

# **Hydrologic Effects of the 2004 Hurricane Season in Northwest Florida**

By Richard Jay Verdi

Open-File Report 2005-1277

**U.S. Department of the Interior**  
**U.S. Geological Survey**

**U.S. Department of the Interior**  
Gale A. Norton, Secretary

**U.S. Geological Survey**  
P. Patrick Leahy, Acting Director

U.S. Geological Survey, Reston, Virginia: 2005

For sale by U.S. Geological Survey, Information Services  
Box 25286, Denver Federal Center  
Denver, CO 80225

For more information about the USGS and its products:  
Telephone: 1-888-ASK-USGS  
World Wide Web: <http://www.usgs.gov/>

Any use of trade, product, or firm names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Although this report is in the public domain, permission must be secured from the individual copyright owners to reproduce any copyrighted materials contained within this report.

Suggested citation:

Verdi, R.J., 2005, Hydrologic Effects of the 2004 Hurricane Season in Northwest Florida: U.S. Geological Survey Open-File Report 2005-1277, 18 p.

# Contents

Abstract.....	1
Introduction.....	1
Relevance and Benefits.....	2
Acknowledgments.....	2
Methods.....	2
Data Collection and Presentation.....	2
Storm Information.....	4
Tropical Storm Bonnie.....	4
Hurricane Charley.....	4
Hurricane Frances.....	4
Hurricane Ivan.....	6
Hurricane Jeanne.....	8
Precipitation.....	8
Storm Surge.....	11
River Discharges and River Levels.....	11
Instantaneous Peak Discharges and River Levels.....	11
Combined September and October Monthly Mean Discharges.....	15
Summary.....	17
References Cited.....	17

## Figures

1-2. Maps showing:	
1. Tracks of tropical storm systems in Florida in 2004.....	1
2. Geographic and hydrologic features and gage locations in northwest Florida.....	3
3. Satellite image of Hurricane Frances taken on September 4, 2004.....	4
4-5. Photographs showing:	
4. Ichetucknee River at U.S. Hwy 27.....	5
5. House on State Road 47 near Rose Sink (Columbia County), September 11, 2004.....	5
6. Satellite image of Hurricane Ivan taken on September 15, 2004.....	6
7-10. Photographs showing:	
7. Interstate 10 (I-10) bridge over Escambia Bay.....	6
8. Semi truck hanging off a broken section of the I-10 bridge, Escambia Bay.....	6
9. High water flooded structures near Blackwater River in Milton.....	7
10. Gazebo near the Blackwater River in Milton.....	7
11. Satellite image of Hurricane Jeanne image taken on September 25, 2004.....	8
12. Photos of house on South Country Club Road in the southeast portion of Lake City situated in a hollow below the L.P. Hill Dam near Alligator Lake (September 11, 2004); and post-Hurricane Jeanne photograph.....	12

13-15. River level hydrographs of:	
13. Waccasassa River near Gulf Hammock, Fla.; Suwannee River above Gopher River near Suwannee, Fla.; and Aucilla River near mouth near Nutall Rise, Fla., showing storm surge and flood peak from Hurricane Frances .....	12
14. Yellow River near Milton, Fla.; Escambia River near Molino, Fla.; and Escambia River near Gonzalez, Fla., showing storm surge and flood peak from Hurricane Ivan .....	12
15. Waccasassa River near Gulf Hammock, Fla.; Suwannee River above Gopher River near Suwannee, Fla.; and Aucilla River near mouth near Nutall Rise, Fla., showing storm surge and flood peak from Hurricane Jeanne.....	13
16. Discharge hydrograph of the Suwannee River at White Springs, Fla.; Suwannee River at Ellaville, Fla.; and Suwannee River at Branford, Fla., showing increased discharge due to rainfall from Tropical Storm Bonnie, and Hurricanes Frances and Jeanne.....	13

## Tables

1. Complete list of sites for this report .....	2
2. Top ten most costly hurricanes .....	9
3. Rainfall totals, Tropical Storm Bonnie (August 12-13, 2004) .....	9
4. Rainfall totals, Hurricane Frances (September 4-8, 2004).....	10
5. Rainfall totals, Hurricane Ivan (September 15-17, 2004) .....	11
6. Rainfall totals, Hurricane Jeanne (September 25-27, 2004).....	11
7. Peak discharges and river levels at selected sites in northwest Florida produced by Hurricanes Frances and Jeanne.....	14
8. Peak discharges and river levels at selected sites in northwest Florida produced by Hurricane Ivan.....	15
9. Relation of period-of-record September and October combined monthly mean discharge to combined mean discharge for September and October 2004, Big Bend.....	16
10. Relation of period-of-record September and October combined monthly mean discharge to combined mean discharge for September and October 2004, western panhandle.....	16

## Conversion Factors

Multiply	By	To obtain
inch (in.)	2.54	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
mile per hour (mi/h)	1.852	kilometer per hour
cubic foot per second (ft <sup>3</sup> /s)	0.02832	cubic meter per second

## Abbreviations & Datum

mbar	millibar
MODIS	Moderate Resolution Imaging Spectroradiometer
NASA	National Aeronautics and Space Administration
NWS	National Weather Service
USGS	U.S. Geological Survey

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 1929); horizontal coordinate information is referenced to the North American Datum of 1983 (NAD83).

## Saffir-Simpson Hurricane Scale

Hurricane Category (miles per hour)	
One	74-95
Two	96-110
Three	111-130
Four	131-155
Five	>155



