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16. Abstract

Transportation facilities in the coastal zone of Louisiana, such as roadways, bridges, and ports, are subject to flooding which must be considered in the design, operation, and maintenance of these facilities. Flooding can result from hurricanes, tidal action, run-off, backwater, and combinations of these events. This report presents the results of a study to determine the hurricane flood elevations in coastal Louisiana which represent average return intervals of 10, 25, 50, 100, and 500 years. Since flood water level statistics are changing in coastal Louisiana due to dredging of channels, levee construction, sea level rise, wetland loss, and subsidence, this study also establishes within LaDOTD the capability for assessing future risk.

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WATER LEVEL STATISTICS FOR DESIGN OF TRANSPORTATION FACILITIES IN COASTAL LOUISIANA

Volume 1

FINAL REPORT

by

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ABSTRACT

Transportation facilities in the coastal zone of Louisiana, such as roadways, bridges, and ports, are subject to flooding which must be considered in the design, operation, and maintenance of these facilities. Flooding can result from hurricanes, tidal action, run-off, backwater, and combinations of these events. This report presents the results of a study to determine the hurricane flood elevations in coastal Louisiana which represent average return intervals of 10, 25, 50, 100, and 500 years. Since flood water level statistics are changing in coastal Louisiana due to dredging of channels, levee construction, sea level rise, wetland loss, and subsidence, this study also establishes within LaDOTD the capability for assessing future risk.

The research used a computer model and landscape data base to develop the water level statistics for coastal Louisiana. The computer model was developed by the Federal Emergency Management Agency for conducting flood insurance studies. The model incorporates land topography, vegetation, coastal bathymetry, rivers, channels, roadways, ridges, and levees. The response of the coastal and wetland water levels to tides, winds, and river discharge are included in the computations. Data used for input to the model were based upon parish and state surveying data, quadrangle sheets, USGS maps, and NOS charts.

Water level statistics are described on a grid having a spacing of 10,000 feet for the all areas of Louisiana south of latitude 30 degrees 30 minutes (Lambert Y = 670,000 ft). For each grid cell, the annual probability of water levels exceeding given elevations were determined. These statistics were used to compute the flood water elevations. Results of the study are presented as water level elevations having average return periods of 10, 25, 50, 100, and 500 years for each cell.

Results of the study indicate that hurricane flooding affects essentially all locations in coastal Louisiana. The 100-year flood elevations range from 11 feet in Cameron Parish to 13 feet in Plaquemines Parish. The north/south variations in the 100 year elevations indicate, as expected, that the highest flood elevations occur at the coastline. But the area of next highest flooding is at the northern edge of the coastal zone, where elevation can reach 8 to 10 feet. The lowest 100-year flood elevations occur in the midsection of the coastal area. A few sites at the northern edge of the coastal zone experience flooding only during extreme storms. The 50-year flood levels are generally two to three feet less than the 100-year levels. Other flood levels, 25- and 10-year, are generally 5 and 7 feet less than the 100-year elevations, though many locations show different relationships. The flood levels are conservative at this time by about one foot.

The study indicates that hurricane flooding level statistics in coastal Louisiana are highly variable and that they are sensitive to the landscape changes occurring in the state. It is recommended that these statistics be updated periodically to allow the effects of these continuing changes to the landscape and the global sea level rise to be accounted for in the flood threat statistics.

ACKNOWLEDGMENTS

This investigation was sponsored by the Louisiana Transportation Research Center (LTRC) and the Federal Highway Administration under State Project No. 736-15-81, Federal Aid Project No. 0010 (016), and Research Project No. 90-9SS.

The authors of this report acknowledge the support and encouragement of the project review committee: Mr. Peter Allain (Federal Projects Engineering Supervisor), Mr. Henry Barousse (Chief, Water Resources Design & Development) and Mr. Edmond G. Preau (Deputy Director, Public Works & Flood Control).

The authors are also grateful to Mr. Paul M. Griffin, P.E., Geophysical Systems Research Administrator of LTRC for his guidance and support.

IMPLEMENTATION STATEMENT

The results of the completed work consist of water level statistics and a flood prediction model.

The water level statistics are presented in a user's guide (Volume II) with accompanying maps. The users guide and maps can be directly used by non-specialist personnel in LaDOTD to determine the flood elevation at a specific site in coastal Louisiana. The water elevation associated with average return intervals of 10, 25, 50, 100, and 500 years are given in the users guide for grid points indicated on the grid maps. Six grid maps at a scale of 1 to 250,000 are used to locate the site for which water level statistics are desired. Once the location is found on the map, the grid cell containing the site is identified. This cell has coordinates k and j, where k is the column and j the row. This pair of numbers is used in the user guide to find the flood elevation listings for that cell. The user guide lists the flood elevations for the various average return periods in feet relative to National Geodetic Vertical Datum. The users guide has instruction material contained in the introduction.

The hurricane flooding computer model has been transferred directly to LaDOTD and is available for periodic updating of the flood elevations, as well as other uses. The computer model has been extensively documented by the Federal Emergency Management Agency.

The LTRC staff has been directly involved in this research to ensure that the results are compatible with LaDOTD requirements. Questions concerning the user guide, the computer program, and the application of these results to specific LaDOTD projects may be directly addressed to LTRC.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

METRIC CONVERSION FACTORS*

To Convert from	To	Multiply by
	Length	
foot	meter (m)	0.3048
inch	millimeter (mm)	25.4
yard	meter (m)	0.9144
mile (statute)	kilometer (km)	1.609
	Area	
square foot	square meter (m^2)	0.0929
square inch	square centimeter (cm^2)	6.451
square yard	square meter (m^2)	0.8361
	Volume (capacity)	
cubic foot	cubic meter (m^3)	0.02832
gallon (U.S. liquid)**	cubic meter (m^3)	0.003785
gallon (Can. liquid)**	cubic meter (m^3)	0.004546
ounce (U.S. liquid)	cubic centimeter (cm^3)	29.57
	Mass	
ounce-mass (avdp)	gram (g)	28.35
pound-mass (avdp)	kilogram (kg)	0.4536
ton (metric)	kilogram (kg)	1000
ton (short, 2000 lbs)	kilogram (kg)	907.2
	Mass per Volume	
pound-mass/cubic foot	kilogram/cubic meter (kg/m^3)	16.02
pound-mass/cubic yard	kilogram/cubic meter (kg/m^3)	0.5933
pound-mass/gallon (U.S.)**	kilogram/cubic meter (kg/m^3)	119.8
pound-mass/gallon (Can.)**	kilogram/cubic meter (kg/m^3)	99.78
	Temperature	
deg Celsius (C)	kelvin (K)	$t_k = (t_c + 273.15)$
deg Fahrenheit (F)	kelvin (K)	$t_k = (t_F + 459.67)/1.8$
deg Fahrenheit (F)	deg Celsius (C)	$t_c = (t_F - 32)/1.8)$

*The reference source for information on SI units and more exact conversion factors is "Metric Practice Guide" ASTM E380.

**One U.S. gallon equals 0.8327 Canadian gallon.

INTRODUCTION

Water level statistics for the design of transportation facilities in coastal Louisiana are needed because this area is subject to flooding by hurricane surges and is undergoing extensive natural and man-made alterations which are causing a modification of the extent of flooding. The use of historic flood levels is misleading in this case since the flood threat is changing with time. This report presents the results of work to provide up-to-date information about hurricane flood water level statistics for coastal Louisiana that reflect present landscape conditions and to provide the ability to easily update flood elevations in the future.

The water level statistics presented in this report are based on a hydrodynamic computer model to compute the threat of hurricane flooding within the coastal zone of Louisiana. Hydrodynamic models of flooding are currently used to determine flood water levels in rivers and channels. The hydrodynamic model used in this study is the overland flooding model of the Federal Emergency Management Agency. This is the same model used to compute the base flood elevations for the National Flood Insurance Program. The model has not been modified in this study, other than to make it more easily operate on a microcomputer. The latest information concerning topographic data and hurricane statistics has been used in the study.

The statistics of the hurricane flood water elevations were defined for several average return periods, i.e., 10, 25, 50, 100, and 500 years. These statistics were determined for locations referenced to Lambert coordinates using a joint probability analysis. In this analysis water levels are forecast for a variety of hurricane storms using the surge simulation computer model.

There has been no previous work on the use of computer model derived hurricane flood statistics for LaDOTD.

geometry, atmospheric pressure and storms, boundary conditions, and bottom friction resistance coefficients. The modelling also included sub-grid barriers such as islands, roadways, levees, and sub-grid channels such as rivers, bayous and canals.

METHODOLOGY

The approach taken in this study was to follow the method recommended by the Federal Emergency Management agency for determining base flood elevations for the Flood Insurance Rate Maps.

The methodology is called the Joint Probability Method (JPM). This method incorporates historical data on representative storm parameters. Statistical distributions of the storm parameters that affect flood levels are then developed. From these distributions, a large population of "synthetic storms" is generated. These storms are called "synthetic" because they resemble historical storms. They could have occurred but may not have been observed. The surge model is then used to determine the storm surge elevations produced along and inland of the coastline of interest for each of these storms. The JPM is used to infer the statistics of these surge levels from the statistics of the meteorological parameters that define the storm. An overview of the JPM follows.

Five storm parameters are used to define synthetic hurricanes. These are the central pressure depression, the radius to maximum winds, storm forward speed, direction of storm motion, and storm track location with respect to the study area. These parameters define the surge-producing potential of a hurricane. The probability distributions of these parameters are derived from a statistical analysis of historical hurricanes that have affected the study area. These probability distributions are then divided into discrete intervals, each interval represented by a single parameter value and an appropriate probability weight. The combination of all discrete parameter values represents a large set, or ensemble, of several synthetic storms.

The actual surge that each synthetic storm produces at a location is determined through detailed hydrodynamic modeling. It is important to realize that the accuracy of the JPM hinges on the use of a simulation model that accurately simulates the surges caused by hurricanes. The required simulation capability actually involves more than one model. One model is used to simulate the hurricane forcing on the ocean. This forcing includes windstress and barometric pressure gradients. Both of these are defined about the center of the hurricane. Their magnitude and areal extent are determined by the central pressure depression and the radius to maximum winds of the storm. The second model is a hydrodynamic model for the area of interest. This model simulates the surge produced by the atmospheric forcing. Surge generation, propagation, and transformation in shallow water are normally modeled using an offshore grid and an inland or nearshore grid.

The peak water-surface elevation that results from the combination of the storm surge with the astronomic tide depends on the magnitude of the astronomic tide and the phasing between the astronomic tide and the storm surge. Because of dynamic coupling, this combination is often non-linear, that is, it is not possible to simply add the computed surge to the known astronomic tide.

The frequency of the storm, and hence the frequency of the storm surge elevation, is defined by the joint probabilities of the storm characteristics. This frequency is computed as the historical density of storms, in events per year per nautical mile, multiplied by the probability of a storm with specific characteristics. These characteristics include the radius to maximum winds, storm speed, central pressure depression, track angle, and storm stack. The joint probability of these various parameters is evaluated as the product of the probabilities of each of the storm parameters. When these parameters are statistically dependant, conditional probabilities should be used. The combination of surge with tide is considered to be random, i.e., the surge has an equal probability of occurring at any phase of the tide.

DATA COLLECTION

Data needed as input to set up and run the simulation of the model was acquired from available sources. The methodology for collecting and using the data needed in the study is described below.

