U. S. ARMY CORPS OF ENGINEERS

LAKE PONTCHARTRAIN, LOUISIANA AND VICINITY
DESIGN MEMORANDUM NO. 1
HYDROLOGY AND HYDRAULIC ANALYSIS

PART II - BARRIER

Prepared in the Office of the District Engineer
New Orleans District, Corps of Engineers
New Orleans, Louisiana

August 1967

LMVED-TD (NOD 7 Aug 67) 3d Ind
SUBJECT: Lake Pontchartrain, Louisiana and Vicinity, Design Memorandum No. 1, Hydrology and Hydraulic Analysis, Part II - Barrier

DA, Lower Miss. Valley Div, CE, Vicksburg, Miss. 39180 23 Oct 67

TO: District Engineer, New Orleans, ATTN: LMNED-PP

Referred to note approval.

FOR THE DIVISION ENGINEER:

A. J. DAVIS
Chief, Engineering Division

ENGCW-EZ (LMNED-PP, 7 Aug 67) 2nd Ind
SUBJECT: Lake Pontchartrain, Louisiana and Vicinity, Design Memorandum No. 1, Hydrology and Hydraulic Analysis, Part II - Barrier

DA, CofEngrs, Washington, D. C., 20315, 18 October 1967

TO: Division Engineer, Lower Mississippi Valley Division

Approved.

FOR THE CHIEF OF ENGINEERS:

wd Incl

WENDELL E. JOHNSON
Chief, Engineering Division
Civil Works

LMVED-TD (NOD 7 Aug 67)   1st Ind

SUBJECT: Lake Pontchartrain, Louisiana and Vicinity, Design Memorandum No. 1, Hydrology and Hydraulic Analysis, Part II - Barrier

DA, Lower Miss. Valley Div, CE, Vicksburg, Miss. 39180 24 Aug 67

TO: Chief of Engineers, ATTN: ENGCW-V/ENGCW-E

Subject design memorandum is forwarded for review and approval pursuant to paragraph 17, ER 1110-2-1150. Approval is recommended.

FOR THE DIVISION ENGINEER:

1 Incl
wd 2 cy

A. J. DAVIS
Chief, Engineering Division

Copy furnished:
NOD, ATTN: LMNED-PP

DEPARTMENT OF THE ARMY
NEW ORLEANS DISTRICT, CORPS OF ENGINEERS
P. O. BOX 60267
NEW ORLEANS, LOUISIANA 70160

IN REPLY REFER TO
LMNED-PP

7 August 1967

SUBJECT: Lake Pontchartrain, Louisiana and Vicinity, Design Memorandum No. 1, Hydrology and Hydraulic Analysis, Part II - Barrier

TO: Division Engineer, Lower Mississippi Valley
ATTN: LMVED-TD

1. Forwarded herewith for review and approval, in accordance with the provisions of ER 1110-2-1150, is the subject design memorandum.

2. Approval of this memorandum is recommended.

1 Incl (9 cys)
DM No. 1

THOMAS J. BOWEN
Colonel, CE
District Engineer

LAKE PONTCHARTRAIN, LOUISIANA AND VICINITY
DESIGN MEMORANDUM NO. 1
HYDROLOGY AND HYDRAULIC ANALYSIS

PART II - BARRIER

STATUS OF DESIGN MEMORANDA

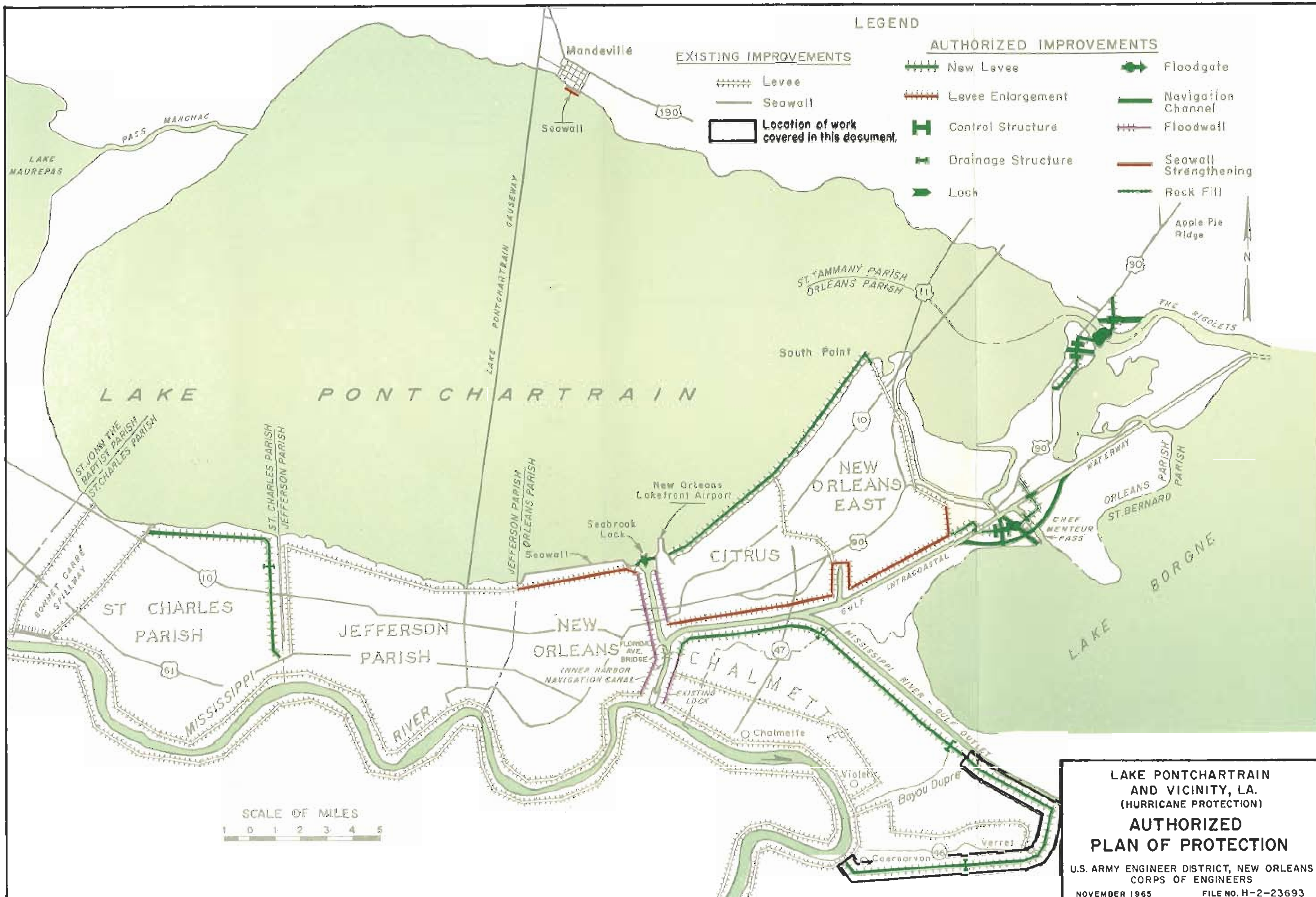
Design memo No.	Title	Status
1	Hydrology and Hydraulic Analysis	
	Part I - Chalmette	Approved 27 Oct 66
	Part II - Barrier	Submitted Aug 67
	Part III - Lakeshore	Scheduled Feb 68
	Part IV - Chalmette Extension	Scheduled Sep 67
2	Lake Pontchartrain Barrier Plan, GDM, Advance Supplement, Inner Harbor Navigation Canal Levees	Submitted Mar 67
2	Lake Pontchartrain Barrier Plan, GDM, Citrus Back Levee	Scheduled Aug 67
2	Lake Pontchartrain Barrier Plan, GDM, Supplement No. 1, Lake Pontchartrain Barrier, Rigolets Control Structure, Closure Dam, and Adjoining Levees	Scheduled Mar 68
2	Lake Pontchartrain Barrier Plan, GDM, Supplement No. 2, Lake Pontchartrain Barrier, Rigolets Lock and Adjoining Levees	Scheduled Mar 68
2	Lake Pontchartrain Barrier Plan, GDM, Supplement No. 3, Lake Pontchartrain Barrier, Chef Menteur Complex	Scheduled Mar 68
2	Lake Pontchartrain Barrier Plan, GDM, Supplement No. 4, New Orleans East Back Levees	Scheduled Jul 68
2	Lake Pontchartrain Barrier Plan, GDM, Supplement No. 5, Orleans Parish Lakefront Levees	Scheduled Apr 70

STATUS OF DESIGN MEMORANDA (cont'd)

Design memo No.	Title	Status
2	Lake Pontchartrain Barrier Plan, GDM, Supplement No. 6, St. Charles Parish Lakefront Levees	Scheduled Dec 68
2	Lake Pontchartrain Barrier Plan, GDM, Supplement No. 7, St. Tammany Parish, Mandeville Seawall	Scheduled Feb 71
2	Lake Pontchartrain Barrier Plan, GDM, Supplement No. 8, IHNC Remaining Levees	Scheduled Nov 67
3	Chalmette Area Plan, GDM	Approved 31 Jan 67
3	Chalmette Area Plan GDM, Supplement No. 1, Chalmette Extension	Scheduled Feb 68
4	Lake Pontchartrain Barrier Plan & Chalmette Area Plan, GDM Florida Avenue Complex, IHNC	Not scheduled
5	Chalmette Area Plan, DDM, Bayous Bienvenue and Dupre Control Structures	Scheduled Jan 68
6	Lake Pontchartrain Barrier Plan, DDM, Rigolets Control Structure and Closure	Scheduled Jan 69
7	Lake Pontchartrain Barrier Plan, DDM, Chef Menteur Control Structure and Closure	Scheduled Jan 69
8	Lake Pontchartrain Barrier Plan, DDM, Rigolets Lock	Scheduled Feb 69
9	Lake Pontchartrain Barrier Plan, DDM, Chef Menteur Navigation Structure	Scheduled Dec 68
10	Lake Pontchartrain Barrier Plan, DDM, Gantry Crane - Chef Menteur Control Structure	Scheduled Jan 70

STATUS OF DESIGN MEMORANDA (cont'd)

Design memo No.	Title	Status
11	Lake Pontchartrain Barrier Plan, DDM, St. Charles Parish Drainage Structure	Scheduled Jan 70
12	Sources of Construction Materials	Approved 30 Aug 66
13	Lake Pontchartrain Barrier Plan, DDM, Gantry Crane - Rigolets Control Structure	Scheduled Jul 70
14	Beautification	Not scheduled
1	Lake Pontchartrain, La. and Vicinity, and Mississippi River-Gulf Outlet, La., GDM, Seabrook Lock	Scheduled Feb 68
2	Lake Pontchartrain, La. and Vicinity, and Mississippi River-Gulf Outlet, La., DDM, Seabrook Lock	Scheduled Oct 68


