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Hurricane Georges:
Headwater Flooding, Storm Surge, Beach Erosion, and Habitat Destruction on the Central Gulf Coast

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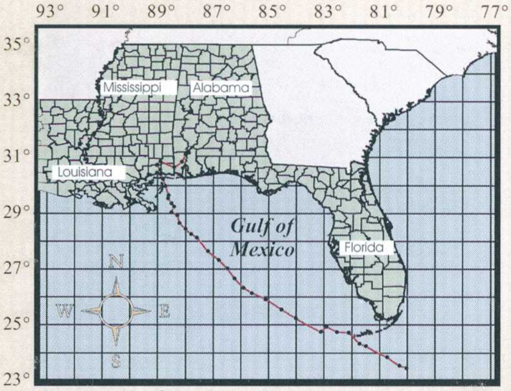

Storm track of Hurricane Georges.

Hurricane Georges (pronounced "Zhorzh"), battered the Lesser Antilles, Puerto Rico, the Dominican Republic, Haiti, Cuba, and the Florida Keys from September 18 through 25, 1998, before slamming into the Gulf Coast areas of Louisiana, Mississippi, Alabama, and the panhandle of Florida from September 28 through 30. Hurricane Georges brought torrents of rain and wind that caused many rivers in the region to flow to all-time record levels. Georges' rampage killed more than 460 people in the Caribbean and United States and was one of the most destructive and deadly storms to form in the Atlantic Ocean in recent years.

In keeping with the mission of the U.S. Geological Survey (USGS) to provide the Nation with reliable, impartial information to describe and understand the Earth, crews from the Water Resources Division (USGS-WRD), in cooperation with many State and local agencies and the U.S. Army Corps of Engineers (USACE), Mobile District, began the hazardous task of measuring water levels and flood flows and surveying storm surge on September 28, soon after landfall of Georges. National Mapping Division (USGS-NMD) personnel worked closely with emergency management agencies to update and maintain the inventory of cartographic products necessary to support emergency management operations. These cartographic products were available in Louisiana, Mississippi, and Florida during the Hurricane Georges disaster. Additional support was provided to the American Red Cross with the distribution of maps in the Central Gulf Coast area. Crews from the Geologic (USGS-GD) and Biological Resources (USGS-BRD) Divisions mobilized immediately after the storm to obtain aerial photography of the barrier islands in the Central Gulf Coast to assess coastal erosion and habitat destruction. This report presents selected provisional data on headwater flooding, storm surge, beach erosion, and habitat destruction caused by Hurricane Georges along the Central Gulf Coast.


Sailboats and debris caused by the winds and storm surge of Hurricane Georges clutter the lawn of a home on Dog River on the Mobile Bay tributary south of Mobile, AL, Wednesday, Sept. 30, 1998. (AP Photo/Mobile Register, G.M. Andrews)

The Tchoutacabouffa River experienced greater than a 100-year recurrence interval flood in this subdivision in Harrison County, MS, because of the rainfall left by Hurricane George. (AP Photo/Stephan Savoia)

HISTORY OF HURRICANE GEORGES

On September 17, Tropical Storm Georges was upgraded to a hurricane after forming as a tropical depression about 400 miles south-southwest of the Cape Verde Islands. By September 19, Georges was only about 200 miles east of the Caribbean Sea; the hurricane had intensified with maximum sustained winds of 150 miles per hour and its lowest pressure of 935 millibars (27.6 inches of mercury), making the hurricane a very dangerous category 4 storm on the Saffir-Simpson scale (fig. 1). As Georges moved through the Leeward Islands, it weakened to a still dangerous category 2 hurricane. After causing the deaths of more than 460 people and damage estimated in the billions of dollars in the Lesser Antilles, Puerto Rico, the Dominican Republic, Haiti, Cuba, and southern Florida, Georges moved into the open waters of the Gulf of Mexico on September 26 with gale force winds extending 200 miles to the north and east of the storm's center.

Georges moved slowly in a northwesterly direction for 2 days, and finally made landfall near the Ocean Springs-Biloxi area of Mississippi at 6:00 a.m. CDT on September 28, with maximum sustained winds of about 105 miles per hour and a measured pressure of 960 millibars (28.4 inches of mercury). At landfall, Georges was a strong category 2 classic, long-track "Cape Verde" hurricane (Atlantic basin tropical cyclones that develop into tropical storms fairly close--within 500-600 miles of the Cape Verde Islands and then become hurricanes before reaching the Caribbean Sea). Georges was downgraded to a tropical storm on September 28 after almost 11 days as a hurricane.