Topographic Data

The topographic data used as input to the numerical calculations was based upon USGS quad sheets, NOS bathymetric charts and topographic data taken by parishes and by the state.

The land topographic data was primarily based upon using 7.5' and 15' USGS quad sheets. The quad sheets used cover all pertinent areas of Louisiana, Mississippi and Texas from 88 degrees west longitude to 96 degrees west longitude and from 30 degrees 30 minutes north latitude southward to the shoreline. The quad sheets used were the latest available and have dates ranging from 1934 to 1985, with the majority of the map dates ranging from 1970 to 1985. The maps contain contours at 5 foot intervals and spot measurements to the nearest foot at scattered points. The datum of the quad sheets is NGVD 1929. Additional data was taken from the USGS metric maps series 1: 100,000. These maps contain information from topographic surveys in the period 1971-1973.

The inland and offshore bathymetric data was based upon NOS charts in the 1100 and 11000 series and quad sheets. The charts cover the same longitude limits as the quad sheets and extend in a north/south direction from the shoreline to beyond the edge of the continental shelf. The dates of the charts are 1984, 1985, and 1986. These charts are also used to define the offshore bathymetry for the calibration simulations. The charts contain contours at 1 fathom intervals and a large number of spot water depths. The datum for the charts is Mean Lower Low Water. This datum differs from mean sea level by about .7 to .8 feet.

The topographic data taken by parishes and by the state were also used in setting up the model. These data were located on the appropriate 7.5' quad sheet being used to set-up the model grid. The topographic data was augmented by using existing aerial photos and acquired satellite images that allowed the areal extent of the topographic features to be assessed.

The topographic data within each grid cell were averaged to determine the ground elevation value input into the model. Where topographic data was lacking, the grid cell elevation was assigned based upon vegetation type. It is known that certain types of marsh plants occupy habitats were water level is at a fixed relation to the tidal datums. Most of the salt marsh areas of the state were taken as a few tenths of a foot above mean tide level. The mean tide level itself is at an elevation of about .5 to 1 foot above the present NGVD datum. The datum for the recently surveyed topographic data is NGVD 1982, although some data refers to NGVD 1965. There is a problem with reconciling the various datums used for different data sets, because in Louisiana the bench marks are sinking while sea level is rising and NGVD is being redefined. In this study all elevations refer to the 1982 NGVD datum.

Barrier and River Data

Barriers and rivers which occur in the coastal zone have a controlling influence on flood levels. Barriers include roadways, levees, and natural features such as cheniers. Rivers include channels, canals, and inlets. These features are typically much smaller in width than a grid cell, having widths that are about 100 to 1000 feet. The information needed about barriers is the elevation, width, and roughness. Data was obtained for the sub-grid scale landscape features of barriers and rivers from a variety of sources. The barrier elevations for the inland grid were taken from the maps used to determine topography. These maps contain selected elevations of the ground around the barrier crest. Additional information was obtained from USGS quad sheets which contain elevations for bench marks.

The river data was taken primarily from the NOS charts used for obtaining the bathymetric data. Additional data was obtained from the Corps of Engineers and from professional surveyors.

Hurricane Statistics

The source of the data and methods used to determine the hurricane frequency and parameter statistics was the report by Ho, et al. *[1]*, referred herein to as NWS86. The data base and methodologies presented in NWS86 were developed specifically for flood forecasting studies and therefore the approach taken herein was to follow

NWS86 as closely as was possible. The NWS86 report presents data which describes the statistics of all of the hurricane storm parameters needed for this study.

The hurricane storm parameter statistics used in this study were taken from NWS86. This data from NWS86 was used to determine the cumulative probabilities for the hurricane parameters for various locations along the Louisiana coast. The readings were taken at various miles along the Louisiana coastline from the appropriate graphs and tables in NWS86.

The approach recommended in NWS86 was used to discretize the hurricane parameter probability distributions for use with the surge model. Representative probability ranges were defined for each parameter and the average value of the parameter in the range was computed and taken as the discrete value. The discretized hurricane distributions were determined for various mileages along the coast. Three discrete ranges have been selected for pressure depression, while two ranges have been selected for radius, forward velocity, and direction, and 14 for distance along the coast. The pressure was discretized into three ranges 936, 963, and 991 millibars. These ranges are consistent with the need to represent the lower pressures with higher resolution. The radius was discretized into ranges having average radii of 13 and 39 nautical miles. The forward velocity was discretized into an 8- and 10-knot range. The direction was discretized into two ranges having values of 140 and 205 degrees. This produced hurricane approach directions that are on either side of 180 degrees. Each range had a probability of 50 percent.

SURGE SIMULATION MODEL

The overland flooding model used in the study has been developed by the Federal Emergency Management Agency to predict hurricane flood elevations for the National Flood Insurance Program. The model uses an explicit, two dimensional spaced-staggered, finite difference scheme to simulate the surges caused by hurricanes. Inputs to the model include the bathymetry, coastline configuration, boundary conditions, and bottom friction and other flow resistance coefficients. Also required are the surface wind stress and atmospheric pressure distributions of the hurricane. The surge model simulates the surge elevations everywhere in the modeled region.

The hydrodynamic model uses the principles of conservation of momentum and mass to simulate the response of the ocean to hurricanes. The momentum equation represents a balance between inertial (acceleration) forces and gravity forces, windstress, atmospheric pressure gradient forces, the reactive bottom friction forces, and the Coriolis acceleration effect caused by the earth's rotation. The model uses a rectangular grid to discretize the simulated region of the ocean. The grid is oriented with the y-axis parallel to the general trend of the coastline and the x-axis extending into the ocean. The top of the grid is located where ground elevations are above the expected maximum surge elevation and/or where the inland propagation of the surge through channels becomes negligible. The model can also simulate the flooding of low lying areas resulting from astronomical tides.

In this application of the model two grids were used. An offshore grid having spacing of 30,000 feet extended out to the deep water of the Gulf of Mexico and had lateral boundaries far removed from Louisiana. The purpose of this grid model is to simulate the storm surge generation over the deep ocean and the continental shelf. A second inland grid having a resolution of 10,000 feet was used to generate the surge elevations used in this study. It more accurately represented the nearshore geometry of the study area. The two grids are embedded such that the inland grid covers in more detail a portion of the offshore grid. Water surface elevations at the boundary of the inland grid are transferred from the offshore simulation.

Grids and Input Files

The offshore and inland grids were based upon the Lambert Plane Coordinates (southern grid). The offshore grid is 100 cells east/west by 37 cells north/south and has a grid size of 30,000 ft, as shown in Figure 1. The grid extends from Lambert X = 400,000 on the west to Lambert X = 3,400,000 on the east and extends from Lambert Y = 700,000 on the north to Lambert Y = - 410,000 on the south. The grids lines were oriented along the lines of the Lambert coordinate axis. The inland grid is 170 cells east/west and 59 cells north/south and has a grid size of 10,000 ft, as shown in Figure 2. The grid has a western boundary of Lambert Y = 1,150,000 on the west and Lambert Y = 2,850,000 on the east. The northern border is Lambert Y = 670,000 feet and the southern boundary is Lambert Y = 80,000 feet. The inland grid was separated into two halves during computations.

The topographic and bathymetric data for each grid were obtained from the maps and charts described previously. The average elevation for each 10,000 ft grid cell was based upon averaging several readings over the grid. For the bathymetric data, the actual soundings within each grid cell were numerically averaged. In most cases there were several soundings per grid cell, with some grid cells having 30 to 40 soundings. For the land grid cells, the average elevation was based upon 9 separate elevations; the center, 4 corners, and 4 boundary midpoints. Where survey data was available it was averaged for a 10,000-foot grid cell and used to adjust the grid cell average value obtained from the quad sheets. The 10,000-foot grid averages themselves were averaged over a 30,000-foot grid and were used for the offshore grid. The offshore grid was extended into Texas along lines that parallel the Texas southern grid. The Louisiana and Texas grids were adjusted at the Texas/Louisiana border.

The number of river segments in the model are limited to 300. In order to accurately represent the effect of rivers on flooding, only rivers trending north/south were included in the river input files. Thus certain sections of the Gulf Intercoastal Waterway, which were near the coast and trending in an east west direction, were not included. River data is shown in Figure 3. The barrier data input to the model was for the main roads and levees in the southern part of coastal area of Louisiana. These barriers were placed at the boundaries of the grid cell nearest to their actual location. The barrier data base is shown in Figure 4. The input files for the offshore grid and the inland grid are presented in Tables 1 and 2.

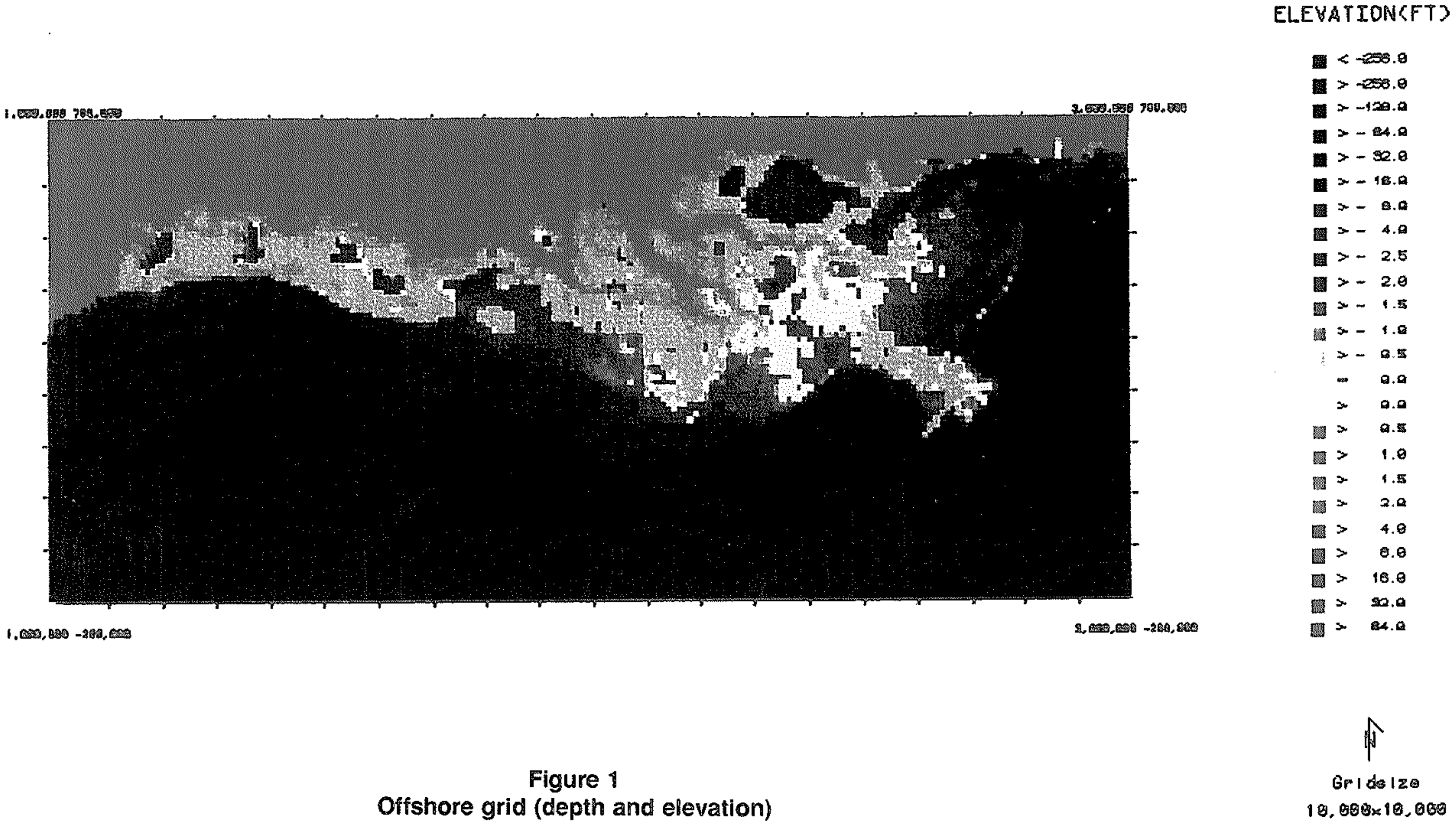

Figure 1
Offshore grid (depth and elevation)