LEGEND
EXISTING IMPROVEMENTS
Levee
Seawall
Location of work covered in this document.
AUTHORIZED IMPROVEMENTS
New Levee
Levee Enlargement
Control Structure
Drainage Structure
Lock
Floodgate
Navigation Channel
Floodwall
Seawall Strengthening
Rock Fill
Mandeville
Seawall
190
PASS MANCHAC
LAKE MAUREPAS
LAKE PONTCHARTRAIN CAUSEWAY
LAKE PONTCHARTRAIN
Apple Pie Ridge
90
N
ST. TAMMANY PARISH
ORLEANS PARISH
11
THE RIGOLETS
South Point
10
NEW ORLEANS EAST
90
WATERWAY
ORLEANS PARISH
ST. BERNARD PARISH
CHEF MENTEUR PASS
New Orleans Lakefront Airport
Seabrook Lock
Seawall
CITRUS
90
GULF INTRACOASTAL
LAKE BORGNE
ST. JOHN THE BAPTIST PARISH
ST. CHARLES PARISH
ST. CHARLES PARISH
JEFFERSON PARISH
JEFFERSON PARISH
ORLEANS PARISH
BONNET CARRE SPILLWAY
10
ST CHARLES PARISH
JEFFERSON PARISH
NEW ORLEANS
FLORIDA AVE. BRIDGE
INNER HARBOR NAVIGATION CANAL
EXISTING LOCK
47
CHALMETTE
MISSISSIPPI RIVER - GULF OUTLET
61
MISSISSIPPI RIVER
Chalmette
Violet
Bayou Dupre
Verret
46
Caernarvon
SCALE OF MILES
1 0 1 2 3 4 5
LAKE PONTCHARTRAIN AND VICINITY, LA.
(HURRICANE PROTECTION)
AUTHORIZED PLAN OF PROTECTION
U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS
NOVEMBER 1965
FILE NO. H-2-23693

REV. MAY 1967

LAKE PONTCHARTRAIN, LOUISIANA AND VICINITY
DESIGN MEMORANDUM NO. 1
HYDROLOGY AND HYDRAULIC ANALYSIS

PART II - BARRIER

TABLE OF CONTENTS

TABLE OF CONTENTS (cont'd)

TABLES

PLATES

GLOSSARY

ASTRONOMICAL TIDE - See PREDICTED NORMAL TIDE.

ATMOSPHERIC PRESSURE ANOMALY - The difference between atmospheric pressure at any point within the hurricane and normal pressure at the periphery of the hurricane.

BUILDUP - The increase, in feet, over that from other causes, of water surface elevation in a body of water resulting from:

a. Convergence in depth or width
b. Construction of a barrier
c. Ponding

CENTRAL PRESSURE INDEX - A parameter of hurricane intensity which reflects the minimum atmospheric pressure attained within the eye of a particular hurricane.

FETCH - The continuous area of water over which the wind blows in essentially a constant direction. Often used synonomously with FETCH LENGTH.

FETCH LENGTH - The horizontal distance over which the wind from a fixed direction may have unobstructed contact with the water surface.

HURRICANE - A cyclonic storm, usually of tropical origin, containing winds of 75 miles per hour or more.

a. DESIGN HURRICANE - That hurricane selected by the reporting office as a basis for design of the proposed plan of improvement.

b. STANDARD PROJECT HURRICANE - A hypothetical hurricane intended to represent the most severe combination of hurricane parameters that is reasonably characteristic of the region involved, excluding extremely rare combinations.

c. PROBABLE MAXIMUM HURRICANE - A hypothetical hurricane that might result from the most severe combination of hurricane parameters that is considered reasonably possible in the region involved. This hurricane is substantially more severe than the standard project hurricane and is seldom used as the controlling consideration in design.

d. MODERATE HURRICANE - A hurricane that may be expected from a combination of hurricane parameters that is frequently experienced in the region.

e. TRANSPOSED HURRICANE - A storm transferred from actually observed location to another location for the purpose of study, with appropriate changes in storm characteristics.

HURRICANE TRACK - The line connecting successive locations of central pressure of the hurricane.

HURRICANE SPEED - The rate of forward movement of the hurricane eye in knots or miles per hour.

HURRICANE SURGE - The mass of water causing an increase in elevation of the water surface above normal tide at the time of a hurricane.

HURRICANE SURGE HEIGHT - The elevation of the stillwater level at a given point resulting from normal tide and hurricane surge action. It may be the result of one or more of the following components:

a. Predicted normal tide
b. Pressure setup
c. Setup due to winds over the continental shelf
d. Buildup

In inland lakes, hurricane surge height is the average lake level and does not include local wind setup.

HURRICANE TIDE - The elevation of the stillwater level at a given point during a hurricane. In inland lakes, it is the sum of hurricane surge height and additional local wind setup.

ISOVEL - Line connecting points of simultaneous equal wind velocities and in this report represents a 5-minute average, 30 feet above ground level.

KNOT - A velocity equal to one nautical mile (6,080 feet) per hour, or about 1.15 statute miles per hour.

LANDFALL - The arrival of a hurricane center at the coastline.

OVERTOPPING - The amount of water passing over the top of a structure as a result of wave runup or surge action.

GLOSSARY (cont'd)

PREDICTED NORMAL TIDE - The periodic rising and falling of the water that results from gravitational attraction of the moon and sun acting upon the rotating earth.

PRESSURE SETUP - A rise in the surface of a large body of water caused by a measurable reduction in local atmospheric pressure at sea level.

RANGE - An imaginary line representing the centerline of a narrow fetch over which the hurricane surge height is computed.

RUNUP - The vertical elevation above stillwater level to which water rises on the face of a structure as a result of wave action.

SETDOWN - The decrease in water surface elevation behind a water-retaining barrier or at a windward shore due to wind action.

SETUP - The vertical rise in the stillwater level, above that which would occur without wind action, caused by wind stresses on the surface of the water.

SIGNIFICANT WAVE - A statistical term denoting waves having the average height and period of the highest one-third waves of a given wave train.

STILLWATER LEVEL - The elevation of the water surface if all wave action were to cease.

STORM SURGE - Same as HURRICANE SURGE, except that it may be caused by storms not of hurricane characteristics as well as by hurricanes.

WAVE HEIGHT - The vertical distance between the crest and the preceding trough. (Referenced to significant waves in this report.)

WAVE ORTHOGONAL - An imaginary line, drawn normal to each individual line of a system representing, in plan presentation, the locations of the crests of each individual wave of a given wave train.

WAVE SETUP - The superelevation of the water surface above the hurricane surge height due to wave action alone.

WAVE TRAIN - A series of waves from the same direction.

WIND SETUP - Same as SETUP.

WIND TIDE LEVEL - Same as STILLWATER LEVEL.

LAKE PONTCHARTRAIN, LOUISIANA AND VICINITY
DESIGN MEMORANDUM NO. 1
HYDROLOGY AND HYDRAULIC ANALYSIS

PART II - BARRIER

SECTION I - GENERAL

1. Project authorization. The project was authorized under Public Law 298, 89th Congress, 1st Session, approved 27 October 1965. General information and basic data on the entire project are available in House Document No. 231, 89th Congress, 1st Session. A number of significant changes in the plans presented in the House Document have been developed during detailed planning and incorporated into the project as departures from the project document plan within the discretionary authority of the Chief of Engineers. These changes include the following:

a. The controlling elevation of the Seabrook Lock was changed from 13.2 feet m.s.l. to 7.2 feet m.s.l.* (Ref. LMNED-PP letter dated 19 October 1966 subject "Lake Pontchartrain, La. and Vicinity - Report on Controlling Elevation of Seabrook Lock" and indorsements thereto.)

b. The Chalmette Area Plan was expanded to include a larger protected area. (Ref. LMNED-PR letter dated 29 November 1966 subject "Lake Pontchartrain, La. & Vicinity - Modification of the Chalmette Area Plan to Include Larger Area" and indorsements thereto.)

c. The Lake Pontchartrain Barrier was relocated between New Orleans East and the east bank of Chef Menteur Pass. (Ref. LMNED-PP letter dated 13 March 1967 subject "Lake Pontchartrain, La. and Vicinity - Evaluation of Alternate Plans Involving Modifications in the Alignment of the Lake Pontchartrain Barrier" and indorsements thereto.)

2. Purpose and scope. Initially, it was planned to present the Hydrology and Hydraulic Analysis Design Memorandum for the Lake Pontchartrain, Louisiana and Vicinity, project, in a series of three separate reports subtitled Part I - Chalmette, Part II - Barrier,

*mean sea level, the datum to which all elevations in this memorandum are referenced, unless otherwise indicated.

and Part III - Lakeshore. As previously mentioned, subsequent to completion of Part I, the project was modified, under the discretionary authority of the Chief of Engineers, to enlarge the protected area of the Chalmette Area Plan; accordingly, Part IV - Chalmette Extension will be prepared to cover the hydraulics of this enlargement. In Part I - Chalmette, the climatology and hydrology for the entire project area and the development of design elevations for the Chalmette, Inner Harbor Navigation Canal, Citrus Back, and New Orleans East back protection works were presented. This document, Part II - Barrier, includes the description and analyses of essential data, assumptions, and criteria used for, and the results of, studies which provide the bases for determining design surge heights, runup, overtopping, and frequencies for the Lake Pontchartrain Barrier. Also included are the average levels of Lake Pontchartrain for the design hurricane on different tracks. These levels reflect the influence of barrier overtopping, direct rainfall, and tributary inflow, and will be used in the hydraulic design of the lakeshore protection to be covered in Part III - Lakeshore.

3. <u>Description</u>.

a. The project area, as shown on plate 1, is located in southeastern Louisiana in the vicinity of New Orleans. The dominant topographic feature is Lake Pontchartrain, a shallow tidal basin approximately 640 square miles in area and averaging 12 feet in depth. Lake Pontchartrain is connected to the Gulf of Mexico through Chef Menteur Pass and the Rigolets, Lake Borgne, and Mississippi and Chandeleur Sounds, and also is connected with lesser Lake Maurepas to the west. Chef Menteur Pass and the Rigolets have developed naturally deep and wide channels having adequate capacity for normal tidal flows and discharges of tributary flow.

b. The area along the south shore of Lake Pontchartrain is essentially uniform in topography. The land slopes gently downward from an average elevation 12 feet along the natural banks of the Mississippi River to approximately sea level near the lakeshores. All of this area is protected from the river overflow by the main line Mississippi River levee system and most of the area is afforded partial protection from tidal overflow. Runoff within the protected areas is pumped into the lake and the pumping operations have lowered the ground water surface causing subsidence of natural ground elevations to as much as -7 by drying the highly organic soils above the water table.

