1,j)\Delta t\Big\} \qquad (31)$$

$$V'(i,j+1) = \frac{1}{G_2(i,j)} \Big\{V(i,j+1) + \frac{g\Delta t}{2\Delta s} [D(i,j+1) + D(i,j)] [H(i,j) - H(i,j+1)] + Y(i,j+1)\Delta t\Big\} \qquad (32)$$

$$H'(i,j) = H(i,j) + \frac{\Delta t}{\Delta s}[U'(i,j) + V'(i,j)$$

$$- U'(i+1,j) - V'(i,j+1)] + R(i,j)\Delta t, \qquad (33)$$

where

$$D(i,j) = H(i,j) - Z(i,j), \qquad (34)$$

and G_1 and G_2 are the factors which incorporate the effect of the friction. These are given by:

$$G_1(i,j) = 1 + f\Delta t \left\{[4U(i+1,j)]^2 + [V(i,j) + V(i+1,j)\right.$$

$$\left. + V(i,j+1) + V(i+1,j+1)]^2\right\}^{\frac{1}{2}} [D(i,j) + D(i+1,J)]^{-2} \qquad (35)$$

and

$$G_2(i,j) = 1 + f\Delta t \left\{[4V(i,j+1)^2 + [U(i,j) + U(i+1,j)\right.$$

$$\left. + U(i,j+1) + U(i+1,j+1)]^2\right\}^{\frac{1}{2}} [D(i,j) + D(i,j+1)]^{-2}. \qquad (36)$$

The latter factors are always somewhat greater than unity unless the flow or friction factor vanishes.

The prediction relation for H given by equation (33) does not consider any possible contribution of flow to or from the block due to the presence of a subgrid scale channel. This will be considered in a subsequent section.

It should also be emphasized that the effect of Coriolis force is not considered. The relative importance of the Coriolis force compared with bottom friction can be estimated in terms of the ratio, r, of these two forces which is of the order,

$$r = \lambda D/fu, \qquad (37)$$

where

λ = Coriolis parameter ($2\Omega \sin \phi$, Ω being the absolute angular speed of the earth and ϕ the latitude);

D = mean depth;

f = bottom-friction coefficient;

u = typical fluid speed in the bay.

For 30° latitude $\lambda = 7.3 \times 10^{-5}$; typical D and f for gulf coast bays are 10 feet and 2×10^{-3}, respectively. For u = 3 feet per second, which is reasonable for storm conditions, r is only 1/10. However, for normal circulational regimes u may be only a fraction of 1 foot per second and r is of order unity. Hence, while it may be justifiable to neglect the Coriolis term for short-duration storm surge studies for shallow bays of limited horizontal dimensions it cannot be neglected in long-term circulational studies.

Although it does not appear difficult to add the effect of Coriolis force, it can be shown (Platzman, 1958) that a different scheme for the U, V, and H arrays is necessary for numerically stable computations using an explicit time-marching procedure as used here. The coupled scheme required for stable explicit computations at least doubles the computing time. The present scheme could be used with an implicit time-marching procedure to maintain stability and similar accuracy, but this too can be achieved only at the cost of an increase in computing time by a factor of at least two. In the presence of friction, the destabilizing effect of the Coriolis terms in an explicit scheme such as that used by Masch (1969) is suppressed; however, this is accomplished only at the sacrifice in rendition of the frictional terms. Thus, the omission of the Coriolis force from a program intended primarily for gulf coast estuaries is motivated primarily for reasons of economy of operation, in respect to surge calculations.

a. Stability. Numerical stability requires that Δt be taken at less than the value $\Delta S/(2gD_{max})^{\frac{1}{2}}$, where D_{max} is the maximum depth to be expected anywhere in the system during the storm surge (Platzman, 1958).

b. Barrier Algorithm. Equations (9) and (10) are assumed to apply for values of q_n, D_b, and ΔH at the same time and in the immediate vicinity of the barrier. In the grid scheme used, however, the flow and the water level are staggered in time; moreover, the water levels like H_1 and H_2 represent in effect the spatial average for blocks 1 and 2, respectively, at a given time rather than local values in the vicinity of a given barrier, which in the schematization are presumed to occur on lines separating two blocks. As a consequence the above relations cannot be applied directly. Instead, the evaluation of U or V across a barrier (if the water level allows such flow) is carried out by a modified version of the predictive equations (1) and (2), or their numerical counterparts, equations (31) and (32), where f is replaced by an effective value related to the barrier discharge coefficient so as to be consistent with equations (9) or (10). The effect is to maintain proper time phasing and to consider possible tilt of water level across the block; i.e., difference of H at barrier relative to the mean value for the block.

Specifically, the frictional terms in equation (1) or (2) are taken as $(\overline{D}/LC_b^2)|q_n'|q_n'/D_b^2$ where C_b is the barrier discharge coefficient

(C_o or C_s, depending on type of barrier), q_n' is the transport per unit width normal to the barrier (either U' or V', depending on barrier orientation), D_b is the water depth over the barrier, and $\overline{D}$ is a mean depth for the effective fetch L across the blocks. The gravitational slope term involves the same scale length, L, and mean depth, $\overline{D}$. The resulting relation for prediction of q_n' at a barrier, given q_n at the previous time step, is:

$$|q_n'|q_n' + \Gamma q_n' = F \, , \tag{38}$$

where

$$\Gamma \equiv \frac{L(C_b D_b)^2}{\overline{D}\Delta t} \tag{39}$$

and

$$F \equiv g(C_b D_b)^2 \Delta H + \Gamma \cdot (q_n + P) \, , \tag{40}$$

P being the wind "push" term ($X\Delta t$ or $Y\Delta t$), and ΔH a head differential dependent on barrier type. For steady state ($q_n' = q_n$) and no wind ($P = 0$), the above reduces to

$$q_n' = \pm \, C_b D_b \sqrt{g|\Delta H|} \, , \tag{41}$$

which is consistent with equation (9) or (10) with C_b and ΔH taken as C_o and D_b or C_s and $(H_1 - H_2)$, respectively, depending on the barrier. The more general relation (eq. 38) provides an added effect of the wind and of the inertia of the water on the blocks. For a submerged barrier, L is taken equal to ΔS; i.e., from the center of block 1 to the center of block 2. For an overflow barrier, L is taken as half this distance since the inertia and wind setup are effective only on the higher of the two blocks.

Thus, C_b, L, H, and D_b are taken as follows:

Submerged barrier ($H_1 > Z_b$ and $H_2 > Z_b$)

$$C_b = C_s$$

$$L = \Delta S \qquad \Delta H = H_1 - H_2$$

$$D_b = \left[(H_1 + H_2)/2\right] - Z_b \tag{42}$$

Overflow barrier ($H_1 > Z_b$ or $H_2 > Z_b$)

$$C_b = C_o$$

$$L = \Delta S/2 \qquad \Delta H = \begin{cases} H_1 - Z_b \text{ (a)} \\ \text{or} \\ Z_b - H_2 \text{ (b)} \end{cases} ,$$

$$D_b = |\Delta H|$$

where Z_b is the elevation of the barrier crest, relation (a) being for $H_1 > Z_b$ and (b) for $H_2 > Z_b$. If Z_b exceeds both H_1 and H_2, then $q_n' = 0$. The meaningful solution of the quadratic equation (38) is

$$q_n' = \pm \{[|F| + (\Gamma/2)^2]^{\frac{1}{2}} - \Gamma/2\}, \qquad (43)$$

where the sign is taken as that of F, as verified from equation (38).

The above relations for barriers differ from that used in Reid and Bodine (1968) and in the original SURGE I program. The present barrier relations have a more realistic response when applied to the numerical simulation of a natural oscillation of a bay having a submerged barrier across it.

c. Barrier Specification. Since only certain blocks contain barriers, they must be identified by I, J location; specifically, the program identifies the Kth barrier block by location I = IB(K) and J = JB(K), K = 1,2 ... KM. A given barrier block potentially has a barrier on the right and upper side of the block in an x, y plot. These are designated x and y, respectively; i.e., an x barrier is one normal to the x-axis (the flow over it being in the x sense). For both potential barriers on a barrier block, values of Z_b, C_o, and C_s must be prescribed. A real barrier is one where Z_b is larger than the Z value for either of the adjoining blocks. A null barrier is one where Z_b equals the larger of the Z values for the adjoining blocks (thus, in effect, the higher block is a potential barrier). The program requires that information pertinent to both null barriers (Z_b, C_o, and C_s) and real barriers be provided.

d. Volume Check. During the recession stage of flooding when water is draining off flooded blocks (via the barrier overflow relation), it is possible for the volume leaving in one time step as computed from $q_n'\Delta t$ to exceed the available volume. Therefore, a test is included in the program such that if this occurs, the flow is adjusted to only drain the block dry (D = 0), and the flow to adjacent blocks adjusted to be consistent.

e. Depth Check. When the water depth is very shallow the effect of the wind is such that a given block could become partially dry unless the fluid is flowing fast enough for the bottom stress to balance the wind stress. To avoid anomalous computations for very small D (e.g., in areas where rainfall is occurring over regions above the surge level), the wind stress is arbitrarily set zero when D is less than 0.1 foot.

2. Channel Algorithm.

a. Channel Specification. As in the case of barriers, those blocks on which channels occur are identified by the I and J values; for channel block K these are denoted by ICG(K) and JCG(K), respectively, where K = 1,2 ... KCM. Also each "channel block" may contain two channels, one on the right denoted the x channel and one on the upper side denoted the y channel. Each of these channel reaches is characterized by a channel width (w), a channel-bed elevation (Z_c), and a channel-friction coefficient (f_c). Figure 5 shows a schematic of a channel block indicating nomenclature for dimensions as used in the SURGE II program. Figure 6 shows the dependent variables pertinent to the channels as used in the program and stored for the channel block K. These include the channel flows, Q, at each end of the channel, one end designated N, the other P (corresponding to the negative and positive characteristic ends of the channel, respectively). Also included is the height, H, of the water level at the point in common to the two channels for block K (HC(K)). The lateral transport (per unit width per unit time) nominally to the channel from block K and from the channel is also indicated: UCT(K) and UCF(K), respectively, for the channel normal to the x-axis, and VCT(K) and VCF(K), respectively, for the channel normal to the y-axis. In the formulas in this study, these are referred to as q_t and q_f, respectively. Note that UCF(K) and VCF(K) correspond to U and V, respectively, on the right and upper sides of the general block flow. Also, the quantity HP(K) corresponds to the block (pool) height for the channel block. Values of H at the "negative" ends of the channels for channel block K are stored as HC values in adjacent channel blocks to minimize duplication of storage.

b. <u>Computation of Channel Variables</u>. The time phasing of block variables versus channel variables is indicated in Table 1. The H values occur at common times thus facilitating evaluation of head differentials used in determining lateral flow between channel and adjacent blocks.

Table 1. Time phasing of computations for blocks and channels.

Time	Block	Channel
$t + \Delta t$	H	H,Q
$t + \Delta t/2$	Q	
t	H	H,Q
$t - \Delta t/2$	Q	
$t - \Delta t$	H	H,Q

For a given channel reach, application of equations (28) and (29) can be made for two characteristic paths, as shown schematically in Figure 7. As in the case of the block computations, the friction term in equation (28) is taken proportional to the product of a new Q and

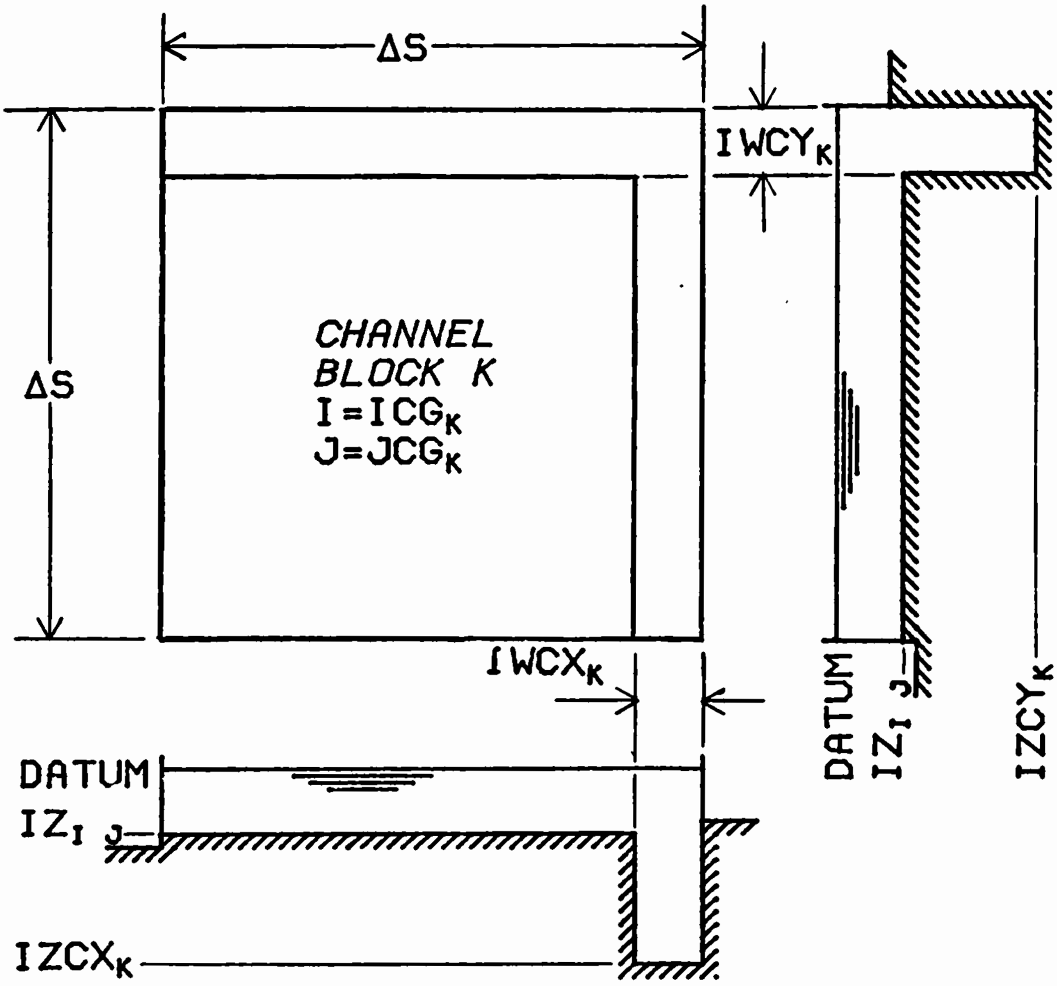

Figure 5. Channel block, showing channels and their dimensions.

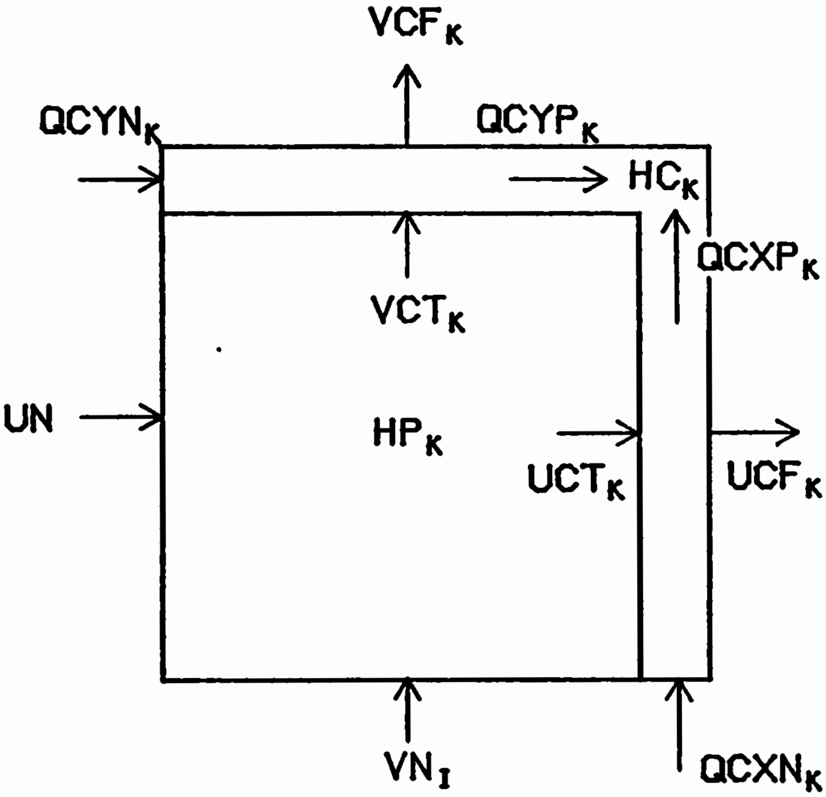

Figure 6. Channel block K at coordinates I = ICG(K) and J = JCG(K), showing associated flows and water level variables.

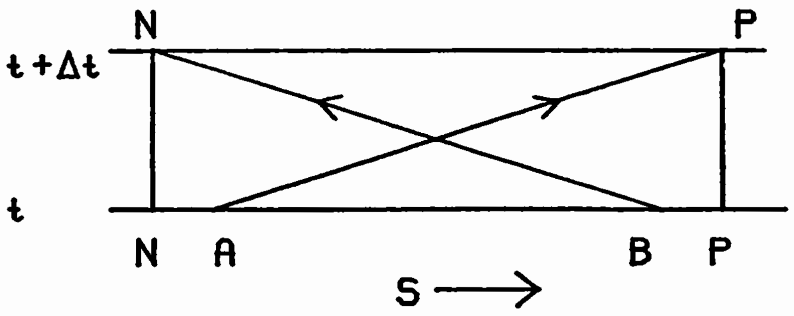

Figure 7. Characteristic paths on the time-distance diagram for an individual channel reach.

the absolute value of the old Q. Specifically, for the positive characteristic path from A to P' in Figure 7, equation (28) is approximated by

$$(Q'_P - Q_A) + w\sqrt{gD}\,(H'_P - H_A) = [WT_s - f_c|\bar{Q}|Q'_P/(\bar{D})^2 w + \sqrt{gD}\,\Delta q]\ \Delta t\ , \qquad (44)$$

where $\bar{D} = (D_N + D_P)/2$, T_s is the appropriate wind-stress component (X or Y) corresponding to time level t for the associated channel block, Δq is the net lateral flow per unit width, and $\bar{Q}$ is taken as

$$\bar{Q} = [(Q_N^2 + Q_P^2)/2]^{\frac{1}{2}}\ . \qquad (45)$$

The subscripts on Q, H, and D designate the points at which these apply (see Fig. 7) and primes denote new time level.

After regrouping terms, equation (44) can be written as

$$Q'_P + (w\ \sqrt{gD}\ /G)H'_P\ = [(Q_A + w\ \sqrt{gD}\ H_A) + (WT_s + \sqrt{gD}\ \Delta q)\ \Delta t]/G\ , \qquad (46)$$

where

$$G \equiv 1 + f_c \Delta t|\bar{Q}|/(\bar{D})^2 w\ . \qquad (47)$$

Similarly, for the negative characteristic from B to N',

$$Q'_N - (w\sqrt{gD}\ /G)H'_N\ = [(Q_B - w\sqrt{gD}\ H_B) + (WT_s - \sqrt{gD}\ \Delta t]/G\ , \qquad (48)$$

where $\bar{D}$ and G are as defined for the positive characteristic.

The values of Q and H at points A and B are determined by interpolation from values at N and P at time t, using equation (29) for the path. The distance from A to P or B to N, using the mean wave speed for the channel at time t is $\sqrt{g\bar{D}}\Delta t$. The interval N to P is equal to Δs. Let

$$\alpha \equiv \sqrt{gD}\ \Delta t/\Delta s\ ; \qquad (49)$$

this should always be less than or at most unity for stability of computation. The linearly interpolated values at A and B are then

$$Q_A = \alpha\, Q_N + (1 - \alpha)\, Q_P$$

$$Q_B = (1 - \alpha)\, Q_N + \alpha\, Q_p , \tag{50}$$

and similarly for H_A and H_B in terms of H_N and H_P.

The evaluation of Δq is the most sensitive part of the computations and is discussed in a subsequent section. Presuming Δq is known, the problem of evaluating the new Q and H individually at the channel-end points is considered. Note that equations (46) and (48) yield predictions for linear combinations of Q and H at two different points. Thus, information from adjoining channels, or other information in the case of channel end points, is needed to solve for the new channel Q and H. For a simple continuous channel without branches and consisting of a series of reaches of length Δs but not necessarily of equal width or depth, then Q and H are readily solved at a common junction, using the information from the positive characteristic from one channel and the negative characteristic from the adjoining channel. However, branches do occur and it is therefore desirable to use a sufficiently general procedure which will accommodate either branching channels or continuous channels.

In the scheme chosen for representing channels in SURGE II it is possible to have four channels merging at a common junction. Figure 8 shows this junction with four different volume transports, but with a common H. The designation of the different Q shown in this figure is that used in the coded program (see App. B); QC for channel transport, X or Y denoting the channel (not the direction of flow), and N or P denoting whether the flow is at the negative or positive end of a given channel reach. Each is identified by a channel block index K.

For any given channel reach equations (46) and (48) predict, for a given point, values of the quantities

$$BP \equiv Q' + \lambda H'$$

$$BN \equiv Q' - \lambda H' , \tag{51}$$

where

$$\lambda \equiv w \sqrt{gD}/G . \tag{52}$$

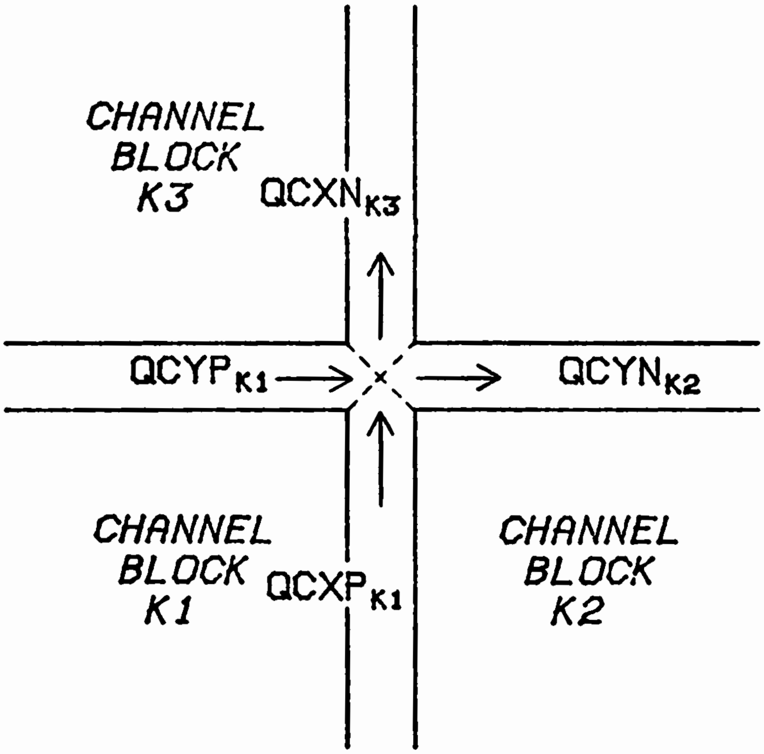

Figure 8. General channel junction, showing flows and channel identification.

For simplicity of notation let 1, 2, 3, and 4 denote the merging channels with 1 being the lower channel, 2 the left channel, 3 the upper channel, and 4 the right channel (Fig. 8). Then, with this notation

$$\begin{aligned} Q1' + \lambda 1 \cdot H' &= BP1 \\ Q2' + \lambda 2 \cdot H' &= BP2 \\ Q3' - \lambda 3 \cdot H' &= BN3 \\ Q4' - \lambda 4 \cdot H' &= BN4 \ . \end{aligned} \tag{53}$$

Now, continuity requires that

$$Q1' + Q2' - Q3' - Q4' = 0 \tag{54}$$

at a common junction. Thus,

$$(\lambda 1 + \lambda 2 + \lambda 3 + \lambda 4)\ H' = BP1 + BP2 - BN3 - BN4 \tag{55}$$

from which H' can be calculated at the junction. With H' known, the values of Q1', Q2', Q3', and Q4' are readily evaluated from equation (40).

For those cases where one or two of the above merging channels do not exist (i.e., null channels), then their width and λ value are zero. Moreover, the program yields zero for the BP or BN values of any null channel. Thus, equations (55) and (53) can apply for a general junction consisting of from two to four real merging channels.

c. Net Lateral Flow. The net time rate of water accumulation in the channel per unit length due to lateral exchange with blocks and by rainfall is

$$\Delta q = q_t - q_f + wR \ , \tag{56}$$

where q_t corresponds (if positive) to the flow (per unit length of channel) from the channel block to the channel (across the "interior" side of the channel, Fig. 6) and q_f (if positive) is the flow (per unit length of channel) from the channel to the adjacent block. These flows can be positive, negative, or zero. To allow for channels which have widths w much smaller than the block grid size Δs, and since the above q values are comparable to those which exist across the sides of blocks, the change in channel water level can be very sensitive to the difference $q_t - q_f$. Hence, special care must be taken in the model to avoid possible instabilities caused by improper calculation of these transverse flows. However, there is no particular difficulty with the rainfall term in equation (56) which is generally at least one order of magnitude smaller than that of the "net" lateral flow. In a sense, the potential difficulty with the transverse flows, q_t and q_f, arises because the Δt chosen for stable calculation on the blocks is usually too large for stable calculation for narrow channels, unless the coupling with blocks exists only in respect to longitudinal flow from the channels to blocks at end points of such channels.

On a given side of a channel, basically four physically distinct situations can occur: (a) a barrier (levee) or block ground level of sufficient height exists to prevent lateral flow; (b) overflow exists from an adjacent flooded block into a channel where the water level is less than the adjacent barrier or ground level; (c) overflow of adjacent barrier (levee) exists from the channel to an adjacent dry block or one where the water level is lower than the barrier elevation; or (d) both the channel water level and the water level on the adjacent block exceed the height of any intervening barrier and the lateral flow depends on the difference of water level. These four situations are illustrated in Figure 9. In the fourth situation, the water level could also be lower on the channel side with the associated lateral flow reversed.

For situation (a) there is no problem, the appropriate lateral flow (q_t or q_f) being constrained to zero value. For situation (c), the predictive-type barrier relation (eq. 55), with auxiliary relations (eqs. 39 and 40), could be used. In principle, the above predictive barrier relations should apply for situation (b) as well, provided that L in equation (39) is taken as the channel width w. However, since w can be much less than Δs for many applications, Γ can be so small that the relation for q_n' reduces virtually to a diagnostic-type relation of equation (40), or more specifically of equation (9) for barrier overflow. Since situation (b) might occur on one side of the channel and situation (c) on the other, and since both should be evaluated by relations compatible with a common time level, the simple diagnostic relation (eq. 9) has been adopted for both situations in the SURGE II program. This, however, still demands special checks and possible adjustments, as will be discussed later. Finally for situation (d), a submerged barrier-type calculation might seem appropriate if the depth over such a barrier is small compared with that of the channel or adjacent block; however, use of such relations in preliminary versions of the program proved to be very vulnerable to numerical instability. The reason for this is related to the above discussion concerning the usual case where $w/\Delta s$ is very small. As a consequence, for situations of type (d), a special calculation is required which treats the channel as essentially an integral part of the associated channel block or the adjacent block.

As stated above, for overflow situations (b) or (c), i.e., to or from the channel, the relation,

$$q_n = \pm\, C_o D_b (g D_b)^{\frac{1}{2}} \;, \tag{57}$$

is used where $D_b = H - Z_b$, H being the water level on the high side of the barrier. While this relation gives a valid value of $q_n (q_t$ or $q_f)$ at the time t, the value of q_n may change significantly over the prediction interval Δt if $(gD_b)^{\frac{1}{2}} > w/\Delta t$.

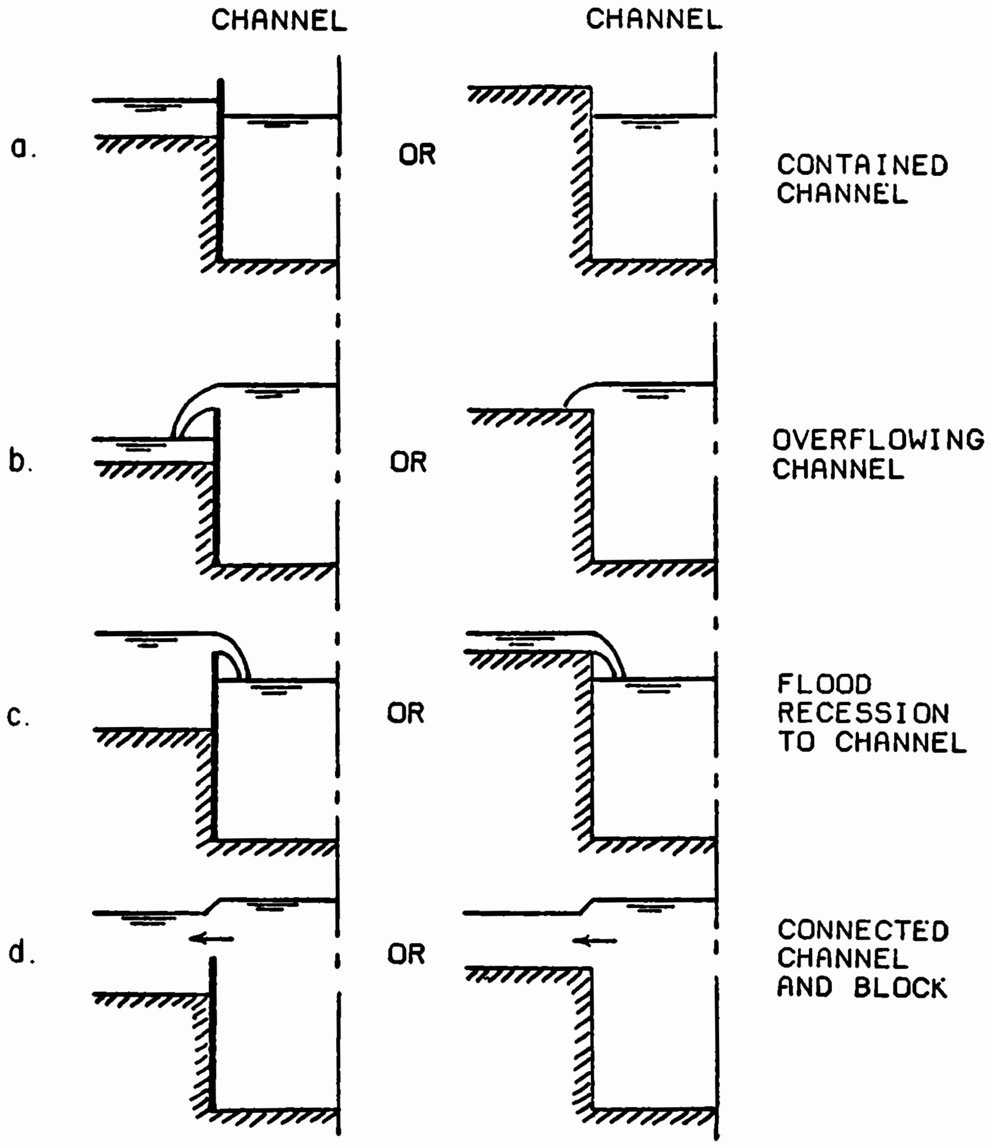

Figure 9. Different situations along a given side of a channel.

Under such circumstances, an approximate prediction based on the initial values of q_n could lead to physically impossible changes of channel level. Thus, tests are included in the program to constrain the lateral flow, such that $q_t - q_f$ alone will not cause the channel level, H_c, to fall below a minimum possible value nor rise above a maximum possible value, depending on the situation. Six different situations requiring tests are illustrated in Figure 10 (the "mirror" version of each is also a possible situation). Situations where one side of the channel is blocked are special cases of those indicated. For situations A, C, and E, outflow exceeds inflow and the horizontal dashline represents a minimum level based on the sill depth of the channel. On the other hand, for situations B, D, and F, the horizontal dashline represents a maximum possible level. In each case, the maximum possible change in H_c is indicated as ΔH_c.

For any of the situations illustrated in Figure 10, the SURGE II program compares $|q_t - q_f|$ with $|wH_c/\Delta t|$. If the latter is exceeded by the trial value of $|q_t - q_f|$ then an adjustment is made in q_t or q_f such that $|q_t - q_f|$ equals $|w\Delta H_c/\Delta t|$. For cases A, B, C, and D, both q_t and q_f are prorated by a common factor to satisfy the above constraint. For cases E and F, only the overflow q is adjusted to be consistent with the above constraint.

For situation (d) where the channel and block are connected by a continuous water surface (Fig. 10), the net lateral flow to the channel, Δq, is taken to be that which would be required to bring HC to a value equal to the existing mean level, HM, of the connected channel and block. For a channel connected to a block on one side only then,

$$HM = \frac{HB \cdot L + HC \cdot W}{(L+W)} , \tag{58}$$

where HB is the water elevation on the water-connected block, L is its width, while HC and W are the water elevation and width for the channel. The block width L is $\Delta S - W$ if the connected block is the channel block containing the channel, or is ΔS for an adjacent water-connected block. If the channel is water connected on both sides, then the above relation is replaced by an appropriate average over both blocks plus the channel.

The Δq for either of these situations is taken as

$$\Delta q = (HM - HC)w/\Delta t . \tag{59}$$

To determine the individual q_t and q_f on either side of the channel, the mean of these is taken to be that which is calculated as the flow

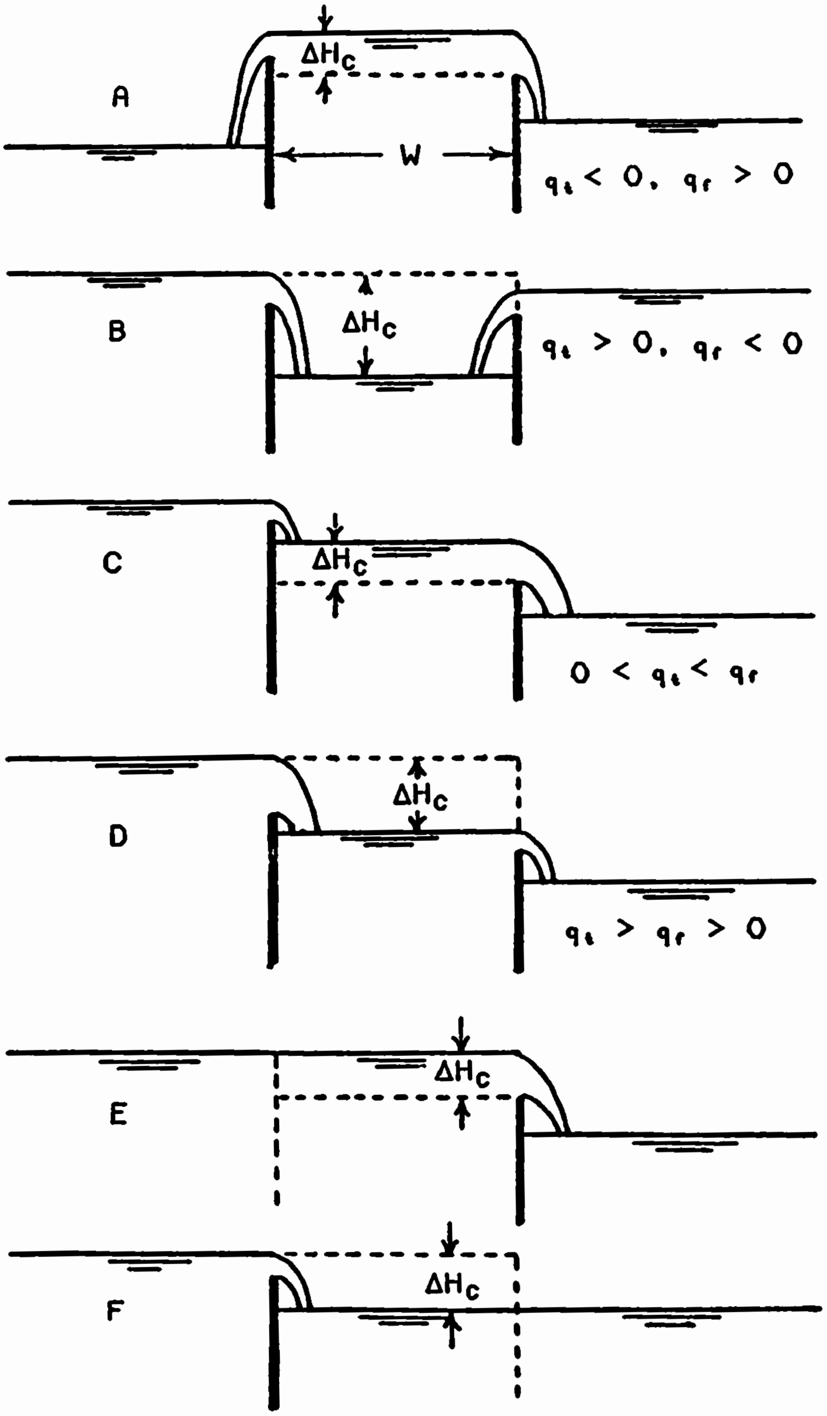

Figure 10. Situations involving overflow to or from a channel which require special checks.

between blocks, ignoring the presence of the channel (but considering barriers). Letting this be denoted q_m, then

$$q_t = q_m + \Delta q/2$$

and (60)

$$q_f = q_m - \Delta q/2 \ .$$

This system of calculation leads to stable results.

d. Channel End-Point Computations. At the end point of a given channel system, special computations are required. Two types of end conditions are used: an "H-end condition" is used where a channel discharges into a lake, bay, or sea, in which case the channel H value at the end point is taken equal to the H of the adjacent channel block into which the channel discharges (or vice versa); a "Q-end condition" is used at the head of a channel or river at which point the discharge is specified.

For a Q-end point

$$Q' = \pm Q'_r$$

$$H' = (Q' - B)/\lambda \ , \tag{61}$$

where Q'_r is the specified river discharge (taken as zero if not specified); B equals BP or $-BN$, as defined by equation (51), for end points occurring at the positive or negative end of the channel reach, respectively, and λ is as defined in equation (52). The sign of Q' is taken such that Q' is directed into the channel, depending on the channel-end orientation. There are four possible orientations (see App. B, Fig. B-3).

The H-end points also have four possible configurations; these are depicted along with the associated adjacent "ponding" areas (i.e., a block with $Z < 0$) in Figure 11. For an H-end point neither the longitudinal flow to or from the channel nor the H at the junction with the ponding block is specified *a priori*. It is required only that the predicted H at the channel-end point and that of the ponding block be the same. Let H^* be the (tentative) predicted H for the ponding block in the absence of any contribution by longitudinal discharge to or from the channel which terminates adjacent to that block. Thus, H^* corresponds to the H resulting from the routine block calculation using equation (33) with appropriate adjustments for contained channels as might occur for situations 3 and 4 shown in Figure 11. These adjustments are discussed in a subsequent subsection. The correct predicted H for the ponding block in the presence of longitudinal discharge from a channel is given by

$$H' = H^* + (Q'_d + Q_d)\Delta t/2A_b \ , \tag{62}$$

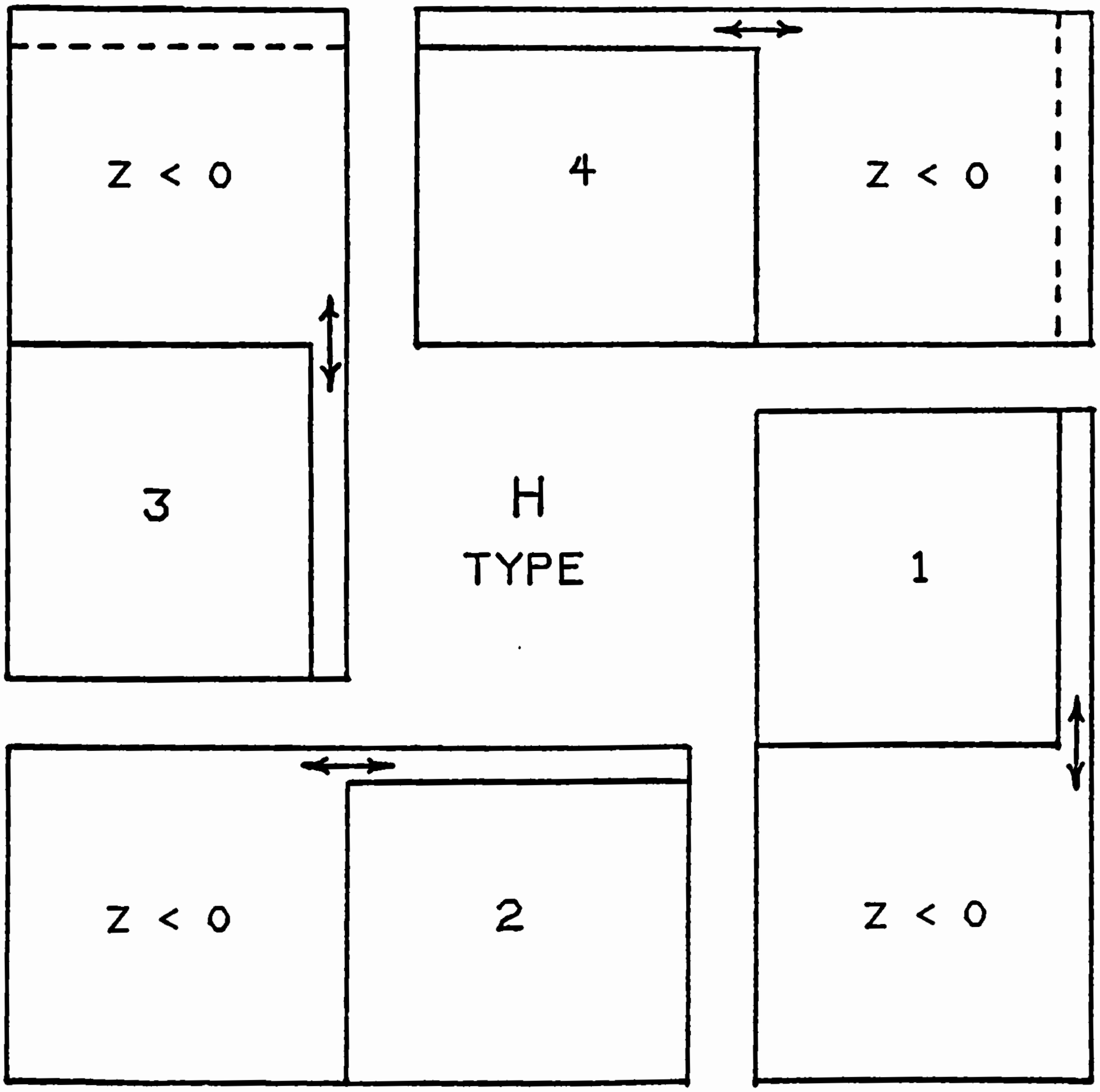

Figure 11. Possible end-point configurations and index identification (1 to 4).

where Q_d' and Q_d are the new and previous values, respectively, of the discharge from channel to ponding block, and A_b is the effective surface area of the block. For situations 1 and 2 in Figure 11, $A_b = (\Delta s)^2$, but for situations 3 and 4 a channel might exist on the ponding block in which case $A_b = (\Delta s - w)\Delta s$.

Equation (62) involves two unknowns H' and Q_d'. However, for the channel,

$$Q_d' + \lambda H' = B \ , \tag{63}$$

where $B = -BN$ for end-point type 1 or 2 and $B = BP$ for end-point type 3 or 4, BN, BP and λ being those quantities defined by equations (46) to (52). Note that for end-point type 1 or 2, Q_d' is the negative of the QC value for the channel.

The resulting H' and Q_d' for an "H-end" condition are

$$H' = (F + B\Delta t/2A_b)/(1 + \lambda\Delta t/2A_b) \tag{64}$$

$$Q' = (B - \lambda F)/(1 + \lambda\Delta t/2A_b) \ , \tag{65}$$

where

$$F \equiv H^* + Q_d\Delta t/2A_b \ . \tag{66}$$

e. Calculation of H on Channel Blocks. For blocks with $D > 0$ and containing one or two channel reaches, the prediction relation for H given by equation (33) is not valid. The correct relation for a channel block k having location i,j is

$$H'(i,j) = H(i,j) + [U'(i,j) - UCT'(k)]\Delta t/(\Delta s - wx)$$
$$+ [V'(i,j) - VCT'(k)]\Delta t/(\Delta s - wy) \tag{67}$$

where UCT and VCT are as shown in Figure 6 and correspond to the q_t discussed previously. If only one channel exists (i.e., if wx or wy is zero), then

$$UCT'(k) = U'(i + 1,j) \text{ if } wx = 0$$

or

$$VCT'(k) = V'(i,j + 1) \text{ if } wy = 0 \ .$$

IV. APPLICATION TO THE SABINE-CALCASIEU SYSTEM

1. Adopted Grid and Simulated Topography.

The Sabine-Calcasieu system geographically bridges the Texas-Louisiana border and is physically linked by a system of manmade channels and a low-lying region extending 25 miles between Sabine Lake and Lake Calcasieu.

A local chart of the region is shown in Figure 12. The rectangular border indicates the region included in the numerical analog. The selection of the size of this rectangle is dictated by the basic hydrodynamic features required to adequately represent the region and then the logistical and economic limitations placed on the computations by the availability of computer storage. The region selected is 56 × 40 nautical miles. The grid size (DELX) is taken as 2 nautical miles, so that IM =28 and JM = 20.

Figure 13 is a contoured plot of the schematized topography superimposed on the selected grid system. The offshore topography is regular with the exception of a shallow region adjacent to Sabine Pass and a slight embayment lying between Sabine Pass and the outlet from Lake Calcasieu at Cameron. Both lakes are adequately represented by the grid interval of 2 nautical miles. Figure 14 clearly delineates three high topographic areas in the numerical model: the Beaumont rise in the northwest, the Orange rise, and a more gradual rise northeastward to the Lake Charles area. The low-lying region between the lakes, immediately behind the shoreline barrier, and forward of the rises, forms a large ponding area during the inundation sequences. Between each rise a major channel is present, the Neches River, the Sabine River, and in the Lake Charles region, the Calcasieu River runs northeastward from Lake Calcasieu.

The deepest block in the system is -24 feet (MSL). Assuming a 10-foot surge, a value of DELT equal to or less than 260 seconds (Sec. III, 1,b) is required. The value chosen for DELT is 240 seconds.

2. Channel and Barrier Schematization.

The numerical discretization of the area shown in Figure 12 is given as an overlay in Figure 15. In this illustration the channel network (shown by full lines) shows the landward interconnection of Sabine and Calcasieu as well as the link with the Intracoastal Waterway as the lower left- and right-hand channels. Each channel segment has been provided the physical characteristics of width and cross-sectional area that best reproduce the pertinent information for the channel reach that was provided by the Corps of Engineers. The extent of the channel system was chosen on the basis of past inundation history and the judgment of the authors.

The barrier system, also shown in Figure 15, represents the major manmade and natural obstructions to flow above MSL. At the shoreline the major dune line is continuous with the exception of an apparent open area east of Sabine Pass. The block elevation of that area equals the adjacent barrier heights. Jetties are included at each of the openings to the Gulf of Mexico. Within the region the majority of barriers are manmade levees erected for protection. The heights of all barriers were chosen on the basis of data provided by the Corps of Engineers.

Appendix D has a listing of all data used for the Sabine-Calcasieu region in the simulation of the Hurricane Carla surge. The topography,

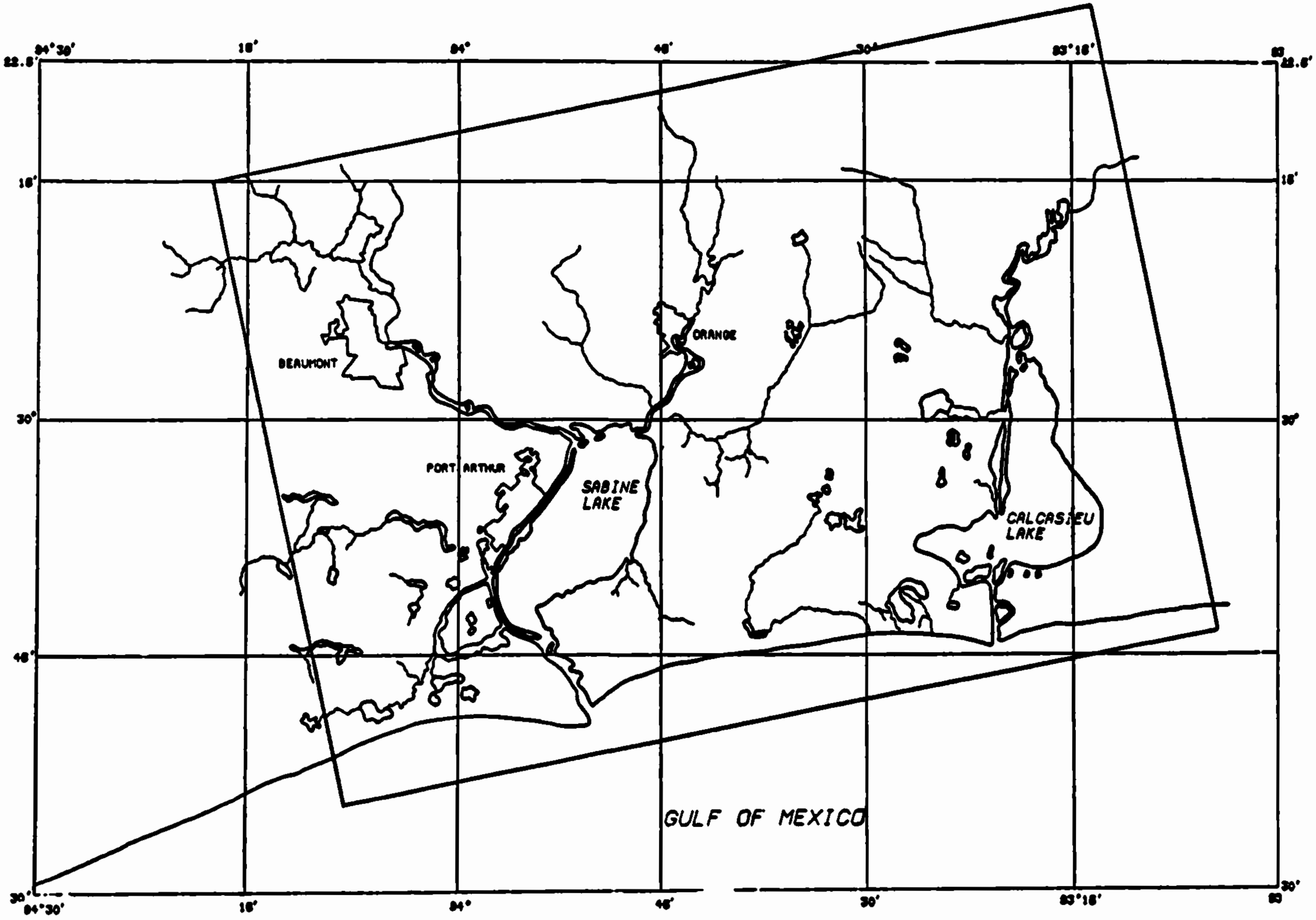

Figure 12. Map of Sabine-Calcasieu region showing grid boundary.

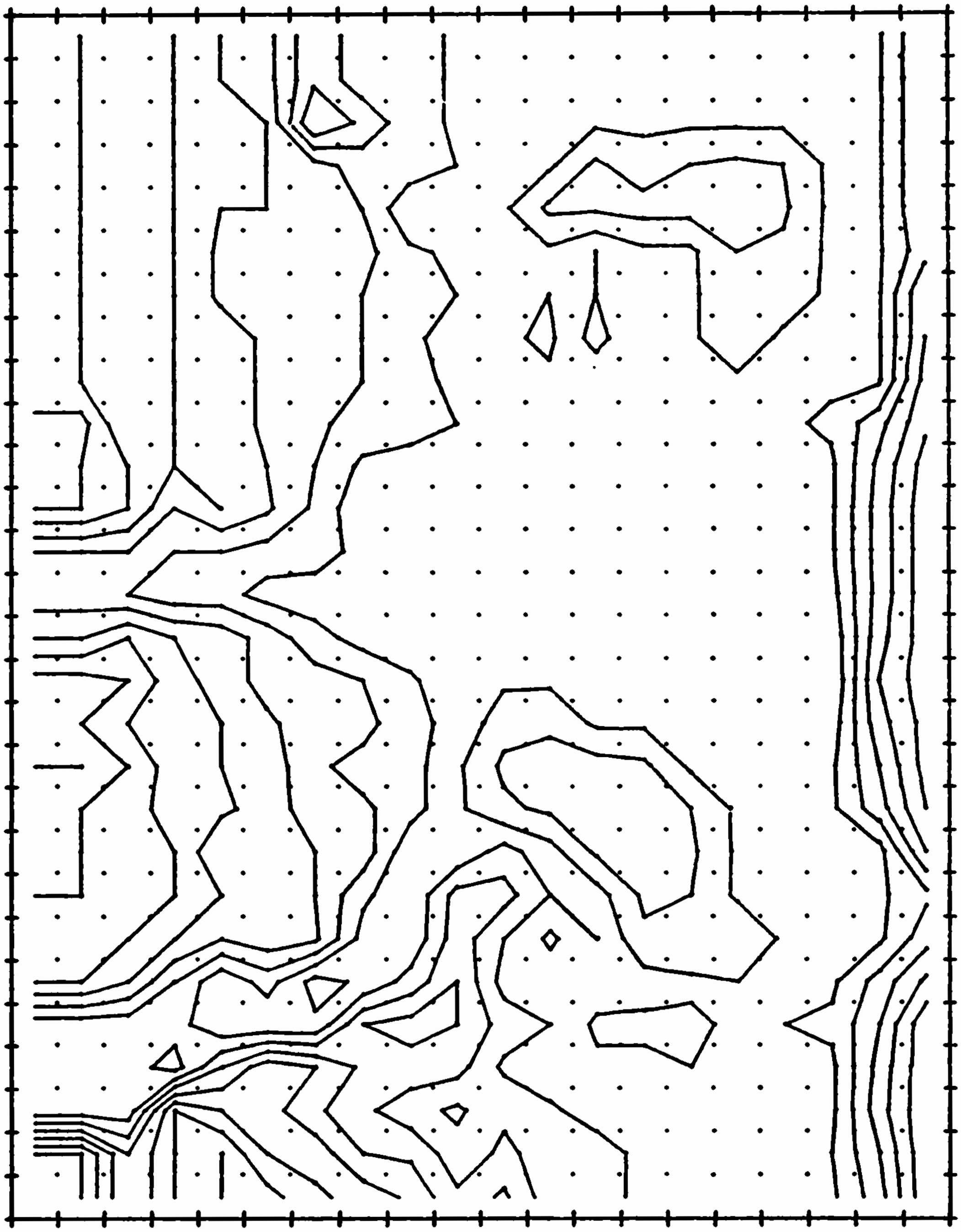

Figure 13. Topography contours at 5-foot intervals for Sabine-Calcasieu region (broad uncontoured area between Lakes Sabine and Calcasieu has elevations between 0 and 5 feet).

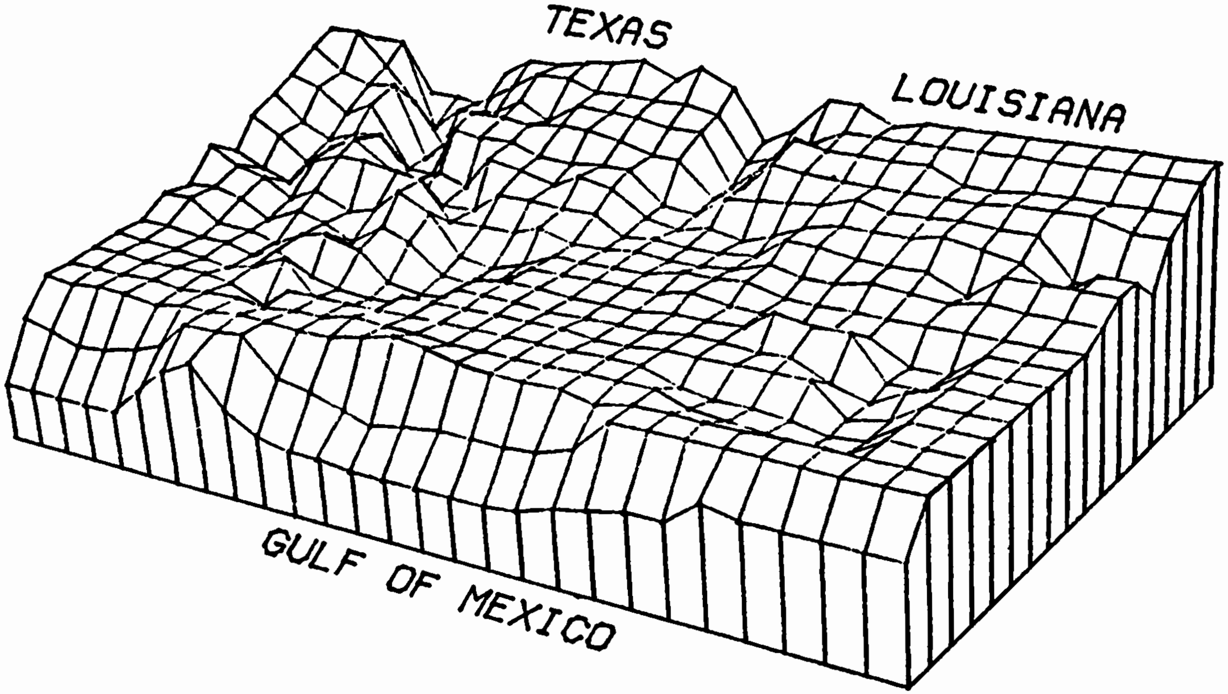

Figure 14. Topography in perspective for the Sabine-Calcasieu region.

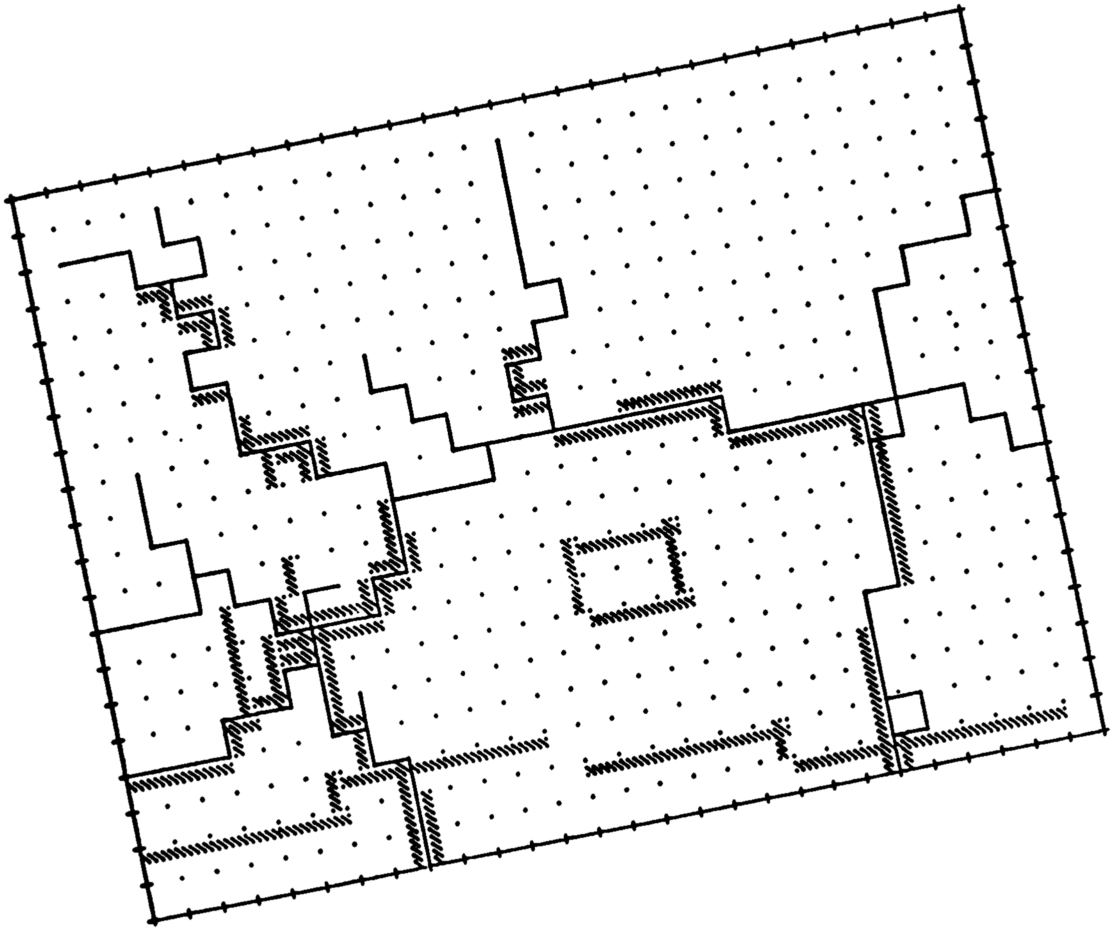

Figure 15. Overlay of grid (dots), channels (full lines) and barriers (hatched) on scale of Figure 12.

barrier data, and channel data are the same for the astrotide simulations and the standard project storms. There are 91 barrier blocks and 121 channel blocks of which 53 are common to barrier blocks. Examples of null channel blocks are for K = 4, 6, 18, 21, 24, etc., a total of 19.

Appendix E shows a plot of the block topography with the channel and barriers superimposed. This plot is given on two pages; x (or I) runs from left to right and y (or J) runs from bottom to the top of the page (I values are indicated along the top of both pages and J along the left side of the first page). Also in Appendix E is a listing of the key arrays for channels as generated by the program. Note that the final array size for channels is 128 (KCMP), there being 6 channels which terminate on the boundary of the grid.

As an illustration of barrier input note from Appendix E that for block (2,2) a y barrier exists, but not an x barrier. The bed elevation of block (2,2) is -10 feet while that of block (3,2) is -13 feet. Thus, a value of ZX of -10 feet should have been input for this block. The listing of the barrier input data in Appendix D gives the information for block (2,2) at K = 12 with ZX = -100 (tenths of feet) which checks. The actual barrier on the upper side indicates a positive 6 feet. However, barrier block K = 13 at the adjacent block (3,2) shows a ZX value of -12 feet. Reference to the topography in Appendix E indicates that this is the elevation of adjoining block (4,2) which is higher than block (3,2) and hence is the correct entry.

For an illustration of the sign coding concerning barriers along channels, refer to the channel input data in Appendix D and the plot in Appendix E. Channel block K = 1 located at (8,1) shows a negative IWCX and a negative IZCX which is the coding for double levees of equal height with the channel in between. This is the location of the double jetty entrance channel for the Sabine region. Channel block 5 at location (7,4) shows a (+,-) signature for the x channel and a (+,+) signature for the y channel. Hence, the barrier for the x channel is on the inner lateral boundary while that for the y channel is on the outer lateral boundary (see App. C,6). Reference to Appendix E key array listings shows KCB = 37 for channel block 5. Barrier block 37 has the same location (7,4) and indicates valid barriers of a 5-foot elevation above MSL for both the x and y channels.

3. River Input and Hydrograph Gage Locations.

There are three river discharge locations provided for the Sabine-Calcasieu region. These locations, as given in block 9 of the input (App. D), are (28,15), (4,19), and (14,19) which are respectively for the Calcasieu River near Lake Charles, the Neches River north of Beaumont, and the Sabine River north of Orange.

Nine gage locations for the astrotide calibration and Hurricane Carla simulation are shown as small circles in Figure 16. All of these with the exception of the North Sabine Lake gage are located on channels.

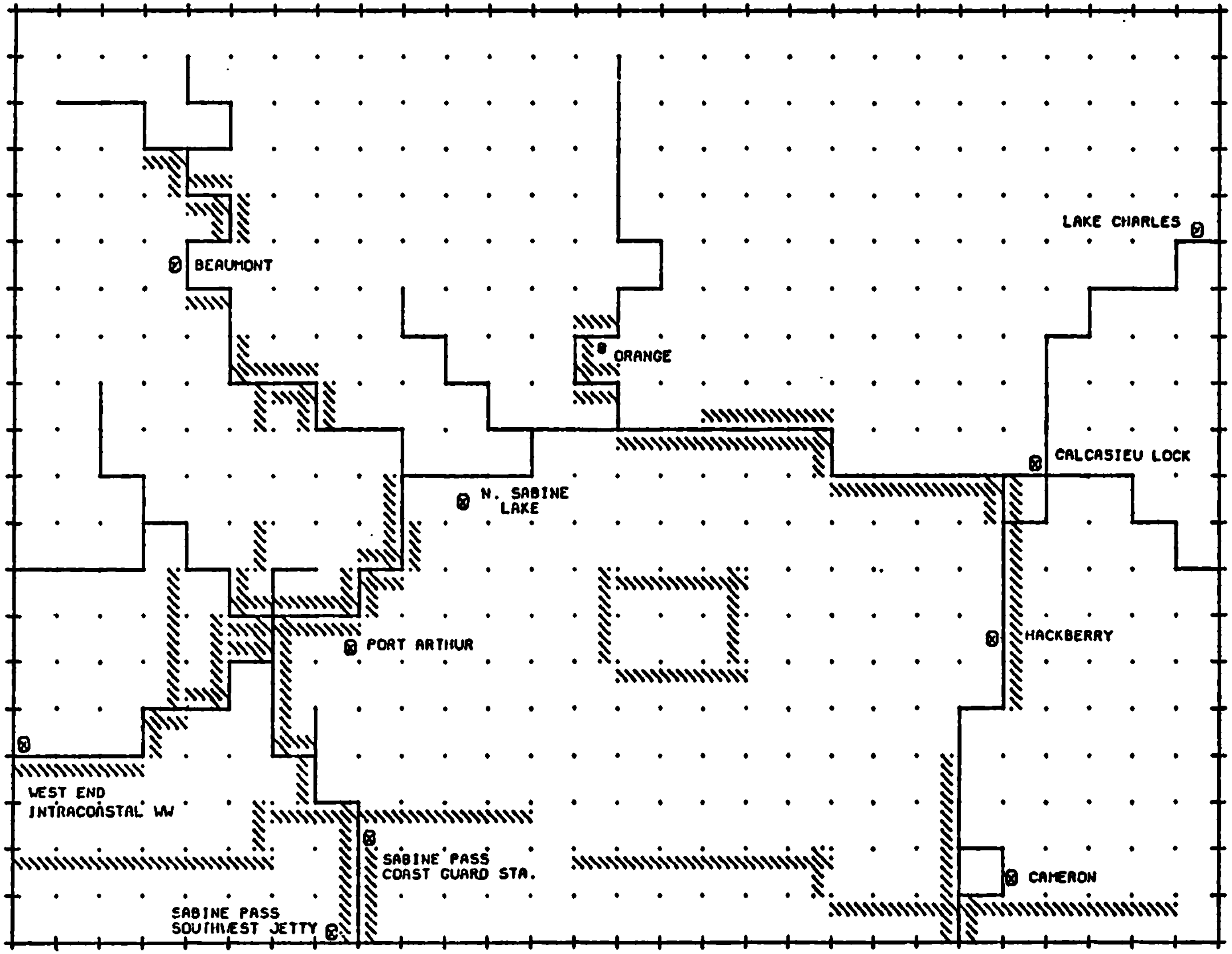

Figure 16. Plot of channels and barriers showing locations of hydrograph gages (θ).

V. TIDAL CALIBRATION

1. Tide Data.

The tidal calibration is a required step in the preparation of the numerical storm surge model. These computations permit the adjustment of the parameters representing the frictional effects in the channels and low-lying regions of tidal inundation. The calibration adjusts the tidal flows in order to adequately predict proper phasing and tidal excursions in the model region. Comparisons are made with actual tide records from geographical locations corresponding to blocks or channels in the grid.

Calibration of the Sabine-Calcasieu region was carried out for the springtide conditions that existed from 0000 hours, 22 August to 0000 hours, 27 August 1973. Tide recordings at nine locations in the region were furnished by two U.S. Army Engineer Districts (Fig. 16): Sabine Pass (southwest jetty), Port Arthur, north Sabine Lake, Brakes Bayou (Beaumont), and Orange, Texas, provided by the Galveston District; Cameron, Hackberry, Calcasieu Lock, and Lake Charles, Louisiana, provided by the New Orleans District.

The tidal calibration must be accomplished during a period when the tide is effectively the only forcing function operating on the system. This requires no abnormal riverflows into the region and winds which will not substantially alter the slope of the water surfaces. Such conditions existed for the first 96 hours of the 120-hour record period and this interval was used in the tidal calibration.

2. Estimation of f_c for Entrance Channels.

Many of the bays or lagoons along the Texas coast are of such dimensions that their largest natural period is small compared with the tide period. Moreover, virtually all have narrow connections with the Gulf of Mexico. These two features conspire to produce a reduction of tidal range and a significant lag within the bay compared with the gulf tide. In addition, the tidal range is nearly uniform throughout the bay except possibly in some of the upper reaches of adjoining rivers. For these systems, the approximate response can be calculated in terms of the channel-friction coefficient, f_c, (or discharge coefficient) plus appropriate dimensions of the bay and entrance channel (Love, 1959). These relations can be used to get at least a preliminary estimate of f_c from the observed response.

Consider a bay of total MSL surface area, A_s, which is connected to the sea by a channel of cross-sectional area A_c, surface width W, effective depth D_c (defined as A_c/W), length L_c, and channel-bed friction coefficient f_c.

Let H be the volumetric response in the bay at time t (where $H \cdot A_s$ represents the impounded tidal volume above MSL at time t); let Q be the tidal flux from the sea to the bay. Then,

$$A_s \frac{dH}{dt} = Q \ . \tag{68}$$

Neglecting the inertia effects in the channel for the slow tidal variation, the slope force in the channel is balanced by friction at any time t; thus,

$$H_g - H = m|Q|Q \ , \tag{69}$$

where H_g is the given tide level at time t outside the bay entrance and m is a dimensional constant for the system given by

$$m = \frac{fL}{gD_c A_c^2} \ . \tag{70}$$

This can also be written in the form,

$$m = \frac{1}{g(C_d \cdot A_c)^2} \ ,$$

where C_d is the discharge coefficient characterizing the constricted opening between bay and sea.

Assuming the input tide H_g is simple harmonic with period T and amplitude a_o then,

$$H_g = a_o \cos \omega t \ , \tag{71}$$

where $\omega = 2\pi/T$. Ignoring the second-order compound tide due to nonlinearity in equation (69), the response will be roughly of the form,

$$H = ra_o \cos (\omega t - \phi) , \tag{72}$$

where ϕ is a phase lag and r is the relative amplitude response. If these are substituted into equations (68) and (69) and the quantity $|Q|Q$ expanded in the Fourier series form, it can be shown that

$$r = \cos \phi \tag{73}$$

and

$$\sin \phi = \frac{\sqrt{1 + B^2} - 1}{B} \ , \tag{74}$$

where

$$B = \frac{8}{3\pi} m(A_s \omega)^2 a_o \tag{75}$$

(Love, 1959). A plot of r and ϕ versus the dimensionless parameter B is shown in Figure 17. The timelag of the high tide in the bay relative to that outside the bay is simply $T = \phi/2\pi$, for ϕ in radians (or $T = \phi/360$ for ϕ in degrees).

Thus, if r or ϕ is estimated from observations it is possible to get an estimate of B. Generally, the value obtained from the observed r will differ from that obtained from the observed ϕ; in this event an average of the values of B can be used to estimate f_c. In terms of B, f_c is given by

$$f_c = \frac{3\pi}{8} \frac{gB}{\alpha^2 A_s^2 \omega^2 a_o} , \tag{76}$$

where

$$\alpha^2 = \frac{L_c}{D_c A_c^2} . \tag{77}$$

It is emphasized that the above analysis pertains to a bay system connected to the sea by a single channel of uniform dimensions. The results can be generalized for the case of a series of N channels of different dimensions or of N channels in parallel or combination of both (as in the Sabine-Calcasieu system) by using an effective value of α^2.

Let α_n^2 designate the value of α^2 for an individual channel as evaluated by equation (77). Then, the effective value of α^2 for a series of N channels is simply

$$\alpha_s^2 = \sum_{n=1}^{N} \alpha_n^2 . \tag{78}$$

However, for N channels in parallel the effective α^2 is given by

$$\alpha_p^2 = \left(\sum_{n=1}^{N} \alpha_n^{-1} \right)^{-2} \tag{79}$$

For a series containing a parallel subset, the effective α^2, for the latter is used in equation (78). If two or more complex entrance channels are in parallel then the effective values of α are used in place of α_n in equation (79).

The use of this procedure will be illustrated for the Sabine-Calcasieu system. In the numerical simulation scheme there is a total of 40 blocks of 2 × 2 nautical miles covered with water and in communication with the sea. This represents a surface area of 5.91×10^9 square feet. In addition, the channels contribute a total of 0.64×10^9 square feet. Thus, the total surface area for the combined system is $A_s = 6.55 \times 10^9$ square feet (3.77×10^9 square feet for the Sabine part and 2.78×10^9 square

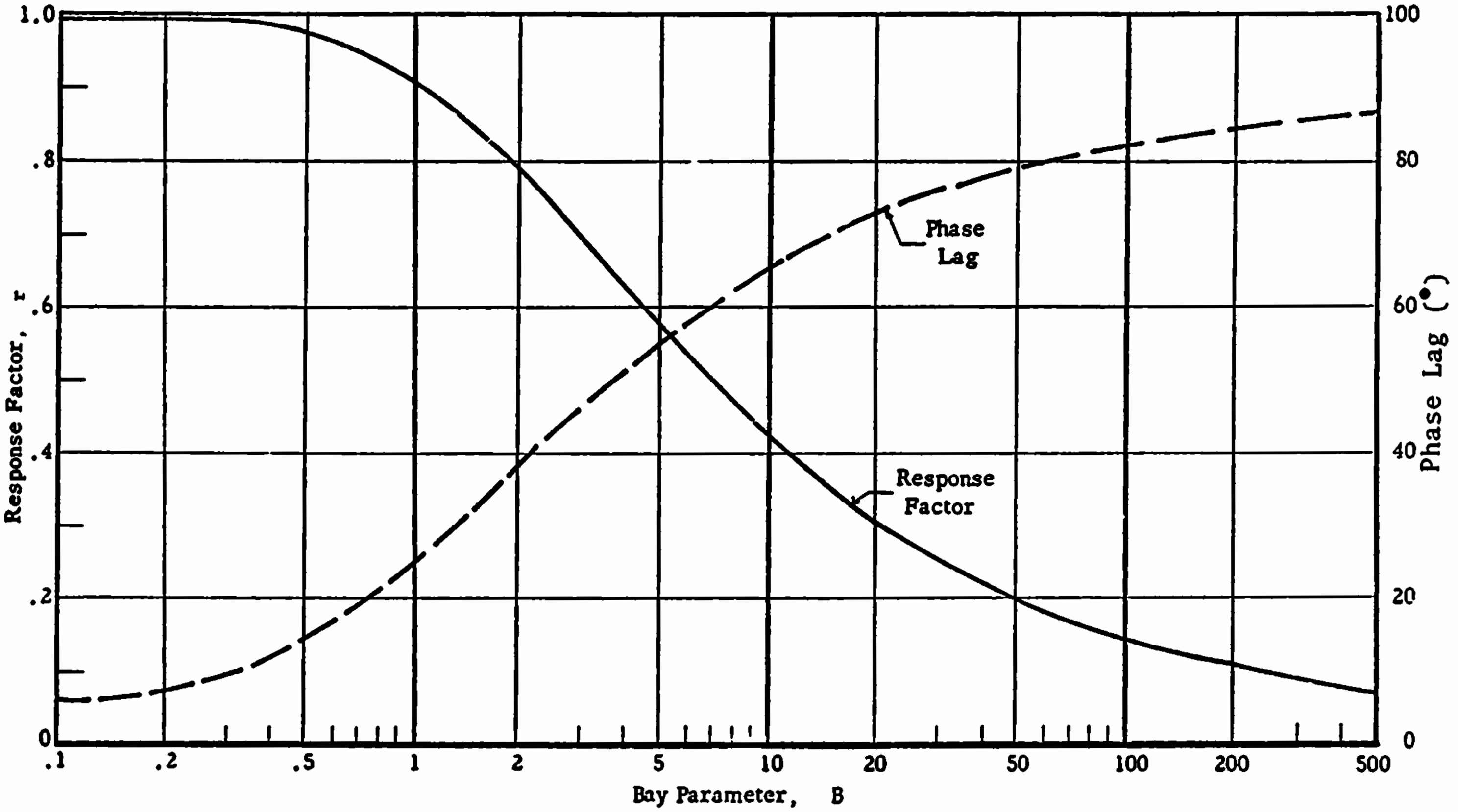

Figure 17. Amplitude response factor (r) and phase lag (ϕ) versus the dimensionless parameter B characterizing a constricted bay.

feet for the Calcasieu part). The two parts of the system are coupled via the Intracoastal Waterway and their responses are about the same, so the combined system is treated as one.

A summary of data and calculations pertinent to the entrance channels for the Sabine-Calcasieu system is given in Table 2 (see also Fig. 15 and App. D). The simulated Sabine Pass between the gulf and Lake Sabine consists of two sections (1 and 2 in Table 2) of different dimensions in series. However, Calcasieu Pass consists of a pair of parallel channels (4 and 5 in Table 2) in series with a simple channel (3 in Table 2). The individual α^2 for each channel is also shown in Table 2. The effective α^2 for Sabine Pass is the first partial sum shown in the last column. The effective value of α^2 for the parallel part of Calcasieu Pass is shown in the last column, opposite entries 4 and 5. The effective value for Calcasieu Pass is the partial sum indicated in the last column. The effective value for the entire pass system is evaluated from the Sabine Pass and Calcasieu Pass values, using equation (79) for parallel systems:

$$\alpha^2 = 0.32 \times 10^{-6} \text{ (square feet)}^{-1} .$$

Table 2. Data on simulated Sabine Pass and Calcasieu Pass.

n	W_c (ft)	D_c (ft)	A_c (ft^2)	L_c (ft)	$\alpha^2 \times 10^6$ (ft^{-2})	$\alpha^2 \times 10^6$ (ft^{-2})
			Sabine Pass			
1	2,330	20	46,600	24,360	0.561	0.561
2	2,860	21	60,060	36,480	0.482	0.482
Subtotal						1.043
			Calcasieu Pass			
3	800	32	25,600	24,360	1.162	1.162
4	500	40	20,000	12,160	0.760	0.455[1]
5	1,000	16	16,000	34,480	8.960	
Subtotal						1.617

[1] Evaluated by parallel channel relation.