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METEOROLOGICAL DATA

Georges brought torrents of rain to the Central Gulf Coast from Gulfport, MS, to the eastern parts of the Florida panhandle (fig. 2). Rainfall amounts ranging from 15 to greater than 25 inches were reported in many areas of southern Alabama, the panhandle of Florida, and the Mississippi Gulf Coast, with one report of 38.46 inches at Munson, FL. Keesler Air Force Base at Biloxi, MS, reported wind gusts of 90-100 miles per hour. Hurricane force winds spread across the Alabama coast; gusts of 80 miles per hour were measured at Dauphin Island, AL.

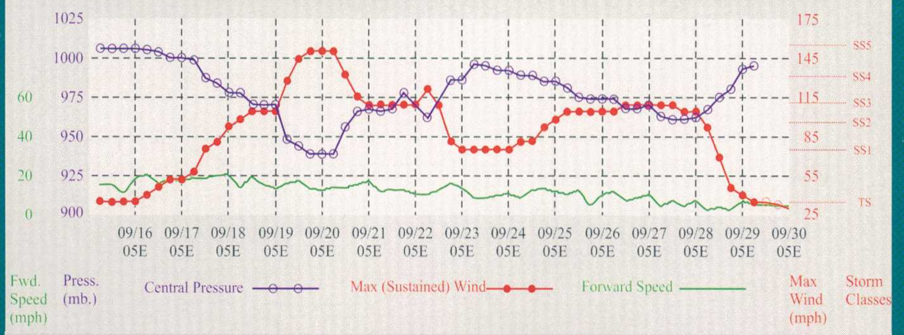


Figure 1. Central barometric pressure (in millibars), maximum sustained wind and forward speed (in miles per hour) for Hurricane Georges from September 16 through 30, 1998. (Courtesy of NOAA/NW Southeast River Forecast Center)

HEADWATER FLOODING

The USGS-WRD maintains a nationwide network of streamgages providing Federal, State and local agencies, institutions, and the private sector with accurate reliable river stage and discharge information for many water-use and design needs. Most of the nation's streamgages and many of the streamgages discussed in this report may be accessed in a real-time mode through the internet at the following address:

http://water.usgs.gov/realtime.html

The following paragraphs discuss river flooding caused by Hurricane/Tropical Storm Georges and in large part reference figure 3.

BILOXI RIVER BASIN

USGS streamgages on the Biloxi River recorded 10- to 25-year recurrence interval floods as a result of Georges. The Biloxi River gage at U.S. Highway 49 at Wortham, MS (site 1, fig. 3), had the second highest peak of record since 1953. The peak discharge of 9,430 cubic feet per second was between a 10- and a 25- year recurrence interval (table 1). The Biloxi River gage at a county road bridge near Lyman, MS (site 2, fig. 3), also recorded the second highest peak of record since 1965 with a peak stage of 21.24 feet and a peak discharge of 25,000 cubic feet per second. The peaks of record for these two gages occurred on May 9 and 10, 1995, respectively. Gages on the Biloxi River Basin have recorded extremely large floods twice in the past 3 years (table 1).

TCHOUTACABOUFFA RIVER BASIN

Streams draining the Tchoutacabouffa River Basin and flowing into the Mississippi Sound near Biloxi recorded floods of more than 100-year recurrence interval. Tuxachanie Creek at the gaging station on old State Highway 15 near Biloxi, MS (site 3, fig. 3), had flood water about 1.5 feet over the handrail of the bridge and had the highest peak of record since 1952. The gage on the Tchoutacabouffa River located on State Highway 15 at D'Iberville (site 4, fig. 3) in southern Harrison County, MS, had its highest peak in 2 years of record and was computed according to Landers and Wilson (1991) to be between a 100- and 200-year flood.

PASCAGOULA RIVER BASIN

Gages on streams that flow into the lower Pascagoula River Basin recorded floods ranging from 5- to 25-year recurrence intervals. Red Creek at the gage at Vestry, MS (site 5, fig. 3), had its third highest peak of record on September 29, 1998, surpassed only by floods in April 1983 and August 1987. At Vestry, the peak discharge caused by Georges was 25,800 cubic feet per second, about a 25-year recurrence interval flood. Gaging stations in the Escatawpa River Basin recorded flooding in the 10- to 25-year recurrence interval range. The Escatawpa River gage near Agricola, MS (site 6, fig. 3), had its peak discharge of 25 years of record on September 30. Peaks of record on the Escatawpa River were recorded at gaging stations with 50 years of record upstream and downstream of the gaging station at Agricola. The peak discharge for Big Creek near Wilmer, AL, of 4,270 cubic feet per second, was its second highest peak in the 8 years of record (site 7, fig. 3).