4. Problem.

a. The area surrounding Lake Pontchartrain is susceptible to flooding from wind-driven hurricane tides from the lake. This condition is aggravated by increases in lake level resulting from the influx of tidal surges from Lake Borgne and the Gulf of Mexico that accompany hurricanes from the southeast, south, and southwest. The occurrence of a standard project hurricane critical to the south shore of Lake Pontchartrain would result in an 11-foot surge in Lake Borgne. This surge would enter Lake Pontchartrain through the Rigolets and Chef Menteur passes, and the Inner Harbor Navigation Canal, raising the average lake elevation by as much as 6 feet.

b. As the hurricane winds blow over the surge-elevated lake, wind tides and waves would be generated against the south shore causing overtopping of all existing protective works and massive ponding in the developed areas. Much of the developed area in the New Orleans area is below mean sea level, some land being as low as 7 feet below and a considerable portion more than 2 feet below. Because of these low elevations, flooding as deep as 16 feet would result from overtopping in a standard project hurricane.

c. On several occasions, the marsh area between Lake Borgne and Lake Pontchartrain has been flooded up to elevations of 11 feet. Prior to 1966, these stages, especially during hurricane "Betsy," have caused overtopping of the then existing Chalmette back levee, the Inner Harbor Navigation Canal levees, and the Citrus and New Orleans East back levees.

5. Plan of protection. The authorized plan of protection is described in the following subparagraphs and shown on plate 2.

a. A barrier will be constructed along the east shore of Lake Pontchartrain extending from the New Orleans levee system to high ground in St. Tammany Parish to control hurricane-generated stages in the lake. Included as parts of the barrier will be navigation and control structures in Chef Menteur Pass and the Rigolets. Existing protective works along the south shore of the lake will be raised, strengthened, and extended. A lock will be constructed at the lakeward end of the Inner Harbor Navigation Canal to alleviate high velocities in the canal, control salt water intrusion into Lake Pontchartrain, and control the entry of hurricane tides into the lake. Protective systems facing Lake Borgne, including the levees along the Inner Harbor Navigation Canal, the Gulf Intracoastal Waterway, and the Mississippi River-Gulf Outlet will be raised and strengthened to provide adequate protection.

The existing seawall at Mandeville on the north shore will be strengthened.

b. A new levee along the south bank of the Mississippi River-Gulf Outlet from the Inner Harbor Navigation Canal to Bayou Dupre, thence returning to the Mississippi River levee at Violet, La., was authorized for the Chalmette area. As previously explained, a departure from the authorized plan to extend the levee along the Gulf Outlet to a point north of Verret, thence to Verret and returning south of Highway 46 to the Mississippi River at Caernarvon, La., has been adopted.

SECTION II - CLIMATOLOGY AND HYDROLOGY

6. Climatology. The project area is located in a subtropical latitude having mild winters and hot, humid summers. Prevailing southerly winds produce conditions favorable to convective thundershowers in the summer season, and in the colder season, frontal passages produce squalls and sudden temperature changes. Refer to Part I - Chalmette of this memorandum for a more detailed discussion of temperature, rainfall, and wind in the project area.

7. Hydrology. The water level in Lake Pontchartrain is subject to variations from direct rainfall, tributary inflow, wind-driven water movements, and flow through Chef Menteur Pass, the Rigolets, and the Inner Harbor Navigation Canal caused by tidal variations originating in the Gulf of Mexico. Infrequently, lake level is influenced by diversion of Mississippi River floodflow through Bonnet Carre' Spillway. Combinations of these factors determine the salinity regimen in the lake. A detailed discussion of project area hydrology is given in Part I - Chalmette.

SECTION III - TIDAL HYDRAULIC DESIGN

8. Barrier structures.

a. General. The purpose of the barrier complex is to lower hurricane tides in Lake Pontchartrain by reducing inflows from Lake Borgne. The barrier alignment, as shown on plate 2, is a departure from the authorized alignment and will extend along the eastern boundary of Lake Pontchartrain with navigation and gated control structures at Chef Menteur Pass and the Rigolets and a lock at Seabrook. Some overtopping of the barrier will occur during the design hurricane and the amount of this overtopping must be known so the average level of Lake

Pontchartrain can be determined. The average level of the lake is used in computations for the hydraulic design of the lakeshore protective system. For economic reasons, each gated control structure will provide a clear opening equal to 25 percent of the existing cross-sectional area of the waterway in which it is located. A model study was made by the U. S. Army Engineer Waterways Experiment Station to determine the effects of the gated control structures in Chef Mentuer Pass and the Rigolets and of the Mississippi River-Gulf Outlet channel on the salinity and flow regimens of Lake Pontchartrain. It was concluded from the model study that construction of gated structures in Chef Menteur Pass and the Rigolets which would reduce the cross-sectional area to 25 percent of the original cross-sectional area would cause no appreciable change in the salinity of Lake Pontchartrain nor would it interfere with tidal interchange or tributary outflow. It was also concluded that a gated structure (Seabrook Lock) to be installed at the lakeward end of the Inner Harbor Navigation Canal could be operated in such a manner that, by increasing or decreasing the discharge through the structure, the salinity regimen in Lake Pontchartrain could be varied over a wide range to produce desirable conditions insofar as the propagation of fish and wildlife and other renewable resources such as clamshells is concerned.

b. Barrier levee. The levee will have a crown elevation of 9 feet and will extend from the existing New Orleans East levee to high ground northeast of the Rigolets. East of Chef Menteur Pass, the embankment of U. S. Highway 90 will, where its grade is adequate, serve, without modification, as the barrier. Levee construction adjacent to the highway will be required where the grade of the highway embankment is less than 9 feet. The location of new levees to be constructed along the barrier alignment is shown on plate 2.

c. Chef Menteur Pass. The barrier complex at Chef Menteur Pass consists of a gated control structure and approach channels, navigation floodgate and approach channels, closure dam, and flanking and connecting levees. The gated control structure, navigation floodgates, and closure dam will have crest elevations of 14 feet. The levees adjacent to the structures and the closure dam will have a crest elevation of 14 feet for a minimum distance of 100 feet, and the levee connecting the closure dam and the control structure will have a crest elevation of 14 feet throughout its length.

d. Rigolets. The barrier complex at the Rigolets will be similar to that at Chef Menteur Pass except that a navigation lock will replace the floodgate. Incorporated into the structure will be a roadway for the relocation of U. S. Highway 90. A more detailed description of the barrier levees and structures will be found in General Design Memorandum No. 2, Lake Pontchartrain Barrier Plan, scheduled for submission in August 1967.

9. Storm surges.

a. General. The method of computing surges was fully described in Part I - Chalmette and will only be summarized herein. In determining critical conditions for the various subareas of the Lake Pontchartrain, Louisiana and Vicinity, project, different hurricane tracks are used. Tracks, A, C, and F are critical to the south shore, north shore, and barrier, respectively, and are used in the hydraulic design of the various features of the protective system at the respective subarea. Tracks A, C, and F along with tracks of the more significant historical hurricanes are shown on plate 3.

b. Synthetic storms. Parameters for certain synthetic storms and methods for derivation of others were furnished by the U. S. Weather Bureau. The standard project hurricane (SPH) is used as the design hurricane for all locations in the project area, the track and forward speed being changed as appropriate. Tracks A, C, and F give three synthetic storms(1)(2)(3)* and they were derived as discussed in paragraph 8.c. of Part I - Chalmette. Table 1 shows the characteristics of the design hurricane for the three tracks. Plates 4, 5, and 6 show isovel patterns for the design hurricane on tracks A, C, and F, respectively, at the hour of maximum storm surge at the barrier. The original SPH isovel patterns were revised based on recent studies by the U. S. Weather Bureau(4)(5)(6).

c. Surges. Maximum surge heights along the barrier were computed by use of a general wind tide formula based on the steady state concept of water superelevation(7)(8)(9) as described in paragraph 8.d. of Part I - Chalmette. Table 2 shows the maximum surge heights computed for Long Point, La.(see plate 1), the location selected as the critical point for surges at the barrier.

*Numbers in parentheses indicate references in Section IV - Bibliography.

10. Development of stage hydrographs.

a. General. The development of stage hydrographs in Lake Borgne at the barrier for tracks A, C, and F is necessary so that determinations of barrier overtopping can be made. Barrier overtopping for tracks A and C must be computed so that the average level of Lake Pontchartrain for both tracks can be determined. These lake levels will be used in the hydraulic design of the protective system along the shores of the lake which will be covered in Part III - Lakeshore. The rate of barrier overtopping for track F is required for a study of barrier slope protection.

TABLE 1
DESIGN HURRICANE CHARACTERISTICS

Track*	C.P.I. inches	Radius of maximum winds nautical miles	Forward speed knots	Max.** wind m.p.h.	Direction of approach
A	27.6	30	6	100	South
C	27.6	30	5	100	SSE
F	27.6	30	11	100	East

* Tracks are shown on plate 3.
**Referenced to 30 feet above the surface.

TABLE 2
SURGE HEIGHTS AT LONG POINT, LA.

Track	Surge adjustment factor (Z)	Time from landfall to maximum surge height hours	Maximum surge height feet
A	0.21	+4	10.50
C	0.21	+2	10.75
F	0.21	+2	12.80

b. Synthetic hydrographs. Prerequisite to any overtopping computation, the choice of an actual or hypothetical hurricane of known or designated characteristics must be made. It is then possible to develop hourly surge heights for any point in Lake Borgne for the selected storm. Long Point, which is east of the mouth of the Rigolets, was selected as the critical point for a hydrograph. The hydrograph for Long Point reflects stages at the mouths of both the Rigolets and Chef Menteur Pass and the marshland between. Construction of the hydrograph of hourly stages was based generally on a method developed by R. O. Reid[10]. In a modification of Reid's method, the maximum surge height computed by the incremental setup method was used as the peak of the hydrograph for the critical hour. A comparison of the rising portion of the hydrograph thus derived with one obtained by computing surge heights at hourly intervals indicated agreement between the two methods. Final stages for the recession portion of the hydrograph could not be computed by the incremental setup method because of the offshore wind directions prevailing after the peak stage. The recession produced by Reid's method, obtained by rotating the hydrograph about the peak ordinate, indicated stages considerably lower than the recession portion of observed stage hydrographs for experienced hurricanes. It was therefore necessary to base the shape of the recession portion of the synthetic hydrographs upon the shape of observed hydrographs. Storm surge hydrographs for Long Point for the design hurricane on tracks A, C, and F were determined by the above procedures and are shown on plate 7.

11. Description of overtopping computation procedures.

a. The amount of wave overtopping of a protective structure depends on the characteristics of the structure (i.e., shape and roughness), the wave characteristics, and the depth of water at the structure. Computations were made to determine wave overtopping of the barrier by the design hurricane.

b. In order to compute wave overtopping of a protective structure, the significant wave height (H_s) and wave period (T) in the vicinity of the structure must be known. They were determined according to Bretschneider[11] and as described in paragraph 1.25 of reference (7) in the bibliography. The windspeed and depth used in determining H_s and T were average values over a 5-mile fetch. Data used to determine significant wave characteristics in the vicinity of the barrier for tracks A, C, and F at the critical hour are shown in table 3.

