A0006177

Part 2 of 2

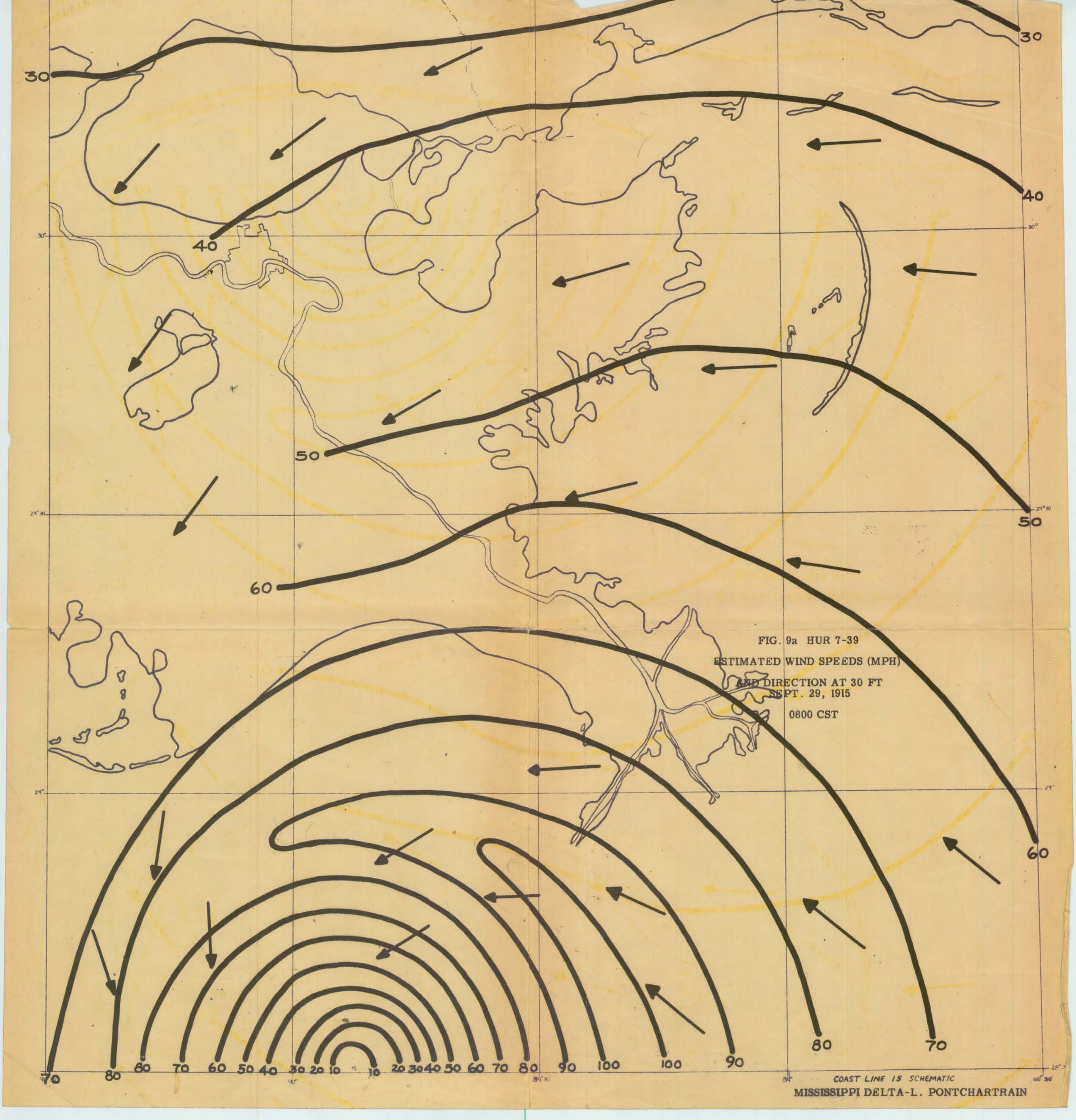

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FIG. 9a HUR 7-39
ESTIMATED WIND SPEEDS (MPH)
AND DIRECTION AT 30 FT
SEPT. 29, 1915
0800 CST
COAST LINE IS SCHEMATIC
MISSISSIPPI DELTA-L. PONTCHARTRAIN

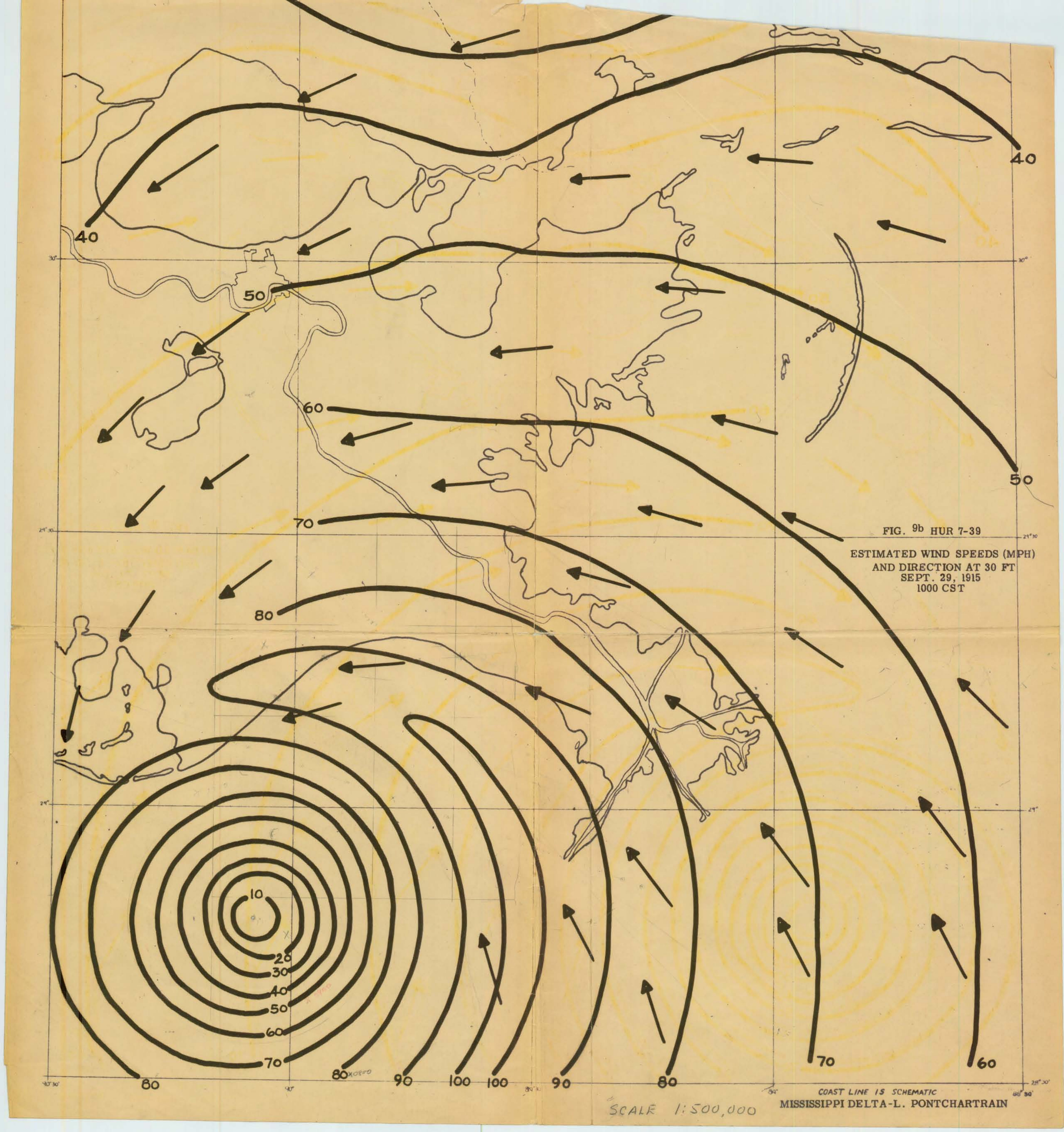

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FIG. 9b HUR 7-39
ESTIMATED WIND SPEEDS (MPH)
AND DIRECTION AT 30 FT
SEPT. 29, 1915
1000 CST
COAST LINE IS SCHEMATIC
SCALE 1:500,000
MISSISSIPPI DELTA-L. PONTCHARTRAIN

FIG. 9c HUR 7-39

ESTIMATED WIND SPEEDS (MPH)
AND DIRECTION AT 30 FT
SEPT. 29, 1915

1200 CST

FIG. 9d HUR 7-39

ESTIMATED WIND SPEEDS (MPH)
AND DIRECTION AT 30 FT
SEPT. 29, 1915

1600 CST

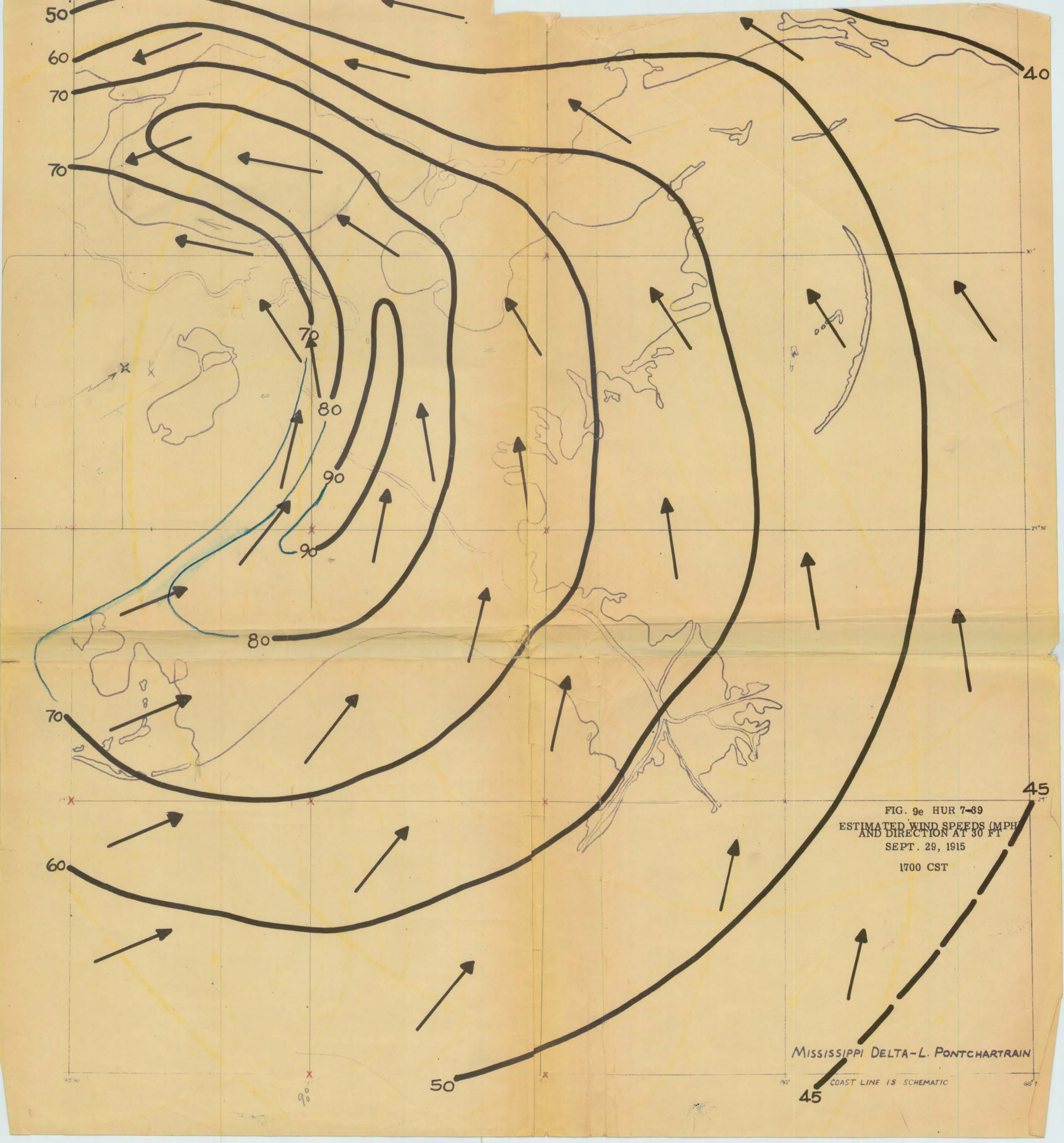

FIG. 9e HUR 7-39
ESTIMATED WIND SPEEDS (MPH) AND DIRECTION AT 30 FT
SEPT. 29, 1915
1700 CST

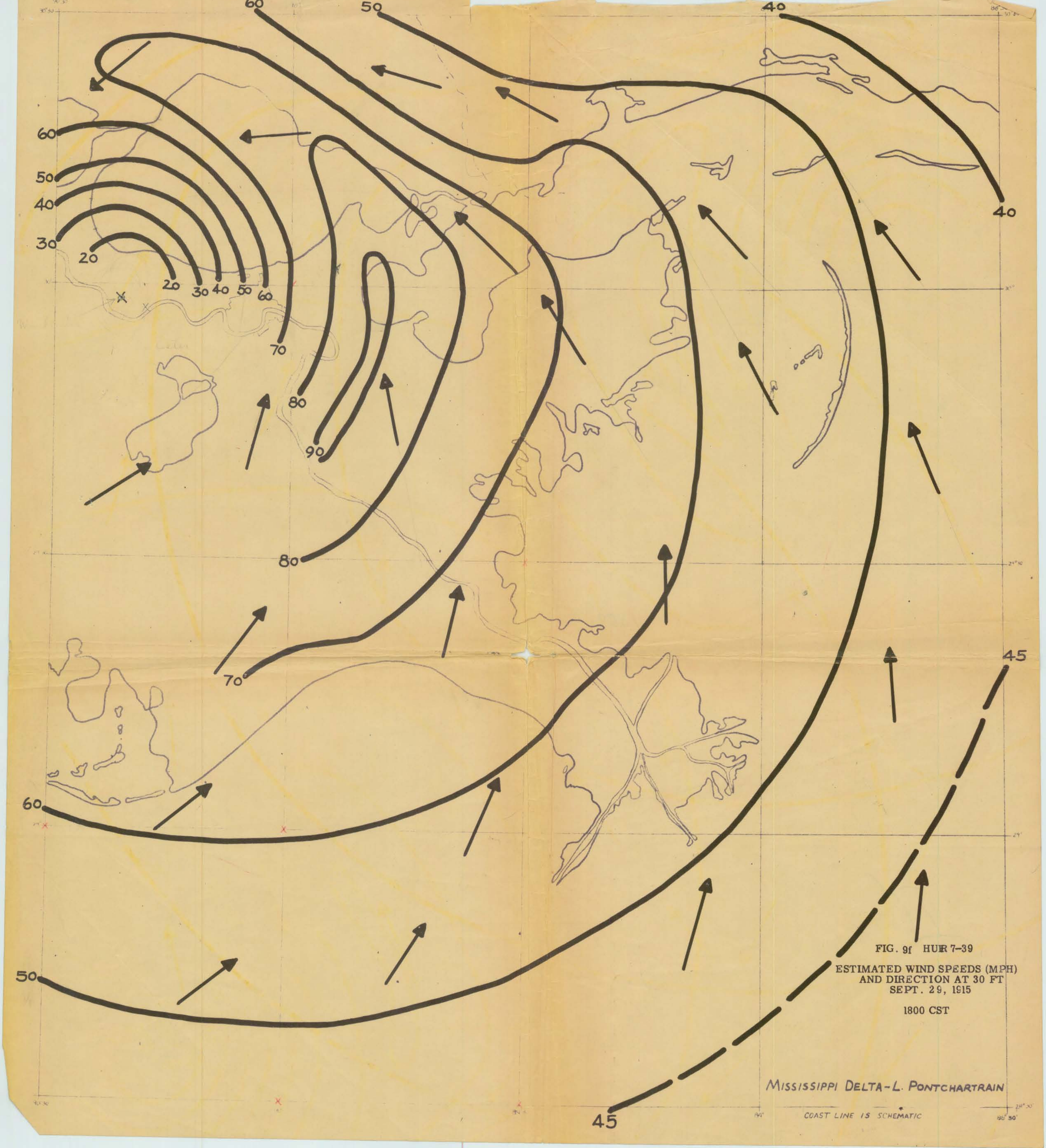

FIG. 9f HUR 7-39

ESTIMATED WIND SPEEDS (MPH)
AND DIRECTION AT 30 FT
SEPT. 29, 1915

1800 CST

FIG. 9g HUR 7-39
ESTIMATED WIND SPEEDS (MPH)
AND DIRECTION AT 30 FT
SEPT 29, 1915
2000 CST

MISSISSIPPI DELTA L. PONTCHARTRAIN

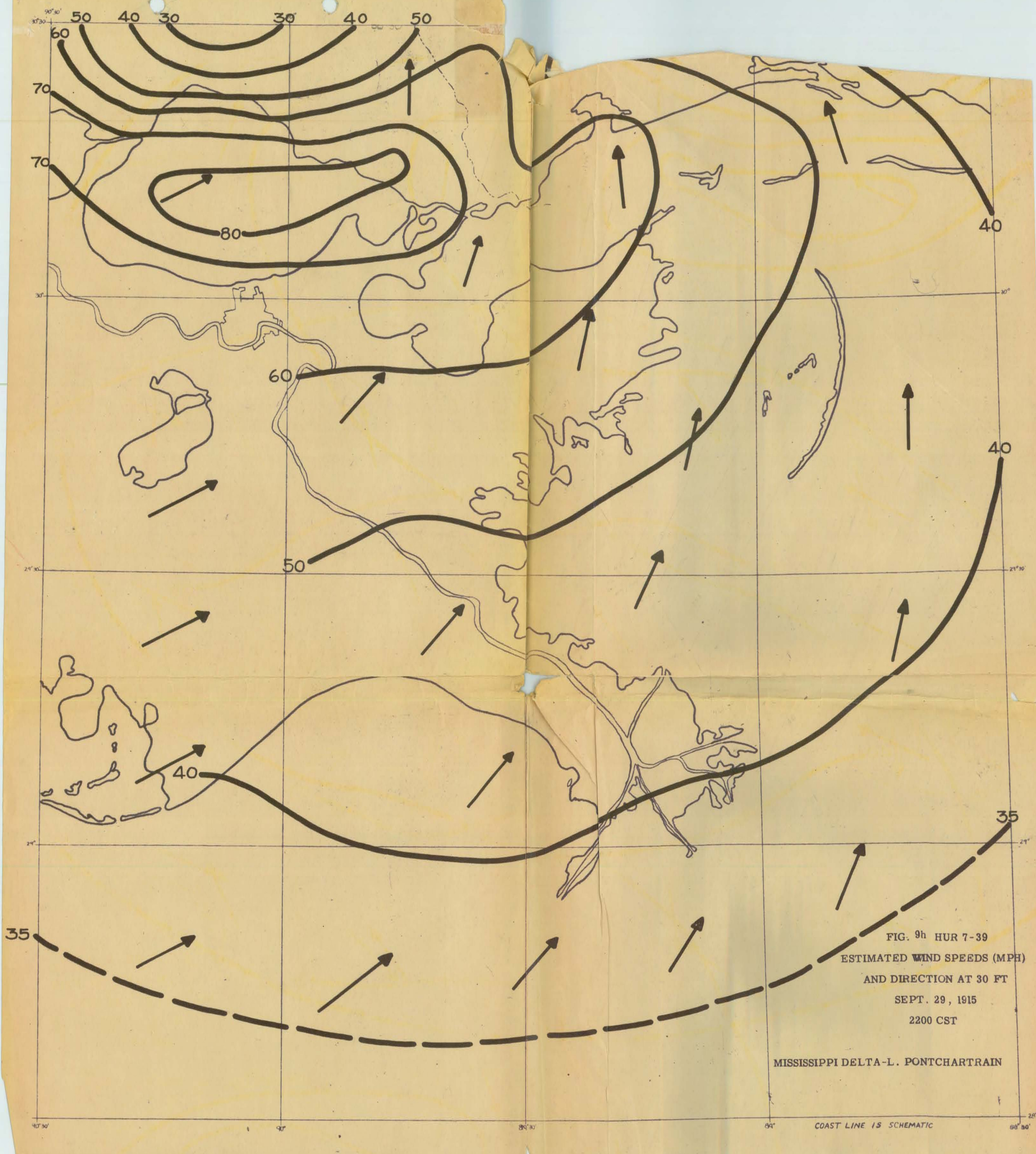

FIG. 9h HUR 7-39
ESTIMATED WIND SPEEDS (MPH)
AND DIRECTION AT 30 FT
SEPT. 29, 1915
2200 CST

MISSISSIPPI DELTA-L. PONTCHARTRAIN

UNITED STATES DEPARTMENT OF COMMERCE
WEATHER BUREAU
WASHINGTON 25

July 19, 1957

IN REPLY, PLEASE ADDRESS
CHIEF OF BUREAU
AND REFER TO

0-6.12

TO : Mr. A. L. Cochran, Civil Works
Office of Chief of Engineers
Corps of Engineers

FROM : Hydrometeorological Section

SUBJECT: MEMORANDUM HUR 7-38, Curving Hurricane Tracks as related to Lake Pontchartrain

Herewith is transmitted the subject memorandum which presents a Hydrometeorological Section Study of the subject and a statement by the Meteorologist in Charge of the New Orleans Weather Bureau Office on critical hurricane paths for Lake Pontchartrain. This completes assignment under paragraph 11b (2) of New Orleans conference notes, June 13-14, 1957.

Charles S. Gilman, Chief
Hydrometeorological Section

Attachments
cc: 2 with attachments to OCE
1 with attachments to HKB

UNITED STATES DEPARTMENT OF COMMERCE
WEATHER BUREAU
WASHINGTON 25

July 19, 1957

IN REPLY, PLEASE ADDRESS
CHIEF OF BUREAU
AND REFER TO

0-6.12

MEMORANDUM HUR 7-38

FROM : Hydrometeorological Section

SUBJECT : Curving hurricane tracks as related to Lake Pontchartrain

REFERENCE: Notes on conference held at New Orleans District Office June 13-14, 1957 re hurricane studies

Enclosed are two attachments regarding curving paths of hurricanes in the vicinity of Lake Pontchartrain. The first is a study by the Hydrometeorological Section of path characteristics in the vicinity of the Lake. The second is a statement by the Meteorologist in Charge of the New Orleans Weather Bureau Office (Hurricane Forecast Center for Middle and Western Gulf) regarding critical paths for Lake Pontchartrain, requested by and endorsed by the Hydrometeorological Section. The critical path exhibited in Attachment 2 of the reference notes is quite similar to the New Orleans WBO most critical path, Track A.

This completes our assignment under paragraph 11b (2) of the reference notes.

Charles S. Gilman, Chief
Hydrometeorological Section

Attachments
cc: 2 with attachments to OCE
1 with attachments to BEB

FURTHER ANALYSIS OF HURRICANE CHARACTERISTICS IN THE VICINITY OF LAKE PONTCHARTRAIN

Introduction

This report is concerned with analyses of hurricane track characteristics in the Lake Pontchartrain area (1, 2), namely:

1) evaluation of a factor related to the degree of turning at recurvature of the tracks of hurricanes passing near Lake Pontchartrain;
2) statistical measures concerning:
   a) the location of recurvature with respect to the Lake,
   b) the relation between the curvature factor and intensity;
3) copies of tracks illustrating:
   a) the typical nature of recurvature and also some of the less common cases of non-recurvature,
   b) loops and eccentric turns.

The data used in the analysis presented below were restricted to storms whose tracks came within 120 nautical miles of the center of Lake Pontchartrain. Such a distance represents more than twice the larger radii of maximum winds observed in strong hurricanes. All tropical storms, regardless of intensity, that met the above criterion, using tracks as shown in Tracks of Tropical Storms (3), were used in the compilations and analysis.

Characteristics

Pertinent characteristics of the storms have been tabulated in table 1. Data for the table were taken for the most part from National Hurricane Research Project Report No. 5 (7) and from Preliminary Summary of Gulf of Mexico Hurricane Data (5).

Column 6 of table 1 lists a factor that gives a rough indication of the sharpness of turning in the region of recurvature along the track. The factor, given, $\Delta\theta/\Delta S$, was adapted from the much more exact function:

$$K = \lim_{\Delta\theta \to 0} \frac{\Delta\theta}{\Delta S} = \text{curvature}$$

where $\Delta\theta$ is the increment of change in the angle between the tangents to the end points of the increment of arc, ΔS, along the curve. The curvature factors given in table 1 were all computed for a fixed length of track of 240 nautical miles (equal to 4 latitude degrees). The larger the factor, therefore, the sharper the turn. Figure 1 shows the distribution of the factor $\Delta\theta/\Delta S$ for all 62 storms. Note that 22 out of the 62 storms, or about 35 percent, continued past Lake Pontchartrain on a roughly straight track, $\Delta\theta/\Delta S = 0$. The point of recurvature (where the $\Delta\theta/\Delta S$ factor was measured) was construed in the usual sense to be the most westerly position of the storm track when making the curve (concave eastward) around the subtropical High. This definition was adapted from Riehl (6, see especially page 341), who stated that "the passage of a storm across the subtropical ridge, is termed recurvature, a somewhat inaccurate but well established name."

Central pressures

The frequency of central pressure values has been graphed in figure 2. The portion of the distribution for central pressures of 29.00 inches or less at landfall was known from data available in previous studies (4, 7). The remainder of the frequency curve for storms with central pressures higher than 29.00 inches is an approximation, based on the negatively skewed distribution of central pressures for all storms, both above as well as below 29.00 inches, that crossed the Gulf Coast. The curve of figure 2 indicates, for example, that 30 percent of all storms that passed within a distance of 120 nautical miles of the center of Lake Pontchartrain had a central pressure of 28.9 inches or less; 60 percent had a central pressure of 29.4 inches or less, etc.

Location of recurvature

A tally indicates that of the 62 storms that approached within a distance of 120 nautical miles of the center of Lake Pontchartrain (table 1), 34 recurved without reaching the longitude of the center of the Lake, 25 tracked farther west than the center, while three moved almost directly over the center of the Lake.

With respect to the latitude of the most westerly position of the track at recurvature, there were 29 occurrences at a latitude below that of the center of the Lake, 11 at a latitude north of the center, while in 22 cases there was no recurvature.

Variation of $\frac{\Delta\theta}{\Delta S}$ with storm intensity

The possibility of a relationship between sharpness of turning at recurvature and central pressure was considered. A scatter diagram was plotted of $\Delta\theta/\Delta S$ against P_o (figure 3), but the wide scatter indicated that the relationship between the two variables was not strong. This check therefore presents another bit of evidence in favor of the generally held belief that factors other than central pressure may have important influence on the nature of recurvature (6).

Typical hurricane tracks

Typical tracks of hurricanes that passed within a distance of 120 nautical miles of the center of Lake Pontchartrain are pictured in figure 4. Note that of the eleven tracks shown, the region of sharpest turning at recurvature is north of the Lake for some and south of the Lake for others. Central pressures and radii of maximum winds at landfall have been indicated along the respective tracks in those instances where the values were readily available. The tracks of several hurricanes that did not enter into the present analyses appear in figure 5. These tracks were selected to illustrate further the nature of the curvature or loops that have occurred in this general area and may recur. The occurrence of such "abnormal" tracks with "all kinds of aberrations" (6, see especially page 341), such as humps, loops, etc., taking place to the north as well as to the south of the Lake should be considered a possibility.

Speed along track versus curvature factor

The average speeds in the region of recurvature, for 32 out of the 62 cases where computations were feasible, were compared with the corresponding curvature factors, given in column 6 of table 1. The scatter diagram of speed against the curvature factor appeared to be random, and the computed coefficient of correlation was zero.

Conclusions

The analysis of a group of tropical storms and hurricanes that tracked near or over Lake Pontchartrain indicates:

1) More than a third of all the storms did not recurve in the usual sense.

2) Recurvature may take place in any direction from the Lake. In the past, the occurrences were more frequently:

    a) to the east rather than to the west of the longitude of Lake Pontchartrain,

    b) to the south rather than to the north of the latitude of Lake Pontchartrain.

3) No strong relationship existed between central pressure and the sharpness of turning of the track at recurvature.

4) Zero correlation was obtained between the speed of the storm center and the sharpness of the turn at recurvature.

The study also indicated the location and shape of both typical and atypical tracks.

References

1. HUR 7-16, Hurricane Characteristics in the Vicinity of Lake Pontchartrain and New Orleans, La. dated October 10, 1956.

2. HUR 2-4, Hurricane Frequency and Correlations of Hurricane Characteristics for the Gulf of Mexico Area, P. L. 71, to be completed shortly.

3. Tracks of Tropical Storms, 1887-1956. Marine Area Section, Office of Climatology, U. S. Weather Bureau, January 1957 (HUR 1-1).

4. Hydrometeorological Section, U. S. Weather Bureau, "Characteristics of United States Hurricanes Pertinent to Levee Design for Lake Okeechobee, Florida," Hydrometeorological Report No. 32, 1954.

5. Preliminary Summary of Gulf of Mexico Hurricane Data. New Orleans Forecast Center, U. S. Weather Bureau, 1956.

6. Tropical Meteorology. H. Riehl. McGraw-Hill, 1954. (See especially page 348)

7. National Hurricane Research Project, Report No. 5, Survey of Meteorological Factors Pertinent to Reduction of Loss of Life and Property in Hurricane Situations. U. S. Weather Bureau, March 1957.

Table 1. Curvature Data of Hurricane Tracks Passing Within 120 Nautical Miles of Lake Pontchartrain continued

Date	P_o - Central Pressure (inches)	Shortest Distance of Track from Center of Lake Pontchartrain (nautical miles)	Longitude of Recurvature (relative to Lake)	Latitude of Recurvature	$\frac{\Delta\theta}{\Delta S}$ at Point of Recurvature (degrees turn per 240 nautical miles of track)	Average Speed at Point of Recurvature (knots)
*Oct. 13-17, 1923	29.10e	30	W	17°30'	31°	16.2
Aug. 21-27, 1926	28.31	60	W	--	--	
Sept. 11-22, 1926	28.20	75	E	--	--	
*July 11-17, 1931	29.70e	75	W	--	--	
*Sept. 18-21, 1932	29.50e	60	W	--	--	
*Oct. 7-18, 1932	29.40e	15	W	23°30'	48°	14.4
Aug. 24-Sept. 3, 1932	28.90e	75	E	34°30'	43°	11.2
June 4-21, 1934	28.52	45	W	32°	38°	13.7
*Oct. 1-6, 1934	M	105	E	26°	63°	9.6
*July 26-27, 1936	29.60e	0	-	30°	67°	
*Aug. 20-22, 1936	M	15	E	--	--	
July 22-Aug. 1, 1936	28.46	120	E	--	--	
*Sept. 29-Oct. 3, 1937	29.50e	90	W	29°30'	46°	
*Sept. 16-21, 1937	29.60e	120	E	22°	50°	
*Sept. 23-26, 1939	29.60e	0	-	29°	23°	
*June 12-16, 1939	29.45e	105	E	--	--	
Aug. 2-10, 1940	28.78	120	W	33°	40°	6.5
*Sept. 19-24, 1940	M	45	W	28°	105°	9.5
*Sept. 11-16, 1941	29.40e	120	W	--	--	
*Sept. 8-10, 1944	29.50e	60	E	25°30'	49°	
*Sept. 3-6, 1945	M	15	E	--	--	
*June 13-16, 1946	M	105	W	--	--	
Sept. 4-21, 1947	28.57	15	W	35°	87°	16.2
*Sept. 7-8, 1947	M	60	E	--	--	
*Aug. 28-Sept. 6, 1948	29.15e	15	E	36°	15°	
*Sept. 3-5, 1949	29.65e	30	W	31°	39°	12.0
Aug. 20-Sept. 1, 1950	28.92	105	E	27°	33°	
*July 28-30, 1954	29.45e	120	W	--	--	
*July 31-Aug. 2, 1955	29.50e	15	W	--	--	
*Aug. 23-29, 1955	29.50e	15	E	34°30'	62°	14.0
*June 11-14, 1956	M	15	W	24°30'	26	
Sept. 21-30, 1956	28.76	75	E	27°	55°	10.4

*Indicates less than hurricane intensity
M-Missing
e-estimated

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KEUFFEL & ESSER CO. MADE IN U.S.A.

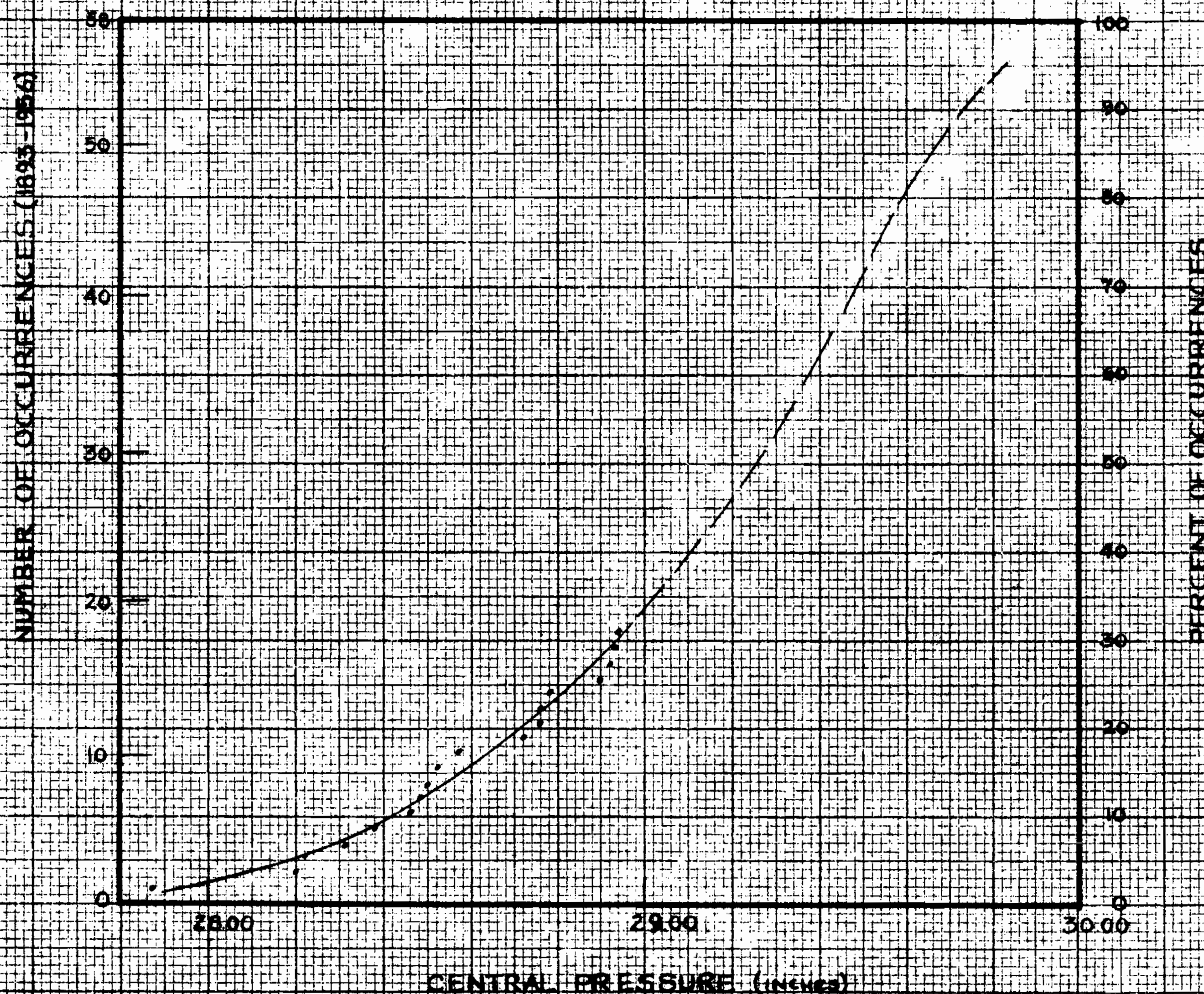
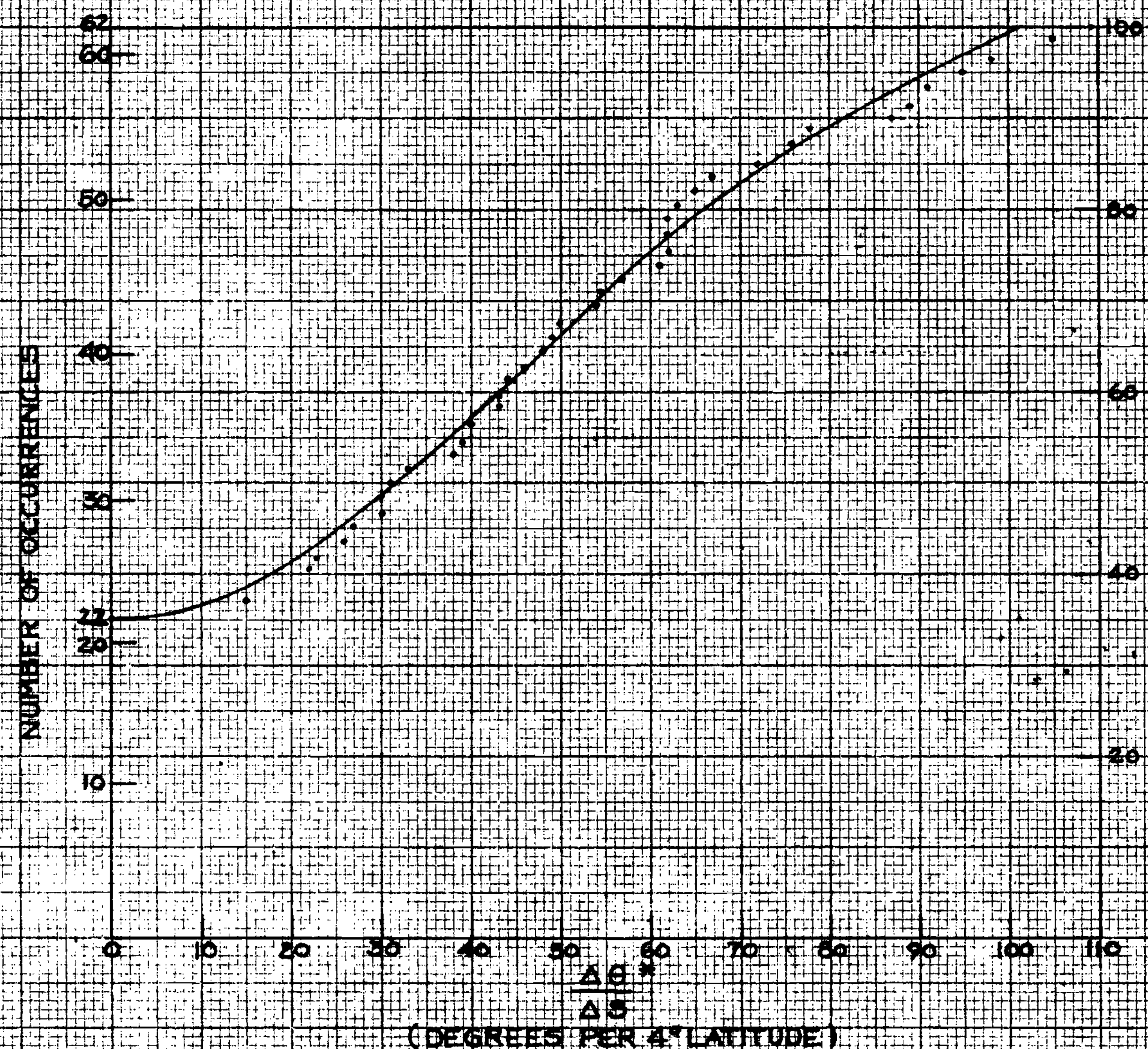


FIG. 2 CUMULATIVE FREQUENCY OF CENTRAL PRESSURES OF 58 TROPICAL STORMS PASSING WITHIN 120 NAUTICAL MILES OF LAKE PONTCHARTRAIN



*For any track $\frac{\Delta\theta}{\Delta S}$ represents the change in tangent to the corresponding length of arc. The ratio is consequently a crude measure of the degree or sharpness of turning along the track, the higher the ratio the sharper the turn for the same length of arc.

FIG. I CUMULATIVE FREQUENCY OF $\frac{\Delta\theta}{\Delta S}$* ALONG STORM TRACKS IN REGION OF RECURVATURE

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KEUFFEL & ESSER CO. MADE IN U.S.A.

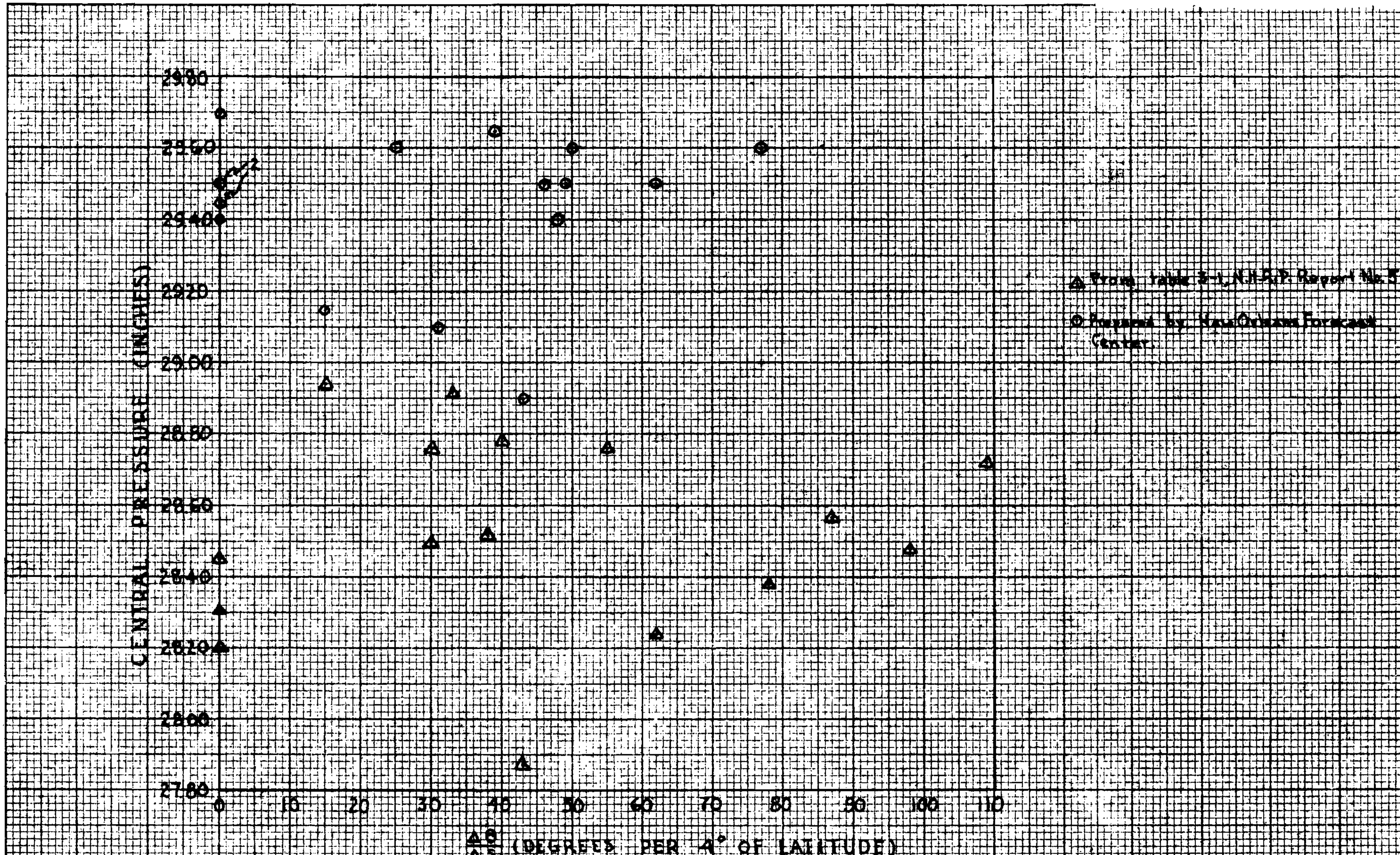


Fig. 3 VARIATION OF $\frac{\Delta\theta}{\Delta S}$ WITH CENTRAL PRESSURE
(CENTER OF STORMS WITHIN 120 NAUT. MILES OF L. PONTCHARTRAIN 1885-1956)

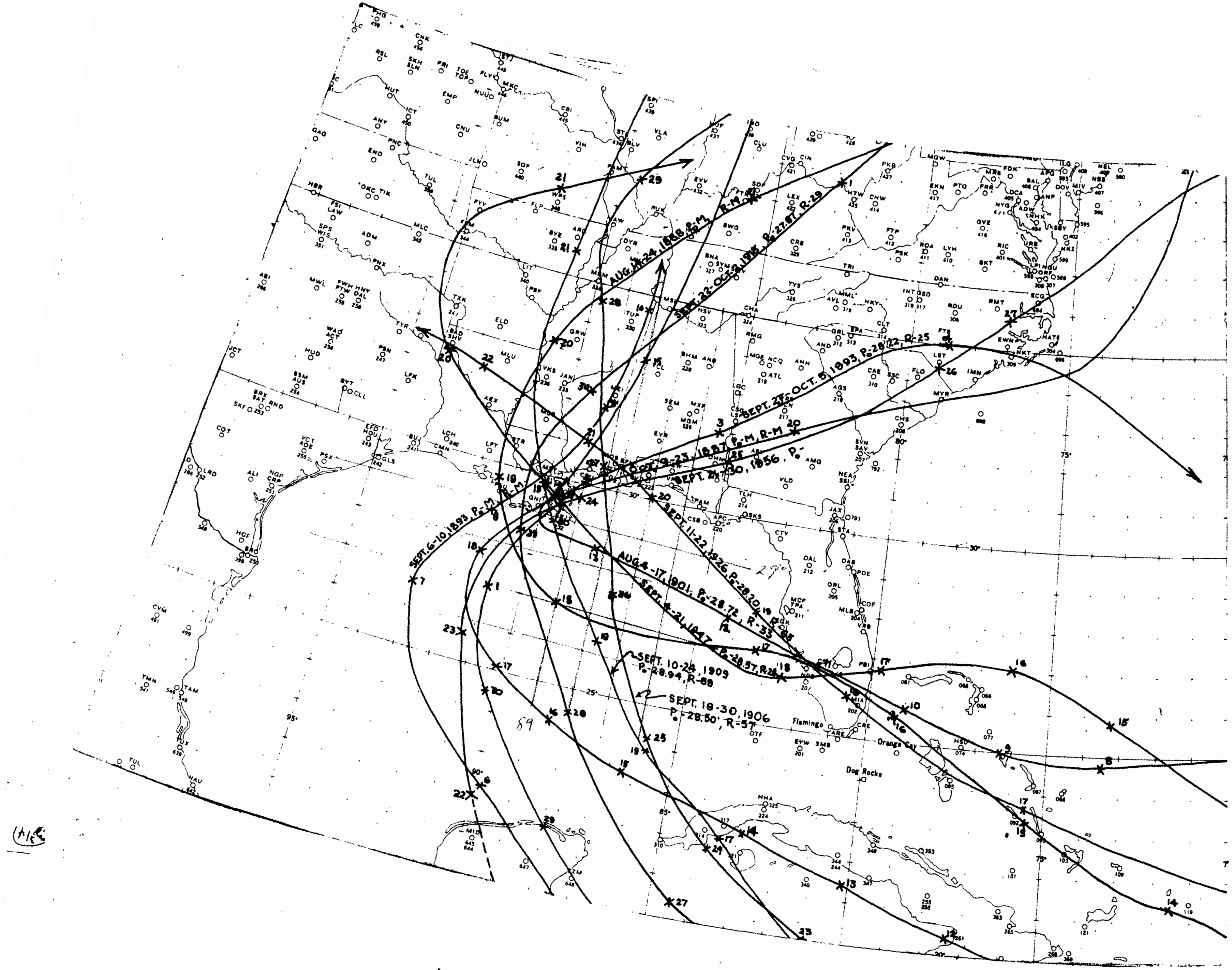


Figure 4

TYPICAL HURRICANE TRACKS

VICINITY LAKE PONTCHARTRAIN

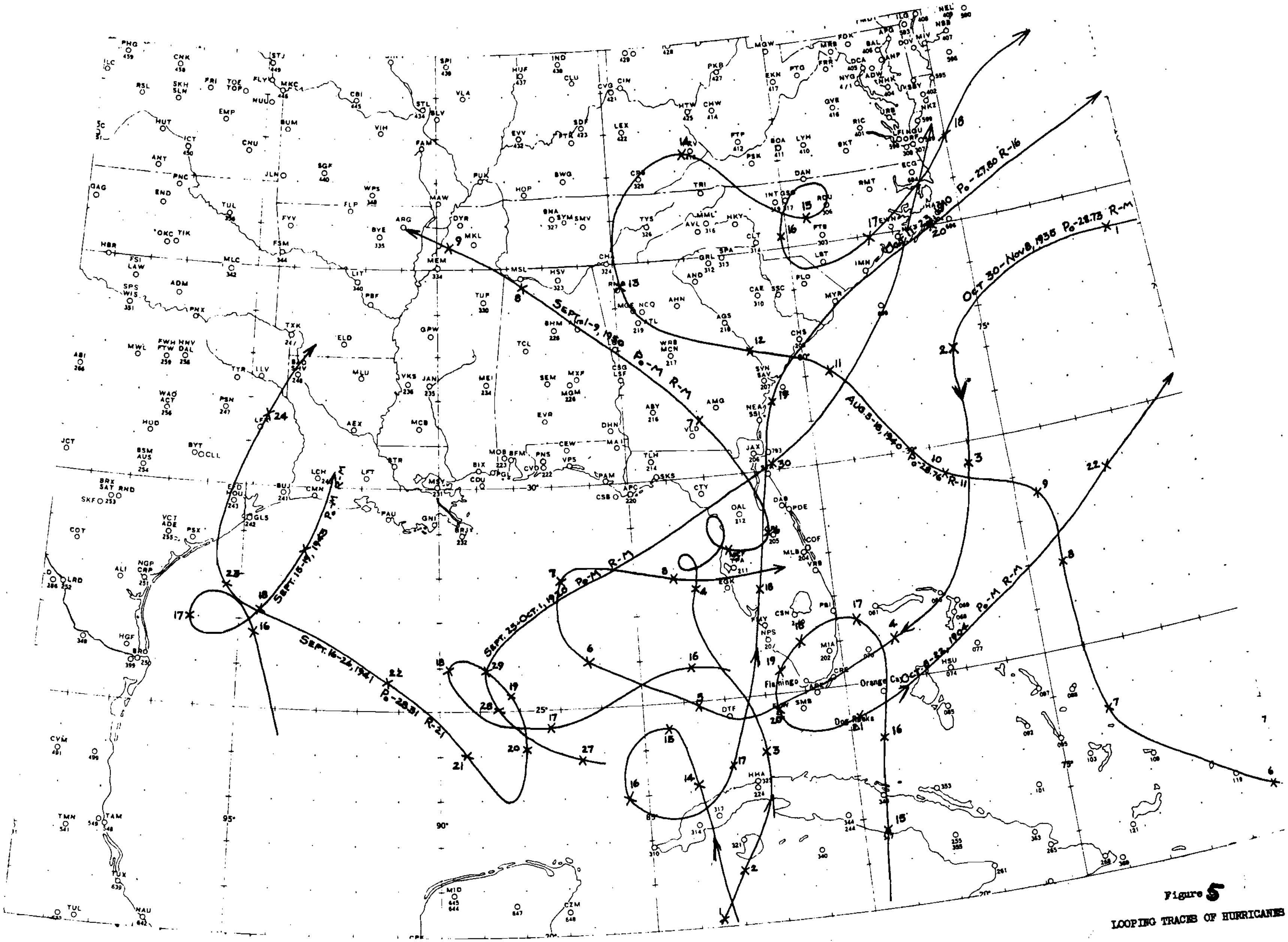


Figure 5

LOOPING TRACES OF HURRICANES

Statement by the Meteorologist In Charge of the New Orleans WBO
(In memorandum to Chief, Hydrologic Services Division, USWB,
dated July 5, 1957)

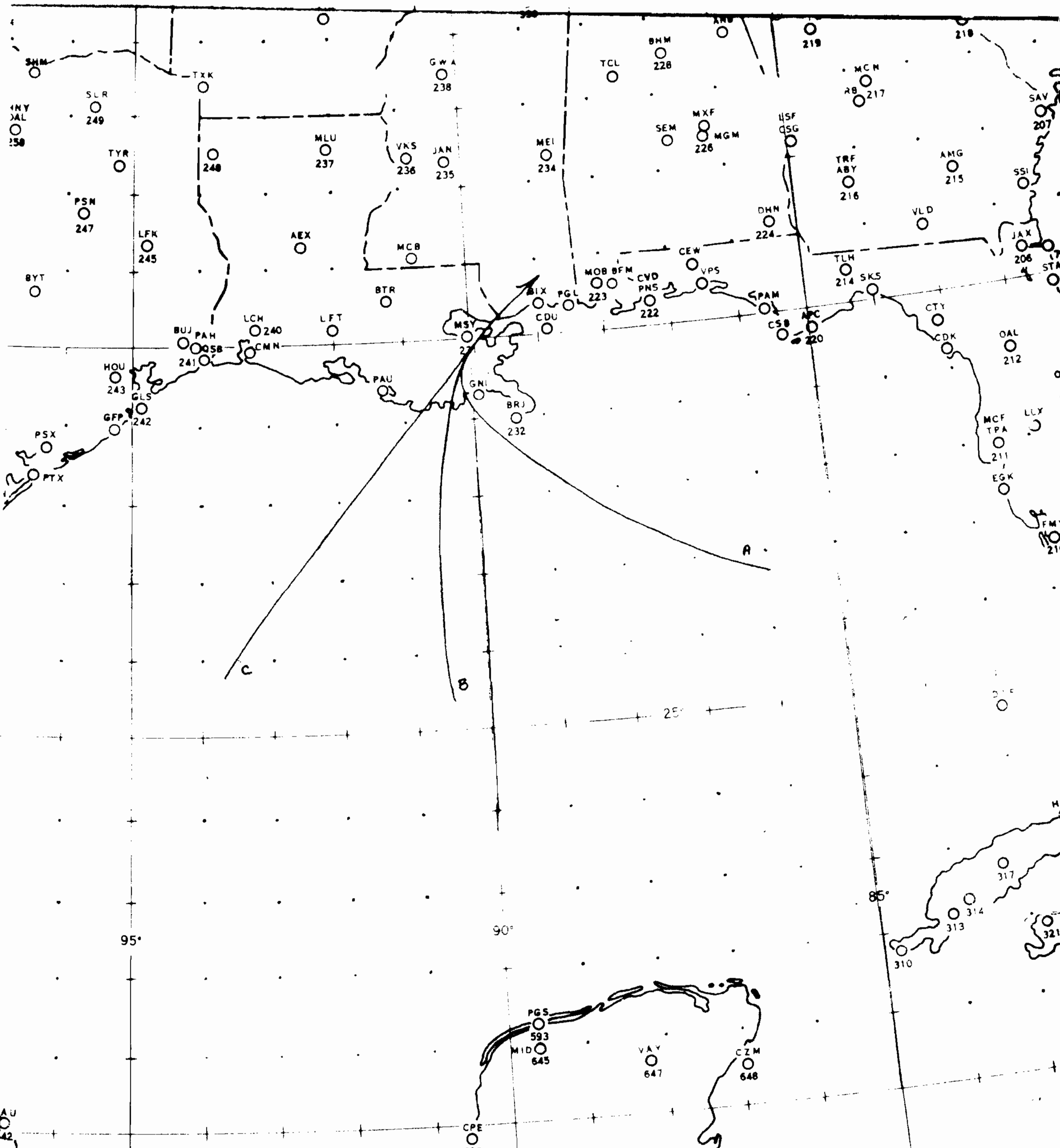
CRITICAL HURRICANE PATH FOR LAKE PONTCHARTRAIN, LA.

