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A BLOCKED MINIMAL TROPICAL DEPRESSION BECOMES A STORM OF RARE OCCURRENCE

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A BLOCKED MINIMAL TROPICAL DEPRESSION BECOMES A STORM OF RARE OCCURRENCE

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ABSTRACT

A small tropical low, marginal in intensity between a depression and disturbance, moved out of the Gulf of Mexico on September 19-20, 1969. An absence of steering currents aloft and the blocking action of a surface high caused the low to become stationary on the Florida coast for approximately 48 hours. Torrential, record-breaking rains occurred in a small area 60-65 miles to the east and 50 miles inland from the point where the low made landfall. Record-breaking floods resulted. The 23-inch maximum rainfall in 1969 was about 9 inches greater than the previous maximum rainfall of record produced by a 1924 tropical storm in the same area. The location of the area of maximum rainfall, with respect to the point of landfall of the low's center, closely follows the pattern previously reported for the more intense hurricanes and tropical storms.

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INTRODUCTION

On September 20-23, 1969, a small tropical low caused heavy rains in parts of the Florida panhandle and extreme southern Georgia with a maximum of over 23 inches on an area 20 miles northwest of Tallahassee, Fla. Heavy flooding occurred along the Little River in Gadsden County, Fla., and in that portion of the Ochlockonee River basin that is in Gadsden, Leon, Liberty, and Wakulla Counties, Fla.

No loss of life resulted from the flooding although property damage was extensive. Several homes, weekend cottages, and house trailers were damaged or destroyed below the Jackson Bluff Dam on the Ochlockonee River west of Tallahassee (fig. 1). Figure 2 shows a typical scene of the flooding that occurred in low spots having poor drainage. Agriculture losses were substantial, being greatest in Gadsden County where they were estimated at $1,000,000. Losses to communication systems, railroads, and other commercial and private interests amounted to several thousands of dollars.

One of the more important aspects of this flood was the number of road closures and the resulting inconvenience to the commuting public. Gadsden County was hardest hit. Here traffic was virtually at a standstill on September 21 and 22, and the main artery through the county, U. S. Highway 90, was closed (fig. 3). There were 51 points where roads were closed because of flooding and flood damage to roads, bridges, and culverts (fig. 4). Nearly $200,000 was required for emergency road and bridge repair, with an additional $522,000 in subsequent contractual work to replace the bridges that were destroyed.

This paper discusses the synoptic situation, radar observations, rainfall, and peak stream discharges associated with the 1969 tropical low and the similarity of this low to a tropical storm that hit the same area in 1924.

SYNOPTIC

The system first became evident on the surface weather analysis late on September 19, when a ship report indicated the presence of a low-pressure area near latitude 25.3° N and longitude 86.4° W, approximately 300 miles west-northwest of Key West, Florida. The surface weather analysis at 1:00 a.m., EST (all clock times shown refer to Eastern Standard Time, 75th Meridian, Time), September 20, revealed a low-pressure area with a closed isobar about a central pressure of 29.70 inches centered at latitude 25.0° N and longitude 88.4° W. This low-pressure area moved northward during the day, reaching land between Panama City and Port St. Joe, Fla., by 4:00 a.m., September 21. Figure 5 shows the surface weather analysis for 7:00 a.m. with the low positioned on the northern Gulf coast. It moved into the dissipating trough of a stationary front along the northern Gulf coast. A large surface high, covering most of the eastern half of

Figure 1. (Right) Ochlocknee River at State Highway 20, 3,000ft downstream from Jackson Bluff Dam. Only roofs of several homes, cottages, and trailers are visible.

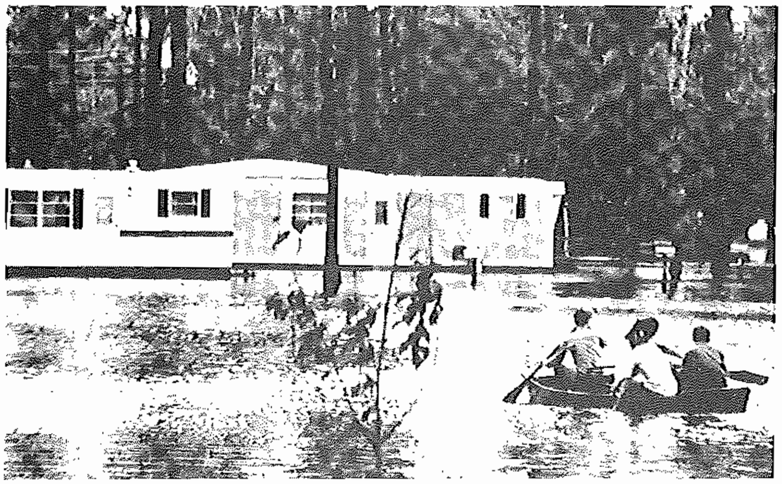
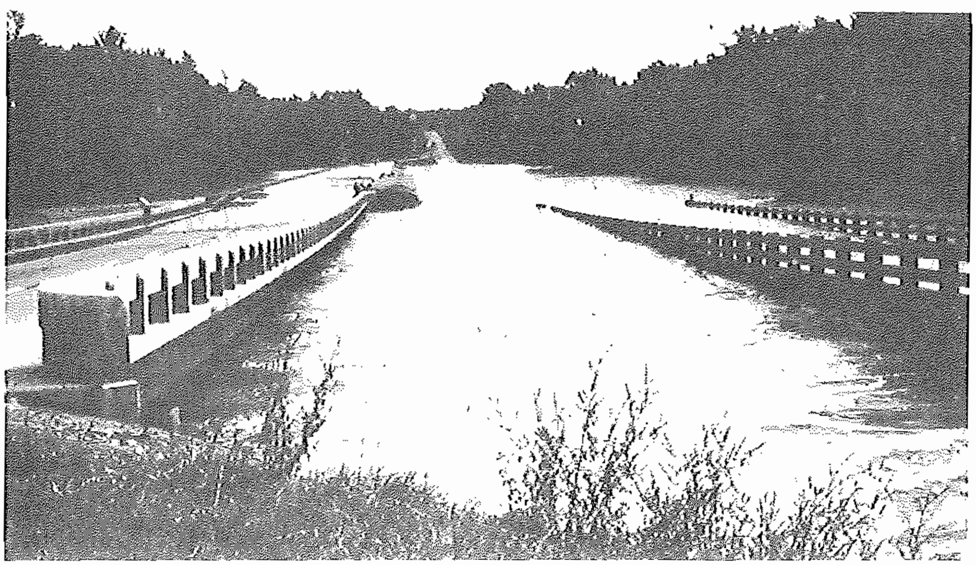
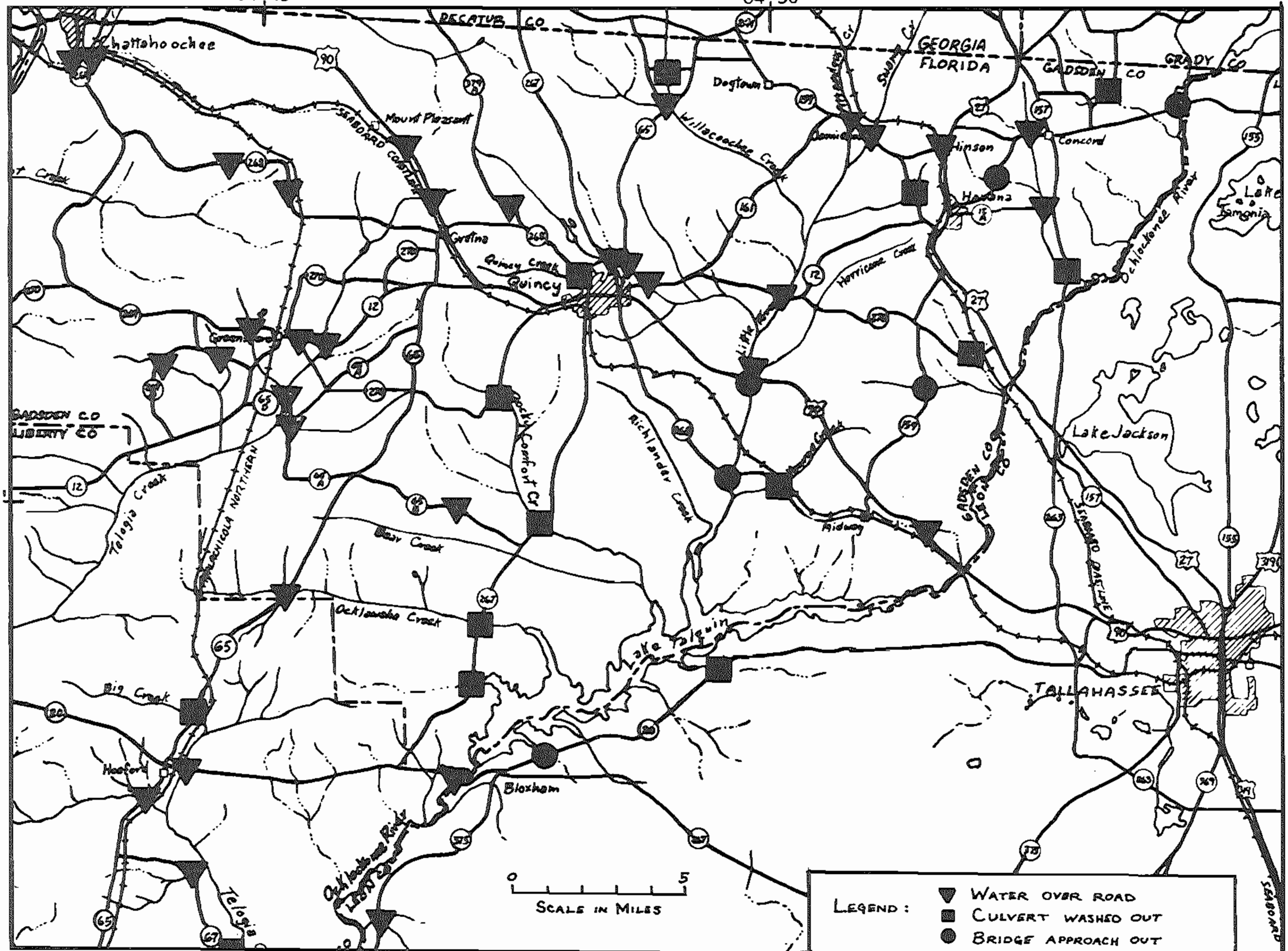