# Hydrologic Effects of the 2004 Hurricane Season in Northwest Florida

By Richard Jay Verdi

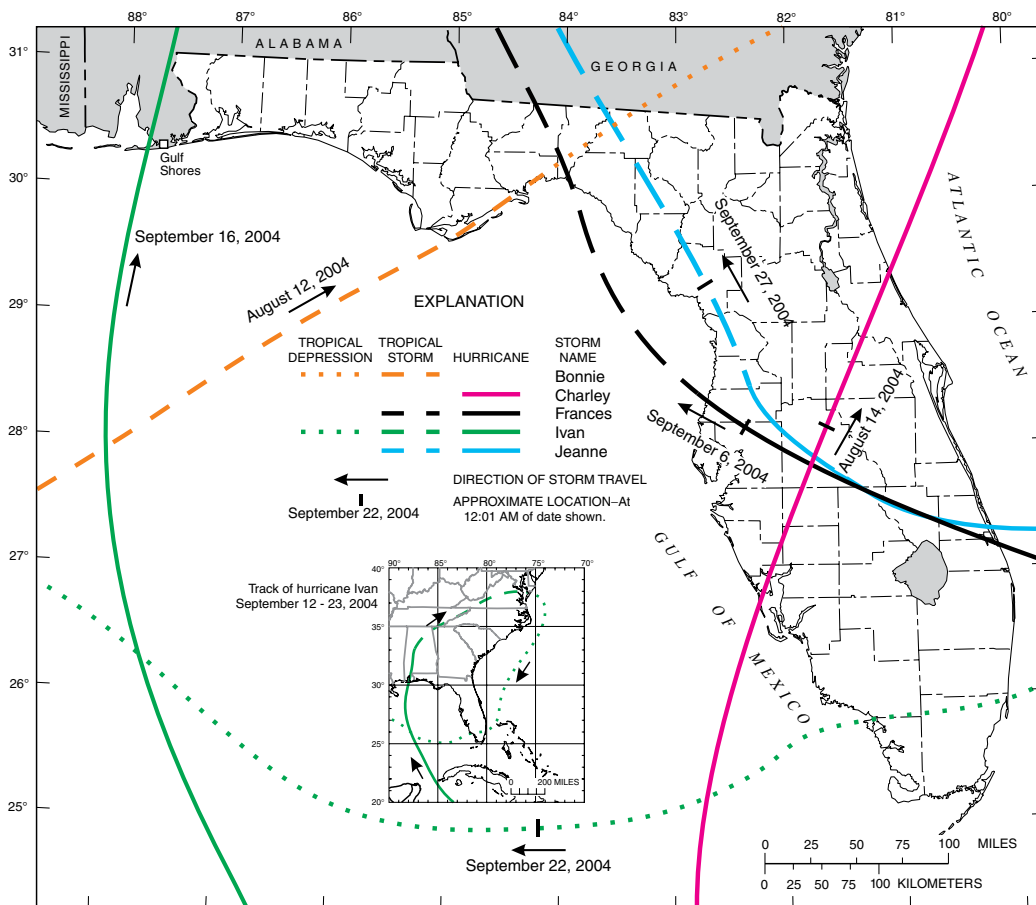
## Abstract

During the 2004 hurricane season, five tropical storm systems: Tropical Storm Bonnie, and Hurricanes Charley, Frances, Ivan, and Jeanne caused significant amounts of rainfall, storm surge, flooding, and hurricane or tropical storm-force winds in northwest Florida. The 2004 hurricane season was one of the most devastating in recorded history for the State of Florida, resulting in billions of dollars in damage and Federal aid. This report focuses on northwest Florida and provides an overview of each storm system and the associated hydrologic effects in the area.

## Introduction

During August and September 2004, northwest Florida experienced impacts from five tropical storm systems: Tropical Storm Bonnie, and Hurricanes Charley, Frances, Ivan, and Jeanne. Tropical Storm Bonnie produced 1.5-2.5 in. of rainfall across several watersheds in the eastern panhandle. Hurricane Charley's landfall in south Florida and its northeastern storm track across central Florida had a negligible effect in northwest Florida. However, Hurricanes Frances and Jeanne produced heavy rainfall, storm surge, and flooding in the Suwannee and Waccasassa River watersheds. Accumulated rainfall from

Tropical Storm Bonnie and Hurricanes Frances and Jeanne ranged from 15 to 18 in. in the Suwannee and Waccasassa River watersheds. Hurricane Ivan primarily affected the basins in the western-most panhandle with high winds and the associated storm surge (fig. 1).



**Figure 1.** Tracks of tropical storm systems in Florida in 2004.

## Relevance and Benefits

The prevention and mitigation of flooding and associated property losses are a concern of local, State, and Federal agencies. The purpose of this report is to: (1) present an overview of the hydrologic data collected during the 2004 hurricane season, and (2) assist engineers, scientists, emergency management operators and regulators, and the general public in understanding the hydrologic effects of the 2004 hurricane season in northwest Florida as well as compare these 2004 events to historical storm events.

## Acknowledgments

The author would like to acknowledge the contributions of the following U.S. Geological Survey (USGS) personnel: Jim Tomberlin, Ron Spencer, Twila Wilson, Teresa Embry, Trey Grubbs, Richard Kane, and Stewart Tomlinson. Jim and Ron were instrumental in formatting and arranging the graphics to make them suitable for printing this report. Twila improved the quality of this report with her editorial review. Layout design was performed by Teresa Embry. Colleague reviews by Trey, Richard, and Stewart contributed to the scientific merit of this report. The author also wishes to acknowledge Don Goin and Mark Stephens at the USGS in Tallahassee for making extra discharge measurements over a period of several days at the Waccasassa River during the floods.

## Methods

### Data Collection and Presentation

The USGS, in cooperation with Federal, State, county and local agencies, operates a network of 77 continuous-record streamflow-gaging stations in northwest Florida. This region, also referred to as the panhandle, is defined as lying between the Waccasassa River watershed in Levy and Gilchrist Counties on the east to the Alabama-Florida State line on the west. Several parameters are collected at these gages, including some or all of the following: (1) river level, (2) velocity, (3) temperature, (4) salinity, (5) specific conductance, and (6) precipitation. Data are recorded at 60-, 30-, 15-, or 10-minute intervals. Fifty-seven of these gages are equipped with real-time satellite telemetry and transmit at intervals of 1 to 4 hours. During critical events, such as floods, data are transmitted as often as the recording interval of the data. These data are essential for flood monitoring, emergency response, and dam and reservoir-system operation. In September and October 2004, USGS field crews made discharge measurements during the floods at several gages to verify ratings after a prolonged period of drought. These data contribute to the understanding of flood behavior and flood mitigation efforts. Data presented in this report were collected from 32 USGS continuous-record streamflow-gaging stations and 17 National Weather Service (NWS) weather gages (table 1 and fig. 2). The term *water year* refers to the time period between October 1 and September 30.