"The most critical path of a hurricane to produce a high tide and wave set up on the south shore of Lake Pontchartrain must meet the following requirements.

1. Hurricane at some time must be in a position to cause hurricane force northerly winds over the Lake.
2. Hurricane at some earlier time must be in a position to produce high tides in Lake Pontchartrain.
3. The greater time the two above conditions persist the more serious the set up becomes. (slow moving hurricane).

These conditions would all be met by a hurricane which became stationary a little southeast of New Orleans regardless of its previous path.

The inclosed track A was selected as the most critical because there have been several tracks (altho rather infrequent) similar to it in the Gulf, and because during the (so called) recurvature period the hurricane would most likely be moving slowly. Tracks B and C would also be critical but the chances are that the forward speed would be greater."



critical Hurricane Paths for Lake Pontchartrain
Weather Bureau Office, New Orleans, La.

Mr. Becnel, Jr. for completion of your File ... HUR 7-37

UNITED STATES DEPARTMENT OF COMMERCE
WEATHER BUREAU
WASHINGTON

July 9, 1957

IN REPLY, PLEASE ADDRESS
CHIEF, U. S. WEATHER BUREAU
WASHINGTON 25, D. C.
AND REFER TO

0-6.12

TO : Mr. A. L. Cochran, Civil Works
Office of Chief of Engineers
Corps of Engineers

FROM : Hydrometeorological Section

SUBJECT: Additional figures for Memorandum HUR 7-37, dated June 12, 1957

Herewith are figures 2A and 2B for the subject memorandum. These present isovel charts for Lake Pontchartrain for two additional times in the September 19, 1947 storm, as requested by you by telephone. Copies of these figures were sent to the Beach Erosion Board on July 8 by special messenger.

Charles S. Gilman

Charles S. Gilman, Chief
Hydrometeorological Section

Attachments
cc: 2 with attachments to OCE
1 " " to BEB

Filed w/other charts
HUR 7-57

[redacted]

[redacted]

June 18, 1957

WM:og
HL

0-6.12

TO : Mr. A. L. Cochran, Civil Works
Office of Chief of Engineers
Corps of Engineers

FROM : Hydrometeorological Section

SUBJECT: MEMORANDUM HUR 7-57, Wind Speed and Direction Charts for the Lake Pontchartrain, Chandeleur and Breton Sounds and Mississippi Delta Regions, September 19, 1947

Herewith is MEMORANDUM HUR 7-57 which furnishes wind speed charts for the Hurricane of September 19, 1947 over southeastern Louisiana and the adjacent Gulf of Mexico waters.

Charles S. Gilman, Chief
Hydrometeorological Section

Attachments:
cc: 3 to OCE with attachments

C O P Y

June 12, 1957

0-6.12

MEMORANDUM HUR 7-57 37

FROM : Hydrometeorological Section

SUBJECT: Wind Speed and Direction Charts for the Lake Pontchartrain, Chandeleur and Breton Sounds and Mississippi Delta Regions, September 19, 1947

References: A. Note from Mr. A. L. Cochran, dated 16 May 1957
B. Telephone request of 2 May 1957 from Mr. Nunn of OCE to Mr. Myers of HMS.

Wind Fields

Please find herewith wind speed charts, Figures 1 through 6, showing computed wind speeds and directions over southeastern Louisiana waters, at selected times along the track of the hurricane of September 19, 1947. Lines of equal wind speed are given by solid curves. The interval between these isotachs is 10 m.p.h- Arrows have been used to indicate the direction of the wind.

Steps Used in Computing the Wind Fields

Recently, an additional amount of data was obtained from the Huey Long Bridge, five miles west-southwest of the center of New Orleans. This data agreed with the track of the storm center shown in Hydrometeorological Report No. 32. Therefore, the above track, Figure 7, was used in the computations.

An average radial pressure profile for the period 0300 CST to 1100 CST inclusive, Sept. 19, 1947, Figure 8, taken from the Hydrometeorological Report 32 work files, based on data from Burrwood, New Orleans, Baton Rouge and Lafayette, adequately covered the period selected for the analysis. The above pressure profile was used to compute the corresponding average wind speed profile at gradient level. The form of the gradient wind equation used was:

$$\frac{V_g}{r} + 2\omega \sin \phi \, V_g = \frac{1}{\rho} (P_n - P_o) \frac{R}{r^2} e^{\frac{-R}{r}}$$

The gradient speed profile was in turn converted to an over-water speed profile by the use of the ratios given in figure 26, Hydrometeorological Report No. 32. Lastly an over-land speed profile was obtained by applying the factor 0.7 to the over-water speeds.

The theoretical over-water and over-land speed profiles were adjusted to the available wind speed observations yielding six consistent speed profiles for each of the times selected for analysis. The observations had been adjusted to a uniform anemometer height of 30 feet above the surface, whenever feasible. An allowance was also made for the component of the wind speed due to the forward motion of the hurricane. All speeds were averages over a ten-minute time interval.

A constant deflection angle of 30° was adopted. This angle represents the best compromise of all the values observed during the analysis period at several stations, at various distances from the storm center.

In summary, the charts represent 10-minute average wind speed values at 30 feet above the ground, adjusted for the character of the underlying surface as well as coastline effects, and including an allowance for the component due to the forward motion of the storm.

Miscellaneous Information

Central pressure at landfall on the Louisiana coast: 28.57 in.
Central pressure at landfall on the Florida coast: 27.76 in.
Radius of maximum winds in the Louisiana region: approx. 34 statute miles.
Speed of storm in the several hours prior to landfall (Gulf Coast): 15-16 m.p.h.
Speed of storm in the first few hours after landfall: approx. 20 m.p.h.

Charles S. Gilman, Chief
Hydrometeorological Section

Attachments
cc: 3 to OCE with attachments

HL:eg
WM

June 12, 1957

0-6.12

MEMORANDUM HUR 7-57

FROM : Hydrometeorological Section

SUBJECT: Wind Speed and Direction Charts for the Lake Pontchartrain, Chandeleur and Breton Sounds and Mississippi Delta Regions, September 19, 1947

References: A. Note from Mr. A. L. Cochran, dated 16 May 1957
B. Telephone request of 2 May 1957 from Mr. Bunn of OCE to Mr. Myers of HMS.

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Steps Used in Computing the Wind Fields

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An average radial pressure profile for the period 0500 CST to 1100 CST inclusive, Sept. 19, 1947, Figure 8, taken from the Hydrometeorological Report 32 work files, based on data from Burrwood, New Orleans, Baton Rouge and Lafayette, adequately covered the period selected for the analysis. The above pressure profile was used to compute the corresponding average wind speed profile at gradient level. The form of the gradient wind equation used was:

$$\frac{V_g^2}{r} + 2\omega \sin\phi \, V_g = \frac{1}{\rho}(P_n - P_o)\frac{R}{r^2}e^{-\frac{R}{r}}$$

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A constant deflection angle of 30° was adopted. This angle represents the best compromise of all the values observed during the analysis period at several stations, at various distances from the storm center.

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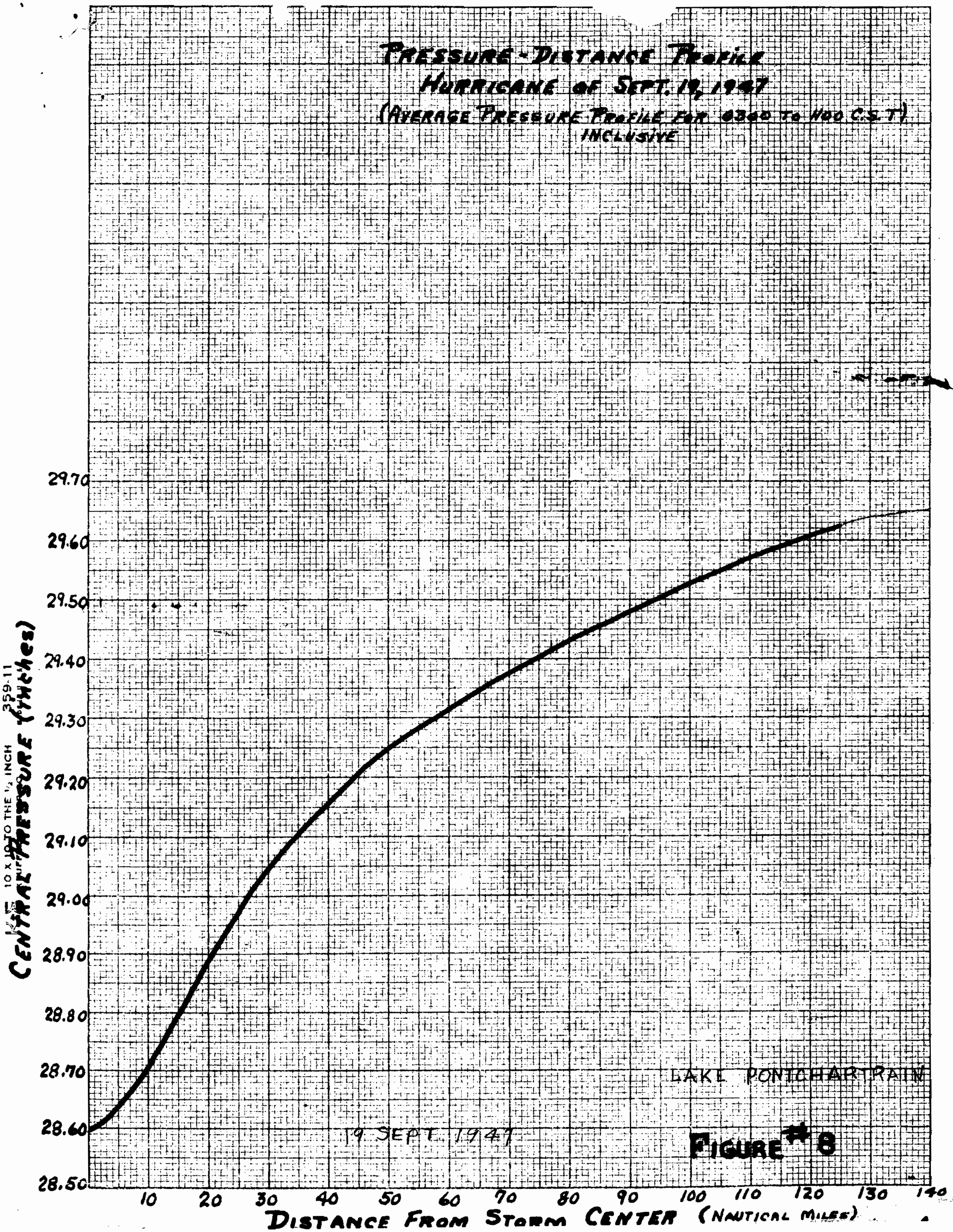
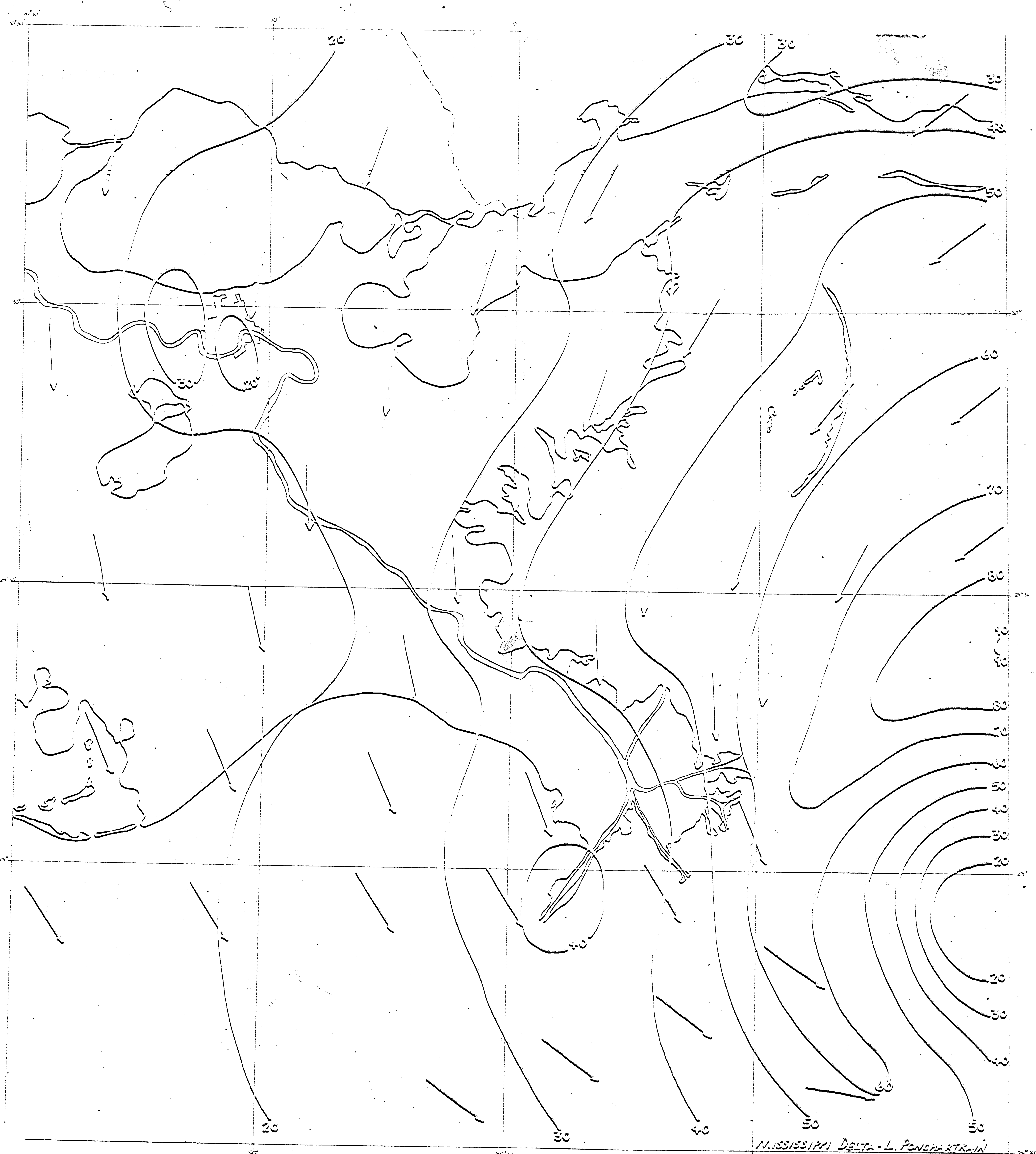
Radius of maximum winds in the Louisiana region: approx. 34 statute miles.
Speed of storm in the several hours prior to landfall
(Gulf Coast: 15-16 m.p.h.
Speed of storm in the first few hours after landfall:
approx. 20 m.p.h.

Charles S. Gilman, Chief
Hydrometeorological Section

ttachments
cc: 3 to OCE with attachments


PRESSURE - DISTANCE PROFILE
HURRICANE OF SEPT. 19, 1947
(AVERAGE PRESSURE PROFILE FOR 0300 TO 1100 C.S.T)
INCLUSIVE
CENTRAL PRESSURE (INCHES)
29.70
29.60
29.50
29.40
29.30
29.20
29.10
29.00
28.90
28.80
28.70
28.60
28.50
10
20
30
40
50
60
70
80
90
100
110
120
130
140
DISTANCE FROM STORM CENTER (NAUTICAL MILES)
LAKE PONTCHARTRAIN
19 SEPT 1947
FIGURE # 8
10 X 10 TO THE 1/2 INCH
359-11



N.ISSISSIPPI DELTA - L. PONCHARTRAIN
COAST LINE IS SCHEMATIC

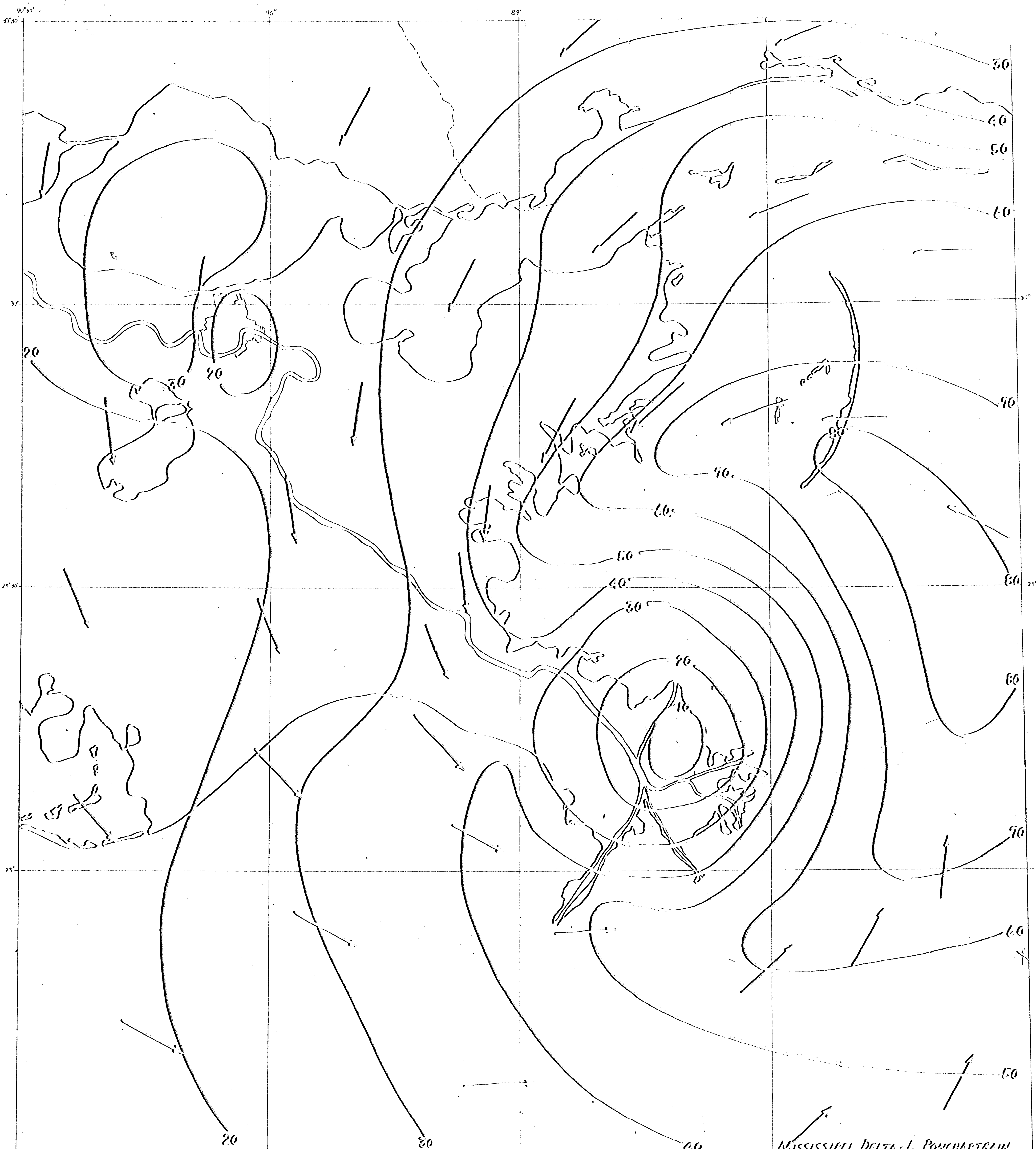
0300 C.S.T.

WIND SPEED (M.P.H.) AND DIRECTION, 0300 C.S.T. SEPT. 19, 1947
COMPUTED 10-MINUTE AVERAGE SPEEDS AT 30 FEET ABOVE THE SURFACE

Scale 1:500,000

FIGURE #1

1:500,000



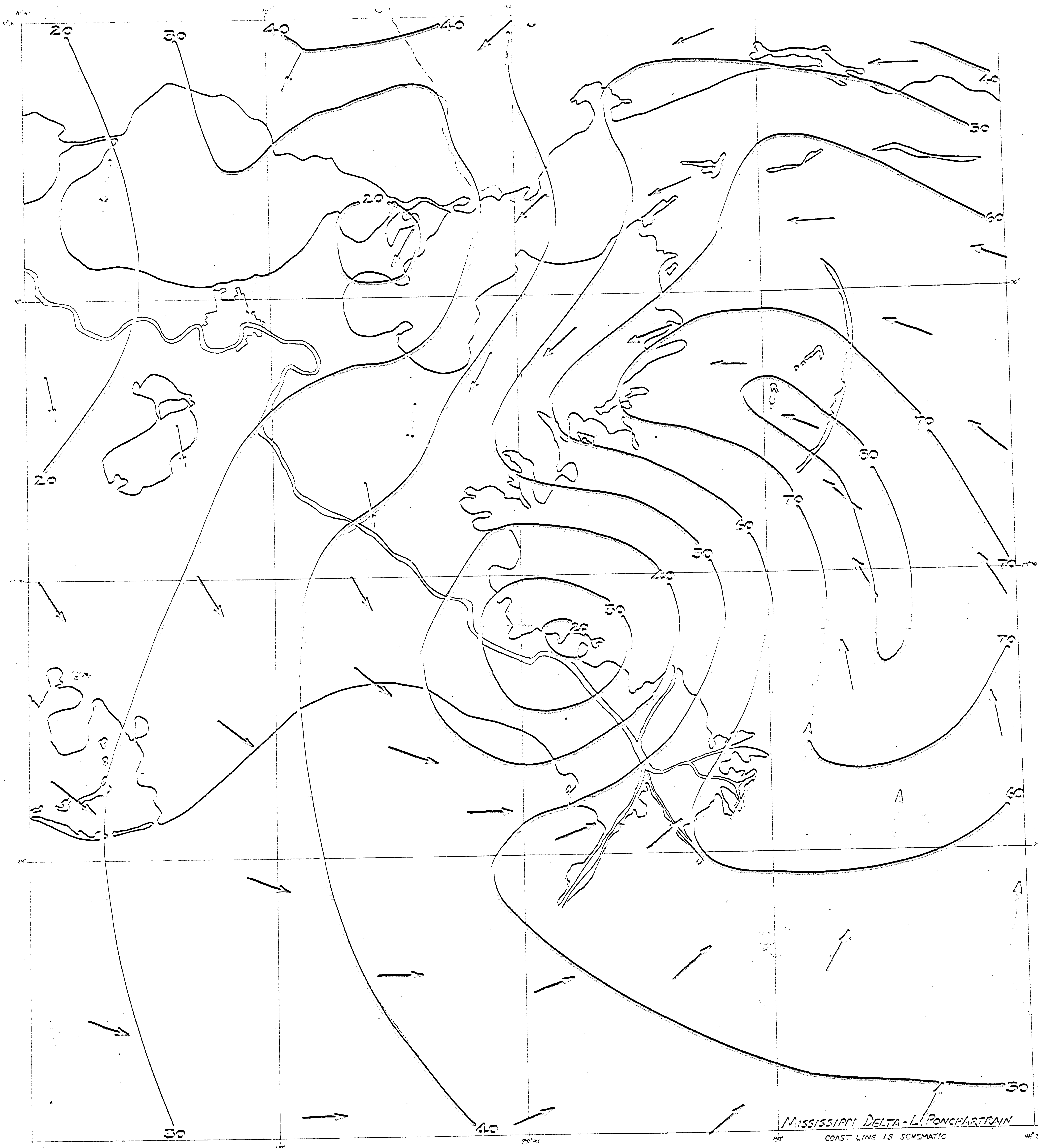
0600 C.S.T.

Wind Speed (mph) and Direction, 0600 C.S.T. Sept. 19, 1947

Computed 10-Minute Average Speeds at 30 feet above the surface

Scale 1:500,000

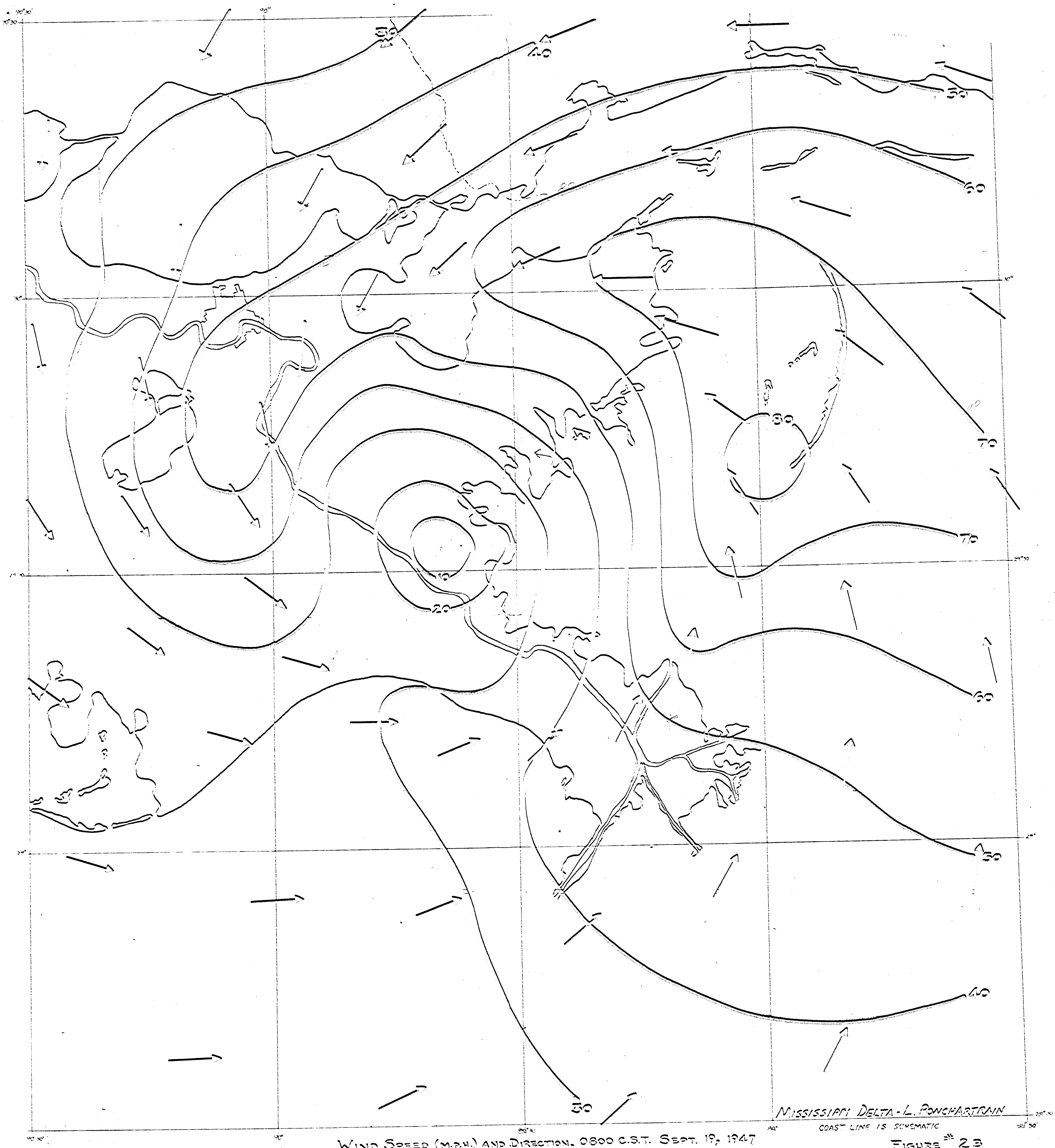
Figure #2



Wind Speed (M.P.H.) and Direction, 0700 C.S.T. Sept. 19, 1947
Computed 10-minute Average Speeds at 30 feet above the Surface

Figure # 2A

Scale 1:500,000



Wind Speed (M.P.H.) and Direction, 0800 C.S.T. Sept. 19, 1947
Computed 10-Minute Average Speeds at 30 feet Above the Surface

Figure # 23

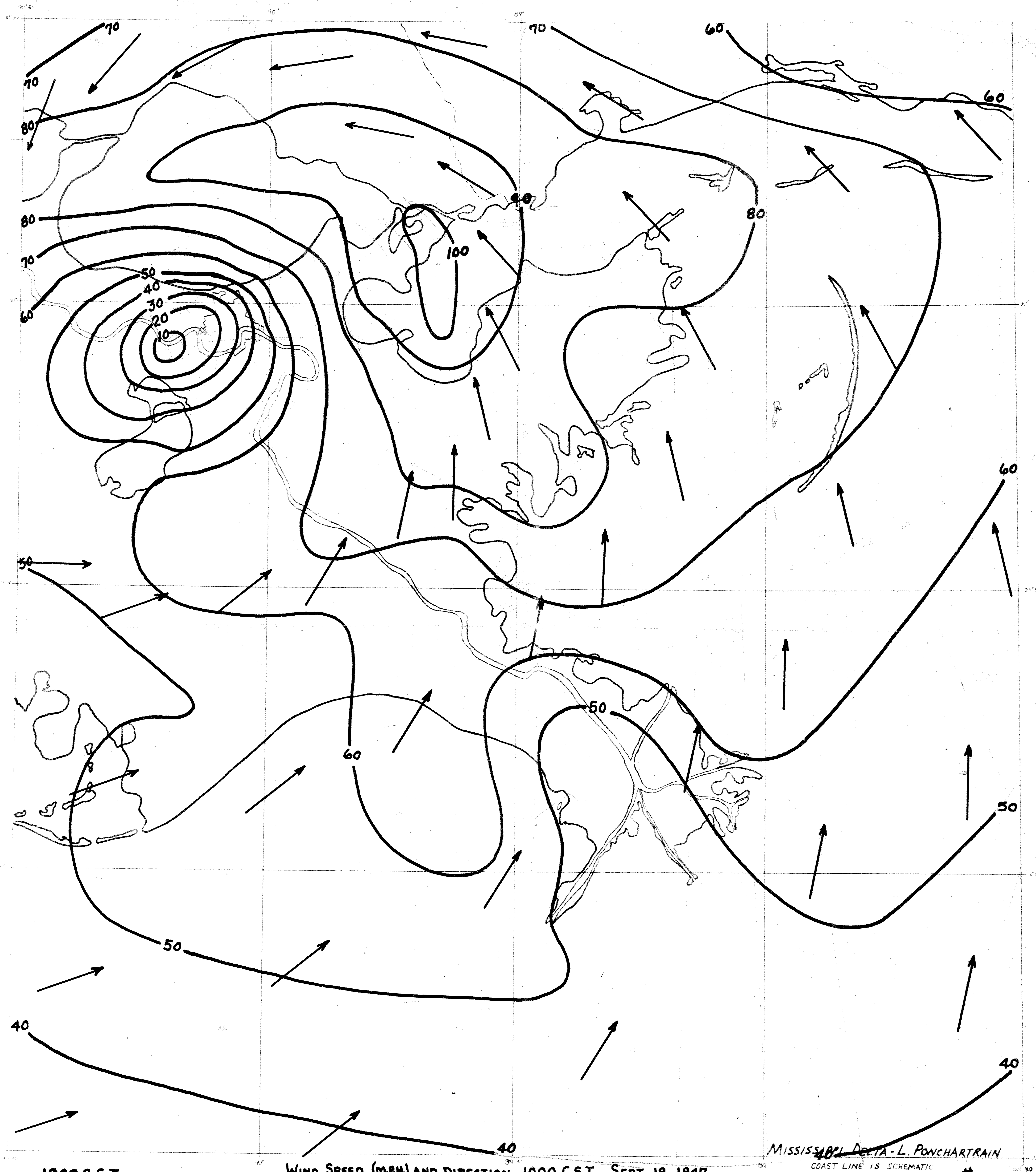
Scale 1:500,000

0900 C.S.T.

Wind Speed (M.P.H.) and Direction, 0900 C.S.T. Sept. 19, 1947
Computed 10-Minute Average Speeds at 30 Feet above the Surface

Figure #3

Scale 1:500,000



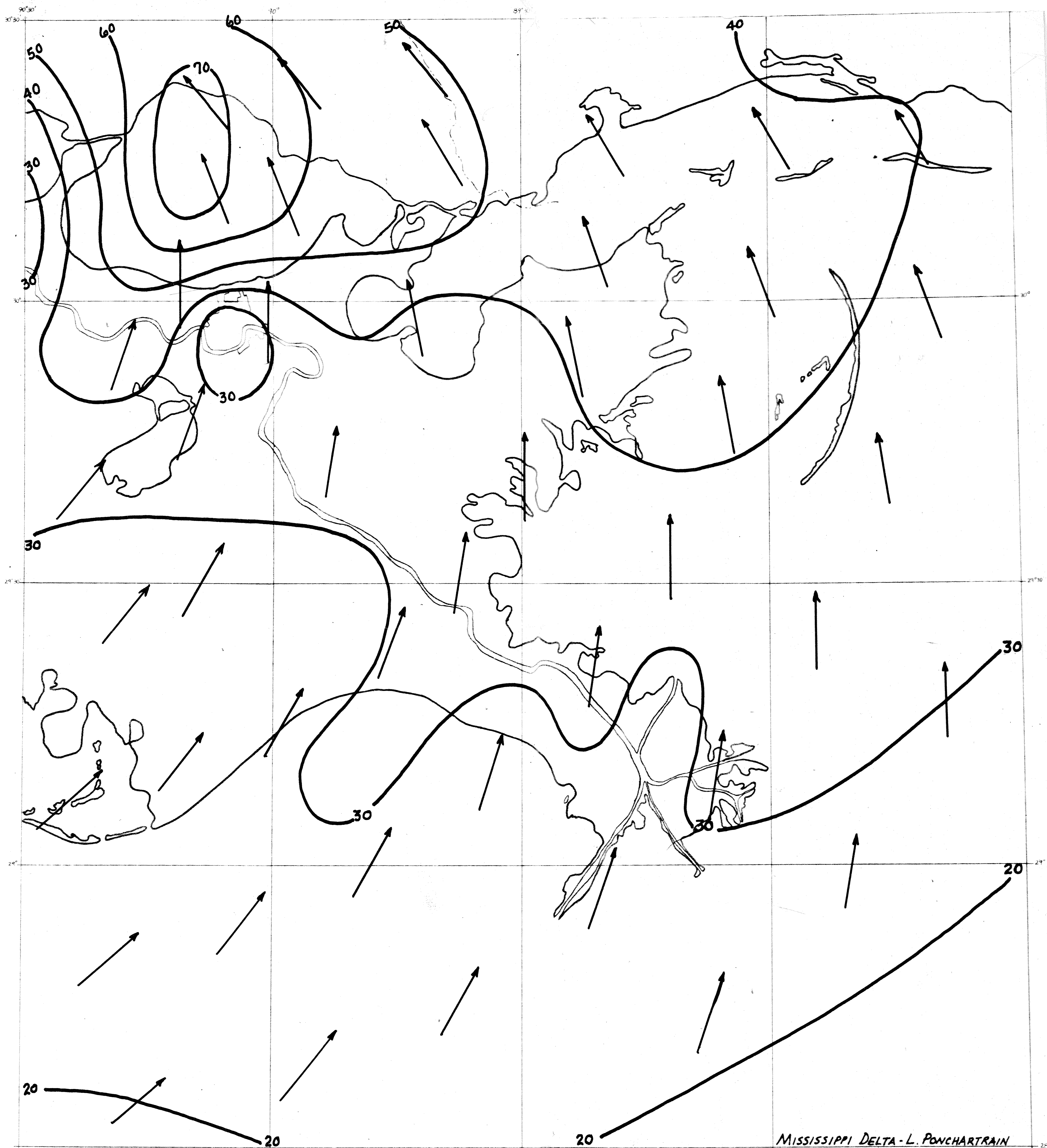
1000 C.S.T.

Wind Speed (M.P.H.) and Direction, 1000 C.S.T. Sept. 19, 1947

Computed 10-Minute Average Speeds at 30 Feet above the Surface

Figure #4

Scale 1:500,000



Mississippi Delta - L. Ponchartrain

COAST LINE IS SCHEMATIC

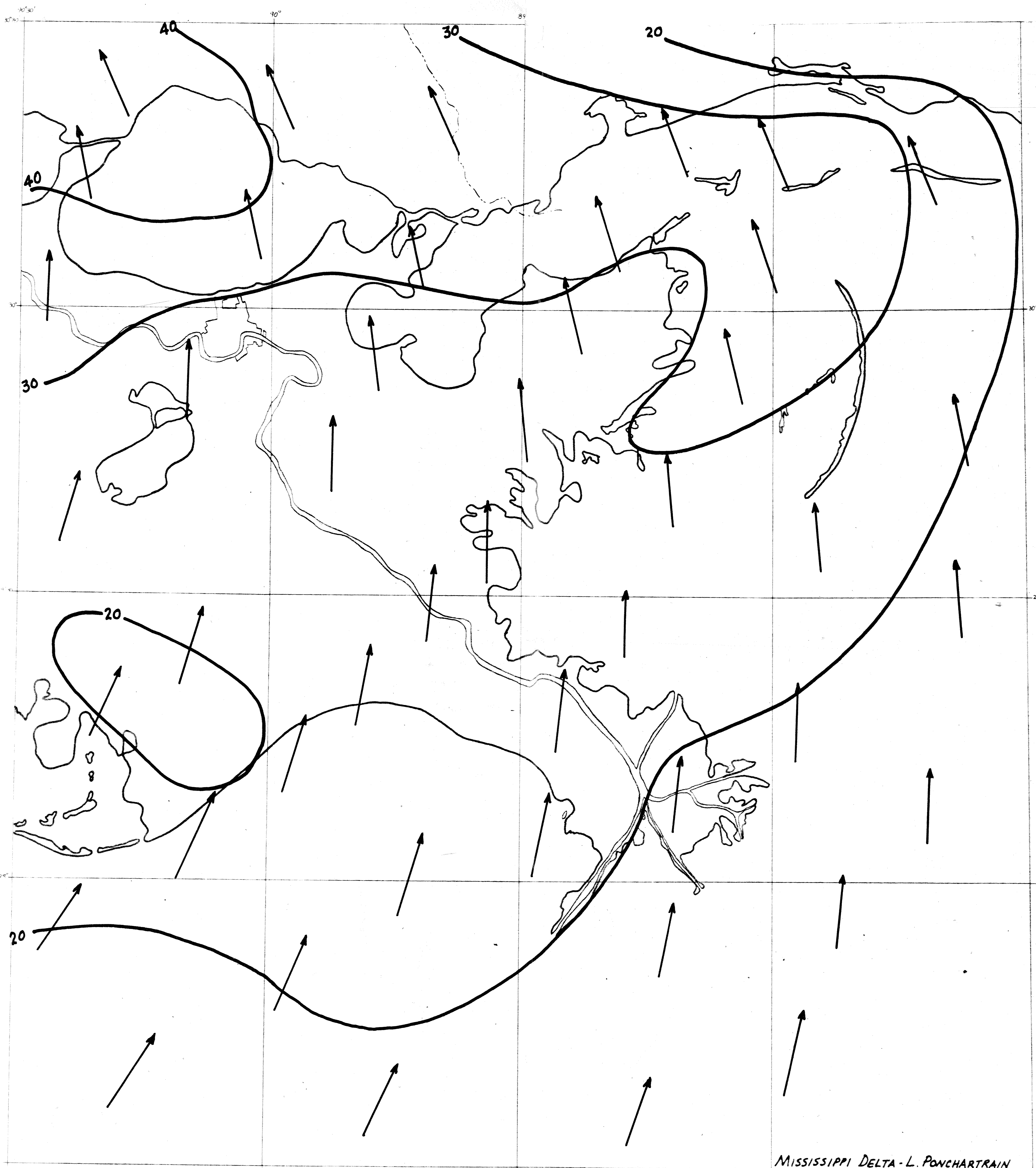
1200 C.S.T.

WIND SPEED (M.P.H.) AND DIRECTION, 1200 C.S.T. SEPT. 19, 1947

COMPUTED 10-MINUTE AVERAGE SPEEDS AT 30 FEET ABOVE THE SURFACE

FIGURE #5

Scale 1:500,000

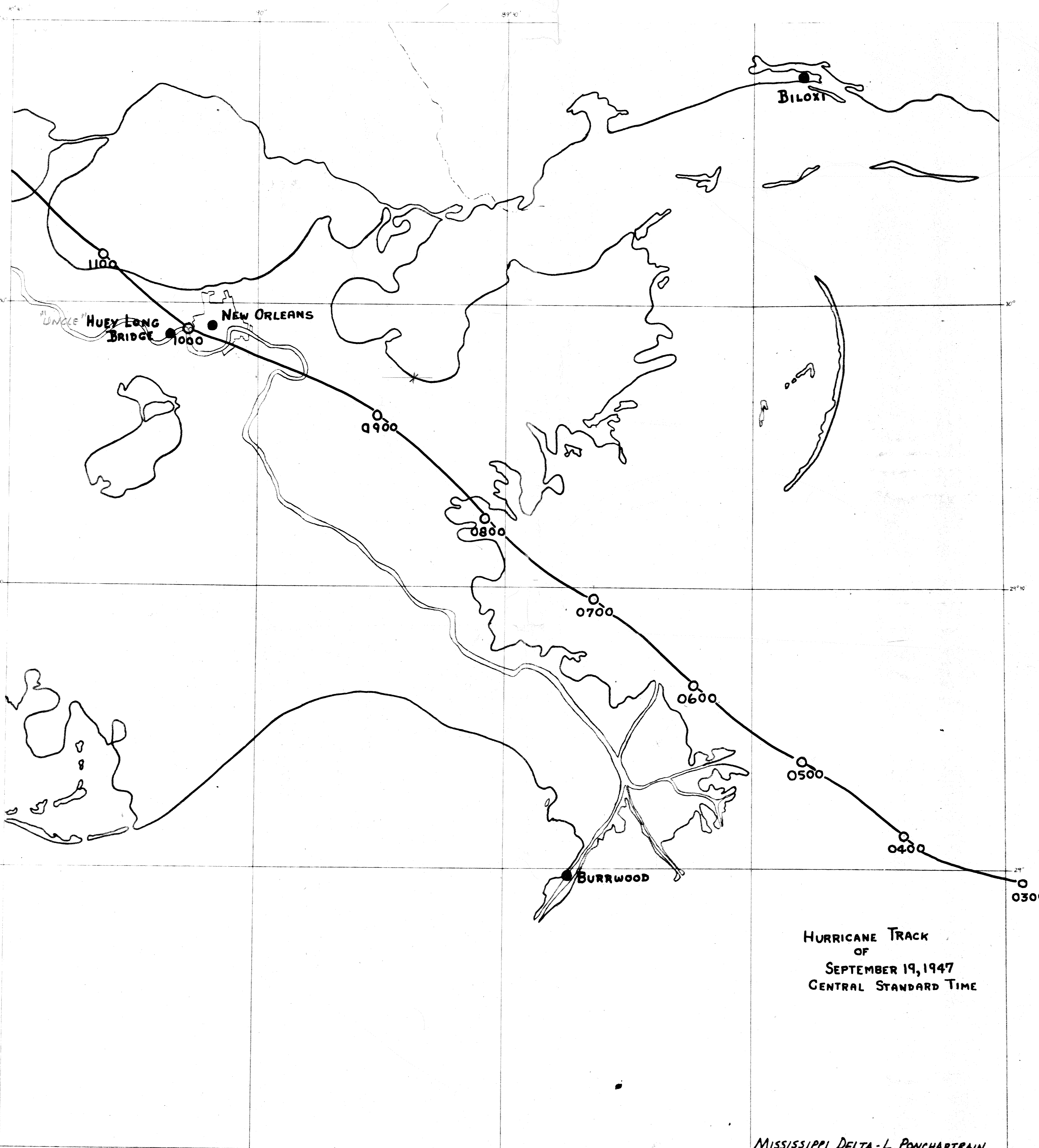


1400 C.S.T.

Wind Speed (M.P.H.) and Direction, 1400 C.S.T. Sept. 19, 1947
Computed 10-Minute Average Speeds at 30 Feet Above the Surface

Figure #6

Scale 1:500,000



Mississippi Delta - L. Ponchartrain

COAST LINE IS SCHEMATIC

Figure #7

Scale 1:500,000

UNITED STATES DEPARTMENT OF COMMERCE
WEATHER BUREAU
WASHINGTON

March 28, 1957

IN REPLY, PLEASE ADDRESS
CHIEF, U. S. WEATHER BUREAU
WASHINGTON 25, D. C.
AND REFER TO

0-6.12

TO : Mr. A. L. Cochran, Civil Works
Office of Chief of Engineers
Corps of Engineers

FROM : Hydrometeorological Section

SUBJECT : MEMORANDUM HUR 7-28, Wind Speed and Direction Charts for the Lake Pontchartrain, Chandeleur and Breton Sounds and Mississippi Delta Regions, September 29, 1915.

Herewith is Memorandum 7-28 which furnishes wind speed charts for the Louisiana Hurricane of 1915 over the Gulf of Mexico waters.

Charles S. Gilman, Chief
Hydrometeorological Section

Attachments
2 copies with attachments to OCE
1 copy to BEB with attachments

[redacted]

UNITED STATES DEPARTMENT OF COMMERCE
WEATHER BUREAU
WASHINGTON

March 25, 1957

IN REPLY, PLEASE ADDRESS
CHIEF, U. S. WEATHER BUREAU
WASHINGTON 25, D. C.
AND REFER TO
0-6.12

MEMORANDUM: HUR 7-28

FROM: Hydrometeorological Section

SUBJECT: Wind Speed and Direction Charts for the Lake Pontchartrain, Chandeleur and Breton Sounds and Mississippi Delta Regions, September 29, 1915.

References: a. Memorandum HUR 7-15 and the references therein.
b. Telephone request of last month from OCE to HMS.

Wind Fields

Herewith are charts (figures 1 through 7) showing computed wind speeds and directions over southeastern Louisiana waters, at selected times along the track of the hurricane of September 29, 1915. In contrast to the charts for Lake Pontchartrain that accompanied Memorandum HUR 7-15, the new figures represent wind fields over a considerably larger area. The times are the same except for the substitution of two charts prior to landfall, at 0800 and 1000 C.S.T., in lieu of wind fields for 1700 and 1900 C.S.T. p reviously submitted.

Steps Used in Computing the Wind Fields

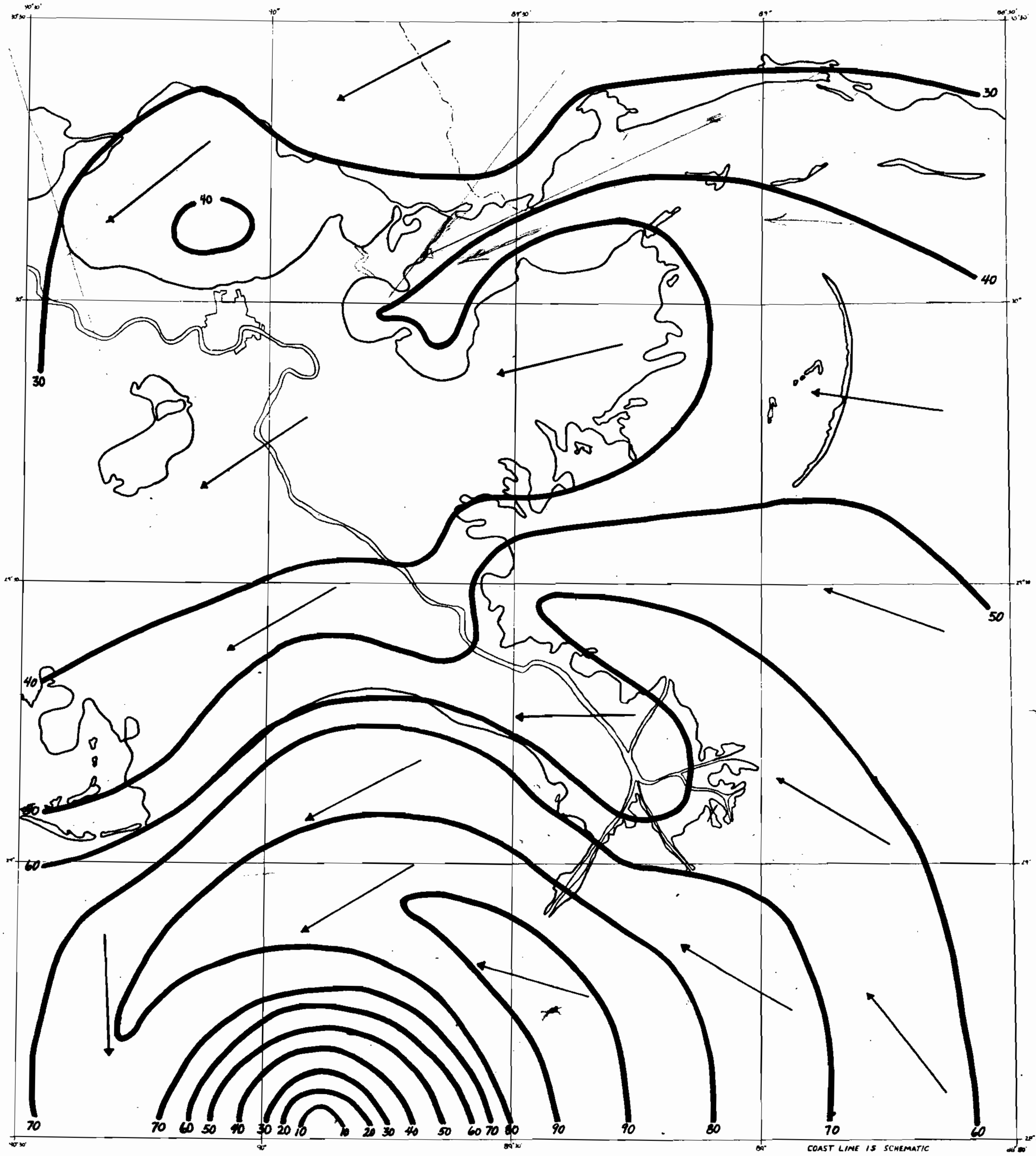
Essentially the same procedures that were followed to derive the figures of HUR 7-15, were used to obtain the new wind charts.

Slight variation in the determination of the angle of inflow toward low pressure was deemed advisable based on additional empirical information. The direction arrows have been adjusted to point in toward low pressure at various angles up to as much as 35 degrees over land and 32 degrees over water, depending upon the topography. The deflection values of 35 and 32 degrees were applied at distances greater than the radius of maximum winds from the center. Lesser deflection angles were indicated by the graph at locations within the radius of maximum winds. In the earlier charts the corresponding values used were slightly higher, being 40 degrees over land and 37 degrees over water respectively.

The speed profile for 1200 C.S.T., September 29, just prior to landfall, was also used for the charts at 1000 and 0800 C.S.T. Otherwise, each of the charts is based upon its respective speed profile, these being identical with the profiles prepared for HUR 7-15.