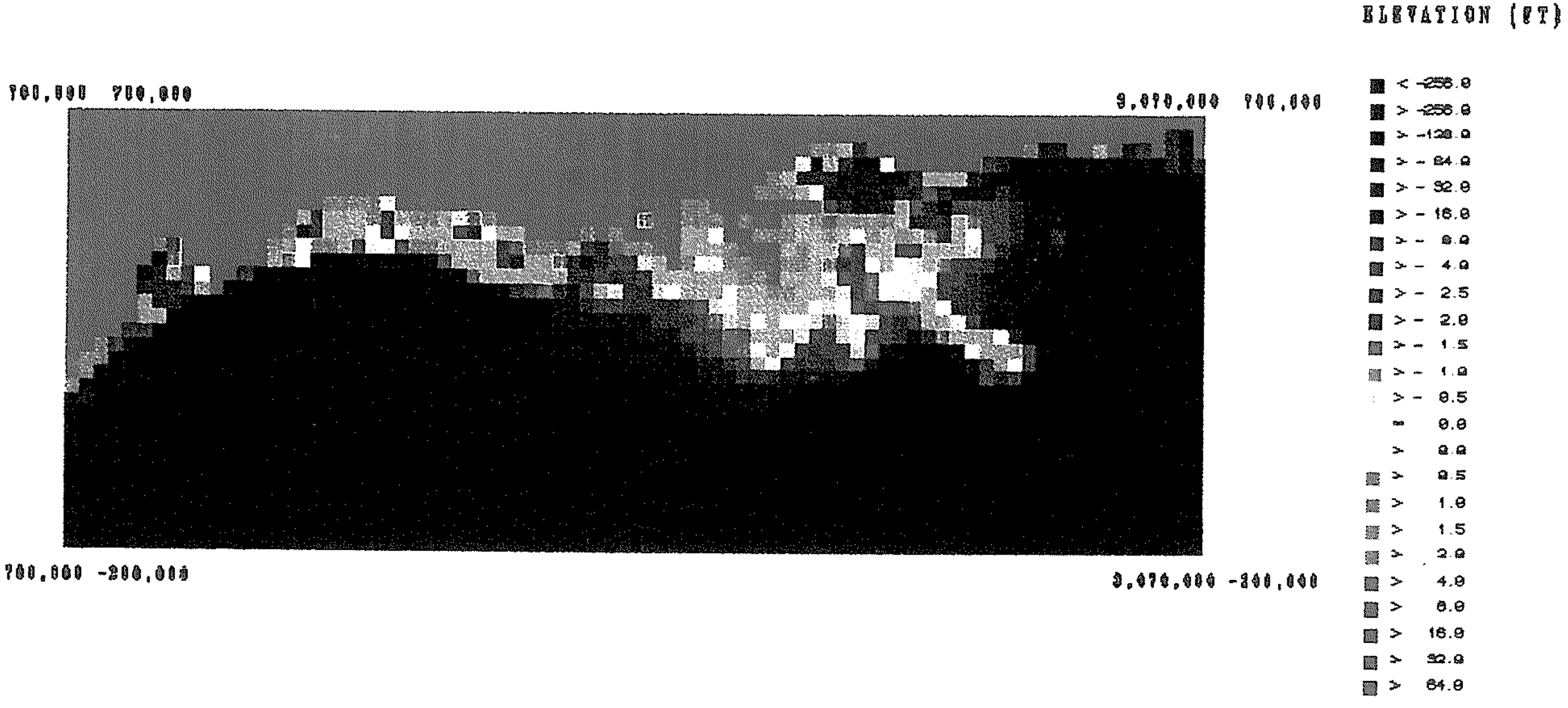

Figure 2
Hurricane coastal flooding simulation

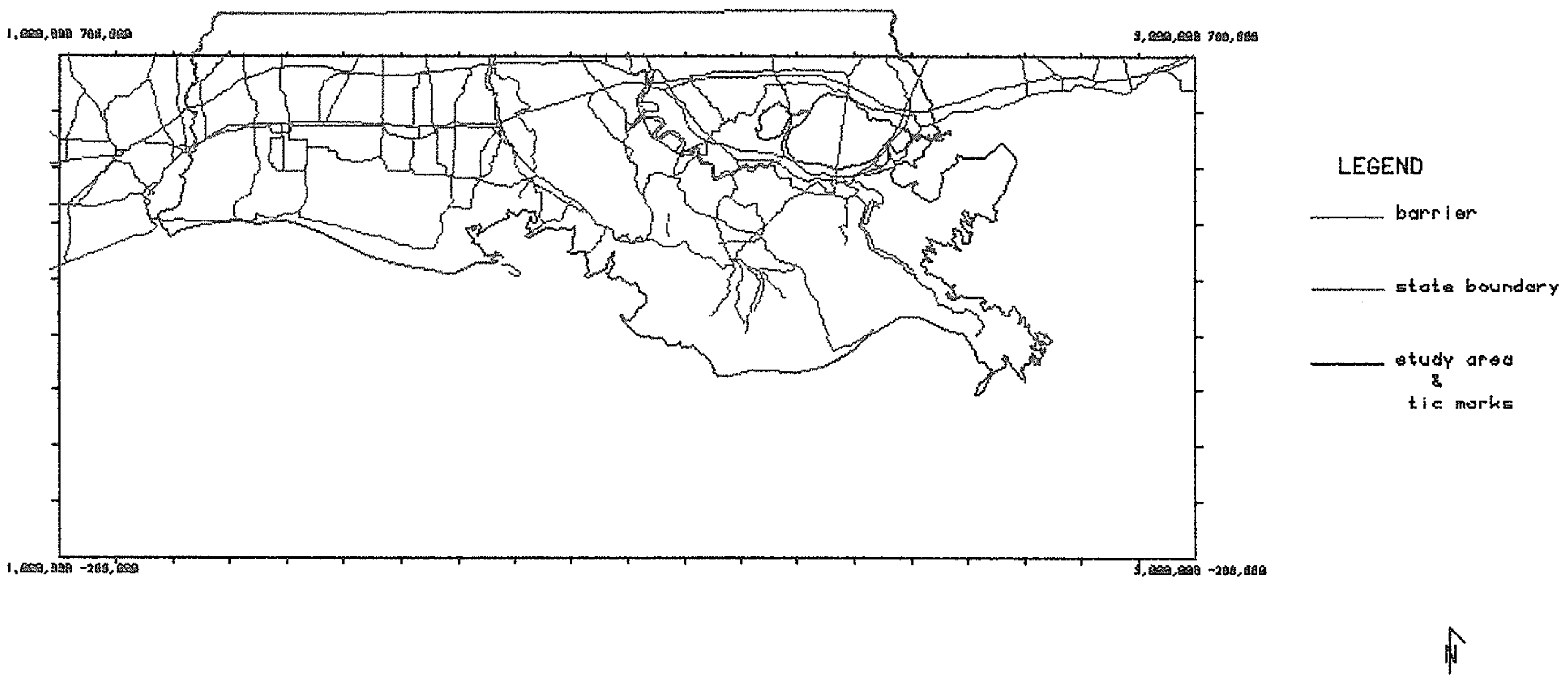

Figure 3
Barrier data

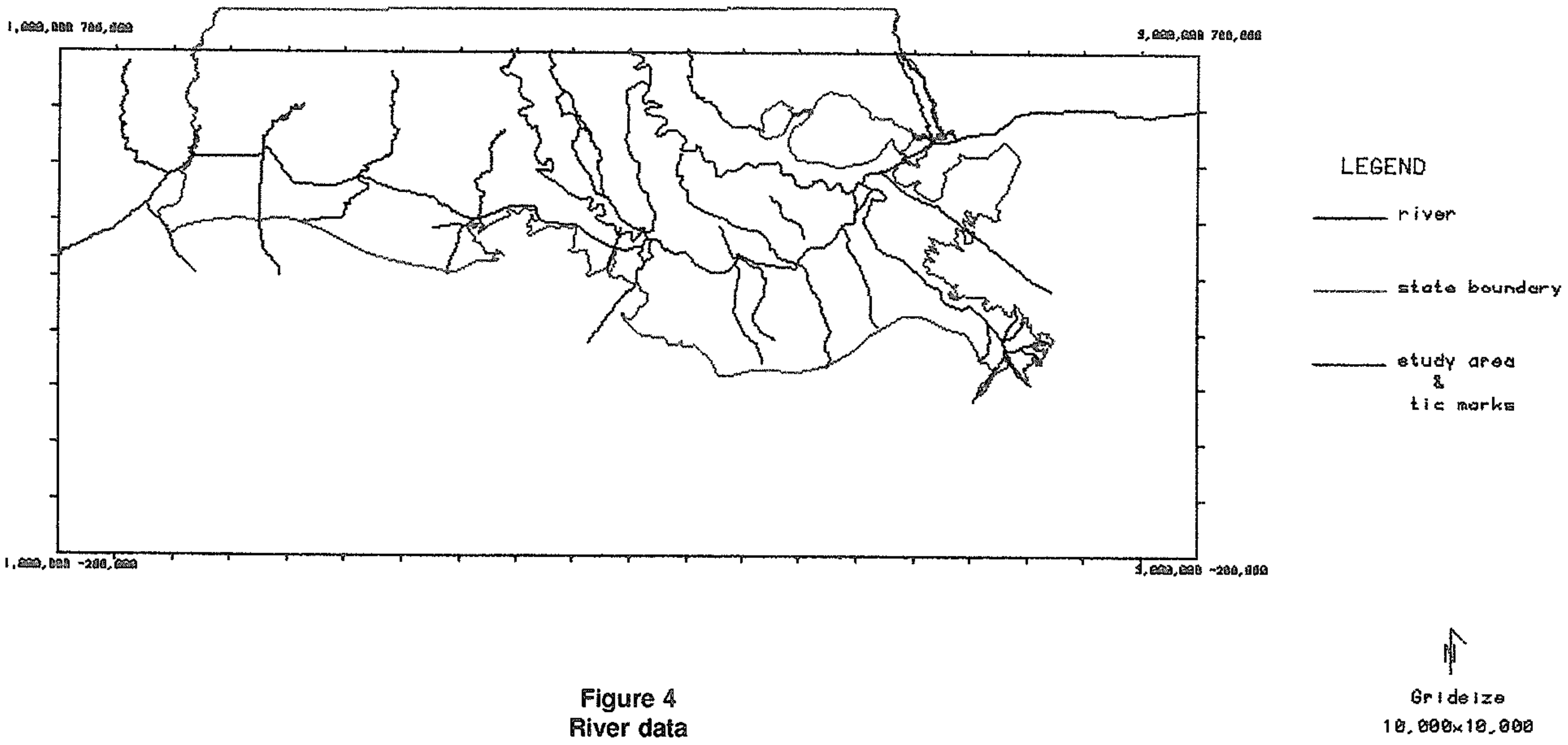

Figure 4
River data

Table 1
Input file for the offshore grid

```
  100   37    1    1    1    1    1  -13    0  999    0    1    2    0
0    0
    30000.    30000.      300.       .99   172800.   999999.      30.0
 0.020
         0      0.00      0.00      0.05      0.00
      67.0      .900        1.        1.     29.92        0.      180.
    0.
    1.1E-6    2.5E-6       14.        .5       75.        0.        0.
    0.
       1.0       1.0       1.0       1.0       1.0       1.0       1.0
   1.0
  29.98000  96.42000        0.
 OFFSHORE - EAST GRID -
    0    1    0    0    0    1    0    0   -2    0    0
      1.00       0.0      25.0     180.0     -15.0     0.035       0.0
  0.00
    8   10   -2    2  100    1   37    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0
   54   14   60   19   68   17   72   12   73   12   73   14   75    4
88    4
    3.2895  220.3947       900.
   47.6970  220.3947        11        46
   72.3681  220.3947
   98.6842  220.3947
   98.6849  235.1973
   98.6849  250.0000
   98.6849  264.8026
   98.6849  279.6052
   98.6849  294.4079
   98.6849  309.2105
   98.6849  324.0131
   98.6849  338.8158
   98.6849  353.6184
   98.6849  368.4210
   98.6849  383.2237
   98.6842  399.6710
   50.9869  399.6710
   31.2500  399.6710
   11.5132  399.6710         4        82
   999999.
         0
```

Table 2
Input file for the inland grid

```
  110   59   -1    1    1    1    1    0    0  999    0    1    2    0    0    0
    10000.    10000.      300.       .99   172800.   999999.      30.0     0.020
         0      0.00       0.0      0.05      0.00
      67.0     0.900        0.        .5     29.92        0.      180.        .7
    1.1E-6    2.5E-6       14.       0.5       75.        0.        0.        0.
       1.0       1.0       1.0       1.0       1.0       1.0       1.0       1.0
HURRICANE ANDREW -                                                1900   7/20/93
    0    1    0  188  170    1    1    0   -2    0    1    0    0
      1.00       0.0       5.0      60.0     -25.0     0.033       0.0       0.0
   16   60    1    1  110    1   59    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   19   32   20   29   24   31   29   30   44   40   57   41   60   29   63   32
   64    6   67   30   69   29   70   35   74   35   80   33   82   32   82   37
    5   21       8.2        0.        0.      100.     5000. .025  .06        0.
    6   21       8.2        0.        0.      100.     5000. .025  .06        0.
    7   21       8.2        0.        0.      100.     5000. .025  .06        0.
    8   20       8.2        0.        0.      100.     5000. .025  .06        0.
    9   20       8.2        0.        0.      100.     5000. .025  .06        0.
    9   30       6.6        0.        0.      100.     5000. .025  .06        0.
   10   21       8.2        0.        0.      100.     5000. .025  .06        0.
   10   29       6.6        0.        0.      100.     5000. .025  .06        0.
   11   21       8.2        0.        0.      100.     5000. .025  .06        0.
   11   25       8.2        0.        0.      100.     5000. .025  .06        0.
   11   28       6.6        0.        0.      100.     5000. .025  .06        0.
   12   22       6.6        0.        0.      100.     5000. .025  .06        0.
   12   27       6.6        0.        0.      100.     5000. .025  .06        0.
   13   22       6.6        0.        0.      100.     5000. .025  .06        0.
   13   27       6.6        0.        0.      100.     5000. .025  .06        0.
   14   23       6.6        0.        0.      100.     5000. .025  .06        0.
   14   27       6.6        0.        0.      100.     5000. .025  .06        0.
   15   24       6.6        0.        0.      100.     5000. .025  .06        0.
   15   26       6.6        0.        0.      100.     5000. .025  .06        0.
   16   24       6.6        0.        0.      100.     5000. .025  .06        0.
   17   25       6.6        0.        0.      100.     5000. .025  .06        0.
   18   25       6.6        0.        0.      100.     5000. .025  .06        0.
   19   26       6.6        0.        0.      100.     5000. .025  .06        0.
   19   33       6.6        0.        0.      100.     5000. .025  .06        0.
   19   34       6.6        0.        0.      100.     5000. .025  .06        0.
   20   27       6.6        0.        0.      100.     5000. .025  .06        0.