TABLE 3
DATA USED TO DETERMINE WAVE CHARACTERISTICS AT BARRIER
DESIGN HURRICANES

Pertinent factor	Tracks A	Tracks C	Tracks F
F - Length of fetch, miles	5	5	5
U - Windspeed, m.p.h.	80	84	91
swl - Stillwater elevation, feet	10.50	10.75	12.80
d - Average depth of fetch, feet	10.00	10.25	12.30
d_t - Depth at toe of structure, feet	10.00	10.25	12.30

c. Wave overtopping was calculated by use of model study data developed by Saville[12]. The average depth (d) of the 5-mile fetch is shown in table 3 and the significant wave height (H_s) and wave period (T) can be determined from the data in table 3. The equivalent deepwater wave height (H_o') can be determined from table D-1 of reference (7) in the bibliography, which relates d/L_o to H/H_o'. The deepwater wave length (L_o) is determined from the equation:

$$L_o = 5.12\ T^2$$

When determining overtopping from the significant wave, H in the term H/H_o' is equal to H_s. Significant wave characteristics used in computing overtopping for tracks A, C, and F at the critical hour are shown in table 4.

TABLE 4
WAVE CHARACTERISTICS AT BARRIER
DESIGN HURRICANE

Characteristics		Tracks		
		A	C	F
H_s	- Significant wave height, feet	4.2	4.3	5.3
T	- Wave period, seconds	5.0	5.1	5.6
L_o	- Deepwater wave length, feet	128	133	161
d/L_o	- Relative depth	0.07813	0.07707	0.07640
H_s/H_o'	- Shoaling coefficient	0.9574	0.9590	0.9601
H_o'	- Deepwater wave height, feet	4.4	4.5	5.5

d. With the terms d_t, H_o', and T known, overtopping of a protective structure can be computed if the slope of the structure is known. Typical levee configurations used in the barrier overtopping computations are shown on plate 8. Where levees have stabilizing berms, these berms break the continuity of the levee slope and Saville's[13] method of determining hypothetical slopes was used (see plate 9). In using this method, the actual composite slope is replaced by a hypothetical single constant slope. This hypothetical slope is the slope of a line from the point where the wave breaks to the crown of the levee. The breaking depth is determined from the equation:

$$d_b = \frac{0.667\ H_o'}{(H_o'/T^2)^{1/3}}$$

Using this hypothetical slope, a value of overtopping is determined.

e. In nature, waves are not of uniform height, but vary substantially over a relatively wide height spectrum. However, rates of wave overtopping calculated by use of model study data are based on a train of waves of uniform height. It was then necessary to reduce these rates in order to obtain rates corresponding to a natural spectrum of wave heights. The spectrum used was presented by Saville[14] as follows:

H/H_s	Percent
1.58	2
1.23	8
0.90	23
0.65	17
0.48	25
0.31	13
0.18	12

Overtopping rates were then computed for each increment of wave height and the total volume for the spectrum obtained. The significant wave and the spectrum wave rates determined for the same segment of shore and period of time were then compared to determine a reduction factor to be used in reducing overtopping rates for the significant wave. Computations were made for several different hours including the critical hour and an average reduction factor was derived for each segment of the barrier. These reduction factors were applied to subsequent computations of overtopping rates based on significant wave heights and varied between 40 and 50 percent, dependent upon wave and structure characteristics.

f. The overtopping rates per foot of structure thus computed were applicable for waves whose orthogonals were normal to the structure alignment. However, when wind directions and wave orthogonals were other than normal to a structure face, the adjustment in overtopping volumes to compensate for the angle of incidence was necessary. The equivalent length of structure was considered to be its length along an airline alignment between both ends. This length was multiplied by the cosine of the angle between wind direction at any given time and a normal to the structure in order to obtain the effective length of structure that is parallel to the wave front and is subject to wave overtopping rates. Varying angles of incidence were used from hour to hour as the wind direction shifted with the passage of the hurricane.

g. Total overflow of the barrier was computed by using a combination of free flow and wave overtopping methods. The application of these methods was as follows:

(1) Case 1. Until the time that the surge height exceeds the elevation of the protective structure, the quantity of flow, Q, over the structure is caused by waves breaking and running up and over the control works. This quantity was calculated as described in paragraphs 11.a. through 11.f. above. The overflow due to wave runup increases as the surge height approaches the crown elevation of the structure and reaches its maximum when the surge elevation equals the crown elevation.

(2) Case 2. When the surge height is at such an elevation that all wave troughs clear the structure, the flow over the structure is unaffected by waves. This condition exists when the hurricane surge reaches an elevation approximately one-half of the wave height above the crown elevation of the structure. The Q for this case was calculated as free flow over a weir, using the appropriate weir formulas(15)(16). The total length of the barrier was used in computing free flow.

(3) Case 3. For surge elevations between the structure crest and an elevation one-half of the wave height above the structure crest, the total overtopping is the sum of both free flow and wave overtopping. The rate of free flow was computed as in Case 2. The rate of overtopping was determined by varying the overtopping rate linearly, using the maximum rate for a surge height at the structure crest as computed in Case 1, and a zero rate for a surge height at the elevation that is one-half of the wave height above the structure crest.

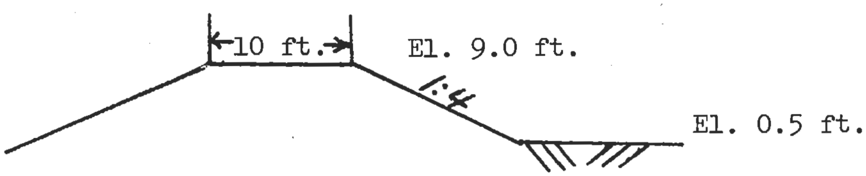
h. Barrier segments. The barrier was divided into segments to facilitate evaluation of variables having different values for each segment at any given time. An example of overtopping computations for a barrier segment is shown in table 5.

12. Rainfall.

a. Precipitation records, including but not limited to hurricane associated rainfall, indicate maximum 24-hour point depths of 21 inches for a standard project rainfall. Based on data available for about 52 gulf region hurricanes, the mean 24-hour maximum point precipitation depth is 9.4 inches. Since hurricanes are usually accompanied by intense rainfalls, it was necessary to estimate cumulative rainfall amounts in Lake Pontchartrain in order to determine the average lake level. The methods used for these rainfall estimates are described in HUR memorandums(17)(18).

TABLE 5
TYPICAL WAVE AND OVERTOPPING DATA (project in place)
DESIGN HURRICANE - TRACK A
Barrier levee segment

Hour	Wind m.p.h.	Av.depth ft.	H_s ft.	T sec.	L_o ft.	s.w.l. ft. m.s.l.	Q_{ff}* c.f.s./ft.	ff Vol ac-ft	Q_{ot} c.f.s./ft.	L Cos θ ft.	ot Vol. ac-ft	Total vol. ac-ft
-2	57	5.2	2.2	3.7	70	5.70	0		0	-		
								0			845	845
0	64	7.5	3.1	4.3	95	8.00	0		0.93	10,900		
								1,788			1,900	3,688
+2	71	9.2	3.7	4.8	118	9.75	1.95		1.15	11,000		
								6,774			1,700	8,474
+4	80	10.0	4.2	5.0	128	10.50	5.49		0.71	10,900		
								7,712			1,625	9,337
+6	78	9.5	4.0	4.9	123	10.00	3.00		1.08	10,900		
								2,725			1,660	4,385
+8	33	8.1	2.2	3.8	74	8.60	0		0.74	11,000		
								0			675	675
+10	24	6.0	1.4	3.1	49	6.50	0		0	-		



Total acre feet = 27,404
$*Q_{ff} = 3.0\ H^{1.49}$
L = 11,000 feet
H = s.w.l. - levee grade

LEGEND

Av.depth = depth + surge height
H_s = height of significant wave
T = wave period
L_o = deepwater wave length
s.w.l. = stillwater level

Q_{ff} = Q resulting from free flow
Q_{ot} = Q resulting from wave overtopping
L = length of protective work
θ = angle between wind direction and a normal to protective work

b. A moderate rainfall was selected for design purposes and on track A the SPH gives point precipitation depths of 8.5 inches for Jefferson Parish, 8.7 inches for New Orleans, and 9.6 inches for Citrus. The SPH track A areal precipitation for Lake Pontchartrain is 7.8 inches. Mass rainfall curves for the SPH on track A are shown on plate 10. Mass rainfall curves were used to determine cumulative rainfall amounts to any hour for Lake Pontchartrain. The same procedure was used to derive rainfall estimates for the SPH on tracks C and F.

13. Tributary inflow.

a. With the barrier structures closed, tributary inflow will increase the level of Lakes Pontchartrain and Maurepas. The increase must be determined so that protective works along the shores of Lake Pontchartrain can be properly designed.

b. A 20-year period of record was investigated and it was determined that the average daily tributary inflow during the hurricane season is 9,200 acre-feet. Knowing the daily tributary inflow, the increase in lake level resulting from the inflow can be determined for any duration of closure. Based on a study of past hurricanes that have occurred in the Gulf of Mexico, it was assumed that the barrier structures would be closed four days before the design hurricane reaches the vicinity of Lake Pontchartrain.

14. Lake level.

a. The average high tide in Lake Pontchartrain during the hurricane season is 1.4 feet. This stage was selected as the average level of Lake Pontchartrain at the time the control structures are closed.

b. Storage tables for a wide range of stages were made for Lakes Maurepas and Pontchartrain. The storage amounts include the volumes contained in the adjacent marsh areas when the stages exceed the surface elevations of these marshes. With the initial lake level of 1.4 feet known, the average level of Lake Pontchartrain can be determined at any hour by using the storage tables and adding the cumulative quantities for barrier overtopping, direct rainfall, and tributary inflow.

c. The average level of Lake Pontchartrain at the critical hour for track A is 2.3 feet. This level is obtained by adding to the initial level of 1.4 feet, 0.2 foot for barrier overtopping, 0.6 foot for direct rainfall, and 0.1 foot for tributary inflow. The level at the critical hour for track C is 2.9 feet, composed of the initial level of 1.4 feet, 0.7 foot for barrier overtopping, 0.7 foot for direct rainfall, and 0.1 foot for tributary inflow. Tracks A and C are critical to the south and north shores of Lake Pontchartrain, respectively, and the lake levels shown above will be used in Part III - Lakeshore to design the required protective works along the shores of the lake.

d. Track F is the most critical track to the barrier but it will not be used in designing the protective works along the shores of Lake Pontchartrain because the winds over the lake for this track are not so critical as those for tracks A and C, and because barrier overtopping occurs on track F after maximum winds have passed over the lake. Therefore, barrier overtopping for track F was investigated only to the extent necessary to determine maximum velocities over the embankment due to overtopping flow for use in determining requirements for erosion protection for the barrier features. It was determined that, during the storm peak, the maximum velocity of flow down the Lake Pontchartrain side of the embankment would be on the order of 15 to 20 feet per second.