Figure 2. (Left) Trailer park on U.S. Highway 90, west of Tallahassee. Water was up to six inches in some trailers which were not moved ahead of flooding.

Figure 3. (Below) Little River at U.S. Highway 90, east of Quincy, September 21, 1969.





Locations of road closures resulting from September 1969 flood.

the U. S., acted as a block to the low. The 500 mb chart (fig. 6) for 7:00 a.m. showed a weak closed circulation aloft. With blocking action at the surface and no distinct steering current, it stalled shortly after reaching the coast and remained practically stationary for approximately 48 hours, maintaining a situation favorable for heavy rain.

Heavy rain fell on the Little and Ochlockonee river basins and on the lower Apalachicola River basin during the time the low was stationary. Map analysis indicated alternate periods of filling and deepening of the system, reflected in the fitful character of the rainfall. By September 23 the high-pressure system along the eastern seaboard weakened, and the low-pressure area filled until it was discernible only as a weak inverted trough.

RADAR

The precipitation area associated with this tropical low was under constant surveillance by National Weather Service radar at Apalachicola, Florida. The radar is a Weather Search Radar-57 with a range of 250 n. mi. (nautical miles). Photographs of the radar scope were made at 5-minute intervals during the entire storm period. The proximity of the radar to the storm path (directly over the installation) and to the area experiencing excessive rainfall and heavy flooding, 20-70 miles, made for excellent coverage.

A large rain area offshore was detected by the radar late on September 19 and early on the 20th. The rain moved northward to the coast by 1:00 a.m. on the 20th. The photograph of the radar scope at 6:50 a.m., September 20 (fig. 7), showed precipitation from 60 n. mi. north-northeast to 150 n.mi. south of Apalachicola. This precipitation area was 50-150 n. mi. wide with nearly 100 percent coverage. Heaviest rain was over the Gulf, to the south of Apalachicola. As the rain area moved northward, there were evidences of strong cells organizing into lines or bands. By 9:25 a.m., two bands were prominent. One was 8-10 n.mi. wide, extending from 20 n.mi. northwest to 75 n.mi. southeast of Apalachicola. The second extended southward from the coast 125 n.mi. Individual cells appeared to be moving north to northwest along the bands while the whole precipitation area drifted slowly northward. By noon, the bands were more nearly spiral with the center of curvature located about 95 n.mi. southwest of Apalachicola.

Light-to-moderate rain began at Havana, Fla., the area that received the greatest storm rainfall, in the early morning of September 20 with heavy rain beginning about 2:00 p.m. The extent of heavy precipitation is indicated in the photograph of the radar scope taken at 2:36 p.m. (fig.8). Moderate-to-heavy precipitation was falling over most of the lower Apalachicola, Little, and Ochlockonee river basins at the time of this photograph, and continued during most of the remainder of the day on the 20th.

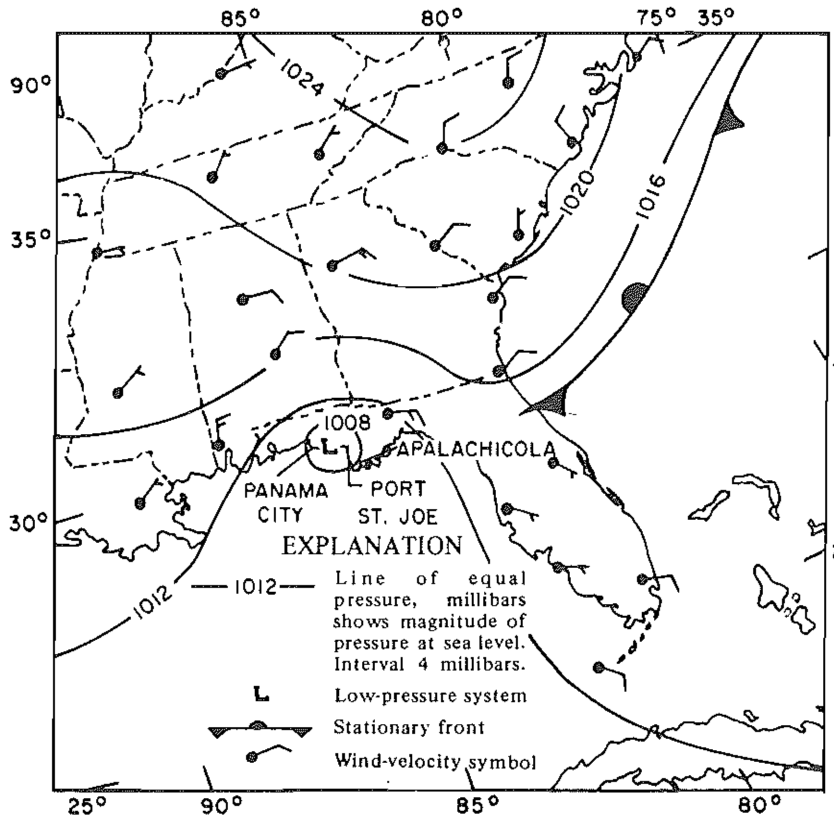


Figure 5. Surface analysis, 0700LST, September 21, 1969.