The observed ranges and times of minimum tide for 25 August 1973 for the Sabine-Calcasieu system are given in Table 3. Gage 1 is used as the input gulf tide. The average of all other gages is used as the response. The indicated amplitude response is

$$r = \frac{1.50}{2.59} = 0.58 .$$

Using a tidal period of 25 hours the indicated phase lag is

$$\phi = (20.8 - 17.5) \frac{360}{25} = 47° .$$

Table 3. Ranges and times (c.d.t.) of available observed tides in the Sabine-Calcasieu system for 25 August 1973.

Gage No.	Place	Range (ft)	Time (hr)
1	Sabine Pass, southwest jetty	2.59	17.5
2	Port Arthur	1.53	19.0
3	North Sabine Lake	1.40	21.5
4	Beaumont	1.52	21.5
5	Orange	1.40	23.0
6	Cameron	2.05	17.5
7	Hackberry	1.06	22.0
8	Calcasieu Lock, west	1.45	20.5
9	Lake Charles	1.60	21.5
Average of 2 to 9, inclusive		1.50	20.8

From Figure 17 the corresponding values of B are 4.7 and 3.6, respectively, with an average of 4.1. The tidal frequency is

$$\omega = \frac{2\pi}{25 \times 3{,}600} = 7.0 \times 10^{-5} \text{ radians per second}$$

and $a_o = 2.57/2$ or 1.3 feet. Consequently, the estimated f_c for the entrance channels is from equation (76): $f_c = 0.0018$.

The final selected value of f_c for the entrance channels is 0.0015 as determined by trial runs. This is somewhat less than the above estimate. The difference might be accounted for by the fact that the tidal hydrograph is not really simple harmonic but contains compound tides (of higher frequency) giving the sharp minimum and broad or double-peaked maxima. The effective frequency is consequently somewhat greater than the ω given above, thus yielding a smaller f_c closer to 0.0015.

3. Final Calibration for Tide.

The major control on the response of the bay to the tides are the dimensions and friction factor for the entrance channels as discussed above. In this connection, it should be pointed out that channel dimensions (width and depth) were taken such that the average cross-sectional area (under MSL conditions) for a given reach is represented by the product of these dimensions. Thus, if the depth is taken as the mean for the reach, then the width will be somewhere between the width of the dredged channel and the surface width of the natural channel.

The values of channel friction for the remaining channels and of the block friction were selected by a trial-and-error procedure, starting with a uniform value throughout. The final values of channel friction for the upper reaches of the Neches and Sabine Rivers were taken as

0.0025 to give a reasonable agreement for the Beaumont and Orange tide response; it was necessary to use a low value (0.0005) for the upper reach of the Calcasieu River to reproduce the Lake Charles tidal hydrograph. The latter three gages (Beaumont, Orange, and Lake Charles) have connections to the inner bay areas only via channels, hence their responses are fairly sensitive to the channel friction. The low value for the Calcasieu River may be due to underestimates of the effective channel widths, which would demand a less than normal friction factor.

The block friction for the tide calculations was taken as 0.0015 to get a reasonable agreement for the north Sabine Lake gage. However, later calculations for the Hurricane Carla simulation (which is more sensitive to block friction than the astrotide) indicated that 0.0025 (as used in the Galveston Bay simulations) was more appropriate.

The results of the final astronomical tide simulations for a 96-hour period starting 0000 hours c.d.t., 22 August 1973, are given in Figures 18 to 26, and Appendix F. The input tide (Fig. 18) corresponds to the observed tide for the period at Sabine Pass (southwest jetty). In the subsequent eight figures the computed (full line) and observed (line with circles) are compared for the eight different gages within the system; the gages are identified in the figures. Note that the observed values for each gage have been adjusted with respect to a local datum, taken as the gage mean for a 120-hour period starting 0000 hours c.d.t., 22 August 1973. In all cases, the computed ranges are in fairly good agreement with the observed; however, there seems to be a consistent tendency for the computed to lag the observed. This might be due to a possible time-shift error for the input gage. Although a lowering of the frictional coefficient for the entrance channel would decrease the lag within the system, it would also increase the range of the tide everywhere in the system. It was felt that it was more important to reproduce the range than the times of high and low water, and hence the value of $f_c = 0.0015$ for the entrance channels was retained.

For the upper Calcasieu River (Figs. 25 and 26) the computed water level (which refers to a common MSL datum for the system) and the observed water level display an apparent vertical shift. This could be related to possible wind effects in the second part of the record, which have been ignored in the computations.

The steady river discharges adopted in the astrotide runs were 800 cubic feet per second for Calcasieu River, 1,100 cubic feet per second for Neches River, and 1,500 cubic feet per second for Sabine River.

Serial listings of the computed water levels at the gages discussed above are given in Appendix F, along with listings of volume transport at six channel positions. Flow at points 1 and 2 correspond to input (if positive) to the system through Sabine Pass and Calcasieu Pass, respectively. Since the tide amplitude is less than the seaward barriers, the two passes represent the only source of water for normal conditions.

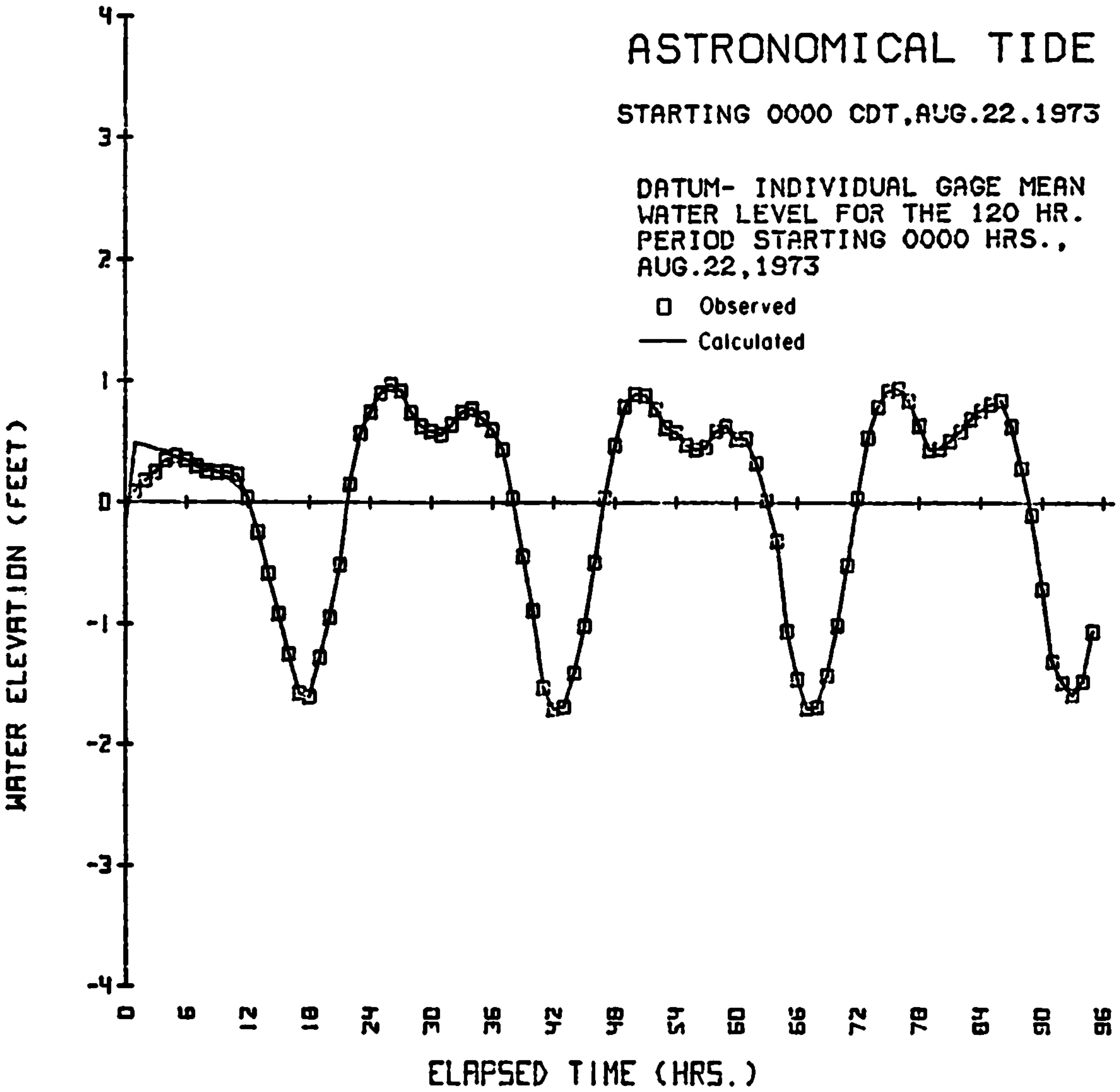

Figure 18. Astronomical tidal hydrograph for Sabine Pass, southwest jetty (input for tide calibration).

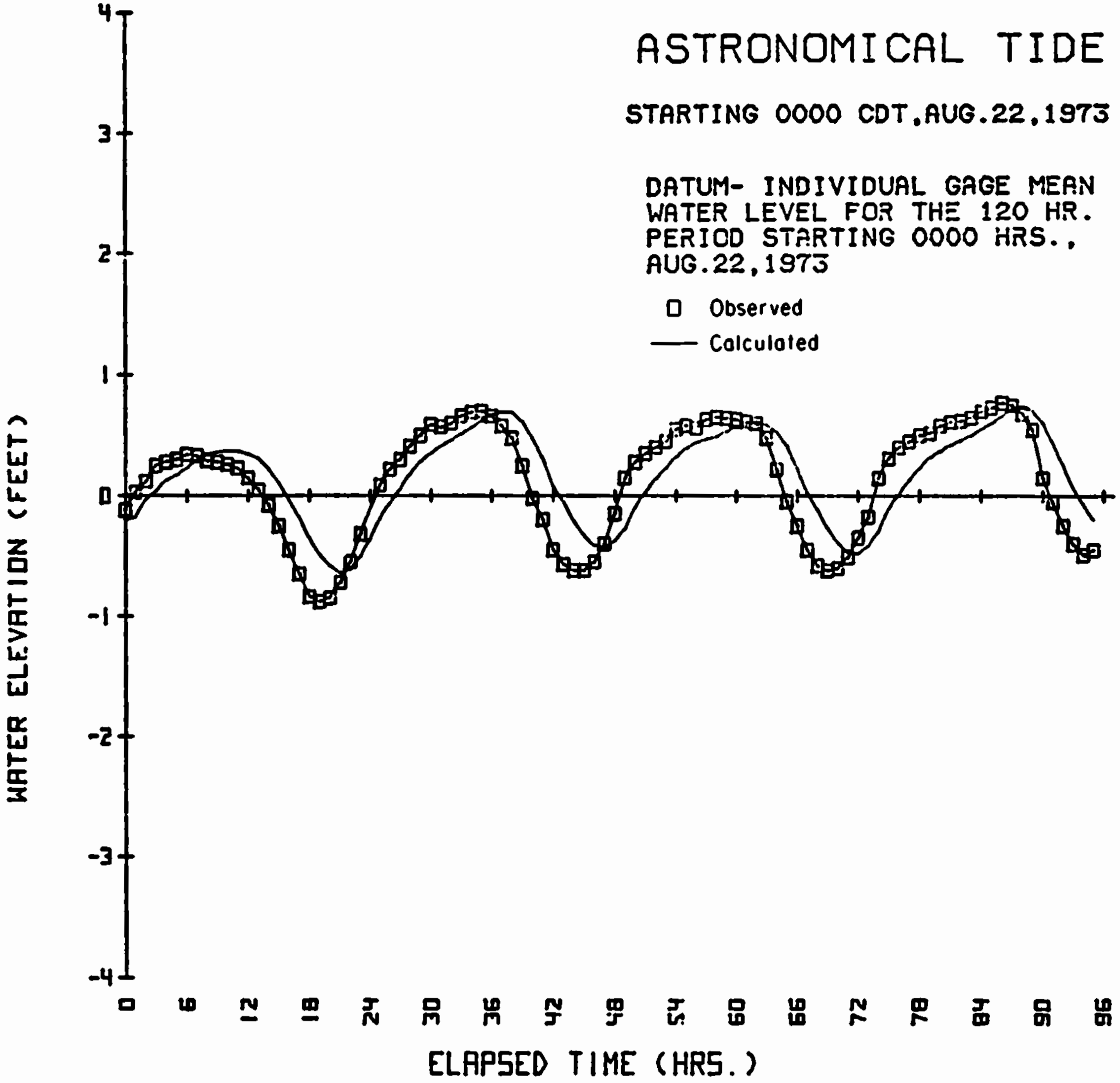

Figure 19. Astronomical tide for Port Arthur corresponding to input of Figure 18.

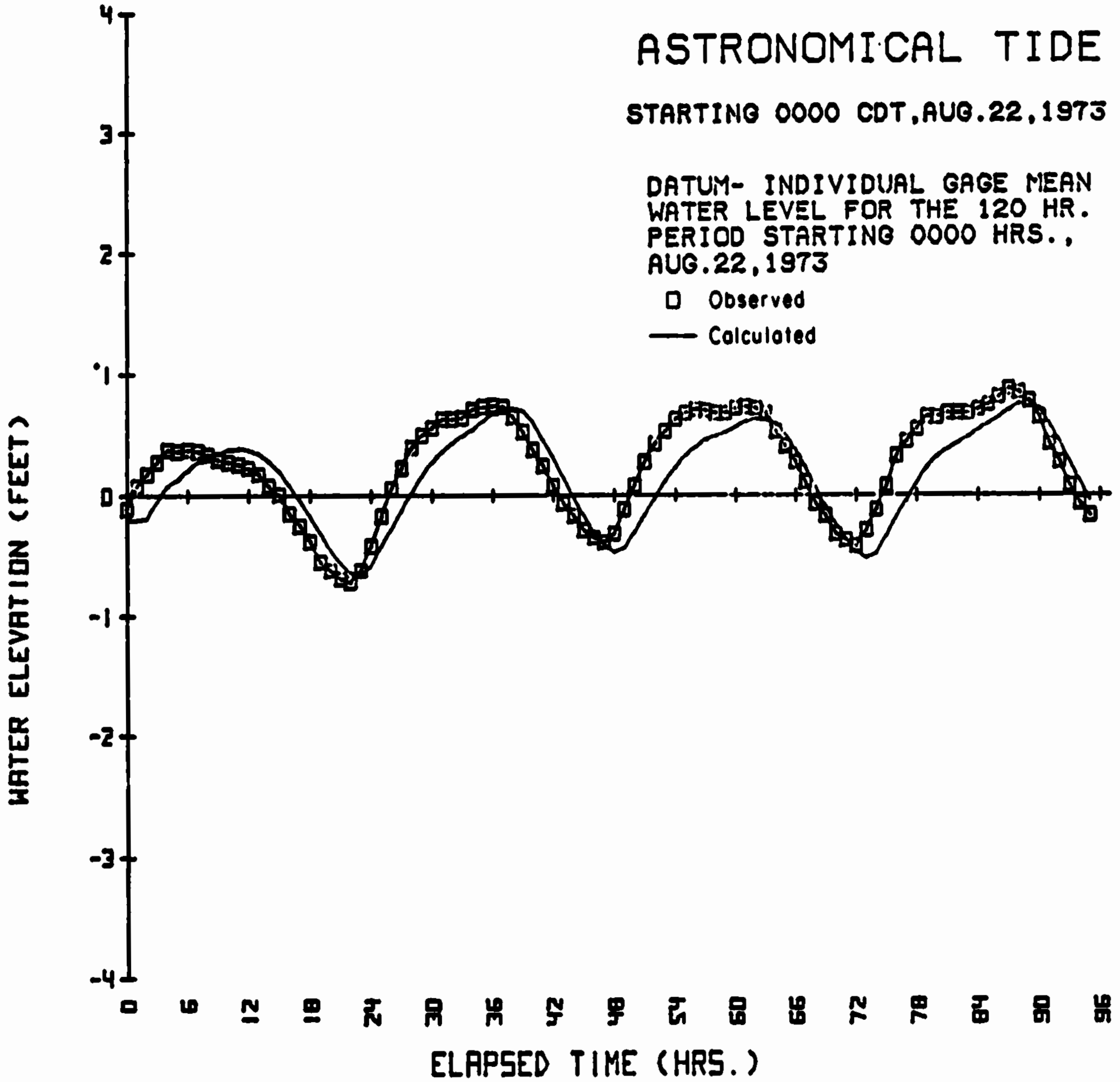

Figure 20. Astronomical tide for north Sabine Lake.

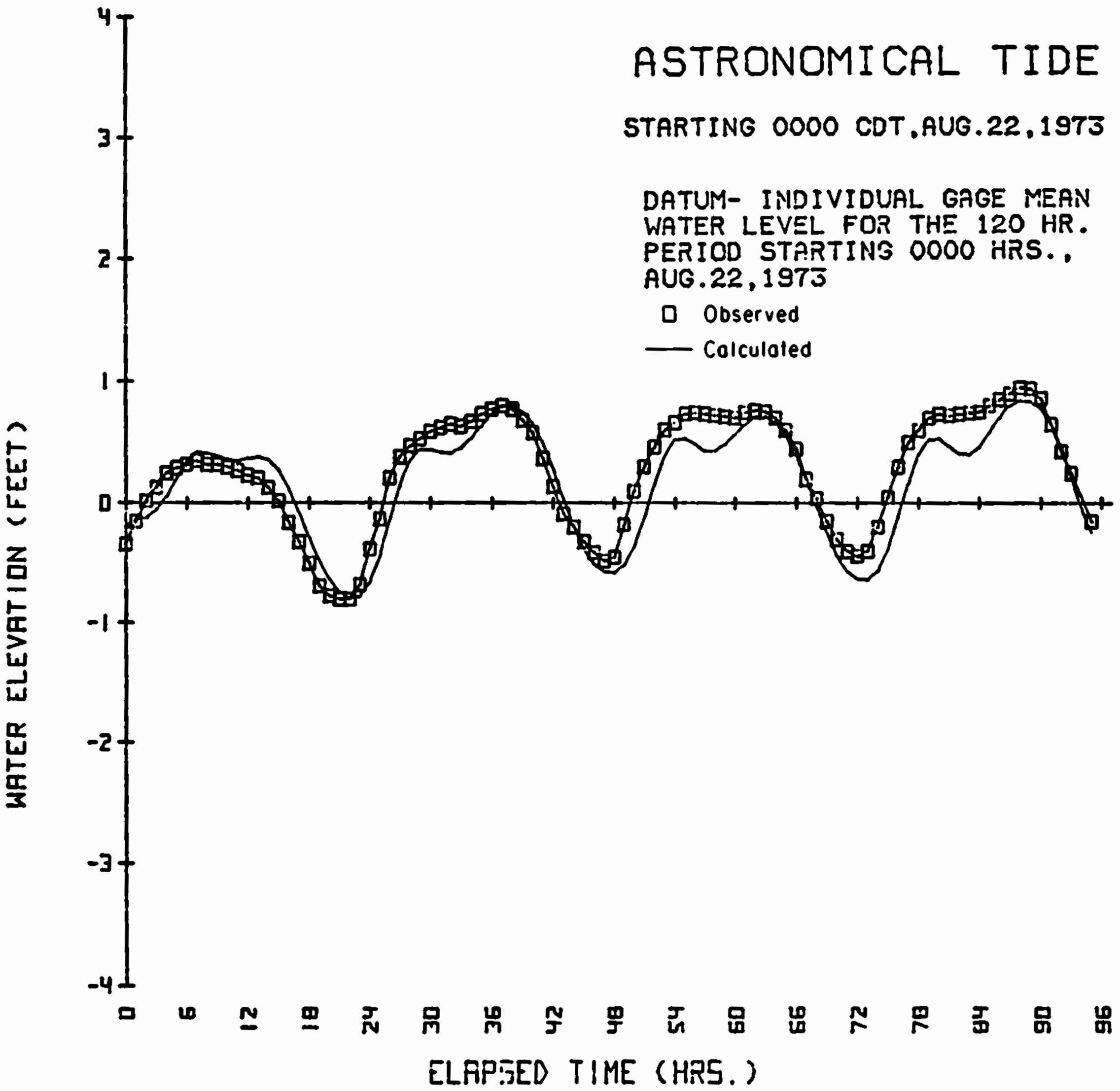

Figure 21. Astronomical tide for Beaumont, Neches River, and Brakes Bayou.

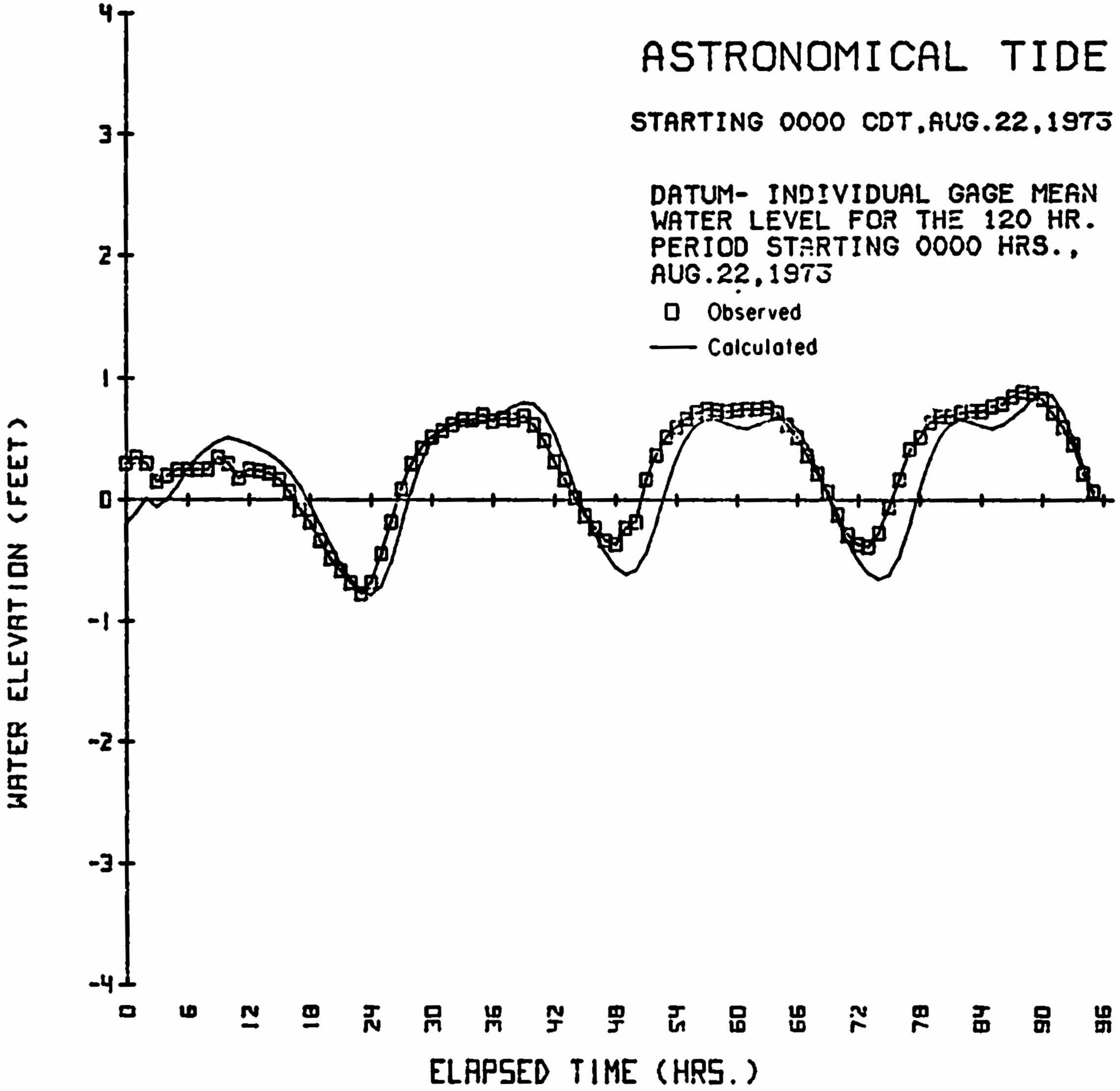

Figure 22. Astronomical tide for Orange Naval Station, Sabine River.

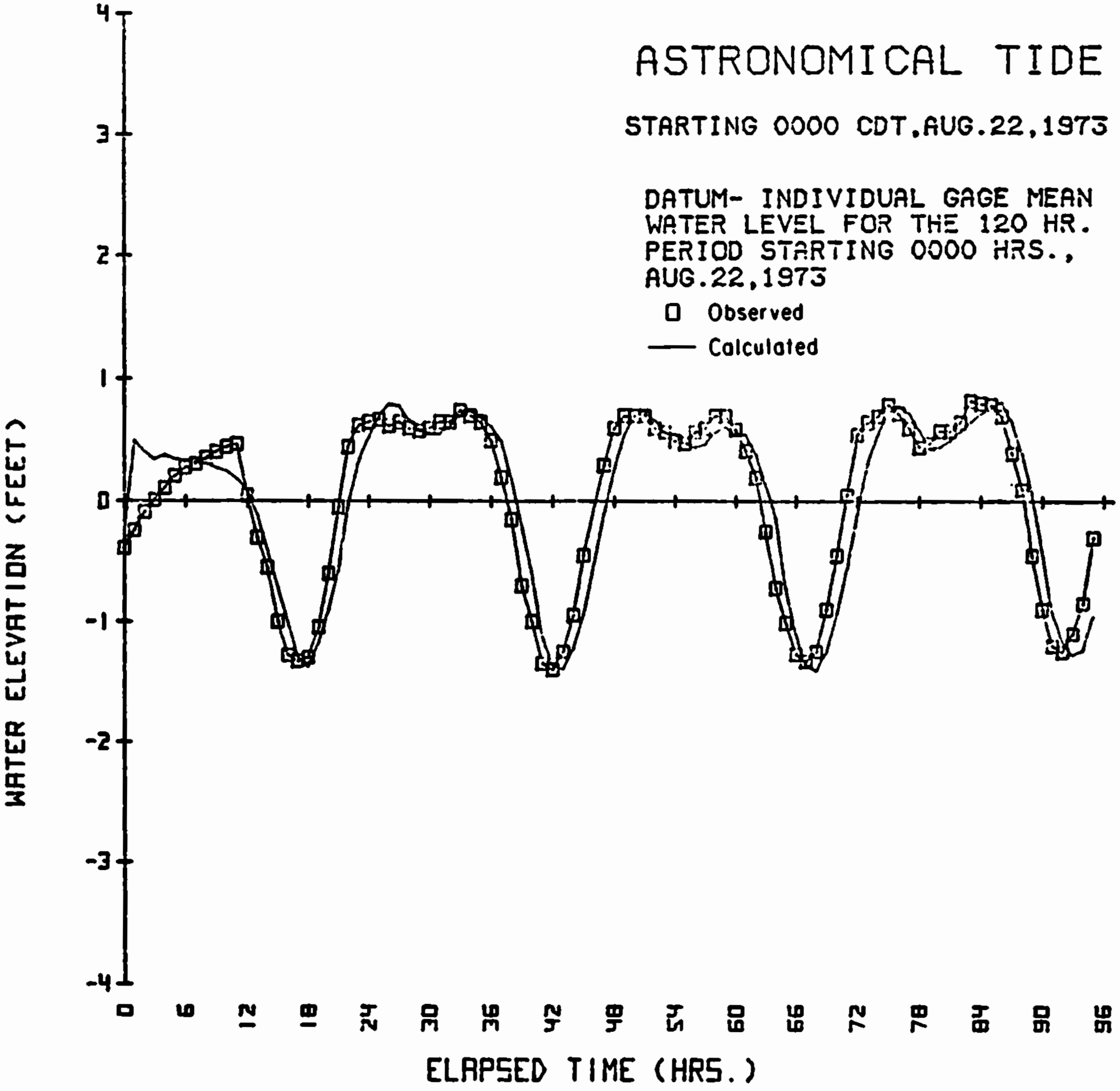

Figure 23. Astronomical tide for Cameron, Calcasieu Pass.

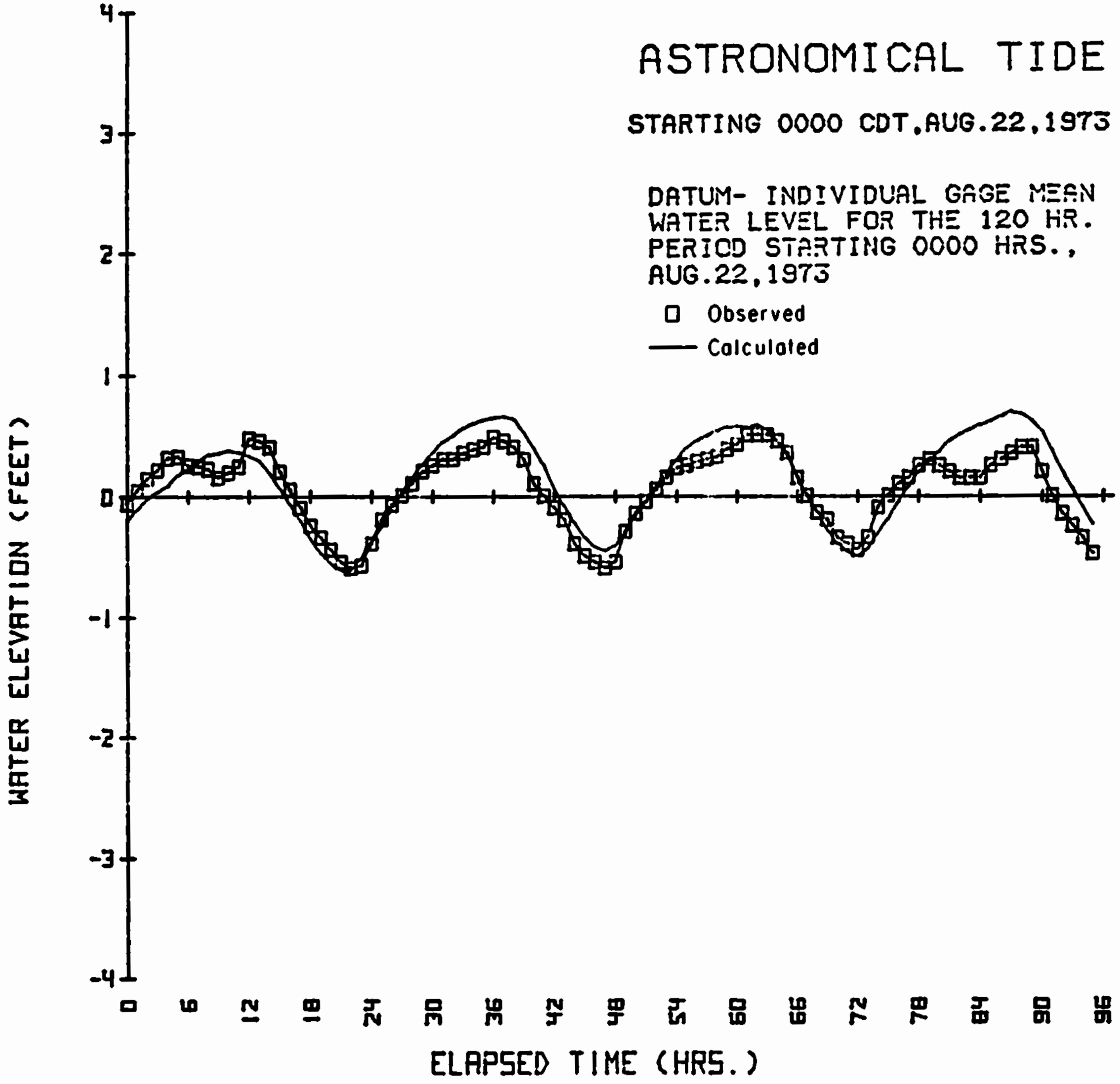

Figure 24. Astronomical tide for Hackberry, Calcasieu River and Pass.

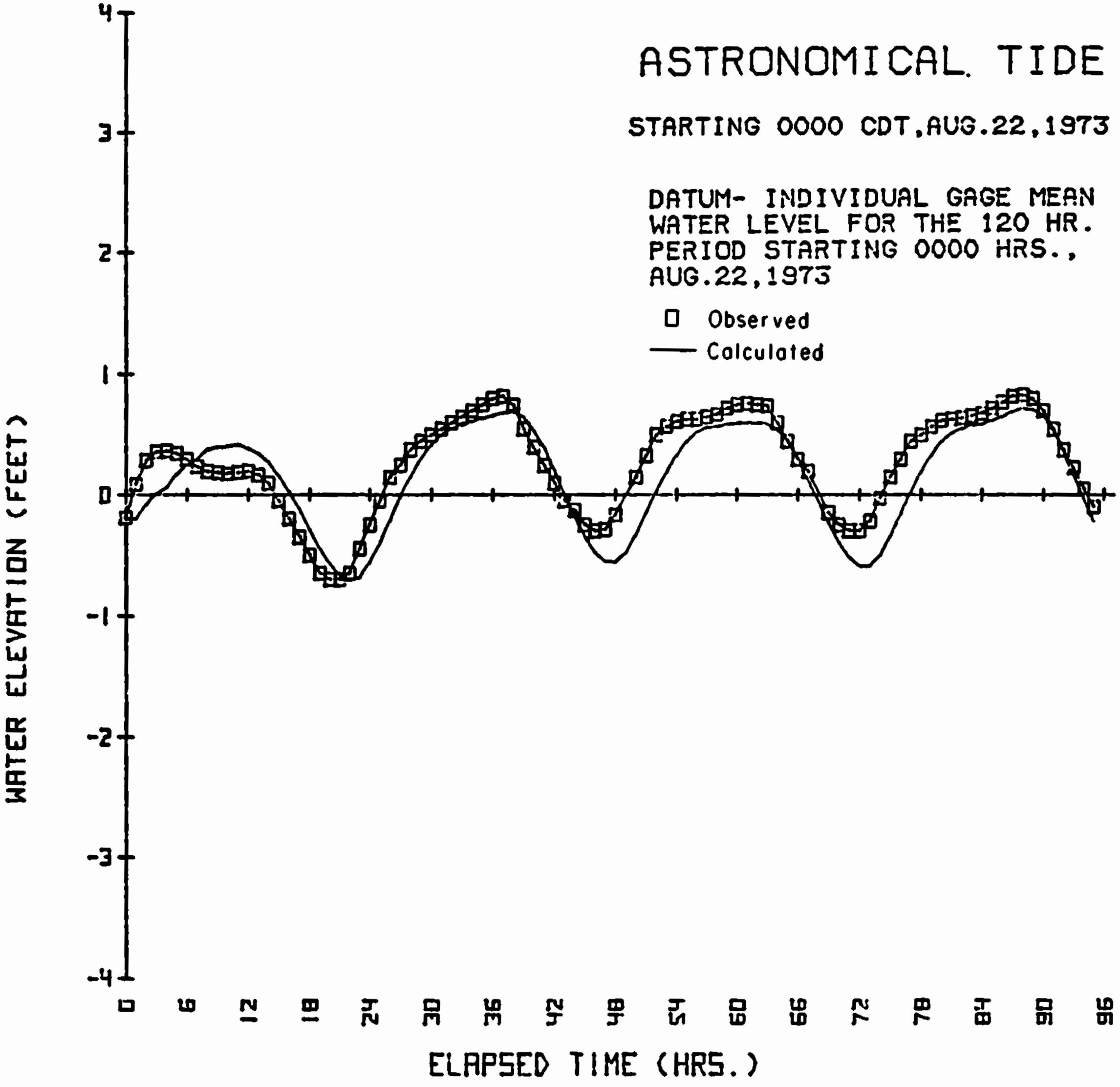

Figure 25. Astronomical tide for Intracoastal Waterway at Calcasieu Lock, west.

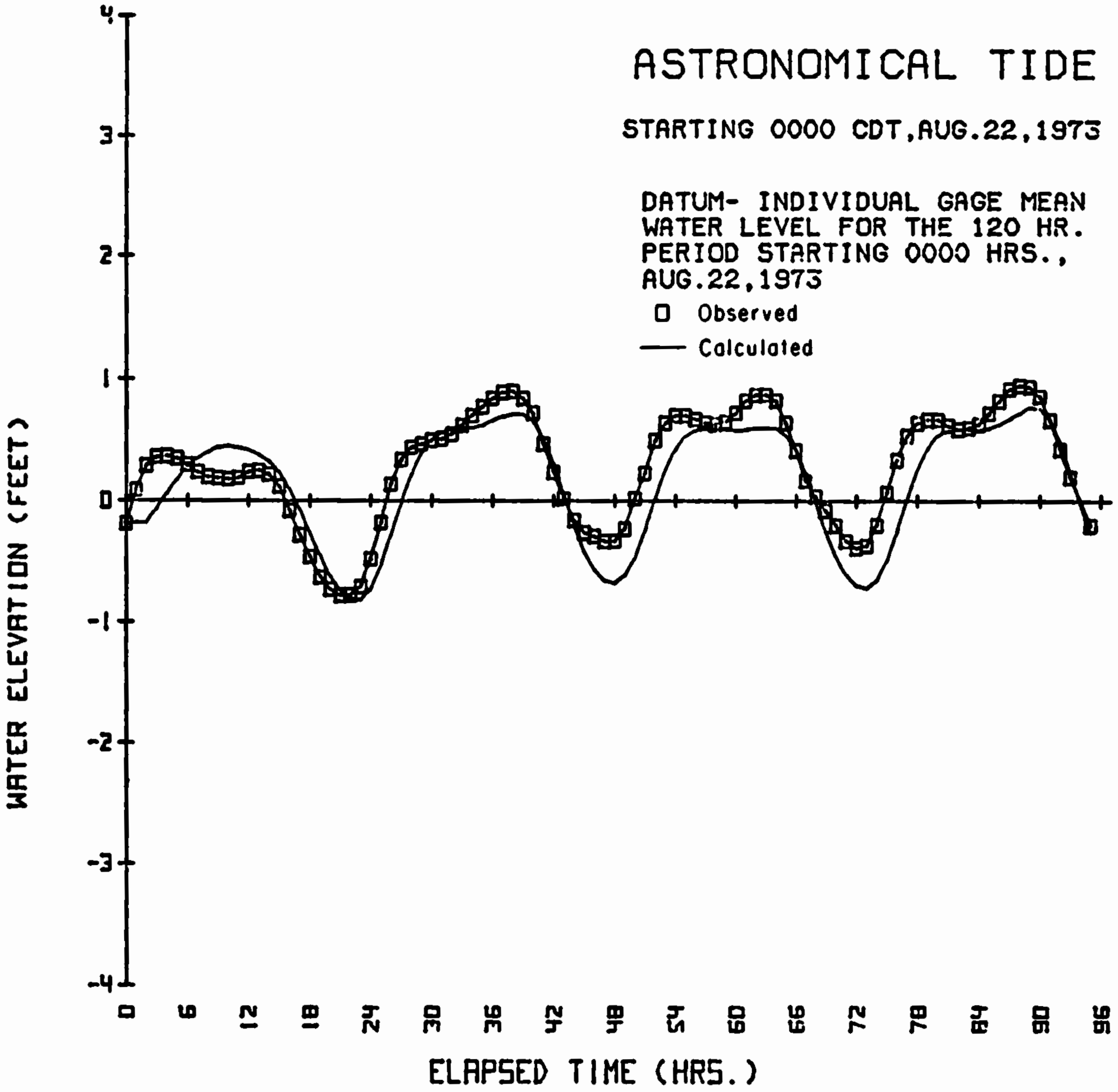

Figure 26. Astronomical tide for Lake Charles, Calcasieu River.

Reproductions of channel output at three different times (30, 60, and 90 hours from start) are shown in Appendix F. The output shows flows (in cubic feet per second), direction of flow, and water level along the various channel reaches at the specified times.

VI. HURRICANE CARLA VERIFICATION

1. Forcing Function Input.

a. Wind-Stress Fields. The x and y components of the wind stress for each 3 hours in a 72-hour period for an 8 by 6 coarse grid for Hurricane Carla are given in the input listings in Appendix D. For convenience in spotting possible errors in input, the wind-stress vectors were plotted, based on the above input, by a special subprogram. Samples of these plots for each 12 hours are shown in Figures 27 to 32. The plots showed suspect entries, which were subsequently corrected before any runs were attempted, and have I increasing upward and J increasing to the left; i.e., the seaward boundary is on the right.

b. River Discharge Input. The river discharges for the Calcasieu River, Neches River, and Sabine River for each 3 hours are listed as block (IDENT) 12 in Appendix D.

c. Gulf Hydrograph Input. The final input for HG, the water level input along the seaward boundary, was taken as interpolated values between Sabine Pass and Calcasieu Pass with input sequences at those passes adjusted to match the observed values at the Sabine Pass U.S. Coast Guard Station and Cameron after some modification due to flow through these passes. The input is given sequentially at 3-hour intervals along with the wind-field input in Appendix D.

2. Further Adjustments and Results.

a. Adjustments. In the series of runs for the Hurricane Carla simulation, it was necessary to make some adjustments in the block topography, particularly in the upper reaches of the Neches River, in order to provide more ponding area at the levels of flooding encountered. These changes, which are reflected in the final topography (App. D), do not change the results of the astronomical tide calibration because the changes were at levels well above those encountered with the astrotide runs.

A further modification was the reduction of the wind-stress values to 80 percent of those shown in the listings and in the vector plots for the upper left-hand region of the grid. Specifically for I.LE.3 and J.GE.4, the wind-stress components were so reduced in the final runs for Hurricane Carla. This reduction was also used in the later application for Standard Project Hurricane (SPH) simulations. The rationale for this adjustment is based on the greater sheltering in this region due to both topography and vegetation. The initial H for all locations in the bay was taken as 3.2 feet.

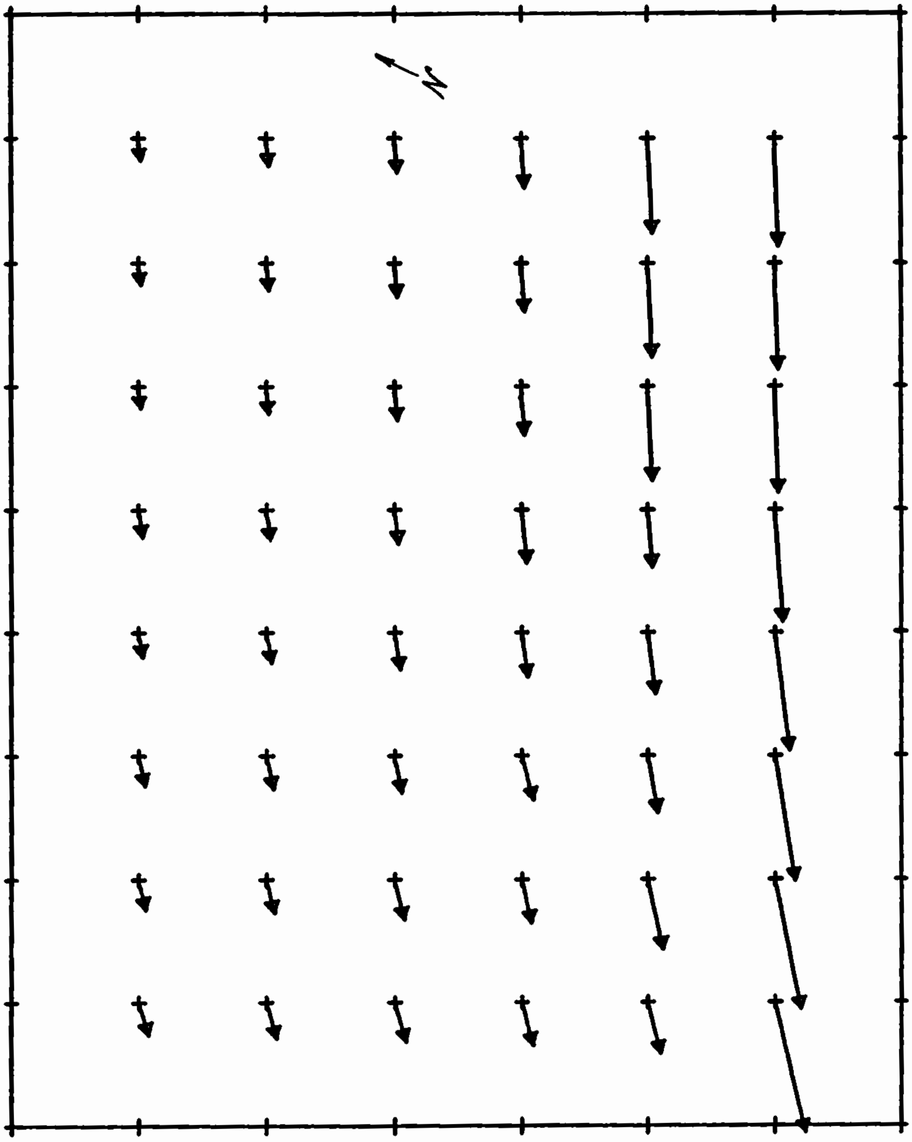

Figure 27. Wind-stress vectors for Hurricane Carla, over Sabine-Calcasieu region on an 8-nautical mile grid; time = 12 hours.

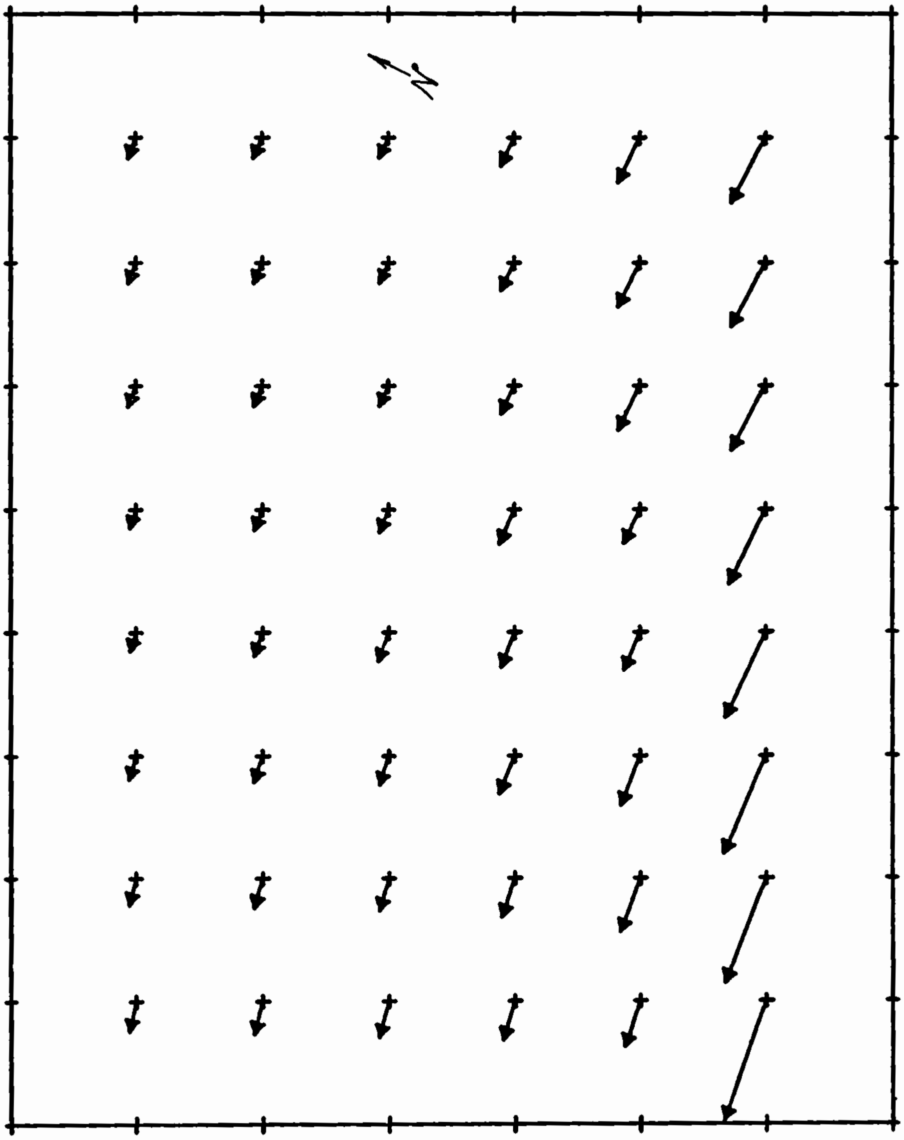

Figure 28. Wind-stress vectors for Hurricane Carla, over Sabine-Calcasieu region on an 8-nautical mile grid; time = 24 hours.

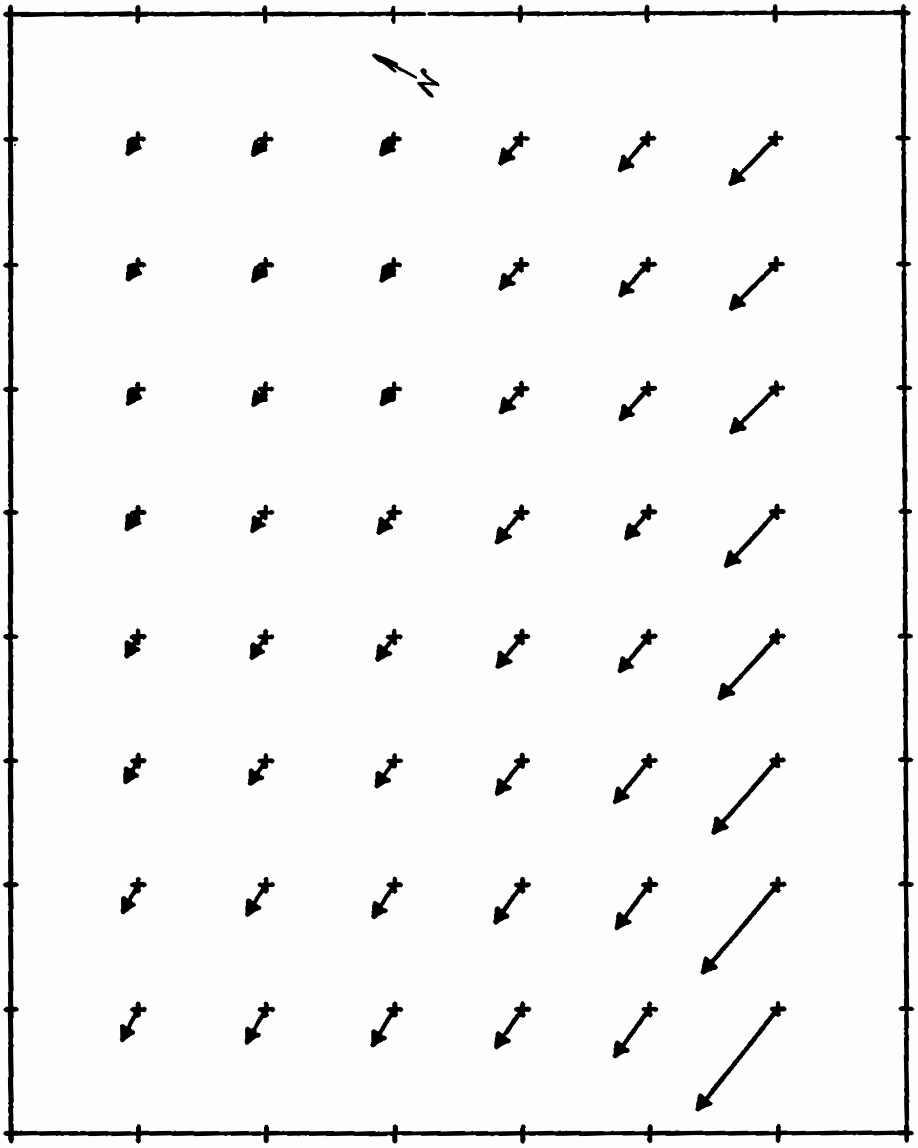

Figure 29. Wind-stress vectors for Hurricane Carla, over Sabine-Calcasieu region on an 8-nautical mile grid; time = 36 hours.

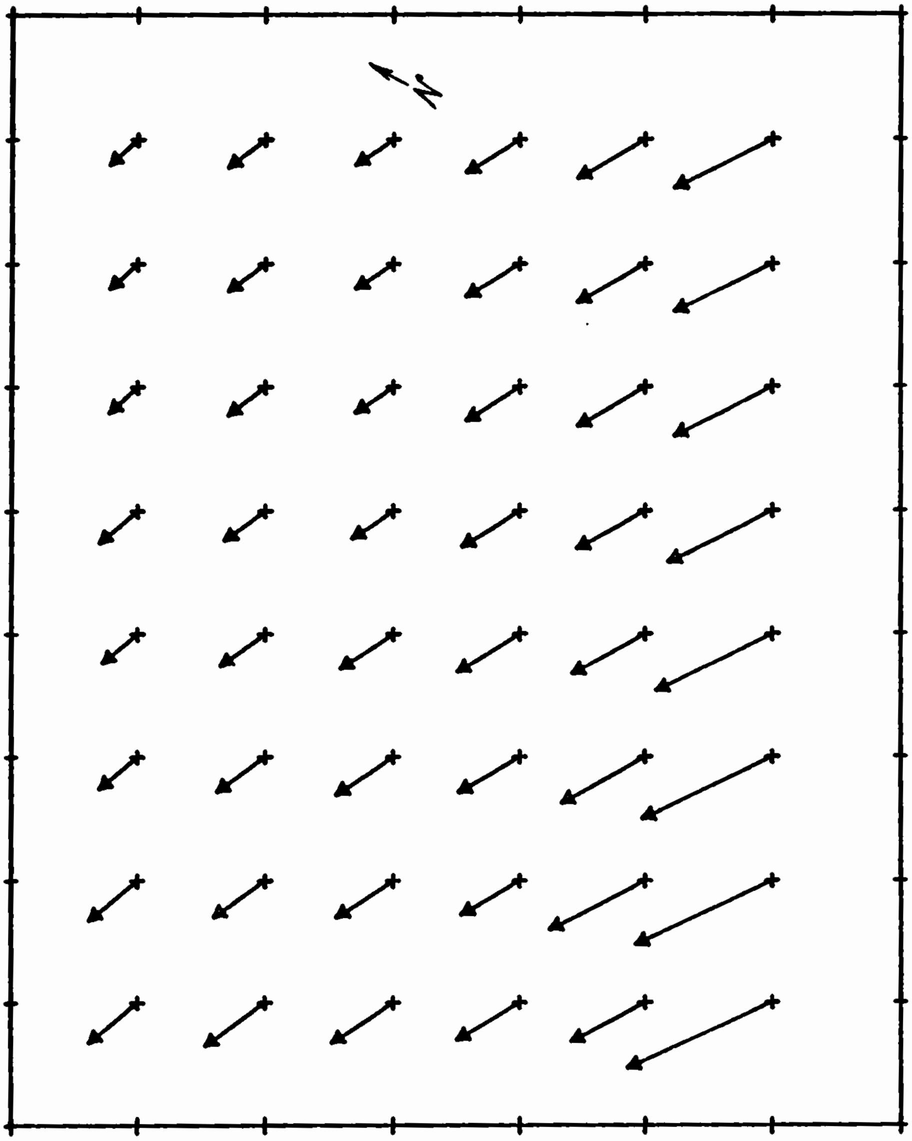

Figure 30. Wind-stress vectors for Hurricane Carla, over Sabine-Calcasieu region on an 8-nautical mile grid; time = 48 hours.

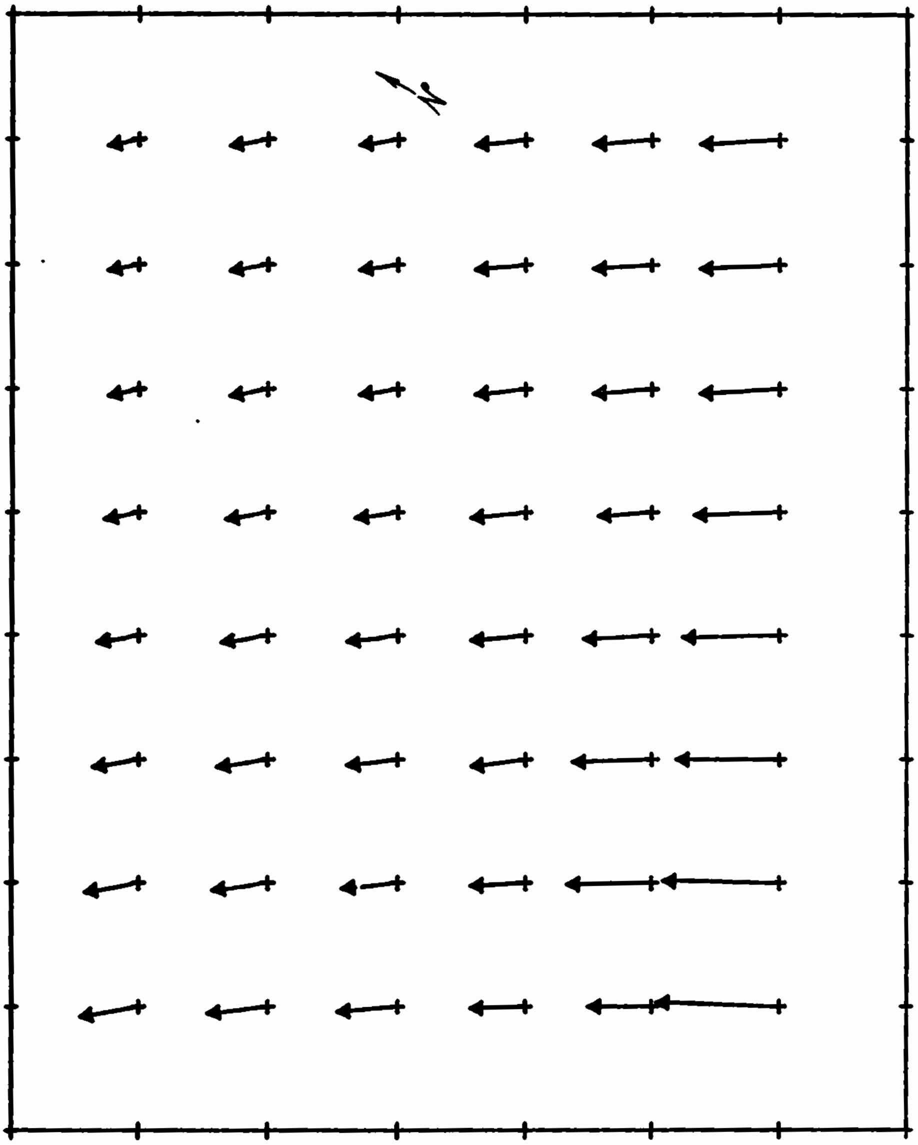

Figure 31. Wind-stress vectors for Hurricane Carla, over Sabine-Calcasieu region on an 8-nautical mile grid; time = 54 hours.

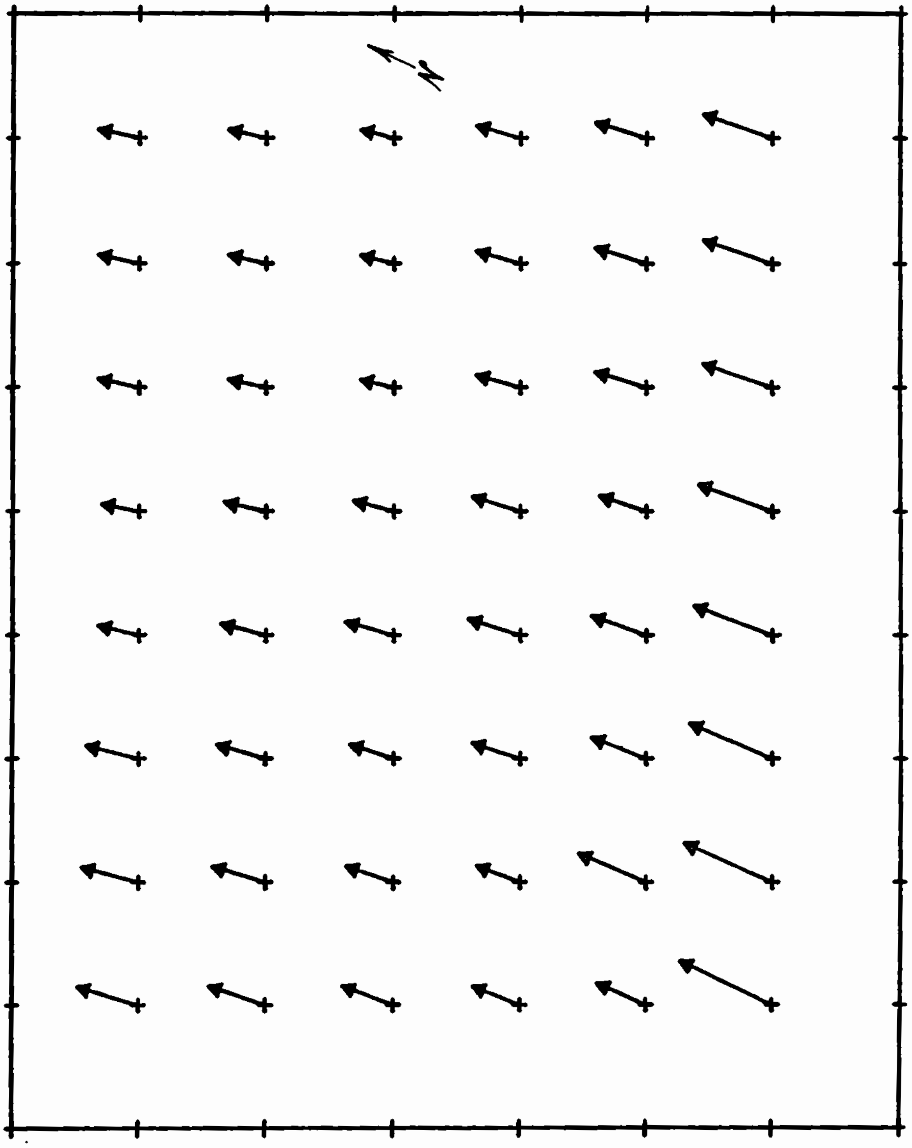

Figure 32. Wind-stress vectors for Hurricane Carla, over Sabine-Calcasieu region on an 8-nautical mile grid; time = 60 hours.

b. Results. The results of the Hurricane Carla simulation are given in Figures 33 to 41, and Appendix G. The input (observed) hydrograph for Sabine Pass is shown in Figure 33 for a 72-hour period starting at 0000 hours c.s.t., 10 September 1961. These results are based on a block friction factor of 0.0010.

The computed and observed values (where available) at gages 2 to 9 are shown in Figures 34 to 41. The principal discrepancy occurs at Beaumont where the computed peak surge exceeds the peak observed value by about 0.8 foot. It was found later that by increasing the block friction to 0.0025, this difference was reduced to 0.4 foot without materially changing the results at other key locations in the system.

The auxiliary sample output for the simulated Hurricane Carla run (App. G) gives, in addition to the serial listings of the above hydrographs and flow at the two main passes, sample listings of channel output at elapsed times of 30 and 60 hours.

VII. STANDARD PROJECT HURRICANE (SPH)

1. LR-ST Storm Data.

The large radius, slow translation (LR-ST) storm was utilized as an atmospheric forcing function for the verified model of the Sabine-Calcasieu system. The storm parameters were extracted from the pertinent gulf coast section of the National Hurricane Research Project Report No. 33 (Graham and Nunn, 1959). Table 4 lists these values which were also used in conjunction with the analytic storm representation given by Jelesnianski (1965).

Table 4. Atmospheric parameters for the large radius, slow translation (ST) and medium translation (MT) storms.

Parameters	ST storm	MT storm
Radius to maximum winds	27 nmi	27 nmi
Maximum windspeed	100 mi/h	100 mi/h
Central pressure	27.55 in	27.55 in
Translation speed	4 kn	11 kn

Wind-stress vector plots have been prepared beginning at t = 30 hours and at 10-hour increments to t = 80 hours (Figs. 42 to 47). The storm track, which is taken normal to the general shoreline, has the Sabine-Calcasieu system on the right-hand side of the storm approaching the coastline. Landfall of the storm center is close to grid block 1,1. The orientation of these plots relative to the topography is similar to the wind fields shown for the Hurricane Carla verification. The gulf hydrographic input, provided by the Galveston District, was developed by an application of a one-dimensional bathystrophic model (Marinos and Woodward, 1968; Bodine, 1971). A tidal component has been added to this

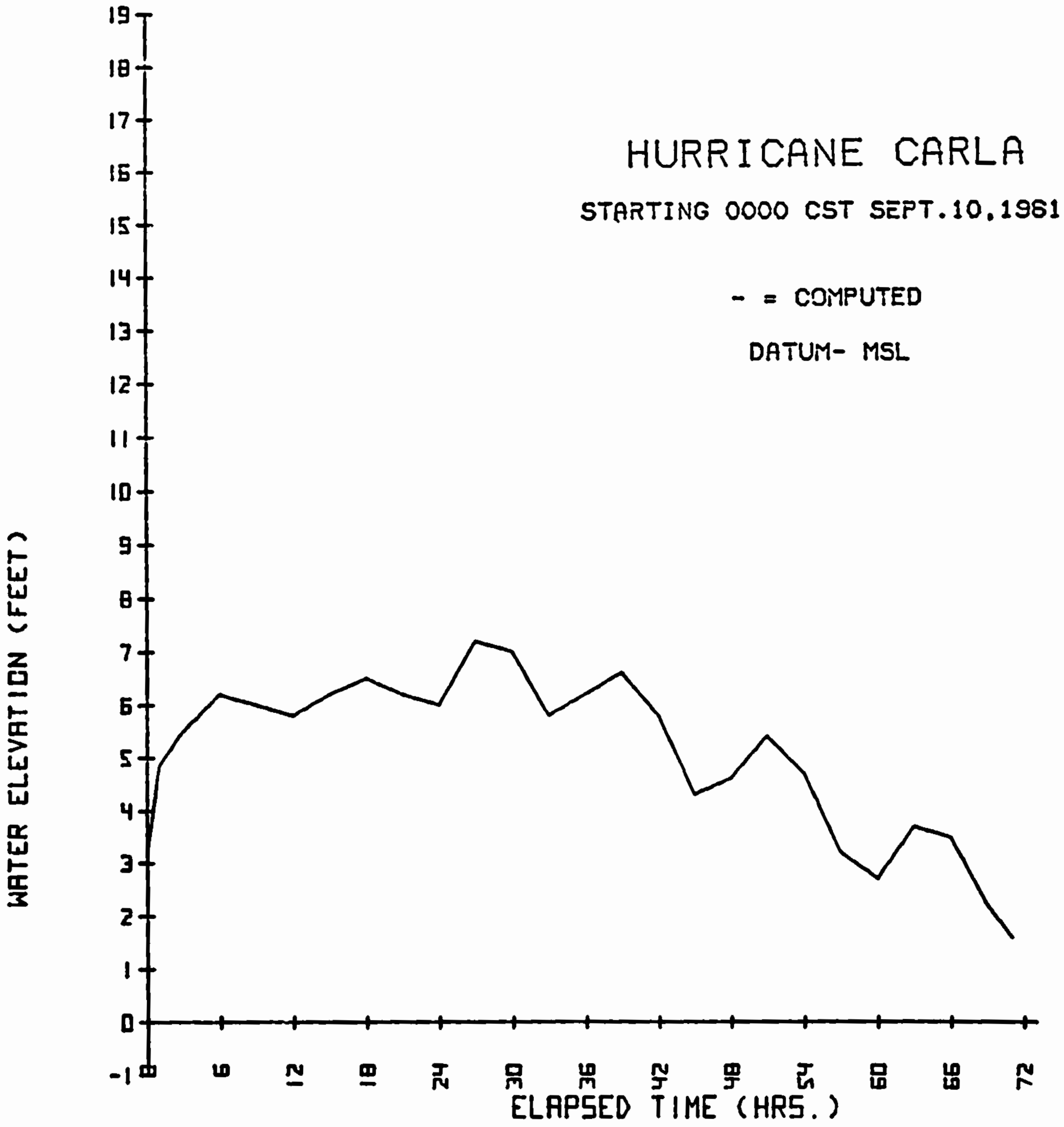

Figure 33. Hydrograph at Sabine Pass, southwest jetty for Hurricane Carla.

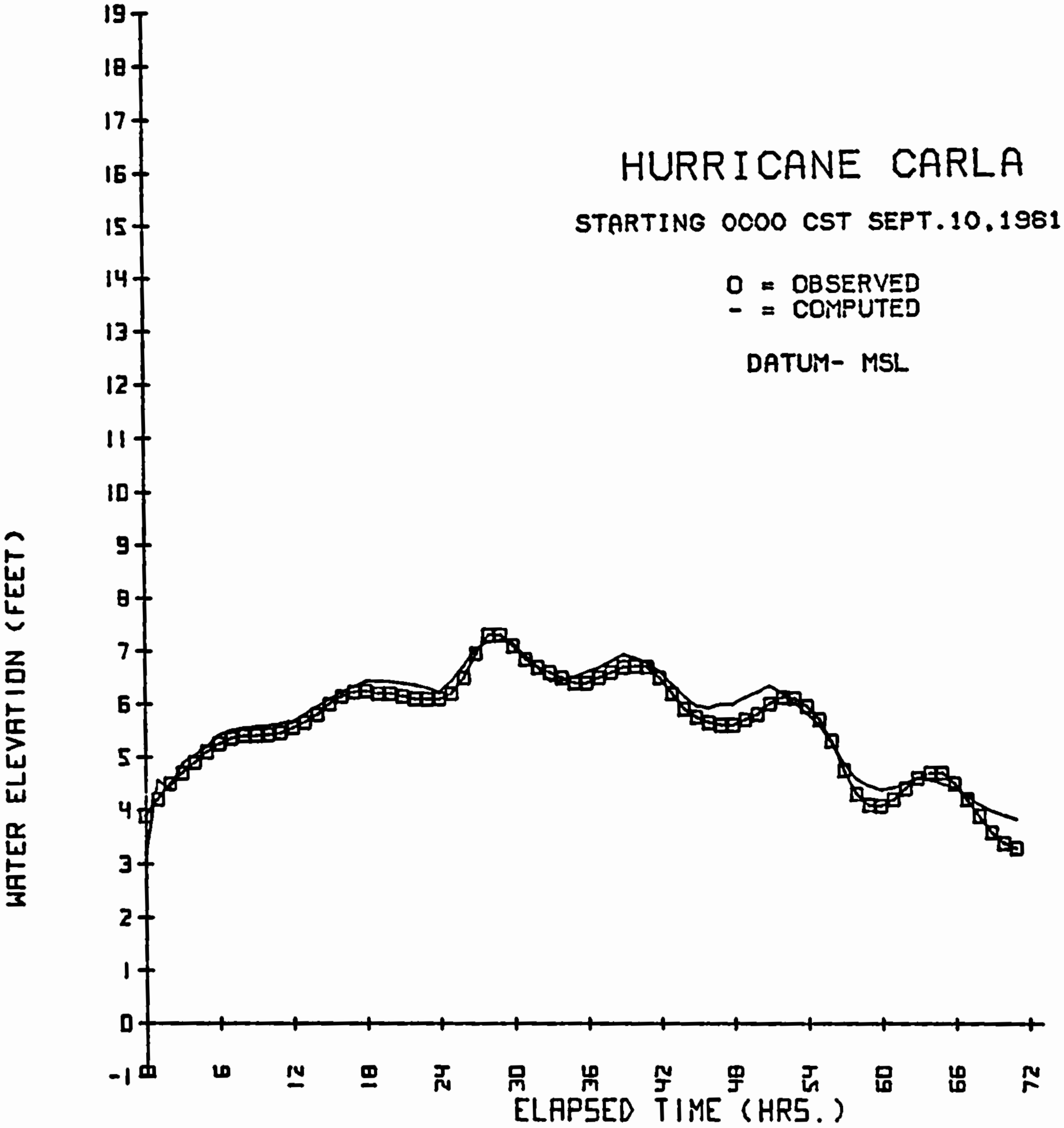

Figure 34. Hydrographs at Sabine Pass, U.S. Coast Guard Station for Hurricane Carla (FK = 0.0010).

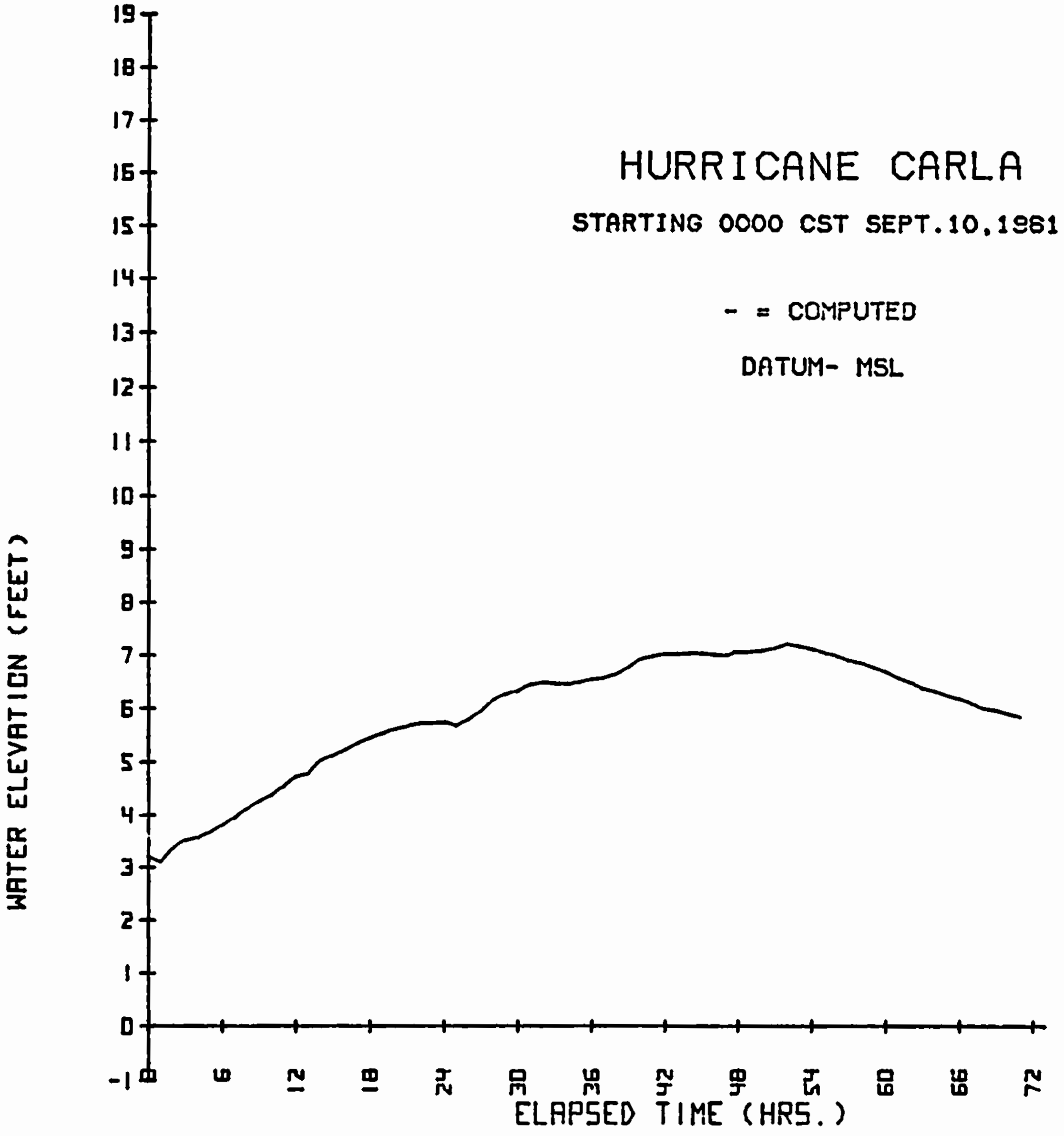

Figure 35. Hydrograph at Port Arthur for Hurricane Carla (FK = 0.0010).

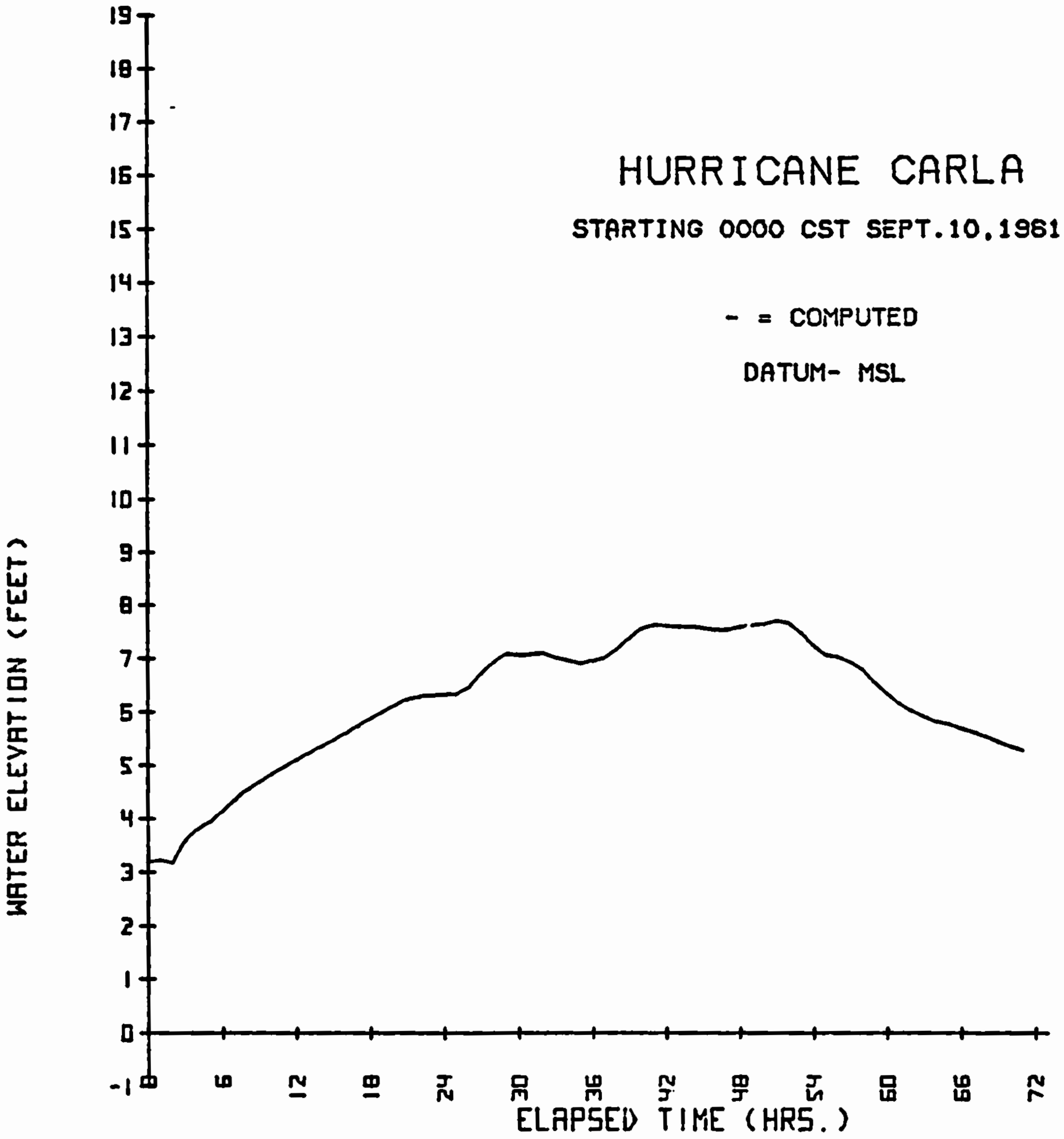

Figure 36. Hydrograph at north Sabine Lake for Hurricane Carla (FK = 0.0010).