15. Frequency estimates. The procedure developed for making frequency estimates is described in paragraph 9.a. of Part I - Chalmette. The SPH stage for track C has the same frequency as the SPH stage for track A.

16. Design hurricane. As previously stated in Part I - Chalmette, the standard project hurricane was selected as the design hurricane due to the urban nature of the project area. The controlling elevation of 9 feet for the barrier will allow some overtopping during the design hurricane; however, this overtopping will be considered in the design of protective works along the shores of Lake Pontchartrain.

SECTION IV - BIBLIOGRAPHY

(1) U. S. Weather Bureau, "Louisiana Hurricane of September 29, 1915, Transposed to a Critical Track," Memorandum HUR 7-40, September 6, 1957.

(2) U. S. Weather Bureau, "SPH Wind Field for Track C with a Rotated SPH Pattern," Memorandum HUR 7-62A, September 28, 1959.

(3) U. S. Weather Bureau, "SPH Wind Fields for Track F with Forward Speed 5 Knots Critical for Area I," Memorandum HUR 7-63, September 21, 1959.

(4) U. S. Weather Bureau, "Standard Project Hurricane Wind Field Patterns (revised) to Replace Existing Patterns in NHRP Report No. 33, for Zones B and C," Memorandum HUR 7-84, August 17, 1965.

(5) U. S. Weather Bureau, "Adjustments to SPH isovel patterns in Memoranda HUR 7-62, 7-62A, 7-63, 7-64, and 7-65," Memorandum HUR 7-85, November 3, 1965.

(6) U. S. Weather Bureau, "Ratio Chart to Adjust Isovel Patterns in HUR 7-40 to Level of Updated SPH Patterns," Memorandum HUR 7-85A, February 17, 1966.

(7) Beach Erosion Board Coastal Engineering Research Center, "Shore Protection Planning and Design," Technical Report No. 4, June 1966.

(8) Saville, Thorndike, Jr., "Wind Set-Up and Waves in Shallow Water." Beach Erosion Board, Technical Memorandum No. 27, June 1952.

(9) U. S. Army Engineer District, Jacksonville, "Design Memorandum, Wind Tides Produced by Hurricanes," Partial Definite Project Report, Central and Southern Florida Project, for Flood Control and Other Purposes, Part IV, Supplement 2, Section 3, July 26, 1956.

(10) Reid, Robert O., "Approximate Response of Water Level on a Sloping Shelf to a Wind Fetch which moves towards Shore," Beach Erosion Board, Technical Memorandum No. 83, June 1956.

(11) Bretschneider, C. L., "Prediction of Wind Waves and Set-Up in Shallow Water, with Special application to Lake Okeechobee, Florida," Unpublished Paper, Texas A&M College, August 1954.

(12) Saville, Thorndike, Jr., "Laboratory Data on Wave Run-Up and Overtopping on Shore Structures," Beach Erosion Board, Technical Memorandum No. 64, October 1955.

(13) Saville, Thorndike, Jr., "Wave Run-Up on Composite Slopes," Proc of the 6th Conference on Coastal Engineering, Council on Wave Research, University of California 1958.

(14) Saville, Thorndike, Jr., Inclosure to letter from Beach Erosion Board to U. S. Army Engineer District, New Orleans, 1 July 1958.

(15) Yarnell, D. L. and Nagler, F. A., "Flow of Flood Water over Railway and Highway Embankments," Public Roads, Vol. II, No. 2, April 1930.

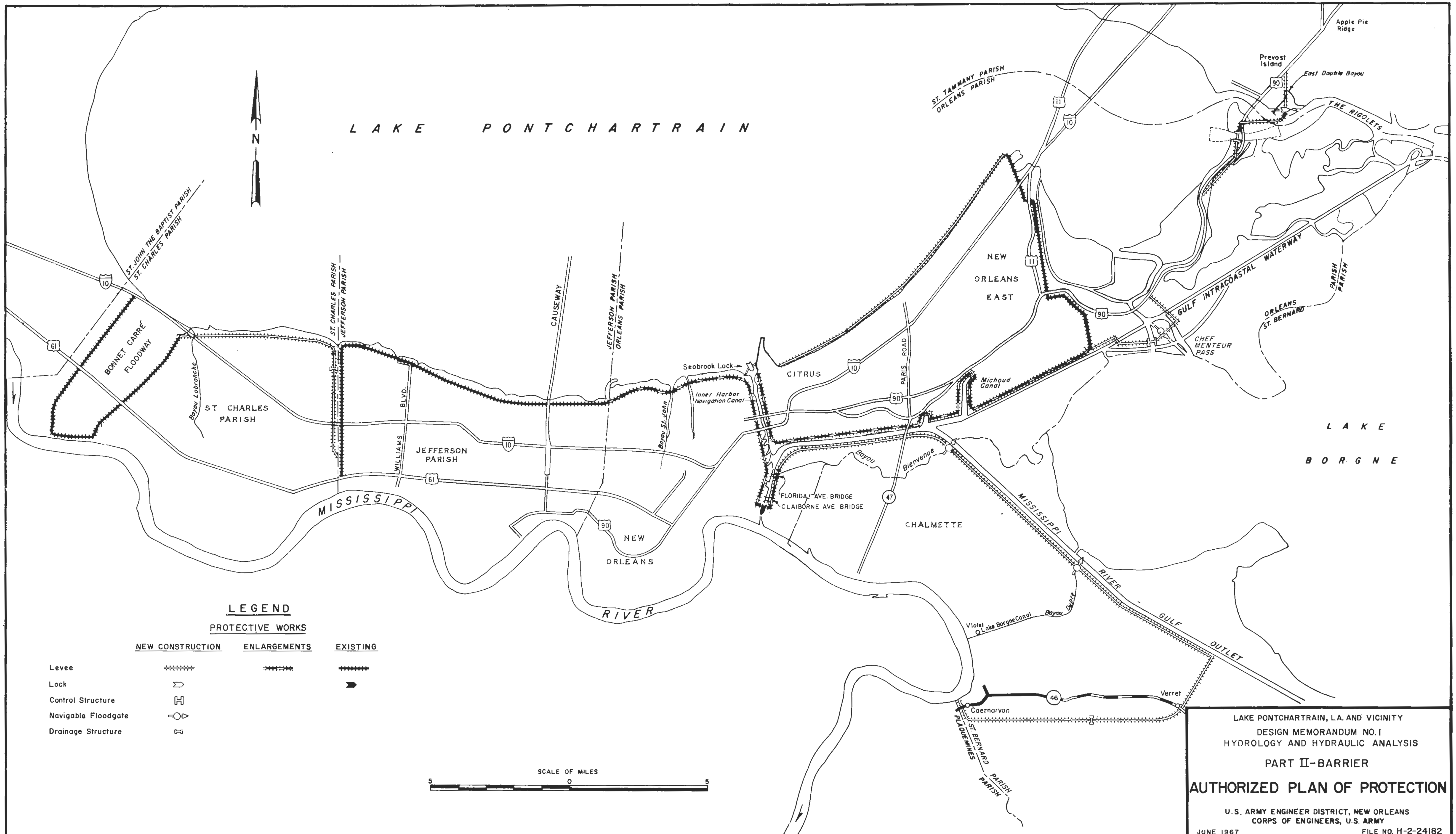
(16) King, H. W., "Handbook of Hydraulics," McGraw-Hill Book Co., Inc., 1954.

(17) U. S. Weather Bureau, "Hurricane Rainfall Estimates Applicable to Middle Gulf Standard Project Hurricanes, Tracks A, C, F, D, and B, New Orleans Study, Zone B," Memorandum HUR 3-5, November 30, 1959.

(18) U. S. Weather Bureau, "Estimates of Moderate Hurricane Rainfall Applicable to Middle Gulf Standard Project Hurricanes," Memorandum HUR 3-5a, December 11, 1959.