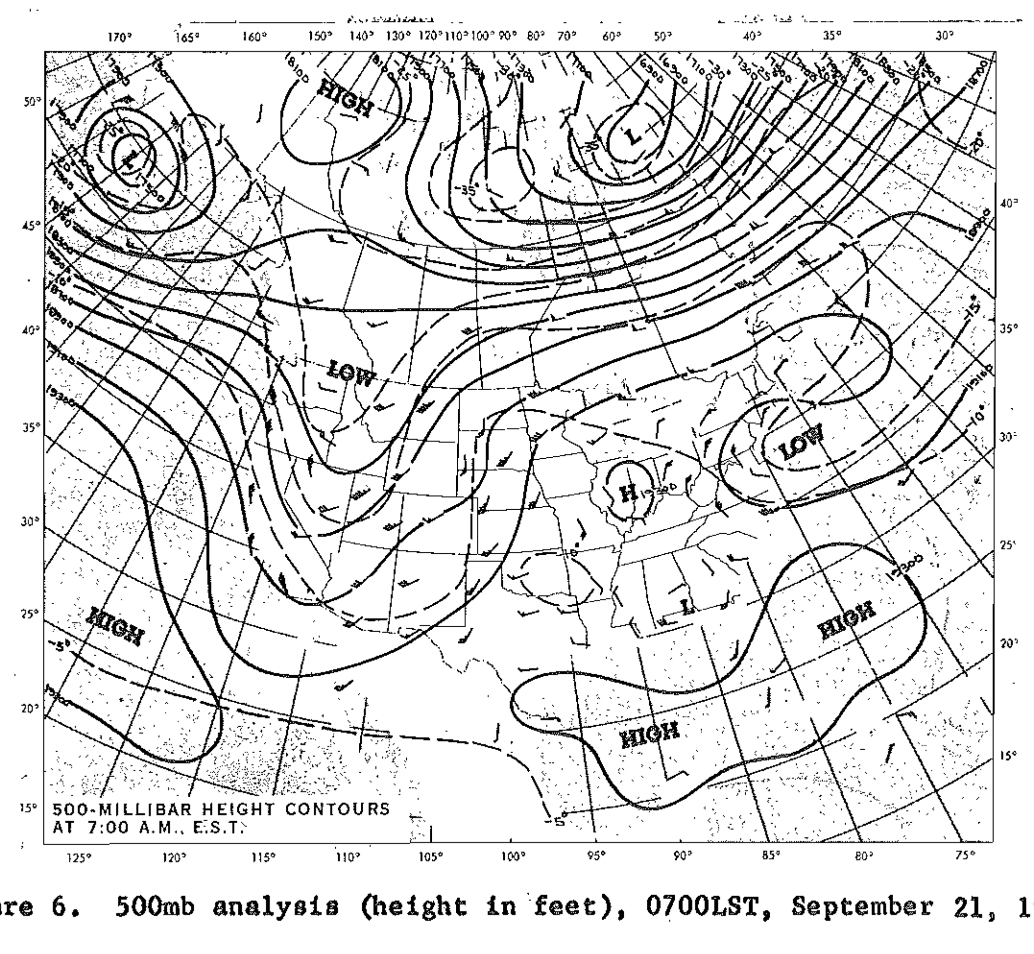


Figure 6. 500mb analysis (height in feet), 0700LST, September 21, 1969.

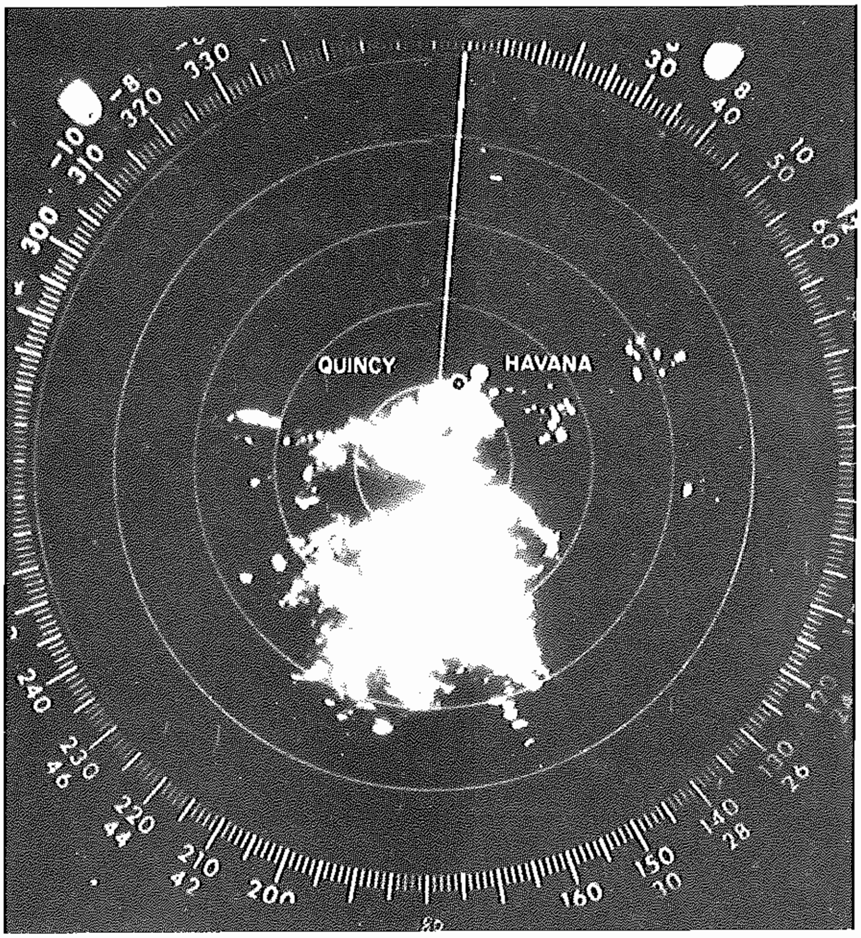


Figure 7. Apalachicola radar (WSR-57), 0550LST, September 20, 1969. 250nm range, no attenuation, antenna elevation ½ degree. Precipitation area extends from 60nm north-northeast to 150nm south.

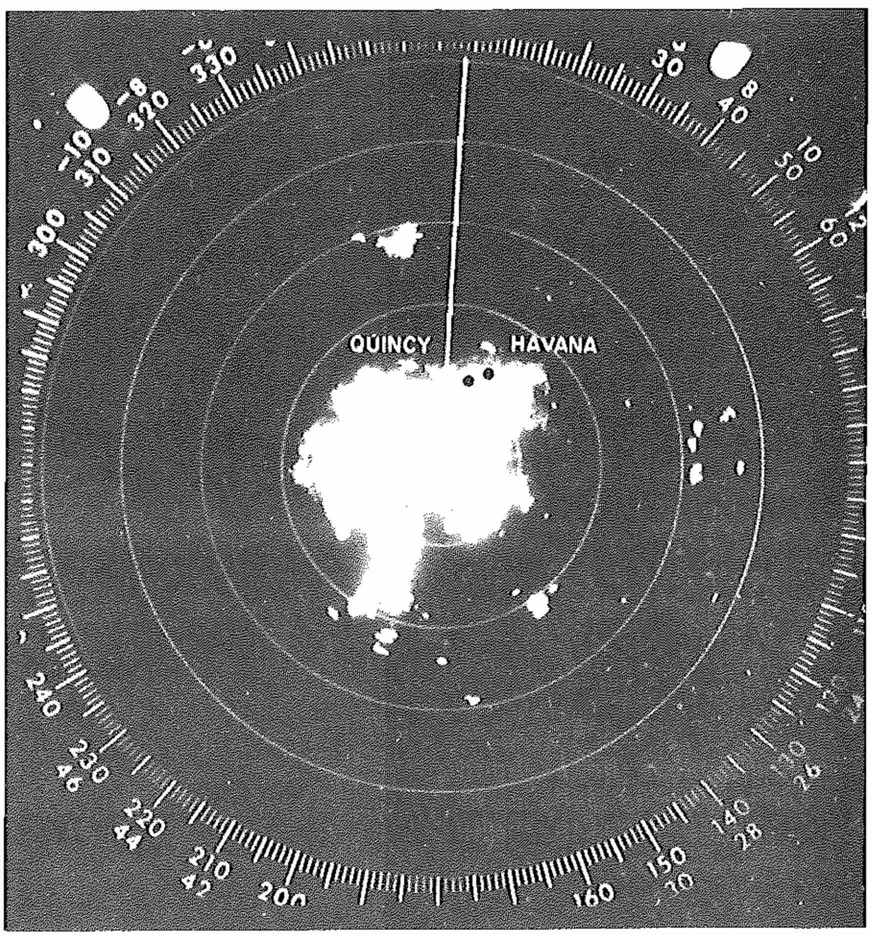


Figure 8. Same as fig. 7, but 1436LST, September 20.