   20   32       6.6        0.        0.      100.     5000. .025  .06        0.
   21   28       6.6        0.        0.      100.     5000. .025  .06        0.
   21   31       6.6        0.        0.      100.     5000. .025  .06        0.
   22   28       6.6        0.        0.      100.     5000. .025  .06        0.
   22   30       6.6        0.        0.      100.     5000. .025  .06        0.
   23   28       6.6        0.        0.      100.     5000. .025  .06        0.
   24   31       6.6        0.        0.      100.     5000. .025  .06        0.
   25   31       6.6        0.        0.      100.     5000. .025  .06        0.
   26   31       6.6        0.        0.      100.     5000. .025  .06        0.
   27   31       6.6        0.        0.      100.     5000. .025  .06        0.
   28   31       6.6        0.        0.      100.     5000. .025  .06        0.
   29   31       6.6        0.        0.      100.     5000. .025  .06        0.
   30   25       6.6        0.        0.      100.     5000. .025  .06        0.
   30   30       6.6        0.        0.      100.     5000. .025  .06        0.
   30   31       6.6        0.        0.      100.     5000. .025  .06        0.
   31   31       6.6        0.        0.      100.     5000. .025  .06        0.
   32   31       6.6        0.        0.      100.     5000. .025  .06        0.
   33   32       6.6        0.        0.      100.     5000. .025  .06        0.
   34   32       6.6        0.        0.      100.     5000. .025  .06        0.
   35   32       6.6        0.        0.      100.     5000. .025  .06        0.
   36   30       6.6        0.        0.      100.     5000. .025  .06        0.
   37   31       6.6        0.        0.      100.     5000. .025  .06        0.
   37   32       6.6        0.        0.      100.     5000. .025  .06        0.
```

38	31	6.6	0.	0.	100.	5000.	.025	.06	0.
38	33	6.6	0.	0.	100.	5000.	.025	.06	0.
38	54	2.0	0.	0.	2000.	5000.	.025	.06	0.
39	30	5.0	0.	0.	200.	5000.	.025	.06	0.
39	33	6.6	0.	0.	200.	5000.	.025	.06	0.
39	54	2.0	0.	0.	2000.	5000.	.025	.06	0.
40	30	5.0	0.	0.	200.	5000.	.025	.06	0.
40	34	5.0	0.	0.	200.	5000.	.025	.06	0.
41	29	5.0	0.	0.	100.	5000.	.025	.06	0.
41	34	5.0	0.	0.	100.	5000.	.025	.06	0.
42	35	5.0	0.	0.	100.	5000.	.025	.06	0.
43	23	5.0	0.	0.	100.	5000.	.025	.06	0.
43	35	5.0	0.	0.	100.	5000.	.025	.06	0.
44	23	5.0	0.	0.	100.	5000.	.025	.06	0.
44	29	5.0	0.	0.	200.	5000.	.025	.06	0.
44	35	5.0	0.	0.	200.	5000.	.025	.06	0.
44	54	3.0	0.	0.	2000.	5000.	.025	.06	0.
45	22	5.0	0.	0.	200.	5000.	.025	.06	0.
45	29	5.0	0.	0.	200.	5000.	.025	.06	0.
45	35	5.0	0.	0.	200.	5000.	.025	.06	0.
45	54	3.0	0.	0.	2000.	5000.	.025	.06	0.
46	29	6.6	0.	0.	2000.	5000.	.025	.06	0.
46	35	6.6	0.	0.	2000.	5000.	.025	.06	0.
46	38	6.6	0.	0.	2000.	5000.	.025	.06	0.
46	44	5.0	0.	0.	2000.	5000.	.025	.06	0.
46	54	3.0	0.	0.	2000.	5000.	.025	.06	0.
47	29	5.0	0.	0.	2000.	5000.	.025	.06	0.
47	35	5.0	0.	0.	2000.	5000.	.025	.06	0.
47	45	5.0	0.	0.	2000.	5000.	.025	.06	0.
47	54	2.0	0.	0.	2000.	5000.	.025	.06	0.
48	29	5.0	0.	0.	200.	5000.	.025	.06	0.
48	36	5.0	0.	0.	200.	5000.	.025	.06	0.
48	43	5.0	0.	0.	200.	5000.	.025	.06	0.
49	30	5.0	0.	0.	100.	5000.	.025	.06	0.
49	36	5.0	0.	0.	100.	5000.	.025	.06	0.
49	40	5.0	0.	0.	200.	5000.	.025	.06	0.
50	18	25.0	0.	0.	100.	5000.	.025	.06	0.
50	30	5.0	0.	0.	100.	5000.	.025	.06	0.
50	31	5.0	0.	0.	100.	5000.	.025	.06	0.
50	36	5.0	0.	0.	100.	5000.	.025	.06	0.
51	18	25.0	0.	0.	100.	5000.	.025	.06	0.
51	28	5.0	0.	0.	100.	5000.	.025	.06	0.
51	33	5.0	0.	0.	100.	5000.	.025	.06	0.
51	36	5.0	0.	0.	100.	5000.	.025	.06	0.
51	53	4.0	0.	0.	2000.	5000.	.025	.06	0.
52	18	25.0	0.	0.	100.	5000.	.025	.06	0.
52	27	5.0	0.	0.	100.	5000.	.025	.06	0.
52	34	5.0	0.	0.	100.	5000.	.025	.06	0.
52	36	5.0	0.	0.	100.	5000.	.025	.06	0.
52	53	4.0	0.	0.	2000.	5000.	.025	.06	0.
53	20	25.0	0.	0.	100.	5000.	.025	.06	0.
53	26	5.0	8.	2000.	100.	5000.	.025	.06	0.
53	35	5.0	0.	0.	100.	5000.	.025	.06	0.
53	36	5.0	0.	0.	100.	5000.	.025	.06	0.
53	54	5.0	0.	0.	2000.	5000.	.025	.06	0.
54	20	25.0	0.	0.	100.	5000.	.025	.06	0.
54	24	5.0	0.	0.	100.	5000.	.025	.06	0.
54	35	5.0	0.	0.	100.	5000.	.025	.06	0.
54	36	5.0	0.	0.	100.	5000.	.025	.06	0.
54	54	5.0	0.	0.	2000.	5000.	.025	.06	0.
55	21	25.0	0.	0.	100.	5000.	.025	.06	0.
55	23	5.0	0.	0.	100.	5000.	.025	.06	0.
55	35	5.0	0.	0.	100.	5000.	.025	.06	0.
55	36	5.0	0.	0.	100.	5000.	.025	.06	0.
56	22	25.0	0.	0.	100.	5000.	.025	.06	0.
56	23	5.0	0.	0.	100.	5000.	.025	.06	0.
56	35	5.0	0.	0.	100.	5000.	.025	.06	0.
57	22	20.0	0.	0.	100.	5000.	.025	.06	0.
57	36	5.0	0.	0.	100.	5000.	.025	.06	0.