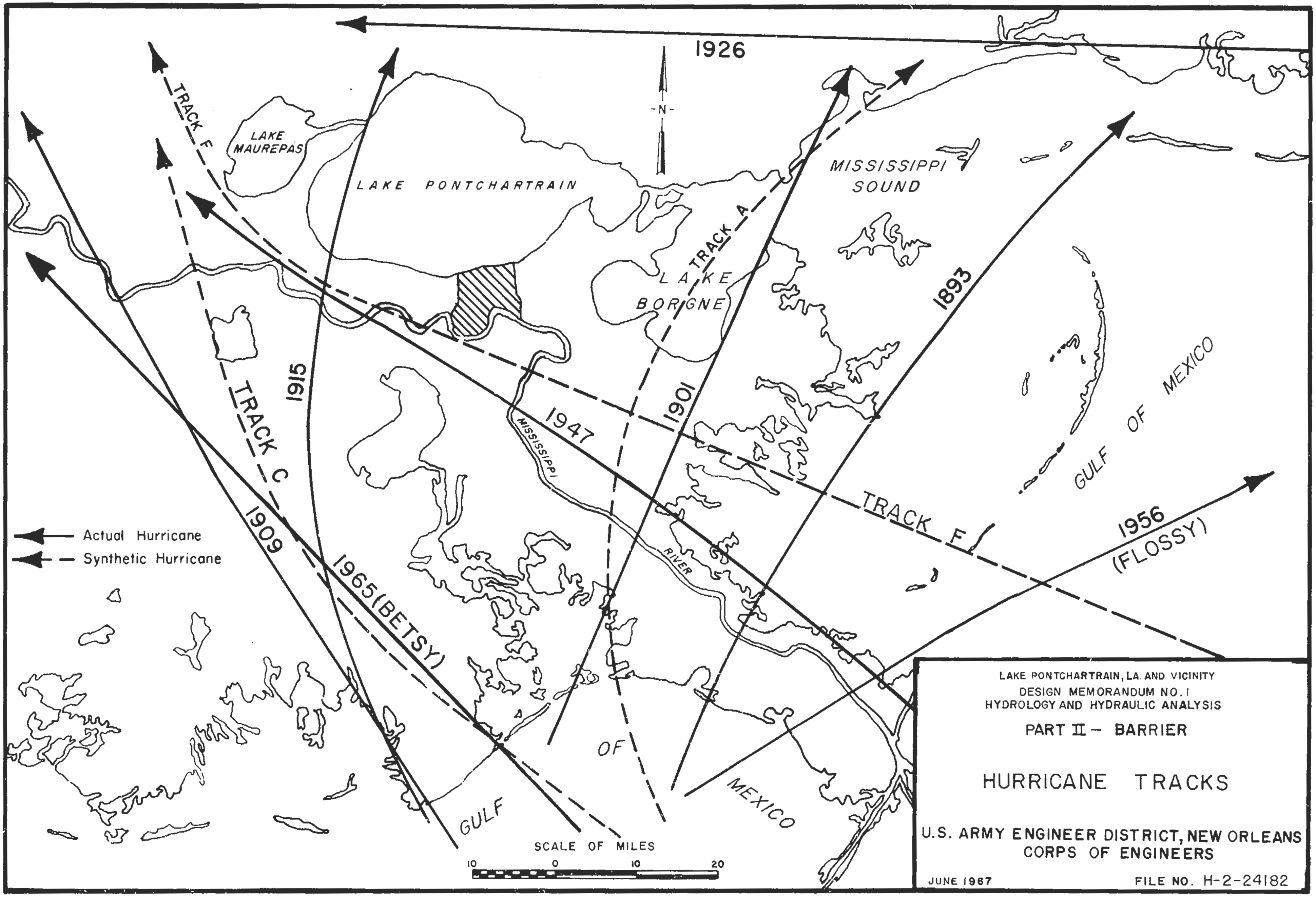

PROJECT AREA
LIVINGSTON PARISH
ASCENSION PARISH
TANGIPAHOA PARISH
ST TAMMANY PARISH
LOUISIANA
MISSISSIPPI
LAKE MAUREPAS
LAKE PONTCHARTRAIN
PASS MANCHAC
Manchac
NEW RIVER CANAL
Sorrento
ST JOHN THE BAPTIST PARISH
ST JAMES PARISH
Frenier Beach
La Place
BONNET CARRE' SPILLWAY
ST CHARLES PARISH
ILLINOIS CENTRAL
JEFFERSON PARISH
New Orleans International Airport (Moisant Field)
Kenner
Metairie
West End
NEW ORLEANS
ORLEANS PARISH
GREATER NEW ORLEANS EXPRESSWAY BRIDGE
Madisonville
Mandeville
Slidell
North Shore
South Shore
Long Point
GRAND ISLAND
MISSISSIPPI SOUND
LAKE ST. CATHERINE
RIGOLETS
CHEF
GULF INTRACOASTAL WATERWAY
MENTEUR PASS
LAKE BORGNE
INNER HARBOR NAVIGATION CANAL
Pontchartrain Beach
New Orleans Airport
Little Woods
LITTLE WOODS CANAL
Citrus
Michoud
DWYER CANAL
Lee Station
FLORIDA AVE CANAL
ST BERNARD PARISH
Chalmette
MISSISSIPPI RIVER GULF OUTLET
Algiers
Gretna
PLAQUEMINES PARISH
Violet
Poydras
Toca
Verret
SOUTHERN PACIFIC
MISSISSIPPI RIVER
PEARL RIVER
VICINITY MAP
MISSISSIPPI
ALABAMA
LOUISIANA
Mobile
Gulfport
Biloxi
Bay St. Louis
NEW ORLEANS
BRETON SOUND
GULF OF MEXICO
SCALE OF MILES
0 50 100
SCALE OF MILES
5 0 5
LEGEND
Existing levee
Existing seawall
Railroad embankment
Levee, new or enlargement
LAKE PONTCHARTRAIN, LA. AND VICINITY
DESIGN MEMORANDUM NO. 1
HYDROLOGY AND HYDRAULIC ANALYSIS
PART IV – CHALMETTE EXTENSION
GENERAL MAP
U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS
SEPT. 1967
FILE NO. H-2-24253

PLATE I



LAKE PONTCHARTRAIN
N
ST. JOHN THE BAPTIST PARISH
ST. CHARLES PARISH
ST. CHARLES PARISH
JEFFERSON PARISH
JEFFERSON PARISH
ORLEANS PARISH
ST. TAMMANY PARISH
ORLEANS PARISH
BONNET CARRÉ FLOODWAY
Bayou Labranche
ST CHARLES PARISH
BLVD.
WILLIAMS
JEFFERSON PARISH
CAUSEWAY
Bayou St. John
Seabrook Lock
Inner Harbor Navigation Canal
CITRUS
PARIS ROAD
NEW ORLEANS EAST
Michoud Canal
Apple Pie Ridge
Prevost Island
East Double Bayou
THE RIGOLETS
GULF INTRACOASTAL WATERWAY
CHEF MENTEUR PASS
ORLEANS PARISH
ST. BERNARD PARISH
LAKE BORGNE
Bayou Bienvenue
FLORIDA AVE. BRIDGE
CLAIBORNE AVE BRIDGE
CHALMETTE
MISSISSIPPI RIVER GULF OUTLET
NEW ORLEANS
MISSISSIPPI
RIVER
Violet
Lake Borgne Canal
Bayou Dupre
Caernarvan
Verret
PLAQUEMINES PARISH
ST. BERNARD PARISH
10
61
90
11
47
46
LEGEND
PROTECTIVE WORKS
NEW CONSTRUCTION
ENLARGEMENTS
EXISTING
Levee
Lock
Control Structure
Navigable Floodgate
Drainage Structure
SCALE OF MILES
5
0
5
LAKE PONTCHARTRAIN, LA. AND VICINITY
DESIGN MEMORANDUM NO. I
HYDROLOGY AND HYDRAULIC ANALYSIS
PART II-BARRIER
AUTHORIZED PLAN OF PROTECTION
U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS, U.S. ARMY
JUNE 1967
FILE NO. H-2-24182

PLATE 2



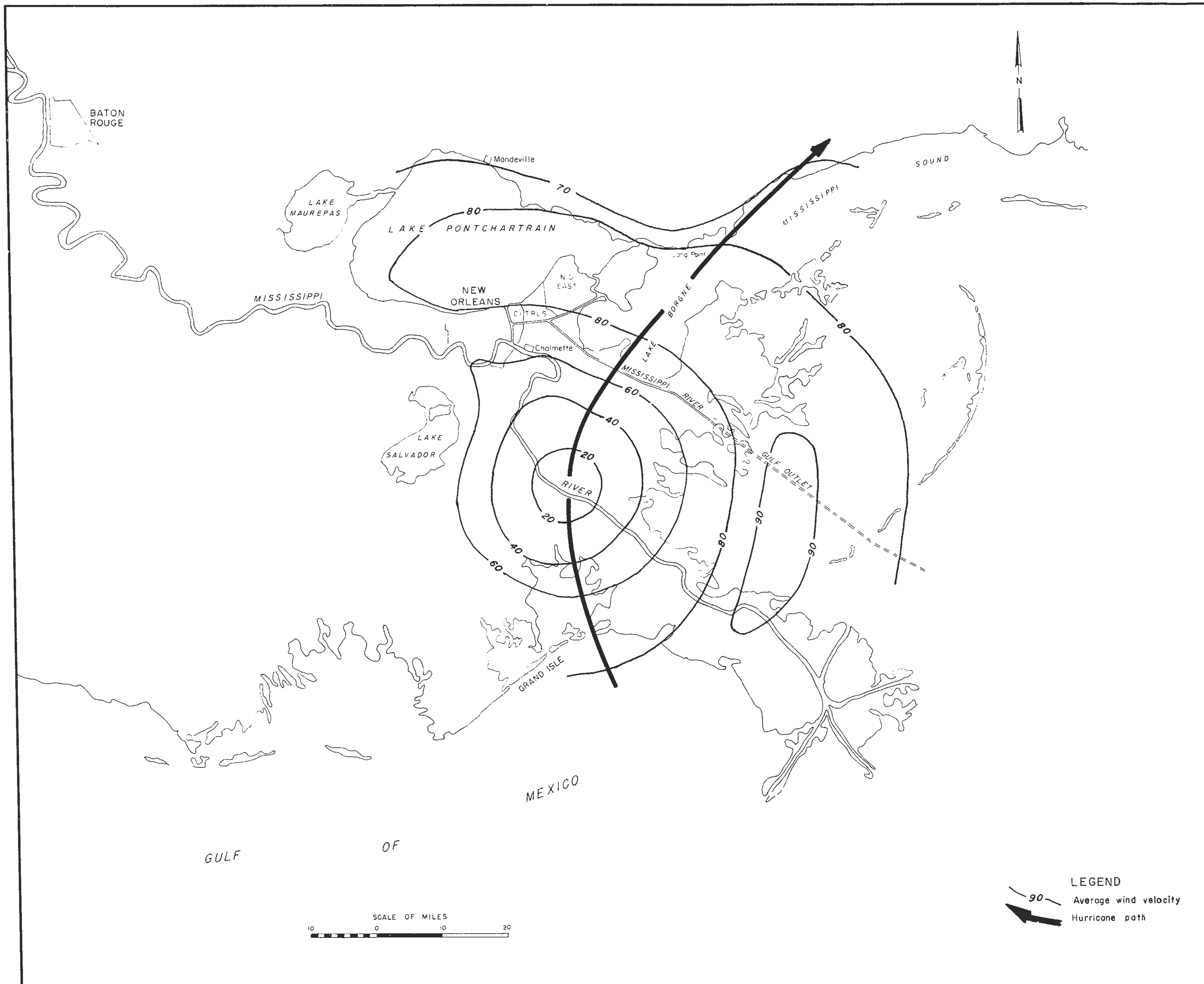
LAKE PONTCHARTRAIN, LA. AND VICINITY
DESIGN MEMORANDUM NO. I
HYDROLOGY AND HYDRAULIC ANALYSIS
PART II – BARRIER