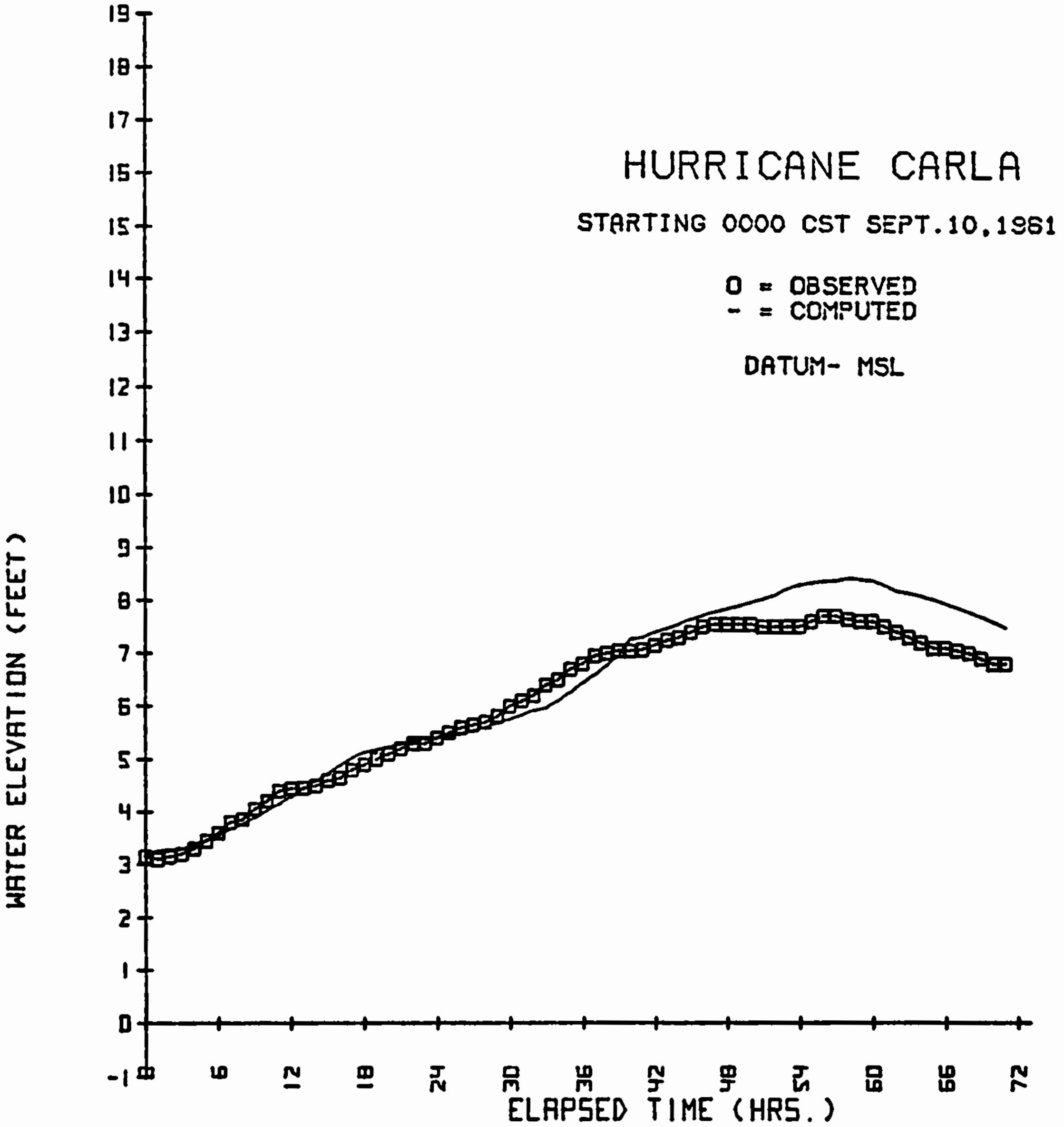

Figure 37. Hydrographs at Beaumont, Neches River, and Brakes Bayou for Hurricane Carla (FK = 0.0010).

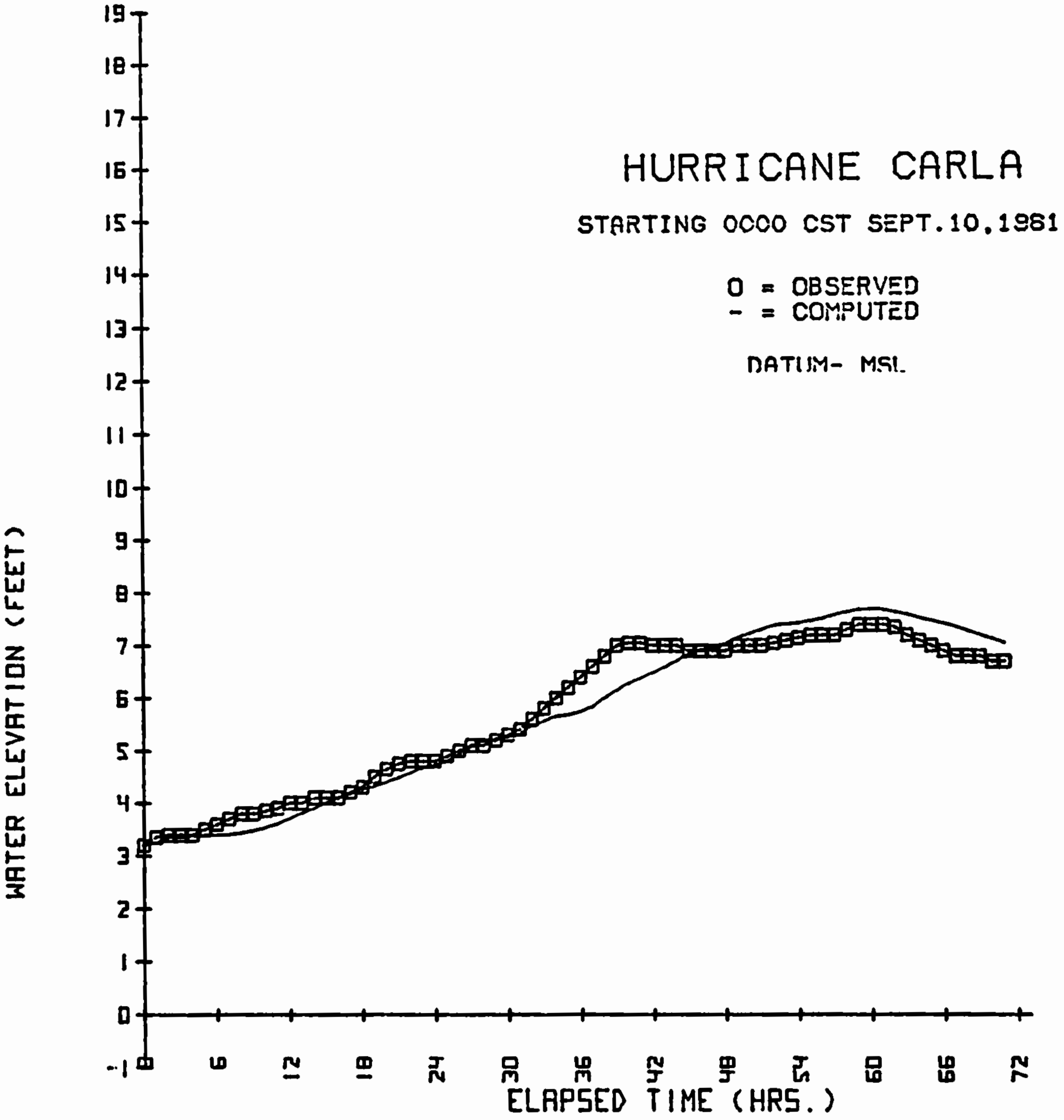

Figure 38. Hydrographs at Orange Naval Station, Sabine River for Hurricane Carla (FK = 0.0010).

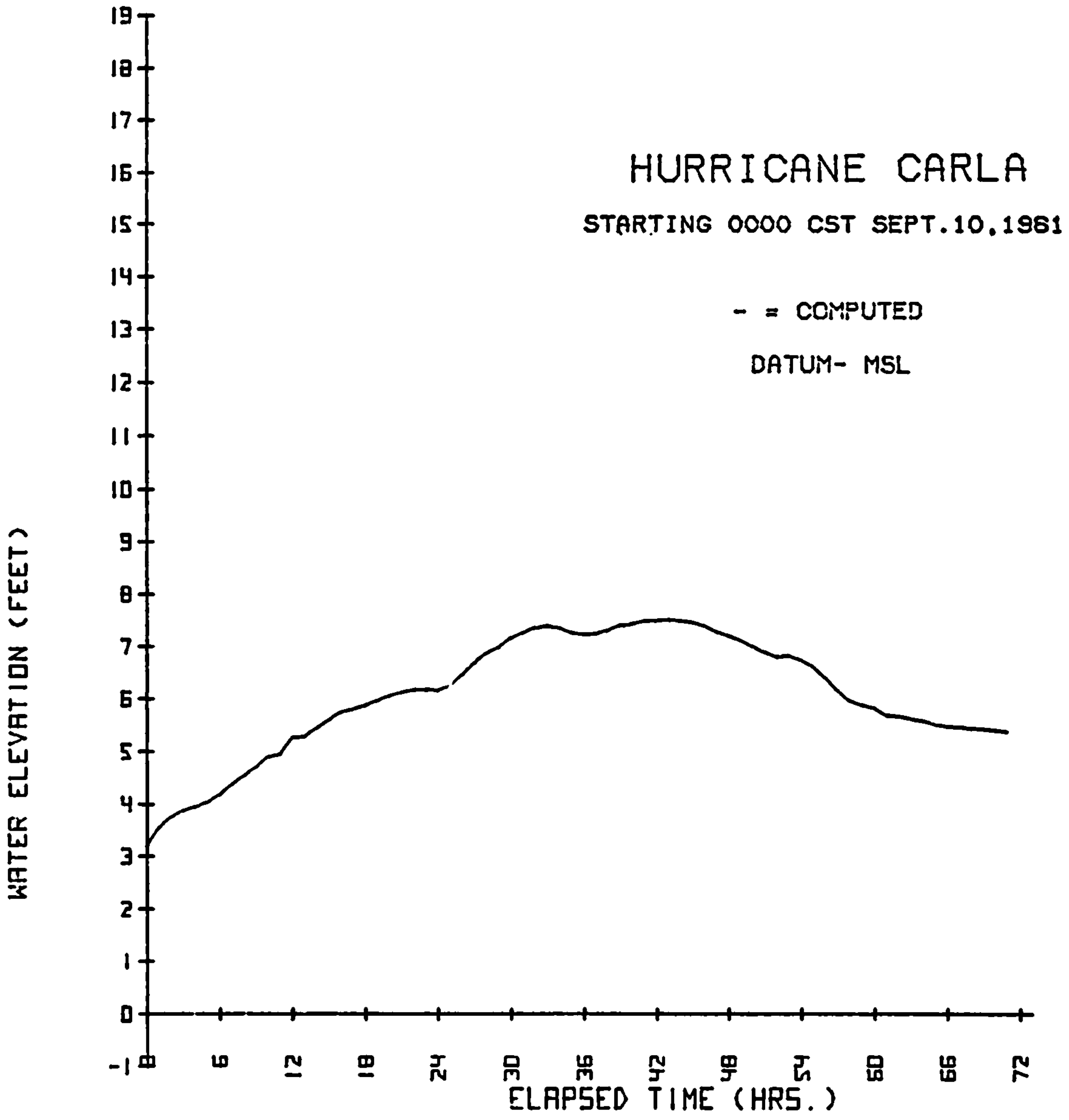

Figure 39. Hydrograph at west end of Intracoastal Waterway for Hurricane Carla (FK = 0.0010).

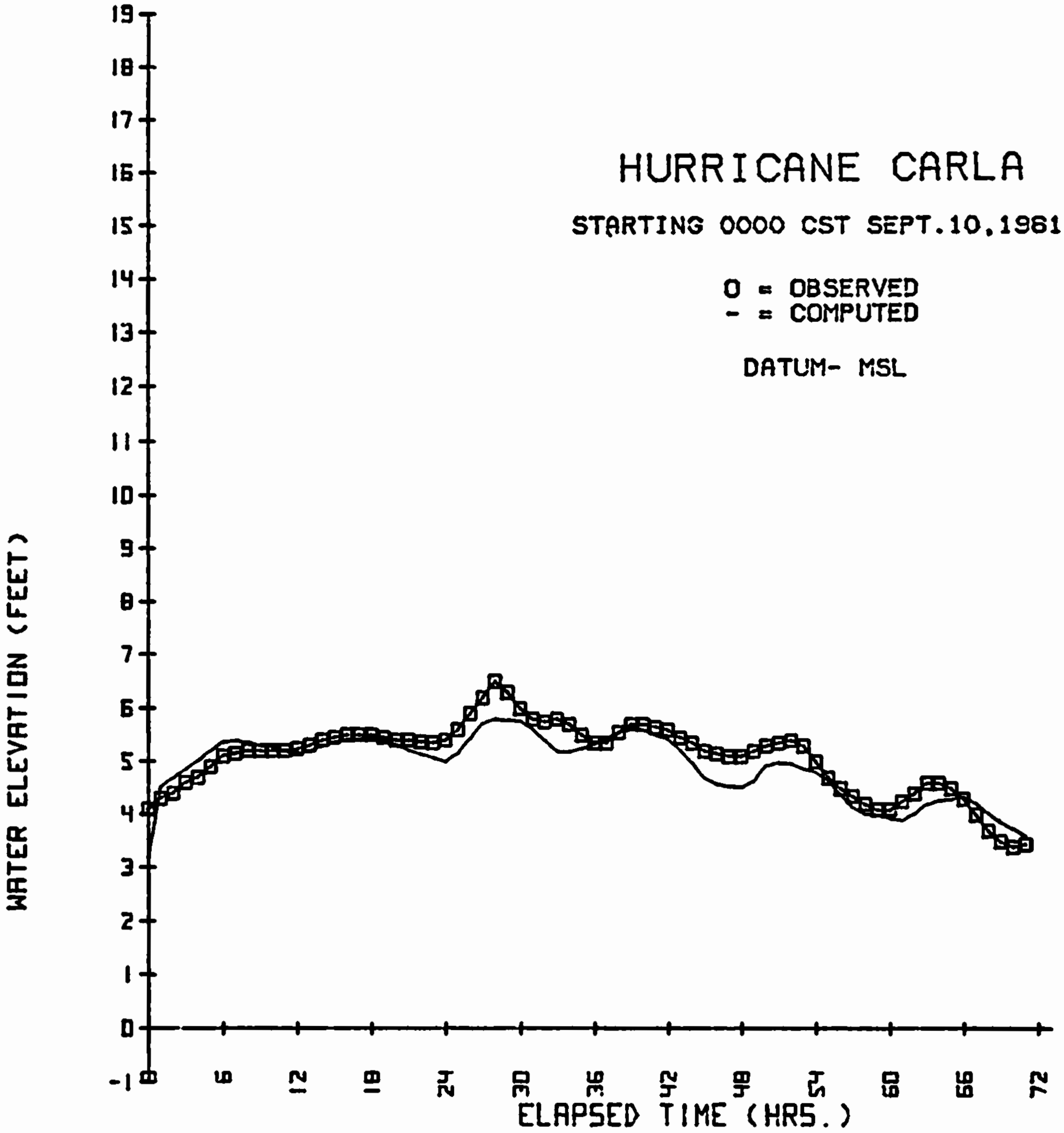

Figure 40. Hydrographs at Cameron, Calcasieu Pass for Hurricane Carla (FK = 0.0010).

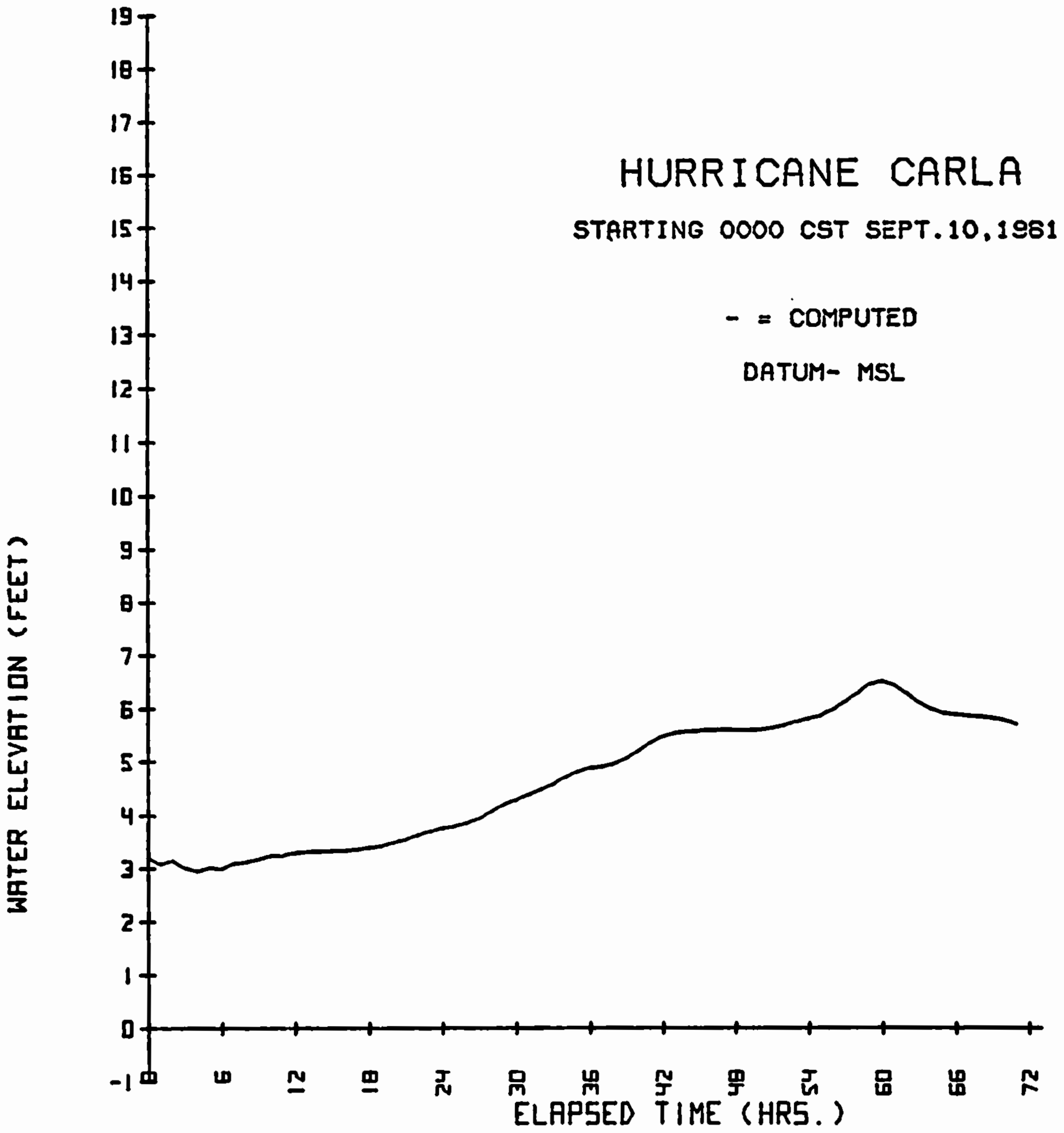

Figure 41. Hydrograph at Lake Charles for Hurricane Carla (FK = 0.0010).

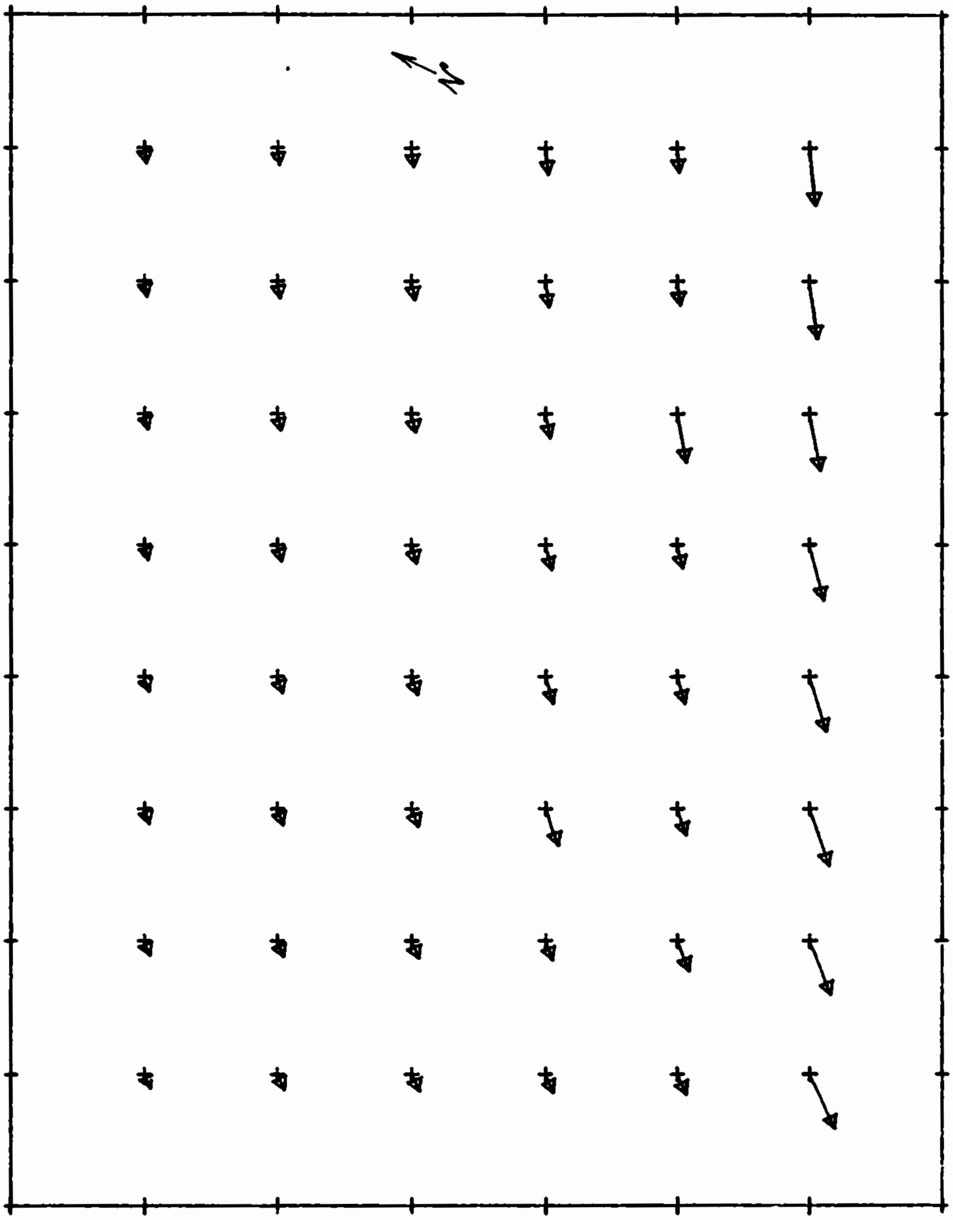

Figure 42. Wind-stress vectors for SPH large radius, slow translation (LR-ST) on an 8-nautical mile grid; time = 30 hours.

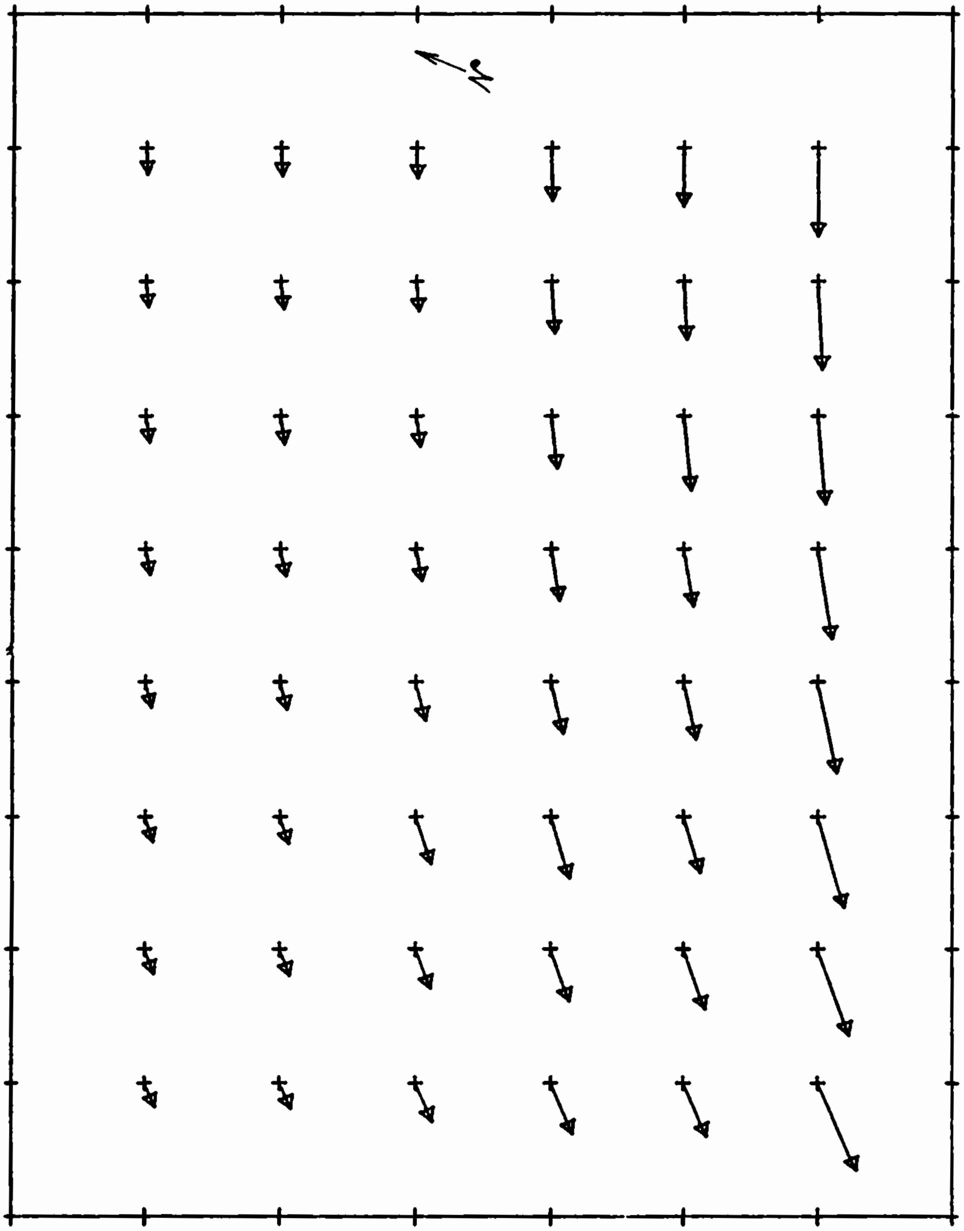

Figure 43. Wind-stress vectors for SPH large radius, slow translation (LR-ST) on an 8-nautical mile grid; time = 40 hours.

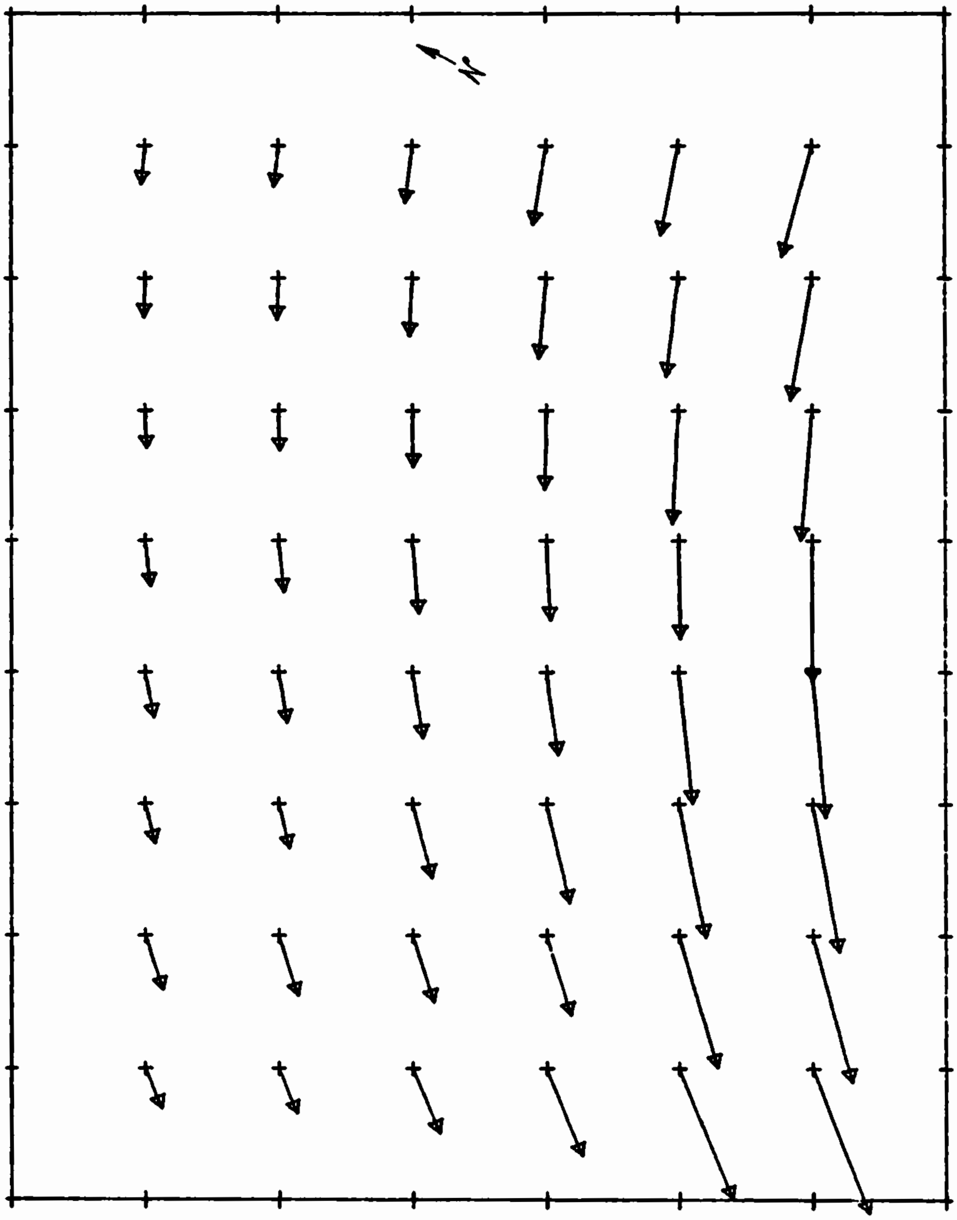

Figure 44. Wind-stress vectors for SPH large radius, slow translation (LR-ST) on an 8-nautical mile grid; time = 50 hours.

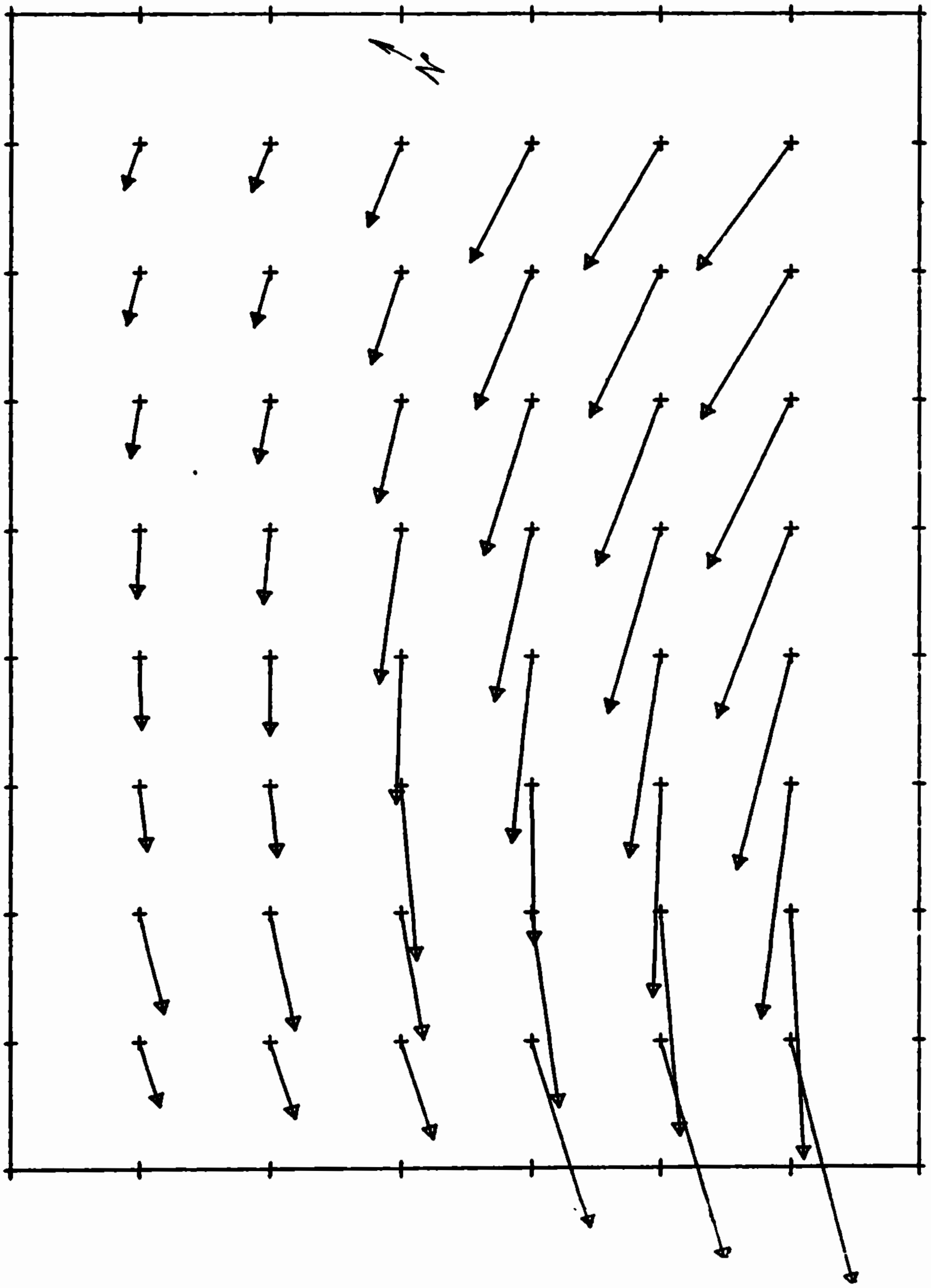

Figure 45. Wind-stress vectors for SPH large radius, slow translation (LR-ST) on an 8-nautical mile grid; time = 60 hours.

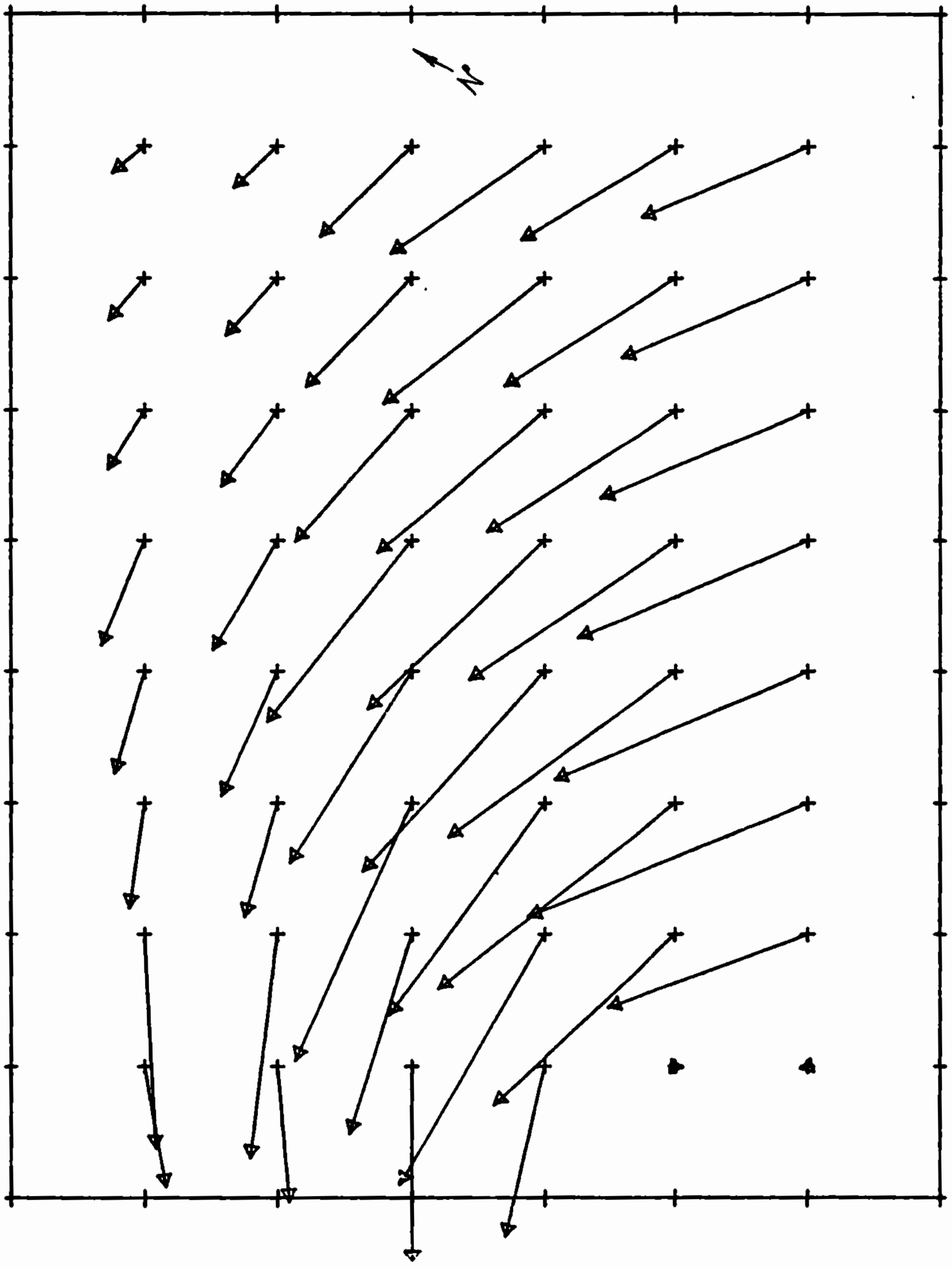

Figure 46. Wind-stress vectors for SPH large radius, slow translation (LR-ST) on an 8-nautical mile grid; time = 70 hours.

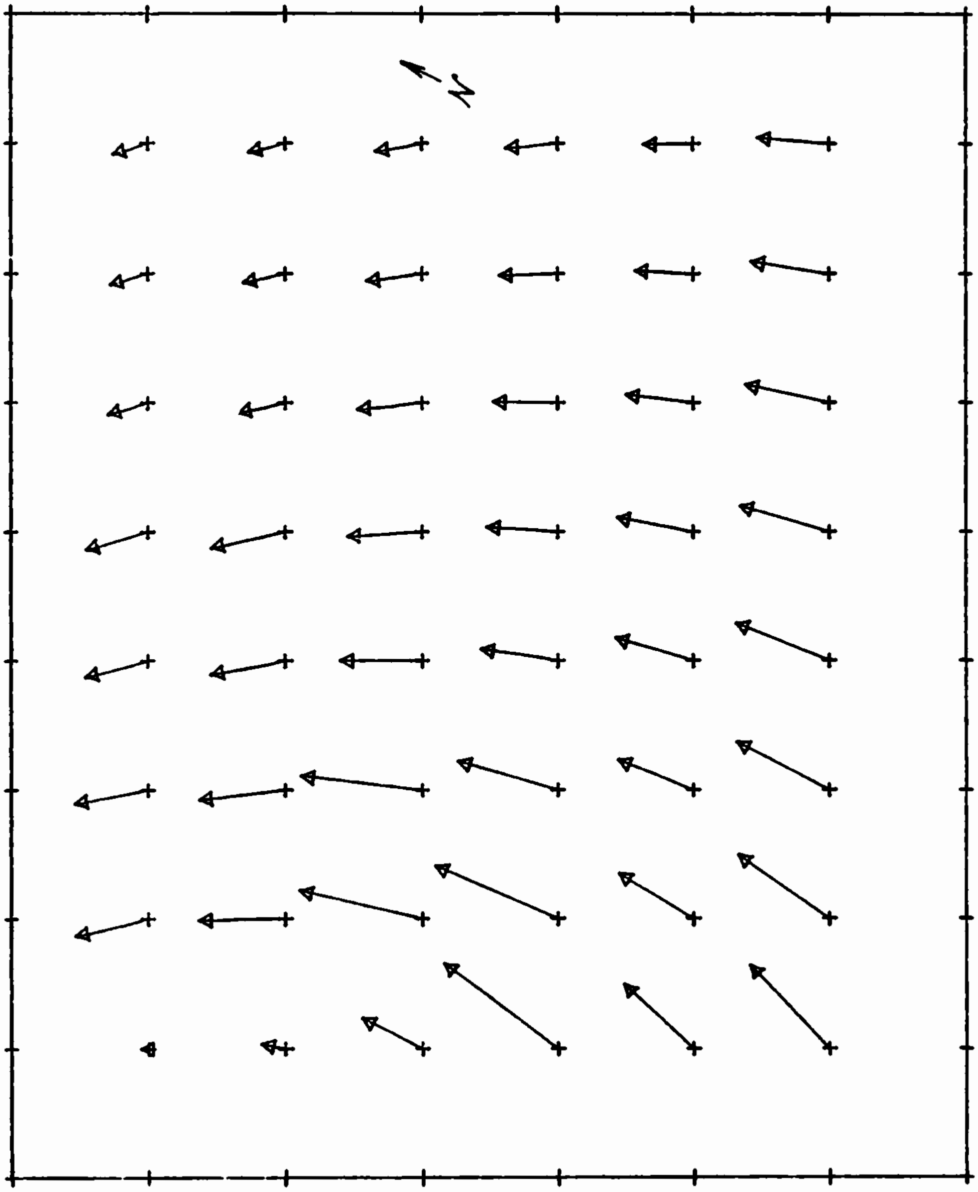

Figure 47. Wind-stress vectors for SPH large radius, slow translation (LR-ST) on an 8-nautical mile grid; time = 80 hours.

open-coast surge. A total rainfall of 16 inches in 24 hours is included as input. The results are based on a block friction factor of 0.0010 and are therefore tentative.

2. LR-ST Storm Results.

Nine simulated hydrographs are presented in Figures 48 to 56. The hydrograph locations are selected to coincide with the locations of the Hurricane Carla graphs and are shown on the base map in Figure 16. The maximum water level excursion in these graphs is nearly 19 feet and occurs at the Beaumont gage (Fig. 52) at approximately t = 80 hours. The highest elevation at Sabine Pass, southwest jetty (Fig. 48) is 13 feet and occurs at t = 77 hours. The Port Arthur surge crests (Fig. 52) at slightly greater than 14 feet shortly after high water is reached on the open coast. The gage at north Sabine Lake (Fig. 51) reaches a maximum of 15.3 feet which coincides with Port Arthur. The surge at Beaumont develops continuously from the 7-foot level at t = 66 hours to a maximum at 80 hours in direct correlation with the surge character at the coastline. However, the 7-foot level is reached at the coast approximately 6 hours before Beaumont. At the Orange Naval Station (Fig. 53) the surge development appears more monotonic with a steady climb from t = 54 hours to the peak surge of nearly 16 feet shortly before the Beaumont peak. The recession stage at Sabine Pass occurs quickly with passage of the storm, and the open-coast water level has returned to normal level by t = 90 hours.

Drainage inland slowly reduces water levels and, at t = 90 hours, Port Arthur and north Sabine Lake have water elevations of approximately 10 feet. Farther inland, the water elevation at Beaumont and Orange stands at 13 feet. The system continues to drain over the next 10 hours of prototype computation but slows considerably since the runoff reaches peak rate at the end of the run.

Recalculations at the Galveston District, using a block friction of 0.0025 which improved the Hurricane Carla simulation, indicated significant reductions in the peak surges for the LR-ST storm (Table 5). The greatest reduction is for Beaumont, as in the case of Hurricane Carla; however, the amount of reduction is disproportionately greater than that seen for Hurricane Carla.

Table 5. Comparison of peak surges for the LR-ST storm, using two different block friction factors.

Location	Surges (ft above MSL)	
	FK = 0.0010	FK = 0.0025
Port Arthur	14.3	14.1
Beaumont	18.7	17.1
Orange Naval Station	15.9	15.2
Lake Charles	14.1	13.9

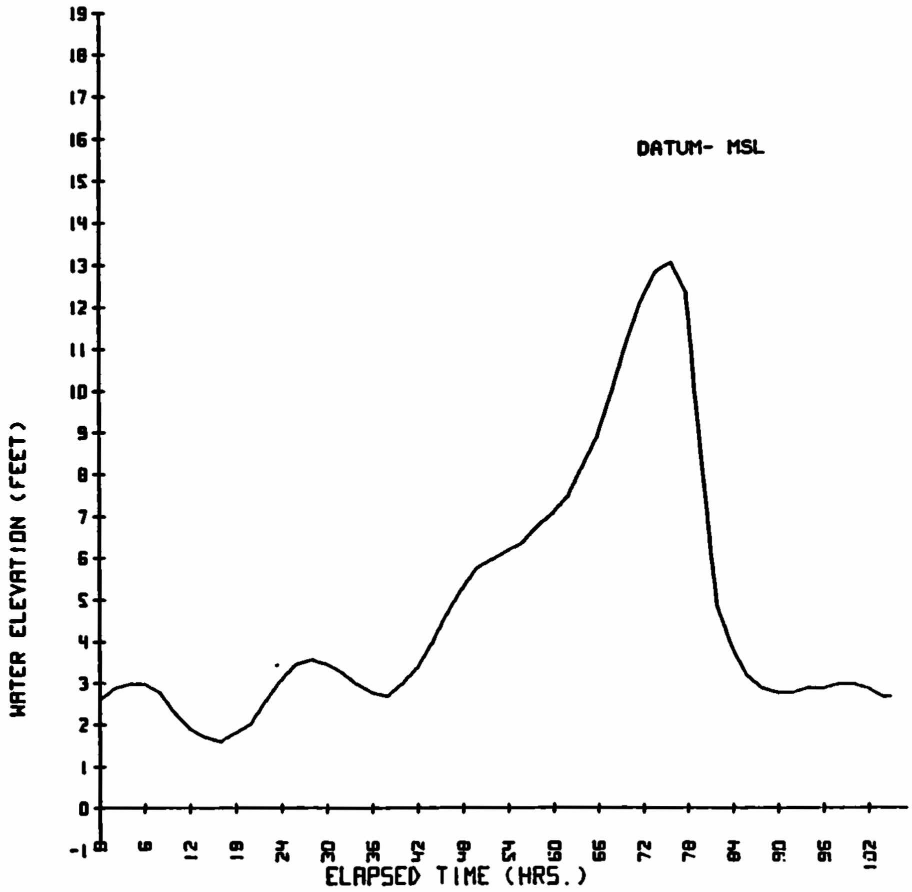

Figure 48. Hydrograph for SPH, LR-ST at Sabine Pass, southwest jetty (FK = 0.0010).

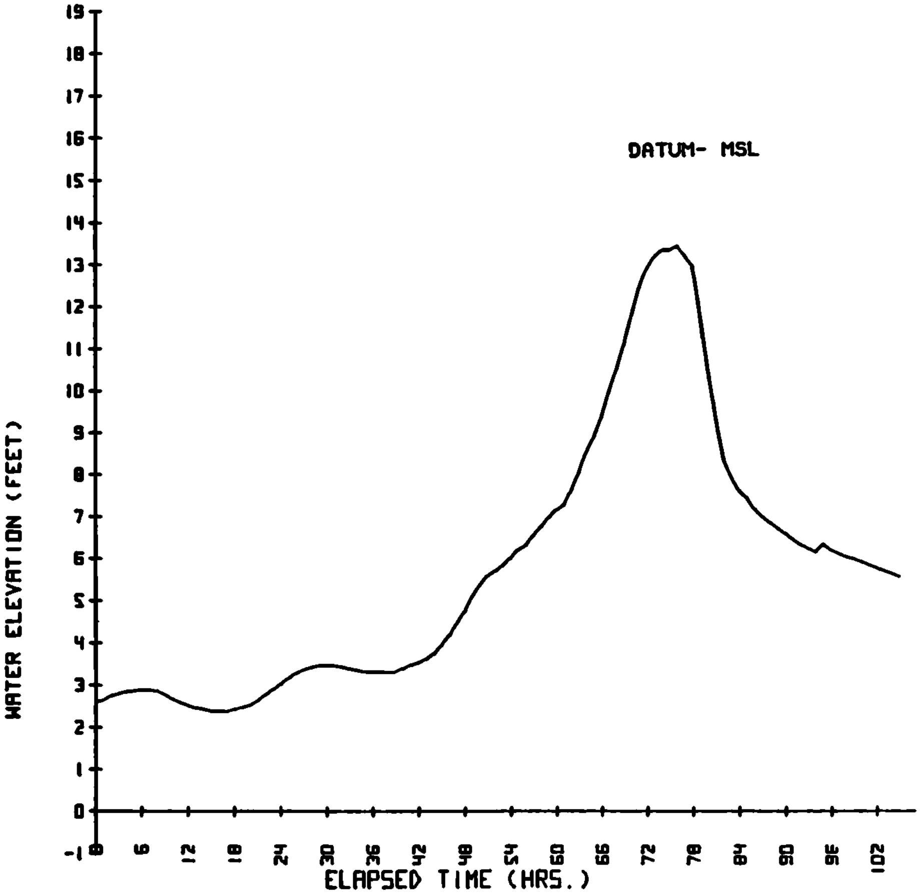

Figure 49. Hydrograph for SPH, LR-ST at Sabine Pass, U.S. Coast Guard Station (FK = 0.0010).

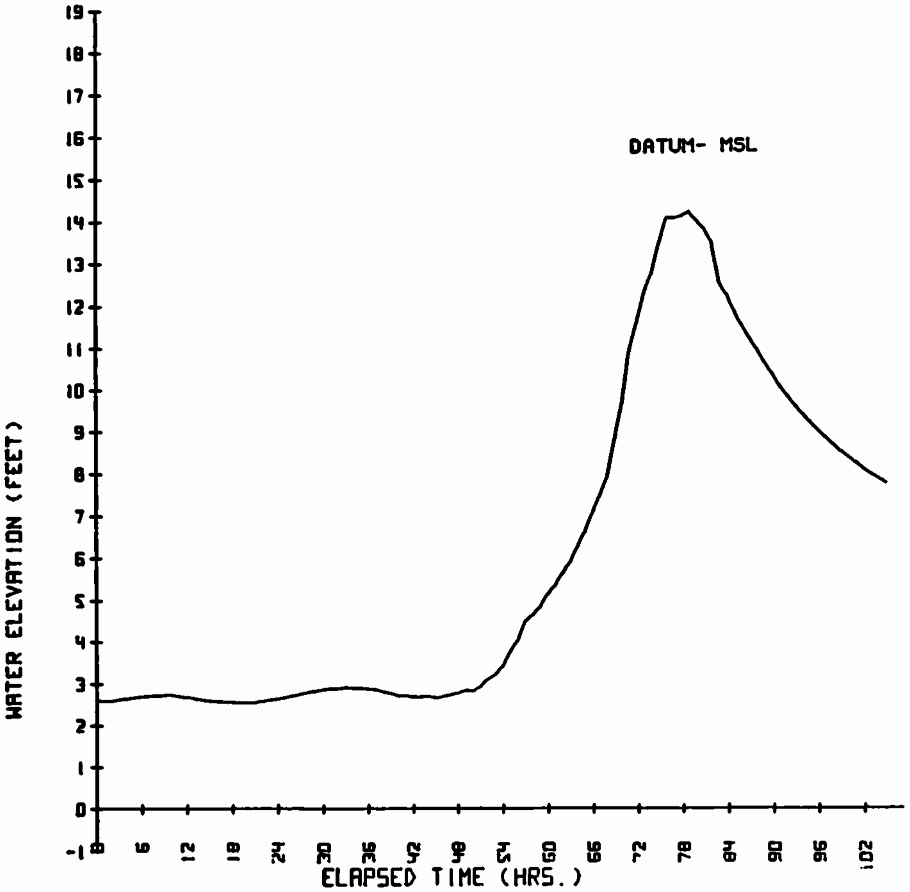

Figure 50. Hydrograph for SPH, LR-ST at Port Arthur (FK = 0.0010).

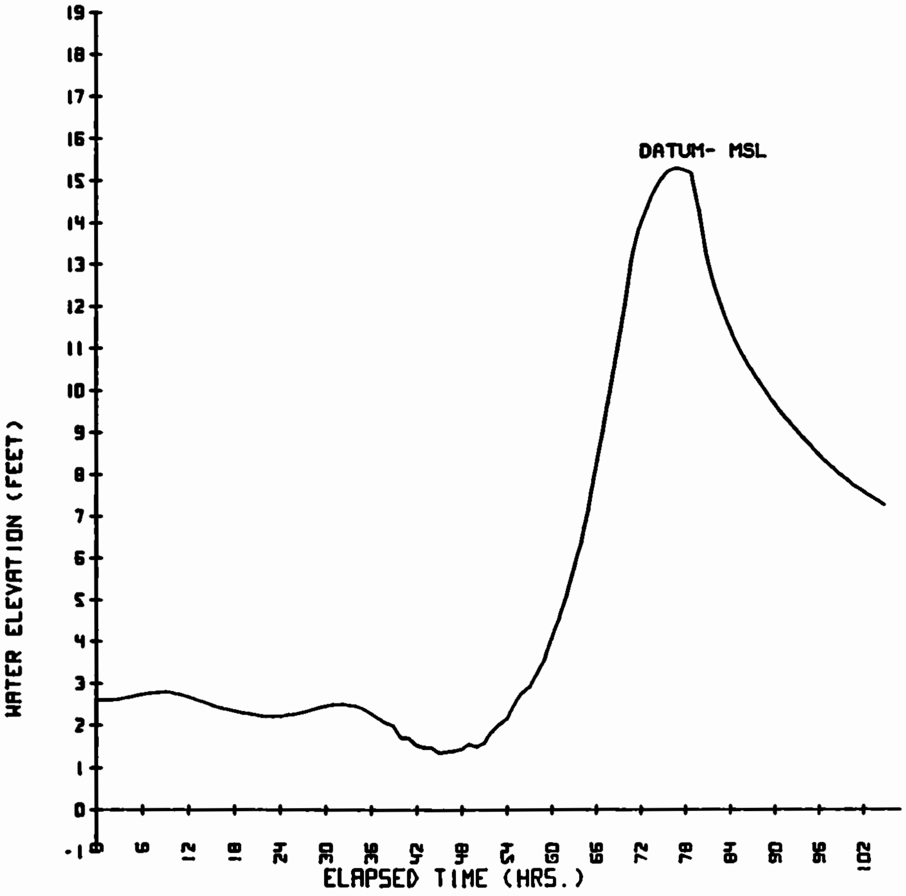

Figure 51. Hydrograph for SPH, LR-ST at north Sabine Lake (FK = 0.0010).

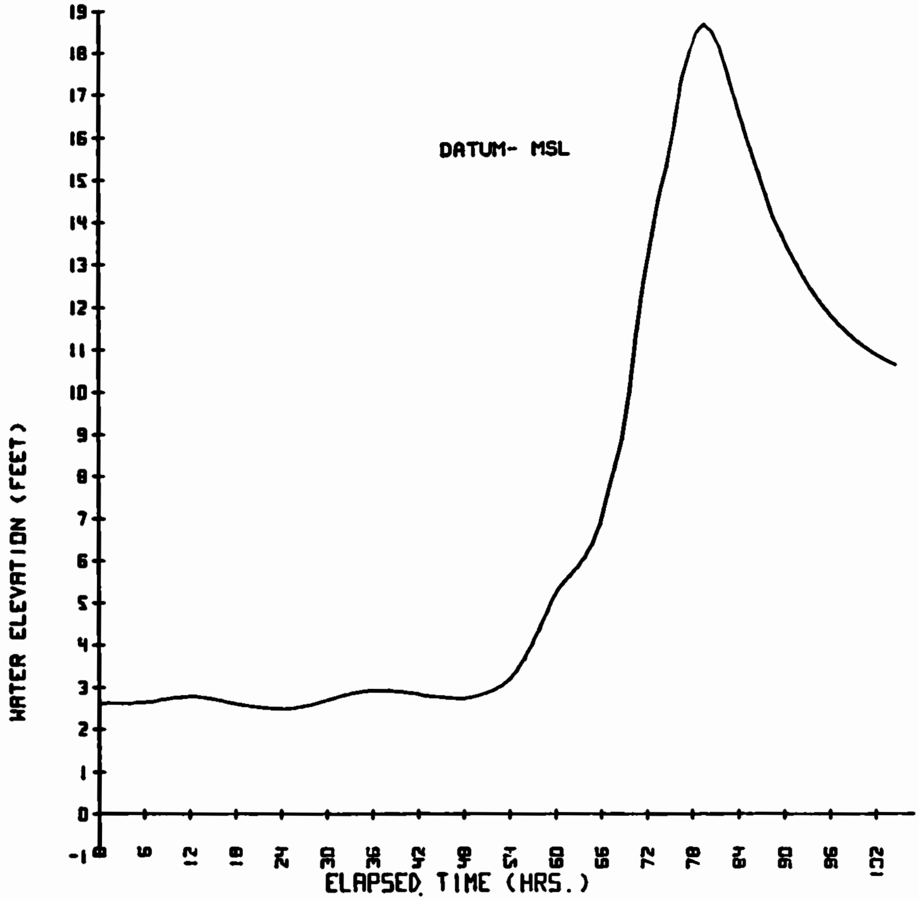

Figure 52. Hydrograph for SPH, LR-ST at Beaumont, Neches River, and Brakes Bayou.

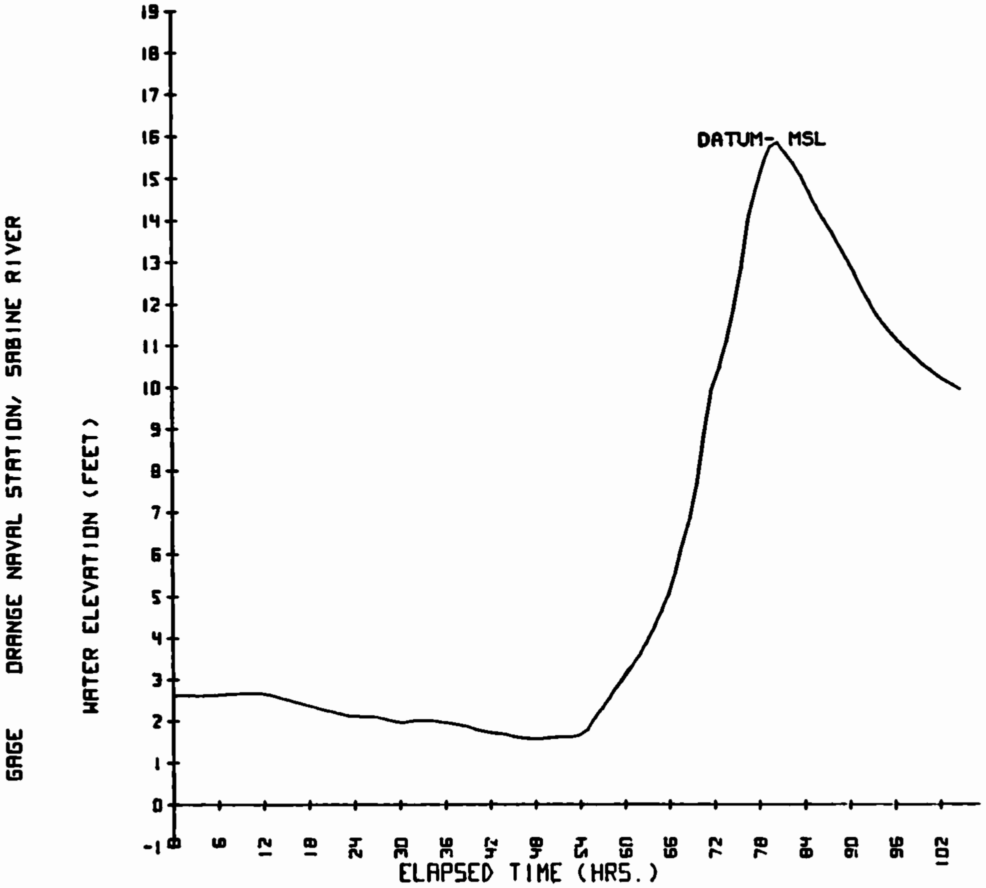

Figure 53. Hydrograph for SPH, LR-ST at Orange Naval Station, Sabine River (FK = 0.0010).

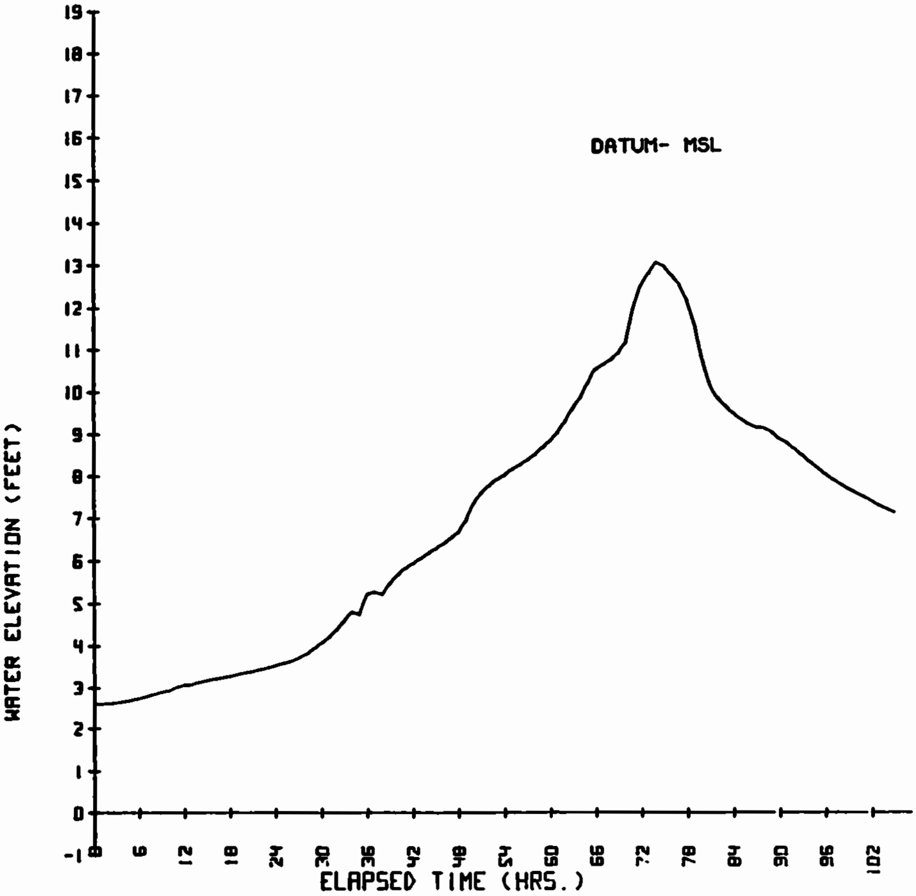

Figure 54. Hydrograph for SPH, LR-ST at west end of Intracoastal Waterway (FK = 0.0010).

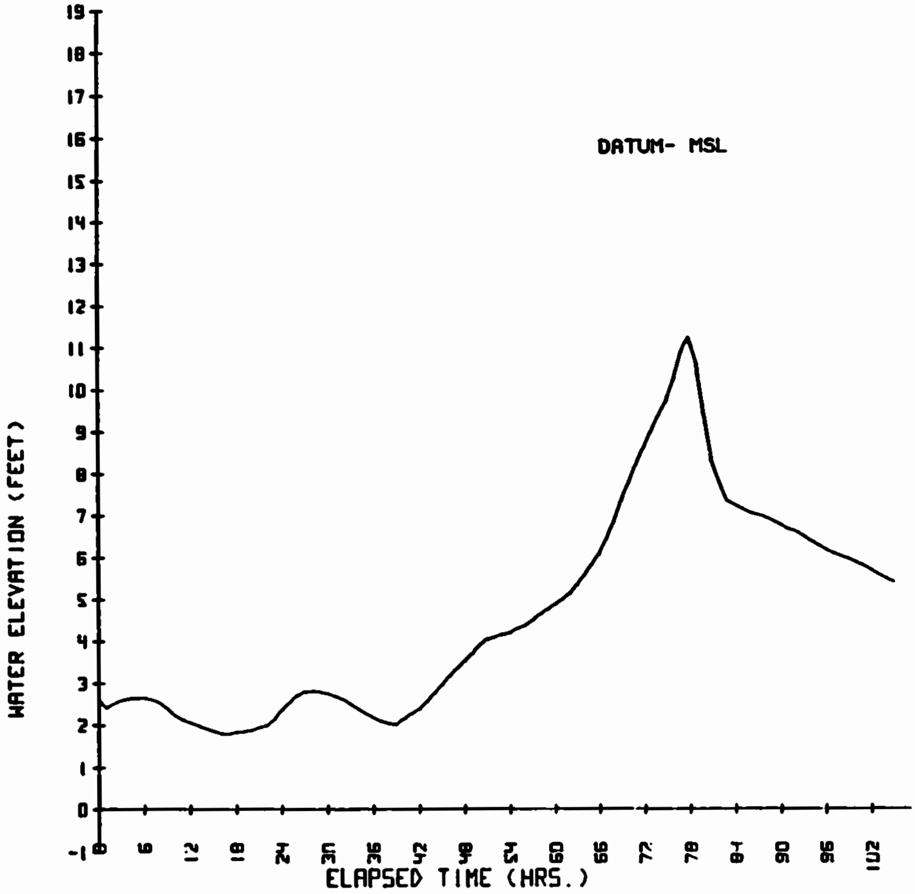

Figure 55. Hydrograph for SPH, LR-ST at Cameron, Calcasieu Pass (FK = 0.0010).

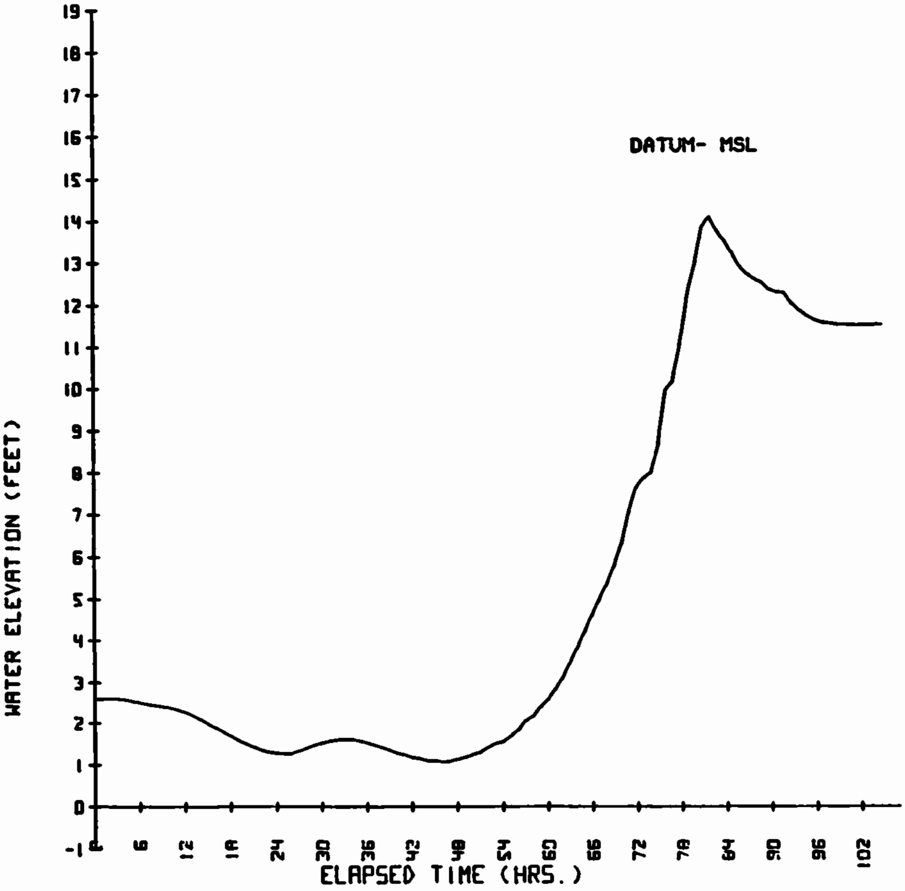

Figure 56. Hydrograph for SPH, LR-ST at Lake Charles, Calcasieu River (FK = 0.0010).

3. LR-MT Storm Data.

The large radius, medium translation (LR-MT) storm has identical characteristics to the LR-ST storm with the exception of a higher translation speed of 11 knots. Wind vector plots from t = 15 hours to t = 40 hours are shown at 5-hour increments in Figures 57 to 62. The storm track is identical to that of the LR-ST storm. The gulf hydrographic input was derived by one-dimensional, bathystrophic analysis and provided by the Galveston District. Runs were made both with and without rainfall. Again, the results given graphically below are the tentative results based on FK = 0.0010.

4. LR-MT Storm Results.

The more rapid movement of the storm center across the Sabine-Calcasieu system yielded generally smaller water level excursions inside the bay system in comparison with the LR-ST storm. Hydrographs at the established prototype locations are shown in Figures 63 to 71 for the computer run with rainfall (16 inches) and without rainfall. Note that direct comparison between the LR-ST results and LR-MT results should be made on the basis of Figures 48 to 56 and 63 to 71, respectively. All of the SPH runs use an initial water level of about 2.5 feet in the bay system.

A summary of the peak values and relative times of water level at seven locations for the three different SPH runs is given in Table 6. Although the absolute values of the water levels depend on the value of FK (as discussed in previous sections), all results in Table 6 are based on the same FK and hence the difference between values is not too sensitive to FK.

Table 6. Comparison of peak surge and time of peak surge, showing effects of translational speed of storm and rainfall (FK = 0.0010 for all three cases).

Location	Slow speed		Medium speed			
	With rainfall		With rainfall		Without rainfall	
	(ft above MSL)	(time[1])	(ft above MSL)	(time)	(ft above MSL)	(time)
Sabine Pass entrance	13.0	0	14.9	0	14.9	0
Port Arthur	14.3	2	13.2	2	12.5	2
North Sabine Lake	15.3	1	15.3	1	14.7	1
Beaumont	18.7	4	15.1	5	11.5	6
Orange Naval Station	15.9	4	14.5	5	11.7	6
Cameron	11.3	1	11.0	1	10.8	1
Lake Charles	14.1	6	14.2	6	13.2	6

[1] Nearest hour after that of Sabine Pass entrance.

Comparison of the first and second sets of peak levels in Table 6 indicates a reduced response at nearly all stations within the Sabine-Calcasieu system with an increase in the translational speed of the storm, in spite of the increased surge at the shoreline (Sabine Pass entrance). A reduction in volume response within the system is expected

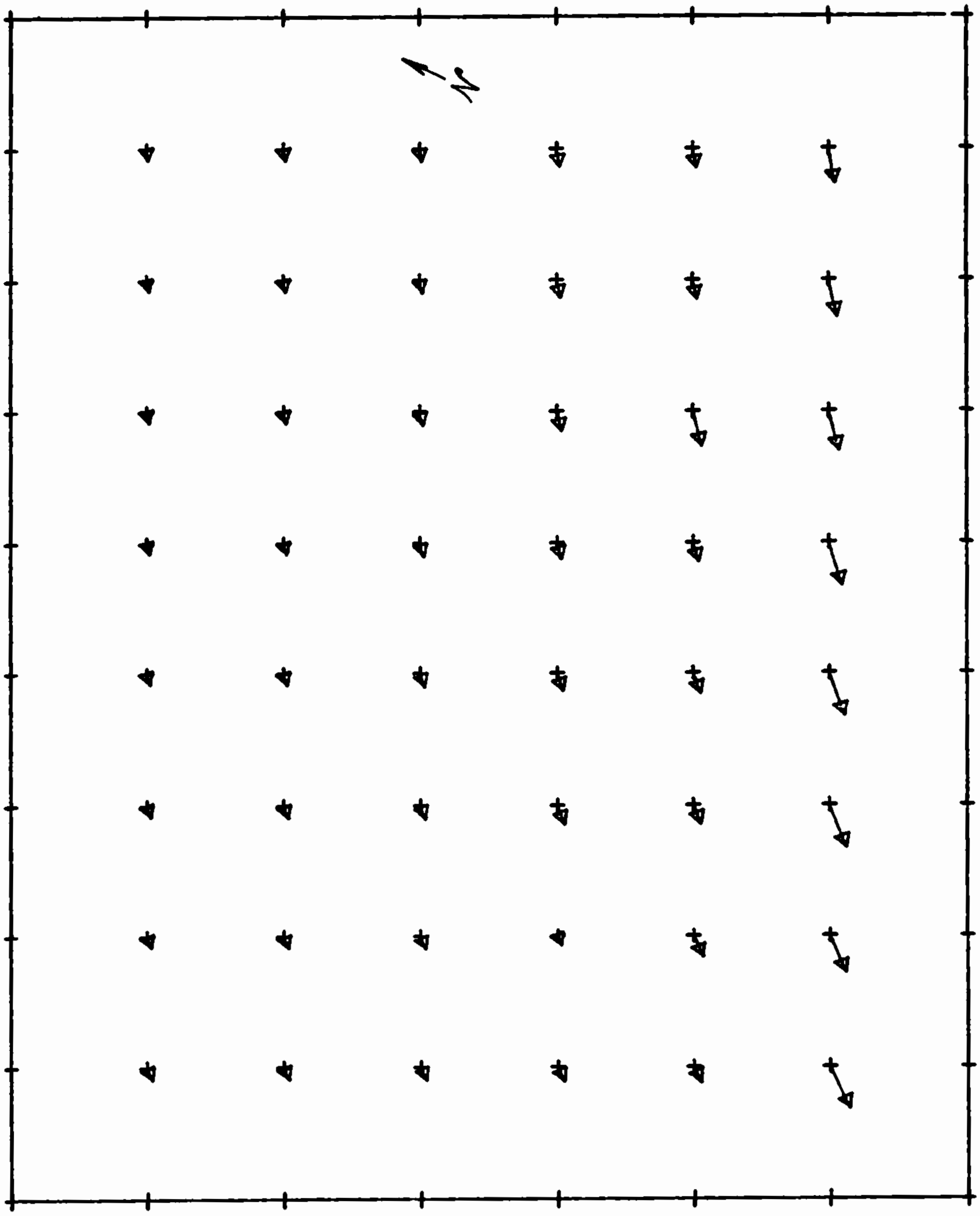

Figure 57. Wind-stress vectors for SPH large radius, medium translation (LR-MT) on an 8-nautical mile grid; time = 15 hours.

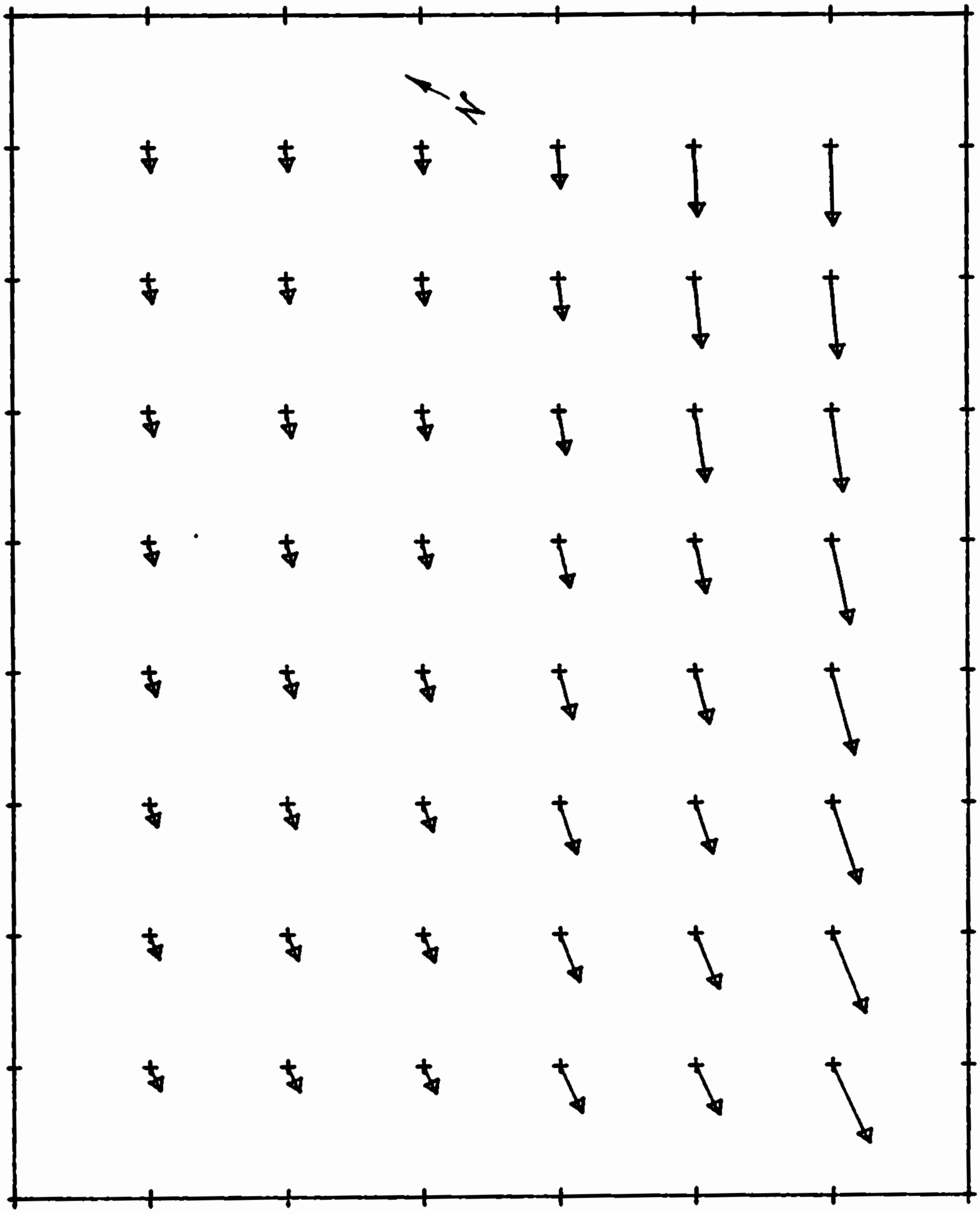

Figure 58. Wind-stress vectors for SPH large radius, medium translation (LR-MT) on an 8-nautical mile grid; time = 20 hours.