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 57   54     5.0      0.      0.    2000.     5000. .025  .06       0.
 58   22    20.0      0.      0.    2000.     5000. .025  .06       0.
 58   39     5.0      0.      0.    2000.     5000. .025  .06       0.
 58   53     5.0      0.      0.    2000.     5000. .025  .06       0.
 59   21    20.0      0.      0.    2000.     5000. .025  .06       0.
 59   41     5.0      0.      0.    2000.     5000. .025  .06       0.
 60   21    20.0      0.      0.    2000.     5000. .025  .06       0.
 60   44     5.0      0.      0.    2000.     5000. .025  .06       0.
 61   22    20.0      0.      0.    2000.     5000. .025  .06       0.
 61   46     5.0      0.      0.    2000.     5000. .025  .06       0.
 62   22    20.0      0.      0.    2000.     5000. .025  .06       0.
 63   23    20.0      0.      0.    2000.     5000. .025  .06       0.
 64   23    20.0      0.      0.    2000.     5000. .025  .06       0.
 64   28     5.0      0.      0.     100.     5000. .025  .06       0.
 64   29     5.0      0.      0.     100.     5000. .025  .06       0.
 64   49     5.0      0.      0.     100.     5000. .025  .06       0.
 65   23    20.0      0.      0.     100.     5000. .025  .06       0.
 65   49     5.0      0.      0.     100.     5000. .025  .06       0.
 66   23    20.0      0.      0.     100.     5000. .025  .06       0.
 66   48     9.0      0.      0.     100.     5000. .025  .06       0.
 67   22    17.0      0.      0.     100.     5000. .025  .06       0.
 67   48     9.0     10.   3000.     100.     5000. .025  .06       0.
 68   18     9.0      0.      0.     100.     5000. .025  .06       0.
 68   25    13.0      0.      0.     100.     5000. .025  .06       0.
 68   30    13.0      0.      0.     100.     5000. .025  .06       0.
 68   47     9.0      0.      0.     100.     5000. .025  .06       0.
 69   18     9.0      0.      0.     100.     5000. .025  .06       0.
 69   21    13.0      0.      0.     100.     5000. .025  .06       0.
 69   24    13.0      0.      0.     100.     5000. .025  .06       0.
 69   32    13.0      0.      0.     100.     5000. .025  .06       0.
 69   47     9.0      0.      0.     100.     5000. .025  .06       0.
 70   18     9.0      0.      0.     100.     5000. .025  .06       0.
 70   21    13.0      0.      0.     100.     5000. .025  .06       0.
 70   24    13.0      0.      0.     100.     5000. .025  .06       0.
 70   33    13.0      0.      0.     100.     5000. .025  .06       0.
 71   18     9.0      0.      0.     100.     5000. .025  .06       0.
 71   22    13.0      0.      0.     100.     5000. .025  .06       0.
 71   24     9.0      0.      0.     100.     5000. .025  .06       0.
 71   34    13.0      0.      0.     100.     5000. .025  .06       0.
 72   17     9.0      0.      0.     100.     5000. .025  .06       0.
 72   24     9.0      0.      0.     100.     5000. .025  .06       0.
 72   34    13.0      0.      0.     100.     5000. .025  .06       0.
 73   17     9.0      0.      0.     100.     5000. .025  .06       0.
 73   24     9.0      0.      0.     100.     5000. .025  .06       0.
 73   34    13.0      0.      0.     100.     5000. .025  .06       0.
 74   17     9.0      0.      0.     100.     5000. .025  .06       0.
 74   24     9.0      0.      0.     100.     5000. .025  .06       0.
 74   24     9.0      0.      0.     100.     5000. .025  .06       0.
 74   35    13.0      0.      0.     100.     5000. .025  .06       0.
 75   16     9.0      0.      0.     100.     5000. .025  .06       0.
 75   24     9.0      0.      0.     100.     5000. .025  .06       0.
 75   36    13.0      0.      0.     100.     5000. .025  .06       0.
 76   13     9.0      0.      0.     100.     5000. .025  .06       0.
 76   25     9.0      0.      0.     100.     5000. .025  .06       0.
 76   37    13.0      0.      0.     100.     5000. .025  .06       0.
 77   12     9.0      0.      0.     100.     5000. .025  .06       0.
 77   25     9.0      0.      0.     100.     5000. .025  .06       0.
 77   38    13.0      0.      0.     100.     5000. .025  .06       0.
 78   11    13.0      0.      0.     100.     5000. .025  .06       0.
 78   39    13.0      0.      0.     100.     5000. .025  .06       0.
 79   39    13.0      0.      0.     100.     5000. .025  .06       0.
 80   39    13.0      0.      0.     100.     5000. .025  .06       0.
 81   42    13.0      0.      0.     100.     5000. .025  .06       0.
 82   43    13.0      0.      0.     100.     5000. .025  .06       0.
 83   43    13.0      0.      0.     100.     5000. .025  .06       0.
 84   43    13.0      0.      0.     100.     5000. .025  .06       0.
 85   43    13.0      0.      0.     100.     5000. .025  .06       0.
 86   43    13.0      0.      0.     100.     5000. .025  .06       0.
 87   44    13.0      0.      0.     100.     5000. .025  .06       0.
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 88   45     12.0      0.       0.     100.    5000. .025  .06        0.
  8   20      5.0      0.       0.     100.    5000. .025  .06        0.
 10   20      5.0      0.       0.     100.    5000. .025  .06        0.
 10   29      6.6      0.       0.     100.    5000. .025  .06        0.
 11   25      6.6      0.       0.     100.    5000. .025  .06        0.
 11   26      6.6      0.       0.     100.    5000. .025  .06        0.
 11   28      6.6      0.       0.     100.    5000. .025  .06        0.
 12   21      6.6      0.       0.     100.    5000. .025  .06        0.
 12   22      6.6      0.       0.     100.    5000. .025  .06        0.
 12   23      6.6      0.       0.     100.    5000. .025  .06        0.
 12   24      6.6      0.       0.     100.    5000. .025  .06        0.
 12   27      6.6      0.       0.     100.    5000. .025  .06        0.
 14   22      6.6      0.       0.     100.    5000. .025  .06        0.
 15   23      6.6      0.       0.     100.    5000. .025  .06        0.
 15   26      6.6      0.       0.     100.    5000. .025  .06        0.
 16   24      6.6      0.       0.     100.    5000. .025  .06        0.
 16   25      6.6      0.       0.     100.    5000. .025  .06        0.
 17   24      6.6      0.       0.     100.    5000. .025  .06        0.
 19   25      6.6      0.       0.     100.    5000. .025  .06        0.
 19   33      6.6      0.       0.     100.    5000. .025  .06        0.
 20   26      6.6      0.       0.     100.    5000. .025  .06        0.
 20   32      6.6      0.       0.     100.    5000. .025  .06        0.
 20   34      6.6      0.       0.     100.    5000. .025  .06        0.
 20   35      6.6      0.       0.     100.    5000. .025  .06        0.
 21   27      6.6      0.       0.     100.    5000. .025  .06        0.
 21   31      6.6      0.       0.     100.    5000. .025  .06        0.
 22   30      6.6      0.       0.     100.    5000. .025  .06        0.
 23   28      6.6      0.       0.     100.    5000. .025  .06        0.
 23   29      6.6      0.       0.     100.    5000. .025  .06        0.
 24   28      6.6      0.       0.     100.    5000. .025  .06        0.
 24   29      6.6      0.       0.     100.    5000. .025  .06        0.
 24   30      6.6      0.       0.     100.    5000. .025  .06        0.
 30   20      6.6      0.       0.     100.    5000. .025  .06        0.
 30   21      6.6      0.       0.     100.    5000. .025  .06        0.
 30   22      6.6      0.       0.     100.    5000. .025  .06        0.
 30   23      6.6      0.       0.     100.    5000. .025  .06        0.
 30   24      6.6      0.       0.     100.    5000. .025  .06        0.
 30   30      6.6      0.       0.     100.    5000. .025  .06        0.
 31   25      6.6      0.       0.     100.    5000. .025  .06        0.
 31   26      6.6      0.       0.     100.    5000. .025  .06        0.
 31   27      6.6      0.       0.     100.    5000. .025  .06        0.
 31   28      6.6      0.       0.     100.    5000. .025  .06        0.
 31   29      6.6      0.       0.     100.    5000. .025  .06        0.
 33   31      6.6      0.       0.     100.    5000. .025  .06        0.
 36   31      6.6      0.       0.     100.    5000. .025  .06        0.
 37   31      6.6      0.       0.     100.    5000. .025  .06        0.
 38   25      6.6      0.       0.     100.    5000. .025  .06        0.
 38   32      6.6      0.       0.     100.    5000. .025  .06        0.
 39   30      6.6      0.       0.     100.    5000. .025  .06        0.
 40   26      6.6      0.       0.     100.    5000. .025  .06        0.
 40   33      6.6      0.       0.     100.    5000. .025  .06        0.
 41   29      6.6      0.       0.     100.    5000. .025  .06        0.
 42   25      6.6      0.       0.     100.    5000. .025  .06        0.
 42   26      6.6      0.       0.     100.    5000. .025  .06        0.
 42   27      6.6      0.       0.     100.    5000. .025  .06        0.
 42   28      6.6      0.       0.     100.    5000. .025  .06        0.
 42   34      6.6      0.       0.     100.    5000. .025  .06        0.
 43   23      6.6      0.       0.     100.    5000. .025  .06        0.
 43   24      6.6      0.       0.     100.    5000. .025  .06        0.
 43   27      6.6      0.       0.     100.    5000. .025  .06        0.
 44   28      6.6      0.       0.     100.    5000. .025  .06        0.
 45   19      6.6      0.       0.     100.    5000. .025  .06        0.
 45   22      6.6      0.       0.     100.    5000. .025  .06        0.
 46   20      6.6      0.       0.     100.    5000. .025  .06        0.
 46   21      6.6      0.       0.     100.    5000. .025  .06        0.
 46   34      6.6      0.       0.     100.    5000. .025  .06        0.
 46   38      5.0      0.       0.     100.    5000. .025  .06        0.
 46   39      5.0      0.       0.     100.    5000. .025  .06        0.
 46   40      5.0      0.       0.     100.    5000. .025  .06        0.
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 46   41      5.0      0.      0.    100.    5000. .025  .06     0.
 46   42      5.0      0.      0.    100.    5000. .025  .06     0.
 46   43      5.0      0.      0.    100.    5000. .025  .06     0.
 47   34      6.6      0.      0.    100.    5000. .025  .06     0.
 47   35      6.6      0.      0.    100.    5000. .025  .06     0.
 47   36      6.6      0.      0.    100.    5000. .025  .06     0.
 47   37      6.6      0.      0.    100.    5000. .025  .06     0.
 47   44      5.0      0.      0.    100.    5000. .025  .06     0.
 48   35      5.0      0.      0.    100.    5000. .025  .06     0.
 48   43      5.0      0.      0.    100.    5000. .025  .06     0.
 48   44      5.0      0.      0.    100.    5000. .025  .06     0.
 48   45      5.0      0.      0.    100.    5000. .025  .06     0.
 48   46      5.0      0.      0.    100.    5000. .025  .06     0.
 49   29      5.0      0.      0.    100.    5000. .025  .06     0.
 49   40      6.6      0.      0.    100.    5000. .025  .06     0.
 49   41      6.6      0.      0.    100.    5000. .025  .06     0.
 49   42      6.6      0.      0.    100.    5000. .025  .06     0.
 50   30      5.0      0.      0.    100.    5000. .025  .06     0.
 50   36      5.0      0.      0.    100.    5000. .025  .06     0.
 50   37      5.0      0.      0.    100.    5000. .025  .06     0.
 50   38      5.0      0.      0.    100.    5000. .025  .06     0.
 50   39      5.0      0.      0.    100.    5000. .025  .06     0.
 51   28      5.0      0.      0.    100.    5000. .025  .06     0.
 51   31      5.0      0.      0.    100.    5000. .025  .06     0.
 51   32      5.0      0.      0.    100.    5000. .025  .06     0.
 52   27      5.0      0.      0.    100.    5000. .025  .06     0.
 52   33      5.0      0.      0.    100.    5000. .025  .06     0.
 53   26      5.0      0.      0.    100.    5000. .025  .06     0.
 53   18     25.0      0.      0.    100.    5000. .025  .06     0.
 53   19     25.0      0.      0.    100.    5000. .025  .06     0.
 53   34      5.0      0.      0.    100.    5000. .025  .06     0.
 53   53      5.0      0.      0.   2000.    5000. .025  .06     0.