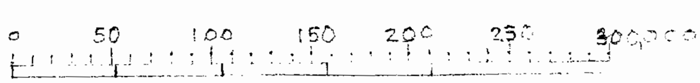
Charles S. Gilman, Chief
Hydrometeorological Section

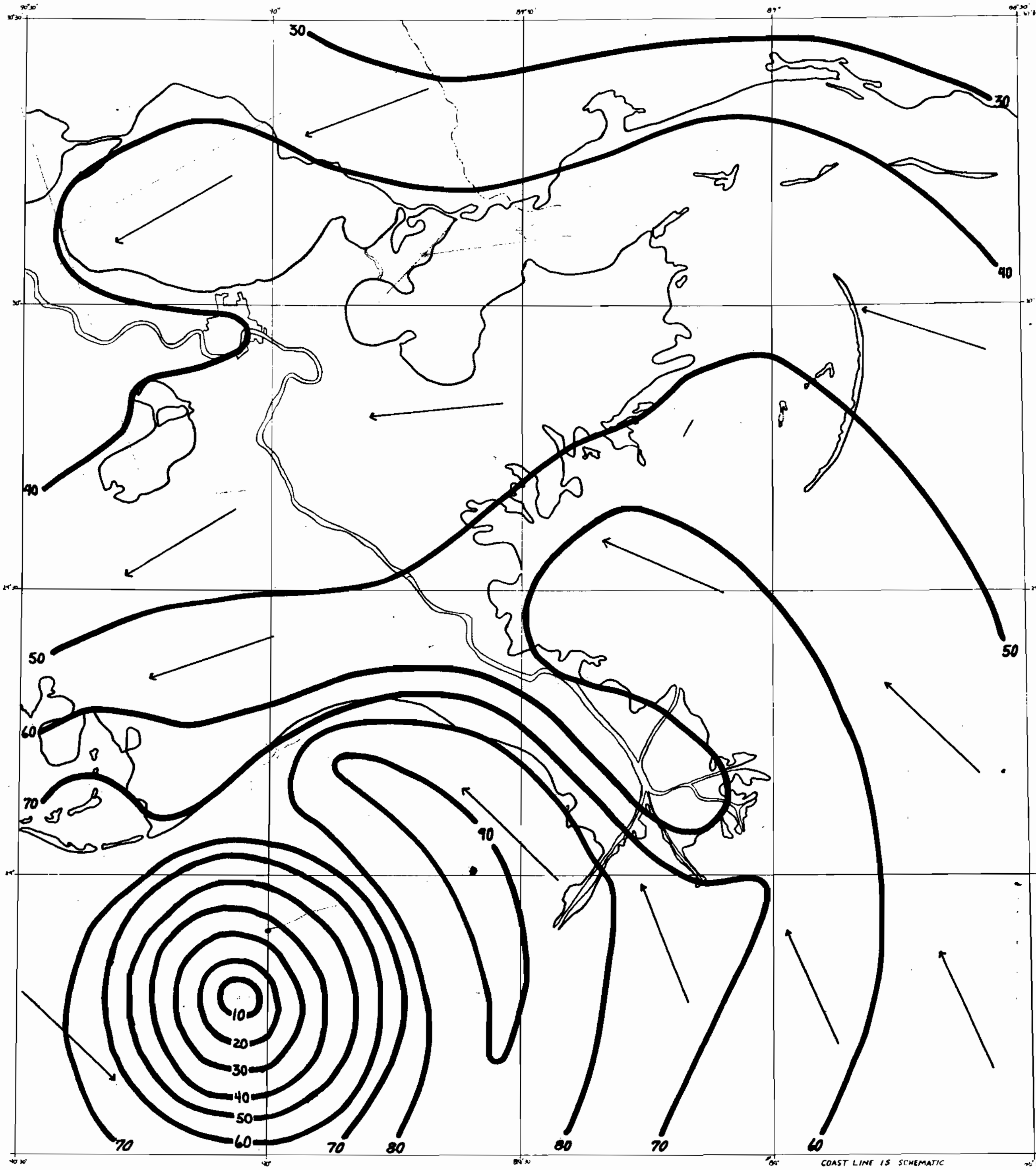
Attachments
2 copies with att. to OCE
1 copy to BEB With attachments



Wind Speed (m.p.h.) and Direction, 0800 C.S.T., Sept. 29, 1915
(Estimated 10-minute Average Velocities at 30 feet Above the Surface)

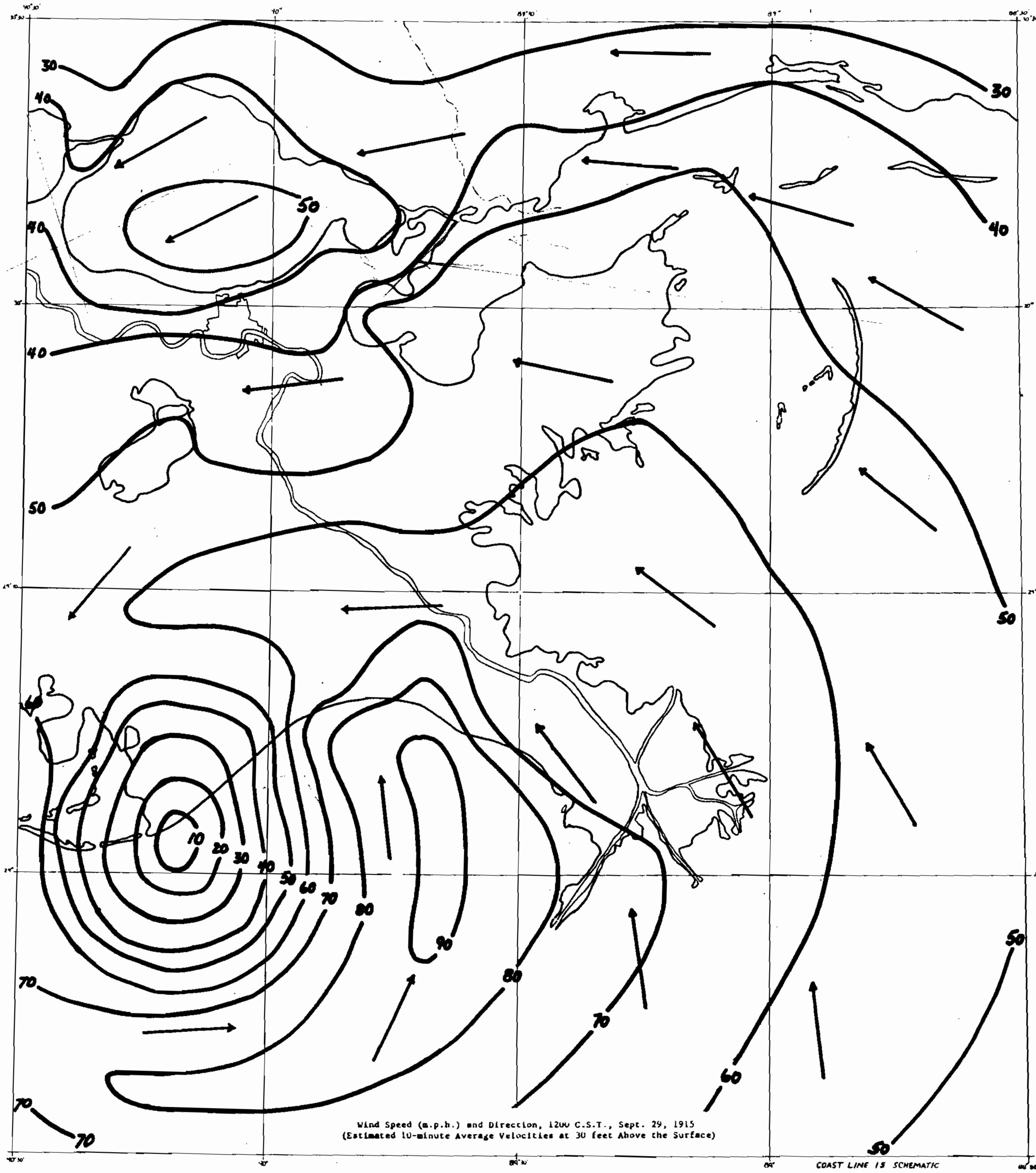
0800 CST





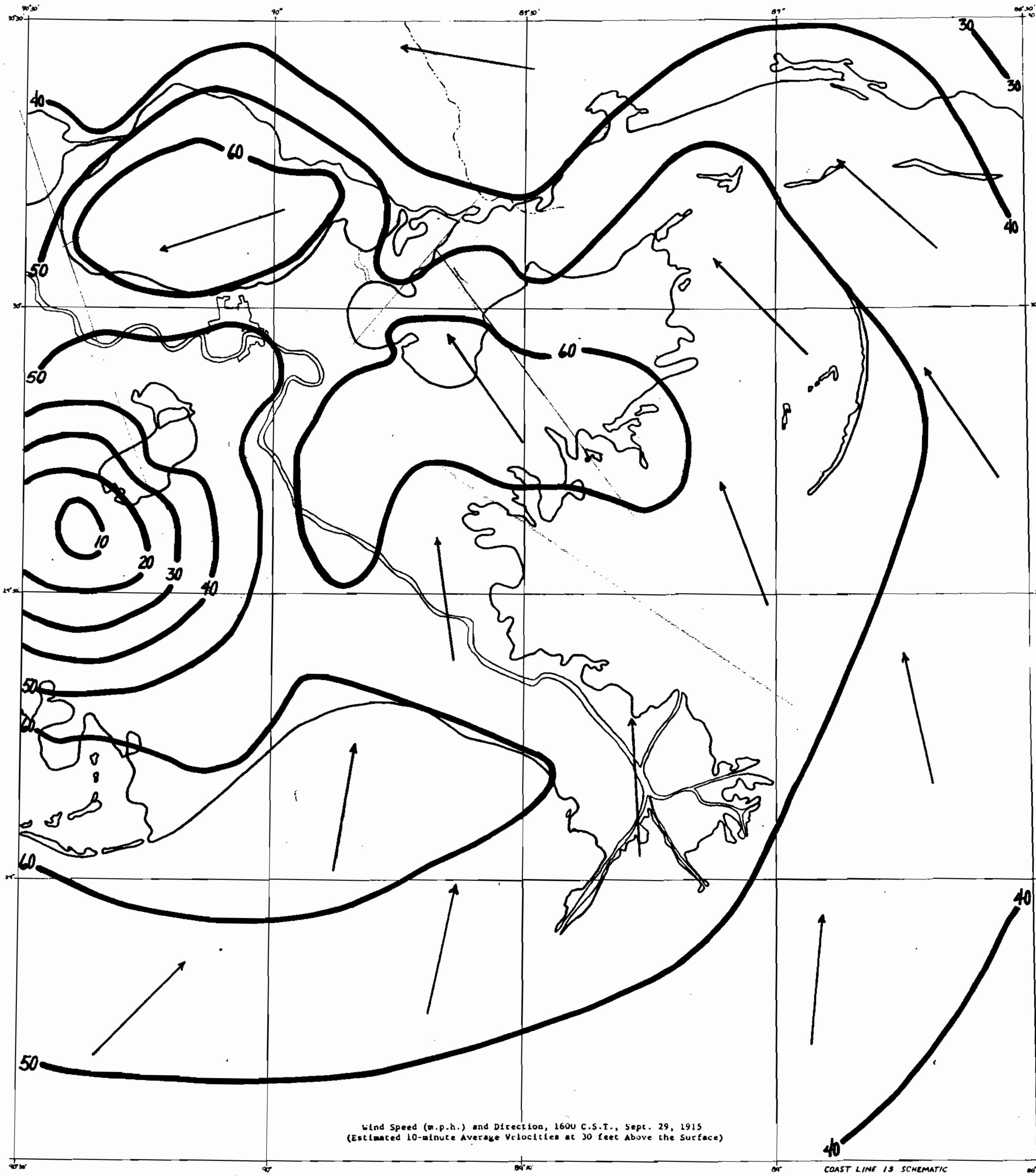
Wind Speed (m.p.h.) and Direction, 1000 C.S.T., Sep. 29, 1915
(Estimated 10-minute Average Velocities at 30 feet Above ... rface)

1000 CST



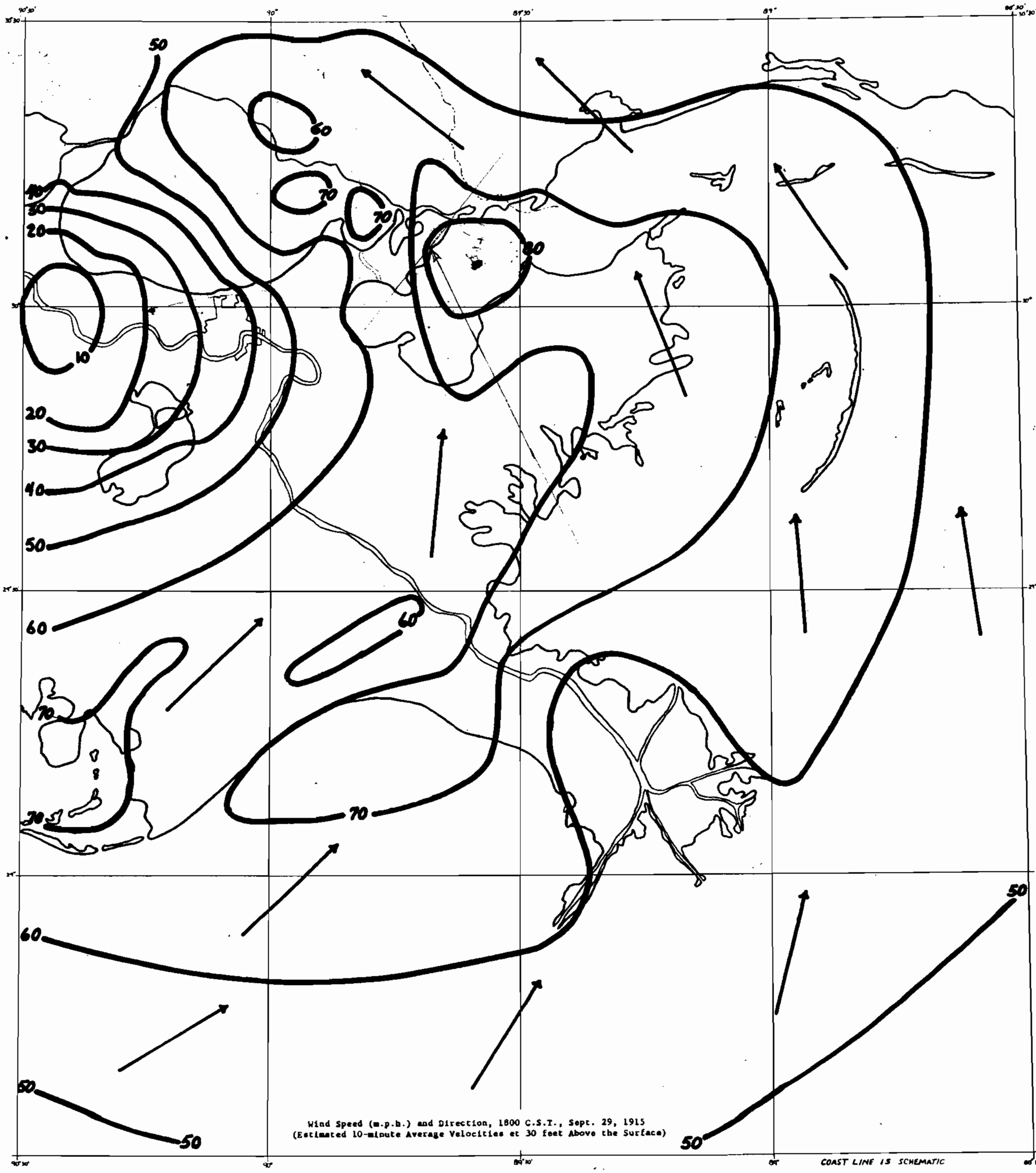
Wind Speed (m.p.h.) and Direction, 1200 C.S.T., Sept. 29, 1915
(Estimated 10-minute Average Velocities at 30 feet Above the Surface)

1200 CST



Wind Speed (m.p.h.) and Direction, 1600 C.S.T., Sept. 29, 1915
(Estimated 10-minute Average Velocities at 30 feet Above the Surface)

1600 CST


50
60
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40
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60
70
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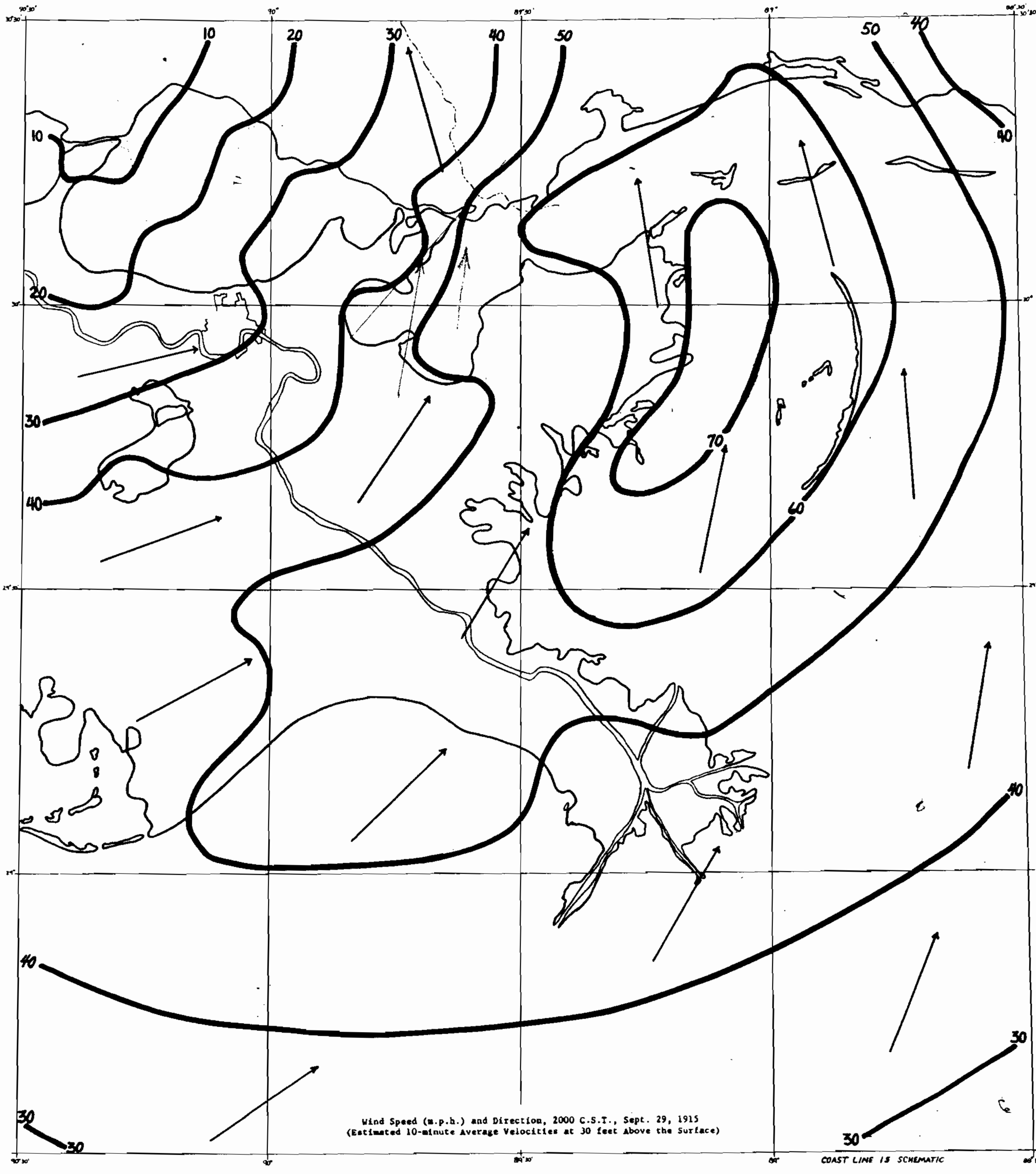
70
60
50
50
50
50
Wind Speed (m.p.h.) and Direction, 1800 C.S.T., Sept. 29, 1915
(Estimated 10-minute Average Velocities at 30 feet Above the Surface)
COAST LINE IS SCHEMATIC

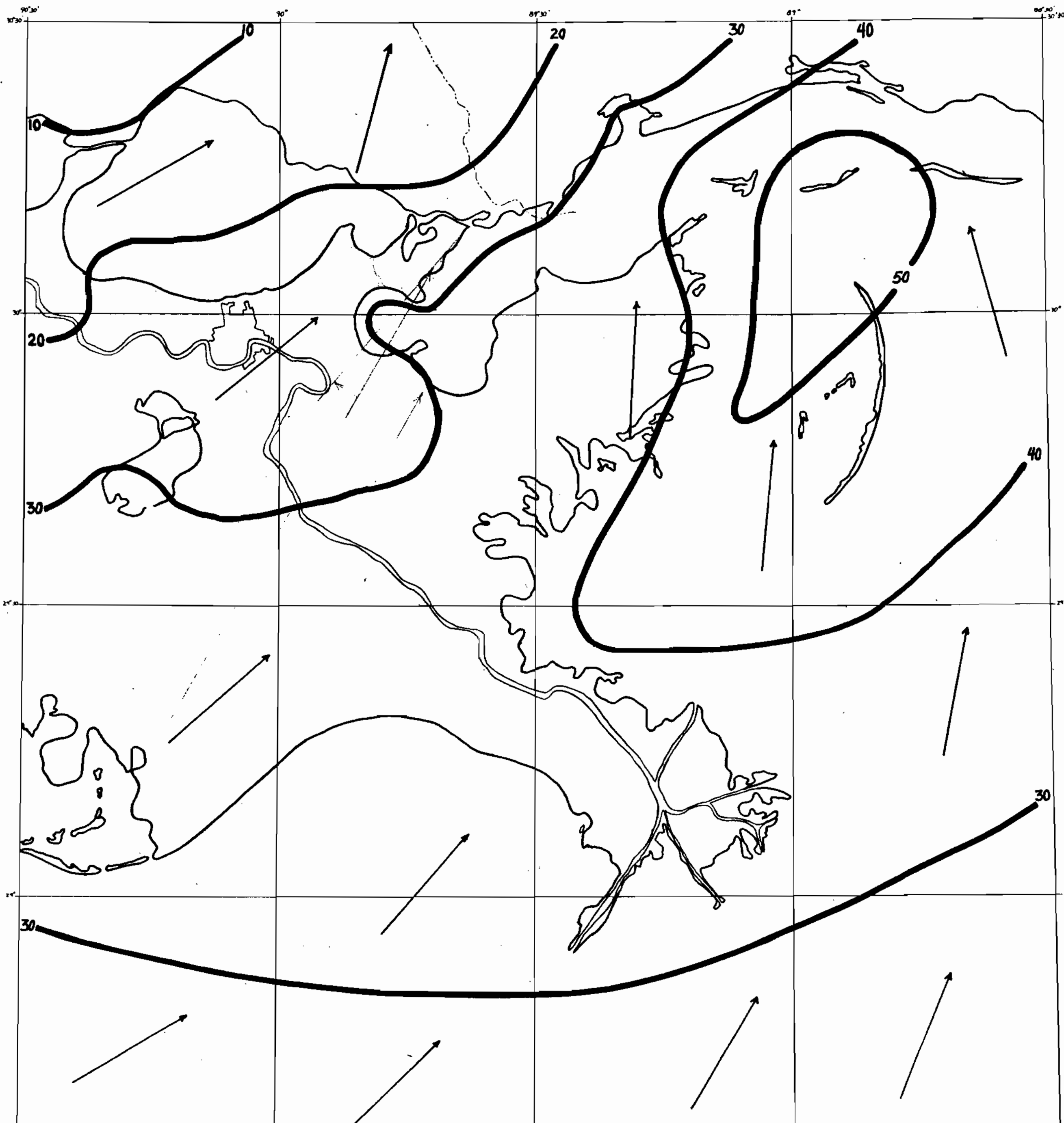
1800 CST



Wind Speed (m.p.h.) and Direction, 2000 C.S.T., Sept. 29, 1915
(Estimated 10-minute Average Velocities at 30 feet Above the Surface)

COAST LINE IS SCHEMATIC

2000 CST



Wind Speed (m.p.h.) and Direction, 2200 C.S.T., Sept. 29, 1915
(Estimated 10-minute Average Velocities at 30 feet Above the Surface)

2200 CST

UNITED STATES DEPARTMENT OF COMMERCE
WEATHER BUREAU
WASHINGTON 25

October 19, 1956

IN REPLY, PLEASE ADDRESS
CHIEF OF BUREAU
AND REFER TO

0-6.12

TO : Mr. A. L. Cochran, Civil Works
Office of Chief of Engineers

FROM : Hydrometeorological Section

SUBJECT : MEMORANDUM HUR 7-17
Hurricane of October 1893 in Louisiana

The subject hurricane produced one of the greatest inundations in the history of Louisiana. Enclosed is Memorandum HUR 7-17 which covers our study of this storm. The study was carried out in connection with our New Orleans-Lake Pontchartrain assignment (memo from OCE July 13, 1956) and is for the information of the New Orleans District Office and other offices concerned.

Charles S. Gilman, Chief
Hydrometeorological Section

Enclosure
cc: 2 with enclosures to OCE
1 with enclosure to BEB

UNITED STATES DEPARTMENT OF COMMERCE
WEATHER BUREAU
WASHINGTON 25

October 10, 1956

IN REPLY, PLEASE ADDRESS
CHIEF OF BUREAU
AND REFER TO

0-6.12

TO : Mr. A. L. Cochran, Civil Works
Office of Chief of Engineers

FROM : Hydrometeorological Section

SUBJECT: MEMORANDUM HUR 7-16
"Hurricane Characteristics in the Vicinity of Lake Pontchartrain and New Orleans, La."

Forwarded herewith is memorandum HUR 7-16 which gives speeds and records of motions, central pressures, radius of maximum winds and other data for use in choosing project hurricanes in the Louisiana area.

Charles S. Gilman, Chief
Hydrometeorological Section

cc: 2 with attachments to OCE
1 with attachments to BEB

UNITED STATES DEPARTMENT OF COMMERCE
WEATHER BUREAU
WASHINGTON 25

October 10, 1956

IN REPLY, PLEASE ADDRESS
CHIEF OF BUREAU
AND REFER TO

0-6.12

TO : Mr. A. L. Cochran, Civil Works
Office of Chief of Engineers

FROM : Hydrometeorological Section

SUBJECT: Hurricane Characteristics in the Vicinity of Lake Pontchartrain and New Orleans, La.

Reference: Memorandum to Dr. C. S. Gilman, HMS 13 July 1956, subject: Hurricane Survey, New Orleans District (item b)
Memorandum from OCE to HMS 2 July 1956, subject: Hurricane Survey, New Orleans District
Conference at HMS 11 July 1956

Tracks

Tracks of hurricanes in the Gulf of Mexico from 1887 through 1955 were examined. Those hurricanes with central pressures at the coast of less than 29.00 inches that passed within 120 nautical miles of New Orleans, La., were studied in detail. Twelve storms met these criteria. (Flossie of 1956 is not included and will be reported on later.)

The dates of the hurricanes are listed in Table 1 and their tracks showing bi-hourly positions of the center are given in figure 1. Numbers to the left of the track give the hourly rate of movement. Mid-Gulf hurricanes a greater distance from New Orleans and Lake Pontchartrain were studied in less detail. The tracks of these additional mid-Gulf hurricanes are shown in figure 2.

Direction of motion

The majority of the twelve storms within 120 miles of Lake Pontchartrain entered the coast from the southwest through southeast and moved north-northwest over the latitude span of the Lake. The hurricanes of August 25, 1926 (figure 1h) and September 20, 1926 (figure 1i) were exceptions. They moved inland and recurved to the west in the general latitude of Lake Pontchartrain.

The average direction of movement across the latitude of the Lake for these storms was from the south, 170°. The direction of movement for each storm across the latitude of the Lake to the nearest 5° is listed in Table 2 and shown graphically in figure 3. The centers of only 3 of the hurricanes passed directly over a portion of the Lake. The direction for the others is the average for the latitude span of the lake (N30° - N30°25'). There was no significant difference in the direction of movement at the latitude of the lake for the hurricanes which passed to the east of the center of the lake and those which passed to the west. Approximately one half or slightly over one half of all tropical storms that reach the Louisiana coastal area recurve to the northeast after moving inland

Forward speed

The average rate of motion across the latitude span of the Lake was 16 knots (Table 2) the rate varied in individual storms from 8 knots in the 1893 hurricane (figure 1a) to 25 knots in the 1916 and 1950 hurricanes (figures 1f and 1m). The forward speed in some hurricanes is quite uniform, in others quite variable. It is interesting to note that in both cases where hurricanes moved northeastward along the southeastern Louisiana coast, 1893 and 1901, the storms slowed down at about the same point in Breton Sound. This suggests the possibility of a hurricane stalling in a position favorable to pushing water into Lake Borgne and Lake Pontchartrain.

Central pressures and radii of maximum winds

The values for hurricane pressure profile parameters in the 12 hurricanes near Lake Pontchartrain are given in Table 1. The hurricane of September 29, 1915 had the lowest central pressure, 944 mb. (27.87 in.); the greatest $P_N - P_o$, 76 mb. (2.24 in); and the highest value of gradient wind V_{gx}, 106 mph. The average central pressure P_o is 966 mb. (28.53 in.); the assymptotic pressure, P_N is 1016 mb. (30.04 in.); and the average $P_N - P_o$, 46 mb. (1.50 in.).

The average radius of maximum winds for these storms in the Lake Pontchartrain area is 38 nautical miles. The greatest radius listed is 88 nautical miles. This last figure was in one of the weaker storms and is not considered representative of an unusually severe hurricane. The values of R and P_o for each hurricane and the values of R and $P_N - P_o$ were graphed in figures 4 and 5 respectively and envelopes drawn to the points. The extreme combinations of these values experienced in this sample of storms can be determined by referring to the envelopes.

Comparison with other regions

Comparison of the pressure profile parameters of Lake Pontchartrain storms were made with pressure profile parameters of hurricanes on the remainder of the mid-Gulf coast, in the vicinity of Lake Okeechobee, and those entering the Texas coast. Values of the hurricane pressure profile parameters of these storms were taken from Table 1 Hydrometeorological Report No. 32 and from other studies made by the Hydrometeorological Section.

Mid-Gulf

The tracks of hurricanes entering the entire mid-Gulf area from the Texas-Louisiana border to Appalachicola were examined and four additional hurricanes with central pressures below 29.00 inches besides those that came within 120 nautical miles of New Orleans were noted.

The tracks of these four hurricanes are shown in figure 2, and the values of their hurricane parameters are listed in Table 3. The most intense mid-Gulf storms are concentrated within the area 120 nautical miles of New Orleans. However, the average values of the parameters of the hurricanes in the New Orleans area differ little from the average values for the entire mid-Gulf area (Table 4).

Lake Okeechobee

Values of the hurricane parameters for the Lake Pontchartrain hurricanes were compared with values of hurricane parameters for Lake Okeechobee. Representative storms in the Lake Okeechobee area, those that passed inland about a degree of latitude north or south of the center of the Lake and moved within 60 nautical miles of the center of the Lake and whose central pressure was less than 29.00 in., were selected from the hurricanes listed in Hydrometeorological Report No. 32. Table 5 lists the parameters of these storms and figure 6 shows their tracks.

Lake Pontchartrain is about a degree and a half of latitude higher than Lake Okeechobee and it could be assumed that most hurricanes reaching Lake Pontchartrain would be in a later stage of development than those passing over Lake Okeechobee. A comparison of hurricane parameters for these areas (Table 4) bears out this assumption. The average central pressure, P_o, for the Lake Okeechobee storms is 17 mb. (0.50 in.) lower than the average central pressure for the Lake Pontchartrain area. The radius of maximum wind for Lake Okeechobee is also smaller, 22 nautical miles compared to 36 nautical miles. The average pressure depression, $(P_N - P_o)$ in the Lake Okeechobee storms is greater 63 mb. (1.86 in.) as compared with 50 mb. (1.48 in.). The average maximum gradient wind, V_{gx}, is also greater, 95 mph compared to 77 mph. Figures 7, 8, and 9 compare the values of central pressures, radii of maximum winds, and pressure differences, respectively, for the Lake Pontchartrain and the Lake Okeechobee storms.

Texas Coast

The 16 hurricanes with central pressures at the coast, of less than 29.00 inches that entered the Texas coast between 1900 and 1949 were also compared with the hurricanes in the Lake Pontchartrain vicinity. (Figure 10, Table 4.) These storms with their hurricane parameters are listed in Table 6. From the values given in Table 4 it appears that the average storm entering the Texas coast tends to have a lower central pressure and radius of maximum wind speed and greater pressure difference $(P_N - P_o)$ than the average storm that approaches New Orleans and Lake Pontchartrain.

Filling

Figure 34 and figure 35 in Hydrometeorological Report 32 shows the average sea-level pressure change in hurricanes entering the U. S. coast and in hurricanes entering the Gulf coast. The rates of filling were available for 2 Lake Pontchartrain hurricanes--June 16, 1934 and September 19, 1947. These values are given in Table 7.

It appears that a vigorous hurricane approaching from the south or southeast could be expected to fill about 10% on the average by the time it reached Lake Pontchartrain (60 miles inland). (10% decrease in $P_N - P_o$. 5% decrease in wind speed at the gradient level). One approaching from the southwest could be expected to fill slightly more.

Charles S. Gilman, Chief
Hydrometeorological Section

cc: 2 with attachments to OCE
1 with attachments to BEB

FIGURES

1. Hurricane Tracks 1887-1955--Vicinity Lake Pontchartrain (a) Oct. 1893; (b) Aug. 1901; (c) Sept. 1906; (d) Sept. 1909; (e) Sept. 1915; (f) Sept. 1916; (g) Sept. 1920; (h) Aug. 1926; (i) Sept. 1925; (j) June 1934; (k) Sept. 1947; (l) Aug. 1950.

2. Additional mid-Gulf Hurricane Tracks 1900-1944.

3. Direction of Movement of Storms Passing over Latitude of Lake Pontchartrain.

4. Hurricanes in the Vicinity of New Orleans 1887-1955 Ratios of Central Pressures, P_o, to Radii of Maximum Wind. R.

5. Hurricanes in the Vicinity of Lake Pontchartrain 1887-1955. Ratios of Pressure Differences (P_N - P_o) to Radii of Maximum Wind.

6. Hurricane Tracks 1900-1949--Lake Okeechobee.

7. Accumulated Frequency of Central Pressures.

8. Accumulated Frequency of Radii of Maximum Winds--Lake Pontchartrain, and Lake Okeechobee.

9. Accumulated Frequency of Hurricane Pressure Differences--Lake Pontchartrain and Lake Okeechobee Vicinity.

10. Regional Accumulated Frequencies of Central Pressures.

Table 1

HURRICANES WITHIN 120 NAUTICAL MILES OF NEW ORLEANS WITH CENTRAL PRESSURES BELOW 29.00 INCHES

	Pressure Profile Parameters						R	V_{gx}
	P_N		P_o		$P_N - P_o$		Nautical	
Date	mb	inches	mb	inches	mb	inches	miles	mph
Aug. 30, 1950	1006	29.71	979	28.92 10	27	0.79 12 –	21	64 12
Sept. 19, 1947	1004	29.70	970	28.61 8	34	1.09 10 ⊙	28	72 10
June 16, 1934	1014	29.94	967	28.58 7	47	1.36 8 –	37	80 8
Sept. 20, 1926	1020	30.15	954	28.20 2	66	1.95 3 –	24	98 3
Aug. 25, 1926	1027	30.35	958	28.31 4	69	2.04 2 –	27	100 2
Sept. 21, 1920	1012	29.90	980	28.95 11	32	0.97 11 –	28	67 11
~~Sept.~~ Jul. 5, 1916	1017	30.05	967	28.57 6	50	1.46 6 –	30	81 7
Sept. 29, 1915	1020	30.14	944	27.87 1	76	2.27 1 –	29	106 1
Sept. 20, 1909	1026	30.30	980	28.94 12	45	1.36 9 –	88	75 9
Sept. 27, 1906	1018	30.07	965	28.50 5	53	1.57 5 –	37	85 6
Aug. 14, 1901	1021	30.16	972	28.72 9	49	1.44 7 ⊙	35	85 5
Oct. 1, 1893	1011	29.99	955	28.22 3	56	1.77 4 ⊙	17	94 4
Sept. 24, 1956	1010	29.83	974	28.76 9a	36	1.06 10a	30	83 6a
Average	1016	30.04	966	28.55 ✓	46	1.50 ✓	36 (37)	77 (83)

11 9 8 3 3 11 7 1 10 5 7 4 8a

Aug 1926 } Recurved to west at
Sep 1926 } latitude of Lake Pont.

Ave. azimuth of movement - 170°

Sep 1915 } Centers passed over a
Sep 1926 } portion of LK. Pont.
Sep 1947 }

Table 2

AVERAGE DIRECTION OF MOTION AND AND AVERAGE SPEED OF HURRICANES AT THE LATITUDE OF LAKE PONTCHARTRAIN

Date	Average Speed knots	Average direction of motion (from)
Oct. 1, 1893	8	210°
Aug. 14, 1901	12	215°
Sept. 27, 1906	16	165°
Sept. 20, 1909	15	170°
Sept. 29, 1915	12	195°
July 5, 1916	25	165°
Sept. 21, 1920	22	160°
Aug. 25, 1926	10	180°
Sept. 20, 1926	13	095°
June 16, 1934	15	180°
Sept. 19, 1947	19	120°
Aug 30, 1950	25	190°
Average	16	170°

Table 3

MID-GULF HURRICANES MORE THAN 120 MILES FROM LAKE PONTCHARTRAIN

Date	P_N mb	P_N inches	P_o mb	P_o inches	$P_N - P_o$ mb	$P_N - P_o$ inches	R Nautical miles	V_{gx} mph
Oct. 18, 1916	1023	30.20	974	28.76	49	.44	44	81
Sept. 28, 1917	1012	29.88	964	28.48	48	1.40	31	81
Sept. 30, 1929	1015	29.96	975	28.80	40	1.16	58	70
July 31, 1936	1016	30.00	975	28.73	45	1.27	19	80
Average	1017	30.01	972	28.69	45	1.07	38	78

Table 4

COMPARISON OF AVERAGE REGIONAL HURRICANE PARAMETERS

Area		P_N		P_o		$P_N - P_o$		R nautical	V_{gx}
	No. cases	mb	inches	mb	inches	mb	inches	miles	mph
Mid-Gulf	16	1016	30.00	964	28.47 28.57	49	1.45 1.39	37 ✓	78 82
Lake Pontchartrain	12	1016	30.00	966	28.53 ✓	50	1.48 1.50	36 37	77 83
Texas Coast	16	1016	30.00	962	28.41	54	1.60	20	89
Lake Okeechobee	9	1012	29.88	949	28.02	65	1.86	22	95

Table 5

PRESSURE-PROFILE PARAMETERS OF HURRICANES IN THE VICINITY OF LAKE OKEECHOBEE
1900-1949

Date	P_N		P_o		$P_N - P_o$		R nautical miles	V_{gx}
	mb	inches	mb	inches	mb	inches	miles	mph
Sept. 11, 1903	1020	30.12	977	28.84	43	1.27	43	76
Oct. 17, 1910	986	29.19	941	27.80	47	1.39	16	84
Sept. 18, 1926	1014	29.95	934	27.59	70	2.07	24	110
Sept. 16, 1928	1029	30.38	935	27.61	94	2.78	28	117
Sept. 4, 1933	1015	29.98	948	27.98	67	1.98	13	101
Sept. 17, 1947	1010	29.83	940	27.76	70	2.07	19	102
Sept. 21, 1948	1003	29.61	935	27.60	68	2.01	7	102
Oct. 5, 1948	1008	29.77	977	28.85	31	0.92	27	67
Aug. 26, 1949	1020	30.12	954	28.16	66	1.95	22	99
Average	1012	29.89	949	28.02	62	1.85	22	95

Table 6

HURRICANES ENTERING THE TEXAS COAST WITH CENTRAL PRESSURES BELOW 29.00 INCHES 1900-1949

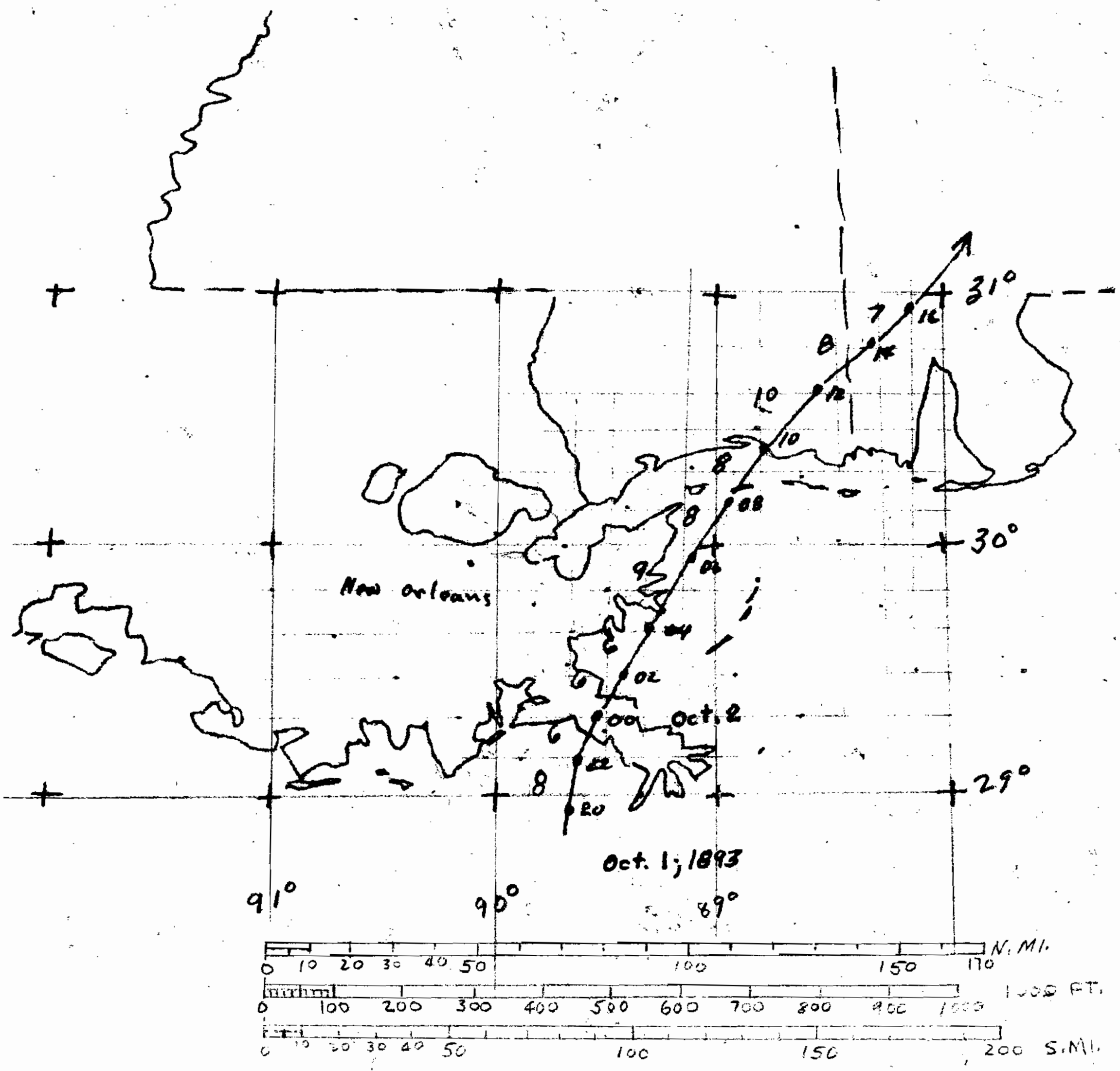
	Pressure Profile Parameters					
	P_N		P_o		R nautical	V_{gx}
Date	mb	inches	mb	inches	miles	mph
Sept. 8, 1900	1008	29.78	936	27.64	14	104
July 21, 1909	1025	30.27	962	28.41	19	99
Aug. 16, 1915	1001	29.57	953	28.14	32	83
Aug. 18, 1916	1042	30.77	948	28.00	35	116
Sept. 14, 1919	1000	29.54	970	28.65	13	75
June 22, 1921	1017	30.03	961	28.38	17	97
June 28, 1929	1015	29.97	969	28.62	13	82
Aug. 13, 1932	1020	30.11	942	27.83	12	108
Aug. 4, 1933	1015	29.96	975	28.80	24	76
Sept. 5, 1933	1024	30.24	949	28.02	30	105
Aug. 7, 1940	1007	29.75	974	28.76	11	71
Sept. 25, 1941	1004	29.66	971	28.66	21	81
Aug. 30, 1942	1004	29.64	951	28.07	18	88
July 27, 1943	1017	30.02	975	28.78	17	78
Aug. 27, 1945	1020	30.13	967	28.57	18	88
Oct. 4, 1949	1020	30.13	978	28.88	28	78
Average	1016	30.00	962	28.40	20	89

Table 7

RATIOS OF FILLING IN TWO MID-GULF HURRICANES

ΔT / r	June 16, 1934			Sept. 19, 1947		
	Hours					
	+2	+4	+6	+2	+4	+6
Nautical miles	Hundreths of an inch					
0	+11	+29	+40			
10	+ 7	+25	+35	+7	+19	+37
20	+ 1	+16	+27	+3	+11	+15
40	0	+ 9	+17	+1	+ 3	+ 5

r = distance from hurricane center, nautical miles, ΔT = no. of hours since storm entered coast. Values in table are departure of central pressure at 0 (at coast) + t time from the central pressure at the coast in hundreths of an inch.

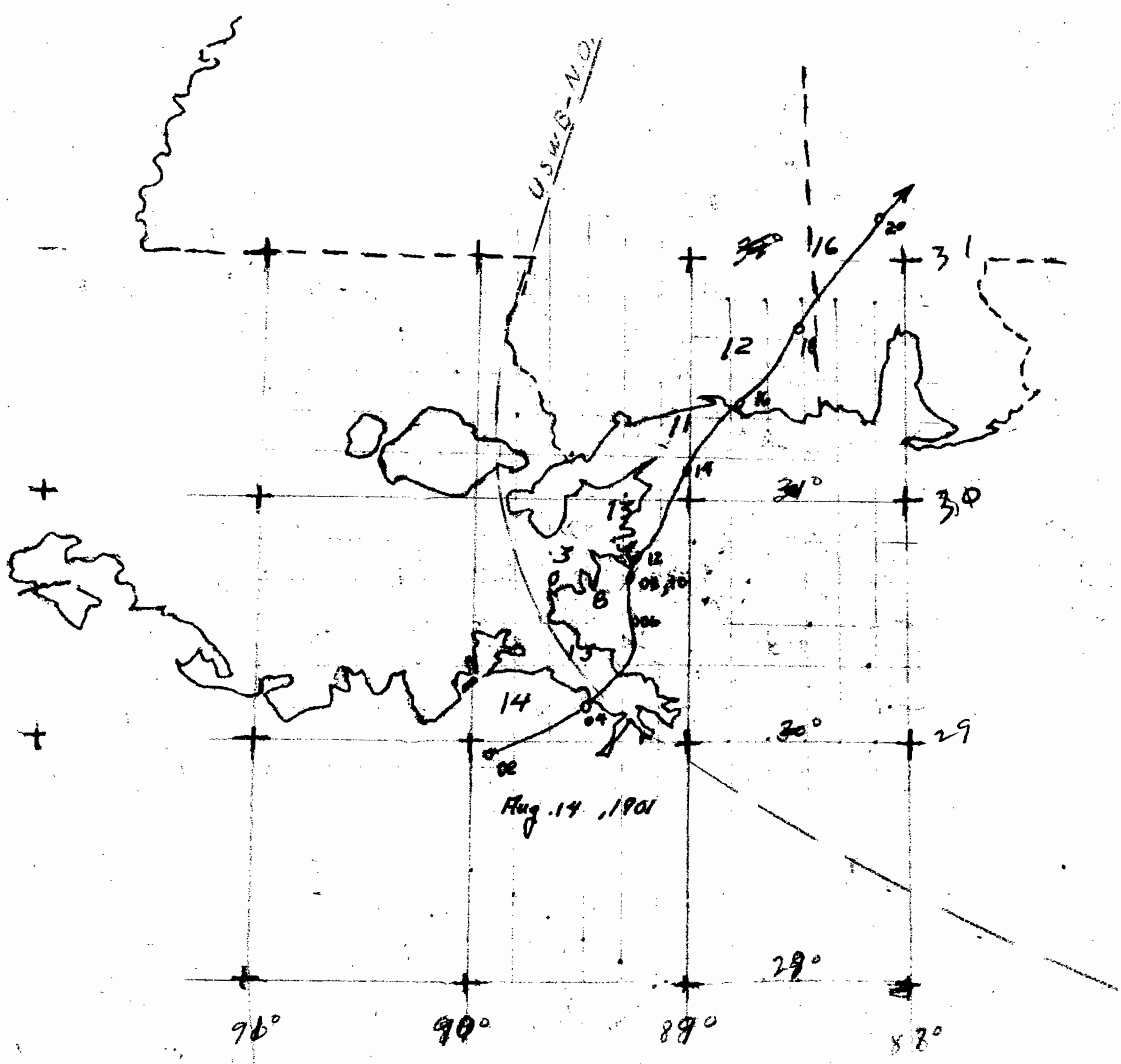


Hurricane Tracks within 120 Nau. Miles of New Orleans
1887-1955

(Hourly rate of forward motion in knots - 90th Mer. Time)

Fig. 1a

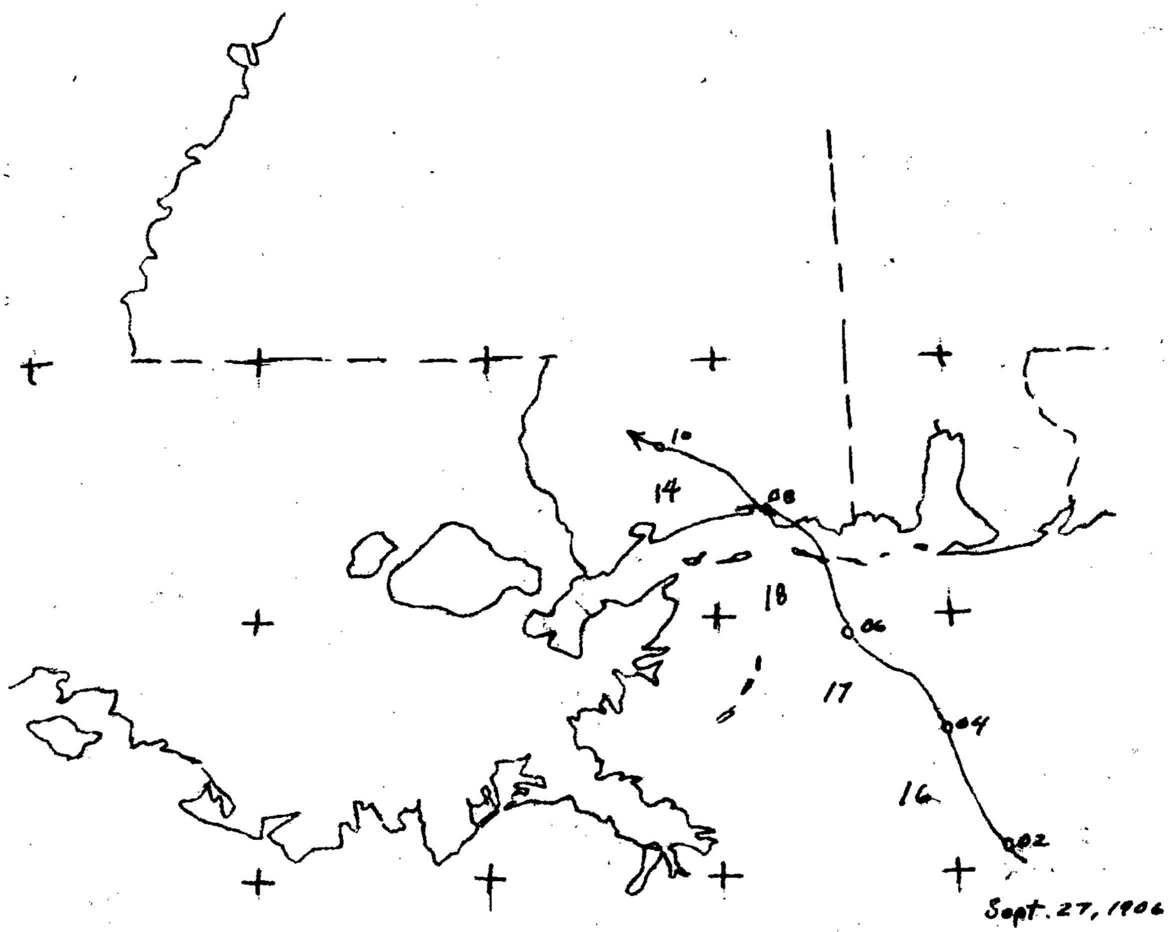
OCT 1893



Hurricane Tracks within 120 Nau. Miles of Lake Pontchartrain, La.
1887 - 1955

Fig. 1b

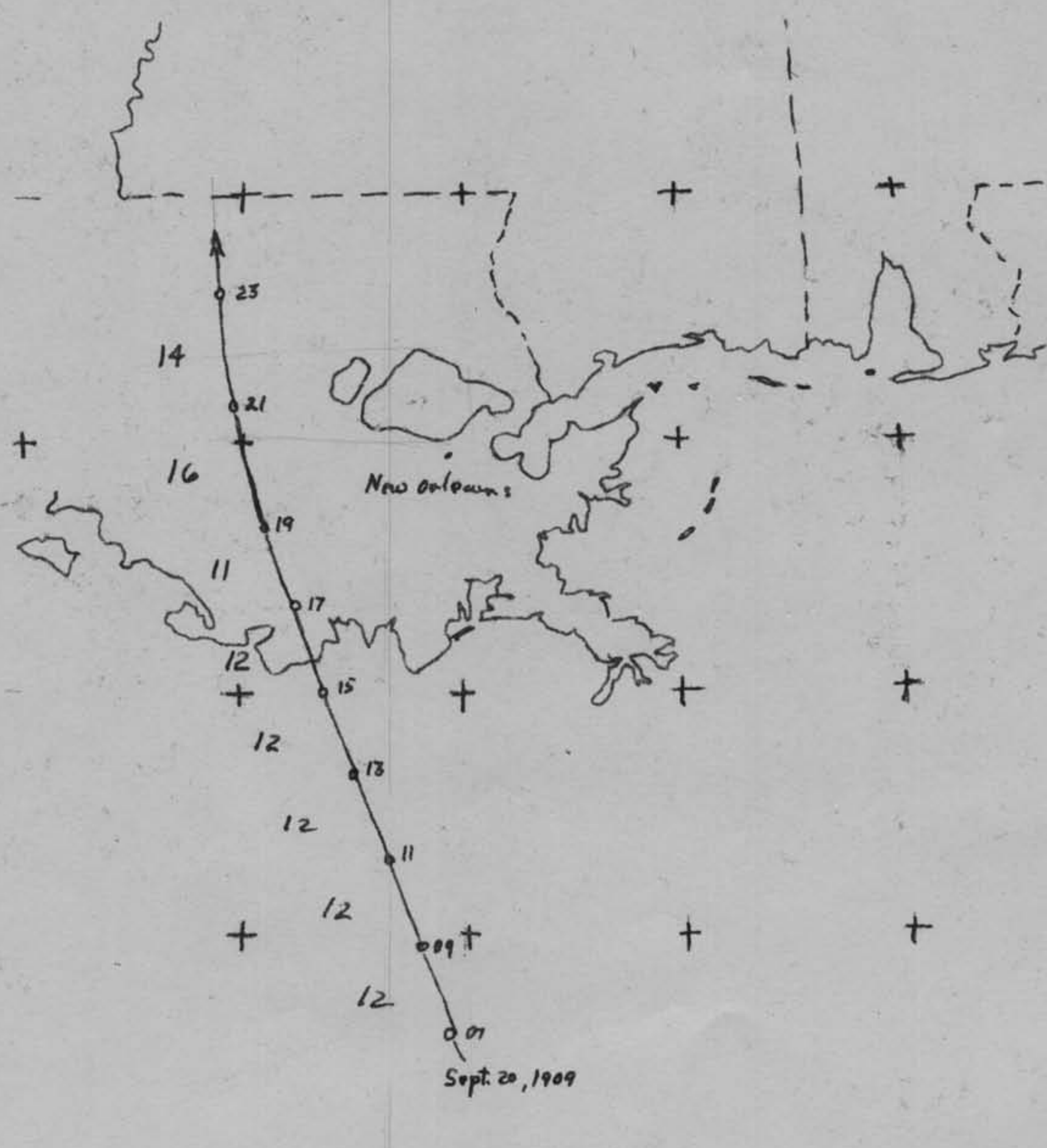
AUG 1901



Hurricane Tracks within 120 Nau. Miles of New Orleans, La.
1887 - 1955

Fig. 1c

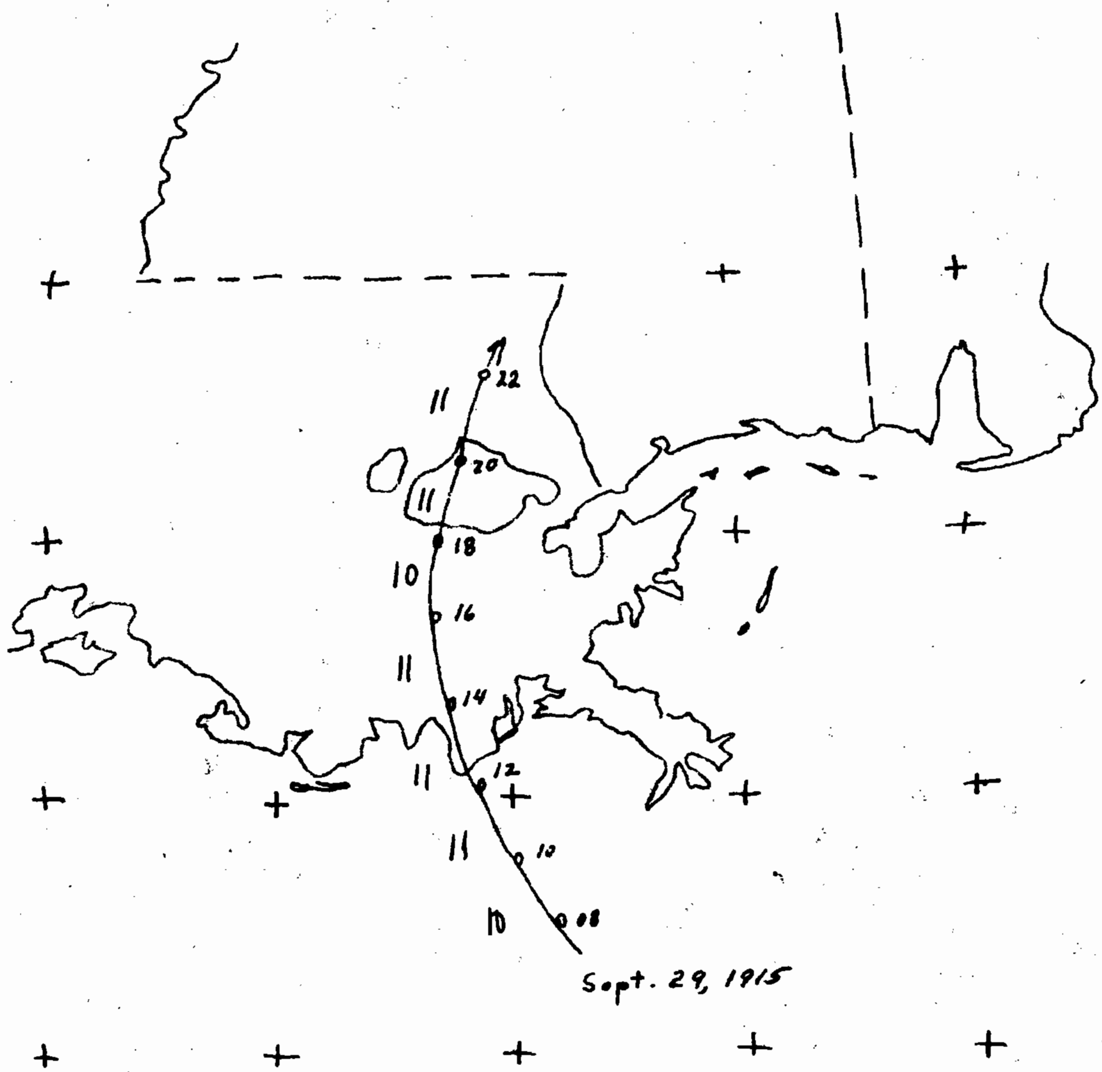
SEP 1906



Hurricane Tracks within 120 Nau. Miles of New Orleans, La.
1887 - 1955

Fig. 1d

SEP 1909

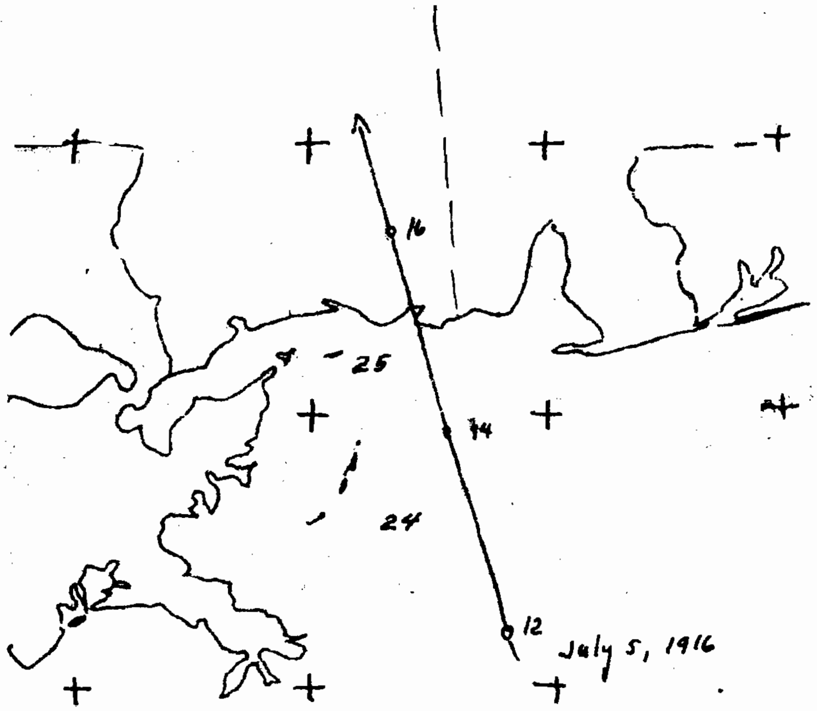


Hurricane Tracks within 120 Nau. Miles of New Orleans
1887-1955

(Hourly rate of forward motion in knots - 90th Mer. Time)

Fig. 1c.