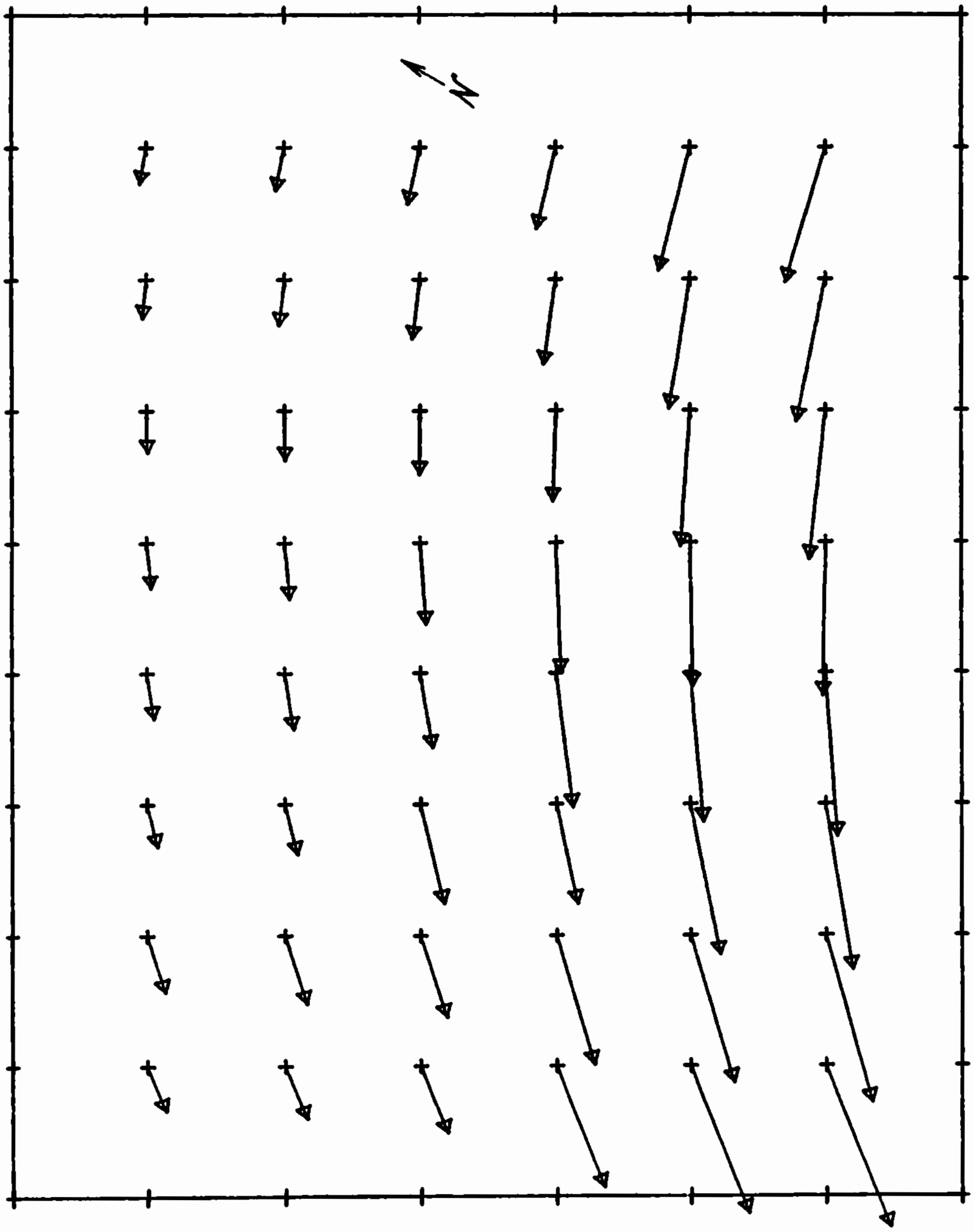

Figure 59. Wind-stress vectors for SPH large radius, medium translation (LR-MT) on an 8-nautical mile grid; time = 25 hours.

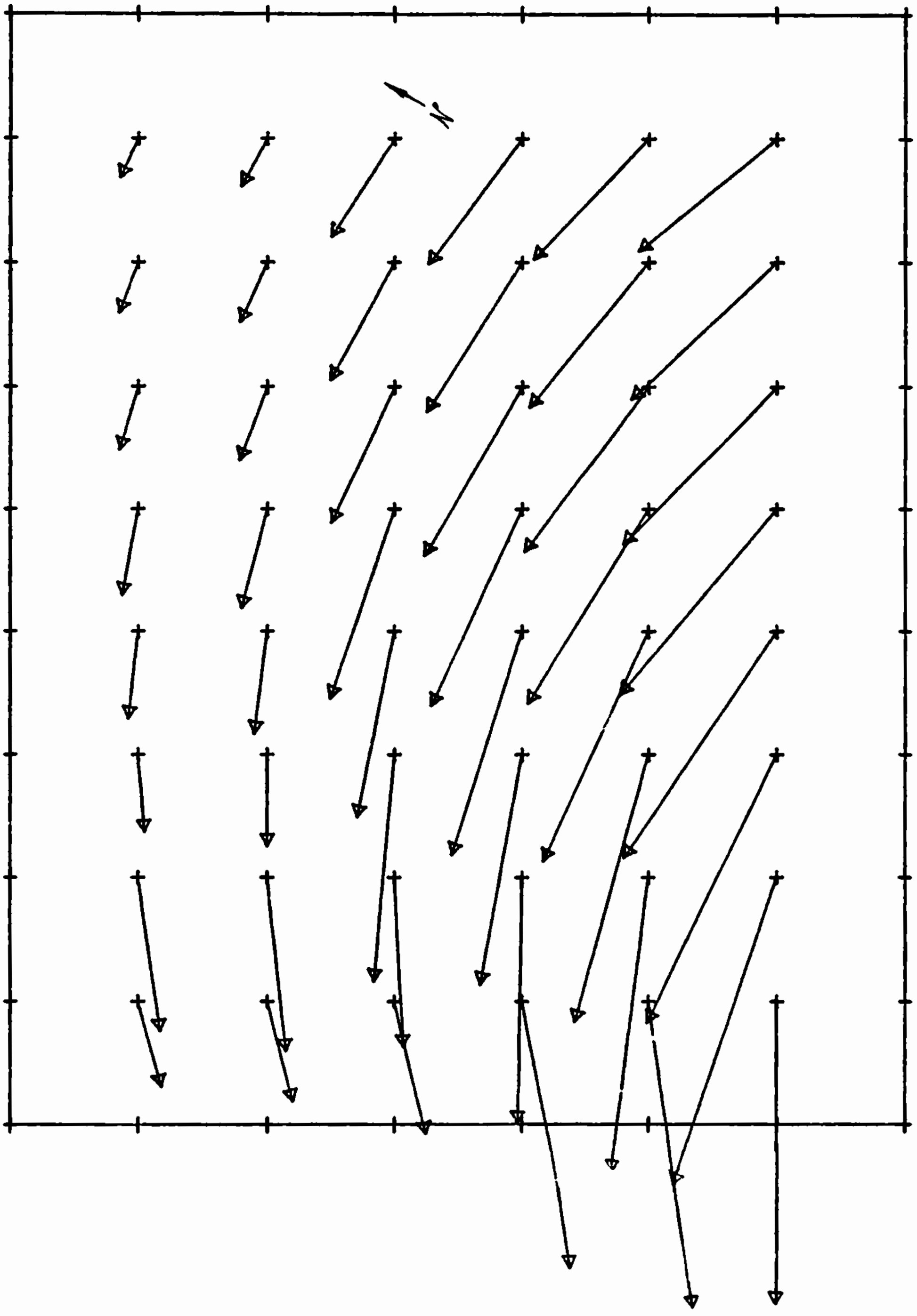

Figure 60. Wind-stress vectors for SPH large radius, medium translation (LR-MT) on an 8-nautical mile grid; time = 30 hours.

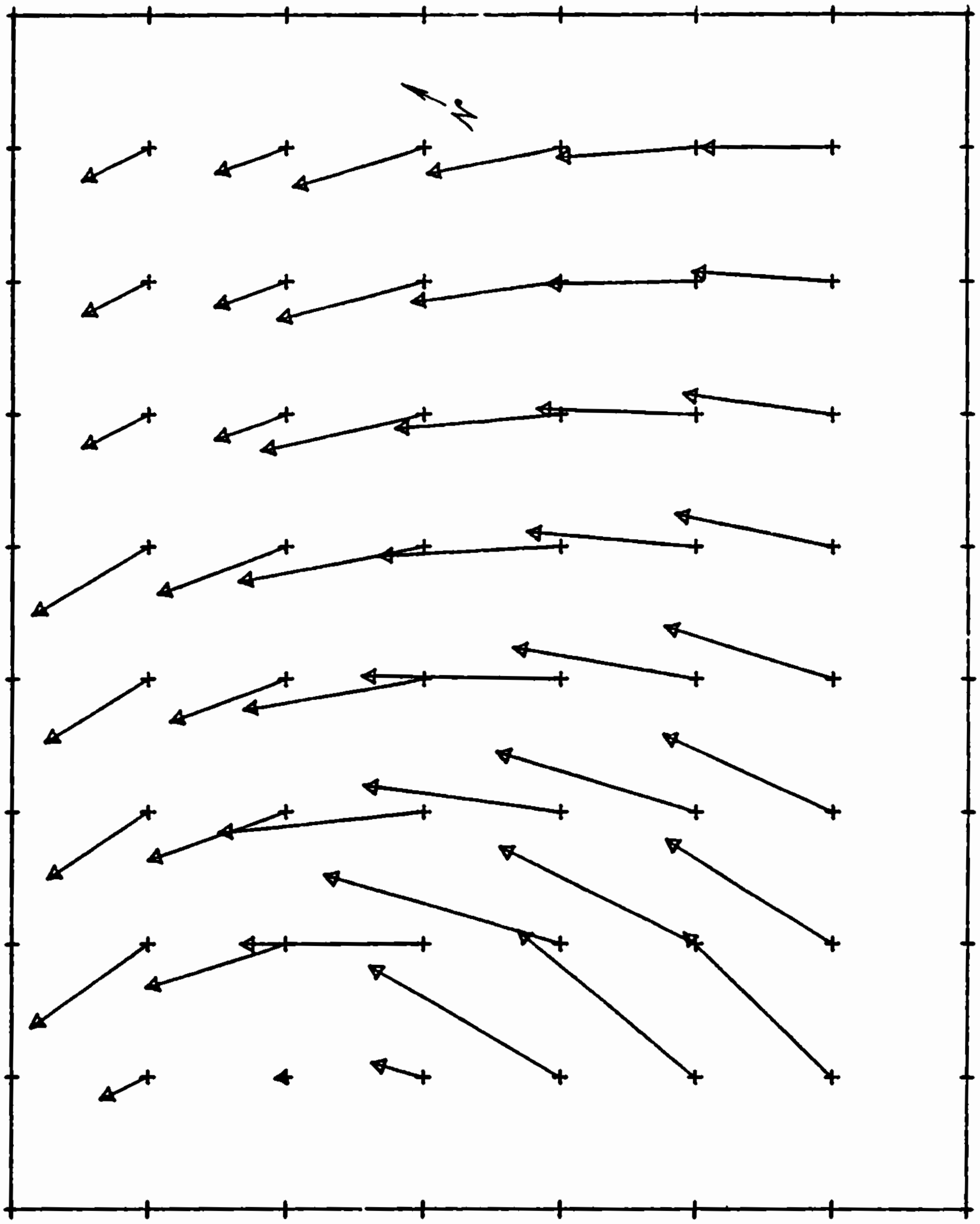

Figure 61. Wind-stress vectors for SPH large radius, medium translation (LR-MT) on an 8-nautical mile grid; time = 35 hours.

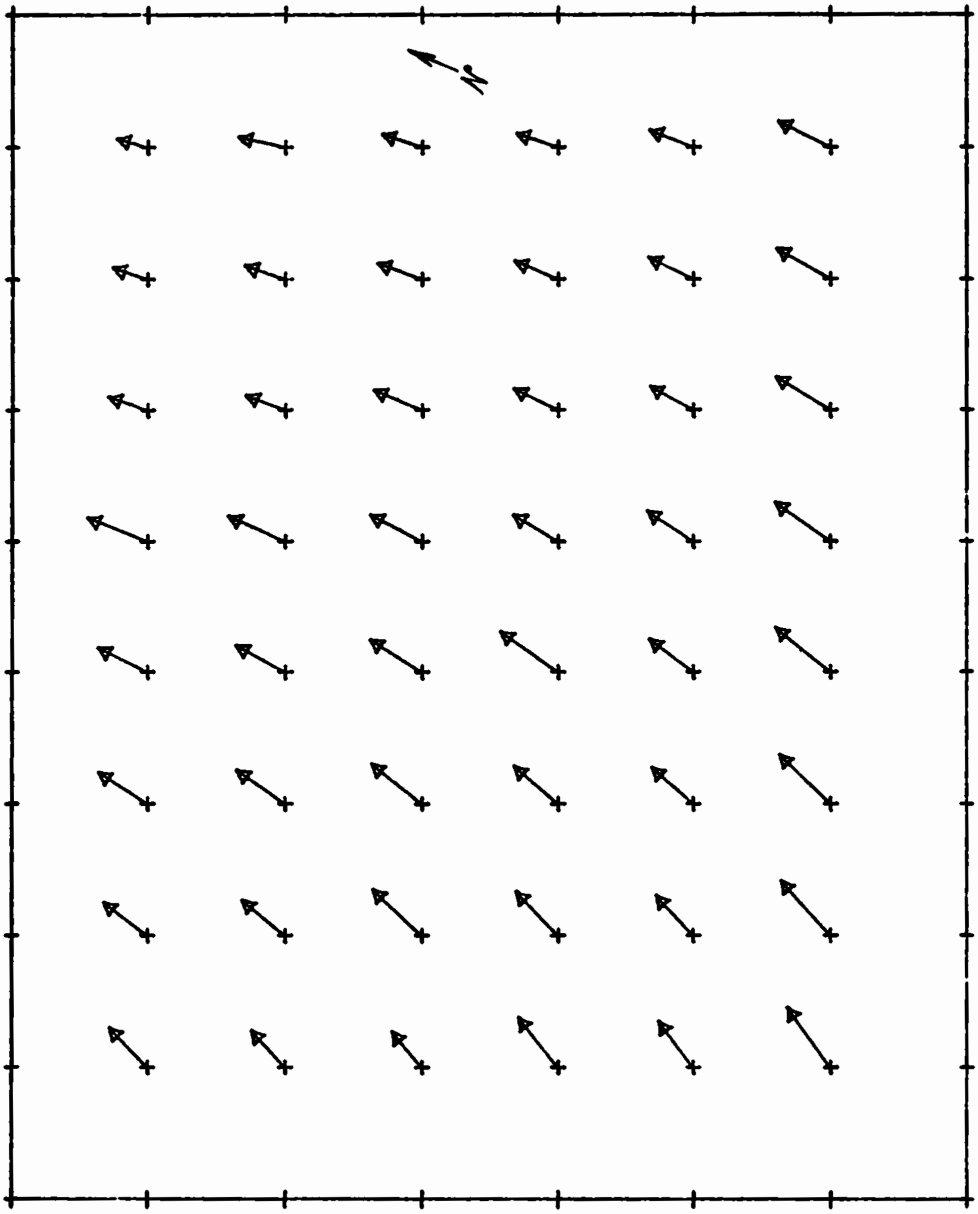

Figure 62. Wind-stress vectors for SPH large radius, medium translation (LR-MT) on an 8-nautical mile grid; time = 40 hours.

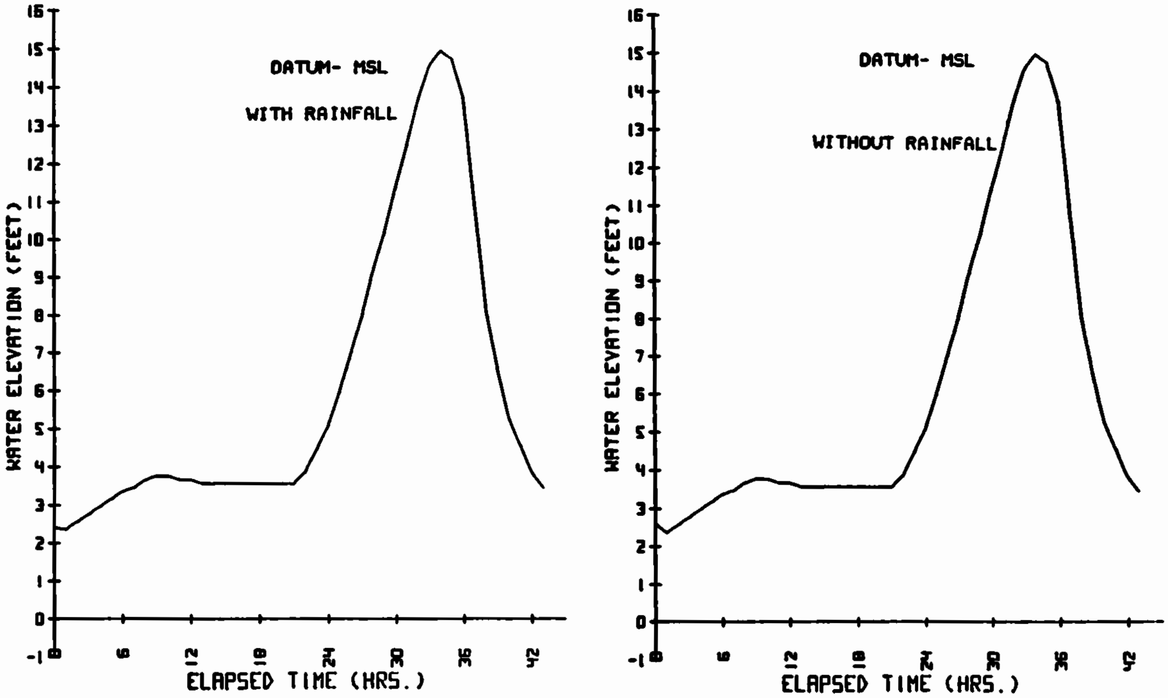

Figure 63. Hydrographs for SPH, LR-MT (with and without rainfall) at Sabine Pass, southwest jetty.

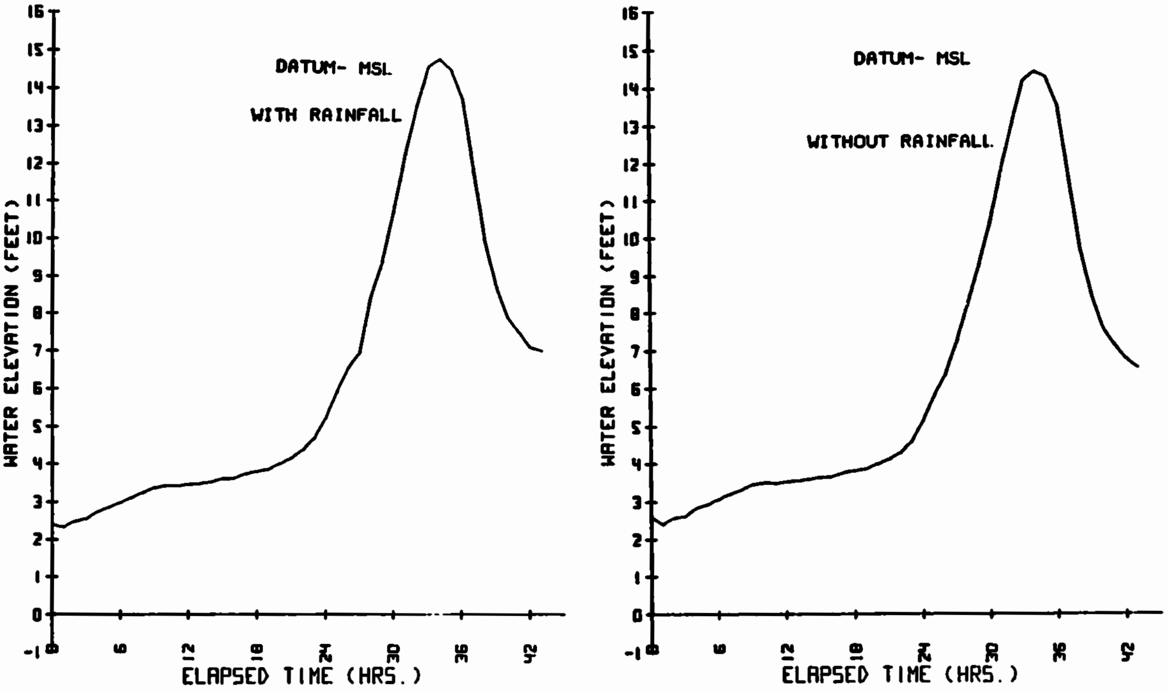

Figure 64. Hydrographs for SPH, LR-MT (with and without rainfall) at Sabine Pass, U.S. Coast Guard Station (FK = 0.0010).

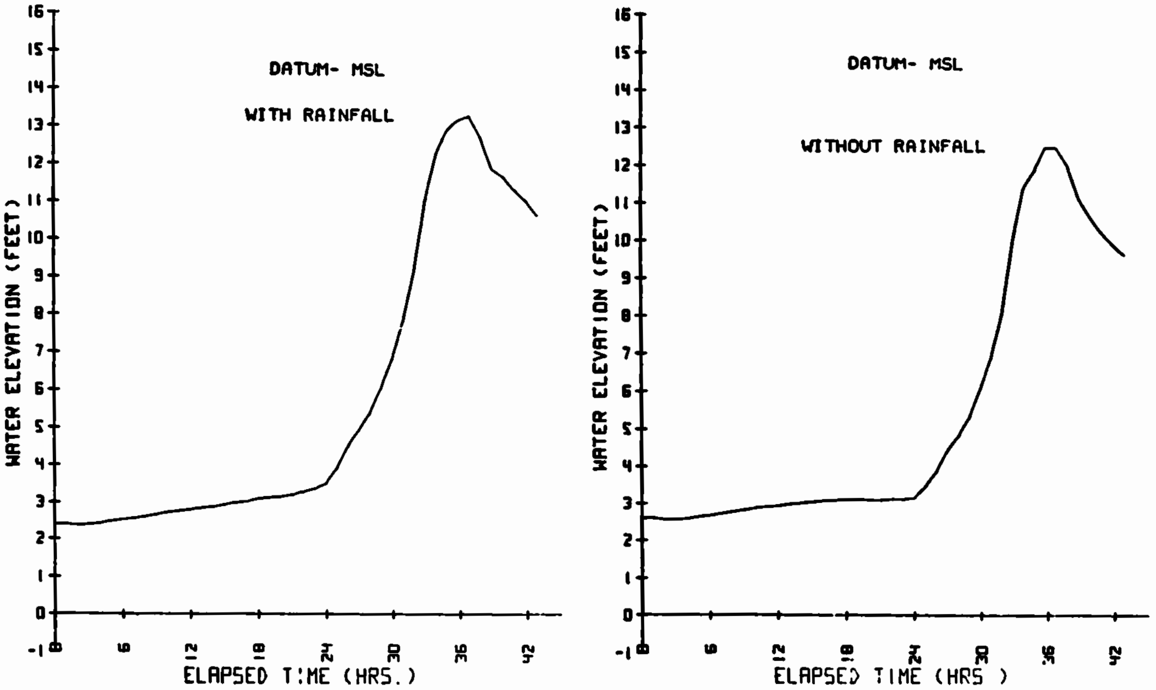

Figure 65. Hydrographs for SPH, LR-MT (with and without rainfall) at Port Arthur (FK = 0.0010).

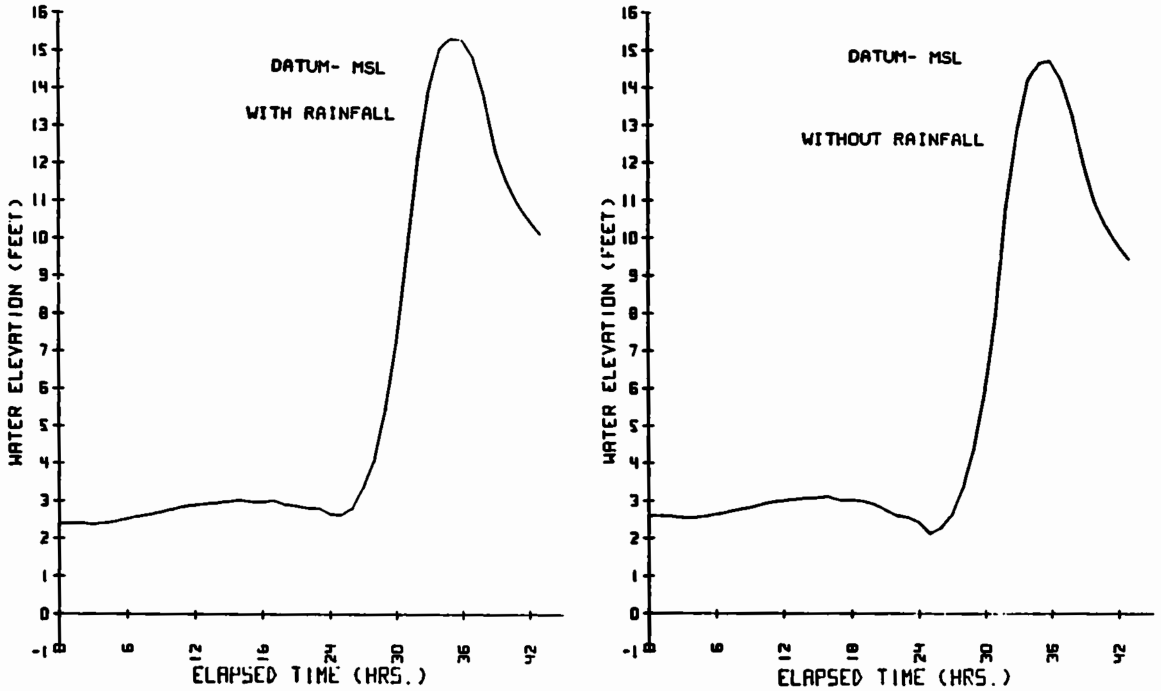

Figure 66. Hydrographs for SPH, LR-MT (with and without rainfall) at north Sabine Lake (FK = 0.0010).

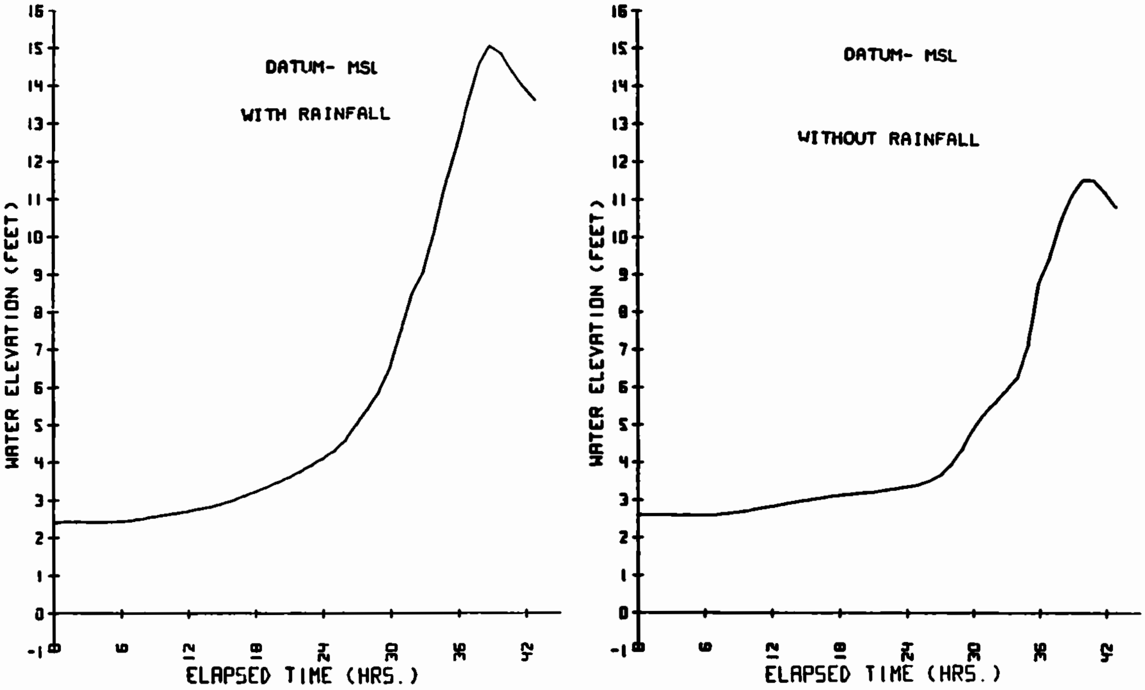

Figure 67. Hydrographs for SPH, LR-MT (with and without rainfall) at Beaumont, Neches River, and Brakes Bayou (FK = 0.0010).

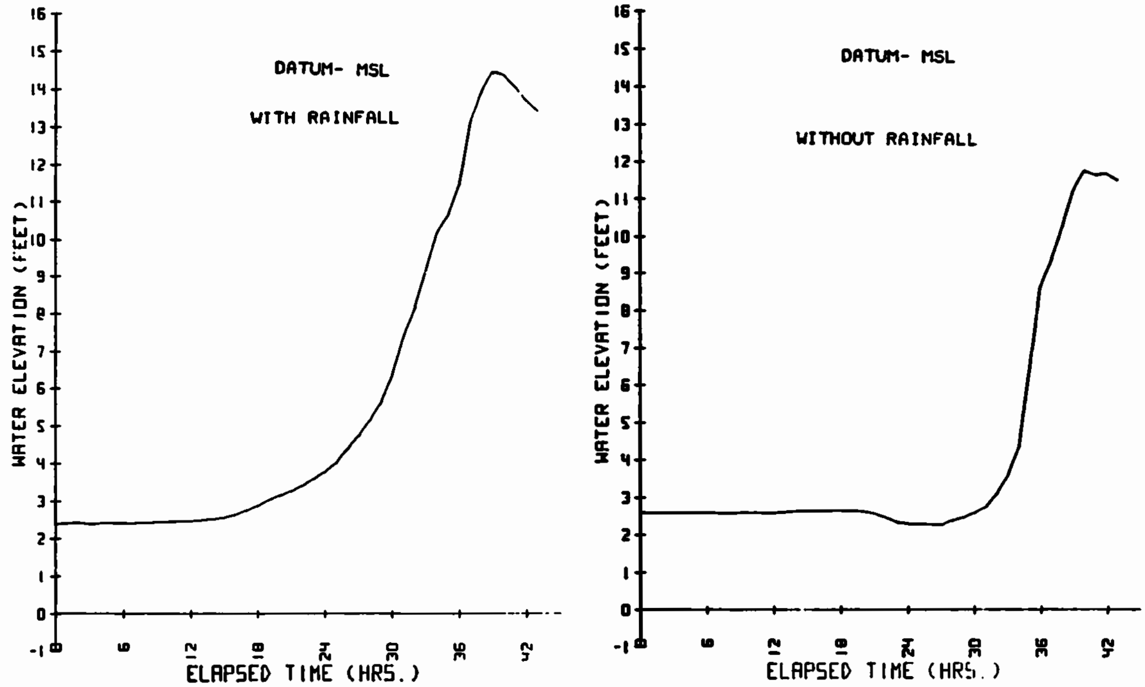

Figure 68. Hydrographs for SPH, LR-MT (with and without rainfall) at Orange Naval Station, Sabine River (FK = 0.0010).

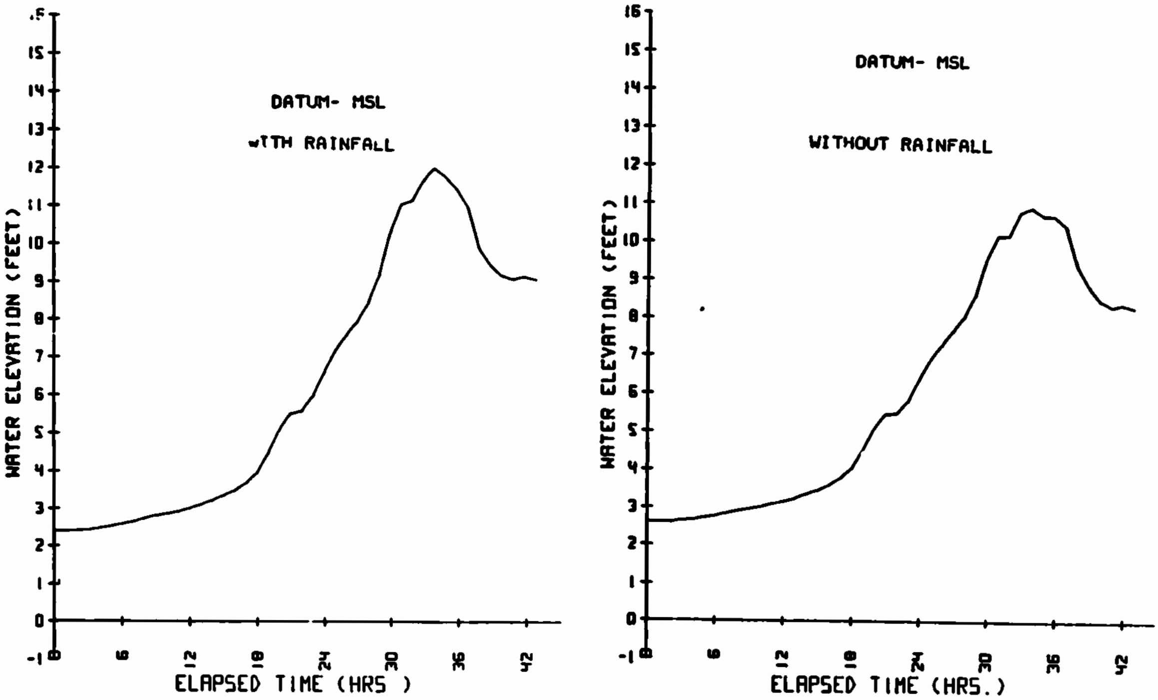

Figure 69. Hydrographs for SPH, LR-MT (with and without rainfall) at west end of Intracoastal Waterway (FK = 0.0010).

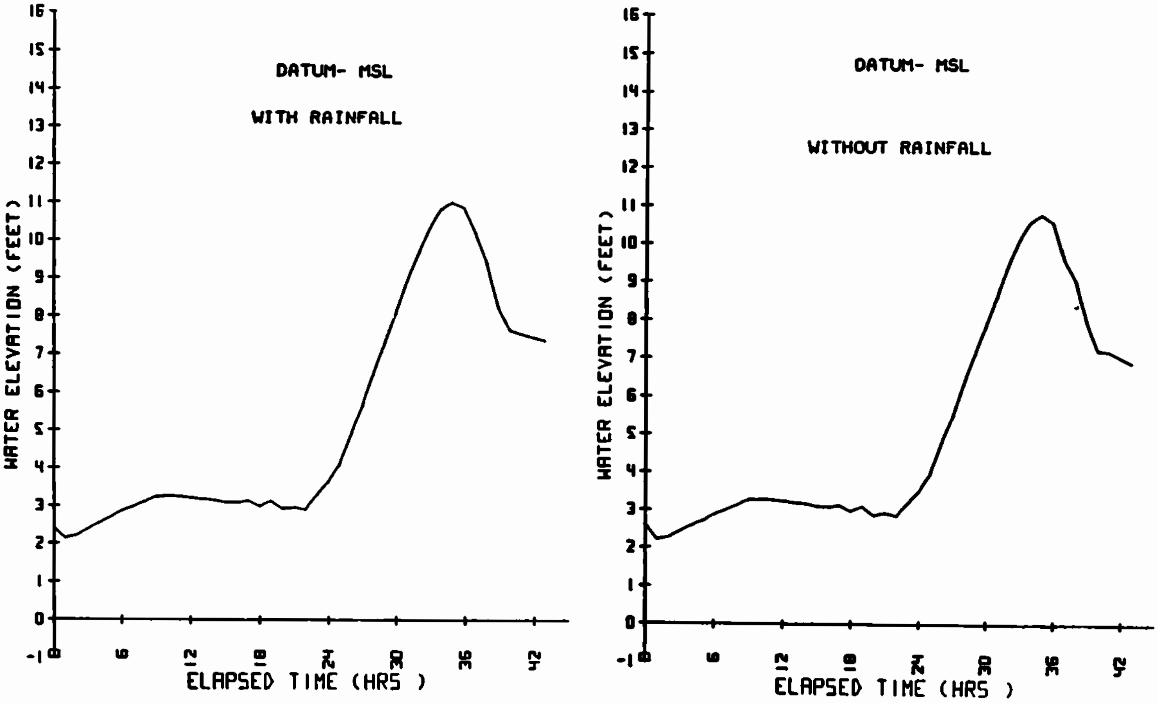

Figure 70. Hydrographs for SPH, LR-MT (with and without rainfall) at Cameron, Calcasieu Pass (FK = 0.0010).

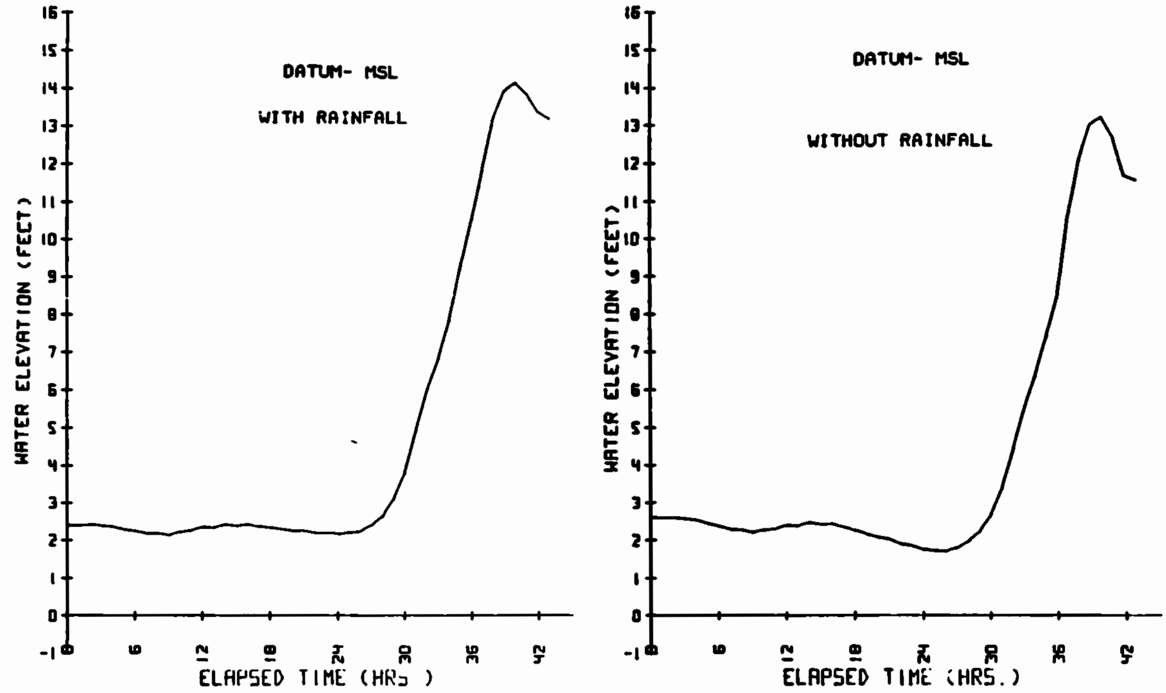

Figure 71. Hydrographs for SPH, LR-MT (with and without rainfall) at Lake Charles, Calcasieu River (FK = 0.0010).

for the greater speed (shorter duration) storm because of the constricted connection to the sea. Port Arthur shows a reduction of 1.1 feet for the MT storm relative to the ST storm; north Sabine Lake appears to show no change. An examination of the wind fields close to the time of the peak surges (Figs. 46 and 61) indicates that a greater wind-induced setup within the lake occurs between Port Arthur and the north Sabine Lake station for the medium speed storm, due to the favorable orientation of the winds near the time of peak surge at the lake entrance.

The response at Beaumont and Orange, both of which are well inland of the main lake area, shows a significant reduction (3.6 and 1.4 feet, respectively) as well as a greater timelag for the faster storm. Moreover, the peak elevations for both of these stations are somewhat less than that at north Sabine Lake for the MT storm in contrast to the situation for the ST storm. The limited access of water to these regions is apparently responsible for this sensitivity to storm duration.

The influence of rainfall and associated runoff from drainage areas well inland is shown very dramatically from a comparison of the second and third sets of peak levels in Table 6, particularly for Beaumont and Orange Naval Station, where runoff produces a differential flooding of 3.6 and 2.8 feet, respectively. A differential of about 0.6 foot due to runoff and rainfall occurs even within Lake Sabine. The effects within Lake Calcasieu and upstream to the northeast are less pronounced due to the smaller runoff.

VIII. CONCLUSION

The use of a modified program for inclusion of subgrid scale channels has been demonstrated to be essential for simulation of tides in the upper reaches of a system like the Sabine-Calcasieu region, where the primary connection to locations such as Beaumont, Orange, and Lake Charles is via river channels which would not otherwise be resolved by a grid scheme of the order of a 1-nautical mile scale. Even for conditions of extreme flooding, as occur during hurricanes, the incorporation of the subgrid scale channels provides a degree of freedom for return flow in the presence of water level gradient, which would otherwise not exist in models which exclude subgrid scale channels. The simulation of Hurricane Carla in particular is improved over that attainable with the SURGE I program which did not allow for the subgrid scale channel subroutine.

While programs such as SURGE I can, in principle, simulate the effects of channels, provided the grid scale is of the order of the channel width, the required computer time is usually prohibitive at least for explicit numerical models. Some advantage can be gained in respect to economy by the use of implicit numerical models such as that of Leendertse (1967); however, the accuracy of such schemes when used on a competitive basis, from the standpoint of economy (large time steps) can suffer relative to that which can be achieved with the subgrid scale channel routine. However, the best procedure for such numerical simulation remains to be determined.

LITERATURE CITED

BODINE, B.R., "Storm Surge on the Open Coast: Fundamentals and Simplified Prediction," TM-35, U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Washington, D.C., May 1971.

DRONKERS, J.J., *Tidal Computations in Rivers and Coastal Waters*, North Holland, Amsterdam, and Wiley and Sons, New York, 1964.

GRAHAM, H.E., and NUNN, D.E., "Meteorological Considerations Pertinent to Standard Project Hurricane, Atlantic and Gulf Coasts of the United States," Report 33, National Hurricane Research Project, U.S. Department of Commerce, Washington, D.C., 1959.

JELESNIANSKI, C.P., "A Numerical Calculation of Storm Tides Induced by A Tropical Storm Impinging on A Continental Shelf," *Monthly Weather Review*, Vol. 93, 1965, pp. 343-358.

JELESNIANSKI, C.P., "Numerical Computations of Storm Surges Without Bottom Stress," *Monthly Weather Review*, Vol. 94, 1966, pp. 379-394.

JELESNIANSKI, C.P., "Numerical Computations of Storm Surges with Bottom Stress," *Monthly Weather Review*, Vol. 95, 1967, pp. 740-756.

LEENDERSTE, J.J., "Aspects of a Computational Model for Long-Period Water Wave Propagation," The Rand Corporation, Santa Monica, Calif., 1967.

LOVE, R.W., "Tidal Response of a Bay with a Constricted Opening to the Sea," Thesis, Texas A&M University, College Station, Tex., 1959.

MARINOS, C., and WOODWARD, J.W., "Estimation of Hurricane Surge Hydrographs," *Journal of the Waterways and Harbors Division*, Vol. XCIV, 1968, pp. 189-216.

MASCH, F.D., et al., "A Numerical Model for the Simulation of Tidal Hydrodynamics in Shallow Irregular Estuaries," University of Texas, Austin, Tex., 1969.

MIYAZAKI, M., "A Numerical Computation of the Storm Surge of Hurricane Carla 1961 in the Gulf of Mexico," Technical Report 10, Department of Geophysical Sciences, University of Chicago, Chicago, Ill., 1963.

PLATZMAN, G.W., "A Numerical Computation of the Surge of 26 June 1954 on Lake Michigan," *Geophysica*, Vol. 6, 1958, pp. 407-438.

REID, R.O., and BODINE, B.R., "Numerical Model for Storm Surges in Galveston Bay, " *Journal of Waterways and Harbors Division*, No. WWI, 1968, pp. 33-57.

STOKER, J.J., *Water Waves, the Mathematical Theory with Applications*, Interscience, New York, 1957.

VAN DORN, W., "Wind Stress on an Artificial Pond," *Journal of Marine Research*, Vol. 2, 1953, pp. 249-276.

APPENDIX A

SURGE II PROGRAM

This appendix includes a complete listing of the SURGE II program. Except for SUBROUTINE CHANL, the program is much the same as that used in Reid and Bodine (1968). It should be emphasized that the coding of calculations of flow and water level for blocks does not include the effect of Coriolis force. Moreover, no attempt has been made to optimize the coding since the original version. The actual new part of the program is embodied in SUBROUTINE CHANL and the way in which the channel computations mesh with the block calculations. Thus, while many users may prefer their own version for calculations over the main grid, it should be possible to incorporate SUBROUTINE CHANL with their own program when applied to systems like the Sabine-Calcasieu region in which allowance for channels is essential.

```
      PROGRAM SURGE(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C
C
C                                                                      C
C**********************************************************************
C
C     SURGE II PROGRAM
C     FOR SIMULATION OF TIDES AND WIND INDUCED SURGES IN BAYS WITH
C     ALLOWANCE FOR SUBGRID-SCALE CHANNELS AND BARRIERS
C     DEVELOPED FOR THE U. S. ARMY CORPS OF ENGINEERS, GALVESTON DISTRICT
C     BY R. O. REID, A. C. VASTANO AND T. J. REID OF
C     COASTAL STUDIES, INC., P.O. BOX 9064, COLLEGE STATION, TX 77843
C     DECEMBER, 1975
C
C**********************************************************************
C
C
C
      COMMON/BLK1/ IB(100),JB(100),IZX(100),IZY(100),ICDOX(100)         MAIN0003
     1,ICDOY(100),ICDSX(100),ICDSY(100),LBCI(8),LBCJ(8),DIST(24)        MAIN0004
     2,CHST(30),RD(8,30),HGP(8),XR(8,6),YR(8,6),HAR(8)                  MAIN0005
C
      COMMON/BLK2/ IZ(28,20),U(28,20),V(28,20),H(28,20),NTIME           MAIN0006
C
      COMMON/BLK3/ NN,MMIN,MMAX,NFU,IAFLD,IM,JM,AM,KMAX,LMAX,DELX,DELT  MAIN0007
     1,CDO,FK,HGI,IOUT,KI,LJ,KII,LJJ,JBL,IBR,KMM,LMM,RF,CONST,S         MAIN0008
     2,IMBO,JMBO,KP,ISTR,IND,NOW,KIM,NORT,MTIME,INTIME,NDAIND,GRAV      MAIN0009
     3,KCMP,DFU,INTER                                                   MAIN0010
C
      COMMON/BLK4/ HRO(8),CRO(8),KB(24),X1(28,21),Y1(28,21),X2(28,21)   MAIN0011
     1,Y2(28,21),X(28),Y(28),HG1(28),HG2(28),HB1(8),HB(9),VN(28)        MAIN0012
     2,HG(28),HB2(8)                                                    MAIN0013
C
      COMMON/BLK5/ ICG(130),JCG(130),IWCX(130),IWCY(130),IZCX(130)      MAIN0014
     1,IZCY(130),DCXP(130),DCXN(130),DCYP(130),DCYN(130),HC(130),HP(130)MAIN0015
     2,KCM,KCX(130),KCY(130),KCH(130),UCT(130),UCF(130),KBI(130),IBOW   MAIN0016
     3,KEN(2,130),VCT(130),VCF(130),ADGX(130),ADGY(130),KCXP(130)       MAIN0017
     4,KCYP(130),KLB(50),KLM,IFC(130),FC                                MAIN0018
C
      COMMON/BLK6/ HGSM(8,25), HARM(8,25), XRM(8,6,25), YRM(8,6,25)     MAIN0019
C
      COMMON/BLK7/ IEND,NF,IBL,NJ,ALPHA(40)                             MAIN0020
C
      COMMON/BLK8/ HS(9,72), QS(5,72), TIME(72)                         MAIN0021
C
      COMMON/BLK9/ KZ,LZ,NUMBO,C1,C2,C3,IMM,JMM,NT,KN,NEXT1,IT,KC,IFIRSTMAIN0022
     1,JWIND,NEW1,XNOW,NEW3,XNJRT, C4,WAIN,AJ,AI,LJK,KIK                MAIN0023
C
      COMMON/BLK10/ NGAGE,NFLOW,IGAGE(12),JGAGE(12),KFLOW(6),XMIN,XMAX  MAIN0024
C
C     CODE WORD (ICARD) ON CARD ONE OF INPUT, CONTROLS INITIAL
C     COMPUTATIONS AND READ ACTIONS AS FOLLOWS
C
```

```
C           ICARD=0   THIS IS FOR STARTING A PROBLEM
C                     CARD INPUT IS ICARD FOLLOWED BY THE FULL GALV
C                     DATA DECK LESS THE BLANK CARD AT THE END
C                     PLUS THE GALV LIST DECK
C                     PLUS THE CHANNEL DATA DECK (IF KCM.GT.ZERO)
C
C           ICARD=1   THIS IS FOR CONTINUING A PROBLEM
C                     CARD INPUT IS ICARD FOLLOWED BY THE CONTIN DECK
C                     THEN FOLLOWED BY THE FIRST FOUR  DATA CARDS OF THE
C                     GALV DATA DECK.  (THE CONTIN DECK IS OUTPUTED FROM
C                     A PREVIOUS RUN)
C
C     CODE WORD (IBL( IS THE STARTING COLUMN IN THE LISTING OF H
C     CODE WORD (KCM( IS THE NUMBER OF BLOCKS WITH CHANNELS
C     CODE WORD (NOWIND( IS NEGATIVE FOR NO WIND FIELD (OMITS CARD INPUT
C         OF X,Y FIELDS AND USES FORMAT 910 FOR HG INPUT)
C     INTER IS THE INTERVAL USED IN THE SAVE H OPERATION
C     NGAGE IS THE NUMBER OF HYDROGRAPHS TO BE SAVED
C     NFLOW IS THE NUMBER OF FLOW GRAPHS TO BE SAVED
C     IMIN AND IMAX ARE THE DESIRED LOWER AND UPPER LIMITS OF H FOR
C
C     GRAPHICAL OUTPUT
      PRINT 10                                                          MAIN0025
   10 FORMAT (1H1)                                                      MAIN0026
      READ 1, ICARD                                                     MAIN0027
    1 FORMAT(I1,I3,10I4)                                                MAIN0028
      IF(ICARD.EQ.0) GO TO 2                                            MAIN0029
C     READS PREVIOUS RESULTS FOR CONTINUATION OF PROBLEM
      CALL CONTIN(1)                                                    MAIN0030
      INTIME=NTIME                                                      MAIN0031
    2 CONTINUE                                                          MAIN0032
      READ 1, IDENT,IBL,KCM,NOWIND,INTER,NGAGE,NFLOW,IMIN,IMAX          MAIN0033
      XMAX = IMAX                                                       MAIN0034
      XMIN = IMIN                                                       MAIN0035
C
   50 FORMAT(3X,(ICARD=(,I2,( IBL=(,I3,( KCM=(,I4,( NOWIND=(,I3         MAIN0036
     1,( INTER=(,I3,( NGAGE=(,I3,( NFLOW=(,I3,( IMIN=(,I3,( IMAX=(,I3,/)MAIN0037
   51 FORMAT(3X,(ICNT=(,I2,( NTIMES=(,I3,( NM=(,I4,( MMIN=(,I4          MAIN0038
     1,( MMAX=(,I4,( NFU=(,I4,( IOUT=(,I4,( INFLO=(,I4)                 MAIN0039
   52 FORMAT(3X,(ICNT=(,I2,( IM=(,I3,( JM=(,I3,( KM=(,I3,( KMAX=(,I3    MAIN0040
     1,( LMAX=(,I3 )                                                    MAIN0041
   53 FORMAT(3X,(ICNT=(,I2,( DELX=(,F4.1,( N MI  DELT=(,F4.0,           MAIN0042
     1 ( SEC  CDD=(,F6.3,( FA=(,F7.4,( FC=(,F7.4,( HGT=(,F6.3,( FT()    MAIN0043
   54 FORMAT(3X,(ICNT=(,I2,( KI=(,I3,( LJ=(,I3,( KIT=(                  MAIN0044
     1,I3,( LJJ=(,I3,( JBL=(,I3,( JAA=(,I3,/)                           MAIN0045
   55 FORMAT(3X,(M=(,I3,( IB=(,I3,( JB=(,I3,( ZX=(, I5,( ZY=(,I5        MAIN0046
     1,( CODX=(,I5,( CODY=(,I5,( COSX=(,I5,( COSY=(,I5)                 MAIN0047
   57 FORMAT(( (,/3X,(ICNT=(,I2,( IMAX=(,I3,( JMAX=(,I3,( KB=(,I3       MAIN0048
     1,( ISTA=(,I3,( INU=(,I3,( NOW=(,I3,( NIM=(,I3,( NOOT=(,I3)        MAIN0049
   58 FORMAT(3X,(ICNT=(,I2,( RF=(,F6.3,( CONST=(,F7.4,( S=(,F8.5)       MAIN0050
   75 FORMAT(3X,(ICNT= 5(,3X,(BARRIER DATA- Z VALUES IN TENTHS OF FEET, MAIN0051
     1 CC VALUES ARE TIMES 1000()                                       MAIN0052
   76 FORMAT(( (,/3X,(ICNT= 6( ,3X,(BLOCK TOPOGRAPHY- Z VALUES IN FEET()MAIN0053
```

```
   79 FORMAT(( (,/3X,(IDNT= 9(,3X,I3,( PATHS OF I,J FOR RUNOFF LOCATIONSMAIN0054
     1()                                                                MAIN0055
   80 FORMAT(( (,/3X,(IDNT= 10(,3X,(PERCENT RAINFALL EACH MAPTIME()     MAIN0056
   81 FORMAT(( (,/3X,(IDNT= 11(,3X,(CHANNEL STRESS VALUES AT MAPTIMES() MAIN0057
   82 FORMAT(( (,/3X,(IDNT= 12(,3X,I3,( SETS OF RUNOFF VALUES IN CFS FORMAIN0058
     1(,I3,( MAPTIMES()                                                 MAIN0059
   83 FORMAT(( (,/3X,(HGH FOLLOWED BY HBR ARRAY (IN FEET) AT MTIME=(,I4)MAIN0060
   84 FORMAT(( (,/3X,(XR VALUES(IDNT=6) AND YR VALUES (IDNT=7) AT MAPTIMMAIN0061
     1E=(,I4)                                                           MAIN0062
C
      PRINT 50, ICARD,IBL,KCM,NOWIND,INTER,NGAGE,NFLOW,IMIN,IMAX        MAIN0063
      READ 100, IDNT1,NTIME,NM,MMIN,MMAX,NFU,IOUT,INFLD                 MAIN0064
      PRINT 51, IDNT1,NTIME,NM,MMIN,MMAX,NFU,IOUT,INFLD                 MAIN0065
  100 FORMAT (I1,2X,I5,9(3X,I5))                                        MAIN0066
  101 FORMAT(1X,I2,I5,9(3X,I5))                                         MAIN0067
      IF(IDNT1-1)1000,150,1000                                          MAIN0068
  150 READ 100, IDNT1,IM,JM,KM,KMAX,LMAX                                MAIN0069
      PRINT  52,IDNT1,IM,JM,KM,KMAX,LMAX                                MAIN0070
      KMM=KMAX-1                                                        MAIN0071
      LMM=LMAX-1                                                        MAIN0072
      IF(IDNT1-2)1000,200,1000                                          MAIN0073
  200 READ 250, IDNT1,DELX,DELT,CDO,FK,FC,HGI                           MAIN0074
      PRINT  53,IDNT1,DELX,DELT,CDO,FK,FC,HGI                           MAIN0075
      DELX=DELX*6080.                                                   MAIN0076
  250 FORMAT (I1,F7.0,9F8.0)                                            MAIN0077
  260 FORMAT (1X,I1,F7.3,9F8.4)                                         MAIN0078
      IF(IDNT1-3)1000,295,1000                                          MAIN0079
  295 IF(ICARD.EQ.0) GO TO 3                                            MAIN0080
      NTIME=INTIME                                                      MAIN0081
      PRINT 10                                                          MAIN0082
      GO TO 705
C
    3 CONTINUE                                                          MAIN0085
      INTIME=NTIME                                                      MAIN0086
  300 READ 100, IDNT1,KI,LJ,KII,LJJ,JBL,JBR                             MAIN0087
      PRINT 54, IDNT1,KI,LJ,KII,LJJ,JBL,JBR                             MAIN0088
      IF(IDNT1-4)1000,350,1000                                          MAIN0089
  350 IF(NFU-MMAX-NM)365,360,365                                        MAIN0090
  360 IF(NFU-MMIN-NTIME)365,368,365                                     MAIN0091
  365 PRINT 366                                                         MAIN0092
  366 FORMAT (21HMMIN OR MMAX IN ERROR   )                              MAIN0093
  368 CONTINUE                                                          MAIN0094
      IF ((KI*KMM)-IM) 440,380,370                                      MAIN0095
  370 IF ((KI*(KMM-1))- IM) 390,440,440                                 MAIN0096
  380 IF ((LJ*LMM)-JM) 440,400,390                                      MAIN0097
  390 IF ((LJ*(LMM-1))-JM)400,440,440                                   MAIN0098
  400 IF (KMM - KII) 410,410,460                                        MAIN0099
  410 IF (LMM - LJJ) 460,460,460                                        MAIN0100
  440 PRINT 450                                                         MAIN0101
  450 FORMAT (1H ,42H    K,L RANGE NOT CONSISTENT WITH I,J RANGE////)   MAIN0102
      GO TO 490                                                         MAIN0103
C
  460 PRINT 470                                                         MAIN0104
```

```
  470 FORMAT (1H ,40H    RANGE OF K OR L TOO LARGE FOR PROGRAM////)       MAIN0105
  480 STOP                                                                MAIN0106
  490 CONTINUE                                                            MAIN0107
      IF(KM.EQ.0) GO TO 501                                               MAIN0108
      PRINT 75                                                            MAIN0109
      DO 500 K=1,KM                                                       MAIN0110
      READ 100, IONT1,IB(K),JB(K),IZX(K),IZY(K),ICOOX(K),ICOOY(K),ICOSX(MAIN0111
     2K),ICOSY(K)                                                         MAIN0112
      PRINT  55,    K,IB(K),JB(K),IZX(K),IZY(K),ICOOX(K),ICOOY(K),ICOSX(MAIN0113
     1K),ICOSY(K)                                                         MAIN0114
      IF(IONT1-5)1000,500,1000                                            MAIN0115
  500 CONTINUE                                                            MAIN0116
  501 CONTINUE                                                            MAIN0117
      PRINT 76                                                            MAIN0118
      DO 550 I=1,IM                                                       MAIN0119
      READ 100, IONT1,(IZ(I,J),J=1,10)                                    MAIN0120
      PRINT 101,    I,(IZ(I,J),J=1,10)                                    MAIN0121
      IF(IONT1-6)1000,540,1000                                            MAIN0122
  540 READ 100, IONT1,(IZ(I,J),J=11,JM)                                   MAIN0123
      PRINT 101,    I,(IZ(I,J),J=11,JM)                                   MAIN0124
      IF(IONT1-6)1000,550,1000                                            MAIN0125
  550 CONTINUE                                                            MAIN0126
      READ 100, IONT1,IMRO,JMRO,KR,ISTR,IND,NO,KTM,NORT                   MAIN0127
      PRINT  57,IONT1,IMRO,JMRO,KR,ISTR,IND,NO,KTM,NORT                   MAIN0128
      IF (IONT1-7)1000,560,1000                                           MAIN0129
  560 READ 250, IONT1,RF,CONST,S                                          MAIN0130
      PRINT  58,IONT1,RF,CONST,S                                          MAIN0131
      IF(IONT1-8)1000,570,1000                                            MAIN0132
  570 PRINT 79, IMRO                                                      MAIN0133
      READ 100, IONT1,(LROI(JJJ),LROJ(JJJ),JJJ=1,5)                       MAIN0134
      PRINT 101,IONT1,(LROI(JJJ),LROJ(JJJ),JJJ=1,5)                       MAIN0135
      IF(IMRO.LT.6) GO TO 575                                             MAIN0136
      READ 100, IONT1,(LROI(JJJ),LROJ(JJJ),JJJ=6,IMRO)                    MAIN0137
      PRINT 101,IONT1,(LROI(JJJ),LROJ(JJJ),JJJ=6,IMRO)                    MAIN0138
  575 CONTINUE                                                            MAIN0139
      IF(IONT1-9)1000,580,1000                                            MAIN0140
  580 IF(NORT-NO)590,590,600                                              MAIN0141
  590 IF(KTM-NO)620,620,600                                               MAIN0142
  600 PRINT 610                                                           MAIN0143
  610 FORMAT (45H KTM OR NORT EXCEEDS NO,OR BOTH EXCEED NO     )          MAIN0144
C
  620 IF(NO-IND.GE.0) GO TO 625                                           MAIN0145
      JMRO= 1                                                             MAIN0146
      GO TO 690                                                           MAIN0147
  625 PRINT 90                                                            MAIN0148
      DO 630 K12=1,2                                                      MAIN0149
      K22=10*(K12-1)+1                                                    MAIN0150
      K23=10*K12                                                          MAIN0151
      READ 250, IONT1,(DIST(K),K=K22,K23)                                 MAIN0152
      PRINT 260,IONT1,(DIST(K),K=K22,K23)                                 MAIN0153
      IF (IONT1-J)999,630,999                                             MAIN0154
  630 CONTINUE                                                            MAIN0155
      READ 250, IONT1,(DIST(K),K=21,24)                                   MAIN0156
```

```
            PRINT 260,IDNT1,(DIST(K),K=21,24)                                 MAIN0157
            IF(IDNT1-0)999,640,999                                            MAIN0158
        640 K33=KK/10                                                         MAIN0159
            IF(KK.EQ.0)  GO TO 690
            IF ( K33 ) 671,670,671                                            MAIN0160
        670 K32 = 0                                                           MAIN0161
            GO TO 672
        671 PRINT 81                                                          0000C0IN0162
            DO680 K=1,K33                                                     0000C0IN0163
            K31=10*(K-1)+1                                                    MAIN0164
            K32=10*K                                                          MAIN0165
            READ 250, IDNT1,(CHST(K4),K4=K31,K32)                             MAIN0166
            PRINT 260,IDNT1,(CHST(K4),K4=K31,K32)                             MAIN0167
            IF(IDNT1-1)999,680,999                                            MAIN0168
        680 CONTINUE                                                          MAIN0169
        672 K31=K32+1
            READ 250, IDNT1,(CHST(K4),K4=K31,KK)                              MAIN0171
            PRINT 260,IDNT1,(CHST(K4),K4=K31,KK)                              MAIN0172
            IF(IDNT1-1)999,690,999                                            MAIN0173
      C
        690 PRINT 82, IMRO, JMRO                                              MAIN0174
            DO 700 J=1,JMRO                                                   MAIN0175
            READ 250, IDNT1,(RO(I,J),I=1,IMRO)                                MAIN0176
            PRINT 261,IDNT1,(RO(I,J),I=1,IMRO) .                              MAIN0177
        261 FORMAT(1X,I1,F7.0,9F8.0)                                          MAIN0178
            IF (IDNT1-2)999,700,999                                           MAIN0179
        700 CONTINUE                                                          MAIN0180
            M=NTIME                                                           MAIN0181
            IT=0                                                              MAIN0182
        705 CONTINUE
            IF(NC-INC.LT.0) GO TO 900                                         MAIN0183
      C
        710 READ 100,   IDNT1,MTIME                                           MAIN0184
        720 IF(IDNT1-3)999,730,999                                            MAIN0185
        730 IF (MTIME-M)740,760,740                                           MAIN0186
        740 PRINT 750,MTIME                                                   MAIN0187
        750 FORMAT (15HMTIME ERROR AT  ,I5)                                   MAIN0188
        760 PRINT 83, MTIME                                                   MAIN0189
            READ 250,   IDNT1,(MGE(K),K=1,KMAX)                               MAIN0190
            PRINT 260,IDNT1,(MGE(K),K=1,KMAX)                                 MAIN0191
            IF (IDNT1-4)999,770,999                                           MAIN0192
        770 READ 250,   IDNT1,(MGR(J),J=2,9)                                  MAIN0193
            PRINT 260,IDNT1,(MGR(J),J=2,9)                                    MAIN0194
            IF(IDNT1-5)999,780,999                                            MAIN0195
        780 PRINT 84, MTIME                                                   MAIN0196
            DO 790 K=1,KMAX                                                   MAIN0197
            READ 250,   IDNT1,(XR(K,L),L=1,LMAX)                              MAIN0198
            PRINT 260,IDNT1,(XR(K,L),L=1,LMAX)                                MAIN0199
            IF (IDNT1-6)999,790,999                                           MAIN0200
        790 CONTINUE                                                          MAIN0201
            DO 800 K=1,KMAX                                                   MAIN0202
            READ 250,   IDNT1,(YR(K,L),L=1,LMAX)                              MAIN0203
            PRINT 260,IDNT1,(YR(K,L),L=1,LMAX)                                MAIN0204
```

```
      IF (IONT1-7)1000,800,999                                          MAIN0205
  800 CONTINUE                                                          MAIN0206
C***********************ADJUST WIND FIELD**********************
      DO 802 K=1,3
      DO 802 L=1,LMAX
      XR(K,L)=0.8*XR(K,L)
      YR(K,L)=0.8*YR(K,L)
  802 CONTINUE
C**************************************************************
  801 IT=II+1                                                           MAIN0207
      DO 810 I=1,KMAX                                                   MAIN0208
      MGRM(I,IT)=MGR(I)                                                 MAIN0209
      DO 820 J=1,LMAX                                                   MAIN0210
      XRM(I,J,IT)=XR(I,J)                                               MAIN0211
  820 YRM(I,J,IT)=YR(I,J)                                               MAIN0212
  810 CONTINUE                                                          MAIN0213
      DO 830 J=2,8                                                      MAIN0214
  830 MBRM(J,IT)=MBR(J)                                                 000000IN0215
      IF(MTIME-MMAX) 710,1015,1015                                      MAIN0216
C
  900 MU=1                                                              000000IN0217
      DO 901 K=1,IMRO                                                   MAIN0218
  901 MGO(K)= RO(K,1)                                                   MAIN0219
      PRINT 914                                                         MAIN0220
  914 FORMAT(( ))                                                       MAIN0221
      PRINT 915                                                         MAIN0222
  905 READ 910,    IGA   ,MTIME,(M(1,J),J=1,12)                         MAIN0223
  910 FORMAT(I2,I4,12F6.2)                                              MAIN0224
  915 FORMAT((    THE FOLLOWING ARE HOURLY TIDE LEVELS OUTSIDE MAIN(,/  MAIN0225
     1 (    PASS FOR TIDE CALIBRATION WITH NO WIND(,/)                  MAIN0226
      PRINT 910, IGA   ,MTIME, (M(1,J),J=1,12)                          MAIN0227
      IONT1= IGA                                                        MAIN0228
      IF(IGA   .NE.1) GO TO 999                                         MAIN0229
      ML=MTIME+1                                                        MAIN0230
      MU=MTIME+12                                                       MAIN0231
      DO 940 J=1,12                                                     MAIN0232
      M=ML+J-1                                                          MAIN0233
      DO 920 I=1,KMAX                                                   000000IN0234
  920 MGRM(I,M)=M(1,J)                                                  000000IN0235
      DO 930 I=2,8                                                      MAIN0236
  930 MBRM(I,M)=M(1,J)                                                  MAIN0237
  940 CONTINUE                                                          MAIN0238
      IF(MU.LT.MMAX) GO TO 905                                          MAIN0239
C
      DO 950 K=1,KMAX                                                   MAIN0240
      DO 950 L=1,LMAX                                                   MAIN0241
      XR(K,L)=0.0                                                       MAIN0242
      YR(K,L)=0.0                                                       MAIN0243
  950 CONTINUE                                                          MAIN0244
      GO TO 1015                                                        MAIN0245
C
  999 IONT1=IONT1+10                                                    MAIN0246
 1000 PRINT 1010,IONT1                                                  MAIN0247

 1010 FORMAT ((  ERROR IN DATA - MISSING (,I5,2X,4HCARD )               MAIN0248
      STOP                                                              MAIN0249
C
 1015 CALL PART 2                                                       MAIN0250
C
 1020 STOP                                                              MAIN0251
      END                                                               MAIN0252
```

```
      C
      C
             SUBROUTINE PART 2                                               PT2-0001
      C
             COMMON/BLK1/ IB(100),JB(100),IZX(100),IZY(100),ICOCX(100)       PT2-0004
            1,ICOCY(100),ICOSX(100),ICOSY(100),LOCI(8),LOCJ(8),DIST(24)      PT2-0005
            2,CHST(30),RO(8,30),NGR(8),XR(8,6),YR(8,6),NRW(8)                PT2-0006
             COMMON/BLK2/ IZ(28,20),U(28,20),V(28,20),H(28,20),TIME          PT2-0007
             COMMON/BLK3/ IN,MMIN,MMAX,NFU,INFLO,IM,JM,KM,KMAX,LMAX,DELX,DELT PT2-0008
            1,CDO,FK,HGI,IOUT,KI,LJ,KII,LJJ,JHL,JCP,KMM,LMM,RF,CONST,S       PT2-0009
            2,IMRO,JMRO,KR,ISTR,IND,NOR,KIM,NORT,NTIME,INTIME,NCHIND,GRAV    PT2-0010
            3,KCMP,DFU,INTER                                                 PT2-0011
             COMMON/BLK4/ HRO(8),CRO(6),KB(24),X1(28,21),Y1(28,21),X2(28,21) PT2-0012
            1,Y2(28,21),X(28),Y(28),HG1(28),HG2(28),HB1(8),HB(9),VN(28)      PT2-0013
            2,HG(28),HH2(2)                                                  PT2-0014
             COMMON/BLK5/ ICG(130),JCG(130),IOCX(130),IOCY(130),IZCX(130)    PT2-0015
            1,IZCY(130),QCXP(130),QCXN(130),QCYP(130),QCYN(130),HC(130),HP(130)PT2-0016
            2,KCM,KCX(130),KCY(130),KCH(130),UCT(130),UCF(130),KPI(130),INOM PT2-0017
            3,KEN(2,130),VCT(130),VCF(130),ADGX(130),ADGY(130),KCXP(130)     PT2-0018
            4,KCYP(130),KLR(50),KLM,IFC(130),FC                              PT2-0019
             COMMON/BLK6/ HGRM(8,25), HBRM(8,25), XRM(8,6,25), YRM(8,6,25)   PT2-0020
             COMMON/BLK7/ TEND,NF,IBL,NJ,ALPHA(60)                           PT2-0021
             COMMON/BLK8/ HS(9,72), QS(9,72), TIME(72)                       PT2-0022
             COMMON/BLK9/ KZ,LZ,NUMRO,C1,C2,C3,IMM,JMM,NT,NN,NEXT1,IT,KC,IFIRSTPT2-0023
            1,JMINU,NEN1,XNO,NEN3,XNCRT, C4,RAIN,AJ,AI,LJK,KIK               PT2-0024
             COMMON/BLK10/ NGAGE,NFLOW,IGAGE(12),JGAGE(12),MFLOW(6),XMIN,XMAX PT2-0025
      C
             ABSF(X)=ABS(X)                                                  PT2-0026
             SQRTF(X)=SQRT(X)                                                PT2-0027
      C
             NUMRO=IMRO                                                      PT2-0028
             KZ=KI                                                           PT2-0029
             LZ=LJ                                                           PT2-0030
             GRAV=32.1456355                                                 PT2-0031
             C1=FK*DELT                                                      PT2-0032
             C2=(GRAV*DELT)/(2.*DELX)                                        PT2-0033
             C3=DELT/DELX                                                    PT2-0034
             IMM=IM-1                                                        PT2-0035
             JMM=JM-1                                                        PT2-0036
             NT=0                                                            PT2-0037
             NN=0                                                            PT2-0038
             NEXT1=1                                                         PT2-0039
             IT=2                                                            PT2-0040
             KC=1                                                            PT2-0041
             IFIRST=-1                                                       PT2-0042
             JMINU=NFU+1                                                     PT2-0043
             DO 130 I=1,IM                                                   PT2-0044
             VN(I)=0.                                                        PT2-0045
             DO 130 J=1,JM                                                   PT2-0046
             H(I,J)=IZ(I,J)                                                  PT2-0047
             Z=IZ(I,J)                                                       PT2-0048
             IF(Z.LT.HGI) H(I,J)=HGI                                         PT2-0049
             U(I,J)=0.                                                       PT2-0050
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             130 V(I,J)=0.                                                        PT2-0051
                 NTIME=-1                                                         PT2-0052
          C
          C      READ CHANNEL DATA AND ESTABLISH KEY ARRAYS
                 IF(KCH.GT.0) CALL CHANL(1)                                       PT2-0053
          C      READ GAGE LOCATIONS FOR SAVING KEY H AND Q VALUES AS TIME SEQUENCE
                 CALL SAVE(1)                                                     PT2-0054
          C      READ LIST DATA AND PRINT PROBLEM IDENTIFICATION AND Z FIELD
                 READ 15,   IDENT,IEND,NF,IBEGIN,NJ,NCARD                         PT2-0055
              15 FORMAT(I1,I4,4I5)                                                PT2-0056
             140 FORMAT(  /1H ,15A2,15A2,10A2)                                    PT2-0057
             220 FORMAT(1H1)                                                      PT2-0058
             230 FORMAT(15A2,15A2,10A2)                                           PT2-0059
                 PRINT 220                                                        PT2-0060
                 DO 250 J=1,NCARD                                                 PT2-0061
                 READ 230, (ALPHA(I),I=1,40)                                      PT2-0062
             250 PRINT 140, (ALPHA(I),I=1,40)                                     PT2-0063
                 PRINT 220                                                        PT2-0064
          C
          C
             148 CONTINUE                                                         PT2-0065
                 RF=(RF/12.)*CONST                                                PT2-0066
                 NEW1=NOW                                                         PT2-0067
                 XNOW=NOW                                                         PT2-0068
                 NEW3=NORT                                                        PT2-0069
                 XNORT=NORT                                                       PT2-0070
                 ISTR=ISTR+NFU                                                    PT2-0071
                 IND=IND+NFU                                                      PT2-0072
                 AJ=LZ                                                            PT2-0073
                 AI=KZ                                                            PT2-0074
                 JMM=JM-1                                                         PT2-0075
                 LJK=LZ-1                                                         PT2-0076
                 KIK=KZ-1                                                         PT2-0077
          C
                 ENTRY PART 2B                                                    PT2-0078
                 NU = (NM-NTIME)/INTER                                            PT2-0079
                 CALL PLOT
          C      PLOT CHANNELS AND BARRIERS
                 CALL SAVE(2)                                                     PT2-0082
                 IF(KCM.GT.0) CALL CHANL(4)                                       PT2-0083
          C      START OF TIME INCREMENTING LOOP
             200 CONTINUE                                                         PT2-0084
                 IF(NOWIND.LT.0) GO TO 430                                        PT2-0085
             300 IF (NEW1-NOW)330,310,310                                         PT2-0086
             310 CW=(CHST(NEXT1+1)-CHST(NEXT1))/XNOW                              PT2-0087
                 BIND=CHST(NEXT1)                                                 PT2-0088
                 NEW1=1                                                           PT2-0089
                 DO 320 NEW2=1,THRO                                               PT2-0090
             320 CHQ(NEW2)=(PO(NEW2,NEXT1+1)-PO(NEW2,NEXT1))/XNOW                 PT2-0091
                 NEXT1=NEXT1+1                                                    PT2-0092
                 GO TO 340                                                        PT2-0093
             330 NEW1=NEW1+1                                                      PT2-0094
             340 AN1=NEW1                                                         PT2-0095
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          CHSTR=BTMP+(AN1-1.)*C-                                       PT2-0096
          YC=CHSTR                                                      PT2-0097
          DO 350 KA=1,IMRO                                              PT2-0098
          NX=NEXT1                                                      PT2-0099
      350 MRO(KA)=RO(KA, NX-1  )+(AN1-1.)*CRO(KA)                       PT2-0100
          IHOUR=NTIME/NFU*NFU                                           PT2-0101
      360 IF(NTIME-ISTR)430,380,370                                     PT2-0102
      370 IF(NTIME-IND)380,410,430                                      PT2-0103
      380 IF(NE-3-NORT)400,390,390                                      PT2-0104
      390 NE-4=(DIST(KC+1)-DIST(KC))/XNORT                              PT2-0105
          KC=KC+1                                                       PT2-0106
          NE-3=1                                                        PT2-0107
          GO TO 420                                                     PT2-0108
      400 NE-3=NE-3+1                                                   PT2-0109
          GO TO 420                                                     PT2-0110
      410 NE-4=0                                                        PT2-0111
          KC=KC+1                                                       PT2-0112
      420 CONTINUE                                                      PT2-0113
          AN3=NE-3                                                      PT2-0114
          AN4=NE-4                                                      PT2-0115
          R=(RF*(DIST(KC-1)+(AN3-1.)*AN4  ))/XNORT                      PT2-0116
          RAIN=R                                                        PT2-0117
          GO TO 440                                                     PT2-0118
      430 RAIN=0.0                                                      PT2-0119
      440 CONTINUE                                                      PT2-0120
C         END OF RAIN AND RO VALUES
C
C         START OF WIND COMPUTATIONS
      500 IF (J-IND-NFU)800,800,510                                     PT2-0121
      510 CONTINUE                                                      PT2-0122
      560 IF (IFIRST)600,570,570                                        PT2-0123
      570 DO 580 I=1,IM                                                 PT2-0124
          HG1(I)=HG2(I)                                                 PT2-0125
          DO 580 J=1,JM                                                 PT2-0126
          X1(I,J)=X2(I,J)                                               PT2-0127
      580 Y1(I,J)=Y2(I,J)                                               PT2-0128
          DO 590 IR1=2,8                                                PT2-0129
      590 HG1(IR1)=HG2(IR1)                                             PT2-0130
      600 NTIME=NTIME+1                                                 PT2-0131
          IT=NTIME+1                                                    PT2-0132
          DO 610 I=1,KMAX                                               PT2-0133
          HGR(I)=HGRM(I,IT)                                             PT2-0134
          IF(MONIND.LT.0) GO TO 610                                     PT2-0135
          DO 620 J=1,LMAX                                               PT2-0136
          XR(I,J)=XRM(I,J,IT)                                           PT2-0137
      620 YR(I,J)=YRM(I,J,IT)                                           PT2-0138
      610 CONTINUE                                                      PT2-0139
          DO 630 J=2,9                                                  PT2-0140
      630 MRR(J)=MRRM(J,IT)                                             PT2-0141
      640 J=IND+1                                                       PT2-0142
          IS=1                                                          PT2-0143
          DO 710 L=1,LMAX                                               PT2-0144
          JC=1+(L7*(L-1))                                               PT2-0145
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                  DO 680 K=1,KMM                                                      PT2-0146
                  I1=1+(KZ*(K-1))                                                     PT2-0147
                  I2=I1+KIK                                                           PT2-0148
                  DXR=(XR(K+1,L)-XR(K,L))/AI                                          PT2-0149
                  DYR=(YR(K+1,L)-YR(K,L))/AJ                                          PT2-0150
                  GO TO (650,660),IS                                                  PT2-0151
              650 DHR=(HGR(K+1)-HGR(K))/AI                                            PT2-0152
              660 DO 680 IC=I1,I2                                                     PT2-0153
                  DFU=IC-I1                                                           PT2-0154
                  Y2(IC,JC)=YR(K,L)+(DYR*(DFU+.5))                                    PT2-0155
                  X2(IC,JC)=XR(K,L)+(DXR*DFU)                                         PT2-0156
                  GO TO (670,680),IS                                                  PT2-0157
              670 HG2(IC)=HGR(K)+DHR*(DFU+.5)                                         PT2-0158
              680 CONTINUE                                                            PT2-0159
                  DO 690 IRT=2,8                                                      PT2-0160
              690 HB2(IRT)=HBR(IRT)                                                   PT2-0161
                  GO TO (700,710),IS                                                  PT2-0162
              700 IS=2                                                                PT2-0163
              710 CONTINUE                                                            PT2-0164
                  DO 740 I=1,IM                                                       PT2-0165
                  DO 730 L=1,LMM                                                      PT2-0166
                  J1=1+(LZ*(L-1))                                                     PT2-0167
                  J2=J1+LJK                                                           PT2-0168
                  J1KI= J1+KZ                                                         PT2-0169
                  J1LJ=J1+LZ                                                          PT2-0170
                  DXR=(X2(I,J1KI )-X2(I,J1))/AI                                       PT2-0171
                  DYR=(Y2(I,J1LJ )-Y2(I,J1))/AJ                                       PT2-0172
                  DO 720 J=J1,J2                                                      PT2-0173
                  DFU=J-J1                                                            PT2-0174
                  X2(I,J)=X2(I,J1)+DXR*(DFU+.5)                                       PT2-0175
                  Y2(I,J)=Y2(I,J1)+DYR*DFU                                            PT2-0176
              720 CONTINUE                                                            PT2-0177
              730 CONTINUE                                                            PT2-0178
              740 CONTINUE                                                            PT2-0179
                  IF (IFIRST)750,800,800                                              PT2-0180
              750 IFIRST=1                                                            PT2-0181
                  GO TO 570                                                           PT2-0182
              800 CONTINUE                                                            PT2-0183
              810 ANUP=NFU                                                            PT2-0184
                  NIND=J-IND                                                          PT2-0185
                  DFU=(NIND-1.)/ANUP                                                  PT2-0186
                  DFUM=DFU+(1./ANUP)                                                  PT2-0187
                  DO 820 K=2,8                                                        PT2-0188
              820 HB(K)=HB1(K)+DFUM*(HB2(K)-HB1(K))                                   PT2-0189
                  HG(IM)= HG1(IM) + DFUM*(HG2(IM)-HG1(IM))                            PT2-0190
            C
            C     SWEEP WHOLE FIELD FOR FLOW FROM BLOCKS
            C
              830 DO 2010 J=1,JMM                                                     PT2-0191
            C     THIS BRANCH SKIPS THE INVESTIGATION OF POSSIBLE BARRIERS FOR THE
            C     ROW J=1. FOR J=1 THE INDICATOR LG=3 IS SET. IF J IS GREATER THAN
            C     1 A SEARCH FOR BARRIERS IN THE ROW WILL TAKE PLACE.
              840 KJ = 0                                                              PT2-0192
```

```
          L=0                                                            PT2-0193
C         A NORMAL  COMPUTATION SEQUENCE WILL OCCUR.THE FIRST X-DIR FLUX
C         TEMPORARY STORAGE IS SET AS THAT OF THE FIRST COLUMN.
C         THE NUMBER AND LOCATIONS OF THE BARRIERS PRESENT IN THE ROW ARE
C         FOUND AND PLACED IN TEMPORARY STORAGE. IF NO BARRIERS ARE PRESENT
C         THE INDICATOR KJ REMAINS ZERO.
          IF (KM.EQ.0) GO TO 870                                         PT2-0194
          DO 860 K=1,KM                                                  PT2-0195
          IF (J-JB(K))860,850,860                                        PT2-0196
      850 KJ = KJ + 1                                                    PT2-0197
          L=L+1                                                          PT2-0198
          KB(L)=K                                                        PT2-0199
C
      860 CONTINUE                                                       PT2-0200
C         BASED ON KJ. THE INDEX LJ IS SET TO INDICATE THE BARRIER SITUATION
C         IN THE MAIN COMPUTATION. LJ=1 FOR NO BARRIERS.
          IF(KJ)870,870,880                                              PT2-0201
      870 LJ=1                                                           PT2-0202
          GO TO 890                                                      PT2-0203
      880 LJ=2                                                           PT2-0204
C
C         THIS IS THE PRIMARY LOOP FOR STEPPING THRU THE IM GRID COLUMNS.
      890 DO 2000 I=1,IMM                                                PT2-0205
C         BEGIN THE EXAMINATION OF THE BASIC TRIAD OF GRID SQUARES. THE
C         DUMMY VARIABLES H1,D1,H2,D2 AND Q ARE USED TO ALLOW ONE ROUTINE TO
C         BE EMPLOYED FOR BOTH SETS OF SQUARES. SQUARES ONE AND TWO ARE
C         TAKEN FIRST.
      900 IF (J-1)910,910,920                                            PT2-0206
      910 HG(I)=HG1(I)+DFUM*(HG2(I)-HG1(I))                              PT2-0207
      920 X(I)=S*(X1(I,J)+DFU*(X2(I,J)-X1(I,J)))                         PT2-0208
          Y(I)=S*(Y1(I,J)+DFU*(Y2(I,J)-Y1(I,J)))                         PT2-0209
          H1 = H(I,J)                                                    PT2-0210
          Z = IZ(I,J)                                                    PT2-0211
          D1 = H1-Z                                                      PT2-0212
C         THIS BRANCH WILL SET UP A SEARCH FOR A BARRIER IN THE SQUARES
C         BEING CONSIDERED IF LJ=2. IF LJ=1 OR THE BARRIER EXISTS BETWEEN
C         THE OTHER PAIR OF SQUARES AN INDEX IS SET. LI=1. FOR A BARRIER,
C         LI=2.
     1000 GO TO (1040,1010),LJ                                           PT2-0213
C         THIS K LOOP SEARCHES FOR A BARRIER IN THE PAIR OF SQUARES.
     1010 DO 1030 K=1,KJ                                                 PT2-0214
          KI= KB(K)                                                      PT2-0215
          IF(I-IB(KI))1030,1020,1030                                     PT2-0216
     1020 LI=2                                                           PT2-0217
          GO TO 1050                                                     PT2-0218
C
     1030 CONTINUE                                                       PT2-0219
     1040 LI=1                                                           PT2-0220
C         THE DUMMY VARIABLES H2 AND D2 ARE SET FOR THE SQUARE ONE AND TWO
C         CALCULATION. THIS IS INDICATED BY LQ=1.
     1050 CONTINUE                                                       PT2-0221
     1053 H2 = H(I+1,J)                                                  PT2-0222
     1054 Z = IZ(I+1,J)                                                  PT2-0223
```

```
      D2 = H2 -Z                                                        PT2-0224
      LO = 1                                                            PT2-0225
C
C     THE INVESTIGATION OF THE RELATION BETWEEN DATUMS OF BOTH PAIRS OF
C     SQUARES BEGINS HERE. THIS BRANCH TESTS LI FOR A BARRIER.
 1060 GO TO (1110,1070),LI                                              PT2-0226
C     A BARRIER EXISTS AND ON THE BASIS OF LO THE DATUM IS ASSIGNED THE
C     PROPER BARRIER HEIGHT.
 1070 GO TO (1080,1090),LO                                              PT2-0227
 1080 ZB =IZX(KI)                                                       PT2-0228
      CODI = ICODX(KI)                                                  PT2-0229
      COSI = ICOSX(KI)                                                  PT2-0230
      GO TO 1100                                                        PT2-0231
 1090 ZB = IZY(KI)                                                      PT2-0232
      CODI = ICODY(KI)                                                  PT2-0233
      COSI = ICOSY(KI)                                                  PT2-0234
 1100 ZB = ZB *0.1                                                      PT2-0235
      CODI = CODI * .001                                                PT2-0236
      COSI = COSI * .001                                                PT2-0237
      GO TO 1140                                                        PT2-0238
C     NO BARRIER EXISTS. THE RELATIVE DATUM HEIGHTS OF THE SQUARES ARE
C     TESTED AND THE HIGHER DATUM SET EQUAL TO ZB.
 1110 CODI = COD                                                        PT2-0239
      IF (H1-D1-H2+D2)1120,1130,1130                                    PT2-0240
 1120 ZB=(H2-D2)                                                        PT2-0241
      GO TO 1140                                                        PT2-0242
 1130 ZB = H1 - D1                                                      PT2-0243
C     THE INVESTIGATION OF THE DEPTH SIGNATURES BEGINS AT THIS POINT.
C     THE PROPER ASSIGNMENT IS MADE FOR THE FLUX CLACULATION.
C
 1140 IF(D1)1150,1160,1190                                              PT2-0244
 1150 LM=1                                                              PT2-0245
      GO TO 1170                                                        PT2-0246
C
 1160 LM=2                                                              PT2-0247
 1170 IF(D2)1360,1360,1180                                              PT2-0248
 1180 IF(H2-ZB)1340,1360,1260                                           PT2-0249
 1190 IF(D2)1200,1210,1230                                              PT2-0250
 1200 LM=1                                                              PT2-0251
      GO TO 1220                                                        PT2-0252
 1210 LM=2                                                              PT2-0253
 1220 IF(H1-ZB)1350,1350,1270                                           PT2-0254
 1230 IF(H1-ZB)1160,1160,1240                                           PT2-0255
 1240 IF(H2-ZB)1250,1250,1280                                           PT2-0256
 1250 LM=2                                                              PT2-0257
      GO TO 1270                                                        PT2-0258
 1260 DH=ZB-H2                                                          PT2-0259
      DP=ABS(DH)                                                        PT2-0260
      TAD = 4.* D2                                                      PT2-0261
      GO TO (1290,1350),LM                                              PT2-0262
C
 1270 DH=H1-ZB                                                          PT2-0263
      DP=ABS(DH)                                                        PT2-0264
```

```
           TAD = 4.* D1                                                       PT2-0265
           GO TO (1300,1350),LM                                               PT2-0266
      1280 GO TO (1460,1330),LI                                               PT2-0267
      1290 H(I,J)=H1-D1                                                       PT2-0268
           GO TO 1350                                                         PT2-0269
      1300 GO TO (1310,1320),LQ                                               PT2-0270
      1310 H(I+1,J) = H2 - D2                                                 PT2-0271
           GO TO 1350                                                         PT2-0272
      1320 H(I,J+1) = H2 - D2                                                 PT2-0273
           GO TO 1350                                                         PT2-0274
      1330 IF (ZA-(H1-D1)) 1460,1460,1340                                     PT2-0275
      1340 IF(ZB-(H2-D2))1460,1460,1370                                       PT2-0276
      1350 IF(CP.LT.0.000001) GO TO 1360                                      PT2-0277
           DREW = (CDOT *DH)*(CDOI*DH)                                        PT2-0278
           GO TO 1380                                                         PT2-0279
      1360 G=0.                                                               PT2-0280
           GO TO 1570                                                         PT2-0281
      1370 DH=H1-H2                                                           PT2-0282
           TAD = D1+D2                                                        PT2-0283
           DH =(((H1+H2)/2.) -ZB) * COSI                                      PT2-0284
           DREW = DH*DH                                                       PT2-0285
      1380 GO TO (1390,1400),LQ                                               PT2-0286
      1390 Q = U(I+1,J)                                                       PT2-0287
           PUSH = X(I  ) * DELT                                               PT2-0288
           GO TO 1450                                                         PT2-0289
      1400 Q =V(I,J+1)                                                        PT2-0290
      1440 PUSH = Y(I) * DELT                                                 PT2-0291
C
C          SPECIAL CALCULATION OF Q FOR BARRIERS
      1450 GDS=GRAV*DREW                                                      PT2-0292
           RG=GDS/(C2*TAD)                                                    PT2-0293
           FORCE=RG*(Q+PUSH)+GDS*DH                                           PT2-0294
           HRG=RG/2.                                                          PT2-0295
           Q = SQRT(ABS(FORCE)+HRG**2) - HRG                                  PT2-0296
           IF(FORCE.LT.0.) Q = -Q                                             PT2-0297
           GO TO 1570                                                         PT2-0298
C
      1460 GO TO (1470,1490),LQ                                               PT2-0299
      1470 Q = U(I+1,J)                                                       PT2-0300
      1480 B1 = V(I,J) + V(I+1,J) + V(I,J+1) + V(I+1,J+1)                     PT2-0301
           PUSH = X(I)* DELT                                                  PT2-0302
           GO TO 1510                                                         PT2-0303
      1490 Q = V(I,J+1)                                                       PT2-0304
      1500 B1 = U(I,J) + U(I+1,J) + U(I,J+1) + U(I+1,J+1)                     PT2-0305
      1505 PUSH=Y(I)*DELT                                                     PT2-0306
      1510 A1 = 4. * Q                                                        PT2-0307
      1520 R = SQRTF  ((A1 *A1 ) + (B1 * B1 ))                                PT2-0308
      1530 G = 1. + ((C1 * R) / ((D1+D2)*(D1+D2)))                            PT2-0309
           TAD = D1+D2                                                        PT2-0310
           DH  = H1-H2                                                        PT2-0311
      1540 IF(PUSH)1541,1542,1542                                             PT2-0312
      1541 IF(D2-0.0)1560,1560,1545                                           PT2-0313
      1545 IF(D2-0.1)1544,1544,1560                                           PT2-0314
```

```
 1542 IF(D1-0.0)1560,1560,1543
 1543 IF(D1-0.1)1544,1544,1560
 1544 PUSH=0.0
      G=(G-1.)*.07+1.
C
C     STANDARD CALCULATION OF G FOR BLOCKS
 1560 G =(1.0/G)*( D +(C2 * TAD * UN)+ PUSH)
C
C     THE H AND D CALCULATIONS ARE MADE ON THE BASIS OF THE INDEX LQ. IF
C     LQ=1 THE CALCULATIONS ARE POSTPONED AND A RETURN TO THE POINT OF
C     INVESTIGATION OF THE DATUM RELATIONSSHIPS IS MADE (STATEMENT 21)
C     AFTER THE DUMMY VARIABLES H2 AND D2 ARE SET UP FOR THE ONE-THREE
C     SQUARES.
 1570 GD1=D1/C3
      GD2=D2/C3
      IF(ABS(D).LT.1.0E-10) G=0.0
      GO TO (1571,1681),LQ
C
 1571 IF(D)1572,1577,1573
 1577 MLA=-1
      GO TO 1580
 1572 MLA=0
      IF(H2-ZF)1576,1575,1575
 1576 G=0.0
      GO TO 1580
 1575 IF(GD2+D)1574,1574,1580
 1574 G=-GD2
      GO TO 1580
 1573 MLA=1
      IF(H1-ZF)1576,1580,1580
 1580 IF(I-1)1590,1590,1630
 1590 IF(J-JBL)1610,1610,1620
C     LEFT HAND SEAWARD BOUNDARY CONDITION
 1610 H(1,J)=HG(1)
 1620 UN=0.
      GO TO 1670
C
 1630 IF(J-JBR)1640,1640,1670
 1640 IF(I-IMM)1670,1650,1670
C     RIGHT HAND SEAWARD BOUNDARY CONDITION
 1650 H(IMM,J) = HG(IMM)
      GO TO 1680
 1670 UN=1.
 1680 H2 = H(I,J+1)
      Z= IZ(I,J+1)
      D2 =H2 -Z
      LQ = 2
 2882 GO TO 1560
C
 1681 IF(D)1671,1674,1673
 1674 IF(MLA)1690,1688,1689
 1671 IF(H2-ZF)1672,1682,1682
 1672 G=0.0
```

```
      1682 IF(ML-M)1684,1684,1685                                       PT2-0355
      1685 IF(QU1-UN1)1686,1686,1684                                    PT2-0356
      1686 UN1=QU1                                                      PT2-0357
      1684 IF(QD2-Q)1687,1687,1690                                      PT2-0358
      1687 Q=QD2                                                        PT2-0359
           GO TO 1689                                                   PT2-0360
      1673 IF(M1-28)1672,1683,1683                                      PT2-0361
      1683 IF(ML-M)1688,1689,1689                                       PT2-0362
      1688 IF(QD1-Q)1692,1692,1690                                      PT2-0363
      1692 Q=QD1                                                        PT2-0364
           GO TO 1689                                                   PT2-0365
      1689 IF(Q+UN1-QD1)1690,1690,1691                                  PT2-0366
      1691 ADDQ = Q+UN1 + 0.00001                                       PT2-0367
           Q = (Q/(ADDQ))*QD1                                           PT2-0368
           UN1 = (UN1/(ADDQ))*QD1                                       PT2-0369
      1690 VN1 = 0                                                      PT2-0370
           U(I,J)=UN                                                    PT2-0371
           UN = UN1                                                     PT2-0372
           V(I,J) = VN(I)                                               PT2-0373
           VN(I) = VN1                                                  PT2-0374
      2000 CONTINUE                                                     PT2-0375
           U(IM,J)=UN1                                                  PT2-0376
      2010 CONTINUE                                                     PT2-0377
           IF(KCH.GT.0) CALL CHANL(2)                                   PT2-0378
C
C          SWEEP WHOLE FIELD FOR H ON BLOCKS
C
           SUM=0.                                                       PT2-0379
           COUNT=0.                                                     PT2-0380
           DO 2020 J=1,JMM                                              PT2-0381
           DO 1790 I=1,IMM                                              PT2-0382
           Z=IZ(I,J)                                                    PT2-0383
           D1=H(I,J)-Z                                                  PT2-0384
           IF(J-1)1700,1700,1710                                        PT2-0385
      1700 H(I,1) = HG(I)                                               PT2-0386
      1710 IF(D1)1740,1720,1720                                         PT2-0387
      1720 IF(J-1)1790,1790,1721                                        PT2-0388
      1721 IF(I-1)1722,1722,1723                                        PT2-0389
      1722 IF(J-JBL)1790,1790,1729                                      PT2-0390
      1723 IF(I-IMM)1729,1724,1724                                      PT2-0391
      1724 IF(J-J99)1790,1790,1729                                      PT2-0392
      1729 SETUP=C3*(U(I,J)-U(I+1,J)+V(I,J)-V(I,J+1))                   PT2-0393
           H(I,J)= H(I,J) + SETUP + RAIN                                PT2-0394
           SUM=SUM+ABSF(H(I,J))                                         PT2-0395
           COUNT=COUNT+1.                                               PT2-0396
           IF ( D1 + SETUP + RAIN) 1740,1740,1750                       PT2-0397
      1740 H(I,J) = IZ(I,J)                                             PT2-0398
C
      1750 IF(KCH.GT.0) GO TO 1790                                      PT2-0399
C
C          ENTER RUNOFF VALUES ON ENTRY BLOCKS ONLY IF CHANNELS NOT PROVIDED
           DO 1770 IJK=1,NUMRO                                          PT2-0400
           IF (LROJ(IJK)-J)1770,1760,1770                               PT2-0401
```

```
 1760 IF(LHOI(IJK)-T)1770,1780,1770                                     PT2-0402
 1770 CONTINUE                                                          PT2-0403
      GO TO 1790                                                        PT2-0404
 1780 H(I,J)= H(I,J) + HRO(IJK)*DELT/(DELX**2)                          PT2-0405
 1790 CONTINUE                                                          PT2-0406
 2020 CONTINUE                                                          PT2-0407
      IF(KCH.GT.0) CALL CHANL(3)                                        PT2-0408
C
C     THE TIME INDICES ARE STEPPED TO THE NEW LEVEL.
      NT = NT +1                                                        PT2-0409
      NTIME = NTIME + 1                                                 PT2-0410
      J=IND=J-IND+1                                                     PT2-0411
      IF(SUM/COUNT-100.) 2075,2140,2140                                 PT2-0412
C     TEST THE STABILITY OF THE COMPUTATIONS VIA AVE ABS(H).
C     COMPUTATIONS ARE STABLE, CALCULATIONS CONTINUE.
C     COMPUTATIONS ARE UNSTABLE, AN ON-LINE MESSAGE IS PRINTED
C
C     TEST NT FOR THE OUTPUT OF U,V,H,D,X,Y FIELDS.
 2075 TIM =NTIME-INTIME                                                 PT2-0413
      ITIM=TIM                                                          PT2-0414
      HINT=INTEP                                                        PT2-0415
      IF((TIM/HINT)-ITIM/INTEP) 2055,2055,2090                          PT2-0416
 2055 CALL SAVE(2)                                                      PT2-0417
 2090 IF(NT-IOUT) 2110,2105,2100                                        PT2-0418
C     OUTPUT U,V,H,D,X,Y FIELDS, RESET NT=0 AND STEP NN.
 2105 IF(INFLD.EQ.0) GO TO 2110                                         PT2-0419
      CALL CHANL(4)                                                     PT2-0420
      GO TO 2110                                                        PT2-0421
 2100 NT = 0                                                            PT2-0422
      NN = NN + 1                                                       PT2-0423
      HOUR = NTIME/NF                                                   PT2-0424
      CALL CHANL(4)                                                     PT2-0427
 2110 CONTINUE                                                          PT2-0428
C
 2130 IF (NN- NTIME) 2160,2160,2140                                     PT2-0429
C     STORM COMPLETED. FINAL OUTPUT ON TAPES.
 2140 PRINT 2150,NN                                                     PT2-0430
 2150 FORMAT (21H STOP AS AT NTIME =    ,I4)                            PT2-0431
      STOP                                                              PT2-0432
C
 2160 CALL SAVE(3)                                                      PT2-0433
      CALL CONTIN(2)                                                    PT2-0434
      RETURN                                                            PT2-0440
      END                                                               PT2-0441
```