MOBILE RIVER BASIN

Gages on streams which are tributary to the lower Mobile River (sites 8-10. fig. 3), or that flow directly into Mobile Bay experienced about 25- to 50-year recurrence interval floods. The gaging station at Chickasaw Creek near Kushla, AL (site 9, fig. 3), recorded its second highest peak of record on September 29, surpassed only by the flood of 1955. The gage on Fowl River in southern Mobile County, AL (site 10, fig. 3), recorded its second highest peak in 4 years of record, exceeded only by that of Hurricane Danny in July 1997.

PERDIDO RIVER BASIN

The Perdido River Basin experienced some of the most severe flooding in the Central Gulf Coast area affected by Hurricane Georges. Elevenmile Creek located near Pensacola, FL (site 11, fig. 3), exceeded its former peak of record by about 3 feet and had a discharge of 13,000 cubic feet per second, which is a 100- to 200-year flood (table 1). A gaging station on Perdido River at Barrineau Park, FL (site 12, fig. 3), has discharge and peak flow information since 1941 and additional information pertaining to the 1929 flood. The September 29 peak exceeded the 1929 peak by 0.6 feet, and the discharge of 44,000 cubic feet per second had a recurrence interval of 50 to 100 years. The Styx River located in Baldwin County, AL, had severe flooding throughout its length. Most bridge crossings were inundated, including those of the gaging station near Elsanor (site 13, fig. 3) and Interstate Highway 10. The peak stage of 28.60 feet at the gaging station near Elsanor was about 7 feet higher than the bridge deck and the peak discharge of 48,000 cubic feet per second corresponds to a recurrence interval of 100 to 200 years (table 1).

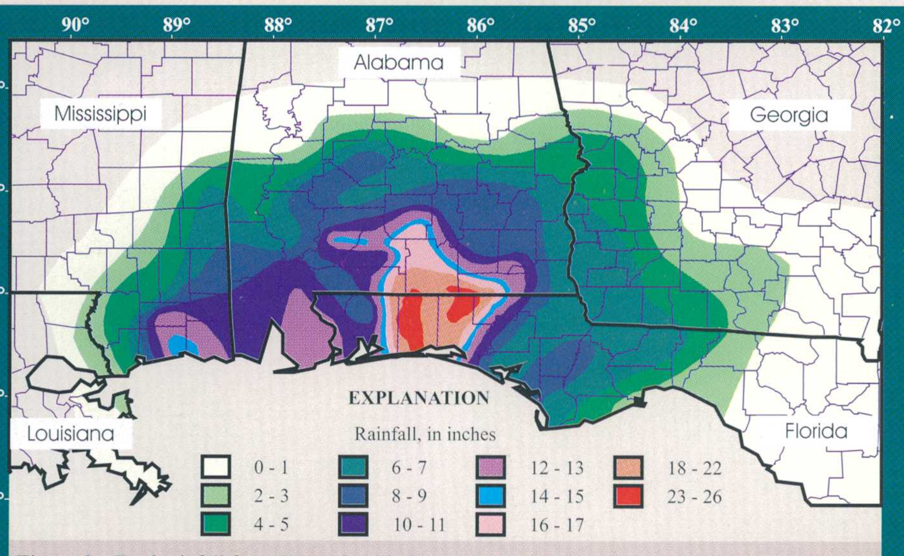


Figure 2. Total rainfall from September 28 through 30, 1998, caused by Hurricane/Tropical Storm Georges. (Courtesy of NOAA/NWS Southeast River Forecast Center)