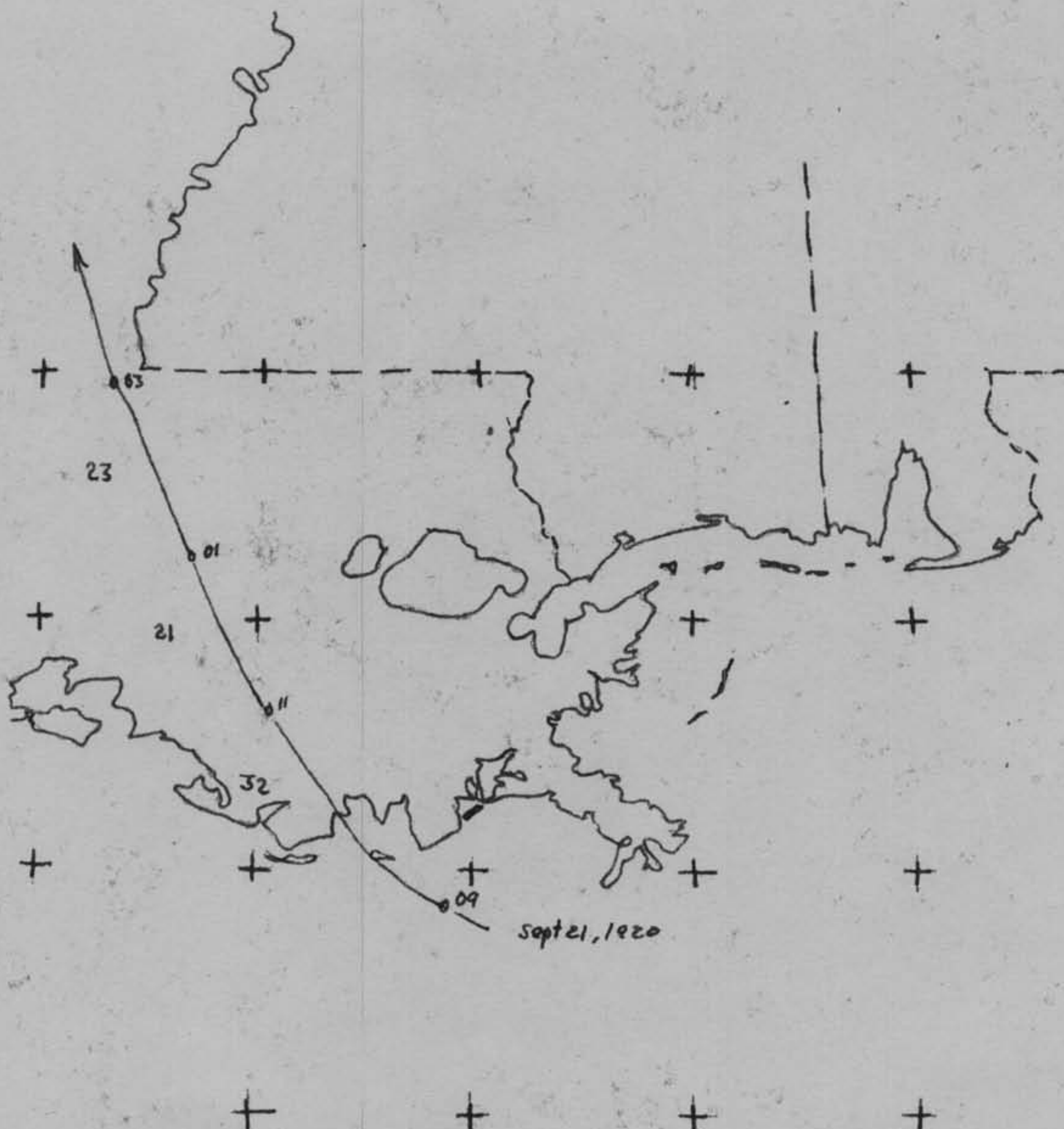
SEP 1915



Hurricane Tracks within 120 nau. miles of New Orleans, La.
1887- 1955

Fig. 1f

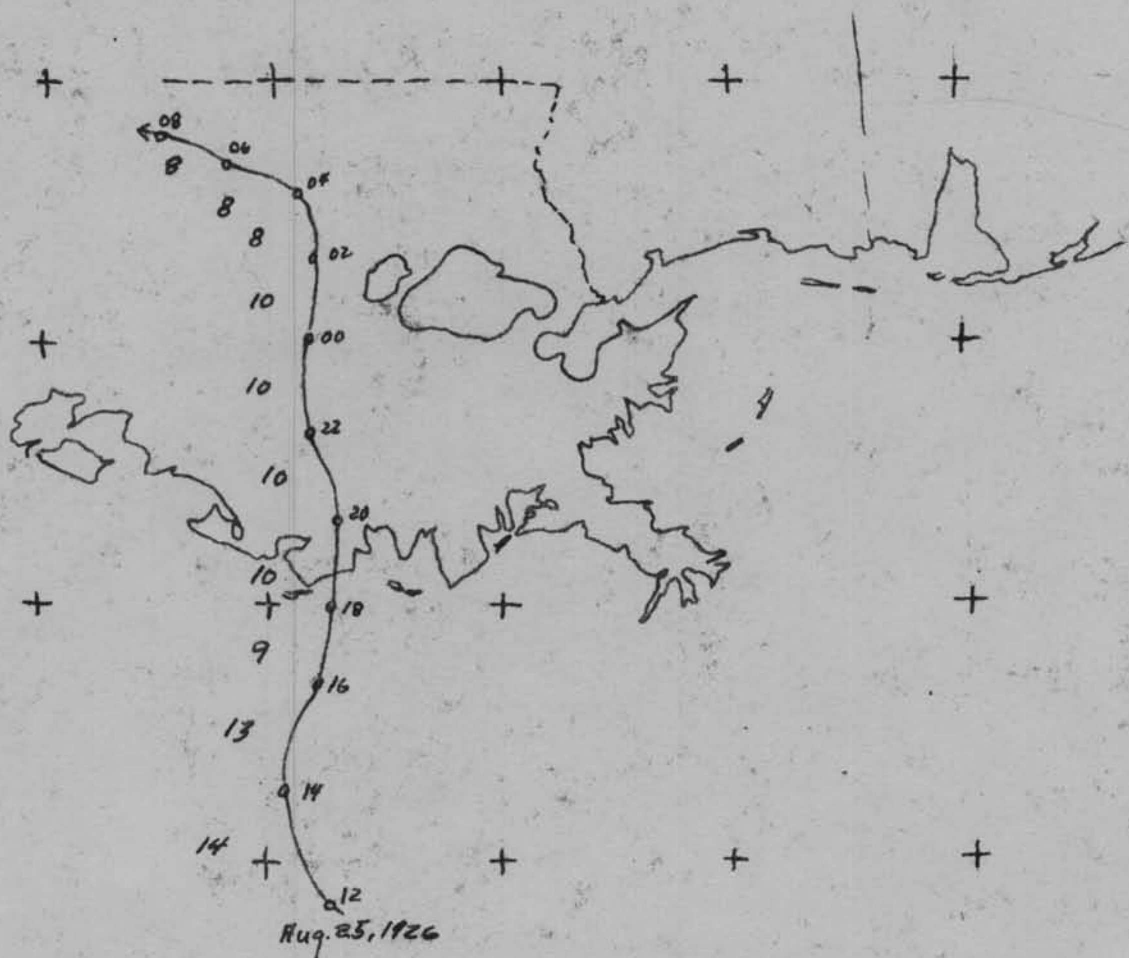
JUL 1916



Hurricane Tracks within 120 Nau. Miles of New Orleans, La.
1887 - 1955

Fig. 1g

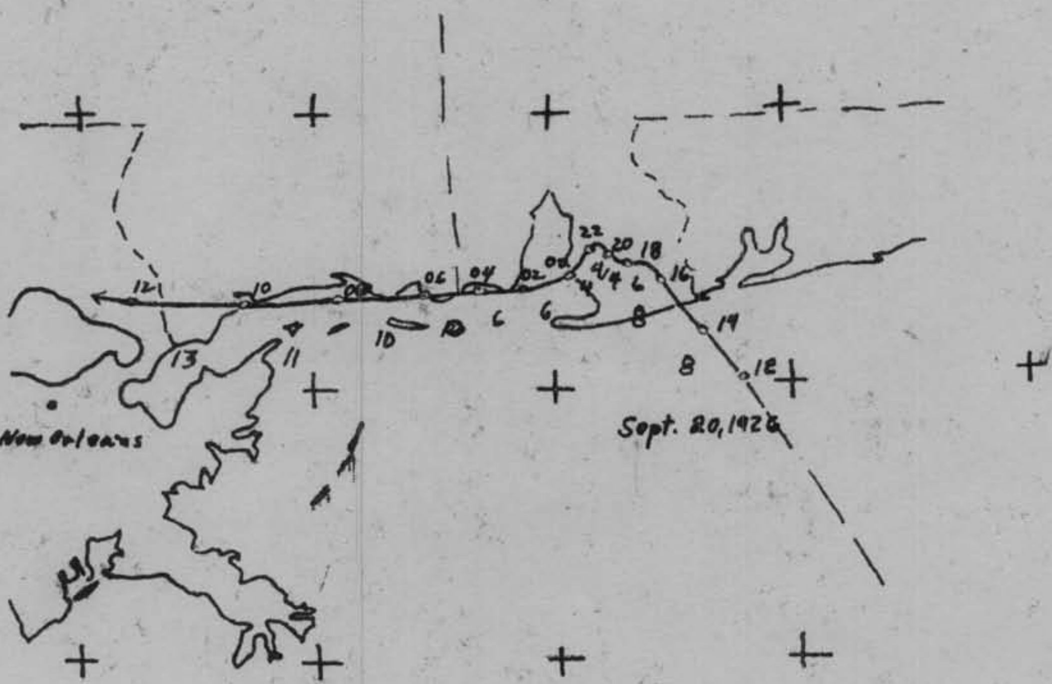
SEP 1920



Hurricane Tracks within 120 Nau. Miles of New Orleans, La.
1887 - 1955

1h

AUG 1926



Hurricane Tracks within 120 Nau. Miles of New Orleans, La.
1887 - 1955

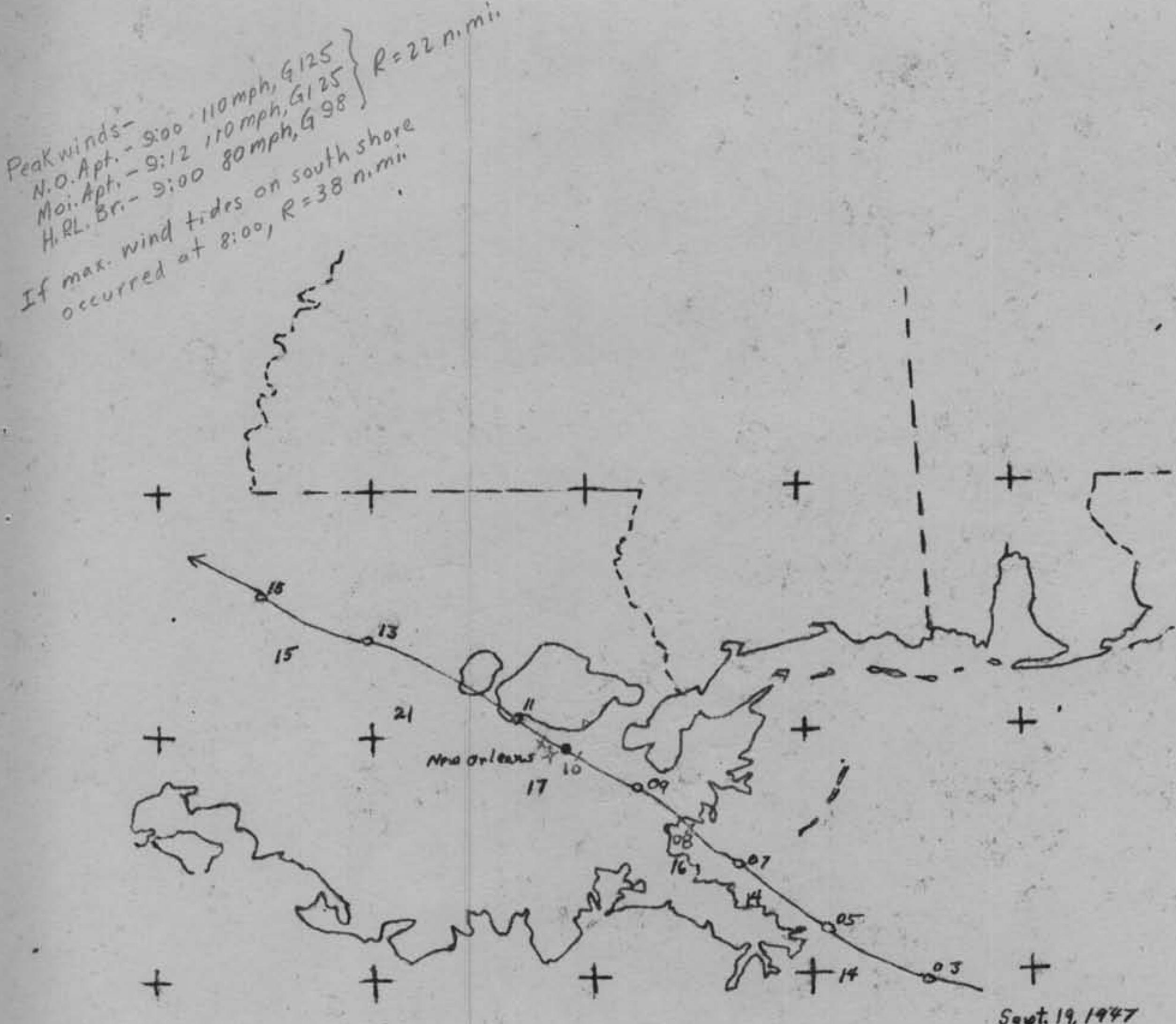
Fig. 1i

SEP 1926

Hurricane Tracks within 120 Nau. Miles of New Orleans, La.
1887 - 1955

Fig. 1j

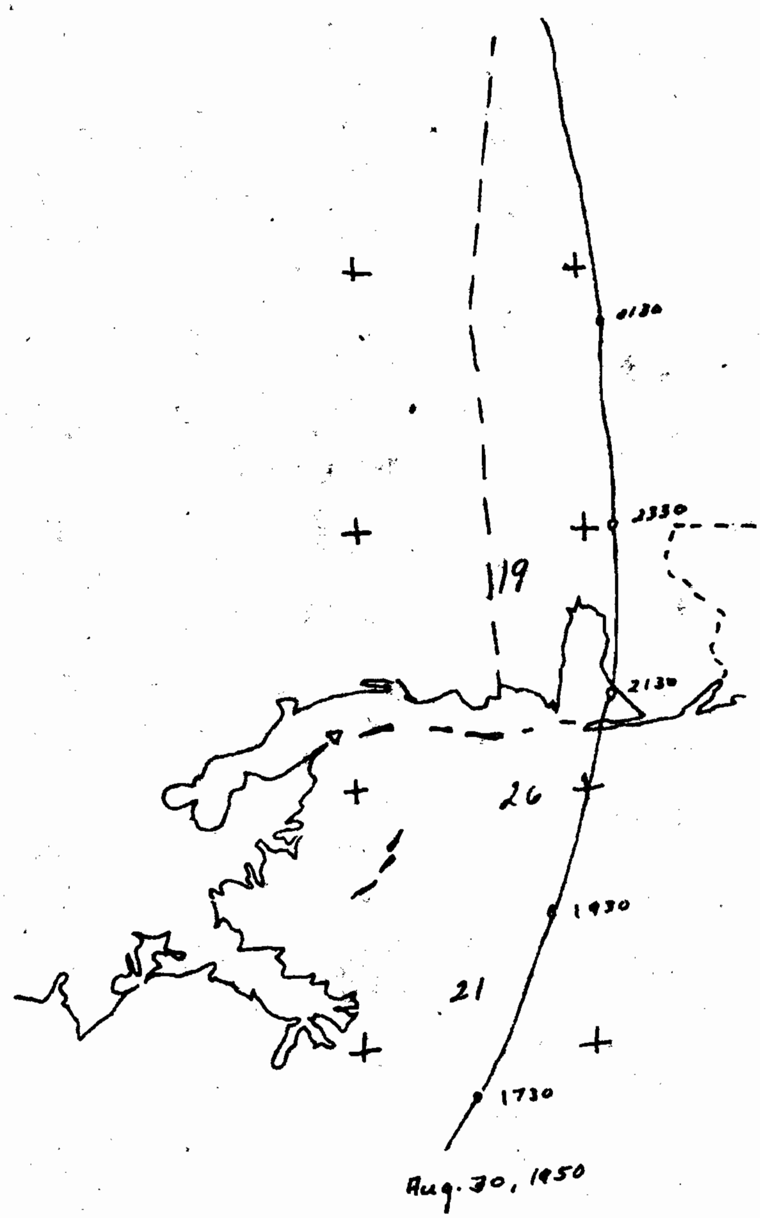
JUN 1934



Hurricane Tracks within 120 Nau. Miles of New Orleans, La.
1887 -1955

Fig.1k

SEP 1947

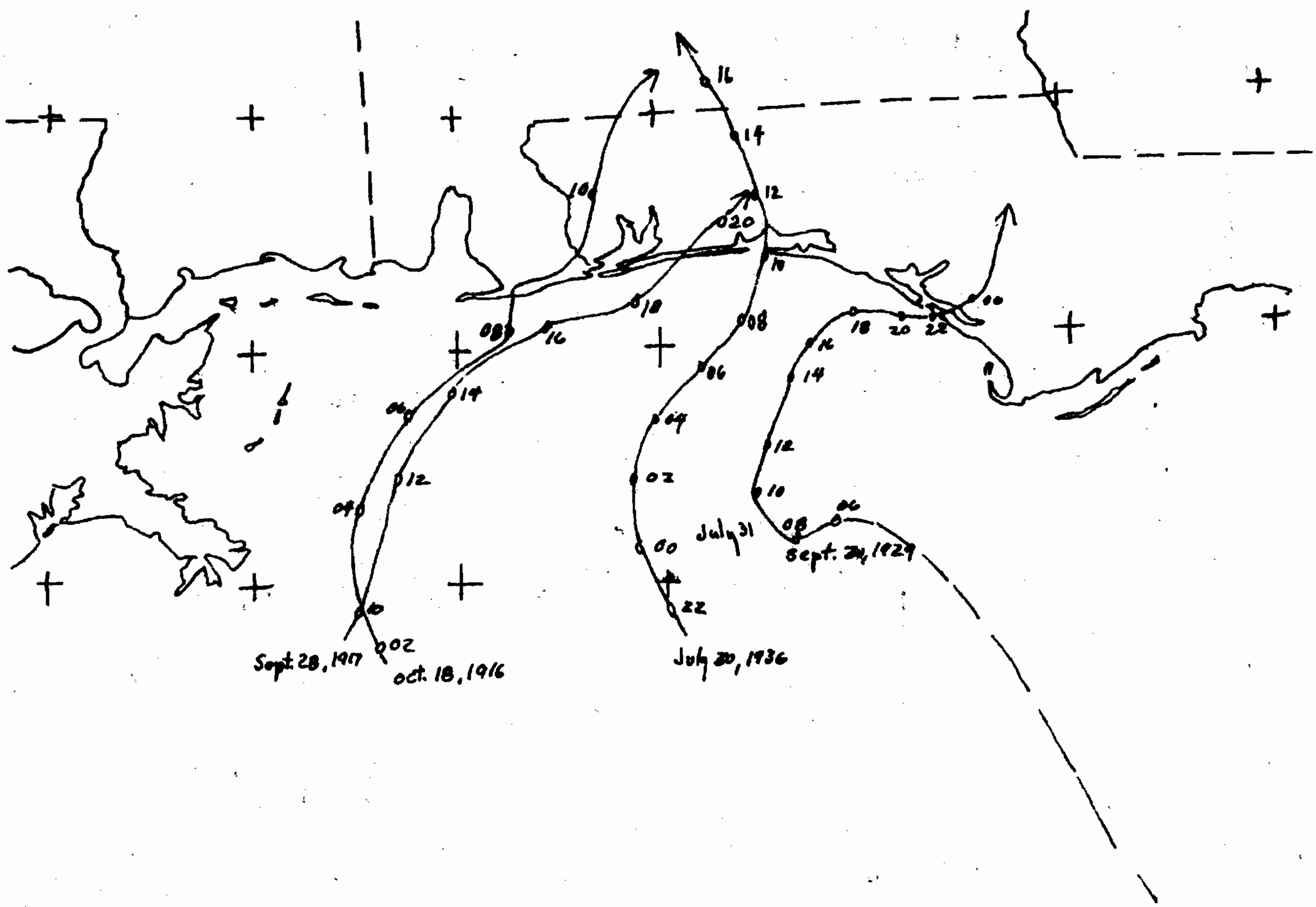


Hurricane Tracks within 120 Nau. Miles of New Orleans
1857-1955

(Hourly rate of forward motion in knots - 90th Mer. Time)

Fig. 1m

AUG 1950



Additional Mid-Gulf Hurricane Tracks 1900-1949

(75 meridian time)

OCT 1916
SEP 1917
SEP 1929
JUL 1936

Fig. 2.

Direction of Movement of Hurricanes Crossing the Latitude of Lake Ponchartrain

(Measured From N 30° Thru N 32° 25')

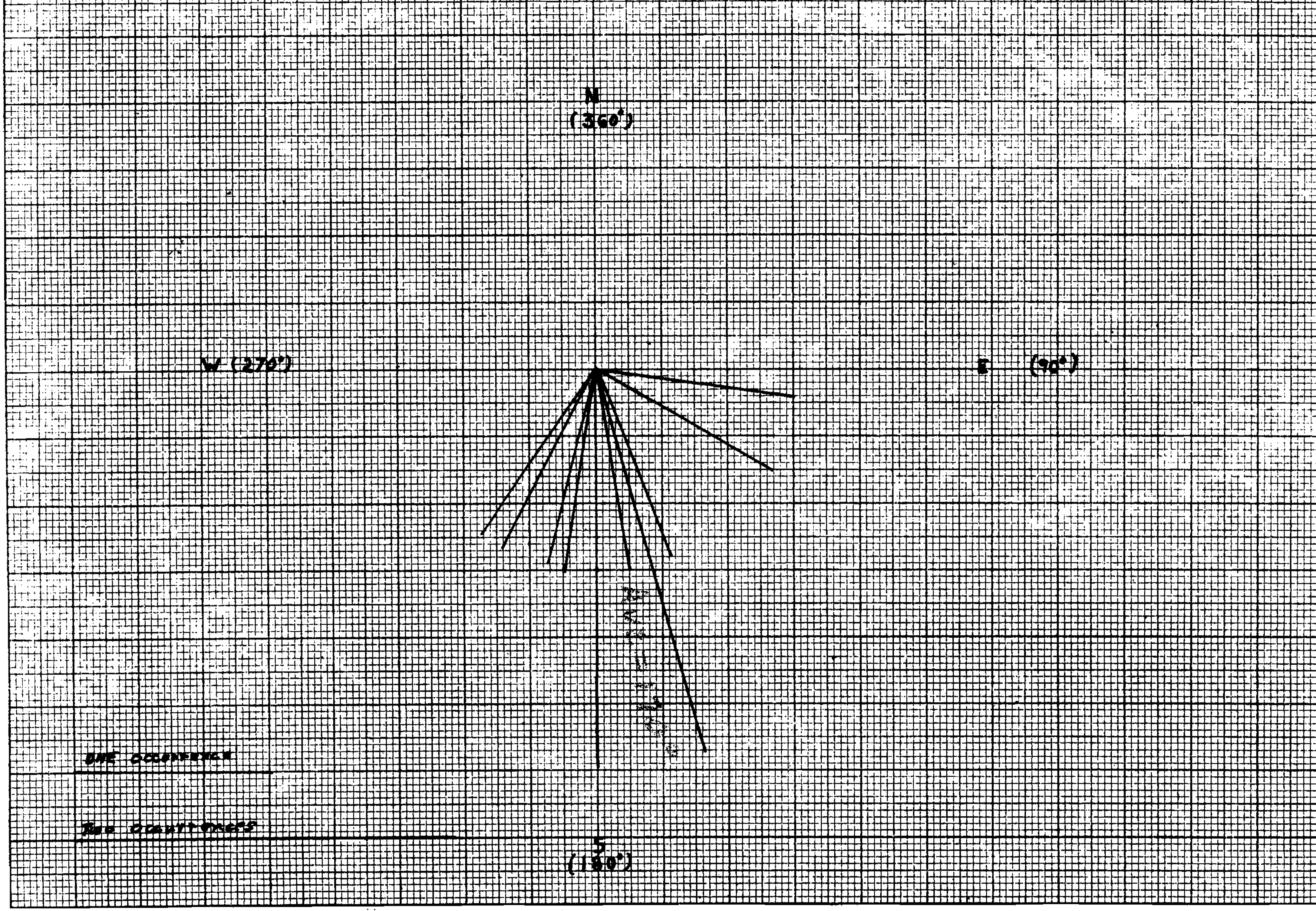


Fig. 3

K+E 10 X 10 TO THE ½ INCH 359-11
KEUFFEL & ESSER CO. MADE IN U.S.A.

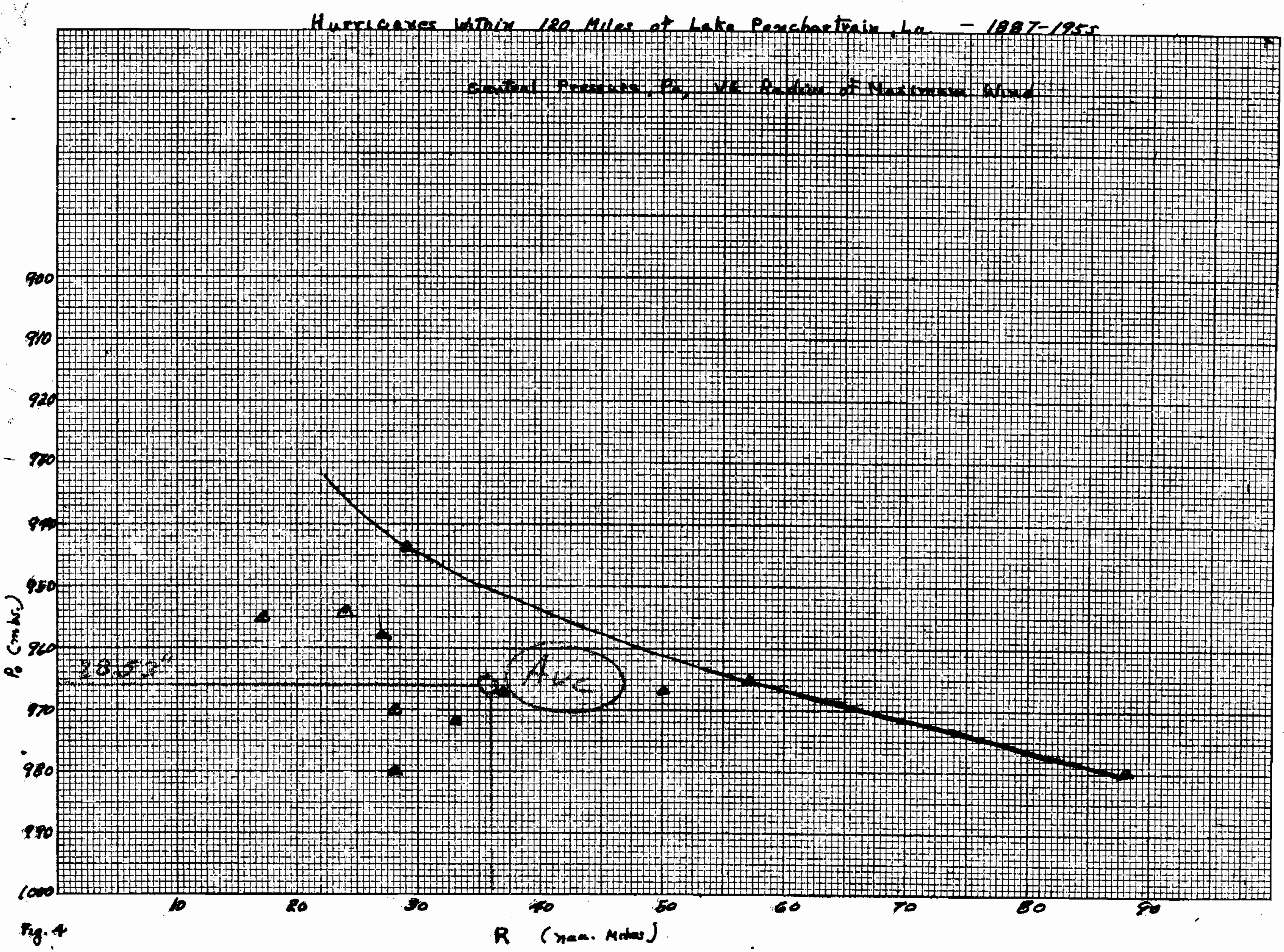


Fig. 4

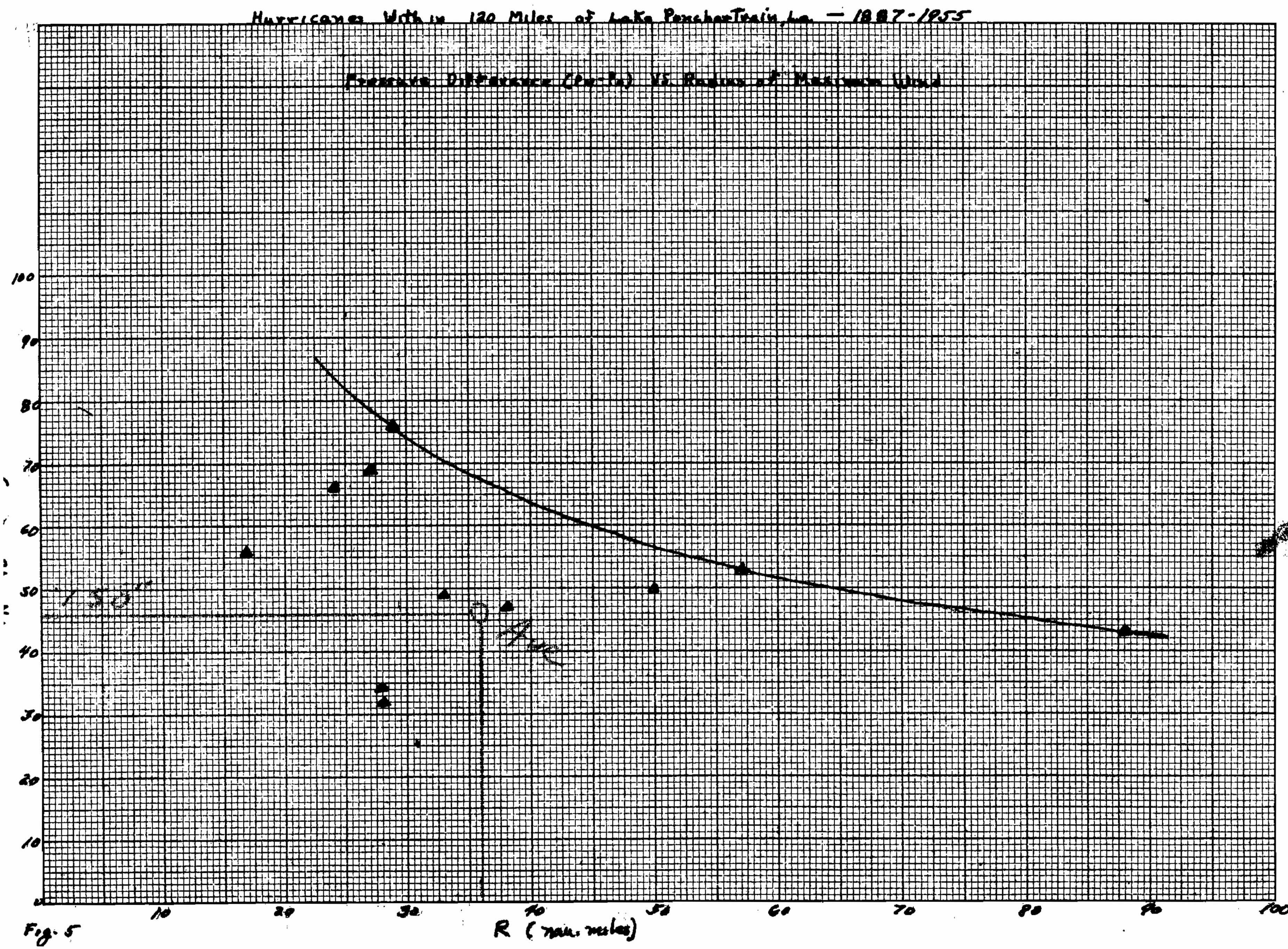
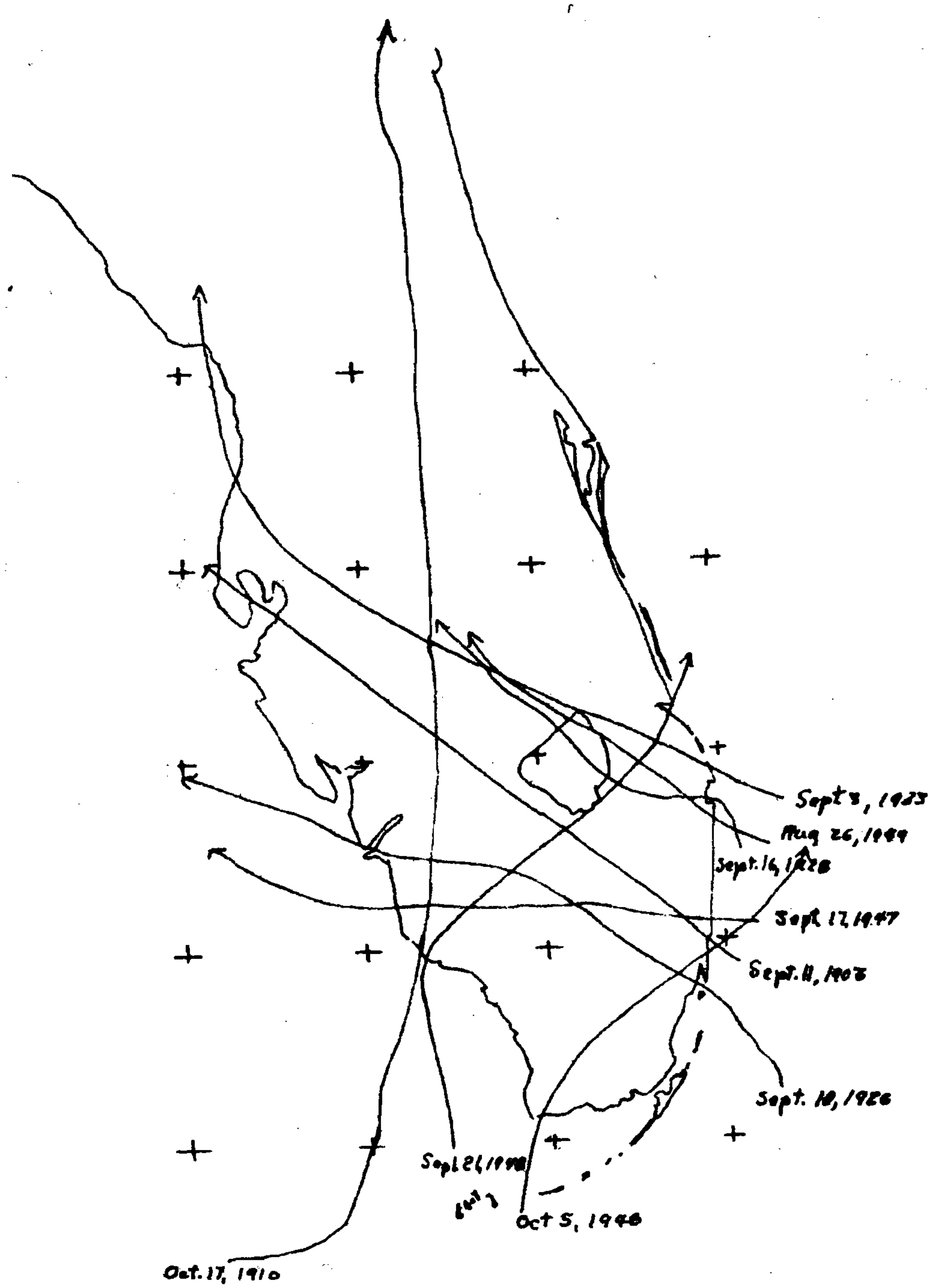

Hurricanes Within 120 Miles of Lake Ponchartrain, La. — 1887-1955
Pressure Difference (Pn-Po) Vs. Radius of Maximum Wind
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
100
1.50"
Ave
R (nau. miles)

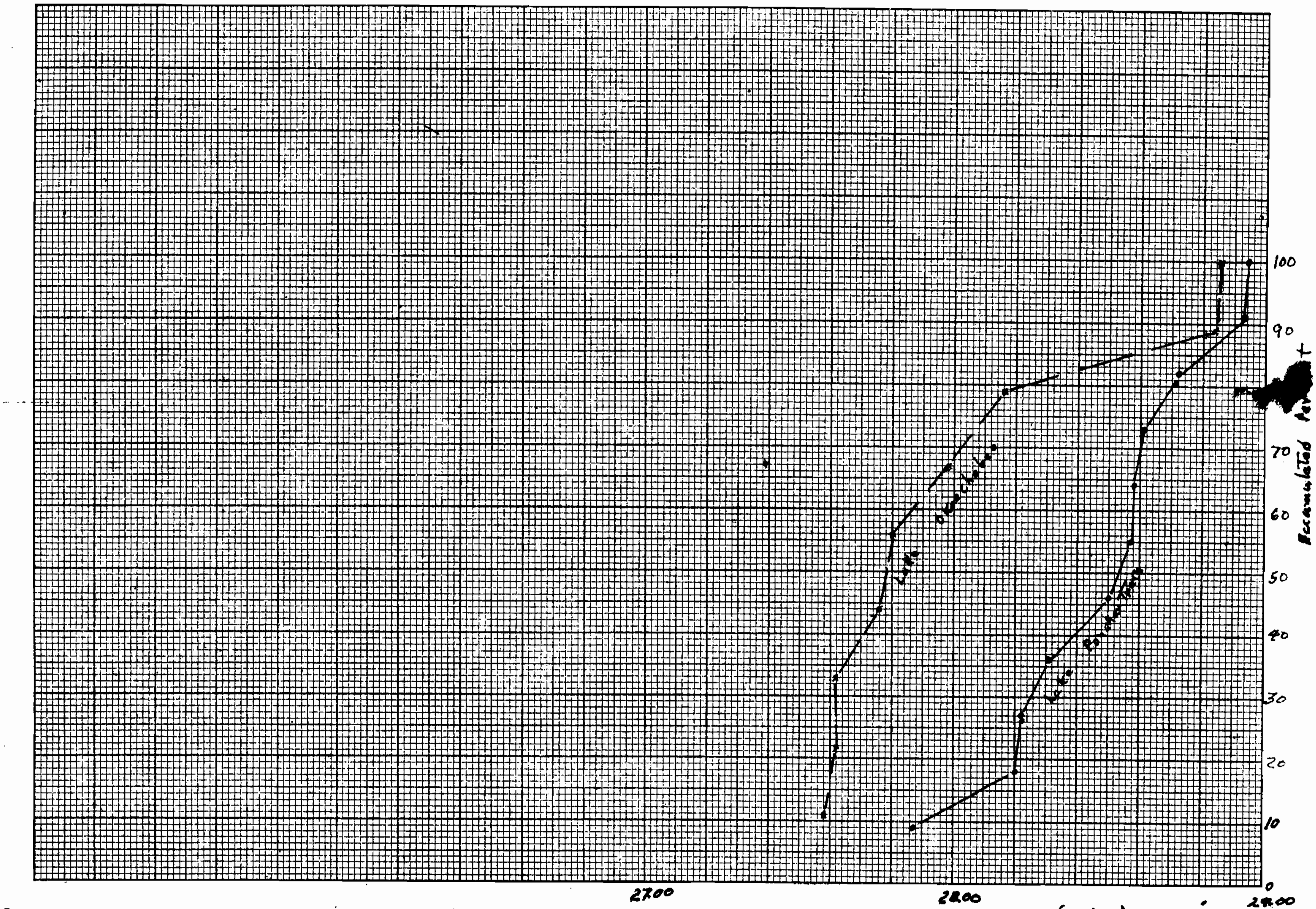
Fig. 5



Hurricane Tracks 1900-1949 – Lake Okeechobee

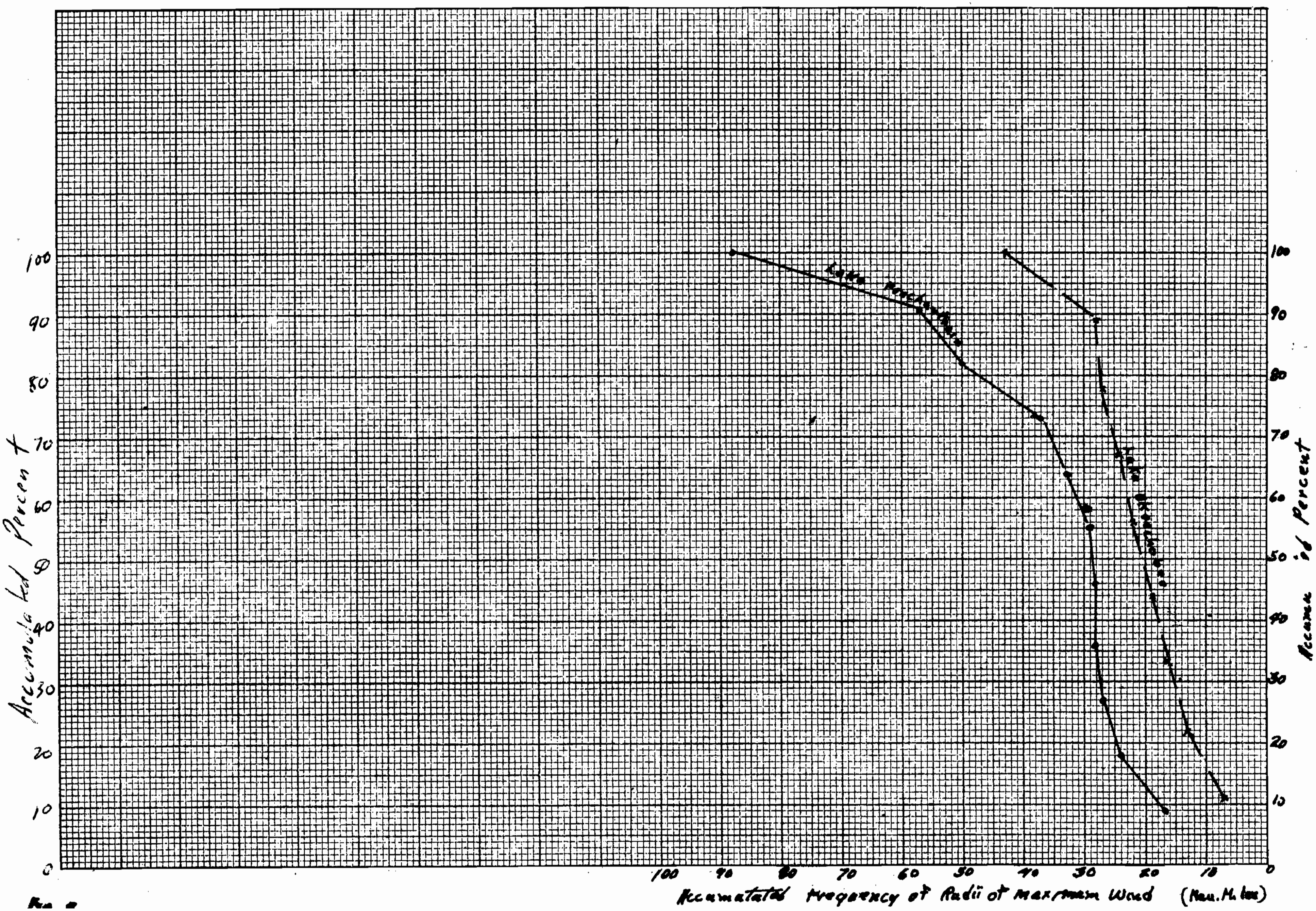
Fig. 6

K+E 10 X 10 TO THE ½ INCH 359-11
KEUFFEL & ESSER CO. MADE IN U.S.A.



ig.7. Accumulated frequencys of central pressures Lake Pontchartrain and Lake Okeechobee Areas

K+E 10 X 10 TO THE ½ INCH 359-11
KEUFFEL & ESSER CO. MADE IN U.S.A.



K+E 10 X 10 TO THE ½ INCH 359-11
KEUFFEL & ESSER CO. MADE IN U.S.A.

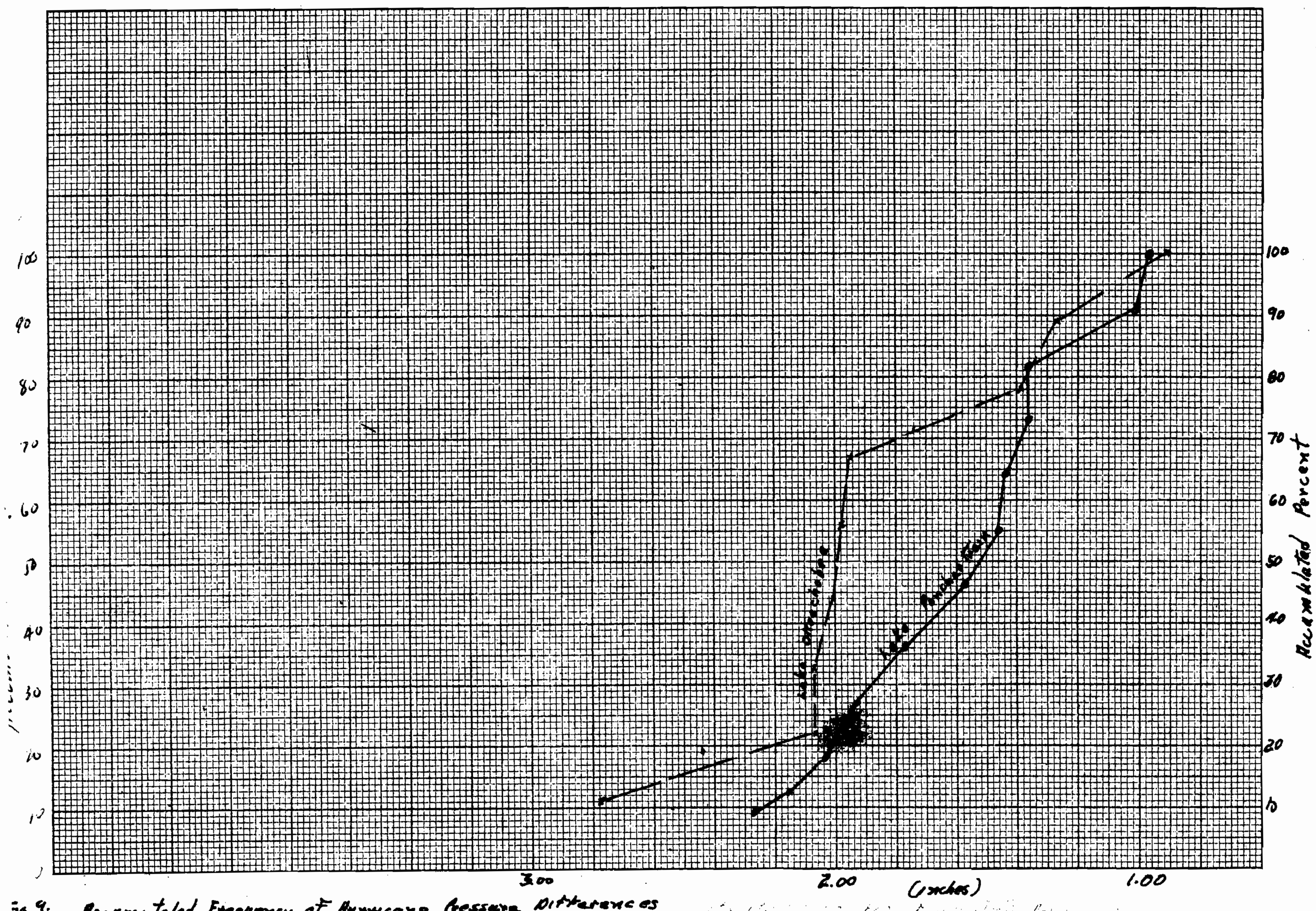


Fig. 4. Accumulated Frequency of Hurricane Pressure Differences

K+E 10 X 10 TO THE ½ INCH 359-11
KEUFFEL & ESSER CO. MADE IN U.S.A.