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      C
      C
            SUBROUTINE CHANL(N)                                               CHNL0001
      C
            COMMON/BLK1/ IA(100),JB(100),IZX(100),IZY(100),ICDCX(100)         CHNL0004
           1,ICDCY(100),ICDSX(100),ICDSY(100),LPOI(8),LPOJ(8),DIST(24)        CHNL0005
           2,CHST(30),RO(8,30),HGR(8),XR(8,6),YR(8,6),HRH(8)                  CHNL0006
            COMMON/BLK2/ IZ(28,20),U(28,20),V(28,20),H(20,20),NTIME           CHNL0007
            COMMON/BLK3/ MM,MMIN,MMAX,NFU,INFLD,IM,JM,KM,KMAX,LMAX,DELX,DELT  CHNL0008
           1,COD,FK,HGI,IOUT,KI,LJ,KII,LJJ,JBL,IAR,KMM,LMM,RF,CONST,S         CHNL0009
           2,IMRG,JMRO,MR,ISTR,IND,NOW,KIM,NORT,MTIME,INTIME,NOWIND,GRAV      CHNL0010
           3,KCMP,DFU,INTER                                                   CHNL0011
            COMMON/BLK4/ HRO(8),CRO(8),KB(24),X1(28,21),Y1(28,21),X2(28,21)   CHNL0012
           1,Y2(28,21),X(28),Y(28),HG1(28),HG2(28),HB1(8),HB(9),VN(28)        CHNL0013
           2,HG(28),HR2(8)                                                    CHNL0014
            COMMON/BLK5/ ICG(130),JCG(130),IACX(130),IACY(130),IZCX(130)      CHNL0015
           1,IZCY(130),QCXP(130),QCXN(130),QCYP(130),QCYN(130),HC(130),HP(130)CHNL0016
           2,KCM,KCX(130),KCY(130),KCB(130),UCT(130),UCF(130),WRI(130),IRON   CHNL0017
           3,KEN(2,130),VCT(130),VCF(130),ACGX(130),ACGY(130),KCXP(130)       CHNL0018
           4,KCYP(130),KLB(50),KLM,IFC(130),FC                                CHNL0019
            COMMON/BLK7/ IEND,NF, IBL  ,NJ,D(40)                              CHNL0020
            COMMON/BLK9/ KZ,LZ,NUMHO,C1,C2,C3,IMM,JMM,NTENP,NFXT1,IT,KC,IFIRSTCHNL0021
           1,JAIND,NEW1,XNOW,NEW3,XNORT, C4,MAIN,AJ,AI,LJM,KIK                CHNL0022
            EQUIVALENCE (DA,DAC)                                              CHNL0023
      C
            ABSF(X) = ABS(X)                                                  CHNL0024
            SQRTF(X) = SQRT(X)                                                CHNL0025
      C
            GO TO (1000,2000,3000,4000) ,N                                    CHNL0026
      C
      C     CHANNEL CODE 1 IS FOR READING CHANNEL DATA AND ESTABLISHING KEY ARRAYS
      C     CHANNEL CODE 2 IS FOR FLOW AND HEIGHT CALCULATIONS IN CHANNELS
      C     CHANNEL CODE 3 IS FOR CALCULATION OF H ON BLOCKS CONTAINING CHANNELS
      C     CHANNEL CODE 4 IS FOR LISTING OF CHANNEL OUTPUT
      C
      C ENTRY POINT 1 FOR READING CHANNEL DATA, INITIALIZATION AND FOR
      C ESTABLISHING KEY ARRAYS FOR ROUTINE CALCUATIONS
      C
       1000 PRINT 509                                                         CHNL0027
            PRINT 500                                                         CHNL0028
        500 FORMAT(1    THE FOLLOWING ARE SUBGRID CHANNEL DATA-  Z VALUES IN FECHNL0029
           1ET,/)                                                             CHNL0030
            C=(DELX**2)/DELT                                                  CHNL0031
      C
      C     A NEGATIVE IACX OR IACY IDENTIFIES THOSE CHANNELS WITH BARRIERS OF
      C     EQUAL ELEVATION ON BOTH SIDES SUCH AS A JETTY SYSTEM
      C     FOR SINGLE BARRIERS, THE LATTER IS TAKEN ON THE INNER SIDE OF THE
      C     CHANNEL BLOCK IF IZC IS NEGATIVE, WHILE ON THE OUTER SIDE IF IZC IS
      C     POSITIVE
            DO 50 K=1,KCM                                                     CHNL0032
            READ 501,   IDENT, ICG(K),JCG(K),IACX(K),IZCX(K),IACY(K),IZCY(K)  CHNL0033
           1,IFC(K)                                                           CHNL0034
            IF(IFC(K).EQ.0) IFC(K)= FC*10000                                  CHNL0035
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  501 FORMAT(I1,2X,I5,9(3X,I5))                                      CHNL0036
      IF(IDENT.NE.8) GO TO 510                                       CHNL0037
   50 CONTINUE                                                       CHNL0038
      DO 100 K=1,KCM                                                 CHNL0039
      KEN(1,K)=0                                                     CHNL0040
      KEN(2,K)=0                                                     CHNL0041
      KBI(K)=0                                                       CHNL0042
      KCX(K) = 0                                                     CHNL0043
      KCY(K) = 0                                                     CHNL0044
      KCXP(K) = 0                                                    CHNL0045
      KCYP(K) = 0                                                    CHNL0046
      I = ICG(K)                                                     CHNL0047
      J = JCG(K)                                                     CHNL0048
      DO 80 L=1,KCM                                                  CHNL0049
      IF(ICG(L).EQ.(I+1).AND.JCG(L).EQ.J) KCYP(K) = L                CHNL0050
      IF(ICG(L).EQ.I.AND.JCG(L).EQ.(J+1)) KCXP(K) = L                CHNL0051
      IF(ICG(L).EQ.(I-1).AND.JCG(L).EQ.J) KCY(K) = L                 CHNL0052
      IF(ICG(L).EQ.I.AND.JCG(L).EQ.(J-1)) KCX(K) = L                 CHNL0053
   80 CONTINUE                                                       CHNL0054
      KCB(K) = 0                                                     CHNL0055
      IF(KM.EQ.0) GO TO 91                                           CHNL0056
      DO 90 L=1,KM                                                   CHNL0057
      IF(IB(L).EQ.I.AND.JB(L).EQ.J) KCB(K) = L                       CHNL0058
   90 CONTINUE                                                       CHNL0059
   91 CONTINUE                                                       CHNL0060
      UCT(K) = 0.0                                                   CHNL0061
      UCF(K) = 0.0                                                   CHNL0062
      VCT(K) = 0.0                                                   CHNL0063
      VCF(K) = 0.0                                                   CHNL0064
      HP(K) = H(I,J)                                                 CHNL0065
      PRINT 502, K,ICG(K),JCG(K),IWCX(K),IZCX(K),IWCY(K),IZCY(K),IFC(K) CHNL0066
  502 FORMAT('   K=',I3,' ICG=',I3,' JCG=',I3,' IWCX=',I5,' IZCX=',I4  CHNL0067
     1,' IWCY=',I5,' IZCY=',I4,' IFC=',I4)                           CHNL0068
  100 CONTINUE                                                       CHNL0069
C
C     ARRAY KLB IDENTIFIES BARRIER BLOCKS WHICH ARE NOT COMMON
C     WITH CHANNEL BLOCKS
      LC= 0                                                          CHNL0070
      DO 105 K=1,KM                                                  CHNL0071
      I=IB(K)                                                        CHNL0072
      J=JB(K)                                                        CHNL0073
      DO 102 L=1,KCM                                                 CHNL0074
      IF(ICG(L).EQ.I.AND.JCG(L).EQ.J) GO TO 105                      CHNL0075
  102 CONTINUE                                                       CHNL0076
      LC=LC+1                                                        CHNL0077
      KLB(LC)=K                                                      CHNL0078
  105 CONTINUE                                                       CHNL0079
      KLM=LC                                                         CHNL0080
C
C     THE FOLLOWING CREATES A SPECIAL INDEX FOR CHANNEL STARTING AND END
C     ANY BLOCK WITH NEGATIVE IGC OR JGC IDENTIFIES A CHANNEL END POINT
C     ARRAY KEN IDENTIFIES WHAT TYPE OF END POINT EXISTS ACCORDING TO THE
C          1  KCX  H          5  KCA  9
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C             2  KCY   M           6  KCY  Q
C             3  KCXP  M           7  KCXP Q
C             4  KCYP  M           8  KCYP Q
C
      IBO=0                                                          CHNL0081
      DO 200 K=1,KCM                                                 CHNL0082
      I=ICG(K)                                                       CHNL0083
      J=JCG(K)                                                       CHNL0084
C
      IF(KCX(K).NE.0) GO TO 110                                      CHNL0085
      IF(I-CX(K).EQ.0) GO TO 110                                     CHNL0086
      IBO=IBO+1                                                      CHNL0087
      KS=KCM+IBO                                                     CHNL0088
      KCX(K)=KS                                                      CHNL0089
      ICG(K)=-I                                                      CHNL0090
      KEN(1,K)=1                                                     CHNL0091
      IF(J.EQ.1) GO TO 110                                           CHNL0092
      Z=IZ(I,J-1)                                                    CHNL0093
      IF((M(I,J-1)-Z).LE.0) KEN(1,K)=5                               CHNL0094
C
  110 IF(KCY(K).NE.0) GO TO 120                                      CHNL0095
      IF(I-CY(K).EQ.0) GO TO 120                                     CHNL0096
      IBO=IBO+1                                                      CHNL0097
      KS=KCM+IBO                                                     CHNL0098
      KCY(K)=KS                                                      CHNL0099
      IF(ICG(K).LT.0) JCG(K)=-J                                      CHNL0100
      ICG(K)=-I                                                      CHNL0101
      L=1                                                            CHNL0102
      IF(JCG(K).LT.0) L=2                                            CHNL0103
      KEN(L,K)=2                                                     CHNL0104
      IF(I.EQ.1.AND.J.LE.JBL) GO TO 120                              CHNL0105
      KEN(L,K)=6                                                     CHNL0106
      IF(I.EQ.1) GO TO 120                                           CHNL0107
      Z=IZ(I-1,J)                                                    CHNL0108
      IF((M(I-1,J)-Z).GT.0) KEN(L,K)=2                               CHNL0109
C
  120 KX=KCXP(K)                                                     CHNL0110
      KY=KCYP(K)                                                     CHNL0111
      IF(I-CY(K).NE.0) GO TO 130                                     CHNL0112
      IF(KY.EQ.0) GO TO 121                                          CHNL0113
      IF(I-CY(KY).NE.0) GO TO 130                                    CHNL0114
  121 IF(KX.EQ.0) GO TO 125                                          CHNL0115
      IF(I-CX(KY).NE.0) GO TO 130                                    CHNL0116
      IBO=IBO+1                                                      CHNL0117
      KCXP(K)=KCM+IBO                                                CHNL0118
  125 IF(ICG(K).LT.0) JCG(K)=-J                                      CHNL0119
      ICG(K)=-I                                                      CHNL0120
      L=1                                                            CHNL0121
      IF(JCG(K).LT.0) L=2                                            CHNL0122
      KEN(L,K)=7                                                     CHNL0123
      IF(J.EQ.JMM) GO TO 130                                         CHNL0124
      Z=IZ(I,J+1)                                                    CHNL0125
      IF((M(I,J+1)-Z).GT.0) KEN(L,K)=3                               CHNL0126
```

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C
  130 IF(I-CX(K).NE.0) GO TO 200                                       CHNL0127
      IF(KX.EQ.0) GO TO 131                                            CHNL0128
      IF(I-CX(KX).NE.0) GO TO 200                                      CHNL0129
  131 IF(KY.EQ.0) GO TO 135                                            CHNL0130
      IF(I-CY(KY).NE.0) GO TO 200                                      CHNL0131
      IBO=IBO+1                                                        CHNL0132
      KCYP(K)=KCM+IBO                                                  CHNL0133
  135 IF(ICG(K).LT.0) JCG(K)=-J                                        CHNL0134
      ICG(K)=-I                                                        CHNL0135
      L=1                                                              CHNL0136
      IF(JCG(K).LT.0) L=2                                              CHNL0137
      KEN(L,K)=6                                                       CHNL0138
      IF(I.GE.IMM.AND.J.GT.JMR) GO TO 200                              CHNL0139
      KEN(L,K)=4                                                       CHNL0140
      IF(I.GE.IMM) GO TO 200                                           CHNL0141
      Z=IZ(I+1,J)                                                      CHNL0142
      IF((H(I+1,J)-Z).LE.0) KEN(L,K)=8                                 CHNL0143
  200 CONTINUE                                                         CHNL0144
C
C     IBOM IS THE TOTAL NUMBER OF CHANNEL END POINTS OF ANY KIND
      IBOM = IBO                                                       CHNL0145
      KCMP=KCM+IBOM+1                                                  CHNL0146
      DO 210 K=1,KCMP                                                  CHNL0147
      HC(K)=HGI                                                        CHNL0148
      QCXP(K) = 0.                                                     CHNL0149
      QCYP(K) = 0.                                                     CHNL0150
      QCXN(K) = 0.                                                     CHNL0151
      QCYN(K) = 0.                                                     CHNL0152
      AQGX(K) = 0.                                                     CHNL0153
      AQGY(K) = 0.                                                     CHNL0154
  210 CONTINUE                                                         CHNL0155
C
C
C     ARRAY KRI IDENTIFIES THE LOCATIONS OF RIVER INPUT FOR Q TYPE END POINTS
      LRM=0                                                            CHNL0156
      LQM=0                                                            CHNL0157
      DO 300 K=1,KCM                                                   CHNL0158
      I= ICG(K)                                                        CHNL0159
      I= IABS(I)                                                       CHNL0160
      J= JCG(K)                                                        CHNL0161
      J= IABS(J)                                                       CHNL0162
      ITOP=KCMP                                                        CHNL0163
      IF(KCX(K).EQ.0) KCX(K)=ITOP                                      CHNL0164
      IF(KCY(K).EQ.0) KCY(K)=ITOP                                      CHNL0165
      IF(KCXP(K).EQ.0) KCXP(K)=ITOP                                    CHNL0166
      IF(KCYP(K).EQ.0) KCYP(K)=ITOP                                    CHNL0167
C
      KRI(K)= 0                                                        CHNL0168
      IF(IMRO.EQ.0) GO TO 480                                          CHNL0169
      LS=1                                                             CHNL0170
      IF(ICG(K).GT.0) GO TO 460                                        CHNL0171
  410 KJ=KEM(LS,K)                                                     CHNL0172
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      IF(KJ.LE.4) GO TO 460                                             CHNL0173
      LOM=LOM+1                                                         CHNL0174
      LR=0                                                              CHNL0175
      DO 450 L=1,IMRO                                                   CHNL0176
      IF(LROI(L).EQ.I.AND.LROJ(L).EQ.J) LR=L                            CHNL0177
  450 CONTINUE                                                          CHNL0178
      KRI(K)=LR                                                         CHNL0179
      IF(LR.GT.0) LRM=LRM+1                                             CHNL0180
  460 IF(JCG(K).GT.0) GO TO 300                                         CHNL0181
      IF(LS.EQ.2) GO TO 300                                             CHNL0182
      LS=2                                                              CHNL0183
      GO TO 410                                                         CHNL0184
  300 CONTINUE                                                          CHNL0185
      IF(LRM.EQ.IMRO) GO TO 480                                         CHNL0186
C
      PRINT 470, LRM,IMRO                                               CHNL0187
  470 FORMAT(( (,//(**********WARNING**********  ONLY(,I3,              CHNL0188
     1 ( CHANNEL END POINTS(,/( MATCH THE(,I3,( RIVER INPUT POSITIONS(  CHNL0189
     2 ,/(****************************************************(,/)CHNL0190
C
  480 CONTINUE                                                          CHNL0191
      PRINT 549                                                         CHNL0192
  549 FORMAT(( ()                                                       CHNL0193
      DO 600 K=1,KCM                                                    CHNL0194
      PRINT 550, K,KCX(K),KCY(K),KCXP(K),KCYP(K),KCB(K),ICG(K),JCG(K)   CHNL0195
     1,KEN(1,K),KEN(2,K),KRI(K)                                         CHNL0196
  550 FORMAT((  K=(,I3,( KCX=(,I3,( KCY=(,I3,( KCXP=(,I3,( KCYP=(,I3,   CHNL0197
     1 ( KCB=(,I3,( ICG=(,I3,( JCG=(,I3,( KEN1=(,I3,( KEN2=(,I3         CHNL0198
     2,( KRI=(,I3)                                                      CHNL0199
  600 CONTINUE                                                          CHNL0200
      PRINT 551, KCMP                                                   CHNL0201
  551 FORMAT (( (,// 10X,(KCMP=(, I5,//)                                CHNL0202
C
      RETURN                                                            CHNL0203
  510 PRINT 503                                                         CHNL0204
  503 FORMAT ((   STOP BECAUSE CARDS WITH IDENT = 8 EXPECTED(,//)       CHNL0205
      PRINT 504, IDENT                                                  CHNL0206
  504 FORMAT(3X,(IDENT=(,I4)                                            CHNL0207
      STOP                                                              CHNL0208
C
C ENTRY POINT 2 FOR FLOW AND HEIGHT CALCULATIONS IN CHANNELS
C
 2000 SDT = S*DELT                                                      CHNL0209
      DO 2500 K=1,KCM                                                   CHNL0210
      I= ICG(K)                                                         CHNL0211
      I= IABS(I)                                                        CHNL0212
      J= JCG(K)                                                         CHNL0213
      J= IABS(J)                                                        CHNL0214
      PUSHU = SDT*(X1(I,J)+DFU*(X2(I,J)-X1(I,J)))                       CHNL0215
      PUSHV = SDT*(Y1(I,J)+DFU*(Y2(I,J)-Y1(I,J)))                       CHNL0216
      H1 = H(I,J)                                                       CHNL0217
      Z1 = IZ(I,J)                                                      CHNL0218
      HCI = HC(K)                                                       CHNL0219
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      D1 = H1-Z1                                                        CHNL0220
      CF= IFC(K)                                                        CHNL0221
      CF= CF*DELT/10000.                                                CHNL0222
      KK = KCA(K)                                                       CHNL0223
      HCS=IHCX(K)                                                       CHNL0224
      HC=ABS(HCS)                                                       CHNL0225
      IF(HC.EQ.0.) GO TO 2250                                           CHNL0226
      LS = 1                                                            CHNL0227
C
      Z2 = IZ(I+1,J)                                                    CHNL0228
      H2 = H(I+1,J)                                                     CHNL0229
      D2 = H2-Z2                                                        CHNL0230
      QN = QCXN(K)                                                      CHNL0231
      QP = QCXP(K)                                                      CHNL0232
      GT = UCT(K)                                                       CHNL0233
      GF = UCF(K)                                                       CHNL0234
      PUT = PUSHU                                                       CHNL0235
      PUC = PUSHV*HC                                                    CHNL0236
      KA=KCX(K)                                                         CHNL0237
      ZCS=IZCX(K)                                                       CHNL0238
      ZC=-ABS(ZCS)                                                      CHNL0239
      IF(KK.EQ.0) GO TO 2010                                            CHNL0240
      ZBC= IZX(KK)                                                      CHNL0241
      ZBC= ZBC/10.                                                      CHNL0242
      CDOI= ICDOX(KK)                                                   CHNL0243
      CDOI= CDOI/1000.                                                  CHNL0244
      CDSI= ICDSX(KK)                                                   CHNL0245
      CDSI= CDSI/1000.                                                  CHNL0246
      GO TO 2020                                                        CHNL0247
C
C*****OUTER RE-ENTRY POINT (X AND Y CHANNELS)
 2010 CDOI = CDO                                                        CHNL0248
      CDSI = CDS                                                        CHNL0249
C
 2020 HN = HC(KA)                                                       CHNL0250
      HAC = (HCI+HN)/2.0                                                CHNL0251
      DAC = HAC-ZC                                                      CHNL0252
      IF(DAC.GT. 0.0) GO TO 20205                                       CHNL0253
C
      PRINT 20206, DAC, K                                               CHNL0254
20206 FORMAT(' DAC=',F7.2,' AT CHANNEL BLOCK',I4,///)                   CHNL0255
      GO TO 4000                                                        CHNL0256
C
20205 CEL = SQRT(GRAV*DAC)                                              CHNL0257
      ALP= C3*CEL                                                       CHNL0258
      CALP = 1.0 - ALP                                                  CHNL0259
      HA = ALP*HN + CALP*HCI                                            CHNL0260
      HE = CALP*HN + ALP*HCI                                            CHNL0261
      GA = ALP*GN + CALP*GP                                             CHNL0262
      GB = CALP*GN + ALP*GP                                             CHNL0263
      LF= 1                                                             CHNL0264
      LO=0                                                              CHNL0265
C
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```
      DI = D1                                                           CHNL0266
      DII = DAC                                                         CHNL0267
      HI = H1                                                           CHNL0268
      HII = HAC                                                         CHNL0269
      QI = QT                                                           CHNL0270
      WI = DELX -WC                                                     CHNL0271
      WII = WC                                                          CHNL0272
      IF(KK.GT.0) GO TO 2022                                            CHNL0273
      ZA=Z1                                                             CHNL0274
      GO TO 2021                                                        CHNL0275
 2022 ZA=ZC                                                             CHNL0276
      IF(WCS.LT.0.) GO TO 2021                                          CHNL0277
      IF(ZCS.GT.0.) ZA=Z1                                               CHNL0278
 2021 LQ=1                                                              CHNL0279
      IF(Z1.GT.ZB) ZA=Z1                                                CHNL0280
      ZB1=ZA                                                            CHNL0281
C
C*****INNER RE-ENTRY POINT (SIDES 1 AND 2 OF CHANNEL)
 2025 IF(HII-ZB)2030,2030,2040                                          CHNL0282
 2030 IF (HI-ZB) 2060,2060,2070                                         CHNL0283
 2040 IF(HI-ZA) 2075,2075,2080                                          CHNL0284
 2060 QOUT = 0.                                                         CHNL0285
      GO TO 2100                                                        CHNL0286
C      OVERFLOW FROM REGION I TO REGION II
 2070 DH=HI-ZB                                                          CHNL0287
      GO TO 2090                                                        CHNL0288
C      OVERFLOW FROM REGION II TO REGION I
 2075 DH=ZB-HII                                                         CHNL0289
      GO TO 2090                                                        CHNL0290
C     SUBMERGED BARRIERS
 2080 GO TO (2081,2082), LF                                             CHNL0291
 2081 QOUT= WI*WII*(HI-HII)/((WI+WII)*DELT)                             CHNL0292
      LF= 2                                                             CHNL0293
      GO TO (2110,2120), LQ                                             CHNL0294
 2082 GO TO (2083,2084), LS                                             CHNL0295
 2083 QOUT= U(I+1,J)                                                    CHNL0296
      GO TO 2085                                                        CHNL0297
 2084 QOUT= V(I,J+1)                                                    CHNL0298
 2085 QT = QOUT + ((H1-2.*HAC+H2)*WC-(H1-HAC)*(WC**2)/DELX)/(2.*DELT)   CHNL0299
      HDQ= (QT-QOUT)/2.
      QT= QOUT+HDQ
      QOUT= QOUT-HDQ
      GO TO 2120                                                        CHNL0302
C
 2090 QOUT = COFI*DH*SQRT(GRAV*ABS(DH))                                 CHNL0303
      LQ=LG                                                             CHNL0304
 2100 GO TO (2110,2120),LQ                                              CHNL0305
C
 2110 DI = DAC                                                          CHNL0306
      DII = D2                                                          CHNL0307
      HI = HAC                                                          CHNL0308
      HII = H2                                                          CHNL0309
      QI = QF                                                           CHNL0310
```

```
      HI = HC                                                           CHNL0311
      HII= DELX                                                         CHNL0312
      QT = QOUT                                                         CHNL0313
      IF(KK.GT.0) GO TO 2112                                            CHNL0314
      ZB=Z2                                                             CHNL0315
      GO TO 2111                                                        CHNL0316
 2112 ZB=ZHC                                                            CHNL0317
      IF(HCS.LT.0.) GO TO 2111                                          CHNL0318
      IF(ZCS.LT.0.) ZH=Z2                                               CHNL0319
 2111 LQ=2                                                              CHNL0320
      IF(Z2.GT.ZB) ZB= Z2                                               CHNL0321
      ZB2=ZB                                                            CHNL0322
      GO TO 2025                                                        CHNL0323
C*****END OF INNER RE-ENTRY
C
 2120 QF=QOUT                                                           CHNL0324
C
C     THE FOLLOWING TESTS CONSTRAIN THE CHANNEL OVERFLOW (QT AND/OR QF) SUCH
C     THAT (QF-QT) CANNOT PRODUCE AN IMPOSSIBLE CHANGE IN HC IN ONE TIME STEP
C     (IE. HC SHOULD NOT FALL BELOW SILL DEPTH NOR RISE ABOVE THE HIGHER
C     OF THE ADJOINING BLOCK H DUE TO OVERFLOW ALONE).
C
      IF(LQ.EQ.0) GO TO 2190                                            CHNL0325
      IF(LF.EQ.2) GO TO 2100                                            CHNL0326
      IF((QF-QT).LE.0.0) GO TO 2140                                     CHNL0327
C     NET OUTFLOW BARRIERS OVERTOPPING
      ZMIN=ZB1                                                          CHNL0328
      IF(ZB2.LT.ZMIN) ZMIN=ZB2                                          CHNL0329
      QNET = (HAC-ZMIN)*AC/DELT                                         CHNL0330
      IF((QF-QT).LE.QNET) GO TO 2190                                    CHNL0331
      IF((QF*QT).GT.0.0) GO TO 2130                                     CHNL0332
      QFS=QF**2                                                         CHNL0333
      QTS=QT**2                                                         CHNL0334
      BUM=QNET/(QFS+QTS)                                                CHNL0335
      QF=BUM*QFS                                                        CHNL0336
      QT=-BUM*QTS                                                       CHNL0337
      GO TO 2190                                                        CHNL0338
 2130 IF(QF.LT.0.0) GO TO 2135                                          CHNL0339
 2134 QF=QNET+QT                                                        CHNL0340
      GO TO 2190                                                        CHNL0341
 2135 QT = -(QNET-QF)                                                   CHNL0342
      GO TO 2190                                                        CHNL0343
C     NET INFLOW BARRIERS OVERTOPPING
 2140 HMAX = H1                                                         CHNL0344
      IF (H2.GT.HMAX) HMAX = H2                                         CHNL0345
      QNET = (HMAX-HAC)*AC/DELT                                         CHNL0346
      IF ((QT-QF).LE.QNET) GO TO 2190                                   CHNL0347
      IF ((QF*QT).GT.0.0) GO TO 2150                                    CHNL0348
      QFS = QF**2                                                       CHNL0349
      QTS = QT**2                                                       CHNL0350
      BUM = QNET/(QFS+QTS)                                              CHNL0351
      QF = -BUM*QFS                                                     CHNL0352
      QT = BUM*QTS                                                      CHNL0353
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             GO TO 2190                                                 CHNL0354
        2150 IF(QF .GT. 0.0)  GO TO 2155                                CHNL0355
        2154 QT = QNET + QF                                             CHNL0356
             GO TO 2190                                                 CHNL0357
        2155 QF = QT - QNET                                             CHNL0358
             GO TO 2190                                                 CHNL0359
        2160 GO TO (2170,2180), LO                                      CHNL0360
        2170 IF(QT.GT.0.) GO TO 2175                                    CHNL0361
       C     BARRIER 1 OVERTOPPING OUTWARDS- OTHER SIDE SUBMERGED
             QNET = (HAC-ZB1)*AC/DELT                                   CHNL0362
             IF((QF-QT).LE.QNET) GO TO 2190                             CHNL0363
             QO = QF-QNET                                               CHNL0364
             IF(QO.GT.0.) QO = 0.                                       CHNL0365
             GO TO 2179                                                 CHNL0366
       C     BARRIER 1 OVERTOPPING INWARDS- OTHER SIDE SUBMERGED
        2175 QNET = (H1-HAC)*AC/DELT                                    CHNL0367
             IF((QT-QF).LE.QNET) GO TO 2190                             CHNL0368
             QO = QNET+QF                                               CHNL0369
             IF(QO.LT.0.) QO = 0.                                       CHNL0370
        2179 QT = QO                                                    CHNL0371
             GO TO 2190                                                 CHNL0372
        2180 IF(QF.LT.0.) GO TO 2185                                    CHNL0373
       C     BARRIER 2 OVERTOPPING OUTWARDS- OTHER SIDE SUBMERGED
             QNET = (HAC-ZB2)*AC/DELT                                   CHNL0374
             IF((QF-QT).LE.QNET) GO TO 2190                             CHNL0375
             QO = QNET+QT                                               CHNL0376
             IF(QO.LT.0.) QO = 0.                                       CHNL0377
             GO TO 2189                                                 CHNL0378
       C     BARRIER 2 OVERTOPPING INWARDS- OTHER SIDE SUBMERGED
        2185 QNET = (H2-HAC)*AC/DELT                                    CHNL0379
             IF((QT-QF).LE.QNET) GO TO 2190                             CHNL0380
             QO = QT-QNET                                               CHNL0381
             IF(QO.GT.0.) QO = 0.                                       CHNL0382
        2189 QF = QO                                                    CHNL0383
       C     END OF ADJUSTMENT OF QT AND/OR QF
        2190 CONTINUE                                                   CHNL0384
       C
       C     CHANNEL COMPUTATIONS
             AA = WC*CFL                                                CHNL0385
             GAM=1.0+CF*SQRT((QM**2+QP**2)/2.)/(WC*DAC**2)              CHNL0386
             AOG = AA/GAM                                               CHNL0387
             BOGM = CE1*(DELT*(QT-QF) + AC*RAIN)                        CHNL0388
             BP=(GA+AA*HA+PUP+BOGM)/GAM                                 CHNL0389
             BM=(GB-AA*HE+PUC-BOGM)/GAM                                 CHNL0390
             GO TO (2200,2300),LS                                       CHNL0391
       C
        2200 QCT(K) = QT                                                CHNL0392
             QCF(K) = QF                                                CHNL0393
             Q(I+1,J) = QF                                              CHNL0394
             QCXP(K) = BP                                               CHNL0395
             QCXM(K) = BM                                               CHNL0396
             AOGX(K) = AOG                                              CHNL0397
       C
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 2250  CS=INCY(K)                                                      CHNL0398
       NC=IABS(NCS)                                                    CHNL0399
       IF(NC.EQ.0.) GO TO 2500                                         CHNL0400
       LS = 2                                                          CHNL0401
       Z2 = IZ(I,J+1)                                                  CHNL0402
       H2 = H(I,J+1)                                                   CHNL0403
       D2 = H2-Z2                                                      CHNL0404
       GN = QCYN(K)                                                    CHNL0405
       GP = QCYP(K)                                                    CHNL0406
       GT = VCT(K)                                                     CHNL0407
       QF = VCF(K)                                                     CHNL0408
       PUT = PUSHV                                                     CHNL0409
       PUC = PUSHUP*C                                                  CHNL0410
       KK = KCV(K)                                                     CHNL0411
       ZCS=IZCV(K)                                                     CHNL0412
       ZC=-ABS(ZCS)                                                    CHNL0413
       IF(KK.EQ.0) GO TO 2010                                          CHNL0414
       ZHC= IZV(KK)                                                    CHNL0415
       ZBC= ZHC/10.                                                    CHNL0416
       CDOI= ICDOY(KK)                                                 CHNL0417
       CDOI= CDOI/1000.                                                CHNL0418
       COSI= ICOSY(KK)                                                 CHNL0419
       COSI= COSI/1000.                                                CHNL0420
       GO TO 2020                                                      CHNL0421
C*****END OF OUTER RE-ENTRY
C
 2300 VCT(K) = QT                                                      CHNL0422
      VCF(K) = QF                                                      CHNL0423
      V(I,J+1) = QF                                                    CHNL0424
      GCYP(K) =GP                                                      CHNL0425
      GCYN(K) =GN                                                      CHNL0426
      AOGY(K) = AOG                                                    CHNL0427
 2500 CONTINUE                                                         CHNL0428
C
      DO 2700 K=1,KCM                                                  CHNL0429
      I= ICG(K)                                                        CHNL0430
      I= IABS(I)                                                       CHNL0431
      J= JCG(K)                                                        CHNL0432
      J= IABS(J)                                                       CHNL0433
      NX= INCX(K)                                                      CHNL0434
      NX= ABSF(NX)                                                     CHNL0435
      NY= INCY(K)                                                      CHNL0436
      NY= ABSF(NY)                                                     CHNL0437
      KX = KCXP(K)                                                     CHNL0438
      KY = KCYP(K)                                                     CHNL0439
      BA = QCXP(K)                                                     CHNL0440
      EB = QCYP(K)                                                     CHNL0441
      AGA = AOGX(K)                                                    CHNL0442
      AGB = AOGY(K)                                                    CHNL0443
      BC=QCXN(KX)                                                      CHNL0444
      AGC=AOGX(KX)                                                     CHNL0445
      BD=QCYN(KY)                                                      CHNL0446
      AGD=AOGY(KY)                                                     CHNL0447
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      C
            HCM = (RA+RB-RC-RD)/(AGA+AGB+AGC+AGD)                              CHNL0448
            QA=RA-AGA*HCM                                                      CHNL0449
            QB=RB-AGB*HCM                                                      CHNL0450
            QCXN(KX) = RC+AGC*HCM                                              CHNL0451
            QCYN(KY) = RD+AGD*HCM                                              CHNL0452
            HC(K)= HCM                                                         CHNL0453
            IF(ICG(K).LT.0) GO TO 2600                                         CHNL0454
            GO TO 2695                                                         CHNL0455
      C
      C     BOUNDARY CONDITIONS FOR Q END POINTS
       2600 L=1                                                                CHNL0456
       2605 KEY=KEN(L,K)                                                       CHNL0457
            GO TO(2690,2690,2630,2640,2650,2660,2670,2680), KEY                CHNL0458
       2630 QA=QCXP(K)                                                         CHNL0459
            GO TO 2690                                                         CHNL0460
       2640 QB=QCYP(K)                                                         CHNL0461
            GO TO 2690                                                         CHNL0462
      C
      C     THE FOLLOWING ASSUMES Q=0 AT END IF NO DISCHARGE DATA EXISTS
       2650 BA=QCXN(K)                                                         CHNL0463
            KS=KCX(K)                                                          CHNL0464
            KT=KHI(K)                                                          CHNL0465
            QCXN(K)= 0.                                                        CHNL0466
            IF(KT.GT.0) QCXN(K)= HRO(KT)                                       CHNL0467
            HC(KS)=(QCXN(K)-BA)/AQGX(K)                                        CHNL0468
            GO TO 2690                                                         CHNL0469
       2660 BA=QCYN(K)                                                         CHNL0470
            KS=KCY(K)                                                          CHNL0471
            KT=KHI(K)                                                          CHNL0472
            QCYN(K)= 0.                                                        CHNL0473
            IF(KT.GT.0) QCYN(K)= HRO(KT)                                       CHNL0474
            HC(KS)=(QCYN(K)-BA)/AQGY(K)                                        CHNL0475
            GO TO 2690                                                         CHNL0476
       2670 BA=QCXP(K)                                                         CHNL0477
            KT=KRI(K)                                                          CHNL0478
            QA= 0.                                                             CHNL0479
            IF(KT.GT.0) QA= -HRO(KT)                                           CHNL0480
            HC(K)=(BA-QA)/AQGX(K)                                              CHNL0481
            GO TO 2690                                                         CHNL0482
       2680 BA=QCYP(K)                                                         CHNL0483
            KT=KRI(K)                                                          CHNL0484
            QB= 0.                                                             CHNL0485
            IF(KT.GT.0) QB= -HRO(KT)                                           CHNL0486
            HC(K)=(BA-QB)/AQGY(K)                                              CHNL0487
      C
       2690 IF(JCG(K).GT.0) GO TO 2695                                         CHNL0488
            IF(L.EQ.2)  GO TO 2695                                             CHNL0489
            L=2                                                                CHNL0490
            GO TO 2605                                                         CHNL0491
      C
       2695 QCXP(K)=QA                                                         CHNL0492
            QCYP(K)=QB                                                         CHNL0493
```

```
 2700 CONTINUE                                                          CHNL0494
C
      RETURN                                                            CHNL0495
C
C ENTRY POINT 3 FOR HEIGHT CALCULATIONS ON BLOCKS WITH CHANNELS
C
 3000 DO 3050 K=1,KCH
      I= ICG(K)                                                         CHNL0497
      I= IABS(I)                                                        CHNL0498
      J= JCG(K)                                                         CHNL0499
      J= IABS(J)                                                        CHNL0500
      IF(I.EQ.IM.OR.J.EQ.JM) GO TO 3050                                 CHNL0501
      Z=IZ(I,J)                                                         CHNL0502
      H(I,J)=HG(I)                                                      CHNL0503
      IF(J.EQ.1) GO TO 3050                                             CHNL0504
      UT=UCT(K)                                                         CHNL0505
      VT=VCT(K)                                                         CHNL0506
      AX= I-CX(K)                                                       CHNL0507
      AX= ABSF(AX)                                                      CHNL0508
      AY= I-CY(K)                                                       CHNL0509
      AY= ABSF(AY)                                                      CHNL0510
      IF(AX.EQ.0.) UT=U(I+1,J)                                          CHNL0511
      IF(AY.EQ.0.) VT=V(I,J+1)                                          CHNL0512
      SETUP=DELT*((U(I,J)-UT)/(DELX*AX)+(V(I,J)-VT)/(DELX*AY))          CHNL0513
      H(I,J)=HP(K)+SETUP+RAIN                                           CHNL0514
      IF(H(I,J).LE.Z) H(I,J)=Z                                          CHNL0515
 3050 HP(K)= H(I,J)                                                     CHNL0516
      DO 3500 K=1,KCH
      I= ICG(K)
      I= IABS(I)
      J= JCG(K)
      J= IABS(J)
      Z= IZ(I,J)
      IF(ICG(K).LT.0) GO TO 3100                                        CHNL0517
      GO TO 3500                                                        CHNL0518
C
C     BOUNDARY CONDITIONS FOR H END POINTS
C     IN THESE CALCULATIONS HC EQUALS THE H OF THE ADJOINING WATER BLOCK
C     HC AND Q ARE SOLVED FROM SIMULTANEOUS EQUATIONS WHICH ALLOW FOR THE
C     VOLUME TRANSPORT TO OR FROM THE ADJOINING BLOCK VIA CHANNEL FLOW Q
 3100 L=1                                                               CHNL0519
      TCF=2.*C4                                                         CHNL0520
 3105 KEY=KEN(L,K)                                                      CHNL0521
      GO TO (3110,3120,3130,3140,3300,3300,3300,3300), KEY              CHNL0522
 3110 KS=KCX(K)                                                         CHNL0523
      BAM=QCXM(K)                                                       CHNL0524
      IF(J.EQ.1) GO TO 3115                                             CHNL0525
      HAM=H(I,J-1)-QCXM(KS)/TCF                                         CHNL0526
      DIV=1.0+AQGY(K)/TCF                                               CHNL0527
      QCXM(K)=(BAM+AQGA(K)*HAM)/DIV                                     CHNL0528
      HC(KS)=(HAM-BAM/TCF)/DIV                                          CHNL0529
      GO TO 3116                                                        CHNL0530
 3115 HC(KS)=HG(I)                                                      CHNL0531
```

```
           QCXN(K)=BAM+ADGX(K)*HC(KS)                                CHNL0532
           GO TO  3300                                               CHNL0533
      3110 H(I,J-1)=HC(KS)                                           CHNL0534
           QCXN(KS)=QCXN(K)                                          CHNL0535
           GO TO 3300                                                CHNL0536
      3120 KS=KCY(K)                                                 CHNL0537
           BAM=QCYN(K)                                               CHNL0538
           IF(I.EQ.1) GO TO 3125                                     CHNL0539
           HAM=H(I-1,J)-QCYN(KS)/TCF                                 CHNL0540
           DIV=1.0+ADGY(K)/TCF                                       CHNL0541
           QCYN(K)=(BAM+ADGY(K)*HAM)/DIV                             CHNL0542
           HC(KS)=(HAM-BAM/TCF)/DIV                                  CHNL0543
           GO TO 3126                                                CHNL0544
      3125 HC(KS)=HG(1)                                              CHNL0545
           QCYN(K)=BAM+ADGY(K)*HC(KS)                                CHNL0546
           GO TO  3300                                               CHNL0547
      3126 H(I-1,J)=HC(KS)                                           CHNL0548
           QCYN(KS)=QCYN(K)                                          CHNL0549
           GO TO 3300                                                CHNL0550
      3130 KS=KCXP(K)                                                CHNL0551
           BAM=QCXP(K)                                               CHNL0552
           VAR=0.5/C4                                                CHNL0553
           IF(KS.GT.NCM) GO TO 3132                                  CHNL0554
           XC= I-CY(KS)                                              CHNL0555
           XC= ABSF(XC)                                              CHNL0556
           VAR=C3*0.5/(DELX*XC)                                      CHNL0557
      3132 HAM=H(I,J+1)+QCXP(KS)*VAR                                 CHNL0558
           DIV=1.0+VAR*ADGX(K)                                       CHNL0559
           QCXP(K)=(BAM-HAM*ADGX(K))/DIV                             CHNL0560
           HC(K)=(BAM*VAR+HAM)/DIV                                   CHNL0561
           H(I,J+1)=HC(K)                                            CHNL0562
           HP(KS)=HC(K)                                              CHNL0563
           QCXP(KS)=QCXP(K)                                          CHNL0564
           GO TO 3300                                                CHNL0565
      3140 KS=KCYP(K)                                                CHNL0566
           BAM=QCYP(K)                                               CHNL0567
           IF(I.EQ.IMM) GO TO 3145                                   CHNL0568
           VAR=0.5/C4                                                CHNL0569
           IF(KS.GT.NCM) GO TO 3142                                  CHNL0570
           XC= I-CX(K)                                               CHNL0571
           XC= ABSF(XC)                                              CHNL0572
           VAR=C3*0.5/(DELX*XC)                                      CHNL0573
      3142 HAM=H(I+1,J)+QCYP(KS)*VAR                                 CHNL0574
           DIV=1.0+VAR*ADGY(K)                                       CHNL0575
           QCYP(K)=(BAM-HAM*ADGY(K))/DIV                             CHNL0576
           HC(K)=(BAM*VAR+HAM)/DIV                                   CHNL0577
           GO TO 3146                                                CHNL0578
      3145 HC(K)=HG(IMM)                                             CHNL0579
           QCYP(K)=BAM-ADGY(K)*HC(K)                                 CHNL0580
           GO TO  3300                                               CHNL0581
      3146 H(I+1,J)=HC(K)                                            CHNL0582
           HP(KS)=HC(K)                                              CHNL0583
           QCYP(KS)=QCYP(K)                                          CHNL0584
```

```
      C
       3300 IF(JCG(K).GT.0) GO TO 3500                                     CHNL0585
            IF(L.EQ.2) GO TO 3500                                          CHNL0586
            L=2                                                            CHNL0587
            GO TO 3105                                                     CHNL0588
      C
       3500 CONTINUE                                                       CHNL0589
      C
            RETURN                                                         CHNL0590
      C
      C ENTRY POINT 4 FOR LIST OF CHANNEL OUTPUT
      C
       4000 IHOUR=NTIME/NF                                                 CHNL0591
       4010 FORMAT(1H1)                                                    CHNL0592
            PRINT 4020, IHOUR, NTIME                                       CHNL0593
       4020 FORMAT(10X,(CHANNEL OUTPUT FOR HOUR=(,I3,40X,(NTIME=(,I5,//    CHNL0594
           1 20X,(ALL H VALUES IN FEET, ALL Q VALUES IN CFS(,//)           CHNL0595
            PRINT 4030                                                     CHNL0596
       4030 FORMAT(7X,(K(,7X,(I(,7X,(J(,6X,(HX(,5X,(QXN(,5X(QXP(,6X,(HY(   CHNL0597
           1,5X,(QYN(,5X,(QYP(,6X,(HC(,5X,(QXT(,5X,(QXF( ,5X,(QYT(,5X,(QYF(,/)CHNL0598
      C
            IR= 1                                                          CHNL0599
            IS= ICG(1)                                                     CHNL0600
            IS= IABS(IS)                                                   CHNL0601
            JS= JCG(1)                                                     CHNL0602
            JS= IABS(JS)                                                   CHNL0603
            DO 4100 K=1,KCH                                                CHNL0604
            KX=KCX(K)                                                      CHNL0605
            KY=KCY(K)                                                      CHNL0606
            QXT=UCT(K)*DELX                                                CHNL0607
            QXF=UCF(K)*DELX                                                CHNL0608
            QYT=VCT(K)*DELX                                                CHNL0609
            QYF=VCF(K)*DELX                                                CHNL0610
            IT= ICG(K)                                                     CHNL0611
            IT= IABS(IT)                                                   CHNL0612
            JT= JCG(K)                                                     CHNL0613
            JT= IABS(JT)                                                   CHNL0614
            IF((IT-IS)**2.EQ.1.AND.JT.EQ.JS) GO TO 4200                    CHNL0615
            IF((JT-JS)**2.EQ.1.AND.IT.EQ.IS) GO TO 4200                    CHNL0616
            PRINT 4050, IR                                                 CHNL0617
            IR= IR+1                                                       CHNL0618
       4200 IS= IT                                                         CHNL0619
            JS= JT                                                         CHNL0620
            PRINT 4040, K,ICG(K),JCG(K),HC(KX),QCXN(K),QCXP(K),HC(KY),     CHNL0621
           1 QCYN(K),QCYP(K),HC(K),QXT    ,QXF    ,QYT    ,QYF             CHNL0622
       4040 FORMAT(3I6,F8.3,2F8.0,F8.3,2F8.0,F8.3,4F8.0)                   CHNL0623
       4050 FORMAT(( (,/ 5X,(CHANNEL REACH(,I3,/)                          CHNL0624
       4100 CONTINUE                                                       CHNL0625
      C
      C     VOLUME COMPUTATION
      C
       5000 VOL=0.                                                         CHNL0626
            C6=DELX**2                                                     CHNL0627
```

```
            JL= JRL                                                             CHNL0628
            IF(JER.GT.JRL) JL=JER                                               CHNL0629
            JL= JL+1                                                            CHNL0630
            DO 5500 I=1,IMM                                                     CHNL0631
            DO 5400 J=JL,JMM                                                    CHNL0632
            Z=IZ(I,J)                                                           CHNL0633
            HIJ=H(I,J)                                                          CHNL0634
            IF(Z.GT.0) HIJ=HIJ-Z                                                CHNL0635
            IF(KCM.EQ.0) GO TO 5200                                             CHNL0636
            DO 5100 K=1,KCM                                                     CHNL0637
            IC= ICG(K)                                                          CHNL0638
            JC= JCG(K)                                                          CHNL0639
            IF(IABS(IC).EQ.I.AND.IABS(JC).EQ.J) GO TO 5300                      CHNL0640
      5100 CONTINUE                                                             CHNL0641
      5200 VOL=VOL+HIJ*C6                                                       CHNL0642
            GO TO 5400                                                          CHNL0643
      5300 MX=I-CX(K)                                                           CHNL0644
            AX= ABSF(MX)                                                        CHNL0645
            MY= J-CY(K)                                                         CHNL0646
            AY= ABSF(MY)                                                        CHNL0647
            KX=KCX(K)                                                           CHNL0648
            KY=KCY(K)                                                           CHNL0649
            VOL=VOL+HIJ*(DELX-AX)*(DELX-AY)+((HC(K)+HC(KX))*AX+                 CHNL0650
          1 (HC(K)+HC(KY))*AY)*DELX/2.-HC(K)*AX*AY                              CHNL0651
      5400 CONTINUE                                                             CHNL0652
      5500 CONTINUE                                                             CHNL0653
            VOL= VOL/1000000.                                                   CHNL0654
            JL= JL-1                                                            CHNL0655
            PRINT 5600, VOL, JL                                                 CHNL0656
      5600 FORMAT(' ',// 10X,'VOLUME OF WATER ABOVE MSL =', F12.1,              CHNL0657
          1 ' MILLIONS OF CU FT',/ 10X,'(THE SEAWARD ROWS THRU J=', I3,         CHNL0658
          2 ' ARE EXCLUDED)',//)                                                CHNL0659
            PRINT 4010                                                          CHNL0660
      C
            IF(N. EQ. 4) RETURN                                                 CHNL0661
      C
            PRINT 5700                                                          CHNL0662
      5700 FORMAT(' ',///' PROBLEM TERMINATED BECAUSE A CHANNEL HAS GONE DRY'CHNL0663
          1,/////)                                                              CHNL0664
            STOP                                                                CHNL0665
      C
            END                                                                 CHNL0665
```

```
      C
      C
              SUBROUTINE SAVE(JIN)                                              SAVE0001
      C
              COMMON/BLK2/ Z(28,20),U(28,20),V(28,20),H(28,20),NTIME            SAVE0004
              COMMON/BLK3/ NM,MMIN,MMAX,NFU,INFLD,IM,JM,KMM,KMAX,LMAX,DELX,DELT SAVE0005
             1,CDO,FK,HGI,IOUT,KI,LJ,KII,LJJ,JBL,JBR,MMM,LMM,RF,CONST,S         SAVE0006
             2,IMRO,JMRO,KR,ISTR,IND,NOW,KIM,NORT,MTIME,INTIME,NOWIND,GRAV      SAVE0007
             3,KCMP,DFU,INTER                                                   SAVE0008
              COMMON/BLK5/ ICG(130),JCG(130),IWCX(130),IWCY(130),IZCX(130)      SAVE0009
             1,IZCY(130),QCXP(130),QCXN(130),QCYP(130),QCYN(130),HC(130),HP(130)SAVE0010
             2,KCM,KCX(130),KCY(130),KCB(130),UCT(130),UCF(130),KRI(130),IBCM   SAVE0011
             3,KEN(2,130),VCT(130),VCF(130),AQGX(130),AQGY(130),KCXP(130)       SAVE0012
             4,KCYP(130),KLB(50),KLM,IFC(130),FC                                SAVE0013
              COMMON/BLK8/ HS(9,72), QS(6,72), TIME(72)                         SAVE0014
              COMMON/BLK9/ KZ,LZ,NUMRO,C1,C2,C3,IMM,JMM,NTANN,NEXT1,IT,KC,IFIRSTSAVE0015
             1,JWIND,NEW1,XNOW,NEW3,XNORT, C4,RAIN,AJ,AI,LJK,KIK                SAVE0016
              COMMON/BLK10/ NGAGE,NFLOW,IGAGE(12),JGAGE(12),KFLOW(6),XMIN,XMAX  SAVE0017
      C
      C       THIS ROUTINE SAVES WATER LEVELS AND FLOW RATES AT CERTAIN
      C       KEY POINTS AS SPECIFIED IN INPUT BY USER. THE TIME SEQUENCES OF
      C       THESE QUANTITIES ARE OUTPUTED BY THE THIRD PART OF THIS ROUTINE.
      C
              GO TO(1000,2000,3000), JIN                                        SAVE0018
         1000 READ 135,     (IGAGE(K),JGAGE(K),K=1,NGAGE)                       SAVE0019
          135 FORMAT(20I4)                                                      SAVE0020
              PRINT 136                                                         SAVE0021
          136 FORMAT(' ',/3X,'HYDROGRAPH GAGE LOCATIONS')                       SAVE0022
              DO 100  K=1,NGAGE                                                 SAVE0023
              I= IGAGE(K)                                                       SAVE0024
              J= JGAGE(K)                                                       SAVE0025
              IF(J.NE.0) GO TO 105                                              SAVE0026
              PRINT 130 , K,I                                                   SAVE0027
          130 FORMAT(5X,'GAGE',I3,' CHANNEL NO.  K=',I4)                        SAVE0028
              GO TO 100                                                         SAVE0029
          105 PRINT 137, K,I,J                                                  SAVE0030
          137 FORMAT(5X,'GAGE',I3,' BLOCK NO.  I=',I3,' J=',I3)                 SAVE0031
          100 CONTINUE                                                          SAVE0032
              PRINT 138                                                         SAVE0033
          138 FORMAT(' ',/3X,'KEY FLOW LOCATIONS')                              SAVE0034
      C
              READ 135,     (KFLOW(K), K=1,NFLOW)                               SAVE0035
              PRINT 139,  (KFLOW(K), K=1,NFLOW)                                 SAVE0036
          139 FORMAT(5X,'CHANNEL BLOCKS',10I4,/)                                SAVE0037
              RETURN                                                            SAVE0038
      C
         2000 T= NTIME-INTIME                                                   SAVE0039
              MINT= INTER                                                       SAVE0040
              N=T/MINT + 1                                                      SAVE0041
              TT= NTIME                                                         SAVE0042
              TIME(N)= TT*DELT/3600                                             SAVE0043
              DO 200 K=1,NGAGE                                                  SAVE0044
              I=IGAGE(K)                                                        SAVE0045
```

```
          J=JGAGE(K)                                                    SAVE0046
          IF (I.GT.KCM) GO TO 199                                       SAVE0047
          HS(K,N)= HC(I)                                                SAVE0048
      199 IF(J.NE.0) HS(K,N)= H(I,J)                                    SAVE0049
      200 CONTINUE                                                      SAVE0050
    C
          DO 300 J=1,NFLOW                                              SAVE0051
          K=KFLOW(J)                                                    SAVE0052
          KEY= KEN(1,K)                                                 SAVE0053
          IF(KEY.NE.0) GO TO 205                                        SAVE0054
          KEY= 2                                                        SAVE0055
          IF(IWCX(K).NE.0) KEY= 1                                       SAVE0056
      205 GO TO(210,220,230,240,210,220,230,240), KEY                   SAVE0057
      210 QS(J,N)= QCXN(K)/1000.                                        SAVE0058
          GO TO 300                                                     SAVE0059
      220 QS(J,N)= QCYN(K)/1000.                                        SAVE0060
          GO TO 300                                                     SAVE0061
      230 QS(J,N)= QCXP(K)/1000.                                        SAVE0062
          GO TO 300                                                     SAVE0063
      240 QS(J,N)= QCYP(K)/1000.                                        SAVE0064
      300 CONTINUE                                                      SAVE0065
          NU=72                                                         SAVE0066
          IF(N.EQ.72) GO TO 310                                         SAVE0067
          RETURN                                                        SAVE0068
    C
     3000 NU = (NM-INTIME)/INTER                                        SAVE0069
          IF(NU.EQ.0) RETURN                                            SAVE0070
      310 PRINT 400                                                     SAVE0071
      400 FORMAT(20X,(WATER LEVEL HYDROGRAPHS (FT) AND KEY FLOWS (1000 CFS)(SAVE0072
         1 ,//)                                                         SAVE0073
          PRINT 410, (J,J=1,NGAGE), (K,K=1,NFLOW)                       SAVE0074
      410 FORMAT(2X,(HOUR(,I6,15I8)                                     SAVE0075
          DO 500 N=1,NU                                                 SAVE0076
          PRINT 420, TIME(N), (HS(J,N),J=1,NGAGE), (QS(K,N),K=1,NFLOW)  SAVE0077
      420 FORMAT(F6.1,15F8.2)                                           SAVE0078

      425 FORMAT(F6.1,12F8.2)                                           SAVE0080
      500 CONTINUE                                                      SAVE0081
          DO 510 N=1,NU                                                 SAVE0082

      430 FORMAT(F6.1,10F8.2)                                           SAVE0084
      510 CONTINUE                                                      SAVE0085
          PRINT 10                                                      SAVE0086
       10 FORMAT(1H1)                                                   SAVE0087
          IF(NU.EQ.72) INTIME=NTIME                                     SAVE0088
          RETURN                                                        SAVE0089
    C
          END                                                           SAVE0090


    C
    C
          SUBROUTINE CONTIN(L)                                          CONT0001
    C
          COMMON/BLK1/A(822)/BLK2/B(1961)/BLK3/C(42)/BLK4/D(2585)/      CONT0002
         1BLK5/E(2759)/BLK6/F(2800)/BLK7/G(44)/BLK9/H(25)/BLK10/P(34)   CONT0003
    C
          GO TO (100,200),L                                             CONT0004
    C
      100 CONTINUE
      700 FORMAT(20A4)                                                  CONT0006
          RETURN                                                        CONT0007
    C
      200 CONTINUE
          RETURN                                                        CONT0009
    C
          END                                                           CONT0010
```

```
C
C
C
C
      SUBROUTINE PLOT                                                   PLOT0005
C
C     PROGRAM TO PLOT CHANNELS AND BARRIERS
C
      COMMON/BLK1/ IB(100),JB(100),IZX(100),IZY(100),ICDOX(100)         PLOT0010
     1,ICDOY(100),ICDSX(100),ICDSY(100),LODI(8),LODJ(8),DIST(24)        PLOT0015
     2,CHST(30),BO(8,30),HGB(8),XP(8,6),YP(8,6),HBR(6)                  PLOT0020
      COMMON/BLK2/ IZ(25,20),U(25,20),V(25,20),H(25,20),NTIME           PLOT0025
      COMMON/BLK5/ ICG(130),JCG(130),IACX(130),IACY(130),IZCX(130)      PLOT0030
     1,IZCY(130),QCXP(130),QCXN(130),QCYP(130),QCYN(130),HC(130),HP(130)PLOT0035
     2,KCM,KCX(130),KCY(130),KCB(130),ICT(130),UCF(130),KPI(130),ISOM   PLOT0040
     3,KEN(2,130),VCT(130),VCF(130),ANGX(130),ANGY(130),KCXP(130)       PLOT0045
     4,KCYP(130),KLB(50),KLM                                            PLOT0050
      COMMON/BLK10/ NGAGE,NFLOW,IGAGE(12),JGAGE(12),KFLOW(6),XMIN,XMAX  MAIN0110
      DIMENSION NUMBER(10),PAGE(114,135)
      LOGICAL XBARR,YBARR,X,BLNK,NUMBER,ONE,PAGE,VLINE,HLINE,PLUS,PERIOD
     1,BLANK
      DATA BLANK/1H /,X/1HX/,BLNK/1H /,NUMBER/1H0,1H1,1H2,1H3,1H4,1H5,
     11H6,1H7,1H8,1H9/,ONE/1H1/,VLINE/1HI/,HLINE/1H-/,PLUS/1H+/,PERIOD/
     21H./
C
C
      DO 100 I=1,15390
      PAGE(I,1)=BLANK
  100 CONTINUE
C
C
      DO 101 I=4,114,4                                                  PLOT0105
      PAGE(I,3) = PERIOD                                                PLOT0110
      PAGE(I,134) = PERIOD                                              PLOT0115
      DO 101 J=9,135,7                                                  PLOT0120
  101 PAGE(I,J) = PERIOD                                                PLOT0125
C
C     DRAW THE BARRIERS
C
      DO 800 KI=1,KCM                                                   PLOT0130
      K = KCM+1-KI                                                      PLOT0135
      I = IABS(ICG(K))*4-1                                              PLOT0140
      J = IABS(JCG(K))*7-6                                              PLOT0145
      I4 = I+3                                                          PLOT0150
      J4 = J+6                                                          PLOT0155
      IF ( KCB(K) .EQ. 0 )  GO TO 600                                   PLOT0160
C
C     TEST FOR BARRIER IN X DIRECTION, Y DIRECTION, OR BOTH
C
      KB = KCB(K)                                                       PLOT0165
      II = IB(KB)                                                       PLOT0170
      JJ = JB(KB)                                                       PLOT0175
      IZ1 = IZ(II,JJ)*10                                                PLOT0180
```

```
      IZ2 = IZ(II+1,JJ)*10                                      PLOT0185
      IZ9 = IZX(KB)                                             PLOT0190
      XBARR = .TRUE.                                            PLOT0195
      IF ( IZ9 .EQ. IZ1  .OR.  IZ9 .EQ. IZ2 )  XBARR = .FALSE.  PLOT0200
      IZ2 = IZ(II,JJ+1)*10                                      PLOT0205
      IZ9 = IZY(KB)                                             PLOT0210
      YBARR = .TRUE.                                            PLOT0215
      IF ( IZ9 .EQ. IZ1  .OR.  IZ9 .EQ. IZ2 )  YBARR = .FALSE.  PLOT0220
C
      IF ( .NOT. XBARR )  GO TO 250                             PLOT0225
C
C     X  BARRIERS
C
      IF ( I-CX(K) .LT. 0 )  GO TO 230                          PLOT0230
      IF ( IZCX(K) .LE. 0 )  GO TO 231                          PLOT0235
C
C     OUTER BARRIER
      DO 202 L=1,10                                             PLOT0240
  202 PAGE(I+4,J+L-3) = X                                       PLOT0245
      GO TO 250                                                 PLOT0250
C
C     INNER BARRIER
  231 DO 203 L=1,10                                             PLOT0255
  203 PAGE(I+2,J+L-3) = X                                       PLOT0260
      GO TO 250                                                 PLOT0265
C
C     BOTH BARRIERS
  230 DO 204 L=1,10                                             PLOT0270
      PAGE(I+4,J+L-3) = X                                       PLOT0275
  204 PAGE(I+2,J+L-3) = X                                       PLOT0280
C
C     Y  BARRIERS
C
  250 IF ( .NOT. YBARR )  GO TO 800                             PLOT0285
      IF ( I-CY(K) .LT. 0 )  GO TO 240                          PLOT0290
      IF ( IZCY(K) .LE. 0 )  GO TO 241                          PLOT0295
C
C     OUTER BARRIER
      DO 205 L=1,5                                              PLOT0300
  205 PAGE(I+L-2,J+4) = X                                       PLOT0305
      GO TO 800                                                 PLOT0310
C
C     INNER BARRIER
  241 DO 206 L=1,5                                              PLOT0315
  206 PAGE(I+L-2,J+4) = X                                       PLOT0320
      GO TO 800                                                 PLOT0325
C
C     BOTH BARRIERS
  240 DO 207 L=1,5                                              PLOT0330
      PAGE(I+L-2,J+4) = X                                       PLOT0335
  207 PAGE(I+L-2,J+4) = X                                       PLOT0340
  800 CONTINUE                                                  PLOT0345
C
```

```
C       LAND BARRIERS
C
        DO 804 K=1,KLM                                                  PLOT0350
C
C       TEST FOR BARRIER IN X DIRECTION, Y DIRECTION, OR BOTH
C
        KB = KLB(K)                                                     PLOT0355
        II = IB(KB)                                                     PLOT0360
        JJ = JB(KB)                                                     PLOT0365
        I = IABS(II)*4-1                                                PLOT0370
        J = IABS(JJ)*7-4                                                PLOT0375
        IZ1 = IZ(II,JJ)*10                                              PLOT0380
        IZ2 = IZ(II+1,JJ)*10                                            PLOT0385
        IZB = IZX(KB)                                                   PLOT0390
        XBARR = .TRUE.                                                  PLOT0395
        IF ( IZB .EQ. IZ1  .OR.  IZB .EQ. IZ2 )  XBARR = .FALSE.        PLOT0400
        IZ2 = IZ(II,JJ+1)*10                                            PLOT0405
        IZB = IZY(KB)                                                   PLOT0410
        YBARR = .TRUE.                                                  PLOT0415
        IF ( IZB .EQ.IZ1  .OR.  IZB .EQ. IZ2 )  YBARR = .FALSE.         PLOT0420
C
C       X BARRIER
C
        IF ( .NOT. XBARR )  GO TO 220                                   PLOT0425
        DO 208 L=1,7                                                    PLOT0430
  208   PAGE(I+2,J+L-3) = X                                             PLOT0435
C
C       Y BARRIER
C
  220   IF ( .NOT. YBARR )  GO TO 804                                   PLOT0440
        DO 209 L=1,5                                                    PLOT0445
  209   PAGE(I+L-3,J+4) = X                                             PLOT0450
  804   CONTINUE                                                        PLOT0455
C
C       DRAW CHANNELS
C
  251   DO 802 K=1,KCM                                                  PLOT0460
        I = IABS(ICG(K))*4-1                                            PLOT0465
        J = IABS(JCG(K))*7-4                                            PLOT0470
        I4 = I+3                                                        PLOT0475
        J4 = J+6                                                        PLOT0480
        IF ( I-CX(K) .EQ. 0 )  GO TO 300                                PLOT0485
        DO 200 L=1,7                                                    PLOT0490
  200   PAGE(I4,J+L-1) = HLINE                                          PLOT0495
        IF ( KCX(K) .GT. KCM )  PAGE(I4,J) = PLUS                       PLOT0500
  300   IF ( I-CY(K) .EQ. 0 )  GO TO 301                                PLOT0505
        DO 201 L=1,3                                                    PLOT0510
        PAGE(I+L-1,J+5) = BLNK                                          PLOT0515
        PAGE(I+L-1,J+7) = BLNK                                          PLOT0520
  201   PAGE(I+L-1,J4) = VLINE                                          PLOT0525
        IF ( KCY(K) .GT. KCM )  PAGE(I,J4) = PLUS                       PLOT0530
  301   PAGE(I4,J4) = PLUS                                              PLOT0535
  802   CONTINUE                                                        PLOT0540

C
C       WRITE OUT THE PAGE
C
        WRITE(6,501)(J,I=1,19),((PAGE(4*K-1,J),J=3,134),K,(PAGE(4*K  ,J),JPLOT0545
     1  =5,134),((PAGE(4*K+I  ,J),J=3,134),I=1,2),K=1,28)               PLOT0550
  501   FORMAT (1H1,18(I4,3X),I4,/,( ,1,5X,17(1,1,6X),1,1,5X,1,1,/,28(1X, PLOT0555
     1   132A1,/,1X,I2,130A1,/,2(1X,132A1,/)),(1()                      PLOT0560
        RETURN                                                          PLOT0565
        END                                                             PLOT0570
```

APPENDIX B

DESCRIPTION OF THE SURGE II CODED PROGRAM

The general strategy of the program is discussed and certain special features are pointed out which may not be apparent without detailed study of the program. Operational aspects of the program are discussed in some detail in Appendix C.