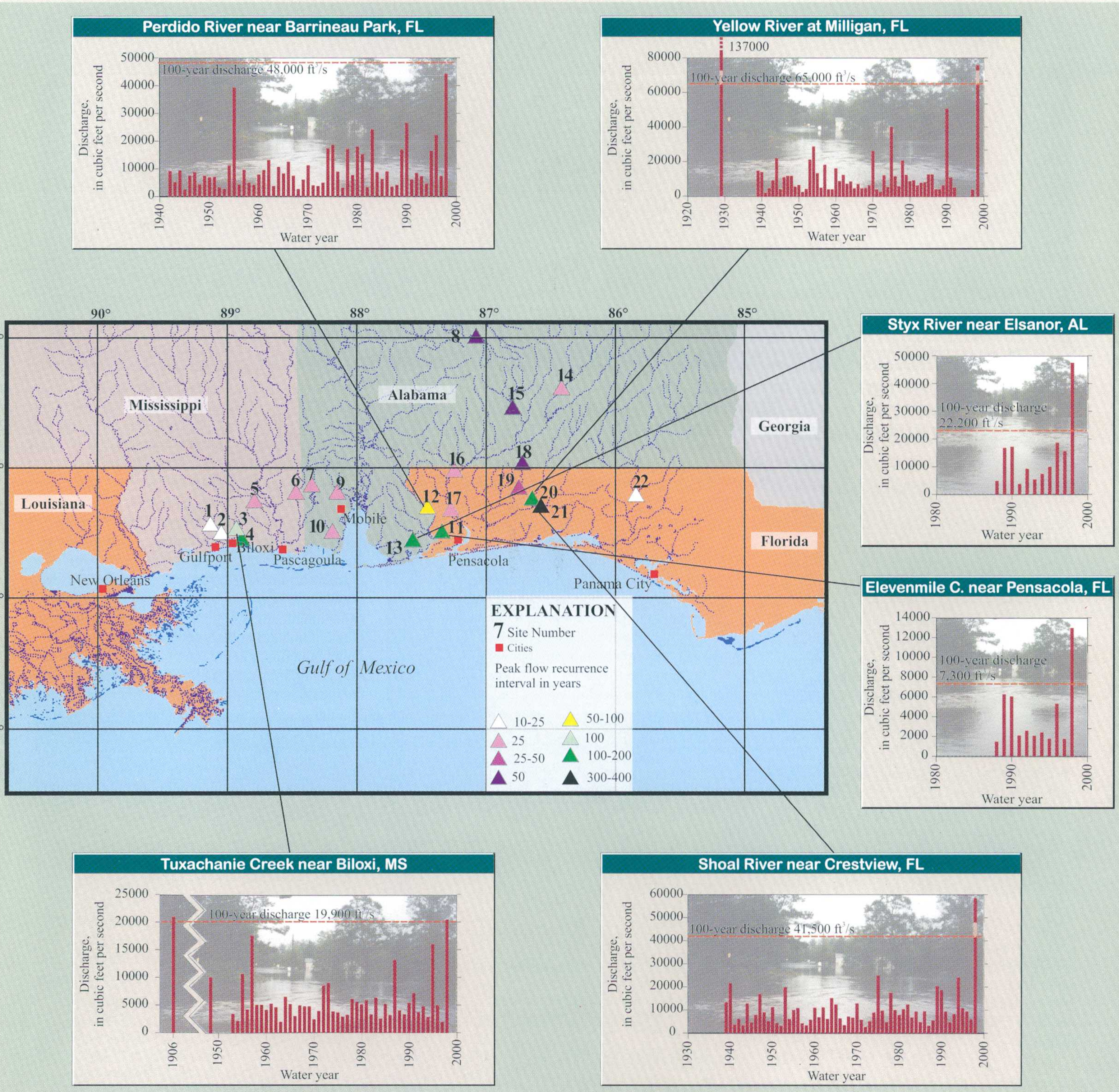


Figure 3. Locations of selected river gages, recurrence intervals, and annual maximum peak discharge for six continuous-record discharge gages affected by severe flooding from Hurricane/Tropical Storm Georges in Mississippi, Alabama, and Florida from September 28 through October 2, 1998.

Recurrence Interval

A statistical technique, called frequency analysis, is used to estimate the probability of the occurrence of a flow having a given magnitude at a gaging station. The recurrence interval (sometimes called the return period) of a peak flow is based on the probability that the flow will be equaled or exceeded in any given year. For example, there is a 1 in 100 chance that a flow of 19,900 cubic feet per second or greater will occur during any year at Tuxachanie Creek near Biloxi, MS (site 3, fig. 3). Thus, a peak flow of 19,900 cubic feet per second at this site is said to have a 100-year recurrence interval. This is not to say that a peak flow of 19,900 cubic feet per second will not occur more than once during a 100-year period at this site, but rather there is only a 1 in 100 chance that a flow of this magnitude or greater will occur in any year. Ten or more years of measured annual peak flows at a gaging station are required to perform a frequency analysis for the station. More confidence can be placed in a frequency analysis based on, for example, 30 years of record at the station than an analysis based on 10 years of record.

Table 1. Provisional flood information resulting from Hurricane/Tropical Storm Georges for selected streamgaging stations in Mississippi, Alabama, and Florida. [mi^2, square mile; ft, feet; ft^3/s, cubic feet per second; R., River; nr., near; C., Creek; AL, Alabama; FL, Florida; MS, Mississippi]