HURRICANE TRACKS

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

JUNE 1967 FILE NO. H-2-24182

PLATE 3

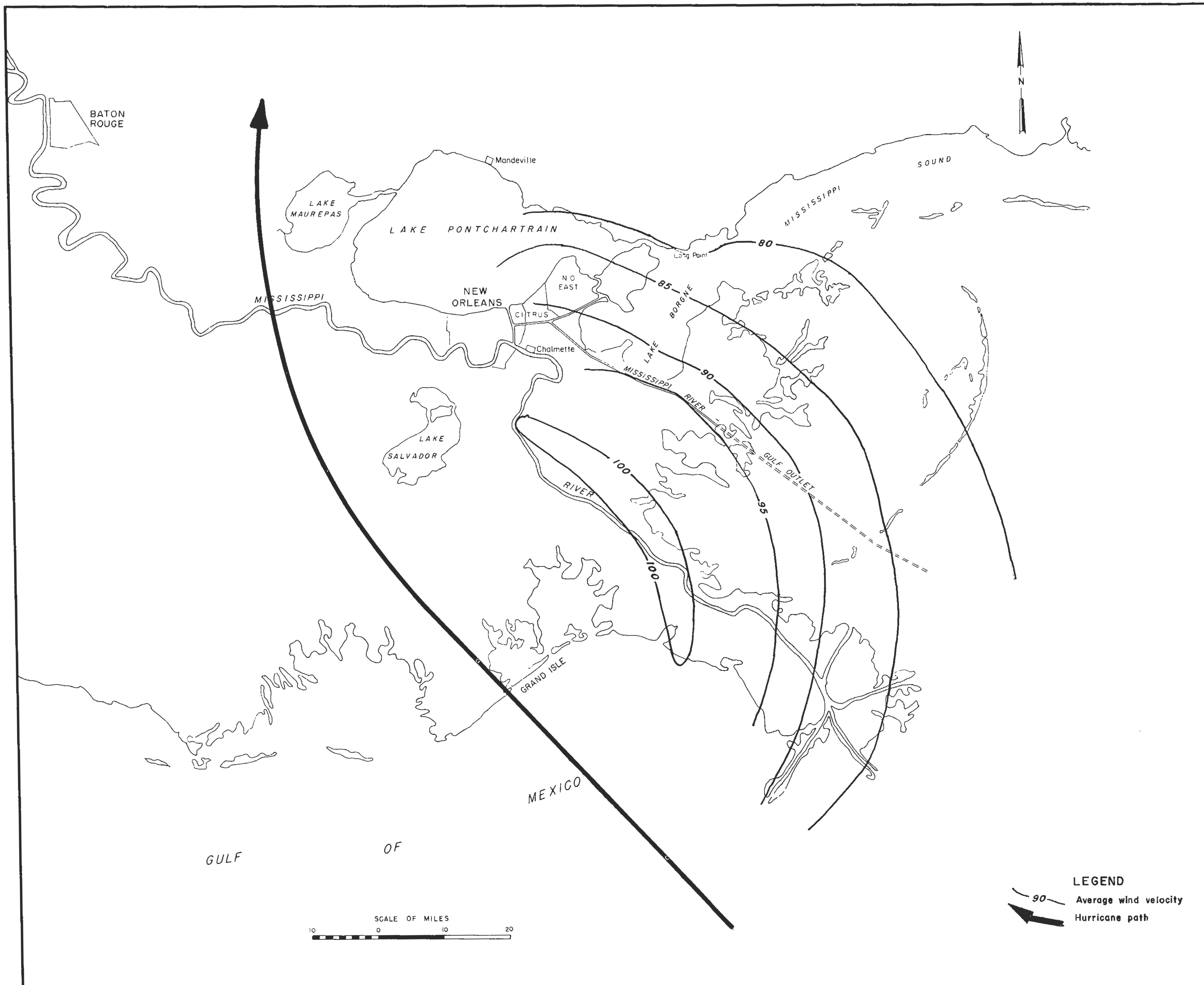


LAKE PONTCHARTRAIN, LA. AND VICINITY
DESIGN MEMORANDUM NO. 1
HYDROLOGY AND HYDRAULIC ANALYSIS
PART II-BARRIER

STANDARD PROJECT HURRICANE ISOVEL PATTERN CRITICAL TO BARRIER TRACK A

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

JUNE 1967 FILE NO. H-2-24182



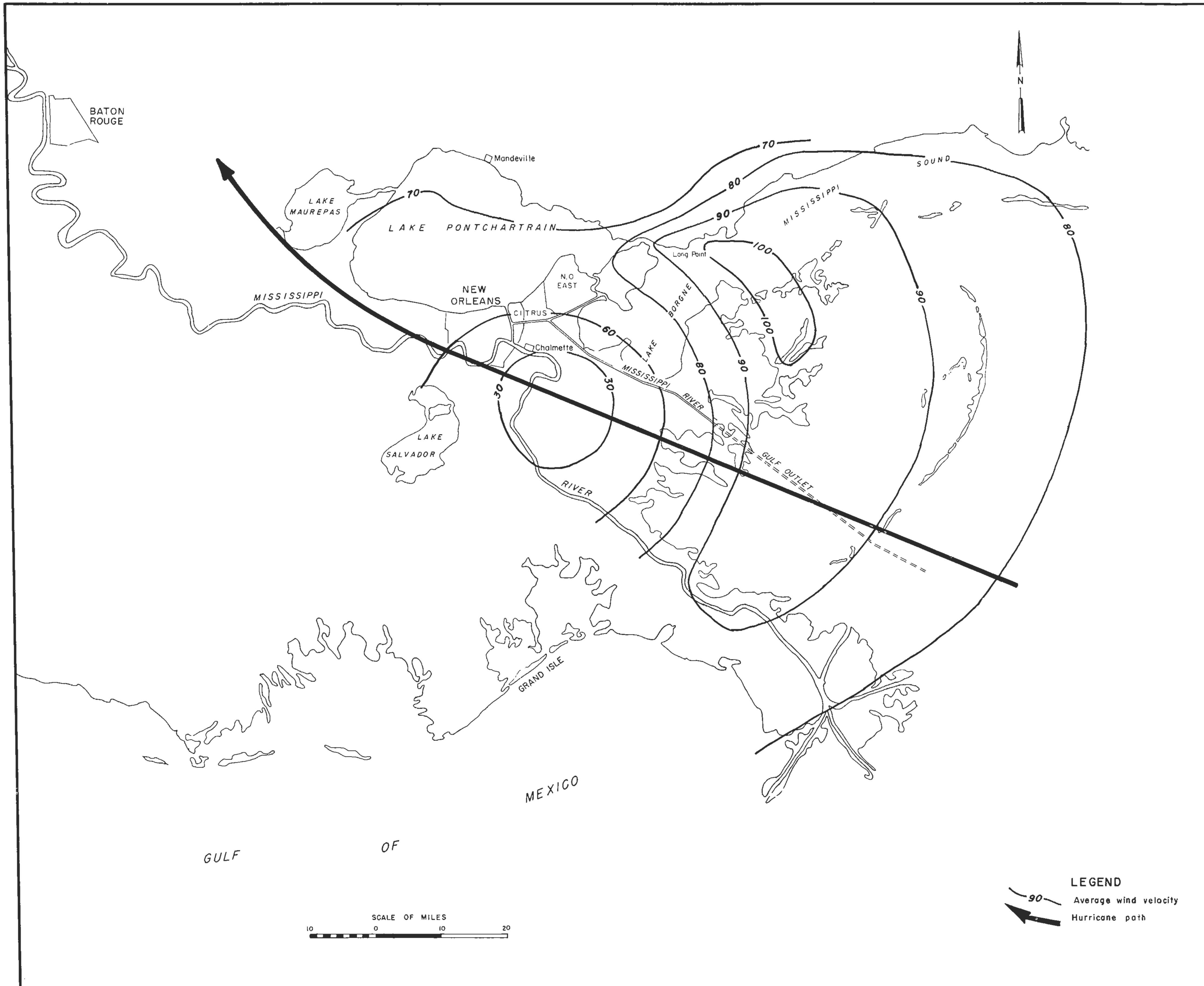
LAKE PONTCHARTRAIN, LA. AND VICINITY
DESIGN MEMORANDUM NO. 1
HYDROLOGY AND HYDRAULIC ANALYSIS
PART II-BARRIER

STANDARD PROJECT HURRICANE ISOVEL PATTERN CRITICAL TO BARRIER TRACK C

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

JUNE 1967 FILE NO. H-2-24182

PLATE 5



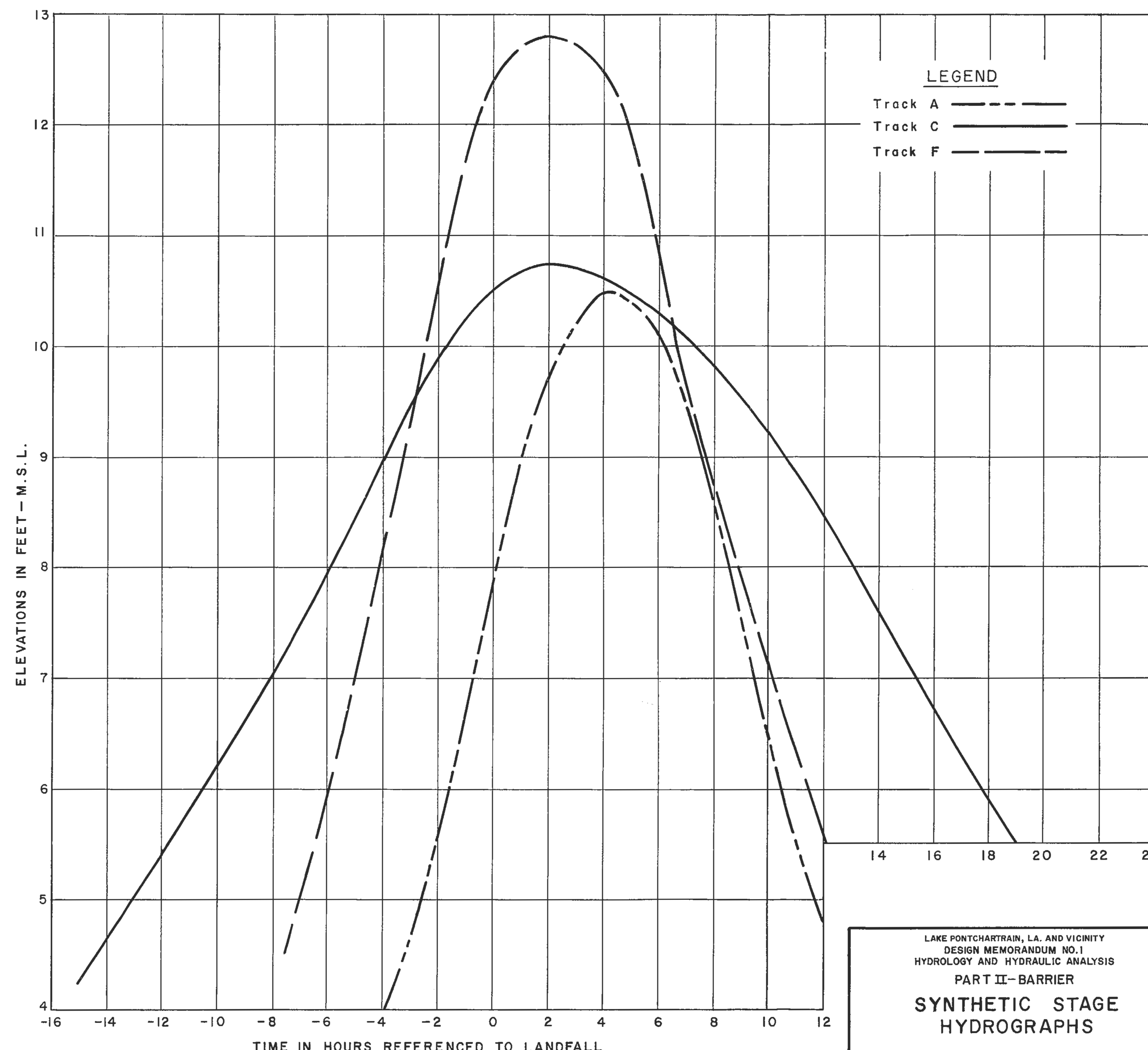
LAKE PONTCHARTRAIN, LA. AND VICINITY
DESIGN MEMORANDUM NO. I
HYDROLOGY AND HYDRAULIC ANALYSIS
PART II-BARRIER