Fig. 10.

Regional Accumulated frequencies of Central Pressures

UNITED STATES DEPARTMENT OF COMMERCE
WEATHER BUREAU
WASHINGTON

October 9, 1956

IN REPLY, PLEASE ADDRESS
CHIEF OF BUREAU
AND REFER TO

0-6.12

MEMORANDUM: HUR 7-15

FROM: Hydrometeorological Section

SUBJECT: Hurricane Data for New Orleans District--September 1915 Hurricane

References:
a. Memorandum from OCE to HMS, subject: Hurricane Survey New Orleans District, 2 July 1956
b. Conference at HMS, 11 July 1956
c. Memorandum from OCE to C. S. Gilman, subject same as under "a", 13 July 1956.

__Tracks__

Tracks of the hurricane of September 29, 1915, as shown by Cline, (1, 2) and in Hydromet. Report No. 32, (3) were reexamined. Some adjustments were considered advisable in view of:

a. Better consistency between positions for the center and comments made by cooperative observers, as listed by Cline.(1)

b. More detailed examination of center positions with respect to times of minimum pressure taken from barograms along the path of the storm.

c. Results obtained by application of several other techniques described in Hydromet. Report No. 32 (3), see especially pages 6 to 14.

The revised track is shown in an attached figure.

__Evaluation of Pertinent Parameters of the Storm__

Pressure profiles were constructed corresponding to critical times when the center was near the Gulf Coast and over Lake Pontchartrain. The final profiles represented a reasonable compromise between all available observed pressure values and the pressure distribution resulting from application of the theoretical radial profile formula number 1, in Hydromet. Report No. 32, see especially page 2. It was assumed that the distribution of pressure in a hurricane was symmetrical and circular around the center. Parameters are listed in last paragraph of memorandum.

UNITED STATES DEPARTMENT OF COMMERCE
WEATHER BUREAU
WASHINGTON 25

October 9, 1956

IN REPLY, PLEASE ADDRESS
CHIEF OF BUREAU
AND REFER TO

0-6.12

TO : Mr. A. L. Cochran, Civil Works
Office of Chief of Engineers

FROM : Hydrometeorological Section

SUBJECT: MEMORANDUM HUR 7-15 see 7-39
"Hurricane Data for New Orleans District--September 1915 Hurricane"

Enclosed is HUR 7-15 which gives parameters for the hurricane of September 1915 and charts of wind speeds and direction over Lake Pontchartrain and vicinity reconstructed for this hurricane. This hurricane appears to have been the most severe of record in the New Orleans area.

Charles S. Gilman, Chief
Hydrometeorological Section

Attachments
cc: 2 with attachments to OCE
1 with attachments to BEB

[redacted]

Wind Speed and Directions over Lake Pontchartrain

The computations that were required in determining the theoretical pressure profiles were carried a few steps further, permitting evaluation of theoretical gradient wind speed profiles. The gradient speed profiles were adjusted to over-water speeds at anemometer level, by application of figure 26 in Hydromet. Report No. 32. When plotting the isotach maps, over-water speeds were converted to over-land speeds by multiplication by .7. This factor was an average value determined by inspection of several ratios of over-water to over-land speeds. Lastly, the wind speed at any given direction from the center, within the storm, was adjusted to include the proper component resulting from the movement of the hurricane as a whole. The direction arrows point in toward low pressure at various angles up to as much as 40 degrees from the gradient wind direction. The deflection angles were taken from a graph showing average deflection (smoothed) of the wind at New Orleans, with distance from the center. 10-minute average wind speeds and directions for Lake Pontchartrain and vicinity are shown in attached charts for seven different hours.

General Summary of Information Pertinent to Hurricane of September 29, 1915

Lowest pressure observed by barometer in Louisiana: 28.01 inches = 948.5 millibars.

Lowest pressure in Louisiana estimated from pressure profiles: 27.87 inches = 943.8 millibars.

Lowest pressure reported by one ship in the western Caribbean: 27.50 inches = 931.3 millibars.

Radius of maximum winds: variable with time, 23 to 66 nautical miles (computed). Cline (1926) stated that the steepest barometric gradients were found 15 to 40 miles from the center. Maximum winds in hurricanes are at approximately twice the radius of the maximum pressure gradient.

Speed of center across Louisiana: 10 to 12 miles per hour.

Wind speeds recorded at New Orleans: (Center passed 15.5 statute miles to the west).

1) Wind speed was 40 mph or higher for 4 hours.
2) Wind speed was 47 mph or higher for 2 hours.
3) Maximum 5-minute average speed was 66 mph from the Southeast.
4) The fastest mile was 98 mph.

Wind speeds recorded at Burrwood, Louisiana:

1) Wind speed averaged 73 mph or over for a 2-hour period.

2) Within above interval, speed was 88 mph for 19 minutes.
3) The maximum 5-minute average speed was 94 mph.
4) The fastest mile was 106 mph.

Variation in Intensity between Louisiana Coastline and Lake Pontchartrain

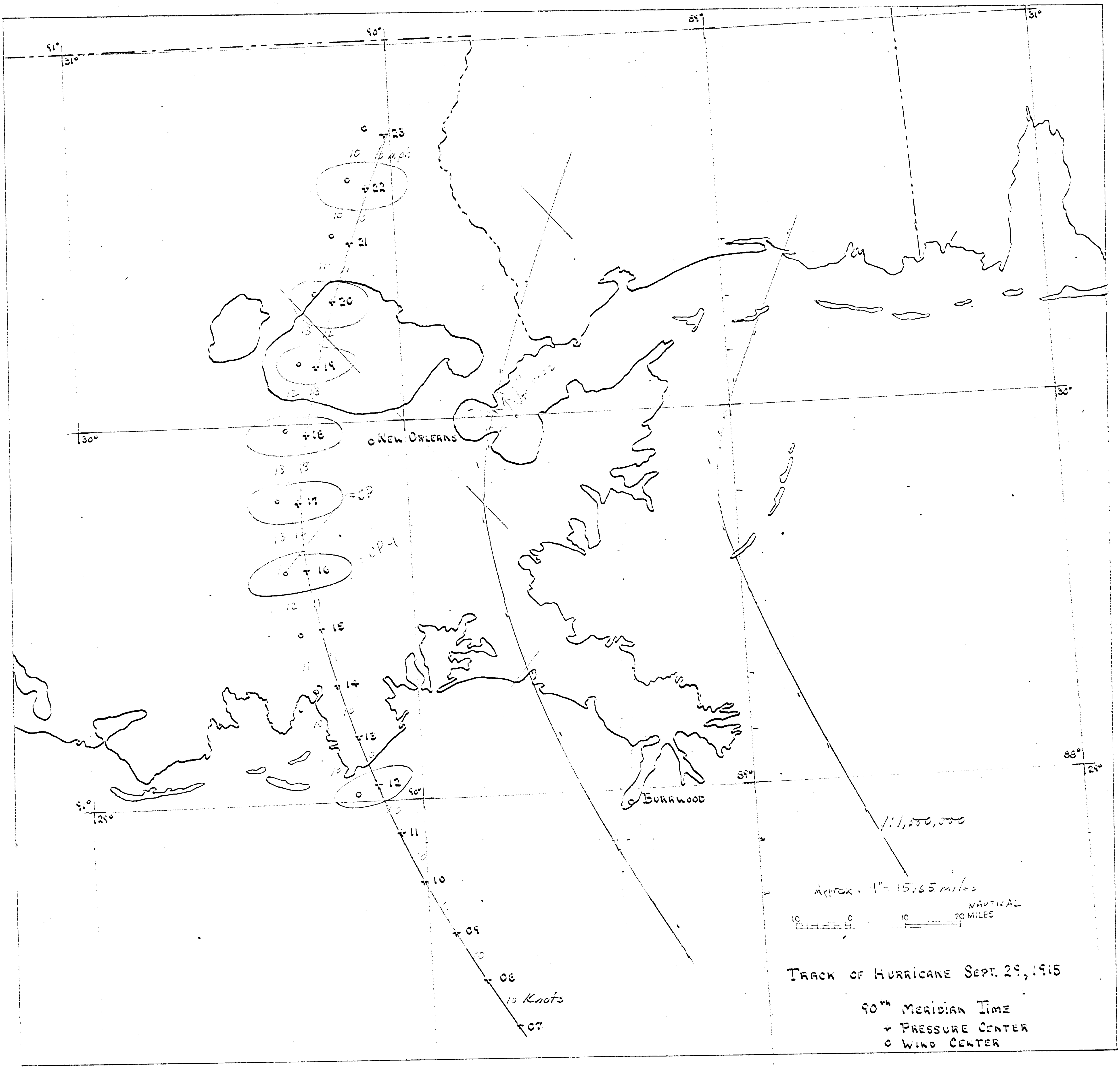
One indication of the strength of a hurricane may be obtained from the difference between the pressure just outside the cyclonic circulation and the pressure at the center, $P_n - P_o$. A comparison on this basis indicates that there was relatively slight variation in intensity from 1200 C.S.T., when the center was just off the Louisiana coast until nearly 1900 C.S.T., when the center was over Lake Pontchartrain. After 1900 C. S. T., the hurricane filled at an accelerating rate. The conclusion that there was little change in intensity between 1200 C.S.T. and 1800 to 1900 C. S. T. is supported by the behavior of the wind speeds at Burrwood. The wind speed at this station was about 73 mph at 1730 C.S.T., when the center was 75 nautical miles distant to the northwest.

References

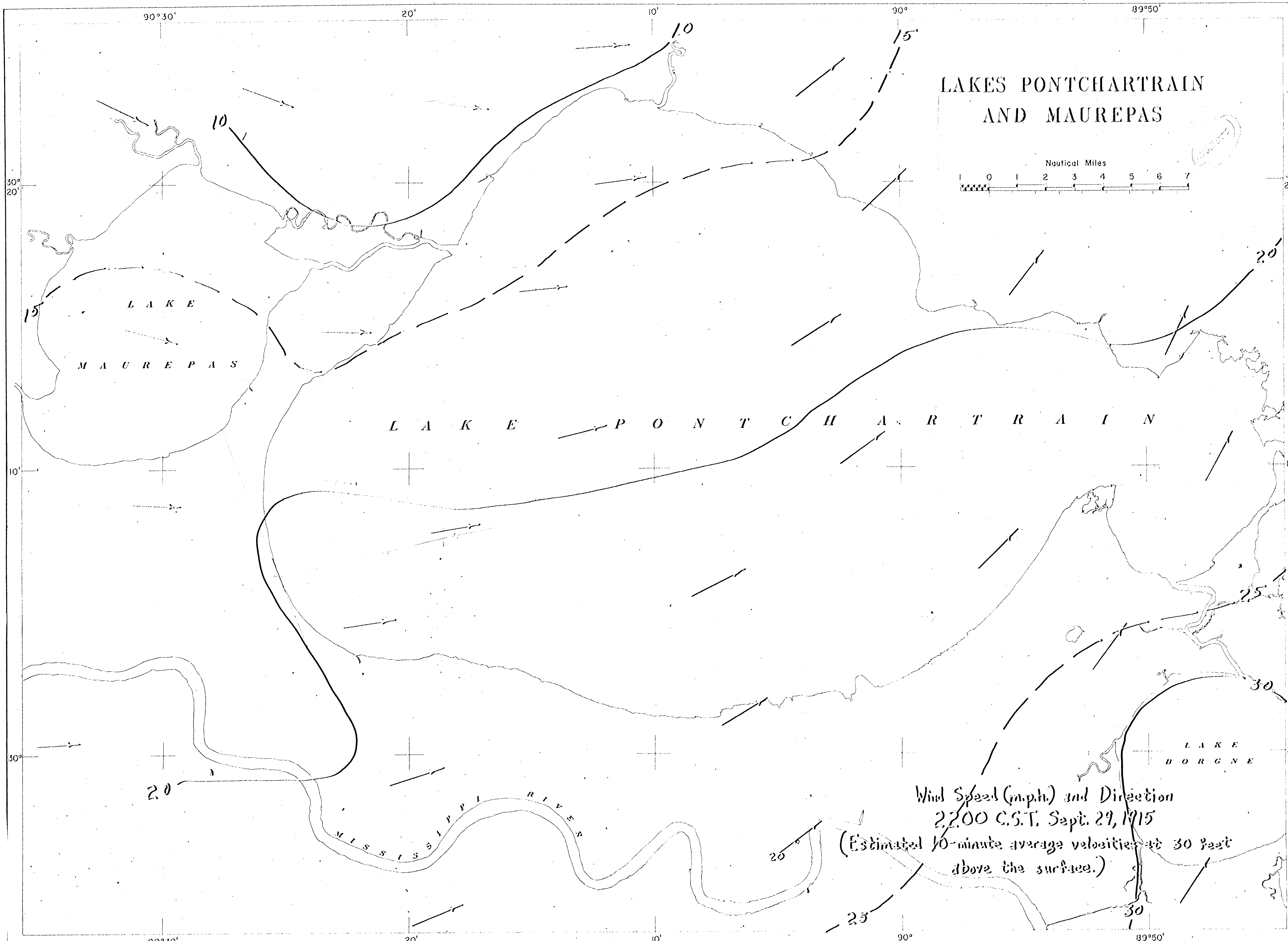
(1) Cline, I. M., 1915: The Tropical Hurricane of September 29, 1915, in Louisiana. Monthly Weather Review, v. 43, No. 9, September 1915, pp. 456-466 (see also Chart III and Figures 1 through 7.)
(2) Cline, I. M., 1926: Tropical Cyclones. The Macmillan Co., N. Y. 301 pp.
(3) Hydrometeorological Section: 1954: Characteristics of U. S. Hurricanes Pertinent to Levee Design for Lake Okeechobee, Florida. U.S.W.B. March 1954. Report 32

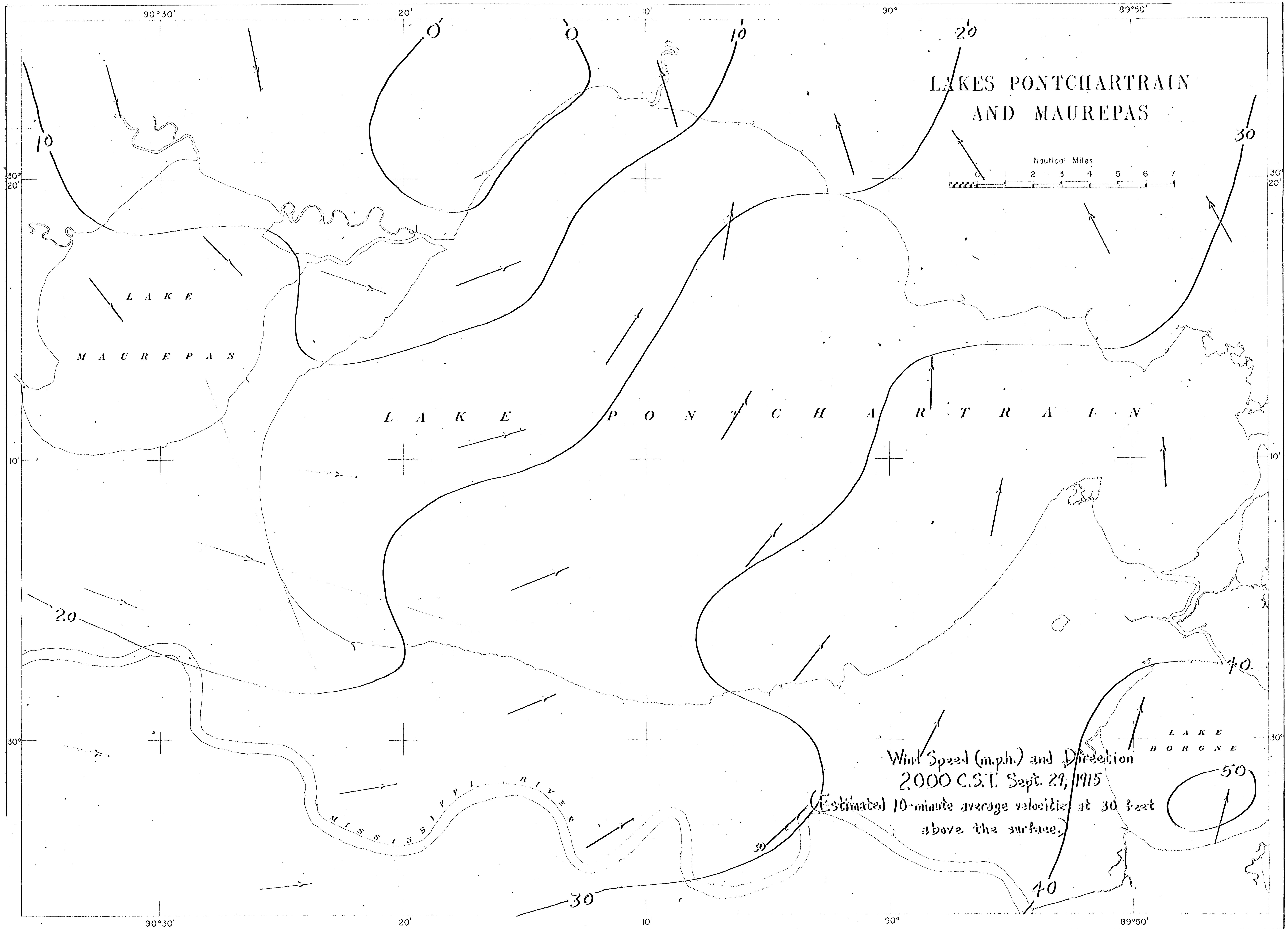
Charles S. Gilman, Chief
Hydrometeorological Section

Attachments
cc: 2 with attachments to OCE
1 with attachments to BEB

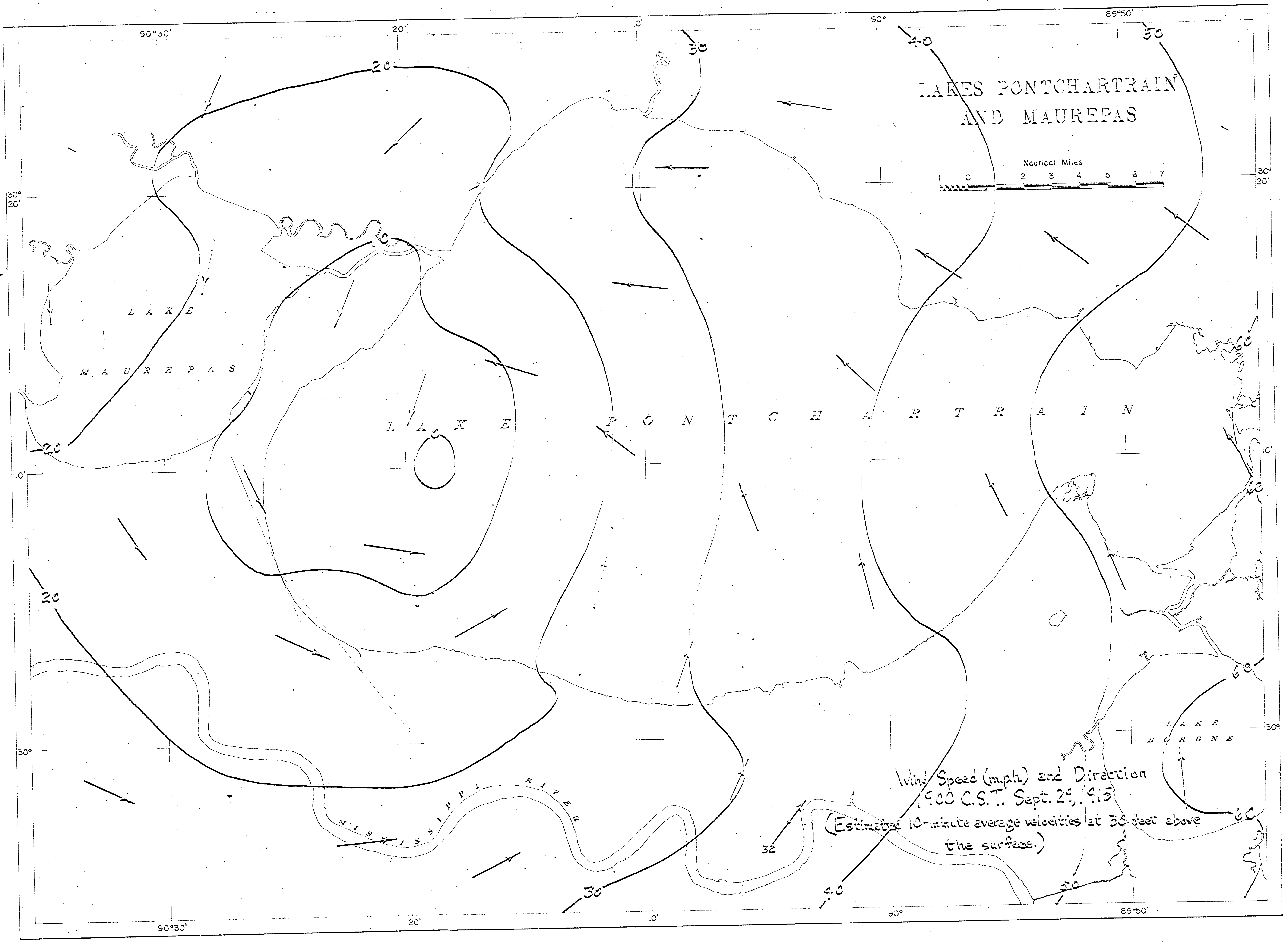


Track of Hurricane Sept. 29, 1915
90th Meridian Time
+ Pressure Center
o Wind Center
New Orleans
Burrwood
1:1,000,000
Approx. 1" = 15.65 miles
Nautical Miles
10 Knots

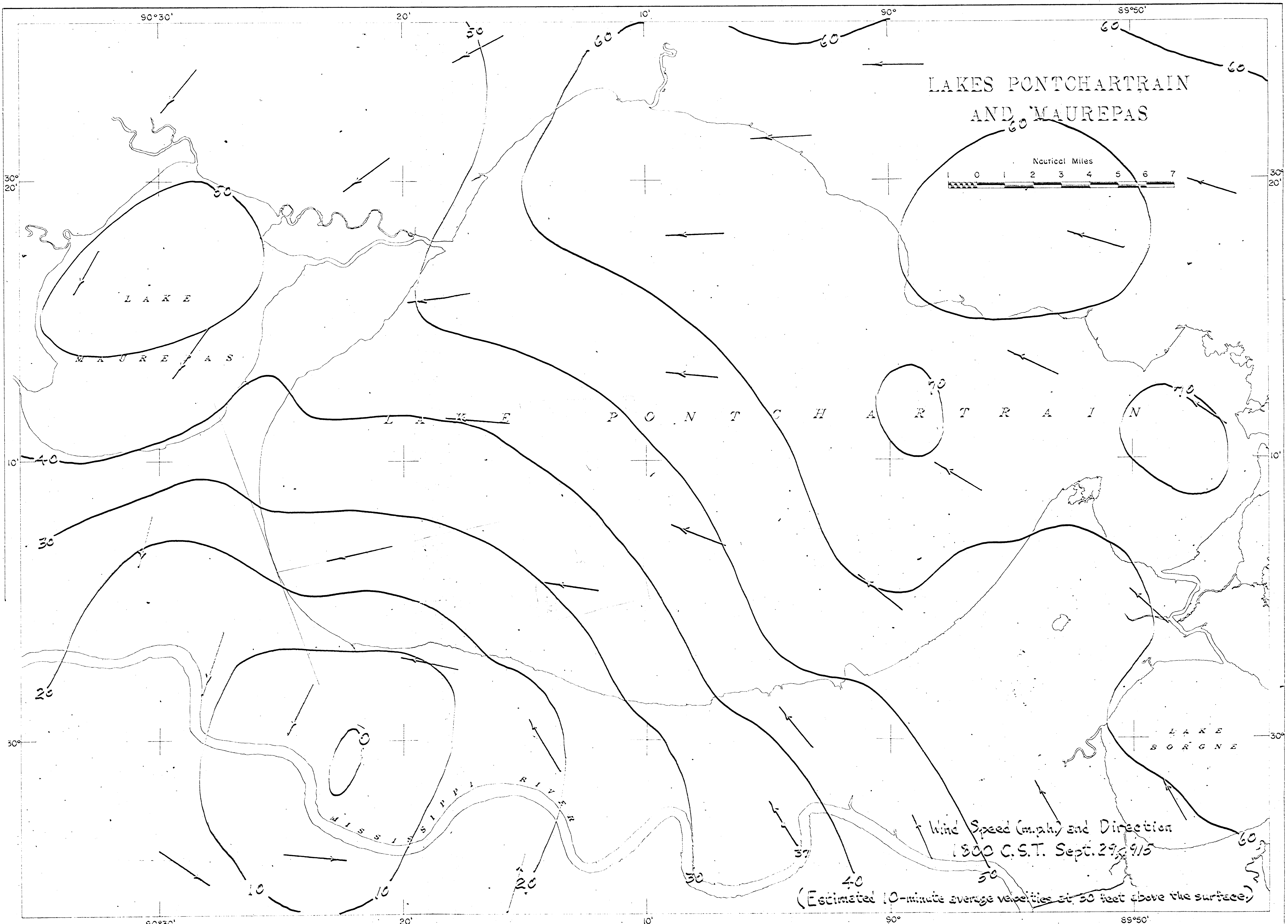

LAKES PONTCHARTRAIN
AND MAUREPAS
Nautical Miles
1 0 1 2 3 4 5 6 7
90°30'
20'
10'
90°
89°50'
30° 20'
10'
30°
LAKE MAUREPAS
LAKE PONTCHARTRAIN
LAKE BORGNE
MISSISSIPPI RIVER
10
15
20
25
30
Wind Speed (m.p.h.) and Direction
2200 C.S.T. Sept. 29, 1915
(Estimated 10-minute average velocities at 30 feet above the surface.)

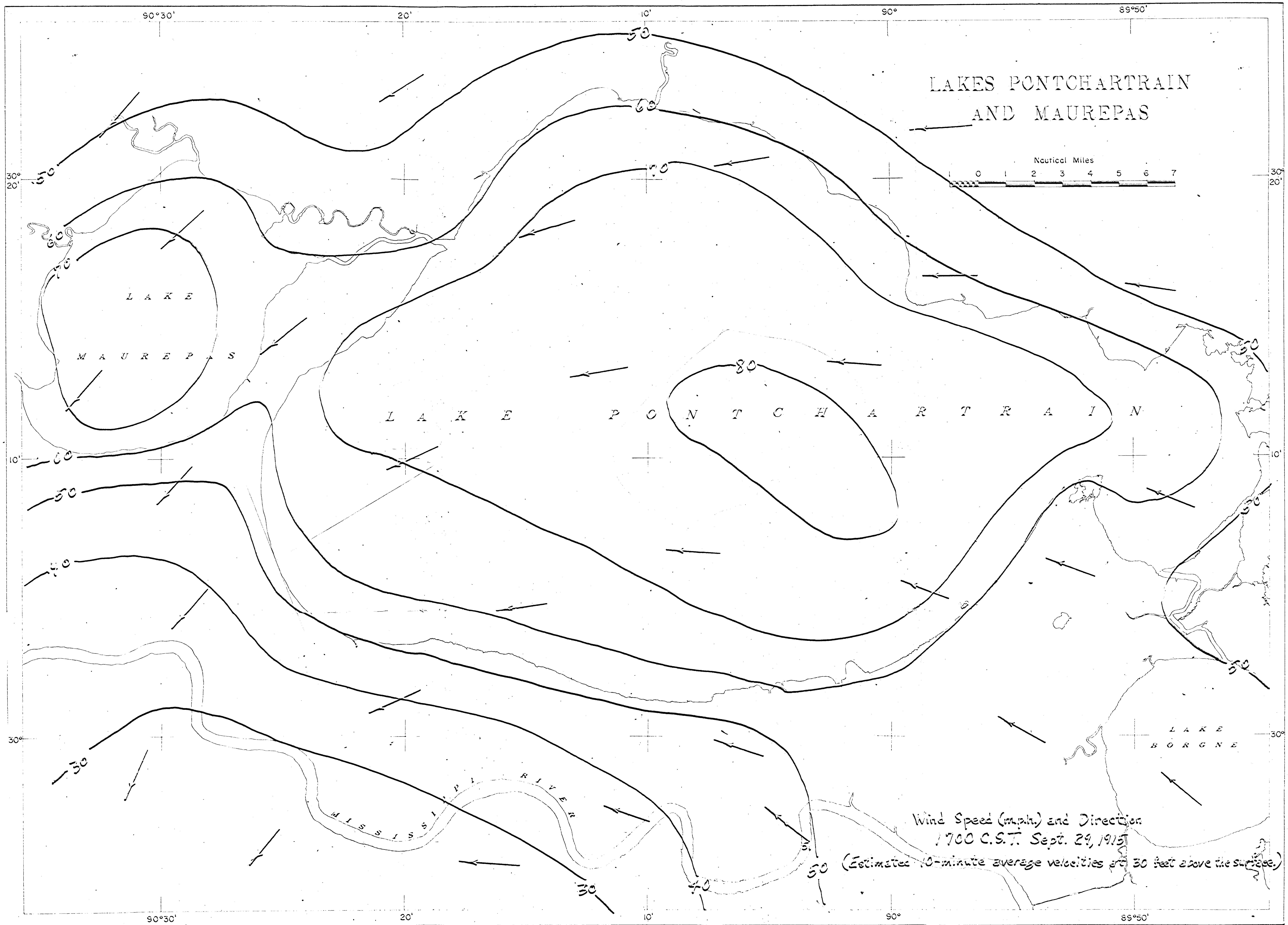


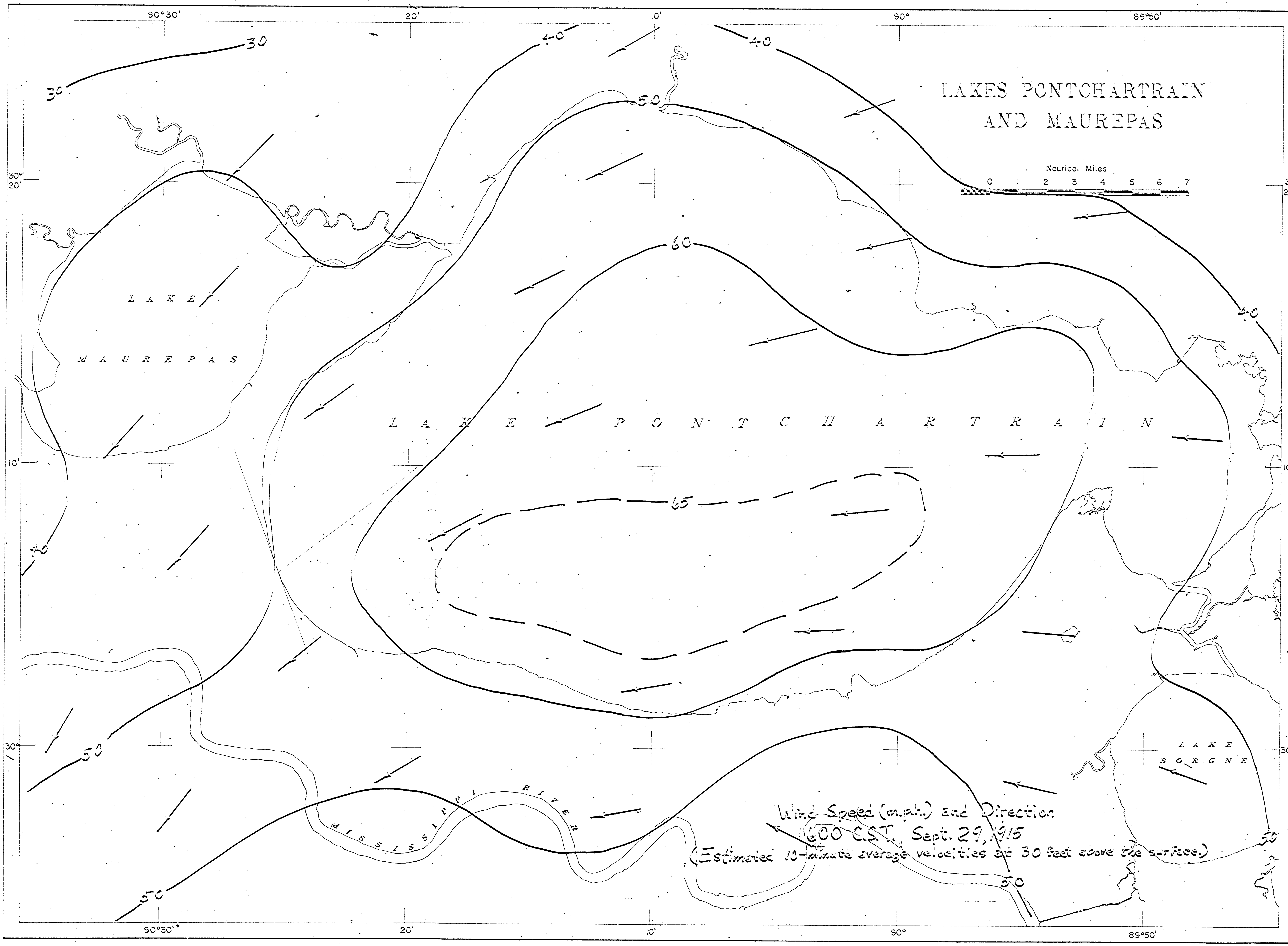
LAKES PONTCHARTRAIN
AND MAUREPAS
Nautical Miles
1 0 1 2 3 4 5 6 7
90°30'
20'
10'
90°
89°50'
30°20'
10'
30°
LAKE MAUREPAS
LAKE PONTCHARTRAIN
LAKE BORGNE
MISSISSIPPI RIVER
0
10
20
30
40
50
Wind Speed (m.p.h.) and Direction
2000 C.S.T. Sept. 29, 1915
(Estimated 10-minute average velocities at 30 feet above the surface.)

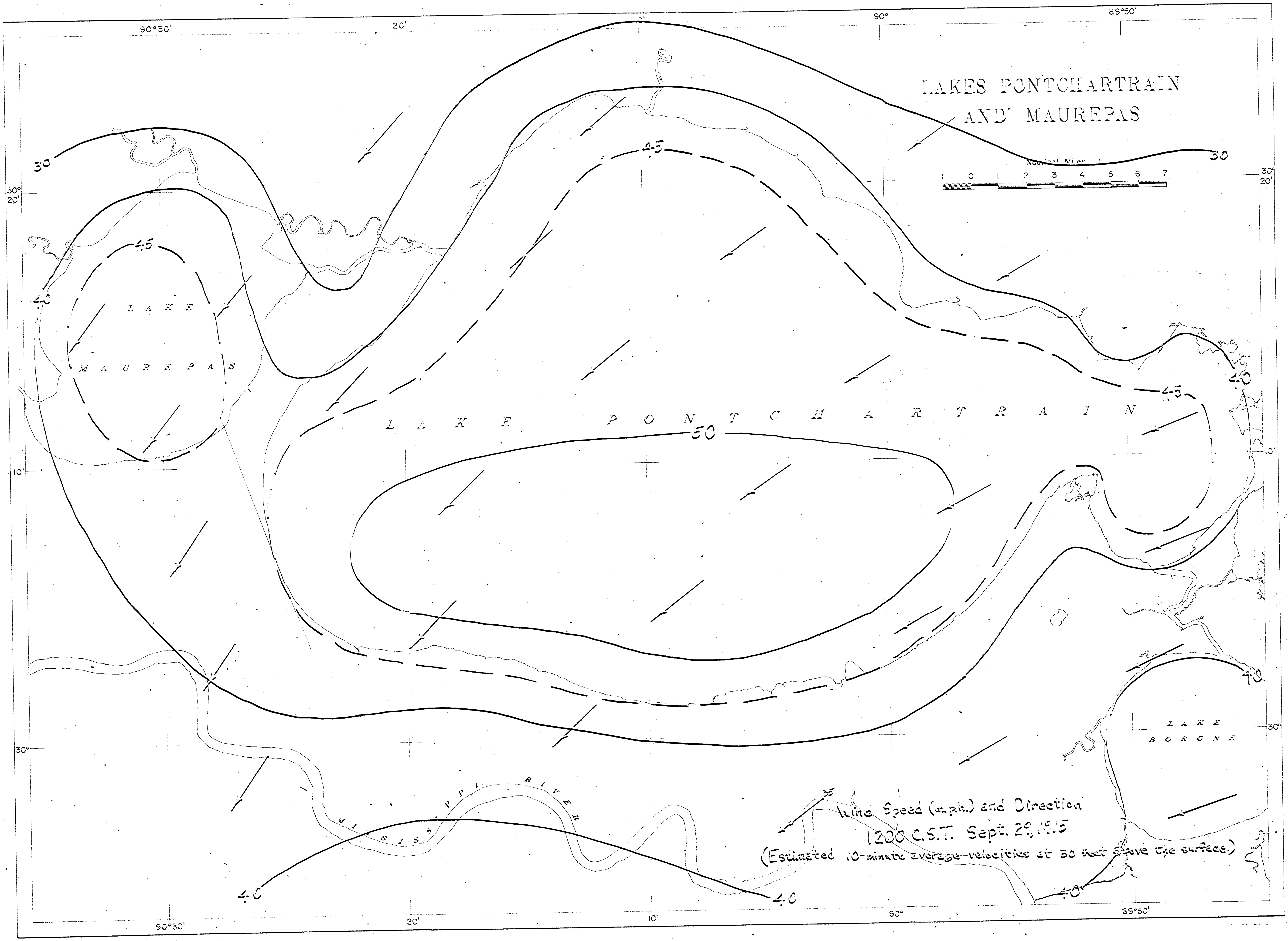


LAKES PONTCHARTRAIN AND MAUREPAS
Nautical Miles
1 0 1 2 3 4 5 6 7
90°30'
20'
10'
90°
89°50'
30° 20'
10'
30°
LAKE MAUREPAS
LAKE PONTCHARTRAIN
LAKE BORGNE
MISSISSIPPI RIVER
20
10
0
30
32
40
50
60
Wind Speed (m.p.h.) and Direction
1900 C.S.T. Sept. 29, 1915
(Estimated 10-minute average velocities at 30 feet above the surface.)


LAKES PONTCHARTRAIN
AND MAUREPAS
Nautical Miles
1 0 1 2 3 4 5 6 7
LAKE
MAUREPAS
LAKE PONTCHARTRAIN
LAKE
BORGNE
MISSISSIPPI RIVER
90°30'
20'
10'
90°
89°50'
30°
20'
10'
30°
60
50
40
30
20
10
0
70
Wind Speed (m.p.h.) and Direction
1800 C.S.T. Sept. 29, 1915
(Estimated 10-minute average velocities at 30 feet above the surface.)


LAKES PONTCHARTRAIN
AND MAUREPAS
Nautical Miles
1 0 1 2 3 4 5 6 7
90°30'
20'
10'
90°
89°50'
30° 20'
30° 10'
30°
LAKE MAUREPAS
LAKE PONTCHARTRAIN
LAKE BORGNE
MISSISSIPPI RIVER
50
60
70
80
40
30
Wind Speed (m.p.h.) and Direction
1700 C.S.T. Sept. 29, 1915
(Estimated 10-minute average velocities at 30 feet above the surface.)


LAKES PONTCHARTRAIN
AND MAUREPAS
Nautical Miles
0 1 2 3 4 5 6 7
90°30'
20'
10'
90°
89°50'
30° 20'
10'
30°
LAKE MAUREPAS
LAKE PONTCHARTRAIN
LAKE BORGNE
MISSISSIPPI RIVER
30
40
50
60
65
Wind Speed (m.p.h.) and Direction
1600 C.S.T. Sept. 29, 1915
(Estimated 10-minute average velocities at 30 feet above the surface.)



LAKES PONTCHARTRAIN
AND MAUREPAS
Nautical Miles
1 0 1 2 3 4 5 6 7
LAKE MAUREPAS
LAKE PONTCHARTRAIN
LAKE BORGNE
MISSISSIPPI RIVER
90°30'
20'
10'
90°
89°50'
30°20'
30°10'
30°
30
45
40
50
35
Wind Speed (m.p.h.) and Direction
1200 C.S.T. Sept. 29, 1915
(Estimated 10-minute average velocities at 30 feet above the surface.)

HEADQUARTERS
DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON 25, D. C.

IN REPLY REFER TO

ENGWE

14 December 1959

SUBJECT: Hurricane Study - Hurricane Rainfall Criteria

TO: Division Engineer
U. S. Army Engineer Division, Lower Mississippi Valley
Vicksburg, Mississippi

1. Reference is made to letter of 20 November 1959 from New Orleans District, subject as above, and 1st Indorsement thereto of 2 December 1959 from OCE transmitting HMS Memo HUR 3-5.

2. In above referenced 1st Indorsement, it was stated that a supplement to HUR 3-5 would be prepared by the Hydrometeorological Section of the Weather Bureau to include estimates of moderate amounts of rainfall that might be associated with standard project hurricane conditions. In accordance therewith two copies of the memorandum HUR 3-5a, subject, "Estimates of Moderate Hurricane Rainfall Applicable to Middle Gulf Standard Project Hurricane", are inclosed.

FOR THE CHIEF OF ENGINEERS:

1 Incl (dup)
HMS Memo HUR 3-5a, 11 Dec 59

F. B. SLICHTER
For Chief, Engineering Division
Civil Works

LMVGK 1st Ind

U. S. Army Engr Div, Lower Mississippi Valley, Vicksburg, Miss. 21 DEC 1959

TO: District Engineer, U. S. Army Engr Dist, New Orleans

1 Incl
dup cy w/d

G. B. D.

UNITED STATES DEPARTMENT OF COMMERCE
WEATHER BUREAU
WASHINGTON

December 11, 1959

IN REPLY, PLEASE ADDRESS
CHIEF, U. S. WEATHER BUREAU
WASHINGTON 25, D. C.
AND REFER TO

0-6.12

HUR 3-5a

TO : Mr. A. L. Cochran, Civil Works
Office of Chief of Engineers
Corps of Engineers

FROM : Hydrometeorological Section

SUBJECT: Estimates of Moderate Hurricane Rainfall Applicable to Middle Gulf Standard Project Hurricanes

Herewith is transmitted supplement to HUR 3-5. This gives factors to be applied to the moderately high values of rainfall estimates applicable to Middle Gulf Standard Project Hurricanes, Tracks A, C, F, D and B, New Orleans Study, Zone B, in order to obtain moderate rainfall values.

Charles S. Gilman, Chief
Hydrometeorological Section

dd:
2 to OCE with attachments
2 to BEB "

UNITED STATES DEPARTMENT OF COMMERCE
WEATHER BUREAU
WASHINGTON

December 11, 1959

IN REPLY, PLEASE ADDRESS
CHIEF, U. S. WEATHER BUREAU
WASHINGTON 25, D. C.
AND REFER TO

0-6.12

MEMORANDUM TO CORPS OF ENGINEERS

HUR 3-5a

FROM : Hydrometeorological Section

SUBJECT : Estimates of Moderate Hurricane Rainfall Applicable to Middle Gulf Standard Project Hurricanes

Reference: HUR 3-5, "Hurricane Rainfall Estimates Applicable to Middle Gulf Standard Project Hurricanes, Tracks A, C, F, D and B," November 30, 1959

The above reference gave estimates of "a moderately high level of precipitation" for Middle Gulf Standard Project Hurricanes. Curve B, Inclosure 1 of the reference was used in preparing the other tables and diagrams. In order to determine estimates of a moderate amount of precipitation, curve A, the regression line which cuts through the average of the data, is used. To adjust the tables and diagrams of the reference to a moderate precipitation amount, the precipitation values at a 5 mph forward speed are multiplied by a percentage factor determined by dividing the 24-hour maximum precipitation at 5 mph on curve A, Inclosure 1 by the maximum precipitation on curve B. This adjustment factor is 68 percent. The same procedure is followed in determining the adjustment factor for the average speed (12.3 knots) and the 15 mph speed. For both these speeds the adjustment factor is 67 percent.

Table 2 of HUR 3-5 remains the same except for column 5 (the 24-hour index rainfall depths). In order to adjust these to a moderate precipitation amount, take 68% of the 5 mph values and 67% of the 15 mph values.

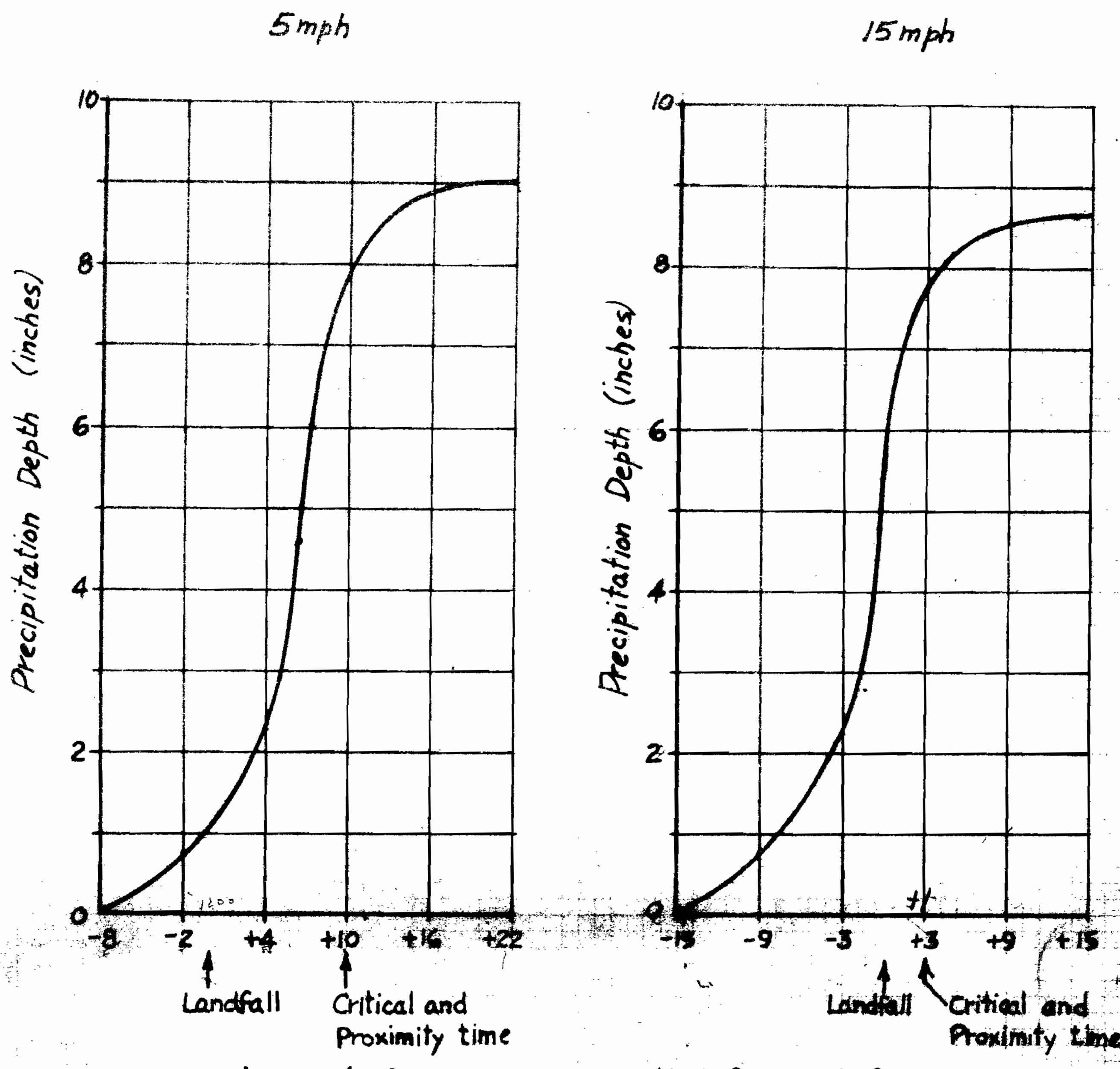
Inclosures 2, 3 and 4 are adjusted to moderate precipitation by taking 67% of the isohyets.

Inclosure 5, representing depth-duration-area percentage relationships is unchanged.

Inclosures 6 and 7 are changed by 67% and are inclosed herein as figures 1 and 2.

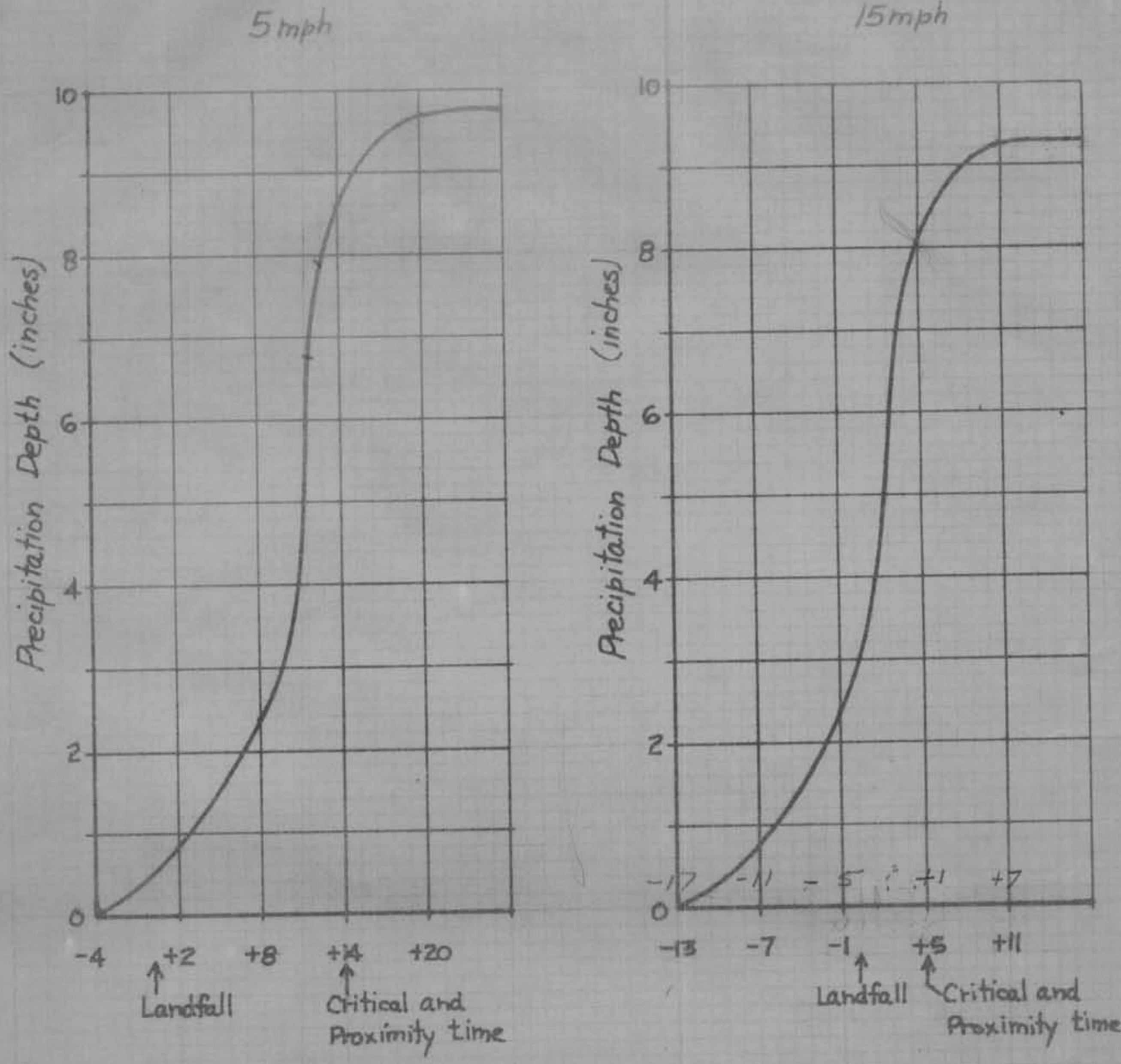
Charles S. Gilman, Chief
Hydrometeorological Section

cc: 2 to OCE with attachments
2 to BEB "



Time scale for New Orleans critical for track A.

Fig. 1. Generalized mass curves for 5mph and 15mph Standard Project Hurricanes with critical stations 24 hour point index depth equal to 9.0 and 8.6 inches, respectively.



Time scale for point on north shore of Lake Ponchartrain Critical for track C.

Fig. 2. Generalized mass curves for 5mph and 15mph Standard Project hurricanes with critical stations 24-hour point index depth equal to 9.8 and 9.3 inches, respectively.

UNITED STATES DEPARTMENT OF COM.
WEATHER BUREAU
WASHINGTON

November 30, 1959

IN REPLY, PLEASE ADDRESS
CHIEF, U. S. WEATHER BUREAU
WASHINGTON 25, D. C.
AND REFER TO
0-6.12

TO: Mr. A. L. Cochran, Civil Works
Office of Chief of Engineers
Corps of Engineers

FROM: Hydrometeorological Section

SUBJECT: HUR 3-5, Hurricane Rainfall Estimates Applicable to Middle Gulf Standard Project Hurricanes, Tracks A, C, F, D and B, New Orleans Study, Zone B

Herewith is transmitted the Subject memorandum which furnishes mass curves for selected critical stations along Standard Project Hurricane Tracks A, C, F, D and B.

Charles S. Gilman, Chief
Hydrometeorological Section

Attachments

cc: 2 to OCE with attachments

UNITED STATES DEPARTMENT OF COMMERCE
WEATHER BUREAU
WASHINGTON

November 30, 1959

IN REPLY, PLEASE ADDRESS
CHIEF, U. S. WEATHER BUREAU
WASHINGTON 25, D. C.
AND REFER TO

0-6.12

MEMORANDUM TO CORPS OF ENGINEERS

HUR 3-5

FROM : Hydrometeorological Section

SUBJECT : Hurricane Rainfall Estimates Applicable to Middle Gulf Standard Project Hurricanes, Tracks A, C, F, D and B

Reference: Memorandum from OCE to HMS August 17, 1959, Subject, "Hurricane Criteria Required for New Orleans Hurricane Studies"

Introduction

Point 24-hour rainfall and mass curves for critical stations relative to Standard Project Hurricanes (Tracks A, C, F, D and B) and a procedure for determining areal hurricane precipitation estimates up to 200 square miles pertaining to any zone B hurricane are submitted.

The point and areal precipitation estimates submitted are based upon the climatology of hurricane rainfall in the middle Gulf Coast. They represent a moderately high level of precipitation estimates but a level that has been equalled or exceeded by several hurricane rainfalls of record in this region. The magnitude of these precipitation estimates are well below Standard Project Storm criteria and Probable Maximum Precipitation estimates which indicate 24-hour point depths of 21 and 40 inches respectively for the Louisiana coastal region. An average 24-hour maximum point precipitation depth based on the mean obtained from 52 hurricanes in the Gulf Region is 9.4 inches. The average forward speed of the 52 hurricanes sampled was 12.3 knots.