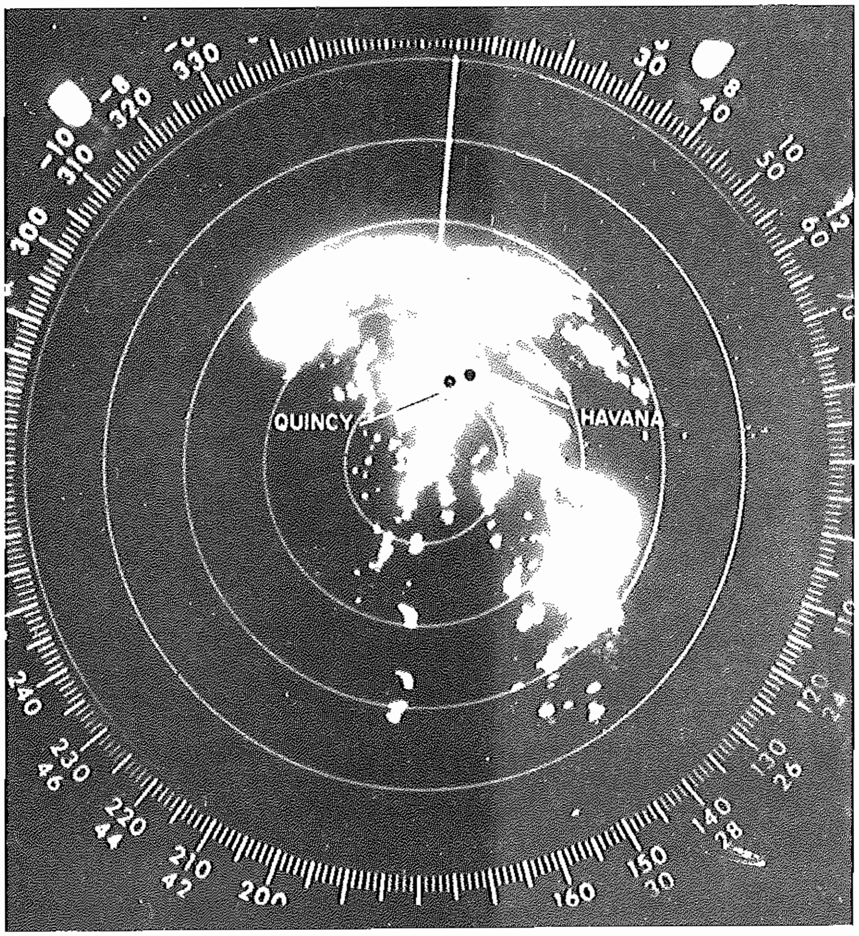


Figure 9. Same as fig. 7, but 0639LST, September 21. Rainfall intensity at this time was in excess of six inches per hour at Quincy.

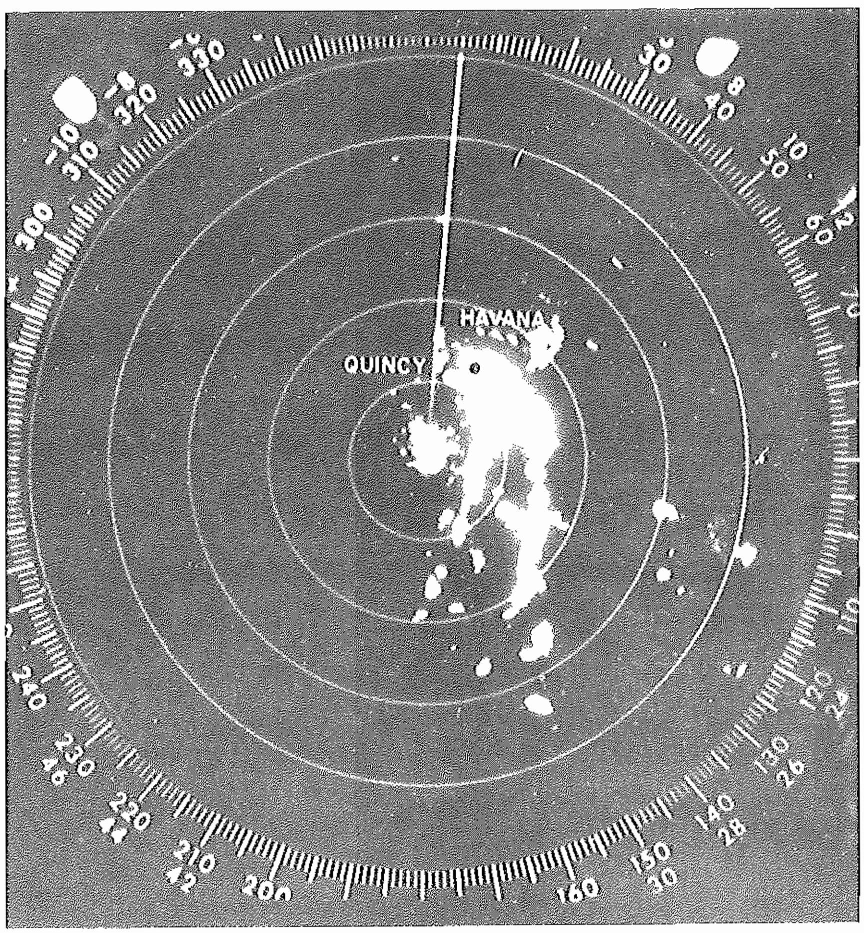


Figure 10. Same as fig. 7, but 2112LST, September 22. The two well developed lines or rain bands converge on an area over the Ochlocknee basin.

After the low reached the coast on the morning of the 21st, radar pictures indicated more of a tendency for the precipitation to be oriented in northwest-southeast to north-south lines with the heaviest precipitation area essentially stationary over Gadsden and neighboring counties of Florida and south Georgia. Individual cells moved northward along the lines converging on this area while the lines moved little. At times, 2 or 3 lines appeared to radiate out of a point centered over, or near, a small area in north Gadsden County and the south parts of Grady and Decatur counties, Ga.

Figure 9 shows the precipitation pattern at 6:39 a.m., September 21, shortly after the start of extremely heavy precipitation at Quincy. Records of recording rain gages showed that this precipitation continued for nearly 3 hours and that, at the time of the photograph, the rainfall rate at Quincy was in excess of 6 inches per hour. The heights of radar echoes measured during the day indicated numerous tops above 40,000-feet.

Precipitation bands continued to converge on the Quincy-Havana area (fig. 10) with individual cells in the bands moving northward and becoming stationary. The photograph in figure 10 was taken at 9:12 p.m. on the 21st. Through the night of September 21, and during the morning of the 22nd, the precipitation pattern continued much as that shown in the figure. The lines slowly disintegrated into disorganized cells during the afternoon only to regroup into well-defined lines after 5:30 p.m. In the early morning hours of the 24th. the precipitation area began to show signs of an eastward movement, and by 9:00 a.m., the lines broke into individual cells which moved rapidly away to the east and northeast.

PRECIPITATION

The heaviest rain occurred in an area having an unusually large number of rain gages. Table 1 lists, in order of decreasing precipitation amounts, the gages which collected 2 inches or more of precipitation during the storm. Most were official National Weather Service gages. These included 2 recording tipping-bucket gages, 2 recording weighing gages, a Fischer-Porter recording gage, and 32 of the standard 8-inch (compound 10 to 1) gages with a capacity of 25 inches. Four of the 8-inch gages were in the small area within the 20-inch isohyet, the maximum precipitation center. Three of these were company gages at mines owned by the Englehart Chemical and Mineral Company.

Twelve of the gages belonged to the Florida Division of Forestry. Four of these were compound gages with a 7-inch capacity. The other 8 gages were plastic, tube-type, with a capacity of 5 inches. The accuracy of the plastic gage is questionable, especially for periods of excessive precipitation. The Division of Forestry pointed out, also, that some of the rainfall reports for the 7-inch gages were in excess of gage capacity and therefore some overflow may have occurred, as was known to have been the case at the Havana Tower.