**Table 1.** Complete list of sites for this report.

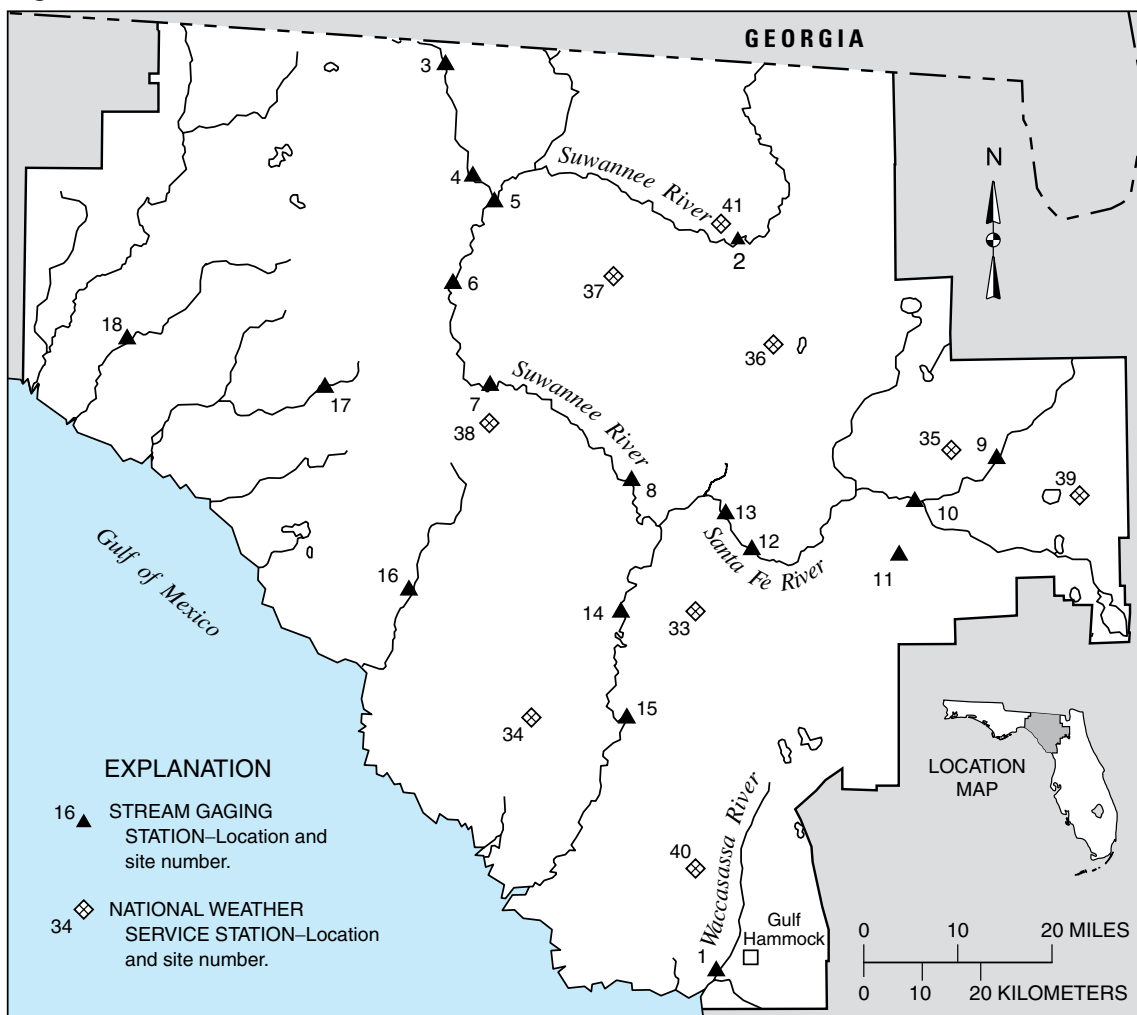
Site number (fig. 2)	Station number	Station
1	02313700	Waccasassa River near Gulf Hammock
2	02315500	Suwannee River at White Springs
3	02319000	Withlacoochee River near Pinetta
4	02319394	Withlacoochee River at Lee
5	02319500	Suwannee River at Ellaville
6	02319800	Suwannee River at Dowling Park
7	02320000	Suwannee River at Luraville
8	02320500	Suwannee River at Branford
9	02321000	New River near Lake Butler
10	02321500	Santa Fe River at Worthington Springs
11	02322049	Bad Dog Run near Alachua
12	02322500	Santa Fe River near Fort White
13	02322800	Santa Fe River at Hildreth
14	02323000	Suwannee River near Bell
15	02323500	Suwannee River near Wilcox
16	02324000	Steinhatchee River near Cross City
17	02324400	Fenholloway River near Foley
18	02326000	Econfina River near Perry
19	02329000	Ochlockonee River near Havana
20	02330000	Ochlockonee River near Bloxham
21	02358789	Chipola River at Marianna
22	02359000	Chipola River near Altha
23	02365200	Choctawhatchee River near Pittman
24	02366500	Choctawhatchee River near Bruce
25	02368000	Yellow River at Milligan
26	02369000	Shoal River near Crestview
27	02369600	Yellow River near Milton
28	02370000	Blackwater River near Baker
29	02370500	Big Coldwater Creek near Milton
30	02375500	Escambia River near Century
31	02376115	Elevenmile Creek near Pensacola
32	02376500	Perdido River at Barrineau Park
33	NWS	Bell 4NW
34	NWS	Cross City 2WNW
35	NWS	Lake Butler
36	NWS	Lake City 2E
37	NWS	Live Oak
38	NWS	Mayo
39	NWS	Starke
40	NWS	Usher Tower
41	NWS	White Springs 7N
42	NWS	Bristol 2S
43	NWS	Clarksville 2N
44	NWS	De Funiak Springs 2W
45	NWS	Marianna 7NE
46	NWS	New Hope
47	NWS	Niceville
48	NWS	Panama City 5N
49	NWS	Pensacola Regional AP



**Western Panhandle**



**Big Bend**



**Figure 2.** Geographic and hydrologic features and gage locations in northwest Florida (western panhandle and Big Bend).

## 4 Hydrologic Effects of the 2004 Hurricane Season in Northwest Florida

Rainfall data presented in this document are from USGS and the NWS rain gages. USGS rain gages are calibrated periodically and are cleaned of debris on scheduled field trips, usually about once every 6 weeks. USGS rainfall data at some sites could be subject to error because of hurricane-force winds, which have the potential to shake the tipping mechanism in the rain gages. This could cause extra tips to be recorded erroneously.

### Storm Information

#### Tropical Storm Bonnie

The center of Tropical Storm Bonnie made landfall just south of Apalachicola near St. Vincent and St. George Islands (fig. 1) as a weak tropical storm on the afternoon of August 12 with sustained wind speeds of about 46 mi/h and a barometric pressure of 1,001 mbar. Quickly weakening to a tropical depression, Bonnie moved northeast across the “Big Bend” and through the Suwannee River watershed before moving into southern Georgia (National Weather Service, 2004a). Hydrologic and wind-force impacts from Bonnie were relatively minor; no deaths in Florida were reported.

#### Hurricane Charley

The center of Hurricane Charley made landfall on the southwest coast of Florida just north of Captiva Island west of Punta Gorda (fig. 1) on the evening of August 13, as a category four hurricane on the Saffir-Simpson scale with sustained wind speeds estimated at 150 mi/h and a barometric pressure of 941 mbar. Charley sped across the peninsula on a northeastward track, exiting into the Atlantic Ocean near Daytona Beach as a weak category one hurricane around 11:30 PM local time on August 13. Hurricane Charley was responsible for 9 direct and 20 indirect deaths in Florida (National Weather Service, 2004b). Because of its southwest Florida landfall and northeastward track, the effects of Charley’s hydrologic and hurricane-force wind impacts in northwest Florida were negligible. Hurricane Charley is documented as the second costliest hurricane to strike the United States, following Hurricane Andrew in 1992 (Insurance Journal, 2004).

#### Hurricane Frances

The center of Hurricane Frances (fig. 3) made landfall on the east coast of Florida on the southern end of Hutchinson Island east of Fort Pierce (fig. 1) on the morning of September 5, as a category two hurricane on the Saffir-Simpson scale with sustained wind speeds estimated at 104 mi/h and a barometric pressure of 960 mbar. The storm weakened to tropical storm

status as it slowly moved overland across central Florida, exiting into the Gulf of Mexico near New Port Richey (fig. 1). Frances made its second Florida landfall near the mouth of the Aucilla River in Jefferson County as a tropical storm with sustained wind speeds estimated at 58 mi/h and a barometric pressure of 982 mbar. After Frances’ second Florida landfall, the storm moved northwestward over Tallahassee and eventually into Georgia. Hurricane Frances was responsible for 5 direct and 32 indirect deaths in Florida (National Weather Service, 2004c). The increased discharge and abundant rainfall from this slow moving storm caused flooding and overland flooding in the Suwannee River and Waccasassa River watersheds (figs. 4-5).



**Figure 3.** Hurricane Frances image taken on September 4, 2004, by Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA’s Terra satellite. Image courtesy of NASA’s Earth observatory website: <http://earthobservatory.nasa.gov/>



**Figure 4.** Ichetucknee River at U.S. Hwy 27 looking upstream (north to northwest), September 18, 2004 (river level: 21.89 ft above NGVD 1929; discharge: 241 ft<sup>3</sup>/s). Image courtesy of Joel Lanier of the National Weather Service.