STANDARD PROJECT HURRICANE
ISOVEL PATTERN CRITICAL TO
BARRIER TRACK F

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

JUNE 1967 FILE NO. H-2-24182

PLATE 6

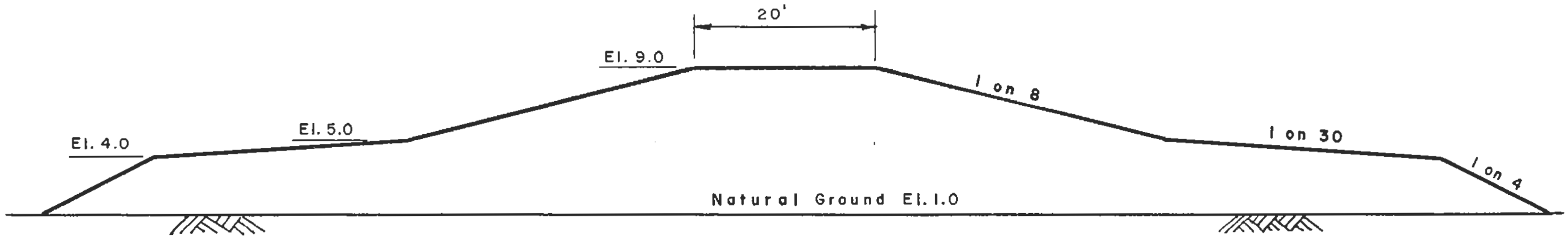


LAKE PONTCHARTRAIN, LA. AND VICINITY
DESIGN MEMORANDUM NO. 1
HYDROLOGY AND HYDRAULIC ANALYSIS
PART II - BARRIER

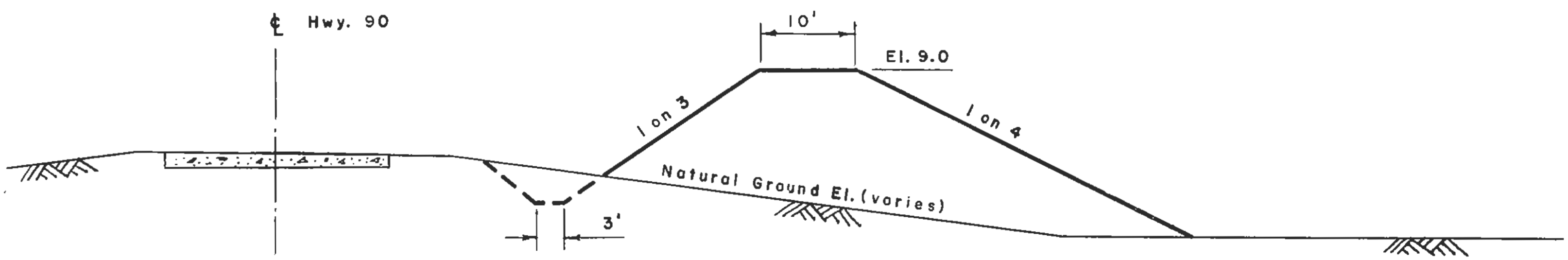
SYNTHETIC STAGE
HYDROGRAPHS

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

JUNE 1967 FILE NO. H-2-24182



NEW EMBANKMENT



EMBANKMENT ENLARGEMENT

SCALE
VERTICAL: 1" = 10'
HORIZONTAL: 1" = 20'

NOTE:
Elevations in feet and refer to Mean Sea Level.

LAKE PONTCHARTRAIN, LA. AND VICINITY
DESIGN MEMORANDUM NO. 1
HYDROLOGY AND HYDRAULIC ANALYSIS

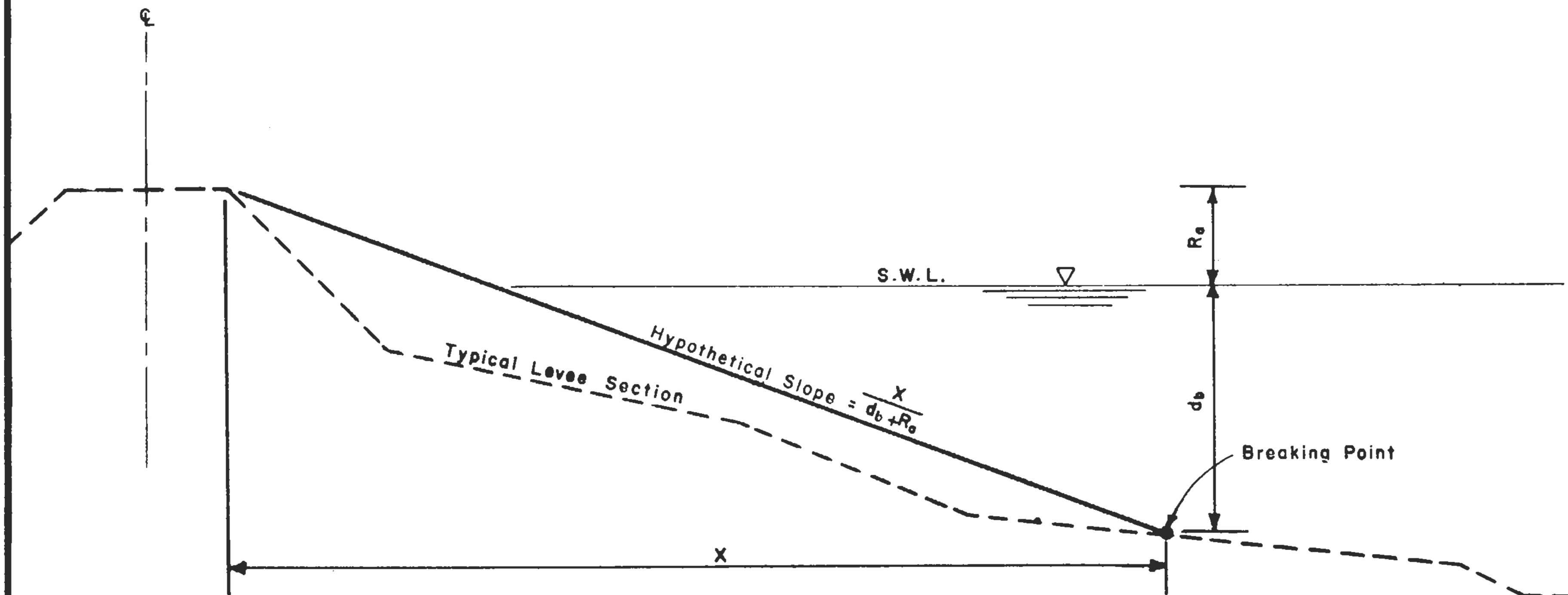
PART II—BARRIER

TYPICAL CROSS-SECTIONS

U. S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

JUNE 1967 FILE NO. H-2-24182

PLATE 8



LEGEND

R_a = assumed runup

d_b = breaking depth of wave

X = horizontal distance from breaking point to elevation of runup

SWL = stillwater level

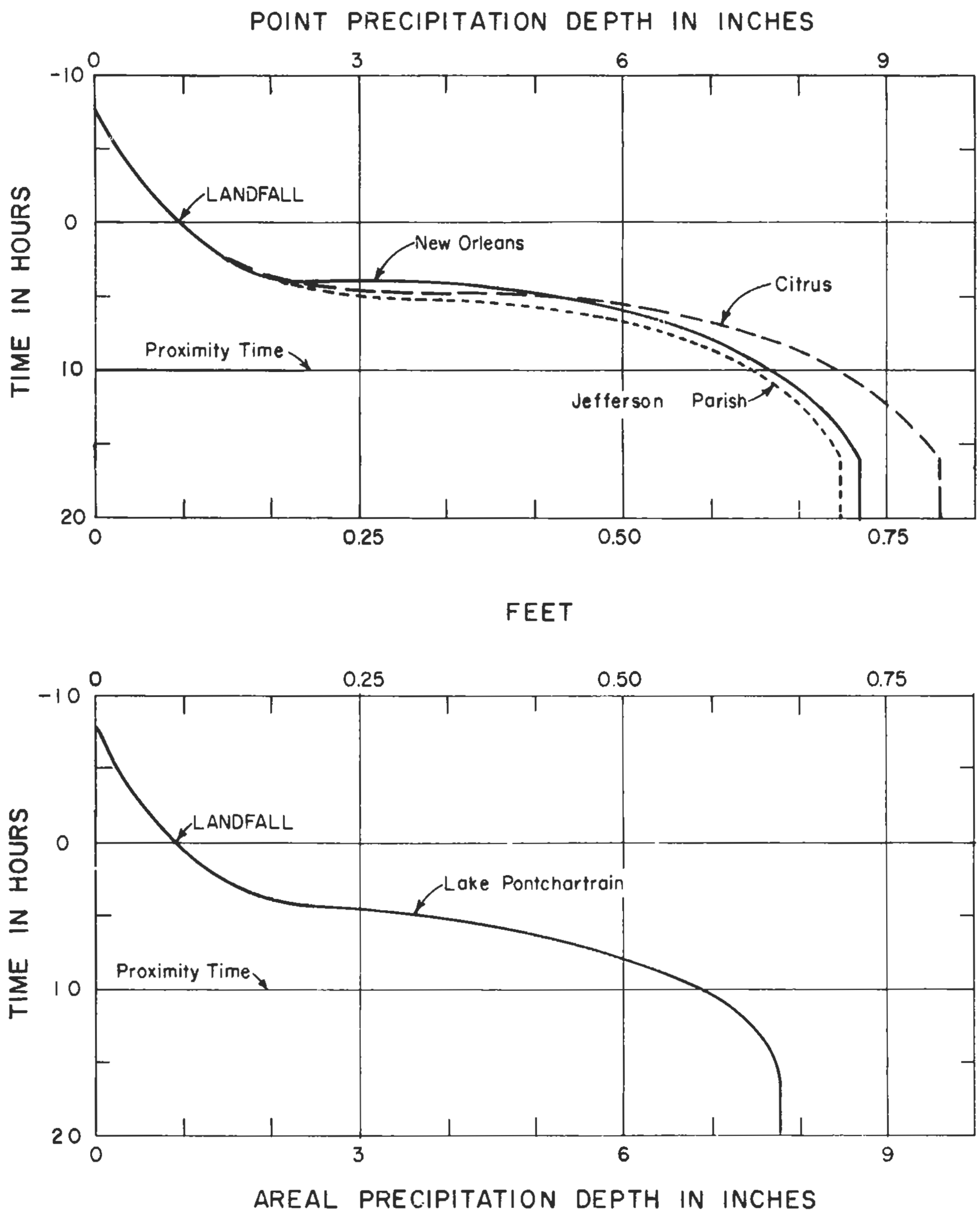
LAKE PONTCHARTRAIN, LA. AND VICINITY
DESIGN MEMORANDUM NO. I
HYDROLOGY AND HYDRAULIC ANALYSIS
PART II – BARRIER

DETERMINATION OF HYPOTHETICAL SLOPE

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

JUNE 1967 FILE NO. H-2-24182

PLATE 9



LAKE PONTCHARTRAIN, LA. AND VICINITY

DESIGN MEMORANDUM NO. 1
HYDROLOGY AND HYDRAULIC ANALYSIS

PART II—BARRIER

MASS RAINFALL CURVES
TRACK A

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

JUNE 1967 FILE NO. H-2-24182