TABLE 1. RAIN GAGES AND TOTAL RAINFALL - SEPTEMBER 20-23, 1969

Gage - Name and Location	Gage Type[b]	Gage Ownership[a]	Total Inches
1. Havana, Fla.	S 8	NWS	23.4
2. LaCamelia mine-7 NNE Quincy, Fla.	S 8	EC&M	22.5
3. Attapulgus mine-1 S Attapulgus, Ga.	S 8	EC&M	22.0
4. Havana Tower-3 W Havana, Fla.	7 C	FDF	21.9*
5. Lock N mine-5 NNE Havana, Fla.	S 8	EC&M	20.0
6. Quincy Tower-4 W Quincy, Fla.	7 C	FDF	19.8
7. Quincy-3 SSW Quincy, Fla.	T B	NWS	18.8
8. Tobacco Station-Quincy, Fla.	W	NWS	18.3
9. Hosford Tower-3 E Hosford, Fla.	5 C	FDF	18.1
10. Wewahitchka, Fla.	S 8	NWS	17.4
11. East Bay Tower-14 S Sumatra, Fla.	5 C	FDF	15.8
12. Exp. Sta.-1 NW Attapulgus, Ga.	S 8	U. Ga.	15.0
13. NOAA-NWSO-5 SW Tallahassee, Fla.	W	NWS	13.8
14. Cape San Blas S Port St. Joe, Fla.	5 C	FDF	13.8
15. FDF Tower-3 SE Tallahassee, Fla.	7 C	FDF	12.9
16. Woodruff Dam, Chattahoochee, Fla.	FP	NWS	12.0
17. Otter Camp-5 S Bloxham, Fla.	ST	USGS	11.7
18. FDF Tower-3 S Chattahoochee, Fla.	5 C	FDF	11.4
19. Bristol Tower-3 E Bristol, Fla.	7 C	FDF	11.3
20. Crawfordville, Fla.	5 C	FDF	11.0
21. Lake Iamonia, Fla.	S 8	NWS	10.4**
22. Blountstown, Fla.	S 8	NWS	10.4
23. Colquitt-2 E Ga.	S 8	NWS	9.1
24. Bainbridge, Ga.	S 8	NWS	9.0
25. Donalsonville, Ga.	S 8	NWS	8.7
26. St. James Tower-3 S Panacea, Fla.	5 C	FDF	8.2
27. Cairo-2 NW Ga.	S 8	NWS	8.2
28. Sanborn Tower-Sanborn, Fla.	S 8	NWS	8.1
29. Apalachicola, Fla.	TB	NWS	7.8
30. St. Marks, Fla.	S 8	NWS	6.7
31. Panama City, Fla.	S 8	NWS	6.5
32. Wacissa, Fla.	5 C	FDF	6.3
33. Newport Tower-Wakulla, Fla.	5 C	FDF	6.0
34. Blakely, Ga.	S 8	NWS	5.9
35. Headland, Ala.	S 8	NWS	5.9
36. Camilla, Ga.	S 8	NWS	5.6
37. Carrabelle, Fla.	S 8	NWS	5.4
38. Greenwood, Fla.	S 8	NWS	4.9
39. Fountain-3 SSE Fla.	S 8	NWS	4.8
40. Thomasville-4 SE Ga.	S 8	NWS	4.7
41. Monticello-3 W Fla.	S 8	NWS	4.6
42. Chipley-3 E Fla.	S 8	NWS	4.0
43. Caryville, Fla.	S 8	NWS	3.8
44. Moultrie-2 ESE Ga.	S 8	NWS	3.7
45. Perry, Fla.	S 8	NWS	3.5
46. Dothan, Ala.	S 8	NWS	3.2

TABLE 1. (continued)

Gage - Name and Location	Gage Type[b/]	Gage Ownership[a/]	Total Inches
47. Quitman, Ga.	S 8	NWS	2.8
48. Geneva, Ala.	S 8	NWS	2.7
49. Valdosta-4 NW Ga.	S 8	NWS	2.4
50. Madison, Fla.	S 8	NWS	2.1

a/ NOAA, National Weather Service (NWS), Englehart Chemical and Mineral (EC&M), Florida Division of Forestry (FDF), U. S. Geological Survey (USGS), University of Georgia (U.Ga.)

b/ Standard 8 inch (S 8), 7-or 5-inch capacity (7 C, 5 C), tipping bucket (TB), weighing (W), Stevens (ST), Fischer & Porter (FP).

* Gage overflowed - total does not include overflow.

** Average of four gages.

One gage is owned and maintained by the U. S. Geological Survey. It is a Stevens Type QA continuous recorder with a capacity of 25 inches.

The isohyetal map for September 20-23 is shown in figure 11. Because of the magnitude of total-storm rainfall, isohyets were drawn at 5-inch intervals instead of the normal 1-inch spacing. The maximum point-rainfall of 23.40 inches was measured at the National Weather Service's agricultural weather reporting station located on Florida State Highway 12, near the western edge of Havana, Fla. The 20-inch isohyet enclosed an area of approximately 160 square miles in which the average precipitation was about 22.0 inches. The 15-inch isohyet enclosed an area of approximately 2,000 square miles. The average rainfall amounts at all the gages within the 15-inch isohyet was 19.8 inches. Rainfall measured at some of the stations may be biased to the low side owing to the intensity of rainfall and the limited capacity of some of the gages.

Mass rainfall curves, showing accumulated precipitation against rainfall duration, for Havana and for the recording gages at Quincy and Tallahassee are shown in figure 12. The Havana curve was estimated from daily rainfall reports and from the Quincy curve.

There were no recording gages within the area represented by the 20-inch isohyet. Radar analysis indicated that rainfall intensities, as recorded at Quincy, were probably representative of intensities within the area of maximum precipitation. The recording gage at the National Weather Service Office, 3 miles south of Quincy, is 12 miles from the Havana gage, which collected the maximum precipitation. This National Weather Service recording gage overflowed for a few minutes, but an adjustment was made for the overflow period using the record from a nearby weighing gage.

Rainfall intensities for the Quincy gage are shown in Table 2. The intensities for 2, 6, 12, 24, 48, 72 hours, and the storm total exceeded the probability of 1 in 100 years (Hershfield 1961, Miller 1964). The 2-day rainfall of 17.71 inches exceeded by 1.71 inches the 1 in 100-year probability of a rainfall of 16 inches for 7 days for Quincy (Miller 1964).

TABLE 2. MAXIMUM PRECIPITATION INTENSITIES
QUINCY, FLORIDA, SEPTEMBER 20-23, 1969

Rainfall Duration	Rainfall (inches)
5 minutes	0.62
10 minutes	1.17
15 minutes	1.61
20 minutes	1.98
30 minutes	2.50
45 minutes	3.24
60 minutes	3.76
2 hours	6.23
3 hours	7.90
6 hours	10.87
12 hours	12.07
24 hours	15.06
48 hours	17.71
72 hours	18.84