**Figure 5.** House on State Road 47 near Rose Sink (Columbia County), September 11, 2004. Note the high water mark on the house. Image courtesy of Al Sandrik of the National Weather Service.

## Hurricane Ivan

The center of Hurricane Ivan (fig. 6) made landfall during the early morning hours of September 16, near Gulf Shores, Alabama (fig. 1) as a strong category three hurricane on the Saffir-Simpson scale with sustained wind speeds estimated at 121 mi/h and a barometric pressure of 946 mbar. The strongest winds occurred near the Alabama-Florida Panhandle

border. Hurricane Ivan was responsible for 14 direct deaths in Florida (National Weather Service, 2004d). Sections of the Interstate 10 bridge across Escambia Bay were torn apart and collapsed into the bay because of the high winds and associated storm surge (figs. 7 and 8). Hurricane Ivan caused significant damage along the coast near Pensacola, including overland flooding in some watersheds (figs. 9 and 10).



**Figure 6.** Hurricane Ivan image taken on September 15, 2004, by MODIS on NASA's Aqua satellite. Image courtesy of NASA's Earth observatory website:  
<http://earthobservatory.nasa.gov/>



**Figure 7.** Interstate 10 (I-10) bridge over Escambia Bay; bridge sections displaced laterally and vertically. Photo courtesy Pensacola News Journal, Copyright 2004.



**Figure 8.** Semi truck hanging off a broken section of the I-10 bridge, Escambia Bay. Photo courtesy Pensacola News Journal, Copyright 2004.



**Figure 9.** High water flooded structures near Blackwater River in Milton. Photo courtesy Pensacola News Journal, Copyright 2004.



**Figure 10.** Gazebo near the Blackwater River in Milton. Photo courtesy Pensacola News Journal, Copyright 2004.

## Hurricane Jeanne

Hurricane Jeanne followed a similar path as Hurricane Frances (fig. 11), with the center making landfall on the east coast of Florida on the southern end of Hutchinson Island east of Fort Pierce (fig. 1) on the morning of September 26. At the time of landfall, Jeanne was a category three hurricane on the Saffir-Simpson scale with sustained wind speeds estimated at 121 mi/h and a barometric pressure of 950 mbar. Jeanne weakened to tropical storm status as it moved across the Florida Peninsula just north of Tampa before turning north-westward towards Georgia. As the storm moved through the eastern panhandle, it produced significant rainfall over the Suwannee River and Waccasassa River watersheds, adding to the high water produced just 3 weeks earlier by Hurricane Frances. Hurricane Jeanne was responsible for three direct deaths in Florida (National Weather Service, 2004e).

After the end of the 2004 hurricane season, Hurricanes Charley, Frances, Ivan, and Jeanne caused a combined estimate of \$21-23 billion in damage to public and private properties (Insurance Journal, 2004; St. Petersburg Times, 2005) and each ranked as one of the Top 10 costliest hurricanes in history to strike the United States (table 2) (Insurance Journal, 2004).



## Precipitation

Significant widespread rainfall generated from some of the storms resulted in high water levels on many rivers and streams in northwest Florida. Tropical Storm Bonnie produced an average of 1.5-2.5 in. of rainfall in several watersheds throughout the central to eastern panhandle from August 12-13, 2004. USGS and NWS gages recorded rainfall amounts ranging from 0.46 in. at Chipola River at Marianna to 2.46 in. at Lake City 2E (table 3).

Hurricane Frances produced an average of 8-9 in. of rain over the Suwannee River and Waccasassa River watersheds from September 4-8, 2004. Rainfall recorded by USGS and NWS gages ranged from 5.40 in. at Withlacoochee River at Lee to 13.84 in. at Lake Butler (table 4). USGS field crews measuring discharge at Waccasassa River at U.S. Hwy. 19 received a report from local residents of an unofficial total of 31-33 in. of rain over a 3-day period during Hurricane Frances. It is important to note that on September 10, 2004, there was a stationary front situated across south Georgia which produced 7.10 in. of rainfall at Lake City (NWS, site No. 36, fig. 2) and 3.52 in. at Starke (NWS, site No. 39, fig. 2) (M. Mcallister, NWS, written commun., March 17, 2005). This additional rainfall added to the localized flooding in the area (fig. 12).

Hurricane Ivan generated an average of 8-9 in. of rain in the Chipola, Choctawhatchee, Shoal, Blackwater, Perdido, Escambia, and Yellow River Basins in the western panhandle. Rainfall recorded by USGS and NWS gages ranged from 3.49 in. at Chipola River near Altha to 25.44 in. at Choctawhatchee River near Bruce (table 5).

Hurricane Jeanne produced an average of 6-7 in. of rain, again primarily in the Suwannee River and Waccasassa River watersheds. The additional rainfall subsequently increased the river levels and discharge in these watersheds. Rainfall recorded by USGS and NWS gages ranged from 0.79 in. at Cross City 2WNW to 10.88 in. at Live Oak (table 6).

**Figure 11.** Hurricane Jeanne image taken on September 25, 2004, by MODIS on NASA's Terra satellite. Image courtesy of NASA's Earth observatory website:  
<http://earthobservatory.nasa.gov/>

**Table 2.** Top ten most costly hurricanes.

[Table compiled by data from the National Weather Service and Insurance Journal, 2004. Figures represented by \$ billions, as of Sept. 30, 2004]

Rank	Year	Hurricane	Category	Areas Impacted	Cost (\$ billions)
1	1992	Andrew	5	Florida, Louisiana	20.3
2	2004	Charley	4	Florida and Mid-Atlantic U.S.	6.8
3	1989	Hugo	4	Mid-Atlantic and Northeastern U.S.	6.2
4	2004	Jeanne	3	Florida, Southeastern, and Mid-Atlantic U.S.	5.0-7.0
5	2004	Frances	2	Florida and East Coast of the U.S.	4.4
6	2004	Ivan	3	Northwestern Florida, Alabama, Southeastern and Mid-Atlantic U.S.	4.0-5.0
7	1998	Georges	2	Florida Keys, Mississippi, Alabama	3.3
8	1995	Opal	3	Northwestern Florida, Alabama	2.5
9	1999	Floyd	2	Mid-Atlantic and Northeastern U.S.	2.2
10	1992	Iniki	Unknown	Kaua'i, Hawaii	2.1

**Table 3.** Rainfall totals, Tropical Storm Bonnie (Aug. 12-13, 2004).

Site number (fig. 2)	Station number	Precipitation station	Rainfall total (inches)
4	02319394	Withlacoochee River at Lee	2.15
6	02319800	Suwannee River at Dowling Park	2.39
7	02320000	Suwannee River at Luraville	1.99
8	02320500	Suwannee River at Branford	2.21
11	02322049	Bad Dog Run near Alachua	1.79
13	02322800	Santa Fe River at Hildreth	2.07
19	02329000	Ochlockonee River near Havana	1.60
20	02330000	Ochlockonee River near Bloxham	1.08
21	02358789	Chipola River at Marianna	0.46
22	02359000	Chipola River near Altha	1.04
33	NWS	Bell 4NW	1.60
34	NWS	Cross City 2WNW	1.77
35	NWS	Lake Butler	0.66
36	NWS	Lake City 2E	2.46
37	NWS	Live Oak	2.22
38	NWS	Mayo	1.88
39	NWS	Starke	1.28
40	NWS	Usher Tower	2.32
41	NWS	White Springs 7N	1.38