					Hurricane/Tropical Storm Georges peak stage, discharge and recurrence interval				Previous peak stage, discharge and recurrence interval		
Site number (fig. 3)	Station number	Station name	Drainage area (mi^2)	Period of record	Date of peak	Peak stage (ft)	Peak discharge (ft^3/s)	Recurrence interval (in years)	Date of peak	Peak stage (ft)	Peak discharge (ft^3/s)
		Biloxi River Basin									
1	02481000	Biloxi R. at Wortham, MS	96.2	1953-98	Sept. 29	25.47	9,430	10-25	05/09/95	28.94	13,500
2	02481130	Biloxi R. nr. Lyman, MS	251.0	1965-98	Sept. 29	21.24	25,000	10-25	05/10/95	23.95	36,800
		Tchoutacabouffa River Basin									
3	02480500	Tuxachanie C. nr. Biloxi, MS	92.4	1952-98	Sept. 29	26.06	20,300	100	09/--/06	23.2	21,000*
4	02480599	Tchoutacabouffa R. at D'Iberville, MS	217.0	1997-98	Sept. 29	16.56	46,000	100-200	05/10/95	14.64	34,500*
		Pascagoula River Basin									
5	02479300	Red C. at Vestry, MS	441.0	1958-98	Sept. 29	20.97	25,800	25	08/15/87	21.48	28,000
6	02479560	Escatawpa R. nr. Agricola, MS	562.0	1974-98	Sept. 30	22.90	30,000	25	04/09/83	22.39	27,000
7	02479945	Big C. nr. Wilmer, AL	31.5	1991-98	Sept. 28	13.11	4,270	25	05/10/91	14.21	6,400
		Mobile River Basin									
8	02427250	Pine Barren C. nr. Snow Hill, AL	261.0	1990-98	Sept. 30	24.73	28,600	50	03/17/90	24.30	23,900
9	02471001	Chickasaw C. nr. Kushla, AL	125.0	1952-98	Sept. 29	22.40	18,500	25	04/13/55	25.40	42,000
10	02471078	Fowl R. nr. Laurendine, AL	16.5	1995-98	Sept. 28	10.37	3,340	25	07/19/97	12.56	6,940
		Perdido River Basin									
11	02376115	Elevenmile C. nr. Pensacola, FL	27.8	1988-98	Sept. 29	17.50	13,000	100-200	06/08/89	14.47	6,310
12	02376500	Perdido R. nr. Barrineau Park, FL	394.0	1941-98	Sept.29	26.30	44,000	50-100	04/15/55	23.94	39,000
13	02377570	Styx R. nr. Elsanor, AL	192.0	1988-98	Sept.29	28.60	48,000	100-200	10/05/95	20.50	18,500
		Escambia River Basin									
14	02372250	Patsaliga C. nr. Brantley, AL	442.0	1975-98	Sept.30	23.71	25,800	25	03/17/90	25.67	43,600
15	02373000	Sepulga R. nr. McKenzie, AL	470.0	1938-98	Oct. 1	27.19	33,500	50	03/18/90	26.28	29,100
16	02375500	Escambia R. nr. Century, FL	3817.0	1934-98	Sept. 30	23.90	97,900	25	03/--/29	37.80	315,000*
17	02376033	Escambia R. nr. Molino, FL	4147.0	1960-98	Oct. 1	15.22	104,000	25	03/23/90	15.72	113,000
		Blackwater River Basin									
18	02369800	Blackwater R. nr. Bradley, AL	87.7	1968-98	Sept. 29	23.25	12,800	50	03/17/90	25.35	24,000
19	02370000	Blackwater R. nr. Baker, FL	205.0	1950-92 1996-98	Sept. 29	25.57	26,200	25-50	06/04/70	25.61	26,200
		Yellow River Basin									
20	02368000	Yellow R. at Milligan, FL	624.0	1938-93 1996-98	Oct. 1	24.09	76,600	100-200	03/--/29	26.20	137,000*
21	02369000	Shoal R. nr. Crestview, FL	474.0	1938-98	Sept. 30	21.40	59,000	300-400	08/01/75	15.58	25,200
		Choctawhatchee River Basin									
22	02365500	Choctawhatchee R. at Caryville, FL	3499.0	1929-94 1996-98	Oct. 2	17.69	79,000	10-25	03/17/29	27.10	206,000*

* Historic peak

Trent Baldwin, USGS hydrologist making a measurement of flow over State Highway 15 on the Tchoutacabouffa River near D'Iberville, MS, September 29, 1998. (USGS Photo/Shane J. Stocks)

ESCAMBIA RIVER BASIN

The Escambia River Basin experienced 25- to 50-year recurrence interval floods as a result of Georges (table 1). Areas near Pensacola, FL, received some of the highest rainfall totals for the storm, amounting to 26.83 inches at Pensacola (National Weather Service, written commun., October 1998). This rainfall produced the second highest discharges for gages on the Escambia River near Century (site 16, fig. 3) and Molino, FL (site 17, fig. 3), for their respective periods of record. These peak discharges were exceeded during the period of record only by the spring floods of 1990 and by the spring floods of 1929, which occurred outside the period of record for both stations. The 1929 flood, which peaked at more than three times the Georges peak of 97,900 cubic feet per second at Century, FL, was determined by the U.S. Army Corps of Engineers to be the greatest flood in the basin since 1850.