Storm Total 18.85 inches
Storm Duration 72 hours and 16 minutes

Rain began 4:10 a.m., September 20
Rain ended 4:26 a.m., September 23

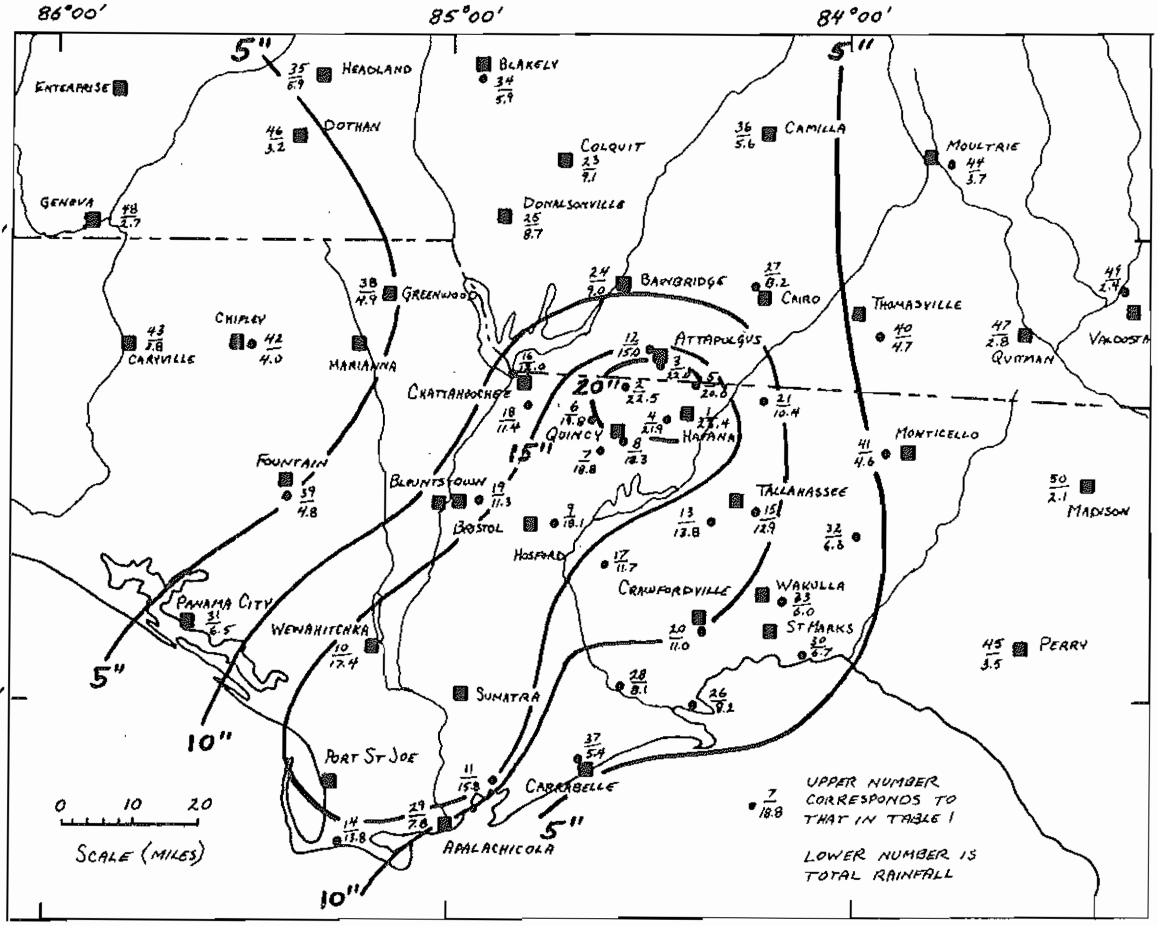


Figure 11. Total storm rainfall, September 20-23, 1969.

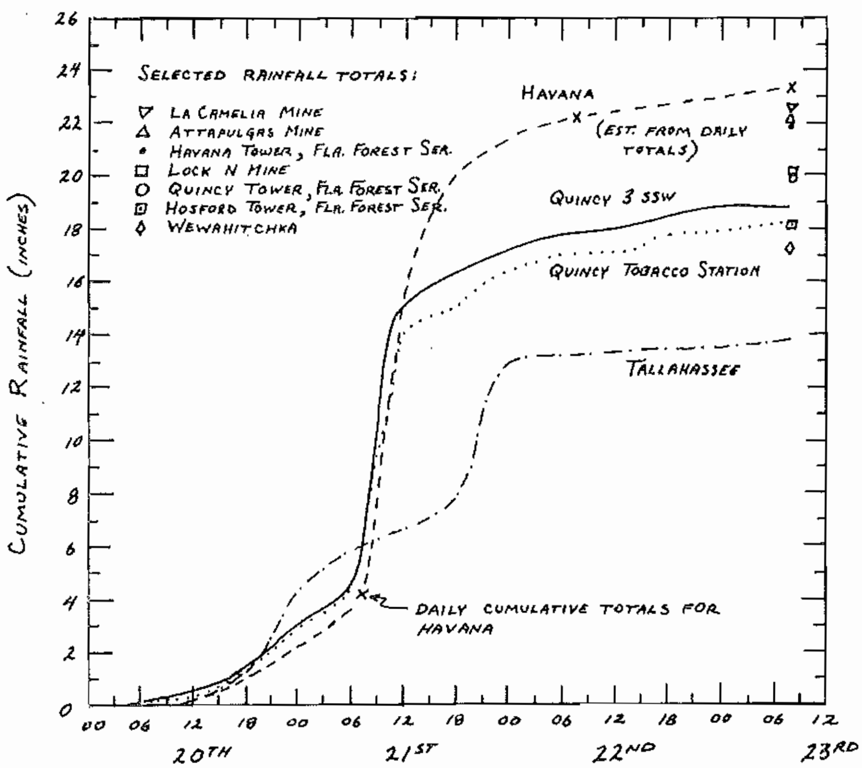


Figure 12. Cumulative rainfall and selected rainfall totals, September 20-23, 1969.

FLOOD PEAK DISCHARGE

High runoff from the excessive precipitation caused streams to swell to record levels. Maximum stages and discharges were recorded at 10 regular gaging stations and partial-record stations and at 13 miscellaneous sites within the flood area. Figure 13 shows locations of the measuring sites. For a detailed description of the sites, see Bridges and Davis (manuscript in review). Peak discharges for 30 sites (fig. 13) were plotted against size of drainage area in figure 14, along with flood-frequency curves. The flood-frequency curves show the relation between peak discharge and drainage area for recurrence intervals of 10, 25, and 50 years (Barnes and Golden, 1966).

Peak discharge measurements at many of the gaging points far exceeded the discharges having a 50-year recurrence interval. For example, the peak discharge shown in figure 14 for site 10 exceeded the discharge for the 50-year flood by a ratio of 2.28 to 1. The peak discharge of the Little River near Quincy (site 13) was 45,600 cfs (cubic feet per second) on September 22; previously the maximum recorded since 1950 was 25,400 cfs on December 4, 1964. The peak discharge of 89,400 cfs for the Ochlockonee River near Bloxham, Florida (site 24) was 1.8 times the previous maximum of 50,200 cfs recorded since 1926. Similarly, peak discharges of record were measured at 8 other gaging stations. A maximum runoff of 1,270 cfs per square mile was measured on a 1.3 square mile area on Midway Branch near Midway, Florida. The magnitude of the peak discharges as well as the rainfall amounts and intensities attest to the fact that this was a storm of rare occurrence.

COMPARISON WITH 1924 STORM

A review of climatic records (Climatological data, Florida section, 1922-70) revealed that the previous record rainfall for the area occurred on September 14-15, 1924. This rainfall was associated with a tropical storm of near hurricane strength that dumped 10 to 13 inches of rain on Gadsden County in a 24-hour period, causing floods and extensive crop damage.

The 1924 and 1969 tropical cyclones made landfall at about the same point on the coast and both were small in diameter. High barometric pressure was reported to the north and east of the 1924 tropical storm, as was the case in 1969. Unlike the 1969 low, however, the 1924 storm did not become stationary. Total precipitation for the center of maximum rainfall in 1924 was approximately 9 inches less than in 1969, but the rain was concentrated over very nearly the same area. Isohyetal maps for the 2 storms reveal strikingly similar rainfall patterns (figs. 11 and 15).

DISCUSSION

Rains of 4 to 6 inches in 24 hours are not uncommon throughout the Gulf of Mexico coastal areas. Rains of 10 or more inches in 24 hours are rare and are likely to occur at most locations something like once in every 100 years (Hershfield 1961).