**Table 4.** Rainfall totals, Hurricane Frances (Sept. 4-8, 2004).

Site number (fig. 2)	Station number	Precipitation station	Rainfall total (inches)
4	02319394	Withlacoochee River at Lee	5.40
6	02319800	Suwannee River at Dowling Park	5.65
8	02320500	Suwannee River at Branford	6.52
11	02322049	Bad Dog Run near Alachua	13.41
13	02322800	Santa Fe River at Hildreth	7.71
33	NWS	Bell 4NW	7.96
34	NWS	Cross City 2WNW	6.55
35	NWS	Lake Butler	13.84
36	NWS	Lake City 2E	10.52
37	NWS	Live Oak	6.34
38	NWS	Mayo	7.91
39	NWS	Starke	9.97
40	NWS	Usher Tower	12.30
41	NWS	White Springs 7N	9.11



**Figure 12.** (upper photo) House on South Country Club Road in the southeast portion of Lake City situated in a hollow below the L.P. Hill Dam near Alligator Lake (September 11, 2004). The Dam overflowed as a result of the heavy rainfall associated with Hurricane Frances and the stationary front over Georgia. Additional rainfall associated with Hurricane Jeanne subsequently increased the water depth. The house remained flooded for more than 30 days.



(lower photo) Post-Hurricane Jeanne photograph (date unknown). (A. Sandrik, NWS, written commun., July 21, 2005.)

Photos courtesy of Al Sandrik.



**Table 5.** Rainfall totals, Hurricane Ivan (Sept. 15-17, 2004).

Site number (fig. 2)	Station number	Precipitation station	Rainfall total (inches)
22	02359000	Chipola River near Altha	3.49*
23	02365200	Choctawhatchee River near Pittman	5.45*
24	02366500	Choctawhatchee River near Bruce	25.44*
25	02368000	Yellow River at Milligan	11.37*
26	02369000	Shoal River near Crestview	7.68*
27	02369600	Yellow River near Milton	19.76*
28	02370000	Blackwater River near Baker	10.41*
29	02370500	Big Coldwater Creek near Milton	5.67*
30	02375500	Escambia River near Century	8.31*
42	NWS	Bristol 2S	7.00
43	NWS	Clarksville 2N	5.62
44	NWS	De Funiak Springs 2W	5.50
45	NWS	Marianna 7NE	5.59
46	NWS	New Hope	5.85
47	NWS	Niceville	8.00
48	NWS	Panama City 5N	6.31
49	NWS	Pensacola Regional AP	5.42

\*Rainfall data could be subject to error because of tropical storm- or hurricane-force winds.

## Storm Surge

Storm surges from three tropical storm systems were detected in river level data collected at several stream gages in northwest Florida. Storm surge is defined as an event that occurs when the winds and forward motion associated with a tropical storm system pile water up in front of the storm system as it moves toward the shore (NOAA, undated). For the purpose of this report, storm surge is reported as the difference between the maximum river level and the approximate maximum river level of the normal tidal cycle at the time of the storm landfall.

During Hurricane Frances, the maximum storm surge recorded was about 8 ft at Waccasassa River near Gulf Hammock (fig. 13). Due to the high winds associated with Hurricane Frances, the water level went below the river level sensor, which shows as a flat line in the hydrograph at the USGS gage near Nutall Rise near the mouth of the Aucilla River (fig. 13). This is near where Hurricane Frances made its second Florida landfall. Hurricane Ivan produced the greatest observed storm surge on a river in northwest Florida, with about a 9-ft rise at the Escambia River near Gonzalez, and a 6-ft surge upstream near Molino (fig. 14). The Waccasassa River near Gulf Hammock gage recorded an approximate 6-ft storm surge from Hurricane Jeanne (fig. 15).

**Table 6.** Rainfall totals, Hurricane Jeanne (Sept. 25-27, 2004).

Site number (fig. 2)	Station number	Precipitation station	Rainfall total (inches)
4	02319394	Withlacoochee River at Lee	5.11
6	02319800	Suwannee River at Dowling Park	4.33
8	02320500	Suwannee River at Branford	7.53
11	02322049	Bad Dog Run near Alachua	7.17
13	02322800	Santa Fe River at Hildreth	5.46
33	NWS	Bell 4NW	6.30
34	NWS	Cross City 2WNW	0.79
35	NWS	Lake Butler	6.00
36	NWS	Lake City 2E	6.43
37	NWS	Live Oak	10.88
38	NWS	Mayo	7.60
39	NWS	Starke	5.43
40	NWS	Usher Tower	6.00
41	NWS	White Springs 7N	6.40