BLACKWATER RIVER BASIN

The Blackwater River Basin had floods with recurrence intervals in the 10- to 50-year range, although the highest rainfall total for a weather station occurred in this basin: 38.46 inches at Munson, FL. The Blackwater River near Baker, FL (site 19, fig. 3), peaked on September 29 at a stage of 25.57 feet. The peak measured flow was 26,200 cubic feet per second, tying the previous record of June 1970 (recurrence interval estimated at 25-50 years). Extensive inundation of the residences in the Milton area was reported during the flood.

YELLOW RIVER BASIN

Record peaks occurred in this basin at two gaging stations on September 30 and October 1. Recurrence intervals for Georges floods in the Yellow River Basin ranged from about 100 to 200 years for the gage at the Yellow River at Milligan, FL (site 20, fig. 3), to about 300 to 400 years for the Shoal River near Crestview, FL (site 21, fig. 3). Flow peaked at the Milligan gage at 24.09 feet, more than 5 feet above the previous peak of record, but still below the historic 1929 peak of 26.20 feet. The peak stage for the Shoal River at Crestview was 21.40 feet, almost 6 feet higher than the previous record. The peak discharge was 59,000 cubic feet per second, more than twice the previous record flow of 25,200 cubic feet per second recorded in 1975.

CHOCTAWHATCHEE RIVER BASIN

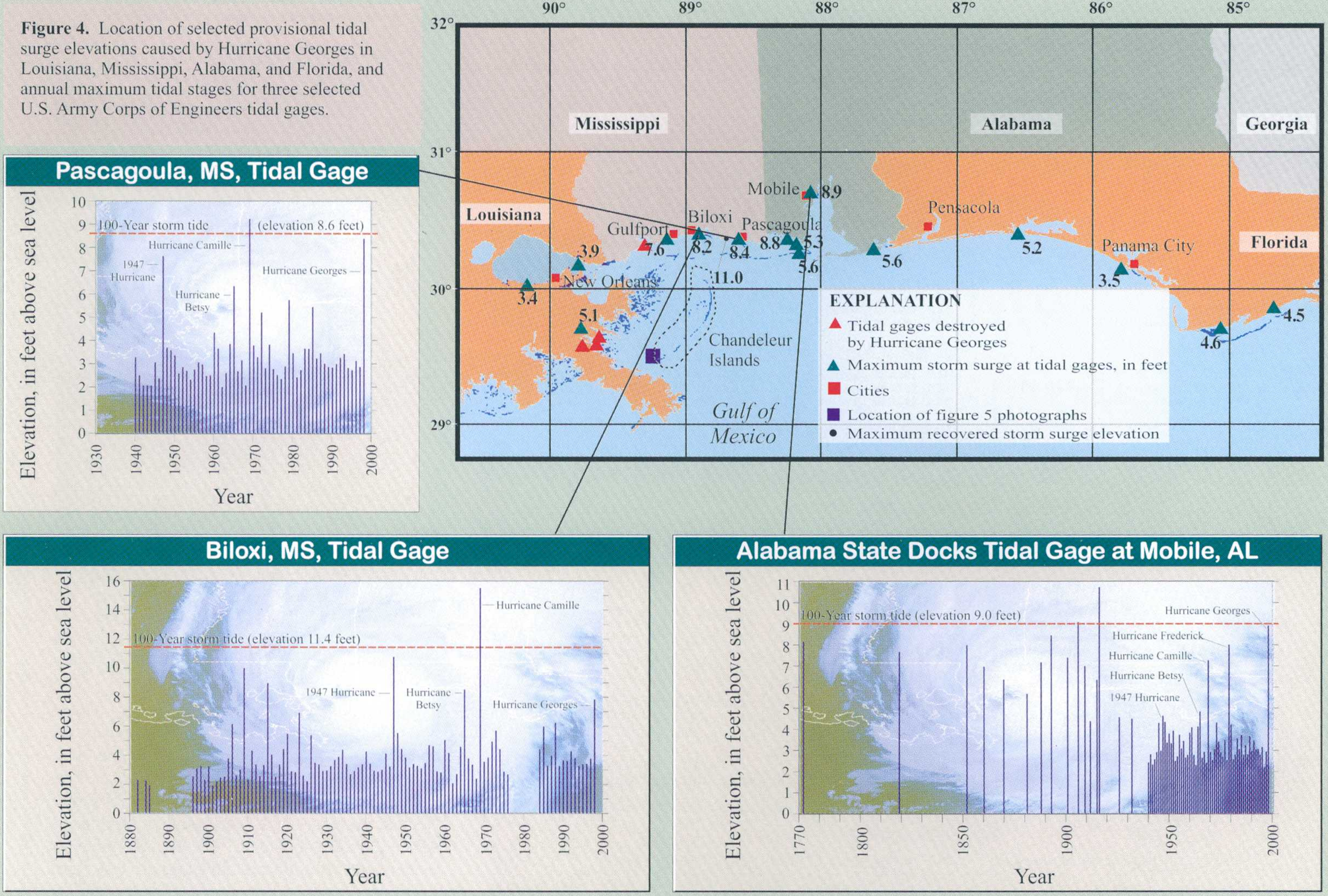
Flooding in the Choctawhatchee River Basin as a result of Georges had a recurrence interval between 10 and 25 years and marked the easternmost basin in the Central Gulf Coast where flows greater than a 10-year recurrence occurred because of the storm. To the east, maximum recurrence intervals were 5 years or less. Significant flooding occurred at Caryville, FL, but residents there previously experienced worse flooding twice in this decade--once in 1990 from spring floods and again in 1994 from Tropical Storm Alberto. A peak stage of 17.69 feet occurred on October 2 at the Choctawhatchee River at the Caryville gage (site 22, fig. 3), which was more than 6 feet lower than the Alberto peak stage; peak discharge was 79,000 cubic feet per second.