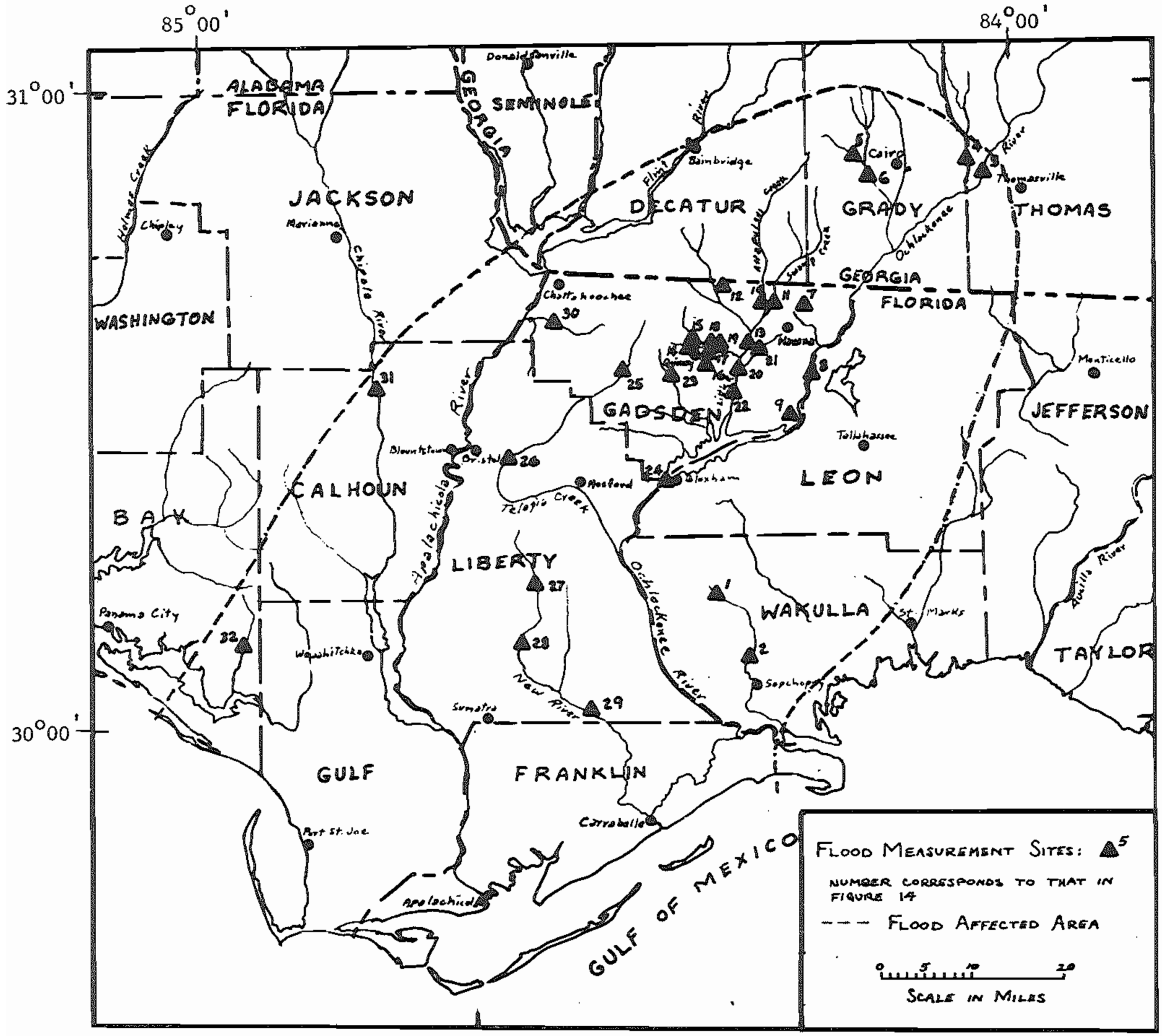


Figure 13. Flood-affected area and locations of flood measurement sites.

A review of climatic records and historical weather maps reveals that excessive rainfall along the Gulf coast may be associated with any one of a number of possible weather systems. Heavy precipitation is occasionally recorded from squall lines or from well developed thunderstorms. Cold fronts moving into the southeast frequently become quasi-stationary along the northern Gulf coast producing rain for 2, 3, or more days with total accumulations of several inches. Extratropical low-pressure systems in the spring may develop over Texas or the western Gulf and move eastward across the northern Gulf producing copious rains over the coastal areas of Louisiana, Mississippi, Alabama, and Florida (Miami Conservancy District 1936, Fla. State Board of Conservation 1955).

The heaviest rains, however, are often the result of cyclonic storms of tropical origin. It is well recognized that rainfall associated with the well developed tropical cyclones, hurricanes and tropical storms, may be heavy and extensive. Perhaps, less recognized is the fact that the weak tropical cyclones including the very weak systems, such as the one described in this paper, can be equally productive of excessive precipitation. Schoner and Molansky (1956) make a comprehensive survey of the rainfall actually produced by hurricanes and weaker tropical disturbances. Their data show that for storms moving out of the Gulf which produced storm rainfall totals of 20 or more inches, about 1/3 were hurricanes, 1/3 were classed as disturbances, and 1/3 were termed weak disturbances, minor disturbances or easterly waves. Furthermore, their data show that approximately 25 percent of all of the tropical systems moving ashore along the Gulf coast of the U.S., which produced 10 or more inches of rain were the weak disturbances.

Goodyear (1968) made an extensive study of the frequency and areal distribution of tropical cyclone rainfall along the gulf coastal region. His study dealt with 46 systems classed either as hurricanes or tropical storms. He found that the average of the point rainfall values for 12-, 24-, and 48-hour periods showed a maximum 25 to 50 miles to the right of the path. The first 24-hour period of rainfall indicated an offshore maximum whereas the second 24 hours showed a slightly larger maximum 25-50 miles inland. There was a 50 percent probability that the 6-hour maximum point rainfall would occur within the 12-hour period from 6 hours before the pressure center moved ashore to 6 hours after landfall.

The maximum 6-hour point rainfall for the 1969 tropical cyclone occurred between 2 and 8 hours after it reached land on the morning of September 21. The center of maximum storm precipitation was 60-65 miles to the right of the point of landfall and some 50 miles inland. The time of the heaviest precipitation and the location of maximum precipitation of this tropical cyclone were similar with respect to time and point of landfall of storm center to those for hurricanes and tropical storms as reported by Goodyear (1968).

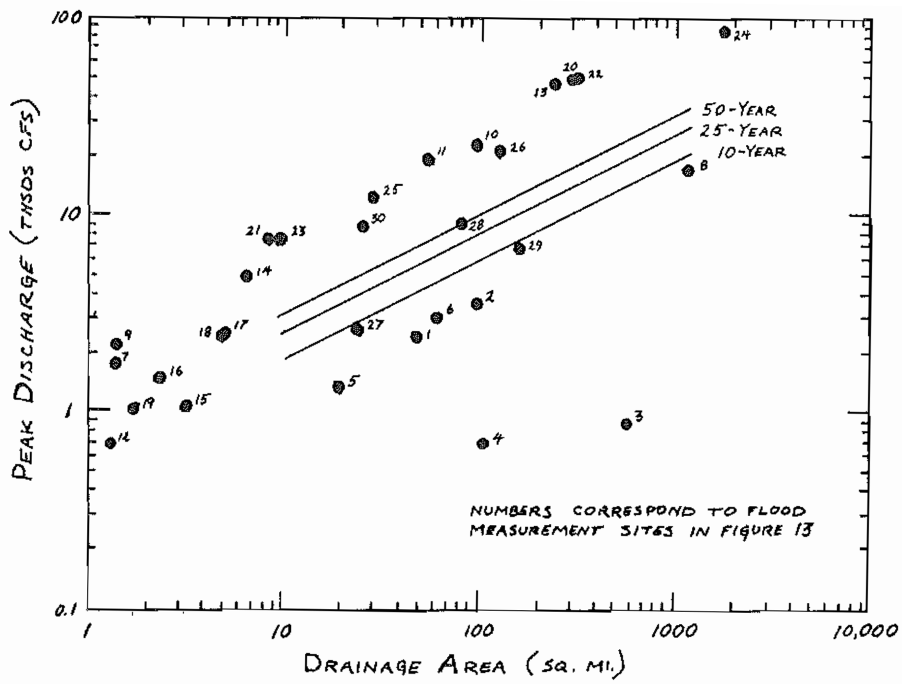


Figure 14, Relation of peak discharges associated with storm of September 20-23, 1969, to regionalized flood-frequency curves.