Hurricane speed-precipitation relationships

A study was made to determine whether speed of hurricane motion influenced the amount of resulting 24-hour maximum point precipitation. A plot of observed 24-hour point precipitation values (inches) versus hurricane speed (knots) was made and is shown by inclosure 1. These data were subjected to a statistical analysis and the regression line obtained is shown by curve A on inclosure 1. It can be seen that there is a very slight negative correlation (-.046) of decreased 24-hour rainfall with increased hurricane speed. However, the slope of the regression line was used as a basis for setting the upper limits of precipitation estimates to be applied to Standard Project Hurricanes. Curve A (regression line) was shifted upward on the chart (inclosure 1) until it undercut 10 percent of the plotted points (5 out of 52). This positioning shown by curve B represents comparable limits of the precipitation index amounts to be used with Standard Project Hurricane considerations. Curve B (inclosure 1) sets the upper limit of maximum 24-hour point precipitation at 14 inches for hurricanes moving through the middle Gulf Region with the average speed, i.e., 12.3 knots, determined from the above statistical analysis.

Areal distribution of 24-hour hurricane precipitation

The areal distribution of 24-hour maximum point hurricane rainfall was determined and is shown by a generalized isohyetal pattern (inclosure 2). This generalized pattern was established by enveloping the 24-hour isohyetal patterns from all hurricane occurrences in the middle Gulf Region (zone B). The chart's origin was fixed at a hurricane's point of landfall and then oriented along the mean 24-hour direction of the hurricane after landfall. The 10-inch isohyet was traced and then the highest point precipitation depth within the 10-inch isohyet was marked at the point of occurrence for each of the hurricanes. After the 10-inch isohyets were traced an enveloping 10-inch isohyet was drawn. Next an envelopment was made of the maximum point depths within the 10-inch isohyet and the 12-inch and 14-inch isohyets were established.

Selection of 24-hour maximum point index rainfall depths

Point rainfall index depths applicable to a Standard Project Hurricane's predetermined critical area may be obtained from the generalized isohyetal pattern (inclosure 2) and then adjusted for the SPH's speed (inclosure 1) in the following manner:

1. Plot the SPH track and measure the distance in miles from landfall to the point on the track that is closest to the critical station. (Selection of critical station is arbitrary but should be near center of critical area).

2. Measure the lateral distance in miles from the point on the track determined in step 1 to the critical station.

3. Enter inclosure 2 with the distances determined by step 1 (horizontal) and step 2 (lateral) and read the 24-hour point rainfall amount denoted by the generalized isohyets at that point. If the critical station is located anywhere within the confines of the 14-inch isohyet use 14 inches as an index depth, otherwise interpolate between isohyets. If the critical station is located outside the 10-inch isohyet then the location is beyond these SPH considerations.

4. To adjust the index depth obtained in item 3 for Standard Project Hurricanes of differing speeds read the 24-hour precipitation index depth along curve B (inclosure 1) that corresponds to the selected Standard Project Hurricane speed. If the index depth in item 3 is less than 14 inches the speed adjustment can be made by multiplying by the ratio of the precipitation

amount at the Standard Project Hurricane's assigned speed to the precipitation amount at the average speed (12.3 knots) of the middle Gulf hurricanes on curve B (inclosure 1).

Example--If the Standard Project Hurricane's assigned speed was 5 mph and the critical station is located 60 miles from landfall along the track and 30 miles to the left of the track the index depth from inclosure 2 is 13 inches. From curve B (inclosure 1) the depth for a hurricane moving 12.3 knots is 14 inches opposed to 14.6 inches at 4 knots, giving an adjustment ratio of 104 percent. Thus the adjusted point precipitation depth is 1.04 x 13 = 13.5 inches. It follows that had the critical station been located within the 14 inch isohyet its index depth for a hurricane moving at 5 mph would be 14.6 inches.

Note--Rainfall amounts taken from the generalized isohyetal pattern (inclosure 2) are considered to be approximations for storms moving at the average speed, i.e. 12.3 knots of hurricanes of the middle Gulf Region.

Determination of 24-hour depth-area precipitation estimates

The isohyetal pattern shown by the clear overlay (inclosure 3) can be used in conjunction with the generalized isohyetal pattern (inclosure 2) to ascertain 24-hour areal precipitation estimates for limited areas. The isohyetal pattern (inclosure 3) shows the shape which envelops all the isohyetal combinations that went into the establishment of the generalized isohyetal pattern. The 14-inch center is marked by an X with the 13, 12, 11 and 10-inch isohyets drawn around it.

Area-depth estimates can be made in the following manner:

1. Follow items 1, 2 and 3 in the procedure outlined for 24-hour point rainfall estimates. The critical station should be located at the center of the critical area.

2. Fit the isohyetal pattern (inclosure 3) with its 14-inch center (X) over the location of the selected critical station on the generalized isohyetal pattern inclosure 2. If the critical point lies on or within the confines of the 14-inch isohyet go to item 3 below; if not, the isohyetal pattern (inclosure 3) must be moved horizontally or laterally until its 14-inch center (X) falls on or within the 14-inch generalized isohyet on inclosure 2, and the critical points assigned 24-hour index depth on inclosure 3 coincides with the depth on the isohyetal pattern inclosure 2. (See remarks below concerning an example of this procedure).

3. Having established the location of the point of maximum rainfall by item 2 above, the pattern on inclosure 3 can be rotated as long as the depths represented on inclosure 3 do not exceed those on inclosure 2.

4. Fix the isohyetal pattern (inclosure 3) in place, after selecting

the permissible rotation, outline the critical area and planimeter it to determine a 24-hour area-depth precipitation estimate.

5. To adjust the precipitation depths for Standard Project Hurricanes of varying speeds use the ratio of selected speed depth to average speed, depth on curve B (inclosure 1).

Examples: Inclosure 4 shows two examples of the recommended process for determining areal precipitation for a hurricane moving at 12.3 knots.

Example A is for a critical area of 100 square miles with its center point located 40 miles along and 20 miles to the right of the hurricane track. The fixed isohyetal pattern shown by the example may be rotated 360 degrees without exceeding any of the isohyets on the generalized isohyetal pattern.

Example B is for a critical area of 100 square miles with its center located 60 miles along and 30 miles to the left of the hurricane track. The fixed isohyetal pattern shown cannot be rotated because it would not meet the requirement of having the critical point on the 13-inch isohyet with the maximum 14-inch isohyet center (X) inside the 14-inch generalized isohyet.

The adjustment factors for either of these two areal depths on inclosure 4 for Standard Project Hurricanes of varying speeds are 104 percent for hurricanes moving at 5 mph and 99 percent for hurricanes moving at 15 mph (from curve B, inclosure 1).

Time distribution of 24-hour point precipitation estimates

In order to provide data for construction of mass curves the 6-hour distribution of maximum 24-hour point rainfall for nine Louisiana coastal hurricanes were reviewed. From these data it was seen that the maximum 6-hour burst of rain varied from 37 to 89 percent of the total 24-hour point rainfall giving an arithmetic average of 63 percent. The second, third and fourth 6-hour ratios averaged 17, 12 and 8 percent of the 24-hour maximum point, respectively. A check was made to determine whether the use of the above 6-hour ratios produced abnormally high precipitation depths. This was done by comparing the observed 6-hour rainfall depths from the major hurricanes of the middle Gulf Region for which Part II data are available to those 6-hour depths computed by using 14 inches as a 24-hour point index and applying the above incremental percentage ratios. It was found that the computed depths fell below the higher values of observed depths.

Since the 24-hour precipitation depths are adjusted for speed by curve B on inclosure 1 only one sequence of placing the 6-hour increments is suggested. The ratios in their respective 6-hour locations with respect to the hurricanes closest point to the critical station (proximity time) are shown on table 1. The ratios are so placed as to show (1) the maximum 6-hour burst of rain during the -6 to 0 hour period, (2) the maximum 12-hour burst during the -12 to 0 hour period and (3) the maximum 18-hour burst during the -12 to +6 period. The 0-hour designates proximity time.

Time distribution of 24-hour areal precipitation estimates

If mass curves are required for areas up to 200 square miles the depth-duration area relationships shown on inclosure 5 can be used. These depth-duration area curves were developed from the same hurricanes that were used in establishing table 1. The 6-hour incremental ratios shown on inclosure 5 can be arranged in the same relative positions as shown in table 1, i.e., maximum 6-hour depth from -6 to 0 hours, maximum 12-hour depth from -12 to 0 hours, etc. The 0-hour designates proximity time. Adjustments for hurricane speed should be made by determining the average areal-depth directly from the use of inclosures 2 and 3 and then corrected for speed by use of ratios obtained from curve B, inclosure 1.

Table 1. Percentage Ratios (by 6-hour increments) to be applied to 24-hour Precipitation Index Amounts for Construction of Standard Project Hurricane Mass Curves.

	Time (by 6-hour increments) from Standard Project Hurricanes Proximity Point to Critical Station			
	-18 to -12	-12 to -6	-6 to 0	0 to +6
Ratio (percent of 24-hr depth)	8	17	63	12
Ratio (accumulative percent of 24-hr depth)	8	25	88	100

Mass curves for critical stations located along Tracks A, C, F, B and D

Four mass curves (inclosure 6, 6a, 7 and 7a) and table 2 are offered for use in determining mass curves for each of the critical stations along Tracks A, C, F, B and D. The four mass curves have been provided with time scales for critical stations along Tracks A and C. The remaining time scale data for the other critical stations and Standard Project Hurricane tracks have been provided in table 2. Table 2 shows (1) The Standard Project Hurricane track considered, (2) the selected critical station, (3) the distance from landfall to the critical stations' proximity point, (4) lateral distance from hurricane track at proximity time, (5) the 24-hour index rainfall depths for 5 mph and 15 mph Standard Project Hurricanes, (6) the critical time expressed in hours from landfall, (7) the proximity time expressed in hours from landfall, and (8) the generalized mass curve inclosure number to apply the scales to.

Two examples as to how to assign the data shown on table 2 to mass curves are shown on inclosure 6 and 6a for the critical station along track A

Table 2. Data for Determining Time Scales to be Applied to the Generalized Mass Curves for Individual Critical Stations Along Standard Project Hurricane Tracks A, C, F, B and D.

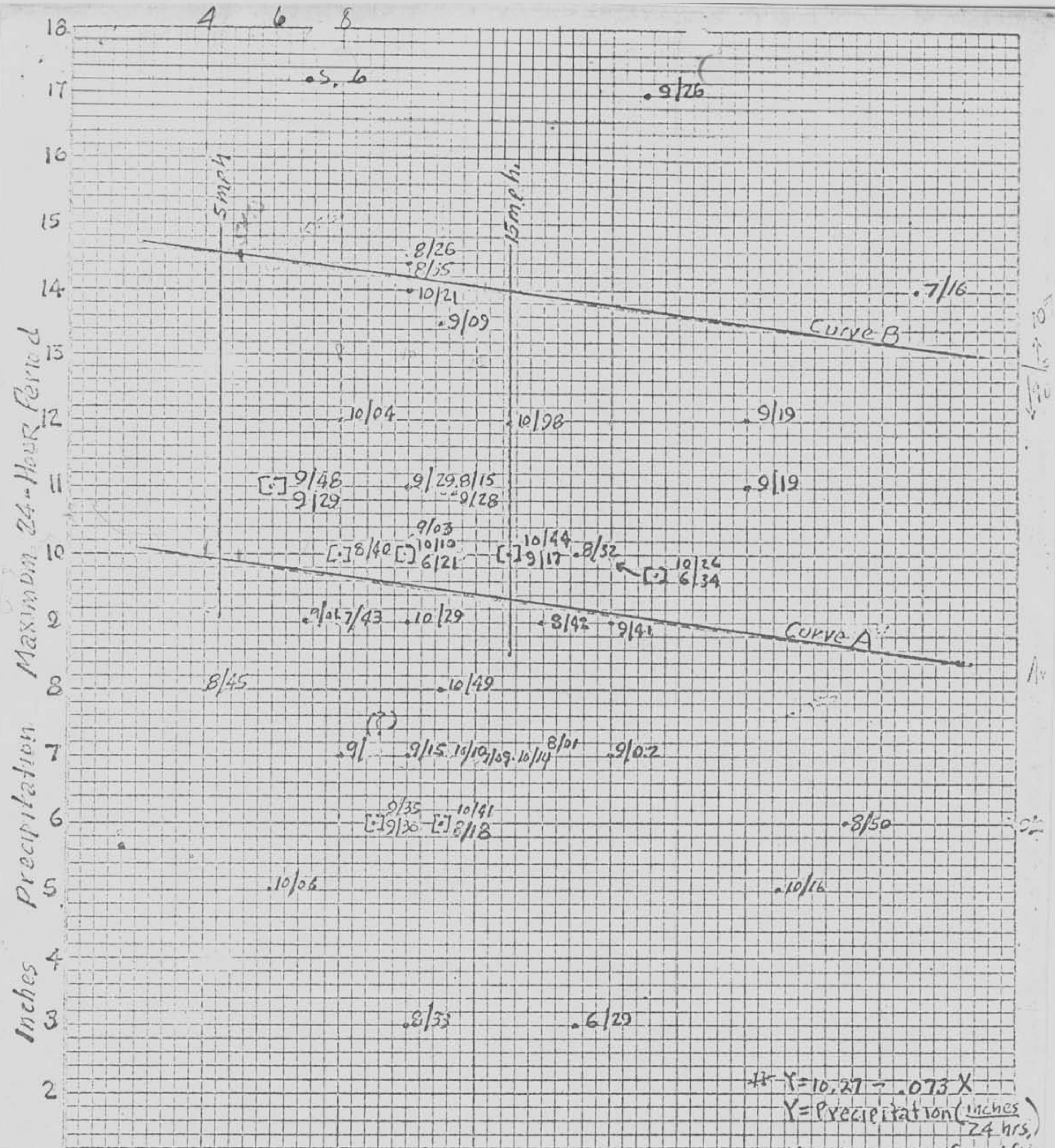
1	2	3	4	5		6		7		8	
Standard Project Hurricane Track Considered	Selected Critical Station	Distance Along Track from Landfall	Lateral Distance From Track At Proximity Time	24-Hour Index Rainfall Depths (inches)		Critical Time Measured in Hours from Landfall Time		Proximity Time Measured in Hours from Landfall Time		Generalized Curve to Use for Critical Station's Mass Curve	
		(miles)	(miles)	5 mph	15mph	5 mph	15 mph	5 mph	15 mph	5 mph	15mph
Track A	New Orleans, La.	50	30 Left	13.5"	12.9"	+10	+3	+10	+3	6	6a
Track C	Point on North shore of Lake Pontchartrain	80	30 Right	14.6	13.9	+14	+5	+14	+5	7	7a
Track F	Rigolets, La.	15	25 Right	14.6	13.9	+6	+1	+3	+1	7	7a
	New Orleans, La.	30	5 Right	14.6	13.9	0	0	+6	+2	7	7a
	Point on North Shore of Lake Pontchartrain	65	30 Right	14.6	13.9	+13	+4	+13	+4	7	7a
Track D	Grand Isle, La.	0	15 Left	14.6	13.9	0	0	-4	-1	7	7a
	Point-a-la Hache, La.	0	25 Left	14.6	13.9	+2	+1	-1	0	7	7a
Track B	Grand Isle, La.	5	15 Right	14.6	13.9	+6	+2	+1	0	7	7a
	Venice, La.	0	45 Right	14.6	13.9	0	0	-2	-1	7	7a
	Myrtle Grove, La.	30	20 Right	14.6	13.9	+11	+4	+6	+2	7	7a

and on inclosure 7 and 7a for the critical station along track C. It can be seen that the location of the proximity time is constant for all mass curves for this time should coincide with the end of the maximum burst. Having this point established all that is needed is to assign new time scales along the abscissas of the generalized mass curve.

Charles S. Gilman, Chief
Hydrometeorological Section

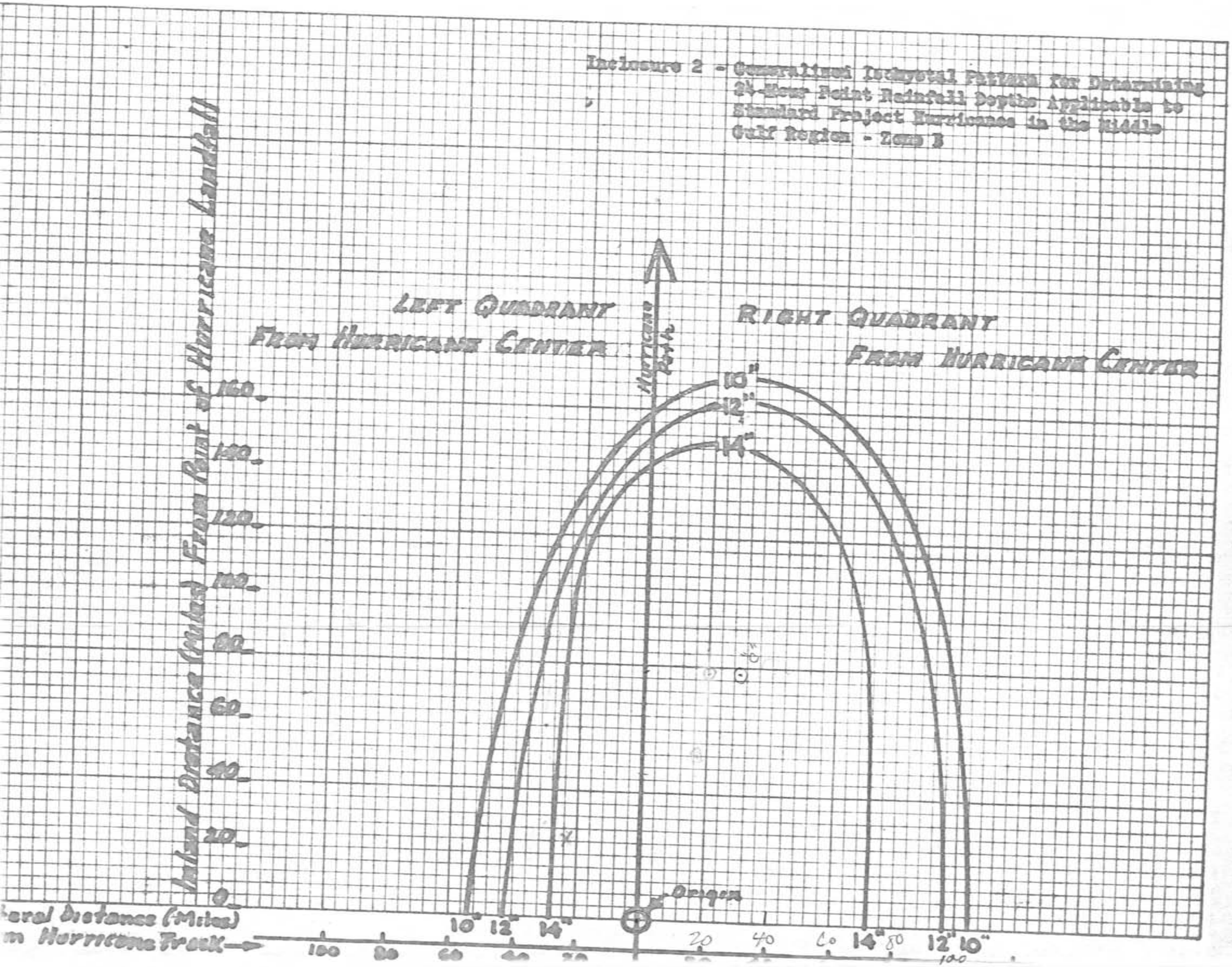
Attachments

cc: 2 to OCE with attachments

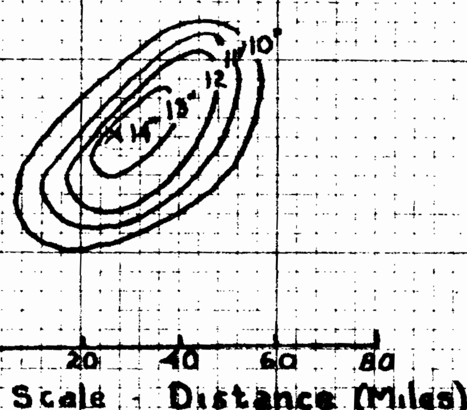


Inclosure 1 - Relationship of 24 Hr. Maximum Precipitation to Hurricane Speed

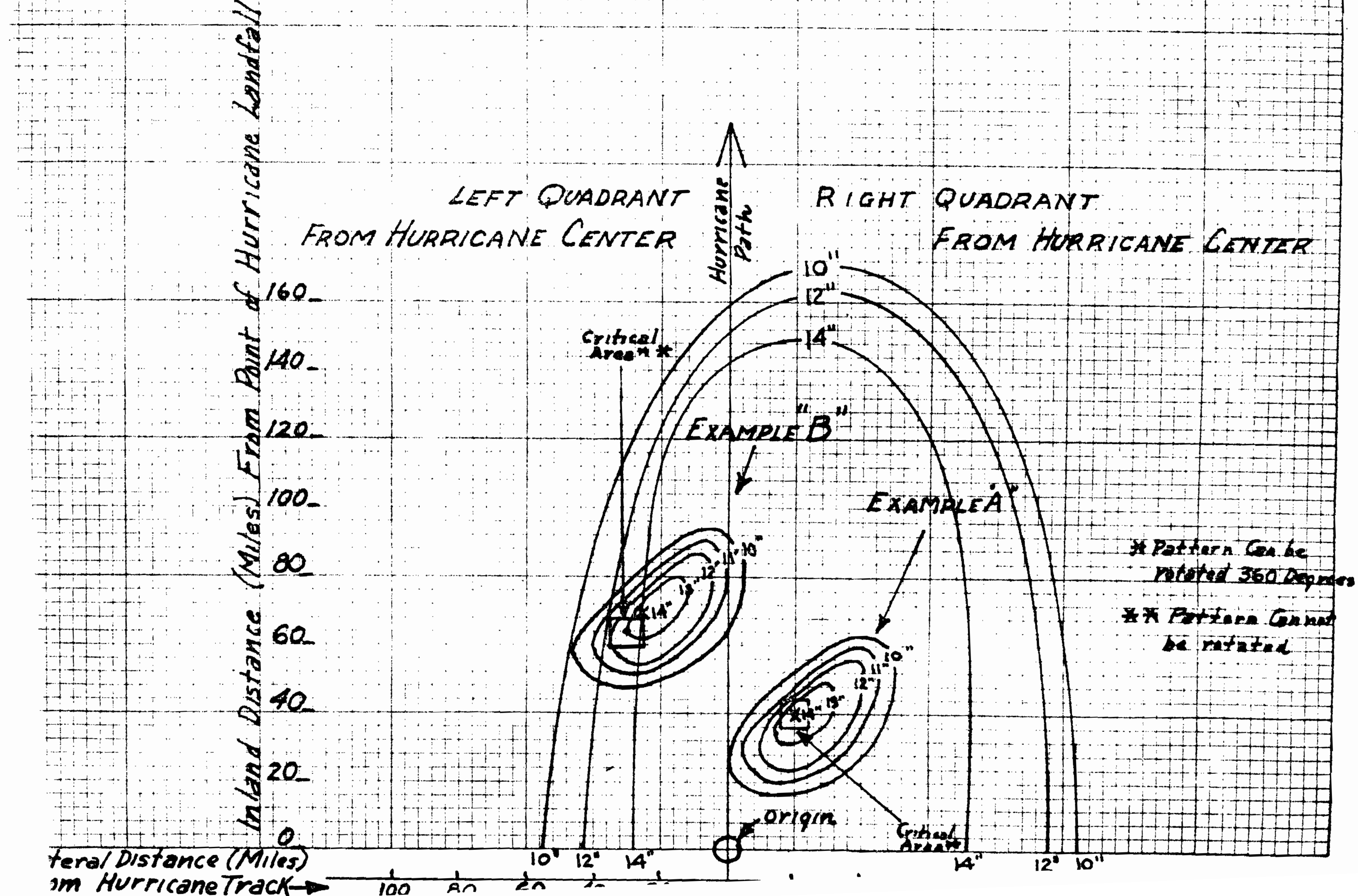
Inclosure 2 - Generalized Isohyetal Pattern for Determining 24-Hour Point Rainfall Depths Applicable to Standard Project Hurricanes in the Middle Gulf Region - Zone B



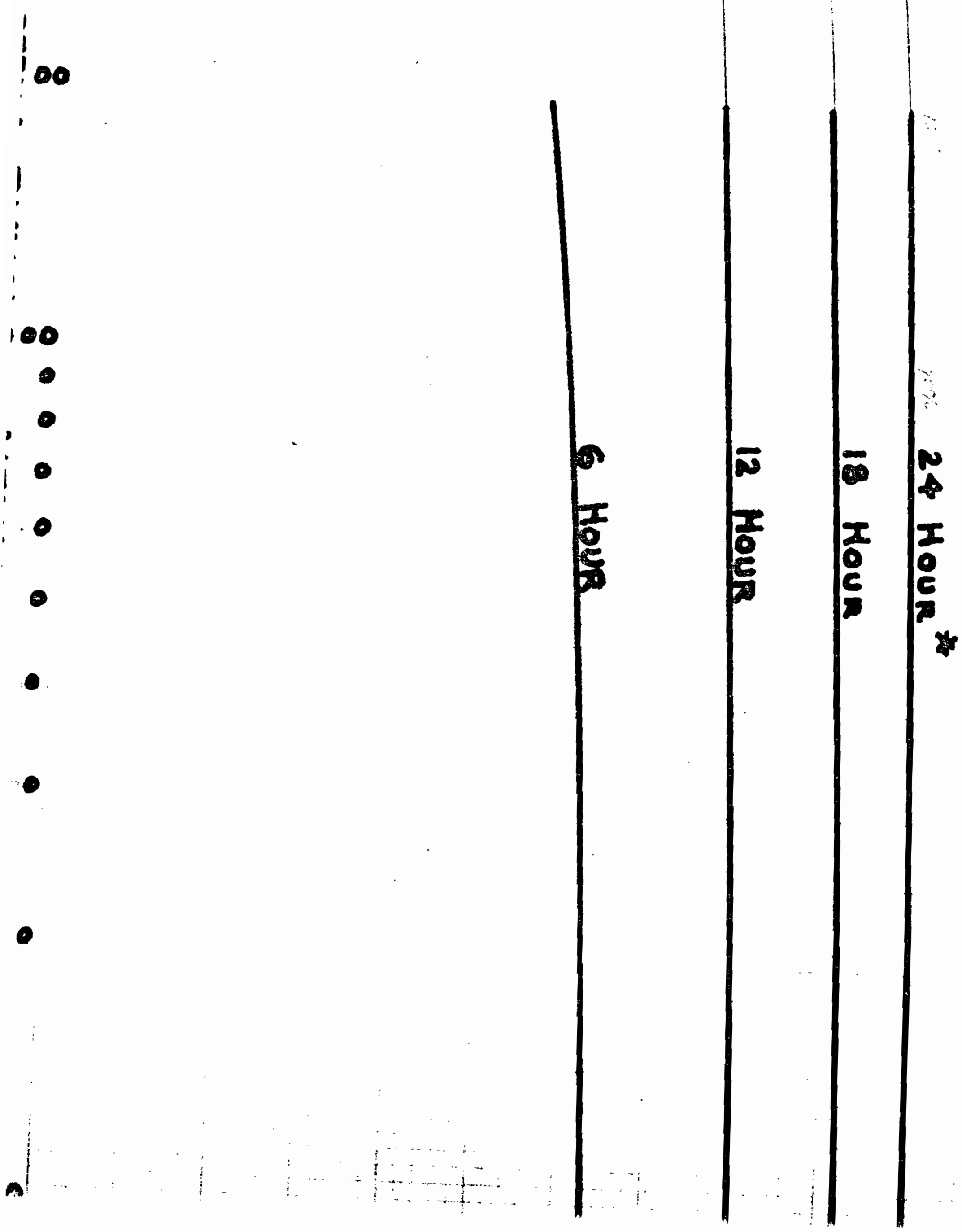
Inclosure 3 - Isohyetal Pattern to be used with Inclosure 2 for determination of Standard Project Hurricane 24-Hour Precipitation Estimates - Middle Gulf Coast (Zone B)

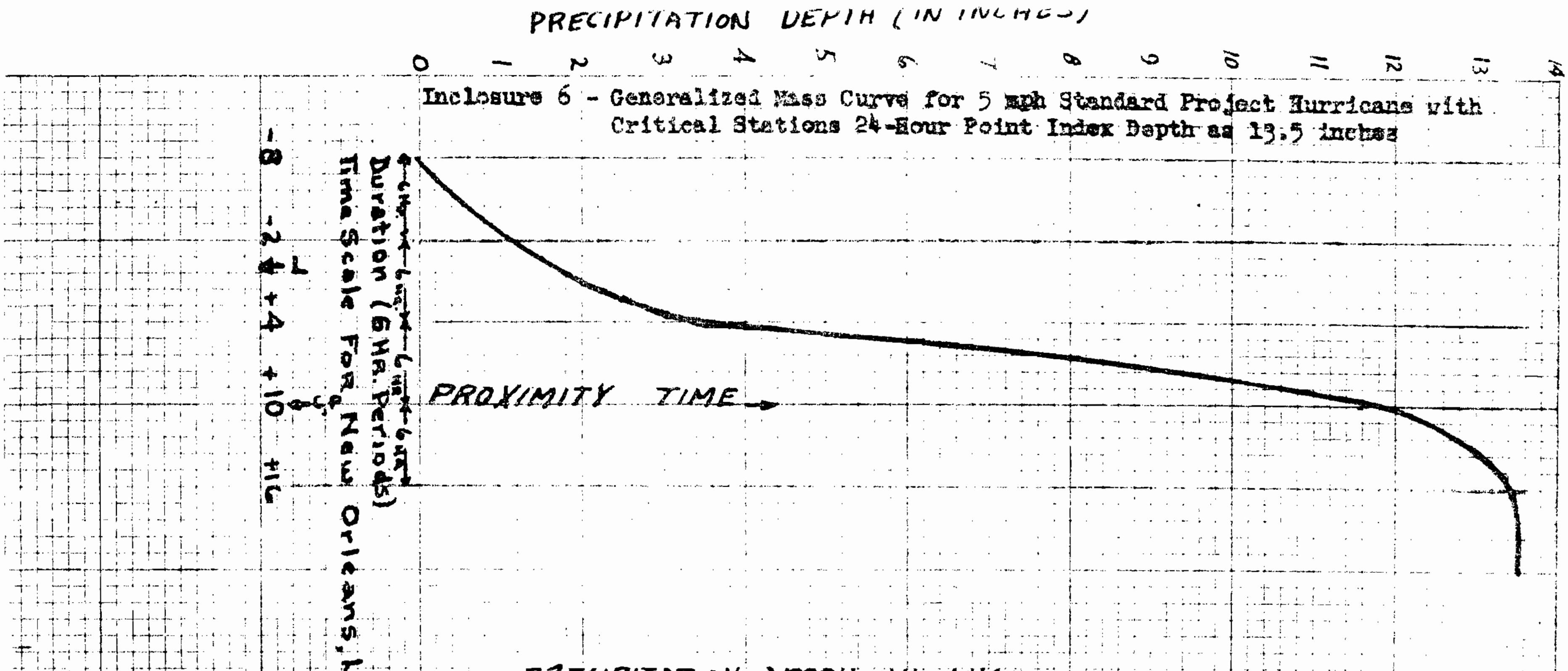


Inclosure 4 - Examples of the use of Isohyetal Pattern (Inclosure 3) with generalized Isohyetal Pattern (Inclosure 2) for determining areal-precipitation estimates

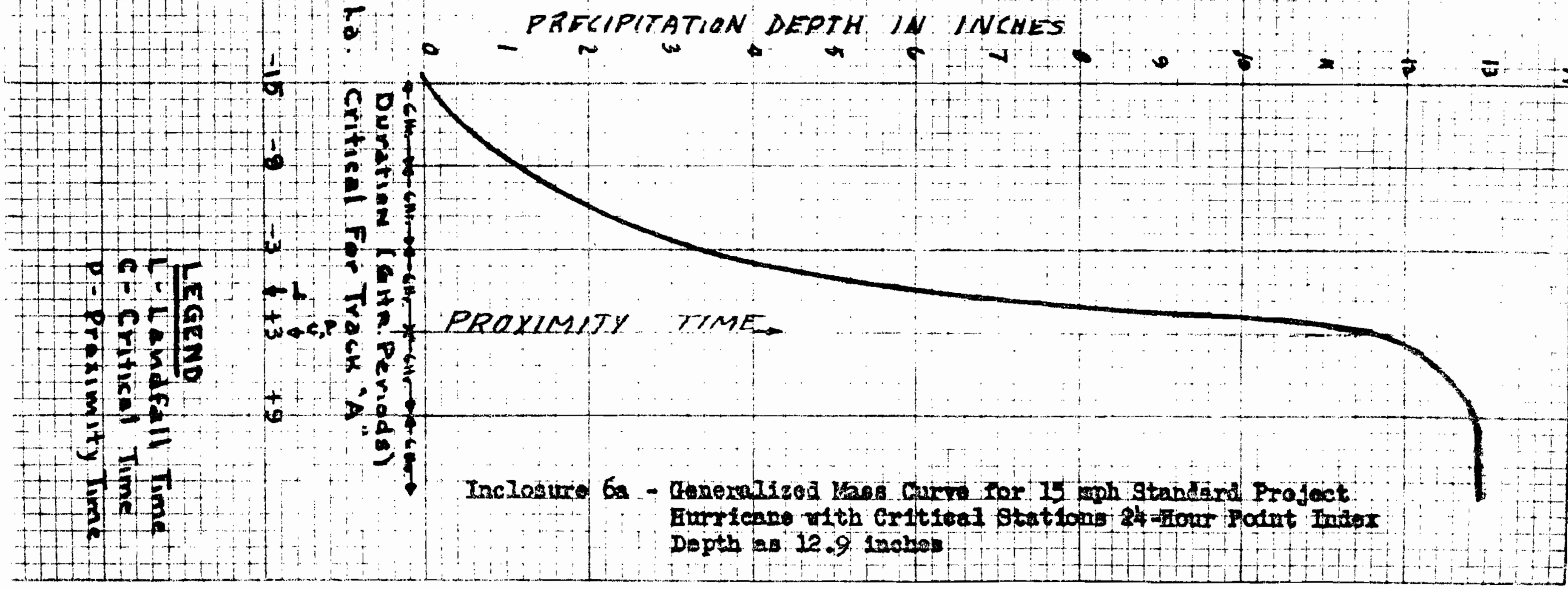


Enclosure 5 - Depth Duration Area Relationship for Hurricane Precipitation Estimates for Areas from 10 to 200 Square Miles and Durations of 6, 12, 18 and 24 Hours for Standard Project Hurricanes in Zone B (Middle Gulf Coast)

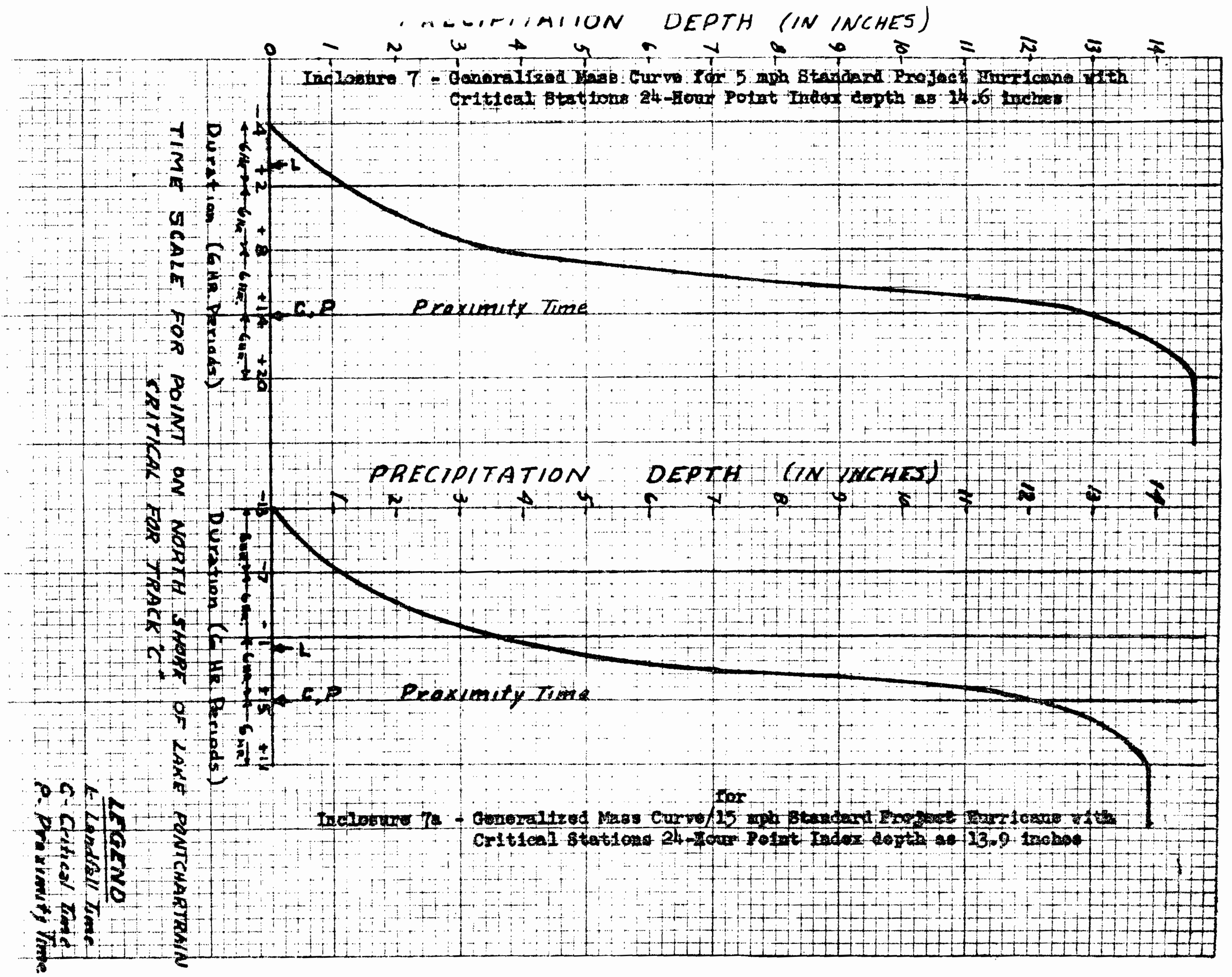




Inclosure 6 - Generalized Mass Curve for 5 mph Standard Project Hurricane with Critical Stations 24-Hour Point Index Depth as 13.5 inches



Inclosure 6a - Generalized Mass Curve for 15 mph Standard Project Hurricane with Critical Stations 24-Hour Point Index Depth as 12.9 inches



Inclosure 7 - Generalized Mass Curve for 5 mph Standard Project Hurricane with Critical Stations 24-Hour Point Index depth as 14.6 inches

Inclosure 7a - Generalized Mass Curve for 15 mph Standard Project Hurricane with Critical Stations 24-Hour Point Index depth as 13.9 inches

UNITED STATES DEPARTMENT OF COMMERCE
WEATHER BUREAU
WASHINGTON

November 30, 1959

IN REPLY, PLEASE ADDRESS
CHIEF, U. S. WEATHER BUREAU
WASHINGTON 25, D. C.
AND REFER TO
0-6.12

TO: Mr. A. L. Cochran, Civil Works
Office of Chief of Engineers
Corps of Engineers

FROM: Hydrometeorological Section

SUBJECT: HUR 3-5, Hurricane Rainfall Estimates Applicable to Middle Gulf Standard Project Hurricanes, Tracks A, C, F, D and E, New Orleans Study, Zone B

Herewith is transmitted the subject memorandum which furnishes mass curves for selected critical stations along Standard Project Hurricane Tracks A, C, F, D and E.

Charles S. Gilman, Chief
Hydrometeorological Section

Attachments

cc: 2 to OCE with attachments

UNITED STATES DEPARTMENT OF COMMERCE
WEATHER BUREAU
WASHINGTON

November 30, 1959

IN REPLY, PLEASE ADDRESS
CHIEF, U. S. WEATHER BUREAU
WASHINGTON 25, D. C.
AND REFER TO
O-6.12

MEMORANDUM TO CORPS OF ENGINEERS

HUR 3-5

FROM : Hydrometeorological Section

SUBJECT : Hurricane Rainfall Estimates Applicable to Middle Gulf Standard Project Hurricanes, Tracks A, C, F, D and B

Reference: Memorandum from OCE to HMS August 17, 1959, Subject, "Hurricane Criteria Required for New Orleans Hurricane Studies"

Introduction

Point 24-hour rainfall and mass curves for critical stations relative to Standard Project Hurricanes (Tracks A, C, F, D and B) and a procedure for determining areal hurricane precipitation estimates up to 200 square miles pertaining to any zone B hurricane are submitted.

The point and areal precipitation estimates submitted are based upon the climatology of hurricane rainfall in the middle Gulf Coast. They represent a moderately high level of precipitation estimates but a level that has been equalled or exceeded by several hurricane rainfalls of record in this region. The magnitude of these precipitation estimates are well below Standard Project Storm criteria and Probable Maximum Precipitation estimates which indicate 24-hour point depths of 21 and 40 inches respectively for the Louisiana coastal region. An average 24-hour maximum point precipitation depth based on the mean obtained from 52 hurricanes in the Gulf Region is 9.4 inches. The average forward speed of the 52 hurricanes sampled was 12.3 knots.

Hurricane speed-precipitation relationships

A study was made to determine whether speed of hurricane motion influenced the amount of resulting 24-hour maximum point precipitation. A plot of observed 24-hour point precipitation values (inches) versus hurricane speed (knots) was made and is shown by inclosure 1. These data were subjected to a statistical analysis and the regression line obtained is shown by curve A on inclosure 1. It can be seen that there is a very slight negative correlation (-.046) of decreased 24-hour rainfall with increased hurricane speed. However, the slope of the regression line was used as a basis for setting the upper limits of precipitation estimates to be applied to Standard Project Hurricanes. Curve A (regression line) was shifted upward on the chart (inclosure 1) until it undercut 10 percent of the plotted points (5 out of 52). This positioning shown by curve B represents comparable limits of the precipitation index amounts to be used with Standard Project Hurricane considerations. Curve B (inclosure 1) sets the upper limit of maximum 24-hour point precipitation at 14 inches for hurricanes moving through the middle Gulf Region with the average speed, i.e., 12.3 knots, determined from the above statistical analysis.

Areal distribution of 24-hour hurricane precipitation

The areal distribution of 24-hour maximum point hurricane rainfall was determined and is shown by a generalized isohyetal pattern (inclosure 2). This generalized pattern was established by enveloping the 24-hour isohyetal patterns from all hurricane occurrences in the middle Gulf Region (zone B). The chart's origin was fixed at a hurricane's point of landfall and then oriented along the mean 24-hour direction of the hurricane after landfall. The 10-inch isohyet was traced and then the highest point precipitation depth within the 10-inch isohyet was marked at the point of occurrence for each of the hurricanes. After the 10-inch isohyets were traced an enveloping 10-inch isohyet was drawn. Next an envelopment was made of the maximum point depths within the 10-inch isohyet and the 12-inch and 14-inch isohyets were established.

Selection of 24-hour maximum point index rainfall depths

Point rainfall index depths applicable to a Standard Project Hurricane's predetermined critical area may be obtained from the generalized isohyetal pattern (inclosure 2) and then adjusted for the SPH's speed (inclosure 1) in the following manner:

1. Plot the SPH track and measure the distance in miles from landfall to the point on the track that is closest to the critical station. (Selection of critical station is arbitrary but should be near center of critical area).

2. Measure the lateral distance in miles from the point on the track determined in step 1 to the critical station.

3. Enter inclosure 2 with the distances determined by step 1 (horizontal) and step 2 (lateral) and read the 24-hour point rainfall amount denoted by the generalized isohyets at that point. If the critical station is located anywhere within the confines of the 14-inch isohyet use 14 inches as an index depth, otherwise interpolate between isohyets. If the critical station is located outside the 10-inch isohyet then the location is beyond these SPH considerations.

4. To adjust the index depth obtained in item 3 for Standard Project Hurricanes of differing speeds read the 24-hour precipitation index depth along curve B (inclosure 1) that corresponds to the selected Standard Project Hurricane speed. If the index depth in item 3 is less than 14 inches the speed adjustment can be made by multiplying by the ratio of the precipitation

amount at the Standard Project Hurricane's assigned speed to the precipitation amount at the average speed (12.3 knots) of the middle Gulf hurricanes on curve B (inclosure 1).

Example--If the Standard Project Hurricane's assigned speed was 5 mph and the critical station is located 60 miles from landfall along the track and 30 miles to the left of the track the index depth from inclosure 2 is 13 inches. From curve B (inclosure 1) the depth for a hurricane moving 12.3 knots is 14 inches opposed to 14.6 inches at 4 knots, giving an adjustment ratio of 104 percent. Thus the adjusted point precipitation depth is 1.04 x 13 = 13.5 inches. It follows that had the critical station been located within the 14 inch isohyet its index depth for a hurricane moving at 5 mph would be 14.6 inches.

Note--Rainfall amounts taken from the generalized isohyetal pattern (inclosure 2) are considered to be approximations for storms moving at the average speed, i.e. 12.3 knots of hurricanes of the middle Gulf Region.

<u>Determination of 24-hour depth-area precipitation estimates</u>

The isohyetal pattern shown by the clear overlay (inclosure 3) can be used in conjunction with the generalized isohyetal pattern (inclosure 2) to ascertain 24-hour areal precipitation estimates for limited areas. The isohyetal pattern (inclosure 3) shows the shape which envelops all the isohyetal combinations that went into the establishment of the generalized isohyetal pattern. The 14-inch center is marked by an X with the 13, 12, 11 and 10-inch isohyets drawn around it.

Area-depth estimates can be made in the following manner:

1. Follow items 1, 2 and 3 in the procedure outlined for 24-hour point rainfall estimates. The critical station should be located at the center of the critical area.

2. Fit the isohyetal pattern (inclosure 3) with its 14-inch center (X) over the location of the selected critical station on the generalized isohyetal pattern inclosure 2. If the critical point lies on or within the confines of the 14-inch isohyet go to item 3 below; if not, the isohyetal pattern (inclosure 3) must be moved horizontally or laterally until its 14-inch center (X) falls on or within the 14-inch generalized isohyet on inclosure 2, and the critical points assigned 24-hour index depth on inclosure 3 coincides with the depth on the isohyetal pattern inclosure 2. (See remarks below concerning an example of this procedure).

3. Having established the location of the point of maximum rainfall by item 2 above the pattern on inclosure 3 can be rotated as long as the depths represented on inclosure 3 do not exceed those on inclosure 2.

4. Fix the isohyetal pattern (inclosure 3) in place, after selecting

the permissible rotation, outline the critical area and planimeter it to determine a 24-hour area-depth precipitation estimate.

5. To adjust the precipitation depths for Standard Project Hurricanes of varying speeds use the ratio of selected speed depth to average speed, depth on curve B (inclosure 1).

Examples: Inclosure 4 shows two examples of the recommended process for determining areal precipitation for a hurricane moving at 12.3 knots.

Example A is for a critical area of 100 square miles with its center point located 40 miles along and 20 miles to the right of the hurricane track. The fixed isohyetal pattern shown by the example may be rotated 360 degrees without exceeding any of the isohyets on the generalized isohyetal pattern.

Example B is for a critical area of 100 square miles with its center located 60 miles along and 30 miles to the left of the hurricane track. The fixed isohyetal pattern shown cannot be rotated because it would not meet the requirement of having the critical point on the 13-inch isohyet with the maximum 14-inch isohyet center (X) inside the 14-inch generalized isohyet.

The adjustment factors for either of these two areal depths on inclosure 4 for Standard Project Hurricanes of varying speeds are 104 percent for hurricanes moving at 5 mph and 99 percent for hurricanes moving at 15 mph (from curve B, inclosure 1).

<u>Time distribution of 24-hour point precipitation estimates</u>

In order to provide data for construction of mass curves the 6-hour distribution of maximum 24-hour point rainfall for nine Louisiana coastal hurricanes were reviewed. From these data it was seen that the maximum 6-hour burst of rain varied from 37 to 89 percent of the total 24-hour point rainfall giving an arithmetic average of 63 percent. The second, third and fourth 6-hour ratios averaged 17, 12 and 8 percent of the 24-hour maximum point, respectively. A check was made to determine whether the use of the above 6-hour ratios produced abnormally high precipitation depths. This was done by comparing the observed 6-hour rainfall depths from the major hurricanes of the middle Gulf Region for which Part II data are available to those 6-hour depths computed by using 14 inches as a 24-hour point index and applying the above incremental percentage ratios. It was found that the computed depths fell below the higher values of observed depths.

Since the 24-hour precipitation depths are adjusted for speed by curve B on inclosure 1 only one sequence of placing the 6-hour increments is suggested. The ratios in their respective 6-hour locations with respect to the hurricanes closest point to the critical station (proximity time) are shown on table 1. The ratios are so placed as to show (1) the maximum 6-hour burst of rain during the -6 to 0 hour period, (2) the maximum 12-hour burst during the -12 to 0 hour period and (3) the maximum 18-hour burst during the -12 to +6 period. The 0-hour designates proximity time.

Time distribution of 24-hour areal precipitation estimates

If mass curves are required for areas up to 200 square miles the depth-duration area relationships shown on inclosure 5 can be used. These depth-duration area curves were developed from the same hurricanes that were used in establishing table 1. The 6-hour incremental ratios shown on inclosure 5 can be arranged in the same relative positions as shown in table 1, i.e., maximum 6-hour depth from -6 to 0 hours, maximum 12-hour depth from -12 to 0 hours, etc. The 0-hour designates proximity time. Adjustments for hurricane speed should be made by determining the average areal-depth directly from the use of inclosures 2 and 3 and then corrected for speed by use of ratios obtained from curve B, inclosure 1.

Table 1. Percentage Ratios (by 6-hour increments) to be applied to 24-hour Precipitation Index Amounts for Construction of Standard Project Hurricane Mass Curves.

	Time (by 6-hour increments) from Standard Project Hurricanes Proximity Point to Critical Station			
	-18 to -12	-12 to -6	-6 to 0	0 to +6
Ratio (percent of 24-hr depth)	8	17	63	12
Ratio (accumulative percent of 24-hr depth)	8	25	88	100

Mass curves for critical stations located along Tracks A, C, F, B and D

Four mass curves (inclosure 6, 6a, 7 and 7a) and table 2 are offered for use in determining mass curves for each of the critical stations along Tracks A, C, F, B and D. The four mass curves have been provided with time scales for critical stations along Tracks A and C. The remaining time scale data for the other critical stations and Standard Project Hurricane tracks have been provided in table 2. Table 2 shows (1) The Standard Project Hurricane track considered, (2) the selected critical station, (3) the distance from landfall to the critical stations' proximity point, (4) lateral distance from hurricane track at proximity time, (5) the 24-hour index rainfall depths for 5 mph and 15 mph Standard Project Hurricanes, (6) the critical time expressed in hours from landfall, (7) the proximity time expressed in hours from landfall, and (8) the generalized mass curve inclosure number to apply the scales to.

Two examples as to how to assign the data shown on table 2 to mass curves are shown on inclosure 6 and 6a for the critical station along track A and on inclosure 7 and 7a for the critical station along track C. It can be seen that the location of the proximity time is constant for all mass curves for this time should coincide with the end of the maximum burst. Having this point established all that is needed is to assign new time scales along the abscissas of the generalized mass curve.