Flooding from Hurricane Georges reached record discharges at many gages in Mississippi, Alabama, and the Florida panhandle. Flow over the road was reported to be more than 8 feet in places. Recurrence intervals of 100 years were common in all three States.

STORM SURGE AND BEACH EROSION

Hurricanes and extreme tropical storms cause elevated sea level near shorelines, known as storm surge, and subsequent extensive shoreline erosion leading to the loss of property and life. The magnitude of this erosion and the extent of geologic impacts cannot yet be predicted with confidence. The variability of shoreline types, including barrier islands of Mississippi, Alabama, and Louisiana, and mangroves of southern Florida, makes predictions especially difficult (Sallenger, 1992). Hurricane Georges moved very slowly just before and after landfall, causing extremely high storm surge in the coastal areas of Mississippi and western Alabama.

Figure 4. Location of selected provisional tidal surge elevations caused by Hurricane Georges in Louisiana, Mississippi, Alabama, and Florida, and annual maximum tidal stages for three selected U.S. Army Corps of Engineers tidal gages.



Soon after landfall of Hurricane Georges, crews from the USGS-WRD in Mississippi, Alabama, and Florida, in cooperation with crews from the USACE-Mobile District, flagged and surveyed highwater marks left behind from the storm surge along the affected area on the Central Gulf Coast (fig. 4). Maximum storm surge high-water marks of about 11 feet were found near Pascagoula, MS, which is within about 1.5 feet of similar marks caused by Hurricane Camille in 1969 (fig. 4).

Private residence near Gautier, MS, depicting severe beach erosion caused by 11 feet of storm surge from Hurricane Georges. (USGS Photo/K. Van Wilson, Jr.)

CHANDELEUR ISLANDS

The Chandeleur barrier islands in eastern Louisiana, a chain of islands 60 miles east of New Orleans, LA, and 30 miles south of Biloxi, MS, were severely affected by Hurricane Georges. Numerous cuts were made in the main Chandeleur island where many areas of vegetated landmasses were swept away, resulting in the worst hurricane damage to the chain in a decade or more.

Prior to and following Georges, the islands were surveyed by the USGS-GD Center for Coastal Geology (CFCG) using low-altitude videography and still photography as part of a cooperative research project between the CFCG and the University of New Orleans. The lighthouse at the northern end of the chain, which prior to Georges was on an island, is now completely surrounded by water. Many new inlets breached the islands and, in places, sand was completely removed from the beaches leaving marshy outcrops behind (fig. 5). Whole islands in the chain have nearly disappeared. Preliminary analyses suggest that the effects of Hurricane Georges, a category 2 storm, were more extensive than the effects of Hurricane Camille, a category 5 storm that hit the Chandeleur Islands in 1969 (Williams and others, 1992). The Hurricane Georges aerial surveys, which included the coasts of eastern Louisiana, Mississippi, and Alabama, are part of a nationwide effort to establish baseline coastal conditions prior to storm impacts to accurately assess storm-generated erosion and accretion. The photographic surveys are now being supplemented by airborne scanning laser altimetry (lidar) as part of a USGS-NASA-NOAA cooperative study. For more information on Hurricane Georges aerial surveys in the central Gulf of Mexico see:
http://coastal.er.usgs.gov/hurricanes/georges/
For more information on the USGS-NASA-NOAA lidar surveys see:
http://aol.wff.nasa.gov/aoltm.html