The version of the program adapted for use on the GE 400 computer system by the Corps of Engineers consists of the following parts or subroutines:

MAIN	whose primary job is to read and check the sequencing of the basic data for the block computations;
PART 2	which controls the basic computational sequencing, initialization, and updating of storage, interpolation of coarse wind fields for the actual grid, and routine computation of U, V, and H for all blocks, considering barriers (basically, the SURGE I program);
CHANL(1)	which is called only once to read channel data and to establish certain key arrays for routine calculation;
CHANL(2)	which is called routinely to compute flow and water levels in channels and at channel end points;
CHANL(3)	whose task is the routine calculation of H on blocks containing channels;
CHANL(4)	which is called for listing of channel computations;
LIST(1)	which is called only once to read control data for block listings and to list the topographic Z field;
LIST(2)	which lists the H field for blocks if called;
LIST(3)	which lists the U, V, and H fields for blocks if called in place of LIST(2);
SAVE(1)	which is called only once to read the positions of certain gage locations for water level or flow;
SAVE(2)	which is called routinely at preselected time intervals to save water levels and flow for gage locations defined by SAVE(1);
CONTIN(1)	which is called only once to read basic storage in COMMON BLOCKS 1 to 10 in the case of a continuation of a given problem;
CONTIN(2)	which is called at the termination of a run to output the continuation data called for by CONTIN(1).

The version of the program used in the testing and calibration work, using an IBM 360/65 computer system, has an additional assembler language subroutine for plotting positions of barriers and channels (see Fig. 15). This is useful in checking input data for channels and barriers to spot possible errors in coding the positions of channel blocks and barrier blocks. Unfortunately, this subroutine is not compatible with the GE 400 system. Subroutine PLOT in Appendix A however can be used for this purpose. Subroutine LIST is not used in the version of the program in Appendix A.

1. Flow Diagram.

A schematic flow diagram for the SURGE II program is given in Figure B-1. If a new problem is being run then the first phase is reading in the basic data and checking the data sequencing to make sure it is in order and complete. This is carried out in MAIN and the beginning of PART 2 which calls subroutines CHANL(1), SAVE(1), and LIST(1).

Initialization of block arrays is carried out in PART 2; initialization of channel arrays and establishing of key arrays are carried out by CHANL(1). These key arrays are discussed in a subsequent subsection.

Step 4 of the flow diagram is the beginning (or reentry point) of the routine computations for each time. After generating, the detailed interpolated fields of x and y components of wind stress for the blocks (step 4) and all blocks (i.e., all I,J) are swept to compute the flow components, U and V, ignoring at first the presence (if any) of subgrid scale channels, but considering barriers for any barrier blocks (step 5).

In step 6 CHANL(2) is called to sweep through all channel blocks to evaluate all channels Q and H except those for H-end points and all lateral flows to and from channels. In the latter operation, the flows U and V computed in step 5 are replaced by corrected U or V between blocks, considering the presence of the channels.

Step 7, which is carried out in PART 2, sweeps all I,J to compute water levels on blocks ignoring for the present, the presence of any subgrid scale channels.

In step 8, CHANL(3) is called to correct the block H values on those blocks containing channels and to compute the H and Q values at H-end points of channels. This also provides corrected H values for those blocks into which the channels discharge.

Steps 10 and 11 are output operations for block and channel computations carried out in PART 2 and CHANL(4). This is followed by a time updating and test for end, dependent upon a prescribed maximum number of time steps. Before termination of a run, the contents of all data in COMMON are saved for possible continuation of the problem, if desired.

2. Identification of Adjacent Channel Blocks.

To provide rapid access to values of H and Q in channels adjoining a given channel reach, special arrays are generated in subroutine

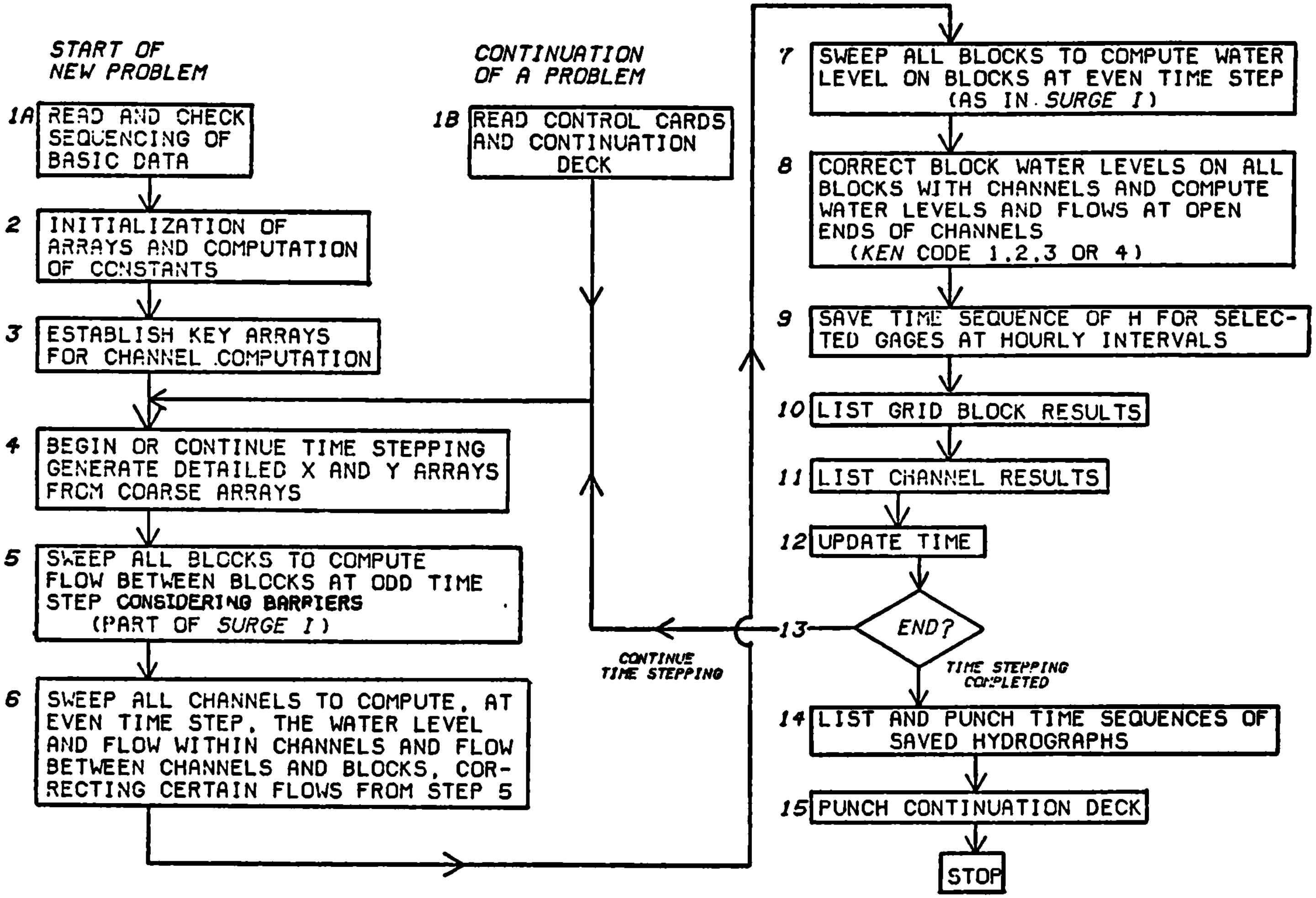

Figure B-1. Generalized flow diagram for SURGE II.

CHANL(1). There are four such arrays: KCX(K), KCY(K), KCXP(K), and KCYP(K). These give the channel block identification index for those channel blocks which are adjacent to the Kth channel block as indicated in Figure B-2. Thus, KCX(K) is the identification of the channel block which has an x-side channel adjoining channel block K on the negative characteristic side (i.e., on a preceding row), while KCXP(K) is the identification of the channel block which has an x-side channel adjoining channel block K on the positive side (i.e., on a following row). KCY(K) and KCYP(K) have analogous meanings for blocks with y-side channels adjoining that of block K. These arrays are generated by an appropriate series of tests in which the I,J values of blocks adjacent to that of channel block K are compared with the ICG and JCG values of all other channel blocks. This is carried out only once during any run, and is not particularly time consuming; moreover, it avoids any human error which may easily occur if such arrays were required as input.

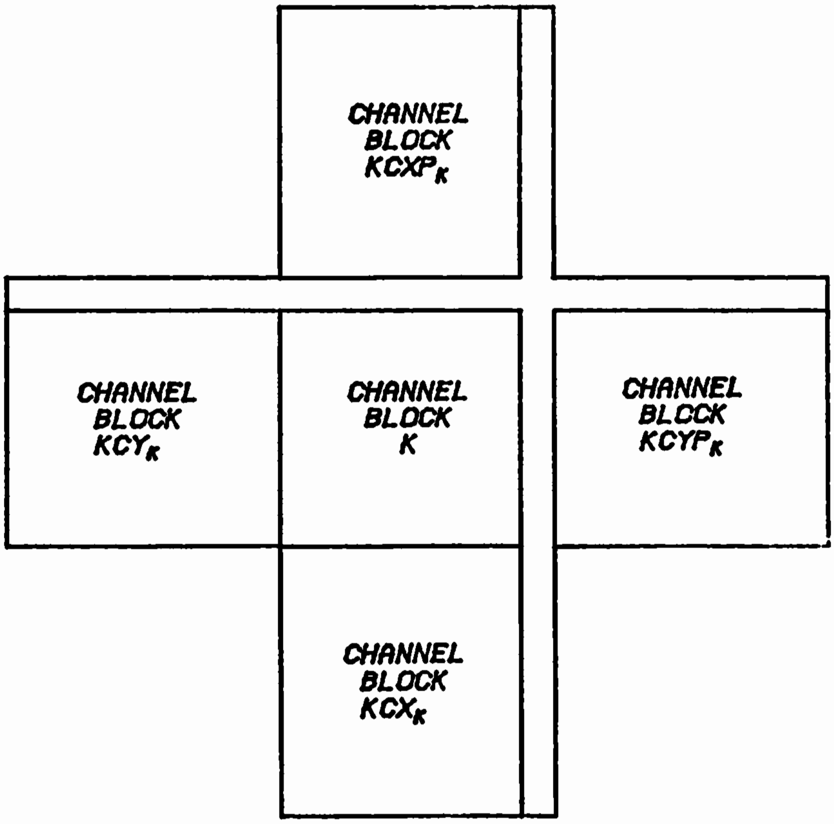

Figure B-2. Channel block identification for channels adjacent to those of block K.

The arrays KCX and KCXP have the properties KCXP(KCX(K)) = K and KCX(KCXP(K)) = K with similar relations for KCY and KCYP.

As an example of the use of such arrays, suppose the value of HC in an x channel adjoining that of channel block K is needed. This could be addressed as HC(KX) where KX = KXC(K). Using Figure 8 as an example, the values of channel flow entering the junction from channels 1 and 2 would be addressed by QCXP(K1) and QCYP(K1), respectively, where K1 designates the channel block containing channels 1 and 2. However, the flow leaving the junction would be addressed by QCYN(K2) where K2 = KCYP(K1) and QCXN(K3) where K3 = KCXP(K1). While redundant storage of such H and Q values would also satisfy the requirement of rapid access to such values adjoining a given channel block, the use of the integral arrays KCX, KCY, KCXP, and KCYP saves storage for most computer systems.

An examination of the listings of the values of the arrays KCX, KCY, KCXP, and KCYP, as output by the program, indicates that the maximum value of any of these can and usually does exceed the number of input channel blocks (KCM). The reason for this is that dummy storage positions are created for blocks adjoining channel end points. This is an artifice of the program which allows routine computation for all channel reaches before special computation for channel end points.

3. Barrier Identification.

The position of the Kth barrier block is given by the array pair, IB(K) and JB(K), which is input to the program. It is convenient to have rapid access to barrier information for those barriers which happen to fall on a given channel block. The array KCB(K) gives the identification of the barrier block which coincides with channel block K. Thus, ICG(K) = IB(KCB(K)) and JCG(K) = JB(KCB(K)). If no barriers exist in a given channel block then the corresponding value of KCB is zero. Thus, in the routine program, a test for zero value KCB is made; if nonzero, then a call can be made for barrier data such as elevation and barrier coefficients via the barrier index KB = KCB(KC) where KC is the channel block concerned.

The array KCB(K) is generated in CHANL(1), via a scan of all IB and JB values for given ICG and JCG for channel block K.

An array KLB(K) is also generated which identifies those barrier blocks not common to channel blocks. This is used only in the IBM 360/65 assembler language plotting routine, not in routine calculations.

4. Channel End-Point Identification.

As a signal that at least one channel end point occurs in a channel block K, the value of ICG(K) is negative. If two end points occur, the value of JCG(K) is also negative; otherwise, it is positive. If no channel end point occurs, then both ICG and JCG for the block are positive. This positive-negative coding is generated automatically in CHANL(1) by appropriate testing; namely, to check if a valid channel connects at each end of a valid channel in the block concerned.

In addition, the arrays KEN(1,K) and KEN(2,K) are generated in CHANL(1) to identify the type of end point for, at most, two potential channel terminations in given channel block K. If there is no channel termination both KEN(1,K) and KEN(2,K) are zero; if one termination occurs for block K, KEN(1,K) will have an integral value from 1 to 8 and KEN(2,K) will be zero; if two terminations occur, both KEN arrays will have nonzero value. In use, KEN(2,K) is called only if JCG(K) is negative.

The coding for the type of end point is indicated schematically in Figure B-3. Values of KEN from 1 to 4 represent "H-end" type terminations where a ponding block immediately adjoins the channel end. Values of KEN from 5 to 8 are those for which Q is specified; e.g., river discharge. Values within either group indicate the relative orientation of the channel end point in question to assure calling the correct data and using the right signs in the routine calculations.

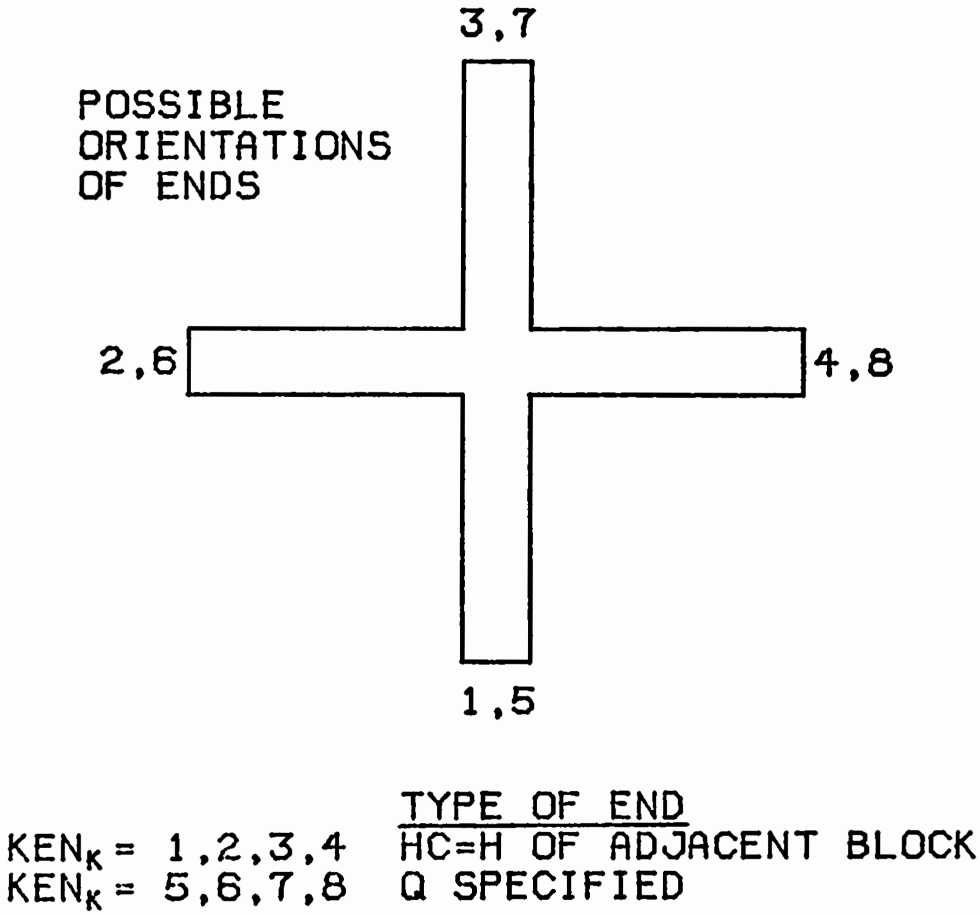

Figure B-3. Identification of type and orientation of a channel end point by the coded identifier KEN(K).

APPENDIX C

USER'S GUIDE TO SURGE II

The coded program SURGE II is intended for use in the numerical simulation of storm surges or astronomical tides in bays and estuaries for specified time sequences of water level at the seaward boundary of the bay or estuary and specified wind stress and other storm data over the bay or estuary. The user may use one of two distinct modes of operation: (a) the storm mode, in which all storm data are required as well as seaward hydrograph data; or (b) the tide mode, in which no storm data are required, the only forcing being the input water level variation at the seaward boundary. Moreover, in both modes the user has the option of initiating a new simulation or continuing a previous simulation, the input requirements being different for each.

In general, the input consists of the following types of information:

(a) Control Data--For input-output operations, initialization, array size, time stepping, and run duration.

(b) Bay Schematization Data--including block topography, barrier data, and channel data.

(c) Forcing Data--including sequences of water level at seaward boundary, wind-stress components over bay, rainfall data over bay, and river discharge data.

(d) Problem Specification Information.

Certain checks are made as the data are read in, with regard to proper order of input, proper amount of sequential data, and proper size arrays. All stops resulting from these editing checks of input are identified.

In the subsequent subsections, the individual input parameters are identified (with appropriate units), the sequence of data input for the different modes of operation is given in some detail, and special requirements concerning data input for barriers and channels are discussed, followed by a summary of output information and output options.

1. Definition of Input Variables.

The following variables are listed in the order in which they are input (asterisks separate data blocks):

ICARD Control index: 0 for starting, 1 for continuation.

***** *Block 0*

IDENT Data block identification;

IBL	starting column (I value) for listing of block H output (normally taken as 1);
KCM	total number of blocks with channels (including null channels, see subsec. 6 of this app.);
NOWIND	control for storm data input: 0 for normal input operation for wind stress, rainfall, and runoff; -1 for omitting such input for tide computations;
INTER	interval in SAVE operation (time interval is INTER*DELT);
NGAGE	number of H gage locations saved;
NFLOW	number of Q gage locations saved;
IMIN	minimum expected H (feet);
IMAX	maximum expected H (feet).

NOTE----IMIN and IMAX are used only in subroutine GRAF, applicable to IBM'360 or 370.

***** *Block 1*

NTIME	Initial time level (normally 0, unless a continuation run is being carried out, in which case NTIME should equal the final value of the previous run);
NM	maximum number of time steps for the problem;
MMIN	minimum "map time" for wind-stress input;
MMAX	maximum map time for wind-stress input;
NFU	number of iterations per map time interval;
IOUT	interval for routine output from blocks and channels equals IOUT + 1;
INFLD	special output flag: 0 for standard output, 1 for extra listing of channel output for one iteration preceding normal listing.

***** *Block 2*

IM	Total number of x-grid intervals;
JM	total number of y-grid intervals;
KM	total number of blocks having barriers;

KMAX	total number of coarse x-grid points for wind-stress input;
LMAX	total number of coarse y-grid points for wind-stress input.
*****	*Block 3*
DELX	Spatial grid interval or block size (nautical miles);
DELT	time interval between block H and flow computations (seconds);
CDO	overflow coefficient for natural low-lying ground such as barrier islands;
FK	bed-resistance coefficient for blocks;
FC	bed-resistance coefficient for channels (used only if values for individual channels are not entered);
HGI	initial water level above MSL in the bay (feet).
*****	*Block 4*
KI	Number of interpolation subdivisions of each coarse x-grid interval KI*(KMAX-1) = IM;
LJ	number of interpolation subdivisions of each coarse y-grid interval LJ*(LMAX-1) = JM;
KII	number of coarse x-grid intervals;
LJJ	number of coarse y-grid intervals;
JBL, JBR	number of "open boundary" J-intervals on left and right of system (not used in version in App. A).
*****	*Block 5*
IB(K)	I location index for barrier block K;
JB(K)	J location index for barrier block K;
IZX(K)	elevation of x-barrier (right side) on barrier block K (tenths of feet);
IZY(K)	elevation of y-barrier (upper side) on barrier block K (tenths of feet);
ICDOX(K)	overflow coefficient for x-barrier (value × 1,000) on Kth barrier block;

ICDOY(K)	overflow coefficient for y-barrier (value × 1,000) on Kth barrier block;
ICDSX(K)	submerged wier coefficient for x-barrier (value × 1,000) on Kth barrier block;
ICDSY(K)	submerged wier coefficient for y-barrier (value × 1,000) on Kth barrier block.
*****	*Block 6*
IZ(I,J)	Elevation of ground or seabed (feet) relative to MSL datum for block location I,J.
*****	*Block 7*
IMRO	Number of river input (runoff) locations;
JMRO	number of map times with runoff values;
KR	number of channel-stress values (normally same as JMRO);
ISTR	start of rain (map time);
IND	end of rain (map time);
NOW	number of iterations between river input values (normally same as NFU);
KIM	number of iterations between channel-stress values (normally same as NFU);
NORT	number of iterations per hour for rain (normally same as INTER).
*****	*Block 8*
RF	Total rainfall (inches);
CONST	fraction of rainfall not absorbed by ground;
S	conversion factor for wind stress $(5,280/3,600)^2 \times 1.1/10$.
*****	*Block 9*
LROI(K)	I location index for Kth river input block;
LROJ(K)	J location index for Kth river input block.

*****	*Block 10*
DIST(M)	Percent of total rainfall per hour for 24 hours.
*****	*Block 11*
CHST(M)	Channel-stress values at map time M (entries are used only if KCM = 0).
*****	*Block 12*
RO(K,M)	Discharge (cubic feet per second) from Kth river input block at map time M.
*****	*Block 13*
MTIME	Map time for given block of wind-stress input and seaward water level.
*****	*Block 14*
HGR(K)	Seaward water level above MSL (feet) at MTIME for coarse grid position K.
*****	*Block 15*
HBR(J)	Water level on right open boundary above MSL (feet) at MTIME for grid position J (not used in version in App. A).
*****	*Block 16*
XR(K,L)	Wind-stress component in the x direction (units of (miles per hour)^2/10) for coarse grid position K,L at time MTIME.
*****	*Block 17*
YR(K,L)	Wind-stress component in the y direction (units of (miles per hour)^2/10) for coarse grid position K,L at time MTIME.
*****	*Block 18*
ICG(K)	I location index for channel block K;
JCG(K)	J location index for channel block K;
IWCX(K)	width of x channel (right side) on channel block K (feet), with sign (see subsec. 6 of this app.);
IZCX(K)	depth of x channel bed on channel block K (feet), with sign (see subsec. 6 of this app.);

IWCY(K)	width of y channel (upper side) on channel block K (feet), with sign (see subsec. 6 of this app.);
IZCY(K)	depth of y channel bed on channel block K (feet), with sign (see subsec. 6 of this app.);
IFC(K)	bed-resistance coefficient for channels on block K (value × 10,000), if entry is zero (blank) then IFC is taken as FC (entered in *Block 3*) × 10,000.
*****	*Block 19*
IGAGE(K)	Location index for the Kth hydrograph, if JGAGE(K) ≠ 0 then IGAGE(K) is the I location of a block H; if JGAGE(K) = 0 then IGAGE(K) is the channel block index for a channel H;
JGAGE(K)	if not zero, this is the J location of a block H; if zero, a channel H is indicated;
KFLOW(K)	channel block index for the Kth flow gage, the flow being that of the lower end of the x channel, or the left end of a y channel if an x channel does not exist, or a channel end point if one exists in the identified channel block.
*****	*Block 20*
IEND	Maximum I in listing of block arrays of H, U, and V;
NF	number of iterations between listings;
IBEGIN	first I in listing of block arrays;
NJ	maximum J in listing of block arrays;
NCARD	total number of alphanumeric problem identification cards;
ALPHA(J)	alphanumeric character data which identify the problem and gage locations by name.

2. Input for Initiating Storm Surge Simulation.

The sequence of input for starting a problem in the storm surge mode is given below in the form of a summary of the READ statements active in this mode, together with a summary of the appropriate FORMATS for data input in different blocks. For all data blocks requiring an entry of the identification integer IDENT, only the *units digit* of the data block number is entered in column 1 of the data input card.

Control Card

```
READ  1 ,    ICARD  (0 for starting)
```

Block 0 (1 card)

```
READ  1 ,    IDENT, IBL, KCM, NOWIND, INTER, NGAGE, NFLOW, IMIN, IMAX
```

NOTE-------IMIN and IMAX are left blank unless subroutine GRAF is used.

Block 1 (1 card)

```
READ  100 ,  IDENT, NTIME, NM, MMIN, MMAX, NFU, IOUT, INFLD
```

Block 2 (1 card)

```
READ  100 ,  IDENT, IM, JM, KM, KMAX, LMAX
```

Block 3 (1 card)

```
READ  250 ,  IDENT, DELX, DELT, CDO, FK, FC, HGI
```

Block 4 (1 card)

```
READ  100 ,  IDENT, KI, LJ, KII, LJJ, JBL, JBR
```

Block 5 (total of KM cards of barrier data)

```
DO    500    K = 1, KM
READ  100 ,  IDENT, IB(J), JB(K), IZX(K), IZY(K), ICDOX(K), ICDOY(K),
             ICDSX(K), ICDSY(K)
      500    CONTINUE
```

Block 6 (total of 2*IM cards of block topography)

```
DO    550    I = 1, IM
READ  100 ,  IDENT, (IZ(I,J), J = 1,10)
READ  100 ,  IDENT, (IZ(I,J), J = 11, JM)
      550    CONTINUE
```

Block 7 (1 card)

```
READ  100 ,  IDENT, IMRO, JMRO, KR, ISTR, IND, NOW, KIM, NORT
```

Block 8 (1 card)

```
READ  250 ,  IDENT, RF, CONST, S
```

Block 9 (1 or 2 cards, dependent on IMRO)

```
READ  100 ,  IDENT, (LROI(K), LROJ(K), K = 1,5)

IF (IMRO.LT.6) GO TO 575

READ  100 ,  IDENT, (LROI(K), LROJ(K), K = 6, IMRO)

      575    CONTINUE
```

Block 10 (3 cards)

```
READ  250 ,  IDENT, (DIST(M), M = 1,10)
READ  250 ,  IDENT, (DIST(M), M = 11,20)
READ  250 ,  IDENT, (DIST(M), M = 21,24)
```

Block 11 (L + 1 card where L = KR/10. If KR = 0, block 11 input is omitted.)

```
READ  250 ,  IDENT, (CHST(K), K = 1,11)
READ  250 ,  IDENT, (CHST(K), K = 11,20)
...
READ  250 ,  IDENT, (CHST(K), K = KL, KR (KL = 10 * L + 1)
```

Block 12 (JMRO cards of river discharge data)

```
DO    700    M = 1, JMRO
READ  250 ,  IDENT, (RO(K,M), K = 1, IMRO)
      700    CONTINUE
```

Wind Stress and Water Level Forcing
(MTL sets of blocks 13 to 17 where MTL = MMAX - MMIN + 1)

```
      710    CONTINUE
```

Block 13 (1 card)

```
READ  100 ,  IDENT, MTIME
```

Block 14 (1 card)

```
READ  250 ,  IDENT, (HGR(K), K = 1, KMAX)
```

Block 15 (1 card)

```
READ  250 ,  IDENT, (HBR(J), J = 2,8)
```

Block 16 (KMAX cards)

```
DO    790    K = 1, KMAX

READ  250 ,  IDENT, (XR(K,L), L = 1, LMAX)

      790    CONTINUE
```

Block 17 (KMAX cards)

```
DO    800    K = 1, KMAX

READ  250 ,  IDENT, (YR(K,L), L = 1, LMAX)

      800    CONTINUE

IF (MTIME - MMAX) 710, 1,015, 1,015  (710 returns to read block 13)

      1,015  (CONTINUE)
```

Block 18 (KCM cards with channel data. If KCM = 0, the READ statement is bypassed and block 18 should be omitted.)

```
IF (KCM.GT.0)  CALL CHANL(1)

DO    50     K = 1, KCM

READ  100 ,  IDENT, ICG(K), JCG(K), IWCX(K), IZCX(K), IWCY(K), IZCY(K),
             IFC(K)

      50     CONTINUE
```

Block 19 (2 cards)

```
CALL SAVE(1)

READ  350 ,  (IGAGE(K), JGAGE(K), K = 1, NGAGE)

READ  350 ,  (KFLOW(K), K = 1, NFLOW)
```

Block 20 (NCARD + 1 card)

```
CALL LIST(1)

READ  1 ,    IDENT, IEND, NF, IBEGIN, NJ, NCARD

DO    250    J = 1, NCARD

READ  450 ,  (ALPHA(J), J = 1,40)

      250    CONTINUE
```

Format Statements for Input. The following formats were used in all the testing operations. It is recommended, however, that for routine operations those READ statements using FORMAT 1 be replaced by FORMAT 100 to make all basic numerical input consistent in card column range.

```
1     FORMAT (I1, I3, 19, I4)

100   FORMAT (I1, 2X, I5, 9(3X, I5)

250   FORMAT (I1, F7.0, 9F 8.0)

350   FORMAT (20 I 4)

450   FORMAT (15A2, 15A2, 10A2)
```

3. Input for Tide Mode.

For calibration of a given bay system, under virtually no wind conditions, for its response to forcing by astronomical tide at the seaward boundary and a steady-state river discharge, allowance is made in the coded program to bypass the detailed input of wind-stress components, and rainfall and channel-stress data; moreover, since a steady river discharge is assumed only a single card is required to define this input. In essence, the data blocks 10 to 17 are replaced by a shortened version of block 12 plus a modified version of block 14 in which tide data at the seaward boundary are prescribed at hourly intervals as the map time intervals. The input is summarized as follows:

Control Card: 0 in column 1

Block 0: see Section IV,1, NOWIND = -1

Blocks 1 to 9 see Section IV,2

Block 12 (1 card for steady river discharges)

```
READ  250 ,  IDENT, (RO(K,M), K = 1, IMRO)
```

Astrotide Block (1 card for each 12 hours)

```
905 READ 910, IGA, MTIME, (H(1,J), J = 1,12)

MU = MTIME + 12

IF (MU.LT.MMAX)  GO TO 905

910 FORMAT (I2, I4, 12F 6.2)

(IGA = 1)
```

Blocks 18 to 20: see Section IV,2

Comments on Tide Mode. The map time interval for the tide mode is 1 hour. The MTIME entry for the astrotide block is the time (hour) of the first of 12-hourly values of HG (entered as H(1,J)). The tide is assumed uniform along the seaward boundary of the bay system, hence one HG value per hour is sufficient.

In starting the tide mode from rest state (U = V = 0 and H = HGI = 0), usually one or two diurnal tide cycles are required for the numerical model to reach a nearly periodic response to an almost periodic input. Thus, if the final diurnal cycle is to be free of initial transients, at least 72 hours of HG data should be provided. This may require an adjustment in the dimensions given in COMMON/BLK6/ which appears in subprograms MAIN, PART 2, and CONTIN, if the full data set is to be stored for one run. An alternative is to make use of the continuation option, using less data input per run (e.g., 24 hours).

4. Input for Continuation of a Run.

Since the main purpose of the tide mode is for calibration of the bed friction coefficients for blocks and channels, it is expected that many trial runs will be made for a given bay system. In order to keep the machine time to a minimum for each successive run, it is desirable to use an initial field of U, V, or H which is close to the true response at the starting time. This can be accomplished by using the resulting U, V, and H arrays from a previous tide run for the bay system as the initial values. (This should be done even if the previous run has different values of the bed friction coefficients.) The mechanism for accomplishing this is the use of the continuation mode option, as controlled by ICARD. In this mode, the contents of common from a previous run are input along with any additional forcing function data.

To make the program as flexible as possible, the continuation option can be used for either storm surge problems or astrotide problems, the only difference in input being in the type of forcing function input. Such forcing function data should be consistent with the continuation time. Moreover, the value of NTIME input in data block 1 should be equal to the final NTIME in the previous run which is continued.

The sequence of input for continuation of a problem is as follows:

Control Card:	1 in column 1
Contin Deck:	Contents of COMMON output from a previous run
Blocks 0 to 3:	see subsection 2 of this app. (4 cards)
Forcing Deck:	For storm surge mode, blocks 13 to 17, inclusive. For tide mode-astrotide deck.

A flow diagram summarizing the READ operations as controlled by ICARD and NOWIND is given in Figure C-1.

5. Comments on Barrier Input.

a. Possible Barrier Locations. All barriers in the schematization occur parallel to the sides of a given barrier block. Barrier data qualified by an X in the coded name (e.g., IZX, ICDOX, ICDXS) refer to barriers normal to the x-axis on the right side of the barrier block; those qualified by a Y in the coded name (e.g., IXY, etc.) refer to barriers normal to the y-axis on the upper side of the barrier block. If a channel exists parallel to either barrier, then such a barrier may occur on either or both sides of the parallel channel, depending upon the coding of the associated channel input data (as discussed in a subsequent subsection). Barriers which might exist along the left or lower side of a given block are represented by appropriate data coding of a barrier block in a previous row or column.

b. Precaution. It should be emphasized that for any barrier block it is up to the user to supply appropriate barrier elevations ZB for both the right and upper sides of the barrier block even if a real barrier occurs only on one side of the block. The important point to observe is that the specified *ZB values should always equal or exceed the larger of the block elevations at or adjacent to the side of the barrier block in question.* Otherwise, errors can occur in the computations.

c. Array Size. The number of barrier blocks KM is normally limited to less than 100.

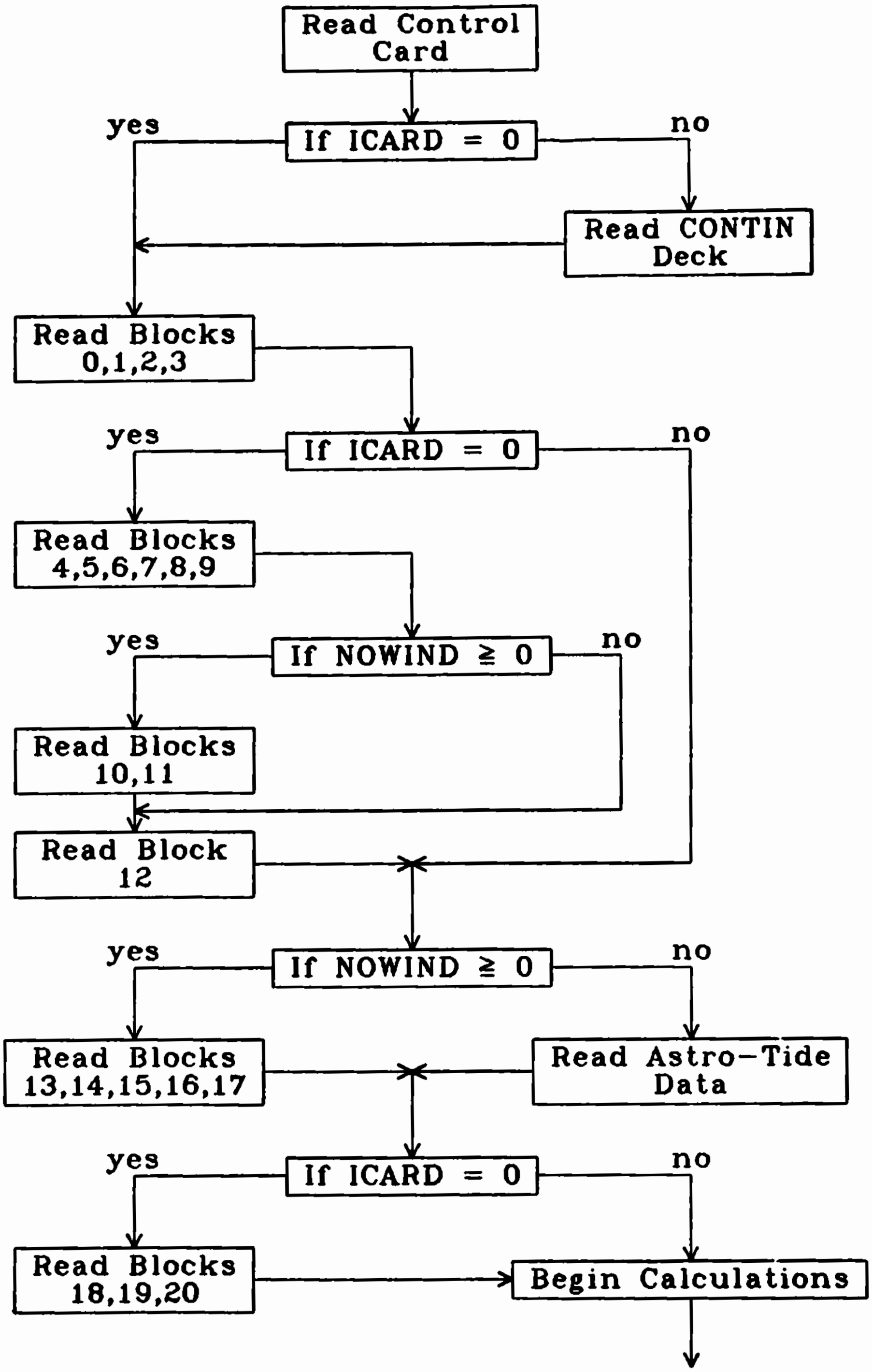

Figure C-1. Flow diagram for read statements.

6. Comments on Channel Input.

a. Possible Channel Locations. All channels in the schematization occur along the right side or the upper side of a given channel block. Channel data qualified by an X in the coded name (e.g., IWCX, IZCX) refer to channels normal to the X-axis on the right side of the channel block; those qualified by a Y in the coded name (e.g., IWCY, IZCY) refer to channels normal to the Y-axis on the upper side of the channel block. If a block has both an X and Y channel, one data card specifies both.

b. Channel Junctions. In the schematization of a channel system junctions can occur with adjoining channel reaches parallel to each other or perpendicular. Moreover, one-, two-, or three-way branches are possible.

Four possible right-angle channel junctions are illustrated in Figure C-2. The simplest junction is that shown in the upper right panel of the figure where the joining channel reaches are in the same channel block K1. Right-angle junctions involving two adjacent channel blocks are illustrated in the upper left and lower right panels of Figure C-2.

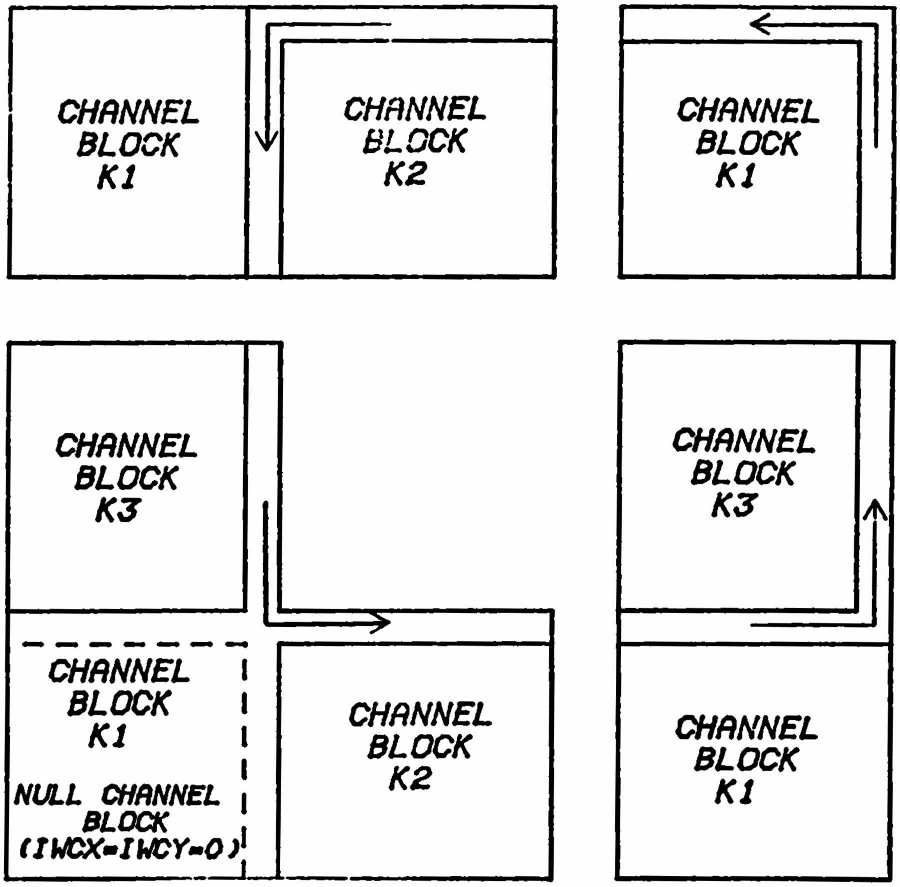

Figure C-2. Four possible simple bends for a channel reach.

The final possible right turn is illustrated in the lower left panel of the figure. In this case, the program requires that a channel block (K1) join the connecting channels of the nonadjoining channel blocks (K2 and K3) even though no channels exist on the joining block K1. In such circumstances, the required "null" channel block would have zero width for both the X and Y channels (IWCS = IWCY = 0) as input. The H value at the junction of the connecting channel reaches for this case is stored as HC(K1); i.e., in association with the null channel block.

Colinear adjoining channels always involve two adjacent channel blocks. Four possible junctions of this type are illustrated in Figure B-2 in relation to central channel block K.

c. Channels with Levees. The program allows for the following possible situations with respect to barriers parallel to channels:

(a) Single barrier on the "inner" lateral boundary of a channel;

(b) single barrier on the "outer" lateral boundary of a channel;

(c) barriers of *equal* elevation on both sides of a channel.

NOTE.--The term inner or outer side of a channel refers respectively to the side common to the channel block containing the channel or the side common to an adjacent block.

The barrier elevation information is input separately from the channel block data and allows only one elevation for the right side and one for the top side of a block (hence, the restriction of equal barrier heights for the double levee situation c above). The specification for situations a, b, or c is accomplished by a sign coding in the channel block data as follows:

(a) Channel width (ICW) positive, channel-bed elevation (IZC)

(b) channel width positive, channel-bed elevation positive;

(c) channel width negative, channel-bed elevation negative.

It is understood that only the magnitude of IWC and IZC for a given channel is used in calculations.

d. Channel Terminations. A channel system can terminate at (a) a larger body of water representing a lake, bay, or sea; or (b) at a boundary or in a landlocked block within the system. In the second case, the program assumes that the flow at the channel end is zero unless a river discharge to the channel is specified (see input) and that the channel end block is one block inside the boundary block.

e. Restriction. Only channels with the channel bed below the mean water level (MWL) reference are allowed. The actual elevation used in calculations is - |IZC|, regardless of the sign on the input of IZC for a given channel.

f. Array Size. The number of channel blocks (including null channel blocks) is KCM. However, (CHANL(1)) creates arrays of length KCMP > KCM. The value of KCMP exceeds KCM by one plus the number of channels which terminate on the exterior boundary of the grid including the seaward boundary. Since KCMP is limited to 130, KCM should be less by the amount described above.

7. Output.

a. Listings of Input and Key Arrays. All input data are listed in easily identifiable form in the order in which the data are entered through block 18. Immediately following the basic channel input is a listing of the key arrays for channels, as discussed in Appendix A, including the assignment of sign coding for ICG and JCG.

Also printed out, in the same block format as the routine listings of H, are the block elevations.

b. Sequential Output. Normally, the routine output of computed values includes block H arrays and listings of all channel variables at predetermined intervals of time (as determined by IOUT). It is possible to list the U, V, and H arrays for blocks by changing the CALL LIST(2) statement following statement 2,100 in PART 2 to CALL LIST(3).

For channel listings, refer to Figure 6 for notation; the listings are ordered by channel block number K. The block location I,J is repeated (negative signs indicating end points). This is followed by HX, the water level (feet) and QXN, the volume transport (cubic feet per second) at the lower end of the x channel, then QCP, the transport at the upper end of the x channel. These are followed by HY, QYN, and QYP representing, respectively, the water level and flow at the left end and flow at the right end of the y channel. Next is HC, the water level at the junction of the x and y channels. The last four entries in the channel listings are the transports (in cubic feet per second) to the channel from the channel block and from the channel to an adjacent block for the x and y channels. The HC value is meaningful for null channels only.

c. Saved Time Sequences. Subroutine SAVE, if used, saves sequences of water level and flow at preselected locations (as identified in block 19 of the input). In the original version of the subroutine used with an IBM 360-65 computer the saved information was punched on cards to facilitate later graphing of the sequences.