 54   24      5.0      0.      0.    100.    5000. .025  .06     0.
 54   25      5.0      0.      0.    100.    5000. .025  .06     0.
 55   20     25.0      0.      0.    100.    5000. .025  .06     0.
 55   23      5.0      0.      0.    100.    5000. .025  .06     0.
 56   21     25.0      0.      0.    100.    5000. .025  .06     0.
 56   35      5.0      0.      0.    100.    5000. .025  .06     0.
 57   22      5.0      0.      0.    100.    5000. .025  .06     0.
 57   35      5.0      0.      0.    100.    5000. .025  .06     0.
 58   35      5.0      0.      0.    100.    5000. .025  .06     0.
 58   37      6.6      0.      0.    100.    5000. .025  .06     0.
 58   38      6.6      0.      0.    100.    5000. .025  .06     0.
 58   53      5.0      0.      0.   2000.    5000. .025  .06     0.
 59   21     20.0      0.      0.    100.    5000. .025  .06     0.
 59   36      5.0      0.      0.    100.    5000. .025  .06     0.
 59   37      5.0      0.      0.    100.    5000. .025  .06     0.
 59   38      5.0      0.      0.    100.    5000. .025  .06     0.
 59   39      5.0      0.      0.    100.    5000. .025  .06     0.
 59   40      5.0      0.      0.    100.    5000. .025  .06     0.
 60   41      5.0      0.      0.    100.    5000. .025  .06     0.
 60   42      5.0      0.      0.    100.    5000. .025  .06     0.
 60   43      5.0      0.      0.    100.    5000. .025  .06     0.
 61   21     20.0      0.      0.    100.    5000. .025  .06     0.
 61   44      5.0      0.      0.    100.    5000. .025  .06     0.
 61   45      5.0      0.      0.    100.    5000. .025  .06     0.
 62   46      5.0      0.      0.    100.    5000. .025  .06     0.
 62   47      5.0      0.      0.    100.    5000. .025  .06     0.
 62   48      5.0      0.      0.    100.    5000. .025  .06     0.
 62   49      5.0      0.      0.    100.    5000. .025  .06     0.
 63   22     17.0      0.      0.    100.    5000. .025  .06     0.
 64   49      5.0      0.      0.    100.    5000. .025  .06     0.
 65   23      5.0      0.      0.    100.    5000. .025  .06     0.
 65   24      5.0      0.      0.    100.    5000. .025  .06     0.
 65   25      5.0      0.      0.    100.    5000. .025  .06     0.
 65   26      5.0      0.      0.    100.    5000. .025  .06     0.
 65   27      5.0      0.      0.    100.    5000. .025  .06     0.
 65   29      5.0      0.      0.    100.    5000. .025  .06     0.
 65   30      5.0      0.      0.    100.    5000. .025  .06     0.
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      66   48      5.0        0.        0.      100.     5000. .025  .06        0.
      68   26     13.0        0.        0.      100.     5000. .025  .06        0.
      68   27     13.0        0.        0.      100.     5000. .025  .06        0.
      68   28     13.0        0.        0.      100.     5000. .025  .06        0.
      68   29     13.0        0.        0.      100.     5000. .025  .06        0.
      68   47      9.0        0.        0.      100.     5000. .025  .06        0.
      69   30     13.0        0.        0.      100.     5000. .025  .06        0.
      69   31     13.0        0.        0.      100.     5000. .025  .06        0.
      69   47      9.0        0.        0.      100.     5000. .025  .06        0.
      70   32     13.0        0.        0.      100.     5000. .025  .06        0.
      71   21     13.0        0.        0.      100.     5000. .025  .06        0.
      71   33     13.0        0.        0.      100.     5000. .025  .06        0.
      72   17      9.0        0.        0.      100.     5000. .025  .06        0.
      72   22     13.0        0.        0.      100.     5000. .025  .06        0.
      72   23     13.0        0.        0.      100.     5000. .025  .06        0.
      74   34     13.0        0.        0.      100.     5000. .025  .06        0.
      75   16      9.0        0.        0.      100.     5000. .025  .06        0.
      75   35     13.0        0.        0.      100.     5000. .025  .06        0.
      76   13      9.0        0.        0.      100.     5000. .025  .06        0.
      76   14      9.0        0.        0.      100.     5000. .025  .06        0.
      76   15      9.0        0.        0.      100.     5000. .025  .06        0.
      76   36     13.0        0.        0.      100.     5000. .025  .06        0.
      77   12      9.0        0.        0.      100.     5000. .025  .06        0.
      77   37     13.0        0.        0.      100.     5000. .025  .06        0.
      78   11      9.0        0.        0.      100.     5000. .025  .06        0.
      78   38     13.0        0.        0.      100.     5000. .025  .06        0.
      81   39     13.0        0.        0.      100.     5000. .025  .06        0.
      81   40     13.0        0.        0.      100.     5000. .025  .06        0.
      81   41     13.0        0.        0.      100.     5000. .025  .06        0.
      82   42     13.0        0.        0.      100.     5000. .025  .06        0.
      87   43     13.0        0.        0.      100.     5000. .025  .06        0.
      88   44     13.0        0.        0.      100.     5000. .025  .06        0.
      89   45     13.0        0.        0.      100.     5000. .025  .06        0.
    30.57466   92.11316    0.0000
        15.0        0.5   12
  Bernstein                10000.       10.        0.     2     0
              8.0     100.0       0.0      .020   64   32
              8.0     100.0       0.0      .020   63   32
  Harvey                   10000.       10.        0.     4     0
             15.0     200.0       0.0      .020   64   36
             15.0     200.0       0.0      .020   64   35
             15.0     200.0       0.0      .020   64   34
             15.0     200.0       0.0      .020   64   33
  B. Perot                 10000.       10.        0.     3     0
             15.0     500.0       0.0      .020   63   31
             15.0     500.0       0.0      .020   62   30
             15.0     500.0       0.0      .020   61   30
  Little Lk                10000.       10.        0.     2     0
             25.0     500.0       0.0      .020   62   35
             20.0     500.0       0.0      .020   61   34
  Rigolets                 10000.       10.        0.     6     0
             25.0    2000.0       0.0      .020   80   14
             25.0    2000.0       0.0      .020   79   13
             25.0    2000.0       0.0      .020   78   13
             25.0    2000.0       0.0      .020   77   13
             25.0    2000.0       0.0      .020   76   13
             25.0    2000.0       0.0      .020   75   13
  ICWW                     10000.       10.        0.    15     0
             12.0     200.0       0.0      .020   45   34
             12.0     200.0       0.0      .020   46   33
             12.0     200.0       0.0      .020   47   34
             12.0     200.0       0.0      .020   48   34
             12.0     200.0       0.0      .020   49   34
             12.0     200.0       0.0      .020   50   35
             12.0     200.0       0.0      .020   51   35
             12.0     200.0       0.0      .020   52   35
             12.0     200.0       0.0      .020   53   35
             12.0     200.0       0.0      .020   54   35
             12.0     200.0       0.0      .020   55   35
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               12.0      200.0        0.0         .020  56  34
               12.0      200.0        0.0         .020  57  33
               12.0      200.0        0.0         .020  57  32
               12.0      200.0        0.0         .020  58  31
Atchaf                      10000.    50000.           0.   31     0
               18.0      400.0        0.0         .030  19  48
               18.0      400.0        0.0         .030  20  47
               18.0      400.0        0.0         .030  21  46
               18.0      400.0        0.0         .030  21  45
               18.0      400.0        0.0         .030  22  44
               18.0      400.0        0.0         .030  23  43
               17.0      400.0        0.0         .030  24  42
               17.0      400.0        0.0         .030  25  41
               17.0      400.0        0.0         .030  25  40
               17.0      400.0        0.0         .030  26  39
               29.0     2000.0        0.0         .030  27  38
               30.0     2000.0        0.0         .030  27  37
               34.0     2000.0        0.0         .030  27  36
               35.0     2000.0        0.0         .030  28  36
               30.0     1500.0        0.0         .030  29  35
               32.0     1500.0        0.0         .030  28  35
               30.0     2000.0        0.0         .030  28  34
               30.0     1250.0        0.0         .030  28  33
               30.0     1250.0        0.0         .030  28  32
               30.0     1500.0        0.0         .030  29  31
               30.0     1500.0        0.0         .030  29  30
               30.0      500.0        0.0         .030  29  29
               30.0     1000.0        0.0         .030  29  28
               30.0     1000.0        0.0         .030  28  28
               30.0     1500.0        0.0         .030  27  28
               20.0     1500.0        0.0         .030  26  28
               12.0     1800.0        0.0         .030  25  27
               12.0     1800.0        0.0         .030  24  26
               12.0     1800.0        0.0         .030  24  25
               12.0     1800.0        0.0         .030  23  24
               12.0     1800.0        0.0         .030  22  23
Barataria                   10000.      100.           0.   21     0
               25.0     3500.0        0.0       0.020  70  46
               25.0     3500.0        0.0       0.020  69  45
                9.0     1000.0        0.0       0.020  68  44
                9.0     1000.0        0.0       0.020  68  43
                9.0     1000.0        0.0       0.020  68  42
                9.0     1000.0        0.0       0.020  68  41
                9.0     1000.0        0.0       0.020  68  40
                9.0     1000.0        0.0       0.020  68  39
                9.0     1000.0        0.0       0.020  68  38
                9.0     1000.0        0.0       0.020  67  37
                9.0     1000.0        0.0       0.020  67  36
                9.0     1000.0        0.0       0.020  67  35
                9.0     1000.0        0.0       0.020  66  34
                9.0     1000.0        0.0       0.020  65  33
                9.0     1000.0        0.0       0.020  65  32
                9.0     1000.0        0.0       0.020  64  31
                9.0     1000.0        0.0       0.020  65  30
                9.0     1000.0        0.0       0.020  64  29
                9.0     1000.0        0.0       0.020  64  28
                9.0     1000.0        0.0       0.020  63  28
                9.0     1000.0        0.0       0.020  62  28
Houma NC                    10000.      100.           0.   18     0
               13.0      500.0        0.0       0.030  50  51
               13.0      500.0        0.0       0.030  49  50
               13.0      500.0        0.0       0.030  49  49
               13.0      500.0        0.0       0.030  48  48
               13.0      500.0        0.0       0.030  47  47
               13.0      500.0        0.0       0.030  46  46
               12.0      500.0        0.0       0.030  45  45
               12.0      500.0        0.0       0.030  45  44
               12.0      500.0        0.0       0.030  45  43
               12.0      500.0        0.0       0.030  45  42
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                 12.0      500.0       0.0      0.030  45   41
                 12.0      500.0       0.0      0.030  45   40
                 12.0      500.0       0.0      0.030  45   39
                 12.0      500.0       0.0      0.030  45   38
                 12.0      500.0       0.0      0.030  45   37
                 12.0      500.0       0.0      0.030  45   36