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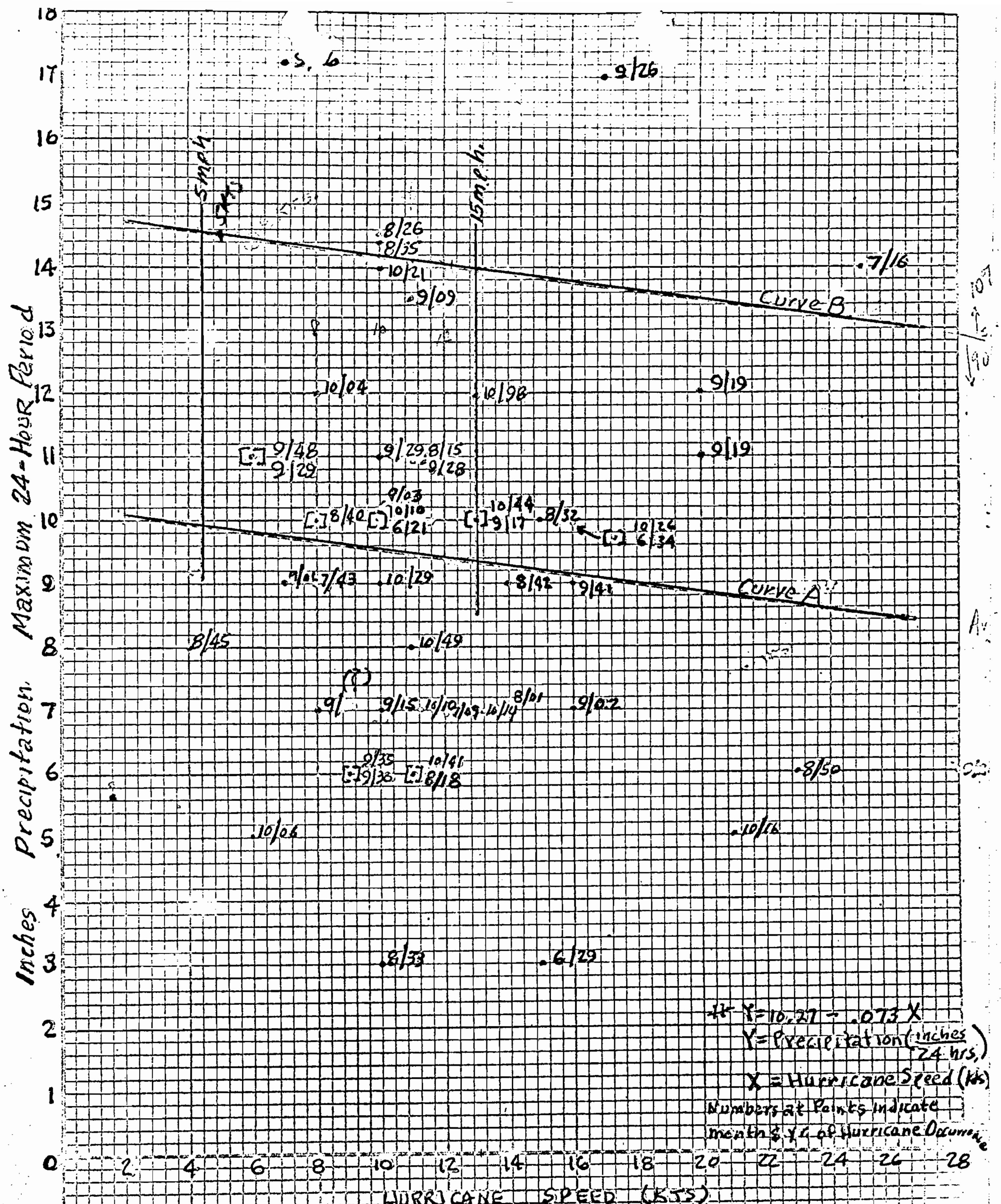
Hydrometeorological Section

Attachments

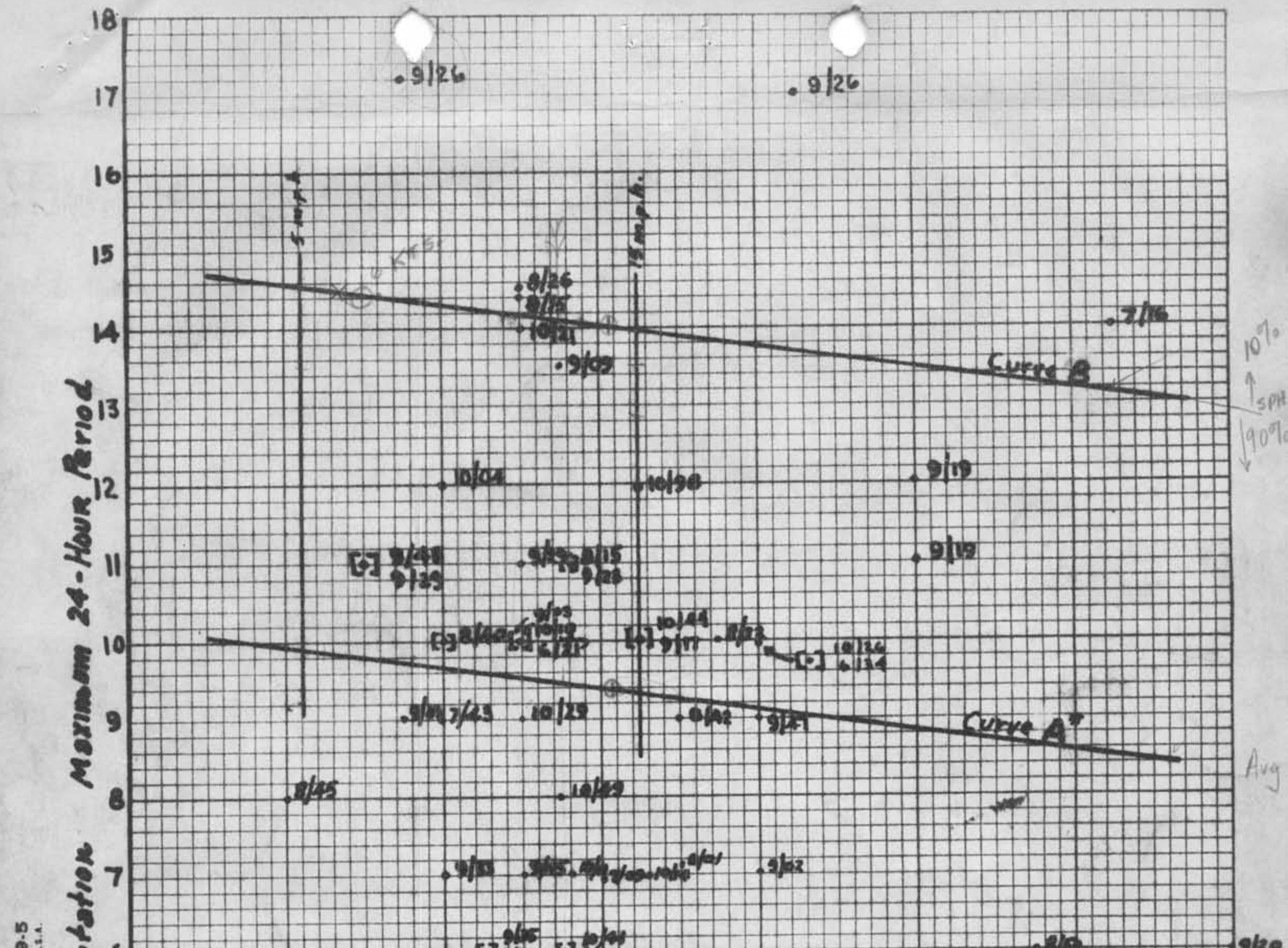
cc: 2 to OCE with attachments

Table 2. Data for Determining Time Scales to be Applied to the Generalized Mass Curves for Individual Critical Stations Along Standard Project Hurricane Tracks A, C, F, B and D.

1	2	3	4	5		6		7		8	
Standard Project Hurricane Track Considered	Selected Critical Station	Distance Along Track from Landfall	Lateral Distance From Track At Proximity Time	24-Hour Index Rainfall Depths (inches)		Critical Time Measured in Hours from Landfall Time		Proximity Time Measured in Hours from Landfall Time		Generalized Curve to Use for Critical Station's Mass Curve	
		(miles)	(miles)	5 mph	15mph	5 mph	15 mph	5 mph	15 mph	5 mph	15mph
Track A	New Orleans, La.	50	30 Left	13.5"	12.9"	+10	+3	+10	+3	6	6a
Track C	Point on North shore of Lake Pontchartrain	80	30 Right	14.6	13.9	+14	+5	+14	+5	7	7a
Track F	Rigolets, La.	15	25 Right	14.6	13.9	+6	+1	+3	+1	7	7a
	New Orleans, La.	30	5 Right	14.6	13.9	0	0	+6	+2	7	7a
	Point on North Shore of Lake Pontchartrain	65	30 Right	14.6	13.9	+13	+4	+13	+4	7	7a
...ck D	Grand Isle, La.	0	15 Left	14.6	13.9	0	0	-4	-1	7	7a
	Point-a-la Hache, La.	0	25 Left	14.6	13.9	+2	+1	-1	0	7	7a
Track B	Grand Isle, La.	5	15 Right	14.6	13.9	+6	+2	+1	0	7	7a
	Venice, La.	0	45 Right	14.6	13.9	0	0	-2	-1	7	7a
	Myrtle Grove, La.	30	20 Right	14.6	13.9	+11	+4	+6	+2	7	7a



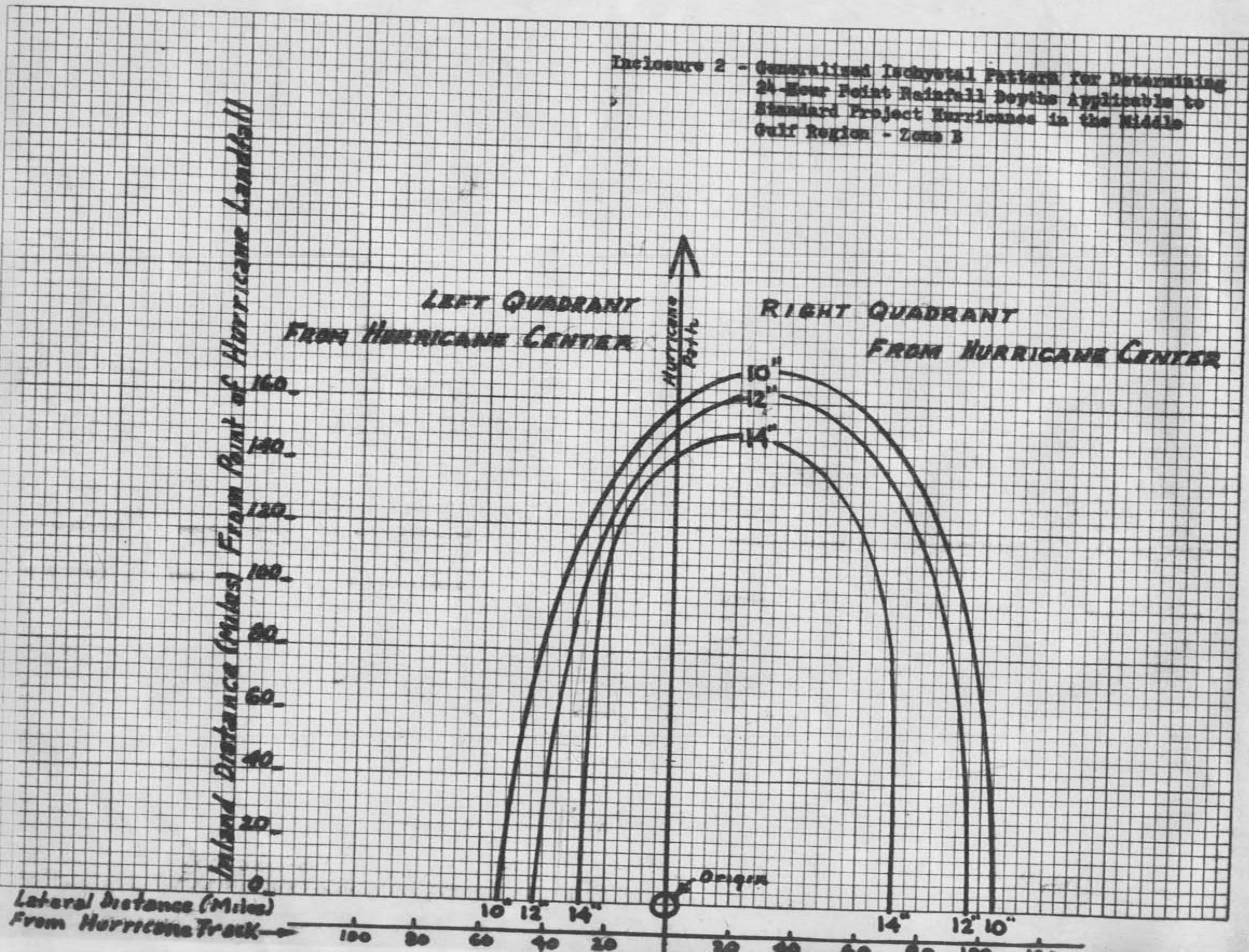
Inclosure 1 - Relationship of 24 Hr. Maximum Precipitation to Hurricane Speed



Inclosure 1 - Relationship of 24 Hr. Maximum Precipitation to Hurricane Speed

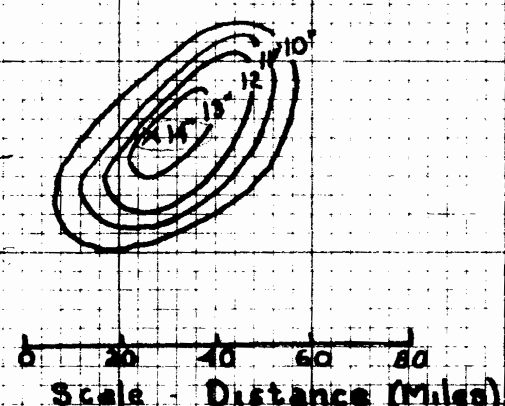
K+E 10 X 10 TO THE INCH 359-5 KEUFFEL & ESSER CO. MADE IN U.S.A.

Inclosure 2 - Generalized Isohyetal Pattern for Determining 24-Hour Point Rainfall Depths Applicable to Standard Project Hurricanes in the Middle Gulf Region - Zone B



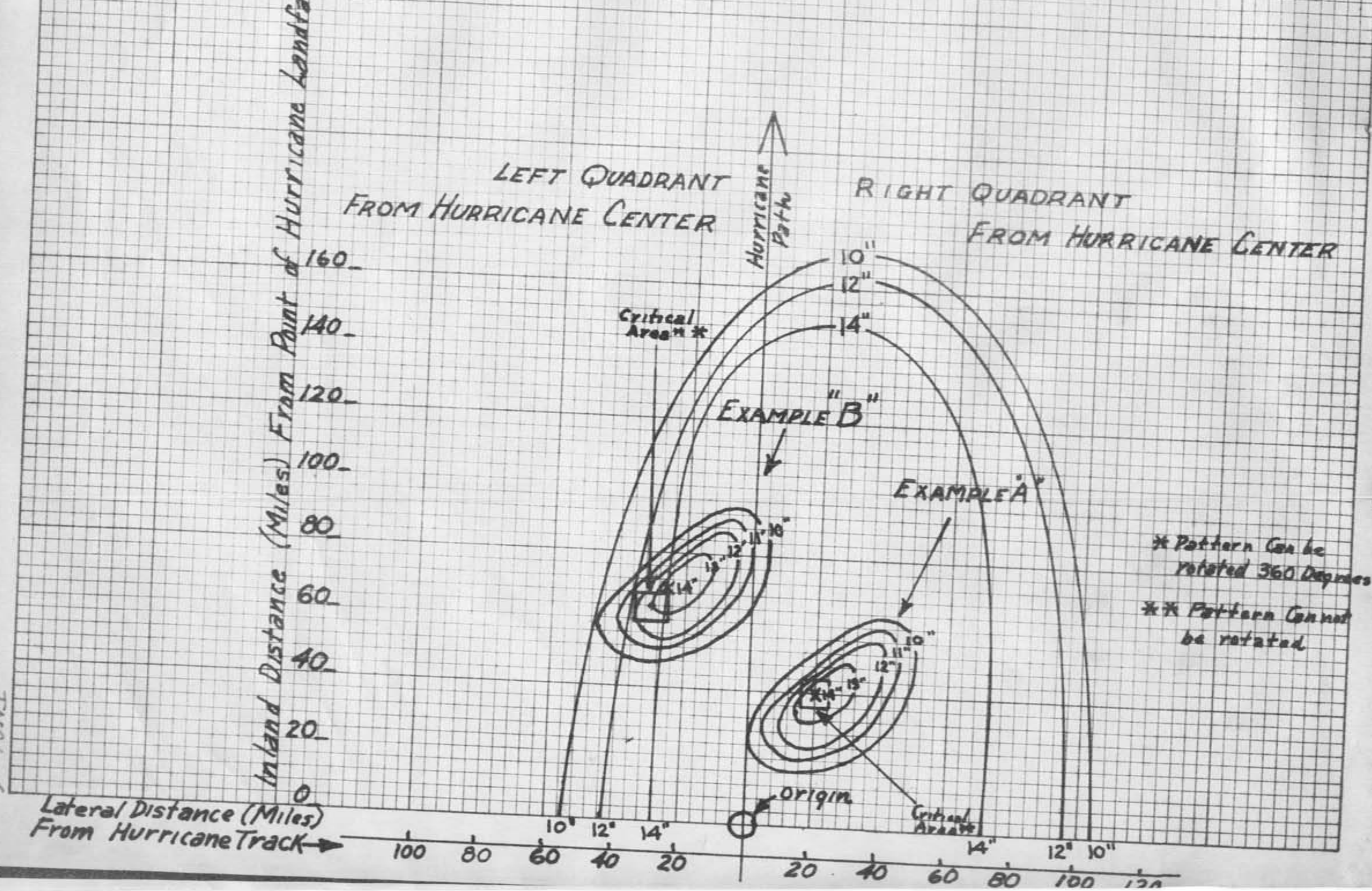
INCL 2

Inclosure 3 - Isohyetal Pattern to be used with Inclosure 2 for determination of Standard Project Hurricane 24-Hour Precipitation Estimates - Middle Gulf Coast (Zone B)



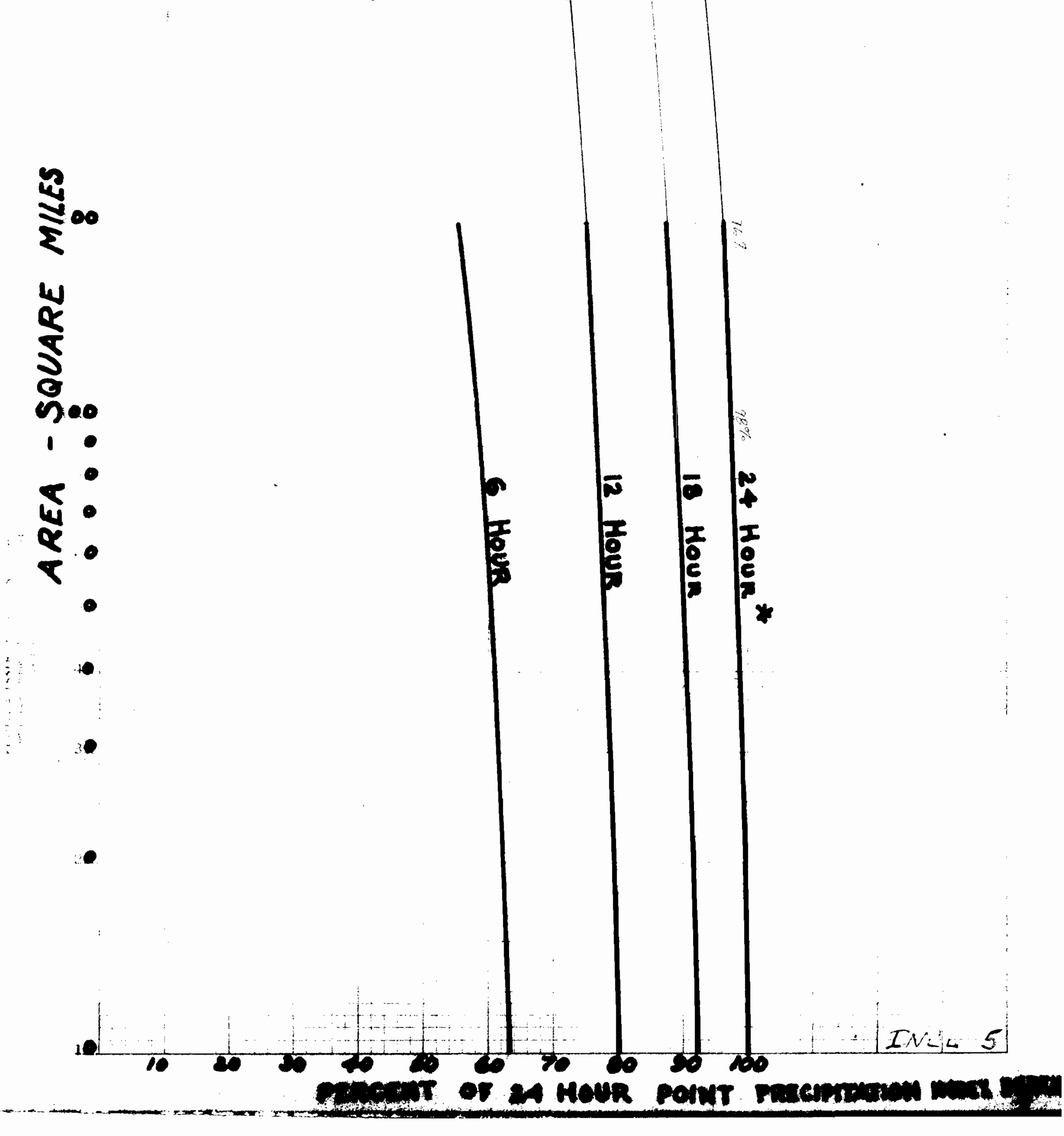
K+E 10 X 10 TO THE INCH 359-5 KEUFFEL & ESSER CO. MADE IN U.S.A.

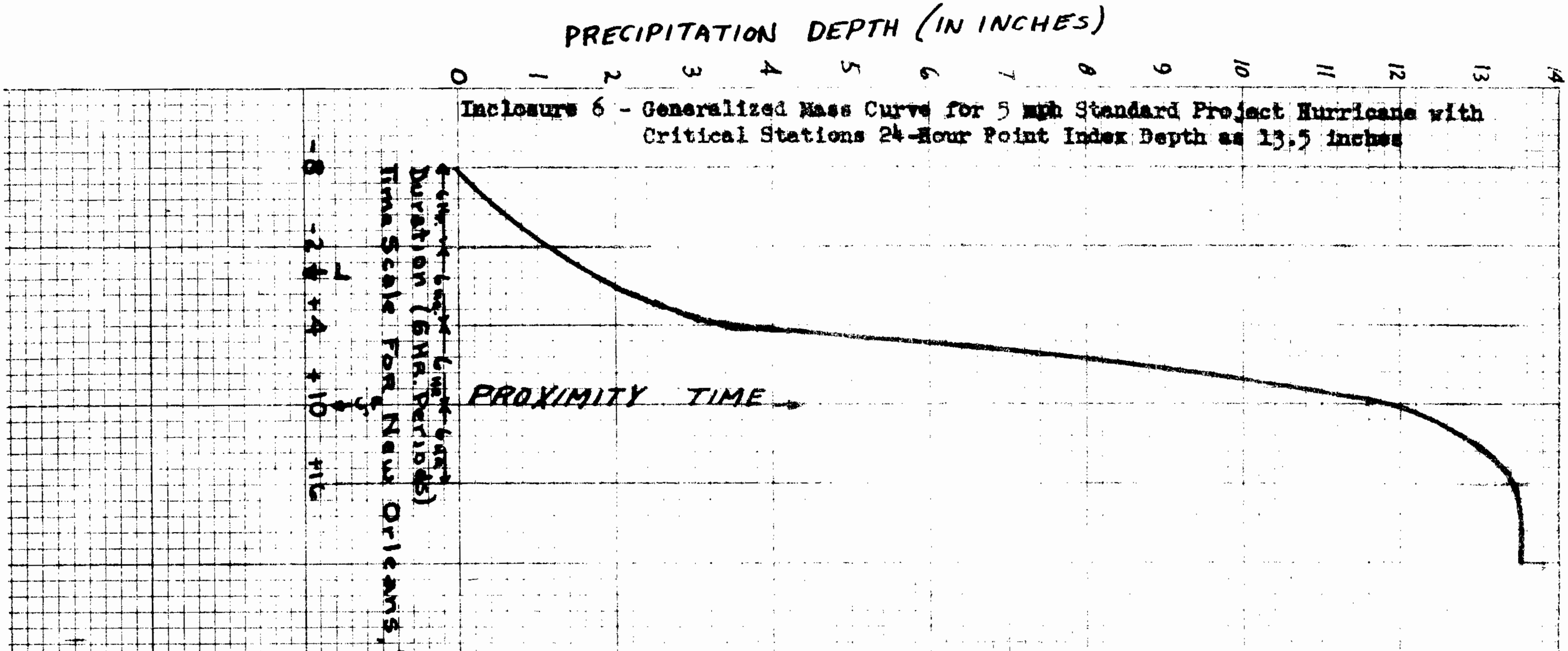
Inclosure 4 - Examples of the use of Isohyetal Pattern (Inclosure 3) with generalized Isohyetal Pattern (Inclosure 2) for determining areal-precipitation estimates



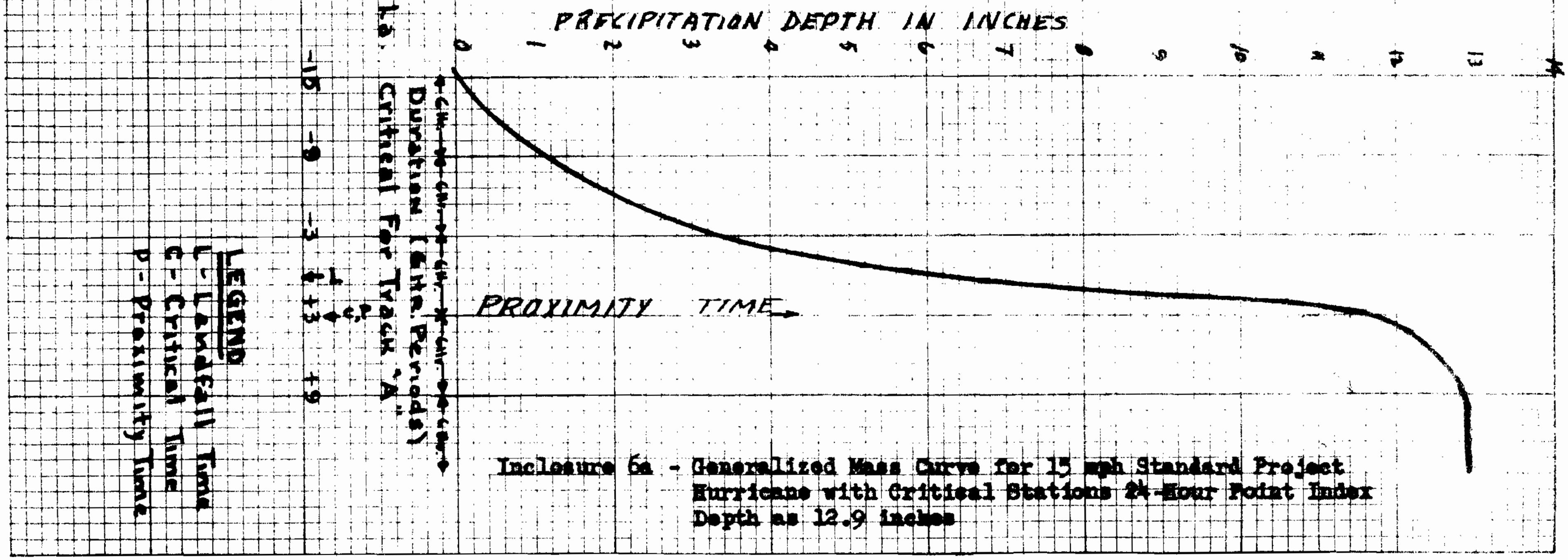
INCL 4

Enclosure 5 - Depth Duration Area Relationship for Hurricane Precipitation Estimates for Areas from 10 to 200 Square Miles and Durations of 6, 12, 18 and 24 Hours for Standard Project Hurricanes in Zone B (Middle Gulf Coast)





Inclosure 6 - Generalized Mass Curve for 5 mph Standard Project Hurricane with Critical Stations 24-Hour Point Index Depth as 13.5 inches



Inclosure 6a - Generalized Mass Curve for 15 mph Standard Project Hurricane with Critical Stations 24-Hour Point Index Depth as 12.9 inches

UNITED STATES DEPARTMENT OF COMMERCE
WEATHER BUREAU
WASHINGTON

August 30, 1957

IN REPLY, PLEASE ADDRESS
CHIEF, U. S. WEATHER BUREAU
WASHINGTON 25, D. C.
AND REFER TO

0-6.12

MEMORANDUM TO CORPS OF ENGINEERS

HUR 2-4

FROM : Hydrometeorological Section

SUBJECT: Hurricane Frequency and Correlations of Hurricane Characteristics for the Gulf of Mexico area, P. L. 71

REFERENCE: OCE memorandum 9 May 1957, subject: Hurricane Frequency and Correlations of Hurricane Characteristics for the Gulf of Mexico area, P. L. 71.

Zones

To facilitate an analysis of the Gulf Coast area of the U. S., the coastal area was divided into three zones; Zone A covers the west coast of Florida, Zone B the Mid Gulf coast and Zone C the Texas coast. Figure 1 shows a breakdown of the Gulf coastal area into the three zones each approximately 80,000 square miles. Each zone is about 400 miles long and extends from 50 miles inland from a generalized coastline to 150 miles off-shore from that line. The boundaries separating zones were selected from the standpoint of data studied and with reference to Corps of Engineers administrative boundaries.

FREQUENCIES OF CENTRAL PRESSURE INDEX

Accumulated frequency

The central pressure index (CPI) is the estimated minimum pressure for individual hurricanes in each zone, and is the principal intensity criterion. Plotted along the top of figure 2a, b, and c is the accumulated number of occurrences of certain central pressure indices or lower values. For example, in zone A the smoothed curve through the data indicates that there has been one hurricane with a CPI of 26.35 inches and 10 hurricanes with a CPI of 28.22 inches or lower. A hurricane is represented only once within any zone but may be represented in two or more zones. The Galveston storm of September 1900, for instance, is shown as an occurrence in zones B and C.

Any tropical storm that was of hurricane intensity while passing through a zone or at any other time in its history is shown in the accumulated number of occurrences for that zone in figures 2a, b, and c. The numbers along the bottom of the charts represent the accumulated number of occurrences at, or below, each CPI expressed as a percent of the total number of hurricanes that have been observed within that zone during the 57 years of record. In zone A, 51 hurricanes have been observed and 44% of those had a CPI of 29.00 inches or lower.

Figure 3 shows the variation of CPI with distance along the Gulf Coast. The values from which the isolines were constructed were taken from figure 2 of accumulated frequency of hurricane central pressure and were plotted against the mean location of the data in each zone and smoothed.

Occurrence per 100 years

On figures 4a, b, and c the CPI data from each zone have been plotted on a probability basis using the formula

$$P = \frac{100(M-0.5)}{Y} \qquad (1)$$

where

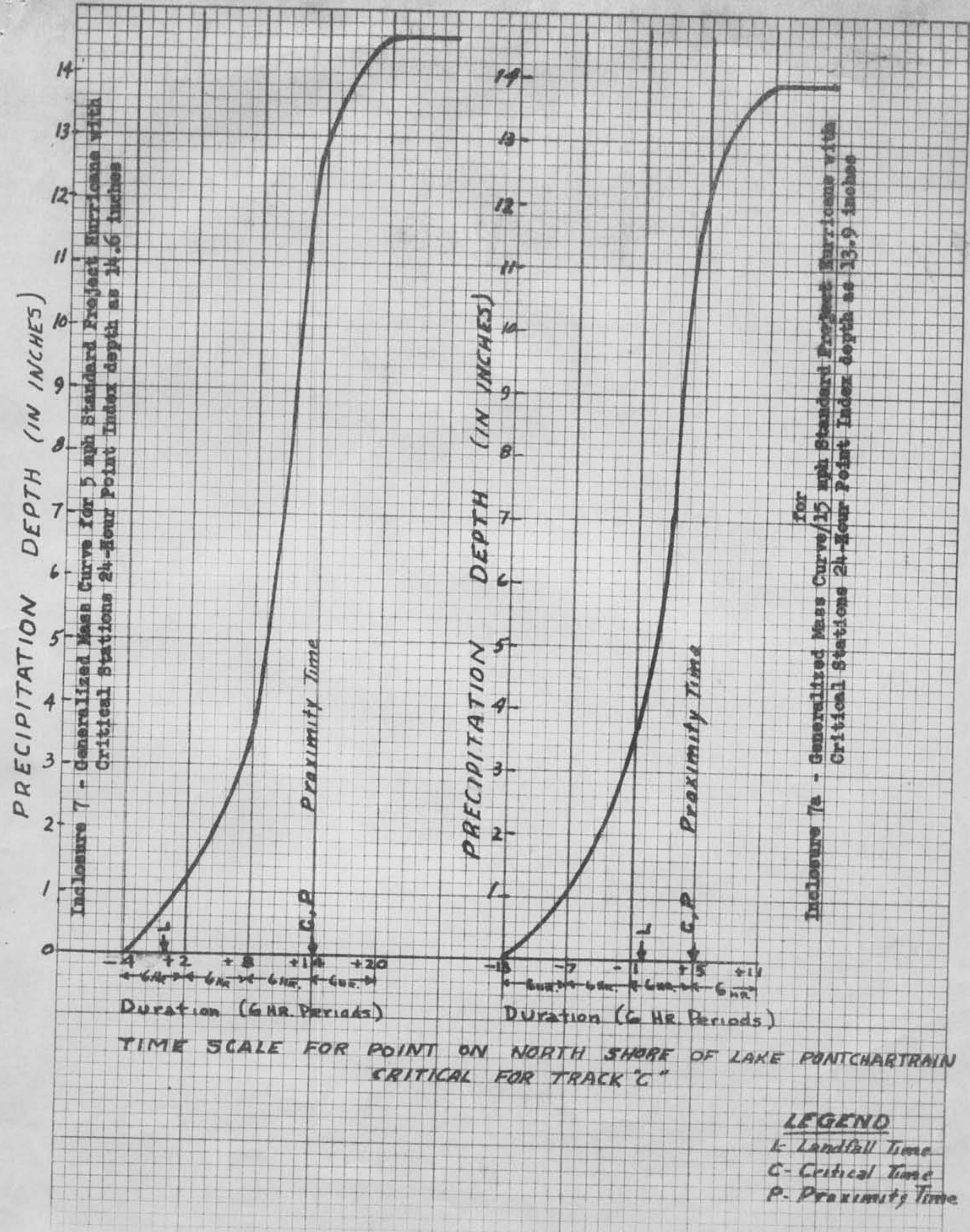
P = percent chance of occurrence per year
M = number of the event (rank)
Y = number of years of record (57)

The plotting position from this formula gives the more rare events a longer return period than some other plotting positions. On this type of scale (normal probability), data with a normal distribution will fall in a straight line.

Figure 5 shows the variation of average frequency on a 100-year basis along the Gulf Coast of the United States for areas of approximately 80,000 square miles. The occurrences per 100 years from figure 4 were plotted against the mean position of the data along the Coast and smooth isolines drawn. In order to have a smooth transition of frequency curves from the east coast of Florida to the west coast, the curves of figure 5 were made to match the corresponding curves from zone 1 (Memo HUR 2-1, figure 4B) at 24° North. 24° North is at mile 1340 of figure 5.

Determination of hurricane CPI frequency at a coastal site

A hurricane passing through a zone need not necessarily severely affect the entire coast within the zone. The frequency of damaging effects at a coastal site depend on many factors including the zonal CPI frequencies (figure 5) and the frequency of storm tracks within damage-producing range of the site as compared with the frequency of tracks through the entire zone.


Inclosure 7 - Generalized Mass Curve for 5 mph Standard Project Hurricane with Critical Stations 24-Hour Point Index depth as 14.6 inches
Inclosure 7a - Generalized Mass Curve for 15 mph Standard Project Hurricane with Critical Stations 24-Hour Point Index depth as 13.9 inches
PRECIPITATION DEPTH (IN INCHES)
Proximity Time
C, P
L
Duration (6 HR. Periods)
TIME SCALE FOR POINT ON NORTH SHORE OF LAKE PONTCHARTRAIN CRITICAL FOR TRACK "C"
LEGEND
L - Landfall Time
C - Critical Time
P - Proximity Time

INCL 7

To facilitate an appraisal of CPI frequency for an area less than total zone size, the following are presented for an area of approximately 10,000 square miles:

1. Total hurricane occurrences per total zone and per approximate 100- x 100-mile subdivision are shown in figure 6.

2. The subdivision occurrences are smoothed by the graph in figure 7. The occurrences per subdivision from figure 6 were plotted and a curve fitted by eye through the data with onshore subdivisions weighted more than offshore.

OTHER HURRICANE CHARACTERISTICS ALONG THE GULF COAST

Radius of maximum winds

General comments. Radius of maximum winds is an index of hurricane size. The size of a hurricane is an important factor in generations of waves and tides. A larger hurricane will have a longer straight-line fetch and thus cause higher waves and tides. The radius, R, has been determined for most of the tropical storms of hurricane intensity (CPI less than 29.00 inches) that passed through zones A, B, or C, and these values are shown in table 1. The R was determined either from observations at a wind reporting station or by computation from the pressure field. The observed R was used, whenever available, for all correlations. In the absence of an observed R the computed value was substituted. To determine the validity of substituting one type of R for another, all observed R's were plotted against computed R's in the same storm. There appears to be no bias for the observed R to average either larger or smaller than the computed R.

Variation of radius of maximum winds with central pressure index. Figure 8 shows the relationship of R to CPI. The data show that the tendency is for hurricanes of lower CPI to also have smaller R's, although there is a considerable degree of variation of R with any given CPI. The relationship of R to CPI observed in the study corresponds with findings of various authors and previous Hydrometeorological Section Studies.* All of the data

*Depperman, C. E. "Some Characteristics of Philippine Typhoons," 1939.
Hydrometeorological Report No. 32, USWB 1954, p. 77.
National Hurricane Research Project Report No. 5, USWB, 1957, p. 38.

from hurricanes occurring in zones A, B, and C are plotted in figure 8. The outside limits of the data are indicated by approximate enveloping curves. The mean curve has been drawn through the data by group averaging aided by fitting by eye.

Variation of radius of maximum winds with latitude and longitude. To determine whether the introduction of other variables will make possible further refinements, the variations of the observed R from the mean curve were plotted against both latitude (figure 9) and longitude (figure 10). The wide scatter of points on figure 9 indicate that, for the Gulf Coast, there is little or no correlation of CPI with latitude. On figure 10, where the variation of observed R from the mean curve of figure 8 is plotted against longitude, the curve, of best fit located by group averaging, through the data suggests that there may be a slight additional variation of R with longitude, the smaller R's occurring in zone C. However, the suggested variation is too small to warrant any further refinement based on longitude.

Forward speed

An investigation of forward speed along the Atlantic Coast (HUR 2-3, June 18, 1957) showed forward speed to have a good relation to latitude. A similar plot for the Gulf Coast area shows no similar significant relationship, probably due to the limited latitudinal variation. Therefore all of the hurricanes were lumped together in figure 11 showing the rate of hurricane center translation against accumulated percent of occurrences. The slowest forward speed was 4 knots and the fastest 28 knots; the average forward speed was 11 knots. Speed has been measured as the average of the period from 2 hours before to 2 hours after entering the Coast.

Direction of movement

The azimuth distribution of paths followed by hurricanes in zones A, B, and C of figure 1 is shown in figures 12a, b, and c, respectively. The storm data from which figure 12 was constructed are listed in table 2. There is no evidence of a correlation between hurricane intensity and path, All tropical storm paths may therefore be used to judge azimuth characteristics of severe storms. The average direction of movement in the Gulf changes slightly from zone to zone. The west coast of Florida receives most hurricanes from the southeast direction but another large group from the south-southwest. Most hurricanes pass through zone B from the south and southeast and in zone C from the east and southeast.

Maximum gradient wind

Figure 13 shows the maximum gradient wind as related to CPI, R, and latitude. Graphs were determined from equation (2), the derivation of which is discussed in Hydrometeorological Report No. 32.

(2) $$V_{gx} = 73 \sqrt{P_n - P_o} - R(0.575f)$$

where

V_{gx} = maximum gradient wind speed in miles per hour
P_o = central pressure in inches
P_n = asymptotic pressure in inches
R = radius of maximum winds in nautical miles
f = coriolis parameter in units of hour $^{-1}$

The maximum cyclostrophic wind (upper graph in figure 13) is a function of $P_n - P_o$. The outer dashed curves in that graph are based on extreme values of P_n, derived in turn from envelopes of a plot (not shown) of P_n vs. P_o values from National Hurricane Research Project Report No. 5, table 3-1, p. 29. Limits of the gradient wind speed at the zone of maximum winds may be determined from figure 13. The maximum wind at 30 feet above open water is on the order of 85 to 100 percent of the maximum gradient wind speed.

Charles S. Gilman

Charles S. Gilman, Chief
Hydrometeorological Section

Attachments:

1 to BEB with attachments
50 to OCE with attachments

Table 1

HURRICANES WITH CENTRAL PRESSURE INDEX LESS THAN 29.00 INCHES GULF COAST UNITED STATES RANKED BY CPI (1900-1956)

Date	CPI (inches)	R (naut. mi.)	F (kts.)	Lat. (deg. N.)	Long. (deg. W.)
		Zone A			
Sept. 2, 1935	26.35	6	9	24.8	80.9
Sept. 9, 1919	27.44	15	8	24.6	82.9
Oct. 20, 1926	27.52	21	16	23.8	81.3
Sept. 21, 1948	27.62	7	8	24.5	81.8
Oct. 17, 1910	27.80	16	11	24.5	82.5
Oct. 18, 1944	28.02	27	13	24.6	82.8
Sept. 17, 1947	28.03	34	-	26.4	81.3
Sept. 18, 1926	28.05	24	17	26.5	81.0
Sept. 28, 1929	28.15	28	10	24.8	81.1
Oct. 25, 1921	28.29	18	10	28.1	82.8
Oct. 11, 1909	28.30	22	10	24.3	81.7
Sept. 16, 1928	28.30	53	-	27.7	81.4
Sept. 4, 1950	28.30	-	-	29.1	83.1
Aug. 26, 1949	28.37	23	14	27.2	81.2
Sept. 15, 1945	28.39	24	10	25.5	81.0
Sept. 4, 1933	28.48	29	11	27.8	81.6
Oct. 19, 1924	28.70	19	8	25.0	83.0
Nov. 4, 1935	28.73	-	-	25.0	81.0
Sept. 11, 1903	28.84	43	7	27.0	81.5
Oct. 18, 1906	28.84	35	6	25.0	81.0
Oct. 5, 1948	28.85	31	13	24.0	81.2
Oct. 18, 1950	28.88	-	-	28.0	81.6
June 17, 1906	28.91	26	-	25.1	80.9
Oct. 7, 1941	28.98	18	11	29.8	84.7

Table 1 (cont'd)

Date	CPI (inches)	R (naut. mi.)	F (kts.)	Lat. (deg. N.)	Long. (deg. W.)
		Zone B			
Sept. 8, 1900	27.64	-	-	27.0	90.5
Sept. 29, 1915	27.87	29	10	29.9	90.1
Sept. 14, 1919	28.00	-	20	26.9	90.2
Sept. 20, 1926	28.20	17	7	30.5	87.5
July 21, 1909	28.31	19	-	26.8	91.0
Aug. 25, 1926	28.31	27	10	29.6	90.7
July 5, 1916	28.38	50	25	30.7	88.0
July 31, 1936	28.46	19	9	30.5	86.5
Sept. 28, 1917	28.48	33	13	30.4	87.2
Sept. 27, 1906	28.50	73	16	30.6	88.5
June 16, 1934	28.52	37	16	29.9	91.7
Sept. 19, 1947	28.57	33	16	29.9	90.1
Aug. 14, 1901	28.72	33	14	29.9	90.1
Oct. 18, 1916	28.76	19	21	30.4	87.2
Aug. 7, 1940	28.76	11	8	29.0	92.8
Sept. 23, 1956	28.76	-	-	30.0	86.5
July 27, 1943	28.78	16	8	28.2	92.0
Sept. 30, 1929	28.80	65	6	30.1	85.7
Aug. 30, 1950	28.92	21	23	30.2	88.0
Sept. 21, 1920	28.93	28	28	29.6	90.7
Sept. 20, 1909	28.94	88	11	29.9	90.1
Oct. 7, 1941	28.98	18	11	29.9	84.7

Table 1 (cont'd)

Date	CPI (inches)	R (naut. mi.)	F (kts.)	Lat. (deg. N.)	Long. (deg. W.)
		Zone C			
Sept. 8, 1900	27.64	14	10	29.2	95.9
Aug. 13, 1932	27.83	12	15	29.1	95.6
Aug. 18, 1916	28.00	35	11	27.5	97.5
Sept. 14, 1919	28.00	-	20	27.7	97.5
Sept. 5, 1933	28.02	20	8	25.9	97.5
Aug. 30, 1942	28.07	18	14	28.5	96.7
Aug. 16, 1915	28.14	32	11	29.8	95.0
June 22, 1921	28.17	17	11	29.7	95.4
July 21, 1909	28.31	19	12	29.0	96.0
Sept. 23, 1941	28.31	21	13	29.7	95.4
Aug. 27, 1945	28.57	18	4	29.0	96.2
June 28, 1929	28.62	13	15	28.5	96.5
Aug. 7, 1940	28.76	11	8	29.9	93.9
July 27, 1943	28.78	16	8	29.5	95.0
Aug. 4, 1933	28.80	25	10	25.9	97.5
Oct. 4, 1949	28.88	28	11	28.9	95.4

Table 2

AVERAGE DIRECTION OF CENTER MOVEMENT OF ALL TROPICAL STORMS IN THE ZONE WHICH REACHED HURRICANE INTENSITY AT ANY TIME

Date	Average direction of movement (degrees from)
	Zone A
Sept. 5, 1900	137
Aug. 10, 1901	110
Sept. 11, 1903	112
Sept. 17, 1904	005
June 16, 1906	170
Oct. 16, 1906	218
Oct. 10, 1909	200
Oct. 17, 1910	182
Aug. 9, 1911	145
Sept. 11, 1912	114
Sept. 2, 1915	157
Nov. 15, 1916	235
Nov. 9, 1919	95
Sept. 29, 1920	245
Oct. 24, 1921	230
Oct. 19, 1924	240
Nov. 30, 1925	221
July 28, 1926	131
Sept. 18, 1926	120
Sept. 16, 1928	150
Aug. 8, 1928	130
Aug. 12, 1928	141
Sept. 27, 1929	135
Sept. 7, 1930	227
Aug. 29, 1932	116
July 30, 1933	90
Sept. 1, 1933	104
Oct. 4, 1933	208
Sept. 3, 1933	145
July 22, 1934	67
Sept. 2, 1935	155
Nov. 4, 1935	90
Nov. 7, 1935	264
July 28, 1936	123
Aug. 2, 1938	70
Sept. 16, 1941	92
Oct. 6, 1941	140

Table 2 (cont'd)

Date	Average direction of movement (degrees from)
	Zone A (cont'd)
Oct. 18, 1944	190
June 23, 1945	239
Sept. 15, 1945	180
Oct. 7, 1946	190
Sept. 17, 1947	109
Aug. 18, 1947	96
Oct. 11, 1947	218
Oct. 4, 1948	220
Sept. 20, 1948	190
Aug. 26, 1949	145
Oct. 20, 1950	210
Sept. 2, 1950	198
Oct. 18, 1950	158
Oct. 1, 1951	270
	Zone B
Sept. 7, 1900	112
Aug. 12, 1901	145
Oct. 9, 1902	200
Sept. 12, 1903	170
Sept. 26, 1906	152
Aug. 10, 1911	138
Sept. 11, 1912	135
June 12, 1912	230
Sept. 3, 1915	180
Sept. 28, 1915	175
Oct. 17, 1916	185
July 4, 1916	170
Sept. 27, 1917	205
Aug. 6, 1918	148
Nov. 12, 1919	100
Sept. 21, 1920	170
Sept. 29, 1920	240
Oct. 15, 1923	190
Sept. 13, 1924	215
Sept. 19, 1926	128
Aug. 24, 1926	180
Aug. 9, 1928	130
Aug. 13, 1928	164
Sept. 29, 1929	180
Aug. 31, 1932	135

Table 2 (cont'd)

Date	Average direction of movement (degrees from)
	Zone B (cont'd)
Aug. 2, 1933	89
July 23, 1934	90
June 15, 1934	179
Aug. 26, 1934	115
Sept. 4, 1935	180
Nov. 7, 1935	255 270?
July 30, 1936	147
Aug. 4, 1938	116
Oct. 6, 1941	180
Aug. 18, 1942	124
July 25, 1943	93
Sept. 19, 1943	212
Sept. 18, 1947	123
Aug. 22, 1947	135
Sept. 3, 1948	200
Oct. 18, 1950	31
Aug. 29, 1950	185
Sept. 25, 1953	221
	Zone C
Sept. 7, 1900	125
June 24, 1902	185
July 20, 1909	96
Aug. 27, 1909	112
Sept. 13, 1910	180
June 11, 1912	198
Oct. 15, 1912	139
June 27, 1913	115
Aug. 16, 1915	165
Aug. 18, 1916	110
Aug. 6, 1918	145
Nov. 13, 1919	90
Sept. 6, 1921	140
June 20, 1921	166
June 15, 1922	125
June 28, 1929	140
Aug. 12, 1932	149
Aug. 3, 1933	75
July 6, 1933	60

Table 2 (cont'd)

Date	Average direction of movement (degrees from)
	Zone C (cont'd)
Sept. 3, 1933	98
July 24, 1934	90
Aug. 26, 1934	32
Aug. 17, 1936	56
June 26, 1936	138
Aug. 14, 1938	160
Aug. 27, 1938	90
Aug. 6, 1938	127
Sept. 22, 1941	166
Aug. 20, 1942	119
Aug. 29, 1942	133
July 26, 1943	122
Sept. 15, 1943	215
Aug. 24, 1945	180
Oct. 22, 1947	128
Oct. 3, 1949	180
June 24, 1954	136
Sept. 4, 1955	100

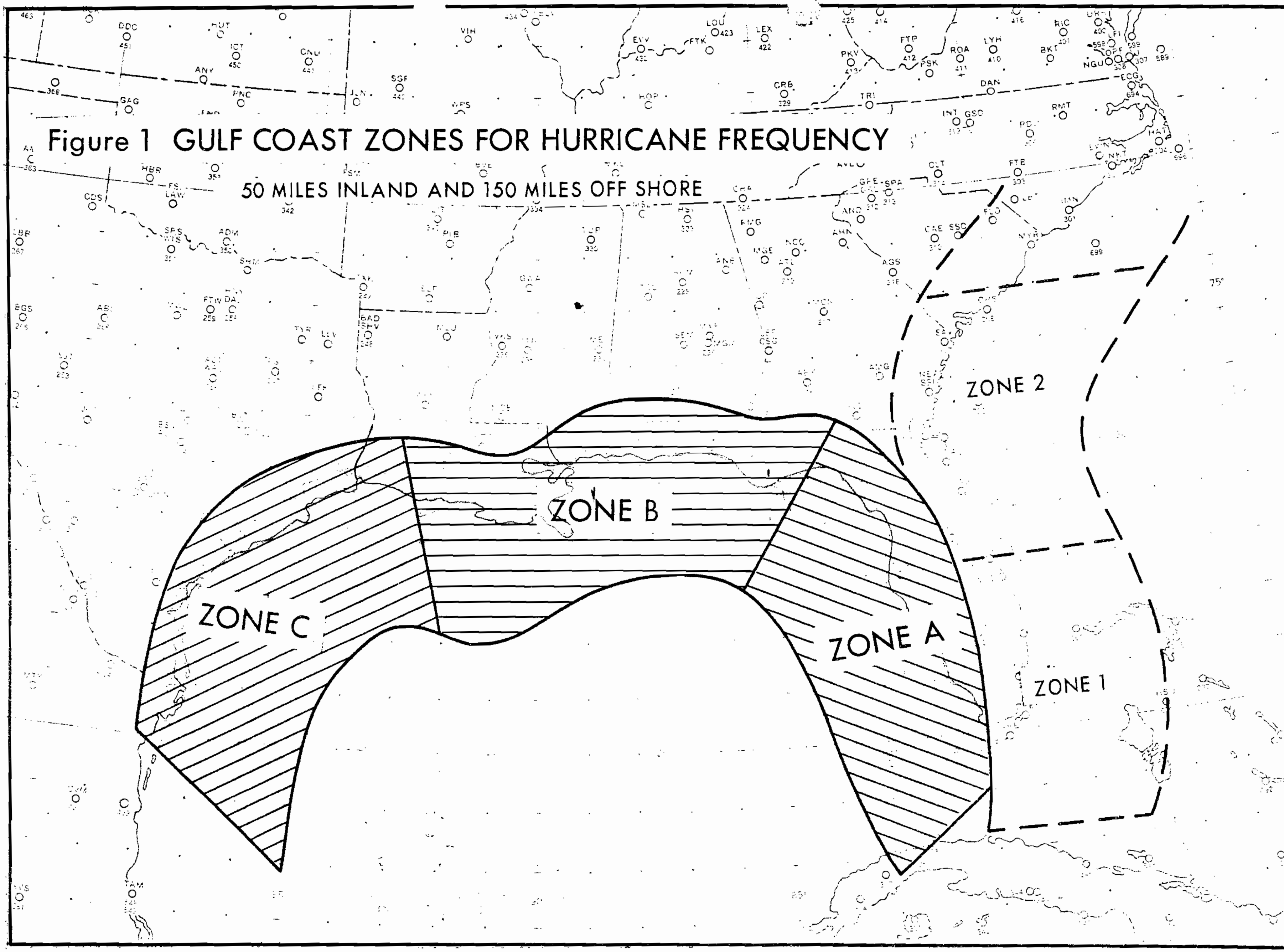
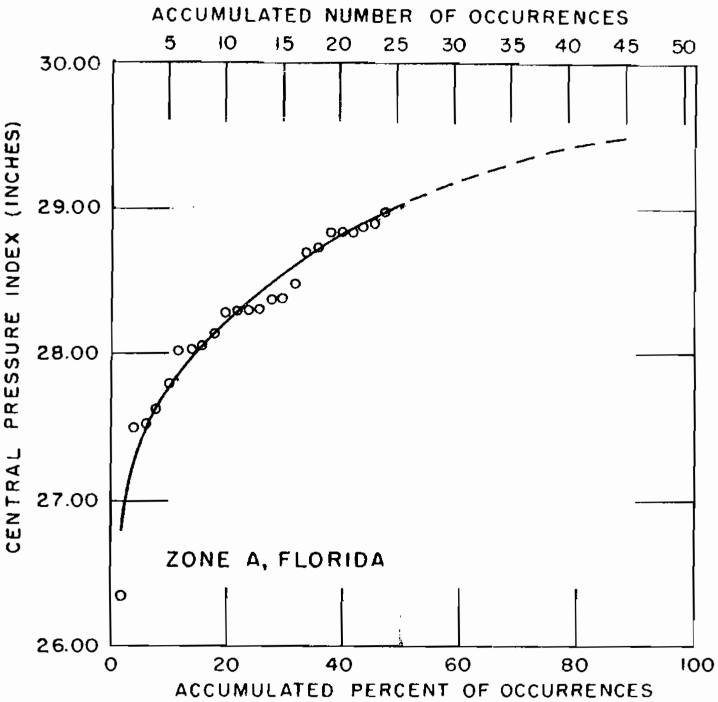


Figure 1 GULF COAST ZONES FOR HURRICANE FREQUENCY

50 MILES INLAND AND 150 MILES OFF SHORE

FIG 1



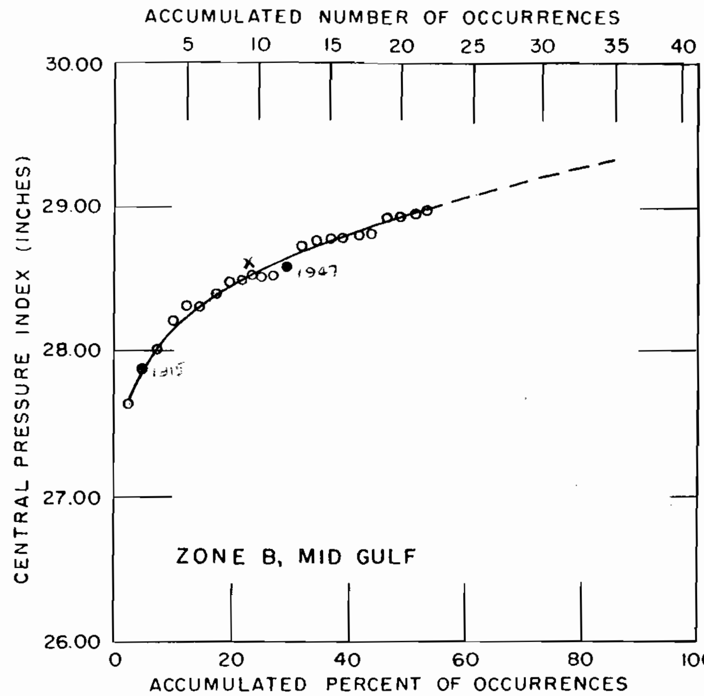


FIGURE 2

ACCUMULATED FREQUENCY
OF HURRICANE CENTRAL PRESSURE
INDEX GULF COAST U. S.
1900-1956

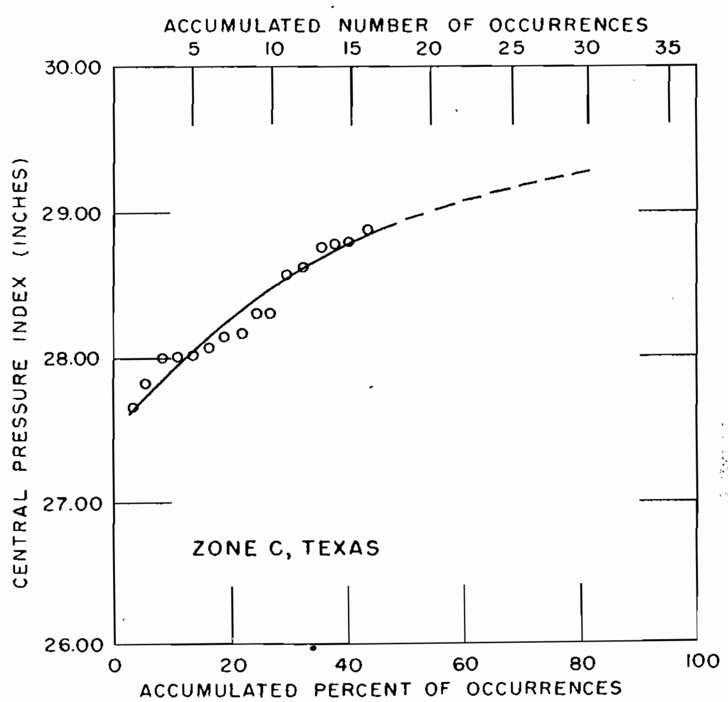


FIG 2

FIG 2

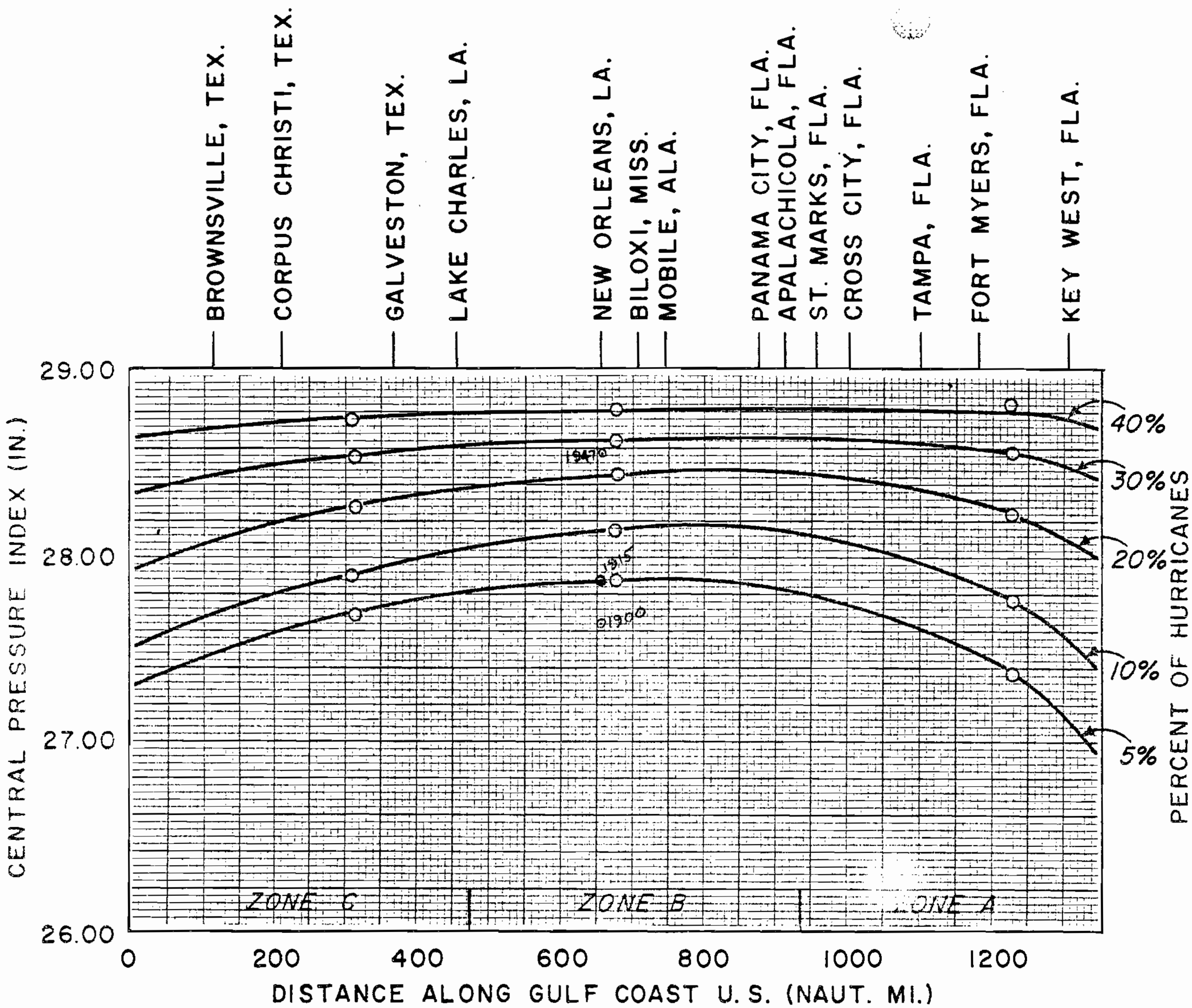
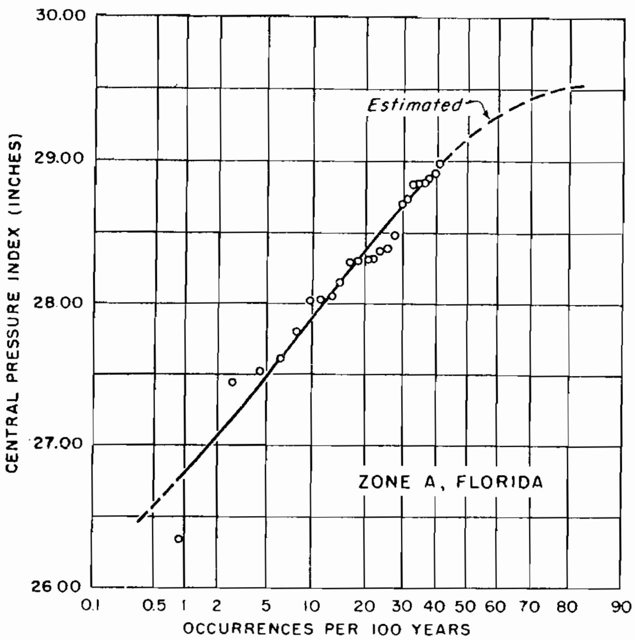


FIG. 3 GEOGRAPHIC VARIATION OF ACCUMULATED FREQUENCY OF HURRICANE CENTRAL PRESSURE INDEX, GULF COAST U. S. (1900-1956) OVER ZONES A, B & C OF APPROXIMATELY 80,000 SQ. MI.