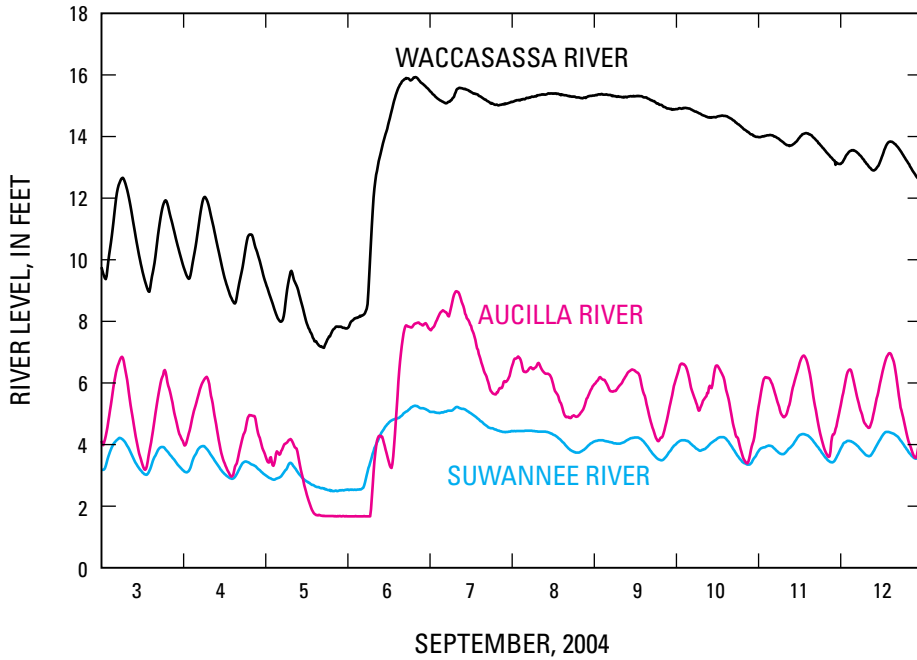
## River Discharges and River Levels

### Instantaneous Peak Discharges and River Levels

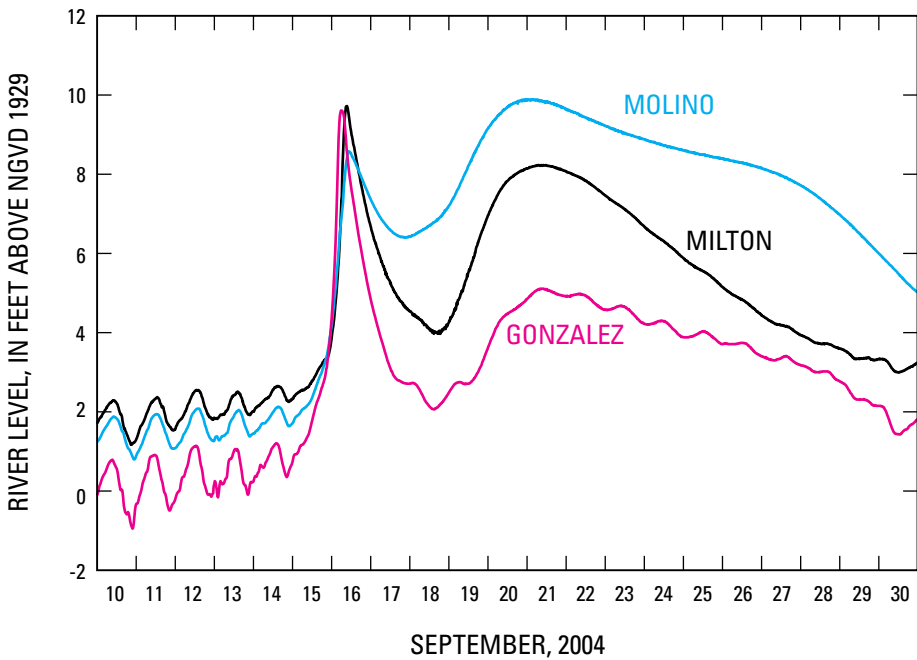
The greatest increase in discharge was associated with Hurricane Frances, which produced the most rainfall. Significant overland flooding occurred in the Santa Fe and middle Suwannee River subbasins from Hurricane Jeanne. At the Suwannee River at Branford gage (fig. 16), the small rise before the larger rise may be due to this localized overland runoff. The small rise in August (fig. 16) is attributed to the impacts of Tropical Storm Bonnie.

Instantaneous peak is defined as a local maximum value in the continuous time series of streamflow or river level, preceded by a period of increasing values and followed by a period of decreasing values (U.S. Geological Survey, 2004). Peaks from rainfall associated with Tropical Storm Bonnie, and Hurricanes Frances and Jeanne were observed in the discharge and river level hydrographs for several gages in the Waccasassa, Suwannee, and Steinhatchee River watersheds. None of the recorded peaks were the highest for the period of record of the gage (table 7).

Flooding was most significant at the Waccasassa River near Gulf Hammock gage, where peak discharge estimated at 8,330 ft<sup>3</sup>/s occurred, the second highest peak for the period of record (1963-present). Based on period-of-record peak time series data, the recurrence interval of this event was greater

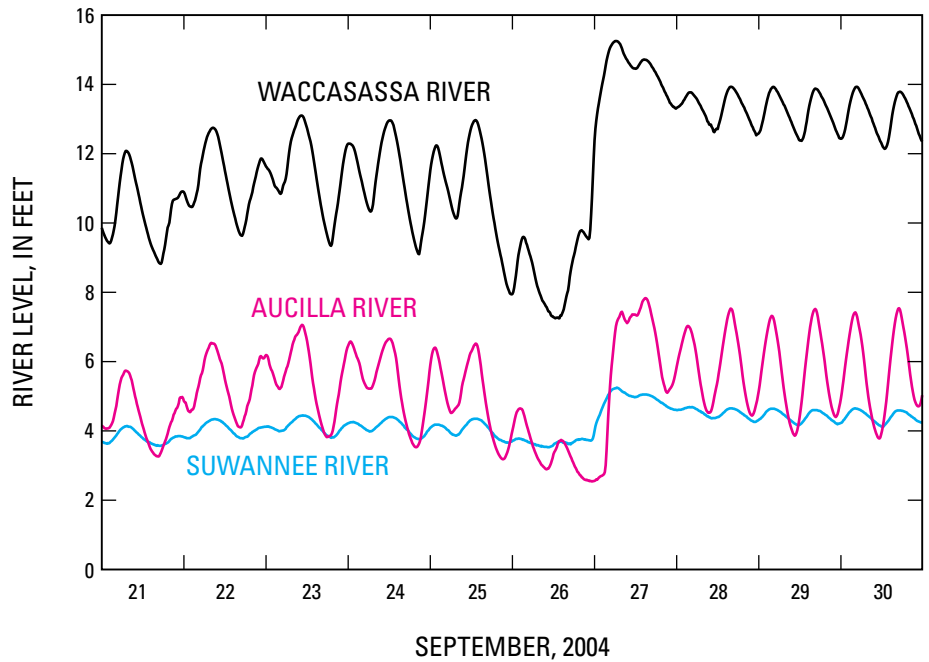


**Figure 13.** River level hydrograph of Waccasassa River near Gulf Hammock, Fla.; Suwannee River above Gopher River near Suwannee, Fla.; and Aucilla River near mouth near Nutall Rise, Fla., showing storm surge and flood peak from Hurricane Frances. (River level reported in feet above gage datum. Waccasassa River: 10.51 ft below NGVD 1929; Suwannee River: 2.10 ft below NGVD 1929; Aucilla River: datum undetermined.)

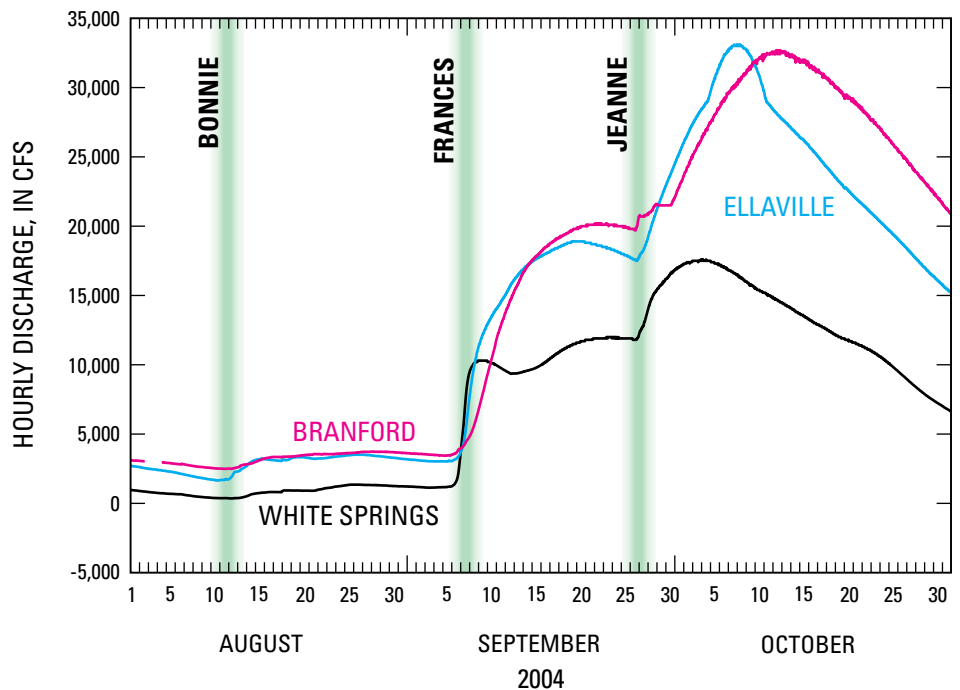


**Figure 14.** River level hydrograph of Yellow River near Milton, Fla.; Escambia River near Molino, Fla.; and Escambia River near Gonzalez, Fla., showing storm surge and flood peak from Hurricane Ivan.