                 12.0      500.0       0.0      0.030  45   35
                 12.0      500.0       0.0      0.030  45   34
Lafourche                   10000.      100.          0.   51     0
                 12.0      800.0       0.0      0.030  61   53
                 12.0      800.0       0.0      0.030  61   52
                 12.0      800.0       0.0      0.030  61   51
                 12.0      800.0       0.0      0.030  61   50
                 12.0      800.0       0.0      0.030  60   49
                 12.0      800.0       0.0      0.030  61   48
                 12.0      800.0       0.0      0.030  61   47
                 12.0      800.0       0.0      0.030  61   46
                  6.0      800.0       0.0      0.030  61   45
                  6.0      800.0       0.0      0.030  61   44
                  6.0      800.0       0.0      0.030  60   43
                  6.0      800.0       0.0      0.030  60   42
                  6.0      800.0       0.0      0.030  60   41
                  6.0      800.0       0.0      0.030  59   41
                  6.0      800.0       0.0      0.030  59   40
                  6.0      800.0       0.0      0.030  58   39
                  6.0      800.0       0.0      0.030  58   38
                  6.0      800.0       0.0      0.030  58   37
                  6.0      800.0       0.0      0.030  58   36
                  6.0      800.0       0.0      0.030  57   35
                  6.0      800.0       0.0      0.030  56   34
                  4.0      300.0       0.0      0.030  55   34
                  4.0      300.0       0.0      0.030  54   34
                  4.0      300.0       0.0      0.030  53   34
                  4.0      300.0       0.0      0.030  52   33
                  4.0      300.0       0.0      0.030  51   32
                  4.0      100.0       0.0      0.030  51   31
                  4.0      100.0       0.0      0.030  50   30
                  4.0      100.0       0.0      0.030  49   29
                  3.0      100.0       0.0      0.030  48   28
                  3.0      100.0       0.0      0.030  47   28
                  3.0      100.0       0.0      0.030  46   28
                  3.0      100.0       0.0      0.030  45   28
                  3.0      100.0       0.0      0.030  44   28
                  3.0      100.0       0.0      0.030  43   27
                  3.0      100.0       0.0      0.030  42   26
                  3.0      100.0       0.0      0.030  41   26
                  3.0      100.0       0.0      0.030  40   26
                  3.0      100.0       0.0      0.030  39   25
                  3.0      100.0       0.0      0.030  38   25
                  3.0      100.0       0.0      0.030  37   24
                  3.0      100.0       0.0      0.030  36   23
                  3.0      100.0       0.0      0.030  36   22
                  3.0       90.0       0.0      0.030  35   21
                  3.0       90.0       0.0      0.030  35   20
                  3.0       90.0       0.0      0.030  35   19
                  3.0       90.0       0.0      0.030  34   19
                  3.0       90.0       0.0      0.030  34   18
                  3.0       90.0       0.0      0.030  35   17
                  3.0       90.0       0.0      0.030  35   16
                  3.0       90.0       0.0      0.030  36   15
Miss R.                     10000.   200000.       0.00  115     0
                 38.0     3300.0       0.0      0.030  86   59
                 38.0     3300.0       0.0      0.030  86   58
                 38.0     3300.0       0.0      0.030  87   57
                 38.0     3300.0       0.0      0.030  88   56
                 38.0     3300.0       0.0      0.030  89   55
                 38.0     3300.0       0.0      0.030  89   54
                 38.0     3300.0       0.0      0.030  90   53
                 38.0     3300.0       0.0      0.030  91   52
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   38.0     3300.0         0.0        0.030   91   51
   38.0     3300.0         0.0        0.030   92   50
   38.0     3300.0         0.0        0.030   92   49
   42.0     2500.0         0.0        0.030   91   48
   51.0     2500.0         0.0        0.030   91   47
   62.0     2100.0         0.0        0.030   90   46
   85.0     2500.0         0.0        0.030   89   45
   58.0     2500.0         0.0        0.030   88   44
   63.0     2600.0         0.0        0.030   88   43
  100.0     2500.0         0.0        0.030   87   42
  100.0     2500.0         0.0        0.030   86   42
  100.0     2500.0         0.0        0.030   85   42
  100.0     2200.0         0.0        0.030   84   42
  100.0     2100.0         0.0        0.030   83   42
   90.0     2300.0         0.0        0.030   81   41
   90.0     2000.0         0.0        0.030   81   40
   85.0     1300.0         0.0        0.030   81   39
   60.0     1300.0         0.0        0.030   80   38
  100.0     1700.0         0.0        0.030   79   38
  100.0     2000.0         0.0        0.030   78   38
  100.0     2500.0         0.0        0.030   77   37
   85.0     2500.0         0.0        0.030   77   36
   80.0     2300.0         0.0        0.030   76   36
   75.0     2800.0         0.0        0.030   75   35
   85.0     2500.0         0.0        0.030   74   34
   85.0     2500.0         0.0        0.030   73   33
   90.0     2400.0         0.0        0.030   72   33
   70.0     2200.0         0.0        0.030   71   33
   85.0     2500.0         0.0        0.030   70   32
   95.0     2000.0         0.0        0.030   69   31
   80.0     2000.0         0.0        0.030   69   30
   90.0     2500.0         0.0        0.030   69   29
   90.0     2500.0         0.0        0.030   68   29
  100.0     2500.0         0.0        0.030   67   28
  100.0     2500.0         0.0        0.030   67   27
   83.0     2300.0         0.0        0.030   67   26
   90.0     2500.0         0.0        0.030   68   25
   80.0     2500.0         0.0        0.030   68   24
  100.0     2500.0         0.0        0.030   69   23
  100.0     2500.0         0.0        0.030   70   23
   95.0     2200.0         0.0        0.030   71   23
   65.0     2700.0         0.0        0.030   71   22
  100.0     2200.0         0.0        0.030   70   21
  100.0     2000.0         0.0        0.030   69   21
   70.0     2700.0         0.0        0.030   68   21
  100.0     2200.0         0.0        0.030   67   21
   90.0     2300.0         0.0        0.030   66   21
   70.0     1900.0         0.0        0.030   66   22
   70.0     1900.0         0.0        0.030   65   22
   70.0     2300.0         0.0        0.030   64   22
   70.0     2300.0         0.0        0.030   63   22
   70.0     2000.0         0.0        0.030   63   21
  100.0     2000.0         0.0        0.030   62   21
   60.0     2400.0         0.0        0.030   61   21
   75.0     2000.0         0.0        0.030   61   20
   70.0     2000.0         0.0        0.030   60   20
   70.0     2100.0         0.0        0.030   59   20
   90.0     1700.0         0.0        0.030   58   21
  100.0     1700.0         0.0        0.030   57   21
   75.0     2100.0         0.0        0.030   56   21
   70.0     2000.0         0.0        0.030   55   20
   75.0     2900.0         0.0        0.030   54   19
  100.0     1900.0         0.0        0.030   53   19
  100.0     1600.0         0.0        0.030   53   18
   70.0     2000.0         0.0        0.030   52   17
  100.0     2000.0         0.0        0.030   51   17
   70.0     2300.0         0.0        0.030   50   17
   95.0     1900.0         0.0        0.030   49   17
   75.0     2000.0         0.0        0.030   48   18
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                 55.0     2000.0        0.0      0.030  47   17
                 55.0     2000.0        0.0      0.030  46   18
                 55.0     2000.0        0.0      0.030  46   18
                 65.0     2500.0        0.0      0.030  45   18
                100.0     2000.0        0.0      0.030  44   18
                 95.0     2400.0        0.0      0.030  43   19
                 85.0     2100.0        0.0      0.030  42   20
                 95.0     2500.0        0.0      0.030  41   19
                 95.0     2500.0        0.0      0.030  41   18
                 55.0     2000.0        0.0      0.030  41   17
                 80.0     1700.0        0.0      0.030  40   17
                 85.0     2000.0        0.0      0.030  39   16
                 85.0     1800.0        0.0      0.030  39   15
                100.0     2000.0        0.0      0.030  38   14
                 50.0     3200.0        0.0      0.030  37   15
                 65.0     2400.0        0.0      0.030  36   15
                100.0     2000.0        0.0      0.030  35   15
                100.0     2000.0        0.0      0.030  35   14
                 90.0     2200.0        0.0      0.030  36   14
                 90.0     2000.0        0.0      0.030  36   13
                 40.0     2800.0        0.0      0.030  35   12
                 55.0     2000.0        0.0      0.030  34   11
                 40.0     2400.0        0.0      0.030  33   12
                 53.0     2200.0        0.0      0.030  32   12
                 40.0     3100.0        0.0      0.030  31   12
                 55.0     2500.0        0.0      0.030  31   11
                 70.0     2800.0        0.0      0.030  32   11
                 85.0     2000.0        0.0      0.030  32   10
                 55.0     2400.0        0.0      0.030  31    9
                 55.0     2800.0        0.0      0.030  30    9
                 60.0     2800.0        0.0      0.030  29    8
                 80.0     1600.0        0.0      0.030  29    7
                 65.0     3500.0        0.0      0.030  28    6
                 40.0     2900.0        0.0      0.030  29    5
                 50.0     2500.0        0.0      0.030  30    4
                 40.0     2400.0        0.0      0.030  30    3
                 40.0     2400.0        0.0      0.030  30    2
                 70.0     2400.0        0.0      0.030  30    1
MRGO                           10000.      100.          0.    31      0
                 40.0      600.0        0.0      0.030  96   37
                 40.0      600.0        0.0      0.030  95   36
                 40.0      600.0        0.0      0.030  94   35
                 40.0      500.0        0.0      0.030  93   34
                 40.0      500.0        0.0      0.030  92   34
                 40.0      500.0        0.0      0.030  91   33
                 40.0      500.0        0.0      0.030  90   32
                 40.0      500.0        0.0      0.030  89   31
                 40.0      500.0        0.0      0.030  88   31
                 40.0      500.0        0.0      0.030  87   30
                 40.0      500.0        0.0      0.030  86   29
                 40.0      500.0        0.0      0.030  85   28
                 40.0      500.0        0.0      0.030  84   28
                 40.0      500.0        0.0      0.030  83   27
                 40.0      500.0        0.0      0.030  82   26
                 40.0      500.0        0.0      0.030  81   25
                 40.0      500.0        0.0      0.030  80   24
                 40.0      500.0        0.0      0.030  79   24
                 40.0      500.0        0.0      0.030  78   24
                 40.0      500.0        0.0      0.030  77   24
                 40.0      500.0        0.0      0.030  76   23
                 40.0      500.0        0.0      0.030  75   22
                 40.0      500.0        0.0      0.030  74   22
                 40.0      500.0        0.0      0.030  73   21
                 40.0      500.0        0.0      0.030  72   20
                 40.0      500.0        0.0      0.030  71   19
                 40.0      500.0        0.0      0.030  70   19
                 40.0      500.0        0.0      0.030  69   19
                 40.0      500.0        0.0      0.030  68   19
                 40.0      500.0        0.0      0.030  67   19
```