FIG 3



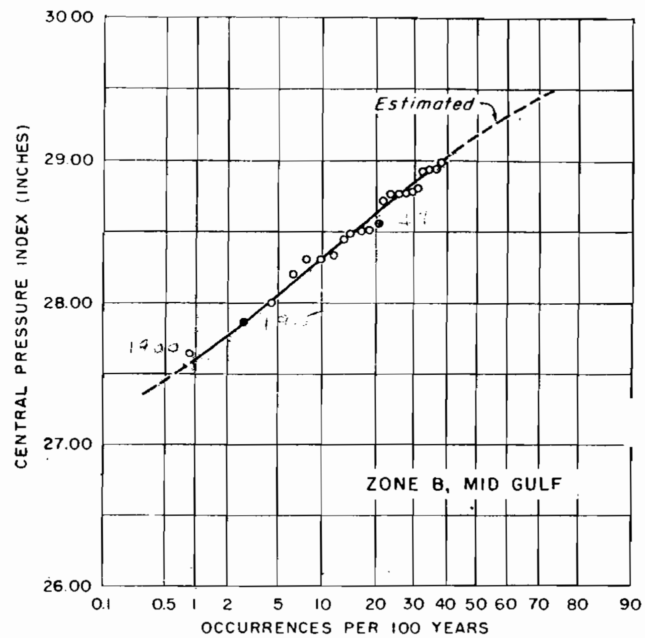


FIGURE 4

ACCUMULATED FREQUENCY
OF HURRICANE CENTRAL PRESSURES
(PLOTTED AS FREQUENCY PER 100 YEARS
BASED ON 1900-1956)

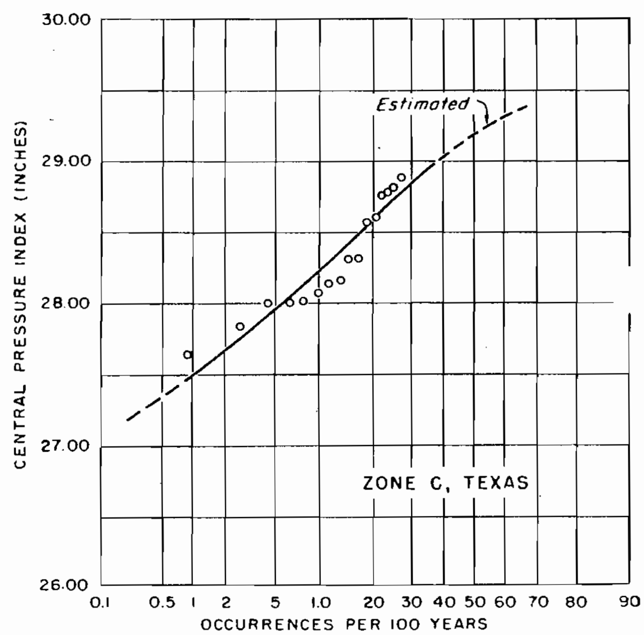


FIG 4 FIG 4

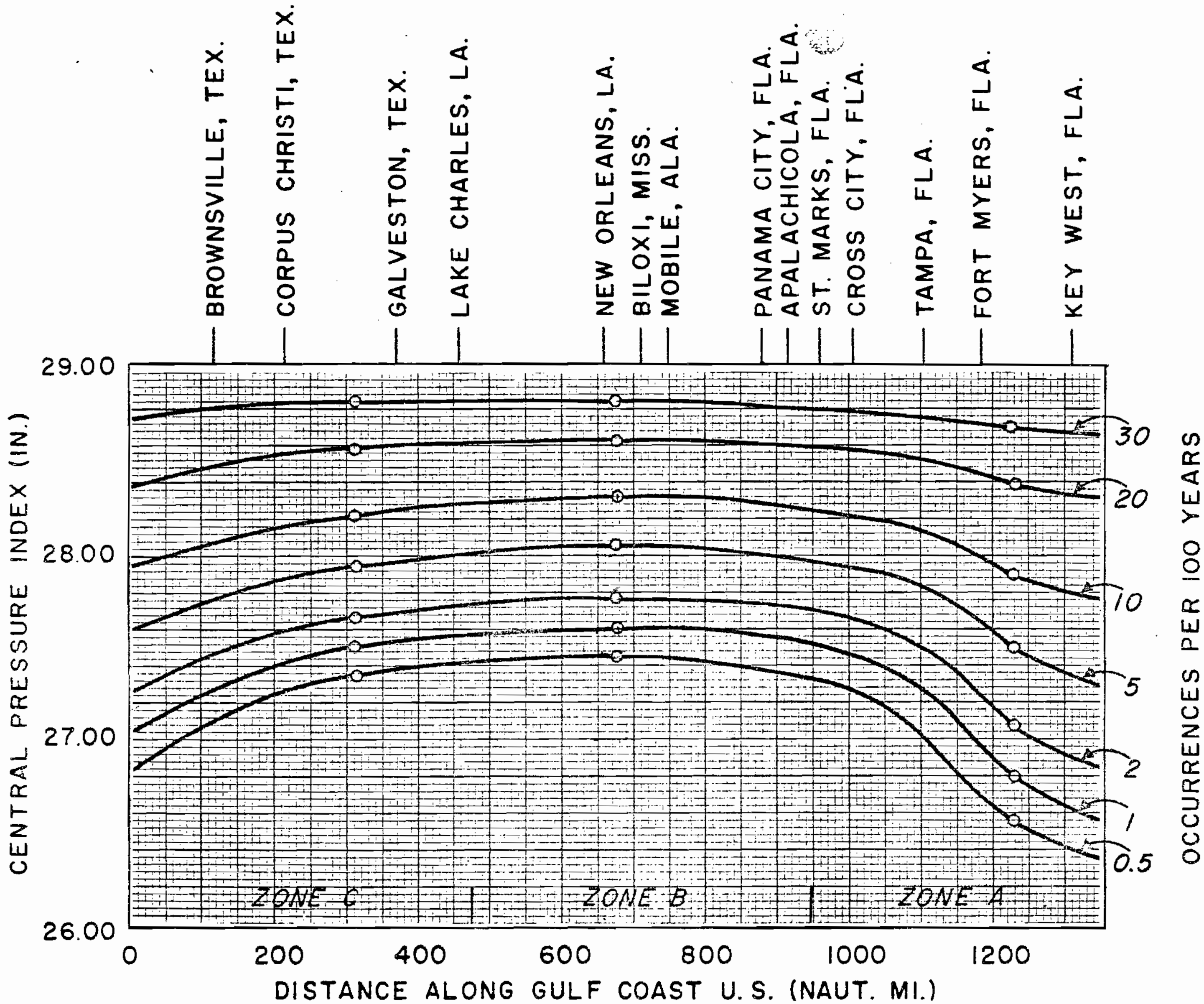
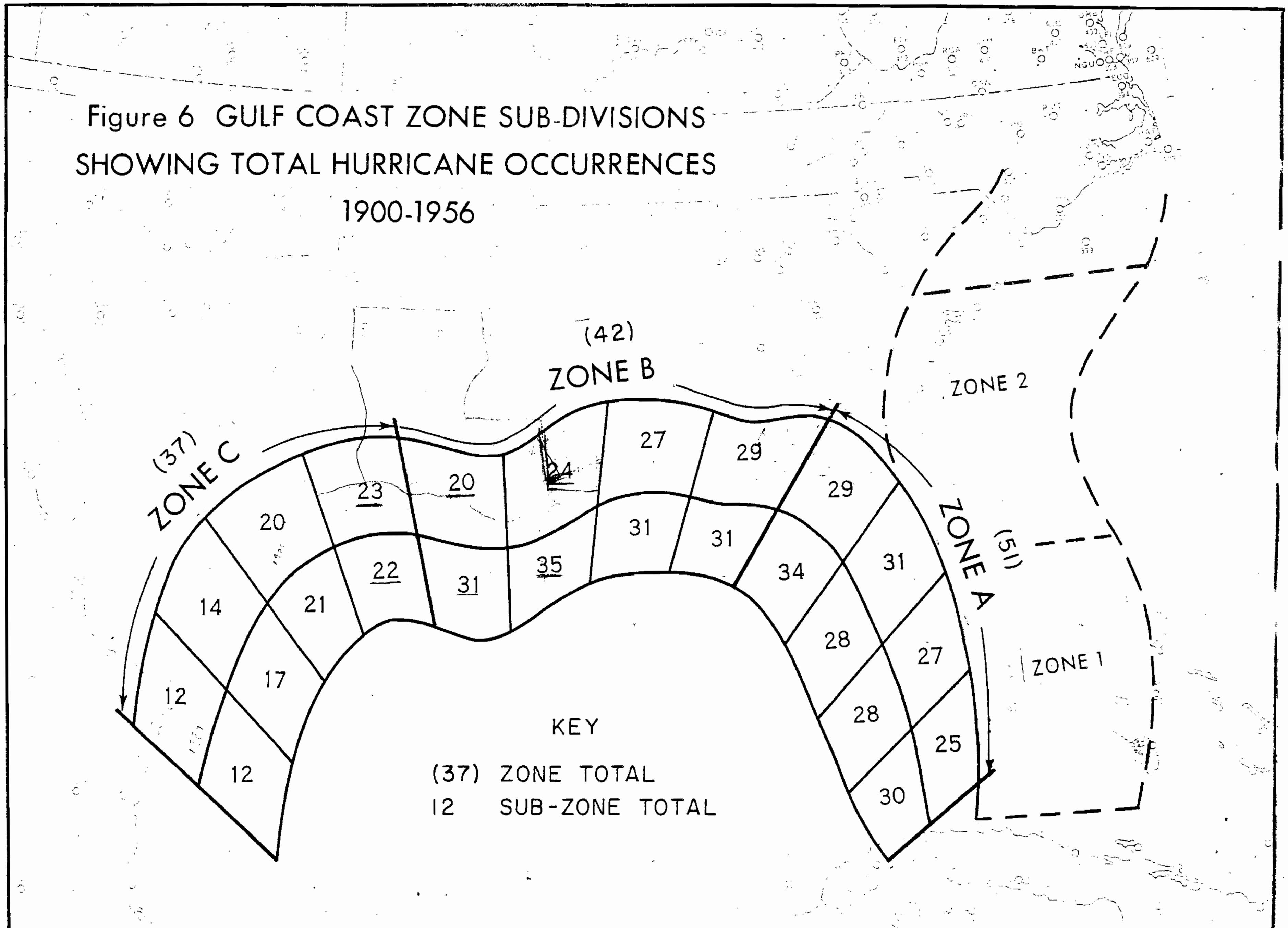
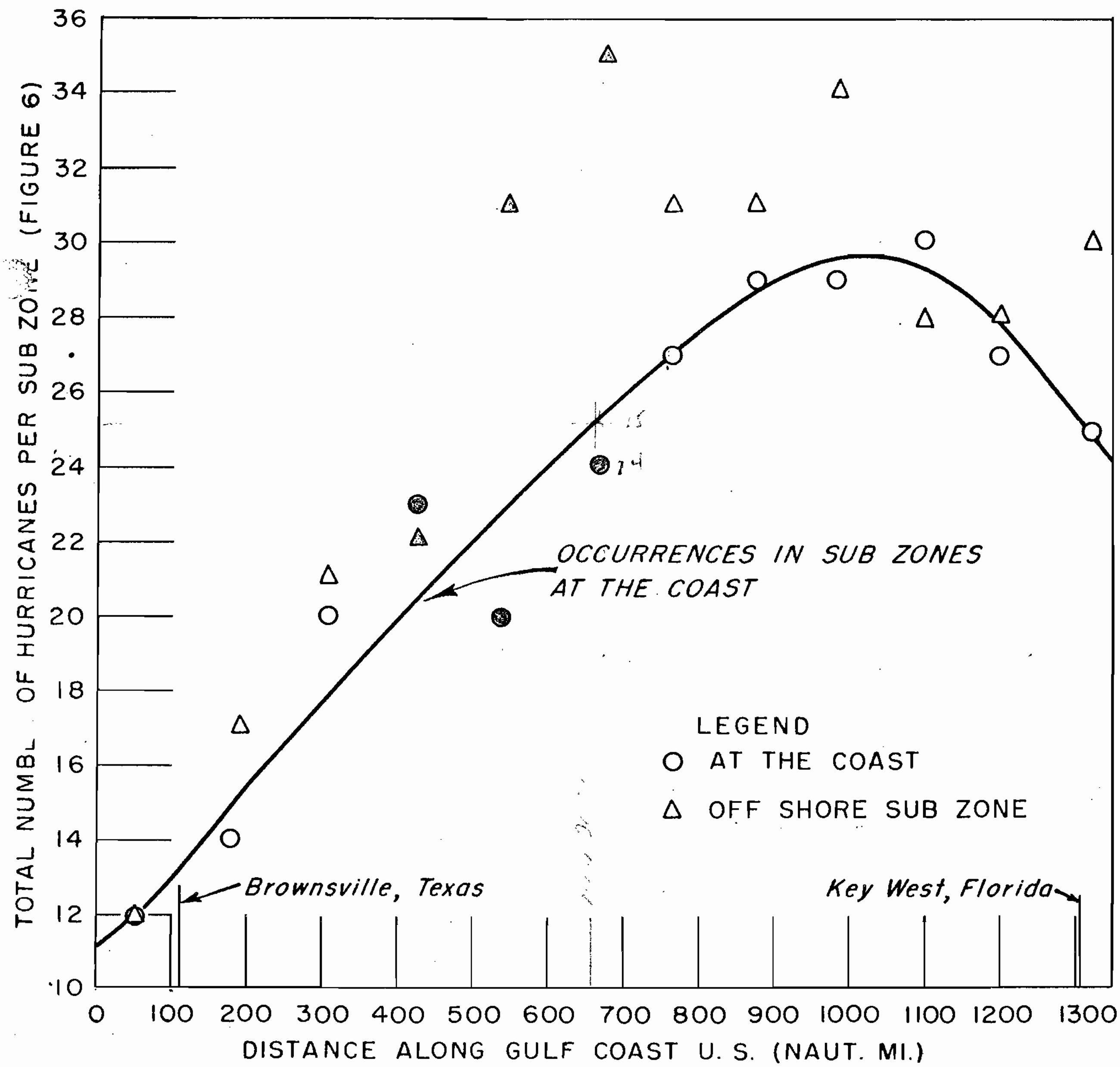


FIG. 5 GEOGRAPHIC VARIATION OF AVERAGE FREQUENCY PER 100 YEARS OF HURRICANE CENTRAL PRESSURE INDEX, GULF COAST U. S. (1900-1956) OVER ZONES OF APPROXIMATELY 80,000 SQ. MI.

Fig 9

Figure 6 GULF COAST ZONE SUB-DIVISIONS SHOWING TOTAL HURRICANE OCCURRENCES 1900-1956





DISTRIBUTION OF HURRICANE OCCURRENCES ALONG THE GULF COAST U. S. (1900-1956) OVER SUB ZONES OF APPROXIMATELY 10,000 SQUARE MI.

FIGURE 7

FIG 7

FIG 8

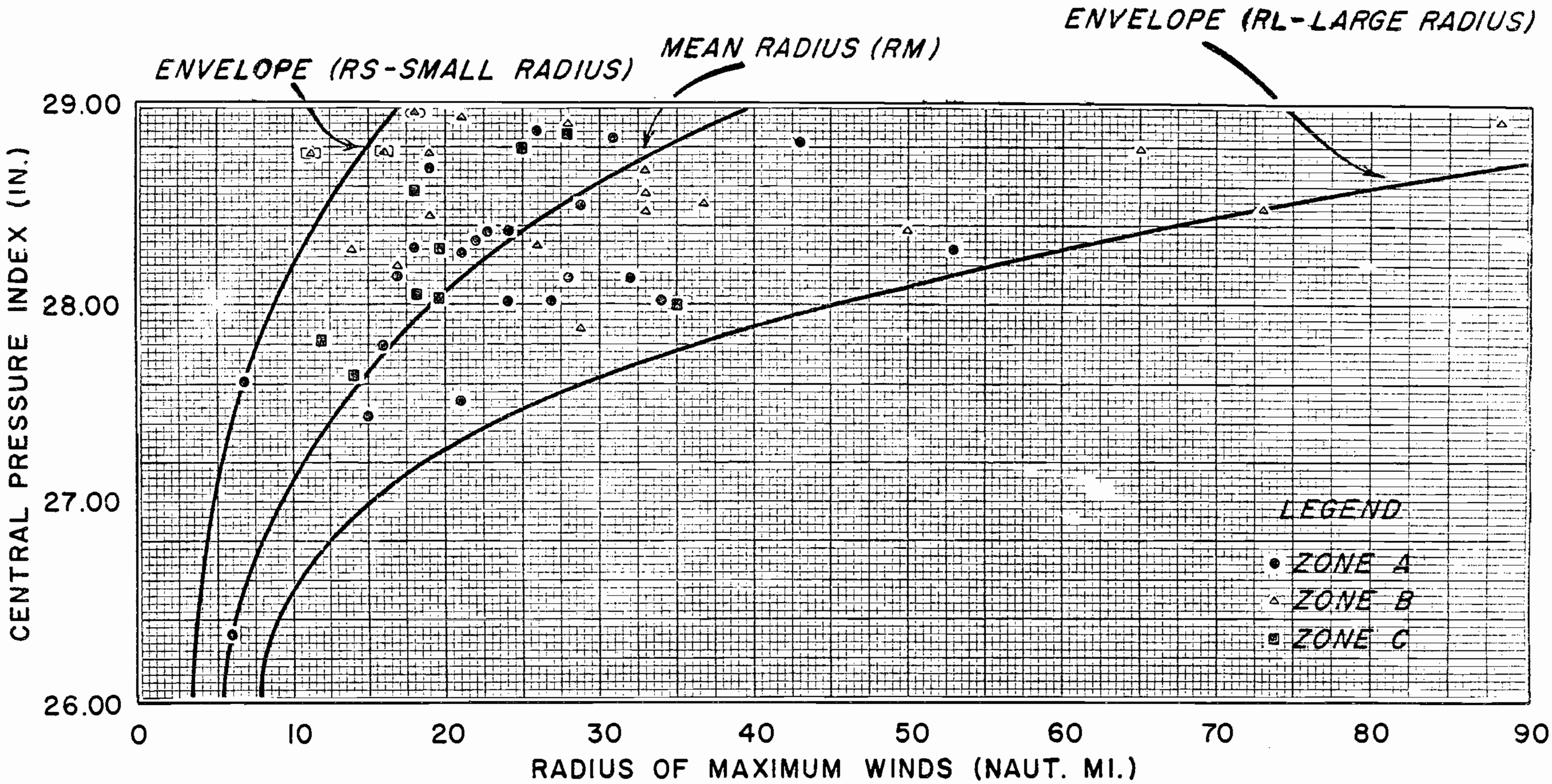
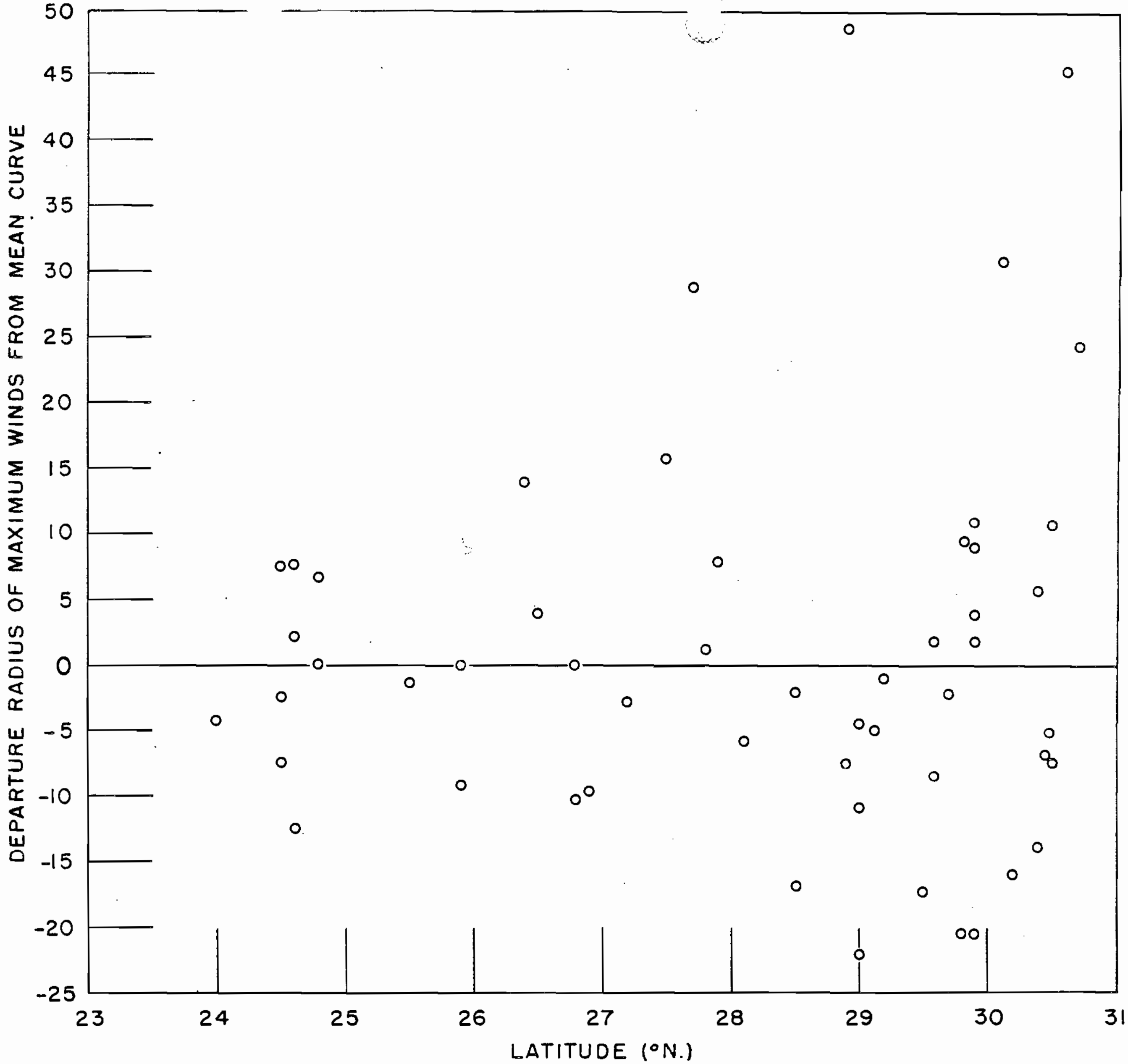


FIG. 8 VARIATION OF RADIUS OF MAXIMUM WINDS WITH CENTRAL PRESSURE INDEX GULF COAST U.S
(BASED ON PERIOD 1900-1956)

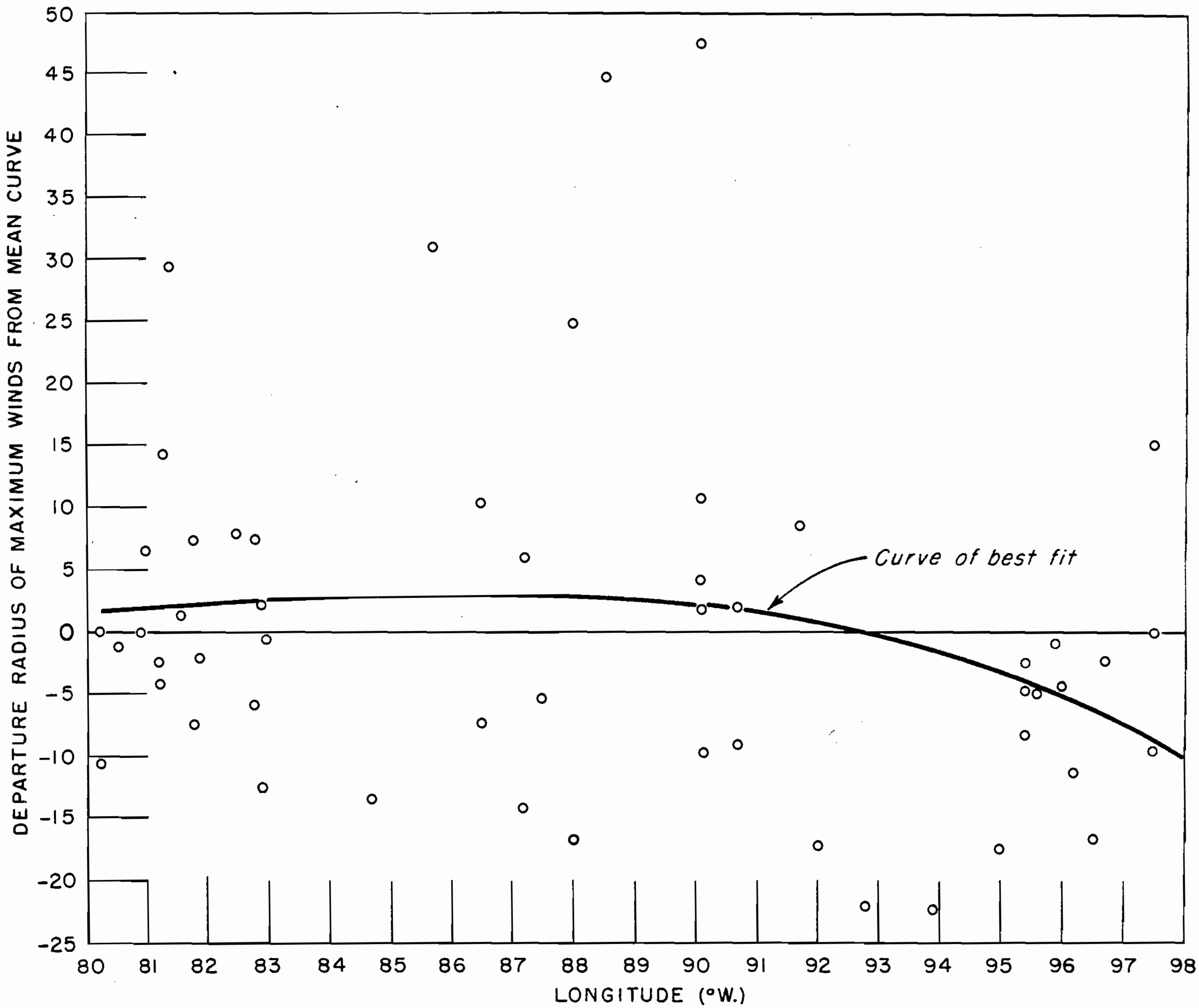
FIG 8



VARIATION WITH LATITUDE OF DEPARTURE OF RADIUS OF MAXIMUM WINDS FROM MEAN CURVE OF FIGURE 9

FIGURE 9

FIG 9

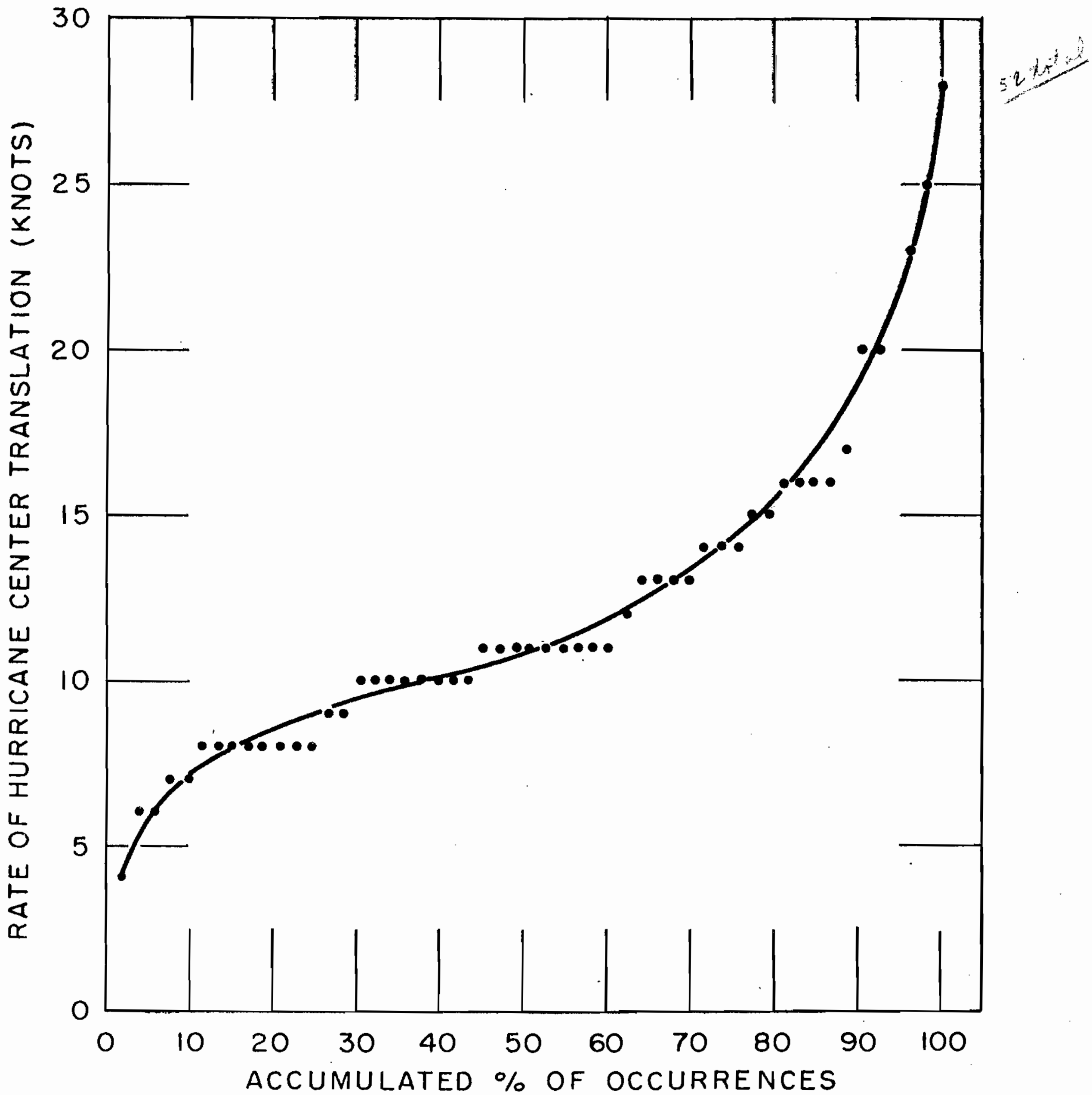


VARIATION WITH LONGITUDE OF DEPARTURE OF RADIUS OF MAXIMUM WINDS FROM MEAN CURVE OF FIGURE 9

FIGURE 10

FIG 10

FIG 10



PERCENTAGE DISTRIBUTION OF RATE OF HURRICANE CENTER TRANSLATION GULF COAST U. S. 1900-1956

FIGURE 11

FIG 11

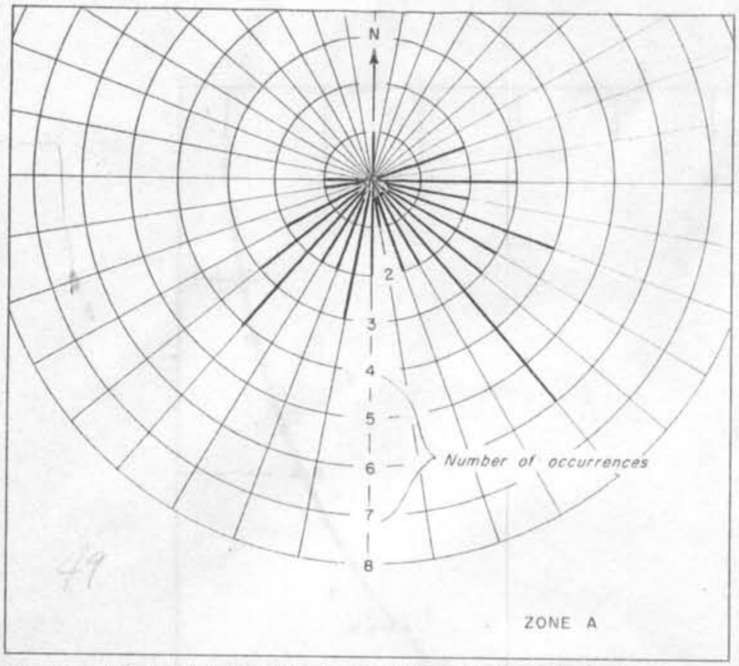


Fig. 12 A AZIMUTH DISTRIBUTION OF HURRICANE PATHS IN ZONE
1900–1956

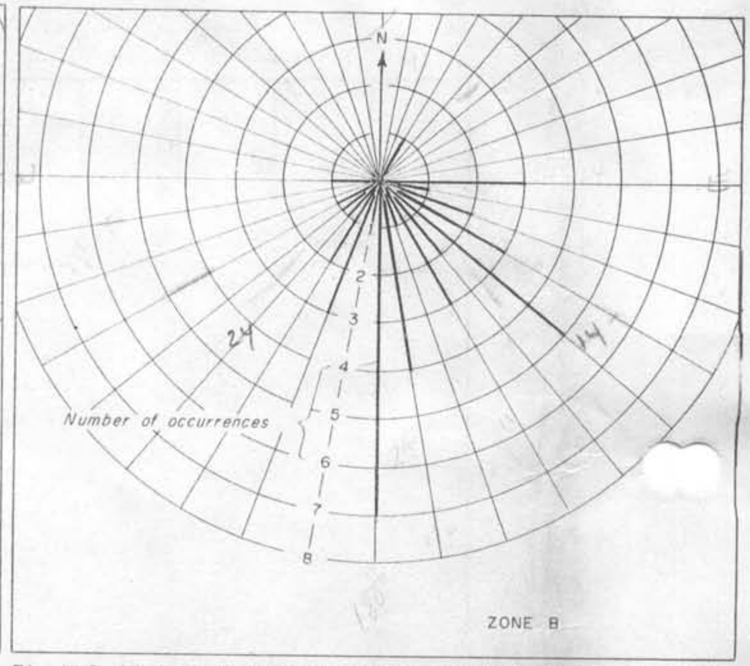


Fig. 12 B AZIMUTH DISTRIBUTION OF HURRICANE PATHS IN ZONE
1900–1956

Zone B
Avg az. E quad - 114.3
(14) (24° S of E)
Avg az S quad - 177.5
(24) (2° E of S)

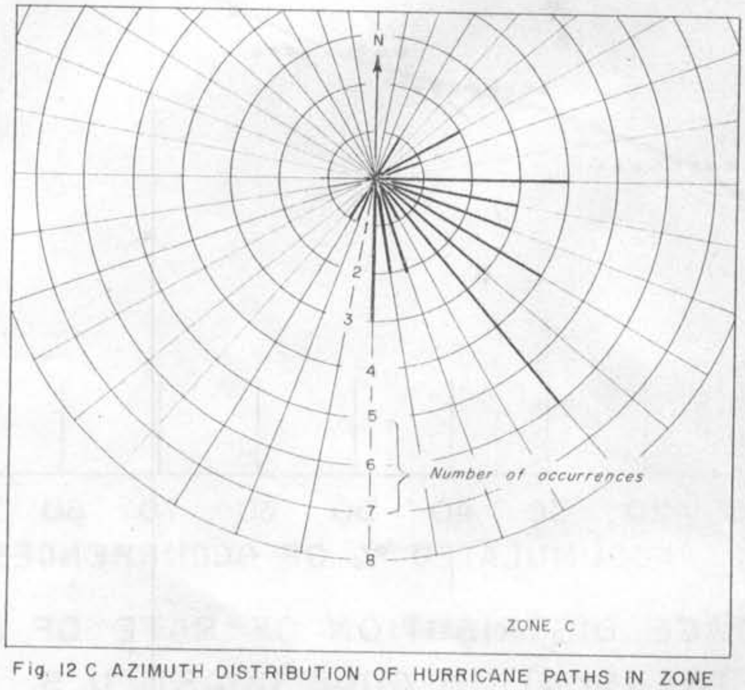
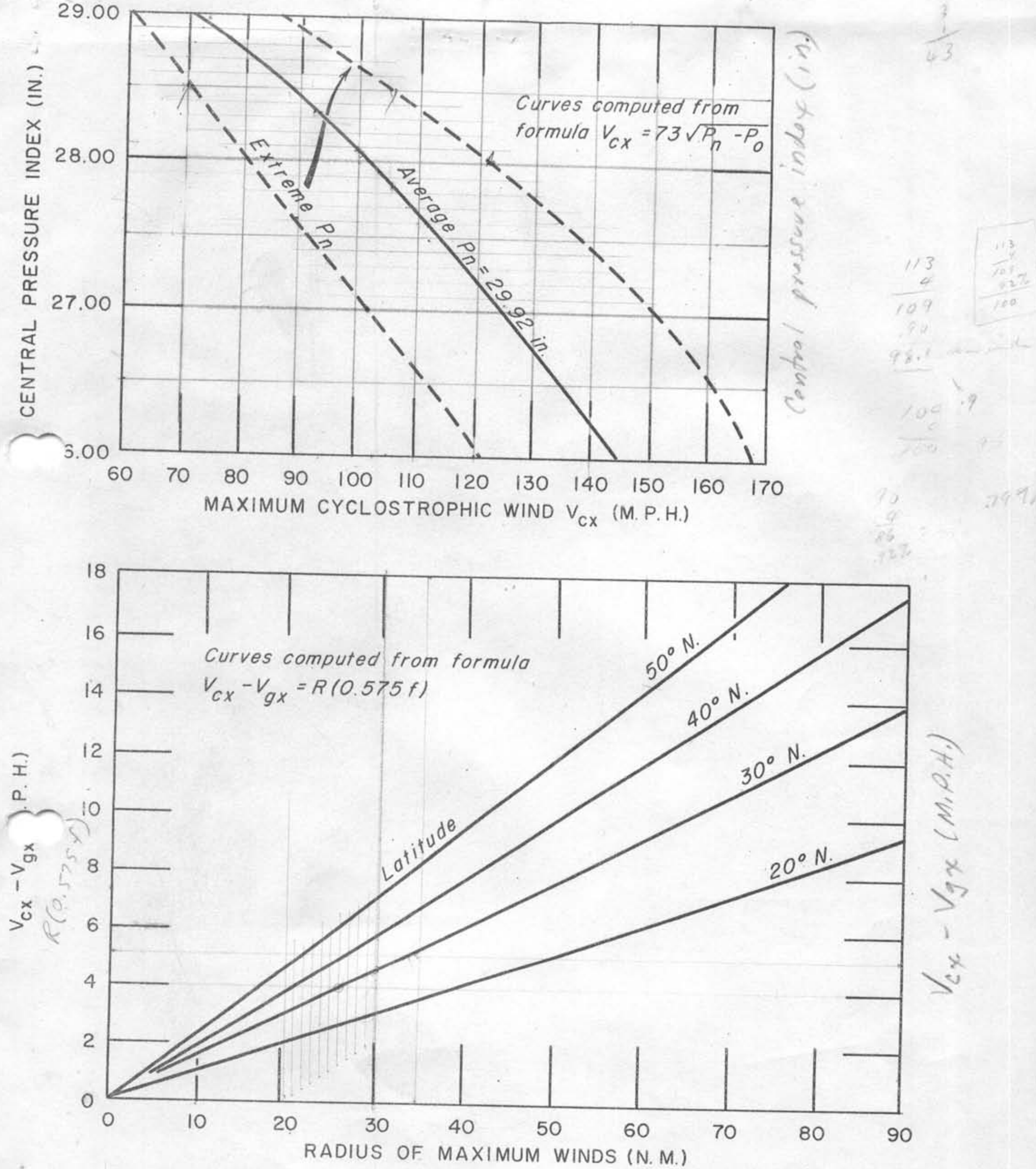


Fig. 12 C AZIMUTH DISTRIBUTION OF HURRICANE PATHS IN ZONE
1900–1956

FIG 12

FIG 12



Note: To obtain maximum gradient wind, V_{gx} find maximum cyclostrophic wind from upper figure and subtract correction obtained from lower figure.

FIG 13

Fig. 13 RELATION OF MAXIMUM GRADIENT WIND TO CENTRAL PRESSURE INDEX

UNITED STATES DEPARTMENT OF COMMERCE
WEATHER BUREAU
WASHINGTON

April 25, 1957

IN REPLY, PLEASE ADDRESS
CHIEF, U. S. WEATHER BUREAU
WASHINGTON 25, D. C.
AND REFER TO

0-6.12

MEMORANDUM HUR 2-2

FROM; Hydrometeorological Section

SUBJECT: Parameters for Hurricane Flossy of 1956

REFERENCES: (1) National Hurricane Research Project, Report No. 5, "Survey of Meteorological Factors Pertinent to Reduction of Loss of Life and Property in Hurricane Situations."
(2) MEMORANDUM HUR 7-16, "Hurricane Characteristics in the Vicinity of Lake Pontchartrain and New Orleans, La."

Hurricane Flossy of September 24, 1956 in the Gulf of Mexico has been analyzed. Parameters for the storm are listed below. These parameters may be added to Table 3-1 of reference (1) and to the various tables of reference (2).

Charles S. Gilman, Chief
Hydrometeorological Section

Attachments
4 cc with attachments to OCE

UNITED STATES DEPARTMENT OF COMMERCE
WEATHER BUREAU
WASHINGTON

April 25, 1957

IN REPLY, PLEASE ADDRESS
CHIEF, U. S. WEATHER BUREAU
WASHINGTON 25, D. C.
AND REFER TO
0-6.12

TO : Mr. A. L. Cochran, Civil Works
Office of Chief of Engineers
Corps of Engineers

FROM : Hydrometeorological Section

SUBJECT: MEMORANDUM HUR 2-2--Parameters for Hurricane Flossy of 1956

The subject memorandum gives central pressure, radius of maximum winds, and other parameters for the hurricane Flossy, for the information of District and Division Offices interested in Gulf of Mexico hurricanes.

Charles S. Gilman, Chief
Hydrometeorological Section

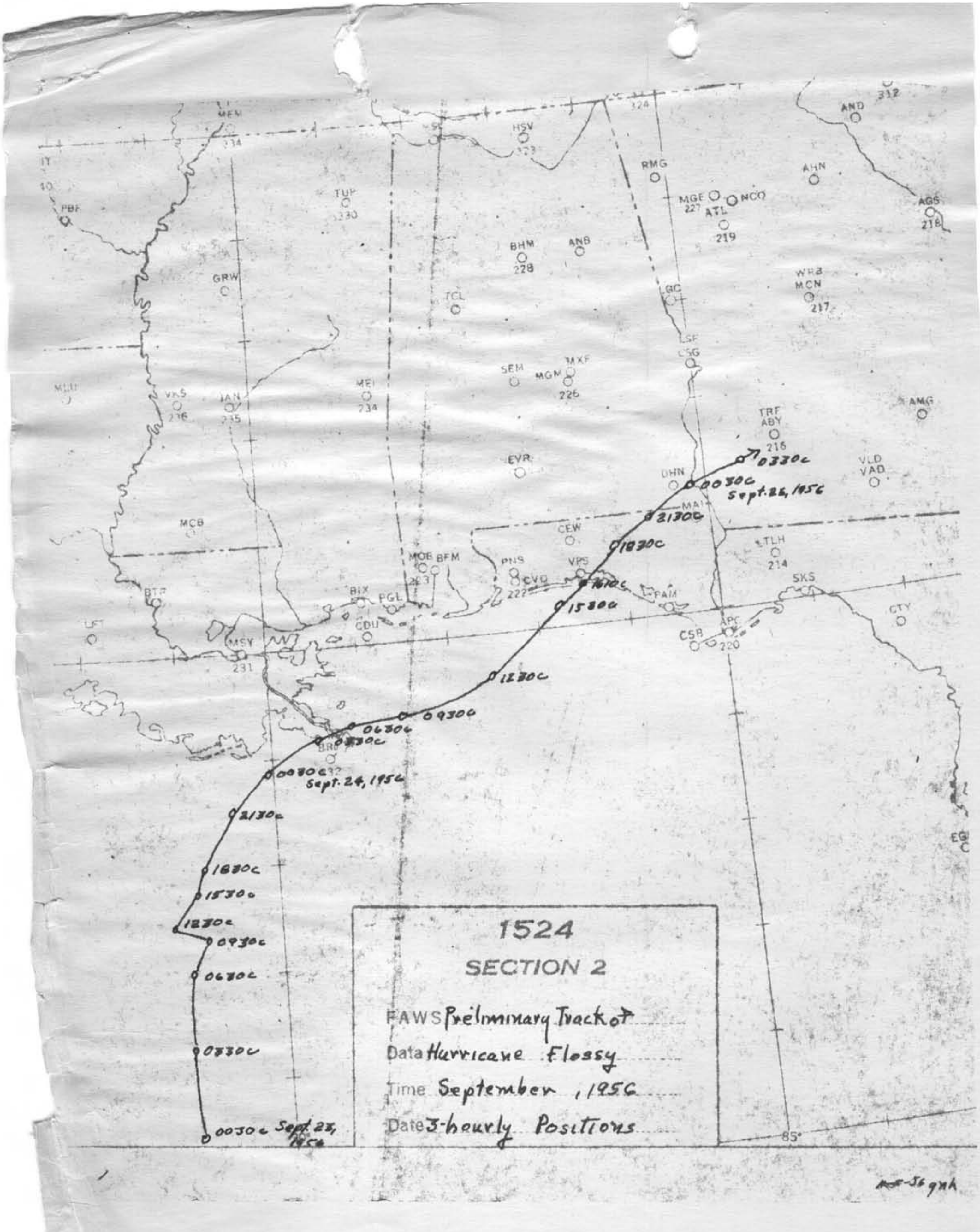
Attachments

4 cc with attachments to OCE

HURRICANE PARAMETERS

Hurricane Flossy September 1956

Date	P_o in.	P_n in.	$P_n - P_o$ in.	P_o mb.	P_n mb.	$P_n - P_o$ mb.	R n. mi. (a)	R n. mi. (b)	V_{gx} mph.	V_{gx} kt.	c kt.	t_c hrs.	P_a in.	P_a mb.	Station
Sept. 24, 1956	28.76	29.83	1.06	974	1010	36	29	30	83	72	20	4	28.78	974.7	Destin, Fl.



1524
SECTION 2
FAWS Preliminary Track of
Data Hurricane Flossy
Time September, 1956
Date 3-hourly Positions
0030c Sept 23, 1956
0330c
0630c
0930c
1230c
1530c
1830c
2130c
0030c Sept. 24, 1956
0330c
0630c
0930c
1230c
1530c
1810c
1830c
2130c
0030c Sept. 25, 1956
0330c
MEM
HSV
TUP
BHM
ANB
RMG
MGE
ATL
NCO
AHN
AND
AGS
GRW
TCL
LGC
WRB
MCN
SEM
MGM
MXF
MEI
JAN
VKS
CSG
LSF
TRF
ABY
AMG
EVR
DHN
VLD
VAD
MAI
CEW
MCB
MOB
BFM
PNS
VPS
TLH
SKS
BTR
BIX
PGL
CVO
PAM
LFT
CDU
MSY
APC
CSB
CTY
PBF
MLU
BRO
85°