APPENDIX D

COMPLETE DATA LISTING OF INPUT FOR SABINE-CALCASIEU REGION WITH FORCING DATA FOR HURRICANE CARLA

```
ICARD= 0 IBL=  1 KCM= 121 NOWIND=  1 INTER= 15 NGAGE=  9 NFLOW=  2 IMIN= -1 IMAX= 10

IDNT= 1 NTIME=  0 NM= 900 MMIN=   0 MMAX=  24 NFU=  45 IOUT= 449 INFLD=   0
IDNT= 2 IM= 28 JM= 20 KM= 91 KMAX=  8 LMAX=  6
IDNT= 3 DELX= 2.0 N MI  DELT=240. SEC  CDO=  .200 FK=  .0010 FC=  .0010 HGI= 3.200 FT
IDNT= 4 KI=  4 LJ=  4 KII=  7 LJJ=  5 JBL=  2 JBR=  1

MIN OR MMAX IN ERROR
  IDNT= 5   BARRIER DATA- Z VALUES IN TENTHS OF FEET.  CD VALUES ARE TIMES 1000
  K=  1 IB=  8 JB=  1 ZX=   50 ZY=   10 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K=  2 IB= 20 JB=  1 ZX= -150 ZY=   60 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K=  3 IB= 21 JB=  1 ZX= -150 ZY=   60 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K=  4 IB= 22 JB=  1 ZX=   50 ZY=   60 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K=  5 IB= 23 JB=  1 ZX=  -80 ZY=   90 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K=  6 IB= 24 JB=  1 ZX= -100 ZY=   50 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K=  7 IB= 25 JB=  1 ZX= -100 ZY=   50 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K=  8 IB= 26 JB=  1 ZX= -100 ZY=   50 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K=  9 IB= 27 JB=  1 ZX= -100 ZY=   50 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 10 IB= 28 JB=  1 ZX= -100 ZY=   50 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 11 IB=  1 JB=  2 ZX=  -80 ZY=   60 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 12 IB=  2 JB=  2 ZX= -100 ZY=   60 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 13 IB=  3 JB=  2 ZX= -120 ZY=   60 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 14 IB=  4 JB=  2 ZX= -100 ZY=   60 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 15 IB=  5 JB=  2 ZX=  -70 ZY=   60 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 16 IB=  6 JB=  2 ZX=   10 ZY=   60 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 17 IB=  8 JB=  2 ZX=   50 ZY=   20 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 18 IB= 13 JB=  2 ZX= -130 ZY=   50 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 19 IB= 14 JB=  2 ZX= -120 ZY=   50 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 20 IB= 15 JB=  2 ZX= -120 ZY=   50 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 21 IB= 16 JB=  2 ZX= -120 ZY=   50 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 22 IB= 17 JB=  2 ZX= -110 ZY=   50 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 23 IB= 18 JB=  2 ZX=  -80 ZY=   50 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 24 IB= 19 JB=  2 ZX=   60 ZY=   50 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 25 IB= 22 JB=  2 ZX=   80 ZY=   10 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 26 IB=  6 JB=  3 ZX=   60 ZY=   10 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 27 IB=  7 JB=  3 ZX=   20 ZY=   50 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 28 IB=  8 JB=  3 ZX=   50 ZY=   50 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 29 IB=  9 JB=  3 ZX=   10 ZY=   50 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 30 IB= 10 JB=  3 ZX=   10 ZY=   40 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 31 IB= 11 JB=  3 ZX=   30 ZY=   40 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 32 IB= 12 JB=  3 ZX=   50 ZY=   50 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 33 IB= 22 JB=  3 ZX=   80 ZY=   10 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 34 IB=  1 JB=  4 ZX=   10 ZY=   50 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 35 IB=  2 JB=  4 ZX=   10 ZY=   50 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 36 IB=  3 JB=  4 ZX=   10 ZY=   50 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 37 IB=  7 JB=  4 ZX=   50 ZY=   50 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 38 IB= 22 JB=  4 ZX=   30 ZY=  -30 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 39 IB=  3 JB=  5 ZX=   50 ZY=   10 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 40 IB=  4 JB=  5 ZX=   10 ZY=   50 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 41 IB=  5 JB=  5 ZX=   10 ZY=   30 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 42 IB=  4 JB=  6 ZX=   30 ZY=   10 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
  K= 43 IB=  6 JB=  5 ZX=   50 ZY=   10 CDOX=  200 CDUY=  200 CDSX=  400 CDSY=  400
```

```
K= 44 I=  5 J=  6 ZX=  30 ZY= -10 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 45 I=  6 J=  6 ZX=  50 ZY=  50 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 46 I= 15 J=  6 ZX=  10 ZY=  50 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 47 I= 16 J=  6 ZX=  10 ZY=  60 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 48 I= 17 J=  6 ZX=   0 ZY=  50 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 49 I= 23 J=  6 ZX= 100 ZY=  10 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 50 I=  4 J=  7 ZX=  30 ZY=  10 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 51 I=  6 J=  7 ZX=  50 ZY=  50 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 52 I=  5 J=  7 ZX=  30 ZY= -10 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 53 I=  7 J=  7 ZX= -40 ZY= 140 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 54 I=  8 J=  7 ZX= -60 ZY= 140 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 55 I= 14 J=  7 ZX=  50 ZY=  10 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 56 I= 17 J=  7 ZX=  40 ZY=   0 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 57 I= 23 J=  7 ZX= 100 ZY=  50 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 58 I=  4 J=  8 ZX=  30 ZY=  10 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 59 I=  5 J=  8 ZX=  50 ZY=  50 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 60 I=  6 J=  8 ZX=  50 ZY=  30 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 61 I=  7 J=  8 ZX=  50 ZY=  60 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 62 I=  8 J=  8 ZX= 140 ZY=  50 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 63 I=  9 J=  8 ZX= -60 ZY= 140 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 64 I= 14 J=  8 ZX=  50 ZY=  10 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 65 I= 15 J=  8 ZX=   0 ZY=  50 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 66 I= 16 J=  8 ZX=   0 ZY=  50 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 67 I= 17 J=  8 ZX=  50 ZY=  50 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 68 I= 23 J=  8 ZX= 120 ZY=  50 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 69 I=  6 J=  9 ZX=  50 ZY=  30 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 70 I=  7 J=  9 ZX=  50 ZY=  50 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 71 I=  9 J=  9 ZX= 140 ZY=  70 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 72 I= 23 J=  9 ZX= 120 ZY=  10 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 73 I=  9 J= 10 ZX= 140 ZY=  70 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 74 I= 20 J= 10 ZX=  10 ZY= 150 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 75 I= 21 J= 10 ZX=  10 ZY= 150 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 76 I= 22 J= 10 ZX=  10 ZY= 150 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 77 I= 23 J= 10 ZX= 120 ZY= 120 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 78 I= 15 J= 11 ZX=  20 ZY=  80 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 79 I= 16 J= 11 ZX=  10 ZY= 100 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 80 I= 17 J= 11 ZX=  20 ZY=  70 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 81 I= 18 J= 11 ZX=  50 ZY=  70 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 82 I= 19 J= 11 ZX= 100 ZY= 100 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 83 I=  6 J= 12 ZX=  40 ZY=  50 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 84 I=  7 J= 12 ZX=  50 ZY=  50 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 85 I= 14 J= 12 ZX=  20 ZY=  50 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 86 I=  5 J= 13 ZX=  50 ZY= 150 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 87 I= 13 J= 13 ZX=  50 ZY= 120 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 88 I= 14 J= 13 ZX=  30 ZY=  50 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 89 I=  5 J= 14 ZX=  10 ZY=  50 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 90 I=  5 J= 16 ZX=  50 ZY=  50 COOX= 200 COOY= 200 COSX= 400 COSY= 400
K= 91 I=  4 J= 17 ZX=  50 ZY= 100 COOX= 200 COOY= 200 COSX= 400 COSY= 400
```

```
  IDNT= 6    BLOCK TOPOGRAPHY- Z VALUES IN FEET
 1  -24     -8      1      1      2      3      3      8      7     16
 1   11     19     23     26     32     35     30     20     35    100
 2  -24    -10      0      1      2      2      3      8      8     11
 2    7     14     15     23     25     35     30     20     35    100
 3  -24    -13      1      1      1      1      1      2      6      9
 3    4      7     11     16     22     25     30      7      7    100
 4  -24    -12      1      1      1      0      1      1      1      4
 4   12     13     14     20     23     15      3      7      7    100
 5  -24    -10     -1      0      1     -1     -1     -1      5      8
 5   15     17     15      1      1      1      7      7      7    100
 6  -16     -7      1      1      0      1      2      3      3      3
 6   15      7      1      1      7      1     10     20     25    100
 7   -8      1      1      1     -5     -5     -4      5     -1      5
 7   13      1      3     16     18     15     20     25     25    100
 8   -4      1      2      0      1     -5     -6      2      5     12
 8   12      1      6     15     18     20     25     25     30    100
 9  -15      2      2      1      1     -6     -7     -6      2      7
 9    1      1     13     15     17     15     25     27     30    100
10  -20     -8      1      1      1     -5     -8     -8     -6     -4
10    1      7     11     12     18     21     22     28     30    100
11  -22    -10      1      3      1      1     -6     -7     -7     -6
11    1      7      8     11     18     20     22     30     35    100
12  -22    -13      3      2      1      1      1      1     -4     -3
12    4      6     12     12     16     20     22     25     30    100
13  -23    -15      5      2      1      1      1      1      1      1
13    1      6     10     12     13     18     22     30     32    100
14  -23    -13      4      1      1      1      1      1      1      1
14    1      1      3      7     13     18     20     25     20    100
15  -23    -12      2      1      1      1      0      0      1      1
15    2      2      1      2      3      7      7     10     12    100
16  -23    -12      1      1      1      1      0      0      1      1
16    1      1      3      8      8     10     10     15     15    100
17  -23    -12      1      1      1      0      0      0      1      3
17    1      1      1      9     16     20     15     25     30    100
18  -22    -11      1      1      1      0      0      1      3      3
18    2      2      4     10     15     18     20     25     30    100
19  -19     -8     -1      1      1      1      1      1      1      4
19    5      8      8     11     14     18     20     20     32    100
20  -17      1      1      1      1      1      1      1      1      1
20    3      8     10     14     14     18     20     22     25    100
21  -15      1      1      1     -4      1      0      7     -1      1
21    3      6     10     12     14     18     20     22     25    100
22  -15      1      1     -3     -4      1      1      5      0      1
22    5      6     10     12     14     14     20     22     25    100
23   -8      1      1     -4     -5      1      1      5      1      1
23    4      6     12     13     14     14     20     22     25    100
24  -10      1      1     -6     -7     -7     -7     -6     -6      1
24    3      1     10     12     15     15     20     22     25    100
25  -10      1      1     -5     -4     -5     -2     -6      1      1
25    5      8      8     12     15     15     20     22     25    100
26  -10      1      1      1      1      1      1      1      1      1
26    4      8      1     -5     15     15     20     22     25    100
27  -10      1      1      1      1      1      1      1      1      1
27    4      8      8      1     12     15     20     22     25    100
28  -10    100    100    100    100    100    100    100    100    100
28  100    100    100    100    100    100    100    100    100    100
```

```
  IDNT= 7 IMRO=  3 JMRO= 25 KF= 25 ISTR= 25 IND= 16 NUW= 45 KIM= 45 NORT= 15
  IDNT= 8 RF= 4.000 CONST=  .9000 S=  .23662

  IDNT= 9      3 PAIRS OF I,J FOR RUNOFF LOCATIONS
 9   28      15       4       19       14       19        0        0        0        0

  IDNT= 10   PERCENT RAINFALL EACH MAPTIME
0   .006    .0070    .0070    .0080    .0100    .0140    .0180    .0230    .0240    .0280
0   .032    .0360    .0470    .0630    .0840    .1070    .1460    .1400    .0650    .0390
0   .030    .0250    .0210    .0200

  IDNT= 11   CHANNEL STRESS VALUES AT MAPTIMES
1  0.000  0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
1  0.000  0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
1  0.000  0.0000   0.0000   0.0000   0.0000

  IDNT= 12      3 SETS OF RUNOFF VALUES IN CFS FOR 25 MAPTIMES
2   800.    1107.    1520.
2   800.    1099.    1480.
2   800.    1099.    1480.
2   800.    1099.    1480.
2   800.    1099.    1480.
2   800.    1099.    1480.
2   800.    1099.    1480.
2   800.    1099.    1480.
2   800.    1099.    1480.
2   900.    1152.    1560.
2   900.    1152.    1560.
2   900.    1152.    1560.
2   900.    1152.    1560.
2   900.    1152.    1560.
2   900.    1152.    1560.
2   900.    1152.    1560.
2   900.    1152.    1560.
2  1310.    1812.    2060.
2  1310.    1812.    2060.
2  1310.    1812.    2060.
2  1310.    1812.    2060.
2  1310.    1812.    2060.
2  1310.    1812.    2060.
2  1310.    1812.    2060.
2  1310.    1812.    2060.
```

```
   HGR FOLLOWED BY HBR ARRAY (IN FEET) AT MTIME=    0
4   4.500  4.5000  4.5000  4.5000  4.5000  4.5000  4.5000  4.5000
5   3.200  3.2000  3.2000  3.2000  3.2000  3.2000  3.2000

   XR VALUES(IONT=6) AND YR VALUES (IONT=7) AT MAPTIME=    0
6  -.029  -.0101  -.0090  -.0080  -.0062  -.0054
6  -.027  -.0169  -.0091  -.0081  -.0063  -.0055
6  -.030  -.0128  -.0100  -.0073  -.0064  -.0055
6  -.028  -.0143  -.0116  -.0073  -.0064  -.0055
6  -.028  -.0130  -.0105  -.0073  -.0064  -.0056
6  -.026  -.0225  -.0094  -.0074  -.0065  -.0056
6  -.026  -.0225  -.0094  -.0074  -.0065  -.0056
6  -.026  -.0225  -.0094  -.0074  -.0065  -.0056
7  -.011  -.0037  -.0033  -.0029  -.0023  -.0020
7  -.009  -.0055  -.0030  -.0025  -.0020  -.0018
7  -.009  -.0057  -.0030  -.0020  -.0017  -.0015
7  -.007  -.0036  -.0031  -.0020  -.0017  -.0015
7  -.006  -.0030  -.0024  -.0017  -.0015  -.0013
7  -.005  -.0044  -.0018  -.0014  -.0013  -.0011
7  -.005  -.0044  -.0018  -.0014  -.0013  -.0011
7  -.005  -.0044  -.0018  -.0014  -.0013  -.0011

   HGR FOLLOWED BY HBR ARRAY (IN FEET) AT MTIME=    1
4   5.500  5.5000  5.5000  5.5000  5.5000  5.5000  5.5000  5.5000
5   4.500  4.5000  4.5000  4.5000  4.5000  4.5000  4.5000

   XR VALUES(IONT=6) AND YR VALUES (IONT=7) AT MAPTIME=    1
6  -.033  -.0112  -.0112  -.0090  -.0070  -.0054
6  -.031  -.0200  -.0102  -.0091  -.0071  -.0054
6  -.032  -.0141  -.0120  -.0091  -.0071  -.0055
6  -.032  -.0172  -.0142  -.0092  -.0072  -.0055
6  -.032  -.0144  -.0117  -.0093  -.0073  -.0055
6  -.030  -.0244  -.0116  -.0083  -.0073  -.0064
6  -.030  -.0244  -.0118  -.0083  -.0073  -.0064
6  -.030  -.0244  -.0118  -.0083  -.0073  -.0064
7  -.013  -.0043  -.0043  -.0035  -.0027  -.0021
7  -.011  -.0059  -.0035  -.0031  -.0025  -.0019
7  -.010  -.0043  -.0036  -.0030  -.0023  -.0018
7  -.009  -.0046  -.0041  -.0027  -.0022  -.0017
7  -.008  -.0033  -.0029  -.0023  -.0020  -.0015
7  -.006  -.0048  -.0025  -.0018  -.0017  -.0015
7  -.006  -.0048  -.0025  -.0018  -.0017  -.0015
7  -.006  -.0048  -.0025  -.0019  -.0017  -.0015
```

```
   HGR FOLLOWED BY HBR ARRAY (IN FEET) AT MTIME=    2
4  6.200  6.2000  6.2000  6.2000  6.2000  6.2000  6.2000  6.2000
5  5.200  5.2000  5.2000  5.2000  5.2000  5.2000  5.2000

   XR VALUES(IDNT=6) AND YR VALUES (IDNT=7) AT MAPTIME=    2
6  -.037  -.0136  -.0123  -.0111  -.0088  -.0053
6  -.036  -.0216  -.0112  -.0101  -.0090  -.0080
6  -.036  -.0169  -.0130  -.0102  -.0091  -.0081
6  -.036  -.0187  -.0155  -.0103  -.0091  -.0081
6  -.034  -.0143  -.0142  -.0104  -.0092  -.0082
6  -.035  -.0282  -.0144  -.0094  -.0083  -.0073
6  -.035  -.0282  -.0144  -.0094  -.0083  -.0073
6  -.035  -.0282  -.0144  -.0094  -.0083  -.0073
7  -.015  -.0056  -.0052  -.0047  -.0038  -.0022
7  -.013  -.0079  -.0043  -.0039  -.0035  -.0031
7  -.012  -.0055  -.0045  -.0035  -.0031  -.0028
7  -.011  -.0054  -.0048  -.0032  -.0030  -.0026
7  -.009  -.0036  -.0038  -.0028  -.0027  -.0024
7  -.007  -.0060  -.0033  -.0022  -.0021  -.0018
7  -.007  -.0060  -.0033  -.0022  -.0021  -.0018
7  -.007  -.0060  -.0033  -.0022  -.0021  -.0018

   HGR FOLLOWED BY HBR ARRAY (IN FEET) AT MTIME=    3
4  6.000  6.0000  6.0000  6.0000  6.0000  6.0000  6.0000  6.0000
5  5.200  5.2000  5.2000  5.2000  5.2000  5.2000  5.2000

   XR VALUES(IDNT=6) AND YR VALUES (IDNT=7) AT MAPTIME=    3
6  -.040  -.0138  -.0125  -.0112  -.0100  -.0089
6  -.038  -.0201  -.0126  -.0102  -.0091  -.0081
6  -.039  -.0203  -.0130  -.0103  -.0092  -.0081
6  -.037  -.0205  -.0142  -.0104  -.0092  -.0082
6  -.035  -.0174  -.0158  -.0105  -.0083  -.0073
6  -.033  -.0305  -.0145  -.0094  -.0083  -.0074
6  -.033  -.0305  -.0145  -.0094  -.0083  -.0074
6  -.033  -.0305  -.0145  -.0094  -.0083  -.0074
7  -.015  -.0053  -.0048  -.0043  -.0040  -.0036
7  -.013  -.0066  -.0044  -.0035  -.0031  -.0028
7  -.011  -.0059  -.0062  -.0032  -.0028  -.0025
7  -.009  -.0051  -.0038  -.0028  -.0027  -.0024
7  -.007  -.0037  -.0037  -.0024  -.0021  -.0018
7  -.005  -.0054  -.0026  -.0018  -.0018  -.0016
7  -.005  -.0054  -.0026  -.0018  -.0018  -.0016
7  -.005  -.0054  -.0026  -.0018  -.0018  -.0016
```

```
   HGR FOLLOWED BY HBR ARRAY (IN FEET) AT MTIME=    4
4  5.800  5.8000  5.8000  5.8000  5.8000  5.8000  5.8000  5.8000
5  5.200  5.2000  5.2000  5.2000  5.2000  5.2000  5.2000

   XR VALUES(IDNT=6) AND YR VALUES (IDNT=7) AT MAPTIME=    4
6  -.052  -.0205  -.0172  -.0156  -.0142  -.0128
6  -.053  -.0282  -.0173  -.0158  -.0130  -.0117
6  -.050  -.0226  -.0175  -.0145  -.0131  -.0118
6  -.048  -.0247  -.0170  -.0146  -.0118  -.0095
6  -.045  -.0229  -.0211  -.0133  -.0119  -.0106
6  -.043  -.0378  -.0194  -.0133  -.0107  -.0085
6  -.043  -.0378  -.0194  -.0133  -.0107  -.0085
6  -.043  -.0378  -.0194  -.0133  -.0107  -.0085
7  -.012  -.0051  -.0046  -.0045  -.0041  -.0039
7  -.010  -.0060  -.0040  -.0037  -.0032  -.0029
7  -.008  -.0040  -.0047  -.0028  -.0028  -.0025
7  -.006  -.0031  -.0025  -.0023  -.0021  -.0017
7  -.003  -.0020  -.0022  -.0016  -.0017  -.0017
7  -.002  -.0020  -.0014  -.0012  -.0011  -.0010
7  -.002  -.0020  -.0014  -.0012  -.0011  -.0010
7  -.002  -.0020  -.0014  -.0012  -.0011  -.0010

   HGR FOLLOWED BY HBR ARRAY (IN FEET) AT MTIME=    5
4  6.200  6.2000  6.2000  6.2000  6.2000  6.2000  6.2000  6.2000
5  5.500  5.5000  5.5000  5.5000  5.5000  5.5000  5.5000

   XR VALUES(IDNT=6) AND YR VALUES (IDNT=7) AT MAPTIME=    5
6  -.065  -.0244  -.0225  -.0189  -.0173  -.0158
6  -.062  -.0373  -.0208  -.0192  -.0159  -.0131
6  -.059  -.0308  -.0210  -.0176  -.0160  -.0145
6  -.057  -.0248  -.0229  -.0177  -.0161  -.0146
6  -.057  -.0268  -.0248  -.0162  -.0147  -.0133
6  -.051  -.0454  -.0212  -.0162  -.0147  -.0133
6  -.051  -.0454  -.0212  -.0162  -.0147  -.0133
6  -.051  -.0454  -.0212  -.0162  -.0147  -.0133
7  -.012  -.0048  -.0048  -.0044  -.0040  -.0039
7  -.009  -.0060  -.0037  -.0034  -.0031  -.0026
7  -.005  -.0033  -.0043  -.0028  -.0026  -.0026
7  -.003  -.0018  -.0020  -.0019  -.0020  -.0021
7  -.001  -.0010  -.0013  -.0011  -.0013  -.0014
7   .001  0.0000  -.0004  -.0006  -.0008  -.0009
7   .001  0.0000  -.0004  -.0006  -.0008  -.0009
7   .001  0.0000  -.0004  -.0006  -.0008  -.0009
```

```
   HGR FOLLOWED BY HHR ARRAY (IN FEET) AT MTIME=   6
4  6.500   6.5000  6.5000  6.5000  6.5000  6.5000  6.5000  6.5000
5  5.600   5.6000  5.6000  5.6000  5.6000  5.6000  5.6000

   XR VALUES(IDNT=6) AND YR VALUES (IDNT=7) AT MAPTIME=   6
6  -.069  -.0248  -.0211  -.0193  -.0161  -.0146
6  -.063  -.0332  -.0211  -.0177  -.0162  -.0146
6  -.060  -.0268  -.0220  -.0162  -.0147  -.0133
6  -.054  -.0230  -.0230  -.0162  -.0133  -.0100
6  -.051  -.0229  -.0229  -.0147  -.0120  -.0096
6  -.045  -.0352  -.0194  -.0133  -.0120  -.0108
6  -.045  -.0352  -.0194  -.0133  -.0120  -.0108
6  -.045  -.0352  -.0194  -.0133  -.0120  -.0108
7  -.005  -.0022  -.0022  -.0024  -.0023  -.0023
7  -.001  -.0012  -.0011  -.0016  -.0017  -.0018
7   .002  0.0000  -.0006  -.0006  -.0010  -.0012
7   .004   .0008   .0004  0.0000  -.0005  -.0008
7   .005   .0020   .0012   .0005   .0002  0.0000
7   .006   .0043   .0017   .0009   .0006   .0004
7   .006   .0043   .0017   .0009   .0006   .0004
7   .006   .0043   .0017   .0009   .0006   .0004

   HGR FOLLOWED BY HHR ARRAY (IN FEET) AT MTIME=   7
4  6.200   6.2000  6.2000  6.2000  6.2000  6.2000  6.2000  6.2000
5  5.400   5.4000  5.4000  5.4000  5.4000  5.4000  5.4000

   XR VALUES(IDNT=6) AND YR VALUES (IDNT=7) AT MAPTIME=   7
6  -.065  -.0247  -.0211  -.0194  -.0178  -.0162
6  -.059  -.0307  -.0211  -.0177  -.0162  -.0147
6  -.056  -.0286  -.0210  -.0162  -.0147  -.0133
6  -.050  -.0207  -.0209  -.0146  -.0132  -.0119
6  -.044  -.0205  -.0207  -.0131  -.0119  -.0107
6  -.039  -.0276  -.0189  -.0117  -.0106  -.0095
6  -.039  -.0278  -.0184  -.0117  -.0106  -.0095
6  -.039  -.0276  -.0189  -.0117  -.0106  -.0095
7   .008   .0026   .0015   .0010   .0006   .0003
7   .010   .0043   .0022   .0015   .0011   .0008
7   .010   .0040   .0030   .0014   .0010   .0007
7   .011   .0044   .0037   .0023   .0018   .0015
7   .012   .0051   .0044   .0025   .0019   .0015
7   .012   .0079   .0047   .0027   .0020   .0017
7   .012   .0079   .0047   .0027   .0020   .0017
7   .012   .0079   .0047   .0027   .0020   .0017
```

```
   HGR FOLLOWED BY HHR ARRAY (IN FEET) AT MTIME=   8
4  6.000  6.0000  6.0000  6.0000  6.0000  6.0000  6.0000  6.0000
5  5.300  5.3000  5.3000  5.3000  5.3000  5.3000  5.3000

   XR VALUES(IUNT=6) AND YR VALUES (IUNT=7) AT MAPTIME=   8
6  -.048  -.0185  -.0156  -.0143  -.0130  -.0118
6  -.042  -.0216  -.0155  -.0128  -.0116  -.0105
6  -.039  -.0198  -.0150  -.0114  -.0103  -.0092
6  -.034  -.0150  -.0138  -.0114  -.0091  -.0072
6  -.030  -.0134  -.0136  -.0089  -.0080  -.0072
6  -.026  -.0175  -.0109  -.0078  -.0079  -.0080
6  -.026  -.0175  -.0109  -.0078  -.0079  -.0080
6  -.026  -.0175  -.0109  -.0078  -.0079  -.0080
7   .017   .0060   .0045   .0038   .0030   .0025
7   .016   .0078   .0050   .0037   .0031   .0026
7   .017   .0076   .0060   .0037   .0031   .0026
7   .016   .0063   .0053   .0042   .0030   .0022
7   .015   .0062   .0056   .0036   .0029   .0023
7   .014   .0085   .0051   .0035   .0032   .0024
7   .014   .0095   .0051   .0035   .0032   .0029
7   .014   .0085   .0051   .0035   .0032   .0024

   HGR FOLLOWED BY HHR ARRAY (IN FEET) AT MTIME=   9
4  7.200  7.2000  7.2000  7.2000  7.2000  7.2000  7.2000  7.2000
5  6.200  6.2000  6.2000  6.2000  6.2000  6.2000  6.2000

   XR VALUES(IUNT=6) AND YR VALUES (IUNT=7) AT MAPTIME=   9
6  -.060  -.0249  -.0216  -.0201  -.0186  -.0171
6  -.057  -.0303  -.0213  -.0183  -.0148  -.0155
6  -.050  -.0296  -.0240  -.0165  -.0152  -.0139
6  -.045  -.0222  -.0208  -.0148  -.0137  -.0126
6  -.037  -.0170  -.0189  -.0133  -.0122  -.0110
6  -.036  -.0248  -.0142  -.0119  -.0108  -.0161
6  -.036  -.0248  -.0142  -.0119  -.0108  -.0161
6  -.036  -.0248  -.0142  -.0119  -.0108  -.0161
7   .027   .0100   .0078   .0065   .0057   .0049
7   .026   .0135   .0086   .0066   .0058   .0050
7   .027   .0150   .0090   .0067   .0058   .0050
7   .025   .0113   .0097   .0066   .0055   .0046
7   .022   .0094   .0096   .0065   .0054   .0049
7   .023   .0148   .0079   .0061   .0053   .0075
7   .023   .0148   .0079   .0061   .0053   .0075
7   .023   .0148   .0079   .0061   .0053   .0075
```

```
   HGR FOLLOWED BY HBR ARRAY (IN FEET) AT MTIME=  10
4  7.000  7.0000  7.0000  7.0000  7.0000  7.0000  7.0000  7.0000
5  6.000  6.0000  6.0000  6.0000  6.0000  6.0000  6.0000

   XR VALUES(IUNT=6) AND YR VALUES (IUNT=7) AT MAPTIME=  10
6  -.048  -.0194  -.0179  -.0166  -.0140  -.0115
6  -.042  -.0224  -.0178  -.0137  -.0125  -.0113
6  -.037  -.0187  -.0150  -.0122  -.0112  -.0101
6  -.032  -.0170  -.0132  -.0109  -.0090  -.0090
6  -.028  -.0141  -.0157  -.0096  -.0087  -.0078
6  -.024  -.0165  -.0104  -.0085  -.0076  -.0068
6  -.024  -.0165  -.0104  -.0085  -.0076  -.0068
6  -.024  -.0165  -.0104  -.0085  -.0076  -.0068
7   .024   .0086   .0070   .0064   .0048   .0035
7   .023   .0109   .0079   .0055   .0048   .0041
7   .021   .0099   .0080   .0054   .0045   .0037
7   .020   .0094   .0067   .0051   .0042   .0034
7   .018   .0081   .0083   .0049   .0041   .0035
7   .016   .0103   .0060   .0045   .0039   .0033
7   .016   .0103   .0060   .0045   .0039   .0033
7   .016   .0103   .0060   .0045   .0039   .0033

   HGR FOLLOWED BY HBR ARRAY (IN FEET) AT MTIME=  11
4  5.800  5.8000  5.8000  5.8000  5.8000  5.8000  5.8000  5.8000
5  5.800  5.8000  5.8000  5.8000  5.8000  5.8000  5.8000

   XR VALUES(IUNT=6) AND YR VALUES (IUNT=7) AT MAPTIME=  11
6  -.054  -.0213  -.0199  -.0169  -.0156  -.0143
6  -.046  -.0245  -.0196  -.0153  -.0140  -.0128
6  -.040  -.0225  -.0180  -.0138  -.0126  -.0114
6  -.037  -.0189  -.0147  -.0123  -.0112  -.0102
6  -.033  -.0157  -.0175  -.0110  -.0099  -.0089
6  -.028  -.0199  -.0130  -.0098  -.0088  -.0079
6  -.028  -.0199  -.0130  -.0098  -.0088  -.0079
6  -.028  -.0199  -.0130  -.0098  -.0088  -.0079
7   .024   .0086   .0072   .0055   .0045   .0036
7   .022   .0109   .0074   .0055   .0045   .0037
7   .021   .0105   .0075   .0053   .0046   .0039
7   .021   .0096   .0069   .0052   .0043   .0035
7   .019   .0083   .0085   .0049   .0042   .0036
7   .018   .0115   .0069   .0045   .0039   .0033
7   .018   .0115   .0069   .0045   .0039   .0033
7   .018   .0115   .0069   .0045   .0039   .0033
```

```
   HGR FOLLOWED BY HBR ARRAY (IN FEET) AT MTIME=  12
4   6.200  6.2000  6.2000  6.2000  6.2000  6.2000  6.2000  6.2000
5   5.300  5.3000  5.3000  5.3000  5.3000  5.3000  5.3000

   XR VALUES(IDNT=6) AND YR VALUES (IDNT=7) AT MAPTIME=  12
6   -.040  -.0186  -.0148  -.0139  -.0129  -.0119
6   -.035  -.0169  -.0146  -.0124  -.0115  -.0105
6   -.029  -.0165  -.0130  -.0100  -.0091  -.0083
6   -.025  -.0136  -.0110  -.0087  -.0081  -.0074
6   -.021  -.0101  -.0115  -.0077  -.0070  -.0063
6   -.018  -.0121  -.0092  -.0059  -.0061  -.0055
6   -.018  -.0121  -.0092  -.0059  -.0061  -.0055
6   -.018  -.0121  -.0092  -.0059  -.0061  -.0055
7    .031   .0135   .0094   .0084   .0071   .0061
7    .029   .0127   .0102   .0080   .0069   .0058
7    .025   .0133   .0095   .0067   .0057   .0048
7    .022   .0114   .0091   .0063   .0052   .0043
7    .020   .0088   .0093   .0058   .0049   .0041
7    .018   .0109   .0077   .0046   .0044   .0037
7    .018   .0109   .0077   .0046   .0044   .0037
7    .018   .0109   .0077   .0046   .0044   .0037

   HGR FOLLOWED BY HBR ARRAY (IN FEET) AT MTIME=  13
4   6.600  6.6000  6.6000  6.6000  6.6000  6.7000  6.7000  6.7000
5   5.800  5.8000  5.8000  5.8000  5.8000  5.8000  5.8000

   XR VALUES(IDNT=6) AND YR VALUES (IDNT=7) AT MAPTIME=  13
6   -.049  -.0255  -.0218  -.0211  -.0201  -.0191
6   -.042  -.0251  -.0199  -.0179  -.0169  -.0159
6   -.037  -.0247  -.0180  -.0174  -.0153  -.0133
6   -.033  -.0197  -.0179  -.0145  -.0126  -.0109
6   -.028  -.0154  -.0150  -.0108  -.0111  -.0102
6   -.024  -.0193  -.0135  -.0096  -.0079  -.0066
6   -.024  -.0193  -.0135  -.0096  -.0079  -.0066
6   -.024  -.0193  -.0135  -.0096  -.0079  -.0066
7    .053   .0246   .0189   .0165   .0146   .0128
7    .047   .0251   .0179   .0144   .0127   .0111
7    .043   .0255   .0170   .0151   .0120   .0093
7    .039   .0211   .0173   .0130   .0102   .0076
7    .033   .0171   .0150   .0101   .0097   .0086
7    .029   .0214   .0140   .0093   .0091   .0085
7    .029   .0214   .0140   .0093   .0091   .0085
7    .029   .0214   .0140   .0093   .0091   .0085
```

```
   HGR FOLLOWED BY HBR ARRAY (IN FEET) AT MTIME=  14
4  5.800  5.8000  5.8000  5.9000  6.0000  6.1000  6.2000  6.2000
5  5.600  5.6000  5.6000  5.6000  5.6000  5.6000  5.6000

   XR VALUES(IDNT=6) AND YR VALUES (IDNT=7) AT MAPTIME=  14
6  -.041  -.0223  -.0188  -.0179  -.0171  -.0163
6  -.036  -.0235  -.0157  -.0151  -.0155  -.0146
6  -.032  -.0201  -.0150  -.0162  -.0142  -.0121
6  -.029  -.0196  -.0155  -.0134  -.0128  -.0121
6  -.025  -.0147  -.0152  -.0110  -.0115  -.0097
6  -.022  -.0183  -.0126  -.0099  -.0102  -.0105
6  -.022  -.0183  -.0126  -.0099  -.0102  -.0105
6  -.022  -.0183  -.0126  -.0099  -.0102  -.0105
7   .044   .0215   .0163   .0144   .0124   .0106
7   .040   .0234   .0142   .0122   .0117   .0102
7   .036   .0207   .0140   .0136   .0107   .0085
7   .032   .0193   .0144   .0117   .0100   .0085
7   .029   .0152   .0147   .0099   .0093   .0071
7   .025   .0196   .0126   .0089   .0086   .0082
7   .025   .0196   .0120   .0089   .0086   .0082
7   .025   .0196   .0126   .0089   .0086   .0082

   HGR FOLLOWED BY HBR ARRAY (IN FEET) AT MTIME=  15
4  4.300  4.3000  4.3000  4.5000  4.7000  4.9000  5.1000  5.1000
5  5.200  5.2000  5.2000  5.2000  5.2000  5.2000  5.2000

   XR VALUES(IDNT=6) AND YR VALUES (IDNT=7) AT MAPTIME=  15
6  -.040  -.0222  -.0190  -.0185  -.0191  -.0181
6  -.036  -.0264  -.0173  -.0168  -.0176  -.0169
6  -.031  -.0233  -.0170  -.0182  -.0160  -.0138
6  -.030  -.0203  -.0173  -.0152  -.0147  -.0140
6  -.029  -.0163  -.0170  -.0128  -.0132  -.0113
6  -.025  -.0218  -.0145  -.0115  -.0119  -.0102
6  -.025  -.0218  -.0145  -.0115  -.0119  -.0102
6  -.025  -.0218  -.0145  -.0115  -.0119  -.0102
7   .049   .0246   .0190   .0166   .0160   .0141
7   .044   .0304   .0179   .0157   .0148   .0127
7   .040   .0267   .0180   .0169   .0139   .0112
7   .037   .0234   .0179   .0147   .0127   .0110
7   .035   .0187   .0182   .0124   .0119   .0095
7   .032   .0250   .0155   .0115   .0111   .0086
7   .032   .0250   .0155   .0115   .0111   .0086
7   .032   .0250   .0155   .0115   .0111   .0086
```

```
   HGR FOLLOWED BY HBR ARRAY (IN FEET) AT MTIME=  16
4  4.600  4.6000  4.6000  4.7000  4.9000  5.0000  5.1000  5.1000
5  5.100  5.1000  5.1000  5.1000  5.1000  5.1000  5.1000

   XR VALUES(IDNT=6) AND YR VALUES (IDNT=7) AT MAPTIME=  16
6  -.027  -.0156  -.0149  -.0162  -.0174  -.0160
6  -.026  -.0201  -.0138  -.0150  -.0150  -.0160
6  -.025  -.0184  -.0140  -.0150  -.0138  -.0125
6  -.023  -.0161  -.0153  -.0139  -.0128  -.0115
6  -.021  -.0150  -.0142  -.0109  -.0117  -.0125
6  -.019  -.0155  -.0132  -.0100  -.0110  -.0099
6  -.019  -.0155  -.0132  -.0100  -.0110  -.0099
6  -.019  -.0155  -.0132  -.0100  -.0110  -.0099
7   .057   .0293   .0247   .0239   .0230   .0190
7   .054   .0378   .0230   .0222   .0198   .0190
7   .051   .0331   .0240   .0222   .0183   .0149
7   .045   .0290   .0245   .0206   .0169   .0136
7   .040   .0271   .0227   .0161   .0155   .0149
7   .038   .0268   .0211   .0148   .0140   .0110
7   .038   .0268   .0211   .0148   .0140   .0110
7   .038   .0268   .0211   .0148   .0140   .0110

   HGR FOLLOWED BY HBR ARRAY (IN FEET) AT MTIME=  17
4  5.400  5.4000  5.4000  5.6000  5.8000  6.0000  6.0000  6.0000
5  5.300  5.3000  5.3000  5.3000  5.3000  5.3000  5.3000

   XR VALUES(IDNT=6) AND YR VALUES (IDNT=7) AT MAPTIME=  17
6  -.015  -.0139  -.0149  -.0138  -.0124  -.0114
6  -.015  -.0125  -.0089  -.0111  -.0121  -.0131
6. -.013  -.0118  -.0089  -.0111  -.0118  -.0122
6  -.014  -.0111  -.0108  -.0104  -.0101  -.0096
6  -.013  -.0097  -.0101  -.0086  -.0094  -.0093
6  -.013  -.0103  -.0092  -.0086  -.0086  -.0085
6  -.013  -.0103  -.0092  -.0086  -.0086  -.0085
6  -.013  -.0103  -.0092  -.0086  -.0086  -.0085
7   .071   .0518   .0486   .0374   .0308   .0243
7   .064   .0464   .0274   .0289   .0285   .0281
7   .058   .0411   .0280   .0290   .0264   .0239
7   .055   .0362   .0314   .0269   .0227   .0189
7   .049   .0317   .0293   .0213   .0210   .0190
7   .044   .0316   .0252   .0213   .0193   .0175
7   .044   .0316   .0252   .0213   .0193   .0175
7   .044   .0316   .0252   .0213   .0193   .0175
```

```
   HGR FOLLOWED BY HBR ARRAY (IN FEET) AT MTIME=  18
4  4.700   4.7000   4.7000   4.9000   5.1000   5.3000   5.4000   5.4000
5  5.000   5.0000   5.0000   5.0000   5.0000   5.0000   5.0000

   XR VALUES(IDNT=6) AND YR VALUES (IDNT=7) AT MAPTIME=  18
6    .002  0.0000  -.0007  -.0020  -.0028  -.0040
6    .001  -.0006  -.0011  -.0022  -.0030  -.0037
6  0.000   -.0011  -.0028  -.0024  -.0031  -.0031
6  -.001   -.0014  -.0019  -.0024  -.0028  -.0026
6  -.001   -.0015  -.0022  -.0023  -.0028  -.0026
6  -.002   -.0016  -.0020  -.0021  -.0026  -.0025
6  -.002   -.0016  -.0020  -.0021  -.0026  -.0025
6  -.002   -.0016  -.0020  -.0021  -.0026  -.0025
7    .048    .0249   .0212   .0229   .0228   .0226
7    .045    .0332   .0211   .0211   .0210   .0208
7    .040    .0310   .0210   .0193   .0192   .0175
7    .038    .0268   .0211   .0193   .0176   .0160
7    .033    .0211   .0211   .0161   .0160   .0131
7    .031    .0229   .0193   .0146   .0145   .0116
7    .031    .0229   .0193   .0146   .0145   .0118
7    .031    .0229   .0193   .0146   .0145   .0118

   HGR FOLLOWED BY HBR ARRAY (IN FEET) AT MTIME=  19
4  3.200   3.2000   3.2000   3.5000   3.8000   4.0000   4.1000   4.1000
5  4.400   4.4000   4.4000   4.4000   4.4000   4.4000   4.4000

   XR VALUES(IDNT=6) AND YR VALUES (IDNT=7) AT MAPTIME=  19
6    .016    .0075   .0056   .0050   .0035   .0025
6    .014    .0096   .0046   .0037   .0028   .0019
6    .012    .0072   .0050   .0030   .0022   .0013
6    .011    .0061   .0043   .0030   .0017   .0007
6    .009    .0048   .0035   .0020   .0012   .0004
6    .008    .0046   .0032   .0015   .0011   .0007
6    .008    .0046   .0032   .0015   .0011   .0007
6    .008    .0046   .0032   .0015   .0011   .0007
7    .057    .0301   .0262   .0284   .0286   .0288
7    .055    .0417   .0264   .0266   .0267   .0268
7    .052    .0371   .0280   .0247   .0248   .0248
7    .050    .0349   .0307   .0247   .0248   .0212
7    .047    .0306   .0286   .0229   .0229   .0230
7    .045    .0329   .0306   .0211   .0211   .0212
7    .045    .0329   .0308   .0211   .0211   .0212
7    .045    .0329   .0308   .0211   .0211   .0212
```

```
   HGR FOLLOWED BY HBR ARRAY (IN FEET) AT MTIME=  20
4  2.700  2.7000  2.7000  2.9000  3.2000  3.4000  3.6000  3.6000
5  4.000  4.0000  4.0000  4.0000  4.0000  4.0000  4.0000

   XR VALUES(IDNT=6) AND YR VALUES (IDNT=7). AT MAPTIME=  20
6    .018    .0086    .0073    .0076    .0075    .0073
6    .015    .0113    .0064    .0063    .0062    .0059
6    .014    .0082    .0060    .0055    .0054    .0051
6    .012    .0078    .0065    .0054    .0046    .0039
6    .011    .0060    .0057    .0042    .0036    .0026
6    .009    .0062    .0049    .0032    .0033    .0034
6    .009    .0062    .0049    .0032    .0033    .0034
6    .009    .0062    .0049    .0032    .0033    .0034
7    .036    .0193    .0190    .0198    .0217    .0236
7    .035    .0206    .0166    .0184    .0203    .0222
7    .033    .0215    .0185    .0169    .0187    .0205
7    .031    .0216    .0201    .0187    .0172    .0158
7    .029    .0185    .0186    .0157    .0158    .0145
7    .027    .0203    .0171    .0130    .0144    .0159
7    .027    .0203    .0171    .0130    .0144    .0159
7    .027    .0203    .0171    .0130    .0144    .0159

   HGR FOLLOWED BY HBR ARRAY (IN FEET) AT MTIME=  21
4  3.700  3.7000  3.7000  3.8000  3.9000  4.0000  4.1000  4.1000
5  4.600  4.6000  4.6000  4.6000  4.6000  4.6000  4.6000

   XR VALUES(IDNT=6) AND YR VALUES (IDNT=7) AT MAPTIME=  21
6    .016    .0074    .0062    .0075    .0070    .0083
6    .013    .0093    .0062    .0063    .0067    .0070
6    .012    .0072    .0060    .0053    .0055    .0058
6    .011    .0070    .0064    .0061    .0048    .0037
6    .010    .0053    .0055    .0043    .0039    .0031
6    .008    .0061    .0043    .0037    .0035    .0030
6    .008    .0061    .0043    .0037    .0035    .0030
6    .008    .0061    .0043    .0037    .0035    .0030
7    .024    .0145    .0134    .0161    .0164    .0195
7    .026    .0190    .0134    .0156    .0165    .0182
7    .026    .0163    .0150    .0138    .0153    .0166
7    .025    .0164    .0166    .0167    .0140    .0114
7    .023    .0136    .0138    .0126    .0128    .0116
7    .022    .0167    .0126    .0114    .0115    .0104
7    .022    .0167    .0126    .0114    .0115    .0104
7    .022    .0167    .0126    .0114    .0115    .0104
```

```
   HGR FOLLOWED BY HBR ARRAY (IN FEET) AT MTIME=  22
4  3.500  3.5000  3.5000  3.7000  3.9000  4.0000  4.1000  4.1000
5  4.400  4.4000  4.4000  4.4000  4.4000  4.4000  4.4000

   XR VALUES(IDNT=6) AND YR VALUES (IDNT=7) AT MAPTIME=  22
6    .013    .0060    .0058    .0063    .0067    .0071
6    .012    .0079    .0056    .0061    .0058    .0062
6    .010    .0067    .0060    .0051    .0054    .0058
6    .010    .0065    .0069    .0060    .0047    .0036
6    .008    .0049    .0049    .0040    .0039    .0033
6    .007    .0058    .0040    .0034    .0037    .0039
6    .007    .0058    .0040    .0034    .0037    .0039
6    .007    .0056    .0040    .0034    .0037    .0039
7    .021    .0104    .0105    .0118    .0132    .0146
7    .020    .0142    .0106    .0119    .0120    .0134
7    .019    .0132    .0120    .0109    .0122    .0136
7    .019    .0133    .0147    .0135    .0111    .0089
7    .018    .0110    .0110    .0100    .0101    .0090
7    .016    .0136    .0100    .0090    .0101    .0114
7    .016    .0136    .0100    .0090    .0101    .0114
7    .016    .0136    .0100    .0090    .0101    .0114

   HGR FOLLOWED BY HBR ARRAY (IN FEET) AT MTIME=  23
4  2.200  2.2000  2.2000  2.4000  2.6000  2.8000  2.9000  2.9000
5  3.500  3.5000  3.5000  3.5000  3.5000  3.5000  3.5000

 . XR VALUES(IDNT=6) AND YR VALUES (IDNT=7) AT MAPTIME=  23
6    .009    .0041    .0046    .0052    .0055    .0056
6    .008    .0052    .0044    .0049    .0048    .0047
6    .007    .0049    .0050    .0043    .0047    .0051
6    .007    .0047    .0056    .0045    .0044    .0033
6    .006    .0035    .0039    .0033    .0036    .0039
6    .006    .0044    .0032    .0032    .0031    .0029
6    .006    .0044    .0032    .0032    .0031    .0029
6    .006    .0044    .0032    .0032    .0031    .0029
7    .013    .0063    .0072    .0091    .0092    .0105
7    .012    .0081    .0073    .0082    .0083    .0084
7    .011    .0082    .0090    .0074    .0084    .0095
7    .013    .0084    .0105    .0085    .0086    .0066
7    .011    .0066    .0076    .0068    .0077    .0088
7    .011    .0086    .0068    .0068    .0069    .0069
7    .011    .0086    .0068    .0068    .0069    .0069
7    .011    .0086    .0068    .0068    .0069    .0069
```

```
  MGP FOLLOWED BY MBR ARRAY (IN FEET) AT MTIME=  24
4  1.300  1.3000  1.3000  1.5000  1.7000  1.9000  2.1000  2.1000
5  3.500  3.5000  3.5000  3.5000  3.5000  3.5000  3.5000

  XR VALUES(IDNT=6) AND YR VALUES (IDNT=7) AT MAPTIME=  24
6    .006    .0030    .0035    .0040    .0044    .0049
6    .006    .0034    .0033    .0038    .0042    .0046
6    .005    .0037    .0037    .0032    .0036    .0040
6    .005    .0031    .0045    .0030    .0034    .0038
6    .004    .0026    .0030    .0029    .0033    .0036
6    .004    .0033    .0024    .0024    .0027    .0027
6    .004    .0033    .0024    .0024    .0027    .0027
6    .004    .0033    .0024    .0024    .0027    .0027
7    .008    .0040    .0046    .0053    .0061    .0070
7    .008    .0046    .0047    .0054    .0062    .0072
7    .007    .0055    .0055    .0048    .0055    .0064
7    .007    .0048    .0072    .0049    .0056    .0065
7    .006    .0042    .0049    .0050    .0057    .0065
7    .006    .0057    .0043    .0043    .0051    .0051
7    .006    .0057    .0043    .0043    .0051    .0051
7    .006    .0057    .0043    .0043    .0051    .0051

  THE FOLLOWING ARE SUBGRID CHANNEL DATA-  Z VALUES IN FEET

  K=  1 ICG=  8 JCG=  1 IWCX=-2330 IZCX= -20 IWCY=    0 IZCY=   0 IFC=  15
  K=  2 ICG=  8 JCG=  2 IWCX=-2330 IZCX= -20 IWCY=    0 IZCY=   0 IFC=  15
  K=  3 ICG=  8 JCG=  3 IWCX= 2860 IZCX= -21 IWCY= 2800 IZCY= -21 IFC=  15
  K=  4 ICG=  7 JCG=  3 IWCX=    0 IZCX=   0 IWCY=    0 IZCY=   0 IFC=  15
  K=  5 ICG=  7 JCG=  4 IWCX= 2860 IZCX= -21 IWCY= 1000 IZCY=  26 IFC=  15
  K=  6 ICG=  6 JCG=  4 IWCX=    0 IZCX=   0 IWCY=    0 IZCY=   0 IFC=  15
  K=  7 ICG=  6 JCG=  5 IWCX= 1000 IZCX=  26 IWCY=    0 IZCY=   0 IFC=  15
  K=  8 ICG=  6 JCG=  6 IWCX=  900 IZCX=  26 IWCY=  300 IZCY=  12 IFC=  20
  K=  9 ICG=  6 JCG=  7 IWCX= -900 IZCX= -21 IWCY= -300 IZCY= -15 IFC=  20
  K= 10 ICG=  7 JCG=  7 IWCX=    0 IZCX=   0 IWCY= -900 IZCY= -26 IFC=  20
  K= 11 ICG=  8 JCG=  7 IWCX=    0 IZCX=   0 IWCY= -900 IZCY= -26 IFC=  20
  K= 12 ICG=  8 JCG=  8 IWCX= -900 IZCX= -26 IWCY=    0 IZCY=   0 IFC=  20
  K= 13 ICG=  9 JCG=  8 IWCX=    0 IZCX=   0 IWCY= -900 IZCY= -26 IFC=  20
  K= 14 ICG=  9 JCG=  9 IWCX= -900 IZCX= -26 IWCY=    0 IZCY=   0 IFC=  20
  K= 15 ICG=  9 JCG= 10 IWCX=  900 IZCX= -26 IWCY=    0 IZCY=   0 IFC=  20
  K= 16 ICG=  9 JCG= 11 IWCX=  400 IZCX= -35 IWCY=  400 IZCY= -35 IFC=  25
  K= 17 ICG=  8 JCG= 11 IWCX=    0 IZCX=   0 IWCY=  400 IZCY= -35 IFC=  25
  K= 18 ICG=  7 JCG= 11 IWCX=    0 IZCX=   0 IWCY=    0 IZCY=   0 IFC=  25
  K= 19 ICG=  7 JCG= 12 IWCX= -400 IZCX= -35 IWCY= -400 IZCY= -35 IFC=  25
  K= 20 ICG=  6 JCG= 12 IWCX=    0 IZCX=   0 IWCY=  350 IZCY=  43 IFC=  25
  K= 21 ICG=  5 JCG= 12 IWCX=    0 IZCX=   0 IWCY=    0 IZCY=   0 IFC=  25
  K= 22 ICG=  5 JCG= 13 IWCX=  350 IZCX=  43 IWCY=    0 IZCY=   0 IFC=  25
  K= 23 ICG=  5 JCG= 14 IWCX=  350 IZCX= -43 IWCY=  350 IZCY= -43 IFC=  25
  K= 24 ICG=  4 JCG= 14 IWCX=    0 IZCX=   0 IWCY=    0 IZCY=   0 IFC=  25
  K= 25 ICG=  4 JCG= 15 IWCX=  300 IZCX= -25 IWCY=    0 IZCY=   0 IFC=  25
  K= 26 ICG=  5 JCG= 15 IWCX=    0 IZCX=   0 IWCY=  400 IZCY= -40 IFC=  25
  K= 27 ICG=  5 JCG= 16 IWCX= -400 IZCX= -40 IWCY= -400 IZCY= -30 IFC=  25
  K= 28 ICG=  4 JCG= 16 IWCX=    0 IZCX=   0 IWCY=    0 IZCY=   0 IFC=  25
  K= 29 ICG=  4 JCG= 17 IWCX=  400 IZCX= -30 IWCY=  150 IZCY= -20 IFC=  25
  K= 30 ICG=  5 JCG= 17 IWCX=    0 IZCX=   0 IWCY=  300 IZCY= -30 IFC=  25
```

```
K= 31 ICG=  5 JCG= 18 IWCX=  400 IZCX= -30 IWCY=  300 IZCY= -30 IFC=  25
K= 32 ICG=  4 JCG= 18 IWCX=    0 IZCX=   0 IWCY=    0 IZCY=   0 IFC=  25
K= 33 ICG=  4 JCG= 19 IWCX=  300 IZCX= -30 IWCY=    0 IZCY=   0 IFC=  25
K= 34 ICG=  3 JCG= 17 IWCX=    0 IZCX=   0 IWCY=    0 IZCY=   0 IFC=  25
K= 35 ICG=  3 JCG= 18 IWCX=  150 IZCX= -20 IWCY=  100 IZCY= -20 IFC=  25
K= 36 ICG=  2 JCG= 18 IWCX=    0 IZCX=   0 IWCY=  100 IZCY= -20 IFC=  25
K= 37 ICG= 10 JCG= 10 IWCX=    0 IZCX=   0 IWCY=  200 IZCY= -12 IFC=  25
K= 38 ICG= 11 JCG= 10 IWCX=    0 IZCX=   0 IWCY=  200 IZCY= -12 IFC=  25
K= 39 ICG= 12 JCG= 10 IWCX=    0 IZCX=   0 IWCY=  200 IZCY= -12 IFC=  25
K= 40 ICG= 12 JCG= 11 IWCX=  200 IZCX= -27 IWCY=  200 IZCY= -20 IFC=  25
K= 41 ICG= 13 JCG= 11 IWCX=    0 IZCX=   0 IWCY=  200 IZCY= -27 IFC=  25
K= 42 ICG= 14 JCG= 11 IWCX=    0 IZCX=   0 IWCY=  200 IZCY= -27 IFC=  25
K= 43 ICG= 14 JCG= 12 IWCX=  200 IZCX= -27 IWCY= -200 IZCY= -27 IFC=  25
K= 44 ICG= 13 JCG= 12 IWCX=    0 IZCX=   0 IWCY=    0 IZCY=   0 IFC=  25
K= 45 ICG= 13 JCG= 13 IWCX=  200 IZCX=  27 IWCY=    0 IZCY=   0 IFC=  25
K= 46 ICG= 14 JCG= 13 IWCX=    0 IZCX=   0 IWCY=  200 IZCY=  27 IFC=  25
K= 47 ICG= 14 JCG= 14 IWCX=  500 IZCX= -20 IWCY=    0 IZCY=   0 IFC=  25
K= 48 ICG= 15 JCG= 14 IWCX=    0 IZCX=   0 IWCY=  350 IZCY= -20 IFC=  25
K= 49 ICG= 15 JCG= 15 IWCX=  350 IZCX= -20 IWCY=  200 IZCY= -20 IFC=  25
K= 50 ICG= 14 JCG= 15 IWCX=    0 IZCX=   0 IWCY=    0 IZCY=   0 IFC=  25
K= 51 ICG= 14 JCG= 16 IWCX=  200 IZCX= -20 IWCY=    0 IZCY=   0 IFC=  25
K= 52 ICG= 14 JCG= 17 IWCX=  200 IZCX= -15 IWCY=    0 IZCY=   0 IFC=  25
K= 53 ICG= 14 JCG= 18 IWCX=  100 IZCX= -10 IWCY=    0 IZCY=   0 IFC=  25
K= 54 ICG= 14 JCG= 19 IWCX=  100 IZCX= -10 IWCY=    0 IZCY=   0 IFC=  25
K= 55 ICG= 11 JCG= 11 IWCX=    0 IZCX=   0 IWCY=    0 IZCY=   0 IFC=   9
K= 56 ICG= 11 JCG= 12 IWCX=  200 IZCX= -20 IWCY=  200 IZCY= -20 IFC=   9
K= 57 ICG= 10 JCG= 12 IWCX=    0 IZCX=   0 IWCY=    0 IZCY=   0 IFC=   9
K= 58 ICG= 10 JCG= 13 IWCX=  200 IZCX= -20 IWCY=  100 IZCY= -20 IFC=   9
K= 59 ICG=  9 JCG= 13 IWCX=    0 IZCX=   0 IWCY=    0 IZCY=   0 IFC=   9
K= 60 ICG=  9 JCG= 14 IWCX=  100 IZCX= -20 IWCY=    0 IZCY=   0 IFC=   9
K= 61 ICG= 15 JCG= 11 IWCX=    0 IZCX=   0 IWCY=  300 IZCY= -12 IFC=   9
K= 62 ICG= 16 JCG= 11 IWCX=    0 IZCX=   0 IWCY=  300 IZCY= -12 IFC=   9
K= 63 ICG= 17 JCG= 11 IWCX=    0 IZCX=   0 IWCY= -300 IZCY= -12 IFC=   9
K= 64 ICG= 18 JCG= 11 IWCX=    0 IZCX=   0 IWCY= -300 IZCY= -12 IFC=   9
K= 65 ICG= 19 JCG= 11 IWCX=  300 IZCX= -12 IWCY= -300 IZCY= -12 IFC=   9
K= 66 ICG= 19 JCG= 10 IWCX=    0 IZCX=   0 IWCY=    0 IZCY=   0 IFC=   9
K= 67 ICG= 20 JCG= 10 IWCX=    0 IZCX=   0 IWCY=  300 IZCY= -12 IFC=   9
K= 68 ICG= 21 JCG= 10 IWCX=    0 IZCX=   0 IWCY=  300 IZCY= -12 IFC=   9
K= 69 ICG= 22 JCG= 10 IWCX=    0 IZCX=   0 IWCY=  300 IZCY= -12 IFC=   9
K= 70 ICG= 23 JCG= 10 IWCX= -400 IZCX= -40 IWCY=  300 IZCY= -12 IFC=   9
K= 71 ICG= 22 JCG=  1 IWCX= -800 IZCX= -32 IWCY=    0 IZCY=   0 IFC=   9
K= 72 ICG= 23 JCG=  1 IWCX=    0 IZCX=   0 IWCY= 1000 IZCY= -16 IFC=  15
K= 73 ICG= 23 JCG=  2 IWCX= 1000 IZCX= -16 IWCY= 1000 IZCY= -16 IFC=  15
K= 74 ICG= 22 JCG=  2 IWCX=  500 IZCX= -40 IWCY=    0 IZCY=   0 IFC=  15
K= 75 ICG= 22 JCG=  3 IWCX=  800 IZCX= -32 IWCY=    0 IZCY=   0 IFC=  15
K= 76 ICG= 22 JCG=  4 IWCX= 1000 IZCX= -20 IWCY=    0 IZCY=   0 IFC=  15
K= 77 ICG= 22 JCG=  5 IWCX= 1000 IZCX= -20 IWCY=    0 IZCY=   0 IFC=   5
K= 78 ICG= 23 JCG=  5 IWCX=    0 IZCX=   0 IWCY=  400 IZCY= -40 IFC=   5
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K= 82 ICG= 23 JCG=  9 IWCX=  400 IZCX=  40 IWCY=    0 IZCY=   0 IFC=   5
K= 83 ICG= 24 JCG=  9 IWCX=    0 IZCX=   0 IWCY=  800 IZCY= -25 IFC=   5
K= 84 ICG= 24 JCG= 10 IWCX=  800 IZCX= -25 IWCY= 1000 IZCY= -20 IFC=   5
```

```
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K= 87 ICG= 24 JCG= 13 IWCX= 1000 IZCX= -25 IWCY=    0 IZCY=   0 IFC=    5
K= 88 ICG= 25 JCG= 13 IWCX=    0 IZCX=   0 IWCY= 1000 IZCY= -25 IFC=    5
K= 89 ICG= 25 JCG= 14 IWCX=  400 IZCX= -40 IWCY=    0 IZCY=   0 IFC=    5
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K=104 ICG=  4 JCG=  5 IWCX=    0 IZCX=   0 IWCY=  300 IZCY= -12 IFC=    9
K=105 ICG=  5 JCG=  5 IWCX=    0 IZCX=   0 IWCY=  300 IZCY=  12 IFC=    9
K=106 ICG=  5 JCG=  6 IWCX=  300 IZCX= -12 IWCY=    0 IZCY=   0 IFC=    9
K=107 ICG=  5 JCG=  7 IWCX=    0 IZCX=   0 IWCY=    0 IZCY=   0 IFC=    9
K=108 ICG=  5 JCG=  8 IWCX=  400 IZCX=  15 IWCY=  400 IZCY=  15 IFC=    9
K=109 ICG=  4 JCG=  8 IWCX=    0 IZCX=   0 IWCY=    0 IZCY=   0 IFC=    9
K=110 ICG=  4 JCG=  9 IWCX=  200 IZCX= -12 IWCY=  200 IZCY= -10 IFC=    9
K=111 ICG=  3 JCG=  9 IWCX=  200 IZCX=  10 IWCY=    0 IZCY=   0 IFC=    9
K=112 ICG=  3 JCG=  8 IWCX=    0 IZCX=   0 IWCY=  200 IZCY= -10 IFC=    9
K=113 ICG=  2 JCG=  8 IWCX=    0 IZCX=   0 IWCY=  200 IZCY= -10 IFC=    9
K=114 ICG=  1 JCG=  8 IWCX=    0 IZCX=   0 IWCY=  200 IZCY= -10 IFC=    9
K=115 ICG=  3 JCG= 10 IWCX=  200 IZCX= -10 IWCY=  200 IZCY= -10 IFC=    9
K=116 ICG=  2 JCG= 10 IWCX=    0 IZCX=   0 IWCY=    0 IZCY=   0 IFC=    9
K=117 ICG=  2 JCG= 11 IWCX=  200 IZCX=  -8 IWCY=    0 IZCY=   0 IFC=    9
K=118 ICG=  2 JCG= 12 IWCX=  200 IZCX=  -8 IWCY=    0 IZCY=   0 IFC=    9
K=119 ICG=  6 JCG=  8 IWCX= -400 IZCX= -20 IWCY=    0 IZCY=   0 IFC=    9
K=120 ICG=  7 JCG=  8 IWCX=    0 IZCX=   0 IWCY=  200 IZCY= -20 IFC=    9
K=121 ICG=  7 JCG=  5 IWCX= 3000 IZCX= -12 IWCY=    0 IZCY=   0 IFC=    9

HYDROGRAPH GAGE LOCATIONS
  GAGE  1 BLOCK H,   I=  8 J=  1
  GAGE  2 CHANNEL H,   K=  11
  GAGE  3 BLOCK H,   I= 11 J= 10
  GAGE  4 CHANNEL H,   K=  25
  GAGE  5 CHANNEL H,   K=  46
  GAGE  6 CHANNEL H,   K=  72
  GAGE  7 CHANNEL H,   K= 100
  GAGE  8 CHANNEL H,   K=   3
  GAGE  9 CHANNEL H,   K=  92

KEY FLOW LOCATIONS
  CHANNEL BLOCKS    1   71
```