```
     40.0      500.0          0.0     0.030   67   20
  .0          .0           .0
   0           0           .0           .0
```

Sensitivity Runs

Several surge simulations were computed to determine the sensitivity of the final water elevations to variations in the input parameters. The sensitivity runs were made using the offshore and inland grids and various combinations of hurricane parameters, barrier locations and elevations, and roughness parameters. The final offshore calibration run uses the values of these parameters that produced the best agreement between the observed surge elevations and the predicted surge elevations at shoreline locations near the transfer grid cells.

The inland sensitivity runs involved varying several parameters; the position of: the hurricane, the river depth turbidity, and roughnesses; the ridge elevations and locations; the overland roughness and the tide level. In order of overall importance, the barrier elevation changes had the greatest effect on the still water elevations, followed by the overland roughness and by the tide level. The sensitivity of the calibration computer runs to various values of the land Manning roughness were investigated in detail. Variable overland roughness was used in several simulations and did not produce a significant difference from constant roughness simulations.

Tide Calibration

The calibration of inland grid was conducted using observed tide range and elevation data for various locations along the Louisiana coast and along waterways. Tide records from continuously recording tide gauges were obtained from the New Orleans District office of the U. S. Army Corps of Engineers. These tide gauges in many cases are at the same locations as gauges which have recorded hurricane surge elevations.

The tidal calibration for the chenier plain focussed on the Calcasieu ship channel. Three tide gauges were used. The first gauge (No. 73650) was located at the mouth of the Calcasieu ship channel south of the city of Cameron. The second gauge was located at Hackberry (No. 73600) about 20 miles north of Cameron. The third gauge was located south of Lake Charles (No. 73550) about 45 miles north of Cameron. The predicted elevations and time lags are comparable to the observed elevations at Cameron and Hackberry. The predicted elevation at Lake Charles was low by about .8 ft. This location is most affected by backwater in the Calcasieu Ship Channel and the operation of the Calcasieu Lock. The tidal ranges, based upon the falling high tide is well predicted at Cameron, but is over-predicted at Hackberry and Lake Charles.

The tidal calibration for the deltaic plain focussed on the Barataria Bay and Lake Pontchartrain basins. Tide gauge records for several locations in both basins were used. Tide gauge locations used in the Barataria Basin were Grand Isle (88410), Bayou Petit Caillou (76305), Bayou Blue (82301), Bayou Barataria at Lafitte (82875), Bayou Barataria at Barataria (82750), Houma (76320), Bayou Des Allemands at Des Allemands (82700), Bayou Chevrenul at Chegby (82525), and Greenwood (52880). In the Pontchartrain Basin, the tide gauges used were Seabrook Bridge (76060), Mississippi River Gulf Outlet at Shell Beach (85800), Mandeville (85575), West End (85625), Mid-lake (85600), Regolets (857001), and Irish Bayou (85675). The tidal calibration simulations showed good agreement in tidal range throughout both basins, however, the predicted tidal crest elevations were lower than the actual elevations. This was because there were mean water changes in the northern parts of the two basins that were related to wind tides and run-off outside of channels that are not accounted for in the model.

Hurricane Calibration

The hurricane calibration was conducted for five storms; Audrey, Carla, Betsy, Camille and Andrew. These storms were selected to give a good geographic coverage of the state, even though several are dated. More recent storms, i.e., Juan, Gilbert, and Frederick, were reviewed but since they produced little overland flooding in coastal Louisiana they were not useful. In order to properly calibrate the simulation model, the conditions which existed at the time of the hurricane would have to be reproduced. Some of the barriers in existence at the present were either absent or had a reduced height in the past, river channels have deepened, several roadways have been raised, and marsh conditions have changed. The approach taken in the calibration effort was to use the present data base for the calibration simulations.

Hurricane Andrew is the most appropriate storm to be used for calibration because it has recently occurred and reflects the current landscape conditions in the state. The storm data has been obtained from Rappaport *[2]* and Martin *[3]*. The central pressure reached a low of 937 millibars after crossing into the Gulf of Mexico. Calibration of the storm involved using 17 data points for which either gauge data or high water marks were available. The comparison of the observed and computed maximum surge elevations showed an average different of -.5 feet and an RMS difference of 1.5'. Thus, the model slightly underpredicted the maximum surge elevations. This occurred near the point of landfall where the wind direction shifted 180° as the storm passed.

Hurricane Audrey is the most appropriate storm for calibrating the chenier plain. The storm had a low central pressure and relatively constant pressure, radius, forward velocity, and direction. It produced water levels that were at or exceeding the 100-year elevation. There are several gauge and overland water level observations available. Hurricane Carla was used as a calibration storm, although it did not produce significant ridge overtopping and therefore could only be used to calibrate river and waterway flooding. The calibration data points and geographic locations for Audrey were taken from *[4]* and *[5]*. These reports lists each observation, its location, and the source of the data. The gauge data stations are located on waterways and can be expected to be strongly influenced by waterway characteristics. This may not necessarily reflect overland water levels, even in close proximity. The high water mark data is extensive and covers the full extent of the parish. Some of the data appears to be affected by both wave action and the exposure of the site. The calibration of the model was accomplished using the observed data to control both the offshore and inland computations. The surge elevations vary an average of about 1 foot for a Manning's change from .033 to .039. The offshore calibration results show a good agreement with the observed surge elevations at the grid points near the boundary transfer to the inland grid. The agreement between the observed and predicted surge elevations for the inland simulation are excellent. There is no average difference and the rms difference was .5 feet. The agreement between observed and predicted surge elevations is very good at critical locations within the parish. At the coast at the Coast Guard station, the observed was 12.1 ft, while the predicted is 12.8. The elevation differences at the Calcasieu Locks is also predicted, i.e., the predicted elevation is 7.6 ft at the West Lock compares to the 7.7 observed. The predicted elevation at the East Lock is 5.9 ft with an observed value of 5.5 ft. The predicted elevation at the Hackberry gauge is 6.4 ft while the observed is 6.7 ft. The still water elevation prediction at the head of Grand Lake is 4.8 ft while the observed value was 5.5 ft. After being calibrated for hurricane Audrey, the surge model was used without changes to the input topographic data.

JOINT PROBABILITY SIMULATIONS

The joint probability (JP) computer runs were conducted using control software developed particularly for the study. The FEMA surge program was re-written to take input files consisting of the depth data, the hurricane data, and the input file. The multiple executions of the surge model were controlled by the batch file program. This batch file executes a Fortran program for each of the JP runs. The JP files for each run are identified by indicating each run parameter, so that the P1R1V1D1.1 represents the first pressure, radius, velocity, direction, and track. The alongshore JP runs are designated as being a fourth direction, i.e., D4.

Set-Up of the Joint Probability Runs

The joint probability runs were based upon the hurricane discretization described in the previous section. The hurricane tracks were set-up such that the track was constrained to pass through fixed points along the coastal line. The control points were along a latitude of 29.75 degrees and were separated by .500 degrees in longitude starting at a longitude of 89.00 and extending westward to 95.0 degrees. The track separation is about 25 nautical miles or about equal to the radius of a hurricane storm. The extreme eastward and westward limits were set based on producing a maximum shoreline surge elevation of less than 8 feet. A total of 408 simulations were run. The output of the maximum elevations of the surge for the inland runs were saved as a maximum water elevation file, with extension MX, i.e., P1R1V1D1.1MX.

Still Water Elevations

The final still water exceedence probabilities for each of the inland grid cells were calculated by summing all the MX files, weighing each elevation with the appropriate probability. Thus, for each cell, the exceedence probability statistics were calculated. From these statistics, the water elevation for a fixed annual probability of rise in water level could be found. Thus, for an annual exceedence probability of .01, the elevation was interpolated from the exceedence statistics. The annual probability of .01 corresponds to an average return period of 100 years. The water elevations having annual exceedence probabilities of .002, .02, .04, and .1 were also interpolated for the average return periods of 500, 50, 25, and 10 years respectively.

The final flood elevations for each cell for average return period of 10, 25, 50 100, and 500 years are presented in the user manual, Volume II of this report. The manual contains instructions for the use of the table.

DISCUSSION OF RESULTS

Data Base

The data used in the study were obtained from a variety of sources having different dates. These data are critical to the accurate prediction of hurricane flood levels in coastal Louisiana. These data were not all checked during the calibration phase of the study. Calibration is particularly sensitive to the hydraulic properties of the rivers and channels in the study area, both because the calibration data is taken in waterways and because all stages of flooding effect waterway water elevations. The ground elevation and roughness properties of marsh areas of the study area could not be as well documented as barrier and river data, nor were there many observations of flooding in marsh areas. Thus, while the marsh areas comprise the vast majority of the area in the study site and have an important effect on flooding, it is the least accurately determined component of the data base.

Model

The surge model used appears to be very well suited to the purposes of this study. It was capable of accommodating the significant landscape features of coastal Louisiana and performed well. Certain limitations of the model exist which could have had a small effect on the computed flood elevations.

The model limits the number of grid cells, barriers, and rivers that can be included in the computations. This prevented some small sub-grid scale features from being included in the modeling. Instabilities during simulations developed during the set-up of the sensitivity runs that required re-assignment of some land elevations near rivers. No difficulties were encountered in the calibration or production runs once these changes were made.

Use of the Model

The set up of the grids based upon the Lambert coordinates was very convenient and allowed the grids to be referenced on virtually any topographic maps. The NOS charts, however, do not include Lambert tick marks and so the use of these charts required manual plotting of Lambert coordinates. The grid sizes used appear to be adequate for the purpose of simulating extreme hurricane surges. For less severe storms, water movement would be influenced by smaller channels than could be represented at the 10,000-foot resolution.

CONCLUSIONS AND RECOMMENDATIONS

Based upon the data base and methodology used in this study it can be concluded that:

1. The hurricane flood elevations in Louisiana indicate that flooding of transportation facilities in coastal Louisiana will be severe enough to require incorporation into design of new facilities.
2. The landscape changes taking place in coastal Louisiana are of sufficient magnitude to modify the threat of hurricane flooding to transportation facilities in this area.

It is recommended that the predicted flood elevations statistics be periodically updated by recomputing the flood statistics using new data as it becomes available. The new data should include new landscape features, such as highways, levees and channels. Also any major changes in the landscape of the coastal zone of Louisiana that are now being planned by the Coastal Restoration Division of DNR will certainly have an effect on hurricane flood elevations and should be incorporated into the model. This update would involve preparing a new users manual which would need to be distributed to the appropriate LaDOTD offices.

It is also recommended that the acquisition of new data for the marsh areas of the coast be initiated and that the data be incorporated into the data base for the model. Specifically, this would include obtaining marsh water level and ground level data referenced to a suitable datum such as the latest NGVD. Data could routinely be obtained from professional surveyors who in the course of their work would survey marsh areas. Also, several federal, state, and local governmental agencies are involved in monitoring water levels within marsh areas. In particular, the Coastal Restoration Division of the Department of Natural Resources is instrumenting several marsh sites in coastal Louisiana with tide gauges. The data from these sources of opportunity would be very useful in the future for updating the hurricane flood elevation statistics.

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