**Figure 15.** River level hydrograph of Waccasassa River near Gulf Hammock, Fla.; Suwannee River above Gopher River near Suwannee, Fla.; and Aucilla River near mouth near Nutall Rise, Fla., showing storm surge and flood peak from Hurricane Jeanne. (River level reported in feet above gage datum. Waccasassa River: 10.51 ft below NGVD 1929; Suwannee River: 2.10 ft below NGVD 1929; Aucilla River: datum undetermined.)



**Figure 16.** Discharge hydrograph of the Suwannee River at White Springs, Fla.; Suwannee River at Ellaville, Fla.; and Suwannee River at Branford, Fla., showing increased discharge due to rainfall from Tropical Storm Bonnie, and Hurricanes Frances and Jeanne.



**Table 7. Peak discharges and river levels at selected sites in northwest Florida produced by Hurricanes Frances and Jeanne.**

[Data compiled from data on file at the U.S. Geological Survey in Tallahassee, Florida; river level, in feet, above NGVD 1929; ft<sup>3</sup>/s, cubic feet per second; >, greater than; <, less than; --, not determined]

Site number (fig. 2)	Station number	Streamflow-gaging station	Period of record through 2004	Peak discharge, September 1-October 15, 2004			Largest historical peak discharge			
				Date	Peak discharge (ft <sup>3</sup> /s)	Peak river level (feet above NGVD 1929)	Recurrence interval (years)*	Date	Magnitude (ft <sup>3</sup> /s)	Recurrence interval (years)*
1	02313700	Waccasassa River near Gulf Hammock	1963-1978, 1980-1984, 1984-1992, 1998-2004	9/06/2004**, 9/08/2004	8,330	5.42**	>25	9/12/1964	12,200	>100
2	02315500	Suwannee River at White Springs	1906-1908, 1927-2004	10/3/2004	17,600	84.03	>10	4/10/1973	38,100	>100
3	02319000	Withlacoochee River near Pinetta	1931-2004	10/4/2004	17,900	77.43	<5	4/5/1948	79,400	>100
5	02319500	Suwannee River at Ellaville	1927-2004	10/8/2004	33,100	56.88	>5	4/7/1948	95,300	>100
8	02320500	Suwannee River at Branford	1931-2004	10/12/2004	32,700	30.42	>5	4/11/1948	83,900	>100
9	02321000	New River near Lake Butler	1950-1971, 1990-2004	9/10/2004	5,330	95.47	<5	9/12/1964	11,400	>25
10	02321500	Santa Fe River at Worthington Springs	1931-2004	9/10/2004	7,900	64.80	<5	9/13/1964	20,000	>25
12	02322500	Santa Fe River near Fort White	1927-1930, 1932-2004	9/12/2004	9,430	30.45	>10	9/16/1964	17,000	>100
14	02323000	Suwannee River near Bell	1932-1956, 2000-2004	10/12/2004	32,600	21.87	>10	4/13/1948	82,300	>100
15	02323500	Suwannee River near Wilcox	1930-1931, 1941-2004	10/15/2004***, 10/14/2004	37,100	13.87***	>5	4/14/1948	84,700	>100
16	02324000	Steinhatchee River near Cross City	1950-2004	9/30/2004	3,500	23.03	<5	9/13/1964	17,600	>100

\*Computed based on period-of-record peaks to water year 2004.

\*\*Data computed using index-velocity method. Peak river level recorded 2 days earlier than peak discharge.

\*\*\*Data computed using index-velocity method. Peak river level recorded 1 day later than peak discharge.

**Table 8.** Peak discharges and river levels at selected sites in northwest Florida produced by Hurricane Ivan.

[Data compiled from data on file at the U.S. Geological Survey in Tallahassee, Florida; river level, in feet, above NGVD 1929; ft<sup>3</sup>/s, cubic feet per second; >, greater than; <, less than; --, not determined]

Site number (fig. 2)	Station number	Streamflow-gaging station	Period of record through 2004	Peak discharge, September 1-October 15, 2004		Largest historical peak discharge				
				Date	Peak discharge (ft <sup>3</sup> /s)	Peak river level (feet above NGVD 1929)	Recurrence interval (years)*	Date	Magnitude (ft <sup>3</sup> /s)	Recurrence interval (years)*
25	02368000	Yellow River at Milligan	1938-1993, 1996-2004	9/19/2004	10,900	56.31	<5	09/30/98	82,800	>100
26	02369000	Shoal River near Crestview	1938-2004	9/18/2004	14,200	59.40	>5	09/30/98	59,100	>100
28	02370000	Blackwater River near Baker	1950-1992, 1996-2004	9/17/2004	5,460	75.76	<5	09/29/98	26,500	>25
29	02370500	Big Coldwater Creek near Milton	1938-1979, 1980-1991, 1997-1999, 2000-2004	9/17/2004	17,100	24.85	<10	03/17/90	36,900	>25
30	02375500	Escambia River near Century	1934-2004	9/18/2004	41,500	47.19	<5	09/30/98	117,000	>50
31	02376115	Elevenmile Creek near Pensacola	1987-2004	9/16/2004	6,180	24.49	--	09/28/98	12,800	--
32	02376500	Perdido River at Barrineau Park	1941-2004	9/18/2004	11,100	42.53	--	09/29/98	44,000	--

\*Computed based on period-of-record peaks to water year 2004.

than 25 years. The highest peak discharge and river level for the period of record was 12,200 ft<sup>3</sup>/s and 6.45 feet above NGVD 1929, respectively, reported on September 12, 1964 (greater than 100-year recurrence interval), a result of heavy rainfall associated with Hurricane Dora (Bridges and Franklin, 1991) (table 7). The 1964 flood also affected the Santa Fe and Steinhatchee Rivers (greater than 25-year to greater than 100-year recurrence intervals) and inundated the town of Live Oak with 4-5 ft of water (Bridges and Franklin, 1991) (table 7).

The recurrence intervals of the peak discharges observed during Tropical Storm Bonnie, and Hurricanes Frances and Jeanne ranged from less than 5 to greater than 25 years. These events may be considered relatively minor when compared to historical floods, such as the 1948 flood that impacted Florida from the middle of the Florida Panhandle to the Atlantic Coast. This flood resulted from 9-10 in. of rainfall caused by a stalled frontal system over northern Florida (Bridges and Franklin, 1991), and discharges on the Suwannee River were greater than 100-year recurrence intervals (table 7).