APPENDIX E

LISTING OF KEY ARRAYS AND CHANNEL AND BARRIER PLOT FOR SABINE-CALCASIEU REGION

```
K=  1 KCX=122 KCY=128 KCXP=  2 KCVP=128 KCB=  1 ICG= -8 JCG=  1 KEN1=  1 KEN2=  0 KRI=  0
K=  2 KCX=  1 KCY=128 KCXP=  3 KCVP=128 KCB= 17 ICG=  8 JCG=  2 KEN1=  0 KEN2=  0 KRI=  0
K=  3 KCX=  2 KCY=  4 KCXP=128 KCVP=128 KCB= 26 ICG=  8 JCG=  3 KEN1=  0 KEN2=  0 KRI=  0
K=  4 KCX=128 KCY=128 KCXP=  5 KCVP=  3 KCB= 27 ICG=  7 JCG=  3 KEN1=  0 KEN2=  0 KRI=  0
K=  5 KCX=  4 KCY=  6 KCXP=121 KCVP=128 KCB= 37 ICG=  7 JCG=  4 KEN1=  0 KEN2=  0 KRI=  0
K=  6 KCX=128 KCY=128 KCXP=  7 KCVP=  5 KCB=  0 ICG=  6 JCG=  4 KEN1=  0 KEN2=  0 KRI=  0
K=  7 KCX=  6 KCY=105 KCXP=  8 KCVP=121 KCB= 43 ICG=  6 JCG=  5 KEN1=  0 KEN2=  0 KRI=  0
K=  8 KCX=  7 KCY=106 KCXP=  9 KCVP=128 KCB= 45 ICG=  6 JCG=  6 KEN1=  0 KEN2=  0 KRI=  0
K=  9 KCX=  8 KCY=107 KCXP=119 KCVP= 10 KCB= 51 ICG=  6 JCG=  7 KEN1=  0 KEN2=  0 KRI=  0
K= 10 KCX=128 KCY=  9 KCXP=120 KCVP= 11 KCB= 53 ICG=  7 JCG=  7 KEN1=  0 KEN2=  0 KRI=  0
K= 11 KCX=128 KCY= 10 KCXP= 12 KCVP=128 KCB= 54 ICG=  8 JCG=  7 KEN1=  0 KEN2=  0 KRI=  0
K= 12 KCX= 11 KCY=120 KCXP=128 KCVP= 13 KCB= 62 ICG=  8 JCG=  8 KEN1=  0 KEN2=  0 KRI=  0
K= 13 KCX=128 KCY= 12 KCXP= 14 KCVP=128 KCB= 63 ICG=  9 JCG=  8 KEN1=  0 KEN2=  0 KRI=  0
K= 14 KCX= 13 KCY=128 KCXP= 15 KCVP=128 KCB= 71 ICG=  9 JCG=  9 KEN1=  0 KEN2=  0 KRI=  0
K= 15 KCX= 14 KCY=128 KCXP= 16 KCVP= 37 KCB= 73 ICG=  9 JCG= 10 KEN1=  0 KEN2=  0 KRI=  0
K= 16 KCX= 15 KCY= 17 KCXP=128 KCVP=128 KCB=  0 ICG=  9 JCG= 11 KEN1=  0 KEN2=  0 KRI=  0
K= 17 KCX=128 KCY= 18 KCXP=128 KCVP= 16 KCB=  0 ICG=  8 JCG= 11 KEN1=  0 KEN2=  0 KRI=  0
K= 18 KCX=128 KCY=128 KCXP= 19 KCVP= 17 KCB=  0 ICG=  7 JCG= 11 KEN1=  0 KEN2=  0 KRI=  0
K= 19 KCX= 18 KCY= 20 KCXP=128 KCVP=128 KCB= 84 ICG=  7 JCG= 12 KEN1=  0 KEN2=  0 KRI=  0
K= 20 KCX=128 KCY= 21 KCXP=128 KCVP= 19 KCB= 83 ICG=  6 JCG= 12 KEN1=  0 KEN2=  0 KRI=  0
K= 21 KCX=128 KCY=128 KCXP= 22 KCVP= 20 KCB=  0 ICG=  5 JCG= 12 KEN1=  0 KEN2=  0 KRI=  0
K= 22 KCX= 21 KCY=128 KCXP= 23 KCVP=128 KCB= 86 ICG=  5 JCG= 13 KEN1=  0 KEN2=  0 KRI=  0
K= 23 KCX= 22 KCY= 24 KCXP= 26 KCVP=128 KCB= 89 ICG=  5 JCG= 14 KEN1=  0 KEN2=  0 KRI=  0
K= 24 KCX=128 KCY=128 KCXP= 25 KCVP= 23 KCB=  0 ICG=  4 JCG= 14 KEN1=  0 KEN2=  0 KRI=  0
K= 25 KCX= 24 KCY=128 KCXP= 28 KCVP= 26 KCB=  0 ICG=  4 JCG= 15 KEN1=  0 KEN2=  0 KRI=  0
K= 26 KCX= 23 KCY= 25 KCXP= 27 KCVP=128 KCB=  0 ICG=  5 JCG= 15 KEN1=  0 KEN2=  0 KRI=  0
K= 27 KCX= 26 KCY= 28 KCXP= 30 KCVP=128 KCB= 90 ICG=  5 JCG= 16 KEN1=  0 KEN2=  0 KRI=  0
K= 28 KCX= 25 KCY=128 KCXP= 29 KCVP= 27 KCB=  0 ICG=  4 JCG= 16 KEN1=  0 KEN2=  0 KRI=  0
K= 29 KCX= 28 KCY= 34 KCXP= 32 KCVP= 30 KCB= 91 ICG=  4 JCG= 17 KEN1=  0 KEN2=  0 KRI=  0
K= 30 KCX= 27 KCY= 29 KCXP= 31 KCVP=128 KCB=  0 ICG=  5 JCG= 17 KEN1=  0 KEN2=  0 KRI=  0
K= 31 KCX= 30 KCY= 32 KCXP=128 KCVP=128 KCB=  0 ICG=  5 JCG= 18 KEN1=  0 KEN2=  0 KRI=  0
K= 32 KCX= 29 KCY= 35 KCXP= 33 KCVP= 31 KCB=  0 ICG=  4 JCG= 18 KEN1=  0 KEN2=  0 KRI=  0
K= 33 KCX= 32 KCY=128 KCXP=128 KCVP=128 KCB=  0 ICG= -4 JCG= 19 KEN1=  7 KEN2=  0 KRI=  2
K= 34 KCX=128 KCY=128 KCXP= 35 KCVP= 29 KCB=  0 ICG=  3 JCG= 17 KEN1=  0 KEN2=  0 KRI=  0
K= 35 KCX= 34 KCY= 36 KCXP=128 KCVP= 32 KCB=  0 ICG=  3 JCG= 18 KEN1=  0 KEN2=  0 KRI=  0
K= 36 KCX=128 KCY=123 KCXP=128 KCVP= 35 KCB=  0 ICG= -2 JCG= 18 KEN1=  6 KEN2=  0 KRI=  0
K= 37 KCX=128 KCY= 15 KCXP=128 KCVP= 38 KCB=  0 ICG= 10 JCG= 10 KEN1=  0 KEN2=  0 KRI=  0
K= 38 KCX=128 KCY= 37 KCXP= 55 KCVP= 39 KCB=  0 ICG= 11 JCG= 10 KEN1=  0 KEN2=  0 KRI=  0
K= 39 KCX=128 KCY= 38 KCXP= 40 KCVP=128 KCB=  0 ICG= 12 JCG= 10 KEN1=  0 KEN2=  0 KRI=  0
K= 40 KCX= 39 KCY= 55 KCXP=128 KCVP= 41 KCB=  0 ICG= 12 JCG= 11 KEN1=  0 KEN2=  0 KRI=  0
K= 41 KCX=128 KCY= 40 KCXP= 44 KCVP= 42 KCB=  0 ICG= 13 JCG= 11 KEN1=  0 KEN2=  0 KRI=  0
K= 42 KCX=128 KCY= 41 KCXP= 43 KCVP= 61 KCB=  0 ICG= 14 JCG= 11 KEN1=  0 KEN2=  0 KRI=  0
K= 43 KCX= 42 KCY= 44 KCXP= 46 KCVP=128 KCB= 85 ICG= 14 JCG= 12 KEN1=  0 KEN2=  0 KRI=  0
K= 44 KCX= 41 KCY=128 KCXP= 45 KCVP= 43 KCB=  0 ICG= 13 JCG= 12 KEN1=  0 KEN2=  0 KRI=  0
K= 45 KCX= 44 KCY=128 KCXP=128 KCVP= 46 KCB= 87 ICG= 13 JCG= 13 KEN1=  0 KEN2=  0 KRI=  0
K= 46 KCX= 43 KCY= 45 KCXP= 47 KCVP=128 KCB= 88 ICG= 14 JCG= 13 KEN1=  0 KEN2=  0 KRI=  0
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K= 48 KCX=128 KCY= 47 KCXP= 49 KCVP=128 KCB=  0 ICG= 15 JCG= 14 KEN1=  0 KEN2=  0 KRI=  0
K= 49 KCX= 48 KCY= 50 KCXP=128 KCVP=128 KCB=  0 ICG= 15 JCG= 15 KEN1=  0 KEN2=  0 KRI=  0
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K= 53 KCX= 52 KCY=128 KCXP= 54 KCVP=128 KCB=  0 ICG= 14 JCG= 18 KEN1=  0 KEN2=  0 KRI=  0
K= 54 KCX= 53 KCY=128 KCXP=128 KCVP=128 KCB=  0 ICG=-14 JCG= 19 KEN1=  7 KEN2=  0 KRI=  3
K= 55 KCX= 38 KCY=128 KCXP= 56 KCVP= 40 KCB=  0 ICG= 11 JCG= 11 KEN1=  0 KEN2=  0 KRI=  0
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```

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K= 79 KCX= 78 KCY=128 KCXP= 80 KCYP=128 KCB= 49 ICG= 23 JCG=  6 KEN1=  0 KEN2=  0 KRI=  0
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K= 82 KCX= 81 KCY=128 KCXP= 70 KCYP= 83 KCB= 72 ICG= 23 JCG=  9 KEN1=  0 KEN2=  0 KRI=  0
K= 83 KCX=128 KCY= 82 KCXP= 84 KCYP=128 KCB=  0 ICG= 24 JCG=  9 KEN1=  0 KEN2=  0 KRI=  0
K= 84 KCX= 83 KCY= 70 KCXP= 85 KCYP= 94 KCB=  0 ICG= 24 JCG= 10 KEN1=  0 KEN2=  0 KRI=  0
K= 85 KCX= 84 KCY=128 KCXP= 86 KCYP=128 KCB=  0 ICG= 24 JCG= 11 KEN1=  0 KEN2=  0 KRI=  0
K= 86 KCX= 85 KCY=128 KCXP= 87 KCYP=128 KCB=  0 ICG= 24 JCG= 12 KEN1=  0 KEN2=  0 KRI=  0
K= 87 KCX= 86 KCY=128 KCXP=128 KCYP= 88 KCB=  0 ICG= 24 JCG= 13 KEN1=  0 KEN2=  0 KRI=  0
K= 88 KCX=128 KCY= 87 KCXP= 89 KCYP=128 KCB=  0 ICG= 25 JCG= 13 KEN1=  0 KEN2=  0 KRI=  0
K= 89 KCX= 88 KCY=128 KCXP=128 KCYP= 90 KCB=  0 ICG= 25 JCG= 14 KEN1=  0 KEN2=  0 KRI=  0
K= 90 KCX=128 KCY= 89 KCXP=128 KCYP= 91 KCB=  0 ICG= 26 JCG= 14 KEN1=  0 KEN2=  0 KRI=  0
K= 91 KCX=128 KCY= 90 KCXP= 92 KCYP=128 KCB=  0 ICG= 27 JCG= 14 KEN1=  0 KEN2=  0 KRI=  0
K= 92 KCX= 91 KCY=128 KCXP=128 KCYP= 93 KCB=  0 ICG= 27 JCG= 15 KEN1=  0 KEN2=  0 KRI=  0
K= 93 KCX=128 KCY= 92 KCXP=128 KCYP=128 KCB=  0 ICG=-28 JCG= 15 KEN1=  8 KEN2=  0 KRI=  1
K= 94 KCX=128 KCY= 84 KCXP=128 KCYP= 95 KCB=  0 ICG= 25 JCG= 10 KEN1=  0 KEN2=  0 KRI=  0
K= 95 KCX= 96 KCY= 94 KCXP=128 KCYP=128 KCB=  0 ICG= 26 JCG= 10 KEN1=  0 KEN2=  0 KRI=  0
K= 96 KCX=128 KCY=128 KCXP= 95 KCYP= 97 KCB=  0 ICG= 26 JCG=  9 KEN1=  0 KEN2=  0 KRI=  0
K= 97 KCX= 98 KCY= 96 KCXP=128 KCYP=128 KCB=  0 ICG= 27 JCG=  9 KEN1=  0 KEN2=  0 KRI=  0
K= 98 KCX=128 KCY=128 KCXP= 97 KCYP= 99 KCB=  0 ICG= 27 JCG=  8 KEN1=  0 KEN2=  0 KRI=  0
K= 99 KCX=128 KCY= 98 KCXP=128 KCYP=128 KCB=  0 ICG=-28 JCG=  8 KEN1=  8 KEN2=  0 KRI=  0
K=100 KCX=128 KCY=125 KCXP=128 KCYP=101 KCB= 34 ICG= -1 JCG=  4 KEN1=  6 KEN2=  0 KRI=  0
K=101 KCX=128 KCY=100 KCXP=128 KCYP=102 KCB= 35 ICG=  2 JCG=  4 KEN1=  0 KEN2=  0 KRI=  0
K=102 KCX=128 KCY=101 KCXP=103 KCYP=128 KCB= 36 ICG=  3 JCG=  4 KEN1=  0 KEN2=  0 KRI=  0
K=103 KCX=102 KCY=128 KCXP=128 KCYP=104 KCB= 39 ICG=  3 JCG=  5 KEN1=  0 KEN2=  0 KRI=  0
K=104 KCX=128 KCY=103 KCXP=128 KCYP=105 KCB= 40 ICG=  4 JCG=  5 KEN1=  0 KEN2=  0 KRI=  0
K=105 KCX=128 KCY=104 KCXP=106 KCYP=  7 KCB= 41 ICG=  5 JCG=  5 KEN1=  0 KEN2=  0 KRI=  0
K=106 KCX=105 KCY=128 KCXP=107 KCYP=  8 KCB= 44 ICG=  5 JCG=  6 KEN1=  0 KEN2=  0 KRI=  0
K=107 KCX=106 KCY=128 KCXP=108 KCYP=  9 KCB= 52 ICG=  5 JCG=  7 KEN1=  0 KEN2=  0 KRI=  0
K=108 KCX=107 KCY=109 KCXP=128 KCYP=119 KCB= 59 ICG=  5 JCG=  8 KEN1=  0 KEN2=  0 KRI=  0
K=109 KCX=128 KCY=112 KCXP=110 KCYP=108 KCB= 58 ICG=  4 JCG=  8 KEN1=  0 KEN2=  0 KRI=  0
K=110 KCX=109 KCY=111 KCXP=128 KCYP=128 KCB=  0 ICG=  4 JCG=  9 KEN1=  0 KEN2=  0 KRI=  0
K=111 KCX=112 KCY=128 KCXP=115 KCYP=110 KCB=  0 ICG=  3 JCG=  9 KEN1=  0 KEN2=  0 KRI=  0
K=112 KCX=128 KCY=113 KCXP=111 KCYP=109 KCB=  0 ICG=  3 JCG=  8 KEN1=  0 KEN2=  0 KRI=  0
K=113 KCX=128 KCY=114 KCXP=128 KCYP=112 KCB=  0 ICG=  2 JCG=  8 KEN1=  0 KEN2=  0 KRI=  0
K=114 KCX=128 KCY=126 KCXP=128 KCYP=113 KCB=  0 ICG= -1 JCG=  8 KEN1=  6 KEN2=  0 KRI=  0
K=115 KCX=111 KCY=116 KCXP=128 KCYP=128 KCB=  0 ICG=  3 JCG= 10 KEN1=  0 KEN2=  0 KRI=  0
K=116 KCX=128 KCY=128 KCXP=117 KCYP=115 KCB=  0 ICG=  2 JCG= 10 KEN1=  0 KEN2=  0 KRI=  0
K=117 KCX=116 KCY=128 KCXP=118 KCYP=128 KCB=  0 ICG=  2 JCG= 11 KEN1=  0 KEN2=  0 KRI=  0
K=118 KCX=117 KCY=128 KCXP=128 KCYP=128 KCB=  0 ICG= -2 JCG= 12 KEN1=  7 KEN2=  0 KRI=  0
K=119 KCX=  9 KCY=108 KCXP=128 KCYP=120 KCB= 60 ICG=  6 JCG=  8 KEN1=  0 KEN2=  0 KRI=  0
K=120 KCX= 10 KCY=119 KCXP=128 KCYP=127 KCB= 61 ICG= -7 JCG=  8 KEN1=  4 KEN2=  0 KRI=  0
K=121 KCX=  5 KCY=  7 KCXP=128 KCYP=128 KCB=  0 ICG= -7 JCG=  5 KEN1=  3 KEN2=  0 KRI=  0

      KCMP=  128
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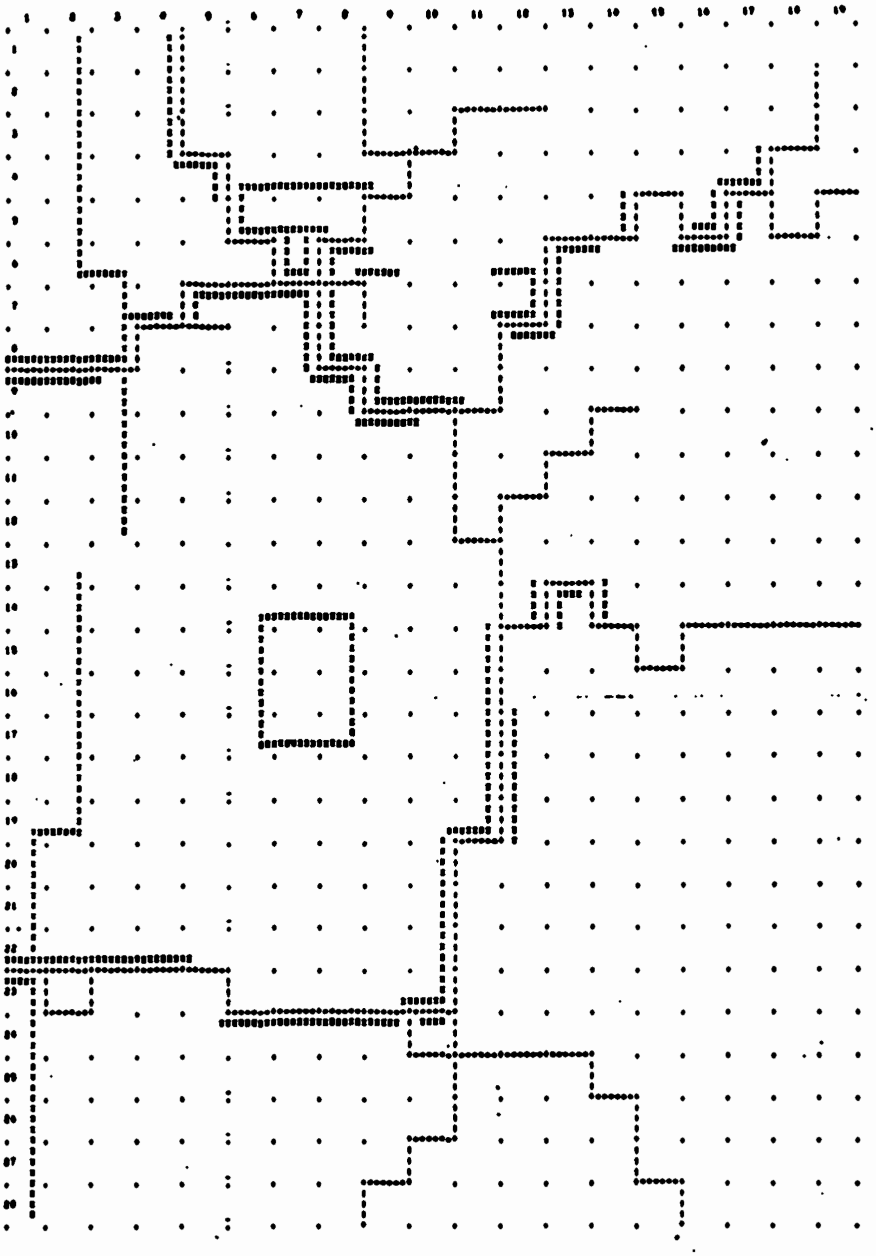

APPENDIX F

IDENTIFICATION OF GAGES FOR SABINE-CALCASIEU ASTROTIDE CALIBRATION

Gages for Sabine-Calcasieu astrotide calibration and time sequences of accepted astrotide simulation at those gages for 72 hours are identified. Also included are listings of the channel output at t = 30, 60, and 90 hours. For explanation of each column see Appendix C,7,b.

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ASTRO TIDE CALIBRATION FOR SABINE-CALCASIEU AREA

SABINE PASS TIDES USED AS INPUT

PERIOD OF RECORD- 0000 AUG.22 TO 2400 AUG.26,1973

CALCULATIONS ALLOW FOR SUB-GRID SCALE CHANNELS AND BARRIERS


TIME SEQUENCES OF WATER LEVEL AND FLOW ARE SAVED FOR THE FOLLOWING PLACES-

GAGE 1  SABINE PASS, SOUTHWEST JETTY

GAGE 2  PORT ARTHUR, CE AREA OFFICE

GAGE 3  NORTH SABINE LAKE

GAGE 4  BEAUMONT, NECHES RIVER AND BRAKES BAYOU

GAGE 5  ORANGE NAVAL STATION, SABINE RIVER

GAGE 6  CAMERON, CALCASIEU PASS

GAGE 7  HACKBERRY, CALCASIEU RIVER AND PASS

GAGE 8  I.W.W. AT CALCASIEU LOCK, WEST

GAGE 9  LAKE CHARLES, CALCASIEU RIVER


FLOW 1  SABINE PASS INFLOW

FLOW 2  CALCASIEU PASS INFLOW

FLOW 3  FLOW TO NECHES RIVER FROM SABINE LAKE AND INTRACOASTAL WATERWAY

FLOW 4  EASTWARD FLOW VIA INTRACOASTAL CANAL JUST EAST OF SABINE RIVER

FLOW 5  FLOW TO SABINE RIVER FROM SABINE LAKE AND INTRACOASTAL WATERWAY

FLOW 6  FLOW TO CALCASIEU RIVER FROM CALCASIEU LAKE AND INTRACOASTAL W.
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                              WATER LEVEL HYDROGRAPHS (FT) AND KEY FLOWS (1000 CFS)

 HOUR      1        2        3        4        5        6        7        8        9        1         2         3        4        5        6
  0.0    0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00      0.00      0.00     0.00     0.00     0.00     0.00
  1.0     .49     -.00     -.00      .07      .09      .33     -.01      .01      .02     29.97     18.72     -.00      .01     -.01     -.15
  2.0     .47      .05      .00      .08      .21      .36      .14      .03      .02     46.82     23.77    -1.23      .80    -1.92     -.15
  3.0     .44      .14      .03      .06      .12      .42      .19      .11      .03     57.49     30.78     -.74      .53    -2.05     2.17
  4.0     .42      .20      .18      .10      .11      .38      .24      .22      .14     62.72     33.49      .55      .29    -1.45     5.70
  5.0     .37      .25      .25      .19      .17      .38      .28      .25      .30     60.82     30.52     1.35      .07     -.57     6.02
  6.0     .35      .26      .27      .32      .29      .36      .32      .33      .37     55.42     26.94     1.68      .20     -.30     4.17
  7.0     .32      .33      .33      .43      .39      .33      .34      .39      .42     42.43     23.21      .75      .16     -.69     2.63
  8.0     .29      .38      .39      .47      .46      .31      .37      .42      .45     31.83     18.45     -.67     -.02    -1.01      .98
  9.0     .26      .39      .41      .48      .51      .28      .39      .45      .45     22.13     13.83    -1.03      .06    -1.12     -.05
 10.0     .21      .40      .41      .42      .54      .25      .39      .43      .46      6.66      7.45    -2.01      .14    -1.36    -1.21
 11.0     .14      .40      .41      .38      .53      .18      .36      .40      .43    -13.69     -1.62    -1.79      .24    -1.79    -2.53
 12.0     .04      .37      .40      .36      .48      .10      .32      .38      .38    -35.07    -11.20    -1.52      .65    -2.06    -3.22
 13.0    -.24      .31      .35      .35      .42     -.13      .25      .31      .34    -63.86    -27.77    -1.69      .79    -2.01    -4.20
 14.0    -.58      .23      .27      .32      .36     -.42      .14      .23      .27    -93.03    -47.50    -2.32      .78    -2.04    -5.72
 15.0    -.92      .12      .18      .25      .29     -.72     -.00      .11      .17   -114.74    -65.01    -3.52     1.09    -2.29    -7.98
 16.0   -1.25     -.03      .06      .12      .19    -1.02     -.15     -.09      .02   -129.41    -79.12    -5.09     1.42    -2.58   -10.64
 17.0   -1.58     -.17     -.09     -.07      .05    -1.31     -.29     -.20     -.18   -141.23    -89.37    -5.69     1.66    -2.86   -12.12
 18.0   -1.61     -.35     -.24     -.27     -.10    -1.40     -.44     -.37     -.36   -137.71    -88.46    -5.90     1.83    -3.03   -12.47
 19.0   -1.28     -.47     -.38     -.48     -.27    -1.19     -.56     -.54     -.55   -117.89    -76.95    -5.45     1.96    -3.07   -12.10
 20.0    -.95     -.57     -.53     -.64     -.44     -.94     -.63     -.67     -.72    -95.99    -63.63    -4.38     2.11    -3.02   -10.36
 21.0    -.51     -.64     -.64     -.76     -.60     -.59     -.67     -.75     -.83    -63.77    -42.83    -3.12     2.09    -2.87    -7.16
 22.0     .15     -.64     -.70     -.81     -.73     -.05     -.69     -.78     -.87     -9.03     -9.70    -1.50     1.93    -2.53    -3.09
 23.0     .57     -.54     -.72     -.79     -.81      .32     -.50     -.75     -.84     57.34     26.11      .40     1.76    -2.09     1.80
 24.0     .74     -.40     -.63     -.68     -.82      .55     -.31     -.57     -.73    108.51     54.93     2.84     1.53    -1.27     8.15
 25.0     .90     -.24     -.41     -.47     -.73      .71     -.15     -.34     -.48    133.20     72.92     5.14     1.11     -.09    14.48
 26.0     .97     -.09     -.24     -.16     -.49      .81     -.00     -.12     -.15    140.55     80.03     5.81      .17     1.33    17.46
 27.0     .92      .02     -.10      .13     -.15      .80      .14      .10      .14    135.10     78.59     4.69     -.72     1.89    16.25
 28.0     .74      .16      .06      .34      .18      .68      .27      .29      .37    118.35     70.23     2.58    -1.09     1.21    12.65
 29.0     .63      .27      .21      .43      .41      .60      .38      .43      .52    103.01     61.91      .19    -1.01      .18     8.[illegible]7
 30.0     .59      .35      .31      .44      .55      .57      .44      .52      .59     90.72     54.56    -1.23    -1.18     -.45     4.02
 31.0     .56      .41      .39      .42      .64      .55      .50      .58      .62     77.38     47.37    -1.31    -1.30     -.89     1.57
 32.0     .64      .46      .46      .41      .68      .62      .54      .59      .63     69.99     43.78     -.60    -1.16    -1.39     -.48
 33.0     .74      .52      .52      .46      .67      .70      .58      .60      .61     67.43     42.31      .43     -.81    -1.78    -1.31
 34.0     .77      .57      .57      .55      .69      .74      .63      .62      .60     64.20     40.36     1.11     -.61    -1.62     -.75
 35.0     .49      .63      .63      .65      .65      .69      .66      .65      .61     54.31     34.88     1.22     -.58    -1.34      .59
 36.0     .60      .68      .69      .74      .68      .63      .66      .67      .66     41.14     27.70      .64     -.45    -1.10     1.50
 37.0     .44      .70      .73      .79      .74      .50      .66      .68      .70     20.35     16.22     -.46     -.22     -.99     1.16
 38.0     .04      .69      .73      .80      .79      .18      .62      .69      .72    -25.89     -6.86    -1.60     -.03    -1.09     -.11
 39.0    -.44      .63      .71      .75      .81     -.22      .49      .65      .71    -86.20    -38.46    -2.73      .17    -1.03    -2.51
 40.0    -.89      .48      .61      .68      .79     -.63      .31      .52      .64   -130.84    -67.81    -4.22      .51    -1.94    -7.08
 41.0   -1.53      .32      .43      .50      .70    -1.16      .14      .33      .45   -162.62    -95.66    -5.70     1.05    -2.74   -12.67
 42.0   -1.71      .13      .26      .28      .51    -1.39     -.05      .11      .18   -166.83   -101.88    -6.51     1.71    -3.56   -16.62
 43.0   -1.69     -.02      .09      .04      .27    -1.43     -.21     -.12     -.10   -159.69   -100.78    -6.94     2.16    -3.86   -17.69
 44.0   -1.41     -.19     -.10     -.21      .02    -1.25     -.35     -.33     -.37   -141.85    -90.32    -6.07     2.38    -3.67   -16.17
 45.0   -1.02     -.32     -.25     -.39     -.19     -.97     -.49     -.49     -.57   -118.83    -75.32    -4.76     2.48    -3.36   -12.82
 46.0    -.49     -.40     -.38     -.52     -.38     -.55     -.52     -.62     -.70    -84.58    -53.32    -3.36     2.49    -3.06    -8.71
 47.0     .04     -.44     -.47     -.58     -.53     -.12     -.52     -.66     -.76    -40.92    -26.45    -1.90     2.45    -2.67    -4.23
 48.0     .47     -.41     -.52     -.59     -.62      .27     -.44     -.63     -.75     15.38      5.78     -.45     2.32    -2.16      .89
 49.0     .79     -.31     -.48     -.52     -.66      .57     -.27     -.51     -.64     82.72     40.97     1.38     2.03    -1.49     6.55
 50.0     .89     -.14     -.33     -.38     -.60      .72     -.08     -.31     -.44    117.75     61.79     3.49     1.70     -.54    12.38
 51.0     .88     -.00     -.19     -.14     -.43      .75      .06     -.07     -.14    125.52     69.90     5.07     1.10      .64    16.37
 52.0     .77      .11      .01      .14     -.14      .69      .19      .14      .17    119.14     68.04     4.89      .07     1.51    16.45
 53.0     .62      .20      .14      .38      .18      .59      .29      .32      .41    104.62     60.50     3.33     -.59     1.41    12.99
 54.0     .58      .29      .26      .51      .44      .55      .38      .45      .55     92.50     54.33      .69     -.65      .52     8.07
 55.0     .48      .38      .35      .52      .60      .48      .45      .54      .61     76.28     45.26    -1.48     -.73     -.44     3.79
 56.0     .44      .43      .42      .47      .68      .45      .50      .59      .63     61.48     37.97    -2.14     -.91    -1.09      .90
 57.0     .46      .47      .48      .42      .69      .47      .53      .59      .63     49.73     32.20    -1.59     -.86    -1.50     -.99
 58.0     .59      .50      .51      .43      .68      .58      .50      .57      .60     46.61     30.48     -.39     -.59    -1.77    -2.39
 59.0     .63      .54      .54      .49      .64      .61      .57      .57      .56     42.99     28.48      .53     -.25    -1.89    -2.44
 60.0     .53      .58      .57      .57      .60      .55      .59      .58      .54     32.09     22.96      .90     -.10    -1.76    -1.10
 61.0     .53      .60      .62      .66      .60      .55      .58      .59      .57     25.56     19.52      .52     -.06    -1.42      .19
 62.0     .33      .62      .64      .71      .62      .39      .57      .59      .60      4.89      7.57     -.58      .10    -1.12      .31
 63.0     .02      .60      .62      .70      .66      .15      .52      .58      .60    -34.09    -12.04    -1.75      .31    -1.18     -.70
 64.0    -.31      .53      .60      .65      .68     -.15      .41      .54      .59    -79.16    -35.58    -2.92      .52    -1.51    -2.75
 65.0   -1.06      .42      .50      .55      .66     -.79      .26      .42      .52   -133.89    -71.70    -4.20      .76    -1.93    -6.40
 66.0   -1.46      .23      .35      .40      .57    -1.13      .06      .29      .36   -152.76    -90.80    -5.22     1.15    -2.56   -11.23
 67.0   -1.70      .03      .19      .21      .42    -1.39     -.11      .04      .13   -161.49   -100.21    -6.21     1.65    -3.26   -15.32
 68.0   -1.69     -.10      .00     -.03      .20    -1.43     -.26     -.18     -.15   -155.55    -98.93    -6.51     2.07    -3.69   -16.95
 69.0   -1.03     -.25     -.16     -.25     -.04    -1.28     -.39     -.37     -.41   -138.90    -88.68    -5.98     2.35    -3.65   -15.57
 70.0   -1.01     -.38     -.32     -.49     -.26     -.97     -.50     -.54     -.60   -113.96    -72.01    -4.95     2.35    -3.35   -12.83
 71.0    -.51     -.47     -.44     -.58     -.43     -.57     -.56     -.65     -.73    -80.92    -51.98    -3.34     2.35    -2.99    -8.67
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     CHANNEL OUTPUT FOR HOUR= 90                                                  NTIME= 450

               ALL H VALUES IN FEET, ALL Q VALUES IN CPS

   K         I         J      HX      QXN      QXP       HY      QYN      QYP       HC     QXT      QXF      QYT      QYF

CHANNEL REACH  1

   1        -8         1    .590   90718.  90905.   0.000      0.       0.      .518      0.       0.       0.       0.
   2         8         2    .519   90905.  90852.   0.000      0.       0.      .445      0.       0.       0.       0.
   3         8         3    .445   90852.  90538.    .375  -87013.  -90538.    .409      0.      -0.       0.    3105.
   4         7         3   0.000       0.      0.   0.000      0.       0.      .375      0.       0.       0.       0.
   5         7         4    .375   87013.  87151.    .338  -21560.  -21809.    .344      0.    -809.       0.       0.
   6         6         4   0.000       0.      0.   0.000      0.       0.      .338      0.       0.       0.       0.
   7         6         5    .338   21560.  19164.    .272      0.       0.      .334  -2172.       0.       0.       0.
   8         6         6    .334   19164.  18953.    .294   -2163.   -2232.    .328      0.       0.       0.       0.
   9         6         7    .328   16721.  16507.    .178   -7511.   -7577.    .319      0.       0.       0.       0.
  10         7         7   0.000       0.      0.    .319    5448.    5234.    .332      0.       0.       0.       0.
  11         8         7   0.000       0.      0.    .332    5234.    5033.    .346      0.       0.       0.       0.
  12         8         8    .346    9033.   4844.    .314      0.       0.      .360      0.       0.       0.       0.
  13         9         8   0.000       0.      0.    .360    4844.    4665.    .373      0.       0.       0.       0.
  14         9         9    .373    4665.   4493.   0.000      0.       0.      .386      0.       0.       0.       0.
  15         9        10    .386    4493.    872.   0.000      0.       0.      .396      0.    3479.       0.       0.
  16         9        11    .396   -1235.  -1296.    .405    1343.    1296.    .401      0.       0.       0.       0.
  17         8        11   0.000       0.      0.    .410    1375.    1343.    .405      0.       0.       0.       0.
  18         7        11   0.000       0.      0.   0.000      0.       0.      .410      0.       0.       0.       0.
  19         7        12    .410   -1375.  -1395.    .418    1404.    1395.    .414      0.       0.       0.       0.
  20         6        12   0.000       0.      0.    .422    1406.    1404.    .418      0.       0.       0.       0.
  21         5        12   0.000       0.      0.   0.000      0.       0.      .422      0.       0.       0.       0.
  22         5        13    .422   -1406.  -1402.   0.000      0.       0.      .425      0.       0.       0.       0.
  23         5        14    .425   -1402.  -1394.    .432    1382.    1394.    .429      0.       0.       0.       0.
  24         4        14   0.000       0.      0.   0.000      0.       0.      .432      0.       0.       0.       0.
  25         4        15    .432   -1382.  -1369.   0.000      0.       0.      .439      0.       0.       0.       0.
  26         5        15    .429       0.      0.    .439   -1369.   -1348.    .442      0.       0.       0.       0.
  27         5        16    .442   -1348.  -1324.    .447    1297.    1324.    .444      0.       0.       0.       0.
  28         4        16    .439       0.      0.   0.000      0.       0.      .447      0.       0.       0.       0.
  29         4        17    .447   -1297.  -1267.    .451      12.      44.    .449      0.       0.       0.       0.
  30         5        17    .444       0.      0.    .449   -1223.   -1197.    .451      0.       0.       0.       0.
  31         5        18    .451   -1197.  -1160.    .453    1130.    1160.    .452      0.       0.       0.       0.
  32         4        18    .449       0.      0.    .452      0.       0.      .453      0.       0.       0.       0.
  33        -4        19    .453   -1130.  -1100.   0.000      0.       0.      .454      0.       0.       0.       0.
CHANNEL REACH  2

  34         3        17   0.000       0.      0.   0.000      0.       0.      .451      0.       0.       0.       0.
  35         3        18    .451     -32.    -19.    .453     10.      19.      .452      0.       0.       0.       0.
  36        -2        18   0.000       0.      0.    .453      0.      10.      .453      0.       0.       0.       0.


                 WATER LEVEL HYDROGRAPHS (FT) AND KEY FLOWS (1000 CFS)

HOUR      1      2      3      4      5      6      7      8      9        1        2      3      4      5      6
 0.0   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00     0.00     0.00   0.00   0.00   0.00   0.00
72.0    .04   -.50   -.54   -.60   -.58   -.12   -.55   -.69   -.80   -35.43   -23.90  -1.96   2.34  -2.63  -4.16
73.0    .54   -.45   -.57   -.65   -.67    .31   -.47   -.67   -.78    27.12    11.46   -.20   2.17  -2.17    .88
74.0    .79   -.33   -.52   -.58   -.71    .57   -.27   -.53   -.67    90.96    44.98   1.83   1.92  -1.48   6.87
75.0    .92   -.16   -.36   -.41   -.65    .74   -.09   -.31   -.46   124.02    66.02   4.06   1.60   -.44  13.15
76.0    .94   -.02   -.17   -.15   -.45    .80    .05   -.08   -.15   131.81    74.06   5.51    .85    .86  17.08
77.0    .84    .09   -.02    .15   -.14    .79    .18    .14    .17   125.43    72.07   4.99   -.18   1.69  16.77
78.0    .64    .20    .13    .39    .19    .61    .30    .32    .41   108.02    63.03   3.18   -.71   1.42  13.18
79.0    .44    .30    .26    .51    .45    .45    .38    .46    .56    86.31    51.12    .52   -.78    .47   8.30
80.0    .45    .36    .35    .51    .60    .45    .43    .54    .62    74.22    44.49  -1.01   -.89   -.42   3.68
81.0    .51    .41    .41    .46    .68    .49    .49    .57    .63    65.23    39.09  -2.33  -1.01  -1.06    .21
82.0    .59    .46    .44    .40    .70    .57    .53    .58    .61    58.60    37.24  -1.77   -.89  -1.62  -1.79
83.0    .69    .51    .50    .49    .66    .66    .57    .58    .57    57.11    36.90   -.25   -.56  -1.98  -2.10
84.0    .76    .56    .56    .47    .61    .73    .60    .59    .56    58.34    36.99   1.12   -.33  -1.84  -1.10
85.0    .81    .60    .61    .59    .60    .78    .64    .61    .58    59.85    37.05   1.75   -.29  -1.41    .65
86.0    .84    .66    .66    .72    .63    .81    .68    .65    .62    58.95    36.55   1.40   -.23  -1.09   1.90
87.0    .63    .72    .72    .80    .69    .46    .71    .69    .68    42.36    27.00    .33   -.09   -.92   2.73
88.0    .29    .75    .77    .84    .76    .40    .69    .73    .74     9.48     9.64   -.73    .01   -.81   2.59
89.0   -.10    .72    .79    .83    .83    .07    .61    .73    .79   -43.11   -16.39  -1.79    .06   -.80    .67
90.0   -.71    .61    .73    .78    .89   -.44    .47    .69    .77  -110.07   -94.85  -3.18    .25  -1.24  -3.71
91.0  -1.31    .45    .58    .66    .86   -.96    .27    .50    .64  -151.77   -80.42  -4.92    .76  -2.26  -9.80
92.0  -1.49    .28    .41    .47    .71  -1.19    .08    .28    .40  -163.02   -96.64  -6.43   1.49  -3.58 -15.59
93.0  -1.59    .11    .22    .21    .46  -1.31   -.07    .05    .09  -163.83  -100.74  -7.06   1.98  -3.95 -18.49
94.0  -1.48   -.04    .05   -.04    .20  -1.27   -.22   -.17   -.20  -151.49   -95.13  -6.67   2.37  -3.93 -17.65
95.0  -1.06   -.19   -.11   -.26   -.04   -.98   -.35   -.36   -.43  -127.23   -79.63  -5.30   2.47  -3.55 -14.95
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CHANNEL REACH  3

 37       10       10     0.000        0.        0.      .396     2106.     1266.      .390        0.        0.     -823.        0.
 38       11       10     0.000        0.        0.      .390     1266.      348.      .416        0.        0.     -866.        0.
 39       12       10     0.000        0.        0.      .416      348.     -924.      .467        0.        0.    -1211.        0.
 40       12       11      .467     -924.    -1013.      .505     -355.     -443.      .494        0.        0.        0.        0.
 41       13       11     0.000        0.        0.      .494    -1456.    -1502.      .511        0.        0.        0.        0.
 42       14       11     0.000        0.        0.      .511    -1542.    -1627.      .527        0.        0.        0.        0.
 43       14       12      .527     -452.     -535.      .543      616.      535.      .535        0.        0.        0.        0.
 44       13       12      .511        0.        0.     0.000        0.        0.      .543        0.        0.        0.        0.
 45       13       13      .543     -616.     -695.     0.000        0.        0.      .549        0.        0.        0.        0.
 46       14       13      .535        0.        0.      .549     -695.     -772.      .555        0.        0.        0.        0.
 47       14       14      .555     -772.     -962.     0.000        0.        0.      .557        0.        0.        0.        0.
 48       15       14     0.000        0.        0.      .557     -962.    -1094.      .560        0.        0.        0.        0.
 49       15       15      .560    -1094.    -1224.      .569     1297.     1224.      .562        0.        0.        0.        0.
 50       14       15      .557        0.        0.     0.000        0.        0.      .568        0.        0.        0.        0.
 51       14       16      .569    -1297.    -1368.     0.000        0.        0.      .573        0.        0.        0.        0.
 52       14       17      .573    -1368.    -1439.     0.000        0.        0.      .586        0.        0.        0.        0.
 53       14       18      .586    -1439.    -1470.     0.000        0.        0.      .752        0.        0.        0.        0.
 54      -14       19      .752    -1470.    -1500.     0.000        0.        0.      .917        0.        0.        0.        0.

CHANNEL REACH  4

 55       11       11      .416        0.        0.     0.000        0.        0.      .509        0.        0.        0.        0.
 56       11       12      .505      355.      266.      .522     -178.     -266.      .515        0.        0.        0.        0.
 57       10       12     0.000        0.        0.     0.000        0.        0.      .522        0.        0.        0.        0.
 58       10       13      .522      178.       89.      .531      -44.      -89.      .526        0.        0.        0.        0.
 59        9       13     0.000        0.        0.     0.000        0.        0.      .531        0.        0.        0.        0.
 60       -9       14      .531       44.        0.     0.000        0.        0.      .532        0.        0.        0.        0.

CHANNEL REACH  5

 61       15       11     0.000        0.        0.      .527    -1175.    -1304.      .534        0.        0.        0.        0.
 62       16       11     0.000        0.        0.      .534    -1304.    -1434.      .538        0.        0.        0.        0.
 63       17       11     0.000        0.        0.      .538    -1434.    -1564.      .540        0.        0.        0.        0.
 64       18       11     0.000        0.        0.      .540    -1564.    -1693.      .540        0.        0.        0.        0.
 65       19       11      .532     1947.     1821.      .540    -1693.    -1821.      .537        0.        0.        0.        0.
 66       19       10     0.000        0.        0.     0.000        0.        0.      .532        0.        0.        0.        0.
 67       20       10     0.000        0.        0.      .532    -1947.    -2067.      .526        0.        0.        0.        0.
 68       21       10     0.000        0.        0.      .526    -2067.    -2180.      .518        0.        0.        0.        0.
 69       22       10     0.000        0.        0.      .518    -2180.    -2283.      .509        0.        0.        0.        0.
 70       23       10      .484     5789.     5677.      .509    -2283.    -2373.      .500        0.        0.        0.        0.

CHANNEL REACH  6

 71      -22        1      .590    54557.    54640.     0.000        0.        0.      .574        0.        0.        0.        0.
 72       23        1     0.000        0.        0.      .574    12749.    12843.      .565        0.        0.        0.        0.
 73       23        2      .565    12843.    12868.      .544   -12884.   -12868.      .555        0.        0.        0.        0.
 74       22        2      .574    41892.    41875.     0.000        0.        0.      .544        0.        0.        0.        0.
 75       22        3      .544    54759.    54752.     0.000        0.        0.      .495        0.        0.        0.        0.
 76       22        4      .495    54752.    41901.     0.000        0.        0.      .371        0.    13290.        0.        0.
 77       22        5      .371    41901.    25348.     0.000        0.        0.      .372   -11303.     5237.        0.        0.
 78       23        5     0.000        0.        0.      .372    25348.    20711.      .393        0.        0.    -4574.        0.
 79       23        6      .393    20711.    20625.     0.000        0.        0.      .415        0.        0.        0.        0.
 80       23        7      .415    20625.    20533.     0.000        0.        0.      .438        0.        0.        0.        0.
 81       23        8      .438    20533.    20434.     0.000        0.        0.      .461        0.        0.        0.        0.
 82       23        9      .461    20434.    20327.     0.000        0.        0.      .484        0.        0.        0.        0.
 83       24        9     0.000        0.        0.      .484    14539.     2173.      .495        0.        0.   -12163.        0.
 84       24       10      .495     2173.     1949.      .500     3304.     3027.      .508        0.        0.        0.        0.
 85       24       11      .508     4423.     4210.     0.000        0.        0.      .524        0.        0.        0.        0.
 86       24       12      .524     4210.     3984.     0.000        0.        0.      .542        0.        0.        0.        0.
 87       24       13      .542     3984.     3750.     0.000        0.        0.      .554        0.        0.        0.        0.
 88       25       13     0.000        0.        0.      .554     3750.     3532.      .566        0.        0.        0.        0.
 89       25       14      .566     3532.     2353.     0.000        0.        0.      .581        0.     1115.        0.        0.
 90       26       14     0.000        0.        0.      .581     2353.     -389.      .589        0.        0.    -2599.        0.
 91       27       14     0.000        0.        0.      .589     -389.     -528.      .591        0.        0.        0.        0.
 92       27       15      .591     -528.     -665.     0.000        0.        0.      .592        0.        0.        0.        0.
 93      -28       15     0.000        0.        0.      .592     -665.     -800.      .592        0.        0.        0.        0.

CHANNEL REACH  7

 94       25       10     0.000        0.        0.      .508      553.      468.      .523        0.        0.        0.        0.
 95       26       10      .547     -285.     -377.      .523      468.      377.      .536        0.        0.        0.        0.
 96       26        9     0.000        0.        0.     0.000        0.        0.      .547        0.        0.        0.        0.
 97       27        9      .561      -95.     -190.      .547      285.      190.      .556        0.        0.        0.        0.
 98       27        8     0.000        0.        0.     0.000        0.        0.      .561        0.        0.        0.        0.
 99      -28        8     0.000        0.        0.      .561       95.        0.      .563        0.        0.        0.        0.
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CHANNEL REACH  8

100     -1      4  0.000     0.      0.    .255      0.    -75.    .258      0.      0.      0.      0.
101      2      4  0.000     0.      0.    .254    -75.   -151.    .252      0.      0.      0.      0.
102      3      4  0.000     0.      0.    .252   -151.   -230.    .248      0.      0.      0.      0.
103      3      5   .248  -230.   -310.   0.000      0.      0.    .244      0.      0.      0.      0.
104      4      5  0.000     0.      0.    .244   -310.  -2015.    .251      0.      0.      0.   1051.
105      5      5  0.000     0.      0.    .251  -2015.  -2092.    .272      0.      0.      0.      0.
106      5      6   .272 -2092.  -2163.   0.000      0.      0.    .284      0.      0.      0.      0.
107      5      7   .284     0.      0.   0.000      0.      0.    .178      0.      0.      0.      0.
108      5      8   .178  7511.   3773.    .150   -280.  -3773.    .154  -3711.      0.  -3434.      0.
109      4      8  0.000     0.      0.    .143      0.      0.    .150      0.      0.      0.      0.
110      4      9   .150   280.    241.    .145   -208.   -241.    .147      0.      0.      0.      0.
111      3      9   .143   -77.   -105.   0.000      0.      0.    .145      0.      0.      0.      0.
112      3      8  0.000     0.      0.    .143    -50.    -77.    .143      0.      0.      0.      0.
113      2      8  0.000     0.      0.    .142    -25.    -50.    .143      0.      0.      0.      0.
114     -1      9  0.000     0.      0.    .142      0.    -25.    .142      0.      0.      0.      0.

CHANNEL REACH  9

115      3     10   .145   103.     74.    .142    -48.    -74.    .143      0.      0.      0.      0.
116      2     10  0.000     0.      0.   0.000      0.      0.    .142      0.      0.      0.      0.
117      2     11   .142    48.     23.   0.000      0.      0.    .142      0.      0.      0.      0.
118     -2     12   .142    23.      0.   0.000      0.      0.    .141      0.      0.      0.      0.

CHANNEL REACH 10

119      6      8   .319  3481.   3383.    .154      0.      0.    .317      0.      0.      0.      0.
120     -7      8   .332     0.      0.    .317   3383.      0.    .314      0.      0.      0.   3354.

CHANNEL REACH 11

121     -7      9   .344 65342.  61083.    .334      0.      0.    .296  -3498.      0.      0.      0.


      VOLUME OF WATER ABOVE MSL =      1535.4 MILLIONS OF CU FT
      (THE SEAWARD ROWS THRU J=  2 ARE EXCLUDED)


    CHANNEL OUTPUT FOR HOUR= 60                                        NTIME=  900

              ALL H VALUES IN FEET, ALL Q VALUES IN CFS

  K       I       J     HX     QXN     QXP      HY     QYN     QYP      HC     QXT     QXF     QYT     QYF

CHANNEL REACH  1

  1     -8      1   .530  32086.  32799.   0.000      0.      0.    .584      0.      0.      0.      0.
  2      8      2   .584  32799.  33388.   0.000      0.      0.    .557      0.      0.      0.      0.
  3      8      3   .557  33388.  33998.    .570 -35602. -33998.    .569      0.     -0.      0.  -1100.
  4      7      3  0.000      0.      0.   0.000      0.      0.    .578      0.      0.      0.      0.
  5      7      4   .578  35602.  36317.    .589 -12523. -12459.    .584      0.   -369.      0.      0.
  6      6      4  0.000      0.      0.   0.000      0.      0.    .589      0.      0.      0.      0.
  7      6      5   .589  12523.  11319.    .581      0.      0.    .592  -1242.      0.      0.      0.
  8      6      6   .592  11319.  11298.    .588  -2377.  -2398.    .588      0.      0.      0.      0.
  9      6      7   .580   8900.   8842.    .488  -6602.  -6034.    .581      0.      0.      0.      0.
 10      7      7  0.000      0.      0.    .581     35.    -50.    .579      0.      0.      0.      0.
 11      8      7  0.000      0.      0.    .579    -50.   -154.    .577      0.      0.      0.      0.
 12      8      8   .577   -154.   -272.    .584      0.      0.    .576      0.      0.      0.      0.
 13      9      8  0.000      0.      0.    .574   -272.   -404.    .572      0.      0.      0.      0.
 14      9      9   .572   -404.   -548.   0.000      0.      0.    .569      0.      0.      0.      0.
 15      9     10   .569   -548.   -394.   0.000      0.      0.    .568      0.   -313.      0.      0.
 16      9     11   .568    904.    829.    .567   -745.   -829.    .567      0.      0.      0.      0.
 17      8     11  0.000      0.      0.    .567   -655.   -745.    .567      0.      0.      0.      0.
 18      7     11  0.000      0.      0.   0.000      0.      0.    .567      0.      0.      0.      0.
 19      7     12   .567    655.    558.    .567   -456.   -558.    .567      0.      0.      0.      0.
 20      6     12  0.000      0.      0.    .568   -362.   -456.    .567      0.      0.      0.      0.
 21      5     12  0.000      0.      0.   0.000      0.      0.    .568      0.      0.      0.      0.
 22      5     13   .568    362.    265.   0.000      0.      0.    .568      0.      0.      0.      0.
 23      5     14   .568    265.    165.    .570    -63.   -165.    .569      0.      0.      0.      0.
 24      4     14  0.000      0.      0.   0.000      0.      0.    .570      0.      0.      0.      0.
 25      4     15   .570     63.    -27.   0.000      0.      0.    .572      0.      0.      0.      0.
 26      5     15   .569      0.      0.    .572    -27.   -149.    .572      0.      0.      0.      0.
 27      5     16   .572   -149.   -272.    .574    397.    272.    .573      0.      0.      0.      0.
 28      4     16   .572      0.      0.   0.000      0.      0.    .574      0.      0.      0.      0.
 29      4     17   .574   -397.   -522.    .576   -114.   -161.    .575      0.      0.      0.      0.
 30      5     17   .573      0.      0.    .575   -683.   -778.    .576      0.      0.      0.      0.
 31      5     18   .576   -778.   -906.    .578   1003.    906.    .577      0.      0.      0.      0.
 32      4     18   .575      0.      0.    .577      0.      0.    .578      0.      0.      0.      0.
 33     -4     19   .578  -1003.  -1100.   0.000      0.      0.    .578      0.      0.      0.      0.

CHANNEL REACH  2

 34      3     17  0.000      0.      0.   0.000      0.      0.    .576      0.      0.      0.      0.
 35      3     18   .576    114.     65.    .578    -33.    -65.    .577      0.      0.      0.      0.
 36     -2     18  0.000      0.      0.    .578      0.    -33.    .578      0.      0.      0.      0.
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CHANNEL REACH  3

 37      10      10   0.000      0.      0.    .568  -1298.  -1319.    .582      0.      0.      9.      0.
 38      11      10   0.000      0.      0.    .582  -1319.  -1499.    .598      0.      0.   -161.      0.
 39      12      10   0.000      0.      0.    .598  -1499.  -1868.    .617      0.      0.   -368.      0.
 40      12      11    .617  -1868.  -1870.    .609      8.      8.    .612      0.      0.      0.      0.
 41      13      11   0.000      0.      0.    .612  -1862.  -1861.    .609      0.      0.      0.      0.
 42      14      11   0.000      0.      0.    .609  -1861.  -1858.    .607      0.      0.      0.      0.
 43      14      12    .607  -1759.  -1753.    .605   1744.   1753.    .606      0.      0.      0.      0.
 44      13      12    .609      0.      0.   0.000      0.      0.    .605      0.      0.      0.      0.
 45      13      13    .605  -1744.  -1731.   0.000      0.      0.    .605      0.      0.      0.      0.
 46      14      13    .606      0.      0.    .605  -1731.  -1715.    .604      0.      0.      0.      0.
 47      14      14    .604  -1715.  -1668.   0.000      0.      0.    .604      0.      0.      0.      0.
 48      15      14   0.000      0.      0.    .604  -1668.  -1634.    .605      0.      0.      0.      0.
 49      15      15    .605  -1634.  -1596.    .611   1574.   1596.    .606      0.      0.      0.      0.
 50      14      15    .604      0.      0.   0.000      0.      0.    .611      0.      0.      0.      0.
 51      14      16    .611  -1574.  -1550.   0.000      0.      0.    .616      0.      0.      0.      0.
 52      14      17    .616  -1550.  -1524.   0.000      0.      0.    .630      0.      0.      0.      0.
 53      14      18    .630  -1524.  -1512.   0.000      0.      0.    .806      0.      0.      0.      0.
 54     -14      19    .806  -1512.  -1500.   0.000      0.      0.    .972      0.      0.      0.      0.

CHANNEL REACH  4

 55      11      11    .598      0.      0.   0.000      0.      0.    .609      0.      0.      0.      0.
 56      11      12    .609     -8.     -6.    .604      5.      6.    .606      0.      0.      0.      0.
 57      10      12   0.000      0.      0.   0.000      0.      0.    .604      0.      0.      0.      0.
 58      10      13    .604     -5.     -2.    .602      1.      2.    .603      0.      0.      0.      0.
 59       9      13   0.000      0.      0.   0.000      0.      0.    .602      0.      0.      0.      0.
 60      -9      14    .602     -1.      0.   0.000      0.      0.    .602      0.      0.      0.      0.

CHANNEL REACH  5

 61      15      11   0.000      0.      0.    .607    -89.    -95.    .606      0.      0.      0.      0.
 62      16      11   0.000      0.      0.    .606    -95.    -95.    .605      0.      0.      0.      0.
 63      17      11   0.000      0.      0.    .605    -95.   -100.    .604      0.      0.      0.      0.
 64      18      11   0.000      0.      0.    .604   -100.   -108.    .604      0.      0.      0.      0.
 65      19      11    .602    130.    118.    .604   -108.   -118.    .603      0.      0.      0.      0.
 66      19      10   0.000      0.      0.   0.000      0.      0.    .602      0.      0.      0.      0.
 67      20      10   0.000      0.      0.    .602   -130.   -142.    .600      0.      0.      0.      0.
 68      21      10   0.000      0.      0.    .600   -142.   -152.    .598      0.      0.      0.      0.
 69      22      10   0.000      0.      0.    .598   -152.   -162.    .596      0.      0.      0.      0.
 70      23      10    .595    571.    560.    .596   -162.   -172.    .593      0.      0.      0.      0.


CHANNEL REACH  6

 71     -22       1    .530  22960.  23228.   0.000      0.      0.    .545      0.      0.      0.      0.
 72      23       1   0.000      0.      0.    .545   5183.   5529.    .548      0.      0.      0.      0.
 73      23       2    .548   5529.   5082.    .559  -6203.  -5082.    .553      0.      0.      0.      0.
 74      22       2    .545  18045.  18201.   0.000      0.      0.    .559      0.      0.      0.      0.
 75      22       3    .559  24404.  24605.   0.000      0.      0.    .570      0.      0.      0.      0.
 76      22       4    .570  24605.  18355.   0.000      0.      0.    .565      0.   6515.      0.      0.
 77      22       5    .565  18355.   7960.   0.000      0.      0.    .573  -2269.   8225.      0.      0.
 78      23       5   0.000      0.      0.    .573   7960.   5086.    .580      0.      0.  -2895.      0.
 79      23       6    .580   5086.   5091.   0.000      0.      0.    .585      0.      0.      0.      0.
 80      23       7    .585   5091.   5091.   0.000      0.      0.    .589      0.      0.      0.      0.
 81      23       8    .589   5091.   5088.   0.000      0.      0.    .592      0.      0.      0.      0.
 82      23       9    .592   5088.   5080.   0.000      0.      0.    .595      0.      0.      0.      0.
 83      24       9   0.000      0.      0.    .595   4509.  -1092.    .595      0.      0.  -5598.      0.
 84      24      10    .595  -1092.  -1116.    .593    389.    358.    .590      0.      0.      0.      0.
 85      24      11    .590  -1100.  -1123.   0.000      0.      0.    .582      0.      0.      0.      0.
 86      24      12    .582  -1123.  -1144.   0.000      0.      0.    .573      0.      0.      0.      0.
 87      24      13    .573  -1144.  -1163.   0.000      0.      0.    .566      0.      0.      0.      0.
 88      25      13   0.000      0.      0.    .566  -1163.  -1183.    .560      0.      0.      0.      0.
 89      25      14    .560  -1183.  -1121.   0.000      0.      0.    .552      0.    -78.      0.      0.
 90      26      14   0.000      0.      0.    .552  -1121.   -740.    .547      0.      0.    399.      0.
 91      27      14   0.000      0.      0.    .547   -740.   -759.    .545      0.      0.      0.      0.
 92      27      15    .545   -759.   -779.   0.000      0.      0.    .544      0.      0.      0.      0.
 93     -28      15   0.000      0.      0.    .544   -779.   -800.    .544      0.      0.      0.      0.

CHANNEL REACH  7

 94      25      10   0.000      0.      0.    .590    343.    325.    .592      0.      0.      0.      0.
 95      26      10    .594   -234.   -288.    .592    325.    288.    .593      0.      0.      0.      0.
 96      26       9   0.000      0.      0.   0.000      0.      0.    .594      0.      0.      0.      0.
 97      27       9    .596    -86.   -166.    .594   -234.    166.    .595      0.      0.      0.      0.
 98      27       8   0.000      0.      0.   0.000      0.      0.    .596      0.      0.      0.      0.
 99     -28       8   0.000      0.      0.    .596     86.      0.    .596      0.      0.      0.      0.
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CHANNEL REACH  8

100     -1      4  0.000      0.      0.   .551      0.    -53.   .551      0.      0.      0.      0.
101      2      4  0.000      0.      0.   .551    -53.   -106.   .551      0.      0.      0.      0.
102      3      4  0.000      0.      0.   .551   -106.   -156.   .551      0.      0.      0.      0.
103      3      5   .551   -156.   -205.  0.000      0.      0.   .551      0.      0.      0.      0.
104      4      5  0.000      0.      0.   .551   -205.  -2305.   .553      0.      0.      0.   2073.
105      5      5  0.000      0.      0.   .553  -2305.  -2345.   .561      0.      0.      0.      0.
106      5      6   .561  -2345.  -2377.  0.000      0.      0.   .568      0.      0.      0.      0.
107      5      7   .568      0.      0.  0.000      0.      0.   .488      0.      0.      0.      0.
108      5      8   .488   4602.   3371.   .474   -254.  -3371.   .475  -3215.      0.  -3075.      0.
109      4      8  0.000      0.      0.   .475      0.      0.   .474      0.      0.      0.      0.
110      4      9   .474    254.    224.   .475   -196.   -224.   .474      0.      0.      0.      0.
111      3      9   .475    -73.    -98.  0.000      0.      0.   .475      0.      0.      0.      0.
112      3      8  0.000      0.      0.   .475    -48.    -73.   .475      0.      0.      0.      0.
113      2      8  0.000      0.      0.   .475    -24.    -48.   .475      0.      0.      0.      0.
114     -1      8  0.000.     0.      0.   .475      0.    -24.   .475      0.      0.      0.      0.

CHANNEL REACH  9

115      3     10   .475     98.     72.   .475    -47.    -72.   .475      0.      0.      0.      0.
116      2     10  0.000      0.      0.  0.000      0.      0.   .475      0.      0.      0.      0.
117      2     11   .475     47.     23.  0.000      0.      0.   .475      0.      0.      0.      0.
118     -2     12   .475     23.      0.  0.000      0.      0.   .475      0.      0.      0.      0.

CHANNEL REACH 10

119      6      8   .581   2172.   2135.   .475      0.      0.   .583      0.      0.      0.      0.
120     -7      8   .579      0.      0.   .583   2135.      0.   .584      0.      0.      0.   2121.

CHANNEL REACH 11

121     -7      5   .584  23858.  23963.   .592      0.      0.   .585     30.      0.      0.      0.

     VOLUME OF WATER ABOVE MSL =      3437.0 MILLIONS OF CU FT
     (THE SEAWARD ROWS THRU J=  2 ARE EXCLUDED)


     CHANNEL OUTPUT FOR HOURS 90                                      NTIME= 1350

               ALL H VALUES IN FEET, ALL Q VALUES IN CFS

  K      I      J     HX     QXN     QXP     HY     QYN     QYP     HC     QXT     QXF     QYT     QYF

CHANNEL REACH  1

  1     -8      1 -.710-110067.-106011.  0.000      0.      0.  -.411      0.      0.      0.      0.
  2      5      2 -.411-106011.-102963.  0.000      0.      0.  -.131      0.      0.      0.      0.
  3      8      3 -.131-102963.-100004.   .211  83895. 100004.   .049      0.     -0.      0. -13912.
  4      7      3  0.000      0.      0.  0.000      0.      0.   .211      0.      0.      0.      0.
  5      7      4   .211 -83895. -85742.   .418  11810.  12451.   .361      0.   4031.      0.      0.
  6      6      4  0.000      0.      0.  0.000      0.      0.   .418      0.      0.      0.      0.
  7      6      5   .418 -11810.  -6459.   .617      0.      0.   .469   4763.      0.      0.      0.
  8      6      6   .469  -6459.  -5977.   .569     46.    185.   .519      0.      0.      0.      0.
  9      6      7   .519  -5792.  -5358.   .644  -3537.  -3442.   .569      0.      0.      0.      0.
 10      7      7  0.000      0.      0.   .569  -8673.  -8214.   .592      0.      0.      0.      0.
 11      8      7  0.000      0.      0.   .592  -8214.  -7809.   .613      0.      0.      0.      0.
 12      8      8   .613  -7809.  -7405.   .604      0.      0.   .633      0.      0.      0.      0.
 13      9      8  0.000      0.      0.   .633  -7405.  -7002.   .653      0.      0.      0.      0.
 14      9      9   .653  -7002.  -6603.  0.000      0.      0.   .671      0.      0.      0.      0.
 15      9     10   .671  -6603.  -4292.  0.000      0.      0.   .685      0.  -1915.      0.      0.
 16      9     11   .685  -3181.  -3010.   .710   2845.   3010.   .698      0.      0.      0.      0.
 17      8     11  0.000      0.      0.   .721   2687.   2845.   .710      0.      0.      0.      0.
 18      7     11  0.000      0.      0.  0.000      0.      0.   .721      0.      0.      0.      0.
 19      7     12   .721  -2687.  -2535.   .740   2390.   2535.   .731      0.      0.      0.      0.
 20      6     12  0.000      0.      0.   .747   2269.   2390.   .740      0.      0.      0.      0.
 21      5     12  0.000      0.      0.  0.000      0.      0.   .747      0.      0.      0.      0.
 22      5     13   .747  -2269.  -2153.  0.000      0.      0.   .754      0.      0.      0.      0.
 23      5     14   .754  -2153.  -2044.   .767   1939.   2044.   .761      0.      0.      0.      0.
 24      4     14  0.000      0.      0.  0.000      0.      0.   .767      0.      0.      0.      0.
 25      4     15   .767  -1939.  -1858.  0.000      0.      0.   .779      0.      0.      0.      0.
 26      5     15   .761      0.      0.   .779  -1858.  -1756.   .783      0.      0.      0.      0.
 27      5     16   .783  -1756.  -1658.   .792   1565.   1658.   .787      0.      0.      0.      0.
 28      4     16   .779      0.      0.  0.000      0.      0.   .792      0.      0.      0.      0.
 29      4     17   .792  -1565.  -1470.   .798     71.    103.   .796      0.      0.      0.      0.
 30      5     17   .787      0.      0.   .796  -1373.  -1309.   .799      0.      0.      0.      0.
 31      5     18   .799  -1309.  -1225.   .802   1162.   1225.   .800      0.      0.      0.      0.
 32      4     18   .796      0.      0.   .800      0.      0.   .802      0.      0.      0.      0.
 33     -4     19   .802  -1162.  -1100.  0.000      0.      0.   .803      0.      0.      0.      0.

CHANNEL REACH  2

 34      3     17  0.000      0.      0.  0.000      0.      0.   .798      0.      0.      0.      0.
 35      3     18   .798    -71.    -40.   .802     20.     40.   .800      0.      0.      0.      0.
 36     -2     18  0.000      0.      0.   .802      0.     20.   .802      0.      0.      0.      0.
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CHANNEL REACH  3

 37     10     10  0.000      0.      0.   .665  -1111.   -836.   .722     0.     0.   204.     0.
 38     11     10  0.000      0.      0.   .722   -836.   -858.   .753     0.     0.   -88.     0.
 39     12     10  0.000      0.      0.   .753   -858.  -1149.   .795     0.     0.  -390.     0.
 40     12     11   .795  -1189.  -1157.   .822    100.    127.   .814     0.     0.     0.     0.
 41     13     11  0.000      0.      0.   .810  -1031.  -1065.   .824     0.     0.     0.     0.
 42     14     11  0.000      0.      0.   .824  -1005.   -983.   .833     0.     0.     0.     0.
 43     14     12   .833  -1235.  -1221.   .842   1216.   1221.   .848     0.     0.     0.     0.
 44     13     12   .824      0.      0.  0.000      0.      0.   .862     0.     0.     0.     0.
 45     13     13   .842  -1210.  -1220.  0.000      0.      0.   .875     0.     0.     0.     0.
 46     14     13   .848      0.      0.   .875  -1270.  -1292.   .886     0.     0.     0.     0.
 47     14     14   .886  -1232.  -1278.  0.000      0.      0.   .891     0.     0.     0.     0.
 48     15     14  0.000      0.      0.   .891  -1278.  -1317.   .897     0.     0.     0.     0.
 49     15     15   .897  -1317.  -1363.   .910   1392.   1363.   .902     0.     0.     0.     0.
 50     14     15   .891      0.      0.  0.000      0.      0.   .910     0.     0.     0.     0.
 51     14     16   .910  -1392.  -1420.  0.000      0.      0.   .918     0.     0.     0.     0.
 52     14     17   .918  -1420.  -1462.  0.000      0.      0.   .932     0.     0.     0.     0.
 53     14     18   .932  -1462.  -1481.  0.000      0.      0.  1.088     0.     0.     0.     0.
 54    -14     19  1.088  -1481.  -1560.  0.000      0.      0.  1.239     0.     0.     0.     0.

CHANNEL REACH  4

 55     11     11   .753      0.      0.  0.000      0.      0.   .822     0.     0.     0.     0.
 56     11     12   .822   -100.    -74.   .833     49.     74.   .828     0.     0.     0.     0.
 57     10     12  0.000      0.      0.  0.000      0.      0.   .833     0.     0.     0.     0.
 58     10     13   .833    -49.    -25.   .839     12.     25.   .836     0.     0.     0.     0.
 59      9     13  0.000      0.      0.  0.000      0.      0.   .839     0.     0.     0.     0.
 60     -9     14   .839    -12.      0.  0.000      0.      0.   .840     0.     0.     0.     0.

CHANNEL REACH  5

 61     15     11  0.000      0.      0.   .833    252.    284.   .823     0.     0.     0.     0.
 62     16     11  0.000      0.      0.   .823    284.    328.   .810     0.     0.     0.     0.
 63     17     11  0.000      0.      0.   .810    328.    384.   .794     0.     0.     0.     0.
 64     18     11  0.000      0.      0.   .794    384.    450.   .775     0.     0.     0.     0.
 65     19     11   .730   -610.   -520.   .775    450.    520.   .754     0.     0.     0.     0.
 66     19     10  0.000      0.      0.  0.000      0.      0.   .730     0.     0.     0.     0.
 67     20     10  0.000      0.      0.   .730    610.    702.   .704     0.     0.     0.     0.
 68     21     10  0.000      0.      0.   .704    702.    802.   .676     0.     0.     0.     0.
 69     22     10  0.000      0.      0.   .676    802.    911.   .646     0.     0.     0.     0.
 70     23     10   .587  -2849.  -2678.   .646    911.   1027.   .613     0.     0.     0.     0.


CHANNEL REACH  6

 71    -22      1  -.710 -54847. -53253.  0.000      0.      0.  -.512     0.     0.     0.     0.
 72     23      1  0.000      0.      0.  -.512 -13162. -11233.  -.439     0.     0.     0.     0.
 73     23      2  -.439 -11233.  -9336.  -.303   7512.   9336.  -.370     0.     0.     0.     0.
 74     22      2  -.512 -40092. -39165.  0.000      0.      0.  -.303     0.     0.     0.     0.
 75     22      3  -.303 -46676. -45377.  0.000      0.      0.  -.091     0.     0.     0.     0.
 76     22      4  -.091 -45377. -25136.  0.000      0.      0.   .161     0. -19621.     0.     0.
 77     22      5   .161 -29136.  -7846.  0.000      0.      0.   .268 -10942. -27390.     0.     0.
 78     23      5  0.000      0.      0.   .268  -7846.  -4313.   .342     0.     0.  3142.     0.
 79     23      6   .342  -4313.  -4014.  0.000      0.      0.   .405     0.     0.     0.     0.
 80     23      7   .405  -4014.  -3749.  0.000      0.      0.   .467     0.     0.     0.     0.
 81     23      8   .467  -3749.  -3519.  0.000      0.      0.   .527     0.     0.     0.     0.
 82     23      9   .527  -3519.  -3325.  0.000      0.      0.   .587     0.     0.     0.     0.
 83     24      9  0.000      0.      0.   .587   -475.  -3015.   .609     0.     0. -3491.     0.
 84     24     10   .609  -3615.  -3292.   .613  -1651.  -1249.   .627     0.     0.     0.     0.
 85     24     11   .627  -3710.  -3407.  0.000      0.      0.   .654     0.     0.     0.     0.
 86     24     12   .654  -3407.  -3099.  0.000      0.      0.   .683     0.     0.     0.     0.
 87     24     13   .683  -3099.  -2784.  0.000      0.      0.   .703     0.     0.     0.     0.
 88     25     13  0.000      0.      0.   .703  -2784.  -2492.   .722     0.     0.     0.     0.
 89     25     14   .722  -2492.  -1854.  0.000      0.      0.   .746     0.  -508.     0.     0.
 90     26     14  0.000      0.      0.   .746  -1854.  -1369.   .759     0.     0.   287.     0.
 91     27     14  0.000      0.      0.   .759  -1369.  -1179.   .764     0.     0.     0.     0.
 92     27     15   .764  -1179.   -989.  0.000      0.      0.   .767     0.     0.     0.     0.
 93    -28     15  0.000      0.      0.   .767   -989.   -800.   .768     0.     0.     0.     0.

CHANNEL REACH  7

 94     25     10  0.000      0.      0.   .627   -831.   -710.   .644     0.     0.     0.     0.
 95     26     10   .670    445.    582.   .644   -710.   -582.   .658     0.     0.     0.     0.
 96     26      9  0.000      0.      0.  0.000      0.      0.   .670     0.     0.     0.     0.
 97     27      9   .683    153.    302.   .670   -445.   -302.   .678     0.     0.     0.     0.
 98     27      8  0.000      0.      0.  0.000      0.      0.   .683     0.     0.     0.     0.
 99    -28      8  0.000      0.      0.   .683   -153.      0.   .685     0.     0.     0.     0.
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CHANNEL REACH  8

100      -1      4  0.000      0.      0.   .703     0.    69.   .702      0.      0.      0.      0.
101       2      4  0.000      0.      0.   .702    69.   138.   .699      0.      0.      0.      0.
102       3      4  0.000      0.      0.   .699   138.   208.   .695      0.      0.      0.      0.
103       3      5   .695    208.    280.  0.000     0.     0.   .688      0.      0.      0.      0.
104       4      5  0.000      0.      0.   .688   290.  -161.   .662      0.      0.      0.    -97.
105       5      5  0.000      0.      0.   .682  -161.   -68.   .617      0.      0.      0.      0.
106       5      6   .617    -68.     40.  0.000     0.     0.   .569      0.      0.      0.      0.
107       5      7   .569      0.      0.  0.000     0.     0.   .604      0.      0.      0.      0.
108       5      8   .604   3537.   1958.   .649    71. -1958.   .635  -1643.     0.  -2068.     0.
109       4      8  0.000      0.      0.   .690     0.     0.   .649      0.      0.      0.      0.
110       4      9   .649    -71.    -50.   .682    45.    50.   .665      0.      0.      0.      0.
111       3      9   .690     16.     23.  0.000     0.     0.   .682      0.      0.      0.      0.
112       3      8  0.000      0.      0.   .695    10.    16.   .690      0.      0.      0.      0.
113       2      9  0.000      0.      0.   .698     5.    10.   .695      0.      0.      0.      0.
114      -1      8  0.000      0.      0.   .699     0.     5.   .698      0.      0.      0.      0.

CHANNEL REACH  9

115       3     10   .682    -22.    -14.   .695     8.    14.   .690      0.      0.      0.      0.
116       2     10  0.000      0.      0.  0.000     0.     0.   .695      0.      0.      0.      0.
117       2     11   .695     -8.     -4.  0.000     0.     0.   .698      0.      0.      0.      0.
118      -2     12   .698     -4.      0.  0.000     0.     0.   .700      0.      0.      0.      0.

CHANNEL REACH 10

119       6      8   .569   -177.      3.   .635     0.     0.   .587      0.      0.      0.      0.
120      -7      8   .592      0.      0.   .587     3.     0.   .604      0.      0.      0.     93.

CHANNEL REACH 11

121      -7      5   .301 -73291. -61573.   .469     0.     0.   .566  10634.      0.      0.      0.

      VOLUME OF WATER ABOVE MSL =      4120.4 MILLIONS OF CU FT
      (THE SEAWARD RUNS THRU JB  2 ARE EXCLUDED)
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APPENDIX G

IDENTIFICATION OF GAGES
FOR
SABINE-CALCASIEU HURRICANE CARLA VERIFICATION

Gages for Sabine-Calcasieu Hurricane Carla verification and time sequences of water level and flow at the identified gage for 60 hours are identified. Also included are listings of detailed channel output at 30 and 60 hours. For explanation of each column see Appendix C,7,b.

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HURRICANE CARLA  CALIBRATION FOR SABINE-CALCASIEU AREA
PERIOD OF RECORD- 0000 SEP 10 TO 0000 SEP 13, 1961
CALCULATIONS ALLOW FOR SUB-GRID SCALE CHANNELS AND BARRIERS

TIME SEQUENCES OF WATER LEVEL AND FLOW ARE SAVED FOR THE FOLLOWING PLACES-
GAGE 1   SABINE PASS, SOUTHWEST JETTY
GAGE 2   PORT ARTHUR, CE AREA OFFICE
GAGE 3   NORTH SABINE LAKE
GAGE 4   BEAUMONT, NECHES RIVER AND BRAKES BAYOU
GAGE 5   ORANGE NAVAL STATION, SABINE RIVER
GAGE 6   CAMERON, CALCASIEU PASS
GAGE 7   WEST END OF INTRACOASTAL WATERWAY
GAGE 8   SABINE PASS, COAST GUARD STATION
GAGE 9   LAKE CHARLES, CALCASIEU RIVER

FLOW 1   SABINE PASS INFLOW
FLOW 2   CALCASIEU PASS INFLOW
```

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                    WATER LEVEL HYDROGRAPHS (FT) AND KEY FLOWS (1000 CFS)

HOUR      1      2      3      4      5      6      7      8      9        1        2
 0.0   3.20   3.20   3.20   3.20   3.20   3.20   3.20   3.20   3.20     0.00     0.00
 1.0   4.83   3.08   3.16   3.27   3.25   4.49   3.55   4.58   3.08   103.46    92.03
 2.0   5.17   3.42   3.15   3.30   3.24   4.50   3.75   4.41   3.14   146.22   128.51
 3.0   5.50   3.54   3.59   3.32   3.21   4.67   3.88   4.88   2.97   132.58   171.46
 4.0   5.73   3.65   3.80   3.41   3.19   4.79   3.94   5.03   2.86   160.98   199.86
 5.0   5.97   3.76   3.95   3.53   3.17   4.93   4.04   5.20   2.89   177.48   216.70
 6.0   6.20   3.91   4.16   3.69   3.20   5.08   4.19   5.43   2.83   179.66   233.63
 7.0   6.13   4.09   4.36   3.83   3.20   5.09   4.38   5.51   2.90   169.05   235.17
 8.0   6.07   4.33   4.57   3.96   3.22   5.03   4.53   5.57   2.88   158.33   233.57
 9.0   6.00   4.43   4.73   4.12   3.26   4.97   4.70   5.59   2.91   143.54   231.81
10.0   5.93   4.68   4.92   4.28   3.31   4.91   4.90   5.65   2.94   128.36   229.76
11.0   5.87   5.02   5.07   4.44   3.39   4.86   4.97   5.08   2.92   111.24   225.86
12.0   5.80   5.01   5.21   4.62   3.49   4.79   5.30   5.72   2.94    90.76   223.02
13.0   5.93   5.14   5.34   4.82   3.62   4.81   5.33   5.65   2.92    79.31   229.31
14.0   6.07   5.23   5.43   4.99   3.77   4.86   5.52   6.00   2.89    64.62   239.04
15.0   6.20   5.34   5.56   5.11   3.92   4.93   5.71   6.15   2.85    55.37   248.26
16.0   6.30   5.45   5.69   5.16   4.02   4.95   5.87   6.27   2.80    46.64   257.14
17.0   6.40   5.54   5.83   5.23   4.15   4.95   5.96   6.37   2.79    42.11   269.48
18.0   6.50   5.64   5.95   5.30   4.32   4.99   6.05   6.47   2.79    42.50   280.16
19.0   6.40   5.72   6.04   5.36   4.44   4.93   6.16   6.46   2.82    34.18   282.00
20.0   6.30   5.80   6.19   5.42   4.58   4.85   6.26   6.44   2.91    23.28   280.14
21.0   6.20   5.85   6.26   5.47   4.77   4.76   6.37   6.40   3.03     3.39   278.90
22.0   6.13   5.89   6.30   5.57   4.98   4.68   6.44   6.37   3.18   -21.15   279.25
23.0   6.07   5.90   6.31   5.68   5.12   4.57   6.45   6.29   3.32   -42.18   286.38
24.0   6.00   5.92   6.30   5.81   5.23   4.51   6.48   6.24   3.44   -53.99   284.92
25.0   6.40   5.96   6.31   5.94   5.37   4.88   6.58   6.38   3.55   -27.87   293.24
26.0   6.80   6.06   6.40   6.06   5.63   5.00   6.81   6.70   3.66    16.03   312.52
27.0   7.20   6.35   6.63   6.17   5.89   5.28   7.07   7.07   3.82    74.96   330.25
28.0   7.13   6.56   6.82   6.32   6.04   5.36   7.26   7.14   3.98    93.92   328.19
29.0   7.07   6.73   6.94   6.57   6.08   5.35   7.40   7.16   4.10    99.89   322.78
30.0   7.00   6.86   6.98   6.87   6.20   5.33   7.57   7.10   4.18    92.34   317.63
31.0   6.60   6.93   7.01   7.22   6.42   5.15   7.67   6.90   4.26    62.47   309.85
32.0   6.20   6.97   7.06   7.34   6.63   4.94   7.71   6.70   4.36    21.24   270.01
33.0   5.80   6.98   7.02   7.47   6.77   4.73   7.74   6.45   4.48   -51.13   255.06
34.0   5.43   6.98   6.96   7.59   6.83   4.72   7.70   6.50   4.61   -93.79   250.66
35.0   6.07   7.00   6.92   7.65   6.83   4.79   7.66   6.58   4.68  -118.94   258.51
36.0   6.20   7.07   6.97   7.67   6.83   4.88   7.60   6.66   4.71  -120.59   269.57
37.0   6.33   7.11   7.05   7.71   6.89   4.98   7.59   6.76   4.72  -112.30   275.67
38.0   6.47   7.16   7.19   7.78   7.01   5.09   7.65   6.86   4.76   -98.98   280.56
39.0   6.60   7.32   7.38   7.90   7.23   5.18   7.71   6.90   4.89   -80.65   294.90
40.0   6.33   7.45   7.53   8.03   7.42   5.12   7.79   6.90   5.08   -90.35   290.06
41.0   6.07   7.54   7.60   8.17   7.51   5.03   7.92   6.81   5.28  -109.32   279.24
42.0   5.80   7.56   7.59   8.30   7.65   4.94   7.97   6.68   5.40  -141.29   267.21
43.0   5.30   7.57   7.59   8.42   7.78   4.76   8.00   6.47   5.44  -178.72   247.17
44.0   4.80   7.55   7.62   8.51   7.89   4.51   8.00   6.24   5.42  -223.61   229.47
45.0   4.30   7.52   7.62   8.61   7.96   4.24   7.98   6.07   5.41  -269.26   210.02
46.0   4.40   7.53   7.60   8.73   8.02   4.14   7.92   6.05   5.42  -263.19   208.77
47.0   4.50   7.55   7.61   8.84   8.06   4.13   7.82   6.11   5.42  -261.43   214.50
48.0   4.60   7.59   7.68   8.95   8.13   4.09   7.71   6.11   5.41  -240.30   221.50
49.0   4.87   7.62   7.73   9.07   8.24   4.22   7.57   6.23   5.41  -220.05   234.07
50.0   5.13   7.65   7.77   9.20   8.37   4.38   7.38   6.34   5.43  -190.00   255.91
51.0   5.40   7.70   7.87   9.31   8.56   4.56   7.21   6.46   5.47  -175.81   277.15
52.0   5.17   7.71   7.91   9.42   8.80   4.51   7.03   6.31   5.53  -182.30   274.94
53.0   4.93   7.69   7.81   9.52   8.82   4.43   6.98   6.14   5.63  -196.34   261.53
54.0   4.70   7.63   7.63   9.57   8.81   4.40   6.92   5.98   5.70  -210.66   242.76
55.0   4.29   7.57   7.50   9.53   8.72   4.28   6.88   5.82   5.79  -250.55   217.02
56.0   3.70   7.47   7.46   9.40   8.67   4.14   6.61   5.51   5.90  -267.89   177.37
57.0   3.20   7.38   7.39   9.27   8.69   3.93   6.25   5.05   6.13  -276.51   136.76
58.0   3.03   7.30   7.27   9.17   8.79   3.85   5.97   4.91   6.43  -264.63   102.29
59.0   2.87   7.16   7.04   9.06   8.85   3.91   5.84   4.76   6.69  -266.28    54.86
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    CHANNEL OUTPUT FOR HR 48 30                                        NTIME= 450

            ALL H VALUES IN FEET, ALL Q VALUES IN CFS

   K        I        J      HX      QXN      QXP      HY      QYN      QYP      HC      QXT      QXF      QYT      QYF

CHANNEL REACH  1

   1       -8        1   7.030   92340.   97785.   3.200       0.       0.   7.030  -25145.  -23084.       0.       0.
   2        8        2   7.030   97785.   95512.   3.200       0.       0.   7.071  -46402.  -52665.       0.       0.
   3        8        3   7.071   95512.  124170.   7.156-115427.-124170.   7.101  -52801.  -81003.   32926.   41853.
   4        7        3   3.200       0.       0.   3.200       0.       0.   7.156       0.       0.       0.       0.
   5        7        4   7.156  115427.   80525.   7.102  -81445.-100131.   7.191  -55840.    -262.  -44157.  -29058.
   6        6        4   3.200       0.       0.   3.200       0.       0.   7.162       0.       0.       0.       0.
   7        6        5   7.162   81445.   70369.   7.147       0.       0.   7.135  -47279.  -36038.       0.       0.
   8        6        6   7.135   70369.   67395.   7.107   -3909.   -7855.   7.070  -45647.  -42096.   16013.   19912.
   9        6        7   7.070   59561.   63665.   7.090     602.   -3562.   6.956  -44978.  -49653.   34173.   38249.
  10        7        7   3.200       0.       0.   6.956  -14847.  -15132.   6.906       0.       0.       0.       0.
  11        8        7   3.200       0.       0.   6.906  -15132.  -15404.   6.857       0.       0.       0.       0.
  12        9        8   6.857  -15404.  -15662.   3.340       0.       0.   6.877       0.       0.       0.       0.
  13        9        8   3.200       0.       0.   6.877  -15662.  -16177.   6.832       0.       0.       0.       0.
  14        9        9   6.832  -16177.  -16428.   3.200       0.       0.   6.847       0.       0.       0.       0.
  15        9       10   6.847  -16428.   -7211.   3.200       0.       0.   6.863       0.   -9546.       0.       0.
  16        9       11   6.863   -4290.    2074.   6.925   -8744.   -2074.   6.857  -92762.  -99309.   98131.   91328.
  17        8       11   3.200       0.       0.   6.959  -14485.   -8744.   6.925       0.       0.       0.   -5916.
  18        7       11   3.200       0.       0.   3.200       0.       0.   6.958       0.       0.       0.       0.
  19        7       12   6.958   14485.   18296.   6.969  -18919.  -18298.   6.974  -33927.  -37896.   25690.   25087.
  20        6       12   3.200       0.       0.   6.947  -19635.  -18919.   6.989       0.       0.       0.    -926.
  21        5       12   3.200       0.       0.   3.200       0.       0.   6.997       0.       0.       0.       0.
  22        5       13   6.947   19635.   20304.   3.200       0.       0.   6.987       0.    -976.       0.       0.
  23        5       14   6.967   20364.   22691.   6.901  -22057.  -22691.   6.976  -45761.  -48437.   39196.   38930.
  24        4       14   3.200       0.       0.   3.200       0.       0.   6.981       0.       0.       0.       0.
  25        4       15   6.981   22657.   20181.   3.200       0.       0.   6.874       0.    2270.       0.       0.
  26        5       15   6.976       0.       0.   6.974   20181.   18767.   6.846       0.       0.   29302.   30322.
  27        5       16   6.846   18767.   15432.   6.844  -14940.  -15432.   6.845   17510.   29478.     -92.       0.
  28        4       16   6.874       0.       0.   3.200       0.       0.   6.844       0.       0.       0.       0.
  29        4       17   6.844   14940.     624.   6.803    -312.    -456.   6.840  -14055.       0.       0.       0.
  30        5       17   6.845       0.       0.   6.840     173.    -130.   6.811       0.       0.       0.       0.
  31        5       18   6.811    -130.    -539.   6.839     844.     539.   6.818       0.       0.       0.       0.
  32        4       18   6.840       0.       0.   6.806       0.       0.   6.839       0.       0.       0.       0.
  33       -4       19   6.839    -844.   -1152.   3.200       0.       0.   6.847       0.       0.       0.       0.

CHANNEL REACH  2

  34        3       17   3.200       0.       0.   3.200       0.       0.   6.863       0.       0.       0.       0.
  35        3       18   6.803     312.     174.   6.892     -85.    -174.   6.866       0.       0.       0.       0.
  36       -2       18   3.200       0.       0.   6.923       0.     -85.   6.892       0.       0.       0.       0.

CHANNEL REACH  3

  37       10       10   3.200       0.       0.   6.803   -2915.    -248.   6.795       0.       0.   53630.   51051.
  38       11       10   3.200       0.       0.   6.795    -248.    2188.   6.720       0.       0.   24697.   22353.
  39       12       10   3.200       0.       0.   6.720    2188.    4322.   6.617       0.       0.   39781.   37519.
  40       12       11   6.617    4322.    6076.   6.721    5033.    8746.   6.618  -23417.  -25233.   -9157.  -12671.
  41       13       11   3.200       0.       0.   6.618   14824.   16663.   6.436       0.       0.   26771.   24830.
  42       14       11   3.200       0.       0.   6.436   15043.   17614.   6.221       0.       0.   98091.   97048.
  43       14       12   6.221   -1396.   -1719.   6.235     653.    1709.   6.222   85475.   85711.   17445.   16328.
  44       13       12   6.436       0.       0.   3.200       0.       0.   6.235       0.       0.       0.       0.
  45       13       13   6.235    -653.    -252.   3.200       0.       0.   6.236       0.    -518.       0.       0.
  46       14       13   6.222       0.       0.   6.236    -252.     206.   6.204       0.       0.     689.       0.
  47       14       14   6.206     206.   -1666.   3.200       0.       0.   6.222       0.    1812.       0.       0.
  48       15       14   3.200       0.       0.   6.222   -1666.   -2165.   6.191       0.       0.   10228.   10285.
  49       15       15   6.191   -2165.   -1245.   6.235     930.    1205.   6.207    1161.       0.     -70.       0.
  50       14       15   6.222       0.       0.   3.200       0.       0.   6.235       0.       0.       0.       0.
  51       14       16   6.235    -930.   -1113.   3.200       0.       0.   6.245       0.       0.       0.       0.
  52       14       17   6.245   -1113.   -1325.   3.200       0.       0.   6.259       0.       0.       0.       0.
  53       14       18   6.259   -1325.   -1440.   3.200       0.       0.   6.309       0.       0.       0.       0.
  54      -14       19   6.309   -1440.   -1560.   3.200       0.       0.   6.373       0.       0.       0.       0.

CHANNEL REACH  4

  55       11       11   6.720       0.       0.   3.200       0.       0.   6.721       0.       0.       0.       0.
  56       11       12   6.721   -5033.    -606.   6.768     172.     606.   6.750       0.   -4408.     361.       0.
  57       10       12   3.200       0.       0.   3.200       0.       0.   6.788       0.       0.       0.       0.
  58       10       13   6.788    -172.     -82.   6.829      36.      82.   6.801       0.       0.       0.       0.
  59        9       13   3.200       0.       0.   3.200       0.       0.   6.829       0.       0.       0.       0.
  60       -9       14   6.829     -36.       0.   3.200       0.       0.   6.840       0.       0.       0.       0.

CHANNEL REACH, 5

  61       15       11   3.200       0.       0.   6.221   19010.   17622.   5.953       0.       0.       0.    1298.
  62       16       11   3.200       0.       0.   5.953   17622.   15806.   5.692       0.       0.       0.    1711.
  63       17       11   3.200       0.       0.   5.692   15806.   15648.   5.437       0.       0.       0.       0.
  64       18       11   3.200       0.       0.   5.437   15648.   15512.   5.182       0.       0.       0.       0.
  65       19       11   4.729  -12644.  -15395.   5.182   15512.   15305.   4.927       0.    2942.       0.       0.
  66       19       10   3.200       0.       0.   3.200       0.       0.   4.729       0.       0.       0.       0.
  67       20       10   3.200       0.       0.   4.729   12440.   12246.   4.546       0.       0.       0.     117.
  68       21       10   3.200       0.       0.   4.546   12246.    4617.   4.419       0.       0.       0.    7718.
  69       22       10   3.200       0.       0.   4.419    4617.    4511.   4.327       0.       0.       0.       0.
  70       23       10   4.192    5364.    5173.   4.327    4511.    7748.   4.200       0.       0.       0.   -3400.
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CHANNEL REACH  6

 71    -22     1   7.000 317027. 335032.   3.200      0.      0.   6.062 -14111. -32523.      0.      0.
 72     23     1   3.200      0.      0.   6.002 114307.  99863.   5.330      0.      0.  32077.  47784.
 73     23     2   5.334  90863.  45264.   5.135   9628. -45264.   5.072   9256.  67216.  82334. 130703.
 74     22     2   6.002 221125. 181244.   3.200      0.      0.   5.135      0.  41783.      0.      0.
 75     22     3   5.135 171616. 136789.   3.200      0.      0.   4.769      0.  36195.      0.      0.
 76     22     4   4.708 134769.  91854.   3.200      0.      0.   4.318 -27876.  19793.      0.      0.
 77     22     5   4.318  91854.  62018.   3.200      0.      0.   4.265-121662. -92366.      0.      0.
 78     23     5   3.200      0.      0.   4.265  62018.  53052.   4.214      0.      0.  91177. 100122.
 79     23     6   4.214  53052.  44600.   3.200      0.      0.   4.205  -6737.      0.      0.      0.
 80     23     7   4.205  44860.  41436.   3.200      0.      0.   4.201  -5363.      0.      0.      0.
 81     23     8   4.201  41436.  41319.   3.200      0.      0.   4.199      0.      0.      0.      0.
 82     23     8   4.199  41319.  31814.   3.200      0.      0.   4.192  -9464.      0.      0.      0.
 83     24     9   3.200      0.      0.   4.192  24510.  18303.   4.169      0.      0. -14730.  -6813.
 84     24    10   4.169  18303.  11790.   4.206  12911.   9212.   4.164 -34337. -27670.  23952.  27297.
 85     24    11   4.164   8333.   6603.   3.200      0.      0.   4.183    447.      0.      0.      0.
 86     24    12   4.183   6083.  13347.   3.200      0.      0.   4.206   7714.      0.      0.      0.
 87     24    13   4.206  13347.  12997.   3.200      0.      0.   4.225      0.      0.      0.      0.
 88     25    13   3.200      0.      0.   4.225  12997.  12064.   4.204      0.      0.      0.      0.
 89     25    14   4.204  12064.  10648.   3.200      0.      0.   4.220      0.   1897.      0.      0.
 90     26    14   3.200      0.      0.   4.220  10648.   6910.   4.196      0.      0.  -3524.      0.
 91     27    14   3.200      0.      0.   4.196   6910.   -462.   4.168      0.      0.  -7162.      0.
 92     27    15   4.158   -462.   -683.   3.200      0.      0.   4.184      0.      0.      0.      0.
 93    -28    15   3.200      0.      0.   4.184   -683.   -900.   4.155      0.      0.      0.      0.

CHANNEL REACH  7

 94     25    10   3.200      0.      0.   4.184  14686.  13275.   3.928      0.      0.  -1345.      0.
 95     26    10   3.608  -9003. -11328.   3.928  13275.  11328.   3.736 -11671. -10231.  -1907.      0.
 96     26     9   3.200      0.      0.   3.210      0.      0.   3.608      0.      0.      0.      0.
 97     27     9   3.459   -200.  -5435.   3.508   9603.   5435.   3.502  -5108.      0.  13392.  17490.
 98     27     8   3.200      0.      0.   3.200      0.      0.   3.459      0.      0.      0.      0.
 99    -28     8   3.200      0.      0.   3.459    200.      0.   3.397      0.      0.      0.      0.


 CHANNEL REACH  8

 100    -1     4   3.200      0.      0.   7.603      0.   4713.   7.573      0.      0.  18851.  13965.
 101     2     4   3.200      0.      0.   7.573   4713.   6561.   7.467      0.      0.  24550.  22509.
 102     3     4   3.200      0.      0.   7.467   6561.   5027.   7.352      0.      0.  25098.  25645.
 103     3     5   7.352   5027.   4621.   3.200      0.      0.   7.385 -25279. -24380.      0.      0.
 104     4     5   3.200      0.      0.   7.385   4621.   3341.   7.269      0.      0.  22011.  23746.
 105     5     5   3.200      0.      0.   7.269   3341.   -248.   7.167      0.      0.  32412.  35883.
 106     5     6   7.167   -248.  -3989.   3.200      0.      0.   7.167 -21252. -17606.      0.      0.
 107     5     7   7.167      0.      0.   3.200      0.      0.   7.090      0.      0.      0.      0.
 108     5     8   7.090  -6082.  -5247.   7.240   6687.   5247.   7.153  29979.  34510.  63046.  62858.
 109     4     8   3.200      0.      0.   7.456      0.      0.   7.240      0.      0.      0.      0.
 110     4     9   7.240  -4007.  -3041.   7.412     94.   3041.   7.305 -32403. -34062.   8351.   5303.
 111     3     9   7.456   3557.   6915.   3.200      0.      0.   7.412 -42020. -45536.      0.      0.
 112     3     8   3.200      0.      0.   7.599    229.   3557.   7.456      0.      0. -35191. -38636.
 113     2     8   3.200      0.      0.   7.732    270.    229.   7.599      0.      0.      0.      0.
 114    -1     8   3.200      0.      0.   7.841      0.    270.   7.732      0.      0.   5977.   5704.

 CHANNEL REACH  9

 115     3    10   7.412   6822.  10086.   7.288  -5973. -10088.   7.325      0.  -3453.      0.   4156.
 116     2    10   3.200      0.      0.   3.200      0.      0.   7.288      0.      0.      0.      0.
 117     2    11   7.288   5073.   2157.   3.200      0.      0.   7.256      0.   3805.      0.      0.
 118    -2    12   7.256   2157.      0.   3.200      0.      0.   7.268      0.   2082.      0.      0.

 CHANNEL REACH 10

 119     6     8   6.956  75150.  68077.   7.153      0.      0.   6.423  12609.  20123.      0.      0.
 120    -7     8   6.906      0.      0.   6.423  68077.  78401.   3.390      0.      0.   3729.  -7978.

 CHANNEL REACH 11

 121    -7     5   7.191 -30086. -53478.   7.135      0.      0.   7.239 -89976. -75915.      0.      0.

      VOLUME OF WATER ABOVE MSL =     162254.6 MILLIONS OF CU FT
      (THE SEAWARD RUNS THRU JN  2 ARE EXCLUDED)
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  CHANNEL OUTPUT FOR HOURS 60                                        NTIME= 900

          ALL H VALUES IN FEET, ALL Q VALUES IN CFS

   K        I        J      HX      QXN      QXP       HY     QYN      QYP        HC     QXT     QXF      QYT      QYF

CHANNEL REACH  1

   1       -8        1   2.700-277231.-276172.   3.200       0.       0.    3.501       0.      0.       0.       0.
   2        8        2   3.501-276172.-275406.   3.200       0.       0.    4.223       0.      0.       0.       0.
   3        8        3   4.223-275406.-318537.   5.062  303734.  318597.    4.714       0.  45990.       0.  -15033.
   4        7        3   3.200       0.       0.   3.200       0.       0.    5.082       0.      0.       0.       0.
   5        7        4   5.062-303734.-279710.   5.733  117952.  127117.    5.500   27099.   2346.   24313.   15000.
   6        6        4   3.200       0.       0.   3.200       0.       0.    5.733       0.      0.       0.       0.
   7        6        5   5.733-117952.-113302.   6.339       0.       0.    6.024   28994.  24412.       0.       0.
   8        6        6   6.024-113302.-110478.   6.406    4356.   12320.    6.423   39551.  34891.   -5395.  -13573.
   9        6        7   6.423 -99151.-102759.   7.273   21320.   25057.    6.925   47027.  52368.  -13725.  -17461.
  10        7        7   3.200       0.       0.   6.925  -30614.  -30098.    6.971       0.      0.       0.       0.
  11        8        7   3.200       0.       0.   6.971  -30098.  -29033.    7.013       0.      0.       0.       0.
  12        8        8   7.013  -29633.  -29177.   7.098       0.       0.    7.086       0.      0.       0.       0.
  13        9        8   3.200       0.       0.   7.060  -29177.  -28708.    7.120       0.      0.       0.       0.
  14        9        9   7.120  -28706.  -28223.   3.200       0.       0.    7.188       0.      0.       0.       0.
  15        9       10   7.188  -28223.  -45030.   3.200       0.       0.    7.269       0.  17522.       0.       0.
  16        9       11   7.269  -44792.  -46054.   7.627   44861.   46654.    7.469  190213. 191729.  -71043.  -72048.
  17        8       11   3.200       0.       0.   7.774   43023.   44841.    7.627       0.      0.       0.   -1676.
  18        7       11   3.200       0.       0.   3.200       0.       0.    7.774       0.      0.       0.       0.
  19        7       12   7.774  -43023.  -43137.   8.092   41731.   43137.    7.957   33981.  34291.  -29236.  -30488.
  20        6       12   3.200       0.       0.   8.191   42281.   41731.    8.092       0.      0.     924.    1064.
  21        5       12   3.200       0.       0.   3.200       0.       0.    8.191       0.      0.       0.       0.
  22        5       13   8.191  -42281.  -41917.   3.200       0.       0.    8.319       0.   -203.       0.       0.
  23        5       14   8.319  -41917.  -40010.   8.513   37275.   40010.    8.439   44351.  42590.  -39092.  -41698.
  24        4       14   3.200       0.       0.   3.200       0.       0.    8.513       0.      0.       0.       0.
  25        4       15   8.513  -37275.  -36230.   3.200       0.       0.    8.919       0.   -960.       0.       0.
  26        5       15   8.439       0.       0.   8.919  -36206.  -37260.    8.992       0.      0.  -68082.  -67586.
  27        5       16   8.992  -37260.  -36656.   9.199   36416.   36656.    9.065  -25029. -25159.  -35893.  -36108.
  28        4       16   8.919       0.       0.   3.200       0.       0.    9.199       0.      0.       0.       0.
  29        4       17   9.199  -36416.  -30740.   9.467    5000.    8221.    9.360    7441.   8048.       0.   -3208.
  30        5       17   9.065       0.       0.   9.360  -28527.  -25822.    9.495       0.      0.  -20598.  -23580.
  31        5       18   9.495  -25822.  -16774.   9.605   11582.   18774.    9.578    6904.      0.    3845.   -3257.
  32        4       18   9.360       0.       0.   9.476       0.       0.    9.605       0.      0.       0.       0.
  33       -4       19   9.605  -11582.   -1812.   3.200       0.       0.    9.652    4927.  -4728.       0.       0.

CHANNEL REACH  2

  34        3       17   3.200       0.       0.   3.200       0.       0.    9.407       0.      0.       0.       0.
  35        3       18   9.407   -5000.   -2513.   9.465      74.    2513.    9.476   12658.  10235.   -1788.   -4181.
  36       -2       18   3.200       0.       0.   9.449       0.      74.    9.465       0.      0.       0.       0.

CHANNEL REACH  3

  37       10       10   3.200       0.       0.   7.269    -215.   -3049.    7.297       0.      0.-162328.-159306.
  38       11       10   3.200       0.       0.   7.297   -3049.   -6424.    7.398       0.      0.-145598.-141987.
  39       12       10   3.200       0.       0.   7.398   -6424.  -10325.    7.660       0.      0.   12059.   16321.
  40       12       11   7.660  -10325.  -13864.   7.809   11813.    9615.    7.792  -29432. -25650.   13747.   15893.
  41       13       11   3.200       0.       0.   7.792   -4249.   -5029.    7.872       0.      0.    8481.   10050.
  42       14       11   3.200       0.       0.   7.872   -5629.   -6896.    7.951       0.      0.  -95104.  -93782.
  43       14       12   7.951  -16586.  -16390.   8.310   17062.   16390.    8.161  -20884. -20964.  -19415.  -18613.
  44       13       12   7.872       0.       0.   3.200       0.       0.    8.310       0.      0.       0.       0.
  45       13       13   8.310  -17062.  -17634.   3.200       0.       0.    8.527       0.    914.       0.       0.
  46       14       13   8.161       0.       0.   8.527  -17834.  -18012.    8.721       0.      0.   36394.   37314.
  47       14       14   8.721  -18612.  -18778.   3.200       0.       0.    8.836   44231.  44706.       0.       0.
  48       15       14   3.200       0.       0.   8.836  -18778.  -17842.    8.963       0.      0.  -53785.  -54504.
  49       15       15   8.963  -17842.  -15696.   9.298   14524.   15096.    9.110  -26378. -28384.  -19764.  -20701.
  50       14       15   8.836       0.       0.   3.200       0.       0.    9.298       0.      0.       0.       0.
  51       14       16   9.298  -14524.  -13779.   3.200       0.       0.    9.594       0.  -1078.       0.       0.
  52       14       17   9.594  -13779.   -8131.   3.200       0.       0.    9.572       0.  -3710.       0.       0.
  53       14       18   9.572   -8131.   -2872.   3.200       0.       0.    9.936       0.  -2750.       0.       0.
  54      -14       19   9.936   -2872.   -2066.   3.200       0.       0.   10.620       0.      0.       0.       0.

CHANNEL REACH  4

  55       11       11   7.308       0.       0.   3.200       0.       0.    7.889       0.      0.       0.       0.
  56       11       12   7.889  -11813.  -12487.   7.700    8974.   12487.    7.822     314.   2201.   -4352.   -5257.
  57       10       12   3.200       0.       0.   3.200       0.       0.    7.780       0.      0.       0.       0.
  58       10       13   7.780   -8974.     -64.   8.074      39.      64.    7.999       0.  -7061.       0.       0.
  59        9       13   3.200       0.       0.   3.200       0.       0.    8.074       0.      0.       0.       0.
  60       -9       14   8.074     -39.       0.   3.200       0.       0.    8.169       0.      0.       0.       0.

CHANNEL REACH  5

  61       15       11   3.200       0.       0.   7.951    9688.   12726.    7.948       0.      0.       0.   -2924.
  62       16       11   3.200       0.       0.   7.948   12726.   17838.    7.877       0.      0.       0.   -5096.
  63       17       11   3.200       0.       0.   7.877   17838.   21112.    7.726       0.      0.  -17336.  -20577.
  64       18       11   3.200       0.       0.   7.726   21112.   27935.    7.463       0.      0.  -16480.  -23488.
  65       19       11   6.711  -19441.  -28040.   7.463   27935.   28040.    7.093       0.   9108.       0.       0.
  66       19       10   3.200       0.       0.   3.200       0.       0.    6.711       0.      0.       0.       0.
  67       20       10   3.200       0.       0.   6.711   19441.   14552.    6.559       0.      0.       0.    5122.
  68       21       10   3.200       0.       0.   6.559   14552.   12030.    6.444       0.      0.       0.    2013.
  69       22       10   3.200       0.       0.   6.444   12030.   12068.    6.319       0.      0.       0.     -11.
  70       23       10   6.060  -39846.  -39759.   6.319   12068.   15476.    6.159       0.      0.       0.   -2853.
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CHANNEL REACH  6

 71      -22      1   3.475 -16093. -15629.   3.200      0.       0.   3.856      0.       0.       0.       0.
 72       23      1   3.200      0.      0.   3.856  33840.    -253.   4.007      0.       0.       0.   34910.
 73       23      2   4.007   -253. -28350.   4.196  43790.   28350.   4.182  32354.   60717.    4972.   20711.
 74       22      2   3.656 -40469. -64333.   3.200      0.       0.   4.196      0.   20488.       0.       0.
 75       22      3   4.196-113701.-107587.   3.200      0.       0.   4.534      0.   -4476.       0.       0.
 76       22      4   4.534-116527.-104070.   3.200      0.       0.   5.071   5752.    1513.       0.       0.
 77       22      5   5.071-106607.-105541.   3.200      0.       0.   5.269 136440.  137361.       0.       0.
 78       23      5   3.200      0.      0.   5.269-105541.-105477.   5.448      0.       0.-103736.-103290.
 79       23      6   5.448-105977.-106045.   3.200      0.       0.   5.628   -415.       0.       0.       0.
 80       23      7   5.628-104405.-100803.   3.200      0.       0.   5.800   5720.       0.       0.       0.
 81       23      8   5.800-100603. -86790.   3.200      0.       0.   5.953  14151.       0.       0.       0.
 82       23      9   5.953 -80780. -65029.   3.200      0.       0.   6.089  21081.       0.       0.       0.
 83       24      9   3.200      0.      0.   6.060 -25941.  -25245.   6.112      0.       0.-117062.-118253.
 84       24     10   6.112 -25245. -19980.   6.159 -20283.  -13077.   6.180 -70164.  -75321.  -45764.  -56227.
 85       24     11   6.180 -21455.  -7980.   3.200      0.       0.   6.261 -34462.  -47852.       0.       0.
 86       24     12   6.261  -7980.  14947.   3.200      0.       0.   6.368  22855.       0.       0.       0.
 87       24     13   6.308  14947.  15121.   3.200      0.       0.   6.457      0.       0.       0.       0.
 88       25     13   3.200      0.      0.   6.457  15121.   15264.   6.518      0.       0.       0.       0.
 89       25     14   6.518  15264.  13190.   3.200      0.       0.   6.622      0.    2184.       0.       0.
 90       26     14   3.200      0.      0.   6.622  13190.    6648.   6.678      0.       0.   -7210.       0.
 91       27     14   3.200      0.      0.   6.678   6098.   -1312.   6.708      0.       0.   -7464.       0.
 92       27     15   6.708  -1312.  -1310.   3.200      0.       0.   6.758      0.       0.       0.       0.
 93      -28     15   3.200      0.      0.   6.758  -1310.   -1310.   6.770      0.       0.       0.       0.

CHANNEL REACH  7

 94       25     10   3.200      0.      0.   6.169 -12229.   -8707.   6.275      0.       0.   29729.   26265.
 95       26     10   6.297   1289.   4076.   6.275  -8707.   -4078.   6.343 -40345.  -43033.   -3623.   -8250.
 96       26      9   3.200      0.      0.   3.200      0.       0.   6.297      0.       0.       0.       0.
 97       27      9   6.271    103.   -130.   6.297  -1289.     130.   6.346   -351.       0.   46643.   45335.
 98       27      8   3.200      0.      0.   3.200      0.       0.   6.271      0.       0.       0.       0.
 99      -28      8   3.200      0.      0.   6.271   -103.       0.   6.295      0.       0.       0.       0.


CHANNEL REACH  8

100       -1      4   3.200      0.      0.   5.751      0.   -5487.   5.802      0.       0.   -5551.    -958.
101        2      4   3.200      0.      0.   5.802  -5487.   -9614.   5.883      0.       0.   -8345.   -4704.
102        3      4   3.200      0.      0.   5.883  -9914.  -10935.   5.992      0.       0.  -11431.   -9411.
103        3      5   5.992 -10935.  -9703.   3.200      0.       0.   6.173  14330.   13229.       0.       0.
104        4      5   3.200      0.      0.   6.173  -9703.   -6408.   6.265      0.       0.  -18304.  -21673.
105        5      6   3.200      0.      0.   6.205  -6408.   -2290.   6.338      0.       0.  -47862.  -51939.
106        5      6   6.338  -2290.   4350.   3.200      0.       0.   6.466  31688.   25392.       0.       0.
107        5      7   6.466      0.      0.   3.200      0.       0.   7.273      0.       0.       0.       0.
108        5      8   7.273 -21320. -18045.   7.400  14477.   18045.   7.395 -13961.  -18634.  -40591.  -49765.
109        4      8   3.200      0.      0.   7.850      0.       0.   7.400      0.       0.       0.       0.
110        4      9   7.400 -14477. -13041.   7.937  12990.   13041.   7.656  41371.   40050.   -4913.   -4860.
111        3      9   7.850  -1072.  -3786.   3.200      0.       0.   7.937  67047.   69285.       0.       0.
112        3      8   3.200      0.      0.   7.859   1864.   -1072.   7.850      0.       0.   49891.   53586.
113        2      8   3.200      0.      0.   7.875   1221.    1864.   7.859      0.       0.      15.    -487.
114       -1      8   3.200      0.      0.   7.867      0.    1221.   7.875      0.       0.      18.   -1069.

CHANNEL REACH  9

115        3     10   7.937 -18776. -18740.   8.849  11104.   18748.   8.522    550.    2676.       0.   -7978.
116        2     10   3.200      0.      0.   3.200      0.       0.   8.809      0.       0.       0.       0.
117        2     11   8.909 -11104.  -6372.   3.200      0.       0.   8.987   9946.    5134.       0.       0.
118       -2     12   8.967  -6372.      0.   3.200      0.       0.   9.062      0.   -6360.       0.       0.

CHANNEL REACH 10

119        6      8   6.925 -47088. -30475.   7.395      0.       0.   7.171 -31386.  -42017.       0.       0.
120       -7      8   6.971      0.      0.   7.171 -30475.  -33139.   7.598      0.       0.  -60590.  -69932.

CHANNEL REACH 11

121       -7      5   5.560-152503.-158599.   6.024      0.       0.   5.784 137692.  144391.       0.       0.

      VOLUME OF WATER ABOVE MSL =     145950.0 MILLIONS OF CU FT
      (THE SEAWARD ROWS THRU 10  2 ARE EXCLUDED)
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Reid, Robert O.
Development of SURGE II Program with application to the Sabine-Calcasieu area for Hurricane Carla and design hurricanes / by Robert O. Reid, Andrew C. Vastano...[et al.]. – Fort Belvoir, Va. : U.S. Coastal Engineering Research Center ; Springfield, Va. : available from National Technical Information Service, 1977.
218 p. : ill. (Technical paper - U.S. Coastal Engineering Research Center ; no. 77-13) Also (Contract - U.S. Coastal Engineering Research Center DACW64-74-C-0015)
Bibliography: p. 117.
SURGE II is a program for calculation of storm surges and tides in a bay or estuary of the type where frictional resistance dominates over Coriolis force.
1. Hurricanes. 2. Hurricane Carla. I. Title. II. Title: SURGE II Program. III. Vastano, Andrew C., joint author. IV. Series: U.S. Coastal Engineering Research Center. Technical paper no. 77-13. V. Series: U.S. Coastal Engineering Research Center. Contract DACW64-74-C-0015.

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1. Hurricanes. 2. Hurricane Carla. I. Title. II. Title: SURGE II Program. III. Vastano, Andrew C., joint author. IV. Series: U.S. Coastal Engineering Research Center. Technical paper no. 77-13. V. Series: U.S. Coastal Engineering Research Center. Contract DACW64-74-C-0015.

TC203 .U581tp no. 77-13 627

Reid, Robert O.
Development of SURGE II Program with application to the Sabine-Calcasieu area for Hurricane Carla and design hurricanes / by Robert O. Reid, Andrew C. Vastano...[et al.]. – Fort Belvoir, Va. : U.S. Coastal Engineering Research Center ; Springfield, Va. : available from National Technical Information Service, 1977.
218 p. : ill. (Technical paper - U.S. Coastal Engineering Research Center ; no. 77-13) Also (Contract - U.S. Coastal Engineering Research Center DACW64-74-C-0015)
Bibliography: p. 117.
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