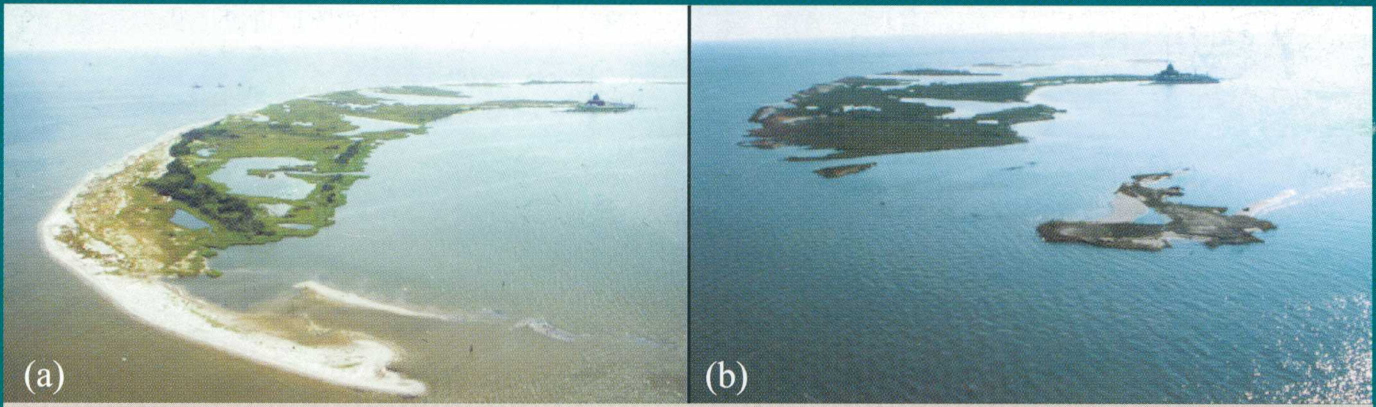


Figure 5. Low oblique color aerial photographs taken (a) July 18, 1996, and (b) October 10, 1998, of part of the Chandeleur Islands near latitude 29°29'26" and longitude 89°11'06", depicting beach erosion caused by Hurricane Georges.(Courtesy USGS/CFCG)

HABITAT DESTRUCTION IN THE CHANDELEUR ISLANDS

Hurricane Georges severely damaged the Chandeleur Islands. The eye of the storm passed 5 miles east of the islands, which are the first line of storm defense for southeastern Louisiana, especially New Orleans, and southern Mississippi. The islands are economically important for recreational and commercial fishing and shellfish such as shrimp. The Chandeleur Islands are a major habitat for birds.

Initial aerial photography made by the USGS National Wetlands Research Center (NWRC) in Lafayette, LA, reveals that the burial of seagrass beds is comparable to that suffered during Hurricane Camille in 1969, when 27 percent of the seagrass beds was lost. How successful these seagrass beds are at recovering depends on the frequency and strength of future hurricanes. Because of sea-level rise and lack of sediment to replenish the islands after storms, the NWRC predicts this chain of islands could disappear in 200 years.

Of concern to USGS biologists are the 20,000 redhead ducks that winter at the Chandeleurs each year. The Chandeleurs are one of four major wintering grounds for redheads, which feed on the rhizomes of shoalgrass, much of which was buried by sand during Georges.

Redhead duck wintering on the Chandeleur Islands in Louisiana (courtesy of USGS-BRD-NWRC)

Shoalgrass, however, is just one of five species of seagrasses that grow out into the Chandeleur Sound and form the basis of an elaborate food web that supports a highly productive ecosystem including: many species of marine snails and bivalves that feed on the leaves themselves as well as the epiphytes that grow on the leaves; numerous crustaceans (shrimp, crabs, amphipods); many finfish (speckled trout, redfish, menhaden); sea turtles; and marine mammals. Birds dependent on this ecosystem include wintering redhead ducks; reddish egrets, great blue herons, great egrets; white pelicans and brown pelicans; gulls, terns, black skimmers, piping plovers and other shorebirds and seabirds; and some birds of prey like the peregrine falcon.

Another biological concern is whether the Chandeleurs will continue to be the site of 8,000 nests of the endangered brown pelican, as it was documented to be in 1998. Additionally, the world's largest known concentration of Sandwich terns nest regularly on the Chandeleur Island chain. Their numbers range from 50,000 to 100,000 birds. USGS biologists estimate that the Chandeleur tern population is 55 to 91 percent of the total U.S. breeding population and is 34 to 61 percent of the world's population. Effects on their nesting will be determined in the year following Georges. USGS biologists also received reports from fishing outfitters in the area of high mortality of marsh birds, probably clapper rails, in some of the island ponds.

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