Peaks from rainfall associated with Hurricane Ivan were observed in the discharge and river level hydrographs for several gages in the western panhandle, including Yellow River, Blackwater River, Escambia River, Elevenmile Creek, and Perdido River watersheds. The peaks observed during Hurricane Ivan ranged from less than 5-year to less than 10-year recurrence intervals. These peaks may be considered relatively minor when compared to the September 1998 flood, which was caused by Hurricane Georges. Hurricane Georges produced 10-20 in. of rain in the western panhandle, although some areas received up to 27 in. Precipitation produced by Hurricane Georges resulted in greater than 25-year to greater than 100-year recurrence interval discharges on the Yellow, Shoal, Blackwater, and Escambia Rivers (table 8).

### Combined September and October Monthly Mean Discharges

Combined monthly mean discharges for September and October 2004 in several eastern panhandle watersheds ranged from 242 to 602 percent of the long term averages due to the impacts of Hurricanes Frances and Jeanne.

## 16 Hydrologic Effects of the 2004 Hurricane Season in Northwest Florida

**Table 9.** Relation of period-of-record September and October combined monthly mean discharge to combined mean discharge for September and October 2004, Big Bend.

Site number (fig. 1)	Station number	Streamflow-gaging station	Period of record through 2004	Period of record combined monthly mean discharge (ft <sup>3</sup> /s)	2004 combined monthly mean discharge (ft <sup>3</sup> /s)	Percent of average
2	02315500	Suwannee River at White Springs	1906-1908, 1927-2004	3,740	22,300	596
3	02319000	Withlacoochee River near Pinetta	1931-2004	1620	9,760	602
5	02319500	Suwannee River at Ellaville	1927-2004	10,300	38,200	371
8	02320500	Suwannee River at Branford	1931-2004	11,600	42,300	365
9	02321000	New River near Lake Butler	1950-1971, 1990-2004	514	2,180	424
10	02321500	Santa Fe River at Worthington Springs	1931-2004	1250	4,800	384
12	02322500	Santa Fe River near Fort White	1927-1930, 1932-2004	3,720	9,000	242
16	02324000	Steinhatchee River near Cross City	1950-2004	792	2,510	317
17	02324400	Fenholloway River near Foley	1955-2004	101	453	449
18	02326000	Econfina River near Perry	1950-2004	261	827	317

**Table 10.** Relation of period-of-record September and October combined monthly mean discharge to combined mean discharge for September and October 2004, western panhandle.

Site number (fig. 1)	Station number	Streamflow-gaging station	Period of record through 2004	Period of record combined monthly mean discharge (ft <sup>3</sup> /s)	2004 combined monthly mean discharge (ft <sup>3</sup> /s)	Percent of average
25	02368000	Yellow River at Milligan	1938-1993, 1996-2004	1,580	3,780	239
26	02369000	Shoal River near Crestview	1938-2004	1,940	3,950	204
28	02370000	Blackwater River near Baker	1950-1992, 1996-2004	530	1,140	215
29	02370500	Big Coldwater Creek near Milton	1938-1979, 1980-1991, 1997-1999, 2000-2004	996	2,440	245
30	02375500	Escambia River near Century	1934-2004	6,320	18,300	290
31	02376115	Elevenmile Creek near Pensacola	1987-2004	210	348	166
32	02376500	Perdido River at Barrineau Park	1941-2004	1,280	2,530	198

In the Suwannee River watershed, discharges averaged highest at the Withlacoochee River near Pinetta gage, and lowest at the Santa Fe River near Fort White gage (table 9).

Due to the impacts of Hurricane Ivan, combined monthly mean discharges for September and October 2004 in the western panhandle ranged from 166 to 290 percent of average in several watersheds, including the Yellow River, Blackwater River, Escambia River, Elevenmile Creek and Perdido River watersheds. The highest discharge occurred in the Escambia River watershed and the lowest in the Elevenmile Creek watershed (table 10).

## Summary

This report provides a comprehensive overview of the hydrologic effects of the 2004 hurricane season in northwest Florida, including rainfall totals for each storm, discharge comparisons, flood statistics, and river level data. Four out of the five tropical storm systems (Tropical Storm Bonnie and Hurricanes Frances, Ivan, and Jeanne) to make landfall in Florida resulted in abundant amounts of rainfall, storm surge, and flooding in the panhandle. The accumulated rainfall from Tropical Storm Bonnie and Hurricanes Frances and Jeanne in the Suwannee and Waccasassa River watersheds ranged from 15 to 18 inches. The western panhandle averaged 8 to 9 in. of rainfall associated with Hurricane Ivan.

The second highest discharge measurement at Waccasassa River near Gulf Hammock was made by USGS personnel, which helped refine the rating at that level. After statistical analyses were completed, it was determined that the flood at that location was a greater than 25-year recurrence interval. Overall, flooding in the Suwannee River watershed during the 2004 hurricane season consisted of less than 25-year recurrence intervals, which is considered relatively minor when compared to the much larger flood of 1948 (greater than 100-year recurrence intervals). Likewise, the flooding in the western panhandle is considered relatively minor (less than 10-year recurrence intervals) when compared to the flood of September 1998 (greater than 25-year to greater than 100-year recurrence intervals).

## References Cited

- Bridges, W.C., and Franklin, M.A., 1991 Florida floods and droughts, *in* National Water Summary 1988-89—Floods and droughts: U.S. Geological Survey Water-Supply Paper 2375, p. 231-238.
- Insurance Journal, 2004, At \$22 Billion, Insured Losses from Four Florida Hurricanes Will Exceed Andrew's Record: accessed May 19, 2005, at <http://www.insurancejournal.com/news/national/2004/10/01/46438.htm>.
- National Oceanic and Atmospheric Administration, [undated], Land Cover Analysis, Glossary of Land Cover Analysis Terms: accessed June 29, 2005, at <http://www.csc.noaa.gov/crs/lca/gloss.html>.
- National Weather Service, 2004a, Tropical Cyclone Report: accessed May 12, 2005, at <http://www.nhc.noaa.gov/2004bonnie.shtml>.
- National Weather Service, 2004b, Tropical Cyclone Report: accessed May 12, 2005, at <http://www.nhc.noaa.gov/2004charley.shtml>.
- National Weather Service, 2004c, Tropical Cyclone Report: accessed May 12, 2005, at <http://www.nhc.noaa.gov/2004frances.shtml>.
- National Weather Service, 2004d, Tropical Cyclone Report: accessed May 12, 2005, at <http://www.nhc.noaa.gov/2004ivan.shtml>.
- National Weather Service, 2004e, Tropical Cyclone Report: accessed May 12, 2005, at <http://www.nhc.noaa.gov/2004jeanne.shtml>.
- St. Petersburg Times, 2005, Get Ready: Hurricane season begins June 1, yet a new poll shows that an alarming number of Floridians are woefully unprepared: accessed May 13, 2005, at [http://www.sptimes.com/2005/05/13/Opinion/Get\\_ready.shtml](http://www.sptimes.com/2005/05/13/Opinion/Get_ready.shtml).
- U.S. Geological Survey, 2004, Water Resources Data, Florida, Water Year 2004, Volume 4. Northwest Florida Water: U.S. Geological Survey Water-Data Report FL-04-4.



Photograph of County Road 232 in Gilchrist County, Florida near State Road 47 (September 18, 2004) after Hurricane Frances. Incidentally this area/road was still flooded (but passable) in February 2005! Image courtesy of Bob Kerns of the National Weather Service.