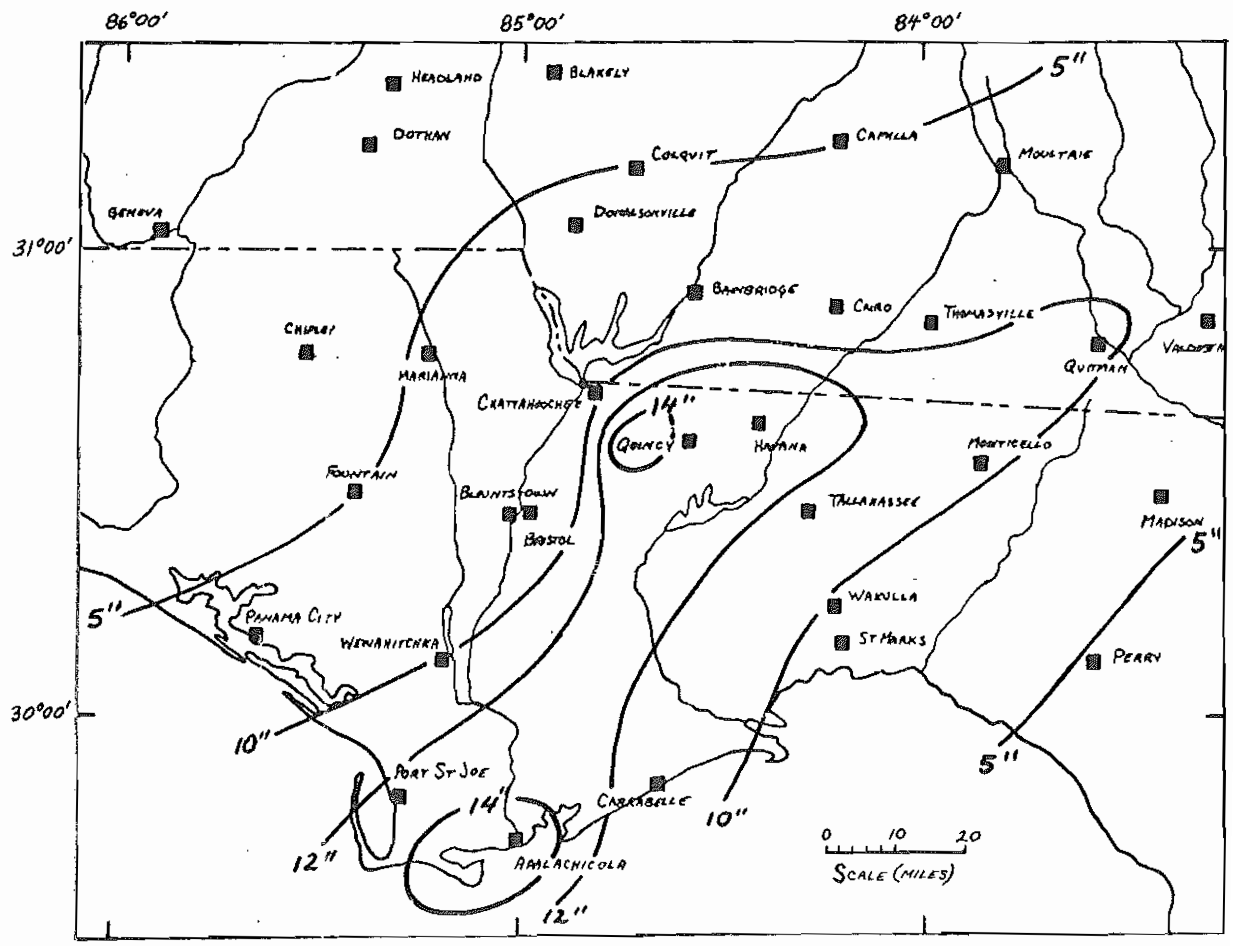


Figure 15. Total storm rainfall, September 14-15, 1924.

The storm of September 1969 was one of the weak tropical cyclones which move out of the Gulf from time to time. They may make landfall at most any point on the Gulf producing heavy rain and local flooding. While areal extent of excessive rainfall associated with the weaker tropical cyclones is limited in comparison to that of hurricanes or tropical storms, their frequency of occurrence as well as the amount of local flooding they are capable of producing, make the minimal tropical systems significant storms to be considered throughout the Gulf area. A better understanding of these tropical cyclones, the rainfall amounts associated with them, and the areal distribution of precipitation with respect to their paths should result in better and more timely local flood forecasts.

SUMMARY

Record-breaking floods in the Florida panhandle on September 20-23, 1969, were the result of unprecedented rainfall produced by a minimal tropical depression which moved out of the Gulf. Blocking action of a surface high over the southeastern states and a weak circulation aloft, caused the low to become stationary near the coast. The system produced heavy rains over a relatively small area of south Georgia and north Florida. Rainfall averaged about 22 inches over 160 square miles and was greater than about 15 inches over 2000 square miles. Precipitation intensities for 2, 6, 12, 24, 48, and 72 hours at Quincy exceeded probabilities of 1 in 100 years. At many sites near and downstream from the center of maximum precipitation, measured peak stream discharges were more than twice as great as the 50-year flood. Precipitation intensities and stream discharges indicate this was a storm of rare occurrence. The 1969 tropical low was similar to a 1924 tropical storm, which produced the previous record rainfall for the same general area. Both were tropical cyclones of small diameter, but the storm of 1924 was of near hurricane intensity and much stronger than the minimal tropical depression of 1969. Landfall of both was at about the same spot on the Florida coast, and in each case the area of maximum rainfall (Quincy-Havana area) was in the same general area despite the fact that the 1969 low stalled near the coastline and the 1924 storm continued to move inland.

The time of maximum 6-hour precipitation of the 1969 tropical low and the location of maximum point-rainfall with respect to the point and time of landfall were similar to those reported for other hurricanes and tropical storms.

The storm of 1969 was a storm of a type that frequently moves out of the Gulf. These storms may make landfall at most any point on the Gulf coastline producing heavy rain and localized flooding. A better understanding of these tropical cyclones, the rainfall amounts associated with them, and the rainfall distribution with respect to path and point of landfall should result in better and more timely flood forecasts.

ACKNOWLEDGMENT

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REFERENCES

Barnes, H. H., Jr., and Golden, H. G., 1966. Magnitude and frequency of floods in the United States, Part 2-B: U.S. Geol. Survey Water Supply Paper 1674, 409 p., pl. 1.

Bridges, W.C., and Davis, D.R., 1971. Floods of September 20-23, 1969, in the Gadsden County area, Florida: Florida Dept. of Natural Resources, Bur. of Geol., Inf. Cir. (in preparation).

Florida State Board of Conservation, 1955. Information on excessive rainfalls in Florida, Water Survey and Research Paper no. 13, 56 p.

Goodyear, Hugo V., 1968. Frequency and areal distribution of tropical storm rainfall in the United States coastal region on the Gulf of Mexico: U.S. Dept. of Commerce, ESSA Technical Report WB-7, 33p.

Hershfield, D. M., 1961. Rainfall frequency atlas of the United States: U. S. Weather Bureau, Tech. Paper 40, 61 p.

Miami (Ohio) Conservancy District, 1936. Storm rainfall of eastern United States, Technical Reports Part V, 352 p.

Miller, John F., 1964. Two to ten-day precipitation for return periods of 2 to 100 years in the contiguous United States: U.S. Dept. of Commerce, Weather Bureau, Tech. Paper No. 49, 29 p.

Schoner, R. W. and Molansky, S., 1956. Rainfall associated with hurricanes and other tropical disturbances, National Hurricane Research Project Report No. 3, Weather Bureau, U. S. Department of Commerce and Corps of Engineers, U. S. Department of the Army, (Pre-printed report prepared under P. L. 71, 84th Congress, 1st Session), 305 p.

U. S. Department of Commerce, Weather Bureau, 1922-70, Climatological Data, State Sections for Gulf coastal states, monthly and annual summaries.

U. S. Department of Commerce, Weather Bureau, 1940-70, Daily Weather Maps.

U. S. Department of Commerce, Weather Bureau, 1940-70, Local Climatological Data for selected cities along Gulf coast, monthly and